NASA Technical Memorandum 4715

The NASA/MSFC Global Reference Atmospheric Model—1995 Version (GRAM–95)

C.G. Justus, W.R. Jeffries III, S.P. Yung, and D.L. Johnson

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PREFACE

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Qualified requesters may purchase copies of the GRAM-95 computer program and "atmosdat" data base by contacting:

COSMIC
The University of Georgia
382 East Broad Street
Athens, GA 30602
Phone: (404) 542–3265

Purchase information for the Global Upper Air Climatic Atlas (GUACA) CD-ROM data sets is provided in appendix A.

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TECHNICAL MEMORANDUM

THE NASA/MSFC GLOBAL REFERENCE ATMOSPHERIC MODEL—1995 VERSION (GRAM-95)

1. INTRODUCTION

1.1 Background and Overview

Reference atmospheric models have long been needed for design and mission planning of various aerospace systems. Standard atmospheres (such as the 1976 U.S. Standard Atmosphere) typically provide complete altitude-dependent values for the thermodynamic variables (pressure, density, temperature, etc.), but typically do not include such other parameters as winds. Standard atmospheres typically do not provide geographical dependence or seasonal or monthly variability of the atmospheric variables. Empirically derived reference atmospheres (such as the NASA Range Reference Atmospheres (RRA)) provide limited altitude coverage (e.g., 0 to 70 km) and are valid only for the selected sites for which they have been prepared.

The NASA/MSFC Global Reference Atmospheric Model (GRAM) was developed in response to the need for a design reference atmosphere that provides complete global geographical variability, and complete altitude coverage (surface to orbital altitudes) as well as complete seasonal and monthly variability of the thermodynamic variables and wind components. Another unique feature of GRAM is that, in addition to providing the geographical, height, and monthly variation of the mean atmospheric state, it includes the ability to simulate spatial and temporal perturbations in these atmospheric parameters (e.g., fluctuations due to turbulence and other atmospheric perturbation phenomena).

The original GRAM version (Justus et al., 1974) has undergone a series of improvements over the years (Justus et al., 1980, 1988, 1991). This report describes further additions and improvements to GRAM, whereby extensive new CD-ROM data sets for the surface to about 27 km (Ruth et al., 1993) have been incorporated, and in which a new variable-scale atmospheric perturbation model has been included. This new perturbation model has many of the features (e.g., intermittency) of the turbulence model of Justus et al. (1990), but in a simplified implementation, accomplished by allowing the perturbation scales to undergo continuous, stochastic variation. This new version is called GRAM-95. GRAM-95 also incorporates new atmospheric variables in the form of water vapor and concentration values for other minor atmospheric constituents (ozone and 10 other trace species).

This section provides an overview of the basic features of GRAM-95, and section 2 provides a more detailed technical description of GRAM-95, concentrating on the newly added features. Section 3 presents some sample results, particularly from the new lower altitude section, from the new perturbation model, and from the new atmospheric species results. Section 4 is a user's guide that describes the program characteristics, the data sets required and the details of how to run the program. Sections 5 and 6 provide a general bibliography of references and the references for the extensive set of papers and reports from which the parameters of the new perturbation model were derived.

1.2 Basic Description of the GRAM-95 Model

Like its predecessor versions, GRAM-95 is an amalgamation of three empirically based models that represent different altitude ranges (and the geographical and temporal variations that occur within these altitude ranges). The mean thermodynamic variables and mean wind components of the upper and middle altitude regions are the same as in GRAM-90, while the new Global Upper Air Climatic Atlas (GUACA) CD-ROM data set of Ruth et al. (1993) provides a revised lower altitude region (fig. 1.1).

The GUACA data base covers the altitude region from 0 to 27 km (in the form of data at the surface and at constant pressure levels from 1,000 to 10 mbar). The middle atmospheric region (20 to 120 km) is provided by a data set compiled from Middle Atmosphere Program (MAP) data (Labitzke et al., 1985) and from other sources whose references are given in the GRAM-90 report (Justus et al., 1991). The highest altitude region (above 90 km) is simulated by the Jacchia (1970) model as implemented in a version called the Marshall Engineering Thermosphere (MET) model (Hickey, 1988a, b). Smooth transition between the altitude regions is provided by fairing techniques. Unlike interpolation (which is used to "fill in" values across a gap in data), fairing is a process that provides a smooth transition from one set of data to another, in regions over which they overlap (e.g., 20 to 27 km for the GUACA and MAP data and 90 to 120 km for the MAP data and the MET model, fig. 1.1).

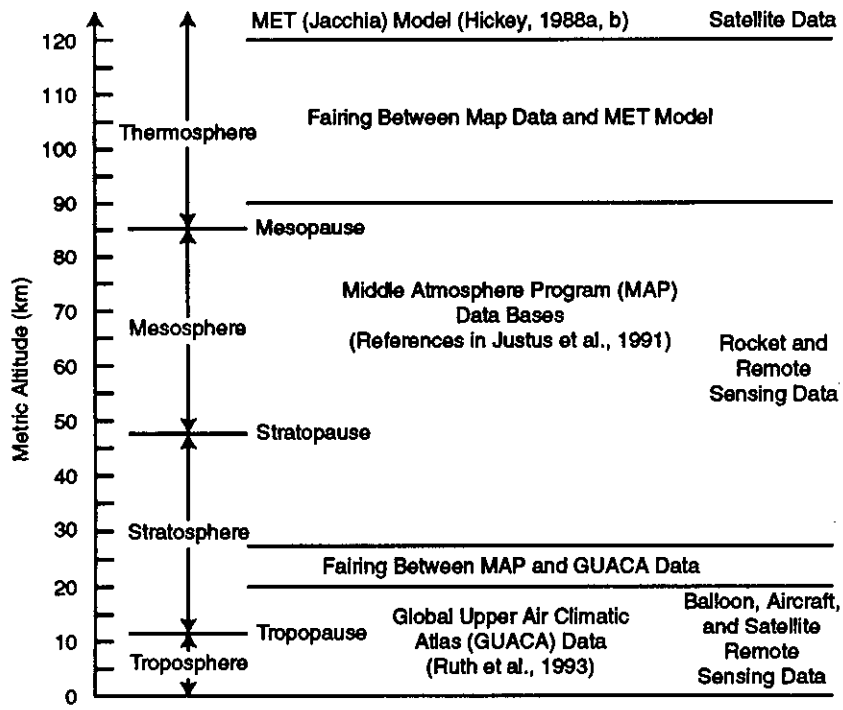

Figure 1.1. Schematic summary of the atmospheric regions in the GRAM-95 program, and the sources for the models and data on which the mean monthly GRAM-95 values are based.

1.3 The New Global Upper Air Climatic Atlas (GUACA) Data

The GUACA data set (available on CD-ROM; Ruth et al., 1993) was produced by the U.S. Navy Naval Oceanography Command Detachment and the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (appendix A). It was summarized from

twice daily (00Z and 12Z) upper air data observations, as processed in the model initialization steps by the European Centre for Medium Range Weather Forecasts (ECMWF). The data are primarily from radiosonde balloon soundings (observations at the fixed, mandatory pressure levels) and have been quality-controlled and interpolated onto a regular 2.5° grid by ECMWF during their model initialization process. Thus, the GUACA data are not the results of the ECMWF forecasts, but are the observed data used to provide the initial conditions for their forecast model runs.

Atmospheric data elements in the GUACA data base are temperature, density, sea-level pressure, geopotential height, eastward and northward wind components, and dewpoint temperature. See section 4.2 and appendix A for further details about the GUACA data base.

Since the GUACA data base includes observed wind component data, winds in this lower altitude region of GRAM-95 no longer have to be estimated from the horizontal pressure gradients (by the geostrophic wind relations), as was the case for GRAM-90.

For the GUACA data base, the twice-daily data observations have been averaged into monthly means (and standard deviations of the observations about the monthly mean) for each of the months of years from 1980 to 1991, as well as for each month in a period-of-record data set representing the averages (and standard deviations) over the 1980 to 1991 period.

1.4 New Atmospheric Species Concentration Data

In addition to the traditional variables of pressure, density, temperature, and wind components, GRAM-95 now provides estimates of atmospheric species concentrations for water vapor (H_2O), ozone (O_3), nitrous oxide (N_2O), carbon monoxide (CO), methane (CH_4), carbon dioxide (CO_2), nitrogen (N_2), molecular oxygen (O_2), atomic oxygen (O), argon (A), helium (He), and hydrogen (H). The MET (Jacchia) model provides the species concentrations for N_2, O_2, O, A, He, and H above 90 km. Air Force Geophysics Laboratory (AFGL) atmospheric constituent profiles (Anderson et al., 1986) are also used extensively for the constituents up to 120-km altitude.

The GUACA data set provides water vapor data from the surface to the 300-mbar pressure level. The NASA Langley Research Center (LaRC) water vapor climatology (McCormick and Chiou, 1994) includes H_2O values from 6.5- to 40.5-km altitude. MAP data (Keating, 1989) include H_2O data from 100 mbar to the 0.01-mbar pressure level. Monthly mean water vapor concentrations in GRAM-95 are based on the height (or pressure level) ranges shown in figure 1.2, with fairing used to insure smooth transition between data sources. Note that a mixture of height (km) and pressure (mbar) units are used in figure 1.2, depending on the tabulation intervals in the original data bases. For standard deviations in water vapor, GUACA data are used from the surface to 300 mbar; an extrapolation of GUACA values, based on relative humidity, is used from 300 to 100 mbar; MAP data are used from 100 to 0.01 mbar; and values based on a σ/mean ratio of 0.36 (Harries, 1976) are used from 0.01 mbar to 120 km.

For mean ozone values, AFGL data are used from the surface to 20 mbar and from 0.003 mbar to 120 km. MAP values are used between 15 and 0.004 mbar, and MAP-AFGL fairing is used between 15 and 20 mbar and between 0.003 and 0.004 mbar.

For N_2O and CH_4 mean values, AFGL data are used from the surface to 20 mbar and from 0.1 mbar to 120 km. MAP values are used between 15 and 0.125 mbar, and MAP-AFGL fairing is used between 15 and 20 mbar and between 0.1 and 0.125 mbar.

Height (km) or Pressure Level (mbar) Range	GRAM-95 Data Source for H_2O Mean Values
surface to 300 mbar	GUACA CD ROM Data Base (Ruth et al., 1993)
300 to 100 mbar	Fairing between GUACA and LaRC data
100 mbar to 39.5 km	LaRC data (McCormick and Chiou, 1994)
39.5 to 40.5 km	Fairing between LaRC and MAP data
40.5 km to 0.02 mbar	MAP Data (Keating, 1989)
0.02 to 0.01 mbar	Fairing between MAP and AFGL data
0.01 mbar to 120 km	AFGL Data (Anderson et al., 1986)
Above 120 km	No data available (output = 0.0)

Figure 1.2. Summary of the atmospheric regions and data sources used for monthly mean water vapor concentration in GRAM-95.

For O concentrations, MAP values are used from 40 to 90 km. MET model values are used above 100 km, and MAP-MET fairing is used between 90 and 100 km. O is output as 0.0 below 40 km.

For N_2, O_2, A, and He values, the AFGL data are used from 0 to 90 km; the MET values are used above 120 km; and MET-AFGL fairing is used from 90 to 120 km. The AFGL data values are used for CO and CO_2 from the surface to 120 km and are output as 0.0 above that altitude. H values are output as 0.0 below 90 km and come from the MET model above this height.

With the exception of water vapor, for which both mean and standard deviation values are provided, only mean values are given for the atmospheric species constituents.

1.5 The New Variable-Scale Perturbation Model

Atmospheric variability on less than monthly time scales is produced by several types of physical phenomena. Planetary scale Rossby waves have periods of several days and, at longer wavelengths, may produce quasi-stationary wave patterns. Baroclinic instability of the Rossby waves produces the familiar patterns of fronts, cyclones, and anticyclones of tropospheric weather. Atmospheric tides, produced primarily by solar heating of water vapor in the troposphere and ozone in the stratosphere, have planetary-scale wavelengths and predominately diurnal and semidiurnal periods. Atmospheric tides tend to amplify with altitude, and are accounted for explicitly in the Jacchia (MET) section of GRAM. Surface heating produces convective circulations that can lead to thunderstorms. Instability or other mechanisms can produce organized lines of thunderstorms and groups of thunderstorms called a mesoscale convective complex. Atmospheric gravity waves may be produced by orographic flow effects or may be triggered by thunderstorms, tropical storms, or other disturbances. Like tides, gravity waves tend to amplify with height but, since they are more irregular in their nature, cannot be modeled explicitly. Atmospheric turbulence occurs at relatively small

scales and can be triggered by surface heating, orographic effects, or instability processes produced by gravity waves, tides, or jet stream shears associated with the Rossby waves.

In GRAM, all of these processes are parameterized stochastically by a random perturbation model. In GRAM-90, a two-scale perturbation model was employed. A smaller scale parameter is used to represent such small-scale processes as turbulence, mesoscale storms, and gravity waves, while a larger scale parameter is used to represent such large-scale processes as Rossby waves, cyclones and anticyclones, and tides. Each of these two scale parameters is used, in the sense of a spectral integral scale, to characterize a spectrum that spans a significant range of wave numbers. These two scale parameters are assumed in GRAM-90 to be altitude and latitude dependent only.

In GRAM-95, a new, variable-scale, small-scale perturbation model is introduced. Through stochastic variation of the value of the small-scale parameter, this model incorporates many of the features of the atmospheric turbulence model of Justus et al. (1990). In particular, the effects of intermittency, the tendency of turbulence to appear in patches or layers, is incorporated. The modeling approach incorporated in GRAM-95, described more fully in section 2.6, results in a simpler implementation, incorporating fewer simulation parameters, than the original Justus et al. model.

1.6 The New Pressure Perturbation Model

Details of the model for pressure perturbations have also been changed, to account for the fact that there is more influence of large scales (and less influence of small scales) on the pressure perturbations than there is on the density and temperature perturbations. This scale-selection mechanism is produced by an effect of the hydrostatic condition on the variances of the large-scale and small-scale components of pressure perturbations. The density perturbations are produced by the same approach as in GRAM-90, but explicit correlation terms are now used in generating the pressure perturbations. The temperature perturbations are now arrived at by invoking a perfect gas-law constraint. Details of the new modeling approach are given in section 2.7.

2. TECHNICAL DESCRIPTION OF THE MODEL

2.1 The Jacchia Section (Above 90 km)

The Jacchia (1970) model for the thermosphere and exosphere was originally implemented to compute atmospheric density and temperature at satellite altitudes. It represents total atmospheric density by summing the densities of six, separately modeled, atmospheric constituents (N_2, O_2, O, A, He, and H). The Jacchia model accounts for temperature and density variations due to solar and geomagnetic activity, and diurnal, seasonal, and latitude-longitude variations throughout the height range above 90 km. The Jacchia model assumes a uniformly mixed composition below 105 km, with diffusive equilibrium among the constituents above 105 km. Fixed (time-independent) boundary values for temperature and density are assumed at 90 km. Alterations, described in Justus et al. (1974a), were made to allow atmospheric pressure to be computed from the density and temperature. Geostrophic wind components, modified by the effects of molecular viscosity (Justus et al., 1991) are evaluated in the Jacchia section by using the Jacchia model to estimate horizontal pressure gradients. In GRAM-90 and GRAM-95, the NASA MET model (Hickey, 1988a,b) has been implemented to characterize the mean atmosphere above 120 km. Between 90 and 120 km, a fairing process, described more fully in section 2.5, insures smooth transition between the MET model values and the middle atmosphere data.

2.2 The Middle Atmosphere (MAP) Section (20 to 120 km)

GRAM characterizes the monthly mean middle atmosphere (20 to 120 km) by two gridded data sets, one representing the zonal mean atmospheric values (gridded by height and latitude) and the other representing the monthly-mean stationary wave patterns (i.e., stationary perturbations about the monthly mean, gridded by height, latitude, and longitude). The zonal mean data set in GRAM-90 and GRAM-95 was merged from six separate data sets covering the 20- to 120-km altitude range (references in Justus et al., 1991). The zonal monthly mean data set (pressure, density, temperature, and mean eastward wind component) is gridded in 10° latitude and 5-km height increments (–80° to +80° and 20 to 120 km). Zonal mean values at ±90° are computed by an across-the-pole interpolation scheme, discussed in section 2.5. Zonal mean values in between the gridded data set values are interpolated vertically by hydrostatic and perfect gas law assumptions and horizontally by two dimensional (latitude-longitude) interpolation methods (also discussed in section 2.5).

The stationary perturbation data set (standing wave perturbations in pressure, density, temperature, and eastward and northward wind components) was merged from three sources of data on planetary-scale standing wave patterns (references in Justus et al., 1991). This data set is gridded in 10° latitude increments (–80° to +80°), 20° longitude increments (180°, 160° W, 140° W,... 140° E, 160° E), and 5-km height intervals (20 to 90 km). Stationary perturbations are identically zero at the poles. Stationary perturbation values are linearly interpolated in the vertical dimension and horizontally by two-dimensional (latitude-longitude) interpolation methods (discussed in section 2.5).

2.3 The GUACA Section (0 to 27 km)

The GUACA data sets contain monthly means and standard deviations in temperature, density, dewpoint temperature, sea level pressure, geopotential height, and eastward and northward wind components. The data are gridded globally at 2.5° by 2.5° resolution in 144 longitudes (0°, 2.5° E, ... 2.5° W) and 73 latitudes (–90°, –87.5°, ... +90°), at the surface and at 14 constant pressure levels from 1,000 to 10 mbar (see details in appendix A).

For grid points where the surface is higher than one or more of the pressure levels, the data at these levels are coded as missing. In order to estimate data at all altitudes from sea level (0 km) and above (e.g., for a "valley" site that is at a lower altitude than the surface at the adjacent 2.5 grid points), GRAM fills in all of the missing data from sea level to the surface at each grid point. This is done by first using the hydrostatic relationship to compute the surface altitude at the grid point, from sea-level pressure and the geopotential height of the lowest altitude grid point value. Next, the hydrostatic assumption is used to fill in the thermodynamic values between sea level and the surface, by assuming a constant temperature over this layer (the standard assumption used in computing sea-level pressure from the measured, station-level pressure).

Array sizes in GRAM-95 are set large enough to read in the full global GUACA data set at one time. This eliminates the feature in earlier GRAM versions whereby only a limited-area latitude-longitude grid of lower altitude data were loaded in at one time. This feature should improve the GRAM-95 performance for such applications as trajectory calculations, since (after the initial data set-up process) there is no need for processing delays while a new low-altitude grid of data has to be read in.

All "fixing" of the GUACA data is done globally as part of the GUACA array set-up and initialization. These processes include the filling in of values between sea level and the surface, filling in of any missing data values, and correcting any discrepancies in the relationship among the

standard deviations in pressure, density, and temperature. Density values at 70 mbar for the period-of-record (1980 to 1991) data set require correction (see appendix A). Missing values (especially winds at the poles and above 70 mbar for some years) are filled in. Dewpoint temperatures above the 300-mbar level are filled in by extrapolation, using a decreasing relative humidity profile. These GUACA-extrapolated moisture values are used only between 300 and 100 mbar, where they are faired (fig. 1.2 and section 2.5) with the LaRC H_2O values (McCormick and Chiou, 1994).

The perfect gas law implies certain constraints on the relationship that must exist between the standard deviations and mean values of pressure, density, and temperature (Buell, 1970, 1972). The GUACA data base values of these standard deviations are subjected to a test for this constraint and are adjusted (so that density-temperature correlation does not exceed 0.999 in magnitude) for all cases that produce a violation. Standard deviations in pressure (above the surface) are computed from the standard deviations in geopotential height by a hydrostatic assumption.

2.4 Water Vapor and Other Atmospheric Species Concentrations

Water vapor and other atmospheric species concentrations are introduced in GRAM-95. Concentration values above 90 km are obtained from the MET model, and values below 90 km are obtained from a new species concentration data base, introduced in section 1.4 and discussed more fully in section 4.3. Water vapor output from GRAM-95 includes both monthly means and standard deviations. The water vapor values vary with month, height, latitude, and longitude within the GUACA height range and vary with month, height, and latitude above this altitude (fig. 1.2).

Means and standard deviations in water vapor are represented in the form of vapor pressure (N/m^2), vapor density (kg/m^3), dewpoint temperature (K), and relative humidity (%). Mean water vapor values in the form of volume concentration (ppmv) and number density ($molecules/m^3$) are also output. Conversions among these various forms, from the form in the input data (dewpoint temperature for the GUACA data and volume concentration for the other water vapor data sources), are performed by various subroutines (wexler, tdbuck, dedt and d2edt2; see appendix D), using methods described by Wexler (1976), Flatau et al. (1992), Buck (1981) and Elliott and Gaffen (1991). Only monthly mean concentration values are output for the species other than water vapor, and their values are output only in the form of volume concentration and number density.

Interpolation of the GUACA dewpoint temperature for altitudes between the input pressure levels and for latitude and longitudes between the input grids points is handled the same as for the other GUACA variables. Height and latitude interpolation between input height-latitude grid points for water vapor above the GUACA range, and for the other species, is done by an adaptation of the two-dimensional interpolation discussed in the following section (to do height-latitude interpolation, rather than latitude-longitude interpolation).

Species concentrations $c(t)$ are assumed to change with year, t, in GRAM-95, according to the relation:

$$c(t) = c(t_0)\,(1+r_t)^{t-t_0} \quad . \tag{2.1}$$

where t_0 is 1976 for the AFGL data and 1981 for the MAP concentration data and r_t is 0.005 for CO_2, 0.009 for CH_4, 0.007 for CO, and 0.003 for N_2O. For ozone, r_t varies linearly from 0.003 at the surface to 0 at 15 km, linearly from 0 at 30 km to –0.005 at 40 km, and again linearly from –0.005 to 0 at 120 km. The rate of change, r_t, for water vapor and the other constituents is assumed to be zero.

These rates of change were estimated from data in table 14.5 and figure 17.1 of Graedel and Crutzen (1993).

2.5 Interpolation and Fairing Techniques

Vertical Interpolation. Pressure $p(z)$, temperature $T(z)$, and density $\rho(z)$, obey the perfect gas law:

$$p = \rho R T \ , \tag{2.2}$$

where R is the gas constant. They also agree very closely with the hydrostatic assumption:

$$dp/dz = -\rho g \ , \tag{2.3}$$

where g is the acceleration of gravity. If we have grid-point pressure values p_1 and p_2 and temperature values T_1 and T_2 at heights z_1 and z_2, then vertical interpolation to any height z (between z_1 and z_2) can be done by assuming a linear temperature variation:

$$T(z) = T_1 + \gamma (z - z_1) \ , \tag{2.4}$$

where γ is the temperature gradient:

$$\gamma = (T_2 - T_1)/(z_2 - z_1) \ . \tag{2.5}$$

The hydrostatic relation, with a constant temperature gradient, implies a power-law variation with pressure. So pressure $p(z)$ may be computed by:

$$p(z) = p_1 \ [T(z)/T_1]^a \ , \tag{2.6}$$

where the exponent a is given by:

$$a = \log(p_2/p_1) \ / \ \log(T_1/T_2) \ . \tag{2.7}$$

The density $\rho(z)$ may in turn be found by solving from the perfect gas law relation (equation (2.2)).

In the GUACA height range, this vertical interpolation is complicated by the fact that the moisture varies with height and the gas constant for moist air depends on the moisture concentration. For the GUACA data, a variant of equation (2.6) is used that makes use of an interpolated gas constant R and the fact that the exponent a should be given by $a = g/(R\gamma)$.

The form of vertical interpolation given by equation (2.6) is used to fill in mean values of pressure, density, and temperature between the input pressure levels of the GUACA data (with z being geopotential height) and to fill in the zonal mean values between the input height grids of the MAP data base. Other variables that do not obey perfect gas law relationships (e.g., wind components, dewpoint temperature, and all standard deviations) are interpolated linearly in the vertical.

Two-Dimensional Interpolation. Let V be a variable that is available on a two-dimensional grid array (in x and y) and consider that we have the grid point values $V_{11} = V(x_1, y_1)$, $V_{12} = V(x_1, y_2)$,

$V_{21} = V(x_2,y_1)$ and $V_{22} = V(x_2,y_2)$. Then any value $V(x,y)$ (for x between x_1 and x_2 and y between y_1 and y_2) may be found by the interpolation scheme:

$$V(x,y) = \alpha'\beta' V_{11} + \alpha'\beta V_{12} + \alpha\beta' V_{21} + \alpha\beta V_{22} \quad , \tag{2.8}$$

where $\alpha = (x-x_1)/(x_2-x_1)$, $\alpha' = 1-\alpha$, $\beta = (y-y_1)/(y_2-y_1)$, and $\beta' = 1-\beta$. This interpolation relation is mathematically equivalent to that used (for latitude-longitude interpolation) in earlier GRAM versions, but it is expressed here in a more symmetric notation.

Equation (2.8) is used to interpolate between latitude-longitude grid points (x = longitude, y = latitude) for the GUACA grids and the stationary perturbation grids of the MAP data. For variables that are dependent on a height-latitude (or a pressure-latitude) grid (such as the species concentration data), then equation (2.8) may be used with y = latitude and x = height (or x = log pressure). The variables actually interpolated for concentration data are the logarithms of the concentration values.

Interpolation Across the Poles. Several of the GRAM-95 data bases that are height-latitude dependent lack values at or near the poles. These can be filled in by an interpolation procedure that assumes a parabolic variation (across both sides of the pole) that fits the last and next-to-last available latitude. The results are always a weighted average of these last and next-to-last latitude values. For example, if values of a parameter are available at ±70° and ±80°, but not at ±90°, then the missing polar values are supplied by:

$$y_{\pm 90} = (4\, y_{\pm 80} - y_{\pm 70})/3 \quad . \tag{2.9}$$

If values are available at ±60° and ±70°, but not at ±80° or ±90°, then the missing values are supplied by:

$$y_{\pm 90} = (9\, y_{\pm 70} - 4\, y_{\pm 60})/5 \quad , \tag{2.10}$$

and

$$y_{\pm 80} = (8\, y_{\pm 70} - 3\, y_{\pm 60})/5 \quad . \tag{2.11}$$

For the species concentration data, this interpolation is done on the logarithm of the concentration values.

Fairing Between Two Data Sets. If we have two data sets $A(z)$ and $B(z)$ that overlap each other throughout the height range from z_1 to z_2 (with A being valid below z_2 and B being valid above z_1, and $z_2 > z_1$), then a fairing process:

$$C(z) = f(z)A(z) + [1-f(z)]\, B(z) \quad , \tag{2.12}$$

can insure a smooth transition for the faired variable C across the height interval from z_1 to z_2 if $f(z_1) = 1$ and $f(z_2) = 0$. Thus, $A(z)$ is used below z_1, $B(z)$ is used above z_2, and the faired variable $C(z)$ varies smoothly between $A(z)$ and $B(z)$ as z varies from z_1 to z_2. A linear form may be used for f:

$$f(z) = (z_2-z)/(z_2-z_1) \quad , \tag{2.13}$$

or, with variables for which continuity of vertical derivatives is important, f may be taken as:

$$f(z) = \cos^2 [(\pi/2)\ (z-z_1)/(z_2-z_1)] \ . \tag{2.14}$$

Equation (2.14) is used for fairing between the GUACA and MAP data between 20 and 27 km, in fairing between the MET model and MAP data between 90 and 120 km, and in fairing the helium number density in the MET model between 440 and 500 km. For fairing the species concentration data (see section 1.4), equation (2.13) is used, with the logarithm of the species concentration being the variable to fair.

Seasonal and Monthly Interpolation. Some of the species concentration data bases do not contain monthly data. For example, the AFGL concentrations are seasonal averages (summer and winter) only; the LaRC water vapor data have four seasonal averages; and the MAP water vapor data have only certain months of the year (November through May). The initialization routines in GRAM use an annual harmonic temporal variation model to estimate the concentration data for the specific month to be simulated. For the AFGL data, this is accomplished by applying precomputed weights to obtain a weighted average of the summer and winter values that is used to estimate the value for the specific month. For the LaRC water vapor data, a weighted average of the two adjacent seasonal values is used to estimate the monthly value (i.e., March-April-May and June-July-August values are used to estimate the monthly values for May and June, with different weights applied for each of these months). For the MAP water vapor data, a combination of annual harmonic Fourier fit and 6-month displacement from northern to southern hemisphere (and vice-versa) is used at initialization to establish the global values for each month from the monthly values of November through May that are in the data base.

2.6 The New Variable-Scale Perturbation Model

GRAM uses a simple, first-order, auto-regressive model to compute a perturbation at each new position from the correlated perturbation value at the previous position. In addition to maintaining the correlation necessary between these successive perturbation values, the model accounts for the effects of variation in the mean values and the standard deviation from one position to another. Consider a normalized variate $\mu(x)$ (i.e., μ is the deviation of the value from the mean value, divided by the standard deviation, all at the vector position x). The perturbation model computes $\mu(x')$, at the next trajectory position x', by the relation:

$$\mu(x') = r\mu(x)+(1-r^2)^{1/2}\, q(x) \ , \tag{2.15}$$

where q is a gaussian-distributed random number with a mean of 0 and a standard deviation of 1, and r is the autocorrelation between the successive values of the normalized variate, i.e.:

$$r = \langle \mu(x')\mu(x) \rangle \ , \tag{2.16}$$

where the angle brackets denote an average. The autocorrelation value r is obviously a function of the vector displacement $\delta x = x'-x$.

For two normalized variates $\mu(x)$ and $\nu(x)$ (each relative to its own mean value and each normalized by its own standard deviation), that have a cross-correlation r_c between them (i.e., $r_c = \langle \mu(x)\ \nu(x) \rangle$), then $\nu(x')$, at the new position, can be computed from $\nu(x)$ and $\mu(x')$ by:

$$\nu(x') = r_\nu \nu(x) + r_\mu \mu(x') + r_q q(x) \quad , \tag{2.17}$$

where the coefficients are given by:

$$r_\nu = r(1-r_c^2)/[1-(r\,r_c)^2] \quad , \tag{2.18}$$

$$r_\mu = r_c(1-r^2)/[1-(r\,r_c)^2] \quad , \tag{2.19}$$

and

$$r_q = (1-r_\nu^2-r_\mu^2-2r_\nu r_\mu r_c r)^{1/2} \quad . \tag{2.20}$$

Autocorrelation values, r, are computed by assuming an exponential correlation function:

$$r(\delta x) = \exp(-\delta h/L_h)\exp(-\delta z/L_z) \quad , \tag{2.21}$$

where δh and δz are the magnitudes of the horizontal and vertical components of $\delta x = x'-x$, and L_h and L_z are horizontal and vertical scale parameters that, in GRAM-90, are functions of height and latitude only.

Both large-scale (representing planetary waves, tides, etc.) and small-scale (representing gravity waves, turbulence, etc.) values of the scale parameters are used to compute separate (large-scale and small-scale) perturbation values.

Cross-correlation values, r_c, for maintaining density-velocity cross-correlations, are read in as part of the GRAM-95 "atmosdat" data base (see section 4.3). Cross-correlation values for density and temperature are computed by the Buell (1970, 1972) relationships as a function of the standard deviations of the thermodynamic variables.

For GRAM-95, it was desired to have a small-scale perturbation model that incorporates many of the features (particularly intermittency effects) of the NASA turbulence model by Justus et al. (1990). The latter model is considerably more involved, however, in that it requires the frequency of occurrence of turbulence by intensity level (severe, moderate, or no turbulence). It also requires several scale lengths, such as the minimum horizontal and vertical sizes for layers of turbulence of various intensities, and several parameters to characterize the spatial variation of the turbulence standard deviations.

After some design and testing, it was concluded that many of the features of the Justus et al. (1990) model could be incorporated, in a more straightforward manner, into the previous GRAM small-scale perturbation model by using a spatially variable length scale, L_h and L_z. To accomplish this, normalized variates, $\mu(x)$ (for the small-scale horizontal scale parameter L_h) and $\nu(x)$ (for the small-scale vertical scale parameter L_z), are used as in equations (2.15) through (2.21).

In addition to the data on turbulence characteristics in the references of Justus et al. (1990), an extensive literature survey was conducted on the characteristics of gravity wave and other small-scale perturbation phenomena (see the bibliography in section 6 for references from which data were taken). These data were summarized into parameterized, height-dependent values for the mean values and standard deviation values for the small-scale, L_h and L_z, as well as scale values to be used in the correlation function, r, for the correlations in the spatial variations of the L_h and L_z values.

The cross-correlation between the horizontal and vertical scale (i.e., the r_c value for the $L_h \cdot L_z$ cross-correlation) was determined to be approximated by:

$$r_c(L_h \cdot L_z) = 0.5 + 0.002\, z \qquad (z < 200 \text{ km}) \ , \tag{2.22}$$

with a fixed value of 0.9 used above 200 km.

For parameters such as density, whose perturbations are computed via equation (2.15), the mean-square density shear for density, $\rho(x)$, is given by:

$$\langle [\rho(x+\delta x) - \rho(x)]^2 / |\delta x|^2 \rangle = 2(1-r)(\sigma_\rho / |\delta x|)^2 \ , \tag{2.23}$$

where r is the autocorrelation for density ρ and σ_ρ is the standard deviation in density. For small values of the separation distance $|\delta x|$, r is given, from equation (2.21), by $r \approx 1 - |\delta x| / L_x$, where L_x is the relevant scale parameter (e.g., L_h or L_z). Therefore, for small displacements along a trajectory, the mean-square density shear becomes $2\sigma_\rho^2 / (|\delta x| L_x)$. Thus, in the variable scale model, as L_h (or L_z) varies along the trajectory (via equation (2.15)), the density shears will tend to become large when the scales, L_h (or L_z), become small.

In this variable-scale perturbation model, the relevant scale parameters are taken to be a function of position, i.e., a new normalized variate for $L_x(x')$ is computed from the previous value of the normalized variate, $L_x(x)$, by either equation (2.15), for $L_h(x')$, or equation (2.17), for $L_z(x')$. When L_x becomes sufficiently small, it is below the size of scales characteristic of turbulence (as set by the turbulence scale values in Justus et al., 1990). When L_x is significantly larger than the turbulence scales, it is characteristic of the gravity wave scales determined in the new bibliographic data search (given in section 6). Thus, the simulation produces intermittent "patches" of turbulence when the scales, L_x, go below this turbulence range. These turbulence scales are taken to be minimum values for the scale parameters to be used in setting the density (or wind) perturbation correlations, in equation (2.21). That is, if the perturbation model produces a value of L_x that is larger than the minimum (turbulence) value, it is used directly in equation (2.21) in computing the density correlations. If the perturbation model produces a value of L_x that is less than the minimum value, the minimum value is used in equation (2.21) (but the smaller L_x value returned by the model is retained in continuing the computations of the scale parameter values).

The scale parameters used for the spatial variations of $L_x(x)$ mean that some distance elapses before the values of L_x return above the minimum (turbulence) scale range. This is the feature of the model that establishes the physical size of the "patches" of turbulence that are encountered intermittently. The use of a minimum value for the scales, L_x, also ensures that the density shears (or wind shears) do not get too large in value (by relation (2.23)).

The necessary parameters for evaluation of the variable-scale perturbation model (assumed to be functions of height only) are read in as part of the "atmosdat" data base (see section 4.3). These parameters are: the height, the mean value for L_h, the standard deviation for L_h, the minimum (turbulence) scale value for L_h, the spatial scale value for L_h (used to determine the autocorrelation values for L_h, via an equation analogous to (2.21)), the mean value for L_z, the standard deviation for L_z, the minimum (turbulence) scale value for L_z, the spatial scale value for L_z, and the standard deviation for the small-scale vertical wind component in meters per second (the vertical wind is also computed by the perturbation model equation (2.15)). All of the scale values in these data are in

units of kilometers. The cross-correlation values maintained between the L_h and L_z values are determined via equation (2.22).

2.7 New Pressure Perturbation Model

Pressure, density, and temperature perturbations (p', ρ', and T') are defined as the deviations from the mean pressure, density, and temperature (p_o, ρ_o, and T_o). In addition to the mean values, the GRAM data bases (i.e., the GUACA and "atmosdat" files) provide values for the standard deviations in pressure, density, and temperature (σ_p, σ_ρ, and σ_T). Perturbations are assumed to consist of both small-scale and large-scale components (denoted by subscripts s and l in the following).

The perfect gas law (equation (2.2)) and the hydrostatic relation (equation (2.3)) impose relationships (Buell, 1972) that must exist between the perturbation values, namely:

$$p'/p_o = \rho'/\rho_o + T'/T_o \quad , \tag{2.24}$$

and

$$\partial(p'/p_o)/\partial z = (T'/T_o)/H \quad , \tag{2.25}$$

where H is the scale height ($H = RT_o/g$).

The first step in simulating the perturbation values is to use relation (2.15), for both small-scale and large-scale density perturbations (i.e., with $\mu_s = \rho'_s/\sigma_{\rho s}$ and $\mu_l = \rho'_l/\sigma_{\rho l}$). The standard deviations of the small-scale and large-scale components are computed from the total standard deviations by the values of the large-scale fractional variance for density, f_L (see section 4.3). That is:

$$\sigma_{\rho l} = (f_L)^{1/2}\,\sigma_\rho \quad ,$$

and

$$\sigma_{\rho s} = (1-f_L)^{1/2}\,\sigma_\rho \quad , \tag{2.26}$$

where σ_ρ is the total standard deviation in density (thus $\sigma_\rho^2 = \sigma_{\rho s}^2 + \sigma_{\rho l}^2$).

The next step in simulating the perturbation values is to use relation (2.17), for both small-scale and large-scale pressure perturbations (i.e., with $v_s = p'_s/\sigma_{ps}$ and $v_l = p'_l/\sigma_{pl}$). Equation (2.25), however, implies that the relative pressure variance $(\sigma_p/p_o)^2$ must depend on both the variances and the scale values of the small-scale and large-scale temperature perturbations, namely:

$$(\sigma_p/p_o)^2 \propto (L_s/H)^2(\sigma_{Ts}/T_o)^2 + (L_l/H)^2(\sigma_{Tl}/T_o)^2, \tag{2.27}$$

where L_s and L_l are the scale values for the small-scale and large-scale components, respectively. Relation (2.27) means that the large-scale fractional variance for pressure, f_{Lp}, is related to the large-scale fractional variance for temperature by the equation

$$f_{Lp} = f_L / [f_L + (L_s / L_l)^2\,(1-f_L)] \quad . \tag{2.28}$$

The relative perturbations in density and pressure are given by:

$$\rho'/\rho_o = (\sigma_\rho/\rho_o)[(1-f_L)^{1/2}\mu_s + f_L^{1/2}\mu_l] \quad , \tag{2.29}$$

and

$$p'/p_o = (\sigma_p/p_o)[(1-f_{Lp})^{1/2}v_s + f_{Lp}^{1/2}v_l] \quad . \tag{2.30}$$

Finally, the relative temperature perturbation (T'/T_o) is found by solving from equation (2.24).

Note that equation (2.28) means that f_{Lp} is considerably closer to 1 than is f_L. For example, if $f_L = 0.7$ and $(L_s/L_l) = 1/5$, then $f_{Lp} = 0.98$. Thus, the hydrostatic constraint (as applied via equations (2.27) and (2.28)) means that (from equation (2.30)) the relative contribution from the large-scale pressure perturbation is enhanced (and the relative contribution from the small-scale pressure perturbation is diminished) relative to what would be present without the scale-selection process imposed by hydrostatics. Examples of this effect are illustrated in section 3.4. Note also that the individual perturbations in pressure, computed as they are from equation (2.17), do not explicitly satisfy the hydrostatic equation (2.25). However, the use of equation (2.17) does insure appropriate values for the pressure autocorrelation (from r_v), the pressure-density cross-correlation (from r_μ), and the pressure standard deviation (from r_q).

The perturbation modeling approach given above differs from that used in GRAM-90 in that the scale dependence on f_{Lp} (equation (2.28)) was not accounted for, and the perturbations were computed first for density, next for temperature, and last for pressure (rather than in the order—density, pressure, temperature—now used). Perturbation modeling for the wind components has not been revised from that used in GRAM-90 (other than the use of the variable-scale approach for the small-scale component, as discussed in the previous section).

3. SAMPLE RESULTS

3.1 GRAM-95 Monthly Mean Data and Comparison With GRAM-90

Figures 3.1 through 3.6 show vertical profiles of monthly mean temperature and density (percent deviation from 1976 U.S. Standard Atmosphere values) and eastward wind component (meters per second) for the months of January and July (period-of-record data) at KSC. Values from both GRAM-90 (diamonds) and GRAM-95 (squares) are shown. For reference, the KSC Range Reference Atmosphere (RRA) values are also shown (asterisks).

Above 30-km altitude, there is no difference between the GRAM-90 and GRAM-95 results in figures 3.1 through 3.6 (because they are both based on the same middle atmosphere data base). In general, the GRAM-95 results agree slightly better with the KSC RRA values than do the GRAM-90 results. No systematic comparison has been made against all of the RRA's, so this level of agreement with GRAM-95 may not be totally consistent across all of the range reference atmosphere sites. Limited comparisons (Edwards Air Force Base (EAFB) and Fairbanks, AK, not shown) indicate that GRAM-95 captures the relevant seasonal and geographic variations quite well (as did GRAM-90). From earlier experiences with GRAM-90, it is known that its lower altitude data base did suffer some problems (missing altitudes, violations of hydrostatic conditions, etc.) in several regions and for several months. Although automated routines in GRAM-90 attempted to correct

these problems whenever they were encountered, these attempts were not always completely successful. The new GUACA data base has been thoroughly quality controlled, and the initialization procedures insure that the data are complete (or are filled in as necessary) and satisfy the perfect gas law and hydrostatic relationships (see section 2.3). Progress messages (see appendix C) advise the user if unusual amounts of data had to be filled in during this initialization process.

Figures 3.7 through 3.10 show height-latitude cross sections (pole-to-pole and 0 to 30 km) of monthly mean values of temperature (K) or density (percent deviation from 1976 U.S. Standard Atmosphere) for the longitude of 80° W (the approximate longitude of KSC) for the month of January (period-of-record), from both GRAM-90 and GRAM-95. There is a great deal of similarity between the GRAM-90 and GRAM-95 results. In general, the contour values are smoother in the GRAM-95 results (figs. 3.8 and 3.10); the GRAM-90 contours indicate several areas of slight roughness (figs. 3.7 and 3.9). Height-latitude (and latitude-longitude) cross sections from GRAM-90, shown in Justus et al. (1991) for heights above 30 km are not changed, because they are based on the same middle atmosphere data base as GRAM-95.

One apparently major anomaly in the GRAM-95 temperature graph (fig. 3.8) is seen in the 220 K contour near height 10 km and latitude 45° N. Examination of the GUACA data base shows that this anomaly could be smoothed away by adjusting the 250-mbar temperatures at 80° W, 45° N, and 47.5° N by less than 1° (from slightly less than 220 K to slightly more than 220 K). This may indicate a slight error (less than 1°) in the mean temperature at these two locations, or it may merely indicate that there is more spatial structure to be seen at some locations because of the new higher spatial resolution (2.5° by 2.5° latitude-longitude grids) in the GUACA data base.

The apparent minor anomalies in the GRAM-95 density contours near the equator at 0 km (fig. 3.10) are due to the fact that (because of the Peruvian Andes) the surface is significantly above sea level (by as much as about 1.6 km) throughout much of this area. See the discussion about "subsurface" data extrapolation in section 2.3.

Figures 3.11 and 3.12 compare similar height-latitude cross sections (at 80° W longitude) of monthly mean eastward wind components (meters per second) from GRAM-90 and GRAM-95. The winds below 25-km height are estimated by the geostrophic wind relations (from horizontal pressure gradients) in GRAM-90. Although the GRAM-90 winds agree fairly well with the GRAM-95 results below about 20 km and for latitudes more than about 20° from the equator, figure 3.11 shows considerable deviation of the GRAM-90 winds in this near-equatorial region and at heights from about 20 to 25 km. The geostrophic winds are known to be unreliable very near the equator, and GRAM-90 attempts to compensate by evaluating near-equatorial winds by interpolation between geostrophic wind values on each side of the equator by about 15°. Figures 3.11 and 3.12 show that the GRAM-90 winds estimated this way are not always very accurate, and that considerable improvement is found by using the observed wind data in the new GUACA data base. Since the geostrophic winds of GRAM-90 must use pressure gradients (small differences in pressure across adjacent grid points in the data base), they are especially subject to small pressure errors. Most of the problems with the geostrophic winds in GRAM-90 come at the higher altitudes (20 to 25 km) of the lower altitude GRAM-90 data base (0 to 25 km). It is in this altitude range that the GRAM-90 data base is most subject to data unavailability or violations of hydrostatic conditions. All of these problems should be corrected with the use of observed wind components in GRAM-95.

