OBSERVATION OF TEC PERTURBATION ASSOCIATED WITH MEDIUM SCALE TRAVELLING IONOSPHERIC DISTURBANCE AT THE BRAZILIAN SECTOR

JONAH O.F., E.A. KHERANI, E.R. DE PAULA

This paper was prepared for presentation during the 14th International Congress of the Brazilian Geophysical Society held in Rio de Janeiro, Brazil, August 3-6, 2015.

Abstract

Using Total Electron Content (TEC) data obtained from GNSS data over the Brazilian region, we investigate two-dimensional structures of Medium-Scale Travelling Ionospheric Disturbances (MSTIDs). Our analyzed data are taken from -55°W to -45°W and -30°S to -20°S for the geomagnetic quiet days of 5 (D5), 6 (D6), 26 (D26), 27 (D27) December 2011 during daytime between 12–17 UT. A new method is applied to derive the perturbation component of TEC, by subtracting average TEC at one location as a function of time from a polynomial best fit of TEC at that location. Consequently, by computing the cross-correlation of the perturbation TEC with change in space-time, we observe the manifestations of MSTIDs characteristics like, velocity, direction of propagation, wavelength etc. Since gravity wave is the principal daytime MSTIDs mechanism, we investigate a possible connection between the observed MSTIDs and Gravity waves by analyzing the temporal variation of the height (h) of the F region over a low-to-mid-latitude station of Cachoeira Paulista, (-45°W, 22°S, dip latitude 16.9° S). This method reveals a maximum correlation between these two parameters suggesting an enhancement of gravity wave activity during the time when MSTIDs were observed.

Introduction

Medium-Scale Traveling ionospheric disturbances (MSTIDs) are generally the ionospheric manifestation of gravity waves propagating in the neutral atmosphere, which travel through the ionosphere over very long distance (Hines, 1960). They are wavelike perturbation of the ionospheric plasmas that are frequently observed at high and middle latitudes (Bristow et al., 1996, Oliver, et al., 1997). Their activities and amplitudes vary depending on latitude, longitude, local time, season, and solar cycle (Kotake, et al., 2006). The MSTIDs have horizontal wavelength corresponding to λ_h < 1000 km, amplitude of 10% of TEC and propagating velocities of 50 - 200 m/s with periods of 10 - 60 minutes, but they are not geomagnetic storm dependent. MSTIDs can also be generally grouped into two main groups: daytime and nighttime MSTIDs. While nighttime MSTIDs are usually characterized with F region irregularity occurrences, the daytime MSTIDs are not associated with them (Ogawa et al., 2009).

Although there have been many studies of MSTIDs using all-sky imager over Brazilian region (Pimenta et al., 2008, Candido et al., 2008, Amorim et al., 2011) none of these studies have shown the plasma perturbation using TEC obtained from GNSS data. In this study, we introduce new methodologies for the determination of MSTIDs and reveal several characteristics of daytime MSTIDs (e.g. new MSTID amplitude up to 1 TECU, and NE propagation directions) over the Brazilian region.

Method

Since MSTIDs are wavelike perturbation of the ionosphere (Bristow et al, 1996, Oliver, et al., 1997, and Nicolls, et al., 2005), perturbation TEC *(ΔTEC)* was derived by taking TEC best fit *(TEC_{fit})* in space (latitude or longitude) and time and subtracting it from the mean of absolute TEC as represented in the equation (1):

$$\Delta TEC = \overline{TEC} - TEC_{fit}(x,t) \qquad (1)$$

where $\overline{TEC} = \dfrac{\sum_{i=1}^{N} TEC_{i(t)}}{N}$, *i* represents each latitude or longitude for all time and *N* is the total number of *i*. Furthermore, we determine the MSTIDs propagation by using the ΔTEC obtained above, by finding the product of change in space and time and normalizing by dividing by square of ΔTEC (which we referred to as cross-correlation in space changed) according to equation (2):

$$MSTID_{PROP} = \frac{\Delta TEC(x,t) \times \Delta TEC(x+\Delta x, t+\Delta t)}{(\Delta TEC)^2} \qquad (2)$$

where $MSTID_{PROP}$ is the propagation, *x* is the space (in longitude or latitude) and (Δx, *t*) is change is space with time.

