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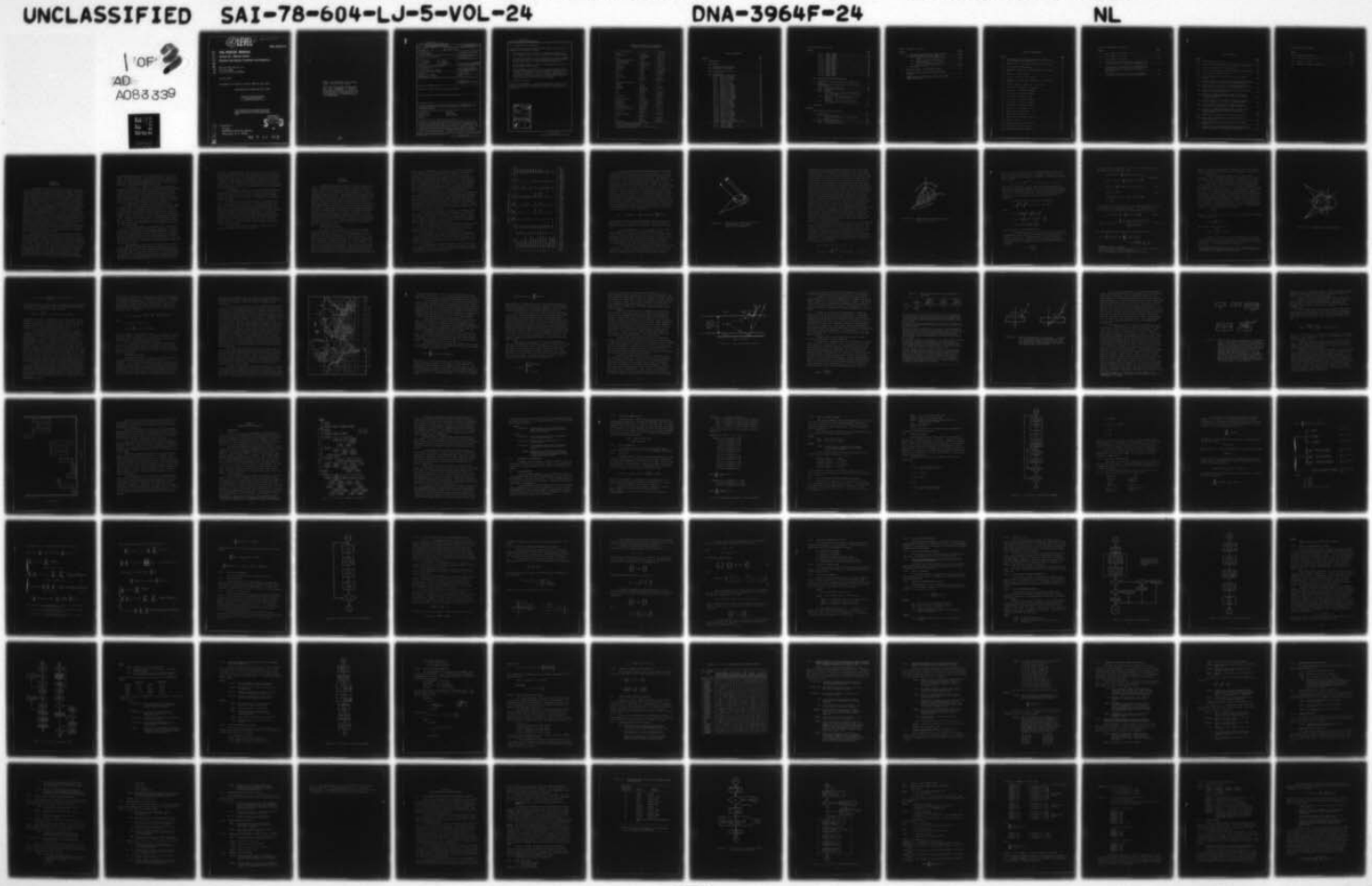

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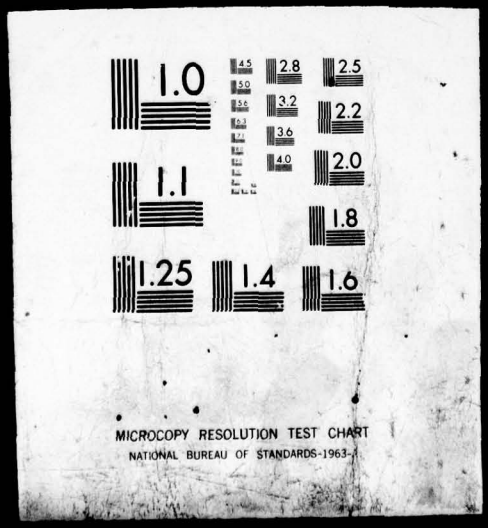

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Volume 24—Natural Clouds

(Physical and Optical Properties and Statistics)

Science Applications, Inc.
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31 July 1979

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
The effect of natural clouds on IR observables from nuclear explosions is modeled for the wavelength range from 2 to 5 microns. A computer code for use with the ROSCOE-IR main program is provided to allow evaluation of the radiance resulting from transmission and reflection by natural clouds. Mie scattering cross-sections are calculated and used to generate transport cross-sections and bidirectional reflectance coefficients. Cloud transmission is treated by diffusion. A deterministic model allows the user to

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18. SUPPLEMENTARY NOTES (Continued)

Incorporation of the Natural Cloud Model into ROSCOE-IR has led to a few differences in the coding, including:

1. The deletion of subroutine CLOUD1 in ROSCOE-IR and placement in subroutine CLDGEOM of calls to entry point CLDETOC in subroutine CLOUD9.

2. The recent establishment in the Cloud Model of a new subroutine CONVERT and the incorporation of the previous subroutines CTTOPOL and POLTOCT as entry points therein (a change not adopted in ROSCOE-IR).

3. The retention in ROSCOE-IR of the older name ALBEDO for a subroutine renamed CLDBDR in the Cloud Model.

4. The replacement of the calculation of the emission radiance in the deterministic cloud submodel by the calculation of only the emissivity, resulting in the deletion in subroutine CLOUD3 of PLANK(AA,TT) as an arithmetic function and as a factor in computing ESAVE and EMISS (each occurs twice). ROSCOE-IR has left the calculation of the emission radiance unaltered in the statistical cloud submodel.

20. ABSTRACT (Continued)

specify the cloud geometry. A statistical model allows selection of geographic weather averages and generates the probability distribution in radiance coefficients. Solar radiation and natural cloud thermal emission are treated.

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Conversion factors for U.S. customary to metric (SI) units of measurement.

To Convert From	To	Multiply By
angstrom	meters (m)	1.000 000 X E -10
atmosphere (normal)	kilo pascal (kPa)	1.013 25 X E +2
bar	kilo pascal (kPa)	1.000 000 X E +2
barn	meter^2 (m^2)	1.000 000 X E -28
British thermal unit (thermochemical)	joule (J)	1.054 350 X E +3
calorie (thermochemical)	joule (J)	4.184 000
cal (thermochemical)/cm^2	mega joule/m^2 (MJ/m^2)	4.184 000 X E -2
curie	*giga becquerel (GBq)	3.700 000 X E +1
degree (angle)	radian (rad)	1.745 329 X E -2
degree Fahrenheit	degree kelvin (K)	$t_K = (t°f + 459.67)/1.8$
electron volt	joule (J)	1.602 19 X E -19
erg	joule (J)	1.000 000 X E -7
erg/second	watt (W)	1.000 000 X E -7
foot	meter (m)	3.048 000 X E -1
foot-pound-force	joule (J)	1.355 818
gallon (U.S. liquid)	meter^3 (m^3)	3.785 412 X E -3
inch	meter (m)	2.540 000 X E -2
jerk	joule (J)	1.000 000 X E +9
joule/kilogram (J/kg) (radiation dose absorbed)	Gray (Gy)	1.000 000
kilotons	terajoules	4.183
kip (1000 lbf)	newton (N)	4.448 222 X E +3
kip/inch^2 (ksi)	kilo pascal (kPa)	6.894 757 X E +3
ktap	newton-second/m^2 (N-s/m^2)	1.000 000 X E +2
micron	meter (m)	1.000 000 X E -6
mil	meter (m)	2.540 000 X E -5
mile (international)	meter (m)	1.609 344 X E +3
ounce	kilogram (kg)	2.834 952 X E -2
pound-force (lbs avoirdupois)	newton (N)	4.448 222
pound-force inch	newton-meter (N·m)	1.129 848 X E -1
pound-force/inch	newton/meter (N/m)	1.751 268 X E +2
pound-force/foot^2	kilo pascal (kPa)	4.788 026 X E -2
pound-force/inch^2 (psi)	kilo pascal (kPa)	6.894 757
pound-mass (lbm avoirdupois)	kilogram (kg)	4.535 924 X E -1
pound-mass-foot^2 (moment of inertia)	kilogram-meter^2 (kg·m^2)	4.214 011 X E -2
pound-mass/foot^3	kilogram/meter^3 (kg/m^3)	1.601 846 X E +1
rad (radiation dose absorbed)	**Gray (Gy)	1.000 000 X E -2
roentgen	coulomb/kilogram (C/kg)	2.579 760 X E -4
shake	second (s)	1.000 000 X E -8
slug	kilogram (kg)	1.459 390 X E +1
torr (mm Hg, 0° C)	kilo pascal (kPa)	1.333 22 X E -1

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.
**The Gray (Gy) is the SI unit of absorbed radiation.

A more complete listing of conversions may be found in "Metric Practice Guide E 380-74," American Society for Testing and Materials.

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SECTION 1
INTRODUCTION

The ROSCOE-IR computer program provides a means for calculating IR observables from nuclear detonations (NUDETS). The general computational scheme in ROSCOE is to calculate the radiance along a line-of-sight (LOS) from the arbitrary location of the sensor looking toward the NUDET source region. By projecting a number of lines-of-sight to the source and its vicinity, it is possible to construct an image for imaging type sensors. For non-imaging sensors with finite field-of-view (FOV), it is possible to assess the radiance transmitted directly from the source and separately to assess the contribution at the detector of backgrounds and scattering contributions along the lines-of-sight not leading directly to the source. In each case, the NUDET source is modeled as a function of time and wavelength and the radiance along the LOS is calculated by integrating along the LOS toward the source. The transmission of the medium and the contribution to radiance by differential elements of the LOS through emission and scattering into the LOS are taken into account. Contributors to the radiance are thus NUDET source radiation at the end of the LOS; emission of the atmospheric elements between source and sensor; and scattering into the LOS of solar radiation, earth-emitted radiation, and NUDET radiation from source points off the LOS.

The presence of natural clouds in the atmosphere influences the observable IR radiance so strongly that the inclusion of a cloud model in the ROSCOE-IR program is essential for the realistic assessment of IR observables. In most areas of the world of interest in connection with nuclear explosions, clouds are present about two thirds of the time and, in fact, clouds will lie in a LOS about one half the time. Clouds produce several kinds of effects which are important both to imaging and non-imaging sensor systems. The most obvious effect of clouds is to obscure the source or to so reduce its intensity that it is not detectable by the sensor. Thick clouds provide direct attenuation factors as high as 10^4 or 10^5 even at the most transparent wavelengths.

In wavelength bands where there is strong absorption, such as at 2.7 microns, attenuation factors of this sort occur even for rather thin clouds. This attenuation by clouds has led to the well known rule of thumb that at many wavelengths NUDETS are not visible from above until the nuclear cloud has risen through the cloud tops.

A second effect of clouds even at moderately transparent wavelengths is to destroy the image of the source by multiple scattering so that the apparent source, when viewed from above, is a circular diffuse spot on the cloud top which may be many kilometers in radius. As the nuclear cloud rises, this diffuse source becomes smaller in radius, turning gradually into the nuclear cloud itself as it emerges from the cloud top. Many seconds typically are involved in the rise of the nuclear cloud from low altitudes to cloud-top altitudes.

A third effect of clouds arises in scattered or broken clouds so arranged that one cloud obscures the direct LOS to the source, while other LOS's lead to cloud edges which are illuminated by the source. Since cloud-edge reflections may contribute greater radiance than that produced along an obscured LOS, this effect gives rise to a number of lighted clouds in the vicinity of the source brighter than the (obscured) source. Other effects of clouds include a higher background radiance than in the absence of clouds because of the high albedo of cloud tops for solar radiation and a spottiness in the background when the clouds are scattered or broken.

It has been the purpose of the ROSCOE natural cloud project to provide a cloud model and the capability in ROSCOE-IR to calculate cloud effects on systems which look at NUDET environments. Satellite systems, particularly, have been kept in mind during the development of this natural cloud capability and the spectral dependence of effects has been sufficiently treated in the 2- to 5-micron region in order that realistic results will be provided for sensors whose spectral sensitivity lies within this range.

The complexity of clouds and the variability of cloudiness in a given region poses an immediate problem in cloud modeling. It is typical that any choice of cloud configurations used for transmission calculations leads to criticism by some reviewer. Such questions arise as, why does the cloud obscure the source when it is quite likely that the source will be visible through breaks? What would be the effect if the source were half obscured and half visible? Why worry about the

brightness of illuminated clouds when the direct view of the source will be so much brighter? Why worry about obscuration of the fireball when waiting awhile will allow it to break through the clouds? Each user who contemplates cloud effects tends to think of configurations which lead to maximum or minimum impact on a system and tends to focus on worst cases or best cases. Each possible cloud configuration has some validity in the problem, but a measure of the likelihood of the case is important for overall assessment.

For the ROSCOE-IR program a cloud-effects capability has been provided which allows the user to specify, within limits, the cloud scene of his choice so that the effects of scenes which he considers likely to be important can be assessed. This capability is called the deterministic model.

In addition to the deterministic model, a statistical cloud model, based on historical observation, is provided for ROSCOE. Frequency of occurrence of cloud types and average descriptions of the properties of each of the cloud types are obtained from a global cloud study and data bank prepared for NASA (Reference 1). By the use of this statistical natural cloud model, the ROSCOE program calculates the probability distribution for radiance along a LOS and thus determines the extremes in radiance which may be exhibited in the presence or absence of clouds. For a problem which has been done by the deterministic mode, the likelihood of such a result based on natural cloud occurrences can be judged.

The physical and geometric treatment of these two cloud models is described in the following section.

SECTION 2
CLOUD MODELS

The ROSCOE-IR program performs very detailed calculations to determine radiance along the line-of-sight to a sensor. The exact geometric location of the sensor and sources including the sun, the earth's surface, and the composition of the atmosphere as a function of location are taken into account. The radiance may be calculated at any wavelength selected in the 2- to 5-micron band. Source spectral powers, absorption and scattering cross-sections, reflectivities, and other physical properties affecting radiation transport must be known in detail as a function of wavelength. A cloud model for use in conjunction with ROSCOE-IR must thus have the same detailed physical and geometric description to enable these calculations to be performed with clouds in the scene. The deterministic and statistical cloud models have been so constructed that each calculation is made in the presence of clouds sufficiently described in physical properties and geometry that such detailed transmission calculations can be performed. For the statistical clouds a whole set of such calculations is done within the cloud model and selected fractiles of the integral distributions of results so obtained are provided as output.

2-1 DETERMINISTIC CLOUD MODEL

The introduction of deterministic clouds into the NUDET environment involves a specification sufficiently complete to allow radiation transmission calculations. Various deterministic cloud shapes have been used in other radiation transmission programs. These include modeling of clouds by horizontal slabs; spheres; hemispheres; round, rectangular, and hexagonal prisms; etc. For the ROSCOE natural cloud routines we have chosen ellipsoids. By the specification of the three axes, these may vary from spherical shapes to elliptical pancake shapes to very elongated rod-like shapes. The three axes are required to lie in the vertical direction and in the horizontal plane and the orientation of the longer axis in the horizontal plane must be specified.

Location in three dimensions of the center of the ellipsoid then completes the specification of the geometric cloud boundary. Any number of clouds up to 20 are permitted in the scene so long as they are not intersecting. This deterministic placement allows the investigation of the effects of obscuration of the source by clouds, the brightness and extent of illuminated cloud edges, and the brightness of edges surrounding a hole through which the source is viewed. The cloud type which is being represented is also identified as one of the naturally occurring types so that the water droplet density and size distribution may be specified. A sample obscuration case is described in Section 4.

Transmission calculations for both deterministic and statistical cloud models have been done by diffusion. The absorption and scattering cross-sections for the water droplets and the scattering phase functions have been calculated (Reference 2) by the Mie theory of scattering of photons by spherical droplet distributions. The droplet size parameters from Reference 1 (Table 6-1) were used and are given in Table 2-1. These mean radius and variance values were used to generate a gamma distribution in droplet size for each cloud type.

Such calculations were made for droplets in the range of radii for 4.5 to 10 μm for which Mie phase-function parameters were readily calculable. These sizes are characteristic of droplet sizes for cloud-types 1 through 10 in Table 2-1. The Mie-theory parameters for 40-μm radius droplets are extremely difficult to calculate and were regarded as being beyond the scope of the investigation.

The so-called 40-μm droplets are in the usual situation actually ice crystals. The approximation of simulating such large crystals by spherical droplets would be dubious, since the dimensions are large enough that irregularities are several wavelengths in size.

The application of the usual scattering and/or diffusion concepts would be seriously complicated by the fact that such crystals are typically spatially oriented, i.e., their axes tend to be aligned. For example, in diffusion this would imply an anisotropic medium, not just anisotropic scattering.

For these reasons Mie-theory parameters were not obtained for cloud-types 11 through 14. Instead, we idealized the droplets as being 40-μm radius water droplets and employed small-wavelength approximations as described at the end of Section 3-2.16.

Table 2-1. Cloud properties by type.

	Type		Layer	Base (km)	Thick (km)	Top (km)	n (cm^{-3})	$\bar{r}$ (μm)	σ_r (μm)	Composition
1.	Cumulus-1	Cu1	Low	.5	.5	1	30	5.5	1.	Water
2.	Cumulus-2	Cu2	Low	1	3	4	70	8	2.	Water
3.	Cumulus-3	Cu3	Low	4	.5	4.5	30	6.5	1.	Water
4.	Stratocumulus	Sc	Low	.3	2	2.3	100	4.5	1.	Water
5.	Stratus	St	Low	.15	1	1.15	150	5	2.	Water
6.	Cumulonimbus-1	Cb1	Low	.5	.5	1	30	5.5	1.	Water
7.	Nimbostratus	Ns	Low	1	3	4	70	5	0.5	Water
8.	Altocumulus	Ac	Mid	2	5(4)*	7(6)	30(40)	4.8	0.5	Water
9.	Altostratus-1	As1	Mid	2	4	6	70	6	0.6	Water
10.	Cumulonimbus-2	Cb2	Mid	1	9(5)	10(6)	70(120)	10	1.	Water
11.	Cumulonimbus-3	Cb3	High	10	2	12	1	40	10.	Ice
12.	Altostratus-2	As2	High	6	4	10	10	40	10.	Ice
13.	Cirrus (Midlatitude)	Ci	High	6	3	9	.8	40	10.	Ice
14.	Cirrostratus (Midlatitude)	Cs	High	6	4	10	2	40	10.	Ice

*Parenthetical values are used in the code calculations to facilitate providing for contiguous layers in the multilayer configuration; see discussion relating to Figure 2-7 and also see Section A-4.3.

The phase functions computed from Mie theory have been used to determine the average cosine of the scattering angle, $\bar{\mu}$. From the cross sections and $\bar{\mu}$ were constructed the macroscopic transport parameters which are used in the diffusion calculations. Ten wavelength values in the 2- to 5-micron range have been selected in such a way that the principal variations in cross section are retained when linear interpolation between these wavelength values is made. The chosen wavelengths are 2.0, 2.5, 2.55, 2.65, 2.75, 2.85, 3.2, 3.5, 4.0 and 5.0. For wavelengths between these values, linear interpolation is used on the macroscopic total cross-section, Σ, the macroscopic scattering cross-section, Σ_s, and the average cosine of the scattering angle, $\bar{\mu}$. Since the absorption cross-section, Σ_a, is the difference between the total cross-section and the scattering cross-section, the necessary quantities are available to determine the macroscopic transport cross-section, Σ_{tr}, the diffusion coefficient, D, and the relaxation rate, K, which are the constants required for solution of the diffusion equation. According to the "standard" evaluation of diffusion parameters in terms of macroscopic cross-sections, we have the relations

$$\Sigma_{tr} = \Sigma - \bar{\mu}\Sigma_s (\mathrm{km}^{-1}),\ D = \frac{\Sigma_s}{3\Sigma\Sigma_{tr}}\ (\mathrm{km}) \text{ and } K = \left(\frac{\Sigma_a}{D}\right)^{\frac{1}{2}}\ (\mathrm{km}^{-1}) \quad .$$

However, that evaluation is strictly applicable only in the limit of small absorption. A more generally applicable evaluation, which we adopted for numerical results in this report, is described in Section A-1.2.

For the deterministic case the ellipsoidal boundary leads to great mathematical complexity in applying boundary conditions. The problem therefore has been treated by means of a Green's function and application of Green's theorem so that the problem is reduced to a two-dimensional surface problem. The surface integrals can conveniently be treated numerically by partition of the surface into a number of facets and summing. The general problem is treated in Section A-3.

A typical geometry for the deterministic cloud problem is shown in Figure 2-1. A point source S illuminates an ellipsoidal cloud and gives rise to radiance in the direction of a detector D. The cloud surface is naturally divided into four regions by the terminators

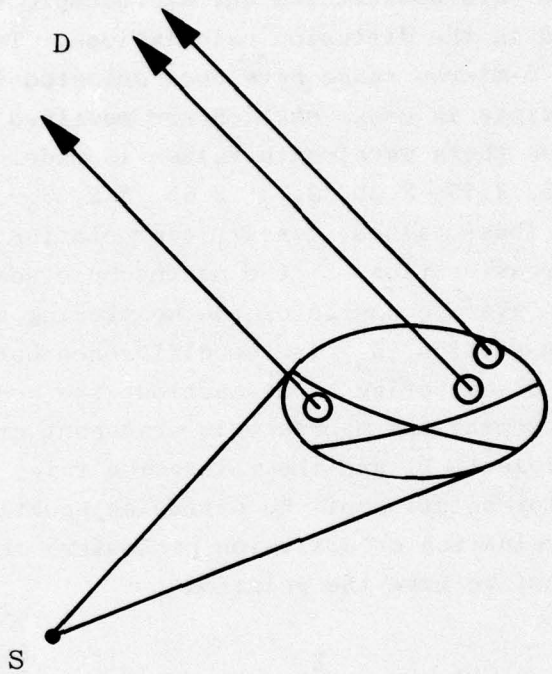


Figure 2-1. Deterministic ellipsoidal cloud model showing four regions produced by terminators.

corresponding to the source and detector points. Thus, there is an illuminated and a shadowed portion of the cloud and a visible and an invisible portion of the cloud. These combine to give four categories of cloud surface, only two of which are visible to the detector. Three lines-of-sight are shown in Figure 2-1, the lowest of which intersects an illuminated visible region while the two upper ones intersect a visible but non-illuminated region. Radiance from this latter region arises entirely from emergence of photons which have diffused through the cloud from the lower illuminated region. Although diffused photons contribute to the lowest line-of-sight also, it is in fact dominated by photons reflected from the surface. This sector of the cloud is therefore treated by bidirectional reflectance, taking into account the incident and emergent directions and the local normal to the cloud surface. Bidirectional reflectance coefficients for this purpose were calculated by Monte Carlo for a thick, flat cloud of stratocumulus (Sc) droplet density and size distribution. (This set of bidirectional reflectance coefficients is used as an approximation to the set for each of the other 13 cloud types.) The emergent photons at 45 directions in exit zenith angle and azimuth were calculated for four incident zenith angles. These tabular data of bidirectional reflectance coefficients are interpolated for use in the deterministic cloud model. The angular distribution for the photons emerging from diffusion transmission to the non-illuminated surfaces is taken to be diffuse (or Lambertian) in angular distribution.

For evaluation of the photons into and out of the deterministic cloud, the cloud is divided into facets as shown in Figure 2-2. The facets are constructed so as to lie between lines of constant θ and constant ϕ, with more facets of smaller area being concentrated near the regions of maximum curvature in the ellipsoid. In the cloud coordinate system, if $\underline{a}$ is the semi-major axis lying in the horizontal plane and $\underline{b}$ is the semi-minor axis, then the division of the azimuthal angle ϕ, where ϕ is measured from the direction of the long axis, is according to the prescription

$$\phi_{6-m} = \frac{\pi}{2} - \psi_m \ , \ \Delta\phi = \Delta\psi \ , \ m = 1,2, \ldots, 5$$

$$\psi_n = \psi_{n-1} + \Delta\psi \left(\frac{b}{a}\right)^{(n-2)\beta} , \ \psi_1 = 0; \ \psi_N = \frac{\pi}{2} , \quad 2 \leq n \leq N = 5$$

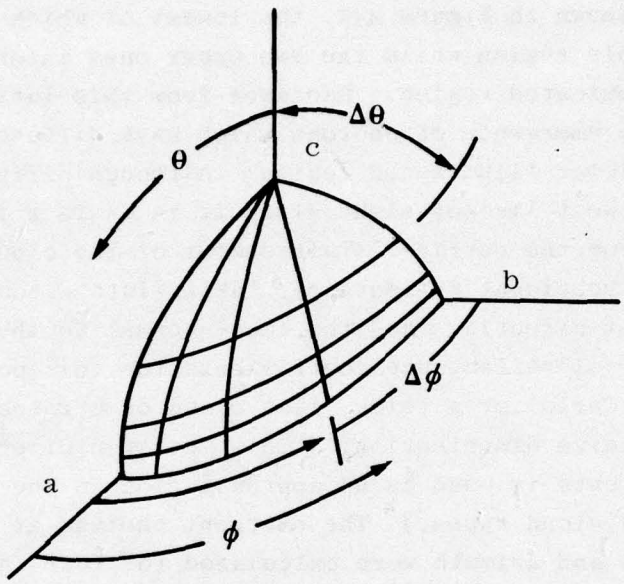


Figure 2-2. Subdivision of ellipsoidal cloud surface into facets.

Given β, this can be solved for $\Delta\phi$, the angular dimension of the first facet, and thus for each of the ϕ_n in a quadrant. Similarly the polar angle θ, measured from the zenith, is divided in a like manner according to the formula

$$\theta_n = \theta_{n-1} + \Delta\theta \left(\frac{c}{a}\right)^{(n-2)\alpha}, \quad \theta_1 = 0; \quad \theta_N = \frac{\pi}{2}, \quad 2 \leq n \leq N = 5 \quad .$$

The explicit formulas for θ_i and ϕ_i are given in Section 3 with the description of subroutine CLDGEOM. Here α and β are arbitrary exponents chosen to accentuate the grouping of facets at regions of high curvature. A value of $\alpha = \beta = 0.8$ has been used. These facets are then reflected through the principal planes into the other seven octants of the ellipsoid.

The area of facet i,j is given by the expression

$$A_{ij} = \int_{\phi_j}^{\phi_{j+1}} d\phi \int_{\theta_i}^{\theta_{i+1}} d\theta \; r^2 \sin\theta \; (1 + S^2 + T^2)^{\frac{1}{2}}$$

where

$$r^{-2} = \sin^2\theta\left(\frac{\cos^2\phi}{a^2} + \frac{\sin^2\phi}{b^2}\right) + \frac{\cos^2\theta}{c^2}$$

$$S = \sin\theta \cos\theta\left[\frac{r^2}{a^2}\cos^2\phi + \frac{r^2}{b^2}\sin^2\phi - \frac{r^2}{c^2}\right]$$

$$T = \sin\theta \sin\phi \cos\phi\left[-\frac{r^2}{a^2} + \frac{r^2}{b^2}\right] \quad .$$

This integration is performed numerically.

As discussed in Section A-3, the solution for the ellipsoid illuminated by a point source is in the form of the outgoing photon flux (radiant exitance), i.e., watts/kilometer^2, per watt emitted by an isotropic point source. Illumination by the source is converted to ingoing photon flux (irradiance) at each of the illuminated facets by computing

$$J_- = \frac{S \cos\theta_i}{4\pi R^2}$$

for a unit source. Specifically, if $J_+(\vec{r})$ and $J_-(\vec{r})$ are the outward and inward fluxes, respectively, then

$$\left.\begin{aligned} J_+(\vec{r}\,') &= S(\vec{r}\,') - \int_\Sigma J_+(\vec{r})G_+(\vec{r},\vec{r}\,')\, d\sigma(\vec{r}) \\ S(\vec{r}\,') &= -J_-(\vec{r}\,') - \int_\Sigma J_-(\vec{r})G_-(\vec{r},\vec{r}\,')\, d\sigma(\vec{r}) \end{aligned}\right\} \qquad (55)^*\&(59)^*$$

$$G_{\pm}(\vec{r},\vec{r}\,') = \frac{\hat{n}(\vec{r})}{2\pi}\cdot \text{grad}\, G(\vec{r},\vec{r}\,') \pm \frac{a}{2\pi b}\, G(\vec{r},\vec{r}\,') \qquad (55)$$

$$G(\vec{r},\vec{r}\,') = e^{-KR}/R \qquad (53)$$

$$\text{grad}\, G(\vec{r},\vec{r}\,') \equiv (\nabla G)_{\vec{r}} = G(\vec{r},\vec{r}\,')\,(K+R^{-1})\,\frac{\vec{r}\,'-\vec{r}}{R}$$

$$R = |\vec{r}-\vec{r}\,'|$$

where $\underline{a}$ and b are given in Table A-2. Note that the gradient of $G(\vec{r},\vec{r}\,')$ is evaluated at the inward-flux position $\vec{r}$. In the application of this, we used, in our early work, the approximate solution, $J_{2,+}(\vec{r}\,')$:

$$J_{1,+}(\vec{r}\,') = S(\vec{r}\,')\Big/\left[1 + \int_\Sigma G_+(\vec{r},\vec{r}\,')\, d\sigma(\vec{r})\right] \qquad (60a)^{*\dagger}$$

$$J_{2,+}(\vec{r}\,') = J_{1,+}(\vec{r}\,') - \frac{\int_\Sigma (J_{1,+}(\vec{r})-J_{1,+}(\vec{r}\,'))G_+(\vec{r},\vec{r}\,')d\sigma(\vec{r})}{1+\int_\Sigma G_+(\vec{r},\vec{r}\,')d\sigma(\vec{r})}\,. \qquad (60b)^{*\dagger\dagger}$$

In the computation, the integrals are approximated by sums,

$$\xi(\vec{r}\,') = \int_\Sigma f(\vec{r})G_{\pm}(\vec{r},\vec{r}\,')d\sigma \simeq \sum_{j\neq i} f(\vec{r}_j)G_{\pm}(\vec{r}_j,\vec{r}_i)A_j + f(\vec{r}_i)\sqrt{\frac{A_i}{\pi}}\left(-\frac{1}{2R_i} \pm \frac{a}{b}\right)$$

---

*Equation numbers in Appendix A.

†The form of $J_{1,+}$ is obtained by ignoring the last term on the right-hand side of Equation (59) in Appendix A.

††$J_{2,+}$ is obtained by combining Equations (59) and (60a).

where A_i is the area associated with the point $\vec{r}_i$, R_i is the average radius of curvature at that point, and $f(\vec{r})$ represents the multiplier of $G_{\pm}$ in the integrals.

Eventually we found an example of $J_{2,+}$ being negative. Accordingly, after considerable review of the situation, we have settled for using $J_{1,+}$ in the computer code until a better solution is found.

The geometry of the computation is summarized in Figure 2-3. A line-of-sight (LOS) of interest from detector to cloud surface has been established. The quantity of interest is the cloud radiance in the (antiparallel) direction of the LOS at the intersection of the LOS with the cloud. An irradiance-to-radiance transfer coefficient, TCOEF, of dimension sr^{-1}, is provided by the cloud routines which, when multiplied by the normal spectral irradiance at the transfer point on the cloud, gives the required spectral radiance.* Transfer point t_1 in Figure 2-3 is on an element of the surface which is visible to the detector D but is not directly illuminated by the source S. It is thus radiant because of an outward flux of photons supplied by diffusion. Assuming diffuse radiance, the spectral radiance L_λ is given by

$$L_\lambda = \frac{J_{+\lambda}(t_1)}{\pi} ,$$

where $J_{+\lambda}$ is a function of all the irradiances $J_{-\lambda}$'s over the illuminated facets (k), given by

$$J_{-\lambda k} = \frac{S_\lambda}{4\pi R^2_{sk}} \cos\theta_{ik} .$$

The transfer coefficient then is

$$TCOEF_\lambda = \frac{4\pi R^2_{st_1}}{S_\lambda} L_\lambda \ (sr^{-1}) .$$

Similarly, for points on cloud facets which are both illuminated and visible, such as t_2 in Figure 2-3, the radiance is dominated by directional reflectivity. By definition of bidirectional reflectance coefficient, ρ', the required spectral radiance is

*In the deterministic model (in contrast with the statistical model) attenuation is not included along the air path. Such attenuation will be computed by the sight-path integration model.

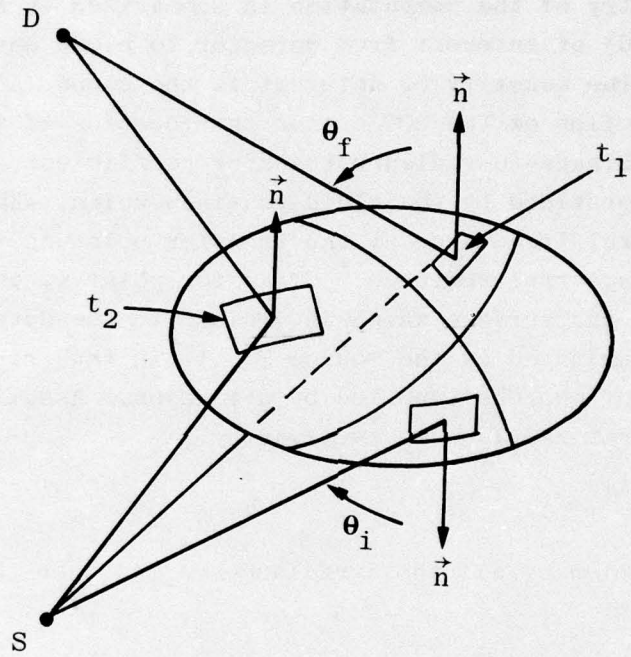


Figure 2-3. Deterministic cloud geometry.

$$L_\lambda = \rho'_\lambda(\theta_i,\theta_f,\phi)\,\frac{S_\lambda \cos\theta_i}{4\pi R^2_{st_2}}\ (\text{watt km}^{-2}\ \text{sr}^{-1}\mu\text{m}^{-1})\ .$$

The transfer coefficient then is again the quantity by which the normal irradiance* at the transfer point must be multiplied to give radiance in the direction of the detector and is given by

$$\text{TCOEF}_\lambda = \frac{4\pi R^2_{st_2}}{S_\lambda}\,L_\lambda = \rho'_\lambda\,(\theta_i,\theta_f,\phi)\,\cos\,\theta_i(\text{sr}^{-1})\ .$$

It should be noted that the bidirectional reflectance coefficient is dependent on the angle of incidence, the angle of reflection, and the azimuthal angle ϕ between the incidence and exit planes. This is the quantity which has been separately calculated by Monte Carlo and tabulated for use in the deterministic cloud problem.

The field-of-view of the detector is one of the specified quantities in the problem. The transfer coefficients are properly averaged over this field-of-view to give an average radiance along the line-of-sight. If the field-of-view is less than the facet area projected normal to the line-of-sight, then the facet radiance is the required average radiance. If, however, another facet lies within a distance equal to 0.7 times the square root of the area of the field-of-view, this facet also contributes to the average radiance and its radiance, weighted by the appropriate projected facet area in the field-of-view, is included in the calculation of the average radiance. When part of the field-of-view does not intersect the cloud, i.e., the cloud fills only a portion of the field-of-view, then the contribution of the off-cloud area to the average radiance is zero according to the cloud model. More properly, the line-of-sight integration module may arrange to provide the earth upwelling radiance in this off-cloud fraction.

In addition to the transfer coefficient which gives radiance resulting from the source, the cloud as an emitter of radiation must be considered. This self-emission radiance is calculated by assuming the cloud to be at the ambient atmosphere temperature at the altitude at which the LOS intersects the cloud and to emit a blackbody spectrum of that temperature with an appropriate emissivity in the direction of the

*See footnote on page 22.

line-of-sight. The directional emissivity is taken to be one minus the directional reflectance, $\rho_{d\lambda}$. The directional reflectance is computed by integrating the bidirectional reflectance coefficient, ρ'_λ, over the 2π solid angle, holding constant the incident direction equal to the angle between the LOS and the normal to the surface. That is, the emission spectral radiance at the transfer point in the direction of the detector, $L_{e\lambda}$, is given by

$$L_{e\lambda} = (1-\rho_{d\lambda}) \frac{c}{4\pi} c_1 \lambda^{-5} \left(e^{c_2/\lambda T}-1\right)^{-1} \text{ (watt/(km}^2 \text{ sr } \mu\text{m))}$$

where

$$c_1 = 8\pi ch, \; c_2 = ch/k, \text{ and}$$

$$\rho_{d\lambda}(\theta_i) = \int_{2\pi} \rho'_\lambda (\theta_i, \theta_f, \phi) \cos\theta_f d\Omega_f \; .$$

Since this radiance is independent of sources in the problem, it is not given as a transfer coefficient but is calculated as a spectral radiance (watt/(km^2 sr μm)). Note that the emissivity of each of the 14 cloud types is taken to be that computed for cloud-type 4.

If the problem being examined is a daytime problem so that the sun also illuminates the cloud, a third source of cloud radiance exists. The solar reflected radiance is calculated exactly as though the sun were another point source and the transfer coefficient for that geometry is the output.

2-2 STATISTICAL CLOUD MODEL

The ROSCOE-IR statistical cloud model is based on the cloud descriptions and cloud occurrence data bank of Fowler et al. (Reference 1). The clouds are described as horizontal plane parallel slabs with a base altitude and a top altitude given for each cloud type, together with water-droplet average densities and droplet-distribution average radii. The occurrence data provide the probability that each such cloud type will occur singly or in multiple layers with other types. The data are further divided into coverage categories ranging

from clear (cover category 1) to full cloud cover (cover category 5) approximately by quarters (compare definitions of CCOVER in Section 4-2), so that the likelihood of a LOS being cloudy or cloud-free may be determined.

The data base is divided into the 30 geographic regions shown in Figure 2-4. Two regions of interest were selected. One of these is region 11 of the global data bank which is a temperate continental region and characterizes the northeast United States and western Europe. The second region is region 4 which is a tropical maritime region and includes, for example, the Hawaiian Islands. For each region, five subsets of the total data base have been selected for use in ROSCOE to provide a total of 10 user options. They are, for each region, the annual average, the winter day average, the winter night average, the summer day average, and the summer night average. For each of these options there is available the probability of occurrence of each of the 14 cloud types singly or in multiple layers, for each of the four cloud-coverage categories, and a probability for cloudless skies. An eleventh option permits the user to construct his own cloud-type occurrence probability table, it being required only that he utilize the same 14 cloud types for which physical descriptions exist. This option permits the user to examine the effect of any one of the cloud types and permits construction of cloud scenes characteristic of the information contained in weather reports or other cloud descriptions.

In the statistical cloud data base there are seven types of low-altitude clouds, three middle types, and four high types. Allowing only one cloud type in each altitude regime, the possible configurations include clear, the 14 types alone as a single layer, 61 combinations of two types in double layers, and 84 triple-layer combinations of three types. Thus 160 configurations are possible, neglecting the possibility of considering the four fractional cloud-coverage categories as the basis of a further factor of four.

This last consideration is avoided by treating only two aspects of each configuration, namely the possibilities of a cloud-free line-of-sight (CFLOS) along the ROSCOE user's LOS and of a LOS obscured by clouds. In the latter case, the clouds are assumed to be extensive in horizontal dimension so that the radiation transfer is the same as for plane parallel

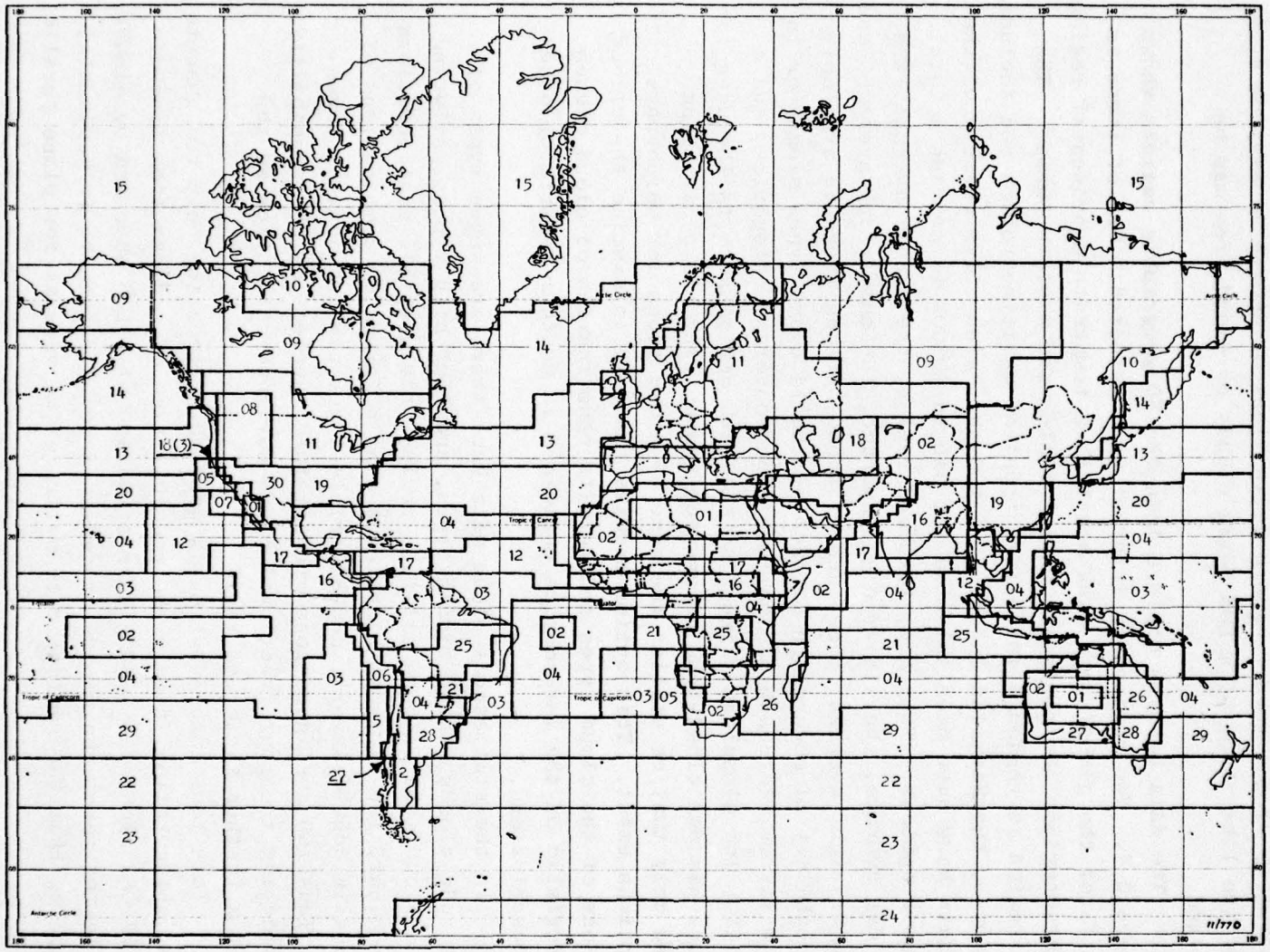


Figure 2-4. Geographic regions of the NASA worldwide cloud data bank.

layers of infinite extent. This is consistent physically with most fractional coverage cases, i.e., the cloud patches are large and the gaps are large. Thus only 160 possible configurations must be addressed.

For the ROSCOE-IR statistical cloud model it was required to provide spectral radiance quantities along the selected line-of-sight, namely radiance quantities arising from NUDET sources, solar reflection, and cloud emission. In order to retain an interface with the main program similar to that of the deterministic cloud model, the effects of NUDET and solar sources were to be returned separately as transfer coefficients, with units of sr^{-1}, and the emission was to be returned separately as a spectral radiance in units of watt km^{-2} sr^{-1} μm^{-1}.

Since the number of possible configurations of clouds is so large, it was decided not to transfer from the main program to the statistical cloud routine and back again for each possible cloud configuration but rather to loop through the configurations, each having its own probability, within the cloud routine and to return to the main program the probability distribution of radiance results.

The probability distribution is the result of the fact that each of the 159 cloudy configuration cases has a probability, or frequency weight, which can be determined from the ratio of the frequency of observed cases of this configuration to the total number of observations. These frequencies are in the data base.

The weights of each configuration are adjusted to take account of the probability of a CFLOS. The weight W(i) for the LOS intersecting the i-th cloudy configuration is thus

$$W(i) = \sum_{cc=2}^{5} W(i)_{r,cc} \, [1-CFLOS_{cc}(\theta)]$$

where $W(i)_{r,cc}$ is the raw weight of the i-th configuration by type, layers, and coverage-category cc and $CFLOS_{cc}(\theta)$ is the probability for a CFLOS at the zenith angle θ and fractional coverage index cc. The CFLOS probabilities are derived from Lund's tables of CFLOS probability for all cloud types combined as a function of zenith angle and fractional coverage (Reference 3). The weight assigned to the clear line-of-sight is then

$$W(\text{clear}) = P(cc=1) + \sum_{i=1}^{159} [1-W(i)]$$

where P(cc=1) is the weight of the clear cloud-coverage category (no clouds) and the sum represents the gap contributions from the partial coverage configurations. A more detailed treatment of these equations is given in the discussion of subroutine CLDWT in Section 3-2.

The statistical cloud routines then perform the appropriate calculation of radiation transmission for 159 configurations of cloud cover and for clear conditions and assign to each the probability weights, W(160) = W(clear) being the clear line-of-sight weight. The result is a distribution of 160 values of the radiance-related quantity calculated, each with its weight, or probability. The distribution is summed to provide an integral or cumulative distribution and radiance-related values from this cumulative distribution and provided as output at designated optional fractile values of probability provided as input in the call. W(clear), known in the code as PCFLOS, is also provided as an output, to be used as an approximation to the probability of a CFLOS to a NUDET source within the detector's field-of-view and below 12-km altitude.

The radiance-related quantities follow the same system as those of the deterministic cloud model, except that distributions rather than single values are the output. For NUDET sources and for the sun, the output is a distribution in transfer coefficients which, when multiplied by the (unattenuated) spectral irradiance at the transfer point from the source, results in a distribution of spectral radiances along the line-of-sight. The required spectral radiance L_λ and the transfer coefficient are related by the expressions

$$L_\lambda = TCOEF_\lambda \cdot \begin{cases} \dfrac{S_\lambda}{4\pi R_{st}^2} & \text{(source)} \\ E_\lambda & \text{(sun)} \end{cases}$$

where S_λ is the isotropic point-source spectral power, R_{st} is the source-to-transfer-point distance, and E_λ is the solar irradiance. The cloud thermal emission output, however, is an actual radiance in units of watt $km^{-2}\mu m^{-1}sr^{-1}$ rather than a coefficient, because the thermal emittance is not related to NUDET or solar source strengths but depends solely on cloud temperature and emission properties. Again, as for the deterministic case, the NUDET, solar, and thermal emission outputs are provided separately.

Figure 2-5 is indicative of the geometry of the statistical cloud problem. One or more cloud layers for each of the 159 configurations will lie somewhere between 0.15-kilometer and 12-kilometer altitude. These are the base of the stratus and the top of the cumulonimbus-3 cloud models, respectively. In addition, a point source will be located somewhere in the figure such as at S1, S2, or S3. The source location will be either below the base of the lowest cloud, somewhere in the region occupied by one or more cloud types, or above the top of the highest cloud. A method has been developed for treating each of these cases. As a matter of fact, during the progression upward of a fireball from a low-altitude explosion, the source will progressively occupy each sort of location relative to the cloud region.

The statistical cloud program calculates the irradiance-to-radiance transfer coefficient along the reverse LOS at a transfer point, tp, which is chosen to be the intersection of the LOS with the 12-kilometer altitude plane, because all cloud tops lie at or below this point. By treating the atmospheric transmission problem in the cloud region within the cloud subroutines, as discussed later, it is possible to avoid having the main program integrate along the LOS to each of the 159 cloud-top altitudes in the entire statistical problem.

In addition to NUDET sources the sun as a radiation source is also indicated in Figure 2-5. For each of the 159 cloud configurations the sun illuminates the highest cloud top of the configuration and by reflectance contributes to the radiance along the LOS. The transfer coefficient corresponding to this solar reflected radiance is again a distribution of 160 points and is provided as a separate output distribution from that of a NUDET source. Note, however, in the 160-point distribution, there are only 10 different values (nine for clouds, one for Earth) because (a) there are only nine different cloud-top altitudes

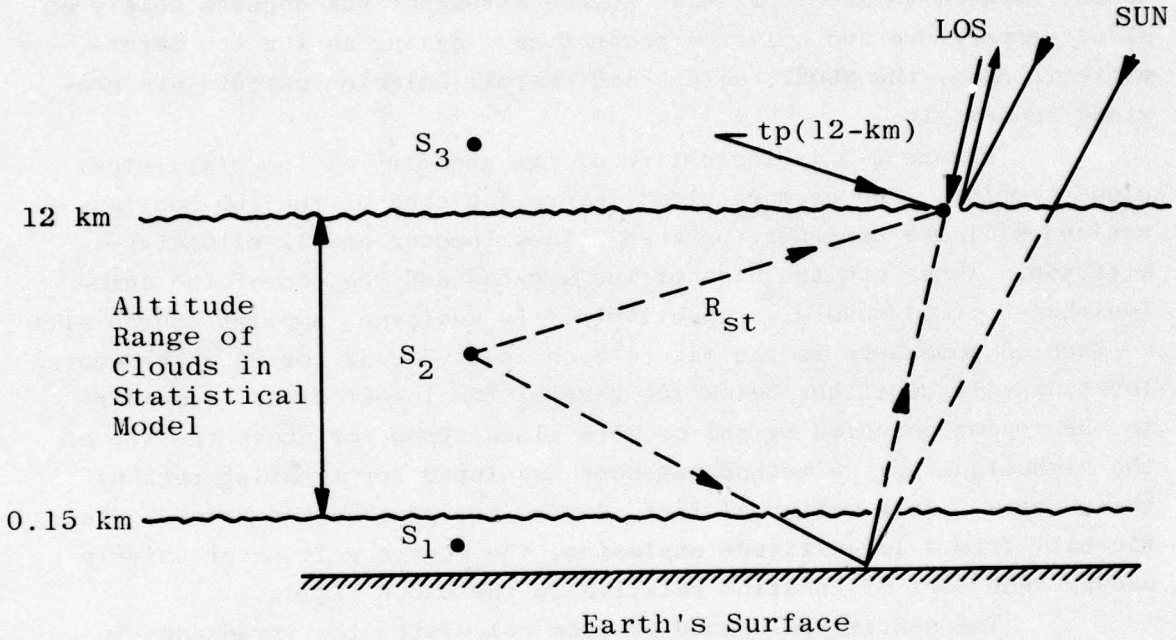


Figure 2-5. Statistical cloud geometry.

(cf. Table 2-1) and (b) the bidirectional reflectance of any cloud is assumed to be approximated by that for cloud-type 4 (stratocumulous).

In addition to the LOS intersecting cloud tops in the 159 cloud configurations, there is the probability of a CFLOS to the Earth's surface, which acts as a solar reflector and as an emitter. The surface may be sunlit or not, the probabilities depending on the probability of a CFLOS to the surface point from the sun. The contribution of the surface reflectance is weighted by the product probability of a two-leg CFLOS.

Finally, as in the case of the deterministic clouds, the statistical cloud tops are emitters which contribute to the radiance along the LOS. The cloud top for each configuration is treated as a blackbody-spectrum emitter at the temperature of the cloud top and with directional emissivity equal to $(1-\rho_d)$ as in the deterministic case. (The directional emissivity computed for cloud-type 4 (stratocumulous) is used for all cloud types.) This emission radiance distribution is again carried separately from the NUDET source and the solar distributions. The surface is again the 160th point in this distribution. As in the solar reflectance case, there are only 10 different values in the 160-point distribution.

A summary guide to the distributions available from the statistical cloud model is given in Table 2-2.

Figure 2-6 is a schematic of one of the calculations. A point source lies below a plane parallel cloud. By the solution of the diffusion problem in cylindrical geometry, described in Section A-2.1.3, the spectral flux leaving the cloud top is calculated and has a bell-shaped radial distribution as indicated in (a). The outgoing flux (radiant exitance or emittance) at the cloud top, J_+, is given by a sum of weighted Bessel functions (Equation (30a), with $Q = S/2$) and the radiance, L, is just this flux divided by π, since the angular distribution is taken to be diffuse. The radiance at the point where the LOS intersects the cloud top is calculated and divided by the cloud-free normal irradiance at the transfer point, TP, to give a transfer coefficient with units of sr^{-1} as in the deterministic case. That is,

$$TCOEF_\lambda = \frac{4\pi R_{st}^2 L_\lambda \tau_\lambda}{S_\lambda}$$

Table 2-2. Guide to distributions from the statistical cloud model.

IDX	LOS Terminates On	Thermal Emission, Radiance $W/(km^2\ sr\ \mu m)$	Solar Source Transfer Coeff., sr^{-1}	Artificial Source Transfer Coeff., sr^{-1}
1 to 159	Clouds	a	c	e
160	Earth	b	d	d

[a]Each emission in the set of 159 is from the top of the uppermost cloud layer and is attenuated along the path to the transfer point at 12-km altitude. There are nine distinct values among the 159 values of such radiance corresponding to the nine different cloud-top altitudes.

[b]The emission is from the Earth's surface (the nature of which can be specified) and is attenuated along the path to the transfer point at 12-km altitude.

[c]Each of the transfer coefficients in the set of 159 corresponds to the bidirectional reflectance of the uppermost cloud layer for the incident- and reflected-photon geometry and includes air transmittance along those portions of the incoming and reflected paths below 12-km altitude. The nine distinct values among the 159 values of such transfer coefficients correspond to the nine different cloud-top altitudes.

[d]The transfer coefficient corresponds to the bidirectional reflectance of the Earth's surface for the incident- and reflected-photon geometry and includes air transmittance along the incoming- and reflected-photon paths below 12-km altitude. The weight for this case includes the (product) probability of a two-leg CFLOS instead of a one-leg CFLOS as for the thermal emission case.

[e]A given transfer coefficient may correspond to either (a) transmittance through cloud layers between the source and the transfer point or (b) bidirectional reflectance from the uppermost cloud layer below the source. Thus the distribution will include a combination of the above two types of transfer coefficients for a source above the lowest cloud-top altitude (1.0 km) and below the highest cloud-top altitude (12.0 km). For each transfer coefficient one includes air transmittance along those portions of (nominal) paths below 12-km altitude.

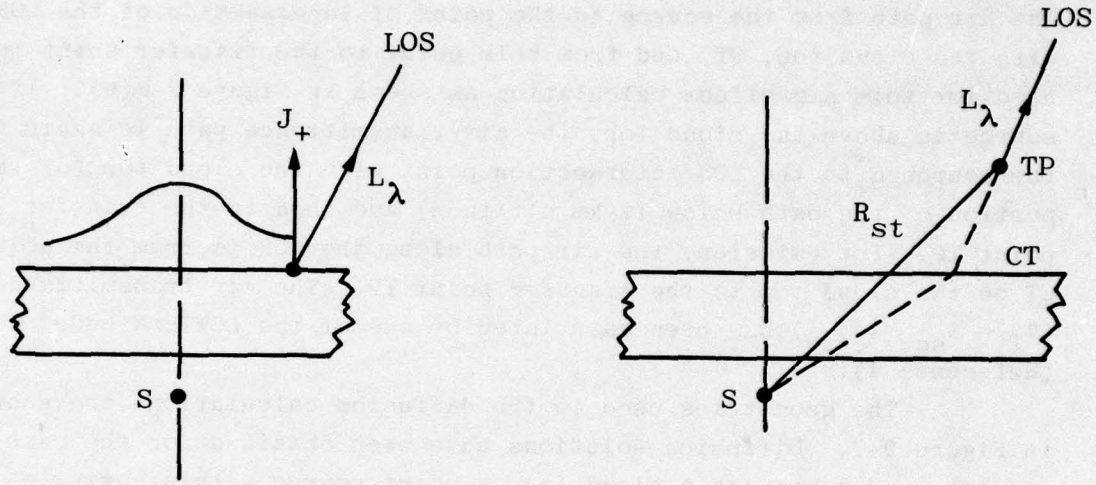


Figure 2-6. Typical statistical cloud geometry. (a) shows the bell-shaped radial distribution of flux, J_+, leaving the cloud top and (b) shows the source-to-transfer-point distance R_{st} and the air transmittance path S-CT-TP.

Since, for statistical clouds in contrast with deterministic clouds, the main-program integration of radiance along the LOS does not extend below 12 kilometers, the air transmission reduction of the source radiance is approximated within the cloud model and reduces the cloud-top radiance, L_λ, prior to calculation of the transfer coefficient. The air path from the source to the point of intersection of the LOS with the cloud top, CT, and from this point to the transfer point is used for this air-effect calculation as shown in Figure 2-6(b). If the source is above the cloud top, the air-transmittance path is again from the source S to the LOS intersection point with the cloud top (or that portion of the path below 12-km altitude) and then to the transfer point TP. For emission, the air path along the LOS is from the point CT on the cloud top to the transfer point TP. The air transmittance ($\tau_\lambda = \tau_{sct}\ \tau_{cttp}$) has been calculated by use of the LOWTRAN code (Reference 4).

The geometries used in the diffusion calculations are shown in Figure 2-7. Diffusion solutions have been obtained for the case of a point source beneath a cloud (a), a point source within a single-layer cloud (b), and for a point source at or below the base of a multi-layered configuration of any number of layers (c). These three cases handle the necessary configurations with two exceptions. First, the cloud-type descriptions do not necessarily result in the base of an upper cloud coinciding with the top of a lower cloud so that gaps or overlaps exist between multiple layers. When this occurs the base of the higher layer is adjusted to coincide with the top of the layer below, the optical thickness of the upper layer being retained by adjustment of the particle number density. In this manner a continuous multi-layer medium is created which is compatible with the available diffusion solutions. Second, when the source lies within a cloud member of a multiple layer as shown in Figure 2-7(d), the cloud region below the source is neglected (truncated) so that the problem is reduced to that of Figure 2-7(c) with the source on the bottom surface. (The two adjustments are not commutative. In the code, we have implemented the second adjustment before the first.) The truncation modification is expected to cause about a 10% reduction in the cloud-top radiance, this being the approximate magnitude of the albedo* for these

*See function RHOEPS for a tabulation at 10 wavelengths of the hemispherical-directional reflectance, or equivalently, directional-hemispherical reflectance.

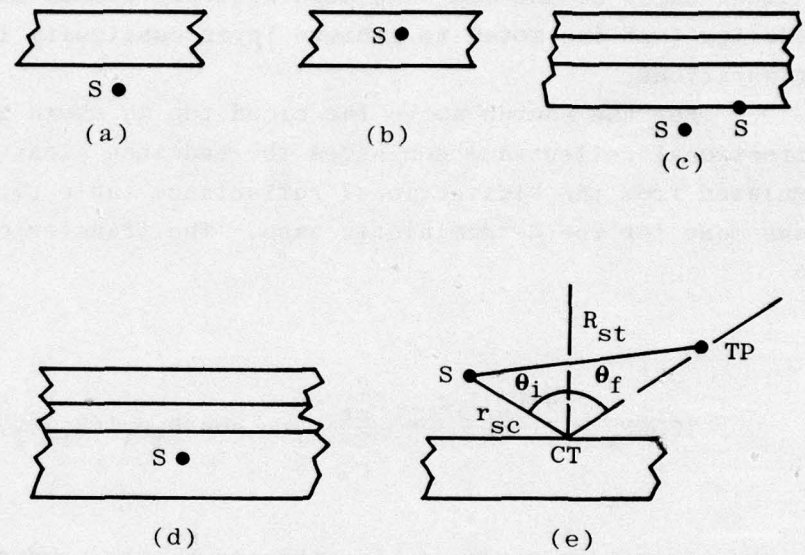


Figure 2-7. Diffusion and reflectance geometries for statistical clouds. Diffusion solutions have been obtained for Cases (a), (b), and (c). Case (d) is treated approximately by truncating the cloud region below the source, thereby converting it to Case (c) with source on surface. The solution for the transmitted photon flux is given by Equation (30a) for Case (a), by Equations (26b) and (40a) for Case (b), and by Equations (69) and (70) for Case (c). Note that Cases (a) and (b) become identical for the source on the surface (h=0). In this regard, one can verify that for h=0, Equation (40a) becomes identical to Equation (29a) provided Q in Equation (29a) is set equal to one-half of the isotropic source strength, S. In Equation (40a), S is tacitly unity.

clouds in the two- to five-micron region. A reflecting layer of albedo ω below the source increases the cloud-top radiance by a factor of about $1/(1-\omega)$, as shown at the end of Appendix D.

Figure 2-8 shows the assumed altitude range of each of the 14 cloud types for single-layer configurations. The dashed lines at the lower edges of the mid- and high-altitude clouds depict the boundaries that are moved to achieve layer contiguity in multilayer configurations.

For the source above the cloud top as shown in Figure 2-7(e), bidirectional reflectance dominates the radiance along the LOS and is calculated from the bidirectional reflectance table (Function CLDBDR) as was done for the deterministic case. The transfer coefficient is then

$$TCOEF_\lambda = \frac{4\pi R_{st}^2 L_\lambda \tau_\lambda}{S} = \frac{R_{st}^2}{r_{sc}^2} \tau_i \tau_r \cos \theta_i \rho_\lambda'(\theta_i, \theta_f, \phi) \quad .$$

Here the air transmittance τ_λ is taken to be the product of the transmittances τ_i and τ_r along those portions of the incoming and reflected paths below 12-km altitude.

Examples of statistical cases are given in Section 4 and show both the radial distribution of radiance across the cloud tops and examples of the probabilistic distributions in radiance arising from the many possible cloud configurations.

Through use of the statistical cloud model the user may obtain three separate distributions for spectral radiance from NUDET sources, from the solar source, and from thermal emission backgrounds. It is rather obvious but perhaps worthy of note that these distribution data are more complex quantities than would be the three simple radiance values from a completely deterministic case. The three simple radiances, for example, can be added to give the total radiance which would be observed by a sensor. They can be divided to give ratios of signal-to-noise, signal-to-solar background, etc. Such quantities are often important measures of sensor effectiveness.

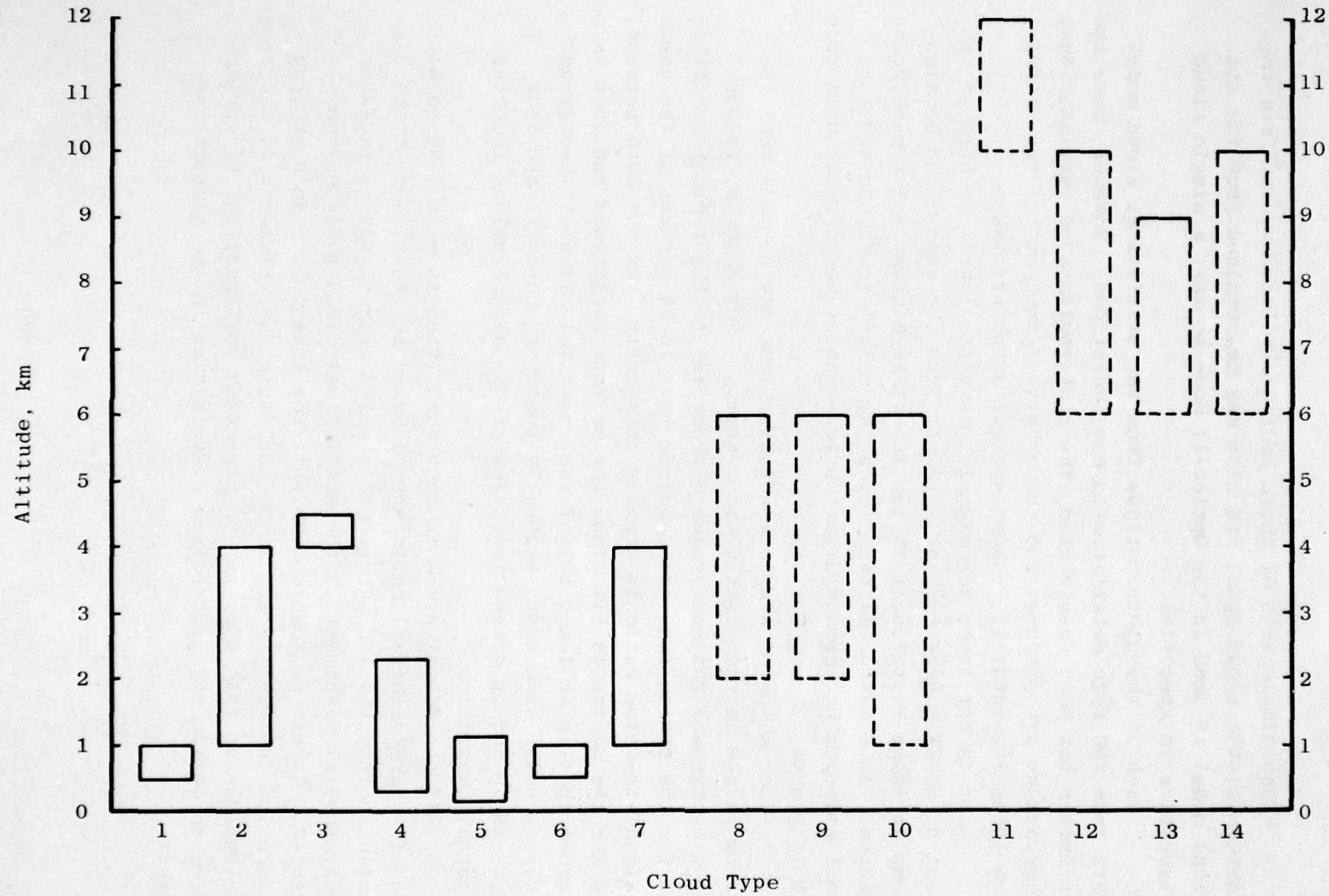


Figure 2-8. Altitude ranges of single-layer cloud types.

Such simple sets of three radiance values are obtained from the deterministic cloud model and also may be obtained from the statistical model if used in the Option-11 mode so that a single cloud configuration is specified.

Each of the distributions from the statistical cloud model results from 160 such deterministic configurations. However, once the distribution has been constructed, the contributions of the individual configurations are obscured and the origin of any part of the distribution loses its identity, unless special steps are taken.

It is not true, for example, that the lowest or highest ten percent of NUDET source radiances result from the same cloud configurations as those that result in the lowest or highest solar background radiances. As a matter of fact, even the solar background and the thermal emission background distributions cannot be correlated in such a simple manner.

Some kinds of simple generalizations may be made when the radiance values in the distributions permit. For example, if the highest background radiance value corresponds to the tenth percentile value for the source, one can conclude that in 90 percent of the cases the signal-to-noise ratio is greater than unity. If the 50th percentile value for the source is six times the maximum background radiance value, one knows that in at least 50% of the cases the signal-to-background ratio is greater than six. Generally speaking, however, the user cannot simply add or divide fractiles of the distributions to obtain meaningful quantities.

If the distribution in such quantities as signal-to-noise ratio of solar-to-thermal ratio are of prime interest, and if the distributions of signal and background overlap appreciably in radiance values, special treatment of the statistical cloud model may be warranted. It may be most convenient, for example, to do a program modification to identify and store the individual elements of the three distributions so that they may be processed configuration by configuration to obtain the probability distribution in the quantity of interest.

SECTION 3
COMPUTER PROGRAM DESCRIPTION

3-1 INTRODUCTION

The main (or driver) program ROSCOER is intended to demonstrate the utility of the ROSCOE-IR cloud computation procedure and to facilitate integration of the subroutines into ROSCOE-IR. All requirements of the computational procedure are met in ROSCOER to provide a stand-alone code and to provide a guide to the intended use of the subroutines. All overall program flow is illustrated in Figure 3-1.

Data provided by ROSCOE-IR (such as source, detector, and sun location) are read by the driver program ROSCOER or are entered via data statements. Calls to the deterministic and statistical cloud submodules are illustrated via ROSCOER. There is no preferential looping on lines-of-sight, wavelength, or cloud number. The calling program, ROSCOER, simply demonstrates how the code can be used. The deterministic check case (Problem 6 in Section 4) loops over the 64 possible lines-of-sight* at the second wavelength in the wavelength table, i.e., $\lambda = 2.5$ μm. A check case for the statistical cloud submodule (Problems 1 to 4, Section 4) loops over as many as 161 lines-of-sight at one-quarter kilometer intervals from the source normal to the lines-of-sight. The transfer coefficient is integrated with proper conversions to give a total transmission

Several parameters are initialized by statements in the main program only as a means of checking the code calculations and demonstrating its utility. The user will necessarily obtain this information by a replacement of this main program. A call to subroutine CLOUDO obtains data that are required only by the cloud package and establishes the mode to be that of either a statistical cloud data base or a set of deterministic clouds. Deterministic cloud properties are still obtained from the preprogrammed data base; however, sizes and shapes, within the ellipsoidal constraint, and locations are to be provided by the user.

*The number of lines-of-sight returned by subroutine LOS has been reduced from a maximum of 64 to a maximum of 16 by incrementing the facet-center indexes by 2's, a procedure that appears to be adequate.

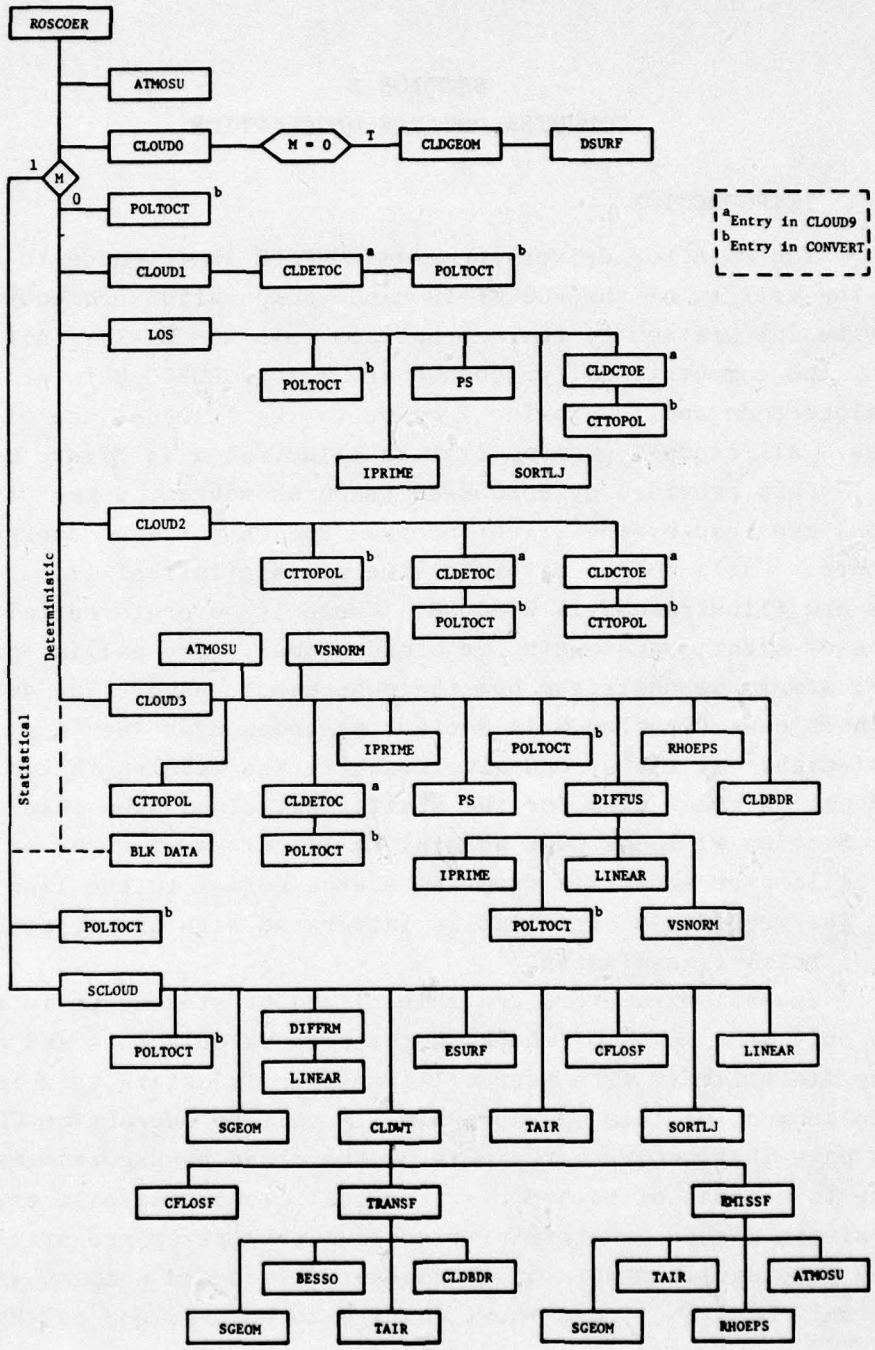


Figure 3-1. Flow chart of ROSCOE-IR cloud module.

The transfer coefficients for the calculations will, of course, be multiplied by a source irradiance to obtain a radiance in the direction of the detector at the transfer altitude of 12 kilometers (for statistical clouds). This coefficient, as well as the emission, has included in it the atmospheric transmission, in both directions, if appropriate, from the 1962 U.S. Standard Atmosphere as calculated from LOWTRAN 3 (Reference 4). No atmospheric attenuation is included in the deterministic case because it will be computed by the line-of-sight integration module in ROSCOE-IR.

Parameters such as lines-of-sight and wavelength are also user defined. A table of wavelengths is provided in common CDDATA at which cross sections are tabulated. This list provides a set of possible wavelengths to check out the code and to make specific calculations. The only restriction on wavelength is that it be between two and five microns.

A line-of-sight must be provided to both the deterministic and statistical subroutines. Possible lines-of-sight are provided for deterministic clouds by a call to subroutine LOS. These are, in turn, available in common LOS. A maximum of 64 lines-of-sight are returned. This table is terminated by zeros in the altitude array HLOS. Any or all of these lines-of-sight are appropriate for subsequent deterministic calculations.

Since a statistical cloud is infinite in lateral extent, there is no mechanism to relate the detector line-of-sight to the cloud. One usually has a particular scenario which directs which way the detector is looking and it is this consideration which gives rise to the input for statistical clouds. There is, however, little reason to make transmission calculations for horizontal distances in excess of five times the source to cloud-top distance. This situation may occur in statistical cases where the transmission is negligible; however, the code doesn't bother to eliminate the calculation.

The routines called to get an answer are CLOUD3 (UL,VL,WL,K, ALAM,TCOEF,EMISS,SINCLD) for deterministic clouds and SCLOUD(ALAM,UL, VL,WL,ISUN) for statistical clouds, where UL,VL,WL are the direction cosines of the LOS, ALAM is the wavelength in microns, TCOEF is the irradiance-to-radiance transfer coefficient at the intersection point of the LOS and cloud-K, EMISS is the thermal emission from the cloud

at the intersection point, and ISUN is a flag to distinguish between an artificial source and the sun. Common PTE variables must be initialized and utilized as follows:

(Input)

P1,P2,P3,P4 - four probability levels (fractiles) for which transfer coefficients and thermal emission are required.

(Output)

T1,T2,T3,T4 - four transfer coefficients corresponding to the P1,P2,P3,P4 above.

E1,E2,E3,E4 - thermal emission corresponding to P1, P2,P3,P4 above.

S1,S2,S3,S4 - four transfer coefficients corresponding to P1,P2,P3,P4 above for the sun as a source.

PCFLOS - probability of the detector seeing the artificial source, either with or without clouds being present, provided the source is within the field-of-view.

3-2 DESCRIPTION OF SUBROUTINES

A summary of the information necessary to execute each of the subroutines is provided in this section. Some of the subroutines are documented to a greater extent than otners as the use of many is self-evident.

3-2.1 Program ROSCOER

The driver program ROSCOER is used to provide test cases for the deterministic and statistical cloud submodules. Data are read for the locations of the source and detector. A call to CLOUD0 reads the data which are required by the cloud module. Branching is directed by a mode flag to the submodules.

The deterministic mode is illustrated by a call to subroutine LOS and subsequent calls to subroutine CLOUD3 for the lines-of-sight determined by LOS. The statistical mode is illustrated by a series of lines-of-sight providing a function which is subsequently integrated across the cloud top to give total transmission.

3-2.2 Subroutine ATMOSU(JJ,ZH)

This subroutine, a dummy routine for the real one (see the ROSCOE Manual, Volume 14a-1), provides the atmospheric density (g/cm^3) and temperature (degrees K) as a function of altitude (km). The common ATMOUP is utilized with the fifth and sixth locations being the density and temperature. The calling sequence is (2,ZH), ZH being the altitude. The value of 2 for JJ denotes an operational call, allowed after ATMOSU has been initialized earlier with JJ=1. The density and temperature are provided by simple expressions:

```
RHO = 1.225E-3 * EXP(-ZH/9.)
T = 288. -ZH * 6.5
```

3-2.3 Function BESS0(X)

This routine provides the zero-order cylindrical Bessel function per formulas 9.4.1 and 9.4.3 in the NBS Handbook (Reference 5).

3-2.4 Block Data

This BLOCK DATA set contains the extinction (SIGT(10,14)) and scattering (SIGS(10,14)) cross-sections and the average cosine of the scattering angle (XMUBAR(10,14)) for the 14 cloud types. Units for the cross sections are square microns; cloud droplet number density is in reciprocal cm^3. The code uses km^{-1} as macroscopic cross-section units with the conversion from microscopic cross-sections being

$$\sigma_x(km^{-1}) = \sigma_x(\mu m^2) \times N(cm^{-3}) \times \frac{10^{-8} cm^2}{\mu m^2} \times 10^5 \frac{cm}{km} .$$

SIGT, SIGS, and XMUBAR are tabulated at 10 wavelengths from 2 to 5 microns. The entries were calculated by Mie theory[a] using cloud properties from Fowler (Reference 1) and given in Table 2-1.

Also tabulated are cloud coverage, CCOVER(5,11), and frequency, CFREQ(17,4,11), data for the statistical module.

[a]See the comment at the end of Section 3-2.16 for an exception to this statement.

CCOVER(1,K) is frequency of clear sky
(2,K) is frequency of cloud-coverage category 2
(3,K) is frequency of cloud-coverage category 3
(4,K) is frequency of cloud-coverage category 4
(5,K) is frequency of cloud-coverage category 5

where K is the model (i.e., time, region) discussed in Section 2-2.

CFREQ(I,J,K), I=1,17; J=1,4: K=1,11

CFREQ(1,J,K) is frequency of Cu1
(2,J,K) is frequency of Cu2
(3,J,K) is frequency of Cu3
(4,J,K) is frequency of Sc
(5,J,K) is frequency of St
(6,J,K) is frequency of Cb1
(7,J,K) is frequency of Ns
(8,J,K) is frequency of Ac
(9,J,K) is frequency of As1
(10,J,K) is frequency of Cb2
(11,J,K) is frequency of Cb3
(12,J,K) is frequency of As2
(13,J,K) is frequency of Ci
(14,J,K) is frequency of Cs

where $\sum_{I=1}^{14} \text{CFREQ}(I,J,K) = 1$

CFREQ(15,J,K) is frequency of 1 layer
(16,J,K) is frequency of 2 layers
(17,J,K) is frequency of 3 layers

where $\sum_{I=15}^{17} \text{CFREQ}(I,J,K) = 1$

J is the cloud-coverage index and K is the model number.

3-2.5 Function CFLOSF(ICC,ANGLE)

This function obtains a value for the probability of a cloud-free line-of-sight from a table by Lund and Shanklin (Reference 3). The array is tabulated for cloud coverage (in 10ths) and for zenith angles in 10-degree increments from 0 to 90°. The table is for all cloud types combined.

The calling sequence requires the cloud-coverage index ICC to be an integer in 10ths and the angle in degrees.

INPUTS:

ICC-1 - cloud coverage (10ths)

ANGLE - zenith angle in degrees

OUTPUT:

CFLOSF - probability of a cloud-free line-of-sight at a given zenith angle for the requested cloud-coverage index ICC

Cloud coverages reported in tenths were grouped into five caregories by the authors of Reference 1 (p.3):

Coverage category 1	0 tenths
Coverage category 2	1,2,3 tenths
Coverage category 3	4,5 tenths
Coverage category 4	6,7,8,9 tenths
Coverage category 5	10 tenths

In our cloud model the decimal cloud-coverage fractions of 0.0, 0.3, 0.5, 0.8, and 1.0 are assigned to the cloud-coverage categories 1,2,3,4 and 5, respectively.

3-2.6 Function CLDBDR (CTHIN,CTHOUT,CPHOUT,ALAM,KCLOUD)

This function contains tables of bidirectional reflectances for a stratocumulus cloud. The data are tabulated in forty-five equal solid angle bins at 10 wavelengths from 2 to 5 microns. The bi-directional reflectance has units of sr^{-1}. In the calling sequence the variables are:

CTHIN - cosine of incident zenith angle

CTHOUT - cosine of exit zenith angle

CPHOUT - cosine of the azimuthal angle between the incident and exit planes

ALAM - wavelength, μm

KCLOUD - not used.

A linear interpolation is performed between wavelengths but no angular interpolation is utilized.

3-2.7 Subroutine CLDGEOM

Required bookkeeping for cloud "facets" is accomplished in this routine. See Figure 3-2 for a flow chart. A maximum of 20 deterministic clouds can be considered in a given job. Areas of the facets, radii to their centers, coordinates of the boundaries, and coordinates of the centers are evaluated and stored in common CDCORD for use by other routines. There is no requirement for user interaction with this subroutine, unless he wants to consider the irradiance on a particular facet and facet orientation to the source and detector. To do so would require a code modification.

Coordinates of the facets are computed according to the prescription:

$$\theta_1 = 0$$

$$\theta_2 = \frac{\pi}{2} \frac{1}{1 + (R1)^{\alpha} + (R1)^{2\alpha} + (R1)^{3\alpha}}$$

$$\theta_3 = [1 + (R1)^{\alpha}]\, \theta_2$$

$$\theta_4 = \frac{\pi}{2} - (R1)^{3\alpha}\, \theta_2$$

$$\theta_5 = \frac{\pi}{2}$$

$$\Delta = \frac{\pi}{2} \frac{1}{1 + (R2)^{\beta} + (R2)^{2\beta} + (R2)^{3\beta}}$$

$$\phi_1 = 0$$

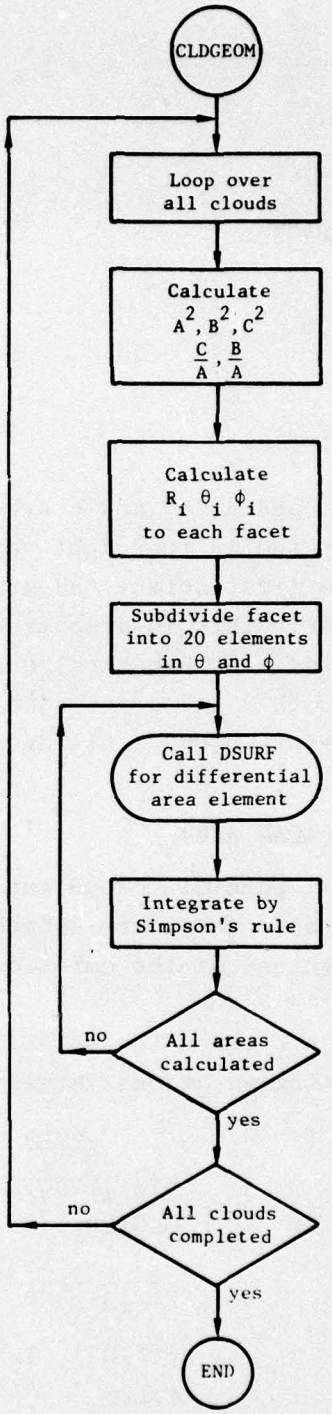


Figure 3-2. Flow chart of subroutine CLDGEOM.

$$\phi_2 = (R2)^{3\beta}\ \Delta$$

$$\phi_3 = \frac{\pi}{2} - [1 + (R2)^{\beta}]\ \Delta$$

$$\phi_4 = \frac{\pi}{2} - \Delta$$

$$\phi_5 = \frac{\pi}{2}$$

where R1 is c/a, R2 is b/a, and a, b, and c are the semi-axis lengths. These coordinates are reflected in the eight octants; consequently, they are calculated only for the first octant and are mapped to the other seven by the function IPRIME. This is also true of areas and radii.

Areas are evaluated by a numerical quadrature (Simpson's rule) using twenty intervals in both θ and ϕ for each facet. Differential area elements are calculated in DSURF. All data obtained from, and returned to, common arrays.

3-2.8 Subroutine CLDWT(ALAM,ANG)

Weightings for all possible cloud and cloud-layer combinations are evaluated in this routine. These are subsequently assigned to the transfer coefficients and values of the emission as calculated by calls to TRANSF and EMISSF.

The correspondence between the notation used in Section 2-2 and that used in the following equations is given below:

Section 2-2	Here
W(clear)	$WT_{new}(160)$
P(cc=1)	CCOVER(1)
$\sum_{i=1}^{159} [1-W(i)]$	$WT_{old}(160)$
W(i), i=1,159	WT(IDX), IDX=1,159
$CFLOS_{cc}(\theta)$	$CFLOS_c$

For any of the 10 location-season averaged cloud models (KMODEL = 1,10), WT(IDX) is the probability that (a) the cloud-configuration set indicated by the index IDX occurs and (b) the LOS at zenith angle θ_e intersects the cloud-configuration set. The total probability of the LOS intersecting clouds is

$$\sum_{IDX = 1}^{159} WT(IDX) \quad .$$

The probability that the LOS does not intersect the clouds but "sees through" the clouds is

$$WT_{old}\ (160) \quad .$$

The probability of seeing the ground without any clouds being present is

$$CCOVER\ (1) \quad .$$

(For brevity we have suppressed the index KMODEL on which the array CCOVER depends.) The probability of seeing the ground either with or without clouds being present is

$$WT_{new}\ (160) = WT_{old}\ (160) + CCOVER\ (1) \quad .$$

The probability of seeing either clouds or the ground (with or without clouds being present) is

$$\sum_{IDX = 1}^{159} WT(IDX) + WT_{new}\ (160) = 1 \quad .$$

$$WT(I) = \sum_{C=1}^{4} CCOVER(C+1)\ (1-CFLOS_c)$$

$$\bullet \begin{cases} \bullet\ CF(15,C) \bullet \begin{cases} TL \bullet \dfrac{CF(L,C)}{TL} & L=1,7 \quad I=1,7 \\[2ex] TM \bullet \dfrac{CF(7+M,C)}{TM} & M=1,3 \quad I=8,10 \\[2ex] TH \bullet \dfrac{CF(10+H,C)}{TH} & H=1,4 \quad I=11,14 \end{cases} \\[4ex] \bullet\ CF(16,C) \bullet \begin{cases} \dfrac{TL \bullet TM}{DEN} \bullet \dfrac{CF(L,C)}{TL} \bullet \dfrac{CF(7+M,C)}{TM} & L=1,7 \quad M=1,3 \quad I=15,35 \\[2ex] \dfrac{TL \bullet TH}{DEN} \quad \dfrac{CF(L,C)}{TL} \bullet \dfrac{CF(10+H,C)}{TH} & L=1,7 \quad H=1,4 \quad I=36,63 \\[2ex] \dfrac{TM \bullet TH}{DEN} \quad \dfrac{CF(7+M,C)}{TM} \bullet \dfrac{CF(10+H,C)}{TH} & M=1,3 \quad H=1,4 \quad I=64,75 \end{cases} \\[4ex] \bullet\ CF(17,C) \bullet 1 \bullet \dfrac{CF(L,C)}{TL} \bullet \dfrac{CF(7+M,C)}{TM} \bullet \dfrac{CF(10+H,C)}{TH} & L=1,7 \quad M=1,3 \quad H=1,4 \quad I=76,159 \end{cases}$$

where

$$CF \equiv CFREQ$$
$$TL \equiv TOTL$$
$$TM \equiv TOTM$$
$$TH \equiv TOTH$$
$$DEN \equiv TL \bullet TM + TL \bullet TH + TM \bullet TH$$

The probability of seeing the ground through the clouds is

$$WT_{old}\,(160) = \sum_{C=1}^{4} CCOVER(C+1) \bullet CFLOS_c \bullet \sum_{\ell=1}^{3} CF(14+\ell,C)$$

$$\bullet \left\{ \begin{array}{ll} \displaystyle\sum_{j=1}^{3} U(j|\ell=1,C) \bullet \sum_{K=KMIN_j}^{KMAX_j} \frac{CF(K|j,C)}{T_j} & \\ \qquad\qquad \text{DO-loops } 101,\ 102,\ 103 & \ell=1 \\ \displaystyle\sum_{j=1}^{2} \sum_{j'>j}^{3} V(j,j'|\ell=2,C) \sum_{K=KMIN_j}^{KMAX_j} \sum_{K'=KMIN_{j'}}^{KMAX_{j'}} \frac{CF(K|j,C)}{T_j} \bullet \frac{CF(K'|j',C)}{T_{j'}} & \\ \qquad\qquad \text{DO-loops } 200,\ 201,\ 202 & \ell=2 \\ \displaystyle W(1,2,3|\ell=3,C) \sum_{K=1}^{7} \sum_{K'=8}^{10} \sum_{K''=11}^{14} \frac{CF(K|1,C)}{T_1} \bullet \frac{CF(K'|2,C)}{T_2} \bullet \frac{CF(K''|3,C)}{T_3} & \\ \qquad\qquad \text{DO-loops } 300 & \ell=3 \end{array} \right.$$

$$= \sum_{C=1}^{4} CCOVER(C+1) \bullet CFLOS_c = \sum_{C=1}^{4} \frac{CFLOS_c}{1-CFLOS_c} \sum_{I=1}^{159} WT(I,C)$$

Here, $U(j|\ell=1,C)$ is the probability of layer j, given one layer and cloud-coverage index C

$V(j,j'|\ell=2,C)$ is the probability of layers j and j′, given two layers and index C

$W(1,2,3|\ell=3,C)$ is the probability of layers 1,2,3, given three layers and index C

These probabilities satisfy the following relations:

$$\sum_{j=1}^{3} U(j|\ell=1,C) = \sum_{j=1}^{3} T_j = \sum_{j=1}^{3} \sum_{K=KMIN_j}^{KMAX_j} CF(K|j,C) = 1$$

$$\sum_{j=1}^{2} \sum_{j'>j}^{3} V(j,j'|\ell=2,C) = \frac{\sum\sum T_j\ T_{j'}}{\sum\sum T_j\ T_{j'}} = 1; \quad W(1,2,3|\ell=3,C) = 1$$

The probability of seeing clouds $= \sum_{I=1}^{159} WT(I)$

$$= \sum_{C=1}^{4} CCOVER\ (C+1) \bullet (1-CFLOS_c) \sum_{\ell=1}^{3} CF(14+\ell,C)$$

$$\bullet \begin{cases} \sum_{j=1}^{3} U(j|\ell=1,C) \sum_{K=KMIN_j}^{KMAX_j} \frac{CF(K|j,C)}{T_j} & \ell=1 \\ \sum_{j=1}^{2} \sum_{j'>j}^{3} V(j,j'|\ell=2,C) \sum_{K=KMIN_j}^{KMAX_j} \sum_{K'=KMIN_{j'}}^{KMAX_{j'}} \frac{CF(K|j,C)}{T_j} \frac{CF(K'|j',C)}{T_{j'}} & \ell=2 \\ W(1,2,3|\ell=3,C) \sum_{K=1}^{7} \sum_{K'=8}^{10} \sum_{K''=11}^{14} \frac{CF(K|1,C)}{T_1} \bullet \frac{CF(K'|2,C)}{T_2} \bullet \frac{CF(K''|3,C)}{T_3} & \ell=3 \end{cases}$$

$$= \sum_{C=1}^{4} \text{CCOVER}(C+1) \cdot (1-\text{CFLOS}_c) \quad .$$

The probability of seeing either clouds or the ground (with or without clouds)

$$= \sum_{I=1}^{159} \text{WT}(I) + \text{WT}_{old}\ (160) + \text{CCOVER}(1)$$

$$= \sum_{C=1}^{4} \text{CCOVER}(C+1)\ [1 - \text{CFLOS}_c + \text{CFLOX}_c] + \text{CCOVER}(1)=1 \quad .$$

3-2.9 Subroutine CLOUD0(MODE)

For a detailed description of CLOUD0 see Section 4-2.

3-2.10 Subroutine CLOUD1

Coordinates of the source (XI,ETA,ZETA) and detector (XID, ETAD,ZETAD) are calculated in the Cartesian coordinate system of each cloud with the quantities stored in common CDCORD. Entry CLD E TO C in subroutine CLOUD9 is used to transform from earth to cloud coordinates.

3-2.11 Subroutine CLOUD2(UL,VL,WL)

The altitude (ALTLK(K)) and geographic coordinates (THETALK(K), PHILK(K)) of the intersection of the line-of-sight and the Kth deterministic cloud are calculated in this routine and outputted in common INTRCPT. These results are not used by other cloud-model routines. However, this routine is a convenience to the user. The sight-path integration module can use results of this routine to avoid calling the cloud transfer-coefficient routine (CLOUD3) until the sight-path integration has reached the cloud top.

The input to this subroutine are the direction cosines (UL,VL,WL) of the line-of-sight. The point of intersection is calculated for all clouds which fall in the path. A flow chart is shown in Figure 3-3.

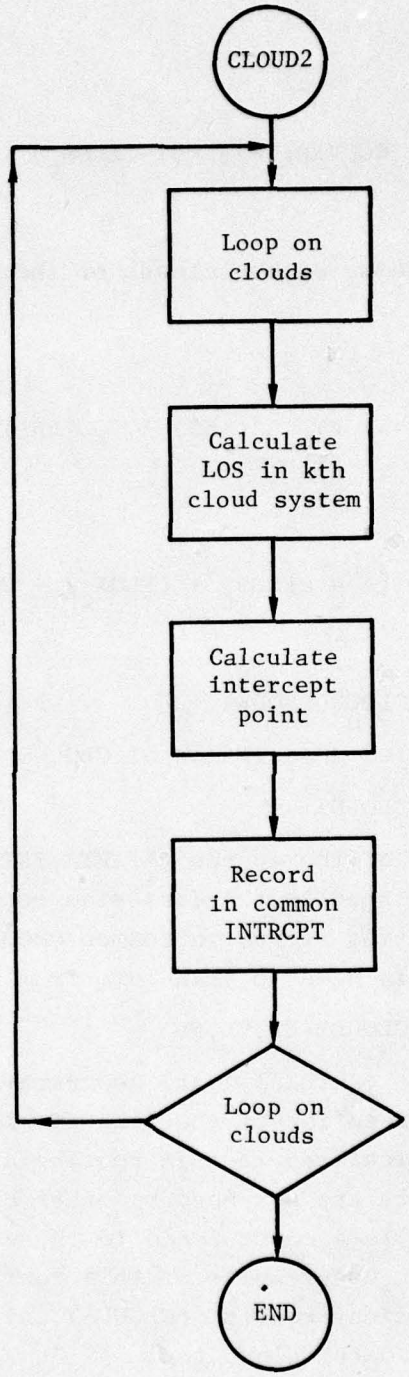


Figure 3-3. Flow chart of subroutine CLOUD2.

3-2.12 Subroutine CLOUD3(UL,VL,WL,K,ALAM,TCOEF,EMISS,SINCLD)

When all of the bookkeeping has been accomplished, CLOUD3 is called to calculate the transfer coefficient (TCOEF) and the emission (EMISS). Branching is required depending upon whether or not the point of intersection of the LOS with the cloud is visible to the source. For those LOS-intersection points which are also illuminated, the bidirectional reflectance is obtained from tables in function CLDBDR. The tabulated values are functions of incident and exit zenith angles and the exit azimuthal angle. The bidirectional reflectance is picked from a bin with no interpolation. The tables are, however, interpolated linearly as a function of wavelength.

The irradiance to all illuminated facets is evaluated. A diffusion calculation is then performed in subroutine DIFFUS to get the radiance exiting the facet of interest.

The thermal emission is calculated from the Planck distribution for the temperature at the point of intersection of the cloud top and line-of-sight.

Before the source irradiation of a cloud is computed, a check is made to determine whether or not the source is either inside the cloud or on its surface. If the source is not outside the cloud, a warning message is printed and, without further calculation, the routine returns a logical variable (SINCLD = .TRUE.) to the main program (ROSCOER) which then proceeds to the next case.

We have also devised a prescription which is used if the artificial (point) source is closer to the cloud surface than (approximately) the radius R_s that is assigned to the finite-size artificial source. Let $\vec{RP}$ be the position of the source in the cloud coordinate system and $\vec{RS}$ be the radial distance to the intersection point S of the ray RP with the cloud surface. At point S the outward unit normal is $\hat{n}(\vec{RS})$. Then, for the purpose of this routine, if

$$(\vec{RP}-\vec{RS}) \cdot \hat{n}(\vec{RS}) < R_s \quad ,$$

the source is moved in the direction of $\hat{n}(\vec{RS})$ an amount δP given by

$$\delta P = 0.5\ [R_s - (\vec{RP}-\vec{RS}) \cdot \hat{n}(\vec{RS})] \quad .$$

A message is printed with the original and altered coordinates of the source.

3-2.13 Subroutine CLOUD9(RTP1,RTP2,RTP3,EC1,EC2,EC3,K)

Transformations are made between the earth-centered polar coordinate system and the cloud-centered Cartesian system of the Kth cloud. This routine has two entry points. Entries CLD E TO C and CLD C TO E transform from earth to cloud and cloud to earth, respectively.

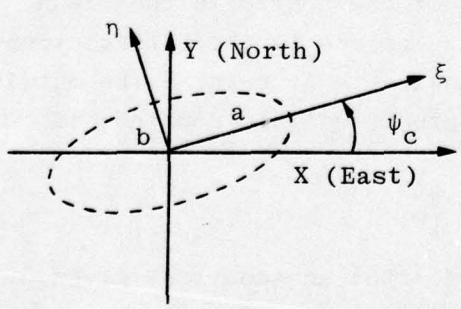
The cloud geometry is most easily described in the cloud principal-axis system (ξ,η,ζ) in which the equation of the cloud surface is

$$\frac{\xi^2}{a^2} + \frac{\eta^2}{b^2} + \frac{\zeta^2}{c^2} = 1 \quad .$$

The location of the cloud center (earth-centered polar coordinates) is (R_c, θ_c, ϕ_c) where

$$R_c = R_{earth} + H_c, \quad H_c = \text{HCLOUD (km)}$$
$$\theta_c = \text{THETCD (degrees)}$$
$$\phi_c = \text{PHICD (degrees)}.$$

Looking from above the cloud toward the earth center:



$$\psi_c = \text{CLDPSI}$$

$$\left.\begin{aligned} \xi &= X \cos \psi_c + Y \sin \psi_c \\ \eta &= Y \cos \psi_c - X \sin \psi_c \\ \zeta &= Z \ . \end{aligned}\right\} \quad (1)$$

The transformation from the earth-centered Cartesian system (x,y,z) to the non-rotated (ψ_c=0) Cartesian system (X,Y,Z) in the cloud can be performed with two rotations and one translation.

The first intermediate coordinate system (x',y',z') is obtained by making a counterclockwise (positive) rotation

$$\phi = \phi_c + \pi/2$$

about the z-axis such that the x'-axis is normal to the vector $\vec{R}_c$ to the cloud center. The ($\pi/2$)-term is introduced to make the positive X-axis of the cloud point east. The transformation is

$$\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = R_1(\phi) \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

where the transformation matrix R_1 is given by

$$R_1(\phi) = \begin{pmatrix} \cos\phi & \sin\phi & 0 \\ -\sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{pmatrix} .$$

The second intermediate coordinate system (z",y",z") is obtained by making a counterclockwise (positive) rotation θ_c about the x'-axis such that the z'-axis lies along the vector $\vec{R}_c$. The transformation is

$$\begin{pmatrix} x'' \\ y'' \\ z'' \end{pmatrix} = R_2(\theta) \begin{pmatrix} x' \\ y' \\ z' \end{pmatrix}$$

where

$$R_2(\theta) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & \sin\theta \\ 0 & -\sin\theta & \cos\theta \end{pmatrix} .$$

Finally, the non-rotated cloud system (X,Y,Z) is related to the (x",y",z") system by a translation along the z"-axis:

$$Z = z'' - R_c$$

where

$$R_c = R_{earth} + H_c \quad .$$

Collating our results we have

$$\begin{pmatrix} X \\ Y \\ Z+R_c \end{pmatrix} = \begin{pmatrix} x'' \\ y'' \\ z'' \end{pmatrix} = R_2(\theta)R_1(\phi) \begin{pmatrix} x \\ y \\ z \end{pmatrix} \tag{2a}$$

with

$$R_2(\theta)R_1(\phi) = \begin{pmatrix} -\sin\phi_c & \cos\phi_c & 0 \\ -\cos\theta_c\cos\theta_c & -\cos\theta_c\sin\phi_c & \sin\theta_c \\ \sin\theta_c\cos\phi_c & \sin\theta_c\sin\phi_c & \cos\theta_c \end{pmatrix} . \tag{2b}$$

Thus, an arbitrary point in earth-centered polar coordinates (R, Θ, Φ) has earth-centered Cartesian coordinates (x,y,z) and cloud principal-axis coordinates (ξ,η,ζ) where

$$(x,y,z) = (R \sin\Theta \cos\Phi,\ R \sin\Theta \sin\Phi,\ R \cos\Theta)$$

and the coordinates (X,Y,Z) and (x,y,z) are related by Equations (2a) and (2b). Finally (ξ,η,ζ) and (X,Y,Z) are related by Equation (1), or equivalently

$$\begin{pmatrix} \xi \\ \eta \\ \zeta \end{pmatrix} = R_1(\psi_c) \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} \quad .$$

The transformation from the cloud system to the earth system may be done by doing the same steps in reverse order and using the transposed transformation matrices.

3-2.14 Subroutine CONVERT(R,TH,PH,X,Y,Z)

This subroutine has entry points to transform from polar to Cartesian and Cartesian to polar coordinates. The entry points are POL TO CT and CT TO POL with arguments as follows:

Y - Cartesian X-coordinate
Y - Cartesian Y-coordinate
Z - Cartesian Z-coordinate
R - Radius in spherical coordinate system
TH - Polar angle in spherical coordinate system
PH - Azimuthal angle in spherical coordinate system.

3-2.15 Subroutine DIFFUS(K,ALAM)

The computations involved in subroutine DIFFUS are those from Appendix A and as described in Section 2-1. Communication with this routine is from CLOUD3.

3-2.16 Subroutine DIFPRM(ALAM)

Given a wavelength between two and five microns, this subroutine interpolates microscopic scattering and extinction cross-sections in μm^2, coverts to macroscopic cross-sections in units of km^{-1}, and records the modified diffusion parameters, as defined in Section A-1.2, for each of the 14 cloud types of the data base.

<u>INPUT</u>:

ALAM: wavelength of photon (μm)

<u>OUTPUT</u>: (common DIFFUS, arrays of 14-word length)

DALFA $\equiv$ a in Appendix A Equation (2) (dimensionless)
DBETA $\equiv$ b in Appendix A Equation (2) (km)
DKAPPA $\equiv$ K in Appendix A Equation (19) (km^{-1})

For large-particle-size clouds (i.e., cloud-types 11,12,13 and 14), the small wavelength approximations $\sigma_T = 2\pi\bar{r}^2$ and $\sigma_S = (1+W)\pi\bar{r}^2$ are used. Here, 1 and W are, respectively, the diffracted and specular-reflected components of the scattering.

3-2.17 Function DSURF(THETA,PHI,K)

Differential area elements on the surface of an ellipsoid are calculated in this routine as a function of θ and ϕ. The cloud number K must also be transmitted to the function as it obtains the ellipsoidal parameters from common CDCORD.

