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# Initial Results of Total Electron Content over Low Latitude Station, Sangli (16°52' N, 74° 34' E)

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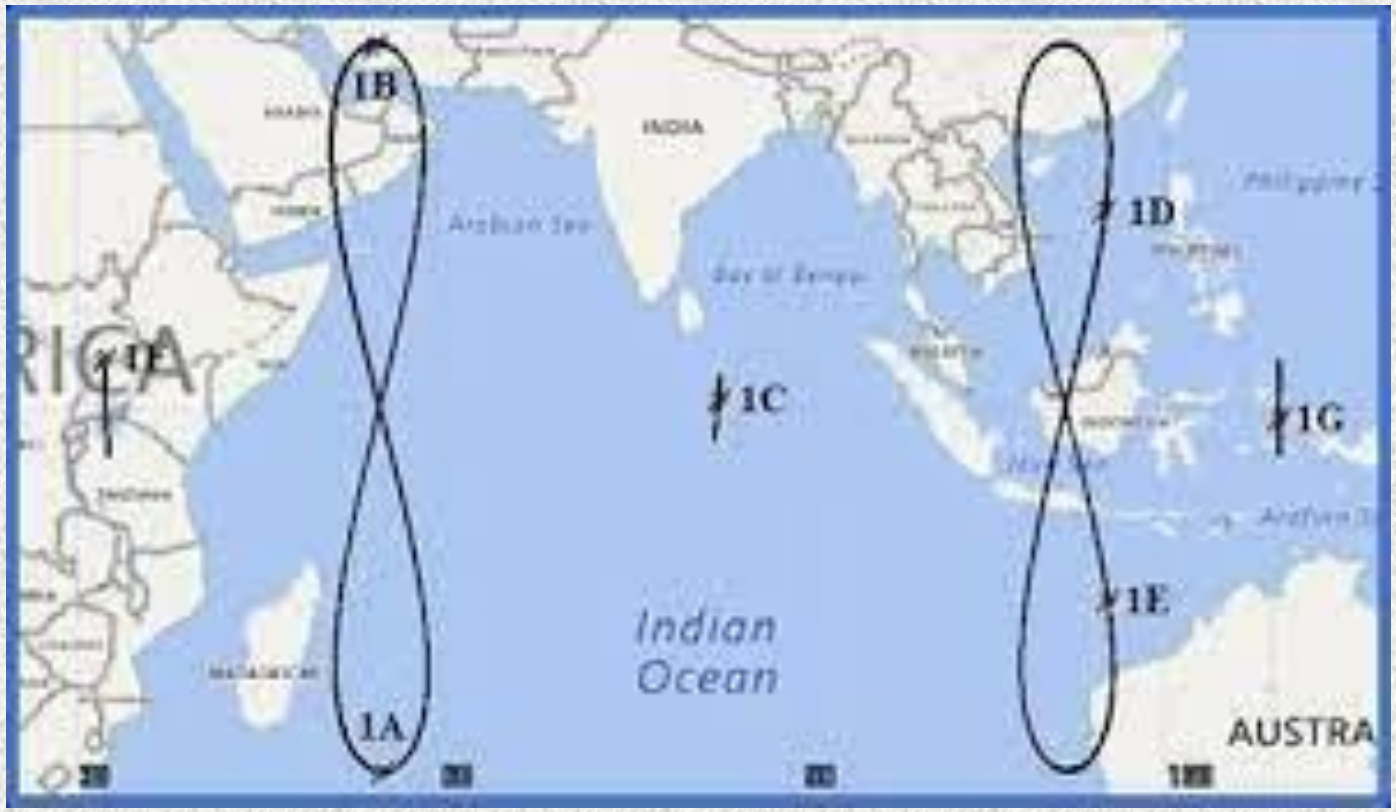
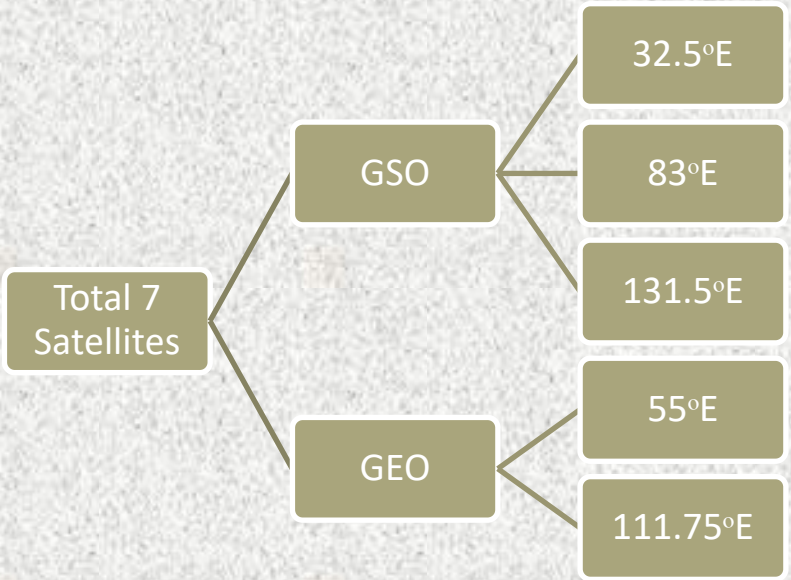
# Outline

- Indian Regional Navigational Satellite System(IRNSS)
- Data Extraction  and Analysis
- RNSS-UR-Output results
- IRNSS-TEC and GPS- TEC
- Conclusions

# IRNSS(Indian Regional Navigational Satellite System)

- Satellite based navigation system offering an independent positioning and timing services over Indian and neighboring regions.
- Satellite Height – 36000 km above earth
- Coverage – 1500 Km




The IRNSS space segment consists of 7 satellites (3 GEO and 4 GSO). The 3 GEOs will be located at 32.5° E, 83°E and 131° E and the 4 GSOs have their longitude crossings 55° E and 111.75° E (two in each plane)

# STEC And VTEC

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

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

ΔP 1, 2 = P1 - P2 where P1 and P2 are pseudo ranges on L1 and L2 respectively

**Differential phase advance STEC**

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

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

ΔL 1,2 = Φ1 - Φ2 where Φ1 and Φ2 are phase measurements on L1 and L2 respectively.

