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Assessing the sources of uncertainty in the radiative forcing in atmospheric models

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Radiation imbalances provide the energy that drives large-scale atmospheric circulation and smaller-scale processes which affect our weather. Radiation in weather models is considered in two parts: shortwave radiation from the sun, and longwave radiation, or thermal radiation, from the Earth. Absorbed shortwave radiation is the dominant source of energy input to the Earth's atmosphere and surface. Along with reflected shortwave radiation and emitted longwave radiation, from the surface and atmosphere, it determines the local radiative heating rates.

The uncertainties in local radiative heating rates primarily arise from external factors such as clouds and aerosols. For instance if clouds are missing from the input data to the radiation scheme, the shortwave, longwave and total radiative heating rates will be incorrect. Top-of-atmosphere solar irradiance and surface radiative properties determine boundary conditions for the radiative transfer calculations and are also a source of uncertainty. Internal computations in the radiation schemes also cause uncertainties, but to a much lesser extent. These include parametrizations of optical properties, radiative transfer and surface-radiation interactions. Additionally, sub-grid scale assumptions can cause considerable uncertainties. These include assumptions about how multi-level clouds overlap within a grid box, and 3-D radiative effects of clouds and complex surface topographies such as mountains. Finally, the discretization of the equations and input in space and time add to uncertainties.

Here we present a quantitative study of these different uncertainties as assessed using the HARMONIE weather model, the ERA5 reanalysis dataset, and the discrete ordinate radiative transfer solver DISORT. The study puts the relative contributions of each of the uncertainties into perspective.