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DNA 3964F-27

AD A102524

THE ROSCOE MANUAL

Volume 27: Natural Background Radiation

Science Applications, Inc.

P.O. Box 2351

La Jolla, California 92038

1 July 1980

DTIC
ELECTE
AUG 5 1981

Final Report for Period 1 January 1976-30 June 1979

CONTRACT No. DNA 001-76-C-0194

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DNA 3964F-27	2. GOVT ACCESSION NO. AD-A102524	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE ROSCOE MANUAL, Volume 27: Natural Background Radiation		5. TYPE OF REPORT & PERIOD COVERED Final Report, for Period 1 Jan 76-30 Jun 79
7. AUTHOR(s) Daniel A. Hamlin Malvin R. Schoonover		6. PERFORMING ORG. REPORT NUMBER SAI-78-604-LJ-6 8. CONTRACT OR GRANT NUMBER(s) DNA 001-76-C-0194
9. PERFORMING ORGANIZATION NAME AND ADDRESS Science Applications, Inc. P.O. Box 2351 La Jolla, California 92038		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Subtask S99QAXHC062-37 Subtask S99QAXHI004-26
11. CONTROLLING OFFICE NAME AND ADDRESS Director Defense Nuclear Agency Washington, D.C. 20305		12. REPORT DATE 1 July 1980 12. NUMBER OF PAGES 344
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES This work sponsored by the Defense Nuclear Agency under RDT&E RMSS Codes B322076464 S99QAXHC06237 H2590D, B322078464 S99QAXHI00426 H2590D, and B322077464 S99QAXHC06237 H2590D, B322079464 S99QAXHI00426 H2590D. B322077464 S99QAXHI00426 H2590D,		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) ROSCOE Directional emissivity Infrared radiation Solar radiation Earth's surface characterization Upwelling natural infrared radiation Bidirectional reflectance-distribution function Directional-hemispherical reflectance		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The Natural Background Radiation Module computes the Earth's natural upwelling spectral radiance (from 2 to 5 μm) by averaging over paths in an Earth-tangent cone with vertex at each selected altitude. The processes contributing to the radiance are emission from air, Earth's surface, and clouds and reflection of solar radiation from Earth's surface and clouds; attenuation is by molecules and aerosols. The Module integrates ROSCOE-IR models for (a) atmosphere, (b) atmospheric thermal emission, (c) molecular		

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20. ABSTRACT (Continued)

transmittance, (d) aerosols, (e) clouds, (f) Earth's surface characterization and radiance, (g) solar radiation, and (h) upwelling natural radiation. Models (f), (g), and (h) are documented fully herein; other models (three of which were developed by other organizations) are documented here mainly in terms of functions performed, inputs, and outputs. The user selects the modeled Earth's surface from one of seven categories (with possibly an associated descriptor): (1) Lambertian surface (and diffuse reflectance), (2) wind-ruffled water (and wind speed), (3) snow (and its age parameter), (4) sand, (5) soil, (6) foliage, and (7) urban material (and degree-of-urbanization parameter).

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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)	3.765 412 X E -5
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
ktp	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 AND OVERVIEW

The Natural Background Radiation (NBR) Module is defined to be a computer program which integrates nine ROSCOE-IR models (see Table 1-1) into a consistent, stand-alone module for the purpose of developing and testing the capability to compute the natural upwelling spectral radiance as a function of altitude. The relationships of the routines in the NBR Module should be similar to the relationships of the routines in the ROSCOE-IR Program except for its use of overlays and a broader use of the GRC Dynamic Storage Allocation (DSA) System [SP-78].

The upwelling radiance will normally be a function of direction; however, for the anticipated applications it is expected that a spatially-averaged value will be adequate. (If later studies show that direction-dependent values are required, relatively minor code changes can be made to retrieve the more detailed information now generated to derive the spatially-averaged value.)

Computation of the upwelling radiance may be described with the aid of Figure 1-1. Point V is at altitude z above a selected reference origin,

Table 1-1. Models Integrated into the NBR Module.

Title	Model Number	Developer	ROSCOE Manual Volume Number
Ambient Atmosphere	1a	SAI/LJ	14a-1, 14c
Atmospheric Aerosols	1c,19:1c	VI	25
Natural Clouds	1d,19:1d	SAI/PA	24
Atmospheric Thermal Emission	20b	GET	28,31
Molecular Transmittance	24d	GET	28,31
Earth Surface Characterization	23a	SAI/LJ	27,Sect.2,3
Earth Surface Radiance	23b	SAI/LJ	27,Sect.5
Upwelling Natural Radiation	23c	SAI/LJ	27,Sect.6
Solar Radiation	23e	SAI/LJ	27,Sect.4

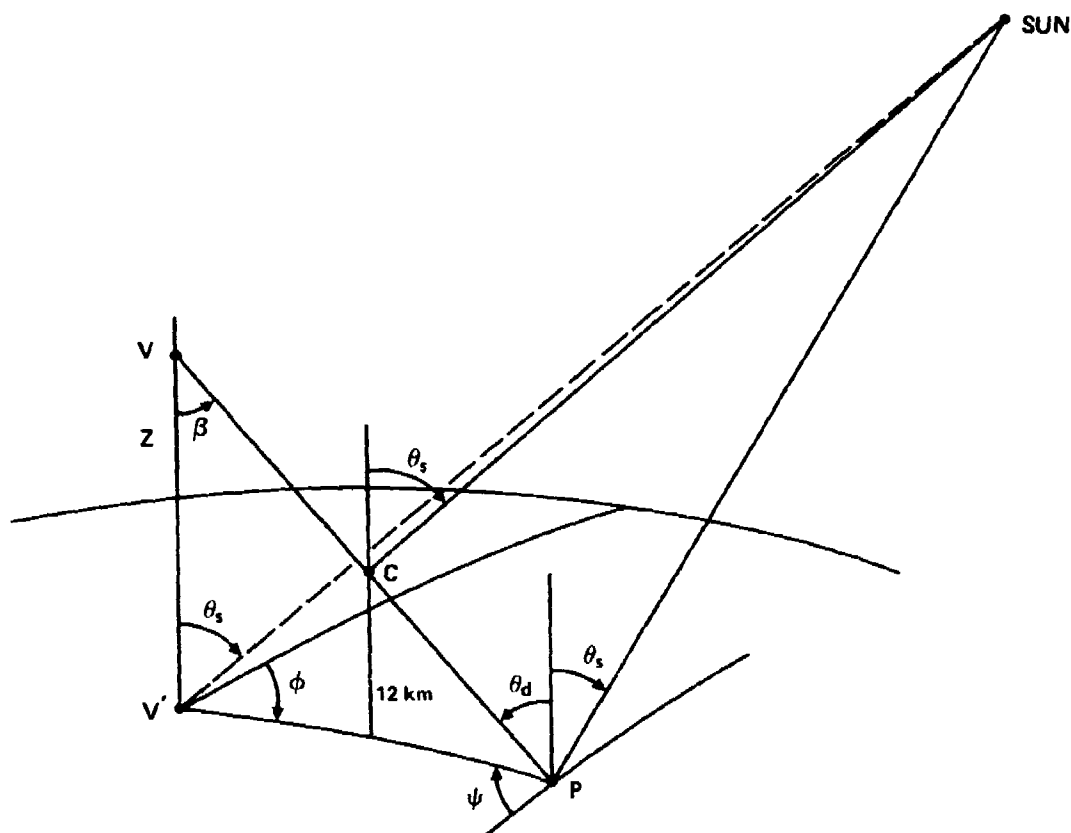


Figure 1-1. Geometry to illustrate the computation of upwelling natural radiation for one viewing direction \vec{VP} .

V'. For a (fictitious) detector at Point V viewing in the direction of Point P on the ground, the processes we include in computing the radiance in the direction of \vec{VP} may be separated into two cases:

A. No Clouds

1. Air emission between V and P, attenuated by molecules and aerosols.
2. Surface emission at Point P (from any of the seven modeled surface materials), attenuated by molecules and aerosols along \vec{VP} .

3. Surface-reflected solar radiation, attenuated by molecules and aerosols along the total path ($\overline{SP} + \overline{PV}$).

B. With Clouds

(Highest cloud tops are at or below Point C at 12-km altitude. The first three processes below are weighted by the probability the line-of-sight along \overline{VC} intercepts clouds.)

1. Air emission between V and C, attenuated by molecules and aerosols.
2. Surface emission from cloud tops at or below 12 km, attenuated by molecules and aerosols along \overline{CV} .
3. Cloud-reflected solar radiation, attenuated by molecules and aerosols along the total path ($\overline{SC} + \overline{CV}$).
4. Processes 1 and 2 from the no-cloud case, weighted by the probability of a one-leg cloud-free line-of-sight along \overline{VP} .
5. Process 3 from the no-cloud case, weighted by the probability of a two-leg cloud-free path along the broken path ($\overline{VP} + \overline{PS}$).

In view of the above-listed contributions to the radiance, it is easy to recognize the need for integrating so many models into the NBR Module. Five of these models, as indicated in Table 1-1, have been reported in other volumes. The remaining four models are documented in this volume. To this documentation we first provide an overall guide, followed by more detailed descriptions.

The Earth Surface Characterization Model is described in Sections 2 and 3. Section 2 contains general information and details for non-water surfaces; the details for water surfaces are given in Section 3. The Solar Radiation Model is described in Section 4 and the Earth Surface Radiance Model in Section 5. In terms of such models, the Upwelling Natural Radiation Model is presented in Section 6 and overall coding information for the stand-alone NBR Module in Section 7.

In Sections 2 and 3 we present the ROSCOE-IR model (23a) for the Earth surface characterization, in the spectral range from 2 to 5 μm (or 5,000 to 2,000 cm^{-1}). The principal routine in the model is Subroutine ESURF which

(with auxiliary routines for water surfaces) provides the (1) monochromatic bidirectional reflectance-distribution function (BRDF), monochromatic directional emissivity, and (3) temperature of the Earth's surface at the intersection point of the optical line-of-sight. Since the surface category is not automatically correlated with the geographic position, the user must select one of the seven categories provided plus an associated descriptor where appropriate: (1) Lambertian surface (and diffuse reflectance), (2) water (and wind speed), (3) snow (and its age-parameter), (4) sand, (5) soil, (6) foliage, and (7) urban material (and degree-of-urbanization parameter). The user calls Subroutine ESURF with the zenith angle of the solar ray at the intersection point, the direction of the detector at the intersection point (specified by the zenith angle and the azimuth angle relative to the principal plane of the solar ray), the altitude at the intersection point, the surface material (and associated descriptor) at the intersection point, and the wavelength.

The BRDF for each of the surfaces (except water) is computed from an invented analytic expression containing spectral and directional parameters which have been fitted to the (meager) available data, presented in Section 2. Also presented are derivations of directional-hemispherical reflectance from the BRDF and the directional emissivity.

For a water surface, Subroutine ESURF calls Subroutine GLITTR to obtain the BRDF and directional emissivity. Subroutine GLITTR, its auxiliary routines, and the underlying model for the glitter from a wind-ruffled water surface are described in Section 3. The model is based largely on the work of Cox and Munk [CM-54], including (1) the basic equation relating the glitter radiance to the wave-facet slope-probability distribution, (2) a two-dimensional isotropic normal distribution for the slope-probability distribution, and (3) a linear relation between the slope variance and the wind speed. Modifications and extensions of the Cox-Munk work include (1) using the Levanon-derived [Le-71b] equations for the slope and angle of incidence required at a viewed point to provide a glint, in terms of the position of an arbitrary-altitude detector viewing a spherical Earth, instead of the equations for a flat Earth as (appropriately) used by Cox and Munk, (2) evaluating the Fresnel equations for the specular reflectance in terms of the complex

index of refraction of water for the 2- to 5- μm region, instead of the visible region, (3) incorporating a shadowing factor (based on the work of Saunders [Sa-67, Sa-67a, Sa-68c] but extended to permit a "bistatic" dependence on the zenith angles of both the incoming and outgoing rays) which multiplies the slope probability distribution and takes account of shadowing of some slopes by others for illuminating and viewing near the horizon, and (4) providing a solution (by iteration) for the location of the specular reflectance point on a spherical-Earth water surface that is smooth for zero wind speed. The directional emissivity of the wind-ruffled water surface is approximated by that for a smooth water surface owing to the complex geometry which prevents analytically integrating the BRDF over a hemisphere.

In Section 4 we present the ROSCOE-IR model (23e) for the solar spectral irradiance at the top of the atmosphere, in the spectral range from 2 to 5 μm . The input data to the model, taken to be the NASA data adopted by the American Society of Testing and Materials, have been fitted by piecewise-continuous power-law expressions. The model may be called with either wavelength (μm) or wavenumber (cm^{-1}) and an index which selects the output spectral irradiance in any of four forms. Therein are presented derivations and a flow diagram of Subroutine SOLRAD.

In Section 5 we present the ROSCOE-IR model (23b) for the Earth surface radiance. The model provides two components of the radiance directed along the path $\vec{P}\vec{V}$ in Figure 1-1: (1) thermal radiation emitted at Point P and (2) solar radiation reflected at Point P. Strictly, the surface-reflected solar radiation is actually provided in an unattenuated form with the path parameters required as part of the input to a later computation of the molecular absorption over the total two-leg path ($\vec{S}\vec{P} + \vec{P}\vec{V}$). The aerosol transmittance along the incoming path $\vec{S}\vec{P}$ is also provided. The principal routine in the model, Subroutine SURRAD, and its auxiliary geometry routine (Subroutine RINOUT) are described, including derivations of the zenith angle of the sun (θ_s), zenith angle of the detector (θ_d), and azimuth angle of the solar ray reflected toward the detector (ψ). We also provide detailed summaries of the inputs and outputs for the routines developed by other organizations (G.E. Tempo and Visidyne, Inc.) which we use to complete the model.

Subroutine SURRAD also provides for natural clouds if they are included in the calculation. While clouds are not strictly an Earth-surface feature, the treatment of the two components of the radiance along the path \vec{CV} in Figure 1-1, resulting from cloud tops (the highest of which is 12 km in the Natural Cloud Model and shown as Point C in Figure 1-1), is analogous to that for Point P and thus is appropriately included.

The ROSCOE-IR model (23e) for the upwelling natural radiation is presented in Section 6. This model evaluates the mean upwelling spectral radiance at Point V (in Figure 1-1) by averaging the radiance over the solid angle (Ω_T) defined by the cone with vertex at Point V and tangent to the Earth's surface. In practice, we average the set of radiances received at Point V by viewing (in the absence of clouds) a set of characteristic Points P on the Earth's surface and within Ω_T . The Points P are selected in terms of a set of angles (θ) measured from the nadir and a set of azimuth angles (ϕ) for each nadir angle. The results from the Earth Surface Radiance Model for each Point P are augmented by computing (1) the air emission along the path \vec{PV} , (2) the molecular path parameters along \vec{PV} , (3) the total path parameters along $(\vec{SP} + \vec{PV})$ by adding those for \vec{SP} and \vec{PV} , (4) the molecular transmittance for the path \vec{PV} and for the total path $(\vec{SP} + \vec{PV})$, and (5) the aerosol transmittance for the path \vec{PV} and the total path $(\vec{SP} + \vec{PV})$.

The inclusion of the statistical submodel of the Natural Cloud Model complicates the modeling. Now, for each Point C there is a distribution of radiance values corresponding to the 159 sets of three-layer cloud configurations. Details are given in Section 6.

The principal routine in the Upwelling Natural Radiation Model is Subroutine UPWELL; it is lengthy, with 20 pages of FORTRAN. In Section 6 we present formulas for the geometry involved, the radiance computed, a detailed summary of the calculational steps, and a detailed summary of the input and output variables.

In Section 6 we also provide detailed summaries of the input and output variables for all the auxiliary routines which are called by Subroutine

UPWELL but which are not so documented elsewhere. These routines include a number prepared by SAI and three important ones (Subroutines TRNSCO, ATMRAD, and TRANS) prepared by G.E. Tempo.

In Section 7 we provide general coding information for the NBR Module, including that required for the stand-alone version. We identify all of the (66 non-DSA) routines in the NBR Module and provide a chart showing their calling-structure relationships. For each of these routines we also state (1) the function it performs, (2) its originator, (3) the location of a listing of the routine, and (for 27 routines) (4) the number of the table in this volume which states in detail the inputs and outputs of the routine. For common blocks we provide (1) a matrix showing routines and the 35 common blocks appearing in them and (2) either definitions of all the variables in the common block and where the variables are set or a specific reference where the definitions are given.

The NBR Module in its stand-alone version is driven by Program DRVUPW (11 pages of FORTRAN). For this program we describe in Section 7 the calculational steps required in both the initialization and operation phases. During the initialization, calls are made to QINITL (for the DSA routines), ATMOSU (for the ambient atmosphere depending on time and location), CLOUDO (for cloud properties), TRANSB (for molecular band-model parameters for transmittance), and SHELLS (for atmospheric grid). During operation, calls are made to SETALT (to determine the altitudes (depending on wavelengths of interest) at which Subroutine UPWELL is to compute the upwelling natural background radiation) and UPWELL. Our development of Subroutine SETALT is described. Summaries of input and output variables are provided for Subroutine SETALT and the G.E. Tempo routines TRANSB and SHELLS.

Finally, in Section 7, we provide some comments on the integration of the NBR Module into ROSCOE-IR, including some of the differences between the stand-alone version and that in ROSCOE-IR. In particular, we summarize the inputs and outputs of Subroutine UPWELL, prepared by GRC, to select the appropriate wavenumber interval and to interpolate in altitude the upwelling natural radiation array.

In Section 8 we provide a listing of those (37) routines in the NBR Module which are not listed elsewhere (at least not as we are using them). These include 19 SAI routines, 17 G.E. Tempo routines, and 1 Visidyne, Inc. routine.

SECTION 2

EARTH SURFACE CHARACTERIZATION: GENERAL AND NON-WATER SURFACES

2-1 INTRODUCTION AND SUMMARY

2-1.1 Requirements for the Model

The characterization of the Earth's surface is required for input to the Earth Surface Radiance Model (23b) and the Upwelling Natural Radiation Model (23c) via Model 23b. For the Earth Surface Radiance Model, Model 23a is required to provide the reflectance, emittance, and temperature of the Earth's surface at the point (P) where the optical line-of-sight intersects the Earth's surface, including directional effects as necessary. For the Upwelling Natural Radiation Model, Model 23a is required to provide the average characteristics (i.e., reflectance, emittance, and temperature) of that portion of the Earth's surface that could be viewed from an altitude of interest.

2-1.2 Approach

The reflectance and emittance properties of the Earth's surface are controlled mainly by composition and to a lesser extent by surface roughness. Since the composition and roughness of the Earth's surface can vary markedly from point to point, so can its optical properties. A useful summary of the reflectance data for the Earth's surface features was prepared by Bartman in his thesis [Ba-67b]; this summary has been reproduced by Kondratyev [Ko-72d] and is shown here as Table 2-1. This table is of general interest for us even though Bartman and Kondratyev were mainly interested in the Earth's total albedo for solar radiation and hence emphasized the visible spectral region.

It has been agreed to represent the Earth's surface in a relatively simple way, yet one which provides a range of reflectance, emittance, and temperature values. The general procedure is to provide for six categories of the Earth's surface: water, snow, sand, soil, foliage, and urban material.

Table 2-1. Summary of reflectance data for the Earth's surface features.
(Reproduced from Ko-72d; originally prepared by Bartman [Ba-67b].)

Surface	Spectral characteristics	Angular distribution of reflectance	Total reflectance
Soils and rocks	<ol style="list-style-type: none"> 1. Increasing to 1 micron 2. Decreasing above 2 microns 3. Moisture decreases reflectance 	<ol style="list-style-type: none"> 1. Backscattering and forward scattering 2. Sand has large forward scattering 3. Loam has small forward scattering 	<ol style="list-style-type: none"> 1. 5-25% 2. Moisture decreases reflectance by 5-20% 3. Smooth surfaces have higher reflectance 4. Diurnal variation; maximum reflectance for small sun angles
Vegetation	<ol style="list-style-type: none"> 1. Small (below 0.5 micron) 2. A small maximum bump at 0.5 to 0.55 micron 3. Chlorophyll absorption at 0.68 micron 4. Sharp increase at 0.7 micron 5. Decrease above 2 microns 6. Depends on growing season 	<ol style="list-style-type: none"> 1. Backscattering 2. Small forward scattering 	<ol style="list-style-type: none"> 1. 5-25% 2. Diurnal effects; maximum reflectance for small angles 3. Marked annual variation
Water basins	<ol style="list-style-type: none"> 1. Maximum at 0.5-0.7 micron 2. Depends on turbidity and waves 	<ol style="list-style-type: none"> 1. Large back and forward scattering 	<ol style="list-style-type: none"> 1. Small reflectance 2. Diurnal variation; maximum for small sun angles 3. Depends on turbidity and waves
Snow and ice	<ol style="list-style-type: none"> 1. Decreases slightly with increasing wavelength 2. Large variability depending on purity, wetness, physical condition 	<ol style="list-style-type: none"> 1. Diffuse component plus mirror component 2. Mirror component increases with increasing angle of incidence 	<ol style="list-style-type: none"> 1. Variable; 25-80% 2. 84% in Antarctic 3. 74% Ross Sea ice 4. 30-40% White Sea ice

For each category the reflectance and emittance have been chosen to be representative of the average value for that category. The chosen values are based on those we have been able to find in the literature so far; one should remain alert to possibly finding improved values. There is no automatic correlation between geographic position and surface category. However, the user could, in principle, place different surfaces as he desires in a given scene when he wants to address surface boundary problems, but the necessary coding has not been implemented. For test and possibly other purposes, we also provide for a Lambertian surface with a user-defined value of the diffuse reflectance.

A review of the literature has convinced the writer that most materials have a strong non-diffuse character. To take account of the non-diffuseness, we postulate a general expression for the bidirectional reflectance-

distribution function (frequently referred to as BRDF) with several parameters that are evaluated on the basis of whatever experimental data are available. (The reader unfamiliar with the quantity we call the BRDF - which has many aliases, including partial reflectance or reflectance-distribution function - may want to refer to the discussions by Wolfe [Wo-65a, pp. 23-28] or by Nicodemus [Ni-65c, Ni-70d, Ni-76].)

Having determined the BRDF for a material, one can then integrate the BRDF over a hemisphere to obtain the directional-hemispherical reflectance (which is equal to the hemispherical-directional reflectance) and thus obtain the directional emissivity for the material by applying Kirchhoff's law [Ni-70d].

2-1.3 The Bidirectional Reflectance-Distribution Function (BRDF)

We follow the recommendation of Nicodemus [Ni-70d] and use the symbol f_r to represent the BRDF, which has the units of sr^{-1} . The general form we propose for the BRDF is

$$f_r = f_r[m, D(m), \lambda; \theta_i, \theta_r, \psi], m \geq 2$$

$$= \rho_{0m}(\lambda) \left\{ 1 + R_m(\psi) \exp(-\alpha_m[(\cos \theta_i)^m + (\cos \theta_r)^m] + s_m(1 - (1 - 2/\pi))) \right\}, \text{sr}^{-1} \quad (1)$$

where

$$R_m(\psi) = R_m(0) - [R_m(0) - R_m(\pi)]\psi/\pi. \quad (2)$$

For the Lambertian surface ($m=1$), the BRDF is a constant, given by

$$f_r = \rho_{01}(\lambda) \quad (1')$$

with

$$R_1(0) = R_1(\pi) = 0. \quad (2')$$

In Equation (1), the symbols have the following meanings.

- m - Index for category of surface material.
- $D(m)$ - Additional descriptor available for the m th material, if needed. For brevity, we will frequently suppress $D(m)$ as an explicit argument.
- λ - Wavelength (μm).
- θ_i - Zenith angle of sun at intersection point (P).
- θ_r - Zenith angle of detector at intersection point (P).
- ψ - Azimuth angle (at intersection point (P)) of vertical plane through line-of-sight, measured relative to the solar principal plane (i.e., vertical plane through the source ray). Values of zero and π for ψ correspond to forward and backward scattering, respectively.

There are six parameters - $\rho_{om}(\lambda)$, $R_m(0)$, $R_m(\pi)$, α_m , β_m , and γ_m - characterizing a material, according to our Equation (1). Note that all of the spectral dependence of the reflectance is contained in the parameter $\rho_{om}(\lambda)$, which has no directional dependence; i.e., we assume that the spectral and directional properties are separable. The parameters $R_m(0)$ and $R_m(\pi)$, together with α_m and γ_m , control the forward and backward reflection in the principal plane; the parameter β_m controls the scattering away from the principal plane.

In addition to the separability of the spectral and directional properties, our expression for the BRDF has two other important properties. The more important of these is that Equation (1) satisfies the Helmholtz reciprocity theorem [Ni-65c] according to which f_r must be invariant to an interchange of the incident and reflected rays. The third principal property of Equation (1) is that f_r is integrable over a hemisphere provided γ_m equals 1 or 2. Whereas we have imposed this restriction in the determination of the other

parameters, we recognize in retrospect that this requirement could probably be relaxed for practical applications in which the quality of the fits to experimental data might be improved if r_m had other values. We do not claim uniqueness for Equation (1), but it is the only expression of its kind of which we are aware. Further thought - with more trials and errors - may lead to a better expression.

Finally, we mention an odd property of our BRDF which is not of much practical consequence but which may be a small wonderment. This property is that, for $\theta_i = \theta_r = 0$ (i.e., normal incidence and reflection), f_r as given by Equation (1) is multivalued in that it depends on the value of ψ . Of course, physically we expect a single value. Our practical solution to this problem, for $\theta_i = \theta_r = 0$, is simply to define f_r to be the value obtained by averaging $f_r(0,0,\psi)$ over ψ , i.e.,

$$f_r|_{\theta_i = \theta_r = 0} = \langle f_r(0,0,\psi) \rangle. \quad (3)$$

From the integrations presented in Section 2-4 we show that

$$\langle f_r(0,0,\psi) \rangle = \rho_{0m} [1 + e^{-2\alpha_m} \bar{R}_m P_1(\alpha_m \beta_m)] \quad (3a)$$

where

$$\bar{R}_m = [R_m(0) + R_m(\pi)]/2 \quad (4a)$$

$$P_1(a) = \int_0^1 dx e^{-ax} = \frac{1}{a} (1 - e^{-a}). \quad (4b)$$

2-1.4 The Directional-Hemispherical Reflectance

The spectral, directional-hemispherical reflectance, denoted here by $\rho_m(\lambda; \theta_i, 2\pi)$, is defined [Ni-65c, Wo-65a] by the integral

$$\rho_m(\lambda; \theta_i, 2\pi) = \int f_r \cos \theta_r d\Omega_r \quad (5)$$

where

$$d\Omega_r = \sin \theta_r d\psi_r d\theta_r. \quad (5a)$$

In Section 2-4 we show that the result of the integration, when Equation (1) is used for f_r , is

$$\rho_m(\lambda; \theta_i, 2\pi) = \pi \rho_{0m}(\lambda) G(\alpha_m, \beta_m, \gamma_m; \theta_i), \quad m \geq 2 \quad (6)$$

with

$$G(\alpha_m, \beta_m, \gamma_m; \theta_i) = 1 + 2 P_1(\alpha_m \beta_m) P_{2\gamma_m}(\alpha_m) R_m F_{\gamma_m}(\alpha_m, \theta_i) \quad (7)$$

$$P_{21}(a) = \int_0^1 dx x e^{-ax} = \frac{1}{a^2} [1 - e^{-a(a+1)}] \quad (8)$$

$$P_{22}(a) = \int_0^1 dx x e^{-ax^2} = \frac{1}{2a} (1 - e^{-a}) \quad (9)$$

$$F_{\gamma_m}(a, \theta) = \exp[-a(\cos \theta)^{\gamma_m}]. \quad (10)$$

For a Lambertian surface ($m=1$),

$$\rho_1(\lambda; \theta_i, 2\pi) = \pi \rho_{01}(\lambda). \quad (6')$$

If the spectral directional-hemispherical reflectance, $\rho_m(\lambda; \theta_i, 2\pi)$, for a material is known from experiment for at least one value of θ_i and if the five directional parameters α_m , β_m , γ_m , $R_m(0)$, and $R_m(\pi)$ are known, then

our spectral parameter $\rho_{om}(\lambda)$ in Equation (1) can be determined from Equation (6) evaluated at the given θ_i . In practice, the directional-hemispherical reflectance is frequently measured for a direction at or near normal incidence. In this case, for at least the materials we have examined, the quantity $G(\alpha_m, \beta_m, \gamma_m; \theta_i=0)$ - which is a measure of the departure of the BRDF from a constant, as it would be for a diffuse reflector - differs from unity by only a few percent (9.5% in one case). Thus, in practice, it would be a good approximation to simply evaluate $\rho_{om}(\lambda)$ by the relation

$$\rho_{om}(\lambda) \approx \pi^{-1} \rho_m(\lambda; \theta_i=0, 2\pi); \quad (11)$$

however, for self-consistency, to get $\rho_{om}(\lambda)$ we have used Equation (6) evaluated at $\theta_i=0$ with $\rho_m(\lambda; \theta_i=0, 2\pi)$ given by (meager) experimental data, i.e., we have used

$$\rho_{om}(\lambda) = \frac{\rho_m(\lambda; \theta_i=0, 2\pi)}{\pi G(\alpha_m, \beta_m, \gamma_m; \theta_i=0)}, \quad m \geq 2 \quad (6'')$$

2-1.5 The Directional Emissivity

The directional emissivity, ϵ_d , for material m , at a zenith angle θ , is [Ni-65c, Ni-70d]

$$\epsilon_d \equiv \epsilon_d(m, \lambda, \theta) = 1 - \rho_m(\lambda; \theta, 2\pi) \quad (12)$$

where the directional-hemispherical reflectance $\rho_m(\lambda; \theta, 2\pi)$ is given by Equation (5) in general and by Equation (6) when our f_r (Equation (1)) is used in Equation (5). For a Lambertian surface ($m=1$),

$$\epsilon_d(1, \lambda, \theta) = 1 - \rho_1(\lambda; \theta, 2\pi) = 1 - \pi \rho_{01}(\lambda). \quad (12')$$

For urban material ($m=7$), see Section 2-3.5.2 for the special form appropriate for urban geometry.

2-1.6 Summary of Parameters for the BRDF

A perusal of the literature, including the putative extensive NASA data base [LE-71a, LE-72c], has so far revealed very few photometric data of the type desired, i.e., bidirectional spectral reflectance data in the 2- to 5- μ m region. The data available typically are broad-band and usually include the visible region. Bidirectionality is usually lost in that the data are usually for hemispherical-directional or hemispherical-hemispherical conditions. Where there are spectral data of interest, the directional data are lacking; similarly, where there are directional data, the spectral region or resolution is wrong. Where the data are taken under field conditions, not only the sun but the sky radiance is mixed in.

Despite these difficulties, however, we have boldly arrived at the values for the parameters, recorded in Tables 2-2a and 2-3. The details of the derivation of these parameters are given in Sections 2-2 and 2-3.

In Table 2-2b, we present the azimuthal dependence of f_r for $\theta_i = \theta_r = 0$, as well as $\langle f_r(0,0,\psi) \rangle$.

2-1.7 Surface Temperature

The remaining required specification, surface temperature, may be chosen to be equal to the ambient air temperature at the Earth's surface. This assumption is reasonably correct for all cases at night, and for water, snow, and foliated surfaces during the day. This assumption leads to significantly low surface temperatures for other surfaces (barren soil, sand, and urban materials) during periods of solar illumination. However, because of the complexity of modeling this phenomenon, and the fact that the natural Earth surface radiance is only a baseline for nuclear effects, use of the ambient air temperature as the surface temperature is currently recommended; however, consideration should be given later (if resources permit) to developing a better prescription for the surface temperature.

Table 2-2a. Spectral and directional parameters for characterization of the BRDF for Earth surface materials.*

Material	m	D(m)	Spectral		Directional				
			$P_{om}(\lambda)$	α_m	β_m	γ_m	$R_m(0)$	$R_m(\pi)$	\bar{R}_m
Lambertian	1	a	$D(1)/\pi$	-	-	-	0	0	0
Water	2	b	f	-	-	-	-	-	-
Snow	3	c	g	3	0.9	1	13	3	8
Sand	4	d	h	3	0.5	1	2.5	4	3.25
Soil	5	d	i	2.5	0.5	2	1	4	2.5
Vegetation	6	d	j	2.5	0.5	2	1	10	5.5
Urban Materials	7	e	k	4	0.5	2	10.5	1	5.75

Directional (continued)					
Material	m	$P_1(\alpha_m, \beta_m)$	$P_{2\gamma_m}(\alpha_m)$	$F_{\gamma_m}(\alpha_m, 0)$	$G(\alpha_m, \beta_m, \gamma_m; 0)$
Lambertian	1	-	-	-	1.00
Water	2	-	-	-	-
Snow	3	.345	.0890	.0498	1.024
Sand	4	.518	.0890	.0498	1.015
Soil	5	.571	.184	.0821	1.043
Vegetation	6	.571	.184	.0821	1.095
Urban Materials	7	.432	.123	.0183	1.011

*Footnotes are on the following page.

Footnotes for Table 2-2a.

-
- ^a $D(1)$ is the diffuse reflectance ($\rho_1 = \pi\rho_{01}$) for a Lambertian surface. A typical value is 0.1.
- ^b $D(2)$ is the wind speed, $0 \leq D(2)$, m/sec.
- ^c $D(3)$ is the snow-age parameter, $0 \leq D(3) \leq 1$. Values of zero and one correspond to new and old snow, respectively.
- ^d Not used.
- ^e $D(7)$ is the degree-of-urbanization factor, $0 \leq D(7) \leq 1$. A value of zero for $D(7)$ provides a spectral-dependent BRDF corresponding to a flat surface with directional reflectance properties equal to the average for concrete and asphalt. A value of one for $D(7)$ provides a spectral-dependent BRDF corresponding to a diffuse reflector but modified by a shadow factor $S(\theta_i, \theta_r) = (\cos \theta_i + \cos \theta_r)/2$.
- ^f See Section 3 for treatment of water.
- ^g Evaluated from Equation (6'') with ρ_3 given in Table 2-3 by a formula with dependence on the snow-age parameter, $D(3)$.
- ^h Evaluated from Equation (6'') with ρ_4 , given in Table 2-3, being the average value for natural gypsum sand [Ho-66, Figure 10] and Russian sand [Kropotkin (1964) per Ba-67b, Figure 82].
- ⁱ Evaluated from Equation (6'') with ρ_5 , given in Table 2-3, being the average value for topsoil [RH-73, p. 15-20], Pawnee Grassland soil [Ho-66, Figure 9], and Russian soil [Kropotkin (1964) per Ba-67b, Figure 82].
- ^j Evaluated from Equation (6'') with ρ_6 , given in Table 2-3, based on data provided by D.C. Anding, said to be an average of many values in LE-71a for $2.0 \leq (\mu m) \leq 2.5$ and estimated for $2.5 < \lambda(\mu m) \leq 5$.
- ^k Evaluated from Equation (6'') with ρ_7 , given in Table 2-3, being the average value for Russian asphalt, asphaltic material [Wo-65a, Figure 4-23], Russian (red) brick, and Russian concrete. Russian data are given by Kropotkin (1964) per Ba-67b, Figure 82.
-

Table 2-2b. $\langle f_r(0,0,\psi) \rangle$ and azimuthal dependence of $f_r(0,0,\psi)$.

m	$\rho_0^{-1} f_r(0,0,0)$	$\rho_0^{-1} f_r(0,0,\pi/2)$	$\rho_0^{-1} f_r(0,0,\pi)$	$\rho_0^{-1} \langle f_r(0,0,\psi) \rangle$
3	1.032	1.0013	1.0074	1.0068
4	1.0062	1.0018	1.0099	1.0042
5	1.0067	1.0048	1.027	1.0096
6	1.0067	1.011	1.067	1.021
7	1.0035	1.00026	1.00034	1.00083

Table 2-3. Normal-incidence--hemispherical reflectance for Earth surface materials.

Snow			
$\rho_3 = [0.44 - 0.12 (\lambda - 2)] [1 - (5/12) D(3)]$			
Soil			
$\lambda, \mu\text{m}$	ρ_5	$\lambda, \mu\text{m}$	ρ_5
2.00	0.262	3.15	0.067
2.08	.272	3.50	.112
2.25	.257	3.70	.158
2.50	.227	3.82	.177
2.62	.198	4.10	.195
2.70	.095	4.60	.158
2.77	.067	4.77	.142
2.92	0.061	5.00	0.113
Sand			
$\lambda, \mu\text{m}$	ρ_4	$\lambda, \mu\text{m}$	ρ_4
2.00	0.205	2.95	0.040
2.05	.238	3.20	.070
2.18	.209	3.30	.093
2.30	.206	3.60	.145
2.45	.177	3.75	.162
2.50	.174	3.90	.152
2.63	.148	4.35	.076
2.73	.114	4.90	.031
2.88	0.080	5.00	0.035
Vegetation			
$\lambda, \mu\text{m}$	ρ_6	$\lambda, \mu\text{m}$	ρ_6
2.00	0.129	3.16	0.033
2.20	.212	3.22	.033
2.64	.059	3.42	.074
2.78	.059	3.58	.074
2.96	.120	3.95	.037
3.03	0.120	5.00	0.021

(continued)

Table 2-3. Normal-incidence--hemispherical reflectance for Earth surface materials^a (Cont'd).

Urban Materials					
$\lambda, \mu\text{m}$	ρ_7	$\lambda, \mu\text{m}$	ρ_7	$\lambda, \mu\text{m}$	ρ_7
2.00	0.347	2.70	0.272	4.00	0.231
2.12	.348	2.85	.145	4.10	.238
2.24	.326	2.89	.118	4.26	.240
2.26	.278	3.00	.090	4.42	.254
2.36	.272	3.10	.091	4.70	.246
2.47	.295	3.24	.100	4.83	.229
2.55	.299	3.62	.149	5.00	0.215
2.63	0.296	3.89	0.193		

^aIn this table, for brevity, we use the notation $\rho_m \equiv \rho_m(\lambda, 0, 2\pi)$ for the spectral, normal-incidence--hemispherical reflectance.

2-2 EVALUATION OF SPECTRAL DATA FOR THE BRDF

2-2.1 Snow

For snow, we have found very limited spectral reflectance data in the 2- to 5- μm region, although there are considerable spectral data in the visible region [Ko-73a, pp. 227-229, 231] and albedo data [Ko-72d]. Kondratyev [Ko-73a, p.234, Figure 4.12] reports spectral reflectance data for old snow for $\lambda \leq 2.5 \mu\text{m}$ and for fresh snow for $\lambda \leq 2.2 \mu\text{m}$; these values are much smaller than those we have adopted, taken from graphs given by Rose et al. [RA-73, Figures 37b, 37c] (or WZ-78, Figure 3-19) and attributed to Russian literature which we have not yet acquired for verification. The data from RA-73, which are limited to $\lambda \leq 4.0 \mu\text{m}$, are replotted in Figure 2-1 where they are extrapolated to 5 μm . By using the slopes of the curves in the 3- to 4- μm region, we have very well fitted the two curves by the single equation

$$\rho_3 = [0.44 - 0.12 (\lambda - 2)] [1 - (5/12) D(3)] \quad (13)$$

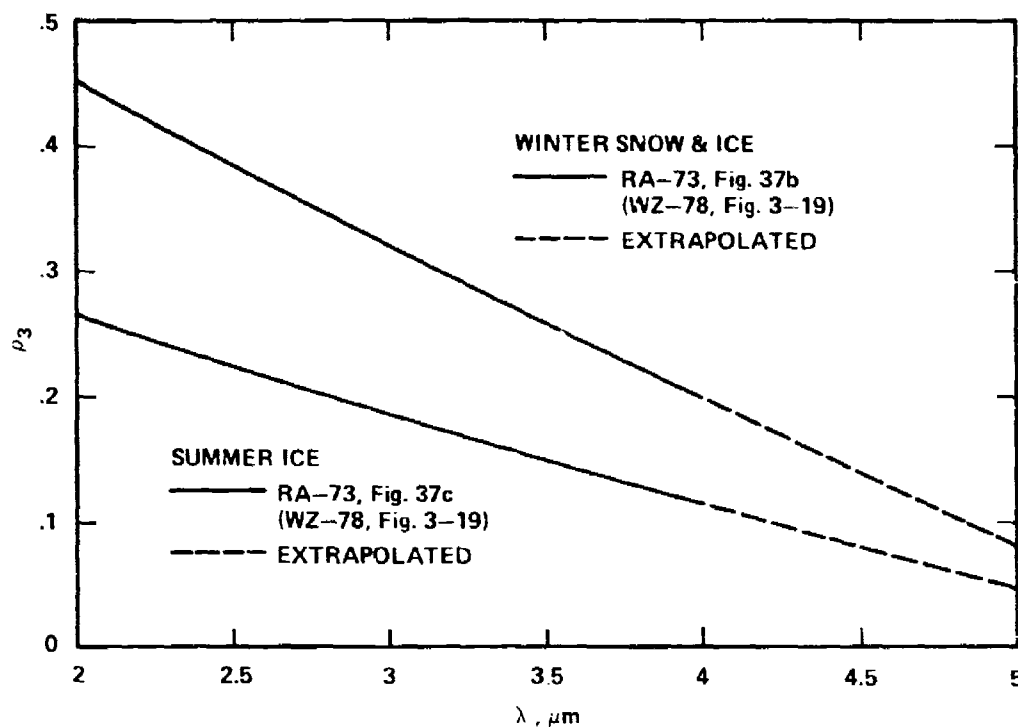


Figure 2-1. Spectral diffuse reflectance of winter snow and ice and summer ice (2 to 5 μm).

in which we have introduced the snow-age parameter $D(3)$ to which we assign the value of zero for winter snow and ice and the value of unity for summer ice. Intermediate curves can be interpolated by using intermediate values of $D(3)$, $0 \leq D(3) \leq 1.0$.

2-2.2 Sand

Hemispherical--normal-directional spectral reflectance data in the range $0.5 < \lambda(\mu\text{m}) \leq 6$ are given by Hovis [Ho-66] for pure silica sand, beach sands (from New Jersey and Florida) which are largely silica, and gypsum sand, common in much of the soil of the western United States, particularly in the sand of the White Sands National Monument in New Mexico. For gypsum sand, Hovis [Ho-66] shows reflectance data for samples of both its natural state and

partially dehydrated state. Spectral data for (Russian) sand, not otherwise identified, are given by Kropotkin [(1964), per Ba-67b, Figure 82]. The data from Kropotkin are reproduced as Figure 2-2. The results of digitizing the Hovis curve [Ho-66, Figure 10] for the natural-state gypsum sand and those for the Russian sand are given in Table 2-4; these data are plotted in Figure 2-3. The results of averaging the digitized data for the natural gypsum sand and the Russian sand are given in Table 2-3 and plotted as the dashed curve in Figure 2-3.

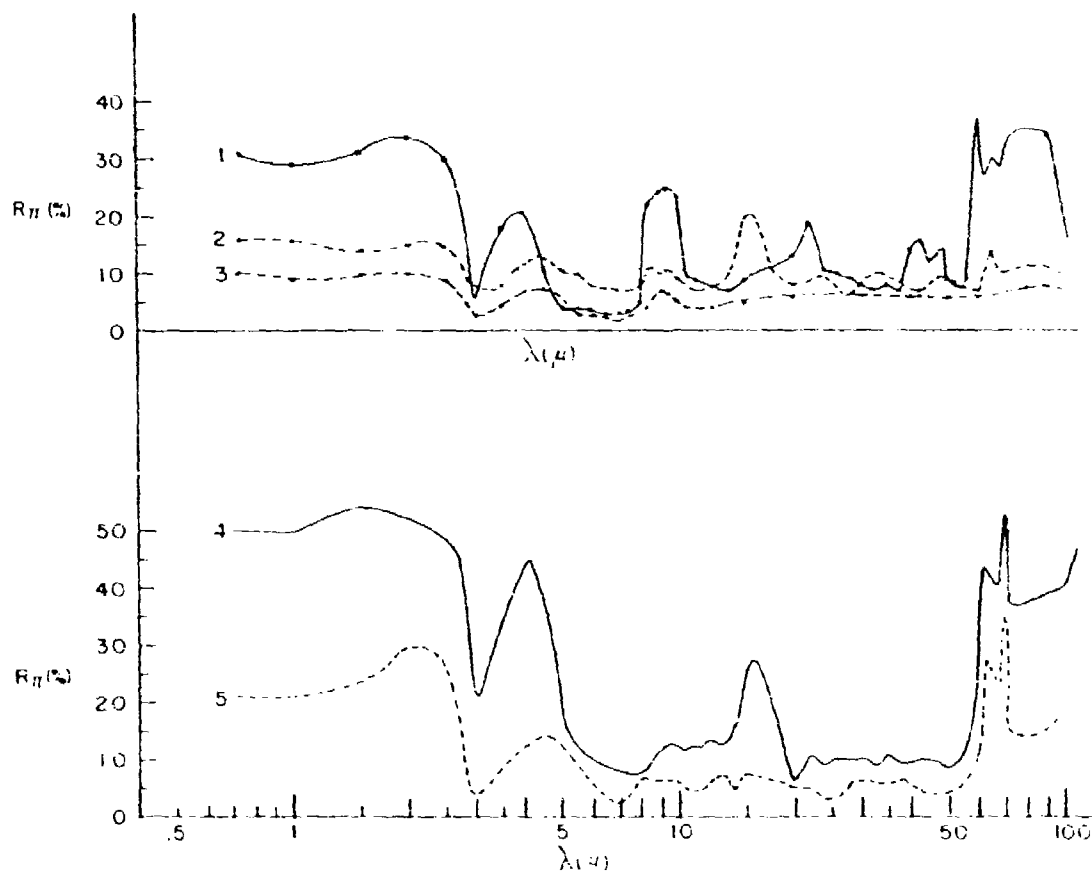


Figure 2-2. Spectral reflectance for (1) sand, (2) soil, (3) asphalt, (4) brick, and (5) concrete (after Kropotkin et al., per Ba-67b, Figure 82).

Table 2-4. Spectral reflectance of sand, ρ_4 .

Natural Gypsum Sand ^a		Russian Sand ^b	
$\lambda, \mu\text{m}$	ρ_4	$\lambda, \mu\text{m}$	ρ_4
2.00	0.07	2.00	0.34
2.05	.14	2.25	.325
2.18	.09	2.50	.30
2.30	.095	2.65	.25
2.45	.05	2.78	.20
2.63	.04	2.88	.15
2.73	.01	2.95	.06
2.87	.01	3.10	.10
2.95	.02	3.30	.15
3.20	.015	3.60	.20
3.75	.12	3.90	.21
4.35	.015	4.00	.20
4.80	.015	4.90	.04
5.00	0.03	5.00	0.04

^aHovis [Ho-66, Figure 10].

^bKropotkin (1964) [Ba-67b, Figure 82].

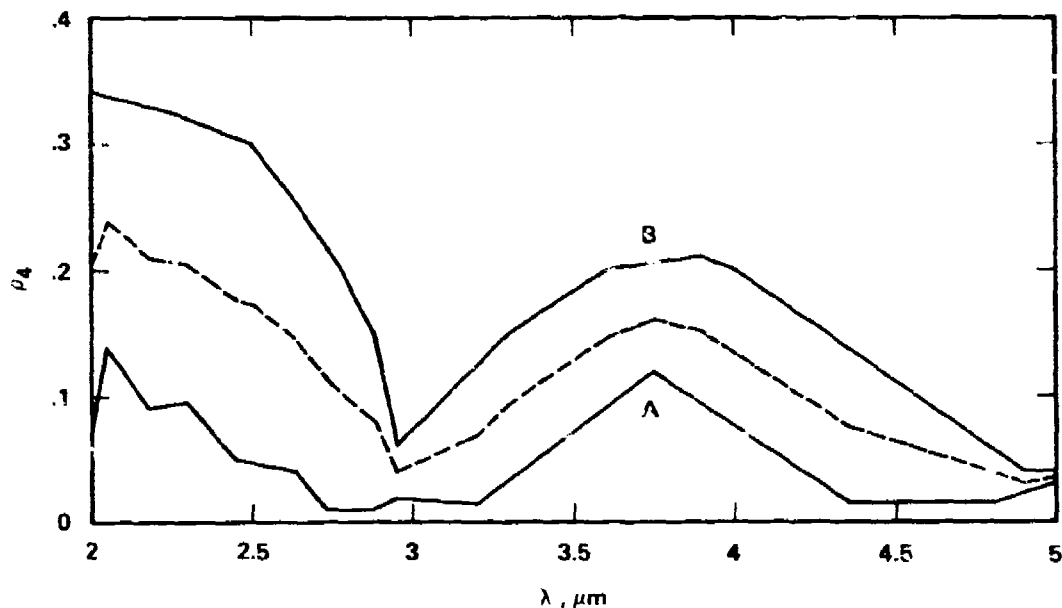


Figure 2-3. Spectral reflectance for sand, ρ_4 . Dashed curve is average of (A) natural gypsum sand [Hovis, Ho-66, Figure 10] and (B) Russian sand (Kropotkin (1964) per Bartman [Ba-67b, Figure 82]).

2-2.3 Soil

Hovis [Ho-66, Figure 9] presents the hemispherical--normal-directional reflectance of soil from the Pawnee Grassland area in Colorado. The results of digitizing the Hovis curve are given in Table 2-5 and plotted in Figure 2-4.

RH-73 (p. 15-20, Figure 10) presents the normal emittance of topsoil. The results of digitizing this curve and computing the normal reflectance are given in Table 2-5 and plotted in Figure 2-4.

Spectral data for (Russian) soil, not otherwise identified, are given by Kropotkin [(1964) per Ba-67b, Figure 82], reproduced here as Figure 2-2. The results of digitizing the Kropotkin curve are given in Table 2-5 and plotted in Figure 2-4.

The results of averaging the digitized data for the Pawnee Grassland soil [Ho-66], the topsoil reported in RH-73, and the Russian soil [Ba-67b] are given in Table 2-3 and plotted in Figure 2-4.

2-2.4 Vegetation

The following spectral reflectance data for vegetation were provided by D.C. Anding who says:

"Values of spectral diffuse reflectance of vegetation representing the averages for many types of vegetation were obtained. The data were taken from LE-71a for $\lambda \leq 2.5 \mu\text{m}$ for which the typical measurement procedure was to illuminate at normal incidence and collect hemispherical output. Values beyond $2.5 \mu\text{m}$ were estimated."

Table 2-5. Spectral reflectance of soil, ρ_5 .

Pawnee Grassland Soil ^a		Topsoil ^b		
$\lambda, \mu\text{m}$	ρ_5	$\lambda, \mu\text{m}$	ϵ_1	$1 - \epsilon_1 = \rho_5$
2.00	0.36	2.00	0.725	0.275
2.08	.395	2.50	.766	.234
2.62	.27	2.61	.800	.200
2.70	.045	2.77	.950	.050
3.15	.045	2.92	.950	.050
3.70	.22	3.15	.920	.080
4.10	.25	3.50	.910	.090
5.00	0.09	3.82	.810	.190
^a Hovis [Ho-66, Fig. 9]		4.15	.790	.210
		4.77	.825	.175
		5.00	0.860	0.140
		^b RH-73, p. 15-20, Fig. 10.		
Russian Soil ^c				
$\lambda, \mu\text{m}$	ρ_5			
2.00	0.150			
2.25	.160			
2.50	.150			
2.70	.125			
2.85	.090			
3.25	.075			
4.10	.130			
4.60	.130			
5.00	0.110			
^c Kropotkin (1964) [Ba-67b, Fig. 82]				

For $\lambda \leq 2.5 \mu\text{m}$, the data are the same as those given in Figure 37e of RA-73 (or Figure 3-19 of WZ-78); at longer wavelengths the curve in Figure 37e of RA-73 differs somewhat from the estimated data provided by Anding. The results of digitizing Anding's curve are given in Table 2-3 and plotted in Figure 2-5. Whereas we will use the curve in Figure 2-5, one should be alert for more specific data.

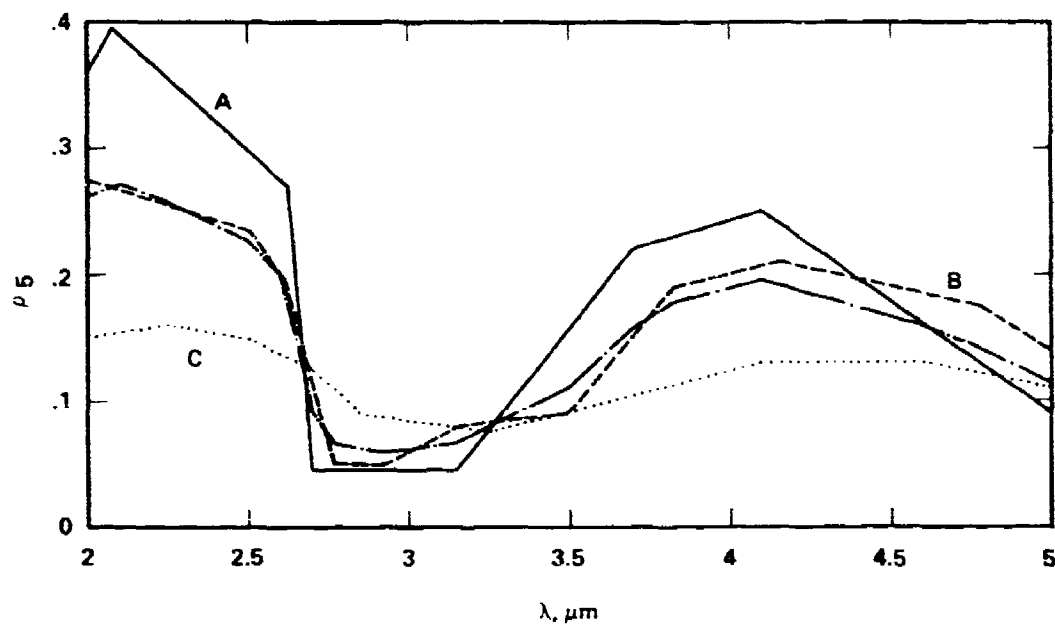


Figure 2-4. Spectral reflectance for soil, ρ_5 . Dash-dot curve is average of (A) Pawnee Grassland soil [Ho-66, Figure 9], (B) Topsoil [RH-73, p. 15-20, Figure 10], and (C) Russian soil [Kropotkin (1964) per Ba-67b, Figure 82].

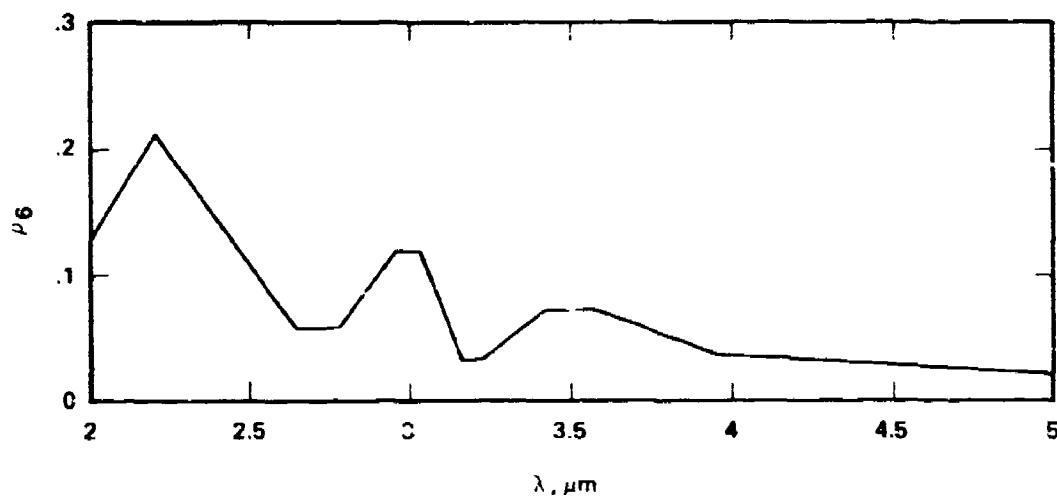


Figure 2-5. Spectral reflectance for vegetation, ρ_6 .

2-2.5 Urban Materials

Wolfe [Wo-65a, Figure 4-23] reports the spectral reflectance of asphaltic road material. The results of digitizing this curve are given in Table 2-6 and plotted in Figure 2-6.

Spectral reflectance data for (Russian) asphalt, brick, and concrete are given by Kropotkin [(1964) per Ba-67b, Figure 67b], reproduced here as Figure 2-2. The result of digitizing these curves are given in Table 2-6 and plotted in Figure 2-6.

The results of averaging the digitized data for the asphaltic road material [Wo-65a] and the Russian asphalt, brick, and concrete are given in Table 2-3 and plotted in Figure 2-6.

2-3 EVALUATION OF DIRECTIONAL DATA FOR THE BRDF

2-3.1 Snow

Salomonson and Marlatt [SM-68, SM-68a] have measured spectrally integrated values (0.55 to 0.85 μm and 0.2 to 4.0 μm) of the BRDF's for clouds, snow, and white gypsum sand. The ordinate in their Cartesian plots is actually π times the BRDF. The relative values of the ordinates on the curves for the 0.2- to 4.0- μm spectral interval have been digitized and they are given in Table 2-7.

The expression we have evaluated as the relative BRDF for snow is the ratio given by Equation (14),

$$F_r(\theta_i; \theta_r, \psi) \equiv \frac{f_r(\theta_i, \theta_r, \psi)}{f_r(\theta_i, \theta_r=0, \psi)}, \quad (14)$$

where $f_r(\theta_i, \theta_r, \psi)$ is given by Equation (1), with the five directional parameters (α_3 , β_3 , α_3 , $R_3(0)$, and $R_3(\pi)$) as given in Table 2-2a for $m=3$. We have

Table 2-6. Spectral reflectance of some urban materials, ρ_7 .

Asphaltic Road Material ^a		Asphalt ^b		Brick ^b		Concrete ^b					
$\lambda, \mu\text{m}$	ρ_7	$\lambda, \mu\text{m}$	ρ_7	$\lambda, \mu\text{m}$	ρ_7	$\lambda, \mu\text{m}$	ρ_7	$\lambda, \mu\text{m}$	ρ_7	$\lambda, \mu\text{m}$	ρ_7
2.00	0.462	2.00	0.100	2.00	0.525	2.00	0.300	2.65	0.200	4.30	0.140
2.12	.480	2.50	.090	2.30	.500	2.20	.300	2.85	.040	4.60	.140
2.24	.411	3.00	.025	2.50	.480	2.40	.275	3.10	.040	5.00	0.125
2.26	.226	4.00	.075	2.65	.465	2.55	0.250	3.60	0.100		
2.36	.226	4.60	.075	3.00	.220						
2.47	.346	5.00	0.060	3.10	.220						
2.63	.436			3.50	.350						
2.70	.436			4.00	.450						
2.89	.100			4.10	.450						
3.00	.074			4.60	.350						
3.15	.077			5.00	0.200						
3.24	.042										
3.38	.042										
3.62	.068										
3.89	.160										
4.00	.279										
4.26	.331										
4.42	.419										
4.62	.439										
4.70	.467										
4.83	.457										
5.00	0.476										

^aWolfe [Wo-65a, Figure 4-23, p. 83]

^bKropotkin [(1964), Ba-67b, Figure 82]

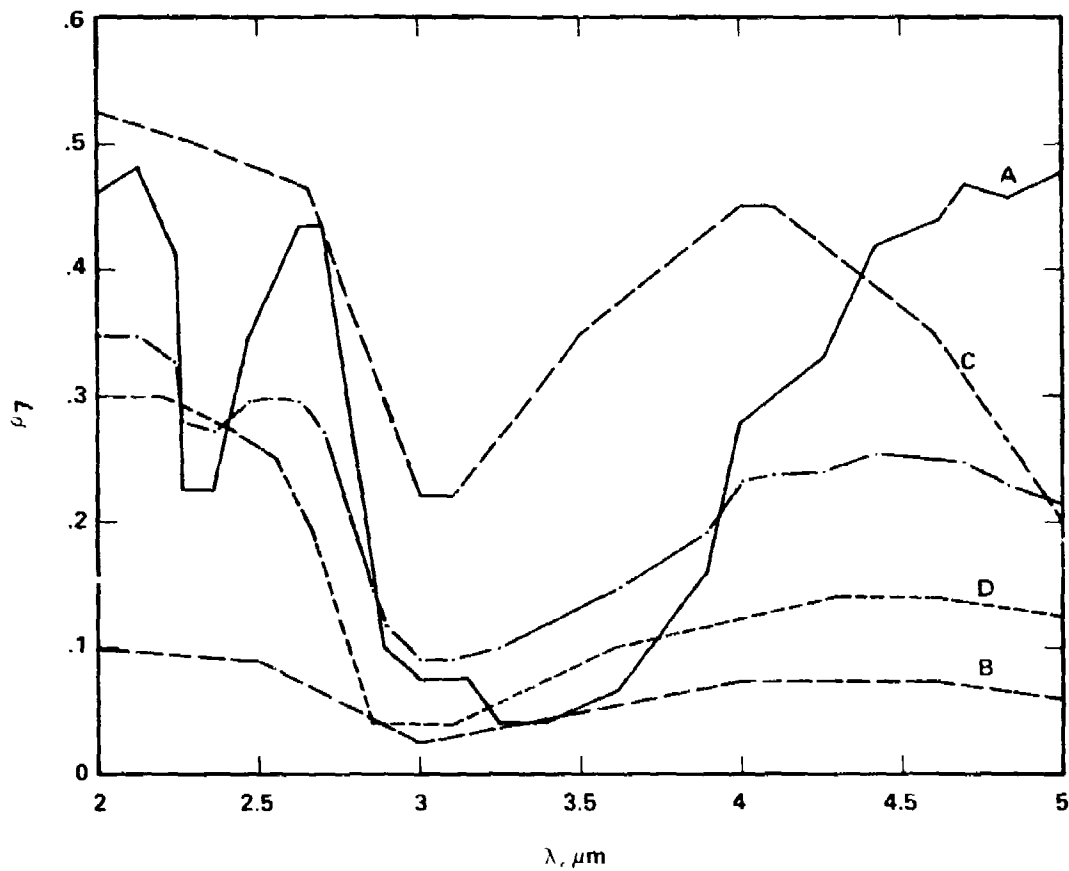


Figure 2-6. Spectral reflectance for urban materials, ρ_T . Dash-dot curve is average of (A) Asphaltic road material [Wo-65a, Figure 4-23, p. 83], (B) Asphalt [Kropotkin (1964) per Ba-67b, Figure 82], (C) Brick [Kropotkin (1964) per Ba-67b, Figure 82], and (D) Concrete [Kropotkin (1964) per Ba-67b, Figure 82].

plotted the results for the forward ($\psi=0$) and backward ($\psi=\pi$) directions as the set of continuous curves in Figure 2-7, with the lowest, middle, and highest portions corresponding to solar zenith angles (θ_i) of 64, 68, and 84 deg. The experimental values of SM-68 are also shown in Figure 2-7 for comparison.

Table 2.7. Relative directional reflectance of snow for solar zenith angles of $\theta_i = 64, 68, 84$ deg, in the spectral range of 0.2 to 4.0 μm .^a

Solar Zenith θ_i	Azimuth Angle ψ	Zenith Angle of Reflected Ray, θ_r			
		0	45	60	75
64	0	1.00	1.26	1.52	1.97
	180		1.03	1.12	1.19
68	0		1.21	1.48	2.36
	180		1.21	1.31	1.48
84	0		1.63	2.26	4.11
	180		1.01	1.34	1.94

^aValues inferred from Figures 16, 8, and 15 of Salomonson and Marlatt [SM-68].

2-3.2 Sand

Salomonson and Marlatt [SM-68] have also obtained results for white gypsum sand. The relative values of the ordinates on their curves for the 0.2- to 4.0- μm spectral interval have been digitized; they are given in Table 2-8.

The expression we have evaluated as the relative BRDF for sand is the ratio given by Equation (14) with the five directional parameters as given in Table 2-2a for $m=4$. We have plotted the results for the forward ($\psi=0$) and backward ($\psi=\pi$) directions as the set of continuous curves in Figure 2-8, with the lowest, middle, and highest portions corresponding to solar zenith angles (θ_i) of 21, 48, and 59 deg. The experimental values of SM-68 are also shown in Figure 2-8 for comparison.

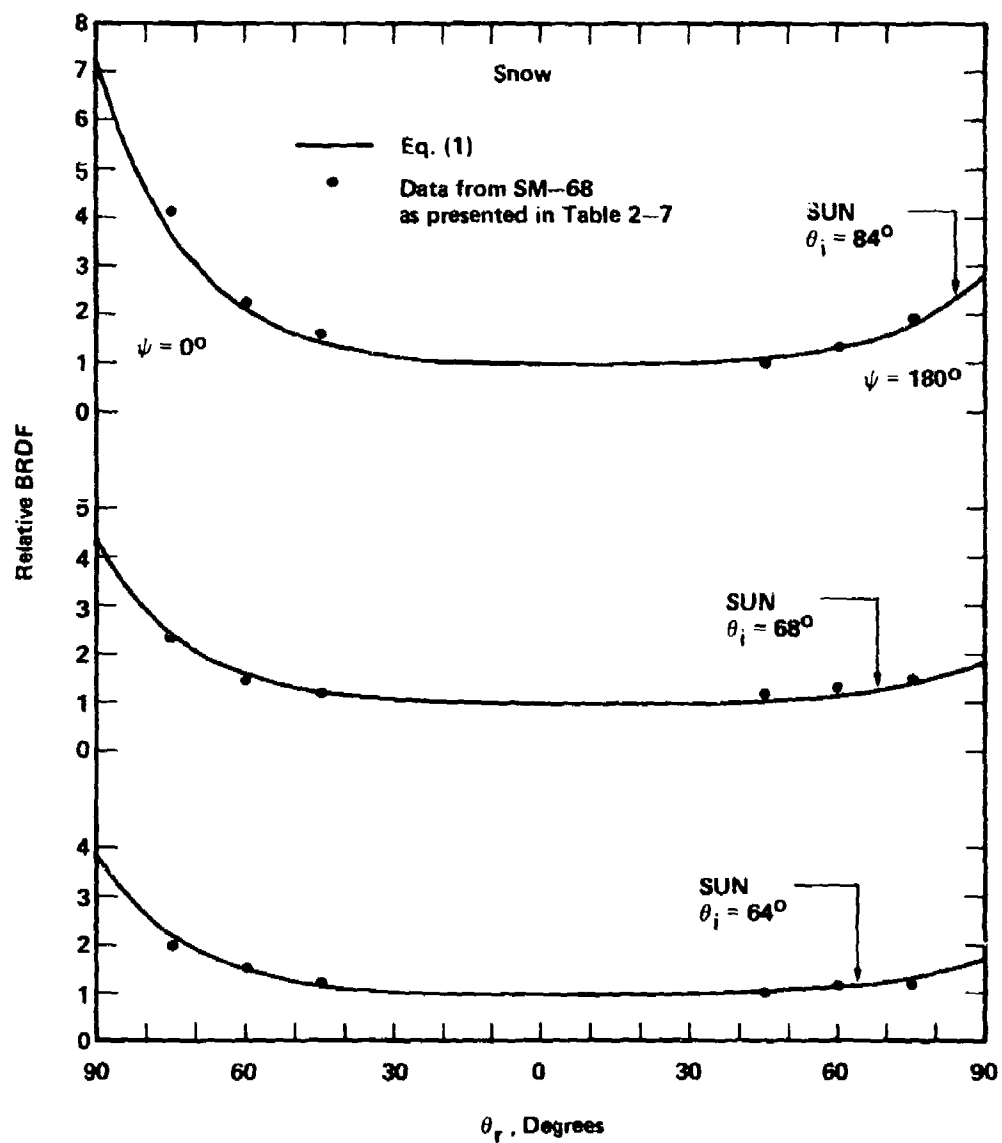


Figure 2-7. Relative BRDF for snow.

Table 2-8. Relative directional reflectance of gypsum sand for solar zenith angles of $\theta_i = 21, 48, 59$ deg, in the spectral range 0.2 to 4.0 μm .

Solar Zenith Angle θ_i	Azimuth Angle ψ	Zenith Angle of Reflected Ray, θ_r			
		0	45	60	75
21	0	1.00	0.95	0.95	0.85
	180		1.04	1.04	0.95
48	0		1.00	1.02	1.04
	180		1.13	1.19	1.19
59	0		1.01	1.10	1.11
	180		1.11	1.22	1.28
59	0		1.04	1.07	1.38
	180		1.10	1.20	1.40

^aValues inferred from Figures 17, 18, 9, and 19 of Salomonson and Marlatt [SM-68].

2-3.3 Soil

Coulson [Co-66a, Figure 4] plots the directional reflectance of black loam soil at three angles of incidence (0, 53, and 78.5 deg) in the principal plane for $\lambda=6430$ Å. Coulson notes that the backward maximum is relatively more pronounced at all three angles than it is for desert sand, and the forward maximum is almost absent at the small angles of incidence.

Duntley, Gordan, et al. [DG-64] measured the directional luminous reflectance of dirt (hard packed, yellowish). Their data are reproduced here in Table 2-9a. We have normalized these data to the nadir value and tabulated the results in Table 2-9b.

The expression we have evaluated as the relative BRDF for soil (dirt) is the ratio given by Equation (14) with the five directional parameters as given in Table 2-2a for $m=5$. We have plotted the results for the forward ($\psi=0$), backward ($\psi=\pi$), and sideward ($\psi=\pi/2$) directions as the set of continuous curves in Figure 2-9. The experimental values of DG-64 are also shown in Figure 2-9 for comparison.

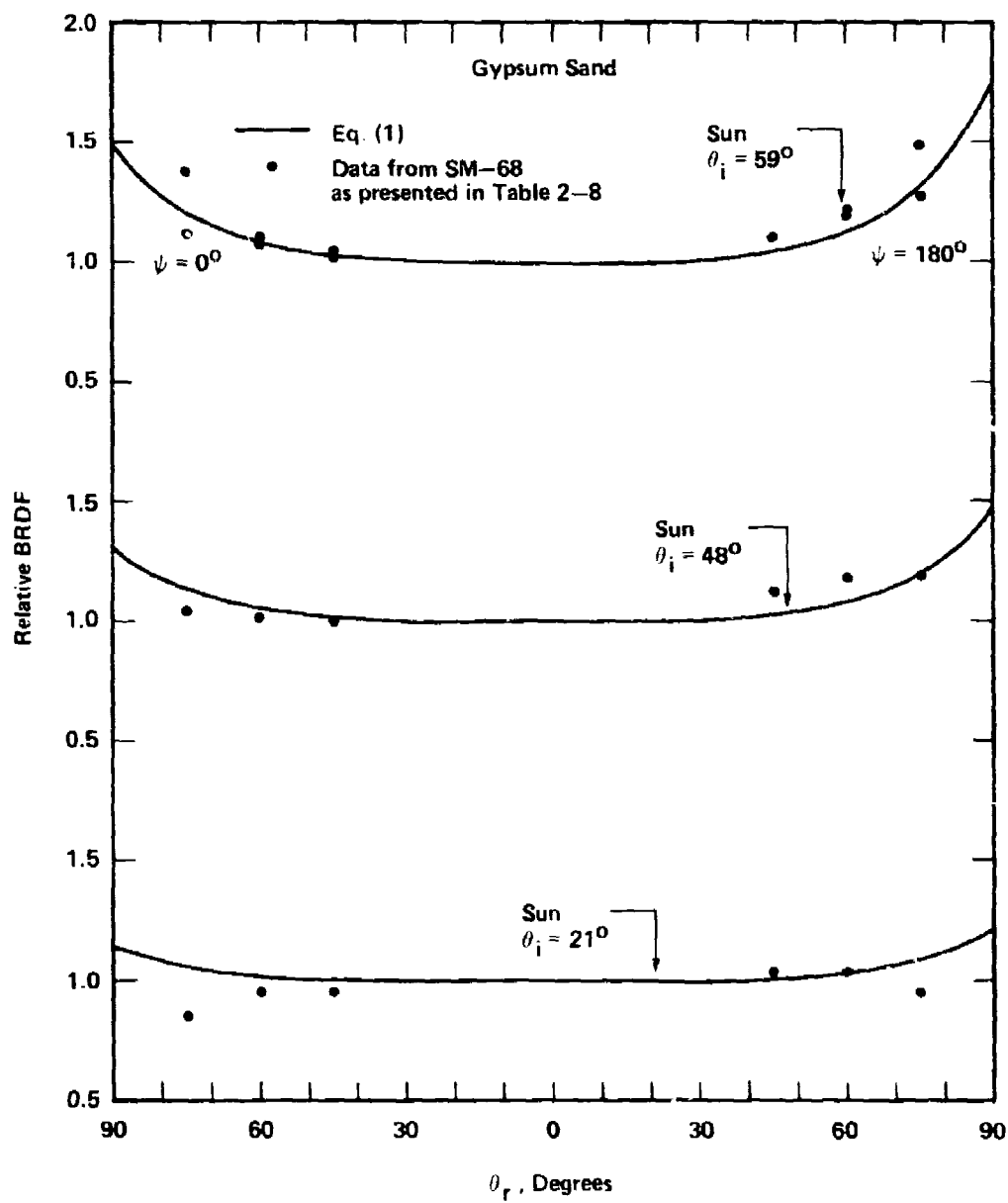


Figure 2-8. Relative BRDF for gypsum sand.

Table 2-9a. Directional luminous reflectance of dirt for solar zenith angles $\theta_i \approx 54$ deg.^a

Solar Zenith Angle θ_i	Azimuth Angle ψ	Zenith Angle of Reflected Ray, θ_r						
		0	15	30	45	60	75	80
53.2	0	0.243	0.230	0.229	0.239	0.252	0.300	0.330
56.5	90		0.243	0.258	0.260	0.276	0.300	0.304
51.1	180		0.272	0.313	0.370	0.422	0.432	0.434

^aDuntley, Gordan et al. [DG-64, Table 3.2]; Item 8 = hard-packed, yellowish dirt.

Table 2-9b. Relative directional luminous reflectance of dirt for solar zenith angles $\theta_i \approx 54$ deg.^a

Solar Zenith Angle θ_i	Azimuth Angle ψ	Zenith Angle of Reflected Ray, θ_r						
		0	15	30	45	60	75	80
53.2	0	1.00	0.95	0.94	0.98	1.04	1.23	1.36
56.5	90		1.00	1.06	1.07	1.14	1.23	1.25
51.1	180		1.12	1.29	1.52	1.74	1.78	1.79

^aDerived from Table 2-9a.

2-3.4 Vegetation

For green grass, Coulson [Co-66a] has measured the directional reflectance at four different wavelengths in the visible and near-IR spectral regions and at three different angles of incidence at $\lambda=6430$ Å, all measurements being in the principal plane.

Duntley, Gordan et al. [DG-64, Table 3.2] have measured the directional luminous reflectance of several types of vegetation. For each type of

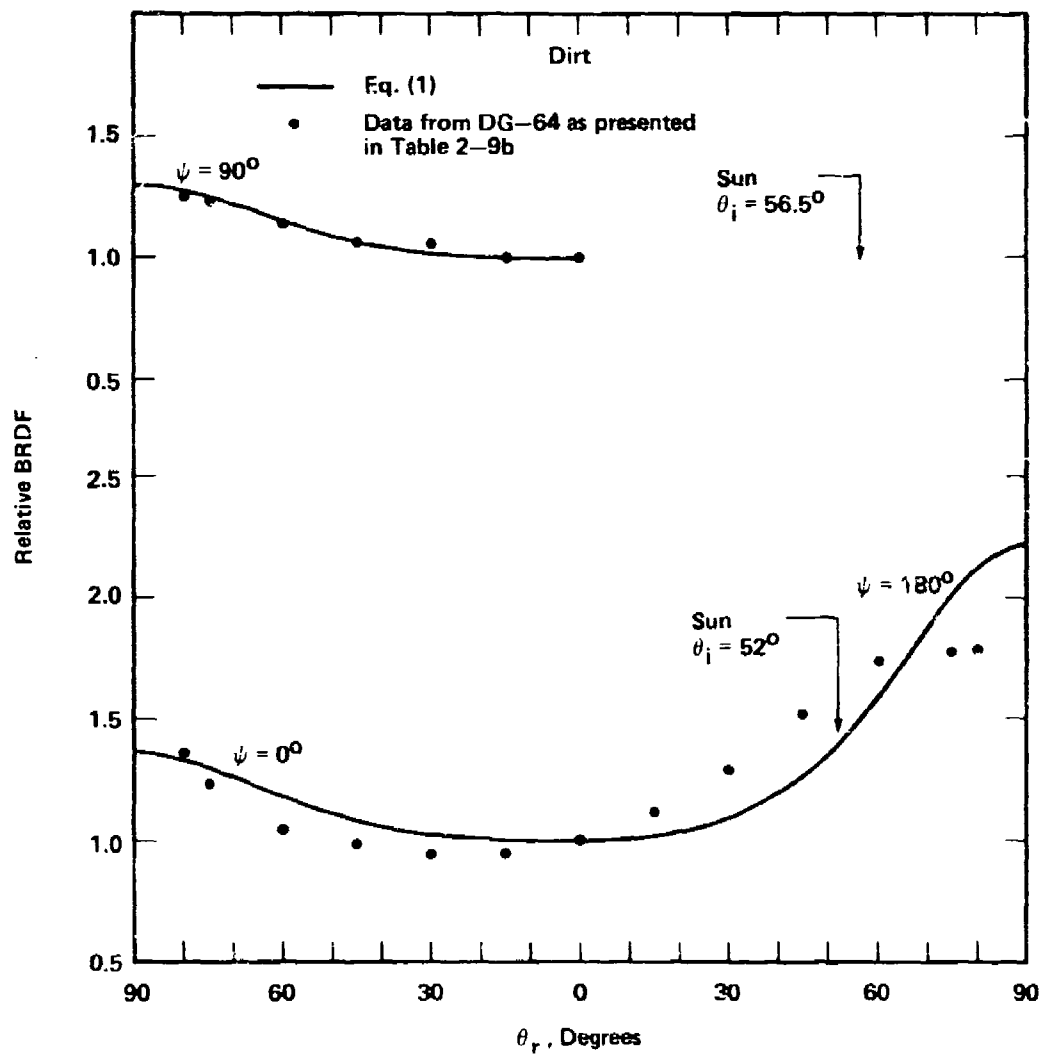


Figure 2-9. Relative BRDF for dirt.

vegetation we have normalized their data to the nadir value for the corresponding type of vegetation and presented the results in Table 2-10. The last set of numbers in Table 2-10 represents an average of the data for the first four types of vegetation.

The expression we have evaluated as the relative BRDF for vegetation is the ratio given by Equation (14) with the five directional parameters as given in Table 2-2a for $m=6$. We have plotted the results for the forward ($\psi=0$), backward ($\psi=\pi$), and sideward ($\psi=\pi/2$) directions as the set of continuous curves in Figure 2-10. The average of the experimental vegetation values, given in Table 2-10, are also shown in Figure 2-10 for comparison.

2-3.5 Urban Materials

2-3.5.1 Concrete and Asphalt

Wolfe [Wo-65a, pp. 88,89] presents directional reflectivity curves for concrete and for asphalt. In fact, results are given for three types of detectors: PbSe, PbS, and thermistor. We have selected the results for the PbSe detector as being of the greatest interest for applications in the 2- to 5- μ m region, as seen by examining the detector characteristic curves presented by Wolfe [Wo-65a: PbSe, pp. 477-479; PbS, pp. 474-476; thermistor, p. 498]. We have digitized the directional reflectivity curves presented by Wolfe [Wo-65a] for the PbSe detector and taken account of the fact that the "directional reflectivity" r_{ir} given in these figures is related to the partial reflectance (which we here call the BRDF, f_r [Ni-70d, Ni-65c]) by the expression

$$r_{ir} = f_r(\theta_i, \theta_r; \psi=0, \pi) \cos \theta_i \cos \theta_r. \quad (15)$$

We have given both the directly-read values r_{ir} and converted values f_r in Tables 2-11a and 2-11b. For each source zenith angle θ_i we have normalized these values of the BRDF to an average of the near-nadir values and tabulated the results in Table 2-11c.

Table 2-10. Relative directional luminous reflectance of several types of vegetation.

(1) Pine Trees; small, uniformly spaced. Data are for unresolved terrain.

Solar Zenith, θ_i	Azimuth ψ	Zenith Angle of Reflected Ray, θ_r							
		0	15	30	45	60	75	80	85
41.5	0	1.00	0.72	0.64	0.64	0.78	1.14	1.39	2.58
	45		.67	.61	.58	.63	.91	1.16	1.65
	90		.95	.93	.95	.95	1.01	1.16	1.39
	135		1.01	1.15	1.18	1.16	1.32	1.39	1.72
	180		1.21	1.33	1.74	1.92	2.14	2.28	2.48

(2) Grass; thick, rather long, pale green, dormant, dryish, little ground showing.

Solar Zenith, θ_i	Azimuth ψ	Zenith Angle of Reflected Ray, θ_r							
		0	15	30	45	60	75	80	85
41.5	0	1.00	0.92	0.86	0.87	1.00	1.07	1.09	1.07
	180		1.11	1.35	1.66	1.70	1.74	1.74	1.82

(3) Grass; lush green, closely mowed thick lawn.

Solar Zenith, θ_i	Azimuth ψ	Zenith Angle of Reflected Ray, θ_r							
		0	15	30	45	60	75	80	
40.4	0	1.00	0.96	0.98	1.08	1.20	1.49	1.68	
39.6	90		1.03	1.10	1.21	1.38	1.59	1.68	
39.6	135		1.07	1.25	1.48	1.66	1.78	1.78	
39.9	180		1.09	1.09	1.19	1.22	1.25	1.25	

(continued)

Table 2-10. Relative directional luminous reflectance of several types of vegetation (Cont'd).

(4) Mixed Green Forest; deciduous (oak) and evergreen (pine).

Solar Zenith, θ_i	Azimuth ψ	Zenith Angle of Reflected Ray, θ_r					
		0	15	30	45	60	75
39.0	0	1.00	0.90	0.81	0.57	0.57	0.95
37.0	180		1.14	1.37	1.37	2.28	7.30

(5) Pine Forest.

Solar Zenith, θ_i	Azimuth ψ	Zenith Angle of Reflected Ray, θ_r					
		0	15	30	45	60	75
33.5	0	1.00	1.00	0.80	0.64	0.64	0.52

(6) Average of First Four Types.

Solar Zenith, θ_i	Azimuth ψ	Zenith Angle of Reflected Ray, θ_r							
		0	15	30	45	60	75	80	85
≈ 40	0	1.00	0.88	0.82	0.79	0.89	1.16	1.39	1.82
	90		0.99	1.01	1.08	1.16	1.30	1.42	
	180		1.14	1.28	1.49	1.78	3.11	1.76	

^aFrom DG-64, Table 3.2

The expression we have evaluated as the relative BRDF for concrete and for asphalt is the ratio given by Equation (14) with the parameters for concrete being $\gamma_{7a} = 2$, $\alpha_{7a} = 4$, $\theta_{7a} = 0.5$, $R_{7a}(0) = 8$, and $R_{7b}(\pi) = 1$ and for asphalt being $\gamma_{7b} = 2$, $\alpha_{7b} = 4$, $\theta_{7b} = 0.5$, $R_{7b}(0) = 13$, and $R_{7b}(\pi) = 1$. We have plotted the results for the forward ($\psi=0$) and backward ($\psi=\pi$) directions in Figure 2-11a and 2-11b. The experimental values reported in Wo-65a are also shown in Figures 2-11a and 2-11b for comparison. For an average of con-

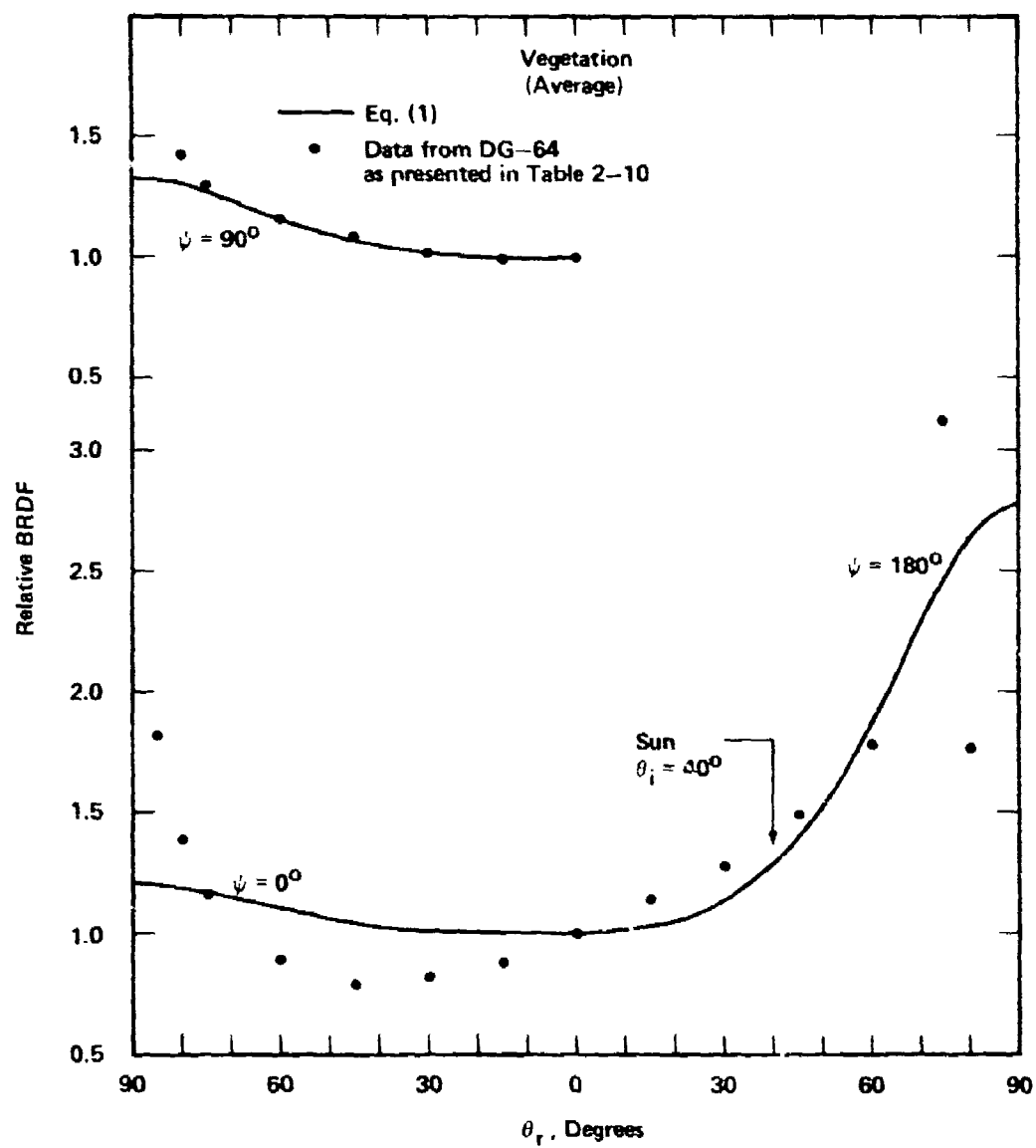


Figure 2-10. Relative BRDF for vegetation.

Table 2-11a. Directional reflectance data for concrete.^a

ψ	θ_r	r_{ir}				f_r, sr^{-1}			
		$\theta_i=0$	$\theta_i=20$	$\theta_i=40$	$\theta_i=60$	$\theta_i=0$	$\theta_i=20$	$\theta_i=40$	$\theta_i=60$
0	80	0.027	0.030	0.030	0.032	0.16	0.18	0.23	0.37
0	70	.039	.040	.045	.055	.11	.12	.17	.32
0	60	.053	.053	.053	.064	.11	.11	.14	.26
0	50	.073	.075	.074	.061	.12	.12	.15	.19
0	40	.086	.081	.075	.057	.11	.11	.13	.15
0	30	.10	.094	.092	.058	.12	.12	.14	.13
0	20	.10	.11	.090	.053	.11	.12	.13	.11
0	10	.11	.12	.088	.059	.11	.13	.12	.12
	0		.11	.089	.064		.12	.12	.13
180	10	.10	.10	.084	.055	.10	.11	.11	.11
180	20	.10		.077	.049	.11		.11	.10
180	30	.10	.094	.073	.046	.12	.12	.11	.11
180	40	.087	.065		.049	.11	.090		.13
180	50	.073	.063	.053	.032	.11	.10	.11	.10
180	60	.061	.040	.050		.12	.085	.13	
180	70	.037	.040	.030		.11	.12	.11	
180	80		.027				.17		

^aValues of r_{ir} read from Wo-65a, p. 88, Figure 4-28, PbSe detector. Values of f_r computed from $f_r = r_{ir}/(\cos \theta_i \cos \theta_r)$.

crete and asphalt we propose the five directional parameters as given in Table 2-2a for $m=7$.

2-3.5.2 Urban Geometry Parameters

Because an urban area has an exceedingly complex geometrical structure, we introduce (1) a (conjectured) shadow-factor, $S(\theta_i, \theta_r)$, given by

$$S(\theta_i, \theta_r) = (\cos \theta_i + \cos \theta_r) / 2 \quad (1c)$$

(which may take on values in the range from 0 to 1 as θ_i and θ_r range from maximum values of $\theta_i = \theta_r = 90^\circ$ to minimum values of $\theta_i = \theta_r = 0$), and (2) a

Table 2-11b. Directional reflectance data for asphalt.^a

ψ	θ_r	r_{ir}				$f_{r, sr^{-1}}$			
		$\theta_i=0$	$\theta_i=20$	$\theta_i=40$	$\theta_i=60$	$\theta_i=0$	$\theta_i=20$	$\theta_i=40$	$\theta_i=60$
0	75			0.0093	0.015			0.047	0.12
0	70	0.0057	0.021	.014	.022	0.017	0.065	.053	.13
0	60	.025	.027	.020	.020	.050	.057	.052	.080
0	50	.025	.025	.020	.022	.039	.043	.041	.068
0	40	.025	.029	.023	.036	.032	.040	.039	.094
0	30	.028	.019	.027	.017	.032	.023	.041	.039
0	20	.020	.025	.031	.013	.021	.028	.043	.028
0	10	.026	.023	.022	.018	.026	.025	.029	.037
	0		.024	.022	.017		.025	.029	.034
180	10	.026	.022	.022	.011	.026	.024	.029	.022
180	20	.020		.018	.014	.021		.025	.030
180	30	.028	.014	.015	.014	.032	.017	.023	.032
180	40	.025	.026		.014	.032	.036		.037
180	50	.025	.025	.016	.012	.039	.041	.032	.037
180	60	.026	.013	.0069		.052	.028	.018	
180	70	.0066		.013	.0053	.019		.050	.031
180	80				.0036				.041

^aValues of r_{ir} read from Wo-65a, p. 89, Figure 4-29, PbSe detector. Values of f_r computed from $f_r = r_{ir}/(\cos\theta_i \cos\theta_r)$.

degree-of-urbanization factor, $D(7)$, with the range $0 \leq D(7) \leq 1$. The BRDF for an urban area will be defined as

$$f_r(m=7) = D(7)\rho_{07}(\lambda) S(\theta_i, \theta_r) + [1-D(7)] \quad \text{given by Eq. (1)].} \quad (17)$$

Thus, for $D(7) = 1$, the spectral BRDF corresponds to a diffuse reflector modified by the shadow factor $S(\theta_i, \theta_r)$. For $D(7)=0$, the spectral BRDF corresponds to a flat surface with average directional-radiance properties of concrete and asphalt.

The directional-hemispherical reflectance defined by Equation (5), with f_r given by Equation (17), is

Table 2-11c. Relative bidirectional reflectance distribution functions for concrete and asphalt.

ψ	Concrete					Asphalt				
	θ_r	$\theta_i=0$	$\theta_i=20$	$\theta_i=40$	$\theta_i=60$	θ_r	$\theta_i=0$	$\theta_i=20$	$\theta_i=40$	$\theta_i=60$
0	80	1.45	1.50	1.92	3.25	75			1.62	3.97
0	70	1.00	1.00	1.42	2.81	70	0.72	2.60	1.83	4.30
0	60	1.00	0.92	1.17	2.28	60	2.13	2.28	1.79	2.65
0	50	1.09	1.00	1.25	1.67	50	1.66	1.72	1.41	2.25
0	40	1.00	0.92	1.08	1.32	40	1.36	1.60	1.34	3.11
0	30	1.09	1.00	1.17	1.14	30	1.36	0.92	1.41	1.29
0	20	1.00	1.00	1.08	0.96	20	0.89	1.12	1.48	0.93
0	10	1.00	1.08	1.00	1.05	10	1.11	1.00	1.00	1.22
	0		1.00	1.00	1.14	0		1.00	1.00	1.13
180	10	0.91	0.92	0.92	0.96	10	1.11	0.96	1.00	0.73
180	20	1.00		0.92	0.88	20	0.89		0.86	0.99
180	30	1.09	1.00	0.92	0.96	30	1.36	0.68	0.79	1.06
180	40	1.00	0.75		1.14	40	1.36	1.44		1.22
180	50	1.00	0.83	0.92	0.88	50	1.66	1.64	1.10	1.22
180	60	1.09	0.71	1.08		60	2.21	1.12	0.62	
180	70	1.00	1.00	0.92		70	0.81		1.72	1.03
180	80		1.42			80				1.36

^aDerived from data in Tables 2-11a and 2-11b.

$$\begin{aligned}
 \langle \rho_7 \rangle &\equiv \langle \rho_7[\lambda; \theta_i, 2\pi; D(7)] \rangle_{D(7)} = \int f_r \cos \theta_r \, d\Omega_r \\
 &= D(7) \rho_{07}(\lambda) \int S(\theta_i, \theta_r) \cos \theta_r \, d\Omega_r \\
 &\quad + [1-D(7)] \int [f_r \text{ given by Eq. (1)}] \cos \theta_r \, d\Omega_r \\
 \langle \rho_7 \rangle &= D(7) \rho_{07}(\lambda) \frac{1}{2} \int (\cos \theta_i + \cos \theta_r) \cos \theta_r \, d\Omega_r \\
 &\quad + [1-D(7)] \pi \rho_{07}(\lambda) G(\alpha_7, \beta_7, \gamma_7; \theta_i) \\
 \langle \rho_7 \rangle &= D(7) \rho_{07}(\lambda) \pi \left[\frac{1}{2} \cos \theta_i + \frac{1}{3} \right] + [1-D(7)] \rho_7(\lambda; \theta_i, 2\pi). \quad (18)
 \end{aligned}$$

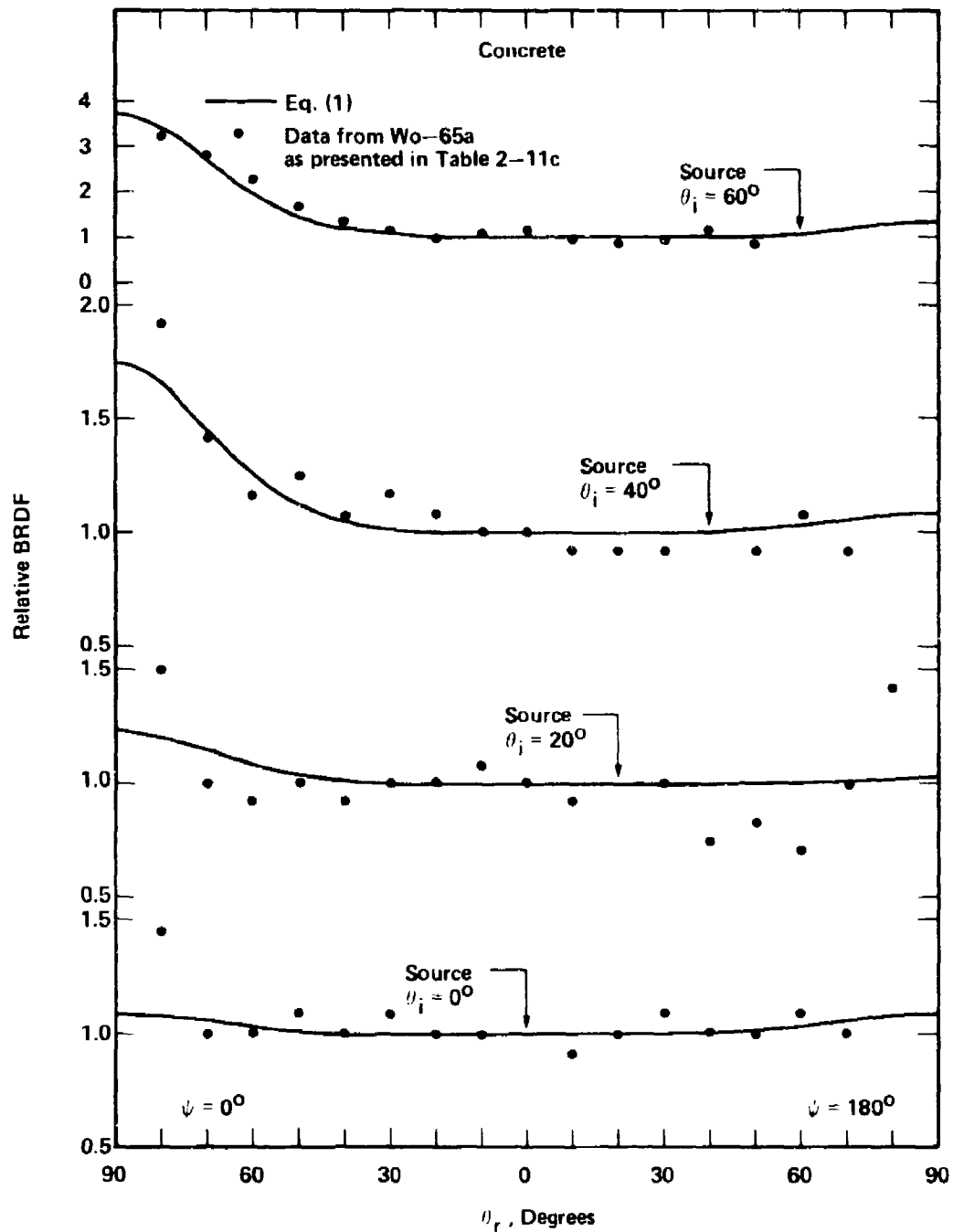


Figure 2-11a. Relative BRDF for concrete.

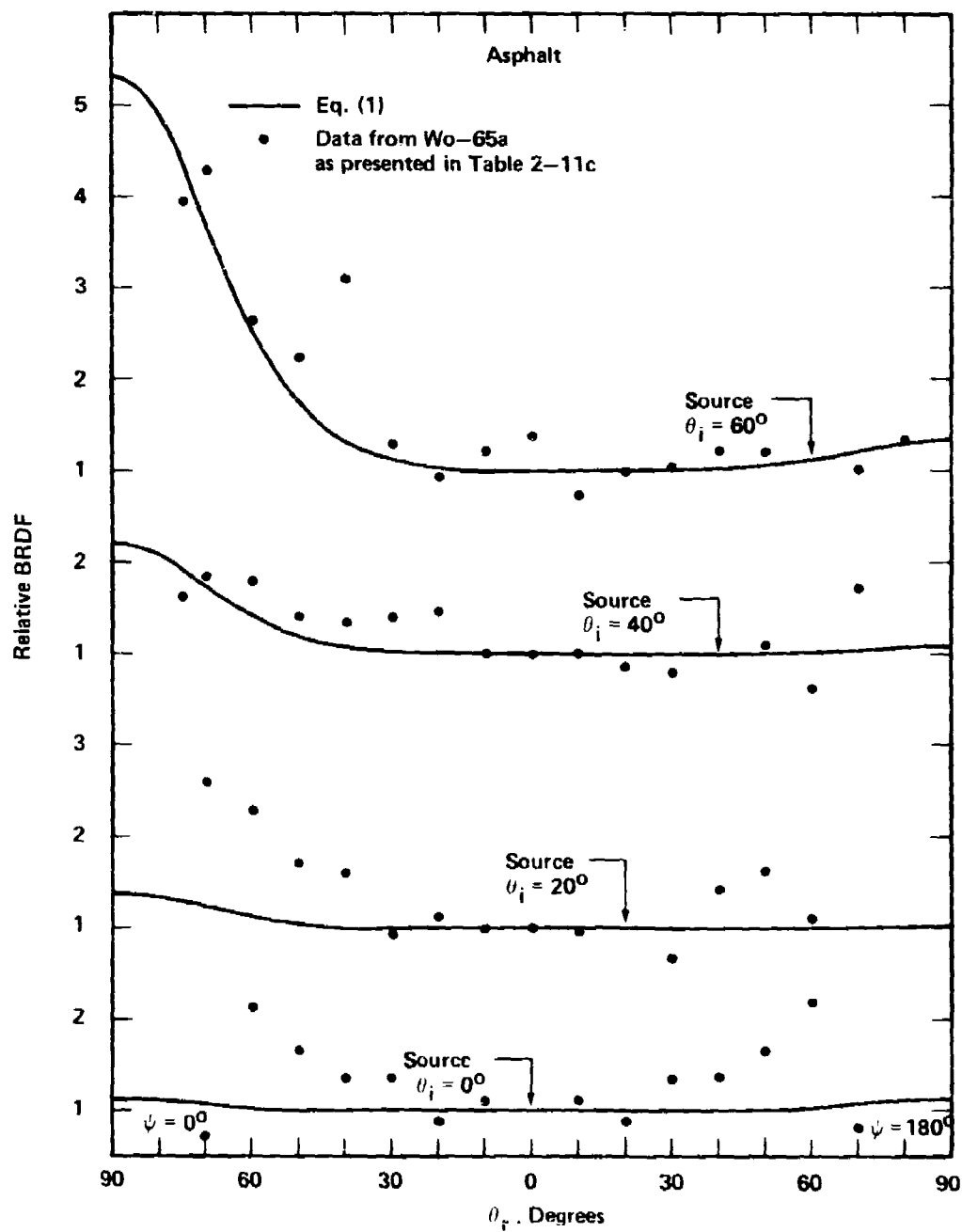


Figure 2-11b. Relative BRDF for asphalt.

The directional emissivity (for $m=7$, at a zenith angle θ) defined by Equation (12) with $\rho_m(\lambda; \theta, 2\pi)$ given by $\langle \rho_7 \rangle$ (in which θ_i is replaced by θ) is

$$\begin{aligned}\epsilon_d(m=7) &\equiv \langle \epsilon_d[m=7, \lambda, \theta; D(7)] \rangle_{D(7)} \\ &= 1 - \langle \rho_7 \rangle\end{aligned}\quad (12'')$$

$$\epsilon_d(m=7) = 1 - \left(\pi \rho_{07}(\lambda) D(7) \left[\frac{\cos \theta}{2} + \frac{1}{3} \right] + \rho_7(\lambda; \theta, 2\pi) [1 - D(7)] \right) \quad (19)$$

Thus, as expected, for $D(7) = 1$, the directional emissivity corresponds to that for a diffuse reflector modified by the shadow-factor quantity (which ranges from $1/3$ for $\theta=90^\circ$ to $5/6$ for $\theta=0^\circ$). For $D(7) = 0$, the directional emissivity corresponds to a flat surface with average directional-emissivity properties of urban materials.

2-4 INTEGRATION OF THE BRDF

The spectral, directional-hemispherical reflectance, denoted here by $\rho(\theta_i, 2\pi)$, is defined [Ni-63, Wo-65a] by the integral

$$\rho(\theta_i, 2\pi) = \int f_r \cos \theta_r \, d\Omega_r \quad (5')$$

where f_r is the bidirectional reflectance-distribution function (BRDF). We want to evaluate this integral when f_r is given by our invented expression for the BRDF, given by Equation (1):

$$f_r \equiv f_r[m, D(m), \lambda; \theta_i, \theta_r, \psi] \equiv f_r(\theta_i; \theta_r, \psi) \quad (20)$$

$$f_r = \rho_0 [1 + F_Y(\theta_i) \Theta_r(\mu) \Psi(\psi)]$$

with

$$F_Y(\theta_i) \equiv F_Y(\alpha, \theta_i) = \exp[-\alpha (\cos \theta_i)^Y] \quad (21a)$$

$$\theta_r(\mu) = \exp[-\alpha\mu^\gamma] \quad (21b)$$

$$\mu = \cos \theta_r \quad (21c)$$

$$\Psi(\psi) = R(\psi) \exp[-\alpha\beta(1-|1-2\psi/\pi|)] \quad (21d)$$

$$R(\psi) = R(0) - \Delta R\psi/\pi \quad (21e)$$

$$\Delta R = R(0) - R(\pi) . \quad (21f)$$

For symmetry about the principal plane, we can write Equation (5') as

$$\rho(\theta_i, 2\pi) = 2\rho_0 \int_0^\pi d\psi \int_0^1 d\mu \mu [1 + \exp(-\alpha\mu^\gamma)\Psi(\psi)F_Y(\theta_i)] \quad (22a)$$

$$= 2\rho_0 \left[\frac{\pi}{2} + F_Y(\theta_i) \int_0^\pi d\psi \Psi(\psi)P_{2Y}(\alpha) \right] \quad (22b)$$

where

$$P_{2Y}(\alpha) = \int_0^1 d\mu \mu \exp(-\alpha\mu^\gamma) \quad (23)$$

$$P_{21}(\alpha) = \frac{1}{\alpha^2} [1 - e^{-\alpha}(\alpha+1)] \quad (23a)$$

$$P_{22}(\alpha) = \frac{1}{2\alpha} (1 - e^{-\alpha}) . \quad (23b)$$

For the ψ -integral, we have

$$\begin{aligned}
I_{\psi} &\equiv \int_0^{\pi} d\psi \, \Psi(\psi) \\
&= \int_0^{\pi/2} d\psi \exp(-2\alpha\beta\psi/\pi) R(\psi) + \int_{\pi/2}^{\pi} d\psi \exp[-2\alpha\beta(\pi-\psi)/\pi] R(\psi) \quad (24)
\end{aligned}$$

$$\begin{aligned}
&= R(0) \int_0^{\pi/2} d\psi \exp(-2\alpha\beta\psi/\pi) - \frac{\Delta R}{\pi} \int_0^{\pi/2} d\psi \, \psi \exp(-2\alpha\beta\psi/\pi) \\
&\quad + R(0) \int_{\pi/2}^{\pi} d\psi \exp[-2\alpha\beta(\pi-\psi)/\pi] - \frac{\Delta R}{\pi} \int_{\pi/2}^{\pi} d\psi \, \psi \exp[-2\alpha\beta(\pi-\psi)/\pi] \quad (24a)
\end{aligned}$$

$$= R(0) \frac{\pi}{2} P_1(\alpha\beta) - \frac{\Delta R}{\pi} \left(\frac{\pi}{2}\right)^2 P_{21}(\alpha\beta) \quad (24b)$$

$$+ R(0) \frac{\pi}{2} P_1(\alpha\beta) - \frac{\Delta R}{\pi} \frac{\pi}{2} [\pi P_1(\alpha\beta) - \frac{\pi}{2} P_{21}(\alpha\beta)]$$

$$= \pi \bar{R} P_1(\alpha\beta) \quad (24c)$$

where

$$P_1(\alpha\beta) = \int_0^1 dy \exp(-\alpha\beta y) = \frac{1}{\alpha\beta} [1 - \exp(-\alpha\beta)] \quad (25a)$$

$$\bar{R} = [R(0) + R(\pi)]/2. \quad (25b)$$

After collecting terms, we have

$$\rho(\theta_i, 2\pi) = \pi \rho_0 [1 + 2 P_1(\alpha\beta) P_{2Y}(\alpha) \bar{R} F_Y(\alpha, \theta_i)] . \quad (26)$$

To compute $\langle f_r(0,0,\psi) \rangle$, we write

$$\langle f_r(0,0,\psi) \rangle \equiv \rho_0 [1 + F_Y(0) \theta_r(1) \langle \psi(\psi) \rangle] \quad (27)$$

$$= \rho_0 [1 + \exp(-2\alpha) \langle \psi(\psi) \rangle] \quad (27a)$$

with

$$\langle \psi(\psi) \rangle = \frac{1}{\pi} \int_0^\pi d\psi \, \psi(\psi) = \bar{R} P_1(\alpha\beta) . \quad (27b)$$

2-5 SUBROUTINE ESURF

Subroutine ESURF provides the bidirectional reflectance-distribution function (BRDF), directional emissivity, and temperature of the Earth's surface at the intersection point of the optical line-of-sight. Since the surface category is not automatically correlated with the geographic position, the user must select one of seven categories provided.

