Relation of multi-frequency GNSS signal scattering with equatorial ionospheric irregularity dynamics at VHF

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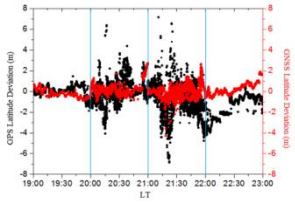
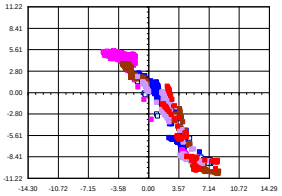
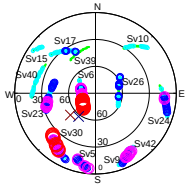
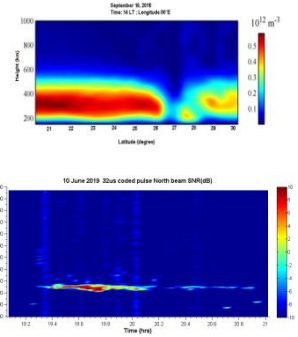
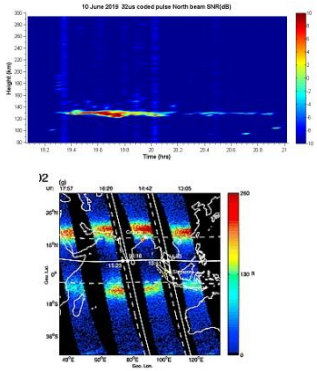










BSS 2019, Olsztyn, August 22, 2019

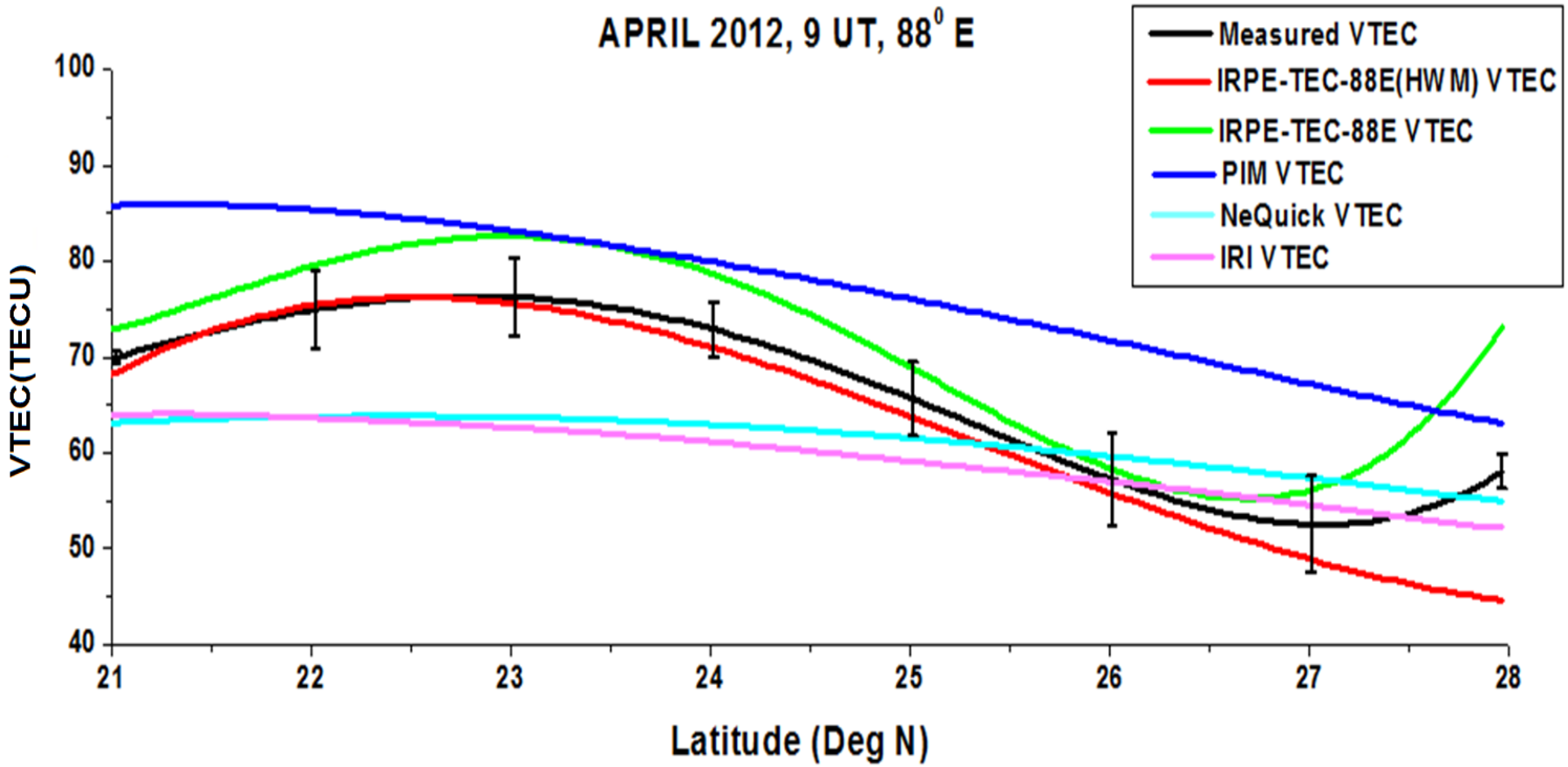
- There is increased interest in the ionosphere from the perspective of satellite-based communication, navigation and other links which operate through it

- GPS, GLONASS, Galileo and Beidou operating at L-band offer simultaneous access to nearly 60-70 satellite links presently

- Signal fading at L-band associated with intersection of such satellite links with ionospheric irregularities may severely compromise the performance of such systems

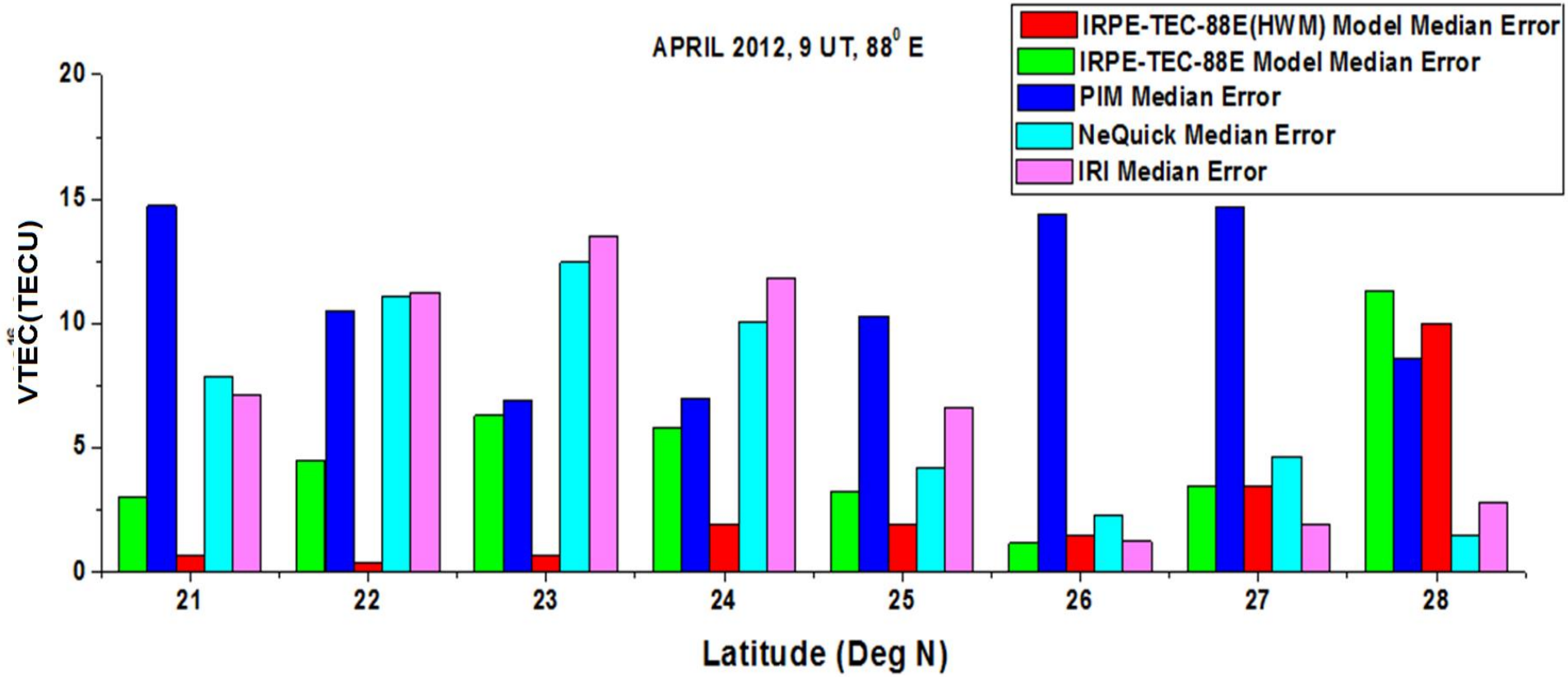
- Relatively simple and inexpensive VHF satellite beacons may effectively be used as proxy indicators of L-band signal deterioration

LATITUDINAL TEC VARIATION FROM DIFFERENT MODELS FOR APRIL 2012



Sur et. al., J. Geophys. Res., Space Physics, 120, 2015

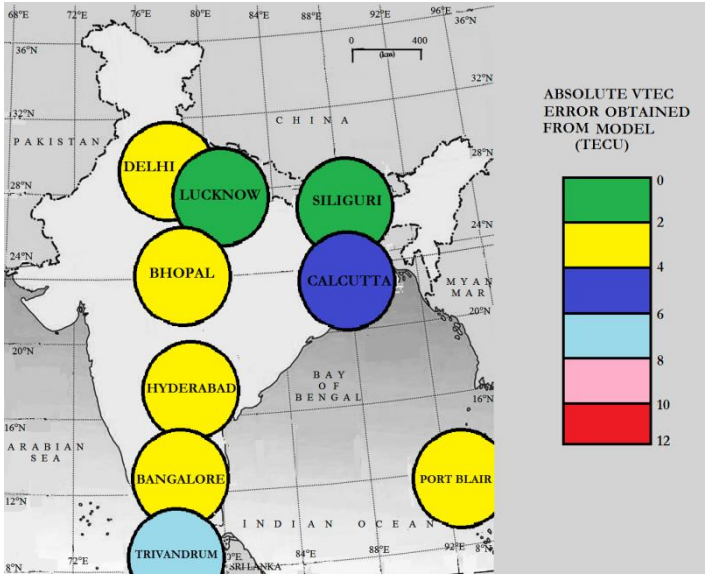
LATITUDINAL MEDIAN TEC ERROR OBTAINED FROM DIFFERENT MODELS FOR APRIL 2012



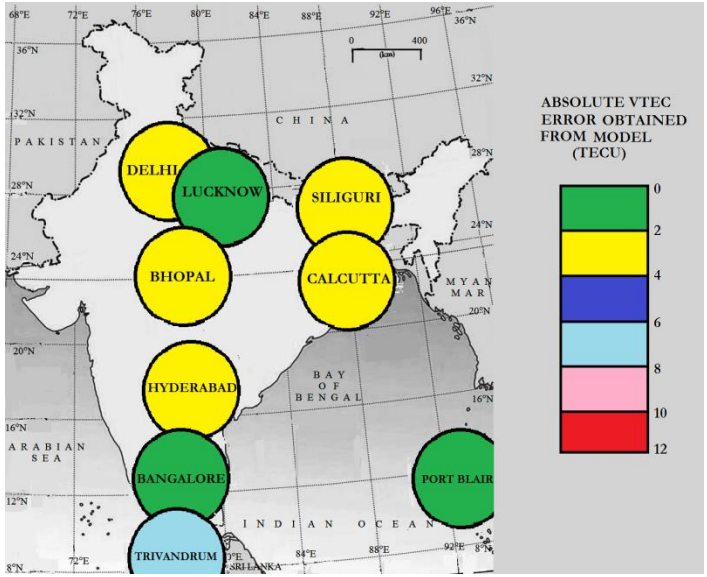
Sur et. al., J. Geophys. Res., Space Physics, 120, 2015

ABSOLUTE ERRORS IN MODEL VTEC

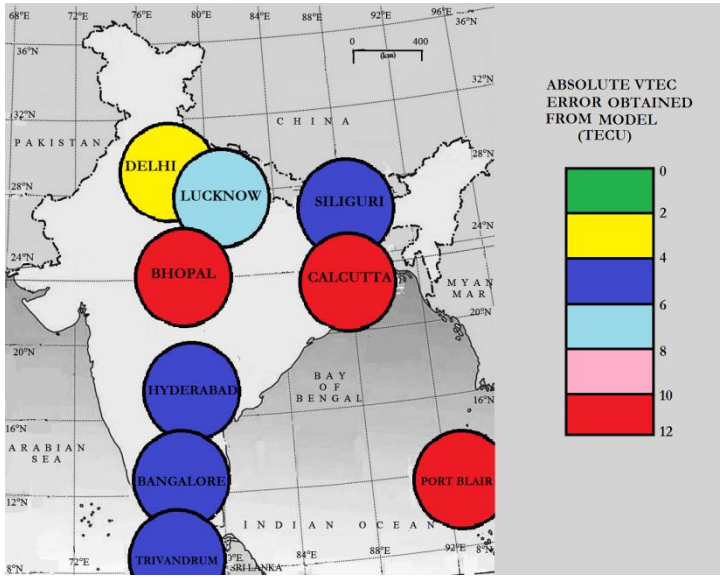
00LT



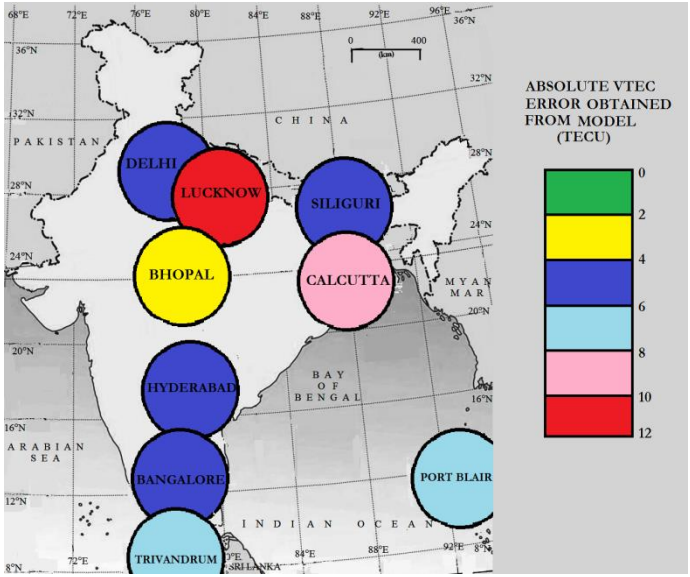
06LT



12LT



18LT



Institute of Radio Physics and Electronics, University of Calcutta operates dual-frequency GPS receiver and a VHF receiver under **Scintillation Network Decision Aid** (SCINDA) program of US Air Force Research Laboratory

The USRP VHF receiver is capable of receiving signals at 240 MHz from geostationary **FLEETSATCOM** (Fleet Satellite Communication or FSC) (350 Km subionospheric point: 21.10°N, 87.25°E, magnetic dip 28.65°N) from two antennas aligned along magnetic east-west direction.

