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The linear additivity of the forcings' responses in the energy and water cycles

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This study investigates the response of the energy and water cycles to different forcing agents in global climate models. Human activities affect the climate system in several ways: 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 triggers responses 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. In order to better understand the sensitivity of the energy and hydrological cycles 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 the linear additivity in the response to forcings. Each simulation consists of 5 100-year runs intended to quantify the model internal variability. First results show that the temperature response to CO2 and solar forcing of the same amplitude is significantly different, which indicates limitations in the definition of radiative forcing. The hydrological sensitivity is also found to be larger for solar forcing compared to CO2 forcing in the global average in agreement with previous studies. Further, the response of most variables does not scale linearly with the forcing for several decades after stabilization. These results have important implications for the scaling of climate change patterns based on simple energy balance models.