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Earth radiation budget from a surface perspective

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The genesis and evolution of Earth's climate is largely regulated by the Earth radiation budget. Despite the central importance of the Earth radiation budget for the climate system and climate change, substantial uncertainties still exist in the quantification of its different components, and their representation in climate models (e.g., Wild et al. 1998 Clim. Dyn., Wild 2008 Tellus). While the net radiative energy flow in and out of the climate system at the top of atmosphere (TOA) is known with considerable accuracy from new satellite programs such as the Clouds and the Earth's Radiant Energy System (CERES) and the Solar Radiation and Climate Experiment (SORCE), much less is known about the energy distribution within the climate system and at the Earth surface.

Here we use direct surface observations from the Baseline Surface Radiation Network (BSRN) and the Global Energy Balance Archive (GEBA) to provide better constraints on the surface radiative components as well as to investigate their temporal changes. We analyze shortwave and longwave radiation budgets of the latest generation of global climate models as used in the Coupled Model Intercomparison Project Phase 5 (CMIP5) and in the upcoming Fifth IPCC assessment report (IPCCAR5). In the shortwave, the CMIP5 models differ in their global mean values up to 10 Wm-2 for the TOA reflected, and up to 16 Wm-2 for the surface downward component. In the longwave, the surface downward components also show a considerably larger spread in their global mean estimates (20 Wm-2) than in the TOA outgoing fluxes (11 Wm-2). At the TOA, the global mean shortwave reflected and outgoing longwave radiation components of the CMIP5 multi-model mean are within a few Wm-2 of the observational reference given by the CERES Energy Balanced and Filled (EBAF) product, and thus show overall no systematic biases. However, compared to a comprehensive set of surface observations from BSRN and GEBA, the CMIP5 models overestimate the shortwave radiation incident at the surface on average by 5-10 Wm-2, indicating a lack of atmospheric absorption in these models. This suggests that the best estimate for the global mean absorbed shortwave radiation at the surface should be lower than the simulated estimates, which are on average slightly below 170 Wm-2, so that a value near 160 Wm-2 might be the most realistic estimate for the global mean absorbed shortwave radiation at the surface. In contrast, the longwave downward radiation at the surface is underestimated by these models compared to available observations, by 6 Wm-2 on average, suggesting that the best estimate for the global mean downward longwave radiation should be rather around 345 Wm-2 than the model average of 338 Wm-2, in line with recent results independently derived from active satellite sensors of the CALIPSO and CloudSat missions.

There is further increasing evidence from the direct observations that the surface radiative fluxes undergo significant changes on decadal timescales, not only in their longwave components as expected from the increasing greenhouse effect, but also in the amount of shortwave radiation that reaches the Earth surface. In the longwave, observations from BSRN suggest an overall increase of downward longwave radiation at the surface of 2 Wm-2 per decade when averaged over the available stations. This is in line with latest projections from the CMIP5 models and expectations from an increasing greenhouse effect. On the other hand, the strong decadal changes in surface shortwave radiation seen in the observations (“dimming/brightening“) are not adequately represented in current climate models.