4th EUROPEAN SPACE SOLUTIONS

The ICG, Multifunction GNSS Signals and How To Protect Them

Space Weather Studies Using GNSS and Space Science Outreach activities at Sangli

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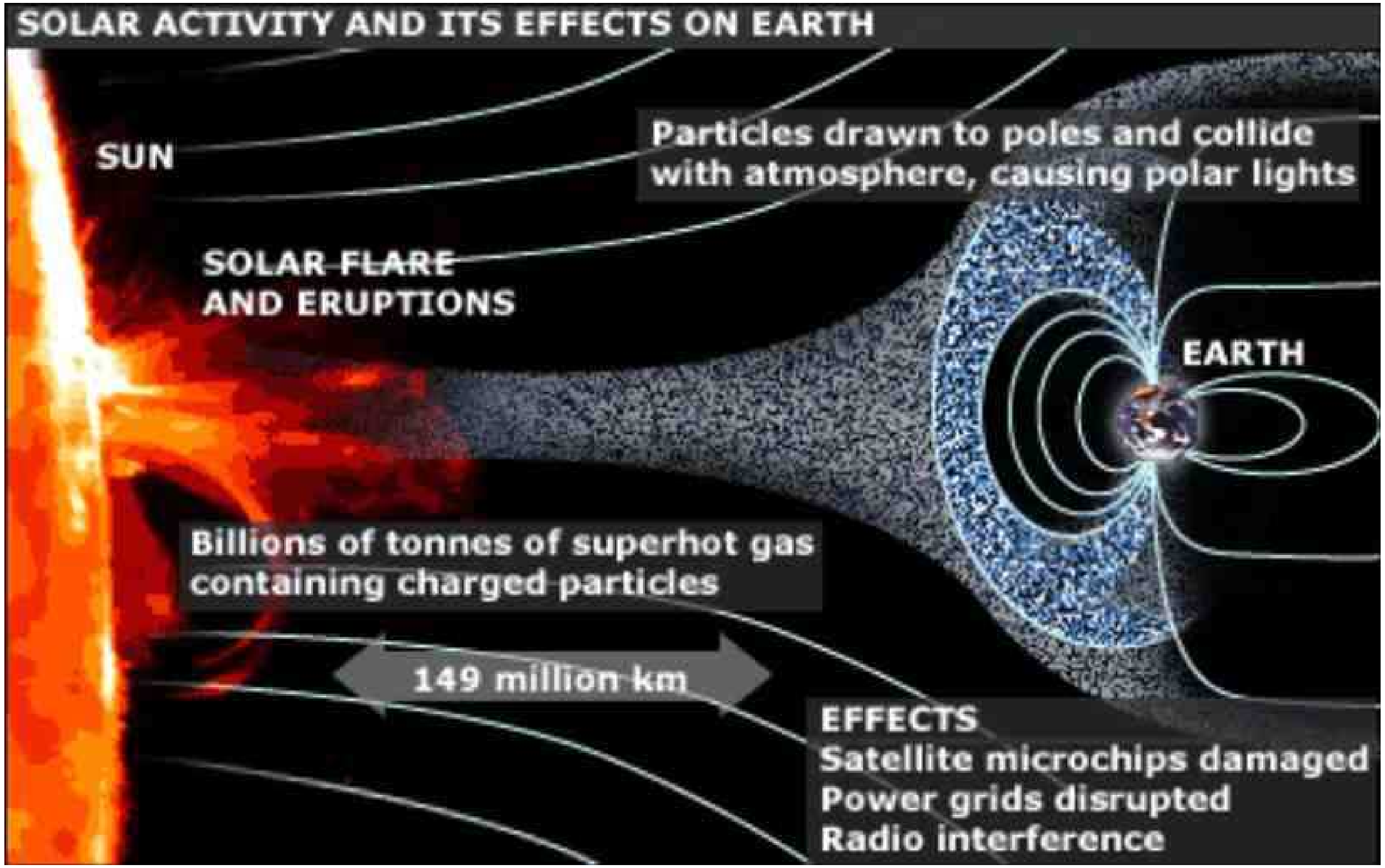
30 May – 03 June 2016

Outline

- Space Whether
- Use of GNSS
- Data Analysis
- Studies Using GNSS
- Outreach Activities

Space Whether

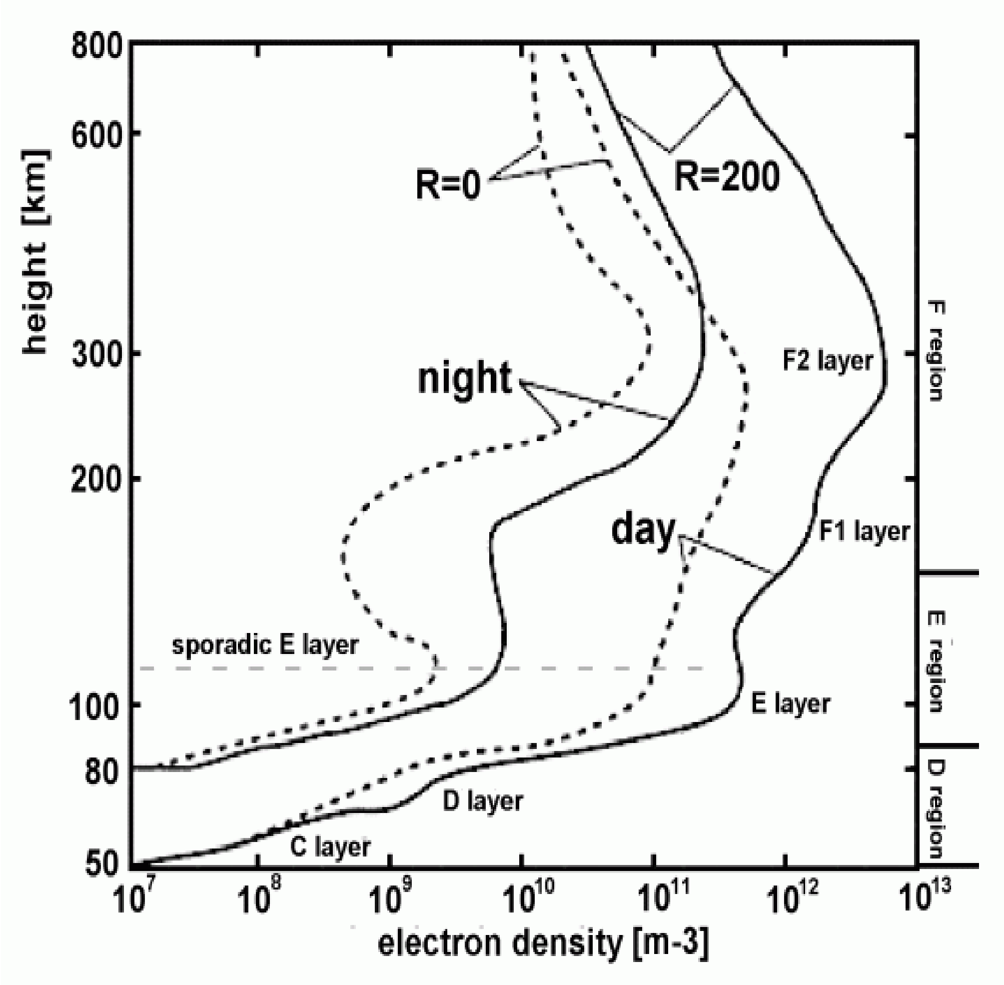


"Conditions on the Sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health" ICG 4, The Hague, Neterlands

Space Whether

IONOSPHERE

- F Region
  - F2 Region
  - F1 Region
- E Region
- D Region



Typical day and night profiles of electron density in the ionosphere

GNSS (GPS-TEC)

