Supplemental Material

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The Role of Soil Texture in Local Land Surface–Atmosphere Coupling and Regional Climate
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Supplementary Material

Comparison of WRF/CLM simulations with Livneh et al. (2015)

Land surface models are particularly challenging to validate. In situ measurements often fall short in scale or duration. Quantities such as evapotranspiration (ET) are not directly measurable and are strongly dependent on parameterization schemes. On the other hand, soil moisture (SM) is considered a model-specific index (Koster, 2009). Nevertheless, it is relevant for a study that does not employ any model calibration to be validated in its quality and realism. To do so, we will provide a comparison of the free-running WRF/CLM simulations used in this study to the long-term mean of a calibrated simulation reported by Livneh et al. (2015).

The Livneh et al. (2013) dataset is publicly available. It is a long-term, gridded dataset of surface meteorological observations and hydrologically-consistent land surface estimates. In 2015, Livneh et al. (2015, hereafter L15) expanded this dataset to include Mexico, the conterminous US (CONUS), and southern Canada at 1/16^{o} spatial resolution (~6 km) from 1950–2013. L15 used the Variable Infiltration Capacity (VIC) land surface model (Liang et al. 1994) forced with the gridded surface meteorological data. VIC parameters were obtained from Livneh et al. (2013), who validated major river discharges over the CONUS region. The resulting calibrated and hydrologically-consistent dataset represents a reliable estimate of land surface states over the region of interest. It is thus suitable for WRF/CLM validation.

The WRF/CLM simulations are compared to the 2003–2013 averaged L15 dataset in terms of ET and normalized SM. Fig. S1 shows the spatial patterns in ET (Figs. S1a, c, e) and the normalized SM (Figs. S1b, d, f) over the Mississippi River Basin. The ET maps reveal very similar patterns, with a gradient in values increasing from west to east, with maximums in all three maps approaching, and in few cases exceeding, 4.5 mm day^{-1}. There is a slight westward shift in higher values in L15 than the model simulations, but overall these products are very similar.

Directly comparing soil moisture is not possible because the VIC and CLM models' structures, equations, and parameters are not the same. Therefore, the comparison is focused on normalized total column soil moisture. Simple linear normalization is used, given by:

$$x_{norm} = \frac{x - x_1}{x_{99} - x_1},$$

Each model is normalized to its own range of values, reducing the dependence on parameters and structure. x_{99}, in this case, is the 99th percentile value of x, and x_1, is the first percentile. The use of percentiles reduces the impact of statistical outliers in determining the normalization range.

It is evident that throughout the Midwest, the two CLM simulations (Figs. S1b, and S1d) are relatively moister compared to L15. The differences in soil moisture could be due to many reasons not to be discussed here. For instance, they could be the result of summer irrigation throughout the midwestern agriculture belt, or they could be an artifact of the years chosen for climatology. Regardless, the WRF/CLM simulations are similar to L15 in the overall pattern—increased wetness throughout the Midwest, a similar gradient as in the ET maps, leading to reduced relative wetness in the high plains along the Front Range of the Rocky Mountains.

The temporal evolution of both ET and normalized SM is assessed using monthly-averaged values over the Mississippi River Basin (Fig. S2). The values of ET (Fig S2a) indicate that the WRF/CLM simulations are quite similar to each other and also similar to the L15 ET values. In more than half of the sub-basins and in the full Mississippi River Basin, the difference between a WRF/CLM simulated ET and L15 ET is smaller than the difference between the two WRF/CLM simulations themselves (See Table S1). These results suggest that the range of values portrayed by the WRF/CLM simulations is reasonable, as defined by the L15 climatology.

The time series of normalized total column SM yields a somewhat different story. The model simulations are very similar to each other, suggesting that the soil texture categorization plays only a small role in normalized full column soil moisture. In all instances in Fig. S2b, the model simulations are more relatively moist than the L15 SM. The normalized scale, according to Eq S1, is limited to values between about 0 and 1. Therefore, the differences between the models and L15 are about 15–20% of the normalized moisture range. These percentagewise differences between WRF/CLM SM and L15 SM are larger than what is shown in the ET analysis.

In conclusion, the unconstrained WRF/CLM model simulations, contrasted to a constrained and validated dataset, produce reasonable ET values in terms of spatial structure, multi-year basin-averages, and monthly time series. Evaluation of normalized SM is more challenging because values are model-specific. Nevertheless, comparing multi-year averages and monthly time series reveals that the differences in relative moisture are on the order of 10–15% of the wetness range.

References

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Figures

Figure S1: Assigned top-layer soil categories for (a) WRF-USGS, (b) WRF-GSDE and (c) the seven most common transitions, as well as associated soil hydro-physical properties: Extractable water (d) for WRF-USGS, (e) WRF-GSDE, and (f) the differences (e - d); and the b-parameter (g) for WRF-USGS, (h) WRF-GSDE, and (i) the differences (h – g).

