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

GFDL-CM2.0 and GFDL-CM2.1

2 May 2005

I. Model identity:
A. Institution, sponsoring agency, country
Geophysical Fluid Dynamics Laboratory
NOAA
USA
B. Model name (and names of component atmospheric, ocean, sea ice, etc. models)
CM2.0 - AOGCM
AM2P13 – atmosphere
OM3P4 - ocean
LM2 - land
SIS – sea ice
C. Vintage (i.e., year that model version was first used in a published application)
2005
D. General published references and web pages
Delworth, T.L. and co-authors, 2004: GFDL's CM2 global coupled climate models -- Part 1: Formulation and simulation characteristics, submitted to J. Climate.

Gnanadesikan, A. and co-authors, 2004: GFDL's CM2 global coupled climate models -- Part 2: The baseline ocean simulation, submitted to J. Climate.

http://data1.gfdl.noaa.gov/nomads/forms/deccen/

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.
CM2.0 was not developed using GFDL's TAR model (MCM) as a starting point. It is a completely new formulation.

References:

Delworth, T.L. and co-authors, 2004: GFDL's CM2 global coupled climate models -- Part 1: Formulation and simulation characteristics, submitted to J. Climate.

Gnanadesikan, A. and co-authors, 2004: GFDL's CM2 global coupled climate models -- Part 2: The baseline ocean simulation, submitted to J. Climate.

Wittenberg, A.T., A. Rosati, N-C Lau, and J. Ploshay, 2004: GFDL's CM2 global coupled climate models, Part 3: Tropical Pacific Climate and ENSO, submitted

to J. Climate.

GFDL GAMDT, 2004: The new GFDL global atmosphere and land model AM2-LM2: Evaluation with prescribed SST simulations, J. Climate, 17, 4641-4673.

Milly, P.C.D, and A.B. Shmakin, 2002: Global modeling of land water and energy balances, Part I: The land dynamics (LaD) model, Journal of Hydrometeorology, 3, 283-299.

Griffies, S.M., A. Gnanadesikan, K.W. Dixon, J.P. Dunne, R. Gerdes, M.J. Harrison, I.M. Held, A. Rosati, J. Russell, B.L. Samuels, M.J. Spelman, M. Winton, and R. Zhang, 2005: Formulation of an ocean model for global climate simulations, in preparation for Ocean Modelling.

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.)

2.9K for a CO2 doubling in a slab model

Reference:

Knutson, T.R., A.J. Broccoli, B.J. Soden, R. Gudgel, R. Hemler, S.A. Weber, and M. Winton, 2005: Equilibrium sensitivity of the GFDL AM2 slab-ocean climate model to a doubling of atmospheric CO2, in preparation.

Transient 1%/yr sensitivity at 2xCO2: 1.6 K

Reference:

Stouffer, R.J, A.J Broccoli, T.L. Delworth, K.W. Dixon, R. Gudgel, I. Held, T. Knutson, H-C Lee, M.D. Schwarzkopf, B. Soden, M.J. Spelman, M. Winton, and F. Zeng, 2004: GFDL's CM2 Global Coupled Climate Models -- Part 4: Idealized climate response, submitted to J. Climate.

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?

All queries: gfdl.climate.model.info@noaa.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?

Not yet

B. interactive biogeochemistry?

Not yet

C. what aerosols and are indirect effects modeled?

No indirect yet

Aerosols – Organic and black carbon, dust (constant in historical/future runs), sulphate, and sea salt.

D. dynamic vegetation?

Not yet

E. ice-sheets?

No

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.

AM2P13 – AMIP – very similar to atmospheric component of CM2.0

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

A. Atmosphere resolution

2.5 degrees longitude, 2.0 degrees latitude, 24 levels

2. numerical scheme/grid (advective and time-stepping schemes; model top; vertical coordinate and number of layers above 200 hPa and below 850 hPa)

B-grid, hybrid sigma-pressure vertical coordinate, 5 levels above 200 hPa, top at 3 hPa, 8 levels below 850 hPa

two level time differencing, gravity waves forward backward stepping (Mesinger 1977); timesteps are 200 s/600 s/1800 s (gravity waves/advection/physics) in CM2.0 and 360 s/1800 s/1800 s in CM2.1.

In CM2.0 horizontal advection uses centered spatial differencing, momentum is 4th order, tracers are 2nd order, vertical advection of tracers is finite volume (Lin et al 1994) piecewise parabolic (Colella and Woodward 1984). In CM2.1 the horizontal discretization is the flux-form semi-Lagrangian as described in Lin and Rood (1997) and Lin (2004).

3. list of prognostic variables (be sure to include, as appropriate, liquid water, chemical species, ice, etc.)