- 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

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

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

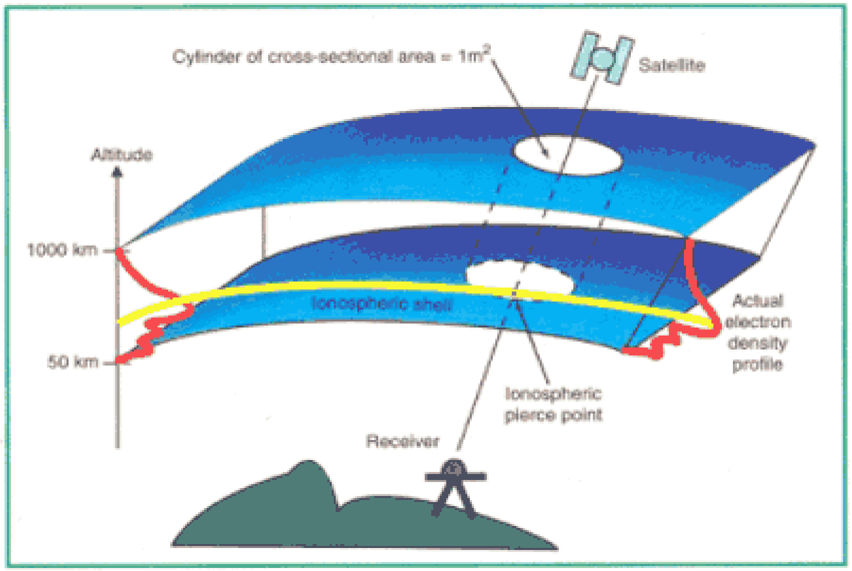
$\Delta P_{1,2} = P1 - P2$ where P1 and P2 are pseudo ranges on L1 and L2 respectively

Differential phase advance STEC

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

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

$\Delta L_{1,2} = \Phi1 - \Phi2$ where $\Phi1$ and $\Phi2$ are phase measurements on L1 and L2 respectively.



Slant TEC to Vertical TEC

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

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

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

R_E -Radius of the Earth

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)

Data Analysis

Software's

- RD_RINEX Software
- UNB Ionospheric Modeling Technique
- WinTec Software
- GopiSeemla Software

Data Analysis

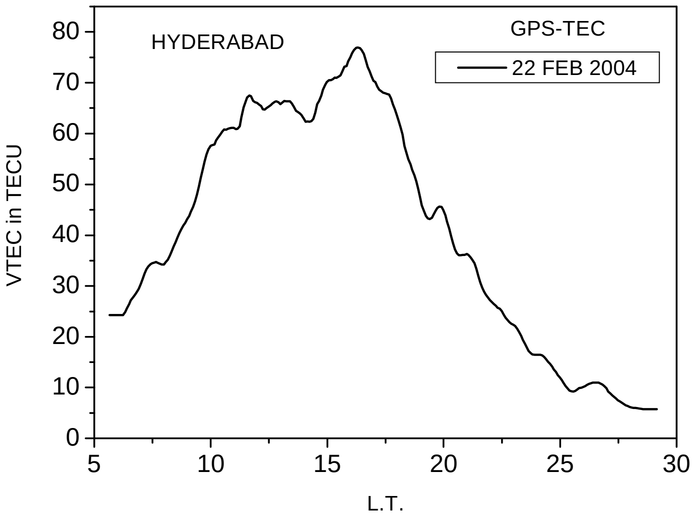
UNB Ionospheric Modelling Technique
(Komjathy, 1996)

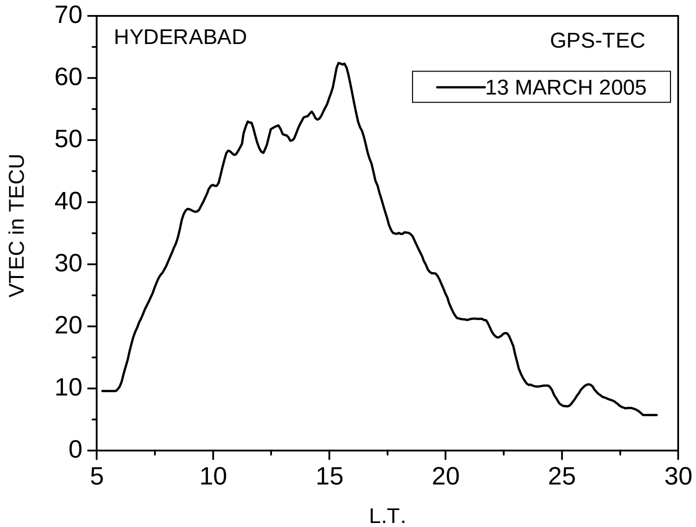
$$I(t) = M(e)[a_0(t) + a_1(t)dl + a_2(t)df] + b_r + b^s$$

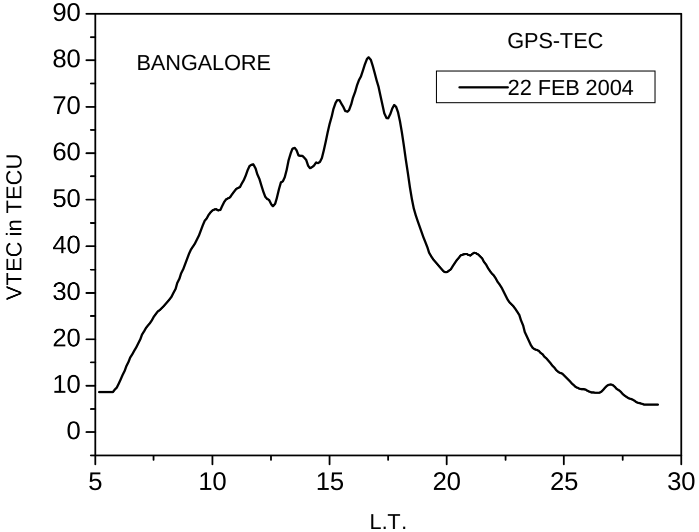
$I(t)$: $L_1 - L_2$ Phase-levelled ionospheric measurement in TECU,
$M(e)$: elevation angle mapping function,
$[a_0(t) + a_1(t)dl + a_2(t)df]$: spatial linear approximation of TEC,
$b_r + b^s$: Receiver plus Satellite instrumental differential delays.

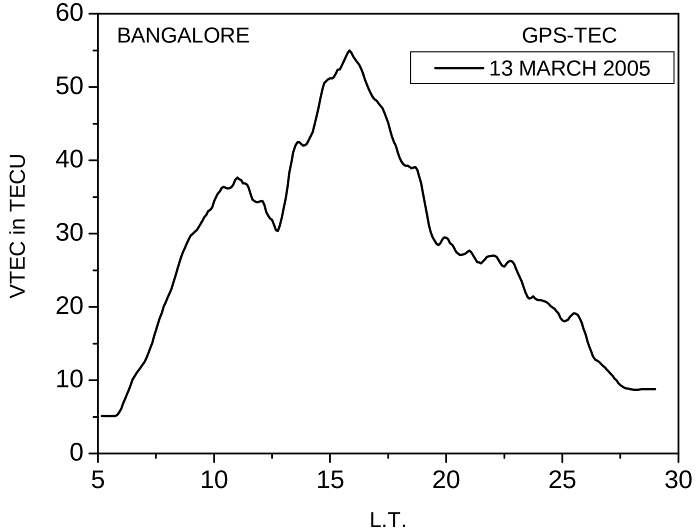
- Solar-geomagnetic reference frame.
- 5 by 5 longitude/latitude degree grid spacing maps.
- TEC at each grid node computed using the 4 closest stations.

