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Post-sunset enhancements in F region ionization over the EIA crest region during quiet and disturbed periods-Causative mechanisms

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The post-sunset enhancements in vertical total electron content (VTEC) an OI 630.0 nm airglow intensity over the crest region of equatorial ionization anomaly (EIA) have been reported in the past. However, the causative mechanism behind these enhancements was not understood till recently. We address this gap area in the present work during both quiet and disturbed periods. These results are important for the evaluation of ionospheric space weather that has implication for the communication and navigational applications.

The investigation during quiet period is carried out based on 10 years' of observations (2010-2019) of VTEC over Ahmedabad (23.0°N, 72.6°E, dip angle 35.2° and campaign based observations of OI 630.0 nm airglow intensity over Mt. Abu (24.6°N, 72.7°E, dip angle 38.0°) and the investigation during disturbed period is carried out based on a few nights of VTEC and airglow data and combining it with global measurements.

During the quiet period, the enhancements in VTEC/airglow intensity over the EIA crest region are observed during post-sunset hours and morphologically, these enhancements are found to start at any time after 1900 LT and peak around 2000 LT. Investigations reveal that these enhancements are primarily caused by the pre-reversal enhancement (PRE) of the zonal electric field over the dip equator. Similar to daytime equatorial plasma fountain (EPF), the re-invigorated EPF by PRE drives the post-sunset enhancement over the EIA crest region that is assisted by the latitudinal plasma density gradients. Interestingly, the post-sunset enhancements in VTEC over the EIA crest region are prominent during the December solstice and Equinox in the high solar activity period only. This is consistent with the seasonal and solar activity dependence of the amplitudes of PRE-associated vertical drifts over the dip equator. This suggests that the post-sunset enhancements are related to PRE. We propose that as the daytime EPF process decides the plasma distribution over the low latitudes, the PRE-driven re-invigorated EPF determines the degree of post-sunset enhancements over the low latitudes. Interestingly, the response time of the EIA crest region corresponding to the PRE-driven plasma fountain is found to be ~1.7 hr in contrast to the 3-4 hrs of response time corresponding to the daytime plasma fountain. This shorter response time during evening hours is explained by the TEC measurements by the Indian Satellite-based Augmentation System (SBAS) GAGAN (GPS Aided Geo Augmented Navigation). The analyses propound that PRE drives plasma from 5°-10° magnetic latitude to the EIA crest region, leading to this shorter response time. Further investigation of Ahmedabad VTEC reveals that the post-sunset enhancements depend on the solar flux levels and are conspicuous if the solar flux level exceeds ~110 sfu during December solstice and Equinox. As PRE also depends on solar flux levels, this provides further credence to the direct role of PRE in driving the post-sunset enhancements over the EIA crest region. However, it is suggested that PRE is a necessary condition but not a sufficient condition for the post-sunset VTEC enhancements over the EIA crest region. The outputs of Thermosphere Ionosphere Electrodynamics- General Circulation Model (TIE-GCM) reveal that latitudinal plasma density gradients work in tandem with the PRE to determine the degree of post-sunset enhancements in plasma density over the EIA crest region.

During the disturbed space weather events, we find instances of anomalous electric field perturbations that cannot be explained based on the conventional penetration electric field paradigm. The investigation shows that unconventional drivers like IMF By, substorm induced electric field etc., have played important roles in modulating the amplitude and polarity of penetration electric field perturbations during both post-sunset hours. These have ramifications for evaluating the state of the low latitude ionosphere at night during disturbed space weather conditions.