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

IPSL-CM4 model.

22 Februry 2005

I. Model identity:

A. Institution, sponsoring agency, country

- Institution: Institut Pierre Simon Laplace (IPSL)
- Main sponsoring agencies: CNRS, CEA.
- Country: France

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

- coupled model: IPSL-CM4 *(TAR = IPCL-CM2)*
- atmosphere: LMDZ-4 *(TAR = LMD5)*
- land-vegetation: ORCHIDEE *(TAR = SECHIBA)*
- ocean: ORCA *(TAR = OPA-7)*
- sea-ice: LIM *(TAR = IGLOO)*

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

- 2005

D. General published references and web pages

- Coupled model:

The IPSL climate system model: IPSL-CM4
http://dods.ipsl.jussieu.fr/omamce/IPSLCM4/DocIPSLCM4/FILES/DocIPSLCM4.pdf

- Atmospheric model.

Hourdin, F., I. Musat, S. Bony, P. Braconnot, F. Codron, J.-L. Dufresne, L. Fairhead, M.-A. Filiberti, P. Friedlingstein, J.-Y. Grandpeix, G. Krinner, P. LeVan, Z.-X. Li, F. Lott: The LMDZ4 general circulation model: climate performance and sensitivity to parametrized physics with emphasis on tropical convection. Climate Dynamics, submitted, 2005.

Also see the atmospheric part of the coupled model documentation above.

- Ocean model.

OPA reference manual (Madec at al 1998) available on the web
http://www.lodyc.jussieu.fr/opa/Docu_Free/Doc_models/Doc_OPA8.1.pdf

- Sea-ice model.

Fichefet, T., and M.A. Morales Maqueda, Sensitivity of a global sea ice model to the treatment of ice thermodynamics and dynamics, J. Geophys. Res., 102, 12,609-12,646, 1997.
Goosse, H., and T. Fichefet, Importance of ice-ocean interactions for the global ocean circulation: A model study, J. Geophys. Res., 104, 23,337-23,355, 1999.

- Land-Surface model.

Krinner, G., N. Viovy, N. de Noblet-Ducoudré, J. Ogée, J. Polcher, P. Friedlingstein, P. Ciais, S. Sitch and I. C. Prentice, A dynamic global vegetation model for studies of the coupled atmosphere-biosphere system. Global Biogeochemical Cycles, in press.
ORCHIDEE documenation : http://www.ipsl.jussieu.fr/~ssipsl/doc/doc_main.html

- Coupler.

OASIS3 users guide: http://www.cerfacs.fr/globc/software/oasis/oasis3_UserGuide.pdf
Sophie Valcke, Arnaud Caubel, Reiner Vogelsang, Damien Declat. 2004: OASIS3 Ocean Atmosphere Sea Ice Soil User's Guide Technical Report TR/CMGC/04/68, CERFACS, Toulouse, France

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.

F. IPCC model version's global climate sensitivity ($KW^{-1}m^2$) to increase in CO_2 and how it was determined (slab ocean expt., transient expt--Gregory method, ±2K Cess expt., etc.)
slab ocean: $\Delta T = 4.4K$; $\Delta F = 3.48 W.m^{-2}$; $\lambda = 1.26\ KW^{-1}m^2$

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

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2. atmosphere

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3. ocean

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4. sea ice

Thierry Fichefet <fichefet@astr.ucl.ac.be>

5. land surface

6. vegetation

Nathalie de Noblet <Nathalie.De-Noblet@cea.fr>

7. coupling procedure

Olivier Marti <olivier.marti@cea.fr>

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? no
B. interactive biogeochemistry? yes, active only for C4MIP
C. what aerosols and are indirect effects modeled? sulfate aerosols only, and first indirect effect only *(TAR = no aerosols)*
D. dynamic vegetation? yes, but not active in the runs currenty stored in the PCMDI database
E. ice-sheets? extension does not change, thickness changes

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.

