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Earth radiation budget from a surface perspective and its representation in CMIP5 models

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The genesis and evolution of Earth's climate is largely regulated by the global energy balance. Despite the central importance of the global energy balance 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 CERES, 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 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). Compared to a comprehensive set of surface observations, the CMIP5 models overestimate the shortwave radiation incident at the surface by 5-10 Wm-2 on average, due to a lack of absorption in the atmosphere. 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 of no more than 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 a similar amount in these models, 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.
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.