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A SYNOPTIC-SCALE MODEL FOR SIMULATING CONDENSED ATMOSPHERIC MOISTURE

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The determination of a synoptic-scale model for simulating condensed atmospheric moisture by the USAFETAC Scientific Services Branch and the applications for which the model may be used are detailed. This study only treats the use of gridded inputs to perform the environmental simulations and, in particular, explains the use of two portions of a data base maintained by USAFETAC. The two data bases are a global cloud analysis (3DNEPH)

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20. ABSTRACT (Cont'd)

and a global analysis of conventional parameters. The input to the model includes low, middle, high, or convective cloud types (3DNEPH), layered cloud amounts (3DNEPH), present weather conditions (3DNEPH), base, tops and midpoints of layers (AFGWC Model Terrain), and temperature and D-Value profiles (AFGWC gridded hemispheric analyses).

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A SYNOPTIC-SCALE MODEL FOR SIMULATING CONDENSED ATMOSPHERIC MOISTURE

1. Introduction.

Historically, the many parameters in the atmosphere that are measured on a routine basis do not include the condensed moisture content, its thermodynamic phase, or its drop-size distribution. The three parameters mentioned above are difficult at best to measure in the free atmosphere and to obtain observations of them on a global scale is presently beyond the state of the art. Even though remote sensing devices using satellite observation platforms are being tested, no adequate,readily available method of observing these elements is in existence. Since numerous present-day problems are deeply concerned with and, in many cases, entirely dependent on such knowledge, the synoptic-scale model for simulating condensed atmospheric moisture (referred to below as the model) was developed. This model is designed to use operationally-produced, gridded global analyses to produce a "best estimate" of condensed moisture content, its thermodynamic phase, and the resultant drop-size distribution at a point in space and time.

A second application allows the user to input summarized cloud data and temperature profiles from station files and produce station analyses of the condensed moisture.

Another application of the model allows the movement (via flight simulation) of a payload to be followed through the simulated weather environment and enables information on the effects that the environment exerts on the specific payload to be collected.

This technical report only treats the use of gridded inputs to perform the environmental simulations and contains discussion of the following major topics:

a. The input data base,including design and source.

b. The method used for specification of total condensed moisture content, its thermodynamic phase, and the subsequent drop-size distribution.

c. Change in parameter determination.

d. Model output.

e. Application.

f. Additional model improvements and conclusions.

2. Input Data Base.

The Air Force Global Weather Central (AFGWC) operationally produces two distinct, gridded data bases. These include a global cloud analysis, referred to as the 3DNEPH, and a second data base consisting of the global analyses of conventional parameters including the Northern Hemisphere Analysis (NHA), the Tropical Weather Analysis (TWA), and the Southern Hemisphere Analysis (SHA) Further development of these data bases for climatological use by the USAF Environmental Technical Applications Center (USAFETAC) are detailed by Feddes, et al, in USAFETAC TN 74-2. Throughout this report the Northern Hemisphere portion of the analysis data base is referred to as the NHA and the Southern as the SHA. Since the Northern and Southern Hemispheres of the 3DNEPH and the analyses are mirrored projections, any programs used in the Northern Hemisphere have direct application in the Southern Hemisphere.

The input to the model utilizes the 3DNEPH box and analysis time files. Input parameters and the source for areal simulation are as follows:

a. Low, middle, high, or convection cloud types - 3DNEPH.

b. Layered cloud amounts - 3DNEPH.

c. Present weather conditions - 3DNEPH.

d. Base, tops, and midpoints of layers - AFGWC Model Terrain.

e. Layers that define low, middle, high, or convective type - AFGWC 3DNEPH Definition.

f. Temperature and D-value profiles (USAFETAC TN 74-2 - Appendix B)

3. Data Compatibility.

Data compatibility, as concerns geographical location of points from the 3DNEPH and the NHA, presents a major problem in the simultaneous use of the two data bases since the 3DNEPH has a nominal horizontal resolution of 25 nm while the NHA has a resolution of 200 nm. Thus, every ninth point on every ninth line of the 3DNEPH corresponds exactly to an NHA point. Using an example of any 2×2 set of points, the corresponding relationship between the NHA and the 3DNEPH points is shown in Figure 1. To preserve the resolution of the 3DNEPH and, therefore, the synoptic scale of the simulation, horizontal interpolation of the NHA parameters is necessary. The parameters to be interpolated include temperature and D-value fields for the standard levels between 1000 and 100 mb and the surface temperature field. An NHA point coincides with every ninth point on every ninth row of the 3DNEPH, thus, the upper left point in a 3DNEPH subbox (Figure 3) is the only one that corresponds to an NHA point. Therefore, 63 double-linear interpolations are used to determine the values of the parameter at the 3DNEPH resolution. Figure 2 is an example of a horizontal temperature interpolation for the point on row 4 and column 4 and indicated by a circle on Figure 1.

The temperature interpolations in the vertical are linear and use a set of predetermined constants based on the terrain for each point, the D-value (height profile, and a temperature profile corresponding to the D-value profile. The predetermined constants based on the terrain are on a set of tapes containing heights of the 3DNEPH layer bases, tops, and midpoints in meters above MSL.

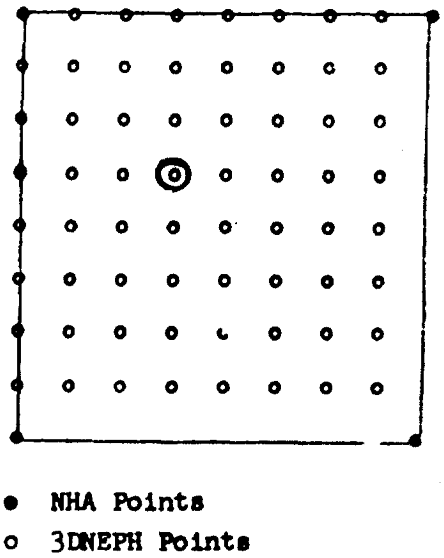

Figure 1. Relationship between NHA and 3DNEPH Points.

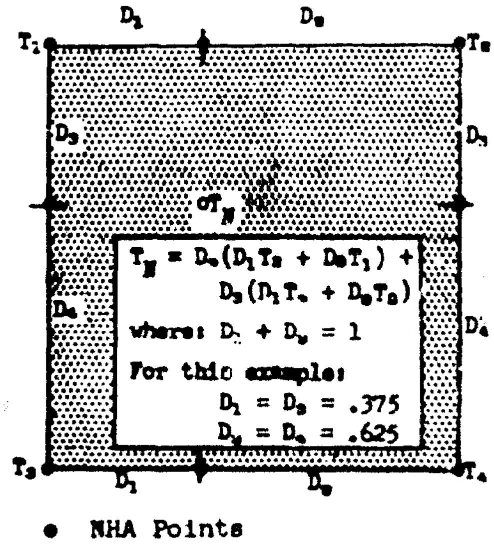

Figure 2. Example of Horizontal Temperature Interpolation.

Table 1. Layer Which Can Contain Clouds with 2500 Meter Mean Sea Level Terrain.