Data Analysis

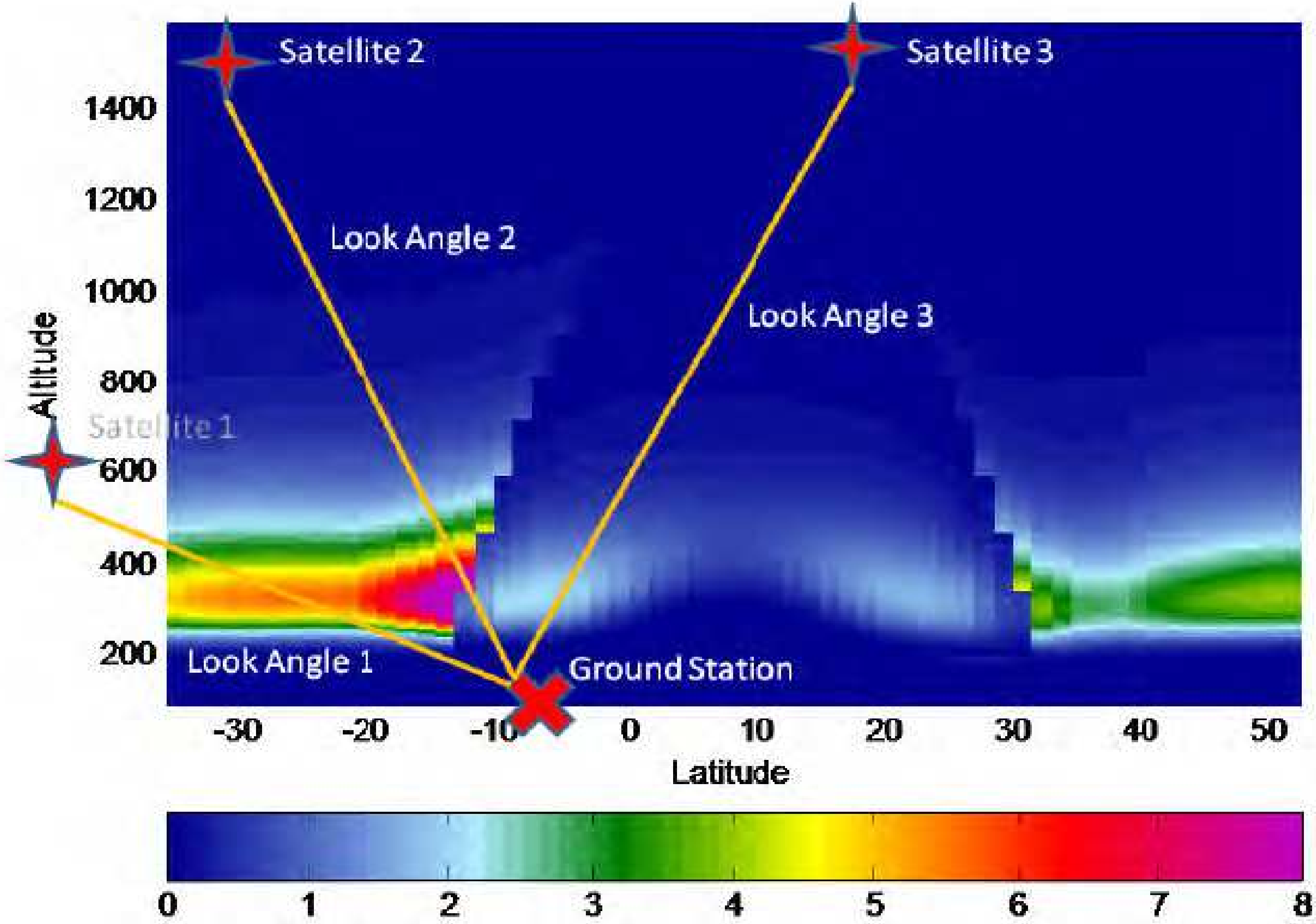






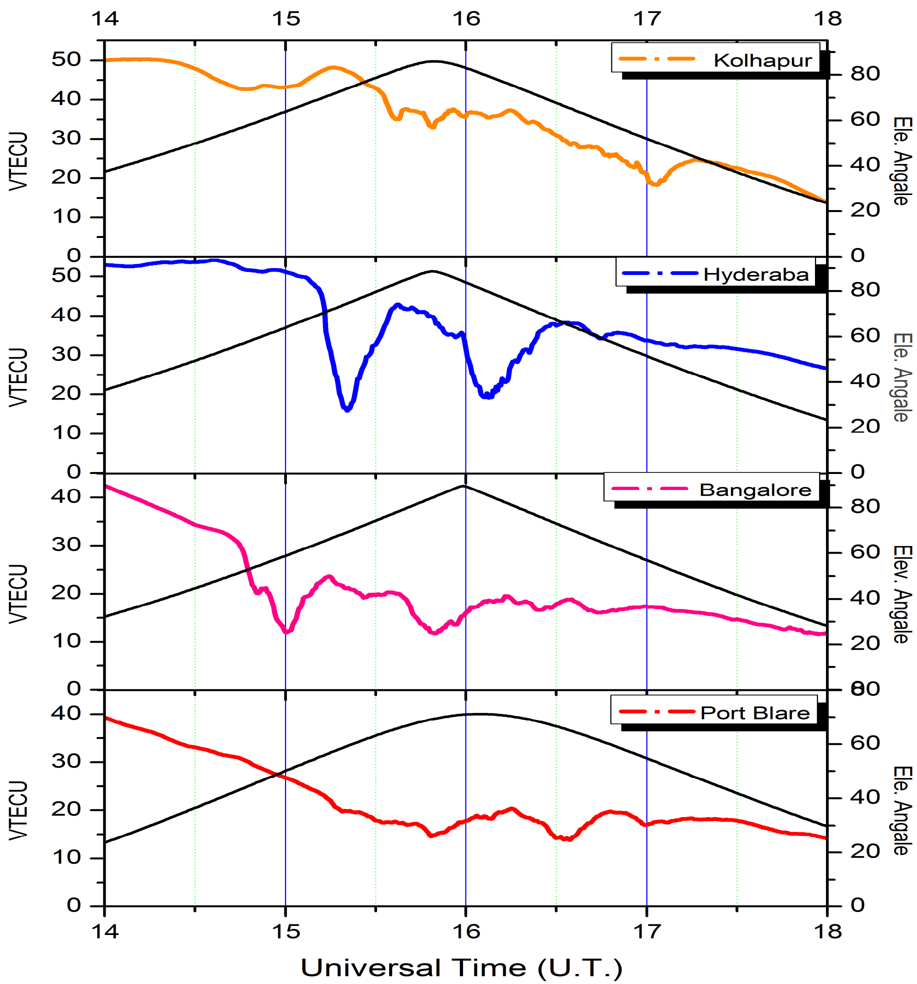


EPBs Using GNSS

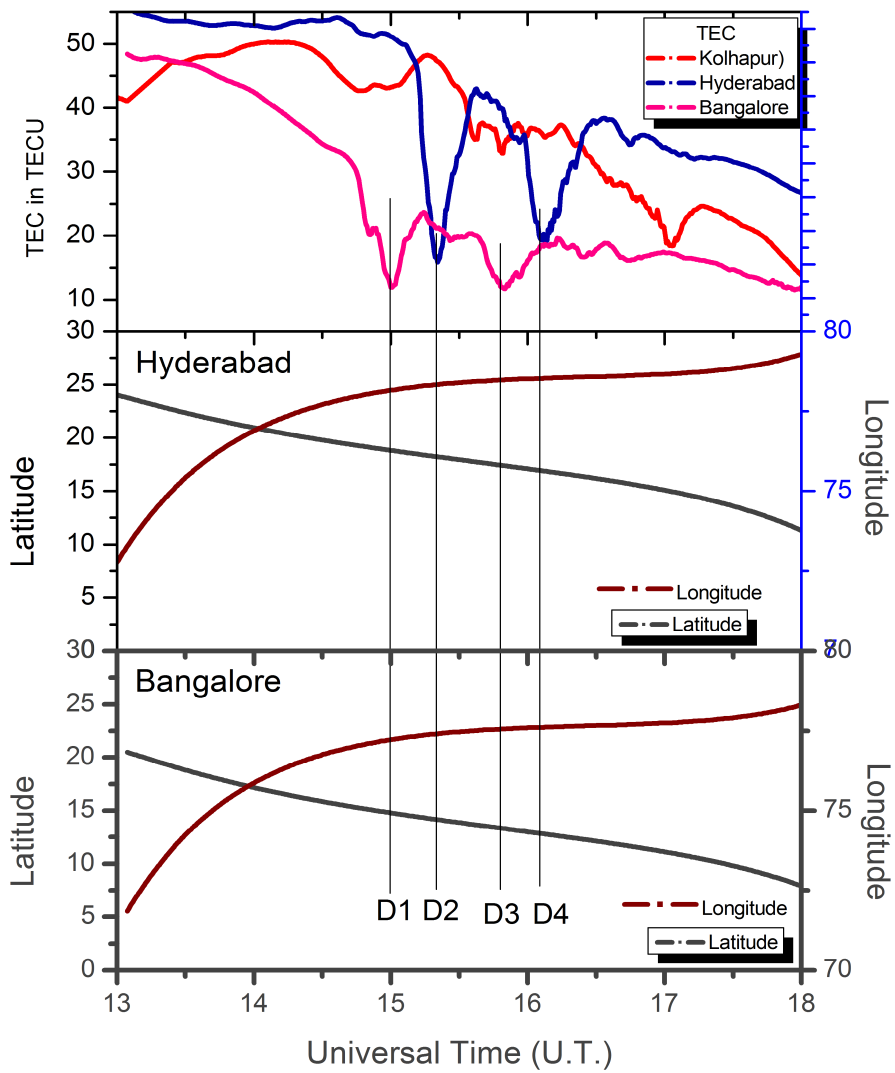


Fenton, 2011

