Contribution of Neutral Wind and Electrojet to the Dynamics of Equatorial Ionization Anomaly

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Summary: The response of Equatorial Ionization Anomaly (EIA) to the variability of the Equatorial Electrojet (EEJ) and neutral winds in the American low latitude regions is studied using ground based observations . The EEJ strengths are determined using magnetometers and the trans-equatorial neutral wind profile during the day is estimated using Second-generation, Optimized, Fabry-Perot Doppler Imager (SOFDI) located near geomagnetic equator. EIA is calculated using total electron content (TEC) data measured by Global Positioning System (GPS) from the Low-Latitude Ionospheric Sensor Network (LISN). We find that the spatial configuration such as strength, shape, amplitude and latitudinal extension of the EIAs are generally affected by equatorial electrojet. The asymmetries on EIA crests are observed more frequently during solstice than in equinox season. Results also show that meridional neutral winds have a significant effect on generation of the asymmetry on EIA crests as seen through TEC distributions.

PRELUDE

- The electric field together with the unique geometry of the geomagnetic field lines near the geomagnetic equator drives the vertical plasma fountain effect that ultimately creates the equatorial ionization anomaly (EIA) in the low latitude ionosphere. Not only eastward electric field and hence EEJ, but the neutral winds also play a decisive role in controlling the actual configuration of the EIA.

