MEMORANDUM

TO: Joel Smith, EPA
FROM: Roy Jenne, NCAR
SUBJECT: Selected Texts About Models and Data

September 18, 1987

The attached texts are in somewhat of a state of flux, but should already contain much of the necessary information:

- GISS GCM Outputs. This includes information about the temperature sensitivity of the model, and the concentration of various gases in the simulations.
- The GFDL model.
- NCAR model.
- Note that the 1x CO₂ assumptions for the three models are: GISS 315 ppm; GFDL 300 ppm; NCAR 330 ppm.
- Desired variables from models, tentative.
- U.S. summary of the day data. Most of these stations should be the same as those listed in the inventory for hourly data; see below.
- Present status of U.S. solar radiation data.
- Selected data for the present climate.
- Daily and monthly data from NMC.
- MOS statistics for temperature, precip.
- Hourly observed data from U.S. surface stations. An inventory.

RLJ:plp

COPY: Ron Nielsen
GISS GCM OUTPUTS

Most of this information is from several phone conversations with Dave Rind, GISS (212) 678-5593.

The GISS model is a grid point model, usually run at resolutions of 8° Lat x 10° Lon or 4 x 5°.

1. Control run for the present climate and 2 x CO₂ run.
   - The control run uses CO₂ at 315 ppm (valid 1958); the 2 x CO₂ run uses 630 ppm.
   - The warming in the 2 x CO₂ compared to control is 4.2° C.
   - Long period monthly statistics are for a ten year period, from years 26 to 35 of the control and 2x model runs. These are on an 8 x 10° grid and cover the whole world.
   - Year - month values are for the same 10-year period. The output includes a large number of diagnostics. Global coverage, 8 x 10° grid.
   - The 8° of latitude in a grid cell is really about 7.8°.
   - Data are available at higher resolution for a 3-year period for control and for 3-years of 2x CO₂. The monthly global 4 x 5° data are available for the three-year control CO₂ run and the three-year 2 x CO₂ run.
   - Three years of daily data. This is output for the U.S. and S. Canada at a resolution of 4° Lat x 5° Lon. This U.S. area has 6 lons by 4 lats for the 8 x 10° grid. The 4 x 5° grid covers the same region but has more points. The three-year model runs of monthly and daily values for the U.S. were done on different computers. Thus, the daily values probably do not correspond to the associated monthly values from another model run. These daily runs are now being made (August 1987).
   - The daily values (13 vrb) are:
     a. precipitation (only total), evaporation, snow amount (kg/m²), soil moisture, runoff
     b. max-min temperature
     c. surface u and v wind
     d. SLP at hour 12 and 24
     e. Solar radiation absorbed at the ground
     f. surface humidity (kg/kg)
   - The outputs are limited because the output of data on tapes at the Goddard Cyber 205 is difficult.

Note: Pages 2-4 of this are in the document dated 25 Feb 1988.
The GFDL Model

(From talk with Wetherall, GFDL)

Two years ago GFDL made a GCM control run and 2x CO₂ run for a "cloud prediction experiment." After model spinup, about 10 years of data were generated.

- The model is R15 resolution. The data are on a related 4.5° Lat x 7.5° Lon grid. The global grid has 48 x 40 points.
- The model handles the gases: O₃, H₂O, CO₂. The concentration of CO₂ is 300 ppm for the control run, 600 ppm for the 2x CO₂ run.
- The 2x CO₂ run was 3.0°C warmer (for the world) than the control with fixed clouds. With variable clouds it was 4.0°C warmer.
- The model does not have diurnal temperature changes.
- With this resolution, no model can handle tropical storms and tropical clusters well. Also the handling of ordinary mid-latitude cyclones leaves a lot to be desired.
- He gets nervous when the model output is used for regional studies. Some of the land area temperatures in some regions can be bad, depending on the season.
- From these model runs GFDL will give out:
  - Long period means for each month, based on 10 years.
  - Up to 160 variables, on global grid. These are means; no interannual or daily vari-
    ances.
- It includes such variables as:
  - surface air temperature
  - surface ground temperature
  - two omega levels
  - total precip/day, averaged over a month
  - winds
  - mixing ratio
  - The bottom sigma level is about 60 m above the ground, and has the usual vari-
    ables, as do the other levels.
New Model runs at GFDL

To obtain better results, new model runs are now being made in two stages. SST and sea ice are imposed on the first run. On the second run the Q-fluxes from the first run are imposed. In the case of the control run, they expect that the result will be a better simulation of the present climate. They will stand a better chance of getting the land temperature right. For the 2x CO₂, the procedure finally gives a different SST and a different amount of sea ice.

GFDL expects that the control and 2x CO₂ runs will be completed by about 1 Nov 87 and that data could be released by about 1 Jan 1988.

Wetherall believes that they will have a good deal more confidence in these new results than in the two year old data now available.
NCAR Model for CO$_2$ Simulations

- The NCAR CO$_2$ runs have been made with the atmospheric CCM coupled to an ocean slab, 50 m deep.
- No diurnal temperature change.
- Twice daily values are on tapes.
- Run on 15 wave model, 9 levels. Bottom sigma level is 0.991.
- Grid is 4.5° Lat by 7.5° long for world.
- Longest archive after spinup is 7 years.
- Have year-month statistics.
- 1x CO$_2$ is 330 ppm, 2x CO$_2$ is 660 ppm.

Comments:
- The high latitudes become too cold in winter because there isn't a heat transport by the ocean, (only a storage term) and there is over extensive sea ice.
- The low latitude lower troposphere becomes too warm because there is no water upwelling to cool off the sea surface temperature.
- There are unrealistic changes in the sea ice.
- The model is better in winter than in summer: It is better in the Northern Hemisphere than in the Southern Hemisphere.
Model output

- Max Min temperature, 1.5m
- Ave temp, 1.5m (24 hr)
- Precip (Total and convective) mm
- Evaporation
- Total snow amount (kg/m²)
- Soil moisture
- Runoff
- Surface abs. humidity (near surface or at lowest model level)
- Solar radiation incident at ground
- Upward solar at ground
- Downward IR at surface
- Outgoing solar, ave (can measure this)
- Outgoing long-wave, ave
- Max, min of outgoing Lwave in 24hr (to help match satellites)
- SLP at 1000 mb # (once at start of day)
- Heights 700 and 300 mb (for flow patterns and mean tropospheric temp)
- Surface heat flux
- Latent flux (ave over day)
- Sensible flux (ave over day)

Add Precip H2O
U.S. Summary of Day for Stations

These daily data are for 1st and 2nd order U.S. stations, now about 380 stations being processed. Deck 3210. The data are mostly from 1948.

Elements: Max-Min Temp, Precip, Snow?, sunshine starts Jan 1965 (% of possible), sky cover from Jan 65 (day and night), a moisture vrbl, daily wind, pressure, days with weather types.

We think that about 240 of the stations give sunshine data. Also note that a "solmet" file has sunshine data.

Data is now through 1965 on 17 tapes (1600 BPI), 1986 also available. (Ordered all this 9 Sept on 6250 BPI).

Earlier data:

1935-44 (deck 331) was microfilmed, cards destroyed. Not available.
1945-47 (deck 343) NCDC will check on this one.

Note: The Cooperative station file has data for about 10,000 stations, including these. It gives data from about 1900 for many stations.

(Info from Dick Davis 4 Sept, Ray Sharp 16 Sept)
Present Status of U.S. Solar Radiation Data

1. Daily solar; Solday.

2. Hourly solar (Solmet).
   1952-76 (different stations from above), 27 stations, 1 tape/stn.

   Hourly, 1977-80. A lot of stations are the same as the 27 stations above. Includes global, direct beam, and diffuse radiation. (On 7 tapes)

   Hourly data, not edited. The 1 min data was combined to hourly. Network getting worse, stations dropping out. Annual tapes 1981-84 (4 tapes). Monthly tapes Jan - Oct 85 (10 tapes).

   Network shut down after Oct 1985. No data after that. A new net was supposed to start but didn't.

   (Info from Dick Cram, NCDC, 15 Sept 1987)

See: Handbook of Applied Meteorology (1985)

Chap 42: Data (by Jenne and McKee)
   P 1198: Solar radiation (some from 1902) and sunshine networks (20 stations in 1891)
   P 1208: State networks
   P 1212: Solar Networks in Canada
   P 1227: Discussion of solar data sets in the USA. Description of correction methods and problems.
   P 1260: Solar data publications

16 Sept: Talk with Tom Stoffel, SERI

They have the basic few minute data and other tapes from NCDC for 1977 - on. Are doing QC on basic data to make hourly. I wrote to SERI, as suggested by Tom, to encourage preparation of daily and monthly data also. By about 4 to 6 months??

For a new net, PC's are in the field plus new trackers from Epply. For 31 or 32 stations. Hopefully the net will start again soon.

The break on the net is a disgrace on the U.S.
September 16, 1987

Roland Hulstrom
Branch Manager
SERI
1617 Cole Blvd.
Golden, CO 80401

Dear Roland:

This concerns the processing of solar data from the U.S. net for 1977 thru October 1985 when the dataflow stopped. I understand from Tom Stoffel that you will be processing much of the data to produce hourly data that you trust.

Tom suggested that I write to you about extending the processing somewhat to prepare files of daily total radiation (for the components global, direct, diffuse), and of monthly energy. Several climate models now output fields of daily incident solar radiation at the surface for the present climate and for one with more CO₂. There are EPA assessment studies that require the downward solar (especially for agriculture), but also for the surface energy that leads to evaporation. For reasons of model development and verification, plus needs for assessments, it would help to have the daily and monthly data.

In the present round of EPA assessments, there won’t be time to directly use model outputs. Also, these fields probably are not good enough yet. Statistical radiation generators based on past radiation and rainfall data will have to be used. However, it still would help to have the basic data available for these efforts in the two to five month time frame from now, or somewhat later if necessary.

Thank you for your consideration.

Sincerely,

Roy L. Jenne
Manager, Data Support

RLJ: plp

Encl: Part of an EPA document
Selected Data for the Present Climate

(Talk with Frank Quinlan, NDC)

Under DOE contract, NCDC prepared yr-monthly data for 1219 U.S. stations, mostly starting about 1900. One went back to 1830.

- The data included the year-monthly averages of daily data:
  1. max temps,
  2. min temps, and
  3. mean temps.

Monthly precip was also included. Monthly pressure is included for part of the period.

- The data are on 2 tapes (6250 BPI), received at NCAR from the CO\textsubscript{2} Information Center (CDIC) of DOE in Oak Ridge.
- Each variable for a station has 3 lines of data: original data, adjusted data, confidence on the adjusted data. The elements are in separate files.
- If there were moves, the older data were adjusted to be consistent with new data. A temperature adjustment was made to compensate for changes in observing time.
- Monthly and annual sunshine data was prepared for the U.S. net for 1891-1984. Only about 15 stations give data for the whole period. In recent years there are about 240 stations. (On one tape) The growth of the network and discussion of the data is shown in the Handbook of Applied Meteorology, 1985, Data chapter.

Project to be finished Oct 1987:

- Monthly vapor pressure for 200 stations from the year 1900.
- Monthly clouds for about 200 stations (sunrise-sunset) from about 1895.
- Daily precip and max-min temps for 70 stations from 1900. This is for a subset of the same 1200 stations that had fewest problems that could cause the records to change, such as station moves.
- There is a station index that includes a flag to give an overall assessment of how good the data are.
- NCDC is preparing monthly station pressure for about 200 stations from early years (station, sea-level, and adjusted to a common local elevation. Note: that many of these stations were located at a city office and later moved to airports. This data will be ready by Jan 1988.
A 1910 Weather Bureau reports shows 215 stations and their starting dates, usually about 1870 to 1900. The list of stations is on P 1180 of the Handbook of applied Met (1985). Another list on P 1178 shows that the U.S. had 12 stations in 1800, 306 by 1860 and 3057 by 1900.

Another project:

NCDC has taken all of their LCD stations (200 to 300) in the U.S. and is preparing monthly max, min, mean, precip, snowfall. Many will start before 1900.
Daily and Monthly sfc Data from NMC
Talk with Chet Ropelewski

1. They have only one version of daily decoded data. On any one day there are around 7400 temperature stns and 5400 with daily precip. In the monthly file he looked for good stations and has a file of:

On Any One Month
6500 stns - some data is just missing
4900 stns with mo temp mean
3500 stns with mo precip mean

(They only allow about 1 day to be misg to calc a value)

2. The monthly data that goes to NCDC has max/min Temperature and calculated precip for months. If a daily precip was missing, it uses old air force rules to use month, latitude and climatology to calculate a daily precip. This is then used in the monthly calc.

3. Chet has a tape from item #1 for 1982, 83, 84. He will send it. When a GTS Climat message and calculated mo data are both available, the CAC makes checks. They have found some Climat reports that report 20°C where it should be 20°C etc.

He would like to see some statistics on differences between our WMSC and his monthly tapes. He got rid of many wild values in his mo data by looking for bad data in analyses.

Note: Global data sets that give max-min daily temperature and precip, as obtained from GTS data can be made available from 1967. There are still problems with the datasets.
MOS statistics for temperature, precipitation

One problem with the low resolution GCM model output is that it does not show enough of the effects of regional terrain features. Some of these effects could be put back into the output. To make this possible, one should also archive some tropospheric data. We should decide whether it is reasonable to extend the archive at this time.

TDL used ideas of what is the best input for making MOS forecasts when they decided on their archive of fields.

Bill Klein notes that forecast model outputs are most valid at 500 mb. To permit the use of MOS procedures, he suggests the archives:

- Save heights 1000, 850, 500, 250 mb
  
  He notes that 700 mb is the best single level.
  
  - The data permit a derivation of thickness temperatures and vorticity.

- Need humidity (very important)
  
  - Schemes usually use sfc-500mb average RH
  
  - Could use total precipitable water
  
  - Maybe obtain RH at levels 1000, 850, 700, 500

- Stability 850-500. We assume that the CCM output of convective precipitation can be used for this.

- Vertical motion is being used by U. Van den Dool at the University of MD and NMC to try to calculate precipitation. See JAS, last year.

- Klein has a scheme running at CAC. It uses 700 mb heights to estimate monthly precipitation.

Talk with William H. Klein
(301/454-4625)
Hourly Observed Data from US Surface Stations

(Area: USA including Alaska and Pacific Islands, 303 stations)
(Time: 1948 - on, in general)

These hourly surface data are in a binary format at NCAR on 24 tapes (6250 BPI). In 1984 NCAR received a tape for each station (303 tapes) in this file from NCDC (their TD-14). Stations that were once active but then stopped are not, in general, included in this dataset. One logical record in the binary format has up to 24 hourly observations, as available. The observations include pressure, temperature, humidity, winds, visibility, weather, clouds, etc.

Volume through 1983: 15.59 x10^9 bits, or 1.949 Gbytes.

The inventory (attached) only shows data through 1983. NCAR has the update data for 1984 and 1985 in a different format. The Volume of the updates is rather high: about 420 megabytes per year on 4 tapes/year.

The first station on the inventory, Flagstaff, shows all ***’s for the whole period 1950 through 1983. This says that there are at least some observations for almost all days in every month. It is therefore likely that the record is very complete for the whole period.
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Status of Selected CO$_2$ Climate Model Runs

This gives a little information about the status of GCM runs in a few laboratories. The data from some of these runs have been used for various assessment studies of the effects of "Global Change," and will be used in a new round of global studies being defined under the IPCC programs and under EPA and US AID activities (crops, rivers, forests). The effects of sea level are also being studied, but these projects do not directly use the model data.

Table 1 gives comparative information for several models.

A. Data From Higher Resolution Climate Models

A brief summary of data available from climate models that have been run at higher resolution than data now available will be given. By Dec. 1989, data from three models were being used for scientific comparisons, but not for general release, as yet. These are:

- GFDL R-30 run completed April 1989 (resolution 2.22° x 3.75°)
- UK run finished Nov. 1989 (resolution 2.5° x 3.75°)
- Canadian (CCC) run completed about Oct. 1989 (resolution 3.75°)

B. GISS Model

In 1982, GISS ran a model having a diurnal cycle and a Q-flux to make the present ocean SST and sea ice correct. This Q-flux idea has since been picked up by others:

- GFDL finished a Q-flux run in Jan 1988
- UK finished a Q-flux run in mid-1987
- OSU is working on a Q-flux run now (May 1989)

Also, GISS was the only model having a diurnal cycle that was used in the EPA studies—but UK finished a diurnal-cycle run mid-1987.

Resolution: The main GISS climate runs have been made at a very low resolution (8 x 10°).

C. CO$_2$ Model Runs at GFDL (written May 1989)

- Some info about GFDL model runs: For EPA studies, GFDL provided data from 9-layer; R-15 runs completed about 1984, 85. As with GISS and OSU models, it had a slab ocean. No ocean Q-flux terms.

- The GFDL model does not have a diurnal cycle (This applies to all of the GFDL experiments, as of Feb. 1990).

- R-15 run with Q-flux (completed Feb. 1988)

  Wetherald completed 1x and 2x CO$_2$ runs that included Q-flux in Feb. 1988. This gets SST and sea ice right for the present climate. It improved the climate
simulation over N. America. He is now providing data from this run for assessment studies.

