•GPS-TEC measurem

United Nations/Austria/European Space Agency Symposium on Data Analysis and Image Processing for Space Applications and Sustainable Development: Space Weather Data

Studies of OI 630.0 nm Night Airglow and GPS-TEC Observations during the Geomagnetic Storm of November 20, 2003

BY

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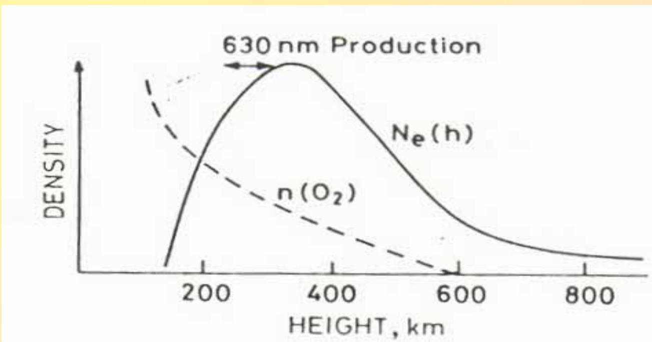
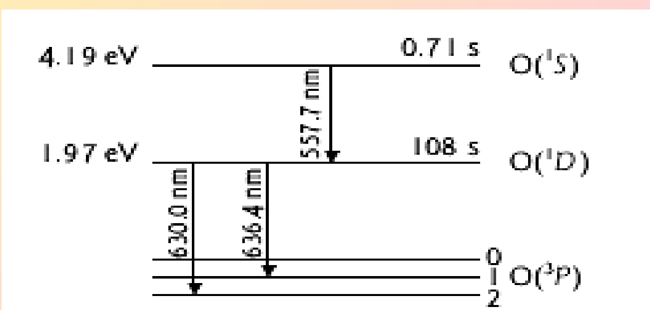
2012

Schematic diagram showing the major parts of the Tilting- filter photometer

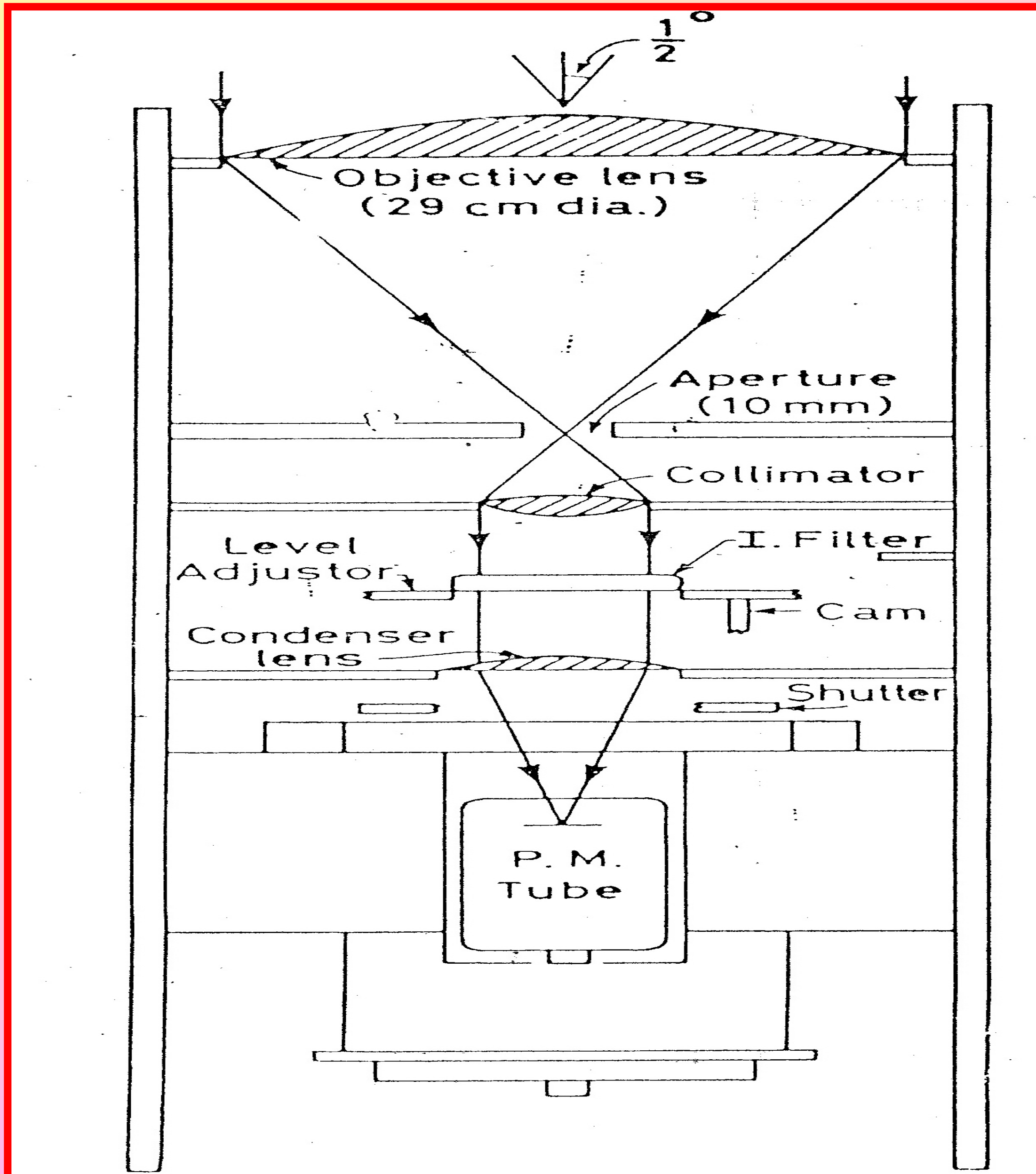
- **The photometer is having a field of view (overall) of about 1° in diameter so that it could be used to monitor the intensities coming from 5 Km diameter at F-region height of 250km in zenith direction**





O^{+2} + e → $O + O^*$ (^1S, ^1D);

O^* (^1D) → O^+ + hv (630 nm)



GPS data Analysis

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

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

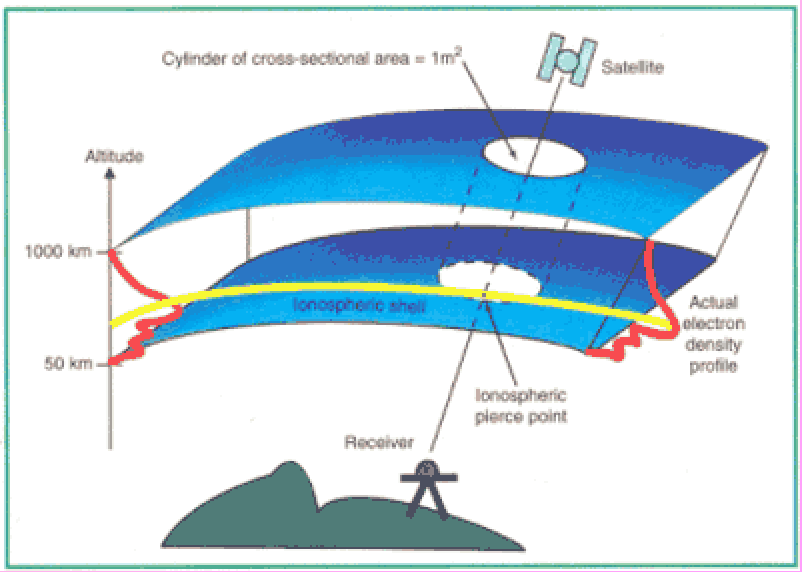


Fig. The ionosphere is represented as thin shell. The variation of electron density shown in red color and the peak value represent the F layer (shown as yellow line) (Fedrizzi et al, 2002)

•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

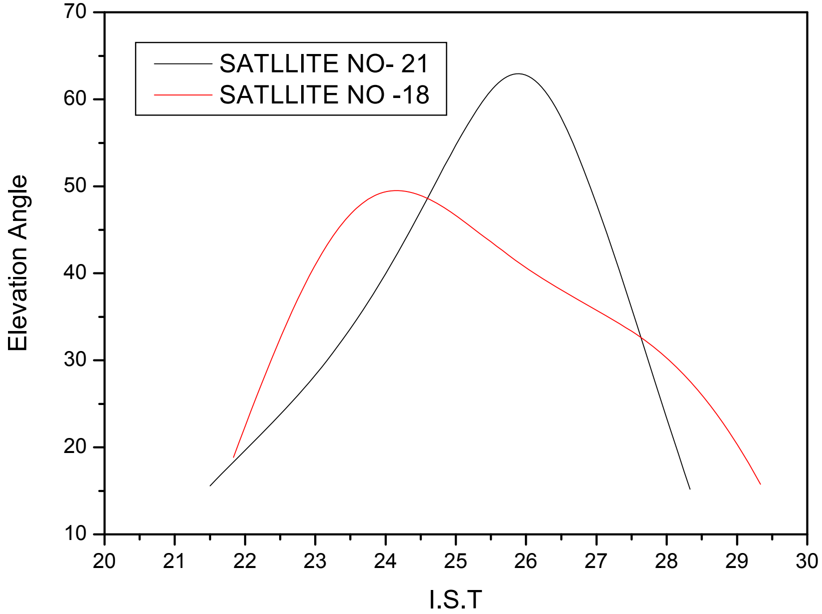
•2004 04 18 15 40 00 01 109141901 -45.77 18.81 49421.89 53.98 57.18 56.87 3.00 17652902.48 5356434.59 19285101.19 1208447.59 5966820.91 1897082.06 3.00

•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

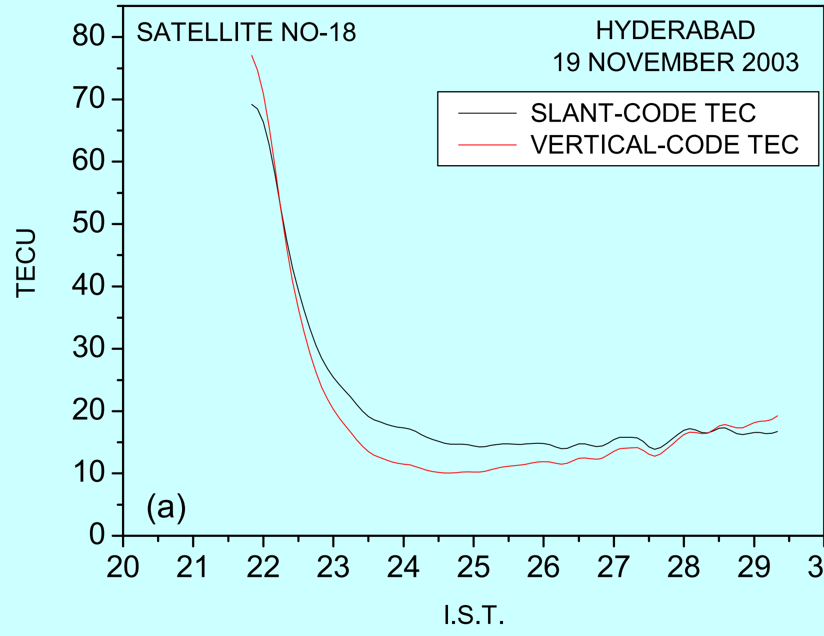
•2004 04 18 15 50 00 01 109141901 -41.99 20.86 49421.89 49.15 46.67 50.39 3.00 16388526.48 6124325.05 20158753.38 1208447.59 5966820.91 1897082.06 3.00

•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

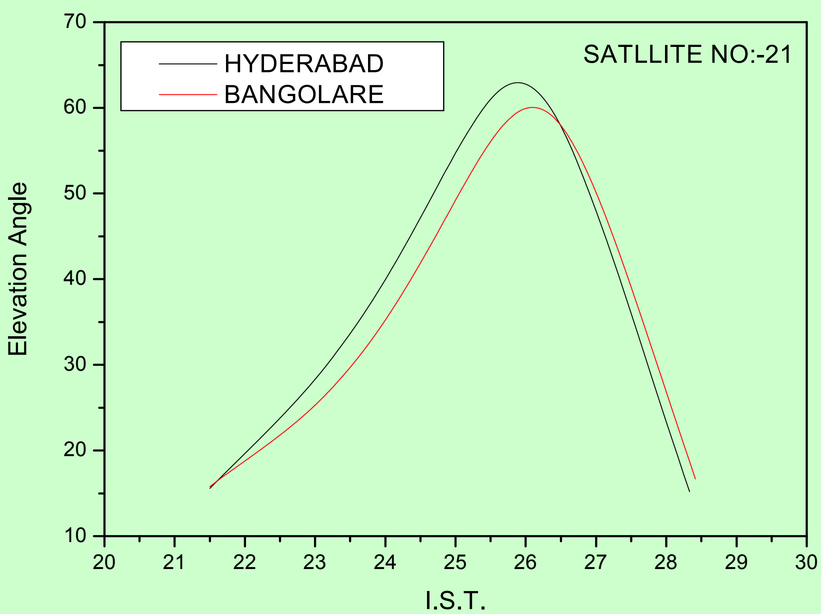
•2004 04 18 16 00 00 01 109141901 -38.27 23.05 49421.89 45.73 47.93 46.26 3.00 15102481.58 6969388.66 20880387.30 1208447.59 5966820.91 1897082.06 3.00



