The NASA/MSFC Global Reference Atmospheric Model - MOD 3
(With Spherical Harmonic Wind Model)

C. G. Justus, G. R. Fletcher,
F. E. Gramling, and W. B. Pace

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FOREWORD

The effort required to develop the Global Reference Atmospheric Model was sponsored by the Atmospheric Sciences Division, Space Sciences Laboratory, NASA Marshall Space Flight Center. This report represents the latest developmental work on the model and was accomplished under the technical monitorship of Mr. Orvel E. Smith, the NASA Contracting Officer's Representative. Qualified requestors may obtain copies of the computer program for this NASA/MSFC Global Reference Atmospheric Model upon request to the Chief, Atmospheric Sciences Division, Space Sciences Laboratory, NASA, Marshall Space Flight Center, Alabama 35812.
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1. INTRODUCTION

In response to needs for empirical model atmospheres of wider scope and application, Georgia Tech developed, under NASA sponsorship, a Global Reference Atmosphere Model (GRAM) with latitude, longitude, and monthly variations over a height range from 0 to 700 km (Justus, et al., 1974 a, b, 1975, 1976). This report describes additions to this model whereby winds can be computed from a spherical harmonic model, based on observed wind data, rather than using the geostrophic relations originally employed. This section describes the basic GRAM model and Section 3 provides a more detailed description of the GRAM program. Section 3 presents some sample results with the new spherical harmonic wind model. Section 4 and 5 are user's manual and programmer's manual section for the GRAM program.

1.1 Description of the Basic Model

The Georgia Tech Global Reference Atmospheric Model (GRAM), is an amalgamation of two previously existing empirical atmospheric models for the low (<25 km) and high (>90 km) atmosphere, with an empirical latitude-longitude dependent model for the middle atmosphere. The high atmospheric region above 115 km is simulated entirely by the Jacchia (1970) model. The Jacchia program sections are in separate subroutines so that later Jacchia models (Jacchia, 1971) or other thermospheric-exospheric models could easily be adapted and substituted into the program if required for special applications. The atmospheric region between 25 km and 115 km is simulated by a latitude-longitude dependent empirical model, which is a modification of the latitude dependent empirical model developed by Groves (1971), described more fully in this report. Between 90 km and 115 km, a smooth transition between the
modified Groves values and the Jacchia values is accomplished by a fairing technique. Below 25 km the atmospheric parameters are computed by a 4-D world-wide atmospheric model developed for NASA by Allied Research Associates (Spiegler and Fowler, 1972). Between 25 and 30 km an interpolation scheme is used between the 4-D results and the modified Groves values. Figure 1.1 presents a schematic summary of the Global Reference Atmospheric Model program atmospheric regions and how they are modeled.

The modifications to Groves model to produce longitude as well as latitude variations in the monthly mean were accomplished in two steps. For the original version, upper air summary map data for monthly means at the 10 mb level for 1966 and 1967 (NOAA, 1969b) and the 2 and 0.4 mb levels for 1966, 1967, and 1968 (NOAA, 1969a, 1970, 1971) were read and converted to values for the 30, 40, and 52 km levels. These upper air map values at the 2 and 0.4 mb levels were extended around the entire northern hemisphere by subjective extrapolation. For the earlier Mod 2 version of GRAM, additional 10 mb data for 1964 and 1965 (NOAA, 1967a) and 2 and 0.4 mb data for 1964 and 1965 (NOAA, 1967 b, c) and 1972 (NOAA, 1975) were also read and added to the earlier data. The 1972 2 and 0.4 mb data extended into the eastern hemisphere, so no extrapolation of it was necessary. Next the 30, 40, and 52 km latitude-longitude dependent values were extrapolated to 90 km by an extrapolation scheme developed by Graves, (1973). All of the map-generated and extrapolated data were converted to percent deviation from the longitudinal mean and these are applied as deviations (called stationary perturbations) to the Groves model values, which are taken as the latitude dependent longitudinal means.

The seasonal variations in the middle atmosphere (25-115 km) are assumed to be the same in northern and southern hemispheres with a six months' phase
Figure 1.1 Schematic summary of the atmospheric regions in the Global Reference Atmospheric Model (GRAM) program and the simulation methods used for mean monthly values in each region.
lag. That is, the southern hemisphere July is the same as the northern hemisphere January. In the 4-D region (<25 km) separate global coverage data values are available for each of the twelve months. A set of annual reference period data are also available for the 4-D and modified Groves regions. If the annual reference period is selected, the Jacchia section sets the exospheric temperature to 1000°K to represent annual mean conditions.

Below 25 km and above 90 km, the monthly mean geostrophic winds are computed from horizontal pressure gradients, estimated by finite differences. Near the equator, a newly devised interpolation scheme is used instead of the geostrophic relation (which approaches infinite values as the latitude approaches zero). In the height range 25 to 90 km, the newly developed spherical harmonic wind model is used, at all latitudes. Mean vertical winds, of the order of 1 cm/sec, are evaluated from the slopes of isentropic surfaces and the horizontal advective winds. Wind shear in the monthly mean horizontal wind is estimated from horizontal temperature gradients in the regions below 25 km and above 90 km. In the 25-90 km height range, mean wind shear is computed from finite differences of the spherical harmonic winds at adjacent height levels.

In addition to the monthly mean values of pressure, density and temperature, two types of perturbations are evaluated: quasi-biennial (QBO) and random. The QBO oscillations in pressure, density, temperature, and winds, empirically determined to be represented by an 870 day period sinusoidal variation, have amplitudes and phases which vary with height and latitude. The QBO amplitudes are primarily significant at low altitudes (≤ 20 - 40 km) at equatorial latitudes and at higher altitudes (50 - 60 km) at higher latitudes. For the earlier Mod 2 version, the QBO amplitudes and phases were newly
evaluated from a larger data set, which included MRN data through 1972.

For realistic simulation of actual atmospheric parameter values as they would likely be at any given time, random perturbations are also computed and applied as perturbations to the monthly mean values. The random perturbations are evaluated by a simulation technique which uses empirical values of variation magnitudes and scales to generate random perturbations which have realistic space and time correlations.

Originally the perturbation model was characterized by a single vertical scale and horizontal scale, and no attempt was made to insure compliance with constraints on the perturbation magnitudes, required by the perfect gas law (Buell, 1970) and hydrostatic equation (Buell, 1972). In an earlier report (Justus and Woodrum, 1975), the revisions were described which improved the data base of the perturbation magnitudes, and adjusted the magnitude profiles to insure compliance with the Buell constraints. For the earlier Mod 2 version reported here, the use of a two scale perturbation model was implemented. This model simulates separately the perturbations of small scale (e.g., turbulence and gravity waves) and large scale (e.g., tides and planetary waves) effects. These perturbations are treated stochastically, however--no deterministic model of these physical processes is used.

The following sections give a technical description of the Global Reference Atmospheric Model - Mod 3 with emphasis on the new additions, and new users manual descriptions of the program aspects of the revised model.
2. TECHNICAL DESCRIPTION OF THE MODEL

2.1 The Jacchia Section

The Jacchia (1970) model for the thermosphere and exosphere was originally implemented to compute atmospheric density at satellite altitudes. The Jacchia model accounts for temperature and density variations due to solar and geomagnetic activity, diurnal and semi-annual variations, and seasonal and latitudinal variations. The Jacchia model assumes a uniformly mixed composition from sea level to 105 km, with diffusive equilibrium among the constituents (nitrogen, oxygen, argon, helium, and hydrogen) above 105 km. Fixed boundary values for temperature and density are assumed at 90 km. Alterations, described in Justus et al. (1974 a), were made to allow atmospheric pressure to be computed from the density and temperature. Geostrophic winds are evaluated in the Jacchia section by computing horizontal pressure gradients with successive evaluations of the Jacchia model at different latitudes and longitudes.

2.2 The 4-D Section (below 25 km)

The 4-D atmospheric model, developed by Allied Research Associates (Spiegler and Fowler, 1972) was designed to extract from data tapes and interpolate on latitude and longitude, mean monthly and daily variance profiles of pressure, density, temperature, at 1 km intervals from the surface to a height of 25 km for any location on the globe. The data tapes contain empirically determined atmospheric parameter profiles at a large array of locations. The northern hemisphere grid array is equivalent to the NMC grid network. Grids spaced at 5 degree intervals of latitude and longitude are used in the equatorial and southern hemisphere regions.

Technical changes made in the 4-D program were: a modified latitude-
longitude interpolation method, previously described in Justus et al. (1974 a), an adjustment routine to modify the variance to comply with the Buell constraints, and a check routine to determine vertical and horizontal consistency of the 4-D data.

The method of application of the 4-D model in the GRAM program is as follows: at the first time that atmospheric parameters at a location below 30 km are required, a set of atmospheric profiles of monthly mean and daily variances of pressure, density, and temperature are generated at a 16 point grid of locations spaced at 5 degree latitude and longitude intervals (a slightly different grid is used near the poles). This grid of profiles, covering 15° x 15° of latitude-longitude is then stored in the computer and all further atmospheric parameter values in the 0-25 km range are found by interpolation between locations within this grid. If the trajectory goes outside this grid while the height remains below 25 km, the program attempts an estimate of the atmospheric parameters by an additional call on the routine which sets up the 4-D data grid.

The location of the grid points to be evaluated is determined dynamically based on the position and direction of travel along the trajectory when the 4-D grid is first required by a procedure described in Justus et al (1974 a). The 4-D data tapes normally contain data for the surface to 25 km in 1 km steps. At locations where the surface is at more than 1 km above sea level the surface value will be followed by one or more zero records, and the first non-zero record above the surface value will be at the lowest integer km higher than the surface. For example, if the surface is at 700 m then there will be data at surface, 1 km, 2 km, etc., but if the surface is at 1.3 km the data will contain the surface, one zero record, 2 km, 3 km, etc. In the Mod-3 version an
interpolation routine (based on the hydrostatic relation and constant lapse rate altitude segments) is used to fill in data between sea level and the first non-zero data above the surface. Interpolation is also used to fill in any missing data immediately below the 25 km height. The basic interpolation equations were described in Justus et al (1974 a).

2.3 The Modified Groves Section (25 - 90 km)

The starting point for the middle atmosphere (25 - 110 km) is the latitude dependent model of Groves (1971). This empirical model combines many observations from a wide range of longitudes. Observational results over approximately six years were used to compute longitudinal averages, which are presented versus latitude and month. Latitude coverage of the Groves model is from the equator to 70° or in some cases 80°. Southern hemisphere data were utilized in developing the Groves model as northern hemisphere data with a 6-month change of date. Tabulations of the Groves model are at intervals of 5 km in height, 10° in latitude (northern hemisphere), and one month in time (southern hemisphere displaced six months). If the Groves values of an atmospheric parameter y were known up to 80° latitude, then the 90° latitude Groves value was computed from

\[ y_{90} = \frac{4y_{80} - y_{70}}{3} \]  

(2.1)

If Groves values of the atmospheric parameter y were known only up to 70° latitude, then the 80° and 90° latitude Groves values was computed from

\[ y_{90} = \frac{9y_{70} - 4y_{60}}{5} \]  

(2.2)

\[ y_{80} = \frac{8y_{70} - 3y_{60}}{5} \]  

(2.3)

The Groves model data has only height and latitude variation for each month. For longitude variation, the Groves model data is modified by longitude,
latitude, and height dependent stationary perturbations. These stationary perturbations are derived, by methods described more fully in Justus et al. (1974 a) from 10, 2, and 0.4 mb map data and extrapolation up to 90 km. The stationary perturbations were evaluated at longitudes 10°, 40°, 70°, ... 340° for latitudes 10°, 30°, 50°, 70°, and 90°.

Originally, only the 1966 and 1967 10 mb monthly mean values (NOAA, 1969 b) were read and averaged. The 2 mb and 0.4 mb weekly mean maps for 1966, 1967, and 1968 (NOAA, 1969 a), 1970, 1971) were read for the first week of each month, and averaged over the three years. For the earlier Mod 2 version, additional 10 mb data for 1964 and 1965 (NOAA, 1967 a) and 2 and 0.4 mb data for 1964 and 1965 (NOAA, 1967 b, c) and 1972 (NOAA, 1975) were also read and added to the earlier data.

After the upper air chart data were averaged, the next step was to convert the readings to constant heights of 30, 40, and 52 km. This was done by assuming that the temperature followed a constant lapse rate between each chart level and the nearest interpolation altitude with lapse rates based on the Groves model.

In order to introduce longitude variability at heights above 52 km, the extrapolation technique of Graves et al. (1973) was used to project the 52 km interpolated chart data up to 90 km. The 5 extrapolation height levels are 60, 68, 76, 84, and 90 km.

After the chart data were interpolated to 30, 40, and 52 km and extrapolated to 60, 68, 76, 84, and 90 km, the stationary perturbations (relative deviations to be added to the Groves values) were calculated. At each altitude and latitude the stationary perturbation $s_y$ for a parameter $y$ (which can represent pressure, density, or temperature) was computed by the relation
\[ s_y = (y - \langle y \rangle) / \langle y \rangle \] (2.4)

where \( \langle y \rangle \) represents the longitude averaged value of \( y \) (i.e. averaged around a circle of fixed latitude). Note that the definition of \( s_y \) makes it be identically zero at the pole. The stationary perturbation \( s_y \) for parameter \( y \) is added to the Groves value \( G_y \) to produce the longitude variable modified Groves value \( G'_y \), according to the relation

\[ G'_y = G_y (1 + s_y) \] (2.5)

The modified Groves values, determined by relation (2.5) are used as the monthly mean values for the altitude range 30 to 90 km.

2.4 Interpolation and Fairing

The 4-D data are available on the data tapes at one km height intervals and at 5° x 5° latitude-longitude grids in the southern and equatorial areas and at the NMC grid locations in the northern hemisphere. NMC grid profiles are always converted (by interpolation) to 5° x 5° grids before interpolation to the trajectory locations. The general interpolation requirements for the 4-D section are height interpolation over 1 km and latitude-longitude interpolation over a 5° x 5° square grid.

The Groves data are tabulated at 5 km height intervals and 10° latitude intervals. Interpolation is required between these tabulated locations. The stationary perturbations are evaluated at 20° latitude and 30° longitude intervals and at 30, 40, 52, 60, 68, 76, 84, and 90 km altitudes. Interpolation between these tabulated locations is also required. For values between 25 km and 30 km interpolation between the 4-D data and Groves-plus-stationary-perturbation data are required. The interpolations are always carried out in the program by doing the latitude (Groves) or latitude-longitude (4-D) interpolation first, and
then doing the height interpolation.

The Jacchia model can be evaluated at any height above 90 km and at any latitude and longitude, so no interpolation is required. However, between 90 and 115 km there is overlap between the Groves data and the Jacchia model, so a fairing procedure is used to effect a smooth transition between the Groves data at 90 km and the Jacchia values at 115 km.

The method used to interpolate pressure, density, and temperature over a height interval between heights $z_1$ and $z_2$ is to assume linear variation of the temperature and of the logarithm of the density. The latitude interpolation for the Groves data is done by assuming linear variation between the latitudes $\phi_1$ and $\phi_2$ (which are at $\Delta \phi = 10^\circ$ apart). Two dimensional latitude-longitude interpolation between a square or rectangular array of positions at latitudes $\phi_1$ and $\phi_2$ and west longitudes $\lambda_1$ and $\lambda_2$, is done by the relation

$$F(\phi, \lambda) = F_0 + (F_1 - F_0) \phi + (F_2 - F_0) \phi + (F_3 - F_1 - F_2 + F_0) \phi_2 \phi \delta \lambda$$

where $\phi$ is $(\phi - \phi_1)/(\phi_2 - \phi_1)$ and $\delta \lambda$ is $(\lambda - \lambda_1)/(\lambda_2 - \lambda_1)$.

To accomplish smooth transition between the Groves values at 90 km and the Jacchia values at 115 km a fairing technique is used. This fairing technique was described in Justus et al (1974 a). The fairing is done only at the altitudes 95, 100, 105, 110, i.e. heights for which there are Groves values. Linear interpolation is then used to fill in the remaining heights, as discussed in the height interpolation section above.

Interpolation of the random perturbation magnitudes is done linearly on the variance ($\sigma^2$) rather than linearly on the magnitude ($\sigma$). This is because the Buell adjustment equations (see later sections) are nearly linear in the variances. Thus, once variances have been Buell adjusted, their adjustment would tend to be preserved by linear interpolation on variances, not
2.5 Geostrophic Winds

The eastward (i.e., blowing toward the east) wind component \( u \) and northward component \( v \) can be evaluated from the geostrophic wind equations

\[
\begin{align*}
    u &= -(1/\rho f) \frac{\partial p}{\partial y} \\
    v &= (1/\rho f) \frac{\partial p}{\partial x}
\end{align*}
\]  

(2.6)

(2.7)

where \( \rho \) is the density, \( f \) is the Coriolis parameter \( (2 \Omega \sin \phi) \) and \( \partial p/\partial x \) and \( \partial p/\partial y \) are the eastward and northward components of the horizontal pressure gradient. For evaluation in the model, the pressure gradient terms must be approximated by finite differences.

Geostrophic wind values are computed in the 4-D height range, by finite differencing of the 4-D pressure data, and in the Jacchia height range by evaluating the Jacchia model at 5 degree increments of latitude and longitude and taking finite differences of the resulting pressure. In a recent comparison between the GRAM-computed winds and observed winds at Eglin AFB, Florida, the mean deviation was 1 m/s EW and -16 m/s NS, with an rms deviation of 60 m/s between model and observed. Thus, the mean winds are modeled with fair accuracy, and the rms deviation is about the same as the wind perturbation magnitude expected on the basis of the GRAM perturbation model.

2.6 Thermal Wind Shear

The wind shear components \( \partial u/\partial z \) and \( \partial v/\partial z \) in the 0-25 km and above 90 km height ranges are evaluated by the thermal wind equations

\[
\begin{align*}
    \frac{\partial u}{\partial z} &= -(g/fT) \frac{\partial T}{\partial y} \\
    \frac{\partial v}{\partial z} &= (g/fT) \frac{\partial T}{\partial x}
\end{align*}
\]  

(2.8)

(2.9)
which is the usual form, leaving off a correction term in \( \partial T / \partial z \), which is normally small. The horizontal temperature gradient terms are estimated by finite differences in a similar manner to the pressure gradient components in equations (2.6) and (2.7).

Thermal wind shears are also computed in the Jacchia height range in a manner similar to that described for the wind calculations. Again, however, for the reasons already discussed, these values should not be taken as precise.

Since the ordinary geostrophic winds are inversely proportional to the coriolis parameter \( f \) (which goes to zero at the equator), these relations give unrealistically large winds at low latitudes. To overcome this problem interpolation between about +15° and -15° latitude is used in the MOD-3 version of GRAM. This interpolation limit, being on the "minimum geostrophic latitude," is specified in the program input.

2.7 The Spherical Harmonic Wind Model

The spherical harmonic equation, including terms through second order in co-latitude \( (\phi) \) and longitude \( (\theta) \), are:

\[
u(m, z, \theta, \phi) = a_1 P_0(\mu) + a_2 P_1(\mu) + [a_3 \cos \theta + a_4 \sin \theta] P_{11}(\mu) + a_5 P_2(\mu) + [a_6 \cos \theta + a_7 \sin \theta] P_{21}(\mu) + [a_8 \cos 2\theta + a_9 \sin 2\theta] P_{22}(\mu)\]

(2.10)

where \( \mu = \cos \phi \), \( m \) is month, \( z \) is height, \( u \) is either the wind component being modeled, and the \( a \) coefficients all depend on both \( m \) and \( z \). The \( P_{ij}(\mu) \) are Legendre functions given by
\[ P_0(\mu) = 1 \]
\[ P_1(\mu) = \mu \]
\[ P_2(\mu) = \frac{(3\mu^2 - 1)}{2} \]
\[ P_{11}(\mu) = \frac{(1 - \mu^2)^{1/2}}{2} \]
\[ P_{21}(\mu) = 3\mu(1 - \mu^2)^{1/2} \]
\[ P_{22}(\mu) = 3(1 - \mu^2) \]

(2.11)

With the substitution of (2.11) into (2.10), the spherical harmonic model representation for a wind component becomes

\[
u(m, z, \theta, \phi) = a_1 + a_2 \cos\phi + a_3 \cos\theta \sin\phi \\
+ a_4 \sin\theta \sin\phi + a_5(3 \cos^2\phi - 1)/2 \\
+ a_6 \cos\theta (3 \sin\theta \cos\phi) + a_7 \sin\theta (3 \sin\phi \cos\phi) \\
+ a_8 (2 \cos^2\theta - 1)(3 \sin^2\phi) + a_9 (2 \sin\theta \cos\theta)(3 \sin^2\phi)
\]

(2.12)

If (2.12) is the representation of the eastward wind component, then a completely analogous equation, with different coefficient values, is used to represent the northward wind component. Appendix A describes the data and processes used to evaluate the spherical harmonic coefficients which are used in the GRAM MOD-3. Values of the spherical harmonic coefficients used in the program are given in the "SCIDAT" data tape listing, in Appendix B.

Spherical harmonic winds are computed at all latitudes, within the height range 25-90 km. Geostrophic winds are used at latitudes above a selected "minimum geostrophic latitude," over the height ranges 0-20 and above 90. Smooth fairing between spherical harmonic winds and geostrophic winds is carried out between 20 and 25 km and between 90 and 95 km.
2.8 Mean Vertical Winds

GRAM also evaluates mean vertical winds from the slope of isentropic surfaces. On such surfaces, the entropy function $\psi$ is constant, where $\psi$ is

$$\psi = C_p T + gz + (u^2 + v^2)/2 = \text{const.} \quad (2.13)$$

Therefore, on isentropic surfaces

$$\frac{\partial \psi}{\partial t} + u\frac{\partial \psi}{\partial x} + v\frac{\partial \psi}{\partial y} + w\frac{\partial \psi}{\partial z} = 0 \quad (2.14)$$

and, if $\frac{\partial \psi}{\partial t}$ is assumed zero, the vertical wind $w$ can be solved for as

$$w = -\frac{[u\frac{\partial \psi}{\partial x} + v\frac{\partial \psi}{\partial y}]}{[\frac{\partial \psi}{\partial z}]} \quad (2.15)$$

By differentiation of (2.13), with the assumption that $u$ and $v$ are the geostrophic winds $U_g$ and $V_g$, and that $\frac{\partial u}{\partial z}$ and $\frac{\partial v}{\partial z}$ are given by the thermal wind relations, (2.15) becomes

$$w = -\frac{C_p [u(\frac{\partial T}{\partial x}) + v(\frac{\partial T}{\partial y})]}{[g + C_p(\frac{\partial T}{\partial z}) + (g/ft)(v(\frac{\partial T}{\partial x}) - u(\frac{\partial T}{\partial y}))]} \quad (2.16)$$

Mean vertical winds evaluated by (2.16) are generally less than a cm/sec, and hence are realistic values for the large scale mean vertical winds affecting mean meridional circulation.

2.9 The Quasi-Biennial Perturbations

In the Mod-0 Global Reference Atmospheric Model, MRN data from 1964-1969 were used to evaluate quasi-biennial amplitudes and phases in the height range 25-65 km. The quasi-biennial period which produce minimum variance, when simultaneously evaluating the annual, semi-annual, and quasi-biennial variation, was found to be 870 days. For the Mod 2 version, the harmonic analysis was done the same way with MRN data for 1970-1972 added to the original data base. Again, the 870 day period was found to produce
minimum variance for the QBO winds, while a 900 day period did slightly better for the thermodynamic variables. In order to retain a single period, the original 870 day period was chosen as still the preferable value overall. The revised quasi-biennial magnitudes and phases are listed in the "SCIDAT" data tape listing at the end of this report (Appendix B).

2.10 The Two-Scale Random Perturbation Model

The original single scale perturbation model in the Global Reference Atmosphere Model (Justus et al., 1974 a) was evaluated by the following method: first the density perturbation $\rho_2'$ at the new location was computed from $\rho_1'$ the density perturbation at the previous location by the relation

$$ \left( \rho_2'/\rho_2 \right) = A(\rho_1'/\rho_1) + B r_1 $$

(2.17)

where $\rho_1$ and $\rho_2$ are the known mean densities at the previous and new positions, $A$ and $B$ are determined from the required conditions, and $r_1$ is a random number selected from a Gaussian distribution with mean zero and unit standard deviation. The required conditions to be used in determining $A$ and $B$ are

$$ \langle \rho_2' \rho_1' \rangle = R \sigma_{\rho_1} \sigma_{\rho_2} $$

(2.18)

$$ \langle \rho_2'^2 \rangle = \sigma_{\rho_2}^2 $$

(2.19)

where $\sigma_{\rho_1}$ and $\sigma_{\rho_2}$ are the known standard deviations in density at the previous and new location, and $R$ is the known autocorrelation in density perturbations between the previous and new locations. Next (with analogous notation as in (2.17) through (2.19), the new temperature perturbation was computed by

$$ \left( T_2'/\bar{T}_2 \right) = C(T_1'/\bar{T}_1) + D(\rho_2'/\bar{\rho}_2) + E r_2 $$

(2.20)

In addition to the autocorrelation $R$ (assumed the same for $T'$ and $\rho'$ in the
original one-scale model) the cross correlation \( (R_{PT})^2 \) was also maintained (through the coefficient \( D \) in equation (2.20)). The correlation \( (R_{PT})^2 \) was determined from the known standard deviations and means by the Buell (1970) relation

\[
(R_{PT})^2 = \frac{[(\sigma_{\rho}^2/\bar{\rho}_p)^2 - [(\sigma_{\rho}^2/\bar{\rho}_p)]^2 - [(\sigma_T^2/T_p)]^2}{2[(\sigma_{\rho}^2/\bar{\rho}_p)] [(\sigma_T^2/T_p)]}
\]  

(2.21)

Once the density and temperature perturbations were evaluated, the pressure perturbation was determined via

\[
(p_2'/p_2) = (\rho_2'/\bar{\rho}_p) + (T_2'/T_p)
\]  

(2.22)

which is a first order perturbation equation from the perfect gas law. In the original single scale perturbation model, wind perturbation components \( u' \) \( v' \) were assumed to be uncorrelated with each other and with the thermodynamic variables, and hence were computed by relations analogous to equation (2.17).

In the original one-scale model, only the total perturbations are considered (e.g. \( \rho = \bar{\rho} + \rho' \)) while in the new two scale model the perturbations are assumed to be made up of a large scale and small scale component (e.g. \( \rho = \bar{\rho} + \rho_L + \rho_S \)). To first order in the perturbations the state of the mean atmosphere is described by

\[
\bar{\rho} = \bar{\rho} R \bar{T}
\]  

(2.23)

and the mean plus large scale perturbations by

\[
(\bar{\rho} + \rho_L) = (\bar{\rho} + \rho_L) R(\bar{T} + T_L)
\]  

(2.24)

and the actual atmospheric parameters \( p, \rho, \) and \( T \) by

\[
p = \rho R T
\]  

(2.25)

Division of equations (2.24) and (2.25) by \( \bar{\rho} \) on the left and by \( \bar{\rho} R \bar{T} \) on the
right yields, to first order in the perturbations

\[ \frac{\rho_L}{\bar{\rho}} = \frac{\rho_L}{\bar{\rho}} + \frac{\rho_L}{\bar{\rho}} + \frac{\rho_L}{\bar{\rho}} + \frac{\rho_L}{\bar{\rho}} + \frac{\rho_L}{\bar{\rho}} + \frac{\rho_L}{\bar{\rho}} \]  \tag{2.26}

\[ \frac{\rho_s}{\bar{\rho}} = \frac{\rho_s}{\bar{\rho}} + \frac{\rho_s}{\bar{\rho}} + \frac{\rho_s}{\bar{\rho}} + \frac{\rho_s}{\bar{\rho}} + \frac{\rho_s}{\bar{\rho}} + \frac{\rho_s}{\bar{\rho}} \]  \tag{2.27}

These results mean that the small scale and large scale perturbations each separately must obey the Buell triangle relationships for their magnitudes. Thus, analogous to equation (2.21), the correlations \( R_{\rho_L T_L} \) for large scale perturbations and \( R_{\rho_s T_s} \) for small scale perturbations are given in terms of their respective magnitudes by

\[ R_{\rho_L T_L} = \frac{(\sigma_{\rho_L} / \bar{\rho})^2 - (\sigma_{\rho_L} / \bar{\rho})^2 - (\sigma_{T_L} / T)^2}{2(\sigma_{\rho_L} / \bar{\rho})(\sigma_{T_L} / T)} \]  \tag{2.28}

\[ R_{\rho_s T_s} = \frac{(\sigma_{\rho_s} / \bar{\rho})^2 - (\sigma_{\rho_s} / \bar{\rho})^2 - (\sigma_{T_s} / T)^2}{2(\sigma_{\rho_s} / \bar{\rho})(\sigma_{T_s} / T)} \]  \tag{2.29}

The large and small scale components are assumed to be independent so correlations such as \( R_{\rho_s T_L} \), \( R_{\rho_L T_s} \) etc. are taken to be zero.

The density perturbations \( \rho_{L_2} \) and \( \rho_{S_2} \) at the new position are thus computed from the known perturbations \( \rho_{L_1} \) and \( \rho_{S_1} \) at the previous position by relations analogous to equation (2.17)

\[ \frac{(\rho_{L_2} / \bar{\rho})}{\rho_{L_1}} = A_L (\rho_{L_1} / \bar{\rho}) + B_L r_{L_1} \]  \tag{2.30}

\[ \frac{(\rho_{S_2} / \bar{\rho})}{\rho_{S_1}} = A_S (\rho_{S_1} / \bar{\rho}) + B_S r_{S_1} \]  \tag{2.31}

where \( A_L, B_L, A_S \) and \( B_S \) can each be determined (as before) from the conditions
where the density autocorrelations $R_L(\rho)$ and $R_S(\rho)$ are determined from the known horizontal and vertical scale of the large scale and small scale perturbations (see the following section on scales). Similarly, the temperature perturbations are computed (analogous to equation (2.20) by

$$
\left( \frac{T_{L2}}{T_2} \right) = C_L \left( \frac{T_{L1}}{T_1} \right) + D_L \left( \frac{\rho_{L2}}{\rho_L} \right) + E_L r_{L2}
$$

$$
\left( \frac{T_{S2}}{T_2} \right) = C_S \left( \frac{T_{S1}}{T_1} \right) + D_S \left( \frac{\rho_{S2}}{\rho_S} \right) + E_S r_{S2}
$$

where again $D_L$ and $D_S$ are determined by the required cross correlations $R_{\rho_S T_S}$ and $R_{\rho_L T_L}$ at the new position, as computed from equations (2.28) and (2.29).

Once the density and temperature perturbations are computed, the pressure perturbations are evaluated from equations (2.26) and (2.27).

A further addition to the new model has been brought about by empirically evaluated correlations $R_{u_L v_L}$, $R_{u_S v_S}$, $R_{u_L \rho_L}$, and $R_{u_S \rho_S}$. The new method of evaluating the velocity perturbation components is somewhat analogous to that employed for the temperature component. The equations used are

$$
u_{L2} = F_{LU_L} + G_{L \rho_{L2}} + H_L r_{u_L}
$$

$$
u_{S2} = F_{SU_L} + G_{S \rho_{S2}} + H_S r_{u_S}
$$
and

\[ v_L = I_L v_{L_1} + J_L u_{L_2} + K_L r_{v_L} \] (2.40)

\[ v_S = I_S v_{S_1} + J_S u_{S_2} + K_S r_{v_S} \] (2.41)

where the coefficients \( G_L \) and \( G_S \) are determined from the newly evaluated correlations \( R_{u_L \rho_L} \) and \( R_{u_S \rho_S} \), and the coefficients \( J_L \) and \( J_S \) are evaluated from the correlations \( R_{u_L v_L} \) and \( R_{u_S v_S} \).

For evaluation of the coefficients \( C, D, \) and \( E \) in (2.36) and (2.37), and the coefficients \( F \) through \( K \) in (2.38) through (2.41), these equations are successively multiplied through by the perturbation quantities on the right-hand side (see Appendix B in Justus et al., 1974 a). The relations thus established for the coefficients \( A \) through \( K \) (with analogous equations for both large scale \( A_L - K_L \) and small scale \( A_S - K_S \)) are

\[ A = R(\rho) \frac{\sigma_{\rho_2}}{\sigma_{\rho_1}} \] (2.42)

\[ B = \frac{\sigma_{\rho_2}}{\sigma_{\rho_1}} \left[ 1 - R^2(\rho) \right]^{1/2} \] (2.43)

\[ C = \left[ R(T) \frac{\sigma_{T_2}}{\sigma_{T_1}} \right] \left[ 1 - R_{T_2 \rho_2} R_{T_1 \rho_1} \right]/ \left[ 1 - R^2(T) R_{T_1 \rho_1} \right] \] (2.44)

\[ D = \left[ R(T) \frac{\sigma_{T_2}}{\sigma_{T_1}} - C_2 \right]/(A \left( \sigma_{T_1 \rho_1} \sigma_{T_1} \right)) \] (2.45)

\[ E = \left[ \frac{\sigma_{T_2}}{\sigma_{T_1}} - C_2 \frac{\sigma_{T_1}}{\sigma_{\rho_2}} - D^2 \right]^{1/2} \]

\[ 2 \sigma_{T_2} \sigma_{T_1} \sigma_{\rho_2} \]

\[ F = \left( \frac{\sigma_{u_2}}{\sigma_{u_1}} \right) \left[ \left( R(u) - R(\rho) \right) R_{u_2 \rho_2} R_{u_1 \rho_1} \right]/ \left[ 1 - R^2(\rho) R_{u_1 \rho_1} \right] \] (2.46)
\[ G = \frac{R(u)}{\sigma_{u_2} - F \sigma_{u_1}} / \left[ R(p) \sigma_{u_1} \sigma_{u_2} \right] \] (2.48)

\[ H = \left[ \sigma_{u_2}^2 - F^2 \sigma_{u_1}^2 - G^2 \sigma_{u_2}^2 - 2 F G R(p) \sigma_{u_1} \sigma_{u_2} \right]^{1/2} \] (2.49)

\[ I = \frac{(\sigma_{v_2}/\sigma_{v_1}) \left[ (R(v) - R(p) R_{v_2}^2 R_{v_1}^2) \right]}{[1 - R^2(p) R_{v_1}^2]} \] (2.50)

\[ J = \frac{R(v) \sigma_{v_2} - I \sigma_{v_1}}{[R(p) R_{v_1}^2 \sigma_{v_2}]} \] (2.51)

\[ K = \left[ \sigma_{v_2}^2 - I^2 \sigma_{v_1}^2 - J^2 \sigma_{v_2}^2 - 2 I J R(p) \sigma_{v_1} \sigma_{v_2} \right]^{1/2} \] (2.52)

where the autocorrelations of density \( R(p) \), temperature \( R(T) \) and wind \( R(u) \) (\( R(u) \) and \( R(v) \) are assumed equal), are determined from the horizontal and vertical scales \( L_Z, L_H, L_T, L_Z, L_H, L_T \) and \( L_H, L_T \) by the relations

\[ R(p) = \exp \left\{ - \left[ \frac{\Delta x^2 + \Delta y^2}{L_H^2} + \frac{\Delta z^2}{L_Z^2} \right]^{1/2} \right\} \] (2.53)

\[ R(T) = \exp \left\{ - \left[ \frac{\Delta x^2 + \Delta y^2}{L_H^2} + \frac{\Delta z^2}{L_Z^2} \right]^{1/2} \right\} \] (2.54)

\[ R(u) = \exp \left\{ - \left[ \frac{\Delta x^2 + \Delta y^2}{L_H^2} + \frac{\Delta z^2}{L_Z^2} \right]^{1/2} \right\} \] (2.55)
3. SAMPLE RESULTS

The ability of the GRAM program to model pressure, density, and temperature fields has been well documented in earlier reports (Justus, et al., 1974 a, b, 1975, 1976). The results shown here are confined to the new spherical harmonic wind model simulations of wind components in the 25 to 90 km height range. Figures 3.1 through 3.12 show observed and spherical harmonic model winds at three low-latitude sites (Kwajalein, Ft. Sherman and Ascension) at mid-latitude and high-latitude northern hemisphere sites (Kennedy SFC, and Ft. Churchill, respectively) and at a southern hemisphere site (Woomena), for the months of June and December. In all cases, the spherical harmonic model winds are seen to reproduce fairly well the features at the observed winds.

Data sources and methods used to evaluate the spherical harmonics appear in Appendix A. The spherical harmonic coefficient values are given in the SCIDAT tape listing in Appendix B.
Figure 3.1. Observed (■ E-W, □ N-S) and Spherical Harmonic Model (□ E-W, ○ N-S) Winds for June at Kwajalein.
Figure 3.2. As in Figure 3.1 for Fort Sherman
Figure 3.3. As in Figure 3.1 for Ascension.
Figure 3.4. As in Figure 3.1 for Kennedy SFC.
Figure 3.5. As in Figure 3.1 for Fort Churchill.
Figure 3.6. As in Figure 3.1 for Woomera.
Figure 3.7. As in Figure 3.1 for December, Kwajalein.
Figure 3.8. As in Figure 3.1 for December, Fort Sherman.
Figure 3.9. As in Figure 3.1 for December, Ascension.
Figure 3.10. As in Figure 3.1 for December, Kennedy SFC.
Figure 3.11. As in Figure 3.1 for December, Fort Churchill.
Figure 3.12. As in Figure 3.1 for December, Woomera.
The Global Reference Atmospheric Model (GRAM) program is designed to produce atmospheric parameter values either along a linear path (to be called a profile) with automatically stepped constant height, latitude, and longitude increments, or along any set of connected positions (to be called a trajectory) which must be input individually into the program.

There are three general types of input to the GRAM program: (1) A set of three cards, called the initial data, which contain the values of the program options, the initial position, the profile increments, and other information required before the calculations are begun, (2) A data tape (SCIDAT) containing parameter values for the Groves (1971) model, the stationary perturbations (deviations from the Groves model, to produce longitude varying monthly means), and random and quasi-biennial perturbation parameter values, and (3) The data tapes with one data file for each month, containing profiles of monthly mean pressure, density, temperature, and their variances from the surface to 25 km, for the entire globe. If it is desired to compute atmospheric parameters along a trajectory instead of a linear profile, then a fourth type of data - the trajectory times and positions - must be input.