- Temperatures are not as extreme over N. America as in the GFDL run used for EPA studies.
- NCAR received data from this run in April 1989. Climate assessment studies that started after June 1989 are using this GFDL run.

- R-30 run: Wetherald finished the higher resolution, R-30 runs in April 1989. These start with output at the end of the R-15 runs to conserve computer time. He found that a five-year run for climate wasn’t enough, so he finished a total of seven years (in March 1989, then decided to complete 10 years). The R-15 climate had too much precipitation in mid-latitudes and too little in the tropics. R-30 seems to fix both problems.

  - The higher resolution helps the precipitation. Wetherald notes that it is not possible to get the precip right with low resolution models.
  - Can probably release output within a year (about April 1990). It was released for limited IPCC research purposes in November 1989.

- Status of R-30 GFDL run (9 Feb. 1990), talk with Wetherald,

  The experiment is being written up now. Perhaps in two months they may be ready to generally release the data. This model run is similar to the R-15 Q-flux run. With the better resolution, the rain is much better. The soil moisture is better, probably because the precipitation is better.

  The sensitivity of the R-30 run was still 4.0°C, the same as for R-15.

  With more intense systems, the humidity criteria has to be changed to create clouds, or else there would be too few clouds. They changed it for the R-30 case and ended up with more clouds than in the R-15 run (about 60% global cloud cover compared to 55% in the R-15 case). With the same humidity criteria as before, the R-30 would have about 45% cover.

  As a matter of interest, the cloud albedo varies with the height of the cloud. The model uses an albedo of about 0.2 for high clouds, 0.5 for mid clouds, and 0.7 for low clouds.

- Transient run with good ocean

  The ocean model has 4° x 4° resolution (96 x 40 grid) and twelve levels. It is coupled with an R-15 atmosphere. The run is described in the Dec. 7, 1989 Nature magazine. This paper shows the very slow warming in the southern half of the southern hemisphere.

  - Atmosphere is R-15, 9 levels. It has a seasonal cycle and predicted clouds.
  - No diurnal cycle

- Coupled ocean has 12 levels (model by Kirk Bryan)
  - About 4° lat resolution, (96 x 40 grid, global)

- A method is used (Q-flux) to get the SST right for the present climate; and also gets sea ice right.
— It also uses a procedure (similar to Q-flux idea) to get the present ocean/atmosphere water flux (P-E) right

• The amount of CO₂ for the base case is taken as 300 ppm (.000456 mix ratio) and defined as valid in 1960 at the start of the transient run. (Note: In 1958 there were really 316 ppm in the atmosphere.

• Transient baseline run, 1960–2060, almost done
  — CO₂ stays at 300 ppm

  — Starts with CO₂ at 300 ppm in 1980 and increases it 1% a year (other gases contribute to this effective 1% rate of increase). At this rate, doubling (to 600 ppm) occurs in 70 years (at about year 2030).

Kirk Bryan says that the ocean mixes more deeply in the S. Hem., so that water doesn't warm as quickly as the N. Oceans in a CO₂ warming. This difference in temperatures leads to climates that are more monsoonal.
  — It will be a year or more before data can be released.

• A 150-year run has been made (written Nov 89).
  — It has the atmosphere and coupled dynamic ocean above.
  — There were no imposed changes in trace gases, etc.
  — The air temperature shows a natural variability of ±2 °C. Thus, the natural range from cool to warm conditions is about 0.4 °C.

• Computer timing at GFDL (Feb. 1990)

  Ron Stouffer is converting their code from CDC 205 to Y-MP. The atmospheric model (R-15) takes about 80 sec. CPU time for 2.75 days on the 205. This becomes 28 sec. on one processor of Y-MP (there will be eight processors on the Y-MP). He likes the Cray Compiler. Getting an SSD (256 K words, he thinks). The GFDL Y-MP comes in April 1990. They will keep one CDC 205 through Sept. 1990.

• Computing; GFDL R-15 Climate Model (Info Oct. 1987): It takes three hours of CPU time (on the CDC-205) per simulation year. It has a mixed-layer ocean. Time-step 30 minutes. They wondered how GISS could use a one-hour time-step. It was because GFDL has more stratospheric levels which resolve this region better; thus, GFDL gets closer to the true high-wind speeds in the stratospheric polar jet. This requires a shorter time-step for computational stability.

The fully coupled ocean/atmosphere model takes five CPU hours on a CDC-205 for each year of simulation. The ocean time-step is three hours, atmosphere 30 minutes. The run is for 100 years.
D. Climate Models at NCAR

NCAR has developed a series of community climate models (CCM). CCM0B originated with a 1979 adiabatic inviscid version of the ECMWF spectral model. It was first set up so that it would exactly duplicate the simulation of the climate produced by CCM0A (a model that had its roots from Australia). Since that time, the basic model structure remains similar to CCM0B, but almost all of the algorithms have been changed to reflect later research. The model is also used for forecast studies, usually at a higher resolution than for climate.

1. CCM1 (an improved model released by NCAR in 1987)

   In July 1987, a new version of CCM0B was released for community use. It had many improvements; it was called CCM1. By mid-1989, most (not all) of the user groups had migrated to the new CCM1 version of the model. In early 1990, the PI groups using the CCM1 were approximately as follows:
   
   - Four foreign research groups use it at their locations
   - Eight US research institutes use it at their site (Livermore, Los Alamos, Argonne, NASA Marshall, Purdue, Georgia Inst. Tech., etc.)
   - About 14 university PI groups use it on NCAR computers
   - About 10 PI groups at NCAR use it

2. New version of the model (CCM2, 1990)

   A prototype of CCM2 is available in June 1990. In July 1991, CCM2 will be released to the community. It incorporates a lot of new features as follows:

PHYSICS ASPECTS

- Hybrid vertical coordinates (generalized \( \sigma \)). With this procedure, a user can have \( \sigma \) coordinates (that follow a smooth terrain) near the surface and then pressure coordinates above 100 mb. CCM1 had \( \sigma \) coordinates only.
- Diurnal cycle (no diurnal cycle before)
- Multilayer heat capacity soil model (no heat capacity before)
- Full IR and Vis radiation is done each hour; this takes 35 to 40% of model time
- Semi-lagrangian transport scheme
  - Permits the model to properly advect water vapor (unlike the past).
  - Provides an arbitrary number of fields to transport chemical constituents and cloud water variables.
- Improvements to representation of moist convection
  - Kuo-like deep convection scheme (similar to previous one)
— New shallow convection scheme (the previous method was poor)

- Improvements to hydrologic processes
  — Better handling of snow-covered surfaces (radiation, albedo, and associated snow melting are better)
- New cloud-fraction parameterization

- Improvements in resolution
  — Horizontal resolution anticipated to be T-42, for most runs. Time step is 15 min. now, hope to use 20 min.
  — 18 vertical levels
  — Running time is expected to be about 8 CPU minutes on one processor of an X-MP per simulated day, (5.5 min on Y-MP). A year of simulation will take 49 CPU hours on X-MP; 34 hours on one processor of a Y-MP.
  — A 9-level R-15 model run on the CRAY 1-A (12.5 ns cycle time) takes about the same total system time as a T-42, 18-level model on a Y-MP with 8 processors (each 6 ns cycle time).

COMPUTATIONAL ASPECTS

- "Plug-compatible" physics structure
- Single-job multitasking capabilities

3. New climate model run (greenhouse gases) at NCAR

Dickinson is making new climate model runs at NCAR for single and double CO$_2$, using a model that includes nearly all of the new physics in CCM2. The model includes a very sophisticated treatment of surface processes. A climate model run for the greenhouse gas problem must have an ocean, so a slab ocean (with a Q-flux procedure) is included.

These runs are being made during January - June 1990. Data will probably be released about September 1990. It is an R-15 model (4.5 x 7.5 degrees) with diurnal cycle, Dickinson's new BATS surface code, and with improved clouds. It is based on an improved version of NCAR's CCM1 (community climate model). Short-wave radiation is calculated each three hours, long-wave each twelve hours.

The soil in the GFDL model tends to be somewhat too wet. In the NCAR model CCM0A, the soil gets too dry, which then helps cause excessive summer warming in the present climate (the published NCAR CO$_2$ runs are from this model). The soil moisture in this new run is between CCM0A and GFDL, which is promising.

4. Previous Greenhouse gas model runs at NCAR

The published versions of double CO$_2$ and transient runs at NCAR have all been based on the CCM0A and GFDL, which has not incorporated many of the improvements made for CCM1 (or CCM2). However, it has included some of these changes, and experiments have been run that include slab oceans (no Q-flux) and others that have a simple dynamic ocean.
E. UK Model Runs

John Mitchell reviewed the best of what had been done in other groups and defined the 1x, 2x CO$_2$ runs (about Nov 1985). The model runs were finished about June 1986.

- This is the only UK model run available at NCAR (as of Feb. 90)
- The main model properties are:
  - It is a grid point model, 5° x 7.5° resolution
  - levels: 11 levels (σ surfaces), plus surface
  - Has a slab ocean, 50 m thick (similar to the other models)
  - Has a full Q-flux to get present SST and sea ice right
  - Has a diurnal cycle
  - Spinup period about 20 years, then collect 15 years of data

- Note: The sensitivity of the model is 5.2°C for CO$_2$ doubling. Most other models are about 4°C. Some think this UK model gets more warming because it has more layers which permits better development of the important high clouds.

- Another model
  - See the section on other UK model runs. The model with 300 km resolution and a sensitivity of 3.2°C is of special interest.


F. Other UK Model Runs (data not at NCAR)

  - These properties tend to make the low, warmer clouds brighter (more reflective) in the 2x CO$_2$ climate, but the cirrus became blacker to IR. The first effect would cool the climate; the cirrus effect would warm it. The guess is that the net effect would be a slight cooling, but it will require GCM simulations to find out.

- UK, Various Model Runs (written Oct 1989)
  1. The UK data at NCAR (as of Sept. 89) has a climate sensitivity of 5.2°C. Resolution is 5° x 7.5° (lat x long).
  2. There is a new UK run like #1, but with a new surface hydrology scheme. This is a "leaky bucket with a sieve on it." The bucket still holds about 15 cm (usually 15-18 cm, not fixed as before). When it rains, part of the water goes into runoff, even without a full bucket. In the control run, all land areas 35-55° N went from 14 cm of water in the bucket in April to 7 cm in September. For central N. America (80-50° N, 85-105° W), the comparable numbers were 14 to 9 cm of water. This is wetter than most models.

The sensitivity of this run was still 5.2°C. There is little enough change from the UK run that NCAR already has, that we will stick with the older one.
3. One run had variable optical properties. This model also simulates the amount of liquid water in a cloud (the cloud is still formed based on a RH threshold). Cloud simulation included water content, and a cirrus dissipation that was too fast (particles fell out quickly). This gave a climate sensitivity of 1.9 °C (surface warming 1x to 2x CO₂). With fewer cirrus clouds, we expect a smaller temperature increase. The size of the change of sensitivity in this run was a real surprise when it happened. A further run with cloud water, but nonvariable radiation properties, gave 2.7 °C for doubling CO₂ (see September 14, 1989 Nature).

4. Another UK run includes water content of clouds, a more realistic cirrus dissipation rate, but not the variable optical properties. It has a sensitivity of 3.2C. Monthly archives were made, not daily. If variable optical properties were added, the sensitivity would probably drop somewhat. It requires a simulation to really determine the effect.

5. Higher resolution run

A run is being made like #4 above, but twice the resolution (2.5 x 3.75°, not 5 x 7.5° as before). This run was finished by Dec. 1989. Output would then be examined and written up. It would be at least six months before the data could be released.

6. Data release policy

The UK is not committed to releasing data from any of the new runs. That will depend on later decisions.

7. More information

See Attachment 1 for more information about the UK Model.

G. Canadian Climate Model (May 1990)

A model has been developed by the Canadian Climate Centre (CCC) and run for 1x and 2x CO₂ conditions. The model has a higher resolution than many climate simulations. Some info about the model:

- T-32 resolution (96 x 48 global points), 10 levels; 3.75° resolution
- Has a 50 m-deep slab ocean, with Q-flux
- Has a typical RH scheme to develop clouds
- Has a deeper soil moisture bucket where there are forests
- See Attachment 2 for more information about the Canadian Climate Model.

DATA RELEASE: Data for N. America and Europe was released in January 1990. All of the data from the run completed November 1989 will probably be released about March 1991 (written May 1990).
H. Compare the Sensitivity of Several Model Runs

<table>
<thead>
<tr>
<th>Model</th>
<th>Temp Increase</th>
<th>Precip Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCC Model</td>
<td>3.5 °</td>
<td>3.8%</td>
</tr>
<tr>
<td>OSU Model (two-levels)</td>
<td>2.8 °</td>
<td>7.8%</td>
</tr>
<tr>
<td>GFDL (Q-flux)</td>
<td>4.0 °</td>
<td>8.3%</td>
</tr>
</tbody>
</table>

Also, refer to Table 1 for information about various model runs.

I. See Figure 1 for a comparison on when selected climate model runs have been completed.

---

**Table 1. Characteristics of Selected Climate Models**

All models are global in extent. All Models have a smoothed topography that varies between models. All models have an annual cycle. The new GFDL run has been added for information. All models (except the transients) give data for the present climate (1x CO₂) and double CO₂ climate (2x CO₂). The EPA studies, based on these models, were made between October 1987 and April 1988.

<table>
<thead>
<tr>
<th>Model</th>
<th>When Calculated</th>
<th>Resolution (lat x lon)</th>
<th>Model Levels**</th>
<th>Diurnal Cycle</th>
<th>Base 1x CO₂ (ppm)</th>
<th>ΔT for Double CO₂</th>
<th>Increase In Global Precip</th>
</tr>
</thead>
<tbody>
<tr>
<td>GISS</td>
<td>1982</td>
<td>7.83 x 10°</td>
<td>9</td>
<td>yes</td>
<td>315</td>
<td>4.2 ° C</td>
<td>11%</td>
</tr>
<tr>
<td>GFDL*</td>
<td>1984-85</td>
<td>4.44 x 7.5°</td>
<td>9</td>
<td>no</td>
<td>300</td>
<td>4.0 ° C</td>
<td>8.7%</td>
</tr>
<tr>
<td>OSU</td>
<td>1984-85</td>
<td>4.00 x 5.0°</td>
<td>2</td>
<td>no</td>
<td>326</td>
<td>2.84 ° C</td>
<td>7.8%</td>
</tr>
<tr>
<td>GISS Transients</td>
<td>1984-85</td>
<td>7.83 x 10°</td>
<td>9</td>
<td>yes</td>
<td>315 (in 1958)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GFDL* (Better Ocean)</td>
<td>Feb. 88(^A)</td>
<td>4.44 x 7.5°</td>
<td>9</td>
<td>no</td>
<td>300</td>
<td>4.0 ° C</td>
<td>8.3%</td>
</tr>
<tr>
<td>UK</td>
<td>June, 1986(^A)</td>
<td>5° x 7.5°</td>
<td>11</td>
<td>yes</td>
<td>320</td>
<td>5.2 ° C</td>
<td>15%</td>
</tr>
<tr>
<td>Canada (CCC)</td>
<td>Nov. 89(^A)</td>
<td>3.75 x 3.75°</td>
<td>10</td>
<td>yes</td>
<td>330</td>
<td>3.5 °</td>
<td>3.8%</td>
</tr>
</tbody>
</table>

\(^{A}\) These are the completion dates of the model run.

\(^{*}\) This is a spectral model that has 15 waves

The other models are gridpoint models with resolution as given

\(\text{**All models make calculations for surface conditions as well as at these upper-air levels.}\)
J. Planetary Albedo and Clouds in Model Runs

Please note that the planetary albedo drops significantly in the 2x CO₂ runs compared to the control run. This lets more energy into atmospheric system and accounts for part of the surface warming. The earth’s present albedo, based on measurements from satellites is between 28 and 30%.

1. GFDL Q-flux Run (completed Feb. 88)

Total global cloud cover (area weighted) and total global planetary albedo will be given from the R15 Q-flux run.

<table>
<thead>
<tr>
<th>Total Global Clouds</th>
<th>Planetary Albedo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1x CO₂ run</td>
<td>50.93%</td>
</tr>
<tr>
<td>2x CO₂ run</td>
<td>50.59%</td>
</tr>
<tr>
<td>Change</td>
<td>- .34%</td>
</tr>
</tbody>
</table>

2. GISS Model Run (dated 1982)

This simulation has relatively low resolution (8° lat x 10° lon), but it already (in 1982) employed a Q-flux procedure, and had a diurnal cycle.

<table>
<thead>
<tr>
<th>Planetary Albedo</th>
<th>Outgoing IR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1x CO₂</td>
<td>30.24%</td>
</tr>
<tr>
<td>2x CO₂</td>
<td>28.80%</td>
</tr>
<tr>
<td>Change</td>
<td>- 1.44%</td>
</tr>
</tbody>
</table>

3. Canadian model run (completed Nov 89)

<table>
<thead>
<tr>
<th>Total Global Clouds</th>
<th>Planetary Albedo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1x CO₂</td>
<td>51.82%</td>
</tr>
<tr>
<td>2x CO₂</td>
<td>50.68%</td>
</tr>
<tr>
<td>Change</td>
<td>- 1.14%</td>
</tr>
</tbody>
</table>
Figure 1. History about selected climate model runs that have been used for studies of 1x, 2x CO2 climates.

