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The global mean energy balance under cloud-free conditions

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A long standing problem of climate models is their overestimation of surface solar radiation not only under all-sky, but also under clear-sky conditions (Wild et al. 1995, Wild et al. 2006). This overestimation reduced over time in consecutive model generations due to the simulation of stronger atmospheric absorption. Here we analyze the clear sky fluxes of the latest climate model generation from the Coupled Model Intercomparison Project Phase 5 (CMIP5) against an expanded and updated set of direct observations from the Baseline Surface Radiation Network (BSRN). Clear sky climatologies from these sites have been composed based on the Long and Ackermann (2000) clear sky detection algorithm (Hakuba et al. 2017), and sampling issues when comparing with model simulated clear sky fluxes have been analyzed in Ott (2017). Overall, the overestimation of clear sky insolation in the CMIP5 models is now merely 1-2 Wm-2 in the multimodel mean, compared to 4 Wm-2 in CMIP3 and 6 Wm-2 in AMIPII (Wild et al. 2006). Still a considerable spread in the individual model biases is apparent, ranging from -2 Wm-2 to 10 Wm-2 when averaged over 53 globally distributed BSRN sites. This bias structure is used to infer best estimates for present day global mean clear sky insolation, following an approach developped in Wild et al. (2013, 2015, Clim. Dyn.) for all sky fluxes. Thereby the flux biases in the various models are linearly related to their respective global means. A best estimate can then be inferred from the linear regression at the intersect where the bias against the surface observations becomes zero. This way we obtain a best estimate of 247 Wm-2 for the global mean insolation at the Earth surface under cloud free conditions, and a global mean absorbed solar radiation of 214 Wm-2 in the cloud-free atmosphere, assuming a global mean surface albedo of 13.5%. Combined with a best estimate for the net influx of solar radiation at the Top of Atmosphere under cloud free conditions from CERES EBAF of 286 Wm-2, this leaves an amount of 72 Wm-2 absorbed solar radiation in the cloud free atmosphere. The 72 Wm-2 closely match our best estimate for the global mean cloud-free atmospheric absorption in Wild et al. JGR (2006) based on older models and their biases against much fewer direct observation. This indicates that the estimate of global mean solar absorption in the cloud free atmosphere slightly above 70 Wm-2 is fairly robust. In comparison, the global mean solar absorption under all sky conditions was estimated in Wild et al. (2015) at 80 Wm-2 based on the same approach. The difference between the all- and clear-sky absorption represents the cloud radiative effect on the atmospheric absorption, and is thus estimated here to be around 8 Wm-2. This is similar in magnitude to the 11 Wm-2 derived by Hakuba et al. (2017) when averaged over the atmospheric cloud effect determined at 36 BSRN station.

We applied the same methodology also for the longwave fluxes. Thereby we obtained a best estimate for the global mean clear sky downward longwave flux at the Earth surface of 214 Wm-2. Together with a surface and TOA upward longwave flux of 398 Wm-2 and 266 Wm-2, respectively, this leaves an atmospheric longwave divergence under clear sky conditions of 182 Wm-2.

Selected related references:

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