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GPS-TEC measurements at low latitude using UNB Ionospheric Modeling Technique

BY

D. J. SHETTI

DEPARTMENT OF PHYSICS,
SMT. KASTURBAI WALCHAND COLLEGE,
SANGLI - 416 416
INDIA (M.S)

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Abstract:

UNB Ionospheric Modeling Techniques computes TEC from GPS observables at both L1 and L2 frequencies in order to provide ionospheric corrections to communication, surveillance and navigation systems operating at one frequency. The software estimates the coefficients of a linear spatial approximation of TEC over each station in addition to the satellite and receiver differential biases, modeling the ionospheric measurements from a dual frequency GPS receiver with the single-layer ionospheric model. The GPS data of IGS Hyderabad station (17.41^{0}N, 78.55^{0}E), Bangalore (13.02^{0}N, 77.57^{0}E) and Kolhapur station (16.8˚N, 74.2˚E) have been used to measure Total Electron Content (TEC) of the ionosphere during the period of different geomagnetic storm events. The effect of the geomagnetic storm on ionosphere shows an increase in the VTEC values, followed by sudden decrease in Dst values in some storm cases. In the next few years there will be ample opportunities to study in detail solar- terrestrial events using UNB Ionospheric Modeling Techniques for better understanding of the effect of solar activity on Total Electron Content (TEC) at low latitudes.

Key Words: GPS, Total Electron Content, Ionosphere

The TEC depends on the geographic latitude, longitude, local time, season, geomagnetic activity and viewing direction

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.

STEC and VTEC

$$STEC = \int_{r}^{sv} N\, dr = \left(\frac{f_2^2}{f_1^2 - f_2^2} \right) \frac{2 f_1^2}{K} \Delta P_{1,2}$$

$$= 9.509\ E16\ \Delta P_{1,2}$$

$\Delta P\ 1,2 = P1 - P2$ where P1 and P2 are pseudo ranges on L1 and L2 respectively

Differential phase advance STEC

$$STEC = \int_{r}^{sv} N\, dr = \left(\frac{f_2^2}{f_1^2 - f_2^2} \right) \frac{2 f_1^2}{K} \Delta L_{1,2}$$

$$= 9.509\ E16\ \Delta L_{1,2}$$

$\Delta L\ 1,2 = \Phi 1 - \Phi 2$ where $\Phi 1$ and $\Phi 2$ are phase measurements on L1 and L2 respectively.

Slant TEC to Vertical TEC

$$TEC = slant\ TEC\ X\ map$$

$$map = \sqrt{1 - \left(\frac{h_{sp} \cos \varepsilon}{h_{sp} + R_E} \right)^2}$$

R_E -Radius of the Earth

h_{sp--} height of the ionospheric pierce point

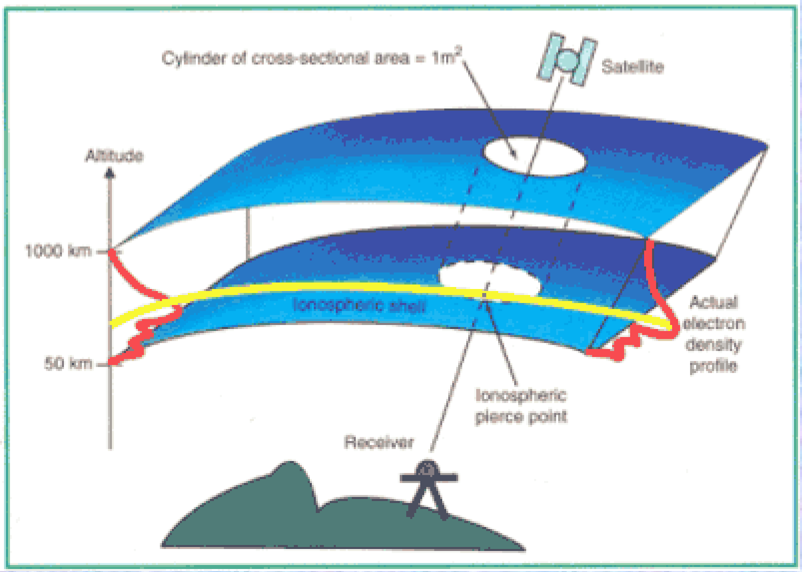

Fig.The ionosphere is represented as thin shell. The variation of electron density shown in red color and the peak value represent the F layer (shown as yellow line) (Fedrizzi et al, 2002)

GPS data Analysis

- 1- RD_RINEX Software
- 2- UNB Ionospheric Modeling Technique
- 3- WinTec Software