In terms of program function, the major elements of the GRAM program are the main segment (GRAM), the subroutine SCIMOD, which is a driver for all of the atmospheric evaluation subroutines, and SETUP, a subroutine used to read the SCIDAT data tape, and load the necessary starting conditions for execution. Figure 4.1 shows a simplified schematic of the main segment and illustrates the function of the SETUP and SCIMOD subroutines.

Output of the GRAM program consists of monthly mean pressure, density, temperature, wind and wind shear, total (mean plus perturbation) values of
Figure 4.1: Simplified flow chart of the GRAM program.
pressure, density, temperature, winds, perturbation values, and magnitudes.

Complete discussion of the input, output, and program operation characteristics for the GRAM program are given in the following sections of the users manual.

4.1 The 4-D Data Tapes (0-25 km)

The description contained in this section was paraphrased from the 4-D program users manual (Fowler and Willard, 1972). For more information on the 4-D section of GRAM, consult that document and Spiegler and Fowler (1972).

The world-wide meteorological data set developed for the 4-D model by Allied Research Associates is stored on three 7-track, 800 bpi binary tapes labelled WWIA-WW3A. Each tape contains four files of data where one file represents one month; WW1A contains months 1-4, WW2A contains months 5-8, and WW3A contains months 9-12. A 13th month containing the annual reference period has been added as a fourth tape.

Within each file are 3490 records representing the values at individual grid points. These points are grouped into three grids: 288 points on the northern hemisphere equatorial (EQN) grid; 1977 points on the northern hemisphere (National Meteorological Center) grid; and 1225 points on the southern hemisphere (SH) grid. On the NMC grid, the data were computed at NMC points and stored in the order given by the NMC grid table shown in the SCIDAT data tape listing in Appendix B. On the other two grids, the data was given at 5° latitude-longitude intersections westward from the Greenwich Meridian to 5° east. The EQN grid covers the latitudes from 0° to 15° north with points occurring in the following order: 1-4 = Lon. 0, Lat. 0, 5, 10, 15; 5-8 = Lon. 5W, Lat. 0, 5, 10, 15; ... 285-288 = Lon. 5° E, Lat. 0, 5, 10, 15. The SH grid contains all data from 5° south to the south
pole as follows: 1 = South Pole, 2-18 = Lon. 0, Lat. -5 to -85; 19-35 = Lon. $5^\circ$ W, Lat. -5 to -85; ... 1209 - 1225 = Lon. $5^\circ$ E, Lat. -5 to -85. It should be noted that the south pole is given only once, as the first point of the SH data set.

Each record consists of 106 36-bit words where the first 104 words contain the computed data for a point and the last two are identifiers. All data values are multiplied by 100 and converted to integer; they are then packed with two 18-bit values to a word. The data is arranged by level for each parameter; thus, the first 13 words contain the pressure means from the surface to 25 km and the next 13 words contain the pressure variances for the same levels. This pattern continues for the 26 levels of temperature means and variances, moisture means and variances, and density means and variances.

Word 105 contains the latitude and longitude of the point in question. There are integer values that have been multiplied by 10; each occupies 18 bits of the word. The latitude is always positive (since the southern hemisphere is identified by grid), and the longitude is always west.

The last word contains three 12 bit integer values. The left-most group of bits is the homogeneous moisture region in which the point lies, the center group is the point number, and the right-most group of bits is the month. It should be noted that the points are numbered within the grid that contains them, and not by their location on tape. Thus the point numbers run from 1-288, 1-1977, and 1-1225, not from 1-3490. Figure 4.2 shows the tape structure for one month.

4.2 The SCIDAT Data Tape

This section describes in detail the data contained on the SCIDAT data tape. A listing of this tape, and a synopsis of the data contained on
This box represents 26 integer values of pressure in millibars \( \times 10^2 \). Each value is packed sequentially as an 18 bit byte, starting with the surface and ending with the 25 km value.

Variances are the square of the standard deviations.

RM denotes end of record mark.

EOF Denotes end of file mark.

<table>
<thead>
<tr>
<th>P</th>
<th>Pressure ((\text{mb} \times 10^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P_v)</td>
<td>Pressure Variance ((\text{mb}^2 \times 10^2))</td>
</tr>
<tr>
<td>T</td>
<td>Temperature ((^0\text{K} \times 10^2))</td>
</tr>
<tr>
<td>(T_v)</td>
<td>Temperature Variance ((^0\text{K}^2 \times 10^2))</td>
</tr>
<tr>
<td>M</td>
<td>Moisture ((\text{g/m}^3 \times 10^2))</td>
</tr>
<tr>
<td>(M_v)</td>
<td>Moisture Variance ((\text{g}^2/\text{m}^6 \times 10^2))</td>
</tr>
<tr>
<td>D</td>
<td>Density ((\text{g/m}^3 \times 10^2))</td>
</tr>
<tr>
<td>(D_v)</td>
<td>Density Variance ((\text{g}^2/\text{m}^6 \times 10^2))</td>
</tr>
<tr>
<td>L</td>
<td>Word 105 Containing Latitude and Longitude</td>
</tr>
<tr>
<td>N</td>
<td>Word 106 Containing Homogeneous Region Number, MSF Point Number, and Month Number</td>
</tr>
</tbody>
</table>

Figure 4.2: Record Structure on the 4-D Data Tapes
NMC Grid Data. This data set gives the 4-D northern hemisphere point number and the dual index for the corresponding NMC location. The NMC grid locations form an octagonal array, centered on the North Pole. The points are at square grid locations on the polar projection used for the NMC grid. A conversion between the latitude and longitude (treated as polar coordinates on the flat NMC grid plane) and the NMC grid indices (treated as Cartesian coordinates on the projection plane) is accomplished by a polar to Cartesian coordinate transformation, via equations programmed into the 4-D model. The NMC grid data on the SCIDAT tape merely establishes the equivalence between the sequential 4-D NMC point number and the two-dimensional x-y NMC grid point location. The NMC grid data constitute the first file on the SCIDAT tape. An end of file marker appears on the tape at the end of the NMC grid data. The NMC grid data file contains 396 FORTRAN readable records with code "N" and 15 integers (A2, 1517 Format) in each record.

Groves Data. The Groves (1971) data for monthly mean pressure, density, and temperature are tabulated at 10 degree latitude intervals from 0 to 90° for each month. The yearly average Groves data is coded as month 13. The southern hemisphere data is the same as the northern hemisphere data displaced by 6 months. Annual mean (month 13) data is the same for both northern and southern hemispheres.

The format of the Groves data is the same as in Groves (1971) original report, except that a prefix code P, D, or T has been added at the front of each record. Each record contains the code, the month, the height in km and the 0, 10, 20, ..., 90° latitude values of the parameter expressed as a three digit integer, with an exponent common to all of the values in the field appearing at the end of the record. Thus a value of 276 with an expon-
ent at the end of the record of -6, would be the same as $276 \times 10^{-6} = 2.76 \times 10^{-4}$. Pressure data are in units of N/m$^2$, density values are in kg/m$^3$, and temperatures are in °K. The Groves data set contains 702 FORTRAN readable records with 13 integer values (13I7) in each record (following the code word P, D, or T, in A2 format).

Stationary Perturbations. The stationary perturbations are latitude-longitude dependent relative perturbations to be applied to the Groves values, considered to be the longitudinal mean value. Data for each of 12 months and for the annual reference period (month 13) are given for the northern hemisphere latitudes. Southern hemisphere data are the same as the northern hemisphere values displaced by 6 months.

Each record contains the code S, the month, the height in km, the west longitude, in degrees, and then 15 values of stationary perturbations in per mill (%/10). The first five of the values are for pressure perturbations at latitudes 10, 30, 50, 70, and 90. The next five values are for density, and the last five values are for temperature. The monthly mean value $y_m$ for parameter $y$ at any latitude and longitude can be computed from the Groves value $G_y$ at the latitude and the stationary perturbation $s_y$ (in per mill) at the latitude and longitude by the relation

$$ y_m = G_y \left(1 + \frac{s_y}{1000}\right) $$

Note that the stationary perturbation values at $90^\circ$ latitude are always zero. However, there is a place for $90^\circ$ values on the data tape, so that if a systematic departure from Groves values is desired at the poles, a set of stationary perturbation data reflecting this condition could be developed and put on the tape. The stationary perturbations listed on the Mod-3 SCIDAT tape have been revised, as described in Section 2, by the addition of data.
read from 1964, 1965, and 1972 upper air charts.

The Groves data and stationary perturbation data constitute the second file on the SCIDAT tape. An end of file marker appears at the end of the stationary perturbation data. The stationary perturbation code S data consists of 1248 FORTRAN readable records, with 18 integer values (18I7) (following the code word S A2 format).

The Random Perturbation Data. Random perturbation magnitudes (standard deviations) are latitude dependent only. Each code R record has the code, the month (1-13) and the height in km, followed by 15 values of random perturbation magnitude, five for pressure (in per mill, at latitudes 10, 30, 50, 70, and 90), five for density, and five for temperature. These data give the relative standard deviations $\sigma_p/p$, $\sigma_\rho/\rho$, and $\sigma_T/T$, for use in the random perturbation model.

The code RW data are similar, except that only ten wind values appear in each record (after the code, month, and height): five for eastward wind magnitude (in m/s at latitudes 10, 30, 50, 70, and 90) and five for northward wind magnitude.

The code R and RW total perturbation magnitudes have been revised by the incorporation of new data sources, as described in Justus and Woodrum, (1975). The code R data have also been subjected to Buell (1970, 1972) adjustment, also described in Justus and Woodrum (1975).

The code R and RW data constitute the third file on the SCIDAT tape. An end-of-file mark appears on the tape at the end of the code RW data. The code R data consist of 260 FORTRAN readable records with 17 integer values (17I7) in each record following the code word R (A2). For the code RW data, there are 325 records with the code word RW and 12 integers (A2, 12I7).
Large Scale Fraction Data. From daily difference analysis described in Section 2, the fraction of the total variance \(\sigma^2\) from code R and RW data) contained in the large scale perturbations has been determined as a fraction of height and latitude. Separate evaluations by month were also made, but were not found to be significantly different from the annual averages. Therefore the SCIDAT tape contains only the annual average fraction (expressed as per mill) of total variance contained in the large scale.

Large scale and small scale magnitudes \(\sigma_L\) and \(\sigma_S\) are computed from the fractional data \(f_L\) in per mill (code P for pressure, density, and temperature or code PW for winds), by the relations

\[
\sigma_L = \sqrt{f_L/1000} \sigma_T \tag{4.2}
\]

\[
\sigma_S = \sqrt{1 - f_L/1000} \sigma_T \tag{4.3}
\]

where \(\sigma_T\) is the total perturbation magnitude (code R or code RW data). The code P and code PW data sets each contain 25 FORTRAN readable records, with code word P or PW, followed by 17 integer values (A2, 1717) on each record.

Density-Velocity Correlations. Daily difference analysis described in Section 2 was also used to evaluate the cross correlations \(R_{up}\) and \(R_{vp}\) for use in the velocity perturbation model (equations (2.38) - (2.41) and (2.44) - (2.50)). Both large scale and small scale values of the density-velocity correlations were evaluated, and are given on the SCIDAT data tape (codes CL and CS) in per mill (i.e. divide by 1000 to get correlations in the range -1 to +1).

The code P large scale fraction data and the code CS and CL density-velocity correlation data constitute the fourth file on the SCIDAT tape. An end-of-file mark appears on the tape at the end of the code CL data.
code CS and CL data consist of 50 FORTRAN readable records, with code word CS or CL, followed by 12 integer values (A2, 1217) in each record.

The Quasi-Biennial Oscillation (QBO) Data. The QBO data consists of height and latitude dependent amplitudes and phases for quasi-biennial variations in pressure (QP), density (QD), temperature (QT), and eastward and northward wind components (QU and QV, respectively). The amplitude of the QBO thermodynamic parameters are in per mill (%/10). The amplitudes of the QBO wind components are in decimeters per second (0.1 m/s). The phases of all of the QBO parameters are measured in days after January 0, 1966 for the occurrence of the first maximum value. Since the period of the QBO variations is taken to be 870 days, the phases could vary from 0 to 870.

Each QBO data record contains the code, the height in km, the amplitude and phase for 10° latitude, the amplitude and phase for 30° latitude, etc. out to the amplitude and phase for 90° latitude. There are 80 FORTRAN readable records in the QBO data set. Each record contains 11 integer values followed by a code word (QP, QD, QT, QU, or QV).

An end of file mark appears at the end of the code QV data.

The Spherical Harmonic (SP) Data. The spherical harmonic coefficient data consists of values of the 9 spherical harmonic coefficients (equation 2.12) for both northward and eastward wind components. Each record consists of the code (SP), the height (km), the month, and 9 spherical harmonic coefficients (in cm/s). Eastward wind component coefficients are first, followed by northward wind component coefficients.

A final end-of-file mark appears at the end of the SP data. Appendix B gives a brief summary of the data on the SCIDAT tape and a listing of all the values appearing in the tape records.
4.3 The Initial Input Data

The initial input data consists of two free field (no set format with commas after each number) cards containing initial position data, program options, and other information required to begin computation, plus an optional third free field card to give initial random perturbation data if random perturbations are to be computed, plus an optional set of trajectory position data cards (followed by a backup card), if trajectory positions are to be read in rather than a linear profile generated automatically in the program. Appendix C gives a brief summary of the input characteristics, a summary of the data deck setup, and some sample input and output for the program. The following gives a more detailed description of each program input card.

Input Card Number 1. The first input card, read in by the main program segment PROFILE in free field format contains the following information. Designation R indicates real quantities, I denotes integer quantities.

1. Initial Height (R): The initial height in km for the beginning point of the profile or trajectory. This can be any non-negative real number. Atmospheric parameters are never evaluated at the first position, which is used only to establish the initial conditions.

2. Initial Latitude (R): The latitude of the initial position in degrees, with southern latitudes negative. If the initial latitude, or any subsequent latitude is greater than 90° in absolute magnitude, then a transformation

\[
\text{lat} = (180° - |\text{lat}|)(\text{lat}/|\text{lat}|) \quad (4.4)
\]

\[
\text{lon} = \text{lon} + 180° \quad (4.5)
\]

is made.

3. Initial West Longitude (R): The west longitude of the initial
position in degrees. East longitude can be put in as negative or converted
to 0 - 360° west longitude. If negative (east) longitudes are input they
are converted to the 0 - 360° scale before being used by the program. At
any time during the run if a longitude gets outside the 0 - 360° range it
is put back into that range by adding or subtracting 360°, as necessary.

4. **F10.7 (R)**: The solar 10.7 cm radio noise flux in units of 10^{-22}
   watts/m^2 (the normal units for this parameter) at the time for which the
   atmospheric values are to be computed. This factor is used only in the
   Jacchia section, so a value of zero can be used on input if the height never
goes above 90 km. A value of 230 for both design steady state conditions
   and for maximum conditions may be used, or consult the Aerospace Environ-
   ment Division (AED) of Marshall Space Flight Center (MSFC) for monthly pre-
   dictions.

5. **Mean F10.7 (R)**: The 81 day mean solar 10.7 cm radio flux. This
   parameter is used in the Jacchia section to compute the nighttime minimum
   global exospheric temperature (equation (14) in Jacchia, 1970). Use zero
   if the height does not go above 90 km. A value of 230 may be used for both
design steady state or maximum conditions, or consult the AED or MSFC for
   monthly predictions.

6. **AP (R)**: The geomagnetic index a_p, used to compute a geomagnetic
   correlation to the exospheric temperature, in equation (22) of Jacchia,
   (1970). Use zero if the height does not go above 90 km. A design steady
   state value of 20.3 and a maximum condition value of 400 may be used for
   a_p, or consult the AED at MSFC for monthly predictions.

7-9. **Date (I)**: The date, for the starting time of the trajectory
   or profile evaluation in month/day/two digit year form, as three integer in-
put values. The day of the month and the year have no direct effect on the program calculations, except in the case of the quasi-biennial oscillation terms. For the annual reference period, use month 13. The quasi-biennial terms are automatically set to zero if month 13 is used. The month is used to establish which Groves data, stationary perturbation data, and random data (including large scale fractions and velocity-density correlations) to load from the SCIDAT data tape into the working arrays. The program will work more efficiently if multiple trajectories or profiles are evaluated during one run operation and the months are the same. (This avoids repeated look-up of the Groves, stationary perturbation, and random data from the SCIDAT tape.)

10-12. **Greenwich Time (I)**: The Greenwich mean time for the starting position in hours, minutes, and seconds as three integer values. Only the Jacchia section is directly affected by the time of day, so unless the height goes above 90 km, the starting time would serve merely as a reference parameter for the particular run being done. Greenwich time corresponding to a local time of 0900 hours should be used for design steady state Jacchia section conditions, and for maximum conditions the local time should be taken as 1400 hours.

13. **Latitude Increment (R)**: If a linear profile is to be generated automatically this is the latitude increment (in degrees) between successive profile positions. The new latitude would be the old latitude plus the latitude increment. For a profile with decreasing latitude (going southward) the increment must be negative. Use zero if separate trajectory position input is to be read in. If a vertical profile (i.e. changing only height) is to be evaluated, then use zero latitude increment.
14. **West Longitude Increment (R):** If a linear profile is to be generated automatically this is the west longitude increment (in degrees) between successive profile positions. The new longitude will be the old longitude plus the longitude increment. For a profile progressing eastward use a negative increment. Use zero if separate trajectory position input is to be read in. If a vertical profile is to be evaluated, then use zero increment.

15. **Height Increment (R):** The height decrease in km between successive positions, for an automatically generated linear profile. The profiles normally are generated downward (descending height). (New height = old height minus the height increment). If an upward generated profile is desired the height increment should be negative. Downward generated profiles will be evaluated until the height is incremented to a negative value or until the maximum number of positions (item 16, 1st card) is exceeded.

16. **Maximum Number of Positions (I):** The maximum number of profile positions to be generated automatically. This does not include the initial position, for which no atmospheric parameters are evaluated. Use zero if trajectory positions are to be read in.

17. **Time Increment (I):** The time displacement (seconds) between successive automatically generated profile positions. This would normally be set to zero, but could be used as a counter to be printed out in the time position with the output. For trajectories the time for each position is read in with the position data (see trajectory input section below). The hours, minutes, and seconds parameters (read in as items 10-12, 1st card) are updated according to the new time generated by the time increment. However, only the elapsed time in seconds is printed out on the present output.
18. **Trajectory Option (I):** This option tells the program whether a trajectory or a linear profile is to be evaluated. A value of 0 means a linear profile is to be generated automatically from the parameters read on the first card. A value greater than zero means that trajectory position data must be read in to determine the positions at which atmospheric parameters are to be evaluated. The unit from which the trajectory data are to be read is specified by the (non-zero) trajectory option. Thus, if trajectory data are to be read in from cards, use a trajectory option of 5 (the card input unit).

19. **Output Option (I):** This option tells the program whether or not to produce non-print output of the atmospheric parameters (see the output description section). Non-print (i.e. disk or cards) output is convenient to use as input to plotter programs. A value of 0 means no non-print output. A value greater than 0 means to output the data on the unit number equal to the output option value.

20. **Minimum Geostrophic Latitude (R):** Below this latitude (in absolute magnitude) the second order geostrophic relations are used. Above this latitude, or above 90 km, only the usual geostrophic relations are used.

With normal numbers of decimal places and no unnecessary blank spaces, the above 20 items should fit onto one card. However, if they occupy more than the 80 columns allowed on one card, they may be spread out onto two cards if the following rules of free field input are observed on the first of the two cards: (1) Do not put a comma after the last number appearing on the first card. (2) If the last number on the first card is an integer, it should be right justified to column 80. For input on
other computers, consult your operations manual for characteristics of free field input.

**Input Card Number 2.** The second input card is read in by the subroutine SETUP and contains various unit numbers to be used and options controlling the random and quasi-biennial calculations. The unit numbers are the parameters used in read statements in the FORTRAN program to control which file is being read from. The unit numbers are required in the input in order to give maximum flexibility in choice of I/O devices for the program. All input items on card number 2 are integers.

1. **Groves Input Unit:** This is the unit number of the SCIDAT tape file. If the SCIDAT tape has been assigned by the UNIVAC control statements -
   
   ```plaintext
   @ ASG, T  SCIDAT, T, U1961 N
   @ USE 3, SCIDAT
   ```

   where U1961 is the reel number for tape SCIDAT, then the Groves input unit number should be 3 on this input card. The Groves and stationary perturbation data must be read from the SCIDAT tape. Later options on this card allow the NMC grid data, the random perturbation data, and the quasi-biennial data each to be read from other files.

2. **Random Input Unit:** This is the unit number for the random perturbation standard deviations (and the large scale fraction data and density-velocity correlations). If this unit number is the same as the Groves input unit number, then all of the random perturbation data are read from the SCIDAT data tape. Otherwise all of the random perturbation data are read from the file for whatever the unit number is set to. For card input, the unit number should be set to 5. The SCIDAT tape is read with NTRAN, but if alternate random data are read in from a different file, the file
must be FORTRAN readable with format

\[ 1X, A1, I2, I4, 3(1X, 5I4) \]

for the random pressure, density, and temperature data (see Appendix B and Section 4.3 for which values must go in each record). For the random wind data the FORTRAN readable format for the alternate data is

\[ 1X, A2, I2, I4, 2(1X, 5I4) \]

If the random data input unit is different from the Groves input unit, then the code P and PW large scale fraction data and code CS and CL density-velocity correlation data must follow (after an end-of-file) the code RW data on the random input unit. The FORTRAN readable format for the large scale fraction (code P) data is

\[ 1X, A1, I2, I4, 3(1X, 5I4) \]

The format for the code PW data is

\[ 1X, A2, I2, I4, 2(1X, 5I4) \]

The format for the CS and CL data is

\[ 1X, A2, I2, I4, 2(1X, 5I5) \]

See Appendix B and Section 4.3 for description of the values which must go in each of these records.

All of the random perturbation data, random pressure, density, and temperature data, random wind data, large scale fraction data, and density-velocity correlation data must be read in from the same file, either all from SCIDAT, or all from the alternate FORTRAN readable file.

3. **QBO Input Unit:** If the QBO data parameters are to be read in from the SCIDAT data tape, this unit number is set the same as the Groves input unit. If alternate QBO parameters are to be read in the QBO unit number can be any FORTRAN readable file. Use Unit 5 for card input. The
format for all of the alternate QBO input is

1X, A2, 13, 5(I4, I5)

(See Appendix B and Section 4.3 for which data values must go into each record). All of the QBO pressure, density, temperature, and wind data must be read from the same file, either all from SCIDAT or all from the alternate QBO input file.

4. 4-D Input Unit: This is the unit number for the 4-D data tape. Any available unit number can be used. If the 4-D tape WW1A, containing the January data, has been assigned by the control statements

@ ASG, T WW1A, T, U 2400 N

@ USE 4, WW1A

then the 4-D input unit number is 4.

5. Random Option: This option tells the program whether or not to compute random perturbations. If the value is 1 random perturbations are computed. If the value is 2 then random perturbations are not computed. If any values other than 1 or 2 are input the run is terminated with a message "ERROR IN SETUP INPUT" and a dump of the parameters most recently read in.

6. QBO Option: This option tells the program whether or not to compute QBO perturbations. If the value is 1 QBO perturbations are computed. For 2 no QBO perturbations are computed, and for any other values the "ERROR IN SETUP INPUT" and dump of most recent parameters read in is given.

7. First Random Number: This number is required as a starting parameter for the random number generating subroutine RAND. Any odd positive integer can be used. Use a value of 1 for a standard design appli-
cation run. Provided all other input is the same, a given value for the starting random number will always produce the same random perturbation output. Therefore, to get a set of different perturbations along a given single trajectory, a set of different starting random numbers should be used. Note, however, that if any other parameters are changed (different spacing along the trajectory, different starting position, etc.) then the same starting random number will produce a different set of random perturbations.

8. **NMC Read Option:** This option tells the program whether to read the NMC grid data from the SCIDAT data tape (value 0 for the option) or from an input card file (any non-zero value for the option).

9. **4-D Scratch Unit:** In order to save array space the 4-D profiles required to interpolate to the $5^\circ \times 5^\circ$ grid locations are read from the tapes to this scratch file rather than being put into arrays. The unit number for this scratch file can be any available unit. Normally the file is a temporary drum file, and, if so, does not (on the UNIVAC) have to be assigned (@ ASG) before execution of the program.

10. **NMC Grid Point Scratch Unit:** Also in order to save computer storage, the NMC grid point array read in from the SCIDAT tape (or from cards) is stored in a temporary scratch file (usually on drum). If the drum scratch file is used, it does not have to be assigned (on the UNIVAC) before execution of the program.

**Input Card Number 3.** This card is read by the SETUP subroutine and contains starting values for the random perturbation parameters at the initial position. If random perturbations are not to be computed (Random Option = 2), then this card should not be put in. All values of this free
field format card are real. For a normal design application the values on this card should all be zero, unless the run is to be a continuation of a previously run trajectory or profile segment, in which case the output random parameters of the last output position are input, and the last output position becomes the initial position of the new run.

1-6. Initial PL, PS, DL, DS, TL, TS: These are initial values of random relative pressure \( p'/\bar{p} \), density \( \rho'/\bar{\rho} \), and temperature \( T'/\bar{T} \) in percent for the large scale (L) and small scale (S) components. These are starting values for the initial position. Use zero for standard design applications.

7-10. Initial UL, US, VL, VS: Initial values of the random eastward (U) and northward (V) random wind components in m/s for the large scale (L) and small scale (S) components. Use zeros for standard design applications.

**Trajectory Input.** The free field trajectory position input and backup record are put in only if a trajectory is to be evaluated, rather than a linear profile, generated automatically in the program from information on the first input card. There is no limit to the number of trajectory position records which can be put in. The program continues evaluating the atmospheric parameters and looping back to read a new trajectory position until a position below the surface is reached, or until the trajectory backup record is reached. Each free field trajectory record has the time (integer seconds), the height (kilometers), the latitude (degrees, southern latitude negative), and the west longitude (degrees, 0-360° or east longitudes negative). Any east longitudes read in as negative values are converted to the 0-360° system before being used by the program. The trajectory backup record has the
same free field form as a regular trajectory record, except any negative value for height is used. The negative height terminates the loop which evaluates atmospheric parameters and reads a new trajectory record. If a trajectory height goes negative, then any remaining trajectory input cards are read and ignored. The trajectory input can either be input from cards (trajectory option = 5) or form any other unit (with trajectory option = unit number). The trajectory option is item 18 on card #1.

4.4 Output of the Program

The first few lines of print output are primarily a listing of the input parameters. Following a heading which describes each output value for the trajectory or profile evaluations, the position, time monthly mean and total pressure, density, temperature, and winds are listed for each position. The thermal wind shear for the monthly mean winds, the percent deviation from the standard atmosphere (p, ρ, and t), the mean vertical wind and the perturbation data are also given for each position. The perturbation data consist of the stationary perturbations, the quasi-biennial values at the position and time, the quasi-biennial magnitudes, the random perturbation values, and the random perturbation standard deviations. Optional non-print (e.g. disk or punch) output for values at each position is also available to be used for input to plotter programs, or for other purposes.

Heading Information. Primarily the heading information contains a listing of the input data values. However, there are some changes from the values input. If an east longitude is put in as a negative value, -180° < lat < 0°, then it is converted to a west longitude in the 0-360 range before the heading is listed. The program evaluates the initial random pressure,
density, temperature and wind standard deviations and the initial density velocity correlation from data on the SCIDAT data tape, and lists the computed values on the heading. The Julian date is computed by the program from the input date and is also listed with the heading information. The Julian date is required by the Jacchia and QBO sections of the program. If month 13 (annual reference period) is input, then the Julian date is set to zero. (The Jacchia section takes the exospheric temperature to be 1000° K and the QBO section is bypassed if month 13 is input).

Position and Time Output. Positions and times as generated by the automatic linear profile features or as input by the trajectory input cards are listed on the output. The time is given in seconds. Within the program, the input time in hours, minutes, and seconds are updated in that form also. However, only a continuously increasing time in seconds is printed out. If time in hours, minutes, and seconds were desired, these variables could easily be printed out by adding them to the output list. All output west longitudes are converted to the 0-360 range before being printed out. If a latitude greater than 90° in absolute magnitude is generated (or input) then a transformation

\[
\text{lat} = (180° - |\text{lat}|) (\text{lat} / |\text{lat}|) \quad (4.6)
\]

\[
\text{lon} = \text{lon} + 180° \quad (4.7)
\]

is made.

Monthly Mean Data. The monthly mean values of pressure, density, and temperatures, consist of either: (1) values from the 4-D data tapes if the height is below 25 km, (2) the sum of Groves plus stationary perturbation values if the height is between 30 and 90 km, (3) an interpolation between 4-D at 25 km and Groves plus stationary perturbations at 30 km if the height
is between 25 and 30 km, (4) Jacchia model values if the height is above 115 km, or (5) faired values between Groves and Jacchia if the height is between 90 and 115 km.

The percent deviations from the U.S. 1962 Standard Atmosphere are evaluated by using standard atmosphere values computed by the subroutine STDATM. The percent deviations are evaluated by the relations $100(T - T_s)/T_s$, $100(p - p_s)/p_s$, and $100(p - p_s)/p_s$, where the subscript $s$ refers to the standard atmosphere values. This subroutine accurately reproduces the tabulated U.S. Standard Atmosphere 1962 values to within an accuracy of better than 0.2% above 90 km. The STDATM values are based on a model of parabolic segments for the height variation of the molecular weight above 90 km. The subroutine reproduces the tabular values even more accurately in the height region below 90 km, where the molecular weight is constant. Since the U.S. 1962 Standard Atmosphere is not defined above 700 km, the percent deviations printed out for heights above 700 km are zero.

The thermal wind shear values are values of $\partial u/\partial z$ and $\partial v/\partial z$ for the monthly mean geostrophic wind (see Section 2). The wind values, computed from the usual geostrophic wind equation or the second order geostrophic relation if the latitude is less than the input value of minimum geostrophic latitude, are determined by horizontal gradients of the monthly mean pressure. The thermal wind shear components, computed by the thermal wind equations, are determined by the horizontal gradients of the monthly mean temperature. Thus, a comparison of numerically differentiated geostrophic mean winds and the thermal wind shear serve as a check of the mean pressure and temperature fields. The mean vertical wind is evaluated, as described in Section 2, by combinations of horizontal and vertical temperature gradients and the geo-
The Total (Mean Plus Perturbation) Data. The parameter values listed under the heading of "Mean Plus Perturbations" are the monthly mean values, as defined above, plus the random perturbations, plus (if the height is between 10 and 90 km) the quasi-biennial perturbations. These mean-plus-perturbation values represent values which would be typical "instantaneous" values of the pressure, density, temperature or winds. The percent deviations from the U.S. Standard atmosphere are computed in the same way as for the percent deviations of the monthly mean values from the standard atmosphere.

Perturbation Values. The data under the "Perturbation Values" heading are the various perturbation values, magnitudes, and amplitudes. The stationary perturbations (denoted SP on the printout) are defined only if the height is between 30 and 90 km. The monthly mean $y_m$ of parameter $y$ should be the Groves value $G_y$, evaluated from the SCIDAT data tape, modified by the given stationary perturbation value $s_y$, in percent, by the relation

$$y_m = G_y (1 + s_y/100)$$  \hspace{1cm} (4.8)

The data labeled "QBO" are the values of the QBO oscillation at the output time and position. The data labeled "MAG" gives the magnitude of the QBO oscillations at the output position and time. The QBO perturbation values should always be less than or equal to the magnitude values in absolute value. The data labeled "RANL", "RANS", "RANT" are the large scale, small scale and total random perturbations evaluated at the output time and place. The data labeled "SIGL", "SIGS", and "SIGT" are the standard deviations of the large scale, small scale, and total random components at the output time and positions. According to the Gaussian distribution, on which the random perturbations are based, the perturbation values should be within the range
+ σ 68% of the time and outside the range + σ 32% of the time. Similarly, the perturbation values should be within the range + 2σ 95% of the time, and outside the range + 2σ 5% of the time. The evaluation of the QBO and random perturbation output can be suppressed by the QBO and random options, if desired.

**Non-Print Output.** The non-print output is available as an option, controlled by the input value of the output option parameter. If non-print output is desired, it comes out in the form of records with format F5.1, F6.2, F7.2, 2F5.1, 3F5.0, 5F5.1, 2E10.3, I5, I3 containing the following information: (1) the height in km, (2) the latitude in degrees, (3) the west longitude in degrees 0-360, (4-5) the percentage deviation of the mean monthly values of pressure and density from the 1962 U.S. Standard Atmosphere, (6) the monthly mean temperature, (7-8) the eastward and northward components of the monthly mean (geostrophic) wind, (9-13) the magnitudes of the total random perturbations in pressure, density, temperature (percent, and eastward and northward wind (m/s), (14-15) the monthly mean pressure (N/m²) and density (kg/m³), (16) the time, in seconds, and (17) the month (with 13 indicating annual mean).

4.5 **Program Diagnostics.** There are several possible reasons which can cause the printing of diagnostic messages and termination of the run during the SETUP phase. If, during the setup procedure, the NMC grid point number data table does not contain the required 1977 values, a message Diagnostic 1: "N RECORDS WRITTEN BY SETNMC IN SCRATCH FILE M" is printed, and EXECUTION IS TERMINATED. This situation should only arise if the NMC grid point table is being read from cards, rather than the SCIDAT data tape. If during the reading of the SCIDAT data tape, any record is read which does
not have the expected code character or characters (N, P, D, T, S, R, RW, P, PW, CS, CL, QP, QD, QT, OU, QV, or SP; see Appendix B), then the message results

**Diagnostic 2:** "ERROR IN SETUP INPUT" followed by a listing of the latest data values read in. This message is also produced if the random option and the quasi-biennial option do not have a value of either 1 or 2. Any condition which results in this error message terminates the execution.

There are also general conditions which could result in diagnostic messages in the 4-D section: If during the reading of the 4-D data tape on the first access of the region below 30 km, a parity error is encountered, a message

**Diagnostic 3:** "INPUT UNIT N0. M IN ERRØR (-3) FØR RECORD NØ N" is printed - execution continues. Such an error will only be of consequence if the particular record read is required for interpolation. If an end of file is read, a message is written

**Diagnostic 4:** "***** UNIT N0. JT IN ERRØR IRC RECORDS READ
IREAD(IRN, 3) + XXXX MP = XX MØNTH = XX IP = XXXX IPT(I, J) = XXXX IRN = XX M STATUS L"

Where

- JT = Unit on which 4-D data tape is mounted
- IRC = Total number of records read thus far from 4-D tape
- IREAD(IRN, 3) = Sequential point number selected by SELEC4
- MP = Month word in last record read
- MØNTH = Run month
- IP = Point number word in last record read
- IPT(I, J) = Point number required for profile J to be interpolated to Ith requested profile
- IRN = Sequential point number required
M = Unit status (READ)
L = NTRAN status (-2 for end of file, -3 for parity, etc.)
and EXECUTION IS TERMINATED

If IRC > IREAD(IRN, 3), the diagnostic message 4 is written - L should be 106, and IRC and IREAD values should indicate this condition. EXECUTION IS TERMINATED.

If MP ≠ MONTH, or IP ≠ IP(I, J) the diagnostic message 4 is printed, again with L = 106, and MP/MONTH or IP/IP(I, J) indicating error. EXECUTION IS TERMINATED.

The writing of scratch file SCRCH1 with data for subsequent unpacking and interpolation is also checked. If there is a write error, the diagnostic 4 is printed, with JT the scratch file unit number, M as WRITE and L as -3 or -4. EXECUTION IS TERMINATED.

These diagnostics can arise if a bad or wrong 4-D data tape is being accessed, or if there is a malfunction of the tape drive. In some cases a tape will, for example, indicate parity errors when being read from one tape drive, but not another.

If, during the course of evaluation of position in the 4-D height range, it is found that the position is outside the previously established 4-D grid, then a new grid is generated by calling GEN4D. If this occurs again, the message results

Diagnostic 5: "UNABLE TO GENERATE 4-D GRID" and EXECUTION IS TERMINATED.

The wind diagnostic symbol (asterisk), has also been added to the program. Presence of the asterisk between the E-W and N-S wind components on the print output indicates a diagnostic condition yielding questionable wind values. The conditions which can produce this is a 4-D data consis-
tency check violation (i.e., unrealistic scale heights or unrealistic horizontal pressure gradients) within the 4 x 4 grid of 4-D data profiles.

Diagnostic 6: "PREMATURE END-OF-FILE FOUND ON UNIT M"

"CALLED FROM SUBROUTINE XXXXXX"

And end-of-file mark was encountered before it was expected by one of the following subroutines while it was loading the associated data.

<table>
<thead>
<tr>
<th>XXXXXX</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>GETNMC</td>
<td>NMC GRID DATA</td>
</tr>
<tr>
<td>RTRAN</td>
<td>STATIONARY OR RANDOM PERTURBATION DATA</td>
</tr>
<tr>
<td>RTRAN1</td>
<td>GROVES DATA</td>
</tr>
<tr>
<td>RTRAN2</td>
<td>QBO DATA</td>
</tr>
</tbody>
</table>

UNIT m refers to the input unit number. This error should never occur while using the SCIDAT data type as the data source.
5. PROGRAMMERS MANUAL

5.1: Description of Subroutines

The following is a brief description of each of the PROFILE program subroutines, in alphabetical order:

**ADJUST:** Adjusts the 4-D profiles of pressure, density, and temperature variance (read from the 4-D tapes) to satisfy the Buell constraints imposed by the perfect gas law and hydrostatic equation.

**CHECK:** A consistency check routine for the 4-D 16 profile grid data produced by GEN4D. CHECK is called for each height to be evaluated, and tests for reasonable values of scale height immediately above and below that height. It also tests for reasonable horizontal pressure gradients. Failure of either test produces the diagnostic asterisk between the output values of wind components.