Note: The OSU model was also used for EPA studies. It was completed in 1984-85; has two atmospheric levels.
Attachment 1

UK Climate Model

The 1x and 2x CO₂ runs from the UK climate model were defined about Nov. 1985 and completed about June 1986. When the model was defined, they tried to include the best features of the various world models (diurnal cycle, ocean slab with Q-flux, etc.). The results are described by Wilson and Mitchell, Nov. 1987. JGR Vol 92, No. D11. Selected fields (for applied studies) from this run are on the NCAR tape.

The following information about the UK model runs is largely from John Mitchell and William Ingram:

1. Model resolution is 5° lat. x 7.5° long.; it is a grid point model, time step 20 minutes.

2. Levels: 11 sigma levels, plus surface. The sigma levels follow the model terrain; they do not intersect it as pressure levels do. Sigma 11 is the bottom level, (Sigma = 0.98744). This is about 100 m above the surface.

3. Model sigma levels are: 0.02207, 0.08856, 0.15741, 0.23047, 0.31738, 0.43626, 0.57717, 0.71772, 0.84380, 0.93710, 0.98744. The last one is the first level above the surface. If the pressure at the model surface happens to be 1000 mb, then the pressure at the bottom sigma level is 987.44 mb; the next sigma is 937.10 mb, etc.

4. The 1x amount of CO₂ is: 320 ppm (2x is 640).

5. Uses a solar constant of 1373 w/m². But 3% of this (41 w/m²) is lost by Rayleigh scattering. This loss becomes part of the overall planetary albedo (as it should).

6. The model has a diurnal cycle.

7. Surface temperature and max/min temperature.

   The temperature that is provided to users is actually a skin temperature. However, the skin formulation assumes a heat capacity equal to 5 cm of water. It may behave like an air temperature. This is discussed more below.

8. The surface wind speed is a proper average over the day. In the model, the appropriate stability is used to interpolate winds down to the near-surface (10 m) in order to calculate fluxes. The surface wind speed is an average of this wind speed, using all model time steps.

9. Model spinup is about 20 years, then data are saved for 15 years. The data are 15-year averages for each month.

10. There is only one type of surface condition (water, forest, ice, etc.) in a grid box - like most other models.

11. The model has a slab ocean, 50 m thick.

12. The model uses a full Q-flux procedure for the ocean. This insures that the simulation of present day sea surface temperature is duplicated in the model for the long-period monthly mean. Year-to-year variations still occur.

   Simulated sea ice is very close to the observed, for the control run (not for 2x CO₂).

   (Note: The rest of this is in a paper near the front.)
Canadian Climate Model Run

A climate model run for 1x and 2x CO₂ climates was defined Fall 88 and completed during November 1989 by George Boer. It is one of the higher resolution runs in the world. Some of the facts are:

- T32 resolution. (48 x 96 global points), (3.75° x 3.75°)
- It has 10 layers; time step 20 minutes
- It has a mixed layer ocean, 50m depth
- It has a Q-flux procedure to get the present sea surface temperature and sea ice right.
- The amount of CO₂ is 330ppm for the 1x CO₂ climate
- The soil moisture scheme includes soil type, vegetation types and varying water capacity
- Solar input: 1370 w/m², with seasonal cycle and diurnal cycle
- Radiation: Full long-wave radiation is calculated each six hours, with updates each 20 minutes. Full short-wave radiation is calculated each three hours, updates each 20 minutes.
- How much model time was needed: For the 1x run, it took five simulation years (of model time) to accumulate Q-flux statistics; two years to achieve a steady climate, plus 10 years for data. For the 2x run, a guess for the new climate temperature was made. It then took eight simulation years to obtain a steady climate, and finally ten years of data. This is a total of 35 model years of simulation, done in 20-minute time steps.
- Data release: Data for N. America and Europe was released in January 1990. All of the data probably won’t be released until at least March 1991.
- Model sensitivity
  - from 1x to 2x CO₂, the global temperature increases by 3.5 °C
  - precipitation increases by 3.8%
  - clouds decrease by 2.2% (of the 1x run). The change is from 51.82% to 50.68%, a drop of 1.14% coverage.
- It has fractional clouds, not just yes/no clouds at a given level.
- Comparison of the way clouds are handled in models
  - the Canadian model has fractional clouds at a grid point
  - the GFDL model has on or off clouds at a grid point
  - the NCAR models CCM1 and CCM2 have clouds with fractional cloud cover. The NCAR CCMOA has yes/no clouds.
- This information is based on written information and telephone conversations provided by George Boer.

SOURCE OF INFORMATION: The source was from George Boer, Canada.
Information About Several Climate Model Runs

This text contains information about several climate model runs using GCMS. Most of this text was written 1987-88. Time has not been available to fully clean it up.

The first section gives references for the various model runs.

The models included in this text are:

1. GFDL model (this run was made 1984-85; used for EPA studies in 1987-88)
2. GFDL with Q-flux procedure (completed Feb. 1988)
3. OSU model (run was made 1984-85)
4. NCAR model
5. GISS model (1x, 2x CO₂, completed 1982)
6. GISS model (two transient runs)

More detailed information about the UK run and the Canadian model are in another text.

CLIMATE MODEL REFERENCES

First the key references for each model will be given. Then the more general references are presented.

1. GISS Model (Goddard Institute for Space Studies, NYC)

The following reference describes the basic GISS model used for GISS 1x, 2x CO₂ runs, and for the transients. It doesn’t include some of the basic assumptions about amounts of trace gases used for the transient runs, but these are given in Table 2.


The control runs for the GISS model sensitivity tests (including the diurnal cycle) were described in a Monthly Weather Review article in April 1983 as above. The 2x CO₂ run was made in 1983 and described in an AGU book: Geophysical Monograph, Vol 29 in 1984 (also called Maurice Ewing series, Vol 5). The paper is: "Climate Processes and Climate Sensitivity."

Overview reference for many GISS model experiments:


Reference for GISS transient model:

2. **GFDL Model (Geophysical Fluid Dynamics Laboratory of NOAA, Princeton)**

2.1 The first of the following two references is the basic one to use for the 1985 model run:


2.2 For GFDL Q-flux models

This includes R15 (done Feb. 1988) and R30 (done April 1989):

Wetherald, R.T. and S. Manabe, est. 1991; A reevaluation of CO2-induced hydrologic change as obtained from low and high resolution versions of the GFDL general circulation model (July 1990, in preparation).

This discusses the R15 and R30 Q-flux versions of the GFDL model with emphasis on precip, evaporation, and soil moisture.

3. **OSU Model (Oregon State University)**

Main references are:


4. **UK Model (run completed June 1988)**


NCAR also has summary information about the UK model (model expert is J.F.B. Mitchell).

5. **Canadian Model (done Nov. 1989)**

Notes from George Boer, Canada. There is no reference as yet.

**COMPARISON OF MODELS**

The output from GFDL, NCAR and GISS models are compared in the following paper. This does not include the OSU and UK (Mitchell) models:

A coming paper in *Bul. Amer. Met. Soc.*, will compare July soil moisture from all five models. Schlesinger (1988) also gives comparisons of all five climate models. Further information can be obtained from M. Schlesinger, Oregon State University, address:

Dr. Michael E. Schlesinger  
Dept of Atmospheric Science  
Oregon State University  
Corvallis, Oregon  97331-2209

OTHER REFERENCES


GFDL Climate Model Runs

Selected information about the GFDL climate model simulations is presented. As noted in the final section, the GFDL model run completed in 1984-85 has been superseded for general use by more recent simulations.

A. The GFDL Model
(From talk with Wetherald, GFDL, 3 Sept. 1987)

Two years ago GFDL made a GCM control run and 2x CO\textsubscript{2} run for a "cloud prediction experiment." After model spin-up, about 10 years of data were generated.

- The model is R15 resolution. The data are on a related 4.5° lat x 7.5° lon grid. The global grid has 48 x 40 points. The simulation was accomplished during 1984-85. The latitude spacing is actually 4.444°.

- The model handles the gases: O\textsubscript{3}, H\textsubscript{2}O, CO\textsubscript{2}. The concentration of CO\textsubscript{2} is 300 ppm for the control run, 600 ppm for the 2x CO\textsubscript{2} run.

- The 2x CO\textsubscript{2} run was 3.0°C warmer (for the world) than the control with fixed clouds. With variable clouds it was 4.0°C warmer.

- The model does not have diurnal temperature changes.

- With this resolution, no model can handle tropical storms and tropical clusters well. Also the handling of ordinary mid-latitude cyclones leaves a lot to be desired.

- He gets nervous when the model output is used for regional studies. Some of the land area temperatures in some regions can be bad, depending on the season.

- From these model runs GFDL will give out
  - long period means for each month, based on 10 years
  - up to 160 variables, on global grid; these are means—no interannual or daily variances

- It includes such variables as
  - surface air temperature
  - surface ground temperature
  - two omega levels
  - total precip/day, averaged over a month
  - winds
  - mixing ratio
  - The bottom sigma level is about 60 m above the ground, and has the usual variables, as do the other levels.
B. GFDL Model (12 Nov. 1987)

1. SURFACE ELEVATION (Zstar): This is the model elevation of the surface of the earth. It gives the height of land, surface of ocean, and top of ice cap. It is smoother than the real earth. The elevation of the water over the oceans is at height equals zero, but in the model the surfaces go up and down by 100 to 200 meters in places. Don't worry about this fact. If sea level pressure is needed, it should be calculated for elevation equals zero.

2. LEVELS IN THE GFDL MODEL: The following table shows the sigma levels of the med point of layers in the GFDL model. The lower model levels are parallel to the earth's model surface elevation.

<table>
<thead>
<tr>
<th>Level</th>
<th>Sigma</th>
<th>Level</th>
<th>Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 (near sfc)</td>
<td>.990</td>
<td>4</td>
<td>.350</td>
</tr>
<tr>
<td>8</td>
<td>.940</td>
<td>3</td>
<td>.205</td>
</tr>
<tr>
<td>7</td>
<td>.830</td>
<td>2</td>
<td>.095</td>
</tr>
<tr>
<td>6</td>
<td>.680</td>
<td>1</td>
<td>.025</td>
</tr>
<tr>
<td>5</td>
<td>.515</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example: Find the pressure at level 7 in the atmosphere (sigma = .830). Take .830 times the surface pressure (not sea level). If the surface pressure happens to be 1000 mb, then the pressure at level 7 will be 830 mb.

3. SURFACE TEMPERATURE: Level 9 of the model is located about 10 mb (or 80 meters) above the model surface (the surface elevation is given by Zstar). The Level 9 temperature is also used for the surface air temperature that is normally measured at about 1.5 meters. Since the boundary layer physics in the model is primitive, it is considered that it doesn't make sense to make a normal "reduction" (change) of the temperature in this boundary layer.

4. SOIL MOISTURE: This is given in mm of water in the soil. Consider also that one gram/cm² of water is the same for practical purposes as one cm of water depth. The soil moisture applies to a variable depth of soil depending on soil type. The soil "bucket" of water becomes full when it has 15 cm of water. Then, any additional water goes into runoff.

5. SURFACE WIND SPEED: It is not possible to obtain a surface average wind speed from the present GFDL model. Therefore we have calculated a vector mean speed (which is a marginal approximation to the average speed). In an overall sense, the winds look rather similar to the wind speeds derived from GISS data.

6. DOWNWARD SOLAR AT THE SURFACE: Net solar and a calculated albedo are available from GFDL. The model inputs a basic constant albedo that includes the effect of soil type and average vegetation (this is constant through the whole year) The calculated albedo changes with snow coverage and sea ice, not with recent rainfall. NCAR has used net solar radiation to calculate a good approximation for downward solar. The downward solar radiation, DS, was approximated by solving for DS in the equation:

\[ \text{net surface short wave radiation} = \text{DS} - (\text{albedo}) \times (\text{DS}) \]
7. RADIATION AT TOP OF ATMOSPHERE: Net short wave is given. In principle, one could calculate the incoming solar and use this to derive the amount reflected, which is what the satellites measure. Actually the satellites don’t measure radiation all the time, but take enough samples at different times of day that averages can be derived.

Outgoing IR at the top of the atmosphere is given. It is labeled as net IR, but since downward IR is zero, it is also the outgoing IR.

8. SOLAR CONSTANT: The model uses 2.07 cal cm⁻² min⁻¹ (1443.7 W/m²). This is higher than what is observed. It is used as a way to tune the model to give a good simulation of the present climate.

9. MISCELLANEOUS: The GFDL model uses 300 ppm as the definition of 1x CO₂. The model does not have a diurnal cycle. GFDL does not have ground temperature (there is skin temperature though). There is no field for plant stress. The present model doesn’t have heat transport by ocean currents, but new results available about Jan 1988 will have this. The latitude points in the GFDL grid are actually valid on a Gaussian grid. Within .01° precision, this is the same as equal latitude spacing until one is very close to the pole. The closest points to the equator are at 2.22° latitude. The spacing is about 4.444°.

If there is any snow cover in the model, it uniformly covers the grid box.

C. Intensity of Precipitation

Many assessment models have a need to estimate the rate of precipitation over local areas. It can make a big difference whether a centimeter of rain falls in 5 minutes or 2 hours. The models often carry some variable that gives the atmospheric stability or the separate amount of convective precipitation. This information could be used to choose space- and time-scales for the precipitation within a grid box.

D. The Q-flux Procedure (written late 1987)

To obtain better results, new climate model runs are now being made in two stages. During the first run a local heat flux (called Q-flux) is calculated that should be added at each ocean location in order to simulate the actual SST and sea ice for the present climate. This is called a Q-flux procedure. It effectively includes heat flux by ocean currents (note that currents are not simulated in these primitive ocean slab models).

On the second run, the Q-fluxes from the first run are imposed. In the case of the control run, the result will be a better simulation of the present climate. They will also stand a better chance of getting the land climate right. For the 2x CO₂ run, the same Q-fluxes are inserted as for the control run. For 2x CO₂, the procedure finally gives a different SST and a different amount of sea ice, because the climate forcings are different.

GISS first used the Q-flux procedure for the 1982 model runs. GFDL finished a Q-flux climate model run in Feb. 1988. Other modeling groups are also using this procedure.

E. The GFDL Q-flux Model (run finished Feb. 1988)

This 1x, 2x CO₂ run was completed Feb. 1988. It uses the Q-flux procedure to improve the slab ocean. It is able to reproduce the SST and ice extent of the present climate. Otherwise it is the same R-15, 9-level model used before. Wetherald (at GFDL) has a good deal more confidence in these new results than in the two year old data now available. The older results were used for the EPA assessment studies made
in 1987-88.

The model sensitivity of the previous model run was 4.0 °C from 1x to 2x CO₂. The new Q-flux run was expected to be less sensitive, but it came out almost exactly the same (within .05 °C). Too much sea ice had been forming in the N. Hem in the simulation of the present climate. This gave a large warming when this melted in the 2x simulation. With this problem fixed, the sensitivity for the N. Hem is less. But it was balanced by a reverse effect in the S. Hem. There, the simulation of sea ice wasn't as great as now observed. With this fixed, the warming from 1x to 2x CO₂ in the S. Hem increased.

R. Wetherald at GFDL has taken preliminary looks at the simulation of temperature and precipitation over N. American and Eurasia. He sees significant improvements, but notes that we are never going to see a huge improvement with models having very low resolution (GFDL's model is R15, similar to the others in resolution).

In the GFDL model, they only get runoff when the soil water "bucket" is full. Other models usually allow some runoff, even if the soil isn't saturated. Since runoff is tricky to get right, people should definitely try to use precipitation instead.

Computer time needed: The 15-wave, 9-level GFDL model takes one hour of CDC-205 CPU time for each three months of model simulation.

The above information is from Dick Wetherald, GFDL (26 Feb 1988).

F. Which GFDL Model Should be Used for Assessment Studies?

- The EPA assessment studies for the US region used the earlier GFDL model output (1x, 2x CO₂).
- The GFDL Q-flux model (1x, 2x CO₂) is a better model run and these results have been used since they became available. NCAR has been emphasizing the use of this run (and delivering it) since at least May 1989.
- A higher resolution version (R30) of the GFDL Q-flux model may become available for general use about Oct. 1990.

On 11 Jul 90 NCAR received the R30 data on 12 tapes (for all 170 yr in the model). This has 10-year long period monthly means for 1x and 2x CO₂. Also it has all of the for each year-month.
DATA FROM OSU 1x, 2x CO₂ MODEL

In this mailing, we are sending data from the Oregon State University (OSU) model received from Mike Schlesinger. Printed data for the seven basic variables are enclosed. The digital data on floppy disk or tape are for all nine variables that are available. The model elevation is also printed so that users can see what elevation the model used. The model effectively "sees" a smooth interpolation between the elevations given, not all the rugged terrain features of the real earth.