The relationship between Subroutine ESURF and the routines it calls is shown in Figure 2-12. Table 2-12 summarizes the inputs and outputs for Subroutine ESURF.

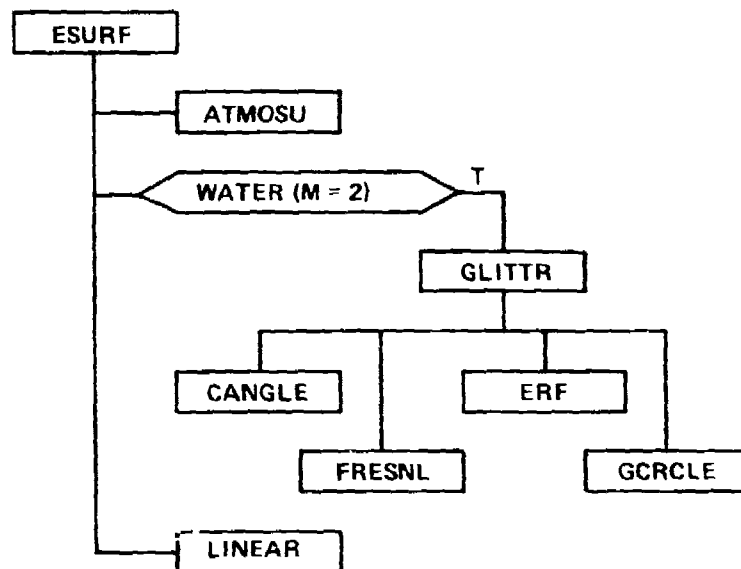


Figure 2- .2. Relationships between the routines in the Earth Surface Characterization Model.

Table 2-12. Input and output variables for Subroutine ESURF

INPUT VARIABLES

Argument List

- THI - Zenith angle of sun at intersection point (P) on Earth's surface. (radians)
- THR - Zenith angle of line-of-sight (from detector) at intersection point (P) on Earth's surface. (radians)
- PSI - Azimuth angle (at intersection point (P)) of vertical plane through line-of-sight, measured relative to the solar principal plane (i.e., vertical plane through solar ray). A value of zero for PSI corresponds to forward scattering. (radians)
- ZKM - Altitude of surface. (km)
- MSM - Index M for category of surface material.
 =1, Lambertian diffuse surface with spectrally-independent reflectance set by DD(1) and emissivity by [1 - DD(1)].
 =2, Water.
 =3, Snow.
 =4, Sand.
 =5, Soil.
 =6, Foliage.
 =7, Urban material.
- DD(M) - Additional descriptor for selected surface material.
 DD(1) = Diffuse reflectance for Lambertian surface.
 Typical value is 0.1.
 DD(2) = Wind speed. (meters/sec)
 DD(3) = Snow-age parameter, between the limiting values of 0 and 1 for new and old snow, respectively.
 DD(M) for M = 4, 5, 6 not used.

(continued)

Table 2-12. Input and output variables for Subroutine ESURF (Cont'd).

-
- DD(7) = Degree-of-urbanization between 0 and 1, for which limits the spectral BRDF corresponds, respectively, to (a) a flat surface with average directional-reflectance properties of concrete and asphalt and (b) a diffuse reflector multiplied by a shadow factor $S(THI,THR)=[\cos THI + \cos THR]/2$.
- SPCULR - Logical variable.
- = .TRUE., Compute coordinates of specular reflection point on an assumed smooth horizontal water surface, if MSM = 2, in which case the variable is passed to Subroutine GLITTR.
- = .FALSE., Do not compute such coordinates.
- ZLAM - Wavelength. (μm)
- IDAY - Index for diurnal condition at Point P.
- = 0, Solar zenith angle > 90 deg.
- = 1, Solar zenith angle \leq 90 deg.
- IFIRES - Flag for inclusion of fireballs as sources. In NBR Module, IFIRFS = 0 always.
- = 0, No fireball is to be considered.
- > 0, Fireballs are to be considered.
- ESURF1 - Logical variable.
- = .TRUE., If ESURF is called for the first time from Subroutine SURRAD and both EPSD and TKS are wanted in addition to SFR as outputs. In NBR Module, ESURF1 = .TRUE. always.
- = .FALSE., If ESURF is not being called for the first time from Subroutine SURRAD and a recomputation of EPSD and TKS is not needed. This possibility occurs only if Subroutine SURRAD is used as a utility routine with fireballs as sources.

(continued)

Table 2-12. Input and output variables for Subroutine ESURF (Cont'd).

ATMOUP Common

TT - Ambient atmospheric temperature at altitude ZKM. (deg K)

OUTPUT VARIABLES

Argument List

SFR - Bidirectional reflectance-distribution function.

= $f_r[M, DD(M), ZLAM; TH1, THR, PSI]$. (1/sr)

EPSD - Directional emissivity

= $1 - \rho_m(ZLAM; THR, 2\pi)$. (dimensionless)

TKS - Surface temperature. (deg K)

POSITN Common

(This output obtains only if MSM=2 and SPCULR=.TRUE.)

SPCLAT, - North latitude and east longitude of the point on an
SPCLON assumed smooth horizontal surface for a specular
reflection from the sun to the detector at Point V.
(radians)

SECTION 3

EARTH SURFACE CHARACTERIZATION: WATER SURFACE

3-1 RADIANCE FROM A WIND-RUFFLED WATER SURFACE

3-1.1 Basic Cox-Munk Formula

The Cox-Munk formula [CM-54, Equation (9)] may be rewritten as

$$L_{CM} = L = N = \frac{\rho(\omega)}{4} \frac{E p(\beta)}{\cos \mu \cos \beta} \quad (1)$$

where L is the spectral radiance of the sea surface in the line-of-sight, $\rho(\omega)$ is the Fresnel specular reflectance of water for radiation of wavelength λ at angle of incidence ω , μ is the zenith angle of the detector, β is the slope (or tilt) of the water facet required to give a specular reflection to the detector, E (called H in CM-54) is the solar spectral irradiance (normal to the solar path) at the sea surface, and $p(\beta)$ is the probability for the occurrence of slope β .

Stegelman and Garvey [SG-73b] derive an equation for the radiance which differs from Equation (1). The ratio of the radiance predicted by Stegelmann and Garvey to that predicted by Cox and Munk is

$$\frac{L_{SG}}{L_{CM}} = \frac{\cos \theta_i \cos \beta}{\cos \omega}, \quad (2)$$

where θ_i is the solar zenith angle. Stegelmann and Garvey seem to imply that Equation (1) is incorrect owing to an incorrect coordinate transformation. We have not checked all of the work in detail, so we don't know what the discrepancies are due to. Since the Cox-Munk formula is widely used in the litera-

ture, we will continue to use it until the cause of the alleged error is identified more explicitly.

3-1.2 Slope Distribution Function

Cox and Munk [CM-54] show that to a first order the slopes are normally distributed and independent of wind direction, according to

$$p = \frac{1}{\pi \sigma^2} \exp[-(z_x^2 + z_y^2)/\sigma^2] \quad (3a)$$

where

σ = rms slope regardless of direction

α = azimuth of the direction of steepest ascent, measured clockwise from the sun

$$z_x = \partial z / \partial x = \sin \alpha \tan \beta \quad (4a)$$

$$z_y = \partial z / \partial y = \cos \alpha \tan \beta \quad (4b)$$

so that

$$p = \frac{1}{\pi \sigma^2} \exp(-\tan^2 \beta). \quad (3b)$$

3-1.3 Relation Between Slope Variance and Wind Speed

3-1.3.1 Cox-Munk Relation (regardless of direction)

Cox and Munk [CM-54, CM-56] computed the mean square slope components, for crosswind (σ_c^2) and up/downwind (σ_u^2), from their glitter photographs. For simplicity we shall use only their results for the mean square slope, $\sigma^2 = \sigma_c^2 + \sigma_u^2$, regardless of wind direction, for a clean surface (as opposed to an oil-slick surface, e.g.).

$$\sigma^2 = \sigma_c^2 + \sigma_u^2 = (3 + 5.14 W) \times 10^{-3} \pm 0.004. \quad (5)$$

This result is based on measurements for wind speeds from about 0.8 to about 14 m/sec [CM-56].

Since one might expect σ to vanish as W vanishes, we have plotted the velocity-dependent portion of Equation (5),

$$\sigma_0 = (0.00512 W)^{1/2}, \quad (5a)$$

as the dash-dot line in Figure 3-1. We also represent Equation (5) in Figure 3-1 by plotting

$$\sigma = (\sigma_0^2 + 0.003)^{1/2} \quad (5b)$$

as the solid line and

$$\sigma_{\pm} = (\sigma^2 \pm 0.004)^{1/2} \quad (5c)$$

as the dashed lines.

3-1.3.2 Some Useful Wind-Related Conversion Factors

Relations between knots, meters per second, and miles per hour are:

$$1 \text{ knot} = 0.5144 \text{ m/sec} = 1.151 \text{ mph.}$$

Relations between sea-states, Beaufort numbers, and wind velocity are shown in Figure 3-2 (adapted from Wu-69a).

There is a significant altitude variation of wind which must be kept in mind while reading the sun-glitter literature.

Duntley [Du-54], in relating his measurements of the distribution of water wave slopes (on a lake) to those of Cox and Munk [CM-54] (in the open

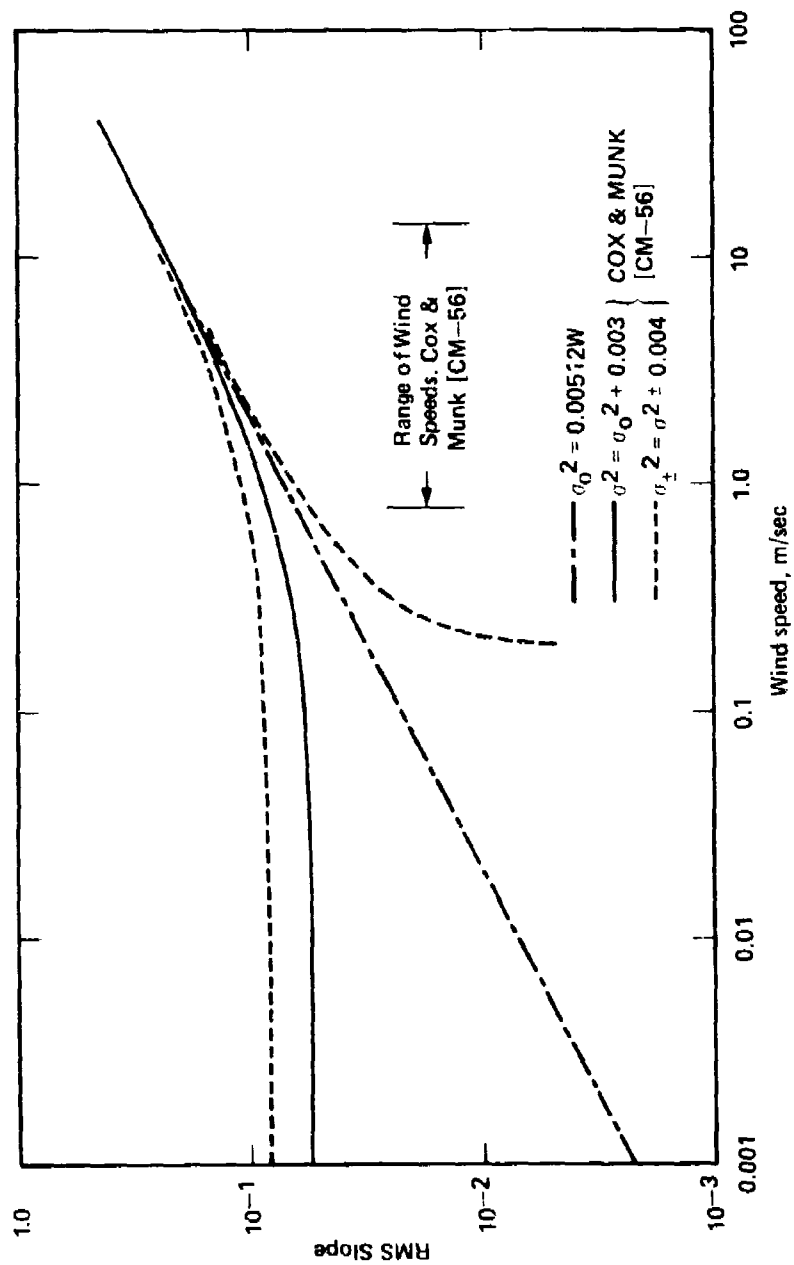


Figure 3-1. Relation between RMS slope and wind speed.

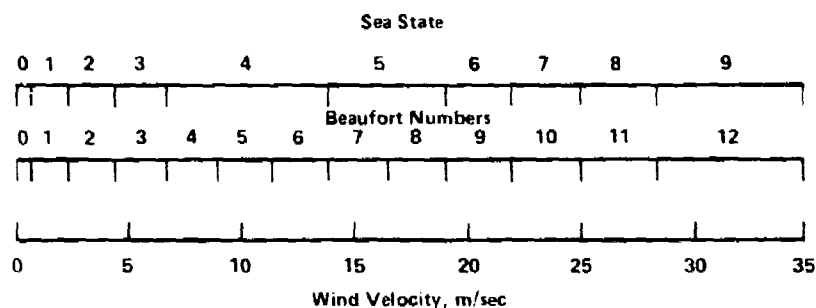


Figure 3-2. Relations between sea-states, Beaufort numbers, and wind speed (from Wu-69a).

sea), speaks of the "customary 2-to-1 ratio between wind speeds measured at 41 feet (12.5 meters) above the mean water level (as for CM-54) and 8 inches [Du-54] above the wave crests."

Cox [Co-58] relates his laboratory measurements to those of Cox and Munk [CM-54]. Cox states:

"Measurements of wind speed in the tank represent average speed throughout the air channel; it may be estimated that the level at which this speed is reached in the boundary layer next to the water is 4 to 8 cm above mean water level. Hence, oceanic measurements of wind speeds made at a height of 12.5 m must be reduced by a large and uncertain correction factor before a useful comparison can be made. I assume the factor is

$$\ln \left[\left(\frac{6.0}{0.1} \right) / \left(\frac{1.25 \times 10^4}{0.1} \right) \right] = 2.2;$$

this assumes (1) a logarithmic velocity profile near the water in both tank and ocean, (2) an effective height of wind

observation in the tank of 6 cm, and (3) a roughness length in both the tank and ocean of 0.1 cm."

3-1.3.3 Limitations on the Cox-Munk Relation

Strong and Ruff [SR-70a] state: "Recent results from Wu [J. Atmos. Sci. 26, 408 (1969)] show a sea-roughness saturation for winds above 15 m/sec, which means one cannot rely on a changing slope distribution at higher wind speeds."

Time does not permit further review of the relation between slope variance and wind speed; some additional relevant references include those by Wu [Wu-69a, Wu-70, Wu-71, Wu-72a, Wu-77] and Cox [Co-74].

3-2 REFLECTION GEOMETRY FOR A SPHERICAL EARTH

Cox and Munk assumed a flat Earth in deriving their reflection geometry. We want to consider a spherical Earth. Fortunately, Levanon [Le-71b] has derived the necessary equations for viewing the reflections from a synchronous satellite. We have not yet verified the equations in detail; so far, we have only determined, by examining Levanon's simplified formulas, that an east longitude relative to the detector is positive and a north latitude is positive. Levanon assumed his satellite was on the equator and at zero-degree longitude. Accordingly, we have modified some of his definitions so as to allow for an arbitrary position of the detector. We reproduce these (slightly modified) definitions and formulas from Levanon's Section 2 [Le-71b]. Anyone studying these equations should consult his Figure 2 which illustrates the reflection geometry.

Levanon has considered the following geometrical question: Given the longitude and latitude of the sun and detector subpoints, and of the point of reflection, what is the tilt magnitude and direction and the angle of incidence, at that point of reflection?

The following notation is adopted:

- O - the center of the Earth
- S - the sun subpoint
- V - the detector
- P - the point of reflection
- i - an index taking values s, p, \hat{i} , \hat{n}
- Q_i - a point defined by the sea surface and a vector parallel to i and starting at O
- θ_i - north latitude of i (or of Q_i)
- ϕ_i - east longitude of i (or of Q_i) relative to that of V
- r - radius of Earth
- h_d - altitude of detector
- h_p - altitude of P (if a lake, e.g.)
- \vec{l} - vector between the detector and the point of reflection
- \hat{n} - the normal required for reflection from P
- θ - the northward tilt at P
- ϕ - the eastward tilt at P
- B - the magnitude of the total tilt at P
- ω - the angle of incidence

For convenience we introduce

$$\epsilon_d = (r + h_p)/(r + h_d).$$

For Point Q_i :

$$\phi_i = \tan^{-1} \left[\frac{-\epsilon_d \cos \theta_p \sin \phi_p}{1 - \epsilon_d \cos \theta_p \cos \phi_p} \right] \quad (L1)$$

$$\theta_i = \tan^{-1} \left[\frac{-\epsilon_d \sin \theta_p}{(1 - 2 \epsilon_d \cos \theta_p \cos \phi_p + \epsilon_d^2 \cos^2 \theta_p)^{1/2}} \right]. \quad (L2)$$

For Point Q_n :

$$\phi_n = \tan^{-1} \left[\frac{\cos \theta_L \sin \phi_L + \cos \theta_S \sin \phi_S}{\cos \theta_L \cos \phi_L + \cos \theta_S \cos \phi_S} \right] \quad (L3)$$

$$\theta_n = \tan^{-1} \left[\frac{\sin \theta_L + \sin \theta_S}{[\cos^2 \theta_L + \cos^2 \theta_S + 2 \cos \theta_L \cos \theta_S \cos (\phi_L - \phi_S)]^{1/2}} \right] \quad (L4)$$

At the point of reflection the tilt toward the east is given by

$$\phi = \phi_n - \phi_p \quad (L5)$$

and the tilt toward the north by

$$\theta = \theta_n - \theta_p. \quad (L6)$$

Since ϕ and θ are orthogonal, the total tilt magnitude is

$$\beta = \tan^{-1} [\tan^2 \theta + \tan^2 \phi]^{1/2} \quad (L7)$$

and the angle of incidence is

$$\omega = \tan^{-1} [\tan^2 (\theta_n - \theta_s) + \tan^2 (\phi_n - \phi_s)]^{1/2}. \quad (L8)$$

In Table 3-1 we have summarized the input and output quantities, based on Levanon's equations.

3-3 REFLECTANCE AND EMISSIVITY

3-3.1 The Bidirectional Reflectance-Distribution Function (BRDF)

The BRDF is defined as

Table 3-1. Input and output quantities for reflection viewed from a detector.

Input Quantities (per Levanon)		
Object	East Longitude	North Latitude
Sun subpoint (S)	$\phi_s = 0$	$\theta_s = 0$
Detector subpoint (V')	ϕ_v	θ_v
Reflection point (P)	ϕ_p	θ_p

Intermediate Output Quantities		
Quantity	Symbol	Le-71b Eq. No.
Longitude of Q_ℓ	ϕ_ℓ	1
Latitude of Q_ℓ	θ_ℓ	2
Longitude of Q_n	ϕ_n	3
Latitude of Q_n	θ_n	4
Eastward tilt at P	ϕ	5 (9) ^b
Northward tilt at P	θ	6 (10) ^b

Final Output Quantities		
Quantity	Symbol	Le-71 Eq. No.
Tilt magnitude at P	β	7 (11) ^b
Angle of incidence at P	ω	8 (12) ^b

^aValues relative to detector subpoint V'.

^bFor small-angle approximation, which we do not use.

$$f_r = L/(E \cos \theta_i) \quad (6)$$

where L is the radiance along the reflected ray and $E \cos \theta_i$ is the irradiance on the (horizontal) sea surface. By using the Cox-Munk formula, Equation (1), for L/E , we have

$$f_r = \frac{\rho(\omega)}{4} \frac{p(\beta)}{\cos \mu \cos \beta \cos \beta_i} \quad (7)$$

(It is not obvious that Equation (7) satisfies the reciprocity law, since β and ω have a very complicated dependence on the coordinates.)

3-3.2 The Directional-Hemispherical Reflectance

The directional-hemispherical reflectance, denoted here by $\rho(\lambda; \theta_i, 2\pi)$, is defined by the integral

$$\rho(\lambda; \theta_i, 2\pi) = \int f_r \cos \theta_r \, d\Omega_r \quad (8)$$

with f_r given by Equation (7); it is understood that

$$\mu \equiv \cos \theta_r. \quad (9)$$

Owing to the complexity of the dependence of ω and β on θ_r , we assume it is impossible to perform an analytic integration indicated in Equation (8).

For now, we shall not pursue further the topic of directional-hemispherical reflectance for a wind-ruffled sea. We were interested in it mainly as a self-consistent way to get the directional emissivity, but we shall content ourselves with an approximate treatment as next described.

3-3.3 The Directional Emissivity

Since we are unable to perform an analytic integration of the BRDF to get the directional-hemispherical reflectance for a wind-ruffled sea, we shall ignore the wind and compute the directional emissivity from the expression (sometimes referred to as Kirchhoff's law)

$$\epsilon_d(\theta) = 1 - \rho(\theta) \quad (10)$$

where $\rho(\theta)$ is the Fresnel specular reflectance next discussed in Section 3-3.4.

We note that Hall [Ha-64b] used Equation (10) for each of the planes of polarization of the radiation in computing the polarized emissivity of (flat and calm) water. We expect that Equation (10) will provide reasonable answers even for a wind-ruffled sea except for large zenith angles. Perhaps one can later make an improvement for such large zenith angles. Papers by Saunders [Sa-67a, Sa-68c] may be helpful.

3-3.4 Fresnel Reflectance of Water

3-3.4.1 Introduction

The factor $\rho(\omega)$ in the Cox-Munk formula, Equation (1), is the Fresnel specular reflectance of water for unpolarized radiation incident on a plane surface at angle of incidence ω . The Solar Radiation Model (23e), described in Section 4, provides E_λ (at the top of the atmosphere). Here, we present the Fresnel equations necessary to compute $\rho(\omega)$ and necessary data for the complex index of refraction for an air-water interface.

3-3.4.2 Formulas

We need the formula for the reflectance $\rho(\omega)$ of a plane electromagnetic wave incident at an angle $\theta_i \equiv \omega$ on a plane, absorbing surface (water). For an unpolarized wave, and a complex index of refraction N ,

$$N = n - ik, \quad (11)$$

where n is the index of refraction, k is the extinction coefficient, and $i = \sqrt{-1}$, the monochromatic specular reflectance is given [Me-60a, p.422; AH-66; SC-66a, p.63] by the expression

$$\rho(\omega) = r_s \frac{c + d^2}{c + 2a_+d + d^2} \quad (12)$$

where

$$r_s = (c - 2a_+e + e^2)/(c + 2a_+e + e^2) \quad (13a)$$

$$c = a_+^2 + a_-^2 \quad (13b)$$

$$d = \sin \omega \tan \omega \quad (13c)$$

$$e = \cos \omega \quad (13d)$$

$$2a_{\pm}^2 = [(n^2 - k^2 - \sin^2 \omega)^2 + 4n^2 k^2]^{1/2} \pm (n^2 - k^2 - \sin^2 \omega). \quad (13e)$$

At normal incidence,

$$\rho(0) = \frac{(n-1)^2 + k^2}{(n+1)^2 + k^2}. \quad (14)$$

We chose the Fresnel formulas as given by Equations (12) and (13) because (1) the form is the simplest we have seen and (2) three different references agree on the formulas. (Note that Me-60a uses $N=n(1-ik)$ instead of $N = n-ik$.) Relatively simple, but different formulas are given by Friedman [Fr-69b] but the two obvious misprints leaves one uncomfortable without verifying the overall formulas. Hall [Ha-64b] also gives the Fresnel formulas but

their form is again different and more complicated than that we have chosen. Other references include Condon and Odishaw [CO-58, 6-8, 6-113, -114], Stratton [St-41], and Born and Wolf [BW-75a]. Boudreau [Bo-73b] gives the Fresnel formulas in a form attributed to Stratton [St-41].

3-3.4.3 Complex Index of Refraction of Water

The most recent values of optical constants for (pure) water in the infrared are those given by Downing and Williams [DW-75] who tabulate $n(\nu)$ and $k(\nu)$, the real and imaginary parts of the complex index $N = n + ik$, in the range from $\lambda = 2 \mu\text{m}$ to $\lambda = 1 \text{ mm}$. In the 2- to 5- μm range of interest to us, 221 sets of data are given for wavenumbers $\nu = 2000(10)4000(50)5000$, entered as data statements in Subroutine FRESNL.

We also note that very recently Querry et al. [QH-77] determined the complex refractive index in the infrared for samples of surface water from five widely separate locations: San Francisco Bay, the Pacific Ocean, the Atlantic Ocean, the Great Salt Lake (Utah), and the Dead Sea (Israel). The variations will be ignored for the purposes of ROSCOE-IR.

3-4 SLOPE-SHADOWING FACTOR

Cox and Munk [CM-55, p. 70; CM-56, p. 470], in computing the albedo of direct sunlight from a rough surface, take account of the fact that large negative slopes in the component z_y (where the y-axis is horizontally away from the sun) are shadowed if they exceed $\cot \theta_i$, with θ_i the solar zenith angle. Cox and Munk include this effect by setting the limits to be $(-\cot \theta_i)$ and $(+\infty)$ for z_y (but $\pm\infty$ for z_x). Thus, while Cox and Munk include the effect in their albedo calculation, they do not mention the effect with respect to the slope distribution function $p(\theta)$ appearing in Equation (1).

Gordan [Go-69b] presents a formula, derived by K. B. MacAdam, for the fraction of the light from a source at zenith angle θ_i which reaches a given point on the sea surface without having first intersected the water surface at some other point. However, in presenting his formula, Gordan [Go-69b, p.20]

fails to note that the derivation is based on a one-dimensional distribution (instead of an isotropic, two-dimensional distribution as we would like). Also, Gordan [Go-69b] does not address the question of shadowing effects on the reflected ray.

Saunders [Sa-67a, Sa-68c] has derived an approximate, slope-shadowing factor, S^* , to account for the fact that, as one views near the horizon, the slopes on the back sides of the waves and deep in the troughs are hidden. For two-dimensional roughness, the factor S^* is stated [Sa-67a, p. 4648; Sa-68c] to be

$$S^*(\theta_r) = 2 \left(1 + \operatorname{erf}(v) + \frac{1}{v\sqrt{\pi}} e^{-v^2} \right)^{-1} \quad (15a)$$

where v , given by

$$v = \sigma^{-1} \tan \left(\frac{\pi}{2} - \theta_r \right) = \sigma^{-1} \cot \theta_r, \quad (15b)$$

is the ratio of the inclination of the line-of-sight to the root-mean-square slope (regardless of direction) and θ_r is the zenith angle of the reflected ray. Presumably $S^*(\theta_r)$ refers to only the reflected ray not escaping in one pass.

To permit a "bistatic" dependence on the zenith angles of both the incoming and outgoing rays, we propose using as the shadow factor

$$S(\theta_i, \theta_r) = S(\theta_i) S(\theta_r) \quad (16)$$

with

$$S(\theta) = 2 \left(1 + \operatorname{erf}(v) + \frac{1}{v\sqrt{\pi}} e^{-v^2} \right)^{-1} \quad (17a)$$

$$v = \sigma_s \cot \theta \quad (17b)$$

$$\sigma_s = (5.12 \times 10^{-3} W)^{1/2} . \quad (17c)$$

For numerical reasons, we need to consider some limiting cases:

- (a) If the wind speed $W = 0$, we set $S(\theta_i, \theta_r) = 1.0$.
- (b) If $\theta < \theta_{v2} \equiv \tan^{-1} (0.5 \sigma_s^{-1})$, we set $S(\theta) = 1.0$. The introduction of the angle θ_{v2} results from the observation that the shadowing factor is essentially unity for $v \geq 2$. Thus, there is no need to compute the shadowing factor unless θ exceeds the angle (θ_{v2}) for which $v=2$, for a given wind speed.
- (c) If $(0.5\pi - \theta) < 1.745 \times 10^{-3}$, set θ to 89.9 deg, an arbitrarily selected value. We do this to avoid possible division by zero or near-zero.

3-5 SPECIAL CASES

3-5.1 Location of Specular Point for Quiet Surface (no wind) on Spherical Earth, Given Locations of Source and Detector

Since we want to consider cases where the Earth-central angle between rays to the sun and the detector is not necessarily small, we cannot use the "lens" equation for a spherical convex mirror (and the concomitant paraxial rays) to aid in determining the reflection point but must resort to an iterative solution.

3.5.1.1 Algebraic Equations for Specular Point

Assume we are given the positions (i.e., the longitudes and latitudes of the subpoints) of the detector and sun, as depicted in Figure 3-3 (Points V' and S' , respectively). The total central angle between the rays OV and OS , α , is given by

$$\alpha_V + \alpha_S = \alpha,$$

(19)

and for each triangle, we have

$$\alpha_V + \beta_V + \gamma = \pi$$

(20a)

$$\alpha_S + \beta_S + \gamma = \pi.$$

(20b)

Thus, from Equations (20a) and (20b), we have

$$\alpha_V + \beta_V = \alpha_S + \beta_S.$$

(21)

Now,

$$r_V \equiv r + h_V = r \cos \alpha_V + s_V \cos \beta_V$$

(22a)

$$r_S \equiv r + h_S = r \cos \alpha_S + s_S \cos \beta_S$$

(22b)

and

$$\frac{s_V}{\sin \alpha_V} = \frac{r}{\sin \beta_V} = \frac{r_V}{\sin \gamma}$$

(23a)

$$\frac{s_S}{\sin \alpha_S} = \frac{r}{\sin \beta_S} = \frac{r_S}{\sin \gamma}.$$

(23b)

(In the code, r is the Earth radius plus the altitude assigned to the Point P.) By eliminating s_V between Equations (22a) and (23a) and s_S between Equations (22b) and (23b), we get

$$r_V = r \cos \alpha_V + r \frac{\sin \alpha_V}{\sin \beta_V} \cos \beta_V \quad (24a)$$

$$r_S = r \cos \alpha_S + r \frac{\sin \alpha_S}{\sin \beta_S} \cos \beta_S \quad (24b)$$

or

$$\epsilon_V^{-1} \equiv \rho_V \equiv \frac{r_V}{r} = \cos \alpha_V + \sin \alpha_V / \tan \beta_V \quad (24c)$$

$$\epsilon_S^{-1} \equiv \rho_S \equiv \frac{r_S}{r} = \cos \alpha_S + \sin \alpha_S / \tan \beta_S \quad (24d)$$

or

$$\beta_V = \tan^{-1} [\epsilon_V \sin \alpha_V (1 - \epsilon_V \cos \alpha_V)^{-1}] \quad (24e)$$

$$\beta_S = \tan^{-1} [\epsilon_S \sin \alpha_S (1 - \epsilon_S \cos \alpha_S)^{-1}] . \quad (24f)$$

Thus we have four equations ((19), (21), (24e), and (24f)) which need to be solved for the four unknowns (α_V , α_S , β_V , and β_S).

In presenting the equations for the specular point we have referred to the sun as the source. Indeed, that is the case within the NBR Module. However, in the original development of the specular point equations, we wanted to allow for non-solar sources at arbitrary altitudes, for which our specular-point equations are valid.

If one does specialize for a solar source, then one can obtain (with an appropriate approximation) a pair of equations (or, equivalently, a single transcendental equation if the user prefers) instead of the set of four equations. That is, for a solar source, as in Section 5-3.2.1 where we obtain the

solar zenith angle, we can assume that the solar ray to the reflection point is essentially parallel to the ray to the subsolar point, an approximation implying that the angle β_s is essentially zero. Thus, in Equation (21), if we set β_s equal to zero and eliminate α_s by use of Equation (19), we obtain

$$\alpha_v = (\alpha - \beta_v)/2 . \quad (24g)$$

Thus we have two equations ((24e) and (24g)) which need to be solved for the two unknowns (α_v and β_v). Of course, one can eliminate α_v between these two equations if he prefers. An iterative solution of the pair of equations should be analogous to that described in Section 3-5.1.2, but we have not implemented such a solution.

3-5.1.2 Iterative Solution of Specular-Point Equations

By using Equations (19), (21), (24e), and (24f), we find the condition to be satisfied is

$$F(\alpha_v) \equiv \alpha - 2\alpha_v + \tan^{-1} \left[\frac{\epsilon_s \sin \alpha_s}{1 - \epsilon_s \cos \alpha_s} \right] - \tan^{-1} \left[\frac{\epsilon_v \sin \alpha_v}{1 - \epsilon_v \cos \alpha_v} \right] = 0 . \quad (25)$$

Now,

$$\frac{dF(\alpha_v)}{d\alpha_v} \equiv F'(\alpha_v) = -2 + \frac{\epsilon_s^2 - \epsilon_s \cos \alpha_s}{1 + \epsilon_s^2 - 2\epsilon_s \cos \alpha_s} + \frac{\epsilon_v^2 - \epsilon_v \cos \alpha_v}{1 + \epsilon_v^2 - 2\epsilon_v \cos \alpha_v} . \quad (26)$$

According to the Newton-Raphson method, our iteration formula is

$$\alpha_v^{(n+1)} = \alpha_v^{(n)} - \frac{F(\alpha_v^{(n)})}{F'(\alpha_v^{(n)})} . \quad (27)$$

It remains to choose a starting value, $\alpha_V^{(0)}$, to be used in Equation (27). To do so, we start with Equation (21) and substitute for β_V and β_S their small-angle approximations from Equations (24e) and (24f). Thus we get

$$\alpha_V + \frac{\epsilon_V \alpha_V}{1 - \epsilon_V} = \alpha - \alpha_V + \frac{\epsilon_S (\alpha - \alpha_V)}{1 - \epsilon_S}. \quad (28)$$

By solving Equation (28) for α_V in terms of α , ϵ_V , and ϵ_S , we get

$$\alpha_V = \left[\frac{1 - \epsilon_V}{(1 - \epsilon_V) + (1 - \epsilon_S)} \right] \alpha. \quad (29)$$

Our iterative procedure now becomes

$$\alpha_V^{(0)} = \left[\frac{1 - \epsilon_V}{(1 - \epsilon_V) + (1 - \epsilon_S)} \right] \alpha \quad (29a)$$

$$\alpha_S^{(0)} = \alpha - \alpha_V^{(0)} \quad (30a)$$

$$\beta_V^{(0)} = \text{From Equation (24e)} \quad (30b)$$

$$\beta_S^{(0)} = \text{From Equation (24f)} \quad (30c)$$

$$F(\alpha_V^{(0)}) = \text{From Equation (25)} \quad (30d)$$

$$F'(\alpha_V^{(0)}) = \text{From Equation (26)} \quad (30e)$$

$$\alpha_V^{(1)} = \alpha_V^{(0)} - \frac{F(\alpha_V^{(0)})}{F'(\alpha_V^{(0)})}. \quad (30f)$$

We now put $\alpha_V^{(1)}$ into Equation (30a) and continue the looping over Equations (30) until we satisfy the condition

$$\alpha_V^{(n)} + \beta_V^{(n)} - (\alpha_S^{(n)} + \beta_S^{(n)}) \equiv \delta^{(n)} \leq 2 \times 10^{-5} . \quad (31)$$

3-5.1.3 Angle of Incidence and Reflection

From Figure 3-4 and Equation (20a), we have

$$\omega = \pi - \gamma = \alpha_V + \beta_V , \quad (32)$$

with α_V and β_V given by the iterative solution in Section 3-5.1.2.

3-5.1.4 Geographic Coordinates of Specular Point

Determination of the geographic coordinates of the specular point, given those for the sun and detector and the central angles α and α_V , is provided by Subroutine GCRCL, discussed in Section 3-6.5.

3.5-2 Radiance and BRDF for Specular Reflection from Smooth Water

To obtain the radiance for specular reflection from a smooth water surface, one can follow, e.g., the detailed development (given for another purpose) by Cox and Munk [CM-54] or immediately write the answer by assuming conservation of radiance for reflection from a perfect reflector. For the latter alternative we have for the specular radiance

$$L_{\text{spec}} = \rho(\omega)E/(\pi c^2) \quad (33)$$

where $\rho(\omega)$ and E are the same as in Equation (1) and c is the angular radius of the sun (16.0 minutes).

The BRDF corresponding to Equation (33) is defined to be

$$f_r = L_{\text{spec}} / (E \cos \theta_i) \quad (34)$$

so that

$$f_r = \rho(\omega) / (\pi \epsilon^2 \cos \theta_i) . \quad (34a)$$

3-5.3 A Limiting Form of Basic Cox-Munk Formula

The Cox-Munk basic formula, Equation (1), explicitly including the formula for the probability for the occurrence of slope B , is

$$L_{\text{CM}} = \frac{\rho(\omega)}{4} \frac{E}{\cos \mu \cos^4 B} \frac{\exp(-\sigma^{-2} \tan^2 B)}{\pi \sigma^2} . \quad (35)$$

For a zenith sun and downward-looking detector, the slope is zero and the zenith angle of the reflected ray equals the angle of incidence, i.e.,

$$\begin{aligned} B &= 0 \\ \mu &= \omega = 0, \end{aligned}$$

so that

$$L_{\text{CM}}(B=0) = \frac{\rho(0)}{4} \frac{E}{\pi \sigma^2} . \quad (36)$$

We note that this radiance is smaller than the specular value given by Equation (33) by the ratio

$$\boxed{\frac{L_{\text{CM}}(B=0)}{L_{\text{spec}}} = \left[\frac{\epsilon}{2\sigma} \right]^2} . \quad (37)$$

since

$$\left[\frac{\epsilon}{\sigma}\right]^2 = \frac{(4.65 \times 10^{-3})^2}{(3 + 5.12W) \times 10^{-3}} \ll 1. \quad (38)$$

The ratio given by Equation (37) will be obtained in another way in Section 3-5.4.

3-5.4 Relation Between Radiances from Smooth- and Rough-Water Surfaces

Saunders [Sa-67, p. 4116] makes a simple estimate of the radiance reflected from a rough-water surface compared with that from a smooth-water surface. He notes that the angular radius of the glitter pattern is approximately 2σ (as is readily seen from Figure 3-5) and hence the solid angle it subtends is $\pi(2\sigma)^2$, where σ is the root-mean-square slope. The solid angle subtended by the mirror image of the sun is [according to Saunders] $\pi\epsilon^2$, where ϵ is the angular radius of the sun's disk. (Saunders did not account for the solid angle of the mirror image of the sun being reduced for an observer at high altitudes, as explained below.) Saunders then states that if the total radiant energy reflected from the surface is independent of roughness (an assumption commented upon below), then the ratio of the intensity in the glitter pattern to the intensity in the mirror image is in the inverse ratio of the solid angles that they subtend, namely, $(\epsilon/2\sigma)^2$. Note that this ratio is just the ratio given by Equation (37).

A smooth-water surface on the spherical Earth acts like a convex spherical mirror of radius R_e . The virtual image of the sun is formed at a depth $R_e/2$ below the surface and the size of the sun's radius in this image is $\epsilon R_e/2$. The area of the virtual image is $\pi(\epsilon R_e/2)^2$ and the solid angle at the observer, at an altitude h from the mirror surface, is

$$\Omega = \frac{(\epsilon R_e/2)^2}{(h + R_e/2)^2} = \pi\epsilon^2 \left| \frac{R_e/2}{h + R_e/2} \right|^2 \quad (39)$$

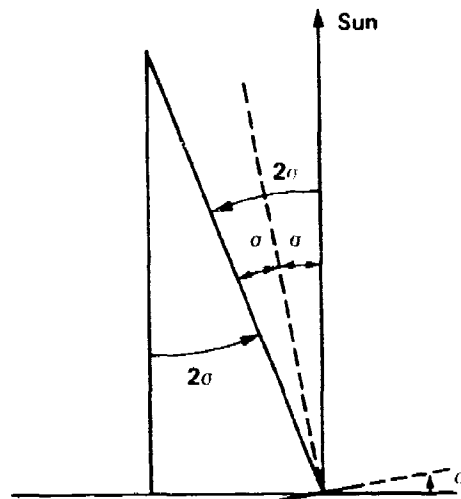


Figure 3-5. Geometry for simple estimate of angular radius of glitter pattern.

$$\rightarrow \begin{cases} \pi \epsilon^2 & \text{for } h \rightarrow 0 \\ \pi \epsilon^2 (R_e/2h)^2 & \text{for } h \gg R_e/2 . \end{cases} \quad (39a)$$

(39b)

The assumption made above by Saunders - that the total radiant energy reflected from the surface is independent of the roughness - is adequate for the order-of-magnitude estimate being made but it is not strictly correct. Cox and Munk [CM-55, Section 3; CM-56] show that the albedo of a rough surface to direct sunlight is slightly larger at high sun angles and substantially smaller at low sun angles than the albedo of a flat surface.

3-6 SUBROUTINES FOR CHARACTERIZATION OF WATER SURFACE

The relationship between the routines characterizing a water surface and Subroutine ESURF (for non-water surface characterization) is shown in Figure 2-12.

3-6.1 Subroutine GLITTR

Subroutine GLITTR is called from Subroutine ESURF when the line-of-sight from the detector (either a fictitious one at Point V in the NBR Module or, more generally, a real detector which may be in a satellite) intersects a wind-ruffled water surface prescribed by the user. Subroutine GLITTR provides (1a) the bidirectional reflectance-distribution function (BRDF) for the wind-ruffled water surface and (1b) the directional emissivity of a smooth-water surface as an approximation to that for the wind-ruffled water surface at the intersection (Point P) of the optical line-of-sight from the detector and, if requested (by the logical variable SPCULR = .TRUE. in the argument list), (2) the geographical coordinates of the point on an assumed smooth horizontal surface (taken to be at the same altitude as Point P) for a specular reflection of a ray from the source to the detector. Only the directional emissivity at Point P is provided if there is no source.

See Table 3-2 for a summary of inputs and outputs for Subroutine GLITTR and Figure 3-6 for a chart of information flow within Subroutine GLITTR.

3-6.2 Function CANGLE

Function CANGLE is called from Subroutines RINOUT and GLITTR to compute the Earth-central angle, CANGLE, between two central rays to Points P1 and P2, given the latitudes and longitudes of Points P1 and P2. Application of the cosine law for a side of the spherical triangle P1-N-P2 in Figure 3-7 gives the relation

$$\cos \alpha_{12} = \cos (\frac{\pi}{2} - \theta_1) \cos (\frac{\pi}{2} - \theta_2) + \sin (\frac{\pi}{2} - \theta_1) \sin (\frac{\pi}{2} - \theta_2) \cos (\varphi_2 - \varphi_1)$$

Table 3-2. Input and output variables for Subroutine GLITTR.

INPUT VARIABLES

Argument List

- THETI - Zenith angle of the source at the intersection point (P) of the line-of-sight from the detector to the Earth's water surface. (radians)

- WIND - Wind speed at 41 feet above sea level. (meters/sec)

- SPCULR - Logical variable.
 - = .TRUE., Compute coordinates of specular reflection point for an assumed smooth surface.
 - = .FALSE., Do not compute such coordinates.

- ZLAM - Wavelength. (μm)

- IDAY - Index for diurnal conditions at Point P.
 - = 0, Solar zenith angle >90 deg.
 - = 1, Solar zenith angle ≤ 90 deg.

- IFIRES - Flag for inclusion of fireballs as sources.
 - = 0, No fireball is being considered (always the case in the NBR Module).
 - > 0 , Fireballs are being considered as sources.

- ESURF1 - Logical variable.
 - = .TRUE., If Subroutine ESURF is called for the first time from Subroutine SURRAD and EPSD is wanted as an output (always the case in the NBR Module).
 - = .FALSE., If Subroutine ESURF is not being called for the first time from Subroutine SURRAD and a recomputation of EPSD is not needed.

TECTOR Common

- DETLT, - Detector (at Point V) altitude, north latitude, and east
- DETLAT, longitude. (km, radians, radians)
- DETLON

(continued)

Table 3-2. Input and output variables for Subroutine GLITTR (Cont'd).

DETZEN - Detector (at Point V) zenith angle at Point P. (radians)

POSITN Common

POSALT, - Altitude, north latitude, and east longitude of intersection
 POSLAT, on Earth's surface (Point P) of line-of-sight from detector
 POSLON (at Point V). (km, radians, radians)

SOURCE Common

SRCALT - Altitude of source, if not the sun. (km)
 SRCLAT, - North latitude and east longitude of source (sun in NBR
 SRCLOM Module, or fireball, more generally). (radians)
 SRCFLG - Flag characterizing source.

= 1, Sun is source (always, in NBR Module).

= 2, Fireball is source (never, in NBR Module).

OUTPUT VARIABLES

Argument List

SFR - Bidirectional reflectance-distribution function for a wind-ruffled water surface at Point P. (sr^{-1})

EPSD - Directional emissivity (of a smooth-water surface as an approximation to that for a wind-ruffled surface) at Point P toward the detector at Point V. (dimensionless)

POSITN Common

(This output obtains only if SPCULR = .TRUE.)

SPCLAT, - North latitude and east longitude of the point on an assumed
 SPCLON horizontal surface for a specular reflection from the source to the detector at Point V. (radians)

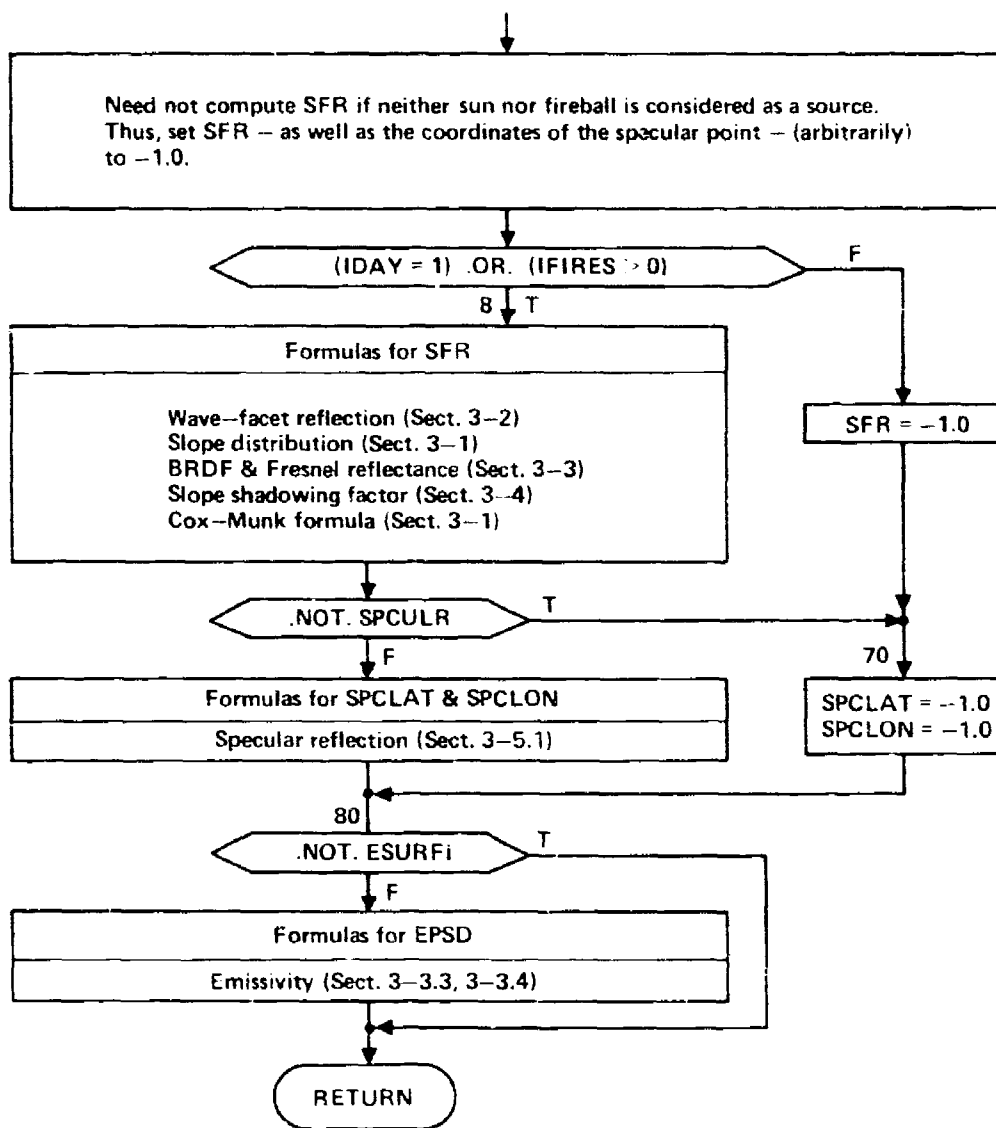


Figure 3-6. Information flow within Subroutine GLITTR

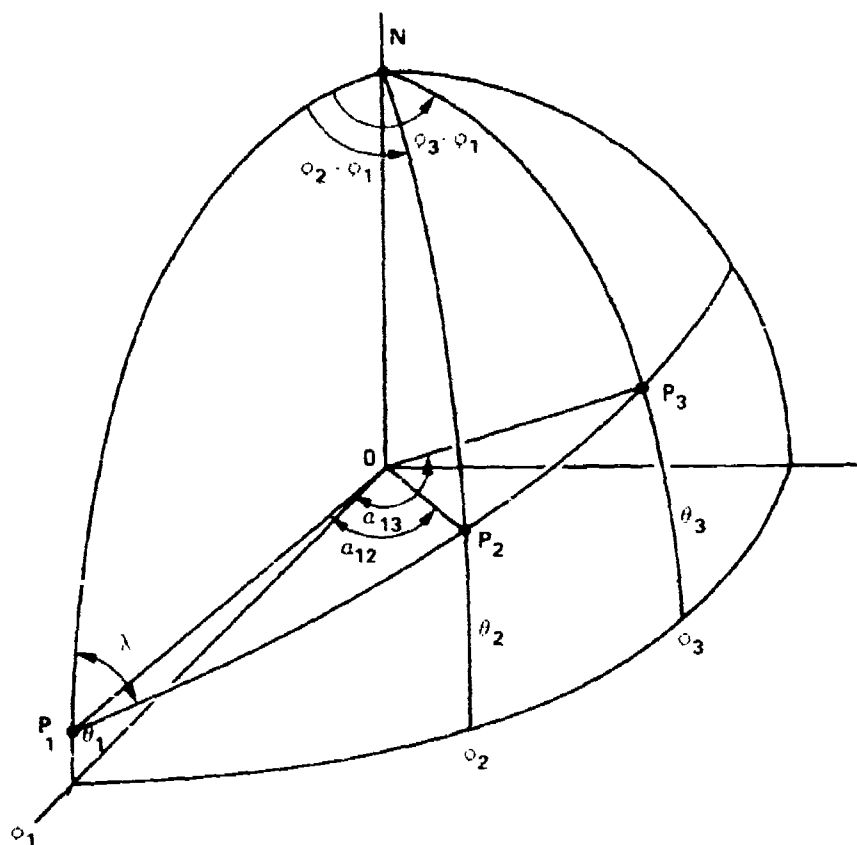


Figure 3-7. Earth geometry used in deriving formulas for Function CANGLE and Subroutine GCRCL.

$$\cos a_{12} = \sin \theta_1 \sin \theta_2 + \cos \theta_1 \cos \theta_2 \cos (\phi_2 - \phi_1)$$

or

$$\text{CANGLE} = a_{12}$$

$$= \cos^{-1} [\sin P1LAT \sin P2LAT + \cos P1LAT \cos P2LAT \cos (P2LON - P1LON)] .$$

See Table 3-3 for a summary of inputs and outputs for Function CANGLE.

Table 3-3. Input and output variables for Function CANGLE.

INPUT VARIABLES

Argument List

P1LAT, - North latitude and east longitude of Point P₁. (radians)
P1LON

P2LAT, - North latitude and east longitude of Point P₂. (radians)
P2LON

OUTPUT FUNCTION

CANGLE - Earth-central angle between rays to Points P₁ and P₂.
(radians)

3-6.3 Function ERF

Function ERF is the error function, based on the rational-approximation formula (7.1.2.6) in AS-64.

3-6.4 Subroutine FRESNL

Fresnel specular reflectance of a (smooth) water surface is discussed in Section 3-3.4. In Subroutine FRESNL, the complex index of refraction of water as given by Downing and Williams [DW-75] is stored as data and the Fresnel reflectance is computed from Equations (12) through (13e) in Section 3-3.4. Table 3-4 summarizes the inputs and outputs for Subroutine FRESNL.

Table 3-4. Input and output variables for Subroutine FRESNL.

INPUT VARIABLES

Argument List

ZLAM - Wavelength. (μm)

OMEGA - Angle of incidence (with respect to normal to smooth element of water surface). (radians)

OUTPUT VARIABLE

Argument List

RHO - Fresnel monochromatic reflectance of plane, unpolarized electromagnetic wave incident at angle ω on plane, absorbing surface of water with complex index of refraction $N=n-ik$ obtained from Downing and Williams [DW-75]. (dimensionless)

3-6.5 Subroutine GRCLE

For three points P_1 , P_2 , and P_3 on a great circle, Subroutine GRCLE computes the latitude and longitude of the intermediate point P_2 , given the latitudes and longitudes of the end points P_1 and P_3 , the central angle α_{13} between the central rays to P_1 and P_3 , and the central angle α_{12} between the central rays to P_1 and P_2 .

Application of the cosine law for a side of the spherical triangle P_1 - N - P_3 in Figure 3-7 gives the relation

$$\cos\left(\frac{\pi}{2}-\theta_3\right) = \cos \alpha_{13} \cos\left(\frac{\pi}{2}-\theta_1\right) + \sin \alpha_{13} \sin\left(\frac{\pi}{2}-\theta_1\right) \cos \lambda$$

or

$$\cos \lambda = \frac{\sin \theta_3 - \cos \alpha_{13} \sin \theta_1}{\sin \alpha_{13} \cos \theta_1}.$$

Similarly, for triangle P_1-N-P_2 in Figure 3-7, we have

$$\cos(\frac{\pi}{2}-\theta_2) = \cos \alpha_{12} \cos(\frac{\pi}{2}-\theta_1) + \sin \alpha_{12} \sin(\frac{\pi}{2}-\theta_1) \cos \lambda$$

or

$$\sin \theta_2 = \cos \alpha_{12} \sin \theta_1 + \sin \alpha_{12} \cos \theta_1 \cos \lambda .$$

Application of the sine law to the spherical triangle P_1-N-P_2 in Figure 3-7 gives

$$\frac{\sin(\phi_2 - \phi_1)}{\sin \alpha_{12}} = \frac{\sin \lambda}{\sin(\frac{\pi}{2}-\theta_2)}$$

or

$$\sin(\phi_2 - \phi_1) = \sin \alpha_{12} \sin \lambda / \cos \theta_2 .$$

Thus,

$$\phi_2 = \phi_1 + (\phi_2 - \phi_1) \times \text{SIGN}(1.0, \phi_3 - \phi_1) .$$

$$\text{If } |\phi_3 - \phi_1| > \pi, \phi_2 = \phi_1 - (\phi_2 - \phi_1) \times \text{SIGN}(1.0, \phi_3 - \phi_1) .$$

$$\text{If } \phi_2 < 0.0, \quad \phi_2 = \phi_2 + 2\pi .$$

$$\text{If } \phi_2 \geq 2\pi, \quad \phi_2 = \phi_2 - 2\pi .$$

See Table 3-5 for a summary of the inputs and outputs for Subroutine GCRCL.

Table 3-5. Input and output variables for Subroutine GCRCLE.

INPUT VARIABLES

Argument List

P1LAT, - North latitude and east longitude of Point P_1 . (radians)
P1LON

P3LAT, - North latitude and east longitude of Point P_3 . (radians)
P3LON

ALP13 - Earth-central angle between rays to Points P_1 and P_3 .
(radians)

ALP12 - Earth-central angle between rays to Point P_1 and P_2 .
(radians)

OUTPUT VARIABLES

Argument list

P2LAT, - North latitude and east longitude of Point P_2 . (radians)
P2LON

SECTION 4

SOLAR RADIATION

4-1 INTRODUCTION

4-1.1 Requirements for the Model

Solar radiation must be modeled because it is a source of sensor illumination, and atmospheric and fireball species excitation, through scattering and/or reflection from the Earth's surface, clouds, aerosols, and dust, either naturally occurring or caused by the fireball.

4-1.2 Model Function

The Solar Radiation Model (23e) consists of a statement of the solar spectral irradiance, at the top of the Earth's atmosphere, in the spectral range from 2 to 5 μm (or 5000 to 2000 cm^{-1}).

4-2 DATA BASE

As a result of extensive work by NASA related to the design of space vehicles, an engineering standard for solar irradiance has been adopted by the American Society of Testing and Materials (ASTM) [Th-74a, Th-76]. We have adopted the tabular data presented by Thekaekara [Th-74a]. Columns 1 and 2 in Table 4-1 present data abstracted from Table I of Th-74a in the spectral range from 2 to 5 μm at 0.1 μm intervals. These data are plotted in Figure 4-1 as the circled points and have been fitted by the following piecewise-continuous power-law expression:

Table 4-1. Solar spectral irradiance (2 to 5 μm).

λ	E_{λ}^a	E_{λ}^b		E_{λ}^d	E_{λ}^e	E_{λ}^f	
	W	W	Percent ^c	10^{10} photon	10^{13} photon	10^{-7} W	
μm	$\text{m}^2 \mu\text{m}$	$\text{m}^2 \mu\text{m}$	Error	$\text{cm}^2 \text{ sec } \mu\text{m}$	$\text{cm}^2 \text{ sec cm}^{-1}$	$\text{cm}^2 \text{ cm}^{-1}$	cm^{-1}
2.0	103	104.62	1.5	10.4	4.15	41.2	5000
2.1	90	90.61	0.7	9.51	4.20	39.7	4762
2.2	79	79.00	0.0	8.75	4.23	38.2	4545
2.3	69	69.30	0.4	7.99	4.23	36.5	4348
2.4	62	61.13	-1.4	7.49	4.31	35.7	4167
2.5	55	54.20	-1.5	6.92	4.33	34.4	4000
2.6	48	48.29	0.6	6.28	4.25	32.4	3846
2.7	43	43.20	0.5	5.84	4.26	31.3	3704
2.8	39	38.81	-0.5	5.50	4.31	30.6	3571
2.9	35	35.00	0.0	5.11	4.30	29.4	3448
3.0	31	29.90	-3.7	4.68	4.21	27.9	3333
3.1	26.0	25.67	-1.3	4.06	3.90	25.0	3226
3.2	22.6	22.15	-2.0	3.64	3.73	23.1	3125
3.3	19.2	19.19	0.0	3.19	3.47	20.9	3030
3.4	16.6	16.71	0.6	2.84	3.28	19.2	2941
3.5	14.6	14.60	0.0	2.57	3.15	17.9	2857
3.6	13.5	13.33	-1.2	2.45	3.17	17.5	2778
3.7	12.3	12.21	-0.7	2.29	3.14	16.8	2703
3.8	11.1	11.21	0.9	2.12	3.07	16.0	2632
3.9	10.3	10.31	0.1	2.02	3.08	15.7	2564
4.0	9.5	9.50	0.0	1.91	3.06	15.2	2550

(continued)

Table 4-1. Solar spectral irradiance (2 to 5 μm) (Cont'd).

λ	E_{λ}^a	E_{λ}^b		E_{λ}^d	E_{ω}^e	E_{ω}^f	ω
	W	W	Percent ^c	10^{16} photon	10^{13} photon	10^{-7} W	
μm	$\text{m}^2 \mu\text{m}$	$\text{m}^2 \mu\text{m}$	Error	$\text{cm}^2 \text{ sec } \mu\text{m}$	$\text{cm}^2 \text{ sec cm}^{-1}$	$\text{cm}^2 \text{ cm}^{-1}$	cm^{-1}
4.1	8.70	8.58	-1.4	1.80	3.02	14.6	2439
4.2	7.80	7.77	-0.4	1.65	2.91	13.8	2381
4.3	7.10	7.05	-0.7	1.54	2.84	13.1	2326
4.4	6.50	6.42	-1.3	1.44	2.79	12.6	2273
4.5	5.92	5.85	-1.2	1.34	2.72	12.0	2222
4.6	5.35	5.34	-0.1	1.24	2.62	11.3	2174
4.7	4.86	4.89	0.6	1.15	2.54	10.7	2128
4.8	4.47	4.48	0.3	1.08	2.49	10.3	2083
4.9	4.11	4.12	0.2	1.01	2.43	9.87	2041
5.0	3.79	3.79	0.0	0.954	2.38	9.47	2000

^aFrom Th-74a, Table I.

^bComputed from fit function, Equation (1).

^cPercent error in fit-function values with respect to Column-2 data.

^dComputed from Equation (4) and Column-2 data.

^eComputed from Equation (5) and Column-2 data.

^fComputed from Equation (6) and Column-2 data.

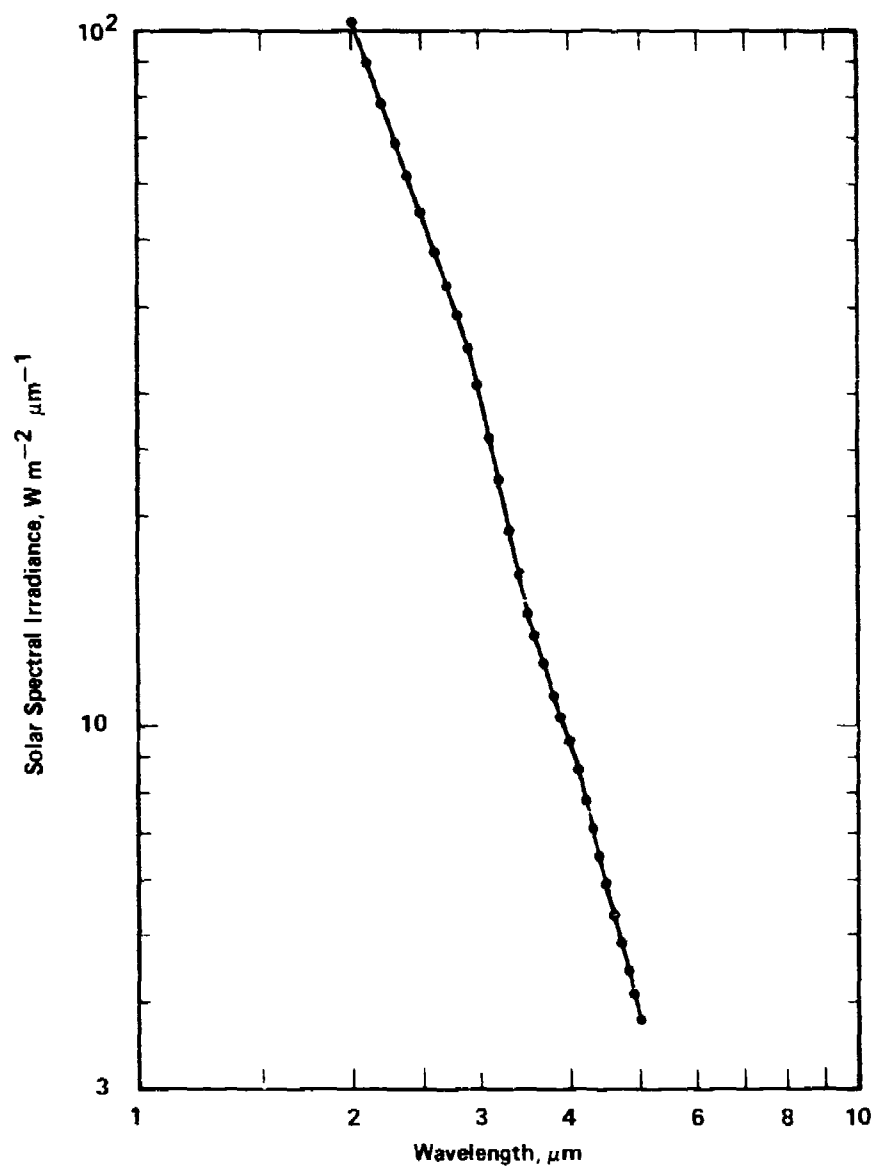


Figure 4-1. Solar spectral irradiance from 2 to 5 μm (units of $\text{W m}^{-2} \mu\text{m}^{-1}$).

$$E_{\lambda} (W m^{-2} \mu m^{-1}) = \begin{cases} E_{2.2}(\lambda/2.2)^a & 2.0 \leq \lambda < 2.9 & (1a) \\ E_{2.9}(\lambda/2.9)^b & 2.9 \leq \lambda < 3.5 & (1b) \\ E_{3.5}(\lambda/3.5)^c & 3.5 \leq \lambda < 4.0 & (1c) \\ E_{4.0}(\lambda/4.0)^d & 4.0 \leq \lambda \leq 5.0 & (1d) \end{cases}$$

where

$$a = \frac{\log E_{2.9} - \log E_{2.2}}{\log 2.9 - \log 2.2} = - 2.94693 \quad (2a)$$

$$b = \frac{\log E_{3.5} - \log E_{2.9}}{\log 3.5 - \log 2.9} = - 4.64938 \quad (2b)$$

$$c = \frac{\log E_{4.0} - \log E_{3.5}}{\log 4.0 - \log 3.5} = - 3.21819 \quad (2c)$$

$$d = \frac{\log E_{5.0} - \log E_{4.0}}{\log 5.0 - \log 4.0} = - 4.11809 \quad (2d)$$

$$E_{2.2} = 79 \quad (3a)$$

$$E_{2.9} = 35 \quad (3b)$$

$$E_{3.5} = 14.6 \quad (3c)$$

$$E_{4.0} = 9.5 \quad (3d)$$

$$E_{5.0} = 3.79 \quad (3e)$$

Evaluation of the fit function gives the values and percentage errors in Columns 3 and 4 of Table 4-1, respectively.

By using the conversion relations derived in Section 4-4, we can convert the units of the spectral irradiance from $E_\lambda [W/(m^2 \mu m)]$ to $E_\lambda [\text{photon}/(cm^2 \text{ sec } \mu m)]$ by writing

$$E_\lambda \left| \frac{\text{photon}}{cm^2 \text{ sec } \mu m} \right| = E_\lambda \left| \frac{W}{m^2 \mu m} \right| \times \frac{(10^{-4}/hc) \lambda \frac{\text{photon}}{W \text{ sec}}}{(10^2 \text{ cm/m})^2}$$

or

$$E_\lambda \left| \frac{\text{photon}}{cm^2 \text{ sec } \mu m} \right| = 5.03404 \times 10^{14} \lambda E_\lambda \left| \frac{W}{m^2 \mu m} \right|. \quad (4)$$

The product hc is expressed in units of $J \text{ cm}$ and λ in μm . Similarly, we can convert from $E_\lambda [W/(m^2 \mu m)]$ to $E_\omega [\text{photon}/(cm^2 \text{ sec } cm^{-1})]$ by writing

$$E_\omega \left| \frac{\text{photon}}{cm^2 \text{ sec } cm^{-1}} \right| = E_\lambda \left| \frac{W}{m^2 \mu m} \right| \times \frac{(10^{-4}/hc) \lambda \frac{\text{photon}}{W \text{ sec}}}{(10^2 \text{ cm/m})^2 10^4 \lambda^{-2} cm^{-1}/\mu m}$$

or

$$E_\omega \left| \frac{\text{photon}}{cm^2 \text{ sec } cm^{-1}} \right| = 5.03404 \times 10^{10} \lambda^3 E_\lambda \left| \frac{W}{m^2 \mu m} \right|. \quad (5)$$

We can convert from $E_\lambda [W/(m^2 \mu m)]$ to $E_\omega [W/(cm^2 cm^{-1})]$ by writing

$$E_\omega \left| \frac{W}{cm^2 cm^{-1}} \right| = E_\lambda \left| \frac{W}{m^2 \mu m} \right| \times \frac{1}{(10^2 \text{ cm/m})^2 10^4 \lambda^{-2} cm^{-1}/\mu m}$$

or

$$E_{\lambda} \left[\frac{W}{cm^2 \cdot cm^{-1}} \right] = 10^{-8} \lambda^2 E_{\lambda} \left[\frac{W}{m^2 \cdot \mu m} \right] \quad (6)$$

The quantities E_{λ} [photon/($cm^2 \cdot sec \cdot \mu m$)], E_{ν} [photon/($cm^2 \cdot sec \cdot cm^{-1}$)], and E_{λ} [$W/(cm^2 \cdot cm^{-1})$] are given in Columns 5, 6, and 7 of Table 4-1, respectively, and are plotted in Figures 4-2, 4-3, and 4-4, respectively.

4-3 SUBROUTINE SOLRAD

For Subroutine SOLRAD, see Table 4-2 for a summary of the input and output variables and Figure 4-5 for a flow chart.

Table 4-2. Input and output variables for Subroutine SOLRAD.

INPUT VARIABLES

Argument List

- K - Index specifying units for input and output
- B - $\begin{cases} \text{Wavenumber (cm}^{-1}\text{) for K=1,2,3,4} \\ \text{Wavelength (}\mu\text{m) for K=5,6,7,8} \end{cases}$

OUTPUT VARIABLES

Argument List

- E - Solar spectral irradiance at the top of the Earth's atmosphere, in units of:
- | | |
|---------------------------------------------------|---------|
| photons $cm^{-2} \cdot sec^{-1} / cm^{-1}$ | K = 1,5 |
| photons $cm^{-2} \cdot sec^{-1} \cdot \mu m^{-1}$ | K = 2,6 |
| $W \cdot cm^{-2} / cm^{-1}$ | K = 3,7 |
| $W \cdot m^{-2} \cdot \mu m^{-1}$ | K = 4,8 |

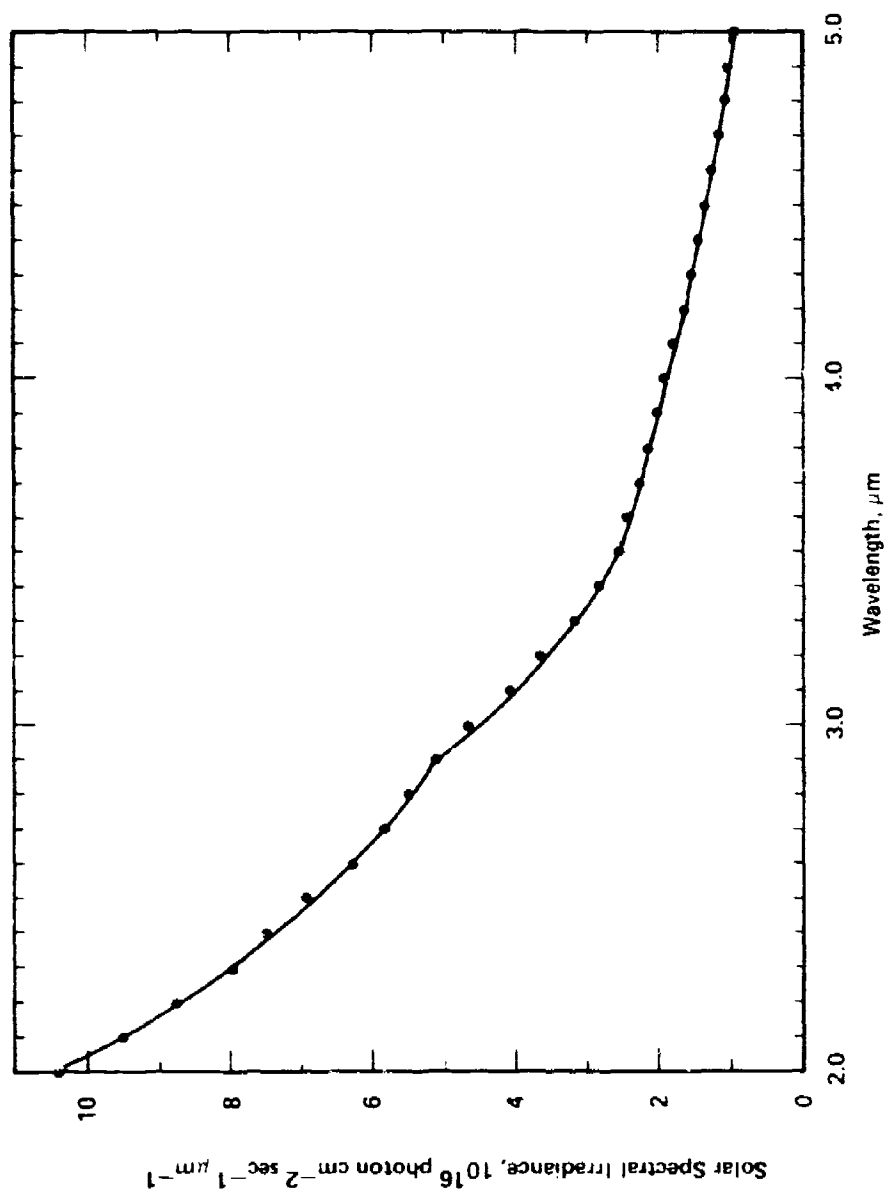


Figure 4-2. Solar spectral irradiance from 2 to 5 μm (units of $\text{photon cm}^{-2} \text{sec}^{-1} \mu\text{m}^{-1}$). The circled points correspond to the data in column 2 of Table 4-1 and the solid curve to the fit function.

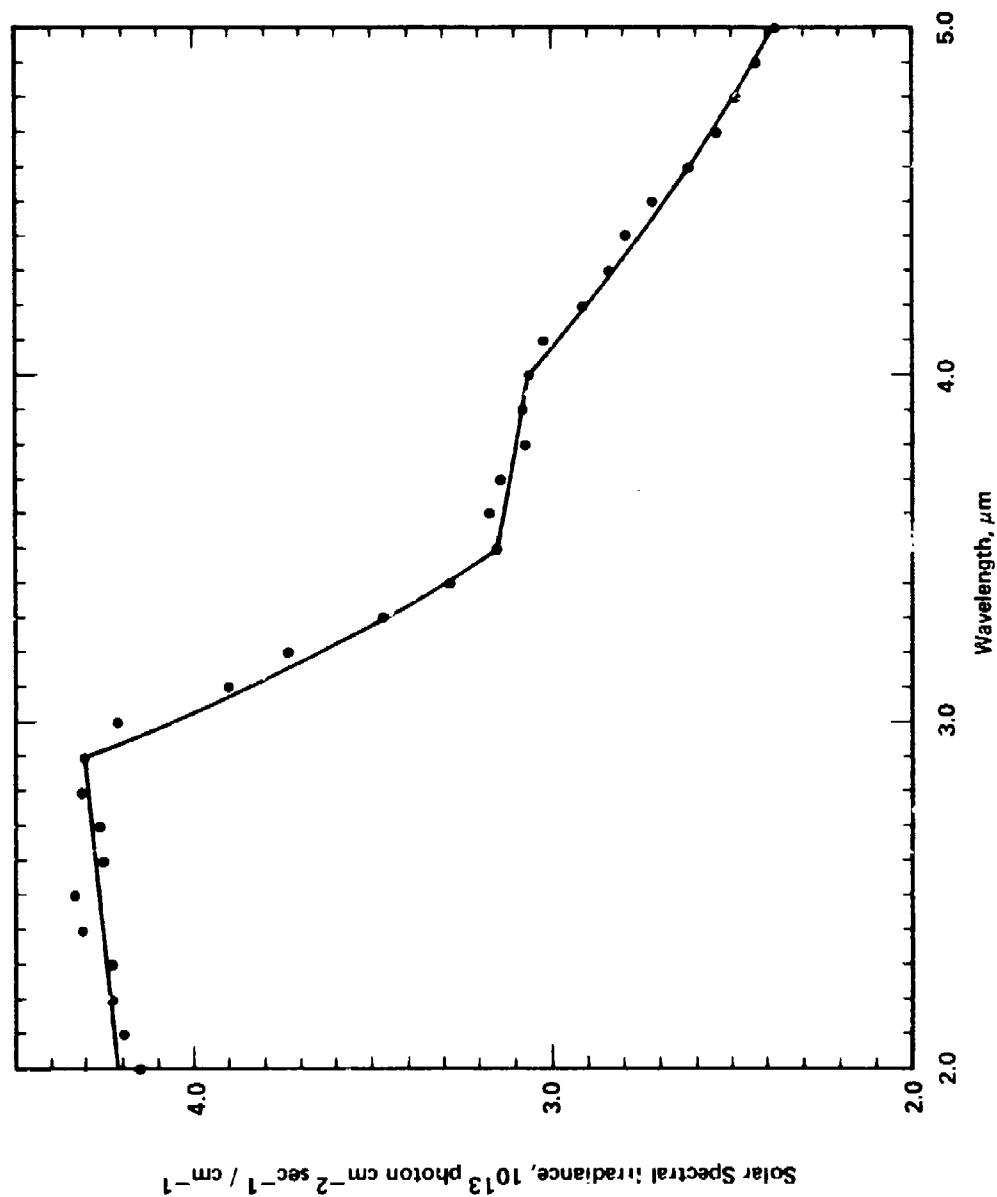


Figure 4-3. Solar spectral irradiance from 2 to 5 μm (units of photon $\text{cm}^{-2} \text{sec}^{-1} / \text{cm}^{-1}$). The circled points correspond to the data in Column 2 of Table 4-1 and the solid curve to the fit function.

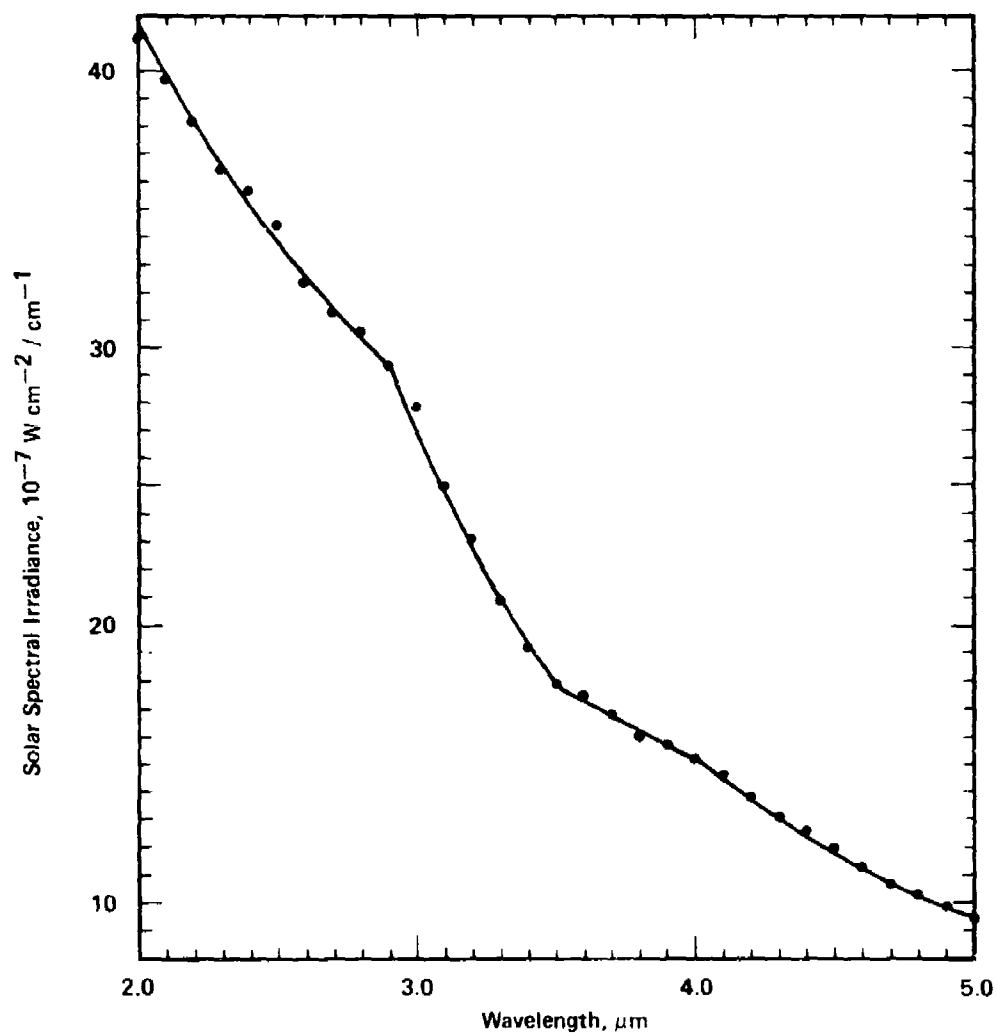


Figure 4-4. Solar spectral irradiance from 2 to 5 μm (units of $\text{W cm}^{-2} / \text{cm}^{-1}$). The circled points correspond to the data in column 2 of Table 4-1 and the solid curve to the fit function.

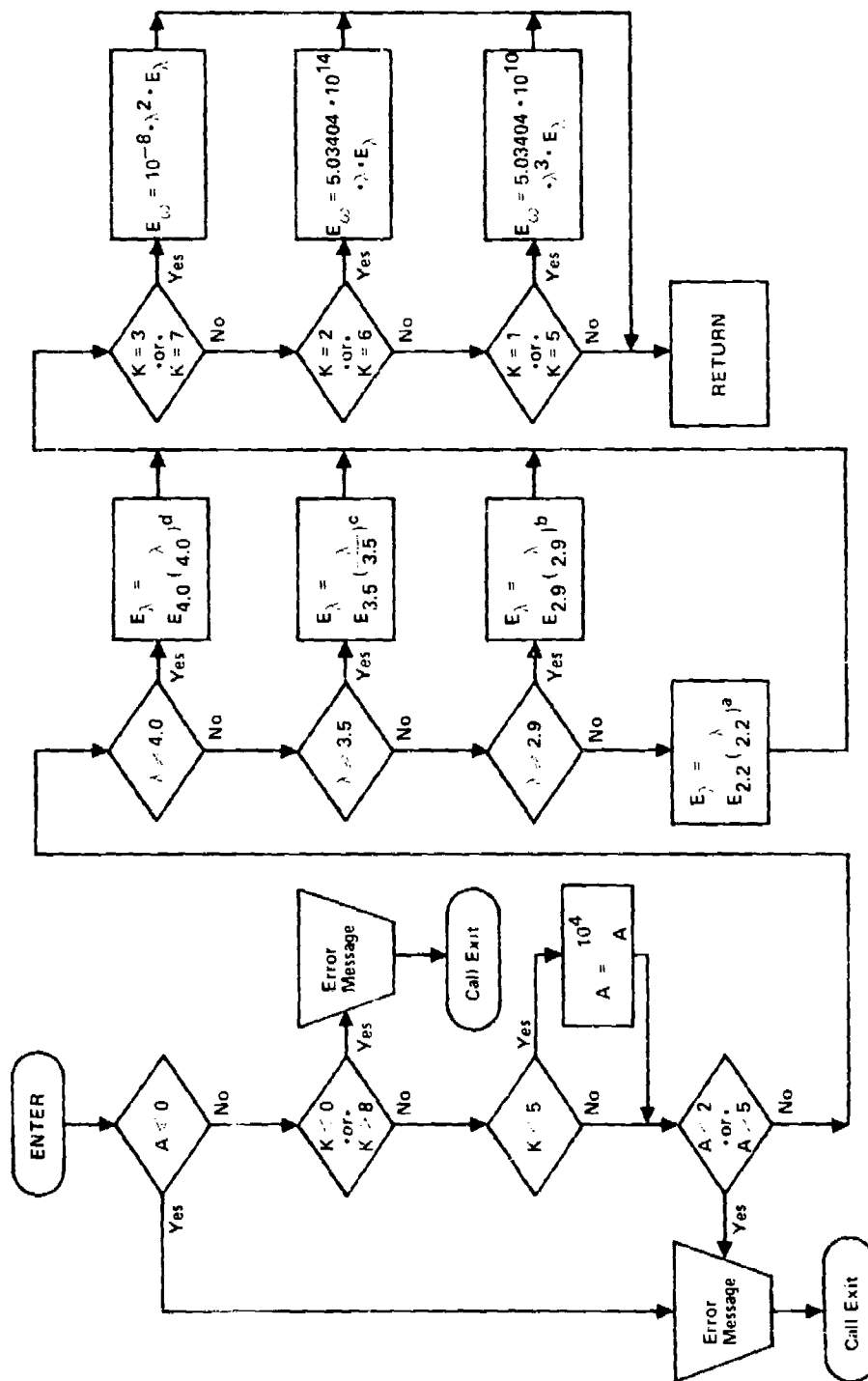


Figure 4-5. Flow chart for Subroutine SOLRAD.

4-4 SOME CONVERSION RELATIONS

Some useful conversion relations may be derived as follows:

$$1. \text{ Energy photon}^{-1} = h\nu = hc/\lambda_{\text{cm}} = hc\omega, \text{ W sec}$$

where hc is expressed in J cm and ω in inverse centimeters. If we use the values of h and c from Cohen and Taylor [CT-73b, Table 33.1 on p. 717], we have

$$hc = \frac{6.626176 \times 10^{-27} \text{ erg sec}}{10^7 \text{ erg/J}} \times 2.997924 \times 10^{10} \text{ cm/sec}$$

$$\begin{aligned} hc &= 1.98648 \times 10^{-23} \text{ J cm} \\ 1/hc &= 5.03404 \times 10^{22} \text{ J}^{-1} \text{ cm}^{-1} \end{aligned}$$

Also,

$$\text{Energy photon}^{-1} = 10^4 hc/\lambda, \text{ W sec}$$

where λ is in micrometers; thus,

$$\begin{aligned} 1 \text{ Watt} &= 10^{-4} \lambda/hc, \text{ photon sec}^{-1} \\ &= 1/hc\omega, \text{ photon sec}^{-1} \end{aligned}$$

$$2. \quad \lambda = 10^4/\omega$$

$$|d\lambda/d\omega| = 10^4/\omega^2$$

$$\text{micron wavenumber}^{-1} = 10^4/\omega^2$$

$$= 10^{-4} \lambda^2$$

or

$$\begin{aligned}\text{wavenumber micron}^{-1} &= 10^{-4} \omega^2 \\ &= 10^4 / \lambda^2\end{aligned}$$

SECTION 5

EARTH SURFACE RADIANCE

5-1 INTRODUCTION

The Earth Surface Radiance Model (23b) provides (essentially), at the Point P where the optical line-of-sight from the detector (which is fictitious in the NBR Module) at Point V intersects the Earth's surface, the upwelling spectral radiance directed toward the detector. The model provides two components of the radiance: (1) thermal radiation emitted at Point P and (2) source radiation reflected at Point P. In the NBR Module, the only source is the sun. Reflected sky radiance is not included.

Strictly, the surface-reflected source radiation is actually provided in an unattenuated form together with the path parameters (areal density U (cm at STP) and the product UP (atm cm, with P the pressure)) integrated along the incoming path from the source. These parameters are required as input to a computation of the molecular absorption over the total two-leg path. The aerosol transmittance along the incoming path from the source to Point P is also provided.

The principal routine in the Earth Surface Radiance Model is Subroutine SURRAD (surface radiance), which makes a number of calls as shown in Figure 5-1. Subroutine SURRAD is discussed in Section 5-2. Subroutine RINOUT (ray-in-out) computes the geometry for the reflected ray and is discussed in Section 5-3. Subroutine ESURF has been discussed in Section 2-5 and Subroutine SOLRAD in Section 4-3. The rest of the routines used in Model 23b, most of which were obtained from other organizations, are described in Section 5-4.

5-2 SUBROUTINE SURRAD

Table 5-1 summarizes the input and output variables for Subroutine SURRAD.

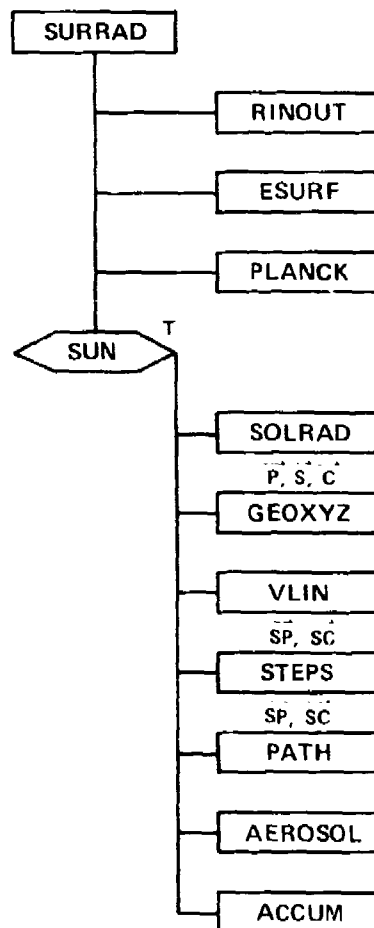


Figure 5--1. Routines called directly from the principal routine (SURRAD) in the Earth Surface Radiance Model. For subsequent calls, see Figure 7--1.

Table 5-1. Input and output variables for Subroutine SURRAD.

INPUT VARIABLES

Argument List

IDETEC - Flag for nature of detector location.

= 1, If detector is at a satellite position (SATLAT, SATLON, SATALT) specified in SATELL Common. (This mode is not used in the NBR Module.)

= 2, If detector is at a position (DETLAT, DETLON, DETALT) specified in TECTOR Common. (This latter option is used when Subroutine SURRAD is called from Subroutine UPWELL in the NBR Module.)

MSM - Index for category of surface material (see Table 2-12 for Subroutine ESURF).

DD - Additional descriptor for selected surface material (see Table 2-12 for Subroutine ESURF).

SPCULR - Logical variable.

= .TRUE., Compute coordinates of specular reflection point on an assumed smooth horizontal water surface.

= .FALSE., Do not compute coordinates of specular reflection point.

(SPCULR appears in SURRAD only to be passed to Subroutine ESURF.)

IUP - Altitude-loop index in Subroutine UPWELL.

JUP - Nadir-loop index in Subroutine UPWELL.

KUP - Azimuth-loop index in Subroutine UPWELL.

LUP - Wavenumber-loop index in Subroutine UPWELL.

(Each of the previous four indices should be set to unity in a call from any routine other than Subroutine UPWELL, which would be a use outside of the NBR Module.)

ZLAM - Wavelength. (μm)

(continued)

Table 5-1. Input and output variables for Subroutine SURRAD (Cont'd).

IFIRES - Flag for inclusion of fireballs as sources.
 = 0, No fireball is to be included (always true in NBR Module where Subroutine SURRAD is called from Subroutine UPWELL).
 > 0, Fireballs (IFIRES, in number) are to be included with position and radiant intensity specified in FIRBAL Common.

FIRBAL Common (not used in NBR Module)

FBALT(I), - Fireball-I altitude, north latitude, east longitude, and
 FBLAT(I), spectral radiant intensity.
 FBLON(I), [km, radians, radians, $W/(sr\ cm^{-1})$]
 FBRINT(I)

POSITN Common

POSALT, - Altitude, north latitude, and east longitude of Point P at
 POSLAT, which line-of-sight from (fictitious) detector at Point V
 POSLON intersects Earth's surface. (km, radians, radians)
 C12ALT, - Altitude, north latitude, and east longitude of Point C at
 C12LAT, which line-of-sight (directed toward Point P from fictitious
 C12LON detector at Point V) intersects the 12-km altitude surface.
 (km, radians, radians)

SATELL Common (not used in NBR Module)

SATALT, - Satellite-borne detector altitude, north latitude, and east
 SATLAT, longitude. (km, radians, radians)
 SATLON

SOLARP Common

SOLLAT, - Subsolar-point north latitude and east longitude. (radians)
 SOLLON

SOURCE Common

(The variables in this Common are returned from a call to Subroutine RINOUT. In the NBR Module, only the sun is used as a source for Subroutine SURRAD. Fireballs are never used in the NBR Module where Subroutine SURRAD is called from Subroutine UPWELL.)

SRCZEN(1) - Zenith angle of solar ray incoming to Point P. (radians)

(continued)

Table 5-1. Input and output variables for Subroutine SURRAD (Cont'd).

(The following two arrays are not used in the NBR Module; L=1, IFIRES)

SRCZEN(L+1) - Zenith angle of Fireball-L ray incoming to Point P.
(radians)

SRCZR(L+1) - Slant range from Fireball-L to Point P. (km)

TECTOR Common

DEALT, - Altitude, north latitude, and east longitude of fictitious
DETLAT, detector at Point V. (km, radians, radians)
DETLON

UPWELS Common

NWAVE(M) - Number of wavenumbers at which the upwelling spectral
radiance is to be computed for broad-band loop-index
M=JBAND.

IDAYV - Index for diurnal condition at Subpoint V'.

= 0, Solar zenith angle > 90 deg.

= 1, Solar zenith angle \leq 90 deg.

IKM - Index for number of altitudes at which calculations are
made when clouds are included (set in Subroutine UPWELL).

UPWELS2 Common

JBAND1 - Same as JBAND in Subroutine UPWELL. Index for list of
(broad) wavelength bands.

Data Statement

NSPCS - Number of species in molecular transmittance model.

NTEMP - Number of temperature bins in molecular transmittance model.

OUTPUT VARIABLES

Argument List

RAD(1) - Radiance emitted from surface material at Point P and
directed toward detector at Point V.
[W/(cm² sr cm⁻¹)]

(continued)

Table 5-1. Input and output variables for Subroutine SURRAD (Cont'd).

RAD(2)	- Radiance of solar radiation reflected at Point P (with incoming ray unattenuated) and directed toward detector at Point Y. [W/(cm ² sr cm ⁻¹)]
For L=1, IFIRES (not used in NBR Module)	
RAD(L+2)	- Radiance of Fireball-L radiation reflected at Point P (with incoming ray unattenuated) and directed toward detector at Point Y. [W/(cm ² sr cm ⁻¹)]
UPS(I,N,1), UPPS(I,N,1)	- Path parameters U (areal density) and UP (product of J and pressure P) for temperature-index-I and species-N along incoming solar path to Point P on Earth's surface. Computed only for LUP=1. (cm at STP, atm-cm at STP)
For L=1, IFIRES (not used in NBR Module)	
UPS(I,N,L+1), UPPS(I,N,L+1)	- Path parameters U and UP along path from Fireball-L to Point P on Earth's surface. Computed only for LUP=1. (cm at STP, atm-cm at STP)
UCS(I,N), UPCS(I,N)	- Similar to UPS(I,N,1) and UPPS(I,N,1) except Point P is replaced by Point C.
AIRSOL Common	
For LUP=1, NWAVE(JBAND)	
TASP(LUP), TASC(LUP)	- Aerosol transmittances for incoming solar rays to Point P on Earth's surface and Point C at 12-km altitude. (Depend only on wavelength and assumed single paths.)
For L=1, IFIRES (not used in NBR Module)	
TAFP(L)	- Aerosol transmittance for incoming ray from Fireball-L to Point P on Earth's surface.
SOLARP Common	
For LL=1, NWAVE(JBAND)	
SOLIRR(LL)	- Solar spectral irradiance at the top of the atmosphere at wavenumber-index LL. [W/(cm ² cm ⁻¹)]

The calculational steps performed in Subroutine SURRAD, as it is employed in the NBR Module, may be described as follows:

- A. Preliminaries (done only for spectral index $L=1$)
 - 1. Call RINOUT to evaluate geometry for solar source, surface point (P), and fictitious detector at Point V. Obtain at Point P:
 - a. Detector zenith.
 - b. IDAY.
 - c. Source zenith (if IDAY=1).
 - d. Detector azimuth (if IDAY=1 and MSM > 2).
 - 2.1 If IDAYV=1 and IDAY=1, set source zenith into THI and detector azimuth into PSI (if MSM > 2).
 - 2.2 If IDAYV=0, set IDAY=0.
 - 3. Set detector zenith into THR.
- B. Call ESURF
Obtain surface temperature (TKS), directional emissivity (EPSD), and (if IDAY=1) bidirectional reflectance-distribution function (SFR). If sun and water surface are present and if SPCULR=.TRUE., also get solar specular reflection point on assumed smooth horizontal water surface.
- C. Compute surface spectral radiance [RAD(1)] by:
 - 1. Call PLANCK (only for $I=J=K=1$).
 - 2. Evaluate $RAD(1) = EPSD \times PLANCK(TKS, W)$.
- D. Compute (unattenuated) surface-reflected solar radiance [RAD(2)] by:
 - 1. Call SOLRAD to get solar irradiance [SOLIRR(L)] at top of the atmosphere (only for $I=J=K=1$).
 - 2. Evaluate $RAD(2) = SFR \times SOLIRR(L) \times \cos(THI)$.
- E. Get path parameters (species areal density U (cm at STP) and the product UP (with P the pressure, atm-cm)) for ray \overrightarrow{SP} from sun to

Point P. Assume path parameters are independent of latitude and longitude of P; therefore, do only for $I=J=K=L=1$. Also get aerosol transmittance from S to P, $TASP(L)$, only for $I=J=K=1$.

1. Call GEOXYZ (Point P, \hat{P})
2. Call GEOXYZ (Point S, \hat{S})
3. Call STEPS (\hat{P} , \hat{S} ,...)
4. Loop over path segments with calls to PATH, AEROSOL, and ACCUM.
5. Preserve $U(I,N,2)$ and $UP(I,N,2)$ arrays as $UPS(I,N,1)$ and $UPPS(I,N,1)$ arrays.

F. Get path parameters for ray \overline{SC} from sun to Point C. (This step is included only if natural clouds are included in the calculation. While clouds are not strictly an Earth-surface feature, the treatment of them is analogous to that for Point P and thus is appropriately described here.) Assume path parameters are independent of latitude and longitude of C; therefore, do only for $I=J=K=L=1$. Also get aerosol transmittance from S to C, $TASC(L)$, only for $I=J=K=1$.

1. Call GEOXYZ (Point C, \hat{C}).
2. Call STEPS (\hat{C} , \hat{S} ,...).
3. Loop over path segments with calls to PATH, AEROSOL, and ACCUM.
4. Preserve $U(I,N,2)$ and $UP(I,N,2)$ arrays as $UCS(I,N)$ and $UPCS(I,N)$ arrays.

5-3 SUBROUTINE RINOUT

5-3.1 Purpose

Subroutine RINOUT, given the geographic locations of the source (sun and/or fireballs), the detector, and the position P of the intersection of the line-of-sight from the detector to the Earth's surface, computes the zenith angle (and, for fireballs, slant range (but not in NBR Module)) of the source from P and the direction of the ray from P toward the detector in terms of the

zenith angle of the detector and (if the surface is not Lambertian (MAT=1) or water (MAT=2)) the absolute value of the azimuth angle of scatter with respect to the principal plane containing the incoming ray.

See Table 5-2 for a summary of the input and output variables for Subroutine RINOUT and Figure 5-2 for a flow chart.

5-3.2 Derivations

5-3.2.1 Zenith Angle of Sun

Since the Earth's radius subtends a maximum angle of about 4.2×10^{-5} radians at the sun, it is a good approximation to assume that the solar ray to Point P is essentially parallel to the ray to the subsolar point. Thus the great circle arc from Point P to the subsolar point is essentially the solar zenith angle, θ_i , at Point P. This angle θ_i is obtained by applying the cosine law for sides to an oblique spherical triangle, with the result

$$\cos \theta_i = \sin \phi_p \sin \phi_s + \cos \phi_p \cos \phi_s \cos (\lambda_s - \lambda_p) \quad (1)$$

where ϕ_p and ϕ_p are the north latitude and east longitude of Point P and ϕ_s and λ_s are the corresponding quantities for the subsolar point. This formula is the same, of course, as that evaluated in Subroutine SOLZEN [Volume 14a-1, HS-79], but we do not use that routine here because it receives its input for Point P from /TIME/, which is inappropriate in the present context.

5-3.2.2 Zenith Angle of Detector

The approximation made in deriving the solar zenith angle is inadequate to use for the zenith angle of a low-altitude detector, as shown in Figure 5-3. Here, the zenith angle is

$$\theta = \theta_d + \theta \quad (2)$$

Table 5-2. Input and output variables for Subroutine RINOUT.

INPUT VARIABLES

Argument List

MAT - Index for category of surface material (see Table 2-12 for Subroutine ESURF).

IFIRE - Number of fireballs to be considered as sources (always zero in NBR Module).

FIRBAL Common (not used in NBR Module)

For L=1, IFIRE

FBALT(L), - Altitude, north latitude, east longitude, and radiant
 FBLAT(L), intensity of Fireball-L.
 FBLON(L), (km, radians, radians, W/sec)
 FBRINT(L)

POSITN Common

POSALT, - Altitude, north latitude, and east longitude of intersection
 POSLAT, (Point P) of line-of-sight from detector (at Point V) to
 POSLON Earth's surface.
 (km, radians, radians)

SOLARP Common

SOLLAT, - North latitude and east longitude of subsolar point.
 SOLLON (radians)

TECTOR Common

DETALT, - Altitude, north latitude, and east longitude of detector
 DETLAT, at Point V. (km, radians, radians)
 DETLON

OUTPUT VARIABLES

Argument List

IDAY - Index for diurnal condition at Point P.
 = 0, Solar zenith angle > 90 deg.
 = 1, Solar zenith angle ≤ 90 deg.

(continued)

Table 5-2. Input and output variables for Subroutine RINOUT (Cont'd).

SOURCE Common	
SRCZEN(1)	- Zenith angle of solar ray incoming to Point P on Earth's surface. (radians)
For L=1, IFIRE (not used in NBR Module)	
SRCZEN(L+1),	- Zenith angle and slant range of Fireball-L ray incoming
SRCR(L+1)	to Point P on Earth's surface. (radians, km)
TECTOR Common	
DETZEN	- Zenith angle of ray reflected at Point P on Earth's surface toward the detector at Point V. (radians)
DETAZI(1)	- Absolute value of azimuth angle of reflected ray, measured from principal plane determined by vertical plane through incoming solar ray. (radians)
For L=1, IFIRE (not used in NBR Module)	
DETAZI(L+1)	- Absolute value of azimuth angle of reflected ray, measured from principal plane determined by vertical plane through incoming ray from Fireball-L. (radians)

where the Earth-central angle α_d is obtained from a call to Subroutine CANGLE (see Table 3-3 for Subroutine CANGLE). Thus we need β .

With

R_e = Earth's radius
 h_p = Altitude of Point P
 h_d = Altitude of Point V,

let

$$b = R_e + h_p \quad (3a)$$

$$c = R_e + h_d \quad (3b)$$

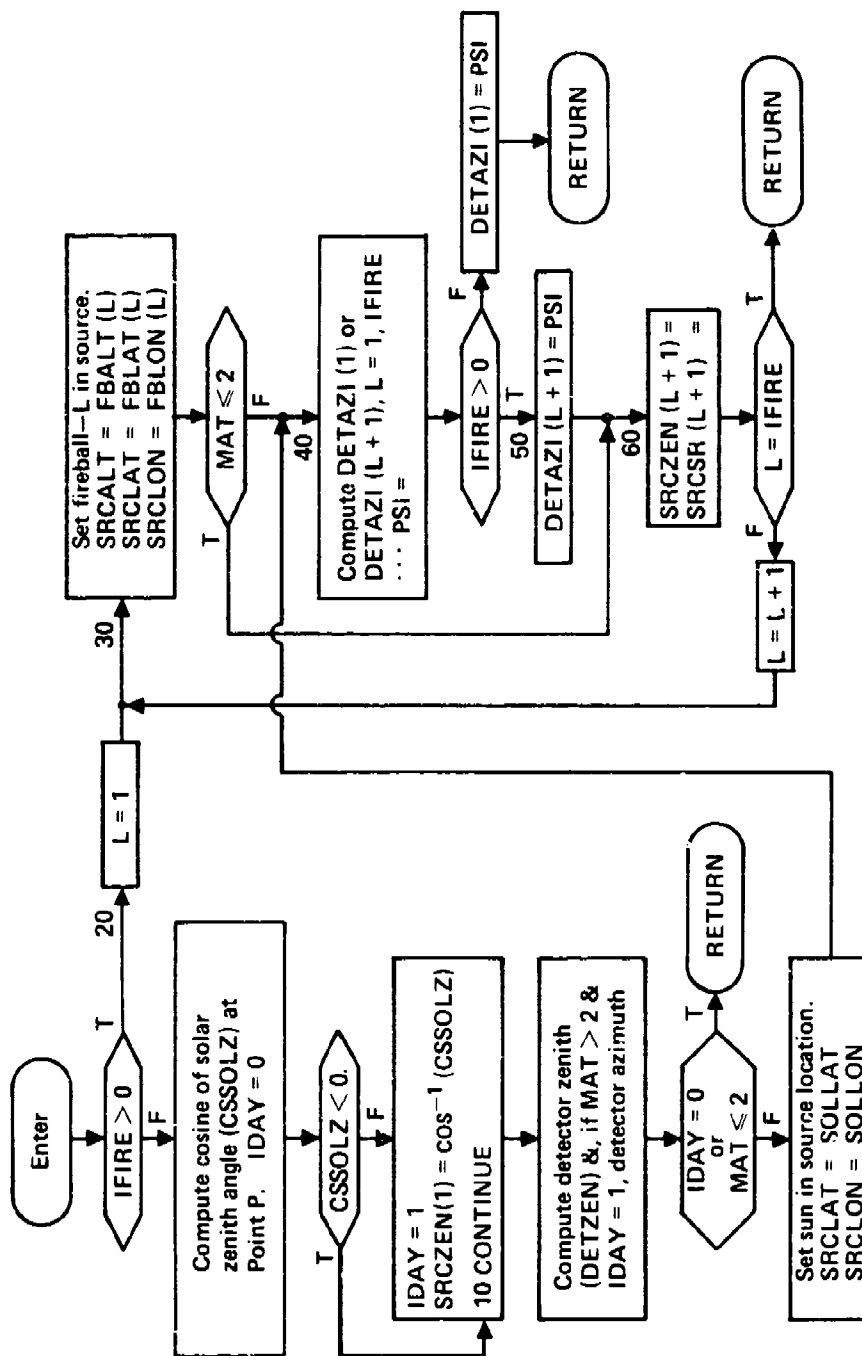


Figure 5-2. Flow chart for Subroutine RINOUT. For completeness, diagram includes calculation for fireball as source, a condition outside the NBR Module.