**CORLAT:** Evaluates the horizontal and vertical scales for large and small scale density, temperature, and wind components, computes the autocorrelations and cross correlations for the two scale perturbation model, and evaluates new perturbation values having appropriate correlations with the perturbations at the previous position.

**DIAGEQ:** A matrix diagonalizing procedure used by the ADJUST subroutine.

**FAIR:** Fairs between the Groves and Jacchia values in the 90 to 115 km height range.

**GEN4D:** Generates the polar (|latitude| > 75°) or non-polar (16 5° x 5° points) grid of pressure, density, temperature and variance profiles. See Figure 5.1 for a flow chart of this subroutine.

**GETNMC:** Reads the NMC grid point values from the SCIDAT data tape or from cards and loads them onto a scratch file. This subroutine is essentially unchanged from the subroutine of the same name in the original 4-D program.

**GRAM:** The main segment of the Global Reference Atmospheric Model program. The main segment serves as a driver for the SETUP and SCIMOD subroutines.
Figure 5.1: Simplified flow chart of the GEN4D subroutine.
GRID4D: After array of 4-D grid lat-lons has been evaluated, this subroutine looks up the data from the 4-D data tapes and interpolates to determine profiles of pressure density, temperature, and variance at the 4-D grid locations. Profiles to be interpolated to 4-D grid locations are loaded onto a scratch file from the tapes before the interpolation is done.

GROUP: A subroutine, called by CHECK, which groups the 16 4-D pressure data at the given height into one or more groups which have consistent and reasonable horizontal pressure gradients within each group. If the subsequent geostrophic wind calculations in WIND use horizontal pressure gradients evaluated from differences across inconsistent groups of 4-D data, the diagnostic asterisk is printed between the output values of wind components.


INTERW: Two variable linear interpolation between known value U1 and V1 at Z1 and U2 and V2 at Z2 to determine U and V at Z, where Z is between Z1 and Z2.

INTERZ: Three variable interpolation, linear on temperature, and gas constant \( R = \frac{p}{\rho T} \), and linear on the logarithm of pressure, with pressure computed from perfect gas law and interpolated temperature and density, and gas constant.

INTER2: Three variable interpolation, linear on all three variables.

INTER4: Interpolates between the pressure, density, and temperature profiles at the 4-D grid locations. This subroutine calls subroutine INTLL to do the latitude interpolation.

INTLL: One variable interpolation between values in an array of latitude and longitude locations by equation (5.6) of Justus et al (1974a).
INTRP4: The subroutine for the latitude-longitude interpolation of values from the 4-D data tapes into the 4-D grid array. This is a modification of the INTERP subroutine of the original 4-D program.

INTRUV: Evaluates the standard deviations of the random wind components at given height and latitude by calling INTERW subroutine.

JAC: Calculates the molecular weight, density, and temperature for the Jacchia model.

JACCH: Main subroutine of the Jacchia section, serves as a driver for JAC and other Jacchia section subroutines. JACCHIA also evaluates the seasonal and latitudinal variations in the lower thermosphere.

NORMAL: Computes two independent random numbers selected from a Gaussian distribution with mean zero and unit standard deviation.

PDTUV: Interpolates the stationary perturbations on latitude and longitude at a given height. This subroutine is similar to INTLL.

PERTRB: Evaluates the pressure, density, temperature and wind component random perturbations by the correlated random perturbation model discussed in Section 8 of the technical description section of the report.

PHASE: A linear height-latitude interpolation routine for the quasi-biennial phase. The interpolation properly accounts for the phase discontinuity between 0 and 870 days (the quasi-biennial period).

QBOGEN: Computes the QBO perturbation values and their amplitudes and phases. The amplitudes and phases of the QBO pressure, density, temperature, and wind perturbations are interpolated from the amplitude and phase data from the SCIDAT data tape, by calling the INTERZ and INTERW subroutines.

RAND: Produces a random number selected from a uniform distribution between 0 and 1. This is required as input to the subroutine NORMAL.

RIG: Computes the acceleration of gravity and the radius from the center of the Earth for a position at a given latitude and height.

RTERP: Computes the standard deviations of the random pressure, density, and temperature perturbations by calling subroutine INTERZ.
RTRAN: This subroutine contains several NTRAN read sections with multiple entry points coming from subroutine SETUP. The NTRAN read statements are for reading the SCIDAT data tape.

SCIMOD: The heart of the GRAM program. This subroutine branches on height to evaluate the atmospheric parameters by the Jacchia, the modified Groves, or the 4-D methods. The QBO and random perturbations are also evaluated and the output is printed (and optionally also punched) by the SCIMOD subroutine. See Figure 5.2 for a flow chart of the SCIMOD subroutine and Figure 4.1, for a flow chart showing how SCIMOD fits into the overall GRAM program.

SELEC4: Selects the 4-D data needed for interpolation. This subroutine is a modification of the INPUT subroutine of the original 4-D program.

SETUP: This subroutine reads in the NMC grid points with the GE/NMC subroutine and reads and loads the data from the required month on the SCIDAT data tapes into arrays. See Figure 5.3 for a flow chart of the SETUP subroutine, and Figure 4.1 for a flow chart showing how SETUP fits into the overall GRAM program.

SORT4: Sorts the 4-D locations for sequential tape reading from the 4-D data tapes. This subroutine is a modification of the SORT subroutine from the original 4-D program.

SPHERE: Called by WIND, this subroutine evaluates the wind components by the spherical harmonic model.

STDATM: Evaluates the 1962 U.S. Standard Atmosphere values of pressure, density, and temperature, at any given height up to 700 km.

TINF: This subroutine computes the exospheric temperature for the Jacchia model.

TME: This subroutine calculates the variables necessary for input into the subroutine TINF in the Jacchia model.

WIND: This subroutine evaluates the geostrophic winds from input values of horizontal pressure gradient if the height is less than 25 km or more than 90 km. If the latitude is below the minimum geo-
strophic latitude, it evaluates geostrophic wind at minimum geostrophic north latitude and at minimum geostrophic south latitude and then interpolates in between. If the height is between 25 and 90 km, the spherical harmonic wind model is used. Between 20 and 25 km and between 90 and 95 km, a smooth fairing between geostrophic and spherical harmonic wind is used.

The UNIVAC tape reading library routine NTRAN is not available on all computers. However, a similar function (reading 36 bit binary integer arrays in tape records) can be performed easily by alternate program techniques. For example, on Georgia Tech's CDC Cyber 74 system, this function is done by BUFFER IN statements. These routines are used to read the SCIDAT and 4-D data tapes. Also the FLD function, a UNIVAC library routine used to divide the 36 bit 4-D tape words onto 2 18 bit integers, must also be programmed by alternate methods on non-UNIVAC machines. On Georgia Tech's CDC machine, this is done by specially written subroutines (WRDCHG, RFLD, and FLD) which utilize the SHIFT and MASK bit manipulating CDC library routines.

If the GRAM program is mapped without segmenting the program, it requires approximately 80 K decimal words core storage on Georgia Tech's CYBER. In order to take up less core storage (e.g., be accommodated into smaller core partitions), the program can be mapped in segmented form. An efficient segment of the program can be accomplished by subdividing the program into a primary segment, a setup segment, a Jacchia segment, and a 4-D segment. The primary segment should contain CORLAT, GRAM, GTERP, INTERW, INTERZ, INTER2, INTRUV, NORMAL, PDTUV, PERTRB, PHASE, QBOGEN, RAND, RIG, RTERP, SCIMOD, SPHERE, STDATM, and WIND. The setup segment should contain: GETNMC, RTRAN, and SETUP. The Jacchia segment should contain: FAIR, JAC, JACCH, TINF, and TME. The 4-D segment should contain: ADJUST, CHECK, DIAGEQ, GEN4D, GRID4D, GROUP, INTER4,
Figure 5.2: An abbreviated flow chart of the SCIMOD subroutine.
Figure 5.3: Abbreviated flow chart of the SETUP subroutine.
INTLL, INTRP4, SELEC4, and SORT4. The following MAP statement for file GRAM to create absolute element ABS will accomplish the mapping of the program with these segments setup as described:

```
@MAP, IS, GRAM.ABS
IN GRAM. CORLAT, GRAM, GTERP, INTERW, INTER2
IN GRAM. INTER2, INTRUV, NORMAL, PDTUV, PERTRB, PHASE
IN GRAM. OBOGEN, RAND, RIG, RTERP
IN GRAM. SCIMOD, SPHERE, STDATM, WIND
NOT TPF$
SEG SETUP*
IN GRAM. GETNMC, RTRAN, SETUP
NOT TPF$
SEG JACCH*, SETUP
IN GRAM. FAIR, JAC, JACCH, TINF, TME
NOT TPF$
SEG SEG4D*, SETUP
IN GRAM. ADJUST, CHECK, DIAGEQ
IN GRAM. GEN4D, GRID4D, INTER4, INTLL, INTRP4
IN GRAM. SELEC4, SORT4, GROUP
NOT TPF$
END
```

This segmented map saves approximately 4 K (decimal) in core storage, but does not significantly affect run time, since the segments being overlayed (the setup, Jacchia, and 4-D segments) only have to be loaded in once during any given trajectory or profile evaluation. If further reduction in size is desired the 4-D segment can be subdivided into two parts, one containing only CHECK, GROUP, INTER4, and INTLL and another segment containing ADJUST, DIAGEQ, GEN4D, GRID4D, INTRP4, SELEC4 and SORT4. This saves another 1 K in storage, approximately.

Some characteristics of some of the subroutines in each of these segments are described more fully in the following sections.

5.2: The Primary Section

This section consists of the main program segment GRAM, the SCIMOD subroutine, the subroutines for evaluating Groves values, the stationary perturbations, the QBO and random perturbations, and general interpolation sub-
routines. With the exception of GRAM and SCIMOD the parts of this section were adequately described in the previous section.

Many of the subroutines transfer their input and output via COMMON statements. This procedure saves much in core storage space. The discussion in this and subsequent sections describes the input and output of some of the subroutines, both by argument lists and via COMMON statements.

Main Segment GRAM. This program serves as a driver for the SETUP and SCIMOD subroutines (see Figure 4.1). It reads one card, the first input card, in free field format. This card contains:

1. The initial height
2. The initial latitude (degrees)
3. The initial west longitude (degrees)
4. The F10.7 solar flux
5. The 81 day mean F10.7 solar flux
6. The a_p geomagnetic index
7-9. The date month/date/2 digit year
10-12. The Greenwich time hours: minutes: seconds
13-15. The latitude, longitude, and height increments
16. The maximum number of profile positions
17. The time increment between profile positions
18. The trajectory option
19. The output option
20. The minimum geostrophic latitude

The trajectory input records (if used) are also read by GRAM, after control has returned from SETUP, which reads the second and third initial data in-
The COMMON "IOTEMP" transfers data from the card input in GRAM to the other subroutines called by GRAM (SETUP, SCIMOD, and RIG).

Subroutine SCIMOD. This program is the primary subroutine of the GRAM program. It serves as a driver for all of the various sections of the atmospheric evaluation. See Figure 5.2 for a flow chart of this subroutine.

The input to SCIMOD, transferred by COMMON statements IOTEMP and PDTCOM, is:

1. Acceleration of gravity (m/sec^2) \( G \)
2. Earth radius to height H (km) \( RI \)
3. Height (km) \( H \)
4. Latitude (radians) \( PHIR \)
5. Longitude (radians) \( THETR \)
6. F10.7 solar flux \( F1O \)
7. Mean F10.7 solar flux \( F1OB \)
8. Geomagnetic index \( a_p \) \( AP \)
9-11. Date \( MN/DA/IYR \)
12-14. Time \( IHR: \ M: ISEC \)
15. Previous height (km) \( HI \)
16. Previous latitude (radians) \( PHIIR \)
17. Previous longitude (radians) \( THETIR \)
18-20. Previous random pressure, density, and temperature perturbations (\%), large scale (L) and small scale (S) \( RPIL, RDIL, RTIL, RPIS, RDIS, RTIS \)
21-23. Previous random pressure, density, and temperature standard deviations (\%), large scale (L) and small scale (S) \( SPIL, SDIL, STIL, SPIS, SDIS, STIS \)
24-25. Previous random winds (m/s), large scale (L) and small scale (S)  RUIL, RVIL, RUIS, RVIS

26-27. Previous standard deviation of random winds (m/s), large scale (L) and small scale (S)  SUIL, SVIL, SUIS, SVIS

The COMMON "PDTCOM" contains data transferred into SCIMOD from SETUP. The COMMON "IOTEMP" transfers data in from GRAM. The COMMON "C4" transfers data out to the 4-D section of the program. The COMMON "COMPER" transfers data out to the random perturbation subroutines.

The SCIMOD subroutine prints and (optionally) punches on a non-print output file, the output described in Section 4 and Appendix C. It also transfers output to other subroutines via the above-mentioned COMMON lists. The SCIMOD subroutine updates the profile or trajectory positions by setting the current position equal to the previous position before exit. The previous position information then stays in the COMMON list unit the next call to SCIMOD. The previous random perturbations are handled in similar fashion.

5.3 The Setup Section

The function of the setup section of the program is to load the initial data and the data from the SCIDAT tape. See Figure 4.1 for a flow chart illustrating how the SETUP subroutine fits into the overall program and Figure 5.2 for a flow chart of the SETUP subroutine.

The SETUP subroutine reads the second and third cards of input. The second cards contains:

1. Groves input unit  IUG
2. Random input unit  IUR
3. QBO input unit  IUQ
4. 4-D input unit  IU4
5. Random option  IOPR
6. QBO option
7. First random number
8. NMC read option
9. 4-D scratch unit
10. NMC grid point scratch unit

The third card (optional, read only if IOPR = 1) contains:

1-6. Initial random perturbations in pressure, density, and temperature (%), large scale (L) and small scale (S)
   RP1L, RD1L, RT1L
   RP1S, RD1S, RT1S

7-10. Initial random wind perturbation (m/s), large scale (L) and small scale (S)
   RU1L, RV1L, RU1S, RV1S

The COMMON list "PDTCOM" transfers the arrays, loaded with the appropriate data from the SCIDAT data tape, to the other subroutines. This COMMON list contains the following arrays:

1-3. Groves pressure, density, and temperature
   PG, DG, TG

4-6. Stationary perturbations in pressure, density, and temperature
   PSP, DSP, TSP

7-11. Amplitudes of QBO pressure, density, and temperature, and winds
   PAQ, DAQ, TAQ, UAQ, VAQ

12-16. Phases of QBO pressure, density, and temperature, and winds
   PDQ, DDQ, TDQ, UDQ, VDQ

17-21. Standard deviations for the random pressure, density, temperature and winds
   PR, DR, TR, UR, VR

The COMMON list "COTRAN" is used to transfer data to setup from the NTRAN read subroutine RTRAN, which has multiple entry points for various different types of data from the SCIDAT data tape. The COMMON "CHIC" is used to transfer the spherical harmonics coefficients to the SPHERE subroutine.

5.4 The Jacchia Section

The subroutine JACCH calculates the pressure, density, and temperature at a point in space for heights above 90 km for a particular time.
1. Height in km
2. Latitude in radians
3. West longitude in degrees (0 to 360 degrees)
4. Solar radio noise flux F10.7 \((10^{-22} \text{ watts/m}^2)\)
5. 81-day average solar flux F10.7
6. Geomagnetic index \(a_p\)
7. Month
8. Day of month
9. Year
10. Hour of day in universal time
11. Minute of hour in universal time
12. Mean Julian day

The outputs are:

1. Pressure in units of \(\text{nt/m}^2\)
2. Density in units of \(\text{kg/m}^3\)
3. Temperature in Kelvin degrees

The theory and methods used in JACCH for calculating the pressure, density, and temperature are given in Jacchia, (1970). A brief explanation will be given below.

The subroutine JACCH consists of four sections: the main routine and three imbedded subroutines. All sections have numerous comments to explain each part of the program.

**Main Routine (JACCH).** The main routine acts as the calling routine, and also, calculates the seasonal - latitudinal variations in the lower thermosphere.

The seasonal - latitudinal density variations are given by equation
The equations for the molecular weight and the relative temperature were given as equations (2.2) and (2.3) of *Justus et al*. The pressure is calculated from the ideal gas law:

\[ p = \frac{\rho RT}{M} \]

where \( \rho \) is the density, \( R \) is the universal gas constant, \( T \) is the temperature, and \( M \) is the molecular weight.

An option is included in the main routine whereby the yearly mean values of the density, pressure, and temperature may be calculated directly. If the value of the month input variable is thirteen, \((MN = 13)\), the exosphere temperature is immediately set equal to 1000° K (which is the recommended design value for annual mean conditions) and the yearly mean density, pressure, and temperature values are calculated. Note that the 1962 U.S. Standard Atmosphere has an exospheric temperature of approximately 1500° K and is thus considerably different from the 1000° K results of the annual mean in the PROFILE program.

**Subroutine TME.** This subroutine calculates variables necessary for input into the subroutine TINF. The input variables are:

1. month (month = 13 denotes annual mean and bypasses this subroutine) \( MN \)
2. day of month \( IDA \)
3. year \( IYR \)
4. hour of day in universal time \( IHR \)
5. minute of day in universal time \( MIN \)
6. mean Julian day \( XMJD \)
7. latitude in radians \( \text{XLAT} \)

8. longitude in degrees (input: 0 to 360 degrees turning westward; output: -180 to +180 degrees) \( \text{XLONG} \)

The output variables are:

1. solar declination angle in radians \( \text{SDA} \)
2. solar hour angle in radians \( \text{SHA} \)
3. day number from January 1 \( \text{DD} \)
4. day number divided by tropical year (365.2422 days) \( \text{DY} \)

**Subroutine TINF.** This subroutine calculates the exospheric temperature. The input variables are:

1. solar radio noise flux \((10^{-22} \ \text{watts/m}^2)\) \( \text{F10} \)
2. 81 - day average \( \text{F10B} \)
3. geomagnetic latitude in radians \( \text{XLAT} \)
4. solar declination angle \( \text{SDA} \)
5. solar hour angle \( \text{SHA} \)
6. day number divided by tropical year \( \text{DY} \)
7. diurnal factor equal to 0.31 \( \text{R} \)

The output is the exospheric temperature, \( T_E \). Factors included in the calculation of the exospheric temperature are solar activity variations, diurnal variations, variations with the geomagnetic activity, and semi-annual variations.

**Subroutine JAC.** This subroutine calculates the molecular weight, density, and temperature without the seasonal - latitudinal variations. The input variables are:

1. height in km \( \text{Z} \)
2. exospheric temperature \( \text{T} \)
The output variables are:

1. temperature \( TZ \)
2. molecular weight \( EM \)
3. density \( DENS \)

5.5 The 4-D Section

GRID4D and subroutines SORT4, INTRP4 and SELEC4 are basically the MAIN PROGRAM, SORT, INTERP and INPUT as documented in the 4-D users reference manual and subsequent updates.

Some changes have been made.

In GRID4D, NTRAN MOVE statements are used to select the appropriate file for a given month on the 4-D data tape mounted on UNIT IT in the UNIVAC version. In Georgia Tech's CDC version, and on other machines, separate reads for each record must be used until an end of file is reached, and reading continues until the proper file is found. If a parity error is encountered in reading IT, a message

"INPUT UNIT NO. IT IN ERROR FOR RECORD NO IRC"

is printed - execution continues. Such an error will only be of consequence if the particular record read in error is required for interpolation.

Grid point profiles for subsequent interpolation are tagged and filed on a dynamically assigned scratch UNIT SCRCH1 (I0TEM1 in calling program), instead of occupying core as in the 4-D model.

Any error in the handling of the 4-D data tape or UNIT SCRCH(I0TEM1 in calling program) by TRID4D which results in a transfer to

STATEMENT NO. 30

is fatal, and results in the printing of an error message and termination of execution (see Section 4.5).
Slight changes have been made to the logic of SØRT4 in the interests of efficiency.

SELEC4 is concerned only with the selection of the record numbers of the appropriate interpolation profiles.

GETNMC has been added to file the NMC grid point data, read either from cards of the SCIDAT data tape on UNIT IUG, on a dynamically assigned scratch file SCRCH2 (IOTEM2 in calling program), instead of occupying 1977 words of core as in the 4-D model. If other than 1977 records are filed, an error message

"N RECORDS WRITTEN BY GETNMC ON SCRATCH FILE M"

is printed and execution terminated.

INTRP4 uses a modified latitude - longitude interpolation scheme in the mixed NMC - equatorial, equatorial and southern hemisphere regions.

The dimensions of some variables have been altered in keeping with the maximum number of profiles to be used in interpolation (16 instead of 25 as in the 4-D model), and to provide the index word for each record of SCRCH1 (IN (107) instead of (106)).

All references to, and subroutines associated with, the determination of the coefficients of the best fit polynomials to the selected profiles, as performed in the original 4-D model, have been deleted. All vertical interpolations required are performed by SCIMØD.
REFERENCES


NOAA, (1967b): "Weekly Synoptic Analyses 5, 2, and 0.4 Millibar Surfaces for 1964," WB2, Staff, Upper Air Branch, NOAA, NMC, April.

NOAA, (1967c): "Weekly Synoptic Analyses, 5, 2, and 0.4 Millibar Surfaces for 1965," WB3, Staff, Upper Air Branch, NOAA, NMC, August.


NOAA (1975): "Synoptic Analyses 5, 2, and 0.4 Millibar Surfaces for January 1972 through June 1973," NASA-SP-3091, Staff, Upper Air Branch, NOAA, NMC.


APPENDIX A

THE SPHERICAL HARMONIC WIND MODEL

The spherical harmonic wind model is based on the second order spherical harmonic expansion relation (equation 2.12)

\[
 u(m, z, \theta, \phi) = a_1 + a_2 \cos \phi + a_3 \cos \theta \sin \phi \\
 + a_4 \sin \theta \sin \phi + a_5 (3 \cos^2 \phi - 1)/2 \\
 + a_6 \cos \theta (3 \sin \phi \cos \phi) + a_7 \sin \theta (3 \sin \phi \cos \phi) \\
 + a_8 (2 \cos^2 \theta - 1)(3 \sin^2 \phi) + a_9 (2 \sin \theta \cos \phi)(3 \sin^2 \phi)
\]

(A-1)

where \( u \) is the eastward wind component (or a similar equation for \( v \), the northward component), \( m \) is the month, \( z \) is the height, \( \theta \) is the longitude, and \( \phi \) is the co-latitude. The coefficients (a's) must be estimated from observed data, as a function of month and height. Five kilometer height intervals were selected at which to evaluate the coefficients.

Estimation of the Model Coefficients

The spherical harmonic model may be expressed as a linear function by the transformation

\[
 x_1 = 1 \\
 x_2 = \cos \phi \\
 x_3 = \cos \theta \sin \phi \\
 x_4 = \sin \theta \sin \phi \\
 x_5 = 3(\cos^2 \phi - 1)/2
\]

A-1
\[ x_6 = \cos \theta (3 \sin \phi \cos \phi) \]
\[ x_7 = \sin \theta (3 \sin \phi \cos \phi) \]
\[ x_8 = (2 \cos^2 \phi - 1) (3 \sin^2 \phi) \]
\[ x_9 = (2 \sin \phi \cos \phi) (3 \sin^2 \phi) \]

Using this transformation, the model becomes

\[ u = \sum_{i=1}^{9} a_i x_i = A \cdot X \]  \hspace{1cm} (A-3)

where \( A \) and \( X \) are 9-component vectors with components \( a_i \) and \( x_i \), respectively. If similar coefficient \( b_i \) are defined for \( v \), the northward component, its representation becomes

\[ v = B \cdot X \]

Since the wind components vary with month and height, the \( A \) and \( B \) vectors will depend on month and height. Over altitudes 25 to 65 km the all a component of the \( A \) and \( B \) coefficient vectors are evaluated every 5 km, for each month. Above 65 km, where fewer wind observations were available, a 5 km height increment was still used, but only the 1st-order coefficients (1-4) were evaluated; the 2nd-order coefficients (5-9) were set identically to zero (see the printout of the spherical harmonic in the SCIDAT tape listing of Appendix B).

The least-squared error approach (Draper and Smith, 1966) was used to estimate the coefficient vectors \( A \) and \( B \).

The Data

Four sources of wind data were available for this analysis. The most
extensive source was the SUMS tape from the World Data Center (NOAA, 1976). This tape contained monthly wind data averaged over the period 1969 to 1976. Up to 20 stations around the world reported winds in the altitude range 25 to 90 km. These stations were located primarily in the Western hemisphere.

Data from three Eastern hemisphere stations—Thumba, India; Volograd, USSR; and Heiss Island—were available (NASA, 1978). This also was monthly averaged data ranging from 25 to 60 km.

The third source of data was grenade soundings from four locations: Point Barrow, Alaska; Wallops Island, Virginia; Fort Churchill, Canada; and Natal/Ascension Island (Theon, et al., 1972). The Natal/Ascension data were annual means; the other stations were averaged over three seasons; summer, winter, and Equinox. A sinusoidally weighted interpolation scheme was used to estimate monthly wind averages. In this scheme, the summer and winter observations were assumed to be the extremes, and the equinox was the nominal wind value.

The fourth data source was from Woomera, Australia (Pearson and Johnson, 1973). Monthly average wind components from 30 to 80 km were available from this source.

The four data sources were combined and used as input to a multiple regression program for estimating the spherical harmonics coefficients, as previously described. Monthly wind averages based on less than three observations were filtered from the data.

Very little southern hemisphere wind data were available, resulting in erratic wind prediction at southern latitudes. To alleviate this problem, data from the northern hemisphere was used as southern hemisphere data, displaced by 6 months, with both latitude and longitude reversed.

The number of stations which had enough wind data for meaningful
averages varied considerably from one month to the next and from one altitude to the next. There was a maximum of 23 stations and a minimum of 5 stations at a given height. The geographic distribution of the stations was strongly biased towards the north-west quarter-sphere. These factors, along with the large variance in the wind data result in the spherical harmonics coefficients having large standard deviations. As a result of this, increased emphasis should be placed on perturbation analysis available in the GRAM program. As more and better wind data becomes available, the spherical harmonics model coefficients may be updated, and better results obtained.

The spherical harmonic model is used at all latitudes to calculate winds between the heights of 25 and 95 km. Between 20 and 25 km and between 90 and 95 km, a Fairing technique is used to smooth the winds between the spherical harmonic model values and the geostrophic winds. At low latitudes (below the "minimum geostrophic latitude" given in the input), the geostrophic relation is not used. Instead interpolation is done between plus and minus minimum geostrophic latitude (below 25 km and above 90 km only).
APPENDIX B
LISTING OF THE REVISED TAPE
"SCIDAT-MOD-3" FOR THE GRAM PROGRAM

The tape contains the following data, identified by code characters at the beginning of each record. Month 13 refers to annual mean values. For code P, D, T, S, R and RW data, southern latitudes are given by northern hemisphere data displaced six months. Annual mean data and the QBO parameters are the same for both southern and northern hemispheres. For a more complete discussion of the input data, see Section 4.2.

<table>
<thead>
<tr>
<th>Code</th>
<th>Data</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>NMC Grid Data</td>
<td>Same as NMC Grid Required by NASA version 4-D program. Data consists of sequential point number followed by the two corresponding NMC grid indices. There are five points per record on the tape.</td>
</tr>
<tr>
<td>P</td>
<td>Groves Pressure (nt/m²)</td>
<td>Month, height, values at latitudes 0, 10, 20, ..., 90 exponent. Same format as in Groves report.</td>
</tr>
<tr>
<td>D</td>
<td>Groves Density (kg/m³)</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>Groves Temperature (°K)</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>Stationary Perturbations in monthly means (per mill)</td>
<td>Month, height, longitude, Δp at north latitude, 10, 30, 50, 70, 90, Δp same, ΔT same.</td>
</tr>
<tr>
<td>R</td>
<td>Random pressure, density and temperature perturbation magnitudes (per mill)</td>
<td>Month, height, Δp at north latitude 10, 30, 50, 70, 90, Δp same, ΔT same</td>
</tr>
<tr>
<td>RW</td>
<td>Random magnitudes wind perturbation (m/s)</td>
<td>Month, height, Δu at north latitude 10, 30, 50, 70, 90, Δv same</td>
</tr>
<tr>
<td>P</td>
<td>Fractional variance in large scale thermodynamic variables</td>
<td>13 (Annual), height, fractional variance in large scale per mill for pressure, density and temperature, each at latitude 10°, 30°, 50°, 70°, 90°</td>
</tr>
<tr>
<td>PW</td>
<td>Fractional variance in large scale winds</td>
<td>13 (Annual), height, fractional variance in u at 10°, 30°, 50°, 70°, 90° latitude, same for v</td>
</tr>
<tr>
<td>Code</td>
<td>Data</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>CS</td>
<td>Small scale density-velocity correlations</td>
<td>13 (Annual), height, ( &lt;\rho v&gt;_s ) at 10°, 30°, 50°, 70°, 90° latitude, same for ( &lt;\rho v&gt;_L )</td>
</tr>
<tr>
<td>CL</td>
<td>Large scale density-velocity correlations</td>
<td>13 (Annual), height, ( &lt;\rho v&gt;_L ) at 10°, 30°, 50°, 70°, 90° latitude, same for ( &lt;\rho v&gt;_L )</td>
</tr>
<tr>
<td>QP</td>
<td>QBO pressure parameters-amplitude (per mill) and phase (days after Jan. 0, 1966 when 1st maximum occurs)</td>
<td>Height, amplitude and phase at 10° latitude, amplitude and phase at 30°, ... , amplitude and phase at 90°</td>
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<td>QBO density parameters (as in QP)</td>
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<td>QBO temperature parameters</td>
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<td>QBO eastward wind parameters-amplitude (0.1 m/s) and phase (days after Jan. 0, 1966)</td>
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<td>SP</td>
<td>Spherical harmonic coefficient</td>
<td>Height, month, and coefficient values ( a_1-a_9 ), cm/s.</td>
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The tape consists of six FORTRAN readable files with an end of file marker after each file. The first file contains the NMC grid data, the second contains the Groves and Stationary perturbation data, the third contains the random perturbation data, the fourth contains the fractional large scale variances and the density-velocity correlations, and the fifth contains the QBO data. Each record of the NMC grid data file contains the code (N) and x-y coordinates for 5 points. The Format is (A2, 15I7). The total number of NMC grid points is 1977. The NMC grid data file contains a total of 396 records, with the last record containing points 1976 and 1977 and zeros for the remaining values. The format for the Groves data is (A2, 13I7),
for the stationary perturbation it is (A2, 1817), for the code-R data it is (A2, 1717), for the code RW data it is (A2, 1217), for the large scale fractional variances in thermodynamic variables it is (A2, 1717), for the large scale fractional wind variances it is (A2, 1217) for the density-velocity correlations (small scale and large scale) it is (A2, 1217), and for the quasi-biennial data it is (A2, 1117), and for the spherical harmonic it is (A2, 1117). The Groves data contains 702 records, the stationary perturbation data contains 1248 records, the code R random data contains 260 records, the code RW random winds data contain 325 records, the code P large scale fractional variances contain 25 records, the code PW large scale fractional wind variances contain 25 records, and code CS and CL density-velocity correlation data contain 25 records each, the QBO data contain 80 records, and the spherical harmonics data contain 336 records.

Following is a listing of the data contained on the SCIDAT tape.
### Stationary Perturbations

| S  | 1   | 10  | -1   | -6  | -48  | -93  | 0  | 2  | 0   | -21  | -33  | 0  | -1  | -7  | -24  | -59  |
| S  | 1   | 30  | -10  | -15  | -66  | -82  | 0  | -25 | -17  | -26  | -46  | 0  | 20  | 2   | -38  | -36  |
| S  | 1   | 30  | 70   | 10   | -23  | -3   | 0  | -9  | -11  | 14   | 7    | 0  | 3   | -11 | -20  | -2   |
| S  | 1   | 30  | 130  | -1   | 11   | 51   | 104 | 0  | 2   | 17   | 48   | 73  | 0   | -6  | -3   | 3   |
| S  | 1   | 30  | 160  | -1   | 11   | 95   | 191 | 0  | 8   | 11   | 72   | 126 | 0   | -10 | -3   | 21  |
| S  | 1   | 30  | 190  | 15   | 28   | 87   | 169 | 0  | 19  | 22   | 43   | 86  | 0   | -1  | 6    | 43  |
| S  | 1   | 30  | 220  | 7   | 19   | 69   | 93  | 0  | 8   | 17   | 14   | 33  | 0   | -6  | 2    | 52  |
| S  | 1   | 30  | 250  | -1   | -6   | 6    | 5   | 0  | -9  | -11  | -26  | -20  | 0  | 3   | 11   | 38   |
| S  | 1   | 30  | 280  | 15   | 11   | -39  | -82 | 0  | 2   | 0    | -38  | -66  | 0  | 7   | 6    | 3    |
| S  | 1   | 30  | 310  | -1   | -6   | -48  | -104 | 0  | 7   | -11  | -38  | -66  | 0  | -1  | 2    | -11  |
| S  | 1   | 30  | 340  | -1   | -15  | -48  | -104 | 0  | 2   | -1   | -26  | -46  | 0  | -6  | -3   | -24  |
| S  | 1   | 40  | 10   | 14   | 18   | -43  | -89 | 0  | 9   | -1   | -63  | -66  | 0  | 5   | 23   | 20   |
| S  | 1   | 40  | 40   | 26   | 79   | -35  | -84 | 0  | 22  | 7    | -57  | -69  | 0  | 5   | 19   | 20   |
| S  | 1   | 40  | 70   | 21   | 25   | -70  | -93 | 0  | 17  | 4    | -102 | -96  | 0  | 5   | 19   | 32   |
| S  | 1   | 40  | 100  | 3    | -28  | -98  | -74 | 0  | 9   | -35  | -110 | -82  | 0  | -7  | 7    | 12   |
| S  | 1   | 40  | 130  | -21  | -43  | -31  | 8   | 0  | -20 | -27  | -5   | -6   | 0  | 1   | -16  | -29  |
| S  | 1   | 40  | 160  | -18  | 13   | 102  | 125 | 0  | 7   | 32   | 158  | 125 | 0  | -11 | -36  | -33  |
| S  | 1   | 40  | 190  | -32  | 12   | 173  | 202 | 0  | -22 | 47   | 207  | 195 | 0  | -7  | -28  | -29  |
| S  | 1   | 40  | 220  | -21  | 11   | 130  | 168 | 0  | -15 | 25   | 124  | 138 | 0  | -7  | -12  | 4    |
| S  | 1   | 40  | 250  | -11  | -21  | 43   | 62  | 0  | -15 | -22  | 23   | 34  | 0  | 1   | 1    | 20   |
| S  | 1   | 40  | 290  | 0    | -3   | -11  | -35 | 0  | -9  | 1    | -11  | -32  | 0  | 8   | 5    | 0    |
| S  | 1   | 40  | 310  | 24   | 0    | -70  | -89 | 0  | 25  | -7   | -52  | -66  | 0  | 1   | 7    | -21  |
| S  | 1   | 40  | 340  | -14  | -3   | -90  | -103 | 0  | 6   | -25  | -93  | -76  | 0  | 8   | 23   | 4    |
| S  | 1   | 52  | 10   | 22   | 40   | -29  | -102 | 0  | 13  | 30   | 18   | 97  | 0  | 9   | 0    | -11  |
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| S  | 1   | 52  | 70   | 27   | 69   | 21   | -52 | 0  | 17  | 62   | -14  | -86  | 0  | 9   | 7    | 36   |
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| PW  | 13 | 120 | 457 | 457 | 457 | 457 | 457 | 457 | 457 | 457 | 457 | 457 |

**Note:** LARGE SCALE U-D AND V-D ANNUAL CORRELATIONS. CODE CS. CL**
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APPENDIX C
SAMPLE INPUT AND OUTPUT FOR THE GRAM PROGRAM

Input to GRAM is as follows:

(All input data cards are in free field format.)

