Model Information of Potential Use to the IPCC Lead Authors and the AR4.

GISS-EH and GISS-ER

7 April 2006

I. Model identity:

A. Institution, sponsoring agency, country

Goddard Institute for Space Studies (GISS), NASA, USA

B. Model name (and names of component atmospheric, ocean, sea ice, etc.. models)

Two versions were submitted to the IPCC archive: GISS ModelE-H and GISS ModelE-R (which differ only in ocean component)

Atmospheric and sea ice model:

GISS ModelE (Schmidt et al, 2005, J. Clim, accepted)
http://www.giss.nasa.gov/tools/modelE

Ocean models:

GISS-ModelE-R - Russell et al (1995; 2000)
GISS-ModelE-H - HYCOM (Bleck 2000; 2002)

C. Vintage (i.e., year that model version was first used in a published application)

2004

D. General published references and web pages

Main web page: http://www.giss.nasa.gov/tools/modelE
AGCM description and evaluation:

Schmidt, G. A. , Reto Ruedy, James E. Hansen, Igor Aleinov, Nadine Bell, Mike Bauer, Susanne Bauer, Brian Cairns, Vittorio Canuto, Ye Cheng, Anthony DelGenio, Greg Faluvegi, Andrew D. Friend, Tim M. Hall, Yongyun~Hu, Max Kelley, Nancy Y. Kiang, Dorothy Koch, Andy A. Lacis, Jean~Lerner, Ken~K.~Lo, Ron L. Miller, Larissa Nazarenko, Valdar Oinas, Jan~Perlwitz, Judith Perlwitz, David Rind, Anastasia Romanou, Gary L. Russell, Makiko~Sato, Drew T. Shindell, Peter H. Stone, Shan Sun, Nick Tausnev, Duane Thresher, Mao-Sung Yao 2005. Present day atmospheric simulations using GISS ModelE: Comparison to in-situ, satellite and reanalysis data. J. Climate, 19, 153-192.
http://www.giss.nasa.gov/tools/modelE/

Hansen et al., 2006. The Efficacy of Climate Forcings. J. Geophys. Res. 100, D18104.
http://www.giss.nasa.gov/data/simodel/efficacy/

Sun, S., R. Bleck 2006. Multi-Century Simulations with the Coupled GISS-HYCOM Climate Model: Control Experiments. Climate Dynamics 26, 407-428.

The Impact of the ocean component on coupled model simulations in GISS ModelE. Romanou, A., G. A. Schmidt, L. Nazarenko, R. Miller, Y. Hu, S. Sun and N. Tausnev. J. Climate. in preparation.

E. References that document changes over the last ~5 years (i.e., since the IPCC TAR) in the coupled model or its components. We are specifically looking for references that document changes in some aspect(s) of model performance.

As above, but also:

Del Genio, A.D., W. Kovari, M.-S. Yao and J. Jonas, 2005: Cumulus microphysics and climate sensitivity. J. Clim., in press.

Friend, A. D. and N. Y. Kiang (2005). "Land Surface Model Development for the GISS GCM: Effects of Improved Canopy Physiology on Simulated Climate." J. Clim. (in press)

Schmidt, G. A., C. M. Bitz, U. Mikolajewicz and L.-B. Tremblay. 2004. Ice-ocean boundary conditions for coupled models. Ocean Modelling, 7, 59--74

F. IPCC model version's global climate sensitivity (KW-1m2) to increase in CO2 and how it was determined (slab ocean expt., transient expt--Gregory method, ±2K Cess expt., etc.)

Slab ocean sensitivity to 2xCO2: 2.7 deg C

G. Contacts (name and email addresses), as appropriate, for:

1. coupled model
2. atmosphere
3. ocean
4. sea ice
5. land surface
6. vegetation
7. other?

For 1,2,4,7: Gavin Schmidt (gschmidt@giss.nasa.gov)
For 3 (ModelE-R): Gavin Schmidt (gschmidt@giss.nasa.gov) and
Gary Russell (cmglr@giss.nasa.gov)
For 4 (ModelE-H): Shan Sun (ssun@giss.nasa.gov)
For 5,6: Igor Aleinov (ialeinov@giss.nasa.gov)
For data, forcing info, etc.: Reto Ruedy (rruedy@giss.nasa.gov)

II. Besides atmosphere, ocean, sea ice, and prescription of land/vegetated surface, what can be included (interactively) and was it active in the model version that produced output stored in the PCMDI database?