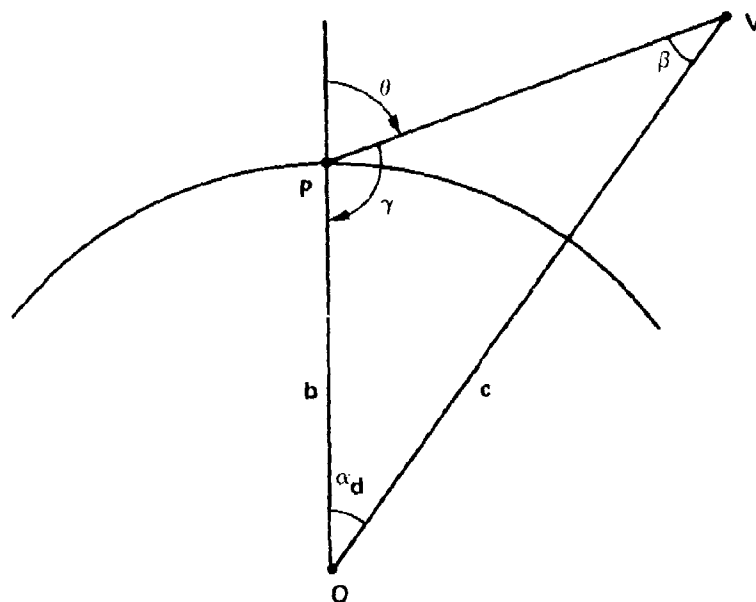


Figure 5-3. Geometry for detector's zenith angle at Point P.

From the law of tangents for a plane triangle, we have

$$\frac{\tan \frac{1}{2} (\gamma + \beta)}{\tan \frac{1}{2} (\gamma - \beta)} = \frac{c + b}{c - b} \quad (4)$$

which, with the use of

$$\gamma + \beta = \pi - \alpha \quad (5)$$

and

$$\epsilon_d \equiv b/c = (R_e + h_p)/(R_e + h_d), \quad (6)$$

becomes

$$\tan \frac{1}{2} (\gamma - \beta) = \frac{1 - \epsilon_d}{1 + \epsilon_d} \tan \frac{1}{2} (\pi - \alpha) \quad (7a)$$

or

$$\gamma - \beta = 2 \tan^{-1} \left[\frac{1 - \epsilon_d}{1 + \epsilon_d} \frac{1}{\tan(\alpha/2)} \right] = C_d \quad (7b)$$

By subtracting Equation (7b) from Equation (5), we have the needed β ,

$$\beta = (\pi - \alpha - C_d)/2, \quad (8)$$

to use in Equation (2) for the detector's zenith angle at Point P.

5-3.2.3 Azimuth Angle of Reflected Ray

We want to compute the azimuth angle ψ shown in Figure 5-4. For simplicity in the formulas, we drop the primes from the subpoints V' and S'. Our derivation (which may not be the simplest) requires solving, in turn, triangles P-N-S, Q-N-S, P-Q-N, and P-V-Q. The numbers on the various sides and angles indicate the sequence of solution.

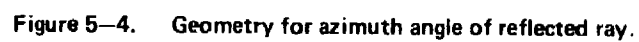
A. For later use, note that NP and NS are known, since

$$NP = \theta_p \quad (9a)$$

$$NS = \theta_s \quad (9b)$$

Define

$$PNS_t = |\phi_s - \phi_p| \quad (10a)$$



$$QNP_t = |\phi_p - \phi_d| \quad (10c)$$

B. For triangle P-N-S,

$$PNS = \begin{cases} PNS_t & \text{if } PNS_t < \pi \\ 2\pi - PNS_t & \text{if } PNS_t \geq \pi \end{cases} \quad (11)$$

$$PS = \text{CANGLE}(\theta_p, \phi_p, \theta_s, \phi_s) \quad (12)$$

where CANGLE is the function routine described in Section 3-6.2 From the law of sines,

$$\sin QSN \equiv \sin PSN = \sin NP \sin PNS / \sin PS \quad (13a)$$

$$QSN = \sin^{-1}(\sin QSN). \quad (13b)$$

To determine the proper quadrant for QSN, we consider the consequence of PSN equaling 90°; i.e., by applying the law of cosines for sides to triangle P-S-N, we have

$$\cos NP = \cos PS \cos NS + \sin PS \sin NS \cos QSN \quad (14a)$$

$$\cos NP_R = \cos PS \cos NS. \quad (14b)$$

If $NP > NP_R$, then $QSN > 90^\circ$; i.e., if $\cos NP < \cos NP_R$, then $QSN > 90^\circ$. Thus,

$$QSN = \begin{cases} QSN_p & \text{if } \cos NP \geq \cos NP_R \\ \pi - QSN_p & \text{if } \cos NP < \cos NP_R \end{cases} \quad (15)$$

where the subscript P denotes the principal value of \sin^{-1} , as returned by the computer.

C. For triangle Q-N-S,

$$QNS = \begin{cases} QNS_t & \text{if } QNS_t < \pi \\ 2\pi - QNS_t & \text{if } QNS_t \geq \pi \end{cases} \quad (16)$$

By applying the law of cosines for angles to triangle Q-N-S, we have

$$SQN = \cos^{-1} (\cos QNS \cos QSN + \sin QNS \sin QSN \cos NS) . \quad (17)$$

By applying the law of sines to triangle Q-N-S, we have

$$QN = \sin^{-1} (\sin QSN \sin NS / \sin SQN) . \quad (18)$$

To determine the proper quadrant for QN, we consider the consequence of QN equaling 90°; i.e., by applying the law of cosines for angles to triangle Q-N-S, we have

$$\cos QSN = -\cos SQN \cos QNS + \sin SQN \sin QNS \cos QN . \quad (19a)$$

For QN = 90°, we have

$$\cos QSN_R = -\cos SQN \cos QNS . \quad (19b)$$

Now, $SQN \leq \pi$; therefore, $\sin SQN \geq 0$. For daylight conditions at the detector, $QNS \leq \pi/2$; therefore, $\sin QNS \geq 0$. Thus, the second term in (19a) is always positive for QN < 90°. Thus

$$QN = \begin{cases} QN_p & \text{if } \cos QSN \geq \cos QSN_R \\ \pi - QN_p & \text{if } \cos QSN < \cos QSN_R \end{cases} \quad (20)$$

D. For triangle P-Q-N,

$$QNP = \begin{cases} QNP_t & \text{if } QNP_t < \pi \\ 2\pi - QNP_t & \text{if } QNP_t \geq \pi \end{cases} \quad (21)$$

By applying the law of sines, we have

$$\sin QP = \sin QNP \sin NP / \sin SQN \quad (22a)$$

or

$$\cos QP = (1 - \sin^2 QNP)^{1/2}, \quad (22b)$$

a quantity we will need later.

E. For triangle P-A-Q, by applying the law of sines, we have

$$\psi = \sin^{-1} (\sin VQ \sin VQP / \sin VP) \quad (23)$$

where VQ is evaluated by noting, for the arc V-Q-N, that

$$VQ = \frac{\pi}{2} - (\theta_d + QN) \quad (24a)$$

$$\sin VQ = \cos (\theta_d + QN); \quad (24b)$$

where VQP is evaluated by noting that

$$VQP = \pi - SQN \quad (25a)$$

$$\sin VQP = \sin SQN; \quad (25b)$$

where VP is evaluated by noting that

$$VP = \alpha_d = \text{CANGLE}(\theta_d, \phi_d, \theta_p, \phi_p). \quad (26)$$

Thus,

$$\psi = \sin^{-1} [\cos(\theta_d + \phi_d) \sin \phi_p / \sin \alpha_d]. \quad (27)$$

To determine the proper quadrant for ψ , we consider the consequence of ψ equaling 90° ; i.e., by applying the law of cosines for sides to triangle P-V-Q, we have

$$\cos VQ = \cos VP \cos QP + \sin VP \sin QP \cos \psi. \quad (28a)$$

For $\psi = 90^\circ$,

$$\cos VQ_R = \cos VP \cos QP \quad (28b)$$

$$= \cos \alpha_d \cos QP. \quad (28c)$$

Thus,

$$\psi = \begin{cases} \psi_p & \text{if } \cos VQ \geq \cos VQ_R \\ \pi - \psi_p & \text{if } \cos VQ < \cos VQ_R. \end{cases} \quad (29)$$

5-4 OTHER ROUTINES IN EARTH SURFACE RADIANCE MODEL

5-4.1 SAI Routines (ESURF, SOLRAD, GEOXYZ)

Among the routines shown in Figure 5-1 to be directly called from Subroutine SURRAD, those (besides RINOUT) that have been prepared by SAI are ESURF (discussed in Section 2-5 and its related water-surface routines in Section 3-6), SOLRAD (discussed in Section 4-3), and GEOXYZ.

Subroutine GEOXYZ converts the geographic coordinates of a point (P) to Earth-centered Cartesian coordinates. Reference to Figure 5-5 aids one in writing the following equations.

$$RP = RE + PH \quad (30)$$

$$RPEQ = RP \times \cos PLAT \quad (31)$$

$$RPX = RPEQ \times \cos PLON \quad (32)$$

$$RPY = RPEQ \times \sin PLON \quad (33)$$

$$RPZ = RP \times \sin PLAT. \quad (34)$$

The input and output variables are summarized in Table 5-3.

5-4.2 Visidyne, Inc. Routine (AEROSOL)

Subroutine AEROSOL, prepared by C.H. Humphrey et al. [Volume 25], computes attenuation coefficients for scattering and absorption (and, though not used in the NBR Module, the asymmetry factor (average cosine of the scattering angle)) due to atmospheric aerosols, given the altitude and wavelength. Table 5-4 summarizes the inputs and outputs for Subroutine AEROSOL.

5-4.3 G.E. Tempo Routines (ACCUM, DOT, FRAC, PATH, PLANCK, SEGMENT, STEP, STEPS, SUBVEC, UNITV, VLIN, XMIT)

Among the routines shown in Figure 5-1 to be directly called from Subroutine SURRAD, those that have been prepared by G.E. Tempo are Function PLANCK, Subroutine VLIN, Subroutine STEPS (and its auxiliary routines SUBVEC, VLIN, DOT, UNITV, STEP, and FRAC), Subroutine PATH (and its auxiliary routines XMIT and SEGMENT), and Subroutine ACCUM. A brief description of the purpose of each of these routines is included in Table 7-3a which summarizes all the routines in the NBR Module. For the longer and more important routines we have summarized their inputs and output: Subroutine PATH (Table 5-5), Function PLANCK (Table 5-6), Subroutine SEGMENT (Table 5-7), Subroutine STEP (Table 5-8), and Subroutine STEPS (Table 5-9). Briefer statements - but in some instances, flow charts - pertaining to these routines have been given by Ewing et al. in Volume 31 (PATH, p. 62; PLANCK, p. 63; SEGMENT, p. 66 with flow chart on p. 67; STEP, p. 68, with flow chart on p. 69; STEPS, p. 70).

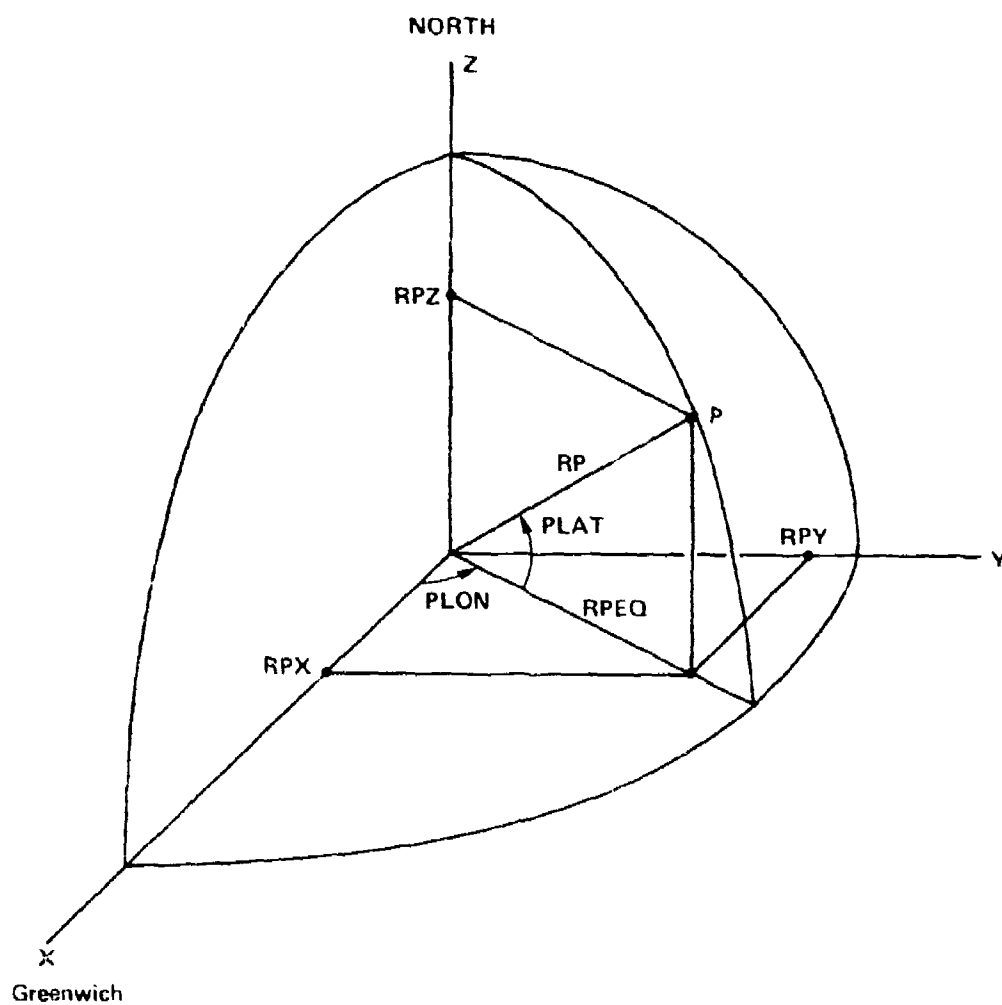


Figure 5-5. Geometry for conversion of geographic coordinates to Earth-centered Cartesian coordinates.

Table 5-3. Input and output variables for Subroutine GEOXYZ.

INPUT VARIABLES

Argument List

PH, - Altitude, north latitude, and east longitude of Point P.
 PLAT, (km, radians, radians)
 PLON

OUTPUT VARIABLES

Argument List

RPX, - Earth-centered Cartesian coordinates X, Y, and Z of Point P.
 RPY, (km)
 RPZ

Table 5-4. Input and output variables for Subroutine AEROSOL.

INPUT VARIABLES

Argument List

HCM - Altitude above sea level. (cm)
 LAMDA - Wavelength. (um)

AEROK Common

KVIS - Visibility range parameter (VR) for $0 \leq HCM \leq 9 \times 10^5$ cm.
 = 1, VR = 50 km
 = 2, VR = 23 km
 = 3, VR = 10 km
 = 4, VR = 5 km
 = 5, VR = 2 km.

KTYPE - Terrain parameter for $0 \leq HCM \leq 2 \times 10^5$ cm.
 = 1, Terrain is rural
 = 2, Terrain is urban
 = 3, Terrain is maritime.

(continued)

Table 5-4. Input and output variables for Subroutine AEROSOL (Cont'd).

OUTPUT VARIABLES

Argument List

XKSCT, - Scattering and absorption coefficients. (cm^{-1})
 XKABS
 GBAR - Asymmetry factor (average cosine of the scattering angle).

Table 5-5. Input and output variables for Subroutine PATH.

INPUT VARIABLES

Argument List

FIRST - Logical variable serving as initialization switch.

= .TRUE., For first call (i.e., corresponding to path from R_X to R_Y in Subroutine TRNSCO).

= .FALSE., For subsequent calls (i.e., corresponding to path from \overrightarrow{RY} to \overrightarrow{RZ} in Subroutine TRNSCO).

```

ISHELL(1), - INDX(1) and INDX(I+1) in calls from Subroutines TRNSCO and
ISHELL(2) SURRAD.

```

DS - DS(I+1) in calls from Subroutines TRNSCO and SURRAD.
Note: It is always true that DS(1) = 0.0 and DS(NC+1) = -1.0, where NC is the number of path segments plus one. Subroutine ATMTRAD will not be called from Subroutine TRNSCO with I=NC.

XFRACS(1), - XFRACS(I) and XFRACS(I+1) in calls from Subroutine TRNSCO
XFRACS(2) and SURRAD.

Notes: (1) Do not confuse this array XFRACS (dimensioned 2) with the array XFRACS (dimensioned 100) in Subroutines STEP, STEPS, and TRNSCO.

(2) For meaning of XFRACS(1), see Table 6-9 for Subroutine ATMBAD.

(continued)

Table 5-5. Input and output variables for Subroutine PATH (Cont'd).

XYZCOM Common

NS - Number of altitude boundaries set in Subroutine SHELLS.

For J=1,NS; N=1,10

TS(J), - Temperature, pressure, and species-N density at altitude
 PS(J), - boundary J.
 XNSPEC(J,N) (deg K, atm, $1/\text{cm}^3$)

OUTPUT VARIABLES

XYZCOM Common

For I=1,2 (adequate for ambient atmosphere); N=1,10

U(I,N,2), - Cumulative value of path parameters U (species-N areal
 UP(I,N,2) density) and UP (product of U and pressure P) for temper-
 ature-index I and species-N at end of line segment DS(J+1).
 (cm at STP, atm-cm at STP)

Table 5-6. Input and output variables for Function PLANCK.

INPUT VARIABLES

Argument List

T - Temperature. (deg K)
 W - Wavenumber. ($1/\text{cm}$)

Data Statements

C - Velocity of light. (cm/sec)
 H - Planck's constant. (J sec)
 CHK - $C \times H/K$, where K is Boltzmann's constant. (cm deg-K)

OUTPUT VARIABLES

Function

PLANCK - Spectral radiance. [$\text{W}/(\text{cm}^2 \text{ sr cm}^{-1})$]

Table 5-7. Input and output variables for Subroutine SEGMENT.

INPUT VARIABLES

Argument List

NSPEC - Number of species (10) in the molecular transmittance model. These species are identified by comments in Table 7-9 for Subroutine SHELLS.

X1 - Distance along line segment; set as 0.0 in call from Subroutine PATH.

For N = 1, NSPEC

NS1(N), - Array of species concentrations, pressure, and temperature
P1, at start of line segment; set in call from PATH as XNS1(10),
T1 PSL1, and TSL1. (1/cm³, atm, deg K)

X2 - Length of line segment; set as DS in call from Subroutine PATH. (cm)

NS2(N), - Array of species concentrations, pressure, and temperature
P2, at end of line segment; set in call from Subroutine PATH as
T2 XNS2(10), PSL2, and TSL2. (1/cm³, atm, deg K)

XY Common

For I = 1, 10

TT(I) - Temperature array used for band-model parameters. (deg K)

OUTPUT VARIABLES

Argument List

For I=1,10; N=1,10

DU(I,N), - Incremental path integrals U (areal density) and UP (product
DUP(I,N) of U and pressure P) for path segment DS, temperature-I,
and species-N. (cm at STP, atm-cm at STP)

Table 5-8. Input and output variables for Subroutine STEP.

INPUT VARIABLES

Argument List

- \vec{RX} - Location vector to one end of transmission path, typically but not necessarily at the detector. (cm)
- \vec{SHAT} - Unit vector along the transmission path from \vec{RY} to \vec{RX} . (cm)
- DIST - Magnitude of distance along transmission path from \vec{RY} to \vec{RX} . (cm)
- NC - Initialization value. Normally set to 0 and leads to DS(1) being set to 0.0.

XYZCOM Common

- NS - Number of shell boundaries in atmospheric transmission model.

OUTPUT VARIABLES

Argument List

- NC - Number of path segments plus one on the transmission path from \vec{RY} to \vec{RX} , or equivalently, the number of end points.

For I=1,NC

- DS(I+1) - Length of line segment I along transmission path. (cm)
Note: It is always true that DS(1) = 0.0 and DS(NC+1) = -1.0. (There are two more values of DS than there are segments.)
- XFRACS(I) - The weight associated with the Ith end point appropriate for finding at that point the linearly-interpolated value of parameters - such as temperature and pressure (or even altitude) - which are specified at the two shell boundaries adjacent to the Ith end point.

Note: For verification of this interpretation, see the usage of XFRAC(1) and XFRAC(2) in Subroutine ATMTRAD for obtaining altitude and temperature at front and back of cell DS. The same conclusion may be drawn from the usage of XFRACS(1) and XFRACS(2) in Subroutine PATH.

(continued)

Table 5-8. Input and output variables for Subroutine STEP (Cont'd).

It is useful to consider a hypothetical example with $HSHELL(I) = 0.0, 1.0, 2.0, 3.0$ for $I=1,2,3,4$ and 45-degree path from altitude 1.9 to 2.9 km. Then, $NC=3$ and we have the following values for the arrays:

<u>I</u>	<u>DS(I)</u>	<u>XFRACS(I)</u>	<u>INDX(I)</u>
1	0.0	0.1	2
2	0.1414	1.0	3
3	1.2728	0.9	4
4	-1.0	Not defined	0

INDX(I) - Index of shell boundary at or just before the start of the line segment I. INDX(NC) will be the index of the shell boundary just after the last endpoint.
Note: INDX(NC+1) = 0.

Table 5-9. Input and output variables for Subroutine STEPS.

INPUT VARIABLES

Argument List

- \vec{RX} - Location vector to one end of transmission path, typically but not necessarily at the detector. (cm)
- \vec{RY} - Location vector to one end of transmission path, typically but not necessarily at the scattering or source point. (cm)
- NC - Initialization value. Normally set to 0 and leads to DS(1) being set to 0.0 in Subroutine STEP.

OUTPUT VARIABLES

Internal Use (for call to Subroutine STEP)

- \vec{SHAT} - Unit vector along the transmission path from \vec{RY} to \vec{RX} . (cm)
- DIST - Magnitude of distance along transmission path from \vec{RY} to \vec{RX} . (cm)

(continued)

Table 5-9. Input and output variables for Subroutine STEPS (Cont'd).

Argument List

The following quantities are obtained by a call to Subroutine STEP
(see Table 5-8 for Subroutine STEP): NC, DS, XFRACS, and INDX.

SECTION 6

UPWELLING NATURAL RADIATION

6-1 INTRODUCTION

6-1.1 Requirement

The Upwelling Natural Radiation Model (23c) is required to provide the mean upwelling spectral radiance at a viewing Point V at any altitude in the atmosphere, with account of the effects of solar radiation reflected from the Earth and clouds, emitted radiation from the Earth, atmosphere, and clouds, and attenuation by atmospheric aerosols.

6-1.2 Approach

The mean upwelling spectral radiance is evaluated, in principle, by averaging the upwelling spectral radiance over the solid angle (Ω_T) defined by the cone with vertex at Point V and tangent to the Earth's surface. In practice, we average the set of spectral radiances received by a (fictitious) detector viewing, from Point V, a set of characteristic Points P on the Earth's surface and within Ω_T . (For now, we ignore clouds.) The selection of the Points P is done by first dividing Ω_T into a number of regions ($N_N \leq 10$) bounded by common-vertex cones, each region with solid angle $\Delta\Omega = \Omega_T/N_N$. For each region we determine an angle θ , measured from the nadir, which defines a cone that bisects $\Delta\Omega$. (For brevity, we will hereafter let the phrase 'nadir angle' mean an angle measured from the nadir, just as 'zenith angle' means an angle measured from the zenith.) For daytime, we assume symmetry about the vertical (or principal) plane passing through Point V and the sun. The region on one side of the principal plane is divided into a number of sectors, each with angle π/N_A ($N_A \leq 6$ for day; $N_A = 1$ for night since complete azimuthal symmetry then obtains). The intersections between the bisecting cones and the planes bisecting the sectors are a set of $N_N \times N_A$ lines which intersect the Earth's surface at a set of points we call Points P. We assume the upwelling

radiance directed from a Point P to Point V is representative of that from the entire facet associated with the Point P.

In the absence of clouds, we model the upwelling radiance directed along a Path PV (i.e., from Point P to Point V) by including contributions from (1) air emission between Points V and P, (2) surface emission at Point P, and (3) solar radiation reflected from the surface at Point P. (We do not include air emission reflected at Point P.) Let us denote such radiance as $UPRAD(I,J,K,L)$, with I,J,K, and L being indices for altitude, nadir angle, azimuth angle, and wavenumber, respectively.

To obtain a mean value for the upwelling radiance, we first average $UPRAD(I,J,K,L)$ over azimuth angles for a constant nadir angle to get $UPRADA(I,J,L)$ and then average $UPRADA(I,J,L)$ over nadir angles to get $UPRADN(I,L)$. Very recently this last array has been extended to $UPRADN(I,L,JBAND)$ to provide for a broad-band spectral index JBAND.

The inclusion of natural clouds complicates the modeling. No attempt is made to include the deterministic cloud submodel. The statistical cloud submodel is included only for altitudes of Point V equal to or greater than the highest altitude (12 km) of a cloud top in that submodel. The general procedure is to first consider a given altitude (now denoted by index IKM), nadir-J, and azimuth-K, just as with no clouds. With the air emission, $ARCVA(IKM,J,L)$, along the line-of-sight (LOS) above 12-km altitude serving as a base value, we obtain a distribution function for the additional radiance corresponding to cloud-free-LOS (CFLOS) and cloudy-LOS extending below 12-km altitude. Because there are 159 cloud configurations in the statistical cloud model, this distribution function has 160 members for nighttime and 161 members for daytime:

- 159 for cloud-top emission and (if daytime) cloud-reflected solar radiation
- 1 for Earth's surface emission and air emission below 12-km altitude (for a 1-leg CFLOS)

- 1 for Earth's surface emission, air emission below 12-km altitude, and (if daytime) ground-reflected solar radiation (for a 2-leg CFLOS, obtaining for daytime).

The last two members are the weighted contributions for CFLOS conditions. (Owing to certain simplifications made in the cloud modeling, there are actually only 9 and not 159 distinct values in the distribution for a cloudy-LOS.) Having determined the distribution function for a given look direction from Point V, we form the integral distribution and compute selected percentiles ($XXX = 10, 25, 50, 90, 100$) of the integral distribution, $RXXX(K,L)$, at implicit altitude- IKM , implicit nadir- J , and explicit azimuth- K . Values of $RXXX(K,L)$ are averaged over azimuth angles to give $RXXXA(IKM,J,L)$. Values of $ARCVA(IKM,J,L)$ and $RXXXA(IKM,J,L)$ are averaged over nadir angles to give $ARCVN(IKM,L)$ and $RXXXN(IKM,L)$, respectively.

Since the inclusion of the broad-band index $JBAND$ was a late change (March 1980), we elected not to modify the arrays $ARCVN(IKM,L)$ and $RXXXN(IKM,L)$ to provide for an explicit dependence on the index $JBAND$ as we did for the array $UPRADN(I,L,JBAND)$. This limitation must be remembered and removed if $JBAND > 1$ and if clouds are included, unless one adopts the GRC definition of $UPRADN(I,L,JBAND)$ (which we give later).

It would probably be more conceptually satisfying if one could perform azimuth- and nadir-averages for each of the cloud configurations, so that one could end up with a distribution function at a given altitude instead of averaged percentile-values. Such a procedure was not followed.

The natural cloud model does not include air emission between cloud tops and 12-km altitude. Hence, such air emission is not included here, either.

6.1-3 Dependence on Other Models

It will be recognized, of course, that the Upwelling Radiation Model depends heavily on other models which we have integrated into it. Obviously

required are the models described in earlier sections of this report (Earth Surface Characterization in Sections 2 and 3, Solar Radiation in Section 4, Earth Surface Radiance in Section 5) as well as the SAI models described elsewhere for the Ambient Atmosphere (Volume 14a-1) and Natural Clouds (Volume 24). In addition, highly essential ingredients are provided by the G.E. Tempo models for Atmospheric Thermal Emission (Volumes 28 and 31) and Molecular Transmittance (Volumes 28 and 31) and the Visidyne, Inc./AFGL model for Atmospheric Aerosols (Volume 25). Explicit recognition of the pertinent routines is given later.

6-2 SUBROUTINE UPWELL

6-2.1 Formulas

6-2.1.1 Geometry

Here we derive the formulas associated with the characteristic Points P.

In Figure 6-1, consider the Point V at altitude h and the ray VT tangent to the Earth's surface. Then, for the right triangle OTV, we have

$$s_T^2 + R^2 = (R+h)^2$$

or

$$s_T = (2hR + h^2)^{1/2}.$$

The nadir angle θ_T at Point V for the tangent ray is

$$\theta_T = \cos^{-1} [s_T / (R+h)].$$

The solid angle between nadir angles θ_1 and θ_2 is

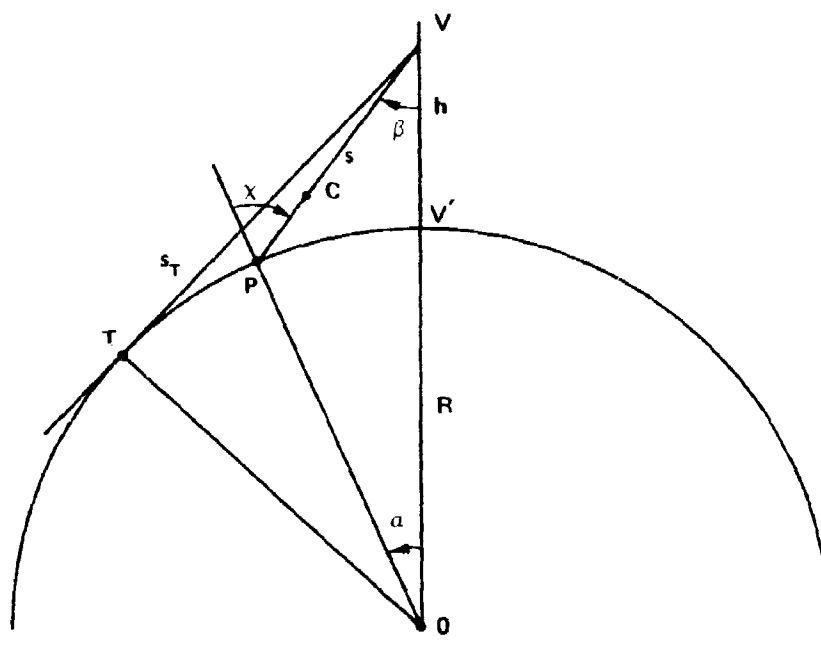


Figure 6-1. Geometry for characteristic points on Earth's surface.

$$\Omega(\beta_1, \beta_2) = 2\pi \int_{\beta_1}^{\beta_2} \sin \beta \, d\beta = 2\pi (\cos \beta_1 - \cos \beta_2).$$

For $\beta_1 = 0$, we have

$$\Omega(0, \beta_2) = 2\pi (1 - \cos \beta_2).$$

For $\beta_1 = 0$ and $\beta_2 = \beta_T$, we have

$$2\pi\Omega_T^1 \equiv \Omega(0, \beta_T) = 2\pi(1 - \cos \beta_T).$$

Consider now the oblique triangle OPV for which

$$\alpha + \beta = \chi$$

where, at Point P, χ is the zenith angle of Point V. From the law of sines, we have

$$\frac{\sin(\pi - \chi)}{R+h} = \frac{\sin \chi}{R+h} = \frac{\sin \alpha}{S} = \frac{\sin \beta}{R}.$$

Consider now the fractiles $(n-1/2)/n_g$ (with $n=1, 2, \dots, n_g$) of the normalized solid angle α'_T . The corresponding angles and distances of interest are:

$$\cos \beta_n = 1 - \frac{n-1/2}{n_g} \alpha'_T$$

$$\beta_n = \cos^{-1} (\cos \beta_n)$$

$$\chi_n = \sin^{-1} \left[\left(1 + \frac{h}{R}\right) \sin \beta_n \right]$$

$$\alpha_n = \chi_n - \beta_n$$

$$s_n = R \sin \alpha_n / \sin \beta_n.$$

These quantities of interest are tabulated in Table 6-1 for altitudes of 1, 10, and 100 km. α'_T has the values of 0.982, 0.944, and 0.825 for $h = 1, 10,$ and 100 km.

For a Point C at 12-km altitude on the ray \overrightarrow{VP} , we have

Table 6-1. Geometrical quantities of interest for Point-V at altitudes of 1, 10, and 100 km.

h = 1 km					
n	B_n	x_n	a_n	Ra_n	s_n
1	18.03	18.03	.00293	0.33	1.05
2	31.50	31.50	.00551	.61	1.17
3	41.02	41.03	.00782	.87	1.33
4	48.99	49.00	.01034	1.15	1.52
5	56.08	56.10	.01338	1.49	1.79
6	62.63	62.64	.01737	1.93	2.18
7	68.80	68.83	.02320	2.58	2.77
8	74.73	74.76	.03298	3.67	3.80
9	80.50	80.55	.05386	5.99	6.07
10	86.16	86.30	.1365	15.18	15.21
h = 10 km					
n	B_n	x_n	a_n	Ra_n	s_n
1	17.67	17.70	.0286	3.19	10.50
2	30.86	30.92	.0538	5.98	11.65
3	40.18	40.26	.0760	8.45	13.10
4	47.96	48.06	.0998	11.10	14.95
5	54.89	55.01	.1281	14.24	17.41
6	61.26	61.43	.1644	18.28	20.85
7	67.27	67.48	.2156	23.98	26.00
8	73.02	73.32	.2971	33.03	34.54
9	78.60	79.06	.4551	50.61	51.62
10	84.08	85.02	.9414	104.68	105.24
h = 100 km					
n	B_n	x_n	a_n	Ra_n	s_n
1	16.51	16.78	.2668	29.7	104.4
2	28.80	29.30	.4957	55.1	114.4
3	37.46	38.15	.6922	77.0	126.6
4	44.66	45.55	.8956	99.6	141.7
5	51.04	52.16	1.1257	125.2	161.0
6	56.88	58.29	1.4052	156.2	186.5
7	62.36	64.13	1.7700	196.8	222.1
8	67.58	69.87	2.2914	254.8	275.6
9	72.61	75.76	3.1488	350.1	366.7
10	77.50	82.58	5.0774	564.6	577.5

$$\frac{\sin(\pi - x_c)}{R+h} = \frac{\sin \theta}{R+C_{12}}$$

or

$$\sin x_c = \frac{R+h}{R+C_{12}} \sin \theta$$

where, at Point C, x_c is the zenith angle of Point V.

The Earth-central angle α_c is

$$\alpha_c = x_c - \theta.$$

6-2.1.2 Radiance

Here we record the general formulas used to compute the radiance directed along the paths from Point P to Point V and from Point C to Point V, shown in Figures 6-2 and 6-3.

6-2.1.2.1 No Clouds

For no clouds (or for Point-V altitudes below 12-km when clouds are included), the radiance may be written as

$$\begin{aligned} [\text{Radiance}]_{pv} &= [\text{Air radiance}]_{pv} + [\text{Ground emission radiance}]_p \\ &\quad \times \text{TTPV}(L) + [\text{Ground-reflected solar radiance}]_p \times \text{ITSPV} \end{aligned}$$

or

$$U(M,N,1) = U_{PS}(M,N,1) + U(M,N,2)$$

$$UP(M,N,1) = U_{PPS}(M,N,1) + UP(M,N,2).$$

6-2.1.2.2 With Clouds ($h \geq 12$ km)

When clouds are included in the calculation on a statistical basis, the problem becomes much more complicated, as inferred from Figure 6-3. The general procedure is to compute the radiance with and without the clouds and (essentially) to weight the two results by the probabilities that the line-of-sight (LOS) from Point V intersects the clouds or does not intersect the clouds (discussed in Section 6-2.3).

If the LOS intersects the clouds, the radiance may be written as

$$[\text{Radiance}]_{CV} = [\text{Air radiance}]_{CV} + [\text{Cloud emission radiance}]_C \times \text{TTCV}(L)$$

$$+ [\text{Cloud-reflected solar radiance}]_C \times \text{TTSCV}(L)$$

or

$$= \text{AECV}(L) + \text{EMISS}(\text{IDX}) \times \text{TTCV}(L) + \text{SOLIRR}(L) \times \text{TRANS}(\text{IDX}) \times \text{TTSCV}(L),$$

where

$$\begin{aligned} \text{TTCV}(L) &= \text{Total transmittance along } \vec{CV} \\ &= \text{Product of molecular transmittance and aerosol transmittance} \\ \text{TTSCV}(L) &= \text{Total transmittance along } (\vec{SC} + \vec{CV}) \\ &= (\text{Molecular transmittance}) \times (\text{Aerosol transmittance}) \\ &= \text{TMSCV}(L) \times [\text{TASC}(L) \times \text{TACV}(L)]. \end{aligned}$$

The molecular transmittance TMSCV depends on the path parameters for the entire path $(\vec{SC} + \vec{CV})$:

$$U\ SCV(M,N,1) = U\ CS(M,N) + U\ CV(M,N)$$

$$UPSCV(M,N,1) = UPCS(M,N) + UPCV(M,N).$$

6-2.2 Input and Output Variables

The input and output variables for Subroutine UPWELL are described in Table 6-2.

6-2.3 Computational Steps

A. Preliminaries

1. Set JBAND1 in /UPWELS2/.
2. Set Subpoint V' in /TECTOP/.
3. Determine solar conditions.
 - a. Solar zenith angle
 - b.1 If IDAYV = 0,
REFAZI = 0.0, $\vec{RS} = 0$.
 - b.2 If IDAYV = 1,
 (1) Call GEOREA for REFAZI
 (2) Call GEOXYZ for \vec{RS} in /SORCE/
 (3) Zero arrays USPVP, UPSPVP, USCV, UPSCV.
4. Set altitude of all Points P.
5. Initialize counter for cloud calculations, IKM = 0.

B. Altitude Loop (I=1,NALT(JBAND)NALTJ)

1. Advance altitude (of fictitious detector) at Point V.
2. Call GEOXYZ for $\vec{RV} \equiv \vec{RD}$ in /SANDD/.
3. Get nadir angle for tangent ray and corresponding solid angle.
4. If IKM=1 (implies ZKM(I,JBAND) = 12.0), compute CFPS, the CFLOS for Path \vec{PS} by using calls to CFLOSF in the following formula:

$$CFPS = \sum_{IC=1}^5 CCOVER(IC,KMODEL) \times CFLOSF[ICC(IC), SOLZ]$$

with ICC(IC) = 1,4,6,9,11 for IC = 1,2,3,4,5.

Table 6-2. Input and output variables for Subroutine UPWELL.

INPUT VARIABLES

Argument List

- MSM - Index for category of surface material (see Table 2-12 for Subroutine ESURF).
- DD - Additional descriptor for selected surface material (see Table 2-12 for Subroutine ESURF).
- WW, - Arrays of central wavenumbers and wavenumber-interval,
DW widths corresponding to broad-band index JBAND. (cm^{-1})
- SPCULR - Logical parameter, passed to Subroutine SURRAD.
= .TRUE., Compute coordinates of specular reflection point on an assumed smooth horizontal water surface, provided MSM=2.
= .FALSE., Do not compute such coordinates.
- LBINT - Word-5 (LHV) in GRC Dataset-BN (No. 114), List of Band-Interval Datasets (BI). Strictly, LBINT is the pointer (i.e., contains the (Q-array) address) for the list header of the Band-Interval Datasets-BI corresponding to Dataset-BN.
- JBAND - Index for list of (broad) wavelength bands. (1 to 5)

AIRSOL Common

For L=1,NWAVEJ

- TASP(L), - Aerosol transmittance for incoming solar rays to Point P on
TASC(L) ground and Point C at 12-km altitude.

CLDFREQ Common

- KMODEL - Index (1 to 11) characterizing a set of statistical averages of cloud-coverage categories, cloud types, and number of cloud layers for a given geographic region. Characterizes a specification of CCOVER(5,11) and CFREQ(17, 4, 11) in Block Data CDATA for KMODEL = 1,10; user must supply his own data for KMODEL=11.

For ICC=1,5; KM=KMODEL=1,11

(continued)

Table 6-2. Input and output variables for Subroutine UPWELL (Cont'd).

CCOVER(ICC,KM) - Fractional occurrence frequency of cloud-coverage category ICC for given KMODEL.

CLDWT Common

IDX - Index for length of arrays returned from Subroutine CLDWT. IDX equals 160 for a full set of 159 cloud-layer and cloud-type configurations and is less for a restricted set.

WT(I) - Probability of configuration-I. IDX equaling 160
I=1,IDX corresponds to a cloud-free line-of-sight.

TRANS(I) - Transfer coefficient for configuration-I. In NBR Module,
I=1,IDX-1 geometry for transmission through clouds is not included; only geometry for reflection of solar ray from the highest-layer cloud in configuration-I is included. Attenuation is included (within the Natural Cloud Model) to 12-km altitude. (1/sr)

EMISS(I) - Thermal emission spectral radiance from the highest-layer
I=1,IDX-1 cloud in configuration-I with attenuation computed (within the Natural Cloud Model) to 12-km altitude.
[W/(km² sr μ m)]

OPTIN1 Common

RADSW - Logical variable serving as option switch for atmospheric volume emission calculation; passed to Subroutine TRNSCO. =.TRUE., Include call (from Subroutine TRNSCO) to Subroutine ATMTRAD. =.FALSE., Bypass call to Subroutine ATMTRAD and perform transmittance calculation in Subroutine TRNSCO without air emission.

OPTION Common

TRNSOPT - Logical variable affecting complexity of molecular transmittance calculation (see Tables 7-3 and 6-10 for Subroutines TRANSB and TRANS). In Subroutine UPWELL, TRNSOPT is used only in the argument list for calls to Subroutine TRANS.

QNCNC Common

NCNC - A variable, set to NC after the double call to Subroutine STEPS in Subroutine TRNSCO, employed to facilitate being

(continued)

Table 6-2. Input and output variables for Subroutine UPWELL (Cont'd).

able to use zero-kilometer altitude in the NBR Module. For more information, see comments preceding label number 22 in Subroutine UPWELL.

SOLARP Common

SOLLAT, - North latitude and east longitude of subsolar point.
SOLLON (radians)

For L=1,NWAVEJ

SOLIRR(L) - Solar spectral irradiance at the top of the Earth's atmosphere at wavenumber-index L. [$W/(cm^2 \text{ cm}^{-1})$]

UPWELS Common

UPWALT, - Surface altitude, north latitude, and east longitude of the
UPWLAT, sub-V-point at which the upwelling radiance is computed.
UPWLON (km, radians, radians)

For I=1,NALTJ; M JBAND=1,NBANDS

NALT(M) - Number of altitudes ZKM(I,M) for (broad) wavelength-band index JBAND. Defines NALTJ.

ZKM(I,M) - Altitudes of Point V above UPWALT at which upwelling radiance is computed. (km)

NNADIR, - Number of nadir and azimuth angles at Point V at which
NAZI upwelling radiance is computed.

NWAVE(M) - Number of wavenumbers at which the upwelling spectral radiance is to be computed for (broad) wavelength-band index JBAND. Defines NWAVEJ.

CLDFLG - Index for optional inclusion of natural clouds
=0., Clouds are not included.
=1., Clouds are included.

OUTPUT VARIABLES

FLAGS Common (differs from GRC's)

ITFLAG - Flag indicating the diurnal condition at Point V', for use by Subroutine CLDWT in the Natural Cloud Module.

(continued)

Table 6-2. Input and output variables for Subroutine UPWELL (Cont'd).

=0, Sun is below the horizon.
 =1, Sun is above the horizon.

POSITN Common

POSALT, - Altitude, north latitude, and east longitude of Point P at
 POSLAT, which line-of-sight (from fictitious detector at Point V)
 POSLON intersects Earth's surface. (km, radians, radians)

 C12ALT, - Altitude, north latitude, and east longitude of Point C
 C12LAT, at which line-of-sight (directed toward Point P from
 C12LON fictitious detector at Point V) intersects the 12-km alti-
 tude surface. (km, radians, radians)

SANDD Common

XS, - Earth-centered Cartesian coordinates of the sun. The
 YS, orientation of the system is shown in Figure 5-5. (km)
 ZS

 XD, - Earth-centered Cartesian coordinates of the fictitious
 YD, detector at Point V. (km)
 ZD

 UL, - Direction cosines of Point P from Point V.
 VL,
 WL

SORCE Common

(Solar coordinates are needed in Subroutine TRANSF of the Natural
 Cloud Module.)

NSORCE - Number of sources. Set to 1 in data statements.

 HSORCE(1) - Altitude of sun (RSUN), set in data statement. (km)

 RSORCE(1) - Radius of source. True value for sun is not relevant for
 this application in the NBR Module. Set to 0.0 in data
 statement.

 THETAS, - Colatitude and east longitude of subsolar point. (degrees)
 PHIS

(continued)

Table 6-2. Input and output variables for Subroutine UPWELL (Cont'd).

TECTOR Common

DETALT, - Altitude, north latitude, and east longitude of fictitious
 DETLAT, detector at Point V. (km, radians, radians)
 DETLON

- o Note: UPRAD(K,L) (in /UPWELS3/), UPRAA(I,J,L) (in /UPWELS3/), and
 UPRAA(I,L,JBAND) (in /UPWELS/) are cloud-free results. For results which
 also include cloud effects for altitudes ≥ 12 km, use the corresponding
 arrays RXXX(K,L), RXXXA(I,J,L), and RXXXN(I,L), all in /UPWELS1/. To these
 arrays one must add, respectively, the base-value quantities ARCVA(I,J,L),
 ARCVA(I,J,L), and ARCVN(I,L) (in /UPWELS1/).

- o In the GRC version, for altitudes ≥ 12 km and if clouds are included, the
 array UPRAA(I,L,JBAND) is reset as

$$\text{UPRAA}(I,L,\text{JBAND}) = \text{R050N}(\text{IKM},L) + \text{ARCVN}(\text{IKM},L),$$

which is transferred through /UPWELS/ to (the GRC) Subroutine UPWELL.
 Thus, in the GRC version, for altitudes $Z_{\text{KM}} \geq 12$ km, UPRAA is not the cloud-
 free result but the 50-percentile of the radiance distribution function for
 statistical clouds (if included in the problem).

UPWELS Common

IDAYV - Index for diurnal condition at sub-V-point.
 =0, Solar zenith angle $> 90^\circ$
 =1, Solar zenith angle $\leq 90^\circ$.

For I=1,NALTJ; L=1,NWAVEJ; M=JBAND=1,NBANDS

UPRAA(I,L,M) - Nadir-averaged value of UPRAA(I,J,L). [$\text{W}/(\text{cm}^2 \text{ sr cm}^{-1})$]

IKM - Index for number of altitudes at which calculations are
 made when clouds are included (used in Subroutine SURRAD).

UPWELS1 Common

For I=1,NALTJ; J=1,NNADIR; K=1,NAZI; L=1,NWAVEJ; M=JBAND=1,NBANDS

(continued)

Table 6-2. Input and output variables for Subroutine UPWELL (Cont'd).

ARCVA(I,J,L)	- When clouds are considered ($ZKM(I,M) \geq 12.0$), a component of the upwelling spectral radiance received at Point V (at altitude-I), from air emission above 12-km altitude, along a ray directed to Point P on the Earth's surface (at nadir-J and independent of azimuth-K). [$W/(cm^2 \text{ sr cm}^{-1})$]
ARCVN(I,L)	- Nadir-averaged value of ARCVA(I,J,L) for $ZKM(I,M) \geq 12.0$ km. [$W/(cm^2 \text{ sr cm}^{-1})$]
For XXX = 10, 25, 50, 90, 100	
RXXX(K,L)	- XXX-percentile of the integral distribution of the total (including that from statistical clouds) natural upwelling spectral radiance received at Point V for wavenumber-L (at implicit altitude-IKM above surface material-MSM) along a ray directed to Point P on Earth's surface (at implicit nadir-J and explicit azimuth-K). [$W/(cm^2 \text{ sr cm}^{-1})$] **Note: RXXX(K,L) does not include ARCVA(I,J,L). Currently, UPRAD(K,L) and RXXX(K,L) are being written in binary form on logical unit No. 8, for all appropriate altitudes and nadirs.
RXXXA(I,J,L)	- Azimuth-averaged value of RXXX(K,L). [$W/(cm^2 \text{ sr cm}^{-1})$]
RXXXN(I,L)	- Nadir-averaged value of RXXXA(I,J,L). [$W/(cm^2 \text{ sr cm}^{-1})$]
UPWELS2 Common	
JBAND1	- Same as JBAND, but made available to Subroutine SURRAD to facilitate print.
UPWELS3 Common	
For I=1,NALTJ; J=1,NNADIR; K=1,NAZI; L=1,NWAVEJ	
UPRAD(K,L)	- Natural upwelling spectral radiance received at Point V (at altitude-I above surface material-MSM) along a ray directed to Point P on Earth's surface (at nadir-J and azimuth-K). (Implicitly, I=1,NALTJ; J=1,NADIR. I- and J-dependences are not stored so user must print UPRAD(K,L) immediately after computation if he wants to see them. Currently, UPRAD(K,L) and RXXX(K,L) are being written in binary form on logical unit No. 8, for all appropriate altitudes and nadirs.) [$W/(cm^2 \text{ sr cm}^{-1})$]
UPRADA(I,J,L)	- Azimuth-averaged value of UPRAD(K,L). [$W/(cm^2 \text{ sr cm}^{-1})$]

- C. Nadir Angle Loop ($J=1, NNADIR$)
 1. Advance fractile (FRCTL) of tangent solid angle (OMEGAT(I)).
 2. For fractile FRCTL, get
 - a. Nadir angle (BETA).
 - b. Zenith angle (CHI) of \vec{PV} .
 - c. Earth-central angle (ALPHA).
 - d. If clouds:
 - (1) Zenith angle (CHIC) of \vec{CV} .
 - (2) Earth-central angle (ALPHAC).
 3. Initialize azimuth loop (number of azimuths and azimuth angle). If IDAYV = 0 or MSM = 1, set NAZI = 1.
- D. Azimuth Angle Loop ($K=1, NAZI$)
 1. Allow solar specular point to be computed (at most) once per altitude.
 2. Advance azimuth angle.
 3. Call AGAGEO to set latitude and longitude of Point P in /POSITN/.
 4. Call GEOXYZ to get \vec{RP} and thence direction cosines (UL, VL, WL) for /SANDD/.
 5. If clouds:
 - a. If IKM=1, Point C is at Point V and $\vec{RC} = \vec{RV}$.
 - b. If IKM > 1:
 - (1) Call AGAGEO to set latitude and longitude of Point C in /POSITN/.
 - (2) Call GEOXYZ to get \vec{RC} for later use in call to TRNSCO.
 6. Initialize position (FILPOS) of file LTMTE (necessary if TRNSOPT = .FALSE.).
- E. Wavenumber Loop ($L=1, NWAVER(JBAND) \Rightarrow NWAVER(J)$)
 1. Advance central wavelength (ZLAM)
 2. Call SURRAD to get:
 - a. At Point P:
 - (1) Emitted radiance, RAD(1); for $L \geq 1$.

- (2.1) Unattenuated reflected solar radiance, $RAD(2)$;
for $L \geq 1$.
- (2.2) Path parameters [$UPS(IT,N,1)$ and $UPPS(IT,N,1)$]
for path \overline{SP} ; for $L=1$.
- (3) Aerosol transmittance, $TASP(L)$ through /AIRSOL/,
for path \overline{SP} ; for $L \geq 1$.
- b. At Point C (if $IKM=1$):
 - (1) Path parameters [$UCS(IT,N)$ and $UPCS(IT,N)$] for
path \overline{SC} ; for $L=1$.
 - (2) Aerosol transmittance, $TASC(L)$ through /AIRSOL/,
for path \overline{SC} ; for $L \geq 1$.
- 3. Call $TRNSCO(\overline{PV})$ to get for path \overline{PV} :
 - a. (Derived from Word-8, -7, and -5 of Dataset-B1,
obtained by calling PREV):
Aerosol transmittance, $TAPV(L)$;
Total (molecular and aerosol) transmittance, $TTPV(L)$;
Air emission, $AEPV(L)$.
 - b. From XYZCOM Common:
Path parameters, $U(IT,N,2)$ and $UP(IT,N,2)$, preserved
as $UPV(IT,N)$ and $UPPV(IT,N)$.
- 4. Compute sum (temporarily defined as $UPRAD(K,L)$ and recog-
nized as azimuthally independent) of (1) the Earth's sur-
face radiance $RAD(1)$, multiplied by the total transmittance
 $TTPV(L)$ along \overline{PV} , and (2) the atmospheric emission $AEPV(L)$
along \overline{PV} :

$$[UPRAD(K,L)]_{old} = RAD(1) \times TTPV(L) + AEPV(L) \quad (K=1, NAZI),$$
 which is the upwelling spectral radiance, for implicit
nadir index-J, at night ($IDAYV=0$) and for no clouds.
- 5. If clouds, call $TRNSCO(\overline{CV})$ to get for path \overline{CV} :
 - a. (Derived from Word-8, -7, and -5 of Dataset-B1, ob-
tained by calling PREV):
Aerosol transmittance, $TACV(L)$;
Total (molecular and aerosol) transmittance, $TTCV(L)$;
Air emission.

b. From XYZCOM Common:

Path parameters, U and UP, preserved as UCV and UPCV.

6. Preserve AECV(L), which is azimuthally independent, with a notation to indicate it is the azimuth average for the current values of IKM, J, and L:

$$ARCVA(IKM,J,L) = AECV(L).$$

7. Set ITFLAG in /FLAGS/ equal to IDAYV, for use in Subroutine TRANSF when called by Subroutine CLDWT.
8. Call CLDWT to obtain through /CLDWT/ the arrays WT, EMISS, and TRANS of lengths IDX=160, IDX-1=159, and IDX-1=159, respectively. IDX equals 160 for a full set of 159 cloud configurations. WT is the array for weights corresponding to the various cloud configurations or sets; at 12-km altitude (Point C) along \overline{PV} , EMISS is the array for cloud-top emission radiances and (if IDAYV=1) TRANS is the array for the (irradiance-to-radiance) transfer coefficients for cloud-top reflection of solar radiation. WT(M), for any of the 10 location-season averaged statistical cloud models (KMODEL=1,10), is the probability that (a) the cloud-configuration set indicated by the index M occurs and (b) the detector's LOS at zenith angle CHI intersects the cloud-configuration set. The probability of the detector's LOS intersecting clouds is $\sum WT(M)$, (M=1,159).
9. Continue with following steps:
 - a. To facilitate computing the radiance distribution function resulting from the statistical treatment of natural clouds, start forming a new radiance distribution function (UPRADC) and corresponding weights (WTC).
 - b. To facilitate assessing the relative importance of emission and reflection contributions, preserve the emission component of UPRADC in another array (UPRDC1).
 - c. Multiply the spectral radiance from the Natural Cloud Module, expressed in $W/(km^2 \text{ sr } \mu m)$, by $1.0E-14 \times (ZLAM)^2$ to obtain $W/(cm^2 \text{ sr } cm^{-1})$.

- d. Include transmittance between Points C and V. For

$M=1,159$:

$$[UPRADC(M)]_{old} = 1.0E-14 \times (ZLAM)^2 \times EMISS(M) \times TTCV(L)$$

$$UPRDC1(M) = [UPRADC(M)]_{old}$$

$$WTC(M) = WT(M)$$

$$SUMWTC = \sum_{M=1}^{159} WTC(M).$$

- e. Now use fact that the radiance at Point V due to air emission along \overline{PV} can be separated into two portions:

$$AEPV(L) = AEPC(L) \times TTCV(L) + AECV(L)$$

or

$$AEPC(L) \times TTCV(L) = AEPV(L) - AECV(L).$$

Hence we need to subtract $AECV(L)$ from $UPRAD(K,L)$ in order that $UPRADC(160)$ will be the air emission along \overline{PC} but attenuated along \overline{CV} .

$$UPRADC(160) = UPRAD(K,L) - AECV(L)$$

$$UPRDC1(160) = UPRADC(160).$$

- f. We need the mean probability of a cloud-free line-of-sight (CFLOS) along \overline{PC} (at zenith angle CHI at Point P corresponding to nadir angle $BETA$ at Point V). As noted in Step 8, the probability of the detector's LOS intersecting clouds is $SUMWT = \sum WT(M)$, ($M=1,159$). Hence we take $(1-SUMWT)$ as the desired probability of a CFLOS, CFPV:

$$CFPV = 1-SUMWTC$$

$$WTC(160) = CFPV.$$

This $WTC(160)$ obtains for night. The daytime value is set later.

10. If $ISAYV=1$, we must include the surface-reflected solar radiation:

- a. In Step 3b, we preserved the path parameters along $\overline{P\bar{V}}$ as $UPV(IT,N)$ and $UPPV(IT,N)$. We now add the parameters for path segments $\overline{S\bar{P}}$ and $\overline{P\bar{V}}$ and preserve as $USPV$ and $UPSPV$ arrays.

$$USPV(IT,N) = UPS(IT,N) + UPV(IT,N).$$

$$UPSPV(IT,N) = UPPS(IT,N) + UPPV(IT,N).$$
 - b. Call $TRANS(...,USPV,UPSPV,...)$ to get the total molecular transmittance ($TMSPV(L)$) for the total path ($\overline{S\bar{P}+P\bar{V}}$).
 - c. To get the aerosol transmittance for the total path ($\overline{S\bar{P}+P\bar{V}}$), use $TASP(L)$ returned through $/AIRSOL/$ from call to Subroutine $SURRAD$ and $TAPV(L)$ from Subroutine $TRNSCO$'s call to Subroutine $ATMRAD$ for path $\overline{P\bar{V}}$.
 - d. Thus the total transmittance for the surface-reflected solar ray along the total path ($\overline{S\bar{P}+P\bar{V}}$) is

$$TTSPV(L) = TMSPV(L) \times [TASP(L) \times TAPV(L)].$$
 - e. The total upwelling radiance along the path $\overline{P\bar{V}}$ (without clouds) is

$$[UPRAD(K,L)]_{new} = [UPRAD(K,L)]_{old} + TTSPV(L) \times RAD(2)$$
 where only $RAD(2)$ may depend on azimuth, which it will for non-Lambertian surface materials ($MSM > 1$). The first term is the sum of the attenuated ground-surface emission and air emission along path $\overline{P\bar{V}}$ (obtained in Step E.4) and the second term is the product of the unattenuated surface-reflected solar radiance (obtained from Step E.2.a.(2.1)) and the total transmittance (obtained from Step E.10.d).
11. If $IDAYV=1$ and clouds are present, one must include the cloud-reflected solar radiation.
 - a. We must convert the transfer coefficients ($TRANS$, from Step E.8) into radiances for the cloud-reflected solar radiation. To do so, we need the solar spectral irradiance $E[W/(cm^2 \text{ cm}^{-1})]$ (normal to the path to the sun) at the 12-km altitude point along the path $\overline{V\bar{P}}$. We use the quantity $SOLIRR(L) = E$, previously obtained

from Subroutine SURRAD's call to SOLRAD and available through /SOLARP/.

- b. We include air transmittance [TTSCV(L)] above 12-km altitude along the total path ($\overline{SC} + \overline{CV}$). TTSCV(L) is given by the product of the molecular transmittance [TMSCV(L)] and the aerosol transmittance [TASC(L) x TACV(L)]. TMSCV(L) will be computed by Subroutine TRANS, given the path parameters USCV and UPSCV. From Subroutine TRNSCO's call to PATH (Step E.5.b), we have the path parameters U(IT,N,2) and UP(IT,N,2) (which we saved as UCV(IT,N) and UPCV(IT,N) for the path \overline{CV}). The path parameters UCS(IT,N) and UPCS(IT,N) were obtained from the call to Subroutine SURRAD [Step E.2.b.(1)]. Add to the path parameters and preserve as USCV and UPSCV arrays.

$$USCV(IT,N) = UCS(IT,N) + UCV(IT,N)$$

$$UPSCV(IT,N) = UPCS(IT,N) + UPCV(IT,N).$$

- c. Call TRANS(...,USCV,UPSCV,...) to obtain the total molecular transmittance TMSCV(L) for the total path ($\overline{SC} + \overline{CV}$).
- d. To get the aerosol transmittance for the total path ($\overline{SC} + \overline{CV}$), use TASC(L) returned through /AIRSOL/ from call to Subroutine SURRAD and TACV(L) from Subroutine TRNSCO's call to Subroutine ATM RAD for path \overline{CV} .
- e. Thus the total transmittance for the cloud-reflected solar ray along the total path ($\overline{SC} + \overline{CV}$) is

$$TTSCV(L) = TMSCV(L) \times [TASC(L) \times TACV(L)].$$
- f. A contribution to the total upwelling radiance along the path \overline{CV} (with clouds at or below Point C) is

$$[UPRADC(M)]_{new} = [UPRADC(M)]_{old} + SOLIRR(L) \times TRANS(M) \times TTSCV(L)$$

$$(M=1,159)$$

where only the transfer coefficient TRANS(M) depends on azimuth. The first term is the cloud-surface emission attenuated along path \overline{CV} (obtained in Step

E.9.d) and the second term is the product of the un-attenuated cloud-surface-reflected solar radiance $[SOLIRR(L) \times TRANS(M)]$ and the total transmittance (obtained from Step E.11.e).

- g. WTC(160) needs to be reset for daytime conditions. We multiply the probability of the (nighttime) one-leg CFLOS by the probability of not having the second (daytime) leg:

$$WTC(160) = CFPV \times (1.0 - CFPS),$$

where CFPV was set in Step E.9.f and CFPS was set in Step B.4.

- h. For daytime, the arrays UPRADC, UPRDC1, and WTC must be augmented by inclusion of members for a two-leg CFLOS:

$$UPRDC1(161) = UPRADC(160)$$

$$UPRADC(161) = UPRADC(160) + RAD(2) \times TTSPV(2)$$

$$WTC(161) = CFPS \times CFPV$$

where UPRADC(160) was set in Step E.9.e, RAD(2) in Step E.2.a.(2.1), and TTSPV(L) in Step E.10.d.

12. For clouds, day or night, the distribution-function arrays must be processed.

- a. Augment each of the three arrays (UPRADC, UPRDC1, and WTC) with a zero-value member, which allows Subroutine LINEAR to interpolate within its given array if the weight of the normally smallest member exceeds the smallest fractile (now 0.10) for which an integral-distribution value is requested.

$$UPRADC(II) = UPRDC1(II) = WTC = 0.0$$

$$II = \begin{cases} 161 & \text{for night} \\ 162 & \text{for day.} \end{cases}$$

- b. Call SORTLJ to sort the radiance array UPRADC in increasing order and carry along the arrays UPRDC1 and WTC.

- c. Sum the weights and normalize to unity (although, in principle, the weights are already so normalized).
- d. Interpolate the array UPRADC (by calling LINEAR) to obtain the percentile values (called RXXX(K,L)) corresponding to XXX = 10, 25, 50, and 90 (i.e., WTC = 0.10, 0.25, 0.50, and 0.90). For XXX = 100, set RXXX(K,L) = UPRADC(II).

C'. Nadir Angle Loop (J=1,NNADIR) Completion

After completing the wavenumber and azimuth loops, compute averages over azimuth angles K at wavenumbers L=1,NWAVEJ; nadir angle J; and altitude I (or IKM for clouds).

$$\text{UPRADA}(I,J,L) = (1/\text{NAZI}) \sum_{K=1}^{\text{NAZI}} \text{UPRAD}(K,L)$$

$$\text{RXXXA}(IKM,J,L) = (1/\text{NAZI}) \sum_{K=1}^{\text{NAZI}} \text{RXXX}(K,L)$$

XXX = 10, 25, 50, 90, 100

D'. Altitude Loop (I=1,NALTJ) Completion

After completing the nadir loop, compute averages over nadir angles J at wavenumbers L=1,NWAVEJ and altitude I (or IKM for clouds):

$$\text{UPRADN}(I,L,\text{JBAND}) = (1/\text{NNADIR}) \sum_{J=1}^{\text{NNADIR}} \text{UPRADA}(I,J,L)$$

$$\text{ARCVN}(IKM,L) = (1/\text{NNADIR}) \sum_{J=1}^{\text{NNADIR}} \text{ARCVA}(IKM,J,L)$$

$$RXXXN(IKM,L) = (1/NNADIR) \sum_{J=1}^{NNADIR} RXXXA(IKM,J,L).$$

Since the inclusion of the index JBAND was a late change, we elected not to modify the arrays ARCVN(IKM,L) and RXXXN(IKM,L) to provide for an explicit dependence on the index JBAND as we did for the array UPRADN(I,L,JBAND). This limitation must be remembered and removed if JBAND > 1 and if clouds are included, unless one adopts the GRC definition of UPRADN(I,L,JBAND), i.e., $UPRADN(I,L,JBAND) = R050N(IKM,L) + ARCVN(IKM,L)$.

6-3 OTHER ROUTINES IN UPWELLING NATURAL RADIATION MODEL

Subroutine UPWELL, the principal routine in the Upwelling Natural Radiation Model, makes a number of calls as shown in Figure 6-4.

6-3.1 SAI Routines

The calls to the left of the vertical line in Figure 6-4 are related to the Natural Cloud Model. Subroutine GEOXYZ has been discussed in Section 5-4.1. Subroutine XMIT is described in Table 7-3a. The routines CFLOSF, CLDWT, SORTLJ, and LINEAR are part of the Natural Cloud Model; listings of them are in Volume 24 and brief descriptions of them are given here in Table 7-3a. Note that the listing of SORTLJ given here in Section 8 differs in an essential aspect from that in Volume 24 and must be used with the NBR Module (the listing in Volume 24 is satisfactory for its use there).

The routines AGAGEO, GEOREA, GEOTAN (called by GEOREA), REATAN (called by AGAGEO), and TANGE0 (called by AGAGEO) provide coordinate transformations. They are described in Table 7-3a. Their input and output variables are given in Tables 6-3 through 6-7, respectively.

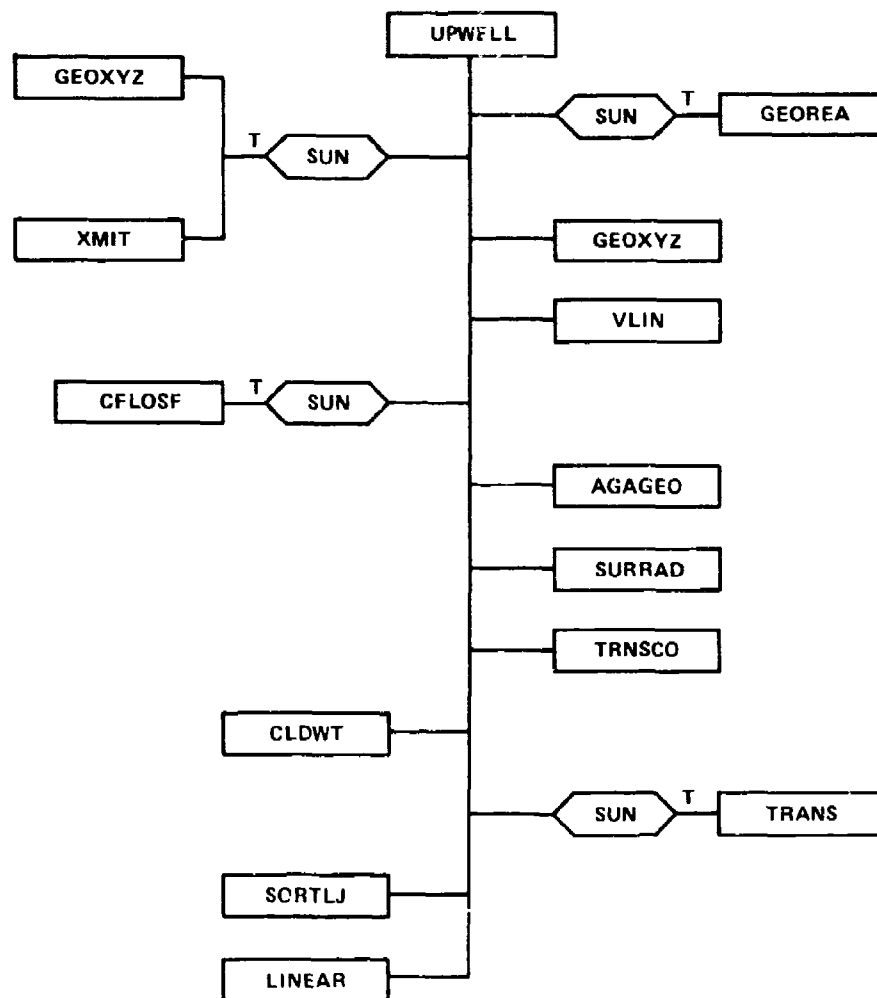


Figure 6-4. Routines called directly from the principal routine (UPWELL) in the Upwelling Natural Radiation Model. For subsequent calls, see Figure 7-1.

Table 6-3. Input and output variables for Subroutine AGAGE0.

INPUT VARIABLES

Argument List

HA1, - Altitude, colatitude, and east longitude of Point 1.
GC1, (cm, radians, radians)
GL1

AZ21, - Azimuth angle and geocentric angle of Point 2 relative
GA21 to Point 1. (radians)

HA2 - Altitude of Point 2. (cm)

OUTPUT VARIABLES

Argument List

GC2, - Colatitude and east longitude of Point 2. (radians)
GL2

Table 6-4. Input and output variables for Subroutine GEOREA.

INPUT VARIABLES

Argument List

HA1, - Altitude, colatitude, and east longitude of Point 1.
GC1, (cm, radians, radians)
GL1

HA2, - Altitude, colatitude, and east longitude of Point 2.
GC2, (cm, radians, radians)
GL2

OUTPUT VARIABLES

Argument List

SR21, - Slant range, elevation, and azimuth of Point 2 relative
EL21, to Point 1. (cm, radians, radians)
AZ21

Table 6-5. Input and output variables for Subroutine GEOTAN.

INPUT VARIABLES

Argument List

HA1, - Altitude, colatitude, and east longitude of Point 1.
GC1, (cm, radians, radians)
GL1

HA2, - Altitude, colatitude, and east longitude of Point 2.
GC2, (cm, radians, radians)
GL2

OUTPUT VARIABLES

Argument List

XE21, - X, Y, and Z coordinates of Point 2 relative to Point 1. (cm)
YN21,
ZV21

Table 6-6. Input and output variables for Subroutine REATAN.

INPUT VARIABLES

Argument List

SR, - Slant range, elevation angle, and azimuth angle of Point P.
EL, (cm, radians, radians)
AZ

OUTPUT VARIABLES

Argument List

XE, - X, Y, and Z coordinates of Point P. (cm)
YN,
ZV

Table 6-7. Input and output variables for Subroutine TANGE0.

INPUT VARIABLES

Argument List

HA1, - Altitude, colatitude, and east longitude of Point 1.
GC1, (cm, radians, radians)
GL1

ZE21, - X, Y, and Z coordinates of Point 2 relative to Point 1. (cm)
YN21,
ZV21

OUTPUT VARIABLES

Argument List

HA2, - Altitude, colatitude, and east longitude of Point 2.
GC2, (cm, radians, radians)
GL2

6-3.2 G.E. Tempo Routines (TRNSCO, ATMRAD, TRANS)

Three very important routines called either directly or indirectly by Subroutine UPWELL are Subroutines TRNSCO, ATMRAD, and TRANS. A brief description of the purpose of each of these routines is included in Table 7-3a. We have summarized their input and output variables here: Subroutine TRNSCO (Table 6-8), Subroutine ATMRAD (Table 6-9), and Subroutine TRANS (Table 6-10). Ewing et al. have given briefer statements about two of the routines in Volume 31: TRNSCO (p. 75) and TRANS (p. 72, with flow chart on p. 73).

Table 6-8. Input and output variables for Subroutine TRNSCO.

INPUT VARIABLES

Argument List

For I=1,3

RX(I), - Location vectors of Points X, Y, and Z which, respectively,
 RY(I), are typically but not necessarily the locations of the
 RZ(I) detector, scattering site, and source. (cm)

LBINT - Word-5 (LHV) in GRC Dataset-BN (No. 114), List of Band-Interval Datasets (BI). Strictly, LBINT is the pointer (i.e., contains the (Q-array) address) for the List Header of the Band-Interval Datasets-BI corresponding to Dataset-BN.

RADSW - Logical variable serving as option switch for atmospheric volume emission calculation.
 =.TRUE., Include call (from Subroutine TRNSCO) to Subroutine ATM RAD.
 =.FALSE., Bypass call to Subroutine ATM RAD and perform transmittance calculation in Subroutine TRNSCO without air emission.

Dataset-BI (Band-Interval Dataset No. 115)

Q(1) = BNLO BI, - Low and high wavelengths for wavelength-band-index
 Q(2) = BNHI BI J. (μm)
 Q(3) = WLO BI, - Low and high wavenumbers for wavelength-band-index
 Q(4) = WHI BI J. (cm^{-1})

XYZCOM Common

LTMTE - Binary file containing the band-model parameters which were derived in Subroutine TRANSB from the basic 5-cm⁻¹ resolution data. Here in Subroutine TRNSCO, File LTMTE is rewound for use in Subroutine TRANS.

OPTION Common

TRNSOPT - Logical variable affecting complexity of molecular transmittance calculation (see Tables 7-8 and 6-10 for Subroutines TRANSB and TRANS). In Subroutine TRNSCO, TRNSOPT is used only in the argument list for the call to Subroutine TRANS, a call that occurs only if RADSW = .FALSE., which is not the case in the NBR Module.

(continued)

Table 6-8. Input and output variables for Subroutine TRNSCO (Cont'd).

OUTPUT VARIABLES

Description of the output requires caveats.

1. In the (rare) event the path should not intersect the shelled-atmosphere, then initialized values of Word-5 (if RADSW = .TRUE.), Word-7, and Word-8 of Dataset-B1 are explicitly set here in Subroutine TRNSCO.

2. In the usual event that the path does intersect the atmosphere, there are two cases to consider:

- 2.1 RADSW = .TRUE. (Applies to NBR Module)

Subroutine ATM RAD is called to evaluate Words-5, -7, and -8 of Dataset-B1, but this dataset is not called here in TRNSCO and thus is not explicitly available in TRNSCO.

- 2.2 RADSW = .FALSE. (Does not apply to NBR Module)

Subroutine ATM RAD is not called. Hence, the calls that ATM RAD makes to get the transmittance calculations done must be made here in TRNSCO. In this case, Word-7 and -8 of Dataset-B1 are explicitly available.

Definitions of Word-5, -7, and -8 of Dataset-B1 follow.

Q(5)=BKGND B1 - In-band-interval radiance (due to atmospheric emission) over the entire path length (which should have 1-leg and not 2-legs). $[W/(cm^2 \text{ sr band-interval})]$

Q(7)=TRANS B1 - Product of molecular and aerosol transmittances over the entire path length.

Q(3)=IDSBX B1 - Aerosol transmittance over the entire path length.

Note: This is a temporary use of Word-8 (and not the GRC dictionary use of Word-8). Here it is used to carry information to Subroutine UPWELL.

QNCNC Common

NCNC - A variable set to NC and made available to Subroutine UPWELL to facilitate being able to use zero-kilometer altitude in the NBR Module. For more information, see comments preceding label number 22 in Subroutine UPWELL.

Table 6-9. Input and output variables for Subroutine ATM RAD.

INPUT VARIABLES

Argument List

- LOGIC - Logical variable.
 =.TRUE., On first entry (for first path segment) from Subroutine TRNSCO (and is reset to .FALSE. in ATM RAD).
 =.FALSE., On subsequent entries along the same path.
- ISHELL(1), - INDX(I) and INDX(I+1) in call from Subroutine TRNSCO.
 ISHELL(2)
 ISHELL(3) - Used in evaluating the logical variable TEST. ISHELL(3) will typically be equal to INDX(I+2), a positive quantity except on the last call to ATM RAD when the last path-segment is being treated, at which time ISHELL(3) will become equal to INDX(NC+1) which had been set to 0 in Subroutine STEP.
- XFRAC(1), - XFRACS(I) and XFRACS(I+1) in call from Subroutine TRNSCO.
 XFRAC(2) To help understand the values and uses of XFRACS(1), (1) recall that the total path has NC-1 segments and NC end points of these segments and (2) see Table 5-8 for Subroutine STEP.
- DS - DS(I+1) in call from Subroutine TRNSCO.
 Note: It is always true that DS(1)=0 and DS(NC+1) = -1.0, where NC is the number of path segments plus one. ATM RAD will not be called with I=NC. (cm)
- LBINT - Word-5 in GRC's Dataset-BN (No. 114). Strictly, LBINT is the pointer (i.e., contains the (Q-array) address) for the List Header of the Band-Interval Datasets-B1 corresponding to Dataset-BN.

XYZCOM Common

- FACT - Path resolution factor controlling the number of altitudes and spacing used in Subroutine SHELLS. See Table 7-9 for Subroutine SHELLS. Here in Subroutine ATM RAD, FACT is used to set TOL, which is used to test temperature differences across cells.

(continued)

Table 6-9. Input and output variables for Subroutine ATMRAD (Cont'd).

For J=1,NS

HSHELL(J), - Altitude and temperature at boundary-J. (HSHELL(1)=0.0)
TS(J) (cm, deg K)

For I=1,2; N=1,10

U(I,N,2), - Cumulative values of path parameters U (areal density) and
UP(I,N,2) UP (product of U and pressure P) for temperature-index-I
and species-N at end of line segment DS.
(cm at STP, atm-cm at STP)

NMOLS - Number (10) of molecular species in molecular transmittance model.

LTMTE - Binary file containing the band-model parameters which were derived in Subroutine TRANSB from the basic 5-cm⁻¹ resolution data. Here in Subroutine ATMRAD, File LTMTE is rewound for use in Subroutine TRANS.

OPTION Common

TRANSOPT - Logical variable affecting complexity of molecular transmittance calculation (see Tables 7-8 and 6-10 for Subroutines TRANSB and TRANS). In Subroutine ATMRAD, TRANSOPT is used only in the argument list for the call to Subroutine TRANS.

Dataset-BI (Band-Interval Dataset No. 115)

Q(1)=BNLO BI, - Low and high wavelengths for wavelength-band-index J.
Q(2)=BNHI BI (μm)
Q(3)=WLO BI, - Low and high wavenumbers for wavelength-band-index J.
Q(4)=WHI BI (cm⁻¹)

OUTPUT VARIABLES

Dataset-BI (Band-Interval Dataset No. 115)

Q(5)=BKGND BI - In-band-interval radiance to back of cell-DS.
[W/(cm² sr band-interval)]

Q(7)=TRANS BI - Product of cumulative molecular and aerosol transmittance to back of cell-DS. (dimensionless)

(continued)

Table 6-9. Input and output variables for Subroutine ATMRAD (Cont'd).

Q(8)=IDSBX BI - Cumulative aerosol transmittance to back of cell-DS.

Note: This is the second of two temporary uses of Word-8 (and not the GRC dictionary use of Word-8). Here, it is used to carry information to Subroutine UPWELL.

Table 6-10. Input and output variables for Subroutine TRANS.

INPUT VARIABLES

Argument List

- NTEMP - Number of temperatures in the atmospheric transmittance model (set to 10 in call from either Subroutine ATMRAD or TRNSCO).
- M - Index for mode of transmittance calculation. Could be 1, 2,...,15. Within the NBR Module (where TRANS is called from ATMRAD, TRNSCO, and UPWELL), M is always 1. (In calls from Program EMISCAT, M is 1, 2 and is allowed values up to 15.) In Subroutine TRANS, M being 1 limits use of the U and UP arrays to their first-half values. This is consistent with the fact that within the NBR Module, Subroutine TRANS is always called with M set to 1, U set to U(1,1,2), and UP set to UP(1,1,2). This is also true for calls with M=1 from Program EMISCAT. But there, when $M \geq 2$, the calls are with U and UP, i.e., the entire arrays.

For $I=1, NTEMP$; $N=1, NSPEC$

- U(I,N,1), - Path parameters U (species-N areal density) and UP
UP(I,N,1) (product of U and pressure P) for temperature-index I and species-N. (cm at STP, atm-cm at STP)
- FK(M) - FK(M) is used only if $M \geq 3$. In the NBR Module, M is always 1. (But for those calls with $M \geq 3$ from Program EMISCAT, FK(M) is a set of weights used to partition the path element.)

(continued)

Table 6-10. Input and output variables for Subroutine TRANS (Cont'd).

-
- WDL, - Lowest and highest wavenumber in the detector interval being
WDH used for which the transmittance is to be computed. (cm^{-1})
- FAST - Logical variable determining complexity of transmittance calculation. In calls to Subroutine TRANS (from Subroutines ATMRAD, TRNSCO, and UPWELL within the NBR Module and from Program EMISCAT outside the NBR Module), FAST is set to TRNSOPT.
 =.TRUE., Transmittance is based on single-level groups and statistical bands.
 =.FALSE., Transmittance is based on multiple-level groups and random Elsasser bands.

In addition, note that for TRNSOPT=.TRUE., Subroutine TRANSB develops the band-model parameters for the user interval of interest and Subroutine TRANS uses these band-model parameters to compute the transmittance and optical depth for the same interval. But for TRNSOPT=.FALSE., Subroutine TRANSB develops band-model parameters for an interval with (probably but not necessarily) higher resolution than the user interval. Thus, to obtain the transmittance and optical depth for the user interval, Subroutine TRANS first computes the optical depth (XS_j) and transmittance [$\exp(-XS_j)$] for the higher-resolution interval j and then obtains the transmittance [$TAU(IS)$] and optical depth [$ABC(IS)$] for species- IS in the user interval by using the following expressions to perform the weighted sum over those higher-resolution intervals overlapping the user interval.

$$TAU(IS) = \sum_j F_j \exp(-XS_j)$$

$$ABC(IS) = \begin{cases} -\ln [TAU(IS)] & \text{for } 10^{-4} < TAU(IS) < 0.9999 \\ \sum_j F_j XS_j & \text{otherwise.} \end{cases}$$

These formulas are not given in Volume 28.

For additional information regarding the consequences for Subroutine TRANS due to the two possibilities for TRNSOPT in Subroutine TRANSB, see Table 7-3 for Subroutine TRANSB.

(continued)

Table 6-10. Input and output variables for Subroutine TRANS (Cont'd).

FILPOS - Position of file LTMTE. Set to 1.E+04 in calls from Subroutine TRNSCO and ATMRAD.

XY Common

For I=1,10

TT(I) - Temperature array in atmospheric transmission model.

XYZCOM Common

LTMTE - Binary file containing the band-model parameters which were derived in Subroutine TRANSB from the basic 5-cm⁻¹ resolution data. Equivalenced (in Subroutine TRANSB) to TAPOT, for which definition see Table 7-8 for Subroutine TRANSB.

* * * * *

For each read of File LTMTE, the 202 words are stored as:

WTL, - Lower and higher wavenumbers of interval. (cm⁻¹)
WTH

For I=1,10; N=1,10

SOD(I,N), - Mean absorption coefficient and inverse of mean line-spacing
DEI(I,N) parameter (or the effective line density) for species-N at
temperature-index-I for the wavenumber interval (WTL,WTH).
[1/cm at STP, lines/(cm⁻¹)]

* * * * *

NSPEC - NMOLS, the number (10) of species in the molecular transmittance model.

OUTPUT VARIABLES

Argument List

For N=1,NSPEC; M=1,15 but M=1 for NBR Module

TAJ(N,M) - Transmittance for species-N. (dimensionless)
ABC(N,M) - Optical depth for species-N. (dimensionless)
TTBL(M) - Molecular transmittance of all the species for mode-M.

SECTION 7

NATURAL BACKGROUND RADIATION (NBR) MODULE

7-1 INTRODUCTION

The NBR Module is defined to be a complete computer program which integrates nine ROSCOE-IR models into a consistent, stand-alone module - similar to the way it exists in the ROSCOE-IR Program - for the purpose of developing and testing the capability to compute the natural upwelling spectral radiance as a function of altitude. Table 7-1 provides a guide to the nine modules so integrated; we also include the Dynamic Storage Allocation (DSA) System [SP-78] because it plays such an important role and it is an entity integrated into the NBR Module.

Table 7-1. Guide to modules integrated into the NBR Module.

<u>Title</u>	<u>Model Number</u>	<u>Developer</u>	<u>ROSCOE Manual Volume Number</u>
Ambient Atmosphere	1a	SAI/LJ	14a-1,14c
Atmospheric Aerosols	1c, 19:1c	VI	25
Natural Clouds	1d, 19:1d	SAI/PA	24
Atmospheric Thermal Emission	20b	GET	28,31
Molecular Transmittance	24d	GET	28,31
Earth Surface Characterization	23a	SAI/LJ	27, Sect. 2,3
Earth Surface Radiance	23b	SAI/LJ	27, Sect. 5
Upwelling Natural Radiation	23c	SAI/LJ	27, Sect. 6
Solar Radiation	23e	SAI/LJ	27, Sect. 4
DSA System		GRC ^a	

^aWe have used a G.E. Tempo version.

7-2 GENERAL CODING INFORMATION FOR NBR MODULE

7-2.1 Routines in NBR Module

Table 7-2a lists all the (non-DSA) routines used in the NBR Module. Those routines from the DSA System [SP-78] we have used in the NBR Module are listed in Table 7-2b. In Table 7-2a, each of the routines is annotated by a letter, defined in the footnotes, which identifies either the module or a category to which it belongs.

7-2.2 Calling Structure of Routines

The essential relationships between all of the routines in the NBR Module are shown in Figure 7-1; however, we have omitted all the DSA routines except for QINITL which we include as a reminder that the DSA system is there. Calls to the left of the heavy vertical line are those required for inclusion of the statistical cloud submodel.

In addition to the routine names in Figure 7-1, we include annotations to enhance the utility of the diagram. Near the top of the figure, a dashed line divides the initializing calls from those made later while looping over the spectral bands. The T (for TRUE) besides the SUN-hexagon means the indicated call is made if the sun is present (above the horizon). Vectors \vec{V} , \vec{P} , \vec{C} , and \vec{S} , refer, respectively, to positions for (a) the (fictitious) viewing point at which the upwelling radiance is being calculated, (b) a representative point on the Earth's surface toward which the (fictitious) detector at Point V is pointed, (c) the intersection of the detector's line-of-sight with the 12-km altitude surface (the highest altitude of cloud tops), and (d) the sun. Vectors such as \vec{PS} denote paths joining the indicated points. The indices I, J, K, M, and L are, respectively, those for altitudes, nadir angles, azimuth angles, broad-bands (from Dataset-BN), and band-intervals within a broad-band (from Dataset-BI). On the second and third pages of Figure 7-1, the indices I, J, K, and L head columns of entries which are either 1 or ≤ 1 . Each row of such entries is correlated with the call to a routine (or a set of routines) on the same line. Such entries denote the values of the indices for which the call is made to achieve maximum economy.

Table 7-2a. Routines in the Natural Background Radiation (NBR) Module.

<u>Routine</u>	<u>Comment*</u>	<u>Routine</u>	<u>Comment</u>	<u>Routine</u>	<u>Comment</u>
ACCUM	T	GEOREA	X	SOLVE	A
AEROSOL	P	GEOTAN	X	SOLZEN	A
AGAGEO	X	GEOXYZ	X	SORTLJ	C
ATMOSU	A,C,T,E	GLITTR	E	SPCMIN	A
ATMRAD ^c	T	H2OSVP	A	STEP	T
BESSO	C	IONOSU	A	STEPS	T
BK CDATA	C	JULIAN	A	SUBVEC	T,V
CANGLE	E	LINEAR	C,E	SURPAD	E
CFLOSF	C	OZONE	A	TAIR	C
CLDBDR	C	PATH	T	TANGEQ	X
CLDGEOM ^a	C	PLANCK	T,E	TEMPZH	A
CLDWT	C	RATCOF	A	TRANS	T
CLOUDO	C	REA TAN	X	TRANSB ^c	T
DOT	T,V	RHOEPS	C	TRANSF ^c	C
DRVUPW ^c	U	RINOUT	E	TRNSCO ^c	T
EMISSF	C	SEGMENT	T	UNITV ^c	T,V
ERF	E	SETALT	U	UPWELL ^c	U
ESURF	E	SGEOM	C	VLIN	T,V
FITTER	A	SHELLS	T	WATER	A
FRAC	T	SOLCYC	A	WVOPT	A
FRESNL	E	SOLORB	A	XMIT ^b	T
GRCLE	E	SOLRAD	S	ZTTOUT	A

- A Routine from Ambient Atmosphere Module.
C Routine from Statistical Submodel of Natural Cloud Module.
E Routine from Earth Surface Characterization and Radiance Module.
P Routine from Atmospheric Aerosols Module.
S Routine from Solar Radiation Module.
T Routine from Atmospheric Thermal Emission and Molecular Transmittance Modules.
U Routine from Upwelling Natural Radiation Module.
V Routine for relations between vectors.
X Routine for transformation of coordinates.
a A dummy routine to simulate that from the Deterministic Submodel of the Natural Cloud Module which, though loaded to satisfy externals, is not otherwise used.
b This routine is a FORTRAN-language version, prepared by L. Ewing, of the COMPASS-language routine used in the GRC DSA System. Here, it is used independent of its role in the DSA System.
c Employs the DSA System.

Table 7-2b. Routines from the DSA System used in the NBR Module.

CREATE ^{P,a}	NEXT ^{P,b}	QCREAT	QGCBLK	QZBLOK
CREATX	NLOKDS	QDSRED	QGDBLK	REMOVE
DSPWRD ^P	PUTAFT	QDSRYT	QGRBAG	WIPOUT ^P
DSTROY ^P	PUTBOT ^{P,c}	QERROR	QGTZWD	XMIT ^P
INDWRD ^P	PUTORD ^d	QFIELD	QINITL ^P	
LOCKDS ^P	QCEASE	QFLDST	QPTZWD	

^PPrimary calls.

^aHas entry point CREATL^P.

^bHas entry points PREV^P and PREVN^P.

^cHas entry point PUTTOP^P.

^dHas entry point PUTORA^P.

7-2.3 Description of Routines: Function Performed, Originator, and Locations of Listing and Input-Output Table

In Table 7-3a, for all the (non-DSA) routines in the NBR Module (as listed in Table 7-2a), we provide a short description of the routine's function. We also identify (a) the organization (if not SAI) originating the routine, (b) the number of the volume in the ROSCOE Manual containing a listing of the routine, and (c) the number of the table in Volume 27 when we have summarized the inputs and outputs for the routine.

In Table 7-3b, we provide a short description of those DSA routines which are called directly from the NBR Module.

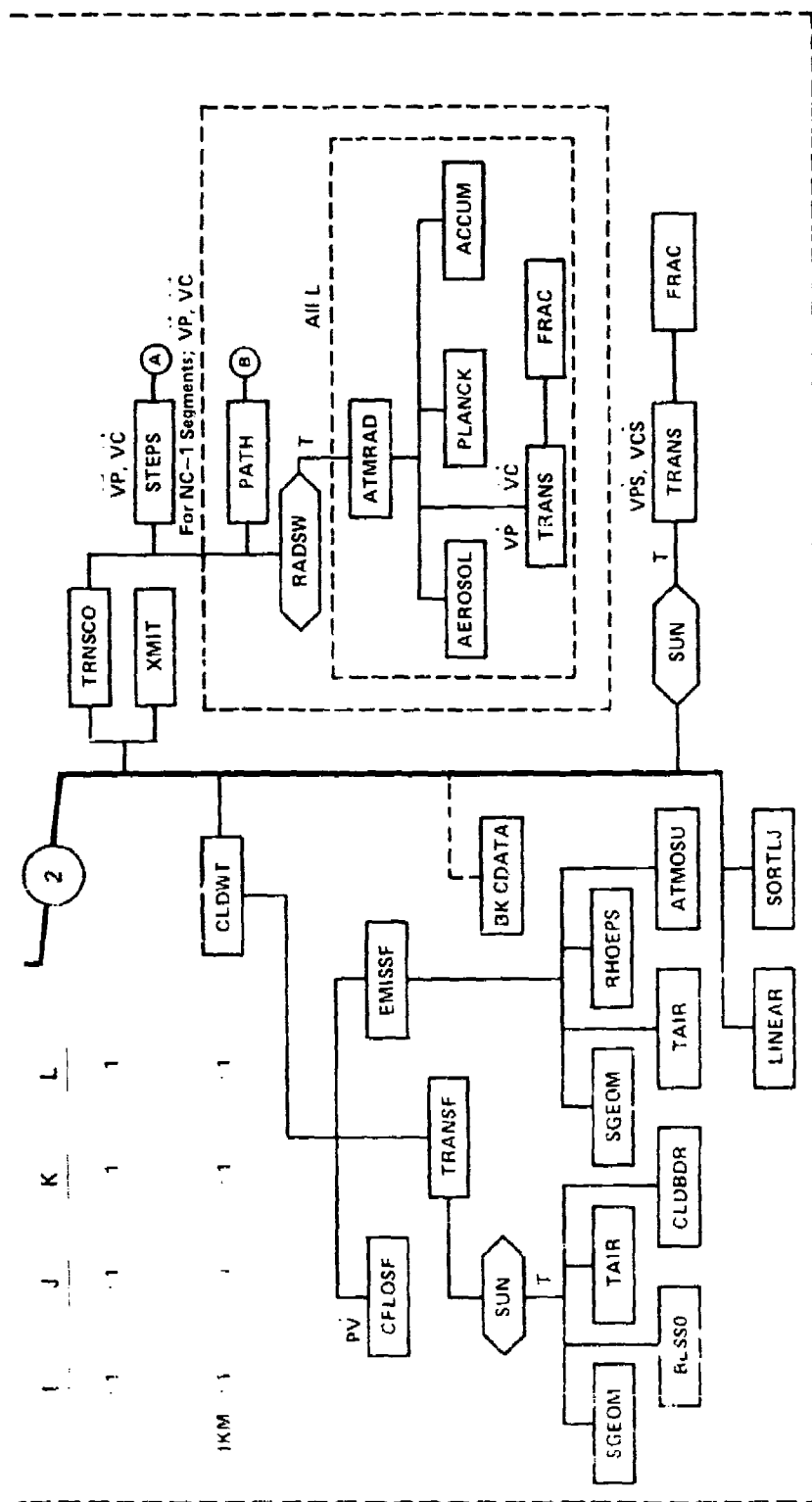


FIGURE 7-1. (CONTINUED)

Table 7-3a. Description of routines in NBR Module: function performed, originator, and locations of listing and input-output table.

<u>Routine</u>	<u>Function performed</u>
ACCUM	Integrates (between $X=A$ and $X=B$) a function $F(X)$ given at two points X_1 and X_2 , by using linear, logarithmic, or power-law interpolation, corresponding to specified $ITYPE = 1, 2, 3$, respectively; uses linear interpolation in case the other methods would fail. (GET routine; listing in Vol. 27.)
AEROSOL	Computes attenuation coefficients for scattering and absorption (and, though not used in the NBR Module, the asymmetry factor (average cosine of the scattering angle)) due to atmospheric aerosols, given the altitude and wavelength. (VI routine; see Vol. 25 for original routine which differs slightly from ours in Vol. 27. Input-output in Table 5-4.)
AGAGEO	Provides the geographic coordinates (colatitude and east longitude) of Point 2, given the geographic coordinates of Point 1, the azimuth and Earth-central angle of Point 2 with respect to Point 1, and the height of Point 2. (A modified MRC HARC routine; listing in Vol. 27. Input-output in Table 6-3.)
ATMOSU	Computes the properties of the undisturbed atmosphere, given the altitude (ZH), after the associated subroutines compute the local apparent time (HL), solar flux (SBAR), and day-or-night parameter (IDORN). (Listing in Vol. 14a-1.)
ATMRAD	Computes the atmospheric volume emission on an optical path. (GET routine; listing in Vol. 27. Input-output in Table 6-9.)
BESSO	Provides the zero-order cylindrical Bessel function per Formulas 9.4.1 and 9.4.3 in AS-54 (Listing in Vol. 24.)
BKDATA CDATA	Provides (1) for 14 cloud types, their (a) base altitude, (b) thickness, (c) water droplet radius, (d) water droplet density, and (e) optical scattering properties (extinction and scattering cross-sections and mean cosine of scattering angle) at 10 wavelengths in the 2- to 5- μ m range, and (2) for Regions 4 and 11 in the NASA cloud-data base, (a) the statistical-cloud index, (b) occurrence frequencies of cloud types, and (c) occurrence frequencies of number of cloud layers. (Listing in Vol. 24.)
CANGLE	Computes the Earth-central angle (CANGLE) between the two central rays to Points P1 and P2, given the north latitudes and east longitudes of Points P1 and P2. (Listing in vol. 27. Input-output in Table 5-5.)

(continued)

Table 7-3a. Description of routines in NBR Module: function performed, originator, and locations of listing and input-output table (Cont'd).

CFLOSF	Computes the probability of a cloud-free line-of-sight (CFLOS) as a function of the cloud coverage (expressed in tenths) and zenith angle of the LOS from the ground. (Listing in Vol. 24.)
CLDBDR	Provides the bidirectional reflectance (1/sr) of a plane, semi-infinite stratocumulus (KLOUD=4) cloud for a photon of wavelength ALAM incident at zenith angle THIN = ACOS(CTHIN) and reflected at zenith angle THOUT = ACOS(CTHOUT) and azimuth angle PHIOUT = ACOS(CPHIOUT). (Listing in Vol. 24.) Known as ALBEDC in ROSCOE-IR.
CLDWT	Computes (for a given source and detector location) three arrays (TRANS, EMISS, and WT), each with IDX members (normally 160). The TRANS and EMISS arrays are, respectively, (1) the distribution of irradiance-to-radiance transfer coefficients (1/sr) at the 12-km altitude transfer point for clouds and (2) the distribution of (attenuated) spectral cloud-emission radiances at 12-km altitude and directed toward the detector. The WT array is the set of weights associated with the set of statistical cloud configurations, influenced by cloud-coverage fractions and cloud-free line-of-sights from the detector. (Listing in Vol. 24.)
CLOUDO	Reads (a) a flag (MODE) indicating by a value of 0 or 1 whether the deterministic- or statistical-cloud submodel is desired, (b) cloud data appropriate to the indicated submodel and makes them available to the appropriate routines. For MODE=1, the routine reads an index KMODEL which selects data from that in the code or allows the user to input his own data. Other flags are read which allow selected portions of the provided data to be overridden. These user-provided data are output through CLDFRQ and CONFIG Commons and override data in BLOCK DATA CDATA. (Listing in Vol. 24.)
DOT	Computes the dot product of two vectors. (GET, GRC routine; listing in Vol. 27.)
DRVUPW	Drives, and provides a means for testing, the NBR Module, by accepting the necessary input data for each of the modules (see Table 7-1) integrated into the NBR Module and printing selected results. (Listing in Vol. 27.)
EMISSF	Computes the (attenuated) spectral radiance at 12-km altitude for radiation emitted (at a specified zenith angle) from a cloud top at a specified altitude. (Listing in Vol. 24.)

(continued)

Table 7-3a. Description of routines in NBR Module: function performed, originator, and locations of listing and input-output table (Cont'd).

ERF	Evaluates the error function, based on the rational-approximation Formula 7.1.2.6 in AS-64. (Listing in Vol. 27.)
ESURF	Provides the bidirectional reflectance-distribution function (BRDF), directional emissivity, and temperature of the Earth's surface at the intersection point of the optical line-of-sight with one of the seven allowed categories of surface materials. (The surface temperature is approximated by using the atmospheric-model temperature.) (Listing in Vol. 27. Input-output in Table 2-12.)
FITTER	Computes, by the method of least squares, the coefficients $Z(J)$ ($J=1,N$) in a polynomial of degree N representing the dependent variable $Y(I)$ (or, optionally, its natural logarithm) specified (and given equal weights) at NPTS values of the independent variable $X(I)$. (Listing in Vol. 14a-1.)
FRAC	Computes the fraction of interval (A,B) either contained in interval (X,Y) if $(A,B) \leq (X,Y)$ or covered by interval (X,Y) if $(A,B) > (X,Y)$. (GET routine; listing in Vol. 27.)
FRESNL	Evaluates the Fresnel (specular) monochromatic reflectance of a smooth water surface (characterized by a complex index of refraction), given the wavelength (in the 2- to 5- μ m range) and angle of incidence. (Listing in Vol. 27. Input-output in Table 3-4.)
GCRGLE	Computes, for three Points P1, P2 and P3 on a great circle, the latitude and longitude of the intermediate point P2, given the latitudes and longitudes of the end points P1 and P3, the central angle ALP13 between the central rays to P1 and P3, and the central angle ALP12 between the central rays to P1 and P2. (Listing in Vol. 27. Input-output in Table 3-5.)
GEOREA	Provides the slant range, elevation angle, and azimuth angle of Point 2 with respect to Point 1, given the geographic coordinates (altitude, colatitude, and east longitude) of the two points. (A modified MRC HARC routine; listing in Vol. 27. Input-output in Table 6-4.)
GEOTAN	Provides the tangent-plane coordinates of Point 2 with respect to Point 1, given the geographic coordinates (altitude, colatitude, east longitude) of the two points. (A modified MRC HARC routine called GEOXYZ; listing in Vol. 27. Input-output in Table 6-5.)

(continued)

Table 7-3a. Description of routines in NBR Module: function performed, originator, and locations of listing and input-output table (Cont'd).

GEOXYZ	Converts the geographic coordinates (altitude, north latitude, east longitude) of a point to Earth-centered Cartesian coordinates. (Listing in Vol. 27. Input-output in Table 5-3.)
GLITTR	Provides, upon being called from Subroutine ESURF when the line-of-sight intersects a water surface, (1a) the bidirectional reflectance-distribution function (BRDF) and (1b) directional emissivity of the water surface at the intersection point of the optical line-of-sight from the detector and (2) the geographic coordinates (north latitude and east longitude) of the point on a smooth horizontal surface for a specular reflection of a ray from the source to the detector, if requested (by logical parameter SPCULR=.TRUE. in argument list). Only the directional emissivity is provided if there is no source. (Listing in Vol. 27. Input-output in Table 3-2.)
H2OSVP	Computes the saturation vapor pressure of water vapor over a plane surface of (1) water for the temperature range from 173.15 to 373.15 deg K (-100 to +100 deg C) and (2) ice for the temperature range from 173.15 to 273.15 deg K (-100 to 0 deg C). (Listing in Vol. 14a-1.)
IGNOSU	Provides the properties of the ambient ionosphere required by all the chemistry modules. (Listing in Vol. 14a-1.)
JULIAN	Converts a Gregorian calendar date to Julian day number DAYJ for Subroutine SOLORB. (Listing in Vol. 14a-1.)
LINEAR	Performs a linear interpolation to find FX0 at a given X0, given the independent variable array XX(1) and the corresponding dependent variable array FXX(1). FX0 is set to zero if X0 is not within the range of XX(1). An efficient search is used. (Listing in Vol. 24.)
OZONE	Computes the latitude and season dependence of ozone for altitudes from 0- to 55-km. (For higher altitudes, see Subroutine SPCMIN.) (Listing in Vol. 14a-1.)
PATH	Develops the cumulative values of the path parameters U(I,N,2) (species-N areal density) and UP(I,N,2) (product of U and pressure P) for temperature-index I and species N at end of line segment DS(J+1), expressed, respectively, in cm at STP and atm-cm at STP (if Loschmidt's number is expressed in molecules/cm ³ at STP). Incremental values are obtained from Subroutine SEGMENT. (GET routine; listing in Vol. 27. Input-output in Table 5-5.)

(continued)

Table 7-3a. Description of routines in NBR Module: function performed, originator, and locations of listing and input-output table (Cont'd).

PLANCK	Computes the blackbody spectral radiance. (GET routine; listing in Vol. 27. Input-output in Table 5-6.)
RATCOF	Provides the rate coefficients needed for the E- and F-region ionosphere model used in ROSCOE-IR. (Listing in Vol. 14a-1.)
REATAN	Provides the tangent-plane coordinates of a point with respect to some reference location, given the slant range, elevation angle, and azimuth angle of the point with respect to the same reference location. (A modified MRC HARC routine called REAXYZ; listing in Vol. 27. Input-output in Table 6-6.)
RHOEPS	Computes the hemispherical-directional reflectance from the (horizontal) surface of cloud-type 4 (stratocumulus) for radiation of wavelength λ reflected into zenith angle μ . (Listing in Vol. 27.)
RINOUT	Computes - when given the geographic location (altitude, north latitude, east longitude) of the sources (sun and/or fireballs), the detector, and the position P of the intersection of the line-of-sight from the detector to the Earth's surface - the zenith angles and slant ranges of the sources from P and the direction of the ray from P toward the detector in terms of the zenith angle of the detector and (if the surface is not Lambertian (MAT=1) or water (MAT=2)) the absolute value of the azimuth angle of scatter with respect to the principal plane containing the incoming ray. (Listing in Vol. 27. Input-output in Table 5-2.)
SEGMENT	Computes the incremental values of the path parameters DU(I,N) and DUP(I,N), for temperature-index I and species N, for the line-segment DS, based on a linear variation of the properties in DS. Units are, respectively, cm at STP and atm-cm at STP (if Loschmidt's number is expressed in molecules/cm ³ at STP). Cumulative values are formed in Subroutine PATH. (GET routine; listing in Vol. 27. Input-output in Table 5-7.)
SETALT	Determines the altitudes at which Subroutine UPWELL computes the upwelling natural radiation. A set of characteristic altitudes has been previously selected for each of the 10 spectral bins spanning the 2- to 5- μ m range. If the wavelength-band of interest (ALMIN, ALMAX) spans more than one bin, a set of altitudes is obtained by combining those for each of the spanned bins. (Listing in Vol. 27. Input-output in Table 7-7.)

(continued)

Table 7-3a. Description of routines in NBR Module: function performed, originator, and locations of listing and input-output table (Cont'd).

