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The NASA/MSFC Global Reference Atmospheric Model—1999 Version (GRAM–99)

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PREFACE

The effort required for these improvements to the NASA/MSFC Global Reference Atmospheric Model (GRAM), was sponsored by the NASA Marshall Space Flight Center through the Environments Group, Engineering Systems Department of the Engineering Directorate.

For those unfamiliar with earlier versions of GRAM, NASA Technical Memorandum 4715 "The NASA/MSFC Global Reference Atmospheric Model – 1995 Version (GRAM-95)", NASA TM-4715, is recommended. That report is available electronically from the NASA Technical Report Server at Internet address

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For information on obtaining the GRAM–99 code and data, as well as additional copies of this report, contact

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Purchase information for the Global Upper Air Climatic Atlas (GUACA) CD-ROM is given in appendix A. Information for purchasing the Global Gridded Upper Air Statistics (GGUAS) CD-ROM is given in appendix B.

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1. Introduction

1.1 Background and Overview

Reference or Standard atmospheric models have long been used for design and mission planning of various aerospace systems. 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). For a summary comparing features of GRAM to characteristics and features of other Reference or Standard atmospheric models, see (Ref. 1).

The original GRAM version (Ref. 2) has undergone a series of improvements over the years (Refs. 3, 4, 5, 6). This report describes recent additions and improvements to GRAM. Section 1 provides an overview of the basic features of GRAM-99. Section 2 provides a more detailed description of GRAM-99 and concentrates on newly added features. Section 3 presents sample results. Appendices A and B describe the Global Upper Air Climatic Atlas data and the Global Gridded Upper Air Statistics data base. Appendix C provides instructions for compiling and running GRAM-99. Appendix D gives a description of the NAMELIST format input required. Appendix E gives sample output. Appendix F provides a list of available parameters for the user to generate special output. Appendix G gives an example and guidance to incorporate GRAM-99 as a subroutine in other programs such as trajectory codes or orbital propagation routines.

1.2 Basic Description of the GRAM-99 Model

Like earlier versions, GRAM-99 is an amalgamation of three empirically-based models that represent different altitude ranges (and the geographical and temporal variations within these altitude ranges). The mean thermodynamic variables and mean wind components of the upper and middle altitude regions are the same as GRAM-95. In addition to using Global Upper Air Climatic Atlas (GUACA)CD-ROM data of Ruth et al. (Ref. 7) for the lower altitude region (0 to 27 km), GRAM-99 alternately allows optional use of a new ASCII-formatted Global Gridded Upper Air Statistics (GGUAS) data base for this height region.

The GUACA (or GGUAS) data cover the altitude region from 0 to 27 km (in the form of data at the surface and at constant pressure levels from 1000 mb to 10 mb). The middle atmospheric region (20 to 120 km) data set is compiled from Middle Atmosphere Program (MAP) data (Ref. 8) and other sources referenced in the GRAM-90 and GRAM-95 reports (Refs. 5, 6). The highest altitude region (above 90 km) is simulated by the Jacchia (1970) model (Ref. 9) and implemented in the Marshall Engineering Thermosphere (MET) model (Refs. 10, 11), specifically the newly-released 1999 version (MET-99) (Ref. 20). Smooth transition between the altitude regions is provided by fairing techniques. Unlike interpolation (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 GUACA/GGUAS and MAP data and 90 to 120 km for MAP data and MET model). Figure 1.1 provides a graphical summary of the data sources and height regions.

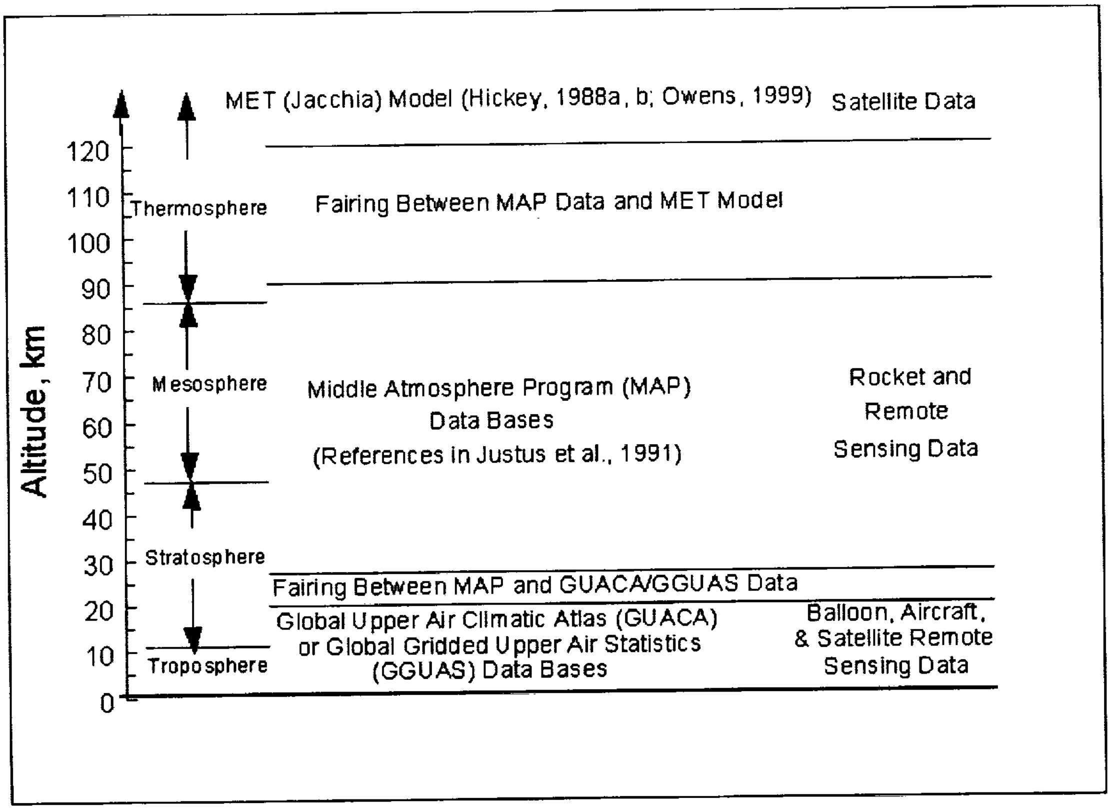

Figure 1.1 Schematic summary of the atmospheric regions in the GRAM-99 program and sources for the models and data on which the mean monthly GRAM-99 values are based

Beginning with GRAM-95, the model 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 (Ar), 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 (Ref. 12) are also used extensively for the constituents to 120-km altitude.

The GUACA data set provides water vapor data from the surface to the 300-mb pressure level. The NASA Langley Research Center (LaRC) water vapor climatology (Ref. 13) includes H_2O values from 6.5- to 40.5-km altitude. Middle Atmosphere Program (MAP) data (Ref. 14) include H_2O data from 100-mb to the 0.01-mb pressure level. Other details of the species concentration model are given in sections 2.4 and 1.4 of Justus et al. (Ref. 6).

1.3 Overview of New Model Features

1.3.1 Revised 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 anti-cyclones 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 semi-diurnal periods. Time-of day variations due to atmospheric tides tend to amplify with altitude, The Jacchia (MET) section of GRAM treats the major aspects of time-of-day variations. 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 these processes are parameterized stochastically by a random perturbation model. In GRAM-90, a 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 wavenumbers. These 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 was 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. (Ref. 15). In particular, the effects of intermittency, the tendency of turbulence to appear in patches or layers, are incorporated. The modeling approach, described more fully in section 2.6 of Justus et al. (Ref. 6), results in a simpler implementation incorporating fewer simulation parameters than the original model (Ref. 15).

In order to produce more obvious intermittency in the perturbation model some revisions were made in the details of calculations of the variable-scale random perturbation model for GRAM-99 i.e.,

(1) The time-series simulations of the variable length scale is used to categorize the turbulence as normal (light-to-moderate) or disturbed (severe). The turbulence (wind, density, temperature, etc.) is in disturbed conditions whenever the length scale drops below a prescribed "minimum" value (described in Ref. 6). The probability, P, of being in disturbed conditions is taken from statistics in NASA Technical Memorandum 4168 (Ref. 15), and varies from 1 to 2.5 percent near the surface to about 0.15 percent near 25-km altitude to about 2 percent near 75-km and back to about 1 percent above 120-km altitude. The values for standard deviation of the length scales were modified in the "atmosdat" data file (described in section 4.2) to get these appropriate probability values (section 2.7.2).

(2) The same total standard deviation values , σ_{tot}, are retained (for density, temperature, wind etc.), but are divided into two values, a smaller "non-severe" standard deviation for normal conditions, σ_{non}, and a larger "severe" standard deviation, σ_{sev}, for disturbed conditions. The standard deviations follow the relation

$$[\sigma_{tot}]^2 = P\,[\sigma_{sev}]^2 + (1\text{-}P)\,[\sigma_{non}]^2 \qquad (1.1)$$

where P is the above-mentioned probability for disturbed (severe) conditions. A parameterization (based on data in Ref. 15) specifies the ratio of σ_{sev} to σ_{non}. From these two conditions, values for both σ_{sev} and σ_{non} are computed (section 2.7.2).

(3) Instead of allowing the perturbation length scale to vary continuously, length scales are set to either a small value (the minimum length scale, L_{min}) if conditions are disturbed, or a large value (L_{max}) if conditions are normal. The value of L_{min} is taken directly from the L_{min} value in the "atmosdat" data file (see section 4.2). The value of L_{max} is determined from L_{min} and L_{avg} (the average scale size from the atmosdat data file, by requiring

$$L_{avg} = P\,L_{min} + (1 - P)\,L_{max} \qquad (1.2)$$

where P is the above-mentioned probability for disturbed conditions (section 2.7.2).

(4) Perturbation magnitudes are larger during disturbed periods because the larger standard deviation applies. "Shears", changes in wind (density, or temperature, etc.), are also larger during disturbed conditions

than in normal periods because the standard deviation is larger and the length scale is smaller (being the minimum value). For a discussion of the effect of length scale on shears, see section 2.6 of Justus et al. (Ref. 6).

1.3.2 Year 2000+ Features GRAM-99 accommodates input and output of either 4-digit years, or 2-digit years (for years 1957-2056), i.e., 00 = 2000, 01 = 2001, 56 = 2056. Two-digit years higher than 56 are interpreted as being in the 20th Century, i.e., 57 = 1957, 99 = 1999. This 2-digit-year "Y2K" feature was supplied as a code patch to the original GRAM-95 release. The 1999 version Marshall Engineering Thermosphere (MET-99) (Ref. 20) that comprises the upper altitude section of GRAM computes Sun positions based on epoch J2000 Equinox coordinates. Tests indicate the epoch change makes no significant difference in MET results. Between years 1900 and 2100, root-mean-square differences in solar declination and solar hour angle computed from the two methods are less than 0.01 degrees and 0.02 degrees, respectively.

1.3.3 Random Perturbation Scales For 0 to 27 km GRAM-99 applies the scaling factor, "rpscale", to scale the random perturbation magnitudes up or down from their nominal values, to the perturbation magnitudes in the height range 0 to 27 km. In the original GRAM-95 release, rpscale was used as a perturbation multiplier above 27 km. Code to use rpscale below 27 km was provided as a "bug-fix" patch to the GRAM-95 code and incorporated as a permanent feature of GRAM-99.

1.3.4 Namelist Format Input Input values are now provided to GRAM-99 in NAMELIST format. An example NAMELIST input file is given in appendix D, which also defines and discusses several new input parameters that control the new optional features in GRAM-99. Definitions and discussion of the original GRAM-95 input parameters are also given in section 4.4 and appendix B of Justus et al. (Ref. 15). The new input parameters discussed in appendix D are

rndpath = path name for file containing (optional) additional random number seed values for the perturbation model
rrapath = Directory name for the directory containing the (optional) Range Reference Atmosphere data
iun = unit number for file containing (optional) additional random number seeds
iurra = unit number for (optional) Range Reference Atmosphere (RRA) input data file
sitelim = outer lat-lon radius, beyond which GRAM data are used, instead of nearest RRA site data
sitenear = inner lat-lon radius, within which RRA data applies at full weight (RRA and GRAM are used as smoothly-varying weighted average between sitenear and sitelim)
initpert = 1 to use user-selected initial perturbations (0 for default, GRAM-derived, random initial perturbation values)
rpinit = initial pressure perturbation value (percent of mean)
rdinit = initial density perturbation value (percent of mean)
rtinit = initial temperature perturbation value (percent of mean)
ruinit = initial eastward velocity perturbation (m/s)
rvinit = initial northward velocity perturbation (m/s)
rwinit = initial upward velocity perturbation (m/s)

1.3.5 New Information On Standard Formatted Output A reference NAMELIST input file is provided in appendix D. Resulting standard formatted output file from this input is described in appendix E. New information appearing on the standard formatted output file include (1) indication whether the Global Upper Air Climatic Atlas (GUACA) or the Global Gridded Upper Air Statistics (GGUAS) data were used for the 0 to 27 km height range, (2) which Range Reference Atmosphere (RRA) site (3-character file extension code) or the code "GRM" if standard GRAM climatology data is used, and (3) the numerical weight (0.0 to 1.0) applied to the RRA site. RRA site and weight information appears on output for each altitude, next to the elapsed time value.

1.3.6 New Optional Surface Data Output As did GRAM-95, GRAM-99 provides a mechanism for the user to easily modify the code to produce a user-defined "special format" output file. Features and output variable selections are discussed in section 4.6 of Justus et al. (Ref. 6). A new GRAM-99 feature is that data values at the terrain surface can also easily be output, having passed from the GUAMOD subroutine via the COMMON BLOCK srfdat. Details of all of the available output parameters are given in appendix F.

1.3.7 New Optional Global Gridded Upper Air Statistics (0 to 27 Km) Data In GRAM-95 climatological data for the 0 to 27 km height range were provided by the Global Upper Air Climatic Atlas (GUACA) data base, described in appendix A. GUACA data includes the period of record averages for 1980 to 1991 as well as individual years 1985 through 1991. The National Climatic Data Center made available in ASCII format a set of lower altitude (0 to 27 km) data for the period of record 1980 to 1995. These new data are called Global Gridded Upper Air Statistics (GGUAS). GRAM-99 includes the option to use GGUAS period-of-record data. A description of the GGUAS data is given in appendix B.

The ASCII-formatted GGUAS files are large (about 32 MB for each month) and conversion from ASCII for use in program calculations is time consuming. Therefore, GRAM-99 is designed to use the GGUAS data in binary form. A program, gguasrd.f, is supplied so the user can read (once) the ASCII-formatted GGUAS data and convert it to binary on his machine, for subsequent use by GRAM-99. The binary-converted GGUAS files are approximately 7.5 MB per month and can be read in GRAM-99 even faster than the GUACA binary data. Details concerning the GGUAS data and the gguasrd.f program are given in appendix B.

1.3.8 PC Version Code Section 4.7 of Justus et al. (Ref. 6) provides a general description of how to modify the GRAM code to allow reading and decoding of the GUACA data under a variety of operating systems. As supplied, GRAM-99 code is designed for running under UNIX (specifically an SGI platform). To convert to another system, the following changes allow GRAM-99 to be compiled and run under Windows on a PC (with a 32-bit FORTRAN compiler):

change iswap to 0 in code line GRAM 69
change dirsep and endsep to '\' in code lines GRAM 74 and GRAM 75
change sysform to 'binary' in code line GRAM 78
change $ to 16# in code lines SHF2 6-7, SHF4 6-9, and VALR 18-19

These are the only code changes required to convert the UNIX version code supplied to a PC version of GRAM-99.

1.3.9 New Optional Range Reference Atmosphere Model (0 to 70 km) Data A major new feature of GRAM-99 is the (optional) ability to use data (in the form of vertical profiles) from a set of Range Reference Atmospheres (RRA) as an alternate to the usual GRAM climatology. With this feature it is possible, for example, to simulate a flight profile that takes off from the location of one RRA site (e.g. Edwards AFB), using the RRA atmospheric data, to smoothly transition into an atmosphere characterized by the GRAM climatology, then smoothly transition into an atmosphere characterized by a different RRA site (e.g. White Sands NM), to be used as the landing site in the simulation. Data for 12 RRA sites are provided. The user can also prepare data (in the appropriate format, described in section 2) for any other site desired for use in this mode. Details of the RRA data files and formats are given in section 2.

Use of the RRA data option in GRAM-99 is controlled by new input parameters (appendix D): rrapath gives the name of the directory containing the RRA data, iurra is the unit number to be used by the program for reading the RRA data, and sitelim and sitenear control the size of the latitude-longitude region in the vicinity of any RRA site for which data from that RRA site is to be used. For any location having a radial distance (in latitude-longitude terms) of less than the value given by sitenear, the RRA data (with a full weight of 1) is used. For any location outside a latitude-longitude radius given by sitelim, the GRAM climatology data is used (i.e., a weight of 0 for the RRA data). Between radial distances of sitenear and sitelim, a weighted average of RRA and GRAM climatology data is used, insuring a smooth transition from RRA to GRAM data.

1.3.10 1999 Marshall Engineering Thermosphere (MET-99) Model (> 90 Km) The newly-released 1999 version Marshall Engineering Thermosphere (MET-99) forms the upper portion (> 90 km) in GRAM-99. As mentioned above, the Equinox of J2000 is now used to compute solar positions. Slight changes were also made in the parameters of the perturbation model input parameters at 200 km and above. These changes make the density perturbations from GRAM-99 more consistent with those determined by Dr. Michael Hickey in his two reports of results from Atmospheric Explorer satellite data (NASA Contractor Report 4605, May, 1994, and NASA Contractor Report 201140, August, 1996). (Refs. 16, 17) Additional details of these changes in MET-99 are discussed in section 2.

1.3.11 New Wave Model For Large-Scale Perturbations A two-scale perturbation model is used in GRAM. Heretofore, perturbations at both large and small scales have been computed by a one-step Markov process (a first-order autoregressive approach, equivalent to the first-order autoregressive model of Hickey (Ref. 17). The combination of small-scale and large-scale one-step Markov processes in GRAM is somewhat more general than the second order autoregressive model used by Hickey at high latitudes.

However, because the one-step Markov process for large-scales can yield somewhat inaccurate results if small steps are taken along a trajectory, a new wave model was developed for the large scale perturbations in GRAM-99. This model uses a cosine wave, with horizontal and vertical wavelengths given by similar horizontal and vertical scales to those previously used in the large-scale one-step Markov model.

Thus, for small-scale perturbations GRAM-99 uses the same one-step Markov process as before (as described in section 2.6 of Justus et al., Ref. 6). For the large scale perturbations, the new cosine wave model replaces the single-step large scale Markov model.

1.3.12 New Option For User-Selected Initial Perturbations Earlier versions of GRAM (through GRAM-90) required the user to specify initial values for all random perturbation variables. For typical Monte-Carlo applications, most users found it difficult to choose different starting values for each set of perturbed profiles to be generated. Using the same starting perturbation values for all profiles (e.g. 0.0) was feasible but not always most appropriate. GRAM-95 was changed to have the program automatically select (with the appropriate range of variability) a random starting value for each perturbation parameter and Monte-Carlo perturbation profile.

GRAM-99 now allows, as a user-controlled option, the input of user-selected initial perturbation values. This option is controlled by the input parameter initpert (with 0, the default value, meaning GRAM-selected random initial values and 1 triggering user-selected initial values).

An example application for user-selected initial perturbations would be the following: Suppose a measured profile (e.g., a day-of-launch atmospheric sounding) is to be used as an actual (perturbed) profile up to the highest measured altitude and a GRAM-99 perturbed profile (or profiles) is desired for higher altitudes. The actual atmospheric values from the measured profile can be used to compute perturbed values to initialize GRAM-99 (methods discussed more fully in section 2). With these initial perturbation values, the GRAM-99 perturbed profile(s) for the higher altitude region have complete continuity with the measured profile from the lower altitude region.

2. Technical Description of the Model

2.1 The Jacchia Section (Above 90 km)

The Jacchia model (Ref. 9) 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, Ar, He, and H). The Jacchia model accounts for temperature and density variations due to solar and geomagnetic activity, 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. (Ref. 2), were made to allow atmospheric pressure to be computed from the density and temperature. Geostrophic wind components, modified by the effects of molecular viscosity (Ref. 5) are evaluated in the Jacchia section by using the Jacchia model to estimate horizontal pressure gradients. In GRAM-90 and GRAM-95, the NASA Marshall Engineering Thermosphere (MET) model (Refs. 10, 11) was implemented to characterize the mean atmosphere above 120 km. GRAM-99 now uses the newly-released 1999 version of MET (MET-99) (Ref. 20). Between 90 and 120 km a fairing process, described in section 2.5, ensures 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 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 was merged from six separate data sets covering the 20 to 120 km altitude range (references in Ref. 5). 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 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 (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 (Ref. 5). 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 (section 2.5).

2.3 The GUACA or GGUAS Section (0 to 27 km)

The Global Upper Air Climatic Atlas (GUACA) or Global Gridded Upper Air Statistics (GGUAS) 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 degree resolution in 144 longitudes (0°, 2.5°E, ... 2.5°W) and 73 latitudes (-90°, -87.5°, ... +90°) at the surface and 14 constant pressure levels from 1000 mb to 10 mb (appendices A and B).

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 at a lower altitude than the surface at the adjacent 2.5° grid points), GRAM fills in all 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 in computing sea level pressure from measured, station-level pressure).

Array sizes in GRAM-99 are set large enough to read in the full global GUACA data set at one time. This eliminates the feature in GRAM versions prior to 1995 whereby only a limited-area latitude-longitude grid of lower altitude data was loaded at one time. This feature improves GRAM 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 is 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 any missing data values, and correcting any discrepancies in the relationship among the standard deviations in pressure, density, and temperature. Density values at 70 mb for the period-of-record (1980 to 1991) data set require correction (appendix A). Missing values (especially winds at the poles and above 70 mb for some years) are filled in. Dewpoint temperatures above the 300-mb level are filled in by extrapolation using a decreasing relative humidity profile. These GUACA-extrapolated moisture values are used only between 300 mb and 100 mb where they are faired with NASA Langley water vapor values (section 2.5).

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. The GUACA data base values of standard deviations are subjected to a test for this constraint and adjusted (so 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 were introduced in GRAM-95, with values above 90 km from the MET model and via a new species concentration data base discussed in section 4.3 of Justus et al. (Ref. 6). Water vapor output from GRAM-99 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 (Figure 1.2 of Ref. 6).

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 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. Only monthly mean concentration values are output for the species, other than water vapor, and in the form of volume concentration and number density.

Interpolation of the GUACA (or GGUAS) dewpoint temperature for altitudes between the input pressure levels and for latitude and longitude between the input grids point is handled the same as the other GUACA (or GGUAS) variables. Height and latitude interpolation between input height-latitude grid points for water vapor above 27 km, and for the other species, is done by an adaptation of the two-dimensional interpolation discussed in next section (to do height-latitude interpolation rather than latitude-longitude interpolation).

Species concentrations c(t) are assumed to change with year, t, according to the relation

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

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.

2.5 Interpolation and Fairing Techniques

2.5.1 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) is 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, $\rho(z)$, is found by solving 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 uses an interpolated gas constant, R, and the fact that the exponent, a, is 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 the geopotential height) and 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.

2.5.2 Two-Dimensional Interpolation Let V be a variable that is available on a two dimensional grid array (x and y) and consider 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

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

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 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 dependent on a height-latitude (or a pressure-latitude) grid (such as the species concentration data), then equation 2.8 is 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.

2.5.3 Interpolation Across the Poles Several GRAM data bases that are height-latitude dependent lack values at or near the poles. These are 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 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

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

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

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

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

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

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

$$C(z) = f(z)\,A(z) + [\,1 - f(z)\,]\,B(z) \qquad (2.12)$$

ensures 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) 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 is used for f

$$f(z) = (z_2 - z)/(z_2 - z_1) \qquad (2.13)$$

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

$$f(z) = \cos^2[\,(\pi/2)\,(z - z_1)/(z_2 - z_1)\,] \qquad (2.14)$$

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

2.5.5 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); 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 pre-computed weights to obtain a weighted average of the summer and winter values 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., Mar-Apr-May and Jun-Jul-Aug values are used to estimate the monthly values for May and June with different weights applied for month). 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 in the data base.

2.6 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 $\mu(\mathbf{x})$ (i.e., μ is the deviation of the value from the mean value, divided by the standard deviation, all at the vector position $\mathbf{x}$). The perturbation model computes $\mu(\mathbf{x}')$ at the next trajectory position $\mathbf{x}'$

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

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

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

where the angle brackets denote an average. The auto-correlation value, r, is obviously a function of the vector displacement, $\delta\mathbf{x} = \mathbf{x}'\text{-}\mathbf{x}$.

Consider two normalized variates, $\mu(\mathbf{x})$ and $\nu(\mathbf{x})$, (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., $r_c = \langle \mu(\mathbf{x})\,\nu(\mathbf{x}) \rangle$). Variate $\nu(\mathbf{x}')$ at the new position is computed from $\nu(\mathbf{x})$ and $\mu(\mathbf{x}')$ by

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

where the coefficients are given by

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

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

and

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

Auto-correlation values, r, are computed by assuming an exponential correlation function

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

where δh and δz are the magnitudes of the horizontal and vertical components of $\delta\mathbf{x} = \mathbf{x}'\text{-}\mathbf{x}$ and L_h and L_z are horizontal and vertical scale parameters that are functions of height and latitude only. Time correlation (even in the special case when the users selects $\delta h = 0$ and $\delta z = 0$) is accounted for by the third exponential term in equation (2.21), where U is the magnitude of the horizontal wind and δt is the magnitude of the time step between data points. The assumed equivalence of time step and spatial step implied by this approach is known as Taylor's hypothesis.

For additional discussion of the perturbation model, see the next section and sections 2.6 and 2.7 of Justus et al. (Ref. 6).

2.7 New Perturbation Model Features

2.7.1 Revised Large Scale Perturbation Model Heretofore, perturbations at both large and small scales have been computed by a one-step Markov process. As discussed by Justus et al. (Ref. 6), the small-scale perturbations in GRAM represent small-scale physical phenomena such as turbulence, mesoscale storm processes, and gravity waves, while the large-scale perturbations represent large-scale phenomena such as tides and baroclinic (Rossby) wave processes.

However, because the one-step Markov process for large-scales can yield somewhat inaccurate results if small steps are taken along a trajectory (step sizes very small compared to the scale length), a new wave model was developed for the large scale perturbations in GRAM-99. This model uses a cosine wave, with horizontal and vertical wavelengths given by horizontal and vertical scales similar to those previously used in the large-scale one-step Markov model. The use of a cosine wave to represent the large-scale perturbations is actually more realistic than a Markov process since both tides and baroclinic waves are more wave-like than stochastic in nature. For Monte-Carlo simulations, a degree of randomness is introduced into the large-scale wave model by randomly selecting the phase of the cosine wave (under control of the same random number seed values used for the small-scale perturbations).

2.7.2 Revised Small Scale Perturbation Model In order to approximate intermittency ("patchiness") in the perturbations, a variable scale model was introduced in GRAM-95 (section 2.6 of Ref. 6). The GRAM database ("atmosdat" data file, described in section 4.2) includes (for both horizontal and vertical scales) values for average scale size (L_{avg}), minimum scale size (L_{min}), and standard deviation of the variable scale size (σ_L). Periods of "severe" perturbations are characterized as having a scale size of L_{min}.

In the revised perturbation model "non-severe" (i.e., light-to-moderate) perturbations are characterized as having a scale size of L_{max}, such that

$$L_{avg} = P_{sev} L_{min} + (1 - P_{sev}) L_{max} \tag{2.22}$$

where P_{sev} is the probability of encountering severe perturbations, given by

$$P_{sev} = P_{tail}((L_{avg} - L_{min})/\sigma_L) \tag{2.23}$$

where P_{tail} is the tail probability of a Gaussian distribution. From equation 2.22 the scale for non-severe perturbations is given by

$$L_{max} = (L_{avg} - P_{sev} L_{min}) / (1 - P_{sev}) \tag{2.24}$$

Furthermore, the variance of the severe perturbations is assumed to be $f_{sev}\,\sigma^2$, and the variance of the non-severe perturbations is assumed to be $f_{non}\,\sigma^2$, where σ^2 is the total variance of the small-scale perturbations (σ, the standard deviation of the small-scale perturbations is also given in the atmosdat file data). Considering the probability of occurrence, σ^2 is given by

$$\sigma^2 = P_{sev} f_{sev} \sigma^2 + (1 - P_{sev}) f_{non} \sigma^2 \tag{2.25}$$

From standard deviation data in (Ref. 15), the factor f_{sev} is approximated as varying with height, z, having values ranging from 6 at z = 0, to 12 at z = 10 km back to 6 at z = 16 km (and higher). With f_{sev} thus specified, f_{non} is calculated from equation (2.25) by

$$f_{non} = (1 - f_{sev} P_{sev}) / (1 - P_{sev}) \quad (2.26)$$

As GRAM-99 simulates perturbations along a given trajectory, it uses a random number generator to decide when (with probability P_{sev}) the perturbations are in the "severe" category. During this time, the variance is adjusted from its non-severe magnitude ($f_{non}\,\sigma^2$) to its severe magnitude ($f_{sev}\,\sigma^2$). An example is shown in section 3.