This mailing contains:

- Information about the model is in this section;
- Sheet by Dennis Joseph explaining the contents of the disk;
- Disk or tape with data for all nine variables, with a program file and a data file;
- Copy of format text (same format as before);
- Print of the model data for the seven variables: average monthly temperature, vector mean wind speed, total precipitation rate, boundary layer mixing ratio, water runoff, surface incident solar radiation, total clouds;
  The print for the other two variables (sea-level pressure and surface evaporation rate) is available on request.
- Drought information: Memo to Joel Smith (19 Feb 88), and figures that present drought information for the 1930s and 1950s.

Some information about the OSU model follows:

- The resolution is exactly 4° lat by 5° lon.
- Amount of CO₂ was 326 ppm for 1x CO₂. Other gases were not changed for the 2x CO₂.
- The solar constant was set at old "best" value of 1.94 cal/(cm²-min), which is 1354 w/m².
- The model does not have a diurnal cycle. In the next model run there will be one.
- This model run was made during 1984, 85.
- The model was spun up for about 40 years using a fast annual cycle to save computer time; This sped up the calculations by a factor of 12 for these years. Then 10 more years were run; they were used to calculate the statistics that are being sent.
- The time step for the motion variables was 7.5 minutes, other terms are calculated each hour. Each model day of calculation took 40 seconds on the NCAR Cray 1A. Thus, each of the last 10 years took 249 minutes of CPU time.
- Overall, the model has somewhat of a warm bias.
The model has a surface layer and two tropospheric layers at about 400 and 800 mb (sigma coordinates) and a slab ocean. It carries pressure at the model surface and later calculates sea level pressure. There is a constant flux layer near the surface.

A given grid box has one type of surface taken from 9 types: water, crops, grassland, trees, steppe, desert, ice, etc. At this model resolution, the Great Lakes do not produce any grid point with water. Hudson Bay does.

Wind data: The wind data are vector mean wind speeds because the vector components were the only data available. The vector speed is significantly less than the average speed. We can only hope that the wind ratio for 2x/1x CO\textsubscript{2} is about the same for scalar wind speed as vector speed. Actually, we would prefer not to be forced to make this assumption. Please also be aware that, in this model, the location of the wind grid points is in the middle of the other grid points. We are sorry for this inconvenience for the PIs.

Wind ratios (2x/1x CO\textsubscript{2}): The change from 1x to 2x CO\textsubscript{2} is given by ratios. This matches what was sent for the GFDL and GISS model runs. There are a very few points where the ratio may be large due to an initial wind near zero. If this happens on a needed grid point, use nearby data as before. You may recall that for the GISS transient runs, we had to use deltas for wind changes, not ratios.

The soil moisture calculations uses a bucket method about the same as in the GFDL model. The soil bucket holds 15 cm of water.

Precipitation and runoff: The model samples instantaneous precipitation each hour and this is used to calculate means. This will give an accurate model precipitation. The runoff was only sampled once each day. Since the model runoff works on the same time scale as the precip, this low sampling rate will probably cause some noise in the runoff. M. Schlesinger has looked at the runoff and the overall patterns appear reasonable.

Radiation at the surface: At NCAR, we noted that the OSU downward solar radiation at the surface was about 30% greater than GISS, yet the clouds are rather similar. M. Schlesinger has noted this also and plans to put a more physically-based cloud scheme into the model. Apparently, the amount of clouds is about right, but the physical properties are off and they let too much energy through. It is also hard to simulate some of the ocean stratus correctly, which also affects the energy balance.

Ocean: The OSU model has a slab ocean that is 60m deep. (It was only 5m deep during the 40-year spinup). It does not have currents. Therefore, the ocean sea surface temperature finally comes into balance with the local surface energy budget. In general, the model gets too warm in the tropics. Unlike the NCAR model, it doesn't seem to get too cold in polar areas and develop too much ice. It melts a little too much ice. There is probably too much radiation that gets through and prevents too much ice from forming. In the next model run, he will probably include a pseudo ocean energy flux term that effectively simulates currents and also corrects for any local imbalance in the surface energy budget when averaged over several years. This procedure forces the model to give back
the same SST as in the present climate for the 1x CO₂ simulation. All models have such small imbalances unless they follow a procedure like this. The problem with this "cure" is that the same pseudo fluxes are then used for the 2x CO₂ run, but we know that they actually should be different. However, with the changed energy budgets, the 2x CO₂ run will develop a new SST, which may be about what one wants.

- The above information is based on conversations with Mike Schlesinger, OSU.

- Main references are two OSU Climatic Research Institute reports:

(2) Michael E. Schlesinger, Zong-ci Zhao, 1988: "Seasonal climate changes induced by doubled CO₂ as simulated by the OSU atmospheric GCM/mixed-layer ocean model." CRI report. 84 pp.
Address: Dr. Michael E. Schlesinger
Dept of Atmospheric Science
Oregon State University
Corvallis, Oregon 97331-2209

Transformations for Moisture Calculations:

Two PIs have asked for equations for transformations such as: (1) given mixing ratio or specific humidity, calculate vapor pressure; (2) given temp and pressure, calculate saturation vapor pressure; (3) given dew point, calculate vapor pressure, etc. If anyone else needs a copy, let us know.

CREDIT: Dean Vickers at OSU calculated the necessary averages and provided the data to Dennis Joseph at NCAR, for use in preparing the disks.
NCAR Model for CO₂ Simulations

- The NCAR CO₂ runs have been made with the atmospheric CCM coupled to an ocean slab, 50 m deep.

- No diurnal temperature change.

- Twice daily values are on tapes.

- Run on 15 wave model, 9 levels. Bottom sigma level is 0.991.

- Grid is 4.5° Lat by 7.5° long for world.

- Longest archive after spinup is 7 years.

- Have year-month statistics.

- 1x CO₂ is 330 ppm, 2x CO₂ is 660 ppm.

Comments:

- The high latitudes become too cold in winter because there isn't a heat transport by the ocean, (only a storage term) and there is over extensive sea ice.

- The low latitude lower troposphere becomes too warm because there is no water upwelling to cool off the sea surface temperature.

- There are unrealistic changes in the sea ice.

- The model is better in winter than in summer: It is better in the Northern Hemisphere than in the Southern Hemisphere.
INFORMATION ABOUT MODELS

See my memo of Sept 18, 1987 to Joel Smith. "Selected texts about models and data." It is also considered to be NCAR/EPA Doc 1.

A. THE GISS MODEL

1. GISS land surface: Each $8^\circ \times 10^\circ$ grid square has a percentage of land, a percentage of water (lakes or ocean), and a percentage of lake or ocean ice (the model changes this). The basic numbers are derived from the Scripps $1^\circ$ topography dataset.

If a grid square has both water and land parts, the surface air temperature in the output data will effectively be an area weighted mean of the temperatures for the land and water components.

The land area in a grid square has percentages of eight types of vegetation cover that range from deciduous forest to shrub, to desert, to land ice. The amount of land ice is fixed and represents permanent glaciers and ice caps. Crops are included in the category of pastures. A given vegetation cover determines the water holding capacity of the soil. It also fixes the background albedo which changes through the seasons. Snowfall also changes the albedo when it happens in the model.

2. Radiative balance: The GISS model would naturally tend to warm up too much, probably because not enough radiation is reflected by clouds or from the surface. To compensate, a global/annual average of 5 watts/m$^2$ is removed from the energy balance at the surface. This compares with an annual average short wave absorption at the surface of 173 w/m$^2$. The average net radiation at the surface is 123 w/m$^2$. The special removal of energy is only over ocean areas; the rate of removal is a function of the intensity of solar incident energy at the surface. This is part of the "tuning" of the model to give a better comparison with the present climate.

3. Solar constant: GISS uses 1367 w/m$^2$ for the annual average constant. This is equivalent to an average of 342 watts on each square meter of the earth (because the surface area of a sphere is 4 times the area of an inscribed circle. The earth is now closest to the sun about Jan 4; the intensity then is nearly 7% greater than in July. All of the models change the intensity through the year in a proper way. The best measured number for the solar constant is about 1365 to 1367 w/m$^2$.

4. Surface air temperature: The GISS model carries the surface skin temperature and the temperature for the lowest model sigma level. From these a temperature is calculated that is valid at about 30 meters over land and 10 m over the ocean and sea ice. Observations of surface air temperature are usually made at about 5 feet (1.5 meters). We should not worry about the difference in heights between model and observed data, especially because the changes are expressed in ratios of $2xCO_2/1xCO_2$.

5. Soil Moisture: The GISS model has two soil layers. The water storage capacity of the top layer is 20 cm of water for rain forests, 3 cm for other forests and crops, and 1 for deserts. The second layer can hold about 30-45 cm of water for all forests, about 20 cm for grass and crops, and only 1 cm for deserts. When the ground is frozen, water can't be taken out of the soil.
6. GISS ocean: has a heat transport by currents. The same currents are used in both the control and 2xCO$_2$ cases. Ocean water temperatures and ice cover are computed based on energy exchange with the atmosphere, the specified ocean heat, transports, and the ocean mixed layer heat capacity.

7. Description of the model: See the paper in Monthly Weather Review, Apr 1983, p609. The model time step is 15 minutes for the dynamics and one hour for the physics.

8. Model levels near the surface: The GISS model has a surface skin temperature and a temperature at the mid-point of the lowest sigma level. A surface air temperature between these is derived.

The average global pressures are as follows for model levels near the ground.

<table>
<thead>
<tr>
<th>Pressure Level</th>
<th>Pressure Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface pressure</td>
<td>984.0 mb</td>
</tr>
<tr>
<td>Pressure at mid point of first layer</td>
<td>958.9</td>
</tr>
<tr>
<td>Pressure at top of first layer</td>
<td>934.0</td>
</tr>
<tr>
<td>Pressure at mid point of 2nd layer</td>
<td>893.8</td>
</tr>
<tr>
<td>Pressure at top of 2nd layer</td>
<td>854.0</td>
</tr>
</tbody>
</table>

Note that the first layer is about 25.1 mb (or 200 meters) above the earth's surface.

9. Model elevation: A print of the GISS model elevation is included since it was not in the earlier print. This shows the smooth terrain that the model sees. It helps to show why small-scale orographic precipitation will not be properly represented.

10. Some facts: GISS uses the CO$_2$ concentration as 315 ppm for the 1xCO$_2$ climate. This was valid about 1958. By 1983 it had increased to 342 ppm (722 giga-tonnes in the atmosphere). The GISS model includes a diurnal cycle.
GISS GCM OUTPUTS

Most of this information is from several phone conversations with Dave Rind, GISS (212) 678-5593.

The GISS model is a grid point model, usually run at resolutions of 6° Lat x 10° Lon or 4 x 5°.

1. Control run for the present climate and 2 x CO₂ run.
   - The control run uses CO₂ at 315 ppm (valid 1958); the 2 x CO₂ run uses 630 ppm.
   - The warming in the 2 x CO₂ compared to control is 4.2° C.
   - Long period monthly statistics are for a ten year period, from years 26 to 35 of the control and 2x model runs. These are on an 8 x 10⁰ grid and cover the whole world.
   - Year-month values are for the same 10-year period. The output includes a large number of diagnostics. Global coverage, 8 x 10⁰ grid.
   - The 8° of latitude in a grid cell is really about 7.8°.
   - Data are available at higher resolution for a 3-year period for control and for 3-years of 2x CO₂. The monthly global 4 x 5° data are available for the three-year control CO₂ run and the three-year 2 x CO₂ run.
   - Three years of daily data. This is output for the U.S. and S. Canada at a resolution of 4° Lat x 5° Lon. This U.S. area has 6 lons by 4 lats for the 8 x 10⁰ grid. The 4 x 5° grid covers the same region but has more points. The three-year model runs of monthly and daily values for the U.S. were done on different computers. Thus, the daily values probably do not correspond to the associated monthly values from another model run. These daily runs are now being made (August 1987).
   - The daily values (13 vrbl) are:
     a. precipitation (only total), evaporation, snow amount (kg/m²), soil moisture, runoff
     b. max-min temperature
     c. surface u and v wind
     d. SLP at hour 12 and 24
     e. Solar radiation absorbed at the ground
     f. surface humidity (kg/kg)
   - The outputs are limited because the output of data on tapes at the Goddard Cyber 205 is difficult.
2. Components of warming for doubled CO₂.

GISS used a 1D model to determine the components of the 4.2°C increase in temperature with the doubling of CO₂. The changes in water vapor and clouds from the full GCM model were used in the 1D model to make these calculations of sensitivity. The following explains nearly all of the changes:

a. Temperature change due to doubling CO₂ alone

b. Water vapor was increased 33% in the total column, and it was located at higher levels

\[ 1.6°C \]

c. There was a decrease of 1.7% in cloud amount, with some increase in cirrus clouds. Cloud tops became somewhat higher.

\[ 0.8°C \]

d. Changes in the surface albedo, mostly due to sea ice

\[ 0.4°C \]

\[ 4.0°C \]

Note: Model run X in Table 1 shows what gas concentrations were used in these "double CO₂" runs. This does not list all of the gases; N₂O was held at 0.295 ppm, appropriate for 1958.

3. Multi-year runs that gradually change CO₂ and other trace gases. (transient runs).

- These runs cover the period 1958-2060 but all runs do not cover the full period.
- The output is saved each hour. It is only saved for U.S. and S. Canada (24 points) and for west and central Europe (24 points).
- It is on a grid 8° Lat x 10° Lon.
- This hourly data could be used to prepare daily data on an 8 x 10° grid.
- Such calculations yield daily data for every year of the long simulations, from about year 2000 when the hourly data was saved.
- The corresponding YR-month data has 60 quantities and covers the whole world (864 points).
- The CO₂ concentration was about 315 ppm in 1958 and 338 in 1980. One of these runs increases this to about 547 ppm by the year 2060, but the other radiative gases are also strongly increased in this run.
- The hourly data has two components of precipitation.
- The transient runs (Runs A and C) are also being rerun for 3 years at the years 2000 and 2030. Similar information (for Runs A, B, C) can be obtained by using 3 years of hourly data taken near these years.
- All data from the transient runs is on the 8 x 10° grid.

4. The GISS model runs that change gradually.

The concentrations of trace gases used in GISS model runs A, B, C are shown in Table 1. One dimensional models were used to obtain an approximate contribution of each trace gas to the overall warming as shown in Table 2. The actual simulated warming from the
GISS GCM is greater than the One-D model warming, due to feedback effects. For example, the Model-A warming of 2.24°C in year 2050 becomes about 3.5°C in the full GCM.

Models A&B Both really start in 1958

Model A Hourly data saved YR 2000-2059 (to yr 2060). No major volcanoes after El Chichon. This simulation completed in early 1986. Note: El Chichon (Mexico, 17.3° N) erupted late March 1982 and on 4 April.


Model B' Same inputs as B except leave out the new major volcanoes. Hourly data for 1958-2029.

Model C Started in 1980, using output of model B at that time. Hourly data are saved for 1980-2039 (So really starts 1958). Has a slow increase in trace gases, and most are held constant after the year 2000. Run C has the same volcano history as run B.

Comments: I think that run B has the most realistic assumptions on the amount of gases. It seems to me that run A increases methane and the freons in an unrealistic way. The release of CO₂ from fossil fuel is now about 5.0 Gtons a year. Assume that it increases to 8 Gtons/yr and then remains at this rate. This would give about 458 ppm in the atmosphere in the year 2050 AD.

5. GISS hopes to complete the various model runs by 1 Oct 87 and could send data within one or two weeks of that time.

6. Comments

One modeling problem mentioned by GISS is that the average rainfall at a low resolution gridpoint (such as 8° Lat x 10° Lon) is usually a very small number. This small amount tended to be absorbed in the soil and then evaporated with very little runoff. The space resolution needs to be improved to about 2° to obtain daily values that are about the right intensity, but then the monthly totals are way too large. Part of this problem is that daily area mean rainfall and precipitation at a local station should be expected to be two different things.

Modelers have noted that total daily precipitation tends to stay more constant from one model formulation to another than do the components of precipitation, (large scale and convective). This is true for the high resolution forecast models at ECMWF. It is also true for the climate models.

Regional statistics: In the MWR for April 1983, GISS shows maps that give the location of where daily data are saved, where regional statistics are saved, etc. The regional statistics are for a collection of grid points.