Complet or in progress: CMIP, CFMIP, AMIP, C4MIP and PMIP
(TAR = CMIP, AMIP, PMIP)

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

A. *atmosphere:* LMDZ-4 model

1. resolution: 2.5° x 3.75° (i.e. 96x71 grid points). Vertical: 19 levels
(TAR = 3.6°x5.625°, i.e. 64x50 grid points; vertical: 15 levels)

2. numerical scheme/grid

The dynamical part of the code is based on a finite-difference formulation of the primitive equations of meteorology. The discretization insures numerical conservation of both enstrophy for barotropic flows and angular momentum for the axi-symetric component. Both vapor and liquid water are advected with a monotonic second order finite volume scheme. The time integration is done with a leapfrog scheme, with, periodically, a predictor/corector time-step. An horizontal dissipation operator is applied on both winds and temperature. For latitudes poleward of 60 degrees, a longitudinal filter is also applied.
On the vertical, the model uses a classical hybrid ♦-P coordinate. They are 5 layers below 850 hPa and 8 layers above 200 hPa.
(TAR = water transport using an upstream scheme. On the vertical, use of ♦ coordinate)

3. list of prognostic variables.
   - temperature
   - northward and eastward wind components
   - total water
   - surface pressure

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

The cloud cover f and in-cloud water q_c are deduced from the large scale total (vapor + condensed) water q and moisture at saturation, q_sat, using a Probablity Distribution Function P(q) for the subgrid-scale total water q. This PDF P(q) is described throug a generalized log-normal function bounded to 0, following Bony and Emmanuel (2001). The PDF moments are diagnosed interactively from the condensated water predicted by the convection scheme at the subgrid scale and from the large scale degree of saturation of the atmosphere.
The indirect effect of aerosols has been introduced using an update version of the formula "D" of Boucher and Lohmann (1995). The parameters of this formula have been adjusted so that the model reproduces the decrease of the effectif radius when the aerosols index increases, as observed by POLDER.
(TAR = The formulation was based on top-hat probabilituy distribution functions of total water (Le Treut and Li, 1991). Indirect effect was not considered)

Bony, S., and K. A. Emmanuel, 2001: A parameterization of the cloudiness associated with cumulus convection; evaluation using TOGA COARE data, J. Atmos. Sci., 58, 3158-3183.

Boucher O,Lohmann U (1995)The sulfate-CCN-cloud albedo effect- a sensitivity study with two general circulation models. Tellus, 47B, 281-300.

b. convection

Condensation is parameterized separately for convective and non-convective clouds. Moist convection is treated using a modified version (Grandpeix et al., 2004) of the Emanuel (1991) scheme.
(TAR = a Manabe-Kuo scheme was used)

Grandpeix, J.-Y., V. Phillips, and R. Tailleux: Improved mixing representation in Emanuel's convection scheme, Q. J. R. Meteorol. Soc., in press.
Emanuel, K. A., A scheme for representing cumulus convection in large-scale models, J. Atmos. Sci., 48, 2313-2335, 1991.

c. boundary layer

Turbulent transport in the planetary boundary layer is treated as a vertical diffusion with an eddy diffusivity depending on the local Ridcharson number (Laval et al., 1981). The formulation of the boundary layer is very sensitive to the minimum diffusivity in high latitudes. Specific care was given to this threshold in order to get the right strength of the polar inversion. The surface boundary layer is treated according to Louis (1979). The formulation of Smith'1988 was introduced to compute the surface roughness length over ocean.
(TAR = since the TAR, the minimum diffusivity was adusted to have a better polar inversion, The stability functions were those of Louis (1982) and Beljaars and Millers (1990))

Laval, K., R. Sadourny, and Y. Serafini, Land surface processes in a simplified general circulation model, Geophys. Astrophys. Fluid Dyn., 17, 129-150, 1981.
Louis, J.-F., A parametric model of vertical eddy fluxes in the atmosphere., Boundary-layer Meteorol., 17, 187-202, 1979.

d. SW, LW radiation

The radiation scheme is the one previously introduced in the model of European Centre for Medium-Range Weather Forecasts (ECMWF) by Morcrete: The solar part is a refined version of the scheme developed by Fouquart and Bonnel (1980) and the thermal infra-red part is due to Morcrette et al. (1986).
(TAR = same code)

e. any special handling of wind and temperature at top of model

No

f. other

Effects of mountains (drag, lifting, gravity waves) are accounted for using a new scheme (Lott and Miller, 1997; Lott, 1999).
For coupling purposes each atmospheric grid box is divided into 4 sub-surfaces corresponding to land surface, free ocean, sea-ice and ice-sheet. For each atmospheric column, vertical diffusion is applied independently for each sub-surface, and the resulting tendencies are averaged.