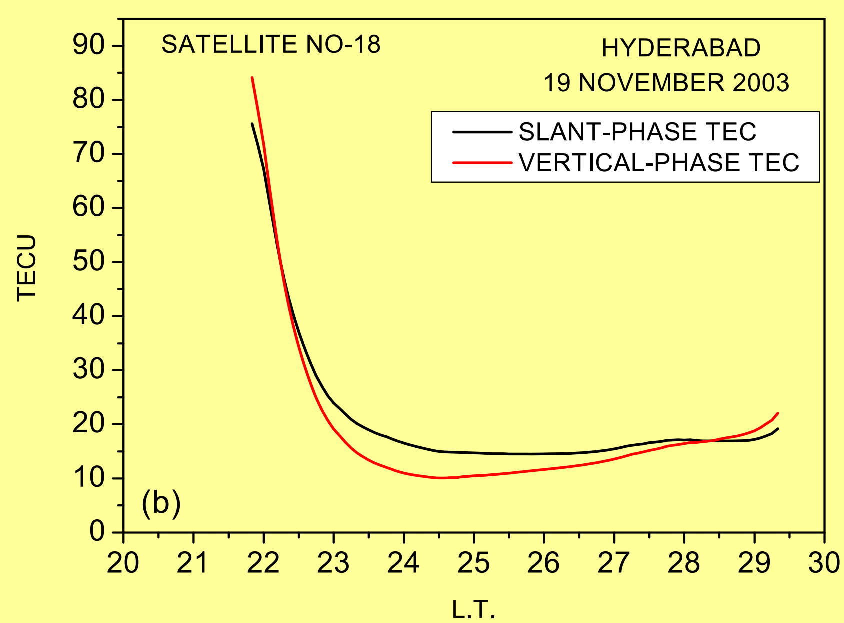
SATLLITE NO- 21
SATLLITE NO -18
Elevation Angle
I.S.T
70
60
50
40
30
20
10
20 21 22 23 24 25 26 27 28 29 30



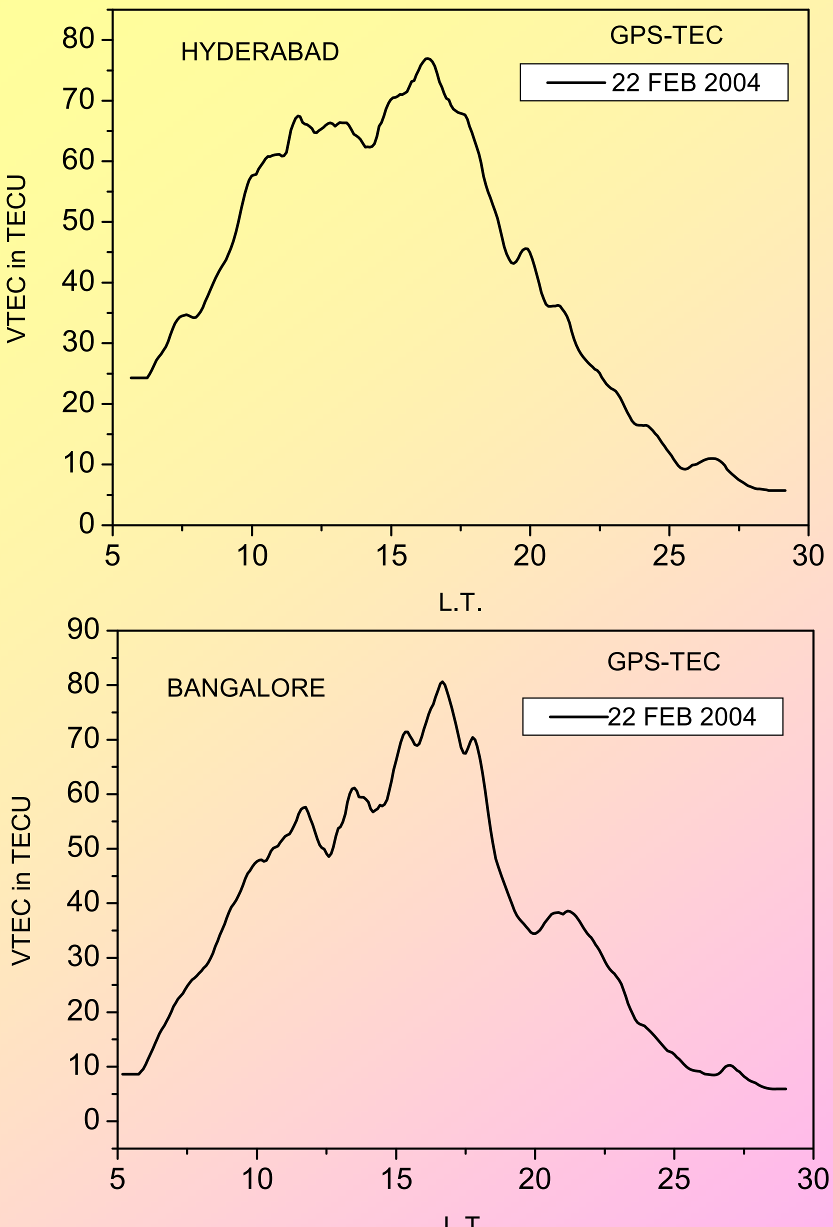
SATELLITE NO-18
HYDERABAD
19 NOVEMBER 2003
SLANT-CODE TEC
VERTICAL-CODE TEC
TECU
(a)
I.S.T.
80
70
60
50
40
30
20
10
0
20 21 22 23 24 25 26 27 28 29 30



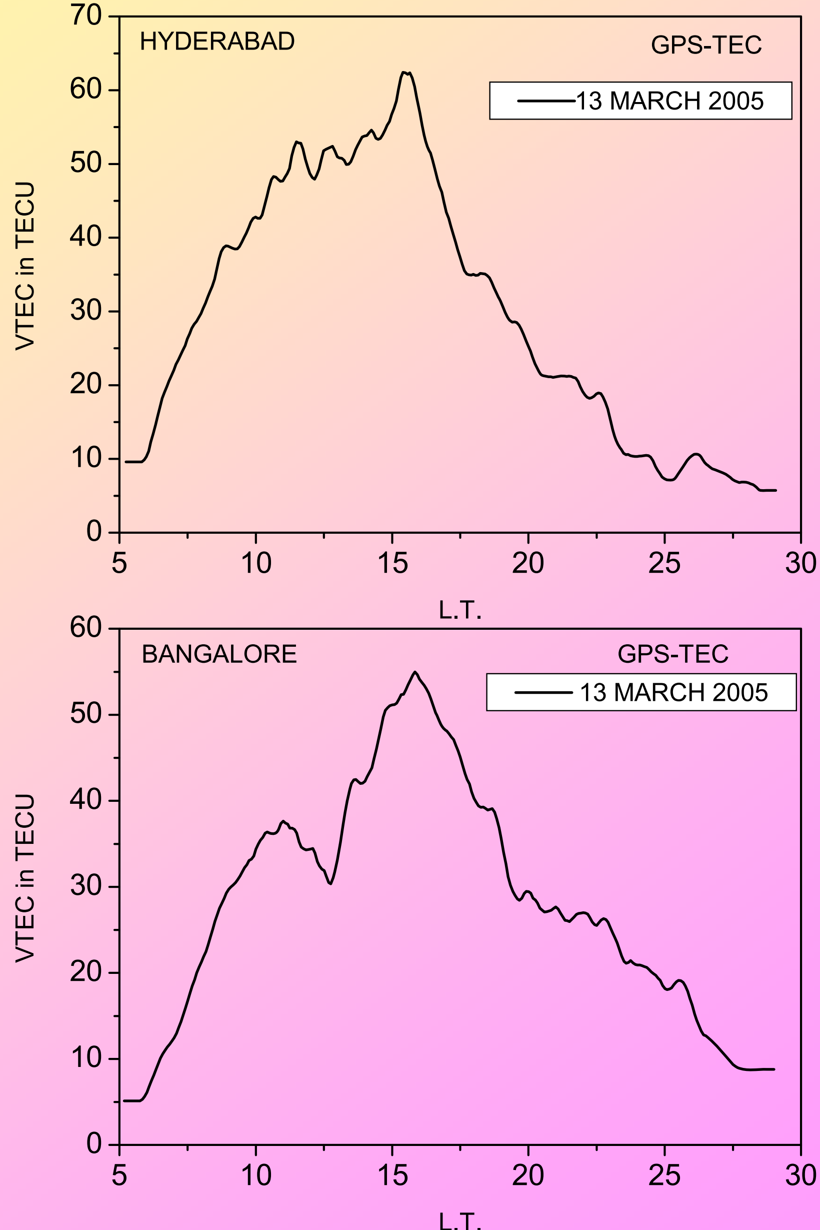
HYDERABAD
BANGOLARE
SATLLITE NO:-21
Elevation Angle
I.S.T.
70
60
50
40
30
20
10
20 21 22 23 24 25 26 27 28 29 30



SATELLITE NO-18
HYDERABAD
19 NOVEMBER 2003
SLANT-PHASE TEC
VERTICAL-PHASE TEC
TECU
(b)
L.T.
90
80
70
60
50
40
30
20
10
0
20 21 22 23 24 25 26 27 28 29 30



•**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**

OI 630 nm Night airglow Emission and TEC

- The distribution of electrons in the F-region of the ionosphere is governed by the equation of continuity.

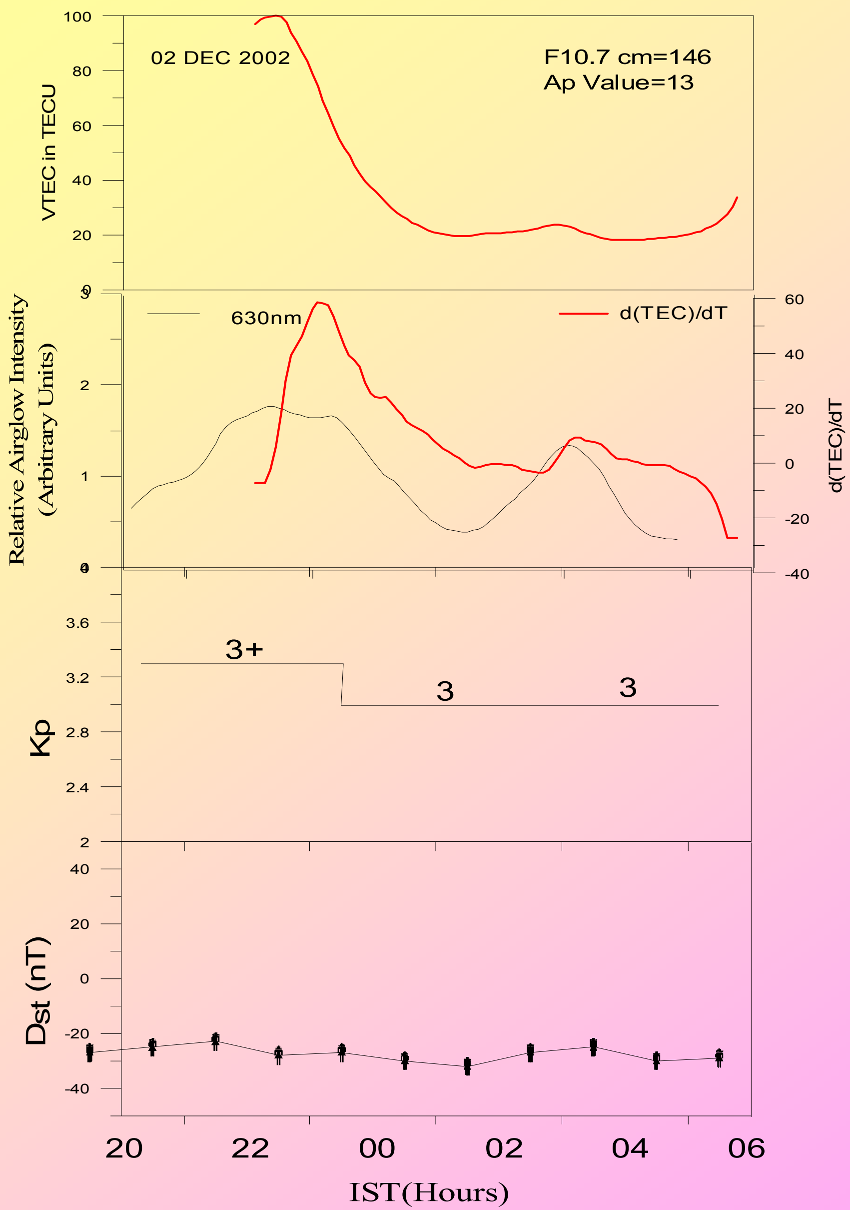
$$\partial Ne/\partial t = P - I_{630}/\xi - v.Ne - Ne.v$$