Volume of daily data. Assume that we save 20 years of model data for 20 variables at 100 different locations, once each day. Volume = (20 YR) (365 days) (20 variables) (100 points) (16 bits) plus 20% overhead. Thus Volume = 2.80 x 10^8 bits (10^9 bits fit on one tape, 6250 BPI).
Table 3. MONTHLY STATISTICS BY GISS

The list of quantities does not include daily variances. The monthly variables for every world point are:

- 1. Mean temperature
- 2. Diurnal range
- 3. Precipitation (only total)
- 4. Evaporation
- 5. Sensible heat flux
- 6. Runoff
- 7. Soil temperature
- 8. Sfc wind
- 9. Jet stream winds
- 10. Total clouds
- 11. Convective clouds
- 12. Low, mid, high clouds
- 13. Cloud top pressure
- 28. Plant water stress
- 29. Monthly average of specific humidity at sfc
- 30. Sfc momentum drag (for ocean stress, etc.)
- 31. N. export of dry static energy by eddies
- 32. Diagnostic on total earth water plus ice (2 ground levels)
- 33. Heights (at 1000, 850, 700, 500, 100, 30 mb)
- 34. Thickness temps (redundant with hts)
- 35. Tropopause static stability

**Top of Atmosphere**

- 14. Planetary albedo
- 15. Outgoing visible
- 16. Amt. of IR in window
- 17. Net solar top atmosphere
- 18. Incoming solar at top

**Surface**

- 19. Incident solar at sfc
- 20. Absorbed solar at sfc
- 21. Net heating at sfc
- 22. Net radiation at sfc
- 23. Water plus ice in two ground levels
- 24. Length of growing season
- 25. Heating degree days (vs 65°F)
- 26. Heat, humidity index (comfort)
- 27. Drought index (close to Palmer index)
Print of US Data from GISS Model

This document has selected printed values from the GISS models for 1X CO$_2$ and 2X CO$_2$. The GISS data has global coverage and is on a $10^\circ$ (lon) by $7.8^\circ$ (lat) grid. Only data for a US window is printed. On the print, the data for the control (present day) 1X CO$_2$ model output is followed by the related numbers for 2X CO$_2$. These are followed by a ratio of the corresponding numbers calculated at NCAR. If the ratio is larger than 5.0 (or is undefined), it is arbitrarily set to 5.0. Note that data for the seasons and annual average are also included. All data are means over a 10 year time period following a 25 year model spinup period. The 26-35 in the print is for years 26-35.

The "latitude" in the print shows a value for "mid" and one for "point". "Point" is the location of the grid point. The other value gives a latitude midway between the gridpoints. It is given for convenience for comparing with the latitudes of observing stations.

The model data on the tape that will be sent will have this same array of numbers that are printed. Within any one variable, the order of the tape fields will be the same as the print. The tape will have at least as much precision as is shown.

The actual spacing of the latitudes of grid points is:

\[ n = \frac{180}{23} = 7.826^\circ \text{ Lat.} \]

There are no points on the equator; the first latitude above the equator is given by $(n/2)^\circ$. On the original tape with global data, the dimension of an array is 36 lons by 24 lat values.

If in the future, we need to use hourly data from the GISS model, then the available window is smaller; it is 6 lons by 4 lats. The lower left point is 27.4$^\circ$N, 120$^\circ$W.

The Data Elements are printed in the following order in Attachment 1:

1. Surface air temperature
2. Precipitation
3. Surface runoff
4. Surface air specific humidity
5. Surface incident solar radiation
6. Total cloud cover
7. Average surface wind speed

The sea level pressure has also been printed just like the variables included in Attachment 1. I don’t think many people need it. Please ask if you want it.

Temperature: The temperature is printed in °C. The ratio is the ratio of the absolute temperatures. When the ratio is used to adjust an observed temperature, the observed value must first be converted to °K by adding 273.15 to the temperature in Celsius.
Precipitation:

The units are mm/day as noted. To get a feel for the numbers, the following comparisons are given:

<table>
<thead>
<tr>
<th>mm/day</th>
<th>cm/month</th>
<th>cm/year</th>
<th>inch/month</th>
<th>inch/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>12.2</td>
<td>146</td>
<td>4.8</td>
<td>57.5</td>
</tr>
<tr>
<td>2.0</td>
<td>6.1</td>
<td>73</td>
<td>2.4</td>
<td>28.7</td>
</tr>
<tr>
<td>0.5</td>
<td>1.5</td>
<td>18</td>
<td>.6</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Surface Runoff:

The units are in mm/day, the same as for the precipitation. This depth of water is what the model gives as run off from any given size of region in the vicinity of the grid points. It should be realized that the model has a smooth terrain; it does not have sharp hills and mountains like the real earth. The run off is undefined over boxes that contain no land.

Humidity

The quantity given is the specific humidity (the mass of water vapor per unit mass of moist air). This contrasts with the mixing ratio which is the mass of water vapor per unit mass of dry air. The specific humidity is unitless; it is kg/kg, g/g, pounds/pound, etc. A typical number printed is 20.0. With the scaling this number is $20.9 \times 10^{-4}$ kg/kg. This is equal to 2.00 g/kg which is often a more familiar term.

Incident Solar Radiation at Surface (W/m²)

The energy flux of the direct beam of solar radiation on a clear day near sea level is about 1000 watts per m². The intensity on a horizontal surface is less; also the sun only shines for part of the day, and clouds reflect part of the radiation. Thus, the average intensity on a horizontal surface in mid latitudes is about 60 W/m² in January and 260 W/m² in summer.

Average Surface Scalar Wind Speed

The monthly surface wind speed was not available on the tape from GISS. However, five fields were available from which this could be calculated; these were two vector components of surface wind, 2 components of surface momentum drag and the magnitude of the momentum drag. NCAR used the equation provided by Dave Rind at GISS:

$$ W_{\text{speed}} = \frac{(m^{\text{mom}} \cdot \sqrt{u^{\text{wind}}^2 + v^{\text{wind}}^2})}{\sqrt{u^{\text{mom}}^2 + v^{\text{mom}}^2}} $$

The wind speed (W speed) is given in m/sec. Conversions are:

- One meter/sec equals: 3.6 km/hr, 1.94254 knots, 2.23694 mi/hr, or 0.77742 °Lat/day.

- End -

See Attachment 1
GISS TRANSIENT RUNS

For the transient runs, GISS first ran a 100-year control run using the atmospheric gas concentrations appropriate to 1958. See Doc 1 (memo to Joel Smith, dated Sep 18, 1987), for these concentrations. The different transient runs then started from this control run. The proper base values to use for the transient runs are the means of years 46-55 of the 100-year control run (info from Dave Rind, GISS). Therefore, these are used for the transient-run data sent to EPA Pls. It would not have been proper to use the same base values as on the 1x CO₂ control run from GISS (so this was not done), because some of the aspects of the model are different for the two control runs. For example, the transient model has a greater mixed layer depth—up to 250 meters. This compares with 65m in the 1x and 2x CO₂ model runs.

Data for Transient Runs:

NCAR received data from GISS for the two transient runs:

Run A: basic monthly data for 1958-2062
Run B: basic monthly data for 1958-2029

Also GISS provided decadal averages 1960-69, 70-79, etc. for each run.

As you recall, the decision was made to use the variability from the present observed climate for the assessment studies, not the variability from the GCM models. Therefore, data for the decadal averages are the basic data sent to Pls. The basic data values from the transient control run are also on the data sent to Pls. For each decade mean value (for each month), the ratios are given and the basic data is omitted. This was done to save volume. Since the transient runs (as used by investigators) will start with data for 1980, we have dropped data for the 1960-69 decade.

One file contains the 10-year mean values (Jan-Dec) for each variable for the control case as described above. Fields of ratios for each month in the midpoint of each decade are included in two files, one for each scenario. The order of the data is:

Data From The Control Run

Transient Run A, 1st Variable
Ratios for monthly average of decade (1970-79) for months 1-12;
Ratios for monthly average of decade (1980-89) for months 1-12;
Etc.
Ratios for monthly average of decade (2050-2059), for months 1-12.

2nd Variable, etc (same sequence of fields)
NOTE: (Winds are a delta change, not a ratio.)
Transient Run B, Each Variable
   Ratios for monthly average of decade (1970-79);
   Etc.
   Ratios for monthly average of decade (2020-2029);

On the dataset for the GISS transient runs, we have included only the 7 primary variables. This has been done to limit the volume. (Attach. 1 shows the fields included in previous data, for comparison):
   • surface air temperature;
   • surface winds;
   • precipitation;
   • surface air humidity (mass of water per unit mass of moist air);
   • surface runoff;
   • incident solar radiation at surface;
   • total cloud cover.

Winds For Transient Model Runs

The winds given for the GISS transient runs differ in two ways from what was sent for the 1x and 2x CO₂ runs. First, they are speeds calculated from the two average wind components for a month; that is they are vector mean speeds rather than scalar speeds. Second, the numbers given show the change of the wind from the control run to the current year, not the ratio as given before. Thus, a value of -1.5 m/sec means that the current year model run has a value 1.5 m/sec less than the control run. Use these as deltas to be added to the observed wind speeds of the present climate. Note that the application of a delta could result in a negative wind speed. If this happens, set it to zero.

The vector speeds (as given) underestimate the true wind speed: if the wind blows from the west at 5 m/sec for half a month and from the east at 5 m/sec the other half, the vector speed is zero, but the average speed is 5 m/sec. We want the average speed, but it wasn’t directly calculated from the model output. We calculated a speed from 5 terms that were saved. It turns out that the formula used is a close approximation, but leaves out the effects of certain changes in drag coefficients. In most cases these are not important, but in certain cases they can lead to a “blowup” of the values such as 21.7 m/sec at 43N, 90W in November for the 2x CO₂ run (This bad value was first noticed by Mike McCormick at the Great Lakes Labs).

Some grid points for the control runs for the transient have such low wind speeds (in either the vector speeds or calculated speeds) that the ratios become unrealistically large. This could cause a problem for 2x CO₂ assessments when used with normal observed wind speeds that are stronger. For example, a ratio of 5 or 10 used with an observed 3 m/sec wind gives a very strong wind. Therefore, we have calculated a delta wind speed change which is a conservative way of doing it. We are sorry for this change. After we (at GISS and NCAR) understood what was happening, we decided the rules should be changed, especially for the transients where a low wind in the control run can give bad ratios through many decades. We do not think that data for the 1x and 2x CO₂ runs should be changed.
DATA FROM CLIMATE MODELS, THE CO₂ WARMING

This text describes data on a tape from three different climate models. It includes data from a control run that should simulate the present climate (called 1x CO₂) and for a computer run where the model atmosphere is brought to steady state for an atmosphere with double the amount of CO₂. In addition, there is data from two long "transient" simulations done by GISS, in which the amount of gases and volcanic activity is gradually changed over a number of decades. The data on the tape are:

1. GISS data 1x, 2x CO₂, US area;
2. GFDL data 1x, 2x CO₂, US area;
3. OSU data 1x, 2x CO₂, US area;
4. Control run used for both of GISS transient runs, US area;
5. Transient A from GISS, US area;
6. Transient B from GISS, US area:

Data for all of N. America, including US, Canada, Alaska, down to about 20° N. The data for the US above is a subset of this grid:

7. GISS data 1x, 2x, N. America;
8. GFDL data 1x, 2x, N. America;
9. OSU data 1x, 2x, N. America.

Transient Runs From GISS:

Data for each year and month was available from the transient runs, but only the decade averages have been put on the NCAR tape for the PIs.

---Years---    ----Tape Has Decade Averages----

The resolution of data above from the three models is:

GISS  7.83° Lat by 10.° Long;
GFDL  4.44° Lat by 7.5° Long;
OSU   4.° Lat by 5.° Long.

In the Attachments, Dennis Joseph provides information about detailed contents, data volume, data formats, etc., for the digital data.

The data on the tape are long-period mean data for each month, except in the case of the transient runs, where means for each decade are given. The elevation for each model is on the tape. The primary variables on the tape from each model are:

1. Surface air temperature;
2. Average surface wind speed. This was desired; often we could only obtain the vector mean speed;

3. Total precipitation;

4. Surface air moisture (specific humidity or mixing ratio);

5. Surface runoff;

6. Surface incident solar radiation;

7. Total cloud cover;

8. Sea-level pressure;


The transient runs on the tape only have the first 7 variables above.

The total number of variables on the tape (not counting model elevation) from each model is as follows:

- **GISS:** 19 variables
- **GFDL:** 19
- **OSU:** 9
- **Transients:** 7

The basic tapes output from the models have many more variables than these. They include radiation budgets at the surface and top of the atmosphere, surface heat budget, temperature and winds in the troposphere, etc.

**Solar Constant Used in the Models:**

- **GISS:** 1367 w/m² for the annual average;
- **GFDL:** 1443.7 w/m². Same as 2.07 cal/(cm² min). This high value is used as a way to tune the model to give a good simulation of the present climate.
- **OSU:** 1354 w/m². This is the same as the "best" old value of 1.94 cal/(cm² min).

The best measured number for the solar constant is about 1365 to 1367 w/m². The earth is now closest to the sun about Jan 4; the intensity then is nearly 7% greater than in July. All of the models change the intensity through the year in a proper way. A solar constant of 1367 w/m² is equivalent to an average of 342 watts on each square meter of the earth (because the area of a sphere is four times the area of an inscribed circle). On a clear day, the intensity of the solar beam when it hits the earth's surface is close to 1000 w/m² (measured perpendicular to the beam). The atmosphere screens out the rest.

**Amount of CO₂ Used in the Control (1x) GCM Model Runs:**

- **GISS** 315 ppm (amount in atmosphere in 1958);
- **GFDL** 300 ppm;
- **OSU** 326 ppm;
- **NCAR** 330 ppm (W. Washington version).
The amount of CO\textsubscript{2} in the atmosphere was measured to be 315 ppm in 1958 and 342 ppm in 1983. Since models are tuned to give a better simulation of the present climate, these differences in the amount of CO\textsubscript{2} used for the control run probably are not significant. The amount of CO\textsubscript{2} used for the 2x CO\textsubscript{2} run is always double the 1x run, as one might expect. When the concentration of CO\textsubscript{2} is 342 ppm, there are 722 giga-tonnes of carbon in the CO\textsubscript{2} molecules in the atmosphere. The world now releases a little over 5 Gtonnes of carbon from fossil fuel burning each year. We also probably release about 1.0 Gtonnes of carbon from biomass changes, but this number is not nearly as reliable as the fossil fuel amount. From measurements, we also accurately know that in recent years, there is a net increase of about 2.9 Gtonnes of carbon in the atmosphere each year.

Levels in Models:

The models are all 9-level models, plus a surface, except that the OSU model has two levels and a surface.

Is There a Diurnal Cycle in the Model?

GISS - yes
GFDL - no
OSU - no

GISS made a parallel model run without a diurnal cycle. The sea-surface temperature was held constant for both runs, with and without the cycle. This was the only change in the model. The climate changes that took place for the run without a diurnal cycle, as compared to one with it were:

- Low-latitude temperature in winter about 10 °C warmer over land without a cycle; high latitude temperatures a few degrees warmer;
- In summer, the high amount of land warming extended to high latitudes;
- The sensible heat flux was higher in winter (because of warmer conditions with no cycle), and lower in summer (because without the boundary layer instability in the afternoon, there was less flux);
- The precipitation over the warmer land (without a diurnal cycle) increased by up to a few mm per day;
- The sea-level pressure was lower over land without a diurnal cycle. This is related to greater ocean-land contrast since ocean SST didn’t change. It is consistent with more monsoon activity and greater rainfall;
- Near the equator, there was a 50% increase in low clouds over land for no cycle. For example, 30% clouds would increase to 45%. This is apparently because the diurnal cycle helps to "burn off" the low clouds in the daytime.

The reader should not expect the climate models without a diurnal cycle to have this much difference from a model with a cycle. The reason is that models are individually tuned to try to obtain a better simulation of the present climate.

Info from Dave Rind, GISS, Feb 1988.
GCM Model Sensitivity:

The sensitivity of a CO$_2$ climate model is often measured by how much the temperature of the surface air warms up, on the global average, when CO$_2$ is doubled.

- GISS model warms 4.2°C with a doubling;
- GFDL model warms 4.0°C with variable clouds for a doubling. These are the data on the tape. With fixed clouds, it was just 3.0°C warmer.
- OSU model warms by 2.8°C for a doubling.

We see above that the OSU model atmosphere heats up by 2.8°C when the amount of CO$_2$ is doubled. This is a smaller warming than from any other of the five main current models (GFDL, GISS, NCAR, OSU, and UK). The warming, due to a doubling of CO$_2$ by itself, is just 1.2°C. Any additional heating is from various feedback processes such as from more water vapor and changes in clouds.

Planetary Albedo, Annual Average:

The planetary albedo gives the fraction of the incoming solar radiation that is reflected back to space.

- GISS model: 30.55%

The best number from radiation budget measurements by satellites is about 30% or a little less. OSU and GFDL are also close to the observed values.

Effects of Clouds on Climate:

Consider a low cloud—the cloud top temperature is about the same as the land, so it loses a lot of IR radiation to space just as the land would. It reflects sunlight, which keeps the lower atmosphere cooler. The lower clouds, thus, have somewhat of a cooling effect, but they do keep the nighttime surface temperature somewhat warmer.

An increase in high clouds warms the climate. The clouds do reflect more solar radiation, which is a cooling effect. However, in the infrared, they radiate at a much lower temperature than either the surface or low clouds would. The net effect of more high clouds is a warming. The details of changes in the high clouds, will have a strong effect in the sensitivity of a model to the doubling of CO$_2$.

GISS Model:

The control runs for the GISS model sensitivity tests (including the diurnal cycle) were described in a *Monthly Weather Review* article in April 1983. The 2x CO$_2$ run was made in 1983 and described in an AGU book: *Geophysical Monograph, Vol 29* in 1984 (also called Maurice Ewing series, Vol 5). The paper is ‘Climate Processes and Climate Sensitivity’.

The transient experiments were run from about 1985-87.

