A Study of Traveling Ionospheric disturbances and Their Associated Scintillation Behaviors at South Pole

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Summary Paper

TIDs are the large scale electron density perturbations that travel in the ionosphere and can be tracked by number of instruments, like incoherent scatter radar, ionosondes, HF Dopler system etc.. They are believed to be the signature of atmospheric gravity wave in the high latitude ionosphere, which are generated due to geomagnetic activities [1].

A new method for analyzing the travelling ionospheric disturbances (TIDs) is developed by using two B-spline basis functions of degree 4 on the total electron content (TEC) data from the ground-based global positioning system (GPS) receivers. This method enhances the spatial resolution to about 0.1° (geographic latitude) x 0.1° (geographic longitude), which is useful in studying all scale (small, medium and large) TIDs. We investigated TIDs and their associated scintillation on 18-19 July 2013 at South Pole and found phase scintillation is more sensitive than the amplitude scintillation to the TIDs. To see the full impact of TIDs over scintillation, we have used proxy phase scintillation index, calculated using geodetic GPS receivers over Antarctica. We have verified the presence of TIDs during these two days by using GNSS-TEC single station approach. Our results show the hidden TEC gradients are the core producer of the ionospheric scintillation. TIDs shape, their elongation and flattening along/across the corrected geomagnetic latitude, directly affect the magnitude and occurrence of ionospheric scintillation indices. Magnetospheric particle precipitation boost hidden TEC gradients and generate stronger amplitude scintillation, however, large scale plasma irregularities cause overall enhancement in magnitude of the phase scintillation index. Due to the high turbulence in the polar ionosphere, TIDs change their shapes quite quickly and/or may disappear in the background ionosphere. B-spline TIDs analysis method is very useful in identifying the visible as well as hidden TIDs parts in the polar ionosphere.

A time series data trend shows some gradual change in the data property over the data interval, however, detrending is a statistical technique for removing a feature thought in the relationship of interest, which is difficult to understand. We have detrended the TEC data using MATLAB 2015 detrending subroutine. Travelling Ionospheric Disturbances (TID) and smoothed TEC are computed by the following formula

$$TIDs(lat, lon) = \sum_{i=60}^{i=90} \sum_{j=-180}^{j=180} \mathrm{Mean(detrended\_TEC)} * \mathrm{N(lat)}_{i,4} \mathrm{M(lon)}_{j,4} \quad (1)$$

$$Smoothed\_TEC(lat, lon) = \sum_{i=60}^{i=90} \sum_{j=-180}^{j=180} \mathrm{Mean(TEC)} * \mathrm{N(lat)}_{i,4} \mathrm{M(lon)}_{j,4} \quad (2)$$

Input detrended TEC data have been averaged for 1° (geographic latitude) X 1° (geographic longitude) resolution. $N_{i,4}$ and $M_{j,4}$ are B-spline basis function for degree 4. B-spline techniques are best for splitting the data for the preferred interval as they preserve the local trend of the data and avoid sudden jumps in the data [2]. The present TID analysis method is capable of generating TEC data for 1/10th resolution of the available input data. Therefore, B-spline technique analyzed TIDs are about 0.1° (geographic latitude) X 0.1° (geographic longitude) resolution. This means that the model analyzed TIDs may have dimensions, less than 50 X 50 kilometers, consequently, we are able to track small to large scale travelling ionospheric disturbances.

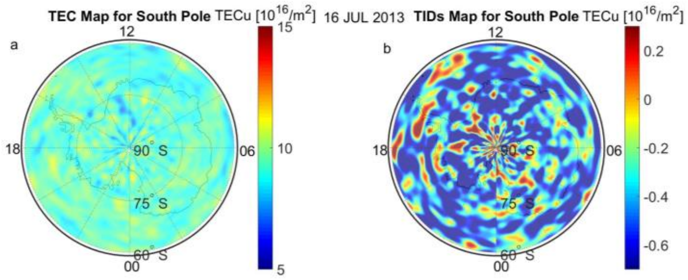

Figure 1. An example of smoothed TEC and B-spline method calculated TIDs map for South Pole on 16 JULY 2013, (a) median filtered (~0.1) smoothed GPS TEC map; (b) B-spline technique calculated TIDs map.

Figure 1, shows an example of the GPS TEC (Figure 1a) and B-spline model calculated TIDs (Figure 1b) on 16 July 2013 for South Pole. These maps are in the CGM LAT (corrected geomagnetic latitude) and MLT (magnetic local time). Bottom of each map represents magnetic midnight while the top represents magnetic noon. The magnetic time circulates in an anticlockwise direction on the maps. This is the full diurnal map of the geomagnetic quiet day (data shown in Figure 2). Figure 1a has been created using the smoothed TEC data calculated using the equation (2) and the resolution of the map is 0.1° (CGM LAT) X 2 minutes (MLT). In this figure the regions of enhanced TEC are quite ambiguous. On the other hand Figure 1b have been created using equation (1) have the same time and space resolution but it brings out the clear picture of regions having a high plasma density or so called TIDs. In Figure 1b we see post magnetic noon enhanced plasma density, magnetic dawn, dusk asymmetry, enhanced plasma density near the magnetic-mid-night auroral oval at ~70-75° S CGM LAT. We also see the enhanced plasma density at the magnetic South Pole for all the MLT. This is an illustrative example which reveals well the capability of our TIDs calculation method. Further, we will use this technique for the case study presented in this paper.

References

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