Users' Guide to the GENESIS Global Climate Model
Version 2.0

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1. INTRODUCTION

This document is a guide to the use of the GENESIS (Global ENvironmental and Ecological Simulation of Interactive Systems) global climate model version 2.0, developed by the Interdisciplinary Climate Systems (ICS) Section of the Climate and Global Dynamics Division at NCAR. GENESIS consists of coupled global models of the atmosphere, ocean, vegetation, soil, snow, icesheets, and sea ice. The atmospheric component is a 3-D atmospheric general circulation model (AGCM), coupled to the land-surface models by a Land-Surface-Transfer scheme (LSX) that computes surface fluxes through vegetation canopies. Vegetation distributions and physical attributes can be prescribed in three ways, one of which uses a new way of categorizing observed distributions and another uses the off-line results of a predictive vegetation model (EVE). The ocean can be represented either by prescribing present-day monthly climatological sea-surface temperatures (SSTs) and sea ice, or by a 50-m slab mixed-layer model and a dynamical sea-ice model.

GENESIS version 2.0 includes many improvements and changes from the previous version 1.02, both in scientific aspects and in the user interface. This document is an all-inclusive guide to the use of version 2.0 and does not assume any knowledge of earlier versions. For previous users familiar with version 1.02, a set of release notes is available that highlight the differences in the new version. The scientific formulation and basic results of GENESIS version 1.02 have been described in Thompson and Pollard (1995) and Pollard and Thompson (1994, 1995a), and a User's Guide to version 1.02 is still available from the authors (Pollard and Thompson, 1992). The scientific formulation and results of GENESIS version 2.0 will be described in several papers starting with Pollard and Thompson (1995b). Note that this guide is *not* intended as a physical model description nor as a documentation of the source code, although such information is included in small amounts where needed to understand the model usage.

As described in more detail below, GENESIS version 2.0 is backward compatible, *i.e.,* runs can be started using restart files generated by version 1.02. Moreover, the horizontal and vertical resolutions of a restart file do not have to agree with the current model resolutions, since input fields can be interpolated to the current resolutions at the start of a run. There are no changes to the formats of model history files, so all post-processing tools developed for version 1.02 will also work for version 2.0.

The model currently runs on two quite different computer systems: CRAY (X-MP, Y-MP, C90 machines with the UNICOS operating system), and Silicon Graphics (SGI Challenge machine with IRIX Unix operating system). On a CRAY, the model can make use of either the NCAR Mass Storage System (MSS) or a standard CRAY Data Migration System (DMS) for archiving output files. Just one set of model source code is maintained for both systems, with unavoidable differences in small code sections handled automatically by compiler pre-processing directives. In a few places below that include system-specific information, we assume a CRAY system for definiteness. The machine binary representation of real and integer numbers differs between these two systems (Cray format for CRAY, IEEE format for SGI), so their GENESIS restart and history files differ in that respect. However the GENESIS version 2.0 code includes a small set of routines that convert real and integer values between CRAY and IEEE formats, called automatically if a CRAY-generated restart file is read by an SGI program or vice-versa; thus GENESIS restart files and runs can be freely mixed between machines.

The model has two types of input that are read at the start of each run: (i) user-settable options entered as Namelist input within the job script, and (ii) a set of data input files containing certain prescribed global fields. Section 2 describes a sample Unix script used to run the model, with details of the Namelist input left to section 3. This input includes such options as the start and end times of the run, history filenames, history fields, on/off toggling of some model processes, etc.

Section 4 describes the data input files (global maps of topography, atmospheric ozone, gravity wave drag roughness, land-ocean-icesheet mask, soil texture, lake areal fraction, prescribed SSTs, etc.) that are read at the start of a run. Sets of data input files for the present climate are stored for various standard resolutions (R15, T31, T42 and $2°\times2°$) and are available to users (see Appendix C.2). Their content and format are described in section 4 in sufficient detail to allow users to generate new maps if desired (*e.g.,* for paleoclimatic simulations).

The model produces basically three types of output files: (i) binary history files containing selected global fields at particular times throughout a run, (ii) binary restart files containing a snapshot of the model state that can be used to initialize subsequent runs, and (iii) various relatively small ascii text files used for monitoring runs and selected details at isolated grid points. Section 5 discusses the binary history and restart files, and section 6 describes the ascii text files. In particular section 6.a walks through the sample "standard-output" run-monitor text file produced by the run script in section 2, and included in its entirety in Appendix D.

We have developed a number of pre and post-processing tools that users may find useful, and section 7 provides brief descriptions of them. They include programs for accessing GENESIS history files and extracting particular fields, converting history files to standard CCM1 format, converting history files to netCDF format, reading "REGHIS" files to drive the RegCM2 regional model, and reading or writing GENESIS-format data input files. These codes and many other GENESIS-related files are available by anonymous ftp as described in Appendix C.

As mentioned above, Appendix A lists all GENESIS version 2.0 history fields, and Appendix B describes the history-file format in detail. Appendix C contains a list of all GENESIS-related files available to users, including the sample job script and run-monitor files mentioned above, sets of data input files at various resolutions for the present day, model source code, and several pre or post-processing utility programs. Appendix D contains the complete sample run-monitor file corresponding to the job script of section 2, and Appendix E lists all program error and warning messages.

2. RUNNING THE MODEL

Figure 1 shows a sample Unix C-shell script used to run GENESIS version 2.0. The script starts with CRAY-specific QSUB lines giving batch-job resource information to the UNICOS Network Queuing System, which are ignored for interactive jobs or on other systems. Then two Unix variables $resa and $ress are set, used later in the script to select the AGCM and surface horizontal resolutions for this run. The next three sections of the script perform various setup operations, mostly specifying directory pathnames and obtaining the EVE data/restart file that will be needed by the model if the EVE vegetation method is used.

Next, the "cat" command is used to create a local file "interm" containing the Namelist parameter settings for this run; this file will be read as standard input by the model at the start of the run. In practice it is convenient to include these settings in the job script itself, but they are shown separately for clarity here in Fig. 2, and the <NAMELIST> line in Fig. 1 marks the place where they would be inserted. Included in the Namelist input are the pathname and filenames for permanent disposition of the model's history and restart files, saved automatically to those locations by the model during the run. The other output files generated by the model (all fort.<n> text files) are copied to the user's remote machine by the "rcp" commands at the end of the script. Namelist input, restart files, history files and other output files are discussed in detail in later sections.

After creating the "interm" file, the script next copies GENESIS data input files from permanent storage to the local directory. The suffixes $resa and $ress are used to select the files with the correct resolutions. Since the Namelist options in this example specify EVE vegetation (VEGTYPE = 2 in Fig. 2), neither of the other two vegetation files are needed (DSBIOME and WISCVEG) so those lines are commented out in Fig. 1. Similarly, since this is to be a prescribed-SST run (OCEANTYPE = 0 in Fig. 2), the line to get the ocean current file OCEAN is commented out.

Next, some cleanup of local output files is performed. For SGI machines only, the Unix stream editor "sed" removes comments and echo flags from the Namelist input file "interm" (since these are not recognized by SGI's Namelist), and the resulting text is prepended to the model standard-output file "fort.6".

The "$STOREXE/genexe_$resa_$ress" command in the script actually runs the model. $STOREXE has been set earlier to the pathname where standard version 2.0 executable files reside, and the suffix "_$resa_$ress" selects the one with the desired horizontal resolutions. On CRAY machines, the surrounding "ja" commands serve to write accounting information to the end of the standard-output file "fort.6" when the run finishes.

3. NAMELIST INPUT

Numerous parameters can be set by the user to control each run, inserted as a block in place of the <NAMELIST> line in the job script described above. This input is read by the program using Namelist I/O, whose format is described in detail in CRAY and SGI Fortran 77 reference manuals. Figure 2 shows a set of Namelist parameters for a typical model run. Note that for most model applications only a small subset of all possible parameters need be entered.

As shown in Fig. 2, the parameters are organised into three groups, one for the overall run including AGCM physics and history files, one for AGCM radiation and radiatively active trace gas amounts, and one for surface (or LSX) physics and history files. As in Fig. 2, the three groups must be entered as separate Namelist groups, with the overall-plus-AGCM group enclosed by the lines E$INPUT and ␣$END, the trace-gas group enclosed by E$RADOTG and ␣$END, and the LSX group enclosed by E$INPUTLSX and ␣$END, where ␣ means a blank space. The groups must occur in the order shown, but within each group the parameters can be entered in any order.

All possible Namelist input parameters for GENESIS version 2.0 are listed and discussed below. Note that there are four or five compulsory parameters that *must* be entered for each run, all in the first "overall" group, flagged by ∗...∗ in the subheaders below. All other parameters are assigned default values if not entered. The Fortran type of each parameter is shown in the subheaders as I for integer, R for real, A for character, or L for logical.

The first few parameters listed below control the timing of a run and its writing of history and restart files. The following principles may help to clarify the overall strategy:

- All time specifications are based on the standard 365-day Julian calendar with no leap years. Most times are given in terms of day number within the current year (or in 'MM/DD' format for convenience). Note that this constrains the timing sequence of history-file and restart-file writes in a multi-year run to a repeating one-year cycle.

- There is no distinction between "initial datasets" and "restart files". The model is always started or restarted from a restart file generated by a previous run (or can be "cold-started" from a zonally symmetric state as explained below).

- Any number of history fields (up to a hard-coded limit) can be chosen from a standard list, and each field can be flagged instantaneous or time-averaged.

- There are two separate streams of history files, one for AGCM fields and one for surface-model fields. The primary reason for this is that the horizontal grid sizes can differ, *e.g.,* $3.75° \times 3.75°$ (T31) for the AGCM and $2° \times 2°$ for the surface models, and post-processing is simpler if a file contains fields of just one horizontal size.

- The program does not read or write records directly to restart and history files in "permanent" areas (MSS for NCAR CRAYs, permanent disk directories for other systems). Instead, the program works on local files with generic names in its working directory, and copies them to or from the permanent files when appropriate. This process is transparent and the user need not be concerned with the generic file names in the working directory; however they are "NSRE" for initial and restart files, "NDATA" for AGCM history files, and "NDATALSX" for surface-model history files. Throughout this document various terms are used synonymously: "local area", "working area", "program area", etc., for the current working directory of the running program, and "permanent area", "permanent storage", etc., for the MSS directory (NCAR CRAYs) or permanent disk directory (other systems).

- The number of history "writes" on one history file is not an explicit parameter, but is determined by the interleaving of the history-write and next-file time lists. In other words, one set of header records and history fields is appended to the current history file each time a history-write time is reached. When a next-file time is reached, the current local history file is disposed to permanent storage using the current name in the history filename list, a new local history file is opened, and the position in the history filename list is incremented by one.

3.a. First Namelist Group (Overall and AGCM History Files)

3.a.1. Run-Timing and Initialization Parameters:

∗ **NSREST** ∗ (I)

Set to −1 for a cold start, 0 for an initial start, or 1 for a restart. For a cold start, the AGCM is initialized to a hard-coded zonally symmetric state with geostrophic east-west velocities and zero specific humidity. All surface-model fields are then initialized based on the AGCM temperature field. This is intended primarily for starting paleoclimatic experiments with very different geography and topography from the present. The initial latitudinal temperature distribution can be controlled using parameters TEQCOLD and TPOCOLD (see section 3.a.6 below).

For an initial start or a restart, the model is initialized from a previously generated restart file designated by MSNAMIN. The only major differences between the two are that for an initial start, (i) the base date is reset to the entered value of BASEDATE, (ii) the filename list pointer for history and restart files is reset to 1, (iii) the orbital elements are re-calculated for the entered BASEDATE, and (iv) the global budget accumulators (reported in fort.6) are reset to zero. Thus NSREST=0 essentially resets all the timing and history information but uses the fields from the end of a previous run. NSREST=1 is a true restart, with the interruption from the previous run having no effect on the results or the sequence of history files.

∗ **BASEDATE** ∗ (A)

Base date of the run, in form 'YY/MM/DD' or 'YYMMDD' (*e.g.,* '101/01/01' for January 1st, 2001). MM must be between 1 and 12, DD between 1 and 31, and YY can be any value with YY measured forward from 1900 AD if positive or zero, or backwards from 1950 AD if negative. (Thus YY=101 denotes 2001 AD, and YY=-6000 denotes 6000 BP, since the BP calendar is relative to 1950 AD.) This parameter must be entered for cold starts or initial starts (NSREST=−1 or 0), in which case the run begins at 00:00 GMT on BASEDATE. For restarts (NSREST=1) the base date is obtained from the restart file and the entered BASEDATE is ignored.

The only effect of YY is to set the appropriate orbital parameters for the insolation calculations using the time series in Berger (1978) (unless ECCU, OBLU, or PRECU are entered, as described below).

∗ **ENDDATE** ∗ (A)

The end date or time of the run. This can be a date in form 'YY/MM/DD' or 'YYMMDD', in which case the run will end at 24:00 GMT on that date. If an integer between -100000 and 100000 is entered between the quotes instead, this is interpreted as a whole number of days (if positive) or model timesteps (if negative) from 00:00 GMT on the base date BASEDATE. For instance if NSREST=–1 or 0, BASEDATE='101/01/01' and ENDDATE='102/12/31', the model will run from 00:00 GMT on January 1st 2001 to 24:00 GMT on December 31st 2002. ENDDATE='1021231', '730' or '–35040' would all be equivalent, the latter assuming a model timestep of 30 minutes. Note that the model uses a standard 365-day year, with no leap years.

