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TEC Variability And Comparison Of Models During Solar Cycle 23 And 24 Over Equatorial Low Latitude IGS Station, Bangalore(13.02° N, 77.57° E)

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Outline

- GPS-TEC
- Station and Data
- Solar Cycle
  - Diurnal Variation
  - Seasonal variation
  - Comparison with Quiet and Disturbed Period
- Compare with Models
  - Correlation Coefficient

IONOSPHERE / GPS-TEC

- Ionized by solar radiation
- Plays as important part in atmosphere electricity and forms inner edge of Magnetosphere.
- Influences radio propagation to distant place on Earth.
- The total electron content (TEC) is the total number of electrons along a path between a transmitter and a receiver.
- The TEC depends on the geographic latitude, longitude, local time, season, geomagnetic activity and viewing direction

GPS – TEC INFORMATION

- To account for the ionospheric delay, the GPS receivers employ two L-Band frequencies (L1=1575 MHz and L2=1227 MHz).
- The TEC can be estimated, either by using GPS carrier phase or pseudo-range delays.
- To calculate the TEC, we can use this formula,

$$TEC = \frac{1}{40.3} \times \frac{(c \times f_{L1}^2 \times f_{L2}^2)}{(f_{L1}^2 - f_{L2}^2)} \times \Delta(\delta t)$$

Where,

L1 and L2 are two band frequencies,

C is speed of light in vacuum,

(δt) is time delay.

1 TEC unit (TECU) = 10^{16} electrons/m^2

DATA AVAILABLE IN IGS BANGALORE STATION

Year	Total Days	Total Quiet Days	Total Disturbed Days
1996	261	93	38
1997	349	115	58
1998	302	103	48
1999	331	106	53
2000	308	106	52
2001	231	78	38
2002	322	113	53
2003	355	119	59
2004	354	115	58
2005	339	112	55
2006	354	117	57
2007	353	116	59
2008	178	56	33

Year	Total Days	Total Quiet Days	Total Disturbed Days
2009	347	111	57
2010	36	117	60
2011	331	109	55
2012	364	118	59
2013	319	108	51
2014	319	104	49
2015	356	114	60
2016	358	117	58
2017	290	84	44
2018	323	94	55
2019	356	115	59
2020	169	60	23

Table :- Number of available data in IGS Bangalore Station

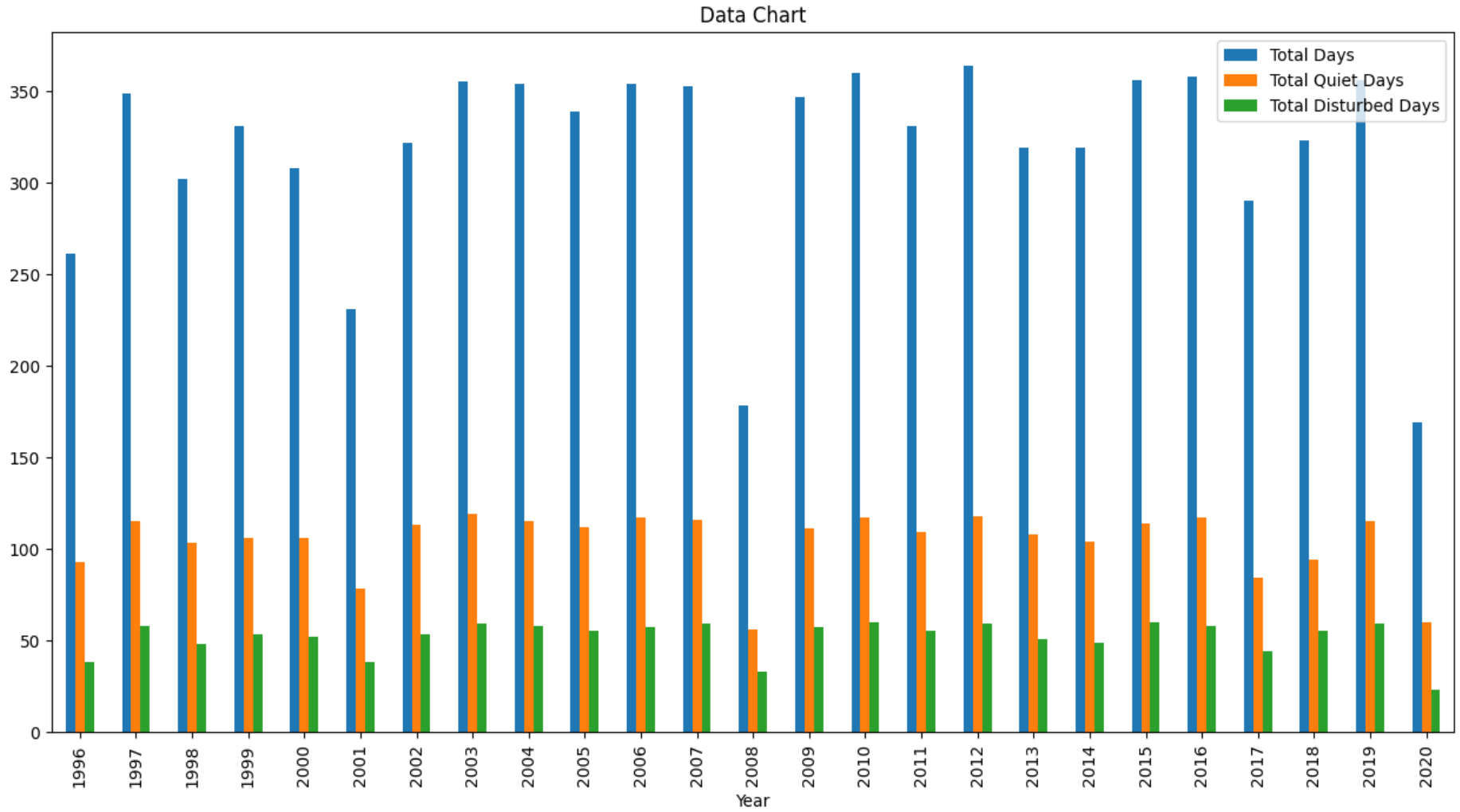


Fig. Graphical Representation of Available Data at IGS Bangalore Station

SOLAR CYCLE

- 11 years of sunspot cycle
- Sunspot cycle 23 = 1996 to 2009
- Sunspot cycle 24 = 2009 to 2020
- Solar Activity depends upon Sunspot Number
- Low Sunspot number = Solar Minimum
- High Sunspot number = Solar Maximum

