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Sampling errors in ensemble Kalman filtering

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Due to the use of ensembles of limited size and the associated sampling errors, the EnKf gives an analysis that suffers on average from systematic underestimation. This study aims to clarify the theoretical understanding of this problem, which can lead to filter divergence, as well as the performance of solutions proposed in the litterature, such as the double ensemble Kalman filter and covariance inflation.

In order to examine the ability of the Ensemble Kalman filter and the so-called Double Ensemble Kalmen filter (DEnKf) to give stable analyses, we have compared the average value of the error of the ensemble mean and the average value of the analysis error covariance matrix.ăTheoretical expressions for these two are established in terms of the sampling noise in the background error covariance matrix (owing to the finite ensemble), and the number of members. It is shown that the DEnKf may provide a stable analysis, though the optimal number of sub-ensembles is problem-dependent. In light of these analytical results, a simple EnKf method using an expression for the optimal covariance inflation factor giving a stable filter is proposed. The inflation factor is expressed in terms of the ensemble size and the trace of matrices products between the Kalman gain and the background error covariance matrix.

We have performed a series of simulations in a perfect model context with a barotropic model that confirms these analytical results and we have compared the performance of each method. It is found that our expression for the optimal covariance inflation is both effective and relatively inexpensive.