#10 Received 12/09/2014

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Detection and Characterisation of Travelling Ionospheric Disturbances Using a Compact GPS Network

Abstract:
We have developed computationally efficient methods for detecting and characterising Travelling Ionospheric Disturbances (TIDs) and other interesting ionospheric phenomena. Innovative techniques to use GPS data to estimate TID motion, including: building a background fit of complex trends in the behaviour of the ionosphere, preserving wave-like behaviour and eliminating noise; inverting waveform changes to mitigate the effect of satellite motion, and cross correlating receiver sites to correct for specific satellite ephemeris; and pre-processing and intelligently down-sampling data to preserve trends while allowing for smaller computational cost.

The GPS data used to compute the motion estimates is collected by 3 GPS receivers, located in a triangle over a 3km baseline. This receiver configuration is unique, and introduces large amounts of subtlety when cross correlating for receiver positions so close to one another. The compact nature of the Network allows for regular maintenance and update of all sites, which leads to much shorter network down time and a quick correction of any receiver error. More novel concept development came from using the aforementioned data to produce results that preserve the subtleties spatio-temporal features of TIDs. While cross correlating data from the three receiver sites, mitigation had to be made for satellite motion. Each site has a corresponding “pierce point” on the ionosphere, which is the point through which the transmission passes on its way from the satellite to the receiver. These pierce points move with respect to one another as the satellite traverses its ephemeris, and this effect must be allowed for as a time dependant variable, and the received waveform has to be correctly modulated to allow for correct ionospheric measurement. These techniques allow confidence in the accuracy of the measurement of ionospheric behaviour. The next step in the process was to develop an intelligent fitting of the background ionosphere, identifying and modelling the complex diurnal trends. This allows preservation of oscillatory features in observed data, divorcing these from the usual but complex behaviour of the ionosphere.

This has been used in two ways; the development of a TID Identification Index, and in TID motion estimation. The Index is a computationally inexpensive tool for indicating the presence of TID like behaviour. By working from complex modelling and analysis described above, it can reliably suggest the presence of TID behaviour, and is an intuitive indication of unexpected phenomena. TID motion estimation is a more complex field, but progress has been made. The clarity offered by the background fitting and ephemeris-aware cross-correlation means that oscillatory behaviour in the Ionosphere can be reliably observed, and as such TID motion can be estimated for comparatively little computation power. Using this, TIDs moving over the UK on a daily basis have been characterised, with regular TIDs travelling in a south-east direction with a speed usually around 100 m/s. Due to the computational efficiency of this innovative solution, these observations have been shown to be relatively constant over many months of observed data, from multiple satellites.