Layer	Tops	Bases	Midpoints
1	2546 m	2500 m	2523 m
2	2591	2546	2569
3	2683	2591	2637
4	2805	2683	2744
5	3110	2805	2958
6	3566	3110	3338
7	4267	3566	3917
8	5486	4267	4876
9	6705	5486	6095
10	7924	6705	7314
11	10667	7924	9295
12	16763	10667	13715
13			
14			
15			

Low Clouds	Layers	1-7
Middle Clouds	Layers	8-10
High Clouds	Layers	11-12
Convective Clds	Layers	1-12
Number of usable	Layers	12

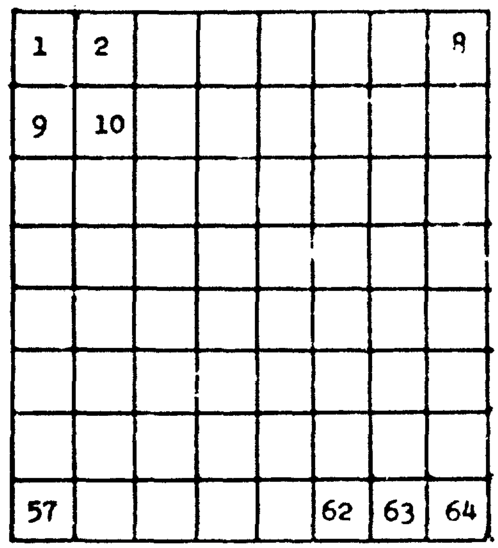

Figure 3. Sub-box Numbers Within a 3DNEPH Box. The sub-box intersections are NHA points.

These tapes also contain information pertaining to the inclusive layers that can contain low, middle, high, and convective clouds, and the number of layers (up to 15) that have clouds. An example of tops, bases, and midpoints of layers that can contain clouds for a terrain of 2500 meters is given in Table 1. The table also gives the inclusive layers for low, middle, high, and convective clouds, plus the number of layers that can contain clouds. This predetermined terrain-dependent information is stored by row within 3DNEPH box/sub-box configuration, i.e., each 3DNEPH box is further divided into 64 sub-boxes (see Figure 3).

Using the results of the horizontally interpolated D-value (height) and temperature profiles and the terrain-dependent constants, the vertical interpolations are performed. Using the two NHA pressure levels that encompass a 3DNEPH-layer midpoint, the layer midpoint temperature is calculated and stored for later use in the model. The 3DNEPH-point parameters listed earlier, the layered cloud amounts converted to MSL, terrain-dependent constants, and the temperature profile become input to the model.

Time compatibility of the 3DNEPH (analyzed every three hours) and the NHA (analyzed every 12 hours) requires that simulation be performed only at 00Z and 12Z until dependable time interpolation techniques can be adapted to the historical time files of the NHA and SHA.

4. Specification of Condensed Moisture Content, Thermodynamic Phase, and Drop-Size Distribution.

The specification of condensed moisture content, its thermodynamic phase, and its subsequent drop-size distribution on a global scale is best performed by the extension of measured parameters through automated estimation. The rationale used in developing the following techniques is contained in USAFETAC TN 74-3 The basic techniques are described below and the reader is referred to the above referenced Technical Note for discussion of the theoretical basis for the parameterizations. Additional refinements to the specifications of condensed moisture content, the thermodynamic phase, and the drop-size distribution are contained here in the section titled "Change in Parameter Determination."

a. Condensed Moisture Content. The condensed moisture content at a point is estimated from five parameters. These parameters are the temperature at the point in question, type of cloud that exists at the point, the percentage that the point is above the cloud base, the amount of cloud for the layer (applied to the point) and whether precipitation exists at the surface below the point. The percentage that the point is above the cloud base is derived by dividing the difference between the height of cloud top and base by the difference between the height of the midpoint of the layer and the cloud base. The quotient is then multiplied by 10

The process begins by taking the cloud type and the temperature at a point and determining the maximum condensed moisture (CM) that can exist for that combination. This maximum CM is evaluated from a "look-up" table developed from the information contained in Table 2. This table is similar to that contained in the USAFETAC Report #6988 by Feddes (unpublished). The Table is a "best estimate" of maximum condensed moisture and was derived from an extensive literature search on measured condensed moisture.

Next, obtain the percent of the maximum condensed moisture which can exist at that level in the particular cloud concerned. The vertical cloud profiles, Figures 4 through 7, from Feddes' USAFETAC Report #6988 are used to determine the condensed moisture content. This produces the maximum amount of condensed moisture to be expected at that 3DNEPH-layer midpoint.

Table 2. The Maximum Condensed Moisture (in g/m^3) that can Occur in a Nonprecipitating Cloud as a Function of Cloud Type and Temperature.

Temperature (degrees C)

Cloud Type	<-25	-25 to -20	-20 to -15	-15 to -10	-10 to -5	-5 to 0	0 to +5	+5 to +10	+10 to +15	> 15
ST	.10	.15	.20	.25	.30	.35	.40	.45	.50	.50
SC	.20	.30	.40	.45	.50	.55	.60	.70	.70	.70
CU	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
NS	.35	.40	.45	.50	.60	.60	.75	.90	.90	.90
AC	.25	.30	.35	.40	.40	.45	.60	.70	.70	.70
AS	.15	.20	.25	.30	.30	.35	.40	.50	.50	.50
CS	.15	.15	.15	.20	.20	.20	.25	.25	.25	.25
CI	.10	.10	.10	.10	.15	.15	.15	.20	.20	.20
CC	.05	.05	.05	.05	.10	.10	.10	.15	.15	.15
CB	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5

If precipitation is occurring at the surface below the point being considered, the precipitating curve on the profile for the appropriate cloud type is used. Also, in cases where precipitation is present, the portion of the condensed moisture to the left of the nonprecipitating curve is considered cloud moisture and the portion between the nonprecipitating value and the precipitating value is precipitation. In cases where the precipitating value is less than the nonprecipitating value, all of the condensed moisture is considered to be moisture in cloud form.

Finally, the amount of condensed moisture to be expected in that layer is multiplied by the percent of cloud amount reported in the 3DNEPH. This last computation assumes that, for layers that are not totally filled with cloud, the clouds that do exist are randomly distributed and, therefore, the condensed moisture is evenly distributed throughout the area defined by the point. A modification of condensed moisture determination in precipitating convective clouds is discussed in the section "Change in Parameter Determination," Para. 5a.

b. Thermodynamic Phase. The thermodynamic phase of the condensed moisture from the previously-discussed process can now be determined. Initially, the formula given in the discussion of the thermodynamic phase by Smith in USAFETAC TN 74-1

$$\text{Percent supercooled water} = 2.5\,(T-233)$$

$$\text{with} \quad 233 \le T \le 273 \quad \text{and}$$

$$T \text{ in degrees Kelvin}$$

was applied to determine what percentage of the total condensed moisture is liquid and what portion is solid. This requires the temperature of the point in question and the total condensed moisture obtained for the layer. Improvement

