Climatology of Low Latitude Ionosphere Under Effect Of Varying Solar Flux During Solar Cycle 23 And 24

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ABSTRACT

For the first time the longest term climatology of quiet time total electron content (TEC) over the Indian sector is obtained using Global Ionospheric Maps (GIM) data. The quiet time equatorial and low latitude TEC are characterised from 1998 to 2014. The paper is composed of main results that include critical overview of present status and necessity of such study for ionospheric forecast, setting up newer criteria and definitions leading to generic formulation of the climatology in terms of mean diurnal cycle, seasonal anomalies, a new insight over correlation between ionospheric electron content and solar EUV flux, and finally a complete wavelet analysis of solar EUV flux and it repercussions over three stations in low latitudes. The results form the only such study performed from Indian and other low latitude sectors around the globe.

Key words: Climatology, Equatorial and low latitude Ionosphere, Global Ionospheric Maps (GIM), Seasonal Anomalies, Solar QBO, high and low solar activity definition.

1. New quiet time criteria

For the first time the analysis is carried out by filtering out the days when solar flares of class M5.5 and above have occurred. Days when Dst fell above -50 nT also have been excluded and the final VTEC time series is prepared for three stations over the low latitude Indian sector, namely dip equator and two low latitude conjugate locations. It is well known equatorial electrodynamics is governed by a complex interplay amongst solar flux, dynamo electric field and meridional winds that determines the day-time ionization as well as the distribution in equatorial ionization anomaly zone. In this study, we have critically examined the role of varying solar flux and the response of low latitude ionosphere with new and standardized definitions. The results are examined and interpreted in the context of a large number of previous studies. The newly found features from this study are as follows.

2. Seasonal anomalies

Even though certain large scale features of the low latitude ionosphere have been studied and documented in the past, there still remain several aspects that are unexplained and warrant for further studies. With the virtue of this long term study, we find that the already known anomalies do not seem to be persistent at all times.

Long absence of winter anomaly both during low and high solar activity (HSA) in LL (low latitude) regions is found. Marked difference in the nature of equinoctial asymmetry is noted between solar cycle 23 and 24. Also, semi annual anomaly is found to reverse during HSA of both solar cycles 23 and 24. Plausible explanations are sought in order to explain these intriguing departures in terms of EXB drifts and changed patterns of meridional wind flow, apart from any lower atmospheric forcing.

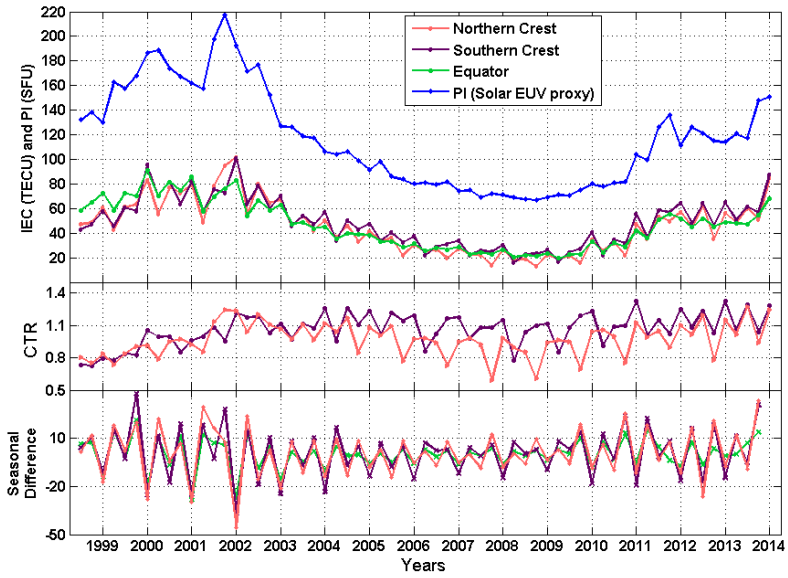

Figure 1. Top panel shows the seasonal mean variation of solar flux Proxy Index (PI) and IEC over the three locations from September equinox of 1998 to September equinox of 2014. Middle panel shows the crest to trough ratio (CTR) for the same duration and the bottom panel shows the difference between successive seasons.

3. New definition of solar high and diurnal cycle

RMS (root mean square) width of PI is used to define the High Solar Activity (HSA). Climatology of the diurnal cycle is provided in four categories namely, the total or gross, HSA of Cycle 23, HSA of Cycle 24 and low solar activity (LSA) periods, using a new criterion for demarcation of solar activity levels. This new method has brought to light the marked difference in the response of ionosphere towards the different solar activity levels. Moreover, this method has shown the importance of a standard demarcation method to assign a day to be of high solar activity.