SQCEM	Computes the geometrical relations between a source, (statistical) cloud layer, and detector. (Listing in Vol. 24.)
SHELLS	Prepares arrays of physical properties at spherical-shell boundaries used in calculating molecular transmittance through the ambient atmosphere. Properties at each shell-boundary are altitude, temperature, pressure, and number densities of species (CH_4 , CO , CO_2 , H_2O , NO , NO_2 , N_2O , O_3 , and OH). For information, the water content of the atmosphere above each shell boundary is also computed, expressed in units of precipitable centimeters. (Modified GET routine; listing in Vol. 27. Input-output in Table 7-9.)
SOLCYC	Computes the solar flux (SBAR), an input to ATMOSU through ATMOUP Common, based on an assumed sinusoidal 11-year (or 4018-day) variation, with the maximum value of 250 for SBAR (associated with the CIRA-65 Model 9) occurring on 1 June 1951, 1 June 1969, 1 June 1980, etc. and with the minimum value of 65 for SBAR (associated with the CIRA-65 Model 1) occurring on 1 December 1963, 1 December 1974, 1 December 1985, etc. (Listing in Vol. 14a-1.)
SOLORB	Computes the north latitude (SOLLAT) and east longitude (SOLLON) of the apparent (actual motion) subsolar point, given the Julian day number at 0 hours UT on 1 January of the year of interest (YRFJ), the Julian date at which vernal equinox occurs (VEQJ), the Julian day number at 0 hours on the day of interest (DAYJ), and the universal time (UT). (Listing in Vol. 14a-1.)
SOLRAD	Provides the solar spectral irradiance at the top of the Earth's atmosphere, in the spectral range from 2- to 5- μm (or 5000- to 2000-wavenumbers). The NASA data adopted by the ASTM have been fitted by piecewise-continuous power-law expressions. (Listing in Vol. 27. Input-output in Table 4-2.)
SOLVE	Solves a set of N simultaneous linear algebraic equations by using the Gauss-Jordan method with maximum pivot feature. (Listing in Vol. 14a-1.)
SOLZEN	Computes (1) the cosine of the zenith angle of the sun at a Point P (COSCHI), given the geographic north latitude (PLAT) and east longitude (PLON) of the Point P and the north latitude (SOLLAT) and east longitude (SOLLON) of the subsolar point, (2) the day-or-night parameter (IDORN), which is 1 if $\text{COSCHI} \geq 0.0$ and 0 otherwise, and (3) the local apparent time (HL), from the Greenwich apparent time (GAT) and the longitude PLON. (Listing in Vol. 14a-1.)

(continued)

Table 7-3a. Description of routines in NBR Module: function performed, originator, and locations of listing and input-output table (Cont'd).

SORTLJ	Sorts an array A of length N from low to high (if LOHI \leq 0) or from high to low (if LOHI $>$ 0). Two additional arrays are simply carried along in the sorting process. (Listing in Vol. 24 is adequate for use with Clouds Module but listing in Vol. 27 must be used for NBR Module.)
SPCMIN	Provides analytic-fit profiles at all altitudes of the minor species (N, NO, NO ₂ , O ₃ , O ₂ (¹ Δ), and H ₂ O) not provided by Subroutine ATMOSU but needed by the chemistry modules, by using tabular data-base species-densities. For ROSGOE-IR, also provides for CO, N ₂ O, CH ₄ , H, OH, HO ₂ , N(² D), N(² P), and O(¹ D), as well as revised profiles of O ₃ , H ₂ O, N, N(⁴ S), and NO. (Listing in Vol. 14a-1.)
STEP	Calculates the intersections of an optical path with the boundaries of the atmospheric shells determined in Subroutine SHELLS. Path elements less than 10 meters in length are assigned to the neighboring shell. The output includes (a) the number of path segments (plus one) on the transmission path, (b) the length of the path segment along the transmission path, (c) the weight associated with the lth end point appropriate for finding at that point the linearly-interpolated value of the parameter, and (d) the index of the shell boundary at or just before the start of the line segment. (GET routine; listing in Vol. 27. Input-output in Table 5-8.)
STEPS	Serves effectively as an entry to Subroutine STEP, given the optical path defined by its end point vectors RX(I) and RY(I). (GET routine; listing in Vol. 27. Input-output in Table 5-9.)
SUBVEC	Returns the difference between vectors VX and VY, i.e., DVXY (1-3) = VX(1-3) - VY(1-3). (GET routine, equivalent to GRC routine with same name and argument list; listing in Vol. 27.)
SURRAD	Provides (essentially) the upwelling radiance directed toward the detector at the point where the optical line-of-sight intersects the Earth's surface. This version of SURRAD provides two components of the radiance: (1) thermally emitted and (2) source (sun or fireball) reflected. Reflected sky radiance is not included. Strictly, the source-reflected component is actually provided in an unattenuated form together with the path parameters (species areal density U and UP, with P the pressure), integrated along the incoming path from the source, required as input to a computation of the molecular absorption over a total

(continued)

Table 7-3a. Description of routines in . Module: function performed, originator, and locations of listing and input-output table (Cont'd).

	path. The aerosol transmittance along the incoming path from the source is also provided. The statistical cloud submodel is also included; see Subroutine UPWELL for comments. Note that the input parameters for Point C in POS1TN Common and IKM in UPWELS Common facilitate providing, as additional outputs for the path from the sun to Point C at 12-km altitude, the path parameters UCS and UPCS and the aerosol transmittance TASC(LUP). (Listing in Vol. 27. Input-output in Table 5-1.)
TAIR	Provides, for use within the statistical-cloud submodel, the molecular transmittance for radiation of wavelength ALAM from altitude ALT to 12 km along a path at zenith angle THETA, by interpolating results from using the AFGL LOWTRAN-III code with the 1962 U.S. Standard Atmosphere. (Listing in Vol. 24.)
TANGE0	Provides the geographic coordinates of a Point 2, given the geographic coordinates of Point 1 and the tangent-plane coordinates of Point 2 with respect to Point 1 (called Subroutine XYZGEO in ROSCOE-Radar). (A modified MRC HARC routine called XYZGEO; listing in Vol. 27. Input-output in Table 6-7.)
TEMPZH	Determines the temperature profile (tabular, 0(4)120 km) by interpolating the data base (U.S. Standard, 1966) for latitude and season, to be used as input to the major atmospheric species model for the low-altitude range from 0- to 120-km altitude. (Listing in Vol. 14a-1.)
TRANS	Provides the molecular transmittance and optical depth for each of the ten species and the total molecular transmittance in a specified wavenumber interval, given the parameters U (cm at STP) and UP (atm-cm at STP) for the total transmission path. (GET routine; listing in Vol. 27. Input-output in Table 6-10.)
TRANSB	Processes the 5-cm^{-1} resolution band-model parameters file so as to (1) eliminate the data for the unwanted spectral regions and (2) derive new parameters with modified resolution in accordance with the user-setting of the logical variable TRNSOPT. The method for TRNSOPT set to .TRUE., for faster but less accurate calculations, provides in-band averaged band-model parameters. The method for TRNSOPT set to .FALSE., for slower but more accurate calculations, provides band-model parameters at a finer resolution, actually 0.5 of the narrowest user wavenumber band-interval, but within the range of 5 to 50 cm^{-1} . The two band-model parameters are (a) S(I,IS), the mean absorption coefficient

(continued)

Table 7-3a. Description of routines in NBR Module: function performed, originator, and locations of listing and input-output table (Cont'd).

	for species-IS at temperature-index-1 for the interval DW , cm^{-1} at STP, and (b) $DE(I,IS)$, the inverse of mean line-spacing parameter, or the effective line density, $\text{lines}/\text{cm}^{-1}$. (GET routine; listing in Vol. 27. Input-output in Table 7-8.)
TRANSF	Computes a quantity defined in the natural statistical-cloud submodel as the irradiance-to-radiance transfer coefficient ($1/\text{sr}$) or simply the transfer coefficient at the intersection of the detector LOS vector with 12-km altitude (known as the transfer point). The transfer coefficient is actually the ratio of a radiance and an irradiance. The radiance is that directed anti-parallel to the detector LOS vector and the irradiance is the (unattenuated) source irradiance at the transfer point. For a source above 12-km altitude and far from the transfer point (as for the sun), the transfer coefficient becomes essentially the bidirectional reflectance of the cloudtop times the cosine of the zenith angle of the incident ray. For a source below or within the clouds (conditions not allowed in NBR Module), the transfer coefficient depends on the details of the diffusion solution to the transport of radiation through the clouds. (Listing in Vol. 24.)
TRNSCO	Provides, for $RADSW=.TRUE.$ as in the NBR Module, a call to Subroutine ATMRAD to evaluate Words-5, -7, and -8 of Dataset-B1 (in-band-interval radiance, product of molecular and aerosol transmittance, and aerosol transmittance). (GET routine; listing in Vol. 27. Input-output in Table 6-8.)
UNITY	Returns the unit vector $VXHAT(1-3)$ along the vector $VX(1-3)$. (GET routine, equivalent to GRC routine with same name and argument list; listing in Vol. 27.)
UPWELL	Computes - for a Point V at each of a set of NALTJ altitudes above a given geographic position, specified in UPWELS Common (UPWALT, UPWLON, UPWLAT) and characterized by material MSM and property DD(MSM) - the natural upwelling spectral radiance directed towards Point V from Points P located on the Earth's surface with respect to Point V at HNADIR representative nadir angles and NAZI representative azimuth angles. This upwelling radiance, $UPRAD(I,J,K,L)$, includes contributions from (1) air emission between Points V and P, (2) surface emission at Point P,

(continued)

Table 7-3a. Description of routines in NBR Module: function performed, originator, and locations of listing and input-output table (Cont'd).

	<p>and (3) the solar-reflected radiation at each of the Points P. Values of the radiance $UPRAD(I,J,K,L)$ are averaged over azimuth angles to give $UPRADA(I,J,L)$ and over nadir angles to give $UPRADN(I,L,JBAND)$. For inclusion of natural (statistical) clouds, distribution functions of the radiance are obtained instead of the single values in the absence of clouds. Selected percentiles (10, 25, 50, 90, 100) of the corresponding integral distributions are output.</p> <p>Note that for the GRC version of the NBR Module integrated into ROSCOE-IR, the array $UPRADN(I,L,JBAND)$ (for altitudes ≥ 12 km and if clouds are included) is reset as $UPRADN(I,L,JBAND) = ROSON(IKM,L) + ARCVN(IKM,L)$, which is transferred through UPWELS Common to (the GRC) Subroutine UPWELT. Thus, in the GRC version, for altitudes $ZKM \geq 12$-km, $UPRADN$ is not the cloud-free result but the 50-percentile of the radiance distribution function for statistical clouds (if included in the problem). (Listing in Vol. 27. Input-output in Table 6-2.)</p>
VLIN	Returns the linear combination of two vectors, $X(1-3) = A*Y(1-3) + B*Z(1-3)$. (GET routine, corresponds to GRC routine VECLIN with transposed arguments; listing in Vol.27.)
WATER	Computes the longitude, latitude, and season dependence of water vapor for altitudes from 0- to 45-km. (For higher altitudes, see Subroutine SPCMIN.) (Listing in Vol. 14a-1.)
WVOPT	Allows the user to bypass the normal treatment (achieved by setting $WVFLAG = 0.0$) of water vapor in Subroutine SPCMIN for the altitude range from 0 to 120 km. The user effects the bypass by reading in $WVFLAG .GT. 0.0$ and his own data in one of four optional forms according to $METHOD = 1, 2, 3, 4$. (Listing in Vol. 14a-1.)
XMIT	Returns an array Y copied from a given array X of length LX if $LX > 0$ and sets Y (of length |LX|) to a constant X(1) if $LX < 0$. (A COMPASS-language version of the routine is used with the GRC DSA system, though no listing of it is included in SP-78. We have used a FORTRAN version of the routine prepared by L. Ewing of G.E. Tempo. Listing in Vol. 27.)
ZTTOUT	Converts a Gregorian calendar date (expressed as 20th century year (1YRS), month (MONS), and day (1DAYS)) and zone time (ZT) at east longitude PLON to the Gregorian calendar date and mean time (UT) at Greenwich. (Listing in Vol. 14a-1.)

Table 7-3b. Description of Dynamic Storage Allocation routines called directly from the NBR Module.

<u>Routine</u>	<u>Function Performed</u>
CREATE	Creates a dataset of (at least) $n+1$ words and returns the dataset index (the pointer to the first (not zeroth) word of the dataset).
CREATL	Performs the same as in Subroutine CREATE, except that the dataset lock value and lock count are set to 1 (locked).
DSPWRD	Returns the pointer to the DSP word for the dataset specified by its index.
DSTROY	Returns to the system the space occupied by the dataset specified by its index.
INDWRD	Returns the index for the dataset specified by the pointer to its DSP word.
LOCKDS	Sets the specified lock number of the dataset specified by its index.
NEXT	Returns the link word and index for a dataset (in forward order) on a list, given initially the pointer to the list header and subsequently the previously-returned link word.
PREV	Returns the link word and index for a dataset (in backward order) on a list, given initially the pointer to the list header and subsequently the previously-returned link word.
PREVNL	Performs the same as Subroutine PREV, except that lock values are not set and reset.
PUTBOT	Places the dataset specified by its index as the bottom dataset on a list specified by its list-header pointer.
PUTORA	Inserts a dataset (specified by its index) into a list of datasets (specified by its list-header pointer) according to the ascending order of the specified n th words (with real values) of the datasets.
PUTTOP	Places the dataset specified by its index as the top dataset on a list specified by its list-header pointer.
QINITL	Initializes the routines in the DSA System.
WIPOUT	Removes all the datasets from the list specified by its list-header pointer and, if the parameter $kdstry=1$, also destroys the datasets.

7-2.4 Routines, Common Blocks, and Common-Block Variables

7-2.4.1 Routines and Common Blocks

In Table 7-4 we provide a matrix which shows the appearance of common blocks in the routines in the NBR Module.

7-2.4.2 Definitions of Common-Block Variables

In this section we either define the variables in a common block or give a reference where the definitions can be found. We also comment on the use of the common block and/or of its variables.

Blank COMMON

Blank COMMON is used only for the DSA System. For definitions of variables, see SP-78.

Common /AEROK/ KVIS, KPTYPE

The variables KVIS and KPTYPE are read in Program DRVUPW and transferred through /AEROK/ to Subroutine AEROSOL.

KVIS - Visibility range parameter (VR) for $0 \leq HCM \leq 9 \times 10^5$ cm

=1, VR = 50 km

=2, VR = 23 km

=3, VR = 10 km

=4, VR = 5 km

=5, VR = 2 km

KPTYPE - Terrain parameter for $0 \leq HCM \leq 2 \times 10^5$ cm

=1, Terrain is rural

=2, Terrain is urban

=3, Terrain is maritime

Common /AIRSOL/ TASP(10), TASC(10), TAFP(10)

The arrays TASP and TASC are set in Subroutine SURRAD and transferred through /AIRSOL/ to Subroutine UPWELL. (The array TAFP was never intended for

Table 7-4. Matrix of routines and common blocks.

Common Block Routine	Table 1																																				
	Blank	AEROK	AIRSOL	ALTODN	ATMOUP	CDATA	CLDFREQ	CLDWT	CLOUD	CONFIG	DIFFUS	FIRBAL	FLAGS	IONOUP	OPTION	OPTIN1	PARAMS	POSITN	QNCNC	SANDD	SATELL	SOLARP	SORCE	SOURCE	TECTOR	TIME	UPWELS	UPWELS1	UPWELS2	UPWELS3	VPC	XY	XYZCOM	ZHCHEX	ZHTEMP		
AEROSOL		X																					X				X								X	X	
ATMOSU				X	X																		X											X			
ATMRAD	X														X																						
BKCDATA						X	X																														
CLODDR						X																															
CLDWT							X	X			X																										
CLOUD0							X			X	X																X	X	X		X	X	X	X	X		X
DRVUPW	X	X													X	X	X										X	X	X		X	X	X	X	X		
EMISSF					X	X												X																			
ESURF					X														X						X	X											
GLITTR																																				X	
IONOSU				X	X										X												X										
JULIAN																											X										
OZONE					X																														X		
PATH																																					
QINITL	X												X						X			X	X	X	X	X											
RINOUT																																			X		
SEGMENT																												X	X								
SETALT																																					
SGEOM																		X																	X		
SHELLS						X																															
SOLCYC						X																					X										
SOLORB																											X										
SOLZEN						X																					X						X			X	
SPCMIN				X	X																						X	X	X	X	X	X	X		X		
SURRAD			X										X							X		X	X	X	X	X									X		
STEP																											X									X	
TEMPZH																																				X	
TRANS																																				X	
TRANSB	X																X								X												
TRANSF							X					X	X					X			X		X		X										X		
TRNSCO	X																X				X															X	
UPWELL	X	X						X	X						X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X		X		
WATER						X																													X		
WVOPT						X																					X										
ZTTOUT																																					

*Could be deleted.

*Could be deleted.

use with the NBR Module but was provided should Subroutine SURRAD be used as a utility routine; this use has not evolved in ROSCOE-IR.)

For LUP=1, NWAVE(JBAND)
TASP(LUP), - Aerosol transmittance for incoming solar rays to Points P on Earth's surface and Point C at 12-km altitude on the VP-path. (Dimensionless; depends only on wavelength and assumed single paths.)
TASC(LUP)

For L=1, IFIRES (not in NBR Module)
TAFP(L) - Aerosol transmittance for incoming ray from Fireball-L to Point P on Earth's surface. (Not used in ROSCOE-IR.)

Common /ALTODN/

Variables in /ALTODN/, defined in Subroutines ATMOSU and SPCMIN in Vol. 14a-1, are of no direct interest for the NBR Module per se.

Common /ATMOUP/ HL, SBAR, IDORN, PP, RHO, TT, SNI(30), HRHO, FEHSEQ

HL - Local apparent time (set by Subroutine SOLZEN).
(decimal hours)

SBAR - Average 10.2-cm solar flux (set by Subroutine SOLCYC).
[$1.0E-22/(m^2 Hz)$]

IDORN - Diurnal parameter (set by Subroutine SOLZEN).
=1, for daytime
=-1, for nighttime

PP - Pressure (set by Subroutine ATMOSU). ($dyne/cm^2$)

RHO - Mass density (set by Subroutine ATMOSU). (g/cm^3)

TT - Temperature (set by Subroutine ATMOSU). (deg K)

SNI(I) - Species-I density. ($1/cm^3$). The full array is defined in Subroutine ATMOSU. See Table 7-9 for those species used in computing the molecular transmittance.

HRHO - Density scale height (set by Subroutine ATMOSU). (km)

FEHSEQ - Fractional error in hydrostatic equilibrium (set by Subroutine ATMOSU).

Common /CDDATA/

The variables in /CDDATA/ are defined on p. 74 of Volume 24.

Common /CLDFREQ/

The variables in /CLDFREQ/ are defined on pp. 74, 75 of Volume 24.

Common /CLDWT/

The variables in /CLDWT/ are defined on p. 76 of Volume 24.

Common /CLOUD/

The variables in /CLOUD/ are defined on pp. 76, 77 of Volume 24.

However, they are used only in the deterministic cloud submodel and hence are not used in the NBR Module.

Common /CONFIG/

The variables in /CONFIG/ are defined on p. 77 of Volume 24.

Common /DIFFUS/

The variables in /DIFFUS/ are defined on p. 78 of Volume 24; however, they are not used in the NBR Module.

Common /FIRBAL/ FBLAT(10), FBLON(10), FBALT(10), FBRINT(10)

/FIRBAL/ appears in two routines (RINOUT and SURRAD) even though the NBR Module does not use any of its variables. The reason for the appearance of /FIRBAL/ is that Subroutine SURRAD was created with a dual purpose in mind:

- (1) As an integral part of the NBR Module, to be called from Subroutine UPWELL with only the sun as a source.
- (2) As a utility routine, to be called by routines (other than UPWELL) needing the surface radiance (thermally emitted and source (sun or fireball) reflected). For such use, /FIRBAL/ was included.

However, Subroutine SURRAD is not used as a utility routine in ROSCOE-IR.

FBALT(L), - Altitude, north latitude, and east longitude of
FBLAT(L), Fireball-L. (km, radians, radians)
FBLON(L)

FBRINT(L) - Radiant intensity of Fireball-L. (W/sec)

Common /FLAGS/ ITFLAG

In order that Subroutine TRANSF in the Natural Cloud Module, called by Subroutine CLDWT, will know whether or not the sun is above or below the horizon, we require Subroutine UPWELL to set ITFLAG in /FLAGS/ before calling Subroutine CLDWT.

ITFLAG - Flag indicating the diurnal condition at Point V'.
=0, Sun is below the horizon
=1, Sun is above the horizon

Common /IONOUP/

The variables in /IONOUP/ are defined on pp. 133, 134 of Volume 14a-1; however, they are not used in the NBR Module.

Common /PTION/ TRNSOPT

See TRNSOPT in Table 7-8 for Subroutine TRANSB, FAST in Table 6-10 for Subroutine TRANS, and TRNSOPT in Table 6-2 for Subroutine UPWELL.

Common /PTIN1/ RADS4

See RADS4 in Table 6-2 for Subroutine UPWELL and Table 6-3 for Subroutine TRNSCO.

Common /PARAMS/

/PARAMS/ contains constants used in the Natural Cloud Module. They are defined on p. 80 of Volume 24 and are set in Program DRVUPW.

Common /POSITN/ POSLAT, POSLON, POSALT, SPCLAT, SPCLON, C12ALT, C12LON, C12ALT

POSALT, - Altitude, north latitude, and east longitude of Point P
POSLAT, - at which line-of-sight (from fictitious detector at
POSLON - Point V) intersects Earth's surface. Set in Subroutine
UPWELL. (km, radians, radians)

SPCLAT, - North latitude and east longitude of the point on an
SPCLON - assumed smooth horizontal surface for a specular reflection from the source to the detector at Point V. (Set in Subroutine GLITTER if SPECULR=.TRUE..) (radians)

C12ALT, - Altitude, north latitude, and east longitude of Point C
C12LAT, - at which line-of-sight (directed toward Point P from
C12LON - fictitious detector at Point V), intersects the 12-km

altitude surface. Set in Subroutine JPWELL. (km,
radians, radians)

Common /NONC/ NONC

See NONC in either Table 6-2 for Subroutine JPWELL or Table 6-3 for Subroutine TRNSCO.

Common /SAND/ XS, YS, ZS, XD, YD, ZD, UL, VL, WL

By calls to Subroutine GEOMXYZ, Subroutine JPWELL sets - for use in Subroutine SGEOM after transfer from Function TRANSF in the Natural Cloud Module - the Earth-centered Cartesian coordinates of the sun (XS, YS, ZS) and of the fictitious detector (XD, YD, ZD) at Point V; the solar coordinates are zeroed if the sun is below the horizon. JPWELL also sets the direction cosines (UL, VL, WL) of Point P as viewed from Point V.

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

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

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

Common /SATELL/ SATLAT, SATLON, SATALT, SATZEN, SATAZI

SATELL is not used in the MBR Module because Subroutine JPWELL does not deal with real sensors. /SATELL/ was included in Subroutine SURRAD on the assumption that it would be a utility routine, used when a real sensor in a satellite looks at the ground. However, SURRAD is not so used.

SATALT, - Altitude, north latitude, and east longitude of
SATLAT, satellite-borne detector. (km, radians, radians)
SATLON

SATZEN - Zenith angle of ray reflected at Point P towards the
satellite. (Not computed.) (radians)

SATAZI - Absolute value of azimuth of reflected ray, measured
from principal plane determined by vertical plane

through incoming ray from sun. (Not computed.)
(radians)

Common /SOLARP/ SOLLAT, SOLLON, SOLIRR(10)

The position variables, set in Subroutine ATMOSU after it calls Subroutine SOLORB during the initialization phase, are used in Subroutine UPWELL, SURRAD, and RINOUT. The irradiance, set in Subroutine SURRAD after it calls Subroutine SOLRAD, is used in Subroutines SURRAD and UPWELL.

SOLLAT, - North latitude and east longitude of subsolar point.
SOLLON (radians)

SOLIRR(L) - Solar spectral irradiance at the top of the atmosphere
L=1,NWAVEJ at wavenumber-index L. [$\text{W}/(\text{cm}^2 \text{cm}^{-1})$]

Common /SORCE/ NSORCE, HSORCE(1), RSORCE(1), THETAS, PHIS

The geometrical variables in /SORCE/ are set by Subroutine UPWELL in terms of the solar position (the only source with which Subroutine UPWELL is concerned) and are passed to Function TRANSF in the Natural Cloud Module.

NSORCE - The number of sources. Set to 1 in data statement in Subroutine UPWELL.

HSORCE(1) - Altitude of sun (RSUN). RSUN is set in data statement in Subroutine UPWELL. (km)

RSORCE(1) - Radius of source. True value for sun is not relevant for applications in NBR Module. Set to 0.0 in data statement in Subroutine UPWELL.

THETAS, - Colatitude and east longitude of subsolar point.
PHIS (degrees)

Common /SOURCE/ SRCLAT, SRCLO, SRCALT, SRCFLG, SRCZEN(11), SRCZR(11)

The geometrical variables in /SOURCE/ are set by Subroutine RINOUT. Currently (April 1980) only the sun is used as a source for Subroutine SURRAD. (Fireballs are never used in the call to Subroutine SURRAD from Subroutine UPWELL in the NBR Module.)

SRCALT - Altitude of source if not the sun. (km)

SRCLAT, - North latitude and east longitude of source (sun or fire-
SRCLO ball). (radians)

SRCFLG - Flag characterizing source
=1, Source is sun
=2, Source is fireball

SRCZEN(1) - Zenith angle of ray incoming to Point P from the sun.
(radians)

For L=1, IF IRES (Not used in NBR Module)
SRCZEN(L+1) - Zenith angle of ray incoming to Point P from Fireball-L.
(radians)

SRCR(1) - Not defined.

SRCR(L+1) - Slant range from Fireball-L to Point P. (km)

Common /TECTOR/ DETLAT, DETLON, DETALT, DETZEN, DETAZI(11)

Subroutine UPWELL uses /TECTOR/ to position a fictitious detector at Point V and pass the information to Subroutines SURRAD, RINOUT, and GLITTR. The scattering angles are set in Subroutine RINOUT and used in Subroutine SURRAD.

DETALT, - Altitude, north latitude, and east longitude of
DETLAT, fictitious detector at Point V. (km, radians, radians)
DETLON

DETZEN - Zenith angle of ray reflected at Point P on Earth's
surface toward the detector at Point V. (radians)

DETAZI(1) - Absolute value of azimuth angle of reflected ray,
measured from principal plane determined by vertical
plane through incoming solar ray. (radians)

For L=1, IFIRE (Not used in NBR Module)
DETAZI(L+1) - Absolute value of azimuth angle of reflected ray,
measured from principal plane determined by vertical
plane through incoming ray from fireball. (radians)

Common /TIME/ IYRS, IMONS, IDAYS, ZT, PLAT, PLON, UT, GAT, FYR, FST, RH05KM,
CHI

The variables IYRS, IMONS, IDAYS, and ZT are read by Program DRVUPW. GCO and GLO are also read, in terms of which PLAT and PLON are set. UT is set by Subroutine ZTTOUT, GAT by Subroutine SOLORB, FYR and FST by Subroutine JULIAN, RH05KM by Subroutine ATMOSU, and CHI by Subroutine SOLZEN.

IYRS - Number of the year in the 1900's at east longitude GLO
(e.g., 1980 becomes 80).

- IMONS - Number of the month at east longitude GLO (e.g., February becomes 2).
- IDAYS - Day of the month at east longitude GLO.
- ZT - Zone time for the 15-degree longitude interval containing east longitude GLO. (decimal hours)
- GCO, - Geographic colatitude and east longitude of grid origin
GLO or whatever reference point is desired. (degrees)
- PLAT, - North latitude and east longitude of grid origin.
PLON (radians)
- UT - Universal time corresponding to zone time ZT. (decimal hours)
- GAT - Greenwich apparent time. (decimal hours)
- FYR - Fractional season-year, being zero on 1 January in the northern hemisphere and zero on 1 July in the southern hemisphere.
- FST - Fractional summer, being one on 1 July and zero on 1 January in the northern hemisphere and reversed in the southern hemisphere.
- RHOSKM - Mass density of dry air at 5-km altitude. (g/cm^3)
- CHI - Zenith angle of the sun at grid origin. (radians)

Common /UPWELS/ UPWALT, UPWLON, UPWLAT, NALT(5), ZKM(13,5), NNADIR, NAZI,
NWAVE(5), IDAYV, CLDFLG, UPRADN(13,10,5), WV(10,5), IKM,
NBANDS

Program DRVUPW sets the variables UPWALT, UPWLON, UPWLAT, and NBANDS and the array NWAVE(M) ($M=JBAND=1, NBANDS$) and reads the variables NNADIR, NAZI, and CLDFLG. Program DRVUPW's call to Subroutine SETALT sets the arrays NALT(M) and ZKM(I,M) ($M=1, NBANDS$; $I=1, NALT(M)$). The call to Subroutine UPWELL sets IDAYV, UPRADN(I,L,M) (for $I=1, NALT(M)$; $L=1, NWAVE(M)$; $M=1, NBANDS$), and IKM.

The array WV(L,M) ($L=1, NWAVE(M)$; $M=1, NBANDS$) is not used in the stand-alone version of the NBR Module but is set in Program C OOK in ROSCOE-IR to record the group of central wavenumbers of the band-intervals used in calling Subroutine UPWELL for each broad-band M.

UPWALT - Surface altitude of the sub-V-point. (km)

UPWALT, - North latitude and east longitude of Point V at which
UPWLON upwelling radiance is computed. (radians)

For I=1,NALT(M); L=1,NWAVE(M); M=1,NBANDS

NALT(M) - Number of altitudes ZKM(I,M) for (broad) wavelength-band
index M. Defines NALTJ.

ZKM(I,M) - Altitudes of Point V above UPWALT at which upwelling
radiance is computed. (km)

NNADIR, - Number of nadir and azimuth angles at Point V at which
NAZI upwelling radiance is computed.

NWAVE(M) - Number of wavenumbers at which the upwelling spectral
radiance is to be computed for (broad) wavelength-band
index M. Defines NWAVEJ.

IDAYV - Index for diurnal condition at sub-V-point.
=0, Solar zenith angle > 90 degrees
=1, Solar zenith angle ≤ 90 degrees

CLDFLG - Index for inclusion of natural clouds.
=0., Natural clouds are not included
=1., Natural clouds are included

UPRADN(I,L,M) - The nadir-averaged value of UPRADA(I,J,L). [$W/(cm^2 \text{ sr} \text{ cm}^{-1})$]

WV(L,M) - The array of central wavenumbers corresponding to
(broad) wavelength-band index M. (Not used in stand-
alone version of the NBR Module. Set in Program OLOOK
and used in Subroutine UPWELL.) (cm^{-1})

IKM - Index for number of altitudes at which calculations are
made when clouds are included. Used in Subroutines
SURRAD and UPWELL.

NBANDS - Number of (broad) wavelength bands.

Common / UPWELSL/ R010(6,10), R010A(6,10,10), R010N(6,10),
R025(6,10), R025A(6,10,10), R025N(6,10),
R050(6,10), R050A(6,10,10), R050N(6,10),
R090(6,10), R090A(6,10,10), R090N(6,10),
R100(6,10), R100A(6,10,10), R100N(6,10)

Each of the arrays in /UPWELSL/ is computed in Subroutine UPWELL.

For XXX=10,25,50,90,100; IKM ≥ 1;

J=1,NNADIR; K=1,NAZI; L=1,NWAVE(M)

RXXX(K,L) - XXX-percentile of the integral distribution of the total (including that from statistical clouds) natural upwelling spectral radiance received at Point V for wave-number-L (at implicit altitude-IKM above surface material MSM) along a ray directed to Point P on Earth's surface (at implicit nadir-J and explicit azimuth-K). $[W/(cm^2 \text{ sr } cm^{-1})]$

Note: RXXX(K,L) does not include ARCVA(IKM,J,L). Currently, UPRAD(K,L) and RXXX(K,L) are being written in binary form on Logical Unit No. 8, for all appropriate altitudes and nadirs.

RXXXA(IKM,J,L) - The₁ azimuth-averaged value of RXXX(K,L). $[W/(cm^2 \text{ sr } cm^{-1})]$

RXXXN(IKM,L) - The₁ nadir-averaged value of RXXXA(IKM,J,L). $[W/(cm^2 \text{ sr } cm^{-1})]$

ARCVA(IKM,J,L) - When clouds are considered, a component of the upwelling spectral radiance received at Point V (at altitude-IKM), from air emission above 12-km altitude, along a ray directed to Point P on the Earth's surface (at nadir-J and independent of azimuth-K). $[W/(cm^2 \text{ sr } cm^{-1})]$

ARCVN(IKM,L) - The₁ nadir-averaged value of ARCVA(IKM,J,L). $[W/cm^2 \text{ sr } cm^{-1})]$

Common /UPWELS2/ JBAND1

The variable JBAND1 is set to the (broad) wavelength-band index JBAND in Subroutine UPWELL and passed through /UPWELS2/ To Subroutine SURRAD to facilitate some print.

Common /UPWELS3/ UPRAD(6,10), UPRADA(13,10,10)

Both of the arrays in /UPWELS3/ are computed in Subroutine UPWELL. (As the code has developed, there remains little reason for including the array UPRAD in /UPWELS3/.

For I=1,NALT(M); J=1,NNADIR; K=1,NAZI; L=1,NWAVE(M)

UPRAD(K,L) - Natural upwelling spectral radiance received at Point V (at altitude-I above surface material MSM) along a ray directed to Point P on Earth's surface (at nadir-J and azimuth-K). I- and J-dependence is not stored, so user must print UPRAD(K,L) immediately after computation if he wants to see them. Currently, UPRAD(K,L) and RXXX(K,L) are being written in binary form on Logical

Unit No. 8, for all appropriate altitudes and nadirs.
[W/(cm² sr cm⁻¹)]

UPRADA(I,J,L) - The azimuth-averaged value of UPRA(K,L). [W/(cm² sr cm⁻¹)]

Common /VPC/ WVFLAG, METHOD

Currently, in Program DRVUPW, we set WVFLAG=0.0 and METHOD=0.

WVFLAG - Flag for optional treatment of water vapor.
= 0.0, Normal treatment
≠ 0.0, Optional treatment

METHOD - Flag indicating one of four options for treatment of water vapor.
=1, Data values in parts per million by mass. (ppmm)
=2, Data values in absolute humidity. (g/m³)
=3, Data values in relative humidity. (percent; 10 percent is input as 10.0, not 0.10)
=4, Data values in dew-point temperature. (deg K)

Common /XY/ TT(10)

TT(I) - Temperature array in atmospheric transmission model.
Set as data in Program DRVUPW and used in Subroutines SEGMENT and TRANS.

Common /XYZCOM/ ITMTE, LTMTE, NS, HShell(81), TS(81), PS(81), XNSPEC(81,10),
U(10,10,2), UP(10,10,2), NMOLS, FACT

The variables ITMTE, LTMTE, and NMOLS are set, and the variable FACT is read, by Program DRVUPW. Subroutine SHELLS sets the variable NS and the arrays HShell(81), TS(81), PS(81), and XNSPEC(81,10). Cumulative values of the path-parameter arrays U(10,10,2) and UP(10,10,2) are set by Subroutine PATH and used by Subroutine TRANS to compute the molecular transmittance.

ITMTE, - Auxiliary input and output data file numbers for
LTMTE Subroutine TRANSB. Set to 2 and 3, respectively, in Program DRVUPW. See TAPIN and TAPOT in Table 7-8 for Subroutine TRANSB for more information.

NS - Number of boundary altitudes used in Subroutine SHELLS.

For J=1,NS
HShell(J), - Altitude, temperature, pressure, and species-N density
TS(J), at altitude-boundary J.
PS(J), (cm, deg K, atm, cm⁻¹)
XNSPEC(J)

For I=1,2 (adequate for ambient atmosphere); N=1,10
 U(I,N,2) - Cumulative value of path parameters U (species-N areal
 UP(I,N,2) density) and UP (product of U and pressure P) for
 temperature-index I and species-N. See Table 5-5 for
 Subroutine PATH and Table 6-10 for Subroutine TRANS.
 (cm at STP, atm-cm at STP)

NMOLS - Number of species. Set in Program DRVUPW and used in
 Subroutines ATM RAD and TRANS (where known as NSPEC).

FACT - Parameter controlling the number of altitude boundaries
 and their spacing. See Table 7-9 for Subroutine SHELLS
 for more information.

Common /ZHCHX/ ZHFLAG, SPIFLG

The variables in /ZHCHX/ are defined and their use (to insure Sub-
 routine ATMOSU is called prior to Subroutines IONOSU and SPCMIN) is described
 in the listings of Subroutines ATMOSU, IONOSU, and SPCMIN in Volume 14a-1.
 /ZHCHX/ does not affect the NBR Module per se.

Common /ZHTEMP/ NZHT, ZHT(31), TZh(31), TPFLAG

For steps required by the user to bypass the code's specification of
 the temperature profile in the low-altitude (0- to 120-km) region, see p. 38
 in Volume 14a-1. (The arrays ZHTZ(3) and TZhZ(3) appearing as arrays in
 /ZHTEMP/ in Volume 14a-1 are development artifacts and should be deleted.)
 Currently, in Program DRVUPW, we set TPFLAG=0.0.

NZHT - Number of altitudes (31) at which the low-altitude tem-
 perature profile is defined.

For I=1,NZHT

ZHT(I) - Altitudes at which the temperature profile is defined.
 =0.0(4.0)120.0 km

TZh(I) - Temperature profile (for TPFLAG=0.0), determined by
 interpolation of the data base [US-66] for latitude and
 season, used as input to the major atmospheric species
 model for the low-altitude range from 0- to 120-km alti-
 tude. (deg K)

- Temperature profile (for TPFLAG \neq 0.0), specified by
 user at altitudes $z = 0(4)120$ km. (deg K)

TPFLAG - Flag for optional treatment of temperature profile.
 = 0.0, Normal treatment

0.0. Optional treatment, allowing Subroutine TEMPZH to read the user-specified profile at altitudes $z = 0(4)120$ km

7-3 DRIVER PROGRAM DRVUPW AND INITIALIZING ROUTINES

7-3.1 Computational Steps in Program DRVUPW

Here we describe the calculational steps required in the driver for the NBR Module, Program DRVUPW.

A. Initialization

1. DSA System
 - a. Set parameters
 - b. Call QINITL
2. Ambient atmosphere
 - a. Read time and place
 - b. Set option parameters for water vapor and temperature profiles
 - c. Call ATMOSU
3. Natural clouds
 - a. Read/set parameters
 - b. Call CLOUD0
4. Create Datasets-BN and -BI
 - a. Read spectral data
 - b. Call CREATE, PUTBOT, or PUTTOP
5. Compute band-model parameters
 - a. Set option
 - b. Call TRANSB
6. Atmospheric shells
 - a. Read/set option
 - b. Call SHELLS
7. Prepare to call UPWELL
 - a. Read/set aerosol parameters

- b. Read/set atmospheric emission option and transmittance parameter
 - c. Read/set geometry parameters for UPWELL
 - d. Read/set surface material parameters
- B. Operation
 - 1. Initiate (broad) wavelength-band spectral loop
 - 2. Get Datasets
 - a. Call PREV for Dataset-BN
 - b. Call PREV for Dataset-BI
 - 3. Set altitudes for UPWELL
 - a. Set (broad) wavelength-band limits
 - b. Call SETALT
 - 4. Call UPWELL
 - 5. Write results

7-3.2 Subroutine SETALT

The purpose of Subroutine SETALT is to provide a set of altitudes at which Subroutine UPWELL, for a given spectral range, will compute the upwelling natural radiation. To minimize the number of such altitudes, we have accounted for the spectral dependence of the air transmittance, as now described.

Our approach in selecting altitudes was to compute the upwelling radiance for a strictly nadir-looking sensor as a function of altitude and wavelength in the 2- to 5- μ m band. The wavelengths used are the 27 test values given in Table 7-5. The resolution was 10 cm^{-1} . The altitudes used are 0(0.1)1(1)10(2)20(5)30(10)100 km. We used an atmosphere (see Volume 14a-1) for a zone time of 0.0 hours on 19 September 1978 at a geographic location of 45-deg north latitude, 0-deg longitude. The version of the code available at the time required the surface temperature to be independently specified. It was set at 288 deg K (instead of the air temperature at the first shell boundary which was 286.6-deg K). The surface emissivity was 0.9. The zoning of the atmosphere into shells was determined by FACT=1, but the algorithm used was not the one currently set by GRC (see Table 7-9 for Subroutine

SHELLS) but the one originally specified by G.E. Tempo, according to which the 76 shell thicknesses were 0.5263 km between 0 and 20 km and 2.105 km from 20 to 100 km.

Table 7-5. Wavelengths used in developing Subroutine SETALT.

Bin No.	Wavelength, μm		
	Bin Edge	Test Values	Bin Edge
1	2.0	2.0	2.1
2	2.1	2.40, 2.50, 2.55	2.575
3	2.575	2.60, 2.65	2.675
4	2.675	2.70	2.725
5	2.725	2.75, 2.80, 2.85	2.825
6	2.875	2.90, 2.95, 3.00, 3.20, 3.50, 4.00, 4.10	4.15
7	4.15	4.20, 4.25, 4.30, 4.40, 4.50	4.55
8	4.55	4.60, 4.70	4.75
9	4.75	4.80	4.85
10	4.85	4.90, 5.00	5.0

The results for these upward-vertical radiance calculations are shown in Figures 7-2a, 7-2b, and 7-2c for the 27 wavelengths. (The peaks at 50-km altitude for the strongly attenuated wavelengths simply reflect a peak in the atmospheric temperature profile at that altitude.) Examination of these curves led us to set the bin altitudes given in Table 7-6. More detailed work may indicate a need for revising the bin edges and/or altitudes. Subroutine SETALT is designed so that if the wavelength band of interest spans more than one bin, a set of altitudes is provided by combining those for each of the spanned bins. Table 7-7 gives the input and output variables for Subroutine SETALT.

The results in Figures 7-2a, 7-2b, and 7-2c are replotted in Figure 7-3 to show the spectral dependence of the upwelling radiance for a nadir-looking sensor, for altitudes of 0, 5, and 50 km. The curve for 0-km altitude is, of course, just that given by the Planck function for $T=288$ deg K and an emissivity of 0.9.

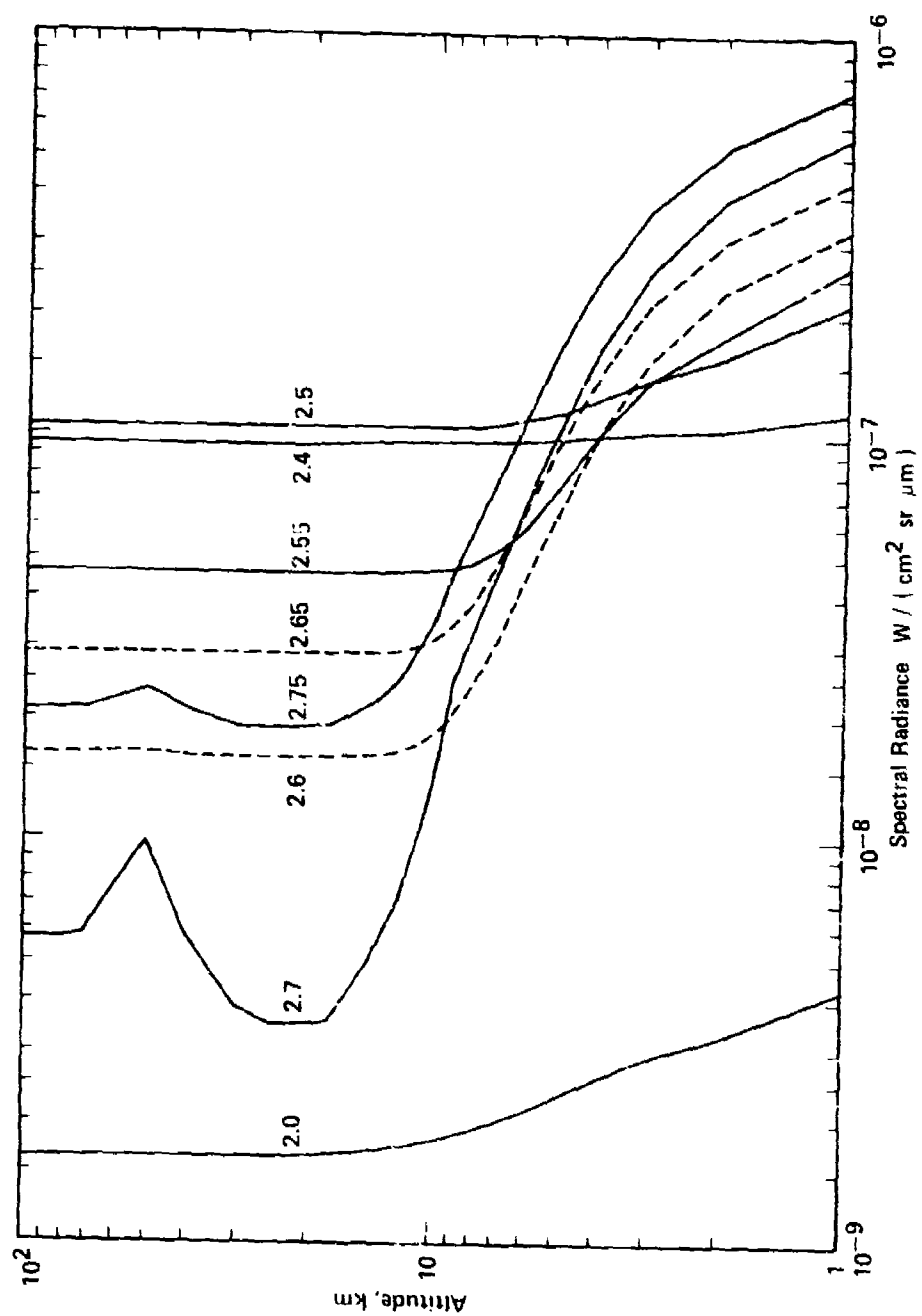


Figure 7-2a. Altitude dependence of spectral radiance (2.0 to 2.5 μm) for nadir-looking sensor.

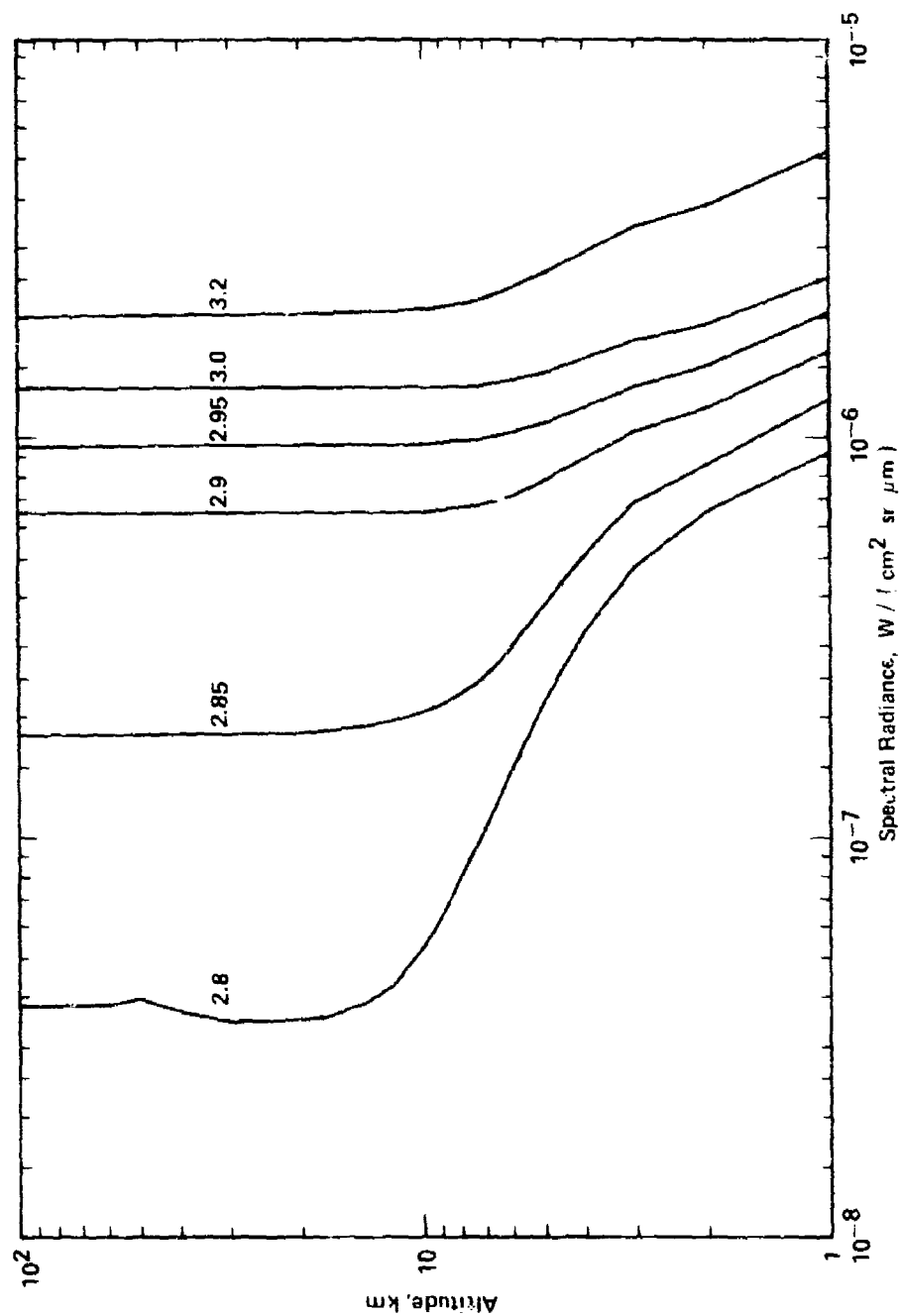


Figure 7 - 2b. Altitude dependence of spectral radiance (2.8 to 3.2 μm) for nadir-looking sensor.

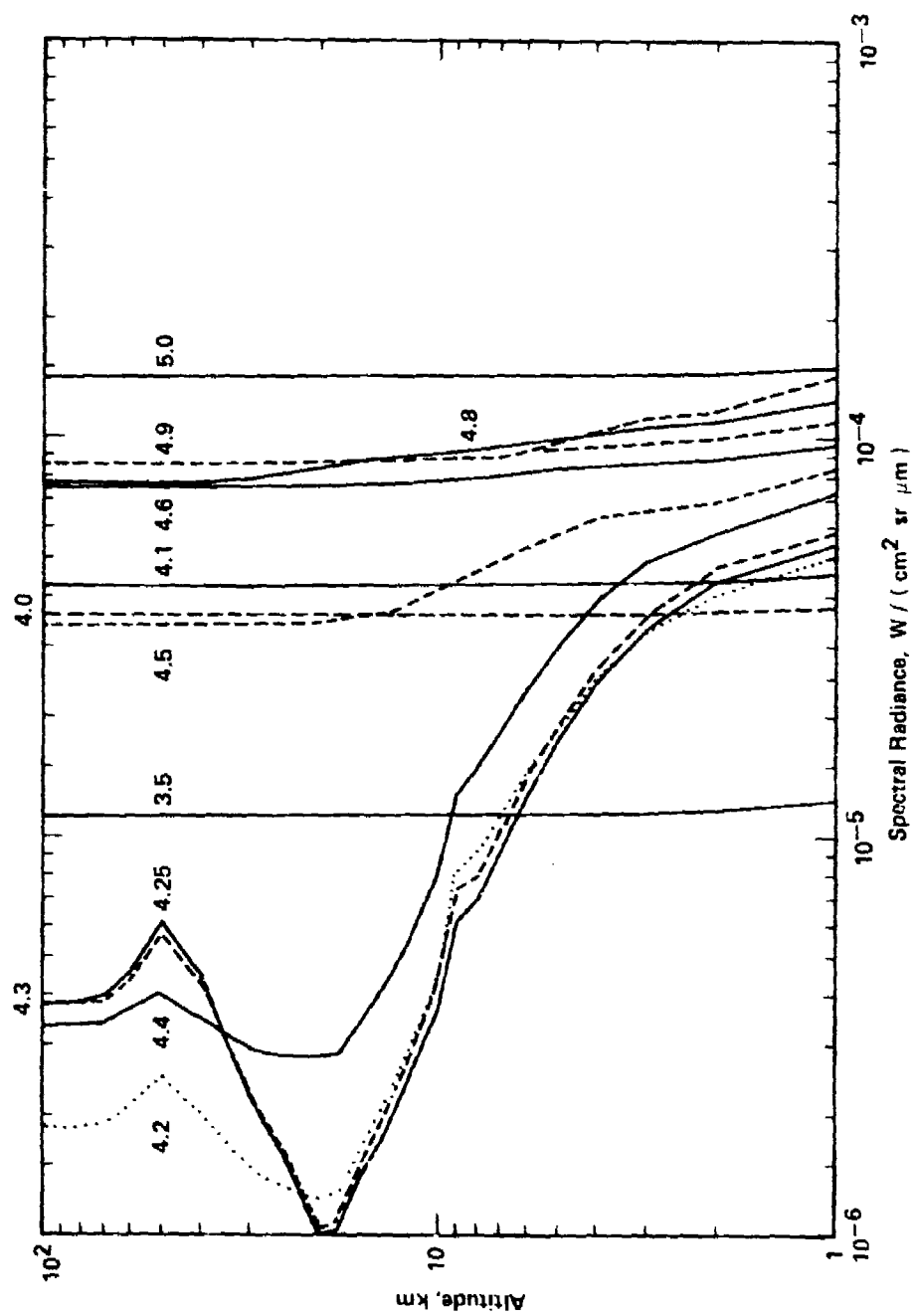


Figure 7-2c. Altitude dependence of spectral radiance (3.5 to 5.0 μm) for nadir-looking sensor.

Table 7-6. Bin altitudes selected for Subroutine SETALT.

Bin	
No.	Altitudes, km
1	0, 1, 12, 20, 100
2	0, 1, 12, 100
3	0, 1, 3, 12, 100
4	0, 1, 2, 4, 9, 12, 20, 30, 50, 70, 100
5	0, 1, 3, 12, 100
6	0, 1, 12, 100
7	0, 1, 3, 6, 12, 20, 50, 70, 100
8	0, 1, 12, 100
9	0, 1, 12, 30, 100
10	0, 1, 12, 100

Table 7-7. Input and output variables for Subroutine SETALT.

INPUT VARIABLES

Argument List

ALMIN, - Minimum and maximum wavelengths for which upwelling natural
ALMAX radiance is to be computed, for (broad) wavelength-band
index JBAND. (μm)

JBAND - Index for list of (broad) wavelength bands. (1 to 5)

Data Statements

NBINL1 - Number of wavelength bins (or number of wavelength-bin
boundaries minus one).

For $L=1, \text{NBINL1}+1$

BINLAM(L) - Wavelength of bin-boundary L. (μm)

For $I=1, \text{NALT}(M), M=1, \text{NBINL1}$

NALT(M) - Number of altitudes for wavelength-bin M.

HUPWEL(I,M) - Altitude-I for wavelength-bin M. (km)

(continued)

Table 7-7. Input and output variables for Subroutine SETALT (Cont'd).

OUTPUT VARIABLES

UPWELS Common

For JBAND = J=1,5; I=1,NALT(J)

NALT(J) - Number of altitudes for (broad) wavelength-band index JBAND

ZKM(I,J) - Altitudes of Point V above reference altitude (UPWALT) at which upwelling natural radiance is computed for (broad) wavelength-band index JBAND. (km)

7-3.3 Other Initialization Routines

7-3.3.1 DSA System

Comments in our listing of Program DRVUPW define the six words and/or arrays that are initialized there before calling QINITL. We also state how to estimate minimum storage requirements for high speed memory in terms of the number and sizes of datasets. For more information on the GRC DSA System, see SP-78. The version of the DSA System we have used was prepared by L. Ewing of G.E. Tempo. Whereas it differs somewhat from the GRC version, it is said to be equivalent, at least for the current application.

7-3.3.2 SAI Routines (ATMOSU, CLOUDU)

Full documentation is given for Subroutines ATMOSU and CLOUDU in Volumes 14a-1 and 24, respectively.

7-3.3.3 G.E. Tempo Routines (TRANSB, SHELLS)

The purpose of Subroutine TRANSB is briefly described in Table 7-3a and in Volume 31 (p. 74). Our more detailed summary of its input and output variables is given in Table 7-8.

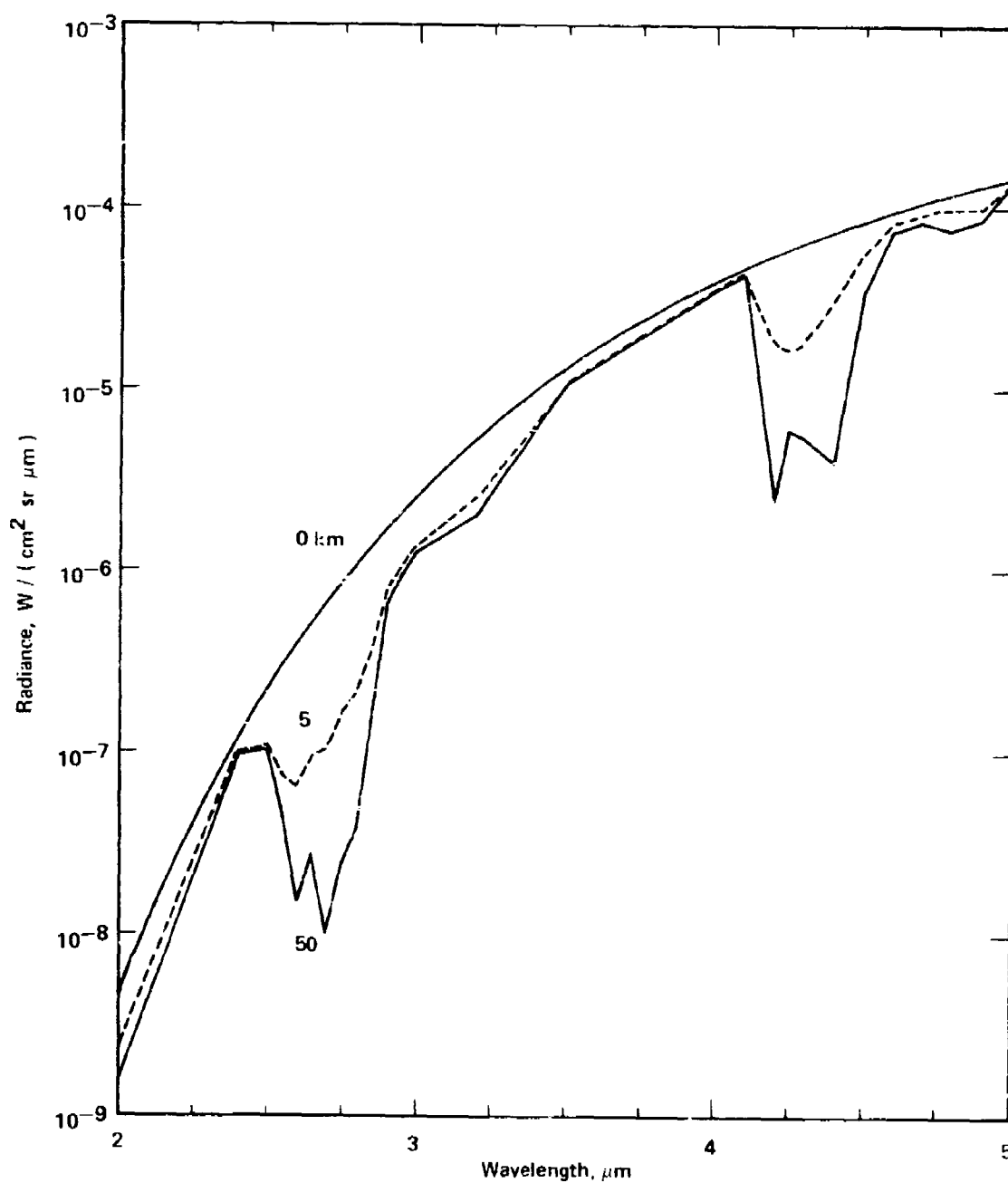


Figure 7-3. Wavelength dependence of spectral radiance (2.0 to 5.0 μm) at 0-, 5-, and 50-km altitude for nadir-looking sensor.

Table 7-8. Input and output variables for Subroutine TRANSB.

INPUT VARIABLES

Argument List

LBAND - List Header Variable (LHV) for Wavelength Bands Dataset-BN (No. 114). Strictly, LBAND is the pointer (i.e., it contains the (Q-array) address) for the list header of the Wavelength Bands Dataset-BN. In GRC usage, LBAND is stored as Word-12 of Dataset-ST (No. 111). In the SAI stand-alone version of the NBR Module, Dataset-ST (No. 111) is not used, but LBAND is still generated in Program DRVUPW and used as the LHV for Dataset-BN.

OPTION Common

TRNSOPT - Logical variable affecting (a) procedure for converting the basic 5-cm¹ resolution band-model parameters to those for the user-specified resolution and (b) possible redundancy of output data if user-selected bands overlap with common spectral intervals.

=.TRUE., TRANSB provides:

(a) in-band (more precisely, "in-interval") averaged band-model parameters. (There is no limit on the allowed coarseness of the resolution. If resolution finer than 5-cm¹ is requested, the code will compute answers, but they may have little or no physical reality.)

(b) band-model parameters for each interval within a band (even though bands may overlap), and the bands are ordered as in the Wavelength Bands Dataset-BN (No. 114).

=.FALSE., TRANSB provides:

(a) band-model parameters at a (below-defined) resolution that may be finer than the requested spectral intervals. In this case the TRANSB-generated resolution (or subinterval) is 0.5 of the narrowest user-specified wavenumber interval, but within the range of 5 to 50 cm⁻¹. The lower edge of the first output interval lies at the lower edge of the lowest wavenumber spectral interval.

(b) non-redundant information for intervals in overlapping bands. (If bands don't overlap, there is nothing to eliminate, of course.)

Note: For additional information regarding use of these band-model parameters, see comments under FAST in Table 6-10 for Subroutine TRANS.

(continued)

Table 7-8. Input and output variables for Subroutine TRANSB (Cont'd).

XYZCOM Common

ITMTE - Auxiliary input data file number (=2 in Program DRVUPW).

LTMTE - Auxiliary output data file number (=3 in Program DRVUPW).

"Dataset-BN"

Note: The spelling (BN) is an unfortunate artifact from the original development of the routine by L. Ewing of G.E. Tempo. We are really dealing with Words-3, -4, and -6 of the GRC dictionary Dataset-BI (No. 115) and not Dataset-BN (No. 114).

WLO BN, - Lowest and highest wavenumbers of spectral interval over
WHI BN which band-model parameters are to be averaged (cm^{-1})

TFLAG BN - Flag to denote whether the wavelength or wavenumber (corresponding to the argument of TFLAG BN) is associated with the first, intermediate, or last spectral division in a band of (ascending) wavelengths or (ascending) wavenumbers.
=1.0, First spectral division (lowest wavelength) in a wavelength band or last spectral division (highest wavenumber) in a wavenumber band.
=0.0, Intermediate spectral division.
=2.0, Last spectral division (highest wavelength) in a wavelength band or first spectral division (lowest wavenumber) in a wavenumber band.

Input Binary File

TAPIN - Equivalent to ITMTE. Contains band-model parameters for 5-cm^{-1} resolution.

WSL, - Lower and higher wavenumber of 5-cm^{-1} interval for the sets
WSH 1997.5(5.0)4997.5 cm^{-1} and 2002.5(5.0)5002.5 cm^{-1} , respectively. (cm^{-1})

For I=1,10; N=1,10

SOD(I,N), - Mean absorption coefficient and inverse of mean line-spacing
DEI(I,N) parameter (or the effective line density) for species-N at temperature-index-I for the wavenumber interval (WSL, WSH). ($1/\text{cm}$ at STP, $\text{lines}/\text{cm}^{-1}$)

(continued)

Table 7-8. Input and output variables for Subroutine TRANSB (Cont'd).

OUTPUT VARIABLES

Output Binary File

TAPOT - Equivalenced to LTMTE. Contains band-model parameters, derived from the 5-cm⁻¹ resolution data, for the user-specified interval DW either (a) communicated through the Dataset-BI if TRNSOPT=.TRUE. or (b) set by an algorithm if TRNSOPT=.FALSE.. The algorithm is that DW equals 0.5 of the minimum DW communicated through the Dataset-BI, but not less than 5.0 or more than 50 cm⁻¹.

WL, - Lower and higher wavenumbers of interval DW. (cm⁻¹)
WH

S(I,N), - Mean absorption coefficient and inverse of mean line-
DE(I,N) spacing parameter (or the effective line density) for species-N at temperature-index-I for the wavenumber interval DW. (1/cm at STP, lines/cm⁻¹)

Note: In Volume 31, L. Ewing briefly comments (on p. 74) on the algorithm in Subroutine TRANSB for using the band-model parameters for the 5-cm⁻¹ resolution (WSL, WSH) to obtain the band-model parameters for the output spectral interval (WL, WH), regardless of TRNSOPT being TRUE or FALSE. The description is not fully satisfying since the evidence is not given. In any event, we record here the formulas used in TRANSB:

DE(lines/cm⁻¹) = DE(I,N) as output from Subroutine TRANSB
= DEI(I,N) as input to Subroutine TRANS
= inverse of mean line-spacing parameter for species-N at temperature-index-I, or the effective line density for the interval

DW = (WL, WH) in TRANSB
= (WTL, WTH) in TRANS.

$$DE = \left[\sum_j F_j / \Delta_j \right]^{-1}$$

S(cm⁻¹ at STP) = S(I,N) as output from Subroutine TRANSB
= SOD(I,N) as input to Subroutine TRANS
= mean absorption coefficient for species-N at temperature-index-I for the interval

(continued)

Table 7-8. Input and output variables for Subroutine TRANSB (Cont'd).

DW \equiv (WL, WH) in TRANSB
 \equiv (WTL, WTH) in TRANS.

$$S = \frac{\sum_j k_j F_j / \Delta_j}{\sum_j F_j / \Delta_j}$$

where:

$k_j \equiv$ SOD(I,N) [not same as input to TRANS]

= mean absorption coefficient for species-N at temperature-index-1 for the 5-cm interval (WSL, WSH). (cm⁻¹ at STP)

$\Delta_j \equiv$ DEI(I,N) [not same as input to TRANS]

= inverse of mean line-spacing parameter, or the effective line density for the 5-cm interval (WSL, WSH). (lines/cm⁻¹)

$F_j \equiv$ FRAC(WL, WH, WSL, WSH)

= fraction of the user interval DW \equiv (WL, WH) covered by the (5-cm⁻¹) basic tape interval (WSL, WSH).

$$\sum_{j=1}^J F_j = 1$$

It is easily shown that, in the special case of uniform line spacing over J intervals, Ewing's formulas give the expected results:

$$DE \rightarrow \frac{1}{\frac{F_0}{\Delta_0} \sum_{j=1}^J 1} = \frac{\Delta_0}{F_0 J} = \Delta_0$$

$$S \rightarrow \frac{\frac{F_0}{\Delta_0} \sum_{j=1}^J k_j}{\frac{F_0}{\Delta_0} \sum_{j=1}^J 1} = \frac{\sum_{j=1}^J k_j}{J}$$

The purpose of Subroutine SHELLS is briefly described in Table 7-3a and very briefly in Volume 31 (p. 68). Our summary of its input and output variables is given in Table 7-9. In our version of Subroutine SHELLS we have added statements (a) to print a table of all the atmospheric properties computed at the shell boundaries and (b) to compute and print the water content of the atmosphere along a vertical path above each of the shell boundaries. The water content is expressed in units of precipitable centimeters. This computation was added to facilitate comparisons with other workers.

Table 7-9. Input and output variables for Subroutine SHELLS.

INPUT VARIABLES

ATMOUP Common

PP - Pressure. (dyne/cm^2)

TT - Temperature. (deg K)

SNI(I) - Density of species-I. (cm^{-3})

Particular species are indicated as follows:

<u>N</u>	<u>I=IMAP(N)</u>	<u>SNI(I)</u>	<u>Set by Subroutine</u>
1	8	NO ₊	SPCMIN
2	11	NO	IONOSU
3	21	N ₂ O	SPCMIN
4	15	NO ₂	SPCMIN
5	14	O ₃	SPCMIN
6	6	CO ₂	ATMOSU
7	20	CO ₂	SPCMIN
8	22	CH ₄	SPCMIN
9	16	H ₂ O	SPCMIN
10	18	OH	SPCMIN

XYZCOM Common

FACT - Parameter controlling the number of altitude boundaries and their spacing. Nominal value is 1.0, but a reasonable range is between 0.1 and 10.0 (per L. Ewing). The original algorithm provided by G.E. Tempo allowed a maximum of 81

(continued)

Table 7-9. Input and output variables for Subroutine SHELLS (Cont'd).

boundaries, but a revision by GRC reduced this number to 61 and also altered the spacings. We have adopted the GRC revision. In the comments of our listing of SHELLS, we have given the boundary altitudes per GET algorithm for FACT=1.0 and per GRC algorithm for FACT=0.1, 1.0, and 10.0. Here, we record the results for GRC's FACT=1.0 ($X_0=1.25$, $X_1=3.125$, $X_2=7.8125$).

<u>J</u>	<u>HS</u>	<u>J</u>	<u>HS</u>	<u>J</u>	<u>HS</u>
1	0.	10 ^a	13.125	18 ^b	42.8125
2	1.25	11	16.250	19	50.6250
3	2.50	12	19.375	20	58.4375
4	3.75	13	22.500	21	66.2500
5	5.00	14	25.625	22	74.0625
6	6.25	15	28.750	23	81.8750
7	7.50	16	31.875	24	89.6875
8	8.75	17	35.000	25	97.5000
9	10.00				

^aJCHNG1

^bJCHNG2

OUTPUT VARIABLES

XYZCOM Common

NS - Number of altitude boundaries

For J=1,NS; N=1,10

HSHELL(J), - Altitude, temperature, pressure, and species-N density at
 TS(J), altitude-boundary J=3
 PS(J), (cm, deg K, atm, cm⁻³)
 XNSPEC(J,N)

7-4 INTEGRATION OF NBR MODULE INTO ROSCOE-IR

7-4.1 General

Table 7-10 provides a guide to the integration of the NBR-Module routines into ROSCOE-IR. For these routines, we now mention some of the differences between the routine in the stand-alone version of the NBR Module and the routine in ROSCOE-IR.

Table 7-10. Guide to integration of NBR Module into ROSCOE-IR.

NBR-Module routine ^a		Program in ROSCOE-IR	
Name	Purpose of call	calling NBR-Module routine	
QINITL	b	ROSMAN, ^c	Overlay (0,0)
ATMOSU ^d	e	ATKGEN,	Overlay (3,1)
CLOUDO	f	ATKGEN,	Overlay (3,1)
TRANSB	g	ATKGEN,	Overlay (3,1)
SHELLS	h	ATKGEN,	Overlay (3,1)
SETALT	i	OLOOK,	Overlay (3,25)
UPWELL	j	OLOOK,	Overlay (3,25)
UPWELT	k	EMISCAT,	Overlay (3,31)

^aEach of these routines (except UPWELT which is not in the stand-alone version of the NBR Module) is called by the driver, Program DRVUPW.

^bTo initialize the DSA routines.

^cStrictly, Subroutine QINITL is called by Subroutine ROSCOE which is called by Program ROSMAIN.

^dKnown as ATMOS in ROSCOE-IR.

^eTo initialize atmospheric routines depending on location and time.

^fTo initialize statistical-cloud submodel properties.

^gTo prepare, from the basic 5-cm⁻¹ resolution band-model parameters file, band-model parameters for prescribed spectral resolution.

^hTo establish atmospheric grid for $h \leq 100$ km.

ⁱTo determine the altitudes (depending on wavelength of interest) at which Subroutine UPWELL is to compute the upwelling natural background radiation.

^jTo compute, for a Point V at each of a set of NALT altitudes above a given geographic position, characterized by Material MSM and Property DD(MSM), the natural upwelling spectral radiance directed toward Point V from Points P on Earth's surface with respect to Point V at NNADIR representative nadir angles and NAZI representative azimuth angles.

^kTo interpolate the upwelling radiation array UPRADN(I,M,L) in altitude (I) and select the appropriate band-interval (M) in broad-band (L). For altitudes ZKM ≥ 12 km, UPRADN is not the cloud-free result but the 50-percentile of the radiance distribution function for statistical clouds (if included in the problem).

Our QINITL was prepared by G.E. Tempo and, while different from GRC's, is said to be equivalent for the present purposes.

Our ATMOSU, documented in Volume 14a-1, does not contain the DSA System as does the GRC version.

GRC's CLOUDO, more restricted than SAI's documented in Volume 24, initializes only statistical (as opposed to deterministic) cloud data. However, with respect to the NBR Module which contains only statistical clouds, the two versions are presumably equivalent (except for GRC's DSA), although the details have not been verified.

Subroutine TRANSB contains the DSA System in both versions and should be the same in both versions except for one small difference. The logical variable TRNSOPT enters through Common OPTION in the SAI version whereas in the GRC version TRNSOPT is set to Word-27 (FAST or GOOD) in the Basic Dataset-80 (No. 9).

Our Subroutine SHELLS is the same as the GRC version in all essential aspects. (See Section 7-3.3.3 for small differences.)

Subroutine SETALT should be the same in both versions.

Subroutine UPWELL, written in terms of the DSA System in both versions, should be essentially the same. SAI's version contains many print statements properly deleted in the GRC version. The comment regarding TRNSOPT in Subroutine TRANSB applies here, too.

Subroutine UPWELT, not in the stand-alone version of the NBR Module, is discussed in Section 7-4.2.

7-4.2 Subroutine UPWELT

Subroutine UPWELT was prepared by GRC to select the appropriate wave-number interval and to interpolate in altitude the upwelling natural radiation

array, UPRADN(I,K,JBAND). For altitudes $ZKM \geq 12$ km, UPRADN is not the cloud-free result but the 50-percentile of the radiance distribution function for statistical clouds (if included in the problem). Table 7-11 gives the input and output variables for Subroutine UPWELT.

Table 7-11. Input and output variables for Subroutine UPWELT.

INPUT VARIABLES

Argument List

- HCM - Altitude at which upwelling spectral radiance is desired in Program EMISCAT. (cm)
- WL, WH - Lower and higher limits of wavenumber interval for which upwelling spectral radiance is desired (set in Program EMISCAT from Dataset-B!). (cm^{-1})

UPWELS Common

For I=1,NALTJ; L=1,NWAVEJ; M=1,NBANDS

- NALT(M) - Number of altitudes ZKM(I,M) at which upwelling spectral radiance has been computed for (broad) wavelength-band index M. Defines NALTJ.
- ZKM(I,M) - Altitudes of Point V above UPWALT at which upwelling radiance is computed. (km)
- NWAVE(M) - Number of wavenumbers at which the upwelling spectral radiance has been computed for (broad) wavelength-band index M. Defines NWAVEJ.
- UPRADN(I,L,M) - The nadir-averaged value of UPRADA(I,J,L). See Table 6-2 for Subroutine UPWELL. In the GRC version, for altitudes $ZKM \geq 12$ km and if clouds are included, UPRADN is not the cloud-free result but the 50-percentile of the radiance distribution function for statistical clouds. [$\text{W}/(\text{cm}^2 \text{ sr cm}^{-1})$]
- WV(L,M) - The array of central wavenumbers corresponding to (broad) wavelength-band index M. Set in Program OLOOK from Dataset-BI. (cm^{-1})
- NBANDS - Number of (broad) wavelength bands.

OUTPUT VARIABLES

Argument list

- RADUP - The value of the upwelling natural radiation for the wavenumber interval (WL,WH), averaged over the downward hemisphere and logarithmically interpolated from the array UPRADN for the input altitude HCM. [$\text{Photons}/(\text{cm}^2 \text{ sec sr cm}^{-1})$]
-

SECTION 8

LISTING OF SELECTED ROUTINES

In this section we provide a FORTRAN listing of those routines in the NBR Module which have not been published elsewhere (or at least not in the form in which they are used in the NBR Module). An index to such routines, as well as their originator, is given in Table 8-1. Table 7-3a tells where listing of the other routines have been published.

Table 8-1. Index to routines with FORTRAN listing in Volume 27.

<u>Routine</u>	<u>Originator^a</u>	<u>Page</u>	<u>Routine</u>	<u>Originator^a</u>	<u>Page</u>
DRVUPW	SAI	227	RINOUT	SAI	268
ACCUM	GET	237	SEGMENT	GET	271
AEROSOL	VI	238	SETALT	SAI	275
AGAGEO	SAI	243	SHELLS	GET	277
ATMRAD	GET	244	SOLRAD	SAI	280
CANGLE	SAI	249	SORTLJ	SAI	281
DOT	GET	249	STEP	GET	282
ERF	SAI	249	STEPS	GET	284
ESURF	SAI	250	SUBVEC	GET	284
FRAC	GET	254	SURRAD	SAI	285
FRESNL	SAI	255	TANGEQ	SAI	295
GCRGLE	SAI	257	TRANS	GET	296
GEOREA	SAI	258	TRANSB	GET	303
GEOTAN	SAI	258	TRNSCO	GET	308
GEOXYZ	SAI	259	UNITV	GET	312
GLITTR	SAI	260	WELL	SAI	312
PATH	GET	265	VLIN	GET	333
PLANCK	GET	267	XMIT	GET	333
REATAN	SAI	267			

^aSAI comments inserted in routines developed elsewhere are denoted by CLJ in the first three columns.

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PROGRAM DRVUPW (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE2,TAPE3, DRVUPW      2
1 TAPE8) DRVUPW      3
CC      DRVUPW      4
CC      THIS ROUTINE IS PROVIDED TO DRIVE AND TEST SUBROUTINE UPWELL AND DRVUPW      5
CC      THE RELATED ROUTINES WHICH COMPRISE THE NATURAL BACKGROUND DRVUPW      6
CC      RADIATION MODEL FOR THE UNDISTURBED ATMOSPHERE, INCLUDING A DRVUPW      7
CC      STATISTICAL TREATMENT OF NATURAL CLOUDS. DRVUPW      8
CC      DRVUPW      9
CC      *** HISTORICAL STATEMENT *** DRVUPW     10
CC      BECAUSE WE WERE GIVEN (6/1/78) A MOLECULAR TRANSMITTANCE DRVUPW     11
CC      MODULE BY G.E. TEMPO THAT HAD SEVERAL ROUTINES (DRIVER PROGRAM DRVUPW     12
CC      ATMOST AND SUBROUTINES ATMRAD, TRANSB, AND TRNSCO) WRITTEN IN DRVUPW     13
CC      TERMS OF THE GRC DSA SYSTEM, WE PREPARED TWO VERSIONS OF THE DRVUPW     14
CC      NATURAL BACKGROUND RADIATION (NBR) MODULE. ONE VERSION, WHICH DRVUPW     15
CC      WE REGARDED AS THE BASIC VERSION, USED DSA IN THE SAT DRIVER DRVUPW     16
CC      PROGRAM DRVUPW, SUBROUTINE UPWELL, AND THE ABOVE-NAMED GET DRVUPW     17
CC      SUBROUTINES. THE OTHER VERSION DID NOT USE DSA. BOTH DRVUPW     18
CC      VERSIONS WERE TESTED ON SEVERAL PROBLEMS AND GAVE THE SAME DRVUPW     19
CC      ANSWERS. DRVUPW     20
CC      (HISTORICALLY, WE FIRST PREPARED THE DSA VERSION AND THEN DRVUPW     21
CC      DEVELOPED THE NON-DSA VERSION BY USING A SET OF ABOUT 235 DRVUPW     22
CC      CORRECTION CARDS (90 ACTION CARDS AND ABOUT 145 COMMENT DRVUPW     23
CC      CARDS). THEN, THE NON-DSA VERSION WAS AVAILABLE FROM A DRVUPW     24
CC      PROGRAM LIBRARY (IN THE CONTEXT OF THE CDC UPDATE UTILITY DRVUPW     25
CC      PROGRAM) AND THE DSA VERSION WAS OBTAINED BY USING THE *YANK DRVUPW     26
CC      UPDATE DIRECTIVE TO DELETE THE NON-DSA CORRECTION SET.) DRVUPW     27
CC      WE EFFECTED THE REMOVAL OF THE DSA-USAGE BY A NON-STANDARD DRVUPW     28
CC      METHOD WHICH RETAINED AS MUCH OF THE DSA CODING AS POSSIBLE DRVUPW     29
CC      BUT WITH NEW MEANINGS TO MANY OF THE DSA VARIABLES. THE DSA DRVUPW     30
CC      STATEMENTS THAT COULD NOT BE USED WERE COMMENTED (C-DSA) AND DRVUPW     31
CC      FOLLOWED WITH THE NECESSARY REPLACEMENT STATEMENTS. DRVUPW     32
CC      (THIS PROCEDURE WAS FEASIBLE FOR US BECAUSE ONLY TWO DATASETS DRVUPW     33
CC      WERE INVOLVED. IT MAY NOT BE FEASIBLE FOR A CASE WITH MANY DRVUPW     34
CC      DATASETS.) DRVUPW     35
CC      DRVUPW     36
CC      IN JANUARY 1980, DURING A REVIEW OF THE INCORPORATION OF THE DRVUPW     37
CC      NBR MODULE INTO ROSCOE, NUMEROUS ERRORS WERE DISCOVERED, SOME DRVUPW     38
CC      OF WHICH WERE COMPOUNDED OWING TO THE FACT THAT THE DATASETS DRVUPW     39
CC      USED IN THE GET ROUTINES WERE INCONSISTENT WITH THE GRC DRVUPW     40
CC      DICTIONARY DATASETS. THE NON-STANDARD DATASETS HAVE NOW BEEN DRVUPW     41
CC      REPLACED BY THE STANDARD DATASETS (EXCEPT IN SUBROUTINE DRVUPW     42
CC      TRANSB). AN EXTENSIVE REVISION OF THE (STAND-ALONE) NBR DRVUPW     43
CC      MODULE WAS REQUIRED TO BRING IT INTO A CLOSE CORRESPONDENCE DRVUPW     44
CC      WITH THE CORRECTED VERSION IN THE ROSCOE CODE. CONSEQUENTLY, DRVUPW     45
CC      IN THIS FINAL VERSION OF THE NBR MODULE, WE DO EMPLOY THE GRC DRVUPW     46
CC      DSA SYSTEM (BUT IN A GET VERSION AND NOT IN THE GRC VERSION) DRVUPW     47
CC      WHERE APPROPRIATE. WE DO NOT PROVIDE A NON-DSA VERSION. DRVUPW     48
CC      DRVUPW     49
CC      COMMON QWAREA, QWAREA(10), QFREHD, QMDTST, QMLNKS, QZSIZE, DRVUPW     50
1      QNZBLK, QZHEAD, QCOUNT(30), QDSIZE(10), QMSIZE, QLUNIT(10), DRVUPW     51
2      QERLUN, QFBITS(2,10), Q(1) DRVUPW     52
CC      INTEGER QWAREA, QWAREA, QFREHD, QMDTST, QMLNKS, QZSIZE, QNZBLK, DRVUPW     53
1      QZHEAD, QCOUNT, QDSIZE, QMDULK, QMSIZE, QLUNIT, QFIELD, DRVUPW     54
2      QERLUN, QFBITS, QRSIZ DRVUPW     55
CC      COMMON / TIME / IYRS, IMONS, IDAYS, ZT, PLAT, PLON, UT, GAT, FYR, DRVUPW     56
1      FST, RHOSKM, CHI DRVUPW     57
CC      COMMON / VPC / WVFLAG, METHOD DRVUPW     58

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COMMON / ZHTEMP / XX(63), TPFLAG
COMMON / XYZCOM / ITMTE, LTMTE, WS, WSHLL(81), TS(81), PS(81),
1      XNSPEC(81,10), U(10,10,2), UP(10,10,2), NMOLS,
2      FACT
COMMON / OPTION / TRNSOPT
COMMON / OPTIN1 / RADSW
COMMON / XY / TT(10)
COMMON / AEROK / KVIS, KPTYPE
COMMON / PARAMS / INFIL, IOFIL, PI, ERAD, DGTOR, RTODG
COMMON / UPWELS / UPWALT, UPWLON, UPWLAT, NALT(5), ZKM(13,5), NNADIR,
*      NAZI, NMAVE(5), IDAYV, CLDFLG, UPRAON(13,10,5),
*      WV(10,5), IKM, NBANDS
COMMON / UPWELS1 /
2      RO10(6,10), RO10A(6,10,10), RO10M(6,10),
3      RO25(6,10), RO25A(6,10,10), RO25M(6,10),
4      RO50(6,10), RO50A(6,10,10), RO50M(6,10),
5      RO90(6,10), RO90A(6,10,10), RO90M(6,10),
6      RIO0(6,10), RIO0A(6,10,10), RIO0M(6,10),
7      ARCYA(6,10,10), ARCYM(6,10)
COMMON / UPWELS3 / UPRA0(6,10), UPRA0A(13,10,10)
CCC      II=NALTJ, JJ=NNADIR, KK=NAZI, LL=NMAVEJ, NN=NBANDS
CCC      UPRA0(KK,LL), UPRA0A(IJ,JJ,LL), UPRAON(IJ,LL,NN)
DIMENSION QXXX(2000)
EQUIVALENCE ( Q, QXXX )
DIMENSION DD(7), WW(10), DW(10), ALAM(10), GLAM(10)
DIMENSION BNLO BN(1), BNHI BN(1), WLO BN(1), WHI BN(1),
*      LINRY BN(1)
EQUIVALENCE ( Q(1), BNLO BN ), ( Q(2), BNHI BN ),
*      ( Q(3), WLO BN ), ( Q(4), WHI BN ),
*      ( Q(5), LINRY BN )
DIMENSION BNLO BI(1), BNHI BI(1), WLO BI(1), WHI BI(1),
*      BKGND BI(1), TFLAG BI(1), TRANS BI(1), IOSBX BI(1)
EQUIVALENCE ( Q(1), BNLO BI ), ( Q(2), BNHI BI ),
*      ( Q(3), WLO BI ), ( Q(4), WHI BI ),
*      ( Q(5), BKGND BI ), ( Q(6), TFLAG BI ),
*      ( Q(7), TRANS BI ), ( Q(8), IOSBX BI )
LOGICAL SPCULR
LOGICAL RADSW, TRNSOPT
DATA TT / 200., 300., 500., 750., 1000., 1500., 2000., 3000.,
*      5000., 7000. /
DATA PI / 3.14159265 /
DATA DD / 0.10, 10., 0.50, 0., 0., 0., 0.5 /

FILE NAMES
* TAPE2 AND TAPE3 ARE IDENTIFIED IN PROGRAM DRVUPW WITH ITMTE
AND LTMTE, RESPECTIVELY.
ITMTE (ALIAS TAPIN) AND LTMTE (ALIAS TAPOT) ARE READ AND
WRITTEN, RESPECTIVELY, BY SUBROUTINE TRANSR.
* TAPE8 IS WRITTEN BY SUBROUTINE UPWELL AND READ BY PROGRAM
DRVUPW.
READ OR OTHERWISE SET THE FOLLOWING PARAMETERS...

PARAMETER  IN COMMON  DEFINED IN  READ/SET  COMMENT
-----
KVIS       AEROK      SUB. AEROSOL  R
KPTYPE     AEROK      SUB. AEROSOL  R

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DRVUPW 59
DRVUPW 60
DRVUPW 61
DRVUPW 62
DRVUPW 63
DRVUPW 64
DRVUPW 65
DRVUPW 66
DRVUPW 67
DRVUPW 68
DRVUPW 69
DRVUPW 70
DRVUPW 71
DRVUPW 72
DRVUPW 73
DRVUPW 74
DRVUPW 75
DRVUPW 76
DRVUPW 77
DRVUPW 78
DRVUPW 79
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DRVUPW 106
DRVUPW 107
DRVUPW 108
DRVUPW 109
DRVUPW 110
DRVUPW 111
DRVUPW 112
DRVUPW 113
DRVUPW 114
DRVUPW 115

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CC	RADSW	OPTINI	SUB. UPWELL	R		DRVUPW	116
CC						DRVUPW	117
CC	TRNSOPT	OPTION	SUB. TRANS	R	I	DRVUPW	118
CC						DRVUPW	119
CC	INFIL	PARAMS		S	B1	DRVUPW	120
CC	IOFIL	PARAMS		S	B2	DRVUPW	121
CC	PI	PARAMS		S		DRVUPW	122
CC	ERAD	PARAMS		S	C	DRVUPW	123
CC	DGTOR	PARAMS		S	D1	DRVUPW	124
CC	RTODG	PARAMS		S	D2	DRVUPW	125
CC						DRVUPW	126
CC	IYRS	TIME	DRVATM	R	E	DRVUPW	127
CC	IMONS	TIME	DRVATM	R	E	DRVUPW	128
CC	IDAYS	TIME	DRVATM	R	E	DRVUPW	129
CC	ZT	TIME	DRVATM	R	E	DRVUPW	130
CC	PLAT	TIME	SUB. SOLZEN	S		DRVUPW	131
CC	PLON	TIME	SUB. SOLZEN	S		DRVUPW	132
CC	GCO	--	DRVATM	R	E,F1	DRVUPW	133
CC	GLO	--	DRVATM	R	E,F2	DRVUPW	134
CC						DRVUPW	135
CC	UPWALT	UPWELS	SUB. UPWELL	S		DRVUPW	136
CC	UPWLOH	UPWELS	SUB. UPWELL	S		DRVUPW	137
CC	UPWLAT	UPWELS	SUB. UPWELL	S		DRVUPW	138
CC	NNADIR	UPWELS	SUB. UPWELL	R		DRVUPW	139
CC	NAZI	UPWELS	SUB. UPWELL	R		DRVUPW	140
CC	NWAVE(5)	UPWELS	SUB. UPWELL	S		DRVUPW	141
CC	CLDFLG	UPWELS	SUB. UPWELL	R		DRVUPW	142
CC	MSM	--	SUB. UPWELL	R		DRVUPW	143
CC	OD(MSM)	--	SUB. UPWELL	S	G	DRVUPW	144
CC	SPCULR	--	SUB. UPWELL	R		DRVUPW	145
CC						DRVUPW	146
CC	WVFLAG	VPC	DRVATM	S	E	DRVUPW	147
CC	METHOD	VPC	DRVATM	S	E	DRVUPW	148
CC						DRVUPW	149
CC	TT(I)	XY	SUB. TRANS	S	G	DRVUPW	150
CC						DRVUPW	151
CC	ITMTE	XYZCOM	SUB. TRANSB	S		DRVUPW	152
CC	LTMTE	XYZCOM	SUB. TRANSB	S		DRVUPW	153
CC	NNOLS	XYZCOM	SUB. TRANS	S		DRVUPW	154
CC	FACT	XYZCOM	SUB. SHELLS	R		DRVUPW	155
CC						DRVUPW	156
CC	TPFLAG	ZHTEMP	DRVATM	S	E	DRVUPW	157
CC						DRVUPW	158
CC	B1	INPUT FILE FOR STATISTICAL CLOUD MODEL				DRVUPW	159
CC	B2	OUTPUT FILE FOR STATISTICAL CLOUD MODEL				DRVUPW	160
CC	C	EARTH RADIUS, KM				DRVUPW	161
CC	D1	DEGREES-TO-RADIANS				DRVUPW	162
CC	D2	RADIANS-TO-DEGREES				DRVUPW	163
CC	E	PROGRAM DRVATM FOR SUBROUTINES ATMOSU, SPCMIN, ETC.				DRVUPW	164
CC	F1	USED TO SET PLAT				DRVUPW	165
CC	F2	USED TO SET PLON				DRVUPW	166
CC	G	SET BY DATA STATEMENT				DRVUPW	167
CC	H1	IDEALLY BUT NOT NECESSARILY SET TO PLAT				DRVUPW	168
CC	H2	IDEALLY BUT NOT NECESSARILY SET TO PLON				DRVUPW	169
CC	I	ALSO SEE SUBROUTINE TRANSB				DRVUPW	170
CC						DRVUPW	171
CC						DRVUPW	172

IN THE FOLLOWING SEVEN STATEMENTS, THE DSA MEANINGS ARE ...