Annual and Day-to-Day Variability of TEC

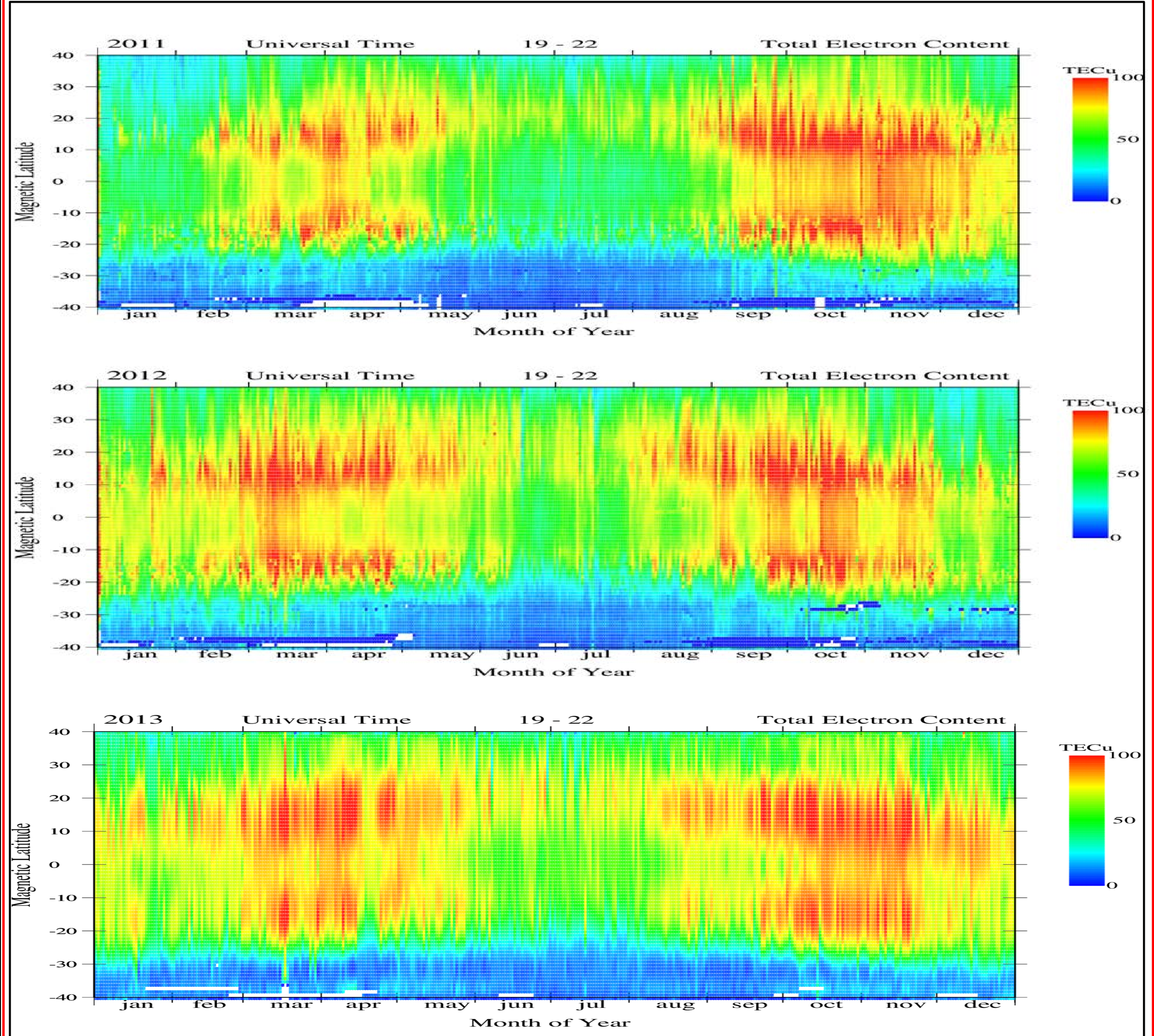


Figure-1: Daily Latitudinal profiles of the EIA of TEC in the western longitudes sector (70°W-80°W) of South America during ascending part of solar activity phase (2011 to 2013) in solar cycle-24. Magnitude of TEC is seen increasing from 2011 to 2013 during both equinox and solstice seasons. It can be seen that anomaly crests are well formed and extended into northern hemisphere on and around June solstice and that into southern hemisphere during December solstice. Most of the asymmetry in anomaly crests are seen during solstice than that of equinox period.