2.8 New Option For User-Selected Initial Perturbations

Earlier versions of GRAM (through GRAM-90) required the user to specify initial values for all of the random perturbation variables. For typical Monte-Carlo applications, most users found it difficult to choose different starting values for each set of perturbed profiles to be generated. Using the same starting perturbation values for all profiles (e.g., 0.0) was feasible but not always most appropriate. GRAM-95 was changed to have the program automatically select (with the appropriate range of variability) a random starting value for each perturbation parameter and each Monte-Carlo perturbation profile.

GRAM-99 now allows, as a user-controlled option, the input of user-selected initial perturbation values. This option is controlled by the input parameter, initpert (with initpert = 0, the default value, meaning that GRAM-selected random initial values are used and initpert = 1 requiring user-selected values for the initial perturbations).

An example application for user-selected initial perturbations is the following: Suppose a measured profile (e.g., a day-of-launch atmospheric sounding) is to be used as an actual (perturbed) profile to the highest measured altitude and a GRAM-99 perturbed profile (or profiles) is desired for higher altitudes. Actual atmospheric values from measured profile are used to compute perturbed values to initialize GRAM-99 (by methods discussed more fully in the next paragraph). With these initial perturbation values GRAM-99 perturbed profile(s) for the higher altitude region have complete continuity with the measured profile from the lower altitude region.

Suppose, in this example, the measured profile extends to an altitude of 25 km. Also suppose the measured values at 25 km are density = 0.044 kg/m^3 and eastward wind = 14 m/s (along with other measured values). To use the user-selected initial perturbation option, first do a GRAM run, starting at 25 km in this example with the same latitude, longitude, and month as the measured profile. Suppose this GRAM run gives a mean density of 0.040 kg/m**3 and mean eastward wind of 20 m/s. The values of user-selected initial density and eastward wind perturbations to use in subsequent GRAM runs are:

initial density perturbation (%) = 100*(measured density - GRAM mean)/GRAM mean
= 100*(0.044-0.040)/0.040 = 10 (%)

initial EW wind perturbation (m/s) = measured eastward wind - GRAM mean eastward wind
= 14 - 20 = -6 m/s.

Similar calculations apply to the pressure, temperature, and other wind components.

For subsequent GRAM runs (in this example), start at 25 km, using initpert = 1, rdinit = 10.0, ruinit = -6.0 (and whatever values apply to the other initial perturbation components). These values ensure that the highest altitude (25 km) data point in the measured profile is consistent with the starting value (at 25 km) of the perturbed profile from GRAM-99. If multiple perturbed profiles are desired for a Monte Carlo application, each is initialized with the same values (rdinit = 10.0 and ruinit = -6.0, etc.).

2.9 New Features In The 1999 Marshall Engineering Thermosphere (MET-99) Model

The newly-released 1999 version Marshall Engineering Thermosphere (MET-99) (Ref. 20) constitutes the upper portion (> 90 km) of GRAM-99. The Equinox of epoch J2000 is used to compute solar positions.

Slight changes were made in the parameters of the perturbation model input parameters used at 200 km and above. These changes make the density perturbations from GRAM-99 more consistent with those determined by Hickey (Refs. 16, 17). In the original GRAM climatology, random perturbation standard deviations in density at 200 km and above were latitude-invariant with a magnitude of 5.2 percent. New density perturbation magnitudes at 200 km and above (code RD data in the atmosdat file) vary from 3.0 percent at the equator to 8.0 percent at the poles. The large scale perturbation fraction, f_L, in section 4.2.4 (code PT data in the atmosdat file) was also changed to a value of 0.131 to reflect a larger fraction of the total density variance in large-scale perturbations. Changing the applicable values of f_L and density standard deviation has a corresponding effect on the magnitudes of pressure and temperature perturbations (discussed in section 2.7 of Ref. 6). As at other altitudes, large-scale perturbations in the GRAM-99 MET region are computed as a cosine wave perturbation rather than the one-step Markov large-scale model in GRAM-95.

From data in Table 2 of Hickey (Refs. 16, 17), the one-step correlation over 15 seconds of movement for the Atmospheric Explorer (AE) satellites is equivalent to an average value of 0.846 (with a standard deviation of 0.040). The length scales used in the perturbation model of GRAM-99 yield a correlation value of 0.870 over the distance the AE satellite moves in 15 seconds (well within the range of variability of the correlation data from Hickey).

2.10 Optional Range Reference Atmosphere (RRA) Data

A major new feature of GRAM-99 is the (optional) ability to use data (in the form of vertical profiles) from a set of Range Reference Atmospheres (RRA) as an alternate to the usual GRAM climatology at RRA site locations. With this feature it is possible, for example, to simulate a flight profile that takes off from one RRA site (e.g., Edwards AFB), using the RRA atmospheric data, to smoothly transition into an atmosphere characterized by the GRAM climatology, then smoothly transition into an atmosphere characterized by a different RRA site (e.g., White Sands, NM), as the landing site.

RRA data includes means and standard deviations of the various parameters at the RRA sites. Under the RRA option, when a given trajectory point is sufficiently close to a RRA site (latitude-longitude radius from site less than "sitenear", see below), the mean RRA data replace the mean values of the conventional GRAM climatology and the RRA standard deviations replace the conventional GRAM standard deviations in the perturbation model computations.

Data for 12 RRA sites are provided in Table 2.1. The user can prepare (in the appropriate format described below) data for any other site desired for use in the RRA mode. In addition to the RRA data files, a file called rrasites.dat is provided that gives the file-extension identifier, latitude, longitude, and site name, for each site. The file rrasites.dat must be augmented with comparable information for any new RRA site provided by the user.

Table 2.1 List of RRA site data provided, "rrasites.dat"

File Ext	Lat Deg N	Lon Deg E	Site Name
asc	7.56	-14.25	Ascension Island
bar	22.02	-159.47	Barking Sands, HI
cap	28.28	-80.33	Cape Canaveral, FL
dug	40.46	-111.58	Dugway Proving Ground, UT
eaf	34.55	-117.54	Edwards Air Force Base, CA
egl	30.29	-83.31	Eglin AFB, FL
kmr	8.44	167.45	Kwajalein Missile Range
ptu	34.07	-119.07	Point Mugu, CA
tag	13.33	144.51	Taquac, Guam
vaf	34.45	-120.34	Vandenberg AFB, CA
wal	37.51	-75.29	Wallops Island, VA
wsm	32.23	-106.29	White Sands, NM

Use of the RRA data option in GRAM-99 is controlled by new input parameters (appendix D) rrapath gives the name of the directory containing the RRA data, iurra is the unit number to be used by the program for reading the RRA data, and sitelim and sitenear control the size of the latitude-longitude region in the vicinity of any RRA site for using data from that RRA site. For any location having a radial distance (in latitude-longitude terms) of less than the value given by sitenear, use the RRA data (with a full weight of 1). For any location outside a latitude-longitude radius given by sitelim, use the GRAM climatology data (i.e., a weight of 0 for the RRA data). Between radial distances of sitenear and sitelim, use a weighted average of RRA and GRAM climatology data to ensure a smooth transition from RRA data to GRAM.

Nominal (default) values are sitenear = 0.5 degrees and sitelim = 2.5 degrees. For these values any latitude-longitude within a radius of 0.5 degrees from any of the RRA sites uses data from that RRA site. Any location beyond a radius of 2.5 degrees uses the GRAM data. Between 0.5 and 2.5 degrees radius, a weighted average of RRA data and GRAM data is used with the RRA data weight smoothly changing from 1 at a radius of 0.5 degrees to 0 at a radius of 2.5 degrees.

Depending on the value of sitelim and the proximity of the various RRA sites used, possibly a given trajectory location is in the vicinity of more than one RRA site (e.g., for locations near Point Mugu, Edwards AFB, and Vandenberg AFB). If a given trajectory location is influenced by more than one RRA site, only use data from the NEAREST (highest weight) site. NOTE if, in such case, the user desires to ALWAYS use a specific RRA site (e.g., Edwards) and NEVER use a nearby RRA site (e.g., Point Mugu), the name and information for the undesired nearby RRA site is removed from the rrasites.dat file list.

RRA data apply from 0 to (at most) 70 km. There is also a smooth fairing process to transition from RRA data to GRAM data as the top of RRA data is approached.

RRA date files for a given site consist of three data files: TABLE1.sss, TABLE2.sss, and TABLE3.sss, where sss is the three-character site code (file extension) from the list of sites in Table 2.1. The RRA data tables are in the format of Range Reference Atmosphere reports (e.g., Ref. 18).

Each TABLEx.sss file contains an annual average data set and 12 monthly data sets. TABLE1 data contain wind statistical parameters height, mean E-W wind, standard deviation in E-W wind, correlation between E-W and N-S wind(*), mean N-S wind, standard deviation in N-S wind, mean wind speed(*), skewness in wind speed(*), and number of observations(*). Asterisks denote parameters not used by GRAM. TABLE2 data contain thermodynamic statistical parameters height, mean pressure, standard deviation in pressure, skewness in pressure(*), mean temperature, standard deviation in temperature, skewness in temperature(*), mean density, standard deviation in density, skewness in density(*), number of pressure observations(*), number of temperature observations(*), and number of density observations(*). TABLE3 data contain moisture related statistical parameters height, mean vapor pressure(*), standard deviation in vapor pressure(*), skewness in vapor pressure(*), mean virtual temperature(*), standard deviation in virtual temperature(*), skewness in virtual temperature(*), mean dewpoint temperature, standard deviation in dewpoint temperature, skewness in dewpoint temperature(*), number of observations of vapor pressure and dewpoint temperature(*), and number of observations of virtual temperature(*). RRA Table 4 data are not used.

User-provided "RRA" data is used if the following conditions are adhered to: Each new "RRA" site is entered into the rrasites.dat file (maximum number of sites allowed is 99). Heights must be in the range 0 to 70 km, in ascending order in TABLEx.sss files with 90 or fewer heights entered (height increments can be any value and fixed height increments do not have to be used). The first data line of each TABLEx.sss may have descriptive information (such as site name). However, the first data line MUST contain the site latitude and longitude. Latitude is given as xx.xxN or xx.xxS, longitude is given as xxx.xxE or xxx.xxW in format (17X,F5.2,A1,2X,F6.2,A1). Latitude and longitude values from the first data line are compared with the latitude and longitude in file rrasites.dat (table 2.1) to ensure that the appropriate site data are used. In file rrasites.dat, north latitudes are positive (south latitudes are negative), while east longitudes are positive (west longitudes are negative). Each TABLEx.sss file MUST start with a set of annual average values followed (in order) by 12 monthly average data sets. The annual and monthly averages may have any number of lines of header information (as long as header information contains at least some character data and does not consist entirely of numbers). Data lines may be in free-field format but MUST contain a numerical value for each of the parameters expected depending on the TABLE type. Parameters not used by GRAM (indicated by asterisks above) may be input as zero values (except for number of observations which can be any number greater than zero). Missing values (i.e., those that will be ignored) may be indicated by using 99.99 or 999.99.

2.11 New Optional Global Gridded Upper Air Statistics (GGUAS) Data

To characterize the lower atmosphere (0 to 27 km) GRAM-99 uses either the original Global Upper Air Climatic Atlas (GUACA) data (described in appendix A) or a new set of data called the Global Gridded Upper Air Statistics (GGUAS described in appendix B).

The GUACA data includes the period of record averages for 1980 to 1991 (accessed by using input option iguayr=1), as well as individual years 1985 through 1991 (accessed by using iguayr = 2 and the specified year value). The GGUAS data contains only the longer period of record 1980 to 1995 (accessed by using iguayr = 3).

The ASCII-formatted GGUAS files are large (about 32 MB per month) and conversion is time consuming. Therefore, GRAM-99 is designed to use GGUAS data in binary form. A program, gguasrd.f, is supplied to read (once) the ASCII-formatted GGUAS data and convert to binary for subsequent use by GRAM-99. GGUAS data consists of 12 files, one for each month of the period of record. The gguasrd.f program is used to read the GGUAS files (directly from the CD if desired by using the GGUAS directory D:\DATA if the CD ROM drive is D:\). The binary-converted files are named guabinmm.dat and mm is the month number. The binary output files are written to the same directory as the location of the gguasrd.f program. After binary-converted files are produced they should be arranged in the same directories and sub-directories as GUACA period-of-record data. Thus, if C:\guadir is the main GUACA directory move each binary GGUAS file guabinmm.dat to the corresponding month's subdirectory C:\guadir\por\mm.

3. Sample Results

3.1 Revised Large-Scale Perturbations

Figure 3.1 illustrates an example of the new large-scale wave perturbation model. Amplitudes of the wave perturbations are established from standard deviation information in the "atmosdat" data base (section 4.2). Wavelengths are established from length scale data in the "pertrb" subroutine of the GRAM code. Phase of the wave perturbation is initialized randomly from the starting random number seed. Thus, in a Monte Carlo run using various seed values different phases of the wave perturbations are sampled.

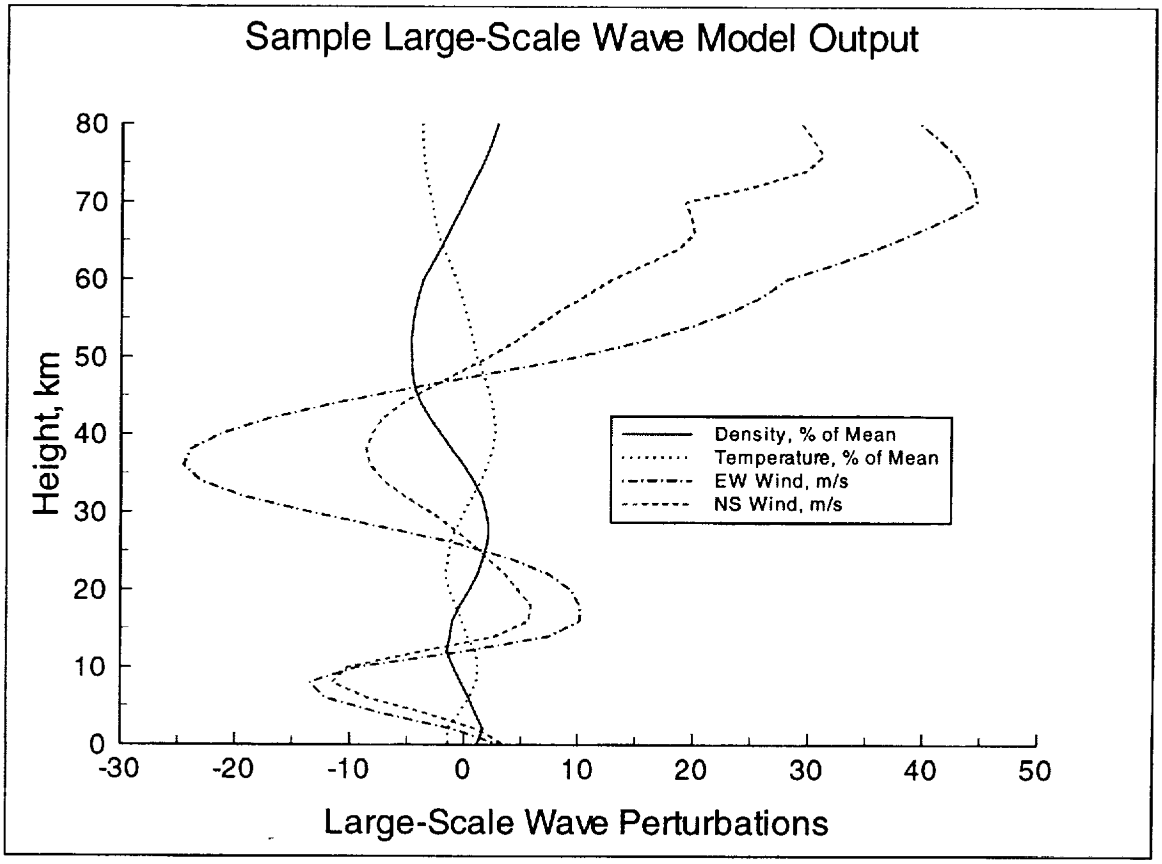

Figure 3.1 Sample vertical profile of wave-form large-scale perturbations

Because the amplitudes and wavelengths of the wave perturbations depend on altitude, the waves are not purely sinusoidal in shape. Generally, the amplitude and wavelength increase as the altitude increases. Relative phases of the various wave perturbations are controlled automatically by the model. Generally, temperature and density wave perturbations tend to be roughly 180 degrees out of phase (Figure 3.1).

3.2 Revised Small-Scale Perturbations

As discussed in sections 1.3.1 and 2.7.2 the revised small-scale perturbation model contains more evident intermittency. This feature is illustrated in Figure 3.2. Example perturbations in this figure are in arbitrary units (percent for density or temperature perturbations or m/s for wind perturbations. In this example, the small periods of time in which the perturbations are disturbed (severe) are indicated by the tick marks at the top of the figure. During the (infrequent) severe perturbation periods the standard deviation is 23.5 units. During the non-severe (light-to-moderate disturbance) periods the standard deviation is 9.7 units. The standard deviation for the total series of perturbations is 10 units in this example (Equation 1.1).

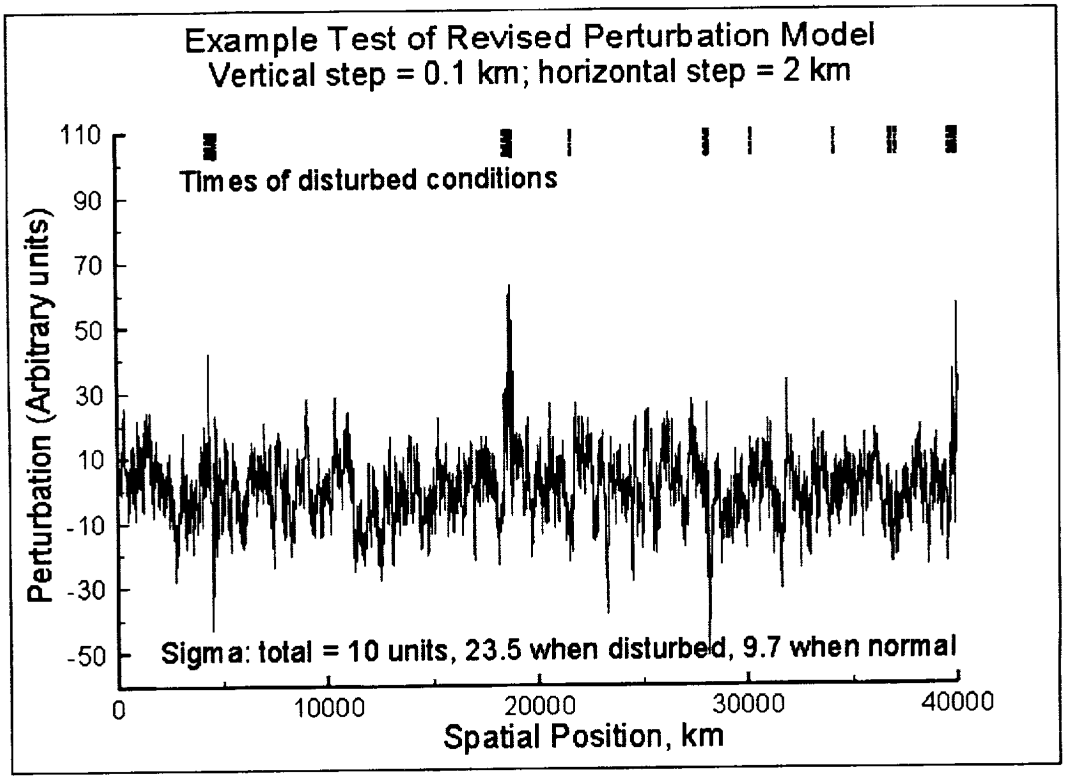

Figure 3.2 Example series of perturbation values (arbitrary units) from revised perturbation model

3.3 Revised Perturbations in the Thermosphere

With only slight modification of perturbation parameters in the atmosdat data above 200 km (section 2.9) the revised perturbation model agrees reasonably well with the thermospheric density variation model of Hickey (Refs. 16, 17). Figure 3.3 shows an example time-series simulation of thermospheric density perturbations and power spectral density of perturbations produced by Hickey's model. Figure 3.4 illustrates comparable time-series and power spectral density results from the GRAM-99 perturbation model. This figure shows a significant degree of similarity between the magnitude and time structure of thermospheric perturbations simulated by these two methods.

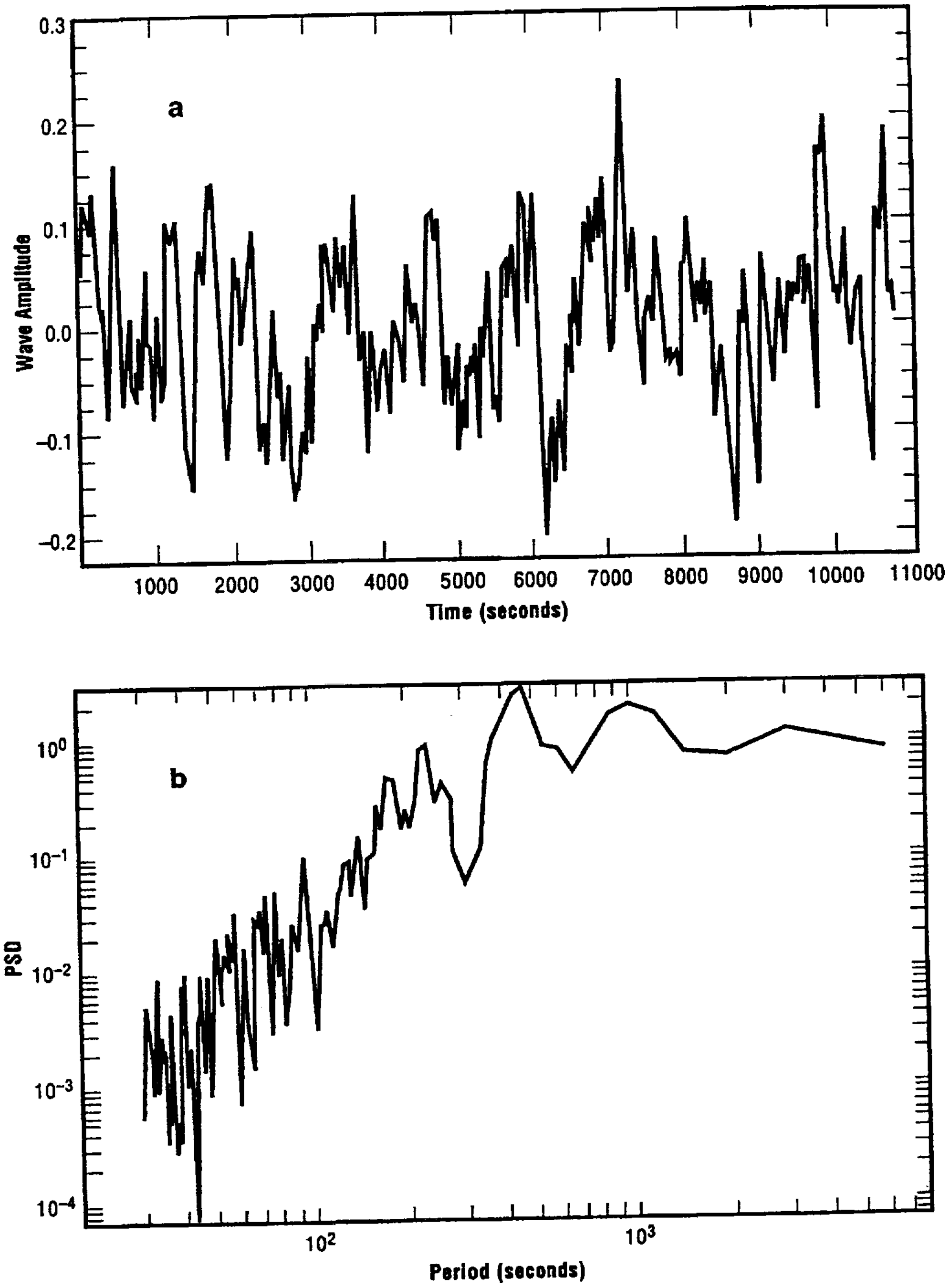

Figure 3.3 Density perturbation values (a) and power spectral density (b) simulated for high latitude and low geomagnetic conditions by the Hickey model (Figure 7, Ref. 17)

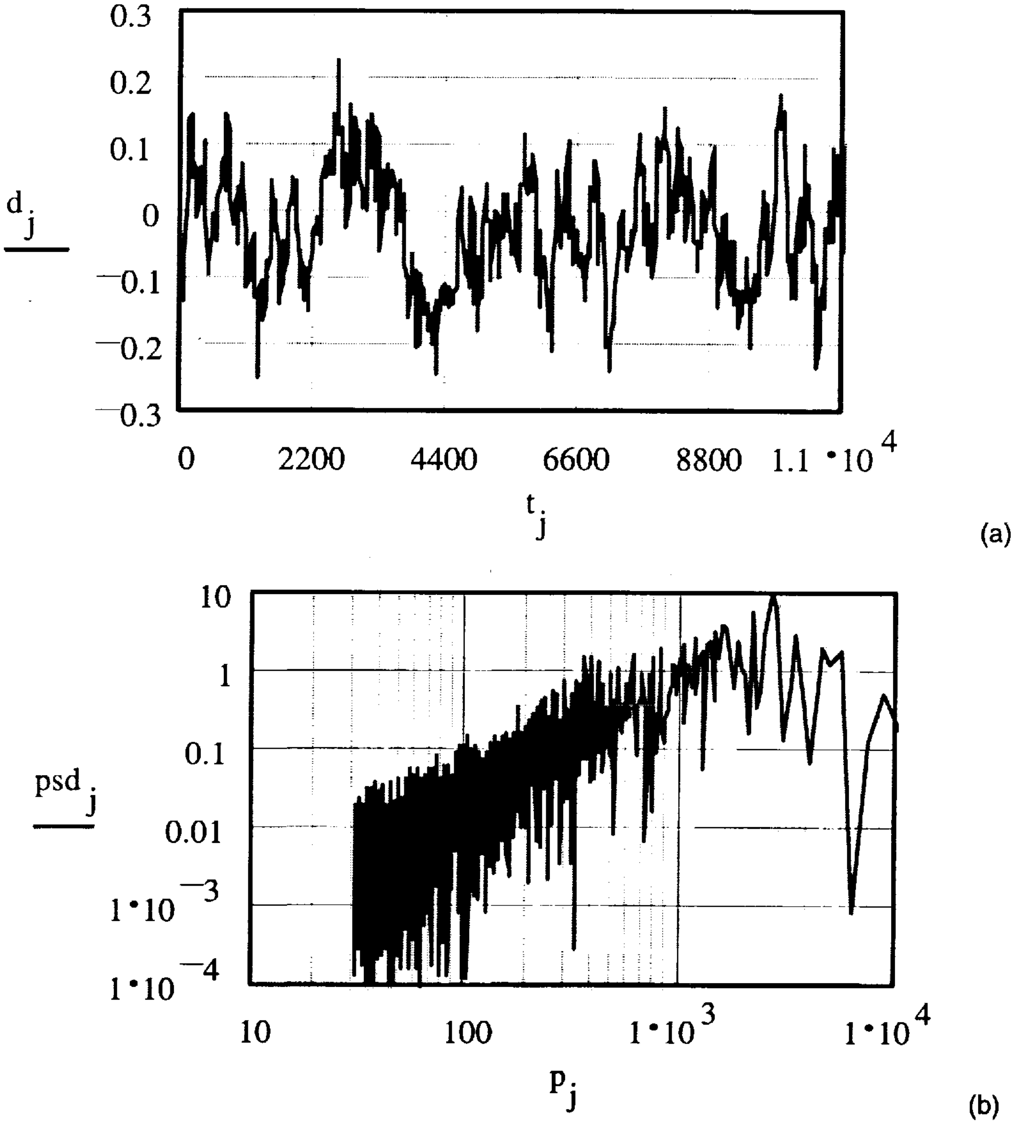

Figure 3.4 Density perturbation values (a) and power spectral density (b) simulated for high latitude and low geomagnetic conditions by the GRAM-99 perturbation model (compare with Figure 3.3)

3.4 Range Reference Atmosphere Data Option

Sections 1.3.9 and 2.10 describe the new Range Reference Atmosphere (RRA) data option for GRAM-99. A simplified example is illustrated in figures 3.5 and 3.6. For this example, a parabolic trajectory is assumed, with take-off from Edwards AFB, flying to an apogee at 100-km altitude, followed by a landing at White Sands Missile Range. Default values are used in this example. Hence, RRA values are used when the trajectory is within a latitude-longitude radius of 0.5 km from either of the RRA sites; GRAM climatology is used when the trajectory is beyond a latitude-longitude radius of 2.5 degrees from either RRA site; a smooth transition is assumed between RRA data and GRAM data between 0.5 and 2.5 degrees latitude-longitude radius.

Figure 3.5 illustrates the temperature profile between take-off and landing for a pure GRAM climatology trajectory (solid line) and the RRA/GRAM option (dotted line). Percentage differences between pure GRAM values and RRA/GRAM values of less than ± 2 between are shown in Figure 3.6.