3.2 Water Vapor and Other Atmospheric Species Concentrations

Figure 3.13 illustrates a height-latitude cross section, at 80° W longitude, for the GRAM-95 water vapor volume concentration (ppmv). As outlined in section 1.4 (fig. 1.2), the GUACA 2.5° gridded data base provides the H_2O information below 300 mbar (about 9 km). Above this level, the H_2O data come from the LaRC data (or fairing between the GUACA and LaRC data). Figure 3.13 shows that these two data sets, and the fairing process between them, provides a continuous, smoothly varying set of profiles over the 0- to 40-km height range. Similarly, the transition to MAP and AFGL H_2O data (see fig. 1.2 for details) is also smooth, as illustrated in figure 3.13.

The comparable height-latitude cross section for ozone, shown in figure 3.14, also indicates that the transition from AFGL to MAP (and back to AFGL) data is smooth (see discussion on ozone height ranges in section 1.4). For ozone, the GRAM-95 data is height and latitude dependent only. There is no longitudinal variability, as is provided for water vapor by the GUACA data base.

Figure 3.14 does not show significantly lower ozone values near the south pole (even for the Southern Hemisphere spring period) as might be expected from "ozone hole" considerations. This is due in part to the fact that the MAP ozone data base is for the period 1978 to 1983, a time period before the ozone hole was most fully developed. Although GRAM-95 projects a height-dependent yearly trend for ozone concentration (see section 2.4, equation (2.1)), the temporal trend is not currently assumed to be latitude dependent. Thus far, the significant temporal increases in the levels of ozone depletion appear to be confined to the near-polar Antarctic regions, and are not a global ozone decrease phenomenon. Another factor in the lack of ozone hole appearance in GRAM-95 is that the MAP data base does not have observations that extend to the South Pole during the winter and early spring, when solar illumination and backscattered UV levels are low. These missing MAP values near the poles are estimated by the "across-the-pole" interpolation scheme, discussed in section 2.5, but this technique may not capture the strong gradients, toward low ozone value near the pole, during an intense ozone hole condition.

3.3 Example Density Perturbations and Comparison With Space Shuttle Data

This section shows results from the new, variable-scale perturbation model in GRAM-95, discussed in section 2.6. Comparisons are made between simulated density perturbations and those observed along space shuttle Space Transportation System (STS) reentry trajectories. Two sets of observed STS reentry density data are compared against the model simulations. In addition to the turbulence model parameters of Justus et al. (1990) and the gravity wave data gathered from the bibliography of references in section 6, the first set of 22 observed STS density profiles (Findlay et al., 1988) were used in part to adjust some of the perturbation model parameters. The second set of 10 observed STS density profiles (Findlay and Jasinski, 1990) were not used as part of the model development, and thus constitute a totally independent data set for model comparisons.

Tables 3.1 through 3.4 give summaries of the model-simulated and STS-observed density perturbations (percent deviation from 1976 U.S. Standard Atmosphere) and density shears (changes in density per change in altitude as the STS vehicle moves along its trajectory, in units of percent per kilometer of height). The STS observations were evaluated along the reentry trajectory at positions that represented every 100 m of vertical displacement. It should be noted that the STS reentry trajectories are rather horizontal (i.e., the horizontal displacements between successive observations may exceed the vertical displacements by several fold). Large density shear values (e.g., the two observations that exceed 100 percent/km) do not necessarily mean large absolute changes in density during short displacements along the trajectory path. For example, a density

shear of 100 percent/km (10 percent per 100 m of vertical displacement) may represent a 10-percent density change that occurs over several km of (nearly horizontal) trajectory path.

Tables 3.1 and 3.2 show the first set of density perturbations and density shears, modeled and observed (Findlay et al., 1988), for the two height regions 45 to 65 km and 65 to 85 km. The STS flight numbers are as used by Findlay et al. (in which STS-11 through STS-32 are used for STS-41-B through STS-61-C). Other columns show the month of the flight, the landing site (EAFB = Edwards AFB; WSMR = White Sands Missile Range; KSC = Kennedy Space Center) and whether the reentry trajectory was at low (L), medium (M), or high (H) latitudes. Data values show, for each height range, the model and observed average value over the height range, the standard deviation over the height range, and the maximum absolute value within the height range. At the bottom of each table, the average, standard deviation, maximum, and minimum values across the complete set of 22 trajectories are shown.

Tables 3.3 and 3.4 show comparable statistics for model versus observed (Findlay and Jasinski, 1990) densities and density shears from the (independent) 10 trajectories for STS-26 through STS-36 (to avoid confusion with similar numbering used by Findlay et al., as shown in tables 3.1 and 3.2, the STS numbers STS-xx in tables 3.3 and 3.4 are shown as STSFxx). Both the dependent (tables 3.1 and 3.2) and independent (tables 3.3 and 3.4) data sets show that the new variable-scale model produces both density perturbations and density shears that are well representative (in their statistical properties) of those observed during actual STS reentry conditions.

Examples of the density perturbation model simulations are provided by figures 3.15 and 3.16, which plot density perturbation (percent deviation from 1976 U.S. Standard Atmosphere) versus height along the trajectory path. Figure 3.15 is for STS-04 (July 4, 1982), which encountered the largest observed value of density shear (12.25 percent over a 100-m vertical displacement; see table 3.2). Figure 3.16 shows the modeled and observed profiles for the STS-32 reentry, during which rather small shears were encountered. The simulated density perturbation profiles in figures 3.15 and 3.16 cannot reproduce all of the details of the observed profiles at each specific altitude. The GRAM-95 perturbation model is statistical, not predictive, in nature. Nevertheless, the simulation results in these figures illustrate that the model results appear similar in general character to the observed perturbations. The statistical summaries in tables 3.1 through 3.4 illustrate that the statistical results from multiple simulations reproduce, in their statistical properties, the observed statistics of actual STS trajectory conditions.

Additional examples of GRAM-95 output and comparisons with GRAM-90 results are provided by Johnson et al. (1995).

3.4 Example Perturbations and Comparison With Rawinsonde and STS Data

Figures 3.17 and 3.18 show a sample of 100 profiles of January density and pressure (expressed as percent deviation from the January monthly mean) for the rawinsonde data set discussed by Smith and Adelfang (1995). The profiles plotted are every tenth one from the total of 1,066 January profiles measured at KSC over the period from 1957 to 1985. The heavy lines in figures 3.17 and 3.18 show the envelope of 3σ values (i.e., 3 times the standard deviation of the 1,066 profiles, also expressed as percent of the mean). Approximately 0.1 percent of statistically independent values should fall above (and 0.1 percent below) this 3σ envelope, if the values are gaussian-distributed. Means and standard deviations observed from the January KSC data set are given in table 1 of Smith and Adelfang (1995).

GRAM simulations (such as those shown in figures 3.1 and 3.3) indicate that the GRAM-95 (GUACA data base) mean values for the period of record (1980 to 1991) at KSC agree closely with those observed from the rawinsonde data set. The GRAM January monthly mean pressure and temperature at KSC differ from the observed values by 0.4-percent root-mean-square (rms); while the GRAM mean density deviates 0.6-percent rms from the observed KSC value.

Figure 3.17 shows a significant amount of small-scale structure in the rawinsonde density profiles, while the pressure profiles in figure 3.18 show that much more of the pressure variation is due to large vertical scales. For comparison, figures 3.19 and 3.20 show a set of 25 profiles of density and pressure simulated for January (period-of-record) by the new perturbation model in GRAM-95 (see section 2.7). Details of the 3σ envelopes are somewhat different between the GRAM simulations and the rawinsonde data set. In part, these differences may be due to the different periods of record (1980 to 1991 for GRAM and 1957 to 1985 for the KSC rawinsondes). Most of the discrepancy in σ values between GRAM and the KSC rawinsondes may be due to local structure that is not resolved in the 2.5° GUACA data base. The KSC station is not one that routinely contributes to the ECMWF model initialization process, on which the GUACA data is based (see appendix A).

The essential features of major small-scale contribution to density perturbations and major large-scale contribution to pressure perturbations, are illustrated in the GRAM results of figures 3.19 and 3.20. Like the rawinsonde observations, the GRAM perturbations tend to cluster at small deviations from the monthly mean, with occasional excursions to near (or exceeding) the 3σ envelope values. In contrast, the model results of Smith and Adelfang (1995) are for extreme-value perturbations. Thus, the perturbation profiles illustrated in their paper appear clustered near the 3σ envelope values, with relatively few values at small deviations from the monthly mean. Although GRAM perturbations may occasionally exceed the 3σ envelope (on the order of 0.1 percent of the time), they represent, with a reasonable degree of realism, the statistical characteristics of typical observed profiles.

Figure 3.21 illustrates the feature of predominant large-scale pressure perturbations, as measured by the space shuttle STS during the STS-04 reentry (July 4, 1982); see also figure 3.15. Density and pressure values in this figure are expressed as percent deviations from the 1976 U.S. Standard atmosphere values. The pressure profile is seen to be considerably smoother than the density profile, reflecting the dominance of the large-scale perturbations in pressure. STS-04 simulations of density and pressure perturbations, simulated by GRAM-95 with the approach discussed in section 2.7, also show considerably less small-scale structure in the pressure profile than the density profile (fig. 3.22). The fact that the GRAM-simulated pressures are not quite as smooth as the STS observed pressure profile may be due in part to excessive smoothing of the STS-derived pressure values. The STS density observations are converted to pressure values by assuming a purely hydrostatic variation with altitude. The actual STS reentry trajectory changes significantly in horizontal distance while the vehicle is moving a relatively small displacement in height (i.e., the trajectory is fairly horizontal at the altitudes of figs. 3.21 and 3.22).

Both the rawinsonde (0- to 25-km altitude) and STS (45- to 95-km altitude) results show that the scale selection process for pressure perturbations (equations (2.28) and (2.30)) do a reasonable job in representing the relative contributions of the large-scale and small-scale components of the pressure perturbations (mostly large-scale) and density and temperature perturbations (significant small-scale contribution).

Table 3.1. GRAM-95 modeled versus observed (Findlay et al., 1988) density perturbation (percent deviation from 1976 U.S. Standard Atmosphere) for the first 22 (dependent) data for the height ranges 45 to 65 km and 65 to 85 km.

Density Perturb. (%).	Entry Data			Height = 45 to 65 km						Height = 65 to 85 km					
								Model/Observed							
Flght	Mon	Site	LH	Average		Std.dev		Max.Abs.Val		Average		Std.dev		Max.Abs.Val	
STS-01	Apr	EAFB	M	1.5	2.2	4.9	3.4	11.6	7.3	0.0	0.5	3.8	2.6	10.9	7.8
STS-02	Nov	EAFB	M	-6.1	-5.6	5.8	2.2	17.2	9.5	-10.7	-11.5	3.2	3.7	21.6	16.9
STS-03	Mar	WSMR	M	-2.7	0.6	4.3	1.7	10.2	3.7	-1.7	-3.0	4.4	1.9	10.9	7.8
STS-04	Jul	EAFB	M	7.1	12.3	4.9	2.3	13.8	15.2	-7.1	-0.3	8.3	6.3	22.2	13.7
STS-05	Nov	EAFB	M	2.2	-2.9	3.7	5.4	12.5	11.9	-5.6	-4.7	4.5	6.7	15.1	23.8
STS-06	Apr	EAFB	L	10.0	7.4	3.5	1.4	17.7	10.4	10.9	0.0	4.2	8.4	19.9	21.8
STS-07	Jun	EAFB	M	15.5	10.9	1.9	2.8	21.1	16.1	6.8	6.6	7.3	3.1	19.6	13.1
STS-08	Sep	EAFB	M	3.8	7.6	5.7	2.7	12.2	13.6	-2.0	-1.8	4.1	4.1	11.6	10.1
STS-09	Dec	EAFB	H	-15.6	-13.1	5.6	5.8	26.8	22.1	-30.6	-36.9	5.1	7.0	38.0	44.9
STS-11	Feb	KSC	M	6.2	-4.6	3.2	4.8	10.8	13.1	3.1	-11.0	2.1	4.1	9.3	21.4
STS-13	Apr	EAFB	M	9.6	1.9	3.9	2.6	15.6	7.1	4.2	-0.1	5.1	5.8	14.5	20.7
STS-14	Sep	EAFB	M	3.1	5.0	4.0	3.2	9.3	11.9	-4.5	-0.8	4.0	2.7	17.0	10.1
STS-17	Oct	KSC	H	-1.7	-1.7	8.5	4.3	21.4	9.9	-22.4	-34.9	8.2	5.9	37.4	41.8
STS-19	Nov	KSC	M	-6.6	-6.6	3.2	2.7	14.8	12.4	-5.2	-5.1	2.7	4.7	12.6	16.2
STS-23	Apr	KSC	M	6.5	6.2	3.2	2.9	11.9	11.4	8.1	0.8	4.9	4.3	20.5	8.6
STS-24	May	EAFB	L	5.1	3.7	2.7	3.0	9.5	8.8	-4.0	-13.3	5.3	7.4	11.9	28.1
STS-25	Jun	EAFB	M	14.5	7.9	3.0	3.9	21.0	13.1	1.3	-4.8	7.7	5.1	20.4	23.7
STS-26	Aug	EAFB	L	9.7	3.8	4.0	5.2	16.7	12.0	2.6	-13.3	3.4	5.6	10.5	23.0
STS-27	Sep	EAFB	M	9.1	4.3	2.8	3.8	13.9	10.3	6.6	-2.8	4.2	5.2	17.6	15.2
STS-30	Nov	EAFB	L	-5.5	-4.3	4.0	2.8	16.8	9.5	-9.7	-12.3	5.8	8.9	18.8	27.6
STS-31	Dec	EAFB	L	-6.9	1.2	3.4	2.2	15.1	5.8	-2.2	-3.7	4.0	3.6	10.6	13.9
STS-32	Jan	EAFB	M	-2.1	-7.2	3.3	3.7	9.8	14.2	-3.5	-14.8	4.6	5.1	12.9	26.8
Average of		22		2.6	1.3	4.1	3.3	15.0	11.3	-3.0	-7.6	4.9	5.1	17.5	19.9
Std.dev of		22		7.6	6.3	1.4	1.2	4.5	3.8	9.4	10.5	1.6	1.8	7.6	9.8
Minimum of		22		-15.6	-13.1	1.9	1.4	9.3	3.7	-30.6	-36.9	2.1	1.9	9.3	7.8
Maximum of		22		15.5	12.3	8.5	5.8	26.8	22.1	10.9	6.6	8.3	8.9	38.0	44.9

Table 3.2. GRAM-95 modeled versus observed (Findlay et al., 1988) density shears (percent density change per km of vertical displacement) for the first 22 (dependent) data for the height ranges 45 to 65 km and 65 to 85 km.

Density Shear (%/km).	Entry Data			Height = 45 to 65 km						Height = 65 to 85 km					
				Model/Observed											
Flght	Mon	SiteLH		Average		Std.dev		Max.Abs.Val		Average		Std.dev		Max.Abs.Val	
STS-01	Apr	EAFB	M	-0.6	-0.3	5.6	2.9	18.7	11.6	0.2	-0.1	14.3	12.3	48.9	57.5
STS-02	Nov	EAFB	M	-0.3	-0.1	7.7	2.7	21.7	8.0	-0.2	-0.6	15.0	11.3	58.5	42.0
STS-03	Mar	WSMR	M	-0.2	-0.4	6.7	3.9	17.1	20.4	0.3	0.0	13.6	10.3	43.7	36.8
STS-04	Jul	EAFB	M	-0.4	-0.2	4.6	1.9	15.2	5.6	-1.3	-1.1	14.1	21.5	52.5	122.5
STS-05	Nov	EAFB	M	-0.2	-0.7	6.9	3.3	21.0	14.3	0.0	-0.8	13.8	10.7	36.2	44.5
STS-06	Apr	EAFB	L	0.4	0.1	8.8	2.4	26.6	6.6	-0.3	-1.8	21.0	11.4	64.7	42.2
STS-07	Jun	EAFB	M	0.2	-0.2	4.9	3.0	13.5	9.7	-1.1	-0.1	16.1	14.0	90.3	57.2
STS-08	Sep	EAFB	M	-0.8	0.1	5.6	3.0	17.2	9.9	0.0	-0.6	17.0	9.6	56.3	39.8
STS-09	Dec	EAFB	H	-0.6	-1.0	7.6	2.9	18.6	11.8	0.4	-0.9	12.2	11.8	40.7	64.0
STS-11	Feb	KSC	M	-0.2	-0.2	6.8	4.0	18.5	14.1	0.1	0.5	13.7	8.3	41.2	37.8
STS-13	Apr	EAFB	M	0.6	0.1	8.3	3.1	18.4	10.4	-1.0	-1.2	16.9	11.6	56.8	57.5
STS-14	Sep	EAFB	M	-0.6	-0.5	5.1	2.8	17.2	7.4	-0.2	-0.3	17.7	8.6	76.9	40.2
STS-17	Oct	KSC	H	-1.3	-0.3	6.8	3.7	16.6	11.7	0.8	-0.7	12.8	7.9	41.1	29.7
STS-19	Nov	KSC	M	0.3	-0.2	9.6	3.9	27.8	11.0	0.3	0.0	14.3	9.2	44.4	32.3
STS-23	Apr	KSC	M	0.2	-0.2	5.8	4.5	16.2	22.4	-0.8	-0.4	18.2	8.5	53.6	25.4
STS-24	May	EAFB	L	-0.3	-0.3	4.7	4.7	10.6	14.4	-0.2	-1.3	11.4	9.4	49.4	37.9
STS-25	Jun	EAFB	M	0.3	-0.5	4.8	3.1	17.5	10.6	-1.0	-1.3	15.2	20.2	48.9	100.2
STS-26	Aug	EAFB	L	-0.3	-0.6	6.5	3.4	20.5	11.2	-0.1	-0.3	12.6	10.0	34.4	51.3
STS-27	Sep	EAFB	M	0.2	-0.3	4.7	2.9	10.4	9.6	-0.2	-0.6	13.9	10.3	50.1	38.8
STS-30	Nov	EAFB	L	-0.2	-0.3	10.4	3.0	25.7	9.8	-0.3	-1.1	16.1	14.5	62.7	99.9
STS-31	Dec	EAFB	L	0.3	-0.1	7.7	2.8	29.3	8.6	-0.4	-0.4	12.8	9.2	49.3	36.1
STS-32	Jan	EAFB	M	-0.5	-0.6	6.5	2.6	15.7	8.8	0.1	-0.7	13.9	8.3	49.6	26.9
Average of		22		-0.2	-0.3	6.6	3.2	18.8	11.3	-0.2	-0.6	14.8	11.3	52.3	50.9
Std.dev of		22		0.4	0.3	1.6	0.7	4.9	3.9	0.5	0.5	2.2	3.5	12.7	24.9
Minimum of		22		-1.3	-1.0	4.6	1.9	10.4	5.6	-1.3	-1.8	11.4	7.9	34.4	25.4
Maximum of		22		0.6	0.1	10.4	4.7	29.3	22.4	0.8	0.5	21.0	21.5	90.3	122.5

Table 3.3. GRAM-95 modeled versus observed (Findlay and Jasinski, 1990) density perturbation (percent deviation from 1976 U.S. Standard Atmosphere) for the second 10 (independent) data for the height ranges 45 to 65 km and 65 to 85 km.

Density Perturb. (%).				Height = 45 to 65 km						Height = 65 to 85 km			
	Entry Data					Model/Observed							
Flght	Mon	SiteLH		Average		Std.dev		Max.Abs.Val		Average		Std.dev		Max.Abs.Val	
STSF26	Oct	EAFB	M	0.7	0.5	4.4	2.4	13.2	4.7	4.0	-3.0	4.8	3.1	10.6	12.5
STSF27	Dec	EAFB	H	-20.6	-18.3	9.5	8.3	34.7	28.6	-36.8	-18.6	5.7	3.6	50.0	25.8
STSF28	Aug	EAFB	L	9.7	8.0	4.2	4.9	19.3	15.7	-2.2	-3.2	5.7	9.6	13.2	21.5
STSF29	Mar	EAFB	M	-4.1	-0.2	7.1	2.4	14.4	5.3	-2.0	1.7	4.0	4.3	10.6	10.1
STSF30	May	EAFB	M	5.8	6.7	3.2	1.4	10.5	9.5	-2.6	-5.5	3.9	9.4	10.2	20.0
STSF31	Apr	EAFB	M	7.3	4.2	3.5	3.1	14.1	10.4	1.3	-1.2	3.6	6.1	8.3	15.9
STSF32	Jan	EAFB	M	-2.9	-4.7	2.3	6.6	8.5	19.1	3.0	-4.6	4.6	3.7	14.6	16.2
STSF33	Nov	EAFB	M	-7.9	-6.7	4.1	2.8	19.2	13.0	-3.7	-3.1	4.2	3.8	14.9	12.4
STSF34	Sep	EAFB	L	3.1	-0.5	4.3	1.8	11.1	3.3	0.1	-4.3	4.5	9.3	10.3	21.9
STSF36	Mar	EAFB	H	-3.4	-14.6	10.1	8.2	21.2	28.8	-18.4	-38.1	5.4	4.1	30.1	43.5
Average of		10		-1.2	-2.6	5.3	4.2	16.6	13.8	-5.7	-8.0	4.6	5.7	17.3	20.0
Std.dev of		10		8.4	8.2	2.6	2.5	7.2	8.8	11.9	11.2	0.7	2.6	12.4	9.2
Minimum of		10		-20.6	-18.3	2.3	1.4	8.5	3.3	-36.8	-38.1	3.6	3.1	8.3	10.1
Maximum of		10		9.7	8.0	10.1	8.3	34.7	28.8	4.0	1.7	5.7	9.6	50.0	43.5

Table 3.4. GRAM-95 modeled versus observed (Findlay and Jasinski, 1990) density shears (percent density change per km of vertical displacement) for the second 10 (independent) data for the height ranges 45 to 65 km and 65 to 85 km.

Density Shear (%/km).			Height = 45 to 65 km						Height = 65 to 85 km					
Entry Data			Model/Observed											
Flght	Mon	SiteLH	Average		Std.dev		Max.Abs.Val		Average		Std.dev		Max.Abs.Val	
STSF26	Oct	EAFB M	-0.3	0.0	8.8	2.6	29.6	7.2	0.4	-0.6	10.0	9.7	28.9	48.5
STSF27	Dec	EAFB H	-1.5	-0.7	8.9	3.2	22.8	9.1	-0.6	0.3	21.2	10.2	79.6	57.0
STSF28	Aug	EAFB L	-0.1	-0.4	10.8	3.4	40.4	10.0	-0.8	-0.5	15.2	21.2	64.5	116.2
STSF29	Mar	EAFB M	-0.4	-0.1	7.2	2.3	22.4	7.4	0.4	0.4	13.6	7.0	57.9	37.6
STSF30	May	EAFB M	0.1	-0.1	4.0	3.7	10.5	11.9	-0.2	-1.1	12.9	11.7	43.7	63.6
STSF31	Apr	EAFB M	0.2	-0.4	8.2	2.5	22.9	8.0	0.0	-0.7	14.9	10.7	41.3	44.3
STSF32	Jan	EAFB M	-0.1	-1.1	8.3	4.6	28.4	15.0	0.7	0.4	16.5	11.1	47.0	55.1
STSF33	Nov	EAFB M	-0.1	0.2	9.4	2.8	23.9	7.0	0.4	0.1	14.8	9.9	47.5	40.2
STSF34	Sep	EAFB L	0.0	-0.1	5.5	2.3	16.0	8.5	-0.1	-1.1	14.1	7.8	45.5	32.9
STSF36	Mar	EAFB H	-1.1	-1.1	9.5	2.3	31.7	8.5	-0.3	0.2	23.4	6.0	78.1	30.0
Average of		10	-0.3	-0.4	8.1	3.0	24.9	9.3	0.0	-0.3	15.7	10.5	53.4	52.5
Std.dev of		10	0.5	0.4	1.9	0.7	7.9	2.4	0.5	0.6	3.7	4.0	15.6	23.6
Minimum of		10	-1.5	-1.1	4.0	2.3	10.5	7.0	-0.8	-1.1	10.0	6.0	28.9	30.0
Maximum of		10	0.2	0.2	10.8	4.6	40.4	15.0	0.7	0.4	23.4	21.2	79.6	116.2

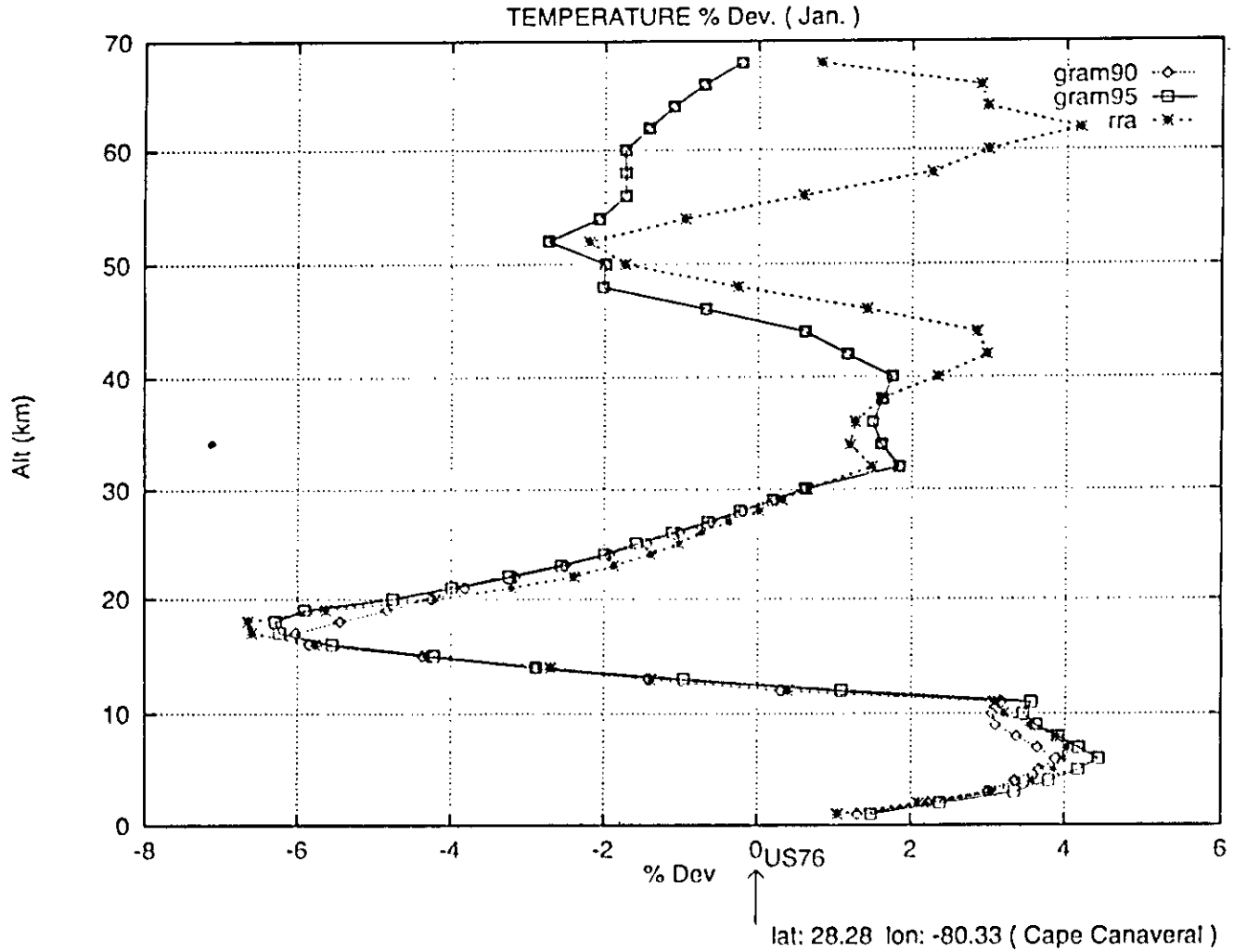

Figure 3.1. Vertical profile of monthly mean temperature (percent deviation from 1976 U.S. Standard Atmosphere) for January period-of-record (1980 to 1991) at KSC. Diamonds = GRAM-90, squares = GRAM-95, asterisks = KSC RRA.

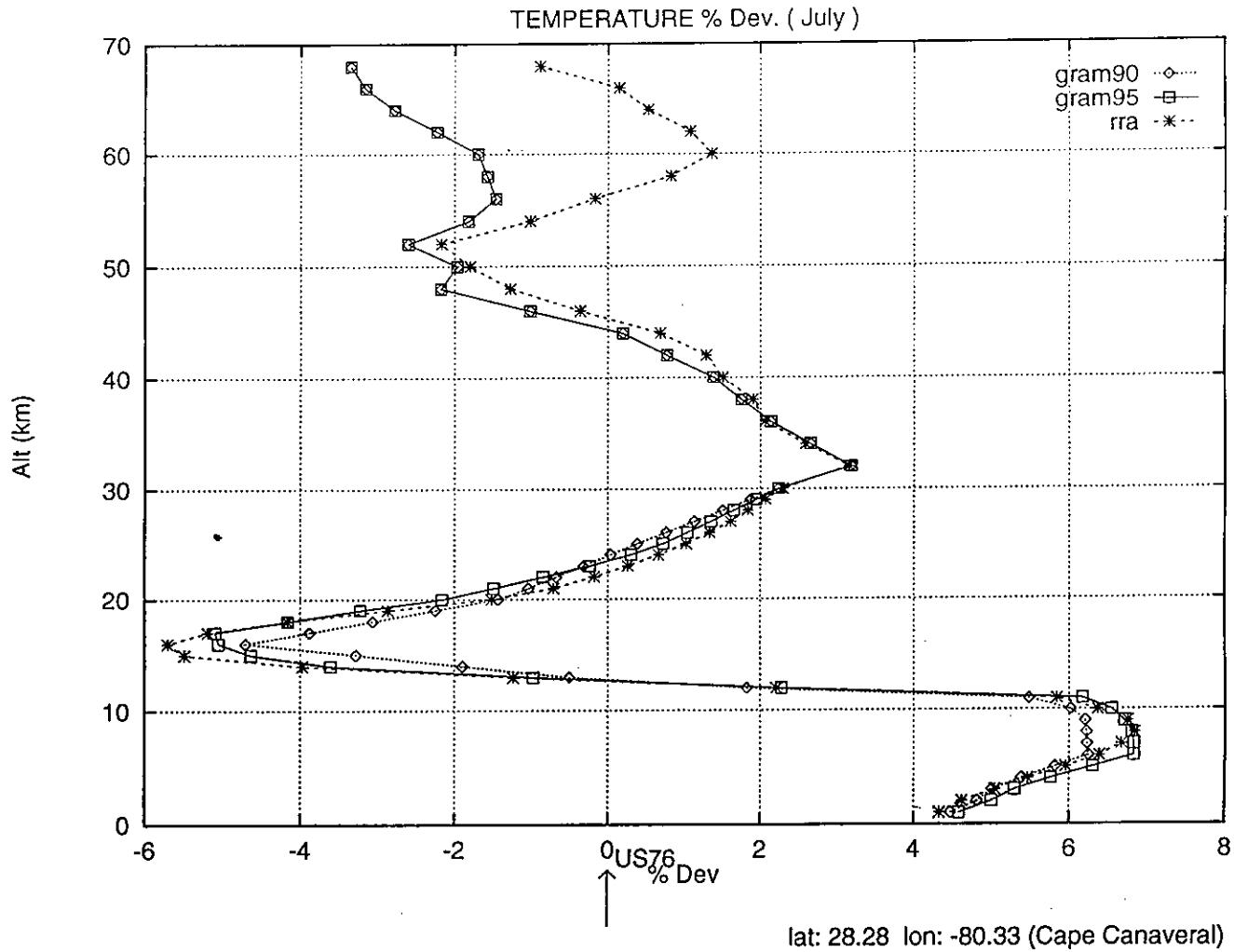

Figure 3.2. Vertical profile of monthly mean temperature (percent deviation from 1976 U.S. Standard Atmosphere) for July period-of-record (1980 to 1991) at KSC. Diamonds = GRAM-90, squares = GRAM-95, asterisks = KSC RRA.

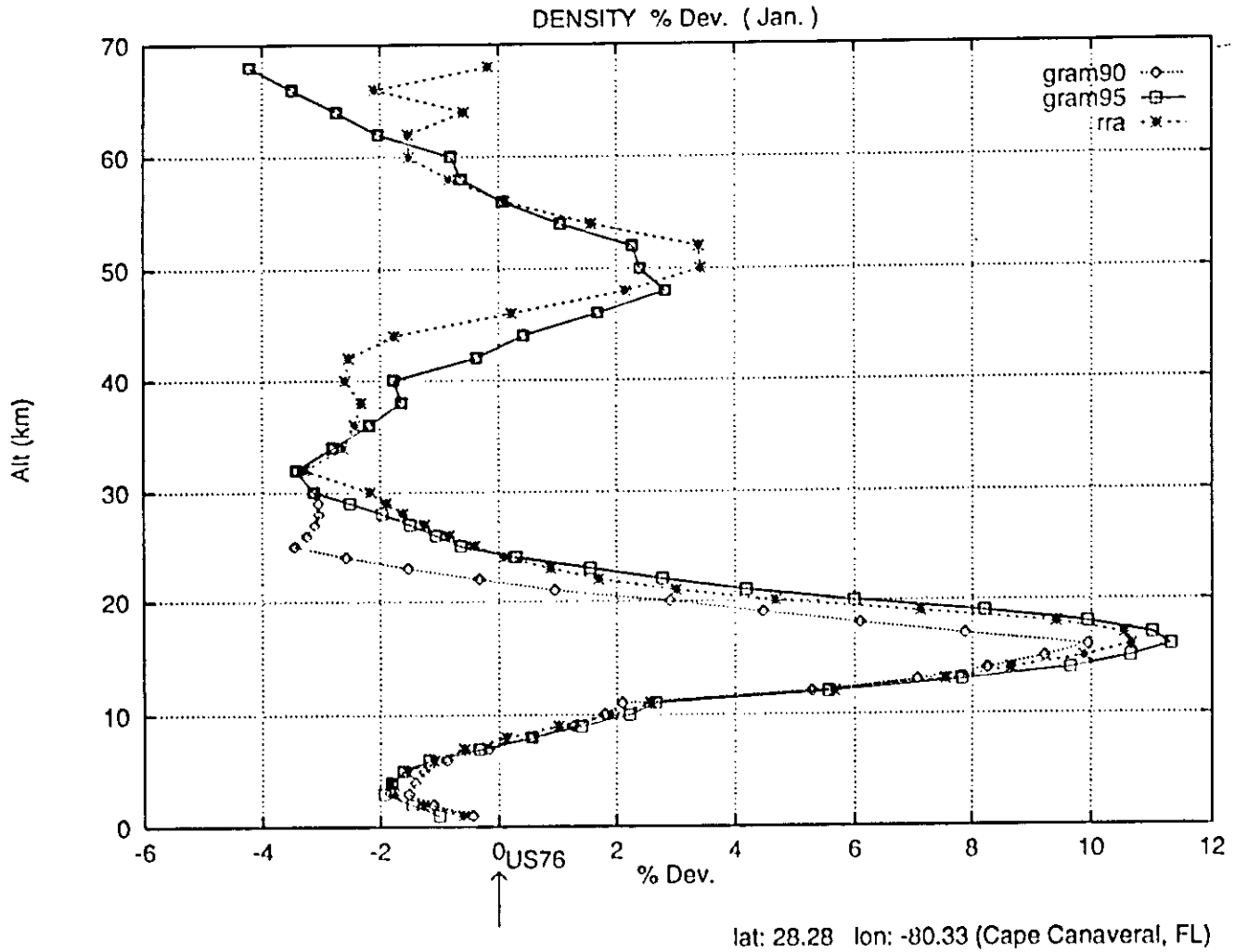

Figure 3.3. Vertical profile of monthly mean density (percent deviation from 1976 U.S. Standard Atmosphere) for January period-of-record (1980 to 1991) at KSC. Diamonds = GRAM-90, squares = GRAM-95, asterisks = KSC RRA.

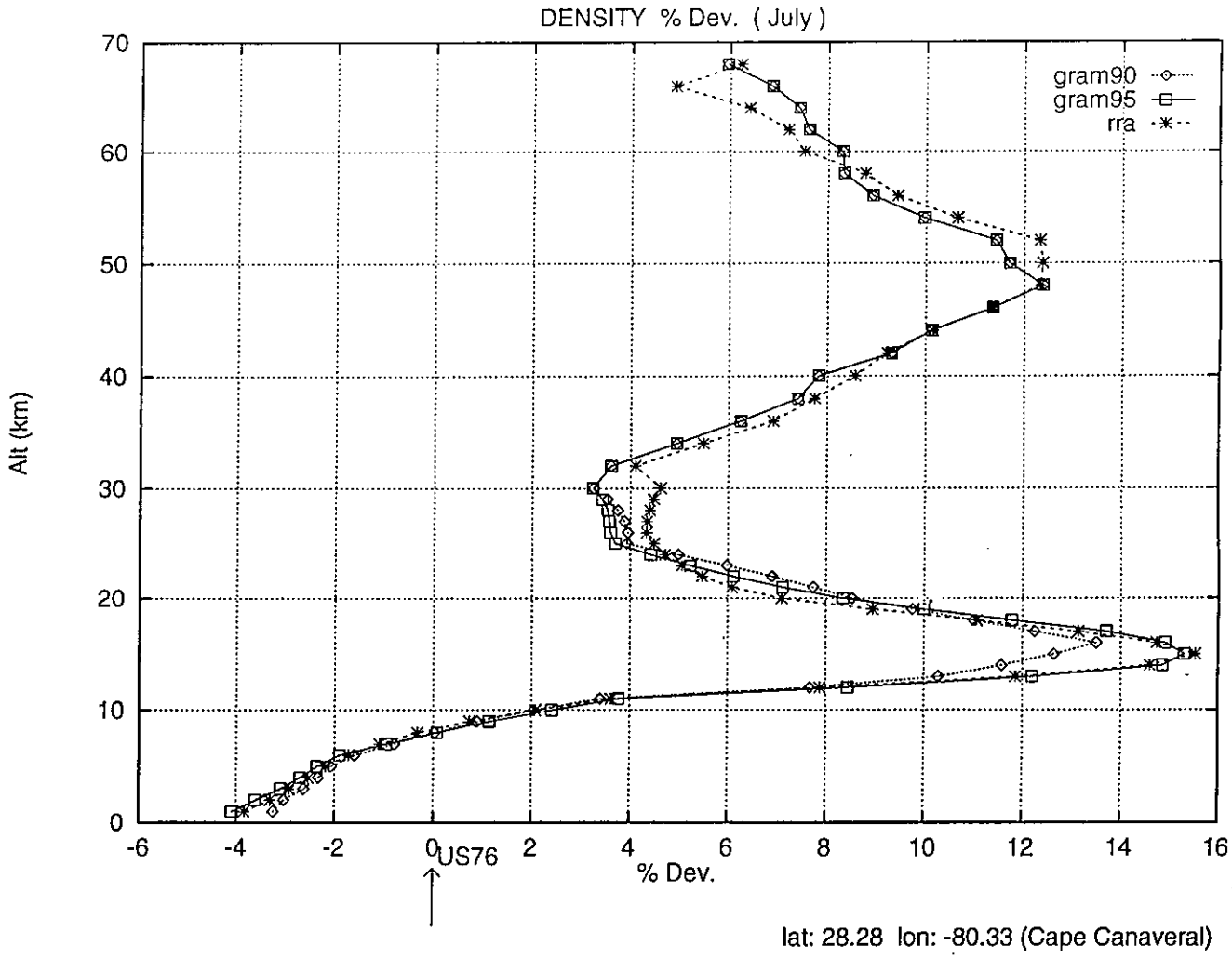

Figure 3.4. Vertical profile of monthly mean density (percent deviation from 1976 U.S. Standard Atmosphere) for July period-of-record (1980 to 1991) at KSC. Diamonds = GRAM-90, squares = GRAM-95, asterisks = KSC RRA.

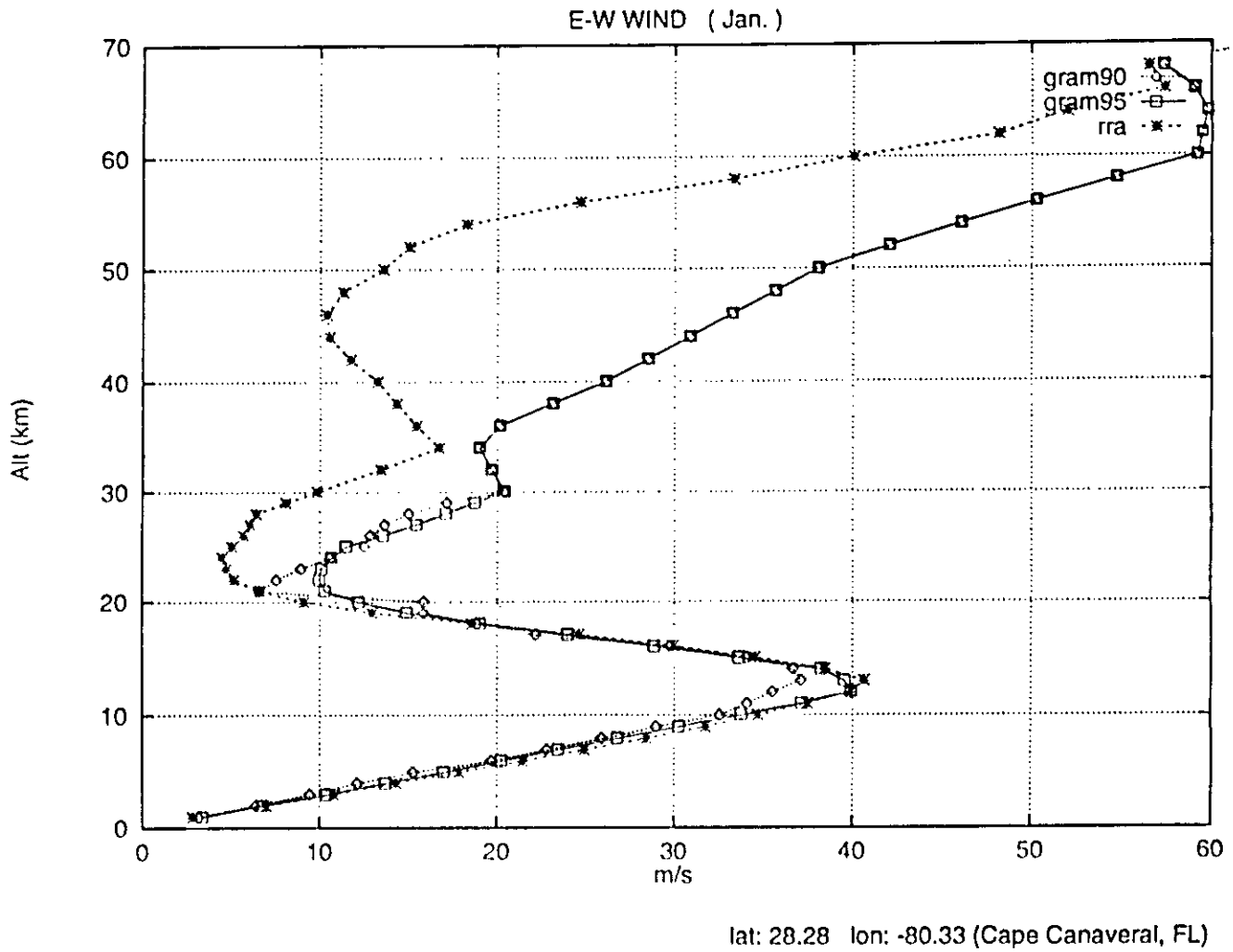

Figure 3.5. Vertical profile of monthly mean eastward wind component (meters per second) for January period-of-record (1980 to 1991) at KSC. Diamonds = GRAM-90, squares = GRAM-95, asterisks = KSC RRA.