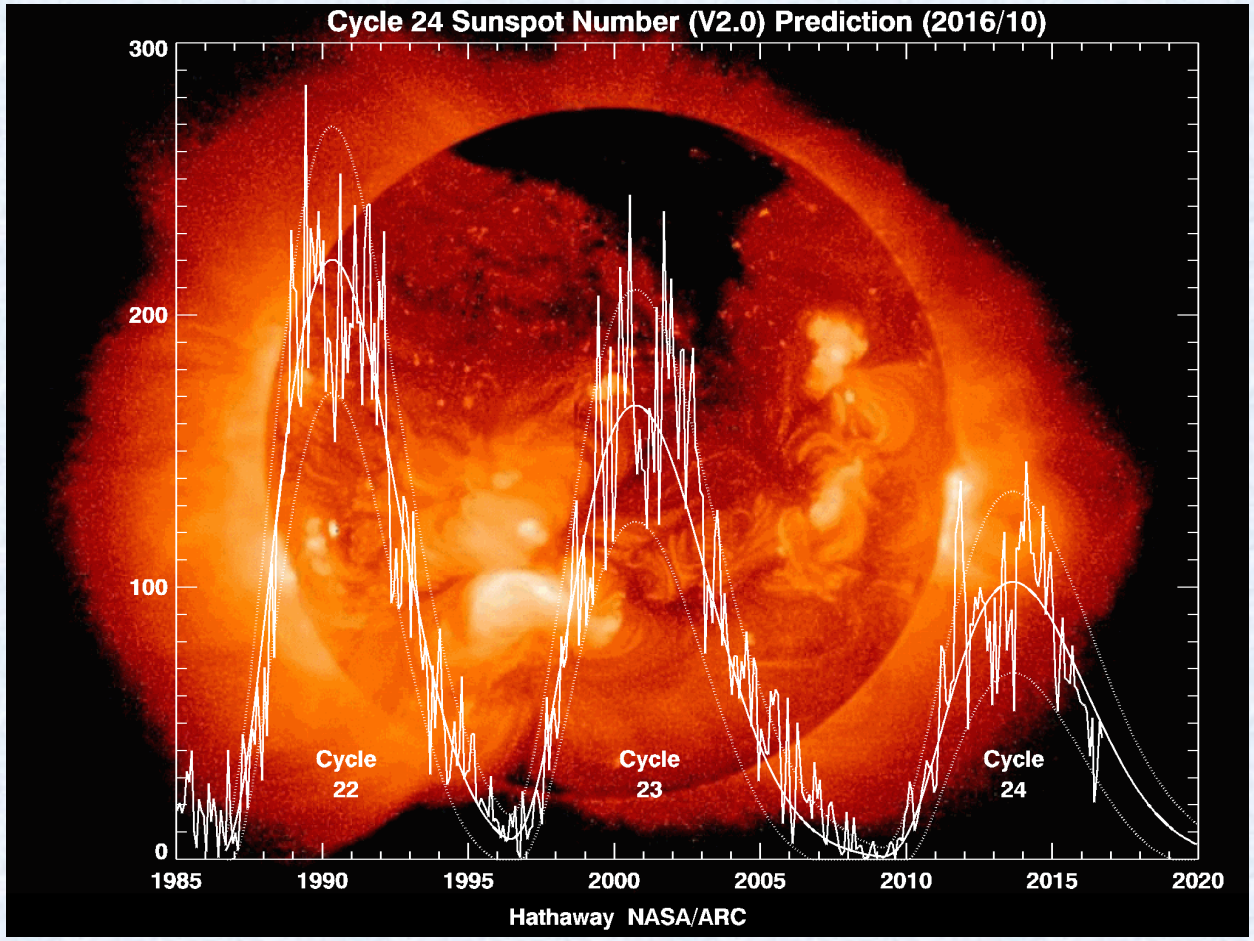


Fig. Variation of sunspots over the cycle

DIURNAL TEC VARIATION

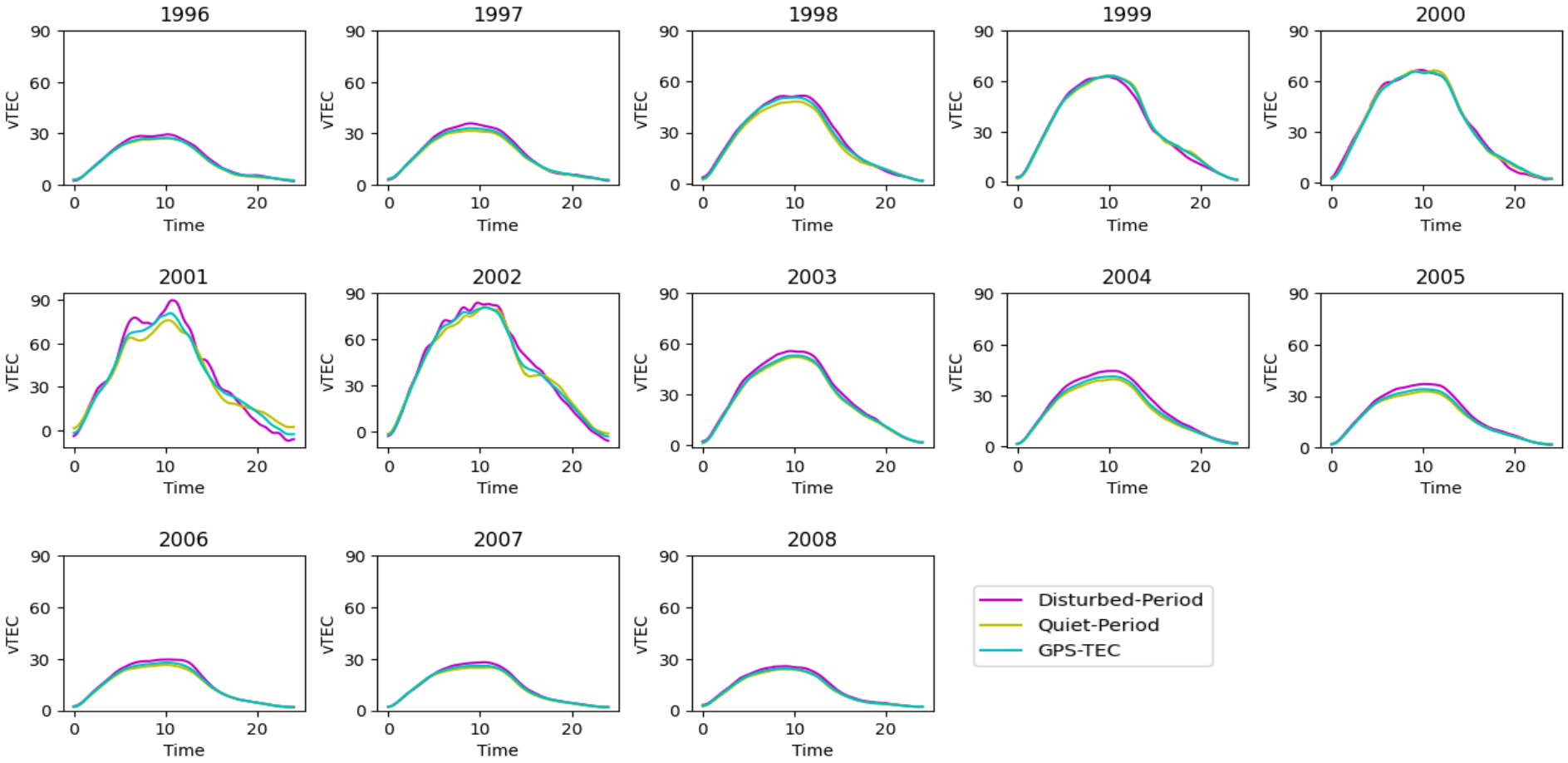


Fig. Diurnal variation of the yearly averaged GPS vTEC in Solar Cycle 23

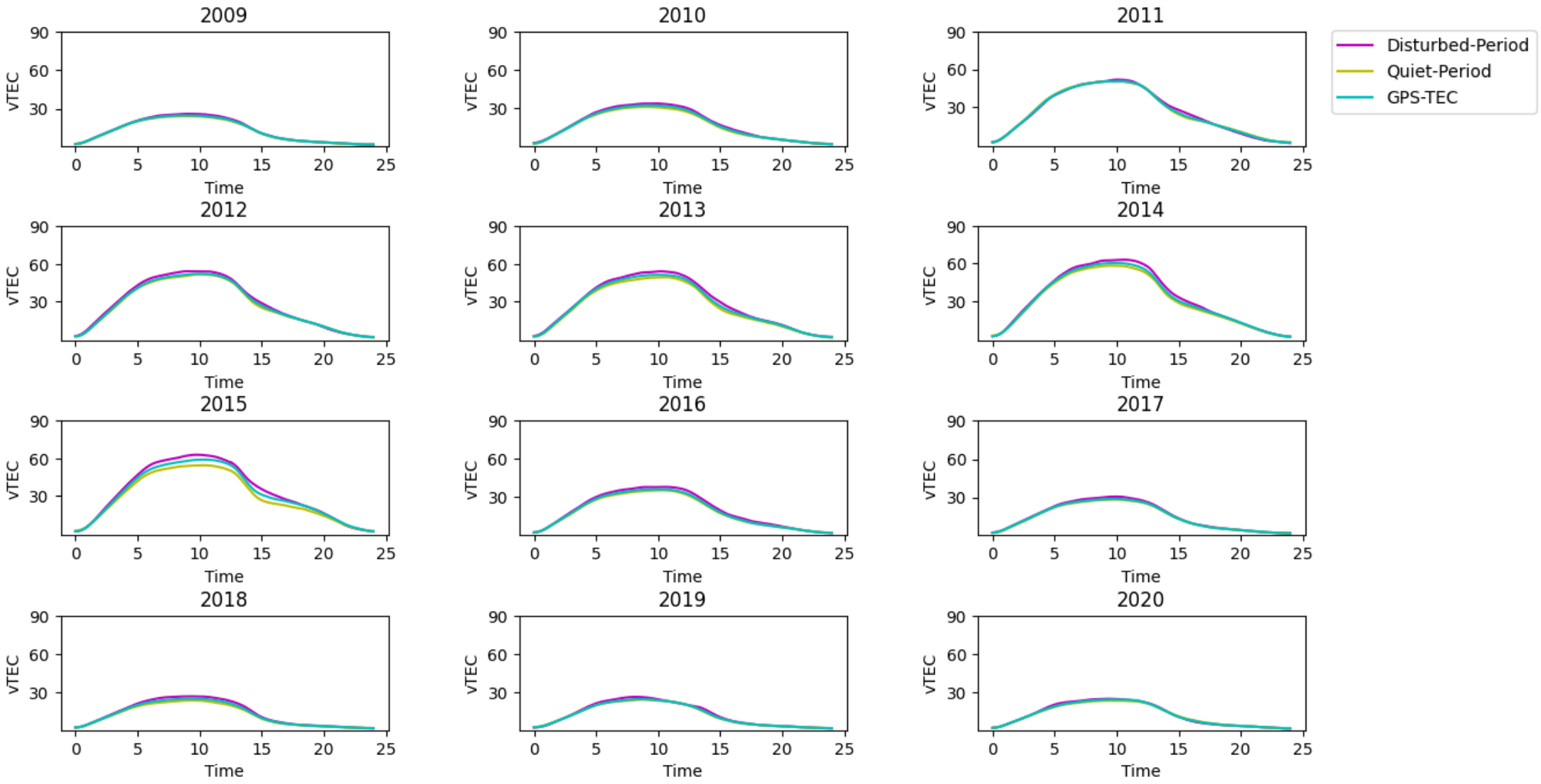