Seasonal EIA Patterns

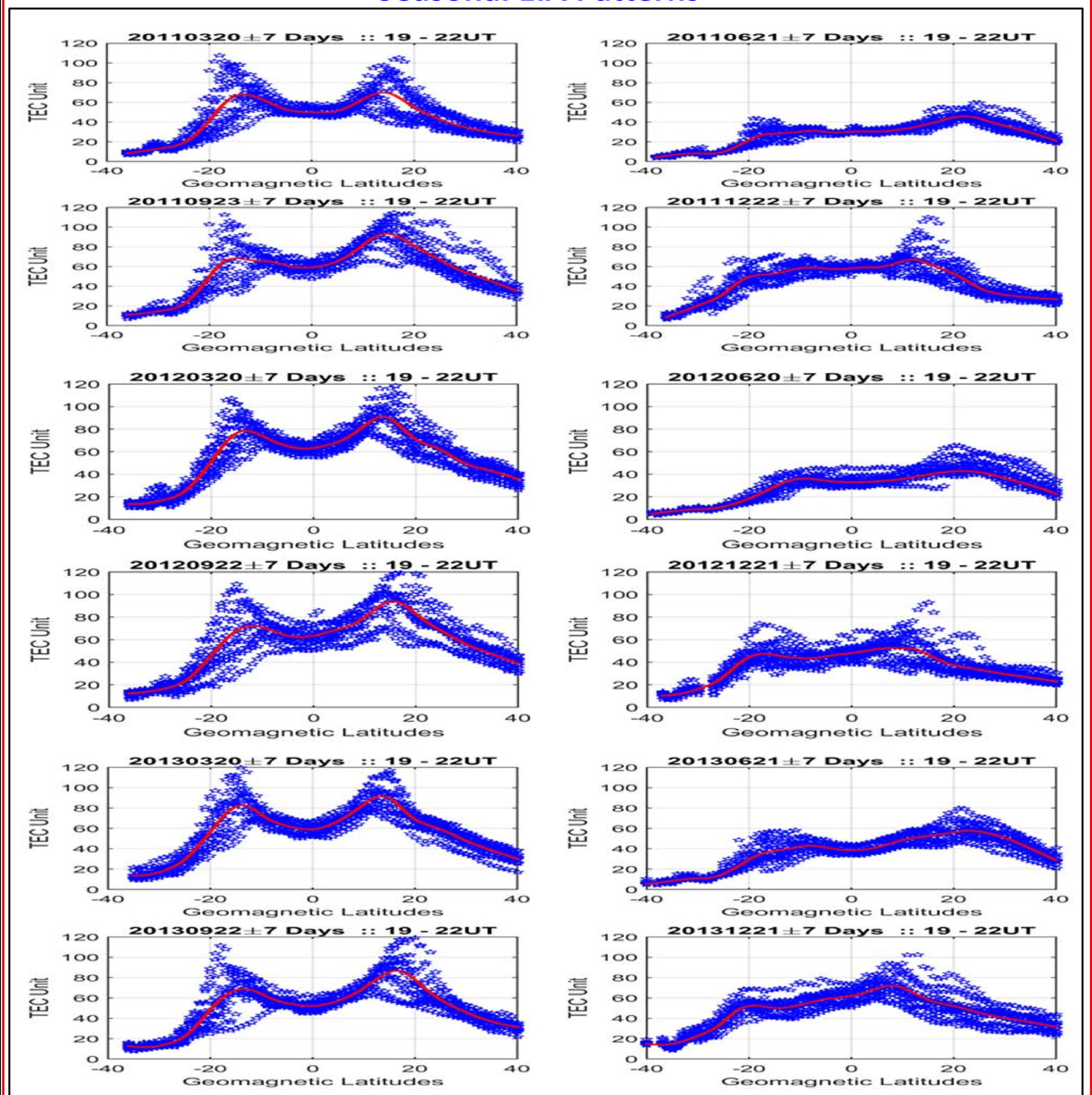
