EXPERIMENTAL AND SIMULATION STUDY OF GEOMAGNETIC CONJUGATE DAYTIME MSTIDS MAPPING USING GNSS-TEC DATA AND SAMI3 MODEL

JONAH O.F[1]., E.A. KHERANI[1], E.R. DE PAULA[1], JOE HUBA[2]

1-National Institute for Space Research (INPE)

2-Naval Research Laboratory, USA.

Abstract

The Total Electron Content (TEC) obtained from a network of GNSS data over Brazilian sector is used to investigate two dimensional structure of geomagnetic conjugate Medium-Scale Travelling Ionospheric Disturbances (MSTIDs) mapping. We analyzed data taken from 60°W to 45°W and 20°S to 0°S for 4 geomagnetic quiet days of 17, 18, 27 28 of December 2014 between 12–17 UT. The propagation direction of the MSTIDs is equatorward/eastward at both hemispheres. It is believed that the source of the MSTIDs could be from either hemisphere (south or north) and mapped to the conjugate hemisphere. SAMI3 model is used to investigate the mechanism responsible for the daytime MSTID mapping. Our results show electric field involvement in the MSTIDs mapping to conjugate hemisphere. The model results show good agreement with the experiment results.

Introduction

Some recent literatures have shown geomagnetic conjugate observation and explained the responsible mechanisms during nighttime, [e.g. Otsuka et al. (2004)]. Otsuka et al. (2004) reported simultaneous observation of MSTIDs at geomagnetic conjugate points using a 630 nm all-sky CCD imager at Sata (northern hemisphere) and at Darwin (southern hemisphere). They showed that MSTIDs at Darwin propagated northwestward at almost same velocity as the MSTIDs observed at Sata. The amplitudes of the airglow intensity perturbations were approximately 20% and 40% of the background at Sata and Darwin, respectively which could imply that the MSTIDs were generated at Darwin and mapped to Sata.

In order to investigate polarization electric field involvement of the MSTID structures between the northern and southern hemispheres, Otsuka et al. (2004) mapped Darwin images from southern hemisphere into the northern hemisphere along the geomagnetic field lines using the International Geomagnetic Reference Field 2000 model (IGRF2000). The eastern part of the airglow images from both Darwin and Sata were superimposed, thereby allowing the two band-like structure of high and low airglow intensities on one side to be smoothly connected to those on the other side of the image. As a consequence, it was evident that the band-like structure over northern hemisphere (Sata) corresponded well with those mapped along magnetic field lines from the southern hemisphere (Darwin).

Huba et al. (2015) also presented a 3-D simulation study of conjugate ionospheric MSTID effects associated with the Tohoku-Oki tsunami of 11 March 2001during nighttime period. Using the SAMI3/ESF, they run a simulation of tsunami-driven gravity wave. It was noted that even though the tsunami driven gravity wave disturbance is in the northern hemisphere, its effects could be observed at the conjugate southern hemisphere because the tsunami induced electric field mapped to the conjugate region on the Alfvenic time scales.

In this research, for the first time over the Brazilian sector, we study the daytime geomagnetic conjugate MSTIDs mapping using observation results and explain the mechanism responsible through simulation results using the SAMI3 model.

Method

TEC disturbance *(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 times 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):

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

(a)

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

Applied Perturbation

The gravity wave perturbation is given as a sinusoid perturbation in the region of interest (magnetic latitude = -15° to -10°). First, we perturb the background density ($\tilde{n}$) with $\tilde{n} \Rightarrow e^{i(k_y\hat{y}+k_x\hat{x}-wt)}$, run the model and obtain the data. Secondly we applied the same perturbation ($\tilde{\upsilon} \Rightarrow e^{i(k_y\hat{y}+k_x\hat{x}-wt)}$) to the meridional wind component (v). The background and the perturbation terms in both cases can be represented as:

$$n \Rightarrow n_o + \tilde{n}$$

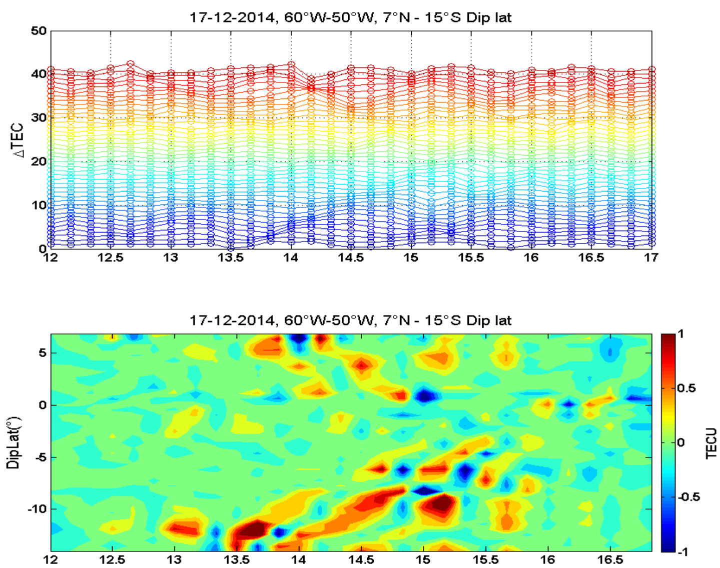
$$\upsilon \Rightarrow \upsilon_o + \tilde{\upsilon}$$

These perturbations are similar to Duly et al. (2014) and Huba et al. (2015). TEC was synthetically generated by integrating vertically the electron density (n_e) from the altitudes of 250 km to 450 km:

$$TEC = \int_{250km}^{450km} n_e \, dh$$

Results

Experimental result



Figures 1 (top and bottom panels) present the derived TEC disturbances from the GNSS measurements during quiet geomagnetic conditions (Kp ≤ 3) on 17, December 2014 during 12-17 UT.

It is possible to clearly observe the TEC perturbation as a result of electric field perturbation mapping to the conjugate hemisphere. Jonah et al. (2016) presented the main important characteristics of daytime MSTIDs.

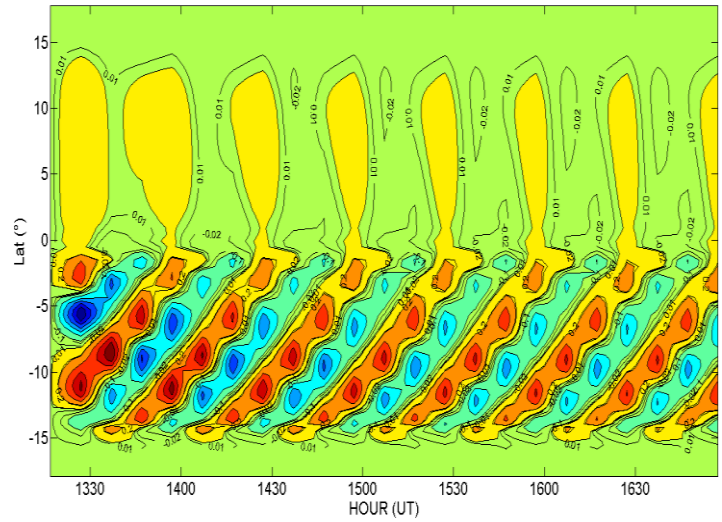


Figure 2: Meridional neutral wind perturbation run obtained by taking the difference in the integrated electron density at current time from initial time.

From Figure 2 it is possible to observe the MSTID mapping to the northern hemisphere. This occurs as a result of the wind induced electric that is mapped along the along magnetic field line, which is reasonably modeled in SAMI3.

Conclusions

- We observed daytime MSTIDs mapping for the first time over the Brazilian sector using the GNSS-TEC data.
- It seems that the MSTIDs events originated in the southern hemisphere are mapped to the conjugate hemisphere.
- Using the SAMI3, we investigated the wind induced electric field involvement of MSTIDs mapping to opposite hemisphere.

Acknowledgments

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References

DULY, T. M; HUBA, J. D; MAKELA, J. J. Self-consistent generation of medium-scale traveling ionospheric disturbances (MSTIDS) within the sami3 numerical model, **Journal of Geophysical Research**, v. *119*, p. 6745–6757, doi:10.1002/2014JA020146, 2014.

HUBA, J. D; DROB, D. P; WU, T. W; MAKELA, J. J. Modeling the ionospheric impact of tsunami-driven gravity waves with SAMI3: Conjugate effects, **Geophysical Research Letter**, v. *42*, p. 5719–5726, doi:10.1002/2015GL064871, 2015.

Jonah, O. F, E. R. de Paula, E. A. Kherani, S. L. G. Dutra, R. R. Paes (2014), Atmospheric and ionospheric response to stratospheric sudden warming of January 2013, *J. Geophys. Res*., 119, doi:10.1002/2013JA019491.

OTSUKA, Y; SHIOKAWA, K; OGAWA, T; WILKINSON, P. Geomagnetic conjugate observations of medium-scale traveling ionospheric disturbances at midlatitude using all-sky airglow imagers, **Geophysical Research Letter**, 31, L15803, doi:10.1029/2004GL020262, 2004.