SCINDA (SCIntillation Network Decision Aid) station of the US Air Force since November 2006 at the Institute of Radio Physics and Electronics, University of Calcutta, Calcutta

Global distribution of SCINDA stations

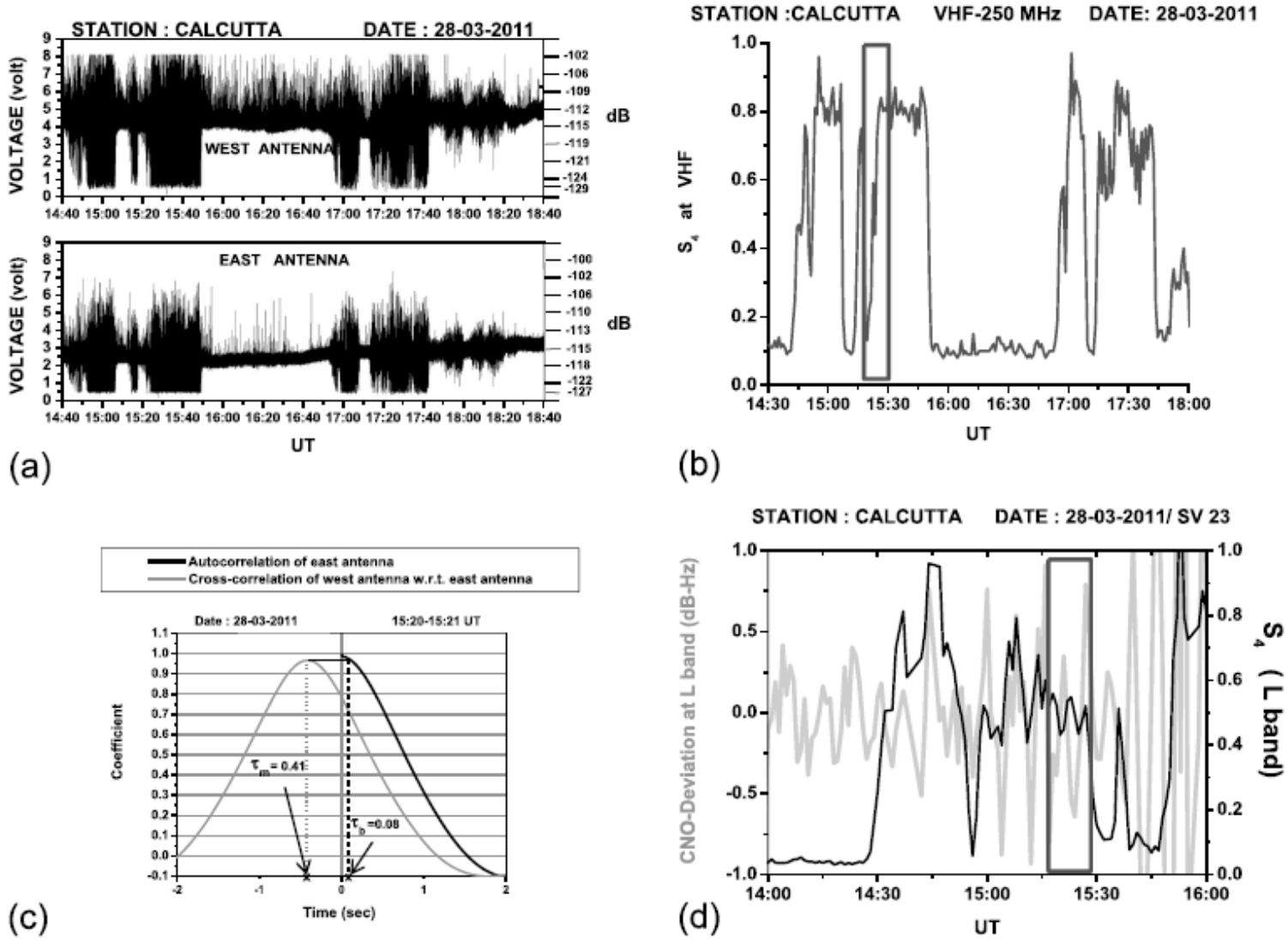
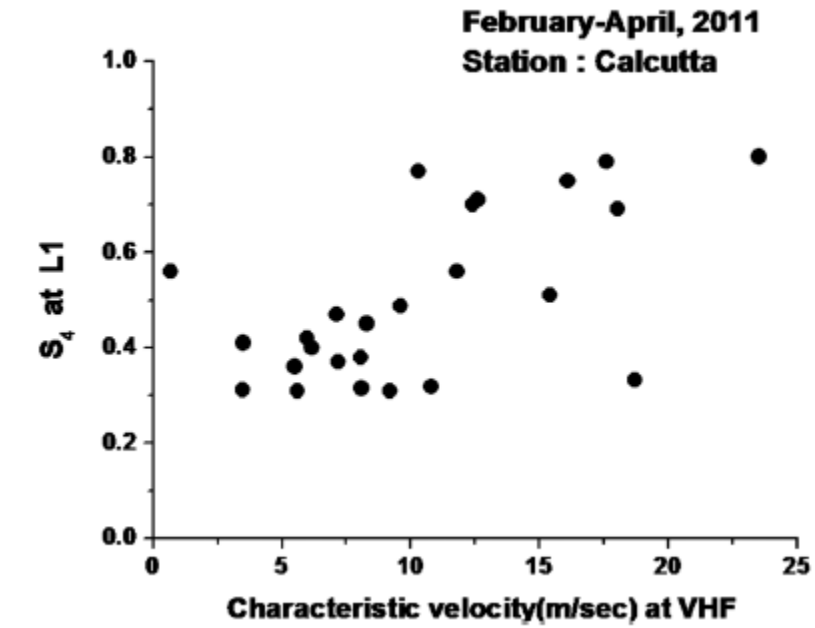
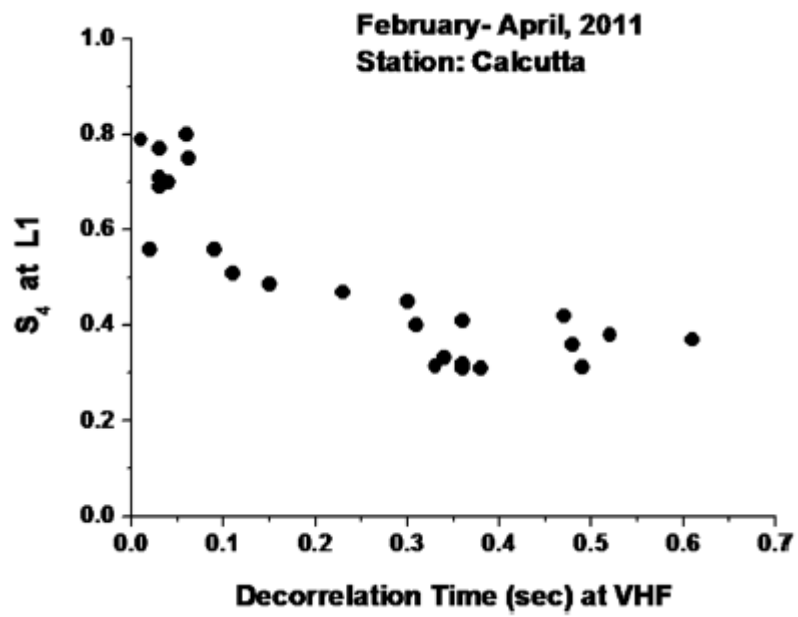
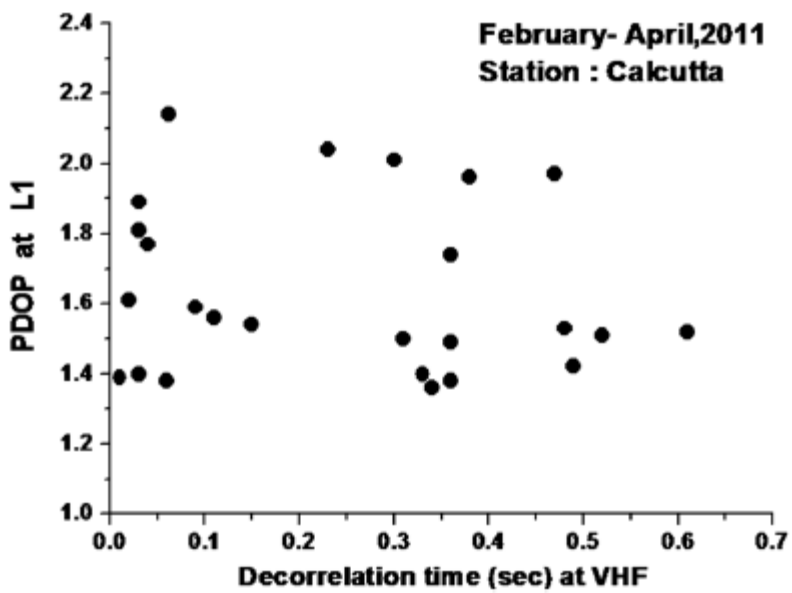


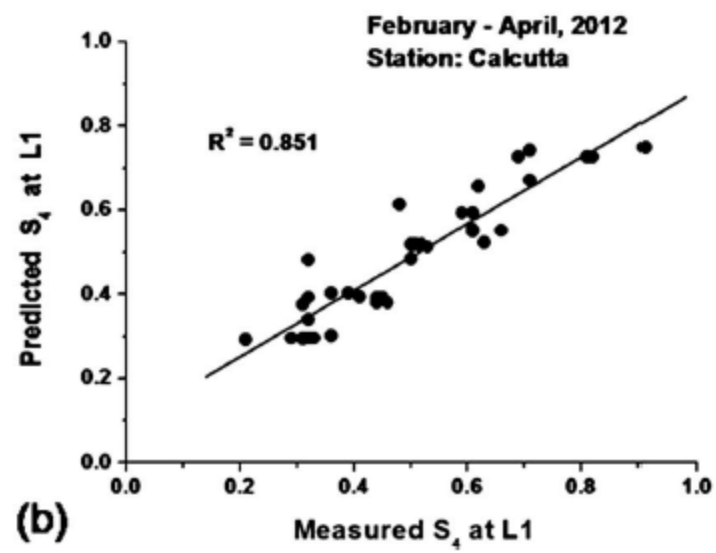
Figure 1. (a) Sample of VHF amplitude scintillations observed on the geostationary FSC link on two antennas aligned along geomagnetic east-west direction during 14:40–18:40 UT on 28 March 2011 at Calcutta. (b) Plot of S_4 index at VHF from FSC on 28 March 2011. (c) Plots of autocorrelation of the east antenna signal and cross correlation of the west antenna signal with respect to the east antenna signal during 15:20-15:21 UT. The values of τ_m and τ_p are indicated in the figure. (d) Corresponding variation of GPS SV23 S_4 index on 28 March 2011.