Figure S2: Timeseries of (a) basin-averaged, monthly ET [mm day^{-1}], and (b) basin-averaged normalized full column soil moisture [%] for (blue) WRF-STATSGO, (red), WRF-GSDE, and (black) L15 mean over the Mississippi River Basin. Solid colored lines are for the 2016 period, dashed lines represent 2017 and dash-dotted line indicate 2018. The solid black line represents L15 average for each variable (2003–2013).

Tables

Table S1: Shows the basin-averaged ET [mm day^{-1}] over the JJA 2016–2018 period for WRF-STATSGO, and WRF-GSDE, and for the JJA 2003–2013 for Livneh. It also shows the basin-averaged normalized full column soil moisture [%] over the JJA 2016–2018 period for WRF-STATSGO, and WRF-GSDE, and for the JJA 2003–2013 for Livneh. Arkansas, Ohio, Missouri, Upper Mississippi, and Lower Mississippi are sub-basins that constitue the Full Mississippi River Basin.

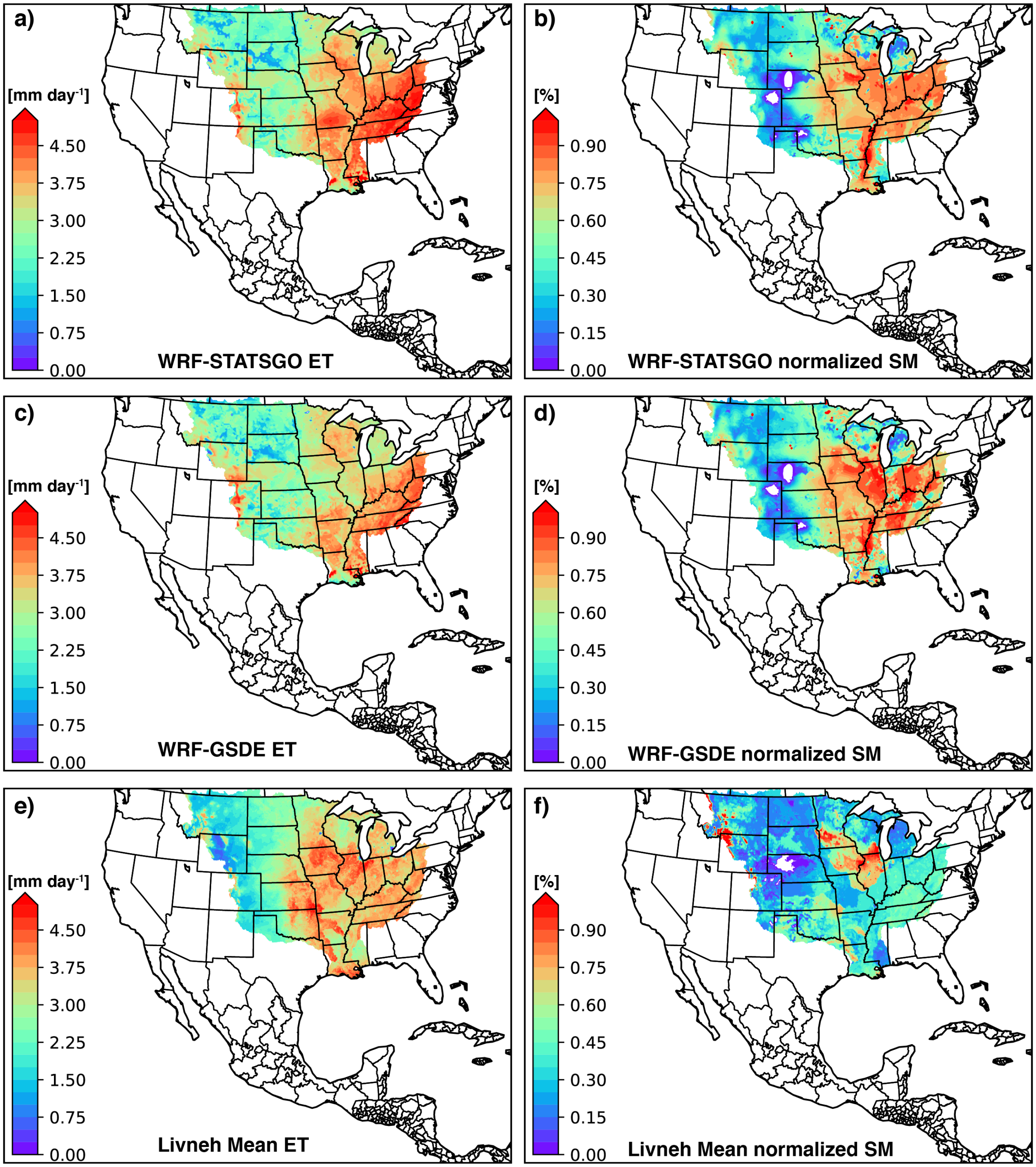
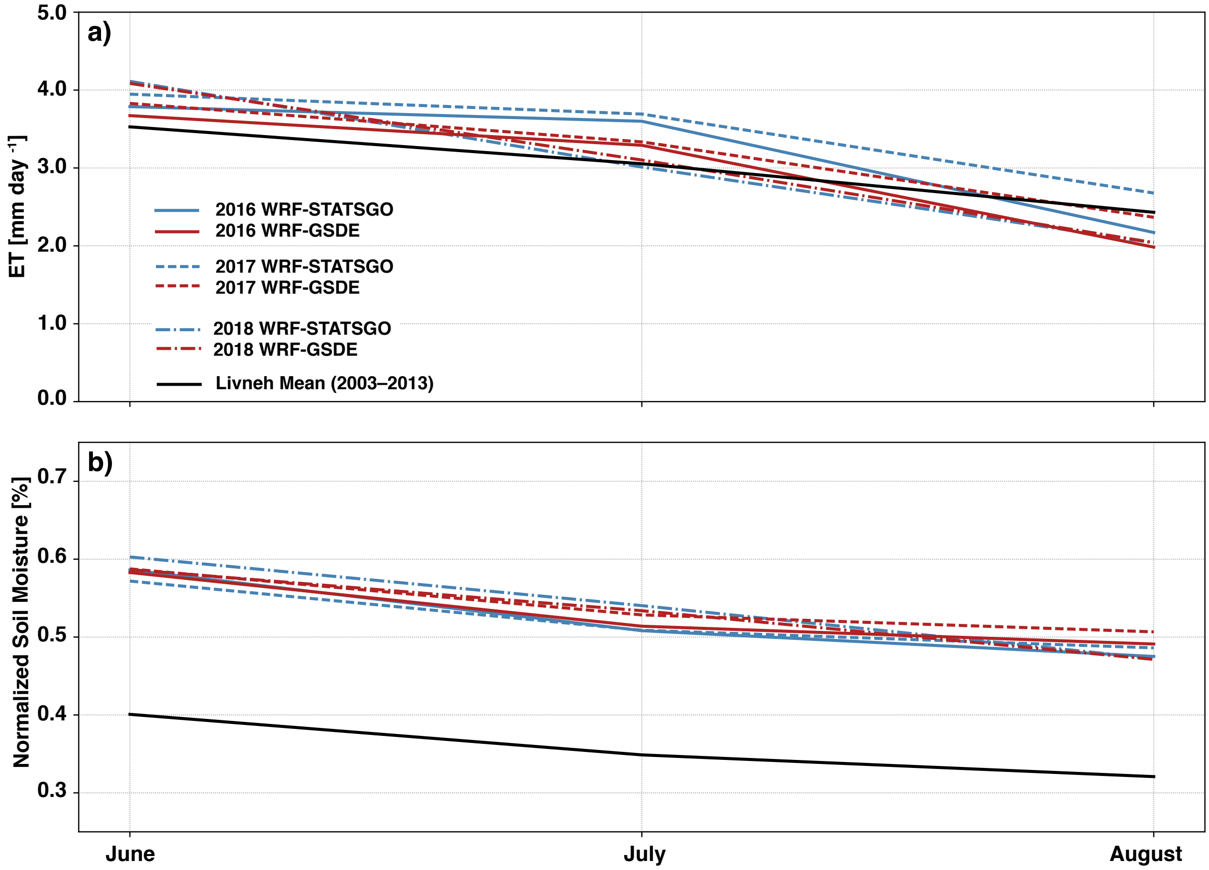