CC	QWAREA	= NUMBER OF STORAGE AREAS.	DRVUPW	173
CC	QWAREA(1)	= NUMBER OF WORDS OF HIGH-SPEED MEMORY (SCM).	DRVUPW	174
CC		NOTE THAT THROUGH THE INITIALIZATION PERFORMED BY	DRVUPW	175
CC		SUBROUTINE QINITL, THE MAXIMUM NUMBER OF WORDS	DRVUPW	176
CC		AVAILABLE IN THE Q-ARRAY IS SET EQUAL TO	DRVUPW	177
CC		QWAREA(1). THUS THE LENGTH OF BLANK COMMON	DRVUPW	178
CC		EQUALS THE SUM OF QWAREA(1) AND THE NUMBER (89)	DRVUPW	179
CC		OF WORDS REQUIRED FOR THE BLANK-COMMON VARIABLES	DRVUPW	180
CC		OTHER THAN Q.	DRVUPW	181
CC		THE MINIMUM VALUE REQUIRED FOR QWAREA(1) MAY BE	DRVUPW	182
CC		DETERMINED BY NOTING THAT	DRVUPW	183
CC	(A)	THE FIRST TWO WORDS AND THE LAST WORD IN THE	DRVUPW	184
CC		Q-ARRAY ARE USED BY THE DSA SYSTEM.	DRVUPW	185
CC	(B)	EACH DATASET HAS A ZEROth WORD.	DRVUPW	186
CC	(C)	THE NUMBER OF WORDS USED BY THE Z-BLOCK	DRVUPW	187
CC		DATASET IS HARDWIRED TO BE 101 (SUBROUTINE	DRVUPW	188
CC		QINITL SETS QZSIZE=100, AND A ZEROth WORD IS	DRVUPW	189
CC		REQUIRED). ONE MAY DETERMINE THE MINIMUM	DRVUPW	190
CC		SIZE REQUIRED FOR THE Z-BLOCK BY NOTING THAT	DRVUPW	191
CC		TWO WORDS (A DATASET POINTER WORD AND A LINK	DRVUPW	192
CC		WORD) ARE REQUIRED FOR EACH DATASET AND ALSO	DRVUPW	193
CC		ONE LIST HEADER WORD FOR THE DATASETS ON A	DRVUPW	194
CC		LIST.	DRVUPW	195
CC		IF TWO BANDS, EACH WITH TWO BAND INTERVALS, ARE	DRVUPW	196
CC		USED FOR A SAMPLE PROBLEM, THEN ONE NEEDS	DRVUPW	197
CC		FOR TWO DATASETS-BN, $2*(5+1)=12$	DRVUPW	198
CC		FOR FOUR DATASETS-BI, $4*(8+1)=36$	DRVUPW	199
CC		FIRST TWO AND LAST WORDS OF Q, $= 3$	DRVUPW	200
CC		Z-BLOCK, $=16$	DRVUPW	201
CC		ZEROth WORD, $= 1$	DRVUPW	202
CC		DATASETS-BN, $1+2*2 = 5$	DRVUPW	203
CC		DATASETS-BI, $2*(1+2*2)= 10$	DRVUPW	204
CC		---	DRVUPW	205
CC		Z-BLOCK TOTAL $= 16$	DRVUPW	206
CC		-----	DRVUPW	207
CC		TOTAL WORDS $=67$	DRVUPW	208
CC		USE OF NEAR-MINIMUM SIZES FOR THE Z-BLOCK AND FOR	DRVUPW	209
CC		QWAREA(1) IS HIGHLY RECOMMENDED WHEN ONE WANTS TO	DRVUPW	210
CC		USE PDUMP TO SEE WHAT IS GOING ON IN BLANK	DRVUPW	211
CC		COMMON.	DRVUPW	212
CC	QWAREA(2)	= NUMBER OF WORDS OF LOW-SPEED MEMORY (LCM).	DRVUPW	213
CC	QZSIZE(1)	= NUMBER OF WORDS IN SMALLEST DATASET.	DRVUPW	214
CC	QZSIZE(2)	= AN ASSIGNED VALUE OF ZERO IMPLIES THAT DATASETS	DRVUPW	215
CC		LARGER THAN THE LAST ASSIGNED INCREMENT WILL BE	DRVUPW	216
CC		ALLOCATED THE EXACT NUMBER OF WORDS REQUIRED.	DRVUPW	217
CC	QERLUN	= LOGICAL UNIT NUMBER OF DEVICE USED FOR SYSTEM	DRVUPW	218
CC		ERROR MESSAGES.	DRVUPW	219
CC	QINITL	= THIS SUBROUTINE INITIALIZES OTHER SYSTEM	DRVUPW	220
CC		VARIABLES AND SETS UP THE FREE LIST.	DRVUPW	221
CC			DRVUPW	222
CC			DRVUPW	223
CC	QWAREA = 2		DRVUPW	224
CC	QWAREA(1) = 2000		DRVUPW	225
CC	QWAREA(2) = 50000		DRVUPW	226
CC	QZSIZE(1) = 5		DRVUPW	227
CC	QZSIZE(2) = 0		DRVUPW	228
CC	QERLUN = 6		DRVUPW	229
CC	CALL QINITL		DRVUPW	230

CCC		DRVUPW	230
CC	* * * INITIALIZE AMBIENT ATMOSPHERE AFTER SETTING PARAMETERS IN	DRVUPW	231
CC	TIME, VPC, AND ZHTEMP COMMONS.	DRVUPW	232
	READ (5,315) IYRS, IMONS, IDAYS, ZT, GCO, GLO	DRVUPW	233
	WRITE(6,316) IYRS, IMONS, IDAYS, ZT, GCO, GLO	DRVUPW	234
	GCO = GCO * PI / 180.	DRVUPW	235
	GLO = GLO * PI / 180.	DRVUPW	236
	PLAT = .5 * PI - GCO	DRVUPW	237
	PLON = GLO	DRVUPW	238
	WVFLAG = 0. \$ METHOD = 0 \$ TPFLAG = 0.	DRVUPW	239
	CALL ATMOSU (1, 120.)	DRVUPW	240
CCC		DRVUPW	241
CC	* * * INITIALIZE NATURAL CLOUDS.	DRVUPW	242
CCC		DRVUPW	243
CC	THE STATISTICAL CLOUD SUBMODEL OF THE SAI/PA NATURAL CLOUD	DRVUPW	244
CC	MODEL (NCM) HAS NOW BEEN INTEGRATED INTO THE UPWELLING	DRVUPW	245
CC	NATURAL RADIATION MODEL. (THERE IS NO INTENTION OF INCORPORATING	DRVUPW	246
CC	THE DETERMINISTIC CLOUD SUBMODEL.) THE INTERFACE OF THE	DRVUPW	247
CC	UPWELLING NATURAL RADIATION MODEL WITH THE NCM IS ACHIEVED IN	DRVUPW	248
CC	TWO GENERAL STEPS. (1) A CALL (FROM THE DRIVER PROGRAM FOR	DRVUPW	249
CC	THIS UPWELLING NATURAL RADIATION MODEL) TO NCM SUBROUTINE	DRVUPW	250
CC	CLOUDO WHICH READS DATA CARDS FOR THE STATISTICAL CLOUD SUB-	DRVUPW	251
CC	MODEL AND (2) REPLACEMENT OF THE CALL FROM THE NCM DRIVER TO	DRVUPW	252
CC	THE NCM SUBROUTINE SCLOUD BY A SET OF CALLS AND OPERATIONS IN	DRVUPW	253
CC	SUBROUTINE UPWELL WHICH, IN THEIR TOTALITY, ADAPT THE ROLE OF	DRVUPW	254
CC	SUBROUTINE SCLOUD TO OUR SPECIAL NEEDS. A FLAG (CLDFLG), SET	DRVUPW	255
CC	BY A READ STATEMENT, HAS BEEN INTRODUCED SO THAT NATURAL	DRVUPW	256
CC	CLOUDS ARE IGNORED IF CLDFLG=0 AND ARE INCLUDED IF	DRVUPW	257
CC	(A) CLDFLG=1 AND (B) THE ALTITUDE ABOVE THE SURFACE AT WHICH	DRVUPW	258
CC	THE UPWELLING RADIATION IS COMPUTED IS AT LEAST 12 KM (THE	DRVUPW	259
CC	HIGHEST ALTITUDE OF THE TOP OF ANY OF THE STATISTICAL CLOUDS).	DRVUPW	260
CCC		DRVUPW	261
	READ (5,300) CLDFLG	DRVUPW	262
	WRITE(6,318) CLDFLG	DRVUPW	263
CC	* SET PARAMETERS IN PARAMS COMMON.	DRVUPW	264
	INFIL = 5 \$ IOFIL = 6	DRVUPW	265
	ERAD = 6371.03	DRVUPW	266
	DGTOR = PI / 180. \$ RTODG = 1.0 / DGTOR	DRVUPW	267
CC	* NOTE THAT SUBROUTINE CLOUDO READS SEVEN CARDS, THE FIRST OF	DRVUPW	268
CC	WHICH IS FOR MODE=1.	DRVUPW	269
	IF(CLDFLG.EQ.1.0) CALL CLOUDO(MODE)	DRVUPW	270
CCC		DRVUPW	271
CC	* * * CREATE DATASETS BN AND BI AND SET WORDS.	DRVUPW	272
CC	WAVELENGTHS IN THESE TWO DATASETS ARE IN MICRONS FOR SAI AND	DRVUPW	273
CC	IN CENTIMETERS FOR GRC.	DRVUPW	274
	J = 0	DRVUPW	275
100	READ (5,320) ALAM1, ALAM2, W1, W2, LINT	DRVUPW	276
C	NEGATIVE WAVELENGTH DENOTES END OF BANDS.	DRVUPW	277
	IF(ALAM1 .LT. 0.) GO TO 105	DRVUPW	278
	J = J + 1	DRVUPW	279
C	DIMENSIONING LIMITS ALLOWED NUMBER OF BANDS TO 5.	DRVUPW	280
	IF(J .GT. 5) GO TO 105	DRVUPW	281
	NWAVE(J) = LINT	DRVUPW	282
	IF(ALAM1 .EQ. 0.) GO TO 102	DRVUPW	283
C	BAND-LIMIT WAVELENGTHS ARE INPUT.	DRVUPW	284
	ALMIN = AMIN1 (ALAM1, ALAM2)	DRVUPW	285
	ALMAX = AMAX1 (ALAM1, ALAM2)	DRVUPW	286

C	CREATE THE 5-WORD DATASET-BN AND SET THE FIRST FOUR WORDS.	DRVUPW	287
	CALL CREATE (5, NBN)	DRVUPW	288
	BNLO BN(NBN) = ALMIN	DRVUPW	289
	BNHI BN(NBN) = ALMAX	DRVUPW	290
	WLO BN(NBN) = 1.E+04/BNHI BN(NBN)	DRVUPW	291
	WHI BN(NBN) = 1.E+04/BNLO BN(NBN)	DRVUPW	292
	DBN = (BNHI BN(NBN) - BNLO BN(NBN)) / FLOAT(LINT)	DRVUPW	293
	WRITE(6,303) ALMIN, ALMAX, FLOAT(LINT), DBN,	DRVUPW	294
*	WLO BN(NBN), WHI BN(NBN)	DRVUPW	295
C		DRVUPW	296
C	LOOP DO-101 IS PATTERNED AFTER LOOP DO-700 IN GRC'S	DRVUPW	297
C	PROGRAM ATKGEN.	DRVUPW	298
	DO 101 I=1,LINT	DRVUPW	299
C	CREATE THE 8-WORD DATASET-BI AND SET THE FIRST SEVEN WORDS.	DRVUPW	300
	CALL CREATE (8, NBI)	DRVUPW	301
	BNLO BI(NBI) = BNLO BN(NBN) + FLOAT(I-1)*DBN	DRVUPW	302
	BNHI BI(NBI) = BNLO BI(NBI) + DBN	DRVUPW	303
	WLO BI(NBI) = 1.E+04/BNHI BI(NBI)	DRVUPW	304
	WHI BI(NBI) = 1.E+04/BNLO BI(NBI)	DRVUPW	305
	BKGND BI(NBI) = 0.	DRVUPW	306
	TRANS BI(NBI) = 0.	DRVUPW	307
	TFLAG BI(NBI) = 0.	DRVUPW	308
	IF(I .EQ. 1) TFLAG BI(NBI) = 1.	DRVUPW	309
	IF(I .GT. 1 .AND. I .EQ. LINT) TFLAG BI(NBI) = 2.	DRVUPW	310
C		DRVUPW	311
C	SET WORD-5 OF DATASET-BN, LINTV BN(NBN), WHICH IS A POINTER TO	DRVUPW	312
C	THE LIST HEADER FOR THE DATASET-BI. THERE IS, OF COURSE, A	DRVUPW	313
C	DIFFERENT POINTER FOR EACH DATASET-BN. USE OF SUBROUTINE	DRVUPW	314
C	PUTBOT MEANS THAT THE HIGHEST WAVELENGTH (OR LOWEST WAVENUMBER	DRVUPW	315
C	) IS ON THE BOTTOM OF THE LIST.	DRVUPW	316
	CALL PUTBOT (LINTV BN(NBN), NBI)	DRVUPW	317
	101 CONTINUE	DRVUPW	318
C		DRVUPW	319
C	GET LBAND, THE POINTER TO THE LIST HEADER FOR DATASET-BN. IF	DRVUPW	320
C	THE INPUT BANDS ARE ORDERED WITH RESPECT TO INCREASING VALUES	DRVUPW	321
C	OF ALAM? (ASSUMING ALAM? .GT. ALAM1), THEN USE OF SUBROUTINE	DRVUPW	322
C	PUTBOT MEANS THAT THE HIGHEST WAVELENGTH (OR LOWEST WAVENUMBER	DRVUPW	323
C	) IS ON THE BOTTOM OF THE LIST.	DRVUPW	324
C		DRVUPW	325
	CALL PUTBOT (LBAND, NBN)	DRVUPW	326
	GO TO 100	DRVUPW	327
CC		DRVUPW	328
C	BAND-LIMIT WAVENUMBERS ARE INPUT.	DRVUPW	329
	102 WMIN = AMIN1 (W1, W2)	DRVUPW	330
	WMAX = AMAX1 (W1, W2)	DRVUPW	331
	ALMIN = 1.E+04/WMAX	DRVUPW	332
	ALMAX = 1.E+04/WMIN	DRVUPW	333
C	CREATE THE 5-WORD DATASET-BN AND SET THE FIRST FOUR WORDS.	DRVUPW	334
	CALL CREATE (5, NBN)	DRVUPW	335
	BNLO BN(NBN) = ALMIN	DRVUPW	336
	BNHI BN(NBN) = ALMAX	DRVUPW	337
	WLO BN(NBN) = WMIN	DRVUPW	338
	WHI BN(NBN) = WMAX	DRVUPW	339
	DWN = (WHI BN(NBN) - WLO BN(NBN)) / FLOAT(LINT)	DRVUPW	340
	WRITE(6,303) ALMIN, ALMAX, WLO BN(NBN), WHI BN(NBN),	DRVUPW	341
*	FLOAT(LINT), DWN	DRVUPW	342
C		DRVUPW	343

C	LOOP DO-103 IS PATTERNED AFTER LOOP DO-702 IN GRC'S	DRVUPW	344
C	PROGRAM ATKGEN.	DRVUPW	345
	DO 103 I=1,LINT	DRVUPW	346
C	CREATE THE 8-WORD DATASET-BI AND SET THE FIRST SEVEN WORDS.	DRVUPW	347
	CALL CREATE (B, NBI)	DRVUPW	348
	WLO BI(NBI) = WLO BN(NBN) + FLOAT(I-1)*DWN	DRVUPW	349
	WHI BI(NBI) = WLO BI(NBI) + DWN	DRVUPW	350
	BNLO BI(NBI) = 1.E+04/WHI BI(NBI)	DRVUPW	351
	BNHI BI(NBI) = 1.E+04/WLO BI(NBI)	DRVUPW	352
	BKGD BI(NBI) = 0.	DRVUPW	353
	TRANS BI(NBI) = 0.	DRVUPW	354
	TFLAG BI(NBI) = 0.	DRVUPW	355
	IF(I .EQ. 1) TFLAG BI(NBI) = 2.	DRVUPW	356
	IF(I .GT. 1 .AND. I .EQ. LINT) TFLAG BI(NBI) = 1.	DRVUPW	357
C		DRVUPW	358
C	SET WORD-5 OF DATASET-BN. USE OF PUTTOP MEANS THAT THE LOWEST	DRVUPW	359
C	WAVENUMBER (OR HIGHEST WAVELENGTH) IS ON THE BOTTOM OF THE	DRVUPW	360
C	LIST.	DRVUPW	361
	CALL PUTTOP (LINRV BN(NBN), NBI)	DRVUPW	362
	103 CONTINUE	DRVUPW	363
C		DRVUPW	364
C	GET LHV (LBAND) FOR DATASET-BN. IF THE INPUT BANDS ARE	DRVUPW	365
C	ORDERED WITH RESPECT TO INCREASING VALUES OF W1 (ASSUMING W2	DRVUPW	366
C	.GT. W1), THEN USE OF PUTTOP MEANS THAT THE LOWEST WAVENUMBER	DRVUPW	367
C	(OR HIGHEST WAVELENGTH) IS ON THE BOTTOM OF THE LIST.	DRVUPW	368
	CALL PUTTOP (LBAND, NBN)	DRVUPW	369
	GO TO 100	DRVUPW	370
	105 NBANDS = MINO(J, 5)	DRVUPW	371
CCC		DRVUPW	372
CC	* * * COMPUTE BAND-MODEL PARAMETERS AFTER SETTING PARAMETERS IN	DRVUPW	373
CC	XYZCOM AND OPTION COMMONS NEEDED FOR SUBROUTINE TRANSB.	DRVUPW	374
	ITMTE = 2 \$ LTMTE = 3	DRVUPW	375
	READ (5,301) TRNSOPT	DRVUPW	376
	WRITE(6,304) TRNSOPT	DRVUPW	377
	CALL TRANSB (LBAND)	DRVUPW	378
CCC		DRVUPW	379
CC	* * * INITIALIZE ATMOSPHERIC SHELLS AFTER SETTING PARAMETER IN	DRVUPW	380
CC	XYZCOM COMMON.	DRVUPW	381
	READ (5,300) FACT	DRVUPW	382
	WRITE(6,302) FACT	DRVUPW	383
	CALL SHELLS	DRVUPW	384
CCF		DRVUPW	385
CC	* * * PREPARE TO CALL SUBROUTINE UPWELL BY SETTING NEEDED PARAMETERS	DRVUPW	386
CC	IN VARIOUS COMMONS.	DRVUPW	387
CC	* SET PARAMETERS IN AEROK COMMON.	DRVUPW	388
	READ (5,315) KVIS, KPTYPE	DRVUPW	389
	WRITE(6,317) KVIS, KPTYPE	DRVUPW	390
CC	* SET PARAMETER IN OPTINI COMMON.	DRVUPW	391
	READ (5,301) RADSW	DRVUPW	392
	WRITE(6,305) RADSW	DRVUPW	393
CC	* SET PARAMETERS IN UPWELS COMMON.	DRVUPW	394
	UPWALT = 0.0 \$ UPWLN = PLON \$ UPWLAT = PLAT	DRVUPW	395
	READ (5,315) NNADIR, NAZI	DRVUPW	396
	WRITE(6,319) NNADIR, NAZI	DRVUPW	397
CC	* SET PARAMETER IN XYZCOM COMMON. NOTE NMOLS IS KNOWN AS NMOLS	DRVUPW	398
CC	IN SUBROUTINE ATMRAD BUT AS NSPEC IN SUBROUTINE TRANS.	DRVUPW	399
	NMOLS = 10	DRVUPW	400

CC	* SET TWO OF THE PARAMETERS FOR SUBROUTINE UPWELL ARGUMENT LIST	DRVUPW	401
	READ (5,315) MSM	DRVUPW	402
	WRITE(6,321) MSM	DRVUPW	403
	SPCULR = .FALSE.	DRVUPW	404
	IF(MSM .EQ. 2) READ (5,301) SPCULR	DRVUPW	405
	WRITE(6,322) SPCULR	DRVUPW	406
CCC		DRVUPW	407
CC	* * * LOOP OVER BROAD BANDS WITH CALLS TO SUBROUTINES SETALT AND	DRVUPW	408
CC	UPWELL. THE PORTION OF THIS LOOP THROUGH THE CALL TO	DRVUPW	409
CC	SUBROUTINE UPWELL (BUT WITHOUT THE SUBSEQUENT PRINT) IS	DRVUPW	410
CC	PATTERNED AFTER THAT IN THE GRC PROGRAM OLOOK.	DRVUPW	411
CC	USE OF PREV IN STATEMENT LABELS 106 AND 107 MEANS THAT BOTH	DRVUPW	412
CC	BANDS AND BAND INTERVALS ARE BEING PROCESSED IN ORDER OF	DRVUPW	413
CC	INCREASING WAVENUMBERS.	DRVUPW	414
C	ON THE FIRST CALL TO SUBROUTINE PREV, THE INPUT VALUE OF	DRVUPW	415
C	LHBAND IS EQUAL TO LBAND, THE (1-FIELD) POINTER TO THE (2-	DRVUPW	416
C	FIELD) LIST HEADER FOR DATASET-BN, WHEREAS THE RETURN VALUE OF	DRVUPW	417
C	LHBAND IS THE LAST (3-FIELD) LINK-WORD FOR DATASET-BN AND THE	DRVUPW	418
C	RETURN VALUE OF NBN, THE DATASET-BN INDEX (OR POINTER), IS THE	DRVUPW	419
C	Q-ARRAY ADDRESS OF THE FIRST (NOT ZEROth) WORD OF DATASET-BN.	DRVUPW	420
C	SUCCESSIVE CALLS TO PREV RETURN SUCCESSIVE LINK WORDS AS THE	DRVUPW	421
C	VARIABLE LHBAND UNTIL THE LAST CALL (WHICH RETURNS ZERO FOR	DRVUPW	422
C	THE DATASET INDEX NBN) RETURNS THE (2-FIELD) LIST HEADER AS	DRVUPW	423
C	THE WORD FOR LHBAND.	DRVUPW	424
	J = 0	DRVUPW	425
	LHBAND = LBAND	DRVUPW	426
106	CALL PREV (LHBAND, NBN)	DRVUPW	427
	IF(NBN .EQ. 0) GO TO 110	DRVUPW	428
	J = J + 1	DRVUPW	429
	IF(J .GT. 5) GO TO 110	DRVUPW	430
	I = 0	DRVUPW	431
C	LBINT IS SAVED FOR CALL TO SUBROUTINE UPWELL.	DRVUPW	432
	LBINT = LINRV BN(NBN)	DRVUPW	433
	LINT = LINRV BN(NBN)	DRVUPW	434
107	CALL PREV (LINT, NBI)	DRVUPW	435
	IF(NBI .EQ. 0) GO TO 108	DRVUPW	436
	I = I + 1	DRVUPW	437
	IF(I .GT. 10) GO TO 108	DRVUPW	438
	WW(I) = 0.5*(WHI BI(NBI) + WLO BI(NBI))	DRVUPW	439
	DW(I) = ABS(WHI BI(NBI) - WLO BI(NBI))	DRVUPW	440
C	ALAM(I) AND DLAM(I) ARE USED ONLY IN PRINTING THE RESULTS SO	DRVUPW	441
C	THAT BOTH WAVENUMBERS AND WAVELENGTHS ARE READILY AVAILABLE.	DRVUPW	442
	ALAM(I) = 1.E+04/WW(I)	DRVUPW	443
	DLAM(I) = ABS(BNHI BI(NBI) - BNLO BI(NBI))	DRVUPW	444
	GO TO 107	DRVUPW	445
108	CONTINUE	DRVUPW	446
	NWAVE(J) = MINO(I, 10)	DRVUPW	447
	NWAVEJ = NWAVE(J)	DRVUPW	448
CC	* SET ARGUMENT-LIST PARAMETERS FOR SUBROUTINE SETALT.	DRVUPW	449
	ALMAX = 1.E+04/(WW(1)-0.5*DW(1))	DRVUPW	450
	ALMIN = 1.E+04/(WW(NWAVEJ)+0.5*DW(NWAVEJ))	DRVUPW	451
	ALMIN = AMAX1 (ALMIN, 2.0)	DRVUPW	452
	ALMAX = AMIN1 (ALMAX, 5.0)	DRVUPW	453
	CALL SETALT (ALMIN, ALMAX, J)	DRVUPW	454
CC	NOTE THAT SUBROUTINE SETALT OUTPUTS, THROUGH UPWELS COMMON,	DRVUPW	455
CC	NALT(J) AND ZKM(II,J).	DRVUPW	456
CC	* NOW READY TO CALL SUBROUTINE UPWELL.	DRVUPW	457

REWIND 8	DRVUPW	458
CALL UPWELL (MSM, DO, WW, DW, SPCULR, LBINT, J)	DRVUPW	459
CC	DRVUPW	460
CC	DRVUPW	461
CC	DRVUPW	462
CC	DRVUPW	463
CC	DRVUPW	464
CC	DRVUPW	465
CC	DRVUPW	466
CC	DRVUPW	467
CC	DRVUPW	468
CC	DRVUPW	469
CC	DRVUPW	470
CC	DRVUPW	471
CC	DRVUPW	472
CC	DRVUPW	473
CC	DRVUPW	474
CC	DRVUPW	475
CC	DRVUPW	476
CC	DRVUPW	477
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CC	DRVUPW	509
CC	DRVUPW	510
CC	DRVUPW	511
CC	DRVUPW	512
CC	DRVUPW	513
CC	DRVUPW	514

CCC	WRITE(6,413)	DRVUPW	515
413	FORMAT (1H0,1X,*AZIMUTH-AVERAGED RESULTS*/3X,*NO CLOUDS*/2X,21H N	DRVUPW	516
	\$ADIR / WAVENUMBER.,5X,13HUPRADA(I,J,L))	DRVUPW	517
	DO 465 JJ=1,MNADIR	DRVUPW	518
	WRITE(6,411) JJ, (UPRADA(II,JJ,LL),LL=1,NWAVEJ)	DRVUPW	519
411	FORMAT (2X, 15 ,1P10E12.4)	DRVUPW	520
465	CONTINUE	DRVUPW	521
CCC		DRVUPW	522
	IF((CLDFLG .EQ. 0.0) .OR. (ZKM(II,J) .LT. 12.0)) GO TO 475	DRVUPW	523
	WRITE(6,613)	DRVUPW	524
613	FORMAT (1H0,3X,*WITH CLOUDS*/2X,21H NADIR / WAVENUMBER.,5X,82HARC	DRVUPW	525
	\$VA(I,J,L), R010A(I,J,L), R025A(I,J,L), R050A(I,J,L), R090A(I,J,L),	DRVUPW	526
	\$ R100A(I,J,L))	DRVUPW	527
	IC = IC + 1	DRVUPW	528
	DO 665 JJ=1,MNADIR	DRVUPW	529
	WRITE(6,6110) JJ, (ARCVN(IC,JJ,LL),LL=1,NWAVEJ)	DRVUPW	530
	WRITE(6,6111) JJ, (R010A(IC,JJ,LL),LL=1,NWAVEJ)	DRVUPW	531
	WRITE(6,6112) JJ, (R025A(IC,JJ,LL),LL=1,NWAVEJ)	DRVUPW	532
	WRITE(6,6113) JJ, (R050A(IC,JJ,LL),LL=1,NWAVEJ)	DRVUPW	533
	WRITE(6,6114) JJ, (R090A(IC,JJ,LL),LL=1,NWAVEJ)	DRVUPW	534
	WRITE(6,6115) JJ, (R100A(IC,JJ,LL),LL=1,NWAVEJ)	DRVUPW	535
6110	FORMAT (1X, 14 , 6H ARCVN,1P10E12.4)	DRVUPW	536
6111	FORMAT (1X, 14 , 6H R010A,1P10E12.4)	DRVUPW	537
6112	FORMAT (1X, 14 , 6H R025A,1P10E12.4)	DRVUPW	538
6113	FORMAT (1X, 14 , 6H R050A,1P10E12.4)	DRVUPW	539
6114	FORMAT (1X, 14 , 6H R090A,1P10E12.4)	DRVUPW	540
6115	FORMAT (1X, 14 , 6H R100A,1P10E12.4)	DRVUPW	541
665	CONTINUE	DRVUPW	542
475	CONTINUE	DRVUPW	543
CCC		DRVUPW	544
	WRITE(6,414)	DRVUPW	545
414	FORMAT (1H0,10X,*AZIMUTH- AND NADIR-AVERAGED RESULTS VS ALTITUDE*)	DRVUPW	546
	WRITE(6,415)	DRVUPW	547
415	FORMAT (1H0,1X,*NO CLOUDS*/2X,17HALT / WAVENUMBER.,5X,*UPRADN(I,L,	DRVUPW	548
	\$J)*)	DRVUPW	549
	DO 490 II=1,NALTJ	DRVUPW	550
	WRITE(6,417) ZKM(II,J), (UPRADN(II,LL,J),LL=1,NWAVEJ)	DRVUPW	551
417	FORMAT (2X,F7.2,1P10E12.4)	DRVUPW	552
490	CONTINUE	DRVUPW	553
CCC		DRVUPW	554
	IF(CLDFLG .EQ. 0.0) GO TO 109	DRVUPW	555
	IC = 0	DRVUPW	556
	WRITE(6,615)	DRVUPW	557
615	FORMAT (1H0,1X,*WITH CLOUDS*/2X,17HALT / WAVENUMBER.,5X,*ARCVN(I,L	DRVUPW	558
	\$), R010N(I,L), R025N(I,L), R050N(I,L), R090N(I,L), R100N(I,L)*)	DRVUPW	559
	DO 690 II=1,NALTJ	DRVUPW	560
	IF(ZKM(II,J) .LT. 12.0) GO TO 690	DRVUPW	561
	IC = IC + 1	DRVUPW	562
	WRITE(6,6170) ZKM(II,J), (ARCVN(IC,LL),LL=1,NWAVEJ)	DRVUPW	563
	WRITE(6,6171) ZKM(II,J), (R010N(IC,LL),LL=1,NWAVEJ)	DRVUPW	564
	WRITE(6,6172) ZKM(II,J), (R025N(IC,LL),LL=1,NWAVEJ)	DRVUPW	565
	WRITE(6,6173) ZKM(II,J), (R050N(IC,LL),LL=1,NWAVEJ)	DRVUPW	566
	WRITE(6,6174) ZKM(II,J), (R090N(IC,LL),LL=1,NWAVEJ)	DRVUPW	567
	WRITE(6,6175) ZKM(II,J), (R100N(IC,LL),LL=1,NWAVEJ)	DRVUPW	568
6170	FORMAT (1X, F6.2 , 6H ARCVN,1P10E12.4)	DRVUPW	569
6171	FORMAT (1X, F6.2 , 6H R010N,1P10E12.4)	DRVUPW	570
		DRVUPW	571

6172	FORMAT (1X, F6.2 , 6H R025N,1P10E12.4)	DRVUPW	572
6173	FORMAT (1X, F6.2 , 6H R050N,1P10E12.4)	DRVUPW	573
6174	FORMAT (1X, F6.2 , 6H R090N,1P10E12.4)	DRVUPW	574
6175	FORMAT (1X, F6.2 , 6H R100N,1P10E12.4)	DRVUPW	575
690	CONTINUE	DRVUPW	576
109	GO TO 106	DRVUPW	577
110	CONTINUE	DRVUPW	578
200	STOP	DRVUPW	579
CC		DRVUPW	580
300	FORMAT (8E10.0)	DRVUPW	581
301	FORMAT(L10)	DRVUPW	582
302	FORMAT (1H0,1X, 6HFACT =,F6.2)	DRVUPW	583
303	FORMAT (1P 6E15.5)	DRVUPW	584
304	FORMAT (1H0,1X, 9HTRNSOPT =,L2)	DRVUPW	585
305	FORMAT (1H0,1X, 7HRAOSW =,L2)	DRVUPW	586
315	FORMAT (3I10, 3E10.0)	DRVUPW	587
316	FORMAT (1H0,1X, 6HIYRS =,I3,7X,7HIMONS =,I3,7X,7HIDAYS =,I3,7X,4HZ \$T =,F6.3,4X,5HGCO =,F8.3,3X,5HGLO =,F8.3)	DRVUPW	588
317	FORMAT (1H0,1X, 6HKVIS =,I2,7X,8HKPTYPE =,I2)	DRVUPW	589
318	FORMAT (1H0,1X, 8HCLOFLG =,F3.0)	DRVUPW	590
319	FORMAT (1H0,1X, 8HNNADIR =,I2,7X,6HNAZI =,I2)	DRVUPW	591
320	FORMAT (4E10.0, 110)	DRVUPW	592
321	FORMAT (1H0,1X, 5HMSM =,I2)	DRVUPW	593
322	FORMAT (1H0,1X, 8HSPCULR =,L2)	DRVUPW	594
323	FORMAT (1H0,1X,5025)	DRVUPW	595
	END	DRVUPW	596
		DRVUPW	597

	FUNCTION ACCUM(ITYPE, X1, X2, F1, F2, A, B)	ACCUM	2
C		ACCUM	3
CLJ	FUNCTION ACCUM INTEGRATES BETWEEN X=A AND X=B A FUNCTION F(X)	ACCUM	4
CLJ	GIVEN AT TWO POINTS X1 AND X2 BY LINEAR, LOGARITHMIC, OR	ACCUM	5
CLJ	POWER-LAW INTERPOLATION, CORRESPONDING TO ITYPE=1,2,3 ,	ACCUM	6
CLJ	RESPECTIVELY. LINEAR INTERPOLATION IS ASSUMED IN CASE THE	ACCUM	7
CLJ	OTHER METHODS WOULD FAIL.	ACCUM	8
C		ACCUM	9
	GO TO (1, 2, 3), ITYPE	ACCUM	10
1	ACCUM = .5 / (X2 - X1) * (F2 * ((B - X1)**2 - (A - X1)**2)	ACCUM	11
1	- F1 * ((B - X2)**2 - (A - X2)**2))	ACCUM	12
	RETURN	ACCUM	13
2	IF (F1 * F2 .LE. 0.) GO TO 1	ACCUM	14
	IF (ABS(1. - F1 / F2) .LT. 0.01) GO TO 1	ACCUM	15
	ALNR = ALOG(F2 / F1)	ACCUM	16
	ACCUM = F1 / ALNR * (EXP((B - X1) / (X2 - X1) * ALNR) -	ACCUM	17
1	EXP((A - X1) / (X2 - X1) * ALNR)) * (X2 - X1)	ACCUM	18
	RETURN	ACCUM	19
3	IF (X1 * X2 .LE. 0. .OR. F1 * F2 .LE. 0.) GO TO 1	ACCUM	20
	EVAL = ALOG(F2 / F1) / ALOG(X2 / X1)	ACCUM	21
	IF (ABS(EVAL) .GT. 10.) GO TO 1	ACCUM	22
	ACCUM = F1 / ((EVAL + 1.) * X1**EVAL) * (B** (EVAL + 1.) -	ACCUM	23
1	A** (EVAL + 1.))	ACCUM	24
	RETURN	ACCUM	25
	END	ACCUM	26

CCC	SUBROUTINE AEROSOL(HCM,LAMDA,XKSC,T,XKABS,GBAR)	AEROSOL	2
C		AEROSOL	3
C	SUBROUTINE AEROSOL COMPUTES ATTENUATION COEFFICIENTS FOR	AEROSOL	4
C	SCATTERING AND ABSORPTION AND THE ASYMMETRY FACTOR (AVERAGE	AEROSOL	5
C	COSINE OF THE SCATTERING ANGLE) DUE TO ATMOSPHERIC AEROSOLS.	AEROSOL	6
C	THIS PROGRAM IS BASED DIRECTLY ON THE WORK OF E.P. SHETTLE AND	AEROSOL	7
C	R.W. FENN OF AFGL AND USES A PORTION OF MATERIAL WHICH WILL	AEROSOL	8
C	APPEAR IN A FORTHCOMING DOCUMENT (AFGL-TR-77-XXXX), 'MODELS OF	AEROSOL	9
C	THE ATMOSPHERIC AEROSOLS AND THEIR OPTICAL PROPERTIES' BY E.P.	AEROSOL	10
C	SHETTLE AND R.W. FENN.	AEROSOL	11
C	IN SUBROUTINE AEROSOL, THE WAVELENGTH REGION IS RESTRICTED TO 2-5	AEROSOL	12
C	MICRONS AND PROPERTIES ARE PRESENTED FOR AVERAGE SEASONAL CONDI-	AEROSOL	13
C	TIONS ONLY AND FOR ALTITUDES LESS THAN 100 KM. THE ALTITUDE	AEROSOL	14
C	REGION FROM SEA LEVEL TO 100 KM IS DIVIDED INTO FOUR REGIONS...	AEROSOL	15
C	A BOUNDARY LAYER 0-2 KM	AEROSOL	16
C	B TROPOSPHERE 2-9 KM	AEROSOL	17
C	C STRATOSPHERE 9-30 KM	AEROSOL	18
C	D UPPER ATMOSPHERE 30-100 KM	AEROSOL	19
C	IN THE TROPOSPHERE AND THE BOUNDARY LAYER REGION, PROPERTIES ARE	AEROSOL	20
C	COMPUTED FOR ONE OF FIVE VISIBILITY RANGES (50,23,10,5,2 KM) AND	AEROSOL	21
C	IN THE BOUNDARY LAYER, FOR ONE OF THREE TERRAIN TYPES (RURAL,	AEROSOL	22
C	URBAN, AND MARITIME). IN THE STRATOSPHERE A CONTRIBUTION FROM	AEROSOL	23
C	VOLCANIC AEROSOLS IS ALSO ADDED TO THAT FROM BACKGROUND AEROSOLS.	AEROSOL	24
C	THE ABSORPTION COEFFICIENTS ARE COMPUTED AS A PRODUCT OF A SCALE	AEROSOL	25
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C	DIFFERENT MODELS TIMES ATTENUATION COEFFICIENTS FOR THE	AEROSOL	27
C	SCATTERING, ABSORPTION AND THE ASYMMETRY FACTOR AS FUNCTIONS OF	AEROSOL	28
C	WAVELENGTH NORMALIZED TO THE EXTINCTION COEFFICIENT AT 0.55	AEROSOL	29
C	MICRONS.	AEROSOL	30
CCC		AEROSOL	31
CLJ		AEROSOL	32
CLJ	VERSION 1 OF THE VISIDYNE-SUPPLIED AEROSOL ROUTINE WAS RECEIVED ON	AEROSOL	33
CLJ	10/13/77. WE HAVE LEFT GBAR, THE ASYMMETRY FACTOR, IN THE ARGU-	AEROSOL	34
CLJ	MENT LIST BUT HAVE COMMENTED OUT THE STATEMENTS WHICH EVALUATE	AEROSOL	35
CLJ	GBAR BECAUSE OUR TREATMENT OF AEROSOL TRANSMITTANCE DOES NOT USE	AEROSOL	36
CLJ	IT. OUR TREATMENT PROVIDES FOR ATTENUATION BY ABSORPTION AND	AEROSOL	37
CLJ	SCATTERING OUT OF THE BEAM BUT FOR NO SCATTERING INTO THE BEAM.	AEROSOL	38
CLJ	IT WAS OUR UNDERSTANDING THAT G.E.TEMPO (EWING, 10/18/77) ALSO	AEROSOL	39
CLJ	PLANNED TO ACCOUNT ONLY FOR SINGLE SCATTERING OF AEROSOLS (AS	AEROSOL	40
CLJ	OPPOSED TO ACCOUNTING FOR MULTIPLE SCATTERING WITHIN NUCLEAR	AEROSOL	41
CLJ	CLOUDS). ON THIS BASIS WE INTEGRATED SUBROUTINE AEROSOL INTO OUR	AEROSOL	42
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CLJ	INSTEAD OF KILOMETERS.	AEROSOL	57
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CLJ	13 DEC 78. THE REVISED SUBROUTINE AERSOL IN THIS REPORT	AERSOL	66
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CLJ	LAMDA=5.0 MICRONS. HOWEVER, SAI HAS RETAINED ITS OWN	AERSOL	68
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CLJ	= 2 CORRESPONDS TO VISIBILITY RANGE = 23 KM	AERSOL	79
CLJ	= 3 CORRESPONDS TO VISIBILITY RANGE = 10 KM	AERSOL	80
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CLJ	= 5 CORRESPONDS TO VISIBILITY RANGE = 2 KM	AERSOL	82
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CLJ	= 2 TERRAIN = URBAN	AERSOL	85
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	1	SCATB(12), ABSOBB(12),	SCATC(12,2),	AERSOL	116
		2ABS0BC(12,2),	SCATD(12), ABS0BD(12),	AERSOL	117
		3 SCAL2(8,2), SCAL3(22), SCAL4(22), SCAL5(15)		AERSOL	118
CC		DIMENSION ASYMA(12,4), ASYMB(12), ASYMC(12,2), ASYMD(12)		AERSOL	119
		COMMON/AEROK / KVIS, KPTYPE		AEROKO	2
		REAL LAMDA		AERSOL	121
		DATA(WAVE(1), I=1,12)/2.0,2.25,2.5,2.7,3.0,3.2,3.392,3.5,3.75,4.0,4		AERSOL	122
		1.5,5.0/		AERSOL	123
		DATA(HITE(I), I=1,4)/0.0,1.0,1.5,2.0/		AERSOL	124
		DATA(SCAL1(I,1), I=1,4)/6.95E-2,2.58E-2,1.81E-2,9.70E-3/		AERSOL	125
		DATA(SCAL1(I,2), I=1,4)/1.57E-1,9.90E-2,7.92E-2,6.21E-2/		AERSOL	126
		DATA(SCAL1(I,3), I=1,4)/3.72E-1,3.72E-1,3.72E-1,6.21E-2/		AERSOL	127
		DATA(SCAL1(I,4), I=1,4)/7.57E-1,7.57E-1,7.57E-1,6.21E-2/		AERSOL	128
		DATA(SCAL1(I,5), I=1,4)/1.88,1.88,1.88,6.21E-2/		AERSOL	129
		DATA(SCATA(I,1), I=1,12)/1.312E-1,1.140E-1,1.016E-1,7.835E-2,		AERSOL	130
		18.330E-2,9.339E-2,9.251E-2,9.598E-2,9.394E-2,9.001E-2,		AERSOL	131
		28.011E-2,7.672E-2/		AERSOL	132
		DATA(ABSOBA(I,1), I=1,12)/2.763E-2,2.894E-2,2.932E-2,6.559E-2,		AERSOL	133
		13.696E-2,2.046E-2,1.979E-2,1.583E-2,1.357E-2,1.465E-2,		AERSOL	134
		22.219E-2,2.033E-2/		AERSOL	135
CC		DATA(ASYMA(I,1), I=1,12)/.715,.7306,.7459,.7863,.7714,.7491,.7456,		AERSOL	136
CC		1.7316,.7337,.7390,.7560,.7636/		AERSOL	137
		DATA(SCATA(I,2), I=1,12)/1.129E-1,9.833E-2,8.758E-2,7.286E-2,		AERSOL	138
		17.209E-2,7.572E-2,7.383E-2,7.500E-2,7.258E-2,6.939E-2,		AERSOL	139
		16.220E-2,5.900E-2/		AERSOL	140
		DATA(ABSOBA(I,2), I=1,12)/1.339E-1,1.240E-2,1.157E-1,1.288E-1		AERSOL	141
		1,1.075E-1,9.346E-2,8.966E-2,8.610E-2,8.063E-2,7.739E-2,		AERSOL	142
		27.474E-2,6.824E-2/		AERSOL	143
CC		DATA(ASYMA(I,2), I=1,12)/.649,.6609,.6730,.6900,.6937,.6894,		AERSOL	144
CC		1.6907,.6841,.6887,.6943,.7099,.7193/		AERSOL	145
		DATA(SCATA(I,3), I=1,12)/7.159E-1,6.772E-1,6.093E-1,4.399E-1,		AERSOL	146
		13.271E-1,4.594E-1,5.670E-1,5.849E-1,5.645E-1,5.289E-1,		AERSOL	147
		24.520E-1,4.072E-1/		AERSOL	148
		DATA(ABSOBA(I,3), I=1,12)/1.380E-2,1.062E-2,2.125E-2,9.134E-2,		AERSOL	149
		13.327E-1,2.208E-1,8.004E-2,4.164E-2,1.718E-2,1.985E-2,		AERSOL	150
		24.247E-2,3.660E-2/		AERSOL	151
CC		DATA(ASYMA(I,3), I=1,12)/.7857,.7931,.8114,.8611,.8205,.7724		AERSOL	152
CC		1,.7448,.7413,.7475,.7530,.7630,.7645/		AERSOL	153
		DATA (SCAL2(I,1), I=1,8) / 9.70E-3,9.25E-3,8.32E-3,7.08E-3,5.63E-3,		AERSOL	154
		1 4.26E-3,2.39E-3,1.40E-3 /		AERSOL	155
		DATA (SCAL2(I,2), I=1,8) / 6.21E-2,3.09E-2,1.53E-2,7.08E-3,5.63E-3,		AERSOL	156
		1 4.26E-3,2.39E-3,1.40E-3 /		AERSOL	157
		DATA(SCATB(I), I=1,12)/6.761E-2,5.005E-2,3.797E-2,2.650E-2,		AERSOL	158
		12.394E-2,2.350E-2,2.133E-2,2.174E-2,1.838E-2,1.564E-2,		AERSOL	159
		21.159E-2,8.487E-3/		AERSOL	160
		DATA(ABSOBB(I), I=1,12)/1.092E-2,1.146E-2,1.157E-2,3.891E-2,		AERSOL	161
		11.589E-2,6.769E-3,6.481E-3,4.826E-3,4.017E-3,4.343E-3,		AERSOL	162
		27.013E-3,6.233E-3/		AERSOL	163
CC		DATA(ASYMB(I), I=1,12)/.5828,.5688,.5551,.5427,.5305,		AERSOL	164
CC		1.5236,.5166,.5089,.4999,.4910,.4739,.4614/		AERSOL	165
		DATA (SCAL3(I), I=1,22) / 1.40E-3,9.64E-4,7.57E-4,6.53E-4,5.70E-4,		AERSOL	166
		1 5.44E-4,5.19E-4,5.12E-4,5.13E-4,5.41E-4,5.37E-4,5.07E-4,		AERSOL	167
		2 4.28E-4,3.58E-4,2.71E-4,1.94E-4,1.41E-4,1.03E-4,7.87E-5,		AERSOL	168
		3 5.94E-5,4.66E-5,3.32E-5 /		AERSOL	169
		DATA (SCAL4(I), I=1,22) / 1.40E-3,1.62E-3,1.95E-3,2.33E-3,2.77E-3,		AERSOL	170
		1 2.89E-3,2.92E-3,2.74E-3,2.46E-3,2.10E-3,1.71E-3,1.35E-3,		AERSOL	171
		21.09E-3,8.60E-4,6.60E-4,5.15E-4,4.10E-4,3.20E-4,2.51E-4,		AERSOL	172

	32.10E-4,1.24E-4,7.60E-5/	AERSOL	173
	DATA(SCATC(I,1),I=1,12)/4.055E-2,2.570E-2,1.560E-2,9.308E-2,	AERSOL	174
	16.321E-3,6.003E-3,6.274E-3,6.232E-3,5.103E-3,4.030E-3,	AERSOL	175
	22.420E-3,1.449E-3/	AERSOL	176
	DATA(ABSOBC(I,1),I=1,12)/1.282E-3,1.574E-3,2.894E-3,4.030E-3,	AERSOL	177
	15.878E-2,7.671E-2,8.300E-2,7.917E-2,6.019E-2,5.391E-2,	AERSOL	178
	24.552E-2,4.132E-2/	AERSOL	179
CC	DATA(ASYMC(I,1),I=1,12)/.3223,.2686,.2233,.1916,.1580,.1416,	AERSOL	180
CC	1.1299,.1242,.1108,.0983,.0780,.0629/	AERSOL	181
	DATA(SCATC(I,2),I=1,12)/1.353E-1,1.020E-1,7.792E-2,6.343E-2,	AERSOL	182
	15.126E-2,4.262E-2,3.761E-2,3.435E-2,2.913E-2,2.394E-2,	AERSOL	183
	21.775E-2,1.204E-2/	AERSOL	184
	DATA(ABSOBC(I,2),I=1,12)/1.019E-2,8.668E-3,8.429E-3,8.424E-3,	AERSOL	185
	19.493E-3,9.361E-3,7.431E-3,6.537E-3,4.879E-3,3.487E-3,	AERSOL	186
	23.186E-3,3.347E-3/	AERSOL	187
CC	DATA(ASYMC(I,2),I=1,12)/.5561,5255,.4958,.4729,.4401,.4196,,	AERSOL	188
CC	14015,.3915,.3699,.3490,.3125,.2773/	AERSOL	189
	DATA(SCATD(I),I=1,12)/4.822E-1,4.160E-1,3.574E-1,3.162E-1,	AERSOL	190
	12.645E-1,2.367E-1,2.147E-1,2.042E-1,1.845E-1,1.700E-1,	AERSOL	191
	21.509E-1,1.378E-1/	AERSOL	192
	DATA(ABSOBD(I),I=1,12)/6.161E-2,7.539E-2,8.943E-2,1.005E-1,	AERSOL	193
	11.161E-1,1.254E-1,1.331E-1,1.368E-1,1.435E-1,1.472E-1;	AERSOL	194
	21.463E-1,1.373E-1/	AERSOL	195
CC	DATA(ASYMD(I),I=1,12)/.6989,.7046,.7099,.7133,.7159,.7155,	AERSOL	196
CC	1.7134,.7116,.7058,.6986,.6827,.6687/	AERSOL	197
	DATA(SCAL5(I),I=1,15)/3.32E-5,1.65E-5,8.00E-6,4.02E-6,	AERSOL	198
	12.10E-6,1.09E-6,5.78E-7,3.05E-7,1.60E-7,6.95E-8,2.90E-8,	AERSOL	199
	21.20E-8,5.10E-9,2.15E-9,9.30E-10/	AERSOL	200
C		AERSOL	201
C		AERSOL	202
C		AERSOL	203
	IF((LAMBDA .GE. 2.0) .AND. (LAMBDA .LE. 5.0)) GO TO 1000	AERSOL	204
	WRITE(6,900) LAMBDA	AERSOL	205
	900 FORMAT (1X,*SUBROUTINE AERSOL HAS BEEN ENTERED WITH LAMBDA =*1PE12.	AERSOL	206
	\$5*, WHICH IS OUTSIDE THE ALLOWED RANGE (2.0 TO 5.0 MICRONS).*/\$ ZE	AERSOL	207
	\$RO-VALUES HAVE BEEN ASSIGNED TO THE OUTPUT PARAMETERS XKSCAT AND XK	AERSOL	208
	\$ABS.*)	AERSOL	209
	GO TO 11	AERSOL	210
1000	CONTINUE	AERSOL	211
	H = 1.0E-05 * HCM	AERSOL	212
	IF(H .LT. 0.) STOP	AERSOL	213
	IF(H.GT.100.) GO TO 11	AERSOL	214
	IF(H.GT. 30.) GO TO 4	AERSOL	215
	IF(H.GT. 9.0) GO TO 3	AERSOL	216
	IF(H.GT. 2.0) GO TO 2	AERSOL	217
C		AERSOL	218
C	ALTITUDE=0-2 KM	AERSOL	219
C		AERSOL	220
	1 DO 8 J=2,4	AERSOL	221
	IF(H.GE.HITE(J)) GO TO 8	AERSOL	222
	COMMON=(H-HITE(J-1))/(HITE(J)-HITE(J-1))	AERSOL	223
	ASCAL=SCAL1(J-1,KVIS)-(SCAL1(J-1,KVIS)-SCAL1(J,KVIS))*COMMON	AERSOL	224
	GO TO 5	AERSOL	225
8	CONTINUE	AERSOL	226
	IF(H.EQ.2.0) ASCAL = SCAL1(4,KVIS)	AERSOL	227
5	DO 6 J=2,12	AERSOL	228
	IF(LAMBDA.GT.WAVE(J)) GO TO 6	AERSOL	229

COMMON=(LAMBDA-WAVE(J-1))/(WAVE(J)-WAVE(J-1))	AERSOL	230
KKSCT=SCATA(J-1,KPTYPE)-(SCATA(J-1,KPTYPE)-SCATA(J,KPTYPE))*COMMON	AERSOL	231
KKABS=ABS0BA(J-1,KPTYPE)-(ABS0BA(J-1,KPTYPE)-ABS0BA(J,KPTYPE))*COMMON	AERSOL	232
1*COMMON	AERSOL	233
CC GBAR=ASYMA(J-1,KPTYPE)-(ASYMA(J-1,KPTYPE)-ASYMA(J,KPTYPE))*COMMON	AERSOL	234
GO TO 100	AERSOL	235
6 CONTINUE	AERSOL	236
C	AERSOL	237
C ALTITUDE=2-9 KM	AERSOL	238
C	AERSOL	239
2 IH=H-1.0	AERSOL	240
HI=IH+1	AERSOL	241
J = 2	AERSOL	242
IF(KVIS.EQ.1) J = 1	AERSOL	243
IF(H.NE.9.0) GO TO 12	AERSOL	244
ASCAL = SCAL2(6,J)	AERSOL	245
GO TO 13	AERSOL	246
12 ASCAL = SCAL2(IH,J)-(SCAL2(IH,J)-SCAL2(IH+1,J))*(H-HI)	AERSOL	247
13 DO 7 J=2,12	AERSOL	248
IF(LAMBDA.GT.WAVE(J)) GO TO 7	AERSOL	249
COMMON=(LAMBDA-WAVE(J-1))/(WAVE(J)-WAVE(J-1))	AERSOL	250
KKSCT=SCATB(J-1)-(SCATB(J-1)-SCATB(J))*COMMON	AERSOL	251
KKABS=ABS0BB(J-1)-(ABS0BB(J-1)-ABS0BB(J))*COMMON	AERSOL	252
CC GBAR=ASYMB(J-1)-(ASYMB(J-1)-ASYMB(J))*COMMON	AERSOL	253
GO TO 100	AERSOL	254
7 CONTINUE	AERSOL	255
C	AERSOL	256
C ALTITUDE=9-30 KM	AERSOL	257
C	AERSOL	258
3 IH=H-8.0	AERSOL	259
HI=IH+8	AERSOL	260
IF(H.NE.30.) GO TO 14	AERSOL	261
FBG = SCAL3(22)	AERSOL	262
VOLC = SCAL4(22)	AERSOL	263
GO TO 15	AERSOL	264
14 FBG = SCAL3(IH)-(SCAL3(IH)-SCAL3(IH+1))*(H-HI)	AERSOL	265
VOLC=SCAL4(IH)-(SCAL4(IH)-SCAL4(IH+1))*(H-HI)	AERSOL	266
15 DO 9 J=2,12	AERSOL	267
IF(LAMBDA.GT.WAVE(J)) GO TO 9	AERSOL	268
COMMON=(LAMBDA-WAVE(J-1))/(WAVE(J)-WAVE(J-1))	AERSOL	269
KKSCT1=SCATC(J-1,1)-(SCATC(J-1,1)-SCATC(J,1))*COMMON	AERSOL	270
KKSCT2=SCATC(J-1,2)-(SCATC(J-1,2)-SCATC(J,2))*COMMON	AERSOL	271
KKABS1=ABS0BC(J-1,1)-(ABS0BC(J-1,1)-ABS0BC(J,1))*COMMON	AERSOL	272
KKABS2=ABS0BC(J-1,2)-(ABS0BC(J-1,2)-ABS0BC(J,2))*COMMON	AERSOL	273
KKSCT=KKSCT1*FBG+KKSCT2*VOLC	AERSOL	274
KKABS=KKABS1*FBG+KKABS2*VOLC	AERSOL	275
CC GBAR1=ASYMC(J-1,1)-(ASYMC(J-1,1)-ASYMC(J,1))*COMMON	AERSOL	276
CC GBAR2=ASYMC(J-1,2)-(ASYMC(J-1,2)-ASYMC(J,2))*COMMON	AERSOL	277
CC GBAR=(KKSCT1*GBAR1+KKSCT2*GBAR2)/(KKSCT1+KKSCT2)	AERSOL	278
GO TO 105	AERSOL	279
9 CONTINUE	AERSOL	280
C	AERSOL	281
C ALTITUDE IS GREATER THAN 30 KM	AERSOL	282
C	AERSOL	283
4 IH=((H-30.0)/5.0)+1.01	AERSOL	284
HI=((IH*5)+25	AERSOL	285
IF(H.NE.100.) GO TO 16	AERSOL	286

ASCAL = SCAL5(15)	AERSOL	287
GO TO 17	AERSOL	288
16 ASCAL = SCAL5(IH)-(SCAL5(IH)-SCAL5(IH+1))*(H-HI)/5.0	AERSOL	289
17 DO 10 J=2,12	AERSOL	290
IF(LAMDA.GT.WAVE(J)) GO TO 10	AERSOL	291
COMMON=(LAMDA-WAVE(J-1))/(WAVE(J)-WAVE(J-1))	AERSOL	292
XK SCT=SCATD(J-1)-(SCATD(J-1)-SCATD(J))*COMMON	AERSOL	293
XKABS=ABSOBD(J-1)-(ABSOBD(J-1)-ABSOBD(J))*COMMON	AERSOL	294
GBAR=ASYMD(J-1)-(ASYMD(J-1)-ASYMD(J))*COMMON	AERSOL	295
GO TO 100	AERSOL	296
10 CONTINUE	AERSOL	297
100 XKABS=XKABS*ASCAL	AERSOL	298
XK SCT=XK SCT*ASCAL	AERSOL	299
GO TO 105	AERSOL	300
11 XKABS = 0.0	AERSOL	301
XK SCT = 0.0	AERSOL	302
GBAR = 0.0	AERSOL	303
105 XKABS = 1.0E-05 * XKABS	AERSOL	304
XK SCT = 1.0E-05 * XK SCT	AERSOL	305
RETURN	AERSOL	306
END	AERSOL	307

SUBROUTINE AGAGEO(HA1,GC1,GL1,AZ21,GA21,HA2,GC2,GL2)	AGAGEO	2
CCC	AGAGEO	3
C SUBROUTINE AGAGEO (A MODIFIED HARC ROUTINE), GIVEN THE	AGAGEO	4
C GEOGRAPHIC COORDINATES OF POINT 1, THE AZIMUTH AND EARTH-CENTRAL	AGAGEO	5
C ANGLE OF POINT 2 WITH RESPECT TO POINT 1, AND THE HEIGHT OF	AGAGEO	6
C POINT 2, PROVIDES THE GEOGRAPHIC COORDINATES OF POINT 2.	AGAGEO	7
CCC	AGAGEO	8
C INPUTS FROM CALL STATEMENT	AGAGEO	9
C HA1 = ALTITUDE OF POINT 1, CM	AGAGEO	10
C GC1 = COLATITUDE OF POINT 1, RADIANS	AGAGEO	11
C GL1 = EAST LONGITUDE OF POINT 1, RADIANS	AGAGEO	12
C AZ21 = AZIMUTH ANGLE OF POINT 2 RELATIVE TO POINT 1, RADS	AGAGEO	13
C GA21 = GEOCENTRIC ANGLE OF POINT 2 RELATIVE TO POINT 1, RAD	AGAGEO	14
C HA2 = ALTITUDE OF POINT 2, CM	AGAGEO	15
C OUTPUTS	AGAGEO	16
C GC2 = COLATITUDE OF POINT 2, RADIANS	AGAGEO	17
C GL2 = EAST LONGITUDE OF POINT 2, RADIANS	AGAGEO	18
CCC	AGAGEO	19
DATA PI,RE / 3.141592653590,6.37103E+08 /	AGAGEO	20
CCC	AGAGEO	21
IF(GA21.EQ.0.0) GO TO 100	AGAGEO	22
R1 = RE+HA1	AGAGEO	23
R2 = RE+HA2	AGAGEO	24
SR12 = SQRT(R1*R1 + R2*R2 - 2.*R1*R2*COS(GA21))	AGAGEO	25
IF(SR12.EQ.0.0) GO TO 100	AGAGEO	26
SINX1 = R2*SIN(GA21)/SR12	AGAGEO	27
COSX1 = (SR12**2 + R1**2 - R2**2)/(2.*SR12*R1)	AGAGEO	28
X1 = ATAN2(SINX1,COSX1)	AGAGEO	29
HALFPI = PI/2.	AGAGEO	30
EL21 = X1-HALFPI	AGAGEO	31
CALL REATAN(SR12,EL21,AZ21,XE,YN,ZV)	AGAGEO	32
CALL TANGEO(HA1,GC1,GL1,XE,YN,ZV,HA22,GC2,GL2)	AGAGEO	33
99 RETURN	AGAGEO	34
100 GC2 = GC1	AGAGEO	35
GL2 = GL1	AGAGEO	36
GO TO 99	AGAGEO	37
END	AGAGEO	38

	SUBROUTINE ATMRAD (LOGIC, ISHELL, XFRAC, DS, LBINT)	ATMRAD	2																				
C		ATMRAD	3																				
C	*ATMRAD* COMPUTES THE ATMOSPHERIC VOLUME EMISSION ON AN OPTICAL	ATMRAD	4																				
C	PATH.	ATMRAD	5																				
C		ATMRAD	6																				
CLJ	INPUT PARAMETERS	ATMRAD	7																				
CLJ	ARGUMENT LIST	ATMRAD	8																				
CLJ	LOGIC = LOGICAL VARIABLE	ATMRAD	9																				
CLJ	= .TRUE. ON FIRST ENTRY FROM SUBROUTINE TRNSCO	ATMRAD	10																				
CLJ	(AND IS RESET TO .FALSE. IN ATMRAD).	ATMRAD	11																				
CLJ	= .FALSE. ON SUBSEQUENT ENTRIES ALONG THE SAME PATH	ATMRAD	12																				
CLJ	ISHELL(1) = INDX(1) IN CALL FROM TRNSCO	ATMRAD	13																				
CLJ	ISHELL(2) = INDX(I+1) IN CALL FROM TRNSCO	ATMRAD	14																				
CLJ	ISHELL(3) - USED IN EVALUATING THE LOGICAL VARIABLE TEST.	ATMRAD	15																				
CLJ	WILL TYPICALLY BE EQUAL TO INDX(I+2), A POSITIVE	ATMRAD	16																				
CLJ	QUANTITY EXCEPT ON THE LAST CALL TO ATMRAD WHEN	ATMRAD	17																				
CLJ	THE LAST PATH-SEGMENT IS BEING TREATED AT WHICH	ATMRAD	18																				
CLJ	TIME ISHELL(3) WILL BECOME EQUAL TO INDX(NC+1)	ATMRAD	19																				
CLJ	WHICH HAD BEEN SET TO 0 IN SUBROUTINE STEP.	ATMRAD	20																				
CLJ	XFRAC(1) = XFRACS(1) IN CALL FROM TRNSCO	ATMRAD	21																				
CLJ	XFRAC(2) = XFRACS(I+1) IN CALL FROM TRNSCO	ATMRAD	22																				
CLJ	NOTE... TO UNDERSTAND THE VALUES AND USES OF	ATMRAD	23																				
CLJ	XFRACS(1), RECALL THAT THE TOTAL PATH HAS NC-1	ATMRAD	24																				
CLJ	SEGMENTS AND NC ENDPOINTS OF THESE SEGMENTS.	ATMRAD	25																				
CLJ	XFRACS(1) (I=1,NC) IS THE WEIGHT ASSOCIATED WITH	ATMRAD	26																				
CLJ	THE I-TH ENDPOINT APPROPRIATE FOR FINDING AT THAT	ATMRAD	27																				
CLJ	POINT THE LINEARLY-INTERPOLATED VALUE OF	ATMRAD	28																				
CLJ	PARAMETERS -- SUCH AS TEMPERATURE AND PRESSURE	ATMRAD	29																				
CLJ	(OR EVEN ALTITUDE) -- WHICH ARE SPECIFIED AT THE	ATMRAD	30																				
CLJ	TWO SHELL BOUNDARIES ADJACENT TO THE I-TH	ATMRAD	31																				
CLJ	ENDPOINT.	ATMRAD	32																				
CLJ	FOR VERIFICATION OF THIS INTERPRETATION, SEE THE	ATMRAD	33																				
CLJ	USAGE OF XFRAC(1) AND XFRAC(2) IN SUBROUTINE	ATMRAD	34																				
CLJ	ATMRAD FOR OBTAINING ALTITUDE AND TEMPERATURE AT	ATMRAD	35																				
CLJ	FRONT AND BACK OF CELL DS. THE SAME CONCLUSION	ATMRAD	36																				
CLJ	MAY BE DRAWN FROM THE USAGE OF XFRACS(1) AND	ATMRAD	37																				
CLJ	XFRACS(2) IN SUBROUTINE PATH.	ATMRAD	38																				
CLJ	CONSIDER A HYPOTHETICAL EXAMPLE WITH HShell(1)=0.,	ATMRAD	39																				
CLJ	1.,2.,3. FOR I=1,2,3,4 AND 45-DEGREE PATH FROM	ATMRAD	40																				
CLJ	ALTITUDE 1.9 TO 2.9 KM. THEN NC=3 AND WE HAVE THE	ATMRAD	41																				
CLJ	FOLLOWING VALUES FOR THE ARRAYS.	ATMRAD	42																				
CLJ	<table border="1"> <thead> <tr> <th>I</th> <th>DS(I)</th> <th>XFRACS(I)</th> <th>INDEX(I)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>0.0</td> <td>0.1</td> <td>2</td> </tr> <tr> <td>2</td> <td>0.1414</td> <td>1.0</td> <td>3</td> </tr> <tr> <td>3</td> <td>1.2728</td> <td>0.9</td> <td>4</td> </tr> <tr> <td>4</td> <td>-1.0</td> <td></td> <td>0</td> </tr> </tbody> </table>	I	DS(I)	XFRACS(I)	INDEX(I)	1	0.0	0.1	2	2	0.1414	1.0	3	3	1.2728	0.9	4	4	-1.0		0	ATMRAD	43
I	DS(I)	XFRACS(I)	INDEX(I)																				
1	0.0	0.1	2																				
2	0.1414	1.0	3																				
3	1.2728	0.9	4																				
4	-1.0		0																				
CLJ		ATMRAD	44																				
CLJ		ATMRAD	45																				
CLJ		ATMRAD	46																				
CLJ		ATMRAD	47																				
CLJ		ATMRAD	48																				
CLJ		ATMRAD	49																				
CLJ	DS = DS(I+1) IN CALL FROM TRNSCO	ATMRAD	50																				
CLJ	NOTE... IT IS ALWAYS TRUE THAT DS(1)=0 AND	ATMRAD	51																				
CLJ	DS(NC+1)=-1., WHERE NC IS THE NUMBER OF PATH	ATMRAD	52																				
CLJ	SEGMENTS PLUS ONE. ATMRAD WILL NOT BE CALLED	ATMRAD	53																				
CLJ	WITH I=NC. (CM)	ATMRAD	54																				
CLJ	LBINT = WORD NO. 5 IN GRC'S DATASET-BN (NO. 114).	ATMRAD	55																				
CLJ	STRICTLY, LBINT IS THE POINTER (I.E., CONTAINS THE	ATMRAD	56																				
CLJ	(0-ARRAY) ADDRESS) FOR THE LIST HEADER OF THE	ATMRAD	57																				
CLJ	BAND-INTERVAL DATASETS-BI CORRESPONDING TO	ATMRAD	58																				

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CLJ			ATMRAD	60
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CLJ		SET IN DRIVER PROGRAM. HERE IN SUBROUTINE ATMRAD,	ATMRAD	63
CLJ		FACT IS USED TO SET TOL, WHICH IS USED TO TEST	ATMRAD	64
CLJ		TEMPERATURE DIFFERENCES ACROSS CELLS.	ATMRAD	65
CLJ	HSHELL(J)	= ALTITUDE BOUNDARY, CM (J=1,NS) (HSHELL(1)=0.)	ATMRAD	66
CLJ	TS(J)	= TEMPERATURE AT ALTITUDE BOUNDARY J, DEG K	ATMRAD	67
CLJ	U(I,N,2)	= CUMULATIVE VALUE OF PATH PARAMETER U (AREAL	ATMRAD	68
CLJ		DENSITY) FOR TEMPERATURE-INDEX I AND SPECIES N AT	ATMRAD	69
CLJ		END OF LINE SEGMENT DS, CM AT STP	ATMRAD	70
CLJ	UP(I,N,2)	= CUMULATIVE VALUE OF PATH PARAMETER UP (PRODUCT OF	ATMRAD	71
CLJ		U AND PRESSURE P) FOR TEMPERATURE-INDEX I AND	ATMRAD	72
CLJ		SPECIES N AT END OF LINE SEGMENT DS, ATM-CM	ATMRAD	73
CLJ		AT STP FOR U AND UP (I=1,2, N=1,10)	ATMRAD	74
CLJ	MMOLS	= NUMBER OF SPECIES, SET IN DRIVER.	ATMRAD	75
CLJ	LTMTE	= BINARY FILE CONTAINING THE BAND-MODEL PARAMETERS	ATMRAD	76
CLJ		WHICH WERE DERIVED IN SUBROUTINE TRANSB FROM THE	ATMRAD	77
CLJ		BASIC 5-(1/CM)-RESOLUTION DATA. HERE IN	ATMRAD	78
CLJ		SUBROUTINE ATMRAD, FILE LTMTE IS REWOUND FOR USE	ATMRAD	79
CLJ		IN SUBROUTINE TRANS.	ATMRAD	80
CLJ	OPTION COMMON		ATMRAD	81
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CLJ		AND TRANS). IN SUBROUTINE ATMRAD, TRNSOPT IS USED	ATMRAD	84
CLJ		ONLY IN THE ARGUMENT LIST FOR THE CALL TO	ATMRAD	85
CLJ		SUBROUTINE TRANS.	ATMRAD	86
CLJ	DATASET B1	(BAND-INTERVAL DATASET, NO. 115)	ATMRAD	87
CLJ	Q(1)	= BNLO BI = LOW WAVELENGTH FOR WAVELENGTH-BAND-INDEX	ATMRAD	88
CLJ		J, MICRONS	ATMRAD	89
CLJ	Q(2)	= BNHI BI = HIGH WAVELENGTH FOR WAVELENGTH-BAND-	ATMRAD	90
CLJ		INDEX J, MICRONS	ATMRAD	91
CLJ	Q(3)	= WLO BI = LOW WAVENUMBER FOR WAVELENGTH-BAND-INDEX	ATMRAD	92
CLJ		J, CM-1	ATMRAD	93
CLJ	Q(4)	= WHI BI = HIGH WAVENUMBER FOR WAVELENGTH-BAND-	ATMRAD	94
CLJ		INDEX J, CM-1	ATMRAD	95
CLJ	OUTPUT PARAMETERS		ATMRAD	96
CLJ	DATASET B1		ATMRAD	97
CLJ	Q(5)	= BKGND BI = IN-BAND RADIANCE TO BACK OF CELL DS,	ATMRAD	98
CLJ		WATTS/(CM**2 SR BAND)	ATMRAD	99
CLJ	Q(7)	= TRANS BI = PRODUCT OF MOLECULAR AND AEROSOL	ATMRAD	100
CLJ		TRANSMITTANCE TO BACK OF CELL DS	ATMRAD	101
CLJ	Q(8)	= IDS BX BI = CUMULATIVE AEROSOL TRANSMITTANCE TO	ATMRAD	102
CLJ		BACK OF CELL DS	ATMRAD	103
CLJ	*** NOTE ***	THIS IS THE SECOND OF TWO TEMPORARY USES OF	ATMRAD	104
CLJ	***	WORD-B (AND NOT THE GRC DICTIONARY USE OF	ATMRAD	105
CLJ	***	WORD-B). HERE, IT IS USED TO CARRY	ATMRAD	106
CLJ	***	INFORMATION TO SUBROUTINE UPWELL.	ATMRAD	107
CLJ			ATMRAD	108
CLJ	WE ALSO NOTE, FOR COMPLETENESS OF DATASET B1,		ATMRAD	109
CLJ	Q(6)	= TFLAG BI - SEE SUBROUTINE TRANSB FOR DEFINITION.	ATMRAD	110
CLJ			ATMRAD	111
CLJ	COMMON QNAREA, QNAREA(10), QFREHD, QNOTST, QNLNKS, QZSIZE,		ATMRAD	112
1	QNZBLK, QZHEAD, QCOUNT(30), QDSIZE(10), QNSIZE, QLUNIT(10),		ATMRAD	113
2	QERLUN, QFBITS(2,10), Q(1)		ATMRAD	114
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*	BKGD BI(1), TFLAG BI(1), TRANS BI(1), IDSBX BI(1)	ATMRAD	121
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*	XKABS BX(1)	ATMRAD	123
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	EQUIVALENCE (Q(1), BNLO BI), (Q(2), BNHI BI),	ATMRAD	125
*	(Q(3), WLO BI), (Q(4), WHI BI),	ATMRAD	126
*	(Q(5), BKGD BI), (Q(6), TFLAG BI),	ATMRAD	127
*	(Q(7), TRANS BI), (Q(8), IDSBX BI)	ATMRAD	128
	EQUIVALENCE (Q(1), TDST BX), (Q(2), DELTS BX),	ATMRAD	129
*	(Q(3), ABCLD BX), (Q(4), UVRB BX),	ATMRAD	130
*	(Q(5), XKABS BX)	ATMRAD	131
CLJ		ATMRAD	132
CLJ	DATASET-BX USED HERE IN SUBROUTINE ATMRAD IS A TEMPORARY	ATMRAD	133
CLJ	FIVE-WORD DATASET WHICH SHOULD NOT BE CONFUSED WITH THE	ATMRAD	134
CLJ	FIFTEEN-WORD DATASET-BX (NO. 118) USED IN THE GRC DICTIONARY	ATMRAD	135
CLJ	OF DATASETS.	ATMRAD	136
CLJ	DATASET-BX PROVIDES VARIOUS PROPERTIES AT THE FRONT OF THE	ATMRAD	137
CLJ	CURRENT CELL DS.	ATMRAD	138
CLJ	Q(1) = TDST BX = CUMULATIVE AEROSOL TRANSMITTANCE TO	ATMRAD	139
CLJ	FRONT OF CURRENT CELL	ATMRAD	140
CLJ	Q(2) = DELTSBX = LENGTH OF LAST CELL (OR CELLS) IF IT (OR	ATMRAD	141
CLJ	THEY) WAS (OR WERE) SKIPPED OVER BECAUSE	ATMRAD	142
CLJ	TEST = .TRUE. CM	ATMRAD	143
CLJ	Q(3) = ABCLD BX = OPTICAL DEPTH AT FRONT OF CURRENT CELL,	ATMRAD	144
CLJ	DIMENSIONLESS	ATMRAD	145
CLJ	Q(4) = UVRB BX = MOLECULAR ABSORPTION COEFFICIENT AT	ATMRAD	146
CLJ	FRONT OF CURRENT CELL DS, 1/CM	ATMRAD	147
CLJ	Q(5) = XKABS BX = AEROSOL ABSORPTION COEFFICIENT, 1/CM	ATMRAD	148
C		ATMRAD	149
	LOGICAL TRNSOPT, LOGIC, TEST	ATMRAD	150
C		ATMRAD	151
	L1 = ISHELL(1)	ATMRAD	152
	L2 = ISHELL(2)	ATMRAD	153
CLJ	HSF, HSB AND TFRONT, TBACK ARE, RESPECTIVELY, THE ALTITUDES	ATMRAD	154
CLJ	AND TEMPERATURES AT THE FRONT AND BACK OF THE CURRENT CELL DS	ATMRAD	155
CLJ	CORRESPONDING TO DS(I+1), CM AND DEG K	ATMRAD	156
	IF (LOGIC) HSF = XFRAC(1) * HSHLL(L1) + (1. - XFRAC(1)) * HSHLL(L2)	ATMRAD	157
\$	HSB = XFRAC(2) * HSHLL(L2) + (1. - XFRAC(2)) * HSHLL(L1)	ATMRAD	158
	IF (LOGIC) TFRONT = XFRAC(1) * TS(L1) + (1. - XFRAC(1)) * TS(L2)	ATMRAD	159
\$	TBACK = XFRAC(2) * TS(L2) + (1. - XFRAC(2)) * TS(L1)	ATMRAD	160
CLJ	SET FILE POSITION FILPOS FOR USE IN SUBROUTINE TRANS.	ATMRAD	161
	FILPOS = 1.E4	ATMRAD	162
CLJ	TEST = .TRUE. PROVIDED THE TEMPERATURE CHANGE ACROSS A CELL IS	ATMRAD	163
CLJ	LESS THAN ONE PERCENT (FOR THE STANDARD ATMOSPHERIC SHELL	ATMRAD	164
CLJ	SPACING SET BY FACT=1) AND PROVIDED IT IS NEITHER THE FIRST	ATMRAD	165
CLJ	NOR LAST CALL TO ATMRAD.	ATMRAD	166
CLJ	*** NOTE *** GRC (IN PROGRAM ATKGEN) SETS FACT TO 10.0 IF	ATMRAD	167
CLJ	TRNSOPT = .TRUE.	ATMRAD	168
	TOL = 0.01 * SORT(FACT)	ATMRAD	169
	TEST = ABS(TFRONT - TBACK) / TFRONT .LT. TOL .AND.	ATMRAD	170
		ATMRAD	171
		ATMRAD	172

\$	ISHELL(3) .GT. 0 .AND. .NOT. LOGIC	ATMRAD	173
CLJ	LOOP OVER SPECTRAL BAND-INTERVALS IN INCREASING WAVENUMBERS.	ATMRAD	174
	LINT = LBINT	ATMRAD	175
2	CALL PREV (LINT, J)	ATMRAD	176
	IF (J .EQ. 0) GO TO 10	ATMRAD	177
CLJ	CREATE A 5-WORD DATASET WITH INDEX JJ. (IN OTHER WORDS, JJ IS	ATMRAD	178
CLJ	THE ADDRESS OF THE FIRST OF THE FIVE WORDS.)	ATMRAD	179
	IF (LOGIC) CALL CREATL (5, JJ)	ATMRAD	180
CLJ	CALL TO DSPWRD RETURNS ADDRESS, IDSXB BI(J) (WHICH IS STORED	ATMRAD	181
CLJ	AS WORD-8 OF DATASET-BI), OF DSP WORD FOR THE DATASET-BX WHOSE	ATMRAD	182
CLJ	FIRST-WORD ADDRESS IS JJ (ALL FOR EACH J). (IN OTHER WORDS,	ATMRAD	183
CLJ	IDSXB BI(J) IS THE POINTER TO THE DSP WORD FOR THE DATASET-BX.	ATMRAD	184
CLJ	) THIS IS THE FIRST OF TWO TEMPORARY USES IN THIS ROUTINE OF	ATMRAD	185
CLJ	WORD-8 OF DATASET-BI. HERE IT IS USED AS A POINTER TO THE DSP	ATMRAD	186
CLJ	WORD FOR THE TEMPORARY DATASET-BX.	ATMRAD	187
	IF (LOGIC) CALL DSPWRD (JJ, IDSXB BI(J))	ATMRAD	188
	IF (LOGIC) TRANS BI(J) = 1.	ATMRAD	189
	IF (LOGIC) BYND BI(J) = 0.	ATMRAD	190
	IF (LOGIC) TOST BX(JJ) = 1.	ATMRAD	191
	IF (LOGIC) ABCLD BX(JJ) = 0.	ATMRAD	192
CLJ	CALL TO INDWRD RETURNS IN JJ THE INDEX (FIRST-WORD ADDRESS)	ATMRAD	193
CLJ	FOR THE DATASET-BX FOR WHICH THE POINTER TO ITS DSP WORD	ATMRAD	194
CLJ	(ZERO-TH-WORD ADDRESS) IS STORED IN IDSXB BI(J) (WORD-8 OF	ATMRAD	195
CLJ	DATASET-BI).	ATMRAD	196
	IF (.NOT. LOGIC) CALL INDWRD (IDSXB BI(J), JJ)	ATMRAD	197
	WDL = WLO BI(J)	ATMRAD	198
	WDH = WHI BI(J)	ATMRAD	199
	W = .5 * (WDL + WDH)	ATMRAD	200
CLJ	SET MEAN WAVENUMBER W FOR CALLING PLANCK AND MEAN WAVELENGTH	ATMRAD	201
CLJ	WAVEL FOR CALLING AEROSOL.	ATMRAD	202
	WAVEL = 1.E4/W	ATMRAD	203
CLJ	DELTSBX(JJ) WILL NORMALLY EQUAL DS BECAUSE THE OLD DELTSBX(JJ)	ATMRAD	204
CLJ	WAS INITIALLY ZEROED BY THE DSA SYSTEM AND SUBSEQUENTLY ZEROED	ATMRAD	205
CLJ	AT THE END OF EACH PASS THROUGH ATMRAD, EXCEPT WHEN	ATMRAD	206
CLJ	TEST = .TRUE.	ATMRAD	207
	DELTS BX(JJ) = DELTS BX(JJ) + DS	ATMRAD	208
	IF (LOGIC) CALL AEROSOL(HSF, WAVEL, XKSCA, XKABS BX(JJ), GBAR)	ATMRAD	209
	CALL AEROSOL(HSB, WAVEL, XKSCA, XKABS, GBAR)	ATMRAD	210
CLJ	XKEXT IS THE AEROSOL EXTINCTION COEFFICIENT (1/CM) AT BACK OF	ATMRAD	211
CLJ	CURRENT CELL AND TOST IS THE AEROSOL TRANSMITTANCE TO THE BACK	ATMRAD	212
CLJ	OF CURRENT CELL	ATMRAD	213
	XKEXT = XKSCA + XKABS	ATMRAD	214
	TOST = EXP(-XKEXT * DS) * TOST BX(JJ)	ATMRAD	215
C	COMPUTE INCREMENTAL RADIANCE WHEN TEMPERATURE	ATMRAD	216
C	CHANGE IS MORE THAN ONE PERCENT AT STANDARD PATH RESOLUTION	ATMRAD	217
	IF (TEST) GO TO 5	ATMRAD	218
CLJ	NOTE THAT SUBROUTINE TRANS RECEIVES THE ARRAYS U(I,N,2) AND	ATMRAD	219
CLJ	UP(I,N,2) AS U(I,N,1) AND UP(I,N,1).	ATMRAD	220
	CALL TRANS (10, 1, U(I,1,2), UP(I,1,2), X1, WDL, WDH, TAU, ABC,	ATMRAD	221
\$	TNEW, TRNSOPT, FILPOS)	ATMRAD	222
CLJ	NOW HAVE...	ATMRAD	223
CLJ	ABC = OPTICAL-DEPTH ARRAY TO BACK OF CURRENT CELL FOR	ATMRAD	224
CLJ	SPECIES N=1,10	ATMRAD	225
CLJ	TNEW = MOLECULAR TRANSMITTANCE TO BACK OF CURRENT CELL	ATMRAD	226
CLJ	TAU = MOLECULAR TRANSMITTANCE ARRAY TO BACK OF CURRENT	ATMRAD	227
CLJ	CELL FOR SPECIES N=1,10 (UNUSED HERE)	ATMRAD	228
CLJ	RESET TNEW TO BE THE PRODUCT OF THE MOLECULAR AND AEROSOL	ATMRAD	229

CLJ	TRANSMITTANCE TO BACK OF CURRENT CELL (DS)	ATMRAD	230
	TNEW = TNEW * TDST	ATMRAD	231
	ABCNEW = 0.	ATMRAD	232
CLJ	COMPUTE OPTICAL DEPTH FOR ALL SPECIES, ABCNEW, TO BACK OF	ATMRAD	233
CLJ	CELL DS.	ATMRAD	234
	DO 3 N=1, NMOLS	ATMRAD	235
	3 ABCNEW = ABCNEW + ABC(N)	ATMRAD	236
	ABCNEW = AMAX1(ABCNEW, ABCLD BX(JJ))	ATMRAD	237
C	ACCUMULATE SPECTRAL RADIANCE AND TRANSMISSION ARRAYS	ATMRAD	238
CLJ	UVRB = MOLECULAR ABSORPTION COEFFICIENT, 1/CM (NORMALLY	ATMRAD	239
CLJ	FOR CELL DS)	ATMRAD	240
	UVRB = (ABCNEW - ABCLD BX(JJ)) / DELTS BX(JJ)	ATMRAD	241
	IF (LOGIC) UVRB BX(JJ) = UVRB	ATMRAD	242
	BBODYF = PLANCK(TFRONT, W)	ATMRAD	243
	BBODYB = PLANCK(TBACK, W)	ATMRAD	244
CLJ	COMPUTE IN-BAND RADIANCE TO BACK OF CELL DS BY AVERAGING OVER	ATMRAD	245
CLJ	PATH SEGMENT DS WITH LOGARITHMIC INTERPOLATION. THIS STEP IS	ATMRAD	246
CLJ	VERY IMPORTANT. THE FACTOR (WDH-WDL) CONVERTS FROM SPECTRAL	ATMRAD	247
CLJ	TO IN-BAND RADIANCE.	ATMRAD	248
	BKGND BI(J) = BKGND BI(J) + ACCUM(2, 0., DS, (UVRB BX(JJ) +	ATMRAD	249
	\$ XKABS BX(JJ)) * BBODYF * TRANS BI(J), (UVRB + XKABS) *	ATMRAD	250
	\$ BBODYB * TNEW, 0., DS) * (WDH - WDL)	ATMRAD	251
CLJ	SET VALUE OF MOLECULAR AND AEROSOL TRANSMITTANCE TO FRONT OF	ATMRAD	252
CLJ	NEXT CELL FOR NEXT CALL TO ATMRAD.	ATMRAD	253
	TRANS BI(J) = TNEW	ATMRAD	254
CLJ	THE FOLLOWING TEST IS FOR THE LAST CELL. THE CALL TO DSTROY	ATMRAD	255
CLJ	REMOVES DATASET-BX AND ITS DSP WORD. (THE INDEX JJ AND THE	ATMRAD	256
CLJ	DSP WORD FOR DATASET-BX ARE SET TO ZERO. THE SIX WORDS USED	ATMRAD	257
CLJ	BY DATASET-BX ARE REGARDED AS FREE BY THE SYSTEM, THOUGH THEY	ATMRAD	258
CLJ	HAVE NOT YET BEEN ZEROED.) INVOKE SECOND TEMPORARY USE OF	ATMRAD	259
CLJ	WORD-8 OF DATASET-BI BY SETTING IT EQUAL TO TDST.	ATMRAD	260
	IF (ISHELL(3) .EQ. 0) CALL DSTROY (JJ)	ATMRAD	261
	IF (ISHELL(3) .EQ. 0) CALL XMIT(1, TDST, IDS BX BI(JJ))	ATMRAD	262
	IF (ISHELL(3) .EQ. 0) GO TO 2	ATMRAD	263
CLJ	ZERO THE PATH-SEGMENT LENGTH, WHICH IS ALWAYS DONE UNLESS	ATMRAD	264
CLJ	TEST = .TRUE. ALSO, SET PROPERTIES AT FRONT OF NEXT CELL	ATMRAD	265
CLJ	FOR NEXT CALL TO ATMRAD...	ATMRAD	266
CLJ	ABCLD BX(JJ) = OPTICAL DEPTH	ATMRAD	267
CLJ	XKABS BX(JJ) = AEROSOL ABSORPTION COEFFICIENT	ATMRAD	268
CLJ	UVRB BX(JJ) = MOLECULAR ABSORPTION COEFFICIENT	ATMRAD	269
CLJ	TDST BX(JJ) = AEROSOL TRANSMITTANCE	ATMRAD	270
	DELTS BX(JJ) = 0.	ATMRAD	271
	ABCLD BX(JJ) = ABCNEW	ATMRAD	272
	XKABS BX(JJ) = XKABS	ATMRAD	273
	UVRB BX(JJ) = UVRB	ATMRAD	274
	5 TDST BX(JJ) = TDST	ATMRAD	275
	GO TO 2	ATMRAD	276
C		ATMRAD	277
	10 IF (TEST) GO TO 11	ATMRAD	278
	REWIND LTMTE	ATMRAD	279
	HSF = HSB	ATMRAD	280
	TFRONT = TBACK	ATMRAD	281
	11 LOGIC = .FALSE.	ATMRAD	282
	RETURN	ATMRAD	283
	END	ATMRAD	284

CCC	FUNCTION CANGLE(P1LAT,P1LON,P2LAT,P2LON)	CANGLE	2
C		CANGLE	3
C	FUNCTION CANGLE COMPUTES THE EARTH-CENTRAL ANGLE, CANGLE,	CANGLE	4
C	BETWEEN THE TWO CENTRAL RAYS TO POINTS P1 AND P2, GIVEN THE	CANGLE	5
C	LATITUDE AND LONGITUDES OF POINTS P1 AND P2.	CANGLE	6
CCC		CANGLE	7
C	INPUT PARAMETERS	CANGLE	8
C	ARGUMENT LIST	CANGLE	9
C	P1LAT - NORTH LATITUDE OF POINT P1, RADIANS	CANGLE	10
C	P1LON - EAST LONGITUDE OF POINT P1, RADIANS	CANGLE	11
C	P2LAT - NORTH LATITUDE OF POINT P2, RADIANS	CANGLE	12
C	P2LON - EAST LONGITUDE OF POINT P2, RADIANS	CANGLE	13
C	OUTPUT PARAMETER	CANGLE	14
C	CANGLE - EARTH-CENTRAL ANGLE BETWEEN RAYS TO POINTS	CANGLE	15
C	P1 AND P2	CANGLE	16
CCC		CANGLE	17
C	CONSIDER THE SPHERICAL TRIANGLE P1-N-P2, WHERE N IS AT	CANGLE	18
C	THE NORTH POLE.	CANGLE	19
CCC		CANGLE	20
	SINSIN = SIN(P1LAT)*SIN(P2LAT)	CANGLE	21
	COSCOS = COS(P1LAT)*COS(P2LAT)	CANGLE	22
	ALPHAC = ACOS(SINSIN + COSCOS*COS(P2LON-P1LON))	CANGLE	23
	CANGLE = ALPHAC	CANGLE	24
	RETURN	CANGLE	25
	END	CANGLE	26

	FUNCTION DOT (X; Y)	DOT	2
C		DOT	3
C	*DOT* FORMS THE DOT PRODUCT OF TWO VECTORS.	DOT	4
C		DOT	5
	DIMENSION X(3), Y(3)	DOT	6
	DOT = X(1) * Y(1) + X(2) * Y(2) + X(3) * Y(3)	DOT	7
	RETURN	DOT	8
	END	DOT	9

	FUNCTION ERF(X)	ERFF	2
C	ERF IS THE ERROR FUNCTION, BASED ON THE RATIONAL-APPROXIMATION	ERFF	3
C	FORMULA 7.1.2.6 IN THE NBS APPLIED MATH. SERIES NO. 55 (BUT	ERFF	4
C	WITH CONSTANTS REDUCED TO SEVEN DIGITS).	ERFF	5
C		ERFF	6
	Y = 1.0	ERFF	7
	IF (ABS(X)-4.0) 1,1,2	ERFF	8
	1 Y = 1.0/(1.+0.3275911*ABS(X))	ERFF	9
	Y = 1. - (((1.061405*T - 1.453152)*T + 1.421414)*T - 0.2844967)*T	ERFF	10
	1 + 0.2548296)*T*EXP(-X*X)	ERFF	11
	2 ERF = SIGN(Y,X)	ERFF	12
	RETURN	ERFF	13
	END	ERFF	14

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SUBROUTINE ESURF(THI,THR,PSI,ZKM,MSM,DD,SPCULR,ZLAM,TDAY,IFIRES, ESURF 2
* ESURF1,SFR,EPSP,TKS) ESURF 3
CCC ESURF 4
C SUBROUTINE ESURF PROVIDES THE BIDIRECTIONAL REFLECTANCE ESURF 5
C DISTRIBUTION FUNCTION (BRDF), DIRECTIONAL EMISSIVITY, AND ESURF 6
C TEMPERATURE OF THE EARTH'S SURFACE AT THE INTERSECTION POINT ESURF 7
C OF THE OPTICAL LINE-OF-SIGHT. SINCE THE SURFACE CATEGORY IS ESURF 8
C NOT AUTOMATICALLY CORRELATED WITH THE GEOGRAPHIC POSITION, ESURF 9
C THE USER MUST SELECT ONE OF THE SEVEN CATEGORIES PROVIDED. ESURF 10
CCC ESURF 11
C INPUT PARAMETERS ESURF 12
C ARGUMENT LIST ESURF 13
C THI = ZENITH ANGLE OF SOURCE (E.G., SUN OR FIREBALL) AT ESURF 14
C INTERSECTION POINT, RADIAN ESURF 15
C WHEN SUBROUTINE SURRAD IS CALLED FROM SUBROUTINE ESURF 16
C UPWELL, AS IT IS IN THE NBR MODULE, THI IS SET IN ESURF 17
C SURRAD TO AN ARBITRARY (NON-PHYSICAL) VALUE OF ESURF 18
C -1.0 FOR NIGHTTIME CONDITIONS. ESURF 19
C THR = ZENITH ANGLE OF LINE-OF-SIGHT AT INTERSECTION ESURF 20
C POINT, RADIAN ESURF 21
C PSI = AZIMUTH ANGLE (AT INTERSECTION POINT) OF VERTICAL ESURF 22
C PLANE THROUGH LINE-OF-SIGHT, MEASURED RELATIVE TO ESURF 23
C THE SOURCE PRINCIPAL PLANE (I.E., VERTICAL PLANE ESURF 24
C THROUGH SOURCE RAY). A VALUE OF PSI=0 CORRESPONDS ESURF 25
C TO FORWARD SCATTERING. IN RADIAN ESURF 26
C FOR NIGHTTIME CONDITIONS, PSI IS SET TO -1.0. SEE ESURF 27
C COMMENT ABOVE FOR THI. ESURF 28
C ZKM = ALTITUDE OF SURFACE, KM ESURF 29
C MSM = INDEX FOR CATEGORY OF SURFACE MATERIAL. ESURF 30
C = 1, LAMBERTIAN DIFFUSE SURFACE WITH SPECTRALLY- ESURF 31
C INDEPENDENT REFLECTANCE SET BY DD(1) AND ESURF 32
C EMISSIVITY BY (1.-DD(1)). ESURF 33
C = 2, WATER ESURF 34
C = 3, SNOW ESURF 35
C = 4, SAND ESURF 36
C = 5, SOIL ESURF 37
C = 6, FOLIAGE ESURF 38
C = 7, URBAN MATERIAL ESURF 39
C DD(M) = ADDITIONAL DESCRIPTOR FOR SELECTED SURFACE ESURF 40
C MATERIAL. ESURF 41
C FOR M = 1, (LAMBERTIAN SURFACE), DD(1) = DIFFUSE ESURF 42
C REFLECTANCE. TYPICAL VALUE IS 0.10 ESURF 43
C FOR M = 2, (WATER), DD(2) = WIND SPEED, M/SEC. ESURF 44
C FOR M = 3, (SNOW), DD(3) = SNOW-AGE PARAMETER, ESURF 45
C DD(3).GE.0. .AND. .LE.1. VALUES OF 0. AND 1. ESURF 46
C CORRESPOND TO NEW AND OLD SNOW RESPECTIVELY. ESURF 47
C FOR M = 4,5,6, DD(M) NOT USED. ESURF 48
C FOR M = 7, (URBAN MATERIAL), DD(7)=DEGREE-OF-URBANIZATION, ESURF 49
C DD(7).GE.0. .AND. .LE.1. FOR DD(7) = 0., THE ESURF 50
C SPECTRAL BRDF CORRESPONDS TO A FLAT SURFACE ESURF 51
C WITH AVERAGE DIRECTIONAL-REFLECTANCE PROPERTIES ESURF 52
C OF CONCRETE AND ASPHALT. FOR DD(7) = 1., THE ESURF 53
C SPECTRAL BRDF CORRESPONDS TO A DIFFUSE ESURF 54
C REFLECTOR MULTIPLIED BY A SHADOW-FACTOR ESURF 55
C S(THI,THR) = ( COS(THI) + COS(THR) )/2. ESURF 56
C SPCULR = LOGICAL PARAMETER ESURF 57
C = .TRUE. COMPUTE COORDINATES OF SPECULAR ESURF 58

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C		REFLECTION POINT	ESURF	59
C	= .FALSE.	DO NOT COMPUTE COORDINATES OF SPECULAR	ESURF	60
C		REFLECTION POINT	ESURF	61
C	ZLAM =	WAVELENGTH, MICROMETERS	ESURF	62
C	IDAY =	INDEX FOR DAYLIGHT CONDITIONS AT POINT P	ESURF	63
C	= 0	IF SOLAR ZENITH ANGLE .GT. 90 DEGREES	ESURF	64
C	= 1	IF SOLAR ZENITH ANGLE .LE. 90 DEGREES	ESURF	65
C	IFIRES =	FLAG FOR INCLUSION OF FIREBALLS	ESURF	66
C	= 0	IF NO FIREBALL IS BEING CONSIDERED	ESURF	67
C		WHICH IS ALWAYS THE CASE IN THE NBR MODULE.	ESURF	68
C	.GT. 0	IF FIREBALLS ARE BEING CONSIDERED	ESURF	69
C	ESURF1 =	LOGICAL PARAMETER	ESURF	70
C	= .TRUE.	IF ESURF IS CALLED FOR THE FIRST TIME FROM	ESURF	71
C		SUBROUTINE SURRAD AND BOTH EPSD AND TKS	ESURF	72
C		ARE WANTED IN ADDITION TO SFR AS OUTPUTS,	ESURF	73
C		WHICH IS ALWAYS THE CASE IN THE NBR MODULE	ESURF	74
C	= .FALSE.	IF ESURF IS NOT BEING CALLED FOR THE FIRST	ESURF	75
C		TIME FROM SUBROUTINE SURRAD AND A RECOMPU-	ESURF	76
C		TATION OF EPSD AND TKS IS NOT NEEDED, A	ESURF	77
C		POSSIBILITY WHICH OCCURS ONLY IF	ESURF	78
C		SUBROUTINE SURRAD IS USED AS A UTILITY	ESURF	79
C		ROUTINE WITH FIREBALLS AS SOURCES.	ESURF	80
CCC			ESURF	81
C	ATMOUP COMMON		ESURF	82
C	TT =	AMBIENT ATMOSPHERIC TEMPERATURE AT ALTITUDE ZKM.	ESURF	83
CCC			ESURF	84
C	OUTPUT PARAMETERS		ESURF	85
C	ARGUMENT LIST		ESURF	86
C	SFR =	FSUBR(M,DD(M),ZLAM,THI,THR,PSI)	ESURF	87
C	=	BIDIRECTIONAL REFLECTANCE DISTRIBUTION	ESURF	88
C		FUNCTION, 1./SR	ESURF	89
C		(COMPUTED ONLY IF SOURCE IS ABOVE THE HORIZON)	ESURF	90
C	EPSD =	1.0 - RHOSUBM(ZLAM,THR,2*PI)	ESURF	91
C	=	DIRECTIONAL EMISSIVITY, DIMENSIONLESS.	ESURF	92
C	TKS =	SURFACE TEMPERATURE, DEG K.	ESURF	93
C	POSITN COMMON		ESURF	94
C	THIS OUTPUT OBTAINS ONLY IF MSM=2 AND SPCULR=.TRUE.		ESURF	95
C	SPCLAT =	NORTH LATITUDE OF POINT ON SMOOTH HORIZONTAL	ESURF	96
C		WATER SURFACE FOR A SPECULAR REFLECTION FROM	ESURF	97
C		THE SOURCE TO THE DETECTOR (COMPUTED IN	ESURF	98
C		SUBROUTINE GLITTR), RADIANS	ESURF	99
C	SPCLON =	EAST LONGITUDE OF POINT ON SMOOTH HORIZONTAL	ESURF	100
C		WATER SURFACE FOR A SPECULAR REFLECTION FROM	ESURF	101
C		THE SOURCE TO THE DETECTOR (COMPUTED IN	ESURF	102
C		SUBROUTINE GLITTR), RADIANS	ESURF	103
CCC			ESURF	104
	DIMENSION	DD(7),ALPM(7),BETM(7),GAMM(7),RMOO(7),RMP1(7),LL(7)	ESURF	105
	DIMENSION	WV4(18),WV5(16),WV3(12),WV7(23),GTH10(7)	ESURF	106
	DIMENSION	SP4(13),SP5(16),SP6(12),SP7(23)	ESURF	107
	COMMON/ATMOUP/	H,SBAR,IDORN,PP,RHO,TT,SNI(30),HRHO,FEMSEQ	ATMOUP	2
	COMMON/POSITN/	POS LAT,POS LON,POS ALT,SPCLAT,SPCLON	POSITN	2
	\$	C12LAT,C12LON,C12ALT	POSITN	3
	LOGICAL	SPCULR,ESURF1	ESURF	110
	DATA	(ALPM(I),I=1,7) / 0.,0.,3.,3.,2.5,2.5,4. /	ESURF	111
	DATA	(BETM(I),I=1,7) / 0.,0.,0.9,0.5,0.5,0.5,0.5 /	ESURF	112
	DATA	(GAMM(I),I=1,7) / 0.,0.,1.,1.,2.,2.,2. /	ESURF	113
	DATA	(RMOO(I),I=1,7) / 0.,0.,13.,2.5,1.,1.,10.5 /	ESURF	114

	DATA (PMPI(I),I=1,7) / 0.,0.,3.,4.,4.,10.,1. /	ESURF	115
	DATA (GTHIO(I),I=1,7) / 1.,0.,1.024,1.015,1.043,1.095,1.011 /	ESURF	116
	DATA (LL(I), I=1,7) / 0.,0.,18,16,12,23 /	ESURF	117
	DATA PI / 3.141592653590 /	ESURF	118
C	SPECTRAL PARAMETERS FOR SAND.	ESURF	119
	DATA (WV4(I),I=1,18) / 2.00,2.05,2.18,2.30,2.45,2.50,2.63,2.73,	ESURF	120
	* 2.88,2.95,3.20,3.30,3.60,3.75,3.90,4.35,	ESURF	121
	* 4.90,5.00 /	ESURF	122
	DATA (SP4(I),I=1,18) / 0.205,0.238,0.209,0.206,0.177,0.174,0.148,	ESURF	123
	* 0.114,0.080,0.040,0.070,0.093,0.145,0.162,	ESURF	124
	* 0.152,0.076,0.031,0.035 /	ESURF	125
C	SPECTRAL PARAMETERS FOR SOIL.	ESURF	126
	DATA (WV5(I),I=1,16) / 2.00,2.08,2.25,2.50,2.62,2.70,2.77,2.92,	ESURF	127
	* 3.15,3.50,3.70,3.82,4.10,4.60,4.77,5.00 /	ESURF	128
	DATA (SP5(I),I=1,16) / 0.262,0.272,0.257,0.227,0.198,0.095,0.067,	ESURF	129
	* 0.061,0.067,0.112,0.158,0.177,0.195,0.158,	ESURF	130
	* 0.142,0.113 /	ESURF	131
C	SPECTRAL PARAMETERS FOR VEGETATION.	ESURF	132
	DATA (WV6(I),I=1,12) / 2.00,2.20,2.64,2.78,2.96,3.03,3.16,3.22,	ESURF	133
	* 3.42,3.58,3.95,5.00 /	ESURF	134
	DATA (SP6(I),I=1,12) / 0.129,0.212,0.059,0.059,0.120,0.120,0.033,	ESURF	135
	* 0.033,0.074,0.074,0.037,0.021 /	ESURF	136
C	SPECTRAL PARAMETERS FOR URBAN MATERIALS.	ESURF	137
	DATA (WV7(I),I=1,23) / 2.00,2.12,2.24,2.26,2.36,2.47,2.55,2.63,	ESURF	138
	* 2.70,2.85,2.89,3.00,3.10,3.24,3.62,3.89,	ESURF	139
	* 4.00,4.10,4.26,4.42,4.70,4.83,5.00 /	ESURF	140
	DATA (SP7(I),I=1,23) / 0.347,0.348,0.326,0.278,0.272,0.295,0.299,	ESURF	141
	* 0.296,0.272,0.145,0.118,0.090,0.091,0.100,	ESURF	142
	* 0.149,0.193,0.231,0.238,0.240,0.254,0.246,0.229,0.215 /	ESURF	143
CCC		ESURF	144
CC	CHECK MATERIAL INDEX FOR PROPER RANGE	ESURF	145
	IF(MSM.LT.1) .OR. (MSM.GT.7)) GO TO 101	ESURF	146
	IF(.NOT.ESURF1) GO TO 50	ESURF	147
CC	GET SURFACE TEMPERATURE TAKEN TO BE AIR TEMPERATURE	ESURF	148
CC	AT ALTITUDE ZKM.	ESURF	149
	CALL ATMOSU(2,ZKM)	ESURF	150
	TKS = TT	ESURF	151
50	IF(MSM.GT.1) GO TO 99	ESURF	152
CC	SET PROPERTIES FOR MSM=1 (THE VALUE -1.0 FOR SFR IS AN	ESURF	153
CC	ARBITRARY DEFAULT SETTING WHICH WILL NEVER BE USED)	ESURF	154
	SFR = -1.0	ESURF	155
	IF((IDAY.EQ.1) .OR. (IFIRES.GT.0)) SFR = DD(1)/PI	ESURF	156
	EPSD = 1.0-DD(1)	ESURF	157
	RETURN	ESURF	158
99	IF(MSM.GT.2) GO TO 100	ESURF	159
	CALL GLITTR(THI,DD(2),SPCULR,ZLAM,IDAY,IFIRES,ESURF1,SFR,EPSD)	ESURF	160
	RETURN	ESURF	161
100	ALPHA = ALPM(MSM)	ESURF	162
	BETA = BETH(MSM)	ESURF	163
	GAMMA = GAMM(MSM)	ESURF	164
	RMZ = RMZO(MSM)	ESURF	165
	RMP = RMPI(MSM)	ESURF	166
	LLM = LL(MSM)	ESURF	167
	GTHIOA = GTHIO(MSM)	ESURF	168
CC	OBTAIN THE SPECTRAL, NORMAL-INCIDENCE--HEMISPHERICAL	ESURF	169
CC	REFLECTANCE, RHOM(ZLAM), BASED ON TABLE 2-3 IN TEXT.	ESURF	170
	GO TO (101,101,103,104,105,106,107), MSM	ESURF	171

101	WRITE(6,13) MSM	ESURF	172
12	FORMAT (44H0 ERROR IN VALUE OF MSM-(SEE ESURF), MSM=,I5)	ESURF	173
	CALL EXIT	ESURF	174
CC	FOR SNOW (MSM=3)	ESURF	175
103	RHOM = (0.44-0.12*(ZLAM-2.))*(1.0-DD(3)*5./12.)	ESURF	176
	GO TO 110	ESURF	177
CC	FOR SAND (MSM=4)	ESURF	178
104	CALL LINEAR (ZLAM,RHOM,WV4,SP4,LLM)	ESURF	179
	GO TO 110	ESURF	180
CC	FOR SOIL (MSM=5)	ESURF	181
105	CALL LINEAR (ZLAM,RHOM,WV5,SP5,LLM)	ESURF	182
	GO TO 110	ESURF	183
CC	FOR FOLIAGE (MSM=6)	ESURF	184
106	CALL LINEAR (ZLAM,RHOM,WV6,SP6,LLM)	ESURF	185
	GO TO 110	ESURF	186
CC	FOR URBAN MATERIAL (MSM=7)	ESURF	187
107	CALL LINEAR (ZLAM,RHOM,WV7,SP7,LLM)	ESURF	188
CC	COMPUTE APPROXIMATE VALUE FOR THE SPECTRAL PARAMETER	ESURF	189
CC	RHOZM(ZLAM) BY USING EQ.(6'') IN TEXT.	ESURF	190
110	RHOZM = RHOM/(PI*GTHIOA)	ESURF	191
CC	PROTECT AGAINST ABORT FOR GRAZING RAYS.	ESURF	192
	CTHI = COS(THI)	ESURF	193
	CTHR = COS(THR)	ESURF	194
CC	IF THI OR THR GREATER THAN 89.9 DEGREES RESET TO 89.9 .	ESURF	195
	IF(ABS(CTHI).LT.1.745E-03) CTHI = 1.745E-03	ESURF	196
	IF(ABS(CTHR).LT.1.745E-03) CTHR = 1.745E-03	ESURF	197
CC	EVALUATE AUXILIARY PARAMETERS NEEDED REGARDLESS OF PRESENCE	ESURF	198
CC	OF SOURCE.	ESURF	199
	RBAR = 0.5*(RMZ+RMP)	ESURF	200
	SA = ALPHA*BETA	ESURF	201
	PIA = (1.0-EXP(-SA))/SA	ESURF	202
CC	NEED NOT COMPUTE SFR IF NEITHER SUN NOR FIREBALL IS	ESURF	203
CC	CONSIDERED AS A SOURCE, SO SET IT (ARBITRARILY) TO -1.0	ESURF	204
	SFR = -1.0	ESURF	205
	IF((IDAY.EQ.0) .AND. (IFIRES.EQ.0)) GO TO 124	ESURF	206
	IF((THI.GT.0.0) .OR. (THR.GT.0.0)) GO TO 120	ESURF	207
CC	EVALUATE SFR AVERAGED OVER AZIMUTH ANGLES, FROM EQ.(3A) IN	ESURF	208
CC	TEXT.	ESURF	209
	SFR = RHOZM*(1.0+RBAR*PIA*EXP(-2.*ALPHA))	ESURF	210
	CTHR = 1.0	ESURF	211
	GO TO 122	ESURF	212
120	ABTF = BETA*(1.0-ABS(1.0-2.*PSI/PI))	ESURF	213
	CGAM = CTHI**GAMMA + CTHR**GAMMA	ESURF	214
	RMPPI = RMZ - (RMZ-RMP)*PSI/PI	ESURF	215
CC	EVALUATE EQ.(1) IN TEXT.	ESURF	216
	SFR = RHOZM*(1.0+RMPPI*EXP(-ALPHA*(CGAM+ABTF)))	ESURF	217
122	IF(MSM.NE.7) GO TO 124	ESURF	218
CC	FOR MSM=7, EVALUATE EQ.(17) IN TEXT FOR SFR.	ESURF	219
	URBAN = RHOZM*DD(7)*(CTHI+CTHR)/2.	ESURF	220
	SFR = URBAN + SFR*(1.0-DD(7))	ESURF	221
124	IF(.NOT.ESURF1) RETURN	ESURF	222
CC	PREPARE TO COMPUTE DIRECTIONAL EMISSIVITY.	ESURF	223
CC	EVALUATE EQ.(10) IN TEXT WITH THETA REPLACED BY THR.	ESURF	224
	FGAMM = EXP(-ALPHA*CTHR**GAMMA)	ESURF	225
	IGAM = GAMMA+0.25	ESURF	226
	GO TO (126,128), IGAM	ESURF	227
CC	EVALUATE EQ.(8) IN TEXT.	ESURF	228

126	P2GAM = (1.0-(ALPHA+1.)*EXP(-ALPHA))/(ALPHA*ALPHA)	ESURF	229
	GO TO 130	ESURF	230
CC	EVALUATE EQ.(9) IN TEXT.	ESURF	231
128	P2GAM = (1.0-EXP(-ALPHA))/(2.*ALPHA)	ESURF	232
CC	FRHOM = DIRECTIONAL-HEMISPHERICAL REFLECTANCE	ESURF	233
CC	EPSD = DIRECTIONAL EMISSIVITY	ESURF	234
CC	EVALUATE EQ.(6) IN TEXT, BUT WITH THI REPLACED BY THR IN THE	ESURF	235
CC	ANTICIPATION THAT FRHOM WILL BE USED IN EQ.(12) FOR THE	ESURF	236
CC	DIRECTIONAL EMISSIVITY.	ESURF	237
130	FRHOM = PI*RHOZM * (1.0+2.*PIA*P2GAM*RBAR*FGAMM)	ESURF	238
	IF(MSM.NE.7) GO TO 140	ESURF	239
CC	FOR MSM=7, EVALUATE EQ.(18) IN TEXT, BUT WITH THI REPLACED BY	ESURF	240
CC	THR IN THE ANTICIPATION THAT FRHOM WILL BE USED IN EQ.(19) FOR	ESURF	241
CC	THE DIRECTIONAL EMISSIVITY.	ESURF	242
	FRHOM = (1.-DD(7))*FRHOM + DD(7)*RHOZM*PI*(0.50*CTHR + 0.333333)	ESURF	243
CC	EVALUATE EQ.(12) IN TEXT.	ESURF	244
140	EPSD = 1.0-FRHOM	ESURF	245
	RETURN	ESURF	246
	END	ESURF	247

	FUNCTION FRAC (A, B, X, Y)	FRAC	2
C		FRAC	3
C	*FRAC* CALCULATES THE FRACTION OF INTERVAL (A,B)	FRAC	4
CLJ	CONTAINED IN INTERVAL (X,Y) IF((A,B) .LE. (X,Y)) OR	FRAC	5
CLJ	COVERED BY INTERVAL (X,Y) IF((A,B) .GT. (X,Y)).	FRAC	6
C		FRAC	7
	D = A - B	FRAC	8
	FR1 = AMAX1(AMIN1((A - Y)/D, 1.), 0.)	FRAC	9
	FR2 = AMAX1(AMIN1((X - B)/D, 1.), 0.)	FRAC	10
	FRAC = FR1 + FR2 - 1.	FRAC	11
	RETURN	FRAC	12
	END	FRAC	13

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SUBROUTINE FRESNL(ZLAM,OMEGA,RHO)
CCC
C      SUBROUTINE FRESNL EVALUATES THE FRESNEL (SPECULAR)
C      MONOCHROMATIC REFLECTANCE OF A SMOOTH WATER SURFACE, GIVEN
C      THE WAVELENGTH AND ANGLE OF INCIDENCE.
CCC
C      INPUT PARAMETERS
C      ARGUMENT LIST
C      ZLAM - WAVELENGTH (MICROMETERS)
C      OMEGA - ANGLE OF INCIDENCE (WITH RESPECT TO NORMAL TO
C      SMOOTH ELEMENT OF WATER SURFACE) (RADIAN)
CCC
C      OUTPUT PARAMETER
C      ARGUMENT LIST
C      RHO - FRESNEL MONOCHROMATIC REFLECTANCE OF PLANE,
C      UNPOLARIZED ELECTROMAGNETIC WAVE INCIDENT AT
C      ANGLE OMEGA ON PLANE, ABSORBING SURFACE WITH
C      COMPLEX INDEX OF REFRACTION  $NN = SN - I*SK$ 
CCC
C      DIMENSION SNNU(222), SKNU(222)
C
C      THE VALUES OF THE COMPLEX INDEX OF REFRACTION ARE TAKEN FROM
C      H. D. DOWNING AND D. WILLIAMS, OPTICAL CONSTANTS OF WATER IN
C      THE INFRARED, J. GEOPHYS. RES. VOL. 80, 1656(1975).
C
DATA (SNNU(I),I=1,142) / 1.321,1.322,1.322,1.323,1.324,1.324,
* 1.325,1.325,1.325,1.325,1.325,1.325,
* 1.326,1.326,1.326,1.327,1.327,1.327,1.327,1.328,1.328,
* 1.329,1.329,1.329,1.330,1.330,1.330,1.331,1.332,1.332,1.333,
* 1.334,1.334,1.335,1.337,1.337,1.338,1.340,1.340,1.341,1.342,
* 1.343,1.344,1.344,1.345,1.346,1.347,1.348,1.348,1.349,1.350,
* 1.351,1.352,1.353,1.354,1.355,1.357,1.358,1.358,1.360,1.361,
* 1.361,1.363,1.365,1.366,1.367,1.369,1.370,1.371,1.372,1.374,
* 1.375,1.377,1.378,1.379,1.382,1.383,1.385,1.387,1.388,1.390,
* 1.392,1.394,1.396,1.398,1.400,1.403,1.405,1.407,1.410,1.413,
* 1.415,1.418,1.421,1.425,1.427,1.431,1.434,1.437,1.441,1.444,
* 1.448,1.451,1.454,1.457,1.461,1.464,1.467,1.472,1.474,1.477,
* 1.479,1.482,1.485,1.486,1.487,1.487,1.487,1.486,1.483,1.480,
* 1.476,1.471,1.465,1.457,1.450,1.442,1.434,1.426,1.417,1.407,
* 1.398,1.386,1.376,1.364,1.353,1.342,1.329,1.317,1.305,1.293 /
DATA (SNNU(I),I=143,222) / 1.282,1.271,1.258,1.246,1.233,
* 1.220,1.212,1.199,1.191,1.183,
* 1.177,1.171,1.165,1.161,1.158,1.154,1.149,1.144,1.141,1.139,
* 1.138,1.138,1.139,1.144,1.149,1.157,1.166,1.172,1.179,1.185,
* 1.191,1.195,1.200,1.205,1.210,1.214,1.218,1.221,1.224,1.227,
* 1.230,1.232,1.235,1.238,1.240,1.241,1.243,1.246,1.247,1.249,
* 1.250,1.252,1.254,1.255,1.256,1.257,1.259,1.260,1.261,1.265,
* 1.270,1.274,1.277,1.280,1.282,1.285,1.287,1.289,1.291,1.293,
* 1.294,1.295,1.296,1.298,1.298,1.300,1.301,1.301,1.303,0.0 /
DATA (SKNU(I),I=1,112) / 1.26E-2,1.29E-2,1.33E-2,1.37E-2,
* 1.40E-2,1.43E-2,1.46E-2,1.48E-2,
* 1.51E-2,1.53E-2,1.55E-2,1.57E-2,1.57E-2,1.57E-2,1.56E-2,1.54E-2,
* 1.52E-2,1.49E-2,1.45E-2,1.40E-2,1.36E-2,1.31E-2,1.26E-2,1.22E-2,
* 1.17E-2,1.12E-2,1.08E-2,1.04E-2,1.00E-2,9.66E-3,9.27E-3,8.96E-3,
* 8.64E-3,8.33E-3,8.06E-3,7.79E-3,7.49E-3,7.22E-3,6.96E-3,6.73E-3,
* 6.53E-3,6.31E-3,6.08E-3,5.86E-3,5.68E-3,5.49E-3,5.31E-3,5.12E-3,
* 4.94E-3,4.79E-3,4.65E-3,4.50E-3,4.33E-3,4.22E-3,4.10E-3,3.99E-3,

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* 3.89E-3,3.78E-3,3.70E-3,3.63E-3,3.52E-3,3.48E-3,3.40E-3,3.39E-3,	FRESNL	59
* 3.35E-3,3.36E-3,3.35E-3,3.40E-3,3.47E-3,3.55E-3,3.63E-3,3.76E-3,	FRESNL	60
* 3.89E-3,4.05E-3,4.24E-3,4.49E-3,4.73E-3,5.06E-3,5.38E-3,5.79E-3,	FRESNL	61
* 6.25E-3,6.83E-3,7.37E-3,8.07E-3,8.66E-3,9.41E-3,1.01E-2,1.10E-2,	FRESNL	62
* 1.18E-2,1.28E-2,1.38E-2,1.51E-2,1.63E-2,1.77E-2,1.93E-2,2.10E-2,	FRESNL	63
* 2.29E-2,2.50E-2,2.62E-2,2.79E-2,2.97E-2,3.15E-2,3.48E-2,3.85E-2,	FRESNL	64
* 4.22E-2,4.62E-2,5.04E-2,5.50E-2,6.00E-2,6.53E-2,7.16E-2,7.85E-2 /	FRESNL	65
DATA (SKNU(I),I=113,222) /	FRESNL	66
* 8.55E-2,9.20E-2,9.94E-2,1.10E-1,	FRESNL	67
* 1.17E-1,1.25E-1,1.34E-1,1.44E-1,	FRESNL	68
* 1.53E-1,1.63E-1,1.73E-1,1.83E-1,1.95E-1,2.04E-1,2.12E-1,2.20E-1,	FRESNL	69
* 2.28E-1,2.36E-1,2.43E-1,2.50E-1,2.55E-1,2.62E-1,2.67E-1,2.72E-1,	FRESNL	70
* 2.76E-1,2.79E-1,2.82E-1,2.82E-1,2.81E-1,2.80E-1,2.76E-1,2.71E-1,	FRESNL	71
* 2.65E-1,2.58E-1,2.49E-1,2.39E-1,2.29E-1,2.18E-1,2.06E-1,1.94E-1,	FRESNL	72
* 1.80E-1,1.67E-1,1.54E-1,1.42E-1,1.31E-1,1.21E-1,1.12E-1,1.02E-1,	FRESNL	73
* 9.27E-2,8.36E-2,7.44E-2,6.49E-2,5.48E-2,4.62E-2,3.80E-2,2.82E-2,	FRESNL	74
* 2.05E-2,1.86E-2,1.64E-2,1.45E-2,1.27E-2,1.05E-2,8.55E-3,7.32E-3,	FRESNL	75
* 6.27E-3,5.36E-3,4.82E-3,4.37E-3,4.02E-3,3.30E-3,2.98E-3,2.70E-3,	FRESNL	76
* 2.57E-3,2.48E-3,2.43E-3,2.39E-3,2.34E-3,2.31E-3,2.27E-3,2.24E-3,	FRESNL	77
* 2.19E-3,2.15E-3,2.12E-3,2.10E-3,2.07E-3,2.05E-3,2.00E-3,1.95E-3,	FRESNL	78
* 1.90E-3,1.56E-3,1.23E-3,9.68E-4,7.92E-4,6.52E-4,5.42E-4,4.65E-4,	FRESNL	79
* 4.16E-4,3.76E-4,3.45E-4,3.38E-4,3.41E-4,3.59E-4,4.00E-4,4.52E-4,	FRESNL	80
* 5.14E-4,6.17E-4,7.31E-4,9.00E-4,1.10E-3,0.0 /	FRESNL	81
C THE FORMULAS FOR THE REFLECTANCE ARE TAKEN FROM, E. G., D. H.		
C MENZEL (EDITOR), FUNDAMENTAL FORMULAS OF PHYSICS, (P. 422),		
C DOVER PUBLICATIONS, INC., NEW YORK, 1960.		
C		
WAVE = 1.0E+04/ZLAM	FRESNL	86
IF(WAVE.GE.4000.) GO TO 10	FRESNL	87
WX = FRACTIONAL NUMBER OF DATA POINTS CORRESPONDING TO WAVE.	FRESNL	88
WX = 1.0 + (WAVE-2000.)/10.	FRESNL	89
GO TO 20	FRESNL	90
10 WX = 201. + (WAVE-4000.)/50.	FRESNL	91
1J = FIRST DATA-POINT INDEX ABOVE WAVE.	FRESNL	92
20 1J = WX+1.0	FRESNL	93
DELW = FRACTIONAL PART OF DATA INTERVAL CORRESPONDING TO WAVE.	FRESNL	94
DELW = WX - FLOAT(1J-1)	FRESNL	95
SN = SMNU(1J-1) + (SMNU(1J)-SMNU(1J-1))*DELW	FRESNL	96
SK = SKNU(1J-1) + (SKNU(1J)-SKNU(1J-1))*DELW	FRESNL	97
SNSQ = SIN(OMEGA)**2	FRESNL	98
SNKS = SN*SN-SK*SK-SNSQ	FRESNL	99
FNK = (2.*SN*SK)**2	FRESNL	100
TRM = SORT(SNKS+SNKS+FNK)	FRESNL	101
SAPSQ = 0.50*(TRM+SNKS)	FRESNL	102
SAMSQ = 0.50*(TRM-SNKS)	FRESNL	103
CC = SAPSQ+SAMSQ	FRESNL	104
SAP = SORT(SAPSQ)	FRESNL	105
EE = COS(OMEGA)	FRESNL	106
EESQ = EE*EE	FRESNL	107
APE2 = 2.*SAP*EE	FRESNL	108
DD = SNSQ/EE	FRESNL	109
DDSQ = DD*DD	FRESNL	110
APD2 = 2.*SAP*DD	FRESNL	111
RS = (CC-APE2+EESQ)/(CC+APE2+EESQ)	FRESNL	112
RHO = RS*(CC+DDSQ)/(CC+APD2+DDSQ)	FRESNL	113
RETURN	FRESNL	114
END	FRESNL	115