3-2.18 Function EMISSF(ALAM,LL,MM,HH)

This function provides the thermal emission ($W/(km^2\ sr\ \mu m)$) from clouds, attenuated by clear air to an altitude of 12 km.

3-2.19 Subroutine ESURF(THI,THR,PSI,ZKM,MSM,DD,SPCULR,ZLAM,IDAY, IFIRES,ESURFI,SFR,EPSD,TKS)

This subroutine, a dummy routine for the real one, provides the surface upwelling radiation and earth bidirectional reflectance. The description is given in Reference 6.

3-2.20 Function IPRIME(II)

This function provides a mapping of the facet areas and radii onto those of the first octant. This symmetry is utilized to obviate storing redundant data.

3-2.21 Subroutine LINEAR(XD,FXD,XX,FXX,NX)

LINEAR performs a linear interpolation with an expeditious technique to find the pair of tabular points which bound the point of interest. The interpolation is then

$$Y = Y_{i-1} + \frac{Y_i - Y_{i-1}}{X_i - X_{i-1}} (X - X_{i-1}) \quad .$$

INPUTS:

XX: array of points in independent variable

FXX: array of points in dependent variable

NX: number of points in the table

XO: value of independent variable for which dependent variable is desired.

OUTPUTS:

FXO: dependent variable at value of XO in independent variable.

3-2.22 Subroutine LOS(K)

Possible lines-of-sight from which the user can select directions are computed and stored in common LOS. There are selection rules based on several criteria. A line-of-sight must obviously intercept a cloud facet; however, the facet is not necessarily illuminated. Facets which would fall within the same field-of-view are not duplicated. See Figure 3-4 for a flow chart.

The first criterion selects first the facets which are both visible and illuminated and orders these from smallest to largest scattering angle. Those facets which are visible but not illuminated are then ordered according to their being closest to the edge of the cloud. The rationale for this ordering is that the cloud will be thinnest along the line-of-sight near the edge.

This routine can produce a maximum of 16 possible lines-of-sight. For a small cloud and large field-of-view, there could possibly be only one.

3-2.23 Function PS(X1,ET1,ZET1,THETA,PHI,K)

This function evaluates a quantity which is proportional to the dot product of the normal to the ellipsoid and a vector from the surface point to the external point. If the quantity is negative, the point is shadowed from the line-of-sight; if positive, the point is visible.

3-2.24 Function RHOEPS(ALAM,CTHETA)

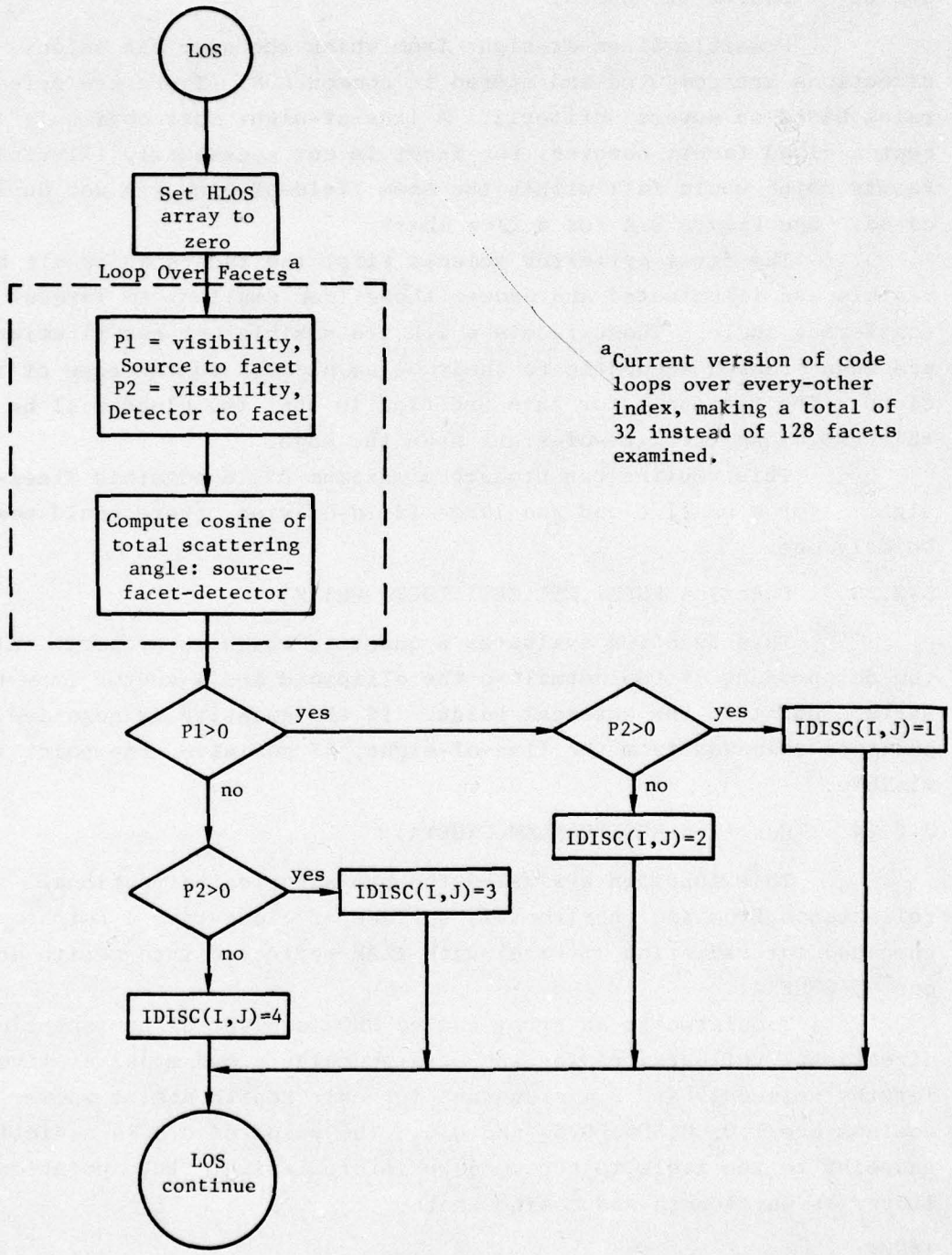
This function evaluates the hemispherical-directional reflectance from the (horizontal) surface of cloud-type 4 (stratocumulus) for radiation of wavelength ALAM reflected into zenith angle $\cos^{-1}$ (CTHETA).

Tabulated in an array called RHO is a set of hemispherical-directional reflectances for the stratocumulus cloud model at wavelengths between 2 and 5 microns and for exit zenith angles whose cosines are 1.0, 0.866, 0.5, and 0.0. The value of 0.0 is a fictitious endpoint to the table to accommodate interpolation. Interpolation is linear in wavelength and cosine theta.

<u>INPUT</u>:

ALAM: wavelength of photon (μm)

CTHETA: cosine of zenith angle for which emissivity is desired.



[a]Current version of code loops over every-other index, making a total of 32 instead of 128 facets examined.

Figure 3-4. Flow chart of subroutine LOS.

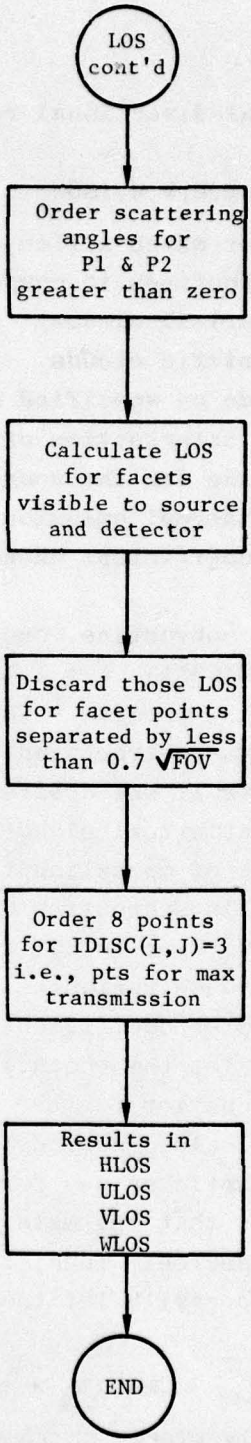


Figure 3-4. Flow chart of subroutine LOS (Cont.).

OUTPUT:

RHOEPS: hemispherical-directional reflectance .

3-2.25 Subroutine SCLOUD(ALAM,U,V,W,ISUN)

Subroutine SCLOUD, for which a flow chart is given in Figure 3-5, calls in the required subroutines to compute transfer coefficients and thermal emission for statistical clouds. A source position must be specified, just as for deterministic clouds. It is also required that the solar longitude and latitude be specified when the solar position is above the local horizon at the intersection of the line-of-sight with the earth. Calculations are made for the source (burst) and solar transfer coefficients and the thermal emission. Calculations are by-passed for the solar transfer coefficient when the sun is below the local horizon.

By interrupting this subroutine, one has access to the entire cumulative arrays (TRANS(I), EMISS(I), I = 1,160) in addition to the four fractiles returned to the calling program. This could easily become a normal mode of operation for system-type studies. Also, this (non-implemented) mode is appropriate if one desires calculations for a specific realization of the statistical cloud configurations without going to the deterministic mode of operating the code.

Subroutine SCLOUD calls subroutine CLDWT to obtain TRANS(I), EMISS(I), and WT(I) for I=1,159. For I=160, when the LOS is cloud-free and terminates on the ground, these variables are evaluated in subroutine SCLOUD. In computing the transfer coefficient for I=160, one could get arbitrarily large values if he let the (point) source get arbitrarily close to the ground (cf. the equation for the reflectance transfer coefficient for the statistical cloud submodel near the end of Section 2). To prevent getting such unrealistic values for the transfer coefficient, we have imposed the requirement that the main program assign a radius R_s to the finite-size artificial source. Then, if the altitude h_s of the source is less than R_s, we temporarily let the effective altitude of the finite-size source be

$$h_{eff} = 0.5\ (R_s + h_s) \quad .$$

Thus, if the source is initially placed on the ground so that $h_s = 0$, our prescription places the effective altitude at $0.5\ R_s$.

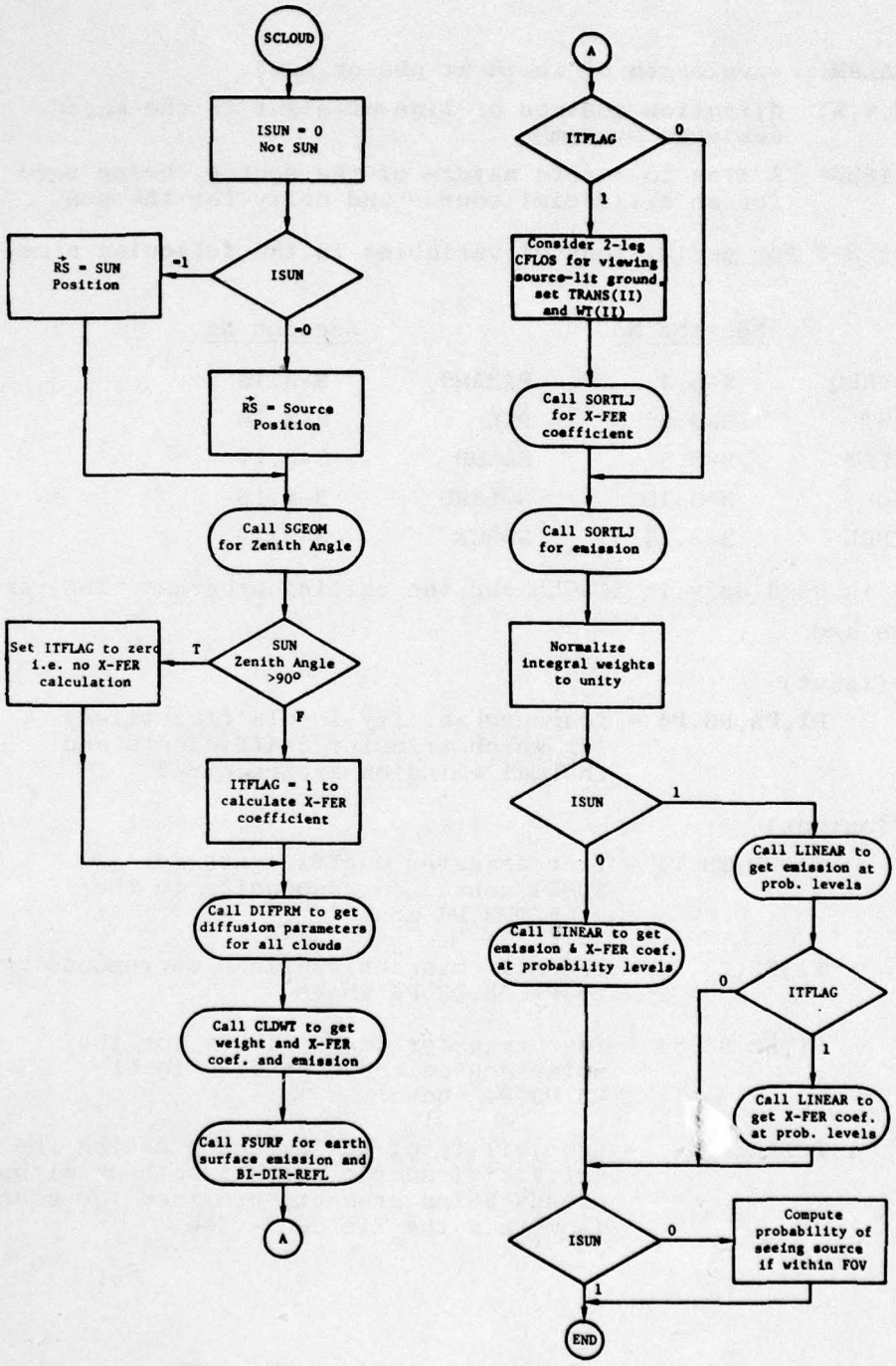


Figure 3-5. Flow chart of subroutine SCLOUD.

INPUTS:

ALAM: wavelength of incident photon (μm)

U,V,W: direction cosines of line-of-sight in the earth-centered system

ISUN: A flag to denote nature of the source, being zero for an artificial source and unity for the sun.

See Section 3-3 for definitions of variables in the following name commons:

	Section No.		Section No.
CLDFREQ	3-3.4	PARAMS	3-3.15
CLDWT	3-3.5	PTE	3-3.16
DETECT	3-3.8	SANDD	3-3.17
FLAGS	3-3.10	SOLARP	3-3.18
MATERL	3-3.14	SORCE	3-3.19

Common PTE is used only in SCLOUD and the calling program. The variable definitions are

(input)

P1,P2,P3,P4 - four probability levels (fractiles) for which transfer coefficients and thermal emission are required.

(output)

T1,T2,T3,T4 - four transfer coefficients for a NUDET source corresponding to the P1,P2,P3,P4 above

E1,E2,E3,E4 - thermal emission radiance corresponding to P1,P2,P3,P4 above

S1,S2,S3,S4 - four transfer coefficients for the solar source corresponding to P1, P2,P3,P4 above

PCFLOS - probability of the detector seeing the artificial source, either with or without clouds being present, provided the source is within the field-of-view.

3-2.26 Subroutine SGEOM(UL,VL,WL,CLDTOP,XD,YD,ZD,XS,YS,ZS,RDIST, SDIST,THETI,THETE,PHIE)

Subroutine SGEOM, for which a flow chart is given in Figure 3-6, computes the incident and exit zenith angles and the azimuthal scattering angle for a specified source and detector geometry and a given line-of-sight. Also evaluated is the distance (SDIST) from the source to the cloud-LOS intersection point and the horizontal component thereof (RDIST).

INPUTS:

UL,VL,WL: direction cosines of the line-of-sight in the earth-centered coordinate system

CLDTOP: altitude of top of cloud or other specified altitude (km)

XD,YD,ZD: rectangular components of detector position vector in earth-centered system (km)

XS,YS,ZS: rectangular components of source position vector in earth-centered system (km)

OUTPUTS:

SDIST: distance from source to intersection of line-of-sight with cloud top (km)

RDIST: horizontal component of SDIST (km)

THETI: zenith angle to source position at intersection point of LOS with CLDTOP-altitude (degrees)

THETE: zenith angle to detector position (degrees)

PHIE: azimuthal angle of scattering of photon (degrees)

3-2.27 Subroutine SORTLJ(A,B,C,N,LOHI)

This subroutine sorts an array in either ascending or descending order and carries two additional arrays with the ordering. The argument-list variables are as follows:

A is the array to be sorted

B array carried along with the sorting on A

C array carried along with the sorting on A

N is the number of elements in arrays A,B, and C

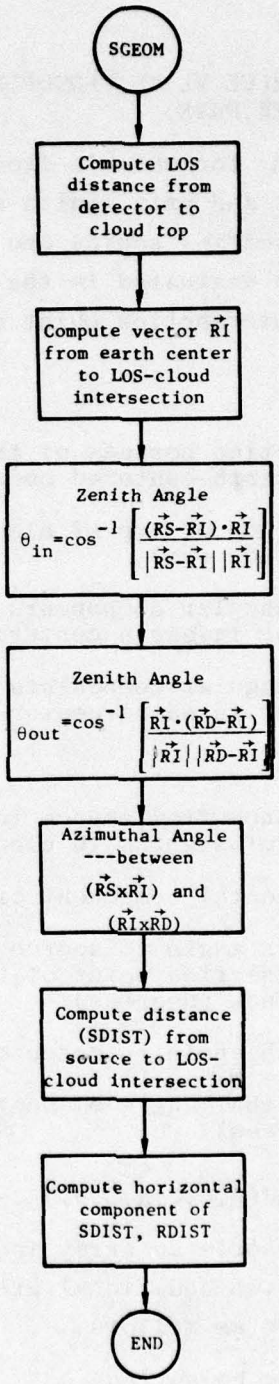


Figure 3-6. Flow chart of subroutine SGEOM.

LOHI is the ordering flag

>0 sorts from high to low

$\leq$0 sorts from low to high.

3-2.28 Function TAIR(ALAM,THETA,ALT)

Air transmittance, T, for radiation of wavelength λ from altitude h to 12 km along a path at zenith angle θ was calculated using LOWTRAN 3 for the U.S. 1962 Standard Atmosphere. The data are cataloged in this function.

The independent variables are:

wavelength: $2 \leq \lambda \leq 5$ microns

zenith angle: $0 \leq \theta \leq 85$ degrees

altitude: $1 < h < 12$ kilometers.

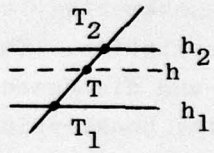
The interpolation (and extrapolation for $\theta > 85$ degrees and $h < 1$ km) used is linear in (T,λ)-, $(\ln T, \sec\theta)$-, and $(\ln T, h)$-space. More explicit formulas follow:

<u>Altitude</u>

$$T = ae^{bh}$$

$$b = \ln\left(\frac{T2}{T1}\right) \Big/ (h_2 - h_1)$$

$$a = T_1 e^{-bh_1} \quad ,$$



which implies

$$\ln T = \ln T_1 - (\ln T_1 - \ln T_2)\,\frac{h-h_1}{h_2-h_1} \quad .$$

<u>Angle</u>

$$T = ab^{\sec\theta}$$

$$b = (T_2/T_1)^{(\sec\theta_2 - \sec\theta_1)^{-1}}$$

$$a = T_1/b^{\sec\theta_1} \quad ,$$

which implies

$$\ln T = \ln T_1 + (\ln T_2 - \ln T_1)\left[\frac{\sec\theta - \sec\theta_1}{\sec\theta_2 - \sec\theta_1}\right] .$$

For θ >85 degrees, we redefine $\sec\theta$ by a parabolic approximation to the Chapman function,

$$\sec\theta = \sec\ (85\ \text{deg}) + 1.1\ (\theta - 85)^2 \quad .$$

<u>Wavelength</u>

$$T = T_1 + (T_2 - T_1)\ \frac{\lambda - \lambda_1}{\lambda_2 - \lambda_1} \quad .$$

3-2.29 Function TRANSF(ALAM,LL,MM,HH)

This function evaluates the transfer coefficient for the set of statistical clouds whose indexes are in the calling sequence: Considerable bookkeeping is accomplished to assign the calculation to the proper prescription. The prescriptions are adequately documented in Appendix A and discussed in Section 2-2.

The bookkeeping, in general, evaluates the diffusion parameters for the appropriate layer number and stores them according to the required variable name for the prescription. The first steps are to determine how many layers are involved in the problem, whether the source is inside or outside, and whether the cloud layers are continuous. These questions are answered and control transferred to the equation for

reflection,
1-layer transmission for source inside,
1-layer transmission for source below,
2-layer transmission for source below,
or 3-layer transmission for source below.

The results are then normalized to get a transfer coefficient, TRANSF, which is returned to subroutine CLDWT.

If the altitude ALT of an artificial source above the top of the topmost layer is less than the radius R_s assigned to the finite-size source, the effective altitude of the source in computing the reflectance transfer coefficient is reset to

$$h_{eff} = CLDTOP + 0.5\ (ALT + R_s)\ .$$

3-2.30 Subroutine VSNORM(X,Y,Z,EN1,EN2,EN3,K)

This subroutine computes a unit vector $\hat{n}$ normal to the surface of the ellipsoid at the Cartesian coordinates x,y,z in cloud K.

$$\hat{n} = \frac{1}{Q}\left[\frac{x}{a^2}\,\hat{i} + \frac{y}{b^2}\,\hat{j} + \frac{z}{c^2}\,\hat{k}\right]$$

$$Q = \left[\left(\frac{x}{a^2}\right)^2 + \left(\frac{y}{b^2}\right)^2 + \left(\frac{z}{c^2}\right)^2\right]^{\frac{1}{2}}\ .$$

3-3 LABELED COMMON VARIABLE DEFINITIONS

Variables in labeled common are described in this section. Since the subroutines which use these variables are designed to be utilized as part of other codes, i.e., the subroutines are submodules, names are located in labeled commons which will tend to minimize their conflict with other code variable names. A list of the names of labeled commons and the subroutines in which they are found is located in Table 3-1.

The name of each common and the variables which are contained therein will be listed just as they are found in the subroutines. A brief description and the variable units follow the statement.

3-3.1 COMMON/ATMOUP/DUM1(4),RHO,TT,DUM2(22)

RHO: RHO(g/cm^3), the air density at altitude z(km), is used by the main program ROSCOER to scale the radius of the artificial source with altitude.

TT: TT (degrees Kelvin), the air temperature at altitude z(km), is used by the cloud routines.

(RHO and TT, the only two variables from this common, are obtained by a call to ATMOSU(2,ZH), where ZH is the altitude of interest, (km)).

Table 3-1. List of subroutines and labeled commons.

SUBROUTINE \ COMMON	ATMOUP	CDCORD	CDDATA	CLDFREQ	CLDWT	CLOUD	CONFIG	DETECT	DIFFUS	FLAGS	FLUX	INTRCPT	LOS	MATERL	PARAMS	PTE	SANDD	SOLARP	SORCE	XX1111
ROSCOER	X					X		X				X	X	X	X	X	X	X	X	X
ATMOSU	X																			
BLKDAT			X	X																
CLDBDR			X																	
CLDGEOM		X				X									X					
CLDWT				X	X		X													
CLOUD0				X		X	X								X					
CLOUD1		X				X		X							X				X	
CLOUD2		X				X		X				X			X					
CLOUD3	X	X				X		X			X				X				X	X
CLOUD9						X									X					
DIFFUS		X	X			X					X				X					
DIFPRM			X						X						X					
DSURF		X																		
EMISSF	X		X												X		X			
LOS		X				X		X					X		X					
PS		X													X					
SCLOUD				X	X			X		X				X	X	X	X	X	X	
SGEOM															X					
TRANSF			X						X	X					X		X		X	
VSNORM		X																		

3-3.2 COMMON/CDCORD/XI(1,20),ETA(1,20),ZETA(1,20),XID(20),ETAD(20), ZETAD(20),ASQ(20),BSQ(20),CSQ(20),CPH(5,20),CTH(5,20),CPHBAR (16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)

Variables in this common provide communication between the geometry routines of the deterministic cloud calculations. Calculations relative to a given cloud are made in a coordinate system centered on that cloud and results, if required, are transformed back to the earth-centered system. Ellipsoidal elemental areas used in integration are referred to as facets.

XI,ETA,ZETA: Cartesian coordinates of the Nth source in the Kth cloud-centered system. N currently is restricted to one. (km)

XID,ETAD,ZETAD: Cartesian coordinates of the detector in the Kth cloud-centered system. (km)

ASQ,BSQ,CSQ: Values of the squares of the semi-axes of an ellipsoid. (km^2)

CPH: Cloud-centered azimuthal angle bounding a facet or area on the surface of the cloud. (radians)

CTH: Cloud-centered polar angle bounding a facet on the surface of the cloud. (radians)

CPHIBAR: Cloud-centered azimuthal angle locating a facet center in the Kth cloud. Symmetry is taken into account in the eight octants. (degrees)

CTHBAR: Cloud-centered polar angle locating a facet center in the Kth cloud. (degrees)

CRBAR: Distance from the cloud center to the facet center, utilized in calculating fluxes. All symmetry is taken into account and the function IPRIME locates the element in the CRBAR array which has the proper distance to one of the 128 facets when there are 16 azimuthal angles and 8 polar angles. (km)

CAREA: Areas of the facets are calculated by a 2-dimensional Simpson's rule of integration in subroutine CLDGEOM with the differential area element being calculated in DSURF. Again, function IPRIME returns the proper index to obtain the desired area element. (km^2)

3-3.3 COMMON/CDDATA/ALAMT(10),SIGT(10,14),SIGS(10,14),W(10), XMUBAR(10,14),DNO(14),RAD(14),CLDBASE(14),CLDTHK(14)

Data in this common are physical and optical properties of the cloud data base. Physical properties are taken from the NASA cloud data base and optical properties for cloud types 1 through 10 are from Mie theory calculations. There are 14 types of clouds in this data base for which data are tabulated at ten wavelengths.

ALAMT: ALAMT is a table of wavelengths for which microscopic cross-sections and mean cosines of scattering angles are tabulated. Values are 2.0, 2.5, 2.55, 2.65, 2.75, 2.85, 3.2, 3.5, 4.0, and 5.0. (μm)

SIGT: Microscopic extinction cross-sections for the 14 cloud types are tabulated at the 10 wavelengths of the ALAMT table. (μm^2)

SIGS: Scattering cross-sections for the 14 cloud types are tabulated at the 10 wavelengths of the ALAMT table. (μm^2)

W: (Normalized) contribution of specularly-reflected radiation to scattered radiation, with the diffracted radiation contributing unity; used only for the large-particle-size clouds, types 11 through 14. (dimensionless)

XMUBAR: Cosine of the scattering angle averaged over the particle size distribution of the cloud type and tabulated at the 10 wavelengths. (dimensionless)

DNO: Droplet density of the given cloud type. (droplets/cm^3)

RAD: Mean droplet radius for the cloud type. (μm)

CLDBASE: Cloud-base altitudes for the 14 cloud types. (km)

CLDTHK: Cloud thickness. (km)

3-3.4 COMMON/CLDFREQ/KMODEL,CCOVER(5,11),CLDFREQ(17,4,11)

Common CLDFREQ has its origin in block data. The index KMODEL selects one of the ten sets of data present in data statements or allows a user-supplied set of data to be input as the eleventh set of data.

KMODEL: A variable which selects the cloud data base to be used in the calculations.

=1 for dry annual average

=2 for dry winter average night

=3 for dry winter average day

=4 for dry summer average night

=5 for dry summer average day

=6 for moist annual average

=7 for moist winter average night

=8 for moist winter average day

=9 for moist summer average night

=10 for moist summer average day

=11 for array supplied by the user.

See Section 4 for a detailed illustration of using KMODEL = 11.

CCOVER: This array provides the probability of the Lth cloud-coverage category for the Kth model, K being defined above, where

$$\sum_{L=1}^{5} \text{CCOVER}(L,K) = 1 \quad .$$

For the K = 11 base, the input instructions in Section 4 illustrate the use of the table. CCOVER(L,K) is a frequency of occurrence of the Lth coverage category.

CLDFREQ: With the indexes (I,L,K), CLDFREQ(I,L,K) is the frequency of the Ith cloud type for I less than fifteen. For I = 15,16,17 it is the frequency of occurrence of 1-layer, 2-layers, or 3-layers, respectively. For K-values between 1 and 10 (inclusive) the array elements are from the model as defined under KMODEL above. For K = 11, the use of the table is described in Section 4. Basically, however, each element is the frequency of the Ith type of cloud:

I=1 for Cu1	I=8 for Ac
I=2 for Cu2	I=9 for As1
I=3 for Cu3	I=10 for Cb2
I=4 for Sc	I=11 for Cb3
I=5 for St	I=12 for As2
I=6 for Cb1	I=13 for Ci
I=7 for Ns	I=14 for Cs

3-3.5 COMMON/CLDWT/IDX,WT(160),TRANS(160),EMISS(160)

The common array WT contains the probability of a given statistical cloud configuration, i.e., the product of the probability of a given cloud-coverage category, the probability of the number of layers in that coverage category, and the probability of an occurrence of a cloud type in that layer and category configuration. This configuration is ultimately weighted by one minus the cloud-free line-of-sight for this cloud coverage and zenith angle.

There are 160 combinations of layer-type-coverage configurations. Subsets of restrictions on any of the components, e.g., coverage category, reduces the 160 to a fewer number of cases.

IDX: This is the total number of configurations which is always less than 160. With a maximum constraint, it can be as few as two, i.e. the cloud type (with coverage category specified) and the cloud-free line-of-sight component.

WT: WT(IDX) is the probability of the IDXth configuration. IDX is less than or equal to 160.

TRANS: TRANS(IDX) is the transfer coefficient for the IDXth configuration. It corresponds to either a transmission or a reflection and includes attenuation by the atmosphere (1962 U.S. standard via LOWTRAN-3) to an altitude of 12 km. (sr^{-1})

EMISS: EMISS(IDX) is the thermal emission spectral radiance attenuated to 12-km altitude. ($W/(km^2\ sr\ \mu m)$)

3-3.6 COMMON/CLOUD/NCLOUD,HCLOUD(20),THETCD(20),PHICD(20), CLOUDA(20),CLOUDB(20),CLOUDC(20),CLDPSI(20),KCLOUD(20)

Input deterministic cloud descriptions are read into these arrays by subroutine CLOUDO. As many as twenty clouds can be part of the calculations; however, there are no interacting clouds, i.e., reflections of one cloud to another are not considered.

NCLOUD: Number of deterministic clouds for which altitude, orientation, and semiaxes are to be read into the arrays. This variable is used as the upper limit on DO-loops throughout the code.

THETCD: Colatitude of the cloud. (degrees)

PHICD: East longitude of the cloud. (degrees)

CLOUDA: Semiaxis of the longer cloud axis in horizontal plane. (km)

CLOUDB: Semiaxis of the shorter cloud axis in the horizontal plane. (km)

CLOUDC: Semiaxis of the cloud in vertical direction. (km)

The values of a,b, and c are those in the equation of an ellipsoid:

$$\left(\frac{x}{a}\right)^2 + \left(\frac{y}{b}\right)^2 + \left(\frac{z}{c}\right)^2 = 1$$

CLDPSI: Azimuthal angle, measured counterclockwise looking down, orienting cloud about (vertical) z-axis. Clouds are normally oriented with (+a)-axis eastward (psi = 0). (degrees)

KCLOUD: Index for Kth cloud, representing one of the 14 cloud types from the data bank.

3-3.7 COMMON/CONFIG/CTYPL(8),CTYPM(4),CTYPH(5),CFLAG,C1,C2

This common is a bit unwieldy but is used in the input routine CLOUDO. The entries are the Hollerith names of the cloud types in the low, middle, or high layer.

CTYPL(LL): Type of cloud LL ($1 \leq LL \leq 7$) or no cloud (LL=8) in the low layer. The variable is left-justified in 5-column fields.

CTYPM(MM): Type of cloud MM ($1 \leq MM \leq 3$) or no cloud (MM=4) in the middle layer.

CTYPH(HH): Type of cloud HH ($1 \leq HH \leq 4$) or no cloud (HH=5) in the high layer.

CFLAG: CFLAG is a coverage category flag. (Not utilized)

C1: C1 is the (integer) index for the first cloud-coverage category being utilized. Normally C1 is 2.

C2: C2 is the upper limit counterpart of C1. Normally C2 is 5.

3-3.8 COMMON/DETECT/HD,THETAD,PHID,FOV

This common contains the location of the detector in an earth-centered polar coordinate system.

HD: Altitude of the detector. (km)

THETAD: Colatitude of detector. (degrees)

PHID: East longitude of detector. (degrees)

FOV: Field-of-view (FOV) of the detector (km^2). Radiances in the deterministic cloud calculations are averaged over the field-of-view. The FOV is also used in subroutine LOS, as potential lines-of-sight are separated by the order of the square root of the FOV.

3-3.9 COMMON/DIFFUS/DALFA(14),DBETA(14),DKAPPA(14)

This common contains the coefficients in the diffusion equation for photon flux transmitted through clouds. They are generated for all fourteen clouds by a single call to DIFPRM for a specified wavelength.

DALFA: Diffusion parameter defined in Appendix A-1.2. (unitless)

DBETA: Diffusion parameter defined in Appendix A-1.2. (km)

DKAPPA: Diffusion parameter defined in Appendix A-1.2. (km^{-1})

3-3.10 COMMON/FLAGS/ITFLAG

This common is currently used only to avoid calculation of the transfer coefficient in function TRANSF in the statistical calculations when only the thermal emission is needed.

ITFLAG: ITFLAG turns off the transfer coefficient computation as described above.

3-3.11 COMMON/FLUX/FIN(8,16),FOUT(8,16)

This common provides communication between subroutine CLOUD3, which generates the input FIN to subroutine DIFFUS and uses the output FOUT, and the subroutine DIFFUS. DIFFUS effects the diffusion solution to get the photon flux output at each of the facets, given the input flux.

FIN: This is 4π times the photons km^{-2} sec^{-1} that are incident normally on each of the cloud facets which are visible to the unit strength, isotropic source.

FOUT: This is 4π times the photon flux (radiant emittance) that is transmitted by each facet, according to the diffusion theory approximation. (4π photons/(km^2 sec), for unit-strength source).

3-3.12 COMMON/INTRCPT/ALTLK(20),THETALK(20),PHILK(20)

This common provides communication between subroutine CLOUD2 and the calling program which is requesting the geographic location of the intersection of the line-of-sight and the cloud.

ALTLK: The altitude at which the line-of-sight intercepts the Kth cloud. (km)

THETALK: The colatitude of the Kth cloud intercept. (degrees)

PHILK: The east longitude of the Kth cloud intercept. (degrees)

3-3.13 COMMON/LOS/HLOS(1,64),ULOS(1,64),VLOS(1,64),WLOS(1,64)

This common contains lines-of-sight to all facets of deterministic clouds which provide reflectance and to those facets which have the highest transmission. These are provided following a call to subroutine LOS with the argument K for the Kth cloud.

HLOS: Altitude at which the line-of-sight from the detector intercepts the Jth facet in the Kth cloud. (km, above mean sea level)

ULOS,VLOS,WLOS: Direction cosines in the earth-centered Cartesian system, of the above-described lines-of-sight.

Each of the vectors (ULOS,VLOS,WLOS) provides to the code user a potential line-of-sight which is separated by approximately the square root of the field-of-view from another possible line-of-sight.

3-3.14 COMMON/MATERL/MSM,DDM(7),SRFALT

MSM: Integer defining susface type.

=1 for Lambertian diffuse surface with spectrally-independent reflectance set by DD(1) and emissivity by (1.-DD(1)).

=2 for water

=3 for snow

=4 for sand

=5 for soil

=6 for foilage

=7 for urban material

DDM(M): Additional descriptor for selected surface material. See comments in subroutine ESURF, a routine provided by the model documented in Reference 6.

SRFALT: Surface altitude. (km)

3-3.15 COMMON/PARAMS/IN,IOUT,PI,RE,DTR,RTD

This common contains program constants, set in program ROSCOER, which are frequently used in numerous routines. The constants can be replaced by equivalencing or renaming variables.

IN: The integer variable name used to identify the input file unit. It is not used consistently.

IOUT: The integer variable name which identifies the output file unit. It is not used consistently.

PI: The value of PI as used throughout the program. It has the numerical value of 3.14159265.

RE: The value used for the Earth's radius and has a numerical value of 6371.03 km.

DTR: This is the conversion factor to convert from degrees to radians and has a numerical value of 0.01745329251994.

RTD: This is the conversion factor from radians to degrees and has a numerical value of 57.2957795131.

3-3.16 COMMON/PTE/P1,P2,P3,P4,T1,T2,T3,T4,S1,S2,S3,S4,E1,E2,E3,E4

P1...P4: Probability fractiles at which transfer coefficients and emission radiances are desired. Set in program ROSCOER.

T1...T4: Transfer coefficients at 12-km altitude for point source. This is the ratio of a radiance to an irradiance. (sr^{-1})

S1...S4: Transfer coefficients at 12-km altitude for sun as a source. (sr^{-1})

E1...E2: Thermal emission (spectral radiance) from top layer of clouds or the ground (for the cloud-free line-of-sight). ($W/(km^2\ sr\ \mu m)$)

PCFLOS: Probability of the detector seeing the artificial source, either with or without clouds being present, provided the source is within the field-of-view.

3-3.17 COMMON/SANDD/XS,YS,ZS,XD,YD,ZD,UL,VL,WL

The common SANDD contains the Cartesian coordinates of the location of both the source and detector, and the direction cosines of the line-of-sight.

XS,YS,ZS: Cartesian coordinates of the source location in the earth-centered system. The x-direction points to zero degrees longitude and ninety degrees colatitude. The z-direction is through the north pole. (km)

XD,YD,ZD: Cartesian coordinates of the detector location in the earth-centered system. (km)

UL,VL,WL: Direction cosines of the line-of-sight vector in the earth-centered system.

3-3.18 COMMON/SOLARP/SOLLAT,SOLLON

SOLLAT: Solar latitude in earth-centered polar coordinates with positive being north of the equator. (radians)

SOLLON: Solar (east) longitude in earth-centered polar coordinates. (radians)

3-3.19 COMMON/SORCE/NSORCE,HSORCE(1),THETAS(1),PHIS(1),RSORCE(1)

NSORCE: This variable is not utilized in this version of the code, and it is always set to one.

HSORCE: Altitude of source. (km)

THETAS: Colatitude of source. (degrees)

PHIS: East longitude of source. (degrees)

RSORCE: Radius of source. (km)

3-3.20 COMMON/XX1111/KCLDK,CLDLAM

KCLDK: A test-flag used in subroutine CLOUD3 to determine whether CLOUD3 is now being called with the same cloud-number K as for its last call.

CLDLAM: A test quantity used in subroutine CLOUD3 to determine whether CLOUD3 is now being called with the same wavelength ALAM as for its last call.

Note: If K and ALAM inputted to subroutine CLOUD3 have the same values as in the last call, the subroutine bypasses its call to subroutine DIFFUS(K,ALAM). Both KCLDK and CLDLAM are initialized in the main program to the arbitrary, out-of-range values of 99 and -99., respectively.

SECTION 4
DATA REQUIREMENTS AND SAMPLE PROBLEMS

4-1 DATA REQUIRED FOR STATISTICAL AND DETERMINISTIC CLOUDS

Required user-supplied data for transmission of IR signatures through clouds are read by CLOUDO. Many of the data, as outlined in the following paragraphs, are stored in the program and the code need only be directed by an appropriate flag to use them. Consequently, only a few directives need be inputted to run standard cases. Data cataloged in the program are described first, followed by descriptions and illustrations for user-supplied data.

Data which are cataloged are accessible to both the statistical and deterministic submodules. Only a limited number of sets of data are included in the code to demonstrate the utility of the code without its becoming unwieldy.

Cloud descriptions in terms of mean water droplet radius (μm), droplet density (cm^{-3}), base altitude (km), and thickness (km) are incorporated into the code via BLOCK DATA. These data are tabulated in Table 2-1. Microscopic extinction and scattering cross-sections (μm^2) and average cosine of the scattering angle, averaged (as described in Reference 2) over droplet size distributions from Table 2-1, are also included in BLOCK DATA for 14 cloud types and 10 wavelengths in the 2- to 5-μm range. No provision has been made to replace or adjust these parameters for user-supplied data. A modification could be implemented to provide such an option.

The only bidirectional reflectance data that are in the code are those for a stratocumulus cloud, a frequently occurring cloud type according to the NASA cloud-data bank. The tables in function CLDBDR are rather lengthy. Some considerable effort has been expended to fit the bidirectional reflectance data for inclusion in the code; however, the code contains only tabulated data.

The cloud-frequency data are stored in an array (CFREQ) in BLOCK DATA dimensioned (14 + 3) by 4 by (10 + 1). For each of the 10 (or 11 including the user-option case) region-averaged data sets, there

are 14 cloud-frequency numbers and three layer-frequency numbers for each of the four nonclear coverage categories. Each specification requires five coverage categories, of which four are independent, ranging from completely clear to complete cloud-cover.

Nominal statistical-cloud data sets are included in the program which include averages over summer, winter, day, night, and annual for a dry and a moist region. They are arranged as in Table 4-1.

4-2. USER-REQUIRED AND USER-OPTIONAL DATA FOR NATURAL CLOUD MODULES

For utilizing the ROSCOE-IR natural cloud module in a stand-alone mode, several data are required to be read by the driver program ROSCOER. ROSCOE-IR will provide these data to the natural cloud module as implemented in the ROSCOE-IR code. The requirements for the driver program will be described first, followed by the description of inputs read by subroutine CLOUDO. Sufficient information is included to illustrate the options and to provide test cases for the stand-alone mode.

Detector and source locations are read by the driver program ROSCOER. The first input record contains H, θ, ϕ, and FOV for the detector; the second record contains the same information (less the FOV) for the source. H is the altitude in kilometers, ϕ is the colatitude (degrees), and is the east longitude (degrees). FOV is the field-of-view (km^2) for the detector. The third input record contains the flag ISUN which is zero if the only source to be considered is the artificial source and which is unity if the sun is to be considered as a source in addition to the artificial source. The solar location is specified in a data statement in ROSCOER. The fourth input record is the wavelength ALAM.

Subroutine CLOUDO, for which a flow diagram is shown in Figure 4-1, reads all of the user-supplied data and sets the proper flags for subsequent code execution. For the statistical case, only data are read; the deterministic mode (MODE=0) also causes the geometry routines (CLDGEOM, and, in turn, DSURF) to be called.

The flags are set by Card 1 and Card 2.

Card 1: MODE (I10 format)
= 0 Deterministic model
= 1 Statistical model
(branch here to required submodule)

Table 4-1. Cloud data bank contained in ROSCOE natural cloud program.

Index for Statistical Cloud Set	Region	Type of Average
1	Dry[a]	Annual
2	Dry[a]	Winter night
3	Dry[a]	Winter day
4	Dry[a]	Summer night
5	Dry[a]	Summer day
6	Moist[b]	Annual
7	Moist[b]	Winter night
8	Moist[b]	Winter day
9	Moist[b]	Summer night
10	Moist[b]	Summer day
11	Array reserved for user-supplied data	

[a,b]Regions 4 and 11 in Reference 1 nomenclature, i.e., continental and maritime.

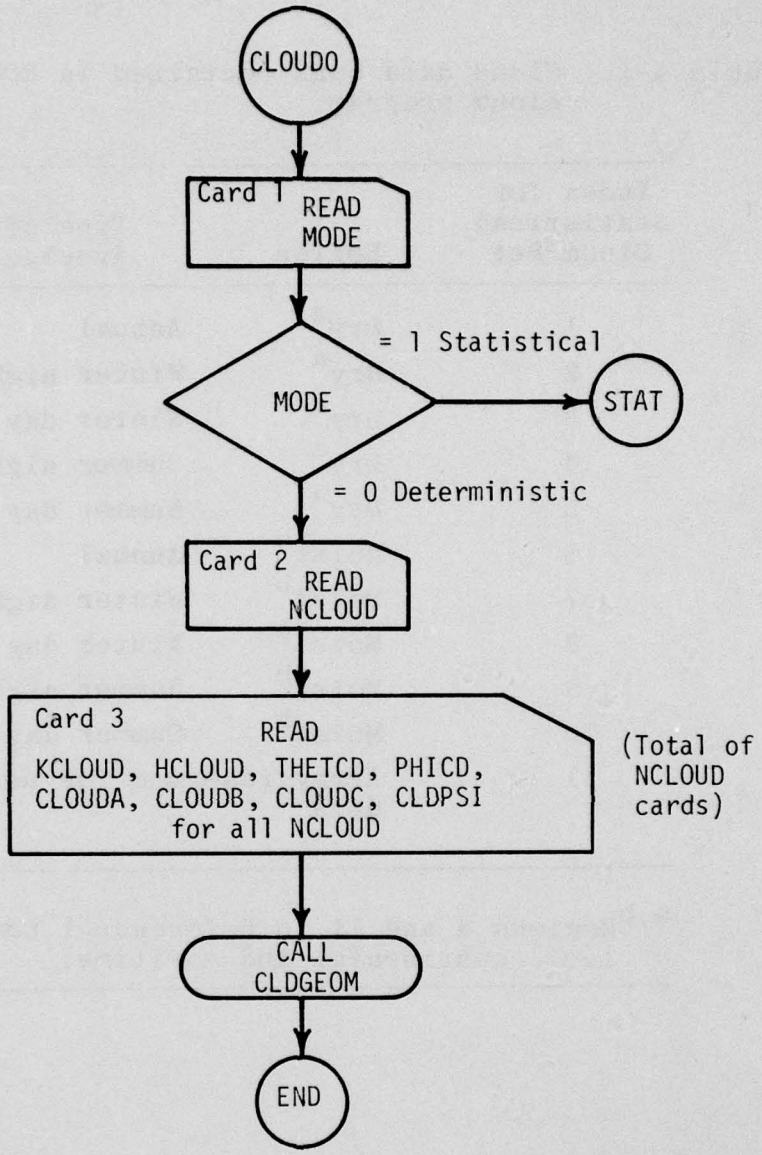


Figure 4-1. Flow chart of subroutine CLOUDO.
(Continued on next page.).

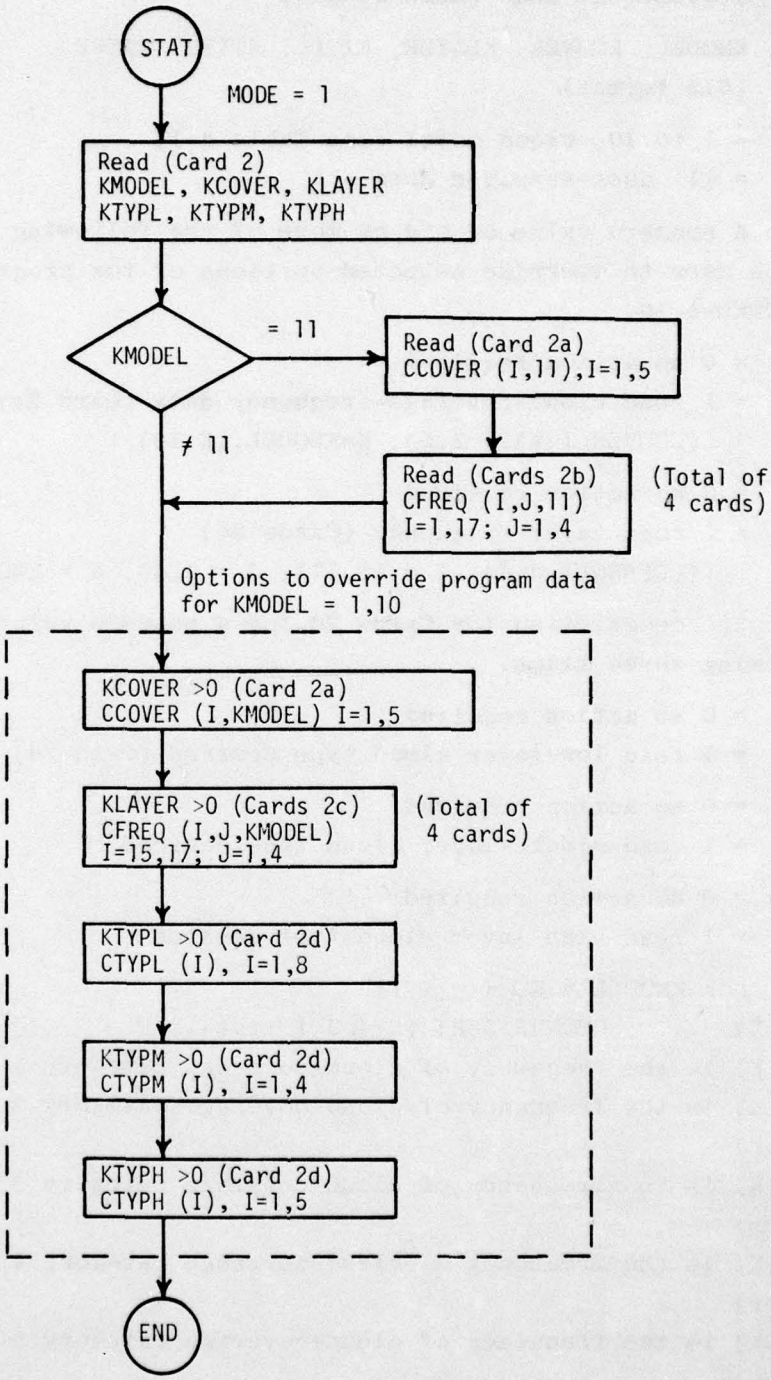


Figure 4-1. Flow chart of subroutine CLOUDO (Cont.).

4-2.1 Statistical Mode (MODE=1) Data

Card 2: KMODEL, KCOVER, KLAYER, KTYPL, KTYPM, KTYPH
(6I5 format)

KMODEL = 1 to 10, cloud model (see Table 4-1)
= 11, user-supplied data

A nonzero value of one or more of the following five flags allows the user to override selected portions of the program data for a given KMODEL=1,10.

KCOVER = 0 no action required
= 1 read cloud-coverage-frequency data (Card 2a)
((CCOVER(I,K),I=1,5), K=KMODEL.LE.10)

KLAYER = 0 no action required
= 1 read layer frequency (Cards 2c)
(((CFREQ(I,J,K), I = 15,17), J = 1,4), K = KMODEL.LE.10)

See description for Cards 2d for a nonzero value of any of the following three flags.

KTYPL = 0 no action required
= 1 read low-layer cloud type desired (Card 2d)

KTYPM = 0 no action required
= 1 read middle-layer cloud type desired

KTYPH = 0 no action required
= 1 read high-layer cloud type desired

Card 2a: for KMODEL = K, K = 1,11
CCOVER(1,K), ... , CCOVER(5,K) (5F4.3 format)
CCOVER(1,K) is the frequency of cloud-coverage category 1 (clear)
CCOVER(2,K) is the frequency of cloud-coverage category 2 (0.3 cloud cover)
CCOVER(3,K) is the frequency of cloud-coverage category 3 (0.5 cloud cover)
CCOVER(4,K) is the frequency of cloud-coverage category 4 (0.8 cloud cover)
CCOVER(5,k) is the frequency of cloud-coverage category 5 (complete cover)

$$\text{where } \sum_{I=1}^{5} \text{CCOVER}(I,K) = 1.0 \quad .$$

Cards 2b: for KMODEL = 11 (four cards)

CFREQ(I,J,11)	$1 \leq I \leq 17,\ 1 \leq J \leq 4$		(17F4.3 format)
CFREQ(1,J,K)	is frequency of	CU1	low-altitude clouds
CFREQ(2,J,K)	is frequency of	CU2	
CFREQ(3,J,K)	is frequency of	CU3	
CFREQ(4,J,K)	is frequency of	SC	
CFREQ(5,J,K)	is frequency of	ST	
CFREQ(6,J,K)	is frequency of	CB1	
CFREQ(7,J,K)	is frequency of	NS	
CFREQ(8,J,K)	is frequency of	AC	mid-altitude clouds
CFREQ(9,J,K)	is frequency of	AS1	
CFREQ(10,J,K)	is frequency of	CB2	
CFREQ(11,J,K)	is frequency of	CB3	high-altitude clouds
CFREQ(12,J,K)	is frequency of	AS2	
CFREQ(13,J,K)	is frequency of	CI	
CFREQ(14,J,K)	is frequency of	CS	

where

$$\sum_{I=1}^{14} \text{CFREQ}(I,J,K) = 1.$$

CFREQ(15,J,K)	is frequency of	1 layer
CFREQ(16,J,K)	is frequency of	2 layers
CFREQ(17,J,K)	is frequebcy of	3 layers

where

$$\sum_{I=15}^{17} \text{CFREQ}(I,J,K) = 1.$$

Cards 2c: for K = KMODEL = 1,10 (3F4.3 format) (four cards)

Cards 2c provide a mechanism to change layer frequencies for KMODEL <11, i.e., (((CFREQ(I,J,KMODEL), I=15,17),J=1,4), KMODEL<11) without changing the individual cloud-type frequencies.

CFREQ(I,J,K), I=15,16,17 and J=1,2,3,4

I=15 is the frequency of 1 layer
=16 is the frequency of 2 layers
=17 is the frequency of 3 layers

Cards 2d: cloud-type specification (8A5 format)
(one, two, or three cards)
Read under 8A5 format (a blank field rejects that cloud type). Data must be left-justified.

For KTYPL = 1 (one card):

CTYPL(I), I=1,8
CTYPL(1) = CU1
CTYPL(2) = CU2
CTYPL(3) = CU3
CTYPL(4) = SC
CTYPL(5) = ST
CTYPL(6) = CB1
CTYPL(7) = NS
CTYPL(8) = CLR = clear

For KTYPM = 1 (one card):

CTYPM(I), I = 1,4
CTYPM(1) = AC
CTYPM(2) = AS1
CTYPM(3) = CB2
CTYPM(4) = CLR

For KTYPH = 1 (one card):

CTYPH(I), I = 1,5
CTYPH(1) = CB3
CTYPH(2) = AS2
CTYPH(3) = CI
CTYPH(4) = CS
CTYPH(5) = CLR

By utilizing combinations of Card 1 through Cards 2d, one can accomplish any degree of specification desired. However, for a complete specification, the problem reduces to that of a deterministic calculation where the thicknesses and altitudes come from the program data bank and the cloud is infinite in lateral extent.

4-2.2 Deterministic Mode (MODE=0) Data

Card 2: NCLOUD (I10 format)

Card 3: KCLOUD(I), HCLOUD(I), THETCD(I), PHICD(I)
CLOUDA(I), CLOUDB(I), CLOUDC(I), CLDPSI(I)
where $1 \leq I \leq$ NCLOUD
(I2, E8.3, 6E10.4 format)

KCLOUD(I) = Cloud-type index of Ith cloud (1,2,...,14)
HCLOUD(I) = Altitude of Ith cloud (km)
THETCD(I) = Colatitude of Ith cloud (degrees)
PHICD(I) = East longitude of Ith cloud (degress)
CLOUDA(I) = Semi-axis in x-direction of Ith cloud (km)
CLOUDB(I) = Semi-axis in y-direction of Ith cloud (km)
CLOUDC(I) = Semi-axis in z-direction of Ith cloud (km)
CLDPSI(I) = Orientation of the a-axis with respect to the east-west direction, i.e., ψ orients the longest (a-axis) at an angle of ψ degrees north of east.

4-3. SAMPLE PROBLEMS

A number of sample computer runs have been made using the ROSCOE natural cloud program. Several of these are included here to facilitate subsequent code comparisons. Listings of input cards necessary for each problem are provided.

Some modifications of the code were required to obtain the data output shown in the samples. Code calculations were affected only as outlined below. Print statements were placed in the code to intercept calculations in a convenient manner for presentation. These are given in Appendix C to facilitate reproducing the output for each problem.

4-3.1 Problems 1 to 4: Use of the Statistical Cloud Submodel in a Limited, Deterministic Mode (with KMODEl=1,10)

The purpose of these four problems, which form a set, is (1) to illustrate use of the statistical cloud submodel in a limited, deterministic mode (with KMODEL=1,10) and (2) to show that diffusion calculations performed by the code for a point source beneath either (a) single-layer (planar) clouds or (b) multilayer (planar) clouds are in good agreement with exact, analytic diffusion calculations.

To help provide the motivation for a portion of these problems, we note that the total transmittance T for a planar slab is given by Equation (31a) of Appendix A, i.e.,

$$T = Q\left[\cosh KL + \tfrac{1}{2}\left(\frac{a}{Kb} + \frac{Kb}{a}\right)\sinh KL\right]^{-1}$$

where Q, the total flux into the slab, can be set to unity. To get a computer code result that can be compared with this transmittance, we must take several steps:

a. Instruct the code to treat a single planar cloud above a point source.

b. Compute the radial distribution of the transmission transfer coefficients, without including air attenuation.

c. Convert this distribution of transfer coefficients to a radial distribution of radiant exitance.

d. Integrate this radial distribution of radiant exitance across the cloud top and divide by the spatially-integrated flux into the slab to obtain a total transmittance.

The quantity that the code was actually instructed to compute is one we shall refer to as a modified transfer coefficient, TC', in units of $km^{-2}\ sr^{-1}$. These units are those of the transfer coefficient (sr^{-1}) divided by the square of the distance from the source to the 12-km altitude transfer point. These units are equivalent to describing TC' as being 4π times the radiance ($W\ km^{-2}\ sr^{-1}$) directed toward the downward-looking radial-scanning detector, for a unit strength isotopic source. (Alternatively, TC' is 4 times the radiant exitance.) This modified transfer coefficient, $4\pi L$, was divided by 4π and multiplied by π to obtain the radiant exitance and was subsequently integrated across the cloud-top radial distribution. Division by the source power incident on the underside of the cloud gave the total transmittance T:

$$T = \frac{1}{(\frac{1}{2}\ \text{source power})}\int_0^\infty \left(\frac{4\pi L}{4\pi}\ \pi\right) 2\pi r dr \quad .$$

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THE ROSCOE MANUAL. VOLUME 24. NATURAL CLOUDS (PHYSICAL AND OPTI--ETC(U)

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UNCLASSIFIED SAI-78-604-LJ-5-VOL-24 DNA-3964F-24 NL

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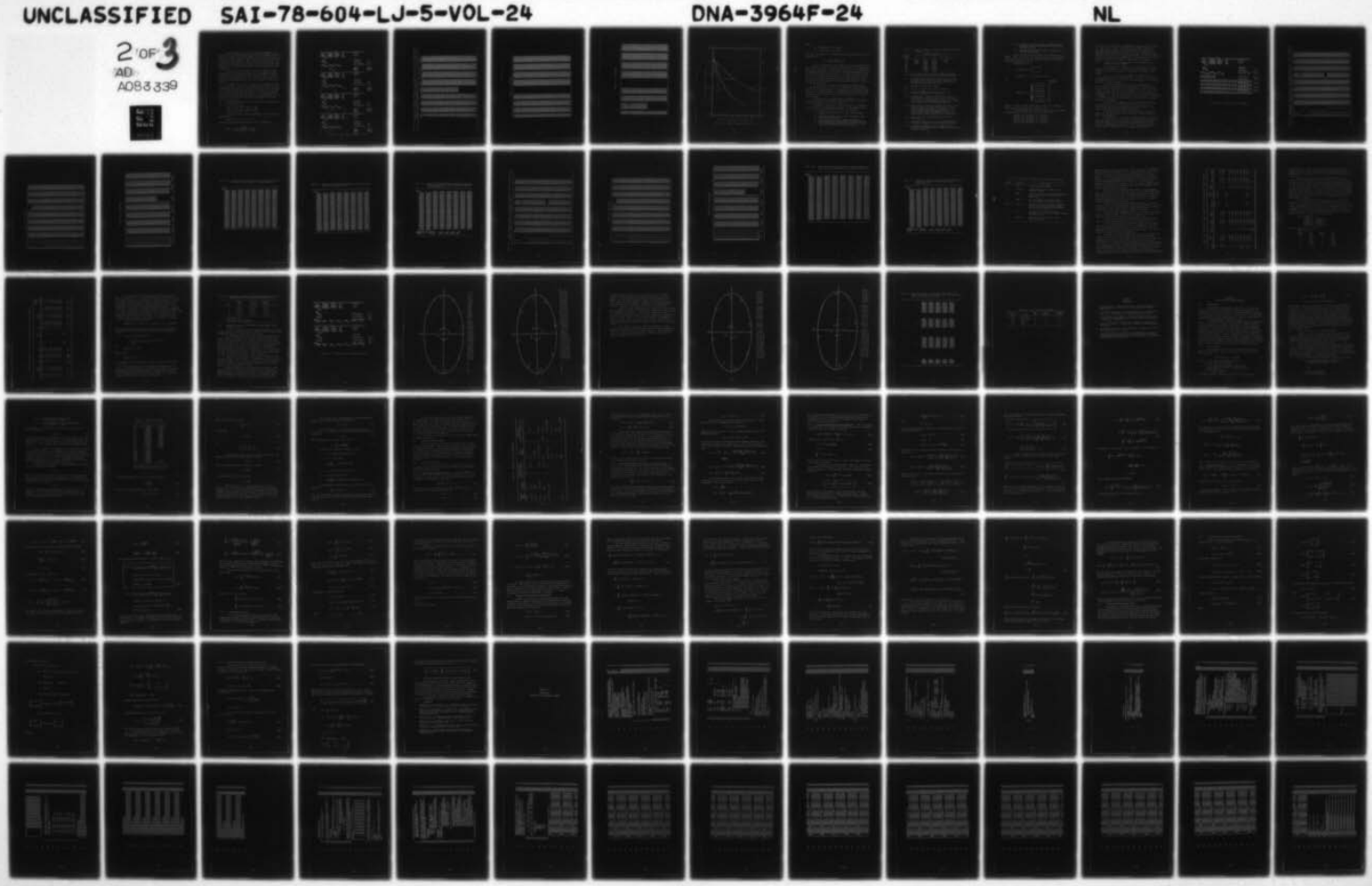

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2 OF 3

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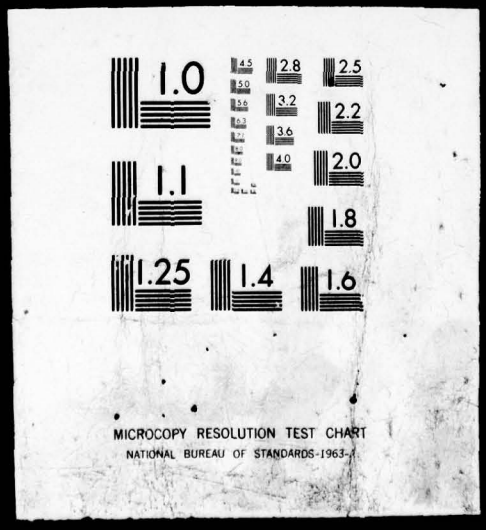

The information on the input cards read by ROSCOER for the detector, source, and wavelength and by subroutine CLOUDO for Cards 1,2 and 2d (cf. Figure 4-1 and corresponding text) is given in Figure 4-2 for the four sample problems. Each of the first three problems treats a different single cloud type, namely, Type 4 (Sc), Type 8 (Ac), and Type 13 (Ci), respectively; the fourth problem treats the three-layer configuration of these same cloud types. We shall discuss the input cards later.

For each of the four problems, and for a range of lateral displacements in 0.25-km steps, the values of the modified transfer coefficient, $4\pi L$, are given in Columns 2 to 5 of Table 4-2. These quantities are plotted in Figure 4-3. Columns 6 to 9 of Table 4-2 give the corresponding values of the radial integrals for the transmittance.

In Figure 4-3 the curve for cloud Sc is not shown at larger distances because it soon develops wiggles and, starting at 35.75 km, an occasional negative value. These features result from limitations of the internal integration scheme which is intended to be efficient in the lateral range of importance but not at very large distances. The curve for cloud Ac begins to wiggle a bit at about 20 km, that for cloud Ci at about 30 km, and that for the combined set of clouds (Sc + Ac + Ci) at 7 km.

The analytic results for the transmittance and reflectance of each of the three layers are:

$$T(Sc) = 0.820 \times 10^{-2} \quad R(Sc) = 0.653$$
$$T(Ac) = 0.113 \times 10^{-1} \quad R(Ac) = 0.637$$
$$T(Ci) = 0.127 \times 10^{-6} \quad R(Ci) = 0.0761$$

The analytic result for the transmittance of the three-layer configuration is

$$T(Sc + Ac + Ci) = 0.211 \times 10^{-10}$$

which was evaluated from the formula, derived in Appendix D,

$$T_{123} = \frac{T_1 T_2 T_3}{(1-R_1R_2)(1-R_2R_3) - R_1R_3T_2^{\,2}}$$

```
******************** PROBLEM 1  ************************************
   HD        THETAD      PHID       FOV                DETECTOR
 35793.     90.00001   -90.0001    1.
HSORCE(1) THETAS(1)   PHIS(1)     WKT                SOURCE
  0.01     90.000001   -90.00      1000.
     ISUN
       1
  ALAM                                                WAVELENGTH
  2.50
     MODE                                             STATISTICAL          CARD 1
       1
 KMODEL     KLAYER     KTYPM                          USER CLOUD MODEL     CARD 2
     KCOVER      KTYPL      KTYPH
   1    0     0     1     1     1
              SC                                      LAYER 1              CARD 2D
              CLR                                     LAYER 2              CARD 2D
                    CLR                               LAYER 3              CARD 2D

******************** PROBLEM 2  ************************************
   HD        THETAD      PHID       FOV                DETECTOR
 35793.     90.00001   -90.0001    1.
HSORCE(1) THETAS(1)   PHIS(1)     WKT                SOURCE
  0.01     90.000001   -90.00      1000.
     ISUN
       1
  ALAM                                                WAVELENGTH
  2.50
     MODE                                             STATISTICAL          CARD 1
       1
 KMODEL     KLAYER     KTYPM                          USER CLOUD MODEL     CARD 2
     KCOVER      KTYPL      KTYPH
   1    0     0     1     1     1
                                    CLR               LAYER 1              CARD 2D
AC                                                    LAYER 2              CARD 2D
                    CLR                               LAYER 3              CARD 2D

******************** PROBLEM 3  ************************************
   HD        THETAD      PHID       FOV                DETECTOR
 35793.     90.00001   -90.0001    1.
HSORCE(1) THETAS(1)   PHIS(1)     WKT                SOURCE
  0.01     90.000001   -90.00      1000.
     ISUN
       1
  ALAM                                                WAVELENGTH
  2.50
     MODE                                             STATISTICAL          CARD 1
       1
 KMODEL     KLAYER     KTYPM                          USER CLOUD MODEL     CARD 2
     KCOVER      KTYPL      KTYPH
   1    0     0     1     1     1
                                    CLR               LAYER 1              CARD 2D
              CLR                                     LAYER 2              CARD 2D
         CI                                           LAYER 3              CARD 2D

******************** PROBLEM 4  ************************************
   HD        THETAD      PHID       FOV                DETECTOR
 35793.     90.00001   -90.0001    1.
HSORCE(1) THETAS(1)   PHIS(1)     WKT                SOURCE
  0.01     90.000001   -90.00      1000.
     ISUN
       1
  ALAM                                                WAVELENGTH
  2.50
     MODE                                             STATISTICAL          CARD 1
       1
 KMODEL     KLAYER     KTYPM                          USER CLOUD MODEL     CARD 2
     KCOVER      KTYPL      KTYPH
   1    0     0     1     1     1
              SC                                      LAYER 1              CARD 2D
AC                                                    LAYER 2              CARD 2D
         CI                                           LAYER 3              CARD 2D
```

Figure 4-2. Input data for Problems 1 to 4.

Table 4-2. Data output for sample problems 1 to 4. Columns 2 to 4 give the cloud-top radiance L times 4π as a function of lateral displacement (km) from a unit-strength source at 0.01-km altitude. Wavelength is 2.5 μm.

RANGE	SC	AC	CI	SC-AC-CI	INT(SC)	INT(AC)	INT(CI)	INT(TOTAL)
.00	.2247E-02	.3315E-03	.1070E-08	.1185E-11	0.	0.	0.	0.
.25	.2165E-02	.3298E-03	.1067E-08	.1179E-11	.213002E-03	.324422E-04	.105007E-09	.115976E-12
.50	.1941E-02	.3249E-03	.1060E-08	.1160E-11	.806992E-03	.128670E-03	.418224E-09	.459677E-12
.75	.1624E-02	.3168E-03	.1049E-08	.1129E-11	.166657E-02	.285835E-03	.935543E-09	.102002E-11
1.00	.1277E-02	.3060E-03	.1033E-08	.1086E-11	.264664E-02	.499383E-03	.165025E-08	.177910E-11
1.25	.9544E-03	.2927E-03	.1013E-08	.1033E-11	.361693E-02	.763311E-03	.255323E-08	.271304E-11
1.50	.6861E-03	.2775E-03	.9891E-09	.9721E-12	.448972E-02	.107051E-02	.363322E-08	.379312E-11
1.75	.4804E-03	.2607E-03	.9620E-09	.9038E-12	.522412E-02	.141316E-02	.487713E-08	.498704E-11
2.00	.3306E-03	.2429E-03	.9320E-09	.8302E-12	.581400E-02	.178309E-02	.627040E-08	.626030E-11
2.25	.2246E-03	.2245E-03	.8996E-09	.7532E-12	.627211E-02	.217220E-02	.779739E-08	.757814E-11
2.50	.1512E-03	.2060E-03	.8652E-09	.6747E-12	.661905E-02	.257278E-02	.944179E-08	.890616E-11
2.75	.1021E-03	.1878E-03	.8293E-09	.5963E-12	.687784E-02	.297778E-02	.111870E-07	.102125E-10
3.00	.7030E-04	.1701E-03	.7925E-09	.5197E-12	.707096E-02	.338103E-02	.130164E-07	.114688E-10
3.25	.4986E-04	.1534E-03	.7552E-09	.4465E-12	.721743E-02	.377731E-02	.149140E-07	.126510E-10
3.50	.3613E-04	.1377E-03	.7177E-09	.3778E-12	.733073E-02	.416245E-02	.168644E-07	.137402E-10
3.75	.2628E-04	.1232E-03	.6805E-09	.3147E-12	.741910E-02	.453325E-02	.188531E-07	.147229E-10
4.00	.1921E-04	.1099E-03	.6440E-09	.2579E-12	.748797E-02	.488744E-02	.208670E-07	.155915E-10
4.25	.1454E-04	.9789E-04	.6084E-09	.2079E-12	.754241E-02	.522354E-02	.228941E-07	.163437E-10
4.50	.1173E-04	.8702E-04	.5739E-09	.1649E-12	.758742E-02	.554071E-02	.249238E-07	.169822E-10
4.75	.9889E-05	.7728E-04	.5408E-09	.1288E-12	.762660E-02	.583865E-02	.269469E-07	.175138E-10
5.00	.8230E-05	.6858E-04	.5092E-09	.9932E-13	.766121E-02	.611747E-02	.289557E-07	.179491E-10
5.25	.6575E-05	.6083E-04	.4792E-09	.7599E-13	.769092E-02	.637756E-02	.309436E-07	.183008E-10
5.50	.5229E-05	.5395E-04	.4508E-09	.5819E-13	.771578E-02	.661951E-02	.329053E-07	.185832E-10
5.75	.4466E-05	.4785E-04	.4240E-09	.4518E-13	.773715E-02	.684409E-02	.348365E-07	.188109E-10
6.00	.4154E-05	.4245E-04	.3988E-09	.3616E-13	.775703E-02	.705215E-02	.367337E-07	.189981E-10
6.25	.3881E-05	.3768E-04	.3752E-09	.3031E-13	.777634E-02	.724465E-02	.385945E-07	.191577E-10
6.50	.3368E-05	.3348E-04	.3531E-09	.2683E-13	.779446E-02	.742260E-02	.404168E-07	.193006E-10
6.75	.2719E-05	.2980E-04	.3324E-09	.2499E-13	.781027E-02	.758706E-02	.421992E-07	.194354E-10
7.00	.2246E-05	.2657E-04	.3129E-09	.2412E-13	.782365E-02	.773910E-02	.439405E-07	.195679E-10
7.25	.2107E-05	.2376E-04	.2947E-09	.2367E-13	.783582E-02	.787981E-02	.456399E-07	.197016E-10
7.50	.2130E-05	.2132E-04	.2777E-09	.2322E-13	.784809E-02	.801024E-02	.472968E-07	.198374E-10
7.75	.2031E-05	.1919E-04	.2616E-09	.2244E-13	.786055E-02	.813142E-02	.489108E-07	.199741E-10
8.00	.1697E-05	.1733E-04	.2466E-09	.2116E-13	.787207E-02	.824425E-02	.504817E-07	.201089E-10
8.25	.1349E-05	.1570E-04	.2324E-09	.1930E-13	.788177E-02	.834957E-02	.520093E-07	.202379E-10
8.50	.1190E-05	.1427E-04	.2191E-09	.1687E-13	.789011E-02	.844810E-02	.534936E-07	.203567E-10
8.75	.1194E-05	.1301E-04	.2066E-09	.1397E-13	.789818E-02	.854044E-02	.549347E-07	.204611E-10
9.00	.1277E-05	.1187E-04	.1948E-09	.1076E-13	.790680E-02	.862709E-02	.563329E-07	.205471E-10
9.25	.1220E-05	.1085E-04	.1837E-09	.7427E-14	.791575E-02	.870847E-02	.576889E-07	.206121E-10
9.50	.9945E-06	.9927E-05	.1734E-09	.4169E-14	.792389E-02	.878492E-02	.590032E-07	.206547E-10
9.75	.7528E-06	.9089E-05	.1637E-09	.1180E-14	.793048E-02	.885676E-02	.602768E-07	.206747E-10
10.00	.7128E-06	.8330E-05	.1546E-09		.793616E-02	.892427E-02	.615107E-07	.206739E-10
10.25	.7998E-06	.7646E-05	.1462E-09		.794218E-02	.898776E-02	.627062E-07	.206550E-10
10.50	.8475E-06	.7034E-05	.1383E-09		.794890E-02	.904755E-02	.638647E-07	.206222E-10
10.75	.7828E-06	.6490E-05	.1310E-09		.795570E-02	.910395E-02	.649878E-07	.205804E-10
11.00	.6016E-06	.6010E-05	.1242E-09		.796160E-02	.915731E-02	.660769E-07	.205349E-10
11.25	.4535E-06	.5587E-05	.1178E-09		.796620E-02	.920796E-02	.671338E-07	.204912E-10
11.50	.4743E-06	.5216E-05	.1120E-09		.797035E-02	.925620E-02	.681600E-07	.204544E-10
11.75	.5675E-06	.4887E-05	.1065E-09		.797511E-02	.930230E-02	.691570E-07	.204206E-10
12.00	.5952E-06	.4591E-05	.1014E-09		.798053E-02	.934648E-02	.701262E-07	.204171E-10
12.25	.4987E-06	.4322E-05	.9663E-10		.798574E-02	.938891E-02	.710689E-07	.204216E-10
12.50	.3755E-06	.4070E-05	.9216E-10		.798998E-02	.942968E-02	.719861E-07	.204428E-10
12.75	.2868E-06	.3832E-05	.8795E-10		.799326E-02	.946885E-02	.728789E-07	.204795E-10
13.00	.3210E-06	.3603E-05	.8397E-10		.799633E-02	.950643E-02	.737479E-07	.205297E-10
13.25	.4113E-06	.3383E-05	.8019E-10		.800011E-02	.954243E-02	.745938E-07	.205900E-10
13.50	.4309E-06	.3172E-05	.7659E-10		.800454E-02	.957685E-02	.754171E-07	.206563E-10
13.75	.3344E-06	.2973E-05	.7316E-10		.800863E-02	.960972E-02	.762182E-07	.207239E-10
14.00	.2257E-06	.2788E-05	.6988E-10		.801167E-02	.964110E-02	.769974E-07	.207883E-10
14.25	.2021E-06	.2619E-05	.6674E-10		.801404E-02	.967109E-02	.777551E-07	.208451E-10
14.50	.2489E-06	.2468E-05	.6375E-10		.801659E-02	.969980E-02	.784916E-07	.208906E-10

Table 4-2. (Continued)

14.75	.3256E-06	.2336E-05	.6089E-10	.801990E-02	.972738E-02	.792073E-07	.209221E-10
15.00	.3276E-06	.2221E-05	.5817E-10	.802371E-02	.975399E-02	.799027E-07	.209380E-10
15.25	.2248E-06	.2121E-05	.5560E-10	.802699E-02	.977977E-02	.805783E-07	.209377E-10
15.50	.1465E-06	.2033E-05	.5316E-10	.802922E-02	.980484E-02	.812348E-07	.209223E-10
15.75	.1522E-06	.1952E-05	.5087E-10	.803106E-02	.982929E-02	.818731E-07	.208938E-10
16.00	.2212E-06	.1876E-05	.4872E-10	.803339E-02	.985315E-02	.824938E-07	.208551E-10
16.25	.2645E-06	.1801E-05	.4671E-10	.803647E-02	.987644E-02	.830980E-07	.208101E-10
16.50	.2465E-06	.1724E-05	.4483E-10	.803975E-02	.989910E-02	.836866E-07	.207628E-10
16.75	.1645E-06	.1645E-05	.4309E-10	.804243E-02	.992110E-02	.842605E-07	.207177E-10
17.00	.9915E-07	.1565E-05	.4146E-10	.804417E-02	.994237E-02	.848207E-07	.206787E-10
17.25	.1243E-06	.1484E-05	.3993E-10	.804568E-02	.996287E-02	.853680E-07	.206493E-10
17.50	.1896E-06	.1405E-05	.3851E-10	.804782E-02	.998257E-02	.859031E-07	.206323E-10
17.75	.2163E-06	.1330E-05	.3716E-10	.805063E-02	.100015E-01	.864268E-07	.206291E-10
18.00	.1709E-06	.1263E-05	.3589E-10	.805335E-02	.100197E-01	.869395E-07	.206403E-10
18.25	.1092E-06	.1203E-05	.3467E-10	.805534E-02	.100372E-01	.874417E-07	.206654E-10
18.50	.6701E-07	.1153E-05	.3350E-10	.805661E-02	.100542E-01	.879335E-07	.207024E-10
18.75	.9523E-07	.1112E-05	.3236E-10	.805780E-02	.100708E-01	.884152E-07	.207489E-10
19.00	.1558E-06	.1078E-05	.3126E-10	.805966E-02	.100870E-01	.888868E-07	.208013E-10
19.25	.1744E-06	.1055E-05	.3018E-10	.806214E-02	.101031E-01	.893482E-07	.208550E-10
19.50	.1227E-06	.1027E-05	.2912E-10	.806440E-02	.101189E-01	.897994E-07	.209086E-10
19.75	.6266E-07	.9940E-06	.2809E-10	.806583E-02	.101345E-01	.902403E-07	.209558E-10
20.00	.5370E-07	.9652E-06	.2708E-10	.806673E-02	.101498E-01	.906708E-07	.209941E-10
20.25	.8741E-07	.9308E-06	.2610E-10	.806785E-02	.101647E-01	.910911E-07	.210209E-10
20.50	.1395E-06	.8969E-06	.2515E-10	.806967E-02	.101794E-01	.915011E-07	.210347E-10
20.75	.1453E-06	.8518E-06	.2423E-10	.807198E-02	.101935E-01	.919010E-07	.210347E-10
21.00	.8538E-07	.8111E-06	.2336E-10	.807386E-02	.102072E-01	.922911E-07	.210215E-10
21.25	.3954E-07	.7766E-06	.2253E-10	.807490E-02	.102203E-01	.926710E-07	.209965E-10
21.50	.4650E-07	.7338E-06	.2176E-10	.807562E-02	.102330E-01	.930436E-07	.209621E-10
21.75	.9394E-07	.7018E-06	.2103E-10	.807682E-02	.102452E-01	.934069E-07	.209214E-10
22.00	.1240E-06	.6740E-06	.2035E-10	.807870E-02	.102570E-01	.937623E-07	.208779E-10
22.25	.1166E-06	.6531E-06	.1972E-10	.808079E-02	.102685E-01	.941105E-07	.208354E-10
22.50	.6654E-07	.6374E-06	.1914E-10	.808240E-02	.102799E-01	.944520E-07	.207974E-10
22.75	.2637E-07	.6191E-06	.1860E-10	.808322E-02	.102910E-01	.947873E-07	.207671E-10
23.00	.4442E-07	.6139E-06	.1810E-10	.808386E-02	.103021E-01	.951170E-07	.207472E-10
23.25	.8985E-07	.6043E-06	.1763E-10	.808508E-02	.103132E-01	.954414E-07	.207392E-10
23.50	.1102E-06	.5897E-06	.1717E-10	.808692E-02	.103241E-01	.957608E-07	.207440E-10
23.75	.8251E-07	.5781E-06	.1674E-10	.808871E-02	.103350E-01	.960755E-07	.207613E-10
24.00	.4315E-07	.5610E-06	.1632E-10	.808988E-02	.103456E-01	.963854E-07	.207898E-10
24.25	.1617E-07	.5436E-06	.1590E-10	.809044E-02	.103561E-01	.966905E-07	.208276E-10
24.50	.3630E-07	.5171E-06	.1548E-10	.809095E-02	.103663E-01	.969908E-07	.208716E-10
24.75	.7885E-07	.4932E-06	.1506E-10	.809206E-02	.103760E-01	.972860E-07	.209188E-10
25.00	.9382E-07	.4738E-06	.1463E-10	.809375E-02	.103855E-01	.975760E-07	.209655E-10
25.25	.6024E-07	.4472E-06	.1421E-10	.809527E-02	.103946E-01	.978605E-07	.210084E-10
25.50	.2007E-07	.4288E-06	.1378E-10	.809607E-02	.104033E-01	.981394E-07	.210444E-10
25.75	.1127E-07	.4135E-06	.1336E-10	.809638E-02	.104118E-01	.984125E-07	.210708E-10
26.00	.3874E-07	.4031E-06	.1294E-10	.809689E-02	.104201E-01	.986797E-07	.210860E-10
26.25	.7616E-07	.3965E-06	.1253E-10	.809807E-02	.104283E-01	.989411E-07	.210890E-10
26.50	.8203E-07	.3877E-06	.1214E-10	.809971E-02	.104364E-01	.991966E-07	.210799E-10
26.75	.4156E-07	.3890E-06	.1177E-10	.810100E-02	.104445E-01	.994467E-07	.210598E-10
27.00	.9858E-08	.3865E-06	.1142E-10	.810154E-02	.104527E-01	.996914E-07	.210304E-10
27.25	.1504E-07	.3796E-06	.1109E-10	.810181E-02	.104609E-01	.999312E-07	.209944E-10
27.50	.4936E-07	.3751E-06	.1079E-10	.810250E-02	.104690E-01	.100166E-06	.209547E-10
27.75	.7232E-07	.3657E-06	.1052E-10	.810382E-02	.104770E-01	.100398E-06	.209140E-10
28.00	.6804E-07	.3558E-06	.1027E-10	.810536E-02	.104849E-01	.100625E-06	.208778E-10
28.25	.3339E-07	.3384E-06	.1004E-10	.810648E-02	.104926E-01	.100849E-06	.208469E-10
28.50	.4927E-08	.3227E-06	.9832E-11	.810690E-02	.104999E-01	.101071E-06	.208246E-10
28.75	.1770E-07	.3106E-06	.9639E-11	.810716E-02	.105071E-01	.101290E-06	.208127E-10
29.00	.4485E-07	.2922E-06	.9489E-11	.810787E-02	.105139E-01	.101507E-06	.208164E-10
29.25	.6737E-07	.2803E-06	.9307E-11	.810915E-02	.105204E-01	.101722E-06	.208352E-10
29.50	.5471E-07	.2711E-06	.9094E-11	.811056E-02	.105268E-01	.101934E-06	.208646E-10

Table 4-2. (Continued)

29.75	.2052E-07	.2640E-06	.8917E-11	.811143E-02	.105330E-01	.102143E-06	.208913E-10
30.00	.1130E-08	.2628E-06	.8734E-11	.811169E-02	.105392E-01	.102350E-06	.209295E-10
30.25	.1623E-07	.2583E-06	.8538E-11	.811189E-02	.105454E-01	.102555E-06	.209711E-10
30.50	.4821E-07	.2588E-06	.8333E-11	.811266E-02	.105515E-01	.102756E-06	.210112E-10
30.75	.6188E-07	.2626E-06	.8142E-11	.811399E-02	.105578E-01	.102954E-06	.210499E-10
31.00	.4245E-07	.2594E-06	.7933E-11	.811525E-02	.105641E-01	.103149E-06	.210853E-10
31.25	.1087E-07	.2578E-06	.7682E-11	.811590E-02	.105705E-01	.103340E-06	.211089E-10
31.50	.6141E-09	.2527E-06	.7466E-11	.811604E-02	.105767E-01	.103527E-06	.211186E-10
31.75	.2162E-07	.2465E-06	.7286E-11	.811632E-02	.105829E-01	.103710E-06	.211217E-10
32.00	.5021E-07	.2374E-06	.7079E-11	.811722E-02	.105890E-01	.103890E-06	.211181E-10
32.25	.5517E-07	.2230E-06	.6852E-11	.811855E-02	.105948E-01	.104065E-06	.211009E-10
32.50	.3123E-07	.2148E-06	.6673E-11	.811965E-02	.106004E-01	.104237E-06	.210723E-10
32.75	.4172E-08	.2038E-06	.6508E-11	.812010E-02	.106057E-01	.104406E-06	.210385E-10
33.00	.2553E-08	.1928E-06	.6354E-11	.812019E-02	.106109E-01	.104572E-06	.210019E-10
33.25	.2713E-07	.1867E-06	.6212E-11	.812057E-02	.106158E-01	.104736E-06	.209645E-10
33.50	.5066E-07	.1822E-06	.6101E-11	.812159E-02	.106206E-01	.104897E-06	.209307E-10
33.75	.4760E-07	.1826E-06	.5997E-11	.812289E-02	.106254E-01	.105057E-06	.209042E-10
34.00	.2142E-07	.1804E-06	.5869E-11	.812381E-02	.106303E-01	.105215E-06	.208819E-10
34.25	.2403E-09	.1822E-06	.5781E-11	.812410E-02	.106351E-01	.105371E-06	.208651E-10
34.50	.6275E-08	.1868E-06	.5728E-11	.812418E-02	.106401E-01	.105526E-06	.208623E-10
34.75	.3217E-07	.1855E-06	.5649E-11	.812471E-02	.106452E-01	.105681E-06	.208739E-10
35.00	.4950E-07	.1855E-06	.5569E-11	.812583E-02	.106503E-01	.105834E-06	.208951E-10
35.25	.3959E-07	.1825E-06	.5464E-11	.812706E-02	.106553E-01	.105987E-06	.209217E-10
35.50	.1330E-07	.1785E-06	.5381E-11	.812779E-02	.106603E-01	.106137E-06	.209528E-10
35.75		.1719E-06	.5289E-11	.812796E-02	.106652E-01	.106286E-06	.209892E-10
36.00		.1608E-06	.5184E-11	.812810E-02	.106699E-01	.106434E-06	.210272E-10
36.25		.1549E-06	.5084E-11	.812877E-02	.106744E-01	.106580E-06	.210647E-10
36.50		.1465E-06	.4971E-11	.812996E-02	.106787E-01	.106723E-06	.211000E-10
36.75		.1379E-06	.4852E-11	.813109E-02	.106828E-01	.106865E-06	.211296E-10
37.00		.1337E-06	.4699E-11	.813165E-02	.106867E-01	.107003E-06	.211473E-10
37.25		.1306E-06	.4574E-11	.813175E-02	.106906E-01	.107138E-06	.211515E-10
37.50		.1317E-06	.4476E-11	.813198E-02	.106944E-01	.107271E-06	.211495E-10
37.75		.1307E-06	.4356E-11	.813281E-02	.106983E-01	.107401E-06	.211414E-10
38.00		.1330E-06	.4223E-11	.813403E-02	.107022E-01	.107529E-06	.211215E-10
38.25		.1378E-06	.4123E-11	.813503E-02	.107063E-01	.107654E-06	.210921E-10
38.50		.1374E-06	.4036E-11	.813544E-02	.107104E-01	.107777E-06	.210594E-10
38.75		.1382E-06	.3952E-11	.813551E-02	.107146E-01	.107898E-06	.210249E-10
39.00		.1366E-06	.3879E-11	.813588E-02	.107188E-01	.108018E-06	.209899E-10
39.25		.1338E-06	.3832E-11	.813684E-02	.107230E-01	.108136E-06	.209598E-10
39.50		.1289E-06	.3786E-11	.813806E-02	.107270E-01	.108254E-06	.209379E-10
39.75		.1200E-06	.3718E-11	.813892E-02	.107309E-01	.108371E-06	.209204E-10
40.00		.1155E-06	.3681E-11	.813920E-02	.107346E-01	.108486E-06	.209083E-10

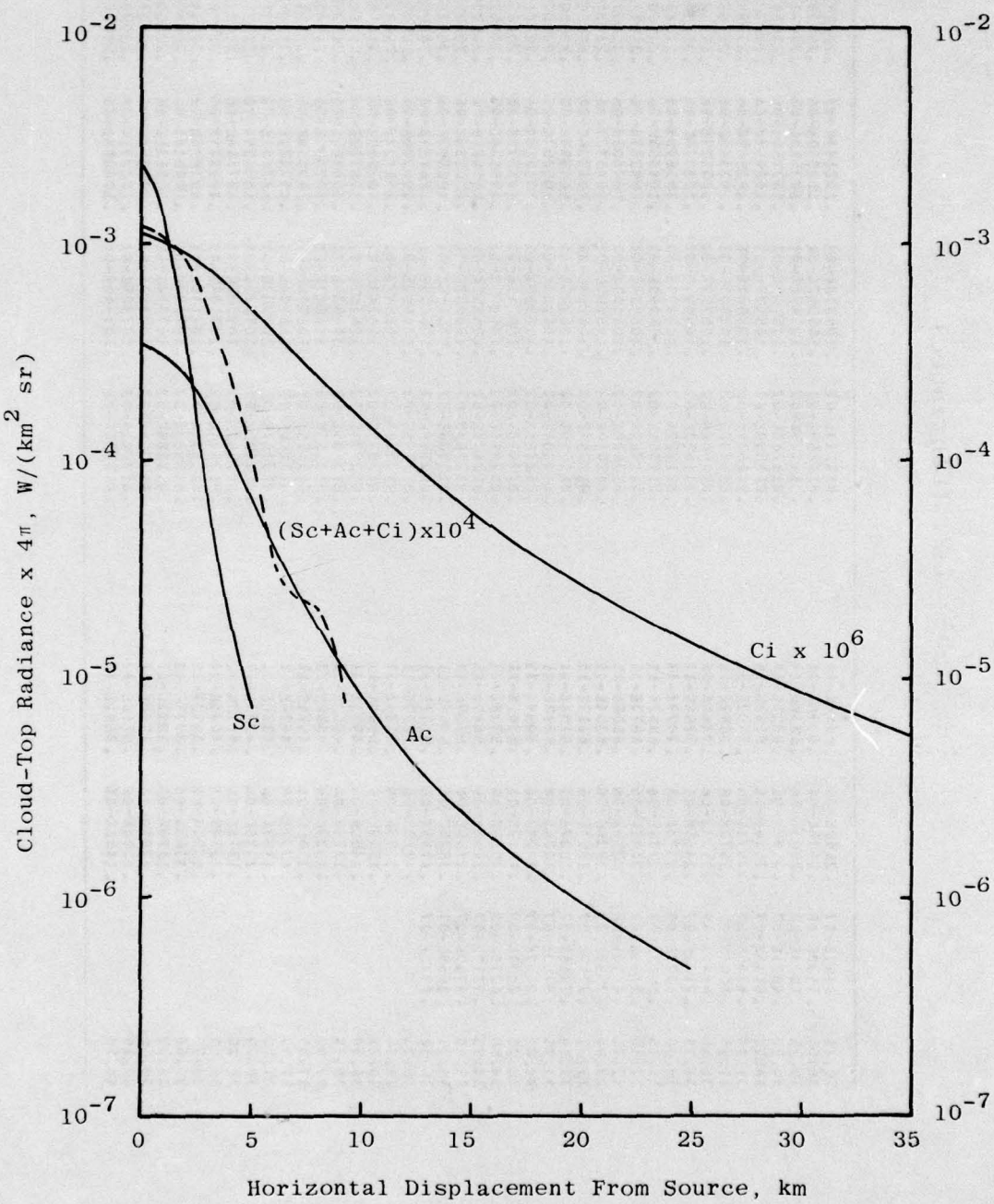

Figure 4-3. Output for sample Problems 1 to 4

where

T_i = transmittance of ith layer

R_i = reflectance of ith layer.

The total reflectance R for a planar slab is given by Equation (31b) of Appendix A as

$$R = T \cdot \tfrac{1}{2} \left(\frac{a}{Kb} - \frac{Kb}{a} \right) \sinh KL \quad .$$

We can now compare our code results with the analytical results. This comparison is given in Table 4-3 where we give, as a function of the lateral displacement from the source, the ratio of the code-computed integrated-transmittance to the analytic integrated-transmittance. We see that for cloud Sc the code result is less than the analytic result by only 7%, 3%, and 2% at distances of 5, 10, and 15 km. For cloud Ac and cloud Ci the code results are small by 5% and 15% even at 40 km. For the three-layer configuration, the code result is small by only 15% at 5 km and 2% at 10 km.

We conclude that, whereas the comparisons between the code results and the analytic results for the integrated transmittance are not perfect for these examples, the comparison is of sufficiently high quality for the radial distances of importance that one can have a high confidence in the diffusion calculations performed in the statistical cloud submodel.

We return now to the input cards for Problems 1 to 4. We have two general choices for KMODEL which can be either (a) any value in the range from 1 to 10 or (b) a value of 11.

If KMODEL is less than 11, it doesn't matter, for Problems 1 to 4, which of the allowed values we choose. We can understand that fact by reviewing how the code operates for, say, Problem 1:

(1) ROSCOER reads the detector, source, and wavelength cards.

(2) Subroutine CLOUDO reads the Type-1 and Type-2 cards and three Type-2d cards.

(2.1) On the Type-2 card we set KCOVER and KLAYER to 0 since we have no need to override the stored data for either the CCOVER or CFREQ arrays; in fact, we really don't use the stored data for these arrays.

Table 4-3. Ratio of T(code)- to T(analytic)-results for sample Problems 1 to 4.

Distance (km)	Cloud Configuration			
	Sc	Ac	Ci	Sc + Ac + Ci
5	0.934	0.543	0.228	0.850
10	0.968	0.792	0.485	0.979
15	0.978	0.866	0.630	
20		0.901	0.714	
25		0.922	0.769	
30		0.936	0.806	
35		0.946	0.834	
40		0.953	0.855	

(2.2) On the Type-2 card we set KTYPL, KTYPM, and KTYPH to 1 to allow the code to read in three Type-2d cards.

(3) The three Type-2d cards specify that the only cloud configuration of interest is that for which the low-altitude layer has cloud Type-4 (Sc) and the mid- and high-altitude layers are clear.

(4) ROSCOER calls subroutine SCLOUD.

(5) Subroutine SCLOUD calls subroutine CLDWT.

(6) Subroutine CLDWT's calculations are very much restricted compared with a normal run.

(6.1) Consider Pass-1 through the DO-500 loop (II=2). In the DO-101 loop, the tests are satisfied only for LL=4. PIJKL is computed and IDX is set to 1. TRANS(1) and WT(160) are also computed (but never used). None of the loops after DO-101 becomes effective.

(6.2) Consider Pass-2 through the DO-500 loop (II=3). Again, in DO-101 loop, tests are satisfied only for LL=4. PIJKL is computed and IDX is again set to 1. This time, computations of TRANS(1) and EMISS(1) are skipped because they were computed on Pass-1. The Pass-1 values of WT(1) and WT(160) are augmented with the Pass-2 values (but, again, will never be used).

(6.3) Pass-3 and Pass-4 through DO-500 loop are just like Pass-2.

(6.4) Subroutine CLDWT returns to subroutine SCLOUD values for TRANS(1), EMISS(1), WT(1), and WT(2) = WT(160).

(7.1) In subroutine SCLOUD we exploit common PTE by arbitrarily setting T4 equal to TRANS(1), the modified transfer coefficient.

(7.2) The code effectively returns to ROSCOER without doing any of the usual calculations or sorting in subroutine SCLOUD.

(8) ROSCOER then performs the radial integration over the cloud-top surface.

We now consider what would happen if we inputted 11 for KMODEL. First, we note that the code would expect to read a Type-2a card and four Type-2b cards. The natural selection of values for these cards would be as follows:

For Problems 1 to 4:

$$\text{CCOVER (I,11)} = \begin{cases} 0.0, & \text{I=1,4} \\ 1.0, & \text{I=5} \end{cases}$$

$$\text{CFREQ(I,J,11)} = 0.0 \ \text{(I=1,17), J=1,3}$$

and

$$\text{CFREQ(I,4,11)} = \begin{cases} \left.\begin{array}{ll} 1.0 & \text{I=4 \& 15} \\ 0.0 & \text{Otherwise} \end{array}\right\} & \text{Problem 1} \\ \left.\begin{array}{ll} 1.0 & \text{I=8 \& 15} \\ 0.0 & \text{Otherwise} \end{array}\right\} & \text{Problem 2} \\ \left.\begin{array}{ll} 1.0 & \text{I=13 \& 15} \\ 0.0 & \text{Otherwise} \end{array}\right\} & \text{Problem 3} \\ \left.\begin{array}{ll} 1.0 & \text{I=4,8,13 \& 17} \\ 0.0 & \text{Otherwise} \end{array}\right\} & \text{Problem 4} \end{cases}$$

However, it really wouldn't matter what is read in for CCOVER and CFREQ since we do not use them in Problems 1 to 4.

Subroutine CLDWT will return the complete arrays for TRANS and EMISS but the WT array will have zeros except that:

WT(4)≠0 and WT(160)≠0 for Problem 1
WT(8)≠0 and WT(160)≠0 for Problem 2
WT(13)≠0 and WT(160)≠0 for Problem 3
WT(114)≠0 and WT(160)≠0 for Problem 4

Of course, we are interested in TRANS(IDX) for selected values of IDX: i.e., IDX = 4,8,13, and 114 for Problems 1,2,3, and 4, respectively. These members of the TRANS array can and should be intercepted in subroutine SCLOUD immediately after the return from subroutine SCLOUD immediately after the return from subroutine CLDWT. Failure to intercept at this point would allow the TRANS array to be sorted, with the loss of identity of the particular member of TRANS that is of interest.

4-3.2 Problem 5: Use of the statistical cloud submodel in the optional mode with KMODEL=11

The purpose of this problem is the illustrate (1) use of the statistical cloud submodel in the optional mode with KMODEL=11 and (2) a detailed printout of the complete results for a statistical cloud problem.

Use of the cloud model with KMODEL=11 requires the user to read in the Type-2a card for (CCOVER(I,11), I=1,5) and four Type-2b cards for (CFREQ(I,J,11), I=1,17; J=1,4), as seen from Figure 4-1. The input data deck is shown in Figure 4-4.

Selection of appropriate data for use with KMODEL=11, i.e., for the CCOVER and CFREQ arrays, is always the user's responsibility. For the authors' convenience, and for illustration, we have arbitrarily selected the data from that given for KMODEL=1, as can be seen by comparing with BLOCK DATA. (In this instance, because we have used data from KMODEL=1, we could get the same results more directly by not inputting 11 for KMODEL and the associated Type-2a and Type-2b cards but instead inputting 1 for KMODEL.)

Because we have inputted a 1 for the source-type flag ISUN, the code will first do the problem with the artificial source as specified and then do the problem with the sun as the source. The emission radiance will be calculated in each case.

The output results for the artificial source are shown in Tables 4-4a through 4-4d and those for the solar source are shown in Table 4-5a thorugh 4-5c.

The quantities in the various columns in Tables 4-4a and 4-5a are described in Table 4-6. The results for IDX=1,159 are provided by subroutine CLDWT for the 159 different cloud configurations. The entries for TRANS≡TCOEF with values of $\sim 10^{-51}$ occur when the argument of the sinh and cosh functions in the integral being evaluated

```
******************** PROBLEM 5  ************************************
    HD       THETAD      PHID       FOV                DETECTOR
  35793.     90.00001   -90.0001    1.0
 HSORCE(1) THETAS(1)   PHIS(1)     WKT                SOURCE
   0.01     90.000001   -90.00      1000.
      ISUN
         1
   ALAM                                               WAVELENGTH
   2.50
      MODE                                            STATISTICAL          CARD 1
         1
KMODEL       KLAYER     KTYPM                         USER CLOUD MODEL     CARD 2
      KCOVER      KTYPL      KTYPH
   11     0     0     0     0     0
I=1 I=2 I=3 I=4 I=5                                   CCOVER(I,11)         CARD 2A
.235.150.070.201.343
                                                      CFREQ(I,1,11)        CARD 2B
I=1 I=2 I=3 I=4 I=5 I=6 I=7 I=8 I=9  10  11  12  13  14  15  16  17
.046.046.046.102.006.005.001.217.005.005.005.005.222.293.768.212.019
                                                      CFREQ(I,2,11)        CARD 2B
I=1 I=2 I=3 I=4 I=5 I=6 I=7 I=8 I=9  10  11  12  13  14  15  16  17
.055.055.055.121.006.008.001.243.009.008.008.009.164.260.542.377.081
                                                      CFREQ(I,3,11)        CARD 2B
I=1 I=2 I=3 I=4 I=5 I=6 I=7 I=8 I=9  10  11  12  13  14  15  16  17
.038.038.038.169.015.010.000.276.012.010.010.012.104.266.415.435.150
                                                      CFREQ(I,4,11)        CARD 2B
I=1 I=2 I=3 I=4 I=5 I=6 I=7 I=8 I=9  10  11  12  13  14  15  16  17
.010.010.010.336.155.010.030.197.023.010.010.023.017.158.448.423.128
```

Figure 4-4. Input data for Problem 5.

Table 4-4a. Initial arrays for artificial source transfer-coefficients, emission radiances, and weights in sample Problem 5. Wavelength = 2.5 μm.

