Reanalysis of ring current electron phase space densities using Van Allen Probe observations, convection model, and log-normal Kalman filter

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Nowcast and forecast of ring current electron dynamics are crucial for space weather applications since the elevated fluxes of the ring current electrons may lead to surface charging of satellites that operate in the inner magnetosphere. Physics-based models of ring current electron dynamics contain uncertainties in boundary conditions, electric and magnetic fields, electron scattering rates, and plasmapause and magnetopause locations. The accuracy of the models can be improved by correcting the model predictions given the information obtained from in-situ satellite measurements by means of data assimilation techniques.

The scarcity of in-situ measurements may complicate the application of data assimilation methods for ring current electrons. The effect of data assimilation methods can be localized in time in space due to the multidimensionality of the ring current models and spatial and temporal limitations of spacecraft measurements. In this work, we investigate whether the Kalman filter can be used to improve ring current model predictions given only sparse satellite measurements. We blend the convection part of the four-dimensional Versatile Electron Radiation Belt code with the Van Allen Probe data, using the log-normal Kalman filter. By using synthetic data, we show that the Kalman filter is capable of correcting errors in model predictions associated with uncertainties in electron lifetimes, boundary conditions, and convection electric fields. We demonstrate that reanalysis retains features that cannot be fully reproduced by the convection model such as storm-time earthward propagation of the electrons down to 2.5 Earth's radii. The Kalman filter can adjust model predictions to satellite measurements even in regions where data are not available. Our results demonstrate that data assimilation can improve the performance of ring current models, better quantify model uncertainties, and help us to improve the nowcast and forecast of the dynamics of the particles in the inner magnetosphere.

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