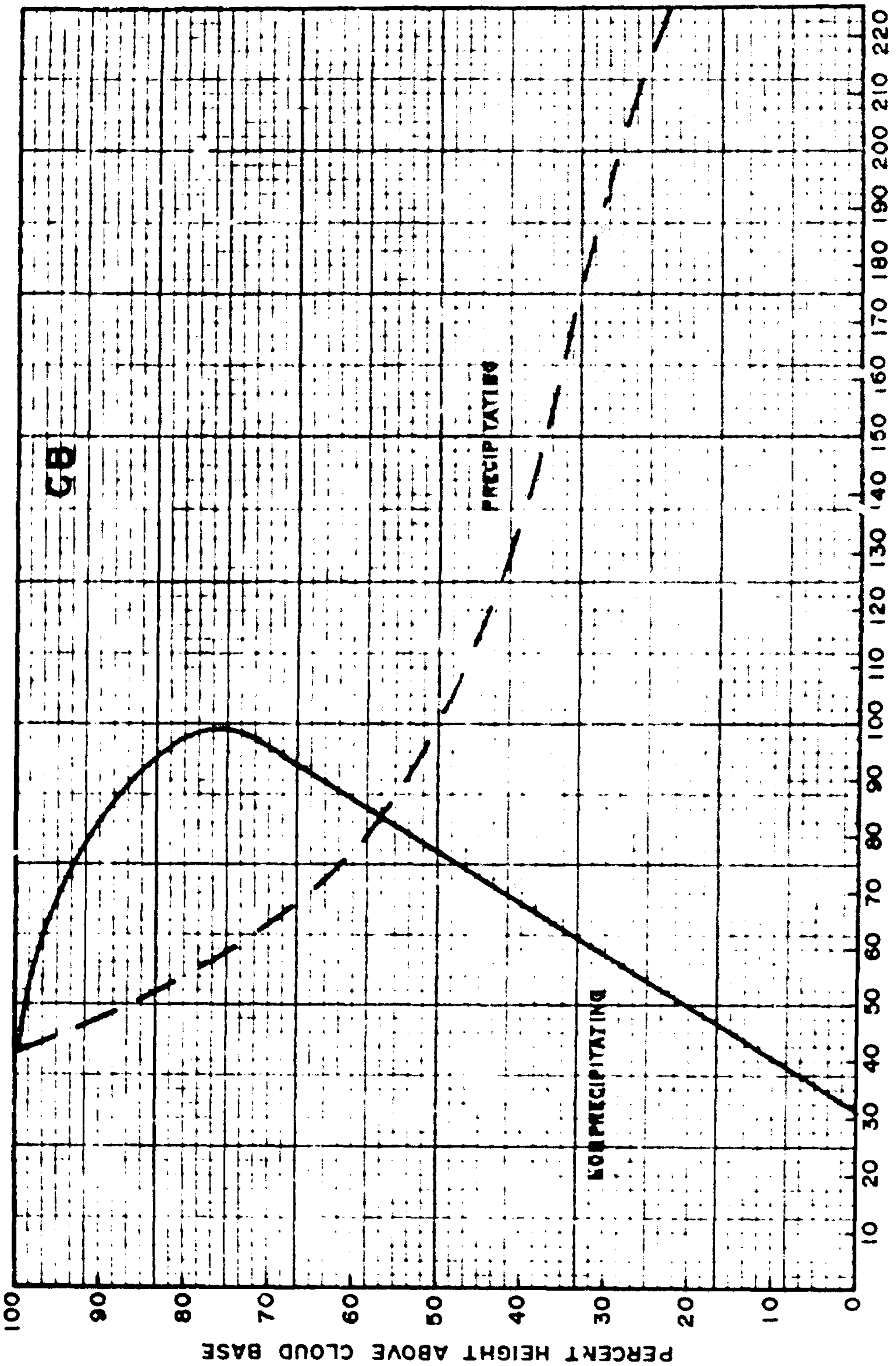

Figure 4. Vertical Cloud Profile, Cumulonimbus (CB).

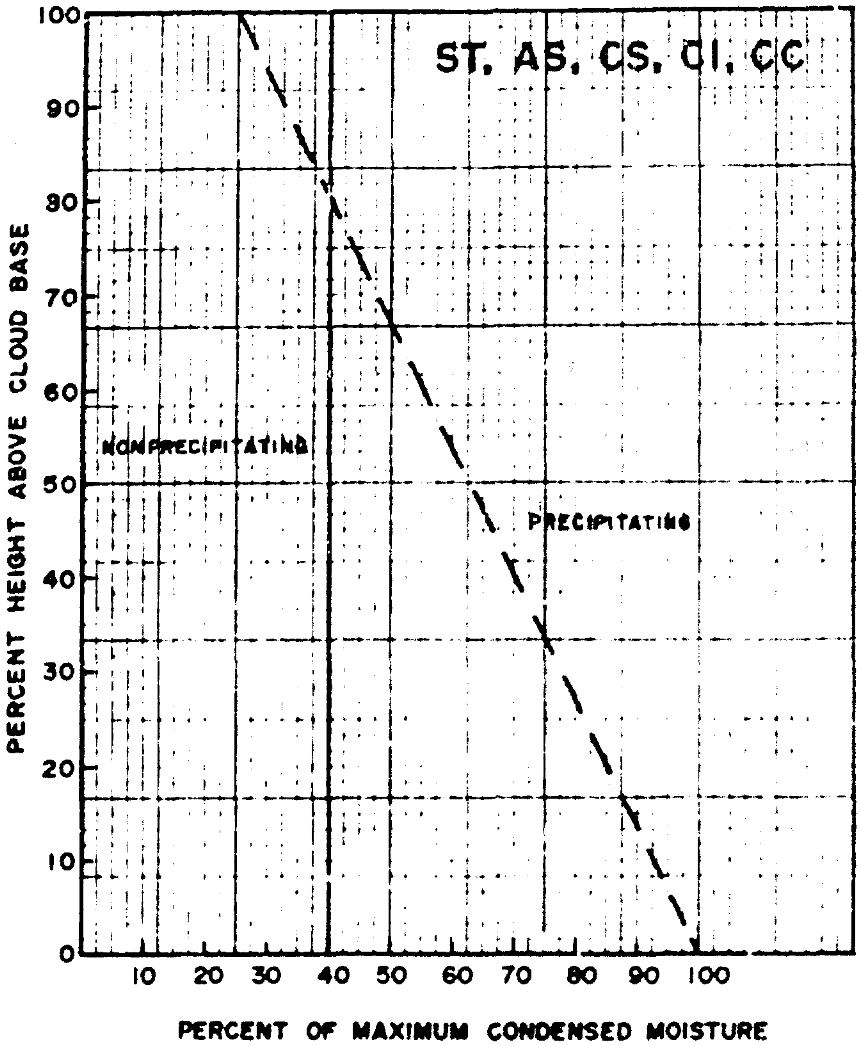

Figure 5. Vertical Cloud Profile, ST, AS, CS, CI, CC.

in this determination is discussed in subparagraph 5b, "Change in Parameter Determination."

If precipitation is present, the thermodynamic phase is applied to cloud water and to rainwater. Therefore, it is possible to have four types of hydrometeors, liquid cloud moisture, solid cloud moisture, liquid rain, and solid rain or snow.

c. Drop-Size Distribution. After the four types of moisture content have been determined, a drop-size distribution can be applied to each.

The cloud moisture is distributed in drop size according to the equation, $\% \ CM = A(r - B)$, as described by Smith in USAFETAC TN 74-1. This relationship gives the percentage of the total cloud moisture (liquid or solid) at a radius r. This percentage is then converted to the number of drops/cm^3 for a radius r. The parameters A and B for each particular cloud type are given by Table 3. Expansion of the drop-size distribution determination technique is discussed in "Change in Parameter Determination," subparagraph 5c.

