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Robust influences of superparameterized rainfall variability and intensity on land-atmosphere energetics including soil moisture, surface fluxes, and temperature

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Land-atmosphere coupling energetics can play critical roles in mediating local weather and climate. Interactions at this hydrologic interface impact the availability of freshwater, droughts, floods, and temperature extremes. Predicting how the hydrological cycle will respond to climate change requires a realistic representation of these complex energy exchange mechanisms in global climate models (GCMs). Conventional GCMs suggest that regions of strong coupling (i.e. where local rainfall and soil moisture fluctuations are correlated) will be most sensitive to climate change. However, these models do not capture some forms of organized convection and are known to distort the diurnal character of rainfall over land. Second-order characteristics of rainfall (variability, frequency, timing, and intensity), in addition to time-integrated climatology, can have a significant impact on the hydrologic cycle. They determine whether rainwater infiltrates the soil or runs off the surface and how much water collected on the vegetation canopy is available for re-evaporation.

Here we investigate land-atmosphere interactions in a GCM that explicitly resolves convection, captures organized storms, and improves the diurnal cycle and intensity distribution of rain. In this multi-scale modeling approach called super-parameterization (SP), simplified cloud resolving models are embedded in each grid column of the NCAR Community Atmosphere Model (CAM) to replace conventional parameterizations. SP-CAM captures the broad rainfall intensity distribution and extreme events that are missing in conventional CAM, especially during the mid-latitude summer and in the tropics, exerting a strong influence during the growing season. More intense rainfall reduces canopy interception (and the re-evaporation of rainwater that is often exaggerated in GCMs), increases the rate of rainfall reaching the ground and thus running off the surface, and generally increases the demand on transpiration. As a result, SP-CAM amplifies the Bowen ratio relative to conventional CAM, which is enhanced further with climate change. This amplified Bowen ratio appears to be a robust effect of SP. It is consistent across many regions and model versions with different resolution, cloud microphysics, and land-surface processes, broadening the temperature distribution to include more extreme heat events in SP-CAM.