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

CSIRO-Mk3.5

13 July 2007

I. Model identity:

A. Institution, sponsoring agency, country

CSIRO, Australia

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

CSIRO Mark 3.5 (abbrev. CSIRO-Mk3.5)

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

2006

D. General published references and web pages

Gordon, H. B., Rotstayn, L. D., McGregor, J. L., Dix, M. R., Kowalczyk, E. A., O'Farrell, S. P., Waterman, L. J., Hirst, A. C., Wilson, S. G., Collier, M. A., Watterson, I. G., and Elliott, T. I. (2002): The CSIRO Mk3 Climate System Model [Electronic publication]. Aspendale: CSIRO Atmospheric Research. (CSIRO Atmospheric Research technical paper; no. 60). 130 pp.
(http://www.dar.csiro.au/publications/gordon_2002a.pdf)

Cai, W., Collier, M.A., Durack P.D., Gordon H.B., Hirst A.C., O'Farrell S.P. and Whetton P.H., 2003: The response of climate variability and mean state to climate change: preliminary results from the CSIRO Mark 3 coupled model. *CLIVAR Exchanges*, **28**, 8-11.

Cai, W., M. A. Collier, H. B. Gordon, and L. J. Waterman, 2003: Strong ENSO variability and a super-ENSO pair in the CSIRO coupled climate model. *Monthly Weather Review*, **131**, 1189-1210.

Cai, W., M. J. McPhaden, M. A. Collier, 2004: Multidecadal fluctuations in the relationship between equatorial Pacific heat content anomalies and ENSO amplitude. *Geophys. Res. Let.*, **31**, L01201, doi:10.1029/2003GL018714

Cai, W., H. Hendon, and G. Meyers, 2005: An Indian Ocean Diploe-like variability in the CSIRO Mark 3 climate model. *J. Climate*, in press.

Cai, W., G. Meyers, and G. Shi, 2005: Transmission of ENSO signals to the Indian Ocean, *Geophys. Res. Let.*, in press.

Cai, W., G. Shi, Y. Li, 2005: Multidecadal fluctuations of winter rainfall over southwest Western Australia simulated in the CSIRO Mark 3 coupled model, *Geophys. Res. Let.*, submitted.

Watterson, I.G., and M. R. Dix, 2005: Effective sensitivity and heat capacity in the response of climate models to greenhouse gas and aerosol forcings. *Q. J. Roy. Met. Soc.*, **131**, 259-280.

Watterson, I.G., 2005: The intensity of precipitation during extra-tropical cyclones in global warming simulations: a link to cyclone intensities? *Tellus A.* Accepted subject to minor revision.

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.
   See technical report – Gordon et al, 2002.

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.)
   Not available yet.

G. Contacts (name and email addresses), as appropriate, for:
   1. coupled model – Hal.Gordon@csiro.au
   2. atmosphere – Hal.Gordon@csiro.au
   3. ocean – Tony.Hirst@csiro.au
   4. sea ice – Siobhan.O'Farrell@csiro.au
   5. land surface – Eva.Kowalczyk@csiro.au
   6. vegetation – Eva.Kowalczyk@csiro.au

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? - No
C. what aerosols and are indirect effects modeled?
   Direct effect of aerosols only using monthly mean sulfate (Penner et al, 1994).
D. dynamic vegetation? - No
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.

Participation carrying over to the IPCC version (CSIRO-Mk3.0):
PILPS 1, 2a,2b,2d, C1

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

See Gordon et al. (2002 – web site as above) for full model details. Overview summary is as follows:

A. Atmosphere

1. resolution

   T63, L18

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

   Spectral for Temperature, Vorticity, Divergence, Surface Pressure
   Moisture variables by semi-Lagrangian methods.
   Timestepping is leapfrog with Robert (1966) time filter.
   Vertical coordinate is hybrid sigma-pressure. Top level at 4.5 hPa.
   Number of layers above 200 hPa is 5
   Number of layers below 850 hPa is 4

3. list of prognostic variables (be sure to include, as appropriate, liquid water, chemical species, ice, etc.). Model output variable names are not needed, just a generic descriptive name (e.g., temperature, northward and eastward wind components, etc.)