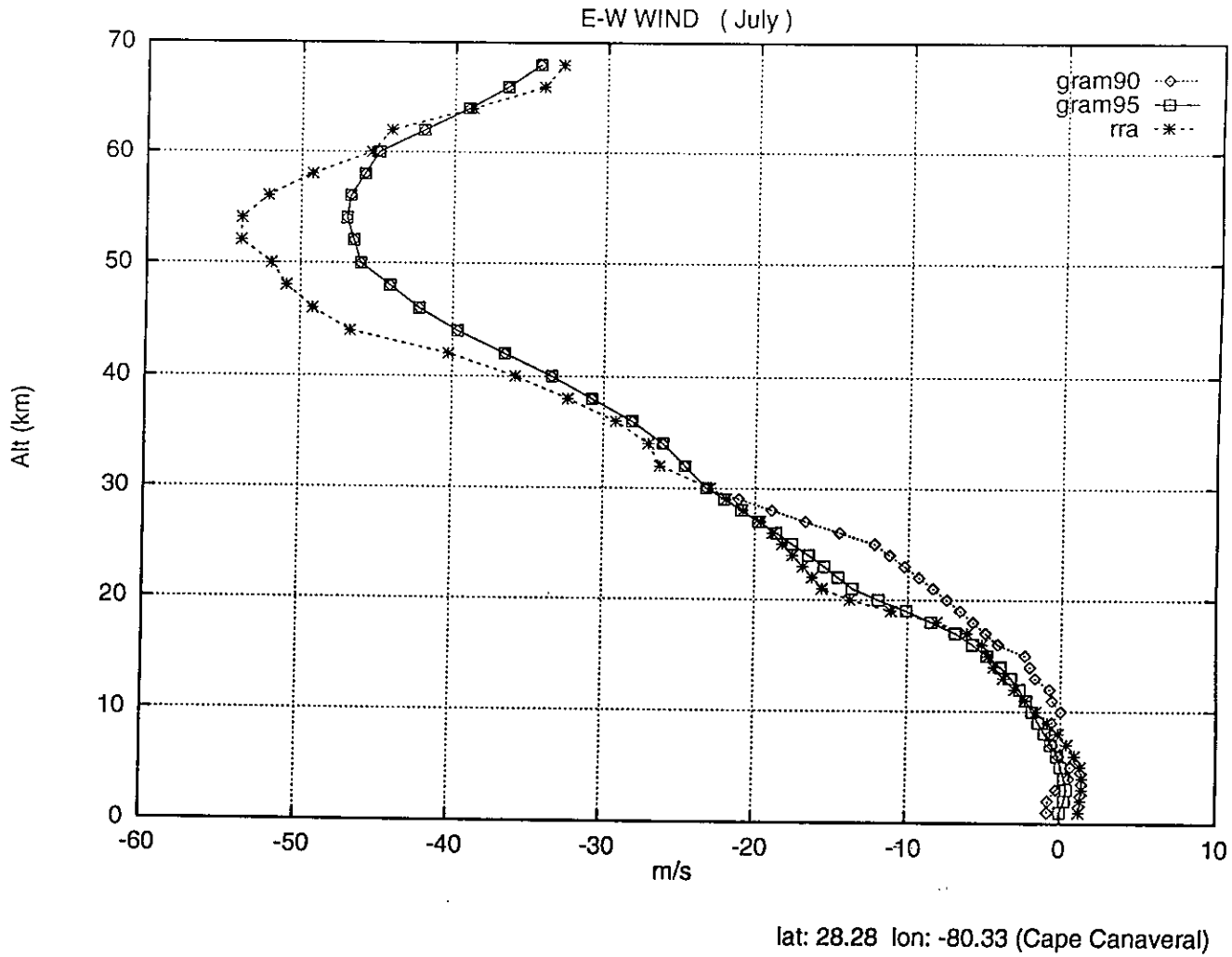

Figure 3.6. Vertical profile of monthly mean eastward wind component (meters per second) for July period-of-record (1980 to 1991) at KSC. Diamonds = GRAM-90, squares = GRAM-95, asterisks = KSC RRA.

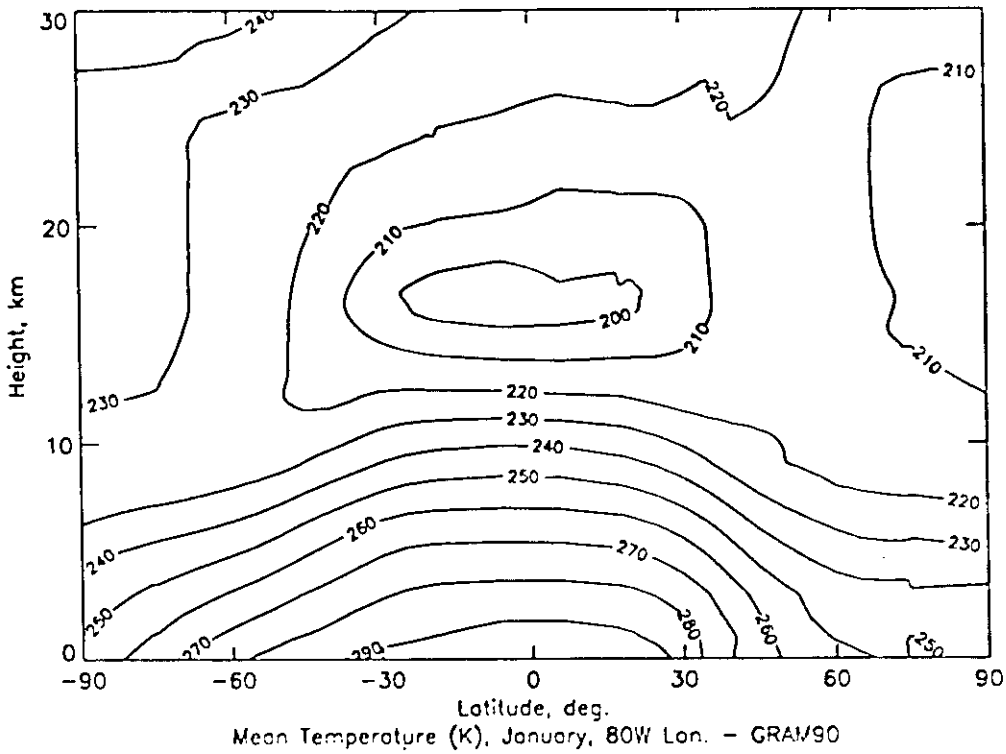

Figure 3.7. Height-latitude cross section (at 80° W longitude) of monthly mean temperature (K) for January (period-of-record) from GRAM-90.

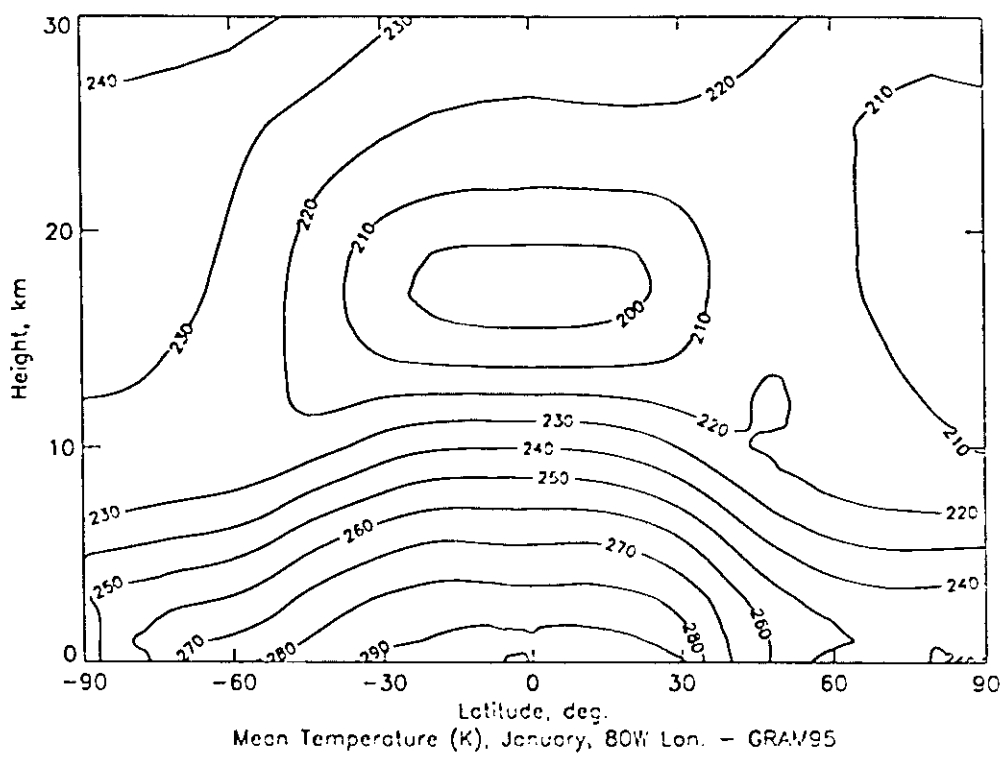

Figure 3.8. Height-latitude cross section (at 80° W longitude) of monthly mean temperature (K) for January (period-of-record) from GRAM-95.

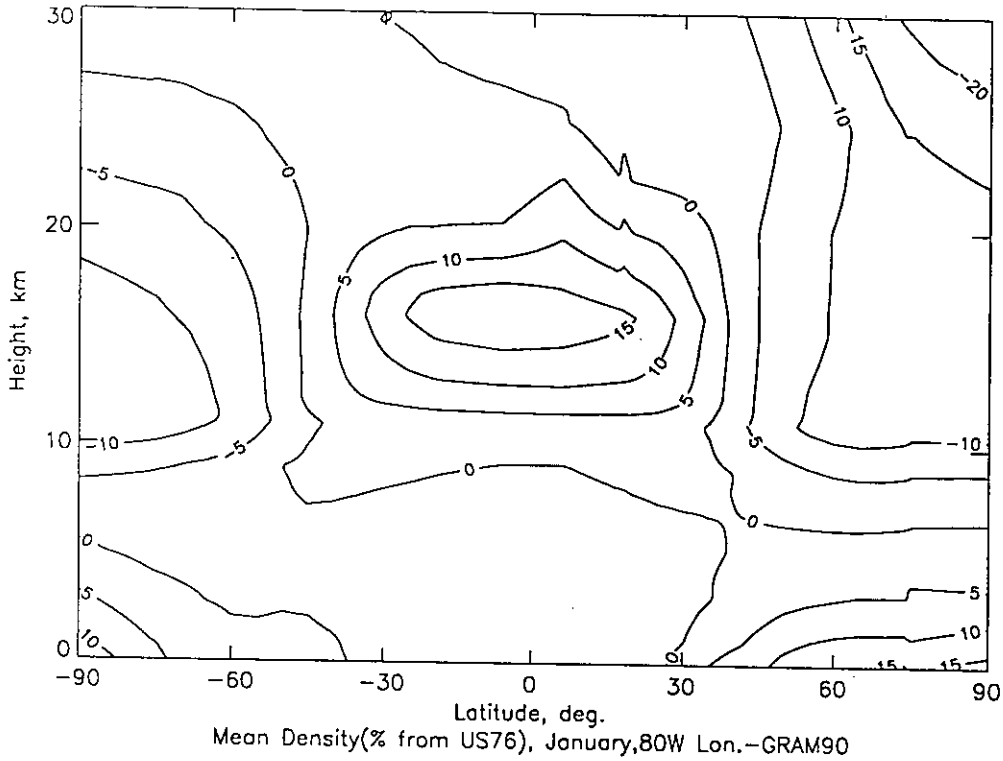

Figure 3.9. Height-latitude cross section (at 80° W longitude) of monthly mean density (percent deviation from 1976 U.S. Standard Atmosphere) for January (period-of-record) from GRAM-90.

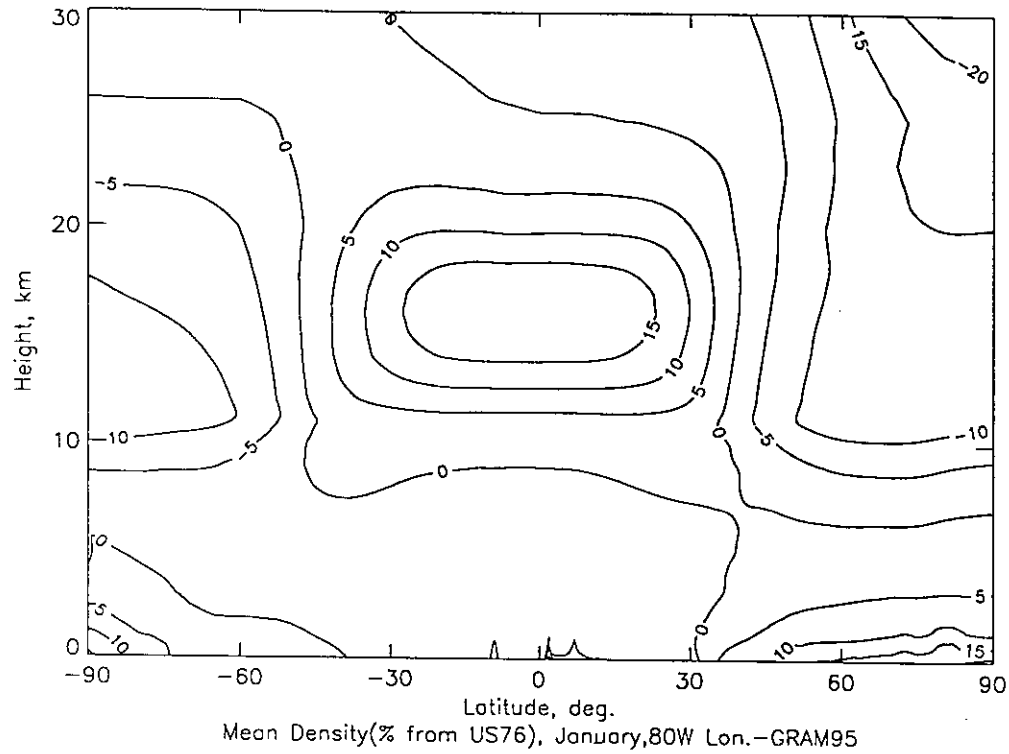

Figure 3.10. Height-latitude cross section (at 80° W longitude) of monthly mean density (percent deviation from 1976 U.S. Standard Atmosphere) for January (period-of-record) from GRAM-95.

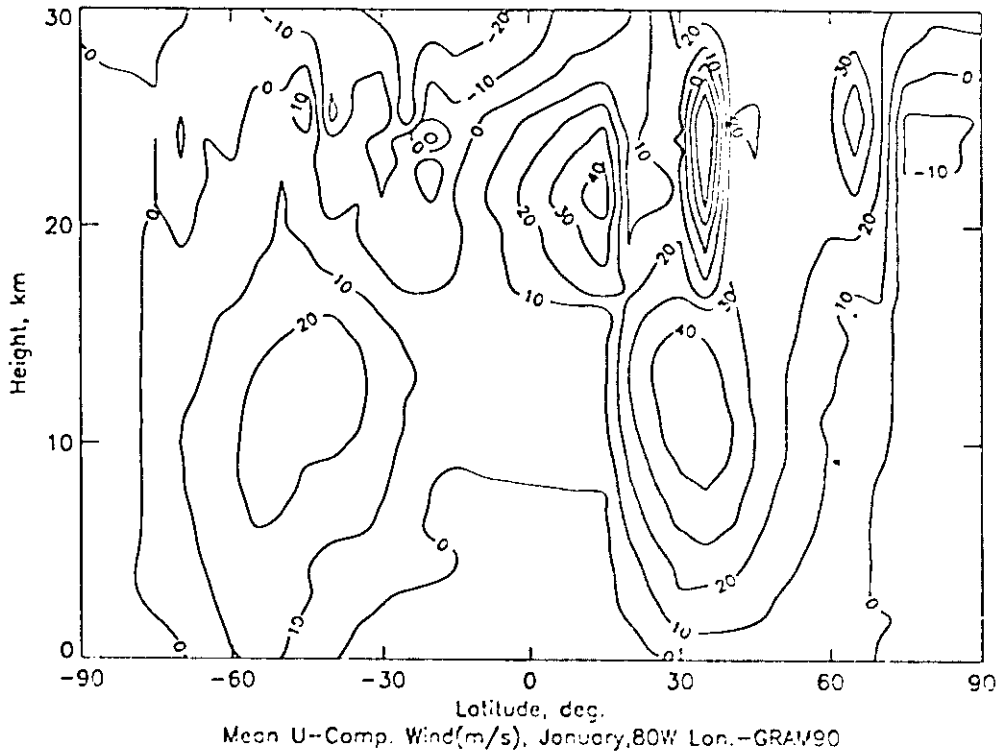

Figure 3.11. Height-latitude cross section (at 80° W longitude) of monthly mean eastward wind component (meters per second) for January (period-of-record) from GRAM-90.

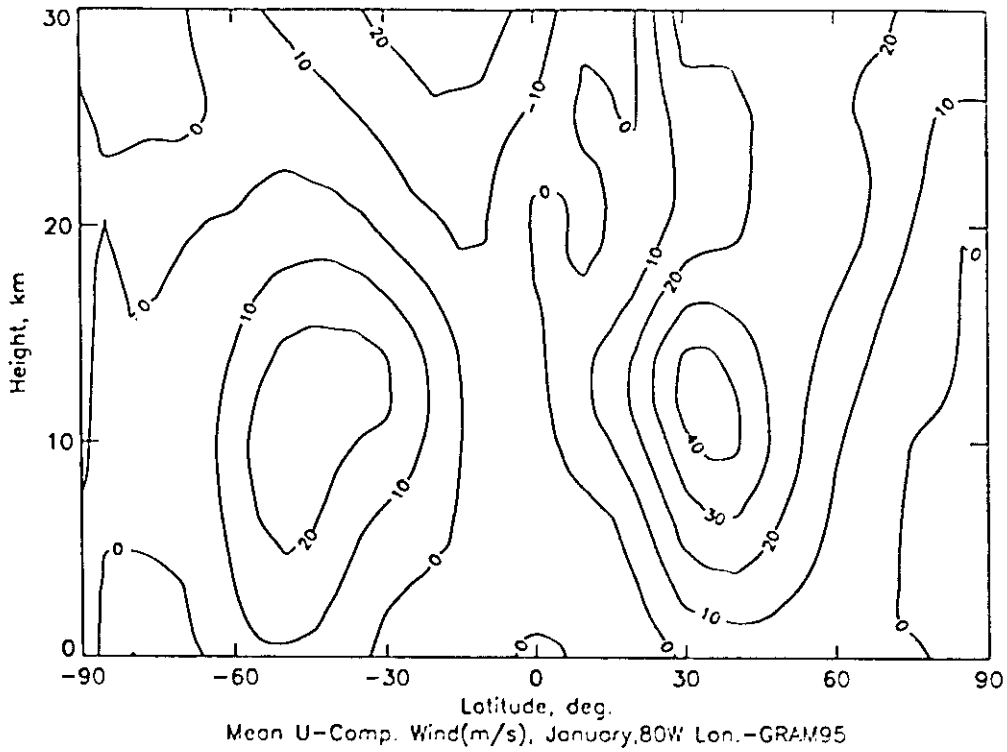

Figure 3.12. Height-latitude cross section (at 80° W longitude) of monthly mean eastward wind component (meters per second) for January (period-of-record) from GRAM-95.

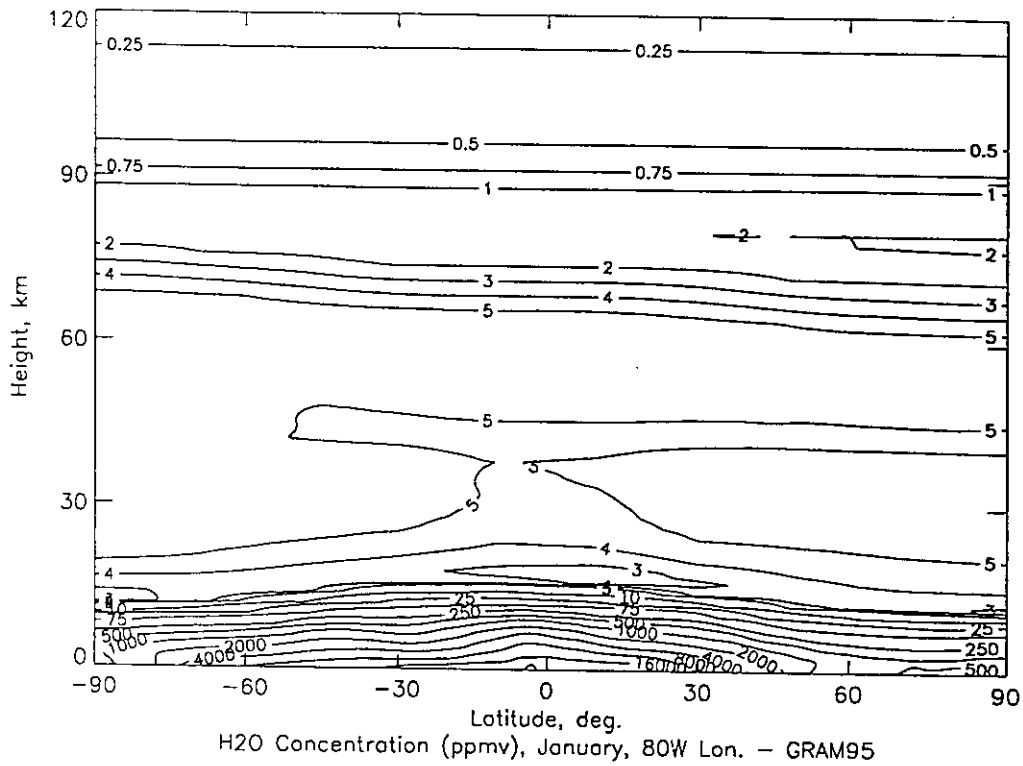

Figure 3.13. Height-latitude cross section of monthly mean water vapor volume concentration (ppmv) for January (period-of-record) from GRAM-95.

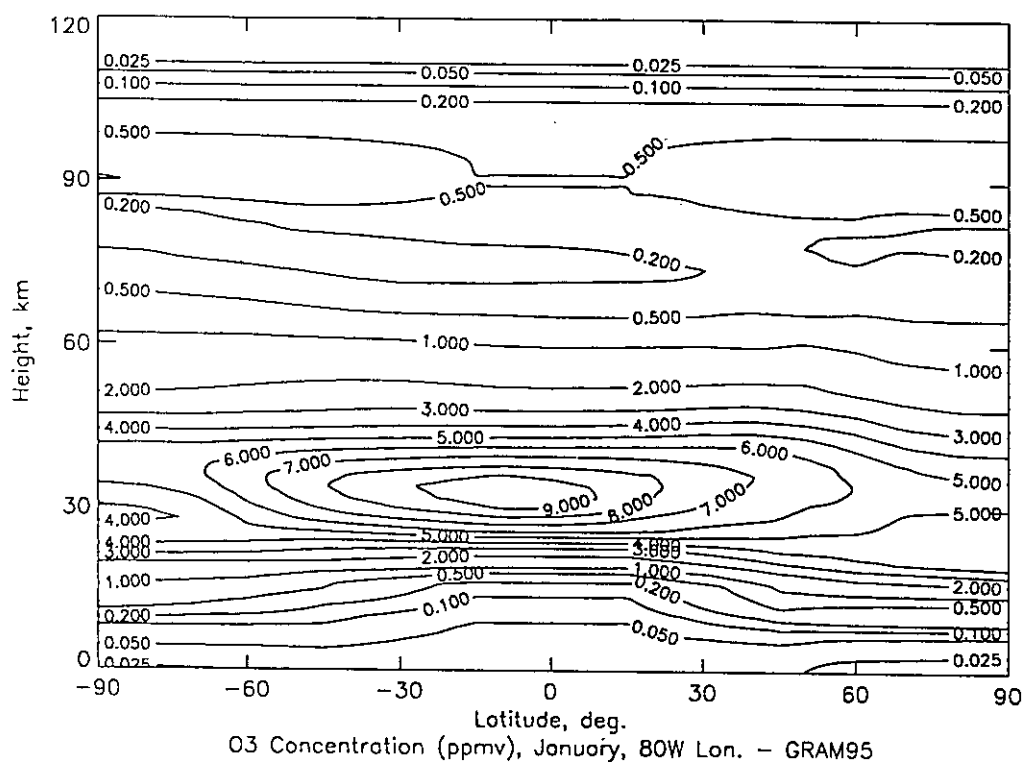

Figure 3.14. Height-latitude cross section of monthly mean ozone volume concentration (ppmv) for January (1995) from GRAM-95.

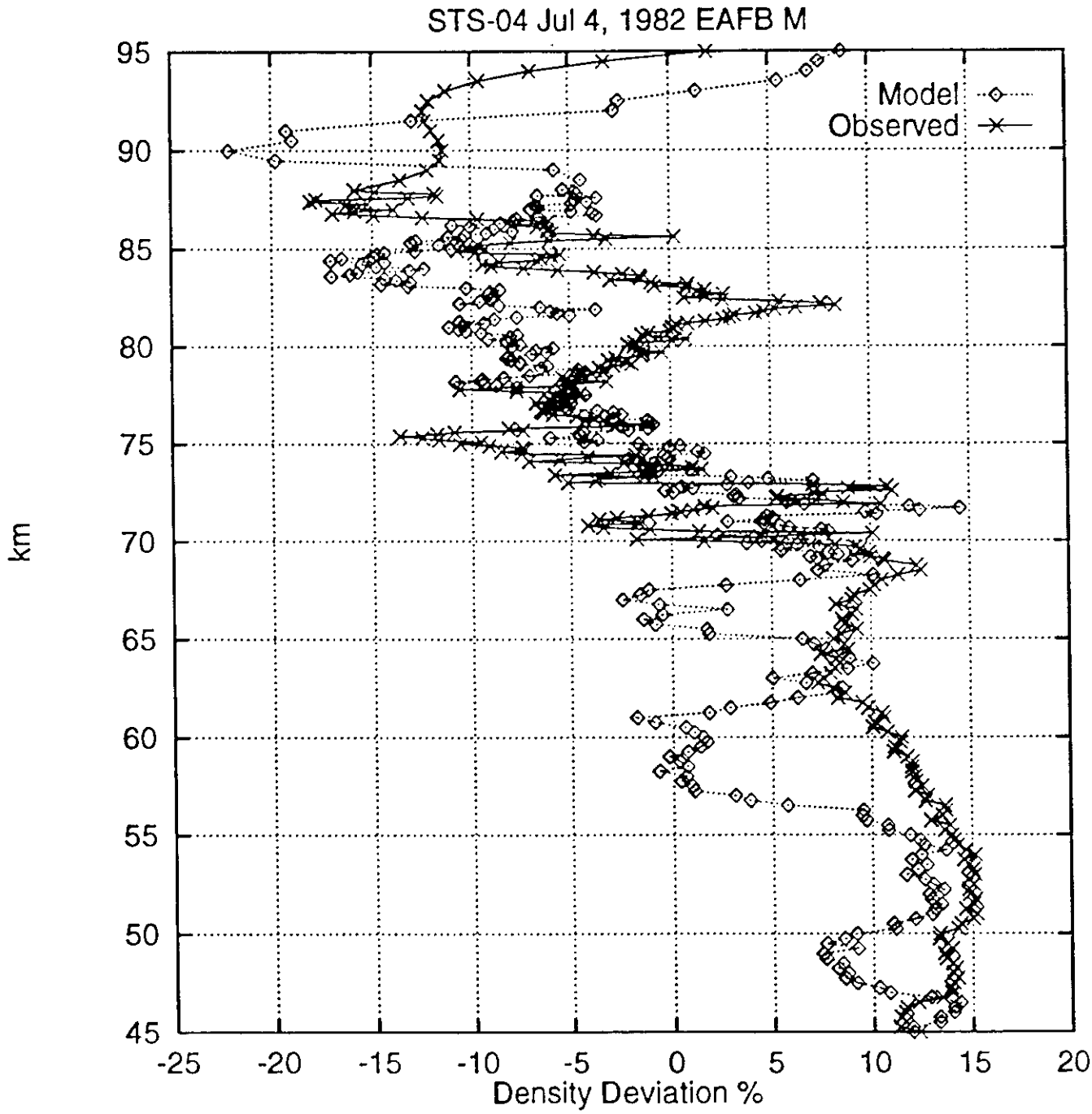

Figure 3.15. Vertical profile of GRAM-95 density perturbations (percent deviation from 1976 U.S. Standard Atmosphere) from the GRAM-95 variable-scale perturbation model (diamonds) and observed (x's) for the STS-04 reentry on July 4, 1982 (largest shears observed over the 32 reentries in tables 3.2 and 3.4).

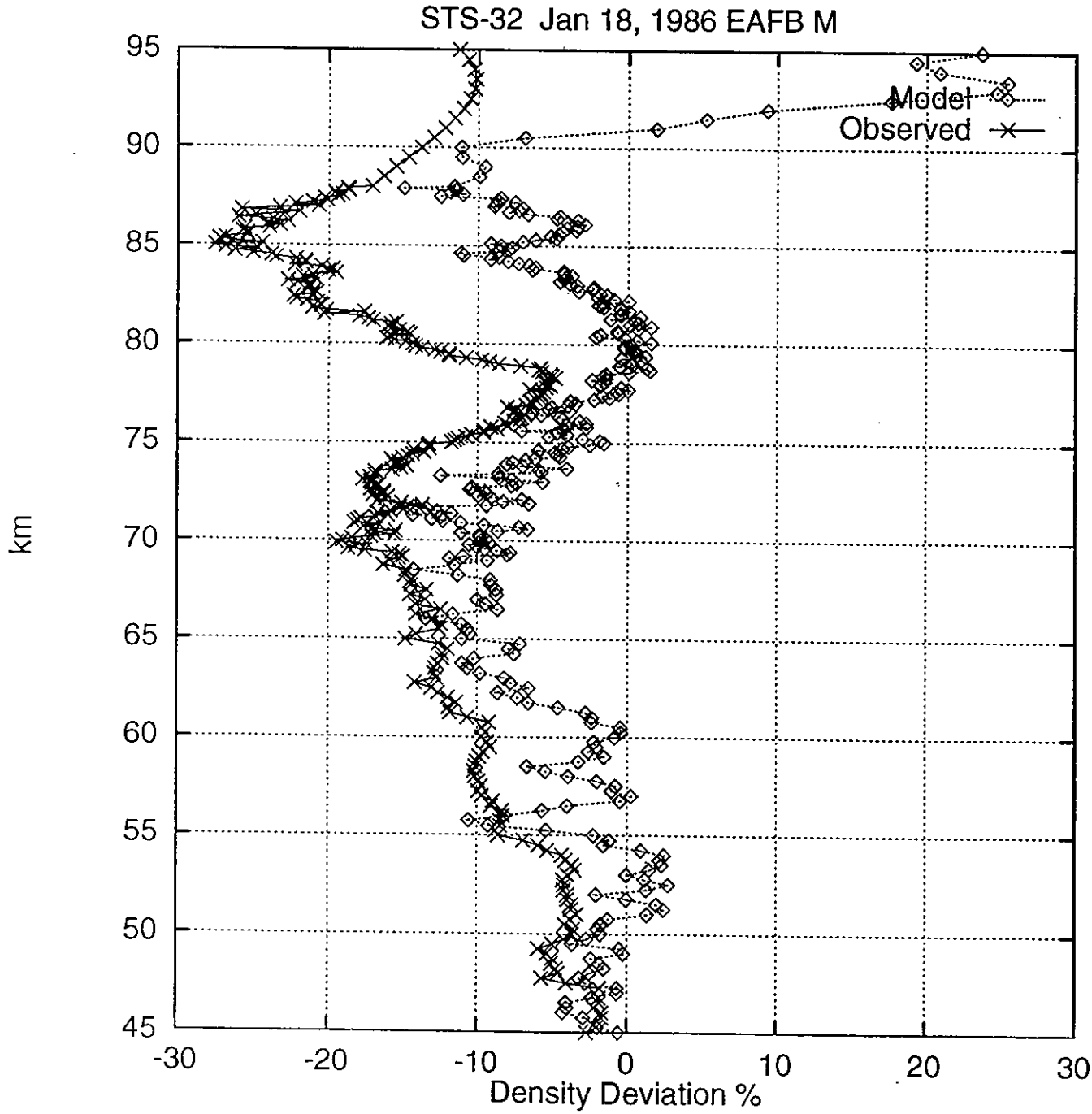

Figure 3.16. Vertical profile of GRAM-95 density perturbations (percent deviation from 1976 U.S. Standard Atmosphere) from the GRAM-95 variable-scale perturbation model (diamonds) and observed (x's) for the "STS-32" (61-C) reentry on January 18, 1986 (one of the small shear cases in tables 3.2 and 3.4).

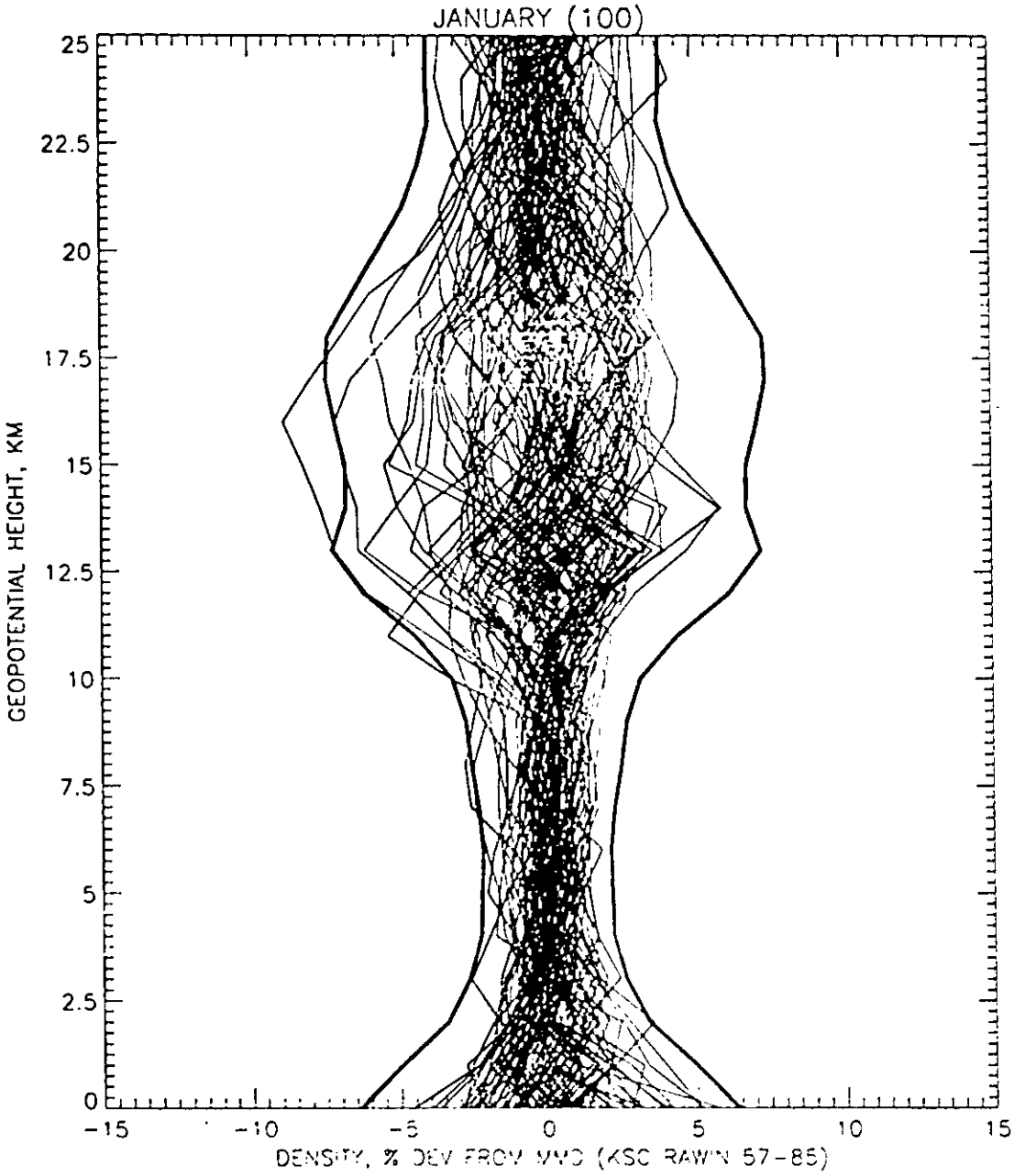

Figure 3.17. A sample of 100 profiles of density (percent deviation from monthly mean), measured by 1-km vertical resolution rawinsondes, for January 1957 to 1985 at KSC. Heavy lines are the envelope of ±3 standard deviations.

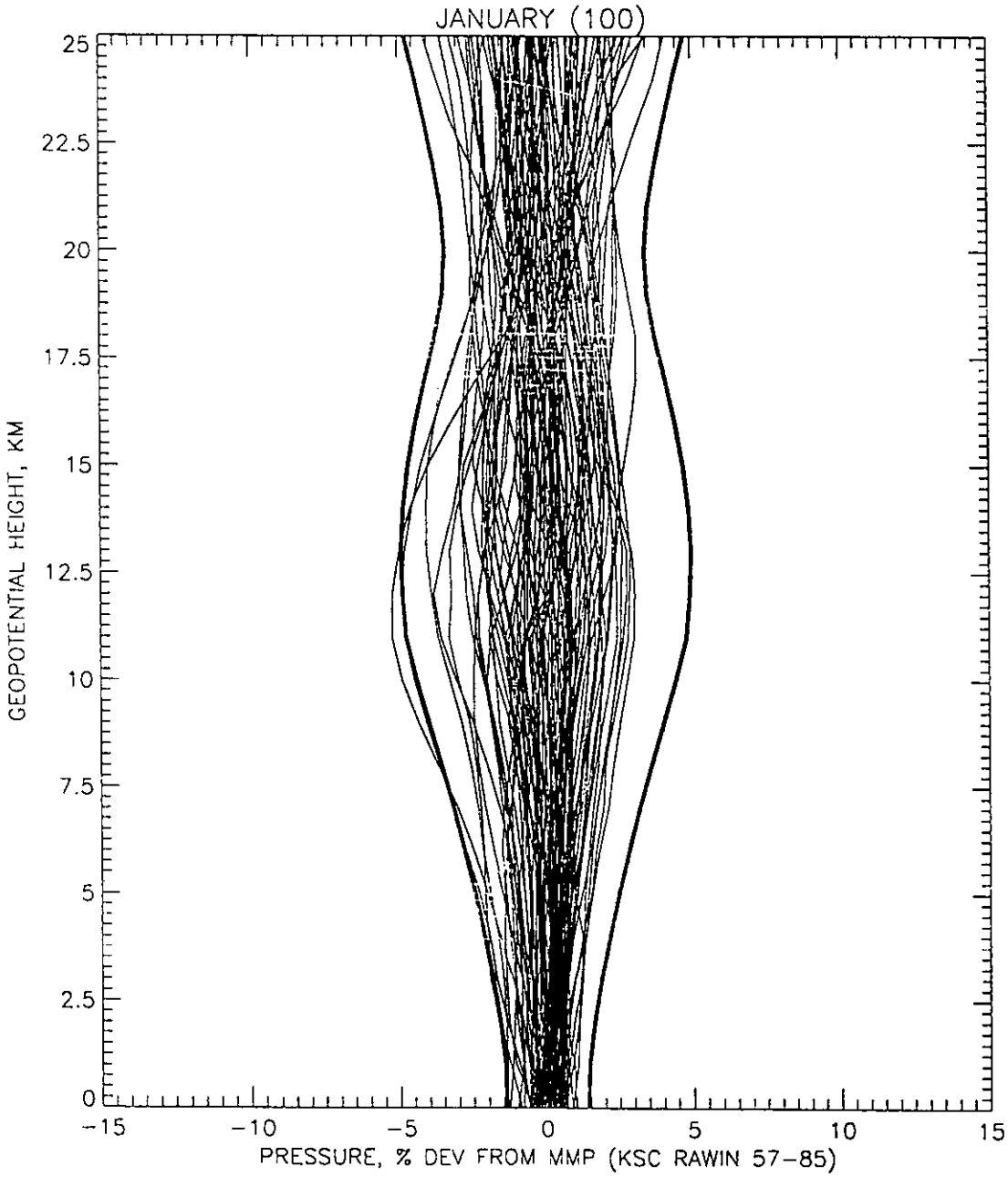

Figure 3.18. A sample of 100 profiles of pressure (percent deviation from monthly mean), measured by 1-km vertical resolution rawinsondes, for January 1957 to 1985 at KSC. Heavy lines are the envelope of ±3 standard deviations.

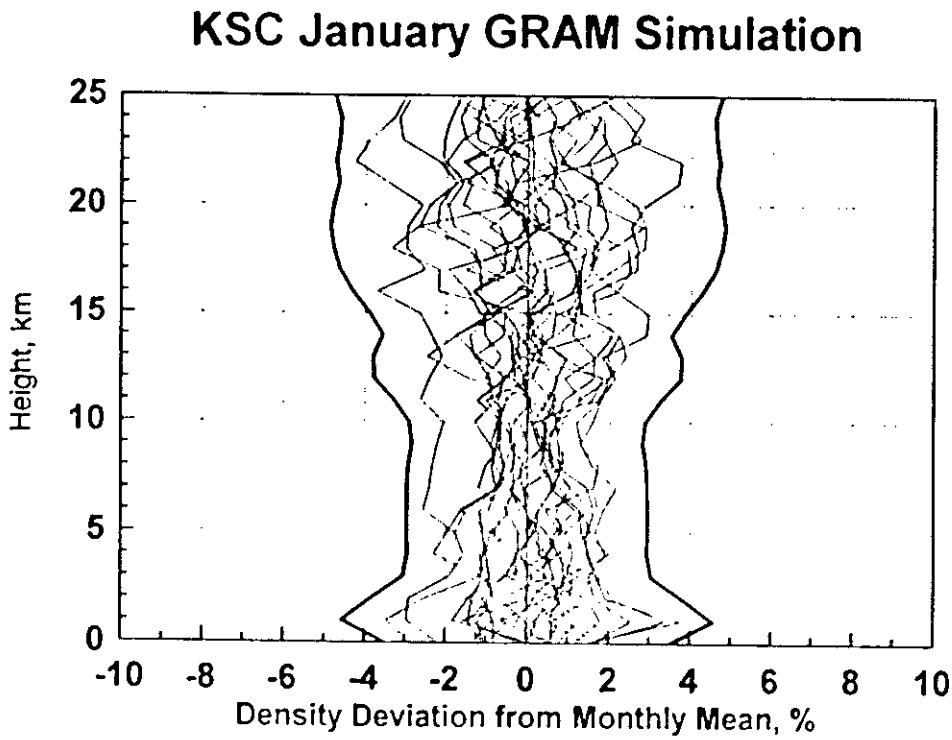

Figure 3.19. A sample of 25 profiles of density (percent deviation from monthly mean), simulated by GRAM-95, for January (1980 to 1991 period of record) at KSC. Heavy lines are the envelope of ±3 standard deviations.

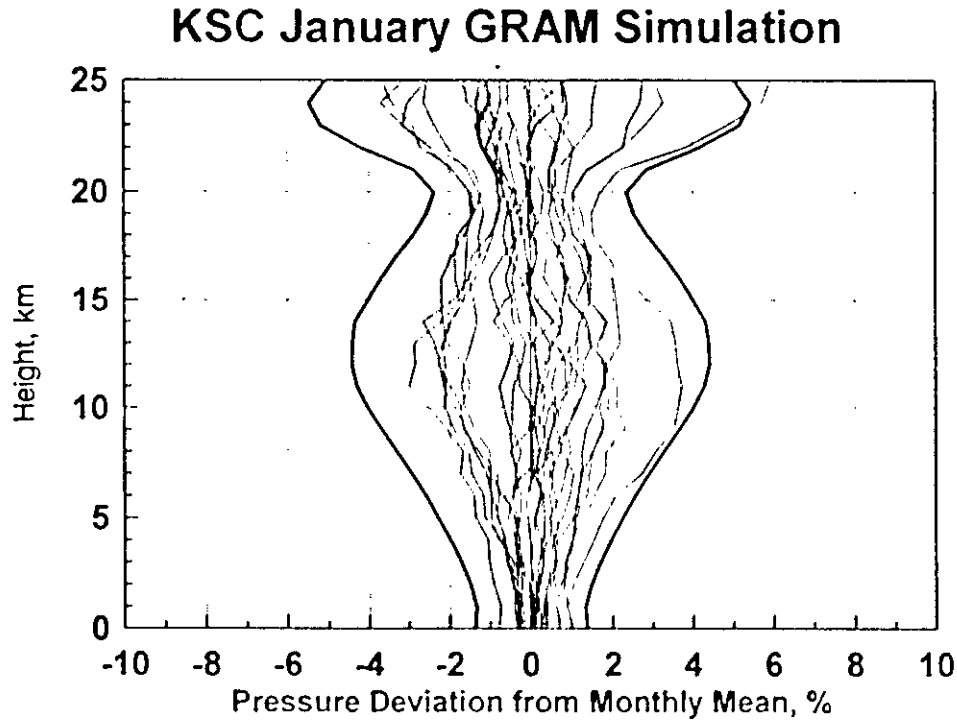

Figure 3.20. A sample of 25 profiles of pressure (percent deviation from monthly mean), simulated by GRAM-95, for January (1980 to 1991 period of record) at KSC. Heavy lines are the envelope of ±3 standard deviations.