Fig. Diurnal variation of the yearly averaged GPS vTEC in Solar Cycle 24

EARTH'S EQUINOXSES AND SOLSTICES

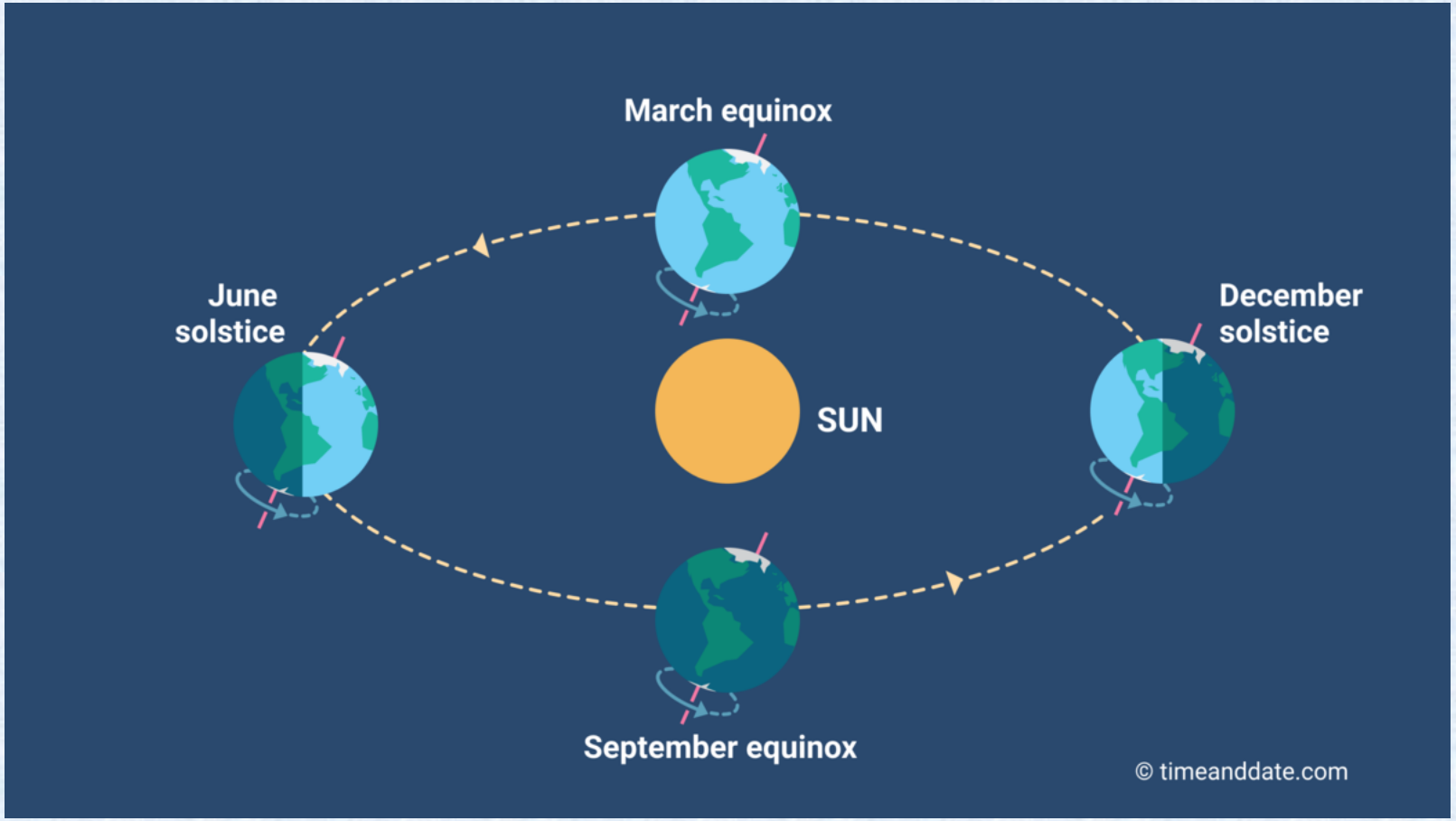


Fig. Seasonal variation on Earth due to its tilted axis

SEASONAL VARIATION

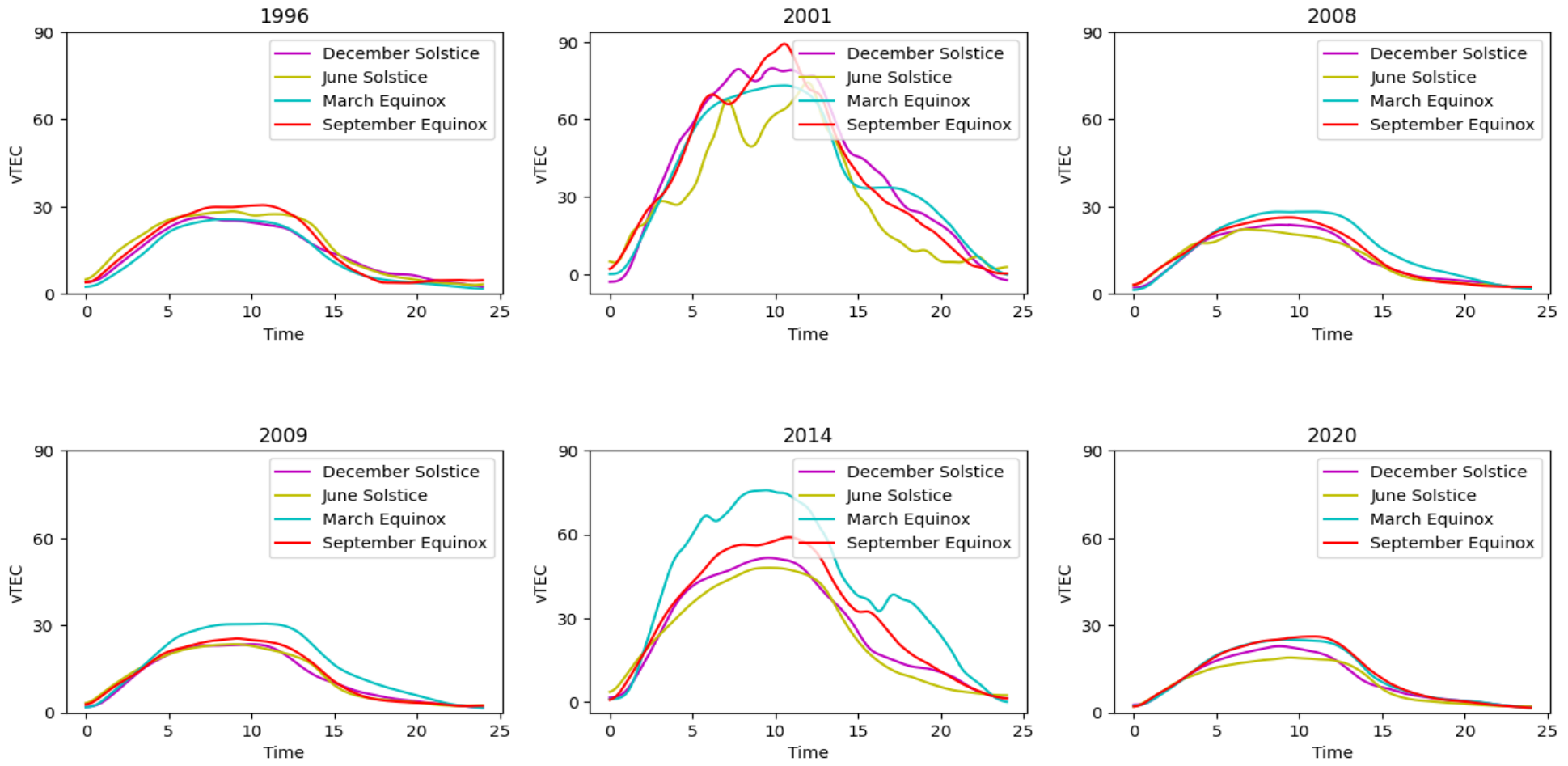