CCC	SUBROUTINE GCRCL(P1LAT,P1LON,P3LAT,P3LON,ALP13,ALP12,P2LAT,P2LON)	GCRCL	2
C		GCRCL	3
C	FOR THREE POINTS P1, P2, AND P3 ON A GREAT CIRCLE, SUBROUTINE	GCRCL	4
C	GCRCL COMPUTES THE LATITUDE AND LONGITUDE OF THE INTER-	GCRCL	5
C	MEDIATE POINT P2, GIVEN THE LATITUDES AND LONGITUDES OF THE	GCRCL	6
C	END POINTS P1 AND P3, THE CENTRAL ANGLE ALP13 BETWEEN THE	GCRCL	7
C	CENTRAL RAYS TO P1 AND P3, AND THE CENTRAL ANGLE ALP12	GCRCL	8
C	BETWEEN THE CENTRAL RAYS TO P1 AND P2.	GCRCL	9
CCC		GCRCL	10
C	INPUT PARAMETERS	GCRCL	11
C	ARGUMENT LIST	GCRCL	12
C	P1LAT - NORTH LATITUDE OF POINT P1, RADIANS	GCRCL	13
C	P1LON - EAST LONGITUDE OF POINT P1, RADIANS	GCRCL	14
C	P3LAT - NORTH LATITUDE OF POINT P3, RADIANS	GCRCL	15
C	P3LON - EAST LONGITUDE OF POINT P3, RADIANS	GCRCL	16
C	ALP13 - EARTH-CENTRAL ANGLE BETWEEN RAYS TO POINTS	GCRCL	17
C	P1 AND P3, RADIANS	GCRCL	18
C	ALP12 - EARTH-CENTRAL ANGLE BETWEEN RAYS TO POINTS	GCRCL	19
C	P1 AND P2, RADIANS	GCRCL	20
CCC		GCRCL	21
C	OUTPUT PARAMETERS	GCRCL	22
C	ARGUMENT LIST	GCRCL	23
C	P2LAT - NORTH LATITUDE OF POINT P2, RADIANS	GCRCL	24
C	P2LON - EAST LONGITUDE OF POINT P2, RADIANS	GCRCL	25
CCC		GCRCL	26
C	DATA F1 / 3.141592653590 /	GCRCL	27
CCC		GCRCL	28
C	CONSIDER THE SPHERICAL TRIANGLE P1-N-P3	GCRCL	29
C	POINT N IS NORTH POLE	GCRCL	30
CCC		GCRCL	31
C	SINCOS = SIN(P3LAT) - COS(ALP13)*SIN(P1LAT)	GCRCL	32
C	SINCOS = SINCOS/(SIN(ALP13)*COS(P1LAT))	GCRCL	33
C	AMDA = ACOS(SINCOS)	GCRCL	34
CCC		GCRCL	35
C	CONSIDER THE SPHERICAL TRIANGLE P1-N-P2	GCRCL	36
CCC		GCRCL	37
C	COSSIN = COS(ALP12)*SIN(P1LAT)	GCRCL	38
C	SINCOS = SIN(ALP12)*COS(P1LAT)	GCRCL	39
C	P2LAT = ASIN(COSSIN + SINCOS*COS(AMDA))	GCRCL	40
CCC		GCRCL	41
C	AGAIN, CONSIDER SPHERICAL TRIANGLE P1-N-P2	GCRCL	42
CCC		GCRCL	43
C	P12 = P1+P1	GCRCL	44
C	P3MP1 = P3LON-P1LON	GCRCL	45
C	P12LON = ASIN(SIN(AMDA)*SIN(ALP12)/COS(P2LAT))	GCRCL	46
C	P2LON = P1LON + P12LON*SIGN(1.0,P3MP1)	GCRCL	47
C	IF(ABS(P3MP1).LE.PI) GO TO 10	GCRCL	48
C	P2LON = P1LON - P12LON*SIGN(1.0,P3MP1)	GCRCL	49
10	IF(P2LON.LT.0.0) P2LON = P2LON+PI2	GCRCL	50
C	IF(P2LON.GE.PI2) P2LON = P2LON-PI2	GCRCL	51
C	RETURN	GCRCL	52
C	END	GCRCL	53

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SUBROUTINE GEOREA(HA1,GC1,GL1,HA2,GC2,GL2,SR21,EL21,AZ21)
CCC
C      SUBROUTINE GEOREA (A MODIFIED HARC ROUTINE). GIVEN THE
C      GEOGRAPHIC COORDINATES OF TWO POINTS, PROVIDES THE SLANT RANGE,
C      ELEVATION ANGLE, AND AZIMUTH ANGLE OF POINT 2 WITH RESPECT TO
C      POINT 1.
CCC
C      INPUTS FROM CALL STATEMENT
C      HA1 = ALTITUDE OF POINT 1, CM
C      GC1 = COLATITUDE OF POINT 1, RADIANS
C      GL1 = EAST LONGITUDE OF POINT 1, RADIANS
C      HA2 = ALTITUDE OF POINT 2, CM
C      GC2 = COLATITUDE OF POINT 2, RADIANS
C      GL2 = EAST LONGITUDE OF POINT 2, RADIANS
C      OUTPUTS
C      SR21 = SLANT RANGE OF POINT 2 RELATIVE TO POINT 1, CM
C      EL21 = ELEVATION OF POINT 2 RELATIVE TO POINT 1, RADIANS
C      AZ21 = AZIMUTH OF POINT 2 RELATIVE TO POINT 1, RADIANS
CCC
CALL GEOTAN(HA1,GC1,GL1,HA2,GC2,GL2,XE21,YN21,ZV21)
XYSQ = XE21**2 + YN21**2
SR21 = SQRT(XYSQ + ZV21**2)
EL21 = ATAN2( ZV21,SQRT(XYSQ) )
AZ21 = 0.0
IF( XYSQ.GT.0.0 ) AZ21 = ATAN2( XE21,YN21 )
RETURN
END

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GEOREA 2
GEOREA 3
GEOREA 4
GEOREA 5
GEOREA 6
GEOREA 7
GEOREA 8
GEOREA 9
GEOREA 10
GEOREA 11
GEOREA 12
GEOREA 13
GEOREA 14
GEOREA 15
GEOREA 16
GEOREA 17
GEOREA 18
GEOREA 19
GEOREA 20
GEOREA 21
GEOREA 22
GEOREA 23
GEOREA 24
GEOREA 25
GEOREA 26
GEOREA 27
GEOREA 28

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SUBROUTINE GEOTAN(HA1,GC1,GL1,HA2,GC2,GL2,XE21,YN21,ZV21)
CCC
C      SUBROUTINE GEOTAN (A MODIFIED HARC ROUTINE CALLED GEOXYZ).
C      GIVEN THE GEOGRAPHIC COORDINATES OF TWO POINTS, PROVIDES THE
C      TANGENT-PLANE COORDINATES OF POINT 2 WITH RESPECT TO POINT 1.
CCC
C      INPUTS FROM CALL STATEMENT
C      HA1 = ALTITUDE OF POINT 1, CM
C      GC1 = COLATITUDE OF POINT 1, RADIANS
C      GL1 = EAST LONGITUDE OF POINT 1, RADIANS
C      HA2 = ALTITUDE OF POINT 2, CM
C      GC2 = COLATITUDE OF POINT 2, RADIANS
C      GL2 = EAST LONGITUDE OF POINT 2, RADIANS
C      OUTPUTS
C      XE21 = X COORDINATE OF POINT 2 RELATIVE TO POINT 1, CM
C      YN21 = Y COORDINATE OF POINT 2 RELATIVE TO POINT 1, CM
C      ZV21 = Z COORDINATE OF POINT 2 RELATIVE TO POINT 1, CM
CCC
DATA RE / 6.37103E+08 /
CCC
GR1 = RE+HA1
GR2 = RE+HA2
GLD = GL2-GL1
SINGC1 = SIN(GC1)
SINGC2 = SIN(GC2)
COSGC1 = COS(GC1)
COSGC2 = COS(GC2)
COSGLD = COS(GLD)
XE21 = GR2*SINGC2*SIN(GLD)
YN21 = GR2*(SINGC1*COSGC2 - COSGC1*SINGC2*COSGLD)
ZV21 = GR2*(COSGC1*COSGC2 + SINGC1*SINGC2*COSGLD) - GR1
RETURN
END

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GEOTAN 2
GEOTAN 3
GEOTAN 4
GEOTAN 5
GEOTAN 6
GEOTAN 7
GEOTAN 8
GEOTAN 9
GEOTAN 10
GEOTAN 11
GEOTAN 12
GEOTAN 13
GEOTAN 14
GEOTAN 15
GEOTAN 16
GEOTAN 17
GEOTAN 18
GEOTAN 19
GEOTAN 20
GEOTAN 21
GEOTAN 22
GEOTAN 23
GEOTAN 24
GEOTAN 25
GEOTAN 26
GEOTAN 27
GEOTAN 28
GEOTAN 29
GEOTAN 30
GEOTAN 31
GEOTAN 32
GEOTAN 33
GEOTAN 34

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CCC	SUBROUTINE GEOXYZ(PH,PLAT,PLON,RPX,RPY,RPZ)	GEOXYZ	2
C		GEOXYZ	3
C	SUBROUTINE GEOXYZ CONVERTS THE GEOGRAPHIC COORDINATES OF A	GEOXYZ	4
C	POINT TO EARTH-CENTERED CARTESIAN COORDINATES.	GEOXYZ	5
CCC	INPUT PARAMETERS	GEOXYZ	6
C	ARGUMENT LIST	GEOXYZ	7
C	PH - ALTITUDE OF POINT P, KM	GEOXYZ	8
C	PLAT - NORTH LATITUDE OF POINT P, RADIANS	GEOXYZ	9
C	PLON - EAST LONGITUDE OF POINT P, RADIANS	GEOXYZ	10
C	OUTPUT PARAMETERS	GEOXYZ	11
C	ARGUMENT LIST	GEOXYZ	12
C	RPX - EARTH-CENTERED CARTESIAN COORDINATE X OF	GEOXYZ	13
C	POINT P, KM	GEOXYZ	14
C	RPY - EARTH-CENTERED CARTESIAN COORDINATE Y OF	GEOXYZ	15
C	POINT P, KM	GEOXYZ	16
C	RPZ - EARTH-CENTERED CARTESIAN COORDINATE Z OF	GEOXYZ	17
C	POINT P, KM	GEOXYZ	18
CCC	DATA RE / 6.37103E+03 /	GEOXYZ	19
CCC		GEOXYZ	20
	RP = RE*PH	GEOXYZ	21
	RPZ = RP*SIN(PLAT)	GEOXYZ	22
	RPEQ = RP*COS(PLAT)	GEOXYZ	23
	RPX = RPEQ*COS(PLON)	GEOXYZ	24
	RPY = RPEQ*SIN(PLON)	GEOXYZ	25
	RETURN	GEOXYZ	26
	END	GEOXYZ	27
		GEOXYZ	28
		GEOXYZ	29

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SUBROUTINE GLITTR(THETA1,WIND,SPCULR,ZLAM,IDAY,IFIRES,ESURF1,    GLITTR    2
* SFR,EPSPD)                                                    GLITTR    3
CCC                                                                GLITTR    4
C      SUBROUTINE GLITTR, CALLED FROM ESURF WHEN THE LINE-OF-SIGHT GLITTR    5
C      INTERSECTS A WATER SURFACE, PROVIDES (1A) THE BIDIRECTIONAL GLITTR    6
C      REFLECTANCE-DISTRIBUTION FUNCTION (BRDF) AND (1B) DIRECTIONAL GLITTR    7
C      EMISSIVITY OF THE WATER SURFACE AT THE INTERSECTION POINT OF GLITTR    8
C      THE OPTICAL LINE-OF-SIGHT FROM THE DETECTOR AND (2) THE GLITTR    9
C      GEOGRAPHIC COORDINATES (NORTH LATITUDE AND EAST LONGITUDE) OF GLITTR   10
C      THE POINT ON A SMOOTH HORIZONTAL SURFACE FOR A SPECULAR GLITTR   11
C      REFLECTION OF A RAY FROM THE SOURCE TO THE DETECTOR, IF GLITTR   12
C      REQUESTED (BY LOGICAL PARAMETER SPCULR = .TRUE. IN ARGUMENT GLITTR   13
C      LIST). ONLY THE DIRECTIONAL EMISSIVITY IS PROVIDED IF THERE GLITTR   14
C      IS NO SOURCE. GLITTR   15
CCC                                                                GLITTR   16
C * * INPUT PARAMETERS GLITTR   17
C ARGUMENT LIST GLITTR   18
C THETA1 = ZENITH ANGLE OF SOURCE (SUN OR FIREBALL) AT THE GLITTR   19
C          INTERSECTION POINT OF LINE-OF-SIGHT FROM DETECTOR GLITTR   20
C          TO EARTH'S SURFACE (RADIAN) GLITTR   21
C WIND = WIND SPEED AT 41 FEET ABOVE SEA LEVEL (METERS/SEC) GLITTR   22
C SPCULR = LOGICAL PARAMETER GLITTR   23
C          = .TRUE. COMPUTE COORDINATES OF SPECULAR GLITTR   24
C          REFLECTION POINT GLITTR   25
C          = .FALSE. DO NOT COMPUTE COORDINATES OF SPECULAR GLITTR   26
C          REFLECTION POINT GLITTR   27
C ZLAM = WAVELENGTH (MICROMETERS) GLITTR   28
C IDAY = INDEX FOR DAYLIGHT CONDITIONS AT POINT P GLITTR   29
C          = 0 IF SOLAR ZENITH ANGLE .GT. 90 DEGREES GLITTR   30
C          = 1 IF SOLAR ZENITH ANGLE .LE. 90 DEGREES GLITTR   31
C IFIRES = FLAG FOR INCLUSION OF FIREBALLS GLITTR   32
C          = 0 IF NO FIREBALL IS BEING CONSIDERED GLITTR   33
C          .GT. 0 IF FIREBALLS ARE BEING CONSIDERED GLITTR   34
C ESURF1 = LOGICAL PARAMETER GLITTR   35
C          = .TRUE. IF ESURF IS CALLED FOR THE FIRST TIME FROM GLITTR   36
C          SURRAD AND EPSPD IS WANTED AS AN OUTPUT, GLITTR   37
C          WHICH IS ALWAYS THE CASE IN THE NBR MODULE GLITTR   38
C          = .FALSE. IF ESURF IS NOT BEING CALLED FOR THE FIRST GLITTR   39
C          TIME FROM SURRAD AND A RECOMPUTATION OF GLITTR   40
C          EPSPD IS NOT NEEDED GLITTR   41
C TECTOR COMMON GLITTR   42
C DETLAT - DETECTOR NORTH LATITUDE, RADIAN GLITTR   43
C DETLON - DETECTOR EAST LONGITUDE, RADIAN GLITTR   44
C DETALT - DETECTOR ALTITUDE, KM GLITTR   45
C DETZEN - DETECTOR ZENITH ANGLE AT POINT P, RADIAN GLITTR   46
C POSITN COMMON GLITTR   47
C POSLAT - NORTH LATITUDE OF INTERSECTION POINT OF LINE-OF- GLITTR   48
C          SIGHT FROM DETECTOR TO EARTH'S SURFACE (RADIAN) GLITTR   49
C POSLON - EAST LONGITUDE OF INTERSECTION POINT OF LINE-OF- GLITTR   50
C          SIGHT FROM DETECTOR TO EARTH'S SURFACE (RADIAN) GLITTR   51
C POSALT - ALTITUDE OF POINT P AT WHICH LINE-OF-SIGHT GLITTR   52
C          INTERSECTS EARTH'S SURFACE, KM GLITTR   53
C SOURCE COMMON GLITTR   54
C SRCLAT - NORTH LATITUDE OF SOURCE (SUN OR FIREBALL) RADIAN GLITTR   55
C SRCLOE - EAST LONGITUDE OF SOURCE (RADIAN) GLITTR   56
C SRCALT - ALTITUDE OF SOURCE, IF NOT THE SUN (KM) GLITTR   57
C SRCFLG - 1, IF SOURCE IS SUN GLITTR   58

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C	- 2, IF SOURCE IS FIREBALL	GLITTR	59
C * *	OUTPUT PARAMETERS	GLITTR	60
C	ARGUMENT LIST	GLITTR	61
C	SFR = F SUB R (2,D(2),ZLAM,THETA1,THETA2) (1/SR)	GLITTR	62
C	- BIDIRECTIONAL REFLECTANCE-DISTRIBUTION FUNCTION	GLITTR	63
C	FOR A WIND-RUFFLED SURFACE.	GLITTR	64
C	EPSD = (1.0-RHO(THETA2)) (DIMENSIONLESS)	GLITTR	65
C	- DIRECTIONAL EMISSIVITY, WHERE RHO(THETA2) IS THE	GLITTR	66
C	SPECULAR REFLECTANCE AT ZENITH ANGLE THETA2	GLITTR	67
C	FOR A SMOOTH HORIZONTAL SURFACE.	GLITTR	68
C	POSITN COMMON	GLITTR	69
C	(THIS OUTPUT OBTAINS ONLY IF SPCULR=.TRUE.)	GLITTR	70
C	SPCLAT - NORTH LATITUDE OF POINT ON SMOOTH HORIZONTAL	GLITTR	71
C	SURFACE FOR A SPECULAR REFLECTION FROM THE	GLITTR	72
C	SOURCE TO THE DETECTOR, RADIANS	GLITTR	73
C	SPCLON - EAST LONGITUDE OF POINT ON SMOOTH HORIZONTAL	GLITTR	74
C	SURFACE FOR A SPECULAR REFLECTION FROM THE	GLITTR	75
C	SOURCE TO THE DETECTOR, RADIANS	GLITTR	76
CCC		GLITTR	77
	COMMON/POSITN/ POSLAT, POSLON, POSALT, SPCLAT, SPCLON	POSITN	2
	, C12LAT, C12LON, C12ALT	POSITN	3
	COMMON/SOURCE/ SRCLAT, SRCCLON, SRCALT, SRCFLG, SRCZEN(11), SRCSCR(11)	SOURCE	2
	COMMON/TECTOR/ DETLAT, DETLON, DETALT, DETZEN, DETAZI(11)	TECTOR	2
	LOGICAL SPCULR, ESURF1	GLITTR	81
	DATA PI, RE / 3.141592653590, 6.37103E+03 /	GLITTR	82
	DATA RSUN, EPSILN / 1.495979E+08, 4.6524E-03 /	GLITTR	83
CC		GLITTR	84
CC	NEED NOT COMPUTE SFR IF NEITHER SUN NOR FIREBALL IS CONSIDERED	GLITTR	85
CC	AS A SOURCE, SO SET IT AS WELL AS THE COORDINATES OF THE	GLITTR	86
CC	SPECULAR POINT (ARBITRARILY) TO -1.0	GLITTR	87
CC	IF((IDAY.EQ.1) .OR. (IFIRES.GT.0)) GO TO 8	GLITTR	88
	SFR = -1.0	GLITTR	89
	DETZENP = DETZEN	GLITTR	90
	GO TO 70	GLITTR	91
CC		GLITTR	92
CCC	FORMULAS FOR SFR * * * * *	GLITTR	93
CCC	FIRST, FOR TILTED FACET AT POINT P, USE LEVAMON'S EQUATIONS	GLITTR	94
CCC	FOR TOTAL TILT MAGNITUDE (BETA) AND DIRECTION (THETA, PHI) AND	GLITTR	95
CCC	ANGLE OF INCIDENCE (OMEGA). WE USE HIS EQUATIONS REWRITTEN IN	GLITTR	96
CCC	TERMS OF OUR PARAMETER EPSA.	GLITTR	97
CC		GLITTR	98
	B EPSA = (RE+POSALT)/(RE+DETALT)	GLITTR	99
CC		GLITTR	100
CC	THETAP - NORTH LATITUDE OF POINT P RELATIVE TO DETECTOR	GLITTR	101
	THETAP = POSLAT-DETLAT	GLITTR	102
	CSTHTP = COS(THETAP)	GLITTR	103
CC		GLITTR	104
CC	PHIP - EAST LONGITUDE OF POINT P RELATIVE TO DETECTOR	GLITTR	105
	PHIP = POSLON-DETLON	GLITTR	106
	CSPHIP = COS(PHIP)	GLITTR	107
CC		GLITTR	108
CC	PHIL - EAST LONGITUDE OF POINT Q-SUB-L RELATIVE TO DETECTOR	GLITTR	109
CC	(LEVAMON (LE-71B) EQ. (1)).	GLITTR	110
CC	POINT Q-SUB-L IS DEFINED BY THE SEA SURFACE AND A	GLITTR	111
CC	VECTOR, STARTING FROM THE EARTH'S CENTER, PARALLEL TO	GLITTR	112
CC	THE RAY FROM THE DETECTOR TO THE REFLECTION POINT P.	GLITTR	113
	EPHTP = EPSA*CSTHTP	GLITTR	114

	PHIL = ATAN(-EPHTP*SIN(PHIP)/(1.-EPHTP*CSPHIP))	GLITTR	115
CC	THETAL = NORTH LATITUDE OF POINT Q-SUB-L RELATIVE TO DETECTOR	GLITTR	116
CC	(LEVANON EQ. (2)).	GLITTR	117
	ROOT = SQRT(1.0-2.*EPHTP*CSPHIP+EPHTP*EPHTP)	GLITTR	118
	THETAL = ATAN(-EPSA*SIN(THETAP)/ROOT)	GLITTR	119
	CSTHTL = COS(THETAL)	GLITTR	120
CC		GLITTR	121
CC	THETAS = NORTH LATITUDE OF SOURCE RELATIVE TO DETECTOR	GLITTR	122
	THETAS = -RCLAT-DETLAT	GLITTR	123
	CSTHTS = COS(THETAS)	GLITTR	124
CC	PHIS = EAST LONGITUDE OF SOURCE RELATIVE TO DETECTOR	GLITTR	125
	PHIS = SRCLON-DETLON	GLITTR	126
CC		GLITTR	127
CC	PHIN = EAST LONGITUDE OF POINT Q-SUB-N RELATIVE TO DETECTOR	GLITTR	128
CC	(LEVANON EQ. (3)).	GLITTR	129
CC	POINT Q-SUB-N IS DEFINED BY THE SEA SURFACE AND A	GLITTR	130
CC	VECTOR, STARTING FROM THE EARTH'S CENTER, PARALLEL TO	GLITTR	131
CC	THE NORMAL REQUIRED FOR REFLECTION FROM POINT P.	GLITTR	132
	AAA = CSTHTL*SIN(PHIP) + CSTHTS*SIN(PHIS)	GLITTR	133
	BBB = CSTHTL*COS(PHIP) + CSTHTS*COS(PHIS)	GLITTR	134
	PHIN = ATAN(AAA/BBB)	GLITTR	135
CC	THETAN = NORTH LATITUDE OF POINT Q-SUB-N RELATIVE TO DETECTOR	GLITTR	136
CC	(LEVANON EQ. (4)).	GLITTR	137
	ROOT = CSTHTL*CSTHTL + CSTHTS*CSTHTS + 2.*CSTHTL*CSTHTS*	GLITTR	138
	COS(PHIP-PHIS)	GLITTR	139
	THETAN = ATAN((SIN(THETAL)+SIN(THETAS))/SORT(ROOT))	GLITTR	140
CC		GLITTR	141
CC	PHI = TILT TOWARD THE EAST AT THE REFLECTION POINT P	GLITTR	142
CC	(LEVANON EQ. (5)).	GLITTR	143
	PHI = PHIN-PHIP	GLITTR	144
CC	THETA = TILT TOWARD THE NORTH AT THE REFLECTION POINT P	GLITTR	145
CC	(LEVANON EQ. (6)).	GLITTR	146
	THETA = THETAN-THETAP	GLITTR	147
CC		GLITTR	148
CC	BETA = TOTAL TILT MAGNITUDE AT THE REFLECTION POINT P	GLITTR	149
CC	(LEVANON EQ. (7)).	GLITTR	150
	ROOT = TAN(THETA)**2 + TAN(PHI)**2	GLITTR	151
	BETA = ATAN(SORT(ROOT))	GLITTR	152
CC		GLITTR	153
CC	OMEGA = ANGLE OF INCIDENCE AT REFLECTION POINT P	GLITTR	154
CC	(LEVANON EQ. (8)).	GLITTR	155
	ROOT = TAN(THETAN-THETAS)**2 + TAN(PHIN-PHIS)**2	GLITTR	156
	OMEGA = ATAN(SORT(ROOT))	GLITTR	157
CC		GLITTR	158
CC	SIGSQ = MEAN SQUARE SLOPE REGARDLESS OF DIRECTION	GLITTR	159
	SIGSQ = (3.0 + 5.12*WIND)*1.E-03	GLITTR	160
CC		GLITTR	161
CC	SMALLP = PROBABILITY FOR OCCURRENCE OF SLOPE BETA	GLITTR	162
	TBETA = TAN(BETA)	GLITTR	163
	SMALLP = EXP(-TBETA*TBETA/SIGSQ)/(PI*SIGSQ)	GLITTR	164
CC		GLITTR	165
	CALL FRESNL(ZLAM,OMEGA,RHO)	GLITTR	166
CC	NOW HAVE FRESNEL MONOCHROMATIC REFLECTANCE (RHO)	GLITTR	167
CC		GLITTR	168
CC	IN COMPUTING SFR, TO AVOID POSSIBLE DIVISION BY ZERO OR	GLITTR	169
CC	NEAR-ZERO IF THETA OR DETZEN EXCEEDS AN ARBITRARILY-	GLITTR	170
CC	SELECTED VALUE, 89.9 DEG., RESET THETA AND/OR DETZEN TO 89.9	GLITTR	171

CC	DEG. DEFINE TEMPORARY VARIABLES TO AVOID ALTERING	GLITTR	172
CC	ORIGINAL VARIABLES.	GLITTR	173
	IWARN = 0	GLITTR	174
	THTAIP = THETA1	GLITTR	175
	DTZENP = DETZEN	GLITTR	176
	PID2 = 0.50*PI	GLITTR	177
	DELTHI = PID2-THETA1	GLITTR	178
	DELTHR = PID2-DETZEN	GLITTR	179
	IF(DELTHI.GE.1.745E-03) GO TO 101	GLITTR	180
	THTAIP = PID2-1.745E-03	GLITTR	181
	IWARN = 1	GLITTR	182
101	IF(DELTHR.GE.1.745E-03) GO TO 102	GLITTR	183
	DTZENP = PID2-1.745E-03	GLITTR	184
	IWARN = 1	GLITTR	185
102	IF(IWARN.EQ.0) GO TO 104	GLITTR	186
CC	WRITE(6,103)	GLITTR	187
103	FORMAT (1H0,9X,44H *** NOTE *** FROM SUBROUTINE GLITTR *** /	GLITTR	188
	1 10X,55H THETA1 OR DETZEN EXCEEDS AN ARBITRARILY-SELECTED VALUE, /	GLITTR	189
	2 10X,55H 89.9 DEGREES, TO WHICH THETA1 OR DETZEN HAS BEEN RESET /	GLITTR	190
	3 10X,55H TO AVOID POSSIBLE DIVISION BY ZERO OR NEAR-ZERO IN /	GLITTR	191
	4 10X,15H COMPUTING SFR. /	GLITTR	192
	5 10X,30H USER SHOULD VERIFY THAT--- /	GLITTR	193
	6 10X,55H (1) THE CODE HAS A PROPER VALUE OF THETA1 OR DETZEN /	GLITTR	194
	7 10X,20H AND, IF SO, /	GLITTR	195
	8 10X,55H (2) WHETHER OR NOT RESETTING OF THETA1 OR DETZEN /	GLITTR	196
	9 10X,40H TO 89.9 DEGREES IS SATISFACTORY.)	GLITTR	197
CC		GLITTR	198
104	SHADOW = 1.0	GLITTR	199
	IF(WIND.EQ.0.0) GO TO 107	GLITTR	200
CC	SHADOW = SHADOWING FACTOR BASED ON WORK OF SAUNDERS (SA-67,	GLITTR	201
CC	SA-68C) BUT EXTENDED TO PERMIT A BISTATIC DEPENDENCE	GLITTR	202
CC	ON THE ZENITH ANGLES OF BOTH INCOMING AND OUTGOING	GLITTR	203
CC	RAY	GLITTR	204
	PISQ = SORT(PI)	GLITTR	205
	SIGS = SORT(5.12E-03*WIND)	GLITTR	206
	THETV2 = ATAN2(0.50,SIGS)	GLITTR	207
CC	THETV2 IS THE ZENITH ANGLE BELOW WHICH ESSENTIALLY	GLITTR	208
CC	NO SHADOWING OCCURS.	GLITTR	209
	SOF SVI = 1.0	GLITTR	210
	IF(THETA1.LT.THETV2) GO TO 105	GLITTR	211
	SVI = 1.0/(SIGS*TAN(THTAIP))	GLITTR	212
	SOF SVI = 2.0/(1.0+ERF(SVI)+EXP(-SVI*SVI))/(PISQ*SVI)	GLITTR	213
105	SOF SVR = 1.0	GLITTR	214
	IF(DETZEN.LT.THETV2) GO TO 106	GLITTR	215
	SVR = 1.0/(SIGS*TAN(DTZENP))	GLITTR	216
	SOF SVR = 2.0/(1.0+ERF(SVR)+EXP(-SVR*SVR))/(PISQ*SVR)	GLITTR	217
106	SHADOW = SOF SVI*SOF SVR	GLITTR	218
CC		GLITTR	219
107	SFR = 0.25*RHO*SMALLP/(COS(DTZENP)*COS(THTAIP))	GLITTR	220
	SFR = SFR*SHADOW/COS(BETA)**4	GLITTR	221
CC		GLITTR	222
CC		GLITTR	223
CC		GLITTR	224
	IF(.NOT.SPCULR) GO TO 70	GLITTR	225
CC		GLITTR	226
CCC	FORMULAS FOR SPCLAT AND SPCLON * * * * *	GLITTR	227
CC		GLITTR	228

CC	ALP = TOTAL EARTH-CENTRAL ANGLE BETWEEN RAYS TO DETECTOR	GLITTR	229
CC	AND SOURCE.	GLITTR	230
	ALP = CANGLE(DETLAT,DETLON,SRCLAT,SRCLON)	GLITTR	231
	KFLG = SRCFLG+0.05	GLITTR	232
	GO TO (10,12), KFLG	GLITTR	233
CC	SET EPSS FOR SUN BEING SOURCE.	GLITTR	234
10	EPSS = (RE+POSALT)/RSUN	GLITTR	235
	GO TO 14	GLITTR	236
CC	SET EPSS FOR FIREBALL BEING SOURCE.	GLITTR	237
12	EPSS = (RE+POSALT)/(RE+SRCALT)	GLITTR	238
C	***	GLITTR	239
C	*** START OF ITERATIVE PROCEDURE FOR THE SOLUTION OF THE	GLITTR	240
C	REFLECTION POINT (IN TERMS OF ALPA AND ALPS).	GLITTR	241
C	THE METHOD USED IS NEWTON-RAPHSON.	GLITTR	242
C	***	GLITTR	243
14	KOUNT = 0	GLITTR	244
	FACT = (1.0-EPSS)/((1.0-EPSS)+(1.0-EPSS))	GLITTR	245
C	THE INITIAL GUESS FOR ALPA IS GIVEN BY FACT*ALP	GLITTR	246
	ALPA = FACT*ALP	GLITTR	247
16	KOUNT = KOUNT+1	GLITTR	248
	ALPS = ALP-ALPA	GLITTR	249
	BETA = ATAN(EPSS*SIN(ALPA)/(1.0-EPSS*COS(ALPA)))	GLITTR	250
	BETS = ATAN(EPSS*SIN(ALPS)/(1.0-EPSS*COS(ALPS)))	GLITTR	251
C	CALCULATE F(ALPA), FOFA, AND F PRIME(ALPA), FOFAP	GLITTR	252
	FOFA = ALP-2.*ALPA+BETS-BETA	GLITTR	253
	DD1 = 1.0 + EPSS*(EPSS-2.*COS(ALPS))	GLITTR	254
	DD2 = 1.0 + EPSS*(EPSS-2.*COS(ALPA))	GLITTR	255
	FOFAP = EPSS*(EPSS-COS(ALPS))/DD1 - 2.0	GLITTR	256
	FOFAP = EPSS*(EPSS-COS(ALPA))/DD2 + FOFAP	GLITTR	257
	DELTA = (ALPA+BETA)-(ALPS+BETS)	GLITTR	258
C	UPDATE ALPA --	GLITTR	259
C	ALPA NEW = ALPA OLD - F(ALPA OLD)/F PRIME(ALPA OLD)	GLITTR	260
	ALPA = ALPA-FOFA/FOFAP	GLITTR	261
C	CHECK FOR SOLUTION OR IF NUMBER OF ALLOWED ITERATIONS	GLITTR	262
C	HAS BEEN EXCEEDED	GLITTR	263
	IF(ABS(DELTA).LE.2.0E-05) GO TO 18	GLITTR	264
	IF(KOUNT.GE.100) GO TO 18	GLITTR	265
	GO TO 16	GLITTR	266
C	***	GLITTR	267
C	*** END OF ITERATIVE PROCEDURE.	GLITTR	268
C	***	GLITTR	269
18	ALPS = ALP-ALPA	GLITTR	270
	ALPSD = ALPS*180./PI	GLITTR	271
	ALPAD = ALPA*180./PI	GLITTR	272
	WRITE(6,5) ALPAD,ALPSD,KOUNT,EPSS,EPSS	GLITTR	273
5	FORMA* (12H0 ALPHA A =,F12.4,5X,11H ALPHA S =,F12.4,5X,15,	GLITTR	274
	* 12H ITERATIONS,5X,6H EPSA=,E12.4,5X,6H EPSS=,E12.4)	GLITTR	275
	CALL GRCLE(DETLAT,DETLON,SRCLAT,SRCLON,ALP,ALPA,SPCLAT,SPCLON)	GLITTR	276
CC	NOW HAVE SPCLAT AND SPCLON	GLITTR	277
CC		GLITTR	278
	GO TO 80	GLITTR	279
70	SPCLAT = -1.0	GLITTR	280
	SPCLON = -1.0	GLITTR	281
80	IF(.NOT.ESURF1) RETURN	GLITTR	282
CC		GLITTR	283
CCC	FORMULAS FOR EPSD *	GLITTR	284
CC		GLITTR	285
	CALL FRESNL(ZLAM,DTZEMP,RHO)	GLITTR	286
CC		GLITTR	287
CC	COMPUTE EPSD	GLITTR	288
	EPSD = 1.0-RHO	GLITTR	289
	RETURN	GLITTR	290
	END	GLITTR	291

SUBROUTINE PATH(FIRST, ISHELL, DS, XFRACS)	PATH	2
C	PATH	3
C *PATH* DEVELOPS THE PATH INTEGRALS FOR ATMOSPHERIC ABSORPTION.	PATH	4
C	PATH	5
CLJ	PATH	6
CLJ INPUT PARAMETERS	PATH	7
CLJ ARGUMENT LIST	PATH	8
CLJ FIRST = LOGICAL INITIALIZATION SWITCH	PATH	9
CLJ = .TRUE. FOR FIRST CALL (I.E., CORRESPONDING TO	PATH	10
CLJ PATH FROM RX TO RY IN TRNSCO)	PATH	11
CLJ = .FALSE. FOR SUBSEQUENT CALLS (I.E., CORRESPONDING	PATH	12
CLJ TO PATH FROM RY TO RZ IN TRNSCO)	PATH	13
CLJ ISHELL(1) = INDX(1) IN CALL FROM TRNSCO OR SURRAD	PATH	14
CLJ ISHELL(2) = INDX(1+1) IN CALL FROM TRNSCO OR SURRAD	PATH	15
CLJ DS = DS(I+1) IN CALL FROM TRNSCO OR SURRAD.	PATH	16
CLJ NOTE... IT IS ALWAYS TRUE THAT DS(1)=0.0 AND	PATH	17
CLJ DS(NC+1)=-1., WHERE NC IS THE NUMBER OF PATH	PATH	18
CLJ SEGMENTS PLUS ONE. ATMTRAD WILL NOT BE CALLED	PATH	19
CLJ WITH !=NC.	PATH	20
CLJ XFRACS(1) = XFRACS(1) IN CALL FROM TRNSCO OR SURRAD	PATH	21
CLJ XFRACS(2) = XFRACS(I+1) IN CALL FROM TRNSCO OR SURRAD.	PATH	22
CLJ NOTE. THIS ARRAY XFRACS (DIMENSIONED 2) IS NOT THE	PATH	23
CLJ SAME AS THE ARRAY XFRACS (DIMENSIONED 10) IN	PATH	24
CLJ SUBROUTINES STEP, STEPS, AND TRNSCO.	PATH	25
CLJ (SEE NOTE IN SUBROUTINE ATMTRAD)	PATH	26
CLJ XYZCOM COMMON	PATH	27
CLJ NS = NUMBER OF ALTITUDE BOUNDARIES	PATH	28
CLJ TS(J) = TEMPERATURE AT ALTITUDE BOUNDARY J, DEG K (J=1,NS)	PATH	29
CLJ PS(J) = PRESSURE AT ALTITUDE BOUNDARY J, ATM (J=1,NS)	PATH	30
CLJ XNSPEC(J,N) = SPECIES-N DENSITY AT ALTITUDE BOUNDARY J, 1/CM**3	PATH	31
CLJ (J=1,NS , N=1,10)	PATH	32
CLJ OUTPUT PARAMETERS	PATH	33
CLJ XYZCOM COMMON	PATH	34
CLJ U(I,N,2) = CUMULATIVE VALUE OF PATH PARAMETER U (AREAL	PATH	35
CLJ DENSITY) FOR TEMPERATURE-INDEX I AND SPECIES N AT	PATH	36
CLJ END OF LINE SEGMENT DS, CM AT STP	PATH	37
CLJ UP(I,N,2) = CUMULATIVE VALUE OF PATH PARAMETER UP (PRODUCT OF	PATH	38
CLJ U AND PRESSURE P) FOR TEMPERATURE-INDEX I AND	PATH	39
CLJ SPECIES N AT END OF LINE SEGMENT DS, ATM-CM	PATH	40
CLJ AT STP FOR U AND UP (I=1,2 , N=1,10)	PATH	41
CLJ	PATH	42
CLJ DIMENSION XNS1(10), XNS2(10), DU(10,10), DUP(10,10), ISHELL(2),	PATH	43
CLJ XFRACS(2)	PATH	44
CLJ COMMON / XYZCOM / ITMTE, LTMTE, NS, HSHLL(81), TS(81), PS(81),	PATH	45
CLJ XNSPEC(81,10), U(10,10,2), UP(10,10,2), NMOLS,	PATH	46
CLJ FACT	PATH	47
C	PATH	48
C LOGICAL FIRST	PATH	49
C	PATH	50
CLJ XINTRP IS AN ARITHMETIC STATEMENT FUNCTION FOR LINEAR	PATH	51
CLJ INTERPOLATION, RETURNING THE VALUE XINTRP AT A FRACTIONAL	PATH	52
CLJ DISTANCE (1.-XFRAC) BETWEEN END-POINT VALUES Z1 AND Z2.	PATH	53
CLJ	PATH	54
CLJ XINTRP(Z1, Z2) = Z1 * XFRAC + Z2 * (1. - XFRAC)	PATH	55
C	PATH	56
C IF (.NOT. FIRST) GO TO 1	PATH	57
C INITIALIZATIONS	PATH	58

	FIRST = .FALSE.	PATH	59
CLJ	NOW ZERO SECOND-HALVES OF U AND UP ARRAYS, WHICH IS WHERE WE	PATH	60
CLJ	ACCUMULATE OUR OUTPUT RESULTS FOR THESE ARRAYS.	PATH	61
	CALL XMIT (-100, 0., U(1,1,2))	PATH	62
	CALL XMIT (-100, 0., UP(1,1,2))	PATH	63
C		PATH	64
1	L1 = ISHELL(1)	PATH	65
	L2 = ISHELL(2)	PATH	66
C	SET SHELL PROPERTIES AT FIRST POINT	PATH	67
CLJ	NOW TRANSFER SECOND-HALVES OF U AND UP ARRAYS TO FIRST-HALVES,	PATH	68
CLJ	I.E., INITIALIZE THE STARTING POINT OF THE SECOND LEG TO	PATH	69
CLJ	VALUES AT END OF FIRST LEG OF PATH.	PATH	70
	CALL XMIT (100, U(1,1,2), U)	PATH	71
	CALL XMIT (100, UP(1,1,2), UP)	PATH	72
	IF (L2 .EQ. 0) RETURN	PATH	73
C	INTERPOLATE FOR P, T, AND C(SPECIES) AT FIRST POINT	PATH	74
	XFRAC = XFRACS(1)	PATH	75
	PSL1 = PS(L1)	PATH	76
	TSL1 = TS(L1)	PATH	77
	IF (XFRAC .EQ. 1.) GO TO 2	PATH	78
	PSL1 = XINTRP(PS(L1), PS(L2))	PATH	79
	TSL1 = XINTRP(TS(L1), TS(L2))	PATH	80
2	DO 3 N=1,10	PATH	81
	XNS1(N) = XNSPEC(L1,N)	PATH	82
	IF (XFRAC .EQ. 1. .OR. XNSPEC(L1,N) + XNSPEC(L2,N) .EQ. 0.)	PATH	83
	\$ GO TO 3	PATH	84
	XNS1(N) = XINTRP(XNSPEC(L1,N), XNSPEC(L2,N))	PATH	85
	3 CONTINUE	PATH	86
C	INTERPOLATE FOR P, T, AND C(SPECIES) AT SECOND POINT	PATH	87
	XFRAC = XFRACS(2)	PATH	88
	PSL2 = PS(L2)	PATH	89
	TSL2 = TS(L2)	PATH	90
	IF (XFRAC .EQ. 1.) GO TO 4	PATH	91
	PSL2 = XINTRP(PS(L2), PS(L1))	PATH	92
	TSL2 = XINTRP(TS(L2), TS(L1))	PATH	93
4	DO 5 N=1,10	PATH	94
	XNS2(N) = XNSPEC(L2,N)	PATH	95
	IF (XFRAC .EQ. 1. .OR. XNSPEC(L1,N) + XNSPEC(L2,N) .EQ. 0.)	PATH	96
	\$ GO TO 5	PATH	97
	XNS2(N) = XINTRP(XNSPEC(L2,N), XNSPEC(L1,N))	PATH	98
5	CONTINUE	PATH	99
C	COMPUTE DIFFERENTIAL U AND UP	PATH	100
	CALL SEGMENT (10, 0., XNS1, PSL1, TSL1, DS, XNS2, PSL2, TSL2,	PATH	101
	\$ DU, DUP)	PATH	102
C	ACCUMULATE U AND UP AT SECOND POINT	PATH	103
	DO 6 N=1,10	PATH	104
	DO 7 I=1,2	PATH	105
	U(I,N,2) = U(I,N,2) + DU(I,N)	PATH	106
	UP(I,N,2) = UP(I,N,2) + DUP(I,N)	PATH	107
6	CONTINUE	PATH	108
	RETURN	PATH	109
	END	PATH	110

C	FUNCTION PLANCK (T, W)	PLANCK	2
C	*PLANCK* GIVES THE BLACK BODY SPECTRUM	PLANCK	3
C	(WATTS CM-2 ST-1 (CM-1)-1)	PLANCK	4
C		PLANCK	5
CLJ		PLANCK	6
CLJ	INPUT PARAMETER	PLANCK	7
CLJ	ARGUMENT LIST	PLANCK	8
CLJ	T = TEMPERATURE, DEG K	PLANCK	9
CLJ	W = WAVENUMBER, 1/CM	PLANCK	10
CLJ	DATA STATEMENTS	PLANCK	11
CLJ	C = VELOCITY OF LIGHT, CM/SEC	PLANCK	12
CLJ	H = PLANCK'S CONSTANT, J SEC	PLANCK	13
CLJ	CHK = C*H/K, CM DEGREE-K	PLANCK	14
CLJ	WHERE K = BOLTZMANN CONSTANT	PLANCK	15
CLJ	= 1.380662E-23 J/(DEGREE-K)	PLANCK	16
CLJ	OUTPUT PARAMETER	PLANCK	17
CLJ	FUNCTION	PLANCK	18
CLJ	PLANCK = SPECTRAL RADIANCE, WATTS/(CM**2 SR CM**-1)	PLANCK	19
CLJ		PLANCK	20
CLJ	DATA C / 2.997925E10 /, CHK / 1.438786 /, H / 6.626176E-34 /	PLANCK	21
CLJ		PLANCK	22
	PLANCK = 0.	PLANCK	23
	IF (T .EQ. 0.) GO TO 2	PLANCK	24
	Z = CHK / T * W	PLANCK	25
	IF (Z .GE. 88.) GO TO 2	PLANCK	26
	PLANCK = (2. * C**2 * W**3 / (EXP(Z) - 1.)) * H	PLANCK	27
CLJ		PLANCK	28
CLJ	TO OBTAIN PLANCK IN THE UNITS USED BY GRC.	PLANCK	29
CLJ	PHOTONS/(CM**2 SEC SR CM**-1),	PLANCK	30
CLJ	DIVIDE BY HCW=H*C*W .	PLANCK	31
CLJ		PLANCK	32
CLJ	TO OBTAIN PLANCK IN UNITS OF W/(CM**2 SR MICRON), MULTIPLY BY	PLANCK	33
CLJ	1.E-04*W*W OR BY 1.E+04/(ZLAMDA*ZLAMDA) WHERE ZLAMDA=1.E+04/W	PLANCK	34
CLJ		PLANCK	35
CLJ		PLANCK	36
	2 RETURN	PLANCK	37
	END	PLANCK	38

CCC	SUBROUTINE REATAN(SR,EL,AZ,XE,YN,ZV)	REATAN	2
C		REATAN	3
C	SUBROUTINE REATAN (A MODIFIED HARC ROUTINE CALLED REAXYZ).	REATAN	4
C	GIVEN THE SLANT RANGE, ELEVATION ANGLE, AND AZIMUTH ANGLE OF A	REATAN	5
C	POINT WITH RESPECT TO SOME REFERENCE LOCATION, PROVIDES THE	REATAN	6
C	TANGENT-PLANE COORDINATES OF THE POINT WITH RESPECT TO THE	REATAN	7
C	SAME REFERENCE.	REATAN	8
CCC		REATAN	9
C	INPUTS FROM CALL STATEMENT	REATAN	10
C	SR = SLANT RANGE OF POINT, CM	REATAN	11
C	EL = ELEVATION ANGLE OF POINT, RADIAN	REATAN	12
C	AZ = AZIMUTH ANGLE OF POINT, RADIAN	REATAN	13
C	OUTPUT:	REATAN	14
C	XE = X COORDINATE OF POINT, CM	REATAN	15
C	YN = Y COORDINATE OF POINT, CM	REATAN	16
C	ZV = Z COORDINATE OF POINT, CM	REATAN	17
CCC		REATAN	18
	COSEL = COS(EL)	REATAN	19
	XE = SR*COSEL*SIN(AZ)	REATAN	20
	YN = SR*COSEL*COS(AZ)	REATAN	21
	ZV = SR*SIN(EL)	REATAN	22
	RETURN	REATAN	23
	END	REATAN	24

CCC	SUBROUTINE RINOUT(MAT,IFIRE,IDAY)	RINOUT	2
C		RINOUT	3
C	SUBROUTINE RINOUT, GIVEN THE GEOGRAPHIC LOCATIONS OF THE	RINOUT	4
C	SOURCES (SUN AND/OR FIREBALLS), THE DETECTOR, AND THE	RINOUT	5
C	POSITION P OF THE INTERSECTION OF THE LINE-OF-SIGHT FROM THE	RINOUT	6
C	DETECTOR TO THE EARTH'S SURFACE, COMPUTES THE ZENITH ANGLES	RINOUT	7
C	(AND, FOR FIREBALLS, SLANT RANGES) OF SOURCES FROM P AND THE	RINOUT	8
C	DIRECTION OF THE RAY FROM P TO DETECTOR IN TERMS OF ZENITH	RINOUT	9
C	ANGLE OF THE DETECTOR AND (IF THE SURFACE IS NOT LAMBERTIAN	RINOUT	10
C	(MAT=1) OR WATER (MAT=2)) THE ABSOLUTE VALUE OF THE AZIMUTH	RINOUT	11
C	ANGLE OF SCATTER WITH RESPECT TO THE PRINCIPAL PLANE	RINOUT	12
C	CONTAINING THE INCOMING RAY.	RINOUT	13
CCC		RINOUT	14
CCC	INPUT PARAMETERS	RINOUT	15
C	ARGUMENT LIST	RINOUT	16
C	IFIRE = NUMBER OF FIREBALLS TO BE CONSIDERED AS SOURCES	RINOUT	17
C	(ALWAYS ZERO IN NBR MODULE)	RINOUT	18
C	MAT = INDEX FOR CATEGORY OF SURFACE MATERIAL	RINOUT	19
C	= 1, LAMBERTIAN DIFFUSE SURFACE = 2, WATER	RINOUT	20
C	= 3, SNOW = 4, SAND = 5, SOIL = 6, FOLIAGE	RINOUT	21
C	= 7, URBAN MATERIAL	RINOUT	22
C	TECTOR COMMON	RINOUT	23
C	DETLAT - NORTH LATITUDE OF DETECTOR SUBPOINT, RADIAN	RINOUT	24
C	DETLON - EAST LONGITUDE OF DETECTOR SUBPOINT, RADIAN	RINOUT	25
C	DEALT - ALTITUDE OF DETECTOR, KM	RINOUT	26
C	FIRBAL COMMON (NOT USED IN NBR MODULE)	RINOUT	27
C	FBLAT(L) - NORTH LATITUDE OF FIREBALL-L, RADIAN	RINOUT	28
C	FBLON(L) - EAST LONGITUDE OF FIREBALL-L, RADIAN	RINOUT	29
C	FBALT(L) - ALTITUDE OF FIREBALL-L, KM	RINOUT	30
C	FBRINT(L) - RADIANT INTENSITY OF FIREBALL-L, WATTS/SEC	RINOUT	31
C	POSITN COMMON	RINOUT	32
C	POSLAT - NORTH LATITUDE OF INTERSECTION POINT OF LINE-OF-	RINOUT	33
C	SIGHT FROM DETECTOR TO EARTH'S SURFACE, RADIAN	RINOUT	34
C	POSLOM - EAST LONGITUDE OF INTERSECTION POINT OF LINE-OF-	RINOUT	35
C	SIGHT FROM DETECTOR TO EARTH'S SURFACE, RADIAN	RINOUT	36
C	POSALT - ALTITUDE OF INTERSECTION POINT OF LINE-OF-SIGHT	RINOUT	37
C	FROM DETECTOR TO EARTH'S SURFACE, KM	RINOUT	38
C	SOLARP COMMON	RINOUT	39
C	SOLLAT - NORTH LATITUDE OF SUBSOLAR POINT, RADIAN	RINOUT	40
C	SOLLOM - EAST LONGITUDE OF SUBSOLAR POINT, RADIAN	RINOUT	41
CCC	OUTPUT PARAMETERS	RINOUT	42
C	ARGUMENT LIST	RINOUT	43
C	IDAY - INDEX FOR DAYLIGHT CONDITIONS AT POINT P	RINOUT	44
C	=0 IF SOLAR ZENITH ANGLE .GT. 90. DEGREES	RINOUT	45
C	=1 IF SOLAR ZENITH ANGLE .LE. 90. DEGREES	RINOUT	46
C	TECTOR COMMON	RINOUT	47
C	DETZEN - ZENITH ANGLE OF RAY REFLECTED AT POINT P TOWARD	RINOUT	48
C	THE DETECTOR, RADIAN	RINOUT	49
C	DETAZI(1) - ABSOLUTE VALUE OF AZIMUTH OF REFLECTED RAY,	RINOUT	50
C	MEASURED FROM PRINCIPAL PLANE DETERMINED BY	RINOUT	51
C	VERTICAL PLANE THROUGH INCOMING RAY FROM SUN,	RINOUT	52
C	RADIAN	RINOUT	53
C	DETAZI(L+1), L=1,IFIRE (NOT USED IN NBR MODULE)	RINOUT	54
C	- ABSOLUTE VALUE OF AZIMUTH OF REFLECTED RAY,	RINOUT	55
C	MEASURED FROM PRINCIPAL PLANE DETERMINED BY	RINOUT	56
C	VERTICAL PLANE THROUGH INCOMING RAY, RADIAN	RINOUT	57
C	SOURCE COMMON	RINOUT	58

C	SRCZEN(1) - ZENITH ANGLE OF RAY INCOMING TO POINT P FROM	RINOUT	59
C	THE SUN, RADIANS	RINOUT	60
C	SRCZEN(L+1), L=1, IFIRE (NOT USED IN NBR MODULE)	RINOUT	61
C	- ZENITH ANGLE OF RAY INCOMING TO POINT P FROM	RINOUT	62
C	FIREBALL-L, RADIANS	RINOUT	63
C	SRCZR(L+1), L=1, IFIRE (NOT USED IN NBR MODULE)	RINOUT	64
C	- SLANT RANGE FROM FIREBALL-L TO POINT P, KM	RINOUT	65
CCC		RINOUT	66
	COMMON/FIRBAL/ FBLAT(10), FBLON(10), FBALT(10), FBRINT(10)	FIRBAL	2
	COMMON/POSITN/ POSLAT, POSLON, POSALT, SPCLAT, SPCLON	POSITN	2
	, C12LAT, C12LON, C12ALT	POSITN	3
	COMMON/SATELL/ SATLAT, SATLON, SATALT, SATZEN, SATAZI	SATELL	2
	COMMON/SOLARP/ SOLLAT, SOLLON, SOLIRR(10)	SOLARP	2
	COMMON/SOURCE/ SRCLAT, SRCLON, SRCALT, SRCFLG, SRCZEN(11), SRCZR(11)	SOURCE	2
	COMMON/TECTOR/ DETLAT, DETLON, DETALT, DETZEN, DETAZI(11)	TECTOR	2
	DATA PI, RE / 3.141592653590, 6.37103E+03 /	RINOUT	73
CCC		RINOUT	74
C	UPON BEING CALLED FROM SUBROUTINE SURRAD INITIALLY WITH	RINOUT	75
C	IFIRE=0 (EVEN THOUGH IFIRES.GT. 0), RINOUT DECIDES WHETHER	RINOUT	76
C	THE SUN CAN BE A SOURCE, DEPENDING ON ITS ZENITH ANGLE.	RINOUT	77
CCC		RINOUT	78
	IF(IFIRE.GT.0) GO TO 20	RINOUT	79
	SINSIN = SIN(POSLAT)*SIN(SOLLAT)	RINOUT	80
	COSCOS = COS(POSLAT)*COS(SOLLAT)	RINOUT	81
	CSSOLZ = SINSIN + COSCOS*COS(POSLON-SOLLON)	RINOUT	82
	IDAY = 0	RINOUT	83
	IF(CSSOLZ.LT.0.0) GO TO 10	RINOUT	84
	IDAY = 1	RINOUT	85
	SRCZEN(1) = ACOS(CSSOLZ)	RINOUT	86
	10 CONTINUE	RINOUT	87
CC		RINOUT	88
CC	COMPUTE DETECTOR ZENITH ANGLE, DETZEN, AND, IF MAT.GT. 2 AND	RINOUT	89
CC	IDAY=1, THE DETECTOR AZIMUTH ANGLE FOR SUN, DETAZI(1).	RINOUT	90
CC	ALPHAD = EARTH-CENTRAL ANGLE BETWEEN RAYS TO DETECTOR AND	RINOUT	91
CC	LINE-OF-SIGHT INTERSECTION POINT	RINOUT	92
	ALPHAD = CANGLE(DETLAT, DETLON, POSLAT, POSLON)	RINOUT	93
	EPSD = (RE+POSALT)/(RE+DETALT)	RINOUT	94
	CD = (1.0-EPSD)/(1.0+EPSD)	RINOUT	95
	CD = 2.0*ATAN(CD/TAN(ALPHAD/2.))	RINOUT	96
	BETAD = 0.5*(PI-ALPHAD-CD)	RINOUT	97
	DETZEN = ALPHAD+BETAD	RINOUT	98
	IF((IDAY.EQ.0) .OR. (MAT.LE.2)) RETURN	RINOUT	99
CC		RINOUT	100
CC	SET SUN INTO SOURCE COORDINATES.	RINOUT	101
	SRCLAT = SOLLAT	RINOUT	102
	SRCLON = SOLLON	RINOUT	103
	GO TO 40	RINOUT	104
20	L=1	RINOUT	105
CC		RINOUT	106
CC	SET FIREBALL-L INTO SOURCE COORDINATES.	RINOUT	107
30	SRCLAT = FBLAT(L)	RINOUT	108
	SRCLON = FBLON(L)	RINOUT	109
	SRCALT = FBALT(L)	RINOUT	110
CC		RINOUT	111
	IF(MAT.LE.2) GO TO 60	RINOUT	112
CC		RINOUT	113
CC	START CALCULATION OF DETAZI(1) OR DETAZI(L+1), (L=1, IFIRE)	RINOUT	114

40	SINNP = COS(POSLAT)	RINOUT	115
	COSNP = SIN(POSLAT)	RINOUT	116
	COSNS = SIN(SRCLAT)	RINOUT	117
	SINNS = COS(SRCLAT)	RINOUT	118
	TWOPI = PI*PI	RINOUT	119
	PNS = ABS(SRCLOW-POSLOW)	RINOUT	120
	IF(PNS.GE.PI) PNS = TWOPI-PNS	RINOUT	121
	SINPNS = SIN(PNS)	RINOUT	122
	PS = CANGLE(POSLAT, POSLOW, SRCLAT, SRCLOW)	RINOUT	123
	SINQSN = SINNP*SINPNS/SIN(PS)	RINOUT	124
CC	SOME NUMERICAL PRECAUTIONS ARE NECESSARY.	RINOUT	125
	ABSQSN = ABS(SINQSN)	RINOUT	126
	ABSOME = ABSQSN-1.0	RINOUT	127
	IF((ABSQSN.GT.1.0) .AND. (ABSOME.LE.1.0E-10))	RINOUT	128
	* SINQSN = SIGN(1.0, SINQSN)	RINOUT	129
	QSN = ASIN(SINQSN)	RINOUT	130
	COSQNP = COSNS*COS(PS)	RINOUT	131
	IF(COSNP.LT.COSQNP) QSN = PI-QSN	RINOUT	132
	COSQSN = COS(QSN)	RINOUT	133
	QMS = ABS(SRCLOW-DETLON)	RINOUT	134
	IF(QMS.GE.PI) QMS = TWOPI-QMS	RINOUT	135
	COSQMS = COS(QMS)	RINOUT	136
	SINQMS = SIN(QMS)	RINOUT	137
	RNQS = ACOS(SINQMS*SINQSN*COSNS - COSQMS*COSQSN)	RINOUT	138
	SINRQS = SIN(RNQS)	RINOUT	139
	QN = ASIN(SINQSN*SINNS/SINRQS)	RINOUT	140
	CSQSNR = -COSQMS*COS(RNQS)	RINOUT	141
	IF(COSQSN.LT.CSQSNR) QN = PI-QN	RINOUT	142
	SINAQ = COS(QN+DETLAT)	RINOUT	143
	PSI = ASIN(SINAQ*SINRQS/SIN(ALPHAD))	RINOUT	144
	COSAQ = SIN(QN+DETLAT)	RINOUT	145
	QNP = ABS(DETLOW-POSLOW)	RINOUT	146
	IF(QNP.GE.PI) QNP = TWOPI-QNP	RINOUT	147
	SINQNP = SIN(QNP)	RINOUT	148
	SINQP = SINQNP*SINNP/SINRQS	RINOUT	149
	SNQPSQ = SINQP*SINQP	RINOUT	150
	COSQP = SQRT(1.0-SNQPSQ)	RINOUT	151
	COSAQR = ALPHAD*COSQP	RINOUT	152
	IF(COSAQ.LT.COSAQR) PSI = PI-PSI	RINOUT	153
	IF(IFIRE.GT.0) GO TO 50	RINOUT	154
	DETAZI(1) = PSI	RINOUT	155
	RETURN	RINOUT	156
CC		RINOUT	157
CC	-----	RINOUT	158
CC	THE REMAINING PORTION OF THIS SUBROUTINE IS NOT USED IN THE	RINOUT	159
CC	MBK MODULE.	RINOUT	160
50	CONTINUE	RINOUT	161
CC	SET DETAZI(L+1).	RINOUT	162
	DETAZI(L+1) = PSI	RINOUT	163
CC		RINOUT	164
CC	COMPUTE SRCZEN(L+1) AND SRCZR(L+1).	RINOUT	165
CC	ALPHA = EARTH-CENTRAL ANGLE BETWEEN RAYS TO FIREBALL AND	RINOUT	166
CC	LINE-OF-SIGHT INTERSECTION POINT	RINOUT	167
60	ALPHA = CANGLE(POSLAT, POSLOW, SRCLAT, SRCLOW)	RINOUT	168
	EPSF = (RE+POSALT)/(RE+SRCALT)	RINOUT	169
	CF = (1.0-EPSF)/(1.0+EPSF)	RINOUT	170
	CF = 2.*ATAN(CF/TAN(ALPHAF/2.))	RINOUT	171
	BETAF = 0.5*(PI-ALPHAF-CF)	RINOUT	172
	SRCZEN(L+1) = ALPHAF+BETAF	RINOUT	173
	SRCZR(L+1) = RE*SIN(ALPHAF)/SIN(BETAF)	RINOUT	174
	IF(L.GE.IFIRE) RETURN	RINOUT	175
	L = L+1	RINOUT	176
	GO TO 30	RINOUT	177
	END	RINOUT	178

	SUBROUTINE SEGMENT (NSPEC, X1, NS1, P1, T1, X2, NS2, P2, T2,	SEGMENT	2
1	DU, DUP)	SEGMENT	3
C		SEGMENT	4
C	*SEGMENT* DEVELOPES THE ABSORBER AND PARTIAL PRESSURE	SEGMENT	5
C	INTEGRALS FOR SPECIES IN THE PATH ELEMENT FROM POINT 1	SEGMENT	6
C	TO POINT 2. ALL PROPERTIES, TEMPERATURE, PRESSURE, AND	SEGMENT	7
C	CONCENTRATIONS, ARE ASSUMED TO VARY LINEARLY THROUGH THE	SEGMENT	8
C	PATH ELEMENT.	SEGMENT	9
C		SEGMENT	10
CLJ	INPUT PARAMETERS	SEGMENT	11
CLJ	ARGUMENT LIST	SEGMENT	12
CLJ	NSPEC = NUMBER OF SPECIES (10, SET IN CALL FROM PATH).	SEGMENT	13
CLJ	THESE SPECIES ARE IDENTIFIED BY COMMENTS IN	SEGMENT	14
CLJ	SUBROUTINE SHELLS.	SEGMENT	15
CLJ	X1 = DISTANCE ALONG LINE SEGMENT (0., SET IN CALL	SEGMENT	16
CLJ	FROM PATH), CM	SEGMENT	17
CLJ	NS1 = XNS1(10)-ARRAY, SET IN CALL FROM PATH.	SEGMENT	18
CLJ	= ARRAY OF SPECIES CONCENTRATIONS AT START OF	SEGMENT	19
CLJ	LINE SEGMENT, 1/CM**3	SEGMENT	20
CLJ	P1 = PSL1, SET IN CALL FROM PATH.	SEGMENT	21
CLJ	= PRESSURE AT START OF LINE SEGMENT, ATM	SEGMENT	22
CLJ	T1 = TSL1, SET IN CALL FROM PATH.	SEGMENT	23
CLJ	= TEMPERATURE AT START OF LINE SEGMENT, DEG K	SEGMENT	24
CLJ	X2 = DS, SET IN CALL FROM PATH.	SEGMENT	25
CLJ	= LENGTH OF LINE SEGMENT, CM	SEGMENT	26
CLJ	NS2 = XNS2(10)-ARRAY, SET IN CALL FROM PATH.	SEGMENT	27
CLJ	= ARRAY OF SPECIES CONCENTRATIONS AT END OF	SEGMENT	28
CLJ	LINE SEGMENT, 1/CM**3	SEGMENT	29
CLJ	P2 = PSL2, SET IN CALL FROM PATH.	SEGMENT	30
CLJ	= PRESSURE AT END OF LINE SEGMENT, ATM	SEGMENT	31
CLJ	T2 = TSL2, SET IN CALL FROM PATH.	SEGMENT	32
CLJ	= TEMPERATURE AT END OF LINE SEGMENT, DEG K	SEGMENT	33
CLJ	XY COMMON	SEGMENT	34
CLJ	TT(1) = TEMPERATURE ARRAY IN ATMOSPHERIC TRANSMISSION	SEGMENT	35
CLJ	MODEL, SET AS DATA IN THE DRIVER PROGRAM. (DEG K)	SEGMENT	36
CLJ	OUTPUT PARAMETERS	SEGMENT	37
CLJ	ARGUMENT LIST	SEGMENT	38
CLJ	DU(10,10) = ARRAYS OF PATH INTEGRALS U(ATM CM) AND UP(ATM**2	SEGMENT	39
CLJ	DUP(10,10) CMV AT 10 TEMPERATURES FOR EACH OF 10 SPECIES.	SEGMENT	40
CLJ	THE UNITS ARE THOSE OF STEPHENS. SA1/L1 PREFERRED	SEGMENT	41
CLJ	UNITS OF CM AT STP FOR U AND ATM-CM AT STP FOR UP.	SEGMENT	42
CLJ	COMMON / XY / TT(10)	SEGMENT	43
CLJ	DIMENSION NS1(NSPEC), NS2(NSPEC), DU(10,NSPEC), DUP(10,NSPEC),	SEGMENT	44
CLJ	1 XT(10), DMSDX(20), XNSO(20)	SEGMENT	45
C		SEGMENT	46
C	REAL NS1, NS2, NL	SEGMENT	47
C	LOGICAL NGRAD	SEGMENT	48
C		SEGMENT	49
CLJ		SEGMENT	50
CLJ	NL = LOSCHMIDT'S NUMBER, MOLECULES/CM**3 AT STP. (STEPHENS	SEGMENT	51
CLJ	PREFERRED 1/4ATM CM**3) WITH STANDARD TEMPERATURE	SEGMENT	52
CLJ	UNDERSTOOD.	SEGMENT	53
CLJ		SEGMENT	54
CLJ	DATA NL / 2.687E19	SEGMENT	55
C		SEGMENT	56
C	CALL XMIT (-10*NSPEC, 0, DU)	SEGMENT	57
C	CALL XMIT (-10*NSPEC, 0, DUP)	SEGMENT	58

	DPRDX = (P2 - P1) / (X2 - X1)	SEGMENT	59
	XPRO = P1 - X1 * DPRDX	SEGMENT	60
	DO 1 M=1, NSPEC	SEGMENT	61
	DNSDX(M) = (NS2(M) - NS1(M)) / ((X2 - X1) * NL)	SEGMENT	62
	XNSO(M) = NS1(M) / NL - X1 * DNSDX(M)	SEGMENT	63
1	CONTINUE	SEGMENT	64
C		SEGMENT	65
	IF (ABS(T2/T1-1.) .GT. .005) GO TO 7	SEGMENT	66
C		SEGMENT	67
C	NEARLY ISOTHERMAL PATH ELEMENT	SEGMENT	68
	TBAR = .5 * (T1 + T2)	SEGMENT	69
	IT = 0	SEGMENT	70
	DO 2 I=1, 10	SEGMENT	71
	IF (TBAR .LE. TT(I)) GO TO 3	SEGMENT	72
	IT = I	SEGMENT	73
2	CONTINUE	SEGMENT	74
C		SEGMENT	75
3	IF (IT .EQ. 0 .OR. IT .EQ. 10) GO TO 5	SEGMENT	76
C		SEGMENT	77
C	TEMPERATURE INSIDE TABLE RANGE	SEGMENT	78
	FN = (TBAR - TT(IT)) / (TT(IT+1) - TT(IT))	SEGMENT	79
	FF = 1. - FN	SEGMENT	80
	DX1 = X2 - X1	SEGMENT	81
	DX2 = X2**2 - X1**2	SEGMENT	82
	DX3 = X2**3 - X1**3	SEGMENT	83
	DO 4 M=1, NSPEC	SEGMENT	84
	IF (NS1(M) + NS2(M) .EQ. 0.) GO TO 4	SEGMENT	85
	TERM = DNSDX(M) * DX2 / 2. + XNSO(M) * DX1	SEGMENT	86
	DU(IT,M) = FF * TERM	SEGMENT	87
	DU(IT+1,M) = FN * TERM	SEGMENT	88
	TERM = DNSDX(M) * DPRDX * DX3 / 3. + (XPRO * DNSDX(M) +	SEGMENT	89
1	XNSO(M) * DPRDX) * DX2 / 2. + XNSO(M) * XPRO * DX1	SEGMENT	90
	DUP(IT,M) = FF * TERM	SEGMENT	91
	DUP(IT+1,M) = FN * TERM	SEGMENT	92
4	CONTINUE	SEGMENT	93
	RETURN	SEGMENT	94
C		SEGMENT	95
C	TEMPERATURE OUTSIDE TABLE RANGE	SEGMENT	96
5	IF (IT .EQ. 0) IT = 1	SEGMENT	97
	DX1 = X2 - X1	SEGMENT	98
	DX2 = X2**2 - X1**2	SEGMENT	99
	DX3 = X2**3 - X1**3	SEGMENT	100
	DO 6 M=1, NSPEC	SEGMENT	101
	IF (NS1(M) + NS2(M) .EQ. 0.) GO TO 6	SEGMENT	102
	DU(IT,M) = DNSDX(M) * DX2 / 2. + XNSO(M) * DX1	SEGMENT	103
	DUP(IT,M) = DNSDX(M) * DPRDX * DX3 / 3. + (XPRO * DNSDX(M) +	SEGMENT	104
1	XNSO(M) * DPRDX) * DX2 / 2. + XNSO(M) * XPRO * DX1	SEGMENT	105
6	CONTINUE	SEGMENT	106
	RETURN	SEGMENT	107
C		SEGMENT	108
C	NON-ZERO TEMPERATURE GRADIENT	SEGMENT	109
7	MGRAD = T2 .LT. T1	SEGMENT	110
	DO 8 I=1, 10	SEGMENT	111
	XT(I) = (T2 - TT(I)) / (T2 - T1) * X1 +	SEGMENT	112
1	(T1 - TT(I)) / (T1 - T2) * X2	SEGMENT	113
8	CONTINUE	SEGMENT	114
	IT = 0	SEGMENT	115

IF (NGRAD) IT = 10	SEGMENT 116
II = 1	SEGMENT 117
DO 15 I=1,10	SEGMENT 118
IP = II	SEGMENT 119
II = I	SEGMENT 120
IF (NGRAD) II = II - 1	SEGMENT 121
IF (I.EQ. 1 .AND. XT(II) .GE. X2) GO TO 5	SEGMENT 122
IF (XT(II) .LE. X1 .OR. XT(IP) .GE. X2) GO TO 15	SEGMENT 123
IF (I .GT. 1) GO TO 11	SEGMENT 124
C FIRST PART OF PATH OUTSIDE TEMPERATURE TABLE RANGE	SEGMENT 125
C	SEGMENT 126
DX1 = XT(II) - X1	SEGMENT 127
DX2 = XT(II)**2 - X1**2	SEGMENT 128
DX3 = XT(II)**3 - X1**3	SEGMENT 129
9 DO 10 M=1,NSPEC	SEGMENT 130
IF (NS1(M) + NS2(M) .EQ. 0.) GO TO 10	SEGMENT 131
DU(II,M) = DU(II,M) + DNSDX(M) * DX2 / 2. + XNSO(M) * DX1	SEGMENT 132
DUP(II,M) = DUP(II,M) + DNSDX(M) * DPRDX * DX3 / 3. + (XPRO *	SEGMENT 133
1 DNSDX(M) + XNSO(M) * DPRDX) * DX2 / 2. +	SEGMENT 134
2 XNSO(M) * XPRO * DX1	SEGMENT 135
10 CONTINUE	SEGMENT 136
GO TO 15	SEGMENT 137
C TEMPERATURE INSIDE TABLE RANGE	SEGMENT 138
C	SEGMENT 139
11 XN = AMAX1(XT(IP), X1)	SEGMENT 140
XF = AMIN1(XT(II), X2)	SEGMENT 141
DX1 = XF - XN	SEGMENT 142
DX2 = XF**2 - XN**2	SEGMENT 143
DX3 = XF**3 - XN**3	SEGMENT 144
DX4 = XF**4 - XN**4	SEGMENT 145
C NEAR SIDE INTEGRAL TO NEXT POINT	SEGMENT 146
C	SEGMENT 147
DXT = XT(II) - XT(IP)	SEGMENT 148
FF = (XF - XT(IP)) / DXT	SEGMENT 149
FN = (XN - XT(IP)) / DXT	SEGMENT 150
IT = II	SEGMENT 151
C INTEGRATE BY PARTS--DIFFERENTIATING THE WEIGHTING FACTOR	SEGMENT 152
C	SEGMENT 153
12 DO 13 M=1,NSPEC	SEGMENT 154
IF (NS1(M) + NS2(M) .EQ. 0.) GO TO 13	SEGMENT 155
DNN = 0.	SEGMENT 156
IF (FF .NE. 0.) DNN = (DNSDX(M)*XF**2/2. + XNSO(M)*XF) * FF	SEGMENT 157
IF (FN .NE. 0.) DNN = DNN - (DNSDX(M) * XN**2 / 2. +	SEGMENT 158
1 XNSO(M) * XN) * FN	SEGMENT 159
DU(IT,M) = DU(IT,M) + DNN - (DNSDX(M) * DX3 / 6. +	SEGMENT 160
1 XNSO(M) * DX2 / 2.) / DXT	SEGMENT 161
DNNPP = 0.	SEGMENT 162
IF (FF .NE. 0.) DNNPP = (DNSDX(M) * DPRDX * XF**3 / 3. +	SEGMENT 163
1 (XPRO * DNSDX(M) + XNSO(M) * DPRDX) *	SEGMENT 164
2 XF**2 / 2. + XNSO(M) * XPRO * XF) * FF	SEGMENT 165
IF (FN .NE. 0.) DNNPP = DNNPP - (DNSDX(M) * DPRDX * XN**3 / 3. +	SEGMENT 166
1 (XPRO * DNSDX(M) + XNSO(M) * DPRDX) *	SEGMENT 167
2 XN**2 / 2. + XNSO(M) * XPRO * XN) * FN	SEGMENT 168
DUP(IT,M) = DUP(IT,M) + DNNPP - (DNSDX(M) * DPRDX * DX4 / 12. +	SEGMENT 169
1 (XPRO * DNSDX(M) + XNSO(M) * DPRDX) * DX3 / 6. +	SEGMENT 170
2 XNSO(M) * XPRO * DX2 / 2.) / DXT	SEGMENT 171
13 CONTINUE	SEGMENT 172

	IF (IT .NE. II) GO TO 14	SEGMENT 173
C		SEGMENT 174
C	FAR SIDE INTEGRAL FROM PASSED POINT	SEGMENT 175
	DXT = XT(IP) - XT(II)	SEGMENT 176
	FF = (XF - XT(II)) / DXT	SEGMENT 177
	FN = (XN - XT(II)) / DXT	SEGMENT 178
	IT = IP	SEGMENT 179
	GO TO 12	SEGMENT 180
C		SEGMENT 181
14	IF (I .LT. 10 .OR. XT(II) .GE. X2) GO TO 15	SEGMENT 182
C		SEGMENT 183
C	LAST PART OF PATH OUTSIDE TEMPERATURE TABLE RANGE	SEGMENT 184
	DX1 = X2 - XT(II)	SEGMENT 185
	DX2 = X2**2 - XT(II)**2	SEGMENT 186
	DX3 = X2**3 - XT(II)**3	SEGMENT 187
	GO TO 9	SEGMENT 188
C		SEGMENT 189
15	CONTINUE	SEGMENT 190
C		SEGMENT 191
	IF (NGRAD) IT = 10 - IT	SEGMENT 192
	IF (IT .EQ. 0 .OR. IT .EQ. 10) GO TO 5	SEGMENT 193
C		SEGMENT 194
	RETURN	SEGMENT 195
	END	SEGMENT 196

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SUBROUTINE SETALT ( ALMIN, ALMAX, JBAND )
CCC
C      SUBROUTINE SETALT, CALLED FROM THE DRIVER PROGRAM DRVUPW,
C      DETERMINES THE ALTITUDES AT WHICH SUBROUTINE UPWELL COMPUTES
C      THE UPWELLING NATURAL RADIATION.
C      A SET OF CHARACTERISTIC ALTITUDES HAS BEEN PREVIOUSLY SELECTED
C      FOR EACH OF THE 10 SPECTRAL BINS. IF THE WAVELENGTH-BAND OF
C      INTEREST (ALMIN,ALMAX) SPANS MORE THAN ONE BIN, WE USE A SET
C      OF ALTITUDES OBTAINED BY COMBINING THOSE FOR EACH OF THE
C      SPANNED BINS.
CCC
C      INPUT PARAMETERS
C      ARGUMENT LIST
C      ALMIN, - MINIMUM AND MAXIMUM WAVELENGTHS FOR WHICH
C      ALMAX  UPWELLING NATURAL RADIATION IS TO BE COMPUTED,
C      MICRONS
C      JBAND - BROAD-BAND LOOP INDEX (1,5)
CCC
C      OUTPUT PARAMETERS
C      COMMON UPWELS
C      NALT(JBAND) - NUMBER OF ALTITUDES FOR BROAD-BAND INDEX
C      JBAND
C      ZKM(I,JBAND) I=1,NALT(JBAND)
C      - ALTITUDES OF POINT V ABOVE UPWALT AT WHICH
C      UPWELLING RADIANCE IS COMPUTED FOR BROAD-
C      BAND INDEX JBAND, KM
CCC
COMMON/UPWELS/ UPWALT,UPWLO,UPWLAT,NALT(5),ZKM(13,5),NNADIR,NAZI,
*             NWAVE(5),IDAYV,CLDFLG,UPRADN(13,10,5),WV(10,5),IKM,
*             NBANDS
COMMON/UPWELS1/
2             RO10(6,10),RO10A(6,10,10),RO10N(6,10),
3             RO25(6,10),RO25A(6,10,10),RO25N(6,10),
4             RO50(6,10),RO50A(6,10,10),RO50N(6,10),
5             RO90(6,10),RO90A(6,10,10),RO90N(6,10),
6             R100(6,10),R100A(6,10,10),R100N(6,10),
7             ,ARCV(6,10,10),ARCVN(6,10)
DIMENSION HUPWEL(11,10),BINLAM(11),NALT(10),ALT(56)
C
C      DEFINITIONS OF DATA...
C      NBINL1 - NUMBER OF WAVELENGTH-BIN BOUNDARIES MINUS ONE
C      BINLAM(L) L=1,(NBINL1+1)
C      - WAVELENGTH OF BIN BOUNDARY, MICRONS
C      NALT(M) M=1,NBINL1
C      - NUMBER OF ALTITUDES FOR WAVELENGTH-BIN M
C      HUPWEL(I,M) I=1,NALT(M) M=1,NBINL1
C      - ALTITUDE-I FOR WAVELENGTH-BIN M, KM
C
DATA NBINL1 / 10 /
DATA BINLAM / 2.000, 2.100, 2.575, 2.675, 2.725, 2.875, 4.150,
$ 4.550, 4.750, 4.850, 5.000 /
DATA NALT / 5, 4, 5, 11, 5, 4, 9,
$ 4, 5, 4 /
DATA HUPWEL / 0., 1., 12., 20., 100., 0., 0., 0., 0., 0.,
2 0., 1., 12., 100., 0., 0., 0., 0., 0., 0.,
3 0., 1., 3., 12., 100., 0., 0., 0., 0., 0.,

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4	0., 1., 2., 4., 9., 12., 20., 30., 50., 70., 100.,	SETALT	50
5	0., 1., 3., 12., 100., 0., 0., 0., 0., 0.,	SETALT	51
6	0., 1., 12., 100., 0., 0., 0., 0., 0., 0.,	SETALT	52
7	0., 1., 3., 6., 12., 20., 50., 70., 100., 0.,	SETALT	53
8	0., 1., 12., 100., 0., 0., 0., 0., 0., 0.,	SETALT	54
9	0., 1., 12., 30., 100., 0., 0., 0., 0., 0.,	SETALT	55
A	0., 1., 12., 100., 0., 0., 0., 0., 0., 0./	SETALT	56
C		SETALT	57
C	DETERMINE WHICH WAVELENGTH BINS THE MINIMUM AND MAXIMUM	SETALT	58
C	WAVELENGTHS, ALMIN AND ALMAX, FALL INTO.	SETALT	59
	IF (ALMIN .LT. 2.0) GO TO 15	SETALT	60
	DO 10 K=1,NBINL1	SETALT	61
	IF (ALMIN .LT. BINLAM(K+1)) GO TO 20	SETALT	62
10	CONTINUE	SETALT	63
15	WRITE(6,16)	SETALT	64
16	FORMAT(1H0,1X,64H4 BOUNDARY WAVELENGTH IS OUTSIDE THE 2.0- TO 5.0-	SETALT	65
	SMICRON INTERVAL)	SETALT	66
	STOP 1	SETALT	67
20	MMIN = K	SETALT	68
C	NOW HAVE INDEX MMIN OF WAVELENGTH BIN FOR MINIMUM WAVELENGTH.	SETALT	69
	DO 25 K=1,NBINL1	SETALT	70
	IF (ALMAX .LE. BINLAM(K+1)) GO TO 35	SETALT	71
25	CONTINUE	SETALT	72
30	WRITE(6,16)	SETALT	73
	STOP 2	SETALT	74
35	MMAX = K	SETALT	75
C	NOW HAVE INDEX MMAX OF WAVELENGTH BIN FOR MAXIMUM WAVELENGTH.	SETALT	76
C		SETALT	77
	IF (MMAX .NE. MMIN) GO TO 50	SETALT	78
	NALTJ = NALTJ(MMIN)	SETALT	79
	NALT(JBAND) = NALTJ	SETALT	80
	DO 40 I=1,NALTJ	SETALT	81
	ZKM(I,JBAND) = HUPWEL(I,MMIN)	SETALT	82
40	CONTINUE	SETALT	83
	GO TO 90	SETALT	84
50	CONTINUE	SETALT	85
	J = 0	SETALT	86
	DO 70 M=MMIN,MMAX	SETALT	87
	NH = NALTJ(M)	SETALT	88
	DO 60 I=1,NH	SETALT	89
	J = J + 1	SETALT	90
	ALT(J) = HUPWEL(I,M)	SETALT	91
60	CONTINUE	SETALT	92
70	CONTINUE	SETALT	93
	JMAX = J	SETALT	94
C	SORT ALT ARRAY IN ORDER OF INCREASING ALTITUDES AND THEN	SETALT	95
C	ELIMINATE REDUNDANT ALTITUDES.	SETALT	96
	CALL SORTLJ(ALT,ALT,ALT,JMAX,0)	SETALT	97
	JMM1 = JMAX - 1	SETALT	98
	J = 1	SETALT	99
	ZKM(1,JBAND) = ALT(1)	SETALT	100
	DO 80 I=1,JMM1	SETALT	101
	IF (ALT(I+1) .EQ. ALT(I)) GO TO 80	SETALT	102
	J = J + 1	SETALT	103
	ZKM(I,JBAND) = ALT(I+1)	SETALT	104
80	CONTINUE	SETALT	105
	NALT(JBAND) = J	SETALT	106
90	CONTINUE	SETALT	107
	END	SETALT	108

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SUBROUTINE SHELLS
C
C *SHELLS* PREPARES A TABLE OF PHYSICAL PROPERTIES FOR THE
C AMBIENT ATMOSPHERE USED IN THE CALCULATION OF ATMOSPHERIC
C TRANSMISSION.
C
CLJ INPUT PARAMETERS
CLJ   ATMOSP COMMON
CLJ     PP = PRESSURE, DYNES/CM**2
CLJ     TT = TEMPERATURE, DEG K
CLJ     SNI(I) = DENSITY OF SPECIES I, 1/CM**3
CLJ     PARTICULAR SPECIES ARE INDICATED AS FOLLOWS...
CLJ     N I=IMAP(N) SNI(I)
CLJ
CLJ       1      8      NO
CLJ       2     11     NO+
CLJ       3     21     N2O
CLJ       4     15     NO2
CLJ       5     14      O3
CLJ       6      6     CO2
CLJ       7     20      CO
CLJ       8     22     CH4
CLJ       9     16     H2O
CLJ      10     18      OH
CLJ
CLJ   XYZCOM COMMON
CLJ     FACT = PATH INTEGRATION FACTOR CONTROLLING THE NUMBER OF
CLJ           ALTITUDES AND SPACING (MAY HAVE A VALUE BETWEEN
CLJ           0.1 AND 10, PER EWING. NOMINAL VALUE IS 1.0)
CLJ     FOR FACT=1.0, WE HAVE NS=77 AND JCHNGE=40.
CLJ
CLJ       J      HS, KM
CLJ       ***      *****
CLJ       1          0.0
CLJ       2        0.526
CLJ      39       20.000
CLJ      40       22.105
CLJ      58       60.0
CLJ      77      100.0
CLJ
CLJ   SUBSEQUENT TO THE INITIAL DEVELOPMENT OF SUBROUTINE SHELLS BY
CLJ   L. EWING OF GET, J. GARBARINO OF GRC SIGNIFICANTLY REVISED THE
CLJ   SETTING OF THE ATMOSPHERIC SHELLS WITH THE INTENT TO REDUCE
CLJ   THE RUNNING TIME. FOR THE ORIGINAL SETTING OF THE ATMOSPHERIC
CLJ   SHELLS, THE MAXIMUM NUMBER OF BOUNDARIES WAS 81. FOR THE GRC
CLJ   SETTING, IT IS 61. THUS, SEVERAL VARIABLES COULD HAVE THEIR
CLJ   DIMENSIONS REDUCED TO 61 FROM 81. GRC HAS ALSO MADE FACT
CLJ   DEPENDENT ON TRNSOPT IN PROGRAM ATKGEN BY SETTING FACT TO 1.0
CLJ   IF TRNSOPT .NE. FAST AND TO 10.0 IF TRNSOPT .EQ. FAST.
CLJ   WE HAVE KEPT FACT INDEPENDENT OF TRNSOPT.
CLJ
CLJ   WE RECORD THE BOUNDARIES FOR THREE VALUES OF FACT, PER GRC.
CLJ
CLJ   FOR FACT = 1, X0=1.25, X1=3.125, X2=7.8125
CLJ   J      HS          J      HS          J      HS
CLJ   - ----          - ----          - ----
CLJ   1  0.          JCHNG1=10  13.125      JCHNG2=18  42.8125
CLJ   2  1.25        11  16.250          19  50.6250

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CLJ	3	2.50	12	19.375	20	58.4375	SHELLS	59
CLJ	4	3.75	13	22.500	21	66.2500	SHELLS	60
CLJ	5	5.00	14	25.625	22	74.0625	SHELLS	61
CLJ	6	6.25	15	28.750	23	81.8750	SHELLS	62
CLJ	7	7.50	16	31.875	24	89.6875	SHELLS	63
CLJ	8	8.75	17	35.000	25	97.5000	SHELLS	64
CLJ	9	10.00					SHELLS	65
CLJ							SHELLS	66
CLJ							SHELLS	67
CLJ							SHELLS	68
CLJ							SHELLS	69
CLJ							SHELLS	70
CLJ							SHELLS	71
CLJ							SHELLS	72
CLJ							SHELLS	73
CLJ							SHELLS	74
CLJ							SHELLS	75
CLJ							SHELLS	76
CLJ							SHELLS	77
CLJ							SHELLS	78
CLJ							SHELLS	79
CLJ							SHELLS	80
CLJ							SHELLS	81
CLJ							SHELLS	82
CLJ							SHELLS	83
CLJ							SHELLS	84
CLJ							SHELLS	85
CLJ							SHELLS	86
CLJ							SHELLS	87
CLJ							SHELLS	88
CLJ							SHELLS	89
CLJ							SHELLS	90
CLJ							SHELLS	91
CLJ							SHELLS	92
CLJ							SHELLS	93
CLJ							SHELLS	94
CLJ							SHELLS	95
CLJ							SHELLS	96
CLJ							SHELLS	97
CLJ							SHELLS	98
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CLJ							SHELLS	100
CLJ							SHELLS	101
CLJ							SHELLS	102
CLJ							SHELLS	103
CLJ							SHELLS	104
CLJ							SHELLS	105
CLJ							SHELLS	106
CLJ							SHELLS	107
CLJ							SHELLS	108
CLJ							SHELLS	109
CLJ							SHELLS	110
CLJ							SHELLS	111
CLJ							SHELLS	112
CLJ							SHELLS	113
CLJ							SHELLS	114
CLJ							SHELLS	115

FOR FACT = 10, X0=3.0, X1=7.5, X2=18.75		J		HS		
J	HS	J	HS	J	HS	
1	0.0	JCHNG1=5	16.5	JCHNG2=8	50.25	
2	3.0	6	24.0	9	69.00	
3	6.0	7	31.5	10	87.75	
4	9.0			11	106.50	

FOR FACT = .1, X0=0.5, X1=1.25, X2=3.125		J		HS		
J	HS	J	HS	J	HS	
1	0.0	JCHNG1=22	11.25	JCHNG2=42	38.125	
2	0.5	23	12.50	43	41.250	
3	1.0	24	13.75	44	44.375	
.	
.	
.	
21	10.0	41	35.00	61	97.500	

OUTPUT PARAMETERS

XYZCOM COMMON

NS = NUMBER OF ALTITUDE BOUNDARIES

HSELL(J) = ALTITUDE BOUNDARIES, CM (J=1,NS)

TS(J) = TEMPERATURE AT ALTITUDE BOUNDARY J, DEG K (J=1,NS)

PS(J) = PRESSURE AT ALTITUDE BOUNDARY J, ATM (J=1,NS)

XNSPEC(J,N) = SPECIES-N DENSITY AT ALTITUDE BOUNDARY J, 1/CM**3 (J=1,NS, N=1,10)

DIMENSION PRWATR(81)

DIMENSION IMAP(10)

COMMON / ATMOSP / HL, SBAR, IDORN, PP, RHO, TT, SNI(30), HRHO,

FEHSEO

COMMON / XYZCOM / ITMTE, LTMTE, NS, HSELL(81), TS(81), PS(81),

XNSPEC(81,10), U(10,10,2), UP(10,10,2), NMOLS,

FACT

C

DATA IMAP / 8, 11, 21, 15, 14, 6, 20, 22, 16, 18 /

C

THE ORIGINAL GET ALGORITHM IS COMMENTED OUT WITH CGET.