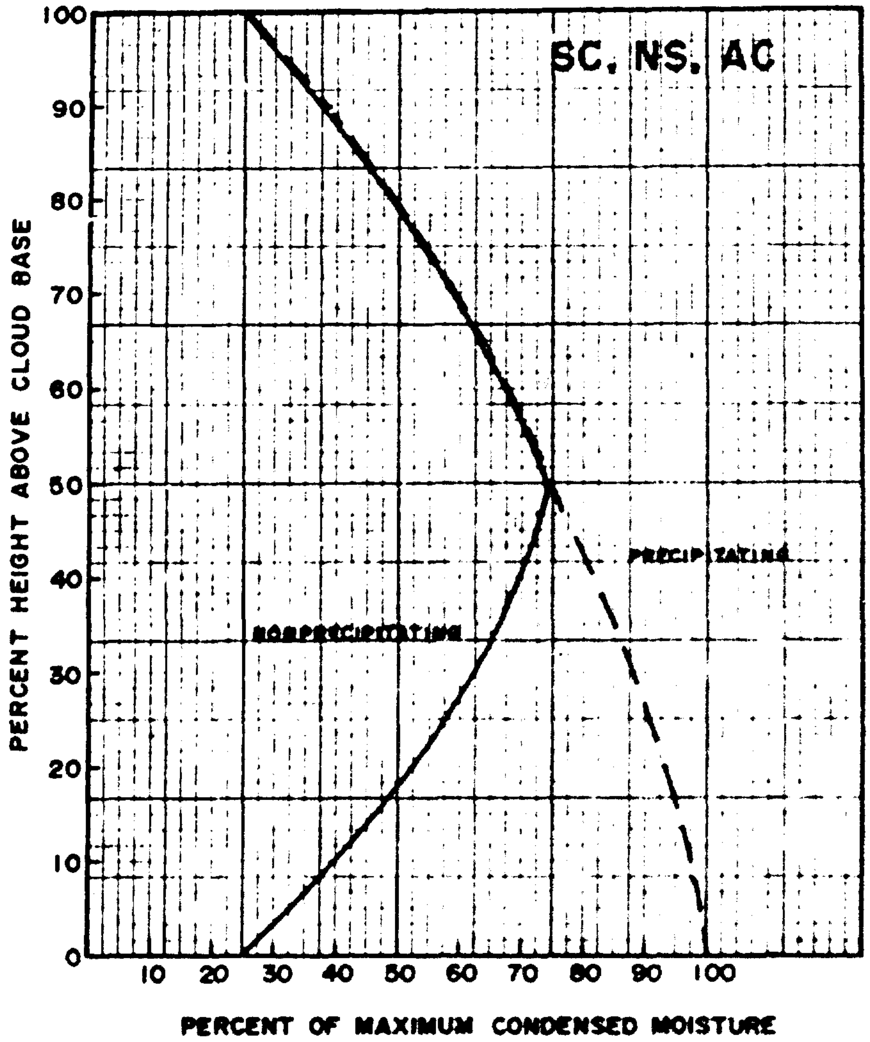

Figure 6. Vertical Cloud Profile, SC, NS, AC.

The precipitation distribution utilizes another equation cited by Smith in USAFETAC TN 74-1, which is:

$$N(r) = 20 \left[\exp\left(\frac{-4.744\ r \times 10^{-3}}{(CM)^{.25}}\right)\right]$$

where r is the drop-size radius in microns, CM is the liquid or solid precipitation in g/m^3, and N(r) is the number density of droplets/m^3/micron interval. This equation was applied as shown with the exception of a slight adjustment of the constant -4.74 to -4.555. The number density distribution was first calculated at whole micron (1-3000) for a particular amount of precipitation using the constant -4.744. Using the number of drops determined at each whole micron radius (1-3000) and the

Table 3. Drop-Size Distribution Cloud Parameters.

CLOUD TYPE	A	B
Cumulus	45/ 8	2
Cumulus Congestus	25/ 9	4
Stratocumulus	60/11	2
Altostratus	30/ 7	3
Nimbostratus	54/19	5
Stratus	30/11	6
Cirrus	48/ 5	8

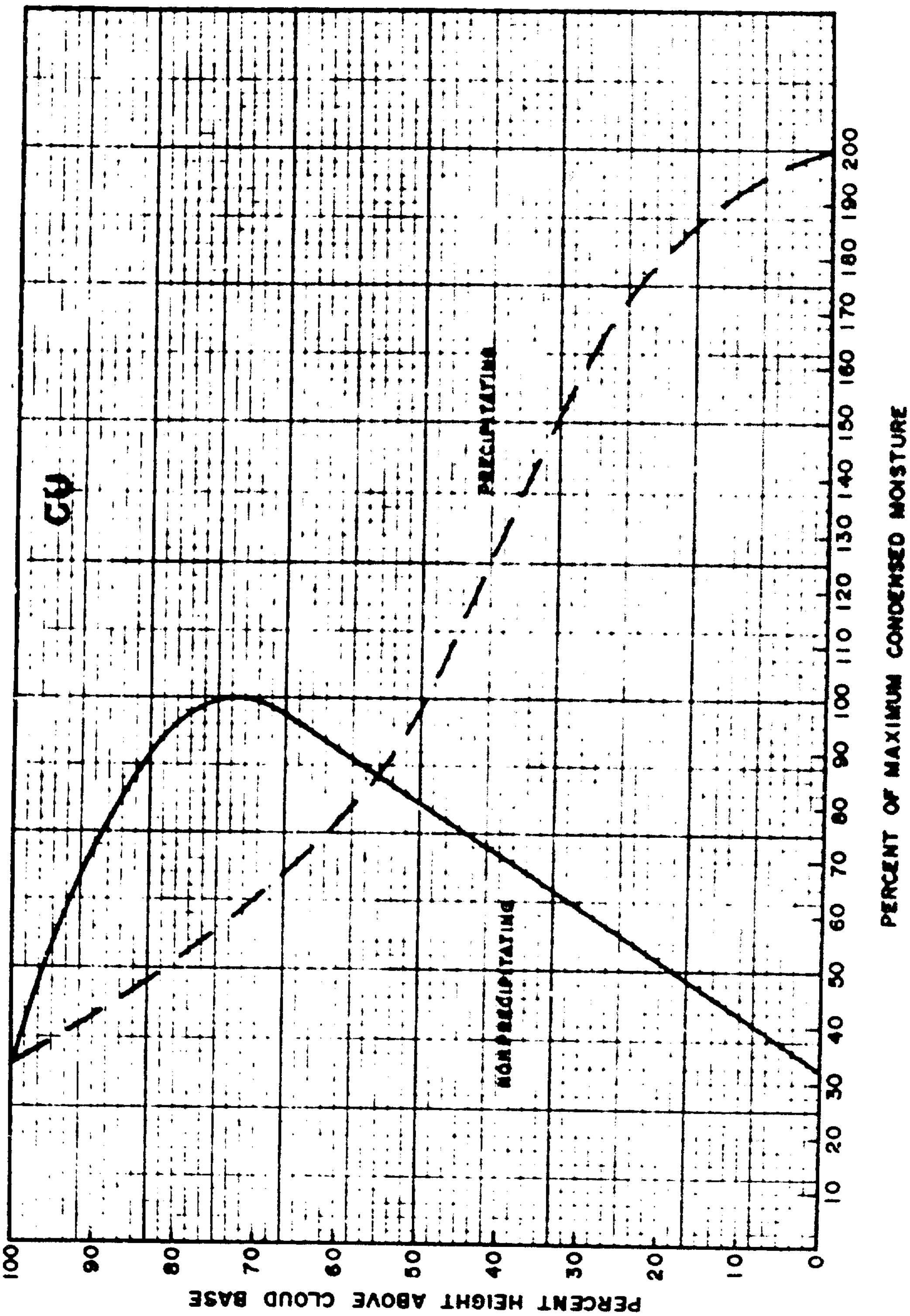

Figure 7. Vertical Cloud Profile, Cumulus (CU).