The output file of RD_RINEX software

```
  yyyy mo dm hh mm ss ## link    azim    elev      Leveling      PhaseTEC    RawCodeTEC
CodeTEC     CodeTECErr          Sat X          Sat Y          Sat Z          Gnd X          Gnd Y
                                    Gnd Z    PhaseTECErr
 2004 04 18 15 25 00 01 109141901  -51.53   15.95      49421.89        64.41        67.98
 66.55          3.00   19478177.63   4352761.91  17704136.00   1208447.59   5966820.91
                                 1897082.06        3.00
 2004 04 18 15 30 00 01 109141901  -49.60   16.88      49421.89        60.86        63.38
 64.08          3.00   18881585.07   4667509.07  18265944.10   1208447.59   5966820.91
                                 1897082.06        3.00
 2004 04 18 15 35 00 01 109141901  -47.68   17.83      49421.89        57.16        60.35
 60.66          3.00   18272581.01   5002054.43  18793260.53   1208447.59   5966820.91
                                 1897082.06        3.00
 2004 04 18 15 40 00 01 109141901  -45.77   18.81      49421.89        53.98        57.18
 56.87          3.00   17652902.48   5356434.59  19285101.19   1208447.59   5966820.91
                                 1897082.06        3.00
 2004 04 18 15 45 00 01 109141901  -43.88   19.82      49421.89        51.47        50.83