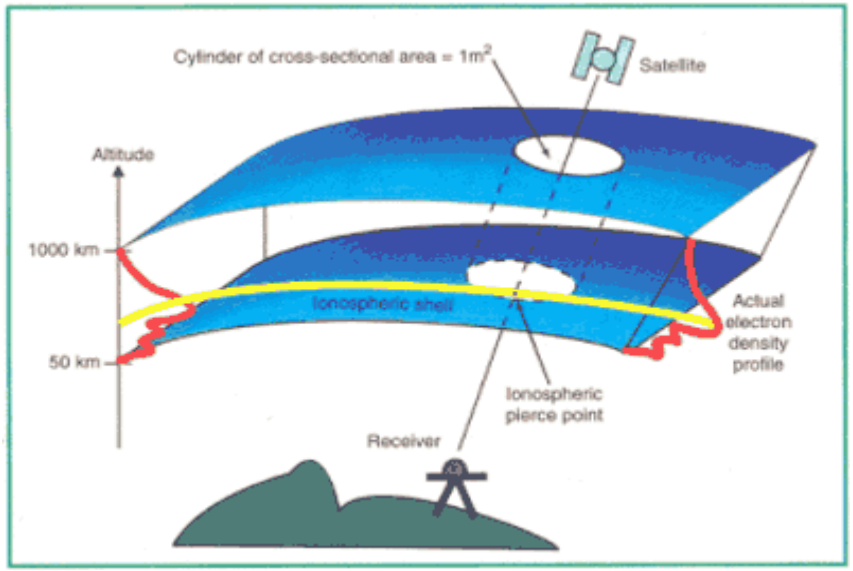
**Slant TEC to Vertical TEC**

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

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

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

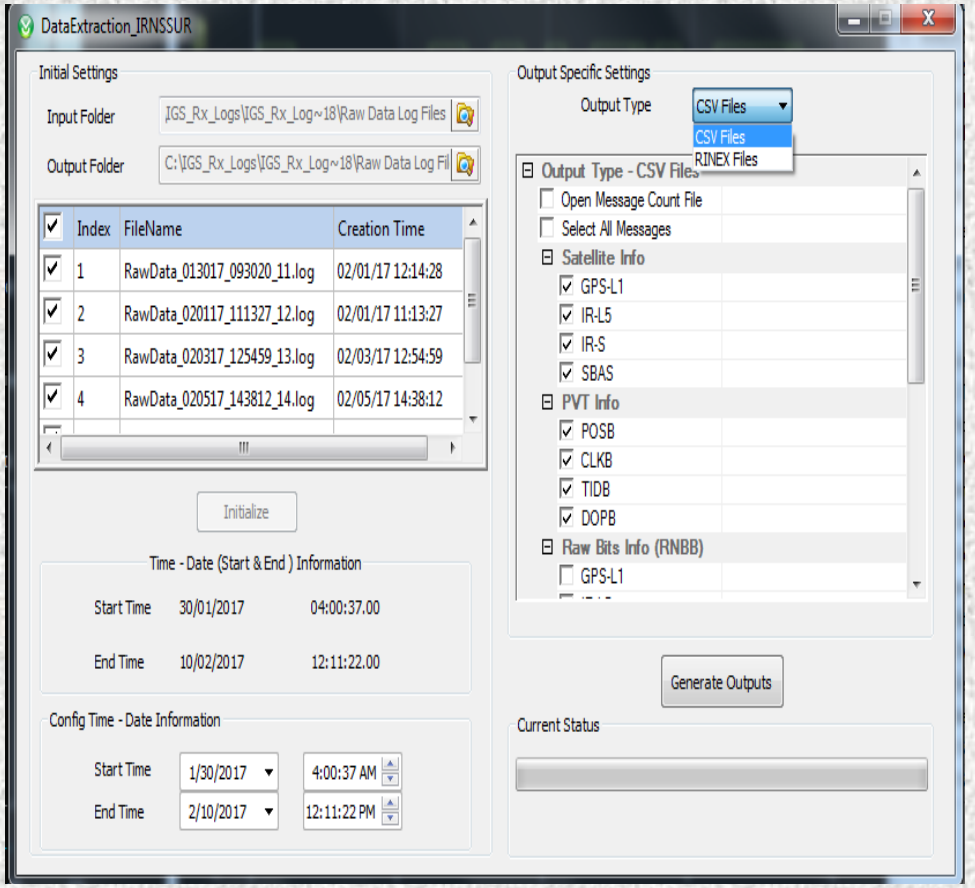
$R_E$ -Radius of the Earth

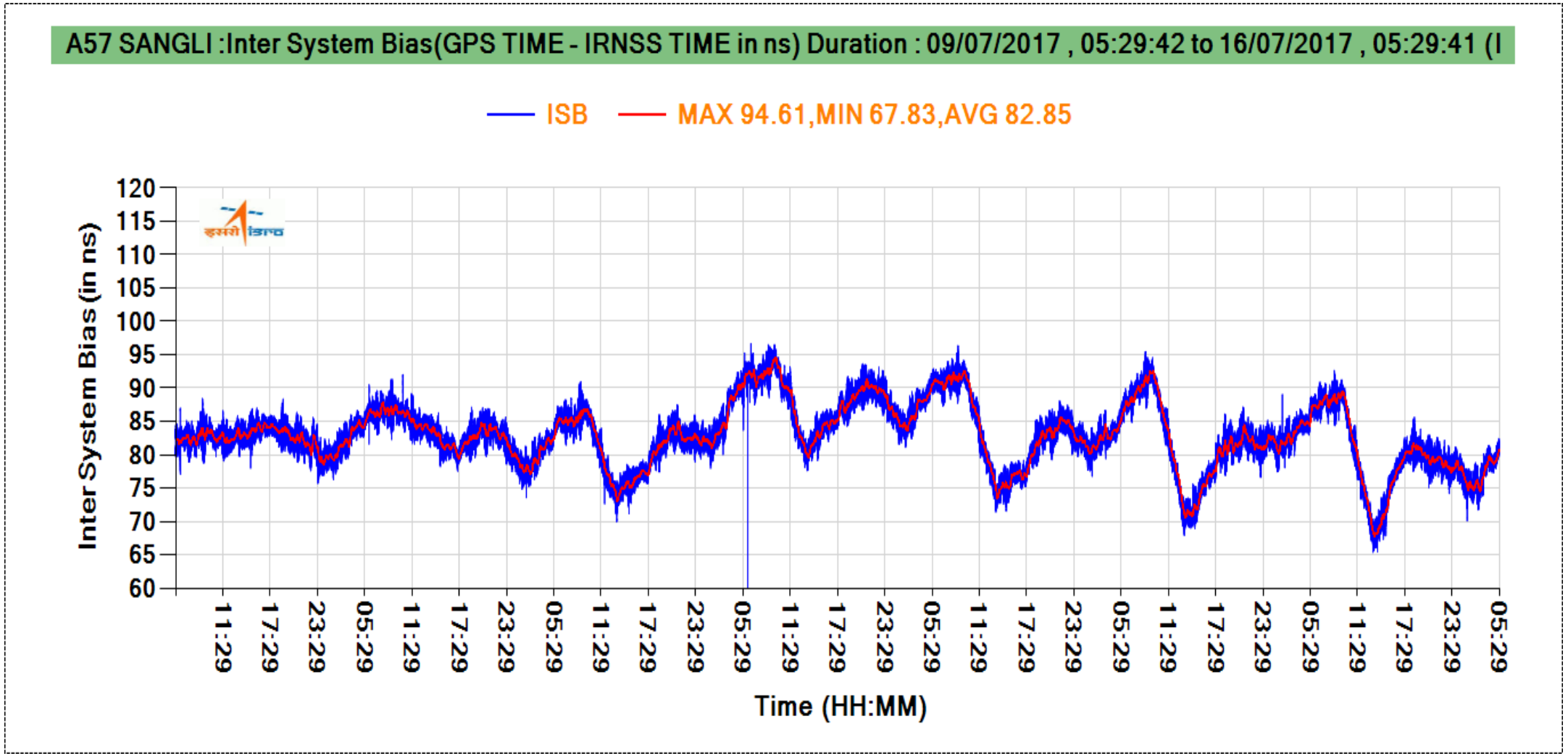



The ionosphere is represented as thin shell. The variation of electron density shown in red color and the peak value represent the F layer (shown as yellow line) (**Fedrizzi et al, 2002**)

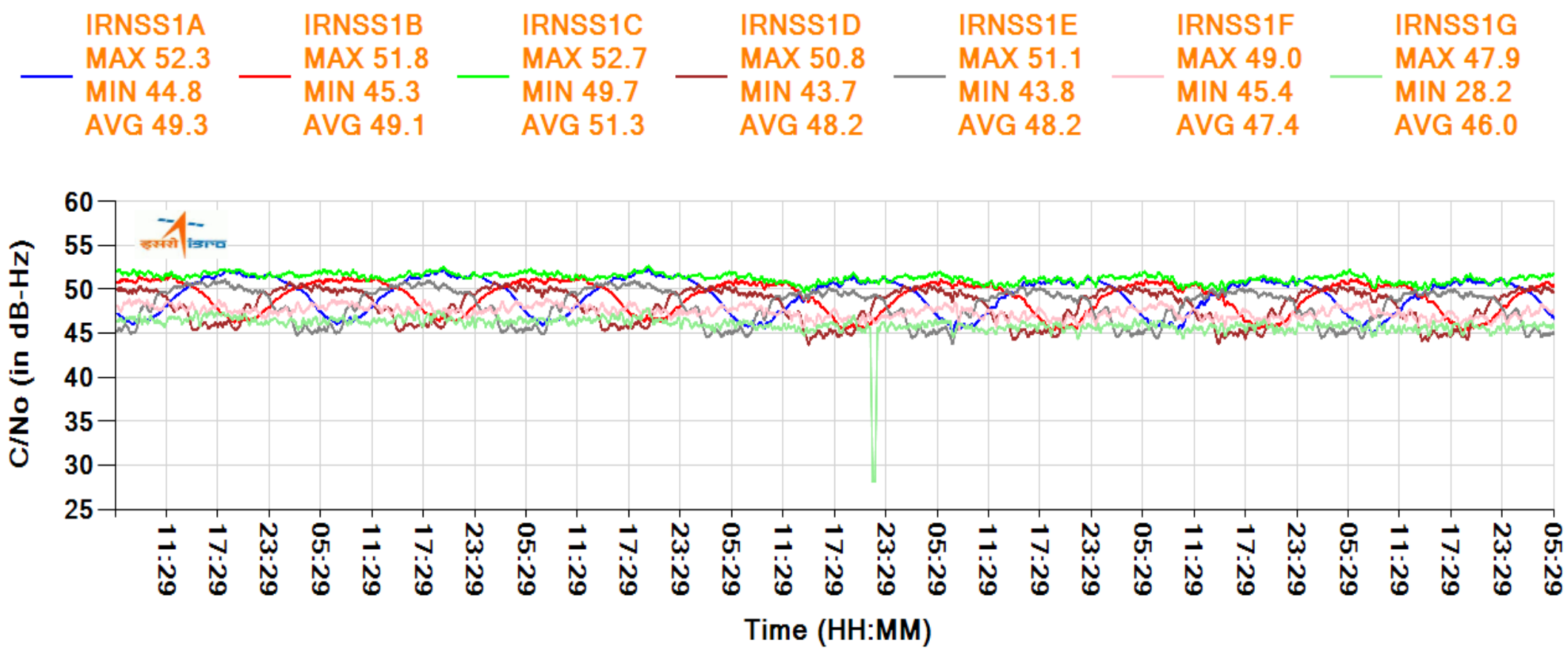
# Data Extraction

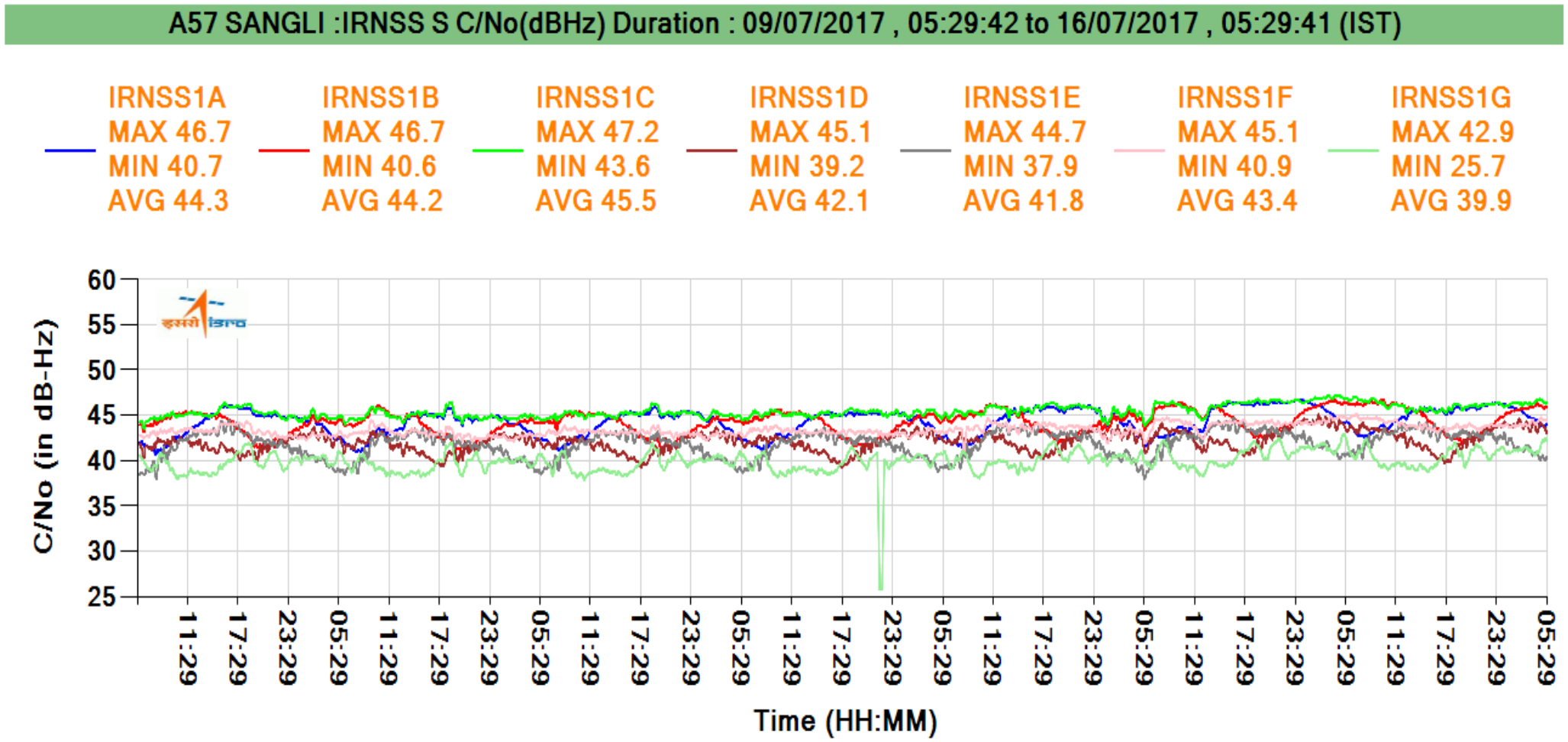
- Data can be Extract in two formats
  - CSV Files
  - Rinex Files




