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Impact on the Satellite Navigation by the Exceptional Ionospheric Variability in the Equatorial and Low latitudes: Diverse sources and Unique responses

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No part of the global ionosphere exhibits more diverse scales of variability than by the equatorial and low latitude ionosphere. Beginning with the primary source, the Sun, with the solar cycle scales of the 11/22 years and the associated climatic variations, the equatorial ionosphere is known to be affected by the change of seasons, and day to night variations. The Solar events like CMEs, CIRs, Flares, HILDCAA and Eclipses directly affect the equatorial ionospheric electron density and TEC. Apart from this, some special phenomena like the EIA, ETWA and EPBs produce multi scale steep gradients (MSSG) in the equatorial and low latitude ionosphere. This part of the ionosphere also greatly responds to the lower atmospheric phenomena. The scales include the planetary and gravity waves, the diurnal and semi-diurnal tides, besides the extreme weather events like cyclones, thunderstorms and deep convection events.

Each of the above mentioned diverse source eventually generates a unique response in the equatorial ionosphere, although on some rare occasions, most of the sources are simultaneously active, producing complex unresolved patterns in the variability. Thus, when it comes to the prediction and forecast of the low latitude ionosphere, most of the state-of-the-art models exhibit major limitations. Additionally, the exceptional ionospheric variability over the equatorial and low latitudes has been a major cause of hurdle for precise positioning using satellite navigation.

The present paper aims to bring together different threads on this subject and present some of the latest intriguing observations from the Indian region including the NARL network of GNSS/NavIC receivers. The results of this paper highlight, at the first, the large variability in the equatorial ionosphere through GNSS observations, then identify the simultaneous presence of multiple drivers, and attempts to quantify the relative roles of some of the drivers. This is achieved by some selected examples of event specific (extreme TEC depletions during equinoxes and scintillations) and long term quiet time studies (2002-2018), and space weather events (St. Patrick's Day storm of 2015).

Finally, a few selected results are used to showcase the relationship between the limitations of the observing and operational instruments (like Loss of Lock, Phase and amplitude scintillations, TEC and signal delay), its relationship with present understanding of the ionospheric variations (space weather events and long term variations) and its impact on the positioning (Kinematic PPP). Results on precise point positioning show major connect with the solar activity, the space weather events, the equatorial plasma bubbles and the cyclonic storms and even a recent event of the Tonga Volcanic Explosion.

This paper is an invited talk and hence tailored to present the theme as whole and its relationship with one of the leading ISRO programs in Satellite Navigation- NaVIC. The paper also suggests a few plans which can be taken up in a coordinated manner by the community for a sustainable resolution of the issues.