   Temperature, Vorticity, Divergence, Surface Pressure
   Atmospheric moisture (vapour, liquid, and ice)

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

   a. clouds

      Stratiform cloud scheme (liquid, ice) following Rotstayn (1997, 1998) and Rotstayn et al. (2000). The convection scheme (see below) also produces a convective cloud fraction.

   b. convection

      UKMO: Gregory and Rowntree (1990)

   c. boundary layer

      Follows Louis (1979) with Smith (1990) enhancements.

   d. SW, LW radiation

      GFDL based (SW: Lacis and Hansen 1974; LW: Fels and Schwarzkopf 1975, 1981; Fels 1985; Schwarzkopf and Fels 1991).

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

      Temperature at top of model for radiation code by simple extrapolation (using vertical coordinate) from top 2 levels.

B. Ocean – MOM2.2 (Pacanowski 1996)

1. resolution

   Horizontal: Matching the T63 atmospheric model, but twice the meridional resolution – 1.875° EW by approximately 0.84° NS.
   Vertical - 31 levels, spacing increasing with depth, from 10 *m* at the surface to 400 *m* in the deep ocean.

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

MOM2.2 model code using Arakawa B grid, leapfrog time stepping. The "quicker" scheme is used for tracer advection, see Leonard (1979) and Pacanowski (1996). Vertical coordinate is layers of prescribed depth (rigid lid). Freshwater flux at surface derived from P-E, river runoff, and ice brine rejection terms, then converted to a virtual salt flux.

3. list of prognostic variables and tracers

   Velocities U and V, Temperature and Salinity.

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

      Adiabatic eddy-induced transport via the Griffies (1998) implementation of the Gent and McWilliams (1990) scheme.

      Vertical mixing of tracers via a modified form of Bryan and Lewis (1979) profile. For tropical regions (15°S to 15°N), the profile is modified to have values decreasing to near zero at the surface.

      Visbeck (1997) scheme to control the strength of the ocean eddy-induced transport coefficient κ.

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

      None.

   c. mixed-layer treatment

      Integer Power vertical mixing scheme (Wilson 2000, 2002), based on the Pacanowski and Philander (1981) scheme.

      Kraus-Turner used for mixing due to wind-generated turbulent kinetic energy.

   d. sunlight penetration

      Paulson and Simpson (1977) dual exponential formulation, using turbidity specified in terms of Jerlov (1976) water types (spatially varying, time invariant).

   e. tidal mixing - none
   f. river mouth mixing - none
   g. mixing isolated seas with the ocean

      Achieved by lateral mixing (at same latitude) to nearest world ocean grid point at a prescribed rate (e.g. Hudson Bay, Mediterranean).

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

      Artificial island with Fourier filtering for latitudes close to North Pole

C. sea ice

1. horizontal resolution, number of layers, number of thickness categories

   Coded as part of the atmospheric model, with the same resolution - equivalent T63 (1.875° EW by approximately 1.875° NS).

   1 or 2 ice layers depending upon ice depth.

   Snow on ice treated as an additional layer. Deep snow to white ice treatment.

2. numerical scheme/grid, including advection scheme, time-stepping scheme,

   Arakawa B-grid (T points match spectral AGCM grid points), NCAR based advection scheme in terms of divergence field (Brieglib). Leapfrog timestepping. Improved since Mk3.0

3. list of prognostic variables

Ice depth; Ice temperature(s) (1 or 2 layers); Snow depth; Snow temperature (1 layer); Brine heat reservoir; Leads fraction; Temperature of mixed layer in leads and under ice.