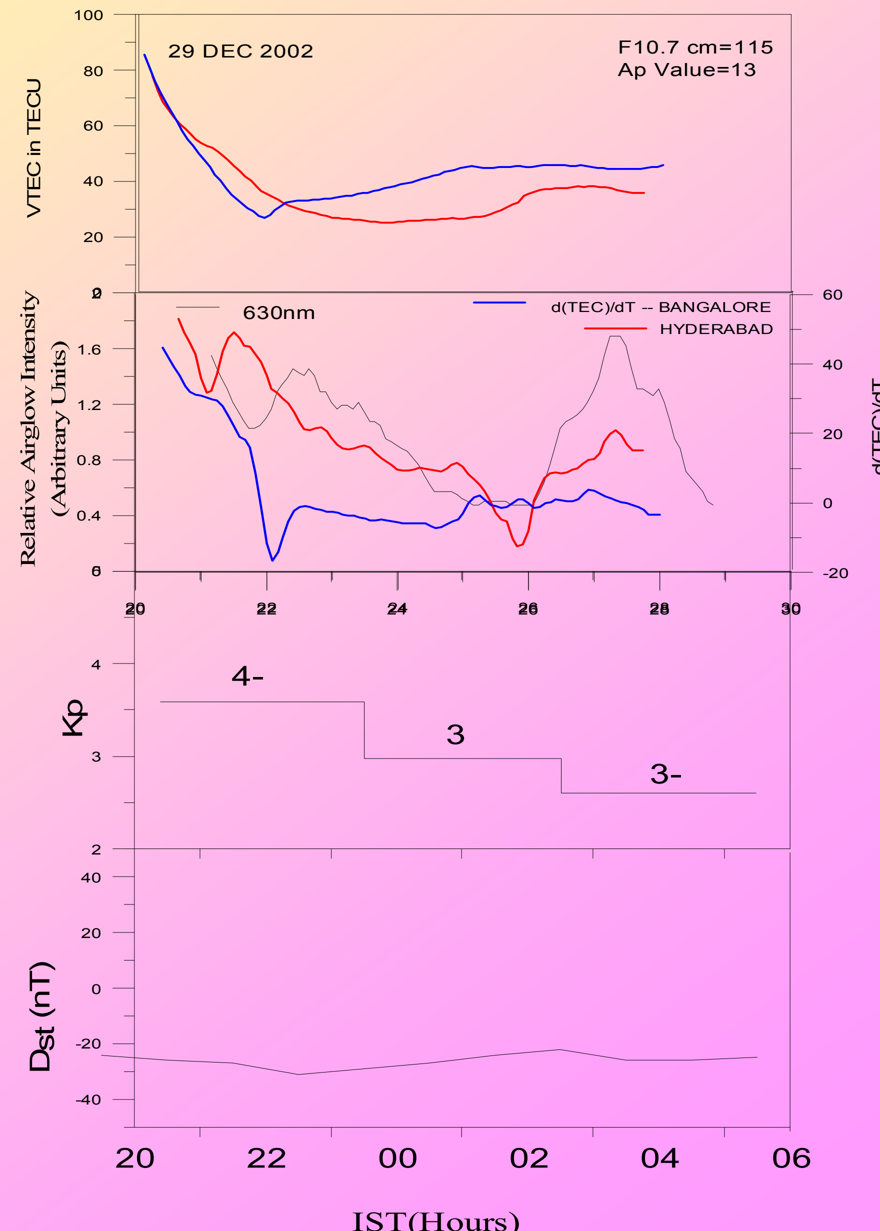
N_e is the electron density
v is the plasma velocity
t is the time
ξ is the quantum efficiency of recombination process
I_{630} is the airglow intensity
I_{630}/ξ is the electron loss rate in the ionosphere

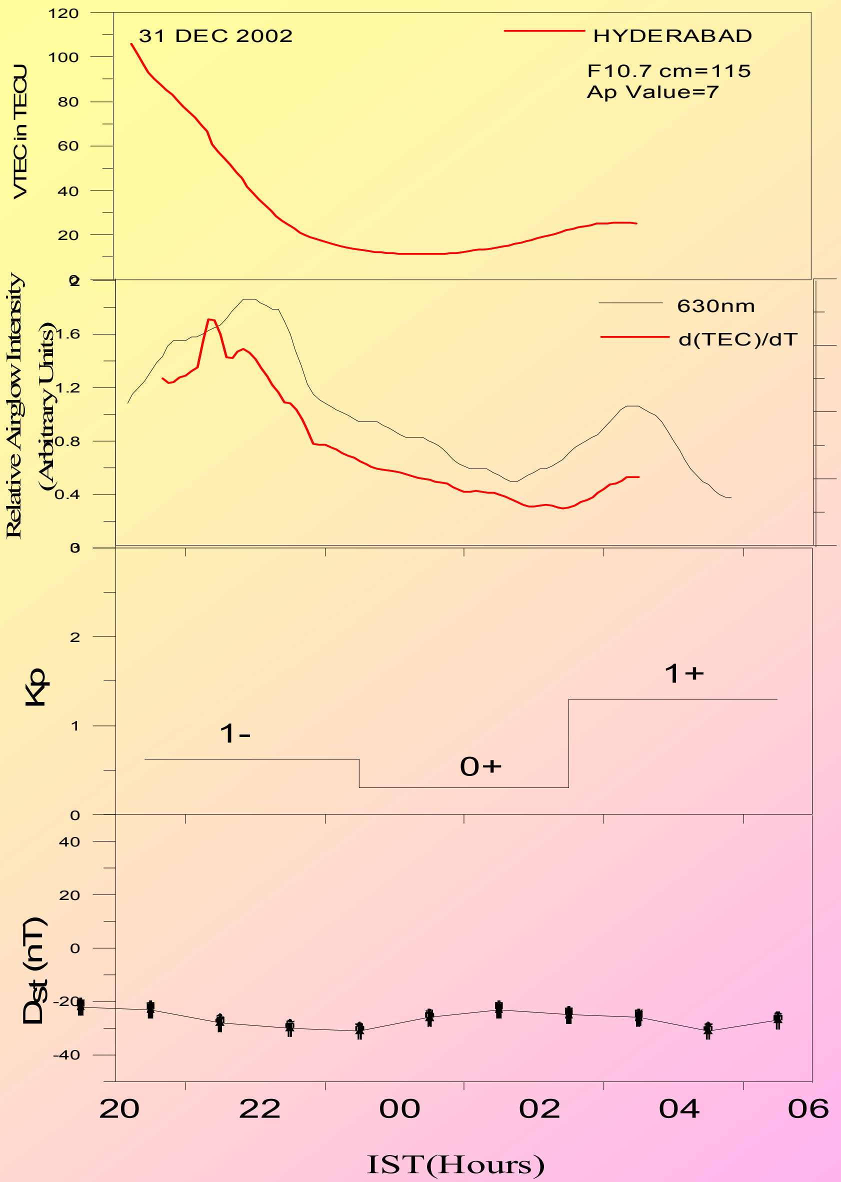
At night time F-region ionosphere is governed by the modified equation of continuity.