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<th>Field</th>
<th>Description</th>
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<tr>
<td>INITIAL HEIGHT</td>
<td>Height of starting position, km</td>
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<tr>
<td>INITIAL LATITUDE</td>
<td>Latitude of starting position (degrees, southern latitudes negative)</td>
</tr>
<tr>
<td>INITIAL WEST LONGITUDE</td>
<td>West longitude of starting position (degrees, 0 to 360 degrees, or east longitudes negative)</td>
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<td>F10.7</td>
<td>Solar 10.7 cm radio noise flux (10^{-22} \text{ watts/m}^2) at time of calculations. Use zero if height does not go over 90 km. Use 230 for design applications or consult Aerospace Environment Division (AED) of Marshall Space Flight Center (MSFC) for monthly predictions.</td>
</tr>
<tr>
<td>MEAN F10.7</td>
<td>81 day mean solar 10.7 cm flux. Use zero if height does not go over 90 km. Use 230 for design applications or consult AED, MSFC for monthly predictions.</td>
</tr>
<tr>
<td>AP</td>
<td>Geomagnetic index (a_p). Use zero if height does not go over 90 km. Use 20.3 for design steady state conditions, or 400 for maximum conditions, or consult AED, MSFC.</td>
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<td>Date for starting time of calculations (month, date, two digit year). Use month 13 for annual reference period.</td>
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<tr>
<td>GREENWICH TIME</td>
<td>Time for starting position (hours, minutes, seconds). Use time corresponding to local time - 0900 for design steady state, or 1400 maximum conditions.</td>
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<td>Latitude displacement (degrees) between successive positions (new lat = old lat + lat increment). Use zero if trajectory positions are to be read in.</td>
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<td>WEST LON INCREMENT</td>
<td>West longitude displacement (degrees) between successive positions (new long = old lon + lon increment). Use zero if trajectory positions are to be read in.</td>
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<td>HEIGHT INCREMENT</td>
<td>Height decrease (km) between successive positions (new height = old height - height increment). Normal profiles are generated downward. If an upward generated profile is desired set height increment negative.</td>
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<tr>
<td><strong>TIME INCREMENT</strong></td>
<td>Time displacement (seconds) between successive positions for automatically generated profiles (new time = old time + time increment)</td>
</tr>
<tr>
<td><strong>TRAJECTORY OPTION</strong></td>
<td>0 for linear profile generated automatically internal to the program, or value equal to unit number (e.g. 5 for card input) for a trajectory with each position to read in.</td>
</tr>
<tr>
<td><strong>OUTPUT OPTION</strong></td>
<td>0 for no non-print output of atmospheric parameter values, or value equal to unit number to get non-print output.</td>
</tr>
<tr>
<td><strong>MIN. GEOSTROPH. LAT.</strong></td>
<td>Lowest latitude (magnitude) for which geostrophic winds are to be used in 4-D (0-25 km) and Jacchia (above 90 km) height segments. Otherwise, interpolation is used to fill in winds. In middle heights (25-90 km), the spherical harmonic model is used at all latitudes.</td>
</tr>
</tbody>
</table>

**CARD 1**

| **GROVES INPUT UNIT**        | Unit number for tape containing Groves and stationary perturbations (SCIDAT tape in Appendix A). Use any available unit number. |
| **RANDOM INPUT UNIT**        | Unit number of file from which random perturbation data are to be read. If same as Groves input unit, these are read from SCIDAT tape. If card input, use 5. |
| **QBO INPUT UNIT**           | Unit number of file from which QBO parameters are to be read. If same as Groves input unit, these are read from SCIDAT tape. If card input, use 5. |
| **4-D INPUT UNIT**           | Unit number for 4-D input data tape. Use any available unit number. |
| **RANDOM OPTION**            | 1 means compute random perturbation output, 2 means do not compute random perturbation output. |
| **QBO OPTION**               | 1 means compute QBO output, 2 means do not compute QBO output. |
| **FIRST RANDOM NUMBER**      | Initial number for random number generator used to compute random perturbations (can be any odd positive integer). Use 1 for standard design applications. |
| **NMC READ OPTION**          | 0 means read NMC grid data from SCIDAT tape, otherwise these data are read from cards. |
| **4-D, P, D, T, SCRATCH UNIT** | Unit number for scratch file for 4-D grid profiles required in computations. Use any available unit number. This normally is a temporary drum file. |
NMC GRID POINTS  SCRATCH UNIT

Unit number for scratch file to store NMC grid point data. Use any available unit number. This normally is a temporary drum file.

INITIAL PL, DL, TL, PS, DS, TS

Initial values of large scale and small scale random relative pressure, density, and temperature perturbations, percent. Use zeros for standard design applications.

INITIAL UL, VL, US, VS

Initial values of large scale and small scale random wind components, m/s. Use zeros for standard design applications.

* - Include card 3 only if random option = 1.

TRAJECTORY INPUT

Use only if linear profile is not to be generated automatically. Each record has time (seconds), height (km), latitude (degrees), and west longitude (degrees).

TRAJECTORY BACKUP RECORD

Only if trajectory input is used. Same form as a trajectory position but with any negative height value.

The trajectory input records are optional, in free field format. If included, use as many records (e.g. cards), as necessary.

Input for the following sample output listing is as follows:

CARD1: 92.0, 28.45, 80.53, .0, .0, .0, 1, 1, 75, 0, 0, 0, .0, .0, 2., 47, 0, 0, 0, 20,
CARD2: 3, 3, 3, 4, 1, 1, 1, 0, 12, 13
CARD3: 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.

A SUMMARY OF THE ORGANIZATION OF AN INPUT DATA DECK IS AS FOLLOWS

Initial Data

Card 1, as described at the beginning of this Appendix
Card 2, as described at the beginning of this Appendix
Card 3, optional, included only if random option = 1
NMC Grid Data

Optional. Include as card input only if this is not to be read from
the SCIDAT data tape.

Random Perturbation Data

Optional. Include as card input only if the random input unit is 5 and
these data are not to be read from the SCIDAT data tape or some other input
file. Do not include if random option = 2.

QBO Parameters

Optional. Include as card input only if the QBO input unit is 5 and
these data are not to be read from the SCIDAT data tape or some other file.
Do not include if QBO option = 2.

Trajectory Position Data and Backup Card

Optional. Include if trajectory, rather than linear profile generated
by the program is to be evaluated, and if trajectory option is 5. Trajec-
tory data is on other file if trajectory unit is not 0 or 5.

More Data of the Same Kind (Starting with Initial Data, Card 1)

If additional trajectories or profiles are to be evaluated, the data
may be input one set immediately after the other. The program is actually
more efficient for such multiple runs if the month remains the same. This
is because as long as the month remains the same the SCIDAT data tape read
can be avoided for each subsequent data set.

OUTPUT TO GRAM IS AS FOLLOWS

JULIAN DATE - Computed from input date, set equal to zero for month 13
INITIAL STANDARD DEVIATIONS IN P, D, T, U,
V FOR LARGE SCALE AND SMALL SCALE

C-4
HEIGHT, LAT, LON, TIME

UNPERTURBED PRESSURE DENSITY, TEMPERATURE AND GEOSTROPHIC WIND (monthly mean values)

TOTAL PRESSURE, DENSITY, TEMPERATURE, AND WIND

THERMAL WIND SHEAR

MEAN VERTICAL WIND

PERTURBATION VALUES

Position and time where atmospheric parameters are evaluated

Computed from Jacchia, 4-D, or Groves - plus - stationary perturbations, depending on height.

Monthly means plus random perturbations and QBO perturbations

From thermal wind equations using finite differences of Jacchia, 4-D, or Groves - plus - stationary perturbations, depending on height.

From mean isentropic surface slopes

Stationary perturbations, QBO perturbations and amplitudes, and random perturbations and magnitudes for the small scale (S), large scale (L), and total (T) perturbations. Perturbations are those which are added to monthly means to produce total results output.

Following is a listing of sample output from the GRAM program. Initial lines of output are merely listings of the input data for easy reference. These listings are provided to indicate formats and kinds of input and output data. For a listing of the input cards for these sample outputs, see earlier in the Appendix.
### GLOBAL REFERENCE ATMOSPHERE - MOD 3

**INITIAL HEIGHT** = 92.00 KM
**INITIAL LAT** = 28.45 DEG
**INITIAL WEST LON** = 80.53 DEG
**DATE** = 1/1/75
**LAT INCREMENT** = 0.00 DEG
**MAXIMUM NUMBER OF POSITIONS** = 47
**TRAJECTORY OPTION** = 0
**GROVES INPUT UNIT** = 3
**RANDOM INPUT UNIT** = 3
**FIRST RANDOM NUMBER** = 1
**WMC READ OPTION** = 0
**WMC GRID POINTS SCRATCH UNIT** = 13
**JULIAN DATE** = 2442414.0

**INITIAL P,T,U =** 0.00 % 0.00 % 0.00 %
**INITIAL T,U,V =** 0.00 M/S 0.00 M/S

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<th>PRES.</th>
<th>DENS.</th>
<th>TEMP</th>
<th>GEOSTROPH.</th>
<th>PRES.</th>
<th>DENS.</th>
<th>TEMP</th>
<th>WIND (M/S)</th>
<th>SHEAR</th>
<th>PERTURBATION VALUES</th>
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<td>(KG/</td>
<td>(Kg/</td>
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### PERCENT DEVIATIONS FROM 1962 US STANDARD ATMOSPHERE APPEAR BELOW PRESSURE, DENSITY AND TEMPERATURE VALUES

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**C-6**
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C-9
| 46.00 | 20.45 | 80.53 | .132E+03 | .168E-02 | 272. | 7.3 | .134E+03 | .174E-02 | 269. | -35. | 9.5 | .6 | -0.07 |
| 0 | .32 | -2.02 | 2.02 | 1.72 | 1.31 | .51 |

| 44.00 | 20.45 | 80.53 | .168E+03 | .216E-02 | 269. | 6. | 2.164E+03 | .218E-02 | 267. | -23. | 7.3 | .7 | -0.07 |
| 0 | -.92 | -4.32 | 3.11 | -3.12 | -5.22 | 2.32 |

| 42.00 | 20.45 | 80.53 | .218E+03 | .268E-02 | 264. | 6. | 0.213E+03 | .283E-02 | 262. | -14. | 7.3 | .7 | -0.05 |
| 0 | -1.02 | -4.52 | 3.32 | -3.12 | -5.42 | 2.32 |

| 40.00 | 20.45 | 80.53 | .279E+03 | .373E-02 | 260. | 5. | -1.287E+03 | .380E-02 | 263. | -11. | 2.3 | .7 | -0.05 |
| 0 | -3.02 | -6.72 | 3.82 | -.02 | -5.02 | 5.12 |

| 38.00 | 20.45 | 80.53 | .365E+03 | .504E-02 | 252. | 6. | -2.380E+03 | .521E-02 | 254. | -17. | 7.4 | .5 | -0.07 |
| 0 | -3.32 | -6.12 | 2.92 | .62 | -2.92 | 3.92 |

C-11
| 36.00 28.45 80.53 | .47E+03  .60E-02 | 244. 7. .510E+03  .700E-02 | 255. -5. -5.4 .5 | -1.3 |
| -9.4 .9 -7.4 6.2 |

| 34.00 28.45 80.53 | .62E+03  .92E-02 | 236. 7. .657E+03  .949E-02 | 242. -19. 5. .6 | -0.18 |
| -5.3 6.7 1.8 3.7 |

| 32.00 28.45 80.53 | .83E+03  .12SE-01 | 233. 5. .85SE+03  .124E-01 | 236. -3. -3. .6 | -1.15 |
| -6.3 8.1 2.2 2.7 |

| 30.00 28.45 80.53 | .110E+04  .169E-01 | 229. 4. .114E+04  .169E-01 | 236. -8. -8. .6 | -0.11 |
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<td>-3.0×10⁴</td>
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<td>-3.14</td>
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C-13
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C-14
APPENDIX D - GRAM PROGRAM LISTING

Following is a listing of the Global Reference Atmospheric Model (GRAM) - Mod 3. Sequence numbers containing a four character subroutine code and a four digit number appear on the right of the printout.
FIRST DATA CARD READS INITIAL HEIGHT (KM), INITIAL LATITUDE (DEG) GRAM 1
INITIAL LONGITUDE (DEG), F10.7, MEAN F10.7, AP, MONTH, DAY, GRAM 2
YEAR (TOTAL YEAR - 1900), GREENWICH HOUR, MINUTES, SECONDS, GRAM 3
LATITUDE INCREMENT (DEG), LONGITUDE INCREMENT (DEG), GRAM 4
HEIGHT DECREASE (KM), MAXIMUM NUMBER OF POSITIONS (EXCLUDING GRAM 5
INITIAL POSITION) TO BE COMPUTED, TIME INCREMENT BETWEEN GRAM 6
POSITIONS, TRAJECTORY OPTION, OUTPUT OPTION, MINIMUM GEOSTROPHICGRAM 7
LATITUDE GRAM 8
COMMON/IOTEMP/IOTEM2/IUG/MMCOR/DDX/XMD/PHI1/PHI GRAM 9
* MONTH, IDA, IYR, H, PHI1, THET1, X, R, RPH1, RTHET1, F10, F10B, AP, GRAM 10
4 R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25, R26, R27
COMMON/CHIC/LA(4,4),NB(2),IWSYH,UXCOEF(I4,9),VCOEF(14,9) GRAM 11
COMMON/WINCOM/ DUMSTF(I7),UPRE,UPRE,DUPRE,DVPRE GRAM 12
FOR GLOBAl REFERENCE ATMOSHERE = MOD 3 *****/) GRAM 13
PI=3.1415927 GRAM 14
FAC=0.017453293 GRAM 15
LOOK=0 GRAM 16
MONTH = 0 GRAM 17
IOPT=0 GRAM 18
H=0 GRAM 19
5 IF(IOPT.EQ.0 .OR. (IOPT.GT.0 .AND. H.LT.0.)) GO TO 6 GRAM 20
READ(IOPT,10) IET,H,PHI1,THET1,FM,IMA,IDA,PLYR,IHRO,NINOR GRAM 21
2 READ(5,10,END=90) HI,PHII,THETI,FIO,F1OB,AP,MM,IDA,IYR,IMD,MIMO,GRAM 22
15 ISECO,DPHI,DTHET,DH,NMAX,INCT,IOPT,IOPP,GLAT GRAM 23
SET NSAME TO AVOID SETUP GRAM 24
IF (NSAME.EQ.MONTH) NSAME = 1 GRAM 25
LOOKUP ON MULTIPLE PASSES GRAM 26
15 IF (MM.EQ.MONTH) NSAME = 1 GRAM 27
CONVERT LATITUDE TO RADIANS GRAM 28
PHII=SIGN(450,-ABS(PHI1),PHII) GRAM 29
THETI=THETI+180. GRAM 30
IF(THETI.GT.360),THETI=THETI-360. GRAM 31
7 IF(THETI.LT.0.0) THETI=THETI+360 GRAM 32
GLAT = ABS(GLAT) GRAM 33
IF (GLAT.LT. 5.) GLAT = 5. GRAM 34
IF (GLAT.GE.180.) GLAT = 17.999 GRAM 35
GLAT=GLAT*FAC GRAM 36
WRITE(6,9010) HI,PHII,THETI,FIO,F1OB,AP,MM,IDA,IYR,IMD,MIMO,GRAM 37
* ISECO,DPHI,DTHET,DH,NMAX,INCT,IOPT,IOPP,GLAT GRAM 38
SET NSAME TO AVOID SETUP GRAM 39
15 IF (MM.EQ.MONTH) NSAME = 1 GRAM 40
LOOKUP ON MULTIPLE PASSES GRAM 41
CONVERT LATITUDE TO RADIANS GRAM 42
PHII=PHII*FAC GRAM 43
CONVERT LONGITUDE TO RADIANS GRAM 44
THETI=THETI*FAC GRAM 45
CONVERT LATITUDE INCREMENT TO RADIANS GRAM 46
DPHI=DPHI*FAC GRAM 47
D-2
C CONVERT LONGITUDE INCREMENT TO RADIANS
DTETHR=DTHET*FAC
C READ DATA TAPE TO Initialise Arrays
CALL SETUP
NT = 1
IF(IOPT.EQ.0) GO TO 18
READ(IOPT,10) IET,HI,PHI,THET
IF(ABS(PHI).LE.90.) GO TO 16
PHI = SIGN(180.-ABS(PHI))*PHI
THET = THET + 180.
16 IF(THET.LT.0.)THET=THET+360.
IF(THET.GT.360.) THET = THET - 360.
PHIR=PHIFAC
THETR=THETFAC
GO TO 19
18 H = HI - DH
C DISPLACES POSITION BEFORE EVALUATION OF ATMOSPHERIC PARAMETERS
IET = \( N \)CT
PHIR=PHIR+DPHIR
THETR=THETR+DTHETR
IF (ABS(PHIR).LE.PI/2.) GO TO 17
PHIR = SIGN(PI-ABS(PHIR))*PHIR
THETR = THETR + PI
17 IF (THETR.GT.2.*PI) THETR = THETR - 2.*PI
IF (THETR.LT.0.) THETR = THETR + 2.*PI
C A = EQUATORIAL EARTH RADIUS; B = POLAR EARTH RADIUS
C EPS= EARTH ECCENTRICITY
19 A = 6378.160
B = 6356.7747
EPS=(1.-(B/B)/(A*A))
C COMPUTES RADIUS TO HEIGHT H, AND GRAVITY AT HEIGHT AND LATITUDE PHIR
CALL RIG
ISEC=ISECO+IET
ISEC=MOD(ISEC,60)
MIN = MINO + IET/60
JHR = JHRO + MIN / 60
MIN = MOD(MIN,60)
C COMPUTES P,D,T,U,V AT FIRST POSITION AFTER Initial POSITION
IF(H.I.LE.30.) LOOK=1
IF(ABS(PHIR).GT.GLATF) GO TO 195
PHIS=PHIR
DPHIS=(PHIR+GLATF)/2.*GLATF)
PHIR=GLATF
CALL SCI0D(O)
UP2=UPRE
VP2=VPRE
DUP2=DUPRE
DVP2=DVPRE
PHIR=-GLATF
CALL SCI0D(O)
UP1=UPRE
VP1=VPRE
DUP1=DUPRE

D-3
DVP1=DVPRE
UPRE=UP1+(UP2-UP1)\#DPHIS
VPRE=VP1+(VP2-VP1)\#DPHIS
DUPRE=DUP1+(DUP2-DUP1)\#DPHIS
DVPRE=DVP1+(DVP2-DVP1)\#DPHIS
PHIR=PHIS
195 CALL SCIMOD(1)
20 IF (IOPT.EQ.0) GO TO 22
READ(IOPT,10) IET,HI,PHI,THET
IF(H.LT.0.0) GO TO 5
IF(ABS(PHI).LE.90.0) GO TO 21
PHI=SIGN(180.-ABS(PHI),PHI)
THET=THET+180.
21 IF(THET.LT.0.)THET=THET+360.,
IF(THET.GT.360.)THET=THET-360.,
PHIR=PHIFAC
THETR=THETFAC
GO TO 25
C INCREMENT THE HEIGHT
22 H = HI - DH
IF (H.LT.0.0) GO TO 5
C INCREMENT THE LATITUDE
PHIR=PHIR+PHIR
C INCREMENT THE LONGITUDE
THETR=THETR+THETR
C......READS NEW INPUT IF ABS(LAT) GTR 90 DEG
IF (ABS(PHR).LE.PI/2) GO TO 23
PHIR=SIGN(PI-ABS(PHIR),PHIR)
THETR=THETR+PI
23 IF (THETR.GT.2.*PI) THETR = THETR - 2.*PI
IF (THETR.LT.0.) THETR = THETR + 2.*PI
C INCREMENT THE TIME
IET=IET+IENC
25 MIN=MIN+IENC/60
ISEC=ISEC+IET
ISEC=MOD(ISEC,60)
MIN=MIN+ISEC/60
MIN=MOD(MIN,60)
C COMPUTE RADIUS AND GRAVITY AT NEW POSITION
CALL RIG
C COMPUTE P,D,T,U,V; AT NEW POSITION
IF(ABS(PHIR).GT.GLAF) GO TO 80
PHIS=PHIR
DPHIS=(PHIR*GLAF)/(2.*GLAF)
PHIR=GLAF
CALL SCIMOD(0)
UP2=UPRE
VPRE=VPRE
DUP2=DUPRE
VVP2=VPRE
PHIR=GLAF
CALL SCIMOD(0)
UP1=UPRE
VP1=UPRE
DUP1=DUPRE
DVP1=DVPRE
UPRE=VP1+(UP2-UP1)*DPHIS
VPRE=VP1+(VP2-VP1)*DPHIS
DUPRE=DUP1+(DUP2-DUP1)*DPHIS
DVPRE=DVP1+(DVP2-DVP1)*DPHIS
PHIR=PHIS

80 CALL SCINOD(1)

C....READS NEW INPUT IF NMORE = 0 OR MAX POINTS COMPUTED
IF(NMORE.EQ.0.OR.(IOPT.EQ.0.AND.NT.GE.NMAX)) GO TO 5
C CYCLE TO NEW POSITION
GO TO 20
90 STOP
9010 FORMAT(5*!INITIAL HEIGHT = 'F7.2,' KN*,T43,*INITIAL LAT = ',F6.2,' DEG*,/,' F10.7 = ',F8.2,
2T43,*MEAN F10.7 = 'F7.2,T83,*AP = 'F8.2,/' DATE = 'I2,'SEC*,/,' GREENWICH TIME = 'I2,*','I2,*'*,/,'I2,*'*,/,'I2,*'*,/,' LAT INCRED = ',F6.2,' DEG*,/,' T43,*HEIGH INCRED = ',F6.2,' DEG*,/,' T43,*WEST INCRED = ',F6.2,' DEG*,/,' T43,*INIT = ',F7.2,' KN*,T43,*MAXIMUM NUMBER OF POSITIONS = ',I4,T43,GRA185
6*TIME INCRED = 'I4,'SEC*/2X*,/,'TRAJECTORY OPTION = ',I4,
7T43,*OUTPUT OPTION = 'I2,T83,*MIN GEOSTROPH LAT = ',F5.1,/
END
SUBROUTINE ADJUST
COMMON/DU1M1(32),HS,P(16,26),T(16,26),SP(16,26)
COMMON/DU2M2(16,26),DU2,H5
COMMON/ADJU/ADJU(26,3),D(26),X(26),KOUNT
DIMENSION PG(26), GO(26), UC(26), VC(26), WC(26), UC(26), VC(26)
$ W(26)
COMMON/SORTM(16,26)

C ASSUMPTIONS
C HS IS THE SURFACE LEVEL
C ALL DATA VALUES ABOVE SURFACE LEVEL ARE IN 1 KM INCREMENTS
E1=0.075
E2=0.150
MAXIT=3
KMAX=10
HSJ=HS
IF (HS.LT.0.) HSJ = 0.
JJ=INT(HSJ/2.)
STEST=0.05
ISS=1
CONST=28703./980.665
N=26
ITER=0
IU1=SQR(SP(KOUNT,1))
IU2=SQR(SD(KOUNT,1))
IU3=SQR(ST(KOUNT,1))
DO 5 I=JJ,N
IU1=SQR(SP(KOUNT,1))
IU2=SQR(SD(KOUNT,1))
IU3=SQR(ST(KOUNT,1))
5 CONTINUE

D-5
C......SETS UP QUADRATURE FACTORS
P0(I)=500.*(FLOAT(INT(HSJH1,))-HS)/(CONST*(KOUNT,J))
Q0(I)=500.*(FLOAT(INT(HSJH1,))-HS)/(CONST*(KOUNT,J))
DO 15 I=JJ,NM
IP=I+1
PQ(I)=500./(CONST*(KOUNT,J))
15 GO TO 58

C......SETS UP COEFFICIENTS
I2=0
DO 35 I=1,NM
IF(I.GT.I,AMD,LT,JJ) GO TO 35
AW=I./SP(KOUNT,I)
BW=I./SD(KOUNT,I)
CW=I./ST(KOUNT,I)
IM=1
IF(I.EQ.JJ) IM=1
IP=I+1
IF (I.EQ.1) IP=JJ
I2=I2+1
AW=I./SP(KOUNT+IP)
BW=I./SD(KOUNT+IP)
CW=I./ST(KOUNT+IP)
IF(I.EQ.1) GO TO 25
A(I2,1)=-(1.-Q0(I))/AW+(1.+PQ(I))*Q0(I)/BW
A(I2,2)=((1.-Q0(I))*Q0(I))/AW+(1.+PQ(I))*Q0(I)/BW
A(I2,3)=-(1.-Q0(I))-Q0(I)/BW
35 CONTINUE
CALL DIAGEQ(I2)

C......FINDS CORRECTIONS
AW=1./SP(KOUNT+1)
BW=1./SD(KOUNT+1)
CW=1./ST(KOUNT+1)
UC(I)=SORT((U(I)+X(I))+(1.+PQ(I))/AW)
VC(I)=SORT((V(I)-X(I))+(1.+PQ(I))/BW)
WC(I)=SORT((W(I)+(1.+PQ(I))/CW)
AW=1./SP(KOUNT+N)
D-7

BN=1./SD(KOUNT+I)
CW=1./ST(KOUNT+I)
UC(N)=SQRT(U(N)-X(I2)*(1.-QQ(NM))/AW)
VC(N)=SQRT(V(N)-X(I2)*QQ(NM)/BW)
WC(N)=SQRT(W(N)+X(I2)*QQ(NM)/CW)

I2=1
DO 40 I=JJ,N
I2=I2+1
I2M=I2-1
AM=1./SP(KOUNT+I)
BN=1./SD(KOUNT+I)
CN=1./ST(KOUNT+I)
IN=I-1
IF(I.EQ.JJ)IN=1
UC(I)=ABS(U(I))+(-X(I2M)*(1.-QQ(IM))*X(I2)*(1.+PQ(I)))/AW
VC(I)=SQRT(VC(I))
WC(I)=ABS(W(I))+(X(I2M)*QQ(IM))*X(I2)*PQ(I)/CW
40 WC(I)=SQRT(WC(I))

C...... GETS ADJUSTED VALUES
C...... ADJUSTS ON TRIANGLE INEQUALITIES
58 K=0
DO 68 I=1,N
IF(I.GT.1.AND.I.LT.JJ) GO TO 68
AU=UC(I)
AV=VC(I)
AH=WC(I)
AMAX=AMAX(AU,AV,AM)
EE=E1*AMAX
EF=E2*AMAX
AM=SP(KOUNT+I)
BM=SD(KOUNT+I)
CM=ST(KOUNT+I)
COR=AHAV-AM-EE
DIV=AH+BM+CW
IF(COR.GT.0.) GO TO 60
COR=(AHAV-AM-EF)/DIV
AU=AU-COR#AM
AV=AV-COR#BW
AH=AH-COR#CW
GO TO 64
60 COR=AHAV-AM-EE
IF(COR.GT.0.) GO TO 62
COR=(AHAV-AM-EF)/DIV
AU=AU-COR#AM
AV=AV-COR#BW
AH=AH-COR#CW
GO TO 64
62 COR=-AHAV+AM-EE
IF(COR.GT.0.) GO TO 66
COR=(-AHAV+AM-EF)/DIV
AU=AU-COR#AM
AV=AV-COR#BW

D-7
AM=AM-COR*CW
64 K=K+1
66 UC(I)=AU
VC(I)=AV
WC(I)=AM
68 CONTINUE
KMAX=K
100 IF((ITER.EQ.0).OR.(KMAX.GE.0)) GO TO 110
GO TO 112
110 ITER=ITER+1
IF(ITER.LE.MAXIT) GO TO 12
112 IF (ISS.GE.1) GO TO 999
114 ITER=1
ISS=2
VTA=VC(1)
WTA=WC(1)
DO 120 I=J,J,MM
IM=1-1
IF(I.EQ.JJ)IM=1
VFB=VC(I)
WTB=WC(I)
VC(I)=(VC(I)+2.0*VTB+WTA)**0.25
WC(I)=(WC(I)+2.0*WTB+WTA)**0.25
VTA=VFB
WTA=WTB
120 CONTINUE
GO TO 12
C.....CALCULATE THE CORRECTED VARIANCES
999 DO 1010 I=1,N
IF(I.GT.1.AND.I.LT.JJ) GO TO 1010
SP(KOUNT,I)=UC(I)**2
SD(KOUNT,I)=VC(I)**2
ST(KOUNT,I)=WC(I)**2
1010 CONTINUE
RETURN
END
SUBROUTINE CHECK
COMMON/CHK/P(4,4,3),RHO(4,4,3),MO(2)
COMMON/WMC/DM,DC,DX5,DYS
COMMON/CHIC,LA(16),MB(2),IV entry,UCOEF(14,9),VCOEF(14,9)
MB(1)=0
MB(2)=0
CALL GROUP
MS=0
MR=1
IF(MO(1).EQ.0.AND.MO(2).EQ.0) GO TO 1000
DO 640 KL=1,2
IF (NO(KL).EQ.0) GO TO 640
450 CONTINUE
MR=MR+1
IF(MO(KL).LE.MR) GO TO 500
MR=MR+1
GO TO 450
500 CONTINUE
II=NR
J1=NO(KL)-(NR-1)&4
SH1 = 6,
SH2 = 6.
DP = P(I1,J1,2) - P(I1,J1,1)
IF (DP) 510:520:510
510 SH1 = ABS(P(I1,J1,2)/DP)
520 DP = P(I1,J1,2) - P(I1,J1,3)
IF (DP) 530:540:530
530 SH2 = ABS(P(I1,J1,2)/DP)
540 IF(SH1.LT.4.0.OR.SH2.LT.4.0) GO TO 640
IF(SH1.GT.9.0.OR.SH2.GT.9.0) GO TO 640
WR=I
--'_+1
640 CONTINUE
RETURN
1000 IWSYH = '***'
RETURN
END
SUBROUTINE CORLAT(A,B,C,E,F,G,H,AD1,AJ1,AK1,SP1,SP2,SD1,SD2,ST1)
IST1,IST2,SUI,SU2,SV1,SV2,UD1,UD2,RD,RT,RV)
IF(SI)IST1$SD2$ST2.6T.O.) GO TO 5
C......DEFAULT VALUES AVOID DIVISION BY ZERO
IF(SD1.LE.0.) SD1=0.001
IF(ST1.LE.0.) ST1=0.001
IF(SD2.LE.0.) SD2=0.001
IF(ST2.LE.0.) ST2=0.001
IF(RD.LE.0.) RD = .00001
IF(RT.LE.0.) RT = .00001
IF(RV.LE.0.) RV = .00001
CONTINUE
5 CONTINUE
IF(ABS(TD1).LE.0.) TD1 = 0.001
IF (ABS(U1).LE.0.) U1 = 0.001
IF (ABS(V1).LE.0.) V1 = 0.001
IF (ABS(SV1).LE.0.) SV1 = 0.001
IF (ABS(U1).GE.1.) U1 = 0.99#U1/ABS(U1)
IF (ABS(V1).GE.1.) V1 = 0.99#V1/ABS(V1)
A=RD*SD2/SD1
B=SD2*SQRT(1-RD*RD)
C=(SP2*SP2-SD2*SD2-ST2*ST2)/(2*SD2*ST2)
D=(SP1*SP1-SD1*SD1-ST1*ST1)/(2*SD1*ST1)
C=E-SD1*SQRT(C+ST1*ST1-D*D1*D2*2*C*D1*D2)/D1
E=ST2*ST2-C*ST1*ST1-D*D1*D2-2*C*D1*D2+ST1*ST1
F=(SU2/SU1)*(RV-RD*UD2*UD1)/(1-RD*RD*UD1*UD1)
G=(RV*SU2+F*SU1)/(RD*UD1*SD2)
H=SU2*SU2-F*SU1*SU1-G*G*SD2*SD2-2*F*G*RD*UD1*SD2*SU1
IF(H.GE.0.) GO TO 10
else GO TO 15
10 E=SQRT(E)
CONTINUE
15 RETURN
H=0.

15 H=SORT(H)

AI=(SV2/SV1)*(RV-RD#VD2#VD1)/(1-RD#VD0#VD1#VD1)

AL=(RV*SV2-AI*SV1)/(RD#VD1#SD2)

AK= SV2*SV2-AI*SV1-AJ#SD2-2*AI#AJ#RD#VD1#SD2#SV1

IF(AK,GE,0.) GO TO 25

AK=0.

25 AK=SORT(AK)

RETURN

END

SUBROUTINE DIAGEQ(N)

A(I,J)=DIAG TERMS; I=ROW NO., J=DIAG NO.

B(I)=RIGHT SIDE TERMS

N=NO. OF ROWS

K=NO. OF BORDER DIAGONALS; M=#+1=INDICES OF PRIM. DIAG

2KH=TOTAL NO. OF DIAGS.

X(I)=SOLUTION

COMMON/ADJ.COM/A(26,3), B(26), X(26)

K = 1

M=K+1

DO 30 L=1,N

AL=A(L,M)

A(L,M)=1.

IF(L.EQ.N) GO TO 15

I2=MNO(K,M-L)

DO 10 I=1,I2

MPI=M+I

10 A(L, MPI)=A(L, MPI)/AL

B(L)=B(L)/AL

IF(L.EQ.N) GO TO 30

DO 25 I=1,I2

LPI=L+I

FACT=A(LPI,M-I)

DO 20 J=1,I2

NJI=H-J-I

20 A(LPI,MJI)=A(LPI,MJI)/FACT

B(LPI)=B(LPI)-B(L)/FACT

25 CONTINUE

X(M)=B(M)

MM1=M-1

DO 50 L=1,MM1

NML=N-L

SUM=0.

I2=MNO(K,L)

DO 40 I=1,I2

SUM-SUM+A(NML+M)*X(NML+I)

40 CONTINUE

50 X(NML)=B(NML)-SUM

RETURN

END

SUBROUTINE FAIR (PG, DG, TG, PJ, DJ, TJ, H, P, B, T)

C......FAIRS BETWEEN GROVES AND JACCHIA VALUES 90 LE HEIGHT LE 115 KM

C......DIMENSION CZ(6)

C......FAIRING VALUES
DATA CZ /1.00.90450850.65450850.34549150.09549150.0/
C = HEIGHT INDEX
I = (IH - 85)/5
C = GROVES FAIRING COEFFICIENT
CZI = CZ(I)
C = JACCHIA FAIRING COEFFICIENT
SZI = 1.0 - CZI
C = FAIRED TEMPERATURE
T = T@CZI + T@SZI
C = FAIRED PRESSURE
P = EXP(ALOG(PG)@CZI + ALOG(PG)@SZI)
C = FAIRED DENSITY
D = EXP(ALOG(DG)@CZI + ALOG(DG)@SZI)
C = DP/DY FOR GEOSTROPHIC WINDS
DPY = DPY@CZI + DPY@SZI
C = DT/DY FOR THERMAL WINDS
DTY = DTY@CZI + DTY@SZI
RETURN
END
SUBROUTINE GEN4D
C.....GENERATES NG = 9 OR 16 4D PROFILES P,D,T AND SIGMAS SP,SD,ST AT
C = GRID OF LATITUDES AND LONGITUDES GLAT,GLON. CURRENT LATITUDE, LONITUDE
C = LONGITUDE=CLAT,CLON. PREVIOUS LATITUDE=PLAT,PLON.
COMMON/C4/GLAT(16),GLON(16),NG,P(16,26),B(16,26),T(16,26),
$ SP(16,26),SD(16,26),ST(16,26),PLON,CLON,HS
COMMON/IOTEM1,IOTEM2,IOUG,WMCOP,DDD,XMDJ,PLAT,CLAT,
$ NSAME,RP1,RT1,SP1,SD1,ST1,KUI,RVI,SUI,SVI,
$ NM,DA,H1,PHIR,THETR,GZ,IR,IZ,PHIR,THETR,F10B,AP,
$ IH,R,M,NMORE,DH,DL,VL,DZ,B,EP,F,TOPP,LOOK,DUMMY(20)
COMMON/POCTON/IU4,MONTH,IOPR,PG(18,19),TG(18,19),DG(18,19),
$ 1 PSP(8,10,12),DSP(8,10,12),TSP(8,10,12)
$ 2 PPAR(17,5),DARP(17,5),TAR(17,5),
$ 3PDP(17,5),DDP(17,5),TDQ(17,5),PR(20,10),DR(20,10),TR(20,10),
$ 4UAQ(17,5),VAQ(17,5),UDQ(17,5),UR(25,10),VR(25,10),
$ 5SPU(00,18),G0,VAR,V0,PG0,D0A,A0A,A0,DAPQ,
$ 6PLP(25,10),DLP(25,10),TLP(25,10),ULP(25,10),VLP(25,10),UFL(25,10),
$ 7101,DLP(25,10),UDS(25,10),VDS(25,10)
COMON/ADJCOM/DMU(130),KOUNT
COMMON/IPRTP/IPRT
IF(NSAME.EQ.0.1) RETURN
IPRT=0
LOOK=0
F = 0.017453293
NG = 16
DX = PLO@ - CLON
C.....LONGITUDE DISPLACEMENT FROM PREVIOUS TO CURRENT POSITION
DY = CLAT - PLAT
C.....LATITUDE DISPLACEMENT FROM PREVIOUS TO CURRENT POSITION
IF (DY) 20,10,20
10 IF (DX) 15,12,15
12 K = 0
GO TO 40

D-11
15 \theta = 180. + \text{SIGH}(90. , \text{DX})

20 \theta = \text{ATAN}(\text{DX/DY})/F

IF (DY.GT.0.) \theta = \theta + 180.

IF (\theta.LT.0.) \theta = \theta + 360.

C...... \theta = AZIMUTH ANGLE OF TRAJECTORY, USED TO ORIENT LAT-LON GRID

30 K = \text{INT}((\theta + 67.5)/45.)

C INDEX USED IN COMPUTED GO TO FOR 110 THRU 180

IF (K.GT.8) K=K-8

C NORTH POLAR GRID

IF (CLAT.GT.75.0.AND.K.GE.3.AND.K.LE.7)GO TO 200

C SOUTH POLAR GRID

IF (CLAT.LT.-75.0.AND.(K.GE.7.OR.K.LE.3))GO TO 200

C...... INITIAL ESTIMATE OF REFERENCE LATITUDE (LOWER LEFT GRID POINT)

40 LATO = 5*\text{INT}(CLAT/5.)

IF (CLAT.LT.0.) LATO = LATO - 5

C...... INITIAL ESTIMATE OF REFERENCE LONGITUDE (LOWER LEFT GRID POINT)

LONO=5*\text{INT}(CLON/5.)

