The Interconnectedness of Ionospheric Phenomena in the Low Latitudes: A Forecasting Sequence for Space Weather

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Abstract: At equatorial and low latitudes, most of the post-sunrise ionospheric plasma behaviors depend on the plasma drifts or electric fields and their drivers, e.g., neutral winds. This process is an indication of the possible connection between pre- and post-sunrise ionospheric electrodynamics. Mutual relationship studies provide a possible route to predict the occurrence of plasma density fluctuation and scintillation in the ionosphere during the late afternoon and night respectively based on daytime measurements of the equatorial ionosphere. Present study aims to develop a technique to predict the interconnection of disturbances of afternoon GPS-derived TEC and scintillation after sunset on the basis of noontime electrojet strengths. Through statistical and case study analyses, the drivers of ionospheric scintillation and disturbance events are investigated in light of different databases observed in the American low-latitude sector. In addition, the role played by various input parameters of the equatorial and low-latitude ionosphere and their electrodynamic processes in the development of irregularities and influences of solar activity on space weather variability will also be discussed. These investigations can provide significant advances to improve the predictability of low-latitude space weather events and mitigate their effects on space-based technologies.

BACKGROUND

Space weather: A broad field covering the conditions of the sun, solar wind, magnetosphere, ionosphere, and thermosphere that can impact the performance and reliability of space-borne and ground-based technological and infrastructure systems and can also endanger human life or health.

A recent study shows that the equatorial region is more susceptible to space weather than previously thought (centered at -40°). The equatorial electrojet (EEJ) is the primary cause of this newly recognized threat, due to its ability to amplify magnetic perturbations from interplanetary shock waves by severalfold (Center et al., 2015).

The elements controlling the ionospheric weather in the low latitude can be represented by: electric field (e.g., EEJ), currents, plasma drifts, instabilities, and plasma structuring. The noon and nighttime ionospheric storm systems are responsible for the generation of the plasma bubble that can cause scintillation or even disruptions of satellite and navigation system (Abdu, 2015).

DATA ANALYSIS

Figure 5: Distributions of day-to-day variability of TEC profile within ±1.5° geomagnetic latitude and polarization in the afternoon. Significant diurnal variations of TEC at equatorial latitudes are related with low geomagnetic activities at low latitudes. The day-to-day variability of ionospheric scintillation (left) and diurnal TEC (right) can be explained by enhanced day-to-day variations at low geomagnetic activities by the equatorial electrojet (EEJ) local noon. The seasonal variations of TEC at equatorial latitudes are related with changes in the EEJ strengths. The shape of the diurnal profile of TEC is determined by the EEJ strength and polarization. The day-to-day variability of TEC during solar maximum period shows a stronger trend compared to solar minimum period. The day-to-day variability of TEC during solar minimum period shows a weaker trend compared to solar maximum period. The day-to-day variability of TEC during solar minimum period shows a weaker trend compared to solar maximum period.

RESULTS

Figure 6: Day-to-day variability of the EEJ during 08-18 UT of the day observed using magnetometers located in Ecuador and Peru. The local noon EEJ is higher during solar minimum period. The local noon EEJ is lower during solar maximum period. The day-to-day variability of the EEJ during solar minimum period shows a stronger trend compared to solar maximum period. The day-to-day variability of the EEJ during solar minimum period shows a weaker trend compared to solar maximum period. The day-to-day variability of the EEJ during solar minimum period shows a weaker trend compared to solar maximum period.

CONCLUSIONS

1. Day-to-day characteristics of EEJ are a useful tool to probe equatorial and low-latitude ionospheric electrodynamics associated with plasma density variabilities a few hours in advance.
2. A clear picture of the seasonal dependence of peak values of afternoon TEC and anomaly separation is seen on noontime EEJ strengths in the low latitude ionosphere. The day-to-day variability and the characteristic features of the DI stresses exhibit a strong correlation with the TEC variability.
3. Minor correlation of peak value of EEJ with net TEC index greater than 0.2 likely exists, but there is no correlation at all below 0.2 for the solar minimum year 2008. Noontime EEJ strengths is not a good predictor for the nighttime scintillation during solar minimum period in the low latitude ionosphere.
4. As in the polar region, the equatorial region is also highly susceptible to ionospheric scintillations during solar storm activity periods. Extending this analysis to solar maximum with larger database of nighttime TEC index will certainly be worthwhile project in assessing correlations with peak values of daytime EEJ.
5. Collection of long-term statistics relating magnetometer-derived drifts and radar-measured drifts can contribute significantly to a more economic way to characterize the occurrence of ionospheric irregularities. The development of such model and statistical relations can help in real-time ionospheric monitoring and improvement in GPS navigation capabilities by assessing space weather impacts.

REFERENCES