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

GISS-AOM

16 February 2005

I. Model Identity:
  A. Institution: NASA Goddard Institute for Space Studies (NASA/GISS), USA
  B. Model name: AOM 4x3
  C. Vintage: AOM 5x4 was first published in 1995;
    AOM 4x3 was completed in 2004
  D. References: Web site for AOM 4x3: http:/aom.giss.nasa.gov
    Refereed publication of AOM 5x4 formulation:
    Russell GL, Miller JR, Rind D, 1995. A coupled atmosphere-ocean model for transient climate change studies. Atmosphere-Ocean 33 (4), 683-730.
  E. Model performance: of AOM 5x4:
    Lucarini L, Russell GL, 2002. Comparison of mean climate trends in the northern hemisphere between National Centers for Environmental Prediction and two atmosphere-ocean model forced runs. JGR, 107 (D15), 10.1029/2001JD001247
  F. Climate sensitivity: Early version of AOM 5x4 was estimated to have dTeq = 2.65 (C) for doubling CO2 by diagnosing ocean heat intake;
    AOM 4x3 has not been examined
  G. Contacts: For all pieces: Gary L. Russell,
    Gary.L.Russell@nasa.gov

II. 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. Aerosols: Boucher's monthly-decade sulfate burden (mg/m^2) (downloaded from PCMDI web site) was converted to an optical depth by global coefficient [.030 (m^2/mg)] and treated as tropospheric sulfate aerosols with particular vertical distribution;
    indirect effects were not separately modeled
  D. Dynamic vegetation: no
  E. Ice sheets: nothing other than that covered under IV. D. 9.

III. Projects: AMIP: 5x4 atmospheric model between AOM 5x4 and AOM 4x3
    CMIP: early version of AOM 5x4, should be discarded

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

A. Atmosphere

1. Resolution: 4 degrees longitude, 3 degrees latitude, 12 vertical layers, heat and water vapor have mean value and three prognostic directional gradients inside each cell
2. Numerical scheme: grid point model;
   forward step, linear upstream shceme used for linear advection (heat and water vapor);
   leap frog, second order center-difference C-grid scheme for non-linear advection (momentum);
   combination of fixed mass and sigma coordinate vertical layering;
   4 layers above 204 hPa on average;
   2 layers below 875 hPa on average;
3. Prognostic variables: all are three dimensional;
   MA = mass (kg/m^2)
   UA = eastward velocity (m/s) on C-grid
   VA = northward velocity (m/s) on C-grid
   H0M = mean potential enthalpy (J)
   HXM, HYM, HZM = eastward, northward and vertical gradients of potential enthalpy (J)
   Q0M = mean water vapor (kg)
   QXM, QYM, QZM = eastward, northward and vertical gradients of water vapor (kg)
4. Parameterizations: AOM web site:
   http://aom.giss.nasa.gov/DOC4X3/ATMOC4X3.TXT
   a. Clouds: see AOM web site
   b. Convection: see AOM web site
   c. Boundary layer: see AOM web site
   d. Radiation: see AOM web site;
      Lacis AA, Oinas V, 1991. A description of the correlated k distributed method for modeling nongray gaseous absorption, thermal emission, and multiple scattering in vertically inhomogeneous atmospheres. JGR, 96, 9027-9063.
   e. Drag at model top: a drag proportional to the square of wind is applied to top layer velocity components

B. Ocean

1. Resolution: 4 degrees longitude, 3 degrees latitude, up to 16 vertical layers, heat and salt have mean value and three prognostic directional gradients inside each cell
2. Numerical scheme: grid point model;
   forward step, linear upstream shceme used

for linear advection (heat and salt);
leap frog, second order center-difference C-grid scheme for non-linear advection (momentum);
sigma coordinate vertical layering but variable number of layers (consequently each layer has approximately the same mass per unit area in all cells);
free surface;
Bousinesq approximation not used;
freshwater fluxes change ocean mass