 53.30          3.00   17024299.16   5730582.10  19740548.59   1208447.59   5966820.91
                                 1897082.06        3.00
 2004 04 18 15 50 00 01 109141901  -41.99   20.86      49421.89        49.15        46.67
 50.39          3.00   16388526.48   6124325.05  20158753.38   1208447.59   5966820.91
                                 1897082.06        3.00
 2004 04 18 15 55 00 01 109141901  -40.12   21.94      49421.89        47.24        49.61
 48.12          3.00   15747338.62   6537387.23  20538935.87   1208447.59   5966820.91
                                 1897082.06        3.00
 2004 04 18 16 00 00 01 109141901  -38.27   23.05      49421.89        45.73        47.93
 46.26          3.00   15102481.58   6969388.66  20880387.30   1208447.59   5966820.91
                                 1897082.06        3.00
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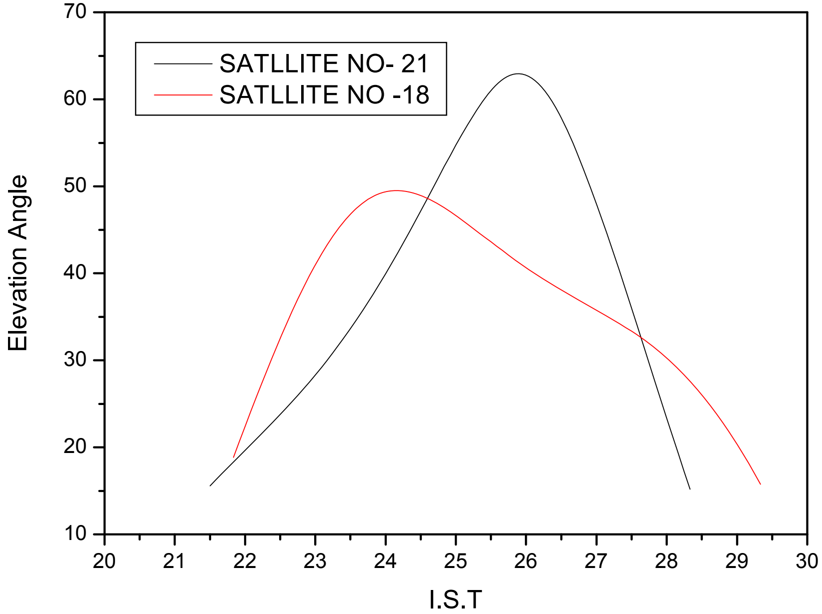
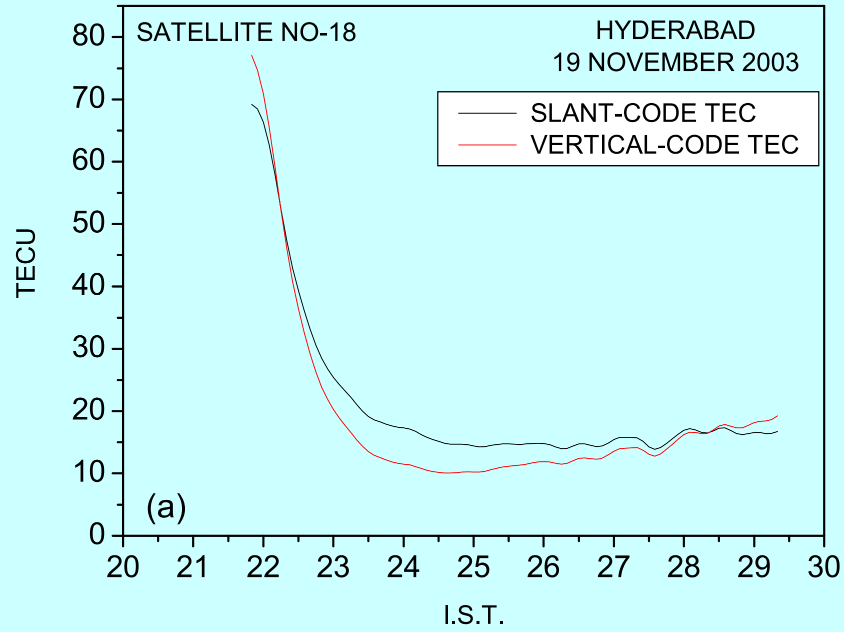
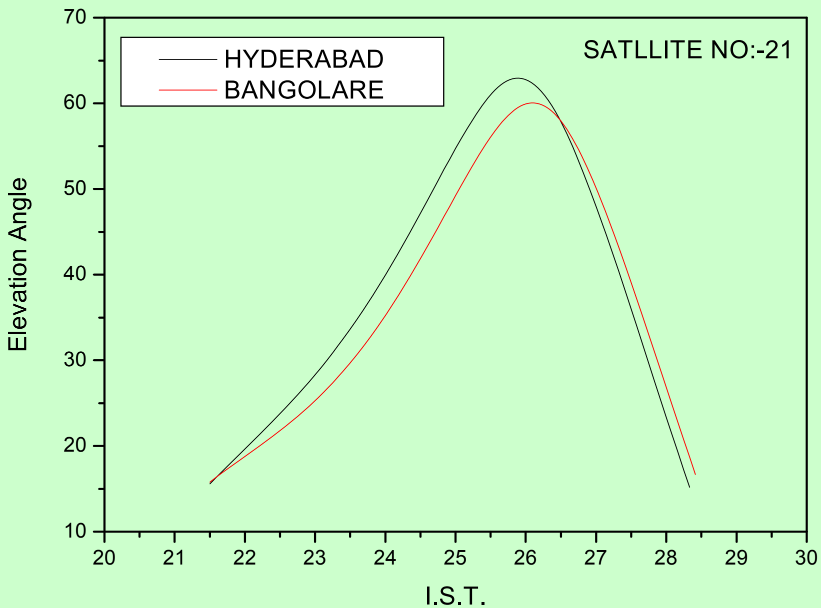
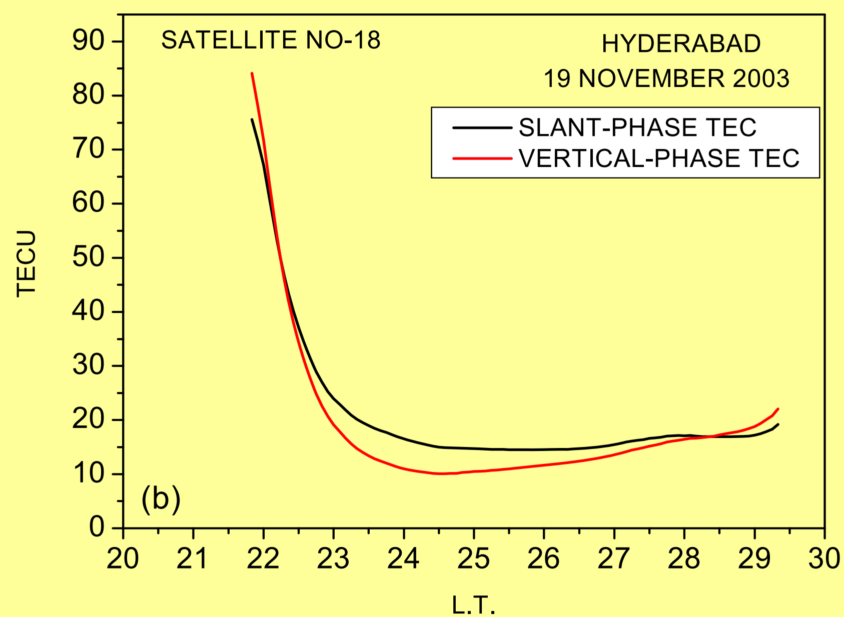

SATLLITE NO- 21
SATLLITE NO -18
Elevation Angle
I.S.T


SATELLITE NO-18
HYDERABAD
19 NOVEMBER 2003
SLANT-CODE TEC
VERTICAL-CODE TEC
TECU
(a)
I.S.T.


HYDERABAD
BANGOLARE
SATLLITE NO:-21
Elevation Angle
I.S.T.


SATELLITE NO-18
HYDERABAD
19 NOVEMBER 2003
SLANT-PHASE TEC
VERTICAL-PHASE TEC