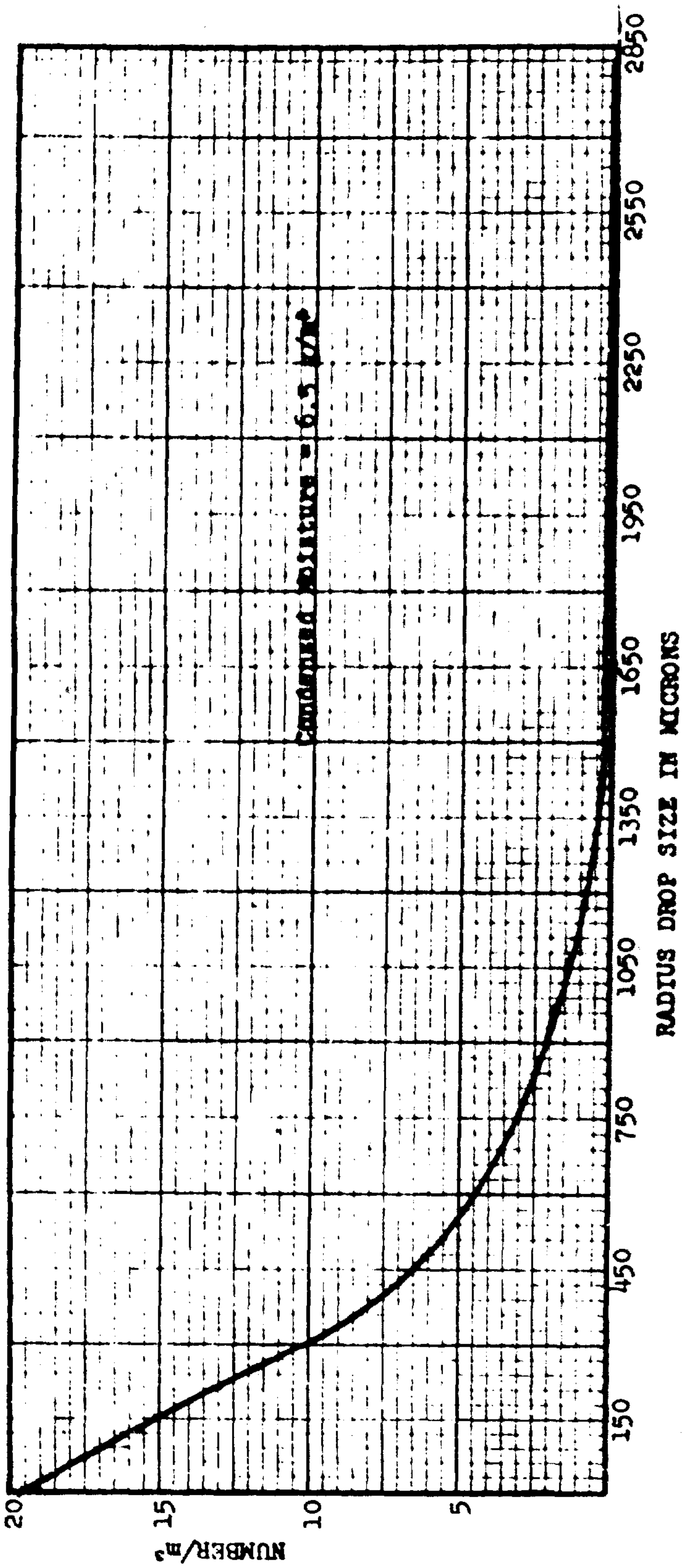

Figure 8. Precipitation Drop-Size Distribution at a Point in Space.

volume of the drop at that radius, the total moisture content was calculated. The resultant summation for the 3000 micron intervals accounted for only 87% of the initial precipitation (CM). It was determined that by adjusting t constant -4.744 to -4.555, a the precipitation is account for from 1 and 3000 microns. This adjustment of the constant makes it impossible to have any drops larger than 3000 microns radius. Thus, the equation used in the mode to calculate precipitation drop-size distribution uses the modified constant (-4.555 The model is set up to return the number density/m^3/micron interval at 150, 450, 750, 1050, 1350, 1650, 1950, 2250, and 2850 microns. The model can easily be adapted to accept other micron intervals. A plot of the drop-size distribution for 6.5 g/m³ of precipitation is shown in Figure 8. As stated earlier, the sar distribution (Figure 8) is applied to both solid and liquid precipitation.

5. Change of Parameter Determination.

Subsequent to the reports by Feddes (ETAC #6988) and Smith (ETAC TN 74-1) further refinements of the model have been made concerning the total condensed moisture in precipitating convective clouds, the thermodynamic phase determination, and the mode of calculating the drop-size distribution. These changes are discussed below.

a. The differential fall velocities of liquid and solid water will decrease the total condensed moisture below the freezing level. This decrease has been substantiated by recent measurements and is accounted for in the model. This change in total condensed moisture at the freezing level will have the greatest effect in the precipitating portion of a convective cloud where maximum moisture contents in excess of 15 g/m^3 have been observed. Below the freezing level in precipitating convective clouds, the liquid precipitation portion of the total condensed moisture in the model has been reduced by a factor of .5 with a corresponding reduction in the overall total.

b. The thermodynamic phase of the condensed moisture initially utilized a linear function to define supercooled water in a temperature range from 0 to -40°C. To further define the amount of supercooled liquid, curvilinear functions were applied and the cloud types were stratified as either stable (strati-form) or unstable (cumulus and cumulonimbus). The supercooled stable cloud curve is of the form:

$$CM_{water} = \left(e^{BX} - 0.0263\right) \times 100\%$$

where B is 0.0909091 $°C^{-1}$, X is the temperature in °C limited by $-40 \leq X \leq 0$, and CM_{water} is the condensed moisture in percent. The ice portion of the supercooled total condensed moisture for stable clouds is:

$$CM_{ice} = 100 - CM_{water}$$

The supercooled unstable cloud curve is of the form:

$$CM_{water} = \left(\cos \frac{\pi}{2} \frac{X}{A}\right) \times 100\%$$

where A is -40°C, X is the temperature in °C limited by $-40 \leq X \leq 0$. The ice portion of the total condensed moisture for unstable cloud is:

$$CM_{ice} = 100 - CM_{water}$$

The curves are represented in graphic form in Figure 9.