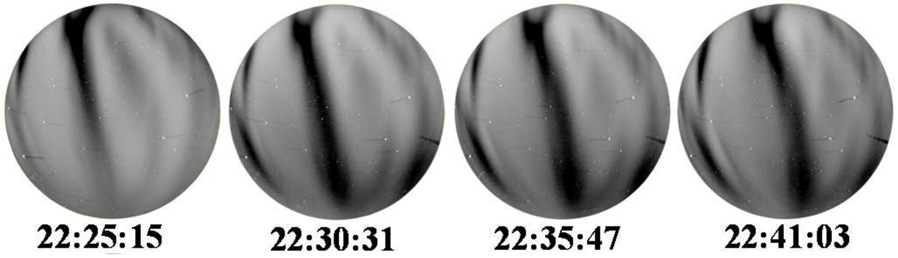
EPBs Using GNSS



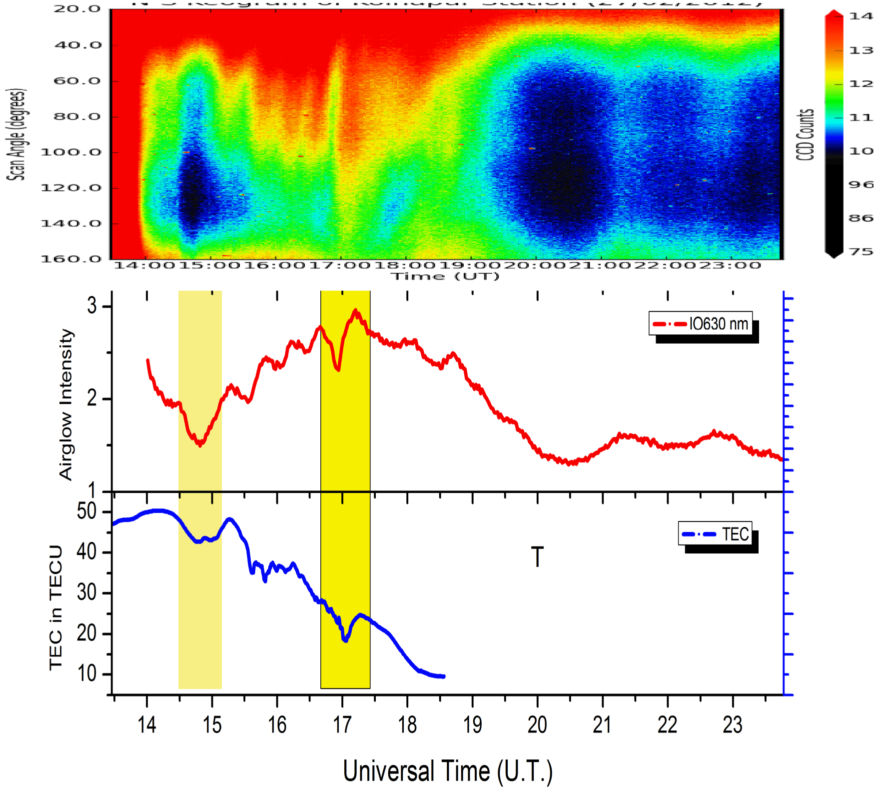
Kolhapur	16.677N	74.26E
Hyderabad	17.42N	78.55E
Bangalore	13.02N	77.57E
Port Blare	11.64N	92.71E

