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

UKMO-HadCM3

28 July 2006

I. Model identity:

A. Institution, sponsoring agency, country
   Hadley Centre for Climate Prediction and Research
   Met Office
   United Kingdom

B. Model name (and names of component atmospheric, ocean, sea ice, etc. models)
   HadCM3

C. Vintage (i.e., year that model version was first used in a published application)
   2000

D. General published references and web pages
   Gordon, C., C. Cooper, C.A. Senior, H.T. Banks, J.M. Gregory, T.C. Johns, J.F.B. Mitchell and R.A. Wood, 2000. The simulation of SST, sea ice extents and ocean heat transports in a version of the Hadley Centre coupled model without flux adjustments. Clim. Dyn., 16, 147-168.
   Pope, V., M.L. Gallani, P.R. Rowntree, R.A. Stratton, 2000, The impact of new physical parameterizations in the Hadley Centre climate model: HadAM3. Clim Dyn 16: 123-146

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.
   Johns T.C., J. M. Gregory, W. J. Ingram, C. E. Johnson, A. Jones, J. A. Lowe, J. F. B. Mitchell, D. L. Roberts, B. M. H. Sexton, D. S. Stevenson, S. F. B. Tett and M. J. Woodage, 2003, Anthropogenic climate change for 1860 to 2100 simulated with the HadCM3 model under updated emissions scenarios, Clim. Dyn 20: 583-612, describe anthropogenic experiments and sulfur cycle

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 2xCO2 : 0.89 K $W^{-1}m^2$
   Coupled : effective climate sensitivity in a transient 1%to2xCO2 at time of doubling : 0.83 K $W^{-1}m^2$

G. Contacts (name and email addresses), as appropriate, for:
   1. coupled model jason.lowe@metoffice.gov.uk
   2. atmosphere gill.martin@metoffice.gov.uk
   3. ocean helene.banks@metoffice.gov.uk
   4. sea ice
   5. land surface
   6. vegetation
   7. scenarios tim.johns@metoffice.gov.uk ; jonathan.gregory@metoffice.gov.uk

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? YES. Sulphate aerosols produced by oxidation of SO2. Oxidants concentrations provided by running offline the STOCHEM model [OH, H_2O_2 and HO_2]).
B. interactive biogeochemistry? NO
C. what aerosols and are indirect effects modeled? Three modes of sulfates aerosols (Aitken, accumulation and dissolved in cloud droplets) with explicit parameterizations of transfers between the different modes. SO2 and DMS are injected at appropriate levels. The direct radiative effect from scattering and absorption is taken into account. The indirect effect was implemented by prescribing cloud changes calculated by offline models (see Johns et al., 2003, Appendix A for more details)
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.**

AMIP :
PMIP2 : uses HadCM3 but with an updated version of the land surface scheme (MOSES II)
CMIP

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

A. Atmosphere
1. resolution
   2.75° latitude by 3.75° longitude
2. numerical scheme/grid (advective and time-stepping schemes; model top; vertical coordinate and number of layers above 200 hPa and below 850 hPa)
   hydrostatic, grid point model using an Arakawa B grid and hybrid vertical coordinates. Eulerian advection scheme.
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
4. descriptive name (e.g., temperature, northward and eastward wind components, etc.)
   temperature,U-V velocity, surface pressure, liquid water content, liquid water potential temperature, cloud fraction, sulfur dioxide (SO2), dimethyl sulfide (DMS) and three modes of sulfate aerosol
5. name, terse descriptions, and references (journal articles, web pages) for all major parameterizations. Include, as appropriate, descriptions of:
   a. clouds
      Smith (1990) modified by Gregory and Morris (1996)
   b. convection
      Gregory and Rowntree (1990) with addition of convective downdrafts (Gregory and Allen 1991)
   c. boundary layer
      Smith (1990, 1993).
   d. SW, LW radiation

Edwards and Slingo (1996). Six spectral band in the shortwave and eight in the longwave. Effects of minor greenhouse gases as well as CO_2, water vapour and ozone are explicitly represented.

