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Reduced rank filtering in chaotic systems using singular vectors

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Enormous state size and chaotic behavior pose serious difficulties for implementing data assimilation techniques in many geophysical systems. Reduced rank filtering algorithms are among the most popular choices for large problems. However, the proper choice of the basis for the reduced rank scheme highly depends on the problem and the dynamical properties of the system. In particular, choosing a basis according to the short term singular vectors of the state transition matrix, which characterize the currently growing modes of the system, enables the filter to capture a significant portion of the structure of the forecast uncertainty.

In this paper, we focus on estimation techniques for chaotic systems. In particular, we propose a quasi-linear filter that operates in the subspace spanned by the singular vectors associated with growing modes. We examine the performance of the singular vector filter on a chaotic Lorenz95 system with 144 state variables, and compare its performance with an Ensemble Kalman Filter with a very large ensemble size. Our results show that as long as the rank reduction space is large enough to capture all of the growing modes, the singular vector filter converges to the EnKF. Additionally, the filter performs equally well in presence and absence of the dynamical noise, and is a suitable algorithm in problems, where the singular vectors may be easily computed via forward and adjoint model integrations.