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A modeling and observational framework for diagnosing local land-atmosphere coupling on diurnal time scales

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Land-atmosphere interactions play a crucial role in determining the diurnal evolution of planetary boundary layer (PBL) temperature and moisture states. The degree of coupling between the land surface and PBL must be represented accurately in models, but remains largely unexplored and undiagnosed due to the complex interactions and feedbacks present across a range of scales. Further, uncoupled systems or experiments (e.g., PILPS) may lead to inaccurate water and energy cycle process understanding by neglecting feedback processes such as entrainment. In this study, a framework for diagnosing local land-atmosphere coupling is presented using a coupled mesoscale model with a suite of PBL and land surface model (LSM) options along with observations during field experiment in the U. S. Southern Great Plains. Specifically, the Weather Research and Forecasting (WRF) model has been coupled to NASA's Land Information System (LIS) and provides a flexible and high-resolution representation and initialization of land surface physics and states. Within this framework, the land surface energy balance and mixed layer equilibrium established by each PBL-LSM pair are evaluated in terms of the diurnal 2-meter potential temperature and humidity evolution. Results show how these variables are sensitive to and, in fact, integrative of the dominant processes involved in local coupling, which are then evaluated and quantified through the use of mixing diagrams. In addition, the relationship between maximum PBL height and surface evaporative fraction is indicative of the coupling strength of a given PBL-LSM combination, and is evaluated across a range of soil moisture and vegetation conditions during the study.

The results presented here provide a potential pathway to study factors controlling local land-atmosphere coupling (LoCo) using the LIS-WRF system, which will serve as the foundation for future experiments to evaluate a range of PBL and land surface modeling efforts within the community. Additional studies and testbeds will enable the impact of land surface heterogeneities (e.g., topography, soils, vegetation, and land cover) and the spatial and temporal scales of LSM physics to be assessed in terms of coupling strength and associated convective initiation, cloud, and precipitation processes. Efforts to assimilate satellite observations (soil moisture, temperature, and snow cover) into water and energy cycle prediction systems are also influenced by local coupling, and will be evaluated using the methodology presented here.