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A practical scheme of the sigma-point Kalman filter for high-dimensional systems

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While applying a sigma-point Kalman filter (SPKF) to a high-dimensional system such as the oceanic general circulation model (OGCM), a major challenge is to reduce its heavy burden of storage memory and costly computation. In this study, we propose a new scheme for SPKF to address these issues. First, a reduced rank SPKF was introduced on the high-dimensional model state space using the truncated single value decomposition (TSVD) method (T-SPKF). Second, the relationship of SVDs between the model state space and a low-dimensional ensemble space is used to construct sigma points on the ensemble space (ET-SPKF). As such, this new scheme greatly reduces the demand of memory storage and computational cost and makes the SPKF method applicable to high-dimensional systems. Two numerical models are used to test and validate the ET-SPKF algorithm. The first model is the 40-variable Lorenz model, which has been a test bed of new assimilation algorithms. The second model is a realistic OGCM for the assimilation of actual observations, including Argo and in situ observations over the Pacific Ocean. The experiments show that ET-SPKF is computationally feasible for high-dimensional systems and capable of precise analyses. In particular, for realistic oceanic assimilations, the ET-SPKF algorithm can significantly improve oceanic analysis and improve ENSO prediction. A comparison between the ET-SPKF algorithm and EnKF (ensemble Kalman filter) is also tribally conducted using the OGCM and actual observations.