Das et al., Radio Sci., 2014

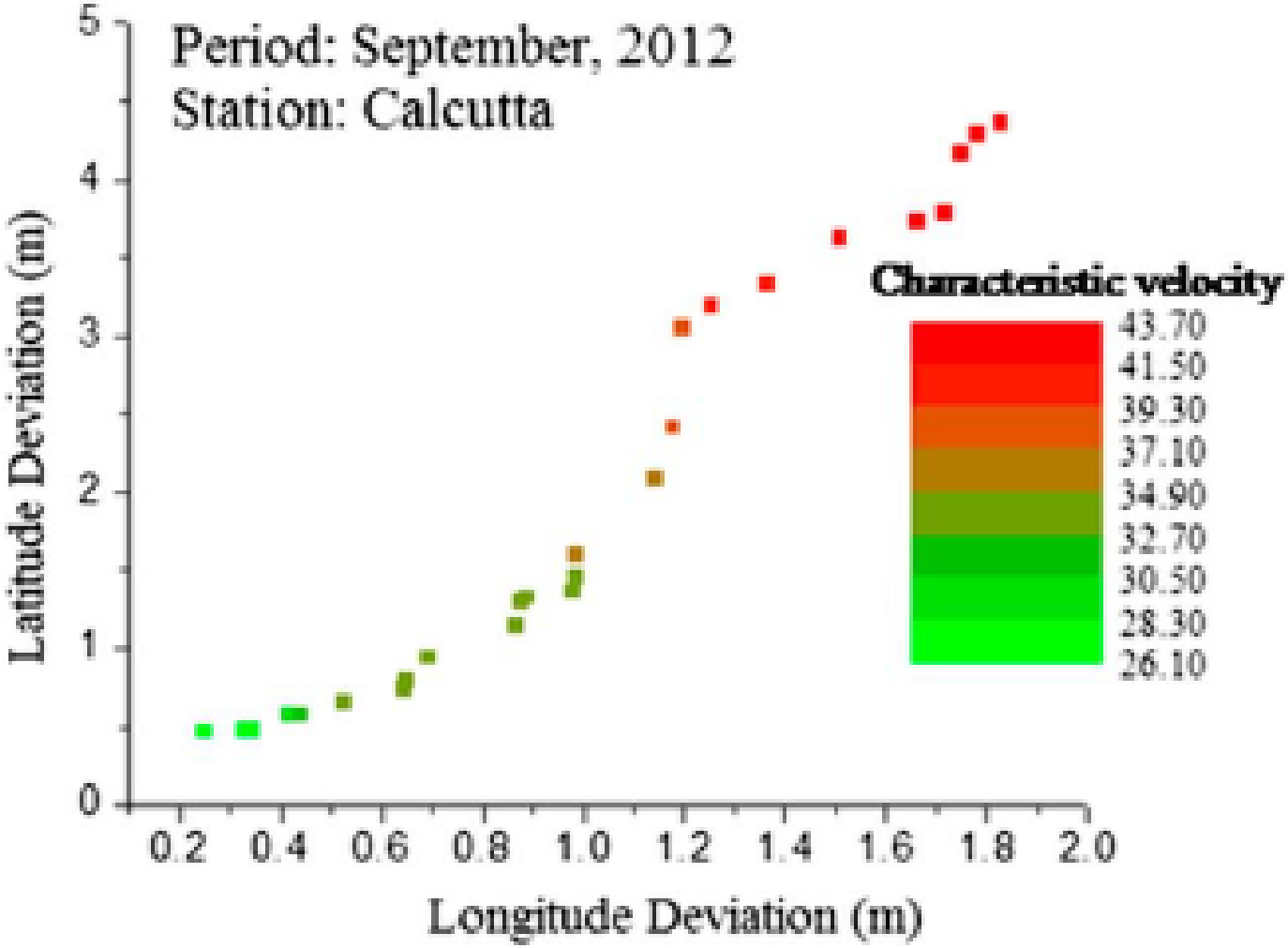








Das et al., Radio Sci., 2014



Paul and Paul, Radio Sci., 2017

VHF Data used for Analyses

- The receiver generates files for two channels from two corresponding antennas.
- Each of these files gives the power of the received signal in dB, the S_4 value and the time in UTC (Universal time).
- Each of these files is processed to generate values of decorrelation time and the zonal drift velocity for the days when S_4>0.2.
- **The data are analyzed for October 2015.**

Analyses of L-band Data

- The GPS data used are obtained from the dual frequency GPS receiver which provides at its output time in UTC, azimuth, elevation, carrier-to-noise ratio (CNO) at sampling rate of 50Hz and scintillation index (S_4) and TEC at a sampling interval of one minute.

- To observe any difference in amplitude scintillations at L1 and L2 frequencies, ***correlations*** were measured between C/N_0 deviations recorded at the two frequencies for samples of amplitude scintillations of 3 minute interval for $S_4 \geq 0.2$.

- A simple yet convenient mathematical formulation for quantifying the decorrelation of a pair of GPS signals has been used which is named as ***scattering coefficient*** [Goswami et al., 2017]. In order to understand the impact of different nature of scattering of transionospheric satellite signals at the dual frequencies, a scattering coefficient (S12) have been defined in the analysis, namely,

$$S12 = \frac{\left[C/N_0 - L1\ deviation\ \sim\ C/N_0 - L2\ deviation\right]}{\left[C/N_0 - L1\ deviation + C/N_0 - L2\ deviation\right]}$$

- The scattering coefficient was estimated for every 3-minute sample of the C/N_0 deviation measurement during a scintillation patch.

- In order to avoid multipath effects, an elevation masking of 15° is done.

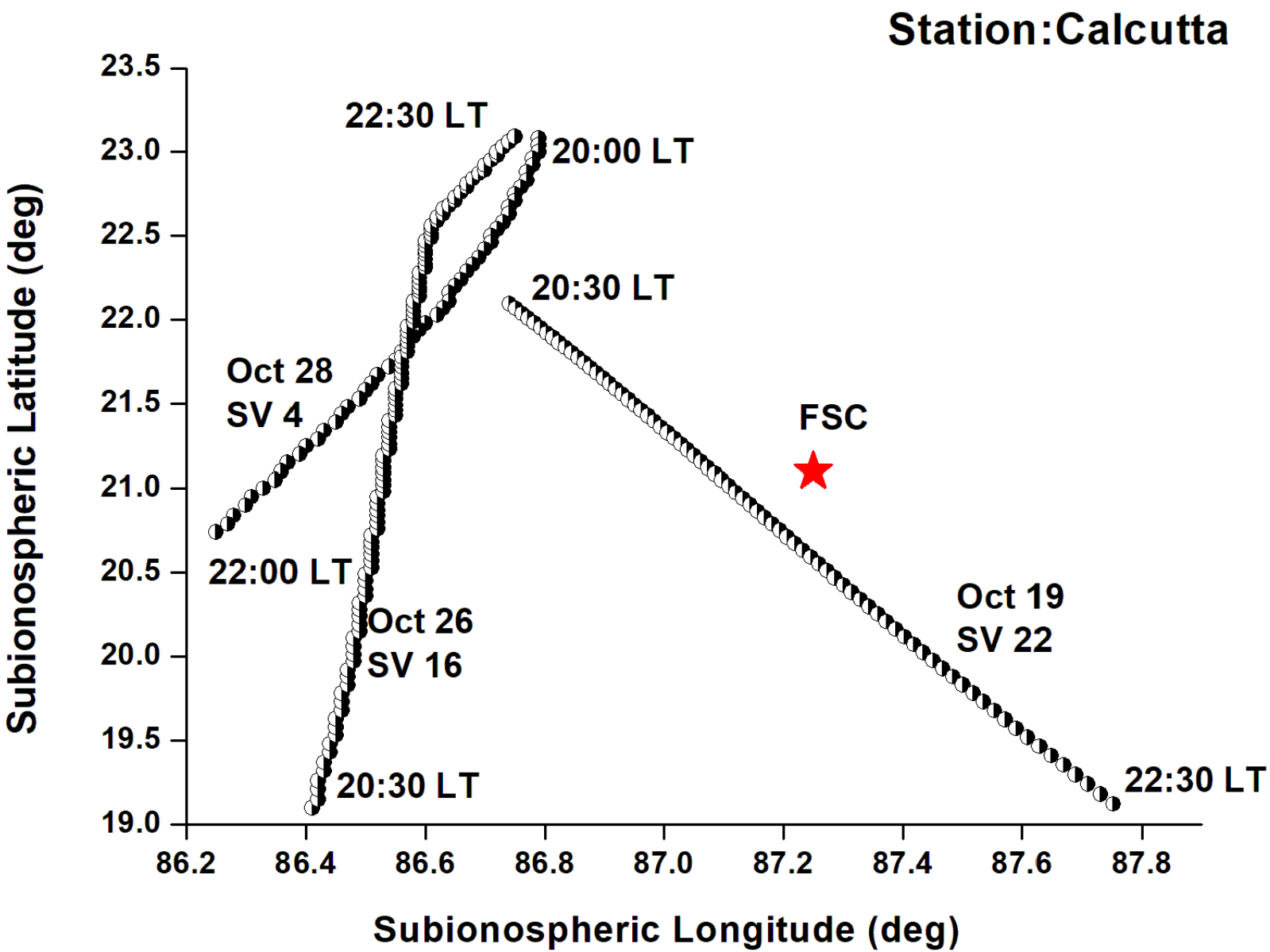
Conditions satisfied for VHF and L-band analyses

- Only those cases have been considered where amplitude scintillations have been observed at VHF and L-band simultaneously.

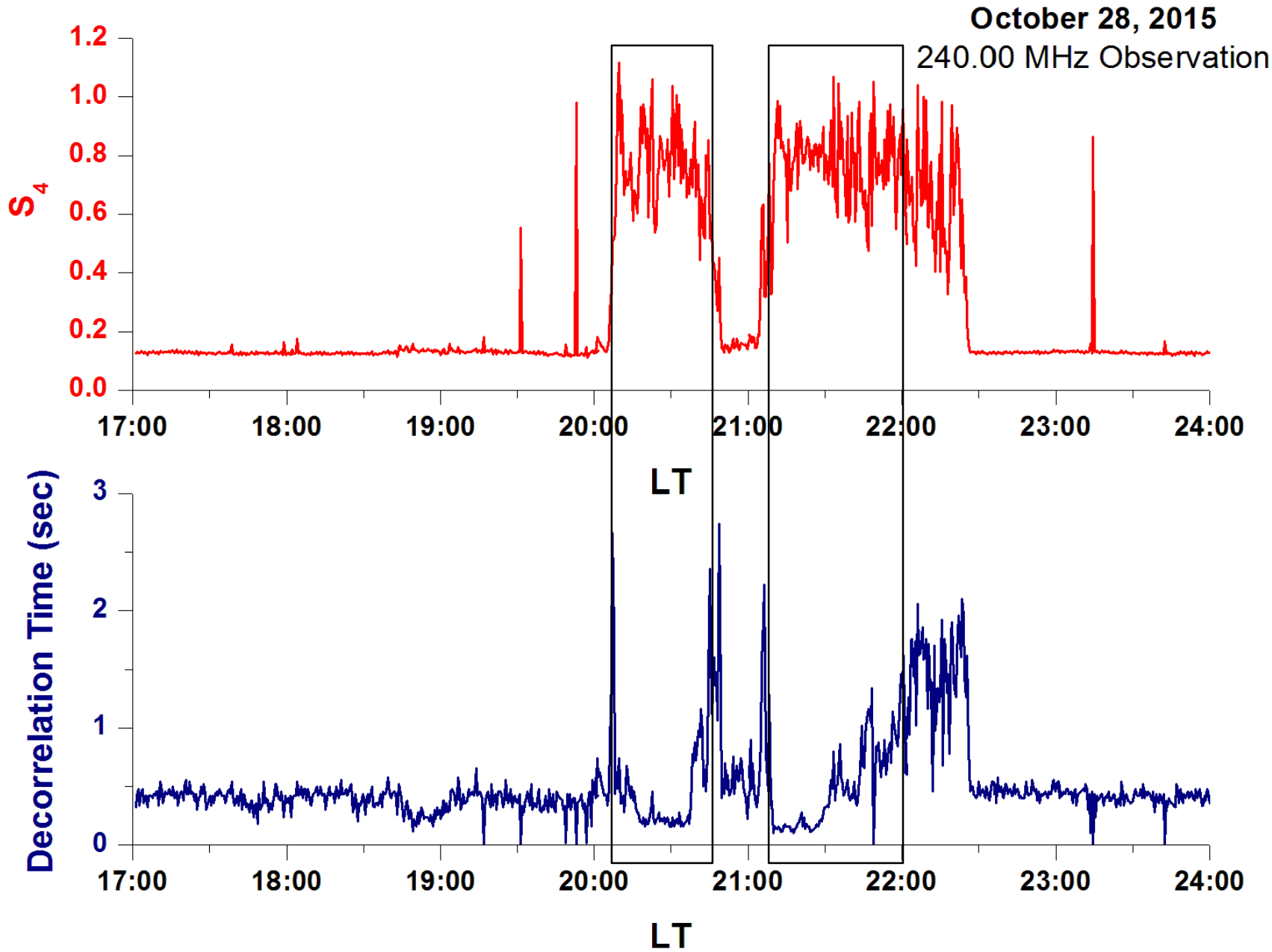
- Estimation of irregularity zonal drift velocities at VHF has been done during 20:00 LT to midnight in order to eliminate any contamination due to the vertical movement of the structure during the early phase of irregularity generation [Kudeki and Bhattacharyya, 1999].

- For this analysis, GPS satellites observed from Calcutta with 350 km subionospheric points lying within latitude swath of 19.10°–23.10° and longitude 86.25°–88.25° were selected around that of FSC.

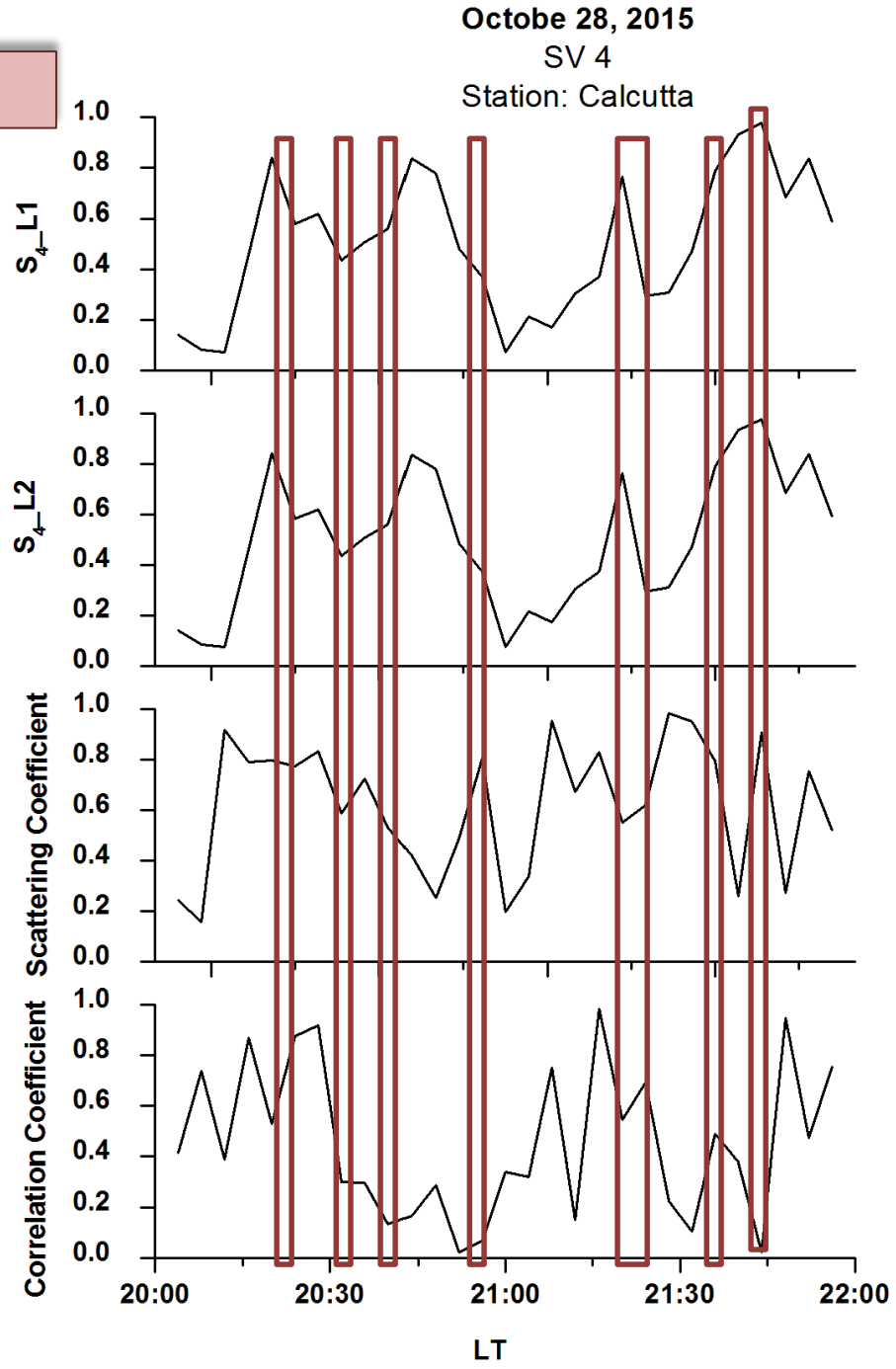
- All of the above analyses were done during geomagnetically quiet times. This has been verified from the Dst values available at **wdc.kugi.kyoto-u.ac.jp/dstdir/** and Kp index values at **www.swpc.noaa.gov**