3. Prognostic variables: all are three dimensional;
   - MO = mass (kg/m^2)
   - UO = eastward velocity (m/s) on C-grid
   - VO = northward velocity (m/s) on C-grid
   - G0M = mean potential enthalpy (J)
   - GXM, GYM, GZM = eastward, northward and vertical gradients of potential enthalpy (J)
   - S0M = mean salt (kg)
   - SXM, SYM, SZM = eastward, northward and vertical gradients of salt (kg)
4. Parameterizations: AOM web site: http://aom.giss.nasa.gov/DOC4X3/ATMOC4X3.TXT
   - a. Eddy parameterization: none
   - b. Bottom boundary: bottom drag, see AOM web site
   - c. Mixed-layer: KPP vertical mixing scheme; Large WG, McWilliams JC, Doney SC, 1994. Oceanic vertical mixing: review and a model with non-local boundary layer parameterization. Rev. Geophys., 32, 363-403.
   - d. Sunlight: penetrates into top 3 layers (about 51 meters); Paulson CA, Simpson JJ, 1977. Irradiance measurements in the upper ocean. J. Appl. Oceanogr., 7, 952-956.
   - e. Tidal mixing: none
   - f. River flow: enters into top ocean layer affecting mass, mean heat, and horizontal gradients of heat and salt
   - g. Isolated seas: subresolution straits connect isolated seas to main ocean (Mediterranean Sea, Baltic Sea, Black Sea, Red Sea, White Sea, Persian Gulf), see AOM web site
   - h. North pole: treated same as in atmosphere, single vector velocity at pole (which appears to rotate); mass, heat and salt have same value at all polar longitudes, GXM=GYM=SXM=SYM=0;

C. Sea Ice

1. Resolution: same as ocean (4x3), 2 mass layers, 4 thermal layers, single ice thickness
2. Numerical scheme: velocity components defined on C-grid;
   advection of ice use modified linear
   upstream scheme;
   call once each hour with other source terms
3. Prognostic variables: RSI = horizontal sea ice cover
   RSIX,RSIY = eastward and northward gradients of horizontal sea ice cover
   MSI(2) = snow and sea ice mass (kg/m^2)
   HSI(4) = heat content of layer (J/m^2)
   PSI = internal sea ice pressure
   USI = eastward velocity (m/s) on C-grid
   VSI = northward velocity (m/s) on C-grid
4. Completeness: sea ice velocity accelerated by seven terms:
   atmospheric stress, ocean drag, Coriolis and metric term, surface pressure and ocean tilt, internal sea ice pressure, parallel sea ice stresses, island and coastline blocking factor;
   minimum open ocean is 6% / [ice thickness (m)];
   snow thicker than 91.66 (kg/m^2) is compacted into ice
5. Salinity: none
6. Brine rejection: all salt drops into ocean when ice forms
7. North pole: velocity not defined nor used;
   RSI,MSI,HSI,PSI have same value at all polar longitudes, RSIX=RSIY=0

D. Continents: each 4x3 cell is either all ocean or all continent

1. Resolution: fixed fractions of continental cell are
   ground, land ice, or lake,
   ground can be partially covered by snow,
   lake can be partially covered by lake ice;
   ground has 4 layers plus fith layer for snow,
   ground layer thicknesses: .0625, .25, 1, 4 (m);
   land ice has 4 layers;
   liquid lake has 2 layers,
   lake ice is treated like sea ice
2. Frozen soil: each ground layer has water mass and heat content which determines frozen fraction
3. Rivers: excess precipitation and snow melt (surface runoff)
   is fed into lake in same cell;
   underground runoff depends on soil types and standard deviation of topography;
   hand made river direction file:
   http://aom.giss.nasa.gov/rdv4x3.html
4. Snow on ground: precipitation is uniform over a grid cell;
   snow on snow-free ground adds to snow-covered ground at rate of 21 (kg/m^2);

when snow on snow-covered ground exceeds 42 (kg/m^2) it spreads covering snow-free ground;
rain compacts some snow into ice;
if snow melts below 20 (kg/m^2), snow-covered ground is reduced horizontally

5. Water storage: each 4 layers of ground cells have fractions of soil types: sand, silt, clay, peat, rock;
   hydraulic diffusivity depends on soil types and liquid water availability;
   water flux depends on hydraulic diffusivity, liquid water, and air space;
   evaporation from root layers 2, 3 and 4 during growing season when sun is up, only from layer 1 othertimes
6. Albedo: determined by visible and near infrared separately;
   integrated snow albedo ranges from .50 to .85 depending on thickness and age;
   integrated ice albedo is .45;
   integrated ground albedo depends on vegetation and season and ranges from .50 for bright desert to .11 for rain forest
7. Vegetation: fixed fractions for 10 different types of ground cells;
   affects surface albedo, surface roughness, evpaoration, hydraulic and thermal diffusivities, and underground runoff
8. Prognostic variables: see http:/aom.giss.nasa.gov/CODE4X3/C477C.S
9. Ice sheets: ice in layers 1 and 2 is 182, 3 is 910, 4 is 6370 (kg/m^2) [sums to about 8.3 (m)];
   snow is distributed uniformly over land ice cell;
   snow exceeding 91.66 (kg/m^2) is compacted into ice, equal amount of ice is removed from layer 4, and ice is then relayered;
   surface melt water can refreeze in any of 4 layers, after that it seeps out into ocean via river direction file