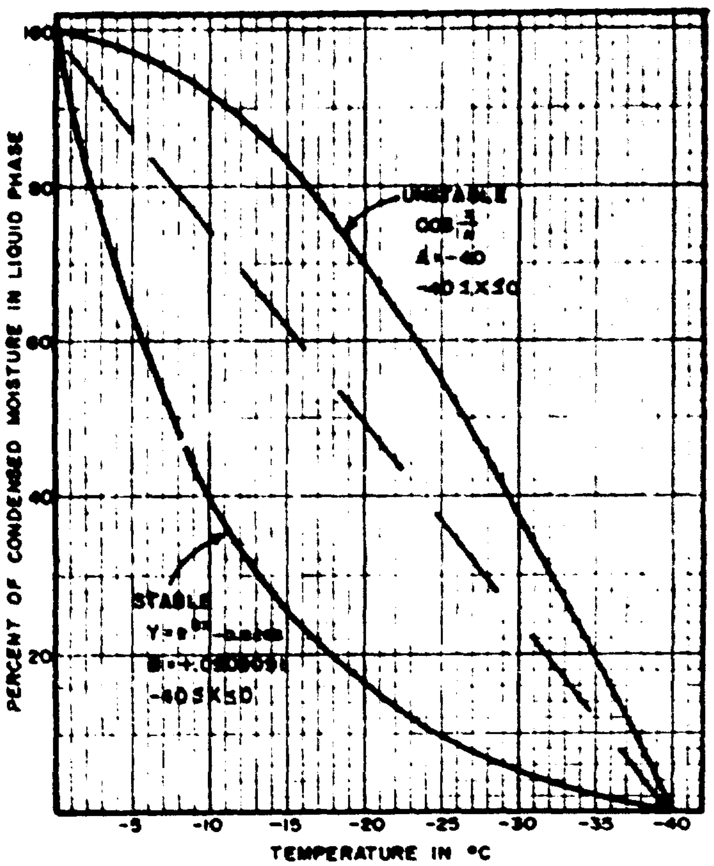

Figure 9. Supercooled Cloud Moisture Curves, Stable and Unstable.

c. The drop-size distributions discussed by Smith in his Technical Note and their derivation in units of number/cm^3/micron radius were generalized by curve-fitting to all cloud types. This change in the specification of drop-size distribution enables the user to specify number density at any point on the curve. The model is arranged to produce number densities at <u>all</u> whole microns (1 through 40). The amount of detail required by the user is a function of the application. The normalized equation for the calculation is of the form:

$$\text{No. of drops} = \left\{\left(\frac{P}{V}\right)(CM)\left(\frac{X-B}{a}\right)^{-m} \exp\left[\left(\frac{m}{S}\right)\left(\frac{X-B}{a}\right)^{-S} - 1\right]\right\} \times 10^{6}$$

where a = point of maximum amplitude
B = location of the origin of the curve
P = percent of CM in 1 micron interval centered at (a)
V = volume of a drop with a radius of (a) (micron^3)
CM = amount of CM for that calculation
X = drop-size (radius) for which calculation is made
S = shape factor of the curve
m = amplitude of the curve

No. of drops = drop density/cm^3/micron radius interval centered at X.

A list of variables for the above equation are given by cloud type in Table 4. The constants are such that the total amount for each moisture type is accounted for within the distribution limits of each cloud type. A typical distribution for each cloud type is graphically displayed in Figures 10a through 10h. The cloud ice always uses the cirrus drop-size distribution (Figure 10g). Also, it should be noted that, for convenience of display, cloud water drop-size distribution is calculated for a cubic centimeter (cm^3), whereas the calculations for precipitation drop-size distribution concern cubic meters (m^3).

Table 4. Variables Used in Curve Fitting.

CLOUD TYPE	P	V	X	S	M	a	B
ST	.0002	65.45	0-40	.1975	6	2.5	0
SC	.0064	65.45	0-25	.436	6	2.5	0
CU	.0045	65.45	0-20	.322	6	2.5	0
NS	.0003	56.45	0-40	.1575	6	2.5	0
AC	.0003	65.45	0-40	.152	6	2.5	0
AS	.0181	1767.15	0-40	.124	36	7.5	0
CS	.0068	1767.15	5-40	.1755	6	7.5	5
CI	.0068	1767.15	5-40	.1755	6	7.5	5
CC	.0068	1767.15	5-40	.1755	6	7.5	5
CB	.0055	4178.21	0-40	.0593	36	10.0	0

6. Model Output

The output required from this environmental simulation is entirely dependent upon its application. The application can range from a frequency distribu-

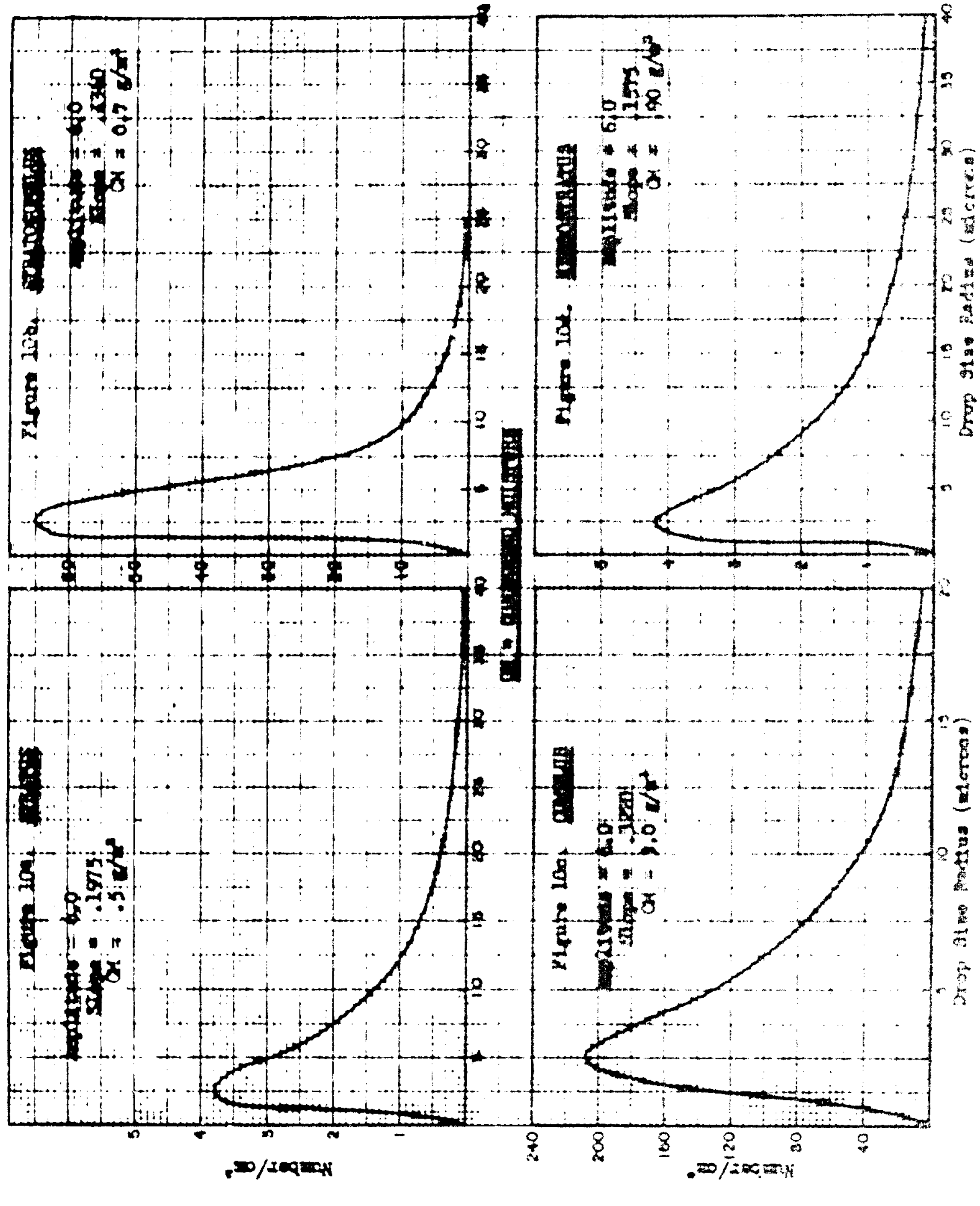

Figure 10. Cloud Droplet Distribution by Size.