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

B. Ocean

1. resolution

   1.25^o x 1.25^o
2. numerical scheme/grid, including advection scheme, time-stepping scheme, vertical coordinate, free surface or rigid lid, virtual salt flux or freshwater flux

   1-hour time step, standard "rigid-lid" barotropic solution, virtual salt flux with a standard salinity of 35 PSU.
3. list of prognostic variables and tracers

   Temperature, Salinity, U and V baroclinic velocity, mixed-layer depth
4. name, terse descriptions, and references (journal articles, web pages) for all parameterizations. Include, as appropriate, descriptions of:

   a. eddy parameterization

      Gent and Mc Williams (1997) with a variable thickness diffusion parameterization (Wright 1997, Visbeck et al., 1997).

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

      Convective adjustment is modified in the region of the Denamk Straits and Iceland-Scotland ridge better to represent down-slope mixing of the overflow water (based on Roether et al., 1994)

   c. mixed-layer treatment

      Kraus-Turner 1967, and K-theory scheme (Pacanowski and Philander 1981) for momentum

   d. sunlight penetration

      two-band scheme (one more penetrative) assuming pure water type 1B (Paulson and Simpson, Journ. Phys. Ocean., 7, p. 952 (1977), with coefficients adjusted.

   e. tidal mixing

      no

   f. river mouth mixing

      no: runoff added to P-E flux in the into top ocean layer.

   g. mixing isolated seas with the ocean

      Mediterranean water is partially mixed with Atlantic water across the Strait of Gibraltar as a simple representation of water mass exchange. Similar parameterization for Hudson Bay.

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

      Artificial island and Fourier filtering North of 74.5^oN.

C. sea ice

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

   same resolution as ocean model.
2. numerical scheme/grid, including advection scheme, time-stepping scheme,
3. list of prognostic variables

   sea-ice fraction, thickness, snow depth, U and V velocities.
4. completeness (dynamics? rheology? leads? snow treatment on sea ice)

simple thermodynamic 1-layer scheme including leads and snow-cover (Cattle and Crossley 1995). Parameterization of ice concentration based on that of Hiblet (1979) + simple parameterization of ice dynamics based on Bryan (1969). Ice rheology crudely represented by preventing convergence of ice once the ice depth reaches 4m.

5. treatment of salinity in ice
   Assume a constant salinity of 0.6 per mil.
6. brine rejection treatment
   Sublimation increases ocean salinity, as the salt is assumed to blow into leads, and white ice formation reduces it to account for the salt added in converting snow to ice.
7. treatment of the North Pole "singularity" (filtering, pole rotation, artificial island?)
   artificial island and Fourier filtering North of 74.5^{o}N.

D. land / ice sheets (some of the following may be omitted if information is clearly included in cited references.
   MOSES I land surface scheme see Cox P., R. Betts, C Bunton, R. Essery, P. R. R. Rowntree, J. Smith, 1999, The impact of new land surface physics on the GCM simulation of climate and climate sensitivity, Clim. Dyn 15 : 183-203
1. resolution (tiling?), number of layers for heat and water
   One tile. 4 layers for heat and water
2. treatment of frozen soil and permafrost
   Diagnostic treatment of frozen water fraction (subsurface temperature updated using a discretised from of the heat diffusion equation)
3. treatment of surface runoff and river routing scheme
   Instantaneous routing of overflow water (surface and sub-surface drainage) to corresponding river mouth.
4. treatment of snow cover on land
   is assumed to be uniformily distributed and the evaporative demand is met by any lying snow first
5. description of water storage model and drainage
   Water fluxes determined by Darcy law closed by Clapp and Hornberger relations. Excess water is drained
6. surface albedo scheme
   all-band surface albedo. Prescribed snow-free albedo. Snow surface albedo is assumed to vary from its snow-free value to its deep-snow (temperature dependent) value at large snow depth. See Cox et al. (1999) Appendix C.
7. vegetation treatment (canopy?)
   canopy conductance calculated on the basis of an diagnostic treatment of net primary producvity. Represents the bulk effect of stomatal openings on plan leaves and the gain of carbon dioxide through photosynthesis.
8. list of prognostic variables
   canopy water, lying snow, total soil moisture and temperature on 4 layers
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 are prescribed and static. See E4 for handling accumulating snow.