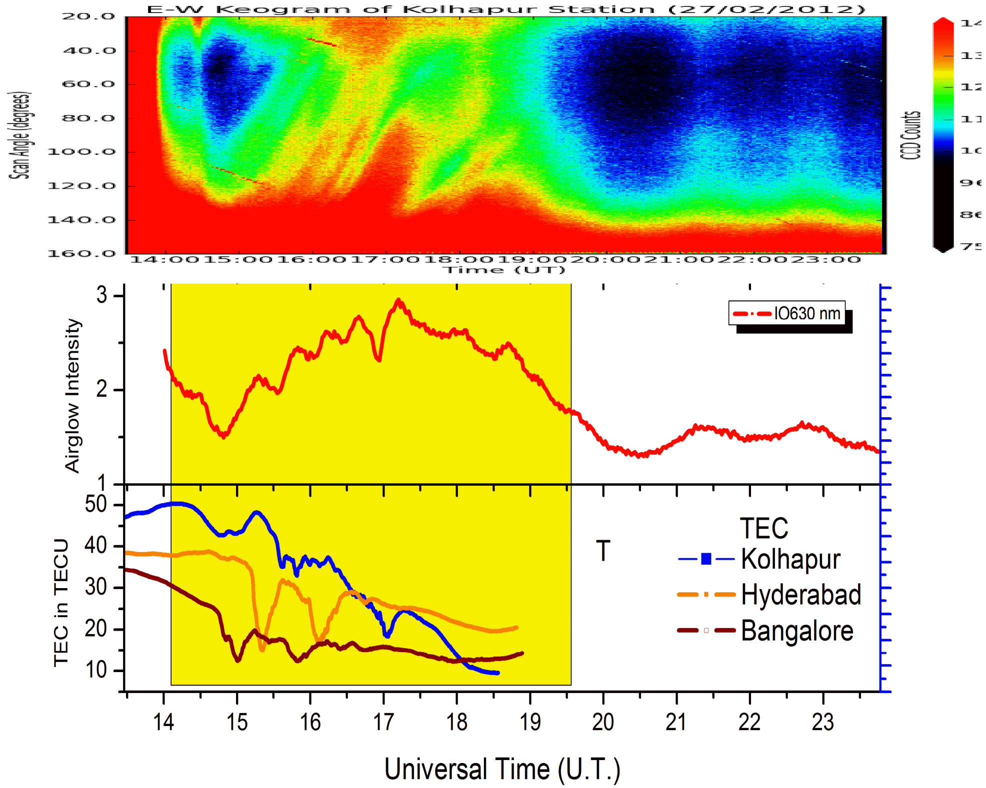


EPBs Using GNSS



Few Sequence of images of OI 630.0 nm obtained at Kolhapur





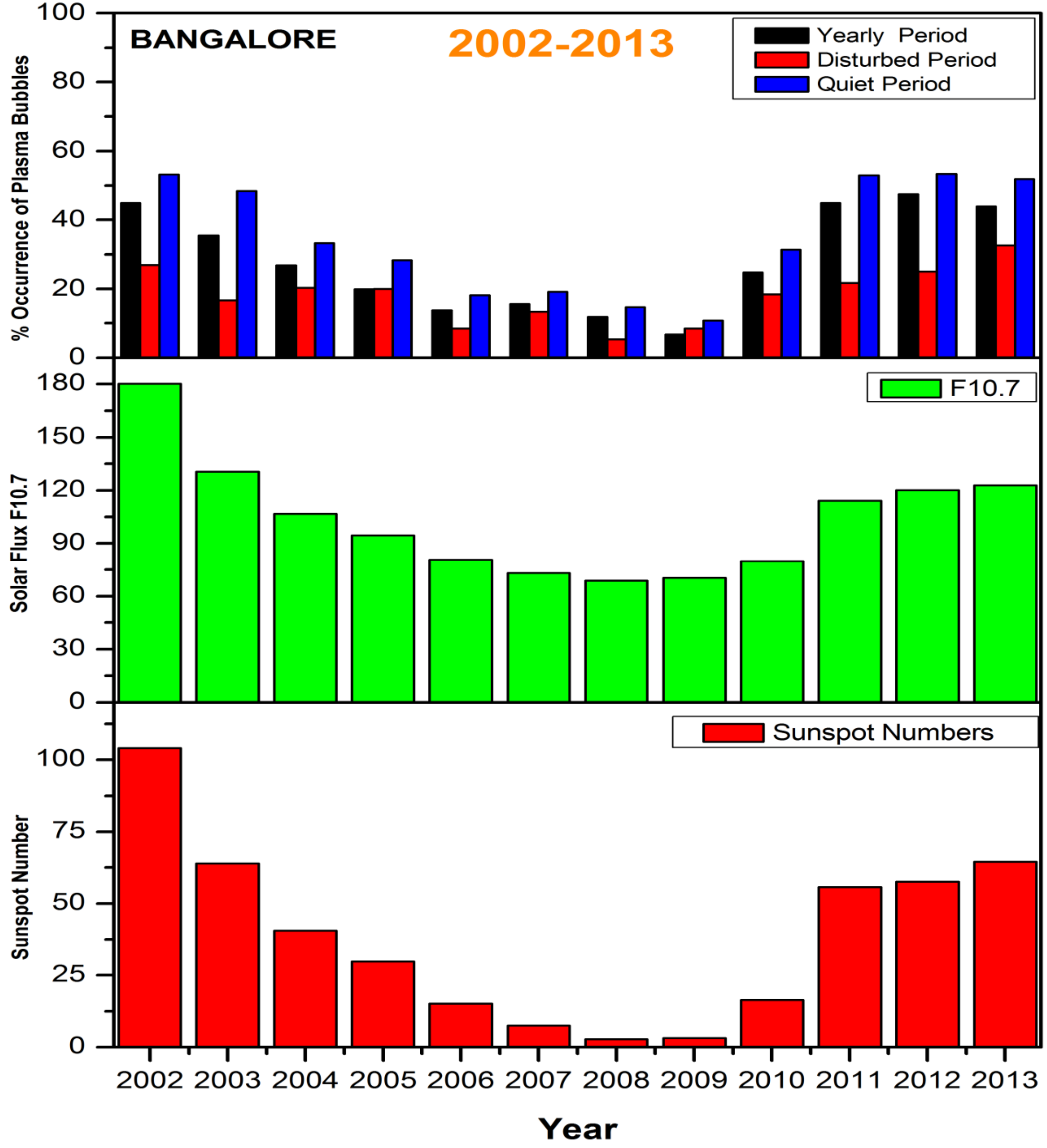
EPBs Using GNSS

Year	Total days	Total EPBs	% EPBs	Disturbed days	EPBs days	% EPBs	Quiet days	Total EPBs	% EPBs
2002	316	142	44.9367089	52	14	26.92307692	113	60	53.09735
2003	364	129	35.4395604	60	10	16.66666667	120	58	48.33333
2004	365	98	26.8493151	59	12	20.33898305	120	40	33.33333
2005	362	72	19.8895028	60	12	20	120	34	28.33333
2006	361	50	13.8504155	59	5	8.474576271	116	21	18.10345
2007	365	57	15.6164384	60	8	13.33333333	120	23	19.16667
2008	337	40	11.8694362	56	3	5.357142857	109	16	14.6789
2009	358	24	6.70391062	59	5	8.474576271	120	13	10.83333
2010	356	88	24.7191011	60	11	18.33333333	115	36	31.30435
2011	363	163	44.9035813	60	13	21.66666667	119	63	52.94118
2012	365	173	47.3972603	60	15	25	120	64	53.33333
2013	317	139	43.8485804	49	16	32.65306122	108	56	51.85185
Total	4229	1175	27.7843462	694	124	17.86743516	1400	484	34.57143