A. atmospheric chemistry?
B. interactive biogeochemistry?
C. what aerosols and are indirect effects modeled?
D. dynamic vegetation?
E. ice-sheets?

Chemistry and aerosols can be interactive, but were not used in the IPCC submissions. These submissions had specified decadally varying chemistry and aerosol fields from previously modelled time slices. IPCC runs included sulfates, dust, nitrates, carbonaceous (OC and BC), and sea salt aerosols. (Also volcanic stratospheric aerosols). Indirect effects 1 and 2 were parameterised from interactive runs. Indirect impacts of soot on ice albedo are parameterised based on Hansen and Nazerenko (2004). Dynamic vegetation is not used, and ice sheets were static.

III. List the community based projects (e.g., AMIP, C4MIP, PMIP, PILPS, etc.) that your modeling group has participated in and indicate if your model results from each project should carry over to the current (IPCC) version of your model in the PCMDI database.

No relevant submissions have yet been made. (i.e. submissions were made with previous versions of the model that are no longer supported). AMIP submissions have been made as part of this project, and PMIP2 submissions will be forthcoming.

IV. Component model characteristics (of current IPCC model version):

A. Atmosphere

1. resolution
2. numerical scheme/grid (advective and time-stepping schemes; model top; vertical coordinate and number of layers above 200 hPa and below 850 hPa)
3. list of prognostic variables (be sure to include, as appropriate, liquid water, chemical species, ice, etc.)
4. name, terse descriptions, and references (journal articles, web pages) for all major parameterizations. Include, as appropriate, descriptions of:
   a. clouds
   b. convection
   c. boundary layer
   d. SW, LW radiation
   e. any special handling of wind and temperature at top of model

1. 4 deg lat, 5 deg long
2. Arakawa B-grid for momentum, quadratic upstream scheme (Prather, 1986) for tracers. Model Top: 0.1 hPa, mixed sigma coordinates + fixed pressure levels above 150mb. 11 levels above 200 hPa, 4 levels below 850 hPa).

3. Potential Temp, Specific Humidity, Total Water Condensate
(either all ice or all liquid).
4. See main documentation above (Schmidt et al, subm).

B. Ocean
1. resolution
2. numerical scheme/grid, including advection scheme,
time-stepping scheme, vertical coordinate, free surface or rigid
lid, virtual salt flux or freshwater flux
3. list of prognostic variables and tracers
4. name, terse descriptions, and references (journal articles,
web pages) for all parameterizations. Include, as appropriate,
descriptions of:
a. eddy parameterization
b. bottom boundary layer treatment and/or sill overflow treatment
c. mixed-layer treatment
d. sunlight penetration
e. tidal mixing
f. river mouth mixing
g. mixing isolated seas with the ocean
h. treatment of North Pole "singularity" (filtering, pole
rotation, artificial island?)

Russell Ocean:
1. 4 deg lat, 5 deg long
2. C grid, linear upstream scheme (Russell and Lerner, 1985)
for tracers, z* coordinate (fixed number of levels with a
fixed proportion of mass in the column), free surface,
non-Boussinesq, mass conserving, natural boundary conditions
(i.e. freshwater fluxes).
3. Potential Enthalpy (J), Salt (kg), Total Mass (kg),
Velocities (m/s).
4. a. GM using Visbeck et al (1997) coefficients as implemented
by Griffies (1998)
b. none
c. KPP
d. yes (to 80m)
e. no
f. no (river outflow is added to the one relevant ocean box)
g. 12 sub-gridscale straits driven by local pressure
gradients.
h. filtering

References:

Russell, G.L., J.R. Miller, and D. Rind 1995. A coupled
atmosphere-ocean model for transient climate change
studies. Atmos.-Ocean 33, 683-730.

Russell, G. L., J. R. Miller, D. Rind, R. A. Ruedy,

G. A. Schmidt, and S. Sheth. 2000. Comparison of model and observed regional temperature changes during the past 40 years. J. Geophys. Res., 105, 14891--14898.

Liu, J., G. A. Schmidt, D. Martinson, D. Rind, G. Russell and X. Yuan. 2003. Sensitivity of sea ice to physical parameterizations in the GISS global climate model. J. Geophys. Res., 108, 3053, doi:10.1029/2001JC001167

HYCOM ocean:

1. Mercator projection below 60N deg, 2deg x 2deg cos(lat) bipolar patch above 60N, 1deg at 60N to 0.5deg at N.Pole

2. C-grid, FCT advection scheme, leapfrog time stepping, vertical coordinate: z near the surface, isopycnic below (Arbitrary Lagrangian-Eulerian, ALE), free surface, virtual salt flux. diapycnal mixing coefficient: 0.002 (cm^2/s^2) /N.

