International Civil Aviation Organization

THE THIRD MEETING OF IONOSPHERIC STUDIES TASK FORCE (ISTF/3)

15 – 17 October 2013, Seoul, Republic of Korea

국토교통부
Ministry of Land, Infrastructure and Transport

Agenda Item 3: Review of status of States' activities

LONGITUDINAL VARIATIONS IN TEC AT LOW LATITUDES

(Presented by India)

SUMMARY

India had shared its results and information related to ionospheric studies for GAGAN during the previous Meetings of Ionospheric Study Task Force (ISTF) held at Tokyo, Japan, and Bangkok, Thailand in 2012. Continuing with this trend, the present paper brought out a newly discovered phenomenon of equatorial ionization anomaly albeit in east-west direction (longitudinal).

The recent published results demonstrate the formation of four peaks of EIA crest around the globe at same local time commonly known as wavenumber-4 structure. These four peaks are formed at West Africa, East Asia, Central Pacific Ocean and South America i.e. at around a longitudinal separation of ~90°. Out of these four, the peak at East Asia (90°-100° E) is observed to be more enhanced.

India has studied its existence using the ground based GPS receivers and found the longitudinal gradient over the zone of 70-95° E. The local time, seasonal and solar cycle dependency on the longitudinal variations of TEC at crest of EIA has been studied.

It is proposed to extend this study further using data from farther east locations in order to characterize this phenomenon which may be useful in developing the region specific iono model for SBAS/GBAS.

1. INTRODUCTION

1.1 It has been recently observed through satellite based measurements that low latitude ionosphere forms a global wavenumber- 4 longitudinal structure with same local time reference. That means the Equatorial Ionospheric Anomaly (EIA) crests are enhanced over West Africa, East Asia, Central Pacific Ocean and South America i.e. at around a longitudinal separation of ~90 degrees [1; 2]. The peak over East Asia is more enhanced compared to other 3 peaks in the wavenumber-4 structure of low latitude ionosphere.

1.2 The continuous TEC measurements under GAGAN project from 2004 to 2012 over Indian low latitude region along the upward slope of this peak, i.e. in the longitude range of ~70-95° E, are utilized to study the existence of longitudinal variability and its morphology. The TEC data from 5 stations which lie in anomaly belt i.e. Ahmedabad (23.02^0 N, 72.51^0 E), Bhopal (23.28^0 N, 77.34^0 E), Raipur (21.18^0 N, 81.74^0 E), Kolkata (22.64^0 N, 88.44^0 E) and Aizwal (23.84^0 N, 92.67^0 E) is analyzed comprehensively in this study.

2. RESULTS OF LONGITUDINAL VARIATIONS

2.1 A qualitative illustration of longitudinal TEC variation in the same local time frame is provided in Figure 1. It shows the longitudinal variation of TEC in 24 hours for the months of January to December, 2012, a moderate solar active year. The *x*-axis and y-axis of figure indicate longitude (70-95° E) and local time (hrs) respectively. The scale of TEC in colorbar is kept the same for each month to delineate the seasonal differences.

2.2 The most prominent and perceivable features in Figure 1 are stronger enhancements in the TEC towards eastern longitudes (~95°E) as compared to western (~70°E) that correlates with the global longitude structure of wavenumber-4. This longitudinal variability is clearly evident in almost all the months but is more pronounced in month of March, April, September and October i.e. the equinoctial months as compared to summer and winter months suggesting a seasonal dependency. Some sort of irregularity can be noticed in month of February as the large enhancement in TEC occurred at 82° E instead of 95^0 E.

3. LONGITUDINAL GRADIENT

3.1 A unique quantitative approach is used to analyze the long term database of 9 years. Since the equatorial anomaly exhibits seasonal and semi-annual variations, the data has been separated into three seasons- equinoctial months (March, April, September and October), Summer solstice (May, June, July and August) and Winter solstice (November, December, January and February).

3.2 Further, the local time is divided into eight bins of three hours each, starting from 00-03 LT to 21-24 LT (e.g. 00-03, 03-06, 06-09, 09-12, 12-15, 15-18, 18-21 and 21-24 LT). Then TEC data for each station is grouped according to LT bins and the mean value of TEC for each bin is computed. Finally, the longitudinal gradient of TEC (slope) in each of the eight LT intervals is calculated using the linear regression method. The sign (positive or negative) and magnitude of slope/gradient describes the presence or absence and also the strength of longitudinal variability respectively. The higher the gradient, stronger is the variability of TEC in the longitude range of 70-95^0 E.