∗ **MSNAMIN** ∗ (A)

Name of the file (up to 16 characters) used to initialize or restart this run. This is a "permanent" file, *i.e.,* it resides either on the MSS for NCAR CRAYs, or in a permanent disk area or DMS storage for other CRAYs or SGI machines, and is copied into the local area by the program. It must be a GENESIS restart file generated by a previous model run, and contains a complete description of an instantaneous state of the model, including all prognostic AGCM and surface-model fields. It is not overwritten by the current run (unless also named by MSNAMRES or MSNAMRE2; see below).

GENESIS version 2.0 is backward compatible, *i.e.,* it can read restart files generated by version 1.02, setting missing fields to reasonable or null values. Moreover, the horizontal and vertical resolutions of the initial/restart file do not have to agree with the current model resolutions, although if different they do have to be specified by other Namelist parameters (see LEVRES, HORRES and HORRESLSX below).

In that case the input fields are interpolated to the current model grids, using bilinear interpolation for continuous fields or nearest-neighbor for discrete fields.

For initial starts or restarts (NSREST=0 or 1) MSNAMIN must be entered, whereas for cold starts (NSREST=–1) MSNAMIN must not be entered or be set to blank. (It is ignored if MSPATHIN is blank, see below.)

MSPATHIN (A)

The pathname of the permanent storage area (MSS directory for NCAR CRAYs, or permanent-disk directory for other systems), to be prepended to the initial/restart filename MSNAMIN. MSPATHIN must include a trailing '/' and can be up to 80 characters long. If MSPATHIN is entered as blank (' '), the program ignores MSNAMIN and does not attempt to copy an initial/restart file from a permanent area, but assumes one already exists in the local area with the program's generic name NSRE. MSPATHIN defaults to the value of MSPATH (see below).

LEVRES (I)

The AGCM vertical resolution (number of vertical levels) of the model that generated the restart file MSNAMIN used to initialize or restart this run. If this is different from the current AGCM resolution, LEVRES must be entered, and atmospheric 3-D input fields are linearly interpolated in sigma/hybrid coordinates to the current AGCM vertical grid. If restarting from version 1.02 files, LEVRES should be set to 12. The standard number of vertical levels in version 2.0 is 18.

HORRES (I,I)

The AGCM horizontal resolution (number of longitudes, number of latitudes) of the model that generated the restart file MSNAMIN used to initialize or restart this run. If either of these differ from the current AGCM resolution, HORRES must be entered and atmospheric input fields are bilinearly interpolated to the current AGCM horizontal grid. If restarting from version 1.02 files with R15 AGCM resolution, HORRES should be set to 48,40.

HORRESLSX (I,I)

The surface-model horizontal resolution (number of longitudes, number of latitudes) of the model that generated the restart file MSNAMIN used to initialize or restart this run. If either of these differ from the current surface model resolution, HORRESLSX must be entered and surface-model input fields are interpolated to the current surface grid (using bilinear interpolation for continuous fields or nearest-neighbor for discrete fields). If restarting from version 1.02 files with R15 surface resolution, HORRESLSX should be set to 48,40. If the surface resolution was $2^\circ \times 2^\circ$, HORRESLSX should be 180,90.

3.a.2. AGCM History File and Restart File Parameters:

MSNAMHIS (A)

A list of up to 1000 filenames (up to 16 characters) for AGCM history files. At times designated by NNEXF, the current history file in the local area (with generic name NDATA) is copied to permanent storage using the current MSNAMHIS filename, a new local history file (NDATA) is started in the working area, and the filename list pointer is incremented by 1 (see NNEXF below). If a single filename is entered and it contains an asterisk ($*$) or string of asterisks, the list is expanded automatically to 1000 entries with the asterisk(s) replaced by '001', '002', '003', etc. Defaults to 'HIST001', 'HIST002', 'HIST003', etc.

MSNAMHIS is the dominant filename list in the sense that it sets the list length for the other filename lists (MSNAMRES and MSNAM_A). Any blank entries in the other lists are filled by appending various suffixes to the corresponding MSNAMHIS entry. Embedded blank entries in the MSNAMHIS list are not allowed.

MSNAMRES (A)

A list of up to 1000 filenames (up to 16 characters) for the model restart files. At times designated by NNEXF, a model restart file is written and copied to permanent storage, and the filename list pointer is incremented by 1 (see NNEXF below). Just as for MSNAMHIS, a single entry containing an asterisk (∗) is expanded automatically to 1000 entries with the asterisk replaced by '001', '002', '003', etc. Defaults to the AGCM history filename list MSNAMHIS with 'RES' appended to each entry.

MSNAMRE2 (A)

A *single* filename (up to 16 characters) for an extra copy of the restart file (over)written at each NSAVE and NNEXF time. The idea is for the user to make this the same as MSNAMIN, so that for restart runs (NSREST=1) the model will effectively restart from the previous NSAVE/NNEXF time in the event of a machine shutdown. Defaults to no extra copy written.

NNEXF (I or A for CRAY, I for SGI)

A list of day numbers at which a set of model restart and history files are saved to permanent storage, new history files are started on the disk and the filename list pointer is incremented. Just as for NSAVE and NHISI, the NNEXF day numbers are relative to the current year, *e.g.,* 60 implies March 1st of any year, and the files are written at the end (24:00 GMT) of each day.

If NNEXF is negative, units of model timesteps are assumed. Alternatively on CRAY systems, NNEXF entries can be written as characters in 'MM/DD' format, *e.g.,* '3/1' for March 1st. This is not possible on SGI systems since their Namelist does not allow type mismatches. NNEXF defaults to the single entry 365, *i.e.,* December 31st of each year.

For simplicity NNEXF applies equally to all three output file types (restart, AGCM history, LSX history), rather than having three separate timing lists. As each NNEXF time is reached, one of each requested file type is written to permanent storage and the pointer to the MSNAMRES, MSNAMHIS and MSNAM_A lists is incremented by one. Thus there is a one-to-one correspondence between all three filename lists.

Not all of the files in a filename list need be written by a run, so that the user does not have to keep updating them in the Namelist input during a series of connected runs. The list pointer is stored on the restart file to be read by the next run, so the process is transparent if the user does not change the filename lists between restarts. (In fact the list pointer from the previous restart file is used even if the user *has* changed the lists, in which case care should be taken to avoid overwriting earlier files.) If the end of a run does not coincide with a NNEXF time, a subsequent restart will correctly access the previous history file and append to it if necessary. Note that this paragraph applies only to restarts (NSREST=1); for cold starts or initial starts (NSREST=–1 or 0) the model always starts at the beginning of the lists.

$*$ **MSPATH** $*$ (A)

The pathname of the permanent storage area (MSS directory for NCAR CRAYs, or permanent-disk directory for other systems), to be prepended to all restart and history files written by this run (MSNAMRES, MSNAMHIS and MSNAM_A). MSPATH must include a trailing '/' and can be up to 80 characters long. If a blank string is entered (' '), the program ignores MSNAMRES, MSNAMHIS and MSNAM_A, and runs without saving any permanent files, but still generates (and possibly overwrites) restart and history files in the local disk area with generic names NSRE, NDATA and NDATALSX. This is useful for making quick diagnostic runs with minimal I/O delays.

PASSWD (A)

The write-password (up to 8 characters) for all restart and history files written to the NCAR MSS. Ignored for other systems. Defaults to no write-password.

RETPD (R)

The retention period in days for all restart and history files written to the NCAR MSS. Ignored for other systems. Defaults to 30 days.

NSAVE (I or A for CRAY, I for SGI)

A list of day numbers at which the current history files are copied and a restart file is written and copied to permanent storage, as insurance against a system crash before the next NNEXF time. Unless an NSAVE time coincides with a NNEXF time, the filename list pointer is not incremented. This NSAVE action is also performed automatically at the last timestep of a run (if not already designated by NNEXF).

Presumably most users will select NSAVE times that are more frequent than the NNEXF times, but less frequent than the NHISI (history-write) times. It would be a waste of I/O to specify more than one NSAVE time between consecutive pairs of NHISI history writes, since exactly the same file would be copied twice to permanent storage.

Just as for NHISI and NNEXF, NSAVE day numbers are relative to the current year, *e.g.,* 60 implies March 1st of any year, and the history write occurs at 24:00 GMT of each day. If NSAVE is negative, units of model timesteps are assumed. Alternatively on CRAY systems, NSAVE entries can be written as characters in 'MM/DD' format, *e.g.,* '3/1' for March 1st. NSAVE defaults to the entered NHISI values.

FATALWMS (L)

If true (.T.), the program aborts if an error occurs in the saving of a history or restart file to the permanent area (at NSAVE or NNEXF times). If false (.F.), the program continues without having successfully saved the file, *i.e.,* with potential loss of data. Defaults to false.

3.a.3. AGCM History-Write Parameters:

NHISI (I or A for CRAY, I for SGI)

A list of day numbers at which a set of AGCM history fields (called a history "write") is written to the current AGCM history disk file, and any time-averaged fields are reset for the next write. Note that this action is *not* performed automatically at the end of a calendar year, nor at next-file (NNEXF) times, nor at the end of a run. So if these times do not coincide with entered NHISI times, some information may be lost for time-averaged fields.

Just as for NNEXF and NSAVE, NHISI day numbers are relative to the current year, *e.g.,* 60 implies March 1st of any year, and the history write occurs at 24:00 GMT of each day. If NHISI is negative, units of model timesteps are assumed. Alternatively on CRAY systems, NHISI entries can be written as characters in 'MM/DD' format, *e.g.,* '3/1' for March 1st. If one and only one numeric (non 'MM/DD') value is entered, it is interpreted as a repeating interval and all multiples from the beginning of the year become NHISI times. NHISI defaults to 12 values corresponding to the last day of each calendar month.

NDHIS (I)

Time in days over which time-averaged AGCM history fields (see CUSHNAM below) are to be accumulated prior to NHISI history writes. A negative value is assumed to be in units of model timesteps. Defaults to the current interval between NHISI times, *i.e.,* time-averaged fields are accumulated 100% of the time. There is no year-end cutoff; *i.e.,* the time-averaging interval for the first history write in a year can extend back past January 1st into the previous calendar year.

CUSHNAM (A)

A list of AGCM history field names to be written to AGCM history files generated by the current run. These must be valid AGCM field names chosen from the standard list in Appendix A.1. At each NHISI time one set of CUSHNAM fields is written to the current AGCM history file. Each field can either be instantaneous or averaged over a previous time interval (NDHIS days). By default all fields are time-averaged, and are changed to instantaneous by appending an asterisk ($*$) to the name in the CUSHNAM list, *e.g.,* ORO$*$ and TOPOG$*$ in Fig. 2. Defaults to no requested fields, *i.e.,* no AGCM history files generated.

NDENS (I)

The packing density to be used for AGCM history-file *data* records on NCAR CRAY systems, passed to the NCAR CRAY library routine PACKA. NDENS must be between 1 (no packing) and 4 (densest packing), and defaults to 1. Ignored for systems other than NCAR CRAYs.

3.a.4. Diagnostic Output Parameters (no effect on results):

BUDFREQ (R)

Length of time in days between AGCM and Surface budget reports and resets. Global budget quantities are time averaged and written to the standard output file fort.6 every BUDFREQ days, measured from the base date BASEDATE. Defaults to 365 days.

LONOLSX and **LATOLSX** (I)

Longitude and latitude of the output point for the surface-model tabular "dump" files fort.50-55 described in section 6.b. If LONOLSX or LATOLSX do not lie exactly on the surface grid, the nearest grid point is used. Longitudes are in degrees eastward from Greenwich (–360 to 360), and latitudes are in degrees north. Default to (–65,–3), *i.e.,* Amazonia.

TIMOLSX (R)

Length of time in hours between outputs to the surface-model "dump" files fort.50-55. One line representing instantaneous surface conditions at coordinates (LONOLSX, LATOLSX) is written to each of these files every TIMOLSX hours. Defaults to 3 hours. If a value less than the model timestep (see DTIME below) is entered including zero, a line is written every timestep.

REGHIS (A)

Prefix part of the name for the AGCM stream of RegCM2-driver files. A stream of history-like files can be written, designed to facilitate the subsequent driving of regional climate models such as RegCM2 (*e.g.,* Giorgi *et al.*, 1993). These are binary files, written at regular intervals (typically 12 hours) and containing a hard-coded set of instantaneous global fields required to drive such models. A post-processing utility is available (see section 7.d and Appendix C.6) that includes code to read them that can be adapted to generate regional-model input files.

Two local files in the working area are used, called REGHIS and REGHISLSX for AGCM fields and surface fields respectively (not to be confused with the

Namelist parameters of the same name). At the end of each month, each is saved to permanent storage (see REGPATH below) using names with prefixes given by the Namelist parameters REGHIS and REGHIS_A, and with suffixes such as _2001_JAN indicating the calendar year and month. For instance, if REGHIS = 'EG', REGHISLSX = 'EGLSX', REGFREQ = 12 hours (see below), and the run starts on January 1st 2001, then the first files would be saved at the end of January with names EG_2001_JAN and EGLSX_2001_JAN, each containing 62 sets of fields from 12:00 GMT January 1st to 24:00 GMT January 31st. REGHIS can be up to 16 characters long, and defaults to no files written.

