Adoption of RRTMG in the NCAR CAM5 and CESM1 Global Climate Models

Research Highlight

Improving cloud, aerosol, and radiative processes in general circulation models (GCMs) is a continuing and critical objective of the U.S. Department of Energy's (DOE) Atmospheric System Research. RRTMG, the broadband, longwave, and shortwave rapid radiation model for GCM applications developed at AER with DOE support, has been formally adopted as the radiation code in the NCAR Community Atmosphere Model (CAM5) and the Community Earth System Model (CESM1) with the public release of these global climate models on 25 June 2010. This accomplishment is a vital contribution to advancing the climate simulation capability of the NCAR models.

RRTMG, which uses the correlated k-distribution radiative transfer technique and a two-stream method for multiple scattering, is an accelerated and reformatted version of the single-column reference radiation model, RRTM. Both models utilize gaseous absorption coefficients derived from the line-by-line radiation model, LBLRTM, which also provides high-resolution reference calculations for validation of the broadband models. All major gaseous absorbers are treated by RRTMG in the longwave and shortwave along with the radiative effects of clouds and aerosols. RRTMG includes a statistical technique for representing sub-grid scale cloud variability known as the Monte-Carlo Independent Column Approximation (McICA), which is also being utilized within the NCAR models. Further information on the AER radiation models and the source code are available at http://rtweb.aer.com/.

The application of RRTMG to CAM5 and CESM1 was completed by the NCAR Atmospheric Model Working Group development team in conjunction with additional substantial changes to the climate model physics. These include modifications or new approaches for treating the planetary boundary layer, cloud microphysics and macrophysics, shallow convection, and aerosols (including representation for the first time of the aerosol indirect effect). These changes were implemented to ensure a greater degree of consistency among the various physics packages, and this will make it possible to investigate new research directions. The integrated effect of these modifications has notably altered the climate simulated by these global models. In the atmospheric model (CAM5), shortwave cloud forcing is improved in the tropics and other regions (Figure 1), and tropical precipitation is better represented. Conversely, the clear sky outgoing longwave radiation and longwave cloud forcing agree less well with observations (Figure 2), and the model is too moist overall. The bias in clear sky outgoing longwave radiation is most likely due to discrepancies in the simulated vertical distributions of temperature and water vapor, since RRTMG has been extensively validated independently.

The mean climate in the coupled model (CESM1) is improved over its predecessors, CCSM3 and CCSM4, with notable reductions in root mean square errors in global mean precipitation and sea surface temperature relative to observations. Simulation of the global mean temperature over the 20th century with CESM1 shows much less warming than CCSM4 and slightly less warming than observed. Shortwave cloud forcing over the 20th century has switched from being positive (warming) in CCSM4 to negative (cooling) with the addition of aerosol indirect forcing effects in CESM1. The latest coupled model also retains many positive features of the CCSM4 climate, including its ability to simulate El Nino variability. More information about the global climate models is available at the NCAR CESM web site (www.cesm.ucar.edu). Publications for a special issue of the Journal of Climate are in preparation that will describe the climate state of the new global models and the impact of the new radiation in greater detail.

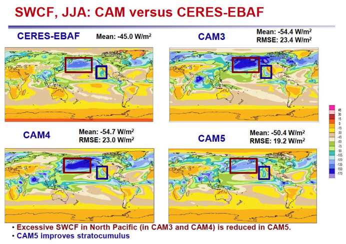

Figure 1. Shortwave cloud forcing for three versions of the NCAR Community Atmosphere Model (CAM) with CERES observations at upper left for Jun–Aug. The latest model, CAM5 (at lower right), shows improvement in both mean error and root mean square error (RMSE), with notable improvement in the tropics, the North Pacific, and the stratocumulus region over the Eastern Pacific. Units are in Wm-2. Figure courtesy of NCAR.

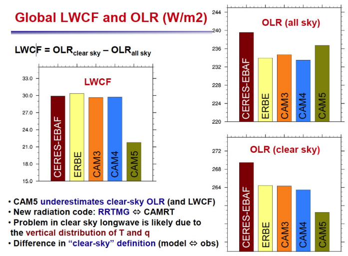

Figure 2. Bar charts of global, annual mean longwave cloud forcing (LWCF), all-sky outgoing longwave radiation (OLR), and clear-sky OLR for three versions of the NCAR Community Atmosphere Model (CAM) and for both CERES and ERBE observations. The latest model, CAM5, underestimates LWCF by 8 Wm-2, which is partly due to discrepancies in clear sky and with clouds present. Units are in Wm-2. Figure courtesy of NCAR.

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Reference(s)

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Cloud-Aerosol-Precipitation Interactions