3. temperature, salinity, layer thickness, velocity, isopycnal/diapynal massflux, mixed layer depth, sea surface height.

4.
a. Interface smoothing with a coefficient of 0.002 (m/s) x meshsize, which is of order 100 m^2/s.
b. no special treatment
c. Kraus-Turner in mixed layer.
d. no special treatment
e. no
f. no
g. no
h. bi-polar patch projection above 60N with poles over Canada/Siberia

References:

Sun, S., and R. Bleck, 2001b: Atlantic thermohaline circulation and its response to increasing CO$_2$ in a coupled atmosphere-ocean model. Geophys. Res. Lett., 28, 4223--4226.

Bleck, R., 2002: An oceanic general circulation model framed in hybrid isopycnic-Cartesian coordinates. Ocean Modelling, 4, 55--88.

Sun, S., and J. Hansen, 2003: Climate simulations for 1951-2050 with a coupled atmosphere-ocean model. J. Climate, 16, 2807--2826.

C. sea ice

1. horizontal resolution, number of layers, number of thickness categories
2. numerical scheme/grid, including advection scheme, time-stepping scheme,
3. list of prognostic variables

4. completeness (dynamics? rheology? leads? snow treatment on sea ice)
5. treatment of salinity in ice
6. brine rejection treatment
7. treatment of the North Pole "singularity" (filtering, pole rotation, artificial island?)

1. Same as atmosphere, 4 layers, 2 categories (no ice, ice)
2. Advection uses viscous-plastic rheology (Zhang and Rothrock, 2000)
3. ice mass, ice enthalpy, salt mass.
4. leads have a minimum value based on ice thickness (below 5m). Snow is one layer on ice. Snow-ice formation is allowed.
5. salt is carried by ice conservatively but does not have a thermodynamic effect.
6. brine is partially rejected at freezing, and then exponential brine flushing with 1 month decay time.
7. None.

D. land / ice sheets (some of the following may be omitted if information is clearly included in cited references.

1. resolution (tiling?), number of layers for heat and water
2. treatment of frozen soil and permafrost
3. treatment of surface runoff and river routing scheme
4. treatment of snow cover on land
5. description of water storage model and drainage
6. surface albedo scheme
7. vegetation treatment (canopy?)
8. list of prognostic variables
9. ice sheet characteristics (How are snow cover, ice melting, ice accumulation, ice dynamics handled? How are the heat and water fluxes handled when the ice sheet is melting?)

1. The land surface part of the GCM cell is split into two fractions: vegetated surface and bare soil, each having its own set of prognostic variables. These fractions are static, i.e. they don't change during the model run. Soil model consists of six layers of soil with the thickness of upper soil layer being 10 cm and the total depth of the soil being 3.5 m.

2. Depending on the amount of heat in the soil layer, part or all water in that layer can be frozen. Frozen water doesn't participate in water exchange until it has melted again. In some areas part or all soil water is frozen all the time, thus forming a permafrost. No special treatment of permafrost is done besides what is obtained automatically from heat and water balance.

3. The incoming flux of water which reaches the soil surface consists of fraction of precipitation not intercepted by vegetation and snow and of meltwater flux produced by

snowpack. Fraction of this incoming flux that falls on saturated soil is completely redirected to the surface runoff. The contribution of the remaining flux to the surface runoff is a function of infiltration capacity and of precipitation fraction. It is modeled according to formula (5) of (Rosenzweig et al.,1997). River routing is based on existing river networks and transports runoff through lakes (where they exist) to the ocean, as a function of the lake/river level over the sill depth and a local topographic gradient. Lakes are modelled using a two layer mass and energy conserving scheme.

4. GISS GCM employs a three layer snow model as described in (Lynch-Stieglitz,1994). Snow fraction is computed according to parametrization of (Roesch et al.,2001). The snow pack is located between the canopy and the first soil layer. Fraction of canopy covered by snow is a function of snow thickness and of the vegetation masking depth.

5. The movement of water between the layers is computed according to Darcy's law. Frozen fraction of the soil doesn't conduct water and the lower boundary of the bottom layer is impermeable. Underground runoff is a function of the average slope and of the density of sinks as described in (Abramopoulos et al.,1988) section 2d.