Lott, F., Alleviation of stationary biases in a gcm through a mountain drag parametrization scheme and a simple representation of mountain lift forces, Mon. Weather Rev., 127, 788-801, 1999.
Lott, F., and M. Miller, A new sub-grid scale orographic drag parametrization: its formulation and testing., Q. J. R. Meteorol. Soc., 123, 101-128, 1997.

B. ***Ocean : OPA***

1. resolution

quasi-isotrope tri-polar grid (2 poles in the northern hemisphere, on over Canada and the other over Siberia. 2° resolution Mercator grid (i.e. $\delta x = \delta y$) with enhanced meridional resolution in the vicinity of the equator and in Med and Red seas (1°)

2. numerical scheme/grid, including advection scheme, time-stepping scheme, vertical coordinate, free surface or rigid lid, virtual salt flux or freshwater flux

advection scheme : 2nd order arakawa
time-stepping : leap-frog except for lateral diffusion (forward) and vertical diffusion (backward)
vertical coordinate : z-coordinate
free surface, freshwater flux

3. list of prognostic variables and tracers

U, V, T, S, TKE

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

All the descrition of the model physics can be found in the OPA reference manual (Madec at al 1998) available on the web
(http://www.lodyc.jussieu.fr/opa/Docu_Free/Doc_models/Doc_OPA8.1.pdf)

a. eddy parameterization

Isopycnal mixing on tracers (no horizontal background) with a constant coefficient of 2000 m2/s (Guyliardi et al 2001, Clim. Dyn.) Eddy induced velocity (Gent and McWilliams 19xx) with a coefficient varying in function of the growth rate of baroclinic instability (ranges 15 m2/s to 2000 m2/s). Note that the coefficient is set to 0 in the vicinity of the equator (lengaigne et al JGR 2003)

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

diffusive bottom boundary layer (Beckmann and Dorscher 19xx)

c. mixed-layer treatment

TKE scheme (Blanke and Delecluse JPO, 1992 + modification Madec et al. 1999)

d. sunlight penetration

yes with 2 master lengths (Blanke and Delecluse 1992)

e. tidal mixing

None

f. river mouth mixing

spread over several grid points (the number depending on the magnitude of the runoffs)

g. mixing isolated seas with the ocean

no mixing (Red and Med seas are explicitly connected to the remaining ocean) . For closed "seas" (Black Sea, Great lakes, Caspian Seas) the mean sea level remain constant, excess (deficit) of water been either redistributed over the world ocean (Caspian Sea) or in St Laurent river mouth (Great lakes) or Dardanel strait area (Black Sea).

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

semi analytical tri-polar grid, no singular point in the ocean domain. based on Madec and Imbar (Clim. Dyn. 1996) and Murray (JCP 1995)

C. sea ice: LIM

1. horizontal resolution, number of layers, number of thickness categories
   - Horizontal resolution: same as ocean model (2° in longitude and roughly 2° cos(phi) in latitude; equations for ice motion and transport written in curvilinear, orthogonal coordinates; staggered spatial grid of type B).
   - Number of layers: 3 (1 in snow and 2 in ice).
   - Number of thickness categories: 2 (level ice and leads).

2. numerical scheme/grid, including advection scheme, time-stepping scheme,
   - Heat-diffusion equation: fully implicit scheme.
   - Momentum equation: semi-implicit scheme (combination of a modified Euler time step scheme and a point successive relaxation procedure).
   - Advection equations: forward time marching scheme which conserves the second-order moments of the spatial distribution of the advected quantities.

3. list of prognostic variables
   - snow thickness;
   - ice thickness;
   - ice concentration;
   - ice velocity;
   - internal temperatures of snow and ice;
   - heat content of brine reservoir.

4. completeness (dynamics? rheology? leads? snow treatment on sea ice)
   - Effective thermal conductivity to account for the effect of the subgrid-scale snow- and ice-thickness distributions on sea-ice thermodynamics.
   - Surface albedo dependent on the state of the surface (frozen or melting), the thickness of the snow and ice covers, and the cloudiness.
   - Parameterisation of leads.
   - Snow-ice formation scheme.
   - Viscous-plastic rheology.

5. treatment of salinity in ice
   - Constant ice salinity.
   - Heat reservoir to account for the storage of latent heat inside the ice resulting from trapping of shortwave radiation by brine pockets

6. brine rejection treatment
   - Salt rejected during ice accretion and snow-ice formation is put in the first oceanic layer.

7. treatment of the North Pole "singularity" (filtering, pole rotation, artificial island?)
   - Same as ocean model (pole rotation).