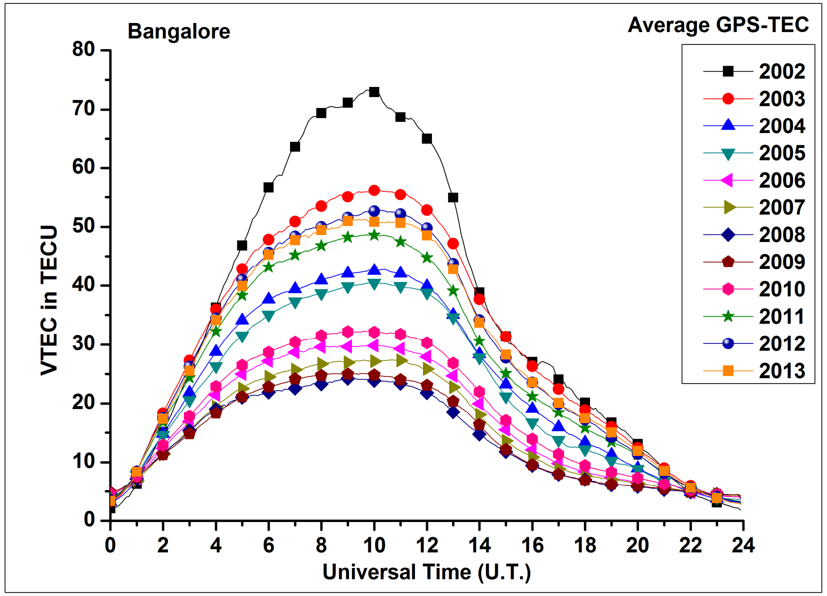
BANGALORE-GPS DATA

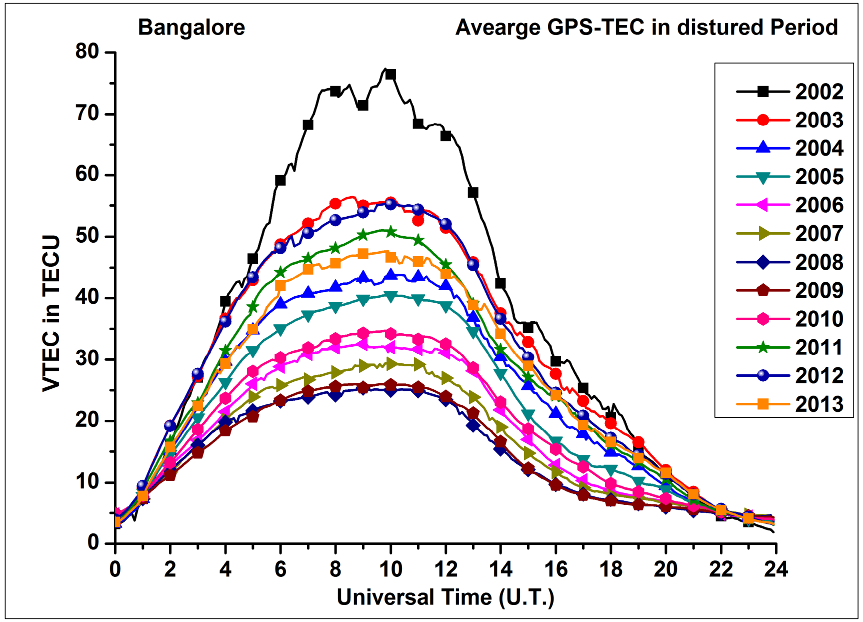
- **Total days (2002-2013) = 4383**
- **Available data = 4229 i.e 96.48%**
- **% EPBs= 27.78%**
- **% EPBs in disturbed days= 17.86%**
- **% EPBs in Quiet days= 34.57%**

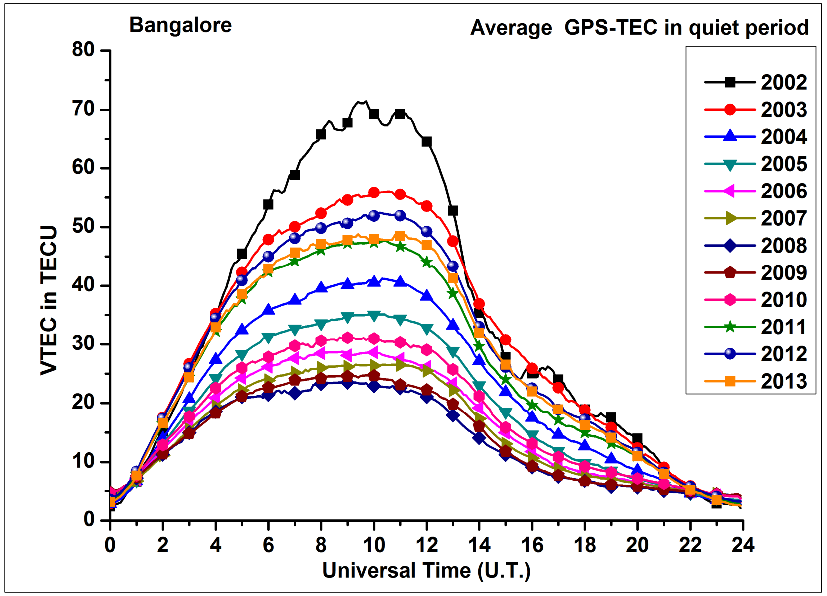
Top panl shows % occurrences rate of Plasma Bubbles over Bangalore, Middle panel shows F10.7 cm solar flux and bottom panel shows sunspot numbers for the period 2002-2013.



TEC and Solar Cycle







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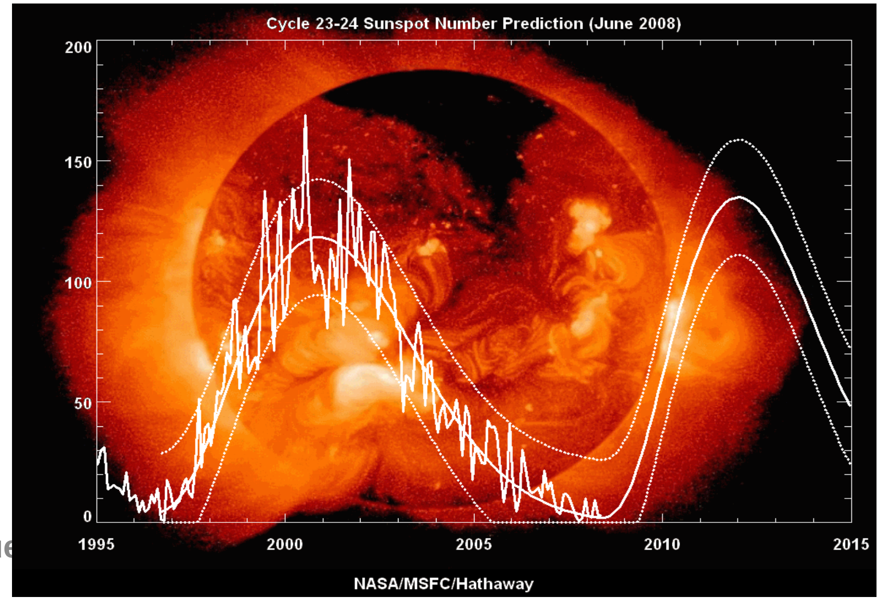
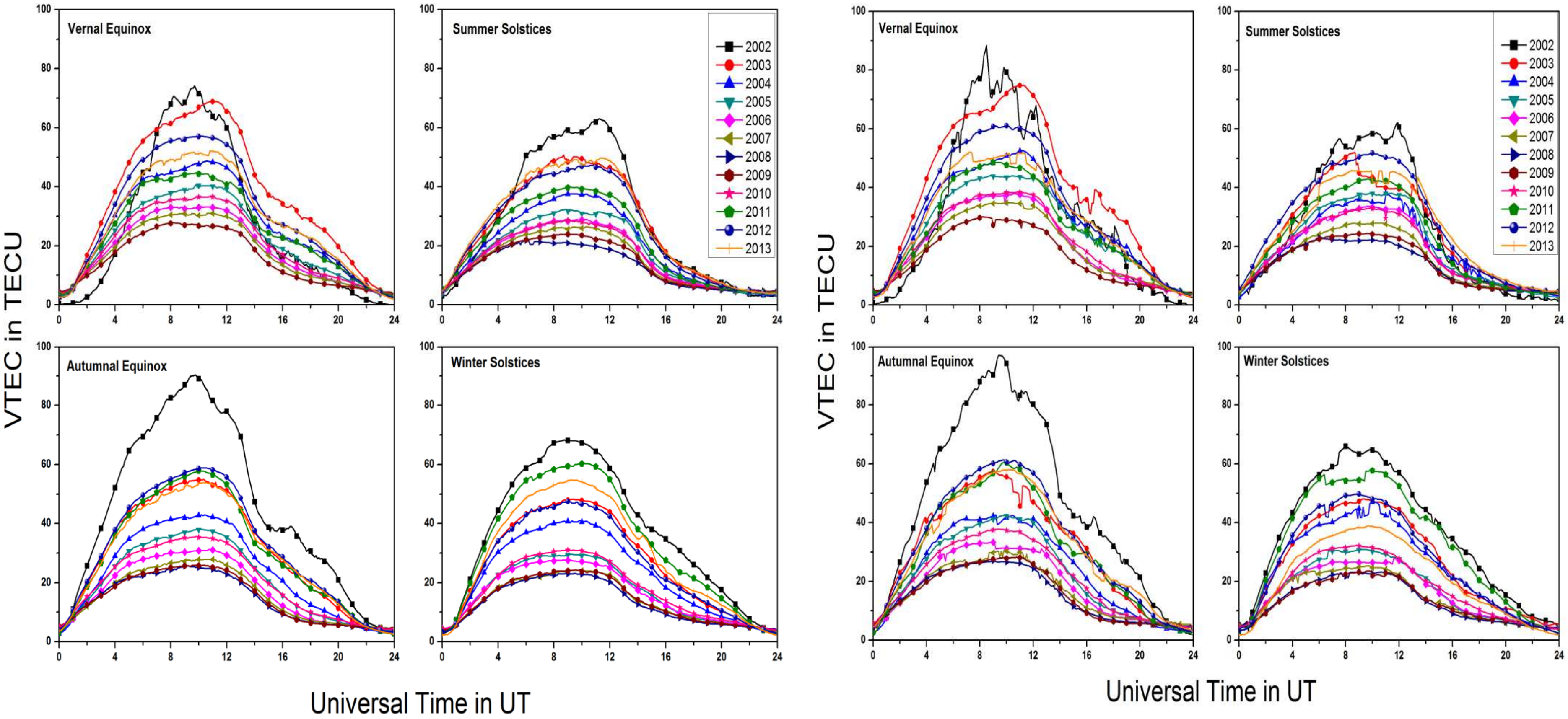
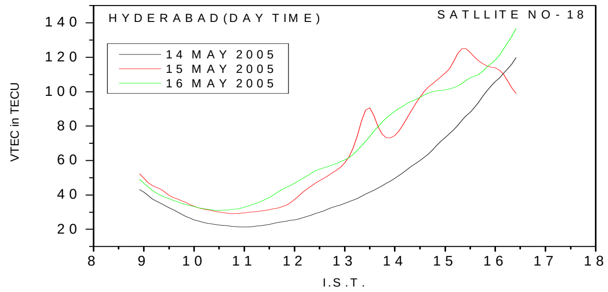


