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Mesoscale ensemble sensitivity analysis for predictability studies and observing network design in complex terrain

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Ensemble sensitivity analysis (ESA) is emerging as a viable alternative to adjoint sensitivity. Several open issues face ESA for forecasts dominated by mesoscale phenomena, including (1) sampling error arising from finite-sized ensembles causing over-estimated sensitivities, and (2) violation of linearity assumptions for strongly nonlinear flows. In an effort to use ESA for predictability studies and observing network design in complex terrain, we present results from experiments designed to address these open issues.

Sampling error in ESA arises in two places. First, when hypothetical observations are introduced to test the sensitivity estimates for linearity. Here the same localization that was used in the filter itself can be simply applied. Second and more critical, localization should be considered within the sensitivity calculations. Sensitivity to hypothetical observations, estimated without re-running the ensemble, includes regression of a sample of a final-time (forecast) metric onto a sample of initial states. Derivation to include localization results in two localization coefficients (or factors) applied in separate regression steps. Because the forecast metric is usually a sum, and can also include a sum over a spatial region and multiple physical variables, a spatial localization function is difficult to specify. We present results from experiments to empirically estimate localization factors for ESA to test hypothetical observations for mesoscale data assimilation in complex terrain. Localization factors are first derived for an ensemble filter following the empirical localization methodology. Sensitivities for a fog event over Salt Lake City, and a Colorado downslope wind event, are tested for linearity by approximating assimilation of perfect observations at points of maximum sensitivity, both with and without localization. Observation sensitivity is then estimated, with and without localization, and tested for linearity.

The validity of the linearity assumptions, and the role of sampling error associated with potentially weak correlations, are largely unknown for smaller and faster scales. We analyze the validity of linearity assumptions for both the fog event and downslope wind event.

Experiments use the Data Assimilation and Research Testbed (DART) and up to 96 WRF ensemble members. Domains of 36-12-4 km and 12-4-1.33 km for the fog and downslope wind case, respectively, allow for comparison between the events and across scales.