TECU
(b)
L.T.

The UNB Ionospheric Modelling Technique

Uses single layer ionospheric model (Komjathy, 1996)

$$I(t) = M(e)[a_0(t) + a_1(t)dl + a_2(t)df] + b_r + b^s$$

$I(t)$: $L_1 - L_2$ Phase-levelled ionospheric measurement in TECU,
$M(e)$: elevation angle mapping function,
$[a_0(t) + a_1(t)dl + a_2(t)df]$: spatial linear approximation of TEC,
$b_r + b^s$: Receiver plus Satellite instrumental differential delays.

- Solar-geomagnetic reference frame.
- 5 by 5 longitude/latitude degree grid spacing maps.
- TEC at each grid node computed using the 4 closest stations.

The UNB Ionospheric Modelling Technique contain 4 modules, which will be here referred by the name of the main executables:

- module "prep"
- module "post_glob"
- module "tecmap"
- module "topiri"

Each module is comprised by the main program, subroutines, executables, etc.

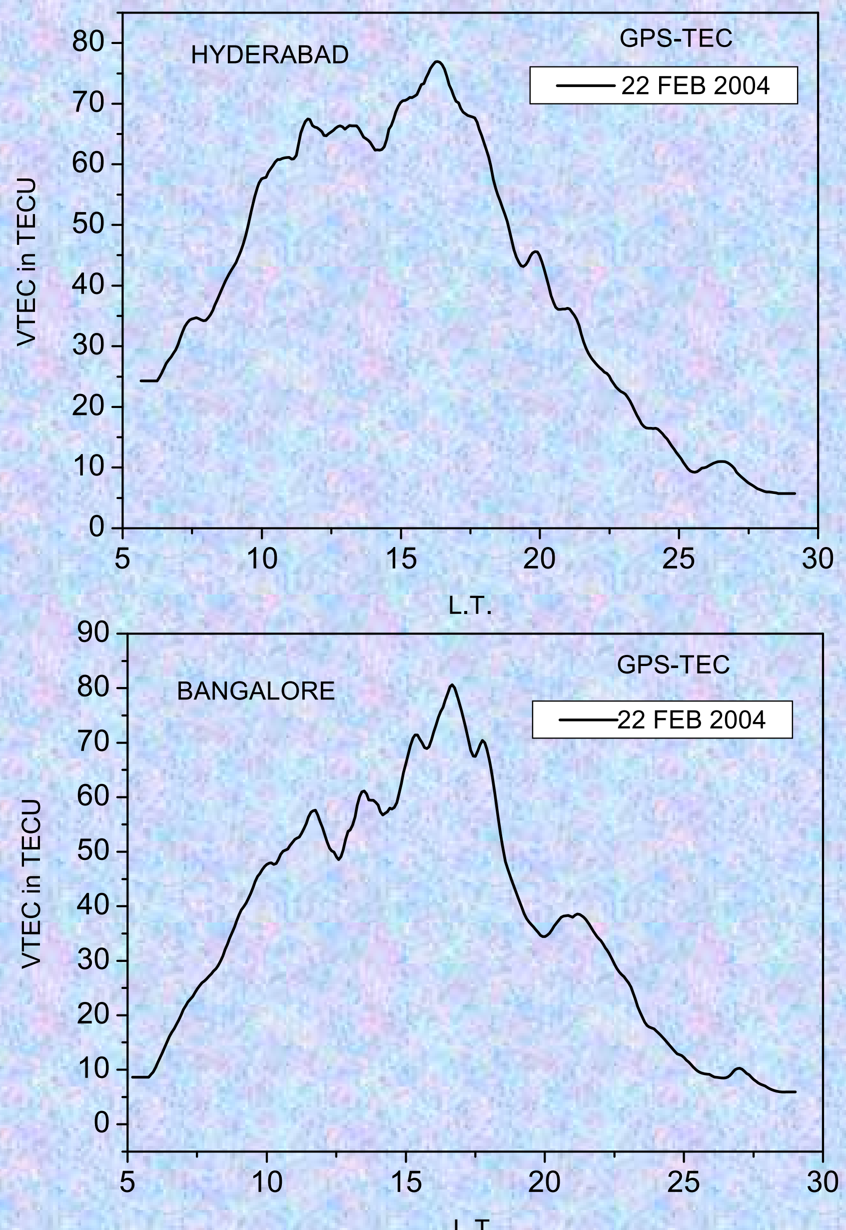


Fig.The VTEC for Hyderabad and Bangalore station on 22 February 2004 respectively using UNB Ionospheric Modeling Technique

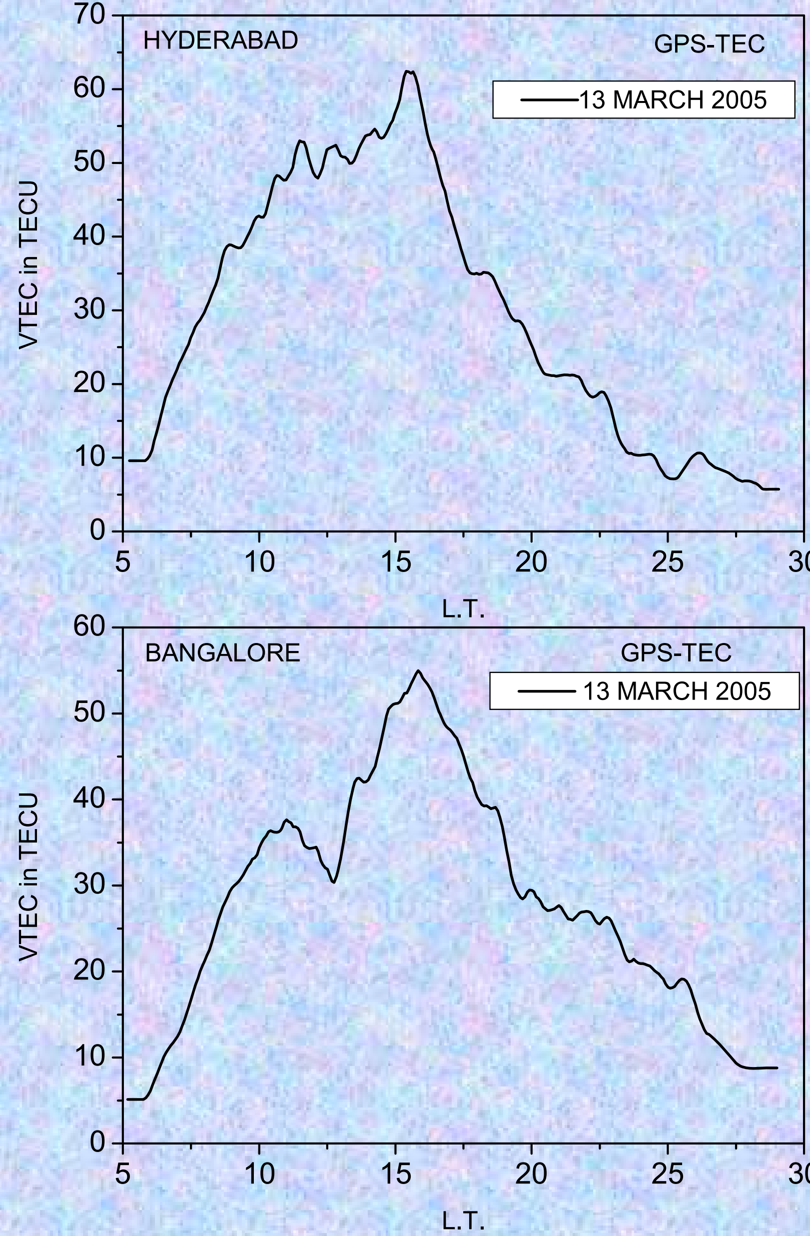
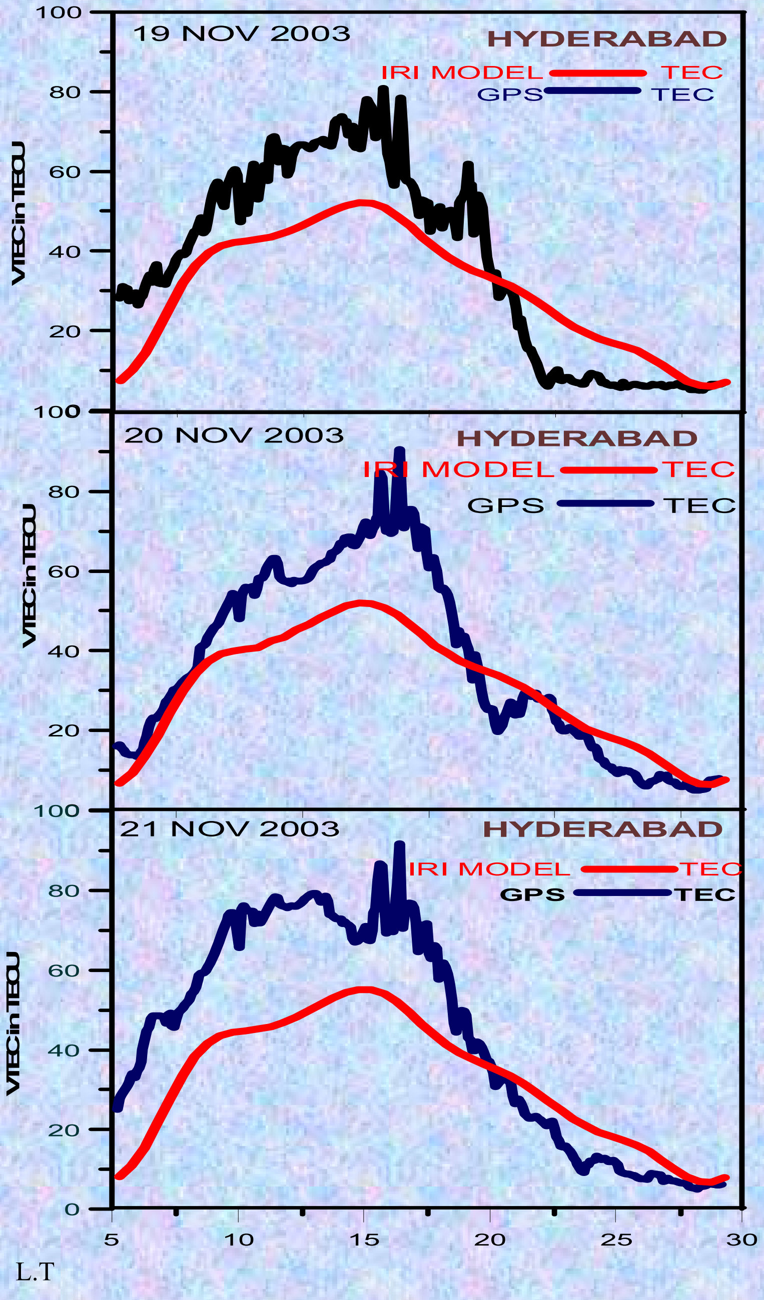


Fig.The VTEC for Hyderabad and Bangalore on 13 March 2004 using UNB Ionospheric Modeling Technique

Comparision between IRI-TEC and GPS-TEC