Station:Calcutta
22:30 LT
20:00 LT
20:30 LT
Oct 28
SV 4
FSC
22:00 LT
Oct 26
SV 16
Oct 19
SV 22
20:30 LT
22:30 LT
23.5
23.0
22.5
22.0
21.5
21.0
20.5
20.0
19.5
19.0
86.2
86.4
86.6
86.8
87.0
87.2
87.4
87.6
87.8
Subionospheric Latitude (deg)
Subionospheric Longitude (deg)

OCTOBER 28, 2015

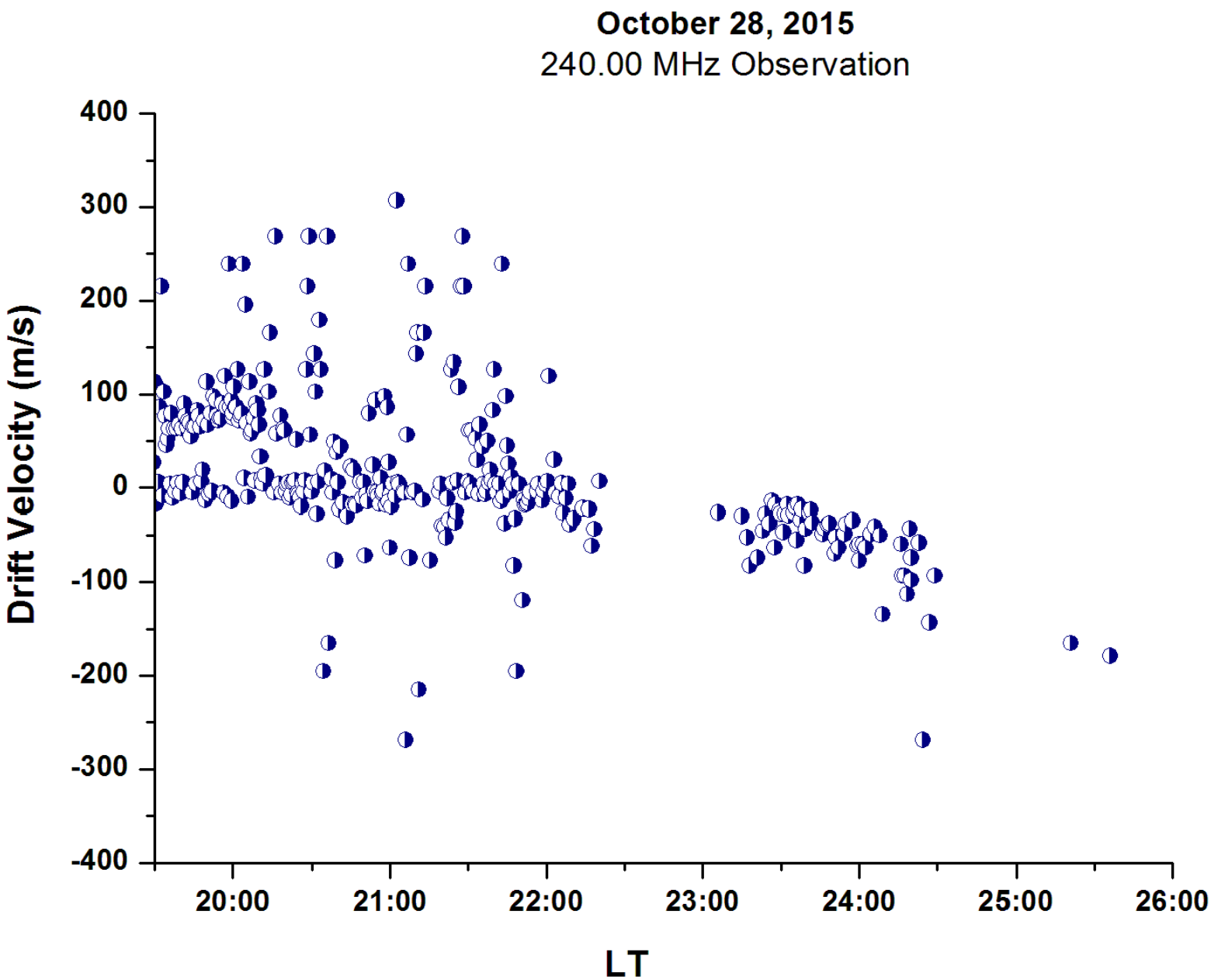

October 28, 2015
240.00 MHz Observation
S_4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
17:00
18:00
19:00
20:00
21:00
22:00
23:00
24:00
LT
Decorrelation Time (sec)
3
2
1
0
17:00
18:00
19:00
20:00
21:00
22:00
23:00
24:00
LT

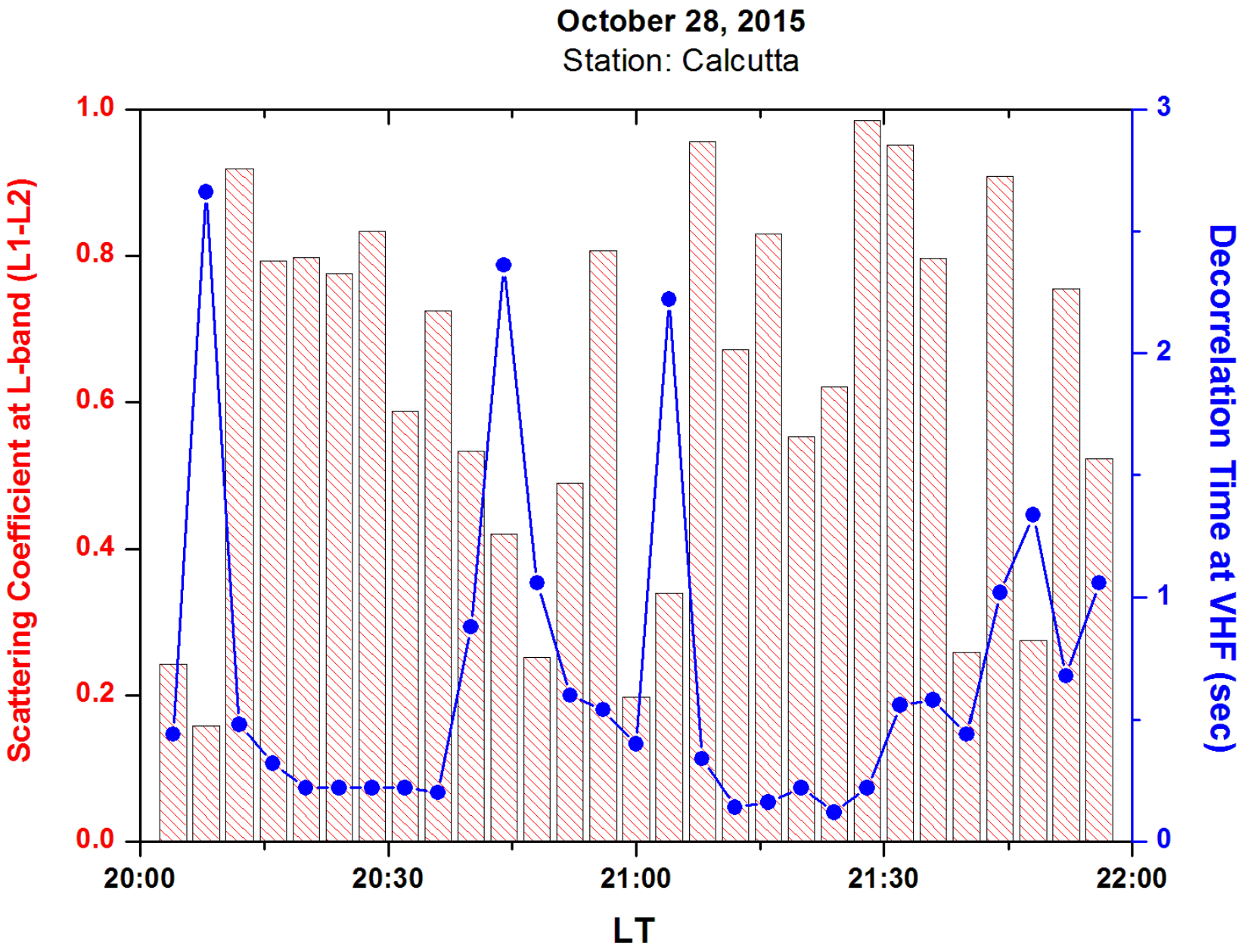
L-band Observation



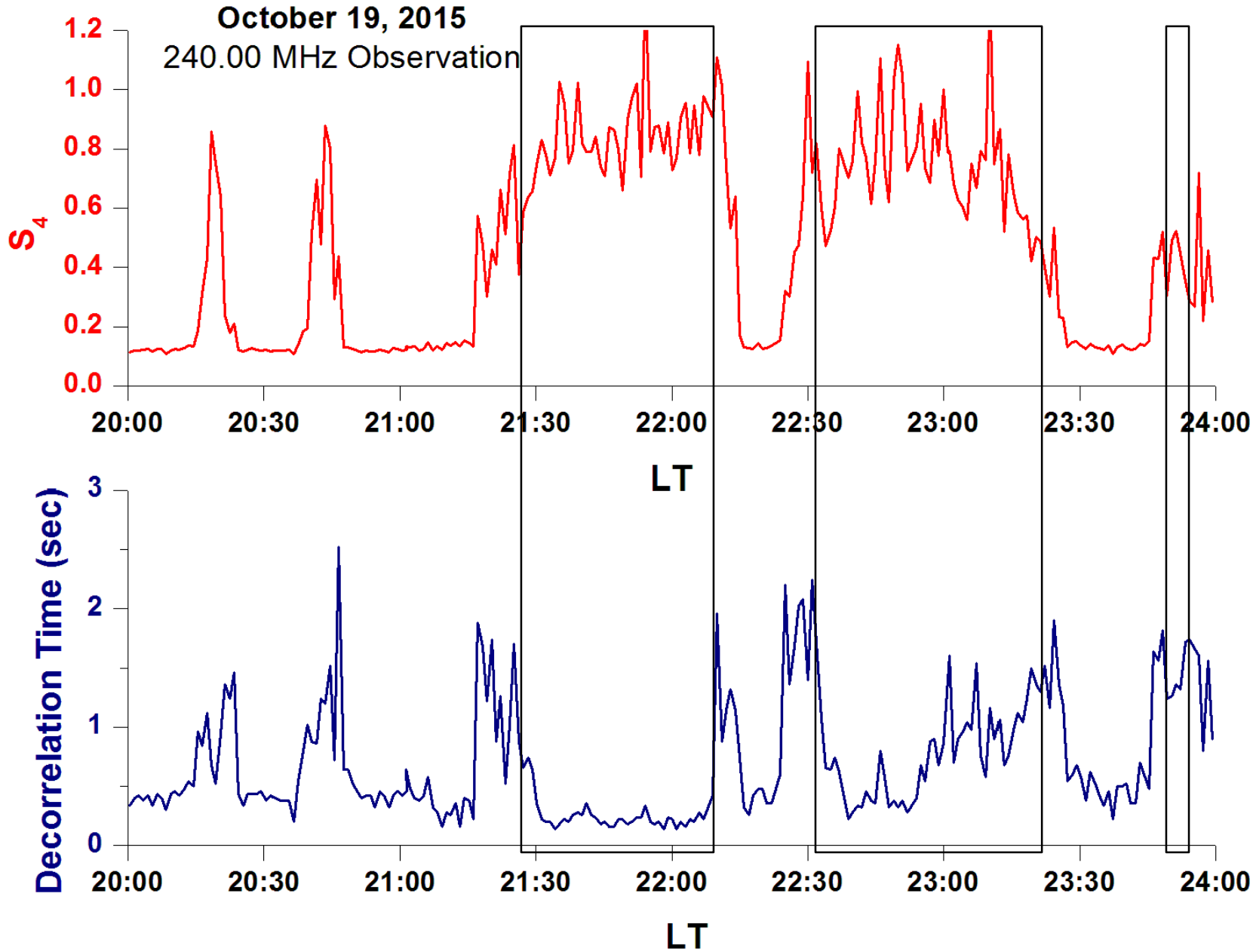
- Out of 112 minutes of observation on L1 and L2 links, 56 minutes of such cases with low correlation coefficient of C/N_0, high values of scattering coefficient and scintillation indices were found on the SV 4 link on October 28, 2015.