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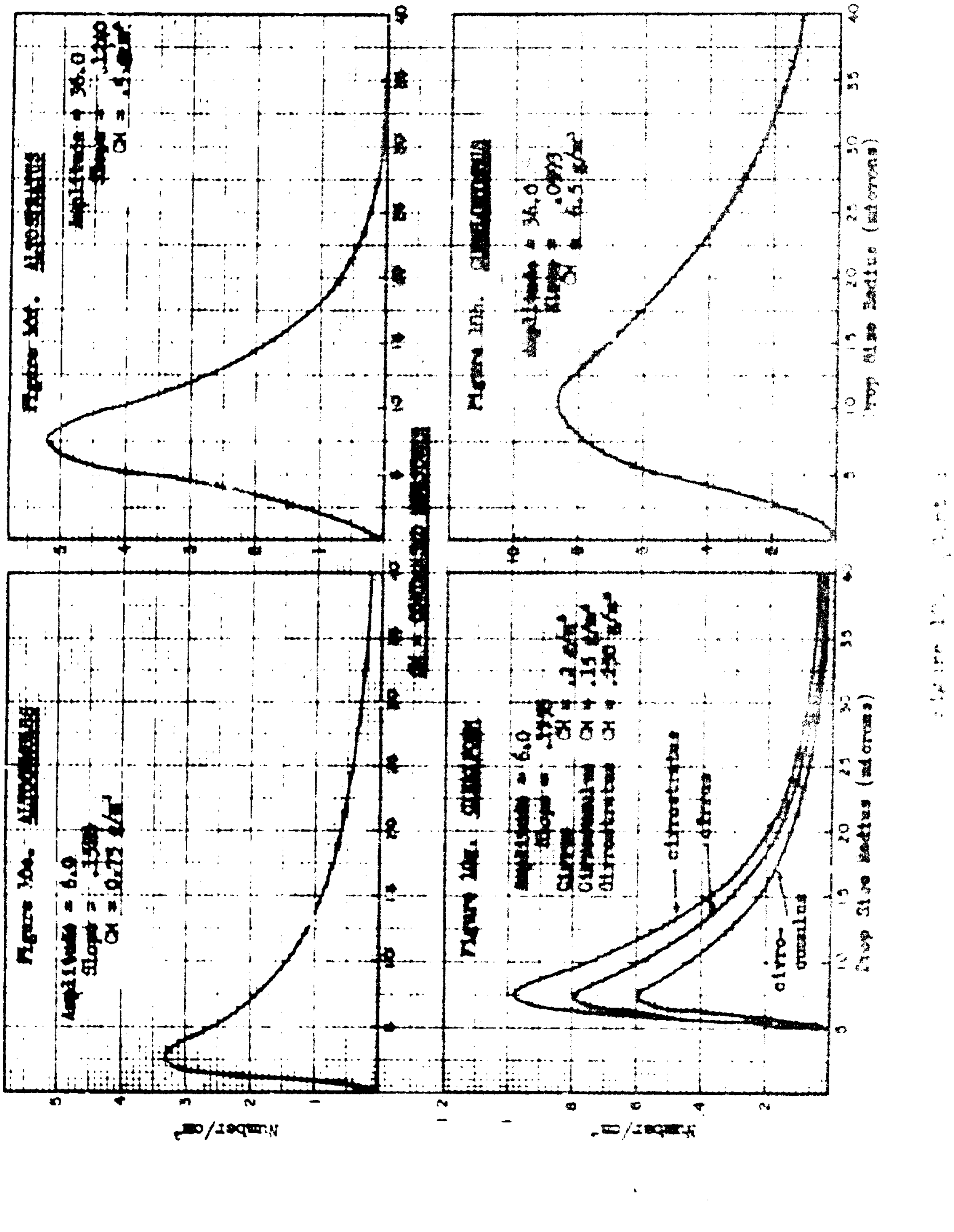

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tion of condensed moisture to the effects of this model environment on a payload, microwave signal, or on a reentry vehicle through the use of flight simulation.

The modular construction of the model itself allows output at three separate exit points. The exit points are sequential such that, the information available at Exit 1 is also available at Exits 2 and 3 and the information at Exit 2 is available at Exit 3. This modular concept will have a major impact on the computer time involved if, in certain instances, execution of the program to the second or third exit points is not required.

All output information is for 3DNEPH-layer midpoints and the model will generate 15-level parameter profiles for a point at each exit as shown:

EXIT		PROFILE
1		Total Condensed Moisture (g/m^3)
2	a.	Cloud Liquid Content (g/m^3)
	b.	Cloud Ice Content (g/m^3)
	c.	Rain Liquid Content (g/m^3)
	d.	Rain Ice Content (g/m^3)
3	a.	Drop-Size Distribution of Cloud Water and Cloud Ice (number/cm^3/micron interval)
	b.	Drop-Size Distribution of Rain Water and Ice Water (number/m^3/micron interval)

Tables 5a and 5b indicate the output at each exit for a precipitating cumulonimbus cloud over water for the appropriate 3DNEPH parameters and temperature profile tabulated in Table 5c.

Table 5a. Model Program Output at Exits 1 and 2 for Precipitating Cumulonimbus Cloud.

Layer	Midpoint (Height-Meters)	Total Condensed Moisture (g/m^3)	Cloud Liquid (g/m^3)	Cloud Ice (g/m^3)	Rain Liquid (g/m^3)	Rain Ice (g/m^3)
1	23	10.140	2.405	0.000	7.735	0.000
2	69	10.140	2.405	0.000	7.735	0.000
3	137	10.140	2.405	0.000	7.735	0.000
4	244	10.140	2.405	0.000	7.735	0.000
5	458	10.140	2.405	0.000	7.735	0.000
6	838	10.140	2.405	0.000	7.735	0.000
7	1295	10.140	2.405	0.000	7.735	0.000
8	1752	10.140	2.405	0.000	7.735	0.000
9	2514	10.140	2.405	0.000	7.735	0.000
10	3657	17.875	2.393	0.012	15.393	0.077
11	4876	17.875	2.344	0.061	15.080	0.390
12	6095	12.675	3.448	0.257	8.347	0.623
13	7314	12.675	3.159	0.546	7.647	1.323
14	9295	6.500	2.874	2.066	0.907	0.653
15	13715	4.095	0.000	4.095	0.000	0.000

Table 5b(1) Model Program Output at Exit 3 for Precipitating Cumulonimbus Cloud: Number of Cloud Particles Per Cubic Centimeter/Micron Radius, Cloud Water - Liquid, Cloud Water - Ice.