Plot the VTEC values using IRI2000 model and UNB Ionospheric Modeling Technique for three consecutive days November 19-21, 2003. It is clearly seen that IRI model values underestimate the computed TEC values from GPS data mostly during day time hours. However, the agreement is good between 20:00 to 06:00 hours LT. This model seems to give less accurate results for Indian region **UNB results are much more sensitive to the variations in the ionosphere**.



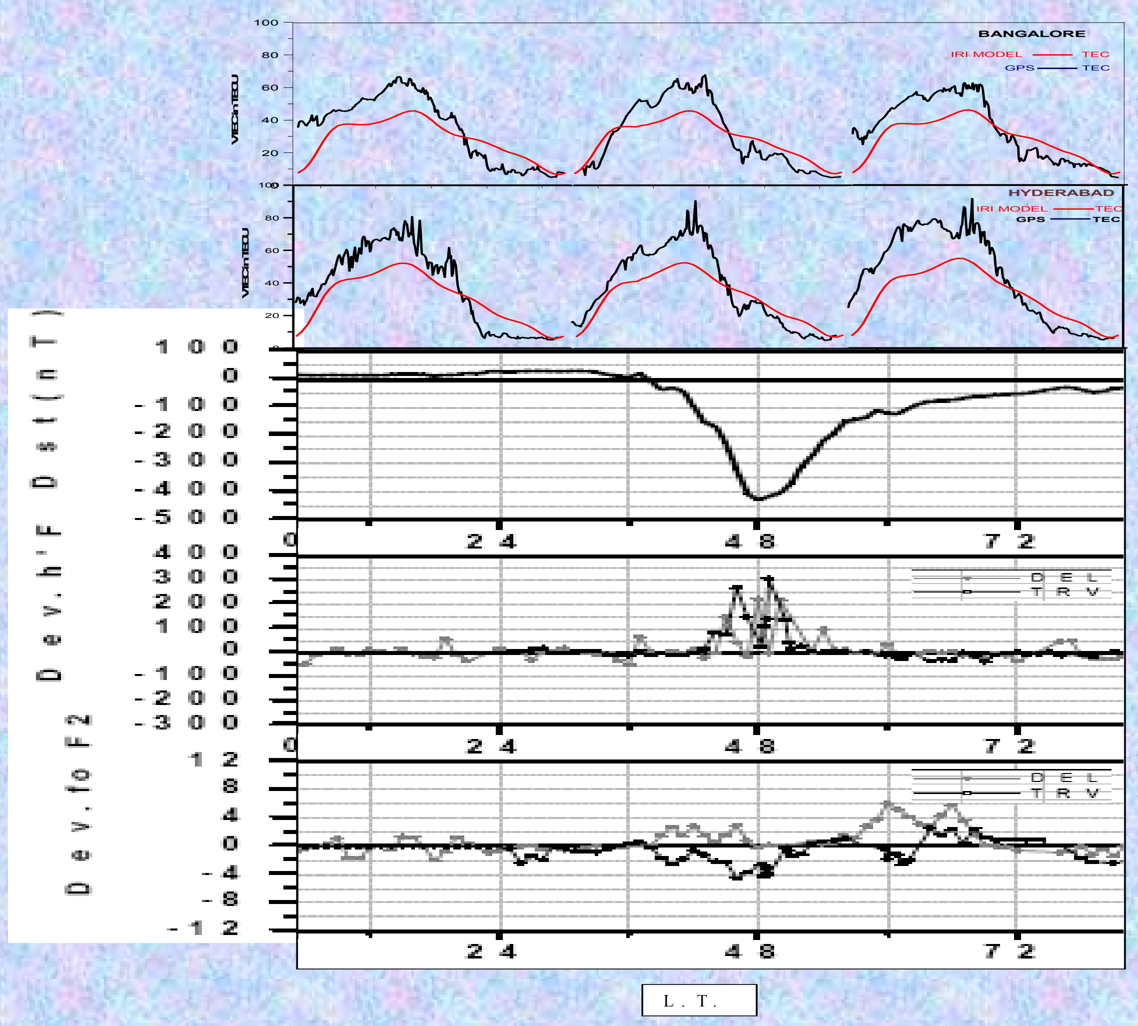


Figure .From top to bottom each panel represents computed VTEC (Bangalore),VTEC with IRI-TEC (Hyderabad), Dst(nT), Deviation of h'F (Delhi and Trivendrium) and in bottom panel deviation of foF2 (Delhi and Trivendrium)

Storm: 13-17 May 2005

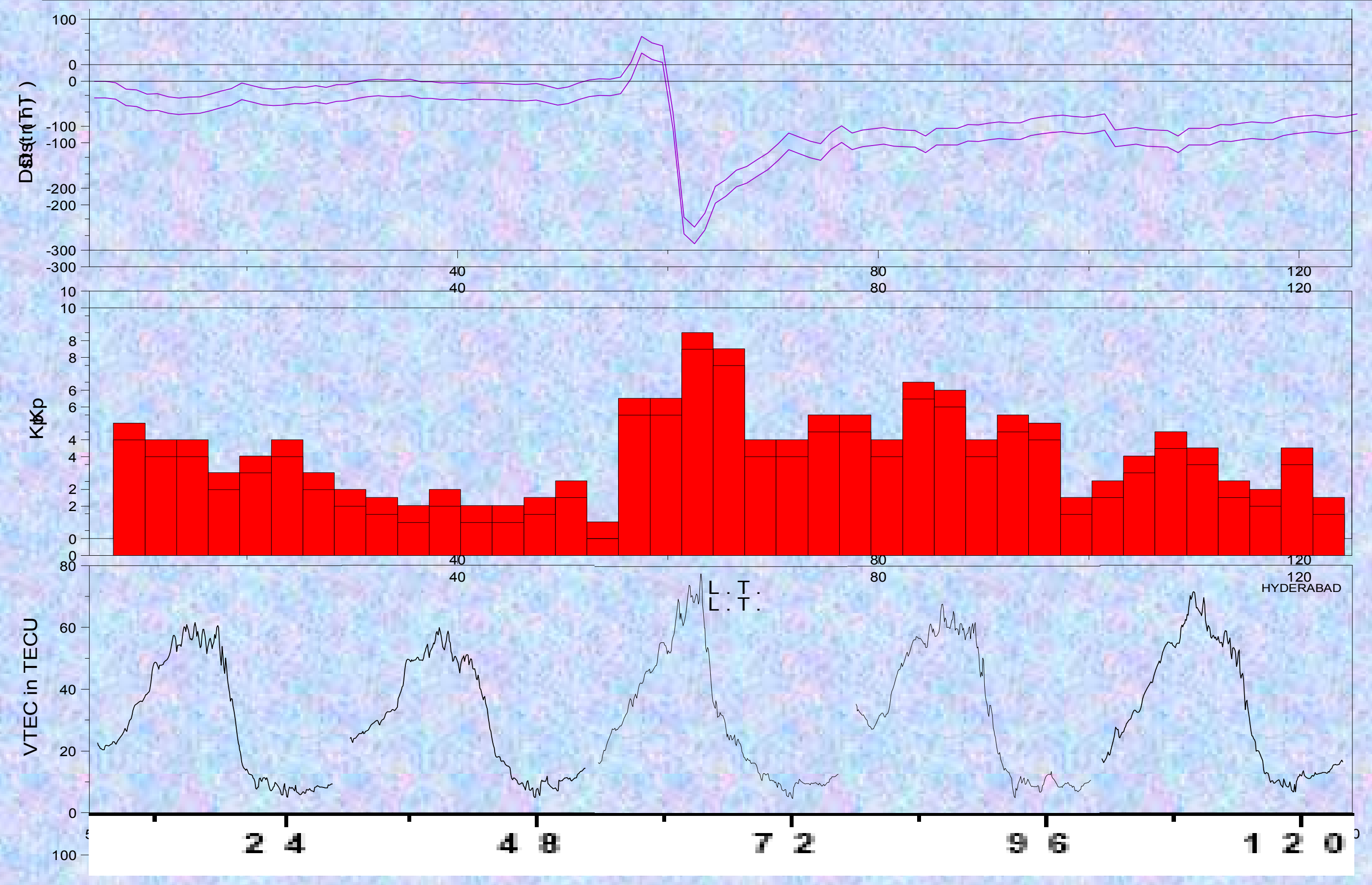
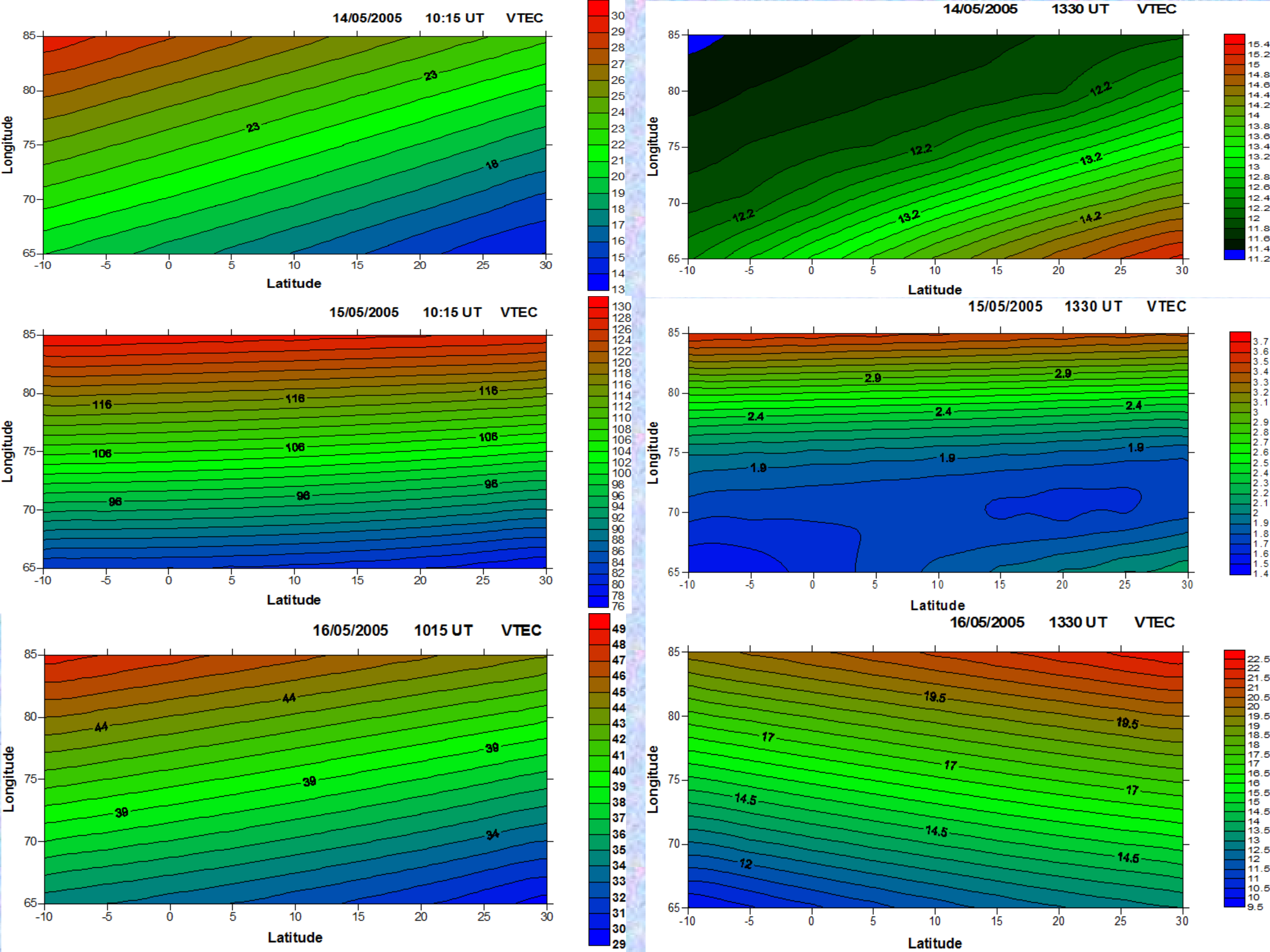
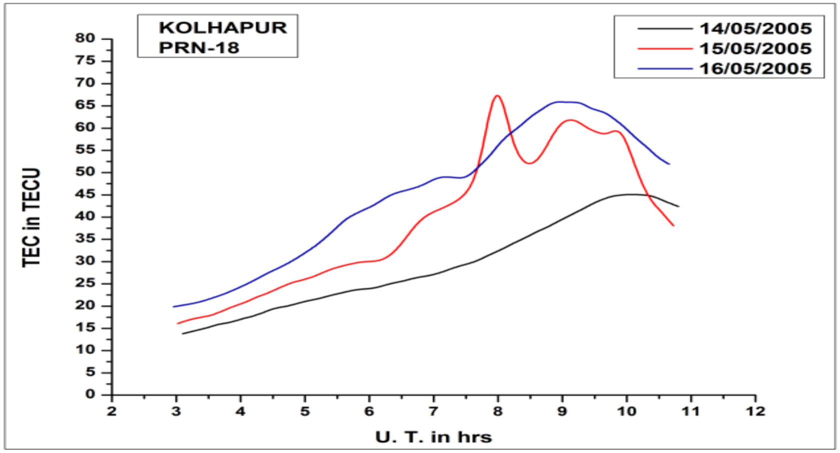
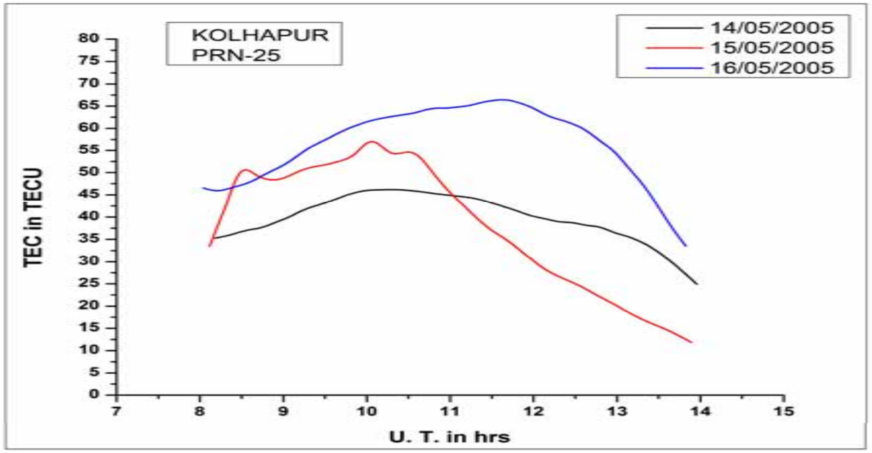
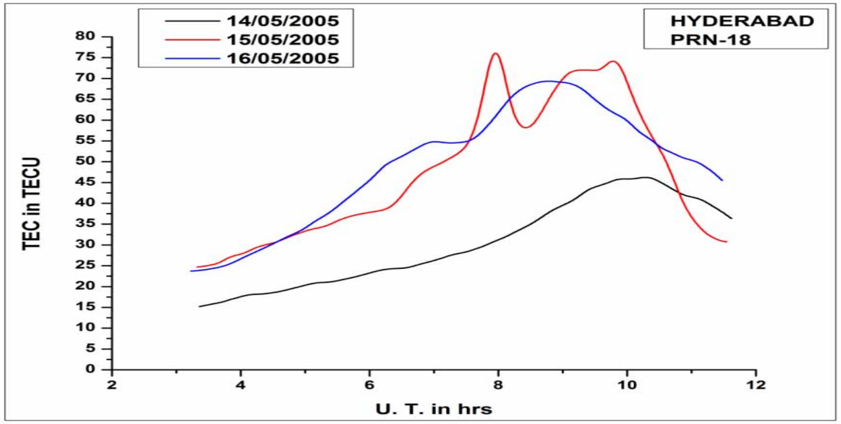


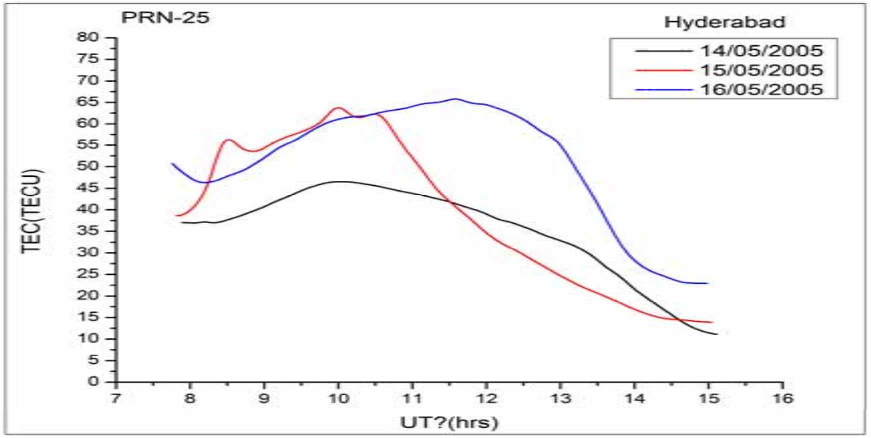
Figure. From bottom to top panel shows VTEC for Hyderabad , bottom panel shows Kp index, and the Dst (nT) index on 13-17 May 2005

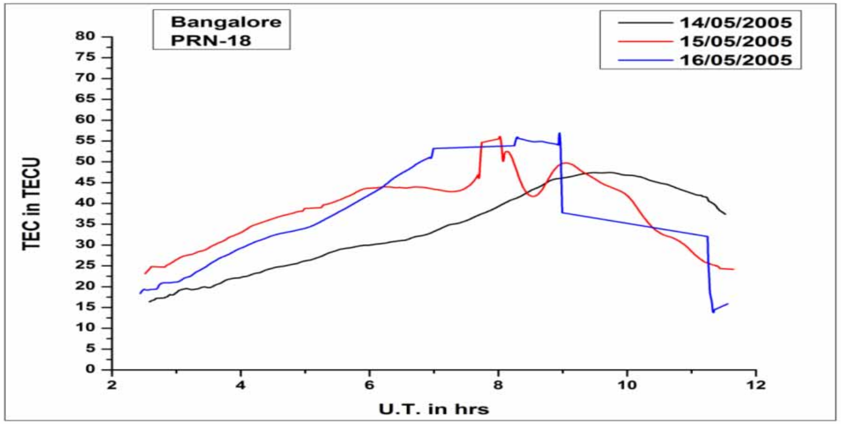

14/05/2005 10:15 UT VTEC
14/05/2005 1330 UT VTEC
15/05/2005 10:15 UT VTEC
15/05/2005 1330 UT VTEC
16/05/2005 1015 UT VTEC
16/05/2005 1330 UT VTEC
Longitude
Latitude

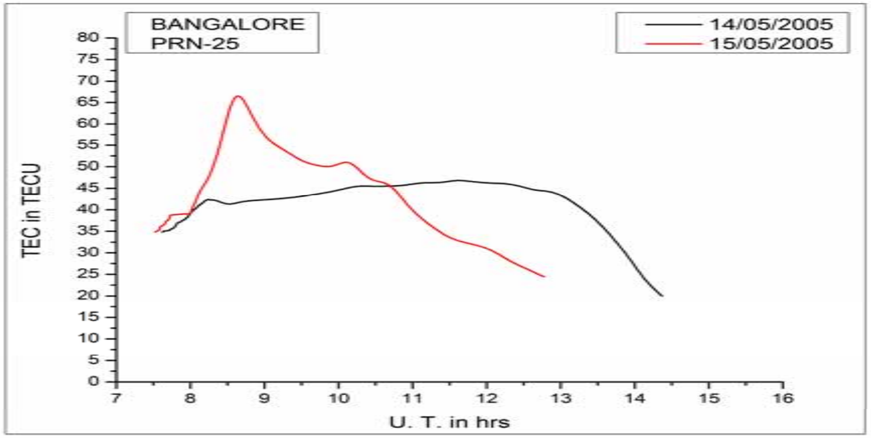

KOLHAPUR
PRN-18
14/05/2005
