Study on the structure and the dynamics of equatorial plasma bubbles using geostationary satellites.

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Abstract

The ionospheric scintillations in radio signals at equatorial regions are essentially caused by the ionospheric plasma density irregularities of centimeters to hundreds of kilometers of scale sizes. The analysis of scintillation patterns, based on satellite spaced- receiver technique, is well accepted methodology to estimate the zonal drift velocity of ionospheric irregularities. Three GNSS receivers installed as part of InSWIM program at a distance of 40 m and 60 m respectively at Trivandrum continuously monitor scintillations. Irregularity movements are caused by the zonal component of the neutral wind and the electric fields. Power spectra and time lag obtained from correlation analyses determine characteristic features of irregularities. Systematic analysis for longer periods helps in a better understanding of irregularity structures over the Indian equatorial and low latitude regions.

Introduction

- Outstanding phenomena of Equatorial Ionosphere is the generation of plasma density irregularities whose presence is observed during nights.
- Radio signal fluctuates while passing through small scale irregularities which act as diffraction grating
- Scintillations causes data loss and sometimes even loss of phase lock.

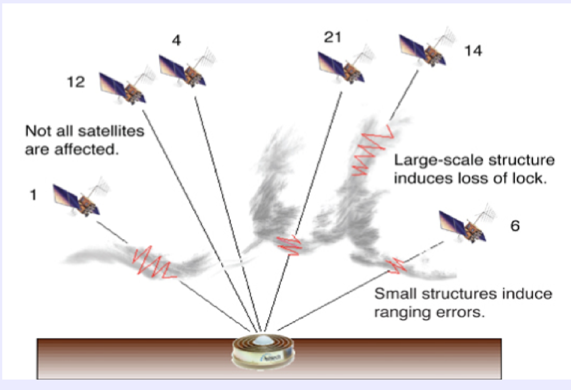


Figure: 1. Ionospheric scintillations

Objectives

- Understand irregularity structures over Indian equatorial region using spaced receiver techniques.
- To perform correlation and power spectrum analyses.
- To study detailed characteristics of equatorial scintillations and the variabilities in irregularity motion causing them.
  - Calculate irregularity parameters and spectral parameters.
  - To estimate drift velocity.
- To understand seasonal patterns in the thermospheric winds.

Data & Methodology

- As part of InSWIM program, three GNSS receivers are installed along the east-west direction at a distance of 40 m and 60 m respectively at Trivandrum (8.4^o N and 76.9^o E).
- They continuously monitor L1 and L5 scintillations of the SBAS satellites (GSAT 8 - PRN 127 and GSAT 10 - PRN 128).

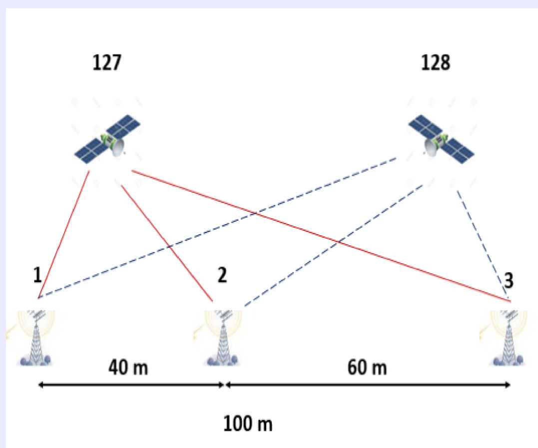


Figure: 2. Alignment of receivers

Geostationary satellites are free from uncertainties imparted due to apparent drift of satellites thus collecting valuble irregularity information.

- The correlation analysis of the scintillation signals received at the three receivers gives the time lag (j) between the signals
- This is used to obtain the eastward drift (ν) of the irregularities, given by

$$\nu = \frac{d}{j/\omega}$$

where 'd' is the distance between receivers and 'ω' is sampling frequency.

