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What the diurnal cycle of precipitation tells us about land-atmosphere coupling strength

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The key attributes of a coupled forecast model are the coupling strengths between the land-atmosphere and ocean-atmosphere schemes. If a model cannot skillfully capture the diurnal cycle of clouds and precipitation, then it likely cannot be expected to yield accurate long-term climate projections. The seasonal drought forecast skill shortfalls of the U.S. NCEP Coupled Forecast System Version 2 (CFSv2) have been directly linked to its unrealistically strong land-atmosphere coupling strength. Most models can be similarly categorized, which is to say, sensitivity to the land physics (i.e. soil moisture constraints on evapotranspiration) is too strong. In nature, the land signal: noise ratio appears to be at a much lower value. Diagnosing land-atmosphere coupling strength requires at a minimum: surface soil moisture state, surface turbulent heat fluxes, and atmospheric moisture and instability. Full-on diagnosis would entail hacking into the code and inserting a number of tracers.

This study addresses the question: What if, given the soil wetness anomaly, model biases in coupling sign and/or strength could be diagnosed from phase shifts in the diurnal precipitation frequency cycle? We use 34-years of output from the North American Regional Reanalysis (NARR) and North American Land Data Assimilation System Phase 2 (NLDAS-2) to investigate the variation in diurnal precipitation frequency cycle between so-called "wet-advantage" and "dry-advantage" coupling regimes over the U.S. southern Great Plains. Wet-advantage occurs when the atmospheric state is closer to the wet adiabatic rate and convection is triggered by a strong increase in the moist static energy from the surface. In contrast, dry-advantage occurs when the atmosphere is drier and the temperature profile is close to the dry adiabatic lapse rate, which favors convection over areas of large boundary layer growth due to high sensible heat fluxes at the surface.

We find that there is a significant difference in the phase of the diurnal precipitation frequency between coupling regimes. Specifically, maximum frequency occurs at 1600 LT and 0500 LT for wet- and dry-advantage samples, respectively. For each of these contrasting regimes, we investigate the relative extent to which diurnal phasing may be attributed to local land—PBL processes versus influences of the Great Plains low-level jet and large-scale atmospheric circulation.