Fig. Seasonal variation of the yearly averaged GPS TEC in Solar Cycle 23 and 24

COMPARISON OF TEC IN QUIET AND DISTURBED PERIOD

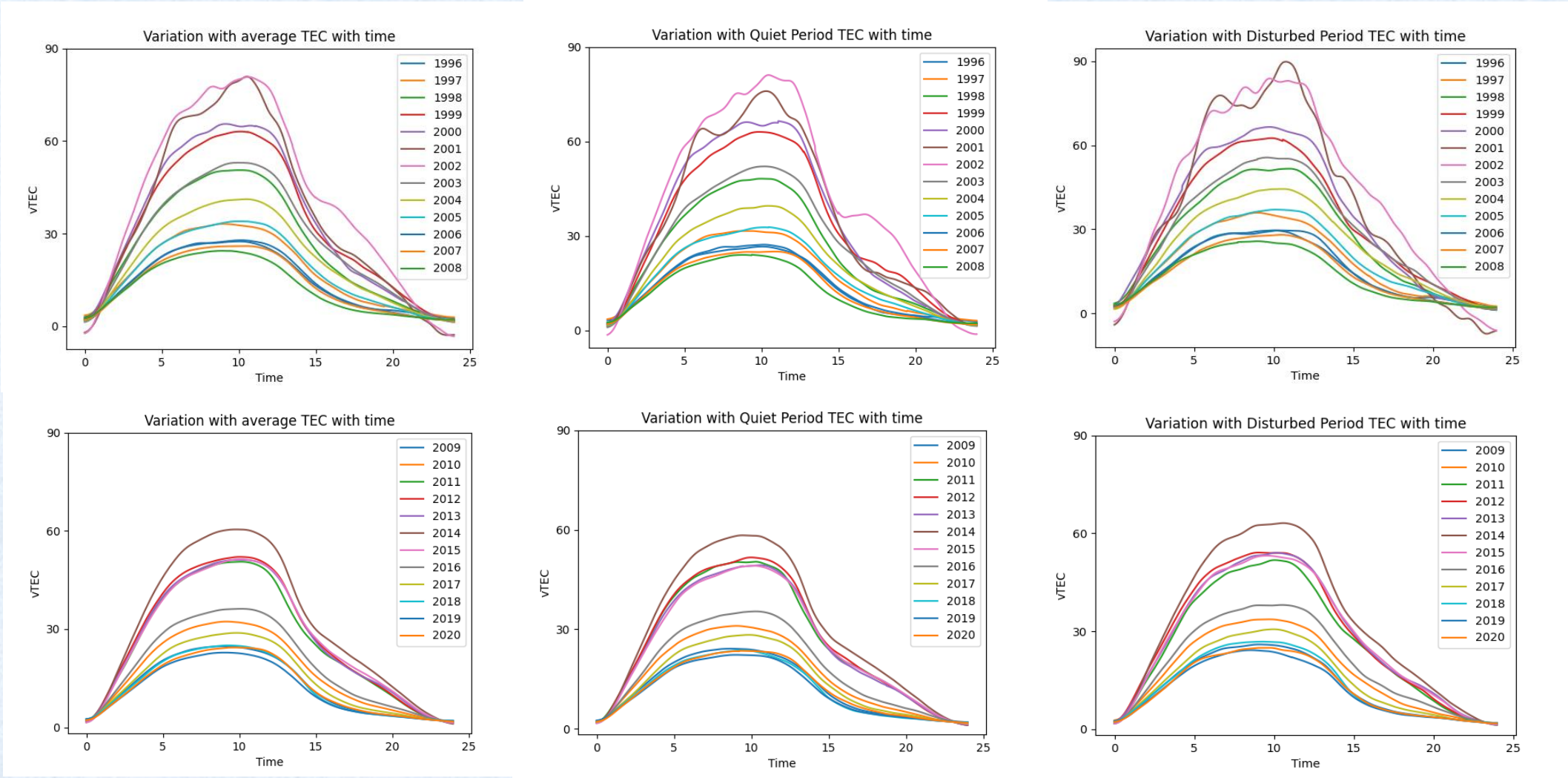


Fig. Variation of TEC with Quiet and Disturbed Period of Solar Cycle 23 and 24

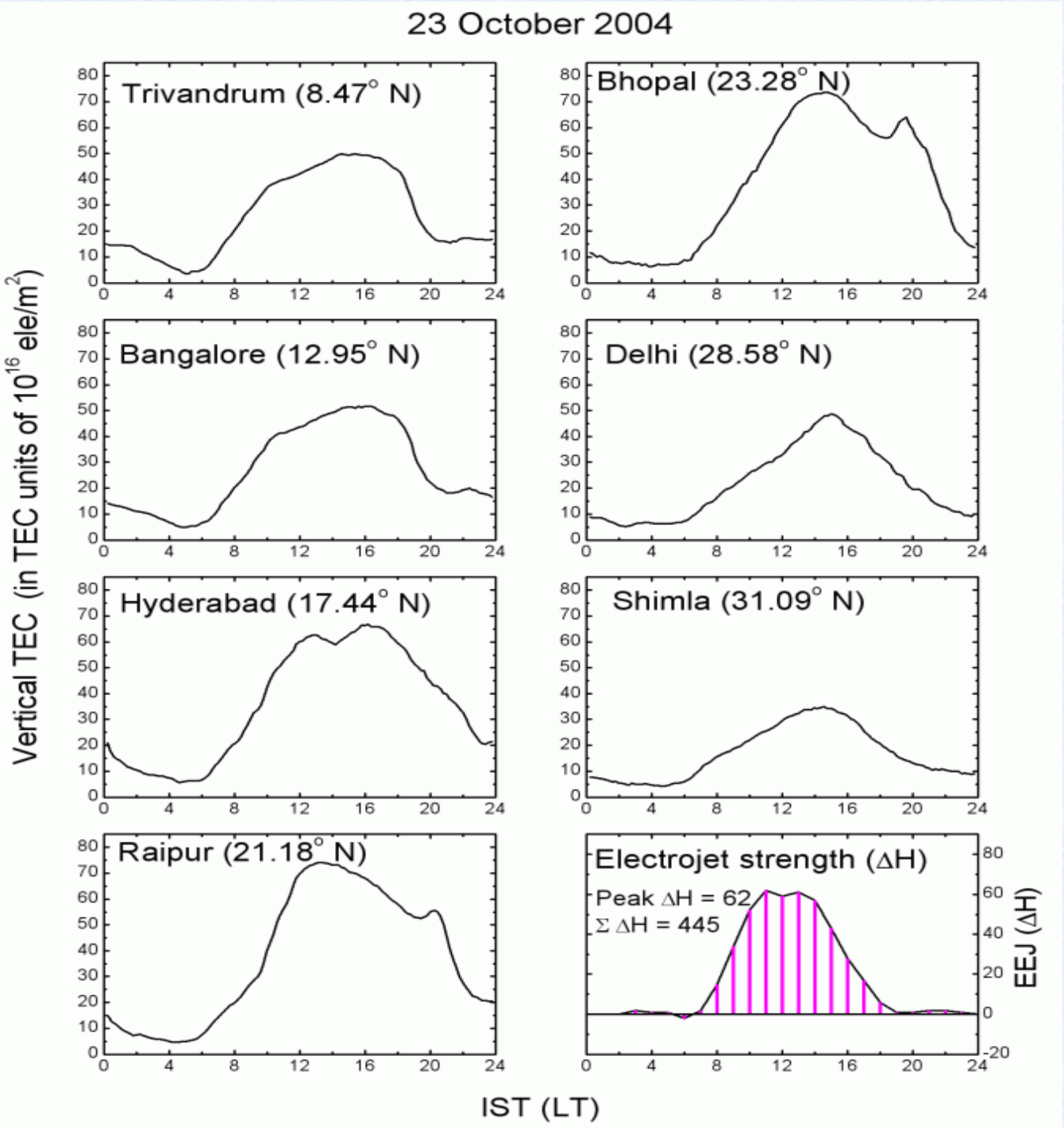


Fig. Diurnal variation of TEC along the common meridian of 77° E longitude from all the seven stations from equator to the anomaly crest and beyond on a typical quiet day of 23rd October 2004 (equinox) along with the corresponding diurnal variation of the equatorial electrojet strengths (EEJ).