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

Surface properties (albedo, roughness...) and variables (temperature, humidity) are specific to each of the 12 PFTs (see below). The soil is decrised into 11 layers for the heat transfer calculations and 2 for water calculation.

2. treatment of frozen soil and permafrost

No

3. treatment of surface runoff and river routing scheme

Yes

4. treatment of snow cover on land

Snow albedo following Chatita and Le Treut (1994).

5. description of water storage model and drainage
6. surface albedo scheme

The albedo values for all PFTs are averaged and combined with the bare soil albedo.

7. vegetation treatment (canopy?)

Vegetation is described using the concept of plant functional type (PFT), and uses 12 PFTs with precribed geographical distribution. Stomatal resistance and photosynrhesis are calculated for each PFT separately following Ball et al. (1987), Fargquhar et al. (1980), Collatz et al.(1992) and depends on CO2 concentration.

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?)

Snow and ice melting and accumulation are like for the other surfaces. The only specificity is that ice sheet fraction does not change (no dynamic), which mean that ice melting does not affect ice thickness and fraction. When ice or snow are melting, the water is drained toward the ocean. In order to ensure watter conservation, when snow accumulates above a threshold, the exeeding snow is drained to the ocean with a 10 years smoothing.

E. <u>coupling details</u>

1. frequency of coupling:
   - atm-land surface: every time step (30 mn)
   - atm-ocean and atm-sea-ice: once a day
   - ocean-sea ice: every oceanic time step
2. Are heat and water conserved by coupling scheme?
   yes
3. list of variables passed between components:
   a. atmosphere – ocean
      - Net short wave on open ocean
      - Non solar flux on open ocean
      - Water budget (precip-evap)
      - Wind stress over open ocean
      - Ocean surface temperature

   b. atmosphere – land
      - Net short wave
      - Non longwave flux
      - water vapor flux
      - liquide precipitations
      - solide precipitations
      - heat flux
      - surface albedo, rougness...

- surface temperature

c. land – ocean
- Runoff
- Ice sheet melting

d. sea ice – ocean
- Stress under sea ice
- Fresh water flux (concentration/dilution)
- Fresh water flux (volume flux for free surface)
- Sea ice fraction
- Ocean surface temperature
- Ocean surface salinity
- Surface current

e. sea ice – atmosphere
- Net short wave on sea ice
- Non solar heat flux on sea ice
- Solid precipitation
- dQ/dT (sensitivity of surface heat flux to surface temperature, sens+lat) over sea ice
- Wind stress over sea ice
- Sea ice fraction
- Sea ice albedo (weighted)
- Sea ice surface temperature (weighted)

4. Flux adjustment? (heat?, water?, momentum?, annual?, monthly?).
   No

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

A. PIcntrl

B. Describe method used to obtain initial conditions for each component model

The spin-up procedure is the following: The ocean starts from rest with temperature and salinity set to the values of the Levitus (1982) atlas. The sea-ice characteristics correspond to a ten years adjustment of the sea-ice model from a forced ocean-ice simulation. The atmosphere is initialized from the ECMWF (ERA15) for 1979, January 1st . The land surface model starts with soil moisture initialized to 300 mm at each grid point and the snow reservoirs start from zero. The concentration of the different trace gazes concentration are prescribed to their pre-industrial values (see below). Starting from those initial states, a coupled run of 330 years is performed, during wich the very last smal adjustments of the model have been included.

C. Radiative forcing agents

For the GHG, we use the same pre-industrial values (circa 1750) as in PMIP: CO2: 280ppm, CH4: 805 ppb, N2O: 276 ppb, CFC11: 0, CFC12: 0. For the sulate aerosols, we use the “natural” distribution as computed and provided by Olivier Boucher. No other aerosols are considered (this is very clear when looking to the clear sky albedo). The solar constant is 1365 W/m2. All these values are maintained constant.
The aerosols distribution comes from : http://www-loa.univ-lille1.fr/~boucher/sres/

A) PDcntrl

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C) Radiative forcing agents.

For the GHG, we use the1980 values: CO2: 348 ppm, CH4: 1650 ppb, N2O: 306 ppb, CFC11:280 ppt, CFC12: 484 ppt. For the sulate aerosols, we use the 1980 distribution as computed and provided by Olivier Boucher. No other aerosols are considerd (this is very clear when looking to the clear sky albedo).The solar constant is 1365 W/m2.
The aerosols distribution comes from : http://www-loa.univ-lille1.fr/~boucher/sres/

A) 20C3M

B) Initial conditions.

