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The role of ensemble-based statistics in variational assimilation of cloud-affected observations from infrared imagers

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Effective assimilation of cloud-affected radiance observations from space-borne imagers, with the aim of improving cloud analysis and forecasting, has proven to be difficult. Large observation biases, nonlinear observation operators, and non-Gaussian innovation statistics present many challenges. Ensemble-variational data assimilation (EnVar) systems offer the benefits of flow-dependent background error statistics from an ensemble, and the ability of variational minimization to handle nonlinearity. The specific benefits of ensemble statistics, relative to static background errors more commonly used in variational systems, have not been quantified for the problem of assimilating cloudy radiances.

A simple experiment framework is constructed with a regional NWP model and operational variational data assimilation system, to provide the basis understanding the importance of ensemble statistics in cloudy radiance assimilation. Restricting the observations to those corresponding to clouds in the background forecast leads to innovations that are more Gaussian. The number of large innovations is reduced compared to the more general case of all observations, but not eliminated. The Huber norm is investigated to handle the fat tails of the distributions, and allow more observations to be assimilated without the need for strict background checks that eliminate them.

Comparing assimilation using only ensemble background error statistics with assimilation using only static background error statistics elucidates the importance of the ensemble statistics. Although the cost functions in both experiments converge to similar values after sufficient outer-loop iterations, the resulting cloud water, ice, and snow content are greater in the ensemble-based analysis. The subsequent forecasts from the ensemble-based analysis also retain more condensed water species, indicating that the local environment is more supportive of clouds. In this presentation we provide details that explain the apparent benefit from using ensembles for cloudy radiance assimilation in an EnVar context.