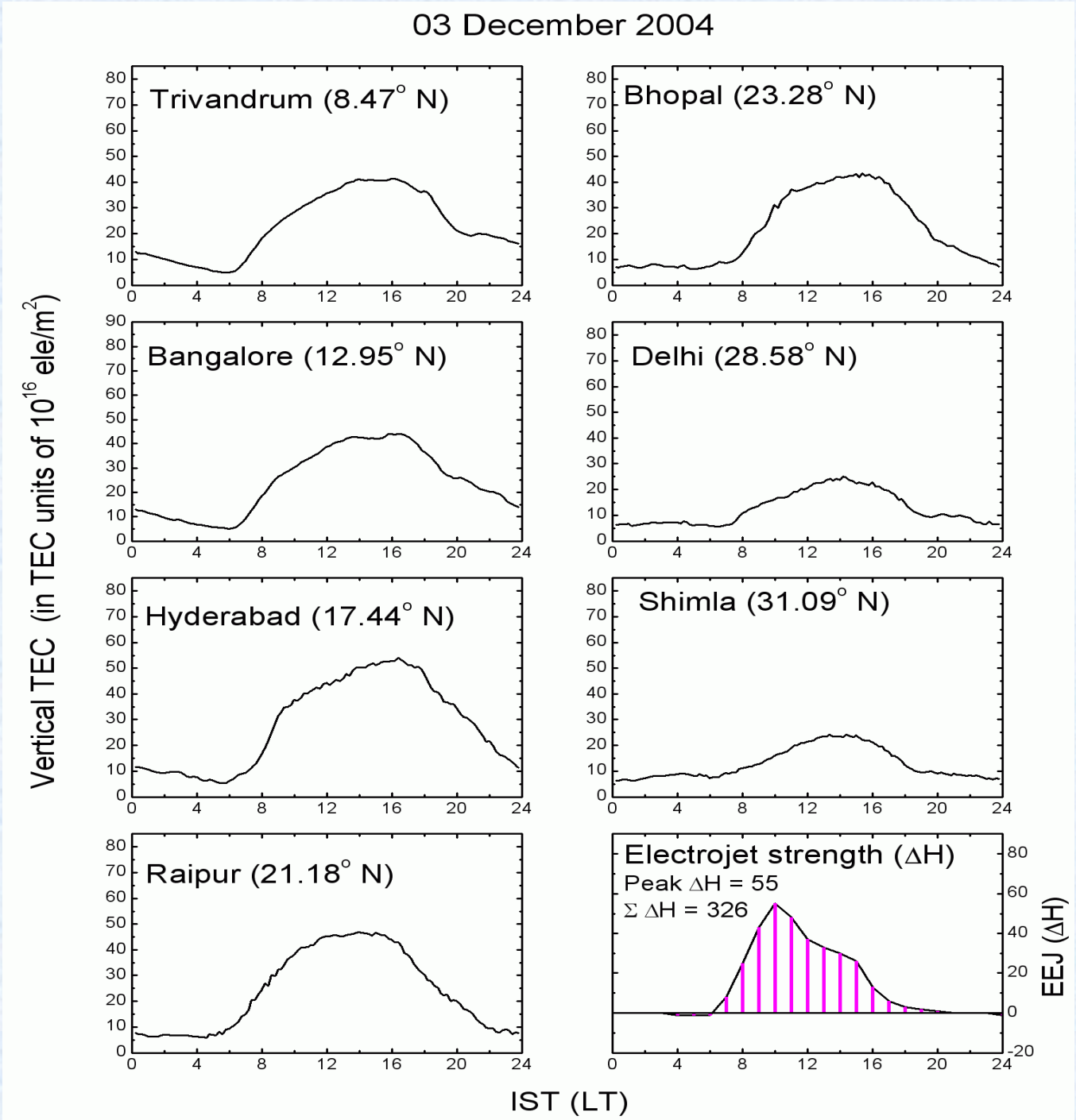


Fig. Diurnal variation of TEC along the common meridian of 77° E longitude from all the seven stations from equator to the anomaly crest and beyond on a typical quiet day of 3rd December 2004 (Winter) along with the corresponding diurnal variation of the equatorial electrojet strengths (EEJ).

