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Ensemble data assimilation of screen-level observations across the atmosphere-land interface enhanced by fingerprint operators

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The sensible heat flux and evapotranspiration couple the atmospheric boundary layer and the land surface together. It was shown that screen-level observations like the 2-metre-temperature contain information about land surface parameters such as the soil moisture. As model biases and parametrizations normally causes problems in operational land surface data assimilation, such screen-level observations are assimilated into the soil moisture with simplified data assimilation methods. Here, we will take another point of view onto the problem and show a potential of advanced ensemble data assimilation methods.

We ask what would happen, if we would have a perfect model and favorable conditions. With the limited-area TerrSysMP modelling framework, in a COSMO-CLM configuration, we perform idealized twin experiments for a seven-day period, where all differences between runs are only due to initial soil conditions or data assimilation. We assimilate sparsely-distributed and synthetic 2-metre-temperature observations from a nature run into the soil moisture. In these idealized experiments, we are able to prove that a localized ensemble transform Kalman filter, as similarly used for operational data assimilation in the mesoscale, can directly assimilate hourly instantaneous screen-level observations without the need of an additional optimal interpolation step. Here, we improve the soil moisture analysis by up to 50% compared to our open-loop run without data assimilation. Furthermore, taking temporal dependencies within a 24-hour window during the correction step into account and using a 4DEnVar-like localized ensemble Kalman smoother improves the analysis by a further 10%.

The approximation of the vertical covariances by the ensemble can nevertheless induce an overconfidence of the analysis, especially in ensemble smoothers where more observations are assimilated at once. Then, the potential of the observations cannot be fully used. An idea to circumvent such problems is to assimilate observational features instead of the raw observations to make the data assimilation problem simpler. We can explicitly construct such features by making use of characteristic fingerprints within the observations that point towards errors within the variable of interest; we term them fingerprint operators. Here, we will show two fingerprint operators for the 2-metre-temperature: the averaged temperature between 6 UTC and 18 UTC and the amplitude of a sine curve, fitted to 2-metre-temperature observations in a 24-hour

window. These fingerprints represent that the soil moisture influences the daytime temperature and the diurnal cycle of the 2-metre-temperature. With these features, we retain useful information about the soil moisture and obtain similar results to the localized ensemble Kalman smoother. As our idealized experiments have by construction favorable conditions for ensemble Kalman smoothers, these results indicate a potential for fingerprint operators in coupled data assimilation across the atmosphere-land interface.