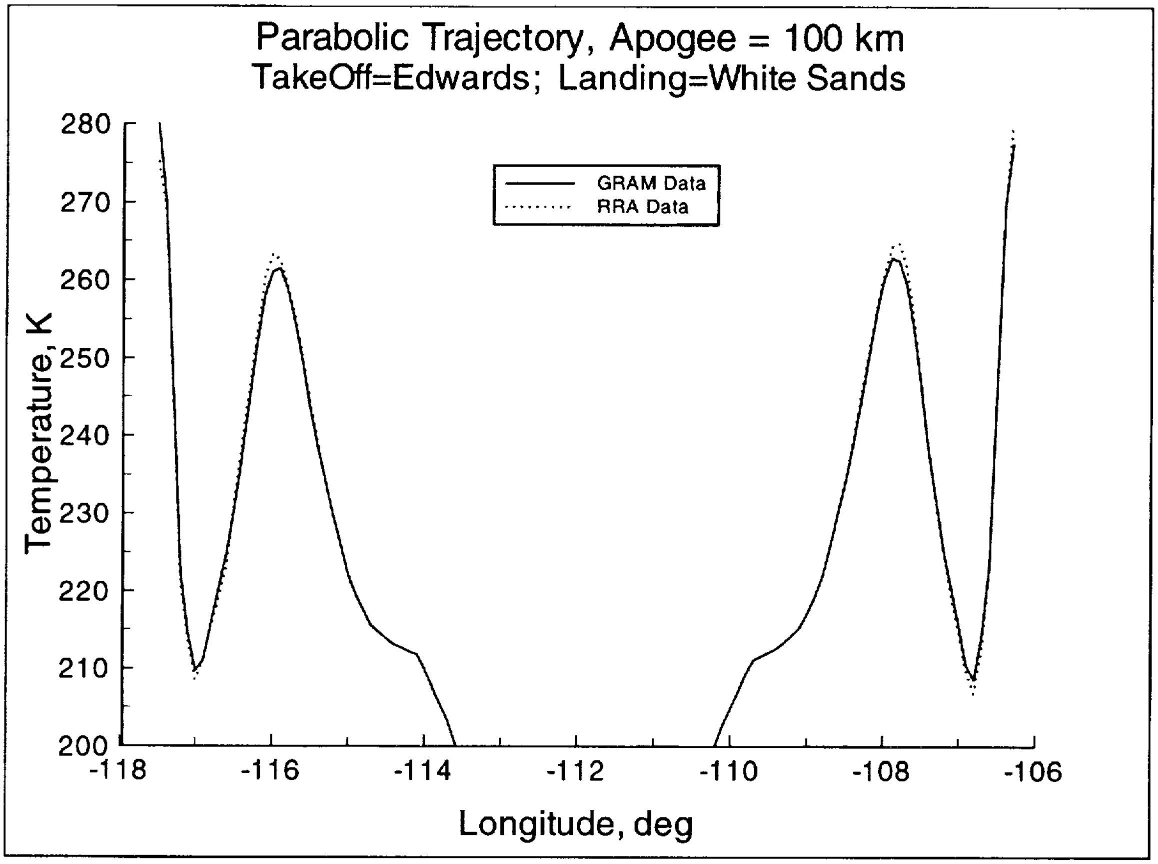

Figure 3.5 GRAM (solid line) or RRA/GRAM (dotted line) profiles of temperature along hypothetical parabolic trajectory between Edwards AFB and White Sands Missile Range with 100 km apogee

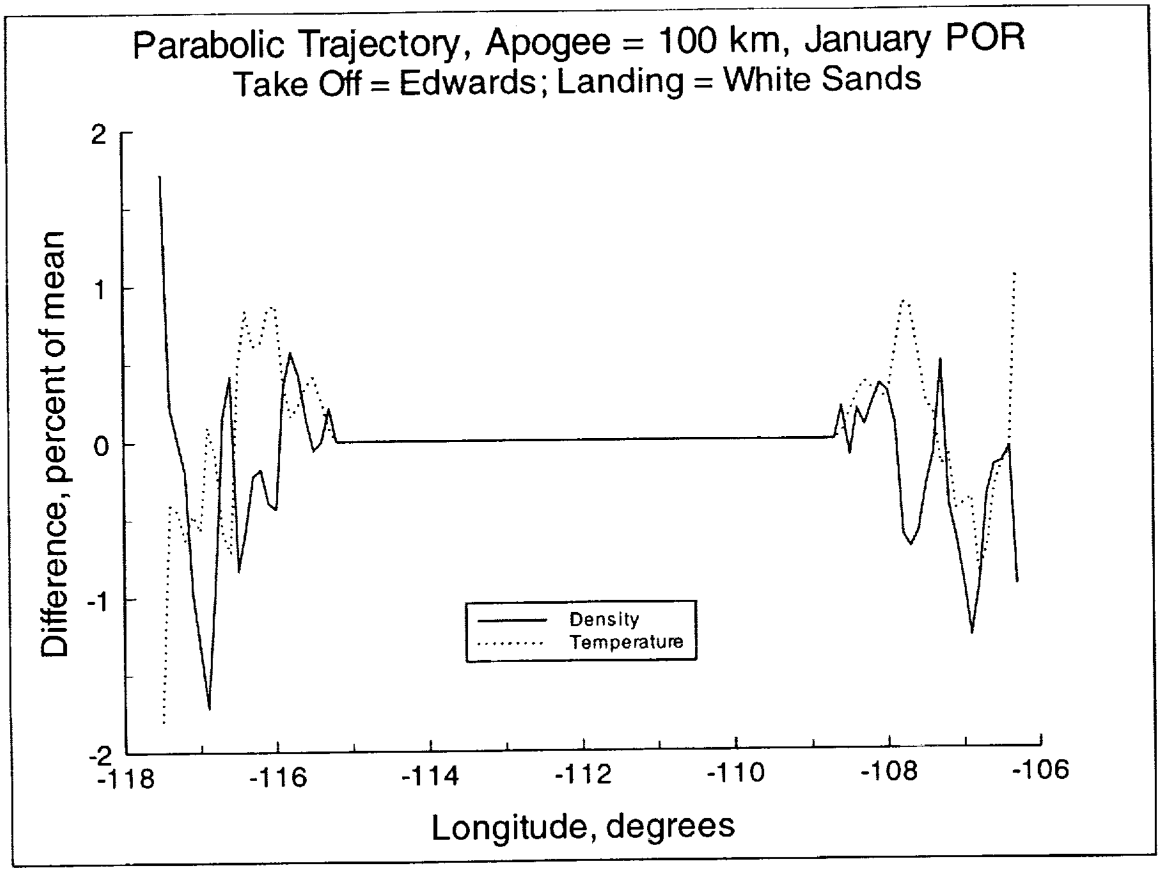

Figure 3.6 Differences in Density (solid line) and Temperature (dotted line) between GRAM and RRA/GRAM values for the hypothetical trajectory of Figure 3.5

4. GRAM-99 Users Guide

4.1 General Program Review

Like its predecessors, the 1999 version of the Global Reference Atmospheric Model, GRAM-99, is designed to produce atmospheric parameter values either along a linear path (a profile), or along any set of related time-position data (a trajectory). Based on user-selected input values, the program can step automatically in height, latitude, longitude, and time along any desired linear profile. For the trajectory evaluation option, times and positions are provided to the program as a separate input (trajectory) file. Optionally GRAM-99 can also be incorporated as a subroutine in the users trajectory (or orbit propagation) code for evaluation along trajectory or orbital positions.

GRAM-99 was developed primarily for a UNIX environment, specifically SGI's IRIX system, but its code may be adapted for other platforms relatively easily (section 4.7 of Ref. 6). Section 1.3.8 describes converting the code for PC FORTRAN.

GRAM-99 uses two required input files and up to four other input files depending on user-selected options. Required files are the NAMELIST-formatted input file (appendix D) and "atmosdat" (section 4.2). Optional input files for the lower atmosphere (0 to 27 km) are either the GUACA data (appendix A) or GGUAS data (appendix B). Optional Range Reference Atmosphere data input are described in section 2.10. Optional trajectory input file format is described in section 4.3. For use in Monte-Carlo analysis with a number of identical profiles or trajectories using different random number seeds, a file of such seed numbers is described in section 4.4

Output of GRAM-99 consists of three files. For cases in which GRAM was incorporated as a subroutine in a user-provided trajectory code, an option exists to suppress all output from GRAM (GRAM-computed values handled as required in the users program (appendix G)). The primary output file is the standard formatted output described in section 4.7 and appendix E. An optional species concentration output file (section 4.7 and appendix E) can be produced. An optional special formatted output file (section 4.7 and appendix F) is designed to make it easy for the user to select from a wide range of output variables and to output them in an easily-modified format.

Path names for the input and output files (except the NAMELIST input file) are provided via input from the NAMELIST input file. Options selected in the NAMELIST input file determine which of the optional input and output files are actually used on a given program run.

4.2 The "atmosdat" File

The "atmosdat" file consists of several types of data in several formats 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 (Ref. 5). The remainder of the file, added for GRAM-95, provides necessary input for recent model features.

4.2.1 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 km to 120 km. Prefix codes, ZP, ZD, ZT, and ZU indicate pressure, density, temperature, and zonal wind, respectively. Each record contains the code, month, height in km, and -90°, -80°, ..., 80°, 90° latitude values of the parameter expressed as a four-digit integer with an exponent common to all 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 $2\,761 \times 10^{-6} = 2.761 \times 10^{-3}$. Pressure data are in units of N/m^2, density values kg/m^3, temperatures K, and zonal winds m/s. The zonal-mean data set contains 1 008 FORTRAN readable records, the code, and 22 integer values in each record (format A2, I4, I5, 19I6, I4).

4.2.2 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 the 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, month, height in km, latitude (-80 to +80) in degrees, and 18 values of stationary perturbations, in per mil (%/10) for thermodynamic variables, and 0.1 m/s for winds at longitude 180, 160 W, 140 W, ..., 140 E, and 160 E degrees. The monthly mean value, y_m, for parameter, y (pressure, density, or temperature), at any latitude and longitude is computed from the zonal-mean value, z_y, at the latitude and stationary perturbation, s_y (in per mil) at the latitude and longitude, by the relation

$$y_m = z_y \, (1 + s_y / 1000) \tag{4.1}$$

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).

4.2.3 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, month, and 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 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 database for both the thermodynamic and wind variables. The random perturbation data consist of 1 596 FORTRAN readable records with code and 22 integer values in each record (format A2, I4, I5, 19I6, I4).

4.2.4 Large-Scale Fraction Data From daily difference analysis described in section 2 of Justus et al. (Ref. 3), the fraction of the total variance (σ^2 from the random perturbation data) contained in the large-scale perturbations was 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- 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

$$\sigma_L = (f_L / 1000)^{1/2} \, \sigma_T \tag{4.2}$$

$$\sigma_S = (1 - (f_L / 1000))^{1/2} \, \sigma_T \tag{4.3}$$

where σ_T is the total perturbation magnitude. The code PT and PW data sets contain 25 FORTRAN readable records, with code word PT or PW, followed by 17 integer values in each record (format A2, 17I7) for code PT and 12 integer values (format A2, 12I7) for PW code records.

4.2.5 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 Justus et al. (Ref. 6) and in Justus et al. (Refs. 3, 4). Both large-scale and small-scale values of the density-velocity correlations were evaluated and are given in the "atmosdat" database (codes CL and CS) in per mil (i.e., divide by 1000 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, 12I7).

All foregoing code values in the "atmosdat" database are ingested into the GRAM program through the subroutine setup in the initial.f file.

4.2.6 Variable-Scale Random Perturbation Model Data Variable-scale random perturbation model data appear next in the "atmosdat" database. They consist of 29 FORTRAN readable records containing a code (RS) and 10 real (floating-point) values each (one height and 9 associated parameters (section 2.6), which are ingested into the GRAM 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" database are values needed for atmospheric constituent concentration calculations.

4.2.7 LaRC Data The next segment of data in the "atmosdat" database is the NASA Langley Research Center (LaRC) concentration data (Ref. 13) for the atmospheric constituent H_2O. The data consist of 4 groups of 35 FORTRAN readable records of a code and nine data values each (one height and 8 associated array values at latitudes -70° through +70°) and are ingested into the GRAM program through the subroutine concinit 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 Dec-Jan-Feb, LMAM for Mar-Apr-May, LJJA for Jun-Jul-Aug, and LSON for Sep-Oct-Nov.

4.2.8 AFGL Data The next-to-last segment of data in the "atmosdat" database is the Air Force Geophysics Laboratory (AFGL) concentration data (Ref. 12) 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 6 values each (one height and 5 associated array values for each of the five constituents) and are ingested into the GRAM program through the subroutine concinit. The five record groups present tropical (AFTR), mid-latitude summer (AFMS), mid-latitude winter (AFMW), sub-arctic summer (AFSS), and sub-arctic winter (AFSW) data. Tropical data are for latitudes of ±15°, mid-latitude data are for ±45°, and sub-arctic data are for ±60°. As necessary, a 6-month displacement is used to estimate southern hemisphere values from northern hemisphere values.

4.2.9 MAP Data The last segment of data in the "atmosdat" data base is the Middle Atmosphere Program (MAP) concentration data (Ref. 14) for the years 1979 to 83. The code O3 data are for ozone at 24 pressure levels (0.003 to 20 mb) for 12 months. Each of the 288 records consists of the code, month, pressure level (mb), 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 mb) for 12 months, followed by 8 annual values (denoted by month 13) for the pressure levels 0.01 to 1.0 mb. There are a total of 140 H2O records. Each contains the code, month, pressure level (mb), and five mean values at latitudes -60°, -45°, ±15°, +45° and +60° (with -60° estimated by 6-month displacement of +60° data), followed by five standard deviation values at these latitudes. The code N2O data are for MAP nitrous oxide (code CH4 data for methane). The N2O and CH4 data consist of 204 records each. Each records contains the code, month (1 to 12), pressure level (17 levels, 0.1 to 20 mb), 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 month. There are 228 total records, each containing the code, month, height (km), 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).

4.3 The Trajectory File

The trajectory file is only required when a trajectory rather than an automatically determined profile is desired. The file may contain an unlimited number of individual list-directed (free-field) records (i.e., lines) consisting of four real values 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 reached.

4.4 Random Number Seed File

If a number of Monte-Carlo simulations are to be computed in one program run, subsequent starting random number seed values are input via a special optional input file. The file contains one random seed number per line. Each random number seed value is an integer, ranging from 1 to 900 000 000. Random seed values do not have to be randomly-generated numbers. Thus, any convenient sequence of consecutive numbers may serve as valid random seed values.

4.5 Output Data Files

4.5.1 The Standard Formatted Output File The standard output file (example in appendix E) has header information consisting of the principal input data values and the Julian date required by the Jacchia section of the program and calculated internally by the program. Positions and times generated by the automatic linear profile feature, or as input by the trajectory input data, are listed on the output with the associated calculated values of the atmospheric variables. If a latitude greater than 90° in absolute magnitude is generated (or input), the transformation

$$\mathrm{lat} = (180^\circ - |\mathrm{lat}|)(\mathrm{lat}/|\mathrm{lat}|) \qquad (4.4)$$

$$\mathrm{lon} = \mathrm{lon} - 180^\circ \qquad (4.5)$$

is made. All longitudes are converted to the range -180 to +180° before being output

The mean values of pressure, density, temperature, and wind components consist of either (Figure 1.1)

1. Values calculated from the GUACA database 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, or
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 US Standard Atmosphere, on the "M-76" line, are evaluated by using standard atmosphere values computed by the subroutine, stdatm, 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 US Standard Atmosphere values 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 US 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 US 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 mean values defined above plus the random and wave model perturbations. These mean-plus-perturbation values represent typical "instantaneous" evaluations of the pressure, density, temperature, and winds. The percent deviations from the US Standard Atmosphere, on the "T-76" line are computed in the same way as 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 (%). Mean water vapor values are computed from the GUACA, LaRC, MAP, or AFGL data according to altitude. Fairing is used for a smooth transition between these data sources. Values on the "sigH" line are standard deviations in water vapor in 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 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 ±σ 68 percent of the time and outside the range ±σ 32 percent of the time. Similarly, the perturbation values should be within the range ±2σ 95 percent of the time and outside the range ± 2σ 5 percent. The values of the foregoing parameters are derived from the variable-scale perturbation model discussed in sections 2.6 and 2.7.

4.5.2 The Species Concentration Output File The species concentration output file (example in appendix E) is also optional and controlled similarily to the special format output file by the value of an input parameter, iuc, and the pathname parameter, conpath. The file's header definition is found in the init subroutine of the initial.f file, in the section near the labels 9091 and 9013, while the output definition is in the atmod subroutine of the models.f file near the label 910.

4.5.3 The "Special" Format Output File The "special" output file is optional, controlled by the input value of the "iopp" parameter switch and special output file pathname "nprpath" (appendix D). As incorporated in the standard distributed code, this output file is configured at two separate locations. The file's header definition is found in the init subroutine of the initial.f file, in the section near format label 954, while the file's parameter output definition is found in the atmod subroutine of the models.f file, in the section near format 9000. The code at both locations may be modified to fit the requirements of the user.

As a further aid to the user in constructing special output files appendix F gives tables listing the standard variables available for output. The tables are also given in the code in the atmod subroutine of the models.f file beginning following format label 910.

4.6 Description of Program Files and Subroutines

There are nine source code files for the basic GRAM-99 program (gram99.f, gramsubs.f, guaca.f, initial.f, met99prg.f, models.f, random.f, rramods.f, and speconc.f). All (except rramods.f) are basically described in section 4.8 and appendix D of Justus et al. (Ref. 6). One new GRAM-99 source code file (rramods.f) has routines for reading the Range Reference Atmosphere (RRA) data files. Another new source code file (gguasrd.f) is a separate program to read (once) the ASCII version Global Gridded Upper Air Statistics (GGUAS) data and write in binary form suitable for reading by GRAM-99. There is also a sample program (gramtraj.f) that illustrates how to incorporate GRAM-99 as a subroutine in user-provided programs. Brief descriptions of these GRAM-99 program source code files and auxiliary source code files are

gram99.f	main program, replaces main program gram95.f
gramsubs.f	general subroutines (section 4.8 and appendix D of (Ref. 6)
guaca.f	reads and prepares GUACA data
initial.f	reads atmosdat file and initializes data
met99prg.f	1999 version Marshall Engineering Thermosphere (MET-99) model
models.f	other subroutines, not in gramsubs
random.f	random number generators
rramods.f	reads the Range Reference Atmosphere (RRA) data
speconc.f	species concentration subroutines
gramtraj.f	alternate routines (replacing gram99 main) that illustrate the use of GRAM-99 as a subroutine in a trajectory-calculating program
gguasrd.f	separate program to read the ASCII format GGUAS files and write in binary, for use by GRAM-99 (see section 2.11 and appendix B)

4.7 Running GRAM-99

Before running GRAM-99, all files must be available in the proper configuration, and the source code (described in section 4.6) must be compiled and linked. See further information about this process in appendix

C. If an executable file called gram99.x was created and a NAMELIST format input file (e.g., called namein.txt) was created in the same directory then the simplest way to execute the program is with the command

```
gram99.x
```

The program then prompts the user to enter a file name for the NAMELIST formatted input file.

In addition, the various input files must be set up in directory structures. The GUACA or GGUAS data must be set up in directory and sub-directory structures described in appendix A and B, and the input pathname parameter "guapath" must point to this directory. Similarly, the input value for "atmpath" must point to the atmosdat file (section 4.2), the input pathname "trapath" to the trajectory file (section 4.3), the "rndpath" parameter to the random number seed file (section 4.4), and the pathname "rrapath" to the directory where the Range Reference Atmosphere data are located (section 2.10).

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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 & 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 & 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-degree grid (10 512 grid points) and 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 observations at irregularly spaced locations are interpolated to regular 2.5-degree 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 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 (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, 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 mb only)	1980-1991
Geopotential Height	1980-1991
U and V Wind Components	1980-1991

Pressure Level 10 mb

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

1000 millibars	130 meters	(400 feet)
850 millibars	1500 meters	(5000 feet)
700 millibars	3000 meters	(10000 feet)
500 millibars	5500 meters	(18000 feet)
400 millibars	7000 meters	(24000 feet)
300 millibars	9000 meters	(30000 feet)
250 millibars	10500 meters	(34000 feet)
200 millibars	12000 meters	(40000 feet)
150 millibars	13500 meters	(44000 feet)
100 millibars	16000 meters	(52000 feet)
70 millibars	18500 meters	(60000 feet)
50 millibars	21000 meters	(69000 feet)
30 millibars	24000 meters	(78000 feet)
10 millibars	31000 meters	(101000 feet)

Dew-point temperature was calculated by NCDC from mixing ratio (to April 1982) and relative humidity (from April 1982 to end of period-of-record). In addition to the above elements, atmospheric density for the surface to 10 millibar 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 (not used in GRAM).

It should be noted that the 70-mb level was missing in the GUACA 1980 data for April. This adversely affected the period-of-record density values for April at 70 mb. 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 and the model initialization procedures undergo continual modification to better model the global atmosphere. The grid point analyses provided are not static but 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 were introduced since 1980.

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

1. Sep 1982 Temperature increase in the tropical middle troposphere--especially at 500 millibars.

2. May 1985 Tropical temperature increase at 700 millibars, and decrease at 850 millibars, stratospheric temperature increase, with slight cooling at 300 millibars, warming in Northern Hemispheric polar region between 850 and 400 millibars, moisture increase at 850 millibars, with decrease above 850 millibars., improvements in tropical wind structure

3. Mar 1986 Significant moistening of the upper troposphere

4. May 1986 Tropical temperatures near tropopause decreased

5. May 1989 Moistening in upper troposphere (300 millibars)

An excellent overview of the ECMWF system and implemented changes is in (Ref. 19).

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 to 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, the following minimum PC system is required:

- IBM 286, 386, 486, Pentium 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 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	315660
Dewpoint Temperature	°C	mdwpxx.dat	sdwpxx.dat	7	147404
Geopotential Height	m	mhgtxx.dat	shgtxx.dat	14	294628
Sea Level Pressure	mb	mslpxx.dat	sslpxx.dat	1	21212
Temperature	°C	mtmpxx.dat	stmpxx.dat	15	315660
Eastward Wind Comp.	m/s	muwdxx.dat	suwdxx.dat	15	315660
Northward Wind Comp.	m/s	mvwdxx.dat	svwdxx.dat	15	315660

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 preceded 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

$$\text{bytes/level} = (2 \times 4) + (144 \times 73 \times 2) = 21032$$

and the size of each file (in bytes) is

$$\text{file-size} = 180 + (21032 \times \text{Number-of-Levels})$$

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 the input array has a number of levels = numlevs). 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 1 (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 pre-read 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 inter-system 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, takes about half the time, the read routine in GRAM takes a few seconds to read each file on an SGI UNIX platform.

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

To purchase a copy of GUACA CD-ROM contact

National Climatic Data Center
151 Patton Avenue, Room 120
Attn: Climate Services Division
Federal Building
Asheville, NC 28801-5001

Phone: (704) 271-4800
Fax: (704) 271-4876
e-mail: orders@ncdc.noaa.gov
internet: http://www.ncdc.noaa.gov/cdrom/cdrom.html#ORDER

Appendix B Data Base Description for Global Gridded Upper Air Statistics

VERSION 1.1

March 1996

CONTENTS

****

1.0 INTRODUCTION

1.1 Background

The Global Gridded Upper Air Statistics (GGUAS) master data base was developed as source data to be coupled with a software access and display package and to be distributed as a 2-volume CD-ROM product entitled "Global Upper Air Climatic Atlas". This CD-ROM product, completed in April 1993, provides a versatile interface enabling the user to select and contour a nearly unlimited variety of climatological charts covering the global upper air environment. Although export of the gridded data is possible from within the CD, users requiring massive data export preferred direct access to the GGUAS data base. Version 1 of this CD-ROM product provided access to data for the original period of record, 1980 to 1991. Version 1.1 updates the period of record to 1980 to 1995.

2.0 GLOBAL GRIDDED UPPER AIR STATISTICS (GGUAS)

2.1 Scope

The GGUAS data set describes the atmosphere for each month of the year represented on a 2.5-degree global grid at 15 standard pressure levels. Mean and standard deviation values were compiled for sea level pressure, wind speed, air temperature, dew point, height and density. Eight-point wind roses were also compiled.

2.2 Source

Source of the GGUAS data set was the European Centre for Medium-Range Weather Forecasts (ECMWF) 0000Z and 1200Z gridded analyses available through and archived at the National Climatic Date Center (NCDC). Analyses are currently provided under the auspices of the Tropical Ocean Global Atmosphere (TOGA) project sponsored by the World Meteorological Organization (WMO). The GGUAS data set was derived from analyses for 1980 to 1995.

2.3 Coverage/Resolution

The GGUAS data set covers the entire globe. The spatial resolution is a 73 by 144 grid spaced at 2.5 degrees, providing a resolution of approximately 100km in the middle latitudes. Temporal resolution is one month.

2.4 Organization

The GGUAS data is in the subdirectory called DATA. The data set contains, for each of 12 months/10 512 grid points/15 levels in the atmosphere, a mean and standard deviation of each of seven elements and an eight-point wind rose.

2.5 Stored Parameters

TABLE 1 lists data parameters stored in the GGUAS data set for each grid point.

2.6 Data Quality

The GGUAS data set was derived from the twice daily analyses produced by ECMWF. The data summaries cover 1980 to 1995 for each element during this period with exception of sea level pressure, surface and 10-mb elements which are only available for 1985 to 1995. Questionable elements (based on quality control procedures) were deleted prior to summarization. The large number of observations to compute the summaries provides an indication of the reliability of the data.

2.7 Point of Contact

About using the CD-ROM

Climate Applications Branch
National Climatic Data Center
151 Patton Ave, Room 468
Asheville, NC 28801-5001

(704) 271-4702

About the data or to purchase a copy of the CD-ROM or other data

Climate Services Division
National Climatic Data Center
151 Patton Ave
Asheville, NC 28801-5001

(704) 271-4800
orders@ncdc.noaa.gov

3.0 DATA BASE FORMAT AND READ INSTRUCTIONS

3.1 General

Each data record contains all elements at each level for a month at a grid point.

3.2 Read Instructions with Format

Data Record	Format
MONTH	I2
YEAR (XX = POR)	A2
LEVEL (MILLIBARS)	A4
LATITUDE (DEGREES TO TENTHS) (POSITIVE FOR NORTH)	F5.1
LONGITUDE (DEGREES TO TENTHS)	F6.1
OBS COUNT	I4
U, MEAN EAST-WEST COMPONENT OF WIND SPEED (M/SEC) (POSITIVE FROM WEST)	F5.1
STANDARD DEVIATION OF EAST-WEST COMPONENT OF WIND SPEED (M/SEC)	F5.1
V, MEAN NORTH-SOUTH COMPONENT OF WIND SPEED (M/SEC) (POSITIVE FROM SOUTH)	F5.1
STANDARD DEVIATION OF NORTH-SOUTH COMPONENT OF WIND SPEED (M/SEC)	F5.1
VECTOR MEAN (M/SEC)	F5.1
VECTOR STANDARD DEVIATION (M/SEC)	F5.1
MEAN SCALAR WIND (M/SEC)	F5.1
STANDARD DEVIATION OF SCALAR WIND (M/SEC)	F5.1
CORRELATION COEFFICIENT OF WIND COMPONENTS	F6.1

MEAN AIR TEMPERATURE (DEGREES C)	F6.1
STANDARD DEVIATION OF AIR TEMPERATURE (DEGREES C)	F6.1
MEAN DEW POINT TEMPERATURE (DEGREES C)	F6.1
STANDARD DEVIATION OF DEW POINT TEMPERATURE (DEGREES C)	F6.1
MEAN HEIGHT (METERS) (If level = SURF, then Mean Sea Level pressure [mb])	F7.1
STANDARD DEVIATION OF HEIGHT (METERS)	F7.1
MEAN DENSITY (KG/M**3)	F6.4
STANDARD DEVIATION OF DENSITY (KG/M**3)	F6.4
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 0 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 0 DEGREES	F5.1
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 45 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 45 DEGREES	F5.1
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 90 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 90 DEGREES	F5.1
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 135 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 135 DEGREES	F5.1
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 180 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 180 DEGREES	F5.1
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 225 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 225 DEGREES	F5.1

MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 270 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 270 DEGREES	F5.1
MEAN WIND SPEED FOR 45 DEGREE SECTOR CENTERED ON 315 DEGREES (M/SEC)	F5.1
PERCENT OCCURRENCE OF WIND DIRECTION WITHIN 45 DEGREE SECTOR CENTERED ON 315 DEGREES	F5.1
PERCENT OCCURRENCE CALM	F5.1

*****Exception

If a grid point has no GGUAS data for a given element/level/month, the field has a negative sign with 9's filling the remainder of the field.

FORMAT

I2, A2, A4, F5.1, F6.1, I4, 8(F5.1), 5(F6.1), 2(F7.1), 2(F6.4), 17(F5.1)

The ASCII data are organized as 204 characters per record. (Note: A CR/LF is included at the end of each record with an additional 2 bytes.)