CLOUD WATER - LIQUID

2.5	7.5	10.0	16.0	22.0	28.0	34.0	40.0
0.384	2.897	3.166	2.506	1.647	1.044	0.665	0.470
0.384	2.897	3.166	2.506	1.647	1.044	0.665	0.470
0.384	2.897	3.166	2.506	1.647	1.044	0.665	0.470
0.384	2.897	3.166	2.506	1.647	1.044	0.665	0.470
0.384	2.897	3.166	2.506	1.647	1.044	0.665	0.470
0.384	2.897	3.166	2.506	1.647	1.044	0.665	0.470
0.384	2.897	3.166	2.506	1.647	1.044	0.665	0.470
0.384	2.897	3.166	2.506	1.647	1.044	0.665	0.470
0.384	2.897	3.166	2.506	1.647	1.044	0.665	0.470
0.382	2.883	3.150	2.494	1.639	1.037	0.662	0.428
0.377	2.824	3.086	2.443	1.606	1.019	0.649	0.419
0.551	4.152	4.538	3.593	2.361	1.457	0.953	0.615
0.505	3.804	4.158	3.292	2.163	1.377	0.873	0.575
0.459	3.461	3.782	2.995	1.965	1.249	0.794	0.514
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

CLOUD WATER - ICE

2.5	7.5	10.0	16.0	22.0	28.0	34.0	40.0
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.046	0.024	0.016	0.008	0.005	0.003	0.002
0.200	0.223	0.182	0.081	0.041	0.028	0.015	0.010
0.000	0.991	0.777	0.343	0.175	0.101	0.063	0.042
0.000	2.103	1.649	0.727	0.371	0.218	0.134	0.089
0.000	7.952	6.236	2.750	1.403	0.909	0.506	0.337
0.000	15.759	12.358	5.450	2.780	1.601	1.003	0.663

Table 5b(2). Model Program Output at Exit 3 for Precipitating Cumulonimbus Cloud: Number of Precipitation Drops Per Cubic Meter Per Micron Radius, Rainwater - Liquid, Rainwater - Ice.

RAINWATER - LIQUID

150	450	750	1050	1350	1650	1950	2250	2550	2850
13.2770	5.8511	2.5786	1.1364	0.5008	0.2207	0.0973	0.0429	0.0189	0.0083
13.2770	5.8511	2.5786	1.1364	0.5008	0.2207	0.0973	0.0429	0.0189	0.0083
13.2770	5.8511	2.5786	1.1364	0.5008	0.2207	0.0973	0.0429	0.0189	0.0083
13.2770	5.8511	2.5786	1.1364	0.5008	0.2207	0.0973	0.0429	0.0189	0.0083
13.2770	5.8511	2.5786	1.1364	0.5008	0.2207	0.0973	0.0429	0.0189	0.0083
13.2770	5.8511	2.5786	1.1364	0.5008	0.2207	0.0973	0.0429	0.0189	0.0083
13.2770	5.8511	2.5786	1.1364	0.5008	0.2207	0.0973	0.0429	0.0189	0.0083
13.2770	5.8511	2.5786	1.1364	0.5008	0.2207	0.0973	0.0429	0.0189	0.0083
13.2770	5.8511	2.5786	1.1364	0.5008	0.2207	0.0973	0.0429	0.0189	0.0083
14.1652	7.1057	3.5644	1.7890	0.8969	0.4499	0.2257	0.1132	0.0568	0.0285
14.1401	7.0680	3.5329	1.7659	0.8827	0.4412	0.2206	0.1102	0.0551	0.0275
13.3799	5.9883	2.6801	1.1994	0.5368	0.2403	0.1075	0.0481	0.0215	0.0096
13.2615	5.9306	2.6437	1.1771	0.4955	0.2179	0.0958	0.0421	0.0185	0.0081
9.9312	2.4488	0.6038	0.1489	0.0367	0.0091	0.0022	0.0006	0.0001	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

RAINWATER - ICE

150	450	750	1050	1350	1650	1950	2250	2550	2850
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5.4733	0.4099	0.0307	0.0023	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
9.4241	1.4946	0.2452	0.0473	0.0083	0.0015	0.0003	0.0000	0.0000	0.0000
9.2700	1.9915	0.4278	0.0919	0.0197	0.0042	0.0009	0.0002	0.0000	0.0000
10.5766	2.9573	0.8272	0.2313	0.0647	0.0181	0.0051	0.0014	0.0004	0.0001
9.3516	2.0445	0.4470	0.0977	0.0214	0.0047	0.0010	0.0002	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 5c. Input Parameters.

Layer (No.)	Cloud Amount (Percent)	Temperature (°C)
1	100	11
2	100	11
3	100	11
4	100	11
5	100	10
6	100	6
7	100	5
8	100	3
9	100	1
10	100	-4
11	100	-9
12	100	-15
13	100	-22
14	100	-38
15	100	-50

Low cloud type - None
Middle cloud type - None
Hith cloud type - None
Convective cloud type - CB
Present Weather Parameter - Rain

7. Application

The input and the output forms described in the preceding section have a wide variety of applications in developing climatologies of specific parameters individually or in combinations thereof. Many of the environmental problems for a specific geographical area and season can be answered with statistical parameters derived from tabulations of variables quantified or utilized in this model. The amount of condensed moisture stratified by temperature for a specific area can produce a probability for successful deployment of a specific weapons system. The same type of tabulation can be used to study the effects of water and ice on the behavior of passive and active electro-optical systems.

Another application of these parameters is their use as input to payload simulation. With this approach, time-by-time environmental effects can be measured for a specific aircraft, signal, or spacecraft and the resulting impact summarized. This would facilitate bringing specific environmental considerations into the design of future systems.

8. Additional Model Improvements and Conclusions.

Future development of the model can be accomplished in four distinct areas: (a) input data accuracy; (b) additional experimental measurements in deriving the tables, curves, and formulas; (c) improvement in the current estimates by more elaborate uses of the data currently available such as wind components and dew-point depressions; and (d) investigate time interpolation of the input to increase the time resolution of the estimates.

Improvement that can be made at USAFETAC is related to (c), above. A specific improvement will be to define the history of the air mass and the geographical location of the area in question. Air mass history can be specified by methods noted by Feddes in ETAC Report #6988 (unpublished). Location of the air mass can be defined by the geographical location of the 3DNEPH box being processed.

Improvements to the input data base are continual at AFGWC. With the addition of more satellite data and refinements in the cloud analyses, major improvements in the quality of the input have been accomplished throughout the period of record. Noting future requirements and the increasing interest in cloud definition above 20,000 feet, a refinement of the vertical resolution of the 3DNEPH is extremely desirable. Forecast models currently exist at AFGWC that could well be applied to this model, thus, giving a greater time resolution to the estimates.

The advent of more and more complex weapons systems continually necessitate the need for more accurate environmental definition. By coupling this model with appropriate simulation techniques, the impact of the environment can become an even more significant input in the design and testing of future systems that operate in and above the earth's atmosphere.

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LIST OF USAFETAC TECHNICAL NOTES

Number	Title	Date
73-1	Interim Instructions for the Use of Air Stagnation Weather Charts and Messages (AWS distribution only)	Jan 73
73-2	The Ocheltree Tornado, A Case Study (AD-768391)	Mar 73
73-3	Listing of Seminars Available at Hq AWS, AWS Wings, and ARGWC (AWS distribution only) (AD-757543)	Mar 73
73-4	USAFETAC Refractive Index Gradient Summaries (AD-762501)	Apr 73
73-5	Short-Range Weather Forecasting: Recent Developments in Air Weather Service, Suggested Techniques (AWS distribution only)	May 73
73-6	A Resumé on the State of the Art for Snow Forecasting (AD-767214)	Jul 73
74-1	Atmospheric Moisture Parameterization (AD-784814)	Jan 74
74-2	Development of a Gridded Data Base ( ) (Publication delayed)	Apr 74
74-3	A Precipitating Convective Cloud Model ( )	May 74
74-4	A Synoptic-Scale Model for Simulating Condensed Atmospheric Moisture ( )	Jun 74