15/05/2005
16/05/2005
TEC in TECU
U. T. in hrs

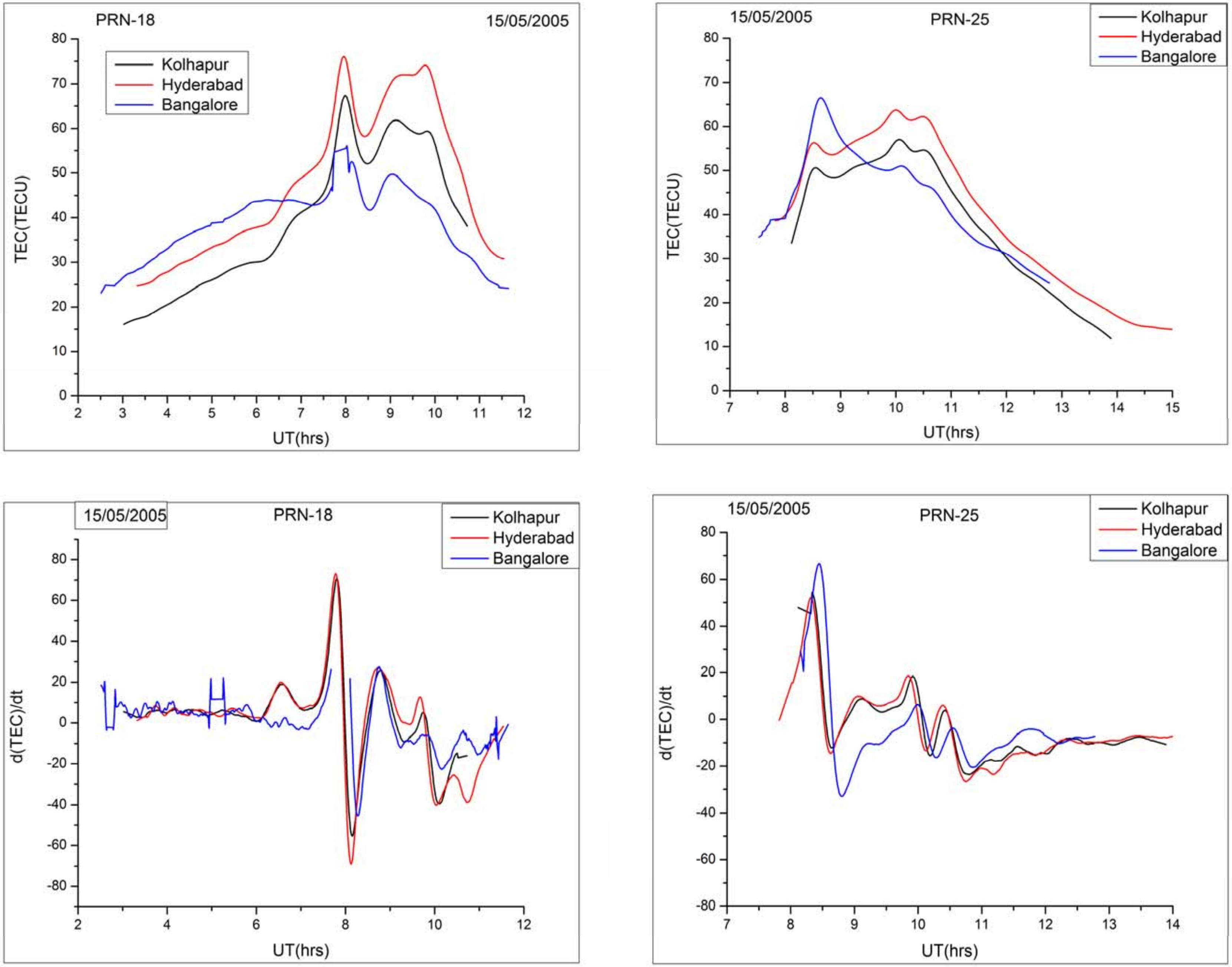

KOLHAPUR
PRN-25
14/05/2005
15/05/2005
16/05/2005
TEC in TECU
U. T. in hrs


14/05/2005
15/05/2005
16/05/2005
HYDERABAD
PRN-18
TEC in TECU
U. T. in hrs


PRN-25
Hyderabad
14/05/2005
15/05/2005
16/05/2005
TEC(TECU)
UT?(hrs)


Bangalore
PRN-18
14/05/2005
15/05/2005
16/05/2005
TEC in TECU
U.T. in hrs

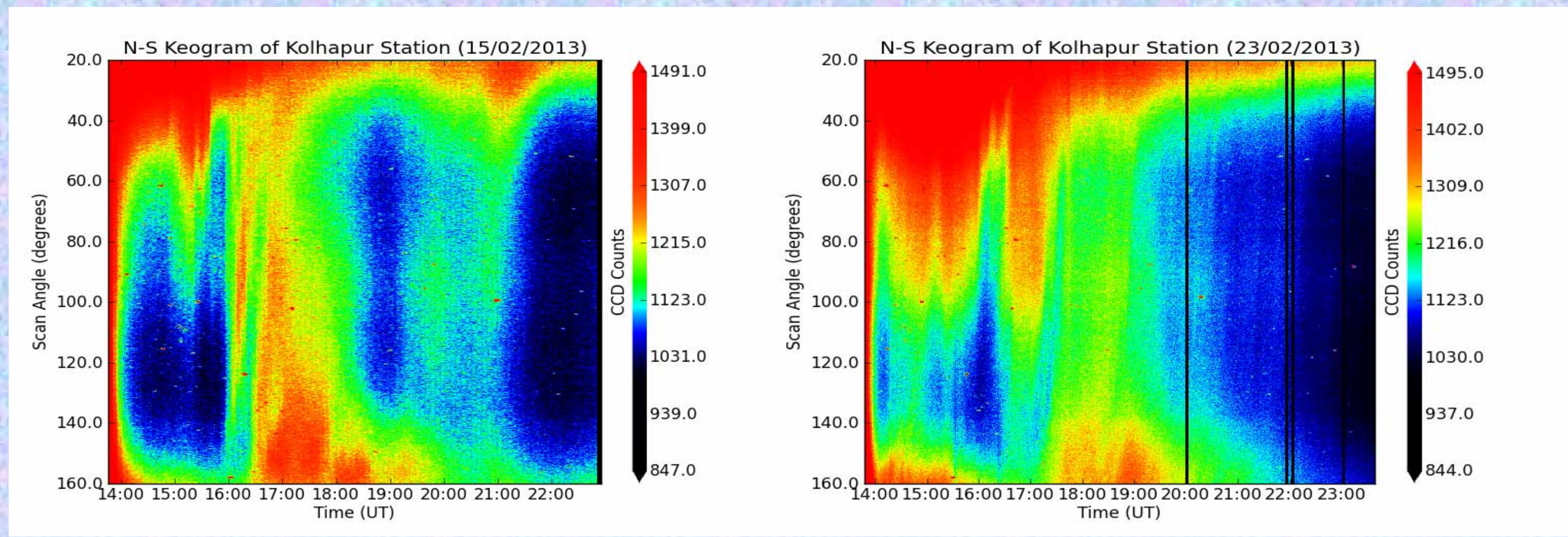

BANGALORE
PRN-25
14/05/2005
15/05/2005
TEC in TECU
U. T. in hrs


PRN-18
15/05/2005
Kolhapur
Hyderabad
Bangalore
TEC(TECU)
UT(hrs)
15/05/2005
PRN-25
Kolhapur
Hyderabad
Bangalore
TEC(TECU)
UT(hrs)
15/05/2005
PRN-18
Kolhapur
Hyderabad
Bangalore
d(TEC)/dt
UT(hrs)
15/05/2005
PRN-25
Kolhapur
Hyderabad
Bangalore
d(TEC)/dt
UT(hrs)

PASKIL
4

All Sky Imager

The Python All-Sky Image Library (PASKIL) is a collection of Python modules designed to manipulate and process all-sky images. Its plug-in architecture enables it to process images and image meta-data of any format.[Niel Peter, 2009]



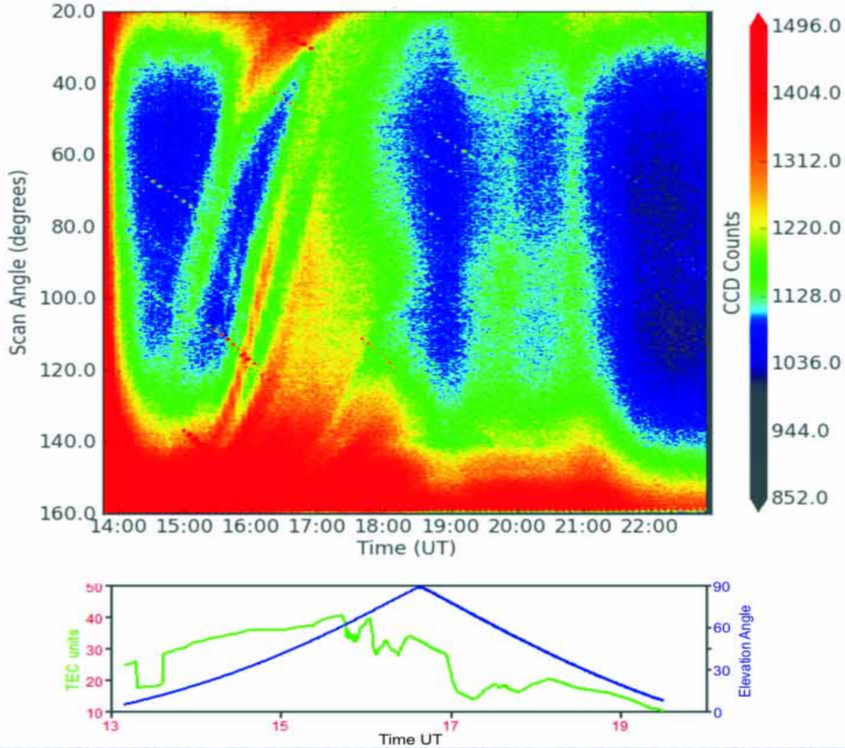


Fig.1: Night Airglow OI630 nm (E-W Keogram of Kolhapur Station) and GPS-TEC observations of Hyderabad station on 15/02/2012.

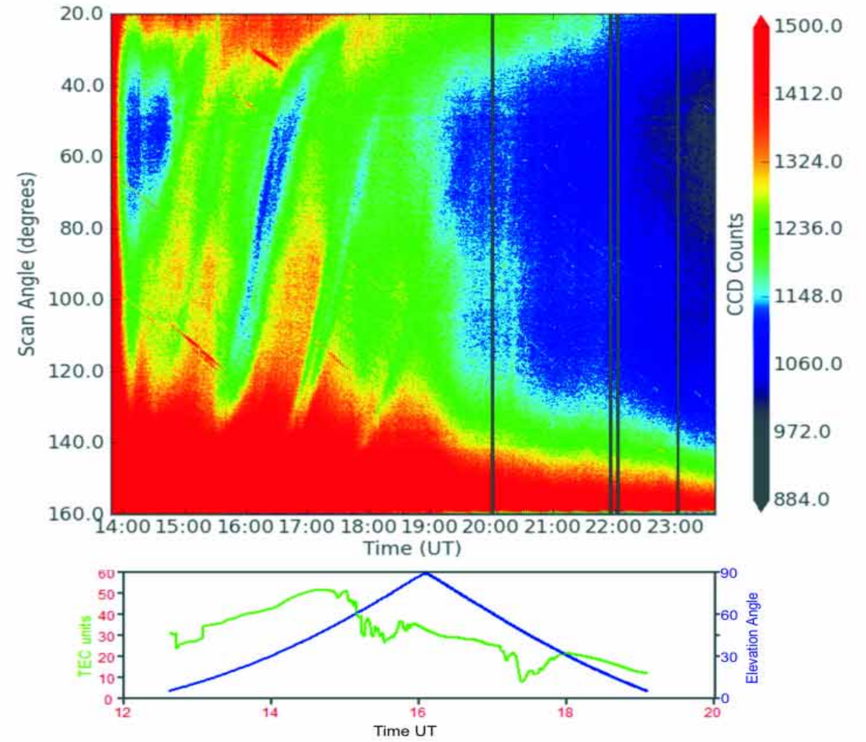
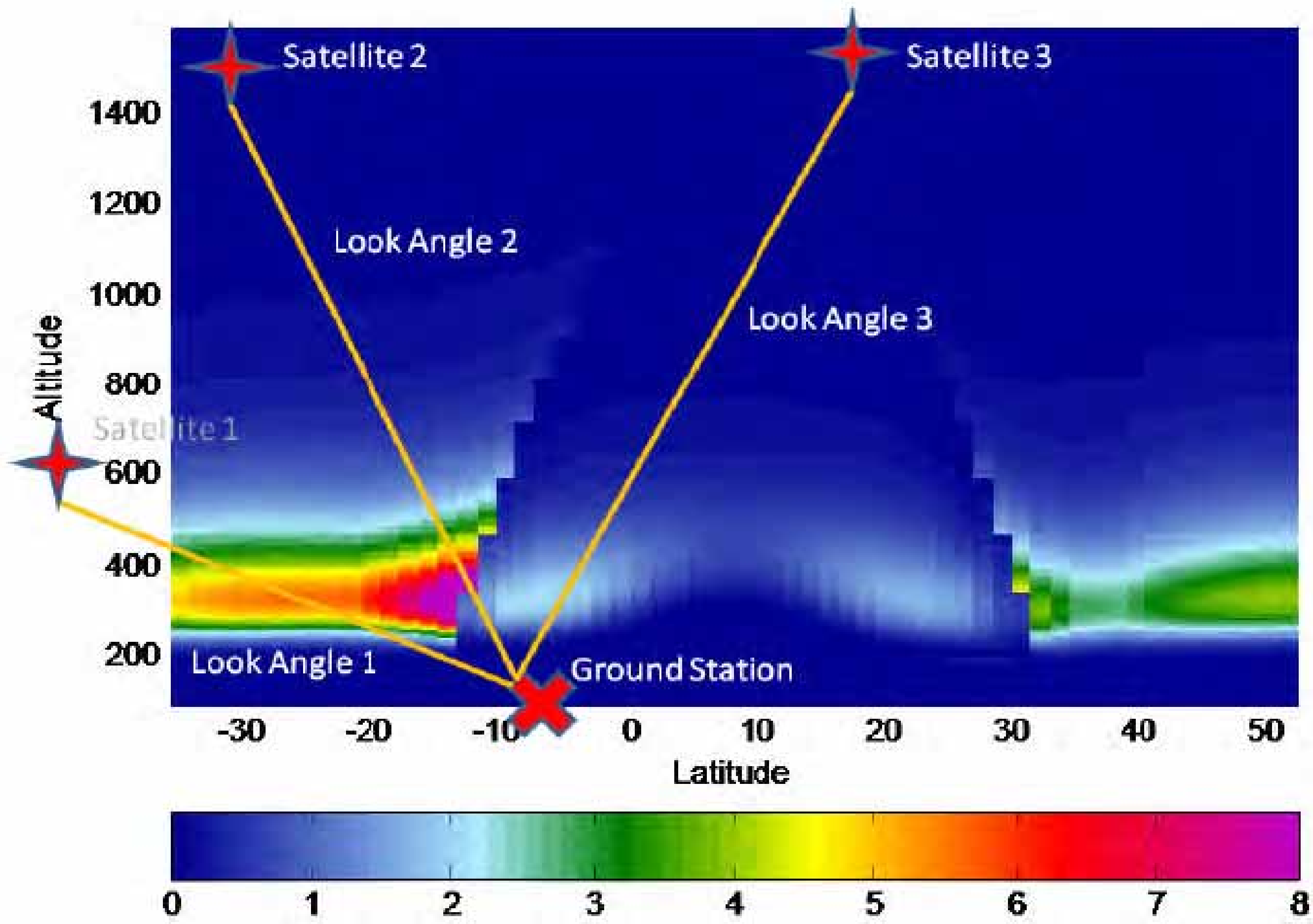
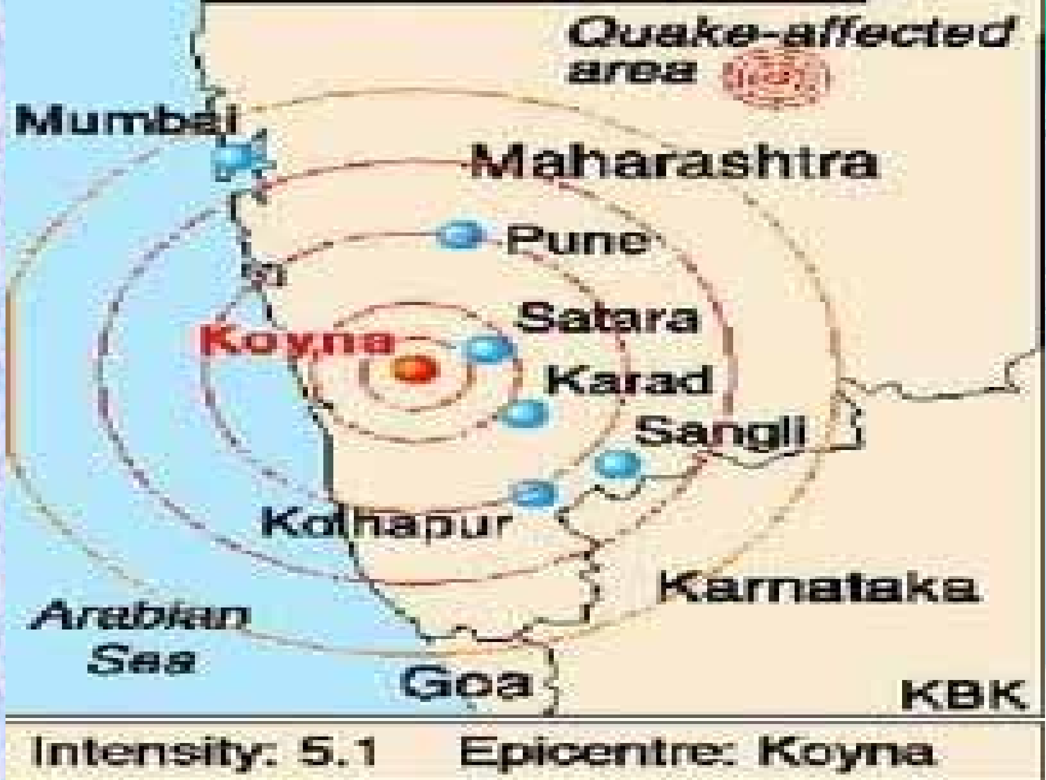