CGET NS = 40.5 - 2.5 * FACT

CGET NS = MAX(30, MIN(2 * NS, 80)) + 1

CGET JCHNGE = 2 + NS / 2

CGET X = 40. / FLOAT(NS - 1)

CLJ

NS = 5.1 + 7./FACT

NS = MAX(10, MIN(60, 2*NS)) + 1

JCHNG1 = 2 + NS/3

JCHNG2 = 2 + 2*NS/3

X = 30./FLOAT(NS-1)

HS = -X	SHELLS	116
WRITE(6,5)	SHELLS	117
5 FORMAT(1H1,44X,43H* * * OUTPUT FROM SUBROUTINE SHELLS * * *,//,1	SHELLS	118
\$H,126H J H\$HELL TS PS NO NO+ N2O	SHELLS	119
\$ NO2 O3 CO2 CO CH4 H2O O	SHELLS	120
\$H/,1H,28H K' DEG K ATMOS,10(3X,7H1/CM**3))	SHELLS	121
DO 10 J=1,NS	SHELLS	122
CGET IF(J.EQ. JCHNGE) X = 4. * X	SHELLS	123
IF(J.EQ. JCHNG1) X = 2.5*X	SHELLS	124
IF(J.EQ. JCHNG2) X = 2.5*X	SHELLS	125
HS = HS + X	SHELLS	126
C ESTABLISH ARRAY OF SHELL-BOUNDARY ALTITUDES.	SHELLS	127
H\$HELL(J) = HS * 1.E5	SHELLS	128
CALL ATMOSU (2, HS)	SHELLS	129
CALL SPCMIN (2, HS)	SHELLS	130
SN1(11) = 0.	SHELLS	131
CLJ	SHELLS	132
CLJ THE TEST ALTITUDE IN THE FOLLOWING IF-STATEMENT, INITIALLY SET	SHELLS	133
CLJ TO 75 KM BY G.E.TEMPO, HAS BEEN CHANGED TO 90 KM BECAUSE	SHELLS	134
CLJ SUBROUTINE IONCSU COMPUTES NO+ ONLY FOR ALTITUDES .GE. 90 KM.	SHELLS	135
CLJ FURTHER, NO+ IS PROBABLY NEGLIBLE BELOW 90 KM.	SHELLS	136
CLJ	SHELLS	137
IF(HS.GE.90.) CALL IONOSU(2,HS)	SHELLS	138
TS(J) = AMIN1(300.,TT)	SHELLS	139
PS(J) = TT / 1.01325E6	SHELLS	140
DO 1 N=1,10	SHELLS	141
I = IMAP(N)	SHELLS	142
XNSPEC(J,N) = SN1(I)	SHELLS	143
1 CONTINUE	SHELLS	144
WRITE(6,11) J,HS,TS(J),PS(J),(XNSPEC(J,N),N=1,10)	SHELLS	145
11 FORMAT (1X,I3,1PE10.3,0PE6.1,1P11E10.3)	SHELLS	146
10 CONTINUE	SHELLS	147
CLJ TO FACILITATE COMPARING OUR ATMOSPHERE WITH THOSE USED BY	SHELLS	148
CLJ OTHER WORKERS, THE FOLLOWING STATEMENTS (DO-LOOP-DO AND	SHELLS	149
CLJ ASSOCIATED PRINT) WERE ADDED TO COMPUTE THE WATER CONTENT	SHELLS	150
CLJ OF THE ATMOSPHERE ALONG A VERTICAL PATH ABOVE EACH OF THE	SHELLS	151
CLJ SHELL BOUNDARIES. THE WATER CONTENT ABOVE BOUNDARY J,	SHELLS	152
CLJ PRWATR(J), IS EXPRESSED IN UNITS OF PRECIPITABLE CENTIMETERS,	SHELLS	153
CLJ I.E.,	SHELLS	154
CLJ PR CM(H2O) = 3.34E+22 MOLECULES/CM**2 .	SHELLS	155
CLJ WE ASSUME AN EXPONENTIAL DEPENDENCE OF THE WATER VAPOR	SHELLS	156
CLJ CONCENTRATION BETWEEN THE BOUNDARIES AND HENCE CALL FUNCTION	SHELLS	157
CLJ ACCUM WITH ITYPE = 2.	SHELLS	158
PRWATR(NS) = 0.	SHELLS	159
DO 20 I=2,NS	SHELLS	160
J = NS - I + 1	SHELLS	161
DELPRW = ACCUM(2, H\$HELL(J), H\$HELL(J+1), XNSPEC(J,9),	SHELLS	162
\$ XNSPEC(J+1,9), H\$HELL(J), H\$HELL(J+1) /3.34E+22	SHELLS	163
PRWATR(J) = PRWATR(J+1) + DELPRW	SHELLS	164
20 CONTINUE	SHELLS	165
WRITE(6,24) (H\$HELL(J), PRWATR(J), J=1,NS)	SHELLS	166
24 FORMAT (*O H\$HELL(KM), PRWATR(PR CM) **//5X,1P10E12.4))	SHELLS	167
RETURN	SHELLS	168
END	SHELLS	169

CCC	SUBROUTINE SOLRAD(K,B,E)	SOLRAD	2
C		SOLRAD	3
C	SUBROUTINE SOLRAD PROVIDES THE SOLAR SPECTRAL IRRADIANCE	SOLRAD	4
C	AT THE TOP OF THE EARTH'S ATMOSPHERE, IN THE SPECTRAL RANGE	SOLRAD	5
C	FROM 2 TO 5 MICROMETERS (OR 5000 TO 2000 WAVENUMBERS).	SOLRAD	6
C	THE NASA DATA ADOPTED BY THE ASTM HAVE BEEN FITTED BY	SOLRAD	7
C	PIECEWISE-CONTINUOUS POWER-LAW EXPRESSIONS.	SOLRAD	8
CCC		SOLRAD	9
C	INPUT PARAMETERS	SOLRAD	10
C	B - WAVENUMBER (CM-1) , K=1,2,3,4	SOLRAD	11
C	- WAVELENGTH (UM) , K=5,6,7,8	SOLRAD	12
C	K - INDEX SPECIFYING UNITS FOR INPUT AND OUTPUT	SOLRAD	13
CCC		SOLRAD	14
C	OUTPUT PARAMETERS	SOLRAD	15
C	E - SOLAR SPECTRAL IRRADIANCE AT THE TOP OF THE EARTH'S	SOLRAD	16
C	ATMOSPHERE, IN UNITS OF...	SOLRAD	17
C	PHOTONS/(CM**2 SEC CM-1) , K=1,5	SOLRAD	18
C	PHOTONS/(CM**2 SEC UM) , K=2,6	SOLRAD	19
C	WATTS/(CM**2 CM-1) , K=3,7	SOLRAD	20
C	WATTS/(M**2 UM) , K=4,8	SOLRAD	21
CCC		SOLRAD	22
	DATA C,H / 2.997925E+10, 6.626176E-27 /	SOLRAD	23
	DATA E2P2,E2P9,E3P5,E4P0,E5P0 / 79.0,35.0,14.6,9.50,3.79 /	SOLRAD	24
	DATA C2P2,C2P9,C3P5,C4P0,C5P0 / 2.2,2.9,3.5,4.0,5.0 /	SOLRAD	25
	DATA FLAG / -2.0 /	SOLRAD	26
CCC		SOLRAD	27
	IF(FLAG.GT.0.0) GO TO 20	SOLRAD	28
	FLAG = +2.0	SOLRAD	29
	HCIV = 1.0E+07/(H*C)	SOLRAD	30
	A2P2 = ALOG(E2P9/E2P2)/ALOG(C2P9/C2P2)	SOLRAD	31
	A2P9 = ALOG(E3P5/E2P9)/ALOG(C3P5/C2P9)	SOLRAD	32
	A3P5 = ALOG(E4P0/E3P5)/ALOG(C4P0/C3P5)	SOLRAD	33
	A4P0 = ALOG(E5P0/E4P0)/ALOG(C5P0/C4P0)	SOLRAD	34
20	CONTINUE	SOLRAD	35
	A = B	SOLRAD	36
	IF(A.LE.0.0) GO TO 27	SOLRAD	37
	IF((K.LE.0) .OR. (K.GT.8)) GO TO 29	SOLRAD	38
	IF(K.LT.5) A = 1.0E+04/A	SOLRAD	39
	IF((A.LT.2.) .OR. (A.GT.5.)) GO TO 27	SOLRAD	40
	IF(A.GE.C4P0) GO TO 23	SOLRAD	41
	IF(A.GE.C3P5) GO TO 22	SOLRAD	42
	IF(A.GE.C2P9) GO TO 21	SOLRAD	43
	E = E2P2*(A/C2P2)**A2P2	SOLRAD	44
	GO TO 24	SOLRAD	45
21	E = E2P9*(A/C2P9)**A2P9	SOLRAD	46
	GO TO 24	SOLRAD	47
22	E = E3P5*(A/C3P5)**A3P5	SOLRAD	48
	GO TO 24	SOLRAD	49
23	E = E4P0*(A/C4P0)**A4P0	SOLRAD	50
24	IF((K.EQ.4) .OR. (K.EQ.8)) GO TO 29	SOLRAD	51
	IF((K.EQ.3) .OR. (K.EQ.7)) GO TO 26	SOLRAD	52
	IF((K.EQ.2) .OR. (K.EQ.6)) GO TO 25	SOLRAD	53
	E = 1.0E-12*HCIV*E*A*A	SOLRAD	54
	GO TO 28	SOLRAD	55
25	E = 1.0E-08*HCIV*E*A	SOLRAD	56
	GO TO 28	SOLRAD	57
26	E = 1.0E-08*E*A*A	SOLRAD	58

28 RETURN	SOLRAD	59
27 PRINT 31, A	SOLRAD	60
31 FORMAT (82H0 SUBROUTINE SOLRAD HAS BEEN CALLED WITH WAVELENGTH (OR	SOLRAD	61
\$ WAVENUMBER) OUT OF RANGE. ,E12.4)	SOLRAD	62
CALL EXIT	SOLRAD	63
29 PRINT 33, K	SOLRAD	64
33 FORMAT (68H0 SUBROUTINE SOLRAD HAS BEEN CALLED WITH IMPROPER VALUE	SOLRAD	65
\$ FOR INDEX K.,110)	SOLRAD	66
CALL EXIT	SOLRAD	67
END	SOLRAD	68

SUBROUTINE SORTLJ(A,B,C,N,LOHI)		SORTLJ	2
CCC	GIVEN THE A ARRAY OF LENGTH N, THIS ROUTINE SORTS THE	SORTLJ	3
C	ARRAY FROM LOW TO HIGH IF LOHI.LE.0 AND FROM HIGH TO LOW	SORTLJ	4
C	IF LOHI.GT.0 .	SORTLJ	5
C	THE B AND C ARRAYS ARE SIMPLY CARRIED ALONG.	SORTLJ	6
CCC	DIMENSION A(1), B(1), C(1)	SORTLJ	7
CCC	M = N	SORTLJ	8
20	M = M/2	SORTLJ	9
	IF(M.EQ.0) GO TO 40	SORTLJ	10
	K = M-M	SORTLJ	11
	J = 1	SORTLJ	12
41	I = J	SORTLJ	13
49	L = I+M	SORTLJ	14
	IF(LOHI) 50,50,52	SORTLJ	15
C	*** SORT LOW TO HIGH.	SORTLJ	16
C	50 IF(A(L).GE.A(I)) GO TO 60	SORTLJ	17
	GO TO 55	SORTLJ	18
C	*** SORT HIGH TO LOW.	SORTLJ	19
C	52 IF(A(L).LE.A(I)) GO TO 60	SORTLJ	20
55	X = A(I)	SORTLJ	21
	Y = B(I)	SORTLJ	22
	Z = C(I)	SORTLJ	23
	A(I) = A(L)	SORTLJ	24
	B(I) = B(L)	SORTLJ	25
	C(I) = C(L)	SORTLJ	26
	A(L) = X	SORTLJ	27
	B(L) = Y	SORTLJ	28
	C(L) = Z	SORTLJ	29
	I = I-M	SORTLJ	30
	IF(I.GE.1) GO TO 49	SORTLJ	31
60	J = J+1	SORTLJ	32
	IF(J-K) 41,41,20	SORTLJ	33
40	RETURN	SORTLJ	34
	END	SORTLJ	35
		SORTLJ	36
		SORTLJ	37
		SORTLJ	38
		SORTLJ	39
		SORTLJ	40

C	SUBROUTINE STEP (RX, SHAT, DIST, NC, DS, XFRACS, INDX)	STEP	2
C		STEP	3
C	*STEP* CALCULATES THE INTERSECTIONS OF AN OPTICAL PATH WITH	STEP	4
C	THE LINEARLY VARYING SHELLS IN THE ATMOSPHERIC MODEL. PATH	STEP	5
C	ELEMENTS LESS THAN TEN METERS IN LENGTH ARE ASSIGNED	STEP	6
C	TO THE NEIGHBORING SHELL.	STEP	7
C		STEP	8
CLJ		STEP	9
CLJ	INPUT PARAMETERS	STEP	10
CLJ	ARGUMENT LIST	STEP	11
CLJ	RX(1) = LOCATION VECTOR TO ONE END OF TRANSMISSION PATH,	STEP	12
CLJ	TYPICALLY BUT NOT NECESSARILY AT THE DETECTOR, CM	STEP	13
CLJ	SHAT(1) = UNIT VECTOR ALONG THE TRANSMISSION PATH FROM RX TO	STEP	14
CLJ	RX, CM	STEP	15
CLJ	(FOR RX AND SHAT I=1,3)	STEP	16
CLJ	DIST = MAGNITUDE OF DISTANCE ALONG TRANSMISSION PATH	STEP	17
CLJ	FROM RX TO RX, CM	STEP	18
CLJ	NC = INITIALIZATION VALUE, NORMALLY SET TO 0 AND LEADS	STEP	19
CLJ	TO DS(1) BEING SET TO 0.0.	STEP	20
CLJ	XYZCOM COMMON	STEP	21
CLJ	NS = NUMBER OF SHELL BOUNDARIES IN ATMOSPHERIC	STEP	22
CLJ	TRANSMISSION MODEL	STEP	23
CLJ	OUTPUT PARAMETERS	STEP	24
CLJ	ARGUMENT LIST	STEP	25
CLJ	NC = NUMBER OF PATH SEGMENTS PLUS ONE ON THE	STEP	26
CLJ	TRANSMISSION PATH FROM RX TO RX, OR EQUIVALENTLY,	STEP	27
CLJ	THE NUMBER OF ENDPPOINTS.	STEP	28
CLJ	FOR I=1,NC	STEP	29
CLJ	DS(I+1) = LENGTH OF LINE SEGMENT I ALONG TRANSMISSION	STEP	30
CLJ	PATH, CM	STEP	31
CLJ	NOTE... IT IS ALWAYS TRUE THAT DS(1)=0. AND	STEP	32
CLJ	DS(NC+1)=1. (THERE ARE TWO MORE VALUES OF DS	STEP	33
CLJ	THAN THERE ARE SEGMENTS.)	STEP	34
CLJ	XFRACS(1) = (SEE NOTE IN SUBROUTINE ATMRAO)	STEP	35
CLJ	INDX(1) = INDEX OF SHELL BOUNDARY AT OR JUST BEFORE THE	STEP	36
CLJ	START OF THE LINE SEGMENT I. INDX(NC) WILL BE THE	STEP	37
CLJ	INDEX OF THE SHELL BOUNDARY JUST AFTER THE LAST	STEP	38
CLJ	ENDPOINT.	STEP	39
CLJ	NOTE... INDX(NC+1) = 0	STEP	40
CLJ		STEP	41
CLJ	DIMENSION DS(100), XFRACS(100), INDX(100), RX(3), SHAT(3)	STEP	42
CLJ	COMMON / XYZCOM / LTMTE, LTMTE, NS, HSHLL(R1), TS(81), PS(81),	STEP	43
1	XNSPEC(R1,10), U(10,10,2), U(10,10,2), W(10,10,2),	STEP	44
2	FACT	STEP	45
C	DATA ERAD / 6.37103E+08 /	STEP	46
C	ERAD = RBODY WHEN /CONCOM/ IS ADDED	STEP	47
C		STEP	48
C	DETERMINE INITIAL DIRECTION OF INTEGRATION	STEP	49
C	RXKDOT = DOT(RX, SHAT)	STEP	50
C	IF (RXKDOT > 2, 2, 1	STEP	51
1	SIGN = 1.	STEP	52
C	IS = 1	STEP	53
C	GO TO 3	STEP	54
2	SIGN = -1.	STEP	55
C	IS = -1	STEP	56
C	INITIALIZE COUNTERS AND OTHER VALUES	STEP	57
3	RXP = DOT(RX, RX)	STEP	58

	RXL = SORT/ RX2)	STEP	59
	RKD2 = RXXDOT**2	STEP	60
	IF (NC .EQ. 0) DS/15 = 0.	STEP	61
	IF (NC .GT. 0) NC = NC - 1	STEP	62
	DOLD = 0.	STEP	63
	SRAD = RXL	STEP	64
	NST = 0	STEP	65
	IF (IS .LT. 0) NST = NS + 1	STEP	66
	N = NST	STEP	67
C	SAVE PREVIOUS SHELL INDEX	STEP	68
4	NOLD = N	STEP	69
C	STEP TO NEXT SHELL	STEP	70
	N = N + IS	STEP	71
C	TEST FOR ATMOSPHERE LIMIT	STEP	72
	IF (N .EQ. 0 .OR. N .GT. NS) GO TO 7	STEP	73
C	UPDATE SHELL RADIUS	STEP	74
	SROLD = SRAD	STEP	75
	SRAD = ERAD + HSHLL(N)	STEP	76
	IF (SRAD .NE. SROLD) XFRAC = FRAC(SRAD, SROLD, SRAD, RXL)	STEP	77
	DISC = RKD2 - (RX2 - SRAD**2)	STEP	78
C	NEGATIVE DISCRIMINANT IMPLIES NO INTERSECTION	STEP	79
	IF (DISC) 8, 5, 5	STEP	80
5	DNEW = AMAX1(SIGN*SORT(DISC) - RXXDOT, 0.)	STEP	81
	DELTA = DNEW - DOLD	STEP	82
	IF (DELTA - 1.E3) 4, 4, 6	STEP	83
C	UPDATE DISTANCE AND STORE INTEGRATION CELL INFORMATION	STEP	84
6	DOLD = DNEW	STEP	85
	NC = NC + 1	STEP	86
	XFRACS(NC) = XFRAC	STEP	87
	INDX(NC) = NOLD	STEP	88
C	IGNORE STEP TO TOP OF ATMOSPHERE	STEP	89
	IF (NOLD .GT. NS) NC = NC - 1	STEP	90
	DS(NC+1) = DELTA	STEP	91
C	TEST DISTANCE LIMIT	STEP	92
	IF (DIST .GE. DNEW+1.E3) IF (NC - 98) 4, 10, 10	STEP	93
	DS(NC+1) = DS(NC+1) - (DNEW - DIST)	STEP	94
C	LAST CELL ON PATH	STEP	95
7	RXL = SQR(RX2 + DIST**2 + 2. * RXXDOT * DIST)	STEP	96
	IF (N .EQ. 0) RXL = ERAD	STEP	97
	NC = NC + 1	STEP	98
	INDX(NC) = INDX(NC-1) + IS	STEP	99
	DS(NC+1) = -1.	STEP	100
	XFRACS(NC) = FRAC(SRAD, SROLD, RXL, SROLD)	STEP	101
	INDX(NC+1) = 0	STEP	102
	RETURN	STEP	103
C	IF INTEGRATION HAS BEEN DOWN, SWITCH TO UP	STEP	104
8	IF (SIGN) 9, 4, 4	STEP	105
9	SIGN = 1.	STEP	106
	IS = 1	STEP	107
C	SET MIDPOINT OF CHORD AS AN INTEGRATION POINT (END OF CELL)	STEP	108
	RXL = SORT(RX2 - RKD2)	STEP	109
	DNEW = RXXDOT	STEP	110
	DELTA = DNEW - DOLD	STEP	111
	IF (DELTA - 1.E3) 4, 4, 6	STEP	112
C	DIMENSION LIMIT HAS BEEN EXCEEDED	STEP	113
10	INDX(99) = INDX(98) + IS	STEP	114
	XFRACS(99) = 1.	STEP	115
	NC = 99	STEP	116
	DS(100) = -1.	STEP	117
	INDX(100) = 0	STEP	118
	RETURN	STEP	119
	END	STEP	120

C	SUBROUTINE STEPS (RX, RY, NC, DS, XFRACS, INDX)	STEPS	2
C		STEPS	3
C	*STEPS* IS AN ENTRY TO *STEP* WHEN THE PATH IS DEFINED BY	STEPS	4
C	ITS END POINTS.	STEPS	5
C		STEPS	6
CLJ		STEPS	7
CLJ	INPUT PARAMETERS	STEPS	8
CLJ	ARGUMENT LIST	STEPS	9
CLJ	RX(I) = LOCATION VECTOR TO ONE END OF TRANSMISSION PATH,	STEPS	10
CLJ	TYPICALLY BUT NOT NECESSARILY AT THE DETECTOR, CM	STEPS	11
CLJ	RY(I) = LOCATION VECTOR TO ONE END OF TRANSMISSION PATH,	STEPS	12
CLJ	TYPICALLY AT THE SCATTERING OR SOURCE POINT, CM	STEPS	13
CLJ	(FOR RX AND RY I=1,3)	STEPS	14
CLJ	NC = INITIALIZATION VALUE. NORMALLY SET TO 0 AND LEADS	STEPS	15
CLJ	TO DS(1) BEING SET TO 0.0 IN SUBROUTINE STEP.	STEPS	16
CLJ	OUTPUT PARAMETERS	STEPS	17
CLJ	INTERNAL USE (FOR CALL TO SUBROUTINE STEP)	STEPS	18
CLJ	SHAT(I) = UNIT VECTOR ALONG TRANSMISSION PATH FROM RY TO RX,	STEPS	19
CLJ	CM (I=1,3)	STEPS	20
CLJ	DIST = MAGNITUDE OF DISTANCE ALONG TRANSMISSION PATH FROM	STEPS	21
CLJ	RY TO RX, CM	STEPS	22
CLJ	ARGUMENT LIST	STEPS	23
CLJ	(FOLLOWING QUANTITIES ARE OBTAINED BY A CALL TO STEP)	STEPS	24
CLJ	NC, DS, XFRACS, AND INDX. (SEE *STEP* FOR DEFINITIONS)	STEPS	25
CLJ		STEPS	26
C	DIMENSION DS(100), XFRACS(100), INDX(100), SHAT(3), RX(3), RY(3)	STEPS	27
C		STEPS	28
C	PATH SEGMENTS LESS THAN 10 METERS IN LENGTH ARE NOT TREATED AS	STEPS	29
C	SEPARATE INTEGRATION STEPS.	STEPS	30
C		STEPS	31
CLJ		STEPS	32
CLJ	SHAT = VECTOR DIFFERENCE BETWEEN VECTORS RY AND RX	STEPS	33
CLJ	DIST = MAGNITUDE OF VECTOR SHAT	STEPS	34
CLJ		STEPS	35
CLJ	CALL SUBVEC (RY, RX, SHAT)	STEPS	36
CLJ	DIST = SQRT(DOT(SHAT, SHAT))	STEPS	37
CLJ	IF (DIST .LT. 1.E3) RETURN	STEPS	38
CLJ		STEPS	39
CLJ	OBTAIN A UNIT VECTOR ALONG THE VECTOR SHAT AND CALL IT SHAT	STEPS	40
CLJ		STEPS	41
CLJ	CALL UNITY (SHAT, SHAT)	STEPS	42
CLJ	CALL STEP (RX, SHAT, DIST, NC, DS, XFRACS, INDX)	STEPS	43
CLJ	RETURN	STEPS	44
CLJ	END	STEPS	45

CLJ	SUBROUTINE SUBVEC (VX, VY, DVXY)	SUBVEC	2
CLJ		SUBVEC	3
CLJ	SUBROUTINE SUBVEC RETURNS THE DIFFERENCE BETWEEN VECTORS VX	SUBVEC	4
CLJ	AND VY, I.E., DVXY(1-3) = VX(1-3) - VY(1-3).	SUBVEC	5
CLJ		SUBVEC	6
CLJ	DIMENSION VX(3), VY(3), DVXY(3)	SUBVEC	7
CLJ	CALL VTM (DVXY, 1., VX, -1., VY)	SUBVEC	8
CLJ	RETURN	SUBVEC	9
CLJ	END	SUBVEC	10

	SUBROUTINE SURRAD(IDETEC,MSM,DD,SPCULR,IUP,JUP,KUP,LUP,ZLAM,	SURRAD	2
	5 IFIRES,RAD,UPS,UPPS,UCS,UPCS)	SURRAD	3
CCC		SURRAD	4
C	SUBROUTINE SURRAD PROVIDES (ESSENTIALLY), AT THE POINT P WHERE	SURRAD	5
C	THE OPTICAL LINE-OF-SIGHT FROM THE DETECTOR (WHICH IS	SURRAD	6
C	FICTITIOUS IN THE NBP MODULE) AT POINT V INTERSECTS THE	SURRAD	7
C	EARTH'S SURFACE, THE UPWELLING RADIANCE DIRECTED TOWARD THE	SURRAD	8
C	DETECTOR. SURRAD PROVIDES TWO COMPONENTS OF THE RADIANCE...	SURRAD	9
C	(1) THERMALLY EMITTED AND (2) SOURCE (SUN OR FIREBALL)	SURRAD	10
C	REFLECTED. REFLECTED SKY RADIANCE IS NOT INCLUDED. STRICTLY,	SURRAD	11
C	THE SOURCE-REFLECTED COMPONENT IS ACTUALLY PROVIDED IN AN	SURRAD	12
C	UNATTENUATED FORM TOGETHER WITH THE PATH PARAMETERS (AREAL	SURRAD	13
C	DENSITY U AND UP, WITH P THE PRESSURE), INTEGRATED ALONG THE	SURRAD	14
C	INCOMING PATH FROM THE SOURCE, REQUIRED AS INPUT TO A COMPU-	SURRAD	15
C	TATION OF THE MOLECULAR ABSORPTION OVER A TOTAL PATH.	SURRAD	16
C	THE AEROSOL TRANSMITTANCE ALONG THE INCOMING PATH FROM THE	SURRAD	17
C	SOURCE IS ALSO PROVIDED.	SURRAD	18
CCC		SURRAD	19
C	THE STATISTICAL CLOUD SUBMODEL HAS NOW BEEN INCLUDED.	SURRAD	20
C	SEE SUBROUTINE UPWELL FOR COMMENTS.	SURRAD	21
C	NOTE THAT THE INPUT PARAMETERS FOR POINT C IN POSITN COMMON	SURRAD	22
C	AND IKM IN UPWELLS COMMON FACILITATE PROVIDING, AS	SURRAD	23
C	ADDITIONAL OUTPUTS FOR THE PATH FROM THE SUN TO POINT C AT	SURRAD	24
C	12-KM ALTITUDE, THE PATH PARAMETERS UCS AND UPCS AND THE	SURRAD	25
C	AEROSOL TRANSMITTANCE TASC(LUP).	SURRAD	26
CCC		SURRAD	27
C	INPUT PARAMETERS	SURRAD	28
C	ARGUMENT LIST	SURRAD	29
C	IDETEC - FLAG FOR NATURE OF DETECTOR LOCATION	SURRAD	30
C	= 1 IF DETECTOR IS AT A SATELLITE POSITION	SURRAD	31
C	(SATLAT,SATLON,SATALT) SPECIFIED IN	SURRAD	32
C	SATELL COMMON	SURRAD	33
C	= 2 IF DETECTOR IS AT A POSITION (DETLAT,	SURRAD	34
C	DETLON,DEALT) SPECIFIED IN TECTOR COMMON.	SURRAD	35
C	THIS LATTER OPTION IS USED WHEN SUBROUTINE	SURRAD	36
C	SURRAD IS CALLED FROM SUBROUTINE UPWELL.	SURRAD	37
C	MSM - INDEX FOR CATEGORY OF SURFACE MATERIAL (SEE	SURRAD	38
C	SUBROUTINE ESURF FOR DEFINITIONS)	SURRAD	39
C	DD - ADDITIONAL DESCRIPTOR FOR SELECTED SURFACE	SURRAD	40
C	MATERIAL (SEE SUBROUTINE ESURF FOR DEFINITIONS)	SURRAD	41
C	SPCULR - LOGICAL PARAMETER	SURRAD	42
C	.TRUE. COMPUTE COORDINATES OF SPECULAR REFLECTION	SURRAD	43
C	POINT ON A SMOOTH HORIZONTAL WATER SURFACE	SURRAD	44
C	.FALSE. DO NOT COMPUTE COORDINATES OF SPECULAR	SURRAD	45
C	REFLECTION POINT	SURRAD	46
C	EACH OF THE FOLLOWING FOUR INDICES SHOULD BE SET TO	SURRAD	47
C	UNITY IN A CALL FROM ANY ROUTINE OTHER THAN SUBROUTINE	SURRAD	48
C	UPWELL.	SURRAD	49
C	IUP - ALTITUDE-LOOP INDEX IN SUBROUTINE UPWELL	SURRAD	50
C	JUP - NADIR-LOOP INDEX IN SUBROUTINE UPWELL	SURRAD	51
C	KUP - AZIMUTH-LOOP INDEX IN SUBROUTINE UPWELL	SURRAD	52
C	LUP - WAVENUMBER-LOOP INDEX IN SUBROUTINE UPWELL	SURRAD	53
C	ZLAM - WAVELENGTH, MICROMETERS	SURRAD	54
C	IFIRES - FLAG FOR NUMBER OF FIREBALLS	SURRAD	55
C	= 0 IF NO FIREBALL IS TO BE INCLUDED	SURRAD	56
C	(AS IS THE CASE WHEN SUBROUTINE SURRAD IS	SURRAD	57
C	CALLED FROM SUBROUTINE UPWELL.)	SURRAD	58

C	.GT. 0 IF IFIRES FIREBALLS ARE TO BE INCLUDED	SURRAD	59
C	WITH POSITION AND RADIANT INTENSITY	SURRAD	60
C	SPECIFIED IN FIRBAL COMMON	SURRAD	61
C	DETECTOR COMMON (USED WITH SUBROUTINE UPWELL)	SURRAD	62
C	DETLAT - DETECTOR NORTH LATITUDE, RADIAN	SURRAD	63
C	DETLON - DETECTOR EAST LONGITUDE, RADIAN	SURRAD	64
C	DEALT - DETECTOR ALTITUDE, KM	SURRAD	65
C	FIRBAL COMMON (NOT USED WITH SUBROUTINE UPWELL)	SURRAD	66
C	FBLAT(I) - FIREBALL-I NORTH LATITUDE, RADIAN	SURRAD	67
C	FBLON(I) - FIREBALL-I EAST LONGITUDE, RADIAN	SURRAD	68
C	FBALT(I) - FIREBALL-I ALTITUDE, KM	SURRAD	69
C	FBRINT(I) - FIREBALL-I SPECTRAL RADIANT INTENSITY,	SURRAD	70
C	WATTS/(SR CM-1)	SURRAD	71
C	POSITN COMMON	SURRAD	72
C	POSLAT - NORTH LATITUDE OF POINT P AT WHICH LINE-OF-	SURRAD	73
C	SIGHT INTERSECTS EARTH'S SURFACE, RADIAN	SURRAD	74
C	POSLO - EAST LONGITUDE OF POINT P AT WHICH LINE-OF-	SURRAD	75
C	SIGHT INTERSECTS EARTH'S SURFACE, RADIAN	SURRAD	76
C	POSALT - ALTITUDE OF POINT P AT WHICH LINE-OF-SIGHT	SURRAD	77
C	INTERSECTS EARTH'S SURFACE, KM	SURRAD	78
C	C12LAT - NORTH LATITUDE OF POINT C AT WHICH LINE-OF-	SURRAD	79
C	SIGHT INTERSECTS THE 12-KM ALTITUDE SURFACE,	SURRAD	80
C	RADIAN	SURRAD	81
C	C12LO - EAST LONGITUDE OF POINT C AT WHICH LINE-OF-	SURRAD	82
C	SIGHT INTERSECTS THE 12-KM ALTITUDE SURFACE,	SURRAD	83
C	RADIAN	SURRAD	84
C	C12ALT - ALTITUDE OF POINT C AT WHICH LINE-OF-SIGHT	SURRAD	85
C	INTERSECTS 12-KM ALTITUDE SURFACE, KM	SURRAD	86
C	SATELL COMMON (NOT USED WITH SUBROUTINE UPWELL)	SURRAD	87
C	SATLAT - SATELLITE NORTH LATITUDE, RADIAN	SURRAD	88
C	SATLO - SATELLITE EAST LONGITUDE, RADIAN	SURRAD	89
C	SATALT - SATELLITE ALTITUDE, KM	SURRAD	90
C	SOLARP COMMON	SURRAD	91
C	SOLLAT - SUBSOLAR POINT NORTH LATITUDE, RADIAN	SURRAD	92
C	SOLLO - SUBSOLAR POINT EAST LONGITUDE, RADIAN	SURRAD	93
C	SOURCE COMMON	SURRAD	94
C	THE VARIABLES IN THIS COMMON ARE RETURNED FROM A CALL TO	SURRAD	95
C	SUBROUTINE RINOUT. CURRENTLY (APRIL 1980) ONLY THE SUN	SURRAD	96
C	IS USED AS A SOURCE FOR SUBROUTINE SURRAD. FIREBALLS	SURRAD	97
C	ARE NEVER USED IN THE CALL TO SUBROUTINE SURRAD FROM	SURRAD	98
C	SUBROUTINE UPWELL.	SURRAD	99
C		SURRAD	100
C	SRCZEN(1) - ZENITH ANGLE OF RAY INCOMING TO POINT P FROM	SURRAD	101
C	THE SUN, RADIAN	SURRAD	102
C	SRCZEN(L+1), L=1,IFIRES (NOT USED WITH SUB. UPWELL)	SURRAD	103
C	- ZENITH ANGLE OF RAY INCOMING TO POINT P FROM	SURRAD	104
C	FIREBALL-L, RADIAN	SURRAD	105
C	SRCZR(L+1), L=1,IFIRES (NOT USED WITH SUB. UPWELL)	SURRAD	106
C	- SLANT RANGE FROM FIREBALL-L TO POINT P, KM	SURRAD	107
C	UPWELLS COMMON	SURRAD	108
C	NWAVE(JBAND)	SURRAD	109
C	- NUMBER OF WAVENUMBERS AT WHICH THE UPWELLING	SURRAD	110
C	SPECTRAL RADIANCE IS TO BE COMPUTED FOR	SURRAD	111
C	BROAD-BAND LOOP-INDEX JBAND	SURRAD	112
C	IDAYV - INDEX FOR DAYLIGHT CONDITION AT SUB-V-POINT	SURRAD	113
C	= 0 IF SOLAR ZENITH ANGLE .GT. 90 DEGREES	SURRAD	114
C	= 1 IF SOLAR ZENITH ANGLE .LE. 90 DEGREES	SURRAD	115

C	IKM - INDEX FOR NUMBER OF ALTITUDES AT WHICH	SURRAD	116
C	CALCULATIONS ARE MADE WHEN CLOUDS ARE INCLUDED.	SURRAD	117
C	(SET IN SUBROUTINE UPWELL)	SURRAD	118
C	XYZCOM COMMON	SURRAD	119
C	NS - NUMBER OF BOUNDARY ALTITUDES USED IN	SURRAD	120
C	SUBROUTINE SHELLS	SURRAD	121
C	DATA STATEMENT	SURRAD	122
C	NSPECS - NUMBER OF SPECIES IN MOLECULAR TRANSMITTANCE	SURRAD	123
C	MODEL	SURRAD	124
C	NTEMP - NUMBER OF TEMPERATURE BINS IN MOLECULAR	SURRAD	125
C	TRANSMITTANCE MODEL	SURRAD	126
CCC		SURRAD	127
C	OUTPUT PARAMETERS	SURRAD	128
C	ARGUMENT LIST	SURRAD	129
C	RAD(1) - RADIANCE EMITTED FROM POINT P TOWARD DETECTOR,	SURRAD	130
C	WATTS/(CM**2 SR CM-1)	SURRAD	131
C	RAD(2) - RADIANCE OF SOLAR REFLECTED RADIATION (WITH	SURRAD	132
C	INCOMING RAY UNATTENUATED), W/(CM**2 SR CM-1)	SURRAD	133
C	RAD(L+2), L=1,IFIRES (NOT USED WITH SUBROUTINE UPWELL)	SURRAD	134
C	- RADIANCE OF FIREBALL-L RADIATION REFLECTED	SURRAD	135
C	TOWARD DETECTOR (WITH INCOMING RAY UNATTEN-	SURRAD	136
C	UATED), WATTS/(CM**2 SR CM-1)	SURRAD	137
C	UPS(I,N,1) - AREAL DENSITY FOR TEMPERATURE I AND SPECIES	SURRAD	138
C	N ALONG INCOMING SOLAR PATH TO POINT ON	SURRAD	139
C	EARTH'S SURFACE, CM AT STP	SURRAD	140
C	(COMPUTED ONLY FOR LUP=1)	SURRAD	141
C	UPS(I,N,L+1), L=1,IFIRES (NOT USED IN NBR MODULE)	SURRAD	142
C	- AREAL DENSITY FOR TEMPERATURE I AND SPECIES N	SURRAD	143
C	ALONG PATH FROM FIREBALL-L TO POINT P ON	SURRAD	144
C	EARTH'S SURFACE, CM AT STP	SURRAD	145
C	(COMPUTED ONLY FOR LUP=1)	SURRAD	146
C	UPPS(I,N,1) - PATH PARAMETER UP (PRODUCT OF U AND	SURRAD	147
C	PRESSURE P) FOR TEMPERATURE I AND SPECIES	SURRAD	148
C	N ALONG INCOMING SOLAR PATH TO POINT P ON	SURRAD	149
C	EARTH'S SURFACE, ATM-CM AT STP	SURRAD	150
C	(COMPUTED ONLY FOR LUP=1)	SURRAD	151
C	UPPS(I,N,L+1), L=1,IFIRES (NOT USED IN NBR MODULE)	SURRAD	152
C	- PATH PARAMETER UP (PRODUCT OF U AND PRESSURE P)	SURRAD	153
C	FOR TEMPERATURE I AND SPECIES N ALONG PATH FROM	SURRAD	154
C	FIREBALL-L TO POINT P ON EARTH'S SURFACE,	SURRAD	155
C	ATM-CM AT STP	SURRAD	156
C	(COMPUTED ONLY FOR LUP=1)	SURRAD	157
C	UCS(I,N), - SIMILAR TO UPS(I,N,1) AND UPPS(I,N,1)	SURRAD	158
C	UPCS(I,N) EXCEPT POINT P IS REPLACED BY POINT C.	SURRAD	159
C	AIRSOL COMMON	SURRAD	160
C	TASP(LUP) LUP=1,NWAVE(JBAND)	SURRAD	161
C	- AEROSOL TRANSMITTANCE FOR INCOMING SOLAR RAY TO	SURRAD	162
C	POINT P ON GROUND.	SURRAD	163
C	TASC(LUP) LUP=1,NWAVE(JBAND)	SURRAD	164
C	- AEROSOL TRANSMITTANCE FOR INCOMING SOLAR RAY TO	SURRAD	165
C	POINT C AT 12-KM ALTITUDE.	SURRAD	166
C	TAFP(L) - AEROSOL TRANSMITTANCE FOR INCOMING RAY FROM	SURRAD	167
C	FIREBALL-L TO POINT P ON GROUND	SURRAD	168
C	SOLARP COMMON	SURRAD	169
C	SOLIRR(K) K=1,NWAVE(JBAND)	SURRAD	170
C	- SOLAR SPECTRAL IRRADIANCE AT THE TOP OF THE	SURRAD	171
C	EARTH'S ATMOSPHERE AT WAVENUMBER-INDEX K	SURRAD	172

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C          WATTS / ( CM**2 CM-1 )
CCC
DIMENSION RF(3),RP(3),RC(3),RS(3),PLNCK(10)
DIMENSION DO(7),RAD(12),UPS(10,10,11),UPPS(10,10,11),
$          UCS(10,10),UPCS(10,10)
DIMENSION DS(100),XFRACS(100),INDX(100)
COMMON/AIRSOL/ TASP(10),TASC(10),TAFP(10)
COMMON/FIRBAL/ FBLAT(10),FBLON(10),FBALT(10),FBRINT(10)
COMMON/POSITN/ POSLAT,POSLOX,POSALT,SPCLAT,SPCLON
$          ,C12LAT,C12LON,C12ALT
COMMON/SATELL/ SATLAT,SATLON,SATALT,SATZEN,SATAZI
COMMON/SOLARP/ SOLLAT,SOLLON,SOLIRR(10)
COMMON/SOURCE/ SRCLAT,SRCLON,SRCLAT,SRCLG,SRCZEN(11),SRCSR(11)
COMMON/TECTOR/ DETLAT,DETLOX,DETALT,DETZEN,DETAZI(11)
COMMON/UPWELS/ UPWALT,UPWLOX,UPWALT,NALT(5),ZKM(13,5),NNADIR,NAZI,
*          ,MWAVE(5),IDAYV,CLDFLG,UPRADN(13,10,5),WV(10,5),IKM,
*          ,NBANDS
COMMON/UPWELS1/
2          ,RO10(6,10),RO10A(6,10,10),RO10N(6,10),
3          ,RO25(6,10),RO25A(6,10,10),RO25N(6,10),
4          ,RO50(6,10),RO50A(6,10,10),RO50N(6,10),
5          ,RO90(6,10),RO90A(6,10,10),RO90N(6,10),
6          ,R100(6,10),R100A(6,10,10),R100N(6,10),
7          ,ARCVA(6,10,10),ARCVN(6,10)
COMMON/UPWELS2/ JBAND1
COMMON/UPWELS3/ UPRA(6,10),UPRA(13,10,10)
COMMON/ XYZCOM/ ITMTE,LTMT,NS,HSELL(81),TPX(81,12),
1          ,U(10,10,2),UP(10,10,2),NMOLS,FACT
LOGICAL FIRST,SPCLR,ESURF1
DATA RSUN / 1.495979E+08 /
DATA NSPCS,NTEMP / 10,10 /

CC
CC          SUBROUTINE SURRAD IS CALLED FROM SUBROUTINE UPWELL FOR ALL
CC          VALUES OF I,J,K,L. HOWEVER, SWITCHES ELIMINATE REDUNDANT
CC          CALCULATIONS. FOR EXAMPLE,
CC          * CALL TO FUNCTION PLANCK DEPENDS ONLY ON L.
CC          * CALL TO SUBROUTINE SOLRAD DEPENDS ONLY ON L.
CC          * PATH PARAMETERS FOR PATH FROM POINT P TO SUN ARE
CC          INDEPENDENT OF L AND ARE ASSUMED (TO A GOOD APPROXIMATION)
CC          TO BE INDEPENDENT OF I,J,K.
CC          LIKEWISE FOR POINT C, EXCEPT THAT ITS ALTITUDE IS NOT 0.0
CC          BUT 12 KM.
CC          * AEROSOL TRANSMITTANCE FROM POINT P TO SUN DEPENDS ONLY ON L
CC          AND THE (ASSUMED) SINGLE PATH.
CC          * AEROSOL TRANSMITTANCE FROM POINT C TO SUN DEPENDS ONLY ON L
CC          AND THE (ASSUMED) SINGLE PATH.
CC
IF( LUP.GT.1 ) GO TO 5
CC
CC          DETERMINE WHETHER DETECTOR IS IN SATELLITE SPECIFIED IN
CC          SATELL COMMON. IDETEC=2 WHEN SUBROUTINE UPWELL CALLS
CC          SUBROUTINE SURRAD.
IF( IDETEC.EQ.2 ) GO TO 1
CC
CC          DETECTOR IS AT SATELLITE, SO RESET DETECTOR LOCATION.
DETLAT = SATLAT
DETLON = SATLON

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SURRAD 173
SURRAD 174
SURRAD 175
SURRAD 176
SURRAD 177
SURRAD 178
AIRSOL 2
FIRBAL 2
POSITN 2
POSITN 3
SATELL 2
SOLARP 2
SOURCE 2
TECTOR 2
UPWELS 2
UPWELS 3
UPWELS 4
UPWELS 5
UPWELS 6
UPWELS 7
UPWELS 8
UPWELS 9
UPWELS 10
UPWELS 11
XYZCOM 2
XYZCOM 3
XYZCOM 4
XYZCOM 5
SURRAD 188
SURRAD 189
SURRAD 190
SURRAD 191
SURRAD 192
SURRAD 193
SURRAD 194
SURRAD 195
SURRAD 196
SURRAD 197
SURRAD 198
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SURRAD 213
SURRAD 214
SURRAD 215
SURRAD 216

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	DETAIL = SATALT	SURRAD	217
CC	FIRST, CONSIDER ONLY THE SUN AS A SOURCE AND ALSO GET DETECTOR	SURRAD	218
CC	ZENITH AND (IF MSM.GT.2 AND IDAY=1) AZIMUTH ANGLES FOR SUN	SURRAD	219
CC	AS SOURCE	SURRAD	220
CC		SURRAD	221
CC	1 CALL RINOUT(MSM, 0, IDAY)	SURRAD	222
CC		SURRAD	223
CC	NOW HAVE IDAY AT POINT P, DETZEN, (IF IDAY=1) SRCZEN(1), AND	SURRAD	224
CC	(IF IDAY=1 AND MSM.GT.2) DETAZI(1).	SURRAD	225
CC		SURRAD	226
CC	THE COMPLICATIONS RESULTING FROM THE SOLAR TERMINATOR BEING	SURRAD	227
CC	VISIBLE FROM POINT V ARE NOT HANDLED IN A COMPLETELY	SURRAD	228
CC	CONSISTENT WAY. IF SUBPOINT V' IS IN DAYLIGHT (IDAYV=1), THE	SURRAD	229
CC	DIURNAL CONDITION AT EACH POINT P (AS INDICATED BY INDEX IDAY)	SURRAD	230
CC	IS RECOGNIZED, BUT IF SUBPOINT V' IS IN DARKNESS (IDAYV=0),	SURRAD	231
CC	THEN DARKNESS IS IMPOSED ON ALL POINTS P BY SETTING IDAY=0.	SURRAD	232
CC		SURRAD	233
CC	IF(IDAYV.EQ.0) IDAY = 0	SURRAD	234
CC		SURRAD	235
CC	IFIRES=0 WHEN SUBROUTINE UPWELL CALLS SUBROUTINE SURRAD.	SURRAD	236
CC	IF(IFIRES.GT.0) CALL RINOUT(MSM,IFIRES,IDAY)	SURRAD	237
CC	NOW HAVE ZENITH ANGLES SRCZEN(L+1) AND SLANT RANGES SRCZR(L+1)	SURRAD	238
CC	OF FIREBALL-L (L=1,IFIRES) AND DETECTOR AZIMUTHS DETAZI(L+1).	SURRAD	239
CC		SURRAD	240
CC	SET PARAMETERS TO CALL ESURF FOR SUN AS SOURCE.	SURRAD	241
CC	THI = -1.0	SURRAD	242
CC	PSI = -1.0	SURRAD	243
CC	IF(IDAY.EQ.1) THI = SRCZEN(1)	SURRAD	244
CC	IF((IDAY.EQ.1) .AND. (MSM.GT.2)) PSI = DETAZI(1)	SURRAD	245
CC	THR = DETZEN	SURRAD	246
CC	HHH = POSALT	SURRAD	247
CC	5 CONTINUE	SURRAD	248
CC	CALL ESURF WITH ESURF1 SET TO .TRUE. SINCE WE WANT ALL THREE	SURRAD	249
CC	OUTPUTS (SFR, EPSD, TKS). NOTE THAT EVERY CALL TO ESURF FROM	SURRAD	250
CC	SURRAD (WITHIN NBR MODULE) QUALIFIES AS A FIRST CALL.	SURRAD	251
CC	ESURF1 = .TRUE.	SURRAD	252
CC	CALL ESURF(THI,THR,PSI,HHH,MSM,DD,SPCULR,ZLAM,IDAY,IFIRES,ESURF1,	SURRAD	253
CC	\$ SFR,EPSD,TKS)	SURRAD	254
CC		SURRAD	255
CC	BYPASS PRINT OF EPSD AND TKS UNLESS INDICES I, J, K, AND L IN	SURRAD	256
CC	SUBROUTINE UPWELL (KNOWN HERE AS IUP, JUP, KUP, AND LUP) HAVE	SURRAD	257
CC	VALUES OF UNITY. HOWEVER, WE AND THE CODE RECOGNIZE THE FACT	SURRAD	258
CC	THAT WHEREAS TKS DEPENDS ONLY ON THE SURFACE ALTITUDE, EPSD	SURRAD	259
CC	DEPENDS ON ANGLE AND WAVELENGTH.	SURRAD	260
CC		SURRAD	261
CC	IJK = IUP + JUP + KUP	SURRAD	262
CC	IJKL = IJK + LUP	SURRAD	263
CC	WE AVOID USING THE QUANTITY (IKM+JUP+KUP+LUP) BECAUSE THE	SURRAD	264
CC	MINIMUM VALUE OF IKM IS 0. THEREFORE, WE USE...	SURRAD	265
CC	JK = JUP + KUP	SURRAD	266
CC	JKL = JK + LUP	SURRAD	267
CC	IF(IJKL.EQ.4) WRITE(6,111) EPSD,TKS	SURRAD	268
CC	111 FORMAT(1H0,1X,* EPSD, TKS = *, 1P2E14.6,* (FROM SUBROUTINE SURRAD	SURRAD	269
CC	\$, FORMAT 111)*)	SURRAD	270
CC		SURRAD	271
CC	NOW HAVE EPSD, TKS, AND (IF IDAY=1) SFR.	SURRAD	272
CC	ALSO, IF IDAY=1, MSM=2, AND SPCULR=.TRUE., WE HAVE (THROUGH	SURRAD	273

CC	POSITN COMMON) THE COORDINATES (SPCLAT,SPCLON) OF THE SOLAR	SURRAD	274
CC	SPECULAR REFLECTION POINT ON A SMOOTH HORIZONTAL WATER SURFACE	SURRAD	275
CC	COMPUTED IN GLITTR. TO FACILITATE PRESERVING THESE COORDINATES,	SURRAD	276
CC	DEFINE NEW VARIABLES.	SURRAD	277
CC		SURRAD	278
	SSPLAT = SPCLAT	SURRAD	279
	SSPLON = SPCLON	SURRAD	280
CC	IF THESE COORDINATES PROVE TO BE OF INTEREST, ADDITIONAL	SURRAD	281
CC	PRESERVING VARIABLES WILL BE NEEDED AS SUBROUTINE UPWELL	SURRAD	282
CC	LOOPS OVER ALTITUDES.	SURRAD	283
CC		SURRAD	284
CC	BYPASS CALL TO FUNCTION PLANCK UNLESS INDICES I,J, AND K IN	SURRAD	285
CC	SUBROUTINE UPWELL (KNOWN HERE AS IUP,JUP, AND KUP) HAVE	SURRAD	286
CC	VALUES OF UNITY.	SURRAD	287
	IF(IJK.GT.3) GO TO 10	SURRAD	288
	W = 1.0E+04/ZLAM	SURRAD	289
	PLNCK(LUP) = PLANCK(TKS,W)	SURRAD	290
10	CONTINUE	SURRAD	291
	RAD(1) = EPSD * PLNCK(LUP)	SURRAD	292
CC	NOW HAVE EMITTED SPECTRAL RADIANCE, RAD(1).	SURRAD	293
CC		SURRAD	294
	RAD(2) = 0.0	SURRAD	295
	IF(IDAYV.EQ. 0) GO TO 50	SURRAD	296
CC		SURRAD	297
CC	ASSUME PATH PARAMETERS FROM POINT P TO THE SUN ARE EFFECTIVELY	SURRAD	298
CC	INDEPENDENT OF THE POINT P LOCATION ON THE SURFACE. THUS,	SURRAD	299
CC	BYPASS ZEROING PATH PARAMETERS HERE, AND THEIR COMPUTATION	SURRAD	300
CC	LATER, UNLESS IUP=JUP=KUP=LUP=1.	SURRAD	301
	IF(IJKL.GT.4) GO TO 21	SURRAD	302
	DO 20 N=1,NSPECS	SURRAD	303
	DO 20 I=1,NTEMP	SURRAD	304
	U PS(I,N,1) = 0.0	SURRAD	305
	UPPS(I,N,1) = 0.0	SURRAD	306
20	CONTINUE	SURRAD	307
21	CONTINUE	SURRAD	308
CC		SURRAD	309
CC	ALSO ASSUME PATH PARAMETERS FROM POINT C TO THE SUN ARE	SURRAD	310
CC	EFFECTIVELY INDEPENDENT OF THE POINT-C LOCATION ON THE 12-KM	SURRAD	311
CC	ALTITUDE SURFACE. THUS BYPASS ZEROING PATH PARAMETERS HERE,	SURRAD	312
CC	AND THEIR COMPUTATION LATER, UNLESS IKM=JUP=KUP=LUP=1.	SURRAD	313
	IF((IKM.NE. 1) .OR. (JKL.GT. 3)) GO TO 23	SURRAD	314
	DO 22 N=1,NSPECS	SURRAD	315
	DO 22 I=1,NTEMP	SURRAD	316
	U CS(I,N) = 0.0	SURRAD	317
	UPCS(I,N) = 0.0	SURRAD	318
22	CONTINUE	SURRAD	319
23	CONTINUE	SURRAD	320
CC		SURRAD	321
CC	IF SUN IS PRESENT, GET THE SOLAR SPECTRAL IRRADIANCE	SURRAD	322
CC	E (W/(CM**2 CM-1)) AT THE TOP OF THE ATMOSPHERE.	SURRAD	323
CC	BYPASS CALL TO SUBROUTINE SOLRAD UNLESS IUP=JUP=KUP=1.	SURRAD	324
	IF(IJK.GT.3) GO TO 25	SURRAD	325
	CALL SOLRAD(3,W,E)	SURRAD	326
	SOLIRR(LUP) = E	SURRAD	327
	NWAVEJ = NWAVE(JBAND1)	SURRAD	328
	IF(LUP.EQ. NWAVEJ) WRITE(6,125) (SOLIRR(LP),LP=1,NWAVEJ)	SURRAD	329
125	FORMAT (1H0,28X,77H* * * SOLAR SPECTRAL IRRADIANCE SOLIRR(L), (L=1	SURRAD	330

	\$, NMAVEJ), W/(CM**2 CM-1) * * /48X, *(FROM SUBROUTINE SURRAD, FORM	SURRAD	331
	\$T 125)* /2X, IF(10E12.4))	SURRAD	332
25	CONTINUE	SURRAD	333
CC		SURRAD	334
CC	COMPUTE SPECTRAL RADIANCE OF (UNATTENUATED) DIRECT SOLAR	SURRAD	335
CC	RADIATION REFLECTED FROM EARTH SURFACE AT POINT P TOWARDS	SURRAD	336
CC	POINT V.	SURRAD	337
	RAD(2) = SFR * SOLIRR(LUP) * COS(TH!)	SURRAD	338
CC		SURRAD	339
	IF(IJKL .GT. 4) GO TO 27	SURRAD	340
CC		SURRAD	341
CC	PREPARE TO GET PATH PARAMETERS FOR PATH FROM POINT P TO SUN,	SURRAD	342
CC	WHICH CARRIES THROUGH TO STATEMENT LABEL 41.	SURRAD	343
CC		SURRAD	344
CC	OBTAIN EARTH-CENTERED CARTESIAN COORDINATES OF POINT P.	SURRAD	345
	CALL GEOXYZ(POSALT, POSLAT, POSLON, RP(1), RP(2), RP(3))	SURRAD	346
	CALL VLIN(RP, 1.0E+05, RP, 0.0, 0.0)	SURRAD	347
CC		SURRAD	348
CC	NEED TO DETERMINE LOCATION OF SUN.	SURRAD	349
	CALL GEOXYZ(RSUN, SOLLAT, SOLLON, RS(1), RS(2), RS(3))	SURRAD	350
	CALL VLIN(RS, 1.0E+05, RS, 0.0, 0.0)	SURRAD	351
CC	HAVE NOW DETERMINED RP AND RS.	SURRAD	352
CC		SURRAD	353
CC	INITIALIZE NC SO THAT DS(1) WILL BE SET TO 0.0 IN SUBROUTINE	SURRAD	354
CC	STEP.	SURRAD	355
	NC = 0	SURRAD	356
	CALL STEPS(RP, RS, NC, DS, XFRACS, INDX)	SURRAD	357
CC	NOW HAVE NC, DS, XFRACS, AND INDX FOR PATH FROM S TO P.	SURRAD	358
CC		SURRAD	359
CC	INITIALIZE LOGICAL VARIABLE, FIRST, IN PREPARATION FOR FIRST	SURRAD	360
CC	CALL TO SUBROUTINE PATH.	SURRAD	361
	FIRST = .TRUE.	SURRAD	362
27	CONTINUE	SURRAD	363
CC		SURRAD	364
	IF(IJK .GT. 3) GO TO 31	SURRAD	365
CC	BEFORE STARTING DO-30 LOOP, OBTAIN THE AEROSOL EXTINCTION	SURRAD	366
CC	COEFFICIENT AT THE INITIAL ENDPPOINT OF THE PATH.	SURRAD	367
	TASP(LUP) = 1.0	SURRAD	368
	L1 = INDX(1) \$ L2 = INDX(2)	SURRAD	369
	HSP = XFRACS(1) * HSELL(L1) + (1.-XFRACS(1)) * HSELL(L2)	SURRAD	370
	CALL AEROSOL (HSP, ZLAM, XKSCOT, XKABS, GBAR)	SURRAD	371
	XKEXTP = XKSCOT + XKABS	SURRAD	372
	DO 30 J=1, NC	SURRAD	373
CC	ON THE PASS FOR WHICH J=NC, DS(NC+1) WILL BE -1.0, INDICATING	SURRAD	374
CC	THAT THE LAST SEGMENT HAS BEEN PROCESSED. (THE LOOP COULD	SURRAD	375
CC	HAVE BEEN FROM J=1 TO J=NC-1 AND THE FOLLOWING TEST	SURRAD	376
CC	ELIMINATED.)	SURRAD	377
	IF(DS(J+1).LT.0.0) GO TO 30	SURRAD	378
	IF(IJKL .EQ. 4) CALL PATH(FIRST, INDX(J), DS(J+1), XFRACS(J))	SURRAD	379
	L1 = INDX(J) \$ L2 = INDX(J+1)	SURRAD	380
	HSP = XFRACS(J+1) * HSELL(L2) + (1.-XFRACS(J+1)) * HSELL(L1)	SURRAD	381
	CALL AEROSOL (HSP, ZLAM, XKSCOT, XKABS, GBAR)	SURRAD	382
	XKEXTQ = XKSCOT + XKABS	SURRAD	383
	XKEXT = ACCUM(2, G., DS(J+1), XKEXTP, XKEXTQ, 0., DS(J+1)) / DS(J+1)	SURRAD	384
	TASP(LUP) = TASP(LUP) * EXP(-XKEXT*DS(J+1))	SURRAD	385
	XKEXTP = XKEXTQ	SURRAD	386
30	CONTINUE	SURRAD	387

31 CONTINUE	SURRAD	388
CC NOW HAVE PATH PARAMETERS U AND UP FOR SOLAR RAY TO POINT P.	SURRAD	389
CC SINCE THESE PATH PARAMETERS ARE INDEPENDENT OF WAVELENGTH,	SURRAD	390
CC THEY NEED BE COMPUTED ONLY ONCE.	SURRAD	391
CC ALSO HAVE AEROSOL TRANSMITTANCE, TASP(LUP), FOR SOLAR RAY TO	SURRAD	392
CC POINT P, WHICH IS WAVELENGTH DEPENDENT.	SURRAD	393
IF(IJXL.GT. 4) GO TO 41	SURRAD	394
CC REDEFINE VARIABLES.	SURRAD	395
DO 40 N=1,NSPECS	SURRAD	396
DO 40 I=1,MTEMP	SURRAD	397
U PS(I,N,1) = U (I,N,2)	SURRAD	398
UPPS(I,N,1) = UP(I,N,2)	SURRAD	399
40 CONTINUE	SURRAD	400
WRITE(6,140)	SURRAD	401
140 FORMAT (1H0,44X,43H* * * PATH PARAMETERS, POINT P TO SUN * */46X	SURRAD	402
\$,*(FROM SUBROUTINE SURRAD, FORMATS 140,142)* /2X,*TEMPERATURE/SPECI	SURRAD	403
\$ES. ((UPS(M,N,1),N=1,NSPECS),M=1,2)*)	SURRAD	404
WRITE(6,141) ((M, (U PS(M,N,1),N=1,NSPECS)),M=1,2)	SURRAD	405
141 FORMAT (2X,13,1P10E12.4)	SURRAD	406
WRITE(6,142)	SURRAD	407
142 FORMAT (1H0,1X,*TEMPERATURE/SPECIES. ((UPPS(M,N,1),N=1,NSPECS),M=1	SURRAD	408
\$,2)*)	SURRAD	409
WRITE(6,141) ((M, (UPPS(M,N,1),N=1,NSPECS)),M=1,2)	SURRAD	410
41 CONTINUE	SURRAD	411
CC	SURRAD	412
CC	SURRAD	413
CC PARAMETERS FOR PATH FROM S TO C NEED BE DONE ONLY ONCE.	SURRAD	414
IF((IKM.NE. 1) .OR. (JK.GT. 2)) GO TO 50	SURRAD	415
IF(LUP.GT. 1) GO TO 42	SURRAD	416
CC	SURRAD	417
CC PREPARE TO GET PATH PARAMETERS FOR PATH FROM POINT C TO SUN.	SURRAD	418
CC	SURRAD	419
CC OBTAIN EARTH-CENTERED CARTESIAN COORDINATES OF POINT C.	SURRAD	420
CALL GEOXYZ(C12ALT,C12LAT,C12LON,RC(1),RC(2),RC(3))	SURRAD	421
CALL VLIN(RC,1.0E+05,RC,0.0,0.0)	SURRAD	422
CC	SURRAD	423
MC = 0	SURRAD	424
CALL STEPS(RC,RS,MC,DS,XFRACS,INDX)	SURRAD	425
CC NOW HAVE MC, DS, XFRACS, AND INDX FOR PATH FROM S TO C.	SURRAD	426
FIRST = .TRUE.	SURRAD	427
42 CONTINUE	SURRAD	428
CC	SURRAD	429
TASC(LUP) = 1.0	SURRAD	430
L1 = INDX(1) \$ L2 = INDX(2)	SURRAD	431
HSP = XFRACS(1) * HSELL(L1) + (1.-XFRACS(1)) * HSELL(L2)	SURRAD	432
CALL AEROSOL (HSP,ZLAM,XKSCT,XKABS,GBAR)	SURRAD	433
XKEXTP = XKSCT + XKABS	SURRAD	434
DO 44 J=1,MC	SURRAD	435
IF(DS(J+1).LT. 0.0) GO TO 44	SURRAD	436
IF(LUP.EQ. 1) CALL PATH(FIRST,INDX(J),DS(J+1),XFRACS(J))	SURRAD	437
L1 = INDX(J) \$ L2 = INDX(J+1)	SURRAD	438
HSQ = XFRACS(J+1) * HSELL(L2) + (1.-XFRACS(J+1)) * HSELL(L1)	SURRAD	439
CALL AEROSOL (HSQ,ZLAM,XKSCT,XKABS,GBAR)	SURRAD	440
XKEXTQ = XKSCT + XKABS	SURRAD	441
XKEXT = ACCUM(2,0.,DS(J+1),XKEXTP,XKEXTQ,0.,DS(J+1)) / DS(J+1)	SURRAD	442
TASC(LUP) = TASC(LUP) * EXP(-XKEXT*DS(J+1))	SURRAD	443
XKEXTP = XKEXTQ	SURRAD	444

44	CONTINUE	SURRAD	445
CC	NOW HAVE PATH PARAMETERS U AND UP FOR SOLAR RAY TO POINT C.	SURRAD	446
CC	SINCE THESE PATH PARAMETERS ARE INDEPENDENT OF WAVELENGTH,	SURRAD	447
CC	THEY NEED BE COMPUTED ONLY ONCE.	SURRAD	448
CC	ALSO HAVE AEROSOL TRANSMITTANCE, TASC(LUP), FOR SOLAR RAY TO	SURRAD	449
CC	POINT C, WHICH IS WAVELENGTH DEPENDENT.	SURRAD	450
	IF(LUP .GT. 1) GO TO 50	SURRAD	451
CC	REDEFINE VARIABLES.	SURRAD	452
	DO 46 N=1, NSPECS	SURRAD	453
	DO 46 I=1, MTEMP	SURRAD	454
	U CS(I,N) = U (I,N,2)	SURRAD	455
	UPCS(I,N) = UP(I,N,2)	SURRAD	456
46	CONTINUE	SURRAD	457
	WRITE(6,146)	SURRAD	458
146	FORMAT (1H0,44X,43H* * * PATH PARAMETERS, POINT C TO SUN * * */46X	SURRAD	459
	\$,*(FROM SUBROUTINE SURRAD, FORMATS 146,148)*2X,*TEMPERATURE/SPECI	SURRAD	460
	\$ES. ((UCS(I,N),N=1,NSPECS),I=1,2)*	SURRAD	461
	WRITE(6,141) ((I, (U CS(I,N),N=1,NSPECS)),I=1,2)	SURRAD	462
	WRITE(6,148)	SURRAD	463
148	FORMAT (1H0,1X,*TEMPERATURE/SPECIES. ((UPCS(I,N),N=1,NSPECS),I=1,2	SURRAD	464
	\$)*	SURRAD	465
	WRITE(6,141) ((I, (UPCS(I,N),N=1,NSPECS)),I=1,2)	SURRAD	466
50	CONTINUE	SURRAD	467
CC		SURRAD	468
CC	THE REMAINING PORTION OF THIS SUBROUTINE, NOT TO BE USED WITH	SURRAD	469
CC	SUBROUTINE UPWELL, IS AVOIDED BY CALLING SUBROUTINE SURRAD	SURRAD	470
CC	WITH IFIRES=0.	SURRAD	471
CC		SURRAD	472
	IF(IFIRES.EQ.0) RETURN	SURRAD	473
CC		SURRAD	474
CC	-----	SURRAD	475
CC	NOW CONSIDER THE FIREBALLS AS SOURCES.	SURRAD	476
CC	NOTE THAT THE NATURAL CLOUD MODULE IS NOT INVOLVED WITH THE	SURRAD	477
CC	REMAINING PORTION OF THIS ROUTINE.	SURRAD	478
CC		SURRAD	479
CC	ASSUME THAT LUP (IN ARGUMENT LIST) ALSO SERVES AS A WAVELENGTH	SURRAD	480
CC	INDEX.	SURRAD	481
	DO 99 L=1, IFIRES	SURRAD	482
CC	GET THE (UNATTENUATED) IRRADIANCE, EFIRE, OF FIREBALL-L AT	SURRAD	483
CC	SLANT RANGE SRCR(L+1), IN WATTS/(CM**2 CM-1).	SURRAD	484
CC		SURRAD	485
	EFIRE = FBRINT(L)/(1.F+10*SRCR(L+1)*SRCR(L+1))	SURRAD	486
CC		SURRAD	487
CC	SET PARAMETERS TO CALL ESURF.	SURRAD	488
	THI = SRCZEN(L+1)	SURRAD	489
	PSI = DETAZI(L+1)	SURRAD	490
CC	CALL ESURF WITH ESURF1 SET TO .FALSE. SINCE THIS IS NOT THE	SURRAD	491
CC	FIRST CALL FROM THIS ROUTINE AND THUS WE DO NOT NEED A	SURRAD	492
CC	RECOMPUTATION OF EPSO AND TKS.	SURRAD	493
	ESURF1 = .FALSE.	SURRAD	494
CC	CALL ESURF WITH SPCULR SET TO .FALSE. UNDER THE TENTATIVE	SURRAD	495
CC	ASSUMPTION THAT WE WILL NOT NEED THE SPECULAR REFLECTION	SURRAD	496
CC	POINTS FOR FIREBALLS (WHICH CAN BE COMPUTED IN GLITTR IF	SURRAD	497
CC	MSM=2). IF THERE IS INTEREST IN KNOWING SUCH REFLECTION	SURRAD	498
CC	POINTS WE WILL NEED TO ESTABLISH APPROPRIATE PRESERVING	SURRAD	499
CC	VARIABLES.	SURRAD	500
	SPCULR = .FALSE.	SURRAD	501

	CALL ESURF(THI,THP,PSI,HMM,MSM,DO,SPCLR,ZLAM,TDAY,IFIRE,ESURF1,	SURRAD	502
	\$ SFR,EPSP,TKS)	SURRAD	503
	RAD(L+2) = SFR*EFIRE*COS(THI)	SURRAD	504
CC	NOW HAVE UNATTENUATED REFLECTED RADIANCE, RAD(L+2), AT	SURRAD	505
CC	POINT P DUE TO FIREBALL-L. NEED PATH PARAMETERS.	SURRAD	506
	IF(LUP.GT. 1) GO TO 60	SURRAD	507
	CALL GEOXYZ(FBALT(L),FBAT(L),FBLON(L),RF(1),RF(2),PF(3))	SURRAD	508
	CALL VLIN(MF,1.0E+05,RF,0.0,0.0)	SURRAD	509
	NC = 0	SURRAD	510
	CALL STEPS(RP,RF,NC,DS,XFRACS,INDX)	SURRAD	511
CC	NOW HAVE NC,DS,XFRACS, AND INDX.	SURRAD	512
	FIRST = .TRUE.	SURRAD	513
60	CONTINUE	SURRAD	514
	TAFP(L) = 1.0	SURRAD	515
	L1 = INDX(1) \$ L2 = INDX(2)	SURRAD	516
	HSP = XFRACS(1) * HSHLL(L1) + (1.-XFRACS(1)) * HSHLL(L2)	SURRAD	517
	CALL AEROSOL (HSP,ZLAM,XKSCT,XKABS,GBAR)	SURRAD	518
	XKEXTP = XKSCT + XKABS	SURRAD	519
	DO 70 J=1,NC	SURRAD	520
	IF(DS(J+1).LT.0.0) GO TO 70	SURRAD	521
	IF(LUP.EQ. 1) CALL PATH(FIRST,INDX(J),DS(J+1),XFRACS(J))	SURRAD	522
	L1 = INDX(J) \$ L2 = INDX(J+1)	SURRAD	523
	HSP = XFRACS(J+1) * HSHLL(L2) + (1.-XFRACS(J+1)) * HSHLL(L1)	SURRAD	524
	CALL AEROSOL (HSP,ZLAM,XKSCT,XKABS,GBAR)	SURRAD	525
	XKEXTQ = XKSCT + XKABS	SURRAD	526
	XKEXT = ACCUM(2,0.,DS(J+1),XKEXTP,XKEXTQ,0.,DS(J+1)) / DS(J+1)	SURRAD	527
	TAFP(L) = TAFP(L) * EXP(-XKEXT*DS(J+1))	SURRAD	528
	XKEXTP = XKEXTQ	SURRAD	529
70	CONTINUE	SURRAD	530
CC	NOW HAVE PATH PARAMETERS U AND UP FOR FIREBALL-L RAY TO	SURRAD	531
CC	POINT P.	SURRAD	532
CC	ALSO HAVE AEROSOL TRANSMITTANCE, TAFP(L), FOR FIREBALL-L	SURRAD	533
CC	RAY FROM RF TO RP.	SURRAD	534
	IF(LUP.GT. 1) GO TO 99	SURRAD	535
CC	REDEFINE VARIABLES.	SURRAD	536
	DO 80 M=1,NSPECS	SURRAD	537
	DO 80 I=1,NTEMP	SURRAD	538
	U PS(I,M,L+1) = U (I,M,2)	SURRAD	539
	UPPS(I,M,L+1) = UP(I,M,2)	SURRAD	540
80	CONTINUE	SURRAD	541
99	CONTINUE	SURRAD	542
	RETURN	SURRAD	543
	END	SURRAD	544

CCC	SUBROUTINE TANGEO(HA1,GC1,GL1,XE21,YN21,ZV21,HA2,GC2,GL2)	TANGEO	2
C		TANGEO	3
C	SUBROUTINE TANGEO (A MODIFIED HARC ROUTINE CALLED XYGEO).	TANGEO	4
C	GIVEN THE GEOGRAPHIC COORDINATES OF POINT 1 AND THE TANGENT-	TANGEO	5
C	PLANE COORDINATES OF POINT 2 WITH RESPECT TO POINT 1, PROVIDES	TANGEO	6
C	THE GEOGRAPHIC COORDINATES OF POINT 2.	TANGEO	7
CCC		TANGEO	8
C	INPUTS FROM CALL STATEMENT	TANGEO	9
C	HA1 = ALTITUDE OF POINT 1, CM	TANGEO	10
C	GC1 = COLATITUDE OF POINT 1, RADIANS	TANGEO	11
C	GL1 = EAST LONGITUDE OF POINT 1, RADIANS	TANGEO	12
C	XE21 = X COORDINATE OF POINT 2 RELATIVE TO POINT 1, CM	TANGEO	13
C	YN21 = Y COORDINATE OF POINT 2 RELATIVE TO POINT 1, CM	TANGEO	14
C	ZV21 = Z COORDINATE OF POINT 2 RELATIVE TO POINT 1, CM	TANGEO	15
C	OUTPUTS	TANGEO	16
C	HA2 = ALTITUDE OF POINT 2, CM	TANGEO	17
C	GC2 = COLATITUDE OF POINT 2, RADIANS	TANGEO	18
C	GL2 = EAST LONGITUDE OF POINT 2, RADIANS	TANGEO	19
CCC		TANGEO	20
C	RESTRICTIONS...	TANGEO	21
C	POINTS 1 AND/OR 2 MAY NOT LIE ON NORTH-SOUTH POLAR AXIS	TANGEO	22
CCC		TANGEO	23
	DATA PI,RE / 3.141592653590,6.37103E+08 /	TANGEO	24
CCC		TANGEO	25
	GR2Z = RE+HA1+ZV21	TANGEO	26
	GR2 = SQRT(XE21**2 + YN21**2 + GR2Z**2)	TANGEO	27
	HA2 = GR2-RE	TANGEO	28
	COSGC1 = COS(GC1)	TANGEO	29
	SINGC1 = SIN(GC1)	TANGEO	30
	COSGC2 = (GR2Z*COSGC1 + YN21*SINGC1)/GR2	TANGEO	31
	SINGC2 = SQRT(1.0-COSGC2**2)	TANGEO	32
	SINGLD = XE21/(GR2*SINGC2)	TANGEO	33
	COSGLD = (GR2Z/GR2 - COSGC1*COSGC2)/(SINGC1*SINGC2)	TANGEO	34
	GC2 = ATAN2(SINGC2,COSGC2)	TANGEO	35
	GLD = ATAN2(SINGLD,COSGLD)	TANGEO	36
	GL2 = GL1+GLD	TANGEO	37
	RETURN	TANGEO	38
	END	TANGEO	39

	SUBROUTINE TRANS(NTEMP, M, U, UP, FK, WDL, WDH, TAU, ABC, TTBL,	TRANS	2
1	FAST, FILPOS)	TRANS	3
C		TRANS	4
CLJ		TRANS	5
CLJ	INPUT PARAMETERS	TRANS	6
CLJ	ARGUMENT LIST	TRANS	7
CLJ	NTEMP = NUMBER OF TEMPERATURES IN ATMOSPHERIC	TRANS	8
CLJ	TRANSMITTANCE MODEL (10, SET IN CALL FROM EITHER	TRANS	9
CLJ	ATMRAD OR TRNSCO)	TRANS	10
CLJ	M = INDEX FOR MODE OF TRANSMITTANCE CALCULATION.	TRANS	11
CLJ	COULD BE 1,2,...,15 . WITHIN THE NATURAL	TRANS	12
CLJ	BACKGROUND RADIATION MODULE (WHERE TRANS IS CALLED	TRANS	13
CLJ	FROM ATMRAD, TRNSCO, AND UPWELL), M IS ALWAYS 1.	TRANS	14
CLJ	(IN CALLS FROM PROGRAM EMISCAT, M IS 1, 2, AND IS	TRANS	15
CLJ	ALLOWED VALUES UP TO 15.)	TRANS	16
CLJ	IN SUBROUTINE TRANS, M=1 LIMITS USE OF THE U AND	TRANS	17
CLJ	UP ARRAYS TO THEIR FIRST HALVES. THIS IS	TRANS	18
CLJ	CONSISTENT WITH THE FACT THAT WITHIN THE NBR	TRANS	19
CLJ	MODULE, SUBROUTINE TRANS IS ALWAYS CALLED WITH M	TRANS	20
CLJ	SET TO 1, U SET TO U(1,1,2), AND UP SET TO	TRANS	21
CLJ	UP(1,1,2). THIS IS ALSO TRUE FOR CALLS WITH M=1	TRANS	22
CLJ	FROM EMISCAT. BUT THERE, WHEN M.GE.2, THE CALLS	TRANS	23
CLJ	ARE WITH U AND UP, I. E., THE ENTIRE ARRAYS.	TRANS	24
CLJ	U(I,N,1) = AREAL DENSITY FOR TEMPERATURE I AND	TRANS	25
CLJ	SPECIES N, CM AT STP (I=1,NTEMP, N=1,NSPEC)	TRANS	26
CLJ	UP(I,N,1) = PATH PARAMETER UP (PRODUCT OF U AND PRESSURE FOR	TRANS	27
CLJ	TEMPERATURE I AND SPECIES N, ATM-CM AT STP	TRANS	28
CLJ	(I=1,NTEMP, N=1,NSPEC)	TRANS	29
CLJ	FK(M) =	TRANS	30
CLJ	(FK(M) IS USED ONLY IF M.GE.3 . CURRENTLY, M IS	TRANS	31
CLJ	SET TO 1 IN CALLS TO TRANS FROM TRNSCO AND ATMRAD)	TRANS	32
CLJ	WDL = LOWEST WAVENUMBER IN DETECTOR INTERVAL BEING	TRANS	33
CLJ	USED, 1/CM	TRANS	34
CLJ	WDH = HIGHEST WAVENUMBER IN DETECTOR INTERVAL BEING	TRANS	35
CLJ	USED, 1/CM	TRANS	36
CLJ	FAST = LOGICAL VARIABLE DETERMINING COMPLEXITY OF	TRANS	37
CLJ	TRANSMISSION CALCULATION. IN CALLS TO SUBROUTINE	TRANS	38
CLJ	TRANS (FROM SUBROUTINES ATMRAD, TRNSCO, AND UPWELL	TRANS	39
CLJ	WITHIN THE NBR MODULE AND FROM PROGRAM EMISCAT	TRANS	40
CLJ	OUTSIDE THE NBR MODULE), FAST IS SET TO TRNSOPT.	TRANS	41
CLJ	=.TRUE., TRANSMITTANCE IS BASED ON SINGLE-LEVEL	TRANS	42
CLJ	GROUPS AND STATISTICAL BANDS. BAND-MODEL	TRANS	43
CLJ	PARAMETERS COMPUTED BY SUBROUTINE TRANSB	TRANS	44
CLJ	FOR TRNSOPT=.TRUE. ARE MATCHED TO USER'S	TRANS	45
CLJ	SPECTRAL INTERVAL.	TRANS	46
CLJ	=.FALSE., TRANSMITTANCE IS BASED ON MULTIPLE-LEVEL	TRANS	47
CLJ	GROUPS AND RANDOM EL SASSER BANDS. BAND-	TRANS	48
CLJ	MODEL PARAMETERS COMPUTED BY SUBROUTINE	TRANS	49
CLJ	TRANSB FOR TRNSOPT=.FALSE. ARE FOR A	TRANS	50
CLJ	HIGHER RESOLUTION THAN THE USER'S SPECTRA	TRANS	51
CLJ	INTERVAL, A FACT TAKEN INTO ACCOUNT IN	TRANS	52
CLJ	COMPUTING THE TRANSMITTANCE.	TRANS	53
CLJ	FILPOS = FILE POSITION. SET TO 1.E+04 IN CALLS FROM	TRANS	54
CLJ	SUBROUTINES TRNSCO AND ATMRAD.	TRANS	55
CLJ	XY COMMON	TRANS	56
CLJ	TT(1) = TEMPERATURE ARRAY IN ATMOSPHERIC TRANSMISSION	TRANS	57
CLJ	MODEL, SET AS DATA IN THE DRIVER PROGRAM.	TRANS	58

CLJ	XYZCOM COMMON	TRANS	59
CLJ	LTMT = BINARY FILE CONTAINING THE BAND-MODEL PARAMETERS	TRANS	60
CLJ	WHICH WERE DERIVED IN SUBROUTINE TRANSB FROM THE	TRANS	61
CLJ	BASIC 5-(1/CM)-RESOLUTION DATA.	TRANS	62
CLJ	LTMT IS IDENTICAL TO TAPOT, THE FILE WRITTEN	TRANS	63
CLJ	BY TRANSB. (SEE TRANSB.)	TRANS	64
CLJ	*****	TRANS	65
CLJ	FOR EACH READ OF THE LTMT FILE, THE 202 WORDS	TRANS	66
CLJ	ARE STORED AS...	TRANS	67
CLJ	WTL = LOWER AND HIGHER WAVENUMBERS OF INTERVAL, CM-1	TRANS	68
CLJ	WTH	TRANS	69
CLJ	FOR I=1,10, IS=1,10	TRANS	70
CLJ	SOD(I,IS) = MEAN ABSORPTION COEFFICIENT FOR SPECIES-IS AT	TRANS	71
CLJ	TEMPERATURE-INDEX-I FOR THE WAVENUMBER INTERVAL,	TRANS	72
CLJ	1/CM AT STP	TRANS	73
CLJ	DEI(I,IS) = INVP. OF MEAN LINE-SPACING PARAMETER, OR THE	TRANS	74
CLJ	EFFECTIVE LINE DENSITY, LINES/(1/CM)	TRANS	75
CLJ	*****	TRANS	76
CLJ	NSPEC = NMOLS, THE NUMBER OF SPECIES. SET IN DRIVER.	TRANS	77
CLJ	OUTPUT PARAMETERS	TRANS	78
CLJ	ARGUMENT LIST	TRANS	79
CLJ	TAU(N,M) = TRANSMITTANCE FOR SPECIES N	TRANS	80
CLJ	(N=1,NSPEC, M=1,15) (BUT M=1 FOR NBR MODULE)	TRANS	81
CLJ	ABC(N,M) = OPTICAL DEPTH FOR SPECIES N, DIMENSIONLESS	TRANS	82
CLJ	(N=1,NSPEC, M=1,15) (BUT M=1 FOR NBR MODULE)	TRANS	83
CLJ	TTBL(M) = MOLECULAR TRANSMITTANCE FOR MODE M	TRANS	84
CLJ	DIMENSION U(NTMP,10,2), UP(NTMP,10,2), FK(M), NSRAY(10),	TRANS	85
CLJ	1 GHAT(13,5), F(13,10), G(13,10), THETA(10), CF(13,10,10),	TRANS	86
CLJ	2 CG(13,10,10), TAU(10,M), XMW(10), SOD(10,10), DEI(10,10),	TRANS	87
CLJ	3 ALS(10), ABC(10,M), TTBL(M)	TRANS	88
C	COMMON / XY / TT(10)	TRANS	89
C	COMMON / XYZCOM / LTMT, LTMT, XXX(1454), NSPEC, FACT	TRANS	90
C	COMMON / CONCOM / PI, RBODY,	TRANS	91
C	LOGICAL TABLIN, FAST	TRANS	92
C		TRANS	93
C		TRANS	94
C		TRANS	95
C	DATA SOD / 100 * 0. /, DEI / 100 * 0. /	TRANS	96
C	DATA NSRAY / 4, 3, 12, 10, 10, 11, 4, 0, 5, 2 /	TRANS	97
C	DATA GHAT / 1, 2, 4, 6, 10, 14, 19, 25, 33, 42, 53, ..	TRANS	98
C	1 66, 80, 1, 1, 3, 3, 6, 7, 10, 12, 14, 17, 19, ..	TRANS	99
C	2 0, 0, 1, 2, 3, 6, 7, 10, 15, 17, 21, 28, 30, 0, ..	TRANS	100
C	3 0, 1, 2, 4, 6, 10, 14, 20, 27, 36, 46, 58, 72, ..	TRANS	101
C	4 0, 1, 1, 3, 3, 3, 6, 7 * 0. /	TRANS	102
C	DATA THETA / 2740, 3420, 850, 1080, 1015, 960, 3123, 0, ..	TRANS	103
C	1 2300, 5350, /	TRANS	104
C	DATA ALS / .04, .04, .08, .10, .11, .07, .06, .06, .04, .06 /	TRANS	105
C	DATA A1 / 0.3480242 /, A2 / -.0958798 /, A3 / 0.7478556 /	TRANS	106
C	DATA P / 0.47047 /	TRANS	107
C	DATA XMW / 30, 30, 44, 46, 48, 44, 28, 16, 18, 17, /	TRANS	108
C	DATA TABLIN / .FALSE. /, WLP / 0. /, WHP / 0. /	TRANS	109
C	DATA PI / 3 24159265 /	TRANS	110
C		TRANS	111
CLJ	ENTRY TRANS1 IS PROVIDED BY SAI (12/29/78) TO AVOID CONFLICT	TRANS	112
CLJ	IN SUBROUTINE UPWELL BETWEEN THE ARRAY TRANS IN COMMON CLOWT	TRANS	113
CLJ	AND THE CALL TO SUBROUTINE TRANS.	TRANS	114
CLJ	ENTRY TRANS1	TRANS	115

M10 = M * 10	TRANS	116
C	TRANS	117
DO 31 I = 1, M10	TRANS	118
ABC(I,1) = 0.	TRANS	119
TAU(I,1) = 0.	TRANS	120
31 CONTINUE	TRANS	121
C	TRANS	122
IF (TABLIN .OR. FAST) GO TO 27	TRANS	123
C	TRANS	124
INITIALIZATIONS	TRANS	125
C	TRANS	126
LOOP OVER SPECIES	TRANS	127
C	TRANS	128
DO 1 IS = 1, NSPEC	TRANS	129
NS = NSRAY(IS) + 1	TRANS	130
C	TRANS	131
LOOP OVER ENERGY BINS	TRANS	132
C	TRANS	133
DO 2 J = 1, NS	TRANS	134
F(J,IS) = 1.	TRANS	135
GO TO (3, 3, 4, 4, 4, 4, 3, 4, 4, 3), IS	TRANS	136
C	TRANS	137
3 F(J,IS) = J	TRANS	138
C	TRANS	139
4 GO TO (5, 6, 7, 8, 9, 10, 6, 11, 12, 5), IS	TRANS	140
C	TRANS	141
5 G(J,IS) = 2.	TRANS	142
GO TO 2	TRANS	143
C	TRANS	144
6 G(J,IS) = 1.	TRANS	145
GO TO 2	TRANS	146
C	TRANS	147
7 G(J,IS) = GHAT(J,1)	TRANS	148
GO TO 2	TRANS	149
C	TRANS	150
8 G(J,IS) = GHAT(J,2) * 100.	TRANS	151
GO TO 2	TRANS	152
C	TRANS	153
9 G(J,IS) = GHAT(J,3) * 100.	TRANS	154
GO TO 2	TRANS	155
C	TRANS	156
10 G(J,IS) = GHAT(J,4)	TRANS	157
GO TO 2	TRANS	158
C	TRANS	159
11 G(J,IS) = 100.	TRANS	160
GO TO 2	TRANS	161
C	TRANS	162
12 G(J,IS) = GHAT(J,5) * 100.	TRANS	163
2 CONTINUE	TRANS	164
C	TRANS	165
1 CONTINUE	TRANS	166
C	TRANS	167
LOOP OVER TEMPERATURES	TRANS	168
C	TRANS	169
DO 13 I = 1, NTEMP	TRANS	170
C	TRANS	171
LOOP OVER SPECIES	TRANS	172

C	DO 14 IS = 1, NSPEC	TRANS	173
C	NS = NSRAY(IS) + 1	TRANS	174
C	FSUM = 0.	TRANS	175
C	LOOP OVER ENERGY BINS	TRANS	176
C	DO 15 J = 1, NS	TRANS	177
C	FJ = J - 1	TRANS	178
C	FSUM = FSUM + F(J,IS) * G(J,IS) * EXP(-THETA(IS) * FJ / TT(I))	TRANS	179
C	15 CONTINUE	TRANS	180
C	FISUM = 0.	TRANS	181
C	LOOP OVER ENERGY BINS	TRANS	182
C	DO 16 J = 1, NS	TRANS	183
C	CF(J,IS,I) = 1.	TRANS	184
C	FJ = J - 1	TRANS	185
C	CF(J,IS,I) = F(J,IS) * G(J,IS) * EXP(-THETA(IS) * FJ / TT(I))	TRANS	186
C	\$ / FSUM	TRANS	187
C	FISUM = FISUM + SORT(CF(J,IS,I) * G(J,IS))	TRANS	188
C	16 CONTINUE	TRANS	189
C	LOOP OVER ENERGY BINS	TRANS	190
C	DO 17 J = 1, NS	TRANS	191
C	CG(J,IS,I) = 1.	TRANS	192
C	FJ = J - 1	TRANS	193
C	CG(J,IS,I) = G(J,IS) / FISUM **2	TRANS	194
C	17 CONTINUE	TRANS	195
C	14 CONTINUE	TRANS	196
C	13 CONTINUE	TRANS	197
C	TABLIN = .TRUE.	TRANS	198
C	27 IF (FAST .AND. (WDL .NE. WLP .OR. WDH .NE. WHP)) GO TO 23	TRANS	199
C	IF (FILPOS .LE. WDL) GO TO 24	TRANS	200
C	REWIND LTMTE	TRANS	201
C	WTL = 0.	TRANS	202
C	WTH = 0.	TRANS	203
C	GO TO 24	TRANS	204
C	READ SPECTRAL DATA FILE	TRANS	205
C	23 READ (LTMTE) WTL, WTH, ((SOD(I,IS), I = 1, NTEMP),	TRANS	206
C	\$ (DEI(I,IS), I = 1, NTEMP), IS = 1, NSPEC)	TRANS	207
C	FILPOS = WTL	TRANS	208
C	WHP = WDH	TRANS	209
C	WLP = WDL	TRANS	210
C	24 OLAP = FRAC(WDL, WDH, WTL, WTH)	TRANS	211
C	IF (WTL .GE. WDH) RETURN	TRANS	212
		TRANS	213
		TRANS	214
		TRANS	215
		TRANS	216
		TRANS	217
		TRANS	218
		TRANS	219
		TRANS	220
		TRANS	221
		TRANS	222
		TRANS	223
		TRANS	224
		TRANS	225
		TRANS	226
		TRANS	227
		TRANS	228
		TRANS	229

IF (OLAP .LE. 0.) GO TO 23	TRANS	230
C	TRANS	231
W = (WTL + WTH) / 2.	TRANS	232
C	TRANS	233
LOOP OVER PATH SEGMENTS	TRANS	234
C	TRANS	235
CLJ IN NBR MODULE USAGE, M IS SET TO 1 IN CALLS TO SUBROUTINE	TRANS	236
CLJ TRANS, BUT IN CALLS TO TRANS FROM PROGRAM EMISCAT, M IS SET TO	TRANS	237
CLJ 1, 2, AND MAY BE UP TO 15.	TRANS	238
DO 22 K = 1, M	TRANS	239
C	TRANS	240
LOOP OVER SPECIES	TRANS	241
C	TRANS	242
DO 19 IS = 1, NSPEC	TRANS	243
ADS = 3.58E-7 * W * SORT(273. / XMW(IS))	TRANS	244
NS = NSRAY(IS) + 1	TRANS	245
IF (FAST) NS = 1	TRANS	246
XS = 0.	TRANS	247
C	TRANS	248
LOOP OVER ENERGY BINS	TRANS	249
C	TRANS	250
CLJ NOTE THAT NS=1 FOR FAST = TRANSOPT = .TRUE. .	TRANS	251
DO 19 J = 1, NS	TRANS	252
XML = 0.	TRANS	253
SUMC = 0.	TRANS	254
SUMD = 0.	TRANS	255
C	TRANS	256
LOOP OVER TEMPERATURES	TRANS	257
C	TRANS	258
CALCULATE OPTICAL DEPTH IN WEAK-LINE APPROXIMATION	TRANS	259
C	TRANS	260
DO 20 I = 1, MTEMP	TRANS	261
IF (M .GE. 3) GO TO 29	TRANS	262
CLJ SINCE M=1 IN NBR-MODULE USAGE, K HAS THE SINGLE VALUE OF 1.	TRANS	263
CLJ THUS, WE ARE SETTING U(I,IS,1) AND UP(I,IS,1) INTO US AND	TRANS	264
CLJ UPS, RESPECTIVELY.	TRANS	265
US = U(I,IS,K)	TRANS	266
UPS = UP(I,IS,K)	TRANS	267
GO TO 30	TRANS	268
C	TRANS	269
CLJ THE FOLLOWING EXPRESSION IS USED ONLY IF M.GE.3, AS MAY OBTAIN	TRANS	270
CLJ FOR CALLS TO TRANS FROM PROGRAM EMISCAT. NBR-MODULE USAGE HAS	TRANS	271
CLJ M=1, SO U(I,IS,2) AND UP(I,IS,2) ARE NOT USED IN SUBROUTINE	TRANS	272
CLJ TRANS, NOR IS THE ARRAY FK, FOR THE NBR MODULE.	TRANS	273
29 US = (1. - FK(K)) * U(I,IS,1) + FK(K) * U(I,IS,2)	TRANS	274
UPS = (1. - FK(K)) * UP(I,IS,1) + FK(K) * UP(I,IS,2)	TRANS	275
C	TRANS	276
30 IF (US .EQ. 0.) GO TO 20	TRANS	277
IF (FAST) GO TO 36	TRANS	278
SODI = CF(J,IS,I) * SOD(I,IS)	TRANS	279
DEII = CG(J,IS,I) * DEI(I,IS)	TRANS	280
GO TO 32	TRANS	281
C	TRANS	282
36 SODI = SOD(I,IS)	TRANS	283
DEII = DEI(I,IS)	TRANS	284
C	TRANS	285
32 XML = XML + SODI * US	TRANS	286

SUMC = SUMC + SQRT(273. / TT(1)) * DEII * SODI * UPS	TRANS	287
SUMD = SUMD + SQRT(TT(1) / 273.) * DEII * SODI * US	TRANS	288
20 CONTINUE	TRANS	289
C	TRANS	290
IF (XWL .LE. 1.E-100) GO TO 34	TRANS	291
C	TRANS	292
C	TRANS	293
C	TRANS	294
C	TRANS	295
ACSJ = ALS(IS) / XWL * SUMC	TRANS	296
ADSJ = ADS / XWL * SUMD	TRANS	297
IF (FAST) GO TO 25	TRANS	298
U2 = PI * XWL **2 / (4. * G(J,IS) **2 * (1. + XWL /	TRANS	299
\$ (4. * ACSJ)))	TRANS	300
TL = 1. / (1. + P * SQRT(U2))	TRANS	301
XRE = -G(J,IS) * (ALOG(A1 * TL + A2 * TL **2 + A3 * TL **3) -	TRANS	302
\$ U2)	TRANS	303
C	TRANS	304
C	TRANS	305
C	TRANS	306
XL = AMINI(XRE, XWL)	TRANS	307
GO TO 33	TRANS	308
C	TRANS	309
25 XL = XWL / SQRT(1. + XWL / (4. * ACSJ))	TRANS	310
C	TRANS	311
C	TRANS	312
C	TRANS	313
33 XD = 1.7 * ADSJ * SQRT(ALOG(1. + (XWL / (1.7 * ADSJ)) **2))	TRANS	314
A = (1. - (XL / XWL) **2) **2	TRANS	315
B = (1. - (XD / XWL) **2) **2	TRANS	316
IF (A + B .LE. 1.E-15) GO TO 21	TRANS	317
Y = SQRT(A * B / (B + A - A * B))	TRANS	318
C	TRANS	319
C	TRANS	320
C	TRANS	321
XS = XS + XWL * SQRT(1. - Y)	TRANS	322
GO TO 19	TRANS	323
C	TRANS	324
21 XS = XS + XWL	TRANS	325
CLJ	TRANS	326
CLJ	TRANS	327
19 CONTINUE	TRANS	328
C	TRANS	329
C	TRANS	330
C	TRANS	331
C	TRANS	332
ABC(IS,K) = ABC(IS,K) + XS * OLAP	TRANS	333
TAU(IS,K) = TAU(IS,K) + EXP(-XS) * OLAP	TRANS	334
GO TO 18	TRANS	335
34 TAU(IS,K) = TAU(IS,K) + OLAP	TRANS	336
CLJ	TRANS	337
18 CONTINUE	TRANS	338
C	TRANS	339
CLJ	TRANS	340
CLJ	TRANS	341
22 CONTINUE	TRANS	342
C	TRANS	343

	IF (WTH .LT. .9999999 * WDH) GO TO 23	TRANS	344
C		TRANS	345
	DO 35 K = 1, M	TRANS	346
	TTBL(K) = 1.	TRANS	347
	DO 35 IS = 1, NSPEC	TRANS	348
CLJ	THE FOLLOWING TWO-LINE CHANGE, RECEIVED IN TWO INSTALLMENTS	TRANS	349
CLJ	FROM L. EWING ON 3/20/79 AND A. KLEIN ON 9/10/79, AFFECTS THE	TRANS	350
CLJ	EMISSION CALCULATION IN SUBROUTINE ATMRAD.	TRANS	351
	IF((TAU(IS,K) .LT. 0.9999) .AND. (TAU(IS,K) .GT. 0.0001))	TRANS	352
	\$ ABC(IS,K) = -ALOG(TAU(IS,K))	TRANS	353
	35 TTBL(K) = TTBL(K) * TAU(IS,K)	TRANS	354
C		TRANS	355
	RETURN	TRANS	356
	END	TRANS	357

C	SUBROUTINE TRANSB (LBAND)	TRANSB	2
C		TRANSB	3
C	*TRANSB* ELIMINATES UNNECESSARY SPECTRAL DATA FROM	TRANSB	4
C	THE EXTERNAL FILE. THE TYPE OF SPECTRAL COVERING GENERATED	TRANSB	5
C	DEPENDS ON TRNSOPT. IF TRNSOPT IS .TRUE., THE FASTEST	TRANSB	6
C	BUT LEAST ACCURATE CALCULATIONS WILL BE DONE.	TRANSB	7
C		TRANSB	8
CLJ		TRANSB	9
CLJ	INPUT PARAMETERS	TRANSB	10
CLJ	ARGUMENT LIST	TRANSB	11
CLJ	LBAND - LIST HEADER VARIABLE (LHV) FOR WAVELENGTH BANDS	TRANSB	12
CLJ	DATASET-BN (NO. 114). STRICTLY, LBAND IS THE	TRANSB	13
CLJ	POINTER (I.E., IT CONTAINS THE (Q-ARRAY) ADDRESS	TRANSB	14
CLJ	FOR THE LIST HEADER OF THE WAVELENGTH BANDS	TRANSB	15
CLJ	DATASET-BN.	TRANSB	16
CLJ	IN GRC USAGE, LBAND IS STORED AS WORD-12 OF	TRANSB	17
CLJ	DATASET-ST (NO. 111).	TRANSB	18
CLJ	IN THE SAI STAND-ALONE VERSION OF THE NBR MODULE,	TRANSB	19
CLJ	DATASET-ST (NO. 111) IS NOT USED, BUT LBAND IS	TRANSB	20
CLJ	STILL GENERATED IN PROGRAM DRVUPW AND USED AS THE	TRANSB	21
CLJ	LHV FOR DATASET-BN.	TRANSB	22
CLJ	XYZCOM COMMON	TRANSB	23
CLJ	ITMTE = AUXILIARY INPUT DATA FILE NUMBER, (=2 IN DRVUPW)	TRANSB	24
CLJ	LTMT = AUXILIARY OUTPUT DATA FILE NUMBER, (=3 IN DRVUPW)	TRANSB	25
CLJ	OPTION COMMON	TRANSB	26
CLJ	TRNSOPT - LOGICAL VARIABLE AFFECTING (A) PROCEDURE FOR	TRANSB	27
CLJ	CONVERTING THE BASIC 5-(1/CM)-RESOLUTION BAND-	TRANSB	28
CLJ	MODEL PARAMETERS TO THOSE FOR THE USER-SPECIFIED	TRANSB	29
CLJ	RESOLUTION AND (B) POSSIBLE REDUNDANCY OF OUTPUT	TRANSB	30
CLJ	DATA IF USER-SELECTED BANDS OVERLAP WITH COMMON	TRANSB	31
CLJ	SPECTRAL INTERVALS.	TRANSB	32
CLJ	=.TRUE., TRANSB PROVIDES...	TRANSB	33
CLJ	(A) IN-BAND (MORE PRECISELY, 'IN-INTERVAL')	TRANSB	34
CLJ	AVERAGED BAND-MODEL PARAMETERS. (THERE IS NO	TRANSB	35
CLJ	LIMIT ON THE ALLOWED COARSENESS OF THE	TRANSB	36
CLJ	RESOLUTION. IF RESOLUTION FINER THAN 5-(1/CM) IS	TRANSB	37
CLJ	REQUESTED, THE CODE WILL COMPUTE ANSWERS, BUT	TRANSB	38
CLJ	THEY MAY HAVE LITTLE OR NO PHYSICAL REALITY.)	TRANSB	39
CLJ	(B) BAND-MODEL PARAMETERS FOR EACH INTERVAL	TRANSB	40
CLJ	WITHIN A BAND (EVEN THOUGH BANDS MAY OVERLAP),	TRANSB	41
CLJ	AND THE BANDS ARE ORDERED AS IN THE WAVELENGTH	TRANSB	42
CLJ	BANDS DATASET-BN (NO. 114).	TRANSB	43
CLJ	=.FALSE., TRANSB PROVIDES...	TRANSB	44
CLJ	(A) BAND-MODEL PARAMETERS AT A (BELOW-DEFINED)	TRANSB	45
CLJ	RESOLUTION THAT MAY BE FINER THAN THE REQUESTED	TRANSB	46
CLJ	SPECTRAL INTERVALS. IN THIS CASE THE TRANSB-	TRANSB	47
CLJ	GENERATED RESOLUTION (OR SUBINTERVAL) IS 0.5 OF	TRANSB	48
CLJ	THE NARROWEST USER-SPECIFIED WAVENUMBER INTERVAL,	TRANSB	49
CLJ	BUT WITHIN THE RANGE OF 5 TO 50 (1/CM). THE	TRANSB	50
CLJ	LOWER EDGE OF THE FIRST OUTPUT INTERVAL LIES AT	TRANSB	51
CLJ	THE LOWER EDGE OF THE LOWEST WAVENUMBER SPECTRAL	TRANSB	52
CLJ	INTERVAL.	TRANSB	53
CLJ	(B) NON-REDUNDANT INFORMATION FOR INTERVALS IN	TRANSB	54
CLJ	OVERLAPPING BANDS. (IF BANDS DON'T OVERLAP,	TRANSB	55
CLJ	THERE IS NOTHING TO ELIMINATE, OF COURSE.)	TRANSB	56
CLJ	NOTE. FOR ADDITIONAL INFORMATION REGARDING USE	TRANSB	57
CLJ	OF THESE BAND-MODEL PARAMETERS, SEE COMMENTS	TRANSB	58

CLJ	UNDER THE LOGICAL VARIABLE FAST IN SUBROUTINE	TRANSB	59
CLJ	TRANS.	TRANSB	60
CLJ	''DATASET-BN''	TRANSB	61
CLJ	** NOTE *	TRANSB	62
CLJ	* THE SPELLING (BN) IS AN UNFORTUNATE ARTIFACT FROM	TRANSB	63
CLJ	* THE ORIGINAL DEVELOPMENT OF THE ROUTINE BY L.	TRANSB	64
CLJ	* EWING OF GET. WE ARE REALLY DEALING WITH WORDS-3,	TRANSB	65
CLJ	* -4, AND -6 OF THE GRC DICTIONARY DATASET-BI (NO.	TRANSB	66
CLJ	* 115) AND NOT DATASET-BN (NO. 114).	TRANSB	67
CLJ	WLO BN, * LOWEST AND HIGHEST WAVENUMBERS OF SPECTRAL	TRANSB	68
CLJ	WHI BN INTERVAL OVER WHICH BAND-MODEL PARAMETERS ARE TO	TRANSB	69
CLJ	BE AVERAGED, CM-1	TRANSB	70
CLJ	TFLAG BN * FLAG TO DENOTE WHETHER THE WAVELENGTH OR	TRANSB	71
CLJ	WAVENUMBER (CORRESPONDING TO THE ARGUMENT OF	TRANSB	72
CLJ	TFLAG BN) IS ASSOCIATED WITH THE FIRST,	TRANSB	73
CLJ	INTERMEDIATE, OR LAST SPECTRAL DIVISION IN A BAND	TRANSB	74
CLJ	OF (ASCENDING) WAVELENGTHS OR (ASCENDING)	TRANSB	75
CLJ	WAVENUMBERS.	TRANSB	76
CLJ	* 1., FIRST SPECTRAL DIVISION (LOWEST WAVELENGTH) IN	TRANSB	77
CLJ	A WAVELENGTH BAND OR LAST SPECTRAL DIVISION	TRANSB	78
CLJ	(HIGHEST WAVENUMBER) IN A WAVENUMBER BAND	TRANSB	79
CLJ	* 0., INTERMEDIATE SPECTRAL DIVISION	TRANSB	80
CLJ	* 2., LAST SPECTRAL DIVISION (HIGHEST WAVELENGTH) IN	TRANSB	81
CLJ	A WAVELENGTH BAND OR FIRST SPECTRAL DIVISION	TRANSB	82
CLJ	(LOWEST WAVENUMBER) IN A WAVENUMBER BAND	TRANSB	83
CLJ	INPUT BINARY FILE	TRANSB	84
CLJ	TAPIN = EQUIVALENCED TO IYMT. CONTAINS BAND-MODEL	TRANSB	85
CLJ	PARAMETERS FOR 5-(CM-1) RESOLUTION	TRANSB	86
CLJ	WSL = LOWER WAVENUMBER OF 5-(CM-1) INTERVAL FOR THE SET	TRANSB	87
CLJ	1997.5(5.0)4997.5 CM-1	TRANSB	88
CLJ	WSH = HIGHER WAVENUMBER OF 5-(CM-1) INTERVAL FOR THE SET	TRANSB	89
CLJ	2002.5(5.0)5002.5 CM-1	TRANSB	90
CLJ	FOR I=1,10 , IS=1,10 ...	TRANSB	91
CLJ	SOD(I,IS) = MEAN ABSORPTION COEFFICIENT FOR SPECIES-IS AT	TRANSB	92
CLJ	TEMPERATURE-INDEX-I FOR THE 5-(CM-1) INTERVAL	TRANSB	93
CLJ	FROM WSL TO WSH, CM-1 AT STP	TRANSB	94
CLJ	DEI(I,IS) = INVERSE OF MEAN LINE-SPACING PARAMETER, OR THE	TRANSB	95
CLJ	EFFECTIVE LINE DENSITY, LINES/(CM-1).	TRANSB	96
CLJ	OUTPUT PARAMETERS	TRANSB	97
CLJ	OUTPUT BINARY FILE	TRANSB	98
CLJ	TAPOT = EQUIVALENCED TO LTMTE. CONTAINS BAND-MODEL	TRANSB	99
CLJ	PARAMETERS, DERIVED FROM THE 5-(CM-1)-RESOLUTION	TRANSB	100
CLJ	DATA, FOR THE USER-SPECIFIED INTERVAL DW EITHER	TRANSB	101
CLJ	(A) COMMUNICATED THROUGH THE DATASET-BI IF	TRANSB	102
CLJ	TRNSOPT = .TRUE. OR (B) SET BY AN ALGORITHM IF	TRANSB	103
CLJ	TRNSOPT = .FALSE. THE ALGORITHM IS THAT DW EQUALS	TRANSB	104
CLJ	ONE-HALF OF THE MINIMUM DW COMMUNICATED THROUGH	TRANSB	105
CLJ	THE DATASET-BI, BUT NOT LESS THAN 5.0 OR MORE	TRANSB	106
CLJ	THAN 50.0 CM-1	TRANSB	107
CLJ	WL, = LOWER AND HIGHER WAVENUMBERS OF	TRANSB	108
CLJ	WH INTERVAL DW, CM-1	TRANSB	109
CLJ	FOR I=1,10 , IS=1,10 ...	TRANSB	110
CLJ	S(I,IS) = MEAN ABSORPTION COEFFICIENT FOR SPECIES-IS AT	TRANSB	111
CLJ	TEMPERATURE-INDEX-I FOR THE INTERVAL DW,	TRANSB	112
CLJ	CM-1 AT STP	TRANSB	113
CLJ	DE(I,IS) = INVERSE OF MEAN LINE-SPACING PARAMETER, OR THE	TRANSB	114
CLJ	EFFECTIVE LINE DENSITY, LINES/(CM-1)	TRANSB	115

DIMENSION SOD(10,10), DEI(10,10), S(10,10), DE(10,10)	TRANSB	116
DIMENSION WLO BN(1), WHI BN(1), TFLAG BN(1)	TRANSB	117
COMMON QWAREA, QWAREA(10), QFREHO, QMDTST, QMLNKS, QZSIZE,	TRANSB	118
1 QNZBLK, QZHEAD, QCOUNT(30), QOSIZE(10), QNSIZE, QLUNIT(10),	TRANSB	119
2 QERLUN, QFBITS(2,10), Q(1)	TRANSB	120
EQUIVALENCE (Q, IQ)	TRANSB	121
DIMENSION IQ(1)	TRANSB	122
COMMON / XYZCOM / ITMTE, LTMTE, NS, WSHLL(81), TS(81), PS(81),	TRANSB	123
1 XNSPEC(81,10), U(10,10,2), UP(10,10,2), NMOLS,	TRANSB	124
2 FACT	TRANSB	125
COMMON / OPTION / TRNSOPT	TRANSB	126
C	TRANSB	127
CLJ ** NOTE * THE THREE WORDS WLO BN, WHI BN, AND TFLAG BN ARE	TRANSB	128
CLJ IN REALITY WORDS-3, -4, AND -6 IN THE GRC	TRANSB	129
CLJ DICTIONARY DATASET-BI (NO. 115). THEIR SPELLING	TRANSB	130
CLJ HERE IS AN ARTIFACT OF THE ORIGINAL PREPARATION OF	TRANSB	131
CLJ THE ROUTINE BY L. EWING OF GET.	TRANSB	132
EQUIVALENCE (Q(3), WLO BN), (Q(4), WHI BN),	TRANSB	133
* (Q(6), TFLAG BN)	TRANSB	134
EQUIVALENCE (ITMTE, TAPIN), (LTMTE, TAPOT)	TRANSB	135
C	TRANSB	136
INTEGER TAPIN, TAPOT	TRANSB	137
LOGICAL TRNSOPT	TRANSB	138
C	TRANSB	139
CLJ THE INITIALIZED VALUES OF THE NEXT FOUR PARAMETERS WILL BE	TRANSB	140
CLJ RESET. FOR EXAMPLE, WSL AND WSH ARE RESET BY DATA-FILE	TRANSB	141
CLJ WAVENUMBERS.	TRANSB	142
DW = 1.E10	TRANSB	143
WDL = 1.E10	TRANSB	144
WSL = 0.	TRANSB	145
WSH = 0.	TRANSB	146
IBAND = 0	TRANSB	147
LINK = LBAND	TRANSB	148
IF (TRNSOPT) GO TO 13	TRANSB	149
C	TRANSB	150
CLJ SCAN SPECTRAL LIST TO OBTAIN BAND LIMITS AND FINEST RESOLUTION	TRANSB	151
9 CALL PREV (LINK, NBN)	TRANSB	152
IF(NBN.EQ. 0) GO TO 11	TRANSB	153
CLJ LINT, WORD-5 OF GRC DICTIONARY DATASET-BN (NO. 114), IS LHV	TRANSB	154
CLJ FOR LIST OF BAND-INTERVAL DATASETS-BI (NO. 115).	TRANSB	155
LINT = IQ(NBN + 4)	TRANSB	156
CLJ DATASET INDEX-J IS USED FOR SIMPLICITY INSTEAD OF THE	TRANSB	157
CLJ TRADITIONAL INDEX-NBI FOR DATASET-BI.	TRANSB	158
10 CALL PREV (LINT, J)	TRANSB	159
IF(J.EQ. 0) GO TO 9	TRANSB	160
CLJ THE ARGUMENT 3 IN THE CALL TO PUTORA CAUSES SORTING WITH	TRANSB	161
CLJ RESPECT TO WLO BN(J).	TRANSB	162
IF (TFLAG BN(J).NE. 0.) CALL PUTORA (IBAND, J, 3)	TRANSB	163
DW = AMIN1(DW, WHI BN(J) - WLO BN(J))	TRANSB	164
WDL = AMIN1(WDL, WLO BN(J))	TRANSB	165
GO TO 10	TRANSB	166
C	TRANSB	167
C SET RESOLUTION FOR OUTPUT FILE.	TRANSB	168
CLJ CHOOSE 0.5 OF THE MINIMUM DW, BUT WITHIN 5 TO 50 CM-1 IN ANY	TRANSB	169
CLJ EVENT.	TRANSB	170
11 DW = AMAX1 (AMIN1(.5 * DW, 50.), 5.)	TRANSB	171
CLJ INITIALIZE VARIABLES USED BELOW. DESPITE SPELLING, WH IS THE	TRANSB	172

CLJ	SAVED-VALUE OF THE LOW END OF BAND.	TRANSB	173
	WH = WDL	TRANSB	174
CLJ	WDL AND WDH ARE THE INITIALIZED VALUES OF THE LOW AND HIGH	TRANSB	175
CLJ	SIDES OF A CONTINUOUS DETECTOR RANGE.	TRANSB	176
	WDL = 1.E10	TRANSB	177
	WDH = 0.	TRANSB	178
	LAP = 0	TRANSB	179
	LIMIT = IBAND	TRANSB	180
C		TRANSB	181
CLJ	SCAN BAND-LIMITS LIST (WHOSE LHV-WORD IS LIMIT=IBAND) FOR	TRANSB	182
CLJ	SPECTRAL COVERING.	TRANSB	183
	12 CALL NEXT (LIMIT, J)	TRANSB	184
	IF (J .EQ. 0) GO TO 7	TRANSB	185
	IF (TFLAG BN(J) .GE. 2.) LAP = LAP + 1	TRANSB	186
CLJ	NOW UPDATE VALUES OF LOW AND HIGH SIDES OF CONTINUOUS DETECTOR	TRANSB	187
CLJ	RANGE.	TRANSB	188
	WDL = AMINI(WDL, WLO BN(J))	TRANSB	189
	WDH = AMAXI(WDH, WHI BN(J))	TRANSB	190
	IF (AMOD(TFLAG BN(J), 2.) .EQ. 1.) LAP = LAP - 1	TRANSB	191
	IF (LAP .GT. 0) GO TO 12	TRANSB	192
CLJ	XSKIP IS NONZERO ONLY IF SPECTRAL BANDS HAVE A GAP BETWEEN	TRANSB	193
CLJ	THEM.	TRANSB	194
	XSKIP = IFIX((WDL - WH) / DW)	TRANSB	195
CLJ	NOW SET THE LOWER EDGE OF THE NEW RANGE AFTER THE GAP.	TRANSB	196
	WH = WH + XSKIP * DW	TRANSB	197
	GO TO 1	TRANSB	198
C		TRANSB	199
C	SCAN SPECTRAL LIST FOR USER DEFINED TABLE RESOLUTION	TRANSB	200
CLJ	THIS BLOCK OF CODING IS USED ONLY FOR TRNSOPT = .TRUE.	TRANSB	201
	13 CALL PREV (LINK, NBN)	TRANSB	202
	IF(NBN .EQ. 0) GO TO 7	TRANSB	203
CLJ	LINT, WORD-5 OF GRC DICTIONARY DATASET-BN (NO. 114), IS LHV	TRANSB	204
CLJ	FOR LIST OF BAND-INTERVAL DATASETS-B1 (NO. 115).	TRANSB	205
	LINT = IQ(NBN + 4)	TRANSB	206
	14 CALL PREV (LINT, J)	TRANSB	207
	IF(J .EQ. 0) GO TO 13	TRANSB	208
	WDL = WLO BN(J)	TRANSB	209
	WDH = WHI BN(J)	TRANSB	210
	DW = WDH - WDL	TRANSB	211
	WH = WDL	TRANSB	212
	IF (WDL .LT. WSL) REWIND TAPIN	TRANSB	213
	IF (WDL .LT. WSL) WSH = 0.	TRANSB	214
	IF (WDL .LT. WSL) WSL = 0.	TRANSB	215
C		TRANSB	216
C	GENERATE COMPRESSED TABLE	TRANSB	217
	1 WL = WH	TRANSB	218
	WH = WH + DW	TRANSB	219
CLJ	ZERO THE S AND DE ARRAYS.	TRANSB	220
	CALL XMIT (-100, 0., S)	TRANSB	221
	CALL XMIT (-100, 0., DE)	TRANSB	222
CLJ	OLAP WILL BE ZERO ON THE FIRST PASS AND POSSIBLY MANY PASSES	TRANSB	223
CLJ	UNTIL WSL.GT.WL.	TRANSB	224
	2 OLAP = FRAC(WL, WH, WSL, WSH)	TRANSB	225
	IF (OLAP .EQ. 0.) GO TO 4	TRANSB	226
C		TRANSB	227
C	ACCUMULATE SPECTRAL PARAMETERS	TRANSB	228
CLJ	THE FIRST 10 IS FOR 10 TEMPERATURES FOR THE FIRST SPECIES.	TRANSB	229

CLJ	NEXT 10 FOR SECOND SPECIES, ETC.	TRANSB	230
	DO 3 I=1,100	TRANSB	231
	IF (DEI(I,1) .EQ. 0.) GO TO 3	TRANSB	232
	DE(I,1) = DE(I,1) + OLAP / DEI(I,1)	TRANSB	233
	S(I,1) = S(I,1) + OLAP * SOD(I,1) / DEI(I,1)	TRANSB	234
3	CONTINUE	TRANSB	235
CLJ	ON FIRST PASS, WILL DROP THROUGH TEST. WHEN THE TEST IS	TRANSB	236
CLJ	SATISFIED, ENOUGH DATA WILL HAVE BEEN ACCUMULATED TO COVER THE	TRANSB	237
CLJ	WIDTH DW.	TRANSB	238
4	IF (WSH .GE. WH) GO TO 5	TRANSB	239
C		TRANSB	240
C	BRING IN 5 CM-1 TABLE PLANE	TRANSB	241
CLJ	NOTE THAT FOR A BINARY FILE NO FORMAT IS NEEDED. READ	TRANSB	242
CLJ	2*((10+10)*10)=202 WORDS AND STORE IN WSL, WSH, ETC.	TRANSB	243
	READ (TAPIN) WSL, WSH, ((SOD(I,1S), I=1,10), (DEI(I,1S), I=1,10	TRANSB	244
	), IS=1,10)	TRANSB	245
CLJ	NOTE THAT THE EOF FUNCTION IS USED TO TEST FOR AN END-OF-FILE	TRANSB	246
CLJ	CONDITION ON UNIT TAPIN FOLLOWING AN UNFORMATTED READ. ZERO	TRANSB	247
CLJ	IS RETURNED IF NO END-OF-FILE IS ENCOUNTERED, OR A NON-ZERO	TRANSB	248
CLJ	VALUE IF END-OF-FILE IS ENCOUNTERED.	TRANSB	249
	IF (EOF(TAPIN) .EQ. 0.) GO TO 2	TRANSB	250
C		TRANSB	251
C	COMPUTE COMPRESSED SPECTRAL PARAMETERS	TRANSB	252
5	DO 6 I=1,100	TRANSB	253
	IF (DE(I,1) .EQ. 0.) GO TO 6	TRANSB	254
	DE(I,1) = 1. / DE(I,1)	TRANSB	255
	S(I,1) = S(I,1) * DE(I,1)	TRANSB	256
6	CONTINUE	TRANSB	257
C		TRANSB	258
C	WRITE COMPRESSED TABLE PLANE	TRANSB	259
	WRITE (TAPOT) WL, WH, ((S(I,1S), I=1,10), (DE(I,1S), I=1,10),	TRANSB	260
	IS=1,10)	TRANSB	261
CLJ	THE FOLLOWING THREE STATEMENTS ARE RELEVANT ONLY FOR TRNSOPT=	TRANSB	262
CLJ	.FALSE. . THE FIRST WDH IS THE HIGH END OF THE BAND. IF TEST	TRANSB	263
CLJ	IS SATISFIED, DO NEXT DW IN BAND. THE NEXT TWO STATEMENTS	TRANSB	264
CLJ	COMPRISE AN INITIALIZATION JUST LIKE THAT BEFORE STATEMENT	TRANSB	265
CLJ	LABEL 12, OF IMPORT ONLY FOR TRNSOPT=.FALSE. .	TRANSB	266
	IF (WH .LT. WDH - .001) GO TO 1	TRANSB	267
	WDL = 1.E10	TRANSB	268
	WDH = 0.	TRANSB	269
CLJ	NOW DO NEXT SPECTRAL INTERVAL IF TRNSOPT=.TRUE. . OTHERWISE,	TRANSB	270
CLJ	CONTINUE WITH SCAN OF THE BAND-LIMITS LIST.	TRANSB	271
	IF (TRNSOPT) GO TO 14	TRANSB	272
	GO TO 12	TRANSB	273
C		TRANSB	274
C	CLEAN UP AND RETURN	TRANSB	275
7	CALL WIPUT (1BAND, 0)	TRANSB	276
	ENDFILE TAPOT	TRANSB	277
	REWIND TAPOT	TRANSB	278
	REWIND TAPIN	TRANSB	279
	RETURN	TRANSB	280
	END	TRANSB	281