C...... ADJUSTS LATO,LONO ACCORDING TO DIRECTION OF TRAJECTORY AZIMUTH

IF (K.GT.0) GO TO 100

LATO = LATO - 5

LONO= LONO + 10

GO TO 190

100 GO TO (110,120,130,140,150,160,170,180),K

110 LATO = LATO-10

LONO= LONO + 10

GO TO 190

120 LATO = LATO-10

LONO= LONO+15

GO TO 190

130 LATO = LATO-5

LONO= LONO+15

GO TO 190

140 LONO= LONO+15

GO TO 190

150 LONO= LONO+10

GO TO 190

160 LONO= LONO+5

GO TO 190

170 LATO = LATO-5

LONO= LONO+5

GO TO 190

180 LATO = LATO-10

LONO= LONO+5

GO TO 190

190 IF (LONO.GT.360) LONO = LONO - 360

DLI=1.25

IF(ABS(CLAT).GE.18) GO TO 192

DLI=3.0

LATO=18

192 DO 195 I=1,4

II2 = II2

DO 195 J=1,II2

GLAT(J) = LATO + 1.25*(J-I)

C...... LATITUDE, LONGITUDE GRID AT 5 DEGREE INTERVALS

D-12
195 \text{GLON}(J) = \text{LONO} - 5 \times (I - 1)

\text{GO TO 400}

\text{C POLAR GRID}

200 \text{MG} = 9

\text{DO 210 } J = 1, 8

\text{C POLAR GRID LATITUDES 1-8 \pm 75 (N) OR \pm 75 (W)}

\text{GLAT}(J) = \text{SIGN}(75, + \text{CLAT})

\text{C POLAR GRID LONGITUDES 1-8 AT 45 DEG INTERVALS}

210 \text{GLON}(J) = 45 \times (J - 1)

\text{C POLAR GRID LATITUDE 9 = POLE \pm 93 OR \pm 90}

\text{GLAT}(9) = \text{SIGN}(90, + \text{CLAT})

\text{C POLAR GRID LONGITUDE 9 = 0}

\text{GLON}(9) = 0,

\text{C GENERATES 16 PROFILES (OR 9 PROFILES FOR POLAR GRID)}

400 \text{CALL GRID4D}

\text{DO 600 } I = 1, \text{NG}

\text{CHECK} = P(I, J) \times D(I, J) \times T(I, J) \times SP(I, J) \times SD(I, J) \times ST(I, J)

\text{C FINDS INDEX } \text{IHV} \text{ OF HIGHEST HEIGHT WITH NON-ZERO DATA}

\text{IHV} = I

\text{IF} (\text{CHECK} > 0) \text{ GO TO 491}

\text{DO 420 } J = 1, 251

\text{J = 26 - J1}

\text{CHECK} = P(I, J) \times D(I, J) \times T(I, J)

\text{IF} (\text{CHECK} > 0) \text{ GO TO 440}

\text{420 CONTINUE}

\text{C HEIGHT = HEIGHT INDEX - 1}

440 \text{Z1 = HV - 1.}

\text{C SP = SP(I, IHV)}

\text{SD = SD(I, IHV)}

\text{ST = ST(I, IHV)}

\text{IF} (\text{HEIGHT} \geq 20 \text{ KM}, \text{ USE GROVES AT 30 KM FOR INTERPOLATION,})

\text{C OTHERWISE USE GROVES AT 25 KM}

\text{IF} (\text{IHV} \geq 21) \text{ GO TO 480}

\text{C EVALUATES GROVES AT 25 KM FOR INTERPOLATION AND}

\text{C FILL IN ZERO DATA}

\text{CALL 6TERP} (25, \text{GLAT}(I), P2, D2, T2, P6, D6, T6, DPY, DPY)

\text{INP} = \text{IHV} + 1

\text{DO 450 } K = \text{INP} + 26

\text{C AVOIDS INTERPOLATION OF P, D, T IF ONLY SIGMANS ARE ZERO}

\text{IF} ((P(I, K) \times D(I, K) \times T(I, K)) \times \text{GT}, 0) \text{ GO TO 445}

\text{H = K - 1}

\text{C INTERPOLATES BETWEEN 4D AT HEIGHT Z1 AND GROVES AT 25 TO FILL}

\text{C IN MISSING DATA}

\text{CALL INTER2} (P(I, IHV), D(I, IHV), T(I, IHV), Z1, P2, D2, T2, 25, \text{PH}, \text{DH}, \text{TH}, \text{H})

\text{PH} \text{ = P(HK)}

\text{DH} \text{ = D(HK)}

\text{TH} \text{ = TH}

445 \text{SP(I, K) = SPR}

\text{END}
SD(I,K)=SDR
C....SETS MISSING SIGMAS EQUAL TO SIGMAS AT HEIGHT ZI
450 ST(I,K)=STR
GO TO 500
C.....EVALUATES GROVES AT 30 KM FOR INTERPOLATION AND FILL IN OF ZERO DATA
480 CALL GTERP(30,GLAT(I)+P2*D2+T2,P6+DGX+TYDTX+DP2Y)
CALL PDMUV(PSP,DSP,TSP,GLAT(I),GLAT(I)+30,DP+DGX+DTX+DPY,DTX,DTY)
C COMPUTE PERTURBATIONS TO GROVES MODEL
$ +DP2X+DP2Y,DPXY)
GEN4 142
GEN4 143
GEN4 144
GEN4 145
C.....ADD STATIONARY PERTURBATIONS TO GROVES MODEL
P2 = P2*(1. + DP)
D2 = D2*(1. + DD)
T2 = T2*(1. + DT)
IHJ = IHV + 1
DO 490 K=IHJ,26
C.....AVoids INTERPOLATING P,D,T IF ONLY SIGMAS ARE ZERO
IF (SP(I,K).LE.0.) SP(I,K) = SP(I,1)
IF (SD(I,K).LE.0.) SD(I,K) = SD(I,1)
IF (ST(I,K).LE.0.) ST(I,K) = ST(I,1)
DO 495 K=IHJ,10
C.......SETS ALL ZERO SIGMAS TO SIGMA AT HEIGHT ZI
IF (SP(I,K).LE.0.) AND (P(I,K).GT.0.) SP(I,K) = SPR
IF (SD(I,K).LE.0.) AND (D(I,K).GT.0.) SD(I,K) = SDR
IF (ST(I,K).LE.0.) AND (T(I,K).GT.0.) ST(I,K) = STR
500 PA = P(I,1)
TA = T(I,1)
R = 287.05
G = 62*(1.+(Z/(RI-Z))**2)
K = 2
510 PB = P(I,K)
TB = T(I,K)
IF (PBGTB) .GT. 0.) GO TO 520
6 K = K + 1
GO TO 510
520 IF (TA-TB) .LT. 560, 570, 560
560 IZ = (TA-TB) / ALOG(TA/TB)
GO TO 575
570 IZ = TA
575 HS = K-1*0.001*RTZ*AL05*(PR/PA)/G
576 KM=K-2
577 IF(ABS(K-1-HS),GT.0.1) GO TO 578
578 GAM=TA-T(I+K+1)
579 IF(GAM) 582,590,582
580 GAM=(TA-TB)/(K-1-HS)
582 KM1=KM1+1
583 IF(ABS(GAM),GT.6) GAM=SIGN(GAM)
584 JD=JD-1
585 TJ=TA-GAM*(J-HS)
586 PJ=PA*GAM**(G/(R*GAM**0.001))
587 DJ=PI/PJ
588 CI(J1)=PJ
589 DI(J1)=DJ
590 TD(J1)=TJ
591 IF(J1).EQ.1 590,591,590
592 DO 593 JD=1,JD1
593 TJ=TA
594 PJ=PA*EXP(-GAM*(J-HS)/(R*0.001*PJ))
595 DJ=PJ/PJ
596 CI(J1)=PJ
597 DI(J1)=DJ
598 TD(J1)=TJ
599 IF(J1).EQ.1 599,600,599
600 CONTINUE
601 RETURN
602 END

SUBROUTINE GETNHC

READS *SETUP* DATA TAPE, OR MMC GRID DATA CARDS, AND WRITES SCRATCH FILE FOR USE BY SELEC4.

DIMENSION IP(15)

COMMON /IOTEMP/,IOTEM1,IOTEM2,IUG,MMCOP,IDUM(60)

NRE=0

IF(NMMCOP.NE.0) GO TO 1

READ(IUG,300,END=90) N,IP

300 FORMAT(A2,9X)

IF(N.NE.'N') 60 TO 3

GO TO 1

READ(5,100) (IP(I)),I=1,15

GO TO 2

FORMAT(15)

DO 4 I=1,15,3

M=IP(I)
IF(M.LT.1) GO TO 5
IJ=IP(I)+1000+IP(I+2)
WRITE(IOTEM2) IJ
NREC=NREC+1
4 CONTINUE
IF(NMCOP.NE.0) GO TO 2
GO TO 1
5 IF(NREC.NE.1977) 60 TO 6
GO TO 1
MOVES PAST FIRST EOF ON UNIT IUG
READ(IUG,9992,END=42) IDU_Y
9999 FORMAT(A10)
GO TO 41
RETURN
6 WRITE(6,200) NREC,IOTEN2
200 FORMAT(1H1/1X,I6,' RECORDS WRITTEN BY GETNMC IN SCRATCH FILE',I3)
STOP
90 WRITE(6,400) IUG
400 FORMAT('/ 1 PREMATURE END-OF-FILE FOUND ON UNIT ',I2/
'0 CALLED FROM SUBROUTINE GETNMC.')
STOP
END
SUBROUTINE GRID4D GRID
INTEGER FLD GRID
C_CON/C4/LAT(16),L_(16),NP,P_6,26),T_16_26),SP(16,26),GRID
GRID_16,26),ST(16,26)
COMMON /PDTCOM/ IT_HONTH GRID
S GRID
SUBROUTINE TO _LECT
LAT/LONS_TEMPERATURE, AND DENSITY PROFILES (GRID TOGETHER WITH THE NORMALIZED VARIANCES IN EACH AT UP TO 16 'GRID GRID AT LAT/LONS SELECTED BY CALLING PROGRAM.
USES NASA HUNTSVILLE MSFC 4-D DATA TAPES
DIMENSION IM(107);BUFFER(64)
COMMON /IOTEMP/ IOTEN1,IOTEN2
COMMON /POINTER/ IPT(16,5),LL(16),DP(16,2)
COMMON /ORDER/ IPTM(16,5),READ(55,3)
COMMON /INT/ D(208,5),IG(5),DXY(2),DLA(4),DL0(4)
INTEGER IOTEN1,READ,WRITE
INTEGER ZERO,ONE,TEM,HUMD,TTHU,READ,WRITE
WRITE=6H WRITE
C
N=MONT\-1-(\#MONTH)/9\#4
IF(MONTH,EQ.13) N=0
NUMEOF = 0
CALL NTRAN(IT,10,22)
IF (N.EQ.0) GO TO 20
CALL NTRAN(IT,8+N,22)
C
APPROPRIATE 4-D INPUT TAPE NOW POSITIONED - FILE NEEDED PROFILES
20 CALL SELEC4
C
IRC=0
IRN=1
IF(IREAD(IRN,3),EQ.0) GO TO 39
21 JT=IT
N=READ
22 CALL NTRAN(IT,2,106,IN,L,22)
IRC =IRC +1
IF (L.EQ.-2) GO TO 39
IF (L.EQ.0) WRITE(6,23) IT,L,IRC
23 FORMAT(* INPUT UNIT NO.*,I3, ' IN ERROR (*,I2,*') FOR RECORD NO.*,ISGRID
1)
IF(IRC.LT.IREAD(IRN,3)) GO TO 22
IF(IRC.GT.IREAD(IRN,3)) GO TO 39
24 I=IREAD(IRN+1)
J=IREAD(IRN+2)
IF(IRN.EQ.1) GO TO 25
IF(IRN.EQ.3) GO TO 27
25 IP=FLD(12+12,IN(106))
MP=FLD(12+12,IN(106))
IF((MP.NE.MONTH),OR,(IP.NE.IPT(I,J))) GO TO 39
DO 26 IK=1,106+1
K=107-IK
IN(K+1)=IN(K)
26 CONTINUE
27 FLD(0,18+IN(1)) = I
FLD(18+18+IN(1)) = J
JT=IOTEM1
M=WRITE
WRITE(IOTEM1) IN
IRN=IRN+1
IF(IREAD(IRN,3),EQ.IRC) GO TO 24
IF(IREAD(IRN,3),EQ.0) GO TO 28
GO TO 21
C
INTERPOLATE TO GIVEN LAT/LON FROM GRID DATA
28 M=READ
DO 38 II=1,MP
DO 29 J=1,5
D(I,J)=0.0
CONTINUE
DO 32 J=1,4  
IF(IPT(I,J).EQ.0) GO TO 32  
FLD(O,18,INDEX) = I  
FLD(18,18,INDEX) = J  
REWIND IOTEM  
READ(IOTEM,END=39) IN  
IF(IN(1).NE.INDEX) GO TO 30  
DO 31 I=2,105  
J2=2*I-2  
J1=J2-1  
D(J1,J)=FLD(O,18,IN(I))/HUND  
D(J2,J)=FLD(18,18,IN(I))/HUND  
31 CONTINUE  
DLA(J)=FLD(O,18,IN(106))/TEN  
DLO(J)=FLD(18,18,IN(106))/TEN  
32 CONTINUE  
C  
IF NECESSARY, INTERPOLATE  
C  
LALO=LL(I)  
DO 33 I=1,5  
IG(I)=IPT(I,I)  
33 CONTINUE  
IF(IG(2).NE.0) GO TO 35  
DO 34 I=1,208  
D(I,5)=D(I,1)  
34 CONTINUE  
GO TO 37  
35 IF(IG(5).NE.2) GO TO 36  
DYX(1)=DYX(II,1)  
DYX(2)=DYX(II,2)  
36 CALL INTRP4 (LALO)  
C  
37 DO 38 I=1,26  
P(I,1)=D(I,5)*HUND  
R(I,1)=D(I+156,5)/THOU  
T(I,1)=D(I+52,5)  
DIVIDE=ONE  
IF(P(I,1).GT.ZERO) DIVIDE=(P(I,1)/HUND)**2  
SP(I,1)=D(I+26,5)/DIVIDE  
DIVIDE=ONE  
IF(R(I,1).GT.ZERO) DIVIDE=(THOU*R(I,1))**2  
SR(I,1)=D(I+182,5)/DIVIDE  
DIVIDE=ONE  
IF(T(I,1).GT.ZERO) DIVIDE=T(I,1)**2  
ST(I,1)=D(I+178,5)/DIVIDE  
38 CONTINUE  
RETURN  
39 WRITE(6,40) J,IRC,IREAD(IRN,3),MP,MONTH,IP,I,J,IPT(I,J)+IRN,M+L  
40 FORMAT(**** UNIT NO.**I3,** IN ERROR**I7,** RECORDS READ/**  
1** IREAD(IRN,3) =**,I5,** MP =**,I3,** MONTH =**,I3,  
2** IP =**,I5,** IPT(**I2,**I1,**I) =**,I5,** IRN =**,I3/A6,** STATUS**,I5)
STOP
END

SUBROUTINE GROUP
DIMENSION KOU(2)
COMMON/CHIC/LA(4,4),NB(2),IMSYN,UCOEF(14,9),UCOEF(14,9)
COMMON/CHK/P(4,4,4),DEN(4,4,4),NO(2)
COMMON/WINCON/DGH,FCOY,DX5,DY5
FCOY = FCOY#DX5/DY5
KK = 1
DO 100 I = 1,4
DO 100 J = 1,4
LA(I, J) = 4*(I-1)+J
100 CONTINUE

200 CONTINUE
DO 250 N = 1,4
DO 250 N = 1,4
IF (KK.EQ.1) GO TO 210
I = 5
J = N
NM = 1
M4 = 1
GO TO 220
210 CONTINUE
I = M
J = N
NM = 1
M4 = 1
220 CONTINUE
IF (M.EQ.4) GO TO 225
DIMX = FCOY#(DEN(I+J, NM) + DEN(I-J, 2))/2
VY = (P(I+J, NM) - P(I-J, 2))/DIMX
IF (ABS(VY).GT.100) GO TO 225
LA(I, J) = MIN0(LA(I, J), LA(I+J, NM))
LA(I+J, NM) = LA(I, J)
225 CONTINUE
IF (M.EQ.4) GO TO 250
DIMY = FCOY#(DEN(I+J, NM) + DEN(I-J, 2))/2
VX = (P(I+J, NM) - P(I-J, 2))/DIMY
IF (ABS(VX).GT.100) GO TO 250
LA(I, J) = MIN0(LA(I, J), LA(I+J, NM))
LA(I+J, NM) = LA(I, J)
250 CONTINUE
KK = KK+1
IF (KK.EQ.2) GO TO 200
NO(1) = 0
NO(2) = 0
II = 1
DO 400 LL = 1, II
KOU(II) = 1
DO 300 I = 1, 4
DO 300 J = 1, 4
IF (LA(I, J).EQ.LL) KOU(II) = KOU(II)+1
300 CONTINUE
IF (KOU(II).GE.7) NO(II) = LL
RETURN
20  A = (Z - Z1)/(Z2 - Z1)
   U = U1 + (U2 - U1) * A
   V = V1 + (V2 - V1) * A

   LINER INTERPOLATION BETWEEN U1, U1 AT HEIGHT Z1 AND U2, V2 AT
   HEIGHT Z2, OUTPUT IS U, V AT HEIGHT Z
   RETURN

C   HEIGHT Z2, OUTPUT IS U, V AT HEIGHT Z
END

SUBROUTINE INTERZ(Pl, P1, T1, T1, Z1, P2, P2, T2, T2, Z2, P, T, Z)
5  IF (Z1 - Z2) 20, 10, 20
10  P = P1
    D = D1
C   SETS P, D, T = P1, D1, T1, IF Z1 = Z2
    T = T1
    RETURN
20  A = (Z - Z1)/(Z2 - Z1)
    T = T1 + (T2 - T1) * A
    D = D1 + (D2 - D1) * A
    P = P1 + (P2 - P1) * A
C   LINEAR INTERPOLATION BETWEEN P1, D1, T1 AT HEIGHT Z1 AND P2, D2, T2
C   AT HEIGHT Z2 TO OUTPUT VALUES OF P, D, T AT HEIGHT Z
   RETURN

END

SUBROUTINE INTER2(Pl, P1, T1, T1, Z1, P2, P2, T2, T2, Z2, P, T, Z)
C   INTERPOLATES BETWEEN P1, P1, T1 AT HEIGHT Z1 AND P2, P2, T2 AT
C   HEIGHT Z2 TO OUTPUT VALUES OF P, D, T AT HEIGHT Z
C   CHECKS FOR T1, D1, T2, D2 PRODUCT = 0; FOR GAS CONSTANT INTERPOLATION
5  IF (CH1) 10, 10, 5
10  P = P1
    D = D1
C   SETS P, D, T = P1, D1, T1 IF Z1 = Z2
    T = T1
    RETURN
20  IF (Pl * D1 * T1 * P2 * D2 * T2 * D2 * T2 * T1) .LE. 0.5) GO TO 30
   A = ALOG(D2/D1)/(Z2 - Z1)
C   LINEAR INTERPOLATION ON LOG D
   DZ = D1 * EXP(A * (Z - Z1))
   A = (Z - Z1)/(Z2 - Z1)
C   LINEAR INTERPOLATION ON T
   TZ = T1 + A * (T2 - T1)
   R1 = P1/(D1 * T1)
   R2 = P2/(D2 * T2)
C   LINEAR INTERPOLATION ON GAS CONSTANT R
   R = (R2 - R1) * A + R1
C   PRESSURE FROM PERFECT GAS LAW
   P = DZ * R * TZ
   D = DZ
   T = TZ
   RETURN
30  P = 0.
    D = 0.
    T = 0.
RETURN

D-21
RETURN
END

SUBROUTINE INTER4 ( CLAT, CLON, IZ, P, D, T)
$ P4, D4, T4, DPX, DPY, DTX, DTY, DPPX, DPPY, DPTX, DPTY)
COMMON/ IOTEMP/ IOTEM1, IOTEM2, IOTEM3, IOTEM4, IOTEM5, IOTEM6
COMMON/ DGRID/ XAX, DAX, XAY, DAXY, XAYX, DAXYX

C....INTERPOLATES BETWEEN 4D ARRAYS P(I,IH),D(I,IH),T(I,IH) AT GRID
C LOCATIONS LATITUDE GLAT(I) LONGITUDE GLON(I).
C CLAT,CLON = CURRENT LATITUDE, LONGITUDE
C IZ = HEIGHT
C OUTPUT = P4,D4,T4 AND DERIVATIVES
C COMMON /C4/ GLAT(16),GLON(16),NG
COMMON/CHIC/IA(4,4),MB(2),IWSYM,UCOEF(14,9),VCOEF(14,9)
DIMENSION P(16,26),D(16,26),T(16,26),LAX(16)
IWSYM = ' '      
ICHK = 0
C HEIGHT INDEX = HEIGHT + 1
IH = IZ + 1
5 IF (ICHK.GT.1) GO TO 220
IF (NG.GT.9) GO TO 100
C NG = 9 MEANS POLAR GRID
DO 10 I=10,16,1
P(I,IH) = P(I-9,IH)
D(I,IH) = D(I-9,IH)
T(I,IH) = T(I-9,IH)
GLAT(I) = GLAT(I-9)
10 GLON(I) = GLON(I-8)
C LOWER RIGHT INTERPOLATION INDEX
IB = INT(CLON/45) + 1
C LOWER LEFT INTERPOLATION INDEX
IA = IB+1
IF (IA.GT.8) IA = IA-8
C POSITION OUTSIDE POLAR GRID
IF (ABS(CLAT).GT.75.) GO TO 20
C UPPER LEFT INTERPOLATION INDEX
IC = IA-8
C UPPER RIGHT INTERPOLATION INDEX
ID = IB + 8
GO TO 300
20 IF(NSAME.EQ.1) NSAME=2
CALL GEM4D
IWSYM = '*'
ICHK = ICHK + 1
GO TO 5
100 XLON = CLON
DO 105 I = 1,4
DO 105 J = 1,4
II6 = 4*(I-1) + J
LAX(I6) = LA(I,J)
105 CONTINUE
IF (CLON.GT.345) XLON = CLON - 360.
C....CHECKS FOR POSITION WITHIN 16 POINT GRID 110=GOOD, 200=POSITION
C OUTSIDE GRID.
IF (CLAT.GE.GLAT(1),AND.,CLAT.LT.GLAT(16),AND.,XLON.LE.GLON(1)) GO TO 110
GO TO 200

110 N=5
IF(A_(CLAT).LT.I8)NDL=12
IA = IA + INT((6LON(I) - XLON) / 5)
CLOWER LEFT (REFERENCE) INTERPOLATION INDEX
IA = IA + 4  INT((CLAT - 6LAT(I)) / NDL)
CLOWER RIGHT INTERPOLATION INDEX
TB = IA + 1
CUPPER LEFT INTERPOLATION INDEX
IC = IA + 4
CUPPER RIGHT INTERPOLATION INDEX
ID = ID + 5
IF(LAX(IA).EQ.ND(I),OR,LAX(IA).EQ.ND(2),OR,LAX(IA).EQ.ND(1),OR,LAX(IA).EQ.ND(3))GO TO 304
6O TO 304
200 IF (NSANE.EQ.1)NSANE=2
CALL 6E_D
IgSYfl = 'S'
ICHK = ICHK + I
GO TO 5
220 WRITE(6,250)
250 FORMAT(" UNABLE TO GENERATE 4-D GRID")
P4=0.
D4=0.
T4=0.
RETURN
CINTERPOLATION FOR POSITION INSIDE 16 POINT GRID OR POLAR GRID
300 CALL INTLL(P;IA;IB;IC;ID;P4;GLAT;GLON;CLAT;CLON;IH)
CALL INTLL(D;IA;IB;IC;ID;D4;GLAT;GLON;CLAT;CLON;IH)
CALL INTLL(T;IA;IB;IC;ID;T4;GLAT;GLON;CLAT;CLON;IH)
CRELATIVE LONGITUDE DISPLACEMENT FROM REFERENCE POSITION (IA)
DLON = (CLON - GLON(IA)) / (GLON(IB) - GLON(IA))
CRELATIVE LATITUDE DISPLACEMENT FROM REFERENCE POSITION (IA)
DLAT = (CLAT - GLAT(IA)) / (GLAT(IC) - GLAT(IA))
DPX=P(IB,IH)-P(IA,IH)
C0.5,DPX/DX FOR GEOSTROPHIC WIND EQUATIONS
DPX = DPX + (P(ID,IH) - P(IC,IH) - DPX)*DLAT
DTX = T(IB,IH) - T(IA,IH)
C0.5,DTX/DX FOR THERMAL WIND EQUATIONS
DTX = DTX + (T(ID,IH) - T(IC,IH) - DTX)*DLAT
DPY=P(IC,IH)-P(IA,IH)
C0.5,DPY/DY FOR GEOSTROPHIC WIND EQUATIONS
DPY = DPY + (P(ID,IH) - P(IB,IH) - DPY)*DBLON
DTY = T(IC,IH) - T(IA,IH)
C0.5,DTY/DY FOR THERMAL WIND EQUATIONS
DTY = DTY + (T(ID,IH) - T(IB,IH) - DTY)*DBLON
IF(MG,GT,9) GO TO 315
DPX=DPX/9.
DTX=DTX/9.
DPY=DPY/3.
DTY=DTY/3.
315 IF(A BS(CLAT).GT.18) GO TO 312
DPY = DPY*5./12
DYY = DYY*5./12
312 IF (W6.GT.9) GO TO 310
DPXX = 0.
DPYY = 0.
DPXY = 0.
RETURN
310 DPXY = P(ID,IH) - P(IC,IH) - P(IB,IH) + P(IA,IH)
IF (MOD(ID+4,ED,0)) GO TO 320
I1 = IA
I2 = IB + 1
I3 = IC
I4 = ID + 1
SX=1.
GO TO 330
320 I1 = IA - 1
I2 = IB
I3 = IC - 1
I4 = ID
SX=-1.
GO TO 330
330 IF(LAX(I1),NE,LAX(IA),OR,LAX(I2),NE,LAX(IA),OR,LAX(I3),NE, 
* LAX(IA),OR,LAX(I4),NE,LAX(IA)) GO TO 360
DPXX = P(I2,IH) - P(I1,IH)
DPXY = DPXX + (P(I4,IH) - P(I3,IH) - DPXY)*BLAT
IF (IC.GT.12) GO TO 340
I1 = IA
I2 = IC + 4
I3 = IB
I4 = ID + 4
SY=1.
GO TO 350
340 I1 = IA - 4
I2 = IC
I3 = IB - 4
I4 = ID
SY=-1.
GO TO 350
350 IF(LAX(I1),NE,LAX(IA),OR,LAX(I2),NE,LAX(IA),OR,LAX(I3),NE, 
* LAX(IA),OR,LAX(I4),NE,LAX(IA)) GO TO 360
DPYY = P(I2,IH) - P(I1,IH)
DPYY = DPYY + (P(I4,IH) - P(I3,IH) - DPYY)*BLON
DPXY =(DPXY - 2.*DPX )*SX
DPYY =(DPYY - 2.*DPY )*SY
RETURN
360 DPXX = 0.
DPYY = 0.
DPXY = 0.
\(IWSYM = "*"\)
RETURN
END

SUBROUTINE INTLL(F,IA,IB,IC,ID,FLL,GLAT,CLAT,CLON,HN)
C.....INTERPOLATES FUNCTION (ARRAY) F FROM VALUES OF GLAT AND CLON AT N_IGHT IN 
C INDEX VALUES IA, IB, IC, ID TO OUTPUT VALUE FLL AT HEIGHT IN 
C AND POSITION CLAT, CLON 
DIMENSION F(16,26),GLAT(16),CLON(16)
C.....NORMALIZES LONGITUDE DISPLACEMENT
      IF(F(IA, IH) & F(IB, IH) & F(IC, IH) & F(ID, IH)) 20, 10, 20
C      FLL=0,
C      RETURN
C      20 X=(CLON-OLON(IA))/(GLON(IA)-OLON(IB))
C.....NORMALIZES LATITUDE DISPLACEMENT
C      Y=(CLAT-OLAT(IA))/(GLAT(IC)-GLAT(IA))
C.....TWO DIMENSIONAL INTERPOLATION
      FLL=F(IB, IH)+(F(IDC, IH)-F(IB, IH))*Y+(F(IA, IH)-F(ID, IH))*X
C      RETURN
CEND
SUBROUTINE INTRP4 (LAGON)
C      SUBROUTINE TO INTERPOLATE VALUES
C      DIMENSION XLL(4), YLL(4), XL(4), YL(4)
C      COMMON/I/D(20B, 5), IG(5), DXY(2), DLA(4), DLO(4)
C
      DEGRAD=3.14159/180.
      LALO=ABS(LALON)
C      L1=LALO/100.
C      L2=LALO-L1/100.
      XLL=0.
C      YLL=Y.
C      IF (LG(5)-2) 30, 20, 10
C      IF (LG(5)-3) 30, 40, 50
C      10 CONTINUE
      DO 25 L=1, 26
C      25 CONTINUE
C      20 CONTINUE
C      DO 22 J=1, 4
C      22 IF (DL(J), LT. 0.01) GO TO 25
C      DO 24 K=1, 8
C      24 CONTINUE
C      RETURN
            C      INTERPOLATE FROM SOUTH GRID
C      DO 32 J=1, 4
C      XL(J)=DL(J)
C      YLL(J)=DLO(J)
C      IF ((YL, GE. 355.), AND, (YLL(J), LT. 0.01)) YLL(J)=360.
C      30 CONTINUE
C      32 CONTINUE
      X=(YLL(1)-YL)/5.
      Y=XL-XLL(1)/5.
C      IF (IG(5), EQ. 3) Y=-Y
DO 38 L=1,26
DO 36 J=1,4
36 IF (D(L,J).LT.0.01) GO TO 38
DO 37 K=1,8
I=(K-1)*26+L
D(I,5)=D(I,1)+X*(D(I,2)-D(I,1))+Y*(D(I,3)-D(I,1))+Z*
1.0*(D(I,4)-D(I,3)-D(I,2)+D(I,1))
37 CONTINUE
38 CONTINUE
RETURN
C INTERPOLATE FROM ACROSS GRIDS
C
50 CONTINUE
IF (IG(5).GE.1133) GO TO 55
IG(5)=3
GO TO 30
55 CONTINUE
IF (IG(5).GE.333) GO TO 60
DLO(I)=(DLO(2)+DLO(3))/2.0
DO 52 I=1,208
52 D(I,4)=D(I,3)
DLO(4)=DLO(3)
60 CONTINUE
DO 62 I=1,4
XLL(I)=DLO(I)
YLL(I)=DLO(I)
IF ((YL.I.T.350.),AND.(YLL(I),L.0.01)) YLL(I)=360.
62 CONTINUE
ITH=0
X=YLL(I)-YL
Y=XLL(I)-XLL(I)
63 CONTINUE
DO 65 I=2,4
XC(I)=YLL(I)-YLL(I)
65 YC(I)=XLL(I)-XLL(I)
TH2=3.14159/4
TH3=3.14159/4
IF (ABS(XC(2)).LT.0.01) TH2=ATAN((YC(2)/XC(2))
IF (ABS(YC(3)).LT.0.01) TH3=ATAN(XC(3)/YC(3))
IF (XC(2),LT.0.01) TH2=3.14159+TH2
IF (XC(3),LT.0.01) TH3=3.14159+TH3
DMN=COS(TH2+TH3)
IF (ABS(DMN).LT.0.001) GO TO 66
ITH=ITH+1
IF (ITH.EQ.2) GO TO 66
XLL(3)=XLL(4)
YLL(3)=YLL(4)
DO 61 I=1,208
61 D(I,3)=D(I,4)
GO TO 63
66 CONTINUE
ZA=SQRT(XC(2)**2+YC(2)**2)
IF (ITH.LT.2) GO TO 69
Z=SQR(T(X**2+Y**2))
E=0.
Z4=0.
GO TO 71

69 CONTINUE
EB=SQR(T(XC(3)**2+YC(3)**2))
Z4=(XC(4)**2+YC(4)**2)**0.5
E=(YC(4)**2+XC(4)**2)**0.5

CONTINUE

DO=O.
C

71 CONTINUE
DO 70 L=1,26
DO 68 J=I,4
IF (D(L,J).LT.0.01) GO TO 70
DO 67 K=I,8
I=(K-1)*26+L
A=D(I,1)
IF (ZA.GT.0.01) B=(D(I,2)-D(I,1))/ZA
IF (EB.GT.0.01) C=(D(I,3)-D(I,1))/EB
IF (ABS(ZA).GT.0.01) AND (ABS(E).GT.0.01)
1 DD=(D(I,4)-A-B*Z4-C*E4)/(Z4**2)
D(I,5)=A+B*Z4+C*E4
CONTINUE
CONTINUE
RETURN
END

SUBROUTINE INT_UV(UR,VR,H,PHI,UH,UH)
C......FINDS RANDOM WIND STANDARD DEVIATION AT HEIGHT H (KM) + LATITUDE
C......PHI (DEGREES), FROM UR AND VR ARRAYS
C......DIMENSION UR(25,10),VR(25,10)
C......I - LOWER HEIGHT INDEX
IF (H.LT.95.) I = 1 + INT(H) / 5
IF (H.GE.95.) I=19+INT(H)-80)/20
IF (I.GT.25) I = 25
C......UPPER HEIGHT INDEX
IF=I+1
IF (IF.GT.25) IF=25
C......LOWER LATITUDE INDEX
J=INT(PHI+110.)/20
C......UPPER LATITUDE INDEX
JP=J+1
IF (JP.GT.10) JP=10
C......PHI1 - LOWER LATITUDE FOR UR AND VR ARRAY VALUES
PHI1=-110.420.*J
C......PHI2 - UPPER LATITUDE FOR UR AND VR ARRAY VALUES
PHI2=-110.420.*JP
IF (I.GT.19) GO TO 10
C......LOWE HEIGHT FOR UR AND VR ARRAY VALUES
Z1=5.*(I-1)
GO TO 20
10 ZI=20.*((I-15)
20 IF (IP.GT.19) GO TO 30
C UPPER HEIGHT FOR UR AM] VR ARRAY VALUES
Z2=5.*((IP-1)
GO TO 40
30 Z2 = 20. * (IP - 15)
C INTERPOLATE ON LATITUDE AT LOWER HEIGHT
40 CALL INTW(UR(I,J),VR(I,J),PHI1,UR(I,JP),VR(I,JP),PHI2,U1,U1, *
$PHI)
C INTERPOLATE ON LATITUDE AT UPPER HEIGHT
C CALL INTW(UR(IP,J),VR(IP,J),PHI1,UR(IP,JP),VR(IP,JP),PHI2,U2,V2,INTR
$PHI)
C INTERPOLATE ON HEIGHT
C CALL INTW(U1,VR1,Z1,U2,V2,Z2,SWH,SWH)
RETURN
END
SUBROUTINE JAC(ZPTZ,I)
C MIA, IQ, IQ, IQ, IQ, IQ, IQ
COMMON/IOTEMP/IOTEM1, IOTEM2, IUS, HCOP, DD, XMJD, PHI1, PHI2, *
1 NSAME, RI, RT1, RT1, SP1, SD1, ST1, RUI, RV1, SUI, SUI, JAC
2 % MM, IDA, IYR, HI, PHI1, PHI1, PHI1, PHI2, PHI2, FIO,FIOB, AP, *
3 IHR, MIN, MMORE, DX, HL, WM, DO
COMMON/CMNJAC/XLAT, XLONG, SDA, SHA, BY, Y, T, EM
DIMENSIONS, ALPHA(6), EI(6), DI(6), D(7), DIT(6)
DO = 100.
DATA ALPHA/0.0,0.0,0.0,0.0,0.0,0.0/  
DATA EI/28.0134,31.9995,15.9999,39.9484,4.0026,1.007979/  
DATA B/28.15204,0.085586,1.2846-04,1.0056E-05,1.021E-05, *
11.5044E-06,9.9828E-08/
AV=6.02257E23  
QM=.76110  
Q02=.20955  
OA=.009343  
QME = 1.289E-5  
FR=6.31432
C TEMPERATURE AT Z = 125 KM, EQ. 9
C TX=444.3807+.023054T -392.8292*EXP(-.0021357*I)
A2=2.81(T-TX)/3.14159265
C
C DIT(6)=0.  
M=10  
EPS=.0001  
C TEMPERATURE FOR 90ZX125, EQ. 10
C T1=1.9*(TX-183.)/35.  
T4=3.0*(TX-183.-2.*T1#35.)/35.**4  
T3=3-1/(3.**5.**2)+4.*T4#35.  
T2=T1+(T-Z125.)**3+(T-Z125.)**4  
IF (Z-105. 43,43,40
C
C MEAN MOLECULAR WEIGHT FOR 90Z105, EQ. 1

43 Z2 = Z - QQ
EN=B(1)+B(2)*Z2+B(3)*Z2**2+B(4)*Z2**3+B(5)*Z2**4+B(6)*Z2**5
1+B(7)*Z2**6
D=Z
CONTINUE

70 INTEGRATION OF EQ. 5 FOR DENSITY BETWEEN 90Z105

A=90.
1+B(6)*(A-QO)**5 +B(7)*(A-QO)**6
FA=FA/80665/((1.+A)/6.356766E+3)**2
FA=FA/(TX+T1*(A-125.)+T3*(A-125.)**3 +T4*(A-125.)**4
FD=B(1)+B(2)*(D-QO)+B(3)*(D-QO)**2+B(4)*(D-QO)**3+B(5)*(D-QO)**4
1+B(6)*(D-QO)**5 +B(7)*(D-QO)**6
FD=FD/80665/((1.+D)/6.356766E+3)**2
FD=FD/(TX+T1*(D-125.)+T3*(D-125.)**3 +T4*(D-125.)**4

SRG4: SIMPSON'S RULE QUADRATURE - 6.F. KUNCIR

DEFINITIONS -
A = LOWER LIMIT OF INTEGRATION
D = UPPER LIMIT OF INTEGRATION
FUNC = INTEGRAND FUNCTION SUBPROGRAM
EPS = RELATIVE ERROR CONVERGENCE CRITERION
N = MAXIMUM NUMBER OF INTEGRATIONS
R = RESULT OF INTEGRATION
N = NUMBER OF INTEGRATIONS9PRIOR ID TO FIND R

MINT = 1
N=0
PREV=0.
SOME=(D-A)*(FA+FD)/2,
71 N=N+1
IF (N-M) 72,72
72 MINT = 2 % MINT
STWO=0.
DEL=(D-A)/FLOAT(MINT)
DO 73 I=1,MINT+2
X=A+DEL*FLOAT(I)
FX=B(1)+B(2)*(X-QO)+B(3)*((X-QO)**2+B(4)*(X-QO)**3+B(5)*(X-QO)**4
1+B(6)*(X-QO)**5 +B(7)*(X-QO)**6
FX=FX/80665/((1.+X)/6.356766E+3)**2
FX=FX/(TX+T1*(X-125.)+T3*(X-125.)**3 +T4*(X-125.)**4
STWO=STWO+FX
CUR=SOME+4.*DEL*STWO
IF (EPS*ABS(CUR)-ABS(CUR-PREV)) 74,75
74 PREV=CUR
SOME=(SOME+CUR)/4.
GO TO 71
75 R=CUR/3
IF (Z-105.) 44,76
76 IF (D-105.) 76,55
44
DENSITY FOR Z=105

\[ \text{DEN} = 3.46E-9 \times 183.3 \times \exp(-R/FK)/(ZT^28.878) \]

\[ D_1 = \log_{10}(\text{DEN}) \]

\[ A_H = \log_{10}(\text{DEN} \times \text{PAR}/28.96) \]

\[ A_0 = \log_{10}(\text{DEN} \times \text{PAR}/28.96) \]

\[ A_0^2 = \log_{10}(\text{DEN} \times \text{PAR}/28.96) \]

\[ \text{RETURN} \]