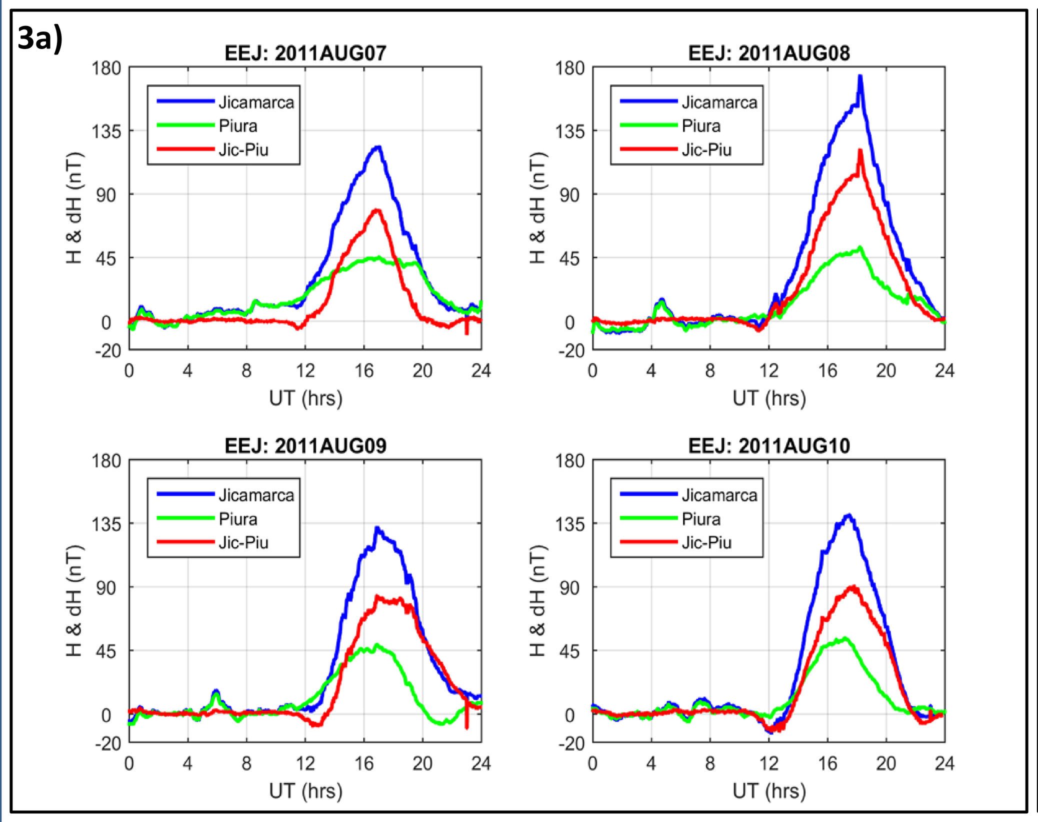
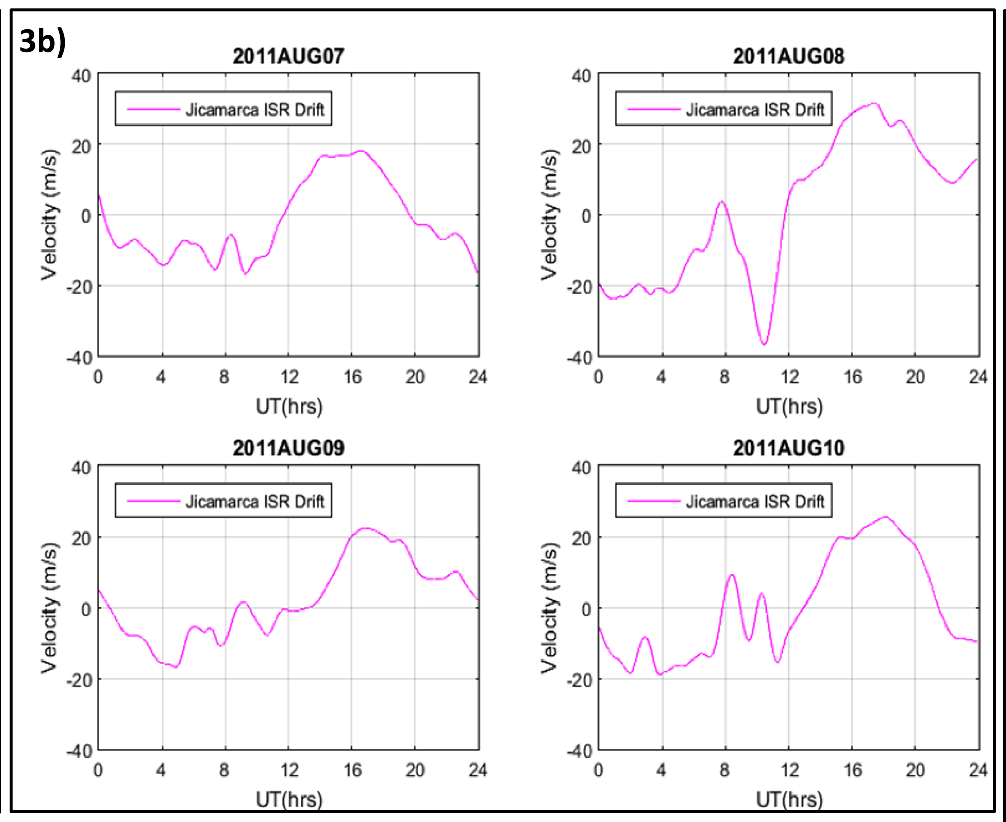