- This is one of the most inexpensive methods to study F-region irregularities.
- Power spectrum analysis is performed to obtain spectral parameters such as slope and roll-off frequency and understand the characteristic features of irregularities.
- Scale size of the irregularities are obtained by dividing the drift velocities with the roll-off frequency from the power spectra.

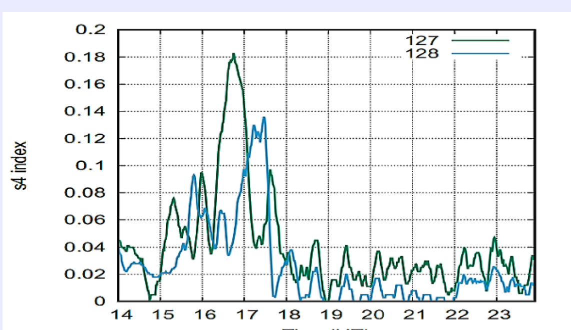


Figure: 3. S4 index

* Scintillation index (S4), Correlation and Power spectrum analyses are all done for 60 seconds of data.

Results and Discussions

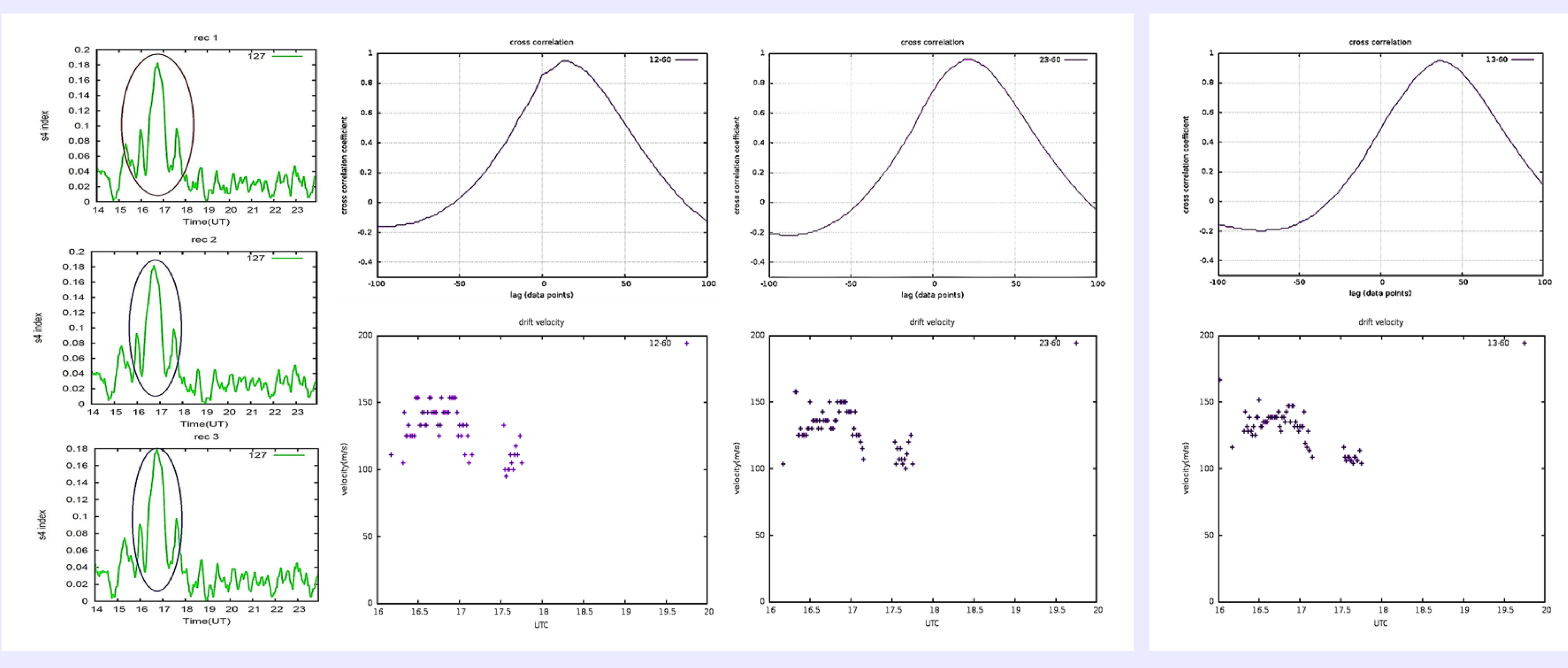


Figure: 4. Drift Velocity estimation for one night using three receivers

- Spectral slopes from power spectral studies yield information on relative contribution of range of different scale sizes involved in signal scattering.
- The received signals when analysed for correlation and power spectra over long time period, yielded a comprehensive understanding of the irregularity structures over the Indian equatorial and low latitude regions.
- Drift velocity and irregularity scale size estimation are carried out only when cross correlation index is above 0.7.