TEMPERATURE AND MEAN MOLECULAR WEIGHT AT Z=105 KM

\[ T_3 = (X+183.3 \times \exp(-R/FK)/(ZT^28.878)) \]

\[ Z_3 = (R+183.3 \times \exp(-R/FK)/(ZT^28.878)) \]

\[ \text{DENSITY AT Z=105 KM} \]

\[ \text{DENSITY ABOVE 105 KM} \]

\[ R=0, \]

\[ D_1=125, \]

\[ A_1=105, \]

\[ \text{CONTINUE} \]

INTEGRATION OF EQUATION 6 FOR DENSITY ABOVE 105 KM

\[ F_A = 9.80665/((1+D_1/6.356766E13)^2) \]

\[ F_D = 9.80665/((1+D_1/6.356766E13)^2) \]

\[ \text{GO TO 51} \]

\[ \text{CONTINUE} \]

\[ N=0 \]

\[ \text{RETURN} \]

\[ \text{END OF PROGRAM} \]
NINT = 2 * NINT
STWO=0.
DEL=(DI-AI)/FLOAT(NINT)
DO 83 I=1,NINT,2
XI=AI+DEL*FLOAT(I)
FXI=9.80665/((1.+XI/6.356766E+3)**2)
IF(XI=125.) 46, 46, 52
46 FXI=FXI/(TX1+TI*(X1-125.))*(T3*(X1-125.))*(3+T4*(X1-125.))*4)
GO TO 83
52 FXI=FXI/(TX1+I2*TAM(T1*(X1-125.))*(1.+T4.5*6*(X1-125.))*2.5)/A2)
STWO=STWO+FXI
CURRE=(SOME+4.*DEL+STWO)
IF (EPSABS(CUR)-ABS(CUR-PREV)) 84, 85, 85
84 PREV=CUR
SOME=(SOME+CUR)/4.
GO TO 81
85 R=CUR/3.4T
IF(AI.EQ.125.) GO TO 430
D1=Z=125.
GO TO 400
CONTINUE
DENSITY ABOVE 105 KM
DO 41 I=1,5
DIT(I)=D(I)**(T2/T2)**(1.+ALPHA(I))*EXP(-EI(I)*R/FK)
CONTINUE
DENS=0
DO 42 I=1,6
DENS=DENS+EI(I)*DIT(I)/AV
CONTINUE
C MEAN MOLECULAR WEIGHT FOR Z 105 KM
E=AV/DIT(1)+DIT(2)+DIT(3)+DIT(4)+DIT(5)+DIT(6))
C LOG DENSITY
DL=ALOG10(DENS)
AM =ALOG10(DIT(1))
AO2=ALOG10(DIT(2))
AO =ALOG10(DIT(3))
AA =ALOG10(DIT(4))
AMH=ALOG10(DIT(5))
IF(Z=-500.) 47, 48, 48
47 DIT(6)=10.**(-6)
48 AM=ALOG10(DIT(6))
AH=AMAX1(-0., AM)
AO2=AMAX1(-0., AO2)
AO =AMAX1(-0., AO)
AA =AMAX1(-0., AA)
AMH=AMAX1(-0., AMH)
AH=AMAX1(-0., AH)
RETURN

C TEMPERATURE AND DENSITY AT Z=500 KM
C
90 S=TX+A2*ATAN(T1*375.*(1.+4.5E-6*375.*2.5)/A2)
   DI(6)=10.*((7.13-39.4*ALOG10(S)+5.5*ALOG10(D)*ALOG10(D))
   AI=500.
   IF(Z<500.) 49,60,60
C INTEGRATION OF EQ. 6 FOR DENSITY FOR Z 125 KM
C
49 AI=Z
60 FA1=9.80665/((1.+AI/6.356766E+3)**2)
   FAI=FA1/(TX+A2*ATAN(T1*(AI-125.)*(1.+4.5E-6*(AI-125.)*2.5)/A2))
   DI=Z
   IF(Z<500.) 61,62,62
61 DI=500.
62 FD1=9.80665/((1.+DI/6.356766E+3)**2)
   FD1=FD1/(TX+A2*ATAN(T1*(DI-125.)*(1.+4.5E-6*(DI-125.)*2.5)/A2))
   N=0
   MINT = 1
   PREV=0
   SOME=(DI-AI)*(FAI+FDI)/2.
   N=N+1
   IF (N-1) 92,92,95
91 N=41
   IF (N-M) 92,92,95
92 NINT = 2 * MINT
   STWO=0.
   DEL=(DI-AI)/FLOAT(MINT)
   DO 93 I=1,MINT,2
      XI=AI+DEL*I
      FXI=9.80665/((1.+X1/6.356766E+3)**2)
      FXI=FXI/(TX+A2*ATAN(T1*(XI-125.)*(1.+4.5E-6*(XI-125.)*2.5)/A2))
      STWO=STWO+FXI
      93 CONTINUE
   CUR=SOME+4.*DEL*STWO
   IF (EPS*ABS(CUR)-ABS(CUR-PREV)) 94,95,95
   PREV=CUR
   SOME=(SOME+CUR)/4.
   GO TO 91
94 R=CUR/3.
C TEMPERATURE AT Z 500 KM
C
95 TZ=TX+A2*ATAN(T1*(Z-125.)*(1.+4.5E-6*(Z-125.)*2.5)/A2)
   IF(Z<500.) 63,64,64
63 R=-R
C DENSITY OF HYDROGEN FOR Z 500 KM
C
64 DIT(6)=DI(6)*(S/TZ)*EXP(-EI(6)*R/FK)
   GO TO 56
END
SUBROUTINE JACCH(Z,PHIR,TNET,PN,BH,TN)
COMM_/Ckli4JAC/XLAT,XLONG,S_,S_,DY,R,T,EM
CO_MON/IOTEMP/IOTEMI,IOTEM2,1_,N_OP,DD,XNJD,PHII,PHI,
**JACCH** calculates the pressure, density, and temperature at a point in space above 90 km for a particular time.

**INPUT**
- **Z** = height in km
- **PHIR** = latitude in radians
- **THET** = longitude in degrees (0 to 360 degrees turning westward)
- **F10** = solar radio noise flux (Xe - 22 watts/m²)
- **F10B** = 81-day average F10
- **AP** = geomagnetic index
- **M** = month (for yearly mean variables M is set to 13)
- **IDA** = day of month
- **IYR** = year
- **IHR** = hour of day (universal time)
- **MIN** = minute (universal time)
- **XJJD** = mean julian day (set equal to zero for annual mean)
- **DO** = day number with respect to Jan 0 of year IYR

**OUTPUT**
- **PH** = pressure in units of N/m²
- **DH** = density in units of kg/m³
- **TH** = temperature in Kelvin degrees
- **DD** = day number with respect to Jan 1 of year IYR

Replacement of subroutine variables to insure no changes in them

R = 0.31
XLAT = PHIR
XLONG = THET

IF (M.EQ.13) GO TO 50

**CALCULATE SOLAR DEC. AND HOUR ANGLE**

**CALL THE**

**EXOSPHERIC TEMPERATURE**

**CALL TINF**

GO TO 75

50 T = 1000.0

**TEMPERATURE, MOLECULAR WEIGHT, AND DENSITY WITHOUT SEASONAL VARIATIONS**

75 CALL JAC(Z,TH,DH)

IF (M.EQ.13) GO TO 300
YDA = 365.0
J1 = MOD(IYR,4)
IF (J1.EQ.0) YDA = 366.0

D-33
C1 = \sin((360. / \pi) \times 0.0174532925 \times (DD + 100.0))

IF (PHIR) 80, 70, 80
70 C2 = 0.0
GO TO 90
80 C2 = (\sin(PHIR) \times 2) \times (PHIR / \text{ABS(PHIR)})

C
DENSITY WITH SEASONAL VARIATIONS
C
90 Z90 = Z - 90.0
DLRHO = 0.02 \times Z90 \times \exp(-0.045 \times Z90) \times C1 \times C2
DM = DH \times \exp(DLRHO)

C
MOLECULAR WEIGHT WITH SEASONAL VARIATION
C
IF (Z - 120.0) 100, 100, 150
100 EM = EM + 0.006 \times Z90 \times C1
GO TO 250
150 IF (Z - 230.0) 200, 250, 250
200 DEM = \exp(-0.02424 \times Z90) \times (0.0316 \times Z90 - 0.0002257 \times Z90) \times C1 \times C2
EM = EM + DEM \times C1 \times 0.5

C
TEMPERATURE WITH SEASONAL VARIATION
C
250 IF (Z - 260.0) 270, 300, 300
270 Z110 = Z - 110.0
DTH = -2.291753 + Z110 + 0.02154336 \times Z110 - 4.1766671E-05 \times Z110 \times 3
DTH = \exp(-0.290655 \times \text{SORT}(\text{ABS(Z110)))) \times DTH
TH = TH + (DTH \times C1 \times C2 \times \text{TH}) / 100.0

C
DENSITY IN METRIC UNITS AND PRESSURE CALCULATED
C
300 DH = DH \times 1000.0
PH = ((DM \times 8.31432 \times TH) / EM) \times 1000.0
RETURN
END

SUBROUTINE NORMAL(D1, D2)
REAL L
50 X = RAND(0)
Y = 2 * RAND(0) - 1
XX = X**2
YY = Y**2
S = XX + YY
IF (S - 1) 51, 51, 50
51 L = \text{SORT}((-2 * \text{ALG}(\text{RAND}(0))) / S)
D1 = (XX - YY) \times L
D2 = 2 \times XX \times YL
RETURN
END

SUBROUTINE PDTUV (PSP, DSP, TSP, CLAT, CLOH, IH, PS, DS, TS, DPX, DPY, DTX, DTY, DPX2, DPY2, DPXY)
C.....INTERPOLATES STATIONARY PERTURBATIONS ON LATITUDE AND LONGITUDE
PDTU 1
PDTU 2
PDTU 3
D-3A
AT HEIGHT IH
DIMENSION PSP(8,10,12), DSP(8,10,12), TSP(8,10,12)
IF (IH.LT.52) GO TO 10
IF (IH.GT.94) GO TO 20
C
HEIGHT INDEX K
K = ((IH4)/8) - 4
GO TO 30
10 K = (IH-20)/10
GO TO 30
20 K = 8
30 XLOW = CLON
IF (CLON.LT.10.) XLOW = 360. + CLON
C
LOWER LONGITUDE INDEX J
J = INT((XLOW + 20.)/30.)
C
DLOW - RELATIVE LONGITUDE DEVIATION FROM CORNER REFERENCE LOCATION
DLOW = (XLOW - 30.*J + 20.)/30.
C
UPPER LONGITUDE INDEX JP
JP = J+1
IF (JP.GT.12) JP=1
C
LOWER LATITUDE INDEX I
I = INT((CLAT + 110.)/20.)
C
UPPER LATITUDE INDEX IP
IP = I+1
IF (IP.GT.10) IP=10
C
DLAT - RELATIVE LATITUDE DEVIATION FROM CORNER REFERENCE LOCATION
DLAT = (CLAT-20.)/20.
C
PRESSURE LAT-LON INTERPOLATION
PS=PSP(K,I,J)+(DSP(K,IP,J)-PSP(K,I,J))/DLAT+(PSP(K,I,JP)-PSP(K,I,J))/DLON
C
DENSITY LAT-LON INTERPOLATION
DS=DSP(K,I,J)+(DSP(K,IP,J)-DSP(K,I,J))/DLAT+(DSP(K,I,JP)-DSP(K,I,J))/DLON
C
TEMPERATURE LAT-LON INTERPOLATION
TS=TSP(K,I,J)+(TSP(K,IP,J)-TSP(K,I,J))/DLAT+(TSP(K,I,JP)-TSP(K,I,J))/DLON
C
DPX - DP/DX FOR GEOSTROPHIC WINDS
DPX = (PSP(K,IP,J) - PSP(K,I,J))/6.
C
DPY - DP/DY FOR GEOSTROPHIC WINDS
DPY = (PSP(K,IP,J) - PSP(K,I,J))/4.
C
DTX - DT/DX FOR THERMAL WINDS
DTX = (TSP(K,IP,J) - TSP(K,I,J))/6.
C
DTY - DT/DY FOR THERMAL WINDS
DTY = (TSP(K,IP,J) - TSP(K,I,J))/4.
C
IF (JP.GT.9) GO TO 90
IF (IP.GT.9) GO TO 90
PPXY = (PSP(K,IP,J) - PSP(K,I,J))/24.
JX = J - 1
IF (JX.LT.1) JX = JX + 12
IY = I - 1
DP2X = (PSP(K,I,X) - PSP(K,I,J))/6.
DP2X = DP2X + ((PSP(K,I,P,JX) - PSP(K,I,J,P))/6. - DP2X)*DLAT
DP2Y = (PSP(K,I,P,J) - PSP(K,I,J))/4.
DP2Y = DP2Y + ((PSP(K,I,P,J) - PSP(K,I,J))/4. - DP2Y)*DLON
RETURN

DP2X = 0.
DP2Y = 0.
DPXY = 0.
RETURN

SUBROUTINE PERTRB
COMM/IDEMP/IOTEN/IOTEM/IOTEN2/IUG/MMCOP/DD/KMJD/PHII/PHII/NSAME,
#PL1,PL1,PL1,PL1,PL1,PL1,PL1,PL1,PL1,PL1,PL1,PL1,PL1,PL1,PL1,PL1,PL1,
1PH+PLAT,
# PLON:G:R;CH;CLAT;CLON:F10:SF10:AP;IHR;NM;MMORE;DX:XL:VL:OZ,
2B:EPS:10PP:LOOK:IET;FLAT:PS1:DS1:TS1:US1;VS1:SPS1:SPS1,
3STG1:SUS1:SVS1:USD1:USU1:USU1:USU1:USU1:USU1:
COMM /COHP/WT/DUM/IM(I1:11)
DLON = ABS(CLON-PLON)
PI = 3.1415927
IF(IIL_.GT.PI) ILY = 27.7 - ILY
DX = RXSQRT((CLAT-PLAT)² + (COS(CLAT) - DLAT)²)
C.....DX IS HORIZONTAL DISTANCE BETWEEN POSITIONS PLAT,PLON AND CLAT,CLON
PERT 18
AH = 800.
RH = 6.
PERT 20
HLL = AH + BHCH
DPhi = (90. - ABS(PHI1))#2
DHT = 0.22 + 0.00254*(SQRT(ABS(CH))#3)
IF (DHTGT.5,) DHT = 5.
VDS = (11.0 - 2.102E-4*DPhi)#DHT
VTS = (3.0 - 5.146E-4*DPhi)#DHT
VUS = (6.2 - 3.615E-4*DPhi)#DHT
VDL = (20.7 - 1.346E-3*DPhi)#DHT
VTL = 7.3#DHT
VUL = (31.2 - 3.503E-3*DPhi)#DHT
HLS = 20. + .0125*CH#CH
IF(HLSGT.400.) HLS = 400.
HLS = (DX/HLS)#2
HLL = (DX/HLL)#2
RDS=SORT(HLS*(OZ/VDS)#2)
IF(RDS.LE.100.) GO TO 10
RDS=0.
GO TO 20
RDS=1./EXP(RDS)
RDS=SORT(HLS*(OZ/VTS)#2)
IF(RDS.LE.100.) GO TO 30
RDS=0.
GO TO 40

30  RTS=1./EXP(RTS)

40  RVS=SQRT(HLS+(DZ/VUS))**2)
    IF(RVS.LE.100.)GO TO 50
    RVS=0.
    GO TO 60

50  RVS=1./EXP(RVS)

60  RDL=SQRT(HLL+(DZ/VTL))**2)
    IF(RDL.LE.100.)GO TO 70
    RDL=0.
    GO TO 80

70  RDL=1./EXP(RDL)

80  RTL=SQRT(HLL+(DZ/VUL))**2)
    IF(RTL.LE.100.)GO TO 90
    RTL=0.
    GO TO 100

90  RTL=1./EXP(RTL)

100 RVL=SQRT(HLL+(DZ/VUL))**2)
    IF(RVL.LE.100.)GO TO 110
    RVL=0.
    GO TO 120

110 RVL=1./EXP(RVL)

120 CONTINUE

 CALL CORKAT(AS,BS,CS,ES,FS,GS,HLS,AJS,AKS,SPS1,SPS2,SPS3)
    1 SPS2,ST51,ST52,SUS1,SUS2,SYS1,SYS2,UDS1,UDS2,VL2,RTS, RVS
    2RDL,RVL

 CALL CORKAT(AL,CL,DL,EL,FL,HL,AJL,AKL,SPL1,SPL2,SDL1, SDL2)
    1 SDL1,STL1,STL2,STL3,STL4,STL5,STL6,STL7,STL8,STL9,STL10
    2SDL2,STL1,STL2,STL3,STL4,STL5,STL6,STL7,STL8,STL9,STL10

 CALL NORMAL(ZD,ZT)
    PS2=DS2+TS2

 CALL NORMAL(ZD,ZT)
    US2=FS*US1+HS*UDS1

 CALL NORMAL(ZD,ZT)
    VS2=AIS*US1+AKS*UDS1

 CALL NORMAL(ZD,ZT)
    DS2=AL*DL1+BL*ZD

 CALL NORMAL(ZD,ZT)
    TL2=CL*TL1+DL2+EL*ZT

 CALL NORMAL(ZD,ZT)
    PL2=DL2+TL2

 CALL NORMAL(ZD,ZT)
    UL2=FL*UL1+BL*UDL1

 CALL NORMAL(ZD,ZT)
    VL2=AIL*UL1+AJL*DL2+AKL

 CALL NORMAL(ZD,ZT)
    P2=PS2+PL2

 CALL NORMAL(ZD,ZT)
    D2=DS2+DL2

 CALL NORMAL(ZD,ZT)
    T2=TS2+TL2

 CALL NORMAL(ZD,ZT)
    U2=US2+UL2

 CALL NORMAL(ZD,ZT)
    V2=VS2+VL2

 CALL NORMAL(ZD,ZT)
    UDL1=UDL2

 CALL NORMAL(ZD,ZT)
    UDS1=UDS2

 CALL NORMAL(ZD,ZT)
    VDL1=VDL2

 CALL NORMAL(ZD,ZT)
    VDS1=VDS2

 RETURN

 END
SUBROUTINE PHASE(D1,X1,D2,X2,D,X)  
PHAS 1
PER = 870.  
PHAS 2
IF (X2-X1) 20,10,20  
PHAS 3
D = D1  
RETURN  
PHAS 4
20 DA = D1  
PHAS 5
DB = D2  
PHAS 6
PER2 = PER/2,  
PHAS 7
IF(ABS(DB-DA),LE.PER2)GO TO 30  
PHAS 8
DA = DA + PER  
PHAS 9
DB = DB + PER  
PHAS 10
30 DA = DA + (DB - DA) *(X - X1)/(X2 - X1)  
PHAS 11
IF(DA.GT.PER) DA = DA - PER  
PHAS 12
IF(DA.LT.0) DA = DA +PER  
PHAS 13
D = DA  
RETURN  
PHAS 14
ENDIF  
PHAS 15
END  
PHAS 16
SUBROUTINE QBOGEN QBO6  
PHAS 17
COMPUTES QBO VALUES PD,DG,TQ,UQ,VQ AT HEIGHT H, LATITUDE PHI  
PHAS 18
ON JULIAN DAY XHJD FROM ARRAYS OF AMPLITUDES PAO,DAO,TAO,QA0  
PHAS 19
UAO,VAO AND PHASES PDQ,DDO,TDQ,U_,VDQ.  
PHAS 20
COMMON/IOTEMP/IOTEMH,IOTEM2,IUS,HMCP,DDD,XHJD,PHI,PHI1,PHI,  
PHAS 21
MSAME,RPI,RT1,RT1,S1,SI,SI,RU,RI1,SI1,SI1,  
PHAS 22
$ NM, IOA, IOY, H1, PHI1,THET1,6,R1,PHI1,THET1,10,FI08,AP,  
PHAS 23
IPH,MIN,MMORE,DX,H1,VL,DZ  
PHAS 24
COMMON/PITCON/IU4/MONTH,IDR,PG(18,19),TG18,19,DG(18,19)  
PHAS 25
, PD(8,10,12)  
PHAS 26
, TPS(8,10,12),PAQ(17,5),DAO(17,5),TAQ(17,5),  
PHAS 27
, PDO(17,5),UDO(17,5),TDQ(17,5),TR(20,10),DR(20,10),  
PHAS 28
QBO(17,5),VAO(17,5),UDDQ(17,5),VDQ(17,5),VR(25,10)  
PHAS 29
, PDQ,DDQ,TDQ,UQ,  
PHAS 30
, PA,TA,UA,VA,IOPOQ  
PHAS 31
IF (XMJD.GT.0.5,IOPOQ.EQ.1) 60 TO 10  
PHAS 32
SETS QBO VALUES TO ZERO FOR ANNUAL MEAN  
PHAS 33
PG =0.  
PHAS 34
DG=0.  
PHAS 35
TG=0.  
PHAS 36
UDQ=0.  
PHAS 37
VQ=0.  
PHAS 38
RETURN  
PHAS 39
LOWER HEIGHT INDEX  
PHAS 40
10 IH = INT((H-5.)/5.)  
PHAS 41
IF (IH.LT.1) IH=1  
PHAS 42
UPPER HEIGHT INDEX  
PHAS 43
IP = IH + 1  
PHAS 44
IF (IP.GT.17) IP = 17  
PHAS 45
PHA = ABS(PHI)  
PHAS 46
LOWER LATITUDE INDEX  
PHAS 47
JL = INT(( PHA + 10.)/20.)  
PHAS 48
UPPER LATITUDE INDEX  
PHAS 49
JP = JL + 1  
PHAS 50
IF (JP.LE.0) JL=1  
PHAS 51
IF (JP.GT.5) JP=5  
PHAS 52
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C JULIAN DAY FOR JAN 0, 1966
XJJD = 2439126
C TIME RELATIVE TO JAN 0, 1966
TMJD = XJJD - XJJD
C 2*PI/PERIOD*PERIOD = 870 DAYS
PER = 870.
TP = 6.2831853/PER
C LOWER HEIGHT
HI = 5. + 5.*IH
C LOWER LATITUDE
C UPPER LATITUDE
C.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.,.
FUNCTION RAND(XO) RAND
C......PRODUCES A RANDOM NUMBER FROM A UNIFORM DIST. FROM 0 TO +1
INTEGER XO RAND
IF (XO.NE.0) X = XO/262144.
X = X*509 RAND
X = X - INT(X) RAND
RETURN
END RAND

SUBROUTINE RIG RIG
COMMON/IOITEM1,IOITEM2,IUG,HMCDP,DJ,WMJD,PHI1,PHI,
$ MN, IDA, IRA, HI, PHIR,HETHIR,GIN,H,PHIR,HETHIR,F10,F10B,AP,
$ IHR,MMIN,MMORE,IX+HL,VL,D2,B,ES
1RPS1,RTIS,RUIS,RVIS,SPIS,SDIS,STIS,SVIS,
2US1,VD1,UL1,VDL1,UDS1,UDS2,UDL2,VDL2
C......GRAVITY G AT H, LATITUDE PHIR (RADIANS)
C......RADIUS RI FROM CENTER OF EARTH TO HEIGHT H
C......B = POLAR EARTH RADIUS, EPS = ECCENTRICITY
CPHI2 = COS(PHIR) ** 2
C EARTH RADIUS
RI = B / SQRT(1. - EPS * CPHI2)
C2PHI = COS(2*PHIR)
C2PHI = 2. * CPHI2 - 1.
C4PHI = COS(4*PHIR)
C4PHI = 8. * CPHI2 * (CPHI2 - 1.)
C......G AT SURFACE
G = 9.80616 * (1. - 0.0026373 * C2PHI + 0.0000059 * C2PHI * C2PHI)
C......EFFECTIVE RADIUS
RE = 2. * G / (3.085462E-3 + C2PHI * 2.27E-6 - C4PHI * 2.9E-9)
C G AT HEIGHT H
G = G / (1. + (H / RE)) ** 2
C RADIUS AT HEIGHT H
RI = RI + H
END

SUBROUTINE RTERP(H,PHI,PR,DR,TR,P,D,T) RTER
C......COMPUTES RANDOM PERTURBATION STANDARD DEVIATIONS P,D,T AT
C HEIGHT H (KM), LATITUDE PHI (DEGREES) FROM SIGMA ARRAYS
C PR,DR,TR AND P
DIMENSION PR(20,10),DR(20,10),TR(20,10)
C......I = LOWER HEIGHT INDEX
IF (H.LT.95.) I = INT((H-20.)/5.) RTER
IF (H.GE.95.) I = 14 + INT((H-80.)/20.) RTER
IP = IH1
IF (IP.GT.20) IP = 20 RTER
C LOWER LATITUDE INDEX
J = INT((PHI + 110.)/20.) RTER
JP = IH1
IF (JP.GT.10) JP = 10 RTER
IF (I.GT.14) GO TO 10 RTER
C LOWER HEIGHT FOR PR,TR,DR ARRAYS
ZI = 5.*IH20.
GO TO 20
C  UPPER HEIGHT FOR PR, DR, TR ARRAYS
Z2=5.*IP+20.
GO TO 40
30 Z2=20.*IP-10
40 PHII=-110.+20.*J
PHI2=-110.+20.*J

C  INTERPOLATE ON LATITUDE AT LOWER HEIGHT
CALL INTERZ(PR(I,J),DR(I,J),TR(I,J),PHII,PR(I,J),DR(I,J),TR(I,J),PHI2)
1
C  INTERPOLATION ON HEIGHT USING LATITUDE INTERPOLATED VALUES
CALL INTERZ(P1,D1,T1,Z1,P2,D2,T2,Z2,P_D,T,H)
RETURN
END

SUBROUTINE RTRAN
C_MON!OTEMPIIOTENI,IOTEN2,IUG
COMMON/COTRAN/NDATA(19),I,J,I2,(IO),IS
C  ENTRY POINT TO READ STATIONARY PERTURBATION DATA, AND
C  RANDOM PERTURBATION DATA IN SETUP
WHERE=2H,
READ(IUG,100,END=3) NDATA
100 FORMAT(A2,1917)
RETURN
ENTRY RTRAN
C  ENTRY POINT TO READ GROVES DATA IN SETUP
WHERE=2H2,
READ(IUG,100,END=3) NDATA
II=NDATA(1)
I2=NDATA(2)
I3=NDATA(3)
I5=NDATA(14)
DO 1 I=1,10
1 14(I)=NDATA(I+3)
RETURN
ENTRY RTRAN2
C  ENTRY POINT TO READ 080 PARAMETERS IN SETUP
WHERE=2H2,
READ(IUG,100,END=3) NDATA
II=NDATA(1)
I3=NDATA(2)
DO 2 I=1,10
2 14(I)=NDATA(2+I)
RETURN
3 WRITE(6,200) IUG,WHERE
200 FORMAT('1 PREMATURE END-OF-FILE FOUND ON UNIT ',A2/
**70 CALLED FROM SUBROUTINE RTRAN',A2)
STOP
END
SUBROUTINE SCIMOD(INFOP)
C  COMPUTES VALUES P,D,T,U,V AND SHEAR DUH,DVH FROM INPUT AND

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ARRAYS IN COMMON/ PDTCOM, INPUT TO SCIMOD ISX

G = GRAVITY AT POSITION  RI = RADIUS AT HEIGHT H
PHIR = LATITUDE (RADIANS)  THEIR = LONGITUDE (RADIANS)
F10 = F10.7 SOLAR FLUX  F1OB = MEAN F10.7 FLUX
AP = SOLAR-GEOMAGNETIC A SUB P INDEX
MN/IDA/IYR = DATA (IYR = FULL YEAR-1900)
IHMIN = TIME  HI = PREVIOUS HEIGHT
PHIR = PREVIOUS LATITUDE  THEIR = PREVIOUS LONGITUDE
SP1,SD1,ST1 = PREVIOUS RANDOM STANDARD DEVIATIONS (SIGMAS)
SU1,SV1 = PREVIOUS RANDOM WIND SIGMAS

COMMON/IPRT/P
COMMON/IOTEMP/IOTEMPHOT2/(IYR-NACOP,DD,XNJD001,PHI,
                    NSA_E,RP0L,RDOL,RTOL,SPIL,SDIL,STIL,
                    RUI,RVI,
                    SUI,SVI,
                    RF1,RDF1,RF1,RF1,
                    SFI,SDI,STI,
                    RUI,RVI,
                    SUI,SVI,
                    C4/4(GLAT(16),GLOR(16),NG,PD416,26,D41626,T41626),
                    SP4(16,26),SD416,26,ST416,26,
                    COMMON/COMPER/SPH,SDH,STH,PRH,DRH,TRH,VRH,SVH,SKH,
                    SPSH,SPSH,SPSH,SPSH,SPSH,SPSH,SPSH,SPSH,
                    COMMON/WICOM/DRH,F Cory,DS1,DS2,DS1,DS2,DS1,DS2,DS1,DS2,
                    TH,DIH,DIH,DIH,DIH,UPRE,UPRE,UPRE,UPRE,
                    COMMON/CHIC/LA(414),X(2),IWSYM+UCOEFF(14,9),UCOEFF(14,9),
                    FACTOR FOR RADIIANS TO DEGEOES
FAC = 57.2957795
IWSYM = ' 
IF(NPOP.NE.O) GO TO 6
UPRE=0.
VPRE=0.
DUPRE=0.
UP=0.

PG=0.

D0=0.
TO=0.
PRH=0.
DRH=0.
TRH=0.
URH=0.
VRH=0.
UQ=0.
VQA=O, SCIN 57
PQA=O, SCIM 58
BOA=O, SCIN 59
TQCF0.
SCIH 60
UA=O, SCIN 61
VA=O, SCIH 62
TH=O, SCIM 63
DSI_
SCIH 64
TSH=O, SCIH 65
MOWTH:HN SCIH 66
C PRESENT LATITUDE, DEG
PHI = PHIR/FAC
C PRESENT LONGITUDE, DEG
THET = THET/FAC
C PREVIOUS LATITUDE, DEG
PHII = PHIR/FAC
C PREVIOUS LONGITUDE, DEG
THET1 = THET1/FAC
C FCORY = NORTH COMPONENT CORIOLIS FACTOR TIMES DISTANCE FOR
C 5 DEGREES OF LATITUDE
DYS = 5000.*RI/FAC
DX5 = DYS*COS(PHIR)
FCORY = DYS*SGN(PHIR)/(120.*FAC)
C IN JACCHIA OR MIXED GROVES-JACCHIA HEIGHT RANGE
8 IF(H.GT.90.0) GO TO 10
C IN 4-D DATA HEIGHT RANGE
IF (H.LE.25.0) GO TO 500
C IN GROVES OR MIXED GROVES 4D HEIGHT RANGE
60 TO 200
C IN MIXED JACCHIA-GROVES RANGE, NEED TO FAIR DATA
10 IF (H.LT.115.) GO TO 20
C FOLLOWING IS THE PURE JACCHIA HEIGHT RANGE SECTION
C JACCHIA VALUES AT CURRENT POSITION
CALL JACCH(H,PHIR,THET,PHI,DH_TH)
PHII = PHIR + 5. / FAC
THETE = THET - 5.
C JACCHIA VALUES AT CURRENT POSITION+5 DEGREES LAT, FOR DP/DY AND
c Tenant
C DT/DY
CALL JACCH(H,PHIR,THET,PHI,DH,TH)
C JACCHIA VALUES AT CURRENT POSITION-5 DEGREES LAT, FOR DP/DX AND
c Tenant
C DT/DX
CALL JACCH(H,PHIR,THET,PHI,DH,THE)
C DP/DY FOR GEOSTROPHIC WIND
DPY=PHI-PH
C DP/DX FOR GEOSTROPHIC WIND
DPX=PHI-PH
C DT/DX FOR THERMAL WIND SHEAR
DTX = THE - TH
C DT/DY FOR THERMAL WIND SHEAR
DTY = THN - TH
C CHANGE NOTATION FOR OUTPUT
PGH=PH
DGH=DH
TGH=TH

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CALL WIND

UM = UGH
VM = VGH
HB = H + 5,
CP = 7.4PH/(2.0H+TH)
CALL JACCH(HB,PHIR,THET,PJB,DFB;TB)
DTZ = (TB - TH)/5000.

C. VERTICAL MEAN WIND

WGH = -CP*(UM*DTX/DX5 + VM*DTY/DY5)/(G + CF*DTZ + UM*DH+VM*DVH)

C. GO TO RANDOM PERTURBATIONS SECTION

GO TO 800

C. FOLLOWING IS THE MIXED JACCHIA-GROVES HEIGHT RANGE SECTION

LOWER HEIGHT INDEX

20 IHA = 5*INT(H)/5

UPPER HEIGHT INDEX

IHB = IHA + 5

LOWER HEIGHT FOR INTERPOLATION

HA = IHA

UPPER HEIGHT FOR INTERPOLATION

HB = IHB

C. JACCHIA VALUES AT LOWER HEIGHT, CURRENT LAT-LON

CALL JACCH(HA,PHIR,THET,PJA,DJA,TJA)

PHIN = PHIR + 5, / FAC

THETE = THET - 5.

C. JACCHIA VALUES AT LOWER HEIGHT, CURRENT LAT-LON+5 DEGREES

LAT, FOR DP/DY AND DT/DY

CALL JACCH(HA,PHIN,THETE,PJN,DJN,TJN)

C. JACCHIA VALUES AT LOWER HEIGHT, CURRENT LAT-LON-5 DEGREES

LOM, FOR DP/DX, AND DT/DX

CALL JACCH(HA,PHIR,THETE,PJE,DJE,TJE)

C. JACCHIA DP/DY AT LOWER HEIGHT

DPXJA - PJE - PJA

C. JACCHIA DP/DY AT LOWER HEIGHT

DPYJA - PJN - PJA

C. JACCHIA DT/DX AT LOWER HEIGHT

DTXJA = TJE - TJA

C. JACCHIA DT/DY AT LOWER HEIGHT

DTYA = TJN - TJN

C. JACCHIA VALUES AT UPPER HEIGHT, CURRENT LAT-LON

CALL JACCH(HB,PHIR,THET,PJB,DJB,TJB)

PHIN = PHIR + 5, / FAC

THETE = THETE - 5.

C. JACCHIA VALUES AT UPPER HEIGHT, CURRENT LAT/LOM+5 DEGREES

LAT, FOR DP/DY AND DT/DY

CALL JACCH(HB,PHIN,THETE,PJN,DJN,TJN)

C. JACCHIA VALUES AT UPPER HEIGHT, CURRENT LAT-LON-5 DEGREES

LOM, FOR DP/DX, AND DT/DX

CALL JACCH(HB,PHIR,THETE,PJE,DJE,TJE)

C. JACCHIA DP/DY FOR GEOSTROPHIC WINDS

DPXJB = PJE - PJB

C. JACCHIA DP/DY FOR GEOSTROPHIC WINDS

DPYJB = PJN - PJB

C. JACCHIA DT/DX FOR THERMAL WIND SHEAR

DTXJB = TJE - TJB
C JACCHIA DT/DY FOR THERMAL WIND SHEAR

\[ DTJB = TJM - TJB \]

C......GROVES AT LOWER HEIGHT, TO BE FAIRED WITH JACCHIA
CALL GTERP(IHA,PHI,PGA,DGA,TGA,PG,DG,DPYGA,DTYGA,DP2YGA)

C......GROVES AT UPPER HEIGHT, TO BE FAIRED WITH JACCHIA
CALL GTERP(IHB,PHI,PGB,DGB,TGB,PG,DG,DPYGB,DTYGB,DP2YGB)

C......FAIRED RESULTS AT LOWER HEIGHT
CALL FAIR(PGA,DGA,TGA,PJA,DJA,TJA,PHA,PHA,PHA,PHA,PHA)
CALL INTER2(PI,DI,TI,HA,P2,D2,T2,HB,PH,DH,TH,H)
CALL INTERW(_XA,_YA,HA,DPXD,DPYB,DYB,DXB,DTX,DTY,H)
CALL INTERW(DTXA,DTYA,HA,DTXD,DTYB,DYB,DTX,DTY,H)

C......FAIRED RESULTS AT UPPER HEIGHT
CALL FAIR(PGB,DGB,TGD,PJD,DJB,TJB,PHA,PHA,PHA,PHA,PHA)
CALL INTER2(PI,DI,TI,HA,P2,D2,T2,HB,PH,DH,TH,H)
CALL INTERW(_XA,_YA,HA,DPXD,DPYB,DYB,DXB,DTX,DTY,H)
CALL INTERW(DTXA,DTYA,HA,DTXD,DTYB,DYB,DTX,DTY,H)

C......EASTWARD COMPONENT OF GEOSTROPHIC WIND
CALL WIND

C CHANGE OF VARIABLES FOR OUTPUT
 PGH=PH
 DGH=DH
 TGH=TH
 UH = UGH
 VH = VGH
 CP = \( \frac{7.4PH}{(2.9DHTH)} \)
 DTZ = (T2 - T1)/5000,

C......VERTICAL MEAN WIND
 WGH = -CP*(UH*DX+VH*DTY)/(G + CP*DTZ + UH*DUN + VH*DUn)

C GO TO RANDOM PERTURBATIONS SECTION
 GO TO 800

C......THE FOLLOWING SECTION IS FOR GROVES OR MIXED GROVES 4D HEIGHTS

C UPPER HEIGHT INDEX
 200 IHGB = 5*(INT(H)/5) + 5
 IF (IHGB.GT.90) IHGB=90

C UPPER HEIGHT
 HGB = IHGB+1.