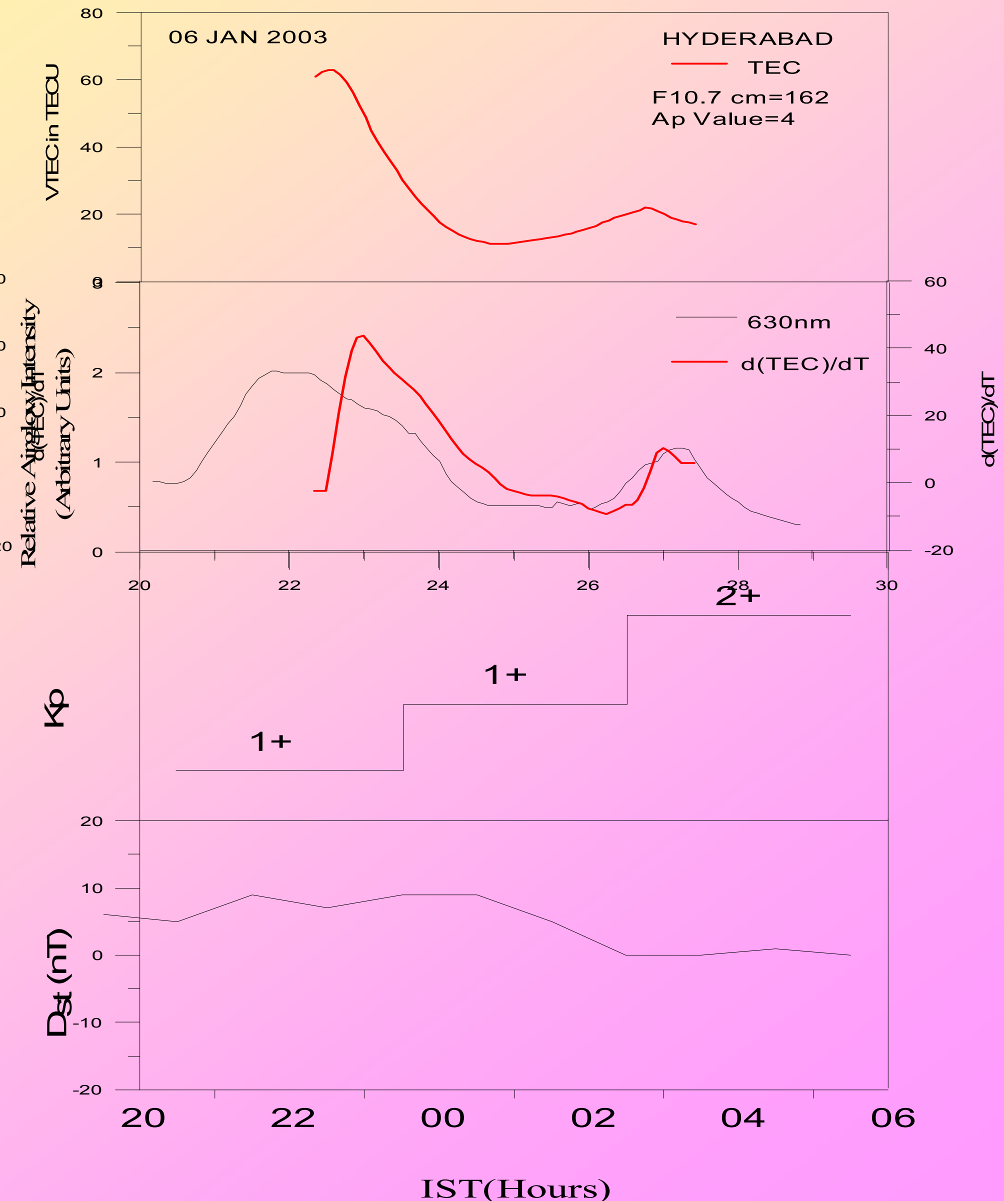
$$dNt/dt = -I_{630}/\xi$$

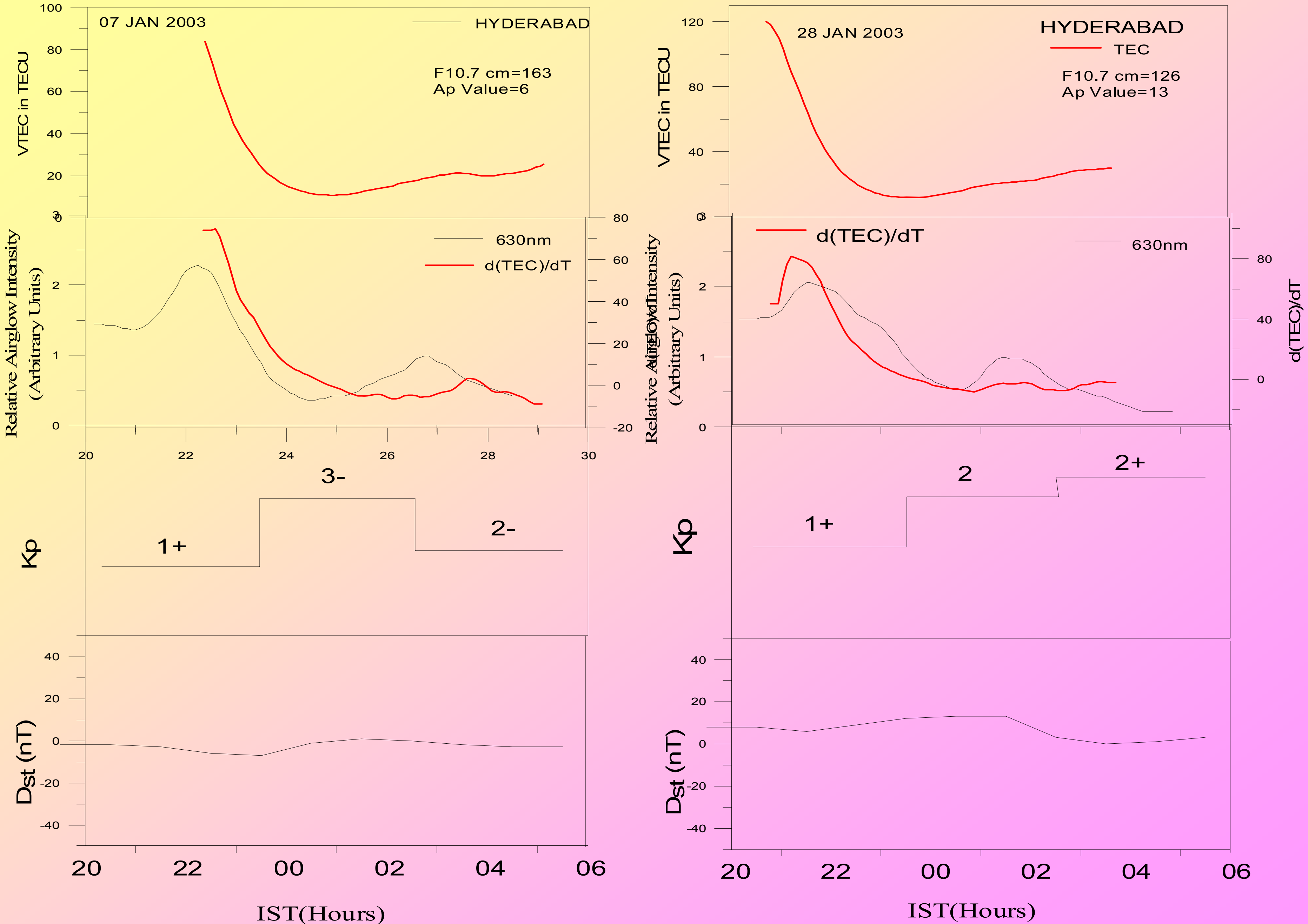
$$d(TEC)/dt = -I_{630}/\xi$$

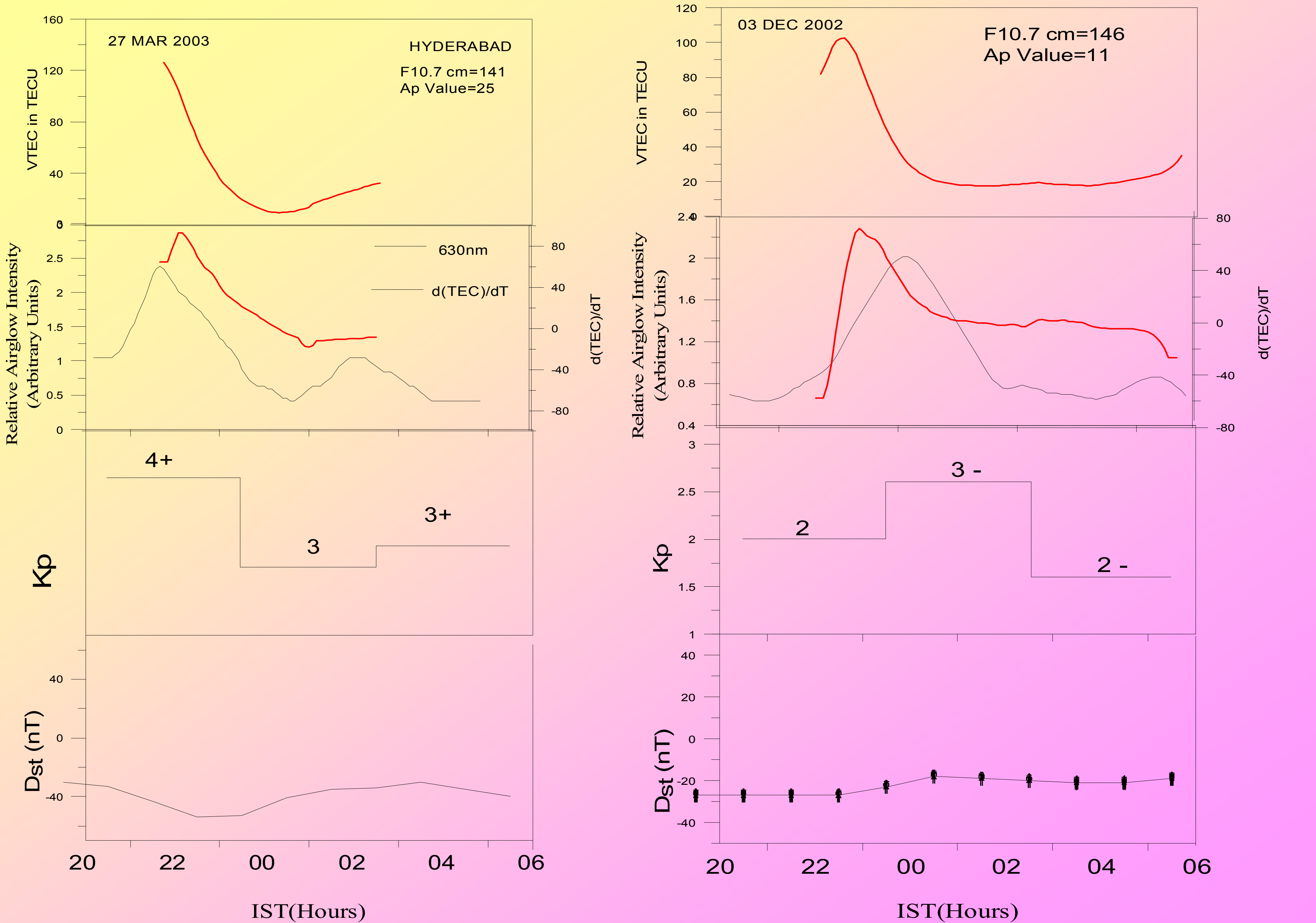

02 DEC 2002
F10.7 cm=146
Ap Value=13
VTEC in TECU
630nm
d(TEC)/dT
Relative Airglow Intensity (Arbitrary Units)
d(TEC)/dT
3+
3
3
Kp
Dst (nT)
20
22
00
02
04
06
IST(Hours)


29 DEC 2002
F10.7 cm=115
Ap Value=13
VTEC in TECU
630nm
d(TEC)/dT -- BANGALORE
HYDERABAD
Relative Airglow Intensity (Arbitrary Units)
d(TEC)/dT
4-
3
3-
Kp
Dst (nT)
20
22
00
02
04
06
IST(Hours)


31 DEC 2002
HYDERABAD
F10.7 cm=115
Ap Value=7
VTEC in TECU
630nm
d(TEC)/dT
Relative Airglow Intensity
(Arbitrary Units)
Kp
1-
0+
1+
Dst (nT)
20
22
00
02
04
06
IST(Hours)

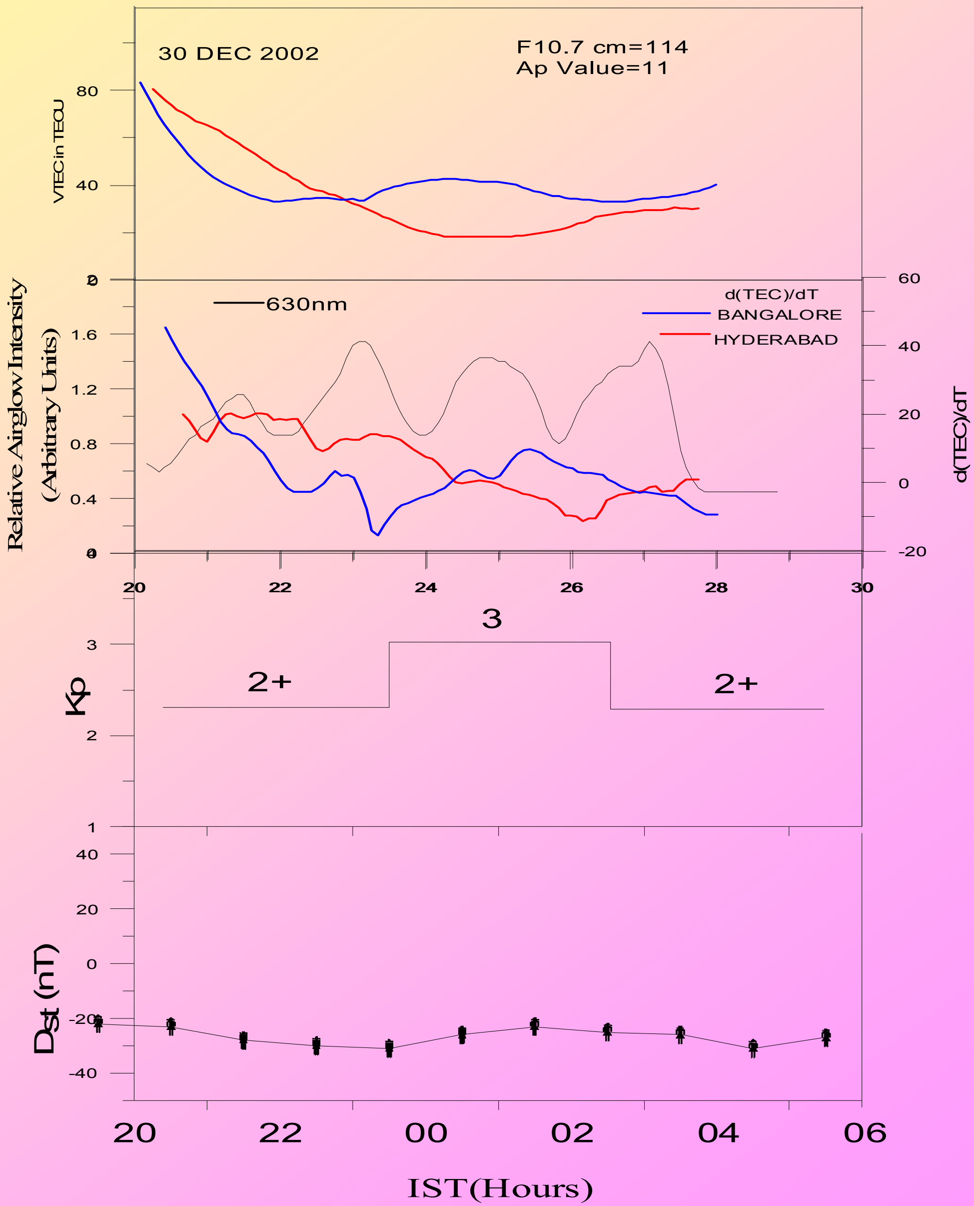

06 JAN 2003
HYDERABAD
TEC
F10.7 cm=162
Ap Value=4
VTEC in TECU
630nm
d(TEC)/dT
Relative Airglow Intensity
(Arbitrary Units)
d(TEC)/dT
Kp
1+
1+
2+
Dst (nT)
20
22
00
02
04
06
IST(Hours)


07 JAN 2003
HYDERABAD
F10.7 cm=163
Ap Value=6
VTEC in TECU
630nm
d(TEC)/dT
Relative Airglow Intensity
(Arbitrary Units)
Kp
3-
1+
2-
Dst (nT)
IST(Hours)
28 JAN 2003
HYDERABAD
TEC
F10.7 cm=126
Ap Value=13
VTEC in TECU
d(TEC)/dT
630nm
Relative Airglow Intensity
(Arbitrary Units)
d(TEC)/dT
Kp
2
2+
1+
Dst (nT)
IST(Hours)



27 MAR 2003
HYDERABAD
F10.7 cm=141
Ap Value=25
VTEC in TECU
160
120
80
40
0
630nm
d(TEC)/dT
Relative Airglow Intensity
(Arbitrary Units)
d(TEC)/dT
3
2.5
2
1.5
1
0.5
0
80
40
0
-40
-80
Kp
4+
3
3+
Dst (nT)
40
0
-40
20
22
00
02
04
06
IST(Hours)
03 DEC 2002
F10.7 cm=146
Ap Value=11
VTEC in TECU
120
100
80
60
40
20
0
2.4
2
1.6
1.2
0.8
0.4
Relative Airglow Intensity
(Arbitrary Units)
d(TEC)/dT
80
40
0
-40
-80
Kp
3
2.5
2
1.5
1
3 -
2
2 -
Dst (nT)
40
20
0
-20
-40
20
22
00
02
04
06
IST(Hours)