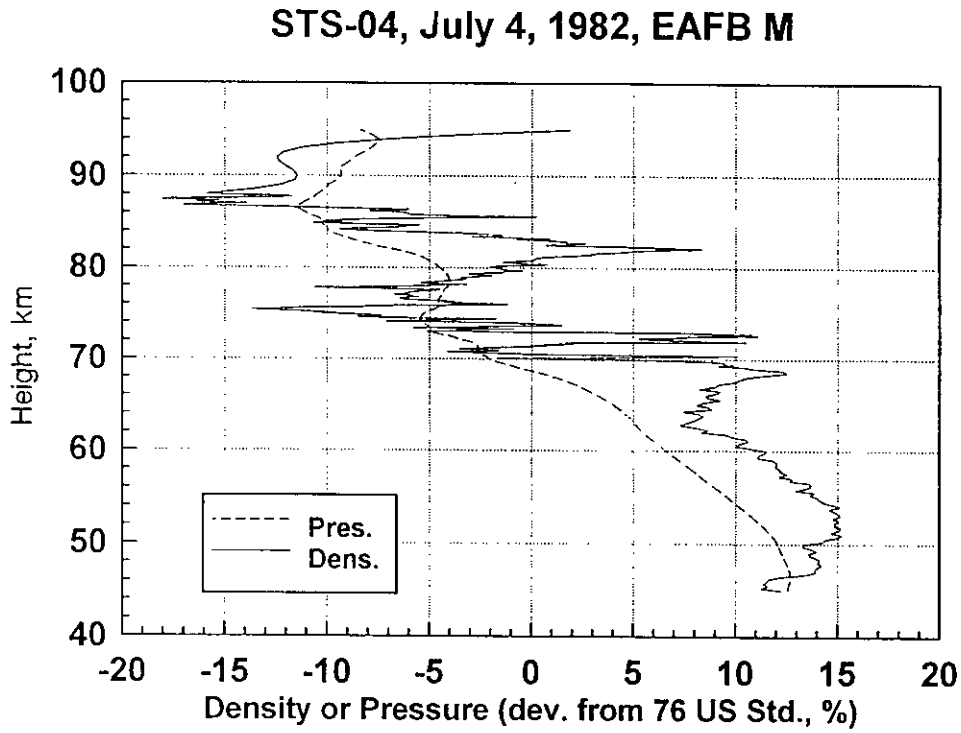

Figure 3.21. The observed profiles of density (solid line) and pressure (dashed line) along the reentry trajectory of STS-04, expressed as percent deviation from the 1976 U.S. Standard Atmosphere values.

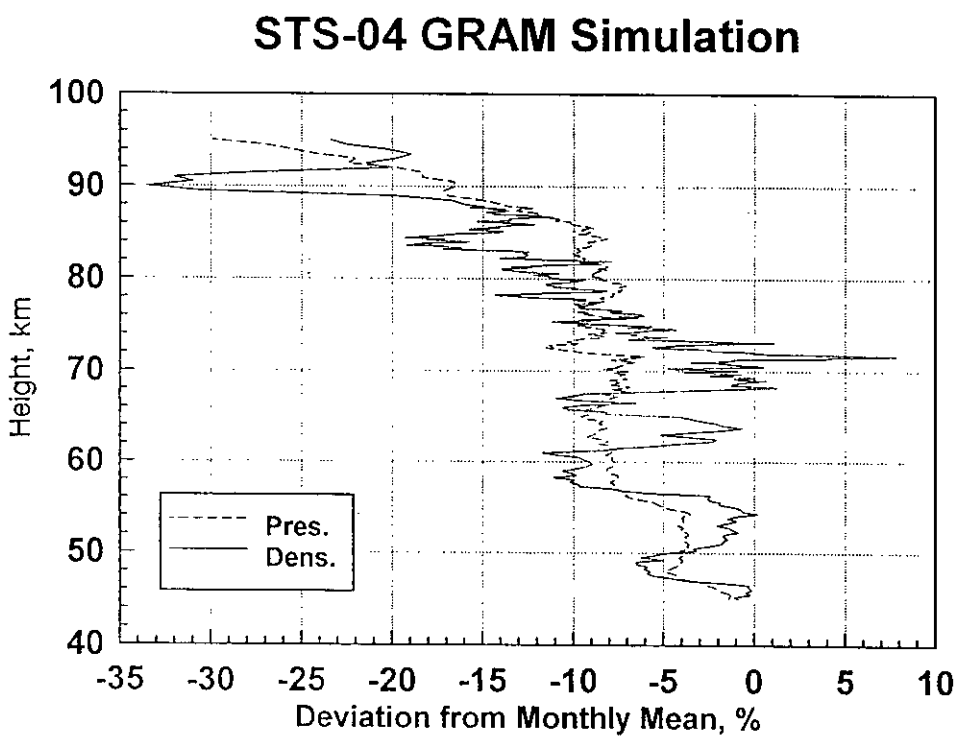

Figure 3.22. GRAM-95 simulated profiles of density (solid line) and pressure (dashed line) along the reentry trajectory of STS-04, expressed as percent deviation from the monthly mean values.

4. GRAM-95 USER'S GUIDE

4.1 General Program Review

The 1995 version of the Global Reference Atmospheric Model, GRAM-95, like its predecessors, is designed to produce atmospheric parameter values either along a linear path (to be called a profile), with automatically stepped height, latitude, longitude, and time increments, or along any set of related time-position data (to be called a trajectory), which must be provided to the program as a separate input file.

The GRAM-95 has been developed primarily for a Unix environment, specifically SGI's IRIX system, but its code may be adapted for other platforms relatively easily (e.g., for VAX platforms set the variable, iswap, to zero in the main driver file, gram95.f, before compiling and running, see section 4.7). However, care must be taken to properly maintain the necessary links to the two data bases (three, if a trajectory data file is desired) needed for proper functioning. These data bases are the GUACA data base, jointly produced by the U.S. Navy and NOAA and supplied via a CD-ROM medium (see appendix A) and the GRAM-95's own "atmosdat" file which includes various data bases for pressure, density, temperature, winds, species concentrations, and random perturbation statistics (see section 4.3). The primary input data file in the Unix environment consists of lines with pathnames pointing to the location of these data bases and to desired output files, as well as two lines of "initial" data containing the values of the program options, initial position, profile increments, solar activity, times of year and day, and other information required before the calculations can begin (see appendix B).

Output of the GRAM-95 may consist of as many as three files. The primary output file presents values of mean pressure, density, temperature, and u, v, w wind components, along with their associated "total" values (i.e., mean plus perturbation), and actual perturbation values which entered into the total calculations. In addition, moisture values have now been included (see appendix B). Another output file, selectable by the user, presents concentration values for several atmospheric species, including water vapor (see appendix B). A third output file was designed to be both selectable and easily modified by the user as input to other programs (fig. 4.2).

A complete discussion of the input, output, program requirements, and operational characteristics of the GRAM-95 program is given in the following sections of this user's guide.

4.2 The GUACA Data Base (0 to 27 km)

The GUACA data base's CD-ROM storage hierarchy has been built into the GRAM-95 code. Thus, if some or all of the data base is to be stored on disk rather than being left accessible via the CD-ROM drive, that same structure must be followed in the disk storage scheme, or the code must be modified accordingly.

All of the GUACA files required by the GRAM-95 program reside on the CD-ROM under the subdirectory, 2p5deg. Under that subdirectory are eight subdirectories for the individual years 1985 through 1991 and the period-of-record (por), the latter presenting the means over the years 1980 to 1991. Each of these "yearly" subdirectories holds 12 subdirectories, one for each individual month, and each monthly subdirectory holds 20 files (except por holds 21), although only the following 14 are needed by the program: mtmpxx.dat, mdenxx.dat, mdwpxx.dat, muwdxx.dat, mvwdxx.dat, mhgtxx.dat, mslpxx.dat, stmpxx.dat, sdenxx.dat, sdwpxx.dat, suwdxx.dat, svwdxx.dat, shgtxx.dat, and sslpxx.dat, where "xx" is the month.

The files' names are indicative of the type of data they hold, those beginning with "m" hold mean data while those beginning with "s" hold the standard deviation of those means. Likewise, those having "tmp" in their names hold temperature data, "den", density, "dwp", dewpoint, "uwd", u-component wind, "vwd", v-component wind, "hgt", height, and "slp", sea-level pressure data.

For more details on the GUACA data base, refer to appendix A. Also see section 4.7 for possible code modifications that might be required to read the GUACA data base on your system.

4.3 The "atmosdat" File

The "atmosdat" file consists of several types of data in several formats, all of which are easily readable as ASCII characters. The file requires a little more than 2.5 Mb of disk storage. The first portion of the file is essentially the same as parts of the "SCIDAT" file of GRAM-90 (Justus et al., 1991). The remainder of the file has been added, expanding capabilities for the current GRAM-95 version.

Zonal-Mean Data. The zonal-mean data consists of 12 monthly sets of zonal-mean values for pressure, density, temperature, and zonal wind, tabulated at 10° latitude intervals from –90° to +90° and 5-km height increments from 20 to 120 km for each month. Prefix codes, ZP, ZD, ZT, and ZU indicate pressure, density, temperature, and zonal wind, respectively. Each record contains the code, the month, the height in km, and the –90°, –80°, ..., 80°, 90° latitude values of the parameter expressed as a four-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 2,761 with an exponent at the end of the record of –6 would be the same as $2{,}761\times10^{-6} = 2.761\times10^{-3}$. Pressure data are in units of N/m^2, density values are in kg/m^3, temperatures are in K, and zonal winds are in m/s. The zonal-mean data set contains 1,008 FORTRAN readable records, with the code and 22 integer values in each record (format A2, I4, I5, 19I6, I4).

Stationary Perturbations. The stationary perturbations are latitude-longitude dependent, relative perturbations, to be applied to the zonal-mean values. Data for each of 12 months are given for both Northern and Southern Hemisphere latitudes. Prefix codes SP, SD, ST, SU, and SV indicate stationary perturbation values for pressure, density, temperature, zonal (eastward), or meridional (northward) wind components, respectively. Each record contains the code, the month, the height in km, the latitude (–80 to +80) in degrees, and then 18 values of stationary perturbations, in per mil (percent/10) for the thermodynamic variables, and 0.1 m/s for the winds, at longitude 180°, 160° W, 140° W, ..., 140° E, and 160° E. The monthly mean value, y_m, for parameter, y (pressure, density or temperature), at any latitude and longitude can be computed from the zonal-mean value, z_y, at the latitude, and the stationary perturbation, s_y (in per mil), at the latitude and longitude, by the relation:

$$y_m = z_y\,(1+s_y/1{,}000)\ . \tag{4.1}$$

For zonal (eastward) wind components, the monthly mean is $u_m = z_u+s_u$, while meridional (northward) mean winds are equal to the stationary perturbation value, i.e., $v_m = s_v$. Note that the stationary perturbation values at 90° latitude are always zero. The stationary perturbation data consists of 15,300 FORTRAN readable records, with a code and 21 integer values in each record (format A2, 21I5).

Random Perturbations. Random perturbation magnitudes (standard deviations) are latitude dependent only. Prefix codes RP, RD, RT, RU, and RV indicate random perturbation magnitudes in pressure, density, temperature, zonal wind, and meridional wind components, respectively. Each random perturbation record has the code, the month, and the height in km, followed by 19 values of random perturbation magnitude, at 10° latitude increments from −90° to +90°, followed by a common exponent value. These data give the relative standard deviations σ_p/p, σ_ρ/ρ, and σ_T/T (in percent) for use in the random perturbation model. The code RU and RV data are similar, except that the wind perturbations are absolute deviations in m/s, and cover the height range 0 to 200 km, whereas the RP, RD, and RT data cover 20 to 200 km. Random perturbation magnitudes for 0- to 27-km altitudes are provided by the GUACA data base for both the thermodynamic and wind variables. The random perturbation data consist of 1,596 FORTRAN readable records with a code and 22 integer values in each record (format A2, I4, I5, 19I6, I4).

Large-Scale Fraction Data. From daily difference analysis described in section 2 of Justus et al. (1980), the fraction of the total variance (σ^2 from the random perturbation data) contained in the large-scale perturbations has been determined as a function of height and latitude. The "atmosdat" file contains the annual average fraction (expressed as per mil) of total variance contained in the large-scale. Large-scale and small-scale magnitudes, σ_L and σ_s, are computed from the fractional data, f_L, in per mil (code PT for pressure, density, and temperature or code PW for winds), by the relations

$$\sigma_L = (f_l/1{,}000)^{1/2}\ \sigma_T\ , \tag{4.2}$$

$$\sigma_s = ((1-f_L)/1{,}000)^{1/2}\ \sigma_T\ , \tag{4.3}$$

where σ_T is the total perturbation magnitude. The code PT and PW data sets each contain 25 FORTRAN readable records, with code word PT or PW, followed by 17 integer values in each record (format A2, 17I5) for code PT and 12 integer values (format A2, 12I5) for PW code records. In the GRAM-95 data base, significant changes have been made in the large-scale fraction values for pressure perturbations, and for density and temperature perturbations below about 40 km (see discussion in section 2.7 and sample results in section 3.4).

Density-Velocity Correlations. Daily difference analysis was also used to evaluate the cross correlations for use in the velocity perturbation model described in section 2 of this report and the Justus et al. (1980, 1988) reports. Both large-scale and small-scale values of the density-velocity correlations were evaluated and are given in the "atmosdat" data base (codes CL and CS) in per mil (i.e., divide by 1,000 to get correlations in the range −1 to +1). The code CL and CS data consist of 50 FORTRAN readable records, with code word CL or CS followed by 12 integer values in each record (format A2, 12I5).

All of the foregoing code values in the "atmosdat" data base are ingested into the GRAM-95 program through the subroutine setup found in the initial.f file.

Variable-Scale Random Perturbation Model Data. Variable-scale random perturbation model data appears next in the "atmosdat" data base. They consist of 29 FORTRAN readable records, containing a code (RS) and 10 real (floating-point) values each (one height and nine associated parameters; see section 2.6 for discussion), which are ingested into the GRAM-95 program through the subroutine scalinit found in the initial.f file. The format is A2, F5.0, 2F7.1, F7.2, F7.1, 5F7.2.

The remaining data in the "atmosdat" data base are values needed for atmospheric constituent concentration calculations.

LaRC Data. The next segment of data in the "atmosdat" data base is the NASA LaRC concentration data (McCormick and Chiou, 1994) for the atmospheric constituent H_2O. The data consist of four groups of 35 FORTRAN readable records of a code and nine data values each (one height and eight associated array values at latitudes –70° through +70°), and are ingested into the GRAM-95 program through the subroutine concinit found in the speconc.f file. The four record groups present seasonal data at latitudes –70° through +70° for heights 6.5 through 40.5 km. Codes are LDJF for December-January-February, LMAM for March-April-May, LJJA for June-July-August, and LSON for September-October-November.

AFGL Data. The next-to-last segment of data in the "atmosdat" data base is the AFGL concentration data (Anderson et al., 1986) for the atmospheric constituents, H_2O, O_3, N_2O, CO ,and CH_4. The data consist of five groups of 50 FORTRAN readable records of six values each (one height and five associated array values, for each of the five constituents), and are also ingested into the GRAM-95 program through the subroutine concinit. The five record groups present tropical (AFTR), midlatitude summer (AFMS), midlatitude winter (AFMW), subarctic summer (AFSS) and subarctic winter (AFSW) data. Tropical data are for latitudes of ±15°; mid-latitude data are for ±45°; and subarctic data are for ±60°. As necessary, a 6-month displacement is used to estimate Southern Hemisphere values from Northern Hemisphere values.

MAP Data. The last segment of data in the "atmosdat" data base is the Middle Atmosphere Program (MAP) concentration data (Keating, 1989) for the years 1979 to 1983. The code O3 data are for ozone at 24 pressure levels (0.003 to 20 mbar) for each of 12 months. Each of the 288 records consists of the code, the month, the pressure level (mbar), and data values for 17 latitudes (–80° to +80°) and a common exponent value. The code H2O data are for water vapor at 11 pressure levels (1.5 to 100 mbar) for each of 12 months, followed by 8 annual values (denoted by month 13) for the pressure levels 0.01 to 1.0 mbar. There are a total of 140 H2O records. Each contains the code, the month, the pressure level (mbar), and five mean values at latitudes –60°, –45°, ±15°, +45°, and +60° (with –60° having been estimated by 6-month displacement of +60° data), followed by five standard deviation values at the same latitudes. The code N2O data are for MAP nitrous oxide (and similarly the code CH4 data are for methane). The N2O and CH4 data consist of 204 records each. Each records contains the code, the month (1 to 12), the pressure level (17 levels, 0.1 to 20 mbar), data at 15 latitudes (–70° to +70°) and a common exponent. The code OX data is for atomic oxygen at 19 altitudes (130 to 40 km) for each of 12 months. There are 228 total records, each containing the code, the month, the height (km), the data values at 17 latitudes (–80° to +80°) and a common exponent. Units of the MAP code OX data are atoms/cm^3. The MAP code O3, H2O, and CH4 species data values are volume concentrations in units of parts per million by volume (ppmv), while the code N2O data are in parts per billion by volume (ppbv).

The LaRC and AFGL data are read in by subroutine concinit, while the MAP concentration data are read in by subroutine mapinit (both in the initial.f file).

4.4 The Input Data File

The input data file (e.g., "input.dat") is read into the program by the init subroutine, located in the initial.f file, and usually consists of eight lines (it may have nine or more if the user desires to run the same profile again with different random number seeds by placing each seed on a new line, as described below). The first six lines consist of "pathnames" (up to 64 characters in length) pointing

to various files, while the last two lines (in the usual case) provide the initialization input data as in previous versions of the GRAM (see example input file in appendix B).

Lines 1 through 6. The first line is the pathname for the "atmosdat" data base (i.e., the atmpath parameter), the second is the pathname for the GUACA data base (guapath), and the third is the pathname for the trajectory data file (trapath) if one is desired, otherwise an entry of "null" is entered. The fourth line is the pathname for the standard output file (prtpath) which, if it does not already exist, and standard output is desired, is created. The fifth line is the pathname for the special user-formatted file (nprpath) if one is desired, otherwise an entry of "null" is entered. The sixth line is the pathname for the species output file (conpath) which, like the standard output file, is created if its output is desired and it does not already exist. If any files, pointed to by the fourth through the sixth lines, do already exist, they will be overwritten, thus some care must be taken to rename the already existing files if the user wishes to keep them.

Line 7. The seventh and eighth lines of the input data file contain free-field (list-directed) initialization data (values may be separated by either spaces or commas). The seventh line consists of 19 values:

1. Initial height—h1: The initial height, in kilometers, for the beginning point of the profile or trajectory (although in the latter case, the beginning point is read in as the first record of the trajectory file). This can be any positive real number.

2. Initial latitude—phi1: 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 is made:

$$\text{lat.} = (180-|\text{lat.}|)(\text{lat.}/|\text{lat.}|) \quad , \tag{4.4}$$

$$\text{lon.} = \text{lon.}+180 \quad . \tag{4.5}$$

Both the initial latitude and initial longitude, below, are real number (floating-point) parameters.

3. Initial longitude—thet1: The longitude of the initial position, in degrees, with west longitudes negative. At any time during the run, if a longitude gets outside the −180° to +180° limits, it is put back into that range by adding or subtracting 360°, as necessary.

4. Solar 10.7-cm flux—f10: The daily value of solar 10.7-cm radio noise flux (F10.7) in units of 10^{-22} Wm^{-2} Hz^{-1} Bandwidth (the normal units for this parameter) at the time for which the atmospheric values are to be computed. This parameter is used only in the altitude range where the NASA/MSFC MET (Jacchia) model (Hickey, 1988a,b) is invoked (via subroutine jacmod and associated subroutines—jacch, j70, tme, tinf, jac, slv, slvh, fair5, and gauss—and functions—molwt and temp, found in the models.f and metprog.f files), thus, for altitudes below 90 km, a value of zero may be used. Historically, a value of 230 has been used for both design steady-state, as well as maximum solar activity conditions. For "quiet sun" conditions, a value of 150 may be used. Both the daily solar 10.7-cm flux and the mean solar 10.7-cm flux, below, are real number variables. When running the GRAM model in the altitude range of the MET model, the following inputs should be used relative to the daily F10.7 values. For dates prior to the current date, the previously observed daily values of F10.7 should be used. For the current date, the currently observed daily value of F10.7 should be used. For dates subsequent to the current date, the appropriate month value of the 13-month, smoothed mean F10.7 (see discussion below) estimated value, based on the output of

the NASA/MSFC linear regression program model, should be used. This output is updated monthly and is available upon request to Chief, Electromagnetics and Environments Branch, NASA/MSFC.

5. Mean solar 10.7-cm flux—f10b: The ±81-day (162-day) mean solar 10.7-cm radio flux, centered at the time for which the atmospheric values are to be computed. This parameter, like the f10 parameter, is used in the altitude range where the MET model is valid, to compute the nighttime minimum global exospheric temperature (equation 14 in Jacchia, 1970). Like the f10 parameter, a value of zero may be used for altitudes below 90 km, a value of 150 for "quiet sun" conditions, and a value of 230 for design or "active sun" conditions. When running the GRAM model in the altitude range of the MET model for dates 81 days or more prior to the current date, the previously observed values of daily F10.7 should be used to calculate the ±81-day (162-day) mean solar 10.7-cm radio flux centered at the time 81 days or more prior to current date. For the dates 81 days prior and up to the current date, the observed daily F10.7 should be used plus the 13-month, smoothed mean F10.7 estimated value given at monthly intervals, based on the previously mentioned NASA/MSFC linear regression program model output, and averaged to obtain a ±81-day (162-day) estimate of the mean solar 10.7-cm radio flux centered at the time for which atmospheric values are to be computed. For dates 81 days or more subsequent to the current date, the 13-month smoothed mean F10.7 estimated value based on the output of the NASA/MSFC linear regression program model should be used for the ±81-day (162-day) mean solar 10.7-cm radio flux value. This 13-month smoothed mean F10.7 output is updated monthly and is also available upon request to Chief, Electromagnetics and Environments Branch, NASA/MSFC.

6. Geomagnetic index—ap: The 3-hourly value geomagnetic index, a_p, taken 6 hours prior to the time for which the atmospheric values are to be computed. This parameter is used to compute a geomagnetic correlation to the exospheric temperature (equation 22 in Jacchia, 1970). As with the solar radio flux parameters (f10 and f10b), this is a real number parameter, and a value of zero may be used for altitudes below 90 km, a value of 20.3 for design steady-state conditions, and a value of 400 for maximum conditions. When running the GRAM model for the altitude range of the MET model for dates prior to the current date and the current date, the observed 3-hourly value of a_p, taken 6 hours prior to the time for which the atmospheric values are to be computed, should be used. For dates subsequent to the current date, the 13-month, smoothed a_p estimated value given for the monthly intervals for which the atmospheric values are to be computed, should be used. The 13-month, smoothed a_p output is updated monthly and, like the previous two values, is available upon request to Chief, Electromagnetics and Environments Branch, NASA/MSFC.

7–9. Date—mn, ida, iyr: The date for the starting time of the trajectory or profile evaluation in month/day/two-digit year form, as three integer values. Except in the Jacchia height range (above 90 km), the day of the month has no direct effect on the program calculations. The month is used to establish which portions of the GUACA and "atmosdat" data bases to read. The year value may also be used to establish which portion of the GUACA data base is to be read in the case where a specific year is desired (i.e., the iguayr parameter is set to 2; see item 6 of the eighth line, below). For years before 1985 or after 1991, individual GUACA years are not available. Above the GUACA altitudes (above 27 km), the year has no effect on the calculations, except for computing the long-term climatological trend values for species O_3, N_2O, CH_4, CO_2, and CO (see section 2.4).

10–12. Greenwich time—ihr0, min0, sec0: The Greenwich mean time (UTC) for the starting position in hours, minutes, and seconds, as two integer values and a real. Since the time of the day impacts only the MET model altitude regions, if heights are below 90 km, the starting time serves 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 MET section conditions, and for maximum conditions, corresponding to a local time of 1400 hours.

13. Latitude increment—dphi: If a linear profile is to be generated automatically, this is the real number latitude increment (in degrees, with northward positive) between successive profile positions. The new latitude would be the old latitude plus the latitude increment. For a profile with decreasing latitude (i.e., on a descending node, or going southward), the increment must be negative. Use zero if a separate trajectory file is to be read in or if a vertical profile (i.e., changing only height) is to be evaluated.

14. Longitude increment—dthet: As with the dphi parameter, if a linear profile is to be generated automatically, a real number value (in degrees, with eastward positive) for the increment between successive profile longitude positions must be provided. For a profile progressing westward, use a negative increment. Again, if a separate trajectory file is to be read in, or a vertical profile is to be evaluated, use a value of zero for this parameter.

15. Height increment—dhgt: The height increase, a real number value in km, for an automatically generated linear profile. For profiles generated downward, use a negative value of height increase. Downward generated profiles will be evaluated until the height is incremented to a value less than zero or until the maximum number of positions (item 16, first line, described next) is exceeded.

16. Maximum number of positions—nmax: The maximum number, as an integer value, of profile positions to be generated automatically, including the initial position. Use zero for this value if trajectory positions are to be read in (i.e., the trajectory option, iopt, item 18, below, has an input value greater than zero).

17. Time increment—delt: The time displacement in seconds, as a real value, between successive, automatically generated profile positions. For vertical profiles, this value is often input as zero, but the parameter may be used as a simple counter with an input value of one, which will then be incremented for each position and printed out in the time position of the output. For trajectories, the time for each position is read in with the position data (see the trajectory file section, below). The hours, minutes, and seconds parameters (read in as items 10–12, above) are updated according to the new time generated by the time increment, but only the elapsed time in seconds is printed out on the standard formatted output.

18. Trajectory option—iopt: This integer parameter tells the program whether a trajectory or a linear profile is to be evaluated. A value of zero means that a linear profile is to be generated automatically from the parameters previously read in from this input line, and a zero value is required if a "null" path is designated for the third line of this input file. 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. This positive value becomes the unit number to which the trajectory file (who's path was read in from the third line of this input file) is linked. It should not equal any "reserved" unit number of the platform being used, and must not equal any of the values chosen for the unit parameters, iopp, iu0, iup, ius, iuc, and iug through iug+14 (the iug units required to read in the needed GUACA data). If the input value for any unit number equals another, the program will flag such choices as errors which must be corrected before the program will run (see section 4.7 for error messages).

19. Output option—iopp: This integer parameter tells the program whether or not to produce a "special", user-configurable, output file (see the output data files section, below) which is convenient as input to other programs (i.e., such as plotting, etc.). As with the trajectory option above, a value of zero means that no special output is desired, and a positive value becomes the internal unit

number to which the special file (its path was read in from the fifth line of this input file) is linked. The choice of input values is governed by the same rules as for the trajectory option values, above.

With normal numbers of decimal places (and no unnecessary blank spaces), the above 19 items should fit onto one line. However, if they occupy more than the number of columns allowed on one line (usually 80) they may be spread out onto two lines if the appropriate rules of free-field input are observed. Consult the operation or FORTRAN manuals for your particular system to determine the characteristics of list-directed (free-field) input.

Line 8. The eighth and (usually) final line contains values for various unit numbers and options controlling functions of the program. The unit numbers are parameters used in read statements in the FORTRAN program to control which file is being read, the scheme being designed to obtain maximum flexibility in I/O device choices. The line consists of nine positive, list-directed (free-field) values, the first eight of which are integers with the last being a real value:

1. Screen output unit—iu0: This value is the unit number controlling program output to a computer screen. It is usually set to 0 or 6 and is one of the "reserved" unit numbers for most platforms.

2. Standard output unit—iup: This value is the unit number for the standard, formatted output file which is linked to the path previously read in from the fourth line of this input file. It may be set to 6, which is also one of the "reserved" unit numbers (usually designated as the printer) for many platforms. Any other convenient unit number may also be used for iup. If iup is input as zero, no standard formatted output is produced. In this case, progress and diagnostic messages (if any) are routed to the screen unit (iu0).

3. The "atmosdat" file input unit—ius: This value is the unit number for the "atmosdat" data file which is linked to the path previously read in from the first line of this input file.

4. Concentration file output unit—iuc: This value is the unit number for the concentration file if one is desired. It is linked to the path previously read in from the sixth line of this input file and must equal zero if that line was "null". Such would be the case if no concentration output was desired.

5. GUACA file input unit—iug: This value is the unit number for the first of the 14 consecutive unit numbers required for the GUACA files, and is linked to the path previously read in from the second line of this input file. If the heights for which calculations are desired are above 27 km, input of the GUACA data is not required and this value may be set equal to zero.

6. GUACA year option—iguayr: This parameter is a switch with valid values of either 1 or 2. If the value is 1, the GUACA period of record (por) data is used from the data base; if it is 2, the actual GUACA year (currently only valid for the 1985-1991 period), based on the iyr parameter's value (item 9 of line seven, above), is used. If invalid values are input, the program terminates with the message, "Year out of range to read GUACA data" (see section 4.7).

7. Random output option—iopr: This parameter is also a switch with valid values of either 1 or 2. A value of 1 signals the program to calculate a random perturbation for each output parameter, add it to the parameter's mean value, and output the result, along with the mean value, for each desired height, in the standard formatted output file. If the value is 2, random perturbations are not calculated. If any values other than 1 or 2 are input, the program terminates with the message, "Error in random option" (see section 4.7).

8. Initial random number—nr1: This value is the initial (seed) random number, which is required if the value of iopr equals 1, and has a valid range from 1 to 9×10^8. If the input value lies outside this range, the program terminates with the message, "First random number out of range." (see section 4.7).

9. Random perturbation scale—rpscale: This parameter is a perturbation magnitude scale, with valid real values of 0.0 to 2.0, that signals the program to calculate perturbations which are more quiescent (<1.0), of normal magnitude (=1.0), or more disturbed (>1.0). A value of zero signifies no perturbations, while a value of two signifies twice normal perturbation magnitudes.

Optional Additional Lines. Additional runs of the same profile/trajectory, with different values for the random number seed only, may be obtained by adding additional lines to the input file. Each line must consist of a single value, the new random number seed, which the program reads, then continues operation, using prior input values for all other parameters, appending the new output to the previously identified files. This process will continue until either an invalid random number seed is read or the end of the input data file is reached.

4.5 The Trajectory File

The trajectory file is only required when a trajectory, rather than an automatically determined profile, is desired. When this is the case, the path to the file must be properly defined on line three of the input file, and the trajectory option, iopt, must be properly set on line seven of the same input file, as described above. The file itself may contain an unlimited number of individual list-directed (free-field) records (i.e., lines) consisting of four real values as shown in figure 4.1: time (real seconds), height (km), latitude (±90°, with southern latitudes being negative), and longitude (±360°, with west longitudes being negative). Using the values in the first record of the trajectory file, the program evaluates the atmospheric parameters and continues looping back to read a new trajectory position until a position below the surface (height < 0.0) or the end of the file is encountered.

```
   0. 1.0947125E+02 3.8193398E+01 -6.5015404E+01
  51. 1.0796375E+02 3.9470779E+01 -6.1290642E+01
  76. 1.0599691E+02 4.0037796E+01 -5.9445267E+01
  96. 1.0402789E+02 4.0452213E+01 -5.8001106E+01
                .
                .
                .
1476.  3.9935970E+00 3.1976276E+01 -7.8639622E+00
1493.  3.0144496E+00 3.2002960E+01 -7.8682141E+00
1512.  2.0187852E+00 3.2030262E+01 -7.8702340E+00
1532.  9.8250437E-01 3.2058865E+01 -7.8725753E+00
1552. -2.1482366E-03 3.2086098E+01 -7.8748112E+00
```

Figure 4.1. Trajectory file example

4.6 The Output Data Files

There are three possible output data files. The first, the standard formatted output file, maintains the familiar arrangement of the print output of previous GRAM versions, but has now been

directed to a file to increase flexibility and to facilitate its transmission from user to user as well as to a printer. The second, the "special" format output file, is also similar in function to an output of previous versions of the GRAM, i.e., the optional "nonprint" output, and like it, has been designed primarily for use by other programs. Its ease of modification has been greatly improved in the GRAM-95, however. The third, the species concentration output file, is completely new in the GRAM-95 and provides users with concentration information for 12 significant atmospheric constituents. Like the special format output file, the species concentration output file is also optional.

The Standard Formatted Output File. The format of the standard output file (see example in appendix B) has been redesigned to be more readily readable on the normal computer screen (i.e., 80 columns) rather than on a normal printer (i.e., 132 columns), and with judicious "folding" of the output data fields, nearly all previous information has been maintained. The typical file size will generally consume 100 kb or less of disk space. Some less-useful output was pruned from heading information printed out in previous GRAM versions, but information on water vapor concentrations has been added. As in previous versions, the heading information contains a listing of the principal input data values and the Julian date, which is required by the Jacchia section of the program and is calculated internally by the program. Additionally, some comments on moisture have been added to the heading and some slight modifications were made to the column labels. A sample of a complete standard formatted output file is included in appendix B.

Positions and times, as generated by the automatic linear profile feature, or as input by the trajectory input data, are listed on the output, along with the associated calculated values of the atmospheric variables, following the column labels. Within the program, the input time in hours, minutes, and seconds are updated in that form, however only a continuously increasing time in seconds is output for each position. Thus, as has been previously mentioned, the time parameter could be used as a counter instead of as a timer, or the format could be changed in the program to output the time in any other desired form. All longitudes are converted to the −180 to +180° range before being output, and if a latitude greater than 90° in absolute magnitude is generated (or input), the transformation of equations (4.4) and (4.5) is made.

The monthly mean values of pressure, density, temperature and wind components consist of either (fig. 1.1):

1. Values calculated from the GUACA data base input if the height is 20 km or below

2. The sum of middle atmosphere zonal-mean plus stationary perturbation values if the height is between 27 and 90 km

3. A value faired between the GUACA data and zonal-mean plus stationary perturbations if the height is between 20 and 27 km

4. Jacchia (MET) model values if the height is above 120 km

5. Faired values between middle atmosphere and MET model values if the height is between 90 and 120 km.

The percent deviations from the 1976 U.S. Standard Atmosphere, on the "M-76" line, are evaluated by using standard atmosphere values computed by the subroutine stdatm, found in the gramsubs.f file. The percent deviations are evaluated by the relations $100(T-T_s)/T_s$, $100(\rho-\rho_s)/\rho_s$, and $100(p-p_s)/p_s$, where the subscript s refers to the standard atmosphere values. This subroutine accurately reproduces the tabulated 1976 U.S. Standard Atmosphere values to within an accuracy of

better than 0.2 percent above 90 km and even more accurately in the height region below 90 km, where the molecular weight is constant. Since the 1976 U.S. Standard Atmosphere is not defined above 1,000 km, the percent deviations output for heights above 1,000 km are zero. Because the MET model is sensitive to solar activity conditions, large deviations from U.S. Standard Atmosphere values can be produced in this height range for certain ranges of F10.7 and a_p values.

The parameter values output on the "Tot." line are the monthly mean values, as defined above, plus the random perturbations. These mean-plus-perturbation values represent those which would be typical "instantaneous" evaluations of the pressure, density, temperature, and winds. The percent deviations from the U.S. Standard Atmosphere, on the "T-76" line, are computed in the same way as for the percent deviations of the monthly mean values from the standard atmosphere.

Values on the "H2O" line are the mean water vapor values, expressed as vapor pressure (N/m^2), vapor density (kg/m^3), dewpoint temperature (K), and relative humidity (percent). Mean water vapor values are computed from the GUACA, LaRC, MAP, or AFGL data, according to altitude. Fairing is also used for a smooth transition between these data sources (fig. 1.2). Values on the "sigH" line are standard deviations in water vapor, in terms of the same units as the mean water vapor values.

The values on the "ranS", "ranL", and "ranT" lines are the small-scale, large-scale, and total random perturbations, evaluated at the output time and place. The values on the "sigS", "sigL", and "sigT" lines are the standard deviations of the small-scale, large-scale, and total random components at the output time and place. According to the gaussian distribution, on which the random perturbations are based, the perturbation values should be within the range $\pm\sigma$ 68 percent of the time and outside the range $\pm\sigma$ 32 percent of the time. Similarly, the perturbation values should be within the range $\pm 2\sigma$ 95 percent of the time and outside the range $\pm 2\sigma$ 5 percent of the time. The values of the foregoing parameters are derived from the new variable-scale perturbation model, discussed in section 2.6.

<u>The "Special" Format Output File</u>. The "special" output file is optional, controlled by the input value of the iopp parameter switch (the 19th and last item on the seventh line of the input file) and the path name (input via the nprpath item of the fifth line) as described above. If chosen for output, it typically requires less than 10 kb of disk space. As incorporated in the "official" distributed code, this output file is configured at two separate locations. The file's header definition may be found in the init subroutine of the initial.f file, in the section near the label 113, while the file's parameter output definition may be found in the atmod subroutine of the models.f file, in the section near the label 9000. Output are the mn, ida, iyr, ihr, h, phi, thet, pgh, dgh, tgh, ugh, vgh, and wgh parameters with formatting of 4I2, F6.2, 1x, F6.2, F7.2, 1x, 1p, 2(E9.3, 1x), 0p, 3(F7.1,1x), F7.4 as depicted in figure 4.2. The code at both of these locations may be modified to fit the requirements of the user, but of course the header section in the init subroutine, if desired at all, should correspond with the data output section in the atmod subroutine.

GRAM-95 - f10.7= 230.00 f10.7bar= 230.00 ap= 20.30

modayrhh	height (km)	lat (deg) (n+s-)	long (deg) (w-e+)	pressure (Nt/m**2)	density (kg/m**3)	temp (deg K)	u-comp (m/s)	v-comp (m/s)	w-comp (m/s)
					---------unperturbed (monthly mean)----------				
1 193 0	140.00	28.45	–80.53	9.481E–04	4.305E–09	670.4	–9.8	–27.7	–0.0042
1 193 0	138.00	28.45	–80.53	1.038E–03	4.929E–09	643.7	–16.2	–25.3	–0.0045
1 193 0	136.00	28.45	–80.53	1.142E–03	5.688E–09	616.3	–22.9	–23.0	–0.0048
1 193 0	134.00	28.45	–80.53	1.262E–03	6.619E–09	588.2	–29.8	–20.7	–0.0050
			.						
			.						
			.						
1 193 0	6.00	28.45	–80.53	4.873E+04	6.525E–01	260.1	20.6	2.8	0.0012
1 193 0	4.00	28.45	–80.53	6.289E+04	8.048E–01	272.0	14.0	2.0	0.0013
1 193 0	2.00	28.45	–80.53	8.037E+04	9.923E–01	281.6	7.0	1.2	0.0018
1 193 0	0.00	28.45	–80.53	1.021E+05	1.212E+00	291.5	0.8	–0.6	0.0000

Figure 4.2. "Special" format output file example

The Species Concentration Output File. The species concentration output file (see example in appendix B) is also optional, and is controlled similar to the special format output file by the value of an input parameter, iuc, which is the fourth item on the eighth line of the input file, and the pathname parameter, conpath, input via the sixth line of the input file. The file typically requires a little more than half the disk space of the standard output file, i.e., about 50 kb or less. The file's header definition may be found in the init subroutine of the initial.f file, in the section near the labels 9091 and 9013, while the output definition may be found in the atmod subroutine of the models.f file, near the label 910. Output are the h, phi, thet, ppmh2o, h2ond, ppmo3, o3nd, ppmn2o, n2ond, ppmco, cond, elt, ppmch4, ch4nd, ppmco2, co2nd, ppmn2, n2nd, ppmo2, o2nd, ppmo, ond, ppmar, arnd, ppmhe, hend, ppmh, and hnd parameters with formatting of F7.2, F8.3, F9.3, 1p, E11.3, E10.3, 2E10.3, 24x, E11.3, E10.3, 2E10.3, 0p, F8.1, 16x, 1p, E11.3, E10.3, 2E10.3, 24x, E11.3, E10.3, 2E10.3, 24x, E11.3, E10.3, 2E10.3, 24x, E11.3, E10.3, and 2E10.3 as shown in appendix B.

Selection of Special Output Parameters. As a further aid to the user, the following tables (fig. 4.3) list the standard variables available for output (e.g., in a modified "special output" file). The tables are also given in the code itself, in the atmod subroutine of the models.f file, beginning near label 920:

Position and Time parameters

h – Height (km)

phi – Latitude (degrees)

thet – Longitude (degrees), East(+) West(–)

elt – Elapsed Time (s)

Thermodynamic, wind and moisture parameters (on standard output)

	Pressure /Vap. Pr (Nt/m^2)	Density/ Vap. Den. (kg/m^3)	Temp./ Dew Pt. (K)	E-W wind (m/s)	N-S wind (m/s)	Vert. wind(m/s) RH(%)
Mean	pgh	dgh	tgh	ugh	vgh	wgh
Mean-76	pghp	dghp	tghp	n/a	n/a	n/a
Perturbed small-scale	prhs	drhs	trhs	urhs	vrhs	n/a
Stand. Dev. small-scale	sphs	sdhs	sths	suhs	svhs	n/a
Perturbed large-scale	prhl	drhl	trhl	urhl	vrhl	n/a
Stand. Dev. large-scale	sphl	sdhl	sthl	suhl	svhl	n/a
Perturbed Total Pert.	prh	drh	trh	urh	vrh	wrh
Stand. Dev. Total Pert.	sph	sdh	sth	suh	svh	swh
Mean plus Perturb.	ph	dh	th	uh	vh	wh
Total-76	php	dhp	thp	n/a	n/a	n/a
Mean H_2O	eofT	rhov	tdgh	n/a	n/a	rhp
Std. Dev. H_2O	seofT	srhov	stdgh	n/a	n/a	srhp

Species concentration parameters (on species output)

	H_2O	O_3	N_2O	CO	CH_4	CO_2	N_2	O_2	O	Ar	He	H
Concen-tration	ppmh2o	ppmo3	ppmn2o	ppmco	ppmch4	ppmco2	ppmn2	ppmo2	ppmo	ppmar	ppmhe	ppmh
Number Density	h2ond	03nd	n2ond	cond	ch4nd	co2nd	n2nd	o2nd	ond	arnd	hend	hnd

Figure 4.3. Standard variables available for output.

4.7 Program Requirements and Diagnostics

Requirements. In order to use the GRAM-95 program without modification, the user must be operating on the equivalent of an SGI computer running the IRIX operating system with sufficient disk space and an attached CD-ROM drive. The eight FORTRAN code files (described in section 4.8) must be acquired, along with the GUACA data base on CD-ROM and the atmosdat file (described in sections 4.2 and 4.3, respectively), the equivalent of an input.dat file (described in section 4.4), and a trajectory file (described in section 4.5) if desired. Then, when the GUACA data base is accessed via the CD-ROM form, the GRAM-95 program requires approximately 20 Mb to prepare the FORTRAN code for execution and then activate the resulting executable code in its native Unix environment.

As an aid to the user, the following list gives some approximate disk space or memory requirements:

FORTRAN code files	- 432 kb
Compiled code file	
(e.g., the gram95.x file)	- 8.3 Mb
Object code files	
(interim files during compilation)	- 8.5 Mb
atmosdat file	- 2.5 Mb
Input and output files	- 100 kb
Miscellaneous files	- variable
	19.8+ Mb

If even 1 month of the GUACA data base should be stored on disk rather than kept on CD-ROM, approximately 3.5 Mb of additional disk space would be required for the necessary 14 files of each month, a total GUACA requirement of nearly 42 additional megabytes of disk space if all 12 months are loaded onto the disk. Consequently, the recommended mode of operation is via CD-ROM if possible.