C......GROVES AT UPPER HEIGHT
 CALL GTERP(IHB,PHI,PGB,DGB,TGB,PG,DG,DPYGB,DTYGB,DP2YGB)

C......UPPER STATIONARY PERTURBATION HEIGHT = 40
 IF (H.LT.40.0) GO TO 210

C......UPPER STATIONARY PERTURBATION HEIGHT = 90
 IF (H.GT.84.0) GO TO 220

C......UPPER STATIONARY PERTURBATION HEIGHT = 52,60,68,76,OR 84
 IHSB = 8*(INT(H) + 4)/8 + 4

C......UPPER STATIONARY PERTURBATION HEIGHT = 52
 IF (IHGB.LT.52.0) IHGB = 52
 GO TO 230

210 IHGB = 10*(INT(H)/10) + 10
 GO TO 230

220 IHGB = 90

C UPPER STATIONARY PERTURBATION HEIGHT
 230 IHGB = IHGB+1.
STATIONARY PERTURBATIONS

CALL PDTUV(PSP, DSP, TSP, PHI, THET, IHSB, PSB, TSB, DSB, DPXB, DPYSB, DTXSB, DTYSB, DP2XS, DP2YSB, DPXYSB)

MIXED GROVES 4D SECTION
IF (H.LT.30.0) GO TO 300

LOWER HEIGHT INDEX
IHA = IHSB - 5

LOWER HEIGHT INDEX
IHA = IHSB + 1

STATIONARY PERTURBATIONS

CALL GTERP(IHGA, PHI, PGA, DGA, TGA, PSG, DSG, TSG, DPYM, DTYGA, DP2YGA, DPYG)

LOWER STATIONARY PERTURBATION
IHA = 30
IF (IHA.LT.40.0) IHA = 40
GO TO 250

240 IHSB = 30

LOWER STATIONARY PERTURBATION
IHA = IHSB + 1

STATIONARY PERTURBATIONS AT LOWER HEIGHT

CALL PDTUV(PSP, DSP, TSP, PHI, THET, IHSB, PSB, TSB, DSB, DPXB, DPYSB, DTXSB, DTYSB, DP2XS, DP2YSB, DPXYSB)

LOWER STATIONARY PERTURBATION HEIGHT = 30
IF (H.LT.40.0) GO TO 240

LOWER STATIONARY PERTURBATION HEIGHT = 40
IF (IHSB.LT.40.0) IHSB = 8Z((INT(H) ÷ 4)/8) - 4
GO TO 250

250 IHSB = IHSB

//... REMAINDER OF CODE...

// UNPERTURBED (MONTHLY MEAN) VALUES FOR OUTPUT
TGH = TGH * (1. + TSH)
PSH = PSH * (1. + PSH)
DGH = DGH * (1. + DSH)

TOTAL DT/DX

DTX = DTXS * TGH

TOTAL DT/DY

DTY = TGMDTYS * DTYG(1. + TSH + DTYS)

TOTAL DP/DX

DPX = DPXS * PSH

TOTAL DP/DY

DPY = PGMDPYS + DPYG(1. + PSH + DPYS)

TOTAL D2P/DX2

D2P/DX2

D-46
\[
\begin{align*}
D_{XX} &= (P_{GH} + 2.0 P_{DYS} - DP_{2YS}) \\
D_{YY} &= (P_{GH} + 2.0 P_{DYS} - DP_{2YS} + (2.0 P_{GY} - DP_{2YG} + (1.0 P_{SH} + DP_{YS}))) \\
D_{XX} &= (P_{GH} + 2.0 P_{DYS} - DP_{2YS}) \\
D_{YY} &= (P_{GH} + 2.0 P_{DYS} + DP_{2YS}) \\
\end{align*}
\]

\[C \quad D_{DP/DBY} \]
\[D_{FX} = (P_{GH} + DP_{YS}) D_{DYS} + DP_{2YS} \]

C... UNPERTURBED VALUES PLUS GBO PERTURBATIONS

\[\begin{align*}
P_{H} &= (1.0 + P_{O}) \times P_{SH} \\
D_{H} &= D_{GH} \times (1.0 + D_{Q}) \\
T_{H} &= (1.0 + T_{Q}) \times T_{GH} \\
\end{align*}\]

C... GENUINE WIND PLUS GBO WIND PERTURBATIONS

\[\begin{align*}
U_{H} &= U_{GH} + U_{DH} \times D_{DYS} \\
V_{H} &= V_{GH} + V_{DH} \times D_{DYS} \\
C &= 7.0 P_{GH} / (2.0 D_{GH} + T_{GH}) \\
D_{TZ} &= (T_{GB} + (1.0 - T_{SB}) - T_{GB} + T_{SB}) / 5000.0 \\
\end{align*}\]

C... VERTICAL MEAN WIND

\[\begin{align*}
\bar{W}_{H} &= C \times \bar{U}_{GH} + \bar{D}_{GH} \times D_{DYS} \\
\bar{V}_{H} &= \bar{V}_{GH} + \bar{V}_{DH} \times D_{DYS} \\
C &= \frac{7.0 P_{GH}}{(2.0 D_{GH} + T_{GH})} \\
D_{TZ} &= \frac{(T_{GB} + (1.0 - T_{SB}) - T_{GB} + T_{SB})}{5000.0} \\
\end{align*}\]

C... THE FOLLOWING IS THE MIXED GROVES 4D SECTION

\[\begin{align*}
\text{IF} \ (H_{1} \geq 30,\ \text{OR} \ \text{LOOK} \geq \text{EQ.1}) \ \text{CALL GEN4D} \\
& \text{CONTINUE} \quad \text{CALL CHECK} \\
\end{align*}\]

C... LAT-LON INTERPOLATION OF 4D DATA AT 25 KM

\[\text{CALL INTER4} (P_{H}, T_{H}, 25, P_{4D}, D_{4D}, T_{4A}, P_{4A}, D_{4A}, T_{4A}) \]

C... 4D GROVES PLUS STATIONARY PERTURBATIONS

\[\begin{align*}
P_{4D} &= P_{GH} \times (1.0 + P_{SB}) \\
D_{4D} &= D_{SH} \times (1.0 + D_{SB}) \\
T_{4D} &= T_{SH} \times (1.0 + T_{SB}) \\
\end{align*}\]

C... HEIGHT INTERPOLATION BETWEEN 4D AND STATIONARY PERTURBATIONS

\[\begin{align*}
P_{4D} &= P_{SH} \times (1.0 + P_{SB} + D_{PSB}) \\
D_{4D} &= D_{SH} \times (1.0 + D_{SB} + D_{PSB} + D_{PSB}) \\
T_{4D} &= T_{SH} \times (1.0 + T_{SB} + T_{PSB}) \\
\end{align*}\]

C... HEIGHT INTERPOLATION BETWEEN 4D AND GROVES AT UPPER HEIGHT

\[\begin{align*}
P_{4D} &= P_{SH} \times (1.0 + P_{SB} + D_{PSB}) \\
D_{4D} &= D_{SH} \times (1.0 + D_{SB} + D_{PSB} + D_{PSB}) \\
T_{4D} &= T_{SH} \times (1.0 + T_{SB} + T_{PSB}) \\
\end{align*}\]

C... 4D AND DP/DY

\[\text{CALL INTERN} (P_{SF}, T_{SF}, 25, P_{D}, D_{D}, T_{F}) \]

C... HEIGHT INTERPOLATION BETWEEN 4D AND GROVES AT UPPER HEIGHT

\[\begin{align*}
P_{SF} &= P_{SH} \times (1.0 + P_{SB} + D_{PSB}) \\
D_{SF} &= D_{SH} \times (1.0 + D_{SB} + D_{PSB} + D_{PSB}) \\
T_{SF} &= T_{SH} \times (1.0 + T_{SB} + T_{PSB}) \\
\end{align*}\]

C... 4D AND DP/DY

\[\text{CALL INTER2} (P_{SF}, T_{SF}, 25, P_{D}, D_{D}, T_{F}) \]

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C......HEIGHT INTERPOLATION BETWEEN 4D AT 25 AND GROVES AT UPPER HEIGHT
C
C DT/DX AND DT/DY
CALL INTERN(DTX4,DTY4,25.,DTXB,DTYB,H$B,DTX,DY,DY,H)
C
C......HEIGHT INTERPOLATION BETWEEN 4D AT 25 KM AND GROVES AT UPPER
C DZ/DX, DZ/DY, AND DZ/4DY
CALL INTERZ(DPXB,DPPYA,DPXYA,25.,DPXXB,DPYYB,DPXX,H$B,DPXX,H)
C
C QUASI BIENIAL PERTRUBATIONS
CALL OBSOGEN
C
C ADD OBS PERTURBATIONS TO P,T
350 PH = PGH*(1. + P0)
DH = DGH*(1. + P0)
TH = TGH*(1. + T0)
CALL WIND
C ADD OBS WIND PERTURBATIONS
UH = UGH + U0
VH = VGH + V0
CP = 7.1*PGH/(2. * DGH*TH)
DZT = (TB - TA)/(1000.*(H$B - 25.)
C
C......VERTICAL MEAN WIND
WGH = CP*(UGH*DTX/DXS + VGH*DTS/DY5)/(6*CP*DTZ*UGH*DX+S*VGH*DV)
C
C GO TO RANDOM PERTURBATIONS SECTION
2000 FORMAT(* LATITUDE',/16F8.3)
2001 FORMAT(* LONGITUDE',/16F8.3,' PRESSURE*)
2002 FORMAT(1X,'/16F8.0)
GO TO 800
500 IF (H.GE.0.0) GO TO 510
IF (H.LT.-0.015) GO TO 505
C IF -15 METER LE H LT 0, H IS SET TO 0
H = 0.
GO TO 510
C NO MORE COMPUTATIONS TO BE MADE IF HEIGHT LT -5 M
505 WHERE = 0
RETURN
C......GENERATE GRID OF 4D PROFILES IF PREVIOUS HEIGHT GE 30
510 IF (H1.GE.30.,.OR.,LOOK.EQ.1) CALL GEN4D
C LOWER HEIGHT INDEX
IH = INT(H)
C LOWER HEIGHT INDEX
IH = IH + 1.
IWSX = IWSYN
IK = IH + 1
DO 511 KX = 1, i3
IK = IK + KND
IF (IK - LT 1) IK = 1
IF (IK .GT. 26) IK = 26
DO 511 KY = 1, i4
DO 511 JY = 1, i4
PCK(IK,JY,K) = P4D(4*K + JY)*KND
DCX(IK,JY,K) = DCX(4*K + JY)*KND
511 CONTINUE
CALL CHECK
C UPPER HEIGHT INDEX
IRB -- IHA + 1
IF(IHB.LE.25) GO TO 513
IHA=24
HA=24.
IHB=25
C UPPER EIGHT
513 HB = IHB+1,
C ...... LAT-LON INTERPOLATION OF 4D VALUES AT UPPER HEIGHT
515 CALL INTER4( PHI,THET,IHB, P4D,D4D,T4D,PB,DB,TB,
$ DPX4B,DPY4B,DTX4B,DTY4B,DPXYA,DPXYB)
IF(IHA.EQ.0.AND.PB#DB#TB,#) GO TO 520
GO TO 540
520 IHB=IHIH'I
C .... LOOP TO FIND LOWEST VALID HEIGHT
HB=HB+1.
GO TO 515
540 IF(IHA.EQ.0)CALL INTER4( PHI,THET,IHA, P4D,D4D,T4D,
1PH#DA#TA#DPX4A,DPY4A,DTX4A,DTY4A,DPXYA,DPXYA)
IF(INSYM.EQ.0)INSX = INSYM
IF(IHA.EQ.0.OR.(PA#DA#TA#LE.0.AND.IHA,LT.10.AND.PB#DB#TB#GT.0.))
160 GO TO 550
GO TO 600
C ...... LAT-LON INTERPOLATION OF 4D VALUES AT LOWER HEIGHT
550 CALL INTER4( PHI,THET:0, P4D,D4D,T4D,
,PA#DA#TA#DPX4A,DPY4A,DTX4A,DTY4A,DPXYA,DPXYA)
IF(INSYM.EQ.0)INSX = INSYM
IF((TA-TB)$560.570.560)
560 TZ=(TA-TB)/ALOG(TA/TB)
GO TO 575
570 TZ=TA
C COMPUTES HEIGHT OF SURFACE
575 HA=HB+0.28705*TZ/ALOG(PB/PA)
IF(H,G,TM,H-,04) 60 TO 600
PH=0.
DH=0.
TH=0.
PGH=0.
DGH=0.
TGH=0.
GO TO 800
C ...... HEIGHT INTERPOLATION OF P,D,T
600 CALL INTER2(PA#DA#TA#HA#PB#DB#TB#HB#PGH,DGH,TGH,H)
C ...... HEIGHT INTERPOLATION OF DP/DX AND DP/DY
CALL INTER2(DPX4A,DPY4A,DTX4A,DTY4A,DPXYA,DPXYA)
C ...... HEIGHT INTERPOLATION OF DT/DX AND DT/DY
CALL INTER2(DTX4A,DTY4A,HP#DB#TB#DTX#DTY#)
C ...... HEIGHT INTERPOLATION OF D2P/DX2, D2P/DY2, AND D2P/DXY
CALL INTER2(DPX4A,DPY4A,DPXYA,HP#DB#TB#DPXYB#DPXYB#DPXYB#DPX#DPY#DPXY)
C CHANGE OF NOTATION FOR OUTPUT
PH = PH
DH = DGH
TH = TGH
IF(PH#DH#TH#LE.0.) GO TO 800
CALL WIND

C CHANGE OF NOTATION FOR OUTPUT

UM = UGH
VM = VGH
CP = 7.27GH/(2.0GHGTGH)

DTZ = (TB - TA)/(1000.*HB - HA))

C VERTICAL MEAN WIND

UH = -CP*(UZHHD/TX/DS + UGHDD/TX/DD)/(G+CP*DTZUM+UH+VHVDVH)

C OBS=D IF H LT 10
IF (H.LT.10.) GO TO 800

C COMPUTES QUASI BIENNIAL PERTURBATIONS
CALL QBOGEN

C ADDS QBO PERTURBATIONS TO P,D,T

C THE FOLLOWING IS THE RANDOM PERTURBATIONS SECTION

C NO RANDOM PERTURBATIONS IF IOPR GT 1

800 CONTINUE
IF(H.GT.30) GO TO 512

C INTERPOLATES RANDOM WIND MAGNITUDES TO HEIGHT H, LATITUDE PHI
CALL INTRUV(UR,VR,H,PHI,SH+SVH)
CALL INTRUV(PLP+DLPH+H,PHI+PLPH,DLPH)
CALL INTRUV(TLP+DLPH+H,PHI+TLPH,TLPH)
CALL INTRUV(ULP+VLP,H,PHI+ULPH+VLPH)
CALL INTRUV(UDS+VDS+H,PHI+UDS2+VDS2)

SUH=SORT(U+ABS(SUH))
SUH=SORT(ULPH#ABS(SUH))
SUH=SORT(ULPH#ABS(SUH))
SUH=SORT(ULPH#ABS(SUH))
SUH=SORT(ABS(SUH))
SUH=SORT(ABS(SUH))

C IF H LE 25 USE 4D DATA RANDOM P,D,T SIGMAS
IF (H.LE.25.) GO TO 610

C INTERPOLATES FR+DR,TR ARRAYS TO GET P,D,T SIGMAS AT HEIGHT H,
C LATITUDE PHI
CALL TTERP(H,PHI,FR,DR,TR,SPH,SDH,STH)
GO TO 820

C LAT-LAT INTERPOLATION ON P,D,T SIGMAS AT LOWER HEIGHT

512 CONTINUE
IF (IOPR.GT.1) GO TO 830

C END
810 CALL INTER4( PHI,THET,HA, SP4,SD4,ST4,PA,DA,TA,  
$ DPX,DPY,DTX,DTY,DPXX,DPYY,DPXY)  
SCIM 489

820 DZ = HI - H
SPHL = SORT((1.-PLPH)ABS(SPH))  
SPHS = SORT((1.-PLPH)ABS(SPH))  
SDHL = SORT((1.-DLPH)ABS(SDH))  
SDHS = SORT((1.-DLPH)ABS(SDH))  
STHL = SORT((1.-TLPH)ABS(STH))  
STHS = SORT((1.-TLPH)ABS(STH))  
SPH = SQRT(ABS(SPH))  
SDH = SQRT(ABS(SDH))  
STH = SQRT(ABS(STH))  

C.....COMPUTES HORIZONTAL DISPLACEMENT DX BETWEEN PREVIOUS AND CURRENT POSITION
C ADDS RANDOM PERTURBATIONS TO PH, DH, TH
825 RPIS = PRH
RDIS = DRH
RTIS = TRH
RPL = PRH
RDL = DRH
RTL = TRH

C.....SETS PREVIOUS RANDOM PERTURBATION IN P, D, T TO CURRENT PERTURBATIONS, FOR NEXT CYCLE
830 RUIS = URH
RVIS = VRH
RUUL = URHL
RVUL = VRHL

C.....SETS PREVIOUS WIND PERTURBATION VALUES TO CURRENT VALUES, FOR NEXT CYCLE
C FOR NEXT CYCLE
835 SUIS = SUNS
51555
SUI5=SVHS
SUI=SVHL
C....SETS PREVIOUS HEIGH TO CURRENT HEIGHT, FOR NEXT CYCLE
830 H1 = H
C....SETS PREVIOUS LATITUDE TO CURRENT LATITUDE, FOR NEXT CYCLE
PHIR=PHIR
C....SETS PREVIOUS LONGITUDE TO CURRENT LONGITUDE, FOR NEXT CYCLE
THEIR=THEIR
C SETS MORE TO COMPUTE MORE DATA ON NEXT CYCLE
MORE = 1
C....NO MORE DATA IF P, D, OR T LEQ 0
IF(PH$DMTH,LE,0.) RETURN
CALL STDATA(H,T,PS,DS)
IF((PS,DS,TS).GT.0) GO TO 870
PGHP=0.
DGHP=0.
TGHP=0.
PHP=0.
DHP=0.
THP=0.
GO TO 880
870 PGHP=100.*(PS-PS)/PS
DGHP=100.*(DS-DS)/DS
TGHP=100.*(TS-TS)/TS
PHP=100.*(PH-PS)/PS
DHP=100.*(DH-DS)/DS
THP=100.*(TH-TS)/TS
C CONVERTS GBO P,D,T TO PERCENT
880 PG=100.*PG
DG=100.*DG
TG=100.*TG
C CONVERTS RANDOM P,D,T TO PERCENT
PRH=100.*PRH
DRH=100.*DRH
TRH=100.*TRH
PRHS=100.*PRHS
DRHS=100.*DRHS
TRHS=100.*TRHS
PRHL=100.*PRHL
DRHL=100.*DRHL
TRHL=100.*TRHL
SPHS = 100.*SPHS
SDHS = 100.*SDHS
STHS = 100.*STHS
SPHL = 100.*SPHL
SDHL = 100.*SDHL
STHL = 100.*STHL
C CONVERTS WIND SHEAR TO M/S/KM
DUM = DUM * 1000.
DVH = DVH * 1000.
C CONVERTS VERTICAL WIND TO CM/S
WGH = WGH*100.
POA=POA*100.
SUBROUTINE SELECT #
INTEGER IOTEM2
COMMON/C4/XL(16),YL(16),NP
C
C
S
C
SUBROUTINE TO SELECT POINTS FOR INTERPOLATION
C
COMMON /IOTEMP/ IOTEM1,IOTEM2
COMMON /POINT/ IPT(16,5),LL(16),DXY(16,2)
COMMON /ORDER/ IPT(16,5),IREAD(65,3)
C
DIMENSION IC(4),IL(2),JL(2),LINL(51),LINU(51)
C
DATA LINL/15,14,13,12,11,10,9,8,7,6,5,4,3,2,231,2,3,4,5,6,7,8,9,10/,
110,11,12,13,14,15/
DATA LINU/33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49/,
50,51,52,53,54,55,56,57,58,59,60/,
144,43,42,41,40,39,38,37,36,35,34,33/,
DATA PL/3.14159/,
C
C
INITIALIZE

PI4=PI/4.
DEGRAD=PI/180.
DO 1 I=1,16
DO 1 J=1,5
1 IPT(I,J)=0

MAJOR LOOP FOR POINTS

DO 100 II=1,MP

LA=ABS(XL(II))\times10.45
LO=YL(II)\times10.45
LL(II)=LA\times10000+LO
IF (XL(II),LT,0.) LL(II)=LL(II)

IF (XL(II)-15.1) 15:30,30
15 IF (XL(II)) 50:40,40

WNC GRID

30 IPT(II,5)=2
EL=(350-YL(II))\times DEGRAD
PHI=XL(II)\times DEGRAD
R=31.204359052*(SIN(PH14-PHI/2.)/COS(PH14-PHI/2.))
XX=R*COS(EL)+24.
YY=R*SIN(EL)+26.
I=XX
J=YY
DX=XX-I
DY=YY-J
DXY(II,1)=DX
DXY(II,2)=DY
IF (XL(II),GT,17,18) GO TO 31
IF (((J,LT,1),OR,(J,GTR,51)) GO TO 70
IF (((I,LT,LIML(J)),OR,(I,GTR,LIMU(J))) GO TO 70
31 IC(1)=I\times1000+J
IF (((ABS(DX),GT,1),OR,(ABS(DY),GT,1)) GO TO 32
IP=1
GO TO 35

CONTINUE

32 CONTINUE
IF (XL(II),GT,17,18) GO TO 34
IF (((I,GTR,LIMU(J)),AND,(J,GTR,15),AND,(J,LE,37)))
1 .OR.(J,GTR,50) GO TO 70
IF (((I+1,GTR,LIMU(J+1)),OR,(I,LT,LIML(J+1))) GO TO 80
IF (((I,EQ,LIMU(J)),OR,(I,EQ,LIML(J))) GO TO 80
34 IP=4
IC(2)=(II)\times1000+J
IC(3)=I\times1000+JH1
IC(4)=(II)\times1000+JH1
35 CONTINUE
REWIND IDTEM2
DO 38 IP6=1,1977

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READ(IO,lM2) IJ
DO 30 K=1,IP
30 IF (IC(K),EQ.IJ) IPT(IJ,K)=IPG
GO TO 100
C EQUATORIAL GRID
C
40 IPT(I,J)=1
L1=XL(I)
L2=YL(I)
IL(1)=L1/5
IL(2)=IL(1)+1
JL(1)=(L2/5)+1
JL(2)=JL(1)-1
DO 45 K1=1,2
DO 45 K2=1,2
IF ((ABS(XL(I)-IL(K1)*5).GT.0.1).OR.(ABS(YL(I)-JL(K2)*5).GT.0.1)) SELE 91
1 ) GO TO 45
IF (JL(K2).EQ.72) JL(K2)=0
IPT(I,J)=JL(K2)*4+IL(K1)*1
GO TO 100
45 CONTINUE
IF (JL(1).EQ.72) JL(1)=0
IPT(I,J)=JL(1)*4+IL(1)*1
IPT(I,J)=JL(2)*4+IL(2)*1
IPT(I,J)=JL(1)*4+IL(2)*1
IPT(I,J)=JL(2)*4+IL(2)*1
GO TO 100
C SOUTHERN HEMISPHERE
C
50 IPT(I,J)=3
L1=XL(I)
L2=YL(I)
IF (ABS(XL(I)).LT.85.0) GO TO 51
IPT(I,J)=1
IF (ABS(XL(I)+90.).LT.0.1) GO TO 100
51 CONTINUE
IL(1)=(L1/5)-1
JL(1)=(L2/5)+1
IL(2)=IL(1)+1
JL(2)=JL(1)-1
DO 52 K1=1,2
DO 52 K2=1,2
IF ((ABS(XL(I)-IL(K1)*5).GT.0.1).OR.(ABS(YL(I)-JL(K2)*5).GT.0.1)) SELE 119
1 ) GO TO 52
IF (JL(K2).EQ.72) JL(K2)=0
IPT(I,J)=JL(K2)*17-IL(K1)*1
IF (IL(K).NE.0) GO TO 100
IPT(I,J)=JL(K2)*4+1
IPT(I,J)=1
GO TO 100
52 CONTINUE
IF (JL(1).EQ.72) JL(1)=0
IF (IPT(II,1).EQ.1) GO TO 54
IPT(II,1)=JL(1)*17-IL(1)+1
IPT(II,2)=JL(2)*17-IL(1)+1
IF (IL(2)) 55,53,55
53 IPT(II,3)=JL(1)*#+1
IPT(II,4)=JL(2)*#+1
IPT(II,5)=100
GO TO 100
54 IPT(II,2)=JL(1)*17-IL(2)+1
IPT(II,3)=JL(2)*17-IL(2)+1
IPT(II,5)=333
GO TO 100
55 CONTINUE
IPT(II,3)=JL(1)*17-IL(2)+1
IPT(II,4)=JL(2)*17-IL(2)+1
GO TO 100
C
C BORDERLINE POINTS
C
70 CONTINUE
C TWO NMC, TWO EQUATORIAL
IPT(II,5)=2211
L=YL(II)
IPT(II,1)=((L/5)+2)*4
IPT(II,2)=IPT(II,1)-4
IF (L.GE.355) IPT(II,1)=4
C
IF (J.LT.1) J=1
IF (J.GT.51) J=51
IF (I.LT.LIM(J)) I=LIM(J)
IF (I.GT.LIMU(J)) I=LIMU(J)
IC(1)=I*1000+J
IF ((J.LT.15).OR.(J.GT.37)) GO TO 72
IC(2)=I*1000+JH1
GO TO 76
72 IF ((J.NE.1).AND.(J.NE.51)) GO TO 74
IF (J.EQ.LIMU(J)) GO TO 73
IC(2)=(I)*1000+J
GO TO 76
73 IC(2)=(I-1)*1000+J
GO TO 76
74 IF (J.EQ.LIM(J)) GO TO 75
IC(2)=LIMU(JH1)*1000+JH1
GO TO 76
75 IC(2)=LIM(JH1)*1000+JH1
C
76 REWIND IOTEM2
DO 77 IPG=1,1977
READ(IOTEM2) IJ
DO 77 K=1,2
77 IF (IC(K).EQ.1) IPT(K+2)=IPG
GO TO 100
C
80 CONTINUE
THREE NMC, ONE EQUATORIAL

IPT(II,5) = 2212

IC(2) = 0

L = YL(II)

IPT(II,2) = (L/5+1) # 4

IF (L .GE. 355) IPT(II,2) = 4

IF (L.EQ.LIM(J)) GO TO 84

IF (J.GT.37) GO TO 82

IC(1) = I*10000+J

IC(3) = I*10000+J+1

IC(4) = (I+1)*10000+J+1

GO TO 88

82 IC(1) = (I+1)*10000+J

IC(3) = I*10000+J

IC(4) = I*10000+J+1

GO TO 88

84 IF (J.GT.37) GO TO 86

IC(1) = (l-j)*10000+J+1

IC(3) = I*10000+J+1

IC(4) = I*10000+J

GO TO 88

86 IC(1) = (I+1)*10000+J+1

IC(3) = (I+1)*10000+J

IC(4) = I*10000+J

88 REMIND IOTEM2

DO 89 IPG = I+1, 1977

READ(IOTEM2, IJ)

DO 89 K = 1, 4

IF(IC(K).EQ.0) GO TO 89

IF(IC(K).GT.0) IPT(II, K) = IPG

89 CONTINUE

100 CONTINUE

DO 150 I = 1, 16

DO 150 J = 1, 5

IPTM(I, J) = IPT(I, J)

CALL SORT4(MP)

RETURN

END

SUBROUTINE SETUP

COMMON/COTRAN/NDATA(19), IC, MI, IH, IX(10), IEX

DIMENSION IF(5), ID(5), IT(5), IDAY(12), BUFFER(64)

COMMON/IOTEM/IOTEM2, IOTEM3, IOTEM4, IUG, NNCOP, DD, XMJD, PHI1, PHI2,

BEGINNAME, RPIL, RDIL, SDL, RUI, RL, RVIL, SVIL, SVIL

$ MM: IDD, IYR, HI, PHIR, THETAIR, DUMS(21), RPS, RDIS

1, RTIS, RUIS, RVIS, SPIS, SDIS, STIS, SUIS, VSIS, UDIS, VDIS,

2, UDS, VDSL, VDSL, VDSL, VDSL

COMMON/POTOCM/I + MO, IREF, IPX, PG(18, 19), TQ(18, 19), DG(18, 19)

+ PSP(8, 10, 12)

1, DSP(8, 10, 12), TSP(8, 10, 12), PAD(17, 5), DAB(17, 5), TAO(17, 5), PDQ(17, 5)

2, DDQ(17, 5), TDO(17, 5), PR(20, 10), OA(20, 10), TR(20, 10), UAR(17, 5)

3, VAB(17, 5), VDB(17, 5), VIR(25, 10), VIR(25, 10)

$ POG, TD, TO, UG, POA, DQA,
TQA, UA, UA, IOPO, PLP(25, 10), DLP(25, 10), JLP(25, 10)

COMMON/CHIC/DIM(18), IWSYM+UCOEF(14, 9), UCOEF(14, 9)

DIMENSION IDUM(9)

DATA IDAY/0, 31, 5/90, 120, 151, 181, 212, 243, 273, 304, 334/

XMJD = 0.
IF (MN.GT.12) GO TO 2
IDA = IDAY(MN) + IDD
DD = IDA
IF (MO(1YR, 4).EQ.0, AND. MN.GT.2) IDA = IDA + 1
XMJD = 2439856. + 365. * (IYR - 68.) + IDA + INT((IYR - 65.) / 4.)

C. SECOND DATA CARD READS, FREE FIELD, THE FOLLOWING DATA:

C IUG = UNIT NUMBER FOR GROVES DATA TAPE
C IUR = UNIT NUMBER FOR RANDOM SIGMA DATA
C (IF IUR=IUG UNIT IUG WILL BE READ)
C IUO = UNIT NUMBER FOR QB0 DATA
C (IF IUO=IUG DATA ON TAPE ON UNIT IUG WILL BE READ)
C IU4 = UNIT FOR 4-D INPUT P+ T 0-25AM DATA
C IOPR = RANDOM OUTPUT OPTION
C IOPO = QBO OUTPUT OPTION
C IOPO=1 RANDOM OUTPUT
C IOPO=2 NO RANDOM OUTPUT
C IOPO=1 QB0 OUTPUT
C IOPO=2 NO QB0 OUTPUT
C NRI = STARTING RANDOM NUMBER
C NMCOP = NMC GRID DATA READ OPTION
C NMCOP=0 READS NMC GRID DATA FROM UNIT IUG; OTHERWISE READS FORM CARDS
C IOTEN1=UNIT FOR 4-D P, D, T DATA (SCRATCH FILE; DOES NOT NEED TO BE ASSIGNED)
C IOTEN2=UNIT FOR NMC GRID POINTS (SCRATCH FILE; DOES NOT NEED TO BE ASSIGNED)
C
READ(5, 10) IUG, IUR, IUQ, IU4, IOPR, IOPO, NRI, NMCOP, IOTEN1, IOTEN2

WRITE(6, 9000) IOG, IUQ, IU4, IOPR, IOPO, NRI, NMCOP, IOTEN1, IOTEN2
$ XMJD
IF (IOPR.LT.I.OR.IOPR.GT.2) GO TO 666
IF (IOPO.LT.I.OR.IOPO.GT.2) GO TO 666
NTH:NN
IF (IOPR.EQ.2) GO TO 7
R=RABD(NRI)
R = RND(0)
R = RND(0)

C. THIRD DATA CARD READS FREE FIELD, THE FOLLOWING DATA:
C RP1 = INITIAL RANDOM PRESSURE PERTURBATION, PERCENT
C RD1 = INITIAL RANDOM DENSITY PERTURBATION, PERCENT
C RT1 = INITIAL RANDOM TEMPERATURE PERTURBATION, PERCENT
C SD1 = INITIAL STANDARD DEVIATION FOR RANDOM DENSITY PERTURBATION, PERCENT
C RUI = INITIAL EASTWARD WIND PERTURBATION, M/S
C RV1 = INITIAL NORTHWARD WIND PERTURBATION, M/S
C SU1 = INITIAL STANDARD DEVIATION FOR RANDOM EASTWARD WIND, M/S
C SV1 = INITIAL STANDARD DEVIATION FOR RANDOM NORTHWARD WIND, M/S
READ(5, 10) RP1, RD1, RT1, SD1, RI, RUI, RV1, SU1, SV1

READ(5, 10) RP1, RD1, RT1, SD1, RI, RUI, RV1, SU1, SV1

D-58
C  AVOIDS TAPE SEARCH IF CURRENT MONTH IS SAME AS PREVIOUS MONTH
       IF (NSAME.GT.0) GO TO 621
       7 IF (NSAME.EQ.1) GO TO 621
       CALL GETMC

C.....LOADS NMC GRID DATA FROM INPUT UNIT TO SCRATCHFILE UNIT ID1N2
       IF (MONTH.LT.13) GO TO 12
       M1=13
       M2=13
       C.....MONTH=13 IS ANNUAL AVERAGE CASE
       GO TO 13
       12 M1=MONTH
       M2=MONTH + 6
       C.....SOUTHERN HEMISPHERE DATA IS 6 MONTHS DISPLACED FOR GROVES,
       STATIONARY PERTURBATIONS, AND RANDOM PERTURBATIONS
       IF (M2.GT.12) M2=M2 - 12
       13 DO 100 I=1,234
       CALL RTRAM1

C.....READS GROVES PRESSURE DATA
       IF (IC.NE."P") GO TO 666
       IF (MI.EQ.M1) GO TO 30
       IF (MI.EQ.M2) GO TO 40
       GO TO 100
       30 KS=1
       GO TO 50
       40 KS=-1
       50 IH=(IH-20)/5
       TENX=10.##IEX
       DO 60 J=1,10
           K=10*KS*(J-1)
           60 PG(IH+K) = IX(J)*TENX

C.....CONVERSION TO REAL AND STORAGE IN ARRAY COMPLETE
       CONTINUE
       DO 200 I=1,234
       CALL RTRAM1

C.....READS GROVES DENSITY DATA
       IF (IC.NE."D") GO TO 666
       IF (MI.EQ.M1) GO TO 130
       IF (MI.EQ.M2) GO TO 140
       GO TO 200
       130 KS=1
       GO TO 150
       140 KS=-1
       150 IH=(IH-20)/5
       TENX=10.##IEX
       DO 160 J=1,10
           K=10*KS*(J-1)
           160 DB(IH+K) = IX(J)*TENX

C.....CONVERSION TO REAL AND STORAGE IN ARRAY COMPLETE
       CONTINUE

D-59
DO 300 I=1,234
CALL RTRAN

C......READS GROVES TEMPERATURE DATA
IF (IC.NE.'T') GO TO 666
IF (MI.EQ.M1) GO TO 230
IF (MI.EQ.M2) GO TO 240
GO TO 300

230 KS=1
GO TO 250

240 KS=-1
250 IH=(IH-20)/5
TENX=10.5**EX
DO 260 J=1,10
K=10*KS*(J-1)
260 TG(IH,K) = IX(J)*TENX

C......CONVERSION TO REAL AND STORAGE IN ARRAY COMPLETE
300 CONTINUE

IF (HONTH.LT,13) GO TO 308
C......ANNUAL _AN CASE _ BOTH HEMISPHERES EQUAL
DO 304 I=1,18
DO 304 J=1,9
J20=2-J
PG(I,J) = PG(I,J20)
 gefset(J) = gefset(J20)
TG(IP,J) = TG(IPJ20)
304 CONTINUE
308  DO 360 I=1,1248
CALL RTRAN
C......READS STATIONARY PERTURBATIONS DATA (TO BE STORED IN PSP, DSP, AND TSP ARKAYS)
C
TSP ARRAYS)
IC=NDATA(1)
MI=NDATA(2)
IH=NDATA(3)
LDN=NDATA(4)
DO 311 K=1,5
IP(K)=NDATA(4+K)
ID(K)=NDATA(9+K)
311 IT(K)=NDATA(14+K)
IF (IC.NE.'S') GO TO 666
IF (MI.EQ.M1) GO TO 320
IF (MI.EQ.M2) GO TO 330
GO TO 360
320 KS=1
GO TO 340
330 KS=-1
340 ISH=2+(IH-44)/8
L=(LDN+20)/30
IF (IH.LT.52) ISH = (IH-20)/10
IF (IH.GT.84) ISH=8
DO 350 J=1,5
K=5*KS*(J*(KS-1)/2)
PSP(ISH,K,L) = IP(J)/1000.
DSP(ISH,K,L) = ID(J)/1000.
350 TSP(ISH,K,L) = IT(J)/1000.
C......CONVERSION TO REAL AND STORAGE IN ARRAYS COMPLETE
360 CONTINUE
   IF (MONTH.LT.13) GO TO 368
C......ANNUAL MEAN CASE - BOTH HEMISPHERES EQUAL
   DO 364 I=1,8
   DO 364 K=1,12
   DO 364 J=1,5
   J10=11-J
   PSP(I,J,K)=PSP(I,J10,K)
   DSP(I,J,K)=DSP(I,J10,K)
   TSP(I,J,K)=TSP(I,J10,K)
364 CONTINUE
C MOVES PAST 2ND EOF ON UNIT IUG
368 READ(IUG,99999,END=369) IDUM
9999 FORMAT(A1)
   GO TO 368
369 CONTINUE
   IF (IOPR.EQ.2) GO TO 440
C......IOPR=1 READS RANDOM SIGMAS, IOPR=2 ZEROS RANDOM SIGMAS
   DO 430 I=1,260
   IF (IUR.EQ.IUG) GO TO 375
   READ (IUR,380) IC,MI,II,IP,ID,IT
C......USES FORTRAN READ ON UNIT IUR IF IUR NEQ IUG
   380 FORMAT(IX,AI,12,14,3(IX,514))
   GO TO 385
375 CALL RTRAN
C......READS FROM UNIT IUG IF IUG = IUR
   IC=NDATA(1)
   MI=NDATA(2)
   II=NDATA(3)
   DO 381 K=1,5
   IP(K)=NDATA(3+K)
   ID(K)=MTA(B+K)
381 IT(K)=NDATA(13+K)
385 IF (IC.NE.'R') GO TO 666
C = NORTHERN HEMISPHERE MONTH
   IF (MI.EQ.M1) GO TO 390
C = SOUTHERN HEMISPHERE MONTH
   IF (MI.EQ.M2) GO TO 400
C......M2 = M1 + 6 UNLESS M1 = M2 = 13
   GO TO 430
390 KS=1
   GO TO 410
400 KS=-1
410 IF (II.LT.95) IHR=(II-20)/5
C = HEIGHT INDEX
   IF (II.GE.95) IHR = 14 + (II - 80) / 20
   DO 420 J=1,5
   K = 5 + KS *( J + (KS - 1) / 2)
C......K = LATITUDE INDEX 1-5 = LAT -90 TO -10, 6-10 = LAT +10 TO +90
   PR(IHR,K) =IP(J,1000,1)**2
   DR(IHR,K) =ID(J,1000,1)**2
   TR(IHR,K) =IT(J,1000,1)**2
420 CONTINUE
D-61
IF (MONTH.LT.13) GO TO 460