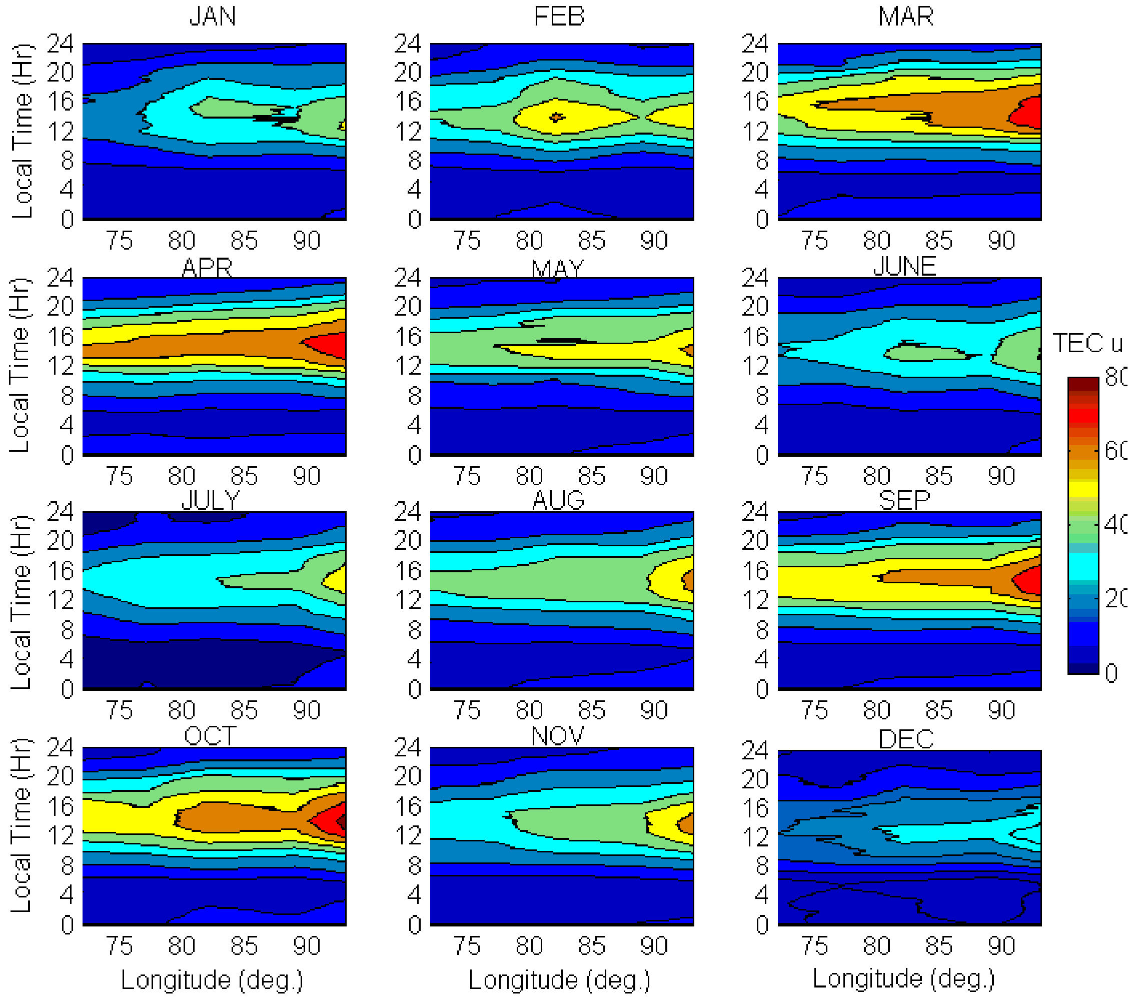

Figure 1: Longitudinal variations of TEC with fixed local time reference in the months of January to December, 2012. The color scale of TEC is same for all the months.

3.3 Figure 2 shows the temporal variation of longitudinal gradient of TEC in Equinox (top panel), Summer (middle panel), and Winter (bottom panel) for 2004-2012. In equinox, the gradient starts increasing at 09-12 LT bin, maximizes at 12-15 LT, then starts decreasing till 15-18 LT bin only to increase again at 18-21 LT bin. It then decreases till 03-06 LT and thereafter, almost vanishes between 03-06 LT to 06-09 LT bins. This means, the longitudinal variation starts to develop at ~09 LT, achieves its maximum strength at 12-15 LT and persists beyond midnight till ~03 LT in equinoctial months. The gradient is positive throughout 2004-2012 during equinox. Its maximum amplitude lies between ~0.3-0.5 TEC/degree at 12-15 LT bin in equinox during 2004-2012 except for an exceptionally higher gradient of 0.9 TEC/degree in 2012.