TABLE 1. GLOBAL GRIDDED UPPER AIR STATISTICS PARAMETERS

Parameter Name	Precision	Value Range
Month	1	00 to 12
Year	1	00 to 99 (XX = POR)
Level	1	SURF, 1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 10
Latitude	0.1	-90.0 to 90.0
Longitude	0.1	0.0 to 357.5 (eastward)
Larger of Number of Occurrences at a Level of U, V, Air Temp, or Height	1	>0
U E-W Component of Wind Speed		
Mean	0.1	-99.9 to 99.9
Standard Deviation	0.1	.0 to 99.9
V N-S Component of Wind Speed		

Mean	0.1	-99.9 to 99.9
Standard Deviation	0.1	.0 to 99.9
Vector Wind Speed		
Mean	0.1	.0 to 99.9
Standard Deviation	0.1	.0 to 99.9
Scalar Wind Speed		
Mean	0.1	.0 to 99.9
Standard Deviation	0.1	.0 to 99.9
Correlation Coefficients of Wind Components	0.1	-0.9 to 99.9
Air temperature		
Mean	0.1	-999.9 to 999.9
Standard Deviation	0.1	.0 to 9999.9
Dew Point Temperature		
Mean	0.1	-999.9 to 999.9
Standard Deviation	0.1	.0 to 9999.9
Height		
Mean	1	-350.0 to 99999.9
Standard Deviation	1	.0 to 99999.9
Density		
Mean	0.0001	.0 to 9.9999
Standard Deviation	0.0001	.0 to 9.9999
Mean Wind Speed for 45 Degree Sector Centered on 0 Degrees	0.1	.0 to 999.9
Percent Occurrence of Wind Direction Within 45 Degree Sector Centered on 0 Degrees	0.1	.0 to 999.9
Mean Wind Speed for 45 Degree Sector Centered on 45 Degrees	0.1	.0 to 999.9
Percent Occurrence of Wind Direction Within 45 Degree Sector Centered on 45 Degrees	0.1	.0 to 999.9
Mean Wind Speed for 45 Degree Sector Centered on 90 Degrees	0.1	.0 to 999.9
Percent Occurrence of Wind Direction Within 45 Degree Sector Centered on 90 Degrees	0.1	.0 to 999.9
Mean Wind Speed for 45 Degree Sector Centered on 135 Degrees	0.1	.0 to 999.9
Percent Occurrence of Wind		

Direction Within 45 Degree Sector Centered on 135 Degrees	0.1	.0 to 999.9
Mean Wind Speed for 45 Degree Sector Centered on 180 Degrees	0.1	.0 to 999.9
Percent Occurrence of Wind Direction Within 45 Degree Sector Centered on 180 Degrees	0.1	.0 to 999.9
Mean Wind Speed for 45 Degree Sector Centered on 225 Degrees	0.1	.0 to 999.9
Percent Occurrence of Wind Direction Within 45 Degree Sector Centered on 225 Degrees	0.1	.0 to 999.9
Mean Wind Speed for 45 Degree Sector Centered on 270 Degrees	0.1	.0 to 999.9
Percent Occurrence of Wind Direction Within 45 Degree Sector Centered on 270 Degrees	0.1	.0 to 999.9
Mean Wind Speed for 45 Degree Sector Centered on 315 Degrees	0.1	.0 to 999.9
Percent Occurrence of Wind Direction Within 45 Degree Sector Centered on 315 Degrees	0.1	.0 to 999.9
Percent Occurrence of CALM	0.1	.0 to 999.9

Appendix C Compiling and Running GRAM-99

One simple way to compile GRAM-99 (in UNIX) is

```
f77 -o gram99.x gram99.f gramsubs.f guaca.f initial.f met99prg.f models.f random.f rramods.f  speconc.f
```

This compiles and links all necessary subroutines and creates and executable file named gram99.x. For Microsoft FORTRAN on a PC, the compile command

```
fl32 gram99.f gramsubs.f guaca.f initial.f met99prg.f models.f random.f rramods.f  speconc.f
```

will compile and link the subroutines and produce an executable code called gram99.exe
The following UNIX makefile (called gram99.mkf) could also be used

```
gram99.x:       gram99.o gramsubs.o guaca.o met99prg.o speconc.o \
                initial.o models.o random.o rramods.o
                f77 -o gram99.x \
                gram99.o gramsubs.o guaca.o met99prg.o speconc.o \
                initial.o models.o random.o rramods.o
gram99.o:       gram99.f
                f77 -w0 -g3 -listing  -c -C gram99.f
gramsubs.o:     gramsubs.f
                f77 -w0 -g3 -listing  -c -C gramsubs.f
guaca.o:        guaca.f
                f77 -w0 -g3 -listing  -c -C guaca.f
met99prg.o:     met99prg.f
                f77 -w0 -g3 -listing  -c -C met99prg.f
speconc.o:      speconc.f
                f77 -w0 -g3 -listing  -c -C speconc.f
initial.o:      initial.f
                f77 -w0 -g3 -listing  -c -C initial.f
models.o:       models.f
                f77 -w0 -g3 -listing  -c -C models.f
random.o:       random.f
                f77 -w0 -g3 -listing  -c -C random.f
rramods.o:      rramods.f
                f77 -w0 -g3 -listing  -c -C rramods.f
```

This makefile creates both object code files (*.o) and listing files (*.L), as well as the executable gram99.x. The makefile is executed with the command

```
make -f gram99.mkf
```

Once the executable file is created and a NAMELIST file (e.g., namein.txt) is prepared, the program can be run by the command

```
gram99.x
```

The program then prompts for the name of the NAMELIST formatted input file. See section 4.7 for information on setting up the various input files required, and appendix D for a description of the NAMELIST input file, including the pathnames for the various inputs files. To incorporate GRAM-99 as a subroutine in your own program(s), see appendix G.

Silicon Graphics Inc. (SGI) users should encounter no serious problems in compiling GRAM-99, since this is the UNIX version that the GRAM-99 code is provided in. Users of other machine types may need to consult section 4.7 of Justus et al. (Ref. 6) for suggestions on possible code changes that might be required for compiling and running in their machine environments. See also the directions for making a PC code version in section 1.3.8.

To facilitate runtime testing, a NAMELIST-formatted standard reference input file, called namein.std, is provided (equivalent to the one in appendix D, without the inline comments). Output files generated by this input file are also provided, named output.ref and species.ref (as given in appendix E). You can run the program using input file namein.std file. The output file generated (output.txt) can be tested against the reference output file by doing

```
diff output.txt output.ref
```

or, in the PC environment

```
fc output.txt output.ref
```

Note that, as supplied, numbers in the output.ref file that are less than 1 (in magnitude) are written in the UNIX format (0.xxx -0.xxx etc.). For checking in the PC environment, such numbers must be edited to be in PC format (.xxx -.xxx etc.), i.e. without the leading zero digit. You can also test the species.ref output file in a similar fashion.

Appendix D Description of NAMELIST Format Input File

Following is a sample NAMELIST format input file for use by GRAM-99. Note that some compilers do not allow the use of inline comments (! character and following text). Note also that some compilers use different formats for the beginning and ending lines of the file. This sample file contains values required to produce the reference output data (file output.ref), which are also the default values. Only values that differ from the default values actually need to be input in the NAMELIST file. Definitions and discussion of GRAM-99 input parameters that are the same as the original GRAM-95 input parameters are also given in section 4.4 and appendix B of Justus et al. (Ref. 6). The input parameters that are new to GRAM-99 are

rndpath = path name for containing (optional) additional random number seed values for the perturbation model
rrapath = Directory name for the directory containing the (optional) Range Reference Atmosphere data
iun = unit number for file containing (optional) additional random number seeds
iurra = unit number for (optional) Range Reference Atmosphere (RRA) input data file
sitelim = outer lat-lon radius, beyond which GRAM data are used, instead of nearest RRA site data
sitenear = inner lat-lon radius, within which RRA data applies at full weight (RRA and GRAM are used as smoothly-varying weighted average between sitenear and sitelim)
initpert = 1 to use user-selected initial perturbations (0 for default, GRAM-derived, random initial perturbation values)
rpinit = initial pressure perturbation value (% of mean)
rdinit = initial density perturbation value (% of mean)
rtinit = initial temperature perturbation value (% of mean)
ruinit = initial eastward velocity perturbation (m/s)
rvinit = initial northward velocity perturbation (m/s)
rwinit = initial upward velocity perturbation (m/s)

See also general introductory discussion in sections 1 and 2 about the new options and features that make use of these input parameters.

Sample NAMELIST File

```
$namein
  atmpath = 'C:\gram99\standard\atmosdat'   ! path name for “atmosdat” atmospheric data file
  guapath = 'D:\2p5deg'                     ! path name for GUACA or GGUAS files
  trapath = 'null'                          ! path name for trajectory input file ('null' if none)
  prtpath = 'output.txt'                    ! path name for standard formatted output file
                                            !  ('null' if none)
  nprpath = 'null'                          ! path name for the "special" format output file
                                            !  ('null' if none)
  conpath = 'species.txt'                   ! path name for species concentration output file
                                            !  ('null' if none)
  rndpath = 'null'                          ! path name for file containing more  random number
                                            !  seed values (if needed)
  rrapath = 'null'                          ! DIRECTORY for RRA data
  h1 = 140.                                 ! initial height (km)
  phi1 = 28.45                              ! initial latitude (degrees, N positive)
  thet1 = -80.53                            ! initial longitude (degrees, East positive)
```

```
f10 = 230.              ! daily 10.7-cm flux (F10.7)
f10b = 230.             ! mean 10.7-cm flux (mean F10.7)
ap = 20.3               ! geomagnetic index (ap)
mn = 1                  ! month (1-12)
ida = 1                 ! day of month
iyr = 99                ! 4-digit year, or 2-digit year: >56=19xx <57=20XX
ihro = 0                ! initial UTC (Greenwich) time hour (0-23)
mino = 0                ! initial UTC (Greenwich) time minutes (0-59)
seco = 0.0              ! initial UTC (Greenwich) time seconds (0.0-60.0)
dphi = 0.0              ! latitude increment (degrees, Northward positive)
dthet = 0.0             ! longitude increment (degrees, Eastward positive)
dhgt = -2.0             ! height increment (km, upward positive)
nmax = 71               ! maximum number of positions (including initial one;
                        !  0 means read trajectory input)
delt = 1.0              ! time increment between positions (real seconds)
iopt = 0                ! trajectory option (0 = no trajectory data; otherwise
                        ! unit number for trajectory input file)
iopp = 17               ! "special" output option (0 = no "special" output;
                        ! otherwise unit number of "special" output file)
iu0 = 0                 ! unit number for screen output (normally 6 or 0)
iup = 6                 ! unit number for standard formatted output file
                        !  (0 for none)
ius = 3                 ! unit number for atmosdat data
iuc = 4                 ! unit number for concentrations output (0 for none)
iug = 22                ! unit for GUACA or GGUAS input data, 0-27km
                        !  (0 for no GUACA or GGUAS data)
iguayr = 1              ! Use: 1 for GUACA period of record,
                        ! 2 for actual GUACA year (1985-1991), based on iyr
                        !  from 1st-line of input (2-digit value),
                        ! 3 for binary data converted from ASCII Global
                        ! Gridded Upper Air Statistics (GGUAS) POR data
                        ! (conversion done with GGUASRD program, provided)
iopr = 1                ! random output option (1 = random output, 2 = none)
nr1 = 1234              ! first starting random number (1 to 9 * 10**8)
iun = 0                 ! unit number for more starting random numbers
                        !  (0 for none)
rpscale = 1.0           ! random perturbation scale; nominal=1.0, max=2.0,
                        ! min=0.1
iurra = 0               ! unit number for Range Reference Atmosphere (RRA)
                        !  data (0 if none used)
sitelim = 2.5           ! lat-lon radius (deg) from RRA site, outside which
                        !   RRA data are NOT used
sitenear = 0.5          ! lat-lon radius (deg) from RRA site, inside which
                        !  RRA data is used with full weight of 1 (smooth
                        !  transition of weight factor from 1 to 0 between sitenear
                        !   and sitelim)
initpert = 1            ! Use 1 for user-selected initial perturbations or 0
                        !  (default) for GRAM-derived, random initial
                        !  perturbation values
rpinit = 10.0           ! initial pressure perturbation value (% of mean)
rdinit = 15.0           ! initial density perturbation value (% of mean)
rtinit = -5.0           ! initial temperature perturbation value (% of mean)
ruinit = 3.             ! initial eastward velocity perturbation (m/s)
rvinit = 5.             ! initial northward velocity perturbation (m/s)
rwinit = 1.             ! initial upward velocity perturbation (m/s)
```

$End

To satisfy the perfect gas law (equation 2.2) for the initial perturbations, values of rpinit, rdinit, and rtinit should be selected such that

rpinit = rdinit + rtinit

(i.e., 10.0 = 15.0 - 5.0 in this example).

Users wishing to use forecast future values of the solar activity parameters (F10.7 and ap) are referred to Marshall Space Flight Center Solar Activity Site web page