A57 SANGLI :Inter System Bias(GPS TIME - IRNSS TIME in ns) Duration : 09/07/2017 , 05:29:42 to 16/07/2017 , 05:29:41 (I
ISB
MAX 94.61,MIN 67.83,AVG 82.85
Inter System Bias (in ns)
120
115
110
105
100
95
90
85
80
75
70
65
60
11:29
17:29
23:29
05:29
Time (HH:MM)

A57 SANGLI :IRNSS L5 C/No(dBHz) Duration : 09/07/2017 , 05:29:42 to 16/07/2017 , 05:29:41 (IST)




A57 SANGLI :IRNSS S C/No(dBHz) Duration : 09/07/2017 , 05:29:42 to 16/07/2017 , 05:29:41 (IST)
IRNSS1A MAX 46.7 MIN 40.7 AVG 44.3
IRNSS1B MAX 46.7 MIN 40.6 AVG 44.2
IRNSS1C MAX 47.2 MIN 43.6 AVG 45.5
IRNSS1D MAX 45.1 MIN 39.2 AVG 42.1
IRNSS1E MAX 44.7 MIN 37.9 AVG 41.8
IRNSS1F MAX 45.1 MIN 40.9 AVG 43.4
IRNSS1G MAX 42.9 MIN 25.7 AVG 39.9
C/No (in dB-Hz)
60
55
50
45
40
35
30
25
11:29
17:29
23:29
05:29
11:29
17:29
23:29
05:29
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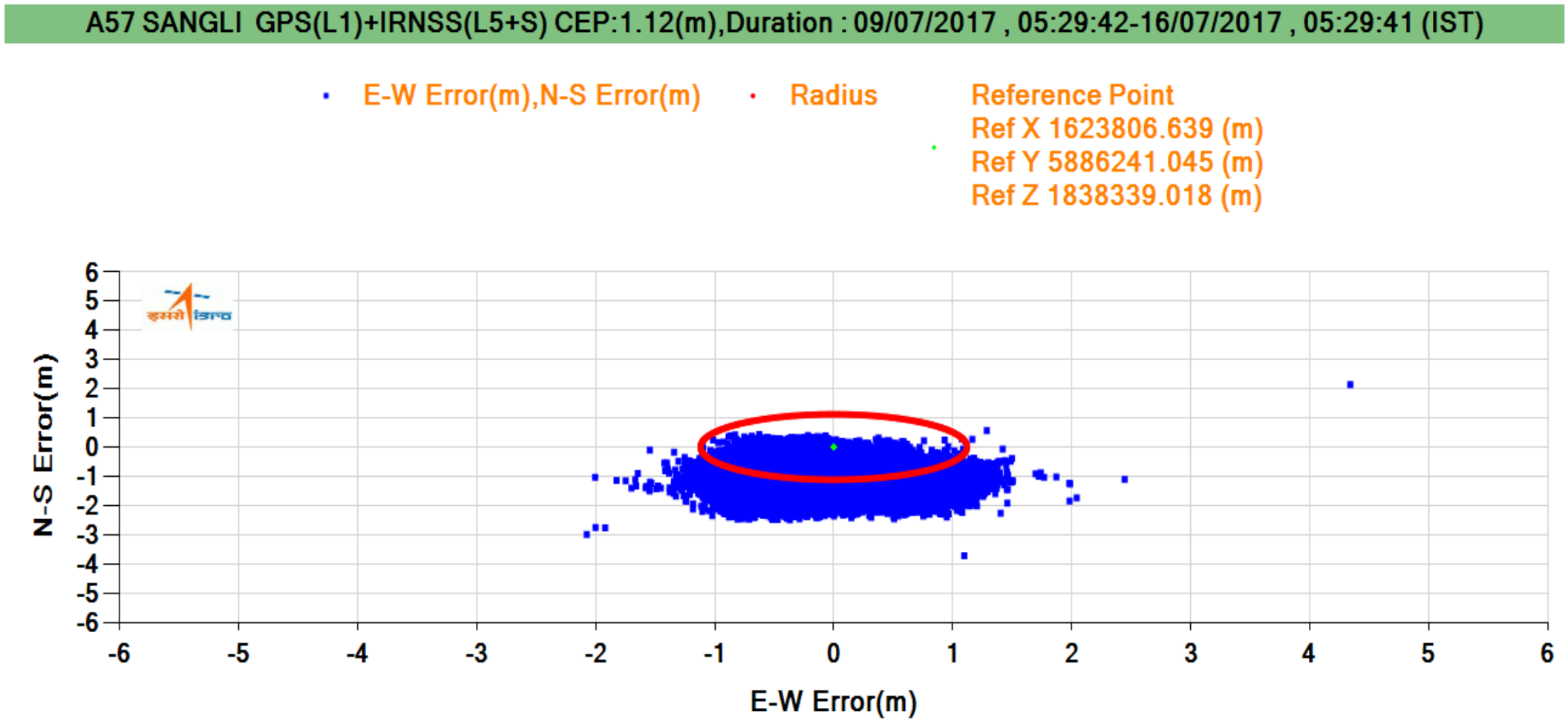
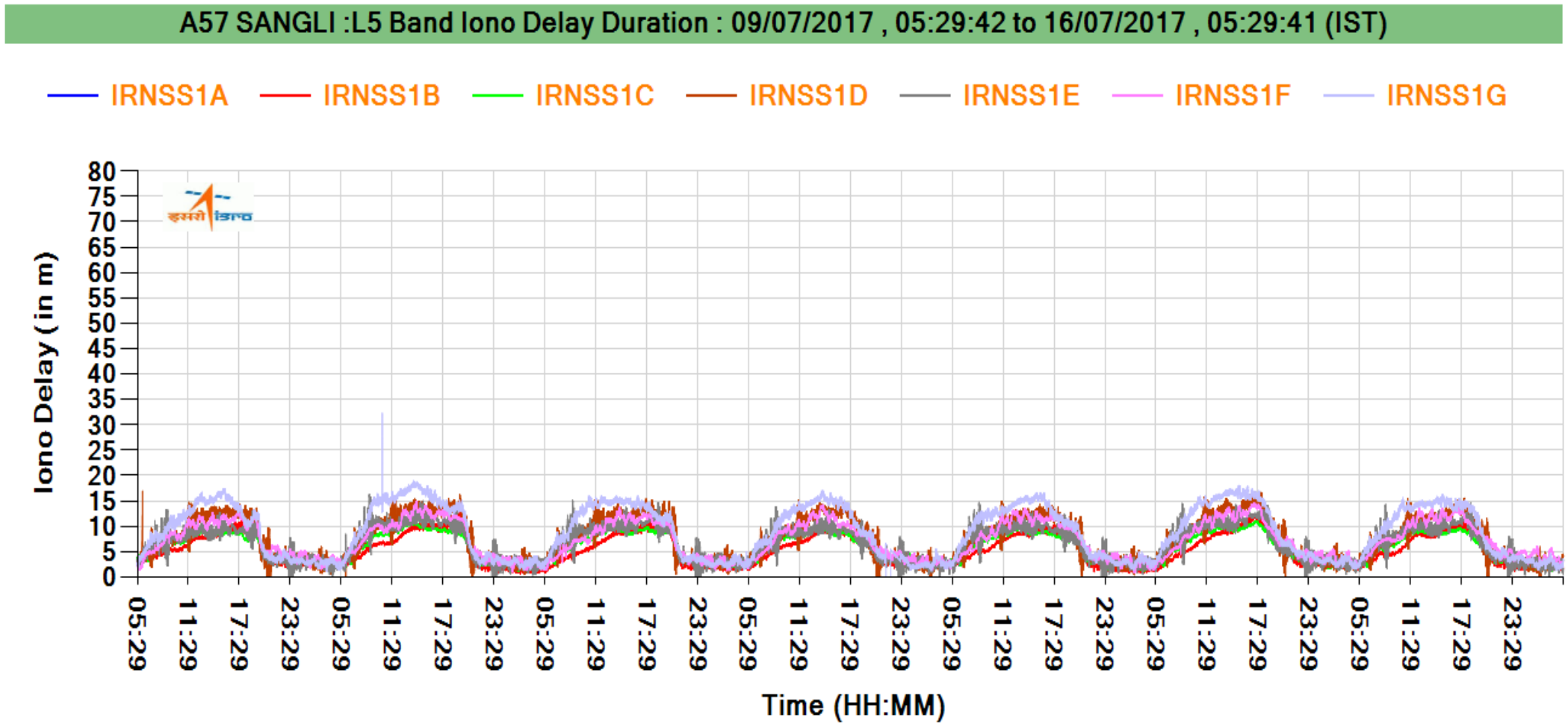
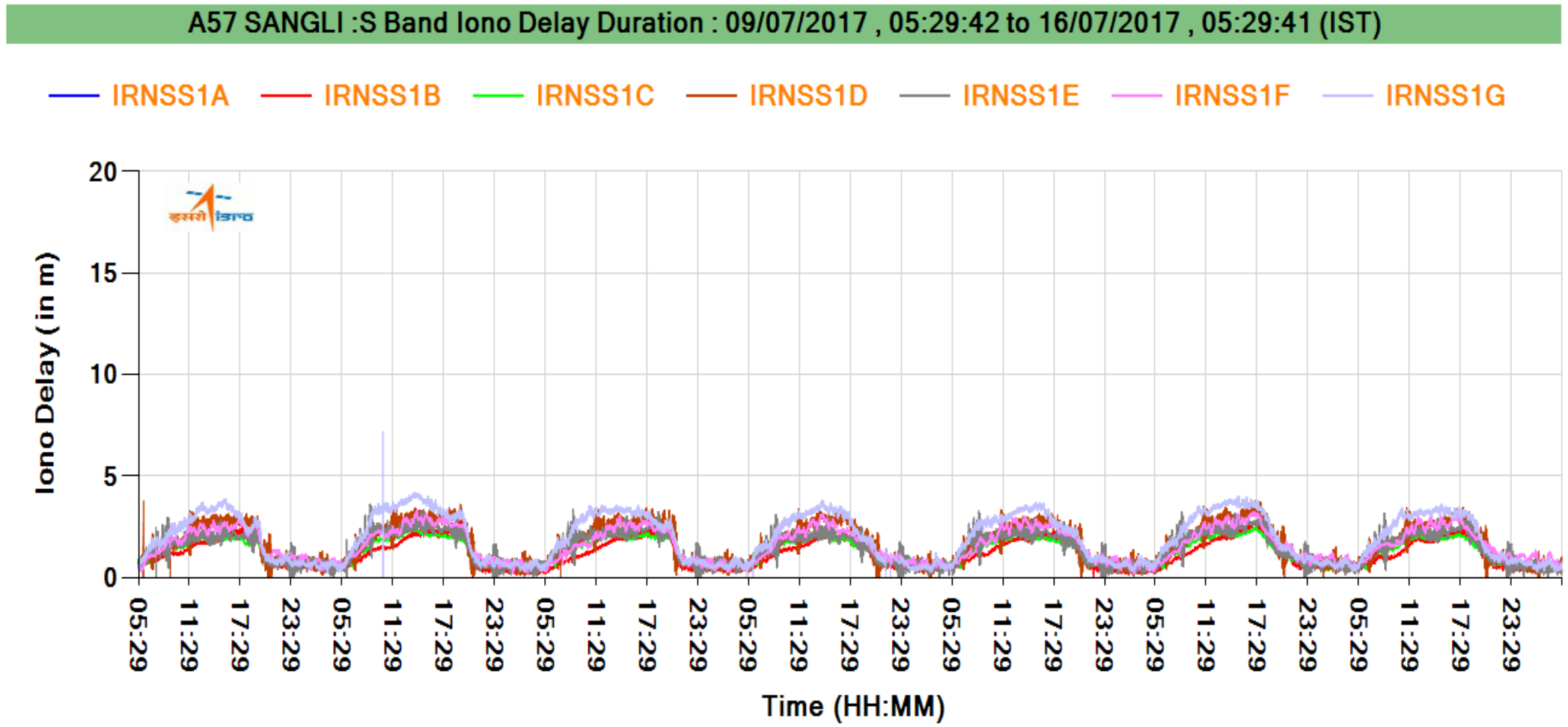
11:29
17:29
23:29
05:29
Time (HH:MM)