Info from Dave Rind, Feb 1988.
How Much Does the Ocean Slow Down a Climate Warming?

Consider a warming of the atmosphere by 1 or 2 degrees (delta T) that is imposed on the ocean. This would start warming the ocean. With a slab ocean 60m thick, the e folding time is about 12 years. That is, the slab would have warmed by about 65% of delta T in 12 years and by about 85% of delta T in 25 years. In high middle latitudes, the ocean is mixed to much deeper depths than such a slab ocean. These regions would further retard an overall atmospheric warming. The actual delays are still in the process of being sorted out. This information was largely based on a conversation with Mike Schlesinger, OSU (Feb 88). He has written about the subject.

Data from these GCM models was assembled to support studies sponsored by EPA in which about 35 PIs across the US have been studying (during 1987-88) the effect of changes in climate. The subjects include crop yields, agricultural economics, water resources/irrigation, power generation, forestry, changes in estuaries and beaches due to sea-level changes, etc. Joel Smith is a key coordinator for EPA.

New Model Run at GFDL (Feb 1988):

The new model runs at GFDL have recently been completed. The model is still essentially the same except that it was forced to reproduce the SST and ice extent of the present climate. The model sensitivity of the previous model run was 4.0 °C from 1x to 2x CO₂. The new run was expected to be less sensitive, but it came out almost exactly the same (within .05 °C). Too much sea ice had been forming in the N. Hem in the simulation of the present climate. This gave a large warming when this melted in the 2x simulation. With this problem fixed, the sensitivity for the N. Hem is less. But it was balanced by a reverse effect in the S. Hem. There, the simulation of sea ice wasn’t as great as now observed. With this fixed, the warming from 1x to 2x CO₂ in the S. Hem increased.

R. Wetherall at GFDL has taken preliminary looks at the simulation of temperature and precipitation over N. American and Eurasia. He sees significant improvements, but notes that we are never going to see a huge improvement with models having very low resolution (GFDL's model is R15, similar to the others in resolution).

In the GFDL model, they only get runoff when the soil water "bucket" is full. Other models usually allow some runoff, even if the soil isn’t saturated. Since runoff is tricky to get right, people should definitely try to use precipitation instead.

Computer time needed: The 15 wave, 9-level GFDL model takes one hour of CDC-205 CPU time for each three months of model simulation.

The data from this run are not yet available in the tapes from NCAR.

The above information is from Dick Wetherall, GFDL (26 Feb 1988).
Print of US Data from GISS Model

This document has selected printed values from the GISS models for 1X CO$_2$ and 2X CO$_2$. The GISS data has global coverage and is on a $10^\circ$ (lon) by $7.8^\circ$ (lat) grid. Only data for a US window is printed. On the print, the data for the control (present day) 1X CO$_2$ model output is followed by the related numbers for 2X CO$_2$. These are followed by a ratio of the corresponding numbers calculated at NCAR. If the ratio is larger than 5.0 (or is undefined), it is arbitrarily set to 5.0. Note that data for the seasons and annual average are also included. All data are means over a 10 year time period following a 25 year model spinup period. The 26-35 in the print is for years 26-35.

The "latitude" in the print shows a value for "mid" and one for "point". "Point" is the location of the grid point. The other value gives a latitude midway between the gridpoints. It is given for convenience for comparing with the latitudes of observing stations.

The model data on the tape that will be sent will have this same array of numbers that are printed. Within any one variable, the order of the tape fields will be the same as the print. The tape will have at least as much precision as is shown.

The actual spacing of the latitudes of grid points is:

$$n = \frac{180}{23} = 7.826^\circ \text{Lat.}$$

There are no points on the equator; the first latitude above the equator is given by $(n/2)^\circ \text{N}$. On the original tape with global data, the dimension of an array is 36 lons by 24 lat values.

If in the future, we need to use hourly data from the GISS model, then the available window is smaller; it is 6 lons by 4 lats. The lower left point is $27.4^\circ \text{N}, 120^\circ \text{W}$.

The Data Elements are printed in the following order in Attachment 1:

1. Surface air temperature
2. Precipitation
3. Surface runoff
4. Surface air specific humidity
5. Surface incident solar radiation
6. Total cloud cover
7. Average surface wind speed

The sea level pressure has also been printed just like the variables included in Attachment 1. I don't think many people need it. Please ask if you want it.

Temperature: The temperature is printed in °C. The ratio is the ratio of the absolute temperatures. When the ratio is used to adjust an observed temperature, the observed value must first be converted to °K by adding 273.15 to the temperature in Celsius.
Precipitation:

The units are mm/day as noted. To get a feel for the numbers, the following comparisons are given:

<table>
<thead>
<tr>
<th>mm/day</th>
<th>cm/month</th>
<th>cm/year</th>
<th>inch/month</th>
<th>inch/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td>12.2</td>
<td>146</td>
<td>4.8</td>
<td>57.5</td>
</tr>
<tr>
<td>2.0</td>
<td>6.1</td>
<td>73</td>
<td>2.4</td>
<td>28.7</td>
</tr>
<tr>
<td>0.5</td>
<td>1.5</td>
<td>18</td>
<td>.6</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Surface Runoff:

The units are in mm/day, the same as for the precipitation. This depth of water is what the model gives as runoff from any given size of region in the vicinity of the grid points. It should be realized that the model has a smooth terrain; it does not have sharp hills and mountains like the real earth. The runoff is undefined over boxes that contain no land.

Humidity

The quantity given is the specific humidity (the mass of water vapor per unit mass of moist air). This contrasts with the mixing ratio which is the mass of water vapor per unit mass of dry air. The specific humidity is unitless; it is kg/kg, g/g, pounds/pound, etc. A typical number printed is 20.0. With the scaling this number is $20.9 \times 10^{-3}$ kg/kg. This is equal to 2.00 g/kg which is often a more familiar term.

Incident Solar Radiation at Surface (W/m²)

The energy flux of the direct beam of solar radiation on a clear day near sea level is about 1000 watts per m². The intensity on a horizontal surface is less; also the sun only shines for part of the day, and clouds reflect part of the radiation. Thus, the average intensity on a horizontal surface in mid latitudes is about 60 W/m² in January and 260 W/m² in summer.

Average Surface Scalar Wind Speed

The monthly surface wind speed was not available on the tape from GISS. However, five fields were available from which this could be calculated; these were two vector components of surface wind, 2 components of surface momentum drag and the magnitude of the momentum drag. NCAR used the equation provided by Dave Rind at GISS:

$$ W_{\text{speed}} = \frac{\text{magmom} \times \sqrt{u_{\text{wind}}^2 + v_{\text{wind}}^2}}{\sqrt{u_{\text{mom}}^2 + v_{\text{mom}}^2}} $$

The wind speed (W speed) is given in m/sec. Conversions are:

One meter/sec equals: 3.6 km/hr, 1.94254 knots, 2.23694 mi/hr, or 0.77742 °Lat/day.

- End -

See Attachment 1
The GFDL Model

(From talk with Wetherall, GFDL)

Two years ago GFDL made a GCM control run and 2x CO$_2$ run for a "cloud prediction experiment." After model spinup, about 10 years of data were generated.

- The model is R15 resolution. The data are on a related 4.5° Lat x 7.5° Lon grid. The global grid has 48 x 40 points.
- The model handles the gases: $O_3$, H$_2$O, CO$_2$. The concentration of CO$_2$ is 300 ppm for the control run, 600 ppm for the 2x CO$_2$ run.
- The 2x CO$_2$ run was 3.0°C warmer (for the world) than the control with fixed clouds. With variable clouds it was 4.0°C warmer.
- The model does not have diurnal temperature changes.
- With this resolution, no model can handle tropical storms and tropical clusters well. Also the handling of ordinary mid-latitude cyclones leaves a lot to be desired.
- He gets nervous when the model output is used for regional studies. Some of the land area temperatures in some regions can be bad, depending on the season.
- From these model runs GFDL will give out:
  - Long period means for each month, based on 10 years.
  - Up to 160 variables, on global grid. These are means; no interannual or daily variances.
- It includes such variables as:
  - surface air temperature
  - surface ground temperature
  - two omega levels
  - total precip/day, averaged over a month
  - winds
  - mixing ratio
  - The bottom sigma level is about 60 m above the ground, and has the usual variables, as do the other levels.
INFORMATION ABOUT MODELS

See my memo of Sept 18, 1987 to Joel Smith. "Selected texts about models and data." It is also considered to be NCAR/EPA Doc 1.

A. THE GISS MODEL

1. GISS land surface: Each 8°x10° grid square has a percentage of land, a percentage of water (lakes or ocean), and a percentage of lake or ocean ice (the model changes this). The basic numbers are derived from the Scripps 1° topography dataset.

If a grid square has both water and land parts, the surface air temperature in the output data will effectively be an area weighted mean of the temperatures for the land and water components.

The land area in a grid square has percentages of eight types of vegetation cover that range from deciduous forest to shrub, to desert, to land ice. The amount of land ice is fixed and represents permanent glaciers and ice caps. Crops are included in the category of pastures. A given vegetation cover determines the water holding capacity of the soil. It also fixes the background albedo which changes through the seasons. Snowfall also changes the albedo when it happens in the model.

2. Radiative balance: The GISS model would naturally tend to warm up too much, probably because not enough radiation is reflected by clouds or from the surface. To compensate, a global/annual average of 5 watts/m² is removed from the energy balance at the surface. This compares with an annual average short wave absorption at the surface of 173 w/m². The average net radiation at the surface is 123 w/m². The special removal of energy is only over ocean areas; the rate of removal is a function of the intensity of solar incident energy at the surface. This is part of the "tuning" of the model to give a better comparison with the present climate.

3. Solar constant: GISS uses 1367 w/m² for the annual average constant. This is equivalent to an average of 342 watts on each square meter of the earth (because the surface area of a sphere is 4 times the area of an inscribed circle. The earth is now closest to the sun about Jan 4; the intensity then is nearly 7% greater than in July. All of the models change the intensity through the year in a proper way. The best measured number for the solar constant is about 1365 to 1367 w/m².

4. Surface air temperature: The GISS model carries the surface skin temperature and the temperature for the lowest model sigma level. From these a temperature is calculated that is valid at about 30 meters over land and 10 m over the ocean and sea ice. Observations of surface air temperature are usually made at about 5 feet (1.5 meters). We should not worry about the difference in heights between model and observed data, especially because the changes are expressed in ratios of 2xCO₂/1xCO₂.

5. Soil Moisture: The GISS model has two soil layers. The water storage capacity of the top layer is 20 cm of water for rain forests, 3 cm for other forests and crops, and 1 for deserts. The second layer can hold about 30-45 cm of water for all forests, about 20 cm for grass and crops, and only 1 cm for deserts. When the ground is frozen, water can't be taken out of the soil.
6. GISS ocean: has a heat transport by currents. The same currents are used in both the control and 2xCO₂ cases. Ocean water temperatures and ice cover are computed based on energy exchange with the atmosphere, the specified ocean heat, transports, and the ocean mixed layer heat capacity.

7. Description of the model: See the paper in Monthly Weather Review, Apr 1983, p609. The model time step is 15 minutes for the dynamics and one hour for the physics.

8. Model levels near the surface: The GISS model has a surface skin temperature and a temperature at the mid-point of the lowest sigma level. A surface air temperature between these is derived.

The average global pressures are as follows for model levels near the ground.

<table>
<thead>
<tr>
<th>Pressure Description</th>
<th>Pressure (mb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>surface pressure</td>
<td>984.0</td>
</tr>
<tr>
<td>pressure at mid point of first layer</td>
<td>958.9</td>
</tr>
<tr>
<td>pressure at top of first layer</td>
<td>934.0</td>
</tr>
<tr>
<td>pressure at mid point of 2nd layer</td>
<td>893.8</td>
</tr>
<tr>
<td>pressure at top of 2nd layer</td>
<td>854.0</td>
</tr>
</tbody>
</table>

Note that the first layer is about 25.1 mb (or 200 meters) above the earth's surface.

9. Model elevation: A print of the GISS model elevation is included since it was not in the earlier print. This shows the smooth terrain that the model sees. It helps to show why small-scale orographic precipitation will not be properly represented.

10. Some facts: GISS uses the CO₂ concentration as 315 ppm for the 1xCO₂ climate. This was valid about 1958. By 1983 it had increased to 342 ppm (722 giga-tonnes in the atmosphere). The GISS model includes a diurnal cycle.

B. GFDL MODEL

1. Surface elevation (Zstar): This is the model elevation of the surface of the earth: it gives the height of land, surface of ocean, and top of ice cap. It is smoother than the real earth. The elevation of the water over the oceans is at height equals zero, but in the model the surfaces go up and down by 100 to 200 meters in places. Don't worry about this fact. If sea level pressure is needed, it should be calculated for elevation equals zero.

2. Levels in the GFDL Model: The following table shows the sigma levels of the model of layers in the GFDL model. The lower model levels are parallel to the earth's model surface elevation.

<table>
<thead>
<tr>
<th>Level</th>
<th>Sigma</th>
<th>Level</th>
<th>Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 (near sfc)</td>
<td>.990</td>
<td>4</td>
<td>.350</td>
</tr>
<tr>
<td>8</td>
<td>.940</td>
<td>3</td>
<td>.205</td>
</tr>
<tr>
<td>7</td>
<td>.830</td>
<td>2</td>
<td>.095</td>
</tr>
<tr>
<td>6</td>
<td>.680</td>
<td>1</td>
<td>.025</td>
</tr>
<tr>
<td>5</td>
<td>.515</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example: Find the pressure at level 7 in the atmosphere (sigma = .830). Take .830 times the surface pressure (not sea level). If the surface pressure happens to be 1000 mb, then the pressure at level 7 will be 830 mb.
3. Surface Temperature: Level 9 of the model is located about 10 mb (or 80 meters) above the model surface (the surface elevation is given by Zstar). The Level 9 temperature is also used for the surface air temperature that is normally measured at about 1.5 meters. Since the boundary layer physics in the model is primitive, it is considered that it doesn't make sense to make a normal "reduction" (change) of the temperature in this boundary layer.

4. Soil Moisture: This is given in mm of water in the soil. Consider also that one gram/cm² of water is the same for practical purposes as one cm of water depth. The soil moisture applies to a variable depth of soil depending on soil type. The soil "bucket" of water becomes full when it has 15 cm of water. Then, any additional water goes into runoff.

5. Surface Wind Speed: It is not possible to obtain a surface average wind speed from the present GFDL model. Therefore we have calculated a vector mean speed (which is a marginal approximation to the average speed). In an overall sense, the winds look rather similar to the wind speeds derived from GISS data.

6. Downward Solar at the Surface: Net solar and a calculated albedo are available from GFDL. The model inputs a basic constant albedo that includes the effect of soil type and average vegetation (this is constant through the whole year). The calculated albedo changes with snow coverage and sea ice, not with recent rainfall. NCAR has used net solar radiation to calculate a good approximation for downward solar. The downward solar radiation, DS, was approximated by solving for DS in the equation:
   net surface short wave rad. = DS - (albedo) (DS)

7. Radiation at Top of Atmosphere: Net shortwave is given. In principle, one could calculate the incoming solar and use this to derive the amount reflected, which is what the satellites measure. Actually the satellites don't measure radiation all the time, but take enough samples at different times of day that averages can be derived.

   Outgoing IR at the top of the atmosphere is given. It is labeled as net IR, but since downward IR is zero, it is also the outgoing IR.

8. Solar Constant: The model uses 2.07 cal cm⁻² min⁻¹ (1443.7 w/m²). This is higher than what is observed. It is used as a way to tune the model to give a good simulation of the present climate.

9. Miscellaneous: The GFDL model uses 300 ppm as the definition of 1xCO₂. The model does not have a diurnal cycle. GFDL does not have ground temperature (there is skin temperature though). There is no field for plant stress. The present model doesn't have heat transport by ocean currents, but new results available about Jan 1988 will have this. The latitude points in the GFDL grid are actually valid on a Gaussian grid. Within .01° precision, this is the same as equal latitude spacing until one is very close to the pole. The closest points to the equator are at 2.22° latitude. The spacing is about 4.444°.

   If there is any snow cover in the model, it uniformly covers the grid box.

C. INTENSITY OF PRECIPITATION

Many assessment models have a need to estimate the rate of precipitation over local areas. It can make a big difference whether a centimeter of rain falls in 5 minutes or 2 hours. The models often carry some variable that gives the atmospheric stability or the separate amount of convective precipitation. This information could be used to choose space- and time-scales for the precipitation within a grid box.

#
DATA FROM OSU 1x, 2x CO₂ MODEL

In this mailing, we are sending data from the Oregon State University (OSU) model received from Mike Schlesinger. Printed data for the seven basic variables are enclosed. The digital data on floppy disk or tape are for all nine variables that are available. The model elevation is also printed so that users can see what elevation the model used. The model effectively "sees" a smooth interpolation between the elevations given, not all the rugged terrain features of the real earth.