3.4 Similarly, during summer, the longitudinal variations starts to develop at 09-12 LT bin, maximizes at 12-15 LT bin and persists in night time as well but only for high solar activity period. In low solar activity period; the longitudinal variations start to develop at 12-15 LT and are noticeable only during day time. These features suggest the strong solar cycle dependence.

3.5 In winter, the longitudinal gradient is significant only during day time i.e. between 09-12 LT to 15-18 LT as shown in Figure 2 (bottom panel). The gradient is maximum at 12-15 LT and its magnitude varies between 0.15 to 0.45 TEC/degree. It is even negative during night in some of the years of observation. These results suggest that, in winter, the longitudinal variability persists only during daytime and disappears in night.

4. SUMMARY

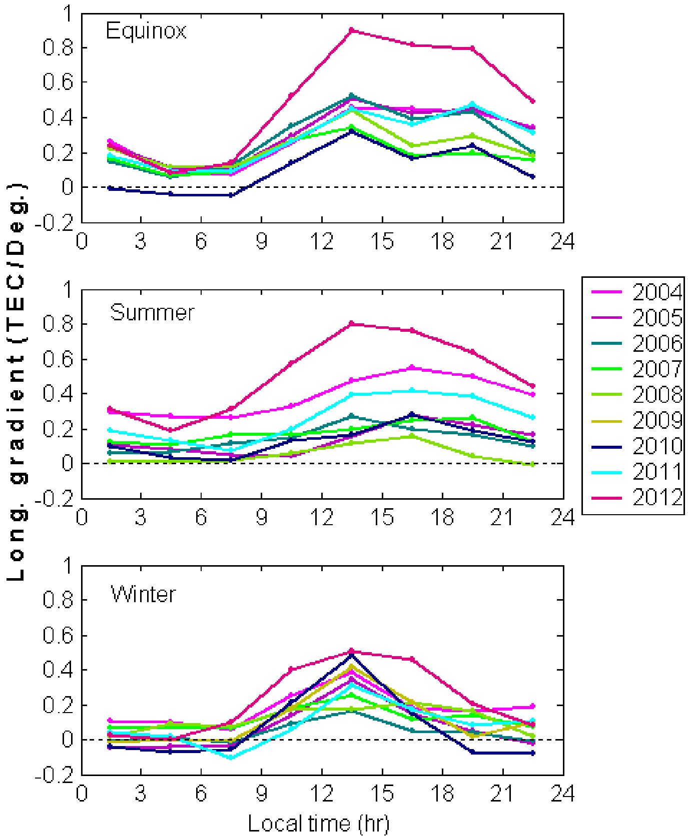

Figure 2: Temporal variation of longitudinal gradient in equinox (top), summer (middle) and winter (bottom). Different colors are used for year 2004-2012. The gradient for each LT bin is obtained by using linear regression line fitting of the data points in each LT bin.

4.1 The longitudinal variations showing gradual enhancement in TEC towards East longitudes with same local time reference is observed in almost all the months of year.

4.2 These variations are more pronounced in daytime compared to nighttime and show a local time as well as seasonal dependency in their evolution.

4.3 The longitudinal gradient i.e. TEC unit/longitude degree is calculated using linear regression method to examine the strength of longitudinal variations. Its strength at 12-15 LT is maximum in the equinox followed by summer and winter. A high value of longitudinal gradient of ~0.9 TEC unit/ degree is observed in 2012 equinox.

4.4 The nonmigrating tides, which are generated by latent heat release due to deep convection in the tropics, are thought to be the main contributor in generating the longitudinal variations along with meridional and zonal winds.

4.5 The results, especially the calculated longitudinal gradient and its morphology, may be useful in developing the ionospheric models over Asia and Pacific region.

4.6 Furthermore, it has been observed that availability of GAGAN service is poor in North-eastern region. One of the possibilities for this degraded performance may be the formation of ionization peak over this region which needs to be addressed properly.

5. ACTION BY THE MEETING

5.1 The meeting is invited to note India's continued support in sharing the results of ionospheric studies for GAGAN.

5.2 A proposal is put forth before the meeting to extend the study on longitudinal variations of TEC using data from farther east locations i.e. beyond 95° E to achieve the objectives of ISTF.

References

[1]. Pedatella, N. M., J. M. Forbes, A. Maute, A. D. Richmond, T.-W. Fang, K. M. Larson, and G. Millward (2011), Longitudinal variations in the F region ionosphere and the topside ionosphere-plasmasphere: Observations and model simulations, *J. Geophys. Res*., 116, A12309, doi:10.1029/2011JA016600.

[2]. Scherliess, L., D. C. Thompson, and R. W. Schunk (2008), Longitudinal variability of low-latitude total electron content: Tidal influences, *J. Geophys. Res*., 113, A01311, doi:10.1029/2007JA012480.

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