A57 SANGLI GPS(L1)+IRNSS(L5+S) CEP:1.12(m),Duration : 09/07/2017 , 05:29:42-16/07/2017 , 05:29:41 (IST)
E-W Error(m),N-S Error(m)
Radius
Reference Point
Ref X 1623806.639 (m)
Ref Y 5886241.045 (m)
Ref Z 1838339.018 (m)
N-S Error(m)
E-W Error(m)
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6


A57 SANGLI :L5 Band Iono Delay Duration : 09/07/2017 , 05:29:42 to 16/07/2017 , 05:29:41 (IST)
IRNSS1A
IRNSS1B
IRNSS1C
IRNSS1D
IRNSS1E
IRNSS1F
IRNSS1G
Iono Delay (in m)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
05:29
11:29
17:29
23:29
Time (HH:MM)


A57 SANGLI :S Band Iono Delay Duration : 09/07/2017 , 05:29:42 to 16/07/2017 , 05:29:41 (IST)
IRNSS1A
IRNSS1B
IRNSS1C
IRNSS1D
IRNSS1E
IRNSS1F
IRNSS1G
Iono Delay ( in m)
20
15
10
5
0
05:29
11:29
17:29
23:29
Time (HH:MM)

# Absolute TEC derivation from IRNSS (code developed):

TECgroup = (P1-P2)* 4.4191

TECphase = (C1 - C2) * 4.4191

where 4.4191 is estimated multiplication factor for IRNSS

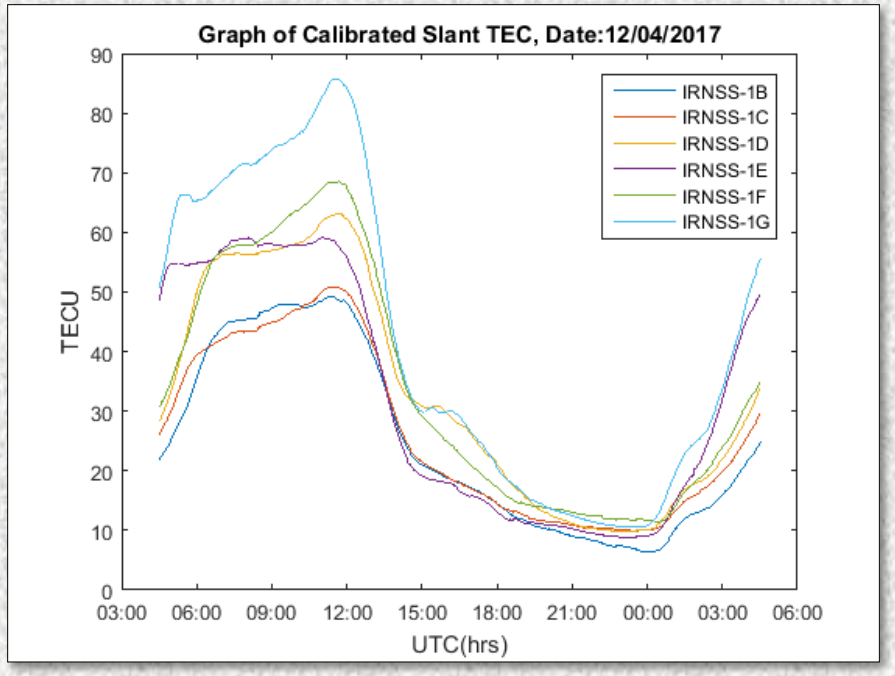



Fig1: Result for Calibrated Slant TEC

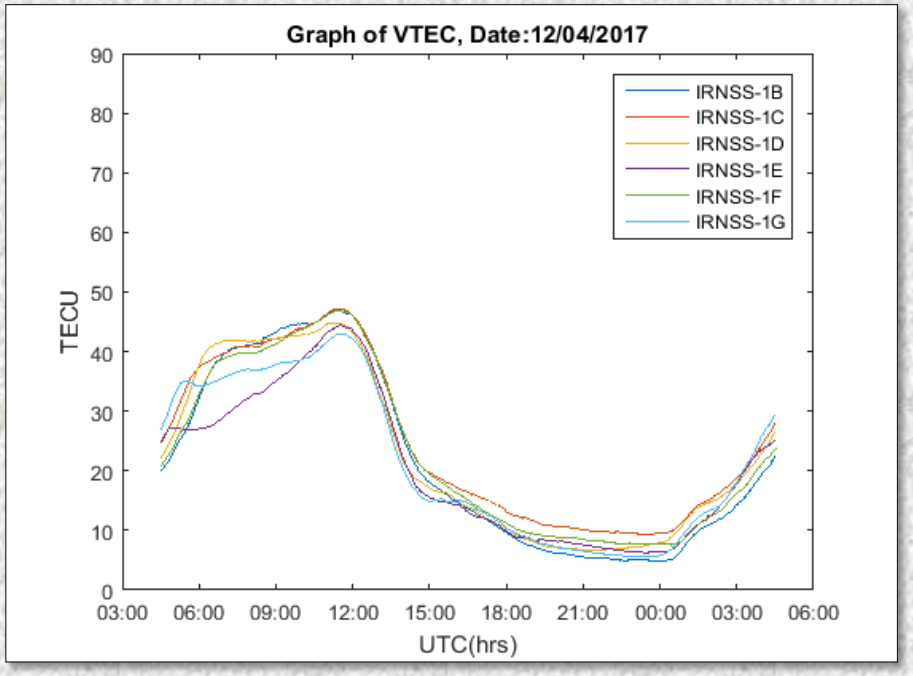



Fig2: Result for VTEC(Biased)

