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Weak hydrological sensitivity to temperature change over land, independent of climate forcing

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As the global surface temperature changes, so will patterns and rates of precipitation. Theoretically, these changes can be understood in terms of changes to the energy balance of the atmosphere, caused by introducing drivers of climate change such as greenhouse gases, aerosols and altered insolation. Climate models, however, disagree strongly in their prediction of precipitation changes, both for historical and future emission pathways, and per degree of surface warming in idealized experiments. The latter value, often termed the apparent hydrological sensitivity, has also been found to differ substantially between climate drivers.

Here, we present the global and regional hydrological sensitivity (HS) to surface temperature changes, for perturbations to CO_2, CH4, sulfate and black carbon concentrations, and solar irradiance. Based on results from 10 climate models participating in the Precipitation Driver and Response Model Intercomparison Project (PDRMIP), we show how modeled global mean precipitation increases by 2-3 % per kelvin of global mean surface warming, independent of driver, when the effects of rapid adjustments are removed. Previously reported differences in response between drivers are therefore mainly ascribable to rapid atmospheric adjustment processes. All models show a sharp contrast in behavior over land and over ocean, with a strong surface temperature driven (slow) ocean HS of 3-5 %/K, while the slow land HS is only 0-2 %/K. Separating the response into convective and large-scale cloud processes, we find larger inter-model differences, in particular over land regions. Large-scale precipitation changes are most relevant at high latitudes, while the equatorial HS is dominated by convective precipitation changes. Black carbon stands out as the driver with the largest inter-model slow HS variability, and also the strongest contrast between a weak land and strong sea response. Convective precipitation in the Arctic and large scale precipitation around the Equator are found to be topics where further model investigations and observational constraints may provide rapid improvements to modelling of the precipitation response to future, CO_2 dominated climate change.