REGHIS_A (A)

Prefix part of the name for the surface-model (LSX) stream of RegCM2-driver files. REGHIS_A can be up to 16 characters long, and defaults to the entered string for REGHIS with 'LSX' appended, or to no files written if REGHIS is not entered either.

REGPATH (A)

The pathname of the permanent storage area (MSS directory for NCAR CRAYs, or permanent-disk directory for other systems), to be prepended to all regional-model driver files written by this run if REGHIS and/or REGHIS_A are entered. REGPATH must include a trailing '/' and can be up to 80 characters long. If a blank string is entered (' '), the program does not dispose the local REGHIS and REGHISLSX files to permanent storage (and overwrites them each month). REGPATH defaults to MSPATH, the permanent area for GENESIS history and restart files (see above).

REGFREQ (R)

The time interval between successive writes to the RegCM2-driver files (see REGHIS and REGHIS_A above), in hours. Defaults to 12 hours.

RUNTITLE (A)

Title (up to 80 characters) for the current run, stored on history and restart files generated by this run. If the last three characters are '...', they are replaced on the history file header records by the current value of the file list pointer. For instance, if RUNTITLE='test ...', the first history file will have 'test 001', the second will have 'test 002', etc. Defaults to blank for cold starts or initial starts (NSREST=–1 or 0), or to that on the previous restart file for restarts (NSREST=1).

SHOWMAPS (L)

If true (.T.), two-dimensional global maps of the data input fields (section 4) are printed to the standard output file fort.6 (section 6.a) at the beginning of the run. Defaults to false (.F.).

3.a.5. Parameters Affecting Results, primarily AGCM:

DELEVTYPE (I)

The topography specified by the data input file TOPOG (see section 4.a.1) is spectrally truncated by the AGCM, which causes Gibbs-ringing near the edges of steep mountain ranges and a spurious lowering of smaller features such as Greenland (Navarra *et al.*, 1994). In GENESIS version 2.0 this can be alleviated by a crude correction to the surface-air temperature passed to the surface models, proportional to the difference in elevation between the truncated and untruncated topography fields at each point. The downward infrared radiation at the surface is also crudely corrected. If DELEVTYPE = 0, no correction is applied. If DELEVTYPE = 1, the correction is applied everywhere. If DELEVTYPE = 2, the correction is applied only over the Greenland and Antarctic icesheets (since their surface-air temperatures are important to mass-balance studies). See the TOPOG2 data input file described in section 4.b.9. Defaults to 0 (no correction).

DIURNAV (L)

If true (.T.), the diurnal cycle is eliminated from the model by using daily-mean solar insolation. Defaults to false (.F.).

DTIME (R)

The overall AGCM and surface model timestep in seconds. Defaults to 1800.

ECCU, OBLU, PRECU (R)

By default, the orbital parameters (eccentricity, obliquity, precession) are set as follows: for initial and cold starts they correspond to the real Earth orbit for the base year in BASEDATE using the time series in Berger (1978), and for restarts they are set to the values used in the previous run. Alternatively they can be prescribed by the parameters ECCU=eccentricity, OBLU=obliquity, and/or PRECU=precession. If a subset of these parameters is entered, the non-entered ones are set to the default values just described. OBLU and PRECU are in positive degrees, and PRECU is the prograde angle from perihelion to the Northern Hemispheric vernal equinox (which differs from some other definitions by multiples of 90°).

GWROUGH (R)

If entered, the sub-grid orographic roughness is set to that single value (in meters) over land, and to zero over ocean. This field is used as a source term in the model's gravity-wave parameterization (McFarlane, 1987). If GWROUGH is not entered or is negative, this field is read from the data input file GWD as described in section 4.a.2. If GWROUGH is set to zero, gravity wave drag is effectively turned off.

JANUARY (L)

If true (.T.), the date is always January 16th as far as prescribed fields are concerned (insolation, ozone, vegetation, and SSTs if OCEANTYPE = 0). All other model functions are unaltered, including the diurnal cycle and history-write timing. Defaults to false (.F.).

JULY (L)

If true (.T.), the date is always July 16th as far as prescribed fields are concerned, and the same remarks as for JANUARY apply. Defaults to false (.F.).

3.a.6. Parameters Affecting Results, primarily Surface Models:

OCEANTYPE (I)

If OCEANTYPE = 0, sea-surface temperatures and sea-ice extents are prescribed from monthly climatological SSTs in the data input file SSTICE (see section 4.b.8), linearly interpolated in time from the dataset's mid-month values. If OCEANTYPE = 1, these fields are predicted by the GENESIS slab mixed-layer model and sea-ice model. Defaults to 1.

DYNAMICE (L)

If true (.T.), sea ice is advected using a "cavitating-fluid" model (Flato and Hibler, 1990, 1992; Pollard and Thompson, 1994). If false (.F.), sea-ice dynamics is deactivated and all sea-ice processes are local to each grid point. (Also see PRESCOUV below regarding ocean currents). DYNAMICE defaults to true.

QFACTOR (R)

Factor multiplying the oceanic heat diffusion coefficient in the slab ocean model (OCEANTYPE = 1). For the slab mixed-layer ocean in GENESIS version 2.0, horizontal heat transport by the ocean is modeled as linear diffusion down the local gradient of slab ocean temperature. The diffusion coefficient is time invariant but depends on latitude and zonal land-ocean fraction, and is multiplied everywhere by QFACTOR. Defaults to 1.

The global integral of the convergence of this diffusive ocean heat transport is automatically zero. However by default it is modified in specific regions by QICEN, QICES and/or QNORWEG (see below), in which case a uniform additive correction is applied at each time step equatorward of 56°S and N (*i.e.,* away from sea ice) to make the global integral identically zero.

QICEN (R)

In the slab ocean model (OCEANTYPE = 1), QICEN and QICES can be used to modify the diffusive ocean heat transport under sea ice. QICEN is the flux convergence under 100% sea-ice cover in the Northern Hemisphere, in W/m^2. Where the sea-ice fraction is less than 100%, the flux convergence is linearly weighted between QICEN and the open-ocean diffusive value. If a value of 0.0 is entered, the flux convergence value below 100% ice will really be 0.0. If a negative value is entered, no modifications to the diffusive values are made. Defaults to 2 W/m^2.

QICES (R)

The same as QICEN but for the Southern Hemisphere. Defaults to 10 W/m^2.

QNORWEG (R)

If greater than zero, a parameterization is used in the slab ocean model (OCEANTYPE = 1) that yields large oceanic heat flux convergence in the Norwegian Sea region in winter. Specifically, whenever the mixed-layer temperature drops below 1.04°C in a rectangular region bounded by 66°N, 78°N, 10°W and 56°E, the flux increases linearly with decreasing temperature to a maximum of QNORWEG W/m^2 at the freezing point -1.96°C. This is meant to simulate the buffering effect of the deepening mixed layer in winter, and strong local advection by warm ocean currents (*e.g.,* Hibler and Bryan, 1987), and keeps the Norwegian Sea ice-free in winter as observed. If a negative or zero value is entered, this feature is turned off. Defaults to 500 W/m^2.

PRESCOUV (L)

If true (.T.), and if the slab mixed-layer model and sea-ice dynamics are both used (see OCEANTYPE and DYNAMICE above), the ocean stress on the bottom of the ice is computed from prescribed ocean surface currents in data input file OCEAN (see section 4.b.7). If false (.F.), the ocean is assumed to be motionless and the data input file OCEAN is not required or is ignored. Defaults to true.

DEPTHML (R)

Depth of the ocean mixed-layer slab (for OCEANTYPE = 1) in meters, set on the first time step and subsequently unchanged through this run. Also used for the depth of "deep" lakes (see the fractional-water data input file FWATER described in section 4.b.2). DEPTHML can be used to experiment with different mixed-layer depths, including very small values (down to 10 cm) to achieve an essentially "swamp" ocean. For numerical stability, entered values less than 0.1 m (10 cm) are increased to 0.1 m. Defaults to 50 m.

DEPTHLAKE (R)

Depth of "shallow" lakes in meters, set on the first time step and subsequently unchanged through this run. (See the fractional-water data input file FWATER described in section 4.b.2). For numerical stability, positive values less than 0.1 m are increased to 0.1 m. Defaults to 5 m.

If DEPTHLAKE is set to 0., the fractional-water data input file is not required or is ignored, and all surface grid points are either 100% land, 100% icesheet or 100% ocean according to the surface-type data input file SURFTYP (see section 4.b.1).

DEPTHICE (R)

A maximum sea-ice thickness in meters to be imposed everywhere just once at the first timestep of this run. Although this may be a significant perturbation, it may be desirable in certain situations, for instance to reset unrealistically thick regions of sea ice. If a value less than 0.20 m (the model's internal minimum sea-ice thickness) is entered, DEPTHICE is reset to 0.20 m. Defaults to no action taken.

DEPTHSNO (R)

A maximum snow thickness in meters to be imposed everywhere just once at the first timestep of this run. In the central regions of Antarctica and Greenland, the model (realistically) produces positive net annual snow accumulations so that total snow thickness increases without limit in multi-year runs. Although this has no serious consequences in the model, for aesthetic reasons the user may want to occasionally reduce snow thicknesses to the DEPTHSNO limit. If a value less than 0.15 m (the model's internal minimum snow thickness) is entered, DEPTHSNO is reset to 0.15 m. Defaults to no action taken.

TEQCOLD and **TPOCOLD** (R)

For cold starts (NSREST=–1), these are the equatorial and polar temperatures of the initial atmospheric temperature field in °K. This field is zonally symmetric and vertically uniform, with a latitudinal dependence

TEQCOLD $\times$ (1-μ^2) + TPOCOLD $\times$ μ^2 where μ is sin(latitude). All surface-model initial temperatures are based on this field, and sea ice is initialized with 2-meter thickness and 95% cover wherever the initial temperature is below the ocean freezing point of 271.2 °K. Default to TEQCOLD = 303 °K and TPOCOLD = 260 °K.

VEGTYPE (I)

Choice of which method of vegetation prescription to use for this run. Once a day, the physical attributes of the lower and upper vegetation canopies needed by LSX are specified at each land grid point. These include leaf area indices (LAI), geometric canopy heights, stomatal resistance parameters, leaf reflectivity and transmissivity, etc. Some of these vary seasonally (*e.g.,* LAI) while others are constant (*e.g.,* geometric height). The three possible ways to obtain this information are chosen by VEGTYPE = 0, 1 or 2 (default = 2), listed below in order of complexity.

If VEGTYPE = 0, vegetation is prescribed from the dataset described in Dorman and Sellers (1989), with global distributions provided in data input file DSBIOME (see section 4.b.3). This is the method used in GENESIS version 1.02.

If VEGTYPE = 1, vegetation is prescribed using a new method of categorizing vegetation developed by Jon Foley and his group at the University of Wisconsin. The global distribution is given in data input file WISCVEG (see section 4.b.4 for more details).

If VEGTYPE = 2, vegetation is prescribed using present-day off-line results of an Equilibrium Vegetation Ecology (EVE) model (Bergengren, 1994; Bergengren and Thompson, 1995), encoded in a separate EVE data/restart file (see section 4.b.5 for more details).

DSBIOME (I)

A single Dorman-Sellers biome type, to be used as a single globally uniform vegetation type for all land points. The types 1-12 are summarized in Table 1 of Dorman and Sellers (1989). If VEGTYPE is 0 and an acceptable value (1-12) of DSBIOME is entered, the global map in the data input file of the same name (DSBIOME in section 4.b.3) is not needed or is ignored. If VEGTYPE is not 0, any entered DSBIOME is ignored. Defaults to no entered value, *i.e.,* to use the global map in the data file DSBIOME if VEGTYPE = 0.

WISCVEG (I)

A single 4-digit vegetation code using the 'Wisconsin' scheme described above for VEGTYPE = 1, to be used as a single globally uniform vegetation type for all land points. If VEGTYPE is 1 and a WISCVEG value is entered, the global map in the data input file of the same name (WISCVEG in section 4.b.4) is not needed or is ignored. If VEGTYPE is not 1, any entered WISCVEG is ignored. Defaults to no entered value, *i.e.,* to use the global map in the data file WISCVEG if VEGTYPE = 1.

SOILTEX (I)

A single soil texture value, to be used as a single globally uniform soil texture type for all soil layers. If an acceptable value of SOILTEX is entered, the global maps in data input files SOIT01 to SOIT06 (section 4.b.6) are not needed or are ignored. The value of SOILTEX is $10000 \times$percent_sand + $100 \times$percent_silt + percent_clay; for instance, 401050 means 40% sand, 10% silt and 50% clay. Defaults to no entered value, *i.e.,* to use the global maps in the files SOIT01 to SOIT06.

3.b. Second Namelist Group (AGCM Radiation and Trace Gases)

SOLFAC (R)

A uniform factor multiplying the insolation at the top of the atmosphere. Defaults to 1.

SOLPAR (R)

The solar constant used by the model, in W/m^2. This is the incident solar flux at the top of the atmosphere on a plane perpendicular to the sun at the ~mean sun-earth (semi-major axis) distance. Defaults to 1365 W/m^2.

CO2PPM (R)

CO_2 (carbon dioxide) atmospheric volume mixing ratio for solar and infrared radiative calculations, uniformly mixed, in parts per million. Defaults to 345 ppm ($\approx$ present day).

CH4PPM (R)

CH_4 (methane) atmospheric volume mixing ratio for infrared radiative calculations, uniformly mixed, in parts per million. Defaults to 1.653 ppm ($\approx$ present day).