# ➢Detection and Correction of Cycle Slips:

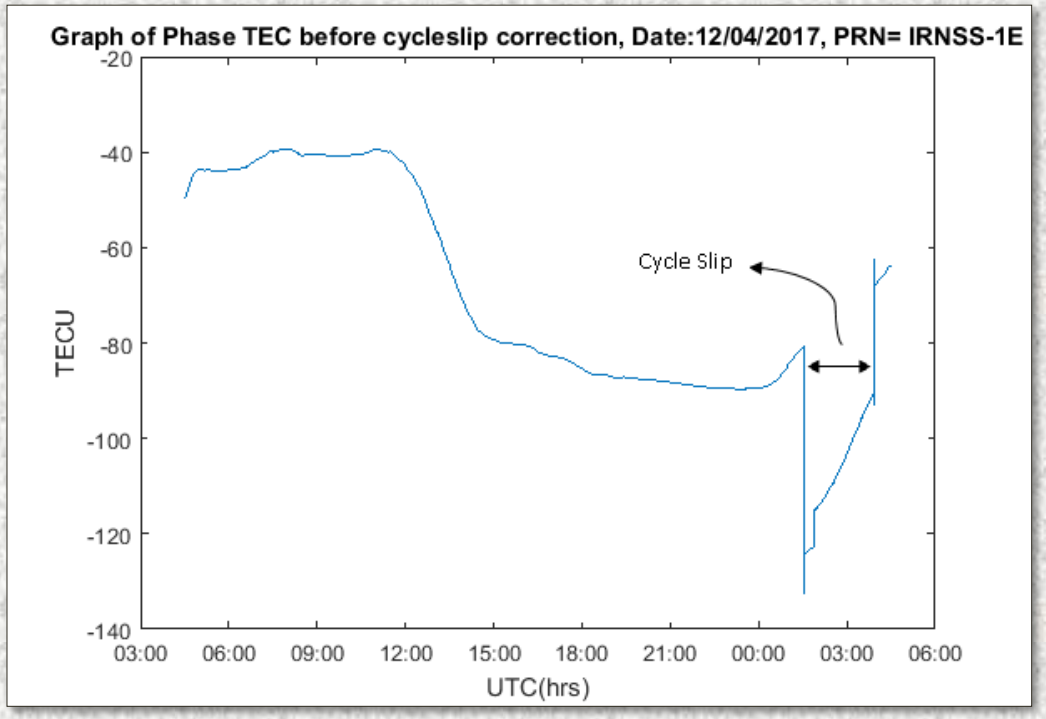



**Fig: Phase TEC Before Cycle Slip Correction (IRNSS-1E)**

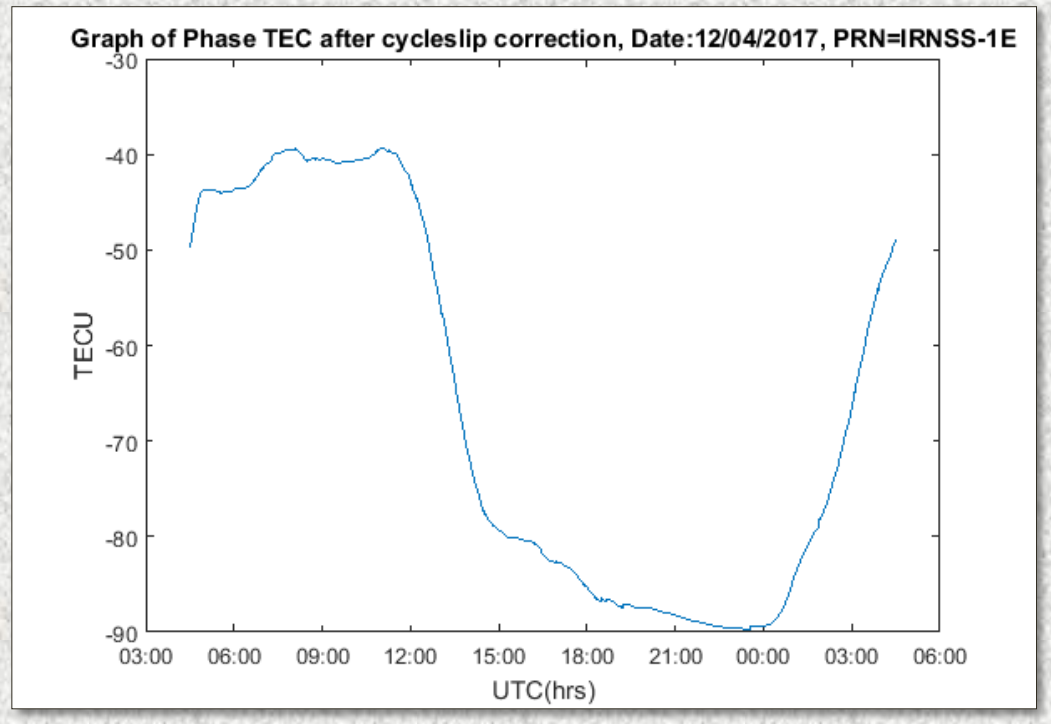



**Fig: After Cycle Slip Correction**

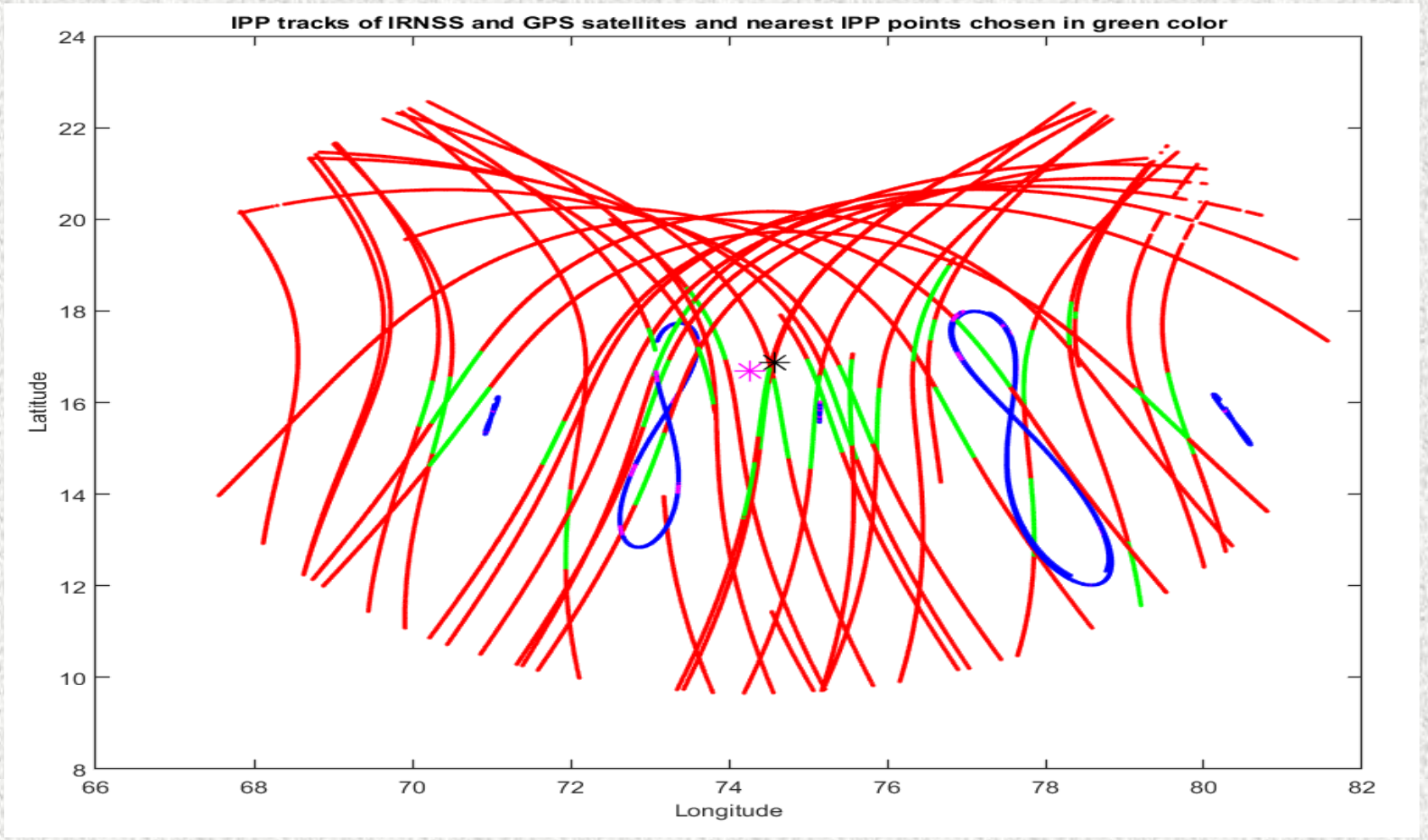



Fig. : *Locations of IPPs for IRNSS (blue color) and GPS (red color), the closer GPS tracks are identified by green color. The black and magenta astericks indicate the locations of Sangli (IRNSS) and Kolhapur (GPS) receiver installations*