IDX	LL	MM	HH	TRANS	EMISS	CC=2	CC=3	CC=4	CC=5	WT	WT(SUM)
1	1			.3798E+01	.2553E+03	.6889E-03	.4799E-03	.1648E-02	.1414E-02	.4231E-02	.4231E-02
2	2			.8990E-08	.1473E+03	.6889E-03	.4799E-03	.1648E-02	.1414E-02	.4231E-02	.8462E-02
3	3			.1276E+00	.1208E+03	.6889E-03	.4799E-03	.1648E-02	.1414E-02	.4231E-02	.1269E-01
4	4			.4617E-01	.2227E+03	.1528E-02	.1056E-02	.7331E-02	.4750E-01	.5741E-01	.7011E-01
5	5			.1158E+00	.2529E+03	.8986E-04	.5236E-04	.6506E-03	.2191E-01	.2271E-01	.9281E-01
6	6			.3798E+01	.2553E+03	.7488E-04	.6981E-04	.4338E-03	.1414E-02	.1992E-02	.9480E-01
7	7			.4801E-02	.1473E+03	.1498E-04	.8726E-05	0.	.4241E-02	.4265E-02	.9907E-01
8		1		.6812E-02	.6389E+02	.3250E-02	.2120E-02	.1197E-01	.2785E-01	.4519E-01	.1443E+00
9		2		.4550E-05	.6389E+02	.7488E-04	.7854E-04	.5205E-03	.3252E-02	.3925E-02	.1482E+00
10		3		.6135E-37	.6389E+02	.7488E-04	.6981E-04	.4338E-03	.1414E-02	.1992E-02	.1502E+00
11			1	.1160E-06	.1126E+01	.7488E-04	.6981E-04	.4338E-03	.1414E-02	.1992E-02	.1522E+00
12			2	.4365E-51	.5296E+01	.7488E-04	.7854E-04	.5205E-03	.3252E-02	.3925E-02	.1561E+00
13			3	.2199E-07	.1073E+02	.3325E-02	.1431E-02	.4511E-02	.2403E-02	.1167E-01	.1678E+00
14			4	.1826E-23	.5296E+01	.4388E-02	.2269E-02	.1154E-01	.2234E-01	.4053E-01	.2083E+00
15	1	1		.6281E-02	.6389E+02	.1337E-03	.2491E-03	.1448E-02	.8958E-03	.2726E-02	.2110E+00
16	1	2		.5278E-05	.6389E+02	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2112E+00
17	1	3		.4506E-37	.6389E+02	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2113E+00
18	2	1		.8333E-10	.6389E+02	.1337E-03	.2491E-03	.1448E-02	.8958E-03	.2726E-02	.2140E+00
19	2	2		.7280E-51	.6389E+02	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2142E+00
20	2	3		.7280E-51	.6389E+02	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2143E+00
21	3	1		.1901E-02	.6389E+02	.1337E-03	.2491E-03	.1448E-02	.8958E-03	.2726E-02	.2171E+00
22	3	2		.8300E-06	.6389E+02	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2172E+00
23	3	3		.3597E-38	.6389E+02	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2173E+00
24	4	1		.2231E-03	.6389E+02	.2964E-03	.5480E-03	.6439E-02	.3010E-01	.3738E-01	.2547E+00
25	4	2		.1553E-06	.6389E+02	.6830E-05	.2030E-04	.2800E-03	.3514E-02	.3821E-02	.2585E+00
26	4	3		.7280E-51	.6389E+02	.6830E-05	.1804E-04	.2333E-03	.1528E-02	.1786E-02	.2603E+00
27	5	1		.9948E-04	.6389E+02	.1744E-04	.2717E-04	.5715E-03	.1388E-01	.1450E-01	.2748E+00
28	5	2		.8970E-07	.6389E+02	.4018E-06	.1006E-05	.2485E-04	.1621E-02	.1647E-02	.2765E+00
29	5	3		.7280E-51	.6389E+02	.4018E-06	.8946E-06	.2071E-04	.7048E-03	.7268E-03	.2772E+00
30	6	1		.6281E-02	.6389E+02	.1453E-04	.3623E-04	.3810E-03	.8958E-03	.1328E-02	.2785E+00
31	6	2		.5278E-05	.6389E+02	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.2787E+00
32	6	3		.4506E-37	.6389E+02	.3348E-06	.1193E-05	.1381E-04	.4547E-04	.6080E-04	.2787E+00
33	7	1		.6474E-04	.6389E+02	.2906E-05	.4529E-05	0.	.2687E-02	.2695E-02	.2814E+00
34	7	2		.3119E-07	.6389E+02	.6696E-07	.1677E-06	0.	.3137E-03	.3140E-03	.2817E+00
35	7	3		.7280E-51	.6389E+02	.6696E-07	.1491E-06	0.	.1364E-03	.1366E-03	.2819E+00
36	1		1	.4614E-06	.1126E+01	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2820E+00
37	1		2	.4365E-51	.5296E+01	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2822E+00
38	1		3	.6192E-07	.1073E+02	.1368E-03	.1681E-03	.5456E-03	.7730E-04	.9278E-03	.2831E+00
39	1		4	.7354E-23	.5296E+01	.1805E-03	.2665E-03	.1395E-02	.7184E-03	.2561E-02	.2856E+00
40	2		1	.3637E-51	.1126E+01	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2858E+00
41	2		2	.4365E-51	.5296E+01	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2859E+00
42	2		3	.4851E-51	.1073E+02	.1368E-03	.1681E-03	.5456E-03	.7730E-04	.9278E-03	.2869E+00
43	2		4	.4365E-51	.5296E+01	.1805E-03	.2665E-03	.1395E-02	.7184E-03	.2561E-02	.2894E+00
44	3		1	.1482E-06	.1126E+01	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2895E+00
45	3		2	.4365E-51	.5296E+01	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2897E+00
46	3		3	.1384E-07	.1073E+02	.1368E-03	.1681E-03	.5456E-03	.7730E-04	.9278E-03	.2906E+00
47	3		4	.1200E-23	.5296E+01	.1805E-03	.2665E-03	.1395E-02	.7184E-03	.2561E-02	.2932E+00
48	4		1	.1033E-07	.1126E+01	.6830E-05	.1804E-04	.2333E-03	.1528E-02	.1786E-02	.2950E+00
49	4		2	.4365E-51	.5296E+01	.6830E-05	.2030E-04	.2800E-03	.3514E-02	.3821E-02	.2988E+00
50	4		3	.1491E-08	.1073E+02	.3033E-03	.3699E-03	.2426E-02	.2597E-02	.5697E-02	.3045E+00
51	4		4	.4355E-51	.5296E+01	.4002E-03	.5864E-03	.6206E-02	.2414E-01	.3133E-01	.3358E+00
52	5		1	.5835E-08	.1126E+01	.4018E-06	.8946E-06	.2071E-04	.7048E-03	.7268E-03	.3366E+00
53	5		2	.4365E-51	.5296E+01	.4018E-06	.1006E-05	.2485E-04	.1621E-02	.1647E-02	.3382E+00
54	5		3	.8534E-09	.1073E+02	.1784E-04	.1834E-04	.2154E-03	.1198E-02	.1450E-02	.3397E+00
55	5		4	.4365E-51	.5296E+01	.2354E-04	.2908E-04	.5508E-03	.1114E-01	.1174E-01	.3514E+00
56	6		1	.4614E-06	.1126E+01	.3348E-06	.1193E-05	.1381E-04	.4547E-04	.6080E-04	.3515E+00
57	6		2	.4365E-51	.5296E+01	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.3516E+00
58	6		3	.6192E-07	.1073E+02	.1487E-04	.2445E-04	.1436E-03	.7730E-04	.2602E-03	.3518E+00
59	6		4	.7354E-23	.5296E+01	.1962E-04	.3877E-04	.3672E-03	.7184E-03	.1144E-02	.3530E+00

Table 4-4a. (Continued)

60	7		1	.3062E-08	.1126E+01	.6696E-07	.1491E-06	0.	.1364E-03	.1366E-03	.3531E+00
61	7		2	.4365E-51	.5296E+01	.6696E-07	.1677E-06	0.	.3137E-03	.3140E-03	.3534E+00
62	7		3	.3234E-09	.1073E+02	.2973E-05	.3057E-05	0.	.2319E-03	.2379E-03	.3537E+00
63	7		4	.4365E-51	.5296E+01	.3924E-05	.4846E-05	0.	.2155E-02	.2164E-02	.3558E+00
64		1	1	.8740E-08	.1126E+01	.1453E-04	.3623E-04	.3810E-03	.8958E-03	.1328E-02	.3572E+00
65		1	2	.4365E-51	.5296E+01	.1453E-04	.4076E-04	.4572E-03	.2060E-02	.2573E-02	.3597E+00
66		1	3	.8132E-09	.1073E+02	.6452E-03	.7428E-03	.3963E-02	.1523E-02	.6873E-02	.3666E+00
67		1	4	.4365E-51	.5296E+01	.8515E-03	.1178E-02	.1014E-01	.1415E-01	.2632E-01	.3929E+00
68		2	1	.3637E-51	.1126E+01	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.3931E+00
69		2	2	.4365E-51	.5296E+01	.3348E-06	.1510E-05	.1988E-04	.2405E-03	.2623E-03	.3933E+00
70		2	3	.4851E-51	.1073E+02	.1487E-04	.2751E-04	.1723E-03	.1778E-03	.3925E-03	.3937E+00
71		2	4	.4365E-51	.5296E+01	.1962E-04	.4361E-04	.4407E-03	.1652E-02	.2156E-02	.3959E+00
72		3	1	.3637E-51	.1126E+01	.3348E-06	.1193E-05	.1381E-04	.4547E-04	.6080E-04	.3959E+00
73		3	2	.4365E-51	.5296E+01	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.3960E+00
74		3	3	.4851E-51	.1073E+02	.1487E-04	.2445E-04	.1436E-03	.7730E-04	.2602E-03	.3963E+00
75		3	4	.4365E-51	.5296E+01	.1962E-04	.3877E-04	.3672E-03	.7184E-03	.1144E-02	.3974E+00
76	1	1	1	.7693E-08	.1126E+01	.6157E-06	.4040E-05	.4570E-04	.2965E-04	.8001E-04	.3975E+00
77	1	1	2	.4365E-51	.5296E+01	.6157E-06	.4545E-05	.5484E-04	.6819E-04	.1282E-03	.3977E+00
78	1	1	3	.7393E-09	.1073E+02	.2734E-04	.8282E-04	.4753E-03	.5040E-04	.6359E-03	.3983E+00
79	1	1	4	.4365E-51	.5296E+01	.3608E-04	.1313E-03	.1216E-02	.4684E-03	.1851E-02	.4001E+00
80	1	2	1	.3705E-11	.1126E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4002E+00
81	1	2	2	.4365E-51	.5296E+01	.1419E-07	.1683E-06	.2384E-05	.7961E-05	.1053E-04	.4002E+00
82	1	2	3	.1339E-12	.1073E+02	.6299E-06	.3067E-05	.2067E-04	.5885E-05	.3025E-04	.4002E+00
83	1	2	4	.4365E-51	.5296E+01	.8314E-06	.4863E-05	.5285E-04	.5469E-04	.1132E-03	.4003E+00
84	1	3	1	.3637E-51	.1126E+01	.1419E-07	.1330E-06	.1656E-05	.1505E-05	.3308E-05	.4003E+00
85	1	3	2	.4365E-51	.5296E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4003E+00
86	1	3	3	.4851E-51	.1073E+02	.6299E-06	.2727E-05	.1722E-04	.2559E-05	.2314E-04	.4003E+00
87	1	3	4	.4365E-51	.5296E+01	.8314E-06	.4323E-05	.4405E-04	.2378E-04	.7298E-04	.4004E+00
88	2	1	1	.3637E-51	.1126E+01	.6157E-06	.4040E-05	.4570E-04	.2965E-04	.8001E-04	.4005E+00
89	2	1	2	.4365E-51	.5296E+01	.6157E-06	.4545E-05	.5484E-04	.6819E-04	.1282E-03	.4006E+00
90	2	1	3	.4851E-51	.1073E+02	.2734E-04	.8282E-04	.4753E-03	.5040E-04	.6359E-03	.4013E+00
91	2	1	4	.4365E-51	.5296E+01	.3608E-04	.1313E-03	.1216E-02	.4684E-03	.1851E-02	.4031E+00
92	2	2	1	.3637E-51	.1126E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4031E+00
93	2	2	2	.4365E-51	.5296E+01	.1419E-07	.1683E-06	.2384E-05	.7961E-05	.1053E-04	.4031E+00
94	2	2	3	.4851E-51	.1073E+02	.6299E-06	.3067E-05	.2067E-04	.5885E-05	.3025E-04	.4032E+00
95	2	2	4	.4365E-51	.5296E+01	.8314E-06	.4863E-05	.5285E-04	.5469E-04	.1132E-03	.4033E+00
96	2	3	1	.3637E-51	.1126E+01	.1419E-07	.1330E-06	.1656E-05	.1505E-05	.3308E-05	.4033E+00
97	2	3	2	.4365E-51	.5296E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4033E+00
98	2	3	3	.4851E-51	.1073E+02	.6299E-06	.2727E-05	.1722E-04	.2559E-05	.2314E-04	.4033E+00
99	2	3	4	.4365E-51	.5296E+01	.8314E-06	.4323E-05	.4405E-04	.2378E-04	.7298E-04	.4034E+00
100	3	1	1	.2590E-08	.1126E+01	.6157E-06	.4040E-05	.4570E-04	.2965E-04	.8001E-04	.4035E+00
101	3	1	2	.4365E-51	.5296E+01	.6157E-06	.4545E-05	.5484E-04	.6819E-04	.1282E-03	.4036E+00
102	3	1	3	.2307E-09	.1073E+02	.2734E-04	.8282E-04	.4753E-03	.5040E-04	.6359E-03	.4042E+00
103	3	1	4	.4365E-51	.5296E+01	.3608E-04	.1313E-03	.1216E-02	.4684E-03	.1851E-02	.4061E+00
104	3	2	1	.3637E-51	.1126E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4061E+00
105	3	2	2	.4365E-51	.5296E+01	.1419E-07	.1683E-06	.2384E-05	.7961E-05	.1053E-04	.4061E+00
106	3	2	3	.4851E-51	.1073E+02	.6299E-06	.3067E-05	.2067E-04	.5885E-05	.3025E-04	.4061E+00
107	3	2	4	.4365E-51	.5296E+01	.8314E-06	.4863E-05	.5285E-04	.5469E-04	.1132E-03	.4062E+00
108	3	3	1	.3637E-51	.1126E+01	.1419E-07	.1330E-06	.1656E-05	.1505E-05	.3308E-05	.4062E+00
109	3	3	2	.4365E-51	.5296E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4062E+00
110	3	3	3	.4851E-51	.1073E+02	.6299E-06	.2727E-05	.1722E-04	.2559E-05	.2314E-04	.4063E+00
111	3	3	4	.4365E-51	.5296E+01	.8314E-06	.4323E-05	.4405E-04	.2378E-04	.7298E-04	.4063E+00
112	4	1	1	.3637E-51	.1126E+01	.1365E-05	.8888E-05	.2033E-03	.9962E-03	.1210E-02	.4075E+00
113	4	1	2	.4365E-51	.5296E+01	.1365E-05	.9999E-05	.2439E-03	.2291E-02	.2547E-02	.4101E+00
114	4	1	3	.4851E-51	.1073E+02	.6062E-04	.1822E-03	.2114E-02	.1694E-02	.4050E-02	.4141E+00
115	4	1	4	.4365E-51	.5296E+01	.8001E-04	.2889E-03	.5406E-02	.1574E-01	.2152E-01	.4357E+00
116	4	2	1	.3637E-51	.1126E+01	.3146E-07	.3292E-06	.8837E-05	.1163E-03	.1255E-03	.4358E+00
117	4	2	2	.4365E-51	.5296E+01	.3146E-07	.3703E-06	.1060E-04	.2675E-03	.2785E-03	.4361E+00
118	4	2	3	.4851E-51	.1073E+02	.1397E-05	.6748E-05	.9190E-04	.1977E-03	.2978E-03	.4364E+00
119	4	2	4	.4365E-51	.5296E+01	.1843E-05	.1070E-04	.2351E-03	.1838E-02	.2085E-02	.4384E+00

Table 4-4a. (Continued)

120	4	3	1	.3637E-51	.1126E+01	.3146E-07	.2926E-06	.7364E-05	.5057E-04	.5826E-04	.4385E+00
121	4	3	2	.4365E-51	.5296E+01	.3146E-07	.3292E-06	.8837E-05	.1163E-03	.1255E-03	.4386E+00
122	4	3	3	.4851E-51	.1073E+02	.1397E-05	.5999E-05	.7659E-04	.8597E-04	.1699E-03	.4388E+00
123	4	3	4	.4365E-51	.5296E+01	.1843E-05	.9510E-05	.1959E-03	.7990E-03	.1006E-02	.4398E+00
124	5	1	1	.3637E-51	.1126E+01	.8031E-07	.4407E-06	.1804E-04	.4596E-03	.4781E-03	.4403E+00
125	5	1	2	.4365E-51	.5296E+01	.8031E-07	.4958E-06	.2165E-04	.1057E-02	.1079E-02	.4414E+00
126	5	1	3	.4851E-51	.1073E+02	.3566E-05	.9035E-05	.1876E-03	.7812E-03	.9815E-03	.4423E+00
127	5	1	4	.4365E-51	.5296E+01	.4706E-05	.1432E-04	.4799E-03	.7261E-02	.7760E-02	.4501E+00
128	5	2	1	.3637E-51	.1126E+01	.1851E-08	.1632E-07	.7844E-06	.5365E-04	.5446E-04	.4502E+00
129	5	2	2	.4365E-51	.5296E+01	.1851E-08	.1836E-07	.9412E-06	.1234E-03	.1244E-03	.4503E+00
130	5	2	3	.4851E-51	.1073E+02	.8216E-07	.3346E-06	.8157E-05	.9121E-04	.9978E-04	.4504E+00
131	5	2	4	.4365E-51	.5296E+01	.1084E-06	.5305E-06	.2086E-04	.8477E-03	.8692E-03	.4512E+00
132	5	3	1	.3637E-51	.1126E+01	.1851E-08	.1451E-07	.6536E-06	.2333E-04	.2400E-04	.4513E+00
133	5	3	2	.4365E-51	.5296E+01	.1851E-08	.1632E-07	.7844E-06	.5365E-04	.5446E-04	.4513E+00
134	5	3	3	.4851E-51	.1073E+02	.8216E-07	.2975E-06	.6798E-05	.3966E-04	.4683E-04	.4514E+00
135	5	3	4	.4365E-51	.5296E+01	.1084E-06	.4716E-06	.1739E-04	.3686E-03	.3865E-03	.4518E+00
136	6	1	1	.7693E-08	.1126E+01	.6693E-07	.5876E-06	.1203E-04	.2965E-04	.4233E-04	.4518E+00
137	6	1	2	.4365E-51	.5296E+01	.6693E-07	.6611E-06	.1443E-04	.6819E-04	.8335E-04	.4519E+00
138	6	1	3	.7393E-09	.1073E+02	.2972E-05	.1205E-04	.1251E-03	.5040E-04	.1905E-03	.4521E+00
139	6	1	4	.4365E-51	.5296E+01	.3922E-05	.1910E-04	.3199E-03	.4684E-03	.8114E-03	.4529E+00
140	6	2	1	.3705E-11	.1126E+01	.1542E-08	.2176E-07	.5229E-06	.3462E-05	.4008E-05	.4529E+00
141	6	2	2	.4365E-51	.5296E+01	.1542E-08	.2449E-07	.6275E-06	.7961E-05	.8615E-05	.4529E+00
142	6	2	3	.1339E-12	.1073E+02	.6847E-07	.4462E-06	.5438E-05	.5885E-05	.1184E-04	.4529E+00
143	6	2	4	.4365E-51	.5296E+01	.9037E-07	.7074E-06	.1391E-04	.5469E-04	.6940E-04	.4530E+00
144	6	3	1	.3637E-51	.1126E+01	.1542E-08	.1935E-07	.4358E-06	.1505E-05	.1962E-05	.4530E+00
145	6	3	2	.4365E-51	.5296E+01	.1542E-08	.2176E-07	.5229E-06	.3462E-05	.4008E-05	.4530E+00
146	6	3	3	.4851E-51	.1073E+02	.6847E-07	.3966E-06	.4532E-05	.2559E-05	.7555E-05	.4530E+00
147	6	3	4	.4365E-51	.5296E+01	.9037E-07	.6288E-06	.1159E-04	.2378E-04	.3609E-04	.4530E+00
148	7	1	1	.3637E-51	.1126E+01	.1339E-07	.7346E-07	0.	.8895E-04	.8903E-04	.4531E+00
149	7	1	2	.4365E-51	.5296E+01	.1339E-07	.8264E-07	0.	.2046E-03	.2047E-03	.4533E+00
150	7	1	3	.4851E-51	.1073E+02	.5943E-06	.1506E-05	0.	.1512E-03	.1533E-03	.4535E+00
151	7	1	4	.4365E-51	.5296E+01	.7844E-06	.2387E-05	0.	.1405E-02	.1409E-02	.4549E+00
152	7	2	1	.3637E-51	.1126E+01	.3084E-09	.2721E-08	0.	.1038E-04	.1039E-04	.4549E+00
153	7	2	2	.4365E-51	.5296E+01	.3084E-09	.3061E-08	0.	.2388E-04	.2389E-04	.4549E+00
154	7	2	3	.4851E-51	.1073E+02	.1369E-07	.5577E-07	0.	.1765E-04	.1772E-04	.4549E+00
155	7	2	4	.4365E-51	.5296E+01	.1807E-07	.8842E-07	0.	.1641E-03	.1642E-03	.4551E+00
156	7	3	1	.3637E-51	.1126E+01	.3084E-09	.2418E-08	0.	.4515E-05	.4518E-05	.4551E+00
157	7	3	2	.4365E-51	.5296E+01	.3084E-09	.2721E-08	0.	.1038E-04	.1039E-04	.4551E+00
158	7	3	3	.4851E-51	.1073E+02	.1369E-07	.4958E-07	0.	.7676E-05	.7739E-05	.4551E+00
159	7	3	4	.4365E-51	.5296E+01	.1807E-07	.7860E-07	0.	.7134E-04	.7143E-04	.4552E+00
160**********				0.	0.	-R	-R	-R	-R	.5435E+00	.9987E+00

IDX = 160 TRANS(160) = .1816E+01 EMISS(160) = .3275E+03 WT (160) = .5399E+00

Table 4-4b. Sorted array for artificial source transfer-coefficients (and carried-along weights) for sample Problem 5.

TRANS,WT =

0.	0.	.3637E-51	.5612E-05	.3637E-51	.8001E-04	.3637E-51	.3308E-05
.3637E-51	.1092E-03	.3637E-51	.3308E-05	.3637E-51	.6080E-04	.3637E-51	.3308E-05
.3637E-51	.5612E-05	.3637E-51	.2400E-04	.3637E-51	.4518E-05	.3637E-51	.4781E-03
.3637E-51	.5446E-04	.3637E-51	.1228E-03	.3637E-51	.1039E-04	.3637E-51	.1962E-05
.3637E-51	.8903E-04	.3637E-51	.5826E-04	.3637E-51	.1255E-03	.3637E-51	.1210E-02
.4365E-51	.5612E-05	.4365E-51	.1132E-03	.4365E-51	.1851E-02	.4365E-51	.1282E-03
.4365E-51	.1053E-04	.4365E-51	.1282E-03	.4365E-51	.7298E-04	.4365E-51	.1132E-03
.4365E-51	.7298E-04	.4365E-51	.1144E-02	.4365E-51	.7298E-04	.4365E-51	.5612E-05
.4365E-51	.1053E-04	.4365E-51	.5612E-05	.4365E-51	.1798E-03	.4365E-51	.1798E-03
.4365E-51	.1132E-03	.4365E-51	.1851E-02	.4365E-51	.1851E-02	.4365E-51	.3865E-03
.4365E-51	.8692E-03	.4365E-51	.1798E-03	.4365E-51	.1228E-03	.4365E-51	.1244E-03
.4365E-51	.2573E-02	.4365E-51	.3140E-03	.4365E-51	.7760E-02	.4365E-51	.2561E-02
.4365E-51	.8114E-03	.4365E-51	.1642E-03	.4365E-51	.2156E-02	.4365E-51	.3925E-02
.4365E-51	.5446E-04	.4365E-51	.2623E-03	.4365E-51	.1079E-02	.4365E-51	.1053E-04
.4365E-51	.1228E-03	.4365E-51	.2164E-02	.4365E-51	.7143E-04	.4365E-51	.4008E-05
.4365E-51	.1409E-02	.4365E-51	.2632E-01	.4365E-51	.2389E-04	.4365E-51	.2047E-03
.4365E-51	.1282E-03	.4365E-51	.8615E-05	.4365E-51	.8335E-04	.4365E-51	.6940E-04
.4365E-51	.3609E-04	.4365E-51	.1039E-04	.4365E-51	.1174E-01	.4365E-51	.2085E-02
.4365E-51	.3133E-01	.4365E-51	.2152E-01	.4365E-51	.1647E-02	.4365E-51	.3821E-02
.4365E-51	.2547E-02	.4365E-51	.1255E-03	.4365E-51	.2785E-03	.4365E-51	.1006E-02
.4851E-51	.6359E-03	.4851E-51	.2314E-04	.4851E-51	.3025E-04	.4851E-51	.4050E-02
.4851E-51	.2314E-04	.4851E-51	.3025E-04	.4851E-51	.9978E-04	.4851E-51	.2314E-04
.4851E-51	.4683E-04	.4851E-51	.3925E-03	.4851E-51	.9815E-03	.4851E-51	.9278E-03
.4851E-51	.2978E-03	.4851E-51	.2602E-03	.4851E-51	.1533E-03	.4851E-51	.7555E-05
.4851E-51	.1699E-03	.4851E-51	.7739E-05	.4851E-51	.1772E-04	.7280E-51	.1092E-03
.7280E-51	.1786E-02	.7280E-51	.1798E-03	.7280E-51	.1366E-03	.7280E-51	.7268E-03
.3597E-38	.1092E-03	.4506E-37	.6080E-04	.4506E-37	.1092E-03	.6135E-37	.1992E-02
.1200E-23	.2561E-02	.1826E-23	.4053E-01	.7354E-23	.1144E-02	.7354E-23	.2561E-02
.1339E-12	.1184E-04	.1339E-12	.3025E-04	.3705E-11	.4008E-05	.3705E-11	.5612E-05
.8333E-10	.2726E-02	.2307E-09	.6359E-03	.3234E-09	.2379E-03	.7393E-09	.1905E-03
.7393E-09	.6359E-03	.8132E-09	.6873E-02	.8534E-09	.1450E-02	.1491E-08	.5697E-02
.2590E-08	.8001E-04	.3062E-08	.1366E-03	.5835E-08	.7268E-03	.7693E-08	.8001E-04
.7693E-08	.4233E-04	.8740E-08	.1328E-02	.8990E-08	.4231E-02	.1083E-07	.1786E-02
.1384E-07	.9278E-03	.2199E-07	.1167E-01	.3119E-07	.3140E-03	.6192E-07	.9278E-03
.6192E-07	.2602E-03	.8970E-07	.1647E-02	.1160E-06	.1992E-02	.1482E-06	.1092E-03
.1553E-06	.3821E-02	.4614E-06	.6080E-04	.4614E-06	.1092E-03	.8300E-06	.1798E-03
.4550E-05	.3925E-02	.5278E-05	.1798E-03	.5278E-05	.1228E-03	.6474E-04	.2695E-02
.9948E-04	.1450E-01	.2231E-03	.3738E-01	.1901E-02	.2726E-02	.4801E-02	.4265E-02
.6281E-02	.2726E-02	.6281E-02	.1328E-02	.6812E-02	.4519E-01	.4617E-01	.5741E-01
.1158E+00	.2271E-01	.1276E+00	.4231E-02	.1816E+01	.5399E+00	.3798E+01	.1992E-02
.3798E+01	.4231E-02						

Table 4-4c. Sorted array for emission radiances (and carried-along weights) for sample Problem 5.

EMISS,WT1 =

0.	0.	.1126E+01	.5612E-05	.1126E+01	.8001E-04	.1126E+01	.3308E-05
.1126E+01	.8001E-04	.1126E+01	.3308E-05	.1126E+01	.1210E-02	.1126E+01	.3308E-05
.1126E+01	.5612E-05	.1126E+01	.1092E-03	.1126E+01	.1992E-02	.1126E+01	.7268E-03
.1126E+01	.1786E-02	.1126E+01	.1092E-03	.1126E+01	.1366E-03	.1126E+01	.1092E-03
.1126E+01	.6080E-04	.1126E+01	.1228E-03	.1126E+01	.1328E-02	.1126E+01	.5612E-05
.1126E+01	.6080E-04	.1126E+01	.2400E-04	.1126E+01	.5446E-04	.1126E+01	.4781E-03
.1126E+01	.4008E-05	.1126E+01	.8001E-04	.1126E+01	.1039E-04	.1126E+01	.8903E-04
.1126E+01	.1962E-05	.1126E+01	.5826E-04	.1126E+01	.4233E-04	.1126E+01	.1255E-03
.1126E+01	.4518E-05	.5296E+01	.7298E-04	.5296E+01	.1132E-03	.5296E+01	.1282E-03
.5296E+01	.5612E-05	.5296E+01	.1053E-04	.5296E+01	.5612E-05	.5296E+01	.1132E-03
.5296E+01	.7298E-04	.5296E+01	.1132E-03	.5296E+01	.1851E-02	.5296E+01	.5612E-05
.5296E+01	.1053E-04	.5296E+01	.1282E-03	.5296E+01	.1798E-03	.5296E+01	.2547E-02
.5296E+01	.2561E-02	.5296E+01	.2152E-01	.5296E+01	.7298E-04	.5296E+01	.2561E-02
.5296E+01	.2561E-02	.5296E+01	.3821E-02	.5296E+01	.1798E-03	.5296E+01	.1798E-03
.5296E+01	.1228E-03	.5296E+01	.1647E-02	.5296E+01	.1144E-02	.5296E+01	.1174E-01
.5296E+01	.3133E-01	.5296E+01	.3925E-02	.5296E+01	.2164E-02	.5296E+01	.4053E-01
.5296E+01	.2573E-02	.5296E+01	.3140E-03	.5296E+01	.2632E-01	.5296E+01	.1228E-03
.5296E+01	.2623E-03	.5296E+01	.1144E-02	.5296E+01	.2156E-02	.5296E+01	.1282E-03
.5296E+01	.1005E-02	.5296E+01	.1851E-02	.5296E+01	.1079E-02	.5296E+01	.1053E-04
.5296E+01	.7760E-02	.5296E+01	.5446E-04	.5296E+01	.1244E-03	.5296E+01	.3865E-03
.5296E+01	.1851E-02	.5296E+01	.8335E-04	.5296E+01	.6940E-04	.5296E+01	.8114E-03
.5296E+01	.4003E-05	.5296E+01	.8615E-05	.5296E+01	.3609E-04	.5296E+01	.2389E-04
.5296E+01	.2047E-03	.5296E+01	.1642E-03	.5296E+01	.1409E-02	.5296E+01	.2785E-03
.5296E+01	.1039E-04	.5296E+01	.2085E-02	.5296E+01	.7143E-04	.5296E+01	.1255E-03
.5296E+01	.8692E-03	.1073E+02	.9278E-03	.1073E+02	.2314E-04	.1073E+02	.2314E-04
.1073E+02	.6359E-03	.1073E+02	.3025E-04	.1073E+02	.2602E-03	.1073E+02	.4050E-02
.1073E+02	.5697E-02	.1073E+02	.2314E-04	.1073E+02	.6359E-03	.1073E+02	.6359E-03
.1073E+02	.1450E-02	.1073E+02	.3925E-03	.1073E+02	.3025E-04	.1073E+02	.9278E-03
.1073E+02	.1905E-03	.1073E+02	.2602E-03	.1073E+02	.9978E-04	.1073E+02	.9278E-03
.1073E+02	.2379E-03	.1073E+02	.2978E-03	.1073E+02	.3025E-04	.1073E+02	.1533E-03
.1073E+02	.6873E-02	.1073E+02	.1699E-03	.1073E+02	.1167E-01	.1073E+02	.1772E-04
.1073E+02	.1184E-04	.1073E+02	.9815E-03	.1073E+02	.4683E-04	.1073E+02	.7739E-05
.1073E+02	.7555E-05	.6389E+02	.1992E-02	.6389E+02	.3821E-02	.6389E+02	.1798E-03
.6389E+02	.1092E-03	.6389E+02	.3738E-01	.6389E+02	.2726E-02	.6389E+02	.1786E-02
.6389E+02	.1450E-01	.6389E+02	.4519E-01	.6389E+02	.3925E-02	.6389E+02	.1092E-03
.6389E+02	.2726E-02	.6389E+02	.6080E-04	.6389E+02	.2695E-02	.6389E+02	.3140E-03
.6389E+02	.1366E-03	.6389E+02	.1798E-03	.6389E+02	.1092E-03	.6389E+02	.1647E-02
.6389E+02	.7268E-03	.6389E+02	.1328E-02	.6389E+02	.1228E-03	.6389E+02	.1798E-03
.6389E+02	.2726E-02	.1208E+03	.4231E-02	.1473E+03	.4265E-02	.1473E+03	.4231E-02
.2227E+03	.5741E-01	.2529E+03	.2271E-01	.2553E+03	.1992E-02	.2553E+03	.4231E-02
.3275E+03	.5435E+00						

Table 4-4d. Cumulative, normalized weight arrays for artificial source transfer-coefficients and emission radiances in sample Problem 5.

WT,WT1 =

0.	0.	.5640E-05	.5620E-05	.8604E-04	.8573E-04	.8936E-04	.8904E-04
.1991E-03	.1691E-03	.2024E-03	.1725E-03	.2635E-03	.1384E-02	.2669E-03	.1387E-02
.2725E-03	.1393E-02	.2966E-03	.1502E-02	.3012E-03	.3497E-02	.7816E-03	.4224E-02
.8364E-03	.6013E-02	.9598E-03	.6122E-02	.9702E-03	.6259E-02	.9722E-03	.6368E-02
.1062E-02	.6429E-02	.1120E-02	.6552E-02	.1246E-02	.7881E-02	.2462E-02	.7887E-02
.2468E-02	.7948E-02	.2581E-02	.7972E-02	.4442E-02	.8026E-02	.4571E-02	.8505E-02
.4581E-02	.8509E-02	.4710E-02	.8589E-02	.4784E-02	.8600E-02	.4897E-02	.8689E-02
.4971E-02	.8691E-02	.6120E-02	.8749E-02	.6194E-02	.8791E-02	.6199E-02	.8917E-02
.6210E-02	.8922E-02	.6216E-02	.8995E-02	.6396E-02	.9108E-02	.6577E-02	.9236E-02
.6691E-02	.9242E-02	.8551E-02	.9253E-02	.1041E-01	.9258E-02	.1080E-01	.9372E-02
.1167E-01	.9445E-02	.1185E-01	.9558E-02	.1198E-01	.1141E-01	.1210E-01	.1142E-01
.1469E-01	.1143E-01	.1500E-01	.1156E-01	.2280E-01	.1174E-01	.2538E-01	.1429E-01
.2619E-01	.1685E-01	.2636E-01	.3039E-01	.2852E-01	.3847E-01	.3247E-01	.4103E-01
.3252E-01	.4359E-01	.3279E-01	.4742E-01	.3387E-01	.4760E-01	.3388E-01	.4778E-01
.3400E-01	.4790E-01	.3618E-01	.4955E-01	.3625E-01	.5070E-01	.3626E-01	.6245E-01
.3767E-01	.9382E-01	.6412E-01	.9776E-01	.6414E-01	.9992E-01	.6435E-01	.1405E+00
.6448E-01	.1431E+00	.6449E-01	.1434E+00	.6457E-01	.1697E+00	.6464E-01	.1699E+00
.6467E-01	.1701E+00	.6469E-01	.1713E+00	.7648E-01	.1734E+00	.7858E-01	.1736E+00
.1101E+00	.1746E+00	.1317E+00	.1764E+00	.1333E+00	.1775E+00	.1372E+00	.1775E+00
.1397E+00	.1853E+00	.1399E+00	.1853E+00	.1401E+00	.1855E+00	.1412E+00	.1859E+00
.1418E+00	.1877E+00	.1419E+00	.1878E+00	.1418E+00	.1879E+00	.1459E+00	.1887E+00
.1459E+00	.1887E+00	.1460E+00	.1887E+00	.1461E+00	.1887E+00	.1461E+00	.1887E+00
.1461E+00	.1890E+00	.1465E+00	.1891E+00	.1475E+00	.1905E+00	.1485E+00	.1908E+00
.1488E+00	.1908E+00	.1490E+00	.1929E+00	.1492E+00	.1930E+00	.1492E+00	.1931E+00
.1493E+00	.1940E+00	.1494E+00	.1949E+00	.1494E+00	.1949E+00	.1495E+00	.1949E+00
.1513E+00	.1956E+00	.1515E+00	.1956E+00	.1516E+00	.1959E+00	.1523E+00	.1999E+00
.1524E+00	.2056E+00	.1525E+00	.2057E+00	.1526E+00	.2063E+00	.1546E+00	.2069E+00
.1572E+00	.2084E+00	.1979E+00	.2088E+00	.1991E+00	.2088E+00	.2016E+00	.2097E+00
.2017E+00	.2099E+00	.2017E+00	.2102E+00	.2017E+00	.2103E+00	.2017E+00	.2112E+00
.2044E+00	.2115E+00	.2051E+00	.2117E+00	.2053E+00	.2118E+00	.2055E+00	.2119E+00
.2061E+00	.2188E+00	.2130E+00	.2190E+00	.2145E+00	.2307E+00	.2202E+00	.2307E+00
.2203E+00	.2307E+00	.2204E+00	.2317E+00	.2212E+00	.2317E+00	.2213E+00	.2317E+00
.2213E+00	.2317E+00	.2226E+00	.2337E+00	.2269E+00	.2376E+00	.2287E+00	.2377E+00
.2296E+00	.2379E+00	.2413E+00	.2753E+00	.2417E+00	.2780E+00	.2426E+00	.2798E+00
.2428E+00	.2943E+00	.2445E+00	.3396E+00	.2465E+00	.3435E+00	.2466E+00	.3436E+00
.2505E+00	.3463E+00	.2505E+00	.3464E+00	.2506E+00	.3491E+00	.2508E+00	.3494E+00
.2548E+00	.3495E+00	.2549E+00	.3497E+00	.2551E+00	.3498E+00	.2578E+00	.3515E+00
.2723E+00	.3522E+00	.3099E+00	.3535E+00	.3126E+00	.3537E+00	.3169E+00	.3539E+00
.3197E+00	.3566E+00	.3210E+00	.3608E+00	.3664E+00	.3651E+00	.4241E+00	.3693E+00
.4469E+00	.4268E+00	.4512E+00	.4495E+00	.9937E+00	.4515E+00	.9957E+00	.4558E+00
.1000E+01	.1000E+01						

STATISTICAL CLOUDS,	P1,P2,P3,P4 =	.10	.25	.50	.90
SOURCE TRANSFER CF	T1,T2,T3,T4 =	.437E-51	.154E-06	.280E+00	.152E+01
EMISSION	E1,E2,E3,E4 =	.530E+01	.639E+02	.261E+03	.314E+03

Table 4-5a. Initial arrays for solar source transfer-coefficients, emission radiances, and weights in sample Problem 5. Wavelength = 2.5 μm.

IDX	LL	MM	HH	TRANS	EMISS	CC=2	CC=3	CC=4	CC=5	WT	WT(SUM)
1	1			.3887E-02	.2553E+03	.6889E-03	.4799E-03	.1648E-02	.1414E-02	.4231E-02	.4231E-02
2	2			.2714E-01	.1473E+03	.6889E-03	.4799E-03	.1648E-02	.1414E-02	.4231E-02	.8462E-02
3	3			.3171E-01	.1208E+03	.6889E-03	.4799E-03	.1648E-02	.1414E-02	.4231E-02	.1269E-01
4	4			.1048E-01	.2227E+03	.1528E-02	.1056E-02	.7331E-02	.4750E-01	.5741E-01	.7011E-01
5	5			.4398E-02	.2529E+03	.8986E-04	.5236E-04	.6506E-03	.2191E-01	.2271E-01	.9281E-01
6	6			.3887E-02	.2553E+03	.7488E-04	.6981E-04	.4338E-03	.1414E-02	.1992E-02	.9480E-01
7	7			.2714E-01	.1473E+03	.1498E-04	.8726E-05	0.	.4241E-02	.4265E-02	.9907E-01
8		1		.5061E-01	.6389E+02	.3250E-02	.2120E-02	.1197E-01	.2785E-01	.4519E-01	.1443E+00
9		2		.5061E-01	.6389E+02	.7488E-04	.7854E-04	.5205E-03	.3252E-02	.3925E-02	.1482E+00
10		3		.5061E-01	.6389E+02	.7488E-04	.6981E-04	.4338E-03	.1414E-02	.1992E-02	.1502E+00
11			1	.8408E-01	.1126E+01	.7488E-04	.6981E-04	.4338E-03	.1414E-02	.1992E-02	.1522E+00
12			2	.7621E-01	.5296E+01	.7488E-04	.7854E-04	.5205E-03	.3252E-02	.3925E-02	.1561E+00
13			3	.7255E-01	.1073E+02	.3325E-02	.1431E-02	.4511E-02	.2403E-02	.1167E-01	.1678E+00
14			4	.7621E-01	.5296E+01	.4388E-02	.2269E-02	.1154E-01	.2234E-01	.4053E-01	.2083E+00
15	1	1		.5061E-01	.6389E+02	.1337E-03	.2491E-03	.1448E-02	.8958E-03	.2726E-02	.2110E+00
16	1	2		.5061E-01	.6389E+02	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2112E+00
17	1	3		.5061E-01	.6389E+02	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2113E+00
18	2	1		.5061E-01	.6389E+02	.1337E-03	.2491E-03	.1448E-02	.8958E-03	.2726E-02	.2140E+00
19	2	2		.5061E-01	.6389E+02	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2142E+00
20	2	3		.5061E-01	.6389E+02	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2143E+00
21	3	1		.5061E-01	.6389E+02	.1337E-03	.2491E-03	.1448E-02	.8958E-03	.2726E-02	.2171E+00
22	3	2		.5061E-01	.6389E+02	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2172E+00
23	3	3		.5061E-01	.6389E+02	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2173E+00
24	4	1		.5061E-01	.6389E+02	.2964E-03	.5480E-03	.6439E-02	.3010E-01	.3738E-01	.2547E+00
25	4	2		.5061E-01	.6389E+02	.6830E-05	.2030E-04	.2800E-03	.3514E-02	.3821E-02	.2585E+00
26	4	3		.5061E-01	.6389E+02	.6830E-05	.1804E-04	.2333E-03	.1528E-02	.1786E-02	.2603E+00
27	5	1		.5061E-01	.6389E+02	.1744E-04	.2717E-04	.5715E-03	.1388E-01	.1450E-01	.2748E+00
28	5	2		.5061E-01	.6389E+02	.4018E-06	.1006E-05	.2485E-04	.1621E-02	.1647E-02	.2765E+00
29	5	3		.5061E-01	.6389E+02	.4018E-06	.8946E-06	.2071E-04	.7048E-03	.7268E-03	.2772E+00
30	6	1		.5061E-01	.6389E+02	.1453E-04	.3623E-04	.3810E-03	.8958E-03	.1328E-02	.2785E+00
31	6	2		.5061E-01	.6389E+02	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.2787E+00
32	6	3		.5061E-01	.6389E+02	.3348E-06	.1193E-05	.1381E-04	.4547E-04	.6080E-04	.2787E+00
33	7	1		.5061E-01	.6389E+02	.2906E-05	.4529E-05	0.	.2687E-02	.2695E-02	.2814E+00
34	7	2		.5061E-01	.6389E+02	.6696E-07	.1677E-06	0.	.3137E-03	.3140E-03	.2817E+00
35	7	3		.5061E-01	.6389E+02	.6696E-07	.1491E-06	0.	.1364E-03	.1366E-03	.2819E+00
36	1		1	.8408E-01	.1126E+01	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2820E+00
37	1		2	.7621E-01	.5296E+01	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2822E+00
38	1		3	.7255E-01	.1073E+02	.1368E-03	.1681E-03	.5456E-03	.7730E-04	.9278E-03	.2831E+00
39	1		4	.7621E-01	.5296E+01	.1805E-03	.2665E-03	.1395E-02	.7184E-03	.2561E-02	.2856E+00
40	2		1	.8408E-01	.1126E+01	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2858E+00
41	2		2	.7621E-01	.5296E+01	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2859E+00
42	2		3	.7255E-01	.1073E+02	.1368E-03	.1681E-03	.5456E-03	.7730E-04	.9278E-03	.2869E+00
43	2		4	.7621E-01	.5296E+01	.1805E-03	.2665E-03	.1395E-02	.7184E-03	.2561E-02	.2894E+00
44	3		1	.8408E-01	.1126E+01	.3080E-05	.8201E-05	.5246E-04	.4547E-04	.1092E-03	.2895E+00
45	3		2	.7621E-01	.5296E+01	.3080E-05	.9226E-05	.6295E-04	.1046E-03	.1798E-03	.2897E+00
46	3		3	.7255E-01	.1073E+02	.1368E-03	.1681E-03	.5456E-03	.7730E-04	.9278E-03	.2906E+00
47	3		4	.7621E-01	.5296E+01	.1805E-03	.2665E-03	.1395E-02	.7184E-03	.2561E-02	.2932E+00
48	4		1	.8408E-01	.1126E+01	.6830E-05	.1804E-04	.2333E-03	.1528E-02	.1786E-02	.2950E+00
49	4		2	.7621E-01	.5296E+01	.6830E-05	.2030E-04	.2800E-03	.3514E-02	.3821E-02	.2988E+00
50	4		3	.7255E-01	.1073E+02	.3033E-03	.3699E-03	.2426E-02	.2597E-02	.5697E-02	.3045E+00
51	4		4	.7621E-01	.5296E+01	.4002E-03	.5864E-03	.6206E-02	.2414E-01	.3133E-01	.3358E+00
52	5		1	.8408E-01	.1126E+01	.4018E-06	.8946E-06	.2071E-04	.7048E-03	.7268E-03	.3366E+00
53	5		2	.7621E-01	.5296E+01	.4018E-06	.1006E-05	.2485E-04	.1621E-02	.1647E-02	.3382E+00
54	5		3	.7255E-01	.1073E+02	.1784E-04	.1834E-04	.2154E-03	.1193E-02	.1450E-02	.3397E+00
55	5		4	.7621E-01	.5296E+01	.2354E-04	.2908E-04	.5508E-03	.1114E-01	.1174E-01	.3514E+00
56	6		1	.8408E-01	.1126E+01	.3348E-06	.1193E-05	.1381E-04	.4547E-04	.6080E-04	.3515E+00
57	6		2	.7621E-01	.5296E+01	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.3516E+00
58	6		3	.7255E-01	.1073E+02	.1487E-04	.2445E-04	.1436E-03	.7730E-04	.2602E-03	.3518E+00
59	6		4	.7621E-01	.5296E+01	.1962E-04	.3877E-04	.3672E-03	.7184E-03	.1144E-02	.3530E+00

Table 4-5a. (Continued)

60	7		1	.8408E-01	.1126E+01	.6696E-07	.1491E-06	0.	.1364E-03	.1366E-03	.3531E+00
61	7		2	.7621E-01	.5296E+01	.6696E-07	.1677E-06	0.	.3137E-03	.3140E-03	.3534E+00
62	7		3	.7255E-01	.1073E+02	.2973E-05	.3057E-05	0.	.2319E-03	.2379E-03	.3537E+00
63	7		4	.7621E-01	.5296E+01	.3924E-05	.4846E-05	0.	.2155E-02	.2164E-02	.3558E+00
64		1	1	.8408E-01	.1126E+01	.1453E-04	.3623E-04	.3810E-03	.8958E-03	.1328E-02	.3572E+00
65		1	2	.7621E-01	.5296E+01	.1453E-04	.4076E-04	.4572E-03	.2060E-02	.2573E-02	.3597E+00
66		1	3	.7255E-01	.1073E+02	.6452E-03	.7428E-03	.3963E-02	.1523E-02	.6873E-02	.3666E+00
67		1	4	.7621E-01	.5296E+01	.8515E-03	.1178E-02	.1014E-01	.1415E-01	.2632E-01	.3929E+00
68		2	1	.8408E-01	.1126E+01	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.3931E+00
69		2	2	.7621E-01	.5296E+01	.3348E-06	.1510E-05	.1988E-04	.2405E-03	.2623E-03	.3933E+00
70		2	3	.7255E-01	.1073E+02	.1487E-04	.2751E-04	.1723E-03	.1778E-03	.3925E-03	.3937E+00
71		2	4	.7621E-01	.5296E+01	.1962E-04	.4361E-04	.4407E-03	.1652E-02	.2156E-02	.3959E+00
72		3	1	.8408E-01	.1126E+01	.3348E-06	.1193E-05	.1381E-04	.4547E-04	.6080E-04	.3959E+00
73		3	2	.7621E-01	.5296E+01	.3348E-06	.1342E-05	.1657E-04	.1046E-03	.1228E-03	.3960E+00
74		3	3	.7255E-01	.1073E+02	.1487E-04	.2445E-04	.1436E-03	.7730E-04	.2602E-03	.3963E+00
75		3	4	.7621E-01	.5296E+01	.1962E-04	.3877E-04	.3672E-03	.7184E-03	.1144E-02	.3974E+00
76	1	1	1	.8408E-01	.1126E+01	.6157E-06	.4040E-05	.4570E-04	.2965E-04	.8001E-04	.3975E+00
77	1	1	2	.7621E-01	.5296E+01	.6157E-06	.4545E-05	.5484E-04	.6819E-04	.1282E-03	.3977E+00
78	1	1	3	.7255E-01	.1073E+02	.2734E-04	.8282E-04	.4753E-03	.5040E-04	.6359E-03	.3983E+00
79	1	1	4	.7621E-01	.5296E+01	.3608E-04	.1313E-03	.1216E-02	.4684E-03	.1851E-02	.4001E+00
80	1	2	1	.8408E-01	.1126E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4002E+00
81	1	2	2	.7621E-01	.5296E+01	.1419E-07	.1683E-06	.2384E-05	.7961E-05	.1053E-04	.4002E+00
82	1	2	3	.7255E-01	.1073E+02	.6299E-06	.3067E-05	.2067E-04	.5885E-05	.3025E-04	.4002E+00
83	1	2	4	.7621E-01	.5296E+01	.8314E-06	.4863E-05	.5285E-04	.5469E-04	.1132E-03	.4003E+00
84	1	3	1	.8408E-01	.1126E+01	.1419E-07	.1330E-06	.1656E-05	.1505E-05	.3308E-05	.4003E+00
85	1	3	2	.7621E-01	.5296E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4003E+00
86	1	3	3	.7255E-01	.1073E+02	.6299E-06	.2727E-05	.1722E-04	.2559E-05	.2314E-04	.4003E+00
87	1	3	4	.7621E-01	.5296E+01	.8314E-06	.4323E-05	.4405E-04	.2378E-04	.7298E-04	.4004E+00
88	2	1	1	.8408E-01	.1126E+01	.6157E-06	.4040E-05	.4570E-04	.2965E-04	.8001E-04	.4005E+00
89	2	1	2	.7621E-01	.5296E+01	.6157E-06	.4545E-05	.5484E-04	.6819E-04	.1282E-03	.4006E+00
90	2	1	3	.7255E-01	.1073E+02	.2734E-04	.8282E-04	.4753E-03	.5040E-04	.6359E-03	.4013E+00
91	2	1	4	.7621E-01	.5296E+01	.3608E-04	.1313E-03	.1216E-02	.4684E-03	.1851E-02	.4031E+00
92	2	2	1	.8408E-01	.1126E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4031E+00
93	2	2	2	.7621E-01	.5296E+01	.1419E-07	.1683E-06	.2384E-05	.7961E-05	.1053E-04	.4031E+00
94	2	2	3	.7255E-01	.1073E+02	.6299E-06	.3067E-05	.2067E-04	.5885E-05	.3025E-04	.4032E+00
95	2	2	4	.7621E-01	.5296E+01	.8314E-06	.4863E-05	.5285E-04	.5469E-04	.1132E-03	.4033E+00
96	2	3	1	.8408E-01	.1126E+01	.1419E-07	.1330E-06	.1656E-05	.1505E-05	.3308E-05	.4033E+00
97	2	3	2	.7621E-01	.5296E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4033E+00
98	2	3	3	.7255E-01	.1073E+02	.6299E-06	.2727E-05	.1722E-04	.2559E-05	.2314E-04	.4033E+00
99	2	3	4	.7621E-01	.5296E+01	.8314E-06	.4323E-05	.4405E-04	.2378E-04	.7298E-04	.4034E+00
100	3	1	1	.8408E-01	.1126E+01	.6157E-06	.4040E-05	.4570E-04	.2965E-04	.8001E-04	.4035E+00
101	3	1	2	.7621E-01	.5296E+01	.6157E-06	.4545E-05	.5484E-04	.6819E-04	.1282E-03	.4036E+00
102	3	1	3	.7255E-01	.1073E+02	.2734E-04	.8282E-04	.4753E-03	.5040E-04	.6359E-03	.4042E+00
103	3	1	4	.7621E-01	.5296E+01	.3608E-04	.1313E-03	.1216E-02	.4684E-03	.1851E-02	.4061E+00
104	3	2	1	.8408E-01	.1126E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4061E+00
105	3	2	2	.7621E-01	.5296E+01	.1419E-07	.1683E-06	.2384E-05	.7961E-05	.1053E-04	.4061E+00
106	3	2	3	.7255E-01	.1073E+02	.6299E-06	.3067E-05	.2067E-04	.5885E-05	.3025E-04	.4061E+00
107	3	2	4	.7621E-01	.5296E+01	.8314E-06	.4863E-05	.5285E-04	.5469E-04	.1132E-03	.4062E+00
108	3	3	1	.8408E-01	.1126E+01	.1419E-07	.1330E-06	.1656E-05	.1505E-05	.3308E-05	.4062E+00
109	3	3	2	.7621E-01	.5296E+01	.1419E-07	.1496E-06	.1987E-05	.3462E-05	.5612E-05	.4062E+00
110	3	3	3	.7255E-01	.1073E+02	.6299E-06	.2727E-05	.1722E-04	.2559E-05	.2314E-04	.4063E+00
111	3	3	4	.7621E-01	.5296E+01	.8314E-06	.4323E-05	.4405E-04	.2378E-04	.7298E-04	.4063E+00
112	4	1	1	.8408E-01	.1126E+01	.1365E-05	.8888E-05	.2033E-03	.9962E-03	.1210E-02	.4075E+00
113	4	1	2	.7621E-01	.5296E+01	.1365E-05	.9999E-05	.2439E-03	.2291E-02	.2547E-02	.4101E+00
114	4	1	3	.7255E-01	.1073E+02	.6062E-04	.1822E-03	.2114E-02	.1694E-02	.4050E-02	.4141E+00
115	4	1	4	.7621E-01	.5296E+01	.8001E-04	.2889E-03	.5406E-02	.1574E-01	.2152E-01	.4357E+00
116	4	2	1	.8408E-01	.1126E+01	.3146E-07	.3292E-06	.8837E-05	.1163E-03	.1255E-03	.4358E+00
117	4	2	2	.7621E-01	.5296E+01	.3146E-07	.3703E-06	.1060E-04	.2675E-03	.2785E-03	.4361E+00
118	4	2	3	.7255E-01	.1073E+02	.1397E-05	.6748E-05	.9190E-04	.1977E-03	.2978E-03	.4364E+00
119	4	2	4	.7621E-01	.5296E+01	.1843E-05	.1070E-04	.2351E-03	.1838E-02	.2085E-02	.4384E+00

Table 4-5a. (Continued)

120	4	3	1	.8408E-01	.1126E+01	.3146E-07	.2926E-06	.7364E-05	.5057E-04	.5826E-04	.4385E+00
121	4	3	2	.7621E-01	.5296E+01	.3146E-07	.3292E-06	.8837E-05	.1163E-03	.1255E-03	.4386E+00
122	4	3	3	.7255E-01	.1073E+02	.1397E-05	.5999E-05	.7659E-04	.8597E-04	.1699E-03	.4388E+00
123	4	3	4	.7621E-01	.5296E+01	.1843E-05	.9510E-05	.1959E-03	.7990E-03	.1006E-02	.4398E+00
124	5	1	1	.8408E-01	.1126E+01	.8031E-07	.4407E-06	.1804E-04	.4596E-03	.4781E-03	.4403E+00
125	5	1	2	.7621E-01	.5296E+01	.8031E-07	.4958E-06	.2165E-04	.1057E-02	.1079E-02	.4414E+00
126	5	1	3	.7255E-01	.1073E+02	.3566E-05	.9035E-05	.1876E-03	.7812E-03	.9815E-03	.4423E+00
127	5	1	4	.7621E-01	.5296E+01	.4706E-05	.1432E-04	.4799E-03	.7261E-02	.7760E-02	.4501E+00
128	5	2	1	.8408E-01	.1126E+01	.1851E-08	.1632E-07	.7844E-06	.5365E-04	.5446E-04	.4502E+00
129	5	2	2	.7621E-01	.5296E+01	.1851E-08	.1836E-07	.9412E-06	.1234E-03	.1244E-03	.4503E+00
130	5	2	3	.7255E-01	.1073E+02	.8216E-07	.3346E-06	.8157E-05	.9121E-04	.9978E-04	.4504E+00
131	5	2	4	.7621E-01	.5296E+01	.1084E-06	.5305E-06	.2086E-04	.8477E-03	.8692E-03	.4512E+00
132	5	3	1	.8408E-01	.1126E+01	.1851E-08	.1451E-07	.6536E-06	.2333E-04	.2400E-04	.4513E+00
133	5	3	2	.7621E-01	.5296E+01	.1851E-08	.1632E-07	.7844E-06	.5365E-04	.5446E-04	.4513E+00
134	5	3	3	.7255E-01	.1073E+02	.8216E-07	.2975E-06	.6798E-05	.3966E-04	.4683E-04	.4514E+00
135	5	3	4	.7621E-01	.5296E+01	.1084E-06	.4716E-06	.1739E-04	.3686E-03	.3865E-03	.4518E+00
136	6	1	1	.8408E-01	.1126E+01	.6693E-07	.5876E-06	.1203E-04	.2965E-04	.4233E-04	.4518E+00
137	6	1	2	.7621E-01	.5296E+01	.6693E-07	.6611E-06	.1443E-04	.6819E-04	.8335E-04	.4519E+00
138	6	1	3	.7255E-01	.1073E+02	.2972E-05	.1205E-04	.1251E-03	.5040E-04	.1905E-03	.4521E+00
139	6	1	4	.7621E-01	.5296E+01	.3922E-05	.1910E-04	.3199E-03	.4684E-03	.8114E-03	.4529E+00
140	6	2	1	.8408E-01	.1126E+01	.1542E-08	.2176E-07	.5229E-06	.3462E-05	.4008E-05	.4529E+00
141	6	2	2	.7621E-01	.5296E+01	.1542E-08	.2449E-07	.6275E-06	.7961E-05	.8615E-05	.4529E+00
142	6	2	3	.7255E-01	.1073E+02	.6847E-07	.4462E-06	.5438E-05	.5885E-05	.1184E-04	.4529E+00
143	6	2	4	.7621E-01	.5296E+01	.9037E-07	.7074E-06	.1391E-04	.5469E-04	.6940E-04	.4530E+00
144	6	3	1	.8408E-01	.1126E+01	.1542E-08	.1935E-07	.4358E-06	.1505E-05	.1962E-05	.4530E+00
145	6	3	2	.7621E-01	.5296E+01	.1542E-08	.2176E-07	.5229E-06	.3462E-05	.4008E-05	.4530E+00
146	6	3	3	.7255E-01	.1073E+02	.6847E-07	.3966E-06	.4532E-05	.2559E-05	.7555E-05	.4530E+00
147	6	3	4	.7621E-01	.5296E+01	.9037E-07	.6288E-06	.1159E-04	.2378E-04	.3609E-04	.4530E+00
148	7	1	1	.8408E-01	.1126E+01	.1339E-07	.7346E-07	0.	.8895E-04	.8903E-04	.4531E+00
149	7	1	2	.7621E-01	.5296E+01	.1339E-07	.8264E-07	0.	.2046E-03	.2047E-03	.4533E+00
150	7	1	3	.7255E-01	.1073E+02	.5943E-06	.1506E-05	0.	.1512E-03	.1533E-03	.4535E+00
151	7	1	4	.7621E-01	.5296E+01	.7844E-06	.2387E-05	0.	.1405E-02	.1409E-02	.4549E+00
152	7	2	1	.8408E-01	.1126E+01	.3084E-09	.2721E-08	0.	.1038E-04	.1039E-04	.4549E+00
153	7	2	2	.7621E-01	.5296E+01	.3084E-09	.3061E-08	0.	.2388E-04	.2389E-04	.4549E+00
154	7	2	3	.7255E-01	.1073E+02	.1369E-07	.5577E-07	0.	.1765E-04	.1772E-04	.4549E+00
155	7	2	4	.7621E-01	.5296E+01	.1807E-07	.8842E-07	0.	.1641E-03	.1642E-03	.4551E+00
156	7	3	1	.8408E-01	.1126E+01	.3084E-09	.2418E-08	0.	.4515E-05	.4518E-05	.4551E+00
157	7	3	2	.7621E-01	.5296E+01	.3084E-09.	.2721E-08	0.	.1038E-04	.1039E-04	.4551E+00
158	7	3	3	.7255E-01	.1073E+02	.1369E-07	.4958E-07	0.	.7676E-05	.7739E-05	.4551E+00
159	7	3	4	.7621E-01	.5296E+01	.1807E-07	.7860E-07	0.	.7134E-04	.7143E-04	.4552E+00
160	**********			0.	0.	-R	-R	-R	-R	.5435E+00	.9987E+00

IDX = 160 TRANS(160) = .6451E-03 EMISS(160) = .3275E+03 WT (160) = .4385E+00

Table 4-5b. Sorted array for solar source transfer-coefficients (and carried-along weights) for sample Problem 5.

TRANS,WT =

0.	0.	.6451E-03	.4385E+00	.3887E-02	.1992E-02	.3887E-02	.4231E-02
.4398E-02	.2271E-01	.1048E-01	.5741E-01	.2714E-01	.4265E-02	.2714E-01	.4231E-02
.3171E-01	.4231E-02	.5061E-01	.4519E-01	.5061E-01	.3925E-02	.5061E-01	.6080E-04
.5061E-01	.2695E-02	.5061E-01	.3140E-03	.5061E-01	.2726E-02	.5061E-01	.1798E-03
.5061E-01	.1092E-03	.5061E-01	.2726E-02	.5061E-01	.1798E-03	.5061E-01	.1992E-02
.5061E-01	.1228E-03	.5061E-01	.1798E-03	.5061E-01	.1092E-03	.5061E-01	.3738E-01
.5061E-01	.3821E-02	.5061E-01	.1786E-02	.5061E-01	.1450E-01	.5061E-01	.1647E-02
.5061E-01	.7268E-03	.5061E-01	.1328E-02	.5061E-01	.2726E-02	.5061E-01	.1092E-03
.5061E-01	.1366E-03	.7255E-01	.9278E-03	.7255E-01	.1167E-01	.7255E-01	.3025E-04
.7255E-01	.2379E-03	.7255E-01	.9278E-03	.7255E-01	.1450E-02	.7255E-01	.9278E-03
.7255E-01	.6873E-02	.7255E-01	.3025E-04	.7255E-01	.2602E-03	.7255E-01	.2602E-03
.7255E-01	.5697E-02	.7255E-01	.2314E-04	.7255E-01	.6359E-03	.7255E-01	.6359E-03
.7255E-01	.4683E-04	.7255E-01	.3925E-03	.7255E-01	.3025E-04	.7255E-01	.1699E-03
.7255E-01	.2314E-04	.7255E-01	.4050E-02	.7255E-01	.6359E-03	.7255E-01	.9815E-03
.7255E-01	.1184E-04	.7255E-01	.2978E-03	.7255E-01	.1772E-04	.7255E-01	.2314E-04
.7255E-01	.7555E-05	.7255E-01	.7739E-05	.7255E-01	.1905E-03	.7255E-01	.1533E-03
.7255E-01	.9978E-04	.7621E-01	.1798E-03	.7621E-01	.2561E-02	.7621E-01	.2561E-02
.7621E-01	.3821E-02	.7621E-01	.1851E-02	.7621E-01	.3133E-01	.7621E-01	.1228E-03
.7621E-01	.2561E-02	.7621E-01	.1144E-02	.7621E-01	.1798E-03	.7621E-01	.3140E-03
.7621E-01	.2632E-01	.7621E-01	.1647E-02	.7621E-01	.2623E-03	.7621E-01	.1174E-01
.7621E-01	.2156E-02	.7621E-01	.1282E-03	.7621E-01	.2164E-02	.7621E-01	.1851E-02
.7621E-01	.2573E-02	.7621E-01	.1798E-03	.7621E-01	.7298E-04	.7621E-01	.1228E-03
.7621E-01	.1282E-03	.7621E-01	.1144E-02	.7621E-01	.8692E-03	.7621E-01	.3925E-02
.7621E-01	.1132E-03	.7621E-01	.4053E-01	.7621E-01	.5612E-05	.7621E-01	.1282E-03
.7621E-01	.5612E-05	.7621E-01	.1053E-04	.7621E-01	.7298E-04	.7621E-01	.1132E-03
.7621E-01	.7298E-04	.7621E-01	.1132E-03	.7621E-01	.1851E-02	.7621E-01	.5612E-05
.7621E-01	.1053E-04	.7621E-01	.1255E-03	.7621E-01	.2785E-03	.7621E-01	.2547E-02
.7621E-01	.2085E-02	.7621E-01	.2152E-01	.7621E-01	.1409E-02	.7621E-01	.7760E-02
.7621E-01	.1006E-02	.7621E-01	.1244E-03	.7621E-01	.1079E-02	.7621E-01	.6615E-05
.7621E-01	.8335E-04	.7621E-01	.5446E-04	.7621E-01	.8114E-03	.7621E-01	.3865E-03
.7621E-01	.1053E-04	.7621E-01	.3609E-04	.7621E-01	.6940E-04	.7621E-01	.2047E-03
.7621E-01	.4009E-05	.7621E-01	.2389E-04	.7621E-01	.1039E-04	.7621E-01	.1642E-03
.7621E-01	.7143E-04	.8408E-01	.1092E-03	.8408E-01	.6080E-04	.8408E-01	.7268E-03
.8408E-01	.1786E-02	.8408E-01	.1092E-03	.8408E-01	.1366E-03	.8408E-01	.6001E-04
.8408E-01	.6080E-04	.8408E-01	.1228E-03	.8408E-01	.1328E-02	.8408E-01	.1092E-03
.8408E-01	.3308E-05	.8408E-01	.5612E-05	.8408E-01	.8001E-04	.8408E-01	.3308E-05
.8408E-01	.8001E-04	.8408E-01	.1255E-03	.8408E-01	.1210E-02	.8408E-01	.3308E-05
.8408E-01	.5612E-05	.8408E-01	.5826E-04	.8408E-01	.4233E-04	.8408E-01	.2400E-04
.8408E-01	.5446E-04	.8408E-01	.4781E-03	.8408E-01	.4008E-05	.8408E-01	.4518E-05
.8408E-01	.1039E-04	.8408E-01	.8903E-04	.8408E-01	.1962E-05	.8408E-01	.5612E-05
.8408E-01	.1992E-02						

Table 4-5c. Cumulative, normalized weight arrays for solar source transfer-coefficients and emission radiances in sample Problem 5.

WT,WT1 =

0.	0.	.4907E+00	.5620E-05	.4929E+00	.8573E-04	.4976E+00	.8904E-04
.5231E+00	.1691E-03	.5873E+00	.1725E-03	.5921E+00	.1384E-02	.5968E+00	.1387E-02
.6015E+00	.1393E-02	.6521E+00	.1502E-02	.6565E+00	.3497E-02	.6566E+00	.4224E-02
.6596E+00	.6013E-02	.6599E+00	.6122E-02	.6630E+00	.6259E-02	.6632E+00	.6368E-02
.6633E+00	.6429E-02	.6663E+00	.6552E-02	.6666E+00	.7881E-02	.6688E+00	.7887E-02
.6689E+00	.7948E-02	.6691E+00	.7972E-02	.6692E+00	.8026E-02	.7111E+00	.8505E-02
.7153E+00	.8509E-02	.7173E+00	.8589E-02	.7336E+00	.8600E-02	.7354E+00	.8689E-02
.7362E+00	.8691E-02	.7377E+00	.8749E-02	.7408E+00	.8791E-02	.7409E+00	.8917E-02
.7410E+00	.8922E-02	.7421E+00	.8995E-02	.7551E+00	.9108E-02	.7552E+00	.9236E-02
.7554E+00	.9242E-02	.7565E+00	.9253E-02	.7581E+00	.9258E-02	.7591E+00	.9372E-02
.7668E+00	.9445E-02	.7669E+00	.9558E-02	.7671E+00	.1141E-01	.7674E+00	.1142E-01
.7738E+00	.1143E-01	.7738E+00	.1156E-01	.7745E+00	.1174E-01	.7753E+00	.1429E-01
.7753E+00	.1685E-01	.7757E+00	.3839E-01	.7758E+00	.3847E-01	.7760E+00	.4103E-01
.7760E+00	.4359E-01	.7805E+00	.4742E-01	.7812E+00	.4760E-01	.7823E+00	.4778E-01
.7824E+00	.4790E-01	.7827E+00	.4955E-01	.7827E+00	.5070E-01	.7827E+00	.6245E-01
.7827E+00	.9382E-01	.7827E+00	.9776E-01	.7830E+00	.9992E-01	.7831E+00	.1405E+00
.7832E+00	.1431E+00	.7834E+00	.1434E+00	.7863E+00	.1697E+00	.7892E+00	.1699E+00
.7935E+00	.1701E+00	.7955E+00	.1713E+00	.8306E+00	.1734E+00	.8307E+00	.1736E+00
.8336E+00	.1746E+00	.8349E+00	.1764E+00	.8351E+00	.1775E+00	.8354E+00	.1775E+00
.8649E+00	.1853E+00	.8667E+00	.1853E+00	.8670E+00	.1855E+00	.8801E+00	.1859E+00
.8825E+00	.1877E+00	.8827E+00	.1878E+00	.8851E+00	.1879E+00	.8872E+00	.1887E+00
.8901E+00	.1887E+00	.8903E+00	.1887E+00	.8903E+00	.1887E+00	.8905E+00	.1887E+00
.8906E+00	.1890E+00	.8919E+00	.1891E+00	.8929E+00	.1905E+00	.8973E+00	.1908E+00
.8974E+00	.1908E+00	.9427E+00	.1929E+00	.9428E+00	.1930E+00	.9429E+00	.1931E+00
.9429E+00	.1940E+00	.9429E+00	.1949E+00	.9430E+00	.1949E+00	.9431E+00	.1949E+00
.9432E+00	.1956E+00	.9433E+00	.1956E+00	.9454E+00	.1959E+00	.9454E+00	.1999E+00
.9454E+00	.2056E+00	.9456E+00	.2057E+00	.9459E+00	.2063E+00	.9487E+00	.2069E+00
.9511E+00	.2084E+00	.9751E+00	.2088E+00	.9767E+00	.2088E+00	.9854E+00	.2097E+00
.9865E+00	.2099E+00	.9867E+00	.2102E+00	.9879E+00	.2103E+00	.9879E+00	.2112E+00
.9880E+00	.2115E+00	.9880E+00	.2117E+00	.9889E+00	.2118E+00	.9894E+00	.2119E+00
.9894E+00	.2188E+00	.9894E+00	.2190E+00	.9895E+00	.2307E+00	.9897E+00	.2307E+00
.9897E+00	.2307E+00	.9898E+00	.2317E+00	.9898E+00	.2317E+00	.9900E+00	.2317E+00
.9900E+00	.2317E+00	.9902E+00	.2337E+00	.9902E+00	.2376E+00	.9910E+00	.2377E+00
.9930E+00	.2379E+00	.9932E+00	.2753E+00	.9933E+00	.2780E+00	.9934E+00	.2798E+00
.9935E+00	.2943E+00	.9936E+00	.3396E+00	.9951E+00	.3435E+00	.9952E+00	.3436E+00
.9952E+00	.3463E+00	.9952E+00	.3464E+00	.9953E+00	.3491E+00	.9953E+00	.3494E+00
.9954E+00	.3496E+00	.9955E+00	.3497E+00	.9969E+00	.3498E+00	.9969E+00	.3515E+00
.9969E+00	.3522E+00	.9970E+00	.3535E+00	.9970E+00	.3537E+00	.9970E+00	.3539E+00
.9971E+00	.3566E+00	.9976E+00	.3608E+00	.9976E+00	.3651E+00	.9977E+00	.3693E+00
.9977E+00	.4268E+00	.9978E+00	.4495E+00	.9978E+00	.4515E+00	.9978E+00	.4558E+00
.1000E+01	.1000E+01						

STATISTICAL CLOUDS,	P1,P2,P3,P4 =	.10	.25	.50	.90
SUN TRANSFER COEF	S1,S2,S3,S4 =	.131E-03	.329E-03	.393E-02	.762E-01
EMISSION	E1,E2,E3,E4 =	.530E+01	.639E+02	.261E+03	.314E+03

Table 4-6. Definitions of quantities in Tables 4-4a and 4-5a.

Column	Heading	Description
1	IDX	Cloud-configuration index
2,3,4	LL,MM,HH	Cloud indexes for low-, medium-, and high-layer clouds
5	TRANS	Transfer coefficient (for artificial source in Table 4-4a and for solar source in Table 4-5a)
6	EMISS	Emission radiance from highest cloud in set (independent of type of source)
7,8,9,10	CC=2,3,4,5	Weights or relative occurrence frequencies of given cloud set with cloud-coverage category CC (or cloud-coverage fractions of 0.3, 0.5, 0.8, and 1.0)
11	WT	Total weight or relative occurrence frequency of given cloud set (sum of weights for CC=2,3,4,5)
12	WT(SUM)	Cumulative sum of WT for all cloud-configuration sets

(Appendix Equation (30a)) exceeds 100. In this event function TRANSF uses the initialized value of FLUX, 1.E-50, an arbitrarily small value. The results for IDX=160 are provided by subroutine SCLOUD for the Earth's surface. The initial setting of WT(160), the probability of seeing the ground with or without clouds being present, occurs in subroutine CLDWT, and the corresponding WT(SUM) would be exactly 1.0 except for small numerical inconsistencies. WT(160) is reset in subroutine SCLOUD to take account of the two-leg CFLOS required to see tha ground lighted by the source (either artificial or the sun).

Before sorting the TRANS and EMISS arrays, we have augmented each of them (as well as the WT and WT1 arrays) with one additional member whose value is set to zero. This procedure allows subroutine LINEAR to interpolate within the array given to it when the weight of the smallest (nonzero) member exceeds the smallest fractile (now 0.10) for which an integral-distribution value is desired.

Tables 4-4b and 4-5b give the TRANS array after it has been sorted (by a call to subroutine SORTLJ from subroutine SCLOUD) in the order of increasing values. The WT array is simply carried along. The TRANS and WT values are presented in pairs in Tables 4-4b and 4-5b.

Table 4-4c gives the EMISS array after it has been sorted in the order of increasing values. The WT1 array is simply carried along. The EMISS and WT1 values are presented in pairs in Table 4-c.

Tables 4-4d and 4-5c give the cumulative, normalized weight arrays WT and WT1; these quantities are also presented in pairs.

At the end of Tables 4-4d and 4-5c the values of the transfer coefficient and emission radiance are given corresponding to the four user-selected fractiles (here taken to be 0.10, 0.25, 0.50, and 0.90) determined from the cumulative, normalized weight arrays WT (for transfer coefficient) and WT1 (for emission radiance).

We repeat, as noted in Section 2.2, that in the 160-member distributions for the solar source transfer-coefficients and emission radiances, there are only 10 different values (nine for clouds, one for the Earth) because (a) there are only nine different cloud-top altitudes (cf. Table 2-1), (b) the bidirectional reflectance of any cloud is assumed to be approximated by that for cloud-type 4 (stratocumulous), and (c) the directional emissivity computed for cloud-type 4 is used for all cloud types. We have collated the essential results for the solar source transfer-coefficient array in Table 4-7a and those for the emission radiance

Table 4-7a. Solar source transfer-coefficient distribution for sample Problem 5.

IDX	TCOEF sr^{-1}	No. Of Cases	Total Weight	Cumul. Weight	Fractiles	TCOEF sr^{-1}	CLDTOP km	TAIR	$(TAIR)^2$
					0.10	0.131^{-3}			
					0.25	0.329^{-3}			
160	0.6451^{-3}	1	0.4907	0.4907			0.0	0.1424	0.02027
1,6	0.3887^{-2}	2	0.0069	0.4976			1.0	0.2150	0.04622
					0.50	0.393^{-2}			
5	0.4398^{-2}	1	0.0255	0.5231			1.15	0.2287	0.05231
4	0.1048^{-1}	1	0.0642	0.5873			2.3	0.3531	0.1247
2,7	0.2714^{-1}	2	0.0095	0.5968			4.0	0.5681	0.3227
3	0.3171^{-1}	1	0.0047	0.6015			4.5	0.6141	0.3771
8,9,10	0.5061^{-1}	24	0.1395	0.7410			6.0	0.7758	0.6019
13	0.7255^{-1}	32	0.0422	0.7832			9.0	0.9289	0.8628
12,14	0.7621^{-1}	64	0.2068	0.9900	0.90	0.762^{-1}	10.0	0.9520	0.9063
11	0.8408^{-1}	32	0.0100	1.0000			12.0	1.0	1.0
		160	1.0000						

array in Table 4-7b. These latter two tables should facilitate understanding the values of the solar transfer-coefficient and emission radiance for the fractiles 0.10, 0.25, 0.50, and 0.90 printed at the end of Table 4-5c.

The variation in values of the (attenuated) solar source transfer-coefficient (TCOEF) for the nine cloud tops is due only to the variation in the (two-leg) air transmittance between the different cloud-top altitudes and 12-km altitude, as verified by our including in Table 4-7a the cloud-top altitude and the air transmittance from the cloud-top altitude to 12-km altitude. The variation in values of the (attenuated) emission radiance (EMISS) for the nine cloud tops is due to the combined effects of (a) the (one-leg) air transmittances from the different cloud-top altitudes to 12-km altitude and (b) the temperature entering the Planck emission function.

In the distributions presented in Tables 4-7a and 4-7b the importance of the Earth's surface is apparent since it has by far the largest single weight associated with it. This feature occurs not only for the data in KMODEL=1 but for the data given in BLOCK DATA for each of the 10 KMODELs. To illustrate this general feature we have evaluated the probability (P_{gnd}) for a detector, pointed straight down, of seeing the ground either with or without clouds being present:

$$
\begin{aligned}
P_{gnd} = {} & \mathrm{CCOVER}(1,K) + \\
& \mathrm{CCOVER}(2,K) \times \mathrm{CFLOSF}(4,\theta) + \\
& \mathrm{CCOVER}(3,K) \times \mathrm{CFLOSF}(6,\theta) + \\
& \mathrm{CCOVER}(4,K) \times \mathrm{CFLOSF}(9,\theta) + \\
& \mathrm{CCOVER}(5,K) \times \mathrm{CLFOSF}(11,\theta)
\end{aligned}
$$

where K = KMODEL and θ = 0 degrees.

The results are:

KMODEL	P_{gnd}	KMODEL	P_{gnd}
1	0.543	6	0.611
2	0.543	7	0.666
3	0.484	8	0.591
4	0.633	9	0.628
5	0.513	10	0.559

Table 4-7b. Emission radiance distribution function for sample Problem 5.

IDX	EMISS $\frac{W}{km^2\ sr\ \mu m}$	No.of Cases	Total Weight	Cumul. Weight	Fractiles	EMISS $\frac{W}{km^2\ sr\ \mu m}$	CLDTOP km	T °K	ε × PLANCK $\frac{W}{km^2\ sr\ \mu m}$	TAIR	ε × PLANCK × TAIR $\frac{W}{km^2\ sr\ \mu m}$
11	1.1	32	0.0089	0.8922^{-2}			12.0	210.00	1.13	1.0	1.1
12,14	5.3	64	0.1851	0.1940	0.10	5.3	10.0	223.00	5.56	0.9520	5.3
13	10.7	32	0.0377	0.2317			9.0	229.50	11.55	0.9289	10.7
8,9,10	63.9	24	0.1249	0.3566	0.25	63.9	6.0	249.00	82.35	0.7758	63.9
3	120.8	1	0.0042	0.3608			4.5	258.75	196.74	0.6141	120.8
2,7	147.3	2	0.0085	0.3693			4.0	262.00	259.25	0.5681	147.3
4	222.7	1	0.0575	0.4268			2.3	273.05	630.64	0.3531	222.7
5	252.9	1	0.0227	0.4495			1.15	280.52	1105.88	0.2287	252.9
1,6	255.3	2	0.0063	0.4558			1.0	281.50	1187.30	0.2150	255.3
					0.50	261					
					0.90	314					
160	327.5	$\frac{1}{160}$	$\frac{0.5442}{1.0000}$	1.0000			0.0	288.00	2300.40	0.1424	327.5

It is instructive to relate some of the Problem-5 results to those for Problems 1 to 3. The cloud configurations for IDX equal to 4, 8, and 13 in Table 4-4a are the same as those for Problems 1, 2, and 3, respectively. Since the source is below all clouds in both cases, we should expect the (transmission) transfer coefficients in Table 4-4a to correspond to those at zero lateral displacement in Problems 1, 2, and 3, except that air attenuation is included in Problem 5 but not in Problems 1, 2, and 3. However, the air-attenuation path is the same (cf. Figure 2-6b) for all cloud configurations in Problem 5. Thus, we expect that the TRANS results given in Table 4-4a for IDX = 4, 8, and 13 will differ by a constant factor from those for zero lateral displacement in Problems 1 to 3. To predict this factor we write:

$$\text{TRANS(Pm 5)} = \text{TC'(Pms 1,2,3)} \times \text{TAIR(2.5,0.,0.01)} \times (\text{SDISTO})^2 .$$

By using the interpolation-extrapolation scheme for air transmittance as described in Section 3-2.28, we hand-calculate the air transmittance to be

$$\text{TAIR} = T_1 \, (T_1/T_2)^{-(h-h_1)/(h_2-h_1)}$$

$$= (0.2150) \, (0.2150/0.3247)^{-(0.01-1)/(2-1)}$$

$$= 0.1430$$

and

$$(\text{SDISTO})^2 = (11.99)^2 \quad .$$

Thus we predict

$$\text{TRANS} = 20.55 \text{ TC'} \quad .$$

It is satisfying that our prediction is correct, as seen from the data in Table 4-8.

The reason we did not include IDX=114 and Problem 4 in this comparison is that the integral to be evaluated for TRANS in Table 4-4a was skipped owing to the large argument of the sinh and cosh functions and the concomitant smallness of the value of TRANS. (See the related comment made previously with respect to Table 4-4a.)

Table 4-8. Comparison of transfer coefficients from Problem 5 with modified transfer coefficients from Problems 1 to 3.

IDX	TRANS[a] sr^{-1}	(TC')[b] $sr^{-1}\ km^{-2}$	TRANS/TC' km^2
4	0.4617^{-1}	0.2247^{-2}	20.55
8	0.6812^{-2}	0.3315^{-3}	20.55
13	0.2199^{-7}	0.1070^{-8}	20.55

[a]From Table 4-4a.
[b]From Table 4-2 for RANGE=0.0.

4-3.3 Problem 6: Use of the deterministic cloud submodel for an ellipsoidal cloud

Problem 6 illustrates the selection by subroutine LOS of lines-of-sight and the evaluation by subroutine CLOUD3 of transfer coefficients and emission radiances for these same lines-of-sight.

For this problem we have placed a single ellipsoidal cloud at 10-km altitude. The lengths of the semiaxes are a=4 km, b=2 km, and c=1 km. The cloud's properties are those for the Type-4 cloud (strato-cumulous; see Table 2-1). The artificial source is also placed at 10-km altitude and 10 km to the east of the cloud center. The solar source has a zenith angle of 45 degrees. The detector is at synchronous altitude, directly above the cloud. Wavelength is 2.5 μm. We have made two runs, one (Problem 6a) with FOV = 1 km^2 and the other (Problem 6b) with FOV = 20 km^2. The input deck is shown in Figure 4-5.

Figure 4-6a is an outline of the cloud in a horizontal plane through its center. The 64 different x,y coordinates of the facet centers are shown by small dots. The 16 x,y coordinates of the facet centers that are considered in subroutine LOS by incrementing the facet-center indexes by two's are denoted by crosses.

Figure 4-6b pertains to the cloud for the artificial source. We show the 16 above-defined facet centers visible to the detector, marked by crosses. Of these, the three that are also visible to the source are marked as RI(R denotes reflective, I the sequence number (1 to 3)). For FOV = 1 km^2, each of these three reflective points

```
******************** PROBLEM 6A ************************************
    HD       THETAD      PHID       FOV                DETECTOR
  35793.     90.00001   -90.0001    1.0
 HSORCE(1) THETAS(1)   PHIS(1)     WKT                SOURCE
   10.      90.000001    -89.90     1000.
      ISUN
         1
   ALAM
   2.50
      MODE                                            DETERMINISTIC        CARD 1
         0
    NCLOUD                                            NO. OF CLOUDS        CARD 2
         1
KCLOUD                                                CLOUD PROPERTIES     CARD 3
    HCLOUD THETCD    PHICD    CLOUDA     CLOUDB     CLOUDC     CLDPSI
 4   10.      90.       -90.        4.0        2.0        1.0        0.

******************** PROBLEM 6B ************************************
    HD       THETAD      PHID       FOV                DETECTOR
  35793.     90.00001   -90.0001    20.
 HSORCE(1) THETAS(1)   PHIS(1)     WKT                SOURCE
   10.      90.000001    -89.90     1000.
      ISUN
         1
   ALAM                                               WAVELENGTH
   2.50
      MODE                                            DETERMINISTIC        CARD 1
         0
    NCLOUD                                            NO. OF CLOUDS        CARD 2
         1
KCLOUD                                                CLOUD PROPERTIES     CARD 3
    HCLOUD THETCD    PHICD    CLOUDA     CLOUDB     CLOUDC     CLDPSI
 4   10.      90.       -90.        4.0        2.0        1.0        0.
```

Figure 4-5. Input data for Problems 6a and 6b.

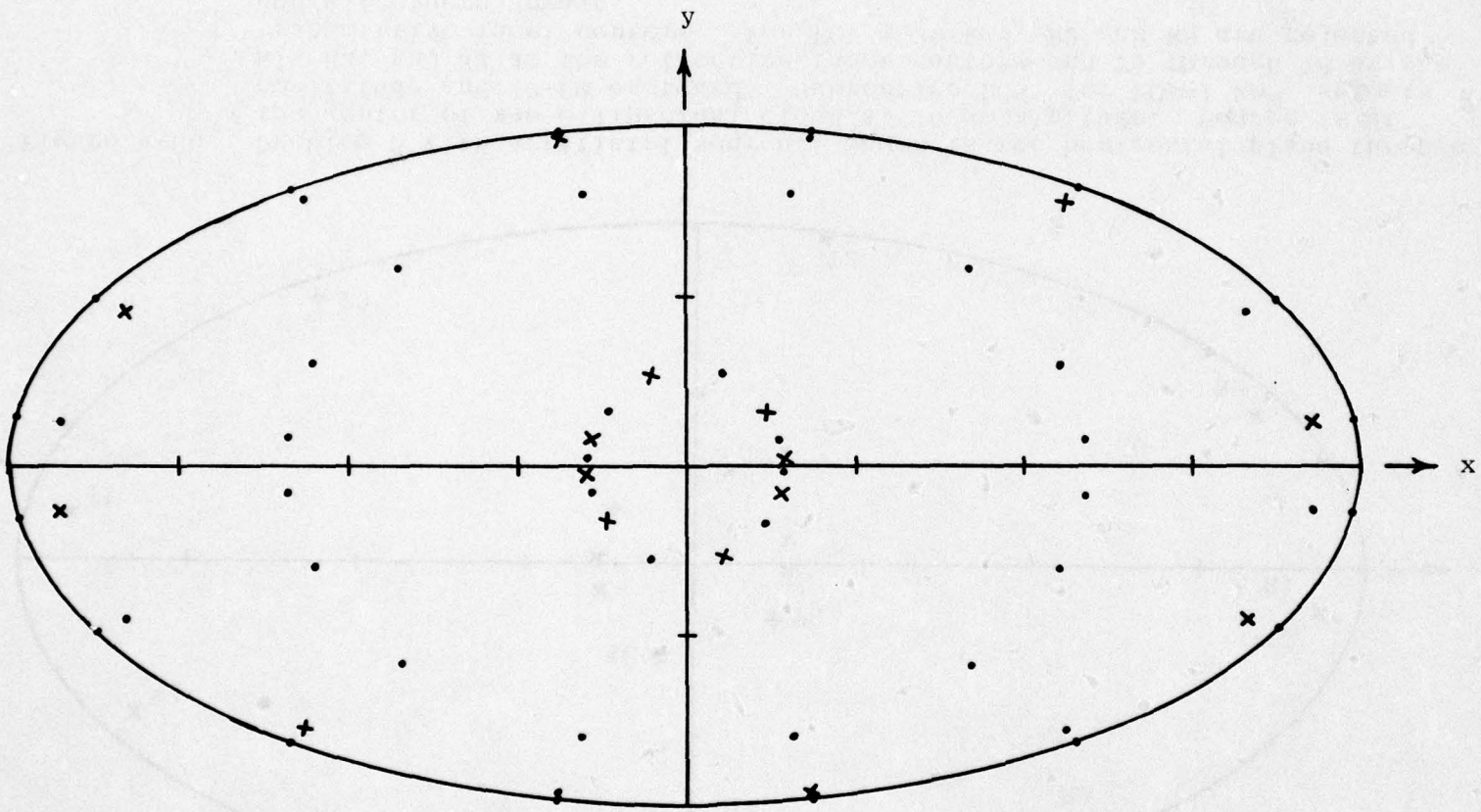

Figure 4-6a. Problem 6 cloud. Shown is the horizontal plane through the center of the ellipsoidal cloud at 10-km altitude. Projected positions of all facet centers are indicated by dots; those examined in subroutine LOS for visibility are marked with crosses.

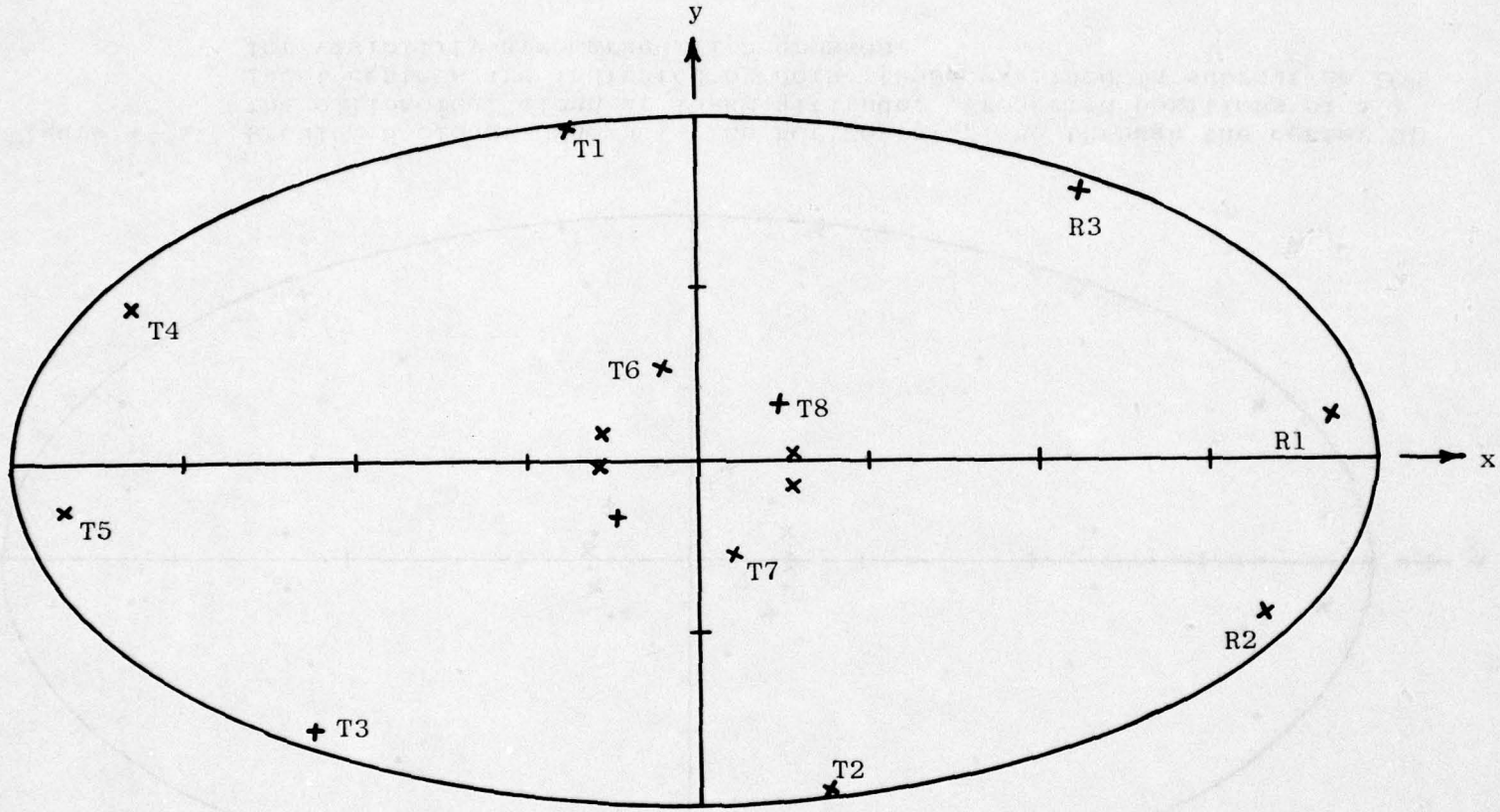

Figure 4-6b. Problem 6 with artificial source. Shown is the horizontal plane through the center of the ellipsoidal cloud at 10-km altitude. Source is at coaltitude and 10-km eastward. Subroutine LOS, for FOV=1 km^2, selects R1, R2, and R3 as the reflective facet centers and T1 through T8 as the transmittive facet centers. For FOV = 20 km^2, R2 and R3 are rejected and all others remain.

survives the selection process since none lines within 0.7 $\sqrt{FOV}$ of another. For FOV = 20 km^2, R2 and R3 do not survive the selection process. The remaining 13 points (16 minus 3) are transmittive; of these, eight (the maximum number of transmittive points retained by the code) are marked as TI (T denotes transmittive, I the sequence number (1 to 8). These same eight points obtain for both values of FOV.

Figures 4-6c and 4-6d pertain to the cloud for the solar source and correspond to FOV being 1 km^2 and 20 km^2, respectively. Again we show the 16 facet centers visible to the detector, marked by crosses. All of these facet centers are visible to the sun; there are no transmittive points. For FOV = 1 km^2, 11 of the points (marked as R1 through R11 in Figure 4-6c) survive the selection process; for FOV = 20 km^2, four of the points (marked as R1 through R4 in Figure 4-6d) survive the selection process.

The transfer coefficients, emission radiances, and cloud coordinates of the facet centers for both sources and FOV's are given in Table 4-9, to which a guide is provided in Table 10. The coordinates of the first reflective point and the eight transmittive points are, of course, the same in Parts (a) and (b).

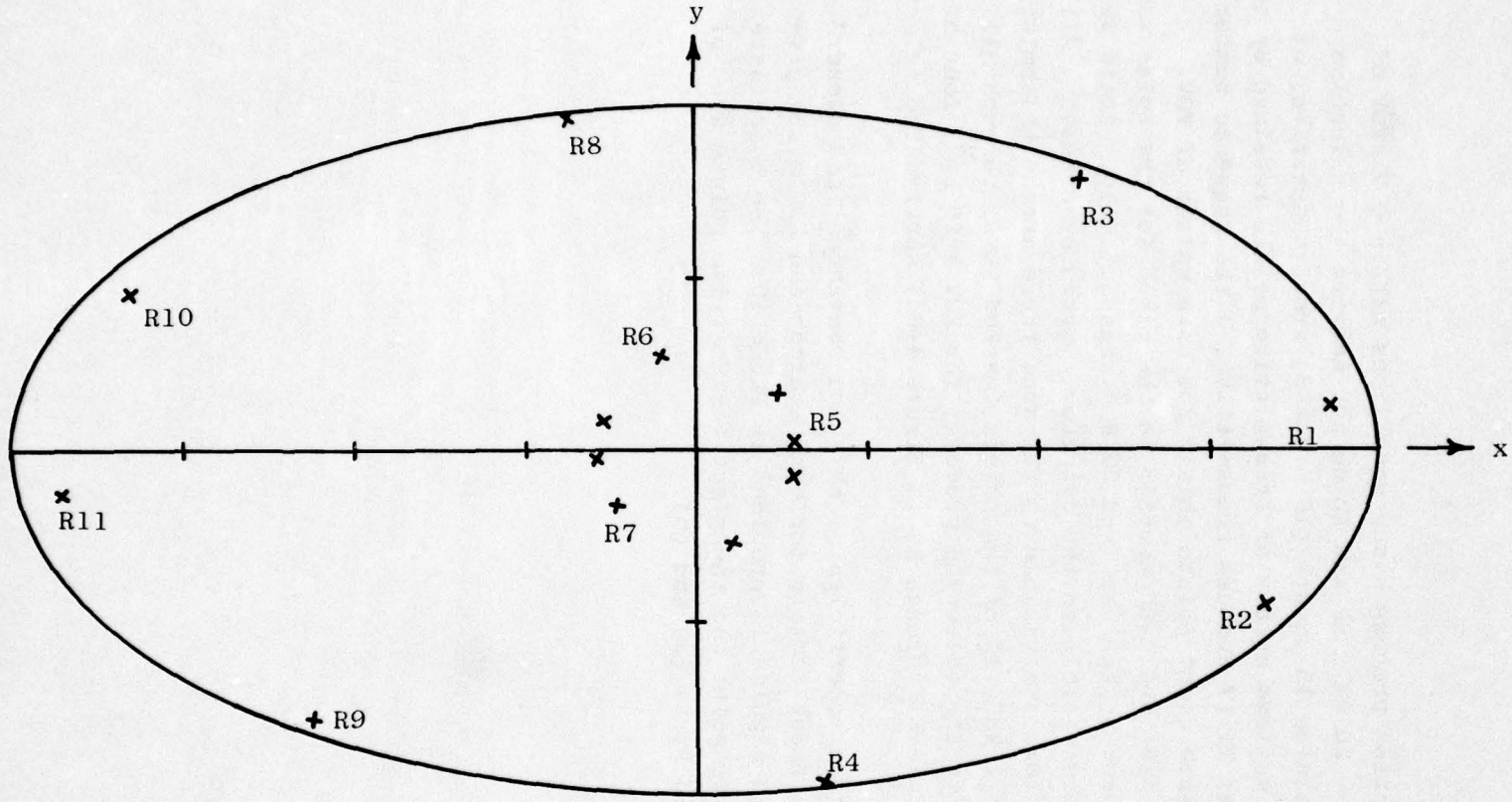

Figure 4-6c. Problem 6a with solar source. Shown is the horizontal plane through the center of the ellipsoidal cloud at 10-km altitude. Source is the sun, eastward at 45-deg zenith angle. Subroutine LOS, for FOV=1 km^2, selects R1 through R11 as the reflective facet centers. There are no transmittive facet centers.

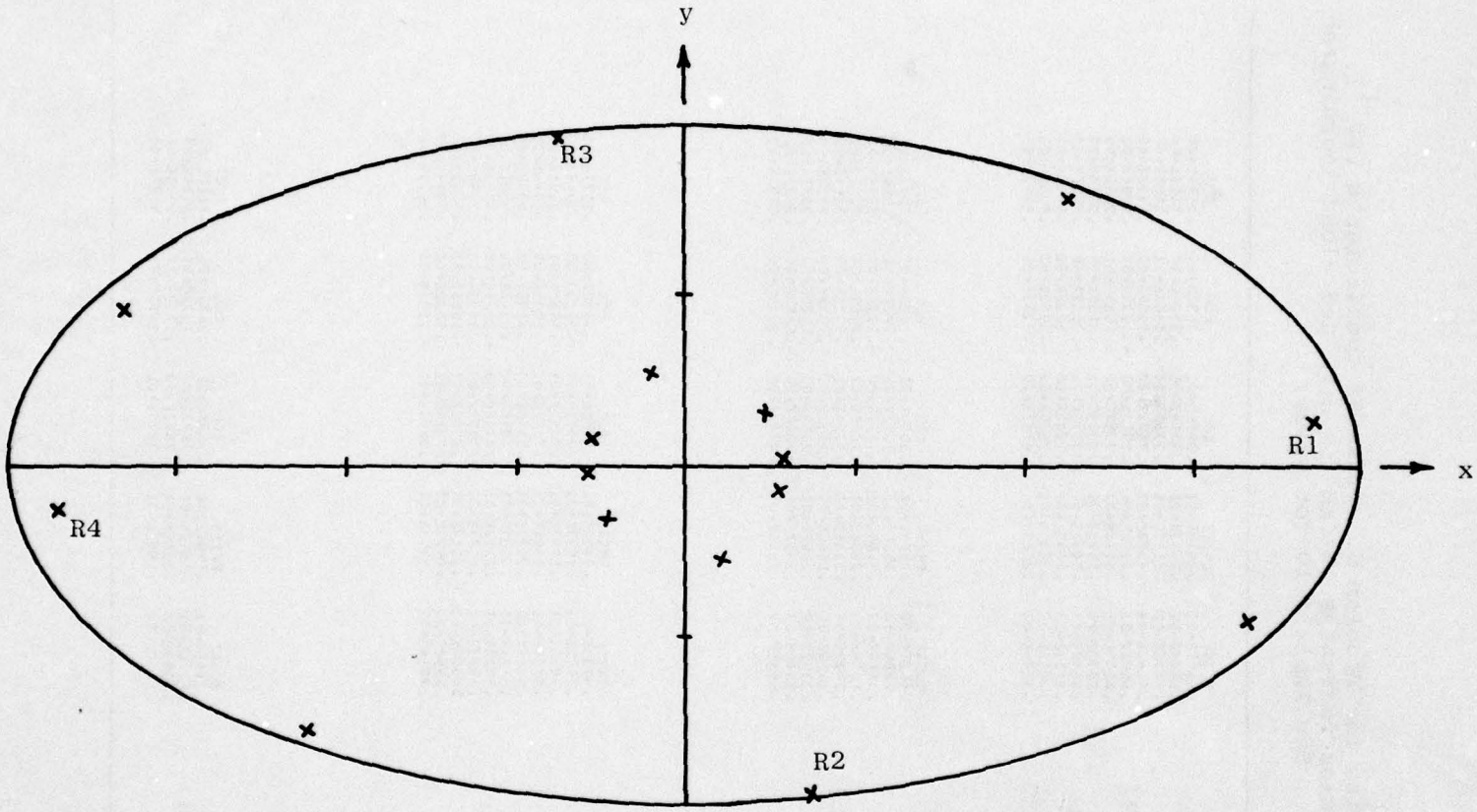

Figure 4-6d. Problem 6b with solar source. Shown is the horizontal plane through the center of the ellipsoidal cloud at 10-km altitude. Source is the sun, eastward at 45-deg zenith angle. Subroutine LOS, for FOV=20 km^2, selects R1 through R4 as the reflective facet centers. There are no transmittive facet centers.

Table 4-9. Results for Problem 6. Transfer coefficients (sr^{-1}), emission radiances ($W/(km^2\ sr\ \mu m)$), and cloud coordinates (km). See Table 4-10 for guide.

(a)

TCOEF	EMISS	XCC	YCC	ZCC
.3483E-01	.2492E+01	.3698E+01	.2633E+00	.3577E+00
.1844E-01	.1573E+01	.3314E+01	-.9026E+00	.3314E+00
.5076E-02	.1117E+01	.2260E+01	.1563E+01	.2651E+00
.4383E-04	.4348E+01	-.7572E+00	.1923E+01	.1994E+00
.6605E-03	.4352E+01	.7572E+00	-.1923E+01	.1994E+00
.5299E-06	.1118E+01	-.2260E+01	-.1563E+01	.2651E+00
.1079E-06	.1573E+01	-.3314E+01	.9026E+00	.3314E+00
.8940E-07	.2493E+01	-.3698E+01	-.2633E+00	.3577E+00
.1151E-03	.2635E+01	-.2080E+00	.5282E+00	.9631E+00
.2615E-03	.2635E+01	.2080E+00	-.5282E+00	.9631E+00
.3276E-03	.2603E+01	.4747E+00	.3283E+00	.9793E+00

(b)

TCOEF	EMISS	XCC	YCC	ZCC
.4626E-02	.1501E+01	.3698E+01	.2633E+00	.3577E+00
.7286E-03	.3561E+01	-.7572E+00	.1923E+01	.1994E+00
.3771E-02	.3565E+01	.7572E+00	-.1923E+01	.1994E+00
.1054E-03	.3086E+01	-.2260E+01	-.1563E+01	.2651E+00
.1722E-04	.2300E+01	-.3314E+01	.9026E+00	.3314E+00
.1650E-05	.1502E+01	-.3698E+01	-.2633E+00	.3577E+00
.2307E-02	.2552E+01	-.2080E+00	.5282E+00	.9631E+00
.3846E-02	.2552E+01	.2080E+00	-.5282E+00	.9631E+00
.5055E-02	.2515E+01	.4747E+00	.3283E+00	.9793E+00

(c)

TCOEF	EMISS	XCC	YCC	ZCC
.4833E-01	.2492E+01	.3698E+01	.2633E+00	.3577E+00
.2992E-01	.1573E+01	.3314E+01	-.9026E+00	.3314E+00
.1930E-01	.1117E+01	.2260E+01	.1563E+01	.2651E+00
.5125E-01	.4352E+01	.7572E+00	-.1923E+01	.1994E+00
.6405E-01	.2581E+01	.5816E+00	.4140E-01	.9892E+00
.5751E-01	.2635E+01	-.2080E+00	.5282E+00	.9631E+00
.5927E-01	.2603E+01	-.4747E+00	-.3283E+00	.9793E+00
.4914E-01	.4348E+01	-.7572E+00	.1923E+01	.1994E+00
.5535E-02	.1118E+01	-.2260E+01	-.1563E+01	.2651E+00
.6696E-02	.1573E+01	-.3314E+01	.9026E+00	.3314E+00
.8916E-02	.2493E+01	-.3698E+01	-.2633E+00	.3577E+00

(d)

TCOEF	EMISS	XCC	YCC	ZCC
.2768E-01	.1501E+01	.3698E+01	.2633E+00	.3577E+00
.4876E-01	.3565E+01	.7572E+00	-.1923E+01	.1994E+00
.4263E-01	.3561E+01	-.7572E+00	.1923E+01	.1994E+00
.1612E-01	.1502E+01	-.3698E+01	-.2633E+00	.3577E+00

Table 4-10. Guide to Table 4-9 results.

