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On the efficiency of covariance localisation of the ensemble Kalman filter using augmented ensembles

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The ensemble Kalman filter (EnKF) has been successfully applied to a wide range of geophysical systems. However, when the ensemble size is small, ensemble estimates are unreliable, which is why localisation has been introduced. In the EnKF, two types of localisation methods have emerged: domain localisation and covariance localisation. Domain localisation is simple to implement and yields parallelisable algorithms. On the other hand, EnKF algorithms using covariance localisation rely on a single global analysis with a localised background covariance. Their implementation is in general more complex, especially in a deterministic context. At the same time, the ability to assimilate non-local observations becomes increasingly important with the prominence of satellite observations. With domain localisation, non-local observations cannot be assimilated without ad hoc approximations, which limits the accuracy of the analysis.

In this presentation, we discuss the implementation of covariance localisation in the deterministic EnKF using *augmented ensemble* during the analysis step, that is when the ensemble size during the analysis step is larger than during the forecast step. The focus is on two crucial points: the accurate representation of a localised background covariance and the perturbation update. We identify and present two methods. The first is based on a factorisation property and already known in the literature under the term *modulation*. The second relies on *randomised singular value decomposition* and has not been applied in this context. The qualitative properties of both methods are illustrated using a simple one-dimensional covariance model.

For both method, we then derive an ensemble square root Kalman filter with covariance localisation (LEnSRF). We compare the performance of the resulting algorithms using twin simulations of the Lorenz 1996 (L96) model. Finally, we introduce a realistic extension of the LEnSRF that uses domain localisation in the horizontal and covariance localisation in the vertical. Using twin simulations of a multilayer extension of the L96 model, we show that this approach is adequate to assimilate satellite radiances, for which domain localisation alone is insufficient.