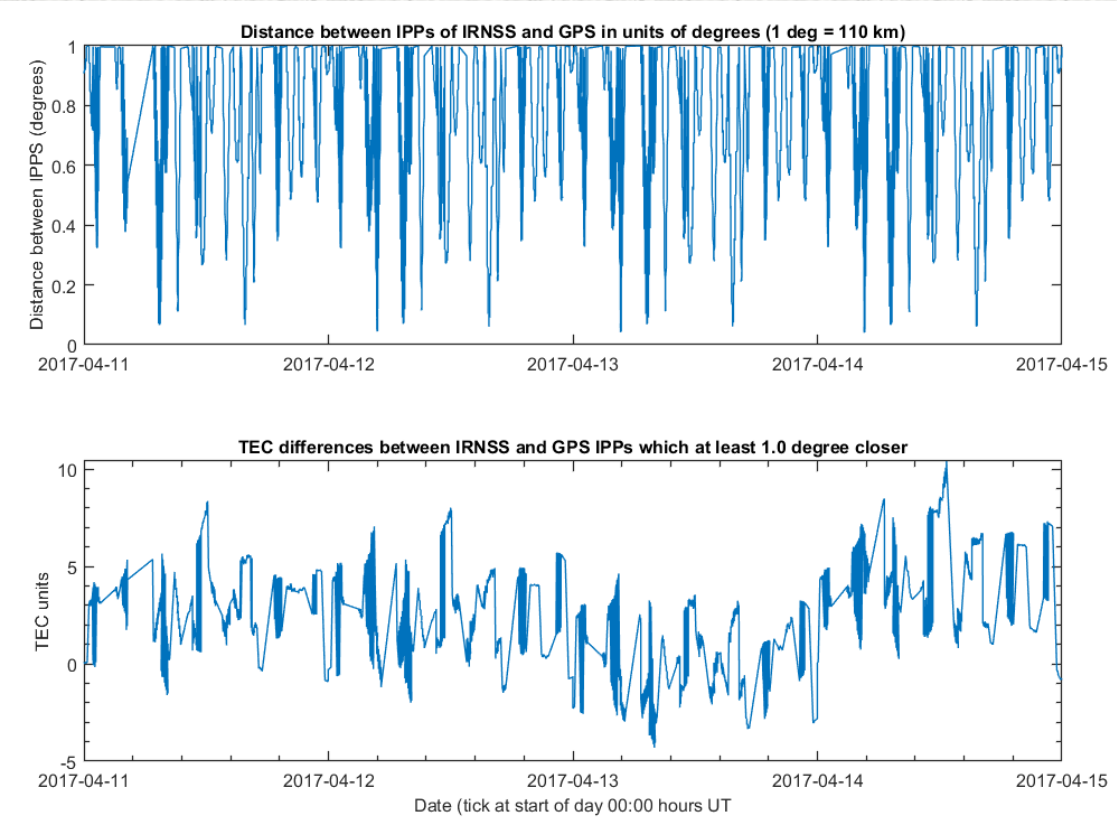



Fig. : *Top panel plot showing the distance between the closest IPP points (in degree on y-axis) with respect to the time of the day, for days 11 to 14th April 2017. And the second panel shows the corresponding differences in TEC values for those closest IPP points between IRNSS and GPS intercepting line of sight at ionospheric height of 350km.*

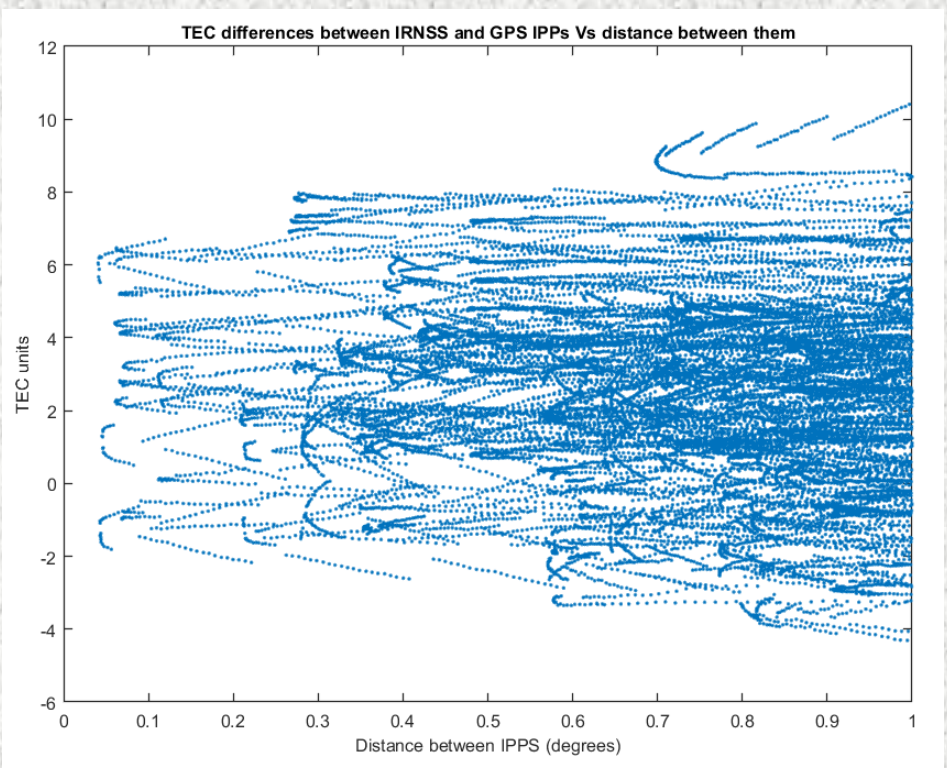



Fig. : *scatter plot for the distance between the IPPs of IRNSS and GPS, and the corresponding differences in TEC values at that IPP.*

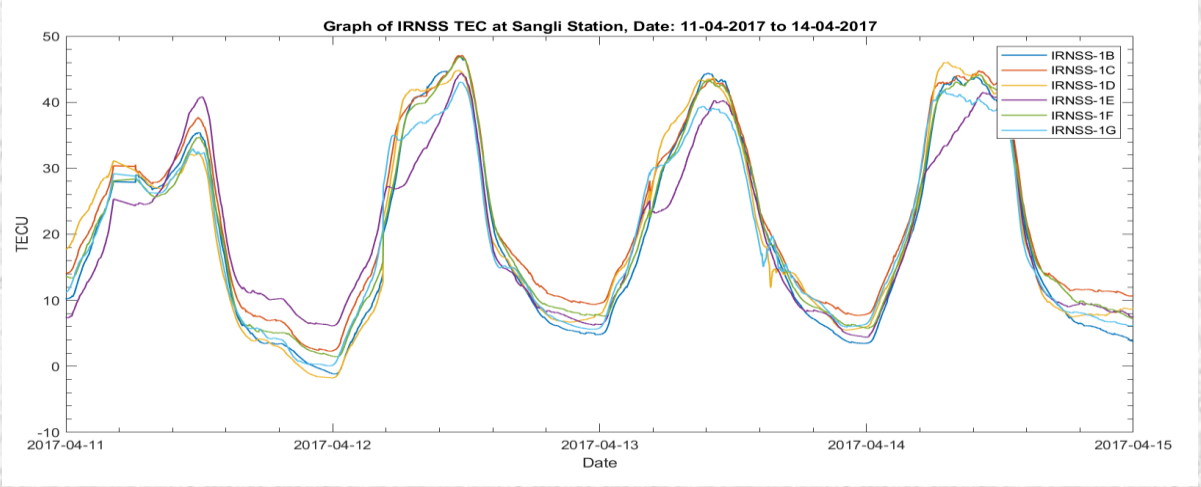



Fig : IRNSS derived TEC variation at Sangli station during equinox (4 days of April 2017)

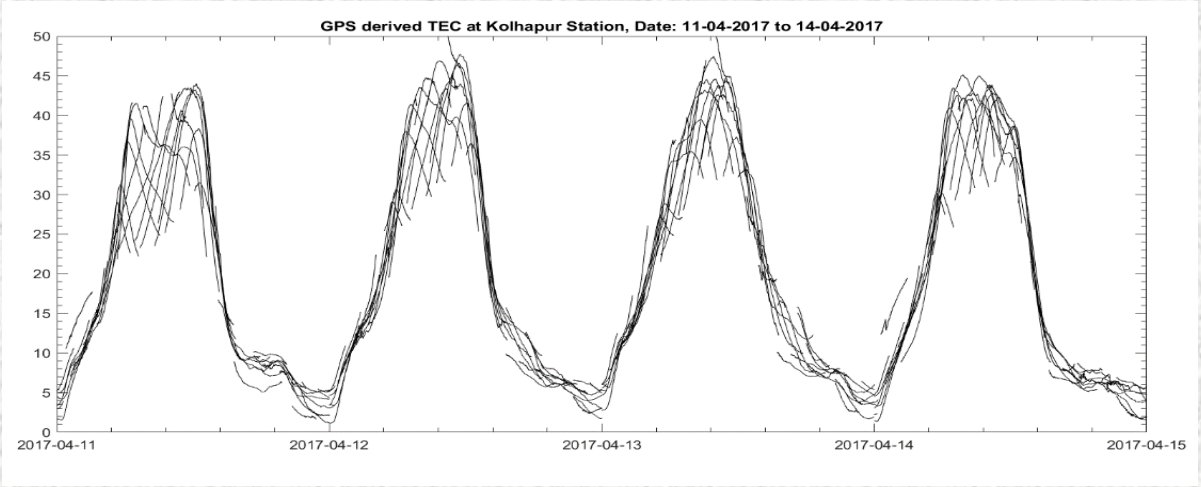



Fig : GPS derived TEC variation at Kolhapur station during equinox (4 days of April 2017)

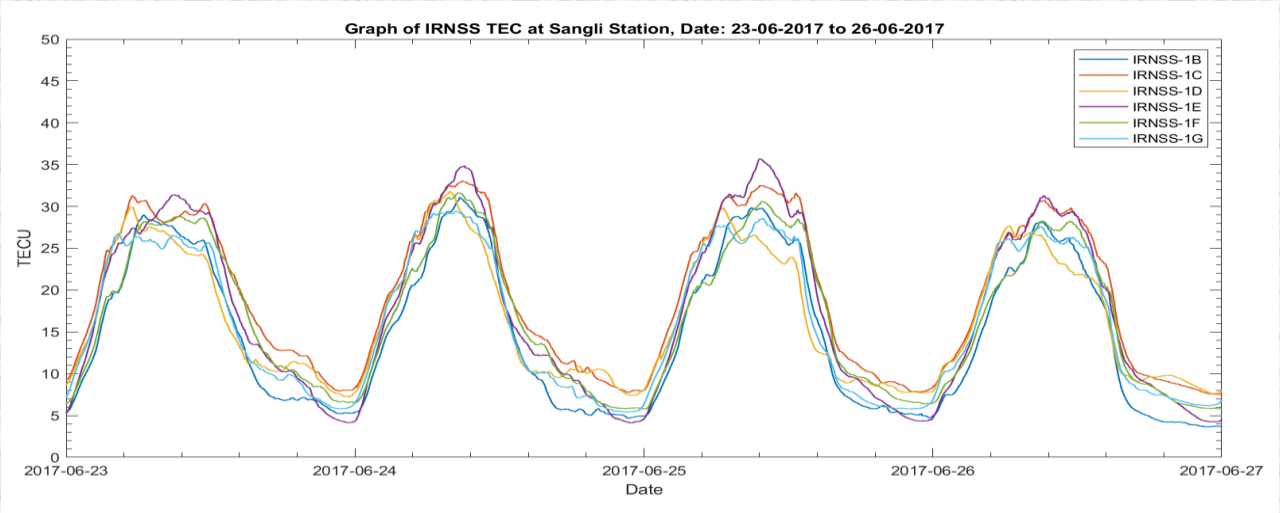



Fig : IRNSS derived TEC variation at Sangli station during summer (4 days of June 2017)