N2OPPM (R)

N_2O (nitrous oxide) atmospheric volume mixing ratio for infrared radiative calculations, uniformly mixed, in parts per million. Defaults to 0.306 ppm ($\approx$ present day).

F11PPB (R)

$CFCl_3$ (CFC-11 chlorofluorocarbon) atmospheric volume mixing ratio for infrared radiative calculations, uniformly mixed, in parts per billion. Defaults to 0.238 ppm ($\approx$ present day).

F12PPB (R)

CF_2Cl_2 (CFC-12 chlorofluorocarbon) atmospheric volume mixing ratio for infrared radiative calculations, uniformly mixed, in parts per billion. Defaults to 0.408 ppm ($\approx$ present day).

H2OOFF (L)

If true (.T.), atmospheric water vapor amounts are set to zero for solar and infrared radiative calculations, but are unaltered for the rest of the model physics. Defaults to false (.F.).

O3OFF (L)

If true (.T.), prescribed atmospheric ozone amounts are set to zero for solar and infrared radiative calculations. In that case the ozone data file (see section 4.a.3) is not required or is ignored. Defaults to false (.F.).

OZONETYPE (I)

If OZONETYPE = 0, prescribed atmospheric ozone amounts are set from a zonally symmetric dataset as a function of latitude, pressure level and season (Bath *et al.*, 1987). If OZONETYPE = 1, they are set from a new 3-D dataset with longitudinal dependence (Wang *et al.*1995). As described in section 4.a.3, the correct data input file must be copied into the local OZONE file by the jobscript depending on whether OZONETYPE = 0 or 1. Defaults to 0.

3.c. Third Namelist Group (LSX History Files and Writes)

MSNAM_A (A)

A list of up to 1000 filenames, up to 16 characters long, for LSX (surface-model) history files. Just as for the AGCM history files, at each NNEXF time the current LSX file (with generic name NDATALSX) is copied to permanent storage using the current MSNAM_A filename, a new local history file (NDATALSX) is started in the working area, and the filename list pointer is incremented by 1 (see NNEXF above). Just as for the AGCM history filenames, a single entry containing an asterisk (∗) is expanded automatically to 1000 entries with the asterisk replaced by '001', '002', '003', etc. Defaults to the AGCM history filename list MSNAMHIS with 'LSX' appended to each entry.

NHISI_A (I or A for CRAY, I for SGI)

A list of day numbers at which a set of surface-model history fields (a history "write") is written to the current LSX history disk file. All conventions described above for the AGCM parameter NHISI apply to NHISI_A. Defaults to the NHISI values (see section 3.a.3)

NDHIS_A (I)

Time in days over which time-averaged surface-model history fields (see CUSHNAM_A below) are to be accumulated prior to NHISI_A history writes.

The same conventions described above for the AGCM parameter NDHIS apply to NDHIS_A. Defaults to the NDHIS value (see section 3.a.3).

CUSHNAM_A (A)

A list of surface-model history field names to be written to LSX history files generated by the current run. These must be valid surface-model field names chosen from the standard list in Appendix A.2. At each NHISI_A time one set of CUSHNAM_A fields is written to the current LSX history file. Each field can either be instantaneous or averaged over a previous time interval (NDHIS_A days). By default all fields are time-averaged, and are changed to instantaneous by appending an asterisk (∗) to the name in the CUSHNAM_A list, *e.g.,* LMASK∗, HOCEAN∗ and FWATER∗ in Fig. 2. Defaults to no requested fields, *i.e.,* no LSX history files generated.

NDENS_A (I)

The packing density to be used for LSX history-file *data* records on NCAR CRAY systems, passed to the NCAR CRAY library routine PACKA. NDENS_A must be between 1 (no packing) and 4 (densest packing), and defaults to 1. Ignored for systems other than NCAR CRAYs.

4. DATA INPUT FILES

This section describes the data input files that are read by the model at the start of each run. The user must select the appropriate files for a given run, and copy them into the local area with generic names before running the model (see the block of "cp" commands in the job script in Fig. 1). For the present day, complete sets of data input files for R15, T31, T42 and $2^\circ \times 2^\circ$ resolutions are available to users (see Appendix C.2). Table 1 lists all the generic filenames and brief descriptions of their contents. Most of these files are required for every run, but some (GWD, SSTICE, OCEAN, FWATER, DSBIOME, WISCVEG, SOIT0* and OZONE) may not be needed depending on the Namelist settings (see GWROUGH in section 3.a.5, OCEANTYPE, PRESCOUV, DEPTHLAKE, VEGTYPE, DSBIOME, WISCVEG, SOILTEX in section 3.a.6, and O3OFF in section 3.b). As a visual check of the input process, the user can have the model print out two-dimensional maps of most data input fields (see SHOWMAPS in section 3.a.4 and section 6.a).

All files have header records containing type and resolution information, and these values are checked for consistency with the model when the files are read. After reading each surface field the model automatically and crudely fixes any inconsistencies between that field and the current surface-type map (for instance, if vegetation is prescribed for ocean points). This minimizes the danger of a model blowup if the user makes minor adjustments to the surface data input files between restarts.

Since users may need to generate their own data input files, for instance for paleoclimatic applications, two generic subroutines are available via ftp that can read and write a GENESIS data input file to and from a Fortran array (see section 7.e). Users will hopefully find these routines convenient in writing their own programs to generate new sets of data input files.

All data input files for version 2.0 are in ascii text format, and are read by Fortran formatted I/O statements. Two examples are shown in Figs. 3 and 4. All have the following common format (except the atmospheric ozone file OZONE, which differs in a couple of details as explained below):

- A header record containing an 8-character keyword (left-justified), followed by the longitudinal and latitudinal dimensions for the file, followed by a descriptive comment that is echoed to the standard output file as mentioned in section 6.a. The first three items are checked for consistency with the current program when the file is read. The Fortran format of this record is (A8, 2I8, 8X, A).

- A blank record, followed by a record containing the longitude grid values, followed by another blank record. These 3 lines are skipped by the model. The longitudes are °E rounded to the nearest integer, and apply to the column below their last (least significant) digit.

- A sequence of data records, each containing data values for one latitude circle. These records run from the northernmost latitude to the southernmost. The first value in each record is the box-center latitude in degrees, followed by as many data values as longitudes in the current resolution. The Fortran format of these records is either (F5.1, 3X, nI5) or (F5.1, 3X, nA1) where n is the number of longitudes. Where possible, data are shown in A1 format with values of 10 and above indicated by the letters A-Z. Where greater precision is needed, the values are I5 format. Blanks are used in most files so that continent-ocean outlines can be recognized, representing null values (zero except as noted below).

The longitude and latitude values shown in the files correspond to model grid box centers. The (longitude,latitude) grid sizes for the various resolutions are as follows: (48,40) for R15, (96,48) for T31, (128,64) for T42, and (180,90) for $2° \times 2°$. Longitudes in the model code are equispaced and run eastward, with the left-hand *edge* of the first box at Greenwich (0°). This differs from the longitude origin in the data input files, which by convention start just east of the dateline (180°W); this shift is accounted for as the model reads each data file.

The atmospheric model uses a Gaussian latitude grid which is close to but not exactly equispaced (Washington and Parkinson, 1986). The Gaussian box-center latitudes are shown in the AGCM data input files TOPOG, GWD and OZONE. The surface models do use equispaced latitudes, as shown in the other data input files. In all cases the *edges* of the southernmost and northernmost grid boxes lie at the poles. The latitude index in the model code runs from south to north, so the required reversal in latitude is performed as the model sequentially reads each data file.

4.a. Data Input Files for the AGCM

4.a.1. Topography (TOPOG)

The AGCM topography field is read from the local file TOPOG. Our present-day files were derived from the U. S. Navy FNOC global elevation dataset at 10 min resolution (Cuming and Hawkins, 1981; Kineman, 1985), averaging up to the model grids by simple "tiling" (*i.e.,* areally averaging all 10 min boxes within each model grid box). The header-record keyword is 'TOPO'. The data are elevations above mean sea level in meters, and are in I5 format.

4.a.2. Gravity-Wave Orographic Roughness (GWD)

The sub-grid gravity-wave surface roughness is read from local file GWD, with keyword 'GWDH' . This is the standard deviation of small-scale orography within each AGCM grid cell, derived for the present day from the same U.S. Navy 10-min dataset as for TOPOG above. This field is used as a source term in the model's gravity-wave parameterization (McFarlane, 1987). The header-record keyword is 'GWDH', and the data are in units of meters in I5 format. As mentioned in section 3.a.5, if the Namelist parameter GWROUGH is entered its value is used for all land points, and the GWD data input file is not required or is ignored.

4.a.3. Atmospheric Ozone Distribution (OZONE)

Atmospheric ozone amounts are prescribed from the local file OZONE. There is a choice (see OZONETYPE in section 3.b) between a zonally symmetric dataset varying with latitude, pressure level and season (Bath *et al.*, 1987), and a new 3-D seasonal ozone climatology with longitudinal dependence (Wang *et al.*, 1995, using data from 1978-1992). Depending on the setting of OZONETYPE, the correct data input file must be copied into the local OZONE file by the job script. OZONETYPE = 0 (the default) requires the zonally symmetric dataset, and OZONETYPE = 1 requires the 3-D dataset. As listed in Appendix C.2, these data files are stored with names 'data_ozone_...' and 'data_ozone3D_...' for the zonally symmetric and the 3-D datasets respectively.

The zonally symmetric files are basically in the standard format, except that (i) each line contains ozone amounts for 23 pressure levels at a given latitude and month, and (ii) the file contains 12 sets of headers and latitude-level cross sections, one for each calendar month, separated by an extra blank line for legibility. The data were obtaine from the standard CCM1 ozone file /CSM/CCM/%DATA%/OZON... on the MSS, described in Fig. 1.3 of Bath *et al.*(1987). The model linearly interpolates the data to the GENESIS vertical sigma/hybrid grid, as if the levels on the file are constant sigma surfaces. The header-record keyword is 'OZONE', and the data are ozone volume mixing ratios in parts per billion, in I5 (not I6) format.

The 3-D files are also basically in the standard format, except that there are 12 pairs of maps, one for each calendar month. The first map of each pair is a zonal latitude-level cross section containing ozone amounts for 49 pressure levels. Its header-record keyword is 'OZONEA' and the data (in I6 format) are in units of $1000 \times \log_{10}$(ppmv) where ppmv is the ozone volume mixing ratio in parts per million. Following an extra blank line, the second map of each pair is a longitude-latitude map of total column ozone amounts. Its header-record keyword is 'OZONEB' and the data (in I5 format) are in Dobson units of $1000 \times$ cm STP. As in Wang *et al.*(1995), the model scales the zonal cross sections by the 2-D total column amounts to produce a 3-D distribution for each month. The model linearly interpolates in time between the mid-month points, and linearly interpolates in pressure (not sigma) to obtain ozone path lengths on the model vertical grid.

As mentioned in section 3.b, if the Namelist parameter O3OFF is set to true, the OZONE data input file is not required or is ignored, and ozone amounts are set to zero for all radiative calculations.

4.b. Data Input Files for the Surface Models

4.b.1. Surface Type (SURFTYP)

The land-icesheet-ocean map for the surface models is read from the local file SURFTYP. The model codes are 1=land, 2=icesheet and 3=ocean, although for display purposes all ocean points are blank on the file. Our present-day maps were derived from the same U.S. Navy 10-min dataset as for TOPOG above, except that icesheet areas were superimposed using Cogley's $1^\circ \times 1^\circ$ Global Hydrographic Dataset (Cogley,1991). The header-record keyword is 'SURT', and the data are in A1 format.

4.b.2. Ocean-Lake Fraction (FWATER)

For each land or icesheet point, GENESIS version 2.0 has the capability of doing two independent surface calculations, one for land/icesheet and one for a well-mixed slab of water. The latter can be used to represent either inland lakes or a fractional amount of ocean for coastal grid boxes. The data file FWATER contains the fractional area of lakes or ocean in each grid box, with the remainder occupied by land or icesheet according to the surface-type map in SURFTYP. The two sets of surface-atmosphere fluxes computed by LSX at each timestep are weighted according to the areal fraction in FWATER before contributing to the fluxes passed back to the AGCM. Note that the lake fraction contains no geographical information about the size of individual water bodies or their sub-grid geographical location, and only represents their integrated area relative to the whole cell.

The slabs of water can have two depths, one representing coastal ocean fractions or "deep" inland lakes, and the other representing "shallow" inland lakes. The deep value is the same as that used for the ocean mixed layer model (DEPTHML in section 3.a.6) with a default = 50 m. The shallow value is set by DEPTHLAKE (section 3.a.6) with a default of 5 m. The water slabs are modelled exactly as in the ocean mixed-layer model, except with no oceanic horizontal heat flux. If the water temperature falls to the freezing point, ice forms and is modelled exactly as in the multilayer sea-ice model, except with no ice advection. As mentioned in section

3.a.6, if DEPTHLAKE is set to -1., the FWATER data input file is not required or is ignored, and all surface grid points are either 100% land, 100% icesheet or 100% ocean according to the surface-type file SURFTYP.