C	SUBROUTINE TRNSCO (RX, RY, RZ, LBINT, RADSW)	TRNSCO	2
CLJ		TRNSCO	3
C	*TRNSCO* ESTABLISHES THE TRANSMITTANCE ON A COMPOUND PATH	TRNSCO	4
CLJ	FROM RX TO RY TO RZ LOCATION VECTORS.	TRNSCO	5
CLJ		TRNSCO	6
CLJ	IF RADSW=.TRUE., SUBROUTINE ATMTRAD WILL BE CALLED TO PERFORM A	TRNSCO	7
CLJ	RADIANCE CALCULATION. IF ONE WANTS RADSW=.TRUE., THEN TRNSCO	TRNSCO	8
CLJ	SHOULD BE CALLED WITH ONLY A STRAIGHT PATH AND NOT A COMPOUND PATH	TRNSCO	9
CLJ	BECAUSE NO ACCOUNT IS TAKEN OF THE SCATTERING EVENT AT THE POINT	TRNSCO	10
CLJ	RY.	TRNSCO	11
CLJ		TRNSCO	12
C		TRNSCO	13
CLJ	INPUT PARAMETERS	TRNSCO	14
CLJ	ARGUMENT LIST	TRNSCO	15
CLJ	RX(1) = LOCATION VECTOR OF POINT X, TYPICALLY BUT NOT	TRNSCO	16
CLJ	NECESSARILY THE DETECTOR, CM	TRNSCO	17
CLJ	RY(1) = LOCATION VECTOR OF POINT Y, TYPICALLY BUT NOT	TRNSCO	18
CLJ	NECESSARILY THE SCATTERING SITE, CM	TRNSCO	19
CLJ	RZ(1) = LOCATION VECTOR OF POINT Z, TYPICALLY BUT NOT	TRNSCO	20
CLJ	NECESSARILY THE SOURCE, CM	TRNSCO	21
CLJ	(FOR RX, RY, AND RZ I=1,3)	TRNSCO	22
CLJ	LBINT = WORD NO. 5 (LMV) IN GRC DATASET-BN (NO. 114),	TRNSCO	23
CLJ	LIST OF BAND-INTERVAL DATASETS (BI).	TRNSCO	24
CLJ	STRICTLY, LBINT IS THE POINTER (I.E., CONTAINS THE	TRNSCO	25
CLJ	(Q-ARRAY) ADDRESS) FOR THE LIST HEADER OF THE	TRNSCO	26
CLJ	BAND-INTERVAL DATASETS-BI CORRESPONDING TO	TRNSCO	27
CLJ	DATASET-BN.	TRNSCO	28
CLJ	RADSW = INITIALIZATION SWITCH FOR ATMOSPHERIC VOLUME	TRNSCO	29
CLJ	EMISSION CALCULATION. IS SET IN INPUT TO DRIVER.	TRNSCO	30
CLJ	= .TRUE., INCLUDE CALL (FROM SUBROUTINE TRNSCO) TO	TRNSCO	31
CLJ	SUBROUTINE ATMTRAD	TRNSCO	32
CLJ	= .FALSE., BYPASS CALL TO SUBROUTINE ATMTRAD AND	TRNSCO	33
CLJ	PERFORM TRANSMITTANCE CALCULATION WITHOUT AIR	TRNSCO	34
CLJ	EMISSION	TRNSCO	35
CLJ	DATASET BI (BAND-INTERVAL DATASET, NO. 115)	TRNSCO	36
CLJ	Q(1) = BNLO BI = LOW WAVELENGTH FOR WAVELENGTH-BAND-INDEX	TRNSCO	37
CLJ	J, MICRONS	TRNSCO	38
CLJ	Q(2) = BNHI BI = HIGH WAVELENGTH FOR WAVELENGTH-BAND-	TRNSCO	39
CLJ	INDEX J, MICRONS	TRNSCO	40
CLJ	Q(3) = WLO BI = LOW WAVENUMBER FOR WAVELENGTH-BAND-INDEX	TRNSCO	41
CLJ	J, CM-1	TRNSCO	42
CLJ	Q(4) = WHI BI = HIGH WAVENUMBER FOR WAVELENGTH-BAND-	TRNSCO	43
CLJ	INDEX J, CM-1	TRNSCO	44
CLJ	XYZCOM COMMON	TRNSCO	45
CLJ	LTMT = BINARY FILE CONTAINING BAND-MODEL PARAMETERS,	TRNSCO	46
CLJ	DERIVED FROM THE 5-(CM-1)-RESOLUTION DATA. (SEE	TRNSCO	47
CLJ	SUBROUTINE TRANSB WHERE TAPOT IS EQUIVALENT TO	TRNSCO	48
CLJ	LTMT.) HERE IN SUBROUTINE TRNSCO, FILE LTMT IS	TRNSCO	49
CLJ	REWOOUND FOR USE IN SUBROUTINE TRANS.	TRNSCO	50
CLJ	OPTION COMMON	TRNSCO	51
CLJ	TRNSOPT = LOGICAL VARIABLE AFFECTING COMPLEXITY OF MOLECULAR	TRNSCO	52
CLJ	TRANSMITTANCE CALCULATION (SEE SUBROUTINES TRANSB	TRNSCO	53
CLJ	AND TRANS). HERE, TRNSOPT IS USED ONLY IN THE	TRNSCO	54
CLJ	ARGUMENT LIST FOR THE CALL TO SUBROUTINE TRANS, A	TRNSCO	55
CLJ	CALL THAT OCCURS ONLY IF RADSW=FALSE., WHICH IS	TRNSCO	56
CLJ	NOT THE CASE FOR THE NBR MODULE.	TRNSCO	57
CLJ	OUTPUT PARAMETERS	TRNSCO	58

CLJ	*** NOTE ***	TRNSCO	59
CLJ	DESCRIPTION OF THE OUTPUT REQUIRES CARE.	TRNSCO	60
CLJ	1. IN THE (RARE) EVENT THE PATH SHOULD NOT INTERSECT THE	TRNSCO	61
CLJ	ATMOSPHERE, THEN INITIALIZED VALUES OF WORD-5 (IF RADSW=.TRUE.)	TRNSCO	62
CLJ	, WORD-7, AND WORD-8 OF DATASET-B1 ARE EXPLICITLY SET HERE IN	TRNSCO	63
CLJ	TRNSCO.	TRNSCO	64
CLJ	2. IN THE USUAL EVENT THAT THE PATH DOES INTERSECT THE ATMOSPHERE,	TRNSCO	65
CLJ	THERE ARE TWO CASES TO CONSIDER.	TRNSCO	66
CLJ	2.1 RADSW=.TRUE. (APPLIES TO NBR MODULE)	TRNSCO	67
CLJ	SUBROUTINE ATMRAD IS CALLED TO EVALUATE WORD-5, -7, -8 OF	TRNSCO	68
CLJ	DATASET-B1, BUT THIS DATASET IS NOT CALLED HERE IN TRNSCO AND	TRNSCO	69
CLJ	THUS IS NOT EXPLICITLY AVAILABLE IN TRNSCO.	TRNSCO	70
CLJ	2.2 RADSW=.FALSE. (DOES NOT APPLY TO NBR MODULE)	TRNSCO	71
CLJ	SUBROUTINE ATMRAD IS NOT CALLED. HENCE THE CALLS THAT ATMRAD	TRNSCO	72
CLJ	MAKES TO GET THE TRANSMITTANCE CALCULATION DONE MUST BE MADE	TRNSCO	73
CLJ	HERE IN TRNSCO. IN THIS CASE WORD-7 AND WORD-8 OF DATASET-B1	TRNSCO	74
CLJ	ARE EXPLICITLY AVAILABLE.	TRNSCO	75
CLJ	DEFINITIONS OF WORD-5, -7, AND -8 OF DATASET-B1 FOLLOW.	TRNSCO	76
CLJ	Q(5) = BKGND BI = IN-BAND-INTERVAL RADIANCE (DUE TO	TRNSCO	77
CLJ	ATMOSPHERIC EMISSION) OVER THE ENTIRE	TRNSCO	78
CLJ	PATH LENGTH (WHICH SHOULD HAVE 1-LEG	TRNSCO	79
CLJ	AND NOT 2-LEGS), W/(CM**2 SR BAND-INT)	TRNSCO	80
CLJ	Q(7) = TRANS BI = PRODUCT OF MOLECULAR AND AEROSOL	TRNSCO	81
CLJ	TRANSMITTANCES OVER THE ENTIRE PATH	TRNSCO	82
CLJ	LENGTH	TRNSCO	83
CLJ	Q(8) = IDS BX BI = AEROSOL TRANSMITTANCE OVER THE ENTIRE	TRNSCO	84
CLJ	PATH LENGTH.	TRNSCO	85
CLJ	*** NOTE *** THIS IS A TEMPORARY USE OF WORD-8 (AND NOT	TRNSCO	86
CLJ	THE GRC DICTIONARY USE OF WORD-8). HERE IT	TRNSCO	87
CLJ	USED TO CARRY INFORMATION TO SUBROUTINE	TRNSCO	88
CLJ	UPWELL.	TRNSCO	89
CLJ	QNCNC COMMON	TRNSCO	90
CLJ	NCNC = VARIABLE SET TO NC. SEE COMMENT ABOVE /QNCNC/.	TRNSCO	91
CLJ		TRNSCO	92
CLJ	DIMENSION DS(100), XFRACS(100), INDX(100), RX(3), RY(3), RZ(3),	TRNSCO	93
CLJ	1 TAU(10), ABC(10)	TRNSCO	94
C		TRNSCO	95
	COMMON QNAREA, QNAREA(10), OFREMO, QMDTST, QNLNKS, QESIZE,	TRNSCO	96
1	QNZBLK, QZHEAD, QCOUNT(30), QOSIZE(10), QMSIZE, QLUNIT(10),	TRNSCO	97
2	QERLUN, QFBITS(2,10), Q(1)	TRNSCO	98
	COMMON / XYZCOM / ITMTE, LTMTE, NS, HSHLL(B1), TS(B1), PS(B1),	TRNSCO	99
1	XNSPEC(B1,10), U(10,10,2), UP(10,10,2), NMOLS,	TRNSCO	100
2	FACT	TRNSCO	101
	COMMON / OPTION / TRNSOPT	TRNSCO	102
CLJ	COMMON QNCNC AND THE LATER STATEMENT IN WHICH NCNC IS SET TO	TRNSCO	103
CLJ	NC ARE ADDED TO FACILITATE BEING ABLE TO CALL THE SAI	TRNSCO	104
CLJ	UPWELLING NATURAL RADIATION MODULE WITH ZERO-KILOMETER	TRNSCO	105
CLJ	ALTITUDE. FOR MORE INFORMATION SEE COMMENTS PRECEDING LABEL	TRNSCO	106
CLJ	NUMBER 22 IN SUBROUTINE UPWELL OF THAT MODULE.	TRNSCO	107
	COMMON/ QNCNC/ NCNC	TRNSCO	108
	DIMENSION BNLO BI(1), BNHI BI(1), WLO BI(1), WHI BI(1),	TRNSCO	109
*	BKGND BI(1), TFLAG BI(1), TRANS BI(1), IDS BX BI(1)	TRNSCO	110
	EQUIVALENCE (Q(1), BNLO BI), (Q(2), BNHI BI),	TRNSCO	111
*	(Q(3), WLO BI), (Q(4), WHI BI),	TRNSCO	112
*	(Q(5), BKGND BI), (Q(6), TFLAG BI),	TRNSCO	113
*	(Q(7), TRANS BI), (Q(8), IDS BX BI)	TRNSCO	114
C		TRNSCO	115

C	LOGICAL RADSW, FIRST, TRANSPORT, LOGIC	TRANSCO	116
C	OBTAIN INTEGRATION LIST	TRANSCO	117
	NC = 0	TRANSCO	118
	CALL STEPS (RX, RY, NC, DS, XFRACS, INDX)	TRANSCO	119
	CALL STEPS (RY, RZ, NC, DS, XFRACS, INDX)	TRANSCO	120
	NCNC = NC	TRANSCO	121
	IF(NC .GT. 1) GO TO 20	TRANSCO	122
CLJ		TRANSCO	123
CLJ		TRANSCO	124
CLJ	PATH DOES NOT INTERSECT ATMOSPHERE. THUS, ONLY CERTAIN	TRANSCO	125
CLJ	INITIALIZATIONS ARE PERFORMED HERE IN LOOP-10.	TRANSCO	126
	LINT = LBINT	TRANSCO	127
10	CALL PREVNL (LINT, J)	TRANSCO	128
	IF (J .EQ. 0) RETURN	TRANSCO	129
	IF(RADSW) BKGND BI(J) = 0.	TRANSCO	130
	TRANS BI(J) = 1.	TRANSCO	131
CLJ	THE FOLLOWING ADDITIONAL INITIALIZATION IS APPROPRIATE WHEN	TRANSCO	132
CLJ	THE SAI NATURAL BACKGROUND RADIATION MODULE IS CALLED WITH	TRANSCO	133
CLJ	ZERO-KILOMETER ALTITUDE.	TRANSCO	134
	CALL XMIT (-1,1,1,DSBX BI(J))	TRANSCO	135
	GO TO 10	TRANSCO	136
CLJ		TRANSCO	137
CLJ		TRANSCO	138
C	PATH INTERSECTS ATMOSPHERE	TRANSCO	139
CLJ	SET LOGIC FOR FIRST CALL TO ATMRAD AND FIRST FOR FIRST CALL	TRANSCO	140
CLJ	TO PATH. SET FILPOS AND REWIND FILE LTMTE FOR USE IN TRANS.	TRANSCO	141
20	LOGIC = .TRUE.	TRANSCO	142
	FIRST = .TRUE.	TRANSCO	143
	FILPOS = 1.E4	TRANSCO	144
	REWIND LTMTE	TRANSCO	145
	DO 30 I=1,NC	TRANSCO	146
CLJ	RECALL THAT DS(NC+1) = -1.0 AND THAT NC-1 = NUMBER OF PATH	TRANSCO	147
CLJ	SEGMENTS.	TRANSCO	148
	IF(DS(I+1) .LT. 0.) GO TO 30	TRANSCO	149
C	INTEGRATE PATH PROPERTIES	TRANSCO	150
	CALL PATH (FIRST, INDX(I), DS(I+1), XFRACS(I))	TRANSCO	151
C	THERMAL EMISSION ON REQUEST	TRANSCO	152
CLJ	*** CAUTION ***	TRANSCO	153
CLJ	F SUBROUTINE TRANSCO IS EXERCISED ON A COMPOUND PATH WITH	TRANSCO	154
CLJ	RADSW=.TRUE., THE TRANSMITTANCE CALCULATION WILL BE CORRECT	TRANSCO	155
CLJ	BUT THE RADIANCE CALCULATION WILL BE INCORRECT BECAUSE NO	TRANSCO	156
CLJ	ACCOUNT HAS BEEN TAKEN OF THE SCATTERING EVENT AT RY.	TRANSCO	157
	IF (RADSW) CALL ATMRAD(LOGIC, INDX(I), XFRACS(I), DS(I+1),	TRANSCO	158
	LBINT)	TRANSCO	159
30	CONTINUE	TRANSCO	160
CLJ	IN NBR MODULE, RADSW=.TRUE., SO WE ARE THROUGH WITH SUBROUTINE	TRANSCO	161
CLJ	TRANSCO.	TRANSCO	162
	IF (RADSW) RETURN	TRANSCO	163
CLJ		TRANSCO	164
CLJ		TRANSCO	165
CLJ		TRANSCO	166
CLJ	*****	TRANSCO	167
CLJ	REMAINING PORTION OF THIS ROUTINE IS NOT USED IN THE	TRANSCO	168
CLJ	STANDARD MODE OF OPERATING THE NBR MODULE WITH RADSW=.TRUE.	TRANSCO	169
CLJ	*****	TRANSCO	170
CLJ	ZERO FIRST HALVES OF THE U AND UP ARRAYS.	TRANSCO	171
	CALL XMIT (-100, 0, 0)	TRANSCO	172

	CALL XMIT (-100, 0., UP)	TRNSCO	173
CLJ	SCAN SPECTRAL BAND-INTERVAL LIST.	TRNSCO	174
	LINT = LBINT	TRNSCO	175
40	CALL PREVNL (LINT, J)	TRNSCO	176
	IF (J.EQ. 0) RETURN	TRNSCO	177
	WL = WLO BI(J)	TRNSCO	178
	WH = WHI BI(J)	TRNSCO	179
CLJ	SET MEAN WAVELENGTH FOR CALL TO AEROSOL.	TRNSCO	180
	W = 0.5*(WL+WH)	TRNSCO	181
	WAVEL = 1.E4/W	TRNSCO	182
C	OBTAIN TRANSMISSION FOR EACH SPECTRAL INTERVAL	TRNSCO	183
CLJ	GET MOLECULAR TRANSMITTANCE AND TEMPORARILY CALL IT	TRNSCO	184
CLJ	TRANS BI(J).	TRNSCO	185
	CALL TRANS (10, 1, U(1,1,2), UP(1,1,2), X1, WL, WH, TAU, ABC,	TRNSCO	186
	TRANS BI(J), TRNSOPT, FILPOS)	TRNSCO	187
CLJ	INITIALIZE THE AEROSOL TRANSMITTANCE TDST	TRNSCO	188
	TDST = 1.	TRNSCO	189
CLJ	GET THE ALTITUDE AT THE FIRST POINT P ALONG THE TRANSMITTANCE	TRNSCO	190
CLJ	PATH.	TRNSCO	191
	L1 = INDX(1) \$ L2 = INDX(2)	TRNSCO	192
	HSP = XFRACS(1) * HShell(L1) + (1.-XFRACS(1)) * HShell(L2)	TRNSCO	193
	CALL AEROSOL (HSP, WAVEL, XKSCA, XKABS, GBAR)	TRNSCO	194
CLJ	XKEXTP IS THE AEROSOL EXTINCTION COEFFICIENT AT POINT P, 1/CM	TRNSCO	195
	XKEXTP = XKSCA + XKABS	TRNSCO	196
	DO 50 I=1,NC	TRNSCO	197
	IF (DS(I+1) .LE. 0.) GO TO 60	TRNSCO	198
	L1 = INDX(I)	TRNSCO	199
	L2 = INDX(I+1)	TRNSCO	200
CLJ	GET THE ALTITUDE AT POINT Q ALONG THE TRANSMITTANCE PATH.	TRNSCO	201
	HSQ = XFRACS(I+1) * HShell(L2) + (1. - XFRACS(I+1)) * HShell(L1)	TRNSCO	202
	CALL AEROSOL (HSQ, WAVEL, XKSCA, XKABS, GBAR)	TRNSCO	203
CLJ	XKEXTQ IS THE AEROSOL EXTINCTION COEFFICIENT AT POINT Q, 1/CM	TRNSCO	204
	XKEXTQ = XKSCA + XKABS	TRNSCO	205
CLJ	FIND THE MEAN AEROSOL EXTINCTION COEFFICIENT OVER THE PATH	TRNSCO	206
CLJ	ELEMENT DS(I+1) BY INTEGRATING THE LOGARITHMICALLY-	TRNSCO	207
CLJ	INTERPOLATED VALUE OF THE EXTINCTION COEFFICIENT OVER DS(I+1)	TRNSCO	208
CLJ	AND DIVIDING BY DS(I+1).	TRNSCO	209
	XKEXT = ACCUM(2, 0., DS(I+1), XKEXTP, XKEXTQ, 0., DS(I+1)) /	TRNSCO	210
	DS(I+1)	TRNSCO	211
CLJ	TDST IS THE AEROSOL TRANSMITTANCE FROM THE START OF THE PATH	TRNSCO	212
CLJ	TO THE BACK OF ELEMENT DS(I+1)	TRNSCO	213
	TDST = TDST * EXP(-XKEXT * DS(I+1))	TRNSCO	214
CLJ	RESET EXTINCTION COEFFICIENT OF NEW POINT P TO THAT AT THE	TRNSCO	215
CLJ	OLD POINT Q.	TRNSCO	216
	XKEXTP = XKEXTQ	TRNSCO	217
	50 CONTINUE	TRNSCO	218
CLJ	TRANS BI(J) IS NOW RESET TO BE THE PRODUCT OF THE MOLECULAR	TRNSCO	219
CLJ	TRANSMITTANCE FOR ALL THE SPECIES AND THE AEROSOL	TRNSCO	220
CLJ	TRANSMITTANCE, EACH FOR THE ENTIRE PATH.	TRNSCO	221
	60 TRANS BI(J) = TRANS BI(J) * TDST	TRNSCO	222
CLJ	PRESERVE THE AEROSOL TRANSMITTANCE BY SETTING IDSBX BI(J).	TRNSCO	223
	CALL XMIT (1,TDST,IDSBX BI(J))	TRNSCO	224
	GO TO 40	TRNSCO	225
	END	TRNSCO	226

CLJ	SUBROUTINE UNITV (VX, VXHAT)	UNITY	2
CLJ		UNITV	3
CLJ	SUBROUTINE UNITV RETURNS THE UNIT VECTOR VXHAT(1-3) ALONG	UNITY	4
CLJ	THE VECTOR VX(1-3).	UNITV	5
CLJ		UNITY	6
	DIMENSION VX(3), VXHAT(3)	UNITV	7
	CALL VLIN (VXHAT, 1./SQRT(DOT(VX,VX)), VX, 0., 0.)	UNITV	8
	RETURN	UNITY	9
	END	UNITV	10

CCC	SUBROUTINE UPWELL (MSM,DD,WW,DW,SPCULR,LBINT,JBAND)	UPWELL	2
C		UPWELL	3
C	SUBROUTINE UPWELL, FOR A POINT V AT EACH OF A SET OF MALTJ	UPWELL	4
C	ALTITUDES ABOVE A GIVEN GEOGRAPHIC POSITION, SPECIFIED IN	UPWELL	5
C	UPWELS COMMON (UPWLAT,UPWLN,UPWALT) AND CHARACTERIZED BY	UPWELL	6
C	MATERIAL MSM AND PROPERTY DD(MSM), COMPUTES THE NATURAL	UPWELL	7
C	UPWELLING SPECTRAL RADIANCE DIRECTED TOWARD POINT V FROM	UPWELL	8
C	POINTS P LOCATED ON THE EARTH'S SURFACE WITH RESPECT TO POINT	UPWELL	9
C	V AT NNADIR REPRESENTATIVE NADIR ANGLES AND NAZI REPRESENTA-	UPWELL	10
C	TIVE AZIMUTH ANGLES. THIS UPWELLING RADIANCE, UPRAD(I,J,K,L),	UPWELL	11
C	INCLUDES CONTRIBUTIONS FROM (1) AIR EMISSION BETWEEN POINTS	UPWELL	12
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C	WL	UPWELL	315
C	UPWELS2 COMMON	UPWELL	316
C	JBAND1 - SAME AS JBAND, BUT MADE AVAILABLE TO SUBROUTINE	UPWELL	317
C	SURRAD TO FACILITATE PRINT.	UPWELL	318
C	CC	UPWELL	319
C	COMMON OBLNKQ(89), Q(1)	UPWELL	320
C	EQUIVALENCE (Q,IQ)	UPWELL	321
C	DIMENSION IQ(1)	UPWELL	322
C	DIMENSION BNLO BI(1), BNHI BI(1), WLO BI(1), WHI BI(1),	UPWELL	323
C	BKGN(BI(1), TFLAG BI(1), TRANS BI(1), IDS BX BI(1)	UPWELL	324
C	*** SEE SUBROUTINE ATMRA(D FOR DEFINITIONS OF DATASET BI	UPWELL	325
C	EQUIVALENCE (Q(1), BNLO BI), (Q(2), BNHI BI),	UPWELL	326
C	(Q(3), WLO BI), (Q(4), WHI BI),	UPWELL	327
C	(Q(5), BKGN BI), (Q(6), TFLAG BI),	UPWELL	328
C	(Q(7), TRANS BI), (Q(8), IDS BX BI)	UPWELL	329
C	DIMENSION RP(3), RC(3), RV(3), TAU(10), OMEGA(T(13), WW(10), DW(10)	UPWELL	330
C	DIMENSION DD(7), RAD(12), UPS(10,10,11), UPPS(10,10,11),	UPWELL	331
C	UCS(10,10), UPCS(10,10),	UPWELL	332
C	UPV(10,10), UPPV(10,10),	UPWELL	333
C	UCV(10,10), UPCV(10,10),	UPWELL	334
C	USPV(10,10), UPSPV(10,10),	UPWELL	335
C	USCV(10,10), UPSCV(10,10)	UPWELL	336
C	DIMENSION TAPV(10), TTPV(10), TTSPV(10), TMSPV(10), AEPV(10)	UPWELL	337
C	DIMENSION TACV(10), TTCV(10), TTSCV(10), TMSCV(10), AECV(10)	UPWELL	338
C	DIMENSION ABC(10)	UPWELL	339
C	DIMENSION WTC(162), UPRA(DC(162), UPRA(DC1(162)	UPWELL	340
C	COMMON/OPTION/ TRNSOPT	UPWELL	341
C	COMMON / OPTIN1 / RADSW	UPWELL	342
C	COMMON/ QMCNC/ NCNC	UPWELL	343

	COMMON/AIRSOL/ TASP(10),TASC(10),TAFP(10)	AIRSOL	2
	COMMON/CLDFREQ/ KMODEL,CCOVER(5,11),CFREQ(17,4,11)	CLDFREQ	2
	COMMON/CLDWT/ IDX,WT(161),TRANS(161),EMISS(161)	CLDBUG	1
	COMMON/POSITN/ POSLAT,POSLOX,POSALT,SPCLAT,SPCLON	POSITN	2
	; C12LAT,C12LON,C12ALT	POSITN	3
	COMMON /SANDD/ XS,YS,ZS,XD,YD,ZD,UL,VL,WL	SANDDQ	2
C	SAI'S /SORCE/ DIFFERS FROM GRC'S.	24APR80	2
	COMMON/ SORCE/ NSORCE,HSORCE(1),RSORCE(1),THETAS,PHIS	KOMATM	1
	COMMON/SOLARP/ SOLLAT,SOLLON,SOLIRR(10)	SOLARP	2
	COMMON/TECTOR/ DETLAT,DETLOX,DETALT,DETZEN,DETAZI(11)	TECTOR	2
	COMMON/UPWELS/ UPWALT,UPWLOX,UPWLAT,NALT(5),ZKM(13,5),NNADTR,NAZI,	UPWELS	2
*	NNAVE(5),IDAYV,CLDFLG,UPRADN(13,10,5),WV(10,5),IKM,	UPWELS	3
*	NBANDS	UPWELS	4
	COMMON/UPWELS1/	UPWELS	5
2	RO10(6,10),RO10A(6,10,10),RO10N(6,10),	UPWELS	6
3	RO25(6,10),RO25A(6,10,10),RO25N(6,10),	UPWELS	7
4	RO50(6,10),RO50A(6,10,10),RO50N(6,10),	UPWELS	8
5	RO90(6,10),RO90A(6,10,10),RO90N(6,10),	UPWELS	9
6	R100(6,10),R100A(6,10,10),R100N(6,10)	UPWELS	10
7	,ARCV(6,10,10),ARCVN(6,10)	UPWELS	11
	COMMON/UPWELS2/ JBAND1	XYZCOM	2
	COMMON/UPWELS3/ UPRAD(6,10),UPRADA(13,10,10)	XYZCOM	3
	COMMON/ XYZCOM/ ITMTE,LTMTTE,NS,HSHELL(81),TPX(81,12),	XYZCOM	4
1	U(10,10,2),UP(10,10,2),NMOLS,FACT	XYZCOM	5
C	SAI'S /FLAGS/ DIFFERS FROM GRC'S.	24APR80	1
	COMMON/ FLAGS/ ITFLAG	FLAGS	2
	LOGICAL SPCULR,SPCLRX,RADSW,TRNSOPT	UPWELL	356
	DATA PI,RE / 3.141592653590,6.37103E+03 /	UPWELL	357
	DATA NSPECS,NTEMP / 10,10 /	UPWELL	358
	DATA NSORCE,RSORCE(1) / 1, 0.0 /	UPWELL	359
	DATA RSUN / 1.495979E+08 /	UPWELL	360
CCC		UPWELL	361
CC	SET JBAND1 IN COMMON /UPWELS2/ TO FACILITATE SOME PRINT IN	UPWELL	362
CC	SUBROUTINE SURRAD.	UPWELL	363
	JBAND1 = JBAND	UPWELL	364
CCC		UPWELL	365
CC	SET VARIABLES IN TECTOR COMMON FOR INITIAL POSITION OF	UPWELL	366
CC	DETECTOR AT SUBPOINT V', FOR USE IN DETERMINING THE REFERENCE	UPWELL	367
CC	AZIMUTH ANGLE.	UPWELL	368
	DETLAT = UPWLAT	UPWELL	369
	DETLOX = UPWLOX	UPWELL	370
	DETALT = UPWALT	UPWELL	371
CC	SET REFERENCE AZIMUTH, REFAZI, TO BE THAT OF THE SUBSOLAR	UPWELL	372
CC	POINT WITH RESPECT TO POINT V IF SUN IS ABOVE THE HORIZON AT	UPWELL	373
CC	SUBPOINT V' OR ZERO OTHERWISE.	UPWELL	374
	PID2 = PI/2.	UPWELL	375
	REFAZI = 0.0	UPWELL	376
CC	IS SUN ABOVE THE HORIZON AT SUBPOINT V'?	UPWELL	377
	SINSIN = SIN(DETLAT)*SIN(SOLLAT)	UPWELL	378
	COSCOS = COS(DETLAT)*COS(SOLLAT)	UPWELL	379
	CSSOLZ = SINSIN + COSCOS*COS(DETLOX-SOLLON)	UPWELL	380
	IDAYV = 0	UPWELL	381
CC		UPWELL	382
CC	WHEN (A) CORE IS PRESET TO NON-ZEROS AND (B) SUN IS BELOW	UPWELL	383
CC	THE HORIZON, WE NEED TO SET THE SOLAR COORDINATES TO ARBITRARY	UPWELL	384
CC	VALUES SO THAT SUBROUTINE SGEOM (CALLED FROM EMISSF, CALLED	UPWELL	385
CC	FROM CLDWT, CALLED FROM UPWELL) WILL NOT ABORT IN TRYING TO	UPWELL	386

CC	COMPUTE SOURCE GEOMETRY EVEN WHEN WE DON'T WANT IT.	UPWELL	387
	XS = 0. \$ YS = 0. \$ ZS = 0.	UPWELL	388
CC		UPWELL	389
	IF(CSSOLZ,LT.0.0) GO TO 10	UPWELL	390
	IDAYV = 1	UPWELL	391
CC	DETERMINE AZIMUTH OF SUBPOINT S' OF SUN BY USING A MODIFIED	UPWELL	392
CC	HARC SUBROUTINE GEOREA. NOTE THAT GEOREA CALLS A HARC ROUTINE	UPWELL	393
CC	GEOXYZ WHICH WE HAVE RENAMED GEOTAN TO DISTINGUISH IT FROM	UPWELL	394
CC	THE SAI ROUTINE GEOXYZ.	UPWELL	395
	DALTCM = 1.0E+05*DETALT	UPWELL	396
	CALL GEOREA(DALTCM,PID2-DETLAT,DETLON,0.0,PID2-SOLLAT,SOLLON,	UPWELL	397
	\$ SR21,EL21,REFAZI)	UPWELL	398
CC	NOW HAVE REFAZI. ALSO HAVE UNNEEDED SR21 AND EL21.	UPWELL	399
CC	GET EARTH-CENTERED CARTESIAN COORDINATES OF SUN FOR SGEOM.	UPWELL	400
	CALL GEOXYZ(RSUM,SOLLAT,SOLLON,XS,YS,ZS)	UPWELL	401
CC	SET COORDINATES OF SUN INTO SOURCE COMMON FOR TRANSF.	UPWELL	402
	HSORCE(1) = RSUM	UPWELL	403
	THETAS = (PID2-SOLLAT)*180./PI	UPWELL	404
	PHIS = SOLLON*180./PI	UPWELL	405
CC		UPWELL	406
CC	ZERO ARRAYS USPV, UPSPV, USCV, AND UPSCV USED LATER TO	UPWELL	407
CC	PRESERVE PATH PARAMETERS FOR THE PATHS SPV AND SCV.	UPWELL	408
	CALL XMIT (-100, 0., U SPV)	UPWELL	409
	CALL XMIT (-100, 0., UPSPV)	UPWELL	410
	CALL XMIT (-100, 0., U SCV)	UPWELL	411
	CALL XMIT (-100, 0., UPSCV)	UPWELL	412
CC		UPWELL	413
	10 CONTINUE	UPWELL	414
CC		UPWELL	415
CC	SET ALTITUDES OF ALL POINTS P (TO BE VIEWED FROM POINT V)	UPWELL	416
CC	EQUAL TO THE SURFACE ALTITUDE OF THE SUB-V-POINT.	UPWELL	417
	POSALT = UPWALT	UPWELL	418
	PALTCM = 1.0E+05*POSALT	UPWELL	419
CC	IKM = INDEX FOR THE NUMBER OF ALTITUDES AT WHICH NATURAL	UPWELL	420
CC	CLOUDS HAVE BEEN INCLUDED IN THE UPWELLING RADIANCE	UPWELL	421
CC	CALCULATION (REQUIRED BECAUSE CLOUDS ARE INCLUDED ONLY FOR	UPWELL	422
CC	ALTITUDES ZKM EQUAL TO OR GREATER THAN 12. KM).	UPWELL	423
	IKM = 0	UPWELL	424
CC	BEGIN LOOP OVER NALTJ ALTITUDES.	UPWELL	425
	NALTJ = NALT(JBAND)	UPWELL	426
	DO 80 I=1,NALTJ	UPWELL	427
CC	IIP,JJP,KKP,LLP ARE THE LOOP INDICES USED IN THE CALL TO	UPWELL	428
CC	SUBROUTINE SURRAD WITHIN THE WAVENUMBER LOOP.	UPWELL	429
	IIP = 1	UPWELL	430
	IF(ZKM(I,JBAND) .LT. 0.001) ZKM(I,JBAND) = 0.001	UPWELL	431
	DETALT = UPWALT + ZKM(I,JBAND)	UPWELL	432
	DALTCM = 1.0E+05*DETALT	UPWELL	433
CC	GET EARTH-CENTERED CARTESIAN COORDINATES OF POINT V.	UPWELL	434
	CALL GEOXYZ(DETALT,DETLAT,DETLON,RV(1),RV(2),RV(3))	UPWELL	435
CC	GET EARTH-CENTERED CARTESIAN COORDINATES OF DETECTOR FOR SGEOM	UPWELL	436
	XD = RV(1)	UPWELL	437
	YD = RV(2)	UPWELL	438
	ZD = RV(3)	UPWELL	439
	CALL VLIN(RV,1.0E+05,RV,0.0,0.0)	UPWELL	440
CC	FOR ALTITUDE DETALT, DETERMINE FRACTION OF 2*PI SOLID ANGLE,	UPWELL	441
CC	OMEGAT, THAT IS SUBTENDED BY THE TANGENT CONE WITH VERTEX AT	UPWELL	442
CC	POINT V. FIRST, COMPUTE SLANT RANGE, SRT, OF TANGENT RAY	UPWELL	443

CC	FROM POINT V.	UPWELL	444
CC	SRT = SQRT((2.*RE+DETALT)*DETALT)	UPWELL	445
CC	COMPUTE COSINE OF MADIR ANGLE, CBETAT = COS(BETAT), CORRES-	UPWELL	446
CC	PONDING TO TANGENT RAY.	UPWELL	447
	CBETAT = SRT/(RE+DETALT)	UPWELL	448
	OMEGAT(1) = 1.0-CBETAT	UPWELL	449
CC	IT MAY NOT BE NECESSARY TO SAVE THESE SOLID ANGLE FACTORS.	UPWELL	450
CC	CLDFG1 - FLAG CONTROLLING A TEMPORARY ASPECT OF THE	UPWELL	451
CC	CLOUD-RELATED CALCULATIONS. CLDFG1 IS ALWAYS 0.0 IF	UPWELL	452
CC	CLDFLG = 0.0 BUT MAY BE 0.0 OR 1.0 IF CLDFLG = 1.0 .	UPWELL	453
CC	CLDFG1 IS SET TO 0.0 JUST BEFORE THE TEST ON ALLOWED	UPWELL	454
CC	ALTITUDES AND MASTER FLAG (CLDFLG) FOR INCLUSION OF CLOUDS	UPWELL	455
CC	AND IS RESET TO 1.0 JUST AFTER THIS TEST.	UPWELL	456
CC	CLDFG1 CONTROLS THE CALCULATION OF (A) CFPV IN MADIR LOOP,	UPWELL	457
CC	SINCE CFPV IS INDEPENDENT OF AZIMUTH BUT DEPENDENT ON MADIR	UPWELL	458
CC	AND HENCE ALTITUDE, AND (B) VARIOUS CLOUD-RELATED QUANTITIES	UPWELL	459
CC	IN WAVENUMBER LOOP.	UPWELL	460
CC	= 1.0 ALLOWS CALCULATION ON FIRST PASS.	UPWELL	461
CC	= 0.0 BYPASSES CALCULATION ON LATER PASSES OR	UPWELL	462
CC	BYPASSES CALCULATION ON ALL PASSES IF CLDFLG=0.0.	UPWELL	463
	CLDFG1 = 0.0	UPWELL	464
	IF((ZKM(I,JBAND) .LT. 12.0) .OR. (CLDFLG .EQ. 0.0)) GO TO 17	UPWELL	465
CCC		UPWELL	466
CC	*** GOT HERE FOR CLOUDS, DAY OR NIGHT *****	UPWELL	467
	IKM = IKM+1	UPWELL	468
	CLDFG1 = 1.0	UPWELL	469
	IF(IKM.GT.1) GO TO 17	UPWELL	470
CCC		UPWELL	471
CC	*** GOT HERE FOR CLOUDS, ZKM(I,JBAND) = 12.0 KM *****	UPWELL	472
CC	SET ALTITUDES OF ALL POINTS C (TO BE VIEWED FROM POINT V)	UPWELL	473
CC	EQUAL TO 12-KM.	UPWELL	474
	C12ALT = 12.0	UPWELL	475
	CALTCM = 1.0E+05*C12ALT	UPWELL	476
CC	THE NATURAL CLOUD MODEL (NCM) FUNCTION CFLOS(ICC,CHI)	UPWELL	477
CC	COMPUTES THE PROBABILITY OF A CLOUD-FREE LINE-OF-SIGHT	UPWELL	478
CC	(CFLOS), GIVEN THE CLOUD COVERAGE IN TENTHS (ICC=1(1)11) AND	UPWELL	479
CC	ZENITH ANGLE CHI (DEGREES). HERE, WE WANT CFPV, A MEAN	UPWELL	480
CC	PROBABILITY OF A CFLOS FROM POINT P TO THE SUN, OBTAINED BY	UPWELL	481
CC	AN AVERAGE OVER THE NCM CLOUD-COVERAGE VALUES OF 0,3,5,8, AND	UPWELL	482
CC	10 TENTHS, OCCURRING WITH PROBABILITIES CCOVER(I,KMODEL)	UPWELL	483
CC	(I=1,5), FOR A SELECTED VALUE OF KMODEL. WE ASSUME THE SOLAR	UPWELL	484
CC	ZENITH ANGLE SOLZ AT THE SUBPOINT V' IS AN EXCELLENT APPROX-	UPWELL	485
CC	IMATION TO THOSE AT ALL POINTS P.	UPWELL	486
	IF(IDAYV .EQ. 0) GO TO 17	UPWELL	487
CCC		UPWELL	488
CC	*** GOT HERE FOR CLOUDS, DAY *****	UPWELL	489
	RTD = 180./PI	UPWELL	490
	SOLZ = RTD*ACOS(CSSOLZ)	UPWELL	491
	CFPS = CCOVER(1,KMODEL)*CFLOS(1,SOLZ)	UPWELL	492
1	+ CCOVER(2,KMODEL)*CFLOS(4,SOLZ)	UPWELL	493
2	+ CCOVER(3,KMODEL)*CFLOS(6,SOLZ)	UPWELL	494
3	+ CCOVER(4,KMODEL)*CFLOS(9,SOLZ)	UPWELL	495
4	+ CCOVER(5,KMODEL)*CFLOS(11,SOLZ)	UPWELL	496
CC	THE ABOVE CALCULATIONS ARE DONE ONLY FOR THE FIRST	UPWELL	497
CC	ALTITUDE AT WHICH A CLOUD CALCULATION IS DONE.	UPWELL	498
CCC		UPWELL	499
	17 CONTINUE	UPWELL	500

CC	*** GOT HERE FOR DAY OR NIGHT, REGARDLESS OF CLOUDS *****	UPWELL	501
CC		UPWELL	502
CC	PREPARE TO LOOP OVER NNADIR NADIR ANGLES CORRESPONDING TO	UPWELL	503
CC	FRACTILES OF OMEGAT, FRCTL.	UPWELL	504
	FNM = NNADIR	UPWELL	505
	DO 70 J=1,NNADIR	UPWELL	506
	JJP = J	UPWELL	507
	FJ = J	UPWELL	508
	FRCTL = (FJ-0.5)/FNM	UPWELL	509
CC	COMPUTE NADIR ANGLE BETA CORRESPONDING TO FRACTILE FRCTL.	UPWELL	510
	BETA = ACO*(1.0-FRCTL*OMEGAT(I))	UPWELL	511
CC	COMPUTE ZENITH ANGLE, CHI, OF POINT V VIEWED FROM POINT P	UPWELL	512
CC	(THE INTERSECTION POINT AT THE EARTH'S SURFACE OF THE RAY	UPWELL	513
CC	FROM POINT V AT NADIR ANGLE BETA).	UPWELL	514
	CHI = ASIN((1.0-DETALT/RE)*SIN(BETA))	UPWELL	515
CC	COMPUTE THE EARTH CENTRAL ANGLE, ALPHA, SUBTENDED BY POINTS P	UPWELL	516
CC	AND V.	UPWELL	517
	ALPHA = CHI-BETA	UPWELL	518
	IF(CLDF61 .EQ. 0.0) GO TO 20	UPWELL	519
CCC		UPWELL	520
CC	*** GOT HERE FOR CLOUDS, DAY OR NIGHT *****	UPWELL	521
CC	COMPUTE ZENITH ANGLE, CHIC, OF POINT V VIEWED FROM POINT C	UPWELL	522
CC	(THE INTERSECTION POINT AT THE 12-KM ALTITUDE SURFACE OF THE	UPWELL	523
CC	RAY FROM POINT V AT NADIR ANGLE BETA TO POINT P).	UPWELL	524
	CHIC = BETA	UPWELL	525
	IF(DETALT .GT. C12ALT) CHIC = ASIN(((RE+DETALT)/(RE+C12ALT))*	UPWELL	526
	SIN(BETA))	UPWELL	527
CC	COMPUTE THE EARTH CENTRAL ANGLE, ALPHAC, SUBTENDED BY POINTS C	UPWELL	528
CC	AND V. ALPHAC IS USED LATER.	UPWELL	529
	ALPHAC = CHIC - BETA	UPWELL	530
CC	EXPRESS CHI IN DEGREES (CHID) AS REQUIRED FOR INPUT TO	UPWELL	531
CC	SUBROUTINE CLOMNT.	UPWELL	532
	CHID = CHI * RTD	UPWELL	533
20	CONTINUE	UPWELL	534
CC		UPWELL	535
CC	PREPARE TO LOOP OVER NAZI AZIMUTH ANGLES. RESET MAXIMUM	UPWELL	536
CC	NUMBER OF AZIMUTH ANGLES, NAZI, TO BE 1 IF IDAYV=0 OR MSM=1.	UPWELL	537
	IF((IDAYV.EQ.0) .OR. (MSM.EQ.1)) NAZI = 1	UPWELL	538
CC	INITIALIZE AZIMUTH ANGLE.	UPWELL	539
	PIDMA = PI/FLOAT(NAZI)	UPWELL	540
	AZI = REFAZI-0.5*PIDMA	UPWELL	541
	DO 60 K=1,NAZI	UPWELL	542
	KKP = K	UPWELL	543
CC		UPWELL	544
CC	ALLOW SOLAR SPECULAR REFLECTION POINT TO BE COMPUTED ONLY ONCE	UPWELL	545
CC	PER ALTITUDE. HOWEVER, IF IDAYV=0 OR MSM.NE.2 WE DO NOT	UPWELL	546
CC	COMPUTE SPECULAR REFLECTION POINT AT ALL.	UPWELL	547
	SPCLRX = SPCLUR .AND. ((J+K).EQ.2)	UPWELL	548
	IF((IDAYV.EQ.0) .OR. (MSM.NE.2)) SPCLRX = .FALSE.	UPWELL	549
	AZI = AZI+PIDMA	UPWELL	550
CC		UPWELL	551
CC	MUST SET LATITUDE AND LONGITUDE OF POINT P IN POSITN COMMON.	UPWELL	552
CC	USE REVISED MARC SUBROUTINE AGAGED WITH POINT 1 BEING POINT V	UPWELL	553
CC	AND POINT 2 BEING POINT P.	UPWELL	554
	CALL AGAGED(DALTCM,PID2-DETLAT,DETLON,AZI,ALPHA,PALTCM,PSCLAT,	UPWELL	555
	\$ POSLON)	UPWELL	556
	POSLAT = PID2-PSCLAT	UPWELL	557

CC	NOW HAVE LATITUDE AND LONGITUDE OF POINT P.	UPWELL	558
CC	GET EARTH-CENTERED CARTESIAN COORDINATES OF POINT P.	UPWELL	559
CC	CALL GEOXYZ(POSALT, POSLAT, POSLON, RP(1), RP(2), RP(3))	UPWELL	560
CC	SET DIRECTION-COSINES UL, VL, AND WL OF POINT P FROM POINT V.	UPWELL	561
	UL = RP(1)-XD	UPWELL	562
	VL = RP(2)-YD	UPWELL	563
	WL = RP(3)-ZD	UPWELL	564
	RR1 = 1.0/SQRT(UL*UL + VL*VL + WL*WL)	UPWELL	565
	UL = UL*RR1	UPWELL	566
	VL = VL*RR1	UPWELL	567
	WL = WL*RR1	UPWELL	568
	CALL VLIN(RP, 1.0E+05, RP, 0.0, 0.0)	UPWELL	569
CC	IF(CLDFG1 .EQ. 0.0) GO TO 21	UPWELL	570
CCC		UPWELL	571
CC	*** GOT HERE FOR CLOUDS, DAY OR NIGHT *****	UPWELL	572
CC	FOR POINT C, SET LATITUDE AND LONGITUDE IN POSITN COMMON AND	UPWELL	573
CC	ALSO GET EARTH-CENTERED CARTESIAN COORDINATES.	UPWELL	574
CC	IF POINT V IS AT 12-KM ALTITUDE, POINT C IS AT POINT V.	UPWELL	575
CC	C12LAT = DETLAT \$ C12LON = DETLON	UPWELL	576
	RC(1) = RV(1) \$ RC(2) = RV(2) \$ RC(3) = RV(3)	UPWELL	577
	IF(DETALT .EQ. C12ALT) GO TO 21	UPWELL	578
CC	*** GOT HERE FOR CLOUDS, DAY OR NIGHT, ZKM(1,JBAND) .GT. 12.0 ****	UPWELL	579
	CALL AGAGEO(DALTCM, P1D2-DETLAT, DETLON, AZI, ALPHAC, CALTCM, CCLAT,	UPWELL	580
	\$ C12LON)	UPWELL	581
	C12LAT = P1D2 - CCLAT	UPWELL	582
	CALL GEOXYZ(C12ALT, C12LAT, C12LON, RC(1), RC(2), RC(3))	UPWELL	583
	CALL VLIN(RC, 1.0E+05, RC, 0.0, 0.0)	UPWELL	584
21	CONTINUE	UPWELL	585
CC		UPWELL	586
CC	SET FILPOS FOR CALL TO TRANS.	UPWELL	587
CC	FILPOS PLAYS NO ROLE IF TRNSOPT .EQ. TRUE AND (AS SHOULD BE	UPWELL	588
CC	THE CASE) ONE USES THE SAME SPECTRAL LISTS AS ARE USED BY	UPWELL	589
CC	TRANSB IN PREPARING TAPOT=LTMT. HOWEVER, IF TRNSOPT .EQ.	UPWELL	590
CC	FALSE, FILPOS IS USED TO ACHIEVE NECESSARY REWINDS OF TAPOT	UPWELL	591
CC	AND AVOID UNNECESSARY REWINDS.	UPWELL	592
	FILPOS = 1.0E+04	UPWELL	593
CC		UPWELL	594
CC	START LOOP OVER WAVENUMBERS.	UPWELL	595
CC	NWAVEJ = NWAVE(JBAND)	UPWELL	596
	DO 58 L=1, NWAVEJ	UPWELL	597
	LLP = L	UPWELL	598
CC		UPWELL	599
CC	THE VARIABLES IJKL AND IKMJKL, NOT USED IN THE GRC VERSION,	UPWELL	600
CC	ARE USED IN THE SAI VERSION TO FACILITATE PRINT STATEMENTS.	UPWELL	601
CC	IJKL = 1 + J + K + L	UPWELL	602
	IKMJKL = IKM + J + K + L	UPWELL	603
CC		UPWELL	604
	ZLAM = 1.0E+04/NW(L)	UPWELL	605
	MDL = NW(L) - 0.5*DW(L)	UPWELL	606
	WDH = NW(L) + 0.5*DW(L)	UPWELL	607
	CALL SURRAD(2, MSM, DD, SCLRX, IIP, JJP, KKP, LLP, ZLAM, 0, RAD, UPS, UPPS,	UPWELL	608
	\$ UCS, UPCS)	UPWELL	609
CC	NOW HAVE AT POINT P ON THE EARTH'S SURFACE THE EMITTED	UPWELL	610
CC	RADIANCE RAD(1) AND (IF IDAY=1 AND IDAY2=1) THE (UNATTENUATED)	UPWELL	611
CC	REFLECTED RADIANCE OF SOLAR RADIATION RAD(2) AND THE PATH	UPWELL	612
CC	PARAMETERS UPS(IT,N,1) AND UPPS(IT,N,1) FOR THE INCOMING SOLAR	UPWELL	613
		UPWELL	614

CC	RAY. ALSO HAVE AEROSOL TRANSMITTANCE (TASP(L)) THROUGH AIRSOL	UPWELL	615
CC	COMMON FOR PATH FROM S TO P, WHICH WILL BE USED LATER. ALSO	UPWELL	616
CC	HAVE AT POINT C THE PATH PARAMETERS UCS(IT,N) AND UPCS(IT,N)	UPWELL	617
CC	FOR THE INCOMING SOLAR RAY AND THE AEROSOL TRANSMITTANCE	UPWELL	618
CC	(TASC(L)) THROUGH AIRSOL COMMON FOR PATH S TO C, ALSO USED	UPWELL	619
CC	LATER. THE PATH PARAMETERS ARE COMPUTED ONLY FOR L=1, BUT	UPWELL	620
CC	TASP(L) AND TASC(L) ARE COMPUTED FOR L=1,NWAVEJ. WE WILL SOON	UPWELL	621
CC	GET SUM OF (1) ATTENUATED RADIANCE EMITTED FROM SURFACE AND	UPWELL	622
CC	(2) ATTENUATED ATMOSPHERIC EMISSION BETWEEN POINTS V AND P.	UPWELL	623
CC	TEMPORARILY USE UPRAD(K,L) FOR THIS SUM WHICH IS INDEPENDENT	UPWELL	624
CC	OF AZIMUTH.	UPWELL	625
CCCC		UPWELL	626
	IF(K .GT. 1) GO TO 30	UPWELL	627
CC	NEED CALL TRNSCO ONLY ON FIRST WAVENUMBER BECAUSE TRNSCO	UPWELL	628
CC	INTERNALLY LOOPS OVER THE WAVENUMBER LIST.	UPWELL	629
	IF(L .GT. 1) GO TO 27	UPWELL	630
CCCC		UPWELL	631
CC	*** GOT HERE FOR DAY OR NIGHT, REGARDLESS OF CLOUDS *****	UPWELL	632
CC	FOR SOME APPLICATIONS IT IS DESIRABLE TO HAVE SUBROUTINE	UPWELL	633
CC	UPWELL RESULTS CORRESPONDING TO ZKM=0.0, EVEN THOUGH THE	UPWELL	634
CC	ROUTINE WAS NOT ORIGINALLY DESIGNED TO BE CALLED WITH ZKM=0.	UPWELL	635
CC	TO CIRCUMVENT THIS DIFFICULTY, WE DEVELOP A PSEUDO ZERO-	UPWELL	636
CC	ALTITUDE ALGORITHM WHICH EXPLOITS THE FEATURE OF SUBROUTINE	UPWELL	637
CC	STEP WHEREIN IT DOES NOT COMPUTE PATH ELEMENTS LESS THAN 10	UPWELL	638
CC	METERS IN LENGTH. THUS, IF THE TOTAL PATH IS LESS THAN 10	UPWELL	639
CC	METERS, THEN SUBROUTINE STEP SETS NC TO ZERO. WE DETECT SUCH	UPWELL	640
CC	A CONDITION BY SETTING A NEW VARIABLE NCNC EQUAL TO NC AFTER	UPWELL	641
CC	THE DOUBLE CALL TO SUBROUTINE STEPS IN SUBROUTINE TRNSCO AND	UPWELL	642
CC	CARRYING NCNC TO UPWELL VIA ONCNC COMMON (KNOWN ONLY TO TRNSCO	UPWELL	643
CC	AND UPWELL). WE MUST ALSO RECOGNIZE THAT SUBROUTINE ATMTRAD	UPWELL	644
CC	NORMALLY PERFORMS TWO OPERATIONS FOR (NC.GT.1) WHICH ARE NOT	UPWELL	645
CC	PERFORMED FOR (NC.LT.2). THESE OPERATIONS ARE (1) REWINDING	UPWELL	646
CC	LTWTE AND (2) ZEROING THE SECOND HALVES OF THE U AND UP	UPWELL	647
CC	ARRAYS. THUS, FOR (NC.EQ.0), WE WANT TO (AND DO) PERFORM	UPWELL	648
CC	THESE TWO OPERATIONS HERE IN UPWELL. SUBROUTINE TRNSCO, FOR	UPWELL	649
CC	(NC.LT.2), WILL RETURN ZERO FOR THE AIR-PATH RADIANCE	UPWELL	650
CC	(BKGMND BI(NBI)) AND UNITY FOR THE AIR-PATH TRANSMITTANCE	UPWELL	651
CC	(TRANS BI(NBI)). THESE VALUES ARE PRECISELY THE VALUES	UPWELL	652
CC	APPROPRIATE FOR THE ALTITUDE EQUALLING ZERO, VALID OF COURSE	UPWELL	653
CC	FOR ALL NADIRS AND AZIMUTHS. THUS, THE PSEUDO ZERO-ALTITUDE	UPWELL	654
CC	ALGORITHM NEED BE EXERCISED ONLY FOR THE FIRST NADIR AND THE	UPWELL	655
CC	FIRST AZIMUTH. TO PROCEED WITH THE PSEUDO ZERO-ALTITUDE	UPWELL	656
CC	ALGORITHM, WE SELECT AN ALTITUDE ZKM LESS THAN 10 METERS, SAY	UPWELL	657
CC	ONE METER = 0.001 KM. WE ALSO PRETEND THAT THE PATH LENGTH	UPWELL	658
CC	NEVER EXCEEDS 10 METERS, REGARDLESS OF THE NADIR ANGLE,	UPWELL	659
CC	PROVIDED IT DID NOT DO SO FOR THE FIRST NADIR. THUS, WE	UPWELL	660
CC	DECREE THAT TRNSCO SHALL NOT BE CALLED FOR (J.GT.1) IF THE	UPWELL	661
CC	PATH LENGTH WAS LESS THAN 10 METERS FOR J=1.	UPWELL	662
CCCC		UPWELL	663
	IF(J .GT. 1) GO TO 23	UPWELL	664
CC	FOLLOWING CALL TO TRNSCO OCCURS FOR J.GE.1, J=K=L=1.	UPWELL	665
CC	TRNSCO'S ARGUMENT-LIST DISTANCES MUST BE IN CM.	UPWELL	666
	CALL TRNSCO(RV, RP, RP, LB*NT, RADSW)	UPWELL	667
	IF(NCNC .GT. 1) GO TO 25	UPWELL	668
CC	SINCE WE ARE SEEKING RESULTS FOR ZKM=0.0, PERFORM THE TWO	UPWELL	669
CC	ABOVE-DESCRIBED OPERATIONS NORMALLY PERFORMED BY SUBROUTINE	UPWELL	670
CC	ATMTRAD.	UPWELL	671

22	REWIND LTMT	UPWELL	672
	CALL XMIT (-100, 0., U(1,1,2))	UPWELL	673
	CALL XMIT (-100, 0., UP(1,1,2))	UPWELL	674
	GO TO 25	UPWELL	675
23	IF(MCNC .GT. 1) GO TO 24	UPWELL	676
	GO TO 22	UPWELL	677
CC	FOLLOWING CALL TO TRNSCO OCCURS FOR I.GE.2, J.GE.2, K=L=1.	UPWELL	678
CC	TRNSCO'S ARGUMENT-LIST DISTANCES MUST BE IN CM.	UPWELL	679
24	CALL TRNSCO(RV, RP, RP, LBINT, RADSW)	UPWELL	680
25	CONTINUE	UPWELL	681
CC	WE ALSO NEED TO PRESERVE PATH PARAMETERS FOR PATH P TO V IN	UPWELL	682
CC	ARRAYS UPV AND UPPV.	UPWELL	683
	CALL XMIT (100, U (1,1,2), U PV)	UPWELL	684
	CALL XMIT (100, UP(1,1,2), UPPV)	UPWELL	685
	WRITE(6,1025)	UPWELL	686
1025	FORMAT (1H0,45X,41H* * * PATH PARAMETERS, POINT P TO V * * */45X,*	UPWELL	687
	S(FROM SUBROUTINE UPWELL, FORMATS 1025,1027)*2X,*TEMPERATURE/SPECI	UPWELL	688
	SES. ((U PV(M,N),N=1,NSPCS),M=1,2)*)	UPWELL	689
	WRITE(6,1026) ((M, (U PV(M,N),N=1,NSPCS)),M=1,2)	UPWELL	690
1026	FORMAT (2X,13,1P10E12.4)	UPWELL	691
	WRITE(6,1027)	UPWELL	692
1027	FORMAT (1H0,1X,*TEMPERATURE/SPECIES. ((UPPV(M,N),N=1,NSPCS),M=1	UPWELL	693
	\$,2)*)	UPWELL	694
	WRITE(6,1025) ((M, (UPPV(M,N),N=1,NSPCS)),M=1,2)	UPWELL	695
CC		UPWELL	696
CC	FOR PATH P TO V, PRESERVE TAPV(L), TTPV(L), AND AEPV(L)	UPWELL	697
CC	(L=1,NWAVEJ) WHICH ARE DERIVED FROM DATASET-B1. SEE	UPWELL	698
CC	SUBROUTINES TRNSCO AND ATMTRAD FOR COMMENTS REGARDING TEMPORARY	UPWELL	699
CC	USE OF WORD-8 OF DATASET-B1 FOR AEROSOL TRANSMITTANCE.	UPWELL	700
	LX = 0	UPWELL	701
	LBINT = LBINT	UPWELL	702
26	CALL PREV (LBINT,NB1)	UPWELL	703
	IF(NB1 .EQ. 0) GO TO 27	UPWELL	704
	LX = LX + 1	UPWELL	705
	IF(LX .GT. 10) GO TO 27	UPWELL	706
	TTPV(LX) = Q(NB1+6)	UPWELL	707
	AEPV(LX) = Q(NB1+4)/DW(LX)	UPWELL	708
	Q(NB1+4) = 0.	UPWELL	709
	TAPV(LX) = Q(NB1+7)	UPWELL	710
	IQ(NB1+7) = 0	UPWELL	711
	GO TO 26	UPWELL	712
27	CONTINUE	UPWELL	713
C		UPWELL	714
CC	THE NEXT STATEMENT PROVIDES THE ABOVE-MENTIONED SUM	UPWELL	715
CC	(TEMPORARILY CALLED UPRAD(K,L)) OF (1) EARTH'S SURFACE	UPWELL	716
CC	RADIANCE RAD(1) MULTIPLIED BY THE TOTAL TRANSMITTANCE TTPV(L)	UPWELL	717
CC	BETWEEN POINTS P AND V AND (2) THE ATMOSPHERIC EMISSION	UPWELL	718
CC	AEPV(L) BETWEEN POINTS V AND P. THE DO-28 LOOP RECOGNIZES	UPWELL	719
CC	THIS SUM IS AZIMUTHALLY INDEPENDENT.	UPWELL	720
	UPRAD(K,L) = RAD(1)*TTPV(L) + AEPV(L)	UPWELL	721
	IF(NAZI .EQ. 1) GO TO 29	UPWELL	722
	DO 28 KKK=2,NAZI	UPWELL	723
	UPRAD(KKK,L) = UPRAD(1,L)	UPWELL	724
28	CONTINUE	UPWELL	725
29	CONTINUE	UPWELL	726
	IF(IJKL .EQ. 4) WRITE(6,100)	UPWELL	727
100	FORMAT (1H1,44X,43H* * * OUTPUT FROM SUBROUTINE UPWELL * * *)	UPWELL	728

	IF(IJXL .EQ. 4) WRITE(6,101)	UPWELL	729
101	FORMAT (1H0,1X,107H I J K L WDL WDH Z	UPWELL	730
	\$LAM RAD(1) TTPV AEPV TAPV)	UPWELL	731
	WRITE(6,102) I,J,K,L,WDL,WDH,ZLAM,RAD(1),TTPV(L),AEPV(L),TAPV(L)	UPWELL	732
102	FORMAT (2X,4I3,1P7(E14.5))	UPWELL	733
	30 CONTINUE	UPWELL	734
CCCC		UPWELL	735
CC	UPRAD IS OUR ANSWER IF IDAY=0 AND IF NO CLOUDS ARE INCLUDED.	UPWELL	736
	IF(CLDFG1 .EQ. 0.0) GO TO 36	UPWELL	737
CCC		UPWELL	738
CC	*** GOT HERE FOR CLOUDS, DAY OR NIGHT *****	UPWELL	739
CC	PREPARE TO CALL NCM SUBROUTINE CLOWT TO GET THE MCDSET-MEMBER	UPWELL	740
CC	ARRAYS FOR WEIGHTS CORRESPONDING TO THE	UPWELL	741
CC	VARIOUS CLOUD CONFIGURATIONS OR SETS (WT), AND, AT 12-KM	UPWELL	742
CC	ALTITUDE (POINT C) ALONG THE PATH FROM POINT P TO POINT V, THE	UPWELL	743
CC	TOP-CLOUD EMISSION RADIANCES (EMISS) AND (IF IDAYV=1) THE	UPWELL	744
CC	TRANSFER COEFFICIENTS (TRANS) FOR THE TOP-CLOUD REFLECTION	UPWELL	745
CC	OF THE SOLAR RADIATION.	UPWELL	746
CC	WT(I), FOR ANY OF THE 10 LOCATION-SEASON AVERAGED STATISTICAL	UPWELL	747
CC	CLOUD MODELS (KMODEL=1,10), IS THE PROBABILITY THAT (A) THE	UPWELL	748
CC	CLOUD-CONFIGURATION SET INDICATED BY THE INDEX I OCCURS AND	UPWELL	749
CC	(B) THE DETECTOR LOS AT ZENITH ANGLE CHI INTERSECTS THE CLOUD-	UPWELL	750
CC	CONFIGURATION SET. THE PROBABILITY OF THE DETECTOR'S LOS	UPWELL	751
CC	INTERSECTING CLOUDS IS SUM(WT(I)) (I=1,IDX-1).	UPWELL	752
CC		UPWELL	753
CC	BEFORE PROCEEDING TO CALL SUBROUTINE CLOWT, WE COMPUTE THE AIR	UPWELL	754
CC	EMISSION BETWEEN POINTS C AND V (ARCVA(IKM,J,L))	UPWELL	755
CC	AND THE AIR TRANSMITTANCE (BOTH MOLECULAR AND AEROSOL) FROM	UPWELL	756
CC	POINT C TO POINT V. THE TOTAL TRANSMITTANCE IS TTCV AND THE	UPWELL	757
CC	AEROSOL TRANSMITTANCE IS TACV. ALL OF THESE QUANTITIES ARE	UPWELL	758
CC	INDEPENDENT OF AZIMUTH, SO THEY NEED BE COMPUTED ONLY FOR K=1.	UPWELL	759
	IF(ZKM(1,JBAND) .GT. 12.0) GO TO 31	UPWELL	760
	IF((J .GT. 1) .OR. (K .GT. 1)) GO TO 33	UPWELL	761
	AECV(L) = 0.0	UPWELL	762
	TTCV(L) = 1.0	UPWELL	763
	TACV(L) = 1.0	UPWELL	764
	IF(L .GT. 1) GO TO 33	UPWELL	765
CC	ZERO ARRAYS PRESERVING PATH PARAMETERS FOR PATH V TO C. NEED	UPWELL	766
CC	BE DONE ONLY ONCE FOR ZKM(1,JBAND) = 12.0 .	UPWELL	767
	CALL XMIT (-100, 0., U CV)	UPWELL	768
	CALL XMIT (-100, 0., UPCV)	UPWELL	769
	GO TO 33	UPWELL	770
31	CONTINUE	UPWELL	771
	IF((K .GT. 1) .OR. (L .GT. 1)) GO TO 33	UPWELL	772
CC	FOLLOWING CALL TO TRNSCO OCCURS FOR CLDFLG.EQ.1,	UPWELL	773
CC	ZKM(1,JBAND).GT.12.0, J.GE.1, K=L=1 .	UPWELL	774
	CALL TRNSCO(RV, RC, RC, LBINT, RADSW)	UPWELL	775
CC	WE ALSO NEED TO PRESERVE PATH PARAMETERS FOR PATH C TO V IN	UPWELL	776
CC	ARRAYS UCV AND UPCV.	UPWELL	777
	CALL XMIT (100, U (1,1,2), U CV)	UPWELL	778
	CALL XMIT (100, UP(1,1,2), UPCV)	UPWELL	779
	WRITE(6,1031)	UPWELL	780
1031	FORMAT (1H0,45X,41H* * * PATH PARAMETERS, POINT C TO V * * */47X,*	UPWELL	781
	\$(FROM SUBROUTINE UPWELL, FORMATS 1031,1033)*2X,*TEMPERATURE/SPECI	UPWELL	782
	\$ES. ((U CV(M,N),N=1,NSPCS),M=1,2)*	UPWELL	783
	WRITE(6,1026) ((M, (U CV(M,N),N=1,NSPCS)),M=1,2)	UPWELL	784
	WRITE(6,1033)	UPWELL	785

1033	FORMAT (IHC,IX,*TEMPERATURE/SPECIES. ((UPCV(M,N),N=1,NSPCS),M=1	UPWELL	786
	\$,2)*)	UPWELL	787
	WRITE(6,1076) ((M, (UPCV(M,N),N=1,NSPCS)),M=1,2)	UPWELL	788
CC		UPWELL	789
CC	FOR PATH C TO V, PRESERVE TACV(L), TTCV(L), AND AECV(L)	UPWELL	790
CC	(L=1,NWAVEJ) WHICH ARE DERIVED FROM DATASET-BI. SEE	UPWELL	791
CC	SUBROUTINES TRNSCO AND ATMRAO FOR COMMENTS REGARDING TEMPORARY	UPWELL	792
CC	USE OF WORD-B OF DATASET-BI FOR AEROSOL TRANSMITTANCE.	UPWELL	793
	LX = 0	UPWELL	794
	LINT = LBINT	UPWELL	795
32	CALL PREV (LINT,NBI)	UPWELL	796
	IF(NBI .EQ. 0) GO TO 33	UPWELL	797
	LX = LX + 1	UPWELL	798
	IF(LX .GT. 10) GO TO 32	UPWELL	799
	TTCV(LX) = Q(NBI+6)	UPWELL	800
	AECV(LX) = Q(NBI+4)/DW(LX)	UPWELL	801
	Q(NBI+4) = 0.	UPWELL	802
	TACV(LX) = Q(NBI+7)	UPWELL	803
	IQ(NBI+7) = 0	UPWELL	804
	GO TO 32	UPWELL	805
33	CONTINUE	UPWELL	806
CC		UPWELL	807
	IF(IKMJL .EQ. 4) WRITE(6,103)	UPWELL	808
103	FORMAT (IHO,IX,* I J K L	ZLAM	UPWELL
	\$	TTCV	AECV
		TACV*)	UPWELL
	WRITE(6,104) I,J,K,L,ZLAM,TTCV(L),AECV(L),TACV(L)	UPWELL	811
104	FORMAT (2X,4I3,2BX,1PE14.5,14X,3(E14.5))	UPWELL	812
CC		UPWELL	813
	IF(K .GT. 1) GO TO 34	UPWELL	814
CC	AECV(L) IS INDEPENDENT OF AZIMUTH, SO WE PRESERVE IT WITH A	UPWELL	815
CC	NOTATION TO DENOTE IT IS THE AZIMUTHAL AVERAGE FOR THE	UPWELL	816
CC	CURRENT VALUES OF IKM, J, AND L.	UPWELL	817
	ARCV(IKM,J,L) = AECV(L)	UPWELL	818
34	CONTINUE	UPWELL	819
CC		UPWELL	820
CC	IN ORDER THAT SUBROUTINE TRANSF IN THE NCM, CALLED BY	UPWELL	821
CC	SUBROUTINE CLOWT, WILL KNOW WHETHER OR NOT THE SUN IS ABOVE OR	UPWELL	822
CC	BELOW THE HORIZON, SET ITFLAG IN THE FLAGS COMMON (USED IN THE	UPWELL	823
CC	NCM AND INCLUDED HERE IN SUBROUTINE UPWELL).	UPWELL	824
	ITFLAG = 0	UPWELL	825
	IF(IDAYV .EQ. 1) ITFLAG = 1	UPWELL	826
	CALL CLOWT(ZLAM,CHID)	UPWELL	827
CC	SUBROUTINE CLOWT HAS PROVIDED, THROUGH COMMON CLOWT, THE	UPWELL	828
CC	ARRAYS WT, TRANS, AND EMISS, OF LENGTHS IDX, IDX-1, AND IDX-1,	UPWELL	829
CC	RESPECTIVELY. IDX EQUALS 160 FOR A FULL SET OF 159 CONFIG-	UPWELL	830
CC	URATIONS AND IS LESS FOR A RESTRICTED SET.	UPWELL	831
CC		UPWELL	832
CC	TO FACILITATE COMPUTING THE RADIANCE DISTRIBUTION FUNCTION	UPWELL	833
CC	RESULTING FROM THE STATISTICAL TREATMENT OF NATURAL CLOUDS,	UPWELL	834
CC	START FORMING A NEW RADIANCE DISTRIBUTION FUNCTION(UPRADC)	UPWELL	835
CC	AND CORRESPONDING WEIGHTS(WTC). IF NCDSET IS THE NUMBER OF	UPWELL	836
CC	STATISTICAL CLOUD SETS, WITH A MAXIMUM OF 159, FOR KMODEL=	UPWELL	837
CC	1,10, THEN THE LENGTH (II) OF THE ARRAYS UPRADC AND WTC WILL	UPWELL	838
CC	BE II=NCDSET+1 IF IDAYV=0 OR II=NCDSET+2 IF IDAYV=1.	UPWELL	839
CC	(THIS STATEMENT DOES NOT INCLUDE THE ZERO-VALUE MEMBERS ADDED	UPWELL	840
CC	(AFTER STATEMENT LABEL 55) FOR INTERPOLATION PURPOSES.)	UPWELL	841
CC		UPWELL	842

CC	TO FACILITATE ASSESSING THE RELATIVE IMPORTANCE OF EMISSION	UPWELL	843
CC	AND REFLECTION CONTRIBUTIONS, PRESERVE THE EMISSION COMPONENT	UPWELL	844
CC	OF UPRADC IN ANOTHER ARRAY (UPRDC1).	UPWELL	845
	NCDSET = IDX-1	UPWELL	846
	SUMWTC = 0.0	UPWELL	847
	DO 35 M=1,NCDSET	UPWELL	848
CC	MULTIPLY THE SPECTRAL RADIANCE FROM THE NCM, EXPRESSED IN	UPWELL	849
CC	UNITS OF WATTS / (KM**2 SR MICRON), BY 1.0E-14*(ZLAM**2) TO	UPWELL	850
CC	OBTAIN WATTS / (CM**2 SR CM-1).	UPWELL	851
CC	ALSO INCLUDE TRANSMITTANCE BETWEEN POINTS C AND V.	UPWELL	852
	UPRAD(M) = (1.0E-14 * ZLAM**2) * EMISS(M) * TTCV(L)	UPWELL	853
	UPRDC1(M) = UPRADC(M)	UPWELL	854
	WTC(M) = WT(M)	UPWELL	855
	SUMWTC = SUMWTC + WTC(M)	UPWELL	856
35	CONTINUE	UPWELL	857
	II = NCDSET+1	UPWELL	858
CC	AT THIS POINT, II WILL NORMALLY BE 160.	UPWELL	859
CC		UPWELL	860
CC	NOW USE FACT THAT RADIANCE AT POINT V DUE TO AIR EMISSION	UPWELL	861
CC	BETWEEN POINTS V AND P CAN BE BROKEN INTO TWO PORTIONS...	UPWELL	862
CC	AEPV(L) = AECV(L) + AEPCL(L)*TTCV(L)	UPWELL	863
CC	THUS AEPCL(L)*TTCV(L) = AEPV(L) - AECV(L)	UPWELL	864
CC	HENCE WE NEED TO SUBTRACT AECV(L) FROM UPRAD(K,L) IN ORDER FOR	UPWELL	865
CC	UPRADC(II) TO CONTAIN THE (ATTENUATED) AIR EMISSION BETWEEN	UPWELL	866
CC	POINTS P AND C.	UPWELL	867
	UPRADC(II) = UPRAD(K,L) - AECV(L)	UPWELL	868
	UPRDC1(II) = UPRADC(II)	UPWELL	869
CC		UPWELL	870
CC	WE NEED THE MEAN PROBABILITY OF A CLOUD-FREE LOS FROM	UPWELL	871
CC	POINT P TO POINT V (AT ZENITH ANGLE CHI CORRESPONDING TO NADIR	UPWELL	872
CC	ANGLE BETA. AS NOTED BEFORE, THE PROBABILITY OF THE	UPWELL	873
CC	DETECTOR'S LOS INTERSECTING CLOUDS IS SUM(WT(I)) (I=1,IDX-1).	UPWELL	874
CC	HENCE, WE TAKE (1.-SUM(WT(I))) AS THE DESIRED PROBABILITY OF A	UPWELL	875
CC	CLOUD-FREE LOS, CFPV.	UPWELL	876
	CFPV = 1. - SUMWTC	UPWELL	877
	WTC(II) = CFPV	UPWELL	878
CC	THIS WTC IS THE ONE OBTAINING FOR NIGHT. FOR DAY, WTC IS	UPWELL	879
CC	RESET AFTER LOOP DO-52.	UPWELL	880
CCC		UPWELL	881
CC	IF IDAYV=1, MUST ADD IN CLOUD-REFLECTED SOLAR RADIATION,	UPWELL	882
CC	AFTER ADDING IN SURFACE-REFLECTED SOLAR RADIATION.	UPWELL	883
CC	*** GOT HERE FOR CLOUDS, DAY OR NIGHT *****	UPWELL	884
	IF(IDAYV.EQ.0) GO TO 55	UPWELL	885
CCC		UPWELL	886
CC	*** GOT HERE FOR CLOUDS, DAY *****	UPWELL	887
	GO TO 37	UPWELL	888
CCC		UPWELL	889
36	CONTINUE	UPWELL	890
CC	*** GOT HERE FOR NO CLOUDS, DAY OR NIGHT *****	UPWELL	891
CC	IF IDAYV=1, MUST ADD IN SURFACE-REFLECTED SOLAR RADIATION.	UPWELL	892
	IF(IDAYV.EQ.0) GO TO 58	UPWELL	893
CCC		UPWELL	894
37	CONTINUE	UPWELL	895
CC	*** GOT HERE FOR DAY, WITH OR WITHOUT CLOUDS *****	UPWELL	896
CC	EARLIER, SUBROUTINE TRNSCO CALLED SUBROUTINE PATH FOR THE PATH	UPWELL	897
CC	FROM V TO P AND WE SAVED THE PATH PARAMETERS U(IT,N,2) AND UP(	UPWELL	898
CC	IT,N,2) AS UPV(IT,N) AND UPPV(IT,N). NOW ADD PATH PARAMETERS	UPWELL	899

CC	FOR SEGMENTS SP AND PV. NEED BE DONE ONLY FOR K=L=1, BUT THEY	UPWELL	900
CC	MUST BE SAVED IN USPV AND UPSPV ARRAYS.	UPWELL	901
	IF(K .GT. 1) GO TO 42	UPWELL	902
	IF(L .GT. 1) GO TO 41	UPWELL	903
	DO 40 NN=1, NSPECS	UPWELL	904
	DO 40 LL=1, 2	UPWELL	905
CCC		UPWELL	906
CC	ONLY TWO TEMPERATURES (SINCE SHELLS LIMITS THE ATMOSPHERIC	UPWELL	907
CC	TEMPERATURE TO 300 DEG K) ARE NEEDED FOR THE AMBIENT	UPWELL	908
CC	ATMOSPHERE, BUT NTEMP MUST BE 55° TO 10 AND NOT TO 2 TO BE	UPWELL	909
CC	CONSISTENT WITH THE DIMENSIONING OF THE U AND UP ARRAYS IN	UPWELL	910
CC	SUBROUTINE TRANS. THE FIRST HALVES OF THE U AND UP ARRAYS	UPWELL	911
CC	WERE ZEROED IN TRNSCO. TRANS (STATEMENT LABELED 30) WILL	UPWELL	912
CC	DETECT THE ZERO VALUES OF U AND UP FOR TEMPERATURE-INDEXES 3	UPWELL	913
CC	THROUGH 10 AND WASTE LITTLE TIME IN COMPUTING THE	UPWELL	914
CC	TRANSMITTANCE FOR ZERO VALUES OF THE PATH PARAMETERS.	UPWELL	915
CCC		UPWELL	916
	U SPV(LL, NN) = U PV(LL, NN) + U PS(LL, NN, 1)	UPWELL	917
	UPSPV(LL, NN) = UPPV(LL, NN) + UPPS(LL, NN, 1)	UPWELL	918
40	CONTINUE	UPWELL	919
	WRITE(6, 1040)	UPWELL	920
1040	FORMAT (1H0, 42X, 48H* * * PATH PARAMETERS, SUN TO POINT P TO V * *	UPWELL	921
	\$*/45X, *(FROM SUBROUTINE UPWELL, FORMATS 1040, 1042)*2X, *TEMPERATUR	UPWELL	922
	\$E/SPECIES. ((U SPV(M, N), N=1, NSPECS), M=1, 2)*	UPWELL	923
	WRITE(6, 1026) ((M, (U SPV(M, N), N=1, NSPECS)), M=1, 2)	UPWELL	924
	WRITE(6, 1042)	UPWELL	925
1042	FORMAT (1H0, 1X, *TEMPERATURE/SPECIES. ((UPSPV(M, N), N= , NSPECS), M=	UPWELL	926
	\$1, 2)*	UPWELL	927
	WRITE(6, 1026) ((M, (UPSPV(M, N), N=1, NSPECS)), M=1, 2)	UPWELL	928
41	CONTINUE	UPWELL	929
CCCC		UPWELL	930
CC	ENTRY TRANS1 IN SUBROUTINE TRANS IS PROVIDED 12/29/78 TO	UPWELL	931
CC	AVOID CONFLICT IN SUBROUTINE UPWELL BETWEEN THE ARRAY TRANS	UPWELL	932
CC	IN COMMON CLOWT AND THE CALL TO SUBROUTINE TRANS.	UPWELL	933
CC	NOTE...WE ARE CALLING SUBROUTINE TRANS WITH THE ARRAY:	UPWELL	934
CC	USPV(10, 10) AND UPSPV(10, 10) WHICH IS SATISFACTORY FOR	UPWELL	935
CC	SUBROUTINE TRANS' CURRENT USE OF M = 1. IN GENERAL,	UPWELL	936
CC	SUBROUTINE TRANS EXPECTS ARRAYS U(IT, N, 2) AND UP(IT, N, 2) WHEN	UPWELL	937
CC	BEING CALLED WITH M=1.	UPWELL	938
	CALL TRANS1(NTEMP, 1, USPV, UPSPV, FK, WDL, WDH, TAU, ABC,	UPWELL	939
	\$ TMSPV(L), TRNSOPT, FILPOS)	UPWELL	940
CCCC		UPWELL	941
CC	TRANS HAS RETURNED THE TOTAL MOLECULAR TRANSMITTANCE TMSPV(L)	UPWELL	942
CC	FOR THE TOTAL PATH (SP+PV), WITH ACCOUNT OF NSPECS SPECIES.	UPWELL	943
CC		UPWELL	944
CC	GET TOTAL TRANSMITTANCE BY INCLUDING AEROSOLS.	UPWELL	945
CC	USE AEROSOL TRANSMITTANCE TASP(L) FROM SUBROUTINE SURRAD FOR	UPWELL	946
CC	PATH SP WITH AEROSOL TRANSMITTANCE TAPV(L) FROM SUBROUTINE	UPWELL	947
CC	TRNSCO'S CALL TO SUBROUTINE ATMTRAD FOR PATH PV TO GET THE	UPWELL	948
CC	AEROSOL TRANSMITTANCE FOR THE TOTAL PATH SPV=(SP+PV).	UPWELL	949
	TTSPV(L) = TMSPV(L) * (TASP(L) * TAPV(L))	UPWELL	950
CC	NOW HAVE TOTAL MOLECULAR AND AEROSOL TRANSMITTANCE FOR	UPWELL	951
CC	SURFACE-REFLECTED SOLAR RAY.	UPWELL	952
42	CONTINUE	UPWELL	953
CC		UPWELL	954
CC	IN FOLLOWING EXPRESSION, ONLY RAD(2) MAY DEPEND ON AZIMUTH,	UPWELL	955
CC	WHICH IT WILL FOR NON-LAMBERTIAN SURFACE MATERIALS (MSM.GT.1).	UPWELL	956


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UPRAD(K,L) = UPRAD(K,L) + TTSPV(L)*RAD(2)          UPWELL 957
CC      NOW HAVE TOTAL UPWELLING RADIANCE DIRECTED FROM POINT P      UPWELL 958
CC      TO POINT V (WITHOUT ANY CLOUDS), THE FIRST TERM BEING THE SUM UPWELL 959
CC      OF THE ATTENUATED GROUND-SURFACE EMISSION AND AIR EMISSION UPWELL 960
CC      BETWEEN POINTS P AND V AND THE SECOND TERM BEING THE UPWELL 961
CC      ATTENUATED SURFACE-REFLECTED SOLAR RAY. UPWELL 962
IF( IJKL.EQ.4 ) WRITE(6,105) UPWELL 963
105 FORMAT (1H0,1X,* I J K L ZLAM UPWELL 964
$      RAD(2) TTSPV TMSPV TASP*) UPWELL 965
WRITE(6,106) I,J,K,L,ZLAM,RAD(2),TTSPV(L),TMSPV(L),TASP(L) UPWELL 966
106 FORMAT (2X,4I3,2BX,1P5(E14.5)) UPWELL 967
IF( CLDFG1.EQ.0.0 ) GO TO 58 UPWELL 968
CCC UPWELL 969
CC *** GOT HERE FOR DAY, WITH CLOUDS ***** UPWELL 970
CC WE MUST CONVERT THE TRANSFER COEFFICIENTS TRANS INTO UPWELL 971
CC RADIANCES FOR THE CLOUD-REFLECTED SOLAR RADIATION. TO DO SO, UPWELL 972
CC WE NEED THE SOLAR SPECTRAL IRRADIANCE E (WATTS/(CM**2 CM-1)) UPWELL 973
CC (NORMAL TO THE PATH TO THE SUN) AT THE 12-KM ALTITUDE POINT UPWELL 974
CC ON THE V-TO-P PATH. HERE WE SHALL USE THE VALUE, SOLIRR(L)=E, UPWELL 975
CC PREVIOUSLY OBTAINED BY A CALL TO SUBROUTINE SOLRAD FROM UPWELL 976
CC SUBROUTINE SURRAD AND AVAILABLE THROUGH SOLARP COMMON. UPWELL 977
CC UPWELL 978
CC WE ALSO INCLUDE AIR TRANSMITTANCE (TTSCV(L)) ABOVE 12-KM UPWELL 979
CC ALTITUDE, ALONG THE PATH FROM S TO C TO V. TTSCV(L) IS GIVEN UPWELL 980
CC BY THE PRODUCT OF THE MOLECULAR TRANSMITTANCE (TMSCV(L)) AND UPWELL 981
CC THE AEROSOL TRANSMITTANCE (TASC(L)*TACV(L)). UPWELL 982
CC TMSCV(L) WILL BE COMPUTED BY SUBROUTINE TRANS, GIVEN THE PATH UPWELL 983
CC PARAMETERS USCV AND UPSCV. FROM TRNSCO'S CALL TO PATH WE HAVE UPWELL 984
CC THE PATH PARAMETERS U(IT,N,2) AND UP(IT,N,2) (WHICH WE SAVED UPWELL 985
CC AS UCV(IT,N) AND UPCV(IT,N) FOR THE PATH FROM POINT V TO POINT UPWELL 986
CC C. THE PATH PARAMETERS UCS(IT,N) AND UPCS(IT,N) WERE OBTAINED UPWELL 987
CC WITH THE CALL TO SUBROUTINE SURRAD. UPWELL 988
CC ADD THE PATH PARAMETERS FOR SEGMENTS SC AND CV. NEED BE DONE UPWELL 989
CC ONLY FOR K=L=1, BUT THEY MUST BE SAVED IN USCV AND UPSCV UPWELL 990
CC ARRAYS. UPWELL 991
IF( K.GT.1 ) GO TO 50 UPWELL 992
IF( L.GT.1 ) GO TO 45 UPWELL 993
DO 44 NN=1,NSPECS UPWELL 994
DO 44 LL=1,2 UPWELL 995
U SCV(LL,NN) = U CV(LL,NN) + U CS(LL,NN) UPWELL 996
UPSCV(LL,NN) = UPCV(LL,NN) + UPCS(LL,NN) UPWELL 997
44 CONTINUE UPWELL 998
WRITE(6,1044) UPWELL 999
1044 FORMAT (1H0,42X,48H* * * PATH PARAMETERS, SUN TO POINT C TO V * * UPWELL 1000
$*/44X,*(FROM SUBROUTINE UPWELL, FORMATS 1044,1046)*2X,*TEMPERATUR UPWELL 1001
SE/SPECIES, ((U SCV(M,N),N=1,NSPECS),M=1,2)* UPWELL 1002
WRITE(6,1026) ((M, (U SCV(M,N),N=1,NSPECS)),M=1,2) UPWELL 1003
WRITE(6,1046) UPWELL 1004
1046 FORMAT (1H0,1X,*TEMPERATURE/SPECIES, ((UPSCV(M,N),N=1,NSPECS),M= UPWELL 1005
$1,2)* UPWELL 1006
WRITE(6,1026) ((M, (UPSCV(M,N),N=1,NSPECS)),M=1,2) UPWELL 1007
45 CONTINUE UPWELL 1008
CC NOTE...WE ARE CALLING SUBROUTINE TRANS WITH THE ARRAYS UPWELL 1009
CC USCV(10,10) AND UPSCV(10,10) WHICH IS SATISFACTORY FOR UPWELL 1010
CC SUBROUTINE TRANS' CURRENT USE OF M = 1. IN GENERAL, UPWELL 1011
CC SUBROUTINE TRANS EXPECTS ARRAYS U(IT,N,2) AND UP(IT,N,2) WHEN UPWELL 1012
CC BEING CALLED WITH M=1. UPWELL 1013

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      CALL TRANS1( NTEMP, 1, USCV, UPSCV, FK, WDL, WDH, TAU, ABC,      UPWELL 1014
$      TMSCV(L), TRNSOPT, FILPOS )      UPWELL 1015
CC      TRANS HAS RETURNED THE TOTAL MOLECULAR TRANSMITTANCE TMSCV(L)      UPWELL 1016
CC      FOR THE TOTAL PATH (SC+CV). USE AEROSOL TRANSMITTANCE TASC(L)      UPWELL 1017
CC      FROM SUBROUTINE SURRAD FOR PATH SC WITH AEROSOL TRANSMITTANCE      UPWELL 1018
CC      TACV(L) FROM TRNSCO'S CALL TO SUBROUTINE ATMTRAD FOR PATH CV TO      UPWELL 1019
CC      GET THE AEROSOL TRANSMITTANCE FOR THE TOTAL PATH SCV=(SC+CV).      UPWELL 1020
      TTSCV(L) = TMSCV(L) * (TASC(L)*TACV(L))      UPWELL 1021
CC      NOW HAVE TOTAL MOLECULAR AND AEROSOL TRANSMITTANCE FOR CLOUD-      UPWELL 1022
CC      REFLECTED SOLAR RAY.      UPWELL 1023
      IF( IKMJL.EQ. 4 ) WRITE(6,107)      UPWELL 1024
107 FORMAT (1H0,IX,* I J K L      ZLAM      UPWELL 1025
$      TTSCV      TMSCV      TASC*)      UPWELL 1026
      WRITE(6,104) 1,J,K,L,ZLAM,TTSCV(L),TMSCV(L),TASC(L)      UPWELL 1027
CCC      UPWELL 1028
50 CONTINUE      UPWELL 1029
CC      NOW GET A CONTRIBUTION TO THE TOTAL UPWELLING RADIANCE      UPWELL 1030
CC      DIRECTED FROM POINT C TO POINT V, THE FIRST TERM BEING THE      UPWELL 1031
CC      CLOUD-SURFACE EMISSION ATTENUATED BETWEEN POINTS C AND V AND      UPWELL 1032
CC      THE SECOND TERM BEING THE ATTENUATED CLOUD-REFLECTED SOLAR      UPWELL 1033
CC      RAY.      UPWELL 1034
      DO 52 M=1,NCDSSET      UPWELL 1035
      UPRADC(M) = UPRADC(M) + SOLIRR(L) * TRANS(M) * TTSCV(L)      UPWELL 1036
52 CONTINUE      UPWELL 1037
CC      UPWELL 1038
CC      AT THIS POINT, II WILL NORMALLY BE 160 .      UPWELL 1039
CC      SINCE WE ARE ABOUT TO INCLUDE THE TWO-LEG CFLOS, WE MUST      UPWELL 1040
CC      MULTIPLY THE PROBABILITY OF THE (NIGHTTIME) ONE-LEG CFLOS BY      UPWELL 1041
CC      THE PROBABILITY OF NOT HAVING THE SECOND (DAYTIME) LEG.      UPWELL 1042
      WTC(II) = CFPV * ( 1. - CFPS )      UPWELL 1043
CC      INCLUDE TWO-LEG CFLOS      UPWELL 1044
      II = II + 1      UPWELL 1045
CC      AT THIS POINT, II WILL NORMALLY BE 161 .      UPWELL 1046
      UPRDC1(II) = UPRADC(II-1)      UPWELL 1047
      UPRADC(II) = UPRADC(II-1) + RAD(2) * TTSPV(L)      UPWELL 1048
      WTC(II) = CFPS * CFPV      UPWELL 1049
CC      *** GOT HERE FOR CLOUDS, DAY *****      UPWELL 1050
55 CONTINUE      UPWELL 1051
CC      UPWELL 1052
CC      *** GOT HERE FOR CLOUDS, DAY OR NIGHT *****      UPWELL 1053
CC      SORT THE RADIANCE ARRAY UPRADC IN INCREASING ORDER AND CARRY      UPWELL 1054
CC      ALONG THE ARRAYS UPRDC1 AND WTC. BEFORE SORTING, AUGMENT THE      UPWELL 1055
CC      THREE ARRAYS WITH THE MEMBERS UPRADC(II+1) * 0.0, UPRDC1(II+1)      UPWELL 1056
CC      = 0.0, AND WTC(II+1) * 0.0, RESPECTIVELY. DOING THIS ALLOWS      UPWELL 1057
CC      SUBROUTINE LINEAR TO INTERPOLATE WITHIN ITS GIVEN ARRAY IF THE      UPWELL 1058
CC      WEIGHT OF THE NORMALLY SMALLEST MEMBER EXCEEDS THE SMALLEST      UPWELL 1059
CC      FRACTILE (NOW 0.10) FOR WHICH AN INTEGRAL-DISTRIBUTION VALUE      UPWELL 1060
CC      IS REQUESTED.      UPWELL 1061
      II = II + 1      UPWELL 1062
CC      AT THIS POINT, II WILL NORMALLY BE 161 FOR NIGHT AND 162 FOR      UPWELL 1063
CC      DAY.      UPWELL 1064
      UPRADC(II) = 0.0      UPWELL 1065
      WTC(II) = 0.0      UPWELL 1066
      UPRDC1(II) = 0.0      UPWELL 1067
      IF( ( IKM.GE. 1 ) .AND. ( IKM.LE. 3 ) ) WRITE(6,1055)      UPWELL 1068
$      (UPRADC(N),UPRDC1(N),WTC(N),N=1,II)      UPWELL 1069
1055 FORMAT (*0 BEFORE SORTING, WE HAVE (FOR M=1,162) THE TRIPLETS UP      UPWELL 1070

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	\$RADC(M),UPRDC1(M),WTC(M)=*/(5X,1P9E12.4))	UPWELL	1071
	CALL SORTLJ(UPRADC, UPRDC1, WTC, II, -1)	UPWELL	1072
CC	SUM THE WEIGHTS AND NORMALIZE THE SUM TO UNITY.	UPWELL	1073
	DO 56 M=2,II	UPWELL	1074
	WTC(M) = WTC(M) + WTC(M-1)	UPWELL	1075
56	CONTINUE	UPWELL	1076
	WTCIIV = 1.0/WTC(II)	UPWELL	1077
	DO 57 M=1,II	UPWELL	1078
	WTC(M) = WTCIIV*WTC(M)	UPWELL	1079
57	CONTINUE	UPWELL	1080
	IF((IKM .GE. 1) .AND. (IKM .LE. 3)) WRITE(6,1056)	UPWELL	1081
	\$ (UPRADC(N),UPRDC1(N),WTC(N),N=1,II)	UPWELL	1082
1056	FORMAT (*O AFTER SORTING AND SUMMING WEIGHTS, WE HAVE (FOR M=1,1	UPWELL	1083
	\$62) THE TRIPLETS UPRADC(M),UPRDC1(M),SUMWTC(M)=*/(5X,1P9E12.4))	UPWELL	1084
CC	INTERPOLATE TO OBTAIN THE INDICATED PERCENTILES.	UPWELL	1085
CC	RESULT IS STORED IN RXXX(K,L).	UPWELL	1086
	CALL LINEAR (0.10,R010(K,L),WTC,UPRADC,II)	UPWELL	1087
	CALL LINEAR (0.25,R025(K,L),WTC,UPRADC,II)	UPWELL	1088
	CALL LINEAR (0.50,R050(K,L),WTC,UPRADC,II)	UPWELL	1089
	CALL LINEAR (0.90,R090(K,L),WTC,UPRADC,II)	UPWELL	1090
	R100(K,L) = UPRADC(II)	UPWELL	1091
CC	STATEMENT 58 IS FOR WAVENUMBER LOOP ON INDEX L	UPWELL	1092
58	CONTINUE	UPWELL	1093
CC	STATEMENT 60 IS FOR AZIMUTH LOOP ON INDEX K	UPWELL	1094
60	CONTINUE	UPWELL	1095
CCC		UPWELL	1096
CCC	WRITE OUT UPRAD(K,L) FOR CURRENT VALUE OF II AND JJ.	UPWELL	1097
CCC	WRITE OUT RXXX(K,L) FOR CURRENT VALUE OF II AND JJ, ONLY	UPWELL	1098
CCC	IF CLDFG1 = 1.0 .	UPWELL	1099
	WRITE(8) ((UPRAD(K,L),K=1,NAZI),L=1,NWAVEJ)	UPWELL	1100
	IF(CLDFG1 .EQ. 1.0) WRITE(8) (((R010(K,L),R025(K,L),R050(K,L),	UPWELL	1101
	\$ R090(K,L),R100(K,L)), K=1,NAZI), L=1,NWAVEJ)	UPWELL	1102
CCC		UPWELL	1103
CC	COMPUTE AVERAGES OVER AZIMUTH ANGLES K AT WAVENUMBERS	UPWELL	1104
CC	L=1,NWAVEJ, NADIR ANGLE J, AND ALTITUDE I.	UPWELL	1105
	FINAZ = 1.0/FLOAT(NAZI)	UPWELL	1106
	DO 64 L=1,NWAVEJ	UPWELL	1107
	SUMM = 0.0	UPWELL	1108
	DO 62 K=1,NAZI	UPWELL	1109
	SUMM = SUMM + UPRAD(K,L)	UPWELL	1110
62	CONTINUE	UPWELL	1111
	UPRADA(I,J,L) = FINAZ*SUMM	UPWELL	1112
64	CONTINUE	UPWELL	1113
CCC		UPWELL	1114
	IF(CLDFG1.EQ.0.0) GO TO 70	UPWELL	1115
	IF(IKM .GT. 6) GO TO 70	UPWELL	1116
CCC		UPWELL	1117
	DO 68 L=1,NWAVEJ	UPWELL	1118
	R010KJ = 0.0	UPWELL	1119
	R025KJ = 0.0	UPWELL	1120
	R050KJ = 0.0	UPWELL	1121
	R090KJ = 0.0	UPWELL	1122
	R100KJ = 0.0	UPWELL	1123
	DO 66 K=1,NAZI	UPWELL	1124
	R010KJ = R010KJ + R010(K,L)	UPWELL	1125
	R025KJ = R025KJ + R025(K,L)	UPWELL	1126
	R050KJ = R050KJ + R050(K,L)	UPWELL	1127

	R090KJ = R090KJ + R090(K,L)	UPWELL	1128
	R100KJ = R100KJ + R100(K,L)	UPWELL	1129
66	CONTINUE	UPWELL	1130
CC	IKM = INDEX FOR ALTITUDES EQUAL TO OR GREATER THAN 12.0 KM	UPWELL	1131
CC	WHEN CLOUDS ARE INCLUDED.	UPWELL	1132
	R010A(IKM,J,L) = FINAZ*R010KJ	UPWELL	1133
	R025A(IKM,J,L) = FINAZ*R025KJ	UPWELL	1134
	R050A(IKM,J,L) = FINAZ*R050KJ	UPWELL	1135
	R090A(IKM,J,L) = FINAZ*R090KJ	UPWELL	1136
	R100A(IKM,J,L) = FINAZ*R100KJ	UPWELL	1137
68	CONTINUE	UPWELL	1138
CC	STATEMENT 70 IS FOR NADIR LOOP ON INDEX J	UPWELL	1139
70	CONTINUE	UPWELL	1140
CCC		UPWELL	1141
CC	COMPUTE AVERAGES OVER NADIR ANGLES J AT WAVENUMBERS	UPWELL	1142
CC	L=1,NWAVEJ AND ALTITUDE I.	UPWELL	1143
	FINAD = 1.0/FLOAT(NNADIR)	UPWELL	1144
	DO 74 L=1,NWAVEJ	UPWELL	1145
	SUMM = 0.0	UPWELL	1146
	DO 72 J=1,NNADIR	UPWELL	1147
	SUMM = SUMM + UPRA(I,J,L)	UPWELL	1148
72	CONTINUE	UPWELL	1149
	UPRADN(I,L,JBAND) = FINAD*SUMM	UPWELL	1150
74	CONTINUE	UPWELL	1151
CCC		UPWELL	1152
	IF(CLDFG1.EQ.0.0) GO TO 80	UPWELL	1153
	IF(IKM .GT. 6) GO TO 80	UPWELL	1154
CCC		UPWELL	1155
	DO 78 L=1,NWAVEJ	UPWELL	1156
	ARCVKJ = 0.0	UPWELL	1157
	R010KJ = 0.0	UPWELL	1158
	R025KJ = 0.0	UPWELL	1159
	R050KJ = 0.0	UPWELL	1160
	R090KJ = 0.0	UPWELL	1161
	R100KJ = 0.0	UPWELL	1162
	DO 76 J=1,NNADIR	UPWELL	1163
	ARCVKJ = ARCVKJ + ARCV(IKM,J,L)	UPWELL	1164
	R010KJ = R010KJ + R010A(IKM,J,L)	UPWELL	1165
	R025KJ = R025KJ + R025A(IKM,J,L)	UPWELL	1166
	R050KJ = R050KJ + R050A(IKM,J,L)	UPWELL	1167
	R090KJ = R090KJ + R090A(IKM,J,L)	UPWELL	1168
	R100KJ = R100KJ + R100A(IKM,J,L)	UPWELL	1169
76	CONTINUE	UPWELL	1170
	ARCVN(IKM,L) = FINAD*ARCVKJ	UPWELL	1171
	R010N(IKM,L) = FINAD*R010KJ	UPWELL	1172
	R025N(IKM,L) = FINAD*R025KJ	UPWELL	1173
	R050N(IKM,L) = FINAD*R050KJ	UPWELL	1174
	R090N(IKM,L) = FINAD*R090KJ	UPWELL	1175
	R100N(IKM,L) = FINAD*R100KJ	UPWELL	1176
CCC		UPWELL	1177
CCC	THE GRC VERSION INSERTS THE FOLLOWING RE-SETTING OF UPRA(I,	UPWELL	1178
CCC	L,JBAND) FOR ALTITUDES .GE. 12 KM AND IF CLOUDS ARE INCLUDED.	UPWELL	1179
CCC	UPRADN(I,L,JBAND) = R050N(IKM,L) + ARCVN(IKM,L)	UPWELL	1180
CCC		UPWELL	1181
78	CONTINUE	UPWELL	1182
CC	STATEMENT 80 IS FOR ALTITUDE LOOP ON INDEX I	UPWELL	1183
80	CONTINUE	UPWELL	1184
	RETURN	UPWELL	1185
	END	UPWELL	1186

	SUBROUTINE VLIN (X, A, Y, B, Z)	VLIN	2
C		VLIN	3
C	*VLIN* FORMS THE LINEAR COMBINATION OF TWO VECTORS.	VLIN	4
CLJ	SUBROUTINE VLIN RETURNS X(1-3) = A*Y(1-3) + B*Z(1-3).	VLIN	5
C		VLIN	6
	DIMENSION X(3), Y(3), Z(3)	VLIN	7
	X(1) = A * Y(1) + B * Z(1)	VLIN	8
	X(2) = A * Y(2) + B * Z(2)	VLIN	9
	X(3) = A * Y(3) + B * Z(3)	VLIN	10
	RETURN	VLIN	11
	END	VLIN	12

C* XMIT		XMIT	2
	SUBROUTINE XMIT (LX, X, Y)	XMIT	3
C		XMIT	4
C	*XMIT* COPIES A CORE BLOCK TO ANOTHER LOCATION.	XMIT	5
C		XMIT	6
CLJ	A GE TEMPO VERSION OF THE GRC ROUTINE XMIT WRITTEN IN COMPASS	XMIT	7
CLJ	LANGUAGE.	XMIT	8
CLJ		XMIT	9
CLJ	INPUT PARAMETERS	XMIT	10
CLJ	ARGUMENT LIST	XMIT	11
CLJ	LX = LENGTH OF ARRAY X	XMIT	12
CLJ	X = THE ARRAY OR CONSTANT TO BE COPIED INTO ARRAY Y.	XMIT	13
CLJ	OUTPUT PARAMETER	XMIT	14
CLJ	ARGUMENT LIST	XMIT	15
CLJ	Y = AN ARRAY, COPIED FROM ARRAY X IF LX.GT.0, AND SET	XMIT	16
CLJ	TO A CONSTANT X(1) IF LX.LT.0.	XMIT	17
CLJ	A RETURN OCCURS IF LX.EQ.0 OR IF THE ADDRESS OF X	XMIT	18
CLJ	EQUALS THE ADDRESS OF Y.	XMIT	19
	DIMENSION X(1), Y(1)	XMIT	20
	IF (LX .LE. 0) GO TO 6	XMIT	21
CLJ	LOCF, A FORTRAN INTRINSIC (INTEGER) FUNCTION, OBTAINS THE	XMIT	22
CLJ	ADDRESS OF A VARIABLE, ARRAY ELEMENT, OR ENTRY POINT OF	XMIT	23
CLJ	EXTERNAL SUBPROGRAM.	XMIT	24
	IF (LOCF(X) - LOCF(Y)) 3, 5, 1	XMIT	25
1	DO 2 I=1,LX	XMIT	26
2	Y(I) = X(I)	XMIT	27
	GO TO 5	XMIT	28
CLJ	THIS BRANCH ALLOWS SHIFTING THE FIRST LX MEMBERS OF ARRAY X TO	XMIT	29
CLJ	START AT SOME MEMBER WHICH LIES WITHIN THE FIRST LX MEMBERS.	XMIT	30
3	K = LX	XMIT	31
	DO 4 I=1,LX	XMIT	32
	Y(K) = X(K)	XMIT	33
4	K = K - 1	XMIT	34
5	RETURN	XMIT	35
6	IF (LX .EQ. 0) RETURN	XMIT	36
	LXX = -LX	XMIT	37
	DO 7 I=1,LXX	XMIT	38
7	Y(I) = X(1)	XMIT	39
	RETURN	XMIT	40
	END	XMIT	41

SECTION 9

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