http://sail.msfc.nasa.gov/nse/solar.html

Appendix E Sample Output of GRAM-99

Sample Standard Formatted Output Produced by Input File of Appendix D

```
      ****** Global Reference Atmospheric Model - 1999 (GRAM-99) ******
                          Version 1, Released May, 1999
MM/DD/YYYY =  1/ 1/1999  HH:MM:SS(UTC) =  0: 0:   .0  Julian Day = 2451179.500
F10.7 =  230.00          Mean F10.7 =  230.00         ap Index =  20.30
Max of   71 positions, generated automatically.
Global Upper Air Climatic Atlas Data
 Path = D:\2p5deg\por\01\
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.
E-W wind positive toward East; N-S wind positive toward North.

Height  Lati-    Long.                      Tempera-                Vert.
 (km)     tude   [E+W-]  Pressure  Density/  ture/    E-W    N-S    Wind
 Time    (deg)    (deg) /Vap.Pr.   Vap.Dens. Dewpt.  Wind   Wind    (m/s)
(sec)     /RRA  /Weight (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  -.004 Mean
                             31.6%      12.4%  19.8%                      M-76
    .0     GRM    .0000        .1%       3.9%  -3.8%   83.9   -8.9        ranS
                              2.9%       6.2%  12.6%   45.0   45.0        sigS
                             16.6%       1.4%   8.9%  -72.9  -73.8        ranL
                             12.2%       3.7%   7.4%   52.3   52.3        sigL
                             16.7%       5.3%   5.1%   11.0  -82.7   7.25 ranT
                             12.5%       7.2%  14.6%   69.0   69.0   8.33 sigT
                         1.106E-03  4.533E-09  704.4    1.2 -110.4   7.25 Tot.
                             53.5%      18.3%  25.9%                      T-76
                         0.000E+00  0.000E+00     .0                  .0% H2O
                         0.000E+00  0.000E+00     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
138.00  28.450  -80.530  1.038E-03  4.929E-09  643.6  -16.2  -25.3  -.005 Mean
                             30.2%      12.1%  18.6%                      M-76
   1.0     GRM    .0000       1.6%       3.1%  -2.9%   63.8  -36.6        ranS
                              3.0%       6.2%  13.2%   44.5   45.8        sigS
                             16.5%       2.2%   8.4%  -69.7  -73.8        ranL
                             12.8%       3.8%   7.9%   52.2   53.8        sigL
                             18.1%       5.4%   5.5%   -6.0 -110.4   7.32 ranT
                             13.2%       7.3%  15.4%   68.6   70.6   8.16 sigT
                         1.225E-03  5.194E-09  679.1  -22.2 -135.7   7.32 Tot.
                             53.7%      18.2%  25.1%                      T-76
                         0.000E+00  0.000E+00     .0                  .0% H2O
                         0.000E+00  0.000E+00     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
136.00  28.450  -80.530  1.142E-03  5.688E-09  616.2  -22.9  -23.0  -.005 Mean
                             28.8%      12.1%  17.3%                      M-76
   2.0     GRM    .0000        .9%       9.7% -17.2%   32.3  -51.0        ranS
                              3.2%       6.3%  13.7%   44.0   46.7        sigS
                             15.8%       3.1%   7.6%  -64.6  -71.7        ranL
                             13.5%       3.9%   8.4%   52.0   55.2        sigL
                             16.7%      12.7%  -9.5%  -32.3 -122.7   7.00 ranT
                             13.9%       7.3%  16.1%   68.1   72.3   7.99 sigT
                         1.332E-03  6.412E-09  557.4  -55.2 -145.7   7.00 Tot.
                             50.3%      26.4%   6.1%                      T-76
                         0.000E+00  0.000E+00     .0                  .0% H2O
                         0.000E+00  0.000E+00     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
```

```
134.00  28.450  -80.530  1.262E-03  6.618E-09  588.2  -29.8  -20.7  -.005 Mean
                           27.6%      12.3%    15.9%                             M-76
   3.0    GRM     .0000      .4%      11.4%   -22.3%   19.1  -53.9        ranS
                            3.3%       6.3%    14.3%   43.5   47.4        sigS
                           14.4%       3.9%     6.4%  -57.7  -67.2        ranL
                           14.1%       3.9%     8.9%   51.9   56.6        sigL
                           14.8%      15.3%   -15.9%  -38.5 -121.1   8.45 ranT
                           14.5%       7.4%    16.8%   67.7   73.8   7.82 sigT
                         1.449E-03  7.632E-09  494.8  -68.3 -141.9   8.45 Tot.
                           46.5%      29.4%    -2.5%                             T-76
                         0.000E+00  0.000E+00     .0                  .0% H2O
                         0.000E+00  0.000E+00     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
132.00  28.450  -80.530  1.404E-03  7.773E-09  559.6  -36.7  -18.6  -.005 Mean
                           26.6%      12.6%    14.5%                             M-76
   4.0    GRM     .0000     1.5%       8.2%   -13.8%    8.5  -44.0        ranS
                            3.4%       6.3%    14.8%   43.0   48.2        sigS
                           12.3%       4.6%     4.7%  -48.9  -60.2        ranL
                           14.7%       4.0%     9.4%   51.7   57.9        sigL
                           13.8%      12.8%    -9.1%  -40.4 -104.3   8.80 ranT
                           15.1%       7.5%    17.5%   67.3   75.4   7.65 sigT
                         1.598E-03  8.769E-09  508.7  -77.1 -122.8   8.79 Tot.
                           44.1%      27.0%     4.1%                             T-76
                         0.000E+00  0.000E+00     .0                  .0% H2O
                         0.000E+00  0.000E+00     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
130.00  28.450  -80.530  1.572E-03  9.220E-09  530.5  -43.4  -16.5  -.005 Mean
                           25.7%      13.1%    13.1%                             M-76
   5.0    GRM     .0000     1.4%      10.4%   -19.1%   14.2  -26.2        ranS
                            3.5%       6.3%    15.3%   42.5   48.9        sigS
                            9.5%       5.2%     2.7%  -38.6  -50.8        ranL
                           15.3%       4.1%     9.8%   51.6   59.3        sigL
                           10.9%      15.6%   -16.4%  -24.4  -77.0   6.03 ranT
                           15.7%       7.6%    18.1%   66.9   76.9   7.48 sigT
                         1.743E-03  1.066E-08  443.5  -67.7  -93.5   6.02 Tot.
                           39.4%      30.8%    -5.5%                             T-76
                         0.000E+00  0.000E+00     .0                  .0% H2O
                         0.000E+00  0.000E+00     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
128.00  28.450  -80.530  1.772E-03  1.106E-08  501.1  -49.7  -14.5  -.005 Mean
                           24.9%      13.8%    11.6%                             M-76
   6.0    GRM     .0000     1.2%      13.1%   -25.5%    -.6   21.3        ranS
                            3.6%       6.4%    15.7%   42.1   49.6        sigS
                            6.2%       5.7%      .3%  -26.8  -39.0        ranL
                           15.8%       4.2%    10.3%   51.4   60.6        sigL
                            7.4%      18.8%   -25.2%  -27.4  -17.7   8.37 ranT
                           16.2%       7.6%    18.8%   66.4   78.4   7.31 sigT
                         1.902E-03  1.313E-08  374.8  -77.1  -32.2   8.37 Tot.
                           34.2%      35.2%   -16.5%                             T-76
                         0.000E+00  0.000E+00     .0                  .0% H2O
                         0.000E+00  0.000E+00     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
126.00  28.450  -80.530  2.013E-03  1.342E-08  471.5  -55.3  -12.6  -.005 Mean
                           24.3%      14.6%    10.1%                             M-76
   7.0    GRM     .0000     1.1%      11.2%   -21.9%  -25.9    7.5        ranS
                            3.7%       6.4%    16.2%   41.6   50.3        sigS
                            2.2%       6.0%    -2.4%  -14.0  -24.9        ranL
                           16.4%       4.3%    10.7%   51.2   62.0        sigL
                            3.3%      17.2%   -24.3%  -39.9  -17.5   6.41 ranT
                           16.8%       7.7%    19.4%   66.0   79.8   7.14 sigT
                         2.080E-03  1.572E-08  356.8  -95.2  -30.1   6.41 Tot.
                           28.5%      34.3%   -16.6%                             T-76
                         0.000E+00  0.000E+00     .0                  .0% H2O
                         0.000E+00  0.000E+00     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
124.00  28.450  -80.530  2.308E-03  1.650E-08  441.8  -60.0  -10.8  -.005 Mean
                           23.9%      15.6%     8.8%                             M-76
```

```
   8.0   GRM      .0000      .3%      12.8%   -27.7%  -53.9     .1        ranS
                            3.8%       6.4%    16.6%   41.1   50.9        sigS
                           -2.2%       6.1%    -5.3%    -.6   -9.1        ranL
                           16.9%       4.4%    11.2%   51.1   63.3        sigL
                           -1.9%      18.9%   -33.0%  -54.5   -8.9  10.94 ranT
                           17.3%       7.8%    20.0%   65.5   81.2   6.97 sigT
                         2.265E-03  1.962E-08  296.0 -114.5  -19.7  10.93 Tot.
                           21.6%      37.5%   -27.1%                      T-76
                         0.000E+00  0.000E+00     .0                  .0% H2O
                         0.000E+00  0.000E+00     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
122.00  28.450  -80.530  2.672E-03  2.057E-08  412.3  -63.6   -9.1  -.004 Mean
                           23.5%      16.5%     7.5%                      M-76
   9.0   GRM      .0000      .6%      15.5%   -33.5%  -10.6  -37.6        ranS
                            3.9%       6.5%    17.0%   40.6   51.5        sigS
                           -6.9%       6.0%    -8.3%   13.1    8.2        ranL
                           17.4%       4.4%    11.6%   50.9   64.6        sigL
                           -6.2%      21.5%   -41.8%    2.6  -29.3   7.10 ranT
                           17.8%       7.8%    20.5%   65.1   82.6   6.80 sigT
                         2.505E-03  2.500E-08  240.0  -61.0  -38.4   7.09 Tot.
                           15.8%      41.5%   -37.4%                      T-76
                         0.000E+00  0.000E+00     .0                  .0% H2O
                         0.000E+00  0.000E+00     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
120.00  28.450  -80.530  3.127E-03  2.602E-08  383.6  -65.9   -7.5  -.004 Mean
                           23.2%      17.1%     6.6%                      M-76
  10.0   GRM      .0000    -1.0%      17.2%   -41.4%  -26.4  -35.6        ranS
                            4.0%       6.5%    17.3%   40.1   52.1        sigS
                          -11.6%       5.7%   -11.3%   26.6   26.3        ranL
                           17.9%       4.5%    12.0%   50.7   65.9        sigL
                          -12.6%      22.8%   -52.7%     .2   -9.3   9.06 ranT
                           18.3%       7.9%    21.1%   64.6   84.0   6.63 sigT
                         2.733E-03  3.196E-08  181.6  -65.7  -16.8   9.06 Tot.
                            7.7%      43.8%   -49.6%                      T-76
                         0.000E+00  0.000E+00     .0                  .0% H2O
                         0.000E+00  0.000E+00     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
118.00  28.450  -80.530  3.693E-03  3.331E-08  355.8  -66.4   -6.0  -.003 Mean
                           22.5%      17.0%     5.9%                      M-76
  11.0   GRM      .0000      .2%      13.4%   -26.4%  -52.1    9.5        ranS
                            3.8%       7.1%    16.2%   39.6   52.9        sigS
                          -15.4%       5.5%   -13.2%   39.2   44.6        ranL
                           17.4%       5.0%    11.4%   50.5   67.4        sigL
                          -15.2%      18.9%   -39.7%  -12.9   54.1   4.76 ranT
                           17.8%       8.7%    19.8%   64.2   85.7   6.49 sigT
                         3.131E-03  3.961E-08  214.7  -79.3   48.1   4.75 Tot.
                            3.9%      39.2%   -36.1%                      T-76
                         1.177E-09  7.778E-15  184.7                  .0% H2O
                         4.236E-10  2.800E-15     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
116.00  28.450  -80.530  4.392E-03  4.309E-08  328.8  -64.6   -4.5  -.003 Mean
                           20.9%      15.8%     5.4%                      M-76
  12.0   GRM      .0000      .1%       8.5%   -14.7%  -65.1   23.9        ranS
                            3.7%       7.7%    15.0%   39.2   53.6        sigS
                          -18.5%       4.9%   -14.1%   50.3   62.1        ranL
                           16.9%       5.5%    10.7%   50.3   68.9        sigL
                          -18.3%      13.4%   -28.9%  -14.8   86.0   7.07 ranT
                           17.3%       9.5%    18.4%   63.8   87.3   6.36 sigT
                         3.588E-03  4.889E-08  233.9  -79.3   81.5   7.07 Tot.
                           -1.2%      31.4%   -25.0%                      T-76
                         1.513E-09  1.077E-14  178.6                  .0% H2O
                         5.448E-10  3.876E-15     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
114.00  28.450  -80.530  5.278E-03  5.654E-08  302.8  -60.7   -3.0  -.002 Mean
                           18.7%      13.6%     5.2%                      M-76
  13.0   GRM      .0000     -.1%       2.3%    -3.7%  -49.6   38.3        ranS
                            3.5%       8.2%    13.8%   38.7   54.3        sigS
```

```
                            -20.6%       3.9% -14.1%   59.5   78.1        ranL
                             16.4%       6.0%  10.0%   50.1   70.4        sigL
                            -20.7%       6.2% -17.8%    9.9  116.4   7.47 ranT
                             16.8%      10.2%  17.1%   63.3   88.9   6.22 sigT
                         4.184E-03  6.003E-08  249.1  -50.9  113.4   7.47 Tot.
                             -5.9%      20.7% -13.5%                      T-76
                         1.956E-09  1.503E-14  172.0                  .0% H2O
                         7.042E-10  5.410E-15     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
112.00  28.450  -80.530  6.435E-03  7.554E-08  278.0  -55.4   -1.6  -.002 Mean
                             15.8%      10.5%   5.3%                      M-76
  14.0     GRM    .0000       -.5%      12.2% -17.1%  -62.7   -1.8        ranS
                              3.4%       8.8%  12.7%   38.2   55.0        sigS
                            -21.8%       2.4% -13.1%   66.1   91.3        ranL
                             15.9%       6.5%   9.3%   49.9   71.8        sigL
                            -22.3%      14.6% -30.2%    3.4   89.5   6.17 ranT
                             16.3%      11.0%  15.7%   62.9   90.5   6.09 sigT
                         5.000E-03  8.658E-08  194.1  -52.0   87.9   6.17 Tot.
                            -10.0%      26.6% -26.5%                      T-76
                         2.552E-09  2.123E-14  164.9                  .0% H2O
                         9.186E-10  7.642E-15     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
110.00  28.450  -80.530  8.000E-03  1.035E-07  253.8  -49.2    -.4  -.001 Mean
                             12.6%       6.6%   5.8%                      M-76
  15.0     GRM    .0000        .6%      11.0% -12.0%  -74.4  -33.3        ranS
                              3.3%       9.4%  11.5%   37.7   55.6        sigS
                            -21.8%        .4% -11.2%   69.7   99.0        ranL
                             15.5%       7.0%   8.6%   49.7   73.3        sigL
                            -21.2%      11.4% -23.2%   -4.7   65.7   3.05 ranT
                             15.8%      11.7%  14.3%   62.4   92.0   5.95 sigT
                         6.301E-03  1.153E-07  194.9  -53.9   65.3   3.04 Tot.
                            -11.3%      18.8% -18.8%                      T-76
                         3.396E-09  3.074E-14  157.3                  .0% H2O
                         1.223E-09  1.107E-14     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
108.00  28.450  -80.530  1.018E-02  1.436E-07  234.7  -41.9     .7  -.001 Mean
                              9.3%       3.9%   5.1%                      M-76
  16.0     GRM    .0000        .8%       8.5%  -7.7%  -41.3  -23.6        ranS
                              3.1%       9.9%  10.4%   37.3   56.3        sigS
                            -20.8%      -2.0%  -8.8%   69.8   99.0        ranL
                             15.0%       7.5%   7.9%   49.5   74.8        sigL
                            -20.0%       6.5% -16.5%   28.5   75.4   3.34 ranT
                             15.3%      12.5%  13.0%   62.0   93.7   5.81 sigT
                         8.150E-03  1.529E-07  195.9  -13.3   76.1   3.34 Tot.
                            -12.5%      10.7% -12.3%                      T-76
                         4.705E-09  4.575E-14  150.8                  .0% H2O
                         1.694E-09  1.647E-14     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
106.00  28.450  -80.530  1.329E-02  2.033E-07  217.8  -34.4    1.6  -.001 Mean
                              6.7%       4.1%   2.3%                      M-76
  17.0     GRM    .0000       -.1%       7.3%  -6.3%  -57.1  -12.9        ranS
                              3.0%      10.4%   9.3%   36.8   57.0        sigS
                            -18.7%      -4.6%  -6.0%   66.3   99.0        ranL
                             14.5%       8.0%   7.1%   49.4   76.4        sigL
                            -18.8%       2.6% -12.3%    9.2   86.1   4.54 ranT
                             14.8%      13.2%  11.7%   61.6   95.3   5.68 sigT
                         1.079E-02  2.087E-07  190.9  -25.2   87.7   4.54 Tot.
                            -13.4%       6.8% -10.3%                      T-76
                         6.686E-09  6.950E-14  144.6                  .0% H2O
                         2.407E-09  2.502E-14     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
104.00  28.450  -80.530  1.780E-02  2.919E-07  204.9  -27.1    2.4  -.001 Mean
                              5.5%       5.4%   -.2%                      M-76
  18.0     GRM    .0000       1.6%      12.5%  -7.9%  -45.7  -78.7        ranS
                              2.8%      10.9%   8.1%   36.4   57.6        sigS
                            -15.6%      -7.4%  -3.2%   59.0   98.5        ranL
                             14.0%       8.6%   6.3%   49.1   77.9        sigL
```

```
                          -14.0%       5.1%   -11.0%   13.2   19.7   5.32 ranT
                           14.2%      13.9%    10.3%   61.1   96.9   5.54 sigT
                         1.531E-02  3.069E-07  182.2  -13.9   22.1   5.32 Tot.
                           -9.3%      10.8%   -11.2%                      T-76
                         9.698E-09  1.064E-13  139.6                  .0% H2O
                         3.489E-09  3.828E-14     .0                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
102.00  28.450  -80.530  2.439E-02  4.204E-07  196.2  -20.5    3.0  -.001 Mean
                            5.5%       6.9%    -1.7%                      M-76
  19.0     GRM    .0000     2.3%      11.2%    -5.3%  -58.4  -69.4        ranS
                            2.7%      11.5%     7.1%   35.9   58.2        sigS
                          -11.8%     -10.1%     -.6%   48.1   85.2        ranL
                           13.5%       9.1%     5.6%   48.9   79.4        sigL
                           -9.5%       1.1%    -5.9%  -10.3   15.8   4.88 ranT
                           13.7%      14.7%     9.0%   60.7   98.5   5.40 sigT
                         2.207E-02  4.249E-07  184.6  -30.8   18.8   4.88 Tot.
                           -4.6%       8.1%    -7.5%                      T-76
                         1.431E-08  1.627E-13  136.1                  .0% H2O
                         5.137E-09  5.842E-14     .1                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
100.00  28.450  -80.530  3.402E-02  6.114E-07  189.5  -14.6    3.5  -.001 Mean
                            6.3%       9.1%    -2.9%                      M-76
  20.0     GRM    .0000     2.8%      17.6%    -7.1%  -72.4   -5.3        ranS
                            2.6%      12.0%     5.9%   35.4   58.8        sigS
                           -7.4%     -12.5%     1.5%   34.0   65.6        ranL
                           12.9%       9.7%     4.7%   48.7   80.9        sigL
                           -4.6%       5.2%    -5.6%  -38.4   60.2   2.87 ranT
                           13.2%      15.4%     7.5%   60.2  100.0   5.26 sigT
                         3.246E-02  6.429E-07  178.9  -52.9   63.8   2.87 Tot.
                            1.4%      14.7%    -8.3%                      T-76
                         2.162E-08  2.527E-13  133.4                  .0% H2O
                         7.701E-09  9.004E-14     .2                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 98.00  28.450  -80.530  4.812E-02  8.802E-07  187.3  -10.7    4.0  -.002 Mean
                            6.9%       9.2%    -2.3%                      M-76
  21.0     GRM    .0000     3.4%       8.9%    -2.7%  -36.9   50.2        ranS
                            2.6%      11.6%     5.9%   34.4   59.7        sigS
                           -2.9%     -13.5%     3.1%   17.6   40.3        ranL
                           13.1%       9.7%     4.8%   48.4   84.1        sigL
                             .5%      -4.6%      .4%  -19.3   90.6   2.03 ranT
                           13.4%      15.1%     7.6%   59.4  103.1   5.16 sigT
                         4.835E-02  8.397E-07  188.0  -30.0   94.5   2.03 Tot.
                            7.4%       4.1%    -1.9%                      T-76
                         3.505E-08  4.122E-13  132.7                  .0% H2O
                         1.236E-08  1.453E-13     .4                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 96.00  28.450  -80.530  6.845E-02  1.266E-06  186.3   -7.9    4.3  -.002 Mean
                            7.4%       9.0%    -1.6%                      M-76
  22.0     GRM    .0000     2.0%       5.6%    -1.9%  -35.5   27.8        ranS
                            2.5%      11.1%     5.9%   33.3   60.5        sigS
                            2.0%     -13.5%     4.6%    -.3    9.2        ranL
                           13.3%       9.6%     4.8%   48.1   87.2        sigL
                            3.9%      -8.0%     2.7%  -35.8   37.0   3.91 ranT
                           13.5%      14.7%     7.6%   58.5  106.1   5.06 sigT
                         7.115E-02  1.166E-06  191.3  -43.7   41.3   3.91 Tot.
                           11.6%        .3%     1.1%                      T-76
                         5.735E-08  6.743E-13  132.6                  .0% H2O
                         1.993E-08  2.344E-13     .6                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 94.00  28.450  -80.530  9.867E-02  1.814E-06  188.2   -5.8    4.6  -.003 Mean
                            9.0%       8.6%      .3%                      M-76
  23.0     GRM    .0000     1.7%      -2.1%     2.0%  -26.6   25.0        ranS
                            2.5%      10.7%     5.9%   32.3   61.2        sigS
                            7.0%     -12.6%     5.8%  -18.4  -26.0        ranL
                           13.4%       9.6%     4.9%   47.7   90.4        sigL
                            8.7%     -14.7%     7.8%  -45.0   -1.0   2.76 ranT
                           13.7%      14.4%     7.7%   57.6  109.2   4.96 sigT
```

```
                         1.073E-01  1.548E-06  203.0  -50.8    3.6   2.76 Tot.
                             18.4%      -7.3%   8.1%                      T-76
                         9.677E-08  1.121E-12  133.9                  .0% H2O
                         3.355E-08  3.887E-13     .7                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 92.00  28.450  -80.530  1.429E-01  2.569E-06  193.0   -4.0    4.7  -.004 Mean
                             10.9%       7.4%   3.3%                      M-76
  24.0     GRM    .0000       1.4%      -1.4%   1.5%  -18.1  -31.7        ranS
                              2.5%      10.2%   5.9%   31.3   61.8        sigS
                             11.8%     -10.6%   6.7%  -35.3  -62.6        ranL
                             13.6%       9.5%   5.0%   47.3   93.6        sigL
                             13.1%     -12.0%   8.3%  -53.4  -94.3   -.94 ranT
                             13.8%      14.0%   7.7%   56.7  112.2   4.85 sigT
                         1.617E-01  2.260E-06  209.0  -57.4  -89.5   -.95 Tot.
                             25.5%      -5.5%  11.8%                      T-76
                         1.667E-07  1.878E-12  136.6                  .0% H2O
                         5.841E-08  6.581E-13     .5                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 90.00  28.450  -80.530  2.048E-01  3.602E-06  197.9   -2.4    4.8  -.004 Mean
                             11.6%       5.4%   5.9%                      M-76
  25.0     GRM    .0000        .2%     -12.2%   7.3%  -18.1   12.1        ranS
                              2.5%       9.8%   5.9%   30.2   62.4        sigS
                             15.8%      -7.8%   7.1%  -49.6  -97.1        ranL
                             13.7%       9.4%   5.1%   47.0   96.9        sigL
                             16.0%     -20.0%  14.4%  -67.7  -85.0  -1.99 ranT
                             14.0%      13.6%   7.8%   55.8  115.2   4.75 sigT
                         2.376E-01  2.882E-06  226.5  -70.2  -80.2  -2.00 Tot.
                             29.4%     -15.6%  21.2%                      T-76
                         2.855E-07  3.126E-12  139.3                  .0% H2O
                         1.008E-07  1.103E-12     .4                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 88.00  28.450  -80.530  2.875E-01  4.968E-06  201.4    4.0    4.6  -.003 Mean
                              9.9%       1.9%   7.8%                      M-76
  26.0     GRM    .0000        .1%      -6.2%   3.8%  -32.9  -25.0        ranS
                              2.1%       8.2%   5.1%   26.8   48.9        sigS
                             15.8%      -3.7%   6.0%  -55.0  -97.9        ranL
                             11.8%       8.2%   4.4%   42.8   78.0        sigL
                             15.9%      -9.8%   9.7%  -87.9 -122.9  -4.96 ranT
                             12.0%      11.6%   6.7%   50.5   92.1   4.49 sigT
                         3.333E-01  4.480E-06  221.0  -83.9 -118.4  -4.96 Tot.
                             27.4%      -8.1%  18.3%                      T-76
                         4.758E-07  5.118E-12  141.4                  .0% H2O
                         1.684E-07  1.811E-12     .3                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 86.00  28.450  -80.530  4.013E-01  6.816E-06  204.9   10.4    4.3  -.003 Mean
                              7.5%      -2.0%   9.7%                      M-76
  27.0     GRM    .0000       -.2%      -8.1%   5.0%  -26.2    3.9        ranS
                              1.7%       6.3%   4.1%   23.2   31.6        sigS
                             13.4%       -.1%   4.2%  -53.3  -72.2        ranL
                              9.5%       6.5%   3.6%   38.0   51.8        sigL
                             13.2%      -8.3%   9.2%  -79.4  -68.3  -1.30 ranT
                              9.6%       9.1%   5.5%   44.5   60.6   4.22 sigT
                         4.543E-01  6.250E-06  223.8  -69.0  -64.0  -1.30 Tot.
                             21.7%     -10.2%  19.8%                      T-76
                         7.887E-07  8.338E-12  143.6                  .0% H2O
                         2.796E-07  2.956E-12     .3                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 84.00  28.450  -80.530  5.563E-01  9.341E-06  207.4   16.8    4.6  -.002 Mean
                              4.8%      -3.6%   8.7%                      M-76
  28.0     GRM    .0000      -1.4%     -10.9%   6.2%   -7.5   15.6        ranS
                              1.4%       5.0%   3.4%   20.6   17.5        sigS
                             10.6%       2.3%   2.7%  -48.2  -41.2        ranL
                              7.9%       5.4%   3.1%   34.7   29.5        sigL
                              9.2%      -8.6%   8.9%  -55.8  -25.6   1.24 ranT
                              8.0%       7.4%   4.6%   40.4   34.3   3.93 sigT
                         6.074E-01  8.536E-06  225.9  -39.0  -21.0   1.24 Tot.
                             14.4%     -11.9%  18.4%                      T-76
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                         1.305E-06  1.363E-11  145.3                   .0% H2O
                         4.624E-07  4.830E-12     .3                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 82.00  28.450  -80.530  7.680E-01  1.282E-05  208.9   23.1    5.3  -.003 Mean
                              2.4%      -4.5%   7.2%                      M-76
  29.0     GRM    .0000      -1.9%      -8.5%   4.5%   -9.8   16.1        ranS
                              1.3%       4.7%   3.3%   19.4   15.6        sigS
                              8.4%       4.3%   1.3%  -41.4  -33.7        ranL
                              7.4%       5.2%   2.9%   33.6   27.0        sigL
                              6.5%      -4.2%   5.8%  -51.2  -17.6   1.88 ranT
                              7.5%       7.0%   4.4%   38.9   31.2   3.62 sigT
                         8.182E-01  1.228E-05  221.0  -28.1  -12.3   1.88 Tot.
                              9.1%      -8.5%  13.5%                      T-76
                         2.158E-06  2.239E-11  146.5                   .0% H2O
                         7.630E-07  7.916E-12     .4                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 80.00  28.450  -80.530  1.057E+00  1.754E-05  210.3   29.4    6.1  -.003 Mean
                               .5%      -5.0%   5.9%                      M-76
  30.0     GRM    .0000      -2.3%      -8.1%   4.0%   -3.6   15.2        ranS
                              1.2%       4.3%   3.1%   18.2   13.6        sigS
                              5.5%       5.7%   -.1%  -30.2  -23.0        ranL
                              6.9%       4.9%   2.8%   32.5   24.2        sigL
                              3.2%      -2.4%   4.0%  -33.7   -7.8   1.86 ranT
                              7.0%       6.5%   4.2%   37.2   27.8   3.30 sigT
                         1.092E+00  1.713E-05  218.6   -4.3   -1.7   1.85 Tot.
                              3.7%      -7.2%  10.1%                      T-76
                         3.393E-06  3.496E-11  147.6                   .0% H2O
                         1.020E-06  1.051E-11     .4                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 78.00  28.450  -80.530  1.450E+00  2.389E-05  211.6   36.3    5.4  -.002 Mean
                             -1.2%      -5.4%   4.5%                      M-76
  31.0     GRM    .0000      -2.7%      -8.7%   4.2%    5.4   18.5        ranS
                              1.2%       4.2%   3.0%   17.7   13.0        sigS
                              2.5%       6.9%  -1.4%  -16.6  -12.6        ranL
                              7.0%       5.1%   2.8%   32.4   23.9        sigL
                              -.2%      -1.8%   2.7%  -11.2    5.9  -1.90 ranT
                              7.1%       6.6%   4.2%   36.9   27.3   2.98 sigT
                         1.447E+00  2.347E-05  217.3   25.2   11.3  -1.90 Tot.
                             -1.4%      -7.0%   7.3%                      T-76
                         3.937E-06  4.032E-11  147.6                   .0% H2O
                         1.398E-06  1.432E-11     .5                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 76.00  28.450  -80.530  1.983E+00  3.246E-05  212.9   43.3    4.7  -.001 Mean
                             -2.5%      -5.4%   3.1%                      M-76
  32.0     GRM    .0000      -2.3%      -8.5%   4.3%   17.7   10.4        ranS
                              1.2%       4.2%   3.0%   17.1   12.5        sigS
                             -1.1%       7.3%  -2.7%    -.4    -.4        ranL
                              7.1%       5.2%   2.8%   32.4   23.6        sigL
                             -3.4%      -1.3%   1.6%   17.3   10.0  -3.48 ranT
                              7.2%       6.6%   4.2%   36.6   26.7   2.67 sigT
                         1.916E+00  3.206E-05  216.3   60.5   14.7  -3.48 Tot.
                             -5.8%      -6.6%   4.8%                      T-76
                         5.722E-06  5.824E-11  148.3                   .0% H2O
                         1.913E-06  1.948E-11     .6                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 74.00  28.450  -80.530  2.709E+00  4.391E-05  214.8   48.6    4.5  -.001 Mean
                             -3.3%      -5.3%   2.1%                      M-76
  33.0     GRM    .0000      -2.5%      -5.6%   2.2%   31.5   23.7        ranS
                              1.1%       4.0%   2.9%   17.1   11.6        sigS
                             -4.5%       6.4%  -3.6%   16.2   11.1        ranL
                              7.0%       5.1%   2.8%   32.2   21.8        sigL
                             -7.0%        .8%  -1.4%   47.7   34.7  -3.53 ranT
                              7.1%       6.5%   4.0%   36.5   24.7   2.39 sigT
                         2.518E+00  4.428E-05  211.8   96.3   39.2  -3.53 Tot.
                            -10.1%      -4.5%    .7%                      T-76
                         8.622E-06  8.695E-11  149.6                   .0% H2O
                         2.613E-06  2.635E-11     .6                   .0% sigH
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 72.00  28.450  -80.530  3.688E+00  5.905E-05  217.5   52.4    4.7  -.001 Mean
                             -3.9%      -5.3%   1.5%                      M-76
  34.0     GRM    .0000      -1.8%      -4.0%   1.5%   19.6   17.1        ranS
                              1.0%       3.6%   2.6%   17.6   10.1        sigS
                             -7.0%       4.5%  -3.9%   30.7   17.6        ranL
                              6.5%       4.9%   2.8%   31.9   18.1        sigL
                             -8.8%        .5%  -2.5%   50.3   34.7  -3.82 ranT
                              6.6%       6.1%   3.8%   36.5   20.7   2.15 sigT
                         3.363E+00  5.932E-05  212.2  102.7   39.4  -3.82 Tot.
                            -12.3%      -4.9%  -1.0%                      T-76
                         1.481E-05  1.476E-10  151.6                   .0% H2O
                         4.191E-06  4.175E-11     .6                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 70.00  28.450  -80.530  5.003E+00  7.912E-05  220.2   56.1    4.9   .000 Mean
                             -4.2%      -4.5%    .3%                      M-76
  35.0     GRM    .0000      -1.2%      -1.2%    .0%   27.5   13.7        ranS
                               .8%       3.3%   2.3%   18.1    7.9        sigS
                             -8.0%       1.9%  -3.6%   40.8   17.7        ranL
                              5.9%       4.6%   2.7%   31.7   13.6        sigL
                             -9.2%        .7%  -3.6%   68.4   31.4  -2.87 ranT
                              6.0%       5.6%   3.5%   36.5   15.8   1.91 sigT
                         4.544E+00  7.970E-05  212.4  124.5   36.3  -2.87 Tot.
                            -13.0%      -3.8%  -3.3%                      T-76
                         2.704E-05  2.660E-10  153.9                   .0% H2O
                         7.238E-06  7.122E-11     .6                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 68.00  28.450  -80.530  6.761E+00  1.049E-04  224.5   57.8    5.0   .001 Mean
                             -4.1%      -4.0%   -.2%                      M-76
  36.0     GRM    .0000       -.4%       1.9%  -1.6%    6.3   16.7        ranS
                               .7%       3.1%   2.2%   17.6    8.5        sigS
                             -7.9%       -.7%  -2.8%   42.2   19.8        ranL
                              5.6%       4.5%   2.8%   29.8   14.0        sigL
                             -8.4%       1.2%  -4.4%   48.5   36.5  -1.86 ranT
                              5.7%       5.4%   3.6%   34.6   16.4   1.76 sigT
                         6.196E+00  1.061E-04  214.6  106.3   41.5  -1.86 Tot.
                            -12.2%      -2.8%  -4.6%                      T-76
                         4.336E-05  4.184E-10  156.6                   .0% H2O
                         8.770E-06  8.463E-11     .4                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 66.00  28.450  -80.530  9.084E+00  1.382E-04  228.9   59.6    5.1   .002 Mean
                             -4.0%      -3.3%   -.7%                      M-76
  37.0     GRM    .0000       -.3%       2.9%  -2.2%    8.3   14.8        ranS
                               .6%       2.9%   2.0%   17.0    9.1        sigS
                             -6.5%      -3.2%  -1.4%   36.0   18.2        ranL
                              5.3%       4.4%   2.9%   27.9   14.3        sigL
                             -6.7%       -.3%  -3.5%   44.4   32.9   -.69 ranT
                              5.4%       5.3%   3.6%   32.7   16.9   1.61 sigT
                         8.471E+00  1.377E-04  220.8  103.9   38.1   -.69 Tot.
                            -10.5%      -3.7%  -4.2%                      T-76
                         6.923E-05  6.554E-10  159.2                   .0% H2O
                         1.059E-05  1.002E-10     .2                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 64.00  28.450  -80.530  1.215E+01  1.813E-04  233.4   60.3    5.2   .003 Mean
                             -3.7%      -2.6%  -1.1%                      M-76
  38.0     GRM    .0000        .1%       2.5%  -1.7%    6.9   -4.1        ranS
                               .6%       2.9%   2.0%   16.5    9.6        sigS
                             -4.1%      -5.2%    .5%   23.7   11.9        ranL
                              5.2%       4.4%   2.9%   26.2   13.7        sigL
                             -4.0%      -2.6%  -1.2%   30.7    7.9   -.73 ranT
                              5.3%       5.2%   3.5%   30.9   16.7   1.55 sigT
                         1.166E+01  1.765E-04  230.6   91.0   13.1   -.72 Tot.
                             -7.5%      -5.2%  -2.3%                      T-76
                         1.031E-04  9.573E-10  161.6                   .0% H2O
                         1.511E-05  1.403E-10     .2                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 62.00  28.450  -80.530  1.616E+01  2.365E-04  238.0   60.1    5.3   .004 Mean
```

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                             -3.2%      -1.8%  -1.5%                      M-76
  39.0     GRM    .0000        .3%       3.0%  -1.7%  -11.8   -5.8        ranS
                               .7%       3.0%   2.0%   16.0    9.8        sigS
                              -.9%      -6.2%   2.0%    7.6    3.3        ranL
                              5.4%       4.4%   2.6%   24.6   12.2        sigL
                              -.5%      -3.2%    .2%   -4.2   -2.5  -2.15 ranT
                              5.4%       5.3%   3.2%   29.4   15.6   1.58 sigT
                         1.607E+01  2.289E-04  238.6   55.9    2.8  -2.15 Tot.
                             -3.7%      -4.9%  -1.2%                      T-76
                         1.478E-04  1.346E-09  164.0                   .0% H2O
                         2.328E-05  2.119E-10     .2                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 60.00  28.450  -80.530  2.138E+01  3.069E-04  242.7   59.8    5.3   .004 Mean
                             -2.7%       -.9%  -1.8%                      M-76
  40.0     GRM    .0000        .5%        .5%    .0%  -21.8  -12.4        ranS
                               .8%       3.1%   2.0%   15.5    9.8        sigS
                              2.8%      -5.9%   2.8%   -8.9   -4.4        ranL
                              5.5%       4.4%   2.3%   23.0   10.7        sigL
                              3.3%      -5.4%   2.8%  -30.7  -16.8  -1.39 ranT
                              5.6%       5.4%   3.0%   27.8   14.5   1.61 sigT
                         2.209E+01  2.904E-04  249.5   29.1  -11.5  -1.38 Tot.
                               .6%      -6.2%   1.0%                      T-76
                         2.055E-04  1.835E-09  166.2                   .0% H2O
                         3.312E-05  2.957E-10     .2                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 58.00  28.450  -80.530  2.812E+01  3.951E-04  248.1   55.3    5.7   .004 Mean
                             -2.1%       -.3%  -1.8%                      M-76
  41.0     GRM    .0000        .6%       1.3%   -.4%   -6.7  -11.1        ranS
                               .9%       3.1%   2.0%   14.8    9.9        sigS
                              5.9%      -3.8%   2.9%  -23.2  -10.2        ranL
                              5.4%       4.2%   2.1%   23.5    9.9        sigL
                              6.4%      -2.5%   2.5%  -29.9  -21.3   -.13 ranT
                              5.5%       5.2%   2.9%   27.8   14.0   1.53 sigT
                         2.993E+01  3.852E-04  254.3   25.5  -15.6   -.13 Tot.
                              4.2%      -2.8%    .7%                      T-76
                         2.631E-04  2.298E-09  168.4                   .0% H2O
                         3.739E-05  3.266E-10     .1                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 56.00  28.450  -80.530  3.678E+01  5.059E-04  253.5   50.9    6.1   .003 Mean
                             -1.6%        .3%  -1.8%                      M-76
  42.0     GRM    .0000        .8%       2.6%  -1.1%    9.0  -23.5        ranS
                               .9%       3.0%   1.9%   14.1    9.9        sigS
                              7.3%       -.9%   2.4%  -32.6  -12.7        ranL
                              5.3%       3.9%   1.9%   24.1    9.2        sigL
                              8.1%       1.7%   1.3%  -23.6  -36.2    .84 ranT
                              5.3%       4.9%   2.7%   27.9   13.5   1.46 sigT
                         3.976E+01  5.144E-04  256.7   27.3  -30.1    .85 Tot.
                              6.4%       2.0%   -.5%                      T-76
                         3.352E-04  2.866E-09  170.5                   .0% H2O
                         4.210E-05  3.599E-10     .1                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 54.00  28.450  -80.530  4.784E+01  6.465E-04  258.0   46.7    6.3   .003 Mean
                             -1.0%       1.2%  -2.1%                      M-76
  43.0     GRM    .0000        .3%        .6%   -.2%   20.2  -19.8        ranS
                               .9%       2.9%   1.8%   13.3    9.9        sigS
                              6.7%       1.9%   1.3%  -33.6  -11.9        ranL
                              5.1%       3.7%   1.7%   24.5    8.9        sigL
                              7.0%       2.5%   1.2%  -13.4  -31.7    .10 ranT
                              5.2%       4.7%   2.5%   27.9   13.3   1.37 sigT
                         5.117E+01  6.627E-04  261.0   33.3  -25.4    .10 Tot.
                              5.9%       3.7%  -1.0%                      T-76
                         4.252E-04  3.571E-09  172.3                   .0% H2O
                         4.730E-05  3.973E-10     .1                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 52.00  28.450  -80.530  6.199E+01  8.257E-04  261.6   42.7    6.1   .002 Mean
                              -.4%       2.5%  -2.8%                      M-76
  44.0     GRM    .0000        .4%       1.7%   -.8%    8.6  -15.6        ranS
```

```
                             .9%       2.7%     1.7%   12.5     9.8        sigS
                            4.0%       4.1%      .0%  -24.2    -7.8        ranL
                            4.8%       3.5%     1.6%   24.9     9.1        sigL
                            4.4%       5.8%     -.8%  -15.6   -23.5    .15 ranT
                            4.9%       4.4%     2.4%   27.9    13.4   1.26 sigT
                       6.469E+01  8.738E-04    259.4   27.1   -17.4    .15 Tot.
                            4.0%       8.5%    -3.6%                       T-76
                       5.485E-04  4.543E-09    173.7                   .0% H2O
                       5.322E-05  4.408E-10       .1                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 50.00  28.450  -80.530  8.004E+01  1.051E-03  265.2   38.7     6.0   .001 Mean
                             .3%       2.4%    -2.0%                       M-76
  45.0     GRM    .0000      .4%       1.3%     -.5%   12.8   -23.7        ranS
                             .8%       2.5%     1.5%   11.6     9.7        sigS
                             .1%       4.7%    -1.2%   -6.1     -.7        ranL
                            4.6%       3.4%     1.5%   25.4     9.3        sigL
                             .5%       6.0%    -1.8%    6.7   -24.4   -.49 ranT
                            4.7%       4.2%     2.2%   27.9    13.4   1.15 sigT
                       8.040E+01  1.114E-03    260.6   45.4   -18.5   -.49 Tot.
                             .8%       8.5%    -3.7%                       T-76
                       6.882E-04  5.622E-09    175.0                   .0% H2O
                       5.311E-05  4.338E-10       .1                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 48.00  28.450  -80.530  1.030E+02  1.353E-03  265.2   36.3     5.7   .000 Mean
                             .7%       2.8%    -2.0%                       M-76
  46.0     GRM    .0000      .1%        .0%      .1%   18.6   -12.4        ranS
                             .8%       2.5%     1.6%   11.0     9.1        sigS
                           -3.6%       3.8%    -2.2%   15.6     7.0        ranL
                            4.4%       3.3%     1.6%   24.7     9.0        sigL
                           -3.4%       3.8%    -2.1%   34.3    -5.4    .24 ranT
                            4.4%       4.1%     2.3%   27.0    12.8   1.05 sigT
                       9.946E+01  1.405E-03    259.5   70.6      .3    .24 Tot.
                           -2.8%       6.7%    -4.1%                       T-76
                       8.430E-04  6.889E-09    174.7                   .0% H2O
                       5.021E-05  4.103E-10       .1                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 46.00  28.450  -80.530  1.326E+02  1.742E-03  265.1   33.9     5.5   .000 Mean
                             .9%       1.6%     -.7%                       M-76
  47.0     GRM    .0000     -.3%      -2.4%     1.4%   12.9    -8.6        ranS
                             .7%       2.4%     1.6%   10.3     8.5        sigS
                           -5.5%       1.3%    -2.3%   30.6    11.7        ranL
                            4.1%       3.3%     1.7%   23.9     8.7        sigL
                           -5.8%      -1.1%     -.9%   43.5     3.1   -.90 ranT
                            4.2%       4.0%     2.4%   26.1    12.1    .94 sigT
                       1.249E+02  1.724E-03    262.8   77.4     8.5   -.90 Tot.
                           -4.9%        .5%    -1.5%                       T-76
                       1.066E-03  8.712E-09    174.6                   .0% H2O
                       7.080E-05  5.787E-10       .1                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 44.00  28.450  -80.530  1.708E+02  2.263E-03  263.0   31.4     5.2  -.001 Mean
                             .8%        .2%      .6%                       M-76
  48.0     GRM    .0000     -.1%       -.6%      .3%   12.5    -6.4        ranS
                             .6%       2.3%     1.6%    9.7     7.8        sigS
                           -5.0%      -1.7%    -1.2%   31.5    10.7        ranL
                            3.9%       3.2%     1.8%   23.0     8.2        sigL
                           -5.1%      -2.3%     -.9%   43.9     4.4   -.02 ranT
                            3.9%       3.9%     2.4%   24.9    11.3    .86 sigT
                       1.620E+02  2.211E-03    260.6   75.4     9.5   -.02 Tot.
                           -4.4%      -2.1%     -.3%                       T-76
                       1.336E-03  1.101E-08    173.6                   .0% H2O
                       8.532E-05  7.030E-10       .1                   .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 42.00  28.450  -80.530  2.208E+02  2.973E-03  258.8   29.0     4.8  -.001 Mean
                             .4%       -.7%     1.2%                       M-76
  49.0     GRM    .0000     -.3%      -1.8%     1.0%   15.4    -3.5        ranS
                             .6%       2.1%     1.5%    9.1     7.1        sigS
                           -2.2%      -3.8%      .6%   17.3     4.4        ranL
```