Our present-day maps were derived by processing individual fields for fresh and ocean water from the same U.S. Navy 10-min dataset used above, and the same Cogley icesheet field as used above. The U.S. Navy fields were first aggregated to the Cogley $1^\circ \times 1^\circ$ resolution, then shallow and deep water fractions were derived at $1^\circ \times 1^\circ$ using a straightforward algorithm. Finally the resulting fields were areally averaged to the model resolutions, and shallow-lake values multiplied by -1, to produce the FWATER files (*i.e.,* shallow lakes are distinguished by negative values in the data files). The header-record keyword is 'FWATER', and the data are in units of +/- percent cover in I5 format.

4.b.3. Dorman-Sellers Vegetation Biomes (DSBIOME)

As described in section 3.a.6, GENESIS version 2.0 has a choice of present-day vegetation prescriptions determined by the Namelist parameter VEGTYPE. If VEGTYPE = 0 the dataset of Dorman and Sellers (1989) is used, using their present-day biome map (their Fig. 1.b) and with physical attributes and seasonal cycles of leaf area index (phenology) for each biome updated daily using only the current calendar date as described in that paper. The DSBIOME data file contains their 4° by 5° biome map interpolated using nearest-neighbor values to the model grid. The header-record keyword is 'VEGT', and the data are in A1 format ranging through biome types 1-12 with blanks for ocean and icesheet points.

4.b.4. 'Wisconsin' Vegetation Categories (WISCVEG)

If the Namelist parameter VEGTYPE = 1, vegetation is prescribed by a 4-digit code for each grid point in the data input file WISCVEG. The codes follow a new method of categorizing vegetation developed by Jon Foley and his group at the University of Wisconsin. Starting from Matthews (1985) present-day dataset, vegetation is described by four independent measures: (i) cover type (forest, woodland, savanna, shrubland, grassland, tundra, desert), (ii) climate zone (tropical, temperate, boreal/subpolar), (iii) phenology (evergreen, deciduous), and (iv) C_3 or C_4 understory. These measures are designed to capture climatically important distinctions rather than biome or species differences. An on-line algorithm uses the 4-digit code, some model climate input and the calendar date to compute the phenology and other physical attributes of the canopy once each day. The climate input consists of 2-week running-mean surface-air temperature and an instantaneous soil-moisture stress term, so there is some interactive feedback between the model climate and the phenology (but not the vegetation distribution). The header-record keyword of the WISCVEG file is 'WISC', and the data (4-digit codes) are in I5 format with blanks for ocean points.

4.b.5. EVE Vegetation Data Files

If the Namelist parameter VEGTYPE = 2 (the default), vegetation is prescribed using present-day results of the EVE Equilibrium Vegetation Ecology model (Bergengren, 1994; Bergengren and Thompson, 1995). These results have been computed off-line by EVE using present-day observed climatology, and are essentially global distributions of $\sim$110 EVE life forms, from which the net phenology and physical attributes of the vegetation community for each model grid box are determined and passed to LSX. The EVE vegetation agrees well with observed global datasets such as Kuchler (1983) and Matthews (1985), to within the level of difference between the observed datasets themselves. Note that EVE only simulates natural vegetation, so produces the forests or grasslands of several hundred years ago in place of present-day agricultural regions.

The required information is provided in an EVE data file with the generic name "leaf_restart_file", and a copy must be present in a local subdirectory called "rf" at the start of the run; this can be accomplished by the jobscript as in Fig. 1. To reduce the size of the EVE data file, the seasonal phenology and some other physical attributes predicted by EVE are not stored but are re-computed on-line once each day using a part of the EVE code linked to GENESIS. The file is still relatively large (several Megabytes), and contains the seasonally invariant life-form maps, observed monthly climatological forcing, and time-dependent spin-up information for attributes with "inertia", *i.e.,* that depend not on instantaneous climate forcing but on running time means. Therefore it is a true restart file with a calendar date associated with it, and its month and day must agree with the start date of the run (BASEDATE if NSREST = 0 or -1, or that of the GENESIS restart file if NSREST = 1). As the model runs a new EVE data/restart file is written to rf/leaf_restart_file at each NSAVE or NNEXF time, (which overwrites the start-up copy), and additional copies are written with time-specific names such as rf/leaf_restart_181_2001 where the first number is the calendar day number (*e.g.,* 181 = June 30th) and the second is the year date (irrelevant since these files are the same from one year to the next). Also the present-day land-ocean map used in generating an EVE data/restart file must be exactly the same as the SURFTYP map (section 4.b.1) of the current run. A set of leaf_restart_... files for various resolutions and calendar dates that are consistent with our present-day SURFTYP maps are available to users as described in Appendix C.2.

Note that the EVE distributions and phenology do *not* depend on the current model climate, so there is no interactive feedback between climate and vegetation. As mentioned earlier, this is the default vegetation method if VEGTYPE is not entered.

4.b.6. Soil Texture vs. Depth (SOIT01 to SOIT06)

In the GENESIS version 2.0 soil model, the thermal, hydraulic and radiative properties of the soil are determined from their empirical dependence on soil texture (*i.e.,* sand-silt-clay ratio). Since soil texture can vary with depth at each point, there is a separate data file for each of the 6 soil model layers, with local names SOIT01 to SOIT06 for the uppermost to the deepest layer respectively. The top-to-bottom soil layer thicknesses are .05, .10, .20, .40, 1. and 2.5 meters, so the mid-layer depths are .025, .10, .25, .55, 1.25 and 3.0 meters below the surface.

We derived these maps from the global soil dataset of Webb *et al.*(1993), which combines Zobler's $1^\circ \times 1^\circ$ global map of soil types with FAO/UNESCO texture profiles vs. depth for each type. We simply found the majority type of all $1^\circ \times 1^\circ$ points lying within each model grid cell, and then translated its vertical profile of soil texture to the model layers by straightforward vertical averaging. The data values in the SOIT.. files are 100×percent_sand + percent_clay; for instance, 4050 means 40% sand, 10% silt and 50% clay. To avoid slight programming difficulties the %sand and %clay values must always be $\geq$1 and $\leq$99. The special value of -2 indicates histosol (peat) soil type, whose physical properties are hard-coded in the soil model. Also -1 indicates icesheet and blank indicates ocean, although these are for display only and are overridden if they differ from the SURFTYP data file. The header-record keywords are 'SOIT01' through 'SOIT06', and the data are in I5 format.

4.b.7. Ocean Surface Currents (OCEAN)

If the slab mixed-layer model and sea-ice dynamics with prescribed ocean currents are used (OCEANTYPE = 1, DYNAMICE = .T., PRESCOUV = .T., which are all defaults; see section 3.a.6), the ocean stress on the bottom of the ice is computed from prescribed ocean surface currents in local file OCEAN. This file contains annual mean surface currents from a 5-year run of a $2^\circ \times 2^\circ$ ocean general circulation model under development for use with GENESIS (Brady, 1995). If PRESCOUV is set to false, the OCEAN file is not needed or is ignored, and ocean currents are assumed to be zero. The data file contains two sets of header records and global maps separated by an extra blank line for legibility; the first shows eastward velocity and the second shows northward velocity. Since the model's velocity grid is staggered in both directions by half a grid box relative to the usual surface grid, the data records in these files run from the North Pole to one box-width above the South Pole, and the longitudes run eastward from 180°W. The header-record keywords are OCNU and OCNV respectively, and the data are in I5 format in units of mm/sec.

4.b.8. Prescribed SST and Sea-Ice Extent (SSTICE)

If OCEANTYPE = 0 (see section 3.a.6), sea-surface temperatures and sea-ice extents are prescribed from monthly climatological SSTs in the data file SSTICE. These files are generated from a global $2^\circ \times 2^\circ$ dataset of SSTs and sea-ice extent by Shea *et al.*(1990), which is based primarily on observations between 1950 and 1979. For model resolutions coarser than $2^\circ \times 2^\circ$ we averaged the data to the model resolution by straightforward areal aggregation ("tiling"). Each OCEAN file contains 12 sets of header records and global maps for the months January through December, each separated by an extra blank line for legibility. If OCEANTYPE = 1, this data file is not needed or is ignored.

As the model runs the SST and sea-ice fraction for each time step are linearly interpolated in time from the two surrounding mid-month values; (the data file's mid-month sea-ice fractions have only two possible values, 0% or 100%). Wherever sea ice occurs, total thickness is hard-coded as a linear function of latitude. The data values are in units of tenths of °C, with a value of –20 indicating 100% sea-ice cover. The header-record keyword is 'SSTI', and the data are in I5 format.

4.b.9. Surface-Model Topography (TOPOG2)

As described in section 3.a.5, if DELEVTYPE = 1 or 2 corrections to surface-air temperature and downward infrared radiation are applied in LSX that crudely account for spectral truncation of the AGCM topography field. Since these corrections are applied on the surface-model grid which may differ from the AGCM grid (*e.g.,* $2^\circ \times 2^\circ$ surface and T31 AGCM), a separate data file with local name TOPOG2 is needed for the global topography on the surface grid. If DELEVTYPE = 0 (the default), the correction is not applied and the TOPOG2 file is not needed or is ignored.

Since the AGCM uses non-equispaced Gaussian latitudes and the surface models use equispaced latitudes, strictly each TOPOG2 file should differ slightly from the AGCM data file TOPOG of the same resolution. To date we have neglected this difference, and make available only one set of present-day topography files based on Gaussian latitudes (see Appendix C.2). The impact should be negligible, especially considering the crudity of the corrections and the magnitude of the spectral distortions. Just as for the TOPOG files described above, the header-record keyword is 'TOPO', the data are elevations above mean sea level in meters, and are in I5 format.

5. HISTORY AND RESTART FILES

5.a. History Files

The model can output two types of history files:

- AGCM history files, containing selected AGCM fields at the AGCM resolution. These files are in binary format. The relevant Namelist parameters are MSPATH, MSNAMHIS, NNEXF, CUSHNAM, NHISI, NDHIS and NDENS (see sections 3.a.2 and 3.a.3).
- LSX history files, containing selected surface-model fields at the surface-model resolution. These files are in binary format. The relevant Namelist parameters are MSPATH, MSNAM_A, NNEXF, CUSHNAM_A, NHISI_A, NDHIS_A and NDENS_A (see sections 3.a.2 and 3.c).

Not all of these file types need be generated in a run. If no history fields are requested (by omitting CUSHNAM or CUSHNAM_A from the Namelist input), no history files of that type are generated.

As discussed in section 3.a.3, whenever the model reaches a time point in the NHISI or NHISI_A lists, a "history write" consisting of four header records and one set of all requested history fields is appended to the appropriate history file. There can be an unlimited number of history writes in any one file, determined by the number of history-write times (NHISI, or NHISI_A) between pairs of times in the next-file list (NNEXF).

The AGCM and LSX history files are in binary format. They are stream files with no physical record structure or embedded control words ("pure" format set by "assign -s bin" for CRAY systems, or set by "form='system'" in the open statement for SGI systems). The "records" referred to below are purely logical or conceptual records, denoting groups of consecutive words in the physical stream. If not packed, the length of each data record is $1 + \text{nlon} \times \text{nlat}$ words where nlon and nlat are the AGCM or LSX longitude and latitude grid sizes respectively. Each data record contains a one-word label followed by one global field at a particular level, with multi-level AGCM fields grouped in consecutive records. Details of the four header records and the data records are given in Appendix B. There are no changes to the formats of model history files, so all post-processing tools developed for version 1.02 will also work for version 2.0.

As described above, current history files are generated in the working disk area with names NDATA and NDATALSX. On the NCAR CRAYs, they are acquired from (if necessary) and disposed to permanent files on the MSS by calls to Fortran-library routines ACQUIREF and DISPOSEF. On other systems they are copied to and from the permanent disk areas by Unix 'cp' commands invoked by calls to the Fortran-library routines ISHELL or SYSTEM.

5.b. Restart File

As mentioned above there is no distinction between initial and restart files, and the model is always started or restarted from a restart file generated by a previous run. The initial/restart file read at the start of a run is set by the Namelist parameters MSNAMIN and MSPATHIN (section 3.a.1), and the restart files generated during a run are controlled by MSPATH, MSNAMRES, MSNAMRE2 and NNEXF (section 3.a.2).

The restart file contains complete information about the state of the model at the time it is written, so results are the same whether a simulation is performed as one long run or as several shorter runs each restarted from the previous one. This is true as long as (i) restarts occur at day boundaries, *i.e.,* 24:00 GMT, and (ii) the user does not prescribe any adjustments to model fields that are done at the first timestep of a run, such as DEPTHICE or DEPTHSNO described in section 3.a.6. The day-boundary restriction is a consequence of performing solar and infrared-absorbtivity radiative calculations at intervals of 1.5 and 24 hours respectively, and storing the results in memory for intervening timesteps.

For simplicity the AGCM and the surface models share one restart file. The primary reason for this is that the horizontal grid sizes can differ, *e.g.,* $3.75° \times 3.75°$ (T31) for the AGCM and $2° \times 2°$ for the surface models, and post-processing is simpler if a file contains fields of just one horizontal size. Also the restart information for the individual models is useless unless it is saved simultaneously, and putting it all in one file simplifies the input of filename lists. The structure of this file is modular in the sense that all AGCM information is written as one block of records, followed by a second block containing all surface model information.

Just as for history files, restart files are binary stream files, *i.e.,* they have no physical record structure or embedded control words ("pure" format set by "assign -s bin" for CRAY systems, or set by "form='system'" in the open statement for SGI systems). There are five relatively short (conceptual) header records, followed by many long records containing AGCM fields, followed by two surface-model header records, followed by many long records containing surface-model fields. The current restart file is generated in the working disk area with local name NSRE, and just as for history files, it is copied to or from permanent files using ACQUIREF/DISPOSEF on NCAR CRAYs and ISHELL or SYSTEM (cp) on other systems.