E. Coupling details:

1. Frequency: atmosphere and subsurface reservoirs exchange fluxes once each hour
2. Conservation: water mass and static energy are conserved exactly;
   surface momentum stresses are conserved between atmosphere and ocean
3. Fluxes:
   a: atmo-ocean: PREC = precipitation (kg/m^2)
   EPRE = energy of precipitation (J/m^2)
   SRHDT = solar radiation absorbed (J/m^2)

TRHDT = thermal radiation emitted (J/m^2)
DMUA = eastward momentum stress (kg/m*s)
DMVA = northward momentum stress (kg/m*s)
W0 = dew minus evaporation (kg/m^2)
E0 = turbulent plus radiation fluxes (J/m^2)

b: atmo-land: PREC = precipitation (kg/m^2)
EPRE = energy of precipitation (J/m^2)
SRHDT = solar radiation absorbed (J/m^2)
TRHDT = thermal radiation emitted (J/m^2)
W0 = dew minus evaporation (kg/m^2)
E0 = turbulent plus radiation fluxes (J/m^2)
WR = evaporation from roots (kg/m^2)

c: land-ocean: MFLUX = mass flux from rivers (kg)
EFLUX = energy flux from rivers (J)
BERGM = ice bergs from Antarctica (kg)
BERGE = energy of ice bergs from Antarctica (J)

d: sea ice-ocean: DMOO = ice formed on open ocean (kg/m^2)
DEOO = energy of ice formation on open ocean
DMOI = ice formed beneath old ice (kg/m^2)
DEOI = energy of ice formation beneath ice
RUNS = melted surface ice (kg/m^2)
ENRG = heat from ocean to melt sea ice
DMO = ice melted at bottom of ice
DRSI = ice melted horizontally
DMUI = eastward momentum stress (kg/m*s)
DMVI = northward momentum stress (kg/m*s)
E1 = conductive energy flux (J/m^2)

e: atmo-sea ice: PREC = precipitation (kg/m^2)
EPRE = energy of precipitation (J/m^2)
SRHDT = solar radiation absorbed (J/m^2)
TRHDT = thermal radiation emitted (J/m^2)
DMUA = eastward momentum stress (kg/m*s)
DMVA = northward momentum stress (kg/m*s)
W0 = dew minus evaporation (kg/m^2)
E0 = turbulent plus radiation fluxes (J/m^2)

f: land ice-sea ice: DRSI = increase in horizontal sea ice cover from Antarctic ice calving
HGIT = energy from Antarctic ice calving

4. Flux adjustments: no

V. Simulation Details

A. PIcntrl: 1850 to 2100
C480: B. 200-year spinup from Levitus climatological conditions
C490: B. 250-year spinup from Levitus climatological conditions
C. Monthly varying, but annually fixed, some industrial and natural aerosols and Boucher's 1850 sulfate burden, see solar constant is fixed at 1367 (W/m^2)

A. 20C3M: 1850 to 2000
C483: B. 200-year spinup from Levitus climatological conditions
C493: B. 250-year spinup from Levitus climatological conditions
D. Greenhouse gases: http://aom.giss.nasa.gov/IN/GHGA1B.LP ;
Boucher's time varying sulfate burden (1850 to 2000), see
http://aom.giss.nasa.gov/cp4x3in.html (#16);
other forcing agents have monthly changes, but no annual
changes

A. SRES B1: 2000 to 2100
C484: B. Initialized from end of C483
C494: B. Initialized from end of C493
D. Greenhouse gases: http://aom.giss.nasa.gov/IN/GHGB1.LP ;
Boucher's time varying sulfate burden (2000 to 2100) for
IPCC SRES B1, see
http://aom.giss.nasa.gov/cp4x3in.html (#16);
other forcing agents have monthly changes, but no annual
changes

A. SRES A1B: 2000 to 2100
C485: B. Initialized from end of C483
C495: B. Initialized from end of C493
D. Greenhouse gases: http://aom.giss.nasa.gov/IN/GHGA1B.LP ;
Boucher's time varying sulfate burden (2000 to 2100) for
IPCC SRES A1B, see
http://aom.giss.nasa.gov/cp4x3in.html (#16);
other forcing agents have monthly changes, but no annual
changes