This mailing contains:

- Information about the model is in this section;
- Sheet by Dennis Joseph explaining the contents of the disk;
- Disk or tape with data for all nine variables, with a program file and a data file;
- Copy of format text (same format as before);
- Print of the model data for the seven variables: average monthly temperature, vector mean wind speed, total precipitation rate, boundary layer mixing ratio, water runoff, surface incident solar radiation, total clouds;
  The print for the other two variables (sea-level pressure and surface evaporation rate) is available on request.
- Drought information: Memo to Joel Smith (19 Feb 88), and figures that present drought information for the 1930s and 1950s.

Some information about the OSU model follows:

- The resolution is exactly 4° lat by 5° lon.
- Amount of CO₂ was 326 ppm for 1x CO₂. Other gases were not changed for the 2x CO₂.
- The solar constant was set at old "best" value of 1.94 cal/(cm²-min), which is 1354 w/m².
- The model does not have a diurnal cycle. In the next model run there will be one.
- This model run was made during 1984, 85.
- The model was spun up for about 40 years using a fast annual cycle to save computer time; This sped up the calculations by a factor of 12 for these years. Then 10 more years were run; they were used to calculate the statistics that are being sent.
- The time step for the motion variables was 7.5 minutes, other terms are calculated each hour. Each model day of calculation took 40 seconds on the NCAR Cray 1A. Thus, each of the last 10 years took 240 minutes of CPU time.
- Overall, the model has somewhat of a warm bias.
• The model has a surface layer and two tropospheric layers at about 400 and 800 mb (sigma coordinates) and a slab ocean. It carries pressure at the model surface and later calculates sea level pressure. There is a constant flux layer near the surface.

• A given grid box has one type of surface taken from 9 types: water, crops, grassland, trees, steppe, desert, ice, etc. At this model resolution, the Great Lakes do not produce any grid point with water. Hudson Bay does.

• Wind data: The wind data are vector mean wind speeds because the vector components were the only data available. The vector speed is significantly less than the average speed. We can only hope that the wind ratio for $2x/1x \text{ CO}_2$ is about the same for scalar wind speed as vector speed. Actually, we would prefer not to be forced to make this assumption. Please also be aware that, in this model, the location of the wind grid points is in the middle of the other grid points. We are sorry for this inconvenience for the PIs.

• Wind ratios (2x/1x $\text{CO}_2$): The change from 1x to 2x $\text{CO}_2$ is given by ratios. This matches what was sent for the GFDL and GISS model runs. There are a very few points where the ratio may be large due to an initial wind near zero. If this happens on a needed grid point, use nearby data as before. You may recall that for the GISS transient runs, we had to use deltas for wind changes, not ratios.

• The soil moisture calculations uses a bucket method about the same as in the GFDL model. The soil bucket holds 15 cm of water.

• Precipitation and runoff: The model samples instantaneous precipitation each hour and this is used to calculate means. This will give an accurate model precipitation. The runoff was only sampled once each day. Since the model runoff works on the same time scale as the precip, this low sampling rate will probably cause some noise in the runoff. M. Schlesinger has looked at the runoff and the overall patterns appear reasonable.

• Radiation at the surface: At NCAR, we noted that the OSU downward solar radiation at the surface was about 30% greater than GISS, yet the clouds are rather similar. M. Schlesinger has noted this also and plans to put a more physically-based cloud scheme into the model. Apparently, the amount of clouds is about right, but the physical properties are off and they let too much energy through. It is also hard to simulate some of the ocean stratus correctly, which also affects the energy balance.

• Ocean: The OSU model has a slab ocean that is 60m deep. (It was only 5m deep during the 40-year spinup). It does not have currents. Therefore, the ocean sea surface temperature finally comes into balance with the local surface energy budget. In general, the model gets too warm in the tropics. Unlike the NCAR model, it doesn't seem to get too cold in polar areas and develop too much ice. It melts a little too much ice. There is probably too much radiation that gets through and prevents too much ice from forming. In the next model run, he will probably include a pseudo ocean energy flux term that effectively simulates currents and also corrects for any local imbalance in the surface energy budget when averaged over several years. This procedure forces the model to give back
the same SST as in the present climate for the 1x CO₂ simulation. All models have such small imbalances unless they follow a procedure like this. The problem with this "cure" is that the same pseudo fluxes are then used for the 2x CO₂ run, but we know that they actually should be different. However, with the changed energy budgets, the 2x CO₂ run will develop a new SST, which may be about what one wants.

- The above information is based on conversations with Mike Schlesinger, OSU.

- Main references are two OSU Climatic Research Institute reports:

  (2) Michael E. Schlesinger, Zong-ci Zhao, 1988: "Seasonal climate changes induced by doubled CO₂ as simulated by the OSU atmospheric GCM/mixed-layer ocean model." CRI report. 84 pp.
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Transformations for Moisture Calculations:

Two PIs have asked for equations for transformations such as: (1) given mixing ratio or specific humidity, calculate vapor pressure; (2) given temp and pressure, calculate saturation vapor pressure; (3) given dew point, calculate vapor pressure, etc. If anyone else needs a copy, let us know.

CREDIT: Dean Vickers at OSU calculated the necessary averages and provided the data to Dennis Joseph at NCAR, for use in preparing the disks.
GISS TRANSIENT RUNS

For the transient runs, GISS first ran a 100-year control run using the atmospheric gas concentrations appropriate to 1958. See Doc 1 (memo to Joel Smith, dated Sep 18, 1987), for these concentrations. The different transient runs then started from this control run. The proper base values to use for the transient runs are the means of years 46-55 of the 100-year control run (info from Dave Rind, GISS). Therefore, these are used for the transient-run data sent to EPA PIs. It would not have been proper to use the same base values as on the 1x CO$_2$ control run from GISS (so this was not done), because some of the aspects of the model are different for the two control runs. For example, the transient model has a greater mixed layer depth—up to 250 meters. This compares with 65m in the 1x and 2x CO$_2$ model runs.

Data for Transient Runs:

NCAR received data from GISS for the two transient runs:

Run A: basic monthly data for 1958-2062
Run B: basic monthly data for 1958-2029

Also GISS provided decadal averages 1960-69, 70-79, etc. for each run.

As you recall, the decision was made to use the variability from the present observed climate for the assessment studies, not the variability from the GCM models. Therefore, data for the decadal averages are the basic data sent to PIs. The basic data values from the transient control run are also on the data sent to PIs. For each decade mean value (for each month), the ratios are given and the basic data is omitted. This was done to save space. Since the transient runs (as used by investigators) will start with data for 1980, we have dropped data for the 1960-69 decade.

One file contains the 10-year mean values (Jan-Dec) for each variable for the control case as described above. Fields of ratios for each month in the midpoint of each decade are included in two files, one for each scenario. The order of the data is:

Data From The Control Run

Transient Run A, 1st Variable
Ratios for monthly average of decade (1970-79) for months 1-12;
Ratios for monthly average of decade (1980-89) for months 1-12;
Etc.
Ratios for monthly average of decade (2050-2059), for months 1-12.

2nd Variable, etc (same sequence of fields)
NOTE: (Winds are a delta change, not a ratio.)
Tape Contents
Climate Model Outputs for EPA Studies
24 Feb 1988
Dennis Joseph
NCAR

NCAR has prepared a tape which contains model output grids from the GISS, GFDL, and OSU models for use in EPA studies. The tape consists of 11 files with a logical record size of 120 bytes and a block size of 4800 bytes. ASCII coding and 1600 bpi are the defaults. EBCDIC coding and 6250 or 800 bpi density are available on request.

The first two files on the tape are FORTRAN programs for reading the data files. The next 9 files contain data grids where each grid consist of several records. A list of the files on the tape is given below.

A summary of the contents of each data file which shows the identification for the first record of each variable type in each file is attached. Most variables represent measurements at the surface or lowest level of the model, but some measurements are for higher levels in the atmosphere and geopotential height fields and u and v wind component fields are included for more than one level. Level indicators are included in the data files as part of the grid identification. For steady state runs, the data values for 1xCO2 and 2xCO2 are always included. A ratio (2xCO2/1xCO2) is included for the first 7 variables. Only ratios (current/control) are given for the transient runs, but actual values can be derived since the control values are given in a separate file. All data files are ordered as follows: variable, year-month, and for steady state runs the run type (1xCO2, 2xCO2, ratio). The GISS steady state values include seasonal and annual means in addition to the 12 monthly means.

A full print of the first 3 grids in each data file is also included (for GFDL and OSU North American grids, only every other longitude is printed). A separate document, "Format for Gridded Fields", describes the format for the data records.

File Content
1 General read and print program for all data files (GRDRD.FOR).
2 Read and interpolation program for transient files (TRANRD.FOR).
3 GISS steady state 1xCO2, 2xCO2, and ratios, US.
4 GFDL steady state 1xCO2, 2xCO2, and ratios, US.
5 OSU steady state 1xCO2, 2xCO2, and ratios, US.
6 GISS control run for transient ratio calculations, US.
7 GISS decadal transient ratios to control for scenario A, US.
8 GISS decadal transient ratios to control for scenario B, US.
9 GISS steady state 1xCO2, 2xCO2, and ratios, No Am.
10 GFDL steady state 1xCO2, 2xCO2, and ratios, No Am.
11 OSU steady state 1xCO2, 2xCO2, and ratios, No Am.
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<td></td>
<td>albedo</td>
</tr>
<tr>
<td>471</td>
<td>10</td>
<td>10</td>
<td>20.0</td>
<td>60.0</td>
<td>-135.0</td>
<td>-67.5</td>
<td>GFDL</td>
<td>1XC02</td>
<td></td>
<td></td>
<td>net solar radiation</td>
</tr>
<tr>
<td>495</td>
<td>10</td>
<td>10</td>
<td>20.0</td>
<td>60.0</td>
<td>-135.0</td>
<td>-67.5</td>
<td>GFDL</td>
<td>1XC02</td>
<td></td>
<td></td>
<td>net long wave</td>
</tr>
<tr>
<td>543</td>
<td>10</td>
<td>10</td>
<td>20.0</td>
<td>60.0</td>
<td>-135.0</td>
<td>-67.5</td>
<td>GFDL</td>
<td>1XC02</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EDF IN FILE NO 4 AFTER 590 GRIDS 7670 RECORDS 920400 BYTES.**
Data from various sources and in a variety of formats have been put into a common grid format for use in this project. The format used for gridded data consists of a series of 120 character records. These records can be read with standard FORTRAN read statements as indicated in the sample read statements below.

The first record of each grid is a general header and contains 104 characters of free form comment information. This information may come from the original data format or it may be generated in the format conversion. This comment information may not be completely accurate since some changes, such as units, were made at NCAR and the comment may apply to the original file. It usually describes the following grid, but a full definition of the grid is contained in the identification variables which are in the next two records, the grid header records. The actual grid data appears in records following the headers. There will be as many records as necessary to contain all grid point values.

The sample FORTRAN statements below, show examples of reading all data for the grid and of skipping over the data and reading only headers. The format allows for a great deal of generality in data layout and formats; but, at least in initial usage, much of this generality is not used. Therefore, it is not necessary to program for all options. When designing programs to use the data, it is suggested that those format options that are not currently used be tested for the current default values, and error exceptions noted if values other than default occur.

Those options not currently used are:

- NSTAT - always 1, no anomalies are used.
- NUNIT - always 0, all variables are converted to default units.
- NSCALE - always 0, no scaling is done.
- NFUJD - always 12, field width is always 12.
- NFORM - always (10E12.5)
- SCALE - not used.
- BASE - not used.
- NGTYP - always 1, all grids are longitude x latitude.
- NORT - always 1.
PROGRAM GRIDRD

C DEFINE ARRAY LARGER THAN LARGEST DATA ARRAY EXPECTED
PARAMETER (IDM=100, JDM=100)
DIMENSION DATA(IDM, JDM), XLON(IDM)
CHARACTER NCMTS*104, NFLG*2, NFORM*10, NFILE*16

C READ OF EPA EXCHANGE FORMAT (RECORD LENGTH = 120 BYTES)
C
2 PRINT 1012
1012 FORMAT(' ENTER FILE NAME FOR READ')
READ(5, 1013, END=95) NFILE
1013 FORMAT(A16)
   IF(NFILE(1:3).EQ.'END') GO TO 95
   PRINT 1014, NFILE
1014 FORMAT(' READ FILE ', A16)
   OPEN(1, FILE=NFILE)
C
   NRP=0
   NFR=0
C
C READ GENERAL HEADER (NFLG=##)
5 CONTINUE
   READ(1, 999, END=90) NFLG, NCNT, NFTYP, NCMTS
999 FORMAT(A2, I6, I8, A104)
   NFR=NFR+1
   NSKP=NCNT
   IF(NFR.GT.3) GO TO 58
   PRINT 1004, NFLG, NCNT, NFTYP, NCMTS
1004 FORMAT(//, 1X, A2, 2I5, A104)
C
C C READ HEADER RECORDS FOR GRID FORMATS.
C
C HEADER 1 (NFLGA=#A) CONTAINS IDENTIFICATION OF GRID AND SCALING
   READ (1, 1000, END=90) NFLGA, NSRC, NDAT, NRUNC, NMEAN, NPER, NLPM,
   2 NSTAT, NXR, NMO, NDX, NRH, NTYP, NUNITS, NSCALE, NFNWID, NFORM,
   3 NLXT, XLY1, XLV2, SCALE, BASE
1000 FORMAT(A2, 4I2, 2I3, I2, I4, 3I2, I4, I2, I2, I2, A10,
   2 I2, 2E16.9, 7X, 2E16.9)
C
   PRINT 1010, NFLGA, NSRC, NDAT, NRUNC, NMEAN, NPER, NLPM,
   2 NSTAT, NXR, NMO, NDX, NRH, NTYP, NUNITS, NSCALE, NFNWID, NFORM,
   3 NLXT, XLV1, XLV2, SCALE, BASE
1010 FORMAT(1X, A2, 4I2, 2I3, I2, I4, 3I2, I4, I2, I2, A10,
   2 I2, 2E16.9, 7X, 2E16.9)
C
C TEST ID AND SELECT GRIDS TO PRINT, SKIP GRIDS NOT WANTED
NSKP=NCNT-1
   IF(MOD(NMO, 6).NE.1 .AND. NMO.NE.0) GO TO 58
C
C HEADER 2 (NFLGB=#B) CONTAINS GRID SPECIFICATIONS
C
C
READ(1,1001,END=90)NFLGB,NGDEF,NGTYP,NORD,NI,NJ,XPI,XPJ,
  2 XNOR,XDI,XDJ
1001 FORMAT(A2,3I2,2I4,24X,5E16.9)
C
PRINT 1011,NFLGB,NGDEF,NGTYP,NORD,NI,NJ,XPI,XPJ,
  2 XNOR,XDI,XDJ
1011 FORMAT(1X,A2,3I2,2I4,24X,5E16.9)
C
C READ DATA POINTS
  READ(1,NFORM,END=90)((DATA(I,J),I=1,NI),J=1,NJ)
C
C SCALE IF NECESSARY
  IF(NSCALE.EQ.0) GO TO 16
  DO 10 J=1,NJ
      DO 10 I=1,NI
          DATA(I,J)=DATA(I,J)*SCALE + BASE
       10 CONTINUE
C
16 CONTINUE
   NRP=NRP+1
   IF(NI.LE.56) GO TO 20
C
C PRINT FIRST 2 AND LAST 2 POINTS FROM DATA ARRAY
  PRINT 1005,DATA(1,1),DATA(2,1),DATA(NI-1,NJ),DATA(NI,NJ)
1005 FORMAT(6E20.12)
  GO TO 5
C
20 CONTINUE
C
C PRINT ENTIRE GRID IF IT FITS ON PAGE
   INC=1.+(FLOAT(NI)-.5)/14.)
   DO 22 I=1,NI
12 XLOX(I)=XPI+XDTP*(I-1)
22 PRINT 1007,(XLOX(I),I=1,NI,INC)
1007 FORMAT(/,9X,14F8.2)
   DO 25 JJ=1,NJ
       J=NJ+1-JJ
       XLAT=XPJ+XDTP*(J-1)
   25 PRINT 1006,XLAT,(DATA(I,J),I=1,NI,INC)
1006 FORMAT(1X,F6.2,2X,14F8.2)
   25 CONTINUE
   GO TO 5
C
58 CONTINUE
C TO SKIP HEADERS AND DATA
   DO 60 I=1,NSKP
       READ(1,1003,END=90)DUMMY
1003 FORMAT(A1)
   60 CONTINUE
   GO TO 5
90 CONTINUE
   PRINT 1015,NFR,NFILE
1015 FORMAT(1X,I8,' GRIDS READ FROM ',A16)
CLOSE(1)
GO TO 2
95 CONTINUE
STOP
END
Variable Definitions for EPA Gridded Format

General Header

NFLG - Flag to allow searching for the general header records, always = "##".

NCNT - Number of records following this header, to allow straightforward skipping to next general header.

NFTYP - Format type.
1 = 2 dimension grid format defined below.

NCMTS - Free form comments of up to 104 characters.

Header 1, for two dimensional grid format.

NFLGA - Flag for first header, always = "#A"

NSRC - Source of this data.
1 = giss
2 = gfdl
3 = osu
4 = ncar
11 = rand climatology

NDAT - Observed or predicted data.
1 = observed data.
2 = model predicted data.

