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Ensemble Data Assimilation to Characterize Surface-Layer Errors In Numerical Weather Prediction Models

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Experiments with the single-column implementation of the Weather Research and Forecasting mesoscale model provide a basis for deducing land-atmosphere coupling errors in the model. Coupling occurs both through heat and moisture fluxes through the land-atmosphere interface and roughness sub-layer, and turbulent heat, moisture, and momentum fluxes through the atmospheric surface layer. This work primarily addresses the turbulent fluxes, which are parameterized following Monin-Obukhov similarity theory applied to the atmospheric surface layer. By combining ensemble data assimilation and parameter estimation, the model error can be characterized. Ensemble data assimilation of 2-m temperature and water vapor mixing ratio, and 10-m wind components, forces the model to follow observations during a month-long simulation for a column over the well-instrumented ARM Central Facility near Lamont, OK. One-hour errors in predicted observations are systematically small but non-zero, and the systematic errors measure bias as a function of local time of day. Analysis increments for state elements nearby (15-m AGL) can be too small or have the wrong sign, indicating systematically biased covariances and model error. Experiments using the ensemble filter to objectively estimate a parameter controlling the thermal land-atmosphere coupling show that the parameter adapts to offset the model errors, but that the errors cannot be eliminated. Results suggest either structural error or further parametric error that may be difficult to estimate. Experiments omitting atypical observations such as soil and flux measurements lead to qualitatively similar deductions, showing potential for assimilating common in-situ observations as an inexpensive framework for deducing and isolating model errors. We finish by presenting recent results from a deeper examination of the second-moment ensemble statistics, which demonstrate the effect of assimilation on the coupling through the stability function in the atmospheric surface layer scheme.