```
                              3.7%       2.9%   1.9%   21.7    7.5        sigL
                             -2.6%      -5.5%   1.6%   32.7     .9    .08 ranT
                              3.7%       3.6%   2.4%   23.5   10.3    .81 sigT
                         2.151E+02  2.809E-03  263.0   61.7    5.7    .08 Tot.
                             -2.2%      -6.2%   2.8%                      T-76
                         1.675E-03  1.402E-08  171.8                  .0% H2O
                         9.201E-05  7.704E-10     .2                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 40.00  28.450  -80.530  2.868E+02  3.924E-03  254.7   26.6    4.4  -.001 Mean
                              -.1%      -1.8%   1.7%                      M-76
  50.0     GRM    .0000        .1%       1.2%   -.9%   14.7    3.6        ranS
                               .5%       1.9%   1.5%    8.6    6.3        sigS
                              1.6%      -3.6%   2.2%   -4.6   -3.3        ranL
                              3.5%       2.7%   1.9%   20.4    6.7        sigL
                              1.6%      -2.4%   1.4%   10.0     .2   -.48 ranT
                              3.5%       3.3%   2.4%   22.1    9.2    .75 sigT
                         2.915E+02  3.829E-03  258.2   36.6    4.7   -.48 Tot.
                              1.5%      -4.2%   3.1%                      T-76
                         2.446E-03  2.081E-08  170.7                  .0% H2O
                         1.059E-04  9.014E-10     .2                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 38.00  28.450  -80.530  3.748E+02  5.251E-03  248.7   23.6    3.9  -.001 Mean
                              -.6%      -2.1%   1.6%                      M-76
  51.0     GRM    .0000        .0%        .8%   -.6%    8.3    5.8        ranS
                               .5%       1.8%   1.5%    8.0    5.9        sigS
                              4.1%      -1.5%   2.5%  -22.1   -8.3        ranL
                              3.2%       2.5%   1.8%   19.1    6.3        sigL
                              4.1%       -.7%   1.9%  -13.9   -2.5    .43 ranT
                              3.3%       3.1%   2.4%   20.7    8.6    .70 sigT
                         3.902E+02  5.212E-03  253.5    9.7    1.5    .43 Tot.
                              3.5%      -2.9%   3.5%                      T-76
                         3.551E-03  3.093E-08  171.9                  .0% H2O
                         1.244E-04  1.084E-09     .2                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 36.00  28.450  -80.530  4.929E+02  7.075E-03  242.8   20.5    3.4   .000 Mean
                             -1.1%      -2.5%   1.5%                      M-76
  52.0     GRM    .0000        .1%       1.0%   -.7%    6.8    5.6        ranS
                               .5%       1.7%   1.5%    7.3    5.5        sigS
                              3.8%       1.3%   1.2%  -24.4   -7.3        ranL
                              2.9%       2.3%   1.8%   17.7    5.9        sigL
                              4.0%       2.4%    .4%  -17.6   -1.7   -.22 ranT
                              3.0%       2.9%   2.3%   19.2    8.1    .65 sigT
                         5.124E+02  7.243E-03  243.9    2.9    1.7   -.22 Tot.
                              2.8%       -.2%   1.9%                      T-76
                         4.557E-03  4.067E-08  172.8                  .0% H2O
                         1.471E-04  1.313E-09     .2                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 34.00  28.450  -80.530  6.528E+02  9.581E-03  237.4   19.4    2.9   .000 Mean
                             -1.6%      -3.1%   1.6%                      M-76
  53.0     GRM    .0000        .1%       1.1%   -.8%    7.0    1.3        ranS
                               .4%       1.6%   1.4%    6.7    5.1        sigS
                               .9%       2.9%  -1.0%   -9.6   -1.1        ranL
                              2.7%       2.1%   1.7%   16.4    5.4        sigL
                              1.0%       4.0%  -1.8%   -2.6     .2   -.53 ranT
                              2.7%       2.7%   2.2%   17.7    7.4    .61 sigT
                         6.596E+02  9.966E-03  233.1   16.8    3.1   -.53 Tot.
                              -.6%        .8%   -.3%                      T-76
                         5.831E-03  5.321E-08  173.8                  .0% H2O
                         1.883E-04  1.720E-09     .2                  .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 32.00  28.450  -80.530  8.701E+02  1.303E-02  232.7   20.1    2.4  -.001 Mean
                             -2.1%      -3.9%   1.8%                      M-76
  54.0     GRM    .0000       -.2%      -1.9%   1.5%     .3    4.4        ranS
                               .4%       1.5%   1.3%    5.9    4.5        sigS
                             -2.2%       2.1%  -2.2%   11.1    4.9        ranL
                              2.4%       1.9%   1.6%   15.0    4.8        sigL
                             -2.4%        .2%   -.7%   11.4    9.3    .24 ranT
```

```
                              2.4%       2.4%     2.1%   16.1     6.5      .57 sigT
                          8.490E+02  1.305E-02  230.9   31.5    11.7      .24 Tot.
                             -4.5%      -3.7%     1.1%                        T-76
                          7.517E-03  7.000E-08  175.0                     .0% H2O
                          2.313E-04  2.156E-09     .2                     .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 30.00  28.450  -80.530  1.166E+03  1.783E-02  227.9   20.8     1.9  -.001 Mean
                             -2.6%      -3.1%     .6%                        M-76
  55.0    GRM    .0000       -.1%       -.5%     .4%   -1.4     3.6        ranS
                              .3%       1.3%     1.2%    5.2     3.8        sigS
                             -3.0%       -.3%   -1.5%   18.9     5.6        ranL
                              2.1%       1.7%     1.5%   13.4     4.1        sigL
                             -3.0%       -.8%   -1.1%   17.5     9.2      .06 ranT
                              2.1%       2.1%     2.0%   14.3     5.6      .53 sigT
                          1.131E+03  1.769E-02  225.4   38.3    11.2      .06 Tot.
                             -5.5%      -3.9%    -.5%                        T-76
                          9.856E-03  9.370E-08  176.4                     .1% H2O
                          2.869E-04  2.730E-09     .2                     .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 28.00  28.450  -80.530  1.575E+03  2.449E-02  224.0   17.4     1.8   .000 Mean
                             -2.6%      -2.4%    -.2%                        M-76
  56.0    GRM    .0000        .0%       -.9%     .7%   -3.0     5.5        ranS
                              .3%       1.1%     1.0%    4.5     3.3        sigS
                             -.9%      -2.1%      .7%    7.7     1.3        ranL
                              1.9%       1.6%     1.4%   11.9     3.6        sigL
                             -1.0%      -2.9%     1.4%    4.7     6.8      .01 ranT
                              1.9%       1.9%     1.7%   12.7     4.9      .50 sigT
                          1.560E+03  2.376E-02  227.2   22.1     8.5      .01 Tot.
                             -3.5%      -5.2%     1.2%                        T-76
                          1.320E-02  1.276E-07  177.9                     .1% H2O
                          3.653E-04  3.536E-09     .2                     .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 26.00  28.450  -80.530  2.137E+03  3.381E-02  220.1   13.8     1.6   .000 Mean
                             -2.4%      -1.3%   -1.1%                        M-76
  57.0    GRM    .0000        .0%        .1%    -.1%   -2.6     4.4        ranS
                              .2%        .9%     .9%    3.8     2.7        sigS
                              1.7%      -1.4%     1.8%   -9.0    -3.3        ranL
                              1.7%       1.4%     1.3%   10.2     3.0        sigL
                              1.8%      -1.3%     1.7%  -11.6     1.1      .00 ranT
                              1.7%       1.7%     1.5%   10.9     4.1      .47 sigT
                          2.174E+03  3.337E-02  223.8    2.3     2.6      .00 Tot.
                              -.6%      -2.6%     .6%                        T-76
                          1.768E-02  1.741E-07  179.5                     .2% H2O
                          5.151E-04  5.077E-09     .2                     .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 24.00  28.450  -80.530  2.916E+03  4.698E-02  216.2   10.8     1.5   .000 Mean
                             -1.9%        .1%   -2.0%                        M-76
  58.0    GRM    .0000        .0%        .0%     .0%    1.5     5.9        ranS
                              .2%        .8%     .8%    3.2     2.6        sigS
                              2.3%        .8%     .8%  -11.6    -3.6        ranL
                              1.8%       1.3%     1.2%    8.7     2.9        sigL
                              2.3%        .7%     .8%  -10.1     2.4     -.49 ranT
                              1.8%       1.5%     1.4%    9.3     3.9      .44 sigT
                          2.983E+03  4.733E-02  217.9     .7     3.8     -.49 Tot.
                              .4%        .8%   -1.2%                        T-76
                          2.315E-02  2.320E-07  180.9                     .5% H2O
                          7.353E-04  7.378E-09     .3                     .0% sigH
------ ------- -------- ---------- ---------- ------ ------ ------ ------ ----
 22.00  28.450  -80.530  4.021E+03  6.621E-02  211.5   10.2     1.4   .000 Mean
                              -.7%       2.6%   -3.2%                        M-76
  59.0    GRM    .0000        .1%       1.0%    -.8%    3.7     5.6        ranS
                              .2%        .9%     .8%    2.9     2.7        sigS
                              -.4%       1.8%   -1.3%     .4     1.1        ranL
                              1.4%       1.3%     1.2%    7.8     3.1        sigL
                              -.3%       2.8%   -2.2%    4.1     6.7     -.35 ranT
                              1.4%       1.6%     1.4%    8.3     4.1      .43 sigT
                          4.009E+03  6.805E-02  206.9   14.3     8.1     -.35 Tot.
```

```
                              -1.0%        5.5%   -5.3%                      T-76
                          2.926E-02   2.997E-07   182.2                 1.1% H2O
                          1.093E-03   1.121E-08      .3                  .1% sigH
 ------ ------- --------  ----------  ----------  ------ ------ ------ ------ ----
  20.00  28.450  -80.530   5.580E+03   9.416E-02   206.5   12.4    1.6   .000 Mean
                                .9%        5.9%   -4.7%                      M-76
   60.0     GRM    .0000        .0%         .4%    -.4%    3.4    6.2        ranS
                                .1%         .9%     .9%    2.6    3.0        sigS
                              -1.1%         .0%    -.9%   10.0    4.8        ranL
                                .8%        1.3%    1.3%    7.2    3.4        sigL
                              -1.1%         .4%   -1.3%   13.4   11.0   -.50 ranT
                                .8%        1.6%    1.6%    7.6    4.5    .42 sigT
                          5.520E+03   9.453E-02   203.8   25.8   12.5   -.50 Tot.
                               -.2%        6.3%   -5.9%                      T-76
                          3.598E-02   3.776E-07   183.4                 2.7% H2O
                          1.851E-03   1.944E-08      .4                  .2% sigH
 ------ ------- --------  ----------  ----------  ------ ------ ------ ------ ----
  18.00  28.450  -80.530   7.789E+03   1.335E-01   203.2   19.2    2.3   .000 Mean
                               3.0%        9.8%   -6.2%                      M-76
   61.0     GRM    .0000        .0%        -.9%     .9%    6.3    -.6        ranS
                                .1%        1.0%    1.0%    2.6    3.9        sigS
                               -.1%       -1.8%    1.3%    2.4    -.2        ranL
                               1.0%        1.3%    1.3%    7.2    4.3        sigL
                               -.1%       -2.7%    2.3%    8.7    -.7    .12 ranT
                               1.0%        1.6%    1.6%    7.6    5.8    .46 sigT
                          7.781E+03   1.299E-01   207.8   27.9    1.5    .12 Tot.
                               2.9%        6.8%   -4.1%                      T-76
                          4.184E-02   4.462E-07   184.2                 5.0% H2O
                          4.138E-03   4.418E-08      .9                  .6% sigH
 ------ ------- --------  ----------  ----------  ------ ------ ------ ------ ----
  16.00  28.450  -80.530   1.088E+04   1.850E-01   204.8   29.1    3.1  -.001 Mean
                               5.1%       11.1%   -5.5%                      M-76
   62.0     GRM    .0000        .0%         .5%    -.4%    7.5    4.0        ranS
                                .2%         .9%     .9%    3.0    5.1        sigS
                               1.7%        -.1%    1.2%  -11.6   -8.2        ranL
                               1.2%        1.1%    1.1%    8.4    5.8        sigL
                               1.8%         .4%     .8%   -4.1   -4.2    .88 ranT
                               1.2%        1.4%    1.4%    8.9    7.7    .49 sigT
                          1.107E+04   1.857E-01   206.4   25.0   -1.1    .88 Tot.
                               6.9%       11.6%   -4.7%                      T-76
                          5.306E-02   5.613E-07   185.1                 4.8% H2O
                          1.761E-02   1.866E-07     3.2                 2.0% sigH
 ------ ------- --------  ----------  ----------  ------ ------ ------ ------ ----
  14.00  28.450  -80.530   1.508E+04   2.495E-01   210.5   38.6    4.0   .000 Mean
                               6.4%        9.5%   -2.9%                      M-76
   63.0     GRM    .0000        .0%         .3%    -.3%    8.2    2.6        ranS
                                .2%         .7%     .7%    3.7    6.7        sigS
                               -.2%        1.3%    -.8%   -1.1    2.1        ranL
                               1.4%         .9%     .9%   10.5    7.7        sigL
                               -.2%        1.6%   -1.1%    7.0    4.6   1.19 ranT
                               1.4%        1.2%    1.2%   11.1   10.2    .53 sigT
                          1.505E+04   2.535E-01   208.2   45.6    8.7   1.19 Tot.
                               6.2%       11.3%   -3.9%                      T-76
                          1.124E-01   1.157E-06   189.4                 4.8% H2O
                          4.087E-02   4.213E-07     3.8                 2.2% sigH
 ------ ------- --------  ----------  ----------  ------ ------ ------ ------ ----
  12.00  28.450  -80.530   2.068E+04   3.291E-01   219.0   40.3    4.6   .001 Mean
                               6.6%        5.5%    1.1%                      M-76
   64.0     GRM    .0000        .0%        -.3%     .3%    1.8    2.1        ranS
                                .2%         .7%     .7%    4.2    8.5        sigS
                              -1.9%        -.5%    -.9%   17.2   12.3        ranL
                               1.5%        1.1%    1.1%   12.4    9.7        sigL
                              -2.0%        -.8%    -.6%   19.0   14.5    .34 ranT
                               1.5%        1.3%    1.3%   13.1   12.9    .58 sigT
                          2.027E+04   3.263E-01   217.7   59.3   19.1    .34 Tot.
                               4.5%        4.6%     .5%                      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   .006 Mean
                             5.7%       2.2%    3.4%                      M-76
  65.0    GRM     .0000       .0%        .5%    -.4%   -4.0    4.4        ranS
                              .1%        .4%     .4%    4.1    8.3        sigS
                             1.3%       -.9%    1.2%   -9.2  -10.1        ranL
                             1.3%        .9%     .9%   12.2    9.6        sigL
                             1.3%       -.4%     .7%  -13.2   -5.7   1.07 ranT
                             1.3%       1.0%    1.0%   12.9   12.7    .63 sigT
                         2.836E+04  4.209E-01  232.5   21.0   -1.7   1.07 Tot.
                             7.0%       1.8%    4.1%                      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   .006 Mean
                             4.4%        .6%    3.8%                      M-76
  66.0    GRM     .0000       .1%        .4%    -.3%   -4.2    3.2        ranS
                              .1%        .4%     .4%    3.4    7.1        sigS
                              .5%       1.2%    -.4%   -6.9   -2.4        ranL
                             1.1%        .9%     .8%   10.4    8.2        sigL
                              .6%       1.6%    -.7%  -11.1     .8   1.89 ranT
                             1.1%       1.0%    1.0%   11.0   10.8    .63 sigT
                         3.746E+04  5.372E-01  243.5   16.1    4.3   1.89 Tot.
                             5.1%       2.2%    3.1%                      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   .001 Mean
                             3.2%      -1.2%    4.4%                      M-76
  67.0    GRM     .0000       .1%       1.1%   -1.0%    -.4     .8        ranS
                              .1%        .4%     .4%    2.8    5.8        sigS
                            -1.1%       -.4%    -.5%   12.2    8.6        ranL
                              .9%        .9%     .9%    8.7    6.7        sigL
                            -1.1%        .7%   -1.5%   11.8    9.4   1.16 ranT
                              .9%       1.0%    1.0%    9.2    8.8    .63 sigT
                         4.820E+04  6.570E-01  256.1   32.4   12.1   1.16 Tot.
                             2.1%       -.5%    2.8%                      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   .001 Mean
                             2.0%      -1.8%    3.7%                      M-76
  68.0    GRM     .0000       .0%        .1%    -.1%    1.4    7.4        ranS
                              .1%        .4%     .4%    2.4    4.6        sigS
                              .8%       -.6%    1.1%   -8.5   -7.1        ranL
                              .7%        .9%     .9%    7.5    5.3        sigL
                              .8%       -.5%    1.0%   -7.1     .3   -.16 ranT
                              .7%       1.0%    1.0%    7.9    7.0    .69 sigT
                         6.342E+04  8.011E-01  274.7    6.9    2.2   -.16 Tot.
                             2.8%      -2.2%    4.8%                      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   .002 Mean
                             1.1%      -1.4%    2.3%                      M-76
  69.0    GRM     .0000       .0%       -.4%     .3%    -.2     .6        ranS
                              .0%        .5%     .5%    2.0    3.7        sigS
                             -.3%       1.5%   -1.5%    2.1    3.1        ranL
                              .5%       1.2%    1.1%    6.4    4.3        sigL
                             -.3%       1.2%   -1.2%    1.9    3.8   -.14 ranT
                              .5%       1.3%    1.2%    6.7    5.7    .82 sigT
                         8.016E+04  1.004E+00  278.3    8.9    5.0   -.14 Tot.
                              .8%       -.3%    1.1%                      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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  .00  28.450  -80.530  1.021E+05  1.212E+00  291.5     .8     -.6    .000 Mean
                              .8%     -1.0%    1.2%                        M-76
  70.0    GRM    .0000        .0%        .4%    -.3%     .3     2.1         ranS
                              .0%        .4%     .4%    1.3     2.8         sigS
                             -.1%     -1.5%    1.2%     2.3      .4         ranL
                              .5%      1.1%    1.0%     4.2     3.3         sigL
                             -.1%     -1.1%     .9%     2.6     2.5   -.23 ranT
                              .5%      1.2%    1.1%     4.4     4.3    .94 sigT
                        1.019E+05  1.198E+00  294.0     3.4     1.9   -.23 Tot.
                              .6%     -2.2%    2.0%                        T-76
                        1.759E+03  1.307E-02  288.1                  80.5% H2O
                        4.644E+02  3.457E-03    4.2                  29.7% sigH
```

Sample Species Concentration Output File Produced by Input File of Appendix D

```
    ****** Global Reference Atmospheric Model - 1999 (GRAM-99) ******
                    Version 1, Released May, 1999
                      Species Concentration Data

MM/DD/YYYY =  1/ 1/1999  HH:MM:SS(UTC) =  0: 0:  .0  Julian Day = 2451179.500
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                   0.000E+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 | Ar
                         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 | Ar
                         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 | Ar
                         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 | Ar
                         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 | Ar
                         1.294E+02 2.351E+13 | 5.503E-06 1.000E+06   He | H
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------ ------- --------  --------- --------- + --------- ---------   ----+----
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 |  Ar
                         1.151E+02 2.471E+13 | 4.661E-06 1.000E+06    He |   H
------ ------- --------  --------- --------- + --------- ---------   ----+----
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 |  Ar
                         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 |  Ar
                         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 |  Ar
                         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 |  Ar
                         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 |  Ar
                         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 | 1.252E-03 9.414E+08   H2O |  O3
                         2.088E-04 1.570E+08 | 5.452E+01 4.098E+13   N2O |  CO
   11.0                  4.864E-02 3.657E+10 | 4.141E+01 3.113E+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 |  Ar
                         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 | 3.137E-03 3.035E+09   H2O |  O3
                         2.200E-04 2.128E+08 | 5.064E+01 4.899E+13   N2O |  CO
   12.0                  6.419E-02 6.210E+10 | 4.368E+01 4.226E+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 |  Ar
                         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 | 7.856E-03 9.918E+09   H2O |  O3
                         2.320E-04 2.928E+08 | 4.680E+01 5.908E+13   N2O |  CO
   13.0                  8.083E-02 1.020E+11 | 4.865E+01 6.142E+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 |  Ar
                         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 | 1.968E-02 3.299E+10   H2O |  O3
                         2.448E-04 4.104E+08 | 4.305E+01 7.217E+13   N2O |  CO
   14.0                  9.714E-02 1.629E+11 | 5.722E+01 9.593E+13   CH4 | CO2
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                          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 |  Ar
                          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 | 4.929E-02 1.125E+11  H2O |  O3
                          2.583E-04 5.896E+08 | 3.959E+01 9.038E+13  N2O |  CO
  15.0                    1.167E-01 2.665E+11 | 6.729E+01 1.536E+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 |  Ar
                          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 | 8.557E-02 2.689E+11  H2O |  O3
                          2.739E-04 8.608E+08 | 3.504E+01 1.101E+14  N2O |  CO
  16.0                    1.238E-01 3.891E+11 | 8.576E+01 2.695E+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 |  Ar
                          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 | 1.486E-01 6.563E+11  H2O |  O3
                          2.904E-04 1.283E+09 | 3.101E+01 1.370E+14  N2O |  CO
  17.0                    1.313E-01 5.799E+11 | 1.093E+02 4.828E+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 |  Ar
                          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 | 2.245E-01 1.413E+12  H2O |  O3
                          3.081E-04 1.939E+09 | 2.713E+01 1.707E+14  N2O |  CO
  18.0                    1.375E-01 8.657E+11 | 1.383E+02 8.707E+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 |  Ar
                          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 | 2.954E-01 2.659E+12  H2O |  O3
                          3.273E-04 2.947E+09 | 2.345E+01 2.111E+14  N2O |  CO
  19.0                    1.424E-01 1.282E+12 | 1.739E+02 1.566E+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 |  Ar
                          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 | 3.887E-01 5.052E+12  H2O |  O3
                          3.477E-04 4.520E+09 | 2.028E+01 2.636E+14  N2O |  CO
  20.0                    1.475E-01 1.917E+12 | 2.187E+02 2.843E+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 |  Ar
                          1.122E+01 1.459E+14 | 7.692E-08 1.000E+06   He |   H
------ ------- --------   --------- --------- + --------- ---------  ----+----
 98.00  28.450  -80.530   4.510E-01 8.392E+12 | 4.616E-01 8.588E+12  H2O |  O3
                          3.712E-04 6.907E+09 | 1.667E+01 3.101E+14  N2O |  CO
  21.0                    1.523E-01 2.833E+12 | 2.491E+02 4.635E+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 |  Ar
                          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 | 5.481E-01 1.459E+13  H2O |  O3
                          3.963E-04 1.055E+10 | 1.370E+01 3.646E+14  N2O |  CO
  22.0                    1.572E-01 4.185E+12 | 2.837E+02 7.552E+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 |  Ar
                          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 | 5.989E-01 2.274E+13  H2O |  O3
                          4.240E-04 1.610E+10 | 1.137E+01 4.316E+14  N2O |  CO
  23.0                    1.621E-01 6.156E+12 | 3.113E+02 1.182E+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 |  Ar
                          1.171E+01 4.444E+14 | 2.634E-08 1.000E+06   He |   H
------ ------- --------   --------- --------- + --------- ---------  ----+----
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 92.00  28.450  -80.530  7.089E-01 3.801E+13 | 6.020E-01 3.227E+13  H2O |  O3
                         4.547E-04 2.438E+10 | 9.531E+00 5.110E+14  N2O |  CO
  24.0                   1.670E-01 8.954E+12 | 3.290E+02 1.764E+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 |  Ar
                         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 | 6.051E-01 4.531E+13  H2O |  O3
                         4.876E-04 3.651E+10 | 7.991E+00 5.984E+14  N2O |  CO
  25.0                   1.720E-01 1.288E+13 | 3.477E+02 2.604E+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 |  Ar
                         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 | 5.587E-01 5.771E+13  H2O |  O3
                         5.259E-04 5.432E+10 | 6.594E+00 6.812E+14  N2O |  CO
  26.0                   1.769E-01 1.827E+13 | 3.521E+02 3.637E+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 |  Ar
                         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 | 4.756E-01 6.740E+13  H2O |  O3
                         5.672E-04 8.037E+10 | 5.441E+00 7.711E+14  N2O |  CO
  27.0                   1.818E-01 2.576E+13 | 3.566E+02 5.054E+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 |  Ar
                         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 | 3.567E-01 6.928E+13  H2O |  O3
                         6.138E-04 1.192E+11 | 4.305E+00 8.362E+14  N2O |  CO
  28.0                   1.843E-01 3.580E+13 | 3.607E+02 7.005E+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 |  Ar
                         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 | 2.860E-01 7.621E+13  H2O |  O3
                         6.664E-04 1.776E+11 | 3.266E+00 8.705E+14  N2O |  CO
  29.0                   1.843E-01 4.912E+13 | 3.643E+02 9.707E+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 |  Ar
                         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 | 2.723E-01 9.931E+13  H2O |  O3
                         7.235E-04 2.639E+11 | 2.478E+00 9.038E+14  N2O |  CO
  30.0                   1.843E-01 6.723E+13 | 3.679E+02 1.342E+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 |  Ar
                         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 | 2.662E-01 1.322E+14  H2O |  O3
                         7.919E-04 3.933E+11 | 1.836E+00 9.119E+14  N2O |  CO
  31.0                   1.843E-01 9.155E+13 | 3.688E+02 1.831E+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 |  Ar
                         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 | 2.325E-01 1.569E+14  H2O |  O3
                         8.668E-04 5.851E+11 | 1.360E+00 9.181E+14  N2O |  CO
  32.0                   1.843E-01 1.244E+14 | 3.697E+02 2.495E+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 |  Ar
                         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 | 1.895E-01 1.731E+14  H2O |  O3
                         9.541E-04 8.711E+11 | 9.886E-01 9.026E+14  N2O |  CO
  33.0                   1.843E-01 1.683E+14 | 3.701E+02 3.379E+17  CH4 | CO2
                         7.808E+05 7.129E+20 | 2.095E+05 1.913E+20   N2 |  O2
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                           9.052E+00 8.265E+15 | 9.340E+03 8.528E+18     O |  Ar
                           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 | 2.038E-01 2.503E+14   H2O |  O3
                           1.056E-03 1.297E+12 | 7.049E-01 8.654E+14   N2O |  CO
   34.0                    1.843E-01 2.263E+14 | 3.701E+02 4.544E+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 |  Ar
                           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 | 2.508E-01 4.126E+14   H2O |  O3
                           1.169E-03 1.923E+12 | 5.025E-01 8.267E+14   N2O |  CO
   35.0                    1.843E-01 3.032E+14 | 3.701E+02 6.089E+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 |  Ar
                           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 | 3.602E-01 7.852E+14   H2O |  O3
                           1.302E-03 2.840E+12 | 3.787E-01 8.256E+14   N2O |  CO
   36.0                    1.843E-01 4.019E+14 | 3.701E+02 8.069E+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 |  Ar
                           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 | 4.577E-01 1.315E+15   H2O |  O3
                           1.451E-03 4.170E+12 | 2.853E-01 8.200E+14   N2O |  CO
   37.0                    1.843E-01 5.297E+14 | 3.701E+02 1.064E+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 |  Ar
                           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 | 5.804E-01 2.187E+15   H2O |  O3
                           1.063E-03 4.006E+12 | 2.266E-01 8.541E+14   N2O |  CO
   38.0                    1.521E-01 5.732E+14 | 3.701E+02 1.395E+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 |  Ar
                           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 | 7.454E-01 3.665E+15   H2O |  O3
                           1.081E-03 5.314E+12 | 1.898E-01 9.330E+14   N2O |  CO
   39.0                    1.575E-01 7.743E+14 | 3.701E+02 1.820E+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 |  Ar
                           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 | 9.708E-01 6.195E+15   H2O |  O3
                           1.233E-03 7.867E+12 | 1.589E-01 1.014E+15   N2O |  CO
   40.0                    1.699E-01 1.084E+15 | 3.701E+02 2.362E+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 |  Ar
                           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 | 1.237E+00 1.016E+16   H2O |  O3
                           1.455E-03 1.195E+13 | 1.358E-01 1.116E+15   N2O |  CO
   41.0                    1.858E-01 1.526E+15 | 3.701E+02 3.040E+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 |  Ar
                           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 | 1.497E+00 1.574E+16   H2O |  O3
                           1.802E-03 1.895E+13 | 1.162E-01 1.222E+15   N2O |  CO
   42.0                    2.153E-01 2.264E+15 | 3.701E+02 3.893E+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 |  Ar
                           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 | 1.778E+00 2.390E+16   H2O |  O3
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                            2.359E-03 3.171E+13 | 9.749E-02 1.310E+15  N2O |  CO
  43.0                      2.559E-01 3.440E+15 | 3.701E+02 4.974E+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  |  Ar
                            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 | 2.086E+00 3.581E+16  H2O |  O3
                            3.086E-03 5.298E+13 | 8.033E-02 1.379E+15  N2O |  CO
  44.0                      2.999E-01 5.148E+15 | 3.701E+02 6.354E+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  |  Ar
                            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 | 2.516E+00 5.498E+16  H2O |  O3
                            3.816E-03 8.340E+13 | 6.619E-02 1.447E+15  N2O |  CO
  45.0                      3.359E-01 7.341E+15 | 3.701E+02 8.089E+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  |  Ar
                            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 | 3.116E+00 8.766E+16  H2O |  O3
                            4.544E-03 1.279E+14 | 5.200E-02 1.463E+15  N2O |  CO
  46.0                      3.635E-01 1.023E+16 | 3.701E+02 1.041E+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  |  Ar
                            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 | 3.873E+00 1.403E+17  H2O |  O3
                            5.793E-03 2.099E+14 | 4.434E-02 1.606E+15  N2O |  CO
  47.0                      4.004E-01 1.451E+16 | 3.701E+02 1.341E+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  |  Ar
                            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 | 4.747E+00 2.233E+17  H2O |  O3
                            7.782E-03 3.661E+14 | 3.919E-02 1.844E+15  N2O |  CO
  48.0                      4.468E-01 2.102E+16 | 3.701E+02 1.741E+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  |  Ar
                            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 | 5.623E+00 3.476E+17  H2O |  O3
                            1.075E-02 6.644E+14 | 3.509E-02 2.169E+15  N2O |  CO
  49.0                      5.008E-01 3.096E+16 | 3.701E+02 2.288E+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  |  Ar
                            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 | 6.441E+00 5.254E+17  H2O |  O3
                            1.430E-02 1.166E+15 | 3.181E-02 2.595E+15  N2O |  CO
  50.0                      5.544E-01 4.523E+16 | 3.701E+02 3.019E+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  |  Ar
                            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 | 6.975E+00 7.615E+17  H2O |  O3
                            2.100E-02 2.293E+15 | 2.927E-02 3.195E+15  N2O |  CO
  51.0                      6.270E-01 6.845E+16 | 3.701E+02 4.041E+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  |  Ar
                            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 | 7.439E+00 1.094E+18  H2O |  O3
                            3.473E-02 5.108E+15 | 2.724E-02 4.007E+15  N2O |  CO
  52.0                      7.452E-01 1.096E+17 | 3.701E+02 5.444E+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  |  Ar
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                      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 | 7.470E+00 1.488E+18  H2O |  O3
                         6.599E-02 1.314E+16 | 2.545E-02 5.069E+15  N2O |  CO
  53.0                   9.246E-01 1.842E+17 | 3.701E+02 7.372E+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 |  Ar
                         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 | 7.285E+00 1.974E+18  H2O |  O3
                         9.078E-02 2.460E+16 | 2.368E-02 6.416E+15  N2O |  CO
  54.0                   1.046E+00 2.834E+17 | 3.701E+02 1.003E+20  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 |  Ar
                         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
                         1.184E-01 4.389E+16 | 2.180E-02 8.081E+15  N2O |  CO
  55.0                   1.177E+00 4.362E+17 | 3.701E+02 1.372E+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 |  Ar
                         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
                         1.599E-01 8.139E+16 | 1.995E-02 1.016E+16  N2O |  CO
  56.0                   1.312E+00 6.679E+17 | 3.701E+02 1.884E+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 |  Ar
                         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
                         1.385E-01 9.735E+16 | 1.842E-02 1.295E+16  N2O |  CO
  57.0                   1.105E+00 7.765E+17 | 3.701E+02 2.602E+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 |  Ar
                         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
                         1.554E-01 1.518E+17 | 1.644E-02 1.605E+16  N2O |  CO
  58.0                   1.235E+00 1.207E+18 | 3.701E+02 3.615E+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 |  Ar
                         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
                         1.750E-01 2.408E+17 | 1.444E-02 1.988E+16  N2O |  CO
  59.0                   1.445E+00 1.990E+18 | 3.701E+02 5.095E+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 |  Ar
                         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
                         2.141E-01 4.192E+17 | 1.561E-02 3.057E+16  N2O |  CO
  60.0                   1.630E+00 3.191E+18 | 3.701E+02 7.245E+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 |  Ar
                         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
                         2.607E-01 7.237E+17 | 2.313E-02 6.422E+16  N2O |  CO
  61.0                   1.753E+00 4.868E+18 | 3.701E+02 1.028E+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 |  Ar
                         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
                         2.952E-01 1.136E+18 | 3.604E-02 1.387E+17  N2O |  CO
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  62.0                    1.833E+00 7.052E+18 | 3.701E+02 1.424E+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 |  Ar
                          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 | 2.648E-01 1.374E+18  H2O |  O3
                          3.116E-01 1.617E+18 | 5.905E-02 3.064E+17  N2O |  CO
  63.0                    1.901E+00 9.861E+18 | 3.701E+02 1.920E+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 |  Ar
                          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 | 1.879E-01 1.286E+18  H2O |  O3
                          3.243E-01 2.219E+18 | 9.169E-02 6.273E+17  N2O |  CO
  64.0                    1.955E+00 1.338E+19 | 3.701E+02 2.532E+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 |  Ar
                          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 | 1.100E-01 9.669E+17  H2O |  O3
                          3.368E-01 2.959E+18 | 1.169E-01 1.027E+18  N2O |  CO
  65.0                    2.015E+00 1.770E+19 | 3.701E+02 3.252E+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 |  Ar
                          5.200E+00 4.569E+19 | 0.000E+00 0.000E+00   He |   H
------ ------- --------   --------- --------- + --------- ---------  ----+----
  8.00  28.450  -80.530   5.421E+02 5.959E+21 | 6.711E-02 7.377E+17  H2O |  O3
                          3.428E-01 3.769E+18 | 1.397E-01 1.536E+18  N2O |  CO
  66.0                    2.050E+00 2.254E+19 | 3.701E+02 4.069E+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 |  Ar
                          5.200E+00 5.716E+19 | 0.000E+00 0.000E+00   He |   H
------ ------- --------   --------- --------- + --------- ---------  ----+----
  6.00  28.450  -80.530   1.166E+03 1.582E+22 | 4.874E-02 6.612E+17  H2O |  O3
                          3.428E-01 4.651E+18 | 1.514E-01 2.055E+18  N2O |  CO
  67.0                    2.072E+00 2.812E+19 | 3.701E+02 5.021E+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 |  Ar
                          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 | 3.673E-02 6.146E+17  H2O |  O3
                          3.428E-01 5.736E+18 | 1.538E-01 2.573E+18  N2O |  CO
  68.0                    2.089E+00 3.495E+19 | 3.701E+02 6.193E+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 |  Ar
                          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 | 3.232E-02 6.669E+17  H2O |  O3
                          3.428E-01 7.073E+18 | 1.644E-01 3.391E+18  N2O |  CO
  69.0                    2.089E+00 4.310E+19 | 3.701E+02 7.635E+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 |  Ar
                          5.200E+00 1.073E+20 | 0.000E+00 0.000E+00   He |   H
------ ------- --------   --------- --------- + --------- ---------  ----+----
   .00  28.450  -80.530   1.697E+04 4.277E+23 | 2.976E-02 7.502E+17  H2O |  O3
                          3.428E-01 8.641E+18 | 1.761E-01 4.439E+18  N2O |  CO
  70.0                    2.089E+00 5.265E+19 | 3.701E+02 9.329E+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 |  Ar
                          5.200E+00 1.311E+20 | 0.000E+00 0.000E+00   He |   H
```

Sample Special Output File Produced by Input File of Appendix D