Results

The following features were observed from our results (A) ΔTEC disturbance oscillates in time at a chosen location with periods covering between 30-60 minutes, (B) the phase of the oscillation shifts in time while going towards equator and eastward, (C) corresponding cross-correlations maximize sometime during 13-16 UT depending on the day, (D) the maxima are observed to commonly shift towards equatorward/eastward with time, (E) these cross-correlation maxima shifts longer and last longer in latitude than in longitude. Qualitatively, similar features are noted during other days of 6, 26 and 27. Noteworthy quantitative differences are the following: (F) maximum amplitudes of ΔTEC disturbances are largest on D5 and lowest on D26, (H) maximum cross-correlation occurs more towards eastward on D5-D6 while occurs more towards westward on D26 -D27.

Conclusions

In the present study, we document MSTIDs over Southern hemisphere during four days, 5-6 and 26-27 December 2011, by using the GNSS network. We examine the spatial-temporal distributions of Total Electron Content (TEC) during 12-17 UT and covering the ionospheric domain 30–20^{o}S latitude and 45–55^{o}W longitude.

For the TEC data, we derive the ΔTEC disturbance by subtracting the TEC from corresponding best fitted (TEC_{fit}) obtained using polynomial fit of order 5.
This fitting is done in time and the temporal variation of ΔTEC is derived at several locations within the ionospheric domain to generate the keogram of TEC. Furthermore, cross-correlation keograms of these spatially distributed ΔTEC are obtained in latitude and longitude.
These keograms suggest that the ΔTEC disturbances acquire the wave characteristics during 13-16 UT that propagate equatorward/eastward having S-N wavelength in 500-800 km range and W-E wavelength in 200-400 km range. These characteristics classify these ΔTEC disturbances as MSTIDs resembling the MSTIDs characteristics widely reported over Northern hemisphere. These are the novel outcomes of the present study which were not reported during daytime over Southern hemisphere.

Acknowledgments

TEC data were collected from the Brazilian Network for Continuous Monitoring (RBMC/IBGE) stations (http://www. ibge.gov.br/home/geociencias/). Jonah O.F. and E.R. de Paula world like to acknowledge the supports from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) under process 133429/2011-3 and 305684/2010-8 grants respectively. E.A. Kherani is grateful to FAPESP under process 2011/21903-3. The authors also acknowledge Dra. Inez S. Batista for the Digisonde data.

References

Amorim, D. C. M., A. A. Pimenta, J. A. Bittencourt, and P. R. Fagundes (2011),
Long term study of medium scale traveling ionospheric disturbances using O I 630
nm all sky imaging and ionosonde over Brazilian low latitudes, J. Geophys. Res.,
116, A06312, doi:10.1029/2010JA016090.

Bristow, W. A. and R. A. Greenwald (1996), Multiradar observations of medium-scale acoustic gravity waves using the Super Dual Auroral Radar Network, *J. Geophys. Res.*, 101, 24499–24511

Candido, C. M. N., A. A. Pimenta, J. A. Bittencourt, and F. Becker-Guedes, (2008), Statistical analysis of the occurrence of medium-scale traveling ionospheric disturbances over Brazilian low latitudes using OI 630.0 nm emission all-sky images, Geophys. Res. Lett., 35, L17105, doi:10.1029/2008GL035043.

Hines, C. O., (1960), Internal atmospheric gravity waves at ionospheric heights, Can. *J. Phys.*, 38, 1441–1481.

Kotake, N., Y. Otsuka, T. Tsugawa, T. Ogawa, and A. Saito (2006), Climatological
study of GPS total electron content variations caused by medium-scale traveling ionospheric disturbances, *J. Geophys. Res.*, 111, A04306, doi:10.1029/2005JA011418.

Kotake, N., Y. Otsuka, T. Tsugawa, T. Ogawa, and A. Saito, (2007), Statistical study of medium-scale traveling ionospheric disturbances observed with the GPS networks in Southern California, *Earth Planets Space*, 59, 95–102.

Ogawa, T., N. Nishitani, Y. Otsuka, K. Shiokawa, T. Tsugawa, and K. Hosokawa (2009), Medium-scale traveling ionospheric disturbances observed with the Super DARN Hokkaido radar, all- sky imager, and GPS network and their relation to concur- rent sporadic-E irregularities, *J. Geophys. Res.*, 114,A03316, doi:10.1029/2008JA013893.

Oliver, W. L., Y. Otsuka, M. Sato, T. Takami, and S. Fukao, (1997), A climatology of F-region gravity wave propagation over the middle and upper atmosphere radar, J. *Geophys. Res.* 102, 14499– 14512.

Pimenta, A. A., M. C. Kelley, Y. Sahai, J. A. Bittencourt, and P. R. Fagundes (2008), Thermospheric dark band structures observed in all-sky OI 630 nm emission images over the Brazilian low-latitude sector, *J. Geophys. Res.*, 113, A01307, doi:10.1029/2007JA012444.