Fig.2: Night Airglow OI630 nm (E-W Keogram of Kolhapur Station) and GPS-TEC observations of Hyderabad station on 23/02/2012.

Simultaneous observations of OI630 nm and TEC were carried out using a CCD based All-Sky Imaging system and GPS system respectively during the month of February /April -2012 at low latitude station Kolhapur (16.8˚N, 74.2˚E). The radio observation of GPS is also carried out at the nearby station, Hyderabad (17.67°N, 83.32°E) and Bangalore (13.020N, 77.570E). The day-to-day variability in the occurrence of Equatorial Spread F (ESF) or Equatorial Plasma Bubble (EPB) is addressed using radio and optical observations from low latitude stations. We have found out the simultaneous occurrence of EPBs in both TEC and OI 630.0 nm emissions using both the techniques.

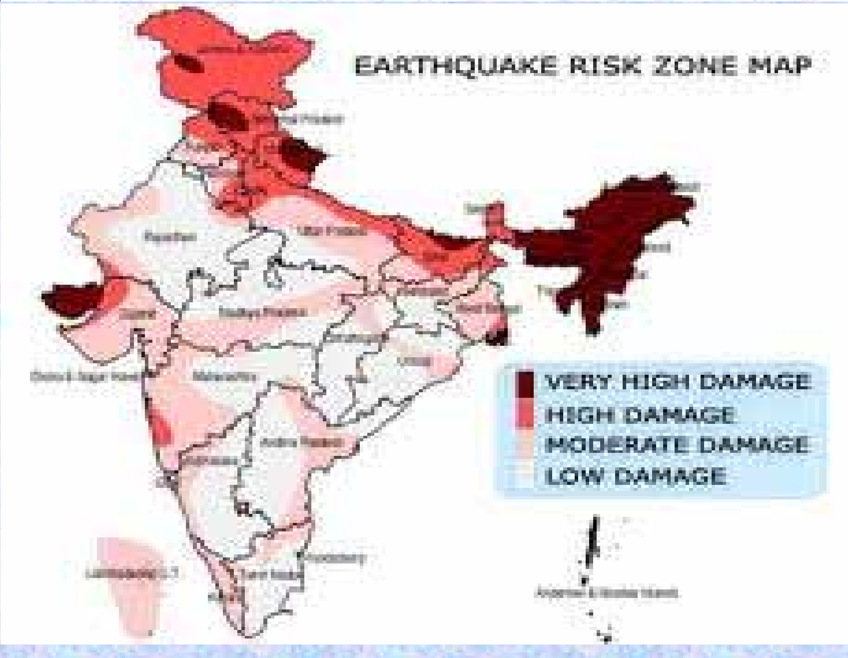


Kenneth R. Fenton,2011



Konyna-Warna region –Western Maharashtra

The geographical location of Kolhapur is considered to be very unique since it lies midway between the geomagnetic equator, which runs through the southern tip of Indian peninsula and the peak electron density in the F-region of the ionosphere called Appleton anomaly, which lies near the tropic of cancer (23.5^0N)



Conclusion