Figure-2: Scatter plots of latitudinal variations of maximum TEC and inferred EIA crests within 70°W-80°W longitudes. The crests were taken exactly ±7 days from equinox (first column) and solstice (second column) days during 19:00-20:00UT interval in 2011 to 2013. The red continuous curve represents average of available maximum TEC in every degree of geomagnetic latitude during geomagnetically undisturbed conditions (K_p < 5). March equinox seasons have purely symmetric EIA crests. During other seasons, they are mostly asymmetric in nature as seen in 3 years TEC distribution patterns.

ANALYSIS & RESULTS

EIA from EEJ Perspectives





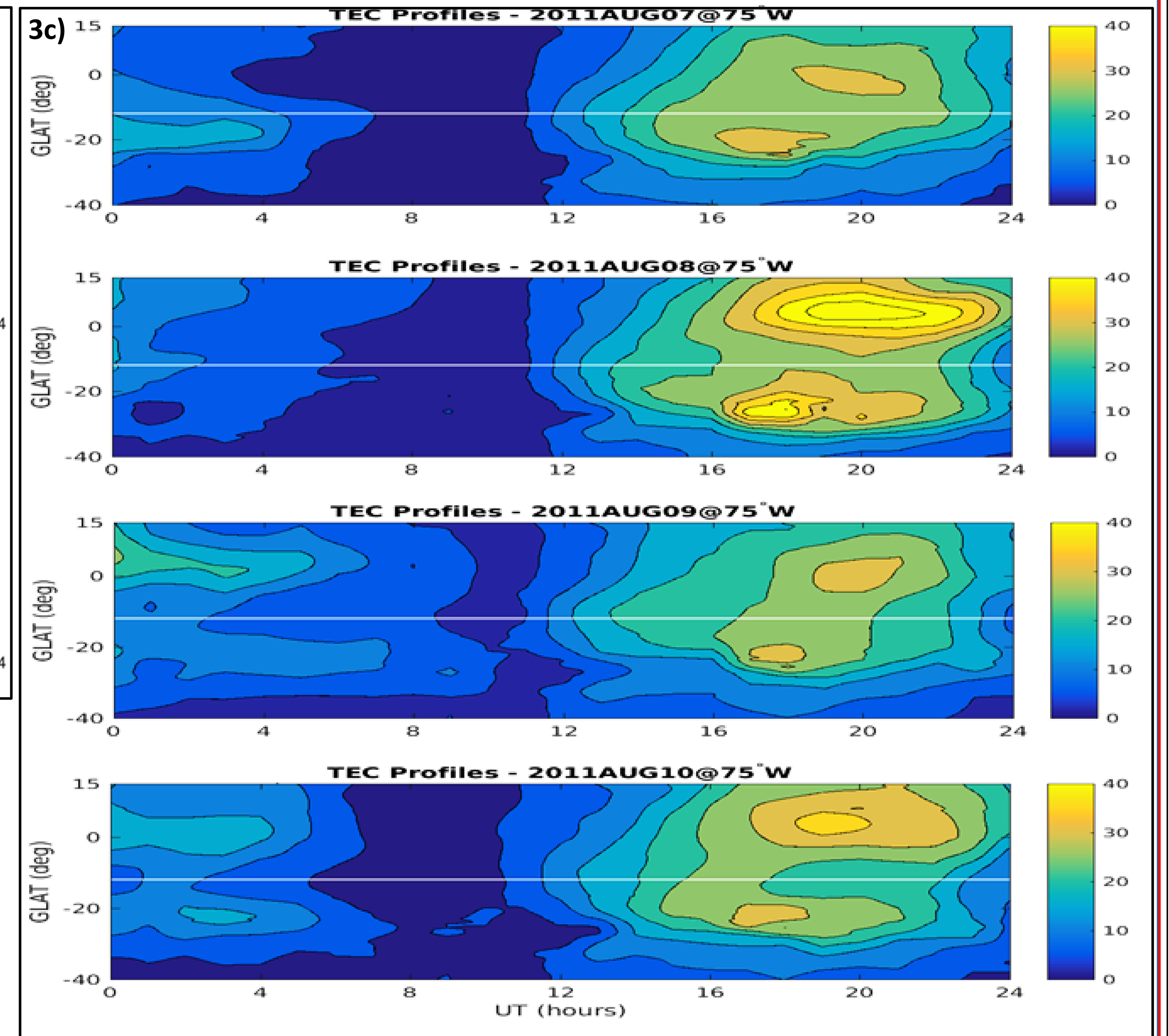


Figure-3:

a) Plots showing normalized earth's H component observed from two magnetometer stations, one located at Jicamarca, an EEJ region (blue) and another at Piura, an off-EEJ region (green). The difference in dH (red) from two magnetometer stations refers noontime enhancement of equatorial electrojet calculated employing *Khadka et al. [2016]* technique which is the proxy of eastward electric field along the geomagnetic equator in the western longitude sector of South America.
b) Plots showing real time measurement of average vertical plasma drift profiles in the ionospheric altitude range 250-400km from Jicamarca incoherent scatter radar (ISR) at geomagnetic equator. Greater drift is followed by higher EEJ and vice versa.
c) Contour plots showing total electron content (TEC) distribution along 75° W longitudes at low latitudes demonstrating equatorial anomaly either side of magnetic equator. The white horizontal line represents the location of the geomagnetic equatorial line. It is seen that strong well separated anomaly crests are corresponding to higher EEJ and greater vertical drift days and vice versa.

