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The role of soil hydrophysical properties in the atmospheric water cycle

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Soil hydrophysical properties are necessary components in weather and climate simulation; yet, the parameter inaccuracies may introduce considerable uncertainty in the representation of surface water and energy fluxes. The surface fluxes not only affect the terrestrial water and energy budgets, but through land-atmosphere interactions, they can influence the boundary layer, atmospheric stability, moisture transports, and regional precipitation characteristics. This study uses seasonal coupled simulations to examine the uncertainties in the North American atmospheric water cycle that result from the use of different soil datasets. Two soil datasets are considered: State Soil Geographic dataset (STATSGO) from the United States Department of Agriculture and Global Soil Dataset for Earth System Modeling (GSDE) from Beijing Normal University. Each dataset's dominant soil category allocations differ significantly at the model's resolution (15 km). It is found that large coherent regional discrepancies exist in the assignments of soil category, such that, for instance, in the Midwestern United States (hereafter, Midwest), there is a systematic reduction in soil grain size. Because the soil grain size is regionally biased, it allows for analysis of the impact of soil hydrophysical properties projected onto regional scales.

The two simulations are conducted from June 1–August 31, 2016–2018 using the Weather Research and Forecasting Model (WRF) coupled with the Community Land Model (CLM) version 4. It is found that in the Midwest, where the soil grain size decreases from STATSGO to GSDE, the GSDE simulation experiences reduced mean latent heat flux (–15 W m^{-2}), and increased sensible heat flux (+15 W m^{-2}). The differences in fluxes lead to differences in low-level specific humidity and 2-m temperature. The boundary layer thermodynamic structure responds to these changes resulting in differences in mean CAPE and CIN. In the GSDE simulation, there is more energy available for convection (CAPE: +200 J kg^{-1}) in the Midwest, but it is more difficult to access that energy (CIN: +75 J kg^{-1}). Furthermore, a reduction in low-level moisture generates a similar reduction in column-integrated moisture (i.e., precipitable water), resulting in conditions that are less conducive for precipitation.

Interestingly, the soil-texture-related surface fluxes are not confined to thermodynamic influence, but their influence extends to dynamic fields as well. Differences in the vertically-integrated wind field suggest a weakening of the continental low-pressure system (i.e., denoted by a reduction in cyclonic rotation) co-located with the decrease in latent heat flux in the Midwest. The associated

vertically-integrated moisture fluxes mirror the dissimilarities in the wind fields. Consequently, the moisture fluxes yield differences in vertically-integrated moisture flux convergence in the same region, as well. This combination of thermodynamic and dynamic variable differences culminates in a reduction of average precipitation in the Midwest, which can be related to changes in the placement of soil hydrophysical properties via soil texture. Through land-atmosphere interactions, it is shown that soil parameters can affect each component of the atmospheric water budget.