Start from first year of PIcntrl run

C) Radiative forcing agents.

The series of annual values of GHG we used have been gathered by J-F Royer (CNRM) in the framework of the ENSEMBLES European project. See: http://www.cnrm.meteo.fr/ensembles/

CO2: Historical CO2 record from the Law Dome DE08, DE08-2, and DSS ice cores. Authors : D.M. Etheridge L.P. Steele R.L. Langenfelds R.J. Francey Division of Atmospheric Research, CSIRO, Aspendale, Victoria, Australia J.-M. Barnola Laboratoire of Glaciologie et Geophysique de l'Environnement, Saint Martin d'Heres-Cedex, France V.I. Morgan Antarctic CRC and Australian Antarctic Division, Hobart, Tasmania, Australia
ftp://ftp.ngdc.noaa.gov/paleo/icecore/antarctica/law/law_co2.txt

CH4: The series for methane CH4 concentrations is generated from the file ftp://ftp.ngdc.noaa.gov/paleo/icecore/antarctica/law/law_ch4.txt
Etheridge, D.M., et al., 2002, Ice Core, Firn Air and Archived Air Atmospheric Methane Concentration Data, IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series #2002-039. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.
Etheridge, D. M., Steele, L. P., Francey, R. J., and Langenfelds, R. L., 1998, Atmospheric methane between 1000 A.D. and present: Evidence of anthropogenic emissions and climatic variability J. Geophys. Res. Vol. 103, No. D13, p. 15,979 (98JD00923)

N2O: The series is derived from the IPCC values for 1970,1980,1990 and 2000 and from the series of measurements in ice from Machida et al (1995). The observed values range from 1735 to 1964 (their table 1)
Machida, T., T. Nakazawa, Y. Fujii, S. Aoki and O. Watanabe, 1995: Increase in the atmospheric nitrous oxide concentration during the last 250 years. Geophysical Research Letters, 22, 2921-2924.

CFC-11, CFC-12: The series is derived from the Reconstructed histories of the annual mean atmospheric mole fractions for the halocarbons CFC-11, CFC-12, CFC-113 and Carbon Tetrachloride (http://gaslab.ucsd.edu/pub/cfchist/) described in: Walker, S. J., R. F. Weiss and P. K. Salameh, Reconstructed histories of the annual mean atmospheric mole fractions for the halocarbons CFC-11, CFC-12, CFC-113 and carbon tetrachloride. Journal of Geophysical Research, 105, C6, 14,285-14,296, 2000

Sulfate aerosols: The aerosols distribution has been provide by Olivier Boucher (LOA/CNRS)
http://www-loa.univ-lille1.fr/~boucher/sres/
Boucher, M. Pham, C. Venkataraman, Simulation of the atmospheric sulfur cycle in the Laboratoire de Meteorologie Dynamique General Circulation Model. Model description, model evaluation, and global and European budgets, Note scientifique de l'IPSL n. 23, juillet 2002.
O. Boucher and M. Pham, History of sulfate aerosol radiative forcings, Geophysical Research Letters, 29(9), 1308, 10.1029/2001GL014048, 2002.

Other variables: All other variables are kept constant. There are no natural forcings.

A) SRESA2, SRESA1B, SRESB1

B) Initial conditions.

Start from end of year 2000 of run 20C3M

C) Radiative forcing agents.

The series of annual values of GHG we used have been gathered by J-F Royer (CNRM) in the framework of the ENSEMBLES European project. See: http://www.cnrm.meteo.fr/ensembles/

GHG concentration are those provided by the IPCC (for CO2, Bern-CC reference model is used).

Sulfate aerosols ate those computed by Olivier Boucher (LOA/CNRS)
http://www-loa.univ-lille1.fr/~boucher/sres/

A) Commit

B) Initial conditions.
Start from end of year 2001 of run 20C3M

C) Radiative forcing agents.

Same as year 2000 of run 20C3M

A) 1%to2x and 1%to4x

B) Initial conditions.
Start from first year of PIcntrl run

C) Radiative forcing agents.
Initial value of CO2: 286 pp. CO2 increase 1%/year during 70 years (1%to2x) or 140 years (1%to4x), then CO2 concentration is kept constant with a value of 574 ppm (%to2x) or 1152 (1%to4x).