- The condition of decorrelated C/N_0 fluctuations associated with high S_4 and high scattering coefficients is found to be valid for 50% of the scintillation patch duration for L1 and L2 frequencies on the SV 4 link.

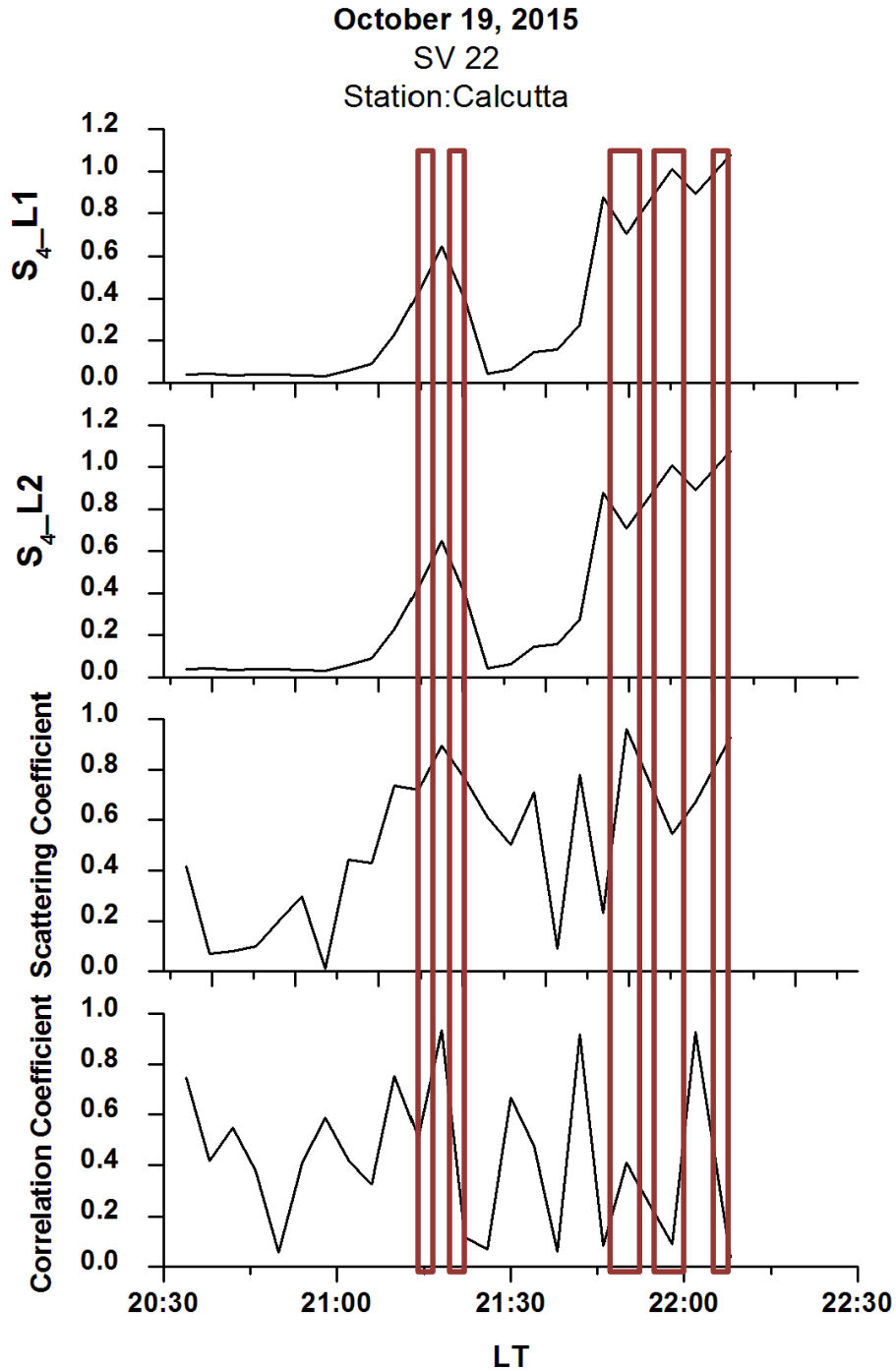

October 28, 2015
240.00 MHz Observation
Drift Velocity (m/s)
400
300
200
100
0
-100
-200
-300
-400
20:00
21:00
22:00
23:00
24:00
25:00
26:00
LT


October 28, 2015
Station: Calcutta
Scattering Coefficient at L-band (L1-L2)
Decorrelation Time at VHF (sec)
LT
1.0
0.8
0.6
0.4
0.2
0.0
3
2
1
0
20:00
20:30
21:00
21:30
22:00

OCTOBER 19, 2015

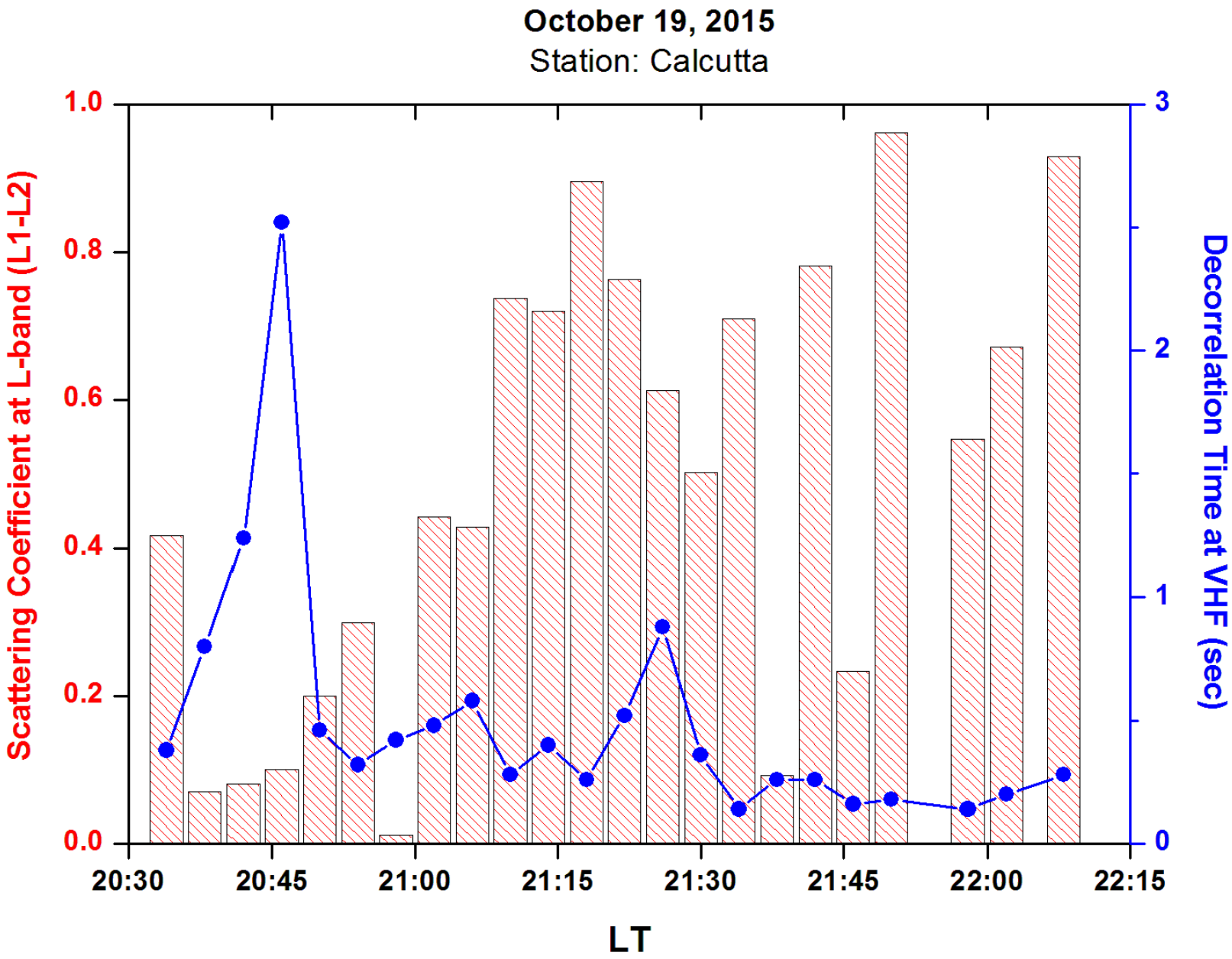

October 19, 2015
240.00 MHz Observation
S4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
20:00
20:30
21:00
21:30
22:00
22:30
23:00
23:30
24:00
LT
Decorrelation Time (sec)
3
2
1
0
20:00
20:30
21:00
21:30
22:00
22:30
23:00
23:30
24:00
LT

L-band Observation

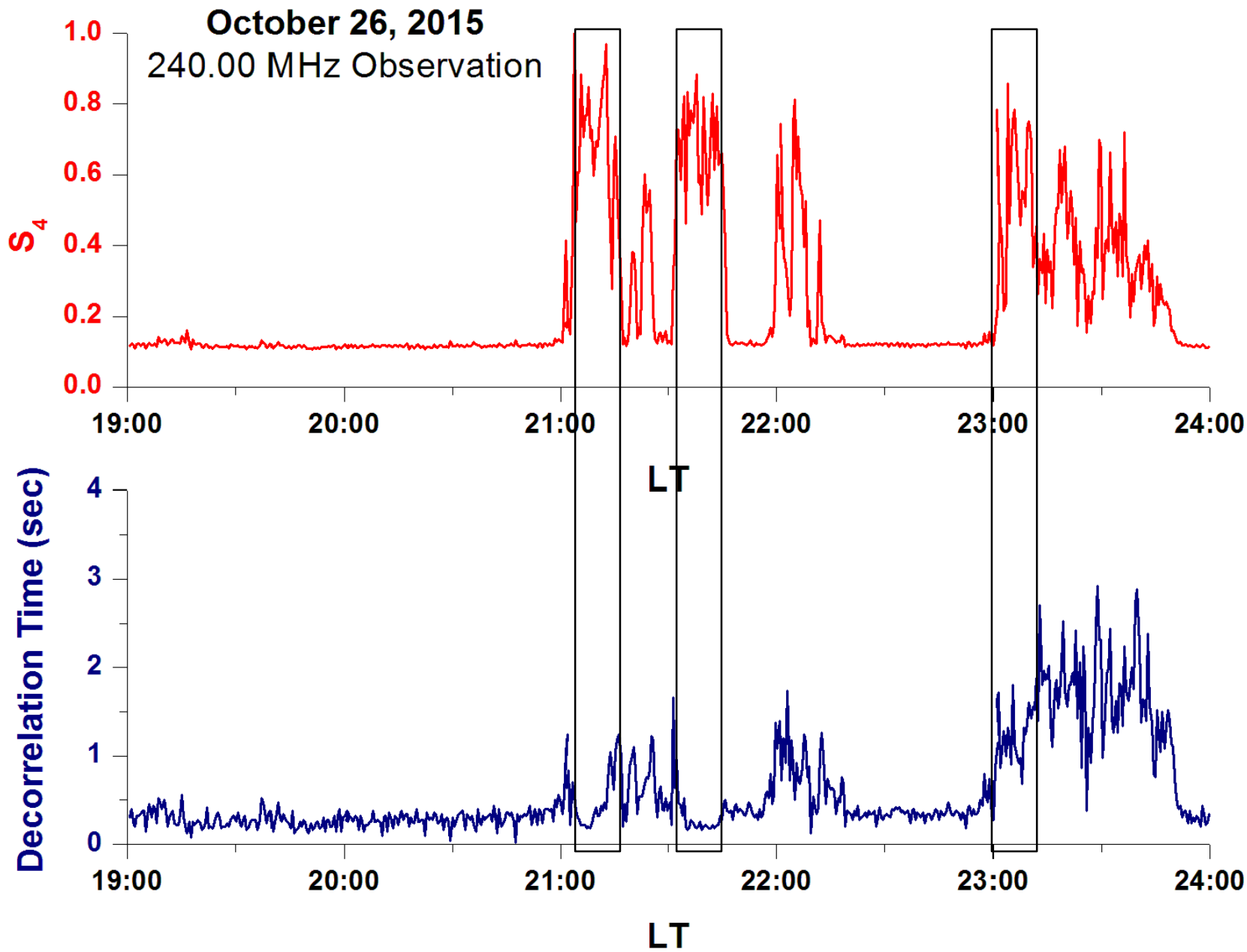


- Out of 94 minutes of observation on L1 and L2 links, 40 minutes of such cases with low correlation coefficient of C/N_0, high values of scattering coefficient and scintillation indices were found on the SV 22 link on October 19, 2015.