Zonal and meridional wind components, surface pressure, temperature, and tracers. The tracers include the specific humidity of water vapor and three prognostic cloud variables: cloud liquid, cloud ice, and cloud fraction

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

A. Microphysics (Rotstayn 2000), macrophysics (Tiedke 1993)

B. Relaxed Arakawa Schubert (Moorthi and Suarez 1992), cloud tracers detrain from convective updrafts to stratiform clouds, updraft detrainment lower bound (Tokioka et al 1988), convective momentum transport represented by diffusion proportional to cumulus mass flux.

C. K-profile scheme with prescribed entrainment for convective layers (Lock et al 2000)

D. SW follows Freidenreich and Ramaswamy (1999) with modifications (GAMDT 2004);
absorption and scattering by H2O, CO2, O3, O2, aerosols and clouds; 18 spectral bands; liquid cloud properties from Slingo (1989), ice cloud from Fu and Liou (1993), diurnal cycle. LW follows Schwarzkopf and Ramaswamy (1999) with modifications (GAMDT 2004); absorption and emission by H2O, CO2, O3, N2O, CH4, 4 halocarbons, aerosols and clouds.

E. Two types of damping are applied to top in CM2.0: 1) Shapiro (1970) filter applied to the departures from the zonal mean of the zonal wind component and to the total meridional wind component, and 2) Rayleigh damping applied to both momentum components with a relaxation time of 30 days. In CM2.1 there is only a weak 2nd order divergence damping.

B. Ocean
1. resolution
1 degree longitudinal, 1 degree latitudinal with enhanced tropical resolution (1/3 on equator)
2. numerical scheme/grid, including advection scheme, time-stepping scheme, vertical coordinate, free surface or rigid lid, virtual salt flux or freshwater flux
3rd-order advection with flux limiters (Hunsdorfer and Trompert, 1994)
CM2.0 uses leapfrog timestepping. CM2.1 uses staggered timestepping (Griffies et al., in prep.)
Level coordinate with partial bottom cells (Pacanowski and Gnanadesikan, 1997)
Free surface with real freshwater flux (Griffies et al., 2001)
3. list of prognostic variables and tracers
Tracers:

temperature, salinity, ideal age

Prognostic variables

u,v,free surface height, temperature and salinity

4. name, terse descriptions, and references (journal articles, web pages) for all parameterizations. Include, as appropriate, descriptions of:

a. eddy parameterization

Isopycnal mixing of tracers and layer thickness (Gent and McWilliams, 1990; Griffies et al., 1998; Griffies, 1998),

Variable coefficient as described in Gnanadesikan et al., (subm.), Griffies et al. (in prep.)

b. bottom boundary layer treatment and/or sill overflow treatment

Along-sigma diffusion when dense water upslope of light water

Beckman and Doscher (1997) as described in Griffies et al. (in prep.)

c. mixed-layer treatment

KPP scheme. Large et al., (1994)

d. sunlight penetration

Spatiotemporally varying chlorophyll-dependent penetration. Sweeney et al., (2005)

e. tidal mixing

Tidal generation of bottom turbulence

Lee et al., (in prep.)

f. river mouth mixing

Insertion of freshwater through top 4 grid boxes as well as mixing. Griffies et al. (in prep.)

g. mixing isolated seas with the ocean

Insertion of freshwater and mixing of tracer. Amount of mixing determined by pressure gradient across land Griffies et al., (in prep.)

h. treatment of North Pole "singularity" (filtering, pole rotation, artificial island?)

tripolar grid, Murray (1996)

REFERENCES

Beckman, A. and R. Doscher, 1997: A method for improved representation of dense water spreading over topography in geopotential-coordinate models, J. Phys. Oceanogr., 27, 581-591.

Gent, P. and J.C. McWilliams, 1990: Isopycnal mixing in ocean circulation models, J. Phys. Oceanogr. 20, 150-155.

Gnanadesikan, A., et al., GFDL's CM2 global coupled climate models- Part 2: The baseline ocean simulation, subm. to Journal of Climate.

Griffies, SM, 1998: The Gent-McWilliams skew-flux, J. Phys. Oceanogr., 28, 831-841.

Griffies, SM, Anand Gnanadesikan, Ronald C. Pacanowski, Vitaly Larichev, John K. Dukowicz, Richard D. Smith, 1998: Isoneutral diffusion in a z-coordinate ocean model, J. Phys. Oceanogr., 28, 805-830.