Wave Like structure



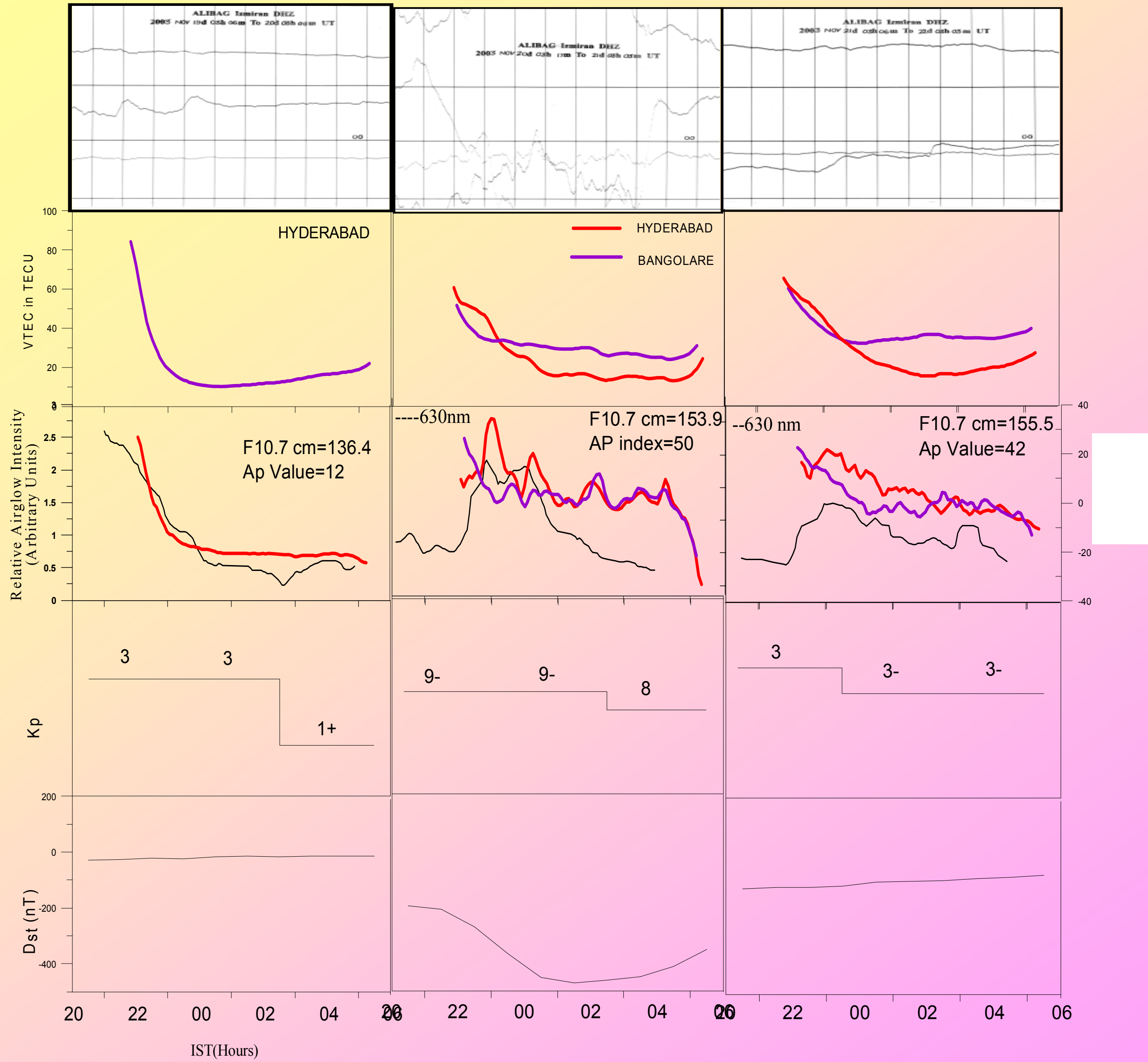


Figure. From top to bottom panels show the magnetogram (H,Z and D variations) of Alibag station, derived TEC, d(TEC)/dT (Hyderabad and Bangalore) with OI 630.0 nm intensity (black curve), Kp index and Dst (nT) on 19,20 and 21 Nov,2003 from left to right column

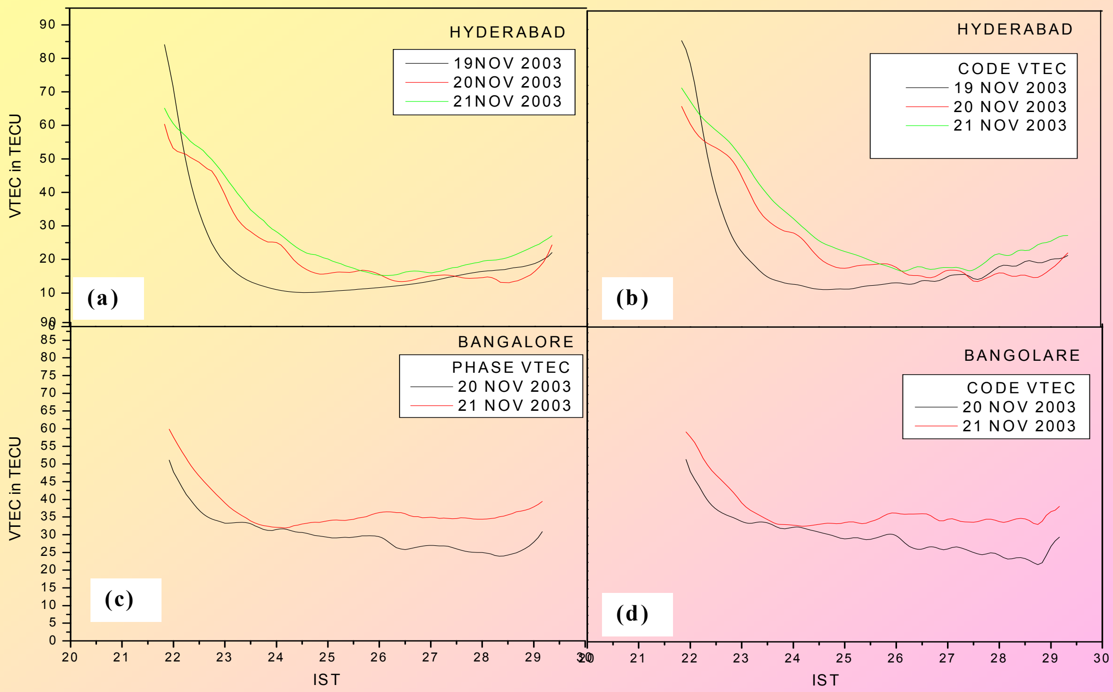


Figure . (a & b) The Phase TEC and Code TEC variations for Hyderabad using satellite no-18 on 19,20 and 21 Nov, 2003.

Figure. (c & d) .The Phase TEC and Code TEC variations for Bangalore using satellite no-18 on 20,21 Nov,2003

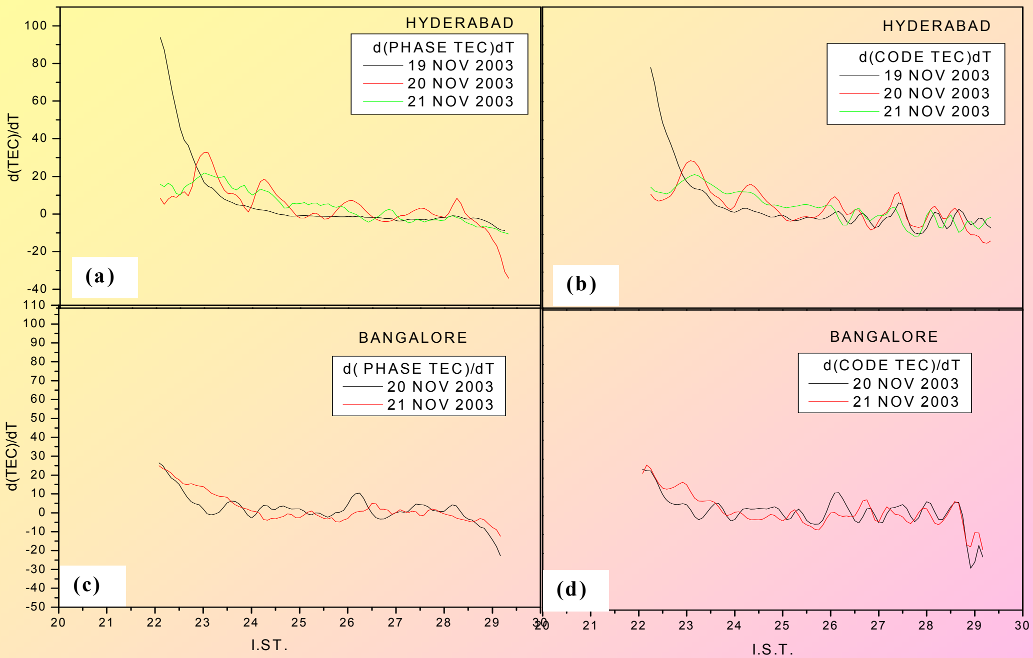


Figure . (a &b) The derivative of Phase and Code TEC variations for Hyderabad using satellite no-18 on 19,20 and 21 Nov,2003.

Figure . (c& d) .The derivative of Phase and Code TEC variations for Bangalore station using satellite no – 18 on 20,21 Nov,2003

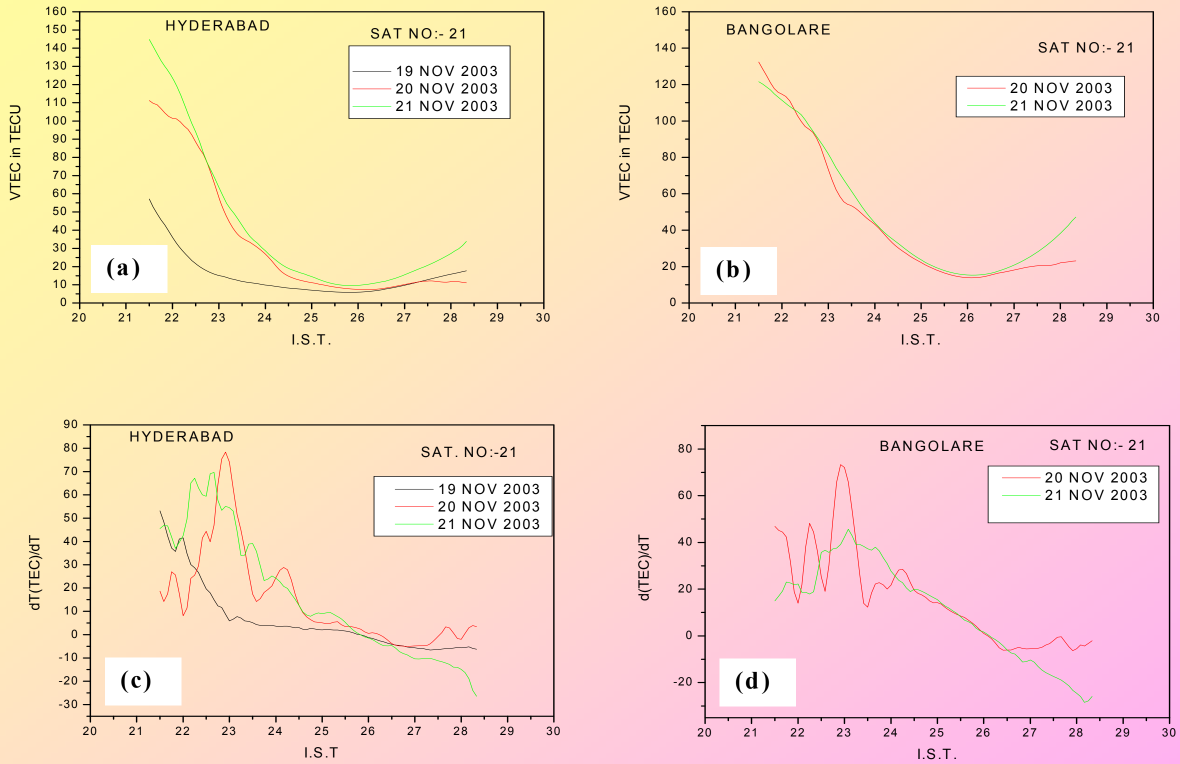


Figure. (a & c) The VTEC and d(TEC)/dT variations for Hyderabad satation on 19,20 and 21 Nov,2003 using satellite no.21

Figure . (b & d) .The VTEC and d(TEC)/dT variations for Bangalore station on 20,21 Nov,2003 using satellite no.21

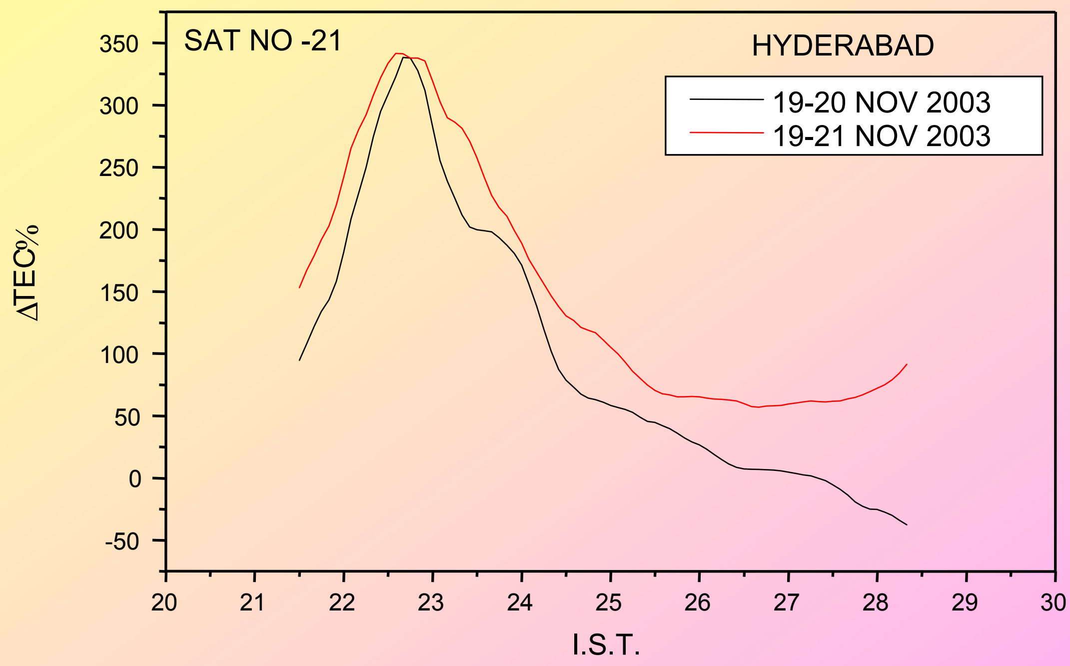


Figure. The percentage deviation of TEC on 20,21 Nov,2003 (disturbed days) relative to 19 Nov,2003 (quiet day)

