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Implications of the form of the ensemble transformation in the ensemble square root filter for nonlinear systems

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Ensemble square root filters (ESRFs) perform a linear transformation of the forecast anomalies that result in matching the analysed covariance with that given by Kalman filter. All possible solutions for the corresponding right-multiplied ensemble transform matrix (ETM) can be represented as a product of the unique symmetric solution by an arbitrary orthonormal mean-preserving matrix. These solutions result in different factorisations of the analysed covariance, but in the case of a linear system all of them indeed result in the same forecast covariance. It is possible therefore to speak about the equivalence between the different ensemble transformations in ESRFs for linear systems.

In nonlinear systems this is no longer true: different solutions will result, generally, in different forecast covariances. In weakly nonlinear systems this difference in the forecast covariance is small; however, it can have accumulating behaviour and therefore can have substantial implications for the performance of the data assimilating system.

This work draws attention to the fact that the outliers in ESRF-based nonlinear systems reported by Lawson and Hansen in 2004 do accumulate gradually and arise only when using the symmetric solution for the ETM or close solutions. They can be easily eliminated by conducting random mean-preserving rotations of the ensemble anomalies in the ensemble space. This is demonstrated by a number of experiments with simple models.