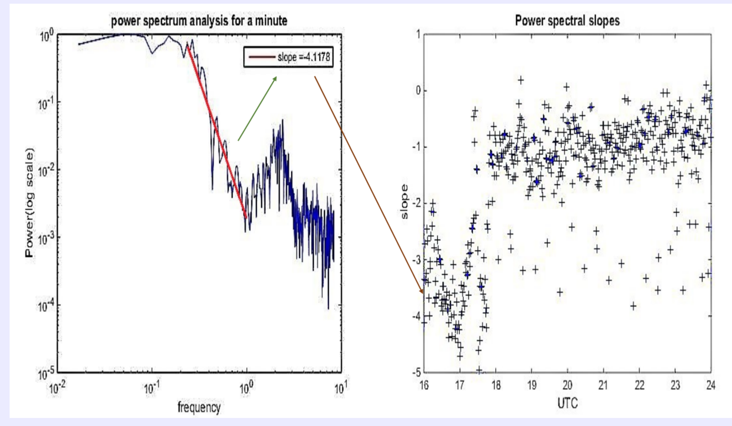


Figure: 5. Power Spectra

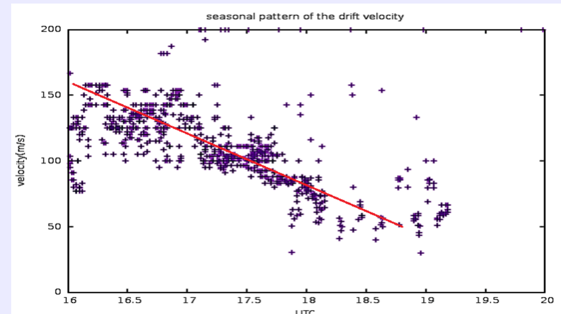