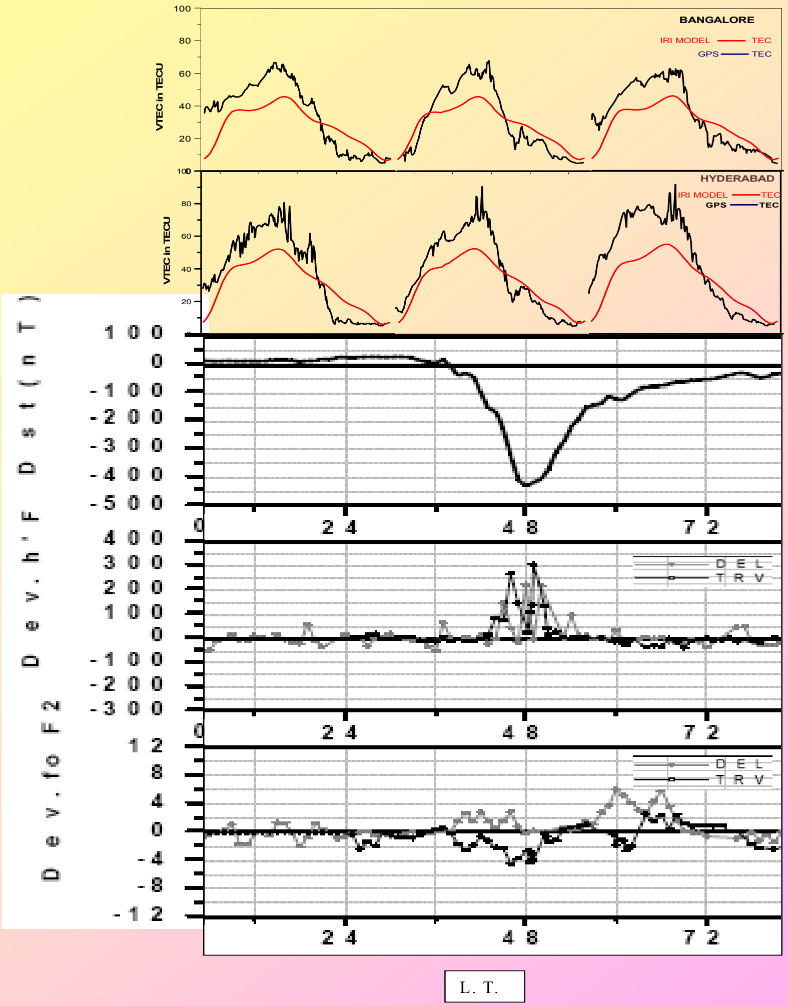
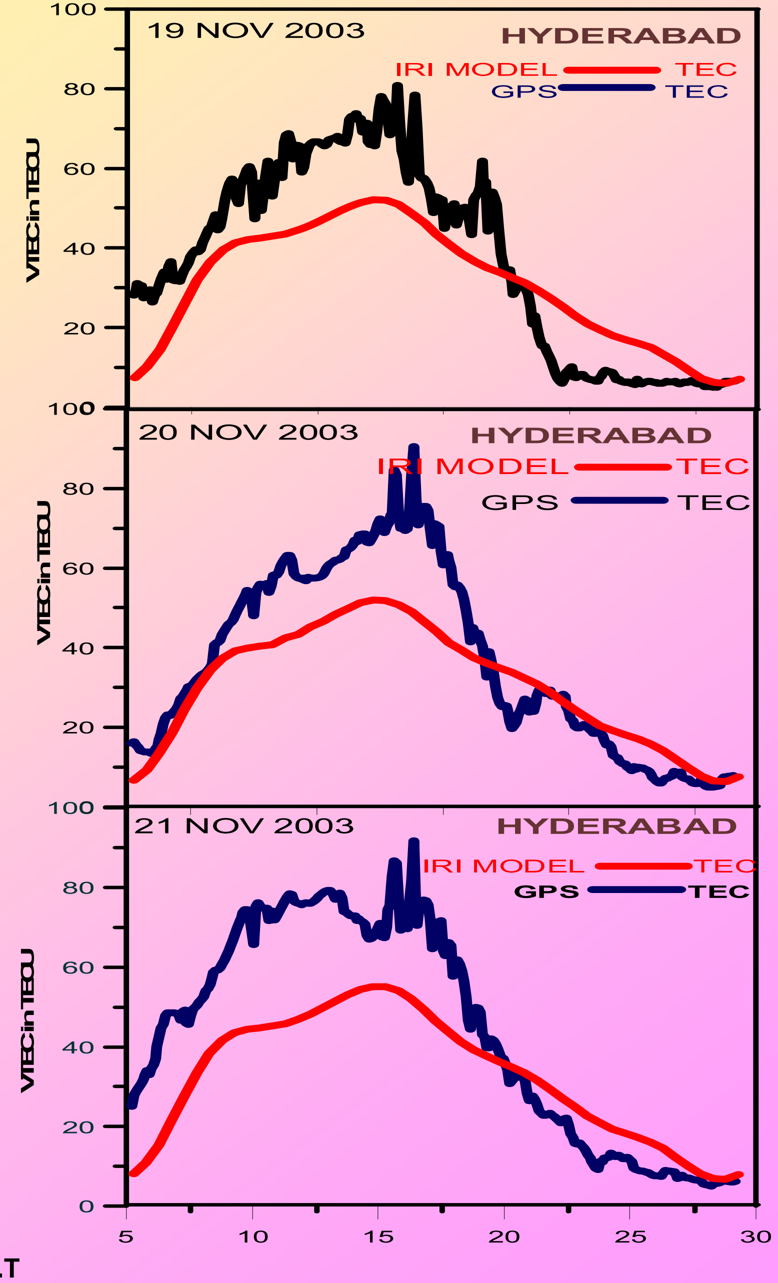


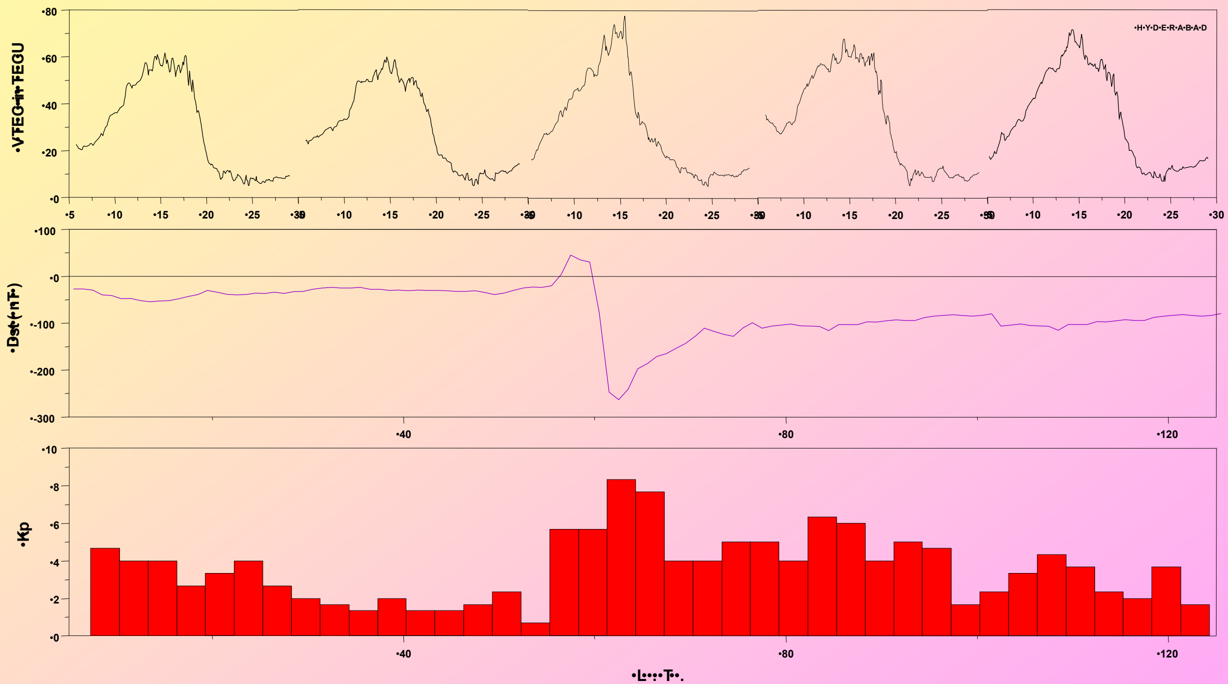
Figure .From top to bottom each panel represents computed VTEC (Bangalore),VTEC with IRI-TEC (Hyderabad), Dst(nT), Deviation of h'F (Delhi and Trivendrium) and in bottom panel deviation of foF2 (Delhi and Trivendrium)

Comparision between IRI-TEC and GPS-TEC

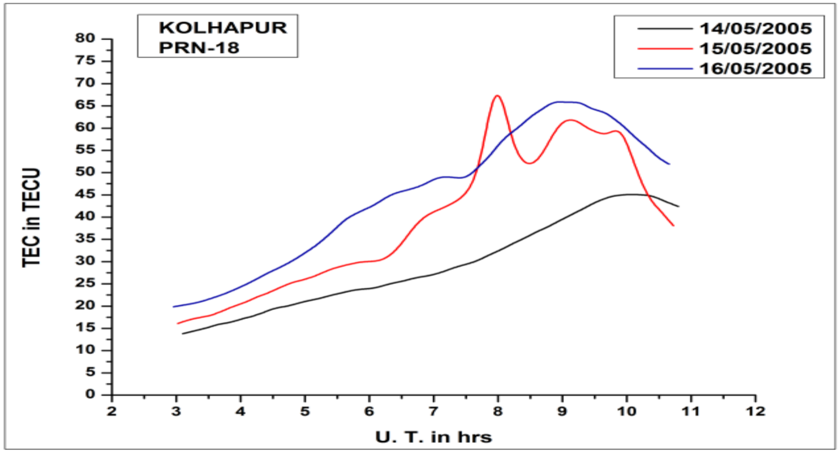


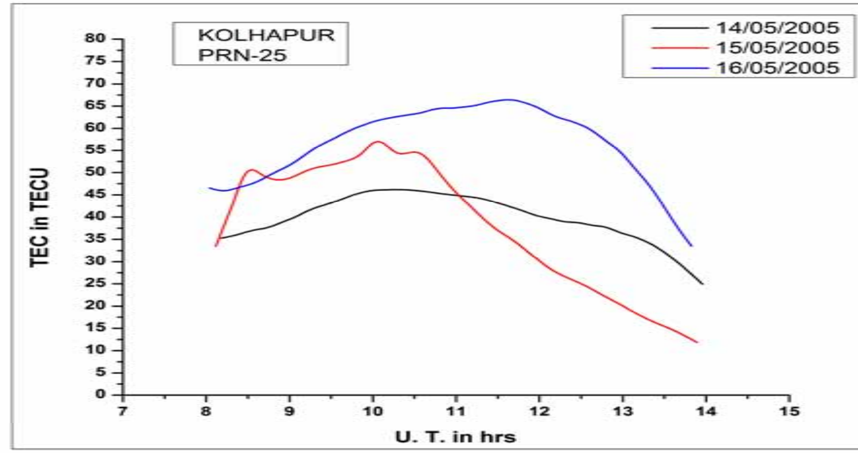
Plot the VTEC values using IRI2000 model and UNB Ionospheric Modeling Technique for three consecutive days November 19-21, 2003. It is clearly seen that IRI model values underestimate the computed TEC values from GPS data mostly during day time hours. However, the agreement is good between 20:00 to 06:00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