NRUNCD - Run code.
0 = n/a
1 = 1 x CO2
2 = 2 x CO2
3 = ratio of 2 x CO2 to 1 x CO2
4 = ratio of transient runs scenario A to 1946-55 control run.
5 = ratio of transient runs scenario B to 1946-55 control run.
6 = control run from 1946-55 decade.
7 = this scenario A run minus 1946-55 control run.
8 = this scenario B run minus 1946-55 control run.

NMEAN - Type of mean.
0 = data applies to date-time specified
1 = mean of an individual continuous period (eg a year-month mean), see NPER for period length
2 = long period mean (an average of many continuous period means, eg a mean of all januaries for 20 years)

NPER - Period of data summary (length of continuous period used in mean)
0 = data applies to date-time specified
1 - 900 = approximate number of days represented by these values

NLPM = Approximate number of periods which went into long period mean
1 - 998 = approximate number of periods which went into long period mean
999 = unknown

NSTAT = Statistics flag
1 = mean or actual value
2 = anomaly from longer period mean

NYR, NMO, NDY, NHR Year, month, day, and hour to which this data applies. Value set to all 9's when it does not apply. Special month codes are 13=DJF, 14=MAM, 15=JJA, 16=SON, 17=Annual.

NTYP = Type of data, see TABLE 1. The value 1000 is added to type numbers in the table to indicate a ratio to a control value rather than actual data values. The value 2000 is added for differences from a control value.

NUNITS = Units of data where 0 is default, 1 is alternate 1, etc, see TABLE 1.

NSCALE = Flag for scaling
0 = no scaling necessary
1 = scaling required, VALUE = RECORDEDVALUE*SCALE + BASE.

NFWID = Field width of each variable in data format (ie 12 for NFORM shown below)

NFORM = Format for data read (eg "(10E12.5)")

NLEVT = Level type on which data is measured.
1 = pressure level (mb)
2 = height from sea level in meters
3 = distance from earth's surface in meters
4 = sigma levels (% of atmosphere above this level)
5 = entire troposphere
51 = layer defined by pressure levels (mb) in XLV1 and XLV2
52 = layer, height levels from sea level (m) in XLV1 and XLV2
53 = layer, heights from earth's surface (m) in XLV1 and XLV2
54 = earths boundary layer

XLV1 = Level definition as specified by NLEVT

XLV2 = Level definition as specified by NLEVT

SCALE = Scale to be applied to data values to recover actual values

BASE = Base to be applied to data values to recover actual values. (where SCALE=1. and BASE=0. the loop applying the BASE and SCALE
is not necessary)

Header 2, for two dimensional grid format.

NFLGB - Flag for second header, always = "#B"

NGDEF - Grid definition
1 = this is exact duplicate of originators grid
2 = this is a subgrid of exact points from originators grid
3 = this is a grid interpolated from originators grid

NGTYP - Grid Type
1 = longitude x latitude grid
3 = polar stereographic grid of nh
4 = polar stereographic grid of sh

NORD - Order in which grid points are written.
1 = first point is lower left, I dimension scans first.
2 = first point is lower left, J dimension scans first.
3 = first point is upper left, I dimension scans first.
4 = first point is upper left, J dimension scans first.

NI - I dimension of grid.
NJ - J dimension of grid.

XPI - grid reference location.
For NGTYP = 1 this is longitude of point at I,J = 1,1 (west is negative)
For NGTYP = 3 or 4 this is exact I index of pole point on this grid

XPJ - grid reference location.
For NGTYP = 1 this is latitude of point at I,J = 1,1 (south is negative)
For NGTYP = 3 or 4 this is exact J index of pole point on this grid

XNOR - Orientation of grid
For NGTYP = 1 this is always 0.
For NGTYP = 3 or 4 this is the longitude of the horizontal line
through and to the right of the pole point.

XDI - Grid spacing in the I direction.
For NGTYP = 1 this is degrees of longitude between consecutive points
For NGTYP = 3 or 4 this is distance in grid units from equator to
pole in the I direction.

XDJ - Grid spacing in the J direction.
For NGTYP = 1 this is degrees of latitude between consecutive points
For NGTYP = 3 this is distance in grid units from equator to pole in
the J direction (usually same as XDI)
### TABLE 1
Type Variable Definitions

<table>
<thead>
<tr>
<th>NTYP</th>
<th>Variable</th>
<th>NUNITS=</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>geopotential height</td>
<td>gpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>pressure</td>
<td>mb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>atmospheric temperature</td>
<td>c</td>
<td>k</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>maximum temperature</td>
<td>c</td>
<td>k</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>minimum temperature</td>
<td>c</td>
<td>k</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>soil temperature</td>
<td>c</td>
<td>k</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>diurnal air temp change</td>
<td>c</td>
<td>k</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>surface skin temperature</td>
<td>c</td>
<td>k</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>u wind component</td>
<td>m/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>v wind component</td>
<td>m/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>wind speed</td>
<td>m/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>vector wind speed</td>
<td>m/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>precipitation</td>
<td>mm/dy</td>
<td>cm/day</td>
<td>.01&quot;/day</td>
</tr>
<tr>
<td>91</td>
<td>snowfall</td>
<td>mm/dy</td>
<td>cm/dy</td>
<td></td>
</tr>
<tr>
<td>92</td>
<td>snow depth</td>
<td>mm</td>
<td>cm</td>
<td></td>
</tr>
<tr>
<td>93</td>
<td>snow &amp; ice cover</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>94</td>
<td>waters ice over land</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>95</td>
<td>specific humidity</td>
<td>(10**-4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>101</td>
<td>mixing ratio</td>
<td>(10**-4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>115</td>
<td>tropospheric stability</td>
<td>k/km</td>
<td></td>
<td>.01&quot;/day</td>
</tr>
<tr>
<td>117</td>
<td>composite evaporation</td>
<td>mm/dy</td>
<td>cm/day</td>
<td>.01&quot;/day</td>
</tr>
<tr>
<td>118</td>
<td>sfc runoff</td>
<td>mm/dy</td>
<td>cm/day</td>
<td>.01&quot;/day</td>
</tr>
<tr>
<td>119</td>
<td>plant water stress</td>
<td>(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>soil moisture</td>
<td>mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>129</td>
<td>earth sfc elevation</td>
<td>m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>161</td>
<td>land (-1.) / sea (0) flag</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>162</td>
<td>land coverage</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>169</td>
<td>albedo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>175</td>
<td>incident solar rad</td>
<td>w/m**2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>178</td>
<td>net solar radiation</td>
<td>w/m**2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>179</td>
<td>net thermal radiation</td>
<td>w/m**2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>180</td>
<td>net long wave</td>
<td>w/m**2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>211</td>
<td>convective cloud</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>220</td>
<td>total cloud</td>
<td>%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Extra Info about the GISS Model, incl sensitivity.

GISS GCM OUTPUTS

Most of this information is from several phone conversations with Dave Rind, GISS (212) 678-5593.

The GISS model is a grid point model, usually run at resolutions of $8^\circ$ Lat x $10^\circ$ Lon or $4^\circ$ x $5^\circ$.

1. Control run for the present climate and $2 \times CO_2$ run.
   - The control run uses $CO_2$ at 315 ppm (valid 1958); the $2 \times CO_2$ run uses 630 ppm.
   - The warming in the $2 \times CO_2$ compared to control is $4.2^\circ$ C.
   - Long period monthly statistics are for a ten year period, from years 26 to 35 of the control and 2x model runs. These are on an $8 \times 10^6$ grid and cover the whole world.
   - Year-month values are for the same 10-year period. The output includes a large number of diagnostics. Global coverage, $8 \times 10^6$ grid.
   - The $8^\circ$ of latitude in a grid cell is really about $7.8^\circ$. \(\frac{180}{23} = 7.8261\)
   - Data are available at higher resolution for a 3-year period for control and for 3-years of $2 \times CO_2$. The monthly global $4 \times 5^\circ$ data are available for the three-year control $CO_2$ run and the three-year $2 \times CO_2$ run.
   - Three years of daily data. This is output for the U.S. and S. Canada at a resolution of $4^\circ$ Lat x $5^\circ$ Lon. This U.S. area has 6 lons by 4 lats for the $8 \times 10^6$ grid. The $4 \times 5^\circ$ grid covers the same region but has more points. The three-year model runs of monthly and daily values for the U.S. were done on different computers. Thus, the daily values probably do not correspond to the associated monthly values from another model run. These daily runs are now being made (August 1987).
   - The daily values (13 vrbl) are:
     a. precipitation (only total), evaporation, snow amount ($kg/m^2$), soil moisture, runoff
     b. max-min temperature
     c. surface u and v wind
     d. SLP at hour 12 and 24
     e. Solar radiation absorbed at the ground
     f. surface humidity ($kg/kg$)
   - The outputs are limited because the output of data on tapes at the Goddard Cyber 205 is difficult.

26
2. Components of warming for doubled CO$_2$.

GISS used a 1-D model to determine the components of the 4.2°C increase in temperature with the doubling of CO$_2$. The changes in water vapor and clouds from the full GCM model were used in the 1-D model to make these calculations of sensitivity. The following explains nearly all of the changes:

a. Temperature change due to doubling CO$_2$ alone
   
   $1.2^\circ$C

b. Water vapor was increased 33% in the total column, and it was located at higher levels
   
   $1.6^\circ$

c. There was a decrease of 1.7% in cloud amount, with some increase in cirrus clouds. Cloud tops became somewhat higher.
   
   $0.8^\circ$

d. Changes in the surface albedo, mostly due to sea ice
   
   $0.4^\circ$

   $4.0^\circ$C

Note: Model run X in Table 1 shows what gas concentrations were used in these "double CO$_2$" runs. This does not list all of the gases; N$_2$O was held at 0.295 ppm, appropriate for 1958.

3. Multi-year runs that gradually change CO$_2$ and other trace gases. (transient runs).

- These runs cover the period 1958-2060 but all runs do not cover the full period.
- The output is saved each hour. It is only saved for U.S. and S. Canada (24 points) and for west and central Europe (24 points).
- It is on a grid 8° Lat x 10° Lon.
- This hourly data could be used to prepare daily data on an 8 x 10° grid.
- Such calculations yield daily data for every year of the long simulations, from about year 2000 when the hourly data was saved.
- The corresponding YR-month data has 60 quantities and covers the whole world (864 points).
- The CO$_2$ concentration was about 315 ppm in 1958 and 338 in 1980. One of these runs increases this to about 547 ppm by the year 2060, but the other radiative gases are also strongly increased in this run.
- The hourly data has two components of precipitation.
- The transient runs (Runs A and C) are also being rerun for 3 years at the years 2000 and 2030. Similar information (for Runs A, B, C) can be obtained by using 3 years of hourly data taken near these years.
- All data from the transient runs is on the 8 x 10° grid.

4. The GISS model runs that change gradually.

The concentrations of trace gases used in GISS model runs A, B, C are shown in Table 1. One dimensional models were used to obtain an approximate contribution of each trace gas to the overall warming as shown in Table 2. The actual simulated warming from the
GISS GCM is greater than the One-D model warming, due to feedback effects. For example, the Model-A warming of 2.24°C in year 2050 becomes about 3.5°C in the full GCM.

Models A&B Both really start in 1958

Model A  Hourly data saved YR 2000-2059 (to yr 2002). No major volcanoes after El Chichon. This simulation completed in early 1986. Note: El Chichon (Mexico, 17.3° N) erupted late March 1982 and on 4 April.


Model B'  Same inputs as B except leave out the new major volcanoes. Hourly data for 1958-2029.

Model C  Started in 1980, using output of model B at that time. Hourly data are saved for 1980-2039 (So really starts 1958). Has a slow increase in trace gases, and most are held constant after the year 2000. Run C has the same volcano history as run B.

Comments:  I think that run B has the most realistic assumptions on the amount of gases. It seems to me that run A increases methane and the freons in an unrealistic way. The release of CO₂ from fossil fuel is now about 5.0 Gtons a year. Assume that it increases to 8 Gtons/yr and then remains at this rate. This would give about 458 ppm in the atmosphere in the year 2050 AD.

5. GISS hopes to complete the various model runs by 1 Oct 87 and could send data within one or two weeks of that time.

6. Comments

One modeling problem mentioned by GISS is that the average rainfall at a low resolution gridpoint (such as 8° Lat x 10° Lon) is usually a very small number. This small amount tended to be absorbed in the soil and then evaporated with very little runoff. The space resolution needs to be improved to about 2° to obtain daily values that are about the right intensity, but then the monthly totals are way too large. Part of this problem is that daily area mean rainfall and precipitation at a local station should be expected to be two different things.

Modelers have noted that total daily precipitation tends to stay more constant from one model formulation to another than do the components of precipitation, (large scale and convective). This is true for the high resolution forecast models at ECMWF. It is also true for the climate models.

Regional statistics: In the MWR for April 1983, GISS shows maps that give the location of where daily data are saved, where regional statistics are saved, etc. The regional statistics are for a collection of grid points.

Volume of daily data. Assume that we save 20 years of model data for 20 variables at 100 different locations, once each day. Volume = (20 YR) (365 days) (20 variables) (100 points) (16 bits) plus 20% overhead. Thus Volume = 2.80 x 10⁸ bits (10⁹ bits fit on one tape, 6250 BPI).
Table 1. The concentrations of selected trace gases for the GISS model runs A, B, C are given in this table. Run X is for the control and double CO₂ runs. Note that the full model runs do not all cover this many years.

<table>
<thead>
<tr>
<th>Model Run</th>
<th>Year</th>
<th>CO₂ (ppm)</th>
<th>CH₄ (ppm)</th>
<th>F12 (ppt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1980</td>
<td>337.6</td>
<td>1.65</td>
<td>.62</td>
</tr>
<tr>
<td>A</td>
<td>2000</td>
<td>370.9</td>
<td>2.2</td>
<td>1.4</td>
</tr>
<tr>
<td>A</td>
<td>2030</td>
<td>443</td>
<td>3.5</td>
<td>3.9</td>
</tr>
<tr>
<td>A</td>
<td>2050</td>
<td>513</td>
<td>4.7</td>
<td>7.3</td>
</tr>
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<td>2.7</td>
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</tr>
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Table 2. Temperature increase in a 1-D model compared to the year 1958. The actual temperature increase is greater from GCMs due to feedback effects. For example, run A in the year 2050 shows a total of 2.24 warming in this Table compared with about 3.5°C from the GCM model and 4.2°C from the model in year 2060.

**TEMPERATURE CHANGE (°C) COMPARED TO 1958**

<table>
<thead>
<tr>
<th>Model Run</th>
<th>Year</th>
<th>Sum</th>
<th>CO₂</th>
<th>N₂O</th>
<th>CH₄</th>
<th>F11</th>
<th>F12</th>
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<td>.09</td>
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<td>.06</td>
<td>.02</td>
<td>.045</td>
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<td>.02</td>
<td>.06</td>
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<td>.27</td>
<td>.02</td>
<td>.06</td>
<td>.01</td>
<td>.03</td>
</tr>
</tbody>
</table>

Note: These warmings must be increased by about 60% due to feedback effects; see caption.
Table 3. MONTHLY STATISTICS BY GISS

The list of quantities does not include daily variances. The monthly variables for every world point are:

1. Mean temperature
2. Diurnal range
3. Precipitation (only total)
4. Evaporation
5. Sensible heat flux
6. Runoff
7. Soil temperature
8. Sfc wind
9. Jet stream winds
10. Total clouds
11. Convective clouds
12. Low, mid, high clouds
13. Cloud top pressure

**Top of Atmosphere**

14. Planetary albedo
15. Outgoing visible
16. Amt. of IR in window
17. Net solar top atmosphere
18. Incoming solar at top

**Surface**

19. Incident solar at sfc
20. Absorbed solar at sfc
21. Net heating at sfc
22. Net radiation at sfc
23. Water plus ice in two ground levels
24. Length of growing season
25. Heating degree days (vs 65°F)
26. Heat, humidity index (comfort)
27. Drought index (close to Palmer index)
28. Plant water stress
29. Monthly average of specific humidity at sfc
30. Sfc momentum drag (for ocean stress, etc.)
31. N. export of dry static energy by eddies
32. Diagnostic on total earth water plus ice (2 ground levels)
33. Heights (at 1000, 850, 700, 500, 100, 30 mb)
34. Thickness temps (redundant with hts)
35. Tropopause static stability

*Note: All of these variables are not on the Tapes for EPA PIs*
Dennis:

As we discussed, these are the in progress runs:

8 x 10^6 transient runs for three years each of yr. 2000, 2030
as well as the control (1958) from scenarios A&C

4 x 5 doubled CO2 run (and control) for three years (hopefully)

Here is what we are saving from these runs, for the region of the U.S.
and Southern Canada, daily:
1. Maximum and minimum temperatures
2. Daily solar radiation absorbed at ground
3. Hydrological variables of precipitation, evaporation, runoff, soil
   moisture, snow depth
4. Surface wind
5. Surface relative humidity
6. Sea level pressure (twice daily)

This is in addition to the many monthly average diagnostics we have
available.

For the transient experiment we have hourly data as indicated on the
accompanying sheet, for the regions shown.

David

GISS models

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