```
 Time Height   Lat.     Lon.    Pressure sigP  Density   sigD  Temp. sigT Uwind sigU Vwind sigV
  sec   km   deg+N-S deg+E-W     N/m**2   %    kg/m**3    %      K     %    m/s  m/s   m/s   m/s
   .0  140.0   28.45  -80.53 9.480E-04 12.5 4.305E-09   7.2  670.3  7.2  -9.8 69.0 -27.7 69.0
```

1.0	138.0	28.45	-80.53	1.038E-03	13.2	4.929E-09	7.3	643.6	7.3	-16.2	68.6	-25.3	70.6
2.0	136.0	28.45	-80.53	1.142E-03	13.9	5.688E-09	7.3	616.2	7.3	-22.9	68.1	-23.0	72.3
3.0	134.0	28.45	-80.53	1.262E-03	14.5	6.618E-09	7.4	588.2	7.4	-29.8	67.7	-20.7	73.8
4.0	132.0	28.45	-80.53	1.404E-03	15.1	7.773E-09	7.5	559.6	7.5	-36.7	67.3	-18.6	75.4
5.0	130.0	28.45	-80.53	1.572E-03	15.7	9.220E-09	7.6	530.5	7.6	-43.4	66.9	-16.5	76.9
6.0	128.0	28.45	-80.53	1.772E-03	16.2	1.106E-08	7.6	501.1	7.6	-49.7	66.4	-14.5	78.4
7.0	126.0	28.45	-80.53	2.013E-03	16.8	1.342E-08	7.7	471.5	7.7	-55.3	66.0	-12.6	79.8
8.0	124.0	28.45	-80.53	2.308E-03	17.3	1.650E-08	7.8	441.8	7.8	-60.0	65.5	-10.8	81.2
9.0	122.0	28.45	-80.53	2.672E-03	17.8	2.057E-08	7.8	412.3	7.8	-63.6	65.1	-9.1	82.6
10.0	120.0	28.45	-80.53	3.127E-03	18.3	2.602E-08	7.9	383.6	7.9	-65.9	64.6	-7.5	84.0
11.0	118.0	28.45	-80.53	3.693E-03	17.8	3.331E-08	8.7	355.8	8.7	-66.4	64.2	-6.0	85.7
12.0	116.0	28.45	-80.53	4.392E-03	17.3	4.309E-08	9.5	328.8	9.5	-64.6	63.8	-4.5	87.3
13.0	114.0	28.45	-80.53	5.278E-03	16.8	5.654E-08	10.2	302.8	10.2	-60.7	63.3	-3.0	88.9
14.0	112.0	28.45	-80.53	6.435E-03	16.3	7.554E-08	11.0	278.0	11.0	-55.4	62.9	-1.6	90.5
15.0	110.0	28.45	-80.53	8.000E-03	15.8	1.035E-07	11.7	253.8	11.7	-49.2	62.4	-.4	92.0
16.0	108.0	28.45	-80.53	1.018E-02	15.3	1.436E-07	12.5	234.7	12.5	-41.9	62.0	.7	93.7
17.0	106.0	28.45	-80.53	1.329E-02	14.8	2.033E-07	13.2	217.8	13.2	-34.4	61.6	1.6	95.3
18.0	104.0	28.45	-80.53	1.780E-02	14.2	2.919E-07	13.9	204.9	13.9	-27.1	61.1	2.4	96.9
19.0	102.0	28.45	-80.53	2.439E-02	13.7	4.204E-07	14.7	196.2	14.7	-20.5	60.7	3.0	98.5
20.0	100.0	28.45	-80.53	3.402E-02	13.2	6.114E-07	15.4	189.5	15.4	-14.6	60.2	3.5	100.0
21.0	98.0	28.45	-80.53	4.812E-02	13.4	8.802E-07	15.1	187.3	15.1	-10.7	59.4	4.0	103.1
22.0	96.0	28.45	-80.53	6.845E-02	13.5	1.266E-06	14.7	186.3	14.7	-7.9	58.5	4.3	106.1
23.0	94.0	28.45	-80.53	9.867E-02	13.7	1.814E-06	14.4	188.2	14.4	-5.8	57.6	4.6	109.2
24.0	92.0	28.45	-80.53	1.429E-01	13.8	2.569E-06	14.0	193.0	14.0	-4.0	56.7	4.7	112.2
25.0	90.0	28.45	-80.53	2.048E-01	14.0	3.602E-06	13.6	197.9	13.6	-2.4	55.8	4.8	115.2
26.0	88.0	28.45	-80.53	2.875E-01	12.0	4.968E-06	11.6	201.4	11.6	4.0	50.5	4.6	92.1
27.0	86.0	28.45	-80.53	4.013E-01	9.6	6.816E-06	9.1	204.9	9.1	10.4	44.5	4.3	60.6
28.0	84.0	28.45	-80.53	5.563E-01	8.0	9.341E-06	7.4	207.4	7.4	16.8	40.4	4.6	34.3
29.0	82.0	28.45	-80.53	7.680E-01	7.5	1.282E-05	7.0	208.9	7.0	23.1	38.9	5.3	31.2
30.0	80.0	28.45	-80.53	1.057E+00	7.0	1.754E-05	6.5	210.3	6.5	29.4	37.2	6.1	27.8
31.0	78.0	28.45	-80.53	1.450E+00	7.1	2.389E-05	6.6	211.6	6.6	36.3	36.9	5.4	27.3
32.0	76.0	28.45	-80.53	1.983E+00	7.2	3.246E-05	6.6	212.9	6.6	43.3	36.6	4.7	26.7
33.0	74.0	28.45	-80.53	2.709E+00	7.1	4.391E-05	6.5	214.8	6.5	48.6	36.5	4.5	24.7
34.0	72.0	28.45	-80.53	3.688E+00	6.6	5.905E-05	6.1	217.5	6.1	52.4	36.5	4.7	20.7
35.0	70.0	28.45	-80.53	5.003E+00	6.0	7.912E-05	5.6	220.2	5.6	56.1	36.5	4.9	15.8
36.0	68.0	28.45	-80.53	6.761E+00	5.7	1.049E-04	5.4	224.5	5.4	57.8	34.6	5.0	16.4
37.0	66.0	28.45	-80.53	9.084E+00	5.4	1.382E-04	5.3	228.9	5.3	59.6	32.7	5.1	16.9
38.0	64.0	28.45	-80.53	1.215E+01	5.3	1.813E-04	5.2	233.4	5.2	60.3	30.9	5.2	16.7
39.0	62.0	28.45	-80.53	1.616E+01	5.4	2.365E-04	5.3	238.0	5.3	60.1	29.4	5.3	15.6
40.0	60.0	28.45	-80.53	2.138E+01	5.6	3.069E-04	5.4	242.7	5.4	59.8	27.8	5.3	14.5
41.0	58.0	28.45	-80.53	2.812E+01	5.5	3.951E-04	5.2	248.1	5.2	55.3	27.8	5.7	14.0
42.0	56.0	28.45	-80.53	3.678E+01	5.3	5.059E-04	4.9	253.5	4.9	50.9	27.9	6.1	13.5
43.0	54.0	28.45	-80.53	4.784E+01	5.2	6.465E-04	4.7	258.0	4.7	46.7	27.9	6.3	13.3
44.0	52.0	28.45	-80.53	6.199E+01	4.9	8.257E-04	4.4	261.6	4.4	42.7	27.9	6.1	13.4
45.0	50.0	28.45	-80.53	8.004E+01	4.7	1.051E-03	4.2	265.2	4.2	38.7	27.9	6.0	13.4
46.0	48.0	28.45	-80.53	1.030E+02	4.4	1.353E-03	4.1	265.2	4.1	36.3	27.0	5.7	12.8
47.0	46.0	28.45	-80.53	1.326E+02	4.2	1.742E-03	4.0	265.1	4.0	33.9	26.1	5.5	12.1
48.0	44.0	28.45	-80.53	1.708E+02	3.9	2.263E-03	3.9	263.0	3.9	31.4	24.9	5.2	11.3
49.0	42.0	28.45	-80.53	2.208E+02	3.7	2.973E-03	3.6	258.8	3.6	29.0	23.5	4.8	10.3
50.0	40.0	28.45	-80.53	2.868E+02	3.5	3.924E-03	3.3	254.7	3.3	26.6	22.1	4.4	9.2
51.0	38.0	28.45	-80.53	3.748E+02	3.3	5.251E-03	3.1	248.7	3.1	23.6	20.7	3.9	8.6
52.0	36.0	28.45	-80.53	4.929E+02	3.0	7.075E-03	2.9	242.8	2.9	20.5	19.2	3.4	8.1
53.0	34.0	28.45	-80.53	6.528E+02	2.7	9.581E-03	2.7	237.4	2.7	19.4	17.7	2.9	7.4
54.0	32.0	28.45	-80.53	8.701E+02	2.4	1.303E-02	2.4	232.7	2.4	20.1	16.1	2.4	6.5
55.0	30.0	28.45	-80.53	1.166E+03	2.1	1.783E-02	2.1	227.9	2.1	20.8	14.3	1.9	5.6
56.0	28.0	28.45	-80.53	1.575E+03	1.9	2.449E-02	1.9	224.0	1.9	17.4	12.7	1.8	4.9
57.0	26.0	28.45	-80.53	2.137E+03	1.7	3.381E-02	1.7	220.1	1.7	13.8	10.9	1.6	4.1
58.0	24.0	28.45	-80.53	2.916E+03	1.8	4.698E-02	1.5	216.2	1.5	10.8	9.3	1.5	3.9
59.0	22.0	28.45	-80.53	4.021E+03	1.4	6.621E-02	1.6	211.5	1.6	10.2	8.3	1.4	4.1
60.0	20.0	28.45	-80.53	5.580E+03	.8	9.416E-02	1.6	206.5	1.6	12.4	7.6	1.6	4.5
61.0	18.0	28.45	-80.53	7.789E+03	1.0	1.335E-01	1.6	203.2	1.6	19.2	7.6	2.3	5.8
62.0	16.0	28.45	-80.53	1.088E+04	1.2	1.850E-01	1.4	204.8	1.4	29.1	8.9	3.1	7.7
63.0	14.0	28.45	-80.53	1.508E+04	1.4	2.495E-01	1.2	210.5	1.2	38.6	11.1	4.0	10.2
64.0	12.0	28.45	-80.53	2.068E+04	1.5	3.291E-01	1.3	219.0	1.3	40.3	13.1	4.6	12.9
65.0	10.0	28.45	-80.53	2.800E+04	1.3	4.226E-01	1.0	230.8	1.0	34.2	12.9	4.0	12.7
66.0	8.0	28.45	-80.53	3.724E+04	1.1	5.287E-01	1.0	245.3	1.0	27.2	11.0	3.5	10.8
67.0	6.0	28.45	-80.53	4.873E+04	.9	6.525E-01	1.0	260.1	1.0	20.6	9.2	2.8	8.8
68.0	4.0	28.45	-80.53	6.289E+04	.7	8.048E-01	1.0	272.0	1.0	14.0	7.9	2.0	7.0
69.0	2.0	28.45	-80.53	8.037E+04	.5	9.923E-01	1.3	281.6	1.3	7.0	6.7	1.2	5.7
70.0	.0	28.45	-80.53	1.021E+05	.5	1.212E+00	1.2	291.5	1.2	.8	4.4	-.6	4.3

Appendix F Parameters Available for Special Output

Following is a listing of the section of GRAM where the "Special Output" can be prepared and generated. This identifies logical places to do computations of special variables (e.g. the examples sound speed, csp, at line ATMD487, pressure scale height, Hgtp, and density scale height, Hgtd, at line ATMD 487b and 487c) or to do units conversions (e.g., multiplying by conversion factors). Comments in this code section also provide lists of the names of the variables that are available for writing to the Special Output. An example of a write statement and user-provided format for writing to the Special Output is given on lines ATMD555 through ATMD557.

A new GRAM-99 feature is the capability to write surface data values to the special output file. Surface data parameter identifiers are discussed on lines ATMD550a-ATMD550r.

```
C.......................................................................ATMD483
C....."Special" output option section                                   ATMD484
      If (iopp.ne.0) Then                                               ATMD485
C       EXAMPLES OF SPECIALLY COMPUTED OUTPUT:                          ATMD485a
C.....  Sound speed (m/s) from pressure (N/m**2) and density (kg/m**3)  ATMD486
C       (Assume mean values and ratio of specific heats = 7/5)          ATMd486a
        csp = Sqrt(1.4*pgh/dgh)                                         ATMD487
C.....  Pressure scale height (m), density scale height (m)             ATMD487a
        Hgtp = pgh/(dgh*g)                                              ATMD487b
        If (h.le.hj1)Then                                               ATMD487c
          Hgtd = Hgtp/(1. + Hgtp*dtz/tgh)                               ATMD487d
        Else                                                            ATMD487e
          Hgtd = Hgtp/(1. + Hgtp*dtz/tgh - Hgtp*dmdz/wtmol)             ATMD487f
        Endif                                                           ATMD487g
C.....  Mean free path (m)  (assume mean values of pressure and temp.)  ATMD487h
        mfpath = 2.333E-5*tgh/pgh                                       ATMD487i
C.....  Gas constant (N m kmol**-1 K**-1), molecular weight (kg/kmol),  ATMD487j
C       specific heat at constant pressure (N m kmol**-1 K**-1)         ATMD487k
C       (Assume mean values and ratio of specific heats = 7/5)          ATMD487l
        gascon = pgh/(dgh*tgh)                                          ATMD487m
        molwgt = 8314.32/gascon                                         ATMD487n
        cpmn = (1.4/0.4)*gascon                                         ATMD487o
C.....  Other variables that are functions of pressure, density,        ATMD488
C       temperature, wind and/or moisture, can be calculated here.      ATMD489
C       Some such variables are: coefficient of viscosity, kinematic    ATMD490
C       viscosity, thermal conduction coefficient, potential            ATMD491
C       temperature, equivalent potential temperature, etc.             ATMD492
C                                                                       ATMD493
C.....  Any change of units for writing to "special" output file can    ATMD494
C       be done here (e.g. MKS to English units, etc.)                  ATMD495
C                                                                       ATMD496
C....   ****  To print out header information, refer to the section     ATMD497
C       ****  near format label 954 in init subroutine of initial.f.    ATMD498
C.......................................................................ATMD499
C                                                                      *ATMD500
C     As an aid to the user, the following tables give the names of    *ATMD501
C     the variables that are available for output:                     *ATMD502
C                                                                      *ATMD503
C.... Position and time parameters                                     *ATMD504
C     ----------------------------                                     *ATMD505
C       h -     Height (km)                                            *ATMD506
C       phi -   Latitude (deg)                                         *ATMD507
C       thet -  Longitude (deg), East(+) West(-)                       *ATMD508
C       elt -   Elapsed Time (sec)                                     *ATMD509
C                                                                      *ATMD510
C.... Thermodynamic, wind and moisture parameters (on standard output) *ATMD511
C     ---------------------------------------------------------------- *ATMD512
C                                                                      *ATMD513
C           Pressure    Density/  Temperature   E-W    N-S    Vert.    *ATMD514
```

```
C             /Vap. Pr      Vap.Dens.    /Dewpt.       Wind   Wind   Wind(m/s)   *ATMD515
C             (Nt/m**2)     (kg/m**3)     (K)          (m/s)  (m/s)  /RH(%)      *ATMD516
C             ---------     --------- -----------      -----  -----  -----       *ATMD517
C*Mean            pgh          dgh          tgh          ugh    vgh    wgh       *ATMD518
C*Mean-76         pghp         dghp         tghp         n/a    n/a    n/a       *ATMD519
C*Perturbed                                                                     *ATMD520
C small-scale     prhs         drhs         trhs         urhs   vrhs   n/a       *ATMD521
C*Stand. Dev.                                                                   *ATMD522
C small-scale     sphs         sdhs         sths         suhs   svhs   n/a       *ATMD523
C*Perturbed                                                                     *ATMD524
C large-scale     prhl         drhl         trhl         urhl   vrhl   n/a       *ATMD525
C*Stand. Dev.                                                                   *ATMD526
C large-scale     sphl         sdhl         sthl         suhl   svhl   n/a       *ATMD527
C*Perturbed                                                                     *ATMD528
C Total Pert.     prh          drh          trh          urh    vrh    wrh       *ATMD529
C*Stand. Dev.                                                                   *ATMD530
C total pert.     sph          sdh          sth          suh    svh    swh       *ATMD531
C*Mean plus                                                                     *ATMD532
C Perturb.        ph           dh           th           uh     vh     wh        *ATMD533
C*Total-76        php          dhp          thp          n/a    n/a    n/a       *ATMD534
C*Mean H2O        eofT         rhov         tdgh         n/a    n/a    rhp       *ATMD535
C*Stand. Dev.                                                                   *ATMD536
C H2O             seofT        srhov        stdgh        n/a    n/a   srhp       *ATMD537
C                                                                               *ATMD538
C....    Species concentration parameters (on species output)                   *ATMD539
C        ----------------------------------------------------                   *ATMD540
C                                                                               *ATMD541
C             H2O  O3    N2O  CO    CH4  CO2    N2  O2    O   Ar   He   H       *ATMD542
C             ---  --    ---  --    ---  ---    --  --    -   --   --   -       *ATMD543
C Concen-     ppmh2o     ppmn2o     ppmch4      ppmn2     ppmo     ppmhe        *ATMD544
C tration           ppmo3      ppmco      ppmco2      ppmo2    ppmar     ppmh   *ATMD545
C ----------------------------------------------------------------------        *ATMD546
C Number      h2ond      n2ond      ch4nd       n2nd      ond      hend         *ATMD547
C Density           o3nd       cond       co2nd       o2nd     arnd      hnd    *ATMD548
C                                                                               *ATMD549
C                                                                               *ATMD550
C....    Surface data (passed from Subroutine guamod, via Common                *ATMD550a
C        Block srfdat)                                                          *ATMD550b
C        ---------------------------------------------------------              *ATMD550c
C        psrf   = surface pressure (N/m**2)                                     *ATMD550d
C        dsrf   = surface density (kg/m**3)                                     *ATMD550e
C        tsrf   = surface temperature (K)                                       *ATMD550f
C        usrf   = surface Eastward wind component (m/s)                         *ATMD550g
C        vsrf   = surface Northward wind component (m/s)                        *ATMD550h
C        hsrf   = height of surface (m, above sea level)                        *ATMD550i
C        tdsrf  = surface dewpoint temperature (K)                              *ATMD550j
C        spsrf  = standard deviation of surface pressure (N/m**2)               *ATMD550k
C        sdsrf  = standard deviation of surface density (kg/m**3)               *ATMD550l
C        stsrf  = standard deviation of surface temperature (K)                 *ATMD550m
C        susrf  = standard deviation of surface Eastward wind (m/s)             *ATMD550n
C        svsrf  = standard deviation of surface Northward wind (m/s)            *ATMD550o
C        shsrf  = std. dev. (uncertainty) of surf. hgt (m, from spsrf)          *ATMD550p
C        stdsrf = standard deviation of surface dewpoint temp. (K)              *ATMD550q
C                                                                               *ATMD550r
C.....At this point, the user is invited to insert whatever output              *ATMD551
C     parameters (in whatever format) are desired for the "special"             *ATMD552
C     output instead of the Write and Format statements below.                  *ATMD553
C                                                                               *ATMD554
      Write(iopp,9000)elt,h,phi,thet,pgh,sph,dgh,sdh,tgh,sdh,ugh,suh,            ATMD555
     & vgh,svh                                                                   ATMD556
 9000 Format(2F7.1,2F8.2,2(1P,E10.3,0P,F5.1),F7.1,F5.1,2(F6.1,F5.1))             ATMD557
C                                                                                ATMD559
C.....  The "special" output option Write and Format section ends here.          ATMD560
      Endif                                                                      ATMD561
C...............................................................................ATMD562
```

Note that the header for the special output is written in the subroutine initial.f. The following code section shows the header that is written for the sample special output list above.