4. Correlation Scenario

To determine the role and fix the contribution of solar flux as one of the drivers of low latitude and equatorial ionosphere correlation study is done. This is targeted keeping in mind that the GIM and PI data sets span for a long period covering 2 high activities and a deep minimum. Highest correlation (77%) between GIM ionospheric electron content (IEC) and PI (solar EUV proxy index) is noted over equator in contrast to previous studies. A novel correlation scenario is found wherein minimum positive contribution of PI in variation of IEC requires minimum of 2 years of data and if more than 7-8 years of data is used, it saturates.

5. Wavelet Analysis

Strong QBO (quasi biennial oscillations) in IEC are noted in tune with the one in PI over both the LL location but QBO remains surprisingly subdued over equator. The semi-annual oscillations in GIM-IEC are found to be stronger at all locations during high solar activity and weaker between 2005 and 2011, whereas, the annual oscillations are found to be substantially stronger only during HSA-23 and weakest over southern LL location throughout 17 years.

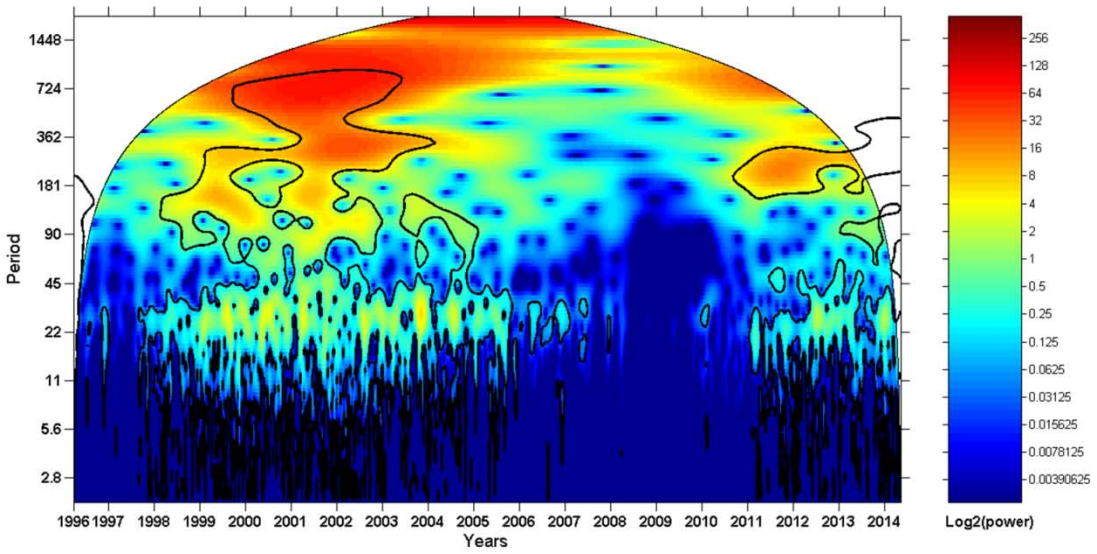

Figure 2. Wavelet spectra for time series of PI from 1996 to 2014. The periods are given in days on y-axis and the contours indicate the power for the respective period with black curve representing 95% confidence levels.

References:

[1] Balan, N., Y. Otsuka, G. J. Bailey, and S. Fukao (1998), Equinoctial asymmetries in the ionosphere and thermosphere observed by the MU radar, J. Geophys. Res., 103(A5), 9481–9495

[2] Fuller-Rowell, T. J (1998), The "thermospheric spoon": A mechanism for the semiannual density variation, J. Geophys. Res., 103, 3951

[3] Millward, G.H., H. Rishbeth, R.J. Moffett, S. Quegan and T.J. Fuller-Rowell (1996), Ionospheric F2 layer seasonal and semiannual variations, J. Geophys. Res., 101 pp. 5149–5156

[4] Rishbeth, H., C. F. Müller-Wodarg, L. Zou, T. J. Fuller-Rowell, G. H. Millward, R. J. Moffett, D. W. Idenden and A. D. Aylward(2000), Annual and semiannual variations in the ionospheric F2–1ayer, II, Physical discussion, Ann. Geophys., 18, 945

[5] Rishbeth, H. and I. C. F Müller-Wodarg, (2006), Why is there more ionosphere in January than in July? The annual asymmetry in the F2-layer, Ann. Geophys., 24, 3293-3311

[6] Schaer, S., G. Beutler, M. Rothacher(1998),Mapping and predicting the ionosphere,Proc. of the IGS AC workshop, Darmstadt, Germany