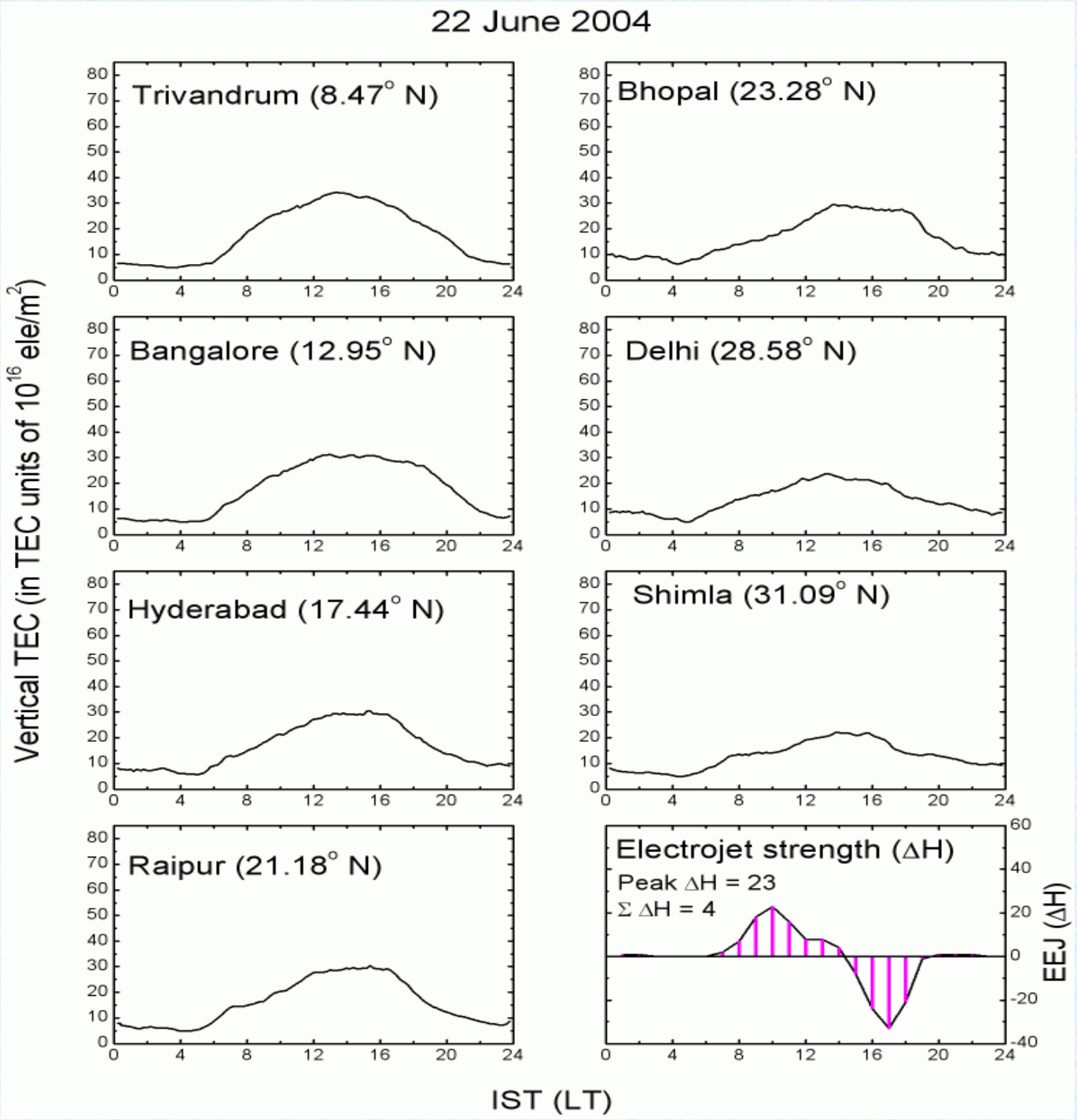


Fig. Diurnal variation of TEC along the common meridian of 77° E longitude from all the seven stations from equator to the anomaly crest and beyond on a typical quiet day of 22nd June 2004 (Summer) along with the corresponding diurnal variation of the equatorial electrojet strengths (EEJ).