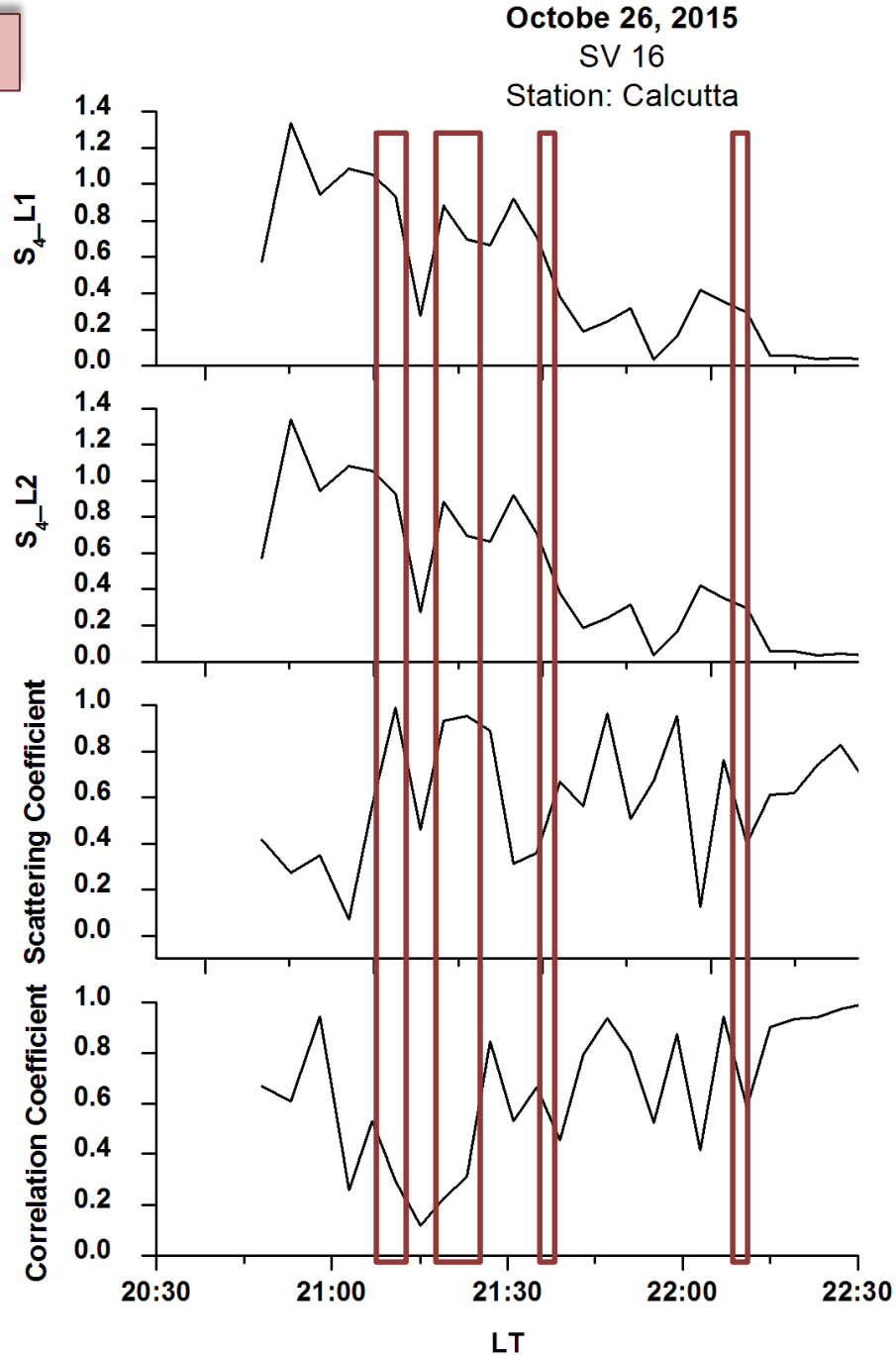
- The condition of decorrelated C/N_0 fluctuations associated with high S_4 and high scattering coefficients is found to be valid for 43% of the scintillation patch duration for L1 and L2 frequencies on the SV 22 link.


October 19, 2015
Station: Calcutta
Scattering Coefficient at L-band (L1-L2)
Decorrelation Time at VHF (sec)
LT
1.0
0.8
0.6
0.4
0.2
0.0
3
2
1
0
20:30
20:45
21:00
21:15
21:30
21:45
22:00
22:15

OCTOBER 26, 2015

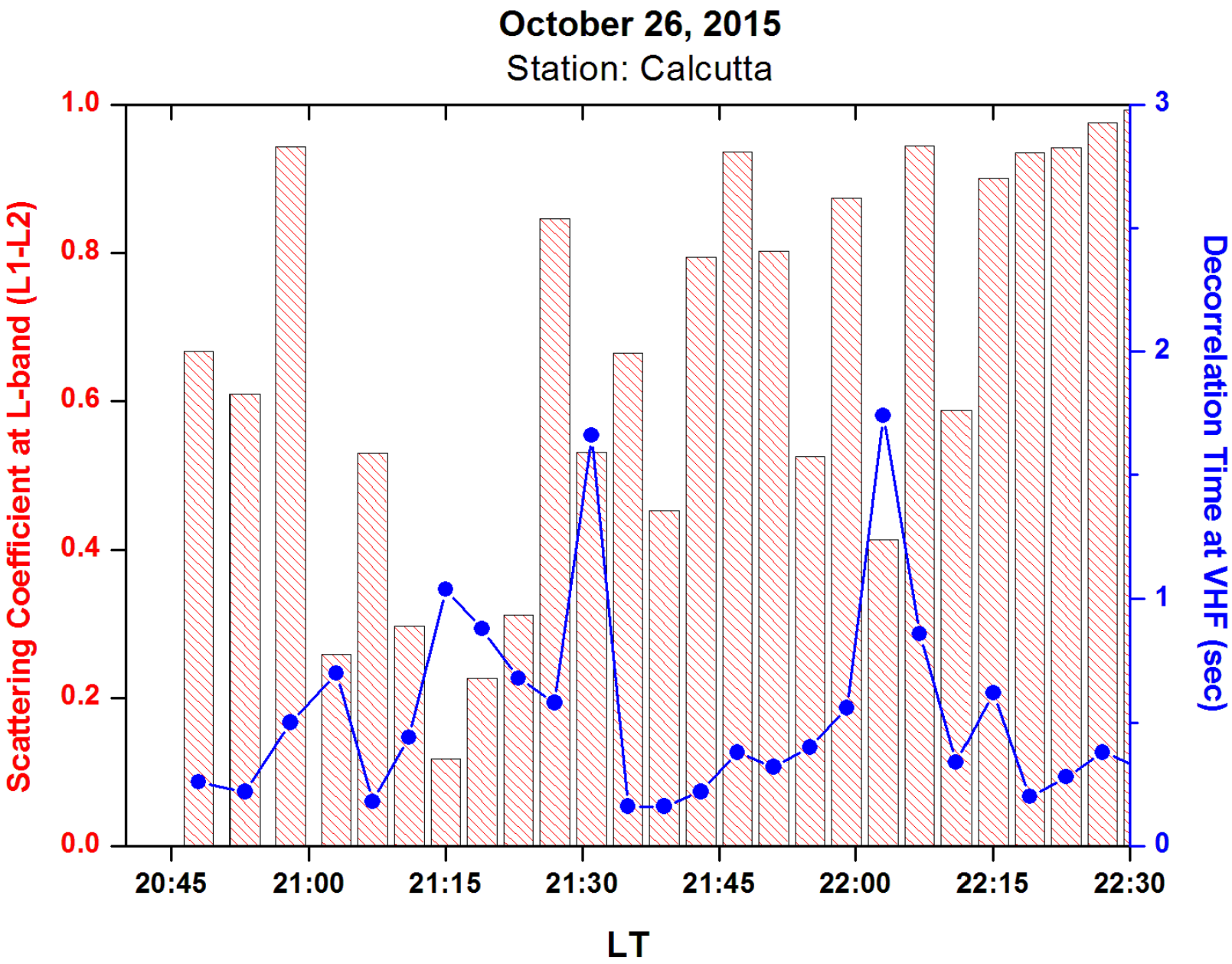

October 26, 2015
240.00 MHz Observation
S_4
1.0
0.8
0.6
0.4
0.2
0.0
19:00
20:00
21:00
22:00
23:00
24:00
LT
Decorrelation Time (sec)
4
3
2
1
0
19:00
20:00
21:00
22:00
23:00
24:00
LT

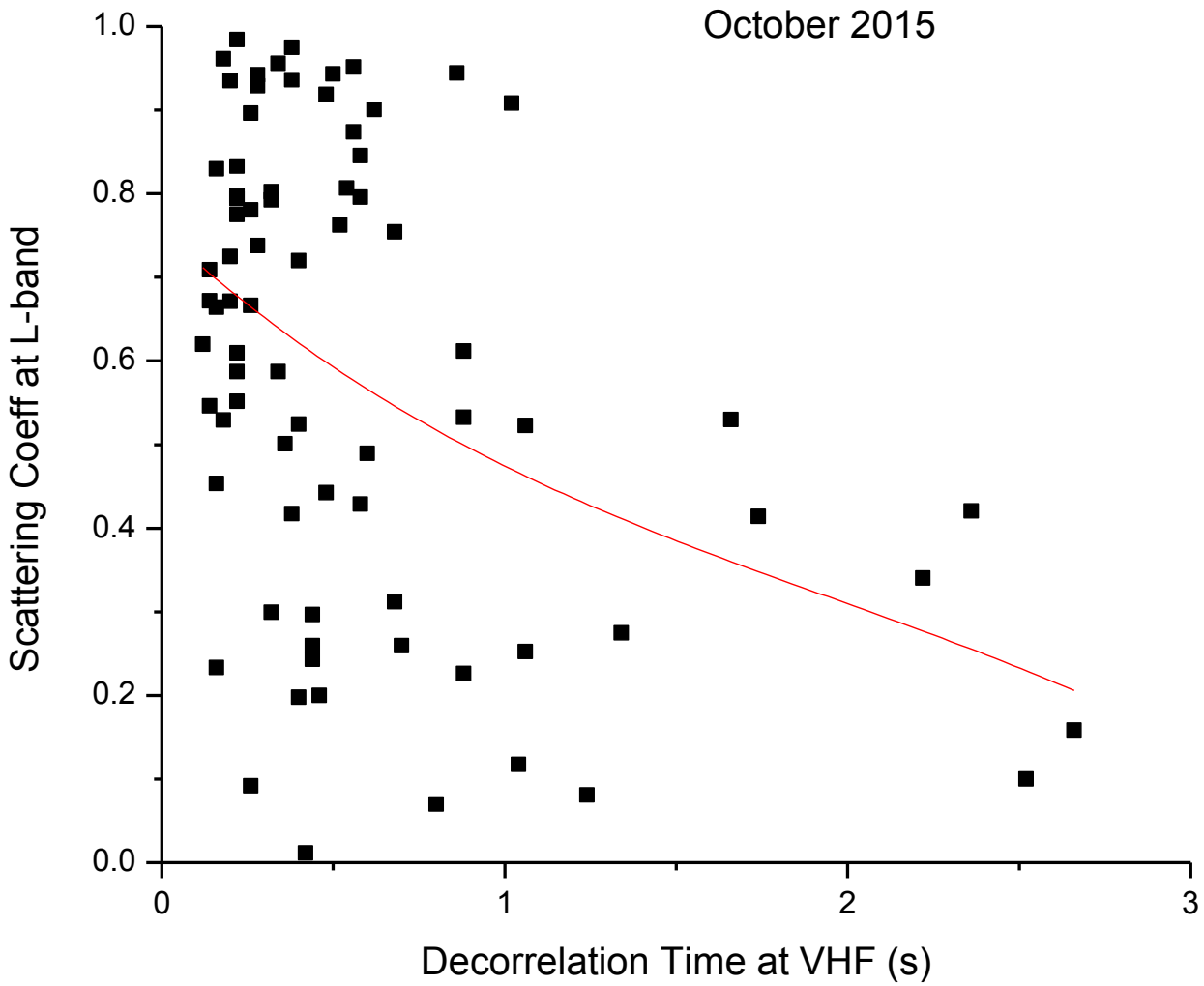
L-band Observation



- Out of 102 minutes of observation on L1 and L2 links, 44 minutes of such cases with low correlation coefficient of C/N_0, high values of scattering coefficient and scintillation indices were found on the SV 16 link on October 26, 2015.

- The condition of decorrelated C/N_0 fluctuations associated with high S_4 and high scattering coefficients is found to be valid for 43% of the scintillation patch duration for L1 and L2 frequencies on the SV 16 link.

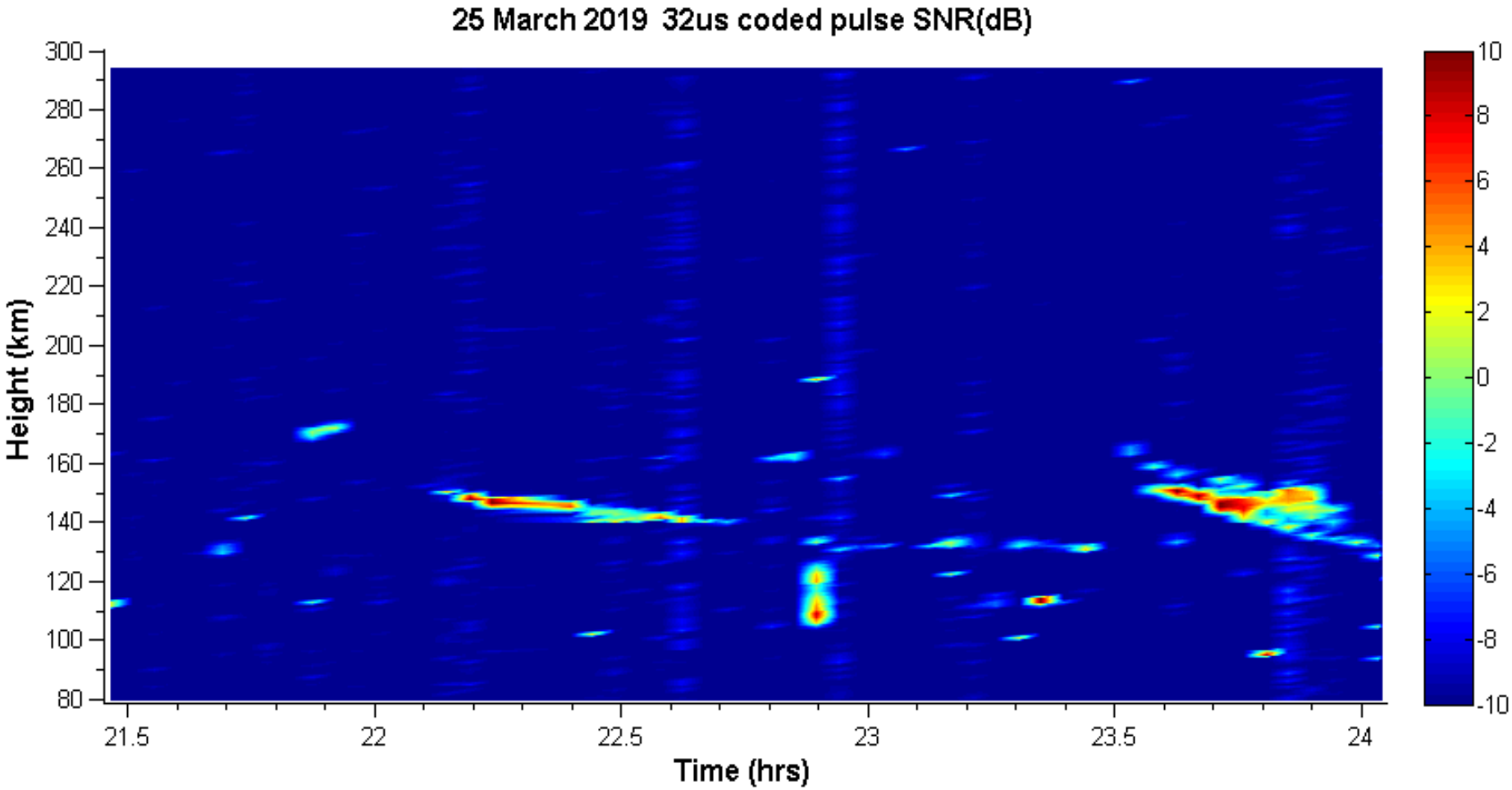

October 26, 2015
Station: Calcutta
Scattering Coefficient at L-band (L1-L2)
Decorrelation Time at VHF (sec)
LT
1.0
0.8
0.6
0.4
0.2
0.0
3
2
1
0
20:45
21:00
21:15
21:30
21:45
22:00
22:15
22:30