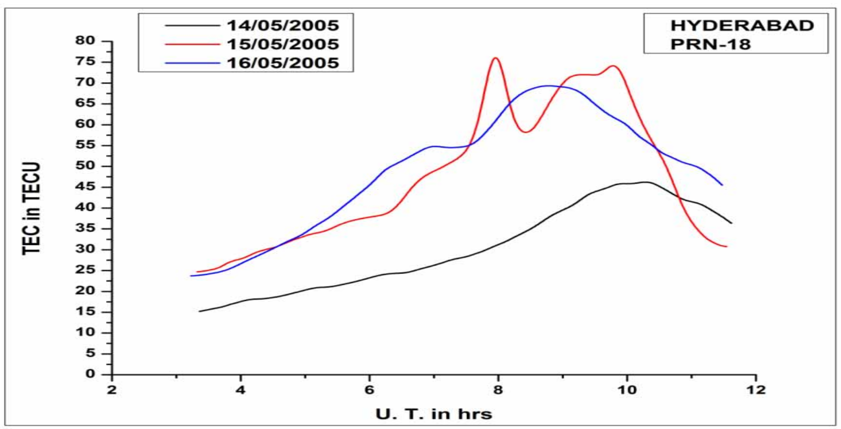
•Storm: 13-17 May 2005

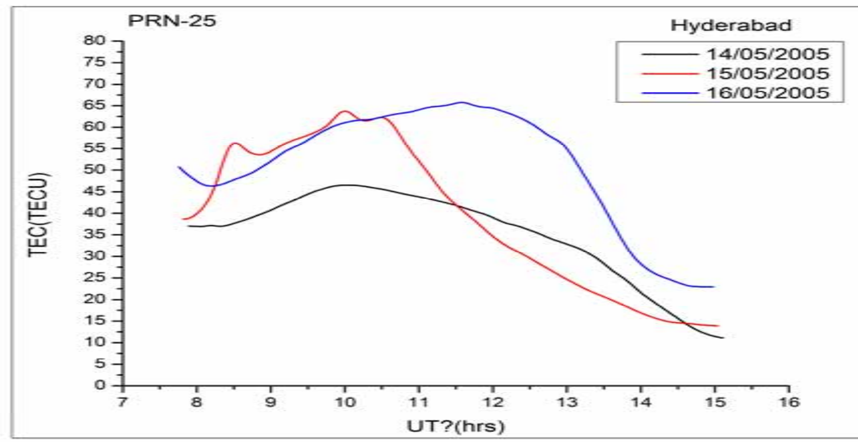


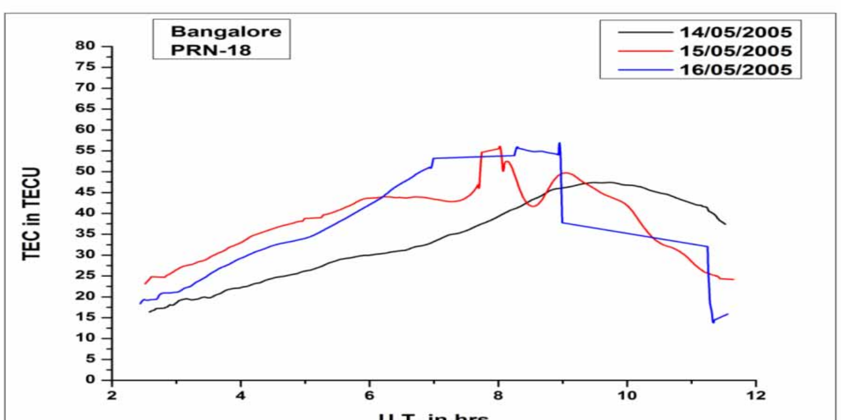
•Figure. From top to bottom panel shows VTEC for Hyderabad ,the Dst (nT) index, and bottom panel shows Kp index on 13-17 May 2005

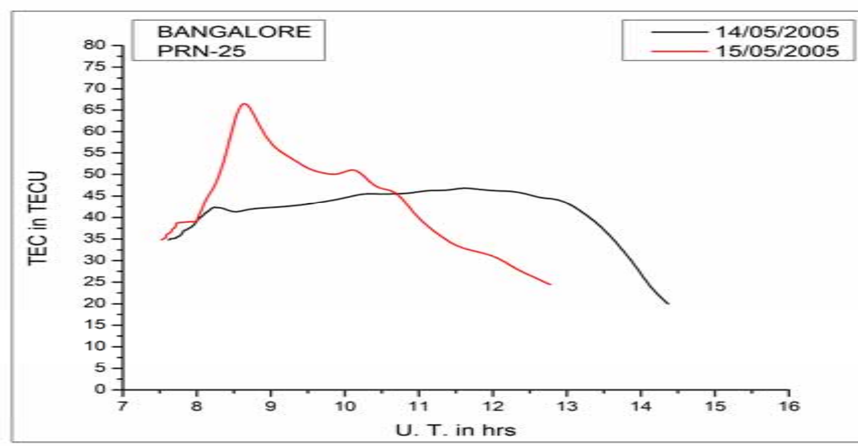

KOLHAPUR
PRN-18
14/05/2005
15/05/2005
16/05/2005
TEC in TECU
U. T. in hrs

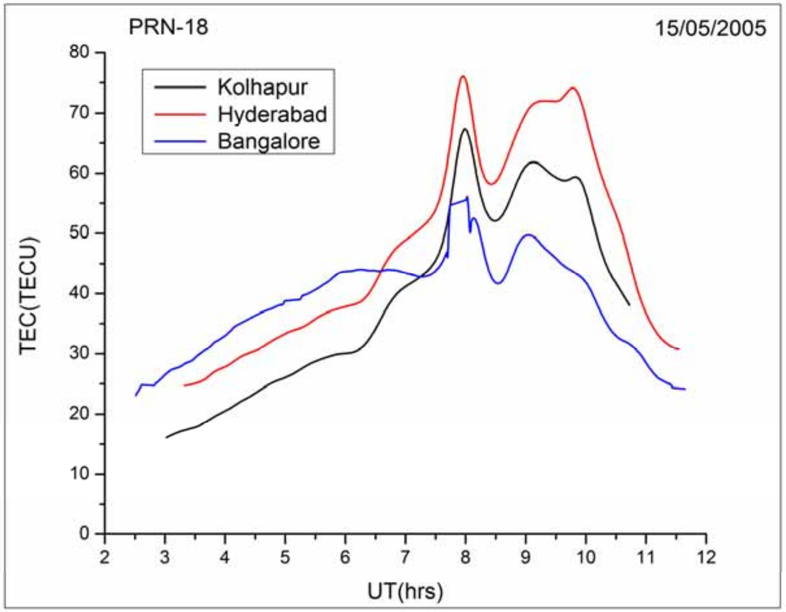

KOLHAPUR
PRN-25
14/05/2005
15/05/2005
16/05/2005
TEC in TECU
U. T. in hrs

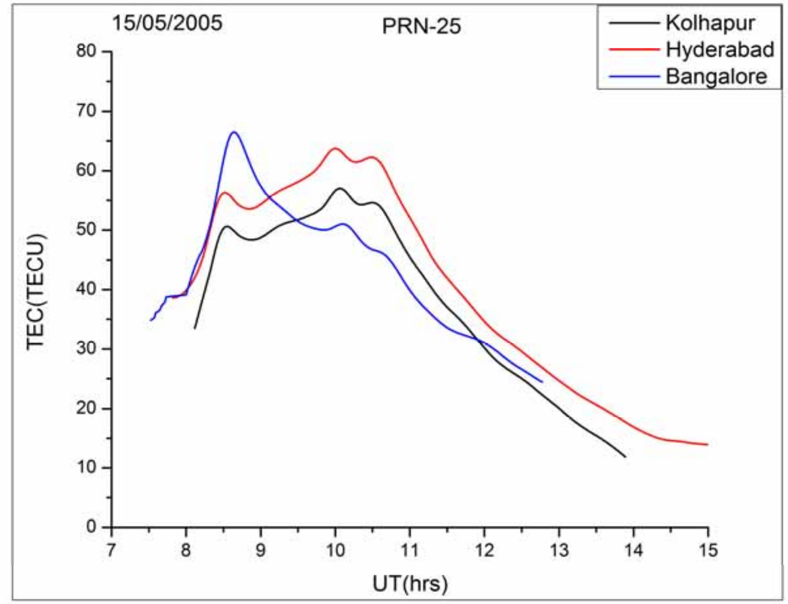

14/05/2005
15/05/2005
16/05/2005
HYDERABAD
PRN-18
TEC in TECU
U. T. in hrs

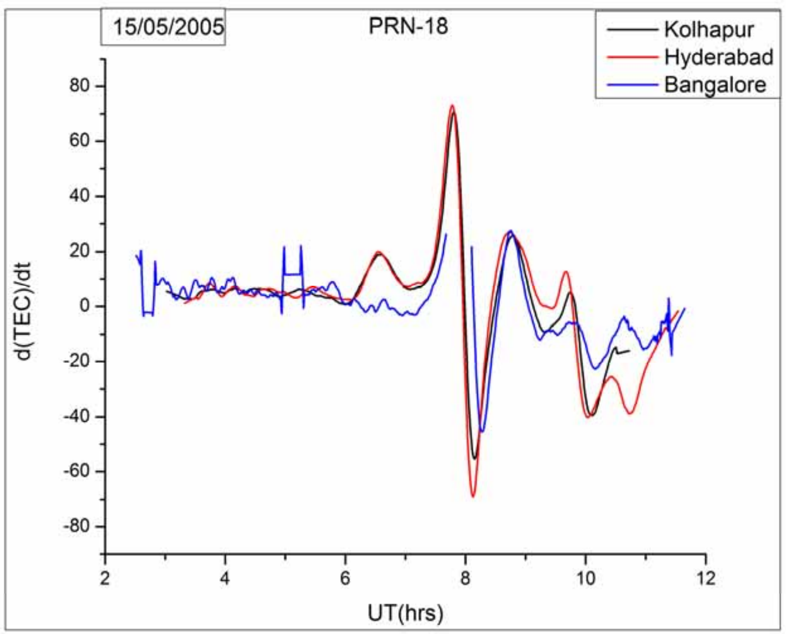

PRN-25
Hyderabad
14/05/2005
15/05/2005
16/05/2005
TEC(TECU)
UT?(hrs)

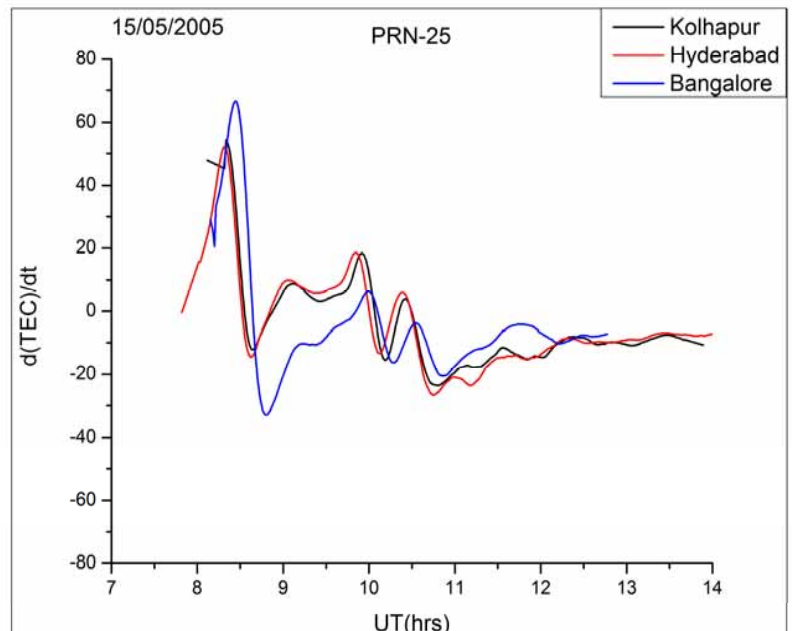

Bangalore
PRN-18
14/05/2005
15/05/2005
16/05/2005
TEC in TECU
U.T. in hrs

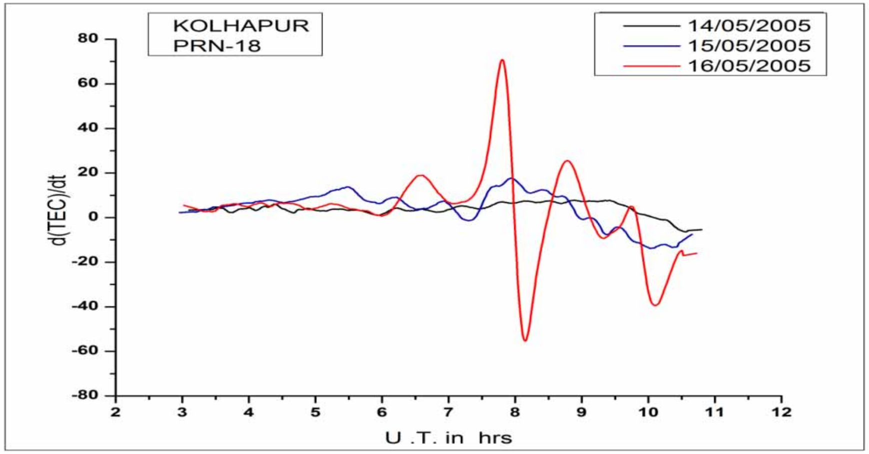

BANGALORE
PRN-25
14/05/2005
15/05/2005
TEC in TECU
U. T. in hrs

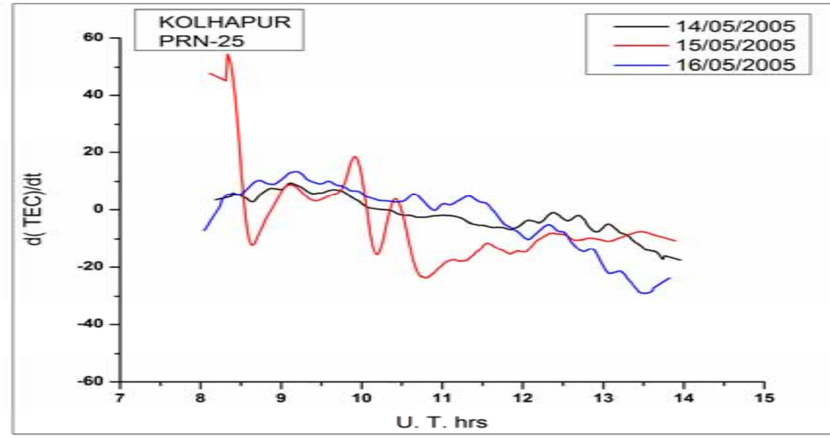

PRN-18
15/05/2005
Kolhapur
Hyderabad
Bangalore
TEC(TECU)
UT(hrs)

