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Forecasting the weather
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The impact of localization and observation averaging for convective-scale data assimilation in a simple stochastic model

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The new generation of kilometre-scale numerical weather prediction models creates new challenges for data assimilation. The models are able to (at least partially) resolve the dynamics of cumulus convection and may potentially benefit from the assimilation of high-resolution data sources like radar. Conventional data assimilation methods can have difficulties in this context because of both the nonlinearity that is associated with the rapid evolution of convective clouds, and the non-Gaussianity of error statistics in a highly intermittent cloud field. Here we propose a simple stochastic model that captures these key characteristics of a convecting atmosphere, and use it to test the performance of some modern data assimilation methods. Convective clouds are represented by a Poisson birth-death process over a spatially extended domain with a prescribed half-life and average density. The random birth and death of clouds gives a nonlinear evolution of the cloud field between observation times, as well as producing spatial intermittency.

In this framework, we evaluate the ETKF (Ensemble Transform Kalman Filter) and SIR (Sequential Importance Resampling) filters, and assess the impact of two strategies to improve their performance and efficiency: localization and observation averaging. In their basic implementations, both filters perform poorly.

The SIR filter rapidly collapses, then very gradually converges to the observations as random perturbations introduced by resampling occasionally improve the analysis.

The ETKF rapidly assimilates the correct locations of convective storms, but has large errors due to creation of spurious clouds by nonlinear amplification of small data assimilation increments.

Localization, i.e. assimilating only local observations to produce the analysis at a given grid point, dramatically improves the performance of the SIR filter, but does not reduce errors in the ETKF.

Observation averaging, i.e. spatially smoothing the observations before assimilation and thus making the distribution more Gaussian, is also effective for the SIR filter, and improves convergence of the ETKF.

Currently we are using a modified shallow water model to test convective interactions (gravity waves).