***The results verified the use of UNB-Ionospheric Modeling Techniques for future ionospheric research over Indian Region.

***The methodology to compute TEC from GPS data is being improved, and the continuously increasing number of permanent GPS stations and Ground Based Instrumentation such as Tilting Photometers , All Sky Camera for Night Airglow (OI 630.0 nm emission) study will make possible a more detailed monitoring of the behavior of the ionosphere.

Future Work

To study the possible mechanism of day-to-day variability in the occurrence of EPBs using radio and optical techniques

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To study the effects of Plasma Bubbles on UNB-IMT

In future GPS data from Kolhapur and other available close stations would be used to compute the TEC using UNB-IMT during quiet and disturbed periods.

References:

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I am also grateful to the IGS community, IIG, New Panvel for making available ground based GPS and Airglow Data and World Data Center for Geomagnetism, Kyoto, Japan for Dst and Kp indices.

Thank You


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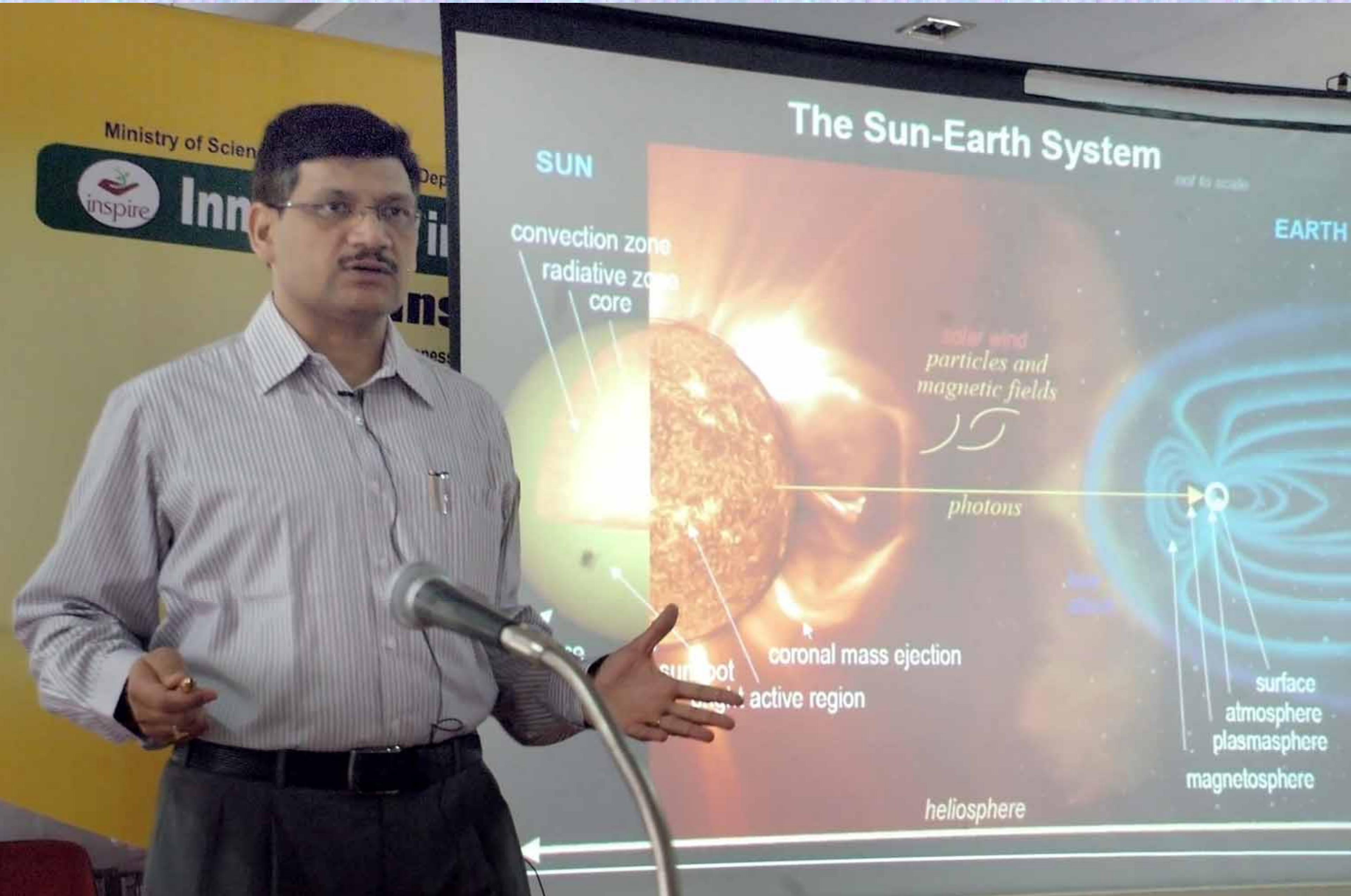

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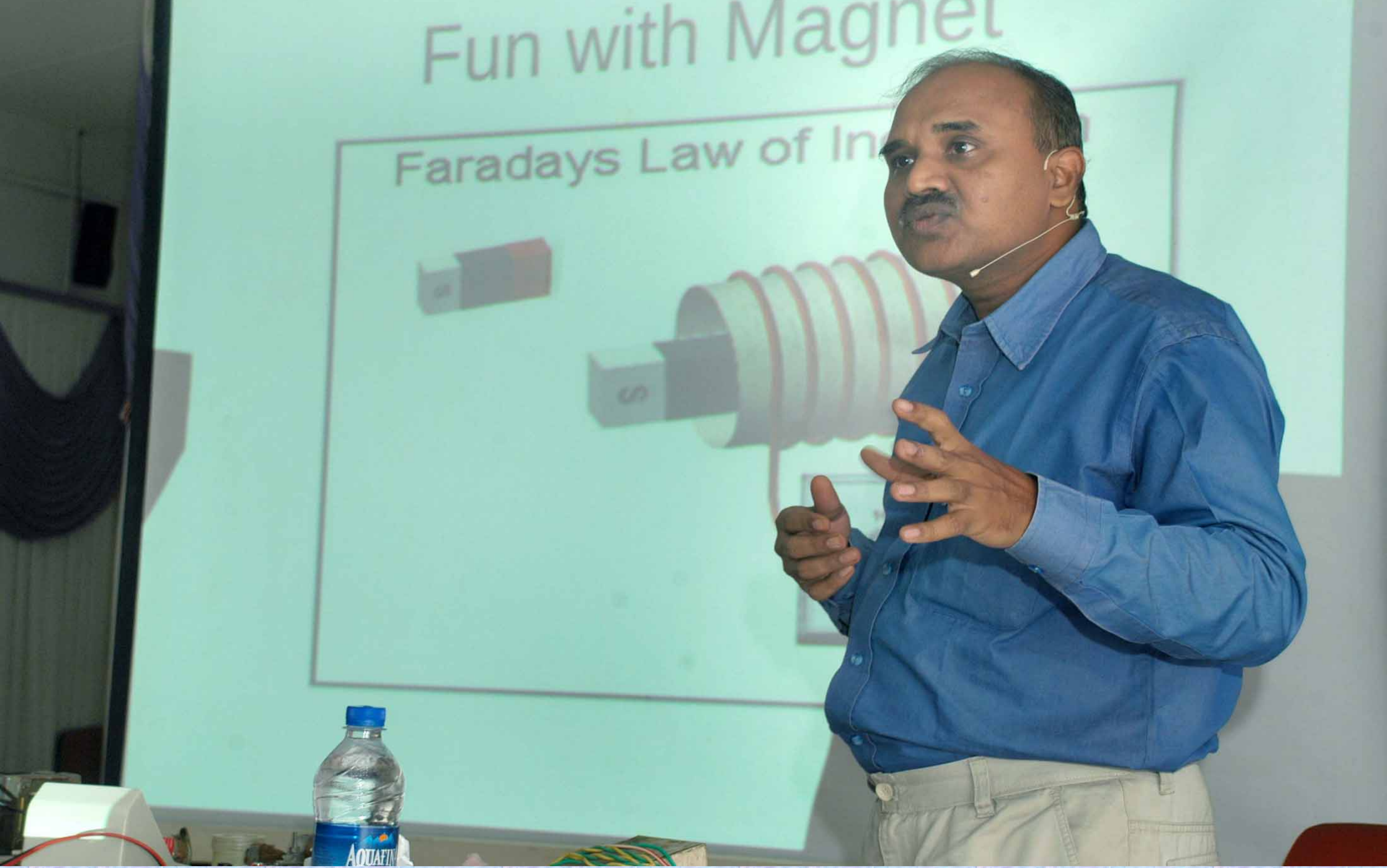
Prof (Dr.). S. Ananatkrishanan

Prof.(Dr.) Anil Kulkarni, SAC, ISRO



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