If problems are encountered when trying to read the GUACA data for the first time on your system, there are nine parameters, whose values can be changed within the main "gram95.f" code, that may allow the data to be read without further code changes. The nine parameters are "iswap," "iblwd," "irlbw," "dirsep," "endsep," "termchar," "nhdr," "sysform," and "scrstat." Parameter iswap is a switch to control byte-swapping in the GUACA data, which may be required for certain platforms, e.g., swapping is required for SGI machines. To prevent swapping (e.g., on a VAX), set iswap = 0. Some platforms allow the byte swapping to be done in an external (system-level) allocate or assign statement. For example, on a Cray (UNICOS) system, the statement:

"assign -F null -N vms -a filepathname fort.uu"

(in place of the FORTRAN "open" statement) assigns FORTRAN unit "uu" as a "pure" (binary) file and performs the byte reversal. Parameter iblwd is the block length, in 4-byte words, if the GUACA files have to be preread into a scratch file (iblwd = 0 means no prereading necessary; on a VAX use iblwd = 128). Parameter irlbw is 4 if unformatted file record lengths are specified in bytes (e.g., Sun, RS/6000); irlbw is 1 if unformatted file record lengths are specified in 4-byte words (e.g., SGI, VAX). Some systems allow the record length specifier to be controlled by a compiler switch. For example, on an SGI, the compiler option "oldrl" causes recl to be in bytes instead of the SGI default of 4-byte words. The combination of values iblwd = 0 and irlbw = 0 triggers the program to try to read the GUACA data as a sequential file (nonzero values use direct access file reads). The parameter nhdr may need to be either 44 or 45 if the sequential mode is used. Parameters dirsep, endsep, and termchar are interior separator, ending separator, and terminating characters in file pathname structures. Examples of the values of dirsep, endsep, and termchar on several system types are as follows:

System	dirsep	endsep	termchar	file path structure
UNIX	'/'	'/'	' '	maindir/subdir/filename.ext
DOS	'\'	'\'	' '	maindir\subdir\filename,ext
VAX/VMS	'.'	']'	' '	[maindir.subdir]filename.ext
IBM/JCL	'.'	'('	')'	maindir.subdir(filename)

These parameters are used to build the file pathnames for the GUACA data files. Thus, to specify the GUACA data file mtmp01.dat, the full pathname may be built as /CDROM/2p5deg/por/01/mtmp01.dat with the Unix separators, as [CDROM.2p5deg.por.01]mtmp01.dat on a VAX system,

with the main directory (/CDROM/2p5deg) read in from the input data file and the subdirectory structure (por/01) supplied automatically by the program (see appendices A and B). Parameter sysform (usually 'system' or 'unformatted') is the form for opening a direct access binary file. Parameter scrstat is the status (usually 'scratch' or 'delete') for a temporary file when using the preread option.

Diagnostics. During the course of a run, various progress messages are written to the screen. If major problems arise in the progress of a run, a diagnostic message will be written to the screen, and sometimes to the standard formatted output file as well. Some error conditions are fatal, with execution being terminated after the diagnostic message is written. A list of the diagnostic and progress messages is given in appendix C.

4.8 Description of Program Files and Subroutines

The GRAM-95 program code is separated into several files, some of which group functionally related subroutines together. However, one file, "gram95.f", consists of a single unit and is the "driver" or "main" portion of the code. It was designed to be easily replaced, to help the user incorporate the remainder of the code into other programs as a coherent set of files, with minimal modification (see appendix E).

The Files. The eight files (including the driver file) which hold the GRAM-95 FORTRAN program code, require approximately 432 kb of disk space and are named:

- gram95.f – The driver portion of the code, which has no included subroutines but calls subroutines init, timestep, and randinit.
- gramsubs.f – Includes function correl, and subroutines caljday, corlat, fair, gterp, intr25, intrw, inter2, interw, interz, intruv, pdtuv, pertrb, rterp, rtran, stdatm, and wind.
- guaca.f – Includes functions gascon and ztoH, and subroutines guacard, guafix, guainit, guaintrp, guamod, and zinterp.
- initial.f – Includes function valreal, Block Data Initval, and subroutines chekunit, init, mapinit, randinit, scalinit, setup, shift2, and shift4.
- metprog.f – Includes functions molwt and temp, and subroutines fair5, gauss, j70, jac, jacch, slv, slvh, tinf, and tme.
- models.f – Includes function mixrat, and subroutines atmod, jacmod, mapmod, rig, and timestep.
- random.f – Includes function ppnd, and subroutines rcarin and rcarry.
- speconc.f – Includes functions dedt, d2edt2, tdbuck, valint, valz, and wexler, and subroutines afglconc, concinit, concvals, larcwat and mapconc.

Additionally, a subroutine (gramtraj.f), with dummy main driver, is also provided to facilitate use of GRAM-95 as a subroutine in user-supplied driver programs (see appendix E).

The Subroutines. The GRAM-95 code consists of the main driver, 51 subroutines, 14 functions, and 1 named Block Data routine. Appendix D gives an alphabetical listing of the names of each of the subroutines and functions, the file in which it is found, the subprogram from which it is called, and briefly describes what the subroutine or function does. In addition, fairly extensive comments have been provided in the code (sometimes including references for the sources of some of the algorithms). Also, since many parameter values are passed between subroutines via common blocks, appendix D gives a list of the common block names and the subroutines in which each is used.

4.9 Running GRAM-95

Before running GRAM-95, all files must be available in the proper configuration, and the source code must have been compiled and linked in some manner. On IBM 3090 platforms, this is accomplished through use of the Job Control Language (JCL), but on Unix platforms, it is through a more direct and perhaps intuitive use of simple commands coupling the files themselves. For instance, to compile the GRAM-95 code in its native SGI IRIX environment, the following relatively simple command string is issued at a terminal:

```
f77 -o gram95.x gram95.f gramsubs.f guaca.f initial.f metprog.f \
    models.f random.f speconc.f
```

This results in the executable file, gram95.x, and an intermediate "object" file for every FORTRAN file (i.e., the ".f" files, above), such as gram95.o, gramsubs.o, etc., which are no longer needed once the executable is obtained. Furthermore, these object files take up about 8.5 Mb of disk space in addition to the more than 8 Mb required by the executable. Thus, they are usually deleted by a command string such as:

```
rm *.o
```

Then, to make the executable file "globally" accessible, a command might be given such as:

```
chmod go+x gram95.x
```

All three of these command strings may be combined in a single executable script file, similar to the example below, which would automatically accomplish the tasks when invoked.

After the executable has been formed, the data bases and other input files must be properly linked. In the SGI IRIX environment, when the user either is running in the directory where the executable is located or has that directory listed in the "path" environmental variable, the simple command string:

```
gram95.x < input.dat
```

may suffice (refer to section 4.4 for a description of the "input.dat" file). Again, however, an executable script file would enhance the run sequence. For example:

```
# Executable "rungram" runs the GRAM-95 program.
#     Usage:  "rungram input-file-pathname"
# If no input-file-pathname is given, the default is a
#     file named "input.dat" in the current directory.
#
if ( $#argv < 1 ) then
   /usr1/people/jeffrwr/Gram95/gram95.x < input.dat
   exit 0
endif
/usr1/people/jeffrwr/Gram95/gram95.x < $1
```

would run the program using the links established in the "input.dat" file. In the example input file in appendix B, for example, links are made to the atmosdat file and the GUACA files on CD-ROM, and three output files are designated. A run is made using the initializing values on lines 7 and 8, with no trajectory file being invoked in the appendix B example (note the "null" input on line 3 and the next-to-last variable on line 7). It should be noted in passing that the above depicted "run script" was developed in a c-shell environment of the SGI platform. To use it in other shells, even if the subdirectory structure was valid, the user must enter some sequence of keystrokes such as: "csh ./rungram" from the subdirectory where the run script is located.

5. REFERENCES

Anderson, G.P., et al. (1986): "AFGL Atmospheric Constituent Profiles (0-120 km)." AFGL-TR-86-0110, Env. Res. Papers No. 954, May.

Buck, A.L. (1981): "New Equations for Computing Vapor Pressure and Enhancement Factor." J. Appl. Meteorol., vol. 20(12), pp. 1527–1532.

Buell, C.E. (1970): "Statistical Relations in a Perfect Gas." J. Appl. Meteorol., vol. 9, pp. 729–731.

Buell, C.E. (1972): "Adjustment of Some Atmospheric Statistics to Satisfy Physical Conditions." J. Appl. Meteorol., vol. 11, pp. 1299–1304.

Elliott, W.P., and Gaffen, P.J. (1991): "On the Utility of Radiosonde Humidity Archives for Climate Studies." Bull. Amer. Meteorol. Soc., vol. 72(10), pp. 1507–1520.

Findlay, J.T., et al. (1988): "Shuttle-Derived Density Profiles in the Middle Atmosphere." NASA CR 4109, February.

Findlay, J.T., and Jasinski, R.A. (1990): "Final Shuttle-Derived Atmospheric Data Base: Development and Results From 32 Flights." NASA Contract NAS9-17394, N91-11310, July.

Flatau, P.J., et al. (1992): "Polynomial Fits to Saturation Vapor Pressure." J. Appl. Meteorol., vol. 31(12), pp. 1507–1513.

Graedel, T.E., and Crutzen, P.J. (1993): "Atmospheric Change, An Earth System Perspective." W.M. Freeman and Co., New York, 446 pp.

Harries, J.E. (1976): "The Distribution of Water Vapor in the Stratosphere," Rev. Geophys. Space Phys., vol. 14(4), pp. 565–575.

Hickey, M.P. (1988a): "The NASA Marshall Engineering Thermosphere Model." NASA CR 179359.

Hickey, M.P. (1988b): "An Improvement in the Numerical Integration Procedure Used in the NASA Marshall Engineering Thermosphere Model." NASA CR 179389.

Jacchia, L.G. (1970): "New Static Models of the Thermosphere and Exosphere With Empirical Temperature Profiles." Smithsonian Astrophysical Observatory, Special Report 313.

Johnson, D.L., Jeffries, W.R. III, Yung, S., and Justus, C.G. (1995): "Improved Global Reference Atmospheric Model (GRAM) Data Base." AIAA 95-0545, 33rd Aerospace Sciences Meeting and Exhibit, Reno, NV, January 9–12.

Justus, C.G., Woodrum, A., Roper, R.G., and Smith, O.E. (1974): "A Global Scale Engineering Atmospheric Model for Surface to Orbital Altitudes, 1: Technical Description." NASA TMX-64871.

Justus, C.G., Fletcher, G.R., Gramling, F.E., and Pace, W.B. (1980): "The NASA/MSFC Global Reference Atmospheric Model—MOD 3 (With Spherical Harmonic Wind Model)." NASA CR-3256, Contract NAS8-32897.

Justus, C.G., Alyea, F.N., Cunnold, D.M., Blocker, R.A., and Johnson, D.L. (1988): "GRAM-88 Improvements in the Perturbation Simulations of the Global Reference Atmospheric Model." NASA Special Report ES44-11-9-88.

Justus, C.G., et al. (1990): "New Atmospheric Turbulence Model for Shuttle Applications." NASA TM-4168.

Justus, C.G., Alyea, F.N., Cunnold, D.M., Jeffries, W.R. III, and Johnson, D.L. (1991): "The NASA/MSFC Global Reference Atmospheric Model—1990 Version (GRAM-90), Part I: Technical/Users Manual." NASA TM-4268, Grant NAG8-078.

Keating, G.M., ed. (1989): "Middle Atmosphere Program—Reference Models of Trace Species for the COSPAR International Reference Atmosphere (Draft)." Handbook for MAP, vol. 31, 180 pp., December.

Labitzke, K., et al. (1985): "Middle Atmosphere Program—Atmospheric Structure and its Variation in the Region 20 to 120 km—Draft of a New Reference Middle Atmosphere." Handbook for MAP, vol. 16, 318 pp., July.

McCormick, M.P., and Chiou, E. W. (1994): "Climatology of Water Vapor in the Upper Troposphere and Lower Stratosphere Determined from SAGE II Observations," Proc. American Meteolo. Soc. 5th Global Change Studies, Nashville, TN, January 23–28.

Ruth, D.B., et al. (1993): "Global Upper Air Climatic Atlas (GUACA)." CD ROM data set, Version 1.0 (vol 1, 1980 to 1987, vol. 2 1985 to 1991), U.S. Navy-U.S. Department of Commerce (NOAA/NCDC), April.

Smith, O.E. and Adelfang, S.I. (1994): "Atmospheric Density Models for Launch Vehicle Design (Dispersed Atmospheric Models 0-25 km Altitude, KSC)." AIAA-95-0057, 33rd Aerospace Sciences Meeting and Exhibit, Reno, NV, January 9–12.

Wexler, A. (1976): "Vapor Pressure Formulation for Water in Range 0° to 100° C. A Revision." J. Res. Natl. Bur. Stand., vol. 80A, pp. 775–785.

6. BIBLIOGRAPHY FOR THE NEW PERTURBATION MODEL CHARACTERISTICS

(1) Tsuda, T., et al. (1994): "Radiosonde Observations of Equatorial Atmosphere Dynamics Over Indonesia 2. Characteristics of Gravity Waves." J. Geophys. Res., vol. 99(D5), pp. 10507–10516.

(2) Heymsfield, G.M., and Blackner, R.H., Jr. (1988): "Satellite-Observed Characteristics of Midwest Severe Thunderstorm Anvils." Monthly Wea. Rev., vol. 116(11), pp. 2200–2224.

(3) Hauchecorne, A, Chanin, M.-L., and Keckhut, P. (1991): "Climatology and Trends of the Middle Atmosphere (33-87 km) as Seen by Rayleigh Lidar Over the South of France." J. Geophys. Res., vol. 96(D8), pp. 15297–15309.

(4) Pfister, L., et al. (1993): "Mesoscale Disturbances in the Tropical Stratosphere Excited by Convection: Observations and Effects on the Stratospheric Momentum Budget." J. Atmos. Sci., vol. 50(8), pp. 1058–1075.

(5) Smith, S.A., et al. (1986): "Simultaneous Rocket and MST Radar Observation of an Internal Gravity Wave Breaking in the Mesosphere." Middle Atmosphere Program (MAP) Handbook, vol. 20, paper 3.2.3, pp. 136–146.

(6) Fritts, D.C., et al. (1988): "Evidence of Gravity Wave Saturation and Local Turbulence Production in the Summer Mesosphere and Lower Thermosphere During the STATE Experiment." J. Geophys. Res., vol. 93(D6), pp. 7015–7025.

(7) Fritts, D.C., et al. (1993): "Gravity Wave and Tidal Structures Between 60 and 140 km Inferred From Space Shuttle Reentry Data." J. Atmos. Sci., vol. 50(6), pp. 837–849.

(8) Blix, T.A., Thrane, E.V., and Andreassen, O. (1990): "In Situ Measurements of the Fine-Scale Structure and Turbulence in the Mesosphere and Lower Thermosphere by Means of Electrostatic Positive Ion Probes." J. Geophys. Res., vol. 95(D5), pp. 5533–5548.

(9) Bills, R.E., and Gardner, C.S. (1993): "Lidar Observations of the Mesopause Region Temperature Structure at Urbana." J. Geophys. Res., vol. 98(D1), pp. 1011–1021.

(10) Kwon, K.H., Senft, D.C., and Gardner, C.S. (1988): "Lidar Observations of Sporadic Sodium Layers at Mauna Kea Observatory, Hawaii." J. Geophys. Res., vol. 93(D11), pp. 14199–14208.

(11) Kwon, K.H., et al. (1990): "Correlative Radar and Airborne Sodium Lidar Observations of the Vertical and Horizontal Structure of Gravity Waves Near the Mesopause." J. Geophys. Res., vol. 95(D9), pp. 13737–13748.

(12) Gardner, C.S., et al. (1989): "Rayleigh Lidar Observations of Gravity Wave Activity in the Upper Stratosphere at Urbana, Illinois." J. Atmos. Sci., vol. 46(12), pp. 1838–1854.

(13) Kitchens, M., and Shutts, G.J. (1990): "Radiosonde Observations of Large-Amplitude Gravity Waves in the Lower and Middle Stratosphere." J. Geophys. Res., vol. 95(D12), pp. 20451–20455.

(14) Kwon, K.H., and Gardner, C.S. (1990): "Airborne Sodium Lidar Measurements of Gravity Wave Intrinsic Parameters." J. Geophys. Res., vol. 95(D12), pp. 20457–20467.

(15) Manson, A.H., and Meek, C.E. (1993): "Charactersitics of Gravity Waves (10 min to 6 hours) at Saskatoon (52N, 107W) Observations by the Phase Coherent Medium Frequency Radar." J. Geophys. Res., vol. 98(D11), pp. 20357–20367.

(16) Lubken et al. (1993): "Experiments Revealing Small Impact of Turbulence on the Energy Budget of the Mesosphere and Lower Thermosphere." J. Geophys. Res., vol. 98(D11), pp. 20369–20384.

(17) Nastrom, G.D., Fritts, D.C., and Gage, K.S. (1987): "An Investigation of Terrain Effects on the Mesoscale Spectrum of Atmospheric Motions." J. Atmos. Sci., vol. 44(20), pp. 3087–3096.

(18) Cornish, C.R., and Larsen, M.F. (1989): "Observations of Low-Frequency Inertia-Gravity Waves in the Lower Stratosphere over Arecibo." J. Atmos. Sci., vol. 46(15), pp. 2428–2439.

(19) Fritts, D.C., Blanchard, R.C., and Coy, L. (1989): "Gravity Wave Structure Between 60 and 90 km Inferred From Space Shuttle Reentry Data." J. Atmos. Sci., vol. 46(3), pp. 423–434.

(20) Wang, D.-Y., and Fritts, D.C. (1990): "Mesospheric Momentum Fluxes Observed by the MST Radar at Poker Flat, Alaska." J. Atmos. Sci., vol. 47(12), pp. 1512–1521.

(21) Jasperson, W.H., Nastron, G.D., and Fritts, D.C. (1990): "Further Study of Terrain Effects on the Mesoscale Spectrum of Atmospheric Motions," J. Atmos. Sci., vol. 47(8), pp. 979–987.

(22) Nastrom, G.D., and Fritts, D.C. (1992): "Sources of Mesoscale Variability of Gravity Waves. Part I: Topographic Excitation." J. Atmos. Sci., vol. 49(2), pp. 101–110.

(23) Fritts, D.C., and Nastron, G.D. (1992): "Sources of Mesoscale Variability of Gravity Waves. Part II: Frontal, Convective and Jet Stream Excitation." J. Atmos. Sci., vol. 49(2), pp. 110–127.

(24) Beatty, T.J., Hostetler, C.A., and Gardner, C.S. (1992): "Lidar Observations of Gravity Waves and Their Spectra Near the Mesopause and Stratopause at Arecibo." J. Atmos. Sci., vol. 49(6), pp. 477–496.

(25) Miller, M.S., Gardner, C.S., and Liu, C.H. (1987): "Rayleigh Lidar Observations of Gravity Wave Activity in the Stratosphere and Lower Mesosphere." NASA-CR-182384, N88-17123.

(26) Kantor, A.J. (1982): "Atlas of Northern Hemisphere Density Between 30 and 60 km." AFGL-TR-82-0282, Environ, Res. Paper 797, AD A125987.

(27) Collins, R.L., Tao, X., and Chester, C.S. (1994): "Gravity Waves in the Upper Mesosphere Over Urbana, Illinois: Comparison of Lidar Observations With Diffusive Filtering Theory." J. Geophys. Res., in press.

(28) Collins, R.L., Nomura, A., and Gardner, C.S. (1994): "Gravity Waves in the Upper Mesosphere Over Antarctica: Lidar Observations at the South Pole and Syowa." J. Geophys. Res., vol. 99(D3), pp. 5475–5486.

(29) Hostetler, C.A., and Gardner, C.S. (1994): "Observations of Horizontal and Vertical Wave Number Spectra of Gravity Waves Motions in the Stratosphere and Mesosphere Over the Mid-Pacific." J. Geophys. Res., vol. 99(D1), pp. 1283–1302.

(30) Vincent, R.A., and Lesica, D. (1991): "Mean Winds, Tides, and Gravity Waves in the Upper Middle Atmosphere During ALOHA-90." Geophys. Res. Lett., vol. 18(7), pp. 1321–1324.

(31) Fritts, D.C. (1984): "Gravity Wave Saturation in the Middle Atmosphere: A Review of Theory and Observations." Rev. Geophys. Space Phys., vol. 22(3), pp. 275–308.

(32) Senft, D.C., and Gardner, C.S. (1991): "Seasonal Variability of Gravity Wave Activity and Spectra in the Mesopause Region at Urbana." J. Geophys. Res, vol. 96(D9), pp. 17229–17264.

(33) Gardner, C.S., and Voelz, D.G. (1987): "Lidar Studies of the Nighttime Sodium Layer Over Urbana, Illinois 2. Gravity Waves." J. Geophys. Res., vol. 92(A5), pp. 4673–4694.

(34) Hauchecorne, A., Chanin, M.L., and Wilson, R. (1987): "Mesospheric Temperature Inversion and Gravity Wave Breaking." Geophys. Res. Lett., vol. 14(9), pp. 933–936.

(35) Hostetler, C.A., et al. (1991): "Spectra of Gravity Wave Density and Wind Perturbations Observed During Aloha-90 on the 25 March Flight Between Maui and Christmas Island." Geophys. Res. Lett., vol. 18(7), pp. 1325–1328.

(36) She, C.Y., et al. (1991): "Na Temperature Lidar Measurements of Gravity Wave Perturbations of Wind, Density, and Temperature in the Mesopause Region." Geophys. Res. Lett., vol. 18(7), pp. 1329–1331.

(37) Jenkins, D.B., et al. (1987): "Upper Stratospheric and Mesospheric Temperatures Derived From Lidar Observations at Aberystwyth." J. Atmos. Terr. Phys., vol. 49(3), pp. 287–298.

(38) Gaigerov, S.S., et al. (1986): "Characteristics of Variations of Temperature Regime and Circulation in the Upper Atmosphere in Middle and High Latitudes." J. Atmos. Terr. Phys., vol. 48(11–12), pp. 1111–1116.

(39) Senft, D.C., Hostetler, C.A., and Gardner, C.S. (1993): "Characteristics of Gravity Wave Activity and Spectra in the Upper Stratosphere and Upper Mesosphere at Arecibo During Early April 1989." J. Atmos. Terr. Phys., vol. 55(3), pp. 425–439.

(40) Yu, J.R., and She, C.Y. (1993): "Lidar-Observed Temperature Structures and Gravity-Wave Perturbations of the Mesopause Region in the Springs of 1990–1992 Over Fort Collins, CO." Appl. Phys., vol. B57, pp 231–238.

(41) Reid, I.M., and Vincent, R.A. (1987): "Measurements of the Horizontal Scales and Phase Velocities of Short Period Mesospheric Gravity Waves at Adelaide, Australia." J. Atmos. Terr. Phys., vol. 49(10), pp. 1033–1048.

(42) Sato, T., and Woodman, R.F. (1982): "Fine Altitude Resolution Observations of Stratospheric Turbulent Layers by the Arecibo 430 Mhz Radar." J. Atmos. Sci., vol. 39(11), pp. 2546–2552.

(43) Vincent, R.A. (1990): "Gravity Waves in the Southern Hemisphere Middle Atmosphere: A Review of Observations." Dynamics, Transport and Photochemistry in the Middle Atmosphere of the Southern Hemisphere, A. O'Neill (ed.), pp.159–170.

(44) Fritts, D.C. (1990): "Gravity Waves in the Middle Atmosphere of the Southern Hemisphere," Dynamics, Transport and Photochemistry in the Middle Atmosphere of the Southern Hemisphere, A. O'Neill (ed.), pp.171–189

(45) Hill, C.K. (1986): "Analysis of Jimsphere Pairs for Use in Assessing Space Vehicle Ascent Capability." NASA Tech. Paper 2573, 102 pp.

(46) Andrews, D.G., Holton, J.R., and Leovy, C.B. (1987): "Middle Atmosphere Dynamics." Academic Press, p. 16.

(47) Hirota, I. (1984): "Climatology of Gravity Waves in the Middle Atmosphere." Dynamics of the Middle Atmosphere, Holton, J.R. and T. Matsuno (eds.), pp. 65–75.

APPENDIX A

Global Upper Air Climatic Atlas (GUACA) Data

(Adapted and expanded from the help file on the GUACA CD's)

GUACA Background

The Global Upper Air Climatic Atlas Version 1.0 (referred to as GUACA), volumes I and II, was produced at the Federal Climate Complex, Asheville, NC. Two organizations cooperated in GUACA's development:

1. Naval Oceanography Command Detachment (NAVOCEANCOM DET), a field activity of the Commander, Naval Oceanography Command.

2. National Climatic Data Center (NCDC), a component of the National Oceanic and Atmospheric Administration's (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS).

GUACA is a U.S. Navy-led effort produced and funded under the authority of the Commander, Naval Oceanography Command (COMNAVOCEANCOM) and partially supported by funding under NOAA's Earth System Data and Information Management Program.

Data Sources

GUACA is based upon twice-daily (00 and 12Z) upper-air analyses provided by the European Centre for Medium-Range Weather Forecasts (ECMWF) for the 1980 to 1991 period. Data were provided for a global 2.5° grid (10,512 grid points) and were summarized by year-month and period of record-month. The observational data are used in the model initialization step for the forecasts produced by ECMWF. As part of the model initialization process, the data are subjected to quality control and the observations at irregularly spaced locations are interpolated to the regular 2.5° grid spacing.

The ECMWF, located in Reading, England, is funded and staffed by member European countries. Primarily responsible for forecast support for the European countries, ECMWF's data collection and assimilation system utilizes global data. A variety of data sources are used in order to produce the most accurate representation of the atmosphere at a given observation time.

These data sources include:

1. Radiosondes—balloon borne instruments released by ground level observers (both land and sea). The instrument package provides temperature, moisture, wind and height data as the balloon rises through the atmosphere. Coverage is sparse over the global ocean environment.

2. Aircraft—reports of flight level wind, temperature and moisture.

3. Satellites—atmospheric profiles of specific elements and estimates of wind data from cloud motion.

The ECMWF GUACA data provides monthly average gridded data for the following levels and meteorological elements, for each year noted and for the 1980 to 1991 period of record:

Surface or Sea Level

Surface Air Temperature	1985–1991
Surface Dew-Point Temperature	1985–1991
Surface U and V Wind Components	1985–1991
Sea Level Pressure	1985–1991

Pressure Levels 1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, and 30 millibars

Air Temperature	1980–1991
Dew-Point Temperature (to 300 mbar only)	1980–1991
Geopotential Height	1980–1991
U and V Wind Components	1980–1991

Pressure Level 10 mbar

Air Temperature	1985–1991
Geopotential Height	1985–1991
U and V Wind Components	1985–1991

An approximate height above sea level for each pressure level is

1,000 millibars	130 meters	(400 feet)
850 millibars	1,500 meters	(5,000 feet)
700 millibars	3,000 meters	(10,000 feet)
500 millibars	5,500 meters	(18,000 feet)
400 millibars	7,000 meters	(24,000 feet)
300 millibars	9,000 meters	(30,000 feet)
250 millibars	10,500 meters	(34,000 feet)
200 millibars	12,000 meters	(40,000 feet)
150 millibars	13,500 meters	(44,000 feet)
100 millibars	16,000 meters	(52,000 feet)
70 millibars	18,500 meters	(60,000 feet)
50 millibars	21,000 meters	(69,000 feet)
30 millibars	24,000 meters	(78,000 feet)
10 millibars	31,000 meters	(101,000 feet)

Dew-point temperature was calculated by NCDC from mixing ratio (to April 1982) and from relative humidity (from April 1982 to end of period-of-record). In addition to the above elements, atmospheric density for the surface to 10 mbar pressure level was calculated from pressure and temperature data. Also, vector and scalar wind and wind rose data were calculated from the u and v wind components (but are not used in GRAM).

It should be noted that the 70 mbar level was missing in the GUACA 1980 data for April. This adversely affected the period-of-record density values for April at 70 mbar. A routine has been included in GRAM to correct these period-of-record values. Because of the change in number of levels and meteorological elements available after 1985, GRAM allows only the individual years 1985 to 1991 and the period-of-record data to be used.

The data analysis/forecast system used by ECMWF, as well as the model initialization procedures, undergoes continual modification to better model the global atmosphere. The grid point analyses provided are not static but are considered evolutionary. The user should note that current year-month gridded data are considered to more accurately represent the real atmosphere. A number of major and minor changes have been introduced since 1980.

Dates of major changes and the effect on the gridded data are:

1. September 1982—temperature increase in the tropical middle troposphere—especially at 500 mbar.

2. May 1985—tropical temperature increase at 700 mbar, and decrease at 850 mbar. Stratospheric temperature increase, with slight cooling at 300 mbar. Warming in Northern Hemispheric polar region between 850 and 400 mbar. Moisture increase at 850 mbar, with decrease above 850 mbar. Improvements in tropical wind structure.

3. March 1986—significant moistening of the upper troposphere.

4. May 1986—tropical temperatures near tropopause decreased.

5. May 1989—moistening in upper troposphere (300 mbar).

An excellent overview of the ECMWF system and implemented changes can be found in NCAR Technical Note 373+STR, dated June 1992.

Accessing the GUACA CD Data

GUACA is a two CD-ROM disk product with year-month statistics for 1980 to 1987 on volume I and year-month statistics for 1985 to 1991 on volume II. Data for 1985-1987 plus the period-of-record statistics (1980 to 1991) are placed on both disks, to fill the disks to near capacity and to mitigate the need for "disk-swapping" if only a single disk CD-ROM reader is available to the user.

Since GRAM does not allow use of the individual years 1980 to 1984, only the GUACA CD volume II is of major interest to GRAM users. A PC DOS-based graphical display package is placed on both disks; therefore they can be used as stand-alone products.

GRAM allows the GUACA data to be read in directly from the CD if a CD-ROM reader is available on the user's system. If the GUACA data must be read in from the CD on a PC and ported to the system on which GRAM resides, then the following minimum PC system is required:

- IBM 286, 386, 486 or compatible PC
- 470k or more of free system memory (RAM)
- MS-DOS version 3.21, or higher
- Either a hard drive or floppy drive for temporary file creation
- A CD-ROM drive.

In addition, if the GUACA graphical display is to be used (not required for GRAM), the following is also needed:

- EGA or VGA graphics card for extended color graphics with memory
- Mouse (optional); must be Microsoft™ compatible.

GUACA Data Formats

Main GUACA directory: /CDROM/2p5deg

Year subdirectories: 1985 1986 1987 1988 1989 1989 1990 1991 por

Monthly subdirectories: 01 02 03 04 05 06 07 08 09 10 11 12

Files in each monthly subdirectory:

Parameter	Units	File Name Mean Values	File Name Std. Devs.	Number of Levels	Size (bytes)
Density	g/m^3	mdenxx.dat	sdenxx.dat	15	315,660
Dewpoint Temperature	°C	mdwpxx.dat	sdwpxx.dat	7	147,404
Geopotential Height	m	mhgtxx.dat	shgtxx.dat	14	294,628
Sea Level Pressure	mbar	mslpxx.dat	sslpxx.dat	1	21,212
Temperature	°C	mtmpxx.dat	stmpxx.dat	15	315,660
Eastward Wind Comp.	m/s	muwdxx.dat	suwdxx.dat	15	315,660
Northward Wind Comp.	m/s	mvwdxx.dat	svwdxx.dat	15	315,660

where xx = month (same as name of monthly subdirectory).

Example file pathname for January, period-of-record mean density:

/CDROM/2p5deg/por/01/mden01.dat

Each pressure level has data values for 144 longitudes (0°, 2.5° E, 5.0° E, ..., 2.5° W) by 73 latitudes (–90°, –87.5°, ..., +90°). Each data value is a 2-byte integer. Each level of data values is preceeded by a 4-byte integer offset value and a 4-byte real scale value. All data values are converted to physical units by the transform

$$\text{physical-value} = (\text{data-value} \times \text{scale} + \text{offset})/100.$$

Each file begins with 180 bytes of header (in ASCII) that describes the parameter and units, and the pressure levels in the file. The amount of data in each pressure level (in bytes) is thus

$$\text{bytes/level} = (2\times4)+(144\times73\times2) = 21{,}032\ ,$$

and the size of each file (in bytes) is

$$\text{file-size} = 180+(21{,}032 \times \text{number-of-levels}).$$

There are no embedded end-of-record (EOR) marks in the file.

If FORTRAN files can be opened as form='binary' (e.g., Microsoft FORTRAN) or form='system' (SGI FORTRAN) (i.e., assuming no embedded EORs or other file management bytes), then each file could be read from the GUACA unit (iug) with the statements

```
      Read(iug)(header(i),i=1,45)
      Do 100 k = 1,numlevs
      Read(iug,end=900)ioffset(k),scale(k),((input(i,j,k),
    & i=1,144),j=1,73)
  100 Continue
```

(assuming the header array has been declared as Character*4, and that the input array has a number of levels = numlevs). This is a type of sequential access (a version of which is one of the read options in the guacard subroutine). The GUACA reading routine in GRAM uses the more standard, form='unformatted' for the file open statements. By declaring the GUACA files as direct access, with fixed record size of one (4-byte) word each, the GUACA read routine provided in GRAM can still read the files directly on some platforms (e.g., SGI UNIX). For systems that must treat the files as some other fixed block (record) size (e.g., 512-byte blocks on a VAX), the option is provided to preread the GUACA files and write them out to direct access, internal files that can be read in records, each consisting of one 4-byte word. This method loses some in run-time efficiency but provides for more intersystem portability (i.e., for those systems that do not allow the form='binary' or form='system' file opens). Although the more efficient reading process, noted above, may take only about half the time, the read routine used in GRAM takes only a few seconds to read each file on an SGI UNIX platform. For details on the various read options in the guacard subroutine, see section 4.7.

Credits

The following people contributed to the GUACA project:

NAVAL OCEANOGRAPHY COMMAND DETACHMENT

Program Direction: LCDR Dennis B. Ruth, USN
Program Concepts: Mr. Brian L. Wallace

NATIONAL CLIMATIC DATA CENTER

Programming: Mr. Claude N. Williams, Jr.
Mr. Eric B. Gadberry

Technical Support: Mr. Michael J. Changery

Problems or Questions

The information in GUACA is presented in a way intended to ease access and understanding. Unlike less-sophisticated data access software, there may be many ways to arrive at a given piece of information. The user may, therefore, happen upon a problem not corrected during development. Please do not hesitate to contact the following if this happens to you.

If problems or questions from military users or DOD contractors arise, they should be forwarded to:

Fleet Numerical Meteorology and Oceanography Command Detachment
Room 563
151 Patton Avenue
Asheville, NC 28801-5014
Phone: (704) 271-4232

Technical or data-specific questions from civilian users should be forwarded to:

National Climatic Data Center
Climate Services Division
Room 468
151 Patton Avenue
Asheville, NC 28801-5001
Phone: (704) 271-4702

To purchase a copy of GUACA contact:

National Climatic Data Center
Climate Services Division
Room 468
151 Patton Avenue
Asheville, NC 28801-5001
Phone: (704) 271-4800
Fax: (704) 271-4876

APPENDIX B

Sample Input and Output of GRAM-95

GRAM 95 reads the following input data:

Lines 1-6: Path names for input/output files (up to 64 characters):

Line 1: atmpath = path name for atmospheric data file ("atmosdat")
Line 2: guapath = path name for GUACA input files (e.g. /CDROM/2p5deg)
Line 3: trapath = path name for trajectory input file ("null" and set iopt = 0 if none)
Line 4: prtpath = path name for standard formatted output file ("null" and set iup = 0 if none)
Line 5: nprpath = path name for the "special" format output file ("null" and set iopp = 0 if none)
Line 6: conpath = path name for species concentration output file ("null" and set iuc = 0 if none)

Lines 7-8: Data lines, in list-directed (free field) format:

Line 7 contains:

h1 = initial height (km)
phi1 = initial latitude (deg, N positive)
thet1 = initial longitude (deg, East positive)
f10 = 10.7 cm flux
f10b = mean 10.7 cm flux
ap = geomagnetic index
mn, ida, iyr = month, day, year (2-digit)
ihr0, min0, sec0 = UTC (Greenwich) hour, minutes, seconds
dphi = latitude increment (deg, Northward positive)
dthet = longitude increment (deg, Eastward positive)
dh = height increment (km, upward positive)
nmax = maximum number of positions (including initial position) to be computed (0 means read trajectory input)
delt = time increment between positions (real seconds)
iopt = trajectory option (0=no trajectory data; otherwise unit number)
iopp = "special" output option (0=no "special" output; otherwise unit number of "special" output file)

Line 8 contains:

iu0 = unit number for screen output
iup = unit number of standard formatted output file (0 for none)
ius = unit number for atmosdat data
iuc = unit for concentrations output (0 for none)
iug = unit number for the 1st of the 14 consecutive unit numbers required for the GUACA input data, 0-27 km (0 for no GUACA data)
iguayr = 1 to use GUACA period of record,
2 to use actual GUACA year (1985-1991), based on 1st-line input value iyr (input as 2-digit year)
iopr = random output option (1 = random output, 2 = none)
nr1 = starting random number (1 to 9×10^8)
rpscale = random perturbation scale, nominal = 1.0
maximum = 2.0 , minimum = 0.0

Optional Lines 9 ...: Additional random number seeds for re-initializing the same profile or trajectory.

Sample Input File:

```
atmosdat
/CDROM/2p5deg
null
output.dat
specout.dat
species.dat
140. 28.45 -80.53 230. 230. 20.3 1 1 95 0 0 0.0 0. 0. -2. 71 1.0 0 21
 0 6 3  4 22  1  1 1234  1.0
```

This assumes that the "atmosdat" file resides in the current directory. A more complete path name may be given if it resides in another directory. The root directory for the CD ROM drive is assumed, for this example, to be /CDROM. From the initial pathname given, GRAM builds the rest of the required pathname, according to the directory structure on the GUACA CD [e.g., /CDROM/2p5deg/por/01/xxxx01.dat, since the input specifies period-of-record and January]. For input GUACA pathnames ending in a directory separator, this character is ignored from the input and supplied by the program. For example, on a VAX, an initial GUACA pathname of [CDROM.2p5deg] will be built as pathnames [CDROM.2p5deg.por.01]xxxx01.dat (see section 4.7). The output files will reside in the current directory in this example. A more complete path name may be specified to route the output files to some other directory. The example input shown here produces a vertical profile for the location of Kennedy Spaceflight Center, analogous to the reference output in Appendix B of the GRAM-90 report (Justus et al., 1991).

The following two listings give the standard formatted output file "output.dat" in this example, and the optional species concentration file, "species.dat" in this example. This input and output is for an automatically-generated profile. If values along a set of pre-computed trajectory positions are desired, then a trajectory input file is also required, an example of which is given in section 4.5.