EIA from Neutral Wind Perspectives

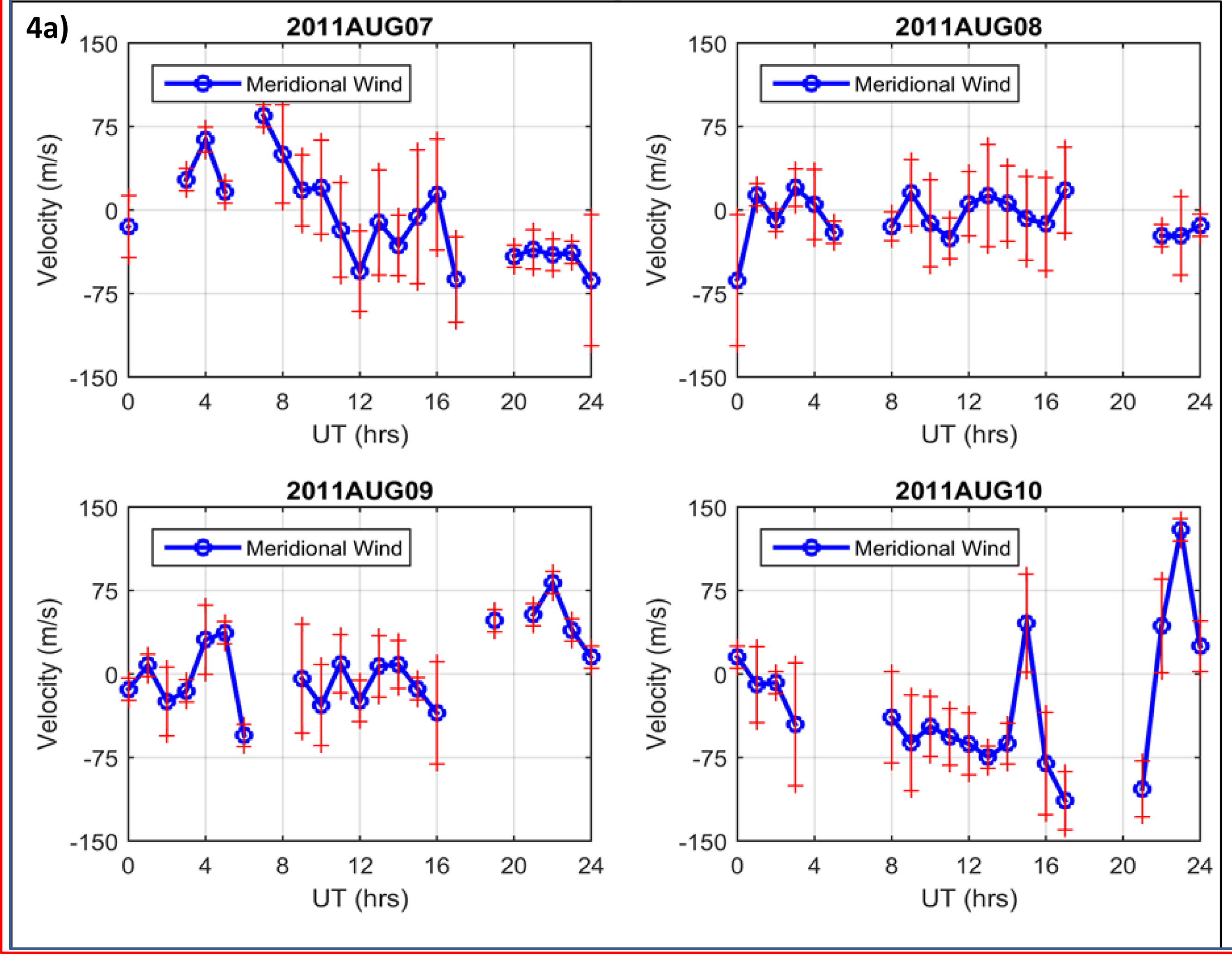
