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Reconstructing the Dynamics of the Outer Electron Radiation Belt by Means of the Standard and Ensemble Kalman Filter With the VERB-3D Code

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Reconstruction and prediction of the state of the near-Earth space environment is important for anomaly analysis, development of empirical models, and understanding of physical processes. Accurate reanalysis or predictions that account for uncertainties in the associated model and the observations, can be obtained by means of data assimilation. The ensemble Kalman filter (EnKF) is one of the most promising filtering tools for nonlinear and high dimensional systems in the context of terrestrial weather prediction. In this study, we adapt traditional ensemble-based filtering methods to perform data assimilation in the radiation belts. By performing a fraternal twin experiment, we assess the convergence of the EnKF to the standard Kalman filter (KF). Furthermore, with the split-operator technique, we develop two new three-dimensional EnKF approaches for electron phase space density that account for radial and local processes, and allow for reconstruction of the full 3D radiation belt space. The capabilities and properties of the proposed filter approximations are verified using Van Allen Probe and GOES data. Additionally, we validate the two 3D split-operator Ensemble Kalman filters against the 3D split-operator KF. We show how the use of the split-operator technique allows us to include more physical processes in our simulations and is a computationally efficient data assimilation tool that delivers an accurate approximation of the optimal KF solution, and is suitable for real-time forecasting.