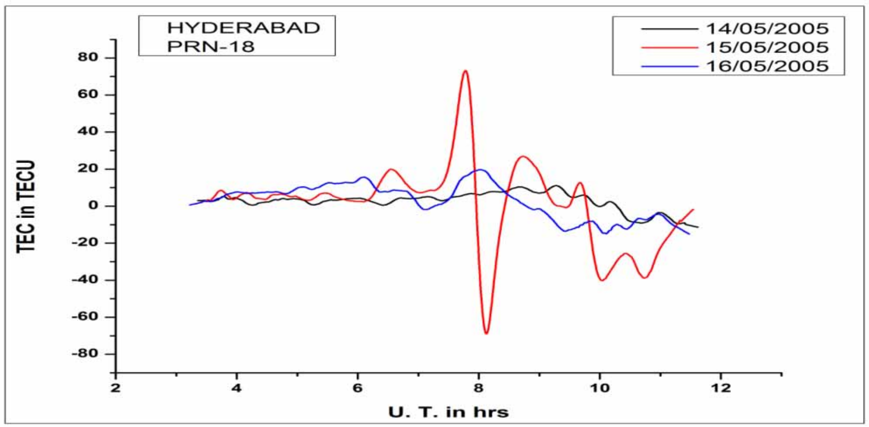

15/05/2005
PRN-25
Kolhapur
Hyderabad
Bangalore
TEC(TECU)
UT(hrs)

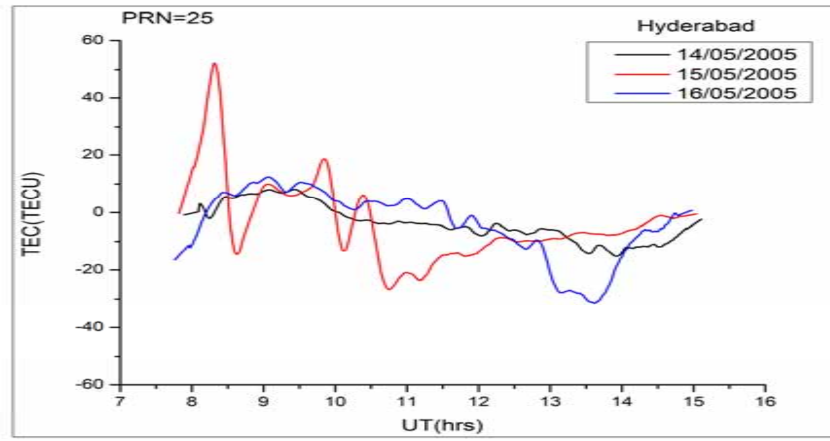

15/05/2005
PRN-18
Kolhapur
Hyderabad
Bangalore
d(TEC)/dt
UT(hrs)

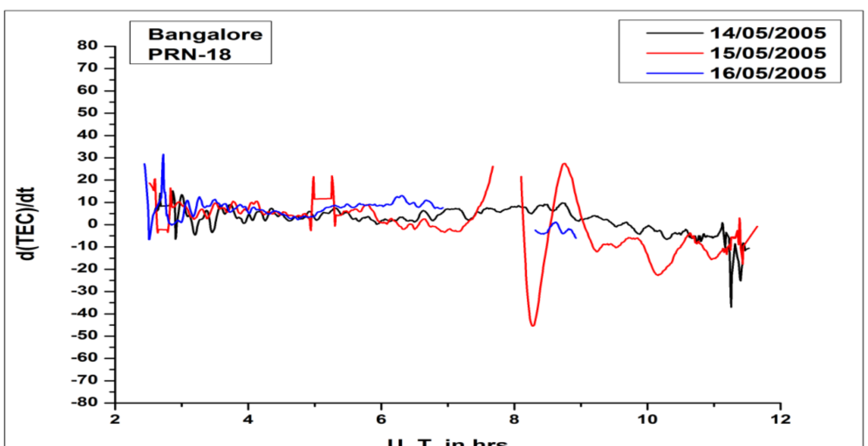

15/05/2005
PRN-25
Kolhapur
Hyderabad
Bangalore
d(TEC)/dt
UT(hrs)

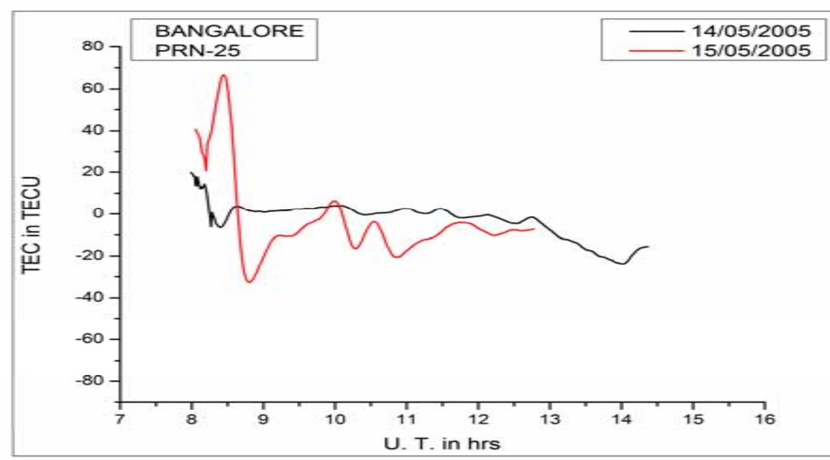

KOLHAPUR
PRN-18
14/05/2005
15/05/2005
16/05/2005
d(TEC)/dt
U .T. in hrs

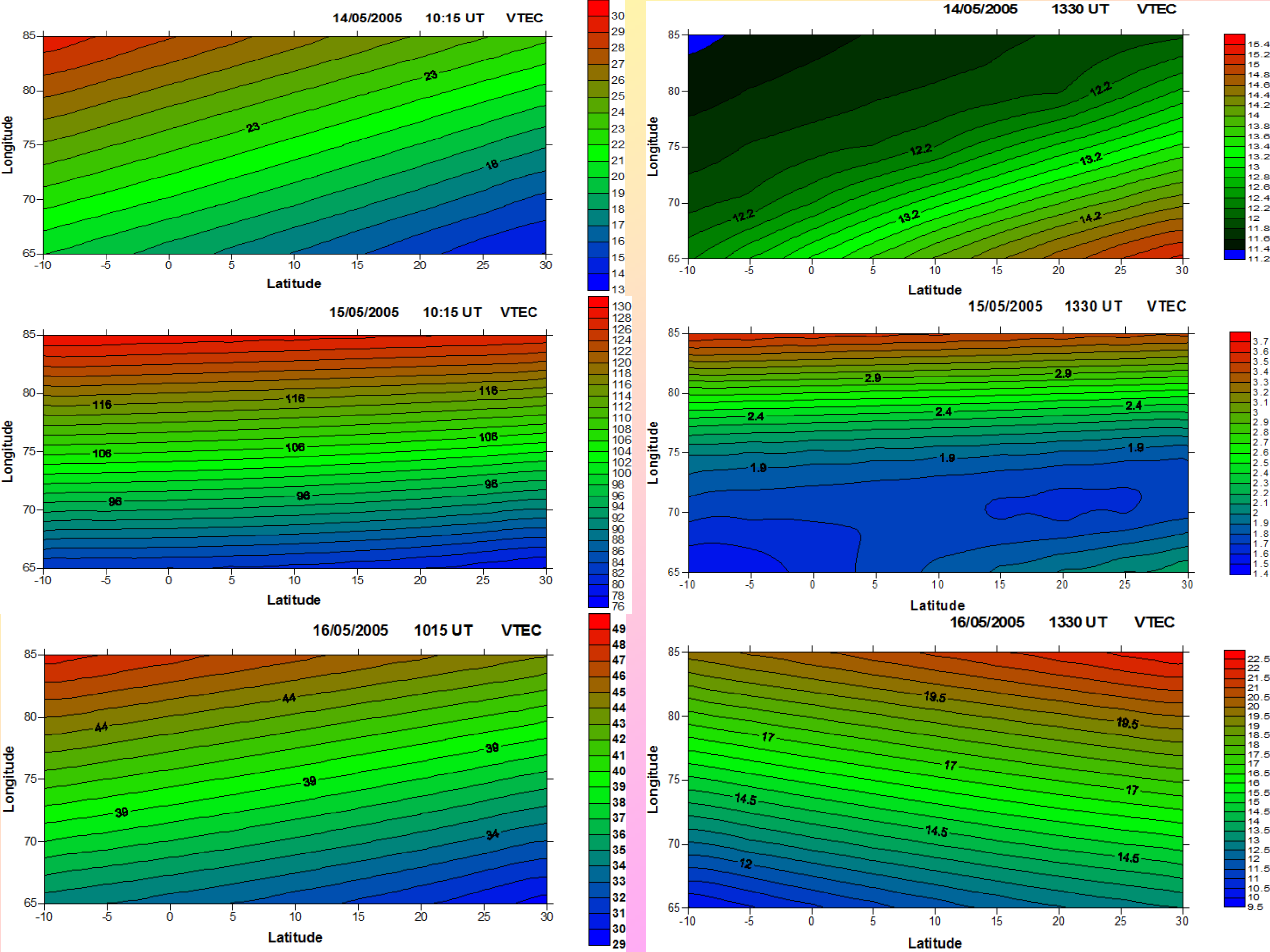

KOLHAPUR
PRN-25
14/05/2005
15/05/2005
16/05/2005
d(TEC)/dt
U. T. hrs


HYDERABAD
PRN-18
14/05/2005
15/05/2005
16/05/2005
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
d(TEC)/dt
U. T. in hrs


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


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

Conclusions

- ➢The signature of midnight temperature maximum (MTM) has been observed in some of the nights in both OI630.0 nm and d(TEC)/dT data.

- ➢The nocturnal variations observed in the atomic oxygen airglow emission at low latitude are well correlated with the dynamical variations seen in the F-region ionospheric parameters such as d(TEC)/dT, for both quiet and disturbed days.

- ➢TEC and OI 630 nm airglow emission both these phenomena are dependent on the electron density of the ionosphere F-region, it is useful to find relationship between the two parameters under geomagnetically quiet and disturbed conditions at one location.

The GPS data of IGS Hyderabad station (17.41^0N, 78.55^0E), Bangalore (13.02^0N, 77.57^0E) 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

Future investigation

- ✓ The signature of MTM has been found in both night airglow (OI630.0 nm) and TEC data. It is suggested that F-region temperature should be simultaneously measured both at equator as well as at Kolhapur to confirm the signature of MTM.

- ✓ In future GPS data from Kolhapur would be used to compare with the night airglow data (OI 630.0 nm) from Kolhapur for quiet and disturbed periods. The tidal periodicities (diurnal, semi-diurnal, ter-diurnal) in wave periods in both OI 630.0 nm and TEC data would be looked into.

- ✓ To know the background conditions of the F-region of the ionosphere during the period of observation, ionosonde data from both equator (Trivandrum) and off equatorial stations (Visakhapatnam and Ahmedabad) would be studied.

- ✓ We would also like to compare the available SROSS –III data of electron density and temperature of the F-region of the ionosphere during the period of our observation.

•Despite the significant progress in understanding the behavior of the ionosphere, there are still many outstanding questions to be answered in order to get a better understanding of the energy coupling processes between the Sun and the Earth.

•The methodology to compute TEC from GPS data is being improved, and the continuously increasing number of worldwide 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 loss and transport processes of the ionosphere.

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References:

1] Araujo-Pradere A. (2005), GPS-derived total electron content response for Bastille Day Magnetic storm of 2000 at a low mid-latitude station, Geofisica International, Vol.44,Num.2,pp.211-218.

2] Bilitza D. (2003) " International Referance Ionosphere 2000: Examples of improvements and New features,", Adv. Space Res., Vol. 31, pp. 757-769.

3] Komjathy A., Langley R. B. (1996), An Assessment of Predicted and Measured Ionospheric Total Electron Content Using a Regional GPS Network. The Proceedings of the National Technical Meeting of The Institute of Navigation, Santa Monica, CA, 22-24 January, 615-624.

4] Mukherjee G. K., and Carlo L., (1994), Night Mesurement of Line from Kolhapur, India and their Association with TEC Enhancements, J. Geomag. Geolectr. 46,1029-1041.

5] Mukherjee G. K., Shetti D. J. (2008) ,Plasma drift in the F-region of the ionosphere using photometric nightglow measurements, Indian Journal of Radio and Space Physics, Vol. 37, pp. 249-257.

6] Scherliess, L., R. W. Schunk, J. J. Sojka, D. C.Thompson, and L. Zhu (2006), Utah State University Global Assimilation of Ionospheric Measurements Gauss-Markov Kalman filter model of the ionosphere: Model description and validation, J. Geophys. Res., 111, A11315, doi:10.1029/2006JA011712.


Thank You