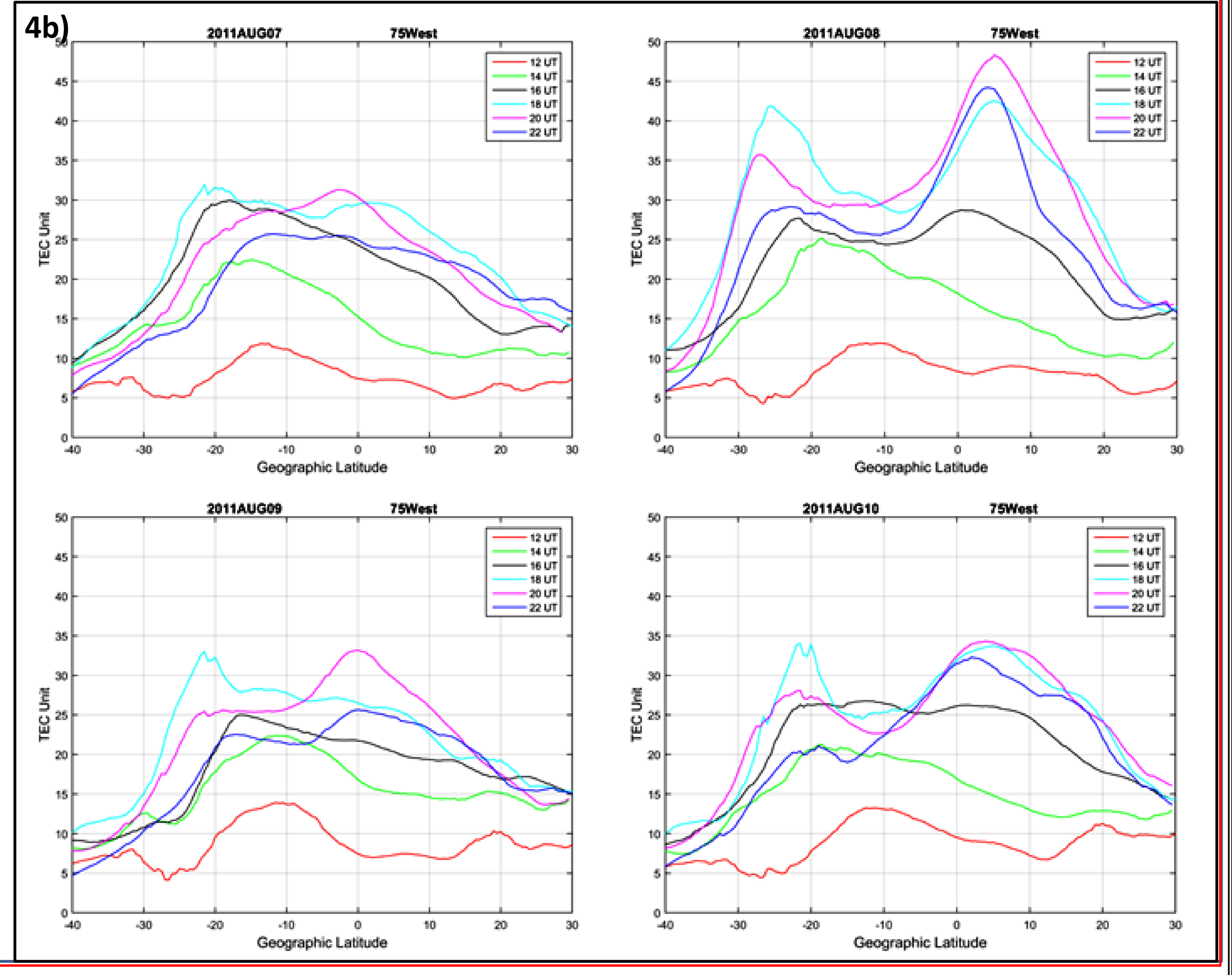