Table 4-9 Part	Source	FOV km^2	Reflective Points	Transmittive Points
(a)	Artificial	1	3	8
(b)	Artificial	20	1	8
(c)	Solar	1	11	0
(d)	Solar	20	4	0

SECTION 5

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APPENDIX A
SOME DIFFUSION PROBLEM SOLUTIONS

A-1 INTRODUCTION

The problem of determining the light flux out of clouds in various configurations of clouds and sources recurs frequently. For convenience the results for a number of such problems are collected here. No claim is made that these are novel or original, many of the solutions being well-known or using standard methods. A unified compilation with a consistent terminology may nevertheless be useful.

A rigorous treatment using the transport equation or Monte Carlo methods to evaluate the effects of scattering and absorption would be, at best, extremely time consuming. Additionally, the specification of the geometry of the clouds only approximates real cloud configurations, making such a careful evaluation of flux overly elaborate. Therefore the approach taken here has been to solve the problem in the approximation of the diffusion equation. The basic assumptions are that there be many scatterings and that precise surface effects be unimportant. An improvement over the most elementary diffusion equation solutions can be achieved by using scattering parameters based on rigorous transport theory or by using the results of Monte Carlo calculations to adjust the results.

A-1.1 Basic Equations

The development follows the lines indicated by Weinberg and Wigner[1] for neutrons. The basic equation to be solved is the diffusion equation:

$$D \text{ div grad } \phi - \Sigma_a \phi + S = \frac{1}{v} \frac{\partial \phi}{\partial t} \tag{1}$$

where: ϕ is the light flux, photons/(cm^2 sec)

D is the diffusion coefficient

Σ_a is the macroscopic absorption cross-section

S is the light source per unit volume per unit time, photons/(cm^3 sec)

v is the speed of light

The required boundary conditions are given in terms of the flux:

$$J_{\pm} = a\phi + b\left(\mp \frac{\partial\phi}{\partial Z} - \frac{3}{2v}\frac{\partial\phi}{\partial t}\right) \qquad (2)$$

$J_{\pm}$ is the flux in the $\pm$ Z direction.

The constants, a and b, are left arbitrary. From the usual definition of flux, b = D/2. In "standard" usage, $a = \Sigma_s/4\Sigma$, $D = \Sigma_s/3\Sigma\Sigma_{tr}$, and $\Sigma_{tr} = \Sigma - \bar{\mu}\Sigma_s$ where Σ, Σ_s, and Σ_{tr} are the macroscopic total, scattering, and transport cross-sections, respectively, and $\bar{\mu}$ is the average cosine of the scattering angle. Here a and b are left undermined to allow later evaluation using better values based on suitable exact calculations. In general the physical boundary conditions require a specified inward flux, sometimes zero. The frequently used "extrapolated end-point" formulation relates ϕ and $\partial\phi/\partial Z$ on the surface. The desired quantities are the emerging fluxes, the actual flux distribution inside the medium being of, at most, peripheral interest.

A-1.2 Diffusion Parameters for an Absorbing medium

In Section A-1.1 the "standard" evaluation was given for the diffusion parameters in terms of the macroscopic cross-sections. That evaluation is strictly applicable only in the limit of small absorption. A more generally applicable evaluation, which we adopt for numerical results in this report, is described in this section.

Case, de Hoffmann, and Placzek[2] provide material suitable for a better evaluation based on exact solutions of some problems. The results of Case et al.[2] are derived for isotropic scattering. In the present application, some modification has been made to account, at least partially, for anisotropic scattering. A judicious utilization of the transport cross-section (which introduces the anisotropy) must be made.

Case et al.[2] use several parameters to which we must refer:

c = average number of emergent particles per collision (cf. Reference 2, p. 43)

$$= \Sigma_s/\Sigma \qquad (3)$$

$$= \begin{cases} 0 \text{ for pure absorption} \\ 1 \text{ for pure scattering} \end{cases}$$

$1/\kappa_o(c)$ = diffusion length (dimensionless)
(cf. Reference 2, p. 55)

$\lambda(c)$ = linear extrapolation length (dimensionless)
(cf. Reference 2, p. 137)

The parameter $\kappa_o(c)$, determined by c according to Equation (68) on p. 55 of Reference 2,

$$c = \kappa_o/\tanh^{-1}\kappa_o \quad , \tag{4}$$

is tabulated and plotted in Reference 2 (pp. 60, 63; Figure 16 on p. 56). The parameter $\lambda(c)$ is also tabulated and plotted in Reference 2 (p. 136; Figure 35 on p. 138). Tabular values of $\kappa_o(c)$ and $\lambda(c)$ are given here in Table A-1. (In the computer code, we use more closely-spaced values of κ_o.)

Since $\kappa_o(c)$ and $\lambda(c)$ are dimensionless, we are free to associate scale lengths with them in some reasonable way. We do so by choosing a suitable effective macroscopic cross-section (equivalent to choosing an effective mean free path). It is by introducing such a scale length that we adapt the results of Case et al.[2] to accommodate non-isotropic scattering through use of the transport cross-section. We first discuss the scale length used with $\kappa_o(c)$ and then that with $\lambda(c)$.

We assume that the dimensioned (1/km) diffusion length, K, and $\kappa_o(c)$ are related by the expression

$$K = \kappa_o(c)\ \sigma \tag{5}$$

where σ is an effective macroscopic cross-section (or inverse mean free path) whose precise form will be established below. We determine σ by the requirement that the diffusion coefficient, D, whose basic definition (Reference 1, pp. 241, 242) is

$$D = \Sigma_a/K^2 \quad , \tag{6}$$

approach its anisotropic-scattering asymptotic value of $(3\Sigma_{tr})^{-1}$ (cf. Reference 1 pp. 196, 197) in the limit that Σ_a approaches zero. To determine σ, we first introduce the usual relation between the total, scattering, and absorption cross-sections,

Table A-1. Values of κ_o and λ[a].

c	κ_o	λ
0.0	1.000000	1.0000
0.1	1.000000	1.0000
0.2	0.999909	0.9993
0.3	0.997414	0.9889
0.4	0.985624	0.9606
0.5	0.957504	0.9201
0.6	0.907332	0.8750
0.7	0.828635	0.8300
0.8	0.710412	0.7871
0.9	0.525430	0.7472
0.92	0.474002	
0.94	0.413976	
0.96	0.340829	
0.98	0.242983	
0.99	0.172511	
1.00	0.000000	0.7104

[a]From Tables 8 and 23 of Case et al.[2]

$$\Sigma_a = \Sigma - \Sigma_s \quad , \tag{7}$$

and then use Equations (3), (5), (6), and (7) to obtain

$$D = \frac{(1-c)\Sigma}{\kappa_o^2 \, o^2} \quad . \tag{8}$$

Next, we use the fact (Reference 2, p. 58) that

$$\kappa_o^2 \to 3\,(1-c) \text{ as } c \to 1 \quad . \tag{9}$$

Thus, in order that we can have

$$D \to \frac{1}{3\Sigma_{tr}} \text{ as } c \to 1 \quad , \tag{10}$$

we must have

$$\frac{\Sigma}{\sigma^2} = \frac{1}{\Sigma_{tr}} \tag{11a}$$

or

$$\boxed{\sigma^2 = \Sigma\Sigma_{tr}} \quad . \tag{11b}$$

By collating our results thus far, we have, first of all, the general relation from the usual definition of flux,

$$b = D/2 \quad . \tag{12}$$

Then, by combining Equations (8) and (11b), we have

$$D = \frac{1-c}{\kappa_o^2 \Sigma_{tr}} \tag{13}$$

and from Equations (5) and (11b) we have

$$K = \kappa_o \sqrt{\Sigma\Sigma_{tr}} \quad . \tag{14}$$

We shall now relate σ, given by Equation (11b), and the parameter $\lambda(c)$. But first, we note that the use of the linear extrapolation length $\lambda(c)$ implies that the relation between ϕ and the normal component of the gradient of ϕ shall be that of the result for a semi-infinite medium, where the value of $\lambda(c)$ is determined by relating the diffusion solution to the exact transport solution.

We now assume that the dimensioned (km) linear extrapolation length, d, and $\lambda(c)$ are related by the expression

$$d = \lambda(c)/\sigma \quad . \tag{15}$$

From the definition of the linear extrapolation length, d (cf. Reference 1, pp. 199, 261), and the relation for the photon current, we must have

$$d = b/a \quad . \tag{16}$$

Thus, from Equations (16), (15), and (5) we have

$$a = \frac{b\sigma}{\lambda(c)} = \frac{bK}{\lambda(c)\kappa_o(c)} \quad . \tag{17}$$

To summarize our parameter evaluation, we have:

1. $c = \Sigma_s/\Sigma$, dimensionless, Equation (3)

2. $\kappa_o(c)$, $\lambda(c)$ from tables

3. $D = \dfrac{1-c}{\kappa_o^2(c)\Sigma_{tr}}$ km, Equation (13)

4. $K = \kappa_o(c)\sqrt{\Sigma\Sigma_{tr}}$, km^{-1}, Equation (14)

5. $b = D/2$, km, Equation (12)

6. $a = \dfrac{bK}{\kappa_o(c)\lambda(c)}$, dimensionless, Equation (17)

An examination of the values for $\kappa_o(c)$ and $\lambda(c)$ in Table A-1 shows that

$$\frac{bK}{a} = \kappa_o(c)\lambda(c) \leq 1 \quad . \tag{18}$$

Thus, the factor $[(a/bK) - bK/a]$, which occurs in the diffusion solutions to be developed later, has the very important feature of never being negative.

The diffusion parameters for both the "standard" usage and our adopted usage, as well as their values in the limiting cases c = 0,1, are given in Table A-2. That the limiting values are valid for $c \to 0$ (pure absorption) can be seen by considering the pure absorption solution for a semi-infinite medium, $\exp(-\Sigma_a Z)$. The positive-direction photon current is just $\exp(-\Sigma_a Z)$, the negative-direction current is 0. For $c \to 1$ (pure scattering), note that for the parameter a, our limiting value differs somewhat from the usual one.

In the code, the variables a,b, and K are known as DALFA, DBETA, and DKAPPA, respectively.

A-2 SINGLE-LAYER PLANAR SLABS

The first problem to be considered is diffusion in a single layer of finite thickness. The sequence of problems is from the simplest to the more complicated. Time-independent problems are treated before time-dependent ones, one-dimensional problems before two-dimensional ones. This sequence has value both from the standpoint of gradually increasing mathematical complexity and from the fact that the simpler solutions can serve as limiting-case checks on the more complicated solutions.

A-2.1 Steady-State Problems

The first category of problems is steady state, hence time-independent. They are of intrinsic value and also serve as checks on later time-dependent problems.

A-2.1.1 Plane Source, Surface Deposition. A slab of thickness L has unit flux per unit area incident on the lower surface (Z = 0), no flux incident on the upper surface. The transmitted and reflected fluxes are sought. This yields the equation for ϕ:

$$\partial^2\phi(Z)/\partial Z^2 - K^2\,\phi(Z) = 0 \tag{19}$$

with $K^2 = \Sigma_a/D$ for the standard usage and $K^2 = K_o^2(c)\Sigma\Sigma_{tr}$ for our adopted usage. The boundary conditions are:

$$J_+(0) = 1 \tag{20a}$$

$$J_-(L) = 0 \quad . \tag{20b}$$

Table A-2. Summary of Diffusion Parameters.

Parameter and Units	"Standard" Usage	"Standard" Usage Limiting Cases		Our Adopted Usage	Our Usage Limiting Cases	
		$c \to 0$	$c \to 1$		$c \to 0$	$c \to 1$
Σ, km^{-1}	$\Sigma_a + \Sigma_s$	Σ_a	Σ_s	$\Sigma_a + \Sigma_s$	Σ_a	Σ_s
Σ_{tr}, km^{-1}	$\Sigma - \bar{\mu}\Sigma_s$	Σ_a	$\Sigma_s(1-\bar{\mu})$	$\Sigma - \bar{\mu}\Sigma_s$	Σ_a	$\Sigma_s(1-\bar{\mu})$
K, km^{-1}	$\sqrt{\Sigma_a/D}$	∞	0	$\kappa_o(c)\sqrt{\Sigma\Sigma_{tr}}$	Σ_a	0
D, km	$\Sigma_s/(3\Sigma\Sigma_{tr})$	0	$1/(3\Sigma_{tr})$	$(1-c)/(\kappa_o^2(c)\Sigma_{tr})$	$1/\Sigma_a$	$1/(3\Sigma_{tr})$
b, km	D/2	0	$1/(6\Sigma_{tr})$	D/2	$1/(2\Sigma_a)$	$1/(6\Sigma_{tr})$
a, unitless	$\Sigma_s/(4\Sigma)$	0	1/4	$bK/(\kappa_o(c)\lambda(c))$	1/2	$1/(6(0.71)\sqrt{1-\bar{\mu}})$
				$\kappa_o^2(c)$	1	$3(1-c)$
				$\lambda(c)$	1	0.7104
σ, km^{-1}				$\sqrt{\Sigma\Sigma_{tr}}$	Σ_a	$\Sigma_s\sqrt{1-\bar{\mu}} \equiv \Sigma_{tr}/\sqrt{1-\bar{\mu}}$

The reflected flux is $J_-(0)$, the transmitted flux is $J_+(L)$. Solution of this problem by elementary methods yields expressions for these quantities.

$$J_+(L) = (\cosh KL + \tfrac{1}{2}\left(\frac{a}{Kb} + \frac{bK}{a}\right) \sinh KL)^{-1} \tag{21a}$$

$$J_-(0) = \tfrac{1}{2}\left(\frac{a}{Kb} - \frac{Kb}{a}\right) \sinh KL \; J_+(L) \quad . \tag{21b}$$

There are several comments to be made about this solution. The condition of small absorption shows up here immediately. For $J_-(0)$ to be a positive quantity (as it should) it is necessary that $K < a/b$. This condition is met for the "standard"-usage parameters if the absorption is small. For our adopted parameters (see Section A-1.2), this condition is always met. Secondly, in the limit of no absorption ($K \to 0$), the sum of the transmitted and reflected fluxes is unity, as it should be. A small effort, and using $b=D/2$, gives the result that

$$J_+(L) + J_-(0) + \int_0^L \Sigma_a \phi(Z) dZ = 1 \quad .$$

Finally, it can easily be shown that $J_+(L) \leq e^{-KL}$, the defect being due to increased loss in multiple collisions.

A-2.1.2 <u>Plane Source, Surface Deposition (alternate treatment)</u>. In Section A-2.1.1 the problem of flow through a slab was treated purely in the diffusion approximation. An alternate approach, based on physical considerations, separates the flux into two parts, that which has had no collisions and the remainder. This leads to an equation for the scattered flux with a source term coming from first collisions. The equation to be solved is

$$D \frac{\partial^2 \phi}{\partial Z^2} - \Sigma_a \phi + \Sigma_s \, e^{-\Sigma Z} = 0 \quad . \tag{22}$$

The source term reflects the exponential decrease in the unscattered flux and the fact that only the scattering (not the absorption) contributes to the source. If $J_\pm$ is now considered as applying to only the scattered flux, the appropriate boundary conditions are that there be no flux incident on the slab surfaces:

$$J_+(0) = J_-(L) = 0 \quad . \tag{23}$$

The solution of this system follows the usual lines. A particular solution of the inhomogeneous equation is

$$C\, e^{-\Sigma Z},\ C = \Sigma_s\, D^{-1}(K^2-\Sigma^2)^{-1}$$

where K^2 is given as before. To this is added a general solution of the homogeneous equation.

$$\phi(Z) = C\, e^{-\Sigma Z} + Ae^{KL} + Be^{-KL} \quad .$$

The values of A and B are determined from the boundary conditions. The quantities of interest, the transmitted flux, $J_+(L)$, and the reflected flux, $J_-(0)$, can then be evaluated. The quantities now include unscattered flux.)

$$J_+(L) = e^{-\Sigma L}\left\{1 + C(a+b\Sigma) + \frac{\frac{C(a-b\Sigma)}{2}\left(\frac{a}{bK} - \frac{bK}{a}\right)\sinh KL}{\text{den}}\right\} \tag{24a}$$

$$- \frac{C(a+b\Sigma)}{\text{den}}$$

$$J_-(0) = C\left\{a-b\,\Sigma - \frac{e^{-\Sigma L}\,(a-b\Sigma) + \frac{a+b\Sigma}{2}\left(\frac{a}{bK} - \frac{bK}{a}\right)\sinh KL}{\text{den}}\right\} \tag{24b}$$

$$\text{den} = \cosh KL + \tfrac{1}{2}\left(\frac{a}{bK} + \frac{bK}{a}\right)\sinh KL\ . \tag{24c}$$

An interesting check on this solution can be made by letting the deposition occur in a thin layer ($\Sigma\to\infty$, Σ_s/Σ finite, with a, b, and K unchanged). The resulting limits,

$$J_+(L) \to \frac{\Sigma_s/\Sigma}{2(\text{den})}$$

$$J_-(0) \to \frac{\Sigma s}{2\Sigma}\left\{1 + \tfrac{1}{2}\left(\frac{a}{bK} - \frac{bK}{a}\right)\sinh KL/(\text{den})\right\} \quad ,$$

can be interpreted (using Equations (21a) and (21b) as a surface source of strength Σ_s/Σ, half entering the medium and being transmitted and reflected according to the prescription of Section A-2.1, and half being emitted outward immediately.

A-2.1.3 External Point Source, Surface Deposition. A slab of thickness L is illuminated by an isotropically emitting point source at a distance h below the slab. The relevant equations are:

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\,\frac{\partial\phi(r,Z)}{\partial r}\right) + \frac{\partial^2\phi(r,Z)}{\partial Z^2} - K^2\phi(r,Z) = 0 \tag{25a}$$

inside the slab, with boundary conditions

$$J_+(r,0) = \frac{Q}{2\pi}\,\frac{h}{(r^2+h^2)^{3/2}} \tag{25b}$$

$$J_-(r,L) = 0 \tag{25c}$$

$$\int_0^\infty J_+(r,0)\,2\pi r dr = Q \quad .$$

Thus Q is the total flux into the slab. This is just half of the total flux emitted by the source.

The solution uses standard methods, although not as elementary as the method of Sections A-2.1.1 and A-2.1.2. As a first step, the problem is reduced to a one-dimensional problem by introducing the Hankel transform.[3]

$$\overline{\phi}(p,Z) = \int_0^\infty \phi(r,Z)\,J_o(pr)rdr \tag{26a}$$

$$\boxed{\phi(r,Z) = \int_0^\infty \overline{\phi}(p,Z)\,J_o(pr)pdp \quad .} \tag{26b}$$

Equation (25a) is multiplied by $rJ_o(pr)$ and integrated. The term involving radial derivatives is integrated by parts twice. Assuming $r^2\phi$ and $(\partial\phi/\partial r)r$ being zero at $r = 0$ and $r^{3/2}\phi$ and $r^{3/2}\partial\phi/\partial r$ being zero at $r = \infty$ then yields the relation

$$\frac{\partial^2 \overline{\phi}(p,Z)}{\partial Z^2} - k^2 \overline{\phi}(p,Z) = 0 \tag{27a}$$

with

$$k^2 = p^2 + K^2 \quad .$$

The corresponding boundary conditions are, using Equations 13.51(5) and 3.7(13) of Reference 4,

$$\overline{J_+}(p,0) = \frac{Q}{2\pi} e^{-ph} \tag{27b}$$

$$\overline{J_-}(p,L) = 0 \tag{27c}$$

$$\overline{J_\pm}(p,Z) = a\,\overline{\phi}(p,Z) \mp b\,\frac{\partial\overline{\phi}(p,Z)}{\partial Z} \quad . \tag{27d}$$

The solution of these equations follows the pattern of Sections A-2.1.1 and A-2.1.2.

$$\overline{J_+}(p,Z) = \frac{Q}{2\pi} e^{-ph} \frac{\cosh k(L-Z) + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh k(L-Z)}{\cosh kL + \frac{1}{2}\left(a/kb + \frac{kb}{a}\right) \sinh kL} \tag{28a}$$

$$\overline{J_-}(p,Z) = \frac{Q}{2\pi} e^{-ph} \frac{\frac{1}{2}\left(\frac{a}{kb} - \frac{kb}{a}\right) \sinh k(L-Z)}{\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL} \quad . \tag{28b}$$

These relations then give the Hankel transforms of the transmitted and reflected fluxes:

$$\boxed{\overline{J_+}(p,L) = \frac{Q}{2\pi} e^{-ph} \Big/ \left[\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL\right]} \tag{29a}$$

$$\overline{J_-}(p,0) = \frac{\frac{Q}{2\pi} e^{-ph}\, \frac{1}{2}\left(\frac{a}{kb} - \frac{kb}{a}\right) \sinh kL}{\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL} \quad . \tag{29b}$$

The actual transmitted and reflected fluxes are evaluated as integrals using Equation (26b):

$$\boxed{J_+(r,L) = \frac{Q}{2\pi} \int_o^\infty \frac{e^{-ph} J_o(pr)\, p}{\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL}\, dp} \tag{30a}$$

$$J_-(r,0) = \frac{Q}{2\pi} \int_o^\infty \frac{e^{-ph} J_o(pr) p\, \frac{1}{2}\left(\frac{a}{kb} - \frac{kb}{a}\right) \sinh kL}{\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL}\, dp \tag{30b}$$

$$\boxed{k^2 = p^2 + K^2;}\quad K^2 = \Sigma_a/D \quad . \tag{30c}$$

A number of quantities can be derived from these accumulated results. The total transmitted and reflected fluxes are easily obtained.

$$\boxed{\int_o^\infty J_+(r,L)\, 2\pi r dr = 2\pi\, \overline{J}_+(0,L) = \frac{Q}{\cosh KL + \frac{1}{2}\left(\frac{a}{Kb} + \frac{Kb}{a}\right) \sinh KL}} \tag{31a}$$

$$\int_o^\infty J_-(r,0)\, 2\pi r dr = 2\pi\, \overline{J}_o(0,0) = \frac{Q\, \frac{1}{2}\left(\frac{a}{Kb} - \frac{Kb}{a}\right) \sinh KL}{\cosh KL + \frac{1}{2}\left(\frac{a}{Kb} + \frac{Kb}{a}\right) \sinh KL} \quad . \tag{31b}$$

These are just the results (adjusted for flux Q incident) of Equations (21a) and (21b). A quantity of some interest is the flux from a strip of width x_o, with one edge going through $r = 0$. Let J_{s+} be the result for the transmitted flux.

$$J_{s+} = \int_0^{x_o} dx \int_{-\infty}^{\infty} dy \; J_+ \left(\sqrt{x^2+y^2}, L\right) \tag{32a}$$

$$= \frac{Q}{\pi} \int_0^{\infty} dp \left(\frac{p \; e^{-ph}}{\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL}\right) \times$$

$$\int_0^{x_o} dx \int_0^{\infty} dy \; J_o\left(p\sqrt{x^2+y^2}\right) . \tag{32b}$$

By Equations 13.47 (5) and 3.4 (6) of Reference 4, the y-integral is

$$\int_0^{\infty} dy \; J_o(p\sqrt{x^2+y^2}) = \frac{2^{-\frac{1}{2}} \; \Gamma(\frac{1}{2})}{p^{\frac{1}{2}} x^{\frac{1}{2}}} \; J_{-\frac{1}{2}}(px)$$

$$= \sqrt{\frac{\pi x}{2p}} \; \sqrt{\frac{2}{\pi p x}} \cos px$$

$$= \cos px/p \quad .$$

The x-integral can be done immediately.

$$J_{s+} = \frac{Q}{\pi} \int_0^{\infty} \frac{\sin px_o}{p} \; \frac{e^{-ph}}{\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL} \, dp \quad . \tag{33a}$$

The analogous result for the reflected flux is J_{s-}:

$$J_{s-} = \frac{Q}{\pi} \int_0^\infty \frac{\sin px_o}{p} \; \frac{e^{-ph} \; \frac{1}{2}\left(\frac{a}{kb} - \frac{kb}{a}\right) \sinh kL}{\cosh kL + \frac{1}{2}\left(\frac{a}{kb} + \frac{kb}{a}\right) \sinh kL} \, dp \quad . \tag{33b}$$

The limiting case as $x_o \to \infty$ can again be compared with previous results. The quantity $\sin px_o/p$ behaves as a Dirac delta-function (see Reference 5, p. 29, Equation (47)).

$$\lim_{x_o \to \infty} \frac{\sin p\, x_o}{p} = \pi\, \delta(p)$$

$$\lim_{x_o \to \infty} J_{s+} = \frac{Q}{2} \frac{1}{\cosh KL + \frac{1}{2}\left(\frac{a}{Kb} + \frac{bK}{a}\right) \sinh KL}$$

$$\lim_{x_o \to \infty} J_{s-} = \frac{Q}{2} \frac{\frac{1}{2}\left(\frac{a}{Kb} - \frac{Kb}{a}\right) \sinh KL}{\cosh KL + \frac{1}{2}\left(\frac{a}{Kb} + \frac{Kb}{a}\right) \sinh KL} \quad .$$

These are just half the results in (31a) and (31b) as they should be.

A-2.1.4 Internal Point Source. A slab of thickness L is illuminated by an isotropic point source located a distance h (<L) above its lower surface (Z = 0). The relevant system of equations to be solved are

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r \frac{\partial \phi(r,Z)}{\partial r}\right) + \frac{\partial^2 \phi(r,Z)}{\partial Z^2} - K^2 \phi(r,Z) + \delta(\vec{r} - \hat{Z}h)/D = 0 \tag{34a}$$

where $\hat{Z}$ is a unit vector in the Z direction, and

$$J_+(r,0) = J_-(r,L) = 0 \quad . \tag{34b}$$

The delta-function part of ϕ can be removed by introducing the infinite medium solution, $G(\vec{r},\vec{r}_o)$, where $\vec{r}_o = \hat{Z}\, h$.

$$G(\vec{r},\vec{r}_o) = \frac{1}{4\pi D} \frac{e^{-K|\vec{r}-\vec{r}_o|}}{|\vec{r}-\vec{r}_o|} \quad . \tag{35}$$

It is easy to show, by differentiation, that G satisfies Equation (34a) except where $\vec{r}=\vec{r}_o$. To evaluate the behavior at $\vec{r}_o$, the usual path of integration over a small sphere, centered at $\vec{r}_o$, is taken. Let T be the sphere volume, Σ its surface, $\rho = |\vec{r}-\vec{r}_o|$, and $d\Omega$ an element of solid angle.

$$\int_T (\text{div grad } G-K^2G)\, d\tau$$

$$= \int_\Sigma \text{grad } G\cdot d\sigma - K^2 \int_T G\, dt$$

$$= \int \frac{1}{4\pi D} e^{-K\rho} \left(\frac{-K}{\rho} - \frac{1}{\rho^2}\right) \rho^2 d\Omega - K^2 \int \frac{1}{4\pi D} \frac{e^{-K\rho}}{\rho} \rho^2 d\Omega d\rho$$

$$\xrightarrow[\rho\to o]{} \frac{-1}{4\pi D} \int d\Omega \quad .$$

If $\vec{r}_o$ is an interior point, $\int d\Omega$ is 4π. Hence $\int_T$ (div grad G - K^2G + $\frac{1}{D}\,\delta(\vec{r}-\vec{r}_o))\, d\tau = -\frac{1}{D} + \frac{1}{D} = 0$. Using these results the solution for ϕ consists of two parts, G and ψ, where ψ satisfies the homogeneous part of the equation.

$$\phi(r,Z) = G(r,Z) + \psi(r,Z) \tag{36a}$$

$$G(r,Z) = \frac{1}{4\pi D} \frac{e^{-K\sqrt{r^2+(Z-h)^2}}}{\sqrt{r^2+(Z-h)^2}} \tag{36b}$$

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\,\frac{\partial\psi(r,Z)}{\partial r}\right) + \frac{\partial^2\psi(r,Z)}{\partial Z^2} - K^2\psi(r,Z) = 0 \tag{36c}$$

$$J_{\pm}(r,Z) = a\ \psi(r,Z) \mp b\ \frac{\partial\psi(r,Z)}{\partial Z} + aG(r,Z) \mp b\ \frac{\partial G(r,Z)}{\partial Z}\ . \tag{36d}$$

As in the previous section, this is solved using Hankel transforms.

$$\overline{\psi}(p,Z) = \int_0^\infty \psi(r,Z)\ J_o(pr)\ r\ dr \tag{37a}$$

$$\frac{\partial^2\overline{\psi}(p,Z)}{\partial Z^2} - k^2\ \overline{\psi}(p,Z) = 0 \tag{37b}$$

$$k^2 = K^2 + p^2\ . \tag{37c}$$

The transformed boundary conditions are

$$a\ \overline{\psi}(p,L) + b\ \frac{\partial\overline{\psi}(r,Z)}{\partial Z}\Big|_{Z=L} = -\ a\overline{G}(p,L) - b\ \frac{\partial\overline{G}(p,Z)}{\partial Z}\Big|_{Z=L} \tag{38a}$$

$$a\ \overline{\psi}(p,0) - b\ \frac{\partial\overline{\psi}(p,Z)}{\partial Z}\Big|_{Z=0} = -\ a\overline{G}(p,0) + b\ \frac{\partial\overline{G}(p,Z)}{\partial Z}\Big|_{Z=L} \tag{38b}$$

$$\overline{G}(p,Z) = \int_0^\infty \frac{1}{4\pi D}\ \frac{e^{-K\sqrt{r^2 + (Z-h)^2}}}{\sqrt{r^2 + (Z-h)^2}}\ J_o(pr)\ rdr\ .$$

This integral can be evaluated using Equation 13.47(2) of Reference 4 in a manner analogous to the derivation there of Equation 13.47(4):

$$\bar{G}(p,Z) = \frac{e^{-k|Z-h|}}{4\pi D\ k} \tag{39a}$$

$$\frac{\partial \bar{G}(p,Z)}{\partial Z} = -\frac{e^{-k|Z-h|}}{4\pi D}\ \frac{Z-h}{|Z-h|}\ . \tag{39b}$$

The solution desired then leads to the result, using b = D/2:

$$\boxed{\begin{aligned}\bar{J}_+(p,L) = \Bigg\{ & \frac{(bk-a)}{16\pi\ ab^2k^2\left(\cosh kL + \frac{1}{2}\left(\frac{a}{bk} + \frac{bk}{a}\right)\sinh kL\right)} \times \\ & \times [(a-bk)\ (a \sinh kh + bk \cosh kh) \\ & + (a+bk)e^{-kL}(a \sinh k(L-h) + bk \cosh k(L-h))]\Bigg\} \\ & + e^{-k(L-h)}(a + bk)/8\pi bk\end{aligned}} \tag{40a}$$

$$\begin{aligned}\bar{J}_-(p,0) = \Bigg\{ & \frac{(bk-a)}{16\pi\ ab^2k^2\left(\cosh kL + \frac{1}{2}\left(\frac{a}{bk} + \frac{bk}{a}\right)\sinh kL\right)} \times \\ & \times [(a+bk)\ (a \sinh kh + bk \cosh kh)\ e^{-kL} \\ & + (a-bk)(a \sinh k(L-h) + bk \cosh k(L-h))]\Bigg\} \\ & + e^{-kh}(a + bk)/8\pi bk\ .\end{aligned} \tag{40b}$$

The evaluation of the actual transmitted fluxes is achieved as in Section A-2.1.3. If desired the second term in each of the expressions can be explicitly integrated. Using Equations 3.71(13) and 13.47(2) of Reference 4,

$$\frac{\int_o^\infty e^{-h\sqrt{p^2+K^2}} J_o(pr)pdp}{\sqrt{p^2+K^2}} = \frac{e^{-K\sqrt{h^2+r^2}}}{\sqrt{h^2+r^2}} \tag{41a}$$

$$\int_o^\infty e^{-h\sqrt{p^2+K^2}} J_o(pr)pdp = \frac{he^{-K\sqrt{h^2+r^2}}}{h^2+r^2}\left(K + \frac{1}{\sqrt{h^2+r^2}}\right) . \tag{41b}$$

However, from a computational viewpoint, the convergence of the integral over p should be improved by not separating these terms. A cursory examination indicates convergence for J_+ to be as $e^{-k(L-h)}$ if separation is done, as $e^{-k(L-h)}/k$ if no separation is done.

As was done in Section A-2.1.3, the integrals over a strip can be found.

$$J_{s+} = 2\int_o^\infty \frac{\sin px_o}{p} \bar{J}_+(p,L)dp \tag{42a}$$

$$J_{s-} = 2\int_o^\infty \frac{\sin px_o}{p} \bar{J}_-(p,0)dp \quad . \tag{42b}$$

Similarly, for total fluxes out,

$$\int_o^\infty J_+(r,L)\ 2\pi r\ dr = 2\pi\ \bar{J}_+(0,L) \tag{43a}$$

$$\int_o^\infty J_-(r,0)\ 2\pi r\ dr = 2\pi\ \bar{J}_-(0,0) \quad . \tag{43b}$$

A-2.2 Time-Dependent Solutions

The only time-dependent solution that is practical from a computational viewpoint is the pure diffusion problem of a plane slab illuminated by a uniform external source. The method of Laplace transforms is used. The relevant transforms are:

$$\tilde{\phi}(z,s) = \int_0^\infty \phi(z,t)e^{-st}dt \tag{44a}$$

$$\tilde{J}_{\pm}(z,s) = \int_0^\infty J_{\pm}(z,t)e^{-st}dt \tag{44b}$$

$$F(s) = \int_0^\infty f(t)e^{-st}dt \tag{44c}$$

where f(t) is the incident flux. For convolution purposes, the case of $f(t) = \delta(t)$, $F(s) = 1$, is of special interest. The equations and boundary conditions satisfied by the transforms are:

$$\frac{\partial^2 \tilde{\phi}(z,s)}{\partial Z^2} = (K^2 + \frac{s}{Dv})\,\tilde{\phi}(z,s) \tag{45a}$$

$$\tilde{J}_{\pm}(z,s) = \left(a - \frac{3bs}{2v}\right)\tilde{\phi}(z,s) \mp b\,\frac{\partial\tilde{\phi}(z,s)}{\partial z} \tag{45b}$$

$$\tilde{J}_{-}(L,s) = 0;\ \tilde{J}_{+}(0,s) = F(s)\ . \tag{45c}$$

Proceeding in a straightforward way,

$$\tilde{J}_{+}(L,s) = F(s)/G(\lambda) \tag{46a}$$

$$\tilde{J}_{-}(0,s) = F(s)\,\tfrac{1}{2}\left(\frac{\alpha}{b\lambda} - \frac{b\lambda}{\alpha}\right)\sinh\lambda L/G(\lambda) \tag{46b}$$

$$G(\lambda) = \cosh\lambda L + \tfrac{1}{2}\left(\frac{\alpha}{b\lambda} - \frac{b\lambda}{\alpha}\right)\sinh\lambda L \tag{46c}$$

where

$$\lambda^2 = K^2 + s/Dv\ , \qquad \alpha = a - \frac{3}{2}\frac{bs}{v}\ .$$

The relation to the steady-state solution is apparent, since the integral of the time-dependent solutions over time is just the value of the transform for s=0.

The actual time-dependent solution is obtained by the usual inverse Laplace transform,

$$J_{\pm}(z,t) = \frac{1}{2\pi i} \int_{-i\infty+\varepsilon}^{i\infty+\varepsilon} \tilde{J}_{\pm}(z,s)e^{st}ds \quad . \tag{47}$$

This is evaluated by contour integration, giving a sum of the residues at the poles of $\tilde{J}_{\pm}(z,s)$. These are at the zeroes of $G(\lambda)$. The exact evaluation of the zeroes is rather intractable, involving a simultaneous evaluation of the real and imaginary parts of λ. For simplicity, an approximate evaluation was used. This approximation neglected the difference between α and a. In terms of the boundary conditions, this is equivalent to neglecting the $\partial\phi/\partial t$ term, compared to ϕ, in the currents,* $J_{\pm}$. Using this approximation, the values of λ are pure imaginary. For the jth *root*

$$\lambda_j = i\eta_j \tag{48a}$$

$$\tan \eta_j L = 2ab\eta_j(b^2\eta_j^2-a^2)^{-1}, \quad \eta\neq 0, j=1,2... \tag{48b}$$

$$s_j = Dv(-\eta_j^2-K^2) \quad . \tag{48c}$$

For the special case, $f(t) = \delta(t)$, the inverse Laplace transforms then yield:

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*Fluxes, for consistency.

$$J_+(L,t) = \sum_{j=1}^{\infty} \frac{e^{-s_j t} Dv\ \eta_j}{-i\ G'(i\eta_j)} \tag{49a}$$

$$J_-(0,t) = \sum_{j=1}^{\infty} \frac{e^{-s_j t}\ \frac{L}{2}\left(\frac{a}{b\eta_j} + \frac{b\eta_j}{a}\right)(\sin\eta_j L)\ Dv\eta_j}{-i\ G'(i\eta_j)} \tag{49b}$$

$$-iG'(i\eta_j) = L \sin \eta_j L - \tfrac{1}{2}\left(\frac{a}{b\eta_j} - \frac{b\eta_j}{a}\right) \cos \eta_j L \tag{49c}$$

$$+ \tfrac{1}{2}\left(\frac{a}{b\eta_j{}^2} + \frac{b}{a}\right) \sin \eta_j L \ .$$

The error in the roots is of the order of D/L times the value of the root. Thus values of the root near zero, which dominate the late-time behavior, are reasonably well determined. The early-time behavior is less well determined. This does not seem a serious deficiency, since the diffusion model is poor for early times in any case, e.g., giving instantaneous transmission independent of thickness.

A-3 STEADY-STATE DIFFUSION FOR CONVEX BODIES

In order to evaluate the reflection and transmission by more general shapes, a numerical method has been developed which is applicable to general convex shapes. The restriction to convex bodies is to prevent one part of the body serving as a source for another part by an exterior path. The equations to be solved are

$$\nabla^2\ \phi(\vec{r}) - K^2\phi(\vec{r}) = 0 \tag{50a}$$

$$J_{\pm}(\vec{r}) = a\ \ \phi(\vec{r}) \mp b \text{ grad } \phi(\vec{r}) \cdot \hat{n}(\vec{r}) \tag{50b}$$

where, on the surface, $J_+(\vec{r})$ is the outward flux and $J_-(\vec{r})$ is the inward flux, with $\hat{n}(\vec{r})$ the outward unit vector normal to the surface.

The usual Green's function solution of this type of equation involves finding a function, $G(\vec{r},\vec{r}')$, which satisfies the Equation (50a) except at $\vec{r} = \vec{r}'$, where it has a delta function type singularity. The usual development proceeds as follows. For a volume, T, with surface Σ,

$$\int_T [G(\vec{r},\vec{r}')(\nabla^2\phi(\vec{r})-K^2\phi(\vec{r})) - \phi(\vec{r})(\nabla^2 G(\vec{r},\vec{r}')-K^2 G(\vec{r},\vec{r}')] \, d\tau$$

$$= \int_\Sigma [G(\vec{r},\vec{r}')\text{grad}\ \phi(\vec{r})\cdot\hat{n} - \phi(\vec{r})\ \text{grad}\ G(\vec{r},\vec{r}')\cdot\hat{n}] \, d\sigma \ . \qquad (51)$$

Since $\phi(\vec{r})$ satisfies Equation (50a) throughout the volume and $G(\vec{r},\vec{r}')$ satisfies it, except at $\vec{r} = \vec{r}'$, the volume integral can be shrunk to be over a sphere of arbitrarily small radius about $\vec{r}'$, volume T_s, surface Σ_s.

$$- \int_T \phi(\vec{r}) \ (\nabla^2 G(\vec{r},\vec{r}') - K^2 G(\vec{r},\vec{r}')) \, d\tau$$

$$= - \int_{T_s} \phi(\vec{r}) \ (\nabla^2 G(\vec{r},\vec{r}') - K^2 G(\vec{r},\vec{r}')) \, d\tau$$

$$= - \int_{T_s} [\text{div}(\phi(\vec{r})\ \text{grad}G(\vec{r},\vec{r}')) - \text{grad}\,\phi\,(\vec{r})\ \text{grad}G(\vec{r},\vec{r}')$$

$$- K^2 G(\vec{r},\vec{r}')] \, d\tau$$

$$= - \int_{\Sigma_s} \phi(\vec{r})\ \text{grad}\ G(\vec{r},\vec{r}')\cdot\hat{n}(\vec{r}) \, d\sigma$$

$$- \int_{T_s} [\text{grad}\,\phi\,(\vec{r})\cdot\text{grad}G(\vec{r},\vec{r}') + K^2 G(\vec{r},\vec{r}')] \, d\tau \ .$$

Since $\nabla^2 G - K^2 G$ has an integrable singularity at $\vec{r}=\vec{r}'$, the second integral vanishes as the sphere radius goes to zero. (Typically G is like $|\vec{r}-\vec{r}'|^{-1}$, grad G like $|\vec{r}-\vec{r}'|^{-2}$ and $d\tau$ like $|\vec{r}-\vec{r}'|^2 d|\vec{r}-\vec{r}'|$.) In the surface integral, since $\phi(\vec{r})$ is continuous, it may be adequately approximated by $\phi(\vec{r}')$ and removed from the integral. Equation (51) can then be written as

$$-\phi(r') \lim \int_{\Sigma_s} \text{grad } G(\vec{r},\vec{r}')\cdot\hat{n}(\vec{r})\, d\sigma$$

$$= \int_{\Sigma} [G(\vec{r},\vec{r}')\,\text{grad}\phi(\vec{r})\cdot\hat{n}(\vec{r}) - \phi(\vec{r})\ \text{grad}G(\vec{r},\vec{r}')\cdot\hat{n}(\vec{r})]\, d\sigma \quad . \tag{52}$$

The limit-integral multiplying $\phi(\vec{r}')$ is here left explicit since its value depends critically on whether the point $\vec{r}'$ is inside the surface or on the surface. In the former case, the sphere radius will be small enough, in the limiting process, that the sphere surrounds the point, $\vec{r}'$. If $\vec{r}'$ is on the surface this will not happen.

In the usual textbook formulation, $G(\vec{r},\vec{r}')$ is chosen to match suitable boundary conditions, e.g., if $\hat{n}\cdot\text{grad}\,\phi$ is given on the surface, $\hat{n}\cdot\text{grad G}$ is zero on the surface; if ϕ is given, G is set to zero. In the method proposed here, following Banaugh,[6] the function G is taken to be the infinite medium function. The boundary conditions specify a linear relation between ϕ and $\hat{n}\cdot\text{grad}\ \phi$ on the boundary. Then, if $\vec{r}'$ is taken to be on the surface, Equation (52) is an integral equation for the *unknown values of ϕ or $\hat{n}\cdot\text{grad}\ \phi$*, as desired, on the surface.

For the problem under consideration, where $\vec{\rho} = \vec{r}-\vec{r}'$ and $d\omega$ is element of solid angle, choose

$$G(\vec{r},\vec{r}') = e^{-K|\vec{r}-\vec{r}'|}\,|\vec{r}-\vec{r}'|^{-1} \tag{53}$$

$$\lim \int_{\Sigma_s} \text{grad } G(\vec{r},\vec{r}')\cdot\hat{n}(\vec{r})d\sigma = \lim \int_{\Sigma_s} \frac{\partial}{\partial\rho}\,(e^{-K\rho}\ \rho^{-1})\rho^2\ d\omega$$

$$= \lim \int_{\Sigma_s} e^{-K\rho}\ (-k\rho^{-1}-\rho^{-2})\rho^2\ d\omega$$

$$= -\int_{\Sigma_s} d\omega \ .$$

Equation (52) then becomes

$$\Omega\phi(\vec{r}\,') = \int_{\Sigma} [G(\vec{r},\vec{r}\,')\mathrm{grad}\phi(\vec{r})\cdot\hat{n}(\vec{r}) - \phi(\vec{r})\mathrm{grad}G(\vec{r},\vec{r}\,')\cdot\hat{n}(\vec{r})]\, d\sigma \tag{54}$$

where Ω is the solid angle subtended by the surface at the point $\vec{r}\,'$, e.g., 4π if $\vec{r}\,'$ is inside the surface, 2π if $\vec{r}\,'$ is on the surface at a point not a "corner".

For the problem at hand, only surface values are of interest and it will be assumed the surface is "smooth." The quantity of actual interest is $J_+(\vec{r})$ with $J_-(\vec{r})$ given. On the surface

$$\phi(\vec{r}) = \frac{1}{2a}\,(J_+(\vec{r}) + J_-(\vec{r}))$$

$$\mathrm{grad}\phi(\vec{r})\cdot\hat{n} = \frac{1}{2b}\,(J_-(\vec{r}) - J_+(\vec{r}))$$

$$\frac{\pi}{a}\,(J_+(\vec{r}\,') + J_-(\vec{r}\,')) = -\int_{\Sigma}\left[\frac{1}{2a}\,(J_+(\vec{r}) + J_-(\vec{r}))\ \mathrm{grad}\ G(\vec{r},\vec{r}\,')\cdot\hat{n} - \frac{1}{2b}\,(J_-(\vec{r}) - J_+(\vec{r}))\ G(\vec{r},\vec{r}\,')\right] d\sigma$$

$$J_+(\vec{r}\,') = -J_-(\vec{r}\,') - \int_{\Sigma} J_-(r)\left[\frac{1}{2\pi}\ \mathrm{grad}\ G(\vec{r},\vec{r}\,')\cdot\hat{n} - \frac{a}{2\pi b}\ G(\vec{r},\vec{r}\,')\right] d\sigma$$

$$- \int_{\Sigma} J_+(\vec{r})\left[\frac{1}{2\pi}\ \mathrm{grad}\ G(\vec{r},\vec{r}\,')\cdot\hat{n} + \frac{a}{2\pi b}\ G(\vec{r},\vec{r}\,')\right] d\sigma\ . \tag{55}$$

The first two terms are, in principle, known, although the actual evaluation of the integral may present some problems. Thus Equation (55) is an integral equation for the values of the emergent flux, J_+, on the surface.

Computationally, the procedure for solving the equation consists of replacing the integral by a set of algebraic equations. A grid of points, $\vec{r}_j$, is established, each having an associated region, Σ_j, and a local vector, $\vec{\rho}_j$.

$$J_+(\vec{r}_j) = -J_-(\vec{r}_j) - \frac{1}{2\pi}\,\Sigma_{k\neq j}\int_{\Sigma_k} J_-(\vec{r}_k+\vec{\rho}_k)\left[\text{grad}_{\rho_k}\, G(\vec{r}_k+\vec{\rho}_k,\vec{r}_j)\cdot\hat{n} - \frac{a}{b}\, G(\vec{r}_k+\vec{\rho}_k,\vec{r}_j)\right] d\sigma_k$$

$$- \frac{1}{2\pi}\,\Sigma_{k\neq j}\int_{\Sigma_k} J_+(\vec{r}_k+\vec{\rho}_k)\left[\text{grad}_{\rho_k} G(\vec{r}_k+\vec{\rho}_k,\vec{r}_j)\cdot\hat{n} + \frac{a}{b}\, G(\vec{r}_k+\vec{\rho}_k,\vec{r}_j)\right] d\sigma_k$$

$$- \frac{1}{2\pi}\int_{\Sigma_j} J_-(\vec{r}_j+\vec{\rho}_j)\left[\text{grad}_{\rho_j} G(\vec{r}_j+\vec{\rho}_j,\vec{r}_j)\cdot\hat{n} - \frac{a}{b}\, G(\vec{r}_j+\vec{\rho}_j,\vec{r}_j)\right] d\sigma_j$$

$$- \frac{1}{2\pi}\int_{\Sigma_j} J_+(\vec{r}_j+\vec{\rho}_j)\left[\text{grad}_{\rho_j} G(\vec{r}_j+\vec{\rho}_j,\vec{r}_j)\cdot\hat{n} + \frac{a}{b}\, G(\vec{r}_j+\vec{\rho}_j,\vec{r}_j)\right] d\sigma_j \quad . \tag{56}$$

(grad_{ρ_j} means a gradient with respect to ρ_j coordinates).

The first term is known. In the sums, $k\neq j$, the integrals may be replaced by suitable averages times the area, Σ_k. Only the last two terms require special care because of the singularity of the function G and its gradient. A demonstration that these integrals are finite and an evaluation, neglecting variation in the J's over the area, is straightforward.

$$\int_{\Sigma_j} G(\vec{r}_j+\vec{\rho}_j,\vec{r}_j)\, d\sigma = \int_{\Sigma_j} (e^{-K\rho_j}\, \rho_j^{-1})\, \rho_j d\rho_j\, d\theta$$

$$= \int_{\Sigma_j} e^{-K\rho_j}\, d\rho_j\, d\theta$$

$$\simeq 2\pi\, \tilde{\rho}_j$$

$$\simeq 2\pi \sqrt{\frac{\Sigma_j}{\pi}} \text{ (where } \pi\rho_j^{\,2} = \Sigma_j)$$

$$\simeq 2 \sqrt{\pi\Sigma_j} \tag{57}$$

$$\int_{\Sigma_j} \text{grad}\rho_j\, G(\vec{r}_j+\vec{\rho}_j,\vec{r}_j)\cdot\hat{n}\, d\sigma = \int_{\Sigma_j} \frac{\partial}{\partial\rho}\left(\frac{e^{-K\rho}}{\rho}\right) \frac{\vec{\rho}\cdot\hat{n}}{\rho}\, \rho d\rho d\theta$$

$$= \int e^{-K\rho}\left(\frac{-K}{\rho} - \frac{1}{\rho^2}\right) \frac{\vec{\rho}\cdot\hat{n}}{\rho}\, \rho d\rho d\theta\ .$$

$$= \int e^{-K\rho}(-K - \frac{1}{\rho}) \frac{\vec{\rho}\cdot\hat{n}}{\rho}\, d\rho d\theta$$

$$\frac{\vec{\rho}\cdot\hat{n}}{\rho} \simeq \frac{\rho}{2R}$$

where R is the local radius of curvature.

$$\int_{\Sigma_j} \text{grad}\ \rho_j\, G(\vec{r}_j+\vec{\rho}_j,\vec{r}_j)\cdot\hat{n}d\sigma \simeq -\int e^{-K\rho}(K\rho+1)\, R^{-1}\, d\rho d\theta \simeq -\frac{1}{R}\sqrt{\pi\Sigma_j}\ . \tag{58}$$

Using these evaluations of the integrals then yields a set of simultaneous linear algebraic equations for the $J_+(\vec{r}_j)$.

An alternate approximate scheme can be developed which does not involve the solution of simultaneous equations, thus avoiding time consuming procedures (in the case of many points). It can best be expressed by reverting to Equation (55). Let $S(\vec{r}')$ denote the known first two terms on the right side and $G_+(\vec{r},\vec{r}')$ the multiplier of J_+ in the integral.

$$J_+(\vec{r}') = S(\vec{r}') - \int_\Sigma J_+(\vec{r})\, G_+(\vec{r},\vec{r}')\, d\sigma$$

$$J_+(\vec{r}') \left(1 + \int_\Sigma G_+(\vec{r},\vec{r}')\, d\sigma\right) = S(\vec{r}') - \int [J_+(\vec{r}) - J_+(\vec{r}')]\, G_+(\vec{r},\vec{r}')\, d\sigma \,. \tag{59}$$

This form shows some immediate advantage since the integral on the right is less singular at $\vec{r} - \vec{r}'$ due to the zero of $J_+(\vec{r}) - J_+(\vec{r}')$. The approximate procedure solves this in two successive approximations.

$$J_{1,+}(\vec{r}') = S(\vec{r}')/\left[1 + \int_\Sigma G_+(\vec{r},\vec{r}')\, d\sigma\right] \tag{60a}$$

$$J_{2,+}(\vec{r}') = J_{1,+}(\vec{r}') - \frac{\int_\Sigma \left[J_{1,+}(\vec{r}) - J_{1,+}(\vec{r}')\right] G_+(\vec{r},\vec{r}')\, d\sigma}{1 + \int_\Sigma G_+(\vec{r},\vec{r}')\, d\sigma} \,. \tag{60b}$$

The actual numerical implementation of this involves the same replacement of the integrals by sums, but each step is now explicit.

A-4 DIFFUSION THROUGH MULTIPLE SLABS

The problem of transmission by multiple contiguous plane slabs, in the pure diffusion case, can be derived from the single slab case. The case of plane source and point source follow similar development. The procedure consists in using the emerging flux from the top (bottom) of a layer as the entering flux on the bottom (top) of the next higher (lower) layer and deriving a set of relations between the surfaces.

A-4.1 Planar Diffusion Through Multiple Slabs

Assume N contiguous layers with bottoms at $d_1 < d_2 < \ldots d_N$, thickness L_1, L_2 ... L_N. In each layer,

$$\nabla^2 \phi_i(Z) - K_i^2 \phi_i(Z) = 0 \tag{61a}$$

$$J_{i,\pm}(Z) = a_i \phi_i \mp b_i \frac{\partial \phi_i}{\partial z} \quad . \tag{61b}$$

The boundary conditions are

$$J_{1,+}(d_1) = f, \; J_{N,-}(d_N + L_N) = 0 \tag{62a}$$

$$J_{i+1,\pm}(d_{i+1}) = J_{i,\pm}(d_i + L_i) \qquad i=1,2,\ldots N-1 \quad . \tag{62b}$$

The desired quantities are $J_{N,+}(d_n + L_N)$ and $J_{1,-}(d_1)$. In the ith layer

$$\phi_i(z) = A_i e^{K_i z} + B_i e^{-K_i z}$$

$$J_{i,\pm}(z) = A_i e^{K_i z} (a_i \mp b_i K_i) + B_i e^{-K_i z} (a_i \pm b_i K_i) \quad .$$

In matrix notation,

$$[J_i(d_i)] = [P_i][\overline{A}_i] \tag{63a}$$

$$[J_i(d_i+L_i)] = [P_i]\,[Q_i]\,[\overline{A}_i] \tag{63b}$$

where

$$[J_i(x)] = \begin{bmatrix} J_{i,+}(x) \\ \\ J_{i,-}(x) \end{bmatrix} \tag{63c}$$

$$[P_i] = \begin{bmatrix} a_i - b_i K_i & a_i + b_i K_i \\ \\ a_i + b_i K_i & a_i - b_i K_i \end{bmatrix} \tag{63d}$$

$$[Q_i] = \begin{bmatrix} e^{K_i L_i} & 0 \\ \\ 0 & e^{-K_i L_i} \end{bmatrix} \tag{63e}$$

$$[\overline{A}_i] = \begin{bmatrix} A_i & e^{K_i d_i} \\ \\ B_i & e^{-K_i d_i} \end{bmatrix} . \tag{63f}$$

The problem has been formulated in terms of a different set of matrices:

$$[T_i] = [R_i]\,[\overline{A}_i] \tag{64a}$$

where

$$[R_i] = \begin{bmatrix} a_i + b_i K_i & a_i - b_i K_i \\ \\ (a_i - b_i K_i)\, e^{K_i L_i} & (a_i + b_i K_i)\, e^{-K_i L_i} \end{bmatrix} \tag{64b}$$

$$[T_i] = \begin{bmatrix} J_{i,-}(d_i) \\ \\ J_{i,+}(d_i + L_i) \end{bmatrix} .$$

A recursion relation is easily developed.

$$[T_i] = [R_i]\,[\overline{A}_i] = [R_i]\,[P_i]^{-1}\,[J_i(d_i)] \quad .$$

By the boundary conditions

$$[J_i(d_i)] = [J_{i-1}(d_{i-1}+L_{i-1})] \quad ,$$

$$[T_i] = [R_i][P_i]^{-1}\ [P_{i-1}]\ [Q_{i-1}]\ [R_{i-1}]^{-1}\ [T_{i-1}]$$

$$= [M_n]\ [T_{i-1}]$$

$$[T_N] = [M_N]\ [M_{N-1}]\ \ldots\ [M_2]\ [T_1]$$

$$= [\mathcal{M}]\ [T_i]$$

$$[T_N] = [R_N]\ [Q_N]^{-1}\ [P_N]^{-1}\ [J_N(d_N+L_N)]$$

$$\begin{bmatrix} J_{N,-}(d_N) \\ \\ J_{N,+}(d_N+L_N) \end{bmatrix} = [R_N]\ [Q_N]^{-1}\ [P_N]^{-1} \begin{bmatrix} J_{N,+}\ (d_N+L_N) \\ 0 \end{bmatrix}$$

$$[T_1] = [R_1]\ [P_1]^{-1}\ [J_1(d_1)]$$

$$\begin{bmatrix} J_{1,-}(d_1) \\ \\ J_{1,+}(d_1+L_1) \end{bmatrix} = [R_1]\ [P_1]^{-1} \begin{bmatrix} f \\ \\ J_{1,-}(d_1) \end{bmatrix} .$$

Defining

$$\hat{D}_i = \cosh K_i L_i - \frac{1}{2}\left(\frac{a_i}{b_i K_i} + \frac{b_i K_i}{a_i}\right) \sinh K_i L_i$$

$$\lambda_i = \frac{1}{2}\left(\frac{a_i}{b_i K_i} - \frac{b_i K_i}{a_i}\right) \sinh K_i L_i$$

$$[\hat{M}_i] = [M_i] \Big/ \hat{D}_{i-1} = \begin{bmatrix} 1 & -\lambda_{i-1} \\ \lambda_{i-1} & \hat{D}_i \hat{D}_{i-1} - \lambda_i \lambda_{i-1} \end{bmatrix}$$

$$[\hat{\mathcal{M}}] = [M_N]\,[M_{N-1}] \ldots [M_2] \quad ,$$

straightforward matrix operations lead to

$$J_{N,+}(d_N + L_N) = \left(\Pi_{i=1}^{N} \hat{D}_i\right) f \Big/ \left\{ [1, -\lambda_N]\,[\hat{\mathcal{M}}] \begin{bmatrix} 1 \\ \lambda_1 \end{bmatrix} \right\} \quad . \qquad (65a)$$

A similar expression can be derived for $J_{1,-}(d_1)$,

$$J_{1,-}(d_1) = \frac{f\,\hat{D}_1\,[1, -\lambda_N]\,[\hat{\mathcal{M}}] \begin{bmatrix} 0 \\ 1 \end{bmatrix}}{[1, -\lambda_N]\,[\hat{\mathcal{M}}] \begin{bmatrix} 1 \\ \lambda_1 \end{bmatrix}} \quad . \qquad (65b)$$

Only Equation (65a) has been introduced into a computer program.

It should be noted that the requirement of contiguous layers is overly restrictive in this one-dimensional case. Actually the requirement is for non-overlapping layers,

$$d_1 \le d_1 + L_1 \le d_2 \le d_2 + L_2 \ldots \le d_N \le d_N + L_N \quad .$$

A-4.2 Point Source Diffusion Through Multiple Slabs

The slab geometry is the same as in Section A-4.1. It is essential, here, that the slabs be contiguous because of cylindrical divergence. The source is a point source at $d_o(\leq d_1)$. In the ith region, the equations to be satisfied are

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial\phi_i}{\partial r}\right) + \frac{\partial^2\phi_i}{\partial z^2} - K_i^{\,2}\,\phi_i = 0 \tag{66a}$$

$$J_{i,\pm}(r,z) = a_i\,\phi_i \mp b_i\,\frac{\partial\phi_i}{\partial z} \quad . \tag{66b}$$

The boundary conditions are that J_+ and J_- are continuous at the boundaries and

$$J_{1,+}(r_1,d_1) = \frac{Q}{2\pi}\,\frac{d_1-d_0}{[r^2+(d_1-d_o)^2]^{3/2}}$$

$$J_{N,-}(r_1,d_N+L_N) = 0 \quad .$$

As in Section A-2.1.3, Hankel transforms are used. Then in the ith slab

$$\frac{\partial^2\,\overline{\phi}_i(p,z)}{\partial z^2} - k_i^{\,2}\,\overline{\phi}_i(p,z) = 0 \tag{67a}$$

$$k_i^{\,2} = p^2 + K_i^{\,2} \tag{67b}$$

$$\overline{J_{i,\pm}}\,(p,z) = a_i\,\overline{\phi}_i(p,z) \mp b_i\,\frac{\partial\overline{\phi}_i\,(p,z)}{\partial z} \quad . \tag{67c}$$

$\overline{J}_{i,+}(p,z)$ and $\overline{J}_{i,-}(p,z)$ are continuous at the interfaces and

$$\overline{J}_{1,+}(p,d_1) = \frac{Q}{2\pi} e^{-p(d_1-d_0)} = \overline{f}(p) \tag{68d}$$

$$\overline{J}_{N,-}(p,d_N+L_N) = 0 \tag{68e}$$

$$\overline{J}_{L+1,\pm}(p,d_{i+1}) = \overline{J}_{i,\pm}(p,d_i+L_i), \quad i=1,2 \ldots N-1 \quad . \tag{68f}$$

The functions of interest are $\overline{J}_{N,+}(p,d_N+L_N)$ and $\overline{J}_{1,-}(p,d_1)$. These equations are formally the same as Equations (61) and (62) in Section A-4.1, with K_i replaced by k_i and p appearing throughout as a parameter.

$$\boxed{\overline{J}_{N,+}(p,d_N+L_N) = \overline{f}(p) \prod_{i=1}^{N} \hat{D}_i \Big/ \left\{ [1,-\lambda_N] \, [\hat{\mathcal{M}}] \begin{bmatrix} 1 \\ \lambda_1 \end{bmatrix} \right\}} \tag{69}$$

with

$$\overline{f}(p) = \frac{Q}{2\pi} e^{-p(d_1-d_o)}$$

$$\hat{D}_i = \cosh k_i L_i - \tfrac{1}{2}\left(\frac{a_i}{b_i k_i} + \frac{b_i k_i}{a_i}\right) \sinh k_i L_i$$

$$\lambda_i = \tfrac{1}{2}\left(\frac{a_i}{b_i k_i} - \frac{b_i k_i}{a_i}\right) \sinh k_i L_i$$

$$k_i^2 = K_i^2 + p^2$$

$$[\hat{\mathcal{M}}] = [\hat{M}_N]\,[\hat{M}_{N-1}] \ \ldots \ [\hat{M}_2]$$

$$[\hat{M}_i] = \begin{bmatrix} 1 & -\lambda_{i-1} \\ \lambda_i & \hat{D}_i\hat{D}_{i-1} - \lambda_i\lambda_{i-1} \end{bmatrix} .$$

The actual value of the emergent flux must be determined by an inversion of the Hankel transform as in Section A-2.1.3.

$$\boxed{J_{N,+}(r,d_N+L_N) = \int_0^\infty \overline{J_{N,+}}(p,d_N+L_N)\, J_o(pr)\, pdp \quad .} \qquad (70)$$

A-4.3 Diffusion Through Overlapping or Non-Contiguous Slabs

The restriction to contiguous layers of Section A-4.2 and to non-overlapping layers of Sections A-4.1 and A-4.2 can be removed in a crude approximation. The recipe proposed consists in fixing the tops of all 14 cloud types and the bottoms of the seven low-altitude cloud types, adjusting the bottoms of the remaining layers (i.e., the mid- and high-altitude cloud types) to give contiguous layers and adjusting the density of each layer to give the original optical thickness.

This procedure is admittedly crude but seems the simplest one that even approximately simulates the actual problem.

A-5 REFERENCES

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APPENDIX B

ROSCOE-IR
NATURAL CLOUD PROGRAM LISTING

```
      PROGRAM ROSCOER(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)                ROSCOER    2
      COMMON/SORCE/  NSORCE,HSORCE(1),RSORCE(1),THETAS(1),PHIS(1)           SORCE      2
      COMMON/ LOS /  HLOS(1,16), ULOS(1,16), VLOS(1,16), WLOS(1,16)         LOS        2
      COMMON/CLOUD/ NCLOUD,                                                 CLOUD      2
     1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),          CLOUD      3
     2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                                 CLOUD      4
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                                PARAMS     2
      COMMON / DETECT/ HD, THETAD,PHID,FOV                                  DET        2
      COMMON /MATERL/MSM,DDM(7),SRFALT                                      MATERL     2
      COMMON/ PTE /  P1,P2,P3,P4,T1,T2,T3,T4,                               PTE        2
     1               S1,S2,S3,S4,E1,E2,E3,E4                                PTE        3
     1              ,PCFLOS                                                 PTE        4
      COMMON/SOLARP/ SOLLAT,SOLLON,DUMDUM(10)                               SOLARC     2
      COMMON/INTRCPT/ ALTLK(20),THETALK(20),PHILK(20)                       INTERCPT   2
      COMMON/ATMOUP/  DUM1(4),RHO,TT,DUM2(32)                               ATMOSX     2
      COMMON/XX1111/  KCLDK, CLDLAM                                         ROSCOER   13
      LOGICAL  SINCLD                                                       ROSCOER   14
      DATA DTR,RTD  / .01745329251994,57.2957795131 /                       ROSCOER   15
      DATA IN/5/, IOUT/6/, PI/3.14159265/, RE/6371.03/                      ROSCOER   16
      DATA  SOLLAT, SOLLON / 0.0, -1.5708 /                                 ROSCOER   17
      DATA RSUN / 1.495979E8/                                               ROSCOER   18
      DATA SRFALT / 0.0 /                                                   ROSCOER   19
C                                                                           ROSCOER   20
C        THIS IS A DRIVER PROGRAM TO CHECK OUT THE INDIVIDUAL               ROSCOER   21
C        ROUTINES                                                           ROSCOER   22
C                                                                           ROSCOER   23
C                                                                           ROSCOER   24
C        ALL DIMENSIONS IN KILOMETERS                                       ROSCOER   25
C        FIELD OF VIEW IN KILOMETERS SQUARED                                ROSCOER   26
C                                                                           ROSCOER   27
C        K IS CLOUD NUMBER                                                  ROSCOER   28
C        UL,VL,WL IS LINE OF SIGHT                                          ROSCOER   29
C        ALAM IS WAVELENGTH (MICRONS)                                       ROSCOER   30
C        TCOEF IS OUTPUT TRANSFER COEFFICIENT                               ROSCOER   31
C                                                                           ROSCOER   32
C        CALL CLOUDO TO GET THE CLOUD INPUTS                                ROSCOER   33
C                                                                           ROSCOER   34
C        SPECTRAL RADIANCES ARE IN UNITS OF WATTS PER SR PER KM**2          ROSCOER   35
C        PER MICRON                                                         ROSCOER   36
C        THE TRANSFER COEFFICIENT HAS UNITS OF SR-1                         ROSCOER   37
CLJ                                                                         ROSCOER   38
CLJ       READ OR SET THE FOLLOWING PARAMETERS...                           ROSCOER   39
CLJ                                                                         ROSCOER   40
CLJ          PARAMETER  IN COMMON  DEFINED IN   READ/SET  COMMENT           ROSCOER   41
CLJ          ---------  ---------  ----------   --------  -------           ROSCOER   42
CLJ          HD         DETECT     SUB. LOS       R                        ROSCOER   43
CLJ          THETAD     DETECT     SUB. LOS       R                        ROSCOER   44
CLJ          PHID       DETECT     SUB. LOS       R                        ROSCOER   45
CLJ          FOV        DETECT     SUB. LOS       R                        ROSCOER   46
CLJ          ALAM        --        SUB. SCLOUD    R                        ROSCOER   47
CLJ          UL,VL,WL    --        SUB. SCLOUD        S                    ROSCOER   48
CLJ                                                                         ROSCOER   49
CLJ          MSM        MATERL     SUB. SCLOUD        S                    ROSCOER   50
CLJ          DDM(MSM)   MATERL     SUB. SCLOUD        S                    ROSCOER   51
CLJ          SRFALT     MATERL     SUB. SCLOUD        S      A             ROSCOER   52
CLJ                                                                         ROSCOER   53
CLJ          INFIL      PARAMS                        S      B1            ROSCOER   54
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CLJ          IOFIL      PARAMS                          S      B2          ROSCOER
CLJ          PI         PARAMS                          S                  ROSCOER
CLJ          ERAD       PARAMS                          S      C           ROSCOER
CLJ          DGTOR      PARAMS                          S      D1          ROSCOER
CLJ          RTODG      PARAMS                          S      D2          ROSCOER
CLJ                                                                       ROSCOER
CLJ          P1,P2      PTE        SUB. SCLOUD          S                  ROSCOER
CLJ          P3,P4      PTE        SUB. SCLOUD          S                  ROSCOER
CLJ                                                                       ROSCOER
CLJ          SOLLAT     SOLARP     SUB. SCLOUD          S      E           ROSCOER
CLJ          SOLLON     SOLARP     SUB. SCLOUD          S      E           ROSCOER
CLJ                                                                       ROSCOER
CLJ          NSORCE     SORCE      SUB. CLOUD1          S                  ROSCOER
CLJ          HSORCE(1)  SORCE      SUB. CLOUD1     R                       ROSCOER
CLJ          THETAS(1)  SORCE      SUB. CLOUD1     R                       ROSCOER
CLJ          PHIS(1)    SORCE      SUB. CLOUD1     R                       ROSCOER
CLJ          WKT         --                         R          F           ROSCOER
CLJ          ISUN        --        SUB. SCLOUD     R                       ROSCOER
CLJ                                                                       ROSCOER
CLJ          KCLDK      XX1111     SUB. CLOUD3          S                  ROSCOER
CLJ          CLDLAM     XX1111     SUB. CLOUD3          S                  ROSCOER
CLJ                                                                       ROSCOER
CLJ          UL,VL,WL    --        SUB. SCLOUD          S                  ROSCOER
CLJ          ------------------------------------------------------        ROSCOER
CLJ          A   SET BY DATA STATEMENT                                     ROSCOER
CLJ          B1  INPUT  FILE FOR NATURAL CLOUD MODEL                       ROSCOER
CLJ          B2  OUTPUT FILE FOR NATURAL CLOUD MODEL                       ROSCOER
CLJ          C   EARTH RADIUS, KM                                          ROSCOER
CLJ          D1  DEGREES-TO-RADIANS                                        ROSCOER
CLJ          D2  RADIANS-TO-DEGREES                                        ROSCOER
CLJ          E   SET BY DATA STATEMENT FOR SIMPLE TEST RUNS WHEN           ROSCOER
CLJ              DUMMY USED FOR SUBROUTINES ATMOSU, SOLORB, ETC.          ROSCOER
CLJ              FOR THE REAL SUBROUTINE ATMOSU, ETC., A NUMBER           ROSCOER
CLJ              OF QUANTITIES MUST BE SET, FOR WHICH SEE PROGRAM         ROSCOER
CLJ              DRIVER FOR SUBROUTINES ATMOSU, ETC.                      ROSCOER
CLJ          F   YIELD OF ARTIFICIAL SOURCE IN KT, USED TO GET            ROSCOER
CLJ              SOURCE RADIUS, BASED ON FORMULA AND ALTITUDE             ROSCOER
CLJ              SCALING FROM GLASSTONE (ENW).                            ROSCOER
CLJ                                                                       ROSCOER
    7 CONTINUE                                                            ROSCOER
C                                                                         ROSCOER
C        READ DETECTOR AND SOURCE DATA                                    ROSCOER
C                                                                         ROSCOER
   10 FORMAT(4E10.3)                                                      ROSCOER
      READ(IN,10)HD,THETAD,PHID,FOV                                       ROSCOER
      IF( HD.LT.0.0 )  GO TO 99                                           ROSCOER
      WRITE(IOUT,20) HD,THETAD,PHID,FOV                                   ROSCOER
   20 FORMAT(*   DETECTOR LOCATION  *4E12.4)                              ROSCOER
      NSORCE = 1                                                          ROSCOER
      READ(IN,10)  HSORCE(1),THETAS(1),PHIS(1),WKT                        ROSCOER
      CALL ATMOSU(2,HSORCE(1))                                            ROSCOER
      RSORCE(1) = 6.70E-02 * WKT**0.40 * (1.2250E-03/RHO)**0.333333       ROSCOER
      WRITE(IOUT,12)  HSORCE(1),THETAS(1),PHIS(1),WKT,RSORCE(1)           ROSCOER
   12 FORMAT (*0   SOURCE LOCATION,  YIELD(KT), AND  RADIUS(KM)  =*,      ROSCOER
     1  5E12.4)                                                           ROSCOER
      READ(IN,14)  ISUN                                                   ROSCOER
   14 FORMAT (I10)                                                        ROSCOER
```

```
      WRITE(IOUT,16)  ISUN                                              ROSCOER  112
   16 FORMAT (*      ISUN = *,I2)                                       ROSCOER  113
      READ(IN,10)  ALAM                                                 ROSCOER  114
      WRITE(IOUT,17)  ALAM                                              ROSCOER  115
   17 FORMAT (*      ALAM = *,E12.4)                                    ROSCOER  116
      CALL CLOUD0(MODE)                                                 ROSCOER  117
      IF( MODE .NE. 0) GO TO 40                                         ROSCOER  118
C                                                                       ROSCOER  119
COMMENT   TO CHECK OUT DETERMINISTIC MODE                               ROSCOER  120
C                                                                       ROSCOER  121
      CALL POL TO CT(RE+HD,THETAD,PHID,XD,YD,ZD)                        ROSCOER  122
      IPASS = 1                                                         ROSCOER  123
   22 CONTINUE                                                          ROSCOER  124
      CALL CLOUD1                                                       ROSCOER  125
C                                                                       ROSCOER  126
      DO 30 K=1,NCLOUD                                                  ROSCOER  127
      KCLDK = 99                                                        ROSCOER  128
      CLDLAM = -99.                                                     ROSCOER  129
      CALL LOS( K )                                                     ROSCOER  130
      DO 30 I=1,64                                                      ROSCOER  131
      IF( HLOS(1,I).EQ.0.0 )  GO TO 33                                  ROSCOER  132
      UL = ULOS(1,I)                                                    ROSCOER  133
      VL = VLOS(1,I)                                                    ROSCOER  134
      WL = WLOS(1,I)                                                    ROSCOER  135
      CALL CLOUD2(UL,VL,WL)                                             ROSCOER  136
      CALL CLOUD3(UL,VL,WL,K,ALAM,TCOEF,TEMISS,SINCLD)                  ROSCOER  137
      IF( SINCLD )  GO TO 7                                             ROSCOER  138
      WRITE(6,25)  KCLOUD(K),TCOEF,ALAM,TEMISS                          ROSCOER  139
      WRITE(6,23)                                                       ROSCOER  140
   23 FORMAT (///)                                                      ROSCOER  141
   25 FORMAT( * THE TRANSFER COEFFICIENT TO CLOUD NO.*I5* IS *E12.4* FOR ROSCOER  142
     X A *F6.2 * MICRON WAVELENGTH* /                                   ROSCOER  143
     X *   THE THERMAL EMISSION (RADIANCE) IS *E12.4 )                  ROSCOER  144
   30 CONTINUE                                                          ROSCOER  145
   33 CONTINUE                                                          ROSCOER  146
      IF( (ISUN.EQ.0) .OR. (IPASS.EQ.2) )  GO TO 31                     ROSCOER  147
C         FOR THE SUN AS A SOURCE, SET...                               ROSCOER  148
      HSORCE(1) = RSUN-RE                                               ROSCOER  149
      THETAS(1) = 90. - SOLLAT*RTD                                      ROSCOER  150
      PHIS(1) = SOLLON*RTD                                              ROSCOER  151
      IPASS = 2                                                         ROSCOER  152
      GO TO 22                                                          ROSCOER  153
   40 CONTINUE                                                          ROSCOER  154
C                                                                       ROSCOER  155
COMMENT  TO CHECK OUT STATISTICAL MODE                                  ROSCOER  156
C                                                                       ROSCOER  157
      KEEPSUN = ISUN                                                    ROSCOER  158
      ISUN = 0                                                          ROSCOER  159
      MSM = 1   $   DDM(1) = 0.10                                       ROSCOER  160
C         GET  A  LOS                                                   ROSCOER  161
      CALL POL TO CT(RE+HD,THETAD,PHID,XD,YD,ZD)                        ROSCOER  162
      CALL POL TO CT(RE+HSORCE(1),THETAS(1),PHIS(1),XS,YS,ZS)           ROSCOER  163
      RR = SQRT((XD-XS)**2 + (YD-YS)**2 + (ZS-ZD)**2 )                  ROSCOER  164
      UL = (XS-XD)/RR  $  VL = (YS-YD)/RR  $  WL = (ZS-ZD)/RR           ROSCOER  165
      WL = SIGN ( AMIN1(ABS(WL*1.01),1.00),WL )                         ROSCOER  166
      VL = SIGN (SQRT(1. - WL**2 - UL**2),VL )                          ROSCOER  167
C                                                                       ROSCOER  168
```

```
C        THIS PRESCRIPTION WORKS ONLY FOR A PARTICULAR SET OF INPUTS
C        I.E., FOR SOURCE AND DETECTOR AT THETA=90. AND PHI=-90.
C
C        INTEGRATE OVER RADIAL DISTRIBUTION ON TOP
C        OF CLOUD TO GET TOTAL TRANSMISSION
      RSUM = 0.0
      DXX = 0.25
      DO 301 I=1,50
      X = DXX*(FLOAT(I)-0.999)
      RR = SQRT( (XD-X)**2          + (ABS(YD)-RE)**2 + ZD**2)
      UL =(X - XD ) / RR
      WL = 0.00000001
      VL = SQRT( 1. - UL**2 )
      WRITE(6,777) X
  777 FORMAT(10X,*RDIST = * E12.4)
      P1 = 0.10    $    P2 = 0.25
      P3 = 0.50    $    P4 = 0.90
      CALL SCLOUD(ALAM,UL,VL,WL,ISUN)
C
C
C        TC10 IS THE TRANSFER COEFFICIENT AT 10 PERCENT, ETC.
      RSUM = RSUM + PI*X*T4
C
      WRITE(6,26)  P1,P2,P3,P4
      WRITE(6,27)  T1,T2,T3,T4
      WRITE(6,29)  E1,E2,E3,E4
   26 FORMAT (*0    STATISTICAL CLOUDS,  P1,P2,P3,P4 =   *4F10.2)
   27 FORMAT (*     SOURCE TRANSFER CF   T1,T2,T3,T4 =   *4E10.3)
   28 FORMAT (*     SUN TRANSFER COEF    S1,S2,S3,S4 =   *4E10.3)
   29 FORMAT (*     EMISSION             E1,E2,E3,E4 =   *4E10.3)
  301 CONTINUE
      RSUM = RSUM*DXX
      WRITE(6,111)  RSUM,ALAM
  111 FORMAT (*      TOTAL TRANSMISSION FOR LAMDA IS  *,E13.5,F10.3)
C
      IF( KEEPSUN.EQ.0 )  GO TO 31
      CALL SCLOUD(ALAM,UL,VL,WL,KEEPSUN)
      WRITE(6,26)  P1,P2,P3,P4
      WRITE(6,28)  S1,S2,S3,S4
      WRITE(6,29)  E1,E2,E3,E4
   31 CONTINUE
      GO TO 7
   99 CONTINUE
      CALL EXIT
      END
```

```
      SUBROUTINE ATMOSU(JJ,ZH)                                          ATMOSU     2
      COMMON/ATMOUP/  DUM1(4),RHO,TT,DUM2(32)                           ATMOSX     2
CC                                                                      ATMOSU     4
CC        THIS IS A DUMMY ROUTINE REQUIRED IF THE CLOUD PACKAGE         ATMOSU     5
CC        IS EXERCISED AS A STAND-ALONE PROGRAM.                        ATMOSU     6
CC                                                                      ATMOSU     7
      TT = 288.0-6.50*ZH                                                ATMOSU     8
      RHO = 1.2250E-03 * EXP(-ZH/9.)                                    ATMOSU     9
      RETURN                                                            ATMOSU    10
      END                                                               ATMOSU    11
```

```
      FUNCTION BESS0(X)                                                 BESS0
C                                                                       BESS0
C EVALUATE BESSEL FUNCTION J0(X)-  (NBS 9.4.1,9.4.3)                    BESS0
C                                                                       BESS0
      IF(ABS(X).GT.3.0) GO TO 200                                       BESS0
  100 Y=X*X/9.                                                          BESS0
      F=1.-2.2499997*Y*(1.-.5624982*Y*(1.-.2499853*Y*(1.-.14048604*Y*   BESS0
     1  (1.-.0887421*Y*(1.-.0532400*Y)))))                              BESS0
      BESS0=F                                                           BESS0
      RETURN                                                            BESS0
  200 Y=3.0/X                                                           BESS0
      F=.79788456-7.7E-7*Y*(1.+7178.4416*Y*(1.+.01720881*Y*(1.-         BESS0
     1  14.427775*Y*(1.-.5305056*Y*(1.-.1988325*Y)))))                  BESS0
      THETA=X-.78539816-.04166397*Y*(1.+9.490214E-4*Y*(1.-66.40693*Y*   BESS0
     1  (1.-.20613315*Y*(1.+.5419492*Y*(1.-.4622098*Y)))))              BESS0
      BESS0=F*COS(THETA)/SQRT(X)                                        BESS0
      RETURN                                                            BESS0
      END                                                               BESS0
```

```
      BLOCK DATA                                                        CDATA      2
      COMMON /CLDFREQ/ KMODEL,CCOVER(5,11),CFREQ(17,4,11)               CLDFREQ    2
      COMMON/CDDATA/ ALAMT(10),SIGT(10,14),SIGS(10,14),W(10),           CDDATA     2
     1  XMUBAR(10,14),DNO(14),RAD(14),CLDBASE(14),CLDTHK(14)            CDDATA     3
      DATA ALAMT /2.00,2.50,2.55,2.65,2.75,2.85,3.20,3.50,4.00,5.00 /   CDATA      5
      DATA RAD/5.5,8.,6.5,4.5,5.,5.5,5.,4.8,6.,10.,40.,40.,40.,40. /    CDATA      6
      DATA  DNO / 30.,70.,30.,100.,150.,30.,70.,40.,70.,120.,1.0,       CDATA      7
     $            10.,0.8,2.0 /                                         CDATA      8
      DATA CLDBASE/.5,1.,4.,.3,.15,.5,1.,2.,2.,1.,10.,6.,6.,6. /        CDATA      9
      DATA  CLDTHK / 0.5,3.0,0.5,2.0,1.0,0.5,3.0,4.0,4.0,5.0,2.0,       CDATA     10
     $               4.0,3.0,4.0 /                                      CDATA     11
CCC                                                                     CDATA     12
CLJ   BLOCK DATA PROVIDES...                                            CDATA     13
CLJ     1. FOR 14 CLOUD TYPES, THEIR                                    CDATA     14
CLJ          A. BASE ALTITUDE,                                          CDATA     15
CLJ          B. THICKNESS,                                              CDATA     16
CLJ          C. WATER DROPLET RADIUS,                                   CDATA     17
CLJ          D. WATER DROPLET DENSITY, AND                              CDATA     18
CLJ          E. OPTICAL SCATTERING PROPERTIES (EXTINCTION AND           CDATA     19
CLJ             SCATTERING CROSS-SECTIONS AND MEAN COSINE OF            CDATA     20
CLJ             SCATTERING ANGLE) AT 10 WAVELENGTHS IN THE 2- TO        CDATA     21
CLJ             5-MICRON RANGE.                                         CDATA     22
CLJ     2. FOR REGIONS 4 AND 11 IN THE NASA CLOUD-DATA BASE,            CDATA     23
CLJ          A. THE STATISTICAL-CLOUD INDEX,                            CDATA     24
CLJ          B. OCCURRENCE FREQUENCIES OF CLOUD TYPES, AND              CDATA     25
CLJ          C. OCCURRENCE FREQUENCIES OF NUMBER OF CLOUD LAYERS.       CDATA     26
CCC                                                                     CDATA     27
CLJ   VARIABLES IN CDDATA COMMON                                        CDATA     28
CLJ          ALAMT(I) = WAVELENGTHS AT WHICH OPTICAL PROPERTIES ARE     CDATA     29
CLJ                     TABULATED, MICRONS                              CDATA     30
CLJ        SIGT(I,K) = TOTAL MICROSCOPIC EXTINCTION CROSS-SECTION AT    CDATA     31
CLJ                     WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K, MICRON**2 CDATA     32
CLJ        SIGS(I,K) = MICROSCOPIC SCATTERING CROSS-SECTION AT          CDATA     33
CLJ                     WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K, MICRON**2 CDATA     34
CLJ              W(I) = (NORMALIZED) CONTRIBUTION OF SPECULARLY-        CDATA     35
CLJ                     REFLECTED RADIATION TO SCATTERED RADIATION WITH CDATA     36
CLJ                     THE DIFFRACTED RADIATION CONTRIBUTING UNITY.    CDATA     37
CLJ                     USED ONLY FOR THE LARGE-PARTICLE-SIZE CLOUDS,   CDATA     38
CLJ                     TYPES 11 THROUGH 14.  (DIMENSIONLESS)           CDATA     39
CLJ      XMUBAR(I,K) = AVERAGE COSINE OF SCATTERING ANGLE AT            CDATA     40
CLJ                     WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K            CDATA     41
CLJ            DNO(K) = NUMBER DENSITY OF WATER DROPLETS IN             CDATA     42
CLJ                     CLOUD-TYPE K, 1/CM**3                           CDATA     43
CLJ            RAD(K) = MEAN RADIUS OF WATER DROPLETS IN                CDATA     44
CLJ                     CLOUD-TYPE K, MICRONS                           CDATA     45
CLJ       CLDBASE(K) = ALTITUDE ABOVE EARTH SURFACE OF BASE OF          CDATA     46
CLJ                     CLOUD-TYPE K, KM                                CDATA     47
CLJ        CLDTHK(K) = THICKNESS OF CLOUD-TYPE K, KM                    CDATA     48
CCC                                                                     CDATA     49
CLJ                 FOR ABOVE VARIABLES   I=1,10  AND  K=1,14           CDATA     50
CCC                                                                     CDATA     51
CLJ   VARIABLES IN CLDFREQ COMMON                                       CDATA     52
CLJ      KMODEL = INDEX (1,11) CHARACTERIZING A SET OF STATISTICAL      CDATA     53
CLJ               AVERAGES OF CLOUD-COVERAGE CATEGORIES, CLOUD TYPES,   CDATA     54
CLJ               AND NUMBER OF CLOUD LAYERS FOR A GIVEN GEOGRAPHIC     CDATA     55
CLJ               REGION.  CHARACTERIZES A SPECIFICATION OF             CDATA     56
CLJ               CCOVER(5,11) AND CFREQ(17,4,11) IN BLOCK DATA FOR     CDATA     57
```

```
CLJ                 KMODEL=1,10.  USER MUST SUPPLY HIS OWN DATA          CDATA
CLJ                 FOR KMODEL=11.                                       CDATA
CLJ        CCOVER(ICC,KMODEL) = FRACTIONAL OCCURRENCE FREQUENCY OF       CDATA
CLJ                             CLOUD-COVERAGE CATEGORY ICC FOR GIVEN    CDATA
CLJ                             KMODEL.  ICC=1,5  KMODEL=1,11            CDATA
CLJ           FOR  ICC=1,  CLOUD-COVERAGE FRACTION = 0.0                 CDATA
CLJ           FOR  ICC=2,  CLOUD-COVERAGE FRACTION = 0.3                 CDATA
CLJ           FOR  ICC=3,  CLOUD-COVERAGE FRACTION = 0.5                 CDATA
CLJ           FOR  ICC=4,  CLOUD-COVERAGE FRACTION = 0.8                 CDATA
CLJ           FOR  ICC=5,  CLOUD-COVERAGE FRACTION = 1.0                 CDATA
CCC                                                                      CDATA
CLJ              FOR  ICC-1=IC=2,5  AND  KMODEL=KM=1,11  WE HAVE         CDATA
CCC                                                                      CDATA
CLJ        CFREQ(K,IC,KM) = FRACTIONAL OCCURRENCE FREQUENCY OF           CDATA
CLJ                         CLOUD-TYPE K FOR GIVEN ICC AND KMODEL.       CDATA
CLJ          SUM( CFREQ(K,IC,KM), K=1,14) = 1.0                          CDATA
CCC                                                                      CDATA
CLJ               CFREQ(15,IC,KM) = FREQUENCY OF ONE LAYER               CDATA
CLJ               CFREQ(16,IC,KM) = FREQUENCY OF TWO LAYERS              CDATA
CLJ               CFREQ(17,IC,KM) = FREQUENCY OF THREE LAYERS            CDATA
CLJ          SUM( CFREQ(L,IC,KM), L=15,17) = 1.0                         CDATA
CCC                                                                      CDATA
CLJ      DATA FOR SIGT(I,K) AND SIGS(I,K) FOR K=11,12,13,14 ARE DUMMY    CDATA
CLJ      DATA SINCE THEY ARE OVERRIDDEN IN SUBROUTINES DIFFUS AND        CDATA
CLJ      DIFFRM BY USE OF THE SMALL-WAVELENGTH APPROXIMATION             CDATA
CLJ             SIGT(I,K) = 2.*PI*RAD(K)**2                              CDATA
CLJ             SIGS(I,K) = 0.5*(1.+W(I))*SIGT(I,K)                      CDATA
CLJ                                                                      CDATA
      DATA SIGT  /232.,210.,246.,318.,269.,224.,233.,224.,247.,325.,     CDATA
     U            469.,481.,469.,539.,536.,469.,483.,492.,492.,503.,     CDATA
     U            309.,282.,283.,438.,382.,307.,318.,334.,289.,394.,     CDATA
     U            151.,173.,200.,197.,167.,156.,160.,157.,205.,229.,     CDATA
     U            202.,213.,222.,255.,227.,202.,209.,218.,230.,257.,     CDATA
     U            232.,210.,246.,318.,269.,224.,233.,224.,247.,325.,     CDATA
     U            194.,188.,240.,254.,212.,186.,194.,161.,241.,292.,     CDATA
     U            170.,186.,232.,228.,191.,172.,178.,151.,234.,269.,     CDATA
     U            284.,217.,259.,389.,327.,262.,274.,271.,255.,379.,     CDATA
     U            698.,719.,789.,650.,742.,702.,719.,717.,814.,674.,     CDATA
     U            999.,999.,999.,999.,999.,999.,999.,999.,999.,999.,     CDATA
     U            999.,999.,999.,999.,999.,999.,999.,999.,999.,999.,     CDATA
     U            999.,999.,999.,999.,999.,999.,999.,999.,999.,999.,     CDATA
     U            999.,999.,999.,999.,999.,999.,999.,999.,999.,999./     CDATA
      DATA  W    /.061,.054,.052,.046,.036,.063,.091,.077,.069,.064/     CDATA
      DATA SIGS  /223.,202.,236.,306.,203.,109.,117.,186.,228.,292.,     CDATA
     V            444.,451.,438.,501.,360.,232.,246.,386.,435.,403.,     CDATA
     V            296.,267.,266.,419.,283.,149.,160.,275.,259.,342.,     CDATA
     V            146.,168.,195.,190.,127.,076.,079.,134.,194.,209.,     CDATA
     V            194.,204.,213.,243.,166.,099.,106.,187.,213.,225.,     CDATA
     V            223.,202.,236.,306.,203.,109.,117.,186.,228.,292.,     CDATA
     V            187.,182.,233.,246.,163.,090.,098.,133.,228.,270.,     CDATA
     V            164.,180.,225.,220.,146.,084.,089.,125.,222.,248.,     CDATA
     V            274.,206.,247.,374.,247.,126.,138.,223.,233.,338.,     CDATA
     V            655.,668.,734.,585.,457.,350.,368.,545.,719.,505.,     CDATA
     V            990.,990.,990.,990.,990.,990.,990.,990.,990.,990.,     CDATA
     V            990.,990.,990.,990.,990.,990.,990.,990.,990.,990.,     CDATA
     V            990.,990.,990.,990.,990.,990.,990.,990.,990.,990.,     CDATA
     V            990.,990.,990.,990.,990.,990.,990.,990.,990.,990./     CDATA
```

```
      DATA XMUBAR/.815,.809,.871,.959,.967,.952,.922,.733,.750,.842,
     W            .850,.846,.858,.938,.955,.962,.937,.830,.784,.793,
     W            .830,.805,.840,.955,.968,.957,.931,.796,.712,.817,
     W            .783,.846,.898,.956,.963,.945,.898,.705,.797,.852,
     W            .817,.839,.875,.951,.965,.951,.913,.756,.776,.826,
     W            .815,.809,.871,.958,.967,.952,.922,.733,.750,.842,
     W            .799,.825,.895,.959,.965,.948,.916,.646,.788,.858,
     W            .783,.838,.901,.958,.964,.947,.934,.641,.799,.859,
     W            .831,.779,.853,.958,.968,.954,.929,.757,.712,.838,
     W            .859,.861,.878,.918,.963,.964,.941,.850,.834,.779,
     W            .975,.979,.980,.984,.988,.977,.945,.963,.968,.973,
     W            .975,.979,.980,.984,.988,.977,.945,.963,.968,.973,
     W            .975,.979,.980,.984,.988,.977,.945,.963,.968,.973,
     W            .975,.979,.980,.984,.988,.977,.945,.963,.968,.973/
C        DATA FOR CLOUD STATISTICS
C
C
C
C        THE DRY CLIMATE IS TAKEN FROM THE NASA DATA BASE
C        FOR REGION 11 AND IS FOR THE NOTHERN U.S. AND WESTERN EUROPE
C
C        THE MOIST CLOMATE IS TAKEN AS REGION 4 AND IS
C        FOR THE SOUTH PACIFIC
C
C
C        1   DRY   ANNUAL    AVERAGE
C
C        2   DRY   WINTER    AVERAGE   NIGHT
C
C        3   DRY   WINTER    AVERAGE   DAY
C
C        4   DRY   SUMMER    AVERAGE   NIGHT
C
C        5   DRY   SUMMER    AVERAGE   DAY
C
C        6  MOIST  ANNUAL    AVERAGE
C
C        7  MOIST  WINTER    AVERAGE   NIGHT
C
C        8  MOIST  WINTER    AVERAGE   DAY
C
C        9  MOIST  SUMMER    AVERAGE   NIGHT
C
C        10 MOIST  SUMMER    AVERAGE   DAY
C
C        11   ARRAY FOR USER SUPPLIED DATA
C
C
      DATA (CCOVER(I,1),I=1,5) /
     X .235,.150,.070,.201,.343 /
      DATA (CFREQ(I,1, 1),I=1,68) /
     X .046,.046,.046,.102,.006,.005,.001,.217,.005,.005,.005,.005,.222,
     X .293,.768,.212,.019,.055,.055,.055,.121,.006,.008,.001,.243,.009,
     X .008,.008,.009,.164,.260,.542,.377,.081,.038,.038,.038,.169,.015,
     X .010,.000,.276,.012,.010,.010,.012,.104,.266,.415,.435,.150,.010,
     X .010,.010,.336,.155,.010,.030,.197,.023,.010,.010,.023,.017,.158,
     X .448,.423,.128/
```

```
      DATA (CCOVER(I,2),I=1,5) /                                        CDATA
     X .306,.123,.048,.127,.396 /                                       CDATA
      DATA (CFREQ(I,1, 2),I=1,68) /                                     CDATA
     X .004,.004,.004,.173,.011,.001,.001,.234,.008,.001,.001,.008,.225, CDATA
     X .331,.895,.105,.001,.006,.006,.006,.203,.004,.004,.001,.302,.012, CDATA
     X .004,.004,.012,.132,.306,.640,.335,.025,.003,.003,.003,.278,.028, CDATA
     X .005,.001,.299,.016,.005,.005,.016,.045,.295,.620,.331,.049,.002, CDATA
     X .002,.002,.407,.226,.004,.046,.154,.019,.004,.004,.019,.007,.108, CDATA
     X .606,.349,.045/                                                  CDATA
      DATA (CCOVER(I,3),I=1,5) /                                        CDATA
     X .213,.128,.052,.179,.428 /                                       CDATA
      DATA (CFREQ(I,1, 3),I=1,68) /                                     CDATA
     X .028,.028,.028,.149,.006,.001,.001,.213,.003,.001,.001,.003,.239, CDATA
     X .302,.798,.185,.017,.036,.036,.036,.195,.015,.001,.001,.232,.006, CDATA
     X .001,.001,.006,.192,.247,.564,.367,.069,.017,.017,.017,.245,.022, CDATA
     X .001,.001,.287,.011,.001,.001,.011,.105,.262,.463,.416,.121,.004, CDATA
     X .004,.004,.395,.213,.002,.035,.162,.019,.002,.002,.019,.017,.122, CDATA
     X .496,.399,.105/                                                  CDATA
      DATA (CCOVER(I,4),I=1,5) /                                        CDATA
     X .296,.182,.084,.197,.241 /                                       CDATA
      DATA (CFREQ(I,1, 4),I=1,68) /                                     CDATA
     X .035,.035,.035,.073,.002,.010,.001,.232,.006,.010,.010,.006,.220, CDATA
     X .327,.758,.226,.016,.032,.032,.032,.091,.002,.016,.001,.298,.009, CDATA
     X .016,.016,.009,.146,.302,.526,.377,.096,.022,.022,.022,.124,.012, CDATA
     X .019,.001,.299,.019,.019,.019,.010,.097,.307,.409,.450,.140,.008, CDATA
     X .008,.008,.260,.095,.027,.022,.238,.036,.027,.027,.036,.016,.191, CDATA
     X .370,.498,.132/                                                  CDATA
      DATA (CCOVER(I,5),I=1,5) /                                        CDATA
     X .128,.164,.096,.299,.313 /                                       CDATA
      DATA (CFREQ(I,1, 5),I=1,68) /                                     CDATA
     X .092,.092,.092,.059,.006,.005,.001,.196,.004,.005,.005,.004,.210, CDATA
     X .230,.667,.296,.038,.104,.104,.104,.077,.006,.008,.001,.177,.008, CDATA
     X .008,.008,.008,.178,.211,.496,.403,.101,.069,.069,.069,.124,.010, CDATA
     X .011,.001,.250,.007,.011,.011,.007,.126,.235,.308,.478,.214,.027, CDATA
     X .027,.027,.265,.074,.011,.015,.243,.021,.011,.011,.021,.029,.218, CDATA
     X .254,.489,.257/                                                  CDATA
      DATA (CCOVER(I,6),I=1,5) /                                        CDATA
     X .181,.220,.124,.263,.212 /                                       CDATA
      DATA (CFREQ(I,1, 6),I=1,68) /                                     CDATA
     X .083,.083,.083,.111,.022,.012,.001,.089,.003,.012,.012,.003,.305, CDATA
     X .181,.715,.270,.014,.072,.072,.072,.117,.029,.026,.001,.137,.004, CDATA
     X .026,.026,.004,.252,.165,.383,.520,.097,.049,.049,.049,.126,.033, CDATA
     X .034,.001,.187,.007,.034,.034,.007,.181,.209,.246,.517,.237,.028, CDATA
     X .028,.028,.211,.135,.027,.017,.173,.026,.027,.027,.026,.055,.194, CDATA
     X .275,.461,.265/                                                  CDATA
      DATA (CCOVER(I,7),I=1,5) /                                        CDATA
     X .321,.200,.085,.184,.210 /                                       CDATA
      DATA (CFREQ(I,1, 7),I=1,68) /                                     CDATA
     X .028,.028,.028,.192,.025,.002,.001,.122,.007,.002,.002,.007,.312, CDATA
     X .245,.866,.130,.004,.023,.023,.023,.244,.050,.004,.001,.198,.006, CDATA
     X .004,.004,.006,.190,.224,.657,.302,.041,.016,.016,.016,.253,.060, CDATA
     X .004,.001,.241,.010,.004,.004,.010,.085,.283,.488,.420,.092,.007, CDATA
     X .007,.007,.323,.230,.011,.030,.153,.032,.011,.011,.032,.011,.135, CDATA
     X .428,.459,.114/                                                  CDATA
      DATA (CCOVER(I,8),I=1,5) /                                        CDATA
     X .150,.237,.124,.251,.238 /                                       CDATA
      DATA (CFREQ(I,1, 8),I=1,68) /                                     CDATA
```

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     X .094,.094,.094,.128,.027,.003,.001,.104,.003,.003,.003,.003,.282, CDATA
     X .161,.737,.249,.014,.078,.078,.078,.151,.034,.004,.001,.176,.005, CDATA
     X .004,.004,.005,.197,.187,.436,.474,.091,.051,.051,.051,.187,.041, CDATA
     X .007,.001,.225,.008,.007,.007,.008,.135,.220,.289,.506,.206,.020, CDATA
     X .020,.020,.285,.197,.007,.020,.156,.031,.007,.007,.031,.025,.171, CDATA
     X .347,.456,.197/                                                  CDATA
      DATA (CCOVER(I,9),I=1,5) /                                        CDATA
     X .197,.232,.118,.256,.197 /                                       CDATA
      DATA (CFREQ(I,1, 9),I=1,68) /                                     CDATA
     X .055,.055,.055,.110,.022,.017,.001,.074,.003,.017,.017,.003,.332, CDATA
     X .240,.721,.269,.010,.050,.050,.050,.145,.029,.025,.001,.142,.005, CDATA
     X .025,.025,.005,.248,.200,.355,.533,.112,.043,.043,.043,.112,.023, CDATA
     X .039,.002,.182,.008,.039,.039,.008,.202,.218,.233,.522,.245,.031, CDATA
     X .031,.031,.154,.065,.041,.011,.196,.025,.041,.041,.025,.089,.221, CDATA
     X .190,.456,.354/                                                  CDATA
      DATA (CCOVER(I,10),I=1,5) /                                       CDATA
     X .057,.212,.167,.360,.204 /                                       CDATA
      DATA (CFREQ(I,1,10),I=1,68) /                                     CDATA
     X .136,.136,.136,.038,.016,.025,.001,.067,.000,.025,.025,.000,.297, CDATA
     X .098,.546,.424,.030,.100,.100,.100,.031,.019,.048,.001,.087,.001, CDATA
     X .048,.048,.001,.311,.106,.227,.654,.119,.065,.065,.065,.052,.025, CDATA
     X .058,.000,.149,.004,.058,.058,.004,.229,.169,.105,.569,.326,.046, CDATA
     X .046,.046,.114,.073,.044,.010,.181,.018,.044,.044,.018,.084,.232, CDATA
     X .120,.472,.408/                                                  CDATA
      DATA (CCOVER(I,11),I=1,5) /   5*0. /                              CDATA
      DATA (CFREQ(I,1,11),I=1,68) /  68*0. /                            CDATA
      END                                                               CDATA
```