Standard Formatted Output Produced by the Input File Above:

```
      ****** Global Reference Atmospheric Model - 1995 (GRAM-95) ******

MM/DD/YY =  1/ 1/95    HH:MM:SS(UTC) =  0: 0: 0.0   Julian Day = 2449718.500
F10.7 =  230.00        Mean F10.7 =  230.00         ap Index =  20.30
GUACA path = /CDROM/2p5deg/por/01/
Max of   71 positions, generated automatically.
Random Option = 1      1st Random No. =     1234    Random Scale Factor = 1.00

Mean-76 and Total-76 are percent deviations from 1976 US Standard Atmosphere.
Other deviations in percent are with respect to mean values. RH is relative
humidity in percent. Zeroes for H2O indicate no estimate available.

Height                                        Tempera-                Vert.
 (km)    Lati-    Long. Pressure   Density/  ture/    E-W    N-S   Wind
 Time     tude   [E+W-] /Vap.Pr. Vap.Dens. Dewpt.  Wind   Wind  (m/s)
(sec)    (deg)    (deg) (Nt/m**2) (kg/m**3)   (K)   (m/s)  (m/s)  RH(%)
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
140.00  28.450  -80.530 9.480E-04  4.305E-09  670.3   -9.8  -27.7 -0.004 Mean
                          31.6%      12.4%    19.8%                       M-76
```

0.0			-4.3%	-2.7%	-1.6%	42.3	-19.8		ranS
			2.9%	6.2%	12.6%	45.0	45.0		sigS
			15.2%	3.2%	12.0%	70.9	-21.5		ranL
			12.2%	3.7%	7.4%	52.3	52.3		sigL
			10.9%	0.5%	10.4%	113.2	-41.3	-0.96	ranT
			12.5%	7.2%	14.6%	69.0	69.0	8.33	sigT
			1.052E-03	4.327E-09	740.2	103.3	-69.0	-0.96	Tot.
			46.0%	12.9%	32.3%				T-76
			0.000E+00	0.000E+00	0.0			0.0%	H2O
			0.000E+00	0.000E+00	0.0			0.0%	sigH
---	---	---	---	---	---	---	---	---	---
138.00	28.450	-80.530	1.038E-03	4.929E-09	643.6	-16.2	-25.3	-0.005	Mean
			30.2%	12.1%	18.6%				M-76
1.0			-4.7%	0.3%	-5.1%	29.6	-23.9		ranS
			3.0%	6.2%	13.2%	44.5	45.8		sigS
			15.1%	3.7%	11.4%	74.9	-29.6		ranL
			12.8%	3.8%	7.9%	52.2	53.8		sigL
			10.4%	4.1%	6.3%	104.5	-53.5	3.96	ranT
			13.2%	7.3%	15.4%	68.6	70.6	8.16	sigT
			1.146E-03	5.130E-09	684.2	88.3	-78.8	3.96	Tot.
			43.7%	16.7%	26.0%				T-76
			0.000E+00	0.000E+00	0.0			0.0%	H2O
			0.000E+00	0.000E+00	0.0			0.0%	sigH
---	---	---	---	---	---	---	---	---	---
136.00	28.450	-80.530	1.142E-03	5.688E-09	616.2	-22.9	-23.0	-0.005	Mean
			28.8%	12.1%	17.3%				M-76
2.0			-3.4%	1.4%	-4.8%	35.8	-0.9		ranS
			3.2%	6.3%	13.7%	44.0	46.7		sigS
			16.4%	3.7%	12.7%	80.1	-35.5		ranL
			13.5%	3.9%	8.4%	52.0	55.2		sigL
			13.1%	5.1%	7.9%	115.9	-36.3	6.01	ranT
			13.9%	7.3%	16.1%	68.1	72.3	7.99	sigT
			1.291E-03	5.979E-09	665.2	93.0	-59.3	6.01	Tot.
			45.6%	17.8%	26.6%				T-76
			0.000E+00	0.000E+00	0.0			0.0%	H2O
			0.000E+00	0.000E+00	0.0			0.0%	sigH
---	---	---	---	---	---	---	---	---	---
134.00	28.450	-80.530	1.262E-03	6.618E-09	588.2	-29.8	-20.7	-0.005	Mean
			27.6%	12.3%	15.9%				M-76
3.0			-3.9%	1.3%	-5.2%	70.5	18.2		ranS
			3.3%	6.3%	14.3%	43.5	47.4		sigS
			17.6%	4.1%	13.5%	76.1	-35.3		ranL
			14.1%	3.9%	8.9%	51.9	56.6		sigL
			13.7%	5.4%	8.3%	146.7	-17.1	1.16	ranT
			14.5%	7.4%	16.8%	67.7	73.8	7.82	sigT
			1.436E-03	6.976E-09	637.2	116.9	-37.9	1.16	Tot.
			45.2%	18.3%	25.6%				T-76
			0.000E+00	0.000E+00	0.0			0.0%	H2O
			0.000E+00	0.000E+00	0.0			0.0%	sigH
---	---	---	---	---	---	---	---	---	---
132.00	28.450	-80.530	1.404E-03	7.773E-09	559.6	-36.7	-18.6	-0.005	Mean
			26.6%	12.6%	14.5%				M-76
4.0			-3.6%	-2.6%	-1.0%	81.0	5.2		ranS
			3.4%	6.3%	14.8%	43.0	48.2		sigS
			17.8%	2.8%	15.0%	92.0	-33.9		ranL
			14.7%	4.0%	9.4%	51.7	57.9		sigL
			14.3%	0.2%	14.1%	173.0	-28.7	0.36	ranT
			15.1%	7.5%	17.5%	67.3	75.4	7.65	sigT
			1.604E-03	7.789E-09	638.2	136.3	-47.3	0.36	Tot.
			44.6%	12.8%	30.6%				T-76

			0.000E+00	0.000E+00	0.0			0.0%	H2O
			0.000E+00	0.000E+00	0.0			0.0%	sigH
130.00	28.450	-80.530	1.572E-03	9.220E-09	530.5	-43.4	-16.5	-0.005	Mean
			25.7%	13.1%	13.1%				M-76
5.0			-4.9%	3.3%	-8.2%	58.3	-11.6		ranS
			3.5%	6.3%	15.3%	42.5	48.9		sigS
			20.5%	2.9%	17.6%	77.0	-43.7		ranL
			15.3%	4.1%	9.8%	51.6	59.3		sigL
			15.6%	6.2%	9.4%	135.3	-55.3	0.44	ranT
			15.7%	7.6%	18.1%	66.9	76.9	7.48	sigT
			1.816E-03	9.791E-09	580.1	91.9	-71.8	0.44	Tot.
			45.2%	20.1%	23.6%				T-76
			0.000E+00	0.000E+00	0.0			0.0%	H2O
			0.000E+00	0.000E+00	0.0			0.0%	sigH
128.00	28.450	-80.530	1.772E-03	1.106E-08	501.1	-49.7	-14.5	-0.005	Mean
			24.9%	13.8%	11.6%				M-76
6.0			-5.8%	1.2%	-7.0%	70.7	-42.5		ranS
			3.6%	6.4%	15.7%	42.1	49.6		sigS
			19.0%	4.4%	14.6%	85.5	-27.2		ranL
			15.8%	4.2%	10.3%	51.4	60.6		sigL
			13.3%	5.7%	7.6%	156.2	-69.7	-3.31	ranT
			16.2%	7.6%	18.8%	66.4	78.4	7.31	sigT
			2.007E-03	1.168E-08	539.2	106.6	-84.2	-3.32	Tot.
			41.5%	20.3%	20.1%				T-76
			0.000E+00	0.000E+00	0.0			0.0%	H2O
			0.000E+00	0.000E+00	0.0			0.0%	sigH
126.00	28.450	-80.530	2.013E-03	1.342E-08	471.5	-55.3	-12.6	-0.005	Mean
			24.3%	14.6%	10.1%				M-76
7.0			-4.8%	2.9%	-7.7%	86.4	-65.6		ranS
			3.7%	6.4%	16.2%	41.6	50.3		sigS
			18.9%	3.1%	15.8%	87.2	-18.7		ranL
			16.4%	4.3%	10.7%	51.2	62.0		sigL
			14.1%	6.0%	8.0%	173.6	-84.4	-1.47	ranT
			16.8%	7.7%	19.4%	66.0	79.8	7.14	sigT
			2.297E-03	1.423E-08	509.3	118.3	-97.0	-1.47	Tot.
			41.8%	21.6%	19.0%				T-76
			0.000E+00	0.000E+00	0.0			0.0%	H2O
			0.000E+00	0.000E+00	0.0			0.0%	sigH
124.00	28.450	-80.530	2.308E-03	1.650E-08	441.8	-60.0	-10.8	-0.005	Mean
			23.9%	15.6%	8.8%				M-76
8.0			-5.6%	9.5%	-15.1%	56.5	-90.0		ranS
			3.8%	6.4%	16.6%	41.1	50.9		sigS
			18.9%	3.0%	15.8%	75.9	-20.0		ranL
			16.9%	4.4%	11.2%	51.1	63.3		sigL
			13.2%	12.5%	0.7%	132.5	-109.9	1.06	ranT
			17.3%	7.8%	20.0%	65.5	81.2	6.97	sigT
			2.613E-03	1.856E-08	445.1	72.5	-120.7	1.06	Tot.
			40.3%	30.0%	9.6%				T-76
			0.000E+00	0.000E+00	0.0			0.0%	H2O
			0.000E+00	0.000E+00	0.0			0.0%	sigH
122.00	28.450	-80.530	2.672E-03	2.057E-08	412.3	-63.6	-9.1	-0.004	Mean
			23.5%	16.5%	7.5%				M-76
9.0			-2.6%	6.3%	-8.9%	55.8	-90.0		ranS
			3.9%	6.5%	17.0%	40.6	51.5		sigS
			22.0%	3.0%	19.0%	76.4	-16.6		ranL

			17.4%	4.4%	11.6%	50.9	64.6		sigL
			19.3%	9.3%	10.1%	132.3	-106.6	0.95	ranT
			17.8%	7.8%	20.5%	65.1	82.6	6.80	sigT
			3.189E-03	2.248E-08	453.8	68.7	-115.7	0.94	Tot.
			47.4%	27.3%	18.3%				T-76
			0.000E+00	0.000E+00	0.0			0.0%	H2O
			0.000E+00	0.000E+00	0.0			0.0%	sigH
---	---	---	---	---	---	---	---	---	---
120.00	28.450	-80.530	3.127E-03	2.602E-08	383.6	-65.9	-7.5	-0.004	Mean
			23.2%	17.1%	6.6%				M-76
10.0			-3.8%	1.3%	-5.2%	54.6	-67.3		ranS
			4.0%	6.5%	17.3%	40.1	52.1		sigS
			22.4%	2.3%	20.0%	86.3	3.5		ranL
			17.9%	4.5%	12.0%	50.7	65.9		sigL
			18.5%	3.7%	14.8%	140.9	-63.8	1.48	ranT
			18.3%	7.9%	21.1%	64.6	84.0	6.63	sigT
			3.706E-03	2.697E-08	440.6	74.9	-71.4	1.48	Tot.
			46.0%	21.4%	22.4%				T-76
			0.000E+00	0.000E+00	0.0			0.0%	H2O
			0.000E+00	0.000E+00	0.0			0.0%	sigH
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118.00	28.450	-80.530	3.693E-03	3.331E-08	355.8	-66.4	-6.0	-0.003	Mean
			22.5%	17.0%	5.9%				M-76
11.0			-3.5%	-5.1%	1.5%	48.3	-44.4		ranS
			3.8%	7.1%	16.2%	39.6	52.9		sigS
			21.6%	1.4%	20.2%	85.5	-3.9		ranL
			17.4%	5.0%	11.4%	50.5	67.4		sigL
			18.1%	-3.7%	21.7%	133.8	-48.3	1.95	ranT
			17.8%	8.7%	19.8%	64.2	85.7	6.49	sigT
			4.359E-03	3.208E-08	433.2	67.4	-54.3	1.95	Tot.
			44.6%	12.7%	28.9%				T-76
			1.177E-09	7.778E-15	184.7			0.0%	H2O
			4.236E-10	2.800E-15	0.0			0.0%	sigH
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116.00	28.450	-80.530	4.392E-03	4.309E-08	328.8	-64.5	-4.5	-0.003	Mean
			20.9%	15.8%	5.4%				M-76
12.0			-1.4%	-9.1%	7.7%	35.2	8.1		ranS
			3.7%	7.7%	15.0%	39.2	53.6		sigS
			18.7%	0.0%	18.7%	99.0	16.6		ranL
			16.9%	5.5%	10.7%	50.3	68.9		sigL
			17.3%	-9.1%	26.4%	134.2	24.7	7.07	ranT
			17.3%	9.5%	18.4%	63.8	87.3	6.36	sigT
			5.152E-03	3.918E-08	415.6	69.7	20.2	7.07	Tot.
			41.8%	5.3%	33.2%				T-76
			1.513E-09	1.077E-14	178.6			0.0%	H2O
			5.448E-10	3.876E-15	0.0			0.0%	sigH
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114.00	28.450	-80.530	5.278E-03	5.654E-08	302.8	-60.7	-3.0	-0.002	Mean
			18.7%	13.6%	5.2%				M-76
13.0			-1.9%	-15.5%	13.6%	3.7	2.5		ranS
			3.5%	8.2%	13.8%	38.7	54.3		sigS
			19.8%	-0.6%	20.4%	88.2	18.0		ranL
			16.4%	6.0%	10.0%	50.1	70.4		sigL
			17.9%	-16.1%	34.0%	91.9	20.5	2.76	ranT
			16.8%	10.2%	17.1%	63.3	88.9	6.22	sigT
			6.223E-03	4.746E-08	405.7	31.1	17.5	2.76	Tot.
			39.9%	-4.6%	40.9%				T-76
			1.956E-09	1.503E-14	172.0			0.0%	H2O
			7.042E-10	5.410E-15	0.0			0.0%	sigH
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112.00	28.450	-80.530	6.435E-03	7.554E-08	278.0	-55.4	-1.6	-0.002	Mean
			15.8%	10.5%	5.3%				M-76
14.0			-2.2%	-14.5%	12.3%	15.2	14.2		ranS
			3.4%	8.8%	12.7%	38.2	55.0		sigS
			20.2%	-0.5%	20.8%	87.8	-8.1		ranL
			15.9%	6.5%	9.3%	49.9	71.8		sigL
			18.0%	-15.1%	33.1%	103.0	6.1	-1.17	ranT
			16.3%	11.0%	15.7%	62.9	90.5	6.09	sigT
			7.594E-03	6.415E-08	370.0	47.6	4.5	-1.17	Tot.
			36.7%	-6.2%	40.1%				T-76
			2.552E-09	2.123E-14	164.9			0.0%	H2O
			9.186E-10	7.642E-15	0.0			0.0%	sigH
110.00	28.450	-80.530	8.000E-03	1.035E-07	253.8	-49.2	-0.4	-0.001	Mean
			12.6%	6.6%	5.8%				M-76
15.0			-2.1%	-23.2%	21.1%	10.2	45.8		ranS
			3.3%	9.4%	11.5%	37.7	55.6		sigS
			21.0%	-1.3%	22.3%	78.3	0.6		ranL
			15.5%	7.0%	8.6%	49.7	73.3		sigL
			18.8%	-24.5%	43.4%	88.5	46.4	2.35	ranT
			15.8%	11.7%	14.3%	62.4	92.0	5.95	sigT
			9.507E-03	7.813E-08	363.9	39.3	46.0	2.35	Tot.
			33.8%	-19.5%	51.6%				T-76
			3.396E-09	3.074E-14	157.3			0.0%	H2O
			1.223E-09	1.107E-14	0.0			0.0%	sigH
108.00	28.450	-80.530	1.018E-02	1.436E-07	234.7	-41.9	0.7	-0.001	Mean
			9.3%	3.9%	5.1%				M-76
16.0			-3.9%	-28.2%	24.2%	19.3	8.1		ranS
			3.1%	9.9%	10.4%	37.3	56.3		sigS
			19.3%	0.9%	18.4%	86.3	19.1		ranL
			15.0%	7.5%	7.9%	49.5	74.8		sigL
			15.3%	-27.3%	42.6%	105.6	27.2	1.95	ranT
			15.3%	12.5%	13.0%	62.0	93.7	5.81	sigT
			1.174E-02	1.044E-07	334.6	63.7	27.8	1.95	Tot.
			26.0%	-24.4%	49.8%				T-76
			4.705E-09	4.575E-14	150.8			0.0%	H2O
			1.694E-09	1.647E-14	0.0			0.0%	sigH
106.00	28.450	-80.530	1.329E-02	2.033E-07	217.8	-34.4	1.6	-0.001	Mean
			6.7%	4.1%	2.3%				M-76
17.0			-4.0%	-30.1%	26.0%	44.0	40.7		ranS
			3.0%	10.4%	9.3%	36.8	57.0		sigS
			14.4%	-4.8%	19.2%	82.5	10.8		ranL
			14.5%	8.0%	7.1%	49.4	76.4		sigL
			10.4%	-34.8%	45.2%	126.4	51.5	0.28	ranT
			14.8%	13.2%	11.7%	61.6	95.3	5.68	sigT
			1.467E-02	1.325E-07	316.3	92.1	53.1	0.27	Tot.
			17.8%	-32.2%	48.6%				T-76
			6.686E-09	6.950E-14	144.6			0.0%	H2O
			2.407E-09	2.502E-14	0.0			0.0%	sigH
104.00	28.450	-80.530	1.780E-02	2.919E-07	204.9	-27.2	2.3	-0.001	Mean
			5.5%	5.4%	-0.2%				M-76
18.0			-5.5%	-30.4%	24.9%	26.5	10.2		ranS
			2.8%	10.9%	8.1%	36.4	57.6		sigS
			13.6%	-4.4%	18.0%	82.8	-16.1		ranL
			14.0%	8.6%	6.3%	49.1	77.9		sigL
			8.1%	-34.8%	42.9%	109.3	-5.9	-2.80	ranT
			14.2%	13.9%	10.3%	61.1	96.9	5.54	sigT

			1.924E-02	1.903E-07	292.7	82.1	-3.6	-2.80	Tot.
			14.0%	-31.3%	42.5%				T-76
			9.698E-09	1.064E-13	139.6			0.0%	H2O
			3.489E-09	3.828E-14	0.0			0.0%	sigH
102.00	28.450	-80.530	2.439E-02	4.204E-07	196.2	-20.5	3.0	-0.001	Mean
			5.5%	6.9%	-1.7%				M-76
19.0			-5.0%	-23.1%	18.1%	-10.9	-13.4		ranS
			2.7%	11.5%	7.1%	35.9	58.2		sigS
			10.4%	-6.0%	16.4%	97.7	7.8		ranL
			13.5%	9.1%	5.6%	48.9	79.4		sigL
			5.4%	-29.1%	34.5%	86.7	-5.6	-4.06	ranT
			13.7%	14.7%	9.0%	60.7	98.5	5.40	sigT
			2.570E-02	2.980E-07	263.9	66.3	-2.6	-4.06	Tot.
			11.1%	-24.2%	32.3%				T-76
			1.431E-08	1.627E-13	136.1			0.0%	H2O
			5.137E-09	5.842E-14	0.1			0.0%	sigH
100.00	28.450	-80.530	3.402E-02	6.114E-07	189.5	-14.6	3.5	-0.001	Mean
			6.3%	9.1%	-2.9%				M-76
20.0			-4.0%	-12.5%	8.5%	-35.6	42.7		ranS
			2.6%	12.0%	5.9%	35.4	58.8		sigS
			7.6%	-1.0%	8.6%	99.0	2.5		ranL
			12.9%	9.7%	4.7%	48.7	80.9		sigL
			3.6%	-13.6%	17.1%	63.4	45.2	-3.26	ranT
			13.2%	15.4%	7.5%	60.2	100.0	5.26	sigT
			3.523E-02	5.285E-07	222.0	48.8	48.8	-3.26	Tot.
			10.1%	-5.7%	13.8%				T-76
			2.162E-08	2.527E-13	133.4			0.0%	H2O
			7.701E-09	9.004E-14	0.2			0.0%	sigH
98.00	28.450	-80.530	4.812E-02	8.802E-07	187.3	-10.7	4.0	-0.002	Mean
			6.9%	9.2%	-2.3%				M-76
21.0			-4.0%	-9.7%	5.7%	-12.9	64.4		ranS
			2.6%	11.6%	5.9%	34.4	59.7		sigS
			7.0%	0.9%	6.0%	99.0	15.2		ranL
			13.1%	9.7%	4.8%	48.4	84.1		sigL
			3.0%	-8.8%	11.8%	86.1	79.6	-3.16	ranT
			13.4%	15.1%	7.6%	59.4	103.1	5.16	sigT
			4.954E-02	8.028E-07	209.3	75.4	83.5	-3.16	Tot.
			10.1%	-0.4%	9.2%				T-76
			3.505E-08	4.122E-13	132.7			0.0%	H2O
			1.236E-08	1.453E-13	0.4			0.0%	sigH
96.00	28.450	-80.530	6.845E-02	1.266E-06	186.3	-7.9	4.3	-0.002	Mean
			7.4%	9.0%	-1.6%				M-76
22.0			-2.3%	0.9%	-3.2%	-34.4	88.4		ranS
			2.5%	11.1%	5.9%	33.3	60.5		sigS
			4.4%	1.4%	3.0%	87.6	32.5		ranL
			13.3%	9.6%	4.8%	48.1	87.2		sigL
			2.1%	2.3%	-0.2%	53.2	120.9	-6.47	ranT
			13.5%	14.7%	7.6%	58.5	106.1	5.06	sigT
			6.989E-02	1.295E-06	185.9	45.3	125.2	-6.48	Tot.
			9.6%	11.5%	-1.8%				T-76
			5.735E-08	6.743E-13	132.6			0.0%	H2O
			1.993E-08	2.344E-13	0.6			0.0%	sigH
94.00	28.450	-80.530	9.867E-02	1.814E-06	188.2	-5.8	4.6	-0.003	Mean
			9.0%	8.6%	0.3%				M-76
23.0			-1.7%	4.4%	-6.1%	-20.4	80.9		ranS

			2.5%	10.7%	5.9%	32.3	61.2		sigS
			4.6%	2.6%	2.0%	53.4	27.8		ranL
			13.4%	9.6%	4.9%	47.7	90.4		sigL
			2.9%	7.0%	-4.1%	33.1	108.7	-7.58	ranT
			13.7%	14.4%	7.7%	57.6	109.2	4.96	sigT
			1.015E-01	1.941E-06	180.5	27.3	113.3	-7.58	Tot.
			12.1%	16.2%	-3.9%				T-76
			9.677E-08	1.121E-12	133.9			0.0%	H2O
			3.355E-08	3.887E-13	0.7			0.0%	sigH
92.00	28.450	-80.530	1.429E-01	2.569E-06	193.0	-4.0	4.7	-0.004	Mean
			10.9%	7.4%	3.3%				M-76
24.0			-1.8%	3.1%	-4.8%	-22.9	14.8		ranS
			2.5%	10.2%	5.9%	31.3	61.8		sigS
			6.4%	2.7%	3.7%	40.0	56.6		ranL
			13.6%	9.5%	5.0%	47.3	93.6		sigL
			4.6%	5.8%	-1.2%	17.1	71.4	-9.72	ranT
			13.8%	14.0%	7.7%	56.7	112.2	4.85	sigT
			1.495E-01	2.718E-06	190.8	13.2	76.1	-9.72	Tot.
			16.0%	13.6%	2.0%				T-76
			1.667E-07	1.878E-12	136.6			0.0%	H2O
			5.841E-08	6.581E-13	0.5			0.0%	sigH
90.00	28.450	-80.530	2.048E-01	3.602E-06	197.9	-2.4	4.8	-0.004	Mean
			11.6%	5.4%	5.9%				M-76
25.0			-1.3%	3.8%	-5.1%	-10.9	22.9		ranS
			2.5%	9.8%	5.9%	30.2	62.4		sigS
			6.2%	4.9%	1.3%	48.5	53.7		ranL
			13.7%	9.4%	5.1%	47.0	96.9		sigL
			4.8%	8.7%	-3.8%	37.6	76.6	-4.57	ranT
			14.0%	13.6%	7.8%	55.8	115.2	4.75	sigT
			2.148E-01	3.914E-06	190.3	35.2	81.4	-4.57	Tot.
			17.0%	14.6%	1.9%				T-76
			2.855E-07	3.126E-12	139.3			0.0%	H2O
			1.008E-07	1.103E-12	0.4			0.0%	sigH
88.00	28.450	-80.530	2.875E-01	4.968E-06	201.4	4.0	4.6	-0.003	Mean
			9.9%	1.9%	7.8%				M-76
26.0			-0.9%	10.0%	-10.9%	6.5	-9.3		ranS
			2.1%	8.2%	5.1%	26.8	48.9		sigS
			4.8%	7.5%	-2.7%	27.9	72.4		ranL
			11.8%	8.2%	4.4%	42.8	78.0		sigL
			4.0%	17.5%	-13.6%	34.4	63.2	-4.42	ranT
			12.0%	11.6%	6.7%	50.5	92.1	4.49	sigT
			2.989E-01	5.839E-06	174.1	38.4	67.7	-4.43	Tot.
			14.2%	19.8%	-6.8%				T-76
			4.758E-07	5.118E-12	141.4			0.0%	H2O
			1.684E-07	1.811E-12	0.3			0.0%	sigH
86.00	28.450	-80.530	4.013E-01	6.816E-06	204.9	10.4	4.3	-0.003	Mean
			7.5%	-2.0%	9.7%				M-76
27.0			-0.1%	1.5%	-1.5%	0.3	-16.5		ranS
			1.7%	6.3%	4.1%	23.2	31.6		sigS
			4.5%	5.5%	-1.1%	35.5	24.2		ranL
			9.5%	6.5%	3.6%	38.0	51.8		sigL
			4.4%	7.0%	-2.6%	35.8	7.8	-3.29	ranT
			9.6%	9.1%	5.5%	44.5	60.6	4.22	sigT
			4.190E-01	7.293E-06	199.7	46.2	12.1	-3.30	Tot.
			12.2%	4.8%	6.8%				T-76
			7.887E-07	8.338E-12	143.6			0.0%	H2O

			2.796E-07	2.956E-12	0.3			0.0%	sigH
84.00	28.450	-80.530	5.563E-01	9.341E-06	207.4	16.8	4.6	-0.002	Mean
			4.8%	-3.6%	8.7%				M-76
28.0			-0.8%	-4.8%	4.0%	6.5	-4.8		ranS
			1.4%	5.0%	3.4%	20.6	17.5		sigS
			3.4%	3.7%	-0.3%	42.9	17.8		ranL
			7.9%	5.4%	3.1%	34.7	29.5		sigL
			2.7%	-1.1%	3.7%	49.4	13.0	-0.56	ranT
			8.0%	7.4%	4.6%	40.4	34.3	3.93	sigT
			5.711E-01	9.241E-06	215.2	66.2	17.6	-0.57	Tot.
			7.5%	-4.7%	12.7%				T-76
			1.305E-06	1.363E-11	145.3			0.0%	H2O
			4.624E-07	4.830E-12	0.3			0.0%	sigH
82.00	28.450	-80.530	7.680E-01	1.282E-05	208.9	23.1	5.3	-0.003	Mean
			2.4%	-4.5%	7.2%				M-76
29.0			-1.3%	-7.7%	6.4%	6.5	-3.2		ranS
			1.3%	4.7%	3.3%	19.4	15.6		sigS
			2.7%	1.3%	1.5%	44.8	20.5		ranL
			7.4%	5.2%	2.9%	33.6	27.0		sigL
			1.4%	-6.5%	7.9%	51.4	17.3	1.17	ranT
			7.5%	7.0%	4.4%	38.9	31.2	3.62	sigT
			7.790E-01	1.199E-05	225.3	74.5	22.7	1.17	Tot.
			3.9%	-10.6%	15.7%				T-76
			2.158E-06	2.239E-11	146.5			0.0%	H2O
			7.630E-07	7.916E-12	0.4			0.0%	sigH
80.00	28.450	-80.530	1.057E+00	1.754E-05	210.3	29.4	6.1	-0.003	Mean
			0.5%	-5.0%	5.9%				M-76
30.0			-1.3%	-3.4%	2.1%	6.9	-9.5		ranS
			1.2%	4.3%	3.1%	18.2	13.6		sigS
			3.4%	0.6%	2.9%	42.7	18.8		ranL
			6.9%	4.9%	2.8%	32.5	24.2		sigL
			2.1%	-2.9%	5.0%	49.6	9.3	-0.79	ranT
			7.0%	6.5%	4.2%	37.2	27.8	3.30	sigT
			1.080E+00	1.704E-05	220.8	79.0	15.4	-0.79	Tot.
			2.6%	-7.7%	11.2%				T-76
			3.393E-06	3.496E-11	147.6			0.0%	H2O
			1.020E-06	1.051E-11	0.4			0.0%	sigH
78.00	28.450	-80.530	1.450E+00	2.389E-05	211.6	36.3	5.4	-0.002	Mean
			-1.2%	-5.4%	4.5%				M-76
31.0			-0.8%	-0.5%	-0.3%	18.2	-14.7		ranS
			1.2%	4.2%	3.0%	17.7	13.0		sigS
			4.8%	1.1%	3.7%	40.7	11.8		ranL
			7.0%	5.1%	2.8%	32.4	23.9		sigL
			4.0%	0.6%	3.4%	58.9	-2.9	-0.88	ranT
			7.1%	6.6%	4.2%	36.9	27.3	2.98	sigT
			1.508E+00	2.403E-05	218.8	95.3	2.4	-0.89	Tot.
			2.7%	-4.8%	8.0%				T-76
			3.937E-06	4.032E-11	147.6			0.0%	H2O
			1.398E-06	1.432E-11	0.5			0.0%	sigH
76.00	28.450	-80.530	1.983E+00	3.246E-05	212.9	43.3	4.7	-0.001	Mean
			-2.5%	-5.4%	3.1%				M-76
32.0			-0.2%	3.4%	-3.5%	18.1	-9.0		ranS
			1.2%	4.2%	3.0%	17.1	12.5		sigS
			5.1%	1.5%	3.6%	30.2	10.1		ranL
			7.1%	5.2%	2.8%	32.4	23.6		sigL

			5.0%	4.9%	0.1%	48.3	1.1	0.43	ranT
			7.2%	6.6%	4.2%	36.6	26.7	2.67	sigT
			2.082E+00	3.405E-05	213.0	91.5	5.8	0.43	Tot.
			2.4%	-0.8%	3.2%				T-76
			5.722E-06	5.824E-11	148.3			0.0%	H2O
			1.913E-06	1.948E-11	0.6			0.0%	sigH
74.00	28.450	-80.530	2.709E+00	4.391E-05	214.8	48.6	4.5	-0.001	Mean
			-3.3%	-5.3%	2.1%				M-76
33.0			0.2%	4.0%	-3.9%	5.6	-14.1		ranS
			1.1%	4.0%	2.9%	17.1	11.6		sigS
			2.3%	0.3%	1.9%	22.3	3.6		ranL
			7.0%	5.1%	2.8%	32.2	21.8		sigL
			2.4%	4.4%	-1.9%	27.9	-10.5	1.72	ranT
			7.1%	6.5%	4.0%	36.5	24.7	2.39	sigT
			2.775E+00	4.583E-05	210.7	76.5	-6.0	1.72	Tot.
			-0.9%	-1.2%	0.2%				T-76
			8.622E-06	8.695E-11	149.6			0.0%	H2O
			2.613E-06	2.635E-11	0.6			0.0%	sigH
72.00	28.450	-80.530	3.688E+00	5.905E-05	217.5	52.4	4.7	-0.001	Mean
			-3.9%	-5.3%	1.5%				M-76
34.0			0.5%	2.9%	-2.4%	12.6	-12.5		ranS
			1.0%	3.6%	2.6%	17.6	10.1		sigS
			1.8%	0.8%	1.0%	20.1	7.8		ranL
			6.5%	4.9%	2.8%	31.9	18.1		sigL
			2.4%	3.8%	-1.4%	32.6	-4.8	0.34	ranT
			6.6%	6.1%	3.8%	36.5	20.7	2.15	sigT
			3.775E+00	6.128E-05	214.4	85.0	-0.1	0.34	Tot.
			-1.6%	-1.8%	0.1%				T-76
			1.481E-05	1.476E-10	151.6			0.0%	H2O
			4.191E-06	4.175E-11	0.6			0.0%	sigH
70.00	28.450	-80.530	5.003E+00	7.912E-05	220.2	56.1	4.9	0.000	Mean
			-4.2%	-4.5%	0.3%				M-76
35.0			0.7%	4.6%	-3.9%	7.3	-6.8		ranS
			0.8%	3.3%	2.3%	18.1	7.9		sigS
			2.2%	1.7%	0.5%	16.2	8.3		ranL
			5.9%	4.6%	2.7%	31.7	13.6		sigL
			2.9%	6.3%	-3.4%	23.4	1.5	0.23	ranT
			6.0%	5.6%	3.5%	36.5	15.8	1.91	sigT
			5.148E+00	8.414E-05	212.6	79.5	6.4	0.23	Tot.
			-1.4%	1.6%	-3.2%				T-76
			2.704E-05	2.660E-10	153.9			0.0%	H2O
			7.238E-06	7.122E-11	0.6			0.0%	sigH
68.00	28.450	-80.530	6.761E+00	1.049E-04	224.5	57.8	5.0	0.001	Mean
			-4.1%	-4.0%	-0.2%				M-76
36.0			0.6%	3.4%	-2.8%	15.9	1.4		ranS
			0.7%	3.1%	2.2%	17.6	8.5		sigS
			3.4%	-0.1%	3.5%	24.6	13.7		ranL
			5.6%	4.5%	2.8%	29.8	14.0		sigL
			4.0%	3.3%	0.7%	40.5	15.1	0.22	ranT
			5.7%	5.4%	3.6%	34.6	16.4	1.76	sigT
			7.032E+00	1.083E-04	226.1	98.3	20.1	0.22	Tot.
			-0.3%	-0.8%	0.5%				T-76
			4.336E-05	4.184E-10	156.6			0.0%	H2O
			8.770E-06	8.463E-11	0.4			0.0%	sigH
66.00	28.450	-80.530	9.084E+00	1.382E-04	228.9	59.6	5.1	0.002	Mean

			-4.0%	-3.3%	-0.7%				M-76
37.0			0.5%	2.3%	-1.8%	28.8	-0.4		ranS
			0.6%	2.9%	2.0%	17.0	9.1		sigS
			3.5%	-0.3%	3.8%	30.4	9.9		ranL
			5.3%	4.4%	2.9%	27.9	14.3		sigL
			4.0%	2.0%	1.9%	59.2	9.5	0.09	ranT
			5.4%	5.3%	3.6%	32.7	16.9	1.61	sigT
			9.444E+00	1.410E-04	233.3	118.8	14.6	0.10	Tot.
			-0.2%	-1.4%	1.2%				T-76
			6.923E-05	6.554E-10	159.2			0.0%	H2O
			1.059E-05	1.002E-10	0.2			0.0%	sigH
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64.00	28.450	-80.530	1.215E+01	1.813E-04	233.4	60.3	5.2	0.003	Mean
			-3.7%	-2.6%	-1.1%				M-76
38.0			0.8%	2.1%	-1.3%	9.2	5.3		ranS
			0.6%	2.9%	2.0%	16.5	9.6		sigS
			1.9%	-1.8%	3.7%	36.8	9.0		ranL
			5.2%	4.4%	2.9%	26.2	13.7		sigL
			2.7%	0.3%	2.4%	45.9	14.3	1.25	ranT
			5.3%	5.2%	3.5%	30.9	16.7	1.55	sigT
			1.247E+01	1.818E-04	238.9	106.2	19.5	1.26	Tot.
			-1.1%	-2.3%	1.2%				T-76
			1.031E-04	9.573E-10	161.6			0.0%	H2O
			1.511E-05	1.403E-10	0.2			0.0%	sigH
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62.00	28.450	-80.530	1.616E+01	2.365E-04	238.0	60.1	5.3	0.004	Mean
			-3.2%	-1.8%	-1.5%				M-76
39.0			1.1%	4.2%	-3.0%	7.7	1.1		ranS
			0.7%	3.0%	2.0%	16.0	9.8		sigS
			1.6%	-0.4%	2.0%	43.9	11.0		ranL
			5.4%	4.4%	2.6%	24.6	12.2		sigL
			2.8%	3.8%	-1.0%	51.6	12.1	-1.19	ranT
			5.4%	5.3%	3.2%	29.4	15.6	1.58	sigT
			1.660E+01	2.454E-04	235.6	111.6	17.3	-1.18	Tot.
			-0.5%	2.0%	-2.5%				T-76
			1.478E-04	1.346E-09	164.0			0.0%	H2O
			2.328E-05	2.119E-10	0.2			0.0%	sigH
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60.00	28.450	-80.530	2.138E+01	3.069E-04	242.7	59.8	5.3	0.004	Mean
			-2.7%	-0.9%	-1.8%				M-76
40.0			1.1%	2.4%	-1.3%	0.8	-5.3		ranS
			0.8%	3.1%	2.0%	15.5	9.8		sigS
			2.7%	-0.2%	2.9%	35.5	5.1		ranL
			5.5%	4.4%	2.3%	23.0	10.7		sigL
			3.8%	2.2%	1.6%	36.3	-0.2	-0.62	ranT
			5.6%	5.4%	3.0%	27.8	14.5	1.61	sigT
			2.219E+01	3.137E-04	246.6	96.1	5.1	-0.61	Tot.
			1.0%	1.3%	-0.2%				T-76
			2.055E-04	1.835E-09	166.2			0.0%	H2O
			3.312E-05	2.957E-10	0.2			0.0%	sigH
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58.00	28.450	-80.530	2.812E+01	3.951E-04	248.1	55.3	5.7	0.004	Mean
			-2.1%	-0.3%	-1.8%				M-76
41.0			1.0%	1.2%	-0.2%	7.2	-9.1		ranS
			0.9%	3.1%	2.0%	14.8	9.9		sigS
			4.3%	0.2%	4.2%	39.6	7.0		ranL
			5.4%	4.2%	2.1%	23.5	9.9		sigL
			5.4%	1.4%	4.0%	46.8	-2.1	1.30	ranT
			5.5%	5.2%	2.9%	27.8	14.0	1.53	sigT
			2.963E+01	4.007E-04	257.9	102.1	3.6	1.30	Tot.

			3.1%	1.1%	2.1%				T-76
			2.631E-04	2.298E-09	168.4			0.0%	H2O
			3.739E-05	3.266E-10	0.1			0.0%	sigH
56.00	28.450	-80.530	3.678E+01	5.059E-04	253.5	50.9	6.1	0.003	Mean
			-1.6%	0.3%	-1.8%				M-76
42.0			1.0%	1.0%	0.0%	-12.2	0.2		ranS
			0.9%	3.0%	1.9%	14.1	9.9		sigS
			3.2%	-0.6%	3.7%	43.6	10.8		ranL
			5.3%	3.9%	1.9%	24.1	9.2		sigL
			4.2%	0.4%	3.7%	31.5	11.0	0.25	ranT
			5.3%	4.9%	2.7%	27.9	13.5	1.46	sigT
			3.831E+01	5.080E-04	262.9	82.4	17.1	0.26	Tot.
			2.5%	0.7%	1.9%				T-76
			3.352E-04	2.866E-09	170.5			0.0%	H2O
			4.210E-05	3.599E-10	0.1			0.0%	sigH
54.00	28.450	-80.530	4.784E+01	6.465E-04	258.0	46.7	6.3	0.003	Mean
			-1.0%	1.2%	-2.1%				M-76
43.0			0.7%	-0.5%	1.2%	-11.2	-0.7		ranS
			0.9%	2.9%	1.8%	13.3	9.9		sigS
			2.3%	-0.6%	3.0%	45.2	12.4		ranL
			5.1%	3.7%	1.7%	24.5	8.9		sigL
			3.0%	-1.2%	4.1%	34.1	11.8	-0.10	ranT
			5.2%	4.7%	2.5%	27.9	13.3	1.37	sigT
			4.926E+01	6.389E-04	268.7	80.8	18.0	-0.10	Tot.
			1.9%	0.0%	2.0%				T-76
			4.252E-04	3.571E-09	172.3			0.0%	H2O
			4.730E-05	3.973E-10	0.1			0.0%	sigH
52.00	28.450	-80.530	6.199E+01	8.257E-04	261.6	42.7	6.1	0.002	Mean
			-0.4%	2.5%	-2.8%				M-76
44.0			0.2%	-0.8%	1.0%	-19.8	-3.5		ranS
			0.9%	2.7%	1.7%	12.5	9.8		sigS
			1.3%	-0.4%	1.7%	42.9	5.3		ranL
			4.8%	3.5%	1.6%	24.9	9.1		sigL
			1.5%	-1.2%	2.7%	23.1	1.8	-0.82	ranT
			4.9%	4.4%	2.4%	27.9	13.4	1.26	sigT
			6.292E+01	8.161E-04	268.6	65.8	7.9	-0.82	Tot.
			1.1%	1.3%	-0.2%				T-76
			5.485E-04	4.543E-09	173.7			0.0%	H2O
			5.322E-05	4.408E-10	0.1			0.0%	sigH
50.00	28.450	-80.530	8.004E+01	1.051E-03	265.2	38.7	6.0	0.001	Mean
			0.3%	2.4%	-2.0%				M-76
45.0			-0.4%	-2.2%	1.8%	-4.8	-9.5		ranS
			0.8%	2.5%	1.5%	11.6	9.7		sigS
			2.2%	-1.4%	3.6%	40.5	3.5		ranL
			4.6%	3.4%	1.5%	25.4	9.3		sigL
			1.8%	-3.6%	5.4%	35.8	-5.9	-0.64	ranT
			4.7%	4.2%	2.2%	27.9	13.4	1.15	sigT
			8.148E+01	1.013E-03	279.6	74.5	0.0	-0.64	Tot.
			2.1%	-1.3%	3.3%				T-76
			6.882E-04	5.622E-09	175.0			0.0%	H2O
			5.311E-05	4.338E-10	0.1			0.0%	sigH
48.00	28.450	-80.530	1.030E+02	1.353E-03	265.2	36.3	5.7	0.000	Mean
			0.7%	2.8%	-2.0%				M-76
46.0			-0.3%	-1.7%	1.4%	-7.5	-13.3		ranS
			0.8%	2.5%	1.6%	11.0	9.1		sigS

			1.8%	-2.9%	4.7%	33.6	5.6		ranL
			4.4%	3.3%	1.6%	24.7	9.0		sigL
			1.5%	-4.6%	6.1%	26.1	-7.8	-0.62	ranT
			4.4%	4.1%	2.3%	27.0	12.8	1.05	sigT
			1.046E+02	1.291E-03	281.4	62.4	-2.1	-0.62	Tot.
			2.2%	-2.0%	4.0%				T-76
			8.430E-04	6.889E-09	174.7			0.0%	H2O
			5.021E-05	4.103E-10	0.1			0.0%	sigH
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46.00	28.450	-80.530	1.326E+02	1.742E-03	265.1	33.9	5.5	0.000	Mean
			0.9%	1.6%	-0.7%				M-76
47.0			-0.4%	-2.0%	1.6%	-18.2	-17.7		ranS
			0.7%	2.4%	1.6%	10.3	8.5		sigS
			1.3%	-4.3%	5.6%	28.2	5.7		ranL
			4.1%	3.3%	1.7%	23.9	8.7		sigL
			0.9%	-6.3%	7.2%	10.0	-12.1	-0.22	ranT
			4.2%	4.0%	2.4%	26.1	12.1	0.94	sigT
			1.337E+02	1.633E-03	284.1	43.9	-6.6	-0.22	Tot.
			1.8%	-4.7%	6.4%				T-76
			1.066E-03	8.712E-09	174.6			0.0%	H2O
			7.080E-05	5.787E-10	0.1			0.0%	sigH
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44.00	28.450	-80.530	1.708E+02	2.263E-03	263.0	31.4	5.2	-0.001	Mean
			0.8%	0.2%	0.6%				M-76
48.0			-0.6%	-1.3%	0.7%	-14.6	-8.4		ranS
			0.6%	2.3%	1.6%	9.7	7.8		sigS
			0.9%	-4.0%	5.0%	25.7	2.9		ranL
			3.9%	3.2%	1.8%	23.0	8.2		sigL
			0.4%	-5.3%	5.7%	11.2	-5.5	0.11	ranT
			3.9%	3.9%	2.4%	24.9	11.3	0.86	sigT
			1.714E+02	2.142E-03	278.0	42.6	-0.3	0.11	Tot.
			1.1%	-5.2%	6.3%				T-76
			1.336E-03	1.101E-08	173.6			0.0%	H2O
			8.532E-05	7.030E-10	0.1			0.0%	sigH
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42.00	28.450	-80.530	2.208E+02	2.973E-03	258.8	29.0	4.8	-0.001	Mean
			0.4%	-0.7%	1.2%				M-76
49.0			-0.5%	-0.5%	0.0%	-10.7	-13.2		ranS
			0.6%	2.1%	1.5%	9.1	7.1		sigS
			0.3%	-4.2%	4.5%	30.7	-0.2		ranL
			3.7%	2.9%	1.9%	21.7	7.5		sigL
			-0.2%	-4.7%	4.5%	20.0	-13.4	0.35	ranT
			3.7%	3.6%	2.4%	23.5	10.3	0.81	sigT
			2.204E+02	2.833E-03	270.5	49.0	-8.6	0.35	Tot.
			0.2%	-5.4%	5.7%				T-76
			1.675E-03	1.402E-08	171.8			0.0%	H2O
			9.201E-05	7.704E-10	0.2			0.0%	sigH
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40.00	28.450	-80.530	2.868E+02	3.924E-03	254.7	26.6	4.4	-0.001	Mean
			-0.1%	-1.8%	1.7%				M-76
50.0			-0.3%	-0.8%	0.4%	-7.7	-3.3		ranS
			0.5%	1.9%	1.5%	8.6	6.3		sigS
			0.9%	-2.9%	3.7%	24.2	-3.4		ranL
			3.5%	2.7%	1.9%	20.4	6.7		sigL
			0.6%	-3.6%	4.2%	16.5	-6.8	0.57	ranT
			3.5%	3.3%	2.4%	22.1	9.2	0.75	sigT
			2.883E+02	3.781E-03	265.4	43.1	-2.4	0.57	Tot.
			0.4%	-5.4%	6.0%				T-76
			2.446E-03	2.081E-08	170.7			0.0%	H2O
			1.059E-04	9.014E-10	0.2			0.0%	sigH

38.00	28.450	-80.530	3.748E+02	5.251E-03	248.7	23.6	3.9	-0.001	Mean
			-0.6%	-2.1%	1.6%				M-76
51.0			-0.1%	2.0%	-2.1%	-2.7	-3.2		ranS
			0.5%	1.8%	1.5%	8.0	5.9		sigS
			0.8%	-2.4%	3.2%	15.8	-1.2		ranL
			3.2%	2.5%	1.8%	19.1	6.3		sigL
			0.7%	-0.4%	1.1%	13.2	-4.4	0.53	ranT
			3.3%	3.1%	2.4%	20.7	8.6	0.70	sigT
			3.774E+02	5.230E-03	251.5	36.7	-0.5	0.53	Tot.
			0.1%	-2.5%	2.7%				T-76
			3.551E-03	3.093E-08	171.9			0.0%	H2O
			1.244E-04	1.084E-09	0.2			0.0%	sigH
36.00	28.450	-80.530	4.929E+02	7.075E-03	242.8	20.5	3.4	0.000	Mean
			-1.1%	-2.5%	1.5%				M-76
52.0			-0.1%	1.1%	-1.2%	5.2	-7.2		ranS
			0.5%	1.7%	1.5%	7.3	5.5		sigS
			0.9%	-1.6%	2.5%	28.5	-2.0		ranL
			2.9%	2.3%	1.8%	17.7	5.9		sigL
			0.8%	-0.5%	1.3%	33.7	-9.1	0.35	ranT
			3.0%	2.9%	2.3%	19.2	8.1	0.65	sigT
			4.968E+02	7.039E-03	245.9	54.2	-5.7	0.35	Tot.
			-0.3%	-3.0%	2.8%				T-76
			4.557E-03	4.067E-08	172.8			0.0%	H2O
			1.471E-04	1.313E-09	0.2			0.0%	sigH
34.00	28.450	-80.530	6.528E+02	9.581E-03	237.4	19.4	2.9	0.000	Mean
			-1.6%	-3.1%	1.6%				M-76
53.0			0.1%	2.9%	-2.8%	8.7	-4.2		ranS
			0.4%	1.6%	1.4%	6.7	5.1		sigS
			0.7%	0.0%	0.7%	20.4	-2.8		ranL
			2.7%	2.1%	1.7%	16.4	5.4		sigL
			0.8%	2.9%	-2.1%	29.1	-7.0	0.60	ranT
			2.7%	2.7%	2.2%	17.7	7.4	0.61	sigT
			6.579E+02	9.854E-03	232.5	48.4	-4.1	0.60	Tot.
			-0.8%	-0.3%	-0.5%				T-76
			5.831E-03	5.321E-08	173.8			0.0%	H2O
			1.883E-04	1.720E-09	0.2			0.0%	sigH
32.00	28.450	-80.530	8.701E+02	1.303E-02	232.7	20.1	2.4	-0.001	Mean
			-2.1%	-3.9%	1.8%				M-76
54.0			0.3%	1.6%	-1.2%	8.4	-4.5		ranS
			0.4%	1.5%	1.3%	5.9	4.5		sigS
			1.1%	0.0%	1.1%	17.4	0.3		ranL
			2.4%	1.9%	1.6%	15.0	4.8		sigL
			1.4%	1.5%	-0.1%	25.8	-4.2	0.41	ranT
			2.4%	2.4%	2.1%	16.1	6.5	0.57	sigT
			8.826E+02	1.323E-02	232.4	45.8	-1.8	0.41	Tot.
			-0.7%	-2.4%	1.7%				T-76
			7.517E-03	7.000E-08	175.0			0.0%	H2O
			2.313E-04	2.156E-09	0.2			0.0%	sigH
30.00	28.450	-80.530	1.166E+03	1.783E-02	227.9	20.8	1.9	-0.001	Mean
			-2.6%	-3.1%	0.6%				M-76
55.0			0.3%	1.0%	-0.7%	6.4	1.2		ranS
			0.3%	1.3%	1.2%	5.2	3.8		sigS
			0.3%	-1.3%	1.6%	4.7	2.0		ranL
			2.1%	1.7%	1.5%	13.4	4.1		sigL
			0.6%	-0.3%	1.0%	11.1	3.2	0.25	ranT