```
C.......................................................................INIT200
      If(iopp.ne.0) Then                                                INIT201
C.....  This is the header for the "special" output file.  The user     INIT202
C       should insure that the 954 format is compatible with the output INIT203
C       format in subroutine atmod near label number 9000 in the        INIT204
C       models.f file.                                                  INIT205
        Write(iopp,954)                                                 INIT208
  954   Format('   Time Height   Lat.    Lon.   Pressure sigP  Density' INIT209
     &   ,'  sigD  Temp. sigT Uwind sigU Vwind sigV'/'    sec   km',    INIT210
     &   '   deg+N-S deg+E-W    N/m**2  %    kg/m**3   %     K    %',   INIT211
     &   '    m/s   m/s  m/s   m/s')                                    INIT212
      Endif                                                             INIT213
C.......The "special" output header Write and Format section ends here. INIT215
C.......................................................................INIT216
```

Appendix G Example Application of GRAM-99 as Subroutines in Another Main Driver

For many applications, it is desirable to use GRAM-99 in the form of subroutines in another program. For example, the main driver program may be a trajectory calculating program, for which GRAM-99 provides the atmospheric density and winds used to update the trajectory positions (or to provide the densities and temperatures to compute heat loads, etc.). The following sample program, called "gramtraj.f " (provided with the regular GRAM-99 code files) serves as an illustration of how to build such an application program.

The real variables n2ond and n2nd and the character variables dirsep, endsep, termchar, scrstat, and sysform must be explicitly declared (lines GRMT 31 to GRMT 33) since these do not follow the FORTRAN conventions for integer or real variables. The common blocks iotemp, iucom, timeo, dircom, readcom, wincom, vert, datacom, speccom, jaccon, and comper must be included (lines GRMT 34 to GRMT 52). GRAM uses common blocks like extended argument lists for subroutines, 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) were 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 used 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 used in some (but not all) of the common block declarations within the GRAM subroutines. In the actual GRAM-99 main driver (gram99.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, nhdr, dirsep, endsep, termchar, scrstat, and sysform - 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 of Ref. 6). These values are set to those required for SGI IRIX in the following example code.

iur - the unit number for reading the input data file

iopt - the trajectory input option (see appendix D). The value is set to 0 (GRMT 79) so that positions will not be read in from a trajectory file, but will be computed from within this main program.

iopr - random perturbation option (see appendix D). No further random number seeds will be read in (GRMT 89), if the iopr value was set to 2 (GRMT 107) in the input data file.

nr1 - the random seed values read from unit iur

h1, 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 80 - GRMT 82) for later re-setting the initial position if cycling back to do multiple trajectories within one run (GRMT 89 - GRMT 90).

h, phi, thet - the "current position" height, latitude and longitude, initially equal to the starting position, used to begin the cycle in which h1, phi1, thet1 become the "previous position" and h, phi, thet are updated to the "current position".

elt - the elapsed time (sec) from the original (initial) position and the current position.

delt, dhgt, dphi, dthet - the time displacement (sec), 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 94 to GRMT 97).

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 106).

nmore - a code returned by the timestep subroutine if trajectory position calculations should be terminated for other reasons (GRMT 106).

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 (comment at GRMT 101 and appendix F).

Following is a simplified outline of the functions required to be performed in the main driver program:

1. Initialize the time and position GRMD 34
2. Set ifirst = 1 and call gramtraj to read the GRAM input fiole and initialize the GRAM atmospheric data GRMD 45-46
3. Initialize the trajectory velocity (or position displacement), if necessary GRMD 54
4. Set ifirst = 0 and start trajectory cycle GRMD 58
5. Update time, position (and velocity or displacement values, if necessary) at each step GRMD 63
6. Call gramtraj to evaluate the GRAM atmospheric data at the next position GRMD 67
7. If ifirst return code is 0, cycle to next position GRMD 76
8. If ifirst return code is -1, reinitialize the position (read a new random number seed in gramtraj) and cycle to next position GRMD 77-89
9. Terminate program for any other value of return code ifirst GRMD 93

Input options allow all of the output files generated by the GRAM-99 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 (appendix D): 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 (appendix C of Ref. 6) 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-99 as Subroutines

```
C     Dummy GRAM driver program using the gramtraj subroutine version   GRMD  1
```

```
C                                                                       GRMD  2
C     To use gramtraj as a subroutine, the user should strip out this   GRMD  3
C     dummy driver, using instead the real driver program (e.g. a       GRMD  4
C     trajectory code).  The dummy subroutines setipos and newpos       GRMD  5
C     (to set the initial position and update the position) should      GRMD  6
C     also be stripped out and replaced by position initialization      GRMD  7
C     and updating operations in the trajectory program. The            GRMD  8
C     subroutine gramtraj should be retained, to compute the            GRMD  9
C     atmospheric variables.  Certain output parameters are currently   GRMD 10
C     passed through the argument list of gramtraj (mean values and     GRMD 11
C     perturbed values of density, pressure, temperature and winds;     GRMD 12
C     US standard atmosphere values of density, pressure, and           GRMD 13
C     temperature).  Other output of atmospheric variables could be     GRMD 14
C     added to the argument list by the user.  See README files for a   GRMD 15
C     description of the available output variable names.              GRMD 16
C                                                                       GRMD 17
C     As an example of how a double precision trajectory code would     GRMD 18
C     be configured, the current argument list variables in gramtraj    GRMD 19
C     have been made double precision (Real*8). If only single          GRMD 20
C     precision is desired, these declarations (and the Dble            GRMD 21
C     assignment statements of the argument list variables in           GRMD 22
C     gramtraj) may be modified accordingly.                            GRMD 23
C                                                                       GRMD 27
      Double Precision ctime,chgt,clat,clon,dctime,dchgt,dclat,dclon,   GRMD 28
     & dmean,pmean,tmean,umean,vmean,wmean,dpert,ppert,tpert,upert,     GRMD 29
     & vpert,wpert,dstand,pstand,tstand,pobs,dobs,tobs,uobs,vobs,wobs   GRMD 30
C                                                                       GRMD 32
      Data pobs,dobs,tobs,uobs,vobs,wobs/6*0.0D0/                       GRMD 32a
C                                                                       GRMD 32b
C     Open a file for dummy test output data                            GRMD 32c
      Open(unit=69,file='gtout.txt')                                    GRMD 33
C                                                                       GRMD 33a
C     Initialize the time (sec) and position (height, km; latitude,     GRMD 33b
C     deg N; longitude, deg E)                                          GRMD 33c
      Call setipos(ctime,chgt,clat,clon)                                GRMD 34
C                                                                       GRMD 35
C     ifirst is used as a parameter to trigger GRAM initialization      GRMD 36
C     (ifirst = 1), and to be used as a return code to trigger any      GRMD 37
C     desired actions by the main program.  In this example, ifirst     GRMD 38
C     = 0 causes recycle to next position; ifirst = -1 causes           GRMD 39
C     re-initialization of position (and velocity) values;              GRMD 40
C     ifirst < -1 causes the program to terminate                       GRMD 41
C                                                                       GRMD 42
C     Initialize the atmospheric variables with the gramtraj routine    GRMD 43
C                                                                       GRMD 44
      ifirst = 1                                                        GRMD 45
C                                                                       GRMD 45a
C...  Sample of how to set initial perturbations:                       GRMD 45b
C...  To set initial perturbations to observed values (pobs, dobs,      GRMD 45c
C     tobs, uobs, vobs, wobs) set iobsset to 1, and use initpert = 1    GRMD 45d
C     on the NAMELIST input.                                            GRMD 45e
C...  To avoid this option and use GRAM-generated initial perturbations GRMD 45f
C     set iobsset to 0 and use initpert = 0 on the NAMELIST input.      GRMD 45g
      iobsset = 1                                                       GRMD 45h
C...  Only set initial perturbations to observed if iobsset = 1         GRMD 45i
      If (iobsset.eq.1)Then                                             GRMD 45j
        uobs = 99.9d0                                                   GRMD 45k
        vobs = 8.8d0                                                    GRMD 45l
        wobs = 0.99d0                                                   GRMD 45m
        pobs = 8.0d+1                                                   GRMD 45n
        dobs = 1.0d-3                                                   GRMD 45o
        tobs = 2.7d+2                                                   GRMD 45p
      Endif                                                             GRMD 45q
      ppert = pobs                                                      GRMD 45r
      dpert = dobs                                                      GRMD 45s
      tpert = tobs                                                      GRMD 45t
```

```
      upert = uobs
      vpert = vobs
      wpert = wobs
C...  Call to gramtraj for setting initial values, including reading of
C     NAMELIST input file, GUACA data and atmosdat files
      Call gramtraj(ifirst,ctime,chgt,clat,clon,dmean,pmean,tmean,
     & umean,vmean,wmean,dpert,ppert,tpert,upert,vpert,wpert,dstand,
     & pstand,tstand,0)
C...  Test write thermodynamic variables (relative to US Standard) and
C     winds (m/s)
      Write(69,30)chgt,ppert/pstand,dpert/dstand,tpert/tstand,upert,
     & vpert,wpert,ifirst
C
C     Initialize the trajectory velocity (or position displacement)
C     values (if initialization is necessary)
C
      Call newpos(ifirst,ctime,chgt,clat,clon,dctime,dchgt,dclat,dclon)
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,dctime,dchgt,dclat,dclon)
C
C     Evaluate the atmospheric parameters at the new position
C
C...  Following is a special feature that initiates a reset of the
C     perturbation values somewhere in the middle of the run (60 km
C     altitude in this example), without a complete re-initialization,
C     including reading of NAMELIST input, GUACA and atmosdat files.
C...  An example application of this feature is a set of Monte-Carlo
C     profiles that use GRAM values all the way for the thermodynamic
C     variables, but switch from measured winds to GRAM winds at some
C     point in the trajectory (e.g. 60 km in this example) where the
C     measured wind data run out.  NOTE THAT MEASURED DATA ARE NOT
C     PROVIDED IN THIS EXAMPLE.
      If (Abs(chgt-60.).lt.0.01)Then
C...    To use this feature, substitute observed data values here with
C       which to re-initialize the GRAM perturbations.  DO NOT RE-SET
C       ANY VALUES (vertical wind, wpert, in this example) for which
C       continuous GRAM values are desired rather than the match-up
C       with observed data values.  To avoid this feature, set 60 km in
C       the above IF statement to 99999 or other impossible condition.
        dpert = dstand
        ppert = pstand
        tpert = tstand
        upert = 66.
        vpert = 16.
C...    wpert = NOT RE-SET
        Call gramtraj(ifirst,ctime,chgt,clat,clon,dmean,pmean,tmean,
     &   umean,vmean,wmean,dpert,ppert,tpert,upert,vpert,wpert,dstand,
     &   pstand,tstand,1)
      Else
C...    Call to gramtraj for next trajectory position, if midpoint
C       reset feature is NOT used
        Call gramtraj(ifirst,ctime,chgt,clat,clon,dmean,pmean,tmean,
     &   umean,vmean,wmean,dpert,ppert,tpert,upert,vpert,wpert,dstand,
     &   pstand,tstand,0)
      Endif
C...  Test write out thermodynamic values and winds
C     Note: If nmax = 1 is read from the namelist input file, this
C     will write an (incorrect) second output line.  For nmax > 1
C     all output is written correctly
      Write(69,30)chgt,ppert/pstand,dpert/dstand,tpert/tstand,upert,
```

```
     & vpert,wpert,ifirst                                               GRMD 70a
   30 Format(F9.2,3F9.3,3F9.1,I3)                                       GRMD 71
c                                                                       GRMD 72
c     Repeat the cycle or terminate, depending on the return value      GRMD 73
c     of the parameter ifirst                                           GRMD 74
c                                                                       GRMD 75
      If (ifirst.eq.0)Goto 20                                           GRMD 76
      If (ifirst.eq.-1)Then                                             GRMD 77
c                                                                       GRMD 78
c       Re-initialize the velocity or position displacement values      GRMD 79
c       (if necessary)                                                  GRMD 80
c                                                                       GRMD 81
        ppert = pobs                                                    GRMD 81b
        dpert = dobs                                                    GRMD 81c
        tpert = tobs                                                    GRMD 81d
        upert = uobs                                                    GRMD 81e
        vpert = vobs                                                    GRMD 81f
        wpert = wobs                                                    GRMD 81g
c...    Call to gramtraj for re-initializing at beginning of next       GRMD 81h
c       Monte-Carlo profile                                             GRMD 81i
        Call gramtraj(ifirst,ctime,chgt,clat,clon,dmean,pmean,tmean,    GRMD 82
     &   umean,vmean,wmean,dpert,ppert,tpert,upert,vpert,wpert,dstand,  GRMD 83
     &   pstand,tstand,0)                                               GRMD 84
c...    Test write out thermodynamic variables and winds                GRMD 84a
        Write(69,30)chgt,ppert/pstand,dpert/dstand,tpert/tstand,upert,  GRMD 85
     &    vpert,wpert,ifirst                                            GRMD 85a
c...    Re-set initial trajectory position for next Monte-Carlo profile GRMD 85b
        Call newpos(ifirst,ctime,chgt,clat,clon,dctime,dchgt,dclat,     GRMD 86
     &    dclon)                                                        GRMD 87
        Goto 20                                                         GRMD 88
      Endif                                                             GRMD 89
c                                                                       GRMD 90
c     Terminate for any other values of ifirst                          GRMD 91
c                                                                       GRMD 92
      End                                                               GRMD 93
c---------------------------------------------------------------------- GRMD 94
      Subroutine setipos(ctime,chgt,clat,clon)                          STIP  1
c                                                                       STIP  2
c...  Dummy subroutine to set initial time (sec) and position (height,  STIP  3
c     km; latitude, degrees, North positive; longitude, degrees, East   STIP  4
c     positive).                                                        STIP  5
c                                                                       STIP  6
      Double Precision ctime,chgt,clat,clon                             STIP  7
c                                                                       STIP  8
      ctime = 0.0D0                                                     STIP  9
      chgt = 50.0D0                                                     STIP 10
      clat = 28.45D0                                                    STIP 11
      clon = -80.53D0                                                   STIP 12
      Return                                                            STIP 13
      End                                                               STIP 14
c---------------------------------------------------------------------- STIP 15
      Subroutine newpos(ifirst,ctime,chgt,clat,clon,dctime,dchgt,dclat, NEWP  1
     &  dclon)                                                          NEWP  2
c     Dummy subroutine to update the position and velocity              NEWP  3
c                                                                       NEWP  4
c     Initialize the velocity (or position displacement) if ifirst is   NEWP  5
c     not zero.  dtime = time step (sec), dchgt = height increment per  NEWP  6
c     time step (km), dclat = latitude increment per time step (deg N), NEWP  7
c     dclon = longitude increment per time step (deg E)                 NEWP  8
c                                                                       NEWP  9
c                                                                       NEWP 10
      Double Precision ctime,chgt,clat,clon,dctime,dchgt,dclat,dclon    NEWP 11
c                                                                       NEWP 12
      If (ifirst.ne.0)Then                                              NEWP 13
        dctime = 1.0D0                                                  NEWP 14
        dchgt = 0.1D0                                                   NEWP 15
        dclat = 0.0D0                                                   NEWP 16
```

```
        dclon = 0.0D0                                                   NEWP 17
      Else                                                              NEWP 18
C                                                                       NEWP 19
C       Update the position (and velocity, if necessary), if ifirst     NEWP 20
C       is zero                                                         NEWP 21
C                                                                       NEWP 22
        ctime = ctime + dctime                                          NEWP 23
        chgt = chgt + dchgt                                             NEWP 24
        clat = clat + dclat                                             NEWP 25
        clon = clon + dclon                                             NEWP 26
C                                                                       NEWP 27
C       Treat special case when trajectory passes over the poles        NEWP 28
        If(Dabs(clat).gt.90.0D0)Then                                    NEWP 29
          clat=Dsign(180.0D0-Dabs(clat),clat)                           NEWP 30
          clon=clon+180.0D0                                             NEWP 31
          dclat = -dclat                                                NEWP 32
        Endif                                                           NEWP 33
C       Treat special cases if longitude outside +/- 180 degrees        NEWP 34
        If(clon.lt.-180.0D0)clon=clon+360.0D0                           NEWP 35
        If(clon.ge.180.0D0)clon=clon-360.0D0                            NEWP 36
      Endif                                                             NEWP 37
      Return                                                            NEWP 38
      End                                                               NEWP 39
C----------------------------------------------------------------------- NEWP 40
      Subroutine gramtraj(ifirst,ctime,chgt,clat,clon,dmean,pmean,      GRMT  1
     & tmean,umean,vmean,wmean,dpert,ppert,tpert,upert,vpert,wpert,     GRMT  2
     & dstand,pstand,tstand,initcall)                                   GRMT  3
C     GRAM subroutine for use in user-provided trajectory program       GRMT  4
C     ifirst = parameter to trigger initialization and to be used as    GRMT  5
C              a return code to trigger any desired actions by the      GRMT  6
C              main program                                             GRMT  7
C     ctime = current elapsed time from beginning of trajectory (sec)   GRMT  8
C     chgt = current height (km)                                        GRMT  9
C     clat = current latitude (degrees, North positive)                 GRMT 10
C     clon = current longitude (degrees, East positive)                 GRMT 11
C     dmean = mean atmospheric density (kg/m**3)                        GRMT 12
C     pmean = mean atmospheric pressure (N/m**2)                        GRMT 13
C     tmean = mean atmospheric temperature (K)                          GRMT 14
C     umean = mean E-W wind (m/s, positive toward East)                 GRMT 15
C     vmean = mean N-S wind (m/s, positive toward North)                GRMT 16
C     wmean = mean vertical wind (m/s, positive upward)                 GRMT 17
C     dpert = perturbed value of atmospheric density                    GRMT 18
C     ppert = perturbed value of atmospheric pressure                   GRMT 19
C     tpert = perturbed value of atmospheric temperature                GRMT 20
C     upert = perturbed value of E-W wind                               GRMT 21
C     vpert = perturbed value of N-S wind                               GRMT 22
C     wpert = perturbed value of vertical wind                          GRMT 23
C     dstand = 1976 US standard value of atmospheric density            GRMT 24
C     pstand = 1976 US standard value of atmospheric pressure           GRMT 25
C     tstand = 1976 US standard value of atmospheric temperature        GRMT 26
C                                                                       GRMT 27
      Double Precision ctime,chgt,clat,clon,dmean,pmean,tmean,umean,    GRMT 28
     & vmean,wmean,dpert,ppert,tpert,upert,vpert,wpert,dstand,pstand,   GRMT 29
     & tstand                                                           GRMT 29a
C                                                                       GRMT 30
      Real n2ond,n2nd                                                   GRMT 31
      Character*1 dirsep,endsep,termchar                                GRMT 32
      Character*16 scrstat,sysform                                      GRMT 33
      Character*12 namefile                                             GRMT 33a
      Common /iotemp/phi1,phi,dummy1(10),h1,dummy2(2),h,dummy3(3),      GRMT 34
     & dummy4(2),elt,dummy5(19),idummy1(6),nmore,idummy4,sec            GRMT 35
C                                                                       GRMT 36
      Common /iucom/idummy5,iur,iup,idummy6(2),iopr,iun,iurra           GRMT 37
      Common /timeo/thet,thet1,dummy6,dphi,dthet,dhgt,delt,dummy7,ho,   GRMT 38
     & phio,theto,dphio,idummy7(2),nmax,iopt,nt,idummy8,nr1,phidens     GRMT 39
      Common /dircom/dirsep,endsep,termchar,scrstat,sysform             GRMT 40
      Common /readcom/iswap,iblwd,irlbw,nhdr                            GRMT 41
```

```
      Common/wincom/dh,dummy8(4),ugh,vgh,th,dummy9(2),ph,wgh,dummya      GRMT 42
      Common /vert/dummyb(2),wrh,swh,dummyc(29)                          GRMT 43
      Common /datacom/pgh,dgh,tgh,pghp,dghp,tghp,uh,vh,wh,php,dhp,thp,   GRMT 44
     & eofT,rhov,tdgh,rhp,seofT,srhov,stdgh,srhp                         GRMT 45
      Common /speccom/ppmh2o,ppmn2o,ppmch4,ppmn2,ppmo,ppmhe,ppmo3,       GRMT 46
     & ppmco,ppmco2,ppmo2,ppmar,ppmh,h2ond,n2ond,ch4nd,o3nd,cond,co2nd   GRMT 47
      Common /jaccon/n2nd,o2nd,ond,arnd,hend,hnd,dummyd,dmdz             GRMT 48
      Common/comper/sph,sdh,sth,prh,drh,trh,urh,vrh,suh,svh,dummye,      GRMT 49
     & prhs,drhs,trhs,urhs,vrhs,prhl,drhl,trhl,urhl,vrhl,                GRMT 50
     & sphs,sdhs,sths,suhs,svhs,sphl,sdhl,sthl,suhl,svhl                 GRMT 51
      Common /pertinit/initpert,rpinit,rdinit,rtinit,ruinit,rvinit,      GRMT 51a
     &  rwinit                                                           GRMT 51b
c                                                                        GRMT 52
c     Initialize everything if ifirst = 1                                GRMT 53
c                                                                        GRMT 54
      If (ifirst.eq.1)Then                                               GRMT 55
c                                                                        GRMT 56
c       Change the following to suit your system characteristics         GRMT 57
        iswap = 0                                                        GRMT 58
        iblwd = 0                                                        GRMT 59
        irlbw = 0                                                        GRMT 60
        iur = 5                                                          GRMT 61
        nhdr = 45                                                        GRMT 62
        dirsep = '\'                                                     GRMT 63
        endsep = '\'                                                     GRMT 64
        termchar = ' '                                                   GRMT 65
        scrstat = 'scratch'                                              GRMT 66
        sysform = 'binary'                                               GRMT 67
c       Open file for NAMELIST input                                     GRMT 67a
        Write(*,*)' Enter NAMELIST INPUT file name'                      GRMT 67b
        Read(*,5)namefile                                                GRMT 67c
    5   Format(A)                                                        GRMT 67d
        Open(unit=iur,file=namefile,status='old',iostat=ioerr)           GRMT 67e
        If (ioerr.ne.0)Then                                              GRMT 67f
          Write(*,*)' File open error for NAMELIST file'                 GRMT 67g
          Stop                                                           GRMT 67h
        Endif                                                            GRMT 67i
c                                                                        GRMT 68
c       Call the GRAM initialization routine                             GRMT 69
c                                                                        GRMT 70
        Call init                                                        GRMT 71
c                                                                        GRMT 72
c       Store initial position values in commons                         GRMT 73
c                                                                        GRMT 74
        elt = 0.                                                         GRMT 75
        h1 = chgt                                                        GRMT 76
        phi1 = clat                                                      GRMT 77
        thet1 = clon                                                     GRMT 78
        iopt = 0                                                         GRMT 79
        ho = h1                                                          GRMT 80
        phio = phi1                                                      GRMT 81
        theto = thet1                                                    GRMT 82
        h = h1                                                           GRMT 83
        phi = phi1                                                       GRMT 84
        thet = thet1                                                     GRMT 85
c                                                                        GRMT 86
c       Evaluate atmospheric values at initial position                  GRMT 87
c                                                                        GRMT 88
c...    Use observed initial perturbations if dpert > 0 and upert ne 0   GRMT 88a
        If (dpert.ne.0.0D0.and.upert.ne.0.0D0)Then                       GRMT 88b
          If (iup.ne.0)Write(iup,10)                                     GRMT 88c
          If (iup.eq.0)Write(iu0,10)                                     GRMT 88d
        Endif                                                            GRMT 88e
   10   Format(/' GRAMTRAJ results to set initial perturbations:'/)      GRMT 88f
        Call randinit                                                    GRMT 89
        Call timestep(0.,0.,0.,0.)                                       GRMT 90
c...    Use input total (perturbed) values to compute initial            GRMT 90a
```

```
C       perturbation values if non-zero perturbed values are provided   GRMT 90b
        If (dpert.ne.0.0D0.and.upert.ne.0.0D0)Then                      GRMT 90c
          rpinit = 100.*(ppert - pgh)/pgh                               GRMT 90d
          rdinit = 100.*(dpert - dgh)/dgh                               GRMT 90e
          rtinit = 100.*(tpert - tgh)/tgh                               GRMT 90f
          ruinit = upert - ugh                                          GRMT 90g
          rvinit = vpert - vgh                                          GRMT 90h
          rwinit = wpert - wgh                                          GRMT 90i
          If(iup.ne.0)Write(iup,20)                                     GRMT 90j
          If(iup.eq.0)Write(iu0,20)                                     GRMT 90k
 20       Format(/' GRAMTRAJ results for prescribed observed data:'/)   GRMT 90l
          Call randinit                                                 GRMT 90m
          Call timestep(0.,0.,0.,0.)                                    GRMT 90n
          nt = nt -1                                                    GRMT 90o
        Endif                                                           GRMT 90p
      Else If (ifirst.eq.0) Then                                        GRMT 91
C                                                                       GRMT 92
C       Evaluate the atmospheric values at subsequent positions         GRMT 93
        delt = ctime - elt                                              GRMT 94
        dhgt = chgt - h1                                                GRMT 95
        dphi = clat - phi1                                              GRMT 96
        dthet = clon - thet1                                            GRMT 97
        If (Abs(dthet).gt.180.)dthet = dthet - Sign(360.,dthet)         GRMT 98
        If (nmax.gt.1)Then                                              GRMT 99a
          Call timestep(delt,dhgt,dphi,dthet)                           GRMT 98b
C         Section that executes new mid-point re-set process            GRMT 99
          If (initcall.eq.1)Then                                        GRMT 99a
            initsave = initpert                                         GRMT 99b
            initpert = 1                                                GRMT 99c
            rpinit = 100.*(ppert - pgh)/pgh                             GRMT 99d
            rdinit = 100.*(dpert - dgh)/dgh                             GRMT 99e
            rtinit = 100.*(tpert - tgh)/tgh                             GRMT 99f
            ruinit = upert - ugh                                        GRMT 99g
            rvinit = vpert - vgh                                        GRMT 99h
            rwinit = wpert - wgh                                        GRMT 99i
            If(iup.ne.0)Write(iup,20)                                   GRMT 99j
            If(iup.eq.0)Write(iu0,20)                                   GRMT 99k
            Call randinit                                               GRMT 99l
            Call timestep(0.,0.,0.,0.)                                  GRMT 99m
            initpert = initsave                                         GRMT 99n
            nt = nt -1                                                  GRMT 99o
          Endif                                                         GRMT 99p
        Else                                                            GRMT 99q
          nmore = 0                                                     GRMT100
        Endif                                                           GRMT100a
C                                                                       GRMT100b
C...    You can use any of the desired atmospheric parameter output     GRMT101
C       values here, e.g. by passing them to a subroutine (see list of  GRMT102
C       available output variables in the README files (also discussed  GRMT103
C       in Section 4.6 of the GRAM-95 report)                           GRMT104
C                                                                       GRMT105
        If(nmore.eq.0.or.(iopt.eq.0.and.nt.ge.nmax))Then                GRMT106
          If (iopr.eq.2)Then                                            GRMT107
C                                                                       GRMT108
C           If random option is off, return ifirst = -2 to signal the   GRMT109
C           driver program to terminate                                 GRMT110
C                                                                       GRMT111
            ifirst = -2                                                 GRMT112
            Return                                                      GRMT113
          Endif                                                         GRMT114
C                                                                       GRMT115
C         Read the next random number and re-initialize the position    GRMT116
C         and atmospheric variables.  Return a value of ifirst = -1     GRMT117
C         to tell the driver program that re-initialization was done    GRMT118
C                                                                       GRMT119
          ifirst = -1                                                   GRMT120
          nt = 0                                                        GRMT121
```

```
          nmore = 1                                                      GRMT122
          If (iun.eq.0)Then                                              GRMT123
C           Return the value ifirst = -9 if the driver program is to     GRMT124
C           terminate                                                    GRMT125
            ifirst = -9                                                  GRMT126
          Else                                                           GRMT127
            Read(iun,*,end=90)nrl                                        GRMT128
          Endif                                                          GRMT129
        Endif                                                            GRMT130
      Else                                                               GRMT131
C...    Re-set position to initial position for Monte-Carlo profile     GRMT131a
        h1 = ho                                                          GRMT132
        phi1 = phio                                                      GRMT133
        thet1 = theto                                                    GRMT134
        h = ho                                                           GRMT135
        phi = phio                                                       GRMT136
        thet = theto                                                     GRMT137
        elt = 0.0                                                        GRMT138
        ctime = 0.0                                                      GRMT139
        chgt = ho                                                        GRMT140
        clat = phio                                                      GRMT141
        clon = theto                                                     GRMT142
        If (dpert.ne.0.0D0.and.upert.ne.0.0D0)Then                       GRMT142a
          If (iup.ne.0)Write(iup,30)                                     GRMT142b
          If (iup.eq.0)Write(iu0,30)                                     GRMT142c
        Endif                                                            GRMT142d
  30    Format(/' GRAMTRAJ results to RE-SET initial perturbations:'/)   GRMT142e
        Call randinit                                                    GRMT143
        Call timestep(0.,0.,0.,0.)                                       GRMT144
C...    Re-set initial conditions for 1st position in next Monte-Carlo GRMT144a
C       profile                                                          GRMT144b
        If (dpert.ne.0.0D0.and.upert.ne.0.0D0)Then                       GRMT144c
          rpinit = 100.*(ppert - pgh)/pgh                                GRMT144d
          rdinit = 100.*(dpert - dgh)/dgh                                GRMT144e
          rtinit = 100.*(tpert - tgh)/tgh                                GRMT144f
          ruinit = upert - ugh                                           GRMT144g
          rvinit = vpert - vgh                                           GRMT144h
          rwinit = wpert - wgh                                           GRMT144i
          If(iup.ne.0)Write(iup,40)                                      GRMT144j
          If(iup.eq.0)Write(iu0,40)                                      GRMT144k
  40      Format(/' GRAMTRAJ RE-SET for prescribed observed data:'/)     GRMT144l
          Call randinit                                                  GRMT144m
          Call timestep(0.,0.,0.,0.)                                     GRMT144n
        Endif                                                            GRMT144o
      Endif                                                              GRMT145
      Goto 100                                                           GRMT146
  90  ifirst = -9                                                        GRMT147
C...  Convert single-precision GRAM variables to double precision       GRMT147a
C     trajectory variables                                               GRMT147b
 100  dmean = Dble(dgh)                                                  GRMT148
      pmean = Dble(pgh)                                                  GRMT149
      tmean = Dble(tgh)                                                  GRMT150
      umean = Dble(ugh)                                                  GRMT151
      vmean = Dble(vgh)                                                  GRMT152
      wmean = Dble(wgh)                                                  GRMT153
      dpert = Dble(dh)                                                   GRMT154
      ppert = Dble(ph)                                                   GRMT155
      tpert = Dble(th)                                                   GRMT156
      upert = Dble(uh)                                                   GRMT157
      vpert = Dble(vh)                                                   GRMT158
      wpert = Dble(wh)                                                   GRMT159
      dstand = Dble(dgh/(1. + dghp/100.))                                GRMT160
      pstand = Dble(pgh/(1. + pghp/100.))                                GRMT161
      tstand = Dble(tgh/(1. + tghp/100.))                                GRMT162
      Return                                                             GRMT163
      End                                                                GRMT164
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13. ABSTRACT *(Maximum 200 words)*

The latest version of Global Reference Atmospheric Model (GRAM-99) is presented and discussed. GRAM-99 uses either (binary) Global Upper Air Climatic Atlas (GUACA) or (ASCII) Global Gridded Upper Air Statistics (GGUAS) CD-ROM data sets, for 0-27 km altitudes. As with earlier versions, GRAM-99 provides complete geographical and altitude coverage for each month of the year. GRAM-99 uses a specially-developed data set, based on Middle Atmosphere Program (MAP) data, for 20-120 km altitudes, and NASA's 1999 version Marshall Engineering Thermosphere (MET-99) model for heights above 90 km. Fairing techniques assure smooth transition in overlap height ranges (20-27 km and 90-120 km). GRAM-99 includes water vapor and 11 other atmospheric constituents (O_3, N_2O, CO, CH_4, CO_2, N_2, O_2, O, A, He and H). A variable-scale perturbation model provides both large-scale (wave) and small-scale (stochastic) deviations from mean values for thermodynamic variables and horizontal and vertical wind components. The small-scale perturbation model includes improvements in representing intermittency ("patchiness"). A major new feature is an option to substitute Range Reference Atmosphere (RRA) data for conventional GRAM climatology when a trajectory passes sufficiently near any RRA site. A complete user's guide for running the program, plus sample input and output, is provided. An example is provided for how to incorporate GRAM-99 as subroutines in other programs (e.g., trajectory codes).

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