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The EnsVar filter: a nonlinear hybrid ensemble/variational filter

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Many data assimilation algorithms have their foundations in linear filtering theory and make a number of assumptions that are not valid in the numerical weather prediction (NWP) context. Nevertheless, these methods have typically worked quite well for synoptic scale assimilation, using traditional observations, where the linear regime of error growth extends over long periods. With increases in computer power it will soon be possible to run operational forecasts at O(1 km) resolution, where the timescales of phenomena of interest, such as convective systems, may be much shorter than the assimilation window. Furthermore, the types of observations that could provide detail on these scales, for example radar, are typically nonlinearly related to the state variables.

In this work we give a few examples to demonstrate the poor performance of quasi-linear assimilation methods in the nonlinear regime. This motivates the development of a new, fully nonlinear filter, based on the ideas of particle filtering. The particle filter consists of a weighted ensemble of forecast states. Observation updates are achieved by simply weighting each ensemble member according to its likelihood given the observation. Such estimates are known to converge to the true distribution in the limit as the ensemble size goes to infinity. Unfortunately, these methods can be very inefficient in high dimensions, with two main difficulties: 1) Increasing weight variance, where all the weight ends up on just one ensemble member, and the other members are redundant. 2) Filter divergence. If the ensemble has diverged from the true state,then each ensemble member is approximately equally unlikely, and the ensemble update essentially ignores the observations. By combining the particle filter with a resampling technique that minimizes a cost function to calculate increments, these problems may be alleviated. This paper will describe the new fully nonlinear filter and present results on its use in idealized systems.