C.....ANNUAL MEAN CASE - BOTH HEMISPHERES EQUAL
    DO 435 I=1,20
    DO 435 J=1,5
    J10=I-J
    PR(I,J)=PR(I,J10)
    DR(I,J)=DR(I,J10)
    TR(I,J)=TR(I,J10)
435 CONTINUE
    GO TO 460
440 DO 450 I=1,20
    DO 450 J=1,10
    PR(I,J)=0.
    DR(I,J)=0.
450 TR(I,J)=0.
460 DO 490 I=1,325
    IF (IUR.EQ.IUG) GO TO 462
    READ(IUR,465) IC, NI, IH, IP, ID
C.....READS RANDOM WIND STANDARD DEVIATIONS WITH FORTRAN READ FROM
    C UNIT IUR IF IUR NEQ IUG
465 FORMAT(IX,A2,12,14,2(IX,514))
462 CALL RTRAN
C.....READS FROM UNIT IUG IF IUG = IUR
    IC=NDATA(1)
    MI=NDATA(2)
    IH=NDATA(3)
    DO 461 K=1,5
    IP(K)=NDATA(3+K)
461 ID(K)=NDATA(8+K)
467 IF (IC.NE."RW") GO TO 466
C NORTHERN HEMISPHERE MONTH
    IF (MI.EQ.MI) GO TO 470
C SOUTHERN HEMISPHERE MONTH
    IF (MI.EQ.M2) GO TO 475
470 KS=1
475 KS=-1
480 IF (IH.LT.95) IHR=1+IH/5
C HEIGHT INDEX
    IF (IH.GE.95) IHR=19+(IH-80)/20
485 J=1,5
C LATITUDE INDEX
    K=5*KS*(JH(KS-1)/2)
485 UR(IHR,K)=IP(J#2)#1.
490 CONTINUE
IF (MONTH,LT,13) GO TO 500
C.....ANNUAL MEAN CASE - BOTH HEMISPHERES EQUAL
   DO 495 I=1,25
   DO 495 J=1,5
   J10=11-J
   UR(I,J)=UR(I,J10)
   VR(I,J)=VR(I,J10)
495 CONTINUE
C MOVES FAST 3RD EOF ON UNIT IUG
IF(IOPR.EQ.2) GO TO 900
500 READ(IUG,9999,END=501) IDUMMY
   GO TO 500
501 CONTINUE
   DO 840 I=1,25
   IF(IUR.EQ.IUG) GO TO 800
   READ(IUR,380) IC,MI,IH,IP,ID,IT
   C.....USES FORTRAN READ ON UNIT IUR IF IUR NE IUG
   GO TO 820
800 CALL RTRAN
C.....READS FROM UNIT IUG IF IUR = IUG
   IC=NDATA(1)
   MI=NDATA(2)
   IH=NDATA(3)
   DO 810 K=1,5
   IP(K)=NDATA(3+K)
   ID(K)=NDATA(8+K)
810 CONTINUE
820 IF(IH.GT.90) IH=70+(IH/4)
   IH=I+(IH/5)
   IF(IC.EQ.'P'.OR.IH.NE.I) GO TO 666
   DO 830 J=1,5
   PLP(I,J5)=IP(J)/1000.
   PLP(I6-J)=IP(J)/1000.
   DLP(I,J5)=ID(J)/1000.
   DLP(I6-J)=ID(J)/1000.
   TLP(I,J5)=IT(J)/1000.
   TLP(I6-J)=IT(J)/1000.
830 CONTINUE
840 CALL RTRAN
   IC=NDATA(1)
   MI=NDATA(2)
   IH=NDATA(3)
   DO 850 K=1,5
   IP(K)=NDATA(3+K)
   ID(K)=NDATA(8+K)
850 CONTINUE
845 CALL RTRAN
   IC=NDATA(1)
   MI=NDATA(2)
   IH=NDATA(3)
   DO 860 J=1,5
   ULP(I,J5)=IP(J)/1000.
   860 CONTINUE
D-63
ULP(I+6,J)=IP(J)/1000.
VLP(I+5,J)=IP(J)/1000.
ULP(I+6,J)=IP(J)/1000.
865 CONTINUE
DO 888 I=1,25
IF(IUR.EQ.IUG) GO TO 870
READ(IUR,868)IC,MI,ID,IP,ID
868 FORMAT(1X,A2,12,I4,2(I1,5S))
GO TO 880
870 CALL RTRAN
IC=MDATA(1)
MI=MDATA(2)
IH=MDATA(3)
DO 875 K=1,5
IP(K)=MDATA(3+K)
ID(K)=MDATA(8+K)
875 CONTINUE
IF(IH,GT,90) IH=70+(IH/4)
IN=IH*(IH/5)
IF(IN,M.E.1,OR.IC.M.E. *CS') GO TO 666
DO 885 J=1,5
UDS(I+5,J)=IP(J)/1000.
USD(I+6,J)=IP(J)/1000.
885 CONTINUE
888 CONTINUE
DO 898 I=1,25
IF(IUR.EQ.IUG) GO TO 890
READ(IUR,868)IC,MI,ID,IP,ID
GO TO 894
890 CALL RTRAN
IC=MDATA(1)
MI=MDATA(2)
IH=MDATA(3)
DO 892 K=1,5
IP(K)=MDATA(3+K)
ID(K)=MDATA(8+K)
892 CONTINUE
IF(IH, GT, 90) IH=70+(IH/4)
IN=IH*(IH/5)
IF(IN,M.E.1,OR.IC.M.E. *CL') GO TO 666
DO 896 J=1,5
UDL(I+5,J)=IP(J)/1000.
UDL(I+6,J)=IP(J)/1000.
896 CONTINUE
898 CONTINUE
GO TO 910
900 DO 905 J=1,25
DO 905 J=1,10
PLP(I,J)=0.
DLP(I,J)=0.
TLF(I,J)=0.
ULP(I,J)=0.
VLP(I,J)=0.
USD(I,J)=0.
905 CONTINUE
GO TO 910
UDL(I,J) = 0.
VDS(I,J) = 0.
VOL(I,J) = 0.

905 CONTINUE

C......MOVES PAST NEXT EOF ON TAPE
IF (IOPQ.EQ.2) GO TO 600

910 READ(IUG,9999,END=911) IDUMWAY
GO TO 910

911 CONTINUE

C......IOPQ=1 READS QBO PARAMETERS, IOPQ=2 ZEROS THESE PARAMETERS
DO 530 I=1,16
IF (IUG.EQ.IUG) GO TO 525
READ(IUO+520) IC,IH,IX

C......READS WITH FORTRAN FROM UNIT IUG IF IUO NEQ IUG
520 FORMAT (1X,A2,13,5(14R15))
GO TO 527

525 CALL RTRAN2

C......READS FROM UNIT IUG IF IUO = IUG
527 IF (IC.NE.'BP') GO TO 666
IH = (IH-5)/5
DO 530 J=1,5

C......CONVERT FROM INTEGER PER MIL - QBO PRESSURE AMPLITUDE
530 PAQ(IH,J) = IX(21J-I)/1000.
DO 531 I = 1,5
PAQ(I,1) = 0.

531 CALL PHASE(PDD(2:I),15.,PDO(3,I),20.,PDO(1,I),10.,)
DO 540 I=1,16
IF (IUO.EQ.IUG) GO TO 535
READ(IUO+520) IC,IN,IX
GO TO 537

535 CALL RTRAN2

537 IF (IC.NE.'BD') GO TO 666
IH = (IH-5)/5
DO 540 J=1,5

C......CONVERT FROM INTEGER PER MIL - QBO DENSITY AMPLITUDE
540 DADO(IH,J) = IX(21J-I)/1000.

C......QBO DENSITY PHASE (DAYS PAST JAN 0, 1966)
540 DADO(IH,J) = IX(21J-I)/1000.
DO 541 I = 1,5
DADO(1,1) = 0.

541 CALL PHASE(DDQ(2:I),15.,DDQ(3,I),20.,DDQ(1,I),10.,)
DO 550 I=1,16
IF (IUO.EQ.IUG) GO TO 545
READ(IUO+520) IC,IN,IX
GO TO 547

545 CALL RTRAN2

547 IF (IC.NE.'QT') GO TO 666
IH = (IH-5)/5
DO 550 J=1,5

C......CONVERTS FROM INTEGER PER MIL - QBO TEMPERATURE AMPLITUDE
TAQ(IH,J) = IX(21J-I)/1000.

C......QBO TEMPERATURE PHASE
550 TDQ(IH,J) = IX(2*J)*1.
DO 551 I = 1,5
   TDQ(I,I) = 0.
551 CALL PHASE(TDQ(2:I),15.,TDQ(3:I),20.,TDQ(1:I),10.).
   DO 560 I=1,16
   IF (IUG.EQ.IUG) GO TO 555
   READ(IUG+520) IC, IH, IX
   GO TO 557
555 CALL RTRAN2
C......READS WITH FORTRAN IF IUQ NEQ IUG
   READ(IUG,520) IC, IH, IX
   GO TO 557
557 IF (IC.NE.'OU') GO TO 666
   IH=(IH-5)/5
   DO 560 I=1,5
C.....EASTWARD WIND QBO AMPLITUDE - CONVERTED TO M/S
   UAO(IH,J) = IX(2*J-I)
   DO 561 I=1,16
   IF (IUG.EQ.IUG) GO TO 565
   READ(IUG+520) IC, IH, IX
   GO TO 567
565 CALL RTRAN2
567 IF (IC.NE.'OU') GO TO 666
   IH=(IH-5)/5
   DO 560 I=1,5
C.....EASTWARD WIND QBO PHASE (DAYS PAST JAN 0, 1966)
   UDQ(IH,J) = IX(2*J-I).
   DO 561 I=1,16
   IF (IUG.EQ.IUG) GO TO 565
   READ(IUG+520) IC, IH, IX
   GO TO 567
565 CALL RTRAN2
567 IF (IC.NE.'OU') GO TO 666
   IH=(IH-5)/5
   DO 560 I=1,5
C.....NORTHWARD WIND QBO AMPLITUDE - CONVERTED TO M/S
   VAO(IH,J) = IX(2*J-I-1)/10.
   DO 571 I=1,15
C.....NORTHWARD WIND QBO PHASE (DAYS PAST JAN 0, 1966)
   VDQ(IH,J) = IX(2*J-I).
   DO 571 I=1,15
   READ(IUG,520) IC, IH, IX
   GO TO 611
571 CALL PHASE(VDQ(2:I),15.,VDQ(3:I),20.,VDQ(1:I),10.).
   DO 600 I=1,IUG
   DO 600 J=1,5
   PAG(I,J) = 0.
   DAG(I,J) = 0.
   TAD(I,J) = 0.
   PAD(I,J) = 0.
   DAD(I,J) = 0.
   TDD(I,J) = 0.
   UAO(I,J) = 0.
   UDO(I,J) = 0.
   VAO(I,J) = 0.
   VDO(I,J) = 0.
   600 CONTINUE
C......MOVE PAST NEXT EOF ON TAPE.
611 READ(IUG,9999,END=609) IDUMMY
   GO TO 611
609 CONTINUE
C....READ IN SPHERICAL HARMONICS COEFFICIENTS ..............................
DO 615 IFR=I+MN
DO 613 JFR=I,14
READ(IUG,640)IFI,IF2,(IDU8(I),I=I,9)
640 FORMAT(2X,19I7)
DO 613 I=I,9
613 UCOEF(I,JFR)=FLOAT(IDU8(J))/#100.
DO 612 JFR=I,14
READ(IUG,640)IFI,IF2,(IDUM(J),I=I,9)
612 VCDEF(JFR)=FLOAT(IDU8(J))/100.
CONTINUE

C.....ZEROS QBO PARAMETERS IF IOPQ = 2
C.....REWINDS TAPE UNIT IUG
REWIND IUG

C

621 R=HI
IF(HI.LT.25.) R=25.
CALL RTERP(R,PHII,HI,PHII,PLP,DLP)
CALL INTRUV(PLP,DLP,HI,PHII,PLP1,DLP1)
CALL INTRUV(TLP,DLP,HI,PHII,TLPI,R)
SPIL=SQRT(PLP#ABS(SPI))/#100.
SPIS=SQRT((1.-PLP)#ABS(SPI))/#100.
SDIL=SQRT(DLP#ABS(SDI))/#100.
SDIS=SQRT((1.-DLP)#ABS(SDI))/#100.
STIL=SQRT(TLPI#ABS(STI))/#100.
STIS=SQRT((1.-TLPI)#ABS(STI))/#100.
CALL INTRW(ULP,VLP,HI,PHII,ULP1,VLPI)
SUIL=SQRT(ULP#ABS(SUI))
SUIS=SQRT((1.-ULP)#ABS(SUI))
SVIL=SQRT(VLP#ABS(SVI))
SVIS=SQRT((1.-VLP)#ABS(SVI))
CALL INTRV(UDL,VDL,HI,PHII,UDL1,VDL1)
UDL1=UDL/#100.
VDL1=VDL/#100.
UDS1=UDS/#100.
VDIS=VDIS/#100.
WRITE(6,9001) RPIL,RPIS,STIL,STIS,RPIL,SPIL,SPIS,SDIL,SDIS,STIL,STIS,
' LARG E' SETU 541
WRITE(6,9001) RPIS,VDIL,RPIL,STIL,STIS,RPIL,SPIL,SPIS,SDIL,SDIS,STIL,STIS,
'SMALL' SETU 542
WRITE(6,9002) UDL1,VDL1,UDS1,VDIS SETU 543
WRITE(6,9003) RPIL,RPIL/100.
RPIL=RPIL/100.
STIL=STIL/100.
SPIL=(SPIL/100.)
STIS=STIS/100.
SUI=SQRT(SUI)
SVIL=SQRT(SVI)
SPIS=SQRT(SPI)
SDIS=SQRT(SDI)
RPIS=RPIS/100.
RPIL=RPIL/100.
RPUL=RPUL/100.
RPUL=RPUL/100.
RPUL=RPUL/100.
RPUL=RPUL/100.
IF(IPT(I,5).EQ.3) GO TO 4
IF(IPT(I,5).EQ.1133) GO TO 6
IF(IPT(I,5).EQ.2211) GO TO 7
IF(IPT(I,5).EQ.2212) GO TO 8
IF (IPT(I,5).EQ.333) GO TO 4
GO TO 10
2 DO 3 J=1,4
IF (IPT(I,J).LT.1) GO TO 3
IPT(I,J)=IPT(I,J)+288
3 CONTINUE
GO TO 9
4 DO 5 J=1,4
IF (IPT(I,J).LT.1) GO TO 5
IPT(I,J)=IPT(I,J)+2265
5 CONTINUE
GO TO 9
6 IF (IPT(I,1).GT.0) IPT(I,1)=IPT(I,1)+2265
IF (IPT(I,2).GT.0) IPT(I,2)=IPT(I,2)+2265
GO TO 9
7 IF (IPT(I,3).GT.0) IPT(I,3)=IPT(I,3)+288
IF (IPT(I,4).GT.0) IPT(I,4)=IPT(I,4)+288
GO TO 9
8 IF (IPT(I,1).GT.0) IPT(I,1)=IPT(I,1)+288
IF (IPT(I,2).GT.0) IPT(I,2)=IPT(I,2)+288
IF (IPT(I,3).GT.0) IPT(I,3)=IPT(I,3)+288
IF (IPT(I,4).GT.0) IPT(I,4)=IPT(I,4)+288
9 CONTINUE
REORDERS POINT NUMBERS FOR READ
10 IR=0
DO 13 K=1,NP
DO 13 L=1,4
MP=IPT(K,L)
IF(MP.LT.1) GO TO 13
11 II=K
JJ=L
DO 12 I=1,NP
DO 12 J=1,4
IF (IPT(I,J).LT.1) GO TO 12
IF(IPT(I,J).GT.3490) GO TO 12
IF(IPT(I,J).GE.MP) GO TO 12
II=I
JJ=J
MP=IPT(I,J)
12 CONTINUE
IF(IPT(II,JJ).GT.3490) GO TO 14
IR=IR+1
IREAD(IR,1)=II
IREAD(IR,2)=JJ
IREAD(IR,3)=IPT(II,JJ)
IPT(II,JJ)=IPT(II,JJ)+9000
MP=IPT(K,L)
IF(MP.GT.3490) GO TO 13
GO TO 11
SUBROUTINE SPHERE(HN,IH,PHIR, THETR,US,VS)
COMMON/CHIC/DUM(18),IWSYM,UCOEFII4,9),VCOEF(14,_)
DIMENSION Z(9)
COSPHI=COS(PHIR)
COSTHET=COS(THETR)
SINPHI=SIN(PHIR)
SINTHET=SIN(THETR)
Z(1)=I.
Z(2)=SINPHI
Z(3)=COSTHET:COSPHI
Z(4)=SINTHET_COSPHI
Z(5)=(3*(SINPHI::2)-1)/2.
Z(6)=COSTHET*(3*COSPHI_SINPHI)
Z(7)=SINTHET*Z(3ZCOSPHItSINPHI)
Z(8)=(2*(COSTHET)_$2-1)t(31(COSPHI)_I2)
IH5=IH/5-4
IFR=9
IF(IH.GT.65)IFR=4
US=O.
VS=O.
DO 10 I=I,IFR
US=US÷Z(1)IUCOEF(IHS,I)
VS=VS+Z(I>IVCOEF(IH591)
10 CONTINUE
RETURN
END

SUBROUTINE STDAATH(Z,T,P,D)
DIMENSION ZS(35),TMS(35),WNS(35),PS(35)
DATA (ZS(I),I=1,35)/O., 11.019, 20.063, 32,162, 47.35,
52.429, 61.591, 79,944,
DATA (TMS(I),I=1,35)/288,15, 216,65,216,65, 228.65, 270.65,270.65,
252,65, 180.65, 180,65, 0,, 210.65, 0., 260.65, 0., 360.65,
DATA (WNS(I),I=1,35)/28.9644, 28.9644, 28,9644, 28.9644,
DATA (PS(I),I=1,35)/1013.25, 54.7487, 8.66043, 1.10905,
5.99055, 1.159499, 1.0537E-2, 1.6438E-3, 0., 3.0075E-4, 0.1,
7.354E-5, 0., 2.5217E-5, 0., 5.061E-6, 0., 3.6943E-6, 0.,
2.792E-6, 0., 1.6852E-6, 0., 6.9604E-7, 0., 1.8838E-7, 0.,
4.9034E-8, 0., 1.6957E-8, 0., 3.4502E-9, 0., 1.1918E-9/
IF(Z.LT.0.) GO TO 90
DO=6351.36
60=9.8066
RETURN
WNO=28.9644           STDA 25
RS=8314.32              STDA 26
ZM=Z*1000.              STDA 27
ROM=6356360.             STDA 28
IF(Z.GE.90.) GO TO 6       STDA 29
DO 3 I=1,8               STDA 30
IF(ZS(I).LE.Z.AND.Z.LT.ZS(I+1)) GO TO 5   STDA 31
3 CONTINUE               STDA 32
5 ZL=INT(ZS(I))$1.        STDA 33
ZU=INT(ZS(I+1))$1.        STDA 34
ZLM=Z*1000.              STDA 35
ZUM=ZU$1000.             STDA 36
IF(I.EQ.8) ZU=88.743      STDA 37
WH=WNO                   STDA 38
HT=(ROZ)/(RO+Z)          STDA 39
HM=HT$1000.             STDA 40
G=(TNS(I+I)-TNS(I))/(ZU-ZL) STDA 41
GH=G*.001                STDA 42
IF(6.LT.0.,OR.GT.0.) GO TO 12 STDA 43
P=PS(I)**EXP(-16G#WNO*(HM-ZLM))/(RS#TNS(I))**100. STDA 44
GO TO 13                 STDA 45
12 P=PS(I)**((TNS(I)/TNS(I)+6*(HT-ZL)))**((GO#WNO)/(RS#GH))**100. STDA 46
13 T=TNS(I)+6*(HT-ZL)     STDA 47
GO TO 25                 STDA 48
6 DO 7 I=9,33,2           STDA 49
IF(ZS(I).LE.Z.AND.Z.LT.ZS(I+2)) GO TO 8 STDA 50
7 CONTINUE               STDA 51
8 I=0.                    STDA 52
P=0.                      STDA 53
D=0.                      STDA 54
RETURN                    STDA 55
8 ZL=ZS(I)                STDA 56
ZU=ZS(I+2)                STDA 57
ZLM=Z*1000.               STDA 58
ZUM=ZU$1000.              STDA 59
ZMID=ZS(I+1)              STDA 60
AO=WNS(I)                 STDA 61
A2=-2.*(Z.*WNS(I+1)-WNS(I+2)-AD)/(ZU-ZL)**2.) STDA 62
A1=(WNS(I+2)-A0-A2*(ZU-ZL)**2.))/(ZU-ZL) STDA 63
WM=AO*A1*(Z-ZL)+A2*(Z-ZL)**2.) STDA 64
G=(TNS(I+2)-TNS(I))/(ZS(I+2)-ZS(I)) STDA 65
GH=G*.001                STDA 66
TK=ZLM-(TNS(I)/GM)        STDA 67
S=(WNS#GO#ROM#GM)/(RS#GM) STDA 68
A=((ROM+ZH)*(ZLM-TK)/((ZM-TK)#(ROM+ZLM))) STDA 69
B=(S/(TK+ROM)**2.))      STDA 70
P=PS(I)*((ROM+ZH)*(ZLM-TK)/((ZM-TK)#(ROM+ZLM)))**(S/(TK+ROM))**100. STDA 71
1**2.))**EXP((-S*(ZLM-ZM))/((TK+ROM)**2*(ZM+ROM)*(ZL+ROM)))#100, STDA 72
TN=TNS(I)+6*Z-ZS(I))     STDA 73
T=(WNS/WNO)/TN           STDA 74
25 D=(WH#P)/(RS#T)       STDA 75
26 RETURN                STDA 76
END                      STDA 77
SUBROUTINE TINF

D-71
COMMON/IOTEMP/IOTEM1/IOTEM2,1UG,WMCDP,DD,XMJD,PHII,PHI, TINF 2
COMMON/RP1, RD1, RT1, SFL, SDI, STL, RUL, RV1, SUI, SUV, TINF 3
$ NM, IDA, IYR, HI, PHI1R,THE1R,G,RI,H,PHIR,THE1R,F10+F10B+GI, TINF 4
 COMMON/COMAC/XLAT/XLONG,SDA,SHA,DY,TE,EM TINF 5

C

SUBROUTINE TINF CALCULATES THE EXOSPHERIC TEMPERATURE ACCORDING TO JATNF 6
C SAO NO. 313 1970. TINF 7
C
C LIST
C F10 = SOLAR RADIO NOISE FLUX (XE-22 WATTS/MM2) TINF 8
C F10B= 51-DAY AVERAGE F10 TINF 9
C GI = GEOMAGNETIC ACTIVITY INDEX: AP TINF 10
C LAT = GEOGRAPHIC LATITUDE AT PERIGEE (IN RAD) TINF 11
C SDA = SOLAR DECLINATION ANGLE (IN RAD) TINF 12
C SHA = SOLAR HOUR ANGLE TINF 13
C NY = 0/7 (DAY NUMBER/TROPICAL YEAR)? 1 TINF 14
C R = 0.31 (DIURNAL FACTOR) TINF 15
C
C CONSTANTS -- C=SOLAR ACTIVITY VARIATION, BETA,ETC. = DIURNAL VARIATION TINF 16
C D=GEOMAGNETIC VARIATION, E=SIMIANNUAL VARIATION. TINF 17
C
C C1 = 383.0 TINF 18
C C2 = 3.32 TINF 19
C C3 = 1.80 TINF 20
C
C PI = 3.14159265 TINF 21
C CDN = 0.01745329252 TINF 22
C BETA= -37.01*CDN TINF 23
C GAMMA= 37.01*CDN TINF 24
C P = 6.0*CDN TINF 25
C XM = 2.5 TINF 26
C XNN = 3.0 TINF 27
C
C D1 = 28.0 TINF 28
C D2 = 0.03 TINF 29
C D3 = 1.0 TINF 30
C D4 = 100.0 TINF 31
C D5 = -0.08 TINF 32
C
C E1 = 2.41 TINF 33
C E2 = 0.349 TINF 34
C E3 = 0.206 TINF 35
C E4 = 360.*CDN TINF 36
C E5 = 226.5*CDN TINF 37
C E6 = 720.*CDN TINF 38
C E7 = 247.6*CDN TINF 39
C E8 = 0.1145 TINF 40
C E9 = 0.5 TINF 41
C E10= E4 TINF 42
C E11= 342.3*CDN TINF 43
C E12= 2.16 TINF 44
C
C C SOLAR ACTIVITY VARIATION
TC = C1 + C2*I0B + C3*(I10 - I0B)

**DIURNAL VARIATION**

ETA = 0.5*ABS(XLAT - SDA)
THETA = 0.5*ABS(XLAT + SDA)
TAU = SHA + BETA + P*SIN(SHA + GAMMA)
TPI = 2*PI
IF(TAU) = 210, 230, 250
210 IF(TAUPI) = 220, 250, 250
220 TAU = TAU + TPI
GO TO 210
230 IF(TAU - PI) = 250, 250, 240
240 TAU = TAU - TPI
GO TO 230
250 CONTINUE

A1 = (SIN(THETA)*X)
A2 = (COS(ETA)*Y)
A3 = (COS(TAU/2.)*Z)
B1 = 1.0 + R*A1
B2 = (A2 - A1)/B1
TV = B1 + B2*A3
TL = TC*TV

**GEOMAGNETIC VARIATION**

TG = D3*GI + D4*(1 - EXP(D5*GI))

**SEMIANNUAL VARIATION**

G3 = 0.5*(1.0 + SIN(E10#DY + E11))
G3 = G3/Z12
TAU1 = DY + E8*(G3 - E9)
G1 = E2 + E3*(SIN(E4#TAU1 + E5))
G2 = SIN(E6#TAU1 + E7)
TS = E1 + F10B#G1*G2

**EXOSPHERIC TEMPERATURE**

TE = TL + TG + TS
RETURN

END SUBROUTINE TME

COMMON/COMJAC/XLAT, XLONG, SDA, SHA, DY, RT, EM
COMMON/IOITEMP/IOITEM, IOITEM2, IUD, XWJU, PHI1, PHI2,
, NSAME, IPI, RDI, RTI, SPI, SUI, SUI, RUI, SUI, SVI, THE

LIST

**INPUT**

MN-MONTH, IDAY = DAY, IYR = YEAR, HR = HOUR, MIN = MINUTE
XLAT = LATITUDE (INPUT-GEODCENTRIC LATITUDE.)
C XLONG= LONGITUDE(INPUT-GEOCENTRIC LONGITUDE, OUTPUT -180 TO +180)THE 12
C OUTPUT
C SDA = SOLAR DECLINATION ANGLE (IN RAD) THE 13
C SHA = SOLAR HOUR ANGLE (IN RAD) THE 14
C DD = DAY NUMBER FROM 1JAN. THE 15
C DY = DD/TROPICAL YEAR THE 16
C
C SET CONSTANTS
C
YEAR = 365.2422 THE 20
YR=IYR THE 21
& DY = DD/YEAR THE 22
30 FMJD = XMJD - 2435839. THE 23
C
C COMPUTE GREENWICH MEAN TIME IN MINUTES GMT
C
XHR =IHR THE 27
XMIN = MIN THE 28
GMT = 60*XHR + XMIN THE 29
C
C COMPUTE GREENWICH MEAN POSITION - GP (IN DEG)
C
XJ = (XMJD - 2415020.0)/(36525.0) THE 33
A1=99.690983 THE 34
A2 = 36000.74854 THE 35
A3 = 0.00038708 THE 36
A4 = 0.25068447 THE 37
GP = A1 + A2*XJ + A3*XJ*XJ + A4*GMT THE 38
N = GP/360. THE 39
XM = N THE 40
GP = GP - XM*360. THE 41
C
C COMPUTE RIGHT ASCENSION POINT - RAP (IN DEG)
C
1ST CONVERT GEOCENTRIC LONGITUDE TO DEG LONGITUDE - WEST NEG & EAST
C
IFACT = XLONG/180. THE 48
XFACT = IFACT THE 49
XLONG = 360. * XFACT - XLONG THE 50
C
RAP = GP + XLONG THE 53
N = RAP/360. THE 54
XN = N THE 55
RAP = RAP - XN*360. THE 56
C
C COMPUTE CELESTIAL LONGITUDE - XLS (IN RAD) - -PI/2 TO +PI/2
C
B1 = 0.017203 THE 58
B2 = 0.0335 THE 59
B3 = 1.410 THE 60
Y1 = B1*FMJD THE 61
XLS = Y1 + B2*SIN(Y1) - B3 THE 62
TP1 = 6.28319 THE 63

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\[ N = \frac{XLS}{TPI} \]
\[ \text{XN} = N \]
\[ XLS = XLS - \text{XN} \times TPI \]

C

COMPUTE SOLAR DECLINATION ANGLE - SDA (IN RAD)

C

\[ B4 = (TPI/360.0) \times 23.45 \]
\[ SDA = \arcsin(\sin(XLS) \times \sin(B4)) \]

C

COMPUTE RIGHT ASCENSION OF SUN - RAS (IN RAD) - \(-PI/2 \) TO \( +PI/2 \)

C

\[ \text{RAS} = \arcsin(\tan(SOA) / \tan(B4)) \]

C

PUT RAS IN SAME QUADRANT AS XLS

C

\[ \text{PI} = 3.14159265 \]
\[ \text{PI2} = \frac{\text{PI}}{2} \]
\[ \text{PI32} = 3. \times \text{PI2} \]
\[ \text{RAS} = \text{ABS}(\text{RAS}) \]
\[ \text{TEMP} = \text{ABS}(XLS) \]
\[ \text{IF}(\text{TEMP} - \text{PI2}) < 130 \rightarrow 130 \]
\[ 100 \rightarrow \text{IF}(\text{TEMP} - \text{PI}) < 105 \rightarrow 105 \]
\[ 105 \rightarrow \text{RAS} = \text{PI} - \text{RAS} \]
\[ \text{GO TO 130} \]
\[ 110 \rightarrow \text{IF}(\text{TEMP} - \text{PI32}) < 115 \rightarrow 115 \]
\[ 115 \rightarrow \text{RAS} = \text{PI} + \text{RAS} \]
\[ \text{GO TO 130} \]
\[ 120 \rightarrow \text{RAS} = \text{PI} - \text{RAS} \]
\[ 130 \rightarrow \text{IF}(XLS) < 135 \rightarrow 135 \]
\[ 135 \rightarrow \text{RAS} = -\text{RAS} \]
\[ 140 \rightarrow \text{CONTINUE} \]

C

COMPUTE SOLAR HOUR ANGLE - SHA (IN DEG) - -

C

\[ \text{SHA} = \text{RAP} \times (\text{PI} / 180.) - \text{RAS} \]
\[ \text{IF}(\text{SHA} < 210 \rightarrow 210) \]
\[ 210 \rightarrow \text{IF}(\text{SHA} < \text{PI}) \rightarrow 220 \]
\[ 220 \rightarrow \text{SHA} = \text{SHA} + \text{PI} \]
\[ \text{GO TO 210} \]
\[ 230 \rightarrow \text{IF}(\text{SHA} < \text{PI}) \rightarrow 240 \]
\[ 240 \rightarrow \text{SHA} = \text{SHA} - \text{PI} \]
\[ \text{GO TO 230} \]
\[ 250 \rightarrow \text{CONTINUE} \]

C

RETURN

END

SUBROUTINE WIND

COMMON /WINCON/RHO;FDORY;DXS;DT5;PX;PY;FX;PYX;YY;U;V; T;TX;TY; WIND 1
* DJ;DV;P;UPRE;UPRE;DUPRE;DUPRE
COMMON /IDTEMP/DUM1(7);PHI;DUM2(11);MM;DM2A(5);G;R;H;PHIR;
*THET;DUM3(15);FLAT
COMMON/CHIC/DUM(18);IWASYM;UCDEP(14,9);BCDEP(14,9)
ABSPHI=ABS(PHI)
IF (RHO.GT.0 .AND. ABSPHI .GT.0.) GO TO 20
WIND 8
U = 0.
V = 0.
IF(ABS_PHI .LE. 0) GO TO 31
RETURN
20 FCORX = FCORYX/DX/DY
U = - PY/(FCORYX/RHO)
V = - FX/(FCORX/RHO)
DU = -(GITY)/(FCORYT)
DV = (GITY)/(FCORX*T)
31 IF(H.GT.20.AND.H.LT.75.)GOTO 99
IF(ABS_PHI.GE.FLAT) RETURN
U=UPRE
V=VPRE
DU=DPRE
DV=DPRE
RETURN
C...SPHERICAL HARMONICS SECTION.................................
99 IH=INT(H)
IF(IN. .LE. 25)GOTO 130
IF(IN.GE.90)GOTO 140
IH=INT(H/5.)
IH2=IH/5
CALL SPHERE(MN,PHIQ,THET,US,VS)
CALL SPHERE(MN,PHIQ,THET,US2,VS2)
FACS=(H-IH)/5,
U=US+US-US*FACS
V=US+US-US*FACS
DU=(US2-US)/5000.
DV=(VS2-VS)/5000.
RETURN
C...LOW ALTITUDE FAIRING
130 CALL SPHERE(MN,25,PHIQ,THET,US,VS)
FACS=(H-20.)/5,
FACG=1.-FACS
U=FACGU*FACS*US
V=FACGV*FACS*VS
CALL SPHERE(MN,30,PHIQ,THET,US2,VS2)
DUS=(US2-US)/5000.
DVS=(VS2-VS)/5000.
RETURN
C...HIGH ALTITUDE FAIRING
140 CALL SPHERE(MN,90,PHIQ,THET,US,VS)
FACS=(H-90.)/5,
FACG=1.-FACS
U=FACGU*FACS*US
V=FACGV*FACS*VS
CALL SPHERE(MN,85,PHIQ,THET,US2,VS2)
DUS=(US2-US)/5000.
DVS=(VS2-VS)/5000.
DU=FACGU*DU*FACS*DU
DV=FACGV*DV*FACS*DV
RETURN
END
APPENDIX E

SUMMARY OF PROGRAM CHARACTERISTICS
(Program Operating Environment)

1. Hardware
   a. Computer - Univac 1108 (implemented at Georgia Tech on the CDC
      Cyber 74 System)
   b. Core Requirements - Approximately 80K on the Georgia Tech CDC.
      The CDC System routines require more core than the Univac rou-
      tine so there is no comparison between the system. See Section
      5.1.
   c. Magnetic Tapes - All 4-D data tapes are 7 tracks. Proper and SCIDAT
      data tapes are 9 track. Tapes required are:
         1 program tape (if the program is stored in UNIVAC COPOUT tape
         format), 1 "SCIDAT" data tape (see Section 4.2), from 1 to
         4 4-D data tapes, depending on the number of months to be used
         under control of one run card (see Section 4.1 and Appendix B).
   d. Card Punch - not required unless optional card output is desired.
   e. Plotter - none required
   f. Drum or Disk - 2 temporary drum or disk files are required. No
      permanent drum or disk files are created by a program run unless
      optional non-print output is generated as a permanent disk or
      drum file.
   g. Other Hardware - none

2. Software
   a. Operating System - UNIVAC EXEC 8 (Georgia Tech version is CDC Nos 1.3)
   b. Language - FORTRAN IV (UNIVAC FORTRAN V)
   c. Type of Run - Batch
   d. Library Subroutines - NTRAN and FLD are UNIVAC subroutines. NTRAN
      reads 36 bit binary integer woods records. FLD manipulates word
      bits and is used to break up 4-D data tape 36 bit words into two
      18 bit integer words.
   e. Program Overlays - (Optional) - see Section 5.1

3. Program Specifications
   a. Common - See Sections 5.2 - 5.4

E-1
3. **Program Specifications (cont'd.)**
   
b. Program Segments - See Sections 5.2 - 5.4

c. Program Subroutines - See Section 5.1

d. Listing - See Appendix D

e. Flow Charts - See Figures 5.1, 5.2, 5.3

f. Sample Input - See Appendix C.

g. Sample Output - See Appendix C.

h. Diagnostic Messages - See Section 4.5
16. ABSTRACT

This report describes recent improvements in the Global Reference Atmospheric Model (NASA TM 64871 and 64872), originally developed as a global scale (all latitudes and longitudes) model from surface to orbital altitudes. The basic model includes monthly mean values of pressure, density, temperature, and geostrophic winds, as well as quasi-biennial and small-scale and large-scale random perturbations. The newer version reported here incorporates a spherical harmonic wind model for the height range 25-90 km. Parameters for the model were determined from wind data determined by Meteorological Rocket Network soundings, and by grenade releases at higher altitudes. For all latitudes and longitudes in the 25-90 km height range, winds are evaluated by the new spherical harmonic model. Below 25 km and above 90 km, the GRAM program continues to use the geostrophic wind equations and data for pressure, in order to compute the mean wind. Another new feature of the program is that, in the altitudes where the geostrophic wind relations are used, an interpolation scheme is employed for estimating winds at low latitudes, where the geostrophic wind relations begin to mesh down. Several sample wind profiles are given, as computed by the new spherical harmonic wind model.