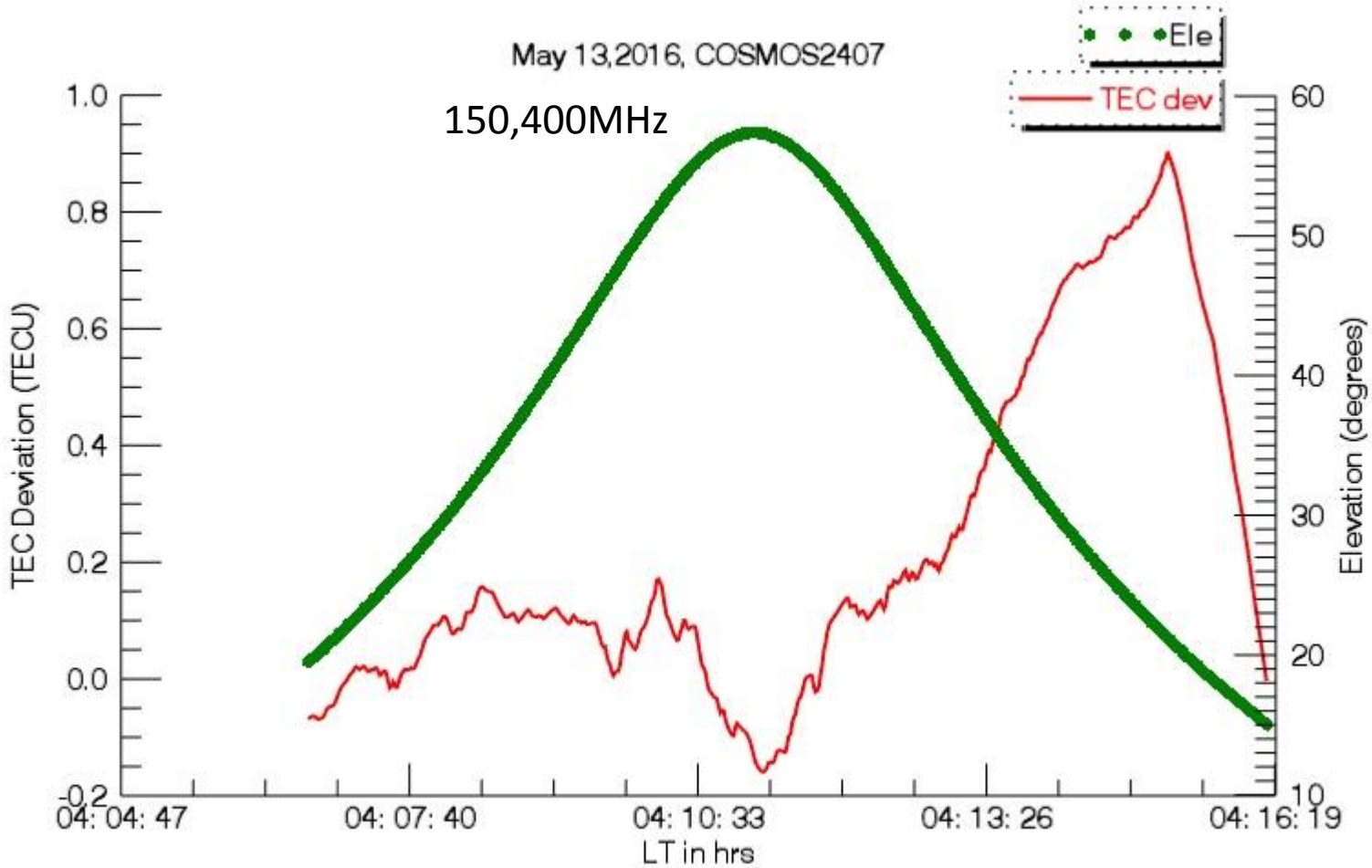
Needs validation during other L-band scintillation cases

Future Programs

25.03.2019 , 21:00 – 24:00 IST



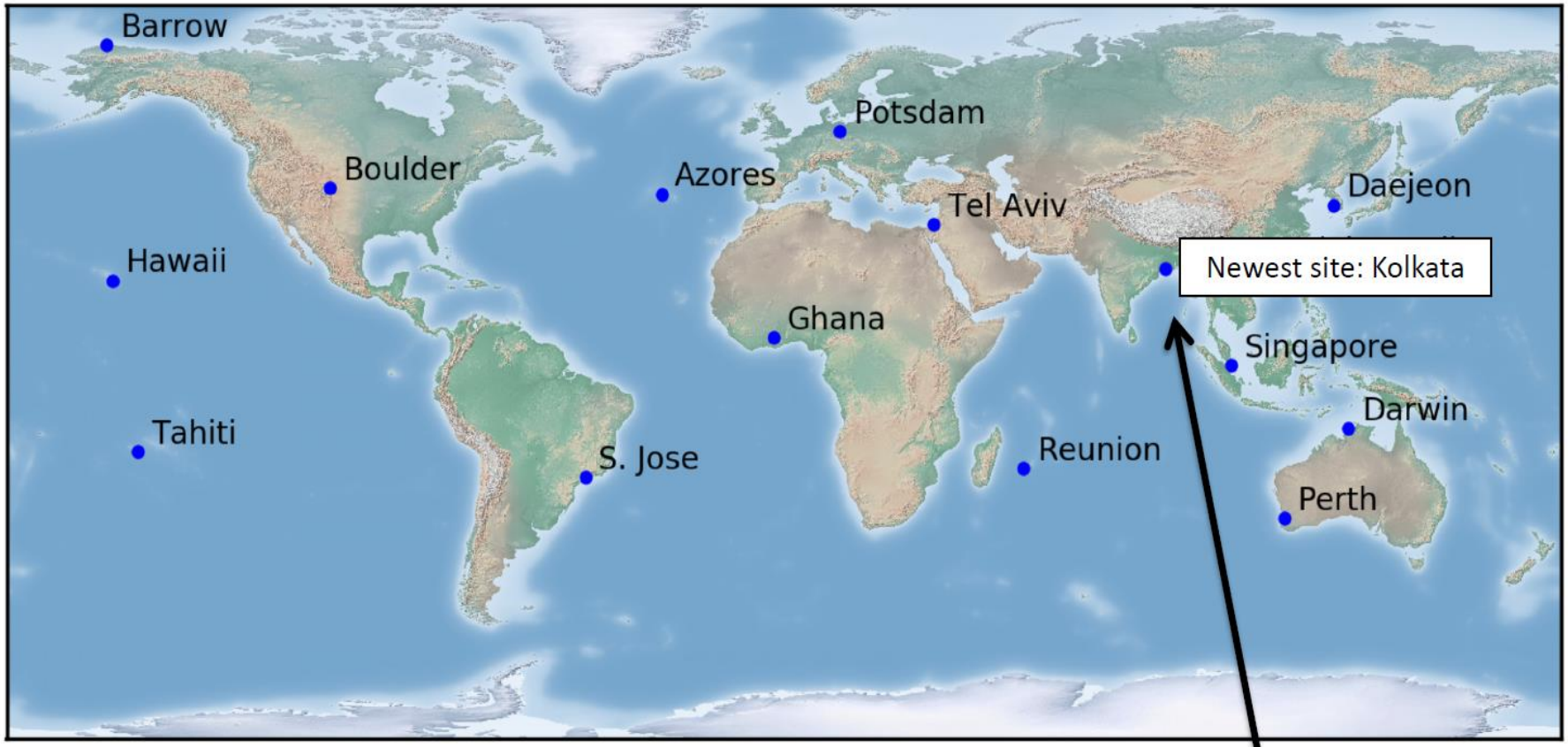
VHF Active Phased Array @53MHZ
at
University of Calcutta



CRABEX receiver at IRPE, CU is part of ISRO INSWIN

GNSS Ground Network

UCAR NDM Network 2019-03



- 2019 additions
  - La Reunion
  - Kolkata

COSMIC 2

septentrio

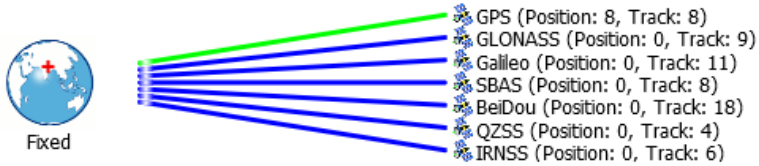
Receiver	Position	Status
PolaRx5S-3023104 (UCIN)	Lat: N22°34'41.1158" 0.000m	Tracked Sats: 64
IP Address (Eth): 10.0.0.2	Lon: E88°22'20.4131" 0.000m	Time: 2019-05-28 09:19:56
Uptime: 0d 01:12:08	Hgt: -30.764m 0.000m	Temp: 52.00 °C — V: 12.25 volts

Fixed
Overall Quality
Corrections
Wifi
Status
Int. Logging
Ext. Logging
OCXO

Overview | GNSS | Station | Communication | Corrections | Data Output | Logging | Admin

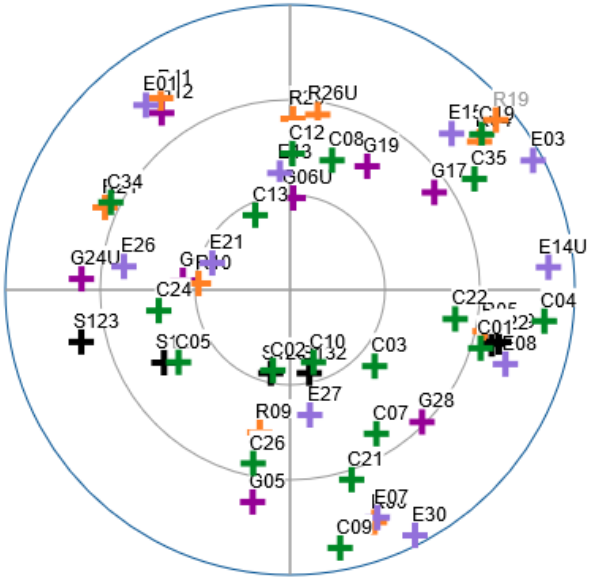
GNSS > Satellites and Signals

GNSS



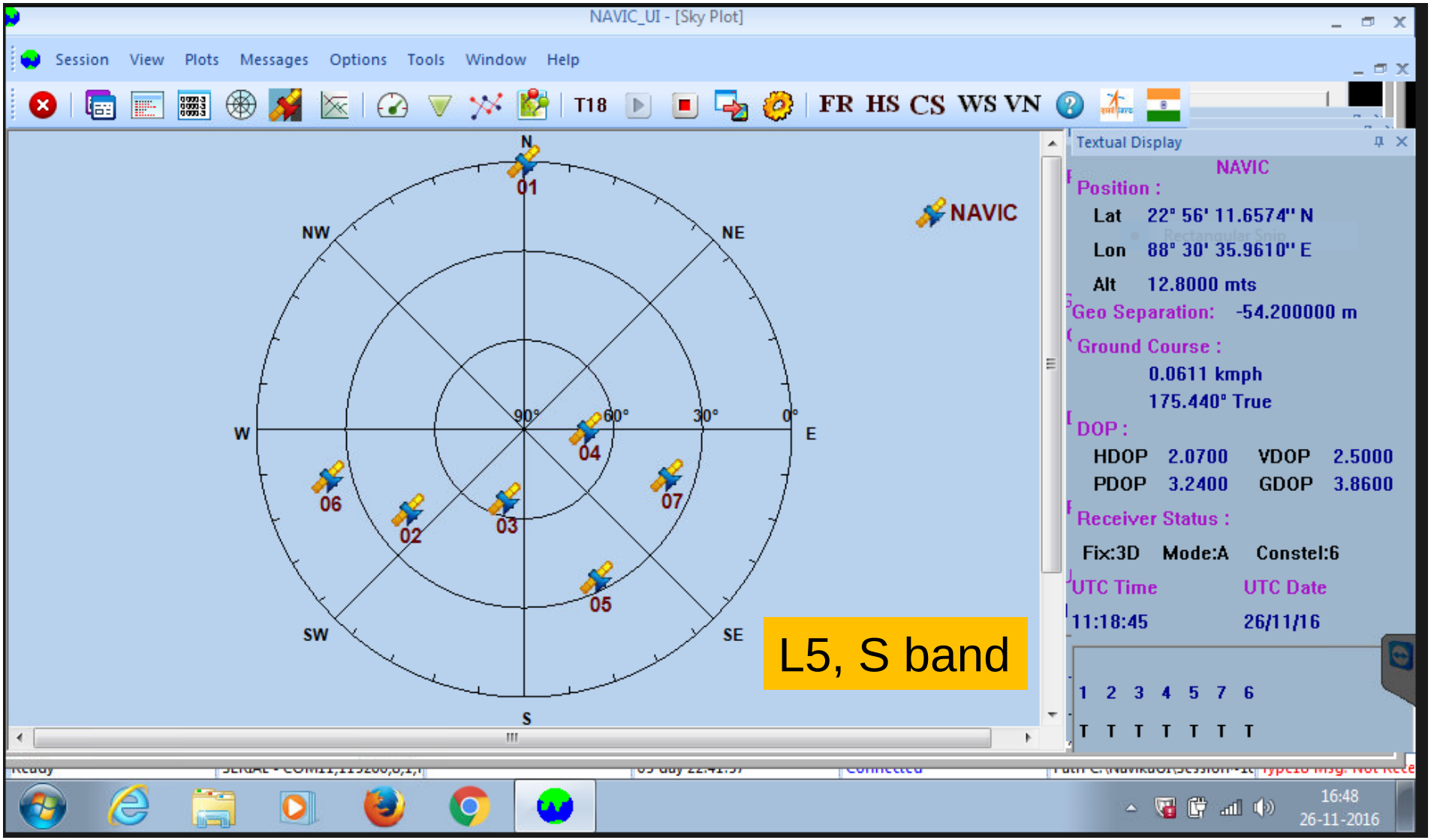
Status | Settings

Sky Plot



☑ GPS ☑ GLONASS ☑ Galileo ☑ SBAS ☑ BeiDou ☑ QZSS ☑ IRNSS

Search 10 Tracking 64 Sync 3 Position 8



Navigation with Indian Constellation (NavIC)