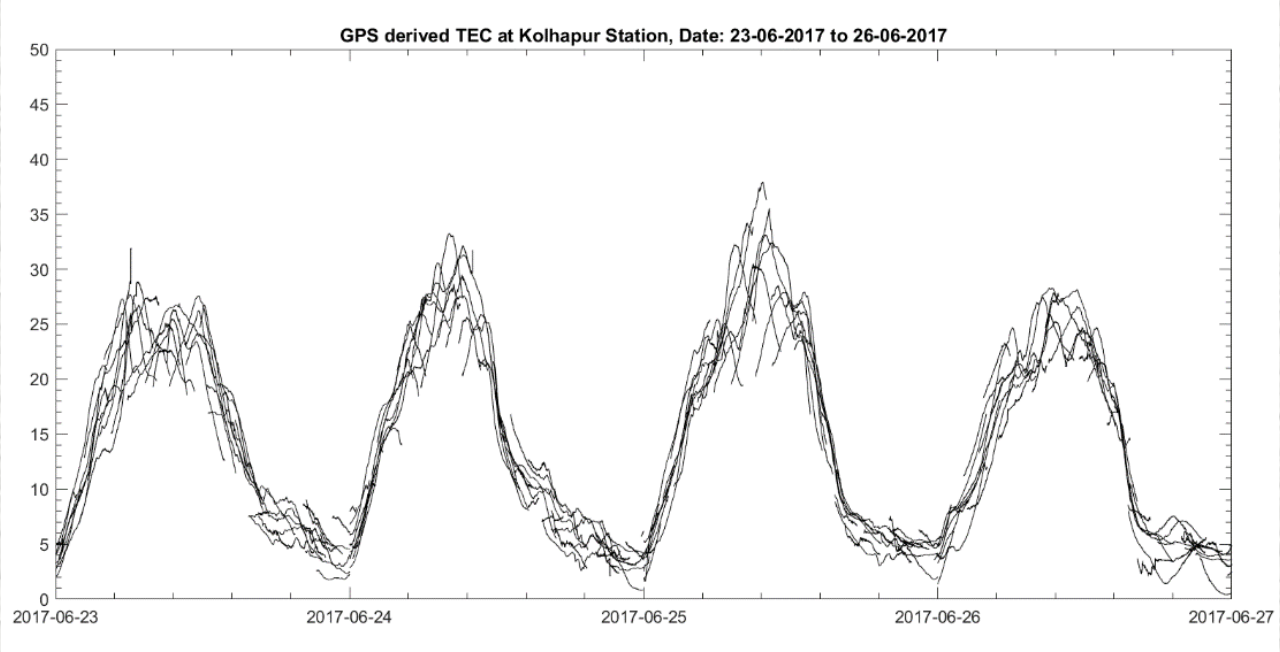



Fig : GPS derived TEC variation at Kolhapur station during summer (4 days of June 2017)

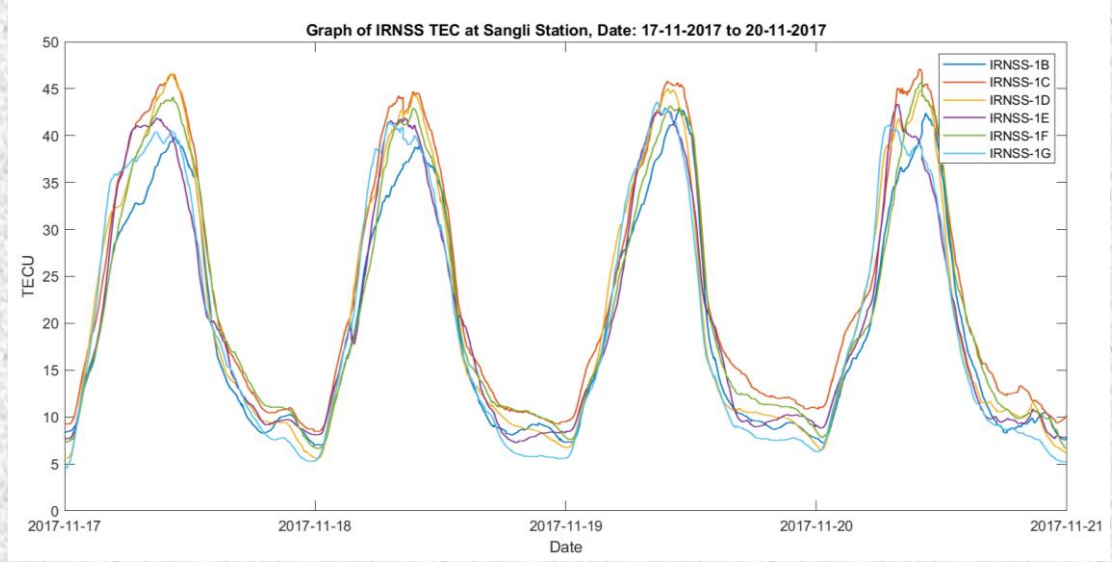



Fig : IRNSS derived TEC variation at Sangli station during winter (4 days of November 2017)

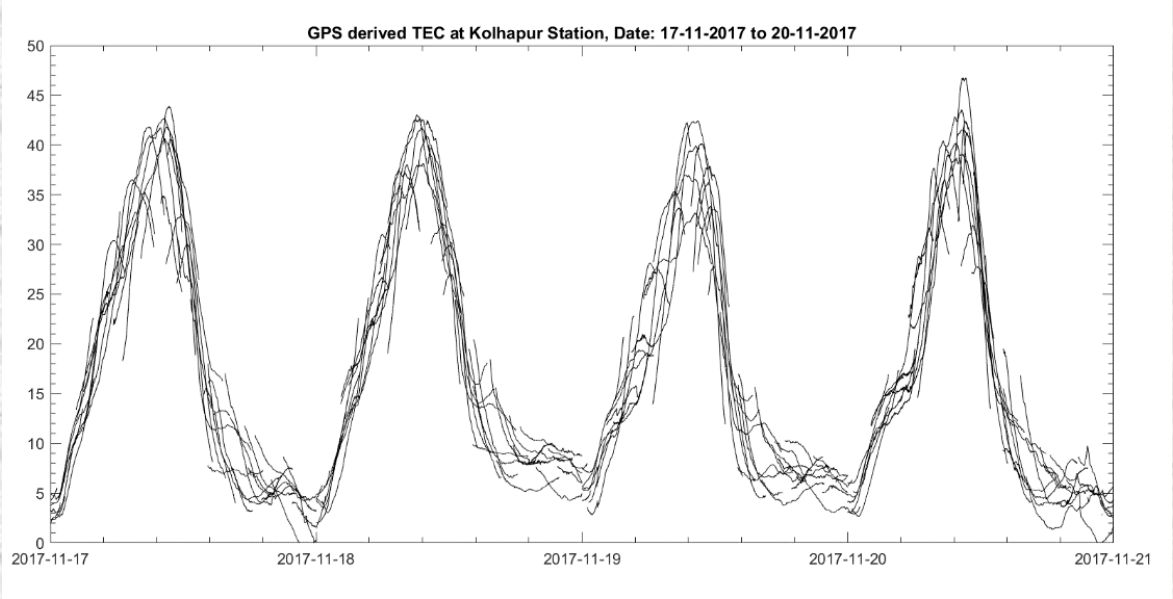



Fig : GPS derived TEC variation at Kolhapur station during winter (4 days of November 2017)