The machine binary representation of real and integer numbers differs between CRAY and SGI systems (Cray format for CRAY, IEEE format for SGI), so their GENESIS restart and history files differ in that respect. However the GENESIS version 2.0 code includes a small set of routines that convert real and integer values between CRAY and IEEE formats, called automatically if a CRAY-generated restart file is read by an SGI program or vice-versa; thus GENESIS restart files and runs can be freely mixed between machines.

As described in more detail below, GENESIS version 2.0 is backward compatible, *i.e.,* runs can be started using restart files generated by version 1.02. (Restart file have their own version number which allows modifications to be made independently of the overall model version number.) Moreover, the horizontal and vertical resolutions of a restart file do not have to agree with the current model resolutions, since input fields can be interpolated to the current resolutions at the start of a run (see LEVRES, HORRES and HORRESLSX in section 3.a.1).

6. TEXT OUTPUT FILES

In addition to the history and restart files, the model writes a number of ascii text files to the local disk area disk. If the job is running in a $TMPDIR directory on NCAR CRAYs, these files must be copied to some permanent area at the end of a run else they are lost along with $TMPDIR, as done for instance by the job script in Fig. 1.

6.a. fort.6

The standard output (written to Fortran unit 6) is redirected by the job script in Fig. 1 to a local file called fort.6. This file is used as a monitor of the run, and also as a catch-all for miscellaneous information from various sources. Appendix D shows the complete fort.6 file from a one-day run using the job script and Namelist input in Figs. 1 and 2. Numbered marker lines have been added in Appendix D (*e.g.,* "(1)======...") to show the individual segments more clearly, and each of the 25 segments is described briefly below.

(1) The initial banner shows the GENESIS model version number and date and time at the beginning of the run.

(2) The first group of Namelist parameters (overall and AGCM) described in section 3.a is read by the program from the standard-input file "interm". If this group contains the echo flag 'E' in column 1, the input is echoed to fort.6 on CRAY systems. (On SGI systems, the entire Namelist "interm" file is pre-pended to fort.6 by the job script.) as they are read at the start of the run. This serves as a useful record of the Namelist parameters entered for each run.

(3) Similarly, the second Namelist group (radiation and trace gases) described in section 3.b is read and optionally echoed to fort.6 at this point.

(4) The group of lines beginning with "Opening initial/restart file..." gives some information from the header records of the restart file used to initialize this run. This includes the version number of the restart file mentioned in section 5.b used for backward compatibility.

(5) The AGCM and surface-model resolutions and the AGCM latitudinal grid, Gaussian weights and vertical levels are shown under the banner "Model Resolutions and Grids".

(6) A line ("Reading...data file...") is written whenever one of the data input files described in section 4 is read. This is followed by two lines echoing the comment text and the resolutions on the file's header records. Many of these files are read at this point near the start of the run; in addition seasonally varying prescribed fields in files OZONE and SSTICE are read at mid-month points throughout the run, and reported to fort.6.

After the AGCM topography file TOPOG is read and the field has been spectrally truncated, the global mean truncated topography is reported to fort.6. At this point the model makes a correction to the global atmospheric mass to produce a realistic global mean sea-level pressure, and the resulting global mass (multiplied by the gravitational acceleration and divided by the global surface area, *i.e.,* in Pascals) is also reported to fort.6.

If the Namelist parameter SHOWMAPS is set to true (section 3.a.4), two-dimensional maps of the data input fields are printed to fort.6 after each "Reading..." line, as a visual confirmation of the input process. Most of the maps are shown in pairs for the eastern and western hemispheres, to limit the line widths in fort.6 to 132 characters or less. For seasonally varying fields (OZONE and SSTICE) only the first field read at the start of the run is shown. (These maps do not occur in Appendix D since SHOWMAPS is false in Fig. 2.)

(7) The third Namelist group (LSX history files) described in section 3.c is read and optionally echoed at this point. Ideally this would appear earlier in fort.6 following the first two Namelist groups, but the order of appearance in fort.6 is dictated by the program's flow and modular design.

(8) If the EVE vegetation prescription is used (see VEGTYPE in section 3.a.6), an EVE module is called by GENESIS to set vegetation attributes at the start of each

day. The first time this occurs, some information concerning EVE's initialization is written to fort.6.

(9) At this point the AGCM seasonal ozone data file OZONE is read. As described in section 4.a.3, the model maintains two sets of arrays containing the prescribed ozone fields for the two mid-month values surrounding the current time. Hence at the start of a run the model must cycle through and possibly rewind the OZONE file to read in the two required fields, as reported to fort.6 at this point. After this the model only needs to read one field at a time when mid-month points are reached during the run.

(10) The orbital eccentricity, obliquity and precession used to compute insolation for this run are reported here. See the discussion of the Namelist parameters BASEDATE, ECCU, OBLU and PRECU in section 3.a.5 for how these are set. Precession is defined here as the prograde angle from perihelion to the N.H. vernal equinox.

(11) At the first timestep of a run, some zonal-mean cross sections of cloud radiative properties are shown versus latitude and sigma/hybrid level. These are *within-cloud* values, and do not reflect the model's prognostic cloud amounts except that their 3-D values are zero where no clouds are present in a grid box; hence the liquid water paths, optical depths and IR emissivities are zero in the upper stratosphere. (Droplet radius is independent of cloud amount).

(12) The global mean optical depths due to prescribed aerosols are reported for the two model solar-radiation wavebands ('vis' = 0.25-0.9 μm and 'nir' = 0.9-4.0 μm). Tropospheric dust aerosols are prescribed in GENESIS version 2.0 with a relatively large uniform value over land, a much smaller uniform value over oceans and icesheets, and an exponential decay with height given by $e^{-4(1-\sigma)}$ where σ is the model's vertical sigma/hybrid coordinate ($\approx$ [pressure]/[surface pressure] in the lower troposphere).

(13) In GENESIS version 2.0 a stochastic term is added to the precipitation at each LSX grid point and time step, to mimic realistic sub-grid variations in instantaneous precipitation intensity. An exponential probability distribution is assumed with precipitation limited to a fraction of the surface grid cell, and with the same overall mean

as the precipitation rate interpolated from the AGCM (Eltahir and Bras, 1993a,b) . Separate stochastic calculations are done for convective and stratiform precipitation, and the assumed wetted grid-cell fractions (qconv and qstrat) are reported here.

(14) If prescribed SSTs and sea ice are specified (OCEANTYPE = 0 in section 3.a.6), the SST-seaice data file SSTICE is first read at this point. Just as for the seasonal OZONE data file above, at the start of the run the model must cycle through and possibly rewind the SSTICE file to read in the two mid-month fields spanning the current model date. After this the model only needs to read one field at a time at mid-month points.

(15) At this point all model initialization is complete and the model time integration begins. At the end of each simulated day a single line with time and date information is written to fort.6; however since this particular run is only 1 day long, the line in Appendix D occurs after a lot of other output for the last day of the run (see segment (22) below).

(16) At the end of each January and July, monthly and zonal mean cross-sections *vs.* latitude and height of various AGCM quantities are shown. These are also shown for short-duration runs ($\leq$31 days) such as this one, time-averaged over the whole run. The first three columns show the vertical sigma/hybrid index, sigma/hybrid value, and approximate height above the surface in km. Cloud values are all areal fractional cover in %. The effective total column-integrated cloudiness is shown on a separate line below each cross section; this is less than the arithmetic sum of the layer amounts for each latitude, since (i) the total cloudiness is derived assuming various amounts of random or stacked overlap for the different cloud types, and (ii) it is calculated at each time step and for each 2-D grid point (non-linear calculations), and zonal and time means of the results are accumulated and shown in fort.6.

In addition cross sections of the AGCM's prognostic total liquid water content (10^{-6} Kg/Kg), relative humidity (%), specific humidity (g/Kg), temperature (°C), potential temperature (°), and vertical velocities within the two types of sub-grid convective plumes (0.1 m/s) are shown. The zonal-mean column mass of liquid water

(10 g/m^2), the global-mean column liquid water (g/m^2), and the zonal-mean column water vapor (Kg/m^2) are also shown below the appropriate cross sections.

(17) Next are several 2-D global maps for the same time period (January, July or whole-run) as for the cross sections above. Maps are shown of total column cloudiness for all clouds and for the individual cloud types (in units of tenths), stratus cloud cover in the lowest model layer (tenths), and lowest-layer air temperature (~60 m height). The latter units are °C, with lower-case letters for values $\geq$ 10 (a = 10, etc.), upper-case letters for values $\leq$ -1 (A = -1, etc.), and various other symbols for values $\leq$ -26.

(18) A few global mean budget quantities are accumulated at every timestep for the surface models, and reported to fort.6 at intervals set by the BUDFREQ Namelist parameter (see section 3.a.4) and at the end of the run. If the default value of BUDFREQ (365 days) is used and runs begin and end on calendar year boundaries, this printout will occur at the end of each run and represent the previous year's simulation.

The energy-flux quantities shown are (i) the net energy flux from the AGCM to all surfaces, (ii) the energy flux associated with net ice-sheet ablation and soil surface runoff plus bottom drainage, (iii) the energy flux associated with oceanic horizontal heat flux (which should be zero) and implicit net change in ocean mass due to oceanic precipitation minus evaporation (iv) the sum of the first three values, (v) the rate of change of total energy storage in all surface models including the ocean, and (vi) model error = (iv) – (v). The model error is only relevant to runs where the slab ocean model is used (OCEANTYPE = 1); if SSTs and sea ice are prescribed (OCEANTYPE = 0), relatively large energy imbalances are to be expected.

The corresponding water-mass-flux quantities are shown in a second (i) to (vi) group. Since the surface models attempt to keep exact track of all forms of energy and phases of water, long-term model errors (vi) should be very small (we find they are typically less than $\sim .001$ W m^{-2} for energy and $\sim .001$ mm/day for water). The last quantity, "soil moisture adjustments", shows the global mean of non-physical corrections in the soil hydrology model to prevent fractional soil moistures significantly greater than unity. These occurrences should be rare or non-existent, so the quantity (vii) should be very small or zero.

(19) This block announces that the current surface-model history file in the local disk area has been copied to permanent storage. See segment (23) below.

(20) Two more AGCM zonal cross-sections are shown for the same time period (January, July or whole-run) as for the others above. These are the eastward and northward accelerations (10 m/s per day) due to the gravity wave drag parameterization. It would be nicer to show these together with the other cross-sections in segment (16), but again the order of output to fort.6 is constrained by the model flow and modular design.

(21) Just as for the surface-model budget in segment (18), AGCM global budget quantities are accumulated at every timestep and reported to fort.6 at intervals set by BUDFREQ and at the end of the run. The same remarks made above for the surface budget concerning BUDFREQ=365 apply here.

The first two groups of quantities reported are similar to those described in section 6.b of Williamson *et al.*(1987), but with some changes and with all units converted to W m^{-2}. The third group "AGCM Total Energy" is pertinent to Appendix B of Thompson and Pollard (1995). Hopefully the few words accompanying each value in the printout are self explanatory. At the end of this segment the minimum and maximum instantaneous air temperatures attained anywhere in the AGCM during the previous budget period are reported in units of °K, along with the 3-D grid indices and time of occurrence.

(22) As mentioned above at segment (15) a single line starting with "Timestep=..." is written at the end of the last timestep (24:00 GMT) of each simulated day, showing the elapsed days and the current calendar date. The elapsed days are measured from 00:00 GMT on the base date of the run. In longer runs many of these lines appear consecutively, but for the one-day run in Appendix D this single line is "buried" below the last-day output.

(23) Whenever a history or restart file is copied from the local area to permanent storage (MSS for NCAR CRAYs, permanent disk for other systems), the event is announced in fort.6 by a line of the form "Local file ... disposed to ...", followed by a block of text under the banner "LSX HISTORY FILE OUTPUT", "AGCM HISTORY FILE OUTPUT" or "RESTART FILE OUTPUT". This records when the file was saved, the permanent filename, the number of history writes currently on a history file, the current filename list pointer, and whether the list pointer is incremented this timestep. The latter two items are shown in the restart file block but apply equally to the current history saves. Note that a restart file is saved whenever history files are (see NSAVE and NNEXF in section 3.a.2). If the filename list pointer is not incremented, the history files are not "full" and are just being saved for safety.

Due to the modular nature of the program flow, the LSX history-file block always occurs first in fort.6, and is sometimes separated from the AGCM history and restart-file blocks by other unrelated segments (see segment (19) above).

(24) At the very end of a run, a banner announces normal job termination, followed by any Fortran system messages and Unix system statistics.

(25) For CRAY systems, the accounting information produced by the UNICOS "ja" utility is appended to the end of fort.6 after the model run is complete by the job script (Fig. 1).

6.b. fort.50-53, fort.55, fort.60-63, fort.65

The LSX model writes detailed information for a particular surface grid point to the files fort.<n> where n = 50 to 53, 55, 60 to 63, and 65. The files with n = 50-55 are for the land or icesheet fraction of the grid cell, and the files with n = 60-65 are for the ocean-lake fraction if any (see DEPTHLAKE in section 3.a.6 and FWATER in section 4.b.2). The file fort.50 gives a general picture of the vegetation, snow and soil; fort.51 contains details of the vegetation layers including intercepted water; fort.52 shows the soil temperatures, soil moisture and soil ice amounts in the top few layers; fort.53 shows various fluxes between LSX and the AGCM, plus the prescribed vegetation amounts; and fort.55 shows a collection of all important quantities. Files fort.60-65 contain similar information for the ocean-lake fraction if any, and possible sea ice and snow on it.