Figure: 6. Drift Velocity for a season

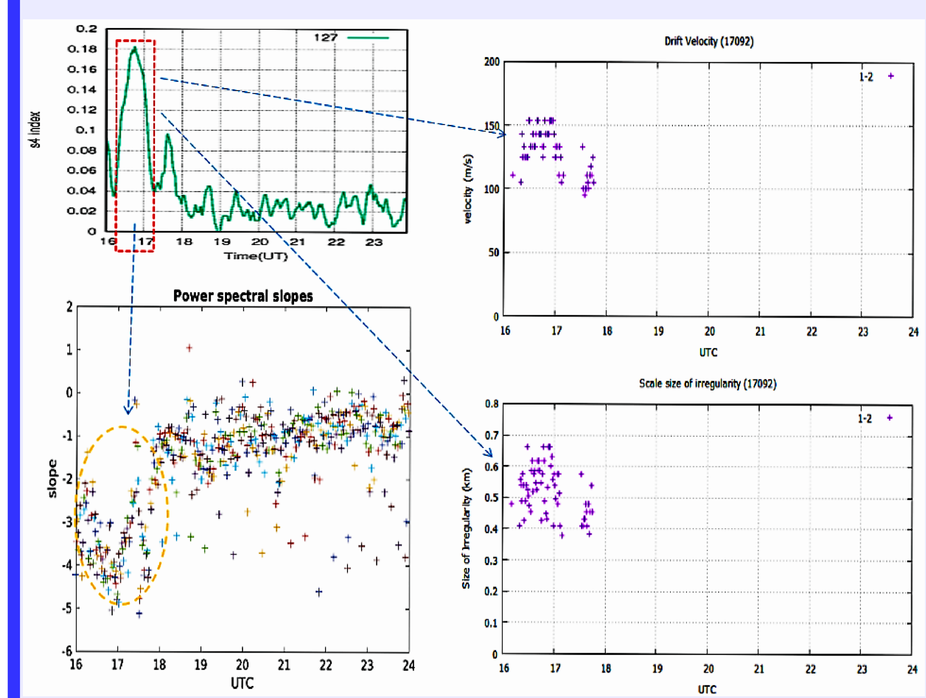
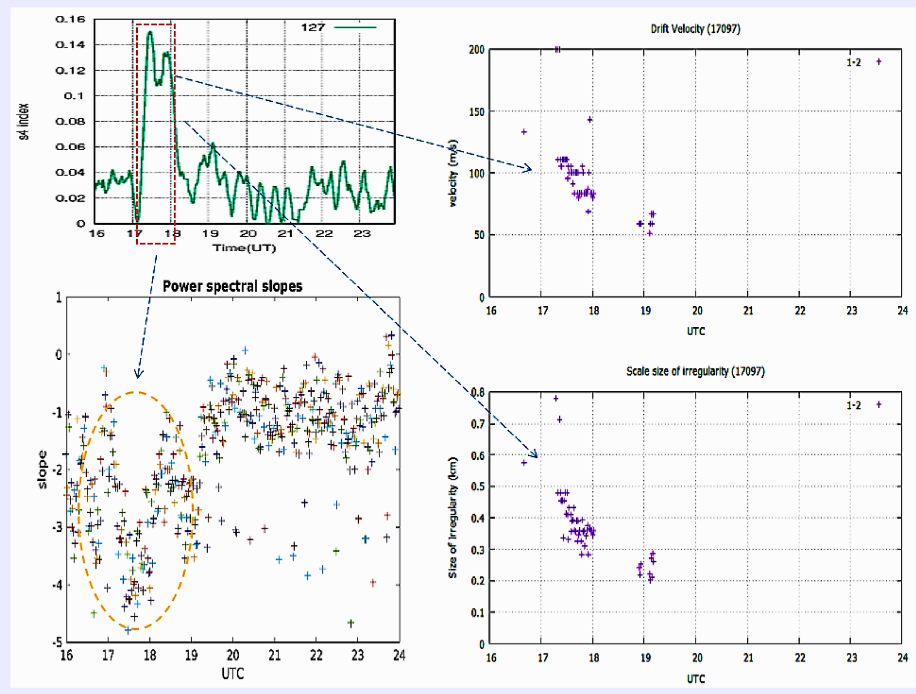