```
      FUNCTION CFLOSF(ICC,ANGLE)                                        CFLOS
      DIMENSION CFLOST(11,10),ANGT(10)                                  CFLOS
C                                                                       CFLOS
COMMENT  THE ITH COL IS THE CLOUD COVERAGE CAT IN 10THS                 CFLOS
C        THE ROW IS ELEVATION ANGLE IN DEGREES                          CFLOS
C                                                                       CFLOS
CCC                                                                     CFLOS
CLJ   FUNCTION CFLOSF COMPUTES THE PROBABILITY OF A CLOUD-FREE          CFLOS
CLJ   LINE-OF-SIGHT (CFLOS) AS A FUNCTION OF THE CLOUD-COVERAGE AND     CFLOS
CLJ   ZENITH ANGLE OF THE LOS FROM THE GROUND.                          CFLOS
CCC                                                                     CFLOS
CLJ   INPUT PARAMETERS                                                  CFLOS
CLJ      ARGUMENT LIST                                                  CFLOS
CLJ          ICC-1 = CLOUD COVERAGE IN TENTHS, 0(1)10                   CFLOS
CLJ          ANGLE = ZENITH ANGLE OF LOS FROM EARTH'S SURFACE, DEGREES  CFLOS
CLJ   OUTPUT PARAMETER                                                  CFLOS
CLJ      FUNCTION                                                       CFLOS
CLJ         CFLOSF = PROBABILITY OF CFLOS FOR GIVEN INPUT PARAMETERS    CFLOS
CLJ   DEFINITION OF DATA                                                CFLOS
CLJ                ANGT(IA) = ZENITH ANGLE OF ((IA-1)*10)-DEGREES       CFLOS
CLJ          CFLOST(ICC,IA) = PROBABILITY OF CFLOS FOR CLOUD-COVERAGE   CFLOS
CLJ                           OF (ICC-1)-TENTHS AND ZENITH ANGLE OF     CFLOS
CLJ                           ((IA-1)*10)-DEGREES                       CFLOS
CLJ                 IA  = 1,10  ROW                                     CFLOS
CLJ                 ICC = 1,11  COLUMN                                  CFLOS
CCC                                                                     CFLOS
CLJ   THE TABULAR DATA (EXCEPT FOR THE BOTTOM ROW) ARE FROM LUND AND    CFLOS
CLJ   SHANKLIN (LS-73, TABLE 3), A CASE FOR WHICH ALL CLOUD TYPES ARE   CFLOS
CLJ   INCLUDED IN THE DATA SAMPLE.  WE OBTAINED THE BOTTOM-ROW VALUES   CFLOS
CLJ   AT 90-DEGREE ZENITH ANGLE BY EXTRAPOLATION.                       CFLOS
CCC                                                                     CFLOS
      DATA ANGT /0.,10.,20.,30.,40.,50.,60.,70.,80.,90. /               CFLOS
      DATA CFLOST/                                                      CFLOS
     X       .99, .97, .92, .87, .81, .77, .70, .62, .48, .31, .08      CFLOS
     X     , .99, .97, .92, .87, .81, .77, .69, .61, .47, .31, .08      CFLOS
     X     , .99, .97, .91, .86, .80, .76, .68, .61, .47, .30, .08      CFLOS
     X     , .99, .96, .90, .85, .80, .75, .66, .60, .46, .29, .08      CFLOS
     X     , .99, .96, .90, .85, .78, .73, .64, .58, .45, .29, .08      CFLOS
     X     , .99, .95, .88, .83, .76, .71, .62, .55, .42, .27, .07      CFLOS
     X     , .98, .93, .86, .80, .73, .66, .57, .50, .38, .24, .06      CFLOS
     X     , .98, .90, .83, .75, .67, .59, .50, .42, .33, .21, .05      CFLOS
     X     , .97, .86, .76, .65, .55, .47, .39, .32, .24, .16, .03      CFLOS
     X     , .94, .79, .66, .52, .40, .32, .27, .21, .14, .08, .00      CFLOS
     X   /                                                              CFLOS
CLJ                                                                     CFLOS
      IF( (ANGLE.LT.0.0) .OR. (ANGLE.GT.90.) )  WRITE(6,101)  ANGLE     CFLOS
  101 FORMAT (32H0  *** WARNING FROM CFLOSF ***  ,5X,8H ANGLE =,F8.3,   CFLOS
     $ 56H   AND IS NOT WITHIN THE TABULAR VALUES OF ZENITH ANGLE.)     CFLOS
CLJ                                                                     CFLOS
      DO 10 I = 2,10                                                    CFLOS
      IA = I - 1                                                        CFLOS
      IF(ANGLE .LT. ANGT(I)) GO TO 20                                   CFLOS
   10 CONTINUE                                                          CFLOS
      IA = 9                                                            CFLOS
   20 CONTINUE                                                          CFLOS
      CFLOSF = CFLOST(ICC,IA) + (CFLOST(ICC,IA+1) - CFLOST(ICC,IA))     CFLOS
     X   *( ANGLE - ANGT(IA)) / (ANGT(IA+1) - ANGT(IA))                 CFLOS
      RETURN                                                            CFLOS
      END                                                               CFLOS
```

```
      FUNCTION CLDBDR(CTHIN,CTHOUT,CPHOUT,ALAM,KCLOUD)                  CLDBDR   2
C                                                                       CLDBDR   3
C        ENTRIES IN THE FOLLOWING TABLES ARE BI-DIRECTIONAL             CLDBDR   4
C        REFLECTANCES FOR A STRATOCUMULUS CLOUD AT THE ANGLES AND       CLDBDR   5
C        WAVELENGTH IN THE ASSOCIATED TABLES                            CLDBDR   6
C                                                                       CLDBDR   7
CCC                                                                     CLDBDR   8
CLJ   FUNCTION CLDBDR PROVIDES THE BIDIRECTIONAL REFLECTANCE (1/SR) OF  CLDBDR   9
CLJ   A PLANE, SEMI-INFINITE STRATOCUMULUS (KCLOUD=4) CLOUD FOR A       CLDBDR  10
CLJ   PHOTON OF WAVELENGTH ALAM INCIDENT AT ZENITH ANGLE THIN=          CLDBDR  11
CLJ   ACOS(CTHIN) AND REFLECTED AT ZENITH ANGLE THOUT=ACOS(CTHOUT) AND  CLDBDR  12
CLJ   AZIMUTH ANGLE PHIOUT=ACOS(CPHIOUT).                               CLDBDR  13
CCC                                                                     CLDBDR  14
CLJ   INPUT PARAMETERS                                                  CLDBDR  15
CLJ      ARGUMENT LIST                                                  CLDBDR  16
CLJ            CTHIN = COSINE OF ZENITH ANGLE OF INCIDENT RAY           CLDBDR  17
CLJ           CTHOUT = COSINE OF ZENITH ANGLE OF EXIT RAY               CLDBDR  18
CLJ           CPHOUT = COSINE OF AZIMUTHAL ANGLE OF EXIT RAY            CLDBDR  19
CLJ             ALAM = WAVELENGTH, MICRONS                              CLDBDR  20
CLJ           KCLOUD = INDEX OF CLOUD TYPE (1 TO 14) NOT CURRENTLY      CLDBDR  21
CLJ                    ( 2/22/78) USED.  DATA FOR ONLY ONE CLOUD TYPE   CLDBDR  22
CLJ                    (STRATOCUMULUS, FOR WHICH KCLOUD=4) ARE INCLUDED. CLDBDR  23
CLJ   OUTPUT PARAMETER                                                  CLDBDR  24
CLJ      FUNCTION                                                       CLDBDR  25
CLJ           CLDBDR = BIDIRECTIONAL REFLECTANCE,  1/SR                 CLDBDR  26
CLJ   DEFINITION OF DATA                                                CLDBDR  27
CLJ      RFL"N"(J,K,I) = BIDIRECTIONAL REFLECTANCE OF A PLANE,          CLDBDR  28
CLJ                      SEMI-INFINITE STRATOCUMULUS (KCLOUD=4) CLOUD   CLDBDR  29
CLJ                      FOR A PHOTON OF WAVELENGTH ALAMT(N) INCIDENT   CLDBDR  30
CLJ                      AT ZENITH ANGLE THIN(I) = ACOS(TCTIN(I)) AND   CLDBDR  31
CLJ                      REFLECTED AT ZENITH ANGLE THOUT(J)=            CLDBDR  32
CLJ                      ACOS( TCTHOUT(J) ) AND                         CLDBDR  33
CLJ                      AZIMUTH ANGLE PHOUT(K) = ACOS(TCPHOUT(K)).     CLDBDR  34
CCC                                                                     CLDBDR  35
CLJ                 WHERE  N=1,10,  J=1,5,  K=1,9, AND I=1,4            CLDBDR  36
CCC                                                                     CLDBDR  37
CLJ                      THE DATA WERE GENERATED BY THE SAI/PALO ALTO   CLDBDR  38
CLJ                      MONTE CARLO IR CODE FOR INCIDENT ZENITH ANGLES CLDBDR  39
CLJ                      OF 0,30,60, AND 80 DEGREES (FOR WHICH COSINES  CLDBDR  40
CLJ                      1.0,0.866,0.5, AND 0.1736).                    CLDBDR  41
CLJ                      TO GENERATE INCIDENT ZENITH-ANGLE              CLDBDR  42
CLJ                      BIN-BOUNDARIES FOR CURRENT APPLICATIONS, WE    CLDBDR  43
CLJ                      SELECT THE MIDPOINT VALUES OF THE COSINES      CLDBDR  44
CLJ                      USED IN THE MONTE CARLO CALCULATION, RESULTING CLDBDR  45
CLJ                      IN ANGLES OF 0.0, 21.09, 46.92, 70.32, AND     CLDBDR  46
CLJ                      90.0 DEGREES.                                  CLDBDR  47
CLJ                      THE COSINES OF THE EXIT ZENITH-ANGLE           CLDBDR  48
CLJ                      BIN-BOUNDARIES ARE 1.0(0.2)0.0 OR ZENITH       CLDBDR  49
CLJ                      ANGLES OF 0.0, 36.87, 53.13, 66.42, 78.46,     CLDBDR  50
CLJ                      AND 90.0 DEGREES.  THE EXIT                    CLDBDR  51
CLJ                      AZIMUTH-ANGLE BIN-BOUNDARIES ARE 0(20)180      CLDBDR  52
CLJ                      DEGREES.  THE ORIGINALLY-RECORDED MONTE CARLO  CLDBDR  53
CLJ                      RESULTS FOR THE NUMBER OF PHOTONS PER BIN WERE CLDBDR  54
CLJ                      DIVIDED BY THE SOLID ANGLE OF THE BIN AND THE  CLDBDR  55
CLJ                      COSINE OF THE EXIT ZENITH ANGLE.               CLDBDR  56
CCC                                                                     CLDBDR  57
      DIMENSION TCPHOUT(9),TCTHOUT(5),TCTHIN(4)                         CLDBDR  58
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      DIMENSION RFL1( 5,9,4),RFL2( 5,9,4),RFL3( 5,9,4),RFL4( 5,9,4)      CLDBDR     59
      DIMENSION RFL5( 5,9,4),RFL6( 5,9,4),RFL7( 5,9,4),RFL8( 5,9,4)      CLDBDR     60
      DIMENSION RFL9( 5,9,4),RFL10(5,9,4)                                CLDBDR     61
      COMMON/CDDATA/ ALAMT(10),SIGT(10,14),SIGS(10,14),W(10),            CDDATA      2
     1  XMUBAR(10,14),DNO(14),RAD(14),CLDBASE(14),CLDTHK(14)             CDDATA      3
      DATA TCTHIN / 0.933,0.683,0.337, 0.  /                             CLDBDR     63
      DATA TCPHOUT / -0.9397,-0.766,-0.5,-0.1736,0.1736,0.5,             CLDBDR     64
     X   .7660,.9397,1.0 /                                               CLDBDR     65
      DATA TCTHOUT / 0.8,0.6,0.4,0.2,0.0 /                               CLDBDR     66
CLJ                                                                      CLDBDR     67
CLJ                                                                      CLDBDR     68
CLJ                EXIT ZENITH-ANGLE BINS AND THEIR COSINES             CLDBDR     69
CLJ   ----------------------------------------------------------------  CLDBDR     70
CLJ        1       2       3       4       5          EXIT ZENITH BIN NO. CLDBDR     71
CLJ   0.00   36.87   53.13   66.42   78.46   90.00  EXIT ZENITH ANGLE   CLDBDR     72
CLJ   1.00    0.80    0.60    0.40    0.20    0.00  EXIT ZENITH COSINE  CLDBDR     73
CLJ                                                                      CLDBDR     74
CLJ       AZIMUTH ANGLE BINS                                             CLDBDR     75
CLJ       ------------------                                             CLDBDR     76
CLJ            160-180                                                   CLDBDR     77
CLJ            140-160                                                   CLDBDR     78
CLJ            120-140                                                   CLDBDR     79
CLJ            100-120                                                   CLDBDR     80
CLJ             80-100                                                   CLDBDR     81
CLJ             60- 80                                                   CLDBDR     82
CLJ             40- 60                                                   CLDBDR     83
CLJ             20- 40                                                   CLDBDR     84
CLJ              0- 20                                                   CLDBDR     85
CLJ                                                                      CLDBDR     86
CLJ                                                                      CLDBDR     87
C     DATA KPN,XLAM,WZERO/  420, 2.00, 1.00000E+00/                      CLDBDR     88
      DATA(RFL1(I,1,1),I=1,45)                                           CLDBDR     89
     X / 8.0183E-02 , 7.7606E-02 , 7.0873E-02 , 5.8618E-02 , 5.0204E-02, CLDBDR     90
     X   7.3561E-02 , 7.4827E-02 , 7.0089E-02 , 5.6753E-02 , 4.3310E-02, CLDBDR     91
     X   8.9787E-02 , 8.0147E-02 , 6.8212E-02 , 5.3634E-02 , 4.5461E-02, CLDBDR     92
     X   7.8864E-02 , 7.5420E-02 , 7.0664E-02 , 6.4422E-02 , 7.0314E-02, CLDBDR     93
     X   8.4760E-02 , 8.2725E-02 , 7.4955E-02 , 5.9629E-02 , 4.6133E-02, CLDBDR     94
     X   7.7259E-02 , 7.8899E-02 , 8.3598E-02 , 9.6162E-02 , 1.6524E-01, CLDBDR     95
     X   8.5633E-02 , 9.9457E-02 , 1.0188E-01 , 8.3087E-02 , 5.4070E-02, CLDBDR     96
     X   8.8204E-02 , 7.9470E-02 , 7.1003E-02 , 6.3169E-02 , 7.0499E-02, CLDBDR     97
     X   7.7388E-02 , 8.5621E-02 , 8.6023E-02 , 7.2751E-02 , 5.4949E-02/ CLDBDR     98
C     DATA KPN,XLAM,WZERO/  420, 2.00, 8.66000E-01/                      CLDBDR     99
      DATA(RFL1(I,1,2),I=1,45)                                           CLDBDR    100
     X / 1.0886E-01 , 1.1597E-01 , 1.1345E-01 , 9.5432E-02 , 7.4834E-02, CLDBDR    101
     X   1.1423E-01 , 1.2180E-01 , 1.2054E-01 , 1.0468E-01 , 8.8306E-02, CLDBDR    102
     X   1.1755E-01 , 1.1679E-01 , 1.0687E-01 , 8.4575E-02 , 6.3128E-02, CLDBDR    103
     X   1.0420E-01 , 1.1626E-01 , 1.1860E-01 , 1.0319E-01 , 8.2334E-02, CLDBDR    104
     X   1.0768E-01 , 1.1415E-01 , 1.1220E-01 , 9.6594E-02 , 8.0478E-02, CLDBDR    105
     X   1.0843E-01 , 1.0430E-01 , 9.6947E-02 , 8.5427E-02 , 8.5490E-02, CLDBDR    106
     X   1.0715E-01 , 1.0204E-01 , 9.7342E-02 , 9.4312E-02 , 1.1929E-01, CLDBDR    107
     X   9.5653E-02 , 1.0515E-01 , 1.1120E-01 , 1.1054E-01 , 1.2766E-01, CLDBDR    108
     X   9.7681E-02 , 1.0920E-01 , 1.1618E-01 , 1.1379E-01 , 1.1930E-01/ CLDBDR    109
C     DATA KPN,XLAM,WZERO/  420, 2.00, 5.00000E-01/                      CLDBDR    110
      DATA(RFL1(I,1,3),I=1,45)                                           CLDBDR    111
     X / 9.8035E-02 , 1.3408E-01 , 1.6575E-01 , 1.7096E-01 , 1.5468E-01, CLDBDR    112
     X   1.0831E-01 , 1.3218E-01 , 1.4879E-01 , 1.4523E-01 , 1.3444E-01, CLDBDR    113
     X   1.0799E-01 , 1.2610E-01 , 1.3620E-01 , 1.2823E-01 , 1.1572E-01, CLDBDR    114
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     X   9.6639E-02 , 1.1830E-01 , 1.3360E-01 , 1.3091E-01 , 1.2179E-01, CLDBDR
     X   1.0559E-01 , 1.2558E-01 , 1.3851E-01 , 1.3389E-01 , 1.2538E-01, CLDBDR
     X   9.6630E-02 , 1.2188E-01 , 1.4431E-01 , 1.5323E-01 , 1.6513E-01, CLDBDR
     X   1.0342E-01 , 1.4198E-01 , 1.8309E-01 , 2.1201E-01 , 2.4983E-01, CLDBDR
     X   1.0525E-01 , 1.5226E-01 , 2.1115E-01 , 2.7332E-01 , 3.8946E-01, CLDBDR
     X   9.7656E-02 , 1.5791E-01 , 2.4487E-01 , 3.5475E-01 , 5.6659E-01/ CLDBDR
C     DATA KPN,XLAM,WZERO/  420, 2.00, 1.73600E-01/                      CLDBDR
      DATA(RFL1(I,1,4),I=1,45)                                           CLDBDR
     X / 8.8371E-02 , 1.1898E-01 , 1.6013E-01 , 2.1793E-01 , 3.8377E-01, CLDBDR
     X   7.6074E-02 , 1.1333E-01 , 1.5625E-01 , 1.8800E-01 , 2.1734E-01, CLDBDR
     X   8.5090E-02 , 1.1552E-01 , 1.4847E-01 , 1.7389E-01 , 2.1357E-01, CLDBDR
     X   7.3286E-02 , 9.3107E-02 , 1.1341E-01 , 1.2897E-01 , 1.6150E-01, CLDBDR
     X   7.4517E-02 , 1.0633E-01 , 1.4107E-01 , 1.6475E-01 , 1.8816E-01, CLDBDR
     X   7.8939E-02 , 1.2188E-01 , 1.7802E-01 , 2.3662E-01 , 3.2885E-01, CLDBDR
     X   8.9686E-02 , 1.5592E-01 , 2.5798E-01 , 3.9300E-01 , 6.4094E-01, CLDBDR
     X   9.3658E-02 , 1.9538E-01 , 3.8712E-01 , 7.0346E-01 , 1.3578E+00, CLDBDR
     X   1.0526E-01 , 2.3634E-01 , 5.1294E-01 , 1.0559E+00 , 2.4709E+00/ CLDBDR
C     DATA KPN,XLAM,WZERO/  425, 2.50, 1.00000E+00/                      CLDBDR
      DATA(RFL2(I,1,1),I=1,45)                                           CLDBDR
     X / 5.3727E-02 , 6.1630E-02 , 6.4746E-02 , 5.8192E-02 , 4.8267E-02, CLDBDR
     X   7.0241E-02 , 7.9019E-02 , 8.0958E-02 , 7.0207E-02 , 5.4988E-02, CLDBDR
     X   7.4191E-02 , 9.9237E-02 , 1.1306E-01 , 9.5938E-02 , 5.6776E-02, CLDBDR
     X   1.0199E-01 , 1.0267E-01 , 1.1479E-01 , 1.5868E-01 , 4.2624E-01, CLDBDR
     X   8.6436E-02 , 7.1816E-02 , 7.1367E-02 , 1.0100E-01 , 3.6964E-01, CLDBDR
     X   6.6220E-02 , 6.7968E-02 , 6.5901E-02 , 5.7996E-02 , 5.3084E-02, CLDBDR
     X   7.9669E-02 , 8.3811E-02 , 8.1954E-02 , 7.0528E-02 , 5.9312E-02, CLDBDR
     X   8.0562E-02 , 9.8494E-02 , 1.0504E-01 , 8.7339E-02 , 5.5538E-02, CLDBDR
     X   8.4083E-02 , 8.4396E-02 , 7.7552E-02 , 6.0925E-02 , 4.4109E-02/ CLDBDR
C     DATA KPN,XLAM,WZERO/  425, 2.50, 8.66000E-01/                      , CLDBDR
      DATA(RFL2(I,1,2),I=1,45)                                           CLDBDR
     X / 8.2263E-02 , 8.7706E-02 , 8.6131E-02 , 7.3159E-02 , 5.8628E-02, CLDBDR
     X   8.8715E-02 , 9.2875E-02 , 9.0141E-02 , 7.6615E-02 , 6.3000E-02, CLDBDR
     X   7.8992E-02 , 8.3588E-02 , 8.4315E-02 , 7.8537E-02 , 7.8790E-02, CLDBDR
     X   7.9467E-02 , 8.7295E-02 , 8.8160E-02 , 7.6728E-02 , 6.2545E-02, CLDBDR
     X   7.9952E-02 , 9.2947E-02 , 9.7663E-02 , 8.5611E-02 , 6.5820E-02, CLDBDR
     X   8.6310E-02 , 9.7049E-02 , 1.0191E-01 , 9.5043E-02 , 8.8214E-02, CLDBDR
     X   8.6138E-02 , 1.0412E-01 , 1.1298E-01 , 1.0095E-01 , 7.7064E-02, CLDBDR
     X   1.0002E-01 , 1.0984E-01 , 1.1135E-01 , 9.8033E-02 , 8.2113E-02, CLDBDR
     X   1.3301E-01 , 1.2562E-01 , 1.1543E-01 , 1.0182E-01 , 1.0465E-01/ CLDBDR
C     DATA KPN,XLAM,WZERO/  425, 2.50, 5.00000E-01/                      , CLDBDR
      DATA(RFL2(I,1,3),I=1,45)                                           CLDBDR
     X / 7.7234E-02 , 9.7073E-02 , 1.0976E-01 , 1.0261E-01 , 8.2614E-02, CLDBDR
     X   1.0562E-01 , 1.1630E-01 , 1.1863E-01 , 1.0770E-01 , 9.7784E-02, CLDBDR
     X   9.9455E-02 , 1.0835E-01 , 1.1120E-01 , 1.0304E-01 , 9.8264E-02, CLDBDR
     X   8.7188E-02 , 1.0490E-01 , 1.1519E-01 , 1.0750E-01 , 9.1368E-02, CLDBDR
     X   1.0139E-01 , 1.2075E-01 , 1.3098E-01 , 1.2027E-01 , 9.9773E-02, CLDBDR
     X   9.5764E-02 , 1.1661E-01 , 1.3587E-01 , 1.4730E-01 , 1.7458E-01, CLDBDR
     X   9.5993E-02 , 1.3746E-01 , 1.8236E-01 , 2.1158E-01 , 2.3687E-01, CLDBDR
     X   1.0420E-01 , 1.5515E-01 , 2.2161E-01 , 2.9586E-01 , 4.3593E-01, CLDBDR
     X   9.7049E-02 , 1.6485E-01 , 2.6470E-01 , 3.8630E-01 , 5.8798E-01/ CLDBDR
C     DATA KPN,XLAM,WZERO/  425, 2.50, 1.73600E-01/                      CLDBDR
      DATA(RFL2(I,1,4),I=1,45)                                           CLDBDR
     X / 6.6116E-02 , 8.1417E-02 , 9.7471E-02 , 1.1189E-01 , 1.4927E-01, CLDBDR
     X   6.5009E-02 , 8.2617E-02 , 9.8767E-02 , 1.0631E-01 , 1.1712E-01, CLDBDR
     X   6.7225E-02 , 8.3578E-02 , 9.9654E-02 , 1.1100E-01 , 1.3633E-01, CLDBDR
     X   7.4215E-02 , 9.1721E-02 , 1.0756E-01 , 1.1547E-01 , 1.3118E-01, CLDBDR
     X   8.2809E-02 , 1.0224E-01 , 1.2230E-01 , 1.3935E-01 , 1.8206E-01, CLDBDR
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     X   8.1586E-02 , 1.1835E-01 , 1.6309E-01 , 2.0617E-01 , 2.7698E-01, CLDBDR
     X   8.7018E-02 , 1.4830E-01 , 2.4356E-01 , 3.7714E-01 , 6.5601E-01, CLDBDR
     X   9.0367E-02 , 1.9329E-01 , 3.9618E-01 , 7.5734E-01 , 1.5910E+00, CLDBDR
     X   9.6798E-02 , 2.3813E-01 , 5.7311E-01 , 1.3384E+00 , 3.7215E+00/ CLDBDR
C     DATA KPN,XLAM,WZERO/  425, 2.55, 1.00000E+00/                      CLDBDR
      DATA(RFL3(I,1,1),I=1,45)                                           CLDBDR
     X / 5.3080E-02 , 5.6633E-02 , 5.5481E-02 , 4.6728E-02 , 3.6680E-02, CLDBDR
     X   5.1942E-02 , 5.5347E-02 , 5.3626E-02 , 4.3847E-02 , 3.2184E-02, CLDBDR
     X   4.2704E-02 , 4.5964E-02 , 4.6054E-02 , 4.0727E-02 , 3.5398E-02, CLDBDR
     X   4.1380E-02 , 4.7951E-02 , 5.1247E-02 , 4.7488E-02 , 4.1724E-02, CLDBDR
     X   4.9008E-02 , 5.9867E-02 , 6.5271E-02 , 5.7953E-02 , 4.2984E-02, CLDBDR
     X   4.6718E-02 , 5.8984E-02 , 6.4441E-02 , 5.4046E-02 , 3.3602E-02, CLDBDR
     X   5.1907E-02 , 5.7727E-02 , 5.8520E-02 , 5.0300E-02 , 3.9182E-02, CLDBDR
     X   5.3280E-02 , 5.3948E-02 , 5.1621E-02 , 4.4863E-02 , 4.0610E-02, CLDBDR
     X   6.6145E-02 , 6.5463E-02 , 5.9458E-02 , 4.6381E-02 , 3.3653E-02/ CLDBDR
C     DATA KPN,XLAM,WZERO/  425, 2.55, 8.66000E-01/                      CLDBDR
      DATA(RFL3(I,1,2),I=1,45)                                           CLDBDR
     X / 5.3116E-02 , 6.0725E-02 , 6.2799E-02 , 5.4263E-02 , 4.1250E-02, CLDBDR
     X   6.2341E-02 , 6.8552E-02 , 6.8937E-02 , 5.9144E-02 , 4.6567E-02, CLDBDR
     X   6.2054E-02 , 6.9266E-02 , 7.0409E-02 , 6.0571E-02 , 4.7049E-02, CLDBDR
     X   5.5733E-02 , 6.6122E-02 , 7.0300E-02 , 6.1344E-02 , 4.5423E-02, CLDBDR
     X   7.4886E-02 , 8.1302E-02 , 8.1426E-02 , 7.0738E-02 , 5.8321E-02, CLDBDR
     X   7.5930E-02 , 8.6479E-02 , 8.8884E-02 , 7.5986E-02 , 5.6630E-02, CLDBDR
     X   7.1444E-02 , 8.3095E-02 , 8.8617E-02 , 8.1038E-02 , 6.8708E-02, CLDBDR
     X   7.9813E-02 , 8.7759E-02 , 9.1947E-02 , 8.8896E-02 , 9.2430E-02, CLDBDR
     X   6.9786E-02 , 8.7299E-02 , 9.9263E-02 , 9.5180E-02 , 8.1806E-02/ CLDBDR
C     DATA KPN,XLAM,WZERO/  425, 2.55, 5.00000E-01/                      CLDBDR
      DATA(RFL3(I,1,3),I=1,45)                                           CLDBDR
     X / 5.9895E-02 , 7.1368E-02 , 7.8590E-02 , 7.5331E-02 , 6.9010E-02, CLDBDR
     X   6.7293E-02 , 7.4836E-02 , 7.8167E-02 , 7.3294E-02 , 6.9907E-02, CLDBDR
     X   6.5089E-02 , 7.7425E-02 , 8.5385E-02 , 8.2462E-02 , 7.7048E-02, CLDBDR
     X   6.7841E-02 , 8.1656E-02 , 9.0735E-02 , 8.7587E-02 , 8.0476E-02, CLDBDR
     X   7.9548E-02 , 9.9686E-02 , 1.1445E-01 , 1.1251E-01 , 1.0224E-01, CLDBDR
     X   7.6502E-02 , 1.0476E-01 , 1.2959E-01 , 1.3360E-01 , 1.2054E-01, CLDBDR
     X   8.1443E-02 , 1.2205E-01 , 1.6570E-01 , 1.8850E-01 , 1.8977E-01, CLDBDR
     X   8.3993E-02 , 1.4186E-01 , 2.2091E-01 , 2.9812E-01 , 3.8109E-01, CLDBDR
     X   8.7714E-02 , 1.5825E-01 , 2.6484E-01 , 3.8856E-01 , 5.5270E-01/ CLDBDR
C     DATA KPN,XLAM,WZERO/  425, 2.55, 1.73600E-01/                      CLDBDR
      DATA(RFL3(I,1,4),I=1,45)                                           CLDBDR
     X / 5.0543E-02 , 5.7898E-02 , 6.4396E-02 , 6.8505E-02 , 8.4270E-02, CLDBDR
     X   5.6872E-02 , 6.6530E-02 , 7.4678E-02 , 7.8390E-02 , 9.0911E-02, CLDBDR
     X   5.5087E-02 , 6.7625E-02 , 7.8474E-02 , 8.2760E-02 , 9.1016E-02, CLDBDR
     X   5.5371E-02 , 7.2550E-02 , 8.8824E-02 , 9.6674E-02 , 1.0493E-01, CLDBDR
     X   5.7212E-02 , 8.6306E-02 , 1.1826E-01 , 1.3645E-01 , 1.4075E-01, CLDBDR
     X   6.6218E-02 , 9.9905E-02 , 1.4261E-01 , 1.8530E-01 , 2.5191E-01, CLDBDR
     X   7.8890E-02 , 1.3997E-01 , 2.3525E-01 , 3.6084E-01 , 5.8200E-01, CLDBDR
     X   9.1536E-02 , 1.9111E-01 , 3.8695E-01 , 7.4777E-01 , 1.6637E+00, CLDBDR
     X   8.3974E-02 , 2.2028E-01 , 5.7006E-01 , 1.4547E+00 , 4.5656E+00/ CLDBDR
C     DATA KPN,XLAM,WZERO/  426, 2.65, 1.00000E+00/                      CLDBDR
      DATA(RFL4(I,1,1),I=1,45)                                           CLDBDR
     X / 6.3315E-02 , 4.0561E-02 , 2.6888E-02 , 1.9253E-02 , 2.0385E-02, CLDBDR
     X   1.5078E-02 , 1.8480E-02 , 2.0599E-02 , 1.9386E-02 , 1.6392E-02, CLDBDR
     X   2.5759E-02 , 2.5570E-02 , 2.3832E-02 , 1.9924E-02 , 1.6919E-02, CLDBDR
     X   1.2604E-02 , 1.8186E-02 , 2.3053E-02 , 2.3090E-02 , 1.8173E-02, CLDBDR
     X   1.5646E-02 , 1.8703E-02 , 2.0181E-02 , 1.8123E-02 , 1.4203E-02, CLDBDR
     X   1.5339E-02 , 1.8986E-02 , 2.0746E-02 , 1.8080E-02 , 1.2618E-02, CLDBDR
     X   1.2337E-02 , 1.6194E-02 , 1.9009E-02 , 1.8237E-02 , 1.4723E-02, CLDBDR
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     X   1.5218E-02 , 1.8083E-02 , 1.9773E-02 , 1.8667E-02 , 1.6569E-02, CLDBDR
     X   1.6500E-02 , 1.8949E-02 , 1.9788E-02 , 1.7442E-02 , 1.3805E-02/ CLDBDR
C     DATA KPN,XLAM,WZERO/  426, 2.65, 8.66000E-01/                      CLDBDR
      DATA(RFL4(I,1,2),I=1,45)                                           CLDBDR
     X / 1.9286E-02 , 1.9867E-02 , 2.1841E-02 , 2.7512E-02 , 5.7734E-02, CLDBDR
     X   2.0659E-02 , 2.1434E-02 , 2.1508E-02 , 2.0491E-02 , 2.2240E-02, CLDBDR
     X   2.9040E-02 , 2.7928E-02 , 2.5564E-02 , 2.1548E-02 , 1.9449E-02, CLDBDR
     X   2.3239E-02 , 2.8073E-02 , 3.0224E-02 , 2.6428E-02 , 1.9196E-02, CLDBDR
     X   4.4608E-02 , 4.2016E-02 , 3.6877E-02 , 2.8621E-02 , 2.1917E-02, CLDBDR
     X   6.3218E-02 , 5.2735E-02 , 4.3015E-02 , 3.4017E-02 , 3.1970E-02, CLDBDR
     X   3.9126E-02 , 4.9393E-02 , 5.5157E-02 , 4.9315E-02 , 3.5587E-02, CLDBDR
     X   5.4105E-02 , 5.3592E-02 , 5.1163E-02 , 4.6063E-02 , 4.6607E-02, CLDBDR
     X   2.7891E-02 , 4.1406E-02 , 5.5037E-02 , 5.9943E-02 , 5.5217E-02/ CLDBDR
C     DATA KPN,XLAM,WZERO/  426, 2.65, 5.00000E-01/                      CLDBDR
      DATA(RFL4(I,1,3),I=1,45)                                           CLDBDR
     X / 2.0567E-02 , 2.1964E-02 , 2.2215E-02 , 2.0493E-02 , 1.9857E-02, CLDBDR
     X   2.3287E-02 , 2.5669E-02 , 2.5258E-02 , 2.0247E-02 , 1.3567E-02, CLDBDR
     X   2.4385E-02 , 2.8598E-02 , 3.0810E-02 , 2.8565E-02 , 2.4735E-02, CLDBDR
     X   2.8298E-02 , 3.4536E-02 , 3.9053E-02 , 3.8628E-02 , 3.6879E-02, CLDBDR
     X   3.5004E-02 , 4.6211E-02 , 5.5837E-02 , 5.7652E-02 , 5.4803E-02, CLDBDR
     X   3.7861E-02 , 5.9642E-02 , 8.2341E-02 , 8.9417E-02 , 7.5610E-02, CLDBDR
     X   3.9138E-02 , 7.3356E-02 , 1.1932E-01 , 1.4985E-01 , 1.4111E-01, CLDBDR
     X   4.3935E-02 , 9.2955E-02 , 1.7236E-01 , 2.5140E-01 , 2.8556E-01, CLDBDR
     X   4.9392E-02 , 1.0765E-01 , 2.1186E-01 , 3.4716E-01 , 4.9702E-01/ CLDBDR
C     DATA KPN,XLAM,WZERO/  426, 2.65, 1.73600E-01/                      CLDBDR
      DATA(RFL4(I,1,4),I=1,45)                                           CLDBDR
     X / 1.5844E-02 , 1.8345E-02 , 1.9749E-02 , 1.8721E-02 , 1.7363E-02, CLDBDR
     X   1.9145E-02 , 2.1033E-02 , 2.1560E-02 , 1.9591E-02 , 1.7653E-02, CLDBDR
     X   2.2144E-02 , 2.3309E-02 , 2.4826E-02 , 2.7362E-02 , 4.0892E-02, CLDBDR
     X   2.4163E-02 , 2.9487E-02 , 3.4828E-02 , 3.9111E-02 , 5.0175E-02, CLDBDR
     X   2.6139E-02 , 4.1230E-02 , 5.7635E-02 , 6.4740E-02 , 5.9121E-02, CLDBDR
     X   3.0903E-02 , 5.6207E-02 , 9.2149E-02 , 1.2538E-01 , 1.4805E-01, CLDBDR
     X   3.6622E-02 , 8.1639E-02 , 1.6582E-01 , 2.8536E-01 , 4.4432E-01, CLDBDR
     X   4.1085E-02 , 1.1829E-01 , 3.1424E-01 , 7.2430E-01 , 1.5853E+00, CLDBDR
     X   4.5844E-02 , 1.5420E-01 , 5.0390E-01 , 1.5769E+00 , 5.7206E+00/ CLDBDR
C     DATA KPN,XLAM,WZERO/  427, 2.75, 1.00000E+00/                      CLDBDR
      DATA(RFL5(I,1,1),I=1,45)                                           CLDBDR
     X / 5.4773E-04 , 8.6908E-04 , 1.2643E-03 , 1.5769E-03 , 1.8229E-03, CLDBDR
     X   6.2783E-04 , 9.1084E-04 , 1.2716E-03 , 1.6691E-03 , 2.4475E-03, CLDBDR
     X   5.7365E-04 , 9.2491E-04 , 1.3430E-03 , 1.6156E-03 , 1.6811E-03, CLDBDR
     X   5.5865E-04 , 8.6923E-04 , 1.2520E-03 , 1.5747E-03 , 1.9052E-03, CLDBDR
     X   5.2488E-04 , 8.8420E-04 , 1.3611E-03 , 1.7849E-03 , 2.1415E-03, CLDBDR
     X   4.5873E-04 , 7.4351E-04 , 1.1143E-03 , 1.4551E-03 , 1.8198E-03, CLDBDR
     X   6.2050E-04 , 9.9749E-04 , 1.4640E-03 , 1.8273E-03 , 2.0795E-03, CLDBDR
     X   6.6493E-04 , 9.4753E-04 , 1.2999E-03 , 1.6780E-03 , 2.4237E-03, CLDBDR
     X   4.3178E-04 , 7.7318E-04 , 1.2855E-03 , 1.8771E-03 , 2.6672E-03/ CLDBDR
C     DATA KPN,XLAM,WZERO/  427, 2.75, 8.66000E-01/                      CLDBDR
      DATA(RFL5(I,1,2),I=1,45)                                           CLDBDR
     X / 7.5118E-04 , 8.1746E-04 , 8.4178E-04 , 7.8933E-04 , 7.7489E-04, CLDBDR
     X   4.9333E-04 , 7.2599E-04 , 8.1920E-04 , 5.6336E-04 , 1.8009E-04, CLDBDR
     X   5.6445E-04 , 8.2179E-04 , 1.0876E-03 , 1.2141E-03 , 1.2153E-03, CLDBDR
     X   7.1208E-04 , 9.9927E-04 , 1.3357E-03 , 1.6462E-03 , 2.1788E-03, CLDBDR
     X   7.1629E-04 , 1.2076E-03 , 1.8132E-03 , 2.2084E-03 , 2.2288E-03, CLDBDR
     X   1.0120E-03 , 1.5881E-03 , 2.2526E-03 , 2.6661E-03 , 2.7682E-03, CLDBDR
     X   9.4973E-04 , 1.7477E-03 , 2.9083E-03 , 4.0415E-03 , 4.9357E-03, CLDBDR
     X   1.0398E-03 , 2.0536E-03 , 3.5957E-03 , 5.0620E-03 , 5.8012E-03, CLDBDR
     X   1.0902E-03 , 2.2364E-03 , 4.1711E-03 , 6.5639E-03 , 9.2685E-03/ CLDBDR
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C     DATA KPN,XLAM,WZERO/  427, 2.75, 5.00000E-01/                    CLDBDR
      DATA(RFL5(I,1,3),I=1,45)                                         CLDBDR
     X / 8.8451E-04 , 5.6244E-04 , 4.0234E-04 , 3.6462E-04 , 6.7453E-04, CLDBDR
     X   9.0642E-04 , 7.3248E-04 , 6.3298E-04 , 6.2908E-04 , 1.0495E-03, CLDBDR
     X   7.1941E-04 , 9.9667E-04 , 1.1849E-03 , 1.0643E-03 , 6.8629E-04, CLDBDR
     X   1.0519E-03 , 1.6260E-03 , 2.1480E-03 , 2.1274E-03 , 1.4890E-03, CLDBDR
     X   1.7983E-03 , 2.5005E-03 , 3.3364E-03 , 4.1638E-03 , 5.7429E-03, CLDBDR
     X   1.9396E-03 , 3.6323E-03 , 6.0243E-03 , 8.0178E-03 , 8.6522E-03, CLDBDR
     X   2.5303E-03 , 5.6484E-03 , 1.1095E-02 , 1.7274E-02 , 2.1269E-02, CLDBDR
     X   2.8208E-03 , 7.2811E-03 , 1.7171E-02 , 3.4485E-02 , 6.3324E-02, CLDBDR
     X   3.2883E-03 , 1.0471E-02 , 2.9484E-02 , 6.6441E-02 , 1.2072E-01/ CLDBDR
C     DATA KPN,XLAM,WZERO/  427, 2.75, 1.73600E-01/                    CLDBDR
      DATA(RFL5(I,1,4),I=1,45)                                         CLDBDR
     X / 7.9174E-04 , 1.4845E-03 , 2.0524E-03 , 1.6054E-03 , 5.0211E-04, CLDBDR
     X   8.5581E-04 , 1.3496E-03 , 1.9477E-03 , 2.4010E-03 , 2.7232E-03, CLDBDR
     X   1.1019E-03 , 1.4719E-03 , 1.9648E-03 , 2.6504E-03 , 4.6203E-03, CLDBDR
     X   1.2554E-03 , 1.5926E-03 , 2.0974E-03 , 3.0019E-03 , 6.4323E-03, CLDBDR
     X   2.4460E-03 , 3.4192E-03 , 4.8724E-03 , 7.2885E-03 , 1.5216E-02, CLDBDR
     X   3.5899E-03 , 6.4264E-03 , 1.1072E-02 , 1.7943E-02 , 3.2504E-02, CLDBDR
     X   3.9642E-03 , 1.0459E-02 , 2.5781E-02 , 5.6485E-02 , 1.2337E-01, CLDBDR
     X   5.0367E-03 , 1.9240E-02 , 6.7252E-02 , 2.0078E-01 , 5.5130E-01, CLDBDR
     X   6.1330E-03 , 2.8126E-02 , 1.2582E-01 , 5.4314E-01 , 2.7604E+00/ CLDBDR
C     DATA KPN,XLAM,WZERO/  428, 2.85, 1.00000E+00/                    CLDBDR
      DATA(RFL6(I,1,1),I=1,45)                                         CLDBDR
     X / 6.5579E-04 , 7.8007E-04 , 9.2441E-04 , 1.1005E-03 , 1.6732E-03, CLDBDR
     X   6.8788E-04 , 8.5770E-04 , 1.0344E-03 , 1.1846E-03 , 1.5459E-03, CLDBDR
     X   6.5625E-04 , 8.6321E-04 , 1.0696E-03 , 1.1963E-03 , 1.3765E-03, CLDBDR
     X   6.0999E-04 , 7.5593E-04 , 9.2363E-04 , 1.1115E-03 , 1.6411E-03, CLDBDR
     X   6.7913E-04 , 8.1517E-04 , 9.5655E-04 , 1.0877E-03 , 1.4685E-03, CLDBDR
     X   7.2494E-04 , 8.4712E-04 , 9.9515E-04 , 1.1949E-03 , 1.8975E-03, CLDBDR
     X   6.7821E-04 , 8.4967E-04 , 1.0193E-03 , 1.1390E-03 , 1.3951E-03, CLDBDR
     X   6.6690E-04 , 8.2228E-04 , 9.8308E-04 , 1.1213E-03 , 1.4712E-03, CLDBDR
     X   7.3536E-04 , 8.4989E-04 , 9.7222E-04 , 1.1035E-03 , 1.5599E-03/ CLDBDR
C     DATA KPN,XLAM,WZERO/  428, 2.85, 8.66000E-01/                    CLDBDR
      DATA(RFL6(I,1,2),I=1,45)                                         CLDBDR
     X / 5.8635E-04 , 8.1882E-04 , 9.7887E-04 , 8.8013E-04 , 5.6286E-04, CLDBDR
     X   6.0742E-04 , 7.2260E-04 , 7.6967E-04 , 6.7172E-04 , 4.9577E-04, CLDBDR
     X   6.3340E-04 , 8.2803E-04 , 9.8242E-04 , 9.8011E-04 , 8.7136E-04, CLDBDR
     X   6.8677E-04 , 8.7159E-04 , 1.0391E-03 , 1.1126E-03 , 1.2127E-03, CLDBDR
     X   7.4732E-04 , 1.0527E-03 , 1.3620E-03 , 1.5157E-03 , 1.5738E-03, CLDBDR
     X   7.4932E-04 , 9.8769E-04 , 1.3128E-03 , 1.7939E-03 , 3.2802E-03, CLDBDR
     X   9.2476E-04 , 1.2135E-03 , 1.5098E-03 , 1.7170E-03 , 2.0599E-03, CLDBDR
     X   8.3896E-04 , 1.1450E-03 , 1.6028E-03 , 2.3829E-03 , 5.0623E-03, CLDBDR
     X   7.2247E-04 , 1.1813E-03 , 1.8736E-03 , 2.8370E-03 , 4.9491E-03/ CLDBDR
C     DATA KPN,XLAM,WZERO/  428, 2.85, 5.00000E-01/                    CLDBDR
      DATA(RFL6(I,1,3),I=1,45)                                         CLDBDR
     X / 7.4576E-04 , 5.8585E-04 , 5.4311E-04 , 6.9888E-04 , 2.2081E-03, CLDBDR
     X   4.5287E-04 , 6.6070E-04 , 8.8152E-04 , 1.0035E-03 , 1.0484E-03, CLDBDR
     X   5.9535E-04 , 6.5035E-04 , 7.5598E-04 , 1.0012E-03 , 2.1838E-03, CLDBDR
     X   8.7711E-04 , 7.6898E-04 , 7.3901E-04 , 8.5629E-04 , 1.8324E-03, CLDBDR
     X   1.1411E-03 , 1.5088E-03 , 1.8541E-03 , 2.0042E-03 , 2.1152E-03, CLDBDR
     X   8.1721E-04 , 1.5524E-03 , 2.6721E-03 , 3.8556E-03 , 4.9271E-03, CLDBDR
     X   1.3445E-03 , 2.5826E-03 , 4.4480E-03 , 6.7856E-03 , 9.9293E-03, CLDBDR
     X   1.1706E-03 , 2.8712E-03 , 6.5034E-03 , 1.2804E-02 , 2.4021E-02, CLDBDR
     X   1.4317E-03 , 3.4986E-03 , 8.3823E-03 , 1.9569E-02 , 5.4852E-02/ CLDBDR
C     DATA KPN,XLAM,WZERO/  428, 2.85, 1.73600E-01/                    CLDBDR
      DATA(RFL6(I,1,4),I=1,45)                                         CLDBDR
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     X / 1.4432E-03 , 1.4302E-03 , 1.5076E-03 , 1.8093E-03 , 3.5716E-03, CLDBDR
     X   1.3499E-03 , 1.8646E-03 , 2.5667E-03 , 3.5513E-03 , 6.2812E-03, CLDBDR
     X   1.5644E-03 , 1.6991E-03 , 1.8934E-03 , 2.2423E-03 , 3.7992E-03, CLDBDR
     X   3.3582E-04 , 7.6495E-04 , 1.6042E-03 , 2.9073E-03 , 4.9624E-03, CLDBDR
     X   1.1218E-03 , 1.4217E-03 , 1.8146E-03 , 2.3751E-03 , 4.1389E-03, CLDBDR
     X   1.0685E-03 , 2.4392E-03 , 4.9467E-03 , 8.0977E-03 , 1.0875E-02, CLDBDR
     X   2.7523E-03 , 5.3205E-03 , 1.0212E-02 , 1.9566E-02 , 4.7256E-02, CLDBDR
     X   3.1640E-03 , 8.9367E-03 , 2.4474E-02 , 6.3939E-02 , 1.9213E-01, CLDBDR
     X   3.3338E-03 , 1.2574E-02 , 4.7551E-02 , 1.8285E-01 , 9.2023E-01/ CLDBDR
C     DATA KPN,XLAM,WZERO/  432, 3.20, 1.00000E+00/                      CLDBDR
      DATA(RFL7(I,1,1),I=1,45)                                           CLDBDR
     X / 2.2381E-03 , 2.5124E-03 , 2.8035E-03 , 3.1294E-03 , 4.4226E-03, CLDBDR
     X   2.4909E-03 , 2.6017E-03 , 2.7447E-03 , 2.9864E-03 , 4.3760E-03, CLDBDR
     X   2.2896E-03 , 2.5921E-03 , 2.9325E-03 , 3.3526E-03 , 4.9532E-03, CLDBDR
     X   2.2124E-03 , 2.3881E-03 , 2.6135E-03 , 2.9711E-03 , 4.6150E-03, CLDBDR
     X   2.1736E-03 , 2.3962E-03 , 2.6508E-03 , 2.9872E-03 , 4.4209E-03, CLDBDR
     X   2.2319E-03 , 2.3962E-03 , 2.6208E-03 , 3.0054E-03 , 4.7983E-03, CLDBDR
     X   2.7621E-03 , 2.7398E-03 , 2.8569E-03 , 3.3162E-03 , 6.0492E-03, CLDBDR
     X   2.3798E-03 , 2.6678E-03 , 3.0376E-03 , 3.6052E-03 , 5.8875E-03, CLDBDR
     X   2.3685E-03 , 2.5606E-03 , 2.8162E-03 , 3.2388E-03 , 5.1581E-03/ CLDBDR
C     DATA KPN,XLAM,WZERO/  432, 3.20, 8.66000E-01/                      CLDBDR
      DATA(RFL7(I,1,2),I=1,45)                                           CLDBDR
     X / 2.5813E-03 , 3.0038E-03 , 3.1291E-03 , 2.6698E-03 , 1.9251E-03, CLDBDR
     X   2.6401E-03 , 2.7600E-03 , 2.8902E-03 , 3.0721E-03 , 4.2584E-03, CLDBDR
     X   3.0477E-03 , 2.8996E-03 , 2.8158E-03 , 2.8774E-03 , 4.1238E-03, CLDBDR
     X   2.3955E-03 , 2.8588E-03 , 3.2771E-03 , 3.5198E-03 , 4.1929E-03, CLDBDR
     X   2.0123E-03 , 2.9603E-03 , 3.9775E-03 , 4.5483E-03 , 4.7496E-03, CLDBDR
     X   2.3615E-03 , 3.3798E-03 , 4.5471E-03 , 5.5008E-03 , 6.7912E-03, CLDBDR
     X   2.2137E-03 , 3.2347E-03 , 4.4515E-03 , 5.5288E-03 , 7.0603E-03, CLDBDR
     X   2.3439E-03 , 3.4192E-03 , 4.8860E-03 , 6.7919E-03 , 1.1297E-02, CLDBDR
     X   2.2418E-03 , 3.5387E-03 , 5.2920E-03 , 7.2229E-03 , 1.0369E-02/ CLDBDR
C     DATA KPN,XLAM,WZERO/  432, 3.20, 5.00000E-01/                      CLDBDR
      DATA(RFL7(I,1,3),I=1,45)                                           CLDBDR
     X / 2.4118E-03 , 3.7976E-03 , 5.0827E-03 , 5.0473E-03 , 3.4680E-03, CLDBDR
     X   2.5424E-03 , 3.5279E-03 , 4.3203E-03 , 4.2175E-03 , 3.2935E-03, CLDBDR
     X   2.6502E-03 , 3.1842E-03 , 3.6294E-03 , 3.8127E-03 , 4.2968E-03, CLDBDR
     X   3.0587E-03 , 3.5391E-03 , 4.0700E-03 , 4.6808E-03 , 6.8123E-03, CLDBDR
     X   2.9507E-03 , 4.3131E-03 , 5.9667E-03 , 7.5186E-03 , 9.9249E-03, CLDBDR
     X   3.1184E-03 , 4.9601E-03 , 7.2599E-03 , 9.1735E-03 , 1.0895E-02, CLDBDR
     X   3.8802E-03 , 6.3366E-03 , 1.0015E-02 , 1.5050E-02 , 2.5831E-02, CLDBDR
     X   4.8843E-03 , 7.3526E-03 , 1.1325E-02 , 1.8439E-02 , 4.2498E-02, CLDBDR
     X   4.7470E-03 , 8.8773E-03 , 1.5891E-02 , 2.6479E-02 , 4.8292E-02/ CLDBDR
C     DATA KPN,XLAM,WZERO/  432, 3.20, 1.73600E-01/                      CLDBDR
      DATA(RFL7(I,1,4),I=1,45)                                           CLDBDR
     X / 2.6928E-03 , 4.0262E-03 , 5.8235E-03 , 8.0003E-03 , 1.2530E-02, CLDBDR
     X   3.3211E-03 , 4.2607E-03 , 5.0165E-03 , 5.0734E-03 , 4.7737E-03, CLDBDR
     X   3.3930E-03 , 4.0589E-03 , 4.6547E-03 , 4.9827E-03 , 5.8714E-03, CLDBDR
     X   3.9449E-03 , 4.7291E-03 , 5.7623E-03 , 7.3286E-03 , 1.2860E-02, CLDBDR
     X   4.3951E-03 , 6.7266E-03 , 9.7828E-03 , 1.3060E-02 , 1.8554E-02, CLDBDR
     X   5.4314E-03 , 8.7131E-03 , 1.3673E-02 , 2.0817E-02 , 3.7717E-02, CLDBDR
     X   6.8674E-03 , 1.2367E-02 , 2.1316E-02 , 3.4192E-02 , 6.0009E-02, CLDBDR
     X   8.5311E-03 , 1.7241E-02 , 3.4637E-02 , 6.9626E-02 , 1.7728E-01, CLDBDR
     X   8.7021E-03 , 2.0829E-02 , 5.4661E-02 , 1.7301E-01 , 1.0120E+00/ CLDBDR
C     DATA KPN,XLAM,WZERO/  435, 3.50, 1.00000E+00/                      CLDBDR
      DATA(RFL8(I,1,1),I=1,45)                                           CLDBDR
     X / 3.9995E-02 , 3.8324E-02 , 3.5939E-02 , 3.2725E-02 , 3.5524E-02, CLDBDR
     X   4.2419E-02 , 4.6002E-02 , 4.5976E-02 , 3.9783E-02 , 3.2545E-02, CLDBDR
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     X   4.5036E-02 , 4.6258E-02 , 4.4954E-02 , 3.9769E-02 , 3.6812E-02, CLDBDR
     X   5.0371E-02 , 4.4566E-02 , 3.9107E-02 , 3.4185E-02 , 3.7512E-02, CLDBDR
     X   5.1055E-02 , 4.6899E-02 , 4.1902E-02 , 3.5924E-02 , 3.5849E-02, CLDBDR
     X   4.3450E-02 , 4.4222E-02 , 4.3337E-02 , 3.9980E-02 , 4.1299E-02, CLDBDR
     X   4.2486E-02 , 4.3113E-02 , 4.1873E-02 , 3.7850E-02 , 3.7434E-02, CLDBDR
     X   4.3339E-02 , 4.0787E-02 , 3.7949E-02 , 3.4960E-02 , 3.9936E-02, CLDBDR
     X   4.5118E-02 , 4.3892E-02 , 4.1443E-02 , 3.7401E-02 , 3.8976E-02/ CLDBDR
C     DATA KPN,XLAM,WZERO/  435, 3.50, 8.66000E-01/                      CLDBDR
      DATA(RFL8(I,1,2),I=1,45)                                           CLDBDR
     X / 5.2061E-02 , 5.8214E-02 , 5.9052E-02 , 5.0329E-02 , 3.8162E-02, CLDBDR
     X   6.2870E-02 , 6.1438E-02 , 5.6146E-02 , 4.5681E-02 , 3.7177E-02, CLDBDR
     X   5.5855E-02 , 5.3309E-02 , 4.8929E-02 , 4.2177E-02 , 4.0516E-02, CLDBDR
     X   4.7769E-02 , 4.8704E-02 , 4.7508E-02 , 4.3096E-02 , 4.2705E-02, CLDBDR
     X   4.8670E-02 , 5.0254E-02 , 4.9573E-02 , 4.5353E-02 , 4.5076E-02, CLDBDR
     X   3.9856E-02 , 4.6006E-02 , 5.0363E-02 , 5.0417E-02 , 5.3297E-02, CLDBDR
     X   4.0213E-02 , 4.6819E-02 , 5.2531E-02 , 5.5576E-02 , 6.6054E-02, CLDBDR
     X   4.4734E-02 , 5.0139E-02 , 5.5470E-02 , 6.0566E-02 , 8.1476E-02, CLDBDR
     X   3.9976E-02 , 5.1867E-02 , 6.3711E-02 , 7.1337E-02 , 8.3797E-02/ CLDBDP
C     DATA KPN,XLAM,WZERO/  435, 3.50, 5.00000E-01/                      CLDBDR
      DATA(RFL8(I,1,3),I=1,45)                                           CLDBDR
     X / 5.2385E-02 , 7.1243E-02 , 9.1024E-02 , 1.0445E-01 , 1.2205E-01, CLDBDR
     X   5.3326E-02 , 7.3399E-02 , 9.1026E-02 , 9.3612E-02 , 8.3417E-02, CLDBDR
     X   4.4951E-02 , 5.8311E-02 , 6.9011E-02 , 6.9362E-02 , 6.3389E-02, CLDBDR
     X   4.5231E-02 , 5.3367E-02 , 6.0240E-02 , 6.3233E-02 , 7.2502E-02, CLDBDR
     X   4.5041E-02 , 5.6263E-02 , 6.7008E-02 , 7.3723E-02 , 8.7425E-02, CLDBDR
     X   4.6345E-02 , 6.1387E-02 , 7.7188E-02 , 8.8923E-02 , 1.0859E-01, CLDBDR
     X   4.8949E-02 , 7.4661E-02 , 1.0795E-01 , 1.4261E-01 , 1.9859E-01, CLDBDR
     X   5.5234E-02 , 8.7770E-02 , 1.3405E-01 , 1.9208E-01 , 3.0603E-01, CLDBDR
     X   5.3656E-02 , 9.1525E-02 , 1.4972E-01 , 2.2876E-01 , 3.8529E-01/ CLDBDR
C     DATA KPN,XLAM,WZERO/  435, 3.50, 1.73600E-01/                      CLDBDR
      DATA(RFL8(I,1,4),I=1,45)                                           CLDBDR
     X / 3.8284E-02 , 7.0000E-02 , 1.1371E-01 , 1.4914E-01 , 1.6055E-01, CLDBDR
     X   4.3095E-02 , 6.3699E-02 , 9.1284E-02 , 1.2477E-01 , 1.9609E-01, CLDBDR
     X   4.2916E-02 , 5.4721E-02 , 6.8268E-02 , 8.2664E-02 , 1.1923E-01, CLDBDR
     X   4.1874E-02 , 5.6292E-02 , 7.1332E-02 , 8.1704E-02 , 9.6526E-02, CLDBDR
     X   4.7868E-02 , 6.5886E-02 , 8.7022E-02 , 1.0750E-01 , 1.4676E-01, CLDBDR
     X   5.1965E-02 , 7.6822E-02 , 1.1108E-01 , 1.5579E-01 , 2.5991E-01, CLDBDR
     X   5.6165E-02 , 9.8673E-02 , 1.6601E-01 , 2.6020E-01 , 4.4713E-01, CLDBDR
     X   6.3932E-02 , 1.3537E-01 , 2.6853E-01 , 4.7584E-01 , 8.4918E-01, CLDBDR
     X   7.3568E-02 , 1.6248E-01 , 3.4828E-01 , 7.1356E-01 , 1.6881E+00/ CLDBDR
C     DATA KPN,XLAM,WZERO/  440, 4.00, 1.00000E+00/                      CLDBDR
      DATA(RFL9(I,1,1),I=1,45)                                           CLDBDR
     X / 5.7056E-02 , 6.6629E-02 , 6.9572E-02 , 5.9369E-02 , 4.2621E-02, CLDBDR
     X   5.6099E-02 , 6.4320E-02 , 6.7310E-02 , 5.9875E-02 , 4.8514E-02, CLDBDR
     X   6.6702E-02 , 6.5828E-02 , 6.3197E-02 , 5.8241E-02 , 6.2522E-02, CLDBDR
     X   6.9785E-02 , 7.0618E-02 , 6.6541E-02 , 5.5368E-02 , 4.5332E-02, CLDBDR
     X   6.3429E-02 , 6.8923E-02 , 6.8352E-02 , 5.7612E-02 , 4.4219E-02, CLDBDR
     X   5.9453E-02 , 6.3887E-02 , 6.4337E-02 , 5.7915E-02 , 5.2577E-02, CLDBDR
     X   6.3321E-02 , 6.4344E-02 , 6.2581E-02 , 5.6645E-02 , 5.6098E-02, CLDBDR
     X   7.4265E-02 , 6.9261E-02 , 6.3393E-02 , 5.6645E-02 , 6.1000E-02, CLDBDR
     X   7.9859E-02 , 8.9348E-02 , 9.0412E-02 , 7.6420E-02 , 5.6797E-02/ CLDBDR
C     DATA KPN,XLAM,WZERO/  440, 4.00, 8.66000E-01/                      CLDBDR
      DATA(RFL9(I,1,2),I=1,45)                                           CLDBDR
     X / 6.9259E-02 , 7.5671E-02 , 7.7308E-02 , 7.0302E-02 , 6.3925E-02, CLDBDR
     X   7.1106E-02 , 8.3547E-02 , 8.7641E-02 , 7.4920E-02 , 5.3569E-02, CLDBDR
     X   8.1744E-02 , 8.2238E-02 , 7.8765E-02 , 6.9495E-02 , 6.5715E-02, CLDBDR
     X   7.4577E-02 , 7.7389E-02 , 7.5623E-02 , 6.6669E-02 , 6.0388E-02, CLDBDR
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     X   7.6929E-02 , 8.1116E-02 , 8.0645E-02 , 7.2508E-02 , 6.7312E-02, CLDBDR
     X   7.5559E-02 , 7.9429E-02 , 7.9236E-02 , 7.2368E-02 , 6.9963E-02, CLDBDR
     X   7.1461E-02 , 8.3150E-02 , 9.0703E-02 , 8.8513E-02 , 8.7244E-02, CLDBDR
     X   6.8598E-02 , 8.5133E-02 , 9.7502E-02 , 9.6936E-02 , 9.1597E-02, CLDBDR
     X   7.3721E-02 , 8.9882E-02 , 1.0252E-01 , 1.0418E-01 , 1.0605E-01/ CLDBDR
C     DATA KPN,XLAM,WZERO/  440, 4.00, 5.00000E-01/                      CLDBDR
      DATA(RFL9(I,1,3),I=1,45)                                           CLDBDR
     X / 8.0568E-02 , 9.1765E-02 , 1.0024E-01 , 1.0231E-01 , 1.1516E-01, CLDBDR
     X   7.8142E-02 , 9.4849E-02 , 1.0484E-01 , 9.8087E-02 , 8.2858E-02, CLDBDR
     X   7.7449E-02 , 8.8103E-02 , 9.2628E-02 , 8.4778E-02 , 7.4174E-02, CLDBDR
     X   7.4176E-02 , 8.6320E-02 , 9.4180E-02 , 9.1932E-02 , 9.0656E-02, CLDBDR
     X   8.5939E-02 , 1.0204E-01 , 1.1336E-01 , 1.1227E-01 , 1.1150E-01, CLDBDR
     X   8.7706E-02 , 1.0866E-01 , 1.2783E-01 , 1.3783E-01 , 1.5769E-01, CLDBDR
     X   8.0221E-02 , 1.1780E-01 , 1.6014E-01 , 1.9014E-01 , 2.1724E-01, CLDBDR
     X   9.9521E-02 , 1.4557E-01 , 2.0498E-01 , 2.7162E-01 , 4.0271E-01, CLDBDR
     X   9.2745E-02 , 1.5082E-01 , 2.3497E-01 , 3.4132E-01 , 5.4450E-01/ CLDBDR
C     DATA KPN,XLAM,WZERO/  440, 4.00, 1.73600E-01/                      CLDBDR
      DATA(RFL9(I,1,4),I=1,45)                                           CLDBDR
     X / 7.1144E-02 , 9.1484E-02 , 1.1183E-01 , 1.2556E-01 , 1.5023E-01, CLDBDR
     X   6.5636E-02 , 8.7610E-02 , 1.1128E-01 , 1.3009E-01 , 1.6269E-01, CLDBDR
     X   6.3826E-02 , 7.9407E-02 , 9.4066E-02 , 1.0268E-01 , 1.2020E-01, CLDBDR
     X   6.0787E-02 , 7.8909E-02 , 9.6056E-02 , 1.0465E-01 , 1.1526E-01, CLDBDR
     X   6.7155E-02 , 9.3466E-02 , 1.2242E-01 , 1.4449E-01 , 1.7479E-01, CLDBDR
     X   7.4152E-02 , 1.0687E-01 , 1.4944E-01 , 1.9961E-01 , 3.0746E-01, CLDBDR
     X   8.9782E-02 , 1.4624E-01 , 2.3114E-01 , 3.4908E-01 , 6.0833E-01, CLDBDR
     X   8.9324E-02 , 1.8376E-01 , 3.6226E-01 , 6.6617E-01 , 1.3467E+00, CLDBDR
     X   9.6655E-02 , 2.2381E-01 , 5.1271E-01 , 1.1642E+00 , 3.2859E+00/ CLDBDR
C     DATA KPN,XLAM,WZERO/  450, 5.00, 1.00000E+00/                      CLDBDR
      DATA(RFL10(I,1,1),I=1,45)                                          CLDBDR
     X / 3.0860E-02 , 3.3706E-02 , 3.4964E-02 , 3.3258E-02 , 3.3592E-02, CLDBDR
     X   2.9041E-02 , 3.2556E-02 , 3.4322E-02 , 3.2562E-02 , 3.1579E-02, CLDBDR
     X   3.2634E-02 , 3.8256E-02 , 4.0401E-02 , 3.5373E-02 , 2.6824E-02, CLDBDR
     X   2.9870E-02 , 3.5884E-02 , 3.8755E-02 , 3.4560E-02 , 2.6475E-02, CLDBDR
     X   3.6096E-02 , 3.9507E-02 , 4.0115E-02 , 3.5719E-02 , 3.0851E-02, CLDBDR
     X   3.3269E-02 , 3.4079E-02 , 3.3990E-02 , 3.2596E-02 , 3.6534E-02, CLDBDR
     X   3.1698E-02 , 3.9824E-02 , 4.4590E-02 , 4.0548E-02 , 3.0629E-02, CLDBDR
     X   3.1945E-02 , 3.6592E-02 , 3.8825E-02 , 3.6015E-02 , 3.2214E-02, CLDBDR
     X   3.7706E-02 , 3.8799E-02 , 3.8327E-02 , 3.5440E-02 , 3.6277E-02/ CLDBDR
C     DATA KPN,XLAM,WZERO/  450, 5.00, 8.66000E-01/                      CLDBDR
      DATA(RFL10(I,1,2),I=1,45)                                          CLDBDR
     X / 2.4429E-02 , 3.3795E-02 , 4.1313E-02 , 4.0358E-02 , 3.1696E-02, CLDBDR
     X   3.4698E-02 , 3.9582E-02 , 4.1167E-02 , 3.6316E-02 , 2.9056E-02, CLDBDR
     X   3.4683E-02 , 4.1094E-02 , 4.3614E-02 , 3.7961E-02 , 2.7992E-02, CLDBDR
     X   3.6829E-02 , 4.2934E-02 , 4.5361E-02 , 4.0192E-02 , 3.1567E-02, CLDBDR
     X   3.9340E-02 , 4.5389E-02 , 4.9049E-02 , 4.7334E-02 , 4.5974E-02, CLDBDR
     X   3.8716E-02 , 4.4921E-02 , 4.8950E-02 , 4.7880E-02 , 4.7629E-02, CLDBDR
     X   3.6380E-02 , 4.9511E-02 , 5.9900E-02 , 5.8573E-02 , 4.7119E-02, CLDBDR
     X   4.1265E-02 , 5.1878E-02 , 6.1588E-02 , 6.6314E-02 , 7.4155E-02, CLDBDR
     X   3.7312E-02 , 5.1642E-02 , 6.5663E-02 , 7.1850E-02 , 7.3425E-02/ CLDBDR
C     DATA KPN,XLAM,WZERO/  450, 5.00, 5.00000E-01/                      CLDBDR
      DATA(RFL10(I,1,3),I=1,45)                                          CLDBDR
     X / 4.0185E-02 , 4.5309E-02 , 4.9320E-02 , 5.0795E-02 , 5.9181E-02, CLDBDR
     X   4.2358E-02 , 5.0768E-02 , 5.6769E-02 , 5.6264E-02 , 5.5279E-02, CLDBDR
     X   4.4703E-02 , 4.9749E-02 , 5.2001E-02 , 4.8800E-02 , 4.6592E-02, CLDBDR
     X   4.1983E-02 , 5.0831E-02 , 5.7154E-02 , 5.6458E-02 , 5.4310E-02, CLDBDR
     X   4.5331E-02 , 6.1865E-02 , 7.5921E-02 , 7.6972E-02 , 6.7106E-02, CLDBDR
     X   4.5283E-02 , 6.6351E-02 , 8.7983E-02 , 9.7564E-02 , 9.5352E-02, CLDBDR
```

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     X   5.4956E-02 , 8.3788E-02 , 1.1842E-01 , 1.4651E-01 , 1.7526E-01, CLDBDR
     X   5.6161E-02 , 9.6111E-02 , 1.5396E-01 , 2.1998E-01 , 3.1559E-01, CLDBDR
     X   5.6652E-02 , 1.0848E-01 , 1.9164E-01 , 2.9381E-01 , 4.2778E-01/ CLDBDR
C     DATA KPN,XLAM,WZERO/  450, 5.00, 1.73600E-01/                      CLDBDR
      DATA(RFL10(I,1,4),I=1,45)                                          CLDBDR
     X / 3.0171E-02 , 4.0968E-02 , 5.2498E-02 , 6.0945E-02 , 7.3305E-02, CLDBDR
     X   3.0411E-02 , 4.0016E-02 , 5.0964E-02 , 6.1708E-02 , 8.5349E-02, CLDBDR
     X   3.1124E-02 , 4.1387E-02 , 5.2687E-02 , 6.2451E-02 , 8.1067E-02, CLDBDR
     X   3.4008E-02 , 4.6370E-02 , 5.8683E-02 , 6.5175E-02 , 7.0335E-02, CLDBDR
     X   4.1566E-02 , 5.8808E-02 , 7.8585E-02 , 9.5280E-02 , 1.2007E-01, CLDBDR
     X   4.3250E-02 , 7.0946E-02 , 1.0915E-01 , 1.5036E-01 , 2.0957E-01, CLDBDR
     X   5.8935E-02 , 1.0602E-01 , 1.8261E-01 , 2.9294E-01 , 5.1499E-01, CLDBDR
     X   5.8149E-02 , 1.3646E-01 , 3.0546E-01 , 6.3216E-01 , 1.4125E+00, CLDBDR
     X   6.0197E-02 , 1.6701E-01 , 4.5542E-01 , 1.2160E+00 , 3.9358E+00/ CLDBDR
      DO 20 I = 1,4                                                      CLDBDR
      ITHIN = I                                                          CLDBDR
      IF(CTHIN .GT. TCTHIN(I)) GO TO 30                                  CLDBDR
   20 CONTINUE                                                           CLDBDR
   30 DO 40 I = 1,5                                                      CLDBDR
      ITHOUT = I                                                         CLDBDR
      IF(CTHOUT .GT. TCTHOUT(I)) GO TO 50                                CLDBDR
   40 CONTINUE                                                           CLDBDR
   50 DO 60 I = 1,9                                                      CLDBDR
      IPHOUT = I                                                         CLDBDR
      IF( CPHOUT .LT. TCPHOUT(I)) GO TO 70                               CLDBDR
   60 CONTINUE                                                           CLDBDR
   70 CONTINUE                                                           CLDBDR
      DO 80 I = 2,10                                                     CLDBDR
      ILAM = I - 1                                                       CLDBDR
      IF(ALAM .LT. ALAMT(I)) GO TO 90                                    CLDBDR
   80 CONTINUE                                                           CLDBDR
   90 CONTINUE                                                           CLDBDR
      XLAM = (ALAM - ALAMT(ILAM)) / (ALAMT(ILAM+1) - ALAMT(ILAM))        CLDBDR
      GO TO(110,120,130,140,150,160,170,180,190 ) ILAM                   CLDBDR
  110 CLDBDR = RFL1(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL2(ITHOUT,IPHOUT,ITHIN) - RFL1(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  120 CLDBDR = RFL2(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL3(ITHOUT,IPHOUT,ITHIN) - RFL2(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  130 CLDBDR = RFL3(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL4(ITHOUT,IPHOUT,ITHIN) - RFL3(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  140 CLDBDR = RFL4(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL5(ITHOUT,IPHOUT,ITHIN) - RFL4(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  150 CLDBDR = RFL5(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL6(ITHOUT,IPHOUT,ITHIN) - RFL5(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  160 CLDBDR = RFL6(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL7(ITHOUT,IPHOUT,ITHIN) - RFL6(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  170 CLDBDR = RFL7(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL8(ITHOUT,IPHOUT,ITHIN) - RFL7(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  180 CLDBDR = RFL8(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL9(ITHOUT,IPHOUT,ITHIN) - RFL8(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  190 CLDBDR = RFL9(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL10(ITHOUT,IPHOUT,ITHIN) - RFL9(ITHOUT,IPHOUT,ITHIN)) *XLAM CLDBDR
      RETURN                                                             CLDBDR
      END                                                                CLDBDR
```

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THE ROSCOE MANUAL. VOLUME 24. NATURAL CLOUDS (PHYSICAL AND OPTI--ETC(U)

JUL 79 R R JOHNSTON, D E STEVENSON, W A ARON DNA001-76-C-0194

UNCLASSIFIED SAI-78-604-LJ-5-VOL-24 DNA-3964F-24 NL

3 OF 3

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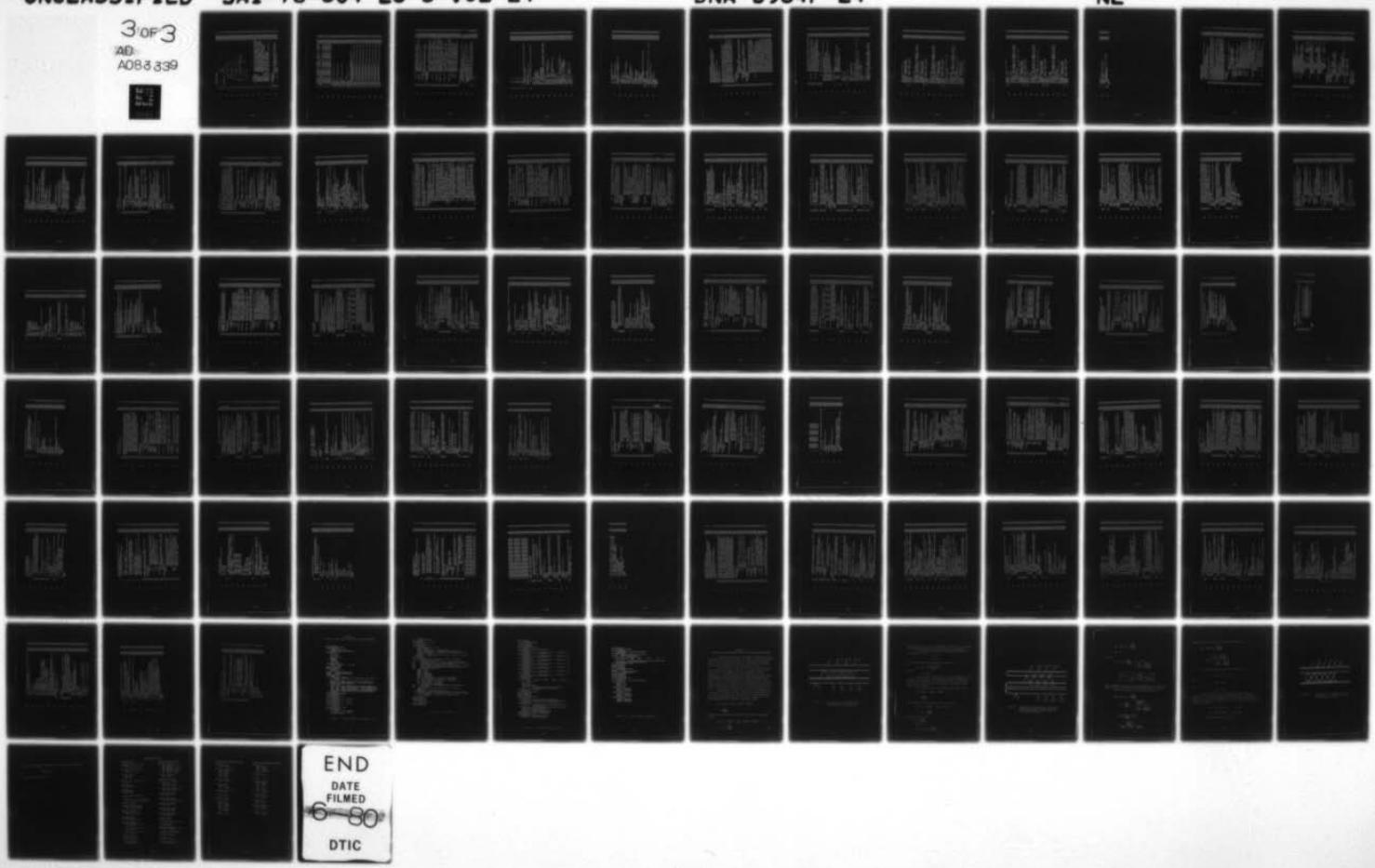

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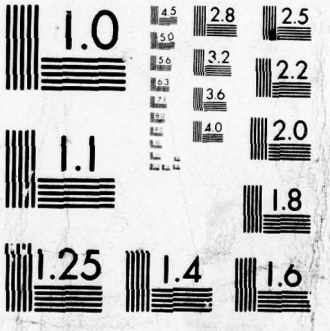

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
      SUBROUTINE CLDGEOM                                                CLDGEOM
C                                                                       CLDGEOM
C                          +                                            CLDGEOM
C                          +                                            CLDGEOM
C                          +                                            CLDGEOM
C                         X+X                                           CLDGEOM
C                       X X+ X X                                        CLDGEOM
   13 FORMAT(7A5)                                                       CLDGEOM
C                      X   +     X                                      CLDGEOM
C                    X     +  X    X                                    CLDGEOM
C                  X   X X +    X    X                                 CLDGEOM
C                X        +         $                                  CLDGEOM
C              X$   X     +      X     X                               CLDGEOM
C             X   X               $                                    CLDGEOM
C             X   $  $  $ +$  $                                        CLDGEOM
C                 X  X  X +       X    $  X                            CLDGEOM
C            X            +         $      X                           CLDGEOM
C            $  $  X    X +       $ X                                  CLDGEOM
C           X       $   $ +$   $             X                         CLDGEOM
C          X       X    X +          X    $                            CLDGEOM
C          X              +        $   $       X                       CLDGEOM
C           $       X   X + $   $     X                                CLDGEOM
C         X    $  $  $  $ ++++++++++++++++++++++++                      CLDGEOM
C         X         X   +X             X      $                        CLDGEOM
C         X          +                     $                            CLDGEOM
C                  +  X   X             X$                              CLDGEOM
C          X     +                    $                                CLDGEOM
C                      X    X     $                                    CLDGEOM
C          X+  $ $ $ $ $ $                                              CLDGEOM
C                                                                       CLDGEOM
C        +                                                              CLDGEOM
C                                                                       CLDGEOM
C                                                                       CLDGEOM
C                                                                       CLDGEOM
C       VOCABULARY                                                      CLDGEOM
C       XI  (10,20)     X COORD OF THE I(I=1,10) TH SOURCE IN JTH CLOUD CLDGEOM
C       ETA (10,20)     Y COORD OF THE I(I=1,10) TH SOURCE IN JTH CLOUD CLDGEOM
C       ZETA(10,20)     YZCOORD OF THE I(I=1,10) TH SOURCE IN JTH CLOUD CLDGEOM
C       RHOS(10,20)     DISTANCE FROM THE SOURCE TO THE CLOUD CENTER    CLDGEOM
C       XID(20)         RECTANGULAR COORD OF DETECTOR W.R.T. JTH CLOUD  CLDGEOM
C       ETAD(20)        RECTANGULAR COORD OF DETECTOR W.R.T. JTH CLOUD  CLDGEOM
C       ZETAD(20)       RECTANGULAR COORD OF DETECTOR W.R.T. JTH CLOUD  CLDGEOM
C       RHOD(20)       DISTANCE OF THE DETECTOR FROM THE JTH CLOUD      CLDGEOM
C       CPHI(4,4,20)    DEFINED THE AREA ELEMENTS  (1ST QUAD ONLY.      CLDGEOM
C       CTH (4,4,20)    DEFINED THE AREA ELEMENTS  (1ST QUAD ONLY.      CLDGEOM
C       CPHIBAR(16,20)   AREAS OVER THE  WHOLE CLOUD                    CLDGEOM
C       CTHBAR ( 8,20)   AREAS OVER THE  WHOLE CLOUD                    CLDGEOM
C       CRBAR(4,4,20) TO MID PT OF EACH AREA ELEMENT                    CLDGEOM
C       CAREA(4,4,20)  FIRST OCTANT AREA - ALL OTHERS ARE SYMMETRIC     CLDGEOM
C                                                                       CLDGEOM
CLJ                                                                     CLDGEOM
CLJ   INPUT PARAMETERS                                                  CLDGEOM
CLJ      CLOUD COMMON                                                   CLDGEOM
CLJ          NCLOUD = NUMBER OF DETERMINISTIC CLOUDS FOR WHICH THE      CLDGEOM
CLJ                   ALTITUDE OF CENTER, SEMI-AXES, AND ORIENTATION    CLDGEOM
CLJ                   ARE READ BY SUBROUTINE CLOUDO                     CLDGEOM
CLJ           FOR K = 1,NCLOUD,                                         CLDGEOM
```

```
     X   5.4956E-02 , 8.3788E-02 , 1.1842E-01 , 1.4651E-01 , 1.7526E-01, CLDBDR
     X   5.6161E-02 , 9.6111E-02 , 1.5396E-01 , 2.1998E-01 , 3.1559E-01, CLDBDR
     X   5.6652E-02 , 1.0848E-01 , 1.9164E-01 , 2.9381E-01 , 4.2778E-01/ CLDBDR
C     DATA KPN,XLAM,WZERO/  450, 5.00, 1.73600E-01/                      CLDBDR
      DATA(RFL10(I,1,4),I=1,45)                                          CLDBDR
     X / 3.0171E-02 , 4.0968E-02 , 5.2498E-02 , 6.0945E-02 , 7.3305E-02, CLDBDR
     X   3.0411E-02 , 4.0016E-02 , 5.0964E-02 , 6.1708E-02 , 8.5349E-02, CLDBDR
     X   3.1124E-02 , 4.1387E-02 , 5.2687E-02 , 6.2451E-02 , 8.1067E-02, CLDBDR
     X   3.4008E-02 , 4.6370E-02 , 5.8683E-02 , 6.5175E-02 , 7.0335E-02, CLDBDR
     X   4.1566E-02 , 5.8808E-02 , 7.8585E-02 , 9.5280E-02 , 1.2007E-01, CLDBDR
     X   4.3250E-02 , 7.0946E-02 , 1.0915E-01 , 1.5036E-01 , 2.0957E-01, CLDBDR
     X   5.8935E-02 , 1.0602E-01 , 1.8261E-01 , 2.9294E-01 , 5.1499E-01, CLDBDR
     X   5.8149E-02 , 1.3646E-01 , 3.0546E-01 , 6.3216E-01 , 1.4125E+00, CLDBDR
     X   6.0197E-02 , 1.6701E-01 , 4.5542E-01 , 1.2160E+00 , 3.9358E+00/ CLDBDR
      DO 20 I = 1,4                                                      CLDBDR
      ITHIN = I                                                          CLDBDR
      IF(CTHIN .GT. TCTHIN(I)) GO TO 30                                  CLDBDR
   20 CONTINUE                                                           CLDBDR
   30 DO 40 I = 1,5                                                      CLDBDR
      ITHOUT = I                                                         CLDBDR
      IF(CTHOUT .GT. TCTHOUT(I)) GO TO 50                                CLDBDR
   40 CONTINUE                                                           CLDBDR
   50 DO 60 I = 1,9                                                      CLDBDR
      IPHOUT = I                                                         CLDBDR
      IF( CPHOUT .LT. TCPHOUT(I)) GO TO 70                               CLDBDR
   60 CONTINUE                                                           CLDBDR
   70 CONTINUE                                                           CLDBDR
      DO 80 I = 2,10                                                     CLDBDR
      ILAM = I - 1                                                       CLDBDR
      IF(ALAM .LT. ALAMT(I)) GO TO 90                                    CLDBDR
   80 CONTINUE                                                           CLDBDR
   90 CONTINUE                                                           CLDBDR
      XLAM = (ALAM - ALAMT(ILAM)) / (ALAMT(ILAM+1) - ALAMT(ILAM))        CLDBDR
      GO TO(110,120,130,140,150,160,170,180,190 ) ILAM                   CLDBDR
  110 CLDBDR = RFL1(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL2(ITHOUT,IPHOUT,ITHIN) - RFL1(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  120 CLDBDR = RFL2(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL3(ITHOUT,IPHOUT,ITHIN) - RFL2(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  130 CLDBDR = RFL3(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL4(ITHOUT,IPHOUT,ITHIN) - RFL3(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  140 CLDBDR = RFL4(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL5(ITHOUT,IPHOUT,ITHIN) - RFL4(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  150 CLDBDR = RFL5(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL6(ITHOUT,IPHOUT,ITHIN) - RFL5(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  160 CLDBDR = RFL6(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL7(ITHOUT,IPHOUT,ITHIN) - RFL6(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  170 CLDBDR = RFL7(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL8(ITHOUT,IPHOUT,ITHIN) - RFL7(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  180 CLDBDR = RFL8(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL9(ITHOUT,IPHOUT,ITHIN) - RFL8(ITHOUT,IPHOUT,ITHIN)) *XLAM  CLDBDR
      RETURN                                                             CLDBDR
  190 CLDBDR = RFL9(ITHOUT,IPHOUT,ITHIN)                                 CLDBDR
     1  + (RFL10(ITHOUT,IPHOUT,ITHIN) - RFL9(ITHOUT,IPHOUT,ITHIN)) *XLAM CLDBDR
      RETURN                                                             CLDBDR
      END                                                                CLDBDR
```

```
CLJ       CLOUDA(K) = LONGEST SEMI-AXIS OF CLOUD-K.  ASSUMED TO BE IN     CLDGEOM    59
CLJ                   HORIZONTAL PLANE AND WILL BE IN EAST-WEST           CLDGEOM    60
CLJ                   DIRECTION IF ORIENTATION ANGLE CLDPSI=0.0,  KM      CLDGEOM    61
CLJ       CLOUDB(K) = SEMI-MINOR AXIS IN HORIZONTAL PLANE OF ELLIPSOIDAL CLDGEOM    62
CLJ                   CLOUD-K,  KM                                        CLDGEOM    63
CLJ       CLOUDC(K) = SEMI-MINOR AXIS IN VERTICAL DIRECTION OF            CLDGEOM    64
CLJ                   ELLIPSOIDAL CLOUD-K,  KM                            CLDGEOM    65
CLJ      PARAMS COMMON                                                    CLDGEOM    66
CLJ             RTD = CONVERSION FACTOR FROM RADIANS TO DEGREES           CLDGEOM    67
CLJ             DTR = CONVERSION FACTOR FROM DEGREES TO RADIANS           CLDGEOM    68
CLJ   OUTPUT PARAMETERS                                                   CLDGEOM    69
CLJ      CDCORD COMMON                                                    CLDGEOM    70
CLJ        CTH(I,K) = POLAR ANGLE IN CLOUD-CENTERED COORDINATES OF A      CLDGEOM    71
CLJ                   BOUNDARY OF THE I-TH POLAR SET OF SURFACE FACETS    CLDGEOM    72
CLJ                   FOR THE PRINCIPAL OCTANT OF THE ELLIPSOIDAL         CLDGEOM    73
CLJ                   CLOUD-K,  RADIANS       I=1,5      K=1,20           CLDGEOM    74
CLJ        CPH(J,K) = AZIMUTHAL ANGLE IN CLOUD-CENTERED COORDINATES OF A CLDGEOM    75
CLJ                   BOUNDARY OF THE J-TH AZIMUTHAL SET OF SURFACE       CLDGEOM    76
CLJ                   FACETS FOR THE PRINCIPAL OCTANT OF THE ELLIPSOIDAL CLDGEOM    77
CLJ                   CLOUD-K,  RADIANS       J=1,5      K=1,20           CLDGEOM    78
CLJ     CTHBAR(I,K) = POLAR ANGLE IN CLOUD-CENTERED COORDINATES OF THE    CLDGEOM    79
CLJ                   CENTER OF THE I-TH POLAR SET OF SURFACE FACETS FOR CLDGEOM    80
CLJ                   ELLIPSOIDAL CLOUD-K,  DEGREES     I=1,8      K=1,20 CLDGEOM    81
CLJ    CPHIBAR(J,K) = AZIMUTHAL ANGLE IN CLOUD-CENTERED COORDINATES OF   CLDGEOM    82
CLJ                   THE CENTER OF THE J-TH AZIMUTHAL SET OF SURFACE     CLDGEOM    83
CLJ                   FACETS FOR ELLIPSOIDAL CLOUD-K,  DEGREES            CLDGEOM    84
CLJ                        J=1,16     K=1,20                              CLDGEOM    85
CLJ    CRBAR(I,J,K) = CLOUD-CENTERED RADIAL DISTANCE TO THE CENTER OF    CLDGEOM    86
CLJ                   SURFACE FACET I,J IN PRINCIPAL OCTANT,  KM          CLDGEOM    87
CLJ                      I=1,4      J=1,4      K=1,20                     CLDGEOM    88
CLJ                   (RESULTS FOR OTHER OCTANTS ARE OBTAINED BY SYMTY.) CLDGEOM    89
CLJ    CAREA(I,J,K) = AREA OF SURFACE FACET I,J IN PRINCIPAL OCTANT OF   CLDGEOM    90
CLJ                   ELLIPSOIDAL CLOUD-K,  KM**2   I=1,4  J=1,4  K=1,20 CLDGEOM    91
CLJ           ASQ(K) = SQUARE OF LENGTH A, THE SEMI-MAJOR AXIS IN         CLDGEOM    92
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2        CLDGEOM    93
CLJ           BSQ(K) = SQUARE OF LENGTH B, THE SEMI-MINOR AXIS IN         CLDGEOM    94
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2        CLDGEOM    95
CLJ           CSQ(K) = SQUARE OF LENGTH C, THE SEMI-MINOR AXIS IN         CLDGEOM    96
CLJ                   VERTICAL DIRECTION OF ELLIPSOIDAL CLOUD, KM**2      CLDGEOM    97
CLJ                                                                       CLDGEOM    98
C                                                                         CLDGEOM    99
      COMMON/CLOUD/ NCLOUD,                                               CLOUD       2
     1     HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),        CLOUD       3
     2     CLOUDC(20),CLDPSI(20),KCLOUD(20)                               CLOUD       4
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                    CDCORD      2
     1               XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)       CDCORD      3
     X  , ASQ(20),BSQ(20),CSQ(20)                                          CDCORD      4
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)           CDCORD      5
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                              PARAMS      2
C        MAPPING OF AREAS AND RBARS                                       CLDGEOM   103
C        FIRST QUAD SYMMETRIC AREA-- ALSO GOOD FOR THE THETA INDEX        CLDGEOM   104
CLJ       FUNCTION IPRIME, CALLED WITH A NUMBER IN THE FIRST COLUMN,      CLDGEOM   105
CLJ       SHOULD RETURN THE PAIRED NUMBER IN THE SECOND COLUMN.           CLDGEOM   106
C        1  -  1                                                          CLDGEOM   107
C        2  -  2                                                          CLDGEOM   108
C        3  -  3                                                          CLDGEOM   109
C        4  -  4                                                          CLDGEOM   110
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C        5  -  4                                                        CLDGEOM  111
C        6  -  3                                                        CLDGEOM  112
C        7  -  2                                                        CLDGEOM  113
C        8  -  1                                                        CLDGEOM  114
C        9  -  1                                                        CLDGEOM  115
C        10 -  2                                                        CLDGEOM  116
C        11 -  3                                                        CLDGEOM  117
C        12 -  4                                                        CLDGEOM  118
C        13 -  4                                                        CLDGEOM  119
C        14 -  3                                                        CLDGEOM  120
C        15 -  2                                                        CLDGEOM  121
C        16 -  1                                                        CLDGEOM  122
C     THE AREAS, RBAR TO THE MIDPOINTS,THBAR AND PHIBAR ARE EVALUATED   CLDGEOM  123
C        FOR EACH OF THE CLOUDS                                         CLDGEOM  124
C                                                                       CLDGEOM  125
      DIMENSION G(21)                                                   CLDGEOM  126
      DATA XINT,NINT,NINTM2/20.,21,19/                                  CLDGEOM  127
C                                                                       CLDGEOM  128
C        STATEMENTS TO DETERMINE THETA AND PHI IN THE CLOUD SYSTEM      CLDGEOM  129
C                                                                       CLDGEOM  130
      ALFA = 0.80                                                       CLDGEOM  131
      BETA = 0.80                                                       CLDGEOM  132
      DO 1000 K=1,NCLOUD                                                CLDGEOM  133
      ASQ(K)= CLOUDA(K)**2                                              CLDGEOM  134
      BSQ(K)= CLOUDB(K)**2                                              CLDGEOM  135
      CSQ(K)= CLOUDC(K)**2                                              CLDGEOM  136
      PIBY2 = PI/2.                                                     CLDGEOM  137
      CBYA = CLOUDC(K)/CLOUDA(K)                                        CLDGEOM  138
      BBYA = CLOUDB(K)/CLOUDA(K)                                        CLDGEOM  139
      DTH = PIBY2/(1.+CBYA**ALFA + CBYA**(2.*ALFA) + CBYA**(3.*ALFA))   CLDGEOM  140
      DPH = PIBY2/(1.+BBYA**BETA + BBYA**(2.*BETA) + BBYA**(3.*BETA))   CLDGEOM  141
      CTH(1,K) = 0.0                                                    CLDGEOM  142
      CTH(2,K) = DTH                                                    CLDGEOM  143
      CTH(3,K) = DTH*(1.0 + CBYA**ALFA)                                 CLDGEOM  144
      CTH(4,K) = PIBY2 - DTH*CBYA**(3.*ALFA)                            CLDGEOM  145
      CTH(5,K) = PIBY2                                                  CLDGEOM  146
      CPH(1,K) = 0.0                                                    CLDGEOM  147
      CPH(2,K) = DPH*BBYA**(3.*BETA)                                    CLDGEOM  148
      CPH(3,K) = PIBY2 - DPH*(1.0 + BBYA**BETA)                         CLDGEOM  149
      CPH(4,K) = PIBY2 - DPH                                            CLDGEOM  150
      CPH(5,K) = PIBY2                                                  CLDGEOM  151
      CPHIBAR(1,K) = 0.                                                 CLDGEOM  152
      CTHBAR(1,K) = 0.                                                  CLDGEOM  153
      DO 10 I = 1,4                                                     CLDGEOM  154
      CPHIBAR(I,K) = (CPH (I,K) + CPH (I+1,K)) / 2.                     CLDGEOM  155
      CTHBAR(I,K) =  (CTH (I,K) + CTH (I+1,K)) / 2.                     CLDGEOM  156
      CTHBAR(9-I,K) = PI - CTHBAR(I,K)                                  CLDGEOM  157
      CPHIBAR(9-I,K) = PI - CPHIBAR(I,K)                                CLDGEOM  158
      CPHIBAR(17-I,K) = 2.*PI - CPHIBAR(I,K)                            CLDGEOM  159
        CPHIBAR(8+I,K) = PI + CPHIBAR(I,K)                              CLDGEOM  160
   10 CONTINUE                                                          CLDGEOM  161
      DO 12 I = 1,16                                                    CLDGEOM  162
      CPHIBAR(I,K) = CPHIBAR(I,K) * RTD                                 CLDGEOM  163
      IF(I .GT. 8) GO TO 12                                             CLDGEOM  164
      CTHBAR(I,K) = CTHBAR(I,K) * RTD                                   CLDGEOM  165
   12 CONTINUE                                                          CLDGEOM  166
      DO 15 I = 1,4                                                     CLDGEOM  167
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      A21 = SIN(DTR*CPHIBAR(I,K))**2                                    CLDGEOM  168
      A12 = 1.0-A21                                                     CLDGEOM  169
      DO 15 J = 1,4                                                     CLDGEOM  170
      A31 = COS(DTR*CTHBAR (J,K) )**2                                   CLDGEOM  171
      A11 = 1.0-A31                                                     CLDGEOM  172
      CRBAR(J,I,K) = 1. / SQRT(A11*A12 / ASQ(K)                         CLDGEOM  173
     X + A11*A21/BSQ(K) + A31/CSQ(K) )                                  CLDGEOM  174
   15 CONTINUE                                                          CLDGEOM  175
C                                                                       CLDGEOM  176
C      EVALUATE AREA                                                    CLDGEOM  177
      SURFAC = 0.                                                       CLDGEOM  178
      THETAM = CTH(1,K)                                                 CLDGEOM  179
      DO 390 I=1,4                                                      CLDGEOM  180
      DTHETA = (CTH(I+1,K)-THETAM)/XINT                                 CLDGEOM  181
      PHIM = CPH(1,K)                                                   CLDGEOM  182
      DO 380 J=1,4                                                      CLDGEOM  183
      CAREA(I,J,K) = 0.                                                 CLDGEOM  184
      DPHI = (CPH(J+1,K)-PHIM)/XINT                                     CLDGEOM  185
      DA = DTHETA * DPHI / 9.0                                          CLDGEOM  186
      DO 360 II=1,NINT                                                  CLDGEOM  187
      G(II)=0.0                                                         CLDGEOM  188
      XII=II-1                                                          CLDGEOM  189
      TII=THETAM+XII*DTHETA                                             CLDGEOM  190
      DO 350 JJ=1,NINTM2,2                                              CLDGEOM  191
      YJJ=JJ-1                                                          CLDGEOM  192
      PJJ1=PHIM+YJJ*DPHI                                                CLDGEOM  193
      PJJ2=PJJ1+DPHI                                                    CLDGEOM  194
      PJJ3=PJJ2+DPHI                                                    CLDGEOM  195
      G(II)=G(II)+DSURF(TII,PJJ1,K)+4.*DSURF(TII,PJJ2,K)+               CLDGEOM  196
     1   DSURF(TII,PJJ3,K)                                              CLDGEOM  197
  350 CONTINUE                                                          CLDGEOM  198
  360 CONTINUE                                                          CLDGEOM  199
      DO 370 II=1,NINTM2,2                                              CLDGEOM  200
      CAREA(I,J,K) = CAREA(I,J,K) + DA*(G(II) + 4.*G(II+1) + G(II+2))   CLDGEOM  201
  370 CONTINUE                                                          CLDGEOM  202
      SURFAC = SURFAC + CAREA(I,J,K)                                    CLDGEOM  203
      PHIM = CPH(J+1,K)                                                 CLDGEOM  204
  380 CONTINUE                                                          CLDGEOM  205
      THETAM = CTH(I+1,K)                                               CLDGEOM  206
  390 CONTINUE                                                          CLDGEOM  207
 1000 CONTINUE                                                          CLDGEOM  208
      RETURN                                                            CLDGEOM  209
      END                                                               CLDGEOM  210
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      SUBROUTINE CLDWT(ALAM,ANG)                                        CLDWT      2
      COMMON /CONFIG/CTYPL(8),CTYPM(4),CTYPH(5),CFLAG,C1,C2             CONFIG     2
      COMMON /CLDFREQ/ KMODEL,CCOVER(5,11),CFREQ(17,4,11)               CLDFREQ    2
      COMMON/CLDWT/IDX,WT(161),TRANS(161),EMISS(161)                    CLDWGT     2
      DIMENSION ALX(20),P(20),W(5)                                      CLDWT      6
      EQUIVALENCE(ALX,P)                                                CLDWT      7
      DIMENSION TYPEL(8),TYPEM(4),TYPEH(5)                              CLDWT      8
      DIMENSION ICC(5)                                                  CLDWT      9
      INTEGER H1,H2,HH,CC,C1,C2                                         CLDWT     10
      INTEGER CFLAG                                                     CLDWT     11
CCC                                                                     CLDWT     12
CLJ   SUBROUTINE CLDWT, FOR GIVEN SOURCE AND DETECTOR LOCATIONS,        CLDWT     13
CLJ   COMPUTES THREE ARRAYS (TRANS, EMISS, AND WT), EACH WITH IDX       CLDWT     14
CLJ   MEMBERS (NORMALLY 160).  THE TRANS AND EMISS ARRAYS ARE,          CLDWT     15
CLJ   RESPECTIVELY, (1) THE DISTRIBUTION OF IRRADIANCE-TO-RADIANCE      CLDWT     16
CLJ   TRANSFER COEFFICIENTS (1/SR) AT THE 12-KM ALTITUDE TRANSFER POINT CLDWT     17
CLJ   AND (2) THE DISTRIBUTION OF (ATTENUATED) SPECTRAL RADIANCES       CLDWT     18
CLJ   (WATTS/(KM**2 SR MICRON)) AT 12-KM ALTITUDE AND DIRECTED TOWARD   CLDWT     19
CLJ   THE DETECTOR.  THE WT ARRAY IS THE SET OF WEIGHTS ASSOCIATED WITH CLDWT     20
CLJ   THE SET OF STATISTICAL CLOUD CONFIGURATIONS, INFLUENCED BY        CLDWT     21
CLJ   CLOUD-COVERAGE FRACTIONS AND CLOUD-FREE LINE-OF-SIGHTS FROM THE   CLDWT     22
CLJ   DETECTOR.                                                         CLDWT     23
CCC                                                                     CLDWT     24
CLJ   INPUT VARIABLES                                                   CLDWT     25
CLJ      ARGUMENT LIST                                                  CLDWT     26
CLJ          ALAM = WAVELENGTH,  MICRONS                                CLDWT     27
CLJ           ANG = ZENITH ANGLE OF THE DETECTOR MEASURED AT THE INTER- CLDWT     28
CLJ                 SECTION POINT OF THE DETECTOR LOS WITH THE EARTH'S  CLDWT     29
CLJ                 SURFACE,  DEGREES                                   CLDWT     30
CLJ      CLDFREQ COMMON                                                 CLDWT     31
CLJ          DEFINITIONS OF THE FOLLOWING THREE QUANTITIES ARE IN       CLDWT     32
CLJ          THE BLOCK DATA ROUTINE.  KMODEL, CCOVER(ICC,KMODEL),       CLDWT     33
CLJ          AND CFREQ(KCLOUD,ICC,KMODEL)                               CLDWT     34
CLJ   OUTPUT VARIABLES                                                  CLDWT     35
CLJ      CLDWT COMMON                                                   CLDWT     36
CLJ           IDX = AS AN OUTPUT QUANTITY, IDX IS ONE PLUS THE TOTAL    CLDWT     37
CLJ                 NUMBER OF CLOUD CONFIGURATIONS, WHICH IS 1+159=160  CLDWT     38
CLJ                 FOR KMODEL=1,10.  FOR KMODEL=11, THE USER SUPPLIES  CLDWT     39
CLJ                 STATISTICAL CLOUD DATA AND IDX MAY BE DIFFERENT.    CLDWT     40
CLJ                 HOWEVER, DIMENSION STATEMENTS CURRENTLY RESTRICT    CLDWT     41
CLJ                 IDX FROM BEING LARGER THAN 160.                     CLDWT     42
CLJ          WT(I) = FOR ANY OF THE 10 LOCATION-SEASON AVERAGED         CLDWT     43
CLJ                 STATISTICAL CLOUD MODELS (KMODEL=1,10), WT(I) IS    CLDWT     44
CLJ                 THE PROBABILITY THAT (A) THE CLOUD-CONFIGURATION    CLDWT     45
CLJ                 SET INDICATED BY THE INDEX I OCCURS AND (B) THE     CLDWT     46
CLJ                 DETECTOR LOS AT ZENITH ANGLE ANG INTERSECTS THE     CLDWT     47
CLJ                 CLOUD-CONFIGURATION SET.  THE TOTAL PROBABILITY OF  CLDWT     48
CLJ                 THE DETECTOR LOS INTERSECTING CLOUDS IS SUM(WT(I))  CLDWT     49
CLJ                 (I=1,IDX-1).  THE PROBABILITY THAT THE LOS DOES NOT CLDWT     50
CLJ                 INTERSECT THE CLOUDS BUT SEES THROUGH GAPS IN THE   CLDWT     51
CLJ                 CLOUDS IS WTOLD(IDX).  THE PROBABILITY OF THE LOS   CLDWT     52
CLJ                 SEEING THE GROUND FOR A 0.0 CLOUD-COVERAGE FRACTION CLDWT     53
CLJ                 IS CCOVER(1,KMODEL) IN THE CODE, ALTHOUGH STRICTLY  CLDWT     54
CLJ                 THIS QUANTITY SHOULD BE MULTIPLIED BY CFLOS(0,ANG). CLDWT     55
CLJ                 THE PROBABILITY OF THE LOS SEEING THE GROUND EITHER CLDWT     56
CLJ                 WITH OR WITHOUT CLOUDS BEING PRESENT IS WTNEW(IDX)= CLDWT     57
CLJ                 WTOLD(IDX)+CCOVER(1,KMODEL).  THE PROBABILITY OF    CLDWT     58
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CLJ                 SEEING EITHER CLOUDS OR THE GROUND (WITH OR WITHOUT  CLDWT
CLJ                 CLOUDS BEING PRESENT) IS SUM(WT(I)), (I=1,IDX-1) +  CLDWT
CLJ                 WTNEW(IDX) = 1.0                                     CLDWT
CLJ      TRANS(I) = THE (ATTENUATED) IRRADIANCE-TO-RADIANCE TRANSFER    CLDWT
CLJ                 COEFFICIENT AT THE 12-KM ALTITUDE TRANSFER POINT     CLDWT
CLJ                 FOR CLOUD-CONFIGURATION SET I,  1/SR                 CLDWT
CLJ                 (MORE INFORMATION IS GIVEN IN FUNCTION TRANSF.)      CLDWT
CLJ      EMISS(I) = THE (ATTENUATED) SPECTRAL RADIANCE AT 12-KM         CLDWT
CLJ                 ALTITUDE FOR RADIATION EMITTED AT ZENITH ANGLE ANG   CLDWT
CLJ                 FROM THE HIGHEST CLOUD-TOP IN CLOUD-CONFIGURATION    CLDWT
CLJ                 SET I,  WATTS/(KM**2 SR MICRON)                      CLDWT
CLJ                                                                      CLDWT
CLJ          FOR  WT, TRANS, AND EMISS  I=1,IDX-1                        CLDWT
CCC                                                                      CLDWT
      DATA TYPEL  /3HCU1,3HCU2,3HCU3,3HSC ,3HST ,3HCB1,3HNS ,3HCLR /     CLDWT
      DATA TYPEM  /3HAC ,3HAS1,3HCB2,3HCLR                         /     CLDWT
      DATA TYPEH  /3HCB3,3HAS2,3HCI ,3HCS ,3HCLR                   /     CLDWT
      DATA L1,L2,M1,M2,H1,H2,C1,C2 /1,7,1,3,1,4,2,5     /                CLDWT
      DATA CTYPL / 3HCU1,3HCU2,3HCU3,3HSC ,3HST ,3HCB1,3HNS ,3HCLR /     CLDWT
      DATA CTYPM / 3HAC ,3HAS1,3HCB2,3HCLR       /                       CLDWT
      DATA CTYPH / 3HCB3,3HAS2,3HCI ,3HCS ,3HCLR        /                CLDWT
      DATA ICC / 1,4,6,9,11 /                                            CLDWT
      DATA CFLAG / 1 /                                                   CLDWT
C                                                                        CLDWT
C      INPUTS AND OUTPUTS                                                CLDWT
C        ALAM       WAVELENGTH IN MICROMETERS                           CLDWT
C        WT         PROBABILITY FN  160 (OR OR FEWER) NUMBERS           CLDWT
C        TRANS      TRANSFER COEF (SR-1)                                CLDWT
C        EMISS      THERMAL EMISSION FROM CLOUD (RADIANCE)              CLDWT
C        ANG        LINE OF SIGHT EXIT ANGLE                            CLDWT
C                                                                        CLDWT
      DO 10 I = 1,160                                                    CLDWT
      WT(I) = 0.                                                         CLDWT
      EMISS(I) = 0.                                                      CLDWT
   10 TRANS(I) = 0.0                                                     CLDWT
C                                                                        CLDWT
      DO 500 II = C1,C2                                                  CLDWT
      CC = II                                                            CLDWT
      IDX = 0                                                            CLDWT
      CFLOS = CFLOSF(ICC(II) , ANG)                                      CLDWT
      W(CC) = CCOVER(CC,KMODEL)                                          CLDWT
      NT = 17                                                            CLDWT
      DO 71 J = 1,NT                                                     CLDWT
   71 P(J) = CFREQ(J,CC-1,KMODEL)                                        CLDWT
      TOTL=ALX(1) + ALX(2) + ALX(3) + ALX(4) + ALX(5) + ALX(6) + ALX(7)  CLDWT
      TOTM = ALX(8) + ALX(9) + ALX(10)                                   CLDWT
      TOTH = ALX(11) + ALX(12) + ALX(13) + ALX(14)                       CLDWT
      IF( TOTL .EQ. 0 ) TOTL = 1.                                        CLDWT
      IF( TOTM .EQ. 0 ) TOTM = 1.                                        CLDWT
      IF( TOTH .EQ. 0 ) TOTH = 1.                                        CLDWT
C    1 LAYER                                                             CLDWT
        MM = 4                                                           CLDWT
      HH = 5                                                             CLDWT
      DO 101 LL = L1,L2                                                  CLDWT
      IF(CFLAG.NE. 0 .AND. CTYPL(LL) .NE. TYPEL(LL) ) GO TO 101          CLDWT
      IF(CFLAG.NE. 0 .AND. CTYPM(MM) .NE. TYPEM(MM) ) GO TO 101          CLDWT
      IF(CFLAG.NE. 0 .AND. CTYPH(HH) .NE. TYPEH(HH) ) GO TO 101          CLDWT
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      PIJKL = P(LL) * P(15) * W(CC)                                     CLDWT    116
      IDX = IDX + 1                                                     CLDWT    117
      IF(TRANS(IDX) .NE. 0.) GO TO 1101                                 CLDWT    118
      TRANS(IDX) = TRANSF(ALAM,LL,MM,HH)                                CLDWT    119
      EMISS(IDX) = EMISSF(ALAM,LL,MM,HH)                                CLDWT    120
 1101 CONTINUE                                                          CLDWT    121
      WT(IDX) = WT(IDX) + PIJKL*(1. - CFLOS)                            CLDWT    122
       WT(160) = WT(160) + PIJKL * CFLOS                                CLDWT    123
  101 CONTINUE                                                          CLDWT    124
        LL = 8                                                          CLDWT    125
      HH = 5                                                            CLDWT    126
      DO 102 MM = M1,M2                                                 CLDWT    127
      IF(CFLAG.NE. 0 .AND. CTYPL(LL) .NE. TYPEL(LL) ) GO TO 102         CLDWT    128
      IF(CFLAG.NE. 0 .AND. CTYPM(MM) .NE. TYPEM(MM) ) GO TO 102         CLDWT    129
      IF(CFLAG.NE. 0 .AND. CTYPH(HH) .NE. TYPEH(HH) ) GO TO 102         CLDWT    130
      PIJKL = P(MM+7) * P(15) * W(CC)                                   CLDWT    131
      IDX = IDX + 1                                                     CLDWT    132
      IF(TRANS(IDX) .NE. 0.) GO TO 1102                                 CLDWT    133
      TRANS(IDX) = TRANSF(ALAM,LL,MM,HH)                                CLDWT    134
      EMISS(IDX) = EMISSF(ALAM,LL,MM,HH)                                CLDWT    135
 1102 CONTINUE                                                          CLDWT    136
      WT(IDX) = WT(IDX) + PIJKL*(1. - CFLOS)                            CLDWT    137
       WT(160) = WT(160) + PIJKL * CFLOS                                CLDWT    138
  102 CONTINUE                                                          CLDWT    139
      LL = 8                                                            CLDWT    140
      MM = 4                                                            CLDWT    141
      DO 103 HH = H1,H2                                                 CLDWT    142
      IF(CFLAG.NE. 0 .AND. CTYPL(LL) .NE. TYPEL(LL) ) GO TO 103         CLDWT    143
      IF(CFLAG.NE. 0 .AND. CTYPM(MM) .NE. TYPEM(MM) ) GO TO 103         CLDWT    144
      IF(CFLAG.NE. 0 .AND. CTYPH(HH) .NE. TYPEH(HH) ) GO TO 103         CLDWT    145
      PIJKL = P(HH+10)*P(15) * W(CC)                                    CLDWT    146
      IDX = IDX + 1                                                     CLDWT    147
      IF(TRANS(IDX) .NE. 0.) GO TO 1103                                 CLDWT    148
      TRANS(IDX) = TRANSF(ALAM,LL,MM,HH)                                CLDWT    149
      EMISS(IDX) = EMISSF(ALAM,LL,MM,HH)                                CLDWT    150
 1103 CONTINUE                                                          CLDWT    151
      WT(IDX) = WT(IDX) + PIJKL*(1. - CFLOS)                            CLDWT    152
       WT(160) = WT(160) + PIJKL * CFLOS                                CLDWT    153
  103 CONTINUE                                                          CLDWT    154
C   2- LAYER                                                            CLDWT    155
      DEN = TOTL * TOTM + TOTL * TOTH + TOTM * TOTH                     CLDWT    156
C     2 LAYER CASE   LL AND MM                                          CLDWT    157
      HH = 5                                                            CLDWT    158
      DO 200 LL = L1,L2                                                 CLDWT    159
      DO 200 MM = M1,M2                                                 CLDWT    160
      IF(CFLAG.NE. 0 .AND. CTYPL(LL) .NE. TYPEL(LL) ) GO TO 200         CLDWT    161
      IF(CFLAG.NE. 0 .AND. CTYPM(MM) .NE. TYPEM(MM) ) GO TO 200         CLDWT    162
      IF(CFLAG.NE. 0 .AND. CTYPH(HH) .NE. TYPEH(HH) ) GO TO 200         CLDWT    163
      PL = ALX(LL)/ TOTL                                                CLDWT    164
      PM = ALX(MM+7) / TOTM                                             CLDWT    165
      PIJKL = PL*PM*TOTL*TOTM/DEN*W(CC) * P(16)                         CLDWT    166
      IDX = IDX + 1                                                     CLDWT    167
      IF(TRANS(IDX) .NE. 0.) GO TO 1201                                 CLDWT    168
      TRANS(IDX) = TRANSF(ALAM,LL,MM,HH)                                CLDWT    169
      EMISS(IDX) = EMISSF(ALAM,LL,MM,HH)                                CLDWT    170
 1201 CONTINUE                                                          CLDWT    171
      WT(IDX) = WT(IDX) + PIJKL*(1. - CFLOS)                            CLDWT    172
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      WT(160) = WT(160) + PIJKL * CFLOS                                 CLDWT   173
  200 CONTINUE                                                          CLDWT   174
C  2 LAYER CASE LL AND HH                                               CLDWT   175
      MM = 4                                                            CLDWT   176
      DO 201 LL = L1,L2                                                 CLDWT   177
      DO 201 HH = H1,H2                                                 CLDWT   178
      IF(CFLAG.NE. 0 .AND. CTYPL(LL) .NE. TYPEL(LL) ) GO TO 201         CLDWT   179
      IF(CFLAG.NE. 0 .AND. CTYPM(MM) .NE. TYPEM(MM) ) GO TO 201         CLDWT   180
      IF(CFLAG.NE. 0 .AND. CTYPH(HH) .NE. TYPEH(HH) ) GO TO 201         CLDWT   181
      PL = ALX(LL)/ TOTL                                                CLDWT   182
      PH = ALX(HH+10) / TOTH                                            CLDWT   183
      PIJKL = PL * PH * TOTL * TOTH / DEN * W(CC) * P(16)               CLDWT   184
      IDX = IDX + 1                                                     CLDWT   185
      IF(TRANS(IDX) .NE. 0.) GO TO 1202                                 CLDWT   186
      TRANS(IDX) = TRANSF(ALAM,LL,MM,HH)                                CLDWT   187
      EMISS(IDX) = EMISSF(ALAM,LL,MM,HH)                                CLDWT   188
 1202 CONTINUE                                                          CLDWT   189
      WT(IDX) = WT(IDX) + PIJKL*(1. - CFLOS)                            CLDWT   190
      WT(160) = WT(160) + PIJKL * CFLOS                                 CLDWT   191
  201 CONTINUE                                                          CLDWT   192
C  2 LAYER CASE MM AND HH                                               CLDWT   193
      LL = 8                                                            CLDWT   194
      DO 202 MM = M1,M2                                                 CLDWT   195
      DO 202 HH = H1,H2                                                 CLDWT   196
      IF(CFLAG.NE. 0 .AND. CTYPL(LL) .NE. TYPEL(LL) ) GO TO 202         CLDWT   197
      IF(CFLAG.NE. 0 .AND. CTYPM(MM) .NE. TYPEM(MM) ) GO TO 202         CLDWT   198
      IF(CFLAG.NE. 0 .AND. CTYPH(HH) .NE. TYPEH(HH) ) GO TO 202         CLDWT   199
      PM = ALX(MM+7) / TOTM                                             CLDWT   200
      PH = ALX(HH+10) / TOTH                                            CLDWT   201
      PIJKL = PM * PH * TOTM * TOTH / DEN * W(CC) * P(16)               CLDWT   202
      IDX = IDX + 1                                                     CLDWT   203
      IF(TRANS(IDX) .NE. 0.) GO TO 1203                                 CLDWT   204
      TRANS(IDX) = TRANSF(ALAM,LL,MM,HH)                                CLDWT   205
      EMISS(IDX) = EMISSF(ALAM,LL,MM,HH)                                CLDWT   206
 1203 CONTINUE                                                          CLDWT   207
      WT(IDX) = WT(IDX) + PIJKL*(1. - CFLOS)                            CLDWT   208
      WT(160) = WT(160) + PIJKL * CFLOS                                 CLDWT   209
  202 CONTINUE                                                          CLDWT   210
C  3 LAYER CASE                                                         CLDWT   211
      DO 300 LL = L1,L2                                                 CLDWT   212
      DO 300 MM = M1,M2                                                 CLDWT   213
      DO 300 HH = H1,H2                                                 CLDWT   214
      IF(CFLAG.NE. 0 .AND. CTYPL(LL) .NE. TYPEL(LL) ) GO TO 300         CLDWT   215
      IF(CFLAG.NE. 0 .AND. CTYPM(MM) .NE. TYPEM(MM) ) GO TO 300         CLDWT   216
      IF(CFLAG.NE. 0 .AND. CTYPH(HH) .NE. TYPEH(HH) ) GO TO 300         CLDWT   217
      PL = ALX(LL)/ TOTL                                                CLDWT   218
      PM = ALX(MM+7) / TOTM                                             CLDWT   219
      PH = ALX(HH+10) / TOTH                                            CLDWT   220
      PIJKL = PL * PM * PH * W(CC) * P(17)                              CLDWT   221
      IDX = IDX + 1                                                     CLDWT   222
      IF(TRANS(IDX) .NE. 0.) GO TO 1301                                 CLDWT   223
      TRANS(IDX) = TRANSF(ALAM,LL,MM,HH)                                CLDWT   224
      EMISS(IDX) = EMISSF(ALAM,LL,MM,HH)                                CLDWT   225
 1301 CONTINUE                                                          CLDWT   226
      WT(IDX) = WT(IDX) + PIJKL*(1. - CFLOS)                            CLDWT   227
      WT(160) = WT(160) + PIJKL * CFLOS                                 CLDWT   228
  300 CONTINUE                                                          CLDWT   229
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  500 CONTINUE                                                          CLDWT   230
C        ADD IN CLEAR SKY                                               CLDWT   231
      WT(160) = WT(160) + CCOVER(1,KMODEL)                              CLDWT   232
      IDX = IDX + 1                                                     CLDWT   233
      WT(IDX) = WT(160)                                                 CLDWT   234
CLJ       TRANS(IDX) AND EMISS(IDX) WILL BE COMPUTED                    CLDWT   235
CLJ       IN SUBROUTINE SCLOUD.                                         CLDWT   236
 1112 RETURN                                                            CLDWT   237
      END                                                               CLDWT   238
```

