IRS2012-328-1
International Radiation Symposium 2012
Dahlem Cube, Berlin, Germany, 06 – 10 August 2012

Assessing TOA and vertical cloud radiative effects in CMIP5 models using CERES data

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Cloud feedback remains the largest source of uncertainty in climate sensitivity estimates by current generation Global Climate Models (GCMs). In this study, we assess radiative fluxes and cloud radiative effects at the top-of-atmosphere (TOA), surface and within the atmosphere in CMIP5 Atmospheric GCMs (AGCMs). Outputs from AMIP (Atmospheric Model Intercomparison Project) simulations are compared with the Clouds and the Earth's Radian Energy System (CERES) data. The CERES data we use includes the Energy Balanced and Filled (EBAF) TOA and surface radiative fluxes, and radiative fluxes within the atmosphere from the monthly regional radiative fluxes and clouds (AVG) data. We first assess the shortwave and longwave cloud radiative effects at TOA and surface in fifteen model simulations in CMIP5. For both TOA and surface, the multi-model mean difference from CERES and inter-model differences show similar spatial pattern. The CMIP5 models show larger model differences from CERES and inter-model differences in shortwave cloud radiative effect than in longwave cloud radiative effect. At TOA, the model uncertainty in longwave cloud radiative effect is mainly over tropical convective region and tropical regions with moderate subsidence, whereas the model uncertainty in shortwave cloud radiative effect is over tropical convective region, the subsidence region over eastern Pacific and the Southern Ocean. Relative to CERES, the CMIP5 models have stronger shortwave cooling over tropical convective regions, yet considerably weaker shortwave cooling over the eastern Pacific and the Southern Ocean. At the surface, the model uncertainty for both the shortwave and longwave radiative fluxes are primarily over the subsidence regions in the eastern Pacific and secondly over tropical convection regions. We further extend our analysis to the vertical profiles of shortwave and longwave radiative fluxes and cloud radiative effects within the atmosphere. Only four models in CMIP5 provide vertical profiles of radiative flux. Through such analysis we further decompose the TOA cloud effects into those at different vertical layers (500 hPa, 200 hPa, and 70hPa), and investigate how model differences from CERES and inter-model differences at TOA are linked to their simulations of cloud height and cloud amount within these vertical layers. The deficiencies in these models as well as the implications of our findings will be discussed.