The output point is specified by its longitude and latitude in the parameters LONOLSX and LATOLSX. Each line contains values at a single timestep, with the time interval set by TIMOLSX (default = 3 hours, see section 3.a.4). More information on the land-surface files fort.50-53 and fort.55 is given in a documentation file for the single-point version of LSX, available via ftp as mentioned in Appendix C.

6.c. fort.54

File fort.54 is written by the dynamic sea-ice model (if OCEANTYPE = 1 and DYNAMICE = .T.; see section 3.a.6). It is intended primarily as a debugging aid, and shows printed maps of various dynamical sea-ice quantities for a limited geographic region at the end of each month. Some of the quantities (wind stresses and sea-ice velocities) are time-averaged over the previous month. The extent of the region and the time interval between printouts are hard coded in the sea-ice dynamics code.

7. UTILITY PROGRAMS

We have developed a number of pre and post-processing tools related to GENESIS version 2.0 that users may find useful. This section provides brief descriptions of their functions. Files containing their source code are available via ftp as described in Appendix C.6. In most cases comments in the files themselves provide more detailed information than given below. Some of the files are all-inclusive Unix scripts that 'cat' the source code, compile, link, 'msread' any required files from the NCAR Mass Storage System, and run the program.

7.a. access

A Fortran subroutine (readfld) is provided that users can call to read a GENESIS history file and return a particular 2-D slice of a history field into a passed array. Our intent is for users to write short main programs that call readfld to extract history fields and use them as input to a plotting package or other post-processing utilities. The main parameters passed to readfld are the history file name, the history field name, the period number within the file, the level number for 3-D AGCM fields, the expected longitude and latitude grid sizes, and a 2-D array in which to return the field. The main program can loop over files and fields and call readfld repeatedly; the subroutines keep track of the current file to avoid unnecessary disk I/O. The user is responsible for copying the history file(s) into the current directory before running the program.

File 'access' contains a sample main program, subroutine readfld and several lower-level subroutines that are called by readfld. The user need only be concerned with the sample main program; none of the subroutines need to be modified. The lower-level subroutines include the same IEEE-CRAY conversion routines used in GENESIS, so that the access program can run on either CRAY or SGI machines and transparently read history files generated on the other machine. It can also detect and read history files in standard CCM1 format (on CRAY machines only).

7.b. convccm1

This utililty reads GENESIS history files and writes equivalent history files in standard CCM1 format (Bath *et al.*, 1987). The converted file can then be plotted using the

NCAR Modular Processor (Buja, 1993). The convccm1 file begins with some Unix script which the user can use to specify the NCAR Mass Storage directory containing the history files (msspath), a list of history filenames to be converted (filelist), whether the files are AGCM or surface-model history files (append), whether to assign midmonth dates for monthly mean files (midmonth), whether to actually save converted files (wantwrite) and whether to write global statistics to ascii information files (wantstat). The Unix script at the end of the convccm1 file loops over the requested file list, msreading each GENESIS file, mswriting each new CCM1 file to the Mass Store with an "A" appended to the name, and rcp-ing each ascii information file to a specified location. The user can of course customize these operations as desired.

7.c. convnet

This utility reads GENESIS history files and writes equivalent history files in netCDF format (Rew et al., 1993). Similarly to the convccm1 utility, the convnet file contains Unix script at the beginning and end to handle lists of filenames and copying to and from the NCAR Mass Storage system. By default each new netCDF file is saved with "B" appended to the old filename.

7.d. regread

As described in section 3.a.4, the Namelist parameters REGHIS, REGHIS_A, REGPATH and REGFREQ can be used to have GENESIS generate a stream of files containing fields needed to drive a regional climate model such as RegCM2 (*e.g.,* Giorgi *et al.*, 1993). These are binary files containing a specific set of instantaneous global fields written at regular intervals (typically 12 hours). The regread utility reads these files into internal arrays, looping over all sets of fields in each file. Our intent is that users can edit the regread source code to generate driver files for specific regional-model applications. The regread code includes CRAY-IEEE conversion routines so that it can run on CRAY or SGI machines and transparently read history files generated on the other machine.

The AGCM stream of REGHIS files contains the following fields: ORO, TOPOG, PS, T, Q, U, V (see Appendix A.1), and also the mean precipitation rate over the preceding REGFREQ interval. The surface-model stream of REGHIS_A files contains: LMASK, TS, SNOWF, SNOWH, ICEF, ICEH (see Appendix A.2), the mean precipitation rate as above, and the 24-hour maximum and minimum 2-m surface air temperatures.

7.e. mapinout

The mapinout file contains two stand-alone Fortran subroutines (readdata and printdata) that (i) read an existing GENESIS data input file into a 2-D array, and (ii) write a new data input file from a 2-D array. One of the arguments passed to these subroutines is a switch choosing between "A1" and "I5" data format (see section 4). We hope that users will find these subroutines useful in writing their own programs that work with data input files, for instance to generate new sets for paleoclimatic applications.

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APPENDIX A: AGCM AND LSX HISTORY FIELDS

All possible GENESIS version 2.0 history fields are listed below. As mentioned above, the user is free to select any subset of these fields (up to hard-coded total limit) for a particular run. The AGCM list is for AGCM history files (see CUSHNAM in section 3.a.3), and the surface-model list is for LSX history files (see CUSHNAM_A in section 3.c). The order of fields in the CUSHNAM and CUSHNAM_A lists is arbitrary and does not have to agree with the order below. Note that fields involving fluxes of water mass (precipitation, evaporation, transpiration, runoff, drainage) are stored in MKS units of m s^{-1} liquid equivalent depth.

A.1. AGCM Fields:

Name	Units	Levels	Description
ORO	flag	1	surface type: 0=ocean, 1=land (derived from LMASK)
TOPOG	m	1	surface topography, spectrally truncated
TOPOGUN	m	1	surface topography, untruncated
PS	Pa	1	surface pressure
PSLEV	Pa	1	sea-level pressure
Z850	m	1	850 mb geopotential height
Z500	m	1	500 mb geopotential height
Z200	m	1	200 mb geopotential height
U	m/s	18	eastward wind
V	m/s	18	northward wind
OMEGA	Pa/s	18	vertical pressure-velocity (dp/dt)
SIGDOT	s^{-1}	18	vertical sigma/hybrid-velocity (d[sig]/dt)
WPLUME0	m/s	18	vertical velocity, "PBL" convective plumes
WPLUME1	m/s	18	vertical velocity, "free" convective plumes
T	K	18	temperature
Q	kg/kg	18	specific humidity
RHUMID	fraction	18	relative humidity
DUH	K/s	18	u horizontal diffusive heating
DVH	K/s	18	v horizontal diffusive heating
DTH	K/s	18	T horizontal diffusion
DUS	W/m2	1	heating from e-w surface stress
DVS	W/m2	1	heating from n-s surface stress
SURWIND	m/s	1	lowest-level horizontal wind speed
TAUX	N/m2	1	eastward wind stress on surface
TAUY	N/m2	1	northward wind stress on surface
HFLR	W/m2	1	upward surface-agcm sensible heat flux
QFLR	W/m2	1	upward surface-agcm latent heat flux

PBL03	m	1	PBL height at 03:00 local time
PBL15	m	1	PBL height at 15:00 local time
QRS	K/s	18	shortwave atmospheric heating rate
QRL	K/s	18	infrared atmospheric heating rate
SOLIN	W/m2	1	solar insolation
SABTP	W/m2	1	absorbed solar flux by model layers + surface
SABAT	W/m2	1	absorbed solar flux above model top
FIRTP	W/m2	1	upward infrared flux at top of atmosphere
CLRST	W/m2	1	net downward clear-sky solar flux at top of atmos.
CLRLT	W/m2	1	upward clear-sky infrared flux at top of atmos.
CLRSS	W/m2	1	net downward clear-sky solar flux at surface
CLRLS	W/m2	1	net upward clear-sky infrared flux at surface
SRAD	W/m2	1	net downward agcm-sfc total radiative flux
FRSA	W/m2	1	net downward agcm-surface solar flux
FRLA	W/m2	1	net upward agcm-surface infrared flux
FRLD	W/m2	1	infrared flux absorbed by surface
FRSAV	W/m2	1	solar flux absorbed by surface, visible waveband
FRSIV	W/m2	1	solar flux downward incident at surface, visible waveband
FRSAN	W/m2	1	solar flux absorbed at surface, near-ir waveband
FRSIN	W/m2	1	solar flux downward incident at surface, near-ir waveband
FRSAVC	W/m2	1	as FRSAV except for clear sky (for NDVI)
FRSIVC	W/m2	1	as FRSIV except for clear sky (for NDVI)
FRSANC	W/m2	1	as FRSAN except for clear sky (for NDVI)
FRSINC	W/m2	1	as FRSIN except for clear sky (for NDVI)
CLOUD	fraction	18	3-D cloud fraction, all cloud types
TOTCLD	fraction	1	total cloudiness, all cloud types
TOTCLDC	fraction	1	convective cloudiness
TOTCLDA	fraction	1	anvil-cirrus cloudiness
TOTCLDS	fraction	1	stratus cloudiness
LWC	kg/kg	18	3-D liquid-water content, all cloud types
CONVLWC	kg/kg	18	3-D liquid-water content, convective clouds
ANVILWC	kg/kg	18	3-D liquid-water content, anvil-cirrus clouds
STRALWC	kg/kg	18	3-D liquid-water content, stratus clouds
TOTLWC	kg/m2	1	total column liquid-water content
PRECL	m/s	1	stratiform precipitation rate
PRECC	m/s	1	convective precipitation rate
RAINF	m/s	1	rainfall rate
SNOWF	m/s	1	snowfall rate
DQASLT	kg/kg/s	18	change in specific humidity from semi-Lagrangian advection

A.2. Surface-Model Fields:

Name	Units	Levels	Description
LMASK	flag	1	surface type: 1=land, 2=icesheet, 3=seaice, 4=ocean
FWATER	fraction	1	areal fraction of water (ocean or lake)
TA	K	1	lowest-level air temperature (from agcm)
RELHUM	fraction	1	lowest-level relative humidity
TS2	K	1	2-meter (screen) temperature
TS	K	1	"solid"-surface temperature (soil/snow/ocean/ice)
TA_M	K	2	daily min/max of TA ("level 1" = min, "level 2" = max)
TS2_M	K	2	daily min/max of TS2
TS_M	K	2	daily min/max of TS
TUL	K	1	upper-story leaf temperature
TUS	K	1	upper-story stem temperature
TLV	K	1	lower-story vegetation temperature
T1...6	K	1	soil/icesheet temperature, top to bottom layers
WET1...6	fraction	1	soil moisture, top to bottom layers (liquid volume relative to ice-free pore space)
WICE1...6	fraction	1	soil ice content, top to bottom layers (ice volume relative to total pore space)
WPUD	m	1	ponded (puddle) liquid depth
WIPUD	m	1	ponded (puddle) ice depth (liquid equivalent depth)
TICE1..3	K	1	sea-ice temperature, top to bottom layers
TAUX	N/m2	1	eastward wind stress on surface
TAUY	N/m2	1	northward wind stress on surface
ROUGHL	m	1	overall surface roughness length
PRECIP	m/s	1	precipitation rate (from agcm)
AVAP	m/s	1	net upward surface-agcm water vapor flux (evapotranspiration)
TRANSP	m/s	1	transpiration rate
INTVAP	m/s	1	evaporation from canopy-intercepted liquid or snow
SURVAP	m/s	1	evaporation from "solid" surface (soil/ice/snow/ocean/snow)
FOGRAT	m/s	1	fog formation rate
RUNOFF	m/s	1	surface runoff rate
DRAIN	m/s	1	sub-surface drainage rate
SOIT	m/s	1	soil saturated hydraulic conductivity (depth-mean)
H2OINT	m	1	net canopy-intercepted liquid or snow (liquid equivalent depth)
LAIT	fraction	1	net one-sided LAI times fractional cover
SAIT	fraction	1	net one-sided SAI times fractional cover
DSBIOME	flag	1	Dorman-Sellers vegetation biomes 1-12
SNOWH	m	1	snow thickness
SNOWF	fraction	1	fractional snow cover
ICEH	m	1	sea-ice thickness
ICEF	fraction	1	fractional sea-ice cover
BRINE	fraction	1	sea-ice brine reservoir / heat to melt column

UICE	m/s	1	eastward sea-ice velocity
VICE	m/s	1	northward sea-ice velocity
FICEADV	1/s	1	∂(sea-ice fraction)/∂t due to advection
HICEADV	m/s	1	∂(sea-ice thickness)/∂t due to advection
QFLUX	W/m2	1	heat convergence due to ocean heat transport
HOCEAN	m	1	ocean/lake mixed-layer depth

APPENDIX B: AGCM AND LSX HISTORY FILE FORMATS

As described in section 5.a, there are two types of history files: AGCM for atmospheric-model fields, and LSX for surface-model fields. They are binary files and have very similar structure as described below.

Each history file consists of multiple history "writes", with one history write containing all requested history fields for a particular time. Each history write starts with four header records followed by the data records. Each data record contains one global horizontal slice for one field, so that one record is needed for each surface field, and 18 consecutive records are needed for 3-D AGCM fields.

