Assimilation of high-rate GNSS Observations into a Global Upper Atmosphere Model

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Abstract

The state-of-the-art in upper atmosphere (ionosphere and thermosphere) modelling fuses mathematical models of the system with a disparate set of observations using a variety of data assimilation techniques. The University of Birmingham, UK has developed the Advanced Ensemble electron density (Ne) Assimilation System (AENeAS) which uses a variant of the ensemble Kalman filter to assimilate GNSS, amongst other, observations into a background physics model of the upper atmosphere.

AENeAS is an established model which is currently being made operational at the UK's Met Office Space Weather Operations Centre. To ease the computational cost of the data assimilation process AENeAS, like most upper atmosphere assimilation models, assumes that the observations are independent of each other (the observation covariance matrix, R, is diagonal).

However, increasing amounts of high-rate GNSS observations are becoming available for assimilation which violates this assumption. This includes ~1 Hz streamed observations from the Network Transport of RTCM via Internet Protocol (NTRIP) as well as radio occultation (RO) data from satellite constellations. Ignoring these correlated error statistics results in sub-optimal filter performance.

In this work we demonstrate the effectiveness of implementing an iterative estimation of the observation covariance matrix using statistical averages of the background and analysis innovations. The results of using a diagonal, and non-diagonal, covariance matrix when assimilating GNSS observations are presented with respect to independent observations. The results show that estimating the correlated observation errors helps improve the specification of both electron and neutral densities in AENeAS.