Figure: 7. 17092



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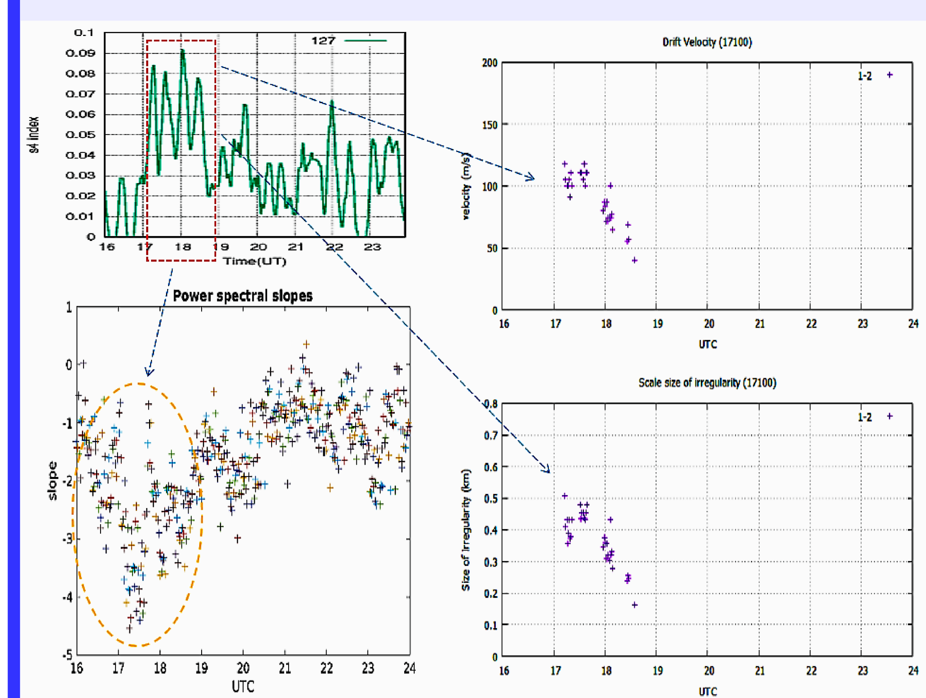

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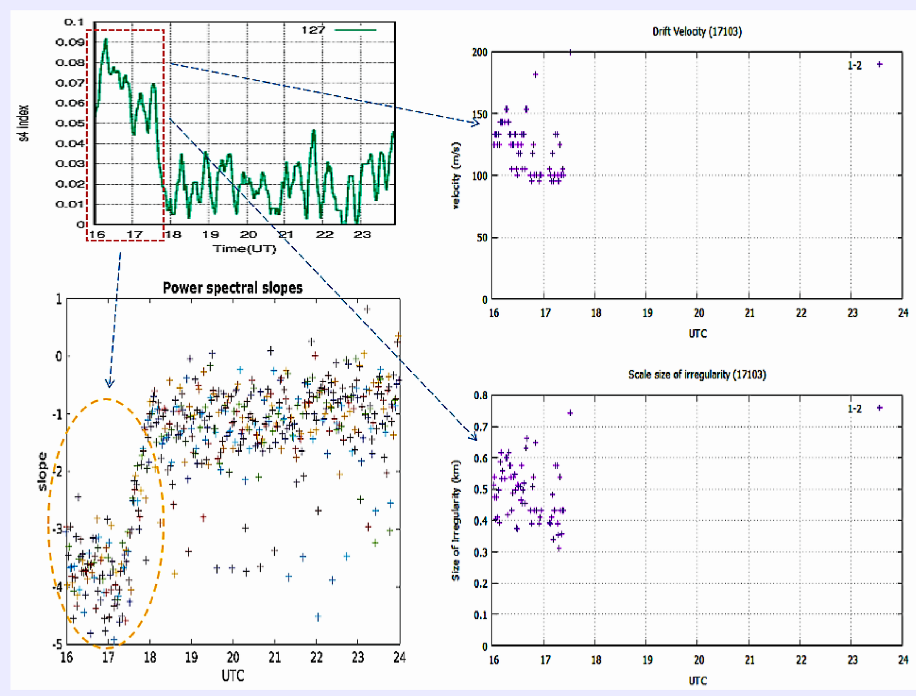

Figure: 10. 17103

Conclusions

- The cross correlation analysis has given us considerable time lag between receivers.
- The drift velocities calculated were in the order of **60m/s to 150 m/s** during the scintillation activity.
- The analysis when done over a long time indicates reduction in the drift velocity pattern as irregularities evolved in time.
- Higher the scintillation activity, steeper is the slope obtained from power spectra.
- The scale size of the irregularities was found to be in order of **400m to 500m**.

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