6. Albedo is computed as a weighted average of albedos of different surface fractions. Those are eight types of vegetations, two types of bare soil and snow fraction. Land snow albedo is computed as described in Hansen et al. (1983) with modifications based on soot emissions (Hansen and Nazarenko, 2004). Each vegetation type has prescribed albedo for four seasons. Actual vegetation albedo is computed by means of linear interpolation between the two closest points in time. Each albedo is computed for six different wavelength bands.

7. The canopy is treated as a single layer which has its own heat and water holding capacities. The distribution of eight types of vegetation is currently prescribed and is fixed in time. Leaf area index, root fractions and vegetation heights have prescribed seasonal variation. Canopy conductance model is based on actual plant physiology. Evapotranspiration is a function of potential evaporation, canopy conductance, root fraction and soil water availability.

Friend, A. D. and N. Y. Kiang (2005). "Land Surface Model Development for the GISS GCM: Effects of Improved Canopy Physiology on Simulated Climate." J. Clim. (in press)

8. Canopy: heat content, water content. Soil: heat content, water content for each layer of soil. Snow: heat content, water content, layer thickness for each layer of snow.

9. Ice sheets have fixed height. If ice mass balance is non-zero, implicit fluxes at the base of the ice are used to match. In control runs, net implicit fluxes are exactly balanced by an ice calving term. Ice sheets albedo is fixed at 0.8 for Greenland and Antarctica. No ice sheet dynamics is included.

E. coupling details
1. frequency of coupling
2. Are heat and water conserved by coupling scheme?
3. list of variables passed between components:
   a. atmosphere - ocean
   b. atmosphere - land
   c. land - ocean
   d. sea ice - ocean
   e. sea ice - atmosphere
4. Flux adjustment? (heat?, water?, momentum?, annual?, monthly?).

1. GISS-ModelE-R: full coupling every 30 minutes.
   GISS-ModelE-H: full coupling every 4 hours.

2. Yes. So is salt.

3. a. precip (and energy of precip), evaporation, momentum stress, solar radiation, sensible (and latent) heat, long wave. surface pressure,u*, SST
   b. precip (and energy of precip), evaporation, solar radiation (diffuse and direct), sensible (and latent) heat, long wave, wind speed, SAT, QS, maximum evaporation possible, u*, ground temperature.fractional snow cover, soil moisture, snow depth.
   c. river runoff, energy of river runoff.
   d. sea ice mass, sea ice melt (+ energy of melt + salt in melt), basal melt/formation rate (+ energy + salt), ocean mixed layer ice formation (+energy + salt), sea ice-ocean stress, sea surface height, SST, SSS, u*, surface ocean velocity.
   e. precip (and energy of precip), evaporation, solar radiation (diffuse and direct), sensible (and latent) heat, long wave, wind speed, SAT, QS, maximum evaporation possible, u*, ground temperature, fractional snow cover, meltpond fraction/depth, snow depth.
4. None.

VI. Simulation Details (report separately for each IPCC simulation contributed to database at PCMDI):

A. IPCC "experiment" name
B. Describe method used to obtain initial conditions for each component model

GISS-ModelE-R:

1 - A: pre-industrial control experiment: E3AoM20A - 1880 atm.conditions
B: initial conditions = final state of a preceding 200 year run;
that model started up from a series of previous models whose combined simulation time added up to 428 years.
The initial run of that series started up from observed atmospheric conditions (1 Dec 1977) and ground conditions from a long series of earlier runs.

2 - A: present day control experiment - nothing submitted

3 - A: 20C3M: ensemble of 9 runs E3Af8[a-i]oM20A
B: E3Af8aoM20A start: 1/1/1880 = 1/1/year 6 of E3AoM20A
E3Af8boM20A start: 1/1/1880 = 1/1/year 7 of E3AoM20A
E3Af8coM20A start: 1/1/1880 = 1/1/year 8 of E3AoM20A
E3Af8doM20A start: 1/1/1880 = 1/1/year 9 of E3AoM20A
E3Af8eoM20A start: 1/1/1880 = 1/1/year 10 of E3AoM20A
E3Af8foM20A start: 1/1/1880 = 1/1/year 31 of E3AoM20A
E3Af8goM20A start: 1/1/1880 = 1/1/year 56 of E3AoM20A
E3Af8hoM20A start: 1/1/1880 = 1/1/year 81 of E3AoM20A
E3Af8ioM20A start: 1/1/1880 = 1/1/year 106 of E3AoM20A

4 - A: committed climate change experiment: E3Af8coM20A
B: extension of one of the 20C3M runs, 1/1/1880=1/1/yr 8 of E3AoM20A