Conclusions:

- Good correspondence is noted between irregularity decorrelation times at VHF with GPS scintillation characteristics

- Scattering coefficient calculated at L-band are found to be high corresponding to low decorrelation times at VHF indicating increased turbulence in the medium of propagation

- Development of a simple inexpensive VHF proxy indicator to L-band scintillations will be useful and could be deployed widely

- Future plans to characterize near-Earth space environment from 53MHz (radar), 150, 240, 400MHz (satellite beacon receivers), 1176.45, 1227.6, 1575.42MHz (GNSS), 2492.5MHz (IRNSS)

Stratosphere Troposphere Radar Facility at University of Calcutta Ionosphere Field Station, Haringhata

The ST (Stratosphere Troposphere) Radar has proved to be a useful and versatile tool for lower atmospheric and ionospheric studies. Appreciating that the lower atmosphere is the seat of many interesting physical phenomena with implications to global change, University of Calcutta is implementing Eastern and North-Eastern India's first ST Radar at 53MHz at the Ionosphere Field Station, Haringhata located about 50 km north-east of the city.

Objectives

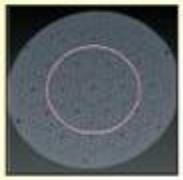
i. To study the dynamics of the tropopause and Stratosphere Troposphere Exchange (STE)
ii. To study the convection process in troposphere
iii. To characterize rain structure based on radar signatures of precipitating layers
iv. To study lower atmospheric turbulence
v. To study gravity waves and planetary scale waves and their effects on the upper atmosphere
vi. To study ionospheric E and F region irregularities

Configuration

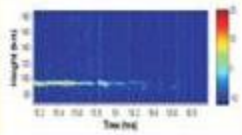
ST Radar is fully active phased array radar, operating at 53MHz. Its planar antenna array consists of 475 numbers of three-element Yagi antennas each fed by a dedicated 2-kW Solid-state coherent Transmit-Receive (TR) Module. The array is configured in a near-circular shape spreading over an area of about 7000m^2. An inter-element spacing of 0.7λ is adopted with an equilateral triangular grid to steer the beam up to a zenith angle of 30°. Antenna array is organized into 25 sub-array groups each consisting of 19 Yagi elements.

Performance Parameters:

Height coverage: 0.5 - 20 km, with useful observations over at least 90% of time under all atmospheric conditions.
Height resolution: 50 m up to 3 km altitude, 150 m from 3 to 20 km altitude
Horizontal wind velocity: 1 - 70 m/s
Vertical wind velocity: 0.1 - 30 m/s
Velocity resolution: Better than 1% of maximum velocity value
Wind accuracy: Horizontal wind speed 1 m/s, direction 10
Time resolution: 5-15 min for full profile
Average power aperture product at the antenna feed point: 3.0x10^{6}wm^2 or better



475 elements
25 subarrays
53MHz operating frequency with 3MHz BW
Peak Power of 2KW per TR Module

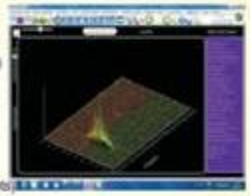


Deliverables:

1. Three component wind measurements provide information about wave disturbances; 2. Spectral width measurements contain information on microscale turbulence; 3. The reflectivity measurements contain information on small scale turbulence as well as large scale temperature gradients associated with tropopause; 4. The most important and unique capability of the ST radars is the measurement of the vertical wind componentwith a high degree of temporal and altitude resolutions (typically ~ 30sec and ~ 150m). This unique capability gives the ST radars an enormous advantage over the conventional wind measurement techniques.

LOW MODE
37.5-m resolution
7 sub arrays (133 Elements)
133-kW Power
0.25-us uncoded pulse
Height coverage : 5km

HIGH MODE
75-150 m resolution
ALL sub arrays (475 Elements)
950-kW Power
coded pulse
Height coverage 20km



Funded by Science and Engineering Research Board (SERB), DST, GoI

Thank You

- The average drift speed (V_0) which is obtained from the spaced receiver measurement, generally differs from the average zonal drift (V_E) of the irregularities as there can be a vertical drift V_Z of the irregularities. In that case (V_o) has contributions from both V_E and V_Z which is determined by the relation

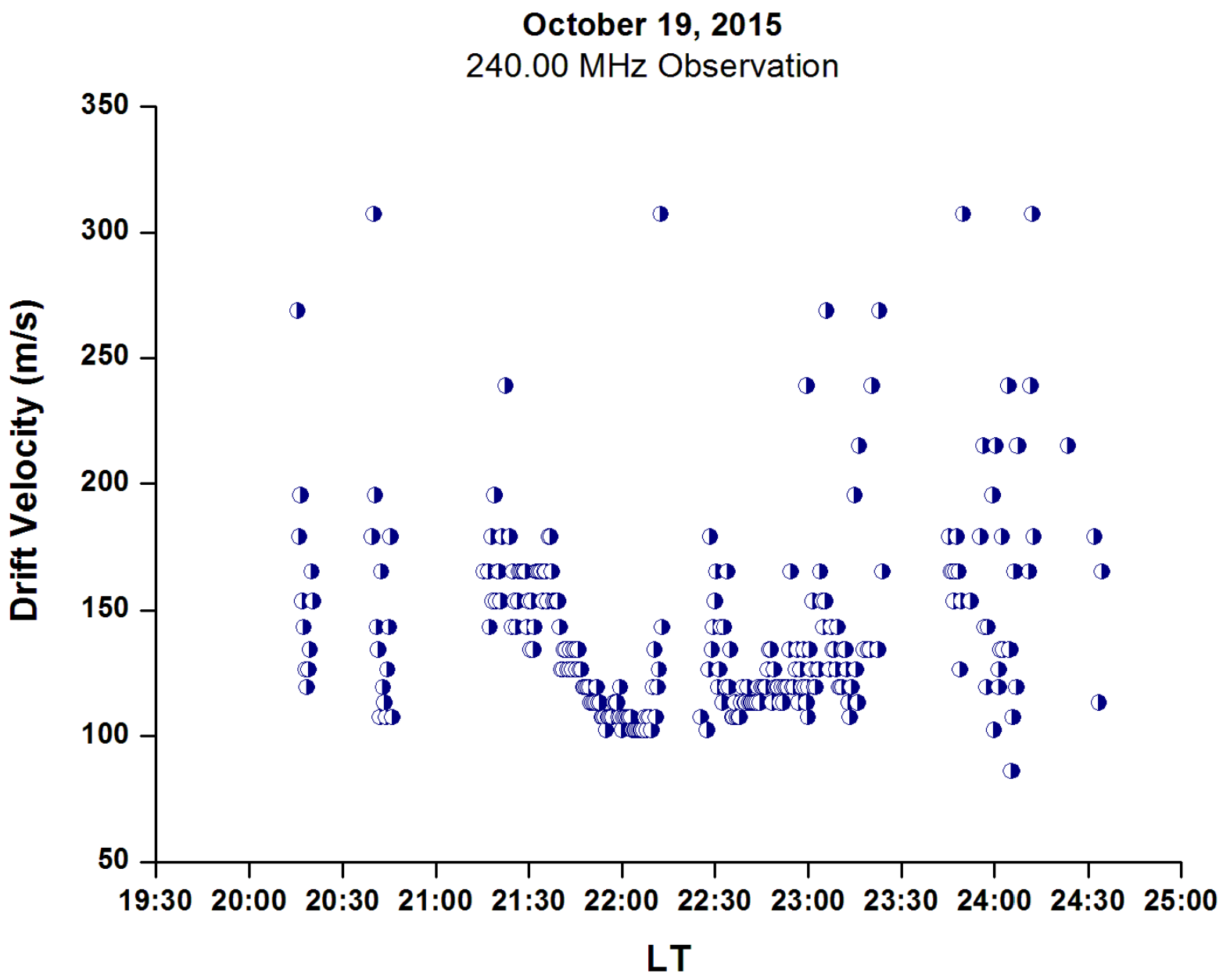
$$V_o = V_E - V_Z \tan\theta \sin\phi$$

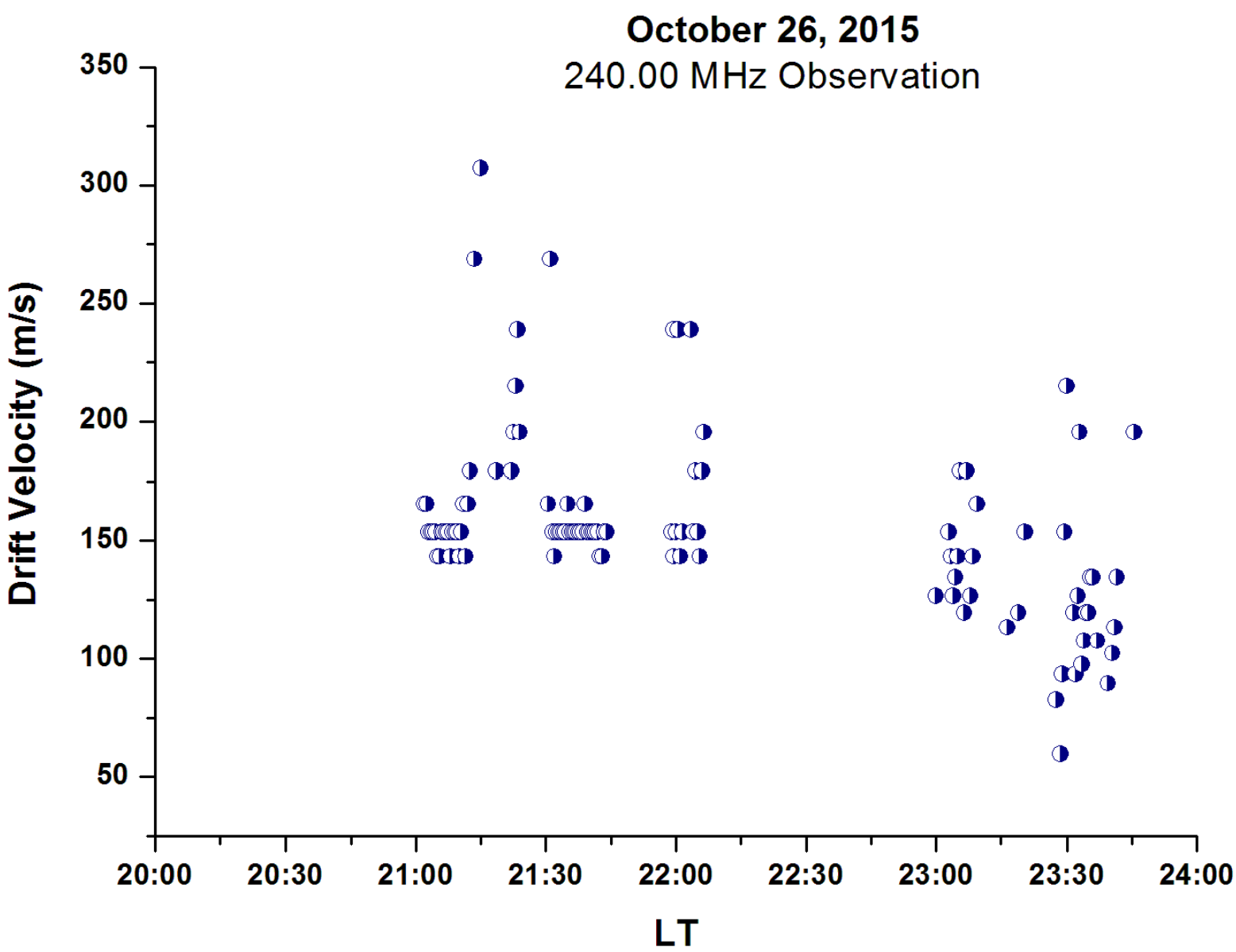
where θ is the zenith angle and ϕ is the azimuth angle of the wave vector from the magnetic plane.

- The 'peak value' method uses the time lag for which the autocorrelation function equals the peak of the cross-correlation function is used. By this method, the zonal drift velocity V_0 are found to be,

$$V_0 = \frac{\Delta x \tau_m}{(\tau_m{}^2 + \tau_p{}^2)}$$

where, τ_m is the time lag for which the cross-correlation function is maximum, τ_p is the time lag for which autocorrelation of amplitude equals the peak of the cross-correlation function for the amplitudes recorded at the two receivers and Δx is the distance between the two antennas placed along the east-west direction.


October 19, 2015
240.00 MHz Observation
Drift Velocity (m/s)
350
300
250
200
150
100
50
19:30
20:00
20:30
21:00
21:30
22:00
22:30
23:00
23:30
24:00
24:30
25:00
LT


October 26, 2015
240.00 MHz Observation
Drift Velocity (m/s)
350
300
250
200
150
100
50
20:00
20:30
21:00
21:30
22:00
22:30
23:00
23:30
24:00
LT