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Surface radiation governs precipitation responses in transient and equilibrium climates

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Changes in radiative forcing are important not only for their impact on the Earth's temperature but also for their impact on the hydrological cycle. We show that model predictions of an amplified hydrological cycle under higher-CO_2 conditions are well explained by changes in the surface energy budget: increased latent heat export largely balances increased downwelling longwave radiation, primarily due to increased humidity in a warmer atmosphere (see also Wild and Liepert 2010). We demonstrate that similar fundamental radiative adjustments govern global precipitation evolution across models, using twenty different GCMs in the Coupled Model Intercomparison Project phase 5 (CMIP5), purpose-run simulations with a fully-coupled GCM (CCSM3), and a simple one-column climate model (CliMT) with no cloud feedbacks but full representations of radiation, convection, turbulence, and surface ocean-atmosphere interaction. Physically understandable surface energy balance changes explain precipitation evolution in both equilibrium and transient climates (the well-documented "fast" and "slow" responses), in cases with different forcing agents (solar insolation and CO_2), and in geo-engineering simulations where reduced shortwave forcing compensates for increased longwave opacity. We show that the enhancement in precipitation after an increase in radiative forcing is primarily due to the radiative effects of increased water vapor, which in turn produces the similarity in precipitation evolution in solar- and CO_2-forced climates. We also show that differences in precipitation evolution between GCMs are due largely to differences in model shortwave feedbacks. The results of this study suggest that changes in the Earth's hydrological cycle under climate change can best be monitored and understood with surface measurements of longwave and shortwave fluxes, especially in the tropics and subtropics that account for the majority of the global moisture supply.

References

Wild, M. and B. Liepert, 2010: The earth radiation balance as driver of the global hydro- logical cycle. Environmental Research Letters, 5 (2), 025 203.