COMPARISON OF GPS-TEC WITH MODELS DURING SOLAR CYCLE

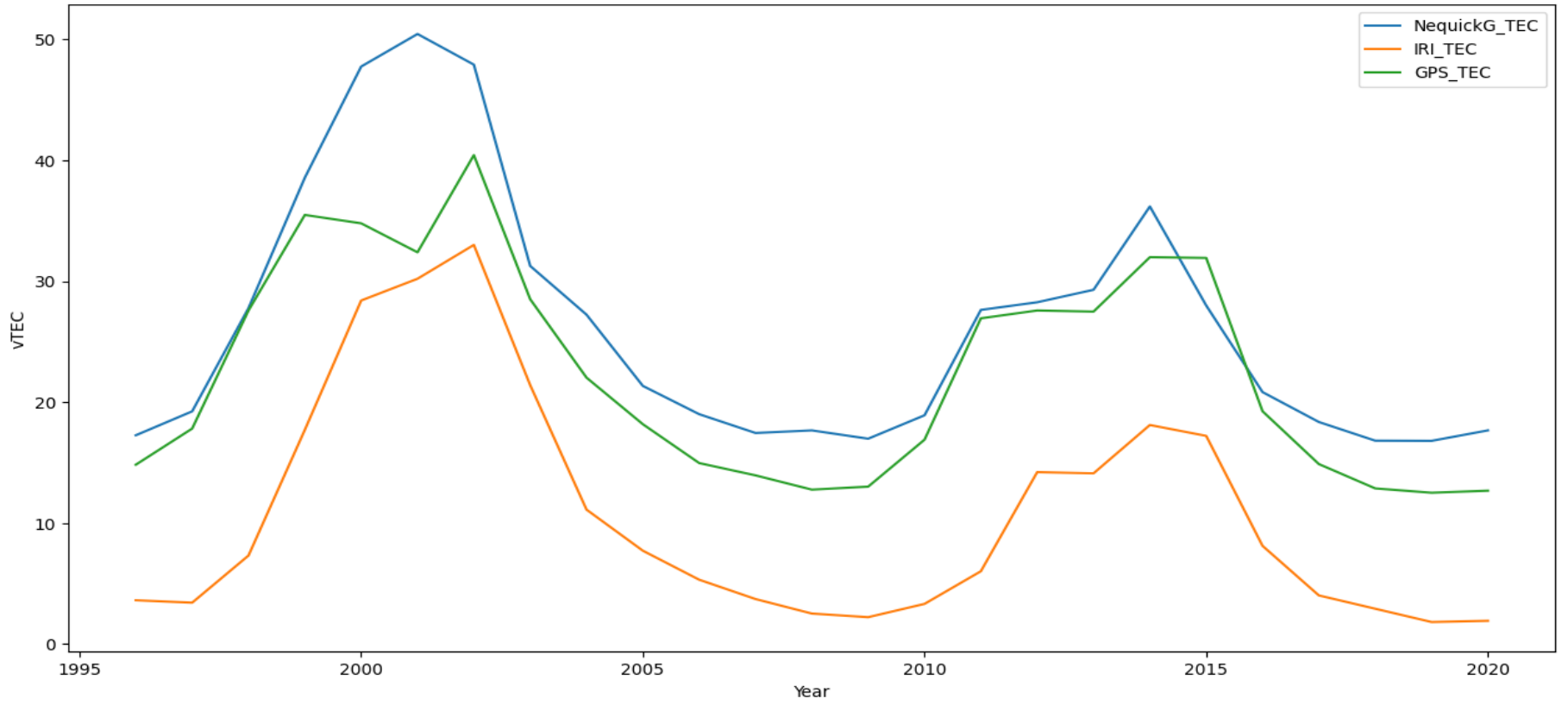


Fig. Comparison of overserved GPS-TEC with IRI and NeQuickG Model

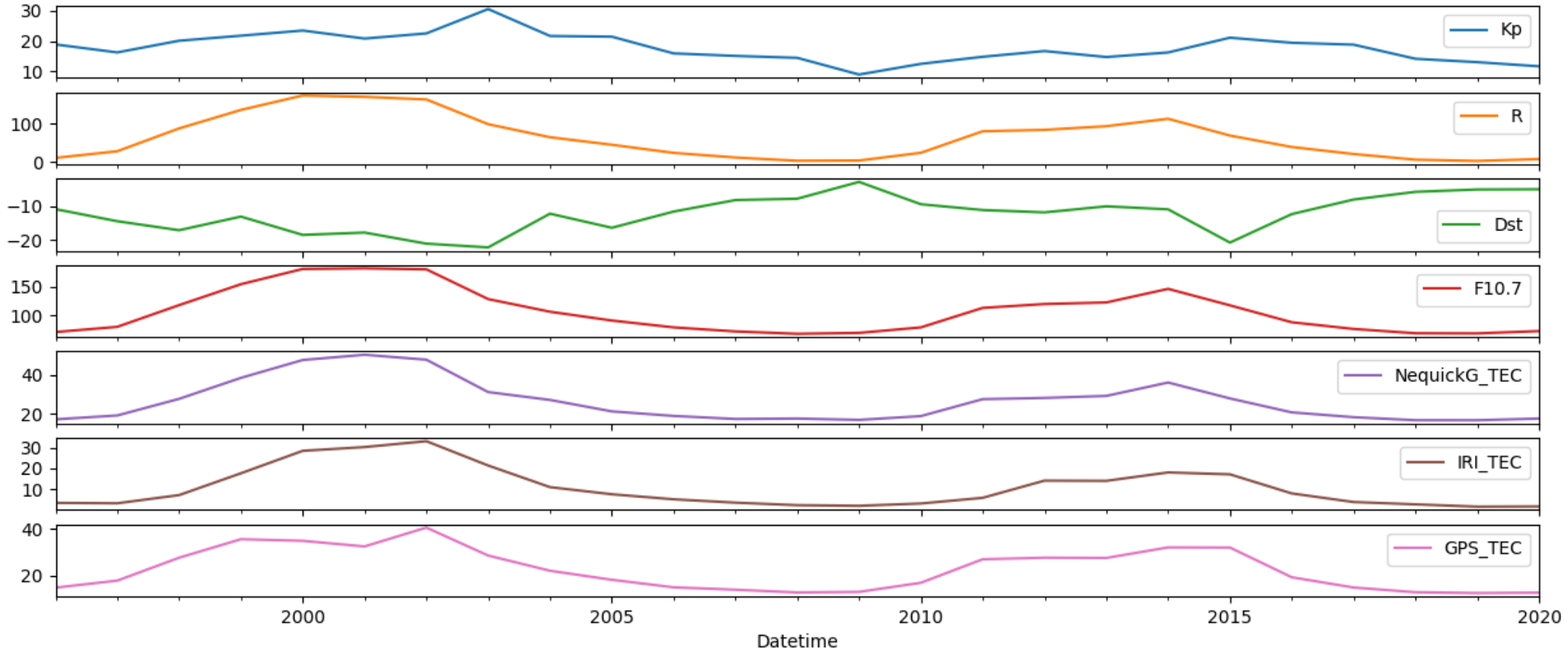
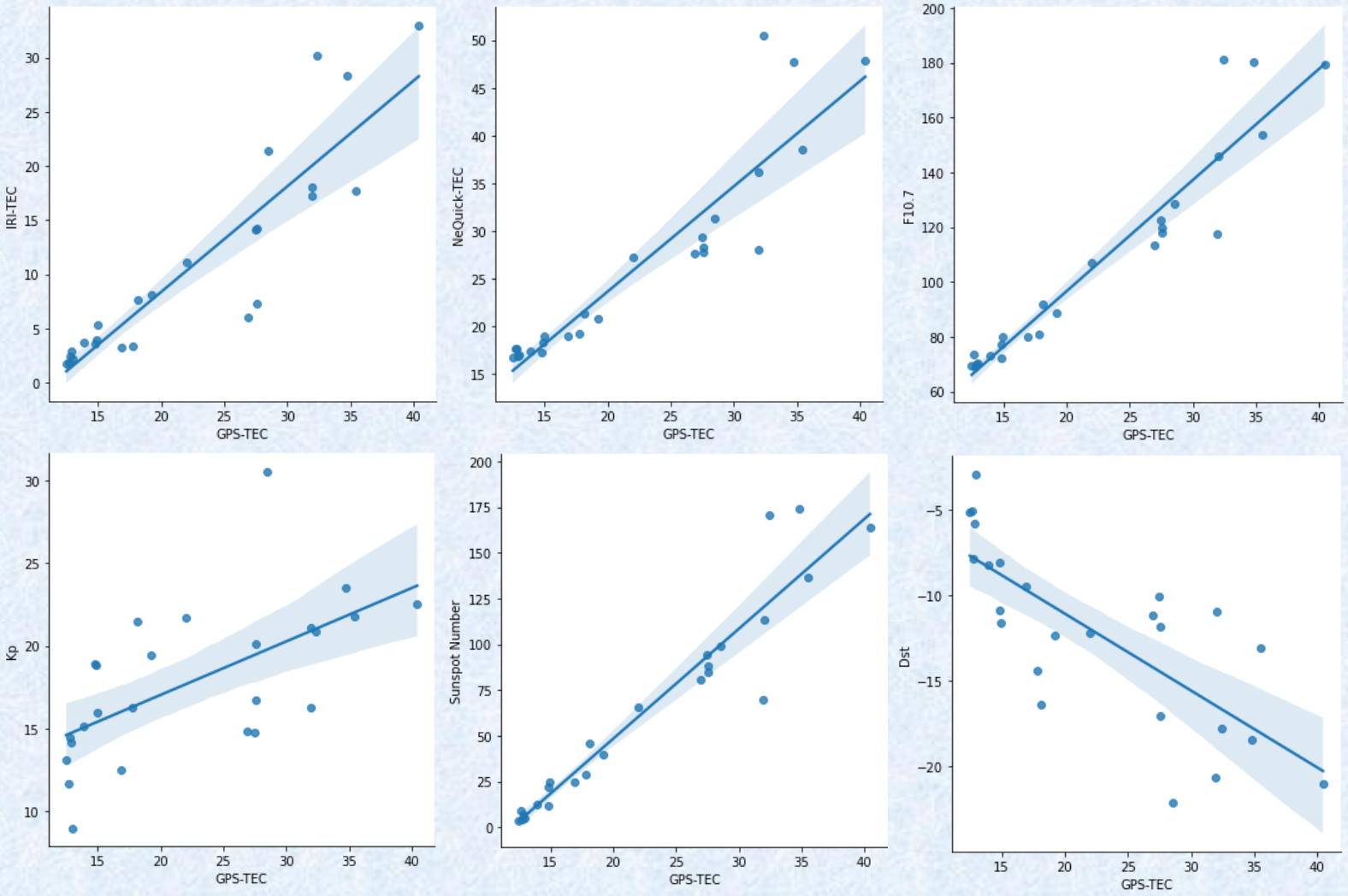


Fig. Year wise graphical representation of different parameters

CORRELATION COEFFICIENT



Correlation coefficient

- GPS-TEC with IRI-TEC = 0.9027
- GPS-TEC with NeQuick TEC = 0.9216
- GPS-TEC with F10.7 = 0.9544
- GPS-TEC with Kp index = 0.6134
- GPS-TEC with Sunspot Number = 0.9531
- GPS-TEC with Dst = -0.7548

Fig. Correlation Coefficient of GPS-TEC with Different parameters

CONCLUSION

- GPS-TEC is derived from IGS Bangalore Station data from 1996 to 2020.
- Due to solar radiation the ionospheric electron concentration vary diurnally, seasonally, latitudinal and over solar cycles.
- Diurnal variation of TEC along the common meridian of 77° E longitude from all the Indian GAGAN seven stations from equator to the anomaly crest and beyond on a typical quiet day in equinox, winter and summer along with the corresponding diurnal variation of the equatorial electrojet strengths (EEJ) is studied.
- GPS-TEC is compared with IRI-TEC and NeQuickG-TEC for two solar cycles period. IRI-TEC is underestimated while NeQuickG-TEC is nearby overestimated as compared with GPS-TEC. The trend of variation of GPS-TEC and models TEC for entire solar cycle period is quiet similar.
- The coefficient correlation between GPS-TEC and models is more than 90%. Also the coefficient correlation of GPS-TEC with F10.7 and sunspot number is 95.44% and 95.30% respectively.

Thank you