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

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

\[ = 9.509 \times 10^{16} \Delta P_{1,2} \]

Differential phase advance STEC

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

\[ = 9.509 \times 10^{16} \Delta L_{1,2} \]

Slant TEC to Vertical TEC

\[ TEC = slant \, TEC \times map \]

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

\[ \text{h}_{sp} - \text{height of the ionospheric pierce point} \]

\[ R_E - \text{Radius of the Earth} \]

\[ \Delta P_{1,2} = P_1 - P_2 \] where P1 and P2 are pseudo ranges on L1 and L2 respectively.

\[ \Delta L_{1,2} = \Phi_1 - \Phi_2 \] where \( \Phi_1 \) and \( \Phi_2 \) are phase measurements on L1 and L2 respectively.

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 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

ISB
MAX 94.61, MIN 67.83, AVG 82.85
A57 SANGLI: IRNSS L5 C/No (dBHz) Duration: 09/07/2017, 05:29:42 to 16/07/2017, 05:29:41 (IST)

IRNSS1A: MAX 52.3, MIN 44.8, AVG 49.3
IRNSS1B: MAX 51.8, MIN 45.3, AVG 49.1
IRNSS1C: MAX 52.7, MIN 49.7, AVG 51.3
IRNSS1D: MAX 50.8, MIN 43.7, AVG 48.2
IRNSS1E: MAX 51.1, MIN 43.8, AVG 48.2
IRNSS1F: MAX 49.0, MIN 45.4, AVG 47.4
IRNSS1G: MAX 47.9, MIN 28.2, AVG 46.0
A57 SANGLI : IRNSS S C/No (dBHz) Duration: 09/07/2017, 05:29:42 to 16/07/2017, 05:29:41 (IST)

IRNSS1A  IRNSS1B  IRNSS1C  IRNSS1D  IRNSS1E  IRNSS1F  IRNSS1G
MAX 46.7  MAX 46.7  MAX 47.2  MAX 45.1  MAX 44.7  MAX 45.1  MAX 42.9
MIN 40.7  MIN 40.6  MIN 43.6  MIN 39.2  MIN 37.9  MIN 40.9  MIN 25.7
AVG 44.3  AVG 44.2  AVG 45.5  AVG 42.1  AVG 41.8  AVG 43.4  AVG 39.9

C/No (in dB-Hz)

Time (HH:MM)

25 30 35 40 45 50 55 60


25 30 35 40 45 50 55 60

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)
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) vs Time (HH:MM)
A57 SANGLI : S Band Iono Delay Duration: 09/07/2017, 05:29:42 to 16/07/2017, 05:29:41 (IST)
• Absolute TEC derivation from IRNSS (code developed):

\[
\text{TECgroup} = (P1-P2) \times 4.4191
\]

\[
\text{TECphase} = (C1 - C2) \times 4.4191
\]

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 asterisks 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.
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Thank You