			2.1%	2.1%	2.0%	14.3	5.6	0.53	sigT
			1.174E+03	1.778E-02	230.1	31.9	5.1	0.25	Tot.
			-1.9%	-3.4%	1.6%				T-76
			9.856E-03	9.370E-08	176.4			0.1%	H2O
			2.869E-04	2.730E-09	0.2			0.0%	sigH
28.00	28.450	-80.530	1.575E+03	2.449E-02	224.0	17.4	1.8	0.000	Mean
			-2.6%	-2.4%	-0.2%				M-76
56.0			0.5%	1.5%	-1.0%	3.5	2.7		ranS
			0.3%	1.1%	1.0%	4.5	3.3		sigS
			0.0%	-0.9%	0.9%	4.9	1.3		ranL
			1.9%	1.6%	1.4%	11.9	3.6		sigL
			0.5%	0.6%	-0.2%	8.4	4.0	-0.05	ranT
			1.9%	1.9%	1.7%	12.7	4.9	0.50	sigT
			1.582E+03	2.464E-02	223.7	25.8	5.8	-0.05	Tot.
			-2.1%	-1.7%	-0.4%				T-76
			1.320E-02	1.276E-07	177.9			0.1%	H2O
			3.653E-04	3.536E-09	0.2			0.0%	sigH
26.00	28.450	-80.530	2.137E+03	3.381E-02	220.1	13.8	1.6	0.000	Mean
			-2.4%	-1.3%	-1.1%				M-76
57.0			0.4%	1.4%	-0.9%	3.4	4.3		ranS
			0.2%	0.9%	0.9%	3.8	2.7		sigS
			-0.3%	-0.9%	0.6%	5.2	2.0		ranL
			1.7%	1.4%	1.3%	10.2	3.0		sigL
			0.2%	0.5%	-0.3%	8.6	6.3	-0.18	ranT
			1.7%	1.7%	1.5%	10.9	4.1	0.47	sigT
			2.140E+03	3.396E-02	219.4	22.4	7.9	-0.18	Tot.
			-2.2%	-0.9%	-1.4%				T-76
			1.768E-02	1.741E-07	179.5			0.2%	H2O
			5.151E-04	5.077E-09	0.2			0.0%	sigH
24.00	28.450	-80.530	2.916E+03	4.698E-02	216.2	10.8	1.5	0.000	Mean
			-1.9%	0.1%	-2.0%				M-76
58.0			0.4%	1.0%	-0.6%	5.8	2.8		ranS
			0.2%	0.8%	0.8%	3.2	2.6		sigS
			-0.7%	-1.2%	0.4%	7.4	3.4		ranL
			1.8%	1.3%	1.2%	8.7	2.9		sigL
			-0.3%	-0.1%	-0.2%	13.2	6.1	-0.26	ranT
			1.8%	1.5%	1.4%	9.3	3.9	0.44	sigT
			2.907E+03	4.692E-02	215.8	24.1	7.6	-0.26	Tot.
			-2.2%	0.0%	-2.2%				T-76
			2.315E-02	2.320E-07	180.9			0.5%	H2O
			7.353E-04	7.378E-09	0.3			0.0%	sigH
22.00	28.450	-80.530	4.021E+03	6.621E-02	211.5	10.2	1.4	0.000	Mean
			-0.7%	2.6%	-3.2%				M-76
59.0			0.3%	-0.2%	0.5%	1.3	1.1		ranS
			0.2%	0.9%	0.8%	2.9	2.7		sigS
			-1.0%	-1.0%	0.0%	6.1	6.1		ranL
			1.4%	1.3%	1.2%	7.8	3.1		sigL
			-0.7%	-1.2%	0.5%	7.4	7.2	0.73	ranT
			1.4%	1.6%	1.4%	8.3	4.1	0.43	sigT
			3.993E+03	6.541E-02	212.6	17.6	8.6	0.73	Tot.
			-1.4%	1.4%	-2.7%				T-76
			2.926E-02	2.997E-07	182.2			1.1%	H2O
			1.093E-03	1.121E-08	0.3			0.1%	sigH
20.00	28.450	-80.530	5.580E+03	9.416E-02	206.5	12.4	1.6	0.000	Mean
			0.9%	5.9%	-4.7%				M-76

60.0			0.2%	0.0%	0.2%	-0.5	-4.4		ranS
			0.1%	0.9%	0.9%	2.6	3.0		sigS
			-0.8%	-0.4%	-0.3%	3.1	5.2		ranL
			0.8%	1.3%	1.3%	7.2	3.4		sigL
			-0.6%	-0.4%	-0.2%	2.6	0.8	0.60	ranT
			0.8%	1.6%	1.6%	7.6	4.5	0.42	sigT
			5.546E+03	9.375E-02	206.1	15.0	2.4	0.60	Tot.
			0.3%	5.4%	-4.9%				T-76
			3.598E-02	3.776E-07	183.4			2.7%	H2O
			1.851E-03	1.944E-08	0.4			0.2%	sigH
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18.00	28.450	-80.530	7.789E+03	1.335E-01	203.2	19.2	2.3	0.000	Mean
			3.0%	9.8%	-6.2%				M-76
61.0			0.1%	-0.9%	1.0%	-2.7	-0.9		ranS
			0.1%	1.0%	1.0%	2.6	3.9		sigS
			-1.1%	-0.9%	-0.2%	2.0	5.8		ranL
			1.0%	1.3%	1.3%	7.2	4.3		sigL
			-1.0%	-1.8%	0.8%	-0.7	4.9	0.65	ranT
			1.0%	1.6%	1.6%	7.6	5.8	0.46	sigT
			7.711E+03	1.311E-01	204.9	18.6	7.2	0.65	Tot.
			1.9%	7.8%	-5.4%				T-76
			4.185E-02	4.462E-07	184.2			5.0%	H2O
			4.138E-03	4.418E-08	0.9			0.6%	sigH
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16.00	28.450	-80.530	1.088E+04	1.850E-01	204.8	29.1	3.1	-0.001	Mean
			5.1%	11.1%	-5.5%				M-76
62.0			0.0%	0.0%	0.1%	-0.6	-1.6		ranS
			0.2%	0.9%	0.9%	3.0	5.1		sigS
			-1.3%	-1.3%	0.0%	2.2	6.2		ranL
			1.2%	1.1%	1.1%	8.4	5.8		sigL
			-1.3%	-1.4%	0.0%	1.6	4.5	1.10	ranT
			1.2%	1.4%	1.4%	8.9	7.7	0.49	sigT
			1.073E+04	1.825E-01	204.9	30.7	7.6	1.10	Tot.
			3.7%	9.6%	-5.4%				T-76
			5.306E-02	5.613E-07	185.1			4.8%	H2O
			1.761E-02	1.866E-07	3.2			2.0%	sigH
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14.00	28.450	-80.530	1.508E+04	2.495E-01	210.5	38.6	4.0	0.000	Mean
			6.4%	9.5%	-2.9%				M-76
63.0			-0.2%	0.1%	-0.3%	1.1	-4.3		ranS
			0.2%	0.7%	0.7%	3.7	6.7		sigS
			-1.7%	-1.1%	-0.6%	5.8	5.2		ranL
			1.4%	0.9%	0.9%	10.5	7.7		sigL
			-1.9%	-0.9%	-0.9%	6.9	1.0	0.01	ranT
			1.4%	1.2%	1.2%	11.1	10.2	0.53	sigT
			1.479E+04	2.472E-01	208.5	45.5	5.0	0.01	Tot.
			4.4%	8.5%	-3.8%				T-76
			1.124E-01	1.157E-06	189.4			4.8%	H2O
			4.087E-02	4.213E-07	3.8			2.2%	sigH
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12.00	28.450	-80.530	2.068E+04	3.291E-01	219.0	40.3	4.6	0.001	Mean
			6.6%	5.5%	1.1%				M-76
64.0			-0.2%	-0.4%	0.1%	0.7	0.1		ranS
			0.2%	0.7%	0.7%	4.2	8.5		sigS
			-1.7%	-1.2%	-0.4%	11.8	6.8		ranL
			1.5%	1.1%	1.1%	12.4	9.7		sigL
			-1.9%	-1.6%	-0.3%	12.5	6.9	0.92	ranT
			1.5%	1.3%	1.3%	13.1	12.9	0.58	sigT
			2.030E+04	3.238E-01	218.3	52.8	11.5	0.92	Tot.
			4.6%	3.8%	0.8%				T-76

			5.375E-01	5.318E-06	199.3			7.8%	H2O
			2.085E-01	2.067E-06	4.8			4.0%	sigH
10.00	28.450	-80.530	2.800E+04	4.226E-01	230.8	34.2	4.0	0.006	Mean
			5.7%	2.2%	3.4%				M-76
65.0			-0.2%	-0.6%	0.4%	5.4	2.2		ranS
			0.1%	0.4%	0.4%	4.1	8.3		sigS
			-1.7%	-1.4%	-0.3%	16.2	4.7		ranL
			1.3%	0.9%	0.9%	12.2	9.6		sigL
			-1.9%	-2.0%	0.1%	21.5	6.9	0.70	ranT
			1.3%	1.0%	1.0%	12.9	12.7	0.63	sigT
			2.748E+04	4.141E-01	231.1	55.7	11.0	0.71	Tot.
			3.7%	0.2%	3.5%				T-76
			6.921E+00	6.494E-05	218.5			26.2%	H2O
			2.731E+00	2.569E-05	6.1			14.1%	sigH
8.00	28.450	-80.530	3.724E+04	5.287E-01	245.3	27.2	3.5	0.006	Mean
			4.4%	0.6%	3.8%				M-76
66.0			-0.2%	-0.8%	0.6%	3.6	-5.0		ranS
			0.1%	0.4%	0.4%	3.4	7.1		sigS
			-1.2%	-1.8%	0.6%	5.5	-1.2		ranL
			1.1%	0.9%	0.8%	10.4	8.2		sigL
			-1.5%	-2.6%	1.2%	9.0	-6.2	0.30	ranT
			1.1%	1.0%	1.0%	11.0	10.8	0.63	sigT
			3.669E+04	5.149E-01	248.1	36.2	-2.8	0.31	Tot.
			2.9%	-2.1%	5.0%				T-76
			2.549E+01	2.250E-04	233.7			35.4%	H2O
			1.536E+01	1.358E-04	7.4			29.9%	sigH
6.00	28.450	-80.530	4.873E+04	6.525E-01	260.1	20.6	2.8	0.001	Mean
			3.2%	-1.2%	4.4%				M-76
67.0			-0.1%	0.8%	-0.9%	6.3	-4.4		ranS
			0.1%	0.4%	0.4%	2.8	5.8		sigS
			-1.0%	-2.1%	1.1%	13.1	-6.1		ranL
			0.9%	0.9%	0.9%	8.7	6.7		sigL
			-1.1%	-1.3%	0.2%	19.4	-10.5	-0.23	ranT
			0.9%	1.0%	1.0%	9.2	8.8	0.63	sigT
			4.819E+04	6.441E-01	260.5	39.9	-7.8	-0.23	Tot.
			2.1%	-2.4%	4.5%				T-76
			7.204E+01	5.999E-04	244.3			28.1%	H2O
			4.382E+01	3.655E-04	8.3			23.8%	sigH
4.00	28.450	-80.530	6.289E+04	8.048E-01	272.0	14.0	2.0	0.001	Mean
			2.0%	-1.8%	3.7%				M-76
68.0			0.0%	0.0%	0.0%	3.1	-7.0		ranS
			0.1%	0.4%	0.4%	2.4	4.6		sigS
			-1.0%	-3.0%	2.0%	5.9	-4.4		ranL
			0.7%	0.9%	0.9%	7.5	5.3		sigL
			-1.0%	-2.9%	1.9%	9.0	-11.4	-0.03	ranT
			0.7%	1.0%	1.0%	7.9	7.0	0.69	sigT
			6.228E+04	7.814E-01	277.2	23.0	-9.5	-0.03	Tot.
			1.0%	-4.6%	5.8%				T-76
			1.964E+02	1.564E-03	255.9			30.9%	H2O
			1.145E+02	9.136E-04	8.5			24.9%	sigH
2.00	28.450	-80.530	8.037E+04	9.923E-01	281.6	7.0	1.2	0.002	Mean
			1.1%	-1.4%	2.3%				M-76
69.0			0.0%	0.2%	-0.2%	3.3	-5.4		ranS
			0.0%	0.5%	0.5%	2.0	3.7		sigS
			-0.8%	-3.2%	2.3%	5.3	-6.0		ranL

			0.5%	1.2%	1.1%	6.4	4.3		sigL
			-0.8%	-3.0%	2.1%	8.7	-11.3	-0.02	ranT
			0.5%	1.3%	1.2%	6.7	5.7	0.82	sigT
			7.969E+04	9.629E-01	287.5	15.6	-10.1	-0.02	Tot.
			0.2%	-4.3%	4.5%				T-76
			5.831E+02	4.485E-03	269.3			45.7%	H2O
			3.542E+02	2.729E-03	10.2			39.0%	sigH
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0.00	28.450	-80.530	1.021E+05	1.212E+00	291.5	0.8	-0.6	0.000	Mean
			0.8%	-1.0%	1.2%				M-76
70.0			0.0%	-0.1%	0.1%	-1.1	-3.1		ranS
			0.0%	0.4%	0.4%	1.3	2.8		sigS
			-0.8%	-2.8%	2.0%	5.8	-3.9		ranL
			0.5%	1.1%	1.0%	4.2	3.3		sigL
			-0.8%	-2.9%	2.1%	4.7	-7.0	-1.40	ranT
			0.5%	1.2%	1.1%	4.4	4.3	0.94	sigT
			1.013E+05	1.177E+00	297.6	5.5	-7.6	-1.40	Tot.
			0.0%	-3.9%	3.3%				T-76
			1.759E+03	1.307E-02	288.1			80.5%	H2O
			4.644E+02	3.457E-03	4.2			29.7%	sigH

Standard Species Concentration Output Produced by the Input File Above:

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****** Global Reference Atmospheric Model - 1995 (GRAM-95) ******

                    Species Concentration Data

MM/DD/YY =  1/ 1/95     HH:MM:SS(UTC) =  0: 0: 0.0    Julian Day =-2449718.500
F10.7 =  230.00         Mean F10.7 =  230.00          ap Index =  20.30

Standard deviations of concentration variation may be a substantial fraction
(50% or more) of the mean value. Zero concentration values indicate no
estimate available.

Height
 (km)    Lati-    Long.  Concen-   Number    |  Concen-   Number
 Time     tude    [E+W-]  tration   Density   |  tration   Density    Species
 (sec)    (deg)    (deg)   (ppmv)   (#/m**3)  |   (ppmv)   (#/m**3)
------ ------- -------- --------- --------- + --------- --------- ----+----
140.00  28.450  -80.530 0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
                        0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
    0.0                 0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                        6.406E+05 6.562E+16 | 8.956E+04 9.174E+15   N2 |  O2
                        2.536E+05 2.598E+16 | 2.224E+03 2.278E+14    O |   A
                        1.934E+02 1.982E+13 | 9.762E-06 1.000E+06   He |   H
------ ------- -------- --------- --------- + --------- --------- ----+----
138.00  28.450  -80.530 0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
                        0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
    1.0                 0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                        6.443E+05 7.525E+16 | 9.132E+04 1.067E+16   N2 |  O2
                        2.447E+05 2.858E+16 | 2.331E+03 2.722E+14    O |   A
                        1.764E+02 2.060E+13 | 8.562E-06 1.000E+06   He |   H
------ ------- -------- --------- --------- + --------- --------- ----+----
136.00  28.450  -80.530 0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
                        0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
    2.0                 0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                        6.477E+05 8.691E+16 | 9.312E+04 1.250E+16   N2 |  O2
                        2.356E+05 3.162E+16 | 2.446E+03 3.282E+14    O |   A
                        1.600E+02 2.147E+13 | 7.453E-06 1.000E+06   He |   H
------ ------- -------- --------- --------- + --------- --------- ----+----
134.00  28.450  -80.530 0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
                        0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
    3.0                 0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                        6.508E+05 1.012E+17 | 9.497E+04 1.476E+16   N2 |  O2
                        2.263E+05 3.518E+16 | 2.570E+03 3.995E+14    O |   A
                        1.443E+02 2.244E+13 | 6.433E-06 1.000E+06   He |   H
------ ------- -------- --------- --------- + --------- --------- ----+----
132.00  28.450  -80.530 0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
                        0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
    4.0                 0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                        6.535E+05 1.188E+17 | 9.688E+04 1.761E+16   N2 |  O2
                        2.167E+05 3.939E+16 | 2.705E+03 4.916E+14    O |   A
                        1.294E+02 2.351E+13 | 5.503E-06 1.000E+06   He |   H
------ ------- -------- --------- --------- + --------- --------- ----+----
130.00  28.450  -80.530 0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  H2O |  O3
                        0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  N2O |  CO
    5.0                 0.000E+00 0.000E+00 | 0.000E+00 0.000E+00  CH4 | CO2
                        6.559E+05 1.407E+17 | 9.886E+04 2.121E+16   N2 |  O2
                        2.069E+05 4.440E+16 | 2.853E+03 6.121E+14    O |   A
                        1.151E+02 2.471E+13 | 4.661E-06 1.000E+06   He |   H
------ ------- -------- --------- --------- + --------- --------- ----+----
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128.00	28.450	-80.530	0.000E+00	0.000E+00	0.000E+00	0.000E+00	H2O	O3
			0.000E+00	0.000E+00	0.000E+00	0.000E+00	N2O	CO
6.0			0.000E+00	0.000E+00	0.000E+00	0.000E+00	CH4	CO2
			6.580E+05	1.685E+17	1.009E+05	2.585E+16	N2	O2
			1.969E+05	5.043E+16	3.016E+03	7.724E+14	O	A
			1.017E+02	2.605E+13	3.905E-06	1.000E+06	He	H
126.00	28.450	-80.530	0.000E+00	0.000E+00	0.000E+00	0.000E+00	H2O	O3
			0.000E+00	0.000E+00	0.000E+00	0.000E+00	N2O	CO
7.0			0.000E+00	0.000E+00	0.000E+00	0.000E+00	CH4	CO2
			6.599E+05	2.041E+17	1.031E+05	3.189E+16	N2	O2
			1.867E+05	5.776E+16	3.198E+03	9.891E+14	O	A
			8.912E+01	2.756E+13	3.233E-06	1.000E+06	He	H
124.00	28.450	-80.530	0.000E+00	0.000E+00	0.000E+00	0.000E+00	H2O	O3
			0.000E+00	0.000E+00	0.000E+00	0.000E+00	N2O	CO
8.0			0.000E+00	0.000E+00	0.000E+00	0.000E+00	CH4	CO2
			6.616E+05	2.504E+17	1.055E+05	3.990E+16	N2	O2
			1.764E+05	6.674E+16	3.402E+03	1.287E+15	O	A
			7.737E+01	2.927E+13	2.643E-06	1.000E+06	He	H
122.00	28.450	-80.530	0.000E+00	0.000E+00	0.000E+00	0.000E+00	H2O	O3
			0.000E+00	0.000E+00	0.000E+00	0.000E+00	N2O	CO
9.0			0.000E+00	0.000E+00	0.000E+00	0.000E+00	CH4	CO2
			6.633E+05	3.113E+17	1.080E+05	5.069E+16	N2	O2
			1.659E+05	7.785E+16	3.635E+03	1.706E+15	O	A
			6.650E+01	3.121E+13	2.131E-06	1.000E+06	He	H
120.00	28.450	-80.530	0.000E+00	0.000E+00	0.000E+00	0.000E+00	H2O	O3
			0.000E+00	0.000E+00	0.000E+00	0.000E+00	N2O	CO
10.0			0.000E+00	0.000E+00	0.000E+00	0.000E+00	CH4	CO2
			6.651E+05	3.927E+17	1.108E+05	6.541E+16	N2	O2
			1.553E+05	9.169E+16	3.901E+03	2.304E+15	O	A
			5.656E+01	3.339E+13	1.694E-06	1.000E+06	He	H
118.00	28.450	-80.530	2.151E-01	1.617E+11	1.253E-03	9.419E+08	H2O	O3
			2.063E-04	1.551E+08	5.302E+01	3.985E+13	N2O	CO
11.0			4.693E-02	3.528E+10	4.059E+01	3.051E+13	CH4	CO2
			6.750E+05	5.074E+17	1.119E+05	8.412E+16	N2	O2
			1.450E+05	1.090E+17	4.222E+03	3.174E+15	O	A
			4.769E+01	3.585E+13	1.330E-06	1.000E+06	He	H
116.00	28.450	-80.530	2.314E-01	2.239E+11	3.140E-03	3.038E+09	H2O	O3
			2.174E-04	2.103E+08	4.924E+01	4.764E+13	N2O	CO
12.0			6.193E-02	5.991E+10	4.282E+01	4.142E+13	CH4	CO2
			6.872E+05	6.648E+17	1.145E+05	1.108E+17	N2	O2
			1.352E+05	1.308E+17	4.615E+03	4.465E+15	O	A
			3.989E+01	3.860E+13	1.034E-06	1.000E+06	He	H
114.00	28.450	-80.530	2.475E-01	3.125E+11	7.868E-03	9.933E+09	H2O	O3
			2.292E-04	2.893E+08	4.551E+01	5.745E+13	N2O	CO
13.0			7.798E-02	9.844E+10	4.769E+01	6.020E+13	CH4	CO2
			6.998E+05	8.834E+17	1.183E+05	1.494E+17	N2	O2
			1.255E+05	1.584E+17	5.086E+03	6.420E+15	O	A
			3.300E+01	4.165E+13	7.922E-07	1.000E+06	He	H
112.00	28.450	-80.530	2.633E-01	4.414E+11	1.972E-02	3.306E+10	H2O	O3
			2.419E-04	4.055E+08	4.186E+01	7.018E+13	N2O	CO
14.0			9.372E-02	1.571E+11	5.609E+01	9.403E+13	CH4	CO2
			7.104E+05	1.191E+18	1.231E+05	2.063E+17	N2	O2

			1.154E+05	1.935E+17	5.629E+03	9.438E+15	O	A
			2.686E+01	4.504E+13	5.965E-07	1.000E+06	He	H
110.00	28.450	-80.530	2.800E-01	6.391E+11	4.941E-02	1.128E+11	H2O	O3
			2.552E-04	5.826E+08	3.850E+01	8.789E+13	N2O	CO
15.0			1.126E-01	2.571E+11	6.596E+01	1.506E+14	CH4	CO2
			7.159E+05	1.634E+18	1.283E+05	2.929E+17	N2	O2
			1.043E+05	2.381E+17	6.214E+03	1.419E+16	O	A
			2.136E+01	4.875E+13	4.381E-07	1.000E+06	He	H
108.00	28.450	-80.530	3.026E-01	9.511E+11	8.582E-02	2.697E+11	H2O	O3
			2.706E-04	8.505E+08	3.408E+01	1.071E+14	N2O	CO
16.0			1.194E-01	3.754E+11	8.406E+01	2.642E+14	CH4	CO2
			7.228E+05	2.272E+18	1.336E+05	4.199E+17	N2	O2
			9.381E+04	2.949E+17	6.931E+03	2.178E+16	O	A
			1.679E+01	5.278E+13	3.182E-07	1.000E+06	He	H
106.00	28.450	-80.530	3.271E-01	1.445E+12	1.491E-01	6.586E+11	H2O	O3
			2.869E-04	1.268E+09	3.016E+01	1.332E+14	N2O	CO
17.0			1.266E-01	5.595E+11	1.071E+02	4.733E+14	CH4	CO2
			7.267E+05	3.211E+18	1.391E+05	6.146E+17	N2	O2
			8.307E+04	3.670E+17	7.727E+03	3.414E+16	O	A
			1.293E+01	5.710E+13	2.263E-07	1.000E+06	He	H
104.00	28.450	-80.530	3.512E-01	2.211E+12	2.254E-01	1.419E+12	H2O	O3
			3.045E-04	1.916E+09	2.638E+01	1.660E+14	N2O	CO
18.0			1.327E-01	8.352E+11	1.356E+02	8.535E+14	CH4	CO2
			7.310E+05	4.601E+18	1.451E+05	9.135E+17	N2	O2
			7.209E+04	4.537E+17	8.147E+03	5.128E+16	O	A
			1.124E+01	7.075E+13	1.589E-07	1.000E+06	He	H
102.00	28.450	-80.530	3.748E-01	3.374E+12	2.967E-01	2.671E+12	H2O	O3
			3.234E-04	2.911E+09	2.281E+01	2.053E+14	N2O	CO
19.0			1.374E-01	1.237E+12	1.705E+02	1.535E+15	CH4	CO2
			7.380E+05	6.643E+18	1.519E+05	1.367E+18	N2	O2
			6.103E+04	5.493E+17	8.150E+03	7.336E+16	O	A
			1.124E+01	1.012E+14	1.111E-07	1.000E+06	He	H
100.00	28.450	-80.530	4.000E-01	5.200E+12	3.906E-01	5.078E+12	H2O	O3
			3.436E-04	4.466E+09	1.972E+01	2.564E+14	N2O	CO
20.0			1.423E-01	1.849E+12	2.144E+02	2.787E+15	CH4	CO2
			7.446E+05	9.680E+18	1.591E+05	2.069E+18	N2	O2
			4.996E+04	6.495E+17	8.132E+03	1.057E+17	O	A
			1.122E+01	1.459E+14	7.693E-08	1.000E+06	He	H
98.00	28.450	-80.530	4.510E-01	8.392E+12	4.641E-01	8.635E+12	H2O	O3
			3.668E-04	6.825E+09	1.621E+01	3.015E+14	N2O	CO
21.0			1.469E-01	2.733E+12	2.442E+02	4.543E+15	CH4	CO2
			7.538E+05	1.402E+19	1.669E+05	3.106E+18	N2	O2
			3.532E+04	6.571E+17	8.227E+03	1.531E+17	O	A
			1.135E+01	2.112E+14	5.375E-08	1.000E+06	He	H
96.00	28.450	-80.530	5.085E-01	1.354E+13	5.514E-01	1.468E+13	H2O	O3
			3.916E-04	1.042E+10	1.332E+01	3.545E+14	N2O	CO
22.0			1.517E-01	4.037E+12	2.781E+02	7.403E+15	CH4	CO2
			7.624E+05	2.029E+19	1.751E+05	4.662E+18	N2	O2
			2.266E+04	6.033E+17	8.343E+03	2.221E+17	O	A
			1.151E+01	3.064E+14	3.757E-08	1.000E+06	He	H
94.00	28.450	-80.530	5.913E-01	2.245E+13	6.028E-01	2.288E+13	H2O	O3

			4.190E-04	1.591E+10	1.106E+01	4.197E+14	N2O	CO
23.0			1.564E-01	5.939E+12	3.052E+02	1.159E+16	CH4	CO2
			7.699E+05	2.923E+19	1.818E+05	6.901E+18	N2	O2
			1.263E+04	4.796E+17	8.484E+03	3.221E+17	O	A
			1.171E+01	4.444E+14	2.634E-08	1.000E+06	He	H
92.00	28.450	-80.530	7.089E-01	3.801E+13	6.062E-01	3.250E+13	H2O	O3
			4.493E-04	2.409E+10	9.269E+00	4.969E+14	N2O	CO
24.0			1.611E-01	8.638E+12	3.225E+02	1.729E+16	CH4	CO2
			7.761E+05	4.161E+19	1.862E+05	9.980E+18	N2	O2
			5.934E+03	3.181E+17	8.695E+03	4.661E+17	O	A
			1.200E+01	6.431E+14	1.865E-08	1.000E+06	He	H
90.00	28.450	-80.530	8.500E-01	6.365E+13	6.096E-01	4.565E+13	H2O	O3
			4.818E-04	3.608E+10	7.771E+00	5.819E+14	N2O	CO
25.0			1.660E-01	1.243E+13	3.408E+02	2.552E+16	CH4	CO2
			7.800E+05	5.841E+19	1.900E+05	1.423E+19	N2	O2
			2.650E+03	1.984E+17	9.340E+03	6.994E+17	O	A
			5.200E+00	3.894E+14	0.000E+00	0.000E+00	He	H
88.00	28.450	-80.530	1.012E+00	1.045E+14	5.632E-01	5.818E+13	H2O	O3
			5.196E-04	5.368E+10	6.413E+00	6.624E+14	N2O	CO
26.0			1.706E-01	1.763E+13	3.452E+02	3.566E+16	CH4	CO2
			7.803E+05	8.061E+19	1.939E+05	2.003E+19	N2	O2
			1.091E+03	1.126E+17	9.340E+03	9.648E+17	O	A
			5.200E+00	5.372E+14	0.000E+00	0.000E+00	He	H
86.00	28.450	-80.530	1.204E+00	1.706E+14	4.797E-01	6.798E+13	H2O	O3
			5.604E-04	7.941E+10	5.292E+00	7.499E+14	N2O	CO
27.0			1.754E-01	2.486E+13	3.496E+02	4.954E+16	CH4	CO2
			7.807E+05	1.106E+20	1.980E+05	2.805E+19	N2	O2
			4.513E+02	6.396E+16	9.340E+03	1.324E+18	O	A
			5.200E+00	7.369E+14	0.000E+00	0.000E+00	He	H
84.00	28.450	-80.530	1.436E+00	2.789E+14	3.599E-01	6.990E+13	H2O	O3
			6.064E-04	1.178E+11	4.187E+00	8.132E+14	N2O	CO
28.0			1.778E-01	3.454E+13	3.535E+02	6.867E+16	CH4	CO2
			7.808E+05	1.517E+20	2.019E+05	3.920E+19	N2	O2
			2.158E+02	4.192E+16	9.340E+03	1.814E+18	O	A
			5.200E+00	1.010E+15	0.000E+00	0.000E+00	He	H
82.00	28.450	-80.530	1.717E+00	4.575E+14	2.887E-01	7.694E+13	H2O	O3
			6.584E-04	1.755E+11	3.177E+00	8.465E+14	N2O	CO
29.0			1.778E-01	4.739E+13	3.571E+02	9.516E+16	CH4	CO2
			7.808E+05	2.081E+20	2.056E+05	5.480E+19	N2	O2
			1.190E+02	3.172E+16	9.340E+03	2.489E+18	O	A
			5.200E+00	1.386E+15	0.000E+00	0.000E+00	He	H
80.00	28.450	-80.530	1.966E+00	7.170E+14	2.750E-01	1.003E+14	H2O	O3
			7.149E-04	2.607E+11	2.410E+00	8.790E+14	N2O	CO
30.0			1.778E-01	6.486E+13	3.606E+02	1.315E+17	CH4	CO2
			7.808E+05	2.848E+20	2.095E+05	7.640E+19	N2	O2
			6.580E+01	2.400E+16	9.340E+03	3.407E+18	O	A
			5.200E+00	1.897E+15	0.000E+00	0.000E+00	He	H
78.00	28.450	-80.530	1.648E+00	8.184E+14	2.690E-01	1.336E+14	H2O	O3
			7.825E-04	3.886E+11	1.785E+00	8.868E+14	N2O	CO
31.0			1.778E-01	8.832E+13	3.615E+02	1.795E+17	CH4	CO2
			7.808E+05	3.878E+20	2.095E+05	1.040E+20	N2	O2
			3.299E+01	1.638E+16	9.340E+03	4.639E+18	O	A

			5.200E+00	2.583E+15	0.000E+00	0.000E+00	He	H
76.00	28.450	-80.530	1.749E+00	1.180E+15	2.351E-01	1.587E+14	H2O	O3
			8.565E-04	5.781E+11	1.323E+00	8.929E+14	N2O	CO
32.0			1.778E-01	1.200E+14	3.624E+02	2.446E+17	CH4	CO2
			7.808E+05	5.270E+20	2.095E+05	1.414E+20	N2	O2
			1.657E+01	1.119E+16	9.340E+03	6.304E+18	O	A
			5.200E+00	3.510E+15	0.000E+00	0.000E+00	He	H
74.00	28.450	-80.530	1.935E+00	1.766E+15	1.917E-01	1.751E+14	H2O	O3
			9.428E-04	8.608E+11	9.614E-01	8.778E+14	N2O	CO
33.0			1.778E-01	1.624E+14	3.628E+02	3.312E+17	CH4	CO2
			7.808E+05	7.129E+20	2.095E+05	1.913E+20	N2	O2
			9.052E+00	8.265E+15	9.340E+03	8.528E+18	O	A
			5.200E+00	4.748E+15	0.000E+00	0.000E+00	He	H
72.00	28.450	-80.530	2.449E+00	3.006E+15	2.063E-01	2.533E+14	H2O	O3
			1.044E-03	1.281E+12	6.855E-01	8.416E+14	N2O	CO
34.0			1.778E-01	2.183E+14	3.628E+02	4.454E+17	CH4	CO2
			7.808E+05	9.586E+20	2.095E+05	2.572E+20	N2	O2
			5.383E+00	6.609E+15	9.340E+03	1.147E+19	O	A
			5.200E+00	6.384E+15	0.000E+00	0.000E+00	He	H
70.00	28.450	-80.530	3.301E+00	5.431E+15	2.539E-01	4.178E+14	H2O	O3
			1.155E-03	1.900E+12	4.887E-01	8.040E+14	N2O	CO
35.0			1.778E-01	2.926E+14	3.628E+02	5.968E+17	CH4	CO2
			7.808E+05	1.285E+21	2.095E+05	3.446E+20	N2	O2
			3.213E+00	5.285E+15	9.340E+03	1.536E+19	O	A
			5.200E+00	8.554E+15	0.000E+00	0.000E+00	He	H
68.00	28.450	-80.530	3.954E+00	8.621E+15	3.649E-01	7.955E+14	H2O	O3
			1.287E-03	2.806E+12	3.682E-01	8.029E+14	N2O	CO
36.0			1.778E-01	3.877E+14	3.628E+02	7.910E+17	CH4	CO2
			7.808E+05	1.702E+21	2.095E+05	4.567E+20	N2	O2
			2.545E+00	5.549E+15	9.340E+03	2.036E+19	O	A
			5.200E+00	1.134E+16	0.000E+00	0.000E+00	He	H
66.00	28.450	-80.530	4.720E+00	1.357E+16	4.639E-01	1.333E+15	H2O	O3
			1.434E-03	4.121E+12	2.775E-01	7.974E+14	N2O	CO
37.0			1.778E-01	5.111E+14	3.628E+02	1.043E+18	CH4	CO2
			7.808E+05	2.244E+21	2.095E+05	6.020E+20	N2	O2
			2.027E+00	5.825E+15	9.340E+03	2.684E+19	O	A
			5.200E+00	1.494E+16	0.000E+00	0.000E+00	He	H
64.00	28.450	-80.530	5.262E+00	1.983E+16	5.886E-01	2.218E+15	H2O	O3
			1.050E-03	3.958E+12	2.204E-01	8.306E+14	N2O	CO
38.0			1.467E-01	5.530E+14	3.628E+02	1.367E+18	CH4	CO2
			7.808E+05	2.943E+21	2.095E+05	7.895E+20	N2	O2
			1.607E+00	6.058E+15	9.340E+03	3.520E+19	O	A
			5.200E+00	1.960E+16	0.000E+00	0.000E+00	He	H
62.00	28.450	-80.530	5.673E+00	2.789E+16	7.563E-01	3.719E+15	H2O	O3
			1.068E-03	5.251E+12	1.845E-01	9.073E+14	N2O	CO
39.0			1.519E-01	7.470E+14	3.628E+02	1.784E+18	CH4	CO2
			7.808E+05	3.839E+21	2.095E+05	1.030E+21	N2	O2
			1.269E+00	6.242E+15	9.340E+03	4.593E+19	O	A
			5.200E+00	2.557E+16	0.000E+00	0.000E+00	He	H
60.00	28.450	-80.530	5.962E+00	3.805E+16	9.855E-01	6.289E+15	H2O	O3
			1.218E-03	7.774E+12	1.545E-01	9.860E+14	N2O	CO

		40.0	1.639E-01	1.046E+15	3.628E+02	2.315E+18	CH4	CO2
			7.808E+05	4.983E+21	2.095E+05	1.337E+21	N2	O2
			1.008E+00	6.431E+15	9.340E+03	5.961E+19	O	A
			5.200E+00	3.319E+16	0.000E+00	0.000E+00	He	H
58.00	28.450	-80.530	5.809E+00	4.772E+16	1.257E+00	1.032E+16	H2O	O3
			1.438E-03	1.181E+13	1.321E-01	1.085E+15	N2O	CO
		41.0	1.793E-01	1.473E+15	3.628E+02	2.980E+18	CH4	CO2
			7.808E+05	6.414E+21	2.095E+05	1.721E+21	N2	O2
			7.543E-01	6.196E+15	9.340E+03	7.673E+19	O	A
			5.200E+00	4.272E+16	0.000E+00	0.000E+00	He	H
56.00	28.450	-80.530	5.663E+00	5.956E+16	1.521E+00	1.600E+16	H2O	O3
			1.781E-03	1.873E+13	1.130E-01	1.188E+15	N2O	CO
		42.0	2.077E-01	2.184E+15	3.628E+02	3.816E+18	CH4	CO2
			7.808E+05	8.212E+21	2.095E+05	2.203E+21	N2	O2
			5.676E-01	5.970E+15	9.340E+03	9.823E+19	O	A
			5.200E+00	5.469E+16	0.000E+00	0.000E+00	He	H
54.00	28.450	-80.530	5.523E+00	7.423E+16	1.808E+00	2.430E+16	H2O	O3
			2.331E-03	3.133E+13	9.481E-02	1.274E+15	N2O	CO
		43.0	2.469E-01	3.319E+15	3.628E+02	4.876E+18	CH4	CO2
			7.808E+05	1.049E+22	2.095E+05	2.815E+21	N2	O2
			4.068E-01	5.468E+15	9.340E+03	1.255E+20	O	A
			5.200E+00	6.989E+16	0.000E+00	0.000E+00	He	H
52.00	28.450	-80.530	5.500E+00	9.442E+16	2.122E+00	3.643E+16	H2O	O3
			3.049E-03	5.235E+13	7.812E-02	1.341E+15	N2O	CO
		44.0	2.893E-01	4.967E+15	3.628E+02	6.228E+18	CH4	CO2
			7.808E+05	1.340E+22	2.095E+05	3.596E+21	N2	O2
			2.773E-01	4.761E+15	9.340E+03	1.603E+20	O	A
			5.200E+00	8.927E+16	0.000E+00	0.000E+00	He	H
50.00	28.450	-80.530	5.346E+00	1.168E+17	2.560E+00	5.595E+16	H2O	O3
			3.771E-03	8.241E+13	6.437E-02	1.407E+15	N2O	CO
		45.0	3.241E-01	7.082E+15	3.628E+02	7.929E+18	CH4	CO2
			7.808E+05	1.706E+22	2.095E+05	4.578E+21	N2	O2
			1.897E-01	4.145E+15	9.340E+03	2.041E+20	O	A
			5.200E+00	1.136E+17	0.000E+00	0.000E+00	He	H
48.00	28.450	-80.530	5.089E+00	1.432E+17	3.172E+00	8.925E+16	H2O	O3
			4.490E-03	1.263E+14	5.057E-02	1.423E+15	N2O	CO
		46.0	3.507E-01	9.867E+15	3.628E+02	1.021E+19	CH4	CO2
			7.808E+05	2.197E+22	2.095E+05	5.893E+21	N2	O2
			1.042E-01	2.931E+15	9.340E+03	2.628E+20	O	A
			5.200E+00	1.463E+17	0.000E+00	0.000E+00	He	H
46.00	28.450	-80.530	4.999E+00	1.811E+17	3.946E+00	1.429E+17	H2O	O3
			5.724E-03	2.074E+14	4.312E-02	1.562E+15	N2O	CO
		47.0	3.863E-01	1.399E+16	3.628E+02	1.314E+19	CH4	CO2
			7.808E+05	2.829E+22	2.095E+05	7.588E+21	N2	O2
			5.723E-02	2.073E+15	9.340E+03	3.383E+20	O	A
			5.200E+00	1.884E+17	0.000E+00	0.000E+00	He	H
44.00	28.450	-80.530	4.864E+00	2.288E+17	4.838E+00	2.276E+17	H2O	O3
			7.689E-03	3.617E+14	3.811E-02	1.793E+15	N2O	CO
		48.0	4.310E-01	2.028E+16	3.628E+02	1.707E+19	CH4	CO2
			7.808E+05	3.673E+22	2.095E+05	9.854E+21	N2	O2
			2.778E-02	1.307E+15	9.340E+03	4.394E+20	O	A
			5.200E+00	2.446E+17	0.000E+00	0.000E+00	He	H

42.00	28.450	-80.530	4.714E+00	2.914E+17	5.734E+00	3.545E+17	H2O	O3
			1.062E-02	6.564E+14	3.413E-02	2.109E+15	N2O	CO
49.0			4.832E-01	2.987E+16	3.628E+02	2.243E+19	CH4	CO2
			7.808E+05	4.827E+22	2.095E+05	1.295E+22	N2	O2
			1.188E-02	7.345E+14	9.340E+03	5.773E+20	O	A
			5.200E+00	3.214E+17	0.000E+00	0.000E+00	He	H
40.00	28.450	-80.530	5.301E+00	4.325E+17	6.571E+00	5.361E+17	H2O	O3
			1.413E-02	1.153E+15	3.093E-02	2.523E+15	N2O	CO
50.0			5.349E-01	4.364E+16	3.628E+02	2.960E+19	CH4	CO2
			7.808E+05	6.370E+22	2.095E+05	1.709E+22	N2	O2
			5.060E-03	4.128E+14	9.340E+03	7.619E+20	O	A
			5.200E+00	4.242E+17	0.000E+00	0.000E+00	He	H
38.00	28.450	-80.530	5.889E+00	6.430E+17	7.087E+00	7.738E+17	H2O	O3
			2.075E-02	2.266E+15	2.846E-02	3.107E+15	N2O	CO
51.0			6.049E-01	6.604E+16	3.628E+02	3.961E+19	CH4	CO2
			7.808E+05	8.525E+22	2.095E+05	2.287E+22	N2	O2
			0.000E+00	0.000E+00	9.340E+03	1.020E+21	O	A
			5.200E+00	5.677E+17	0.000E+00	0.000E+00	He	H
36.00	28.450	-80.530	5.747E+00	8.453E+17	7.529E+00	1.107E+18	H2O	O3
			3.432E-02	5.047E+15	2.649E-02	3.897E+15	N2O	CO
52.0			7.189E-01	1.058E+17	3.628E+02	5.336E+19	CH4	CO2
			7.808E+05	1.149E+23	2.095E+05	3.081E+22	N2	O2
			0.000E+00	0.000E+00	9.340E+03	1.374E+21	O	A
			5.200E+00	7.649E+17	0.000E+00	0.000E+00	He	H
34.00	28.450	-80.530	5.552E+00	1.106E+18	7.530E+00	1.500E+18	H2O	O3
			6.520E-02	1.299E+16	2.475E-02	4.930E+15	N2O	CO
53.0			8.920E-01	1.777E+17	3.628E+02	7.227E+19	CH4	CO2
			7.808E+05	1.555E+23	2.095E+05	4.173E+22	N2	O2
			0.000E+00	0.000E+00	9.340E+03	1.860E+21	O	A
			5.200E+00	1.036E+18	0.000E+00	0.000E+00	He	H
32.00	28.450	-80.530	5.370E+00	1.455E+18	7.315E+00	1.982E+18	H2O	O3
			8.970E-02	2.430E+16	2.303E-02	6.239E+15	N2O	CO
54.0			1.009E+00	2.734E+17	3.628E+02	9.830E+19	CH4	CO2
			7.808E+05	2.116E+23	2.095E+05	5.675E+22	N2	O2
			0.000E+00	0.000E+00	9.340E+03	2.531E+21	O	A
			5.200E+00	1.409E+18	0.000E+00	0.000E+00	He	H
30.00	28.450	-80.530	5.253E+00	1.948E+18	6.942E+00	2.574E+18	H2O	O3
			1.170E-01	4.336E+16	2.120E-02	7.858E+15	N2O	CO
55.0			1.135E+00	4.209E+17	3.628E+02	1.345E+20	CH4	CO2
			7.808E+05	2.895E+23	2.095E+05	7.766E+22	N2	O2
			0.000E+00	0.000E+00	9.340E+03	3.463E+21	O	A
			5.200E+00	1.928E+18	0.000E+00	0.000E+00	He	H
28.00	28.450	-80.530	5.209E+00	2.652E+18	6.462E+00	3.290E+18	H2O	O3
			1.580E-01	8.042E+16	1.940E-02	9.877E+15	N2O	CO
56.0			1.266E+00	6.444E+17	3.628E+02	1.847E+20	CH4	CO2
			7.808E+05	3.975E+23	2.095E+05	1.066E+23	N2	O2
			0.000E+00	0.000E+00	9.340E+03	4.755E+21	O	A
			5.200E+00	2.647E+18	0.000E+00	0.000E+00	He	H
26.00	28.450	-80.530	5.144E+00	3.616E+18	5.806E+00	4.081E+18	H2O	O3
			1.369E-01	9.619E+16	1.792E-02	1.259E+16	N2O	CO
57.0			1.066E+00	7.492E+17	3.628E+02	2.550E+20	CH4	CO2