Griffies, S.M., et al., Formulation of an ocean model for global climate simulations, in prep. for Ocean Modelling (should be submitted by end of Feb. 2005)

Griffies, S.M., R.C. Pacanowski, R.M. Schmidt, and V. Balaji, 2001: Tracer conservation with an explicit free surface m,ethod for z-coordinate ocean models, Mon. Wea. Rev., 129, 1081-1098.

Hundsdorfer, W. and R. Trompert, 1994: Method of lines and direct discretization: a comparison for linear advection, Appl. Num. Math., 469-490.

Large, W., J.C. McWilliams, and S.C. Doney, 1994: Oceanic vertical mixing: A review and a model with a nonlocal boundary mixing parameterization, Rev. Geophys., 32, 363-403.

Lee, H.-C., A. Rosati, M. Spelman and T. Delworth, 2005: Barotropic tidal mixing impact in a coupled climate model: ocean condition and meridional overturning circulation in the the northern Atlantic, subm., Ocean Modelling

Murray, R.J., 1996: Explicit generation of orthogonal grids for ocean models, J. Comput. Phys., 126, 251-273.

Pacanowski, R.C. and A. Gnanadesikan, 1998: Transient response in a z-level ocean model that resolves topography with partial cells, Mon. Wea. Rev., 126, 3248-3270.

Sweeney, C., A. Gnanadesikan, S.M. Griffies, M. Harrison, A. Rosati and B. Samuels, 2005: Impacts of shortwave penetration depth on large-scale ocean circulation and heat transport, J. Phys. Oceanogr., in press.

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 horizontal grid as ocean; vertical resolution: 1 snow layer; 2 ice layers; 5 ice thickness categories and open water (leads);

2\. B-grid differencing; upstream advection.

3. U and V; for each of 5 ice thicknesses: concentration, snow thickness, ice thickness, upper and lower ice temperatures

4. Dynamics: Elastic-viscous-plastic rheology; Coriolis, sea slope, and time change terms; Thermodynamics: Modified Semtner 3-layer (Winton 2000); Thickness category management: Delworth et al (2005) appendix I.

5. Constant salinity of 5 per mil

6. Brine rejection rate is the ice growth rate times the salinity difference between the sea ice and sea water.

7. Tripolar grid; meridion cut hemsiphere embedded north of Arctic circle has its poles over land (Murray 1996).

Reference:

Winton, M., 2000: A reformulated three-layer sea ice model, Journal of Atmospheric and Oceanic Technology, 17(4), 525-531.

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. Same grid as atmosphere except coastal cells are partial to accommodate ocean; 18 soil levels to 6m depth; levels have sensible and (fixed) latent heat capacity.

2. Fixed freezable water content

3. Routing of frozen and liquid runoff to ocean

4. A single, non-insulating, snow reservoir

5. Snow, root zone, and groundwater stores.

7. Fixed, 8 vegetation types

8. Soil temperature, snow, root zone water, groundwater, frozen fraction

9. Fixed ice sheet cover, net melting allowed (does not contribute to water balance)?

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. two hour atmosphere-ocean coupling
2. yes
3. variables include
   a. SST, SSS, surface current, roughnesses, albedo, radiative and turbulent heat fluxes, frozen and liquid precipitation, vector stress
   b. Surface temperature, roughness, albedo, radiative and turbulent heat fluxes, frozen and liquid precipitation
   c. Frozen and liquid discharge
   d. SST, SSS, surface current, Water, salt, vector stress, pass through of atmospheric fluxes
   e. Surface temperature, roughness, albedo, surface velocity, radiative and turbulent heat fluxes, liquid and frozen precipitation
4. no flux adjustments

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
   1. If initialized from a control run, which month/year.
   2. For control runs, describe spin-up procedure.

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.

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.

A. gfdl_cm2_0 and gfdl_cm2_1

B. pre-industrial spin-up: integrated 300 years from Levitus initial conditions, all 1860 forcings added by year 200;

Reference:

Stouffer, R.J., A.J. Weaver, and M. Eby, 2004: A method for obtaining pre-twentieth century initial conditions for use in climate change studies, Climate Dynamics, 23, 327—339.

C. Well mixed greenhouse gases (CO2, CH4, N2O, 4 CFC's), ozone, tropospheric aerosols, volcanic aerosols, solar irradiance, and land use. See http://nomads.gfdl.noaa.gov/nomads/forms/deccen/CM2.X/faq/question_13.html

D. SRES emissions processed with MOZART to obtain forcings; solar, land use, and volcanic aerosols vary in 20th century runs but held fixed in future runs; time varying forcing agents are atmospheric CO2, CH4, N2O, halons, tropospheric and stratospheric O3, anthropogenic tropospheric sulfates, black and organic carbon; direct effect of tropospheric aerosols is calculated by the model but not the indirect effects.