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Surface and TOA Earth Radiation Budget Evaluation of CMIP3 and CMIP5 20th Century Simulations

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As with any planet, the most fundamental characteristics of Earth's climate lies in the manner that radiation balance is achieved and perturbed through various climate processes and feedbacks and external forcings. Recognition of this first-order principle is exhibited by the relatively early development, and continuation, of accurate satellite measurements of top of the atmosphere (TOA) radiation (e.g. SRB, ERBE, CERES) and their use to constrain and evaluate GCM representations of climate. While it is generally understood that GCMs seek, and for the most part tend to achieve global energy balance consistent with these observations and their uncertainties, it is also recognized that there remains considerable biases in radiation in space and time and associated with the relevant inner workings of the (modeled) climate system (e.g. circulation, clouds, water vapor). In this study, we provide a robust evaluation and analysis of the TOA and surface radiation budgets of the CMIP5 20th century simulations, and compare their fidelity to those from CMIP3. To account for observational uncertainty, we utilize a number of contemporary satellite measurements for the TOA and surface (e.g. CERES-Aqua, CERES-Terra, ERBE) and observationally/satellite-constrained model calculations for the surface (e.g. CERES product, CloudSat FLXHR-LIDAR ERB product, ISCCP product). Using the mean and standard deviation of these products for observational reference, we evaluate the GCM fidelity in representing TOA outgoing longwave radiation (OLR) and reflective shortwave radiation, including their clear-sky values, as well as surface values of net shortwave and longwave. Based on examination of 17 CMIP5 and 12 CMIP3 GCMs over the period 1970-2005 and 1970-1999, respectively, we find that there is no significant improvement in the magnitude and spatial structure of the biases in either the TOA or the surface. In fact, while the multi-model global mean OLR bias is about the same between CMIP3 and CMIP5, the size of the cancelling errors across the globe is bigger in CMIP5 than CMIP3. Our study quantifies these and other biases, and also includes an assessment of how the models represent variability in the Earth's radiation budget, including extremes on a monthly time scale. For example, the manner the GCMs represent the teleconnection response of the radiation terms to large-scale SST changes (e.g. ENSO) varies dramatically – a characteristic that can be broken down into circulation and cloud response contributions. In addition, a persistent bias between CMIP3 and CMIP5 is the overestimate of OLR and surface shortwave in the strongly convective region of the tropics. Based on our previous and ongoing studies (e.g. Waliser et al. 2011; Li et al. 2012, Stephens et al. 2011), we will suggest that at least part of this persistent bias stems from GCMs ignoring the effects of precipitating ice and liquid in their radiation calculations.

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