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Ensemble Data Assimilation for Thermospheric Mass Density Specification and Forecasting

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Even though the Earth's upper atmosphere density is tenuous, it is substantial enough to exert significant drag on orbiting spacecraft and debris. The largest uncertainty in low-Earth orbit prediction is aerodynamic drag estimation. Thermospheric mass density variation is the major source of drag estimation errors at altitudes below about 700 km. This paper demonstrates how the limit of predictability of thermospheric mass density variability can be extended by means of ensemble data assimilation.

To assimilate observations of the thermosphere and ionosphere, we use an ensemble data assimilation procedure constructed with the Data Assimilation Research Testbed and the Thermoshere-Ionosphere Electrodynamics General Circulation Model, two sets of community software offered by NCAR. An important attribute of our approach is that the ionosphere-thermosphere coupling is self-consistently treated in both the forecast model and the assimilation scheme. This enables the inference of unobserved thermospheric states from the relatively plentiful observations of the ionosphere. Given the ever-expanding global navigation satellite infrastructure, this is indeed a promising prospect for upper atmosphere data assimilation. Another relevant strategy is using data assimilation to estimate the model forcing parameters that control states of the thermosphere and ionosphere. In comparison to the lower atmosphere, the upper atmosphere is a dissipative, strongly forced dynamical system, so estimation of model forcing parameters can have a dramatic impact on the quality of ensemble forecasting and assimilation of the upper atmosphere.

In this paper, we present results from our ensemble assimilation experiments with thermospheric mass densities obtained from the accelerometer on board the CHAMP satellite, and electron density profiles obtained from the COSMIC/FORMOSAT-3 mission.

Keywords: thermosphere-ionosphere coupling, data assimilation, parameter and state estimation, thermospheric mass density, aerodynamic drag estimation, LEO orbit prediction