```
      SUBROUTINE CLOUDO(MODE)                                           CLOUDO    2
      COMMON/CLOUD/ NCLOUD,                                             CLOUD     2
     1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),      CLOUD     3
     2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                             CLOUD     4
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS    2
      COMMON /CONFIG/CTYPL(8),CTYPM(4),CTYPH(5),CFLAG,C1,C2             CONFIG    2
      COMMON /CLDFREQ/ KMODEL,CCOVER(5,11),CFREQ(17,4,11)               CLDFREQ   2
CCC                                                                     CLOUDO    7
CLJ   SUBROUTINE CLOUDO FIRST READS A FLAG (MODE) INDICATING BY A VALUE CLOUDO    8
CLJ   OF 0 OR 1 WHETHER THE DETERMINISTIC- OR STATISTICAL-CLOUD SUB-    CLOUDO    9
CLJ   MODEL IS DESIRED.  THE ROUTINE THEN READS CLOUD DATA APPROPRIATE  CLOUDO   10
CLJ   TO THE INDICATED SUBMODEL AND MAKES THEM AVAILABLE TO THE         CLOUDO   11
CLJ   APPROPRIATE ROUTINES.                                             CLOUDO   12
CLJ   FOR THE DETERMINISTIC SUBMODEL (MODE=0), THE NUMBER OF CLOUDS,    CLOUDO   13
CLJ   THEIR LOCATIONS, TYPES, SIZES, AND (AZIMUTHAL) ORIENTATIONS ARE   CLOUDO   14
CLJ   READ AND OUTPUTTED THROUGH CLOUD COMMON.                          CLOUDO   15
CLJ   FOR THE STATISTICAL SUBMODEL (MODE=1), THE ROUTINE READS AN INDEX CLOUDO   16
CLJ   KMODEL WHICH SELECTS DATA FROM THAT IN THE CODE OR ALLOWS THE     CLOUDO   17
CLJ   USER TO INPUT HIS OWN DATA.  OTHER FLAGS ARE READ WHICH ALLOW     CLOUDO   18
CLJ   SELECTED PORTIONS OF THE PROVIDED DATA TO BE OVERRIDDEN.  THESE   CLOUDO   19
CLJ   USER-PROVIDED DATA ARE OUTPUTTED THROUGH CLDFREQ AND CONFIG       CLOUDO   20
CLJ   COMMONS AND OVERRIDE DATA IN BLOCK DATA.                          CLOUDO   21
CCC                                                                     CLOUDO   22
CLJ   INPUT VARIABLES                                                   CLOUDO   23
CLJ      READ IN                                                        CLOUDO   24
CLJ            MODE = FLAG FOR DETERMINISTIC- OR STATISTICAL-CLOUD      CLOUDO   25
CLJ                   SUBMODEL                                          CLOUDO   26
CLJ                 = 0  FOR DETERMINISTIC-CLOUD SUBMODEL               CLOUDO   27
CLJ                 = 1  FOR STATISTICAL-CLOUD SUBMODEL                 CLOUDO   28
CLJ       FOR MODE=0 READ...   (DETERMINISTIC SUBMODEL)                 CLOUDO   29
CLJ          NCLOUD    = NUMBER OF CLOUDS                               CLOUDO   30
CLJ       FOR I=1,NCLOUD...                                             CLOUDO   31
CLJ          KCLOUD(I) = CLOUD-TYPE INDEX,  1,2,...14                   CLOUDO   32
CLJ          HCLOUD(I) = ALTITUDE OF CLOUD-I CENTER ABOVE THE           CLOUDO   33
CLJ                      SURFACE,  KM                                   CLOUDO   34
CLJ          THETCD(I) = COLATITUDE OF CLOUD-I,  DEGREES                CLOUDO   35
CLJ           PHICD(I) = EAST LONGITUDE OF CLOUD-I,  DEGREES            CLOUDO   36
CLJ          CLOUDA(I) = PRINCIPAL SEMIAXIS OF ELLIPSOIDAL CLOUD-I      CLOUDO   37
CLJ                      IN HORIZONTAL DIRECTION,  KM                   CLOUDO   38
CLJ          CLOUDB(I) = PRINCIPAL SEMIAXIS OF ELLIPSOIDAL CLOUD-I      CLOUDO   39
CLJ                      IN HORZONTAL DIRECTION,  KM                    CLOUDO   40
CLJ          CLOUDC(I) = PRINCIPAL SEMIAXIS OF ELLIPSOIDAL CLOUD-I      CLOUDO   41
CLJ                      IN VERTICAL DIRECTION,  KM                     CLOUDO   42
CLJ          CLDPSI(I) = AZIMUTHAL ANGLE, MEASURED COUNTERCLOCKWISE     CLOUDO   43
CLJ                      LOOKING DOWN, ORIENTING CLOUD ABOUT (VERTICAL) CLOUDO   44
CLJ                      Z-AXIS.  CLOUDS ARE NORMALLY ORIENTED WITH     CLOUDO   45
CLJ                      (+A)-AXIS EASTWARD (PSI=0.),  DEGREES          CLOUDO   46
CLJ       FOR MODE=1 READ...   ( STATISTICAL  SUBMODEL)                 CLOUDO   47
CLJ          KMODEL = FLAG CONTROLLING THE READING OF USER-SUPPLIED     CLOUDO   48
CLJ                   STATISTICAL CLOUD DATA (FURTHER DESCRIPTION IN    CLOUDO   49
CLJ                   BLOCK DATA)                                       CLOUDO   50
CLJ                 - 1,10  CODE USES DATA IN BLOCK DATA                CLOUDO   51
CLJ                 - 11    USER MUST READ IN FOLLOWING QUANTITIES...   CLOUDO   52
CLJ                         CCOVER(ICC,11)  ICC=1,5                     CLOUDO   53
CLJ                         CFREQ(K,ICC-1,11)  K=1,17   ICC=2,5         CLOUDO   54
CLJ                         (DEFINITIONS IN BLOCK DATA)                 CLOUDO   55
CLJ          KCOVER = FLAG CONTROLLING THE READING OF OVERRIDE DATA     CLOUDO   56
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CLJ                 FOR CCOVER(ICC,KMODEL),   ICC=1,5                    CLOUDO
CLJ               - 0  DO NOT READ OVERRIDE DATA                         CLOUDO
CLJ               - 1  DO READ OVERRIDE DATA                             CLOUDO
CLJ        KLAYER = FLAG CONTROLLING THE READING OF OVERRIDE DATA FOR    CLOUDO
CLJ                 CFREQ(I,ICC-1,KMODEL),  I=15,17   ICC=2,5            CLOUDO
CLJ               - 0  DO NOT READ OVERRIDE DATA                         CLOUDO
CLJ               - 1  DO READ OVERRIDE DATA                             CLOUDO
CLJ         KTYPL = FLAG CONTROLLING THE READING OF HOLLERITH            CLOUDO
CLJ                 ABBREVIATIONS SPECIFYING TYPES OF THE SEVEN          CLOUDO
CLJ                 POSSIBLE LOW-ALTITUDE CLOUDS OR CLEAR SKY (CLR)      CLOUDO
CLJ               - 0  DO NOT READ DATA                                  CLOUDO
CLJ               - 1  DO READ DATA                                      CLOUDO
CLJ                        CTYPL(1)  =  CU1        CTYPL(5)  =  ST       CLOUDO
CLJ                        CTYPL(2)  =  CU2        CTYPL(6)  =  CB1      CLOUDO
CLJ                        CTYPL(3)  =  CU3        CTYPL(7)  =  NS       CLOUDO
CLJ                        CTYPL(4)  =  SC         CTYPL(8)  =  CLR      CLOUDO
CLJ         KTYPM = FLAG CONTROLLING THE READING OF HOLLERITH            CLOUDO
CLJ                 ABBREVIATIONS SPECIFYING TYPES OF THE THREE          CLOUDO
CLJ                 POSSIBLE MID-ALTITUDE CLOUDS OR CLEAR SKY (CLR)      CLOUDO
CLJ               - 0  DO NOT READ DATA                                  CLOUDO
CLJ               - 1  DO READ DATA                                      CLOUDO
CLJ                        CTYPM(1)  =  AC         CTYPM(3)  =  CB2      CLOUDO
CLJ                        CTYPM(2)  =  AS1        CTYPM(4)  =  CLR      CLOUDO
CLJ         KTYPH = FLAG CONTROLLING THE READING OF HOLLERITH            CLOUDO
CLJ                 ABBREVIATIONS SPECIFYING TYPES OF THE FOUR           CLOUDO
CLJ                 POSSIBLE HIGH-ALTITUDE CLOUDS OR CLEAR SKY (CLR)     CLOUDO
CLJ               - 0  DO NOT READ DATA                                  CLOUDO
CLJ               - 1  DO READ DATA                                      CLOUDO
CLJ                        CTYPH(1)  =  CB3        CTYPH(4)  =  CS       CLOUDO
CLJ                        CTYPH(2)  =  AS2        CTYPH(5)  =  CLR      CLOUDO
CLJ                        CTYPH(3)  =  CI                               CLOUDO
CLJ   OUTPUT VARIABLES                                                   CLOUDO
CLJ      ARGUMENT LIST                                                   CLOUDO
CLJ            MODE = SEE INPUT FOR DEFINITION                           CLOUDO
CLJ      OUTPUT VARIABLES IF MODE=0                                      CLOUDO
CLJ      CLOUD COMMON                                                    CLOUDO
CLJ             NCLOUD,  FOR I=1,NCLOUD...                               CLOUDO
CLJ                 HCLOUD(I),  THETCD(I),    PHICD(I),                  CLOUDO
CLJ                 CLOUDA(I),  CLOUDB(I),  CLOUDC(I)                    CLOUDO
CLJ                   (DEFINITIONS GIVEN ABOVE IN INPUT)                 CLOUDO
CLJ      OUTPUT VARIABLES IF MODE=1                                      CLOUDO
CLJ      CLDFREQ COMMON                                                  CLOUDO
CLJ             KMODEL,  IF KMODEL=11...                                 CLOUDO
CLJ                 CCOVER(I,11)  I=1,5                                  CLOUDO
CLJ                 CFREQ(I,J,11)  I=1,17   J=1,4                        CLOUDO
CLJ                     IF KMODEL=1,10... AND IF                         CLOUDO
CLJ                 KCOVER=1,  CCOVER(I,KMODEL)  I=1,5                   CLOUDO
CLJ                 KLAYER=1,  CFREQ(I,J,KMODEL)  I=15,17   J=1,4        CLOUDO
CLJ      CONFIG COMMON                                                   CLOUDO
CLJ                 KTYPL=1,  CTYPL(I)  I=1,8                            CLOUDO
CLJ                 KTYPM=1,  CTYPM(I)  I=1,4                            CLOUDO
CLJ                 KTYPH=1,  CTYPH(I)  I=1,5                            CLOUDO
CCC                                                                      CLOUDO
      READ(IN,10) MODE                                                   CLOUDO
      IF(MODE .EQ. 1) GO TO 4                                            CLOUDO
       READ(IN,10) NCLOUD                                                CLOUDO
      WRITE(6,6) MODE,NCLOUD                                             CLOUDO
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```
    6 FORMAT(* MODE=*,I2 /* NCLOUD=*,I2/ )                                CLOUD0
      DO 5 I=1,NCLOUD                                                    CLOUD0
      READ(IN,19)KCLOUD(I),HCLOUD(I),THETCD(I),PHICD(I),CLOUDA(I),       CLOUD0
     X CLOUDB(I),CLOUDC(I),CLDPSI(I)                                     CLOUD0
    5 CONTINUE                                                           CLOUD0
      WRITE(IOUT,30)                                                     CLOUD0
      WRITE(IOUT,50)                                                     CLOUD0
      WRITE(IOUT,21)( KCLOUD(I),HCLOUD(I),THETCD(I),PHICD(I),CLOUDA(I),  CLOUD0
     X CLOUDB(I),CLOUDC(I),CLDPSI(I),I=1,NCLOUD )                        CLOUD0
      CALL CLDGEOM                                                       CLOUD0
      RETURN                                                             CLOUD0
C        READ STATISTICAL CLOUD INFORMATION                              CLOUD0
    4 CONTINUE                                                           CLOUD0
      READ(5,8) KMODEL,KCOVER,KLAYER,KTYPL,KTYPM,KTYPH                   CLOUD0
    8 FORMAT(6I5)                                                        CLOUD0
      WRITE(IOUT,15)  MODE,KMODEL,KCOVER,KLAYER,KTYPL,KTYPM,KTYPH        CLOUD0
   15 FORMAT (*0  MODE  =*,I4,4X,*KMODEL =*,I4,4X,*KCOVER =*,I4,4X,      CLOUD0
     1 *KLAYER =*,I4/*   KTYPL =*,I4,4X,* KTYPM =*,I4,4X,* KTYPH =*,I4)  CLOUD0
      IF(KMODEL .LT. 11) GO TO 17                                        CLOUD0
      READ(5,12) (CCOVER(I,11),I=1,5)                                    CLOUD0
      WRITE(IOUT,16)  (CCOVER(I,11),I=1,5)                               CLOUD0
      DO 7 J = 1,4                                                       CLOUD0
      READ(5,12)(CFREQ (I,J,11),I=1,17)                                  CLOUD0
      WRITE(IOUT,18)  J, (CFREQ(I,J,11),I=1,17)                          CLOUD0
    7 CONTINUE                                                           CLOUD0
   17 CONTINUE                                                           CLOUD0
   12 FORMAT(17F4.3)                                                     CLOUD0
   13 FORMAT(8A5)                                                        CLOUD0
   16 FORMAT (*0   CCOVER(I,11)= *, 5F6.3)                               CLOUD0
   18 FORMAT (*   CFREQ(I,*,I1,*,11) =*,17F6.3)                          CLOUD0
C                                                                        CLOUD0
C        READ MODIFICATIONS TO CLOUD STATISTICS HERE                     CLOUD0
C        I.E. PARTICULAR CLOUD COVERAGE CATEGORY                         CLOUD0
C                                                                        CLOUD0
      IF(KCOVER .GT. 0) READ(5,12) (CCOVER(I,KMODEL),I=1,5)              CLOUD0
      IF(KLAYER .GT. 0) READ(5,12) (( CFREQ(I,J,KMODEL),I=15,17),J=1,4)  CLOUD0
CLJ       NOTE THAT THE VARIABLES CTYPL(I), CTYPM(I), AND CTYPH(I)       CLOUD0
CLJ       MUST BE LEFT-JUSTIFIED IN THE 5-COLUMN FIELDS.                 CLOUD0
      IF(KTYPL .GT. 0) READ(5,13) (CTYPL(I),I=1,8)                       CLOUD0
      IF(KTYPM .GT. 0) READ(5,13) (CTYPM(I),I=1,4)                       CLOUD0
      IF(KTYPH .GT. 0) READ(5,13) (CTYPH(I),I=1,5)                       CLOUD0
C                                                                        CLOUD0
C                                                                        CLOUD0
C                                                                        CLOUD0
C                                                                        CLOUD0
C                                                                        CLOUD0
C                                                                        CLOUD0
  100   WRITE(IOUT,40)                                                   CLOUD0
      RETURN                                                             CLOUD0
   10 FORMAT(I10)                                                        CLOUD0
   19 FORMAT(I2,E8.3,6E10.4)                                             CLOUD0
   21 FORMAT(5X,I5,1P7E11.4)                                             CLOUD0
   30 FORMAT(20X*OPERATING IN THE DETERMINISTIC MODE *)                  CLOUD0
   40 FORMAT(20X * OPERATING IN THE STATISTICAL MODE*)                   CLOUD0
   50 FORMAT(30X* CLOUD DATA*/4X*KCLOUD*3X*ALT*7X*THETA*5X*PHI*7X,       CLOUD0
     X *A*9X*B*9X*C*9X*PSI*/)                                            CLOUD0
      END                                                                CLOUD0
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```
      SUBROUTINE CLOUD1                                                 CLOUD1
C                                                                       CLOUD1
C      GET SOURCE POSITIONS AND DETECTOR POSITION IN CLOUD COORDINATES  CLOUD1
C                                                                       CLOUD1
CLJ                                                                     CLOUD1
CLJ   INPUT PARAMETERS                                                  CLOUD1
CLJ      CLOUD COMMON                                                   CLOUD1
CLJ          NCLOUD = NUMBER OF DETERMINISTIC CLOUDS (READ IN SUBROUTINE CLOUD1
CLJ                   CLOUDO)                                           CLOUD1
CLJ      DETECT COMMON                                                  CLOUD1
CLJ              HD = ALTITUDE OF DETECTOR,  KM                         CLOUD1
CLJ          THETAD = COLATITUDE OF DETECTOR,  DEGREES                  CLOUD1
CLJ            PHID = EAST LONGITUDE OF DETECTOR, DEGREES               CLOUD1
CLJ      PARAMS COMMON                                                  CLOUD1
CLJ              RE = EARTH'S RADIUS,  KM                               CLOUD1
CLJ      SORCE COMMON                                                   CLOUD1
CLJ          NSORCE = NUMBER OF SOURCES (CURRENTLY RESTRICTED TO ONE)   CLOUD1
CLJ       HSORCE(I) = ALTITUDE OF SOURCE-I ABOVE SURFACE,  KM           CLOUD1
CLJ       THETAS(I) = COLATITUDE OF SOURCE-I,  DEGREES                  CLOUD1
CLJ         PHIS(I) = EAST LONGITUDE OF SOURCE-I,  DEGREES              CLOUD1
CLJ   OUTPUT PARAMETERS                                                 CLOUD1
CLJ      CDCORD COMMON                                                  CLOUD1
CLJ        XI(I,K), = COORDINATES OF SOURCE-I IN K-TH CLOUD-CENTERED    CLOUD1
CLJ       ETA(I,K),   CARTESIAN SYSTEM,  KM        I=1        K=1,20    CLOUD1
CLJ      ZETA(I,K)                                                      CLOUD1
CLJ         XID(K), = COORDINATES OF DETECTOR IN K-TH CLOUD-CENTERED    CLOUD1
CLJ        ETAD(K),   CARTESIAN SYSTEM,  KM        K=1,20               CLOUD1
CLJ       ZETAD(K)                                                      CLOUD1
CLJ                                                                     CLOUD1
      COMMON/CLOUD/ NCLOUD,                                             CLOUD    2
     1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),      CLOUD    3
     2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                              CLOUD    4
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS   2
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                  CDCORD   2
     1               XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)    CDCORD   3
     X  , ASQ(20),BSQ(20),CSQ(20)                                       CDCORD   4
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)         CDCORD   5
      COMMON/SORCE/  NSORCE,HSORCE(1),RSORCE(1),THETAS(1),PHIS(1)       SORCE    2
      COMMON / DETECT/ HD, THETAD,PHID,FOV                              DET      2
      DO 58 K=1,NCLOUD                                                  CLOUD1  36
      DO 55 I=1,NSORCE                                                  CLOUD1  37
C                                                                       CLOUD1  38
      CALL CLD E TO C(RE+HSORCE(I),THETAS(I),PHIS(I),XI(I,K),           CLOUD1  39
     X ETA(I,K),ZETA(I,K),K )                                           CLOUD1  40
C                                                                       CLOUD1  41
   55 CONTINUE                                                          CLOUD1  42
C                                                                       CLOUD1  43
      CALL CLD E TO C(RE +HD,THETAD,PHID,XID(K),ETAD(K),ZETAD(K),K)     CLOUD1  44
C                                                                       CLOUD1  45
   58 CONTINUE                                                          CLOUD1  46
      RETURN                                                            CLOUD1  47
      END                                                               CLOUD1  48
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      SUBROUTINE CLOUD2(UL,VL,WL)                                       CLOUD2     2
CLJ                                                                     CLOUD2     3
CLJ   SUBROUTINE CLOUD2 IS AN AUXILIARY SUBROUTINE, OUTSIDE THE MAIN    CLOUD2     4
CLJ   FLOW OF INFORMATION IN THE DETERMINISTIC CLOUD SUBMODEL.  ITS     CLOUD2     5
CLJ   OUTPUT IS NOT USED BY ANY OF THE OTHER ROUTINES IN THE NATURAL    CLOUD2     6
CLJ   CLOUD MODEL.  HOWEVER, CLOUD2 IS AN IMPORTANT ROUTINE, DESIGNED   CLOUD2     7
CLJ   MAINLY FOR THE USE OF THE SIGHT-PATH-INTEGRATION MODELER IN       CLOUD2     8
CLJ   ROSCOE-IR.  GIVEN THE DIRECTION COSINES OF AN ARBITRARY LOS (NOT  CLOUD2     9
CLJ   NECESSARILY ONE OF THE IMPORTANT SET SELECTED BY SUBROUTINE LOS), CLOUD2    10
CLJ   CLOUD2 WILL DETERMINE WHETHER OR NOT THE LOS INTERCEPTS ANY OF THE CLOUD2    11
CLJ   DETERMINISTIC CLOUDS.  FOR EACH INTERCEPT THE ALTITUDE (ALTLK(K)) CLOUD2    12
CLJ   AND GEOGRAPHIC (POLAR) COORDINATES (THETALK(K),PHILK(K)) OF THE   CLOUD2    13
CLJ   INTERCEPT ARE SET IN INTRCPT COMMON.                              CLOUD2    14
CLJ                                                                     CLOUD2    15
CLJ   INPUT PARAMETERS                                                  CLOUD2    16
CLJ      ARGUMENT LIST                                                  CLOUD2    17
CLJ             UL, = DIRECTION COSINES IN EARTH-CENTERED CARTESIAN     CLOUD2    18
CLJ             VL,   SYSTEM OF A USER-SPECIFIED LOS (SET IN DRIVER)    CLOUD2    19
CLJ             WL                                                      CLOUD2    20
CLJ      CDCORD COMMON                                                  CLOUD2    21
CLJ         XID(K), = COORDINATES OF DETECTOR IN K-TH CLOUD-CENTERED    CLOUD2    22
CLJ        ETAD(K),   CARTESIAN SYSTEM,  KM        K=1,20               CLOUD2    23
CLJ       ZETAD(K)                                                      CLOUD2    24
CLJ      CLOUD COMMON                                                   CLOUD2    25
CLJ          NCLOUD = NUMBER OF DETERMINISTIC CLOUDS (READ IN SUBROUTINE CLOUD2    26
CLJ                   CLOUDO)                                           CLOUD2    27
CLJ      DETECT COMMON                                                  CLOUD2    28
CLJ              HD = ALTITUDE OF DETECTOR,  KM                         CLOUD2    29
CLJ          THETAD = COLATITUDE OF DETECTOR,  DEGREES                  CLOUD2    30
CLJ            PHID = EAST LONGITUDE OF DETECTOR, DEGREES               CLOUD2    31
CLJ      PARAMS COMMON                                                  CLOUD2    32
CLJ             DTR = CONVERSION FACTOR FROM DEGREES TO RADIANS         CLOUD2    33
CLJ              RE = EARTH'S RADIUS,  KM                               CLOUD2    34
CLJ   OUTPUT PARAMETERS                                                 CLOUD2    35
CLJ      INTRCPT COMMON                                                 CLOUD2    36
CLJ        ALTLK(K) = ALTITUDE AT WHICH THE USER-SPECIFIED LOS          CLOUD2    37
CLJ                   INTERCEPTS CLOUD-K,  KM                           CLOUD2    38
CLJ      THETALK(K) = GEOGRAPHIC POLAR COORDINATE AT WHICH THE USER-    CLOUD2    39
CLJ                   SPECIFIED LOS INTERCEPTS CLOUD-K,  DEG            CLOUD2    40
CLJ        PHILK(K) = GEOGRAPHIC AZIMUTHAL COORDINATE AT WHICH THE USER- CLOUD2    41
CLJ                   SPECIFIED LOS INTERCEPTS CLOUD-K,  DEG            CLOUD2    42
CLJ                                                                     CLOUD2    43
      COMMON/CLOUD/ NCLOUD,                                             CLOUD      2
     1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),      CLOUD      3
     2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                              CLOUD      4
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS     2
      COMMON / DETECT/ HD, THETAD,PHID,FOV                              DET        2
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                  CDCORD     2
     1               XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)     CDCORD     3
     X  , ASQ(20),BSQ(20),CSQ(20)                                       CDCORD     4
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)         CDCORD     5
      COMMON/INTRCPT/ ALTLK(20),THETALK(20),PHILK(20)                   INTERCPT   2
      CT = COS(DTR * THETAD)                                            CLOUD2    49
      CP = COS(DTR * PHID)                                              CLOUD2    50
      ST = SIN( DTR*THETAD )                                            CLOUD2    51
      SP = SIN( DTR*PHID )                                              CLOUD2    52
C                                                                       CLOUD2    53
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C                                                                       CLOUD2     54
C         TRANSFORM LOS TO CLOUD CENTERED SYSTEM                        CLOUD2     55
CLJ        ADD UNIT LOS VECTOR TO DETECTOR POSITION IN EARTH-CENTERED   CLOUD2     56
CLJ        CARTESIAN SYSTEM.                                            CLOUD2     57
      RD = (RD + RE)                                                    CLOUD2     58
      X= RD*ST*CP + UL                                                  CLOUD2     59
      Y = RD*ST*SP + VL                                                 CLOUD2     60
      Z = RD * CT   + WL                                                CLOUD2     61
C                                                                       CLOUD2     62
      CALL CT TO POL(RH,TH,PH,X,Y,Z)                                    CLOUD2     63
CLJ        NOW HAVE GEOGRAPHIC POLAR COORDINATES (RH,TH,PH) OF TIP OF   CLOUD2     64
CLJ        UNIT LOS VECTOR STARTING FROM THE DETECTOR.                  CLOUD2     65
      DO 100 K = 1,NCLOUD                                               CLOUD2     66
CLJ        OBTAIN CLOUD-K CARTESIAN COORDINATES OF TIP OF UNIT LOS VECTOR CLOUD2  67
CLJ        (XX,YY,ZZ)                                                   CLOUD2     68
      CALL CLD E TO C (RH,TH,PH,XX,YY,ZZ,K)                             CLOUD2     69
CLJ        NOTE...RHO IS A UNIT VECTOR                                  CLOUD2     70
      RHO=SQRT((XID(K)-XX)**2 + (ETAD(K)-YY)**2 +(ZETAD(K)-ZZ)**2  )    CLOUD2     71
      WRITE(6,1001)  K,RH,TH,PH,XX,YY,ZZ,RHO                            CLOUD2     72
 1001 FORMAT (*  PRINTED FROM CLOUD2 -FORMAT 1001  * /                  CLOUD2     73
     1 *  K,RH,TH,PH, XX,YY,ZZ, RHO  * I2,1P7E13.5)                    CLOUD2     74
C         LINE OF SIGHT VECTOR                                          CLOUD2     75
      ULC =      ( XX -    XID(K))/ RHO                                CLOUD2     76
      VLC =      ( YY -   ETAD(K))/ RHO                                CLOUD2     77
      WLC =      ( ZZ -  ZETAD(K))/ RHO                                CLOUD2     78
C         EVALUATE THE POSITION OF INTERCEPT ON                         CLOUD2     79
C         K-TH CLOUD IN CLOUD COORD SYSTEM                              CLOUD2     80
      A = ULC**2 / ASQ(K) + VLC**2 / BSQ(K) + WLC**2 / CSQ(K)           CLOUD2     81
      B = ULC*XID(K)/ASQ(K)+VLC*ETAD(K)/BSQ(K)+WLC*ZETAD(K)/CSQ(K)      CLOUD2     82
      C=XID(K)**2/ASQ(K) + ETAD(K)**2/BSQ(K) + ZETAD(K)**2/CSQ(K) - 1.  CLOUD2     83
      WRITE(6,1003)K,X,Y,Z,ULC,VLC,WLC,A,B,C                            CLOUD2     84
 1003 FORMAT(19 ,*CLD2 K XYZ UVW ABC*I2,1P9E12.5)                       CLOUD2     85
C        NO INTERCEPT                                                   CLOUD2     86
      IF( B**2 - A*C .LT. 0.) GO TO 100                                 CLOUD2     87
      S = ( - B - SQRT(B**2 - A*C) )/A                                  CLOUD2     88
      XIL    =   XID(K) + ULC*S                                         CLOUD2     89
      ETAL   =  ETAD(K) + VLC*S                                         CLOUD2     90
      ZETAL  = ZETAD(K) + WLC*S                                         CLOUD2     91
C                                                                       CLOUD2     92
      CALL CLD C TO E ( R,THETALK(K),PHILK(K),XIL,ETAL,ZETAL,K )        CLOUD2     93
      ALTLK(K) = R - RE                                                 CLOUD2     94
C                                                                       CLOUD2     95
      WRITE(6,1002) UL,VL,WL,K,ALTLK(K),THETALK(K),PHILK(K)             CLOUD2     96
 1002 FORMAT(* PRINTED FROM CLOUD2 */* THE LOS (* 3E12.4 * ) INTERCEPTS CLOUD2     97
     XCLOUD *I2*  AT*3E11.3  )                                          CLOUD2     98
  100 CONTINUE                                                          CLOUD2     99
      RETURN                                                            CLOUD2    100
      END                                                               CLOUD2    101
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      SUBROUTINE CLOUD3(UL,VL,WL,K,ALAM,TCOEF,EMISS,SINCLD)                CLOUD3    2
CLJ                                                                        CLOUD3    3
CLJ   SUBROUTINE CLOUD3, GIVEN THE DIRECTION COSINES OF A LOS FROM THE    CLOUD3    4
CLJ   DETECTOR (AS SPECIFIED BY THE DRIVER) FIRST DETERMINES WHETHER OR   CLOUD3    5
CLJ   NOT THE LOS INTERSECTS CLOUD-K.  IF NO INTERCEPT, TCOEF AND EMISS   CLOUD3    6
CLJ   ARE SET TO ZERO AND A RETURN IS MADE TO THE CALLING ROUTINE (THE    CLOUD3    7
CLJ   DRIVER).  IF THE LOS INTERSECTS CLOUD-K, THE ROUTINE CONTINUES.     CLOUD3    8
CLJ                                                                        CLOUD3    9
CLJ   THE DO-100 LOOPS COMPUTE THE NORMAL PHOTON FLUX (IRRADIANCE)        CLOUD3   10
CLJ   INCIDENT ON EACH FACET VIEWED BY THE SOURCE.  SUBROUTINE DIFFUS     CLOUD3   11
CLJ   THEN IS CALLED TO OBTAIN THE PHOTON FLUX (RADIANT EMITTANCE)        CLOUD3   12
CLJ   EXITING FROM EACH FACET.                                            CLOUD3   13
CLJ                                                                        CLOUD3   14
CLJ   THE DO-200 LOOPS ARE OVER ALL FACETS.                               CLOUD3   15
CLJ     1. ONE DETERMINES IF THE FACET CENTER IS VISIBLE TO THE DETECTOR  CLOUD3   16
CLJ     2. IF THE FACET CENTER IS VISIBLE TO THE DETECTOR,                CLOUD3   17
CLJ        A. THE CLOUD-CARTESIAN COORDINATES OF THE FACET CENTER ARE     CLOUD3   18
CLJ           DETERMINED (XC,ETC,ZETC).                                   CLOUD3   19
CLJ        B. THE DISTANCE (SDIST) FROM THE FACET CENTER NORMAL TO THE    CLOUD3   20
CLJ           LOS IS DETERMINED.  THE SMALLEST VALUE OF SDIST IS ALWAYS   CLOUD3   21
CLJ           SAVED.                                                      CLOUD3   22
CLJ        C. IF(SDIST.GT.0.7*SQRT(FOV)) AND IF THE CODE HAS PREVIOUSLY   CLOUD3   23
CLJ           FOUND A FACET CENTER WITHIN (0.7*SQRT(FOV)) OF THE LOS,     CLOUD3   24
CLJ           INDICATED BY KFLAG=1, THE FACET IS IGNORED.  BUT IF THE     CLOUD3   25
CLJ           CODE HAS NOT PREVIOUSLY FOUND A FACET CENTER WITHIN         CLOUD3   26
CLJ           (0.7*SQRT(FOV)) OF THE LOS, INDICATED BY KFLAG=0, AND IF    CLOUD3   27
CLJ           (SDIST.GT.0.7*SQRT(FOV)), THEN A TRANSFER COEFFICIENT AND   CLOUD3   28
CLJ           EMISSION WILL BE FOUND FOR ANY FACET FOR WHICH SDIST IS     CLOUD3   29
CLJ           THE SMALLEST OF THOSE YET PROCESSED.                        CLOUD3   30
CLJ        D. IF(SDIST.LE.0.7*SQRT(FOV)) THE DIRECTION COSINES TO THE     CLOUD3   31
CLJ           SOURCE FROM THE FACET CENTER ARE DETERMINED.                CLOUD3   32
CLJ     3. FURTHER TREATMENT OF THE FACET DEPENDS ON WHETHER OR NOT THE   CLOUD3   33
CLJ        FACET CENTER IS VISIBLE TO THE SOURCE                           CLOUD3   34
CLJ        A. IF THE FACET IS NOT VISIBLE TO THE SOURCE, ONE DETERMINES    CLOUD3   35
CLJ           (1) THE COSINE OF THE ZENITH ANGLE (CTHOUT) TO THE DETECT.  CLOUD3   36
CLJ           (2) THE AREA (AREAN) OF THE FACET NORMAL TO THE LOS         CLOUD3   37
CLJ           (3) THE EMISSIVITY (EMISS) OF THE FACET, WEIGHTED BY AREAN  CLOUD3   38
CLJ           (4) THE IRRADIANCE-TO-RADIANCE TRANSFER COEFFICIENT         CLOUD3   39
CLJ               (TCOEF) (AS DETERMINED BY DIFFUSION), WEIGHTED BY       CLOUD3   40
CLJ               AREAN                                                   CLOUD3   41
CLJ        B. IF THE FACET IS VISIBLE TO THE SOURCE, ONE DETERMINES       CLOUD3   42
CLJ           (1) THE INCIDENT ZENITH ANGLE AND THE EXIT ZENITH AND       CLOUD3   43
CLJ               AZIMUTHAL ANGLE (FOR THE SOURCE-FACET-DETECTOR PATH)    CLOUD3   44
CLJ               AND THE CORRESPONDING BIDIRECTIONAL REFLECTANCE         CLOUD3   45
CLJ           (2) THE AREA (AREAN) OF THE FACET NORMAL TO THE LOS         CLOUD3   46
CLJ           (3) THE EMISSIVITY (EMISS) OF THE FACET, WEIGHTED BY AREAN  CLOUD3   47
CLJ           (4) THE IRRADIANCE-TO-RADIANCE TRANSFER COEFFICIENT         CLOUD3   48
CLJ               (TCOEF) (AS DETERMINED BY BIDIRECTIONAL REFLECTANCE),   CLOUD3   49
CLJ               WEIGHTED BY AREAN                                       CLOUD3   50
CLJ        C. THE AVERAGE VALUES OF TCOEF AND EMISS ARE FOUND BY          CLOUD3   51
CLJ           DIVIDING BY THE SUM OF THE WEIGHTED AREAS AREAN, TAREA,     CLOUD3   52
CLJ           INCLUDED IN THE CALCULATION.                                CLOUD3   53
CLJ        D. IF THE FOV IS SO SMALL THAT NO FACET CENTER LIES WITHIN     CLOUD3   54
CLJ           (0.7*SQRT(FOV)) OF THE LOS, THEN THE SUBROUTINE RETURNS     CLOUD3   55
CLJ           THE VALUE OF TCOEF AND EMISS FOR THAT FACET-CENTER THAT     CLOUD3   56
CLJ           IS CLOSEST TO THE LOS.                                      CLOUD3   57
CLJ   INPUT PARAMETERS                                                    CLOUD3   58
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CLJ      ARGUMENT LIST                                                    CLOUD3
CLJ            UL, = DIRECTION COSINES IN EARTH-CENTERED CARTESIAN        CLOUD3
CLJ            VL,   SYSTEM OF A USER-SPECIFIED LOS (SET IN DRIVER)       CLOUD3
CLJ            WL                                                         CLOUD3
CLJ             K = CLOUD NUMBER (SET IN DRIVER)                          CLOUD3
CLJ          ALAM = WAVELENGTH, MICRONS (SET IN DRIVER)                   CLOUD3
CLJ      ATMOUP COMMON                                                    CLOUD3
CLJ             TT = TEMPERATURE OF AMBIENT ATMOSPHERE AT THE ALTITUDE    CLOUD3
CLJ                  IN THE ARGUMENT LIST OF SUBROUTINE ATMOSU,  DEG K    CLOUD3
CLJ      COCORD COMMON                                                    CLOUD3
CLJ        XI(I,K), = COORDINATES OF SOURCE-I IN K-TH CLOUD-CENTERED      CLOUD3
CLJ       ETA(I,K),   CARTESIAN SYSTEM,  KM        I=1        K=1,20      CLOUD3
CLJ      ZETA(I,K)                                                        CLOUD3
CLJ          XID(K), = COORDINATES OF DETECTOR IN K-TH CLOUD-CENTERED     CLOUD3
CLJ        ETAD(K),   CARTESIAN SYSTEM,  KM        K=1,20                 CLOUD3
CLJ       ZETAD(K)                                                        CLOUD3
CLJ      CLOUD COMMON                                                     CLOUD3
CLJ       HCLOUD(K) = ALTITUDE OF CLOUD-K CENTER ABOVE THE SURFACE,  KM   CLOUD3
CLJ     CTHBAR(I,K) = POLAR ANGLE IN CLOUD-CENTERED COORDINATES OF THE   CLOUD3
CLJ                   CENTER OF THE I-TH POLAR SET OF SURFACE FACETS FOR CLOUD3
CLJ                   ELLIPSOIDAL CLOUD-K,  DEGREES    I=1,8     K=1,20 CLOUD3
CLJ    CPHIBAR(J,K) = AZIMUTHAL ANGLE IN CLOUD-CENTERED COORDINATES OF   CLOUD3
CLJ                   THE CENTER OF THE J-TH AZIMUTHAL SET OF SURFACE    CLOUD3
CLJ                   FACETS FOR ELLIPSOIDAL CLOUD-K,  DEGREES           CLOUD3
CLJ                           J=1,16     K=1,20                          CLOUD3
CLJ    CRBAR(I,J,K) = CLOUD-CENTERED RADIAL DISTANCE TO THE CENTER OF    CLOUD3
CLJ                   SURFACE FACET I,J IN PRINCIPAL OCTANT,  KM         CLOUD3
CLJ                      I=1,4      J=1,4      K=1,20                    CLOUD3
CLJ                   (RESULTS FOR OTHER OCTANTS ARE OBTAINED BY SYMTY.) CLOUD3
CLJ    CAREA(I,J,K) = AREA OF SURFACE FACET I,J IN PRINCIPAL OCTANT OF   CLOUD3
CLJ                   ELLIPSOIDAL CLOUD-K,  KM**2   I=1,4  J=1,4  K=1,20 CLOUD3
CLJ          ASQ(K) = SQUARE OF LENGTH A, THE SEMI-MAJOR AXIS IN          CLOUD3
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2       CLOUD3
CLJ          BSQ(K) = SQUARE OF LENGTH B, THE SEMI-MINOR AXIS IN          CLOUD3
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2       CLOUD3
CLJ          CSQ(K) = SQUARE OF LENGTH C, THE SEMI-MINOR AXIS IN          CLOUD3
CLJ                   VERTICAL DIRECTION OF ELLIPSOIDAL CLOUD, KM**2     CLOUD3
CLJ      DETECT COMMON                                                    CLOUD3
CLJ             HD = ALTITUDE OF DETECTOR, KM                             CLOUD3
CLJ         THETAD = COLATITUDE OF DETECTOR, DEGREES                      CLOUD3
CLJ           PHID = EAST LONGITUDE OF DETECTOR, DEGREES                  CLOUD3
CLJ            FOV = FIELD OF VIEW OF DETECTOR AT EARTH'S SURFACE,KM**2   CLOUD3
CLJ      PARAMS COMMON                                                    CLOUD3
CLJ            DTR = CONVERSION FACTOR FROM DEGREES TO RADIANS            CLOUD3
CLJ             RE = EARTH'S RADIUS,  KM                                  CLOUD3
CLJ      FLUX COMMON                                                      CLOUD3
CLJ       FOUT(I,J) = 4.*PI TIMES THE OUTGOING PHOTON FLUX (RADIANT       CLOUD3
CLJ                   EMITTANCE) FROM ELLIPSOIDAL-SURFACE FACET (I,J)    CLOUD3
CLJ                   FOR A UNIT STRENGTH, ISOTROPIC POINT SOURCE        CLOUD3
CLJ                   (ONE PHOTON PER SEC), (4.*PI*PHOTONS)/(KM**2 SEC)  CLOUD3
CLJ      SORCE COMMON                                                     CLOUD3
CLJ          NSORCE = NUMBER OF SOURCES (CURRENTLY RESTRICTED TO ONE)     CLOUD3
CLJ       RSORCE(1) = RADIUS OF SOURCE-I,  KM                             CLOUD3
CLJ      XX1111 COMMON                                                    CLOUD3
CLJ           KCLDK = A TEST FLAG USED TO DETERMINE WHETHER CLOUD3 IS     CLOUD3
CLJ                   NOW BEING CALLED WITH THE SAME CLOUD-NUMBER K AS   CLOUD3
CLJ                   FOR ITS LAST CALL.                                 CLOUD3
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CLJ          CLDLAM = A TEST QUANTITY USED TO DETERMINE WHETHER CLOUD3
CLJ                   IS NOW BEING CALLED WITH THE SAME WAVELENGTH ALAM
CLJ                   AS FOR ITS LAST CALL.
CLJ       IF BOTH K AND ALAM INPUTTED TO SUBROUTINE CLOUD3 HAVE THE SAME
CLJ       VALUES AS IN THE LAST CALL TO SUBROUTINE CLOUD3, THE
CLJ       SUBROUTINE BYPASSES ITS CALL TO SUBROUTINE DIFFUS(K,ALAM).
CLJ       BOTH KCLDK AND CLDLAM ARE INITIALIZED IN THE MAIN PROGRAM
CLJ       TO THE ARBITRARY, OUT-OF-RANGE VALUES OF 99 AND -99.,
CLJ       RESPECTIVELY.
CLJ   OUTPUT PARAMETERS
CLJ      ARGUMENT LIST
CLJ           TCOEF = IRRADIANCE-TO-RADIANCE TRANSFER COEFFICIENT AT THE
CLJ                   INTERSECTION POINT (IF ANY) BETWEEN THE USER-
CLJ                   SUPPLIED LOS AND CLOUD-K.  THE SOURCE WHICH
CLJ                   IRRADIATES CLOUD-K MAY OR MAY NOT SEE THE
CLJ                   INTERSECTION POINT.  (1/SR)
CLJ           EMISS = THERMAL EMISSION FROM THE CLOUD AT THE ABOVE-
CLJ                   DESCRIBED INTERSECTION POINT.
CLJ                     (WATTS/(KM**2 SR MICRON))
CLJ       BOTH TCOEF AND EMISS ARE MEAN QUANTITIES, AVERAGED OVER A
CLJ       PRESCRIBED PROJECTED AREA (TAREA) OF THE CLOUD IF TAREA
CLJ       EXCEEDS FOV OR OVER FOV IF FOV EXCEEDS TAREA.  THE RADIANCES
CLJ       CORRESPONDING TO TCOEF AND EMISS WILL BE MULTIPLIED BY THE
CLJ       DETECTOR'S FIELD-OF-VIEW SOLID ANGLE, FOV/R**2, TO OBTAIN
CLJ       THE IRRADIANCE AT THE DETECTOR.
CLJ          SINCLD = LOGICAL VARIABLE SET BY TESTING WHETHER OR NOT
CLJ                   THE SOURCE IS ON OR INSIDE THE SURFACE OF THE
CLJ                   K-TH DETERMINISTIC CLOUD.
CLJ                   - TRUE , SOURCE ON OR INSIDE SURFACE OF CLOUD
CLJ                   - FALSE, SOURCE OUTSIDE SURFACE OF CLOUD
CLJ      FLUX COMMON
CLJ        FIN(I,J) = 4.*PI TIMES THE INCOMING (NORMAL) PHOTON FLUX
CLJ                   (IRRADIANCE) AT ELLIPSOIDAL-SURFACE FACET (I,J) AT
CLJ                   DISTANCE R FROM A UNIT STRENGTH, ISOTROPIC POINT
CLJ                   SOURCE (I.E., (R DOT N)/R**3),   I=1,8    J=1,16
CLJ                     4*PI*PHOTONS/(KM**2 SEC) FOR UNIT SOURCE
CLJ
      COMMON/CLOUD/ NCLOUD,
     1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),
     2    CLOUDC(20),CLDPSI(20),KCLOUD(20)
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),
     1               XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)
     X  , ASQ(20),BSQ(20),CSQ(20)
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD
      COMMON / DETECT/ HD, THETAD,PHID,FOV
      COMMON/SORCE/  NSORCE,HSORCE(1),RSORCE(1),THETAS(1),PHIS(1)
      COMMON/ATMOUP/  DUM1(4),RHO,TT,DUM2(32)
      COMMON/FLUX/  FIN(8,16),FOUT(8,16)
      COMMON/XX1111/  KCLDK, CLDLAM
      LOGICAL  SINCLD
CLJ       THE ARITHMETIC FUNCTION PLANK(AA,TT) EVALUATES THE PLANCK
CLJ       SPECTRAL FUNCTION AT WAVELENGTH AA=ALAM(MICRONS) AND
CLJ       TEMPERATURE TT(DEG K),  WATTS/(KM**2 SR MICRON)
      PLANK(AA,TT) = 1.191E14/(AA**5*(EXP(14388./(AA*TT))-1.))
C
C        UL,VL,WL  ARE THE DIRECTION COSINES OF L-O-S
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C         IN THE EARTH SYSTEM                                          CLOUD3   168
C                                                                      CLOUD3   169
C         GENERATE THE FIN ARRAY BY CYCLING THROUGH THE SOURCES,       CLOUD3   170
C         ADDING THE CONTRIBUTION OF EACH TO EVERY FIN(I,J)            CLOUD3   171
CLJ            ENTER WITH A SIGHT-PATH IN EARTH COORDINATES,           CLOUD3   172
C         CLOUD NUMBER,  WAVELENGTH, AND A SET OF NSORCE SOURCES.      CLOUD3   173
C              THE SOURCES ARE IN COMMON/SORCE/ WHICH HAS TO BE FILLED CLOUD3   174
CLJ       BY THE USER.  DUPLICATE THE INSTRUCTIONS FROM CLOUD2 TO      CLOUD3   175
CLJ       TRANSFORM LOS TO CLOUD-CENTERED CARTESIAN SYSTEM.            CLOUD3   176
      RD = (HD + RE)                                                   CLOUD3   177
      ST = SIN( DTR*THETAD )                                           CLOUD3   178
      SP = SIN( DTR*PHID )                                             CLOUD3   179
      CT = COS( DTR*THETAD )                                           CLOUD3   180
      CP = COS( DTR*PHID )                                             CLOUD3   181
      X = RD * ST* CP + UL                                             CLOUD3   182
      Y = RD * ST * SP + VL                                            CLOUD3   183
      Z = RD * CT    + WL                                              CLOUD3   184
      WRITE(6,1001)K,X,Y,Z,SQRT(X**2+Y**2+Z**2),UL,VL,WL               CLOUD3   185
 1001 FORMAT(* CLOUD3 FORMAT 1001 ---K,XYZ,R,UVW* I3,1P7E11.3 )        CLOUD3   186
C                                                                      CLOUD3   187
      CALL CT TO POL(RHO,TH,PHI,X,Y,Z)                                 CLOUD3   188
      CALL CLD E TO C (RHO,TH,PHI,XX,YY,ZZ,K)                          CLOUD3   189
C         LOS VECTOR IN THE K-TH CLOUD COORD SYSTEM                    CLOUD3   190
CLJ        NOTE...RHO IS OF UNIT LENGTH.                               CLOUD3   191
      RHO=SQRT( (XX-XID(K))**2 + (YY-ETAD(K))**2 + (ZZ-ZETAD(K))**2  ) CLOUD3   192
      ULC =      ( XX -    XID(K))/ RHO                                CLOUD3   193
      VLC =      ( YY -   ETAD(K))/ RHO                                CLOUD3   194
      WLC =      ( ZZ -  ZETAD(K))/ RHO                                CLOUD3   195
C                                                                      CLOUD3   196
C         EVALUATE THE POSITION OF INTERCEPT ON                        CLOUD3   197
C         K-TH CLOUD IN CLOUD COORD SYSTEM                             CLOUD3   198
      A = ULC**2 / ASQ(K) + VLC**2 / BSQ(K) + WLC**2 / CSQ(K)          CLOUD3   199
      B = ULC*XID(K)/ASQ(K)+VLC*ETAD(K)/BSQ(K)+WLC*ZETAD(K)/CSQ(K)     CLOUD3   200
      C = XID(K)**2 / ASQ(K) + ETAD(K)**2/BSQ(K) + ZETAD(K)**2/CSQ(K)-1. CLOUD3   201
      IF ( (B**2 - A*C ) .GT. 0.) GO TO 15                             CLOUD3   202
      TCOEF = 0.                                                       CLOUD3   203
      EMISS = 0.0                                                      CLOUD3   204
      WRITE(6,10) UL,VL,WL,K                                           CLOUD3   205
   10 FORMAT(*   CAUTION--- LOS (*3E12.5* ) DIDNT INTERSECT CLOUD *I4,* CLOUD3   206
     1 PRINTED FROM FORMAT 10 CLOUD3  *)                               CLOUD3   207
      RETURN                                                           CLOUD3   208
   15 CONTINUE                                                         CLOUD3   209
      S = ( - B - SQRT(B**2 - A*C) )/A                                 CLOUD3   210
CLJ        XIL, ETAL, ZETAL ARE THE COORDINATES OF THE INTERCEPT POINT CLOUD3   211
CLJ        IN THE CLOUD-CENTERED CARTESIAN SYSTEM.                     CLOUD3   212
      XIL    =   XID(K) + ULC*S                                        CLOUD3   213
      ETAL   =  ETAD(K) + VLC*S                                        CLOUD3   214
      ZETAL  = ZETAD(K) + WLC*S                                        CLOUD3   215
      WRITE(6,1003)K,XIL,ETAL,ZETAL,SQRT(XIL**2+ETAL**2+ZETAL**2),S,ULC, CLOUD3   216
     X VLC,WLC                                                         CLOUD3   217
 1003 FORMAT(* 2 K XIL ETAL ZETAL R S ULC V W*I3,1P8E10.2)             CLOUD3   218
      CIPALT = HCLOUD(K) + ZETAL                                       CLOUD3   219
      CALL ATMOSU(2,CIPALT)                                            CLOUD3   220
      TK = TT                                                          CLOUD3   221
CLJ        WE HAVE JUST COMPUTED THE TEMPERATURE, TK, AT THE INTERCEPT CLOUD3   222
CLJ        POINT THAT WILL BE USED LATER IN THE PLANCK FUNCTION WHEN   CLOUD3   223
CLJ        COMPUTING THE EMISSION.  WE IGNORE ANY DEPARTURE OF THE     CLOUD3   224
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CLJ       CLOUD TEMPERATURE FROM THIS SINGLE VALUE.                          CLOUD3   225
C                                                                            CLOUD3   226
CLJ      LOOP OVER THE CLOUD-SURFACE FACETS (CTHBAR AND CPHIBAR)             CLOUD3   227
CLJ      I - INDEX ON CTHBAR                                                 CLOUD3   228
CLJ      J - INDEX ON CPHIBAR                                                CLOUD3   229
CLJ      IP - FIRST-OCTANT INDEX CORRESPONDING TO I                          CLOUD3   230
CLJ      JP - FIRST-OCTANT INDEX CORRESPONDING TO J                          CLOUD3   231
C                                                                            CLOUD3   232
      NS = 1                                                                 CLOUD3   233
CLJ       BEFORE COMPUTING SOURCE-IRRADIATION OF CLOUD-K, CHECK WHETHER      CLOUD3   234
CLJ       SOURCE IS INSIDE CLOUD-K.  IF IT IS, PRINT A WARNING MESSAGE       CLOUD3   235
CLJ       TO THAT EFFECT AND RETURN TO DRIVER PROGRAM WITHOUT ATTEMPTING     CLOUD3   236
CLJ       FURTHER CALCULATIONS.  (WE MAY BE ABLE TO DEVELOP AN APPROX.       CLOUD3   237
CLJ       TREATMENT LATER.)                                                  CLOUD3   238
      SINCLD = ( (XI(NS,K)**2 / ASQ(K) + ETA(NS,K)**2 / BSQ(K)               CLOUD3   239
     $         + ZETA(NS,K)**2 / CSQ(K)) .LE. 1.0 )                          CLOUD3   240
      IF( .NOT.SINCLD )  GO TO 80                                            CLOUD3   241
      WRITE(6,1005)  NS, K                                                   CLOUD3   242
 1005 FORMAT (*0  SOURCE *,I4,* IS INSIDE (OR POSSIBLY ON THE SURFACE)*,     CLOUD3   243
     1 * OF CLOUD-K =*,I4 / *   THEREFORE NO ATTEMPT HAS BEEN MADE TO*,      CLOUD3   244
     2 * COMPUTE THE SOURCE-IRRADIATION OF CLOUD-K. *)                       CLOUD3   245
      RETURN                                                                 CLOUD3   246
   80 CONTINUE                                                               CLOUD3   247
C                                                                            CLOUD3   248
CLJ       WE TAKE (APPROXIMATE) ACCOUNT OF THE FINITE SIZE OF AN             CLOUD3   249
CLJ       ARTIFICIAL SOURCE WHEN ITS DISTANCE FROM THE SURFACE OF A          CLOUD3   250
CLJ       CLOUD IS LESS THAN (APPROXIMATELY) THE RADIUS, RSORCE(1),          CLOUD3   251
CLJ       ASSIGNED TO THE SOURCE.  WE DO THIS BY RESETTING THE SOURCE        CLOUD3   252
CLJ       POSITION, THEREBY PREVENTING THE OCCURRENCE OF AN ARBITRARILY      CLOUD3   253
CLJ       SMALL DISTANCE FROM THE (POINT) SOURCE TO THE CLOUD SURFACE.       CLOUD3   254
CLJ       THE TECHNIQUE IS SIMILAR TO THAT EMPLOYED IN THE STATISTICAL       CLOUD3   255
CLJ       CLOUD SUBMODEL TO PREVENT CALCULATING ARBITRARILY LARGE            CLOUD3   256
CLJ       TRANSFER COEFFICIENTS FOR REFLECTION.                              CLOUD3   257
CLJ       THE DISTANCE RP FROM THE CENTER OF CLOUD-K TO SOURCE NS=1 IS       CLOUD3   258
CLJ                                                                          CLOUD3   259
      RP = SQRT( XI(1,K)**2 + ETA(1,K)**2 + ZETA(1,K)**2 )                   CLOUD3   260
CLJ                                                                          CLOUD3   261
CLJ       THE DIRECTION COSINES, IN THE CLOUD-K COORDINATE SYSTEM, OF        CLOUD3   262
CLJ       THE SOURCE POSITION ARE...                                         CLOUD3   263
      RPX =   XI(1,K)/RP                                                     CLOUD3   264
      RPY =  ETA(1,K)/RP                                                     CLOUD3   265
      RPZ = ZETA(1,K)/RP                                                     CLOUD3   266
CLJ       THE CLOUD-K COORDINATES X,Y,Z AT WHICH THE RAY TO THE SOURCE       CLOUD3   267
CLJ       INTERSECTS THE CLOUD SURFACE ARE GIVEN BY                          CLOUD3   268
CLJ            X = RS*RPX,    Y = RS*RPY,    Z = RS*RPZ                      CLOUD3   269
CLJ       WHERE RS IS THE RADIAL DISTANCE TO THE POINT X,Y,Z, OBTAINED       CLOUD3   270
CLJ       BY SUBSTITUTING THE ABOVE EXPRESSIONS FOR X,Y,Z INTO THE           CLOUD3   271
CLJ       EQUATION FOR AN ELLIPSOID AND SOLVING FOR RS...                    CLOUD3   272
CLJ                                                                          CLOUD3   273
      RS = 1.0/SQRT( RPX*RPX/ASQ(K) + RPY*RPY/BSQ(K) + RPZ*RPZ/CSQ(K) )      CLOUD3   274
CLJ                                                                          CLOUD3   275
CLJ       THE DISTANCE RPMRS OF THE SOURCE FROM THE CLOUD SURFACE,           CLOUD3   276
CLJ       MEASURED ALONG THE RAY RP, IS...                                   CLOUD3   277
CLJ                                                                          CLOUD3   278
      RPMRS = RP - RS                                                        CLOUD3   279
      X = RS*RPX                                                             CLOUD3   280
      Y = RS*RPY                                                             CLOUD3   281
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      Z = RS*RPZ                                                        CLOUD3   282
CLJ                                                                     CLOUD3   283
CLJ       AT THE INTERSECTION POINT X,Y,Z THE UNIT OUTWARD NORMAL HAS   CLOUD3   284
CLJ       COMPONENTS VX,VY,VZ, OBTAINED FROM SUBROUTINE VXNORM...       CLOUD3   285
CLJ                                                                     CLOUD3   286
      CALL VSNORM(X,Y,Z,VX,VY,VZ,K)                                     CLOUD3   287
CLJ                                                                     CLOUD3   288
CLJ       SAVE ORIGINAL SOURCE POSITION.                                CLOUD3   289
      XISV   =   XI(1,K)                                                CLOUD3   290
      ETASV  =  ETA(1,K)                                                CLOUD3   291
      ZETASV = ZETA(1,K)                                                CLOUD3   292
CLJ       THE COMPONENT OF RPMRS IN THE DIRECTION OF THE UNIT NORMAL AT CLOUD3   293
CLJ       THE POINT X,Y,Z IS (V DOT RPMRS = V DOT SP), I.E.,            CLOUD3   294
      VDOTSP = ( VX*RPX + VY*RPY + VZ*RPZ ) * RPMRS                     CLOUD3   295
      IF( VDOTSP.GE.RSORCE(1) )  GO TO 40                               CLOUD3   296
CLJ       OTHERWISE, WE MOVE THE SOURCE A DISTANCE DELP IN THE DIRECTION CLOUD3   297
CLJ       OF THE UNIT NORMAL AT X,Y,Z, HAVING SAVED THE ORIGINAL SOURCE CLOUD3   298
CLJ       POSITION.  (WE USE THIS PARTICULAR UNIT NORMAL BECAUSE IT IS  CLOUD3   299
CLJ       READILY FOUND, WHEREAS THE PERPENDICULAR FROM THE SOURCE TO   CLOUD3   300
CLJ       THE CLOUD SURFACE IS NOT READILY FOUND.)                      CLOUD3   301
      DELP = 0.5*(RSORCE(1)-VDOTSP)                                     CLOUD3   302
      XI(1,K)   =   XI(1,K) + DELP*VX                                   CLOUD3   303
      ETA(1,K)  =  ETA(1,K) + DELP*VY                                   CLOUD3   304
      ZETA(1,K) = ZETA(1,K) + DELP*VZ                                   CLOUD3   305
      WRITE(6,1006)  NS,K,XISV,ETASV,ZETASV,XI(1,K),ETA(1,K),ZETA(1,K)  CLOUD3   306
 1006 FORMAT (*0   MESSAGE FROM SUBROUTINE CLOUD3  */                   CLOUD3   307
     1 *0   THE COORDINATES OF SOURCE NS=*,I4,* , RELATIVE TO CLOUD K=*, CLOUD3   308
     2 I4,* , HAVE BEEN CHANGED...*/                                    CLOUD3   309
     3 *    FROM XI,ETA,ZETA =*,3E14.5/*      TO XI,ETA,ZETA =*,3E14.5) CLOUD3   310
   40 CONTINUE                                                          CLOUD3   311
      IF( (K.EQ.KCLDK) .AND. (ALAM.EQ.CLDLAM) )  GO TO 110              CLOUD3   312
CLJ       START LOOP TO COMPUTE SOURCE-IRRADIATION OF CLOUD-K           CLOUD3   313
CLJ       OBTAIN FIN(I,J)                                               CLOUD3   314
      DO 100 I = 1,8                                                    CLOUD3   315
      IP = IPRIME(I)                                                    CLOUD3   316
      DO 100 J = 1,16                                                   CLOUD3   317
      JP = IPRIME(J)                                                    CLOUD3   318
      FIN(I,J) = 0.                                                     CLOUD3   319
C        CHECK TO SEE IF AREA(I,J) IS VISIBLE TO SOURCE                 CLOUD3   320
C        IF NOT, GO TO NEXT AREA                                        CLOUD3   321
      IF(PS(XI(NS,K),ETA(NS,K),ZETA(NS,K),CTHBAR(I,K),CPHIBAR(J,K),K)   CLOUD3   322
     1  .LE. 0) GO TO 100                                               CLOUD3   323
C                                                                       CLOUD3   324
CLJ       GET CLOUD-FACET CENTER IN CLOUD-CENTERED CARTESIAN            CLOUD3   325
CLJ       COORDINATES (XC,ETC,ZETC)                                     CLOUD3   326
      CALLPOL TO CT(CRBAR(IP,JP,K),CTHBAR(I,K),CPHIBAR(J,K),XC,ETC,ZETC) CLOUD3   327
C                                                                       CLOUD3   328
CLJ       GET UNIT VECTOR NORMAL TO ELLIPSOIDAL SURFACE AT (XC,ETC,ZETC) CLOUD3   329
C        CALL IT AN1,AN2,AN3                                            CLOUD3   330
      CALL VSNORM(XC,ETC,ZETC,AN1,AN2,AN3,K)                            CLOUD3   331
CLJ       RSQ=SQUARE OF DISTANCE FROM SOURCE TO VISIBLE FACET-CENTER    CLOUD3   332
      RSQ=(XC-XI(NS,K))**2 + (ETC-ETA(NS,K))**2 + (ZETC-ZETA(NS,K))**2  CLOUD3   333
      FIN(I,J) = FIN(I,J) -                                             CLOUD3   334
     1 (AN1*(XC-XI(NS,K))+ AN2*(ETC-ETA(NS,K))+AN3*(ZETC-ZETA(NS,K)))   CLOUD3   335
     1   / SQRT(RSQ)**3                                                 CLOUD3   336
  100 CONTINUE                                                          CLOUD3   337
CLJ                                                                     CLOUD3   338
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C         CALCULATE FOUT                                                CLOUD3   339
      CALL DIFFUS(K,ALAM)                                               CLOUD3   340
C                                                                       CLOUD3   341
  110 KCLDK = K                                                         CLOUD3   342
      CLDLAM = ALAM                                                     CLOUD3   343
C         LOOP OVER ALL AREAS VISIBLE TO AND IN FOV OF DETECTOR         CLOUD3   344
C         SUM THE TOTAL AREA OF THE CLOUD FACETS NORMAL TO LOS          CLOUD3   345
C                                                                       CLOUD3   346
      EMISS = 0.                                                        CLOUD3   347
      TCOEF = 0.                                                        CLOUD3   348
      TAREA = 0.                                                        CLOUD3   349
CLJ       TO FORCE THE SUBROUTINE TO COMPUTE AND RETURN NOT ZEROS BUT   CLOUD3   350
CLJ       THE BEST POSSIBLE ANSWERS FOR TCOEF AND EMISS WHEN NO FACET   CLOUD3   351
CLJ       CENTER IS WITHIN (0.7*SQRT(FOV)) OF THE LOS, WE INTRODUCE TWO CLOUD3   352
CLJ       VARIABLES, SSAVE AND KFLAG, TO FACILITATE TREATING THIS SMALL- CLOUD3   353
CLJ       FOV CONDITION.  SSAVE ULTIMATELY BECOMES THE SMALLEST VALUE OF CLOUD3   354
CLJ       SDIST FOR THE SMALL-FOV CONDITION BUT IT IS INITIALIZED TO AN CLOUD3   355
CLJ       ARBITRARILY LARGE VALUE.  KFLAG IS INITIALIZED TO 0 BUT IS    CLOUD3   356
CLJ       RESET TO 1 IF AND WHEN THE CODE FINDS A FACET CENTER WITHIN   CLOUD3   357
CLJ       (0.7*SQRT(FOV)) OF THE LOS.                                   CLOUD3   358
      SSAVE = 1.0E+10                                                   CLOUD3   359
      KFLAG = 0                                                         CLOUD3   360
      DO 200 I = 1,8                                                    CLOUD3   361
      IP = IPRIME(I)                                                    CLOUD3   362
      DO 200 J = 1,16                                                   CLOUD3   363
      JP = IPRIME(J)                                                    CLOUD3   364
CLJ       IF FACET CENTER IS NOT VISIBLE TO DETECTOR, GO TO NEXT FACET  CLOUD3   365
      IF(PS(XID(K),ETAD(K),ZETAD(K),CTHBAR(I,K),CPHIBAR(J,K),K)         CLOUD3   366
     1   .LT. 0.) GO TO 200                                             CLOUD3   367
      CALLPOL TO CT(CRBAR(IP,JP,K),CTHBAR(I,K),CPHIBAR(J,K),XC,ETC,ZETC) CLOUD3   368
      CALL VSNORM(XC,ETC,ZETC,AN1,AN2,AN3,K)                            CLOUD3   369
C                                                                       CLOUD3   370
CLJ       THE CURRENT(I,J)-FACET CENTER IS VISIBLE TO A WIDE-ANGLE      CLOUD3   371
CLJ       DETECTOR, BUT IS IT WITHIN THE FOV OF THE DETECTOR SPECIFIED. CLOUD3   372
CLJ       LET SDIST BE THE DISTANCE, (APPROXIMATELY) NORMAL TO THE LOS, CLOUD3   373
CLJ       TO THE FACET CENTER.                                          CLOUD3   374
CLJ       GET ARG, THE COSINE OF THE ANGLE BETWEEN THE LOS AND THE      CLOUD3   375
CLJ       DIRECTION TO THE FACET CENTER FROM THE DETECTOR.              CLOUD3   376
CLJ       LET SDIST TEMPORARILY BE THE INVERSE DISTANCE FROM THE        CLOUD3   377
CLJ       DETECTOR TO THE FACET CENTER.                                 CLOUD3   378
      SDIST = 1.                                                        CLOUD3   379
     1    / SQRT( (XC-XID(K))**2+(ETC-ETAD(K))**2+(ZETC-ZETAD(K))**2)   CLOUD3   380
      ARG =(ULC*(XC-XID(K)) + VLC*(ETC-ETAD(K))+WLC*(ZETC-ZETAD(K)) )   CLOUD3   381
     1   * SDIST                                                        CLOUD3   382
      IF(ABS(ARG) .GT. 1.) ARG = 1.                                     CLOUD3   383
      SDIST = ACOS(ARG) / SDIST                                         CLOUD3   384
      IF( SDIST.GT.SSAVE )  GO TO 150                                   CLOUD3   385
      SSAVE = SDIST                                                     CLOUD3   386
  150 IF( (KFLAG.EQ.1) .AND. (SDIST.GT.0.7*SQRT(FOV)) )  GO TO 200      CLOUD3   387
CLJ       RR=DISTANCE FROM THE SOURCE TO THE FACET CENTER               CLOUD3   388
      RR = SQRT( (XC - XI(NS,K))**2 + (ETC-ETA (NS,K))**2 +             CLOUD3   389
     1   (ZETC - ZETA(NS,K) )**2  )                                     CLOUD3   390
CLJ       ULS,VLS,WLS ARE THE DIRECTION COSINES OF A UNIT VECTOR TOWARD CLOUD3   391
CLJ       THE SOURCE FROM A FACET CENTER THAT IS EITHER WITHIN THE FOV  CLOUD3   392
CLJ       OF THE DETECTOR OR IS A CANDIDATE FOR BEING THE CLOSEST TO    CLOUD3   393
CLJ       THE FOV.                                                      CLOUD3   394
      ULS = (XI(NS,K)-XC)/RR                                            CLOUD3   395
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      VLS = (ETA(NS,K)-ETC)/RR                                          CLOUD3   396
      WLS = (ZETA(NS,K)-ZETC)/RR                                        CLOUD3   397
CLJ       IF THE DETECTOR-VIEWED FACET-CENTER IS VISIBLE TO THE SOURCE, CLOUD3   398
CLJ       SKIP TO STATEMENT-201 TO COMPUTE THE TRANSFER COEFFICIENT     CLOUD3   399
CLJ       FOR REFLECTANCE.                                              CLOUD3   400
      IF(PS(XI(NS,K),ETA(NS,K),ZETA(NS,K),CTHBAR(I,K),CPHIBAR(J,K),K)   CLOUD3   401
     1  .GT. 0) GO TO 201                                               CLOUD3   402
CLJ       THE DETECTOR-VIEWED FACET-CENTER IS NOT VISIBLE TO THE SOURCE CLOUD3   403
CLJ       SO COMPUTE THE TRANSFER COEFFICIENT FOR TRANSMISSION.         CLOUD3   404
      CTHOUT = -( AN1*ULC+AN2*VLC+AN3*WLC)                              CLOUD3   405
      AREAN = CTHOUT * CAREA(IP,JP,K)                                   CLOUD3   406
      IF( (KFLAG.EQ.1) .OR. (SDIST.LE.0.7*SQRT(FOV)) )  GO TO 160       CLOUD3   407
      IF( SDIST.NE.SSAVE )  GO TO 200                                   CLOUD3   408
      ESAVE = (1.-RHOEPS(ALAM,CTHOUT)) * PLANK(ALAM,TK) * AREAN         CLOUD3   409
      TSAVE = 0.25*AREAN*FOUT(I,J)/(PI*PI)                              CLOUD3   410
      ASAVE = AREAN                                                     CLOUD3   411
      GO TO 200                                                         CLOUD3   412
  160 CONTINUE                                                          CLOUD3   413
      EMISS = EMISS + (1. - RHOEPS(ALAM,CTHOUT))*PLANK(ALAM,TK)*AREAN   CLOUD3   414
CLJ       THE FOLLOWING EXPRESSION FOR TCOEF, WHILE CORRECT AS USED,    CLOUD3   415
CLJ       LACKS BEING A TRANSFER COEFFICIENT (FOR TRANSMISSION) BECAUSE CLOUD3   416
CLJ       (1) IT LACKS THE FACTORS 4.*PI*DISTANCE**2 SUPPLIED AT THE END CLOUD3   417
CLJ       OF THE ROUTINE AND (2) IT INCLUDES A WEIGHTING FACTOR, AREAN, CLOUD3   418
CLJ       USED IN DETERMINING AN AVERAGE VALUE.  (STRICTLY, A FACTOR    CLOUD3   419
CLJ       DISTANCE**2 SHOULD HAVE BEEN INCLUDED IN THE QUANTITY BEING   CLOUD3   420
CLJ       AVERAGED.)  THE FACTOR 0.25/PI COMPENSATES FOR THE RADIANT    CLOUD3   421
CLJ       EXITANCE, FOUT, BEING LARGE BY A FACTOR OF 4.*PI.  THE FACTOR CLOUD3   422
CLJ       1./PI CONVERTS THE RADIANT EXITANCE TO RADIANCE.              CLOUD3   423
      TCOEF = FOUT(I,J) / PI**2*0.25 * AREAN + TCOEF                    CLOUD3   424
      TAREA = TAREA + AREAN                                             CLOUD3   425
CLJ       WE HAVE FOUND A FACET CENTER WITHIN (0.7*SQRT(FOV)) OF THE    CLOUD3   426
CLJ       LOS SO SET KFLAG EQUAL TO 1.                                  CLOUD3   427
      KFLAG = 1                                                         CLOUD3   428
      GO TO 200                                                         CLOUD3   429
  201 CONTINUE                                                          CLOUD3   430
CLJ       THE DETECTOR-VIEWED FACET-CENTER IS VISIBLE TO THE SOURCE.    CLOUD3   431
      CTHIN = ULS * AN1 + VLS * AN2 + WLS * AN3                         CLOUD3   432
      CTHOUT = -( AN1*ULC+AN2*VLC+AN3*WLC)                              CLOUD3   433
      AREAN = CTHOUT * CAREA(IP,JP,K)                                   CLOUD3   434
      THE = ACOS( CTHOUT )                                              CLOUD3   435
      THI = ACOS( CTHIN )                                               CLOUD3   436
      CPHOUT = 1.0                                                      CLOUD3   437
      IF( (THE.EQ.0.0) .OR. (THI.EQ.0.0) )  GO TO 165                   CLOUD3   438
      CPHOUT = (CTHOUT*CTHIN + (ULS*ULC + VLS*VLC + WLS*WLC)) /         CLOUD3   439
     $         (SIN(THE) * SIN(THI))                                    CLOUD3   440
  165 CONTINUE                                                          CLOUD3   441
      IF( (KFLAG.EQ.1) .OR. (SDIST.LE.0.7*SQRT(FOV)) )  GO TO 170       CLOUD3   442
      IF( SDIST.NE.SSAVE )  GO TO 200                                   CLOUD3   443
      ESAVE = (1.-RHOEPS(ALAM,CTHOUT)) * PLANK(ALAM,TK) * AREAN         CLOUD3   444
      TSAVE = CLDBDR(CTHIN,CTHOUT,CPHOUT,ALAM,KCLOUD(K))                CLOUD3   445
     $      * AREAN*FIN(I,J)/(4.*PI)                                    CLOUD3   446
      ASAVE = AREAN                                                     CLOUD3   447
      GO TO 200                                                         CLOUD3   448
  170 CONTINUE                                                          CLOUD3   449
CLJ       THE FOLLOWING EXPRESSION FOR TCOEF, WHILE (ESSENTIALLY)       CLOUD3   450
CLJ       CORRECT AS USED, LACKS BEING A TRANSFER COEFFICIENT (FOR      CLOUD3   451
CLJ       REFLECTANCE) BECAUSE (1) IT (EFFECTIVELY) INCLUDES IN ITS     CLOUD3   452
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CLJ       DENOMINATOR THE FACTORS 4.*PI*DISTANCE**2 TO COMPENSATE FOR    CLOUD3   453
CLJ       THE SIMILAR FACTORS SUPPLIED AT THE END OF THE ROUTINE AND (2) CLOUD3   454
CLJ       IT INCLUDES A WEIGHTING FACTOR, AREAN, USED IN DETERMINING AN  CLOUD3   455
CLJ       AVERAGE VALUE.  THE USE OF FIN(I,J) IS A WAY OF INTRODUCING    CLOUD3   456
CLJ       THE REQUIRED CTHIN FACTOR AND THE COMPENSATING 1./DISTANCE**2  CLOUD3   457
CLJ       FACTOR.  (STRICTLY, THE VARIOUS FACTORS OF DISTANCE**2 USED    CLOUD3   458
CLJ       HERE DO NOT EXACTLY COMPENSATE FOR THE SINGLE DISTANCE**2      CLOUD3   459
CLJ       FACTOR USED AT THE END OF THE ROUTINE.)                        CLOUD3   460
      TCOEF = AREAN*FIN(I,J)*CLDBDR(CTHIN,CTHOUT,CPHOUT,ALAM,KCLOUD(K))  CLOUD3   461
     $  / (4.*PI) + TCOEF                                                CLOUD3   462
      TAREA = TAREA + AREAN                                              CLOUD3   463
      EMISS = EMISS + (1. - RHOEPS(ALAM,CTHOUT))*PLANK(ALAM,TK)*AREAN    CLOUD3   464
      KFLAG = 1                                                          CLOUD3   465
  200 CONTINUE                                                           CLOUD3   466
C        XIL,ETAL,ZETAL IS THE POSITION IN THE K'TH CLOUD COORDINATE     CLOUD3   467
C        SYSTEM OF INTERSECTION ..  GET DISTANCE FROM SOURCE TO THIS PT  CLOUD3   468
CLJ       RDIST2=SQUARE OF DISTANCE FROM SOURCE TO CLOUD-INTERCEPT POINT CLOUD3   469
      RDIST2 = (XIL - XI(NS,K))**2 + (ETAL - ETA(NS,K))**2               CLOUD3   470
     X   + (ZETAL - ZETA(NS,K))**2                                       CLOUD3   471
      IF( TCOEF.GT.0.0 )  GO TO 220                                      CLOUD3   472
      EMISS = ESAVE                                                      CLOUD3   473
      TCOEF = TSAVE                                                      CLOUD3   474
      TAREA = ASAVE                                                      CLOUD3   475
CLJ       IN THE FOLLOWING TWO EXPRESSIONS THE DIVISION BY FOV IF FOV    CLOUD3   476
CLJ       EXCEEDS TAREA (WHEN THE CLOUD EFFECTIVELY BECOMES A POINT      CLOUD3   477
CLJ       SOURCE) IS PROPER IF THE USER MULTIPLIES THE RADIANCES         CLOUD3   478
CLJ       CORRESPONDING TO TCOEF AND EMISS BY THE SOLID ANGLE OF THE     CLOUD3   479
CLJ       DETECTOR, FOV/R**2, TO OBTAIN THE IRRADIANCE AT THE DETECTOR,  CLOUD3   480
CLJ       AT DISTANCE R FROM THE CLOUD.                                  CLOUD3   481
  220 TAFOV = AMAX1( TAREA,FOV )                                         CLOUD3   482
      TCOEF = TCOEF / TAFOV * (4.*PI*RDIST2)                             CLOUD3   483
      EMISS = EMISS / TAFOV                                              CLOUD3   484
CLJ       RESTORE SOURCE POSITION...                                     CLOUD3   485
      XI(1,K)   =   XISV                                                 CLOUD3   486
      ETA(1,K)  =  ETASV                                                 CLOUD3   487
      ZETA(1,K) = ZETASV                                                 CLOUD3   488
      RETURN                                                             CLOUD3   489
      END                                                                CLOUD3   490
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      SUBROUTINE CLOUD9(RTP1,RTP2,RTP3,EC1,EC2,EC3,K)                   CLOUD9    2
CLJ                                                                     CLOUD9    3
CLJ   SUBROUTINE CLOUD9 HAS TWO ENTRY POINTS.                           CLOUD9    4
CLJ   ENTRY-(CLD E TO C) CONVERTS FROM GEOGRAPHIC POLAR COORDINATES TO  CLOUD9    5
CLJ   CLOUD-CENTERED CARTESIAN COORDINATES.                             CLOUD9    6
CLJ   ENTRY-(CLD C TO E) CONVERTS FROM CLOUD-CENTERED CARTESIAN         CLOUD9    7
CLJ   COORDINATES TO GEOGRAPHIC POLAR COORDINATES.                      CLOUD9    8
CLJ                                                                     CLOUD9    9
CLJ   INPUT PARAMETERS                                                  CLOUD9   10
CLJ      ARGUMENT LIST (FOR ENTRY CLD E TO C)                           CLOUD9   11
CLJ            RTP1, = GEOGRAPHIC POLAR COORDINATES (RTP1=RADIUS, KM.   CLOUD9   12
CLJ            RTP2,      RTP2=POLAR ANGLE (COLATITUDE), DEG.           CLOUD9   13
CLJ            RTP3       RTP3=AZIMUTHAL ANGLE (EAST LONGITUDE), DEG.)  CLOUD9   14
CLJ                  K = CLOUD NUMBER                                   CLOUD9   15
CLJ      ARGUMENT LIST (FOR ENTRY CLD C TO E)                           CLOUD9   16
CLJ             EC1, = CLOUD-K CENTERED CARTESIAN COORDINATES, KM       CLOUD9   17
CLJ             EC2, AND EC3                                            CLOUD9   18
CLJ                 K = CLOUD NUMBER                                    CLOUD9   19
CLJ      CLOUD COMMON                                                   CLOUD9   20
CLJ       THETCD(K) = COLATITUDE OF CLOUD-K, DEG                        CLOUD9   21
CLJ        PHICD(K) = EAST LONGITUDE OF CLOUD-K, DEG                    CLOUD9   22
CLJ       CLDPSI(I) = AZIMUTHAL ANGLE, MEASURED COUNTERCLOCKWISE        CLOUD9   23
CLJ                   LOOKING DOWN, ORIENTING CLOUD ABOUT (VERTICAL)    CLOUD9   24
CLJ                   Z-AXIS.  CLOUDS ARE NORMALLY ORIENTED WITH        CLOUD9   25
CLJ                   (+A)-AXIS EASTWARD (PSI=0.)   DEGREES             CLOUD9   26
CLJ      PARAMS COMMON                                                  CLOUD9   27
CLJ              DTR = CONVERSION FACTOR FROM DEGREES TO RADIANS        CLOUD9   28
CLJ               RE = EARTH'S RADIUS, KM                               CLOUD9   29
CLJ   OUTPUT PARAMETERS                                                 CLOUD9   30
CLJ      ARGUMENT LIST (FOR ENTRY CLD E TO C)                           CLOUD9   31
CLJ             EC1, = CLOUD-K CENTERED CARTESIAN COORDINATES, KM       CLOUD9   32
CLJ             EC2, AND EC3                                            CLOUD9   33
CLJ      ARGUMENT LIST (FOR ENTRY CLD C TO E)                           CLOUD9   34
CLJ            RTP1, = GEOGRAPHIC POLAR COORDINATES (RTP1=RADIUS, KM.   CLOUD9   35
CLJ            RTP2,      RTP2=POLAR ANGLE (COLATITUDE), DEG.           CLOUD9   36
CLJ            RTP3       RTP3=AZIMUTHAL ANGLE (EAST LONGITUDE), DEG.)  CLOUD9   37
      COMMON/CLOUD/ NCLOUD,                                             CLOUD     2
     1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),      CLOUD     3
     2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                             CLOUD     4
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS    2
      DIMENSION  DA(3,3), XYZ(3)                                        CLOUD9   40
      EQUIVALENCE (DR,DTR),(REARTH,RE)                                  CLOUD9   41
CLJ                                                                     CLOUD9   42
CLJ       ENTRY CLD E TO C CONVERTS FROM GEOGRAPHIC POLAR COORDINATES   CLOUD9   43
CLJ       (RTP(1,2,3) IN THE ARGUMENT LIST) TO CLOUD-CENTERED CARTESIAN CLOUD9   44
CLJ       COORDINATES (EC(1,2,3) IN THE ARGUMENT LIST).                 CLOUD9   45
CLJ                                                                     CLOUD9   46
      ENTRY CLD E TO C                                                  CLOUD9   47
C                                                                       CLOUD9   48
      IFLAG = 1                                                         CLOUD9   49
C                                                                       CLOUD9   50
C***** DEFINE (X,Y,Z) EARTH CENTERED COORDINATES                        CLOUD9   51
C                                                                       CLOUD9   52
      CALL POL TO CT ( RTP1,RTP2,RTP3,X,Y,Z )                           CLOUD9   53
C                                                                       CLOUD9   54
      XYZ(1) =  X                                                       CLOUD9   55
      XYZ(2) =  Y                                                       CLOUD9   56
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      XYZ(3) =  Z                                                       CLOUD9    57
C                                                                       CLOUD9    58
C***** SET UP MATRIX DA( 3 BY 3 )                                       CLOUD9    59
      SINPHI = SIN( DR*PHICD(K) )                                       CLOUD9    60
      COSPHI = COS( DR*PHICD(K) )                                       CLOUD9    61
      SINTHE = SIN( DR*THETCD(K) )                                      CLOUD9    62
      COSTHE = COS( DR*THETCD(K) )                                      CLOUD9    63
      DA(1,1) = -SINPHI                                                 CLOUD9    64
      DA(2,1) = -COSTHE*COSPHI                                          CLOUD9    65
      DA(3,1) =  SINTHE*COSPHI                                          CLOUD9    66
      DA(1,2) =  COSPHI                                                 CLOUD9    67
      DA(2,2) = -COSTHE*SINPHI                                          CLOUD9    68
      DA(3,2) =  SINTHE*SINPHI                                          CLOUD9    69
      DA(1,3) =  0.0                                                    CLOUD9    70
      DA(2,3) =  SINTHE                                                 CLOUD9    71
      DA(3,3) =  COSTHE                                                 CLOUD9    72
C                                                                       CLOUD9    73
C***** CALCULATE FINAL CLOUD CENTERED COORDINATE SYSTEM                 CLOUD9    74
    1 CONTINUE                                                          CLOUD9    75
      X=0. $ Y=0. $ Z=0.                                                CLOUD9    76
      DO 11 J=1,3                                                       CLOUD9    77
      X = X + DA(1,J)*XYZ(J)                                            CLOUD9    78
      Y = Y + DA(2,J)*XYZ(J)                                            CLOUD9    79
   11 Z = Z + DA(3,J)*XYZ(J)                                            CLOUD9    80
C                                                                       CLOUD9    81
      IF( IFLAG .EQ. 2 ) GO TO 14                                       CLOUD9    82
      EC1   = X*COS( DR*CLDPSI(K) ) + Y*SIN( DR*CLDPSI(K) )             CLOUD9    83
      EC2   = Y*COS( DR*CLDPSI(K) ) - X*SIN( DR*CLDPSI(K) )             CLOUD9    84
      EC3   = Z - ( REARTH + HCLOUD(K) )                                CLOUD9    85
      RETURN                                                            CLOUD9    86
C                                                                       CLOUD9    87
   14 CALL CT TO POL(RTP1,RTP2,RTP3,X,Y,Z)                              CLOUD9    88
C                                                                       CLOUD9    89
      RETURN                                                            CLOUD9    90
CLJ                                                                     CLOUD9    91
CLJ       ENTRY CLD C TO E CONVERTS FROM CLOUD-CENTERED CARTESIAN       CLOUD9    92
CLJ       COORDINATES (EC(1,2,3) IN THE ARGUMENT LIST) TO GEOGRAPHIC    CLOUD9    93
CLJ       POLAR COORDINATES (RTP(1,2,3) IN THE ARGUMENT LIST).          CLOUD9    94
CLJ                                                                     CLOUD9    95
      ENTRY CLD C TO E                                                  CLOUD9    96
C                                                                       CLOUD9    97
      IFLAG = 2                                                         CLOUD9    98
C                                                                       CLOUD9    99
      XYZ(1) = EC1*COS( DR*CLDPSI(K) ) - EC2*SIN( DR*CLDPSI(K) )        CLOUD9   100
      XYZ(2) = EC1*SIN( DR*CLDPSI(K) ) + EC2*COS( DR*CLDPSI(K) )        CLOUD9   101
      XYZ(3) = EC3 + ( RE + HCLOUD(K) )                                 CLOUD9   102
C                                                                       CLOUD9   103
C      TRANSPOSE MATRIX                                                 CLOUD9   104
      SINPHI = SIN( DR*PHICD(K) )                                       CLOUD9   105
      COSPHI = COS( DR*PHICD(K) )                                       CLOUD9   106
      SINTHE = SIN( DR*THETCD(K) )                                      CLOUD9   107
      COSTHE = COS( DR*THETCD(K) )                                      CLOUD9   108
      DA(1,1) = -SINPHI                                                 CLOUD9   109
      DA(1,2) = -COSTHE*COSPHI                                          CLOUD9   110
      DA(1,3) =  SINTHE*COSPHI                                          CLOUD9   111
      DA(2,1) =  COSPHI                                                 CLOUD9   112
      DA(2,2) = -COSTHE*SINPHI                                          CLOUD9   113
      DA(2,3) =  SINTHE*SINPHI                                          CLOUD9   114
      DA(3,1) =  0.0                                                    CLOUD9   115
      DA(3,2) =  SINTHE                                                 CLOUD9   116
      DA(3,3) =  COSTHE                                                 CLOUD9   117
C                                                                       CLOUD9   118
CLJ       CALCULATE FINAL GEOGRAPHIC POLAR COORDINATES.                 CLOUD9   119
      GO TO 1                                                           CLOUD9   120
      END                                                               CLOUD9   121
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      SUBROUTINE CONVERT(R,TH,PH,X,Y,Z)                                 CONVERT
CLJ                                                                     CONVERT
CLJ   SUBROUTINE CONVERT HAS TWO ENTRY POINTS.                          CONVERT
CLJ   ENTRY-(CT TO POL) CONVERTS FROM THE CARTESIAN COORDINATES (X,Y,Z) CONVERT
CLJ   TO THE POLAR COORDINATES (R,TH,PH).                               CONVERT
CLJ   ENTRY-(POL TO CT) CONVERTS FROM THE POLAR COORDINATES (R,TH,PH)   CONVERT
CLJ   TO THE CARTESIAN COORDINATES (X,Y,Z).                             CONVERT
CLJ                                                                     CONVERT
CLJ   INPUT PARAMETERS                                                  CONVERT
CLJ      ARGUMENT LIST (FOR ENTRY CT TO POL)                            CONVERT
CLJ               X, = CARTESIAN COORDINATES, USUALLY IN KM             CONVERT
CLJ               Y, AND Z                                              CONVERT
CLJ      ARGUMENT LIST (FOR ENTRY POL TO CT)                            CONVERT
CLJ                R = RADIUS, USUALLY IN KM                            CONVERT
CLJ               TH = POLAR ANGLE (COLATITUDE), DEG                    CONVERT
CLJ               PH = AZIMUTHAL ANGLE (EAST LONGITUDE), DEG            CONVERT
CLJ   OUTPUT PARAMETERS                                                 CONVERT
CLJ      ARGUMENT LIST (FOR ENTRY CT TO POL)                            CONVERT
CLJ                R = RADIUS, SAME UNITS AS X,Y,Z                      CONVERT
CLJ               TH = POLAR ANGLE (COLATITUDE), DEG                    CONVERT
CLJ               PH = AZIMUTHAL ANGLE (EAST LONGITUDE), DEG            CONVERT
CLJ      ARGUMENT LIST (FOR ENTRY POL TO CT)                            CONVERT
CLJ               X, = CARTESIAN COORDINATES, SAME UNITS AS R           CONVERT
CLJ               Y,Z  (EARTH-CENTERED IF (R,TH,PH) ARE EARTH-CENTERED) CONVERT
CLJ                                                                     CONVERT
      DATA DTR,RTD  / .01745329251994,57.2957795131 /                   CONVERT
CLJ                                                                     CONVERT
      ENTRY CT TO POL                                                   CONVERT
CLJ                                                                     CONVERT
      R= SQRT( X**2 + Y**2 + Z**2 )                                     CONVERT
      TH= ACOS( Z/R)*RTD                                                CONVERT
      PH = ATAN2( Y,X )*RTD                                             CONVERT
      RETURN                                                            CONVERT
CLJ                                                                     CONVERT
      ENTRY POL TO CT                                                   CONVERT
CLJ                                                                     CONVERT
      CT = COS( DTR*TH ) $ ST = SIN( DTR*TH )                           CONVERT
      CP = COS( DTR*PH ) $ SP = SIN( DTR*PH )                           CONVERT
      X= R*ST*CP                                                        CONVERT
      Y= R*ST*SP                                                        CONVERT
      Z= R*CT                                                           CONVERT
      RETURN                                                            CONVERT
      END                                                               CONVERT
```

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      SUBROUTINE DIFFUS(K,ALAM)                                         DIFFUS
CLJ                                                                     DIFFUS
CLJ   SUBROUTINE DIFFUS PROVIDES THE OUTGOING PHOTON FLUX (RADIANT      DIFFUS
CLJ   EMITTANCE) FROM A SURFACE ELEMENT ON AN ELLIPSOIDAL CLOUD         DIFFUS
CLJ   IRRADIATED BY A UNIT-STRENGTH, ISOTROPIC POINT SOURCE (BASED ON AN DIFFUS
CLJ   APPROXIMATE, ITERATIVE SOLUTION OF THE DIFFUSION EQUATION).       DIFFUS
CLJ                                                                     DIFFUS
CLJ   INPUT PARAMETERS                                                  DIFFUS
CLJ      ARGUMENT LIST                                                  DIFFUS
CLJ              K = CLOUD NUMBER                                       DIFFUS
CLJ           ALAM = WAVELENGTH, MICRONS                                DIFFUS
CLJ      CDCORD COMMON                                                  DIFFUS
CLJ          ASQ(K) = SQUARE OF LENGTH A, THE SEMI-MAJOR AXIS IN        DIFFUS
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2      DIFFUS
CLJ          BSQ(K) = SQUARE OF LENGTH B, THE SEMI-MINOR AXIS IN        DIFFUS
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2      DIFFUS
CLJ          CSQ(K) = SQUARE OF LENGTH C, THE SEMI-MINOR AXIS IN        DIFFUS
CLJ                   VERTICAL DIRECTION OF ELLIPSOIDAL CLOUD, KM**2    DIFFUS
CLJ     CTHBAR(I,K) = POLAR ANGLE IN CLOUD-CENTERED COORDINATES OF THE  DIFFUS
CLJ                   CENTER OF THE I-TH POLAR SET OF SURFACE FACETS FOR DIFFUS
CLJ                   ELLIPSOIDAL CLOUD-K,  DEGREES    I=1,8     K=1,20 DIFFUS
CLJ    CPHIBAR(J,K) = AZIMUTHAL ANGLE IN CLOUD-CENTERED COORDINATES OF  DIFFUS
CLJ                   THE CENTER OF THE J-TH AZIMUTHAL SET OF SURFACE   DIFFUS
CLJ                   FACETS FOR ELLIPSOIDAL CLOUD-K,  DEGREES          DIFFUS
CLJ                          J=1,16    K=1,20                           DIFFUS
CLJ     CRBAR(I,J,K) = CLOUD-CENTERED RADIAL DISTANCE TO THE CENTER OF  DIFFUS
CLJ                   SURFACE FACET I,J IN PRINCIPAL OCTANT,  KM        DIFFUS
CLJ                      I=1,4     J=1,4     K=1,20                     DIFFUS
CLJ                   (RESULTS FOR OTHER OCTANTS ARE OBTAINED BY SYMTY.) DIFFUS
CLJ     CAREA(I,J,K) = AREA OF SURFACE FACET I,J IN PRINCIPAL OCTANT OF DIFFUS
CLJ                   ELLIPSOIDAL CLOUD-K,  KM**2   I=1,4  J=1,4  K=1,20 DIFFUS
CLJ      CDDATA COMMON                                                  DIFFUS
CLJ          ALAMT(I) = WAVELENGTHS AT WHICH OPTICAL PROPERTIES ARE     DIFFUS
CLJ                     TABULATED, MICRONS                              DIFFUS
CLJ         SIGT(I,K) = TOTAL MICROSCOPIC EXTINCTION CROSS-SECTION AT   DIFFUS
CLJ                     WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K, MICRON**2 DIFFUS
CLJ         SIGS(I,K) = MICROSCOPIC SCATTERING CROSS-SECTION AT         DIFFUS
CLJ                     WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K, MICRON**2 DIFFUS
CLJ               W(I) = (NORMALIZED) CONTRIBUTION OF SPECULARLY-       DIFFUS
CLJ                     REFLECTED RADIATION TO SCATTERED RADIATION WITH DIFFUS
CLJ                     THE DIFFRACTED RADIATION CONTRIBUTING UNITY.    DIFFUS
CLJ                     USED ONLY FOR THE LARGE-PARTICLE-SIZE CLOUDS,   DIFFUS
CLJ                     TYPES 11 THROUGH 14.  (DIMENSIONLESS)           DIFFUS
CLJ       XMUBAR(I,K) = AVERAGE COSINE OF SCATTERING ANGLE AT           DIFFUS
CLJ                     WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K            DIFFUS
CLJ            DNO(K) = NUMBER DENSITY OF WATER DROPLETS IN             DIFFUS
CLJ                     CLOUD-TYPE K, 1/CM**3                           DIFFUS
CLJ      CLOUD COMMON                                                   DIFFUS
CLJ       KCLOUD(K) = CLOUD-TYPE INDEX (1,14) FOR CLOUD K,  K=1,20      DIFFUS
CLJ      FLUX COMMON                                                    DIFFUS
CLJ        FIN(I,J) = 4.*PI TIMES THE INCOMING (NORMAL) PHOTON FLUX     DIFFUS
CLJ                   (IRRADIANCE) AT ELLIPSOIDAL-SURFACE FACET (I,J) AT DIFFUS
CLJ                   DISTANCE R FROM A UNIT STRENGTH, ISOTROPIC POINT  DIFFUS
CLJ                   SOURCE (I.E., (R DOT N)/R**3),   I=1,8    J=1,16  DIFFUS
CLJ                     4*PI*PHOTONS/(KM**2 SEC) FOR UNIT SOURCE        DIFFUS
CLJ      PARAMS COMMON                                                  DIFFUS
CLJ              PI = 3.14159265                                        DIFFUS
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CLJ   OUTPUT PARAMETER                                                  DIFFUS    59
CLJ      FLUX COMMON                                                    DIFFUS    60
CLJ       FOUT(I,J) = 4.*PI TIMES THE OUTGOING PHOTON FLUX (RADIANT     DIFFUS    61
CLJ                   EMITTANCE) FROM ELLIPSOIDAL-SURFACE FACET (I,J)   DIFFUS    62
CLJ                   FOR A UNIT STRENGTH, ISOTROPIC POINT SOURCE       DIFFUS    63
CLJ                   (ONE PHOTON PER SEC), (4.*PI*PHOTONS)/(KM**2 SEC) DIFFUS    64
CLJ                                                                     DIFFUS    65
      COMMON/CLOUD/ NCLOUD,                                             CLOUD      2
     1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),      CLOUD      3
     2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                              CLOUD      4
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS     2
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                  CDCORD     2
     1               XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)     CDCORD     3
     X  , ASQ(20),BSQ(20),CSQ(20)                                       CDCORD     4
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)         CDCORD     5
       DIMENSION SR(8,16),QR(8,16),F1(8,16)                             DIFFUS    69
      COMMON/CDDATA/ ALAMT(10),SIGT(10,14),SIGS(10,14),W(10),           CDDATA     2
     1  XMUBAR(10,14),DNO(14),RAD(14),CLDBASE(14),CLDTHK(14)            CDDATA     3
      COMMON/FLUX/  FIN(8,16),FOUT(8,16)                                FLUX       2
      DIMENSION  XIK(8,16),ETAK(8,16),ZETAK(8,16)                       DIFFUS    72
      DIMENSION  CXTRAP(11),XTRAP(11),CRELAX(29),RELAX(29)              DIFFUS    73
CLJ                                                                     DIFFUS    74
CLJ       XTRAP(CXTRAP(I)) AND RELAX(CRELAX(I)) ARE, RESPECTIVELY, THE  DIFFUS    75
CLJ       (DIMENSIONLESS) LINEAR EXTRAPOLATION LENGTHS AND RELAXATION   DIFFUS    76
CLJ       RATES, AT NXTRPC AND NRELXC VALUES CXTRAP(I) AND CRELAX(I) OF DIFFUS    77
CLJ       THE PARAMETER C (RATIO OF SCATTERING TO TOTAL CROSS-SECTION), DIFFUS    78
CLJ       TAKEN FROM TABLES 23 AND 9, RESPECTIVELY, OF INTRODUCTION TO  DIFFUS    79
CLJ       THE THEORY OF NEUTRON DIFFUSION, VOLUME 1, BY K.M. CASE,      DIFFUS    80
CLJ       F. DE HOFFMANN, AND G. PLACZEK, LASL, JUNE 1953.              DIFFUS    81
CLJ                                                                     DIFFUS    82
      DATA  NXTRPC,NRELXC / 11, 29 /                                    DIFFUS    83
      DATA  CXTRAP / 0.0   , 0.1   , 0.2   , 0.3   , 0.4   , 0.5   ,   DIFFUS    84
     1               0.6   , 0.7   , 0.8   , 0.9   , 1.0   /          DIFFUS    85
      DATA   XTRAP / 1.0000, 1.0000, 0.9993, 0.9889, 0.9606, 0.9201,   DIFFUS    86
     1               0.8750, 0.8300, 0.7871, 0.7472, 0.7104/           DIFFUS    87
      DATA CRELAX/0.00    ,0.10    ,0.20    ,0.30    ,0.35    ,0.40    ,DIFFUS    88
     1            0.45    ,0.50    ,0.55    ,0.60    ,0.65    ,0.70    ,DIFFUS    89
     2            0.75    ,0.80    ,0.82    ,0.84    ,0.86    ,0.88    ,DIFFUS    90
     3            0.90    ,0.91    ,0.92    ,0.93    ,0.94    ,0.95    ,DIFFUS    91
     4            0.96    ,0.97    ,0.98    ,0.99    ,1.00    /        DIFFUS    92
      DATA  RELAX/1.000000,1.000000,0.999909,0.997414,0.993164,0.985624,DIFFUS    93
     1            0.973976,0.957504,0.935529,0.907332,0.872065,0.828635,DIFFUS    94
     2            0.775516,0.710412,0.680241,0.647220,0.610884,0.570591,DIFFUS    95
     3            0.525430,0.500615,0.474002,0.445270,0.413976,0.379485,DIFFUS    96
     4            0.340829,0.296381,0.242983,0.172511,0.0      /       DIFFUS    97
CLJ       THE ARITHMETIC FUNCTION DIST(X1,Y1,Z1,X2,Y2,Z2) COMPUTES THE  DIFFUS    98
CLJ       DISTANCE BETWEEN THE POINTS (X1,Y1,Z1) AND (X2,Y2,Z2).        DIFFUS    99
      DIST(X1,Y1,Z1,X2,Y2,Z2) =SQRT((X2-X1)**2+(Y2-Y1)**2+(Z2-Z1)**2)   DIFFUS   100
C        EVALUATE THE CART COORD OF THE 128 AREAS IN THE K TH CLD      DIFFUS   101
      DO 10 I =.1,8                                                     DIFFUS   102
      IP  = IPRIME(I)                                                   DIFFUS   103
       DO 10 J = 1,16                                                   DIFFUS   104
      JP = IPRIME(J)                                                    DIFFUS   105
      CALL POL TO CT(CRBAR(IP,JP,K),CTHBAR(I,K),CPHIBAR(J,K),           DIFFUS   106
     X   XIK(I,J),ETAK(I,J),ZETAK(I,J) )                                DIFFUS   107
   10 CONTINUE                                                          DIFFUS   108
C                                                                       DIFFUS   109
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C        CALCULATE THE DIFFUSION PARAMETERS                                DIFFUS
C                                                                          DIFFUS
C        K IS THE CLOUD NO. INDEX                                          DIFFUS
C        KK IS THE TYPE INDEX FROM KCLOUD(K) TO GET AT                     DIFFUS
C        THE CLOUD PROPERTIES                                              DIFFUS
C                                                                          DIFFUS
      KK = KCLOUD(K)                                                       DIFFUS
       DO 20 I = 2,10                                                      DIFFUS
      IF(ALAMT(I) .GT. ALAM) GO TO 25                                      DIFFUS
   20 CONTINUE                                                             DIFFUS
      I = 10                                                               DIFFUS
   25 XX = ( ALAM - ALAMT(I-1) )/( ALAMT(I) - ALAMT(I-1) )                 DIFFUS
      SGT= ( SIGT(I-1,KK) + ( SIGT(I,KK) - SIGT(I-1,KK) )*XX)*DNO(KK)*     DIFFUS
     X 1.E-3                                                               DIFFUS
      SGS= ( SIGS(I-1,KK) + ( SIGS(I,KK) - SIGS(I-1,KK) )*XX)*DNO(KK)      DIFFUS
     X *1.E-3                                                              DIFFUS
      WI = W(I-1) + ( W(I)-W(I-1) )*XX                                     DIFFUS
      IF( KK.GT.10 )  SGT = 2.*PI*RAD(KK)**2 * DNO(KK) * 1.0E-03           DIFFUS
      IF( KK.GT.10 )  SGS = 0.5*(1.+WI)*SGT                                DIFFUS
      XMU = XMUBAR(I-1,KK)+(XMUBAR(I,KK)-XMUBAR(I-1,KK) ) * XX             DIFFUS
CLJ        IN THE FOLLOWING EXPRESSIONS,                                   DIFFUS
CLJ              SGT = MACROSCOPIC TOTAL CROSS-SECTION, 1/KM               DIFFUS
CLJ              SGS = MACROSCOPIC SCATTERING CROSS-SECTION, 1/KM          DIFFUS
CLJ             SGTR = MACROSCOPIC TRANSPORT CROSS-SECTION, 1/KM           DIFFUS
CLJ              DDD = DIFFUSION COEFFICIENT, KM                           DIFFUS
CLJ               DA = 0.25 TIMES THE RATIO OF SCATTERING CROSS-SECTION    DIFFUS
CLJ                    TO TOTAL CROSS-SECTION FOR PHOTONS OF WAVELENGTH    DIFFUS
CLJ                    ALAM IN CLOUD-TYPE KK                               DIFFUS
CLJ        THE ABOVE DEFINITIONS FOR THE DIFFUSION PARAMETERS APPLY TO A   DIFFUS
CLJ        WEAKLY ABSORBING MEDIUM.  FOR A STRONGLY ABSORBING MEDIUM,      DIFFUS
CLJ        MODIFIED DIFFUSION PARAMETERS ARE REQUIRED.  WE ALSO COMPUTE    DIFFUS
CLJ        THE LATTER TYPE AND USE THEM AFTER 9/30/78.                     DIFFUS
      SGTR = SGT - XMU * SGS                                               DIFFUS
      GO TO 35                                                             DIFFUS
      DDD= SGS / (3.*SGT*SGTR)                                             DIFFUS
      DK = (SGT-SGS) / DDD                                                 DIFFUS
CLJ              DK = INVERSE DIFFUSION LENGTH, 1/KM                       DIFFUS
      DK = SQRT(DK)                                                        DIFFUS
      DA = 0.25 * SGS / SGT                                                DIFFUS
      DB = DDD/2.                                                          DIFFUS
      WRITE(6,1010)  KK,DA,DB,DK                                           DIFFUS
 1010 FORMAT (*0  FOR CLOUD-TYPE K = *,I3,* THE STANDARD DIFFUSION PARAM   DIFFUS
     1ETERS ARE DA,DB,DK = *,1P3E12.4)                                     DIFFUS
   35 CONTINUE                                                             DIFFUS
CLJ                                                                        DIFFUS
CLJ        WE NOW COMPUTE THE MODIFIED DIFFUSION PARAMETERS FOR AN         DIFFUS
CLJ        ABSORBING MEDIUM.                                               DIFFUS
CLJ                                                                        DIFFUS
      C = SGS/SGT                                                          DIFFUS
      CALL LINEAR( C,XTRAPC,CXTRAP,XTRAP,NXTRPC )                          DIFFUS
      CALL LINEAR( C,RELAXC,CRELAX,RELAX,NRELXC )                          DIFFUS
      DDD = (1.-C)/(RELAXC*RELAXC*SGTR)                                    DIFFUS
      DK = RELAXC*SQRT( SGT*SGTR )                                         DIFFUS
      DB = DDD/2.                                                          DIFFUS
      DA = DB*DK/(XTRAPC*RELAXC)                                           DIFFUS
      GO TO 37                                                             DIFFUS
      WRITE(6,1020)  KK,DA,DB,DK                                           DIFFUS
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 1020 FORMAT (*   FOR CLOUD-TYPE K = *,I3,* THE MODIFIED DIFFUSION PARAM DIFFUS    167
     1ETERS ARE DA,DB,DK = *,1P3E12.4)                                  DIFFUS    168
   37 CONTINUE                                                          DIFFUS    169
C                                                                       DIFFUS    170
C                                                                       DIFFUS    171
C                                                                       DIFFUS    172
CLJ       DO-200 LOOPS ARE OVER THE OUT-FACETS                          DIFFUS    173
      DO 200 IO = 1,8                                                   DIFFUS    174
      IOP = IPRIME(IO)                                                  DIFFUS    175
      DO 200 JO = 1,16                                                  DIFFUS    176
      JOP = IPRIME(JO)                                                  DIFFUS    177
      SR(IO,JO) = - FIN(IO,JO)                                          DIFFUS    178
      QR(IO,JO) = 1.                                                    DIFFUS    179
CLJ       DO-100 LOOPS ARE OVER THE IN-FACETS                           DIFFUS    180
      DO 100 II = 1,8                                                   DIFFUS    181
      IIP = IPRIME(II)                                                  DIFFUS    182
      DO 100 JI = 1,16                                                  DIFFUS    183
      JIP = IPRIME(JI)                                                  DIFFUS    184
      IF(IO .EQ. II  .AND.  JO .EQ. JI) GO TO 50                        DIFFUS    185
CLJ               R = DISTANCE BETWEEN IN-FACET AND OUT-FACET, KM       DIFFUS    186
      R = DIST(XIK(IO,JO),ETAK(IO,JO),ZETAK(IO,JO),                     DIFFUS    187
     1   XIK(II,JI),ETAK(II,JI),ZETAK(II,JI)  )                         DIFFUS    188
      GR = EXP(-DK*R) / R                                               DIFFUS    189
      EN DOT DG = GR *(DK + 1. / R)                                     DIFFUS    190
      CALL VSNORM(XIK(II,JI),ETAK(II,JI),ZETAK(II,JI),AN1,AN2,AN3,K)    DIFFUS    191
      EN DOT DG = EN DOT DG*(( XIK(IO,JO) - XIK(II,JI) )*AN1            DIFFUS    192
     1                      + (ETAK(IO,JO) - ETAK(II,JI) ) *AN2         DIFFUS    193
     X + ( ZETAK(IO,JO) - ZETAK(II,JI) )*AN3)/R                         DIFFUS    194
      FP = DA * GR + EN DOT DG * DDD/2.                                 DIFFUS    195
      FM =-DA * GR + EN DOT DG * DDD/2.                                 DIFFUS    196
      GO TO 90                                                          DIFFUS    197
C                                                                       DIFFUS    198
C        CALCULATE A LOCAL RADIUS OF CURVATURE                          DIFFUS    199
C        BASED UPON AN AVERAGE OF THE TWO RADII OF CURVATURE            DIFFUS    200
   50 RBARX = ( XIK(II,JI)/ASQ(K))**2 +                                 DIFFUS    201
     1        (ETAK(II,JI)/BSQ(K))**2 +                                DIFFUS    202
     1       (ZETAK(II,JI)/CSQ(K))**2                                  DIFFUS    203
      RBAR =  (RBARX -(   XIK(II,JI)/ASQ(K))**2)/ASQ(K)  +              DIFFUS    204
     1        (RBARX -(  ETAK(II,JI)/BSQ(K))**2)/BSQ(K)  +              DIFFUS    205
     2        (RBARX -( ZETAK(II,JI)/CSQ(K))**2)/CSQ(K)                 DIFFUS    206
CLJ       THE FINAL RBAR IS THE MEAN CURVATURE (I.E., ONE-HALF THE SUM  DIFFUS    207
CLJ       OF THE TWO PRINCIPAL CURVATURES).                             DIFFUS    208
      RBAR = 1. / (RBAR*ASQ(K)*BSQ(K)*CSQ(K)*SQRT(RBARX)*0.5)           DIFFUS    209
      GPC = 2.*SQRT(PI/CAREA(IIP,JIP,K))                                DIFFUS    210
      FP = GPC *(  DA  -  DDD/2.*RBAR/2.)                               DIFFUS    211
      FM = GPC * (-DA  -  DDD/2.*RBAR/2.)                               DIFFUS    212
   90 CONTINUE                                                          DIFFUS    213
      SR(IO,JO) = SR(IO,JO) - FIN(II,JI)*FM*CAREA(IIP,JIP,K)/(PI*DDD)   DIFFUS    214
      QR(IO,JO) = QR(IO,JO) + FP*CAREA(IIP,JIP,K)/ ( PI * DDD)          DIFFUS    215
  100 CONTINUE                                                          DIFFUS    216
      F1(IO,JO) = SR(IO,JO) / QR(IO,JO)                                 DIFFUS    217
      FOUT(IO,JO) = F1(IO,JO)                                           DIFFUS    218
  200 CONTINUE                                                          DIFFUS    219
C        UNTIL A MORE SATISFACTORY SOLUTION CAN BE FOUND,               DIFFUS    220
C        WE WILL USE THE FIRST TERM IN THE NEUMANN SOLUTION             DIFFUS    221
      GO TO 210                                                         DIFFUS    222
      WRITE(6,4000) (J,(FIN (I,J),I=1,8),J=1,16)                        DIFFUS    223
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      WRITE(6,4000) (J,(SR  (I,J),I=1,8),J=1,16)                        DIFFUS   224
      WRITE(6,4000) (J,(QR  (I,J),I=1,8),J=1,16)                        DIFFUS   225
      WRITE(6,4000) (J,(FOUT(I,J),I=1,8),J=1,16)                        DIFFUS   226
 4000 FORMAT(1H0,I4,1P8E12.4/(1X,I4,1P8E12.4))                          DIFFUS   227
  210 CONTINUE                                                          DIFFUS   228
      RETURN                                                            DIFFUS   229
CLJ       HAVING OBTAINED THE FIRST-APPROXIMATION SOLUTION FOR THE      DIFFUS   230
CLJ       PHOTON FLUX, WE PROCEED TO OBTAIN THE SECOND-APPROXIMATION    DIFFUS   231
CLJ       SOLUTION.  MOST OF THE STEPS ARE A REPETITION OF THOSE ABOVE. DIFFUS   232
CLJ                                                                     DIFFUS   233
CLJ       DO-400 LOOPS ARE OVER THE OUT-FACETS                          DIFFUS   234
CLJ                                                                     DIFFUS   235
      DO 400 IO = 1,8                                                   DIFFUS   236
      IOP = IPRIME(IO)                                                  DIFFUS   237
      DO 400 JO = 1,16                                                  DIFFUS   238
      JOP = IPRIME(JO)                                                  DIFFUS   239
      FOUT(IO,JO) = F1(IO,JO)                                           DIFFUS   240
CLJ       DO-300 LOOPS ARE OVER THE IN-FACETS                           DIFFUS   241
      DO 300 II = 1,8                                                   DIFFUS   242
      IIP = IPRIME(II)                                                  DIFFUS   243
      DO 300 JI = 1,16                                                  DIFFUS   244
      IF(IO.EQ.II .AND. JO.EQ.JI) GO TO 300                             DIFFUS   245
      JIP = IPRIME(JI)                                                  DIFFUS   246
      R = DIST(XIK(IO,JO),ETAK(IO,JO),ZETAK(IO,JO),                     DIFFUS   247
     1   XIK(II,JI),ETAK(II,JI),ZETAK(II,JI)  )                         DIFFUS   248
      GR = EXP(-DK*R) / R                                               DIFFUS   249
      EN DOT DG = GR *(DK + 1. / R)                                     DIFFUS   250
      CALL VSNORM(XIK(II,JI),ETAK(II,JI),ZETAK(II,JI),AN1,AN2,AN3,K)    DIFFUS   251
      EN DOT DG = EN DOT DG*(( XIK(IO,JO) - XIK(II,JI) )*AN1            DIFFUS   252
     1                       + (ETAK(IO,JO) - ETAK(II,JI) ) *AN2        DIFFUS   253
     X + ( ZETAK(IO,JO) - ZETAK(II,JI) )*AN3)/R                         DIFFUS   254
      FP = DA * GR + EN DOT DG * DDD/2.                                 DIFFUS   255
      FM =-DA * GR + EN DOT DG * DDD/2.                                 DIFFUS   256
      FOUT(IO,JO) = FOUT(IO,JO) - (F1(II,JI) - F1(IO,JO)) *             DIFFUS   257
     X   FP*CAREA(IIP,JIP,K) / (PI*DDD*QR(IO,JO))                       DIFFUS   258
  300 CONTINUE                                                          DIFFUS   259
  400 CONTINUE                                                          DIFFUS   260
      RETURN                                                            DIFFUS   261
      END                                                               DIFFUS   262
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      SUBROUTINE DIFPRM(ALAM)                                           DIFPRM     2
C        ALAMT     WAVELENGTH TABLE  IN MICRONS                         DIFPRM     3
C     SIGT,SIGS,  MICROSCOPIC CROSS SECTIONS IN MICRONS SQUARED         DIFPRM     4
C        DNO       PARTICLE DENSITY IN  CM**-3                          DIFPRM     5
C                                                                       DIFPRM     6
C        DALFA,DBETA,DKAPPA   ARE DIFFUSION PARAMETERS                  DIFPRM     7
CCC                                                                     DIFPRM     8
CLJ   SUBROUTINE DIFPRM PROVIDES THREE DIFFUSION PARAMETERS FOR EACH    DIFPRM     9
CLJ   OF THE 14 CLOUD TYPES AT WAVELENGTH ALAM.                         DIFPRM    10
CCC                                                                     DIFPRM    11
CLJ   INPUT PARAMETERS                                                  DIFPRM    12
CLJ      ARGUMENT LIST                                                  DIFPRM    13
CLJ            ALAM = WAVELENGTH,  MICRONS                              DIFPRM    14
CLJ      CDDATA COMMON                                                  DIFPRM    15
CLJ           ALAMT(I)    = WAVELENGTHS AT WHICH OPTICAL PROPERTIES ARE DIFPRM    16
CLJ                         TABULATED,  MICRONS                         DIFPRM    17
CLJ            SIGT(I,K) = TOTAL MICROSCOPIC EXTINCTION CROSS-SECTION   DIFPRM    18
CLJ                        AT WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K,     DIFPRM    19
CLJ                         (MICRONS)**2                                DIFPRM    20
CLJ            SIGS(I,K) = MICROSCOPIC SCATTERING CROSS-SECTION         DIFPRM    21
CLJ                        AT WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K,     DIFPRM    22
CLJ                         (MICRONS)**2                                DIFPRM    23
CLJ              W(I) = (NORMALIZED) CONTRIBUTION OF SPECULARLY-        DIFPRM    24
CLJ                     REFLECTED RADIATION TO SCATTERED RADIATION WITH DIFPRM    25
CLJ                     THE DIFFRACTED RADIATION CONTRIBUTING UNITY.    DIFPRM    26
CLJ                     USED ONLY FOR THE LARGE-PARTICLE-SIZE CLOUDS,   DIFPRM    27
CLJ                     TYPES 11 THROUGH 14.  (DIMENSIONLESS)           DIFPRM    28
CLJ          XMUBAR(I,K) = AVERAGE COSINE OF SCATTERING ANGLE AT        DIFPRM    29
CLJ                        WAVELENGTH ALAMT(I) FOR CLOUD-TYPE K         DIFPRM    30
CLJ             DNO(K)   = NUMBER DENSITY OF WATER DROPLETS IN          DIFPRM    31
CLJ                        CLOUD-TYPE K,  1/CM**3                       DIFPRM    32
CLJ             RAD(K)   = MEAN RADIUS OF WATER DROPLETS IN             DIFPRM    33
CLJ                        CLOUD-TYPE K,  MICRONS                       DIFPRM    34
CCC                                                                     DIFPRM    35
CLJ                 FOR ABOVE VARIABLES   I=1,10  AND  K=1,14           DIFPRM    36
CCC                                                                     DIFPRM    37
CLJ   OUTPUT PARAMETERS                                                 DIFPRM    38
CLJ      DIFFUS COMMON                                                  DIFPRM    39
CLJ           DALFA(K) = 0.25 TIMES THE RATIO OF SCATTERING CROSS-      DIFPRM    40
CLJ                      SECTION TO TOTAL CROSS-SECTION FOR PHOTONS OF  DIFPRM    41
CLJ                      WAVELENGTH ALAM IN CLOUD-TYPE K, DIMENSIONLESS DIFPRM    42
CLJ           DBETA(K) = 0.50 TIMES THE DIFFUSION COEFFICIENT FOR       DIFPRM    43
CLJ                      PHOTONS OF WAVELENGTH ALAM IN CLOUD-TYPE K,  KM DIFPRM    44
CLJ          DKAPPA(K) = INVERSE DIFFUSION LENGTH FOR PHOTONS OF        DIFPRM    45
CLJ                      WAVELENGTH ALAM IN CLOUD-TYPE K,  1/KM         DIFPRM    46
CCC                                                                     DIFPRM    47
CLJ                 FOR ABOVE VARIABLES   K=1,14                        DIFPRM    48
CLJ       THE ABOVE DEFINITIONS FOR THE DIFFUSION PARAMETERS APPLY TO A DIFPRM    49
CLJ       WEAKLY ABSORBING MEDIUM.  FOR A STRONGLY ABSORBING MEDIUM,    DIFPRM    50
CLJ       MODIFIED DIFFUSION PARAMETERS ARE REQUIRED.  WE ALSO COMPUTE  DIFPRM    51
CLJ       THE LATTER TYPE AND USE THEM AFTER 9/30/78.                   DIFPRM    52
CCC                                                                     DIFPRM    53
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS     2
      COMMON/CDDATA/ ALAMT(10),SIGT(10,14),SIGS(10,14),W(10),           CDDATA     2
     1  XMUBAR(10,14),DNO(14),RAD(14),CLDBASE(14),CLDTHK(14)            CDDATA     3
      COMMON/DIFFUS/DALFA(14),DBETA(14),DKAPPA(14)                      DIFCOM     2
      DIMENSION  CXTRAP(11),XTRAP(11),CRELAX(29),RELAX(29)              DIFPRM    57
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CLJ                                                                     DIFPRM     58
CLJ       XTRAP(CXTRAP(I)) AND RELAX(CRELAX(I)) ARE, RESPECTIVELY, THE  DIFPRM     59
CLJ       (DIMENSIONLESS) LINEAR EXTRAPOLATION LENGTHS AND RELAXATION   DIFPRM     60
CLJ       RATES, AT NXTRPC AND NRELXC VALUES CXTRAP(I) AND CRELAX(I) OF DIFPRM     61
CLJ       THE PARAMETER C (RATIO OF SCATTERING TO TOTAL CROSS-SECTION), DIFPRM     62
CLJ       TAKEN FROM TABLES 23 AND 9, RESPECTIVELY, OF INTRODUCTION TO  DIFPRM     63
CLJ       THE THEORY OF NEUTRON DIFFUSION, VOLUME 1, BY K.M. CASE,      DIFPRM     64
CLJ       F. DE HOFFMANN, AND G. PLACZEK, LASL, JUNE 1953.              DIFPRM     65
CLJ                                                                     DIFPRM     66
      DATA  NXTRPC,NRELXC / 11, 29 /                                    DIFPRM     67
      DATA  CXTRAP / 0.0    , 0.1    , 0.2    , 0.3    , 0.4    , 0.5    ,  DIFPRM     68
     1               0.6    , 0.7    , 0.8    , 0.9    , 1.0    /        DIFPRM     69
      DATA   XTRAP / 1.0000, 1.0000, 0.9993, 0.9889, 0.9606, 0.9201,    DIFPRM     70
     1               0.8750, 0.8300, 0.7871, 0.7472, 0.7104/            DIFPRM     71
      DATA CRELAX/0.00     ,0.10     ,0.20     ,0.30     ,0.35     ,0.40     ,  DIFPRM     72
     1            0.45     ,0.50     ,0.55     ,0.60     ,0.65     ,0.70     ,  DIFPRM     73
     2            0.75     ,0.80     ,0.82     ,0.84     ,0.86     ,0.88     ,  DIFPRM     74
     3            0.90     ,0.91     ,0.92     ,0.93     ,0.94     ,0.95     ,  DIFPRM     75
     4            0.96     ,0.97     ,0.98     ,0.99     ,1.00     /          DIFPRM     76
      DATA  RELAX/1.000000,1.000000,0.999909,0.997414,0.993164,0.985624,  DIFPRM     77
     1            0.973976,0.957504,0.935529,0.907332,0.872065,0.828635,  DIFPRM     78
     2            0.775516,0.710412,0.680241,0.647220,0.610884,0.570591,  DIFPRM     79
     3            0.525430,0.500615,0.474002,0.445270,0.413976,0.379485,  DIFPRM     80
     4            0.340829,0.296381,0.242983,0.172511,0.0      /          DIFPRM     81
CLJ                                                                     DIFPRM     82
      COSH(ARG) = (EXP(ARG) + EXP(-ARG)) / 2.                           DIFPRM     83
      SINH(ARG) = (EXP(ARG) - EXP(-ARG)) / 2.                           DIFPRM     84
CLJ                                                                     DIFPRM     85
CLJ       TRANSMITTANCE T AND REFLECTANCE R OF PLANAR SLAB, PER         DIFPRM     86
CLJ       EQUATIONS (31A) AND (31B) OF APPENDIX A, NATURAL CLOUDS, THE  DIFPRM     87
CLJ       ROSCOE MANUAL VOL. 24.                                        DIFPRM     88
CLJ                                                                     DIFPRM     89
      T(X,Y) = 1.0 / ( COSH(X) + 0.5*( Y+1./Y )*SINH(X) )               DIFPRM     90
      R(X,Y) = 0.5*T(X,Y)*( Y-1./Y )*SINH(X)                            DIFPRM     91
CLJ                                                                     DIFPRM     92
      DO 20 I = 2,10                                                    DIFPRM     93
      IF (ALAMT(I) .GT. ALAM) GO TO 25                                  DIFPRM     94
   20 CONTINUE                                                          DIFPRM     95
      I = 10                                                            DIFPRM     96
   25 XX = (ALAM - ALAMT(I-1)) / (ALAMT(I) - ALAMT(I-1))                DIFPRM     97
C                                                                       DIFPRM     98
C                                                                       DIFPRM     99
C                                                                       DIFPRM    100
C        INTERPOLATE FOR DIFFUSION PARAMETERS AT GIVEN WAVELENGTH       DIFPRM    101
C        FOR ALL 14 CLOUD TYPES                                         DIFPRM    102
C                                                                       DIFPRM    103
      WI = W(I-1) + ( W(I)-W(I-1) )*XX                                  DIFPRM    104
      GO TO 111                                                         DIFPRM    105
CLJ                                                                     DIFPRM    106
CLJ       FOR EDUCATIONAL PURPOSES, THE TRANSMITTANCE T AND REFLECTANCE DIFPRM    107
CLJ       R OF CLOUD-TYPE KK WITH THICKNESS CLDTHK(KK) ARE EVALUATED    DIFPRM    108
CLJ       FIRST FOR THE STANDARD DIFFUSION PARAMETERS AND THEN FOR THE  DIFPRM    109
CLJ       MODIFIED DIFFUSION PARAMETERS FOR AN ABSORBING MEDIUM.  THE   DIFPRM    110
CLJ       LATTER PARAMETERS HAVE BEEN USED SINCE 9/30/78.               DIFPRM    111
CLJ                                                                     DIFPRM    112
      WRITE(6,110)                                                      DIFPRM    113
  110 FORMAT (2H1 ,*    KK      ALFA        BETA        KAPPA       CLDTHK DIFPRM    114
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     $          T            R     *)                                          DIFPRM
  111 CONTINUE                                                                 DIFPRM
      DO 30 KK = 1,14                                                          DIFPRM
      SGT = (SIGT(I-1,KK)+(SIGT(I,KK) - SIGT(I-1,KK))*XX)*DNO(KK)*1.E-3        DIFPRM
      SGS = (SIGS(I-1,KK)+(SIGS(I,KK) - SIGS(I-1,KK))*XX)*DNO(KK)*1.E-3        DIFPRM
      IF(KK .GT. 10) SGT = 2.*PI*RAD(KK)**2 * DNO(KK) * 1.E-3                  DIFPRM
      IF(KK .GT. 10)  SGS = 0.5*(1.+WI)*SGT                                    DIFPRM
      XMU = XMUBAR(I-1,KK) + (XMUBAR(I,KK) - XMUBAR(I-1,KK))*XX                DIFPRM
      SGTR = SGT - XMU * SGS                                                   DIFPRM
      GO TO 27                                                                 DIFPRM
      DD = SGS / (3.*SGT*SGTR)                                                 DIFPRM
      DK = SQRT((SGT - SGS)/DD)                                                DIFPRM
      DA = 0.25  * SGS / SGT                                                   DIFPRM
      DALFA(KK) = DA                                                           DIFPRM
      DBETA(KK) = DD/ 2.                                                       DIFPRM
      DKAPPA(KK) = DK                                                          DIFPRM
      X = DKAPPA(KK)*CLDTHK(KK)                                                DIFPRM
      Y = DALFA(KK) / (DKAPPA(KK)*DBETA(KK))                                   DIFPRM
      TKK = T(X,Y)                                                             DIFPRM
      RKK = R(X,Y)                                                             DIFPRM
      WRITE(6,120)  KK,DALFA(KK),DBETA(KK),DKAPPA(KK),CLDTHK(KK),TKK,RKK       DIFPRM
  120 FORMAT (5X,I3,1P6E12.4)                                                  DIFPRM
   27 CONTINUE                                                                 DIFPRM
CLJ                                                                            DIFPRM
CLJ       WE NOW COMPUTE THE MODIFIED DIFFUSION PARAMETERS FOR AN              DIFPRM
CLJ       ABSORBING MEDIUM.                                                    DIFPRM
CLJ                                                                            DIFPRM
      C = SGS/SGT                                                              DIFPRM
      CALL LINEAR( C,XTRAPC,CXTRAP,XTRAP,NXTRPC )                              DIFPRM
      CALL LINEAR( C,RELAXC,CRELAX,RELAX,NRELXC )                              DIFPRM
      DD  = (1.-C)/(RELAXC*RELAXC*SGTR)                                        DIFPRM
      DKAPPA(KK) = RELAXC*SQRT( SGT*SGTR )                                     DIFPRM
      DBETA(KK) = DD/2.                                                        DIFPRM
      DALFA(KK) = DBETA(KK)*DKAPPA(KK)/(XTRAPC*RELAXC)                         DIFPRM
      GO TO 29                                                                 DIFPRM
      X = DKAPPA(KK)*CLDTHK(KK)                                                DIFPRM
      Y = DALFA(KK)/(DKAPPA(KK)*DBETA(KK))                                     DIFPRM
      TKK = T(X,Y)                                                             DIFPRM
      RKK = R(X,Y)                                                             DIFPRM
      WRITE(6,120)  KK,DALFA(KK),DBETA(KK),DKAPPA(KK),CLDTHK(KK),TKK,RKK       DIFPRM
   29 CONTINUE                                                                 DIFPRM
   30 CONTINUE                                                                 DIFPRM
      RETURN                                                                   DIFPRM
      END                                                                      DIFPRM
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      FUNCTION DSURF(THETA,PHI,K)                                       DSURF      2
C EVALUATES ELLIPSOIDAL SURFACE ELEMENT AT THETA,PHI                    DSURF      3
C         (  INPUT ANGLES IN RADIANS  )                                 DSURF      4
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                  CDCORD     2
     1               XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)     CDCORD     3
     X  , ASQ(20),BSQ(20),CSQ(20)                                       CDCORD     4
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)         CDCORD     5
CCC                                                                     DSURF      6
CLJ   INPUT PARAMETERS                                                  DSURF      7
CLJ      ARGUMENT LIST                                                  DSURF      8
CLJ           THETA = POLAR ANGLE IN CLOUD-CENTERED COORDINATE SYSTEM   DSURF      9
CLJ                   AT WHICH FUNCTION DSURF IS TO BE EVALUATED, RADIAN DSURF     10
CLJ             PHI = AZIMUTHAL ANGLE IN CLOUD-CENTERED COORDINATE      DSURF     11
CLJ                   SYSTEM AT WHICH FUNCTION DSURF IS TO BE EVALUATED, DSURF    12
CLJ                   RADIANS                                           DSURF     13
CLJ               K = CLOUD-NUMBER INDEX                                DSURF     14
CLJ      CDCORD COMMON                                                  DSURF     15
CLJ         FOLLOWING PARAMETERS ARE SET IN SUBROUTINE CLDGEOM FOR      DSURF     16
CLJ         K=1,NCLOUD (.LE.20)                                         DSURF     17
CLJ          ASQ(K) = SQUARE OF LENGTH A, THE SEMI-MAJOR AXIS IN        DSURF     18
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2      DSURF     19
CLJ          BSQ(K) = SQUARE OF LENGTH B, THE SEMI-MINOR AXIS IN        DSURF     20
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2      DSURF     21
CLJ          CSQ(K) = SQUARE OF LENGTH C, THE SEMI-MINOR AXIS IN        DSURF     22
CLJ                   VERTICAL DIRECTION OF ELLIPSOIDAL CLOUD, KM**2    DSURF     23
CLJ   OUTPUT PARAMETER                                                  DSURF     24
CLJ      FUNCTION                                                       DSURF     25
CLJ           DSURF = FOR CLOUD K, THE PRODUCT OF SIN(THETA) AND THE    DSURF     26
CLJ                   ELLIPSOIDAL SURFACE AREA PER UNIT SOLID ANGLE IN  DSURF     27
CLJ                   THE DIRECTION (THETA,PHI),  (SIN(THETA)*KM**2)/SR DSURF     28
CLJ                                                                     DSURF     29
      ST = SIN(THETA)                                                   DSURF     30
      CT = COS(THETA)                                                   DSURF     31
      SP = SIN(PHI)                                                     DSURF     32
      CP = COS(PHI)                                                     DSURF     33
      R = ST*ST*(CP*CP/ASQ(K)+SP*SP/BSQ(K))+CT*CT/CSQ(K)                DSURF     34
      RSQ = 1. / R                                                      DSURF     35
      S = RSQ * ST*CT*(CP*CP/ASQ(K)+SP*SP/BSQ(K) - 1./CSQ(K) )          DSURF     36
      T = RSQ*ST*SP*CP*  (1./ASQ(K) - 1. / BSQ(K) )                     DSURF     37
      DSURF=RSQ*ST*SQRT(1.0+S*S+T*T)                                    DSURF     38
      RETURN                                                            DSURF     39
      END                                                               DSURF     40
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      FUNCTION EMISSF(ALAM,LL,MM,HH)                                    EMISSF     2
      COMMON/CDDATA/ ALAMT(10),SIGT(10,14),SIGS(10,14),W(10),           CDDATA     2
     1  XMUBAR(10,14),DNO(14),RAD(14),CLDBASE(14),CLDTHK(14)            CDDATA     3
      COMMON/ATMOUP/  DUM1(4),RHO,TT,DUM2(32)                           ATMOSX     2
      COMMON /SANDD/ XS,YS,ZS,XD,YD,ZD,UL,VL,WL                         SANDD      2
      COMMON /PARAMS/ IN,IOUT,PI,RF, DTR,RTD                            PARAMS     2
      INTEGER HH                                                        EMISSF     7
CCC                                                                     EMISSF     8
CLJ   FUNCTION EMISSF COMPUTES THE (ATTENUATED) SPECTRAL RADIANCE AT    EMISSF     9
CLJ   12-KM ALTITUDE FOR RADIATION EMITTED AT ZENITH ANGLE THETE FROM   EMISSF    10
CLJ   A CLOUD TOP AT ALTITUDE CLDTOP.   ( WATTS/(KM**2 SR MICRON) )     EMISSF    11
CCC                                                                     EMISSF    12
CLJ   INPUT PARAMETERS                                                  EMISSF    13
CLJ      ARGUMENT LIST                                                  EMISSF    14
CLJ            ALAM = WAVELENGTH,  MICRONS                              EMISSF    15
CLJ              LL = INDEX (1,7) OF ONE OF SEVEN LOW-ALTITUDE CLOUDS   EMISSF    16
CLJ                 = KCLOUD                                            EMISSF    17
CLJ              MM = INDEX (1,3) OF ONE OF THREE MID-ALTITUDE CLOUDS   EMISSF    18
CLJ                 = KCLOUD-7                                          EMISSF    19
CLJ              HH = INDEX (1,4) OF ONE OF FOUR HIGH-ALTITUDE CLOUDS   EMISSF    20
CLJ                 = KCLOUD-10                                         EMISSF    21
CLJ                   (KCLOUD = CLOUD-TYPE INDEX)                       EMISSF    22
CLJ      CDDATA COMMON                                                  EMISSF    23
CLJ         CLDBASE(K) = ALTITUDE ABOVE EARTH SURFACE OF BASE OF        EMISSF    24
CLJ                      CLOUD-TYPE K,  KM     K=1,14                   EMISSF    25
CLJ         CLDTHK(K) = THICKNESS OF CLOUD-TYPE K,  KM      K=1,14      EMISSF    26
CLJ      SANDD COMMON                                                   EMISSF    27
CLJ         UL,VL,WL = DETECTOR LOS DIRECTION COSINES                   EMISSF    28
CLJ         XD,YD,ZD = DETECTOR GEOCENTRIC CARTESIAN COORDINATES,  KM   EMISSF    29
CLJ         XS,YS,ZS = SOURCE GEOCENTRIC CARTESIAN COORDINATES,  KM     EMISSF    30
CLJ   OUTPUT PARAMETER                                                  EMISSF    31
CLJ      FUNCTION                                                       EMISSF    32
CLJ         EMISSF = THE (ATTENUATED) SPECTRAL RADIANCE AT 12-KM        EMISSF    33
CLJ                  ALTITUDE FOR RADIATION EMITTED AT ZENITH ANGLE     EMISSF    34
CLJ                  THETE FROM A CLOUD TOP AT ALTITUDE CLDTOP,         EMISSF    35
CLJ                  WATTS/(KM**2 SR MICRON)                            EMISSF    36
CLJ      DEFINITION OF MAIN VARIABLES                                   EMISSF    37
CLJ         RHOEPS(ALAM,CTHETE) = HEMISPHERICAL-DIRECTIONAL REFLECTANCE EMISSF    38
CLJ                               AT WAVELENGTH ALAM AND ZENITH ANGLE   EMISSF    39
CLJ                               ACOS(CTHETE) FOR CLOUD-TYPE 4         EMISSF    40
CLJ                               (STRATOCUMULUS)                       EMISSF    41
CLJ         ENN = DIRECTIONAL EMISSIVITY CORRESPONDING TO RHOEPS        EMISSF    42
CLJ             = 1.0-RHOEPS                                            EMISSF    43
CLJ         TAIR(ALAM,THETE,CLDTOP) = TRANSMITTANCE FOR RADIATION OF    EMISSF    44
CLJ                                   WAVELENGTH ALAM AT ZENITH ANGLE   EMISSF    45
CLJ                               THETE FROM ALTITUDE CLDTOP TO 12 KM   EMISSF    46
CCC                                                                     EMISSF    47
      IF(LL .LE. 7) N=LL                                                EMISSF    48
      IF(MM.LE. 3) N = MM + 7                                           EMISSF    49
      IF(HH .LE.4) N = HH + 10                                          EMISSF    50
      CLDTOP = CLDBASE(N) + CLDTHK(N)                                   EMISSF    51
      CALL SGEOM(UL,VL,WL,CLDTOP,XD,YD,ZD,XS,YS,ZS,RD,SD,               EMISSF    52
     X   THETI,THETE,PHIE)                                              EMISSF    53
      TX = 1.0                                                          EMISSF    54
      IF( N.EQ.11 )  GO TO 10                                           EMISSF    55
      TX = TAIR(ALAM,THETE,CLDTOP)                                      EMISSF    56
   10 ENN = 1.0 - RHOEPS(ALAM,COS(THETE*DTR))                           EMISSF    57