E. coupling details
1. frequency of coupling
   1-day

2. Are heat and water conserved by coupling scheme?
   Yes
3. list of variables passed between components:
   a. atmosphere – ocean : atmosphere to ocean : wind-stress, penetrative solar radiation, non-penetrative net heat flux, precipitation minus evaporation, river outflow, snowfall, sublimation and sea ice top and bottom melting; ocean to atmosphere : surface circulation, ice concentration, ice depth, snow depth and ice, and sea surface temperature.
   b. atmosphere – land : fluxes (heat, moisture, momentum), surface and air temperature, humidity, snow fraction
   c. land – ocean
   d. sea ice – ocean : heat fluxes, top and bottom ice melt, temperature, snow and ice fraction and thickness
   e. sea ice – atmosphere
4. Flux adjustment? (heat?, water?, momentum?, annual?, monthly?).
   NO, but freshwater imbalance due to snow accumulating over ice sheets returned to ocean by an appropriate water flux over the areas of the adjacent oceans where icebergs occur. The largest local value of the iceberg term are about 0.15 $mm.day^{-1}$, i.e., 5 % of the P-E term in the North Atlantic, and up to 20 % near the coast around Antarctica.

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

A. IPCC "experiment" name
   PIcntrl
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.
      Initialised directly from the Levitus observed ocean state (Levitus and Boyer 1994; Levitus 1995)
      Run 1. is after 300 years spin-up
      Run 2 is after 150 years spin-up
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.
   TSI : 1365 W/m2 (constant)
   CO2 : 289.6 ppmv; CH4 = 790.2 ppbv ; N2O = 285.1 ppbv
   No natural emissions of sulfur aerosols in control run.
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. IPCC "experiment" name
   1%to2x

B. Describe method used to obtain initial conditions for each component model
   run 1 is parallel to PIcntrl, run 2
   run 2 is parallel to PIcntrl, run 1
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
   CO2 increased by 1% compound to doubling, then stabilised

A. IPCC "experiment" name
   20C3M
B. Describe method used to obtain initial conditions for each component model
   First year of Run 1 (labeled 1859) corresponds to year 1 of PIcntrl, run 1
   First year of Run 2 (labeled 1859) corresponds to year 151 of PIcntrl, run 1

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.
   anthropogenic greenhouse gas forcing (as specified in the IPCC 1995 report, to give IS92a-like forcing variations, see Table 1a in Johns et al., 2003); + sulphate aerosol direct + indirect forcing (via calibrated delta-albedo; see Johns et al, 2003 Appendix 1A); sulphur chemistry without natural DMS & 3D SO2 background emissions, (ie. anthropogenic SO2 emissions surface and high level only, taken from a personal communication with Steve Smith and Nakicenovic et al 2000.).
   Tropospheric/stratospheric ozone (reconstruction for the period 1858 – 1970).

A. IPCC "experiment" name
   Commit
B. Describe method used to obtain initial conditions for each component model
   Branches on year Dec1999 of 20C3M, run 2
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.
   all forcings kept constant from the beginning of the run (perpetual annual cycle of ozone)

A. IPCC "experiment" name
   SRESA2
B. Describe method used to obtain initial conditions for each component model
   Branches on year Dec1999 of 20C3M, run 1
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

   GHG : See table 1a in Johns et al., 2003. Sulfur emissions according to SRES A2 scenario (Steve Smith personal communication). See Table 2 in Johns et al., 2003

A. A. IPCC "experiment" name
   SRESB2
B. Describe method used to obtain initial conditions for each component model
   Branches on year Dec1999 of 20C3M, run 1
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
   GHG : See table 1a in Johns et al., 2003. Sulfur emissions according to SRES B2 scenario (Steve Smith personal communication). See Table 2 in Johns et al., 2003

A. IPCC "experiment" name
   SRESA1B
B. Describe method used to obtain initial conditions for each component model
   Branches on year Dec1999 of 20C3M, run 2
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

As SRESB2, but the CO2 concentrations were obtained from the 'Bern' model values in IPCC TAR annex II.2. CH4, N2O and the HFCs are also from the TAR appendix. The CFCs are the same as in B1. For HCFC22 we used the average of offline STOCHEM calculations for B1 and A1FI.