5 - A: SRES A2 experiment: E3IP_A2oM20
B: start Jul 1,2003 of E3Af8coM20A, 1/1/1880=1/1/yr 8 of E3AoM20A

6 - A: SRES A1B experiment: ensemble of 5 runs E3IP_A1B[^f-i]oM20
B: E3IP_A1BoM20 start: 7/1/2003 of E3Af8coM20A, 1/1/1880=1/1/yr 8 of E3AoM20A
E3IP_A1BfoM20 start: 7/1/2003 of E3Af8foM20A, 1/1/1880=1/1/yr 31 of E3AoM20A
E3IP_A1BgoM20 start: 7/1/2003 of E3Af8goM20A, 1/1/1880=1/1/yr 56 of E3AoM20A
E3IP_A1BhoM20 start: 7/1/2003 of E3Af8hoM20A, 1/1/1880=1/1/yr 81 of E3AoM20A
E3IP_A1BioM20 start: 7/1/2003 of E3Af8ioM20A, 1/1/1880=1/1/yr 106 of E3AoM20A

7 - A: SRES B1 experiment: E3IP_B1oM20
B: start 7/1/2003 of E3Af8coM20A, 1/1/1880=1/1/yr 8 of E3AoM20A

8 - A: 1%/year CO2 increase experiment (to doubling): E3Ato2CO2oM20
B: start 1/1/yr 81 of E3AoM20A (first 69.5 years run as E3Ato4CO2oM20, deviating from that run starting 7/1/year 70)

9 - A: 1%/year CO2 increase experiment (to quadrupling): E3Ato4CO2oM20
B: start 1/1/yr 81 of E3AoM20A

10 - A: slab control experiment: E3qM20A
B: start: 1/1/year 11 of E3M20A(=run with prescribed 1876-1885 mean observed ocean)
E3M20A started with 12/1/1977 observed atmospheric initial conditions but used mean 1880 atmospheric composition; fluxes at the sea surface were collected over the last 10 years and used to compute the horizontal heat transports in the ocean.

11 - A: 2xCO2 equilibrium experiment
B: start: 1/1/year 11 of E3M20A (same start as control run E3qM20A)

12 - A: AMIP simulation: ensemble of 4 runs E3OCNf8[a-d]M20A
While those runs simulated years 1880-present, only years 1979-present were submitted.
B: start: at 1/1/1880 from 1/1/year 51 of a run with prescribed 1876-1885 mean observed ocean data. The initial atmospheric temperatures were randomly perturbed by amounts < 1C for the 3 runs E3OCNf8[b-d]M20A.

GISS-ModelE-H:
1 - A: Pre-industrial control:
B: No spin up, starts from observed state (Levitus).

2 - A: 20C3M
B: 5 runs start at yrs 120,130,140,150,160 of the PI control run

3 - A: 1% CO2 up to doubling
B: starts at year 110 of the PI control run.

C. For pre-industrial and present-day control runs, describe radiative forcing agents (e.g., non-anthropogenic aerosols, solar variability) present. Provide references or web pages containing further information as to the distribution and temporal changes in these agents.

CO2, CH4, N2O, CFCs, O3, dust, sulfate, nitrate, cabonaceous (OC +BC), sea salt, volcanic stratospheric aerosols, solar (spectral).
http://www.giss.nasa.gov/tools/modelE/
http://www.giss.nasa.gov/data/simodel/

D. For perturbation runs, describe radiative forcing agents (e.g., which greenhouse gases, which aerosols, ozone, land surface changes, etc.) present. Provide references or web pages containing further information as to the distribution and temporal changes in these agents.

CO2, CH4, N2O, CFCs: as observed (to 2001, then as scenario)
O3 strat: observed trend
(**Note:** the above submissions had an error in the implementation of the Randel and Wu trend in stratospheric ozone. This lead to an underestimate of the changes from 1979 to 1997 by a factor

of 5/9. Updated runs using a correct ozone trend will be forthcoming, but preliminary tests indicate that only the lower stratospheric temperature trends are much affected. Surface radiative forcing is very similar (leading to about 0.01C difference in the 120 year change, less than the run to run variability)).

O3 trop: modelled in decadal time slices as function of emissions of precursors.
sulfate, nitrate, cabonaceous (OC+BC): modelled as function of emissions, indirect effects based on Menon et al (2002), Hansen and Nazarenko (2004).
volcanic stratospheric aerosols (Sato and Hansen)
solar (spectral) (Lean 2002)
land use (Foley and Ramankutty, 1999)

http://www.giss.nasa.gov/tools/modelE/
http://www.giss.nasa.gov/data/simodel/