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The sensitivity of the surface energy budget and hydrological cycle to different forcing agents

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This study investigates the response of the surface radiation budget to different forcing agents, as well as precipitation changes in global climate models.
The impact of human activities on the climate system can be summarized as follows: on the one hand, greenhouse gases warm the oceans and the atmosphere by blocking outgoing longwave radiation, while aerosols have a predominantly cooling effect by scattering incoming shortwave radiation. Both forcings alter the energy budget of the Earth, which reacts through complex feedback mechanisms in order to reach a new equilibrium state. Among all these mechanisms, the ones modifying the processes leading to precipitation formation are of particular interest because human societies as well as ecosystems will likely have difficulties to adapt to changing precipitation patterns.
Therefore, in order to better understand the sensitivity of the hydrological cycle to different forcing agents, a set of idealized transient simulations with a fully coupled ocean has been performed with the NCAR CCSM3.5 climate model. First, the model is run with a transient increase of CO2 from 355 ppm up to 710 ppm. Then, to investigate the response of the hydrological cycle to radiative effects of aerosols, the solar constant is transiently increased to reach a radiative forcing that corresponds to a doubling of CO2 (i.e. 3.7 W/m2). In addition, simulations are also performed for CO2 and solar forcings of doubled intensity along with a simulation combining both forcings. This allows for the investigation of potential linear additivity in the response to forcings. Each simulation consists of 5 100-year runs intended to quantify the model internal variability.
The surface energy budget is shown for all simulations on spatial scales ranging from grid point up to global means, with a particular attention to land-ocean and hemispheric differences. Changes in the four components of the surface energy budget (longwave, shortwave, latent and sensible heat fluxes) as a response to the different forcing agents are put in relation with changes in cloud cover, water vapor and precipitation. The hydrological sensitivity is larger for solar forcing compared to CO2 forcing in the global average in agreement with previous studies. However, internal variability appears to dominate the response to the forcing in terms of precipitation at most latitudes.