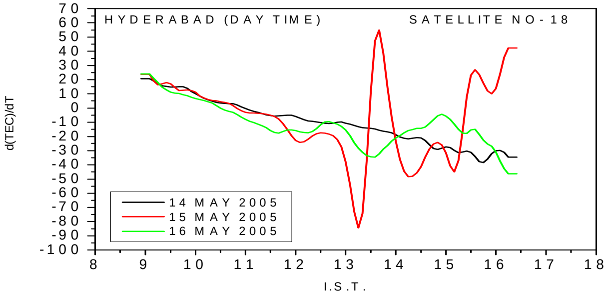
TEC: Seasonal Variation

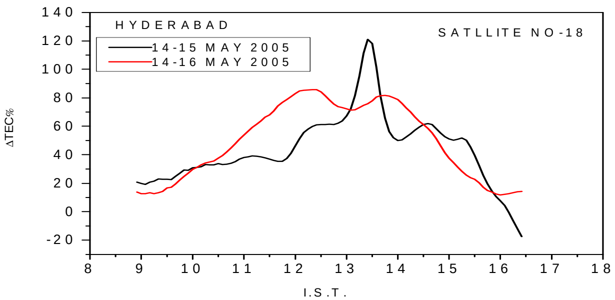


Seasonal variations of GPS-TEC during quiet and disturbed period (2002-2013) over Bangalore station.

