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The importance of satellite soil moisture assimilation for low-level jet forecasts

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The U.S. Great Plains low-level jet (LLJ) is active on 26% and 62% of May-September days in the northern and southern Plains, respectively. Characterized by a diurnally-oscillating low-level wind maximum below 700 hPa, large vertical wind shear, and enhanced atmospheric moisture convergence, LLJs have been shown to fuel extreme wind- and precipitation generating mesoscale convective systems. Overall, they explain 30-50% of May-September precipitation in the Plains. The considerable societal impacts of LLJs, which span agriculture, severe weather, and wind energy, have long motivated meteorologist-led investigations into their dynamics and predictability. The sensitivity of LLJs to regional soil moisture gradients was established over thirty years ago. However, it was only recently that our work provided the first estimates of the added-value of satellite soil moisture data assimilation (DA) to LLJ forecasts.

In this presentation, we review and expand upon our previous analysis of 75 NASA Unified WRF LLJ case studies simulated with- and without weakly-coupled NASA Soil Moisture Active Passive (SMAP) soil moisture DA. Of the 75-jet cases, 43 are uncoupled LLJs and 32 are coupled LLJs. Their dynamical classification corresponds with the probable efficacy of land data assimilation. Cyclone-induced coupled LLJs, found in the warm sector of frontal systems, are strongly driven by synoptics and less likely to be influenced by land forcing. Conversely, uncoupled LLJs that occur during quiescent conditions of an anticyclonic high pressure ridge system are likely to be more strongly affected by terrain and soil moisture gradient-induced circulations.

It is shown that SMAP DA is generally more effective in uncoupled LLJ cases. However, significant SMAP DA-induced wind speed differences are noted for both LLJ types at their core and exit regions. Notably, the range of SMAP DA-induced wind speed differences between LLJs of the same class (i.e., uncoupled LLJs) is comparable to the range of differences between LLJs of different classes (i.e., coupled vs. uncoupled). Follow-on analyses presented here address the question of what differs between LLJs with small and large SMAP DA effects. Specifically, we explore attribution of event-scale differences in the added-value of SMAP DA to factors including SMAP spatial coverage, antecedent soil moisture, and the strength of synoptic forcing. Finally, a closer look is given to the verification of jet exit region SMAP DA-induced wind speed shifts using Rapid Refresh.