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A Surface Energy Perspective on Climate Change

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Climate change is often understood in the context of forcings and feedbacks, which are usually quantified from top-of-atmosphere or tropopause radiation fluxes. But understanding how climate change mechanisms impact the surface energy balance, and how this imbalance is restored, is more useful for interpreting hydrological cycle changes. Here we analyze time-dependent climate change from a surface energy perspective. The analysis allows the separation of fast tropospheric adjustments to the climate system and slow climate feedbacks that scale with global temperature change. The framework is illustrated primarily using 2xCO2 climate model experiments and is found to be robust across models. For 2xCO2 the positive downwards radiative component of forcing is smaller at the surface than at the tropopause, and so a rapid reduction in the upwards surface latent heat flux is induced to conserve the tropospheric heat budget; this reduces the precipitation rate. On longer timescales, as global-mean temperature increases, net surface longwave radiation provides a positive surface feedback due to the atmosphere becoming warmer and moisture, while stability is achieved through a strong negative latent heat feedback (which strengths the global hydrological cycle). In comparison the net surface shortwave and sensible heat fluxes change little.

We compare 2xCO2 results to a solar increase experiment and show that some fast responses are forcing dependent. In particular a significant forcing from the fast hydrological response found in the CO2 experiments is much smaller in the solar experiment. The different fast response explains why previous equilibrium studies found differences in the hydrological sensitivity between these two forcings. We find that in contrast to their fast responses, the longer term response to global warming of both surface energy fluxes and the global hydrological cycle are similar for the different forcing agents.