			7.808E+05	5.488E+23	2.095E+05	1.472E+23	N2	O2
			0.000E+00	0.000E+00	9.340E+03	6.565E+21	O	A
			5.200E+00	3.655E+18	0.000E+00	0.000E+00	He	H
24.00	28.450	-80.530	4.934E+00	4.820E+18	4.492E+00	4.387E+18	H2O	O3
			1.536E-01	1.500E+17	1.598E-02	1.561E+16	N2O	CO
58.0			1.192E+00	1.164E+18	3.628E+02	3.544E+20	CH4	CO2
			7.808E+05	7.627E+23	2.095E+05	2.046E+23	N2	O2
			0.000E+00	0.000E+00	9.340E+03	9.123E+21	O	A
			5.200E+00	5.079E+18	0.000E+00	0.000E+00	He	H
22.00	28.450	-80.530	4.522E+00	6.225E+18	3.003E+00	4.133E+18	H2O	O3
			1.729E-01	2.380E+17	1.404E-02	1.933E+16	N2O	CO
59.0			1.394E+00	1.919E+18	3.628E+02	4.994E+20	CH4	CO2
			7.808E+05	1.075E+24	2.095E+05	2.884E+23	N2	O2
			0.000E+00	0.000E+00	9.340E+03	1.286E+22	O	A
			5.200E+00	7.158E+18	0.000E+00	0.000E+00	He	H
20.00	28.450	-80.530	4.003E+00	7.836E+18	1.955E+00	3.828E+18	H2O	O3
			2.116E-01	4.142E+17	1.518E-02	2.973E+16	N2O	CO
60.0			1.573E+00	3.079E+18	3.628E+02	7.102E+20	CH4	CO2
			7.808E+05	1.529E+24	2.095E+05	4.101E+23	N2	O2
			0.000E+00	0.000E+00	9.340E+03	1.828E+22	O	A
			5.200E+00	1.018E+19	0.000E+00	0.000E+00	He	H
18.00	28.450	-80.530	3.318E+00	9.214E+18	8.977E-01	2.493E+18	H2O	O3
			2.575E-01	7.151E+17	2.249E-02	6.245E+16	N2O	CO
61.0			1.692E+00	4.697E+18	3.628E+02	1.007E+21	CH4	CO2
			7.808E+05	2.168E+24	2.095E+05	5.816E+23	N2	O2
			0.000E+00	0.000E+00	9.340E+03	2.593E+22	O	A
			5.200E+00	1.444E+19	0.000E+00	0.000E+00	He	H
16.00	28.450	-80.530	2.777E+00	1.068E+19	3.623E-01	1.394E+18	H2O	O3
			2.917E-01	1.122E+18	3.505E-02	1.348E+17	N2O	CO
62.0			1.769E+00	6.804E+18	3.628E+02	1.396E+21	CH4	CO2
			7.808E+05	3.004E+24	2.095E+05	8.058E+23	N2	O2
			0.000E+00	0.000E+00	9.340E+03	3.593E+22	O	A
			5.200E+00	2.000E+19	0.000E+00	0.000E+00	He	H
14.00	28.450	-80.530	4.149E+00	2.152E+19	2.646E-01	1.373E+18	H2O	O3
			3.079E-01	1.597E+18	5.743E-02	2.979E+17	N2O	CO
63.0			1.834E+00	9.513E+18	3.628E+02	1.882E+21	CH4	CO2
			7.808E+05	4.051E+24	2.095E+05	1.087E+24	N2	O2
			0.000E+00	0.000E+00	9.340E+03	4.846E+22	O	A
			5.200E+00	2.698E+19	0.000E+00	0.000E+00	He	H
12.00	28.450	-80.530	1.416E+01	9.686E+19	1.876E-01	1.283E+18	H2O	O3
			3.205E-01	2.192E+18	8.917E-02	6.101E+17	N2O	CO
64.0			1.886E+00	1.291E+19	3.628E+02	2.482E+21	CH4	CO2
			7.808E+05	5.342E+24	2.095E+05	1.433E+24	N2	O2
			0.000E+00	0.000E+00	9.340E+03	6.390E+22	O	A
			5.200E+00	3.558E+19	0.000E+00	0.000E+00	He	H
10.00	28.450	-80.530	1.337E+02	1.174E+21	1.097E-01	9.639E+17	H2O	O3
			3.328E-01	2.924E+18	1.137E-01	9.991E+17	N2O	CO
65.0			1.944E+00	1.708E+19	3.628E+02	3.188E+21	CH4	CO2
			7.808E+05	6.861E+24	2.095E+05	1.840E+24	N2	O2
			0.000E+00	0.000E+00	9.340E+03	8.206E+22	O	A
			5.200E+00	4.569E+19	0.000E+00	0.000E+00	He	H

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  8.00   28.450   -80.530   5.421E+02 5.959E+21 | 6.682E-02 7.345E+17  H2O |  O3
                            3.387E-01 3.724E+18 | 1.359E-01 1.494E+18  N2O |  CO
   66.0                     1.978E+00 2.174E+19 | 3.628E+02 3.988E+21  CH4 | CO2
                            7.808E+05 8.583E+24 | 2.095E+05 2.303E+24   N2 |  O2
                            0.000E+00 0.000E+00 | 9.340E+03 1.027E+23    O |   A
                            5.200E+00 5.716E+19 | 0.000E+00 0.000E+00   He |   H
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  6.00   28.450   -80.530   1.166E+03 1.582E+22 | 4.847E-02 6.576E+17  H2O |  O3
                            3.387E-01 4.595E+18 | 1.473E-01 1.998E+18  N2O |  CO
   67.0                     1.999E+00 2.713E+19 | 3.628E+02 4.922E+21  CH4 | CO2
                            7.808E+05 1.059E+25 | 2.095E+05 2.842E+24   N2 |  O2
                            0.000E+00 0.000E+00 | 9.340E+03 1.267E+23    O |   A
                            5.200E+00 7.055E+19 | 0.000E+00 0.000E+00   He |   H
------ ------- --------    --------- --------- + --------- ---------  ----+----
  4.00   28.450   -80.530   2.543E+03 4.255E+22 | 3.648E-02 6.104E+17  H2O |  O3
                            3.387E-01 5.668E+18 | 1.496E-01 2.503E+18  N2O |  CO
   68.0                     2.015E+00 3.372E+19 | 3.628E+02 6.071E+21  CH4 | CO2
                            7.808E+05 1.307E+25 | 2.095E+05 3.505E+24   N2 |  O2
                            0.000E+00 0.000E+00 | 9.340E+03 1.563E+23    O |   A
                            5.200E+00 8.701E+19 | 0.000E+00 0.000E+00   He |   H
------ ------- --------    --------- --------- + --------- ---------  ----+----
  2.00   28.450   -80.530   5.789E+03 1.194E+23 | 3.207E-02 6.616E+17  H2O |  O3
                            3.387E-01 6.988E+18 | 1.598E-01 3.298E+18  N2O |  CO
   69.0                     2.015E+00 4.158E+19 | 3.628E+02 7.485E+21  CH4 | CO2
                            7.808E+05 1.611E+25 | 2.095E+05 4.321E+24   N2 |  O2
                            0.000E+00 0.000E+00 | 9.340E+03 1.927E+23    O |   A
                            5.200E+00 1.073E+20 | 0.000E+00 0.000E+00   He |   H
------ ------- --------    --------- --------- + --------- ---------  ----+----
  0.00   28.450   -80.530   1.697E+04 4.277E+23 | 2.949E-02 7.433E+17  H2O |  O3
                            3.387E-01 8.538E+18 | 1.713E-01 4.317E+18  N2O |  CO
   70.0                     2.015E+00 5.080E+19 | 3.628E+02 9.144E+21  CH4 | CO2
                            7.808E+05 1.968E+25 | 2.095E+05 5.280E+24   N2 |  O2
                            0.000E+00 0.000E+00 | 9.340E+03 2.354E+23    O |   A
                            5.200E+00 1.311E+20 | 0.000E+00 0.000E+00   He |   H
```

APPENDIX C

List of Diagnostic and Progress Messages

If a major problem arises in the progress of a run, one of the following diagnostic messages will be printed both to the standard formatted output file and to the screen unit. They are listed alphabetically.

1. "Error exit from trajectory file in Subroutine timestep." – This fatal error is generated from the timestep subroutine of the models.f file when the trajectory option has been chosen and an error is encountered while reading a record of the trajectory file. Correct the error before rerunning the program.

2. "Error in Subroutine setup, with input: ius=iiiii, iopr= iiiii, nr1=iiiiiiiiii, month= iii, ic=aa, mi=iii, ih=iiii ix=iiii iiii iiii iiii iiii iiii iiii iiii iiii iiii, iex=iiii ip=iiii iiii iiii iiii iiii, id=iiii iiii iiii iiii iiii, it=iiii iiii iiii iiii iiii ndata=iiiiii iiiiii ...iiiiii" – This fatal error is generated from the setup subroutine of the initial.f file when an attempt to read any atmosdat record beginning with a code fails. To aid the user in troubleshooting, various parameters are output along with the data read from the atmosdat record. Correct the problem before rerunning the program.

3. "Error reading file ii in Subroutine rtran at entry point aaa..." – This fatal error is generated from the rtran subroutine found in the gramsubs.f file when the program reads data from an erroneous atmosdat file. Replace or repair the file, then rerun.

4. "Error termination reading atmosdat file in MAPINIT" – This fatal error is generated from the mapinit subroutine in the speconc.f file when an error occurs in reading a record from the MAP 31 data of the atmosdat file. Repair the record and the file before rerunning the program.

5. "Error termination while reading file in CONCINIT routine." – This fatal error is generated from the concinit subroutine in the speconc.f file when an error occurs in reading a record from either the LaRC or AFGL portion of the atmosdat file. Correct the underlying problem before rerunning.

6. "Height error reading AFGL concentration data." – This fatal error is generated from the concinit subroutine of the speconc.f file when invalid heights are invoked for reading the AFGL data from the atmosdat file. Correct the underlying problem before rerunning.

7. "Height error reading LaRC water data." – This fatal error is generated from the concinit subroutine of the speconc.f file when invalid heights are invoked for reading the LaRC data from the atmosdat file. Correct the underlying problem before rerunning.

8. "Height error reading OX data: month = ii Level = iii" – This fatal error is generated from the mapinit subroutine in the speconc.f file when errors occur in the MAP 31 oxygen values of the atmosdat file. Correct them before rerunning.

9. "Premature end-of-file found on unit ii called from Subroutine rtran at entry point aaa..." – This fatal error is generated from the rtran subroutine found in the gramsubs.f file when the program finds the atmosdat file shorter than expected. Replace or repair the file, then rerun.

10. "Premature EOF reading atmosdat file in MAPINIT" – This fatal error is generated from the mapinit subroutine in the speconc.f file when an end-of-file is encountered while reading a record from the MAP 31 data of the atmosdat file. Repair the record and the file before rerunning the program.

11. "Premature EOF while reading file in CONCINIT routine." – This fatal error is generated from the concinit subroutine of the speconc.f file when an end-of-file is encountered while reading a record from either the LaRC or AFGL portion of the atmosdat file. Repair the record and file, then rerun.

12. "Pressure level error reading MAP aaa data Month = ii Level = ii" – This fatal error is generated from the mapinit subroutine in the speconc.f file when errors occur in the MAP 31 parameter values of the atmosdat file. Correct the values and the file before rerunning the program.

13. "Unexpected exit from trajectory file with h<0 in Subroutine timestep." – This fatal error is generated from the timestep subroutine in the models.f file when the trajectory option has been chosen and a height below sea level is encountered during reading of a record in the trajectory file. Correct the error before rerunning.

14. "Unit number conflict in Subroutine chekunit: iopp = iii iopt = iii ius = iii iuc = iii iug = iii Error number = iii" – This fatal error is generated from the chekunit subroutine in the initial.f file when the program finds conflicts in any assigned unit number. Choose different unit numbers to resolve any conflict, then rerun the program. Conflicts occur if any of the unit numbers are duplicates or conflict with reserved unit numbers (e.g., 5 or 6). Conflicts must not exist for any of the unit numbers between iug and iug+14.

During the course of a run, some of the following diagnostic and progress messages will be printed to the chosen screen unit only:

1. "Below GUACA height and iug = 0" – This fatal error is generated from the atmod subroutine in the models.f file when the "current" height is below 27 km but the GUACA option has been set to zero. Correct the discrepancy before rerunning the program.

2. "Computing data" – This comment originates in the gram95.f file after the data is initialized at the start of the run.

3. "Concentration data written to file aaa..." – This comment originates in the gram95.f file when the entire run is complete, if the option to output species concentrations has been chosen.

4. End-of-file error on GUACA file, unit= iii" – This fatal error is generated from the guacard subroutine if a premature end-of-file is encountered on any of the GUACA input files.

5. "End-of-file reading scale data" – This fatal error is generated from the scalinit subroutine of the initial.f file when end-of-file (EOF) is reached during the reading of the variable-scale random perturbation model data from an erroneous atmosdat file. Repair or replace the file before rerunning.

6. "Error in GUACA pathname found in Subroutine guainit" – This fatal error is generated from the guainit subroutine of the guaca.f file at initialization when either the guapath parameter equals zero or it is longer than 64 characters. Correct either situation before rerunning if the GUACA data base is to be invoked.

7. "Error in random option" – This fatal error is generated from the init subroutine of the initial.f file when the iopr parameter has been set to a value which is neither 1 nor 2. If perturbed values are desired as well as mean values of the standard output parameters, set iopr to 1 and rerun. If only mean values of the parameters are desired, set iopr to 2 and rerun.

8. "Error opening file!! status= iii unit= iii aaa..." – This fatal error is generated from the guainit subroutine of the guaca.f file at initialization when an attempt fails to open one of the file units from which the GUACA data will be read. To aid the user, both the unit number and pathname are output. Refer to the operation or FORTRAN manuals of the client system to determine the

meaning of the status number, then correct the underlying cause before rerunning the program.

9. "Error opening file!! Status= iii Unit= iii Path= aaa..." – This fatal error is generated from the setup subroutine of the initial.f file when an attempt to open the atmosdat file fails. It differs slightly from the foregoing error to aid the user, but again, the unit number assigned to the atmosdat file and the path to it are output. Refer to the operation or FORTRAN manuals of the client system to determine the meaning of the status number however, then correct the underlying cause of the error before rerunning the program.

10. "Error opening GUACA scratch file, status = iii" – This fatal error is generated from the guacard subroutine of the guaca.f file when an error occurs in opening the GUACA scratch file. Refer to the operation or FORTRAN manuals of the client system to determine the meaning of the status number, then correct the underlying cause before rerunning the program.

11. "Error or EOF reading 1st trajectory input" – This fatal error is generated from the init subroutine of the initial.f file when the trajectory option has been chosen and the file pointed to with the trapath parameter either does not exist, is empty of records, or the records hold inappropriate data. Correct the error before rerunning the program.

12. "Error reading input data file in Subroutine init." – This fatal error is generated from the init subroutine of the initial.f file when any one of the 6 path variables have been incorrectly identified or formulated. Correct the error in the appropriate path variable before rerunning.

13. "Exit with input data EOF in subroutine init." – This fatal error is generated from the init subroutine in the initial.f file when an unexpected end of file is reached as one of the path parameters are read by the program. Correct the error before rerunning the program.

14. "Filled in iii... missing sigmas." – This comment originates in the guafix subroutine of the guaca.f file when missing sigmas are found at any level of the GUACA data base and replaced by the program.

15. "Filled in iii... missing temperatures." – This comment originates in the guafix subroutine of the guaca.f file when missing temperatures are found in the GUACA data base above 70 mbar and replaced by the program.

16. "Filled in iii... missing winds."	– This comment originates in the guafix subroutine of the guaca.f file when missing winds are found in the GUACA data base above 70 mbar and replaced by the program.
17. "Finished computations. Formatted output written to file aaa..."	– This comment originates in the gram95.f subroutine/file at the completion of the entire run.
18. "Finished GUACA initialization"	– This comment originates in the init subroutine of the initial.f file immediately after the GUACA data base has been initialized.
19. "Finished SETUP routine"	– This comment originates in the init subroutine of the initial.f file immediately after the setup subroutine of the initial.f file has completed its actions.
20. "Finished profile, starting next with nr1 = iii..."	– This comment originates in the gram95.f main program file at the end of one run and the beginning of the next when a new random number seed is read in.
21. "First random number out of range."	– This fatal error is generated from the randinit subroutine of the initial.f file when the random option was chosen but the initial seed was selected outside of the range, 1 to 9×10^8. Correctly choose the initial seed before rerunning.
22. "Fixing GUACA data"	– This comment originates in the guainit subroutine of the guaca.f file at the call to the guafix subroutine, which accomplishes various quality control checks and makes appropriate corrections to the loaded GUACA data.
23. "Height error on scale data: nnnnn.n"	– This fatal error is generated from the scalinit subroutine of the initial.f file when a height error is encountered after reading the variable-scale random perturbation model data from the atmosdat file. Correct the error before rerunning the program.
24. "Illegal GUACA file block size, iblwd=iiii"	– This fatal error is generated from the guacard subroutine of the guaca.f file when the parameter iblwd is > 0 but is < 46 or > 512. Correct the error before rerunning the program.

25. "Month out of range to read GUACA data."	– This fatal error is generated from the init subroutine of the initial.f file when the mn parameter has been chosen outside the range of 1 -12. Choose an mn value within the range of 1 - 12 before rerunning.
26. "Normal exit from trajectory file in Subroutine timestep."	– This comment originates in the timestep subroutine of the models.f file when the trajectory option has been chosen and the end of the trajectory file has been reached.
27. "Note: Exit height incrementation with h<0 in Subroutine timestep." Plus under some conditions: "Note: nt= iii, nmax= iii"	– This fatal error is generated from the timestep subroutine of the models.f file when automatic incrementation of the profile option yields a height value more than 5 meters below sea level. If the height value is less than 5 meters below sea level, the nt and nmax values are not output. This error message occurs because of a discrepancy between the input values of dhgt and nmax, and should be resolved before rerunning.
28. "Open error for GUACA unit, status, file=iiii iiii aaa..."	– This fatal error is generated from the guacard subroutine of the guaca.f file when an error occurs in opening the GUACA file from either the "pre-read" or normal read code section. Refer to the operation or FORTRAN manuals of the client system to determine the meaning of the status numbers, then correct the underlying cause before rerunning the program.
29. "Opening and reading GUACA files"	– This comment originates in the guainit subroutine of the guaca.f file before the opening of the file unit numbers from which the GUACA data will be loaded.
30. "Read error on GUACA file, unit,rec,recl,iostat=iiii iiii iiii iiii"	– This fatal error is generated from the guacard subroutine of the guaca.f file when an error occurs in reading the GUACA file data. Refer to the FORTRAN manuals of the client system to determine the meaning of the status number, then correct the underlying cause before rerunning the program.
31. "Read error on scale data"	– This fatal error is generated from the scalinit subroutine of the initial.f file when reading erroneous variable-scale random perturbation data from the atmosdat file. Correct the error before rerunning the program.

32. "Special output written to file aaa..."	– This comment originates in the gram95.f main program file at the completion of the entire run if the option for the special format output has been chosen.
33. "Starting GUACA initialization"	– This comment originates in the init subroutine of the initial.f file immediately before the GUACA data base is initialized.
34. "Starting SETUP routine"	– This comment originates in the init subroutine of the initial.f file immediately before the setup subroutine of the initial.f file is invoked.
35. "Year out of range to read GUACA data."	– This fatal error is generated from the init subroutine of the initial.f file when the iguayr parameter has been set to a value of 2 and the iyr parameter has been chosen outside the range 85 - 91. Either reset iguayr to a value of 1, or choose iyr in the range 85 - 91 before rerunning.

APPENDIX D

List of Subroutines, Functions, and Common Blocks

List of Subroutines:

Subroutine	In File	Called by	Description
afglconc	speconc	concvals	Manipulates the AFGL concentration data.
atmod	models	timestep	Principal computation of pressure, density, temperature and winds.
Block Data Initval	initial	none	Initializes common block variables.
caljday	gramsubs	init, tme	Computes Julian day.
chekunit	initial	init	Checks for conflicts in unit numbers.
concinit	speconc	init	Reads and initializes all concentration data.
concvals	speconc	atmod	Computes concentration values, including the time changes to date.
corlat	gramsubs	pertrb	Computes perturbation model coefficients.
fair	gramsubs	atmod	Fairs thermodynamic and wind parameters between middle atmosphere and MET regions (90-120 km).
fair5	metprog	j70	Fairs between region below and above 500 km.
guacard	guaca	guainit	Open files and reads GUACA CD data.
gauss	metprog	jac	Calculates gaussian quadrature.
gterp	gramsubs	mapmod	Evaluates middle atmosphere zonal-mean data by linear interpolation.

Subroutine	In File	Called by	Description
guafix	guaca	guainit	Corrects problems with GUACA CD data arrays.
guainit	guaca	init	Drives the opening, reading, and fixing of GUACA CD data.
guaintrp	guaca	guamod	Interpolates GUACA data.
guamod	guaca	atmod	Calculates means and standard deviations from GUACA data.
init	initial	main (gram95)	Reads and initializes input data.
inter2	gramsubs	mapmod	Linearly interpolates vertically between three thermodynamic variables with hydrostatic relation for pressure.
interw	gramsubs	intruv, intr25, mapmod	Linearly interpolates vertically between horizontal wind components.
interz	gramsubs	rterp, mapmod	Linearly interpolates vertically between three variables, without using the hydrostatic relation.
intr25	gramsubs	atmod, randinit	Calculates large-scale fractional variances.
intruv	gramsubs	atmod, randinit	Calculates standard deviations for random horizontal wind components.
intrw	gramsubs	atmod, pertrb, randinit	Calculates standard deviation for random vertical wind component.
j70	metprog	jacch	Initializes data for Jacchia (MET) region.

Subroutine	In File	Called by	Description
jac	metprog	j70	Calculates molecular weight, density and temperature in MET region.
jacch	metprog	jacmod	Calculates MET region parameters except winds.
jacmod	models	atmod	Drives all MET region calculations.
larcwat	speconc	concvals	Calculates moisture from LaRC data.
mapconc	speconc	concvals	Drives determination of MAP concentration data.
mapinit	initial	init	Reads and initializes MAP concentration data.
mapmod	models	atmod	Calculates thermodynamic and wind variables in MAP region.
pdtuv	gramsubs	mapmod	Interpolates stationary perturbations.
pertrb	gramsubs	atmod	Calculates thermodynamic and wind random perturbation values.
rcarin	random	randinit	Initializes random number generator.
rcarry	random	pertrb, randinit	Generates random numbers.
randinit	initial	main (gram95)	Initializes random perturbation models.
rig	models	guamod, timestep	Calculates distance from Earth's center and acceleration of gravity.
rterp	gramsubs	atmod, randinit	Calculates standard deviations of random thermodynamic perturbations.

Subroutine	In File	Called by	Description
rtran[1]	gramsubs	setup	Reads first portions of atmosdat file data.
scalinit	initial	init	Reads and initializes variable-scale random perturbation values.
setup	initial	init	Drives reading of first portion of atmosdat file data and initializes values.
shift2	initial	guainit	Interchanges 2 bytes of integer*2 data.
shift4	initial	guainit	Reverses byte order of integer*4 data.
slv	metprog	j70	Computes seasonal-latitudinal variation of density in MET region.
slvh	metprog	j70	Computes seasonal-latitudinal variation of helium number density above 500 km.
stdatm	gramsubs	atmod	Evaluates U.S. Standard Atmosphere variables.
timestep	models	main (gram95)	Controls evaluation of all variables at new timestep.
tinf	metprog	j70	Calculates exospheric temperature in MET region.
tme	metprog	j70	Calculates solar variables.
wind	gramsubs	jacmod	Calculates MET region wind components.
zinterp	guaca	guamod	Interpolates variables from pressure levels in GUACA region.

[1] Includes two entry points, rtran1 and rtran2.

List of Functions:

Function	In File	Called by	Description
correl	gramsubs	pertrb	Calculates distance correlations.
dedt	speconc	atmod, d2edt2	Calculates Wexler formulation of saturation vapor pressure first derivative.
d2edt2	speconc	atmod	Calculates Wexler formulation of saturation vapor pressure second derivative.
gascon	guaca	guafix, zinterp	Calculates gas constant.
mixrat	models	atmod	Calculates water vapor volume mixing ratio.
molwt	metprog	gauss, jac	Calculates molecular weight of air at a height.
ppnd	random	pertrb, randinit	Calculates normal distributed random values.
tdbuck	speconc	atmod, guafix	Calculates dewpoint temperatures.
temp	metprog	gauss, jac	Calculates temperatures above 90 km.
valint	speconc	afglconc	2-D height-latitude interpolation of the concentration values, logarithmically.
valreal	initial	guacard	Converts scale factors of GUACA data from integer to real form.
valz	speconc	afglconc	1-D height interpolation of concentration values, logarithmically.
wexler	speconc	atmod, dedt, d2edt2, gascon, guafix, tdbuck	Calculates Wexler formulation for saturation vapor pressure.
ztoH	guaca	zinterp	Converts from geometric to geopotential height.

List of Common Blocks:

Common Block	Used in
afglcom	afglconc, Block Data Initval, concinit, concvals
comper	atmod, guamod, jacmod, main (gram95.f), mapmod, pertrb
concom	atmod, concvals
cotran	rtran, setup
datacom	atmod, main
dircom	guacard, guainit, main
guacom	Block Data Initval, guainit, guamod
iotemp	atmod, guamod, init, jacc, jacmod, main, mapmod, pertrb, randinit, rtran, setup, timestep, wind
iucom	atmod, chekunit, guacard, guafix, guainit, guamod, init, jacmod, main, mapmod, randinit, rtran, setup, timestep
jaccon	atmod, jacmod, main
larccom	Block Data Initval, concinit, concvals, larcwat
map31com	mapconc, mapinit
pathname	init, main, setup
pdtcom	atmod, mapmod, randinit, setup
RCSET1	rcarin, rcarry
readcom	guacard, main
scalecom	atmod, init, pertrb, randinit, scalinit
speccom	atmod, main
timeo	atmod, guamod, init, jacmod, main, mapmod, pertrb, randinit, setup, timestep
vert	atmod, guamod, init, jacmod, main, mapmod, pertrb, randinit, scaleinit
wincom	atmod, guamod, jacmod, main, mapmod, pertrb, wind

APPENDIX E

Example Application of GRAM-95 as Subroutines in Another Main Driver

For many applications, it is desirable to use GRAM-95 in the form of subroutines in another program. For example, the main driver program may be a trajectory calculating program, for which GRAM-95 is to provide the atmospheric density and winds that are used to update the trajectory positions (or to provide the densities and temperatures used to compute heat loads, etc.). The following sample program, called "gramtraj.f" (and provided along with the regular GRAM-95 code files), serves as an illustration of how to build such an application program. The following discussion describes the various features of the example gramtraj.f code, which is very similar to the gram95.f code.

The sample code consists of a dummy driver (lines GRMD 1 through GRMD 66), a dummy subroutine "setipos" to initialize the position (lines STIP 1 through STIP 13) and a dummy subroutine "newpos" to update the position and velocity, if necessary (lines NEWP 1 through NEWP 38). The gramtraj subroutine for actual incorporation into a user-provided main (lines GRMT 1 through GRMT126) uses arguments: (1) ifirst—a parameter to trigger initialization and to be used as a return code to trigger various desired functions in the driver program, (2) ctime—the current elapsed time (seconds), (3) chgt—the current height (km), (4) clat—the current latitude (degrees, North positive), and (5) clon—the current longitude (degrees, East positive).

Values of the atmospheric variables computed by GRAM can be passed to other subroutines or output to storage devices from within the gramtraj subroutine (see comment starting at line GRMT 80).

Within the gramtraj subroutine, the real variables n2ond and n2nd and the character variables dirsep and endsep must be explicitly declared (lines GRMT 11, GRMT 12, and GRMT 13), since these do not follow the FORTRAN conventions for integer or real variables. The common blocks iotemp, iucom, timeo, dircom, wincom, vert, datacom, speccom, jaccon, and comper must be included (lines GRMT 14 through GRMT 31). GRAM uses common blocks like extended argument lists for subroutines (see appendix D) as a means of passing variable values among the subroutines and between the main driver and the subroutines. Like subroutine argument lists (in which different variable names may be used in the subroutine definition and in the subroutine calling statement), the names of the variables in the common block statements sometimes change from one subroutine to another. As shown in the gramtraj.f code, all unnecessary variables (i.e., those not actually used in this main driver) have been identified by using dummy names (dummyx for real variables not needed and idummyx for integer variables not needed). This use of dummy variable names is a way of avoiding problems of duplicate variable names being used both as a global variable (one defined in a common block) and as a local variable (one intended to be defined within a specific subroutine only). Dummy variable names are also used in this way in some (but not all) of the common block declarations within the GRAM subroutines. In the actual GRAM-95 main driver (gram95.f) code, the common blocks have the global variables declared with their actual names rather than the dummy names used here.

The variables used in the sample gramtraj.f code are:

iswap, iblwd, irlbw, direp, and endsep – parameters that can be set for your particular system, in order to be able to read the GUACA data in the form that it appears on the GUACA-CD (see

section 4.7). These values are set to those required for SGI IRIX in the following example code (lines GRMT 38 through GRMT 47).

iur – the unit number for reading the input data file (see section 4.4 and appendix B), used also for reading subsequent random number initial seed values (line GRMT103).

iopt – the trajectory input option (see section 4.4 and appendix b). The value is set to 0 (GRMT 59) so that the positions will not be read in from a trajectory file, but will be computed from within this main program.

iopr – random perturbation option (see section 4.4 and appendix B). No further random number seeds will be read in (GRMT 87), if the iopr value was set to 2 in the input data file.

nrl – the random seed values read from unit iur.

n1, phi1, thet1 – the starting position coordinates of initial height (km), latitude (degrees, North positive), and longitude (degrees, East positive).

ho, phio, theto – the initial height, latitude, and longitude values, saved (GRMT 60 through GRMT 62) for later resetting the initial position if cycling back to do multiple trajectories within one run (GRMT107 through GRMT109).

h, phi, thet – the "current position" height, latitude, and longitude, initially equal to the starting position, used to begin the cycle in which hl, phil, thetl becomes the "previous position" and h, phi, and thet are updated to the "current position."

elt – the elapsed time (seconds) from the original (initial) position and the current position.

delt, dhgt, dphi, dthet – the time displacement (seconds), and the increments in height, latitude, and longitude used to update the new elapsed time from the previous elapsed time and to update the previous position to the current position (GRMT 74 through GRMT 79).

nt, nmax – the current counter number for the trajectory position, and the maximum value this counter can achieve. Processing terminates if nt ≥ nmax is encountered (GRMT 86).

nmore – a code returned by the timestep subroutine if trajectory position calculations should be terminated for other reasons (GRMT 86).

The variables declared in the common blocks wincom, vert, datacom, speccom, jaccon, and comper are potential variables for use on output or as passing as input to other subroutines from this main driver (see comment at GRMT 80 and section 4.6).

A simplified outline for the functions required to be performed in the main driver program is:

1. Initialize the time and position	GRMD 18
2. Set ifirst = 1 and call gramtraj to read the GRAM input file and initialize the GRAM atmospheric data	GRMD 29-30
3. Initialize the trajectory velocity (or position displacement), if necessary	GRMD 35

4. Set ifirst = 0 and start trajectory cycle — GRMD 39

5. Update the time, position (and velocity or displacement values, if necessary) at each step — GRMD 44

6. Call gramtraj to evaluate the GRAM atmospheric data at the next position — GRMD 48

7. If ifirst return code is 0, cycle to next position — GRMD 53

8. If ifirst return code is -1, reinitialize the position (read a new random number seed in gramtraj) and then cycle to next position — GRMD 54-61

9. Terminate program for any other value of return code ifirst — GRMD 65

Input options allow all of the output files that are generated by the GRAM-95 subroutines to be suppressed if all of the output variable handling is to be done in the main program. This is accomplished by setting the following values in the input data file (see appendix B): iup = 0 suppresses the standard formatted output file; iuc = 0 suppresses the species concentration output file; and iopp = 0 suppresses the special formatted output file. Progress and diagnostic messages (see appendix C) that would normally be routed to the standard formatted output file are sent to the screen unit (iu0) if iup = 0 is selected.

Listing of Example Main Driver Program (gramtraj.f) Using GRAM-95 as Subroutines

```
C     Dummy GRAM driver program using the gramtraj subroutine version:
C
C     To use gramtraj as a subroutine, the user should strip out this
C     dummy driver, using instead the real driver program (e.g., a
C     trajectory code). The dummy subroutines setipos and newpos
C     (to set the initial position and update the position) should
C     also be stripped out and replaced by position initialization
C     and updating operations in the trajectory program. The
C     subroutine gramtraj should be retained, to compute the
C     atmospheric variables. Any output of the atmospheric variables
C     (or passing of their values to other subroutines) should be
C     done from within the gramtraj subroutine (see comments in
C     the gramtraj code).
C
C     Initialize the time (sec) and position (height, km; latitude,
C     deg N; longitude, deg E).
C
      Call setipos (ctime,chgt,clat,clon)
C
C     ifirst is used as a parameter to trigger GRAM initialization
C     (ifirst = 1), and to be used as a return code to trigger any
C     desired actions by the main program. In this example, ifirst
C     = 0 causes recycle to next position; ifirst = -1 causes
C     re-initialization of position (and velocity) values;
C     ifirst < -1 causes the program to terminate.
C
C     Initialize the atmospheric variables with the gramtraj routine.
C
      ifirst = 1
      Call gramtraj(ifirst,ctime,chgt,clat,clon)
C
```

```
C     Initialize the trajectory velocity (or position displacement)
C     values (if initialization is necessary).
C
      Call newpos(ifirst,ctime,chgt,clat,clon,dtime,dhgt,dlat,dlon)
C
C     Begin cycle of positions and atmospheric values.
C
   20 ifirst = 0
C
C     Update the velocity (or position displacement) values and the
C     time and position values.
C
      Call newpos(ifirst,ctime,chgt,clat,clon,dtime,dhgt,dlat,dlon)
C
C     Evaluate the atmospheric parameters at the new position.
C
C     Call gramtraj(ifirst,ctime,chgt,clat,clon)
C
C     Repeat the cycle or terminate, depending on the return value
C     of the parameter ifirst.
C
      If (ifirst.eq.0)Goto 20
      If (ifirst.eq.-1)Then
C
C       Re-initialize the velocity or position displacement values
C       (if necessary).
C
        Call newpos(ifirst,ctime,chgt,clat,clon,dtime,dhgt,dlat,dlon)
        Goto 20
      Endif
C
C     Terminate for any other values of ifirst.
C
      End
C-----------------------------------------------------------------------
      Subroutine setipos(ctime,chgt,clat,clon)
C
C...  Dummy subroutine to set initial time (sec) and position (height),
C     km; latitude, degrees, North positive; longitude, degrees, East
C     positive).
C     The following test input is for the reference case (appendix B).
      ctime = 0.
      chgt = 140.
      clat = 28.45
      clon = -80.53
      Return
      End
C-----------------------------------------------------------------------
      Subroutine newpos(ifirst,ctime,chgt,clat,clon,dtime,dhgt,dlat,
     & dlon)
C     Dummy subroutine to update the position and velocity.
C
C     Initialize the velocity (or position displacement) if ifirst is
C     not zero. dtime = time step (sec), dhgt = height increment per
C     time step (km), dlat = latitude increment per time step (deg N),
C     dlon = longitude increment per time step (deg E).
C
C     The following test input is for the reference case (appendix B).
C     If (ifirst.ne.0)Then
        dtime = 1.
```

```
        dhgt = -2.                                                      NEWP 13
        dlat = 0.                                                       NEWP 14
        dlon = 0.                                                       NEWP 15
      Else                                                              NEWP 16
C                                                                       NEWP 17
C       Update the position (and velocity, if necessary), if ifirst     NEWP 18
        is zero.                                                        NEWP 19
C                                                                       NEWP 20
        ctime = ctime + dtime                                           NEWP 21
        chgt = chgt + dhgt                                              NEWP 22
        clat = clat + dlat                                              NEWP 23
        clon = clon + dlon                                              NEWP 24
C                                                                       NEWP 25
C       Treat special case when trajectory passes over the poles.       NEWP 26
        If(Abs(clat).gt.90.)Then                                        NEWP 27
          clat=Sign(180.-Abs(clat),clat)                                NEWP 28
          clon=clon+180.                                                NEWP 29
          dlat = -dlat                                                  NEWP 30
        Endif                                                           NEWP 31
C       Treat special cases if longitude outside +/- 180 degrees.       NEWP 32
        If(clon.lt.-180.)clon=clon+360.                                 NEWP 33
        If(clon.ge.180.)clon=clon-360.                                  NEWP 34
      Endif                                                             NEWP 35
      Return                                                            NEWP 36
      End                                                               NEWP 37
C-----------------------------------------------------------------------NEWP 38
      Subroutine gramtraj(ifirst,ctime,chgt,clat,clon)                  GRMT  1
C     GRAM subroutine for use in user-provided trajectory program:      GRMT  2
C     ifirst = parameter to trigger initialization and to be used as    GRMT  3
               a return code to trigger any desired actions by the      GRMT  4
               main program.                                            GRMT  5
C     ctime = current elapsed time from beginning of trajectory (sec).  GRMT  6
C     chgt = current height (km).                                       GRMT  7
C     clat = current latitude (degrees, North positive).                GRMT  8
C     clon = current longitude (degrees, East positive).                GRMT  9
C                                                                       GRMT 10
      Real n2ond,n2nd                                                   GRMT 11
      Character*1 dirsep,endsep,termchar                                GRMT 12
      Character*16 scrstat,sysform                                      GRMT 13
      Common /iotemp/idummy1,phi1,phi,dummy1(10),idummy2(3),h1,         GRMT 14
     & dummy2(2),h,dummy3(3),idummy3(2),nmore,dummy4(2),idummy4,elt,    GRMT 15
     & dummy5(19)                                                       GRMT 16
      Common /iucom/idummy5,iur,idummy6(3),iopr                         GRMT 17
      Common /timeo/thet,thet1,idummy7(2),dummy6,dphi,dthet,dhgt,nmax,  GRMT 18
     & delt,iopt,nt,idummy8,nr1,dummy7,ho,phio,theto,dphio              GRMT 19
      Common /dircom/dirsep,endsep,termchar,scrstat,sysform             GRMT 20
      Common /readcom/iswap,iblwd,irlbw,nhdr                            GRMT 21
      Common/wincom/dh,dummy8(4),ugh,vgh,th,dummy9(2),ph,wgh,dummya     GRMT 22
      Common /vert/dummyb(2),wrh,swh,dummyc(29)                         GRMT 23
      Common /datacom/pgh,dgh,tgh,pghp,dghp,tghp,uh,vh,wh,php,dhp,thp,  GRMT 24
     & eofT,rhov,tdgh,rhp,seofT,srhov,stdgh,srhp                        GRMT 25
      Common /speccom/ppmh2o,ppmn2o,ppmch4,ppmn2,ppmo,ppmhe,ppmo3,      GRMT 26
     & ppmco,ppmco2,ppmo2,ppmar,ppmh,h2ond,n2ond,ch4nd,03nd,cond,co2nd  GRMT 27
      Common /jaccon/n2nd,o2nd,ond,arnd,hend,hnd,dummyd                 GRMT 28
      Common/comper/sph,sdh,sth,prh,drh,trh,urh,vrh,sub,svh,dummye,     GRMT 29
     & prhs,drhs,trhs,urhs,vrhs,prh1,drh1,trh1,urh1,vrh1,               GRMT 30
     & sphs,sdhs,sths,suhs,svhs,sph1,sdh1,sth1,suh1,svh1                GRMT 31
C                                                                       GRMT 32
C      Initialize everything if ifirst = 1.                             GRMT 33
C                                                                       GRMT 34
```

```
      If (ifirst.eq.1)Then
C
C       Change the following to suit your system characteristics.
        iswap = 1
        iblwd = 0
        irlbw = 0
        iur = 5
        nhdr = 45
        dirsep = '/'
        endsep = '/'
        termchar = ' '
        scrstat = 'scratch'
        sysform = 'system'
C
C       Call the GRAM initialization routine.
C
        Call init
C
C       Store initial position values in commons.
C
        elt = 0.
        h1 = chgt
        phi1 = clat
        thet1 = clon
        iopt = 0
        ho = h1
        phio = phi1
        theto = thet1
        h = h1
        phi = phi1
        thet = thet1
C
C       Evaluate atmospheric values at initial position.
C
        Call randinit
        Call timestep(0.,0.,0.,0.)
      Else
C
C       Evaluate the atmospheric values at subsequent positions.
        delt = ctime - elt
        dhgt = chgt - h1
        dphi = clat - phi1
        dthet = clon - thet1
        If (Abs(dthet).gt.180.)dthet = dthet - Sign(360.,dthet)
        Call timestep(delt,dght,dphi,dthet)
C
C...    You can use any of the desired atmospheric parameter output
C       values here, e.g. by passing them to a subroutine (see list of
C       available output variables near label 920 in the atmod
C       subroutine and Section 4.6 of the report).
C
        If(nmore.eq.0.or.(iopt.eq.0.and.nt.ge.nmax))Then
          If (iopr.eq.2)Then
C
C           If random option is off, return ifirst = -2 to signal the
C           driver program to terminate.
C
            ifirst = -2
            Return
          Endif
```

```
C                                                                       GRMT 95
C         Read the next random number and re-initialize the position   GRMT 96
C         and atmospheric variables. Return a value of ifirst = -1      GRMT 97
C         to tell the driver program that re-initialization was done.   GRMT 98
C                                                                       GRMT 99
          ifirst = -1                                                   GRMT100
          nt = 0                                                        GRMT101
          nmore = 1                                                     GRMT102
          Read(iur,*,end=90)nrl                                         GRMT103
          h1 = ho                                                       GRMT104
          phi1 = phio                                                   GRMT105
          thet1 = theto                                                 GRMT106
          h = ho                                                        GRMT107
          phi = phio                                                    GRMT108
          thet = theto                                                  GRMT109
          elt = 0.0                                                     GRMT110
          ctime = 0.0                                                   GRMT111
          chgt = ho                                                     GRMT112
          clat = phio                                                   GRMT113
          clon = theto                                                  GRMT114
          Call randinit                                                 GRMT115
          Call timestep(0.,0.,0.,0.)                                    GRMT116
        Endif                                                           GRMT117
      Endif                                                             GRMT118
      Return                                                            GRMT119
C                                                                       GRMT120
C     Return the value ifirst = -9 if the driver program is to          GRMT121
C     terminate.                                                        GRMT122
C                                                                       GRMT123
 90   ifirst = -9                                                       GRMT124
      Return                                                            GRMT125
      End                                                               GRMT126
```

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13. ABSTRACT *(Maximum 200 words)*

The latest version of the Global Reference Atmospheric Model (GRAM-95) is presented and discussed. GRAM-95 uses the new Global Upper Air Climatic Atlas (GUACA) CD-ROM data set, for 0- to 27-km altitudes. As with earlier versions, GRAM-95 provides complete geographical and altitude coverage for each month of the year. Individual years 1985 to 1991 and a period-of-record (1980 to 1991) can be simulated for the GUACA height range. GRAM-95 uses a specially developed data set, based on Middle Atmosphere Program (MAP) data, for the 20- to 120-km height range, and the NASA Marshall Engineering Thermosphere (MET) model for heights above 90 km. Fairing techniques assure a smooth transition in the overlap height ranges (20 to 27 km and 90 to 120 km). In addition to the traditional GRAM variables of pressure, density, temperature and wind components, GRAM-95 now includes water vapor and 11 other atmospheric constituents (O3, N2O, CO, CH4, CO2, N2, O2, O , A, He, and H). A new, variable-scale perturbation model provides both large-scale and small-scale deviations from mean values for the thermodynamic variables and horizontal and vertical wind components. The perturbation model includes new features that simulate intermittency (Òpatchinessó) in turbulence and small-scale perturbation fields. The density perturbations and density gradients (density shears) computed by the new model compare favorably in their statistical characteristics with observed density perturbations and density shears from 32 space shuttle reentry profiles. GRAM-95 provides considerable improvement in wind estimates from the new GUACA data set, compared to winds calculated from the geostrophic wind relations previously used in the 0- to 25-km height range. The GRAM-95 code has been put into a more modular form, easier to incorporate as subroutines in other programs (e.g., trajectory codes). A complete user's guide for running the program, plus sample input and output, is provided.

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