Figure-4:

a) Plots showing 24 hours meridional wind profiles calculated from SOFDI data observed at Huancayo located in the geomagnetic equatorial latitude. Blue curve with circles is hourly meridional wind velocity whereas vertical red lines are error bar as 1- sigma on meridional wind. The detail description of the optical geometry, instrumentation, observation and extraction of neutral wind data obtained by removing background from dayglow emission is explained in *Gerrard and Meriwether [2011]*.

a) Mass plots showing every two hours variations of TEC against geographic latitude along 75° latitudes at about low latitudes region in the local daytime. All the TEC profiles show asymmetry on EIA crests where the meridional neutral wind has significant effects. The troughs of EIA crest fall about ~12° geographic latitude which is geomagnetic equatorial location at that longitude sector.



INTERPRETATION

There are various factors that cause EIA asymmetry. The role of meridional neutral wind on asymmetry generation can be explained in following ways:

a) Plasma Recombination Method - If meridional neutral wind is blowing north to south (south to north), it will drive plasma little bit up in ionospheric height where less recombination of ions occurs that leads to higher plasma density in northern (southern) hemisphere than that in southern (northern) hemisphere.

b) Plasma Transport Method - If meridional neutral wind is blowing north to south (south to north), it will transport plasma along Earth's magnetic field lines and will dump in opposite hemisphere. That leads to higher plasma density in southern (northern) hemisphere than that in northern (southern) crests.

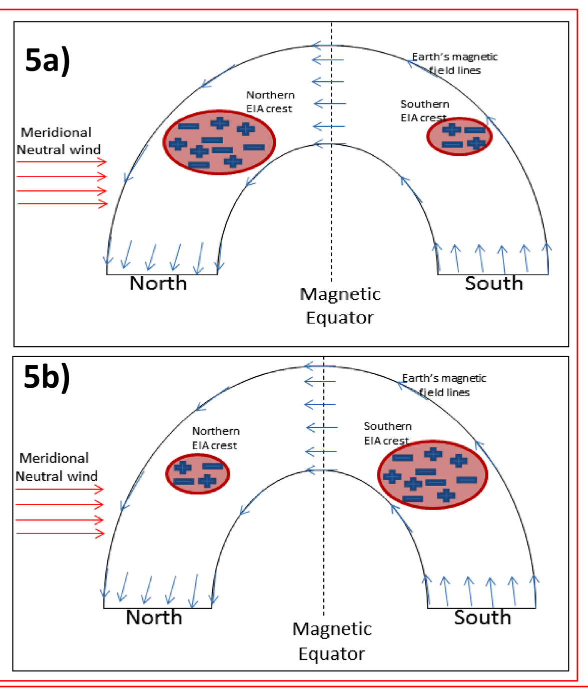


Figure-5: A cartoon illustration of EIA asymmetry caused by meridional neutral wind, looking eastward. The size of shaded oval shape represents strength of EIA crest in the two hemispheres.

CONCLUSIONS

- The latitudinal extension and strength of anomaly crests are controlled by EEF then EEJ in general, but meridional neutral wind mainly engaged to create unequal strength on crests to form equatorial anomaly asymmetries in the low latitudes and plays a decisive role for the generation of asymmetry structure in the equatorial ionization anomaly.
- The anomaly crests look more symmetric in equinox than solstice seasons. The asymmetry on EIA in December solstice poses higher values than June solstice as an indicator of seasonal variation whereas September equinox is less symmetric than March equinox seasons. Most of equinoctial anomaly crests are symmetric during geomagnetically undisturbed conditions
- The results presented here highlight the importance of understanding the physics behind electric field plus thermospheric wind mechanism, and real time as well as further modeling investigation are required to develop a better understanding of the EIA features in details.

References:

1. Gerrard, A. J., and J. W. Meriwether (2011), Initial daytime and nighttime SOFDI observations of thermospheric winds from Fabry-Perot Doppler shift measurements of the 630-nm OI line-shape profile, Ann. Geophys., 29.
2. Khadka, S. M., C. Valladares, R. Pradipta, E. Pacheco, and P. Condor (2016), On the mutual relationship of the equatorial electrojet, TEC and scintillation in the Peruvian Sector. Radio Sci., 51, doi: 10.1002/2016RS005966.

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