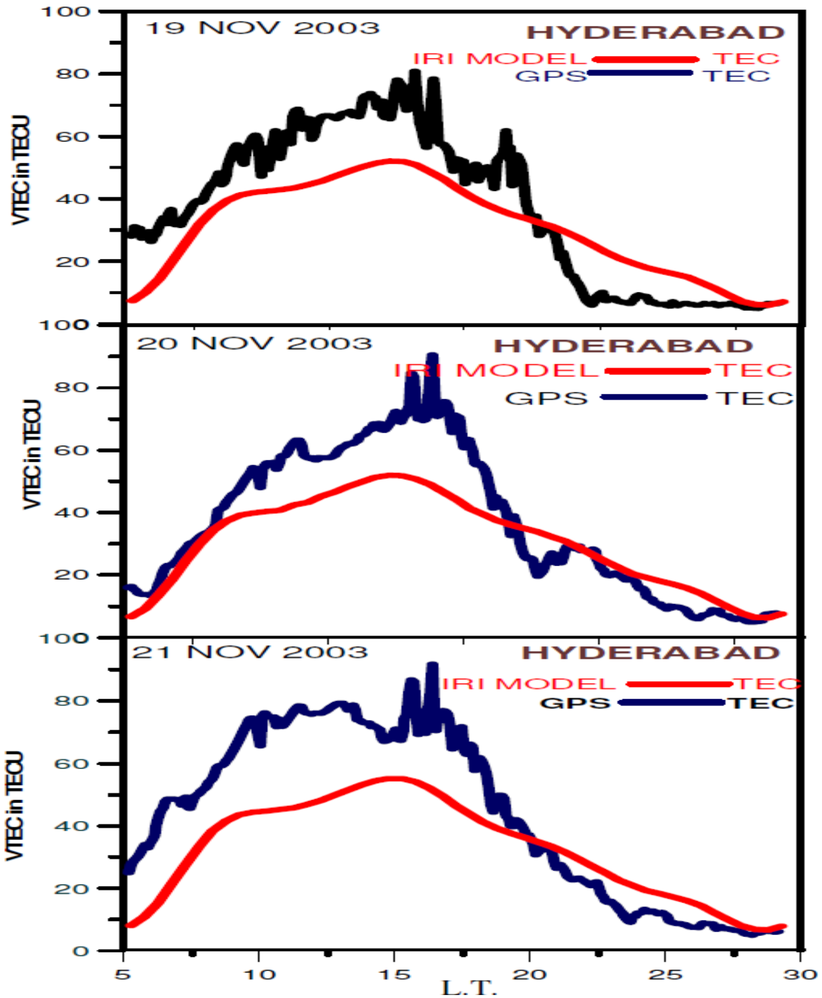
TEC: Storm Variation





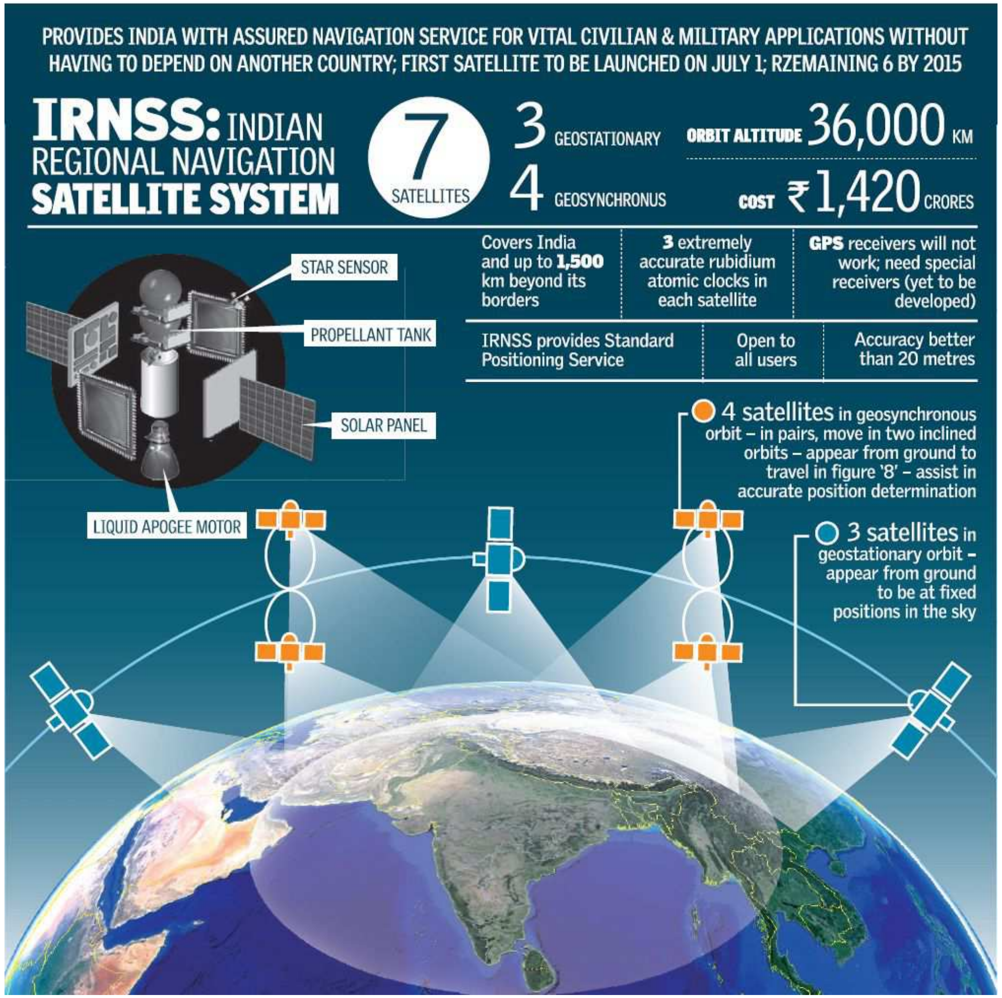


TEC variation for Hyderabad during 13-15 May ,2005



The VTEC from IRI 2000 and GPS on 19-21 November 2003

GNSS Activities



Installation of IRNSS Receiver at Sangli

GNSS Activities

The SCOSTEP/ISWI International School on Space Science, which is sponsored by the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) and the International Space Weather Initiative (ISWI) will take place during November 7 to 17, 2016. The school will be an excellent learning and enrichment opportunity for graduate students. The school is aimed at students who are perusing PhD in solar terrestrial physics and space science. Some masters students who have already some exposures in solar/space physics may also apply. The school will be held at the Smt. Kasturbai Walchand College of Science & Arts, Rajnemi Campus, Timber Area, Sangli-416416, India. (http://www.kwcsangli.in/Default.aspx)

ORGANIZING INSTITUTIONS AND SPONSORS

SPACE SCINCE ACTIVITIES

2015

SMT. KASTURBAI WALCHAND COLLEGE,
INDIA

SWC: Objectives

- Excellence in space weather research and conducting extensive outreach programs.
- Minor and major research projects related to space weather areas for students leading them to M. Sc and Ph. D degrees.
- Participating in the national and international programs involving research, outreach and capacity building in the programs covering solar terrestrial physics and influence of the Sun on the planetary environment, life and society.
- Collaboration with the national & international research institutes for installing new instruments at our Space Weather Center and initiate the joint research programs.
- Organization of the workshops and schools for teachers and students in order to attract them and exploit their talents towards space science.
- Frequent organization of popular/ public lectures on space science and allied subjects in schools, colleges and public societies.

Space Weather Center

Zero Gravity Instrument Inaugural Function

Public Address by Dr. N. GopalSwamy

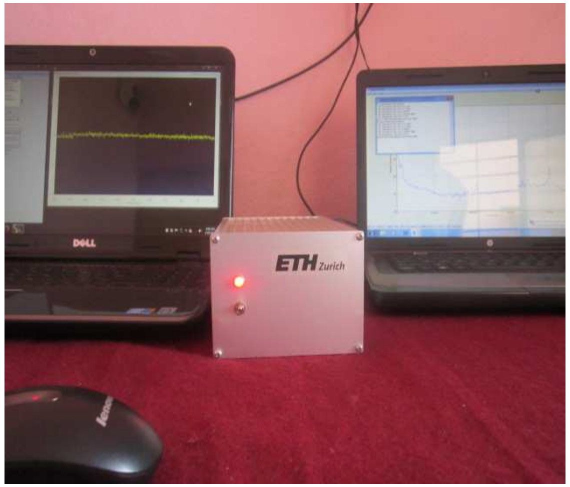
SWC: Activities

Public Lecture on Light by

Prof. Pramod Kale

Ex-Director SAC, ISRO

SWC: Instruments

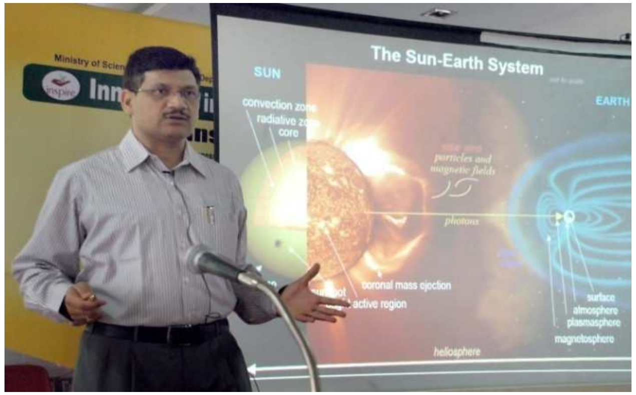


Super SID | **e-Callisto** | **IRNSS Receiver**

Space Science Activities

Space Science Activities

Lectures by Scientists



Conclusions

The occurrence percentage of EPBs is positively correlated with solar activity.

Average annual TEC measured during quiet & disturbed period shows positive correlation with solar activity (F10.7cm flux).

The occurrence percentage of EPBs in quiet period was higher than the disturbed period.

The occurrence percentage of EPBs increases with increase in average TEC

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

- **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**

- **The % occurrence rate is maximum in quiet period and it increases with solar activity. This directly affects the communication system, mainly due to the depletion in the TEC which produces most of the effects on GPS signal.**

- **The behavior of equatorial ionosphere in more complicated due to equatorial plasma bubble, MTM and other local phenomena. So in the modeling of the equatorial ionosphere, local phenomena may be incorporated. And also to understand the possible mechanism of day-to-day variability in the occurrence of EPBs**

- **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

- **Characterization of Bubble width with seasonal and solar activity.**

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- **% of Occurrence of plasma bubble with Local Time.**

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- **Comparison of the drift velocity during magnetic disturbances with interplanetary electric field.**

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- **Effect of X-class solar flares on GPS-TEC**

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- **For a better understanding of the low latitude TEC responses to prompt penetration and disturbance dynamo e-fields we will compare with the storm-time inter-planetary e-field and magnetic field**

Future Plan

- ❖ Proto Precession Magnetometer.
- ❖ Day & Night airglow Photometer/ Imager
- ❖ Earthquake Monitor (Seismograph).
- ❖ Solar Microwave Radiometer.
- ❖ Solar Optical flare Monitor.
- ❖ Flux –gate tri axis magnetometer
- ❖ Scintillation Network Decision Aid (SCINDA)
- ❖ H-alpha filter (Continuous H-alpha Imaging Network (CHAIN))
- ❖ Automatic Weather Station.

These experiments may be setup in a phase-wise manner in this decade

Acknowedgement

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Niel Peter for providing PASKIL4 codes

Prof. Richard Langley ,Dr. Mariangel Fedrizzi of Geomatics Engineering, University of New Brunswick (UNB), Canada and Dr.Daniel M Moeketsi, Research Scientist Center for High Performance, Computing ,South Africa for providing us a Unix/Linux-based FORTRAN code for the UNB ionospheric modelling technique for scientific research purposes.

Dr. Gopi Seemala for providing software

Dr. Don Thompson ,Research Scientist,Center for Atmospheric and Space,Sciences,Utah State University, Logan,USA for providing us RD_RINEX code for scientific research purposes

Dr. Eduardo A. Araujio-Pradere,Research Scientist,CIRES- University of Colorado, NOAA-Space Enviroment Center, Boulder, for the WinTEC software for scientific research purposes.

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.

UNOOSA for providing financial support to participate in 4th ESS, Netherlands.


Thank You