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The cloud-free global energy balance and inferred cloud radiative effects: An assessment based on direct observations and climate models

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In recent studies we quantified the global mean Earth energy balance based on direct observations from surface and space. Here we infer complementary estimates for its components specifically under cloud-free conditions. While the clear-sky fluxes at the Top of Atmosphere (TOA) are accurately known from satellite measurements, the corresponding fluxes at the Earth's surface are not equally well established, as they cannot be directly measured from space. This is also evident in 38 global climate models from CMIP5, which are shown to greatly vary in their clear-sky surface radiation budgets. To better constrain the latter, we use newly derived clear-sky reference climatologies of surface downward shortwave and longwave radiative fluxes from worldwide distributed Baseline Surface Radiation Network (BSRN) sites. 33 out of the 38 CMIP5 models overestimate the clear-sky downward shortwave reference climatologies, whereas both substantial overestimations and underestimations are found in the longwave counterparts in some of the models.

From the bias structure of the CMIP5 models we infer best estimates for the global mean surface downward clear-sky shortwave and longwave radiation, at 247 and 314 Wm-2, respectively. With a global mean surface albedo of 13.5% and net shortwave clear-sky flux of 287 Wm-2 at the TOA this results in a global mean clear-sky surface and atmospheric shortwave absorption of 214 and 73 Wm-2, respectively.

From the newly-established diagrams of the global energy balance under clear-sky and all-sky conditions, we quantify the cloud radiative effects not only at the TOA, but also within the atmosphere and at the surface.

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