Near Real-Time Estimation of the Ionosphere Using Wavelet-Based Sequential Filters

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The ionosphere which includes the highest density of free electrons in the Earth’s atmosphere has a crucial impact on many Earth observation and communication systems. The electron density distribution within the ionosphere shows a heterogeneous character and the structure of the medium varies with time and location. The ionosphere layer affects the propagation of electromagnetic waves and causes signal delays, since it shows a dispersive behaviour for signals at certain frequencies. The magnitude of the delay depends on the electron content along the ray path.

Many space geodetic techniques, such as GNSS, satellite altimetry and radio occultations, have been used to reveal the structure of the ionospheric density distribution. In Fig. 1, an example of a global distribution of data from GPS, GLONASS and altimetry techniques is shown which provides ionospheric information.

In this context, a wavelet series expansion combined with recursive filtering methods (e.g. Kalman, Unscented Kalman and Ensemble Kalman filters) for assimilating new observations from different techniques seems to be a promising alternative to the classical approach in spherical harmonics to improve the representation of variations within the ionosphere with a multi resolution approach in a near-real time processing framework.

The main objective of this research is to establish a wavelet based recursive filtering system to estimate a 3D ionospheric structure (electron density) on a regional area to obtain high accurate products in near-real time.

To establish this recursive data assimilation framework, some challenges will be investigated which can be summarized as given below:
• Investigation of contributions to the electron density modelling in terms of accuracy and computational efficiency which might be provided by different recursive filtering methods.

• Incorporation of the wavelet based multi resolution analysis into a recursive filtering framework.

• Combination of the measurements with different time delays from various sensors which have essential importance for the real/near-real time estimation problem.

• Selection of proper prediction models to represent temporal variations of ionospheric target parameters for short term and long-term forecasts.

• Ensuring that the system can behave adaptively and robust in case of any severe circumstance, for instance, rapid change of the atmospheric conditions, varying solar activity, and the existence of inaccurate measurements which can affect the quality of the system models.

Fig. 1: Global hourly ionosphere data distribution from GPS (red), GLONASS (green) and altimetry (blue) for the time interval of 07:30h – 08:30h on 05.03.2015

Fig. 2: Example of recursive filtering for ionosphere modelling; comparison of IGS final VTEC products with results of Kalman filtering which make use of hourly GPS data.

References


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