4. completeness (dynamics? rheology? leads? snow treatment on sea ice)
   Thermodynamics – Semtner (1976) 3 layer thermodynamics
   Rheology – Flato and Hibler (1990), O'Farrell (1998)
   Leads – Computed fraction, with lateral ice growth/melting
   Snow on ice – Has internal layer temperature, surface temperature, ice-snow interface temperature.
5. treatment of salinity in ice
   Ice salinity set at 0.01
6. brine rejection treatment
   Ice formation/melting gives brine rejection/uptake (relative to 0.035 reference).
7. treatment of the North Pole "singularity" (filtering, pole rotation, artificial island?)
   Artificial island at North Pole. Ice motion filtered towards slab rotation near pole.

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
   For details of land/vegetation scheme see technical report (Gordon et al, 2002). The Land model has T63 resolution, and 6 soil layers (temperature and water/ice). There are 9 soil types and 13 vegetation types (one soil type and one vegetation type per grid point). No tiling, except each land point has prescribed amount of vegetation and bare ground. Separate flux calculations for each.
2. treatment of frozen soil and permafrost
   Water in soil is allowed to freeze.
3. treatment of surface runoff and river routing scheme (improved since Mk3.0)
   Surface runoff taken instantly to oceans by downslope method.
4. treatment of snow cover on land
   Snow on land has 3 layers (temperatures, snow densities), total snow mass, age dependent albedo.
5. description of water storage model and drainage
   Each grid point has an assosciated field capacity.
   Drainage from lowest soil level if moisture exceeds field capacity.
6. surface albedo scheme
   Land surface albedo taken from Sib data set (varying monthly).
   Snow albedo changes according to snow age and zenith angle.
7. vegetation treatment (canopy?)
   Canopy: big-leaf model
8. list of prognostic variables
   Surface temperature;
   6 levels of soil temperature and water amount;
   If land is frozen, then ice amount per 6 levels;
   Moisture amount on vegetation canopy;
   Puddle depth on land;
   If snow on land:
      3 snow layer temperatures,
      3 snow densities,

Total snow mass,
Snow age.

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?) – Ice sheets not included.

E. coupling details
   1. frequency of coupling
      Every timestep (15 minutes)
   2. Are heat and water conserved by coupling scheme?
      Yes
   3. list of variables passed between components:
      The CSIRO Mk3 coupled model consists of 2 major components:
      (a) The AGCM + Land + Ice model (the "atmosphere" below)
      (b) The Ocean model
      Fluxes are essentially passed between these 2 components:
      a. atmosphere – ocean
         Heat flux
         Water flux
         Solar flux into ocean
         Surface stresses. (Note that in CSIRO Mk3.5, the surface wind velocity used in the wind stress calculation is that relative to the moving ocean surface layer, whereas in the CSIRO Mk3.0 model, the absolute velocity was used.
      b. ocean – atmosphere
         Sea surface temperature
         Ocean surface velocities u,v (for driving ice model within AGCM for influencing surface wind stress as noted above).
   4. Flux adjustment? (heat?, water?, momentum?, annual?, monthly?).
      None

a) 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.

References quoted above under CSIRO Mk3 specifications:

Bryan, K., and L.J. Lewis, 1979: A water mass model of the world ocean. *J. Geophys. Res.*, **84**, 347-376.

Cai , W.J., Collier, M.A., Durack P.D., Gordon H.B., Hirst A.C., O'Farrell S.P. and Whetton P.H., 2003: The response of climate variability and mean state to climate change: preliminary results from the CSIRO Mark 3 coupled model. *CLIVAR Exchanges*, **28**, 8-11.

Cai , W.J., Collier, M.A., and Gordon, H.B., 2003: Strong ENSO variability and a super-ENSO pair in the CSIRO Mark 3 coupled climate model. *MWR*, **131**, 1189-1210.

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Louis, J-F., 1979: A parametric model of vertical eddy fluxes in the atmosphere. *Bound.-Layer Meteor*., **17**, 187-202.

O'Farrell, S.P., 1998: Investigation of the dynamic sea-ice component of a coupled atmosphere sea-ice general circulation model. *J. Geophys. Res*., **103** (C8), 15751-15782.

Pacanowski, R.C., and S.G.H. Philander, 1981: Parameterization of vertical mixing in numerical models of tropical oceans. *J. Phys. Oceanogr*., **11**, 1443-1451.

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