      CALL ATMOSU(2,CLDTOP)                                             EMISSF    58
      T = TT                                                            EMISSF    59
      EMISSF = TX*1.191E14*ENN/ALAM**5 /(EXP(14388./(ALAM*T))- 1. )     EMISSF    60
      RETURN                                                            EMISSF    61
      END                                                               EMISSF    62
```

```
      SUBROUTINE ESURF(T1,T2,T3,T4,MSM,DD,T7,T8,T9,T10,T11,SFR,EPSD,TKS) ESURF
CC                                                                      ESURF
CC        THIS IS A DUMMY ROUTINE REQUIRED IF THE CLOUD PACKAGE         ESURF
CC        IS EXERCISED AS A STAND-ALONE PROGRAM.                        ESURF
CC                                                                      ESURF
C         INPUT PARAMETERS(SELECTED)                                    ESURF
C             ARGUMENT LIST                                             ESURF
C               MSM = INDEX FOR CATEGORY OF SURFACE MATERIAL.           ESURF
C                   = 1, LAMBERTIAN DIFFUSE SURFACE WITH SPECTRALLY-    ESURF
C                        INDEPENDENT REFLECTANCE SET BY DD(1) AND       ESURF
C                        EMISSIVITY BY (1.-DD(1)).                      ESURF
C             DD(M) = ADDITIONAL DESCRIPTOR FOR SELECTED SURFACE        ESURF
C                     MATERIAL.                                         ESURF
C             FOR M = 1, (LAMBERTIAN SURFACE), DD(1) = DIFFUSE          ESURF
C                        REFLECTANCE. TYPICAL VALUE IS 0.10             ESURF
C         OUTPUT PARAMETERS                                             ESURF
C             ARGUMENT LIST                                             ESURF
C               SFR = FSUBR(M,DD(M),ZLAM'THI,THR,PSI)                   ESURF
C                   = BIDIRECTIONAL REFLECTANCE DISTRIBUTION            ESURF
C                     FUNCTION,  1./SR                                  ESURF
C              EPSD = 1.0 - RHOSUBM(ZLAM'THETA,2*PI)                    ESURF
C                   = DIRECTIONAL EMISSIVITY, DIMENSIONLESS.            ESURF
C               TKS = SURFACE TEMPERATURE, DEG K.                       ESURF
CC                                                                      ESURF
      DIMENSION  DD(7)                                                  ESURF
      DATA  PI / 3.14159265 /                                           ESURF
CC                                                                      ESURF
      SFR = DD(1)/PI                                                    ESURF
      EPSD = 1.0-DD(1)                                                  ESURF
      TKS = 288.                                                        ESURF
      RETURN                                                            ESURF
      END                                                               ESURF
```

```
      FUNCTION IPRIME(II)                                               IP
      IPRIME     = AND( XOR( XOR(II-1,4)+1-II ,II-1), 3 ) + 1           IP
CCC                                                                     IP
CLJ       THE VALUES THAT IPRIME SHOULD RETURN ARE GIVEN IN SUBROUTINE  IP
CLJ       CLDGEOM FOR II=1,16.                                          IP
CLJ                                                                     IP
CLJ      NOTE...                                                        IP
CLJ                 USING THIS ROUTINE MAY GIVE ERRONEOUS RESULTS.      IP
CCC                                                                     IP
CLJ                 FOR CERTAIN VALUES OF THE INPUT VARIABLE II         IP
CLJ                 A ONE'S COMPLEMENT MACHINE (CDC-6600, CDC-7600)     IP
CLJ                 AND A TWO'S COMPLEMENT MACHINE (IBM-360, IBM-370)   IP
CLJ                 DO NOT RETURN THE SAME VALUE FOR IPRIME.            IP
CCC                                                                     IP
CLJ                 A MACHINE INDEPENDENT SCHEME SHOULD BE USED.        IP
CCC                                                                     IP
      RETURN                                                            IP
      END                                                               IP
```

```
      SUBROUTINE LINEAR(XO,FXO,XX,FXX,NX)                                LINEAR
CCC                                                                      LINEAR
C         GIVEN THE INDEPENDENT VARIABLE ARRAY, XX(I), AND THE           LINEAR
C         CORRESPONDING DEPENDENT VARIABLE ARRAY, FXX(I),                LINEAR
C         SUBROUTINE LINEAR WILL DO A LINEAR INTERPOLATION AND           LINEAR
C         RETURN FXO AT A GIVEN XO.                                      LINEAR
C                                                                        LINEAR
C         NX IS THE LENGTH OF THE ARRAYS XX AND FXX.                     LINEAR
C                                                                        LINEAR
C         IF XO IS NOT WITHIN THE RANGE OF XX(I), FXO IS SET TO ZERO.    LINEAR
CCC                                                                      LINEAR
      DIMENSION XX(1), FXX(1)                                            LINEAR
      IF( XO .LT. XX(1) .OR. XO .GT. XX(NX) ) GO TO 22                   LINEAR
      NX1 = 1                                                            LINEAR
      NX3 = NX                                                           LINEAR
      IF(NX.EQ.2) GO TO 6                                                LINEAR
    2 NX2 = (NX1 + NX3)/2                                                LINEAR
      IF( XO-XX(NX2) ) 4,18,10                                           LINEAR
    4 IF( NX2-NX1-1 ) 8,6,8                                              LINEAR
    6 NNX = NX1                                                          LINEAR
      GO TO 16                                                           LINEAR
    8 NX3 = NX2                                                          LINEAR
      GO TO 2                                                            LINEAR
   10 IF( NX3-NX2-1 ) 14,12,14                                           LINEAR
   12 NNX = NX2                                                          LINEAR
      GO TO 16                                                           LINEAR
   14 NX1 = NX2                                                          LINEAR
      GO TO 2                                                            LINEAR
   16 FXO = FXX(NNX) + ( XO-XX(NNX) )*( FXX(NNX+1)-FXX(NNX) )/           LINEAR
     X ( XX(NNX+1)-XX(NNX) )                                             LINEAR
      GO TO 20                                                           LINEAR
   18 FXO = FXX(NX2)                                                     LINEAR
   20 RETURN                                                             LINEAR
   22 FXO = 0.0                                                          LINEAR
      RETURN                                                             LINEAR
      END                                                                LINEAR
```

```
      SUBROUTINE LOS(K)                                                 LOSK
C                                                                       LOSK
C      TO BE CALLED FOR EACH CLOUD                                      LOSK
C                                                                       LOSK
CLJ                                                                     LOSK
CLJ   SUBROUTINE LOS COMPUTES THE DIRECTION COSINES, IN THE EARTH-      LOSK
CLJ   CENTERED CARTESIAN SYSTEM, OF A SELECTED SET OF LINE-OF-SIGHTS    LOSK
CLJ   FROM THE DETECTOR TO FACETS OF THE DETERMINISTIC CLOUDS.  THE     LOSK
CLJ   ALTITUDE AT WHICH EACH LOS INTERCEPTS A FACET IS ALSO COMPUTED.   LOSK
CLJ      THE SELECTED SET OF LINES-OF-SIGHT CONSISTS OF TWO SUBSETS.    LOSK
CLJ      THE FIRST SUBSET CONSISTS OF THOSE TO REFLECTIVE POINTS (I.E., LOSK
CLJ      VISIBLE TO DETECTOR AND SOURCE), THE SECOND TO DIFFUSIVE       LOSK
CLJ      POINTS (VISIBLE TO DETECTOR BUT NOT TO SOURCE).  BY            LOSK
CLJ      CONSIDERING ONLY EVERY OTHER FACET, ONE HAS ONLY 32 (INSTEAD   LOSK
CLJ      OF 128) POINTS ON THE ELLIPSOID OF WHICH A MAXIMUM OF 16 ARE   LOSK
CLJ      VISIBLE TO THE DETECTOR.  ANY REFLECTIVE POINT THAT WOULD BE   LOSK
CLJ      LESS THAN 0.7*SQRT(FOV) FROM ANOTHER REFLECTIVE POINT IS       LOSK
CLJ      ELIMINATED.  DIFFUSIVE POINTS ARE LIMITED TO A MAXIMUM OF      LOSK
CLJ      EIGHT CLOSEST TO THE PERIMETER OF THE CLOUD.                   LOSK
CLJ                                                                     LOSK
CLJ   INPUT PARAMETERS                                                  LOSK
CLJ      ARGUMENT LIST                                                  LOSK
CLJ                K = DETERMINISTIC CLOUD NUMBER (SET IN DRIVER)       LOSK
CLJ      DETECT COMMON                                                  LOSK
CLJ              HD = ALTITUDE OF DETECTOR, KM                          LOSK
CLJ          THETAD = COLATITUDE OF DETECTOR, DEGREES                   LOSK
CLJ            PHID = EAST LONGITUDE OF DETECTOR, DEGREES               LOSK
CLJ             FOV = FIELD OF VIEW OF DETECTOR AT EARTH'S SURFACE,KM**2 LOSK
CLJ      CDCORD COMMON                                                  LOSK
CLJ        XI(I,K), = COORDINATES OF SOURCE-I IN K-TH CLOUD-CENTERED    LOSK
CLJ       ETA(I,K),   CARTESIAN SYSTEM, KM        I=1       K=1,20       LOSK
CLJ      ZETA(I,K)    (SET IN CLOUD1)                                   LOSK
CLJ        XID(K), = COORDINATES OF DETECTOR IN K-TH CLOUD-CENTERED     LOSK
CLJ       ETAD(K),   CARTESIAN SYSTEM, KM        K=1,20                 LOSK
CLJ      ZETAD(K)    (SET IN CLOUD1)                                   LOSK
CLJ     CTHBAR(I,K) = POLAR ANGLE IN CLOUD-CENTERED COORDINATES OF THE LOSK
CLJ                   CENTER OF THE I-TH POLAR SET OF SURFACE FACETS FOR LOSK
CLJ                   ELLIPSOIDAL CLOUD-K,  DEGREES    I=1,8     K=1,20 LOSK
CLJ     CPHIBAR(J,K) = AZIMUTHAL ANGLE IN CLOUD-CENTERED COORDINATES OF LOSK
CLJ                   THE CENTER OF THE J-TH AZIMUTHAL SET OF SURFACE  LOSK
CLJ                   FACETS FOR ELLIPSOIDAL CLOUD-K,  DEGREES         LOSK
CLJ                           J=1,16    K=1,20                         LOSK
CLJ     CRBAR(I,J,K) = CLOUD-CENTERED RADIAL DISTANCE TO THE CENTER OF LOSK
CLJ                   SURFACE FACET I,J IN PRINCIPAL OCTANT,  KM       LOSK
CLJ                      I=1,4     J=1,4     K=1,20                    LOSK
CLJ                   (RESULTS FOR OTHER OCTANTS ARE OBTAINED BY SYMTY.) LOSK
CLJ      CLOUD COMMON                                                   LOSK
CLJ       HCLOUD(K) = ALTITUDE OF CLOUD-K CENTER ABOVE THE SURFACE, KM  LOSK
CLJ                   K=1,NCLOUD   (READ IN CLOUD0)                    LOSK
CLJ   OUTPUT PARAMETERS                                                 LOSK
CLJ      LOS COMMON                                                     LOSK
CLJ       HLOS(1,L) = ALTITUDE AT WHICH LOS FROM DETECTOR INTERCEPTS    LOSK
CLJ                   L-TH FACET OF (IMPLICITLY) CLOUD-K, KM           LOSK
CLJ                   (1.LE.L.LE.16)                                   LOSK
CLJ       ULOS(1,L), = DIRECTION COSINES, IN EARTH-CENTERED CARTESIAN  LOSK
CLJ       VLOS(1,L),   SYSTEM, OF ABOVE-DESCRIBED LINES-OF-SIGHT.      LOSK
CLJ       WLOS(1,L)    FOR THESE VARIABLES, (1.LE.L.LE.16).  MAXIMUM   LOSK
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CLJ                    VALUE OF L DETERMINED BY INTERNAL SELECTION          LOSK
CLJ                    PROCESS ACCORDING TO SEVERAL CRITERIA.               LOSK
CLJ                                                                         LOSK
      COMMON/CLOUD/ NCLOUD,                                                 CLOUD
     1    HCLOUD(20),THETCD(20),PHICD (20),CLOUDA(20),CLOUDB(20),          CLOUD
     2    CLOUDC(20),CLDPSI(20),KCLOUD(20)                                 CLOUD
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                      CDCORD
     1               XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)         CDCORD
     X  , ASQ(20),BSQ(20),CSQ(20)                                           CDCORD
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)             CDCORD
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                                PARAMS
      COMMON / DETECT/ HD, THETAD,PHID,FOV                                  DET
      COMMON/ LOS /  HLOS(1,16), ULOS(1,16), VLOS(1,16), WLOS(1,16)         LOS
      DIMENSION IDISC(8,16),PSS(8,16),PDD(8,16)                             LOSK
      DIMENSION THSCAT(8,16),XX(8,16),YY(8,16),ZZ(8,16)                     LOSK
      DIMENSION  THS(16),II(16),JJ(16),IS(16),JS(16)                        LOSK
CLJ                                                                         LOSK
CLJ       THE ARITHMETIC FUNCTION CTSCAT COMPUTES THE COSINE OF THE         LOSK
CLJ       SCATTERING ANGLE OF A PHOTON MOVING FROM THE SOURCE AT POINT      LOSK
CLJ       (X1,Y1,Z1) TO THE CENTER OF AN ELLIPSOIDAL-SURFACE FACET AT       LOSK
CLJ       POINT (X,Y,Z) AND THEN DIRECTLY TO THE DETECTOR AT POINT          LOSK
CLJ       (X2,Y2,Z2).  COORDINATES ARE IN CLOUD-K CARTESIAN SYSTEM.         LOSK
CLJ                                                                         LOSK
      CTSCAT( X,Y,Z,X1,Y1,Z1,X2,Y2,Z2 ) =                                   LOSK
     1              ( (X-X1)*(X2-X) + (Y-Y1)*(Y2-Y) + (Z-Z1)*(Z2-Z) ) /    LOSK
     2          SQRT( ((X-X1)**2 + (Y-Y1)**2 + (Z-Z1)**2) *                 LOSK
     3                ((X2-X)**2 + (Y2-Y)**2 + (Z2-Z)**2) )                 LOSK
C                                                                           LOSK
      CALL POL TO CT( HD+RE,THETAD,PHID,XD,YD,ZD )                          LOSK
      NS = 1                                                                LOSK
CLJ                                                                         LOSK
CLJ       LOOP OVER FACETS TO DETERMINE THEIR VISIBILITY TO DETECTOR        LOSK
CLJ       AND TO SOURCE.                                                    LOSK
CLJ       WE HAVE ADOPTED J. GARBARINO'S SUGGESTION TO REDUCE THE NUMBER    LOSK
CLJ       OF FACETS EXAMINED BY CONSIDERING ONLY EVERY OTHER FACET.         LOSK
CLJ       THIS RESULTS IN THE FOLLOWING (I,J) SETS FOR THE 32 POINTS...     LOSK
CLJ            1,1   1,3   ...   1,15                                        LOSK
CLJ            3,1   3,3   ...   3,15                                        LOSK
CLJ            5,1   5,3   ...   5,15                                        LOSK
CLJ            7,1   7,3   ...   7,15                                        LOSK
CLJ                                                                         LOSK
      DO 40 I=1,8,2                                                         LOSK
      IP= IPRIME(I)                                                         LOSK
      DO 40 J=1,16,2                                                        LOSK
      JP= IPRIME(J)                                                         LOSK
      P1= PS( XI(NS,K),ETA(NS,K),ZETA(NS,K),CTHBAR(I,K),CPHIBAR(J,K),K )    LOSK
      P2= PS( XID(K),ETAD(K),ZETAD(K),CTHBAR(I,K),CPHIBAR(J,K),K)           LOSK
C                                                                           LOSK
      PSS(I,J)= P1                                                          LOSK
      PDD(I,J) = P2                                                         LOSK
C                                                                           LOSK
      CALL POL TO CT( CRBAR(IP,JP,K),CTHBAR(I,K),CPHIBAR(J,K),              LOSK
     X XX(I,J),YY(I,J),ZZ(I,J) )                                            LOSK
C                                                                           LOSK
CLJ       DETERMINE COSINE OF SCATTERING ANGLE (AS DEFINED ABOVE).          LOSK
      THSCAT(I,J)=CTSCAT(XX(I,J),YY(I,J),ZZ(I,J),XI(NS,K),ETA(NS,K)         LOSK
     X   ,ZETA(NS,K),XID(K),ETAD(K),ZETAD(K)   )                            LOSK
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      IF( P1.GT. 0. .AND. P2 .GT. 0.) IDISC(I,J) = 1                    LOSK     111
      IF( P1.GT. 0. .AND. P2 .LT. 0.) IDISC(I,J) = 2                    LOSK     112
      IF( P1.LT. 0. .AND. P2 .GT. 0.) IDISC(I,J) = 3                    LOSK     113
      IF( P1.LT. 0. .AND. P2 .LT. 0.) IDISC(I,J) = 4                    LOSK     114
   40 CONTINUE                                                          LOSK     115
C                                                                       LOSK     116
C                                                                       LOSK     117
      DO 45 L=1,64                                                      LOSK     118
      HLOS(1,L) = 0.0                                                   LOSK     119
   45 CONTINUE                                                          LOSK     120
C                                                                       LOSK     121
C                                                                       LOSK     122
C                                                                       LOSK     123
C        ORDER THE POINTS                                               LOSK     124
CLJ      SORT THE FACET-CENTERS VISIBLE TO BOTH SOURCE AND DETECTOR IN  LOSK     125
CLJ      ORDER OF INCREASING SCATTERING ANGLE.                          LOSK     126
C                                                                       LOSK     127
      L = 0                                                             LOSK     128
      DO 60 I=1,8,2                                                     LOSK     129
      DO 60 J=1,16,2                                                    LOSK     130
      IF(IDISC(I,J)  .NE. 1) GO TO 60                                   LOSK     131
      L = L + 1                                                         LOSK     132
      THS(L) = THSCAT(I,J)                                              LOSK     133
CLJ       ESTABLISH INDEX-ARRAYS FOR IDISC-1 POINTS.                    LOSK     134
      II(L) = I                                                         LOSK     135
      JJ(L) = J                                                         LOSK     136
   60 CONTINUE                                                          LOSK     137
      LL = 0                                                            LOSK     138
      IF(L .EQ. 0) GO TO 75                                             LOSK     139
CLJ      SORTING FROM HIGH TO LOW IN COSINE CORRESPONDS TO SORTING FROM LOSK     140
CLJ      LOW TO HIGH IN SCATTERING ANGLE.                               LOSK     141
      CALL SORTLJ(THS,II,JJ,L,+1)                                       LOSK     142
CLJ       THE FIRST CANDIDATE POINT IS AUTOMATICALLY MADE THE FIRST     LOSK     143
CLJ       SELECTED POINT.                                               LOSK     144
      LL = 1                                                            LOSK     145
CLJ       ABBREVIATE INDEXES OF FIRST SELECTED POINT TO AID IN GETTING  LOSK     146
CLJ       ITS LOS VECTOR.                                               LOSK     147
      IC = II(LL)                                                       LOSK     148
      JC = JJ(LL)                                                       LOSK     149
CLJ       ESTABLISH INDEX-ARRAYS FOR SELECTED POINTS, IS(LL) AND JS(LL). LOSK     150
      IS(LL) = II(LL)                                                   LOSK     151
      JS(LL) = JJ(LL)                                                   LOSK     152
      CALL CLD C TO E(R,T,PH,XX(IC,JC),YY(IC,JC),ZZ(IC,JC),K)           LOSK     153
      CALL POL TO CT(R,T,PH,XC,YC,ZC)                                   LOSK     154
      RR = SQRT( (XD-XC)**2 + (YD-YC)**2 + (ZD-ZC)**2  )                LOSK     155
      HLOS(NS,LL) = R - RE                                              LOSK     156
      ULOS(NS,LL) = ( XC - XD ) / RR                                    LOSK     157
      VLOS(NS,LL) = ( YC - YD ) / RR                                    LOSK     158
      WLOS(NS,LL) = ( ZC - ZD ) / RR                                    LOSK     159
CLJ       CHECK REST OF CANDIDATE POINTS, FOR WHICH L= THEIR TOTAL NO.  LOSK     160
      DO 70 I = 2,L                                                     LOSK     161
CLJ       ABBREVIATE INDEXES OF CANDIDATE POINT.                        LOSK     162
      IC = II(I)                                                        LOSK     163
      JC = JJ(I)                                                        LOSK     164
C                                                                       LOSK     165
C                                                                       LOSK     166
CLJ      FOR EACH NEW (TRIAL) LOS WITHIN THE SET SORTED WITH RESPECT TO LOSK     167
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CLJ       INCREASING SCATTERING ANGLE, FIND THE SEPARATION DISTANCE        LOSK
CLJ       (SEPAR),  MEASURED AT THE CLOUD AND NORMAL TO THE TRIAL LOS,     LOSK
CLJ       FROM EACH PREVIOUSLY SELECTED LOS.  THE TRIAL LOS IS REJECTED    LOSK
CLJ       IF SEPAR IS LESS THAN THE ADOPTED CRITERION FOR ANY PREVIOUSLY   LOSK
CLJ       SELECTED LOS.                                                    LOSK
CLJ        LL = NUMBER OF SELECTED POINTS.                                 LOSK
      DO 65 KK = 1,LL                                                      LOSK
CLJ        ABBREVIATE INDEXES OF THE SELECTED POINT BEING COMPARED WITH.   LOSK
      IL = IS(KK)                                                          LOSK
      JL = JS(KK)                                                          LOSK
CLJ        RDICJC = DISTANCE FROM DETECTOR TO CANDIDATE POINT (IC,JC)      LOSK
CLJ        RDILJL = DISTANCE FROM DETECTOR TO A SELECTED POINT (IL,JL)     LOSK
      RDICJC = SQRT( (XID(K)-XX(IC,JC))**2 + (ETAD(K)-YY(IC,JC))**2        LOSK
     $             + (ZETAD(K)-ZZ(IC,JC))**2 )                             LOSK
      RDILJL = SQRT( (XID(K)-XX(IL,JL))**2 + (ETAD(K)-YY(IL,JL))**2        LOSK
     $             + (ZETAD(K)-ZZ(IL,JL))**2 )                             LOSK
CLJ        DOT = COSINE OF ANGLE BETWEEN VECTORS FROM (1) DETECTOR TO      LOSK
CLJ        CANDIDATE POINT AND (2) DETECTOR TO A SELECTED POINT.           LOSK
      DOT = (                                                              LOSK
     X  (  XID(K) - XX(IC,JC)) * (  XID(K) - XX(IL,JL)) +                  LOSK
     X  ( ETAD(K) - YY(IC,JC)) * ( ETAD(K) - YY(IL,JL)) +                  LOSK
     X  (ZETAD(K) - ZZ(IC,JC)) * (ZETAD(K) - ZZ(IL,JL)) )                  LOSK
     $  / (RDICJC*RDILJL)                                                  LOSK
      IF(DOT .GT. 1.0) DOT = 1.0                                           LOSK
      SEPAR = RDICJC * ACOS( DOT )                                         LOSK
      IF(SEPAR .LT. 0.7*SQRT(FOV) )  GO TO 70                              LOSK
   65 CONTINUE                                                             LOSK
C                                                                          LOSK
CLJ        CANDIDATE POINT HAS PASSED TEST.  INCREMENT SELECTED-POINT      LOSK
CLJ        INDEX LL AND ADD SUCCESSFUL-CANDIDATE INDEXES TO THOSE OF       LOSK
CLJ        SELECTED POINTS.  PROCEED TO OBTAIN LOS VECTOR OF NEWLY-        LOSK
CLJ        SELECTED POINT.                                                 LOSK
      LL = LL + 1                                                          LOSK
      IS(LL) = IC                                                          LOSK
      JS(LL) = JC                                                          LOSK
      CALL CLD C TO E(R,T,PH,XX(IC,JC),YY(IC,JC),ZZ(IC,JC),K)              LOSK
      RLOS(NS,LL) = R - RE                                                 LOSK
      CALL POL TO CT(R,T,PH,XC,YC,ZC)                                      LOSK
      RR = SQRT( (XD-XC)**2 + (YD-YC)**2 + (ZD-ZC)**2  )                   LOSK
      ULOS(NS,LL) = ( XC - XD ) / RR                                       LOSK
      VLOS(NS,LL) = ( YC - YD ) / RR                                       LOSK
      WLOS(NS,LL) = ( ZC - ZD ) / RR                                       LOSK
   70 CONTINUE                                                             LOSK
   75 CONTINUE                                                             LOSK
CLJ        SAVE THE NUMBER OF POINTS, LL1=LL, SELECTED FROM THOSE HAVING   LOSK
CLJ        IDISC=1.                                                        LOSK
      LL1 = LL                                                             LOSK
C                                                                          LOSK
CLJ       SORT THE FACET-CENTERS VISIBLE TO DETECTOR BUT NOT TO SOURCE IN  LOSK
CLJ       ORDER OF THEIR CLOSENESS TO THE TERMINATOR AS VIEWED FROM THE    LOSK
CLJ       DETECTOR.  FUNCTION PS IS POSITIVE FOR SUCH POINTS AND RANGES    LOSK
CLJ       FROM ZERO FOR A POINT ON THE TERMINATOR TO +1.0 FOR A POINT      LOSK
CLJ       WHOSE ELLIPSOIDAL-SURFACE NORMAL LIES ANTIPARALLEL TO THE LOS.   LOSK
      L = 0                                                                LOSK
      DO 80 I=1,8,2                                                        LOSK
      DO 80 J=1,16,2                                                       LOSK
      IF(IDISC(I,J)  .NE. 3) GO TO 80                                      LOSK
```

```
      L = L + 1                                                         LOSK
      THS (L) = PDD(I,J)                                                LOSK
CLJ       ESTABLISH INDEX-ARRAYS FOR IDISC-3 POINTS.                    LOSK
      II(L) = I                                                         LOSK
      JJ(L) = J                                                         LOSK
   80 CONTINUE                                                          LOSK
CLJ       SAVE THE NUMBER OF IDISC-3 POINTS, LL3=L.                     LOSK
      LL3 = L                                                           LOSK
      IF( L.EQ. 0) GO TO 95                                             LOSK
      CALL SORTLJ(THS,II,JJ,L,-1)                                       LOSK
CLJ       LIMIT THE DIFFUSIVE POINTS TO THOSE CLOSEST TO THE PERIMETER. LOSK
CLJ       THIS LIMIT WOULD BE 16 IF 128 FACETS WERE CONSIDERED BUT IS   LOSK
CLJ       ONLY 8 IF 32 FACETS ARE CONSIDERED.                           LOSK
      LMAX1 = MIN0( L,8 )                                               LOSK
      DO 90 I = 1,LMAX1                                                 LOSK
CLJ       INCREMENT SELECTED-POINT INDEX LL, ABBREVIATE INDEXES OF      LOSK
CLJ       IDISC-3 POINT, AND PROCEED TO GET ITS LOS VECTOR.             LOSK
      LL = LL + 1                                                       LOSK
      IC = II(I)                                                        LOSK
      JC = JJ(I)                                                        LOSK
      CALL CLD C TO E(R,T,PH,XX(IC,JC),YY(IC,JC),ZZ(IC,JC),K)           LOSK
      HLOS(NS,LL) = R - RE                                              LOSK
      CALL POL TO CT(R,T,PH,XC,YC,ZC)                                   LOSK
      RR = SQRT( (XD-XC)**2 + (YD-YC)**2 + (ZD-ZC)**2  )                LOSK
      ULOS(NS,LL) = ( XC - XD ) / RR                                    LOSK
      VLOS(NS,LL) = ( YC - YD ) / RR                                    LOSK
      WLOS(NS,LL) = ( ZC - ZD ) / RR                                    LOSK
   90 CONTINUE                                                          LOSK
   95 CONTINUE                                                          LOSK
C                                                                       LOSK
      WRITE(6,1001) (L,ULOS(1,L),VLOS(1,L),WLOS(1,L),L=1,LL)            LOSK
 1001 FORMAT(* LOS  LL UVW*I3,1P3E20.12)                                LOSK
      WRITE(6,1002)  LL1                                                LOSK
 1002 FORMAT (44H0 NUMBER OF SELECTED LOS FOR IDISC=1 IS LL1=,I5)       LOSK
C                                                                       LOSK
      WRITE(6,1003)  LL3                                                LOSK
 1003 FORMAT (44H0 NUMBER OF SELECTED LOS FOR IDISC=3 IS LL3=,I5)       LOSK
      RETURN                                                            LOSK
       END                                                              LOSK
```

```
      FUNCTION PS(X1,ET1,ZET1,THETA,PHI,K)                              PS        2
CLJ                                                                     PS        3
CLJ   FUNCTION PS IS A QUANTITY WHOSE SIGN DETERMINES THE VISIBILITY OF PS        4
CLJ   A POINT (THETA,PHI) ON THE ELLIPSOIDAL CLOUD SURFACE FROM AN      PS        5
CLJ   EXTERIOR POINT.                                                   PS        6
CLJ                                                                     PS        7
CLJ   INPUT PARAMETERS                                                  PS        8
CLJ      ARGUMENT LIST                                                  PS        9
CLJ             X1, = COORDINATES OF AN EXTERIOR POINT (WHICH MAY BE    PS       10
CLJ            ET1,   EITHER THE SOURCE OR THE DETECTOR) IN THE K-TH    PS       11
CLJ           ZET1    CLOUD-CENTERED CARTESIAN COORDINATE SYSTEM,  KM   PS       12
CLJ                   NOTE. THE COORDINATES ARE XI(1,K), ETA(1,K),      PS       13
CLJ                         ZETA(1,K) IF THE POINT IS AT THE SOURCE AND PS       14
CLJ                         XID(K), ETAD(K), ZETA(K) IF AT THE DETECTOR. PS       15
CLJ          THETA, = POLAR AND AZIMUTHAL COORDINATES OF A GIVEN FACET  PS       16
CLJ            PHI    CENTER ON CLOUD K                                 PS       17
CLJ              K = CLOUD NUMBER   K=1,20                              PS       18
CLJ      CDCORD COMMON                                                  PS       19
CLJ         FOLLOWING PARAMETERS ARE SET IN SUBROUTINE CLDGEOM FOR      PS       20
CLJ         K=1,10                                                      PS       21
CLJ          ASQ(K) = SQUARE OF LENGTH A, THE SEMI-MAJOR AXIS IN        PS       22
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2      PS       23
CLJ          BSQ(K) = SQUARE OF LENGTH B, THE SEMI-MINOR AXIS IN        PS       24
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2      PS       25
CLJ          CSQ(K) = SQUARE OF LENGTH C, THE SEMI-MINOR AXIS IN        PS       26
CLJ                   VERTICAL DIRECTION OF ELLIPSOIDAL CLOUD, KM**2    PS       27
CLJ      PARAMS COMMON                                                  PS       28
CLJ             DTR = CONVERSION FACTOR FROM DEGREES TO RADIANS         PS       29
CLJ   OUTPUT PARAMETER                                                  PS       30
CLJ      FUNCTION                                                       PS       31
CLJ               PS = QUANTITY PROPORTIONAL TO THE DOT PRODUCT OF THE  PS       32
CLJ                   OUTWARD NORMAL AT THE POINT (THETA,PHI) AND THE   PS       33
CLJ                   VECTOR FROM THE POINT (THETA,PHI) TO THE EXTERIOR PS       34
CLJ                   POINT.  THE CALLING SUBROUTINE (EITHER LOS OR     PS       35
CLJ                   CLOUD3) DETERMINES THAT THE POINT IS VISIBLE IF   PS       36
CLJ                   PS IS POSITIVE AND HIDDEN IF PS IS ZERO OR        PS       37
CLJ                   NEGATIVE.  (THE UNITS HAPPEN TO BE 1/KM, BUT      PS       38
CLJ                         THAT IS UNIMPORTANT.)                       PS       39
CLJ                                                                     PS       40
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                  CDCORD    2
     1              XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)      CDCORD    3
     X  , ASQ(20),BSQ(20),CSQ(20)                                       CDCORD    4
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CRBAR(4,4,20),CAREA(4,4,20)         CDCORD    5
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS    2
C        IS THE POINT(THETA,PHI) ON THE ELLIPSOID SURFACE               PS       43
C        VISIBLE TO THE POINT XI,ETA,ZETA                               PS       44
      ST = SIN(THETA*DTR)                                               PS       45
      CT = COS(THETA*DTR)                                               PS       46
      SP = SIN(PHI*DTR)                                                 PS       47
      CP = COS(PHI*DTR)                                                 PS       48
      R = 1. / SQRT(ST*ST*CP*CP/ASQ(K)+ST*ST*SP*SP/BSQ(K)+              PS       49
     1   CT*CT/CSQ(K))                                                  PS       50
      PS = X1*ST*CP/ASQ(K) + ET1*ST*SP/BSQ(K) + ZET1*CT/CSQ(K) - 1./R   PS       51
      RETURN                                                            PS       52
      END                                                               PS       53
```

```
      FUNCTION RHOEPS(ALAM,CTHETA)                                      RHOEPS   2
C                                                                       RHOEPS   3
C        ALAM IS WAVELENGTH IN MICRONS                                  RHOEPS   4
C        CTHETA IS COS(EXIT ANGLE)                                      RHOEPS   5
C        RHOEPS IS DIRECTIONAL RHO                                      RHOEPS   6
C        THE RHOTABLE COMES FROM CLOUD TYPE 4, I.E. CS                  RHOEPS   7
C        FOR 4 ANGLES AND 10 WAVELENGTHS                                RHOEPS   8
C                                                                       RHOEPS   9
      DIMENSION TLAM(10),CTHET(4),RHO(4,10)                             RHOEPS  10
CCC                                                                     RHOEPS  11
CLJ   FUNCTION RHOEPS COMPUTES THE HEMISPHERICAL-DIRECTIONAL            RHOEPS  12
CLJ   REFLECTANCE FROM THE (HORIZONTAL) SURFACE OF CLOUD-TYPE 4         RHOEPS  13
CLJ   (STRATOCUMULUS) FOR RADIATION OF WAVELENGTH ALAM REFLECTED INTO   RHOEPS  14
CLJ   ZENITH ANGLE ACOS(CTHETA).                                        RHOEPS  15
CCC                                                                     RHOEPS  16
CLJ   INPUT PARAMETERS                                                  RHOEPS  17
CLJ      ARGUMENT LIST                                                  RHOEPS  18
CLJ            ALAM = WAVELENGTH,  MICRONS                              RHOEPS  19
CLJ          CTHETA = COSINE OF ZENITH ANGLE THETA                      RHOEPS  20
CLJ   OUTPUT PARAMETER                                                  RHOEPS  21
CLJ      FUNCTION                                                       RHOEPS  22
CLJ          RHOEPS = HEMISPHERICAL-DIRECTIONAL REFLECTANCE FOR         RHOEPS  23
CLJ                   RADIATION OF WAVELENGTH ALAM REFLECTED AT ANGLE   RHOEPS  24
CLJ                   THETA FROM THE NORMAL TO THE SURFACE OF A SEMI-   RHOEPS  25
CLJ                   INFINITE SLAB OF CLOUD-TYPE 4 (STRATOCUMULUS)     RHOEPS  26
CLJ   DEFINITION OF DATA                                                RHOEPS  27
CLJ           RHO(I,N) = HEMISPHERICAL-DIRECTIONAL REFLECTANCE FOR      RHOEPS  28
CLJ                      RADIATION OF WAVELENGTH TLAM(N) REFLECTED AT   RHOEPS  29
CLJ                      ANGLE THETA(I)=ACOS(CTHET(I)) FROM THE NORMAL  RHOEPS  30
CLJ                      TO THE SURFACE OF A SEMI-INFINITE SLAB OF      RHOEPS  31
CLJ                      CLOUD-TYPE 4 (STRATOCUMULUS)                   RHOEPS  32
CLJ           THETA(I) = 0,30,60,90  DEGREES                            RHOEPS  33
CCC                                                                     RHOEPS  34
CLJ                 FOR ABOVE VARIABLES   I=1,4  AND  N=1,10            RHOEPS  35
CCC                                                                     RHOEPS  36
CLJ      VALUES OF RHO(I,N) ARE DERIVED FROM THE BIDIRECTIONAL          RHOEPS  37
CLJ      REFLECTANCE DATA RFLN(J,K,I) IN FUNCTION CLDBDR BY THE         RHOEPS  38
CLJ      (SCHEMATIC) FORMULA...                                         RHOEPS  39
CCC                                                                     RHOEPS  40
CLJ          RHO(I,N) = 2.*SUM( SUM( RFLN(J,K,I)*CTHOUT(J)*DELCTH(J)    RHOEPS  41
CLJ                                  *DELPHI(K) ) )  K=1,9  J=1,5       RHOEPS  42
CLJ          CTHOUT(J) = 0.1 + 0.2*(J-1)   J=1,5                        RHOEPS  43
CLJ          DELCTH(J) = 0.20   J=1,5                                   RHOEPS  44
CLJ          DELPHI(K) = PI/9.   K=1,9                                  RHOEPS  45
CCC                                                                     RHOEPS  46
CLJ          RHO(I,N) = (2.*PI/45.)*SUM( CTHOUT(J)*SUM( RFLN(J,K,I),    RHOEPS  47
CLJ                     K=1,9 ), J=1,5 )                                RHOEPS  48
CCC                                                                     RHOEPS  49
CLJ      THE MONTE CARLO RESULTS OBTAINED FOR AN INCIDENT ZENITH ANGLE  RHOEPS  50
CLJ      OF 80 DEGREES ARE APPLIED HERE AT THETA(4)=90 DEGREES, A       RHOEPS  51
CLJ      NECESSARY APPROXIMATION IN ORDER TO SPAN THE ENTIRE RANGE.     RHOEPS  52
CCC                                                                     RHOEPS  53
      DATA TLAM / 2.,2.5,2.55,2.65,2.75,2.85,3.2,3.5,4.,5. /            RHOEPS  54
      DATA  CTHET / 1.00,0.866,0.500,0.0 /                              RHOEPS  55
      DATA RHO /                                                        RHOEPS  56
     *   .246738,  .337347,  .438561,  .582364,                         RHOEPS  57
     *   .263120,  .292961,  .408229,  .567398,                         RHOEPS  58
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     *   .164484,  .228606,  .344201,  .535932,                          RHOEPS
     *   .065790,  .114484,  .196950,  .405818,                          RHOEPS
     *   .003113,  .004874,  .019022,  .111126,                          RHOEPS
     *   .002738,  .003339,  .007853,  .041029,                          RHOEPS
     *   .008453,  .010461,  .019127,  .057703,                          RHOEPS
     *   .133816,  .159922,  .240649,  .372372,                          RHOEPS
     *   .207125,  .248432,  .362510,  .529662,                          RHOEPS
     *   .110265,  .136137,  .234503,  .413162                           RHOEPS
     X   /                                                               RHOEPS
C                                                                        RHOEPS
C        INTERPOLATION  -LINEAR IN BOTH WAVELENGTH AND COSINE OF ANGLE   RHOEPS
C                                                                        RHOEPS
      DO 10 II = 2,10                                                    RHOEPS
      I = II - 1                                                         RHOEPS
      IF(ALAM .LT. TLAM(II)) GO TO 15                                    RHOEPS
   10 CONTINUE                                                           RHOEPS
      I = 9                                                              RHOEPS
   15 CONTINUE                                                           RHOEPS
      DO 20 JJ = 2,4                                                     RHOEPS
      J = JJ - 1                                                         RHOEPS
      IF( CTHETA .GT. CTHET(JJ)) GO TO 25                                RHOEPS
   20 CONTINUE                                                           RHOEPS
      J = 3                                                              RHOEPS
   25 CONTINUE                                                           RHOEPS
      DEN = ( CTHETA-CTHET(J) )/( CTHET(J+1)-CTHET(J) )                  RHOEPS
      A1 = RHO(J, I ) + (RHO(J+1, I )-RHO(J, I )) * DEN                  RHOEPS
      A2 = RHO(J,I+1) + (RHO(J+1,I+1)-RHO(J,I+1)) * DEN                  RHOEPS
      RHOEPS = A1 + ( A2-A1 )*( ALAM-TLAM(I) )/( TLAM(I+1)-TLAM(I) )     RHOEPS
      RETURN                                                             RHOEPS
      END                                                                RHOEPS
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      SUBROUTINE SCLOUD(ALAM,U,V,W,ISUN)                                SCLOUD
CLJ                                                                     SCLOUD
CLJ   SUBROUTINE SCLOUD, THE BASIC SUBROUTINE IN THE STATISTICAL-CLOUD  SCLOUD
CLJ   SUBMODEL, SERVES AS THE INTERMEDIARY BETWEEN THE DRIVER PROGRAM   SCLOUD
CLJ   AND ALL THE REMAINING ROUTINES IN THE STATISTICAL CLOUD SUBMODEL. SCLOUD
CLJ                                                                     SCLOUD
CLJ   INPUT PARAMETERS                                                  SCLOUD
CLJ      ARGUMENT LIST                                                  SCLOUD
CLJ            ALAM = WAVELENGTH, MICRONS                               SCLOUD
CLJ          U,V,W = DIRECTION COSINES IN EARTH-CENTERED CARTESIAN      SCLOUD
CLJ                  SYSTEM OF A USER-SPECIFIED LOS (SET IN DRIVER)     SCLOUD
CLJ           ISUN = FLAG TO DENOTE NATURE OF SOURCE                    SCLOUD
CLJ                = 0  ARTIFICIAL SOURCE                              SCLOUD
CLJ                = 1  SUN                                            SCLOUD
CLJ      CLDFREQ COMMON                                                 SCLOUD
CLJ          DEFINITIONS OF THE FOLLOWING THREE QUANTITIES ARE IN       SCLOUD
CLJ          THE BLOCK DATA ROUTINE.  KMODEL, CCOVER(ICC,KMODEL),       SCLOUD
CLJ          AND CFREQ(KCLOUD,ICC,KMODEL)                               SCLOUD
CLJ      CLDWT COMMON                                                   SCLOUD
CLJ          DEFINITIONS OF THE FOLLOWING FOUR QUANTITIES ARE IN        SCLOUD
CLJ          CLDWT ROUTINE.  IDX, WT(I), TRANS(I), AND EMISS(I)         SCLOUD
CLJ          WHERE  I=1,IDX-1                                           SCLOUD
CLJ      DETECT COMMON                                                  SCLOUD
CLJ             HD = ALTITUDE OF DETECTOR,  KM                          SCLOUD
CLJ          THETAD = COLATITUDE OF DETECTOR,  DEGREES                  SCLOUD
CLJ            PHID = EAST LONGITUDE OF DETECTOR, DEGREES               SCLOUD
CLJ      MATERL COMMON                                                  SCLOUD
CLJ            MSM = INDEX FOR CATEGORY OF SURFACE MATERIAL (SET IN     SCLOUD
CLJ                  DRIVER PROGRAM)                                    SCLOUD
CLJ                = 1, LAMBERTIAN DIFFUSE SURFACE WITH SPECTRALLY-     SCLOUD
CLJ                     INDEPENDENT REFLECTANCE SET BY DD(1) AND        SCLOUD
CLJ                     EMISSIVITY BY (1.-DD(1)).                       SCLOUD
CLJ                = 2, WATER          = 3, SNOW                        SCLOUD
CLJ                = 4, SAND           = 5, SOIL                        SCLOUD
CLJ                = 6, FOLIAGE        = 7, URBAN MATERIAL              SCLOUD
CLJ           DD(M) = ADDITIONAL DESCRIPTOR FOR SELECTED SURFACE        SCLOUD
CLJ                  MATERIAL (SET IN DRIVER PROGRAM)                   SCLOUD
CLJ           FOR M = 1, (LAMBERTIAN SURFACE), DD(1) = DIFFUSE          SCLOUD
CLJ                     REFLECTANCE. TYPICAL VALUE IS 0.10              SCLOUD
CLJ           FOR M = 2, (WATER), DD(2) = WIND SPEED, M/SEC.            SCLOUD
CLJ           FOR M = 3, (SNOW), DD(3) = SNOW-AGE PARAMETER,            SCLOUD
CLJ                     DD(3).GE.0. .AND. .LE.1.   VALUES OF 0. AND 1.  SCLOUD
CLJ                     CORRESPOND TO NEW AND OLD SNOW RESPECTIVELY.    SCLOUD
CLJ           FOR M = 4,5,6,  DD(M) NOT USED.                           SCLOUD
CLJ           FOR M = 7, (URBAN MATERIAL), DD(7) = DEGREE-OF-URBANITY,  SCLOUD
CLJ                     DD(7).GE.0. .AND. .LE.1.   FOR DD(7) = 0., THE  SCLOUD
CLJ                     SPECTRAL BRDF CORRESPONDS TO A FLAT SURFACE     SCLOUD
CLJ                     WITH AVERAGE DIRECTIONAL-REFLECTANCE PROPERTIES SCLOUD
CLJ                     OF CONCRETE AND ASPHALT. FOR DD(7) = 1., THE    SCLOUD
CLJ                     SPECTRAL BRDF CORRESPONDS TO A DIFFUSE          SCLOUD
CLJ                     REFLECTOR MULTIPLIED BY A SHADOW-FACTOR         SCLOUD
CLJ                     S(THI,THR) = ( COS(THI) + COS(THR) )/2.         SCLOUD
CLJ        SRFALT = ALTITUDE OF SURFACE, KM   (CURRENT FORMULATION OF   SCLOUD
CLJ                 CLOUD MODEL REQUIRES THIS PARAMETER TO BE SET TO    SCLOUD
CLJ                  0.0)                                               SCLOUD
CLJ      PARAMS COMMON                                                  SCLOUD
CLJ              RE = EARTH'S RADIUS, KM                                SCLOUD
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CLJ            DTR = CONVERSION FACTOR FROM DEGREES TO RADIANS          SCLOUD     59
CLJ      PTE COMMON                                                     SCLOUD     60
CLJ            P1, = PROBABILITY LEVELS (FRACTILES) AT WHICH TRANSFER   SCLOUD     61
CLJ            P2,   COEFFICIENTS AND EMISSION RADIANCES ARE DESIRED.   SCLOUD     62
CLJ           P3,P4  SET IN DRIVER PROGRAM.                             SCLOUD     63
CLJ      SOLARP COMMON                                                  SCLOUD     64
CLJ          SOLLAT = NORTH LATITUDE OF SUBSOLAR POINT (RADIANS)        SCLOUD     65
CLJ          SOLLON = EAST LONGITUDE OF SUBSOLAR POINT (RADIANS)        SCLOUD     66
CLJ      SORCE COMMON                                                   SCLOUD     67
CLJ       HSORCE(I) = ALTITUDE OF SOURCE-I ABOVE SURFACE,  KM           SCLOUD     68
CLJ       THETAS(I) = COLATITUDE OF SOURCE-I,  DEGREES                  SCLOUD     69
CLJ         PHIS(I) = EAST LONGITUDE OF SOURCE-I,  DEGREES              SCLOUD     70
CLJ       RSORCE(I) = RADIUS OF SOURCE-I,  KM                           SCLOUD     71
CLJ   OUTPUT PARAMETERS                                                 SCLOUD     72
CLJ      FLAGS COMMON                                                   SCLOUD     73
CLJ          ITFLAG = 0  IF SUN IS BELOW THE HORIZON                    SCLOUD     74
CLJ                 = 1  IF SUN IS ABOVE THE HORIZON                    SCLOUD     75
CLJ                      OR IF AN ARTIFICIAL SOURCE IS PRESENT          SCLOUD     76
CLJ      PTE COMMON                                                     SCLOUD     77
CLJ            T1, = TRANSFER COEFFICIENTS AT 12-KM ALTITUDE FOR        SCLOUD     78
CLJ            T2,   ARTIFICIAL POINT SOURCE, CORRESPONDING TO P1,P2,   SCLOUD     79
CLJ            T3,   P3,P4.  A TRANSFER COEFFICIENT IS THE RATIO OF A   SCLOUD     80
CLJ            T4    RADIANCE TO AN IRRADIANCE.  (1/SR)                 SCLOUD     81
CLJ            S1, = TRANSFER COEFFICIENTS AT 12-KM ALTITUDE FOR SUN AS SCLOUD     82
CLJ            S2,   A SOURCE, CORRESPONDING TO P1,P2,P3,P4.  (1/SR)    SCLOUD     83
CLJ           S3,S4                                                     SCLOUD     84
CLJ            E1, = THERMAL EMISSION (SPECTRAL RADIANCE) FROM TOP      SCLOUD     85
CLJ            E2,   LAYER OF CLOUDS OR THE GROUND (FOR THE CLOUD-FREE  SCLOUD     86
CLJ            E3,   LINE-OF-SIGHT), CORRESPONDING TO P1,P2,P3,P4.      SCLOUD     87
CLJ            E4    (WATTS/(KM**2 SR MICRON))                          SCLOUD     88
CLJ          PCFLOS = PROBABILITY OF THE DETECTOR SEEING THE ARTIFICIAL SCLOUD     89
CLJ                   SOURCE, EITHER WITH CLOUDS PRESENT (FOR WHICH WE  SCLOUD     90
CLJ                   HAVE USED A POSTULATED ALTITUDE-DEPENDENT CFLOS   SCLOUD     91
CLJ                   FUNCTION) OR WITHOUT CLOUDS BEING PRESENT.        SCLOUD     92
CLJ                   A VALUE OF 0.0 IS RETURNED IF THE SOURCE IS NOT   SCLOUD     93
CLJ                   WITHIN THE FIELD-OF-VIEW.                         SCLOUD     94
CLJ                                                                     SCLOUD     95
      COMMON /CLDFREQ/ KMODEL,CCOVER(5,11),CFREQ(17,4,11)               CLDFREQ     2
      COMMON / DETECT/ HD, THETAD,PHID,FOV                              DET         2
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS      2
      COMMON/SORCE/  NSORCE,HSORCE(1),RSORCE(1),THETAS(1),PHIS(1)       SORCE       2
      COMMON/CLDWT/IDX,WT(161),TRANS(161),EMISS(161)                    CLDWGT      2
      COMMON/FLAGS/  ITFLAG                                             FLAGS       2
      COMMON /MATERL/MSM,DDM(7),SRFALT                                  MATERL      2
      COMMON/ PTE /  P1,P2,P3,P4,T1,T2,T3,T4,                           PTE         2
     1               S1,S2,S3,S4,E1,E2,E3,E4                            PTE         3
     1              ,PCFLOS                                             PTE         4
      COMMON /SANDD/ XS,YS,ZS,XD,YD,ZD,UL,VL,WL                         SANDD       2
      COMMON/SOLARP/ SOLLAT,SOLLON,DUMDUM(10)                           SOLARC      2
      DIMENSION WT1(161)                                                SCLOUD    106
      LOGICAL SPCULR,ESURF1                                             SCLOUD    107
      DATA  RSUN / 1.495979E+08 /                                       SCLOUD    108
CLJ       THE ARITHMETIC FUNCTION PLANK PROVIDES SPECTRAL RADIANCE AT   SCLOUD    109
CLJ       WAVELENGTH AA(MICRONS) AND TEMPERATURE TT(DEG KELVIN),        SCLOUD    110
CLJ       WATTS/(KM**2 SR MICRON))                                      SCLOUD    111
      PLANK(AA,TT) = 1.191E14/(AA**5*(EXP(14388./(AA*TT))-1.))          SCLOUD    112
CLJ       THE ARITHMETIC FUNCTIONS CFLOSC AND CFLOSH RESULT FROM OUR    SCLOUD    113
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CLJ       POSTULATING A SIMPLE ALTITUDE-DEPENDENCE TO THE CFLOS
CLJ       FUNCTIONS FOR THE RESPECTIVE PATHS FROM (A) THE ARTIFICIAL
CLJ       SOURCE TO THE GROUND AND (B) THE ARTIFICIAL SOURCE TO THE
CLJ       DETECTOR.  THE ALTITUDE-DEPENDENT FACTOR F IS DEFINED IN THE
CLJ       ROUTINE BEFORE USING THESE ARITHMETIC FUNCTIONS.
CLJ
      CFLOSG( KQ,QA,QF ) = 1.0 - ( QF * (1.0-CFLOSF( KQ,QA ) ) )
      CFLOSH( KQ,QA,QF ) = QF + (1.0-QF) * CFLOSF( KQ,QA )
CLJ
      UL = U
      VL = V
      WL = W
C
      NS = 1
      ALT = HSORCE(NS)
      IF( ISUN.EQ.0 )  CALL POL TO CT(ALT+RE,THETAS(NS),PHIS(NS),
     $ XS,YS,ZS)
      IF( ISUN.EQ.1 )  CALL POL TO CT(RSUN,90.-SOLLAT*RTD,SOLLON*RTD,
     $ XS,YS,ZS)
      HSAVE = HSORCE(1)
      IF( ISUN.EQ.1 )  HSORCE(1) = RSUN-RE
      CALL POL TO CT(HD+RE,THETAD,PHID,XD,YD,ZD)
C
CLJ       THIS CALL TO SGEOM GETS (1) THE ANGLE THI USED TO TEST WHETHER
CLJ       OR NOT THE SUN IS ABOVE THE HORIZON AND (2) THE LOS ZENITH
CLJ       ANGLE THR FOR USE BY SUBROUTINE CLDWT IN CALLING CFLOSF.  THE
CLJ       ANGLE THR AND THE AZIMUTHAL ANGLE PSI ARE ALSO USED IN CALLING
CLJ       SUBROUTINE ESURF, AND THE ANGLE THI MAY ALSO BE USED IN THAT
CLJ       CALL.  HOWEVER, IF THE SOURCE IS AN ARTIFICIAL ONE AND ITS
CLJ       ALTITUDE IS LESS THAN THE RADIUS ASSIGNED TO THE FINITE-S+OE
CLJ       SOURCE, IT IS THEN NECESSARY TO RESET THE ANGLE THI WITH
CLJ       ANOTHER CALL TO SUBROUTINE SGEOM BEFORE CALLING SUBROUTINE
CLJ       ESURF.
      CALL SGEOM(UL,VL,WL,SRFALT,XD,YD,ZD,XS,YS,ZS,
     X       RDIST,SDIST,THI,THR,PSI)
CC
      IDAY = 1
      IF( THI.GT.90. )  IDAY = 0
      ITFLAG = 1
      IF( IDAY.EQ.0 .AND. ISUN.EQ.1 )  ITFLAG = 0
C        CALL DIFPRM TO GET DIFFUSION PARAMETERS
C        FOR GIVEN WAVELENGTH FOR ALL 14 CLOUDS
      CALL DIFPRM(ALAM)
      CALL CLDWT(ALAM,THR)
      II = IDX
C     GET ESURF PARAMETERS
      ZLAM = ALAM
      ZKM = SRFALT
      IFIRES = 0.
      SPCULR =  .FALSE.
      ESURFI = .TRUE.
CLJ       RESET THI TO THIEFF AND SDIST TO SDEFF IF ISUN=0 AND
CLJ       IF HSORCE(1) .LT. RSORCE(1).
      IF( (ISUN.EQ.1) .OR. (ALT.GE.RSORCE(1)) )  GO TO 2
      HSEFF = 0.5*(ALT + RSORCE(1))
      CALL POL TO CT(RE+HSEFF,THETAS(NS),PHIS(NS),XSEFF,YSEFF,ZSEFF)
      CALL SGEOM(UL,VL,WL,SRFALT,XD,YD,ZD,XSEFF,YSEFF,ZSEFF,
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     $            RDEFF,SDEFF,THIEFF,THR,PSI)                          SCLOUD   171
      SDIST = SDEFF                                                    SCLOUD   172
      THI = THIEFF                                                     SCLOUD   173
CLJ       FOR LATER USE, SAVE AND SET...                               SCLOUD   174
      HSAVE2 = HSORCE(1)                                               SCLOUD   175
      HSORCE(1) = HSEFF                                                SCLOUD   176
    2 CONTINUE                                                         SCLOUD   177
      CALL ESURF(THI*DTR,THR*DTR,PSI*DTR,ZKM,MSM,DDM(1),               SCLOUD   178
     X  SPCULR,ZLAM,IDAY,IFIRES,ESURF1,SFR,EPSD,TKS  )                 SCLOUD   179
      T2TP = TAIR(ALAM,THR,ZKM)                                        SCLOUD   180
      EMISS(II) = EPSD * PLANK(ALAM,TKS) * T2TP                        SCLOUD   181
      IF( ITFLAG.EQ.0 )  GO TO 4                                       SCLOUD   182
CLJ       WE NOW DEVELOP THE WEIGHT TO BE USED IN RESETTING WT(II) TO  SCLOUD   183
CLJ       ACCOUNT FOR THE TWO-LEG CFLOS NEEDED TO VIEW THE SOURCE-LIT  SCLOUD   184
CLJ       GROUND.                                                      SCLOUD   185
CLJ       IF THE ARTIFICIAL SOURCE WERE ABOVE THE TOP OF THE HIGHEST   SCLOUD   186
CLJ       CLOUD TOP IN THE STATISTICAL MODEL (I.E., ABOVE 12-KM        SCLOUD   187
CLJ       ALTITUDE), THE PROBABILITY OF THE DETECTOR SEEING THE SOURCE-SCLOUD   188
CLJ       LIT GROUND WOULD BE THE SAME AS THAT FOR THE SUN.  IF THE    SCLOUD   189
CLJ       ARTIFICIAL SOURCE WERE BELOW SUCH AN ALTITUDE, THEN IT IS    SCLOUD   190
CLJ       LIKELY THAT THE VALUE OF AN APPROPRIATE CFLOSF(ICC,THI)      SCLOUD   191
CLJ       WOULD BE LARGER THAN THAT FOR THE SUN, WITH THE EXACT AMOUNT SCLOUD   192
CLJ       DEPENDING ON THE ALTITUDE.  SUCH A DATA BASE IS NOT READILY  SCLOUD   193
CLJ       AVAILABLE (IF IT EXISTS AT ALL), SO WE SHALL USE AN          SCLOUD   194
CLJ       APPROXIMATION.  DEFINE THE FACTOR F...                       SCLOUD   195
      F = 1.0                                                          SCLOUD   196
      IF( HSORCE(1).LT.12. )  F = 1. - (12. - HSORCE(1)) / 11.85       SCLOUD   197
      IF( HSORCE(1).LT.0.15)  F = 0.                                   SCLOUD   198
CLJ       THEN THE POSTULATED CFLOS-FUNCTION FOR THE DOWNWARD LEG IS   SCLOUD   199
CLJ       GIVEN BY THE ARITHMETIC FUNCTION CFLOSG(ICC,THI,F).          SCLOUD   200
CLJ       NOTE THAT IF F=1., THEN CFLOSG(ICC,THI,1.)=CFLOSF(ICC,THI).  SCLOUD   201
CLJ       THE PROBABILITY OF THE DETECTOR SEEING THE SOURCE-LIT GROUND SCLOUD   202
CLJ       THROUGH THE CLOUDS IS SLGCLD, GIVEN BY...                    SCLOUD   203
      SLGCLD = CCOVER(2,KMODEL) * CFLOSF( 4,THR) * CFLOSG( 4,THI,F)    SCLOUD   204
     $       + CCOVER(3,KMODEL) * CFLOSF( 6,THR) * CFLOSG( 6,THI,F)    SCLOUD   205
     $       + CCOVER(4,KMODEL) * CFLOSF( 9,THR) * CFLOSG( 9,THI,F)    SCLOUD   206
     $       + CCOVER(5,KMODEL) * CFLOSF(11,THR) * CFLOSG(11,THI,F)    SCLOUD   207
CLJ       THE PROBABILITY OF SEEING THE SOURCE-LIT GROUND WITHOUT      SCLOUD   208
CLJ       CLOUDS IS (ESSENTIALLY) SLGCLR...                            SCLOUD   209
CLJ                                                                    SCLOUD   210
      SLGCLR = CCOVER(1,KMODEL)                                        SCLOUD   211
CLJ                                                                    SCLOUD   212
CLJ       WHICH SHOULD, IN A SENSE, BE MULTIPLIED BY THE TWO FACTORS   SCLOUD   213
CLJ       CFLOSF(1,THR) AND CFLOSF(1,THI).  WE SHALL NOT USE THE FACTORS SCLOUD   214
CLJ       HERE FOR CONSISTENCY WITH SUCH NONUSAGE ELSEWHERE IN THE CODE. SCLOUD   215
CLJ       (THE CONFUSION ARISES FROM THE AMBIGUITY IN THE LITERATURE AS SCLOUD   216
CLJ       TO WHAT IS MEANT BY A CLOUD COVER OF ZERO TENTHS, WHEN CFLOSF SCLOUD   217
CLJ       IS LESS THAN UNITY FOR SUFFICIENTLY LARGE ZENITH ANGLES.  A  SCLOUD   218
CLJ       COMPLEMENTARY-TYPE AMBIGUITY EXITS FOR A CLOUD COVER OF TEN  SCLOUD   219
CLJ       TENTHS, WHEN CFLOSF IS GREATER THAN ZERO.)                   SCLOUD   220
CLJ       THE PROBABILITY OF SEEING THE SOURCE-LIT GROUND EITHER WITH  SCLOUD   221
CLJ       OR WITHOUT CLOUDS BEING PRESENT IS SLG...                    SCLOUD   222
      SLG = SLGCLD + SLGCLR                                            SCLOUD   223
      IF( SLG.GT.1.0 )  SLG = 1.0                                      SCLOUD   224
CLJ       TO REFERENCE THE TRANSFER COEFFICIENT TO 12-KM ALTITUDE, WE  SCLOUD   225
CLJ       NEED SDIST0.  IN DOING THIS WE USE THE ORIGINAL SOURCE       SCLOUD   226
CLJ       POSITION, WITHOUT ANY RESETTING IF THE SOURCE IS ARTIFICIAL, SCLOUD   227
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CLJ       EVEN THOUGH ITS ALTITUDE MAY BE LESS THAN ITS RADIUS.
      TPALT = 12.
      CALL SGEOM(UL,VL,WL,TPALT,XD,YD,ZD,XS,YS,ZS,
     $           RDIST,SDISTO,THETI,THETE,PHIE)
      T12 = TAIR(ALAM,THI,ZKM)
      IF( HSORCE(1).LT.12. )  T12 = T12/TAIR(ALAM,THI,HSORCE(1))
      TRANS(II) = SFR*COS(THI*DTR)*T12*T2TP*(SDISTO/SDIST)**2
      HSORCE(1) = HSAVE2
    4 CONTINUE
CLJ       BEFORE DUPLICATING THE WT ARRAY AND BEFORE SORTING THE TRANS
CLJ       AND EMISS ARRAYS, AUGMENT THE TRANS ARRAY WITH THE MEMBER
CLJ       TRANS(II+1) = 0.0, THE EMISSION ARRAY WITH THE MEMBER
CLJ       EMISS(II+1) = 0.0, AND THE WT ARRAY WITH THE MEMBER
CLJ       WT(II+1) = 0.0.  DOING THIS ALLOWS SUBROUTINE LINEAR TO
CLJ       INTERPOLATE WITHIN ITS GIVEN ARRAY IF THE WEIGHT OF THE
CLJ       NORMALLY SMALLEST MEMBER EXCEEDS THE SMALLEST FRACTILE (NOW
CLJ       0.10) FOR WHICH AN INTEGRAL-DISTRIBUTION VALUE IS REQUESTED.
      IISAVE = II
      II = II + 1
      TRANS(II) = 0.0
      EMISS(II) = 0.0
      WT(II) = 0.0
      DO 5 I = 1,II
    5 WT1(I) = WT(I)
CLJ       NOW RESET WT(IISAVE) TO ACCOUNT FOR A TWO-LEG CELOS.
      IF( ITFLAG .NE. 0 )  WT(IISAVE) = SLG
C
CLJ       SORT THE ARRAYS FOR TRANSFER COEFFICIENT AND EMISSION, TRANS
CLJ       AND EMISS, FROM LOW TO HIGH.
C
      IF( ITFLAG.NE.0 )  CALL SORTLJ(TRANS,WT,WT,II,0)
      CALL SORTLJ(EMISS,WT1,WT1,II,0)
C        ACCUMULATE THE WEIGHTING FUNCTION AND NORMALIZE
      DO 10 I = 2,II
      WT1(I) = WT1(I-1) + WT1(I)
   10 WT(I) = WT(I-1) + WT(I)
      DO 15 I = 1,II
      WT1(I) = WT1(I) / WT1(II)
   15 WT(I) = WT(I) / WT(II)
C
CLJ       INTERPOLATE TO THE FRACTILES P1,P2,P3,P4 SET IN THE DRIVER.
      IF( ISUN.EQ.1 )  GO TO 22
      CALL LINEAR(P1,E1,WT1,EMISS,II)
      CALL LINEAR(P2,E2,WT1,EMISS,II)
      CALL LINEAR(P3,E3,WT1,EMISS,II)
      CALL LINEAR(P4,E4,WT1,EMISS,II)
      CALL LINEAR(P1,T1,WT,TRANS,II)
      CALL LINEAR(P2,T2,WT,TRANS,II)
      CALL LINEAR(P3,T3,WT,TRANS,II)
      CALL LINEAR(P4,T4,WT,TRANS,II)
      IF( ISUN.EQ.0 )  GO TO 24
   22 CONTINUE
      CALL LINEAR(P1,E1,WT1,EMISS,II)
      CALL LINEAR(P2,E2,WT1,EMISS,II)
      CALL LINEAR(P3,E3,WT1,EMISS,II)
      CALL LINEAR(P4,E4,WT1,EMISS,II)
      IF( ITFLAG.EQ.0 )  GO TO 24
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      CALL LINEAR(P1,S1,WT,TRANS,II)                                    SCLOUD   285
      CALL LINEAR(P2,S2,WT,TRANS,II)                                    SCLOUD   286
      CALL LINEAR(P3,S3,WT,TRANS,II)                                    SCLOUD   287
      CALL LINEAR(P4,S4,WT,TRANS,II)                                    SCLOUD   288
   24 CONTINUE                                                          SCLOUD   289
      HSORCE(1) = HSAVE                                                 SCLOUD   290
      IF( ISUN.EQ.1 )  GO TO 30                                         SCLOUD   291
CLJ       FINALLY, WE RETURN TO THE USER THROUGH PTE COMMON THE         SCLOUD   292
CLJ       PROBABILITY (PCFLOS) OF SEEING THE ARTIFICIAL SOURCE          SCLOUD   293
CLJ       (PROVIDED IT IS WITHIN THE FIELD-OF-VIEW), EITHER WITH CLOUDS SCLOUD   294
CLJ       BEING PRESENT (AND WITH ACCOUNT OF OUR POSTULATED ALTITUDE-   SCLOUD   295
CLJ       DEPENDENT CFLOS FUNCTION) OR WITHOUT CLOUDS BEING PRESENT.    SCLOUD   296
CLJ                                                                     SCLOUD   297
      PCFLOS = 0.0                                                      SCLOUD   298
CLJ                                                                     SCLOUD   299
CLJ       THE CHARACTERISTIC HALF-ANGLE OF THE FIELD-OF-VIEW IS         SCLOUD   300
CLJ       TAKEN TO BE CHIFOV...                                         SCLOUD   301
CLJ                                                                     SCLOUD   302
      CHIFOV = SQRT( FOV/PI ) / HD                                      SCLOUD   303
CLJ                                                                     SCLOUD   304
CLJ       GET THE DIRECTION COSINES OF A VECTOR FROM THE DETECTOR       SCLOUD   305
CLJ       TO THE SOURCE.                                                SCLOUD   306
      RSD = SQRT( (XS-XD)**2 + (YS-YD)**2 + (ZS-ZD)**2 )                SCLOUD   307
      US = (XS-XD)/RSD                                                  SCLOUD   308
      VS = (YS-YD)/RSD                                                  SCLOUD   309
      WS = (ZS-ZD)/RSD                                                  SCLOUD   310
CLJ       THE ANGLE BETWEEN THE INPUT LOS AND THE DETECTOR-TO-SOURCE    SCLOUD   311
CLJ       VECTOR IS CHISL...                                            SCLOUD   312
      CHISL = ACOS( US*UL + VS*VL + WS*WL )                             SCLOUD   313
      IF( CHISL.GT.CHIFOV )  GO TO 30                                   SCLOUD   314
CLJ       SINCE THE SOURCE IS WITHIN THE FIELD-OF-VIEW, COMPUTE PCFLOS. SCLOUD   315
      PCFLOS = CCOVER(2,KMODEL) * CFLOSH( 4,THR,F)                      SCLOUD   316
     $       + CCOVER(3,KMODEL) * CFLOSH( 6,THR,F)                      SCLOUD   317
     $       + CCOVER(4,KMODEL) * CFLOSH( 9,THR,F)                      SCLOUD   318
     $       + CCOVER(5,KMODEL) * CFLOSH(11,THR,F) + CCOVER(1,KMODEL)   SCLOUD   319
   30 CONTINUE                                                          SCLOUD   320
      RETURN                                                            SCLOUD   321
      END                                                               SCLOUD   322
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      SUBROUTINE SGEOM(UL,VL,WL,CLDTOP,XD,YD,ZD,XS,YS,ZS,                SGEOM     2
     X RDIST,SDIST,THETI,THETE,PHIE )                                   SGEOM     3
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS    2
C        ANGLES IN DEGREES AND DISTANCES IN KILOMETERS                  SGEOM     5
C                                                                       SGEOM     6
C        INPUTS                                                         SGEOM     7
C        UL,VL,WL   ARE LOS DIRECTION COSINES                           SGEOM     8
C        CLDTOP   CLOUD TOP ALTITUDE                                    SGEOM     9
C        XD,YD,ZD - XS,YS,ZS  DETECTOR AND SOURCE LOCATION..EARTH CENT  SGEOM    10
C                                                                       SGEOM    11
C        THIS IS CODE FOR THE INCIDENT AND EXIT LOOK ANGLES             SGEOM    12
C        AND THE AZIMUTHAL ANGLE FOR SOURCE ABOVE THE CLOUD             SGEOM    13
C        THE VECTOR RI IS TO THE CLOUD TOP FROM THE EARTH CENTER        SGEOM    14
C        S IS THE DISTANCE FROM THE DETECTOR TO THE CLOUD TOP           SGEOM    15
C                                                                       SGEOM    16
C        THETI IS THE INCIDENT LOOK ANGLE                               SGEOM    17
C        THETE IS THE EXIT LOOK ANGLE                                   SGEOM    18
C        PHIE IS THE AZIMUTHAL ANGLE I.E. THE ANGLE BETWEEN THE         SGEOM    19
C        RS,RI PLANE AND THE RD,RI PLANE                                SGEOM    20
C        SDIST IS DISTANCE FROM SOURCE TO INTERSECTION OF CLOUD TOP AND SGEOM    21
C        LINE-OF-SIGHT  (KILOMETERS)                                    SGEOM    22
C        RDIST IS HORIZONTAL COMPONENT OF SDIST                         SGEOM    23
C                                                                       SGEOM    24
CCC                                                                     SGEOM    25
CLJ   SUBROUTINE SGEOM COMPUTES THE GEOMETRICAL RELATIONS BETWEEN       SGEOM    26
CLJ   A SOURCE, STATISTICAL CLOUD, AND DETECTOR.                        SGEOM    27
CCC                                                                     SGEOM    28
CLJ   INPUT PARAMETERS                                                  SGEOM    29
CLJ      ARGUMENT LIST                                                  SGEOM    30
CLJ          UL,VL,WL = DIRECTION COSINES IN THE GEOCENTRIC CARTESIAN   SGEOM    31
CLJ                     COORDINATE SYSTEM OF THE LINE-OF-SIGHT (LOS)    SGEOM    32
CLJ                     VECTOR FROM THE DETECTOR                        SGEOM    33
CLJ          CLDTOP   = ALTITUDE OF THE (STATISTICAL) CLOUD TOP INTER-  SGEOM    34
CLJ                     SECTED BY THE LOS FROM THE DETECTOR,  KM        SGEOM    35
CLJ          XD,YD,ZD = GEOCENTRIC CARTESIAN COORDINATES OF THE         SGEOM    36
CLJ                     DETECTOR,  KM                                   SGEOM    37
CLJ          XS,YS,ZS = GEOCENTRIC CARTESIAN COORDINATES OF THE         SGEOM    38
CLJ                     SOURCE,  KM                                     SGEOM    39
CLJ      PARAMS COMMON                                                  SGEOM    40
CLJ             DTR = CONVERSION FACTOR FROM DEGREES TO RADIANS, PI/180 SGEOM    41
CLJ             RTD = CONVERSION FACTOR FROM RADIANS TO DEGREES, 180/PI SGEOM    42
CLJ              RE = EARTH RADIUS,  KM                                 SGEOM    43
CLJ   OUTPUT PARAMETERS                                                 SGEOM    44
CLJ      ARGUMENT LIST                                                  SGEOM    45
CLJ           SDIST = DISTANCE FROM THE SOURCE TO THE INTERSECTION OF   SGEOM    46
CLJ                   THE DETECTOR LOS VECTOR WITH THE HORIZONTAL       SGEOM    47
CLJ                   SURFACE WHOSE ALTITUDE IS INPUTTED TO THIS        SGEOM    48
CLJ                   ROUTINE AS CLDTOP, KM                             SGEOM    49
CLJ                   (INTERSECTION POINT DENOTED BY VECTOR RI IN THE   SGEOM    50
CLJ                   GEOCENTRIC CARTESIAN COORDINATE SYSTEM)           SGEOM    51
CLJ           RDIST = COMPONENT OF SDIST NORMAL TO THE VECTOR RI,  KM   SGEOM    52
CLJ           THETI = ZENITH ANGLE OF SOURCE AT POINT RI,  DEGREES      SGEOM    53
CLJ           THETE = ZENITH ANGLE OF DETECTOR AT POINT RI,  DEGREES    SGEOM    54
CLJ            PHIE = AZIMUTHAL ANGLE THROUGH WHICH A PHOTON IS         SGEOM    55
CLJ                   DEFLECTED AT THE POINT RI WHILE GOING FROM THE    SGEOM    56
CLJ                   SOURCE TO THE DETECTOR,  DEGREES                  SGEOM    57
CCC                                                                     SGEOM    58
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      RD = XD**2 + YD**2 + ZD**2                                        SGEOM
      S = UL*XD + VL*YD + WL*ZD                                         SGEOM
      S = - S - SQRT(S**2 - RD + (RE+CLDTOP)**2)                        SGEOM
      RD = SQRT(RD)                                                     SGEOM
      XI = XD + S*UL                                                    SGEOM
      YI = YD + S*VL                                                    SGEOM
      ZI = ZD + S*WL                                                    SGEOM
C                                                                       SGEOM
C        READ THE VARIABLE NAMES AS                                     SGEOM
C        R DMIDMI  MEANING (RD MINUS RI) DOT (RD MINUS RI) ETC.         SGEOM
      RDMIDMI = (XD-XI)*(XD-XI) + (YD-YI)*(YD-YI) + (ZD-ZI)*(ZD-ZI)     SGEOM
      RSMISMI = (XS-XI)*(XS-XI) + (YS-YI)*(YS-YI) + (ZS-ZI)*(ZS-ZI)     SGEOM
      SDIST = SQRT( RSMISMI )                                           SGEOM
      RISMI  =      XI * (XS-XI) +   YI *  (YS-YI) +    ZI * (ZS-ZI)    SGEOM
       R DDOTI = XD*XI + YD*YI + ZD*ZI                                  SGEOM
       R DDOTS = XD*XS + YD*YS + ZD*ZS                                  SGEOM
       R SDOTI = XI*XS + YI*YS + ZI*ZS                                  SGEOM
       R IDOTI = XI*XI + YI*YI + ZI*ZI                                  SGEOM
       R DDOTD = XD*XD + YD*YD + ZD*ZD                                  SGEOM
       R SDOTS = XS*XS + YS*YS + ZS*ZS                                  SGEOM
      RS = SQRT( XS**2 + YS**2 + ZS**2 )                                SGEOM
      US = XS / RS                                                      SGEOM
      VS = YS / RS                                                      SGEOM
      WS = ZS / RS                                                      SGEOM
      RI = SQRT( RIDOTI )                                               SGEOM
      D1 = XI*US + YI*VS + ZI*WS                                        SGEOM
      D2 = XI*UL + YI*VL + ZI*WL                                        SGEOM
      D3 = UL*US + VL*VS + WL*WS                                        SGEOM
      THETE = ACOS( -D2/RI )                                            SGEOM
      THETI = ACOS( RISMI/( RI*SDIST ) )                                SGEOM
C                                                                       SGEOM
C        CHECK FOR COLINEARITY,  IF SO, PHIE = 0                        SGEOM
C                                                                       SGEOM
      PHIE = 1.0E-05                                                    SGEOM
      IF(ABS (RSDOTS*RIDOTI / RSDOTI**2)  .GT. .999999) GO TO 10        SGEOM
      IF(ABS (RDDOTD*RIDOTI / RDDOTI**2)  .GT. .999999) GO TO 10        SGEOM
      PHIE = 0.0                                                        SGEOM
      IF( (THETE.EQ.0.0) .OR. (THETI.EQ.0.0) )  GO TO 10                SGEOM
      PHIE = ACOS( (RI*COS(THETE)*D1 + RIDOTI*D3) /                     SGEOM
     $       (RIDOTI*SIN(THETE)*SIN(THETI)) )                           SGEOM
   10 CONTINUE                                                          SGEOM
      THETE = THETE * RTD                                               SGEOM
      THETI = THETI * RTD                                               SGEOM
      PHIE = PHIE * RTD                                                 SGEOM
      RDIST = SDIST * SIN(THETI*DTR)                                    SGEOM
      RETURN                                                            SGEOM
      END                                                               SGEOM
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      SUBROUTINE SORTLJ(A,B,C,N,LOHI)                                   SORTLJ
CCC                                                                     SORTLJ
C        GIVEN THE A ARRAY OF LENGTH N, THIS ROUTINE SORTS THE          SORTLJ
C        ARRAY FROM LOW TO HIGH IF LOHI.LE.0 AND FROM HIGH TO LOW       SORTLJ
C        IF LOHI.GT.0  .                                                SORTLJ
C        THE B AND C ARRAYS ARE SIMPLY CARRIED ALONG                    SORTLJ
CCC                                                                     SORTLJ
      DIMENSION  A(2), B(2), C(2)                                       SORTLJ
      M = N                                                             SORTLJ
   20 M = M/2                                                           SORTLJ
      IF( M.EQ.0 ) GO TO 40                                             SORTLJ
      K = N-M                                                           SORTLJ
      J = 1                                                             SORTLJ
   41 I = J                                                             SORTLJ
   49 L = I+M                                                           SORTLJ
      IF( LOHI )  50,50,52                                              SORTLJ
C                                                                       SORTLJ
C * * * SORT LOW TO HIGH.                                               SORTLJ
   50 IF( A(L).GE.A(I) ) GO TO 60                                       SORTLJ
      GO TO 55                                                          SORTLJ
C                                                                       SORTLJ
C * * * SORT HIGH TO LOW.                                               SORTLJ
   52 IF( A(L).LE.A(I) ) GO TO 60                                       SORTLJ
   55 X = A(I)                                                          SORTLJ
      A(I) = A(L)                                                       SORTLJ
      A(L) = X                                                          SORTLJ
      Y = B(I)                                                          SORTLJ
      Z = C(I)                                                          SORTLJ
      B(I) = B(L)                                                       SORTLJ
      C(I) = C(L)                                                       SORTLJ
      B(L) = Y                                                          SORTLJ
      C(L) = Z                                                          SORTLJ
      I = I-M                                                           SORTLJ
      IF( I.GE.1 ) GO TO 49                                             SORTLJ
   60 J = J+1                                                           SORTLJ
      IF( J-K ) 41,41,20                                                SORTLJ
   40 RETURN                                                            SORTLJ
      END                                                               SORTLJ
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      FUNCTION TAIR(ALAM,THETA,ALT)                                     TAIR
      DIMENSION T(10,6,4)                                               TAIR
      DIMENSION TLAM(10),TALT(6),STHET(4)                               TAIR
      DATA TLAM / 2.0,2.5,2.55,2.65,2.75,2.85,3.2,3.5,4.0,5.0 /         TAIR
      DATA TALT / 1.,2.,4.,6.,8.,12.  /                                 TAIR
      DATA STHET / 1.,2.,3.864,11.4737 /                                TAIR
C                                                                       TAIR
C                                                                       TAIR
C        THE FIRST INDEX IS ON WAVELENGTH                               TAIR
C        THE SECOND INDEX IS ON ALTITUDE                                TAIR
C        THE THIRD INDEX IS ON ANGLE                                    TAIR
C                                                                       TAIR
CLJ       THE INTERPOLATION (AND EXTRAPOLATION FOR THETA .GT. 85        TAIR
CLJ       DEGREES AND ALT .LT. 1 KM) IS LINEAR IN (LN(T),SEC(THETA))-,  TAIR
CLJ       (T,ALAM)-, AND (LN(T),ALT)-SPACE.  HOWEVER, FOR THETA .GT.    TAIR
CLJ       85 DEGREES, SEC(THETA) IS REDEFINED BY A PARABOLIC            TAIR
CLJ       APPROXIMATION TO THE CHAPMAN FUNCTION.                        TAIR
C                                                                       TAIR
C                                                                       TAIR
C        THE TRANSMISSION IS FROM LOWTRAN III FOR 1962 STD ATMOSPHERE   TAIR
C                                                                       TAIR
C        THE FOLLOWING TABLE CONTAINS THE TRANSMISSION                  TAIR
C        FROM 1 TO 12KM, 2 TO 12KM ETC., NOT FROM ONE ALTITUDE TO       TAIR
C        THE TOP OF THE ATMOSPHERE                                      TAIR
C                                                                       TAIR
CCC                                                                     TAIR
CLJ   FUNCTION  TAIR COMPUTES THE TRANSMITTANCE FOR RADIATION OF        TAIR
CLJ   WAVELENGTH ALAM FROM ALTITUDE ALT TO 12 KM ALONG A PATH AT        TAIR
CLJ   ZENITH ANGLE THETA.                                               TAIR
CCC                                                                     TAIR
CLJ   INPUT PARAMETERS                                                  TAIR
CLJ      ARGUMENT LIST                                                  TAIR
CLJ            ALAM = WAVELENGTH,  MICRONS                              TAIR
CLJ           THETA = ZENITH ANGLE,  DEGREES                            TAIR
CLJ             ALT = ALTITUDE,  KM                                     TAIR
CLJ   OUTPUT PARAMETER                                                  TAIR
CLJ      FUNCTION                                                       TAIR
CLJ            TAIR = TRANSMITTANCE FOR RADIATION OF WAVELENGTH ALAM    TAIR
CLJ                   FROM ALTITUDE ALT TO 12 KM ALONG PATH AT          TAIR
CLJ                   ZENITH ANGLE THETA                                TAIR
CLJ   DEFINITION OF DATA                                                TAIR
CLJ          T(I,J,K) = TRANSMITTANCE FOR RADIATION OF WAVELENGTH       TAIR
CLJ                     TLAM(I) ALONG PATH AT ZENITH ANGLE THETA(K)=    TAIR
CLJ                     ACOS( 1./STHET(K) ) FROM ALTITUDE TALT(J) TO    TAIR
CLJ                     12 KM            I=1,10  J=1,6  K=1,4           TAIR
CLJ          THETA(K) = 0,60,75,85  DEGREES        K=1,4                TAIR
CCC                                                                     TAIR
      DATA (T(I,1,1) ,I=1,60) /                                         TAIR
     X .4093,.2150,.0009,.0009,.0001,.0107,.2042,.8398,.8973,.4081,     TAIR
     X .4690,.3247,.0010,.0010,.0001,.0370,.3038,.8880,.9239,.5183,     TAIR
     X .5800,.5681,.0232,.0198,.0001,.1893,.5217,.9474,.9568,.7284,     TAIR
     X .6834,.7758,.1834,.1723,.0043,.4413,.7199,.9744,.9762,.8636,     TAIR
     X .7788,.9064,.5081,.4649,.0440,.7240,.8549,.9925,.9889,.9479,     TAIR
     X .9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999   /  TAIR
      DATA (T(I,1,2) ,I=1,60) /                                         TAIR
     X .2753,.1063,.0008,.0008,.0001,.0007,.0978,.7645,.8070,.2728,     TAIR
     X .3313,.1952,.0009,.0009,.0001,.0073,.1753,.8257,.8544,.3863,     TAIR
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     X .4151,.4358,.0033,.0022,.0001,.0898,.3853,.9150,.9163,.6227,      TAIR
     X .5648,.5823,.0848,.0765,.0003,.3065,.6127,.9625,.9531,.8081,      TAIR
     X .6817,.8623,.3792,.3652,.0094,.6060,.7874,.9861,.9733,.9210,      TAIR
     X .9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999   /   TAIR
      DATA (T(I,1,3) ,I=1,60) /                                          TAIR
     X .1151,.0363,.0008,.0008,.0001,.0006,.0338,.6544,.6620,.1559,      TAIR
     X .2069,.0960,.0008,.0008,.0001,.0007,.0822,.7461,.7401,.2579,      TAIR
     X .3179,.3065,.0009,.0009,.0001,.0287,.2587,.8683,.8460,.5006,      TAIR
     X .4347,.5742,.0259,.0224,.0001,.1855,.4908,.9388,.9125,.7328,      TAIR
     X .5725,.8094,.2502,.2368,.0011,.4807,.7131,.9755,.9549,.8818,      TAIR
     X .9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999   /   TAIR
      DATA (T(I,1,4) ,I=1,60) /                                          TAIR
     X .0330,.0014,.0006,.0006,.0001,.0004,.0017,.3949,.3140,.0344,      TAIR
     X .0586,.0125,.0007,.0007,.0001,.0004,.0096,.5349,.4282,.0874,      TAIR
     X .1291,.1208,.0008,.0008,.0001,.0009,.0879,.7463,.6242,.2915,      TAIR
     X .2294,.3680,.0010,.0009,.0001,.0476,.2729,.8674,.7712,.5590,      TAIR
     X .3658,.6700,.0828,.0745,.0001,.2725,.5372,.9405,.8768,.7991,      TAIR
     X .9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999,.9999   /   TAIR
CCC                                                                      TAIR
      BETA = AMIN1( THETA,(180.-THETA) )                                 TAIR
      STHETA = 1.0 / COS( BETA/57.2958 )                                 TAIR
CCC                                                                      TAIR
CLJ       FOR BETA .GT. 85 DEGREES, REDEFINE SEC(BETA) BY A SIMPLE       TAIR
CLJ       PARABOLIC APPROXIMATION TO THE CHAPMAN FUNCTION.               TAIR
CCC                                                                      TAIR
      IF( BETA.GT.85. )  STHETA = 1.0 / COS( 85./57.2958 )               TAIR
     $                           + 1.1*(BETA-85.)**2                     TAIR
CCC                                                                      TAIR
CLJ       FIND THE INDEX I FOR THE FIRST TABULAR WAVELENGTH LESS THAN    TAIR
CLJ       OR EQUAL TO ALAM (USE I=9 IF ALAM=5.0).                        TAIR
      DO 10 II = 2,10                                                    TAIR
      I = II   - 1                                                       TAIR
      IF(ALAM .LT. TLAM(II))GO TO 15                                     TAIR
   10 CONTINUE                                                           TAIR
      I = 9                                                              TAIR
   15 CONTINUE                                                           TAIR
CLJ       FIND THE INDEX J FOR THE FIRST TABULAR ALTITUDE LESS THAN      TAIR
CLJ       OR EQUAL TO ALT (BUT ONLY LESS IF ALT=12.0.  ALSO, USE J=1 IF  TAIR
CLJ       ALT .LE. 1.0).                                                 TAIR
      DO 20 JJ = 2,6                                                     TAIR
      J = JJ - 1                                                         TAIR
      IF(ALT .LT. TALT(JJ) ) GO TO 25                                    TAIR
   20 CONTINUE                                                           TAIR
      J = 5                                                              TAIR
   25 CONTINUE                                                           TAIR
CLJ       FIND THE INDEX K FOR THE FIRST TABULAR SEC(THETA) LESS THAN    TAIR
CLJ       OR EQUAL TO STHETA (BUT USE K=3 IF 85.LE.THETA.LE.90 DEGREES)  TAIR
      DO 30 KK = 2,4                                                     TAIR
      K = KK - 1                                                         TAIR
      IF(STHETA .LT. STHET(KK)) GO TO 35                                 TAIR
   30 CONTINUE                                                           TAIR
      K = 3                                                              TAIR
   35 CONTINUE                                                           TAIR
      H = ALT                                                            TAIR
CLJ       FIND THE FRACTIONAL DISTANCE, TLAMX, ALAM LIES BETWEEN         TAIR
CLJ       TLAM(I) AND TLAM(I+1).                                         TAIR
      TLAMX = (ALAM - TLAM(I)) / (TLAM(I+1) - TLAM(I))                   TAIR
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C
      TL1 = T(I,J  ,K  ) + (T(I+1,J  ,K  ) - T(I,J  ,K  )) * TLAMX
      TL2 = T(I,J  ,K+1) + (T(I+1,J  ,K+1) - T(I,J  ,K+1)) * TLAMX
      TL3 = T(I,J+1,K  ) + (T(I+1,J+1,K  ) - T(I,J+1,K  )) * TLAMX
      TL4 = T(I,J+1,K+1) + (T(I+1,J+1,K+1) - T(I,J+1,K+1)) * TLAMX
      B1 = (TL2/TL1)**(1. / (STHET(K+1) - STHET(K)))
      B2 = (TL4/TL3)**(1. / (STHET(K+1) - STHET(K)))
      A1 = TL1 / (B1**STHET(K))
      A2 = TL3 / (B2**STHET(K))
      TLT1 = A1*B1**STHETA
      TLT2 = A2*B2**STHETA
      B = ALOG(TLT2 / TLT1) / (TALT(J+1) - TALT(J))
      A = TLT1 / EXP(B*TALT(J))
      TAIR = A * EXP(B * H)
      RETURN
      END
```

```
      FUNCTION TRANSF(ALAM,LL,MM,HH)                                    TRANS     2
      COMMON /PARAMS/ IN,IOUT,PI,RE, DTR,RTD                            PARAMS    2
      COMMON/SORCE/  NSORCE,HSORCE(1),RSORCE(1),THETAS(1),PHIS(1)       SORCE     2
      COMMON/CDDATA/ ALAMT(10),SIGT(10,14),SIGS(10,14),W(10),           CDDATA    2
     1  XNUBAR(10,14),DNO(14),RAD(14),CLDBASE(14),CLDTHK(14)            CDDATA    3
      COMMON/DIFFUS/DALFA(14),DBETA(14),DKAPPA(14)                      DIFCOM    2
      COMMON/FLAGS/  ITFLAG                                             FLAGS     2
      COMMON /SANDD/ XS,YS,ZS,XD,YD,ZD,UL,VL,WL                         SANDD     2
      DIMENSION THKN(3),DALFAN(3),DBETAN(3),DKAPPAN(3)                  TRANS     9
      DIMENSION LINDEX(3),A(4)                                          TRANS    10
      INTEGER HH                                                        TRANS    11
CCC                                                                     TRANS    12
CLJ   FUNCTION TRANSF COMPUTES A QUANTITY DEFINED IN THE NATURAL CLOUD  TRANS    13
CLJ   MODEL AS THE IRRADIANCE-TO-RADIANCE TRANSFER COEFFICIENT (1/SR)   TRANS    14
CLJ   OR SIMPLY THE TRANSFER COEFFICIENT AT THE INTERSECTION OF THE     TRANS    15
CLJ   DETECTOR LOS VECTOR WITH 12-KM ALTITUDE (KNOWN AS THE TRANSFER    TRANS    16
CLJ   POINT).  THE TRANSFER COEFFICIENT IS ACTUALLY THE RATIO OF A      TRANS    17
CLJ   RADIANCE AND AN IRRADIANCE.  THE RADIANCE IS THAT DIRECTED ANTI-  TRANS    18
CLJ   PARALLEL TO THE DETECTOR LOS VECTOR AND THE IRRADIANCE IS THE     TRANS    19
CLJ   (UNATTENUATED) SOURCE IRRADIANCE AT THE TRANSFER POINT.  FOR A    TRANS    20
CLJ   SOURCE ABOVE 12-KM ALTITUDE AND FAR FROM THE TRANSFER POINT (AS   TRANS    21
CLJ   FOR THE SUN), THE TRANSFER COEFFICIENT BECOMES ESSENTIALLY THE    TRANS    22
CLJ   BIDIRECTIONAL REFLECTANCE OF THE CLOUD TOP TIMES THE COSINE OF    TRANS    23
CLJ   THE ZENITH ANGLE OF THE INCIDENT RAY.  FOR A SOURCE BELOW OR      TRANS    24
CLJ   WITHIN THE CLOUDS, THE TRANSFER COEFFICIENT DEPENDS ON THE        TRANS    25
CLJ   DETAILS OF THE DIFFUSION SOLUTION TO THE TRANSPORT OF RADIATION   TRANS    26
CLJ   THROUGH THE CLOUDS.                                               TRANS    27
CCC                                                                     TRANS    28
CLJ   INPUT PARAMETERS                                                  TRANS    29
CLJ      ARGUMENT LIST                                                  TRANS    30
CLJ            ALAM = WAVELENGTH,  MICRONS                              TRANS    31
CLJ              LL = INDEX (1,7) OF ONE OF SEVEN LOW-ALTITUDE CLOUDS   TRANS    32
CLJ                 = KCLOUD                                            TRANS    33
CLJ              MM = INDEX (1,3) OF ONE OF THREE MID-ALTITUDE CLOUDS   TRANS    34
CLJ                 = KCLOUD-7                                          TRANS    35
CLJ              HH = INDEX (1,4) OF ONE OF FOUR HIGH-ALTITUDE CLOUDS   TRANS    36
CLJ                 = KCLOUD-10                                         TRANS    37
CLJ                   (KCLOUD = CLOUD-TYPE INDEX)                       TRANS    38
CLJ      FLAGS COMMON                                                   TRANS    39
CLJ          ITFLAG = 0  IF SUN IS BELOW THE HORIZON                    TRANS    40
CLJ                 = 1  IF SUN IS ABOVE THE HORIZON                    TRANS    41
CLJ      CDDATA COMMON                                                  TRANS    42
CLJ         CLDBASE(K) = ALTITUDE ABOVE EARTH SURFACE OF BASE OF        TRANS    43
CLJ                      CLOUD-TYPE K,  KM        K=1,14                TRANS    44
CLJ          CLDTHK(K) = THICKNESS OF CLOUD-TYPE K,  KM     K=1,14      TRANS    45
CLJ      DIFFUS COMMON                                                  TRANS    46
CLJ           DALFA(K) = 0.25 TIMES THE RATIO OF SCATTERING CROSS-      TRANS    47
CLJ                      SECTION TO TOTAL CROSS-SECTION FOR PHOTONS OF  TRANS    48
CLJ                      WAVELENGTH ALAM IN CLOUD-TYPE K, DIMENSIONLESS TRANS    49
CLJ            DBETA(K) = 0.50 TIMES THE DIFFUSION COEFFICIENT FOR      TRANS    50
CLJ                      PHOTONS OF WAVELENGTH ALAM IN CLOUD-TYPE K,  KM TRANS    51
CLJ           DKAPPA(K) = INVERSE DIFFUSION LENGTH FOR PHOTONS OF       TRANS    52
CLJ                      WAVELENGTH ALAM IN CLOUD-TYPE K,  1/KM         TRANS    53
CCC                                                                     TRANS    54
CLJ                 FOR ABOVE VARIABLES   K=1,14                        TRANS    55
CLJ       THE ABOVE DEFINITIONS FOR THE DIFFUSION PARAMETERS APPLY TO A TRANS    56
CLJ       WEAKLY ABSORBING MEDIUM.  FOR A STRONGLY ABSORBING MEDIUM,    TRANS    57
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CLJ       MODIFIED DIFFUSION PARAMETERS ARE REQUIRED.  WE ALSO COMPUTE   TRANS
CLJ       THE LATTER TYPE AND USE THEM AFTER 9/30/78.                    TRANS
CCC                                                                      TRANS
CLJ      SANDD COMMON                                                    TRANS
CLJ          UL,VL,WL = DETECTOR LOS DIRECTION COSINES                   TRANS
CLJ          XD,YD,ZD = DETECTOR GEOCENTRIC CARTESIAN COORDINATES,  KM   TRANS
CLJ          XS,YS,ZS = SOURCE GEOCENTRIC CARTESIAN COORDINATES,  KM     TRANS
CLJ      SORCE COMMON                                                    TRANS
CLJ          NSORCE    = NUMBER OF SOURCES BEING CONSIDERED              TRANS
CLJ          HSORCE(N) = ALTITUDE OF SOURCE-N                            TRANS
CLJ       RSORCE(N) = RADIUS OF SOURCE-N,  KM                            TRANS
CLJ   OUTPUT PARAMETER                                                   TRANS
CLJ      FUNCTION                                                        TRANS
CLJ          TRANSF = THE IRRADIANCE-TO-RADIANCE TRANSFER COEFFICIENT    TRANS
CLJ                   AT THE TRANSFER POINT,  1/SR                       TRANS
CLJ                   (SEE ABOVE FOR FULLER DESCRIPTION)                 TRANS
CCC                                                                      TRANS
      SINH(ARG) = (EXP(ARG) - EXP(-ARG)) / 2.                            TRANS
      COSH(ARG) = (EXP(ARG) + EXP(-ARG)) / 2.                            TRANS
COMMENTS....                                                             TRANS
CLJ       THERE ARE 7 LOW-LAYER CLOUDS FOR WHICH THE INDEX IS LL=1,7     TRANS
CLJ       THERE ARE 3 MID-LAYER CLOUDS FOR WHICH THE INDEX IS MM=1,3     TRANS
CLJ       THERE ARE 4  HI-LAYER CLOUDS FOR WHICH THE INDEX IS HH=1,4     TRANS
C                                                                        TRANS
C        LL = 8 MEANS NO LOW CLOUD                                       TRANS
C        MM = 4 MEANS NO MID CLOUD                                       TRANS
C        HH = 5 MEANS NO HI CLOUD                                        TRANS
C                                                                        TRANS
CLJ       EVALUATE LAYER PARAMETERS.  SORALT IS SOURCE ALTITUDE ABOVE    TRANS
CLJ       THE GROUND.  COUNT THE NUMBER OF LAYERS, NLAYER, ABOVE THE     TRANS
CLJ       SOURCE, INCLUDING THE ONE CONTAINING THE SOURCE.               TRANS
C        GET HORIZONTAL DISTANCE OF SOURCE FROM POINT OF                 TRANS
C        INTERSECTION OF LOS AND CLOUD TOP...RDIST                       TRANS
C                                                                        TRANS
C        MAKE NO CALCULATIONS FOR SUN BELOW HORIZON                      TRANS
      TRANSF = 0.                                                        TRANS
      IF( ITFLAG.EQ.0 )  RETURN                                          TRANS
CLJ       DETERMINE INDEX OF CLOUD IN HIGHEST LAYER PRESENT.             TRANS
      KCLOUD = HH + 10                                                   TRANS
      IF(HH .LT. 5) GO TO 4                                              TRANS
      KCLOUD = MM + 7                                                    TRANS
      IF(MM .LT. 4) GO TO 4                                              TRANS
      KCLOUD = LL                                                        TRANS
    4 CLDTOP = CLDBASE(KCLOUD) + CLDTHK(KCLOUD)                          TRANS
CLJ       DETERMINE RDIST AND OTHER GEOMETRICAL QUANTITIES FOR           TRANS
CLJ       ABOVE-IDENTIFIED CLOUD.                                        TRANS
      CALL SGEOM(UL,VL,WL,CLDTOP,XD,YD,ZD,XS,YS,ZS,                      TRANS
     $     RDIST,SDIST,THETI,THETE,PHIE)                                 TRANS
      SORALT = HSORCE(NSORCE)                                            TRANS
      AZPU = 0.                                                          TRANS
      NLAYER = 0                                                         TRANS
CLJ       SKIP TO 10 IF NO LOW-LAYER CLOUD OR IF IT IS BELOW SOURCE.     TRANS
      IF(LL .GT. 7) GO TO 10                                             TRANS
      IF(SORALT .GT. CLDBASE(LL) + CLDTHK(LL) ) GO TO 10                 TRANS
      NLAYER = NLAYER + 1                                                TRANS
      THKN(NLAYER ) = CLDTHK(LL)                                         TRANS
CLJ       RESET THKN(NLAYER) BY TRUNCATING PORTION OF CLOUD BELOW SOURCE TRANS
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      IF(SORALT .GT. CLDBASE(LL) ) THKN(NLAYER) = CLDTHK(LL) +          TRANS
     1   CLDBASE(LL) - SORALT                                           TRANS
CLJ       AZRO = DISTANCE OF SOURCE BELOW BOTTOM OF LOWEST-ALTITUDE     TRANS
CLJ              CLOUD LAYER.                                           TRANS
      IF(SORALT .LT. CLDBASE(LL)) AZRO = CLDBASE(LL) - SORALT           TRANS
CLJ       CORRELATE CLOUD-TYPE DIFFUSION PARAMETERS WITH LAYER DIFFUSION TRANS
CLJ       PARAMETERS.                                                   TRANS
      DALFAN(NLAYER) = DALFA(LL)                                        TRANS
      DBETAN(NLAYER) = DBETA(LL)                                        TRANS
      DKAPPAN(NLAYER) = DKAPPA(LL)                                      TRANS
CLJ       CORRELATE CLOUD-TYPE INDEX WITH LAYER INDEX.                  TRANS
      LINDEX(NLAYER) = LL                                               TRANS
CLJ       SET ALTITUDE OF BOTTOM OF CLOUD NLAYER=1                      TRANS
      A(NLAYER) = AMAX1(CLDBASE(LL),SORALT)                             TRANS
CLJ       SET ALTITUDE OF TOP OF CLOUD NLAYER=1                         TRANS
      A(NLAYER+1) = A(NLAYER) + THKN(NLAYER)                            TRANS
   10 CONTINUE                                                          TRANS
CLJ       SKIP TO 20 IF NO MID-LAYER CLOUD OR IF IT IS BELOW SOURCE.    TRANS
      IF(MM .GT. 3) GO TO 20                                            TRANS
      IF(SORALT .GT. CLDBASE(MM+7) + CLDTHK(MM+7) ) GO TO 20            TRANS
      NLAYER = NLAYER + 1                                               TRANS
      THKN(NLAYER ) = CLDTHK(MM+7)                                      TRANS
CLJ       RESET THKN(NLAYER) BY TRUNCATING PORTION OF LAYER BELOW SOURCE TRANS
      IF(SORALT .GT. CLDBASE(MM+7) ) THKN(NLAYER) = CLDTHK(MM+7) +      TRANS
     1   CLDBASE(MM+7) - SORALT                                         TRANS
      IF(SORALT .LT. CLDBASE(MM+7) .AND. NLAYER .EQ. 1)                 TRANS
     1  AZRO = CLDBASE(MM+7) - SORALT                                   TRANS
CLJ       CORRELATE CLOUD-TYPE DIFFUSION PARAMETERS WITH LAYER DIFFUSION TRANS
CLJ       PARAMETERS.                                                   TRANS
      DALFAN(NLAYER) = DALFA(MM+7)                                      TRANS
      DBETAN(NLAYER) = DBETA(MM+7)                                      TRANS
      DKAPPAN(NLAYER) = DKAPPA(MM+7)                                    TRANS
CLJ       CORRELATE CLOUD-TYPE INDEX WITH LAYER INDEX.                  TRANS
      LINDEX(NLAYER) = MM + 7                                           TRANS
CLJ       SET ALTITUDE OF BOTTOM OF CLOUD NLAYER=1                      TRANS
      IF(NLAYER .EQ. 1) A(NLAYER) = AMAX1(CLDBASE(MM+7),SORALT)         TRANS
CLJ       SET ALTITUDE OF TOP OF CLOUD NLAYER+1                         TRANS
      A(NLAYER+1) = AMAX1(CLDBASE(MM+7),SORALT) + THKN (NLAYER)         TRANS
   20 CONTINUE                                                          TRANS
CLJ       SKIP TO 30 IF NO HIGH-LAYER CLOUD OR IF IT IS BELOW SOURCE.   TRANS
      IF(HH .GT. 4) GO TO 30                                            TRANS
      IF(SORALT .GT. CLDBASE(HH+10) + CLDTHK(HH+10) ) GO TO 30          TRANS
      NLAYER = NLAYER + 1                                               TRANS
      THKN(NLAYER ) = CLDTHK(HH+10)                                     TRANS
      IF(SORALT .GT. CLDBASE(HH+10) ) THKN(NLAYER) = CLDTHK(HH+10) +    TRANS
     1   CLDBASE(HH+10) - SORALT                                        TRANS
      IF(SORALT .LT. CLDBASE(HH+10) .AND.  NLAYER .EQ. 1)               TRANS
     1  AZRO = CLDBASE(HH+10) - SORALT                                  TRANS
      DALFAN(NLAYER) = DALFA(HH+10)                                     TRANS
      DBETAN(NLAYER) = DBETA(HH+10)                                     TRANS
      DKAPPAN(NLAYER) = DKAPPA(HH+10)                                   TRANS
      LINDEX(NLAYER) = HH + 10                                          TRANS
      IF(NLAYER .EQ. 1) A(NLAYER) = AMAX1(CLDBASE(HH+10),SORALT)        TRANS
      A(NLAYER+1) = AMAX1(CLDBASE(HH+10),SORALT) + THKN (NLAYER)        TRANS
   30 CONTINUE                                                          TRANS
C         CHECK FOR 1,2, OR 3 LAYERS                                    TRANS
C         IF THERE IS ONLY ONE LAYER, USE FORMALISM PREVIOUSLY DEVELOPED TRANS
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C                                                                       TRANS    172
C        IF NO LAYERS ABOVE, WE HAVE AN ALBEDO FROM THE TOP LAYER       TRANS    173
C        IN THE LL,NM,HH COMBINATION.                                   TRANS    174
      IF(NLAYER .EQ. 0) GO TO 400                                       TRANS    175
CLJ       T1 = THICKNESS OF LAYER-1.                                    TRANS    176
      T1 = A(2) - A(1)                                                  TRANS    177
CLJ       RE-LABEL DIFFUSION PARAMETERS FOR LAYER-1.                    TRANS    178
      DA1 = DALFAN(1)                                                   TRANS    179
      DB1 = DBETAN(1)                                                   TRANS    180
      DK1 = DKAPPAN(1)                                                  TRANS    181
      IF(NLAYER .EQ. 1 .AND. AZRO .EQ. 0.) T1 = CLDTHK(LINDEX(NLAYER))  TRANS    182
      IF(NLAYER .EQ. 1) GO TO 100                                       TRANS    183
      T2 = A(3) - A(2)                                                  TRANS    184
CLJ       SCALE DIFFUSION PARAMETERS BETA AND KAPPA TO ACCOUNT FOR      TRANS    185
CLJ       ADJUSTED THICKNESS OF A HIGHER LAYER MADE CONTIGUOUS WITH A   TRANS    186
CLJ       LOWER LAYER.                                                  TRANS    187
CLJ       NOTE THAT DBETA (THE DIFFUSION COEFFICIENT) IS INVERSELY      TRANS    188
CLJ       PROPORTIONAL TO THE DENSITY (OR PROPORTIONAL TO THE RATIO     TRANS    189
CLJ       THK-NEW TO THK-OLD) AND DKAPPA (THE INVERSE DIFFUSION LENGTH) TRANS    190
CLJ       IS PROPORTIONAL TO THE DENSITY (OR INVERSELY PROPORTIONAL TO  TRANS    191
CLJ       THE RATIO THK-NEW TO THK-OLD).  DALFA IS DIMENSIONLESS AND    TRANS    192
CLJ       REQUIRES NO CHANGE.                                           TRANS    193
      DA2 = DALFAN(2)                                                   TRANS    194
      DB2 = DBETAN(2) * T2 / THKN(2)                                    TRANS    195
      DK2 = DKAPPAN(2) * THKN(2) / T2                                   TRANS    196
      IF(NLAYER .EQ. 2) GO TO 200                                       TRANS    197
      T3 = A(4) - A(3)                                                  TRANS    198
CLJ       SCALE DIFFUSION PARAMETERS BETA AND KAPPA TO ACCOUNT FOR      TRANS    199
CLJ       ADJUSTED THICKNESS OF A HIGHER LAYER MADE CONTIGUOUS WITH A   TRANS    200
CLJ       LOWER LAYER.                                                  TRANS    201
      DA3 = DALFAN(3)                                                   TRANS    202
      DB3 = DBETAN(3) * T3 / THKN(3)                                    TRANS    203
      DK3 = DKAPPAN(3) * THKN(3) / T3                                   TRANS    204
      IF(NLAYER .EQ. 3) GO TO 300                                       TRANS    205
  100 CONTINUE                                                          TRANS    206
C                                                                       TRANS    207
C                                                                       TRANS    208
C                                                                       TRANS    209
C        ONE-LAYER  USE ORIGINAL FORMALISM                              TRANS    210
C                                                                       TRANS    211
C                                                                       TRANS    212
      IF(SORALT .LE. CLDBASE(LINDEX(1))) GO TO 105                      TRANS    213
C        FOR SOURCE INSIDE OF THE CLOUD                                 TRANS    214
      H = SORALT - CLDBASE(LINDEX(1))                                   TRANS    215
      FLUX = 0.                                                         TRANS    216
      PMIN = 1.E-20                                                     TRANS    217
      PMAX = 10. / T1                                                   TRANS    218
      NNP = AMIN1(AMAX1(50.,PMAX*RDIST/6.28*10.),200.)                  TRANS    219
      P = 1.E-10                                                        TRANS    220
      ANS = 0.                                                          TRANS    221
      DELTP = (PMAX - PMIN) / NNP                                       TRANS    222
      DSK1 = SQRT(DK1**2 + P**2 )                                       TRANS    223
      C = 1.                                                            TRANS    224
      CKT = EXP(DSK1 * T1)                                              TRANS    225
      CKH = EXP(DSK1 * H)                                               TRANS    226
      CKA = EXP(DSK1*(T1 - H))                                          TRANS    227
      SKT = 0.5 *(CKT - 1. / CKT)                                       TRANS    228
```

```
CLJ       REDEFINE  CKT.                                                TRANS
      CKT = 0.5 *( CKT + 1. / CKT)                                      TRANS
      SKH = 0.5 *(CKH - 1. / CKH)                                       TRANS
CLJ       REDEFINE  CKH.                                                TRANS
      CKH = 0.5 *(CKH + 1. / CKH)                                       TRANS
      SKA = 0.5 *(CKA - 1. / CKA)                                       TRANS
CLJ       REDEFINE  CKA.                                                TRANS
      CKA = 0.5 * (CKA + 1. / CKA)                                      TRANS
      ANS = ANS + C*((DB1*DSK1 - DA1) / (DA1*(DB1*DSK1)**2 * 4. *       TRANS
     1  (CKT + 0.5*(DA1/(DB1*DSK1) + DB1*DSK1/DA1) * SKT))              TRANS
     2 *((DA1 - DB1*DSK1)*(DA1*SKH + DB1*DSK1*CKH)                      TRANS
     3 + (DA1 + DB1*DSK1)*(DA1*SKA + DB1*DSK1*CKA) * EXP(-DSK1*T1))     TRANS
     4  + EXP(-DSK1*(T1-H)) * (DA1 + DB1*DSK1) / (DB1*DSK1*2.))         TRANS
     5  * BESSO(P*RDIST) * P                                            TRANS
      C = 2.                                                            TRANS
      DO 104 I = 1,NNP                                                  TRANS
      P = P + DELTP                                                     TRANS
      C = 6. - C                                                        TRANS
      CKT = EXP(DSK1 * T1)                                              TRANS
      CKH = EXP(DSK1 * H)                                               TRANS
      CKA = EXP(DSK1*(T1 - H))                                          TRANS
      SKT = 0.5 *(CKT - 1. / CKT)                                       TRANS
      CKT = 0.5 *( CKT + 1. / CKT)                                      TRANS
      SKH = 0.5 *(CKH - 1. / CKH)                                       TRANS
      CKH = 0.5 *(CKH + 1. / CKH)                                       TRANS
      SKA = 0.5 *(CKA - 1. / CKA)                                       TRANS
      CKA = 0.5 * (CKA + 1. / CKA)                                      TRANS
      ANS = ANS + C*((DB1*DSK1 - DA1) / (DA1*(DB1*DSK1)**2 * 4. *       TRANS
     1  (CKT + 0.5*(DA1/(DB1*DSK1) + DB1*DSK1/DA1) * SKT))              TRANS
     2 *((DA1 - DB1*DSK1)*(DA1*SKH + DB1*DSK1*CKH)                      TRANS
     3 + (DA1 + DB1*DSK1)*(DA1*SKA + DB1*DSK1*CKA) * EXP(-DSK1*T1))     TRANS
     4  + EXP(-DSK1*(T1-H)) * (DA1 + DB1*DSK1) / (DB1*DSK1*2.))         TRANS
     5  * BESSO(P*RDIST) * P                                            TRANS
  104 CONTINUE                                                          TRANS
      FLUX = ANS * DELTP / 3.                                           TRANS
C        CHECK UNITS HERE                                               TRANS
C                                                                       TRANS
C                                                                       TRANS
      GO TO 500                                                         TRANS
  105 CONTINUE                                                          TRANS
CLJ       CONSIDER THE CASE OF A POINT SOURCE BELOW A SINGLE-LAYER      TRANS
CLJ       CLOUD.                                                        TRANS
CLJ       THE FOLLOWING STEPS EVALUATE THE INTEGRAL IN EQ. (30A) OF THE TRANS
CLJ       CLOUD REPORT.  THIS INTEGRAL (HERE GIVEN THE FORTRAN NAME     TRANS
CLJ       FLUX), WHEN DIVIDED BY (4.*PI), WILL BE THE TRANSMITTED FLUX  TRANS
CLJ       (OR BETTER, RADIANT EXITANCE OR EMITTANCE) FOR A UNIT-STRENGTH TRANS
CLJ       SOURCE EMITTING ISOTROPICALLY INTO 4*PI STERADIANS.           TRANS
      FLUX = 1.E-50                                                     TRANS
      PMIN = 1.E-20                                                     TRANS
      PMAX = 10. / (T1 + AZRO)                                          TRANS
CLJ       LIMIT THE NUMBER OF INTERVALS, NNP, IN THE SIMPSON-INTEGRATION TRANS
CLJ       RULE TO THE RANGE FROM 50 TO 200.  NO ATTEMPT IS MADE TO      TRANS
CLJ       INSURE THAT NNP IS EVEN.                                      TRANS
      NNP = AMIN1(AMAX1(50.,PMAX*RDIST/6.28*10.),200.)                  TRANS
      DELTP = (PMAX - PMIN) / NNP                                       TRANS
      C = 1.000                                                         TRANS
CLJ       THE FOLLOWING P IS THE EFFECTIVE P-SUB-0.                     TRANS
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      P = 1.E-10                                                        TRANS    286
      DSK1 = SQRT(DK1**2 + P**2)                                        TRANS    287
CLJ       IF THE ARGUMENT OF THE SINH AND COSH FUNCTIONS EXCEEDS 100,   TRANS    288
CLJ       SKIP THE INTEGRATION AND USE THE ABOVE-INITIALIZED VALUE OF   TRANS    289
CLJ       FLUX TO SET AN ARBITRARILY SMALL VALUE.                       TRANS    290
      IF(DSK1 * T1 .GT. 100.) GO TO 111                                 TRANS    291
      AL1 = DB1 * DK1 / DA1                                             TRANS    292
      DD1 = COSH(DSK1*T1) - 0.5*(1./AL1+AL1) * SINH(DSK1*T1)            TRANS    293
      AL1 = 0.5*(1./AL1 - AL1) * SINH(DSK1*T1)                          TRANS    294
      FBAR = EXP(-P * AZRO )                                            TRANS    295
      DENOM = 1. - AL1**2                                               TRANS    296
CLJ       BY USING THE RELATION 1. = (COSH( ))**2 - (SINH( ))**2 IN     TRANS    297
CLJ       DENOM, ONE CAN SHOW THAT DD1/DENOM IS THE DENOMINATOR IN THE  TRANS    298
CLJ       INTEGRAL BEING EVALUATED.                                     TRANS    299
      SIGMA = DD1 * FBAR / DENOM                                        TRANS    300
CLJ       THE SECOND TERM IN THE FOLLOWING EXPRESSION IS FLUX-SUB-0.    TRANS    301
      FLUX = FLUX + SIGMA * BESS0 (P*RDIST) * P * C                     TRANS    302
      C = 2.                                                            TRANS    303
CLJ       IN DO-110, THE UPPER LIMIT SHOULD BE NNP-1 IF NNP IS EVEN.    TRANS    304
CLJ       THE CONSEQUENCE IS THAT FLUX-SUB-NNP WILL BE GIVEN TWICE THE  TRANS    305
CLJ       WEIGHT IT SHOULD HAVE.  IF NNP IS ODD, A DIFFERENT (SMALL)    TRANS    306
CLJ       ERROR WILL RESULT.                                            TRANS    307
      DO 110 I = 1,NNP                                                  TRANS    308
      P = P + DELTP                                                     TRANS    309
      C = 6. - C                                                        TRANS    310
      DSK1 = SQRT(DK1**2 + P**2)                                        TRANS    311
      IF(DSK1 * T1 .GT. 100.) GO TO 111                                 TRANS    312
      AL1 = DB1 * DK1 / DA1                                             TRANS    313
      DD1 = COSH(DSK1*T1) - 0.5*(1./AL1+AL1) * SINH(DSK1*T1)            TRANS    314
      AL1 = 0.5*(1./AL1 - AL1) * SINH(DSK1*T1)                          TRANS    315
      FBAR = EXP(-P * AZRO )                                            TRANS    316
      DENOM = 1. - AL1**2                                               TRANS    317
      SIGMA = DD1 * FBAR / DENOM                                        TRANS    318
      FLUX = FLUX + SIGMA * BESS0 (P*RDIST) * P * C                     TRANS    319
  110 CONTINUE                                                          TRANS    320
  111 FLUX = FLUX * DELTP / 3.                                          TRANS    321
C        CHECK UNITS HERE                                               TRANS    322
C                                                                       TRANS    323
C                                                                       TRANS    324
      GO TO 500                                                         TRANS    325
C                                                                       TRANS    326
C        TWO LAYERS INTEGRATE OVER P                                    TRANS    327
C                                                                       TRANS    328
  200 CONTINUE                                                          TRANS    329
      FLUX = 1.E-50                                                     TRANS    330
      PMIN = 1.E-20                                                     TRANS    331
      PMAX = 10. / (T1 + T2 + AZRO)                                     TRANS    332
      NNP = AMIN1(AMAX1(50.,PMAX*RDIST/6.28*10.),200.)                  TRANS    333
      DELTP = (PMAX - PMIN) / NNP                                       TRANS    334
      C = 1.000                                                         TRANS    335
      P = 1.E-10                                                        TRANS    336
      DSK1 = SQRT(DK1**2 + P**2)                                        TRANS    337
      DSK2 = SQRT(DK2**2 + P**2)                                        TRANS    338
      IF(DSK1 * DSK2 * T1 * T2 .GT. 100.) GO TO 121                     TRANS    339
      AL2 = DB2 * DK2 / DA2                                             TRANS    340
      AL1 = DB1 * DK1 / DA1                                             TRANS    341
      DD1 = COSH(DSK1*T1) - 0.5*(1./AL1+AL1) * SINH(DSK1*T1)            TRANS    342
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      DD2 = COSH(DSK2*T2) - 0.5*(1./AL2+AL2) * SINH(DSK2*T2)          TRANS    343
      AL1 = 0.5*(1./AL1 - AL1) * SINH(DSK1*T1)                        TRANS    344
      AL2 = 0.5*(1./AL2 - AL2) * SINH(DSK2*T2)                        TRANS    345
      FBAR = EXP(-P * AZRO )                                          TRANS    346
      DENOM = 1. - AL2**2 - AL1**2 - AL2*AL1*(DD2*DD1 - AL2*AL1)      TRANS    347
      SIGMA = DD2*DD1*FBAR/DENOM                                      TRANS    348
      FLUX = FLUX + SIGMA * BESS0 (P*RDIST) * P * C                   TRANS    349
      C = 2.                                                          TRANS    350
      DO 120 I =  1,NNP                                               TRANS    351
      C = 6. - C                                                      TRANS    352
      P = P + DELTP                                                   TRANS    353
      DSK1 = SQRT(DK1**2 + P**2)                                      TRANS    354
      DSK2 = SQRT(DK2**2 + P**2)                                      TRANS    355
      IF(DSK1 * DSK2 * T1 * T2 .GT. 100.) GO TO 121                   TRANS    356
      AL1 = DB1 * DK1 / DA1                                           TRANS    357
      AL2 = DB2 * DK2 / DA2                                           TRANS    358
      DD1 = COSH(DSK1*T1) - 0.5*(1./AL1+AL1) * SINH(DSK1*T1)          TRANS    359
      DD2 = COSH(DSK2*T2) - 0.5*(1./AL2+AL2) * SINH(DSK2*T2)          TRANS    360
      AL1 = 0.5*(1./AL1 - AL1) * SINH(DSK1*T1)                        TRANS    361
      AL2 = 0.5*(1./AL2 - AL2) * SINH(DSK2*T2)                        TRANS    362
      FBAR = EXP(-P * AZRO )                                          TRANS    363
      DENOM = 1. - AL2**2 - AL1**2 - AL2*AL1*(DD2*DD1 - AL2*AL1)      TRANS    364
      SIGMA = DD2*DD1*FBAR/DENOM                                      TRANS    365
      FLUX = FLUX + SIGMA * BESS0 (P*RDIST) * P * C                   TRANS    366
  120 CONTINUE                                                        TRANS    367
  121 FLUX = FLUX * DELTP / 3.                                        TRANS    368
C        UNITS FOR FLUX ARE (1/KM**2)                                 TRANS    369
C                                                                     TRANS    370
C                                                                     TRANS    371
      GO TO 500                                                       TRANS    372
  300 CONTINUE                                                        TRANS    373
C                                                                     TRANS    374
C        THREE LAYERS                                                 TRANS    375
C                                                                     TRANS    376
      FLUX = 1.E-50                                                   TRANS    377
      PMIN = 1.E-20                                                   TRANS    378
      PMAX = 10. / (T1 + T2 + T3 + AZRO)                              TRANS    379
      NNP = AMIN1(AMAX1(50.,PMAX*RDIST/6.28*10.),200.)                TRANS    380
      DELTP = (PMAX - PMIN) / NNP                                     TRANS    381
      C = 1.000                                                       TRANS    382
      P = 1.E-10                                                      TRANS    383
      AL1 = DB1 * DK1 / DA1                                           TRANS    384
      AL2 = DB2 * DK2 / DA2                                           TRANS    385
      AL3 = DB3 * DK3 / DA3                                           TRANS    386
      DSK1 = SQRT(DK1**2 + P**2)                                      TRANS    387
      DSK2 = SQRT(DK2**2 + P**2)                                      TRANS    388
      DSK3 = SQRT(DK3**2 + P**2)                                      TRANS    389
      IF(DSK1*DSK2*DSK3 * T1*T2*T3 .GT. 100.) GO TO 131               TRANS    390
      DD1 = COSH(DSK1*T1) - 0.5*(1./AL1+AL1) * SINH(DSK1*T1)          TRANS    391
      DD2 = COSH(DSK2*T2) - 0.5*(1./AL2+AL2) * SINH(DSK2*T2)          TRANS    392
      DD3 = COSH(DSK3*T3) - 0.5*(1./AL3+AL3) * SINH(DSK3*T3)          TRANS    393
      AL1 = 0.5*(1./AL1 - AL1) * SINH(DSK1*T1)                        TRANS    394
      AL2 = 0.5*(1./AL2 - AL2) * SINH(DSK2*T2)                        TRANS    395
      AL3 = 0.5*(1./AL3 - AL3) * SINH(DSK3*T3)                        TRANS    396
      FBAR = EXP(-P * AZRO )                                          TRANS    397
      DENOM = 1. - AL1**2 - AL2**2 - AL3**2                           TRANS    398
     1  -AL1*AL2*(DD2*DD1-AL2*AL1) - AL2*AL3*(DD3*DD2-AL3*AL2)        TRANS    399
```

```
     2 + AL1**2*AL3**2 -AL3*AL1*(DD3*DD2 - AL3*AL2)*(DD2*DD1 - AL2*AL1)  TRANS   400
      SIGMA = DD3*DD2*DD1*FBAR / DENOM                                   TRANS   401
      FLUX = FLUX + SIGMA * BESS0 (P*RDIST) * P * C                      TRANS   402
      C = 2.                                                             TRANS   403
      DO 130 I = 1, NWP                                                  TRANS   404
      C = 6. - C                                                         TRANS   405
      P = P + DELTP                                                      TRANS   406
      AL1 = DB1 * DK1 / DA1                                              TRANS   407
      AL2 = DB2 * DK2 / DA2                                              TRANS   408
      AL3 = DB3 * DK3 / DA3                                              TRANS   409
      DSK1 = SQRT(DK1**2 + P**2)                                         TRANS   410
      DSK2 = SQRT(DK2**2 + P**2)                                         TRANS   411
      DSK3 = SQRT(DK3**2 + P**2)                                         TRANS   412
      IF(DSK1*DSK2*DSK3 * T1*T2*T3 .GT. 100.) GO TO 131                  TRANS   413
      DD1 = COSH(DSK1*T1) - 0.5*(1./AL1+AL1) * SINH(DSK1*T1)             TRANS   414
      DD2 = COSH(DSK2*T2) - 0.5*(1./AL2+AL2) * SINH(DSK2*T2)             TRANS   415
      DD3 = COSH(DSK3*T3) - 0.5*(1./AL3+AL3) * SINH(DSK3*T3)             TRANS   416
      AL1 = 0.5*(1./AL1 - AL1) * SINH(DSK1*T1)                           TRANS   417
      AL2 = 0.5*(1./AL2 - AL2) * SINH(DSK2*T2)                           TRANS   418
      AL3 = 0.5*(1./AL3 - AL3) * SINH(DSK3*T3)                           TRANS   419
      FBAR = EXP(-P * AZRO )                                             TRANS   420
      DENOM = 1. - AL1**2 - AL2**2 - AL3**2                              TRANS   421
     1  -AL1*AL2*(DD2*DD1-AL2*AL1) - AL2*AL3*(DD3*DD2-AL3*AL2)           TRANS   422
     2 + AL1**2*AL3**2 -AL3*AL1*(DD3*DD2 - AL3*AL2)*(DD2*DD1 - AL2*AL1)  TRANS   423
      SIGMA = DD3*DD2*DD1*FBAR / DENOM                                   TRANS   424
      FLUX = FLUX + SIGMA * BESS0 (P*RDIST) * P * C                      TRANS   425
  130 CONTINUE                                                           TRANS   426
  131 FLUX = FLUX * DELTP / 3.                                           TRANS   427
C        UNITS FOR FLUX ARE (1/KM**2)                                    TRANS   428
C                                                                        TRANS   429
C                                                                        TRANS   430
      GO TO 500                                                          TRANS   431
  400 CONTINUE                                                           TRANS   432
CLJ       NOW COMPUTE AIR TRANSMITTANCE FOR CASE THAT THE SOURCE IS      TRANS   433
CLJ       ABOVE THE HIGHEST CLDTOP.                                      TRANS   434
CLJ       IF THE SOURCE IS AN ARTIFICIAL ONE AND ITS ALTITUDE ABOVE      TRANS   435
CLJ       CLDTOP IS LESS THAN THE RADIUS (RSOURCE(1)) ASSIGNED TO THE    TRANS   436
CLJ       FINITE-SIZE SOURCE, IT IS THEN NECESSARY TO RESET THE SOURCE   TRANS   437
CLJ       ALTITUDE (SORALT) TO HSEFF AND HENCE ZS TO RE+HSEFF AND TO     TRANS   438
CLJ       RECOMPUTE THE SOURCE ZENITH ANGLE (THIEFF) AND SOURCE-TO-      TRANS   439
CLJ       INTERCEPT-POINT DISTANCE (SDEFF).                              TRANS   440
      ALT = SORALT - CLDTOP                                              TRANS   441
      IF( ALT.GE.RSORCE(1) )  GO TO 450                                  TRANS   442
      HSEFF = CLDTOP + 0.5*(ALT + RSORCE(1))                             TRANS   443
      CALL SGEOM(UL,VL,WL,CLDTOP,XD,YD,ZD,XS,YS,RE+HSEFF,                TRANS   444
     $           RDEFF,SDEFF,THIEFF,THETE,PHIE)                          TRANS   445
      SDIST = SDEFF                                                      TRANS   446
      THETI = THIEFF                                                     TRANS   447
      SORALT = HSEFF                                                     TRANS   448
  450 CONTINUE                                                           TRANS   449
      T1 = 1.0                                                           TRANS   450
      IF( SORALT.LT.12. )  T1 = TAIR(ALAM,THETI,SORALT)                  TRANS   451
      T2 = 1.0                                                           TRANS   452
      IF( CLDTOP.LT.12. )  T2 = TAIR(ALAM,THETI,CLDTOP)                  TRANS   453
      TSX = T2 / T1                                                      TRANS   454
      TDX = 1.0                                                          TRANS   455
      IF( CLDTOP.LT.12. )  TDX = TAIR(ALAM,THETE,CLDTOP)                 TRANS   456
```

```
      FLUX=CLDRDR(COS(THETI*DTR),COS(THETE*DTR),COS(PHIE*DTR)
     X   ,ALAM,KCLOUD)
      TPALT = 12.
CLJ        IN COMPUTING SDISTO WE USE THE ORIGINAL ZS, WITHOUT ANY
CLJ        RESETTING IF THE SOURCE IS ARTIFICIAL, EVEN THOUGH ITS
CLJ        ALTITUDE ABOVE CLDTOP MAY BE LESS THAN ITS RADIUS.
      CALL SGEOM(UL,VL,WL,TPALT,XD,YD,ZD,XS,YS,ZS,
     X   RDIST,SDISTO,THETIO,THETE,PHIE)
      TRANSF = FLUX * TSX * TDX * COS(THETI/57.295) *(SDISTO/SDIST)**2
      RETURN
  500 CONTINUE
CLJ        NOW COMPUTE AIR TRANSMITTANCE FOR CASE THAT THE SOURCE IS
CLJ        BELOW THE HIGHEST CLDTOP.
      THI = 180.-THETI
      T1 = TAIR(ALAM,THI,SORALT)
      T2 = TAIR(ALAM,THI,CLDTOP)
      TSX = T1 / T2
      TPALT = 12.
      CALL SGEOM(UL,VL,WL,TPALT,XD,YD,ZD,XS,YS,ZS,
     $   RDIST,SDISTO,THETI,THETEC,PHIE)
      TDX = TAIR(ALAM,THETE,CLDTOP)
      TRANSF = FLUX * TSX * TDX / PI * SDISTO**2
      IF( TRANSF.GE.0.0 )  GO TO 600
      WRITE(6,550)  TRANSF,RDIST
  550 FORMAT (*0     WARNING ... WARNING ... WARNING
     1 *  (SUBROUTINE TRANSF)  */
     2 *0   THE PROGRAM HAS COMPUTED A NEGATIVE VALUE FOR THE*,
     3 * TRANSMITTANCE TRANSFER COEFFICIENT, TRANSF =*,E14.5/
     4 *    AT A LATERAL DISPLACEMENT OF RDIST =*,E14.5,* KM */
     5 *    THE PROGRAM ALSO TOOK THE ABSOLUTE VALUE OF TRANSF AND*,
     6 * PROCEEDED NORMALLY, TO FACILITATE THE USER */
     7 *    MAKING A NOMINAL RUN.  THE ABSOLUTE MAGNITUDE OF TRANSF*,
     8 * IS LIKELY LESS THAN THE CORRECT VALUE, */
     9 *    BUT THE RESULTS AT SUCH A LARGE VALUE OF RDIST ARE NOT*/
     A * RELIABLE BECAUSE THE INTERNAL INTEGRATION */
     B *    SCHEME WAS NOT INTENDED TO TREAT SUCH CASES.*)
      TRANSF = ABS( TRANSF )
  600 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE VSNORM(X,Y,Z,EN1,EN2,EN3,K)                            VSNORM    2
CLJ                                                                     VSNORM    3
CLJ   SUBROUTINE VSNORM COMPUTES THE COMPONENTS, IN THE K-TH CLOUD-     VSNORM    4
CLJ   CENTERED CARTESIAN COORDINATE SYSTEM, OF THE UNIT VECTOR NORMAL   VSNORM    5
CLJ   TO THE ELLIPSOIDAL-SURFACE POINT X,Y,Z.                           VSNORM    6
CLJ                                                                     VSNORM    7
CLJ   INPUT PARAMETERS                                                  VSNORM    8
CLJ      ARGUMENT LIST                                                  VSNORM    9
CLJ           X,Y,Z = COORDINATES OF AN ELLIPSOIDAL-SURFACE POINT IN THE VSNORM   10
CLJ                   K-TH CLOUD-CENTERED CARTESIAN COORDINATE SYSTEM   VSNORM   11
CLJ               K = CLOUD NUMBER                                      VSNORM   12
CLJ      CDCORD COMMON                                                  VSNORM   13
CLJ         FOLLOWING PARAMETERS ARE SET IN SUBROUTINE CLDGEOM FOR      VSNORM   14
CLJ         K=1,10                                                      VSNORM   15
CLJ          ASQ(K) = SQUARE OF LENGTH A, THE SEMI-MAJOR AXIS IN        VSNORM   16
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2      VSNORM   17
CLJ          BSQ(K) = SQUARE OF LENGTH B, THE SEMI-MINOR AXIS IN        VSNORM   18
CLJ                   HORIZONTAL PLANE OF ELLIPSOIDAL CLOUD, KM**2      VSNORM   19
CLJ          CSQ(K) = SQUARE OF LENGTH C, THE SEMI-MINOR AXIS IN        VSNORM   20
CLJ                   VERTICAL DIRECTION OF ELLIPSOIDAL CLOUD, KM**2    VSNORM   21
CLJ   OUTPUT PARAMETERS                                                 VSNORM   22
CLJ      ARGUMENT LIST                                                  VSNORM   23
CLJ            EN1, = COMPONENTS, IN THE K-TH CLOUD-CENTERED CARTESIAN  VSNORM   24
CLJ            EN2,   COORDINATE SYSTEM, OF THE UNIT VECTOR NORMAL TO   VSNORM   25
CLJ            EN3    THE ELLIPSOIDAL-SURFACE POINT X,Y,Z.              VSNORM   26
CLJ                                                                     VSNORM   27
      COMMON/CDCORD/ XI( 1,20),ETA( 1,20),ZETA( 1,20),                  CDCORD    2
     1               XID(20),ETAD(20),ZETAD(20),CPH(5,20),CTH(5,20)     CDCORD    3
     X  , ASQ(20),BSQ(20),CSQ(20)                                       CDCORD    4
     2 ,CPHIBAR(16,20),CTHBAR(8,20),CKBAR(4,4,20),CAREA(4,4,20)         CDCORD    5
      EN1 = X/ASQ(K)                                                    VSNORM   29
      EN2 = Y / BSQ(K)                                                  VSNORM   30
      EN3 = Z / CSQ(K)                                                  VSNORM   31
      R = SQRT(EN1**2 + EN2**2 + EN3**2 )                               VSNORM   32
      EN1 = EN1 / R                                                     VSNORM   33
      EN2 = EN2 / R                                                     VSNORM   34
      EN3 = EN3 / R                                                     VSNORM   35
      RETURN                                                            VSNORM   36
      END                                                               VSNORM   37
```