Figure S1: Left column shows the multi-year JJA-averaged evapotranspiration [mm day^{-1}] for (a) WRF-STATSGO (2016–2018), (c) WRF-GSDE (2016–2018) and (e) L15 (2003–2013). The right column shows normalized full column soil moisture [%] for (b) WRF-STATSGO (2016–2018), (d) WRF-GSDE (2016–2018) and (f) L15 (2003–2013).



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Basin-averaged Evapotranspiration [mm day^{-1}]			
Basin Name	**WRF-STATSGO**	**WRF-GSDE**	**Livneh (2003–2013)**
Arkansas	3.01	2.86	2.79
Ohio	4.36	3.91	3.71
Missouri	2.61	2.58	2.39
Upper Mississippi	3.25	3.11	3.41
Lower Mississippi	4.04	3.80	3.57
Full Mississippi	3.23	3.07	3.00
Normalized Full Column Soil Moisture [%]			
Basin Name	**WRF-STATSGO**	**WRF-GSDE**	**Livneh (2003–2013)**
Arkansas	0.500	0.520	0.337
Ohio	0.670	0.645	0.524
Missouri	0.551	0.545	0.227
Upper Mississippi	0.541	0.561	0.334
Lower Mississippi	0.598	0.661	0.389
Full Mississippi	0.538	0.549	0.356