Ph.D. Defense Announcement
Aryeh Drager
March 6, 2020 at 1:00 p.m.

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Ph.D. Defense

Friday, March 6, 2020
1:00 p.m.

Defense
ATS Large Classroom (101 ATS)

Post Defense Meeting
Riehl Conference Room (211 ACRC)

Committee:
Susan van den Heever (Adviser)
Christopher Davis (NCAR)
Michael Bell
Wayne Schubert
Michael Kirby (Computer Science)

Response of Convective Cold Pools and Precipitation to Changes in Soil Moisture

In Part 1 of this dissertation, we examine the role of soil moisture in modulating convective cold pool properties. This investigation is performed within an idealized modeling framework that featuring a cloud-resolving model coupled to an interactive land surface model. Five high-resolution simulations of tropical continental convection are conducted in which the initial soil moisture is varied. The hundreds of cold pools forming within each simulation are identified and composited across space and time using an objective cold pool identification algorithm. Several important findings emerge from this analysis. Lower initial soil moisture results in greater daytime heating of the surface, which produces a deeper, drier subcloud layer. As a result, latent cooling through the evaporation of precipitation is enhanced, and cold pools are stronger and deeper. Increased gust front propagation speed, combined with wider rain shafts, results in wider cold pools. Finally, the "water vapor rings" that surround each cold pool under wet-soil conditions disappear under dry-soil conditions, due to the suppression of surface latent heat fluxes. Instead, when soils are dry, short-lived "puddles" of enhanced water vapor permeate the interiors of the cold pools. The results are nonlinear in that the properties of the cold pools in the two driest-soil simulations depart substantially from the cold pool properties in the three simulations initialized with wetter soil. The dividing line between the resulting wet-soil and dry-soil regimes is the permanent wilting point (PWP), below which transpiration is subdued. Land surface-boundary layer-cloud interactions are found overall to play a key role in governing the properties of cold pools.

During Part 1 of this dissertation, we identify a novel "intermediate-soil moisture disadvantage" regime in which soils whose initial liquid water content slightly exceeds the PWP receive the least rainfall. In Part 2, we investigate the physical mechanisms behind this result. Four suites of ten idealized, high-resolution numerical experiments are conducted using the same modeling system used in Part 1. Each suite uses a distinct combination of soil type and vegetation, and within each suite, each simulation is initialized with a different amount of soil moisture. The "intermediate soil-moisture disadvantage" from Part 1 is reproduced. This result is found to stem from differing amounts of subcloud rain evaporation across the simulations, as well as from divergent balances between the level of free convection and the strength of boundary layer vertical motions. However, the result only holds for vegetated surfaces; bare-soil surfaces are instead found to exhibit a pure "wet-soil advantage" relationship. These results have important implications for the design of future process-level studies and large-scale model parameterizations.