APPENDIX C

LISTING OF UPDATE CARDS NECESSARY FOR SAMPLE PROBLEMS

```
*IDENT TPROB1/4
*/    FOR PROGRAM ROSCOER
*INSERT ROSCOER.13
      COMMON/ TPM4 /  IFLAG4
      DIMENSION  RRR(161), RRTR(161,4)
*DELETE ROSCOER.94
      KKK = 0
      DO 9 J=1,4
      DO 9 I=1,161
      RRTR(I,J) = 0.0
    9 CONTINUE
    7 CONTINUE
      KKK = KKK+1
      IFLAG4 = -2
*DELETE ROSCOER.176
      PIDX2 = PI*DXX/2.0   $   JR = 161
      DO 301 I=1,JR
*DELETE ROSCOER.182
*INSERT ROSCOER.188
      RRR(I) = X
      RRTR(1,KKK) = T4
*DELETE     ROSCOER.192,ROSCOER.194
*DELETE     ROSCOER.206,ROSCOER.208
*INSERT ROSCOER.211
      WRITE(6,103)
  103 FORMAT (1H1,*  RANGE *,*      SC          AC          CI    *,
     $ *  SC-AC-CI  *,*  INT(  SC )    INT(  AC )    INT(  CI )  *,
     $ *  INT(TOTAL)  *)
      RSM1 = 0.0  $  RSM2 = 0.0  $  RSM3 = 0.0  $  RSM4 = 0.0
      WRITE(6,105)  RRR(1),(RRTR(1,J),J=1,4),RSM1,RSM2,RSM3,RSM4
  105 FORMAT (1X,F8.2,4E12.4,4E14.6)
      DO 110 I=2,JR
      RSM1 = RSM1 + PIDX2*( RRR(I)*RRTR(I,1) + RRR(I-1)*RRTR(I-1,1) )
      RSM2 = RSM2 + PIDX2*( RRR(I)*RRTR(I,2) + RRR(I-1)*RRTR(I-1,2) )
      RSM3 = RSM3 + PIDX2*( RRR(I)*RRTR(I,3) + RRR(I-1)*RRTR(I-1,3) )
      RSM4 = RSM4 + PIDX2*( RRR(I)*RRTR(I,4) + RRR(I-1)*RRTR(I-1,4) )
      WRITE(6,105)  RRR(I),(RRTR(I,J),J=1,4),RSM1,RSM2,RSM3,RSM4
  110 CONTINUE
*/    FOR SUBROUTINE DIFPRM
*INSERT DIFPRM.81
      DATA IF1234 / -1 /
*DELETE DIFPRM.105
      IF( IF1234 .GT. 0 )  GO TO 111
*DELETE DIFPRM.124
      IF( IF1234 .GT. 0 )  GO TO 27
*DELETE DIFPRM.149
      IF( IF1234 .GT. 0 )  GO TO 29
*INSERT DIFPRM.156
      IF1234 = +2
*/    FOR SUBROUTINE SCLOUD
*INSERT SCLOUD.157
      E4 = EMISS(1)
      IF( ISUN.EQ.0 )  T4 = TRANS(1)
      IF( ISUN.EQ.1 )  S4 = TRANS(1)
      HSORCE(1) = HSAVE
```

Figure C-1. Update IDENT for Problems 1 to 4.

```
      GO TO 30
*/    FOR FUNCTION TRANSF
*BEFORE TRANS.9
      COMMON/ TPM4 /  IFLAG4
*INSERT TRANS.11
      DATA  KCLDZ / 0 /
*INSERT TRANS.101
      IF( KCLOUD.EQ.KCLDZ )  GO TO 6
      KCLDZ = KCLOUD
      PRODKL = DKAPPA(KCLOUD) * CLDTHK(KCLOUD)
      ADIVKB = DALFA(KCLOUD) / (DKAPPA(KCLOUD)*DBETA(KCLOUD))
      T = 1.0 / (COSH(PRODKL) + 0.5*(ADIVKB + 1.0/ADIVKB)*SINH(PRODKL))
      WRITE(6,13)  KCLOUD, T
   13 FORMAT (*0   TOTAL TRANSMISSION FOR KCLOUD = *,I4,*  IS *,E12.4)
    6 CONTINUE
*INSERT TRANS.386
CLJ        THE MAIN PROGRAM INITIALIZES IFLAG4 TO A NEG. VALUE.
      IF( IFLAG4.GT.0 )  GO TO 1301
CLJ        FOR SAMPLE PROBLEM NO. 4 WE WANT TO EVALUATE THE ANALYTIC
CLJ        EXPRESSION FOR THE TOTAL (SPATIALLY-INTEGRATED) TRANSMITTANCE
CLJ        THROUGH THREE LAYERS ABOVE A POINT SOURCE.
CLJ        FIRST, EVALUATE THE TRANSMITTANCE S AND REFLECTANCE R FOR EACH
CLJ        OF THE THREE LAYERS SEPARATELY, PER EQS. (31A) AND (31B) IN
CLJ        CLOUD REPORT APPENDIX A.
      DK1T1 = DK1*T1
      DK2T2 = DK2*T2
      DK3T3 = DK3*T3
      HSKT1 = SINH(DK1T1)
      HSKT2 = SINH(DK2T2)
      HSKT3 = SINH(DK3T3)
      S1 = 1.0/( COSH(DK1T1) + 0.5*(1./AL1 + AL1)*HSKT1 )
      S2 = 1.0/( COSH(DK2T2) + 0.5*(1./AL2 + AL2)*HSKT2 )
      S3 = 1.0/( COSH(DK3T3) + 0.5*(1./AL3 + AL3)*HSKT3 )
      R1 = S1*0.5*(1./AL1 - AL1)*HSKT1
      R2 = S2*0.5*(1./AL2 - AL2)*HSKT2
      R3 = S3*0.5*(1./AL3 - AL3)*HSKT3
CLJ        NOW EVALUATE THE TOTAL TRANSMITTANCE FOR THE THREE-LAYER
CLJ        CASE, S123.
      S123 = S1*S2*S3/( (1.-R1*R2)*(1.-R2*R3) - R1*R3*S2*S2 )
      IFLAG4 = +2
      WRITE(6,1300)  S1,S2,S3,R1,R2,R3,S123
 1300 FORMAT (*0   TRANSMITTANCES AND REFLECTANCES FOR EACH OF THREE*,
     1 * CLOUDS ARE...*/*     T1,T2,T3 =*,3E14.5/*    R1,R2,R3 =*,3E14.5/
     2 *0   TRANSMITTANCE FOR THREE-LAYER COMBINATION IS...*,
     3 * T123 =*,E14.5)
 1301 CONTINUE
*DELETE TRANS.390
*DELETE TRANS.413
*DELETE TRANS.478
      TRANSF = FLUX / PI
*DELETE TRANS.480
*DELETE TRANS.493
```

Figure C-1. (Continued)

```
*IDENT TPROB/5
*/    FOR PROGRAM ROSCOER
*DELETE ROSCOER.176
      DO 301 I=1,1
*DELETE ROSCOER.201
*/    FOR SUBROUTINE CLDWT
*INSERT CLDWT.7
      DIMENSION  LLMH(160,3),ZCFLOS(160,4)
*INSERT CLDWT.123
      LLMH(IDX,1) = LL    $   LLMH(IDX,2) = MM    $   LLMH(IDX,3) = HH
      ZCFLOS(IDX,II-1) = PIJKL*(1.0-CFLOS)
*INSERT CLDWT.138
      LLMH(IDX,1) = LL    $   LLMH(IDX,2) = MM    $   LLMH(IDX,3) = HH
      ZCFLOS(IDX,II-1) = PIJKL*(1.0-CFLOS)
*INSERT CLDWT.153
      LLMH(IDX,1) = LL    $   LLMH(IDX,2) = MM    $   LLMH(IDX,3) = HH
      ZCFLOS(IDX,II-1) = PIJKL*(1.0-CFLOS)
*INSERT CLDWT.173
      LLMH(IDX,1) = LL    $   LLMH(IDX,2) = MM    $   LLMH(IDX,3) = HH
      ZCFLOS(IDX,II-1) = PIJKL*(1.0-CFLOS)
*INSERT CLDWT.191
      LLMH(IDX,1) = LL    $   LLMH(IDX,2) = MM    $   LLMH(IDX,3) = HH
      ZCFLOS(IDX,II-1) = PIJKL*(1.0-CFLOS)
*INSERT CLDWT.209
      LLMH(IDX,1) = LL    $   LLMH(IDX,2) = MM    $   LLMH(IDX,3) = HH
      ZCFLOS(IDX,II-1) = PIJKL*(1.0-CFLOS)
*INSERT CLDWT.228
      LLMH(IDX,1) = LL    $   LLMH(IDX,2) = MM    $   LLMH(IDX,3) = HH
      ZCFLOS(IDX,II-1) = PIJKL*(1.0-CFLOS)
*BEFORE CLDWT.233
      WRITE(6,303)
  303 FORMAT (2H1 ,* IDX  LL   MM   HH   *,*    TRANS        EMISS    *,
     $ *    CC=2         CC=3         CC=4         CC=5          WT      *,
     $ *   WT(SUM)   *)
      RSUM = 0.0
      DO 310 IX=1,160
      RSUM = RSUM + WT(IX)
      WRITE(6,305)  IX,(LLMH(IX,I),I=1,3),TRANS(IX),EMISS(IX),
     $              (ZCFLOS(IX,I),I=1,4),WT(IX),RSUM
  305 FORMAT (2X,4I4,2X,8E12.4)
  310 CONTINUE
*/    FOR SUBROUTINE DIFPRM
*DELETE DIFPRM.105
*DELETE DIFPRM.124
*DELETE DIFPRM.149
*/    FOR SUBROUTINE SCLOUD
*INSERT SCLOUD.254
      WRITE(6,103)  IDX,TRANS(160),EMISS(160),WT(160)
  103 FORMAT (2H0 ,4X,* IDX = *,I5,5X,* TRANS(160) = *,E12.4,5X,
     $ * EMISS(160) = *,E12.4,5X,*   WT (160) = *,E12.4)
*INSERT SCLOUD.260
      WRITE(6,111)     SLGCLD,SLGCLR,SFR,THI,T12,T2TP,RDIST,SDISTO,
     $              THETI,THETE,PHIE
  111 FORMAT (*0     SLGCLD,SLGCLR,SFR,THI,T12,T2TP,RDIST,SDISTO,*,
     $ *THETI,THETE,PHIE*,/(5X,6E12.4))
      WRITE(6,113)  (TRANS(I),WT (I),I=1,II)
      WRITE(6,115)  (EMISS(I),WT1(I),I=1,II)
  113 FORMAT (*0  TRANS,WT  =*/(5X,8E12.4))
  115 FORMAT (*0  EMISS,WT1 =*/(5X,8E12.4))
*INSERT SCLOUD.266
      WRITE(6,117)  (WT(I),WT1(I),I=1,II)
  117 FORMAT (*0  WT,WT1 =*/(5X,8E12.4))
```

Figure C-2. Update IDENT for Problem 5.

```
*IDENT TPROB/6
*/    FOR PROGRAM ROSCOER
*INSERT ROSCOER.13
      COMMON/XX0000/  XCC(64),YCC(64),ZCC(64)
*DELETE ROSCOER.17
      DATA  SOLLAT, SOLLON / 0.0, -0.785398 /
*DELETE     ROSCOER.139,ROSCOER.140
      IF( I.EQ.1 )  WRITE(6,123)
  123 FORMAT (*1CLOUD   ALAM     TCOEF       EMISS        XCC    *,
     1 *      YCC          ZCC     *)
      WRITE(6,125)  KCLOUD(K),ALAM,TCOEF,TEMISS,XCC(I),YCC(I),ZCC(I)
  125 FORMAT (1X,I5,F8.2,E12.4,E12.4,3E12.4)
*/    FOR SUBROUTINE CLOUD2
*DELETE CLOUD2.72
*DELETE CLOUD2.84
*DELETE CLOUD2.96
*/    FOR SUBROUTINE CLOUD3
*DELETE CLOUD3.185
*DELETE      CLOUD3.216,CLOUD3.217
*/    FOR SUBROUTINE DIFFUS
*DELETE DIFFUS.143
*DELETE DIFFUS.165
*DELETE DIFFUS.222
*/    FOR SUBROUTINE LOS
*BEFORE LOSK.67
      COMMON/XX0000/  XCC(64),YCC(64),ZCC(64)
*INSERT LOSK.118
      XCC(L) = 0.0
      YCC(L) = 0.0
      ZCC(L) = 0.0
*INSERT LOSK.153
      XCC(LL) = XX(IC,JC)
      YCC(LL) = YY(IC,JC)
      ZCC(LL) = ZZ(IC,JC)
*INSERT LOSK.203
      XCC(LL) = XX(IC,JC)
      YCC(LL) = YY(IC,JC)
      ZCC(LL) = ZZ(IC,JC)
*INSERT LOSK.245
      XCC(LL) = XX(IC,JC)
      YCC(LL) = YY(IC,JC)
      ZCC(LL) = ZZ(IC,JC)
```

Figure C-3. Update IDENT for Problem 6.

APPENDIX D

TRANSMITTANCE AND REFLECTANCE OF TWO- AND THREE-LAYER PLANAR SLABS

To help validate the code it is valuable to compare the code's results with information obtained by other means. One type of calculation performed by the code is the computation of the photon flux emerging from one- two-, and three-layer slabs at a given lateral displacement from the vertical through the point source below the slabs.

Sample Problems 1 to 3 in Section 4-3 are for one-layer slabs and Problem 4 is for a three-layer slab. To provide a check on the code's operation for Problems 1 to 3, we used Equation (32a) in Appendix A for the spatially-integrated transmittance of a planar slab. By performing a spatial integration of the code-computed flux, we compared the code's result with the analytic result in Equation (32a). Problem 4, with its three layers, is more complicated. Hence, we need another exact, analytic expression for the transmittance of three layers, given the transmittance and reflectance of each of the three separate layers. We derive such a formula here; it is applied in Section 4-3.1.

The approach is to derive formulas for the transmittance and reflectance of two layers and then to apply the two-layer formulas to the three-layer configuration. The derivation is greatly facilitated by drawing an appropriate diagram, such as that in Figure D-1. The total transmitted flux is seen to be a geometric series:

$$T_{12} = T_2T_1 \left[1 + R_2R_1 + (R_2R_1)^2 + (R_2R_1)^3 + \ldots\right]$$

$$= \frac{T_2T_1}{1-R_2R_1} \tag{1}$$

Similarly, the reflectance from the lower layer includes a geometric series:

$$R_{12} = R_1 + T_1{}^2R_2 \left[1 + R_2R_1 + (R_2R_1)^2 + (R_2R_1)^3 + \ldots\right]$$

$$= R_1 + \frac{T_1{}^2R_2}{1-R_2R_1} \tag{2}$$

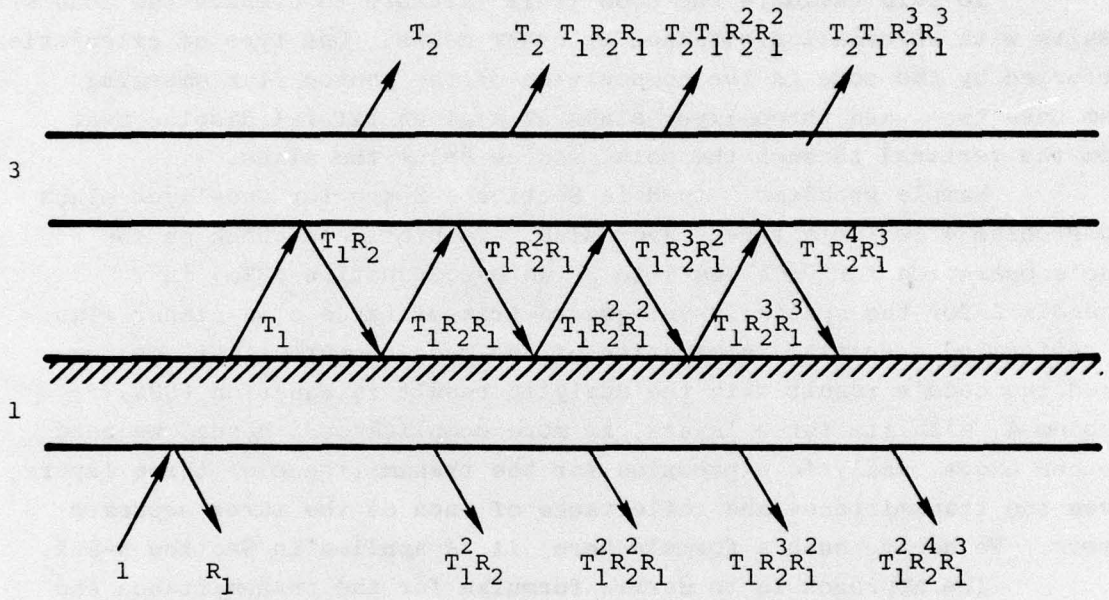

Figure D-1. Illustration of contributions to transmitted and reflected fluxes for a two-layer configuration.

Note that Equation (1) for the transmittance is symmetric in the indices 1 and 2 whereas Equation (2) for the reflectance is not symmetric.

If one makes the assumption of conservative scattering (i.e., no absorption), so that

$$T_1 + R_1 + 1$$

$$T_2 + R_2 = 1 \quad ,$$

then one can show that the reflectance is symmetric, i.e.,

$$R_{12} = R_{21} = \frac{R_1 + R_2 - 2R_1R_2}{1-R_1R_2}$$

and that

$$T_{12} + R_{12} + 1 \quad .$$

For three layers, consider Figure D-2 where we denote the pair of Layers 1 and 2 as Layer A and Layer 3 as Layer B. The symbol R_{A+} denotes the net reflectance for flux incident on the Layer-1 side of Layer A and R_{A-} denotes the net reflectance for flux incident on the Layer-2 side of Layer A.

The transmittance for flux incident on the Layer-1 side is

$$T_{AB} = T_BT_A \left[1 + R_BR_{A-} + (R_BR_{A-})^2 + \ldots\right]$$

$$= \frac{T_BT_A}{1-R_BR_{A-}} \quad .$$

The reflectance for flux incident on the Layer-1 side is

$$R_{AB} = R_{A+} + T_A{}^2R_B \left[1 + R_BR_{A-} + (R_BR_{A-})^2 + \ldots\right]$$

$$= R_{A+} + \frac{T_A{}^2R_B}{1-R_BR_{A-}} \quad .$$

By using the expressions

$$T_A = \frac{T_2T_1}{1-R_2R_1}$$

$$T_B = T_3$$

$$R_{A+} \equiv R_{12} = R_1 + \frac{T_1{}^2R_2}{1-R_2R_1}$$

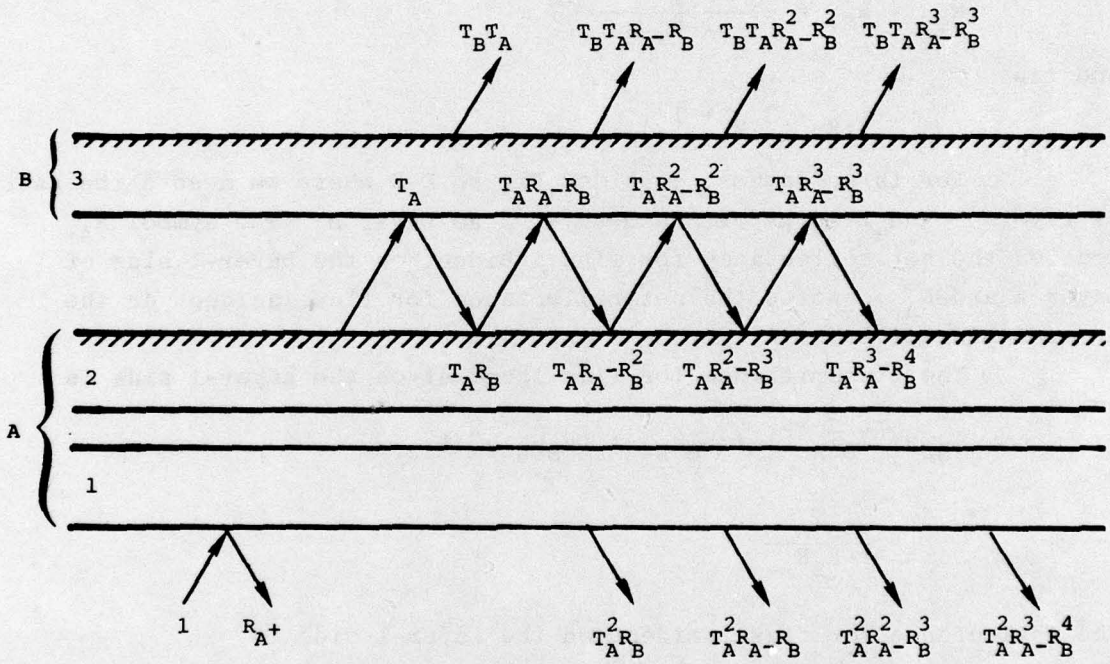

Figure D-2. Illustration of contributions to transmitted and reflected fluxes for a three-layer configuration expressed in terms of those for a two-layer configuration.

$$R_{A-} \equiv R_{21} = R_2 + \frac{T_2^{\,2} R_1}{1-R_1R_2}$$

$$R_B = R_3$$

we find

$$T_{123} \equiv T_{AB} = \frac{T_3T_2T_1}{1-R_2R_1} \; \frac{1}{1 - R_3\left[R_2 + \frac{T_2^{\,2}R_1}{1-R_1R_2}\right]}$$

$$\boxed{T_{123} = \frac{T_3T_2T_1}{(1-R_2R_1)\,(1-R_3R_2) - T_2^{\,2}R_3R_1}}$$

which is symmetric with respect to an interchange of the 1 and 3 and hence is valid for the source irradiating either Layer 1 or Layer 3.

The reflectance R_{123} for a source below Layer 1 is

$$R_{123} \equiv R_{AB} = R_{A+} + \frac{T_A^{\,2}R_B}{1-R_BR_{A-}}$$

$$= R_1 + \frac{T_1^{\,2}R_2}{1-R_2R_1} + \frac{\left(\frac{T_2T_1}{1-R_2R_1}\right)^2 R_3}{1 - R_3\left[R_2 + \frac{T_2^{\,2}R_1}{1-R_1R_2}\right]}$$

$$= \frac{R_1\,(1-R_2R_1) + T_1^{\,2}R_2}{1-R_2R_1}$$

$$+ \frac{\frac{(T_2T_1)^2}{1-R_2R_1}\,R_3}{(1-R_3R_2)\,(1-R_2R_1) - T_2^{\,2}R_3R_1}$$

whereas the reflectance R_{321} for a source above Layer 3 is

$$R_{321} \equiv R_{BA} = R_B + \frac{T_B^{\,2} R_{A-}}{1-R_B R_{A-}}$$

$$= R_3 + \frac{T_3^{\,2}\left(R_2 + \dfrac{T_2^{\,2} R_1}{1-R_1 R_2}\right)}{1 - R_3\left[R_2 + \dfrac{T_2^{\,2} R_1}{1-R_1 R_2}\right]} \quad .$$

One can show that for conservative scattering, i.e.,

$$T_i + R_i = 1 \quad \text{for } i = 1,2,3 \quad ,$$

that

$$R_{123} = R_{321}$$

and

$$T_{123} + R_{123} = 1 \quad .$$

Finally, in Figure D-3 we illustrate the enhanced effective transmission of a single layer due to a reflecting surface located below the source. Let T be the transmittance of the layer without the reflecting surface. With the reflecting surface present, there are two contributions to the transmittance:

$$T_1 = T + TR^2 + TR^4 + \ldots = T/(1-R^2)$$

$$T_2 = TR + TR^3 + TR^5 + \ldots = TR/(1-R^2)$$

$$T_1 + T_2 = T(1+R)/(1-R^2) = T/(1-R) \; .$$

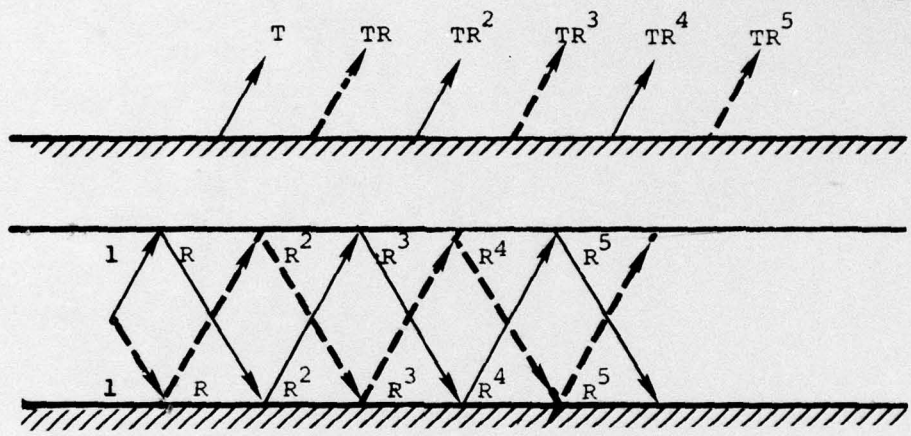

Figure D-3. Illustration of enhanced effective transmission of a single layer due to a reflecting surface.

The factor of increased transmittance due to the reflecting surface is

$$\frac{T_1+T_2}{T} = \frac{1}{1-R} \quad ,$$

a result stated in Section 2-2.

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