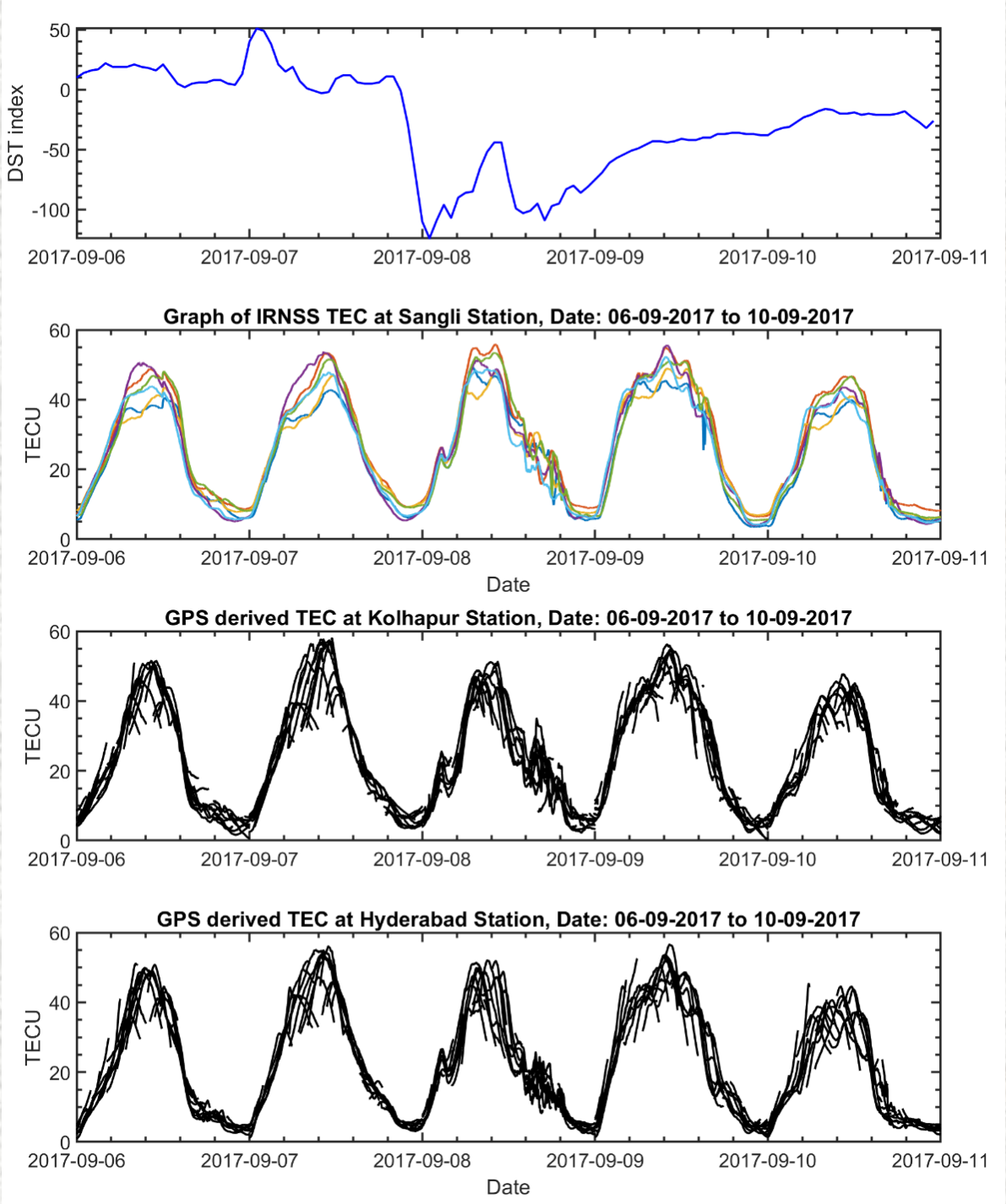
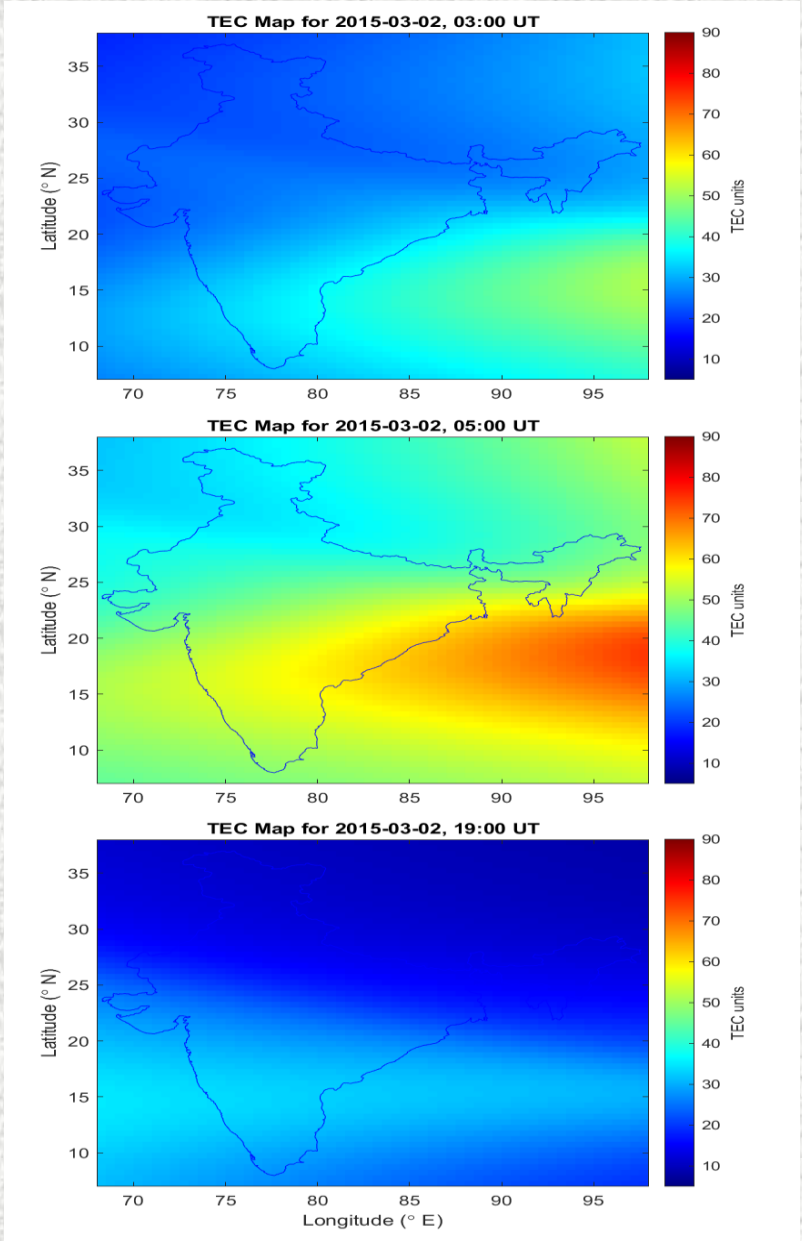
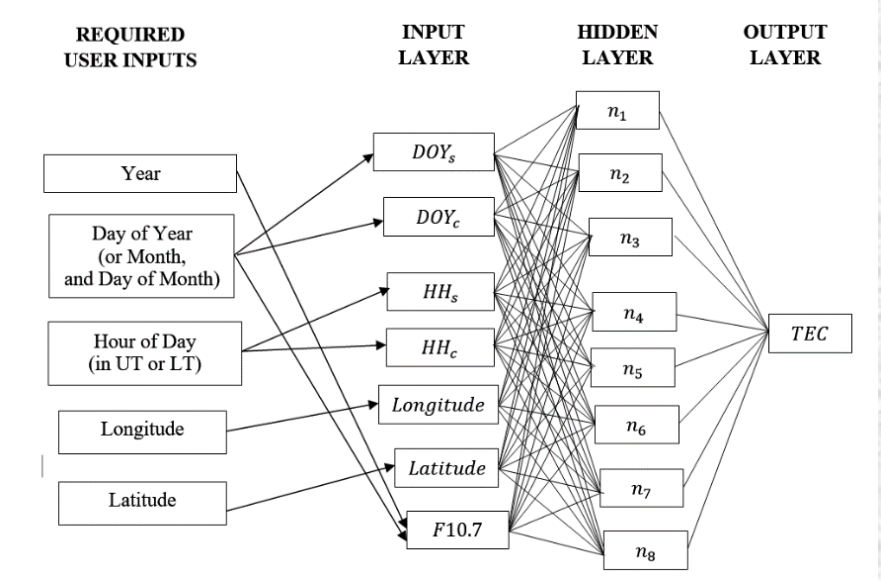



Fig : *Response of IRNSS TEC (panel b), GPS TEC (panels c & d) to the September geomagnetic storm event as shown in Dst variation in panel (a). The panels b, c, d represent the TEC variation of IRNSS at Sangli, GPS at Kolhapur and Hyderabad*

# Ionospheric Variability in TEC and generate TEC map over Indian region



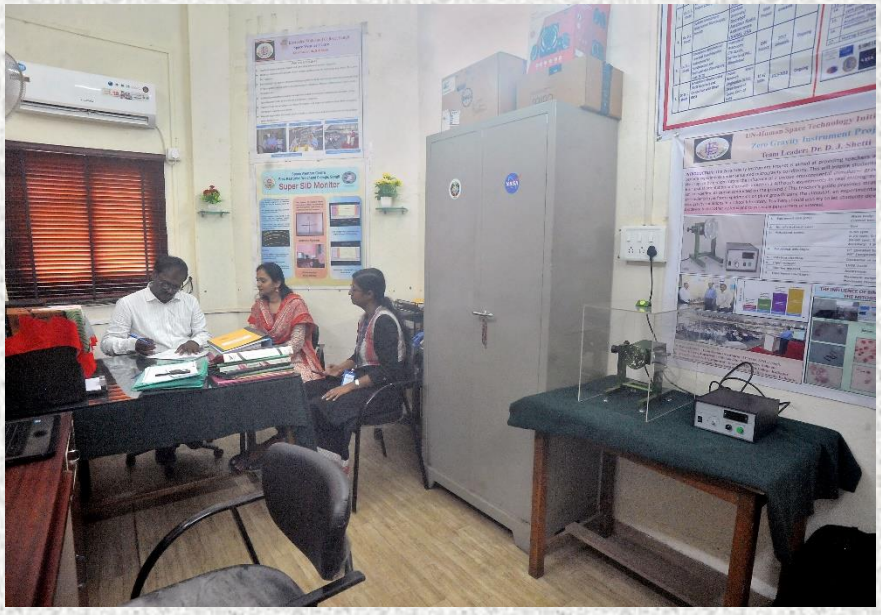

*Graphical Representation of Artificial Neural Network used in developing the Indian TEC Map using GAGAN data (*Dr. Gopi Seemala, IIG, Mumbai)
*).*

# Conclusions

- TEC derived from IRNSS at Sangli (16.861 N, 74.577 E) was compared with the GPS derived TEC from Kolhapur (16.677, 74.255 E; about 40 km from Sangli) and also from GPS - TEC from Hyderabad (17.417 N, 78.550 E) during a geomagnetic storm event. TEC derived from both systems IRNSS and GPS show the similar diurnal pattern.

- The TEC derived from IRNSS can be relatively accurate than GPS once the bias corrections are correctly applied.

# DECU-SAC, ISRO team visit for 'Impact Assessment of SAC RESPOND Projects at Academic Institutions'



# Acknowledgements:


- We thank SAC-ISRO for providing us IRNSS receiver.

- We also thank ISRO for sanctioning this ISRO Respond Project.

- We extend our thanks to Dr. Dr. Gopi Seemala form IIG Mumbai for providing GPS-TEC software.


Thank You