These are binary stream files with no physical record structure or embedded control words ("pure" format set by "assign -s bin" for CRAY systems, or set by "form='system'" in the open statement for SGI systems). The "records" referred to below are purely logical or conceptual records, denoting groups of consecutive words in the physical stream. If not packed, the length of each data record is 1 + nlon×nlat words where nlon and nlat are the AGCM or LSX longitude and latitude grid sizes respectively. "Words" here means 64-bit (8-byte) words; on both CRAY and SGI systems the program and its history files use 64-bit reals and 64-bit integers.

The four header records and the data records are described in detail below. The last column shows the Fortran type of each word as I for integer, R for real or A for character.

Header Record # 1 (Model Information):

Word	Description	Type
1	Bytes 1-4: Label ("CCM " for AGCM files, "LSX " for LSX files)	(A)
	Bytes 5-8: Label ("CRAY" for CRAY systems, "IEEE" for SGI systems)	(A)
2	Number of words on this record containing information	(I)
3	Number of header records	(I)
4	Number of data records for this history write	(I)
5	Packing density for CRAY-system data records (1 to 4, 1 = no packing)	(I)
6	Record length of each data record in words	(I)
7	Version number of this history file	(R)
8	Version number of the overall model (1.02, 2.0, etc.)	(A)
9	Base date for current series of runs in form YYMMDD (BASEDATE)	(I)
10	Model time step (seconds)	(R)

11	Longitude resolution (48 for R15, 96 for T31, 128 for T42, 180 for $2°\times2°$)	(I)
12	Latitude resolution (40 for R15, 48 for T31, 64 for T42, 90 for $2°\times2°$)	(I)
13	Vertical resolution (18 for AGCM, fake for LSX)	(I)
14	NTRK spectral truncation parameter (30 for R15, 31 for T31, 42 for T42, fake for LSX)	(I)
15	NTRM spectral truncation parameter (15 for R15, 31 for T31, 42 for T42, fake for LSX)	(I)
16	NTRN spectral truncation parameter (15 for R15, 31 for T31, 42 for T42, fake for LSX)	(I)
16+..	Longitudes (radians, eastward from first grid point east of Greenwich)	(R)
16+..	Latitudes (radians, south to north)	(R)
16+..	Sigma/hybrid mid-layer levels (top to bottom for AGCM, fake for LSX)	(R)
16+..	Sigma/hybrid interface levels (0. to 1. for AGCM, fake for LSX)	(R)

Header Record # 2 (History-File Information):

Word	Description	Type
1	Label ("FILE")	(A)
2	Number of words on this record containing information	(I)
3	Number of filenames in the AGCM or LSX history filename list	(I)
4	Current pointer to filename lists (IFILE)	(I)
5	NSREST flag (–1=cold start, 0=initial start, 1=restart)	(I)
6	Spare	(A)
7-16	Run title (RUNTITLE)	(A)
17-26	Pathname for initial/restart file read at start of run (MSPATHIN)	(A)
27-28	Initial/restart file read at start of run (MSNAMIN)	(A)
29-38	Pathname for history and restart files generated this run (MSPATH)	(A)
39-40	Current AGCM history filename MSNAMHIS (IFILE)	(A)
41-42	Current LSX history filename MSNAM_A (IFILE)	(A)
43-44	Spare	(A)
45-46	Current restart filename MSNAMHIS (IFILE)	(A)

Header Record # 3 (History-Write Information):

Word	Description	Type
1	Label ("WRITE")	(A)
2	Number of words on this record containing information	(I)
3	Number of this history write within this file	(I)
4	Length of accumulation period for time-averaged fields, in timesteps	(I)
5	Start of this accumulation period, in timesteps since base date	(I)
6	Current model time, in timesteps since base date	(I)
7	Start of this accumulation period, in seconds since base date	(I)
8	Current model time, in seconds since base date	(I)
9	Current date in form YYMMDD	(I)
10	Seconds into current day (GMT)	(I)

Header Record # 4 (History-Fields Information):

Word	Description	Type
1	Label ("FIELDS")	(A)
2	Number of words on this record containing information	(I)
3	Number of history fields for this history write	(I)
4-end	Information for *n-th* history field in groups of 8 words:	
	$4+(n-1)\times 8$: field label	(A)
	$5+(n-1)\times 8$: field units	(A)
	$6+(n-1)\times 8$: spare	(I)
	$7+(n-1)\times 8$: number of levels (1,2 or 18)	(I)
	$8+(n-1)\times 8$: number of first data record within this data block	(I)
	$9+(n-1)\times 8$: number of last data record within this data block	(I)
	$10+(n-1)\times 8$: 0 for instantaneous field, 1 for time-averaged field	(I)
	$11+(n-1)\times 8$: number of accumulations for time-averaged fields	(I)

Data Records:

Each data record starts with a one-word label ("DATA" or "DATALSX" for AGCM or LSX files respectively), followed by nlon$\times$nlat words containing data for one horizontal global field, where nlon and nlat are the AGCM or LSX longitude and latitude grid sizes. The data consist of an unformatted Fortran write of an array dimensioned (nlon, nlat) with the subscripts as described in section 5.a. Multi-level AGCM fields are contained on 18 consecutive data records, from the highest sigma/hybrid level (.005) to the lowest (.993).

APPENDIX C: LISTS OF AVAILABLE FILES

This appendix lists all files related to GENESIS version 2.0 that are available to users. These include the sample job script and run-monitor files discussed in this document, data input files for the present day at various resolutions, executable files, restart files,and several pre and post-processing utilities (see section 7). All these files are available by anonymous ftp to biscuit.cgd.ucar.edu under the directory pub/v2.0. The files are grouped into further subdirectories as noted in the subheaders below. Unless otherwise stated, all files are ascii text. Source code files for GENESIS version 2.0 are listed below and are also accessible by ftp, but require a different login and password which can be requested from the authors.

C.1. Miscellaneous (in pub/v2.0/Misc)

Filename	Description
genrefs	reference list of GENESIS-related papers
historyfiles	history-file information for version 2.0 control runs
release_notes_2.0	release notes outlining new physics in version 2.0
sample.fort.6	standard output file (Appendix D)
sample.jobscript	job script (similar to Figs. 1 and 2)

C.2. Data Input Files (in pub/v2.0/Inputfiles or pub/v2.0/Eve)

Sets of data input files at various horizontal resolutions have been generated for present-day conditions as described in section 4. All files for a given resolution are based on a consistent continent-icesheet-ocean map. The symbols [R15, T31, T42, 2X2] below indicate a group of files with each three-letter suffix representing the file's horizontal resolution.

Filename	Description	
data_top_[R15, T31, T42]	agcm topography	(section 4.a.1)
data_gwd_[R15, T31, T42]	agcm gravity-wave roughness	(section 4.a.2)
data_ozone_[R15, T31, T42]	agcm ozone amounts, zonally symmetric	(section 4.a.3)
data_ozone3D_[R15, T31, T42]	agcm ozone amounts, 3-dimensional	(section 4.a.3)
data_sur_[R15, T31, T42, 2X2]	land-icesheet-ocean mask	(section 4.b.1)
data_fwater_[R15, T31, T42, 2X2]	ocean-lake fraction	(section 4.b.2)

data_biome_[R15, T31, T42, 2X2]	Dorman-Sellers vegetation biomes	(section 4.b.3)
data_wisc_[R15, T31, T42, 2X2]	'Wisconsin' vegetation categories	(section 4.b.4)
leaf_001_[R15, T31, T42, 2X2]	EVE veg. data/restart file, January 1st	(section 4.b.5)
leaf_181_[R15, T31, T42, 2X2]	EVE veg. data/restart file, July 1st	(section 4.b.5)
data_soit01_[R15, T31, T42, 2X2]	soil texture, layer 1 (top)	(section 4.b.6)
data_soit02_[R15, T31, T42, 2X2]	soil texture, layer 2	(section 4.b.6)
data_soit03_[R15, T31, T42, 2X2]	soil texture, layer 3	(section 4.b.6)
data_soit04_[R15, T31, T42, 2X2]	soil texture, layer 4	(section 4.b.6)
data_soit05_[R15, T31, T42, 2X2]	soil texture, layer 5	(section 4.b.6)
data_soit06_[R15, T31, T42, 2X2]	soil texture, layer 6 (bottom)	(section 4.b.6)
data_soit06_[R15, T31, T42, 2X2]	soil texture, layer 6 (bottom)	(section 4.b.6)
data_ouv_[R15, T31, T42, 2X2]	ocean surface currents	(section 4.b.7)
data_sst_[R15, T31, T42, 2X2]	ocean prescribed SST and sea ice	(section 4.b.8)
data_top_[R15, T31, T42, 2X2]	surface topography	(section 4.b.9)

tardatav2.0_R15	tar file containing all R15 data files
tardatav2.0_T31	tar file containing all T31 data input files
tardatav2.0_T42	tar file containing all T42 data input files
tardatav2.0_2X2	tar file containing all $2° \times 2°$ data input files

C.3. Executable and Restart Files (in pub/v2.0/Binary)

Binary executable files for GENESIS version 2.0 on CRAY systems are available for various combinations of AGCM and surface resolutions. The first suffix in the filename (R15, T31 or T42) indicates the AGCM resolution (all with 18 vertical levels), and the second (R15, T31, T42 or 2X2) indicates the surface-model resolution. As discussed above in sections 1, 3 and 5, GENESIS version 2.0 can read restart files generated by earlier model versions including 1.02. Also, it can read restart files with resolutions different from the current model (using LEVRES, HORRES and/or HORRESLSX described in section 3.a.1). Hence users can start version 2.0 runs using existing restart files from earlier experiments. In addition, we provide two CRAY-binary restart files saved at the end of multi-year present-day control runs with version 2.0, using T31 AGCM resolution and either T31 or $2° \times 2°$ surface resolution. These runs have essentially reached climatic equilibrium and the restart files represent the model state at 00:00 GMT January 1st.

Filename	Description
genexe_[R15, T31, T42]_[R15, T31, T42, 2X2]	version 2.0 executable files (for CRAY)
PRES000RES_T31_[T31, 2X2]	version 2.0 restart files for January 1st

C.4. Source Code Files

As noted above the source code is in a separate protected ftp area. The source code for the AGCM is split into several '.f' files, and all common blocks are collected into a single file 'commons'. The code for LSX and other surface models is also in several '*.f' and 'com*' files to allow them to be run in stand-alone mode for a single point (see Appendix C.5); however they are collected into two files 'surf.f' and 'surf.com' for incorporation into the global GENESIS model, and the latter two files are available as listed below. Similarly, the dynamic sea-ice code is collected into the files 'dice.f' and 'dice.com' for incorporation into the global model.

Filename	Description
cloud.f	agcm cloud fraction
commons	agcm common blocks
convec.f	agcm convection, cloud mass, precipitation
convert.c	CRAY$\leftrightarrow$IEEE binary conversion
dice.f	sea-ice dynamics code
filio.f	disk and MSS file I/O
genctl.f	overall Genesis driver *et al.*
hisres.f	agcm history files and budget
init.f	agcm initialization, restart files
inline.f	short utility routines inlined on CRAYs
radaer.f	agcm solar radiation
radctl.f	agcm overall radiation driver
radiat.f	agcm infrared radiation
slth.f	agcm semi-Lagrangian transport
spect.f	agcm spectral-transform dynamics
surf.com	surface model common blocks
surf.f	surface model source code
util.f	various utility routines
vdif.f	agcm background vertical diffusion
targenv2.0	tar file containing all source code files
makeusercray	makefile for compiling and linking on CRAY machines
makeusersgi	makefile for compiling and linking on SGI machines

C.5. Single-Point LSX (in pub/v2.0/Lsxpoint)

Filename	Description
lsxpoint_readme	'read-me' file for single-point LSX setup

lsxpoint_doc	documentation for using single-point LSX
tarlsxpointv2.0	tar file containing source and make files

C.6. Utility Programs (in pub/v2.0/Utilities)

Filename	Description (see section 7)
access	utility to read a history field from a history file
convccm1	utility to convert a history file to standard-CCM1 format
convnet	utility to convert a history file to netCDF format
regread	reads RegCM2-driver files
mapinout	Fortran subroutines to read and write a data input file

APPENDIX D: SAMPLE RUN-MONITOR OUTPUT FILE

The run-monitor file shown below was written by a one-day run using nearly the same job script as in Figs. 1 and 2, except that this run used predicted slab-ocean SSTs (OCEANTYPE = 1). Its contents are described in section 6.a. In order to relate the individual segments to the discussion in that section, marker lines such as "(1)======..." have been edited into the file shown below. Also the Namelist input (similar to Fig. 2) echoed in segments 2, 3 and 7 of the output file has been removed for brevity.

APPENDIX E: ERROR MESSAGES

During the initialization phase of a run the program performs numerous checks concerning the validity and consistency of the Namelist input, data input files and the initial restart file. Resulting error messages are written to the standard output file, and following most of them the program terminates immediately. During the execution phase of a run, error messages may also be written concerning problems with writing history and restart files, and if atmospheric temperatures exceed reasonable bounds.

All program error messages are listed below, with some additional explanation for those that are not self evident. They are grouped into the following catagories: Namelist Input (see section 3), Data Input Files (see section 4), Restart and History File I/O (see section 5), and Execution Phase. Names or values that change from run to run are shown below by "...".