Statistical Analysis of Nighttime TEC Depletions and GPS Loss of Lock in the Crest of Anomaly Region

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Outline

- Objectives
- Data and Methodology
- Results and Discussion
- Conclusion

Objectives

- **To statistically study the nighttime TEC depletions and associated scintillations near the crest of equatorial ionization anomaly (EIA), Bhopal (Geog. 23.2° N, 77.4° E, and MLAT 14.2° N) for the solar minimum period 2005-06.**

- **To study ROTI as an irregularity index**

- **To compare the in situ density (electron and ion density) fluctuations measured by the DEMETER satellite with ground based GPS receiver measurements at the equatorial anomaly station Bhopal for the low solar activity year, 2005-06**

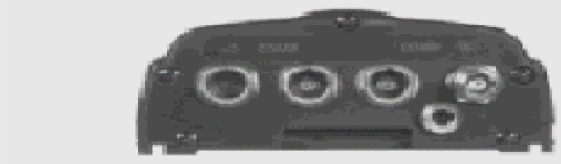
- **To compare the strength of equatorial electrojet with the density fluctuations and scintillations**

THE GPS DATA

This Scintillation and TEC monitoring receiver with special firmware, provides true amplitude, single frequency carrier phase measurements and TEC measurements from up to eleven GPS satellites at the L1 frequency (1575.42 MHz) and the L2 frequency (1227.60 MHz).

PowerPak

GPStation



GPS antenna

THE DEMETER SATELLITE

- The DEMETER satellite was launched on June 29, 2004, from Baikonour (Kazakhstan).
- The measurements made by the DEMETER experiment are intended to study the emissions of electromagnetic waves observed during earthquakes and volcanic eruptions, disturbances in the ionosphere and the upper atmosphere and the corresponding precipitation of particles, systematically.
- DEMETER (Detection of Electromagnetic Emissions Transmitted from Earthquake Regions) is the first of the microsatellites developed by CNES.

The DEMETER Satellite in flight configuration

Mission	Study Earth's electromagnetic environment
Launch date	29 June 2004
Partners	CNRS, CEA, University of Clermont, ESA, Centrum Bada? Kosmicznych (Space Research Centre (SRC), Poland), University of Electro-communications (Japan)
Instruments	•Plasma analyser •Langmuir probe •Particle detector •Electric sensors •Magnetic sensors
Localisation	Near-sun-synchronous circular orbit, altitude 715 km to December 2005 then lowered to 660 km
Mission lifetime	2 years, extended to 5 years

DEMETER EXPERIMENTS

THE LANGMUIR PROBE EXPERIMENT (ISL) **measures:-**

-electron density of plasma (in the range 10^2 – 5.10^6 particles/cm^{-3})

-electron temperature (in the range 600 K – 10000 K)

-potential of the satellite (in the range ±3V)

THE PLASMA ANALYSIS INSTRUMENT (IAP) **measures:-**

-Densities of the major ionospheric ions H^+, He^+ and O^+

-Temperature of the ions

THE ELECTRIC FIELD EXPERIMENT (ICE) **measures:-**

-Three components of the electric field, in a wide frequency range (DC – 3 MHz)

THE MAGNETIC FIELD EXPERIMENT (IMSC) **measures:-**

- Three magnetic components in a wide frequency range

PLASMA DETECTOR INSTRUMENT (IDP)

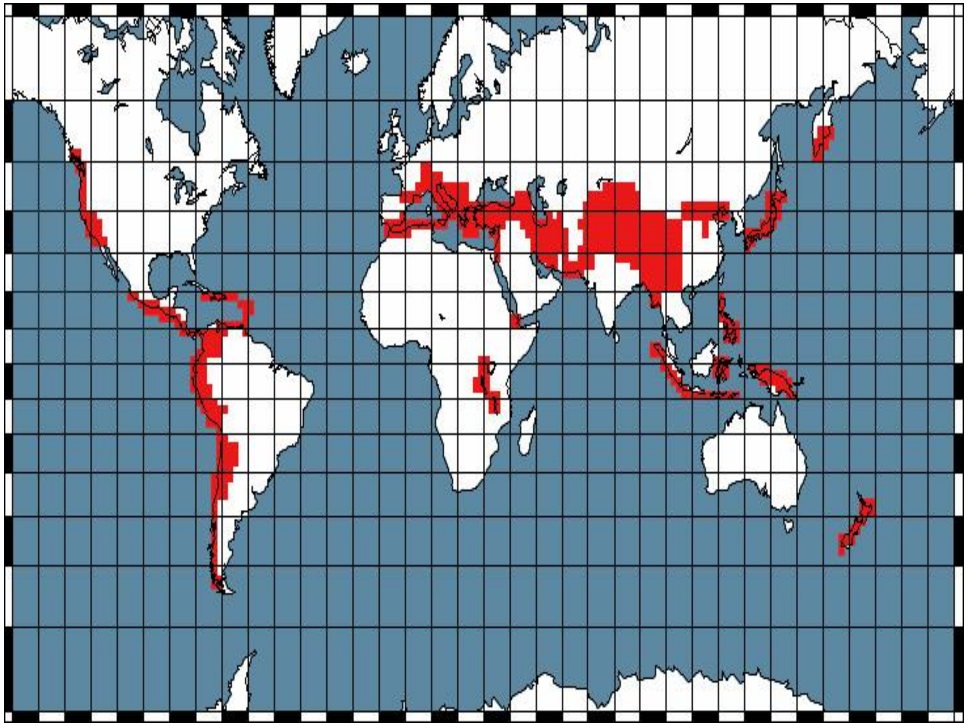
-**The energy spectrum of electrons perpendicular to the magnetic field (in the 30 keV – 2 MeV range)**

Electronic module BANT

-**Provides interface between the six scientific experiments and the onboard calculator of the platform named Equipement de Gestion de la Charge Utile (EGCU)**

Observation strategy

- The orbit of DEMETER is polar, circular with an altitude of 710 km
- There are two modes of operation for the DEMETER payload that affect the data acquisition
- a survey mode all around the Earth with low resolution
- a burst mode with high resolution above main seismic zones



SCIENTIFIC DATA PROCESSING

DEMETER scientific payload performs measurements in the invariant latitude interval [-65° to +65°]. All experiment data files are organized per data identifier and per half orbit. The data processing is organized in four levels

1. Level 0 – Raw data (Only experimenters have access to this data)
2. Level 0' – Quickview images are created by calibration of the raw data. (Only experimenters have access to this data)
3. Level 1 - All scientific data are converted into physical value data
   - Auxiliary data are integrated to make the level -1 data auto consistent
   - Guest investigators can download this data from the DEMETER web server (http://demeter.cnrs-orleans.fr)
   - Blocks
   - Programs to convert the binary data into ascii data are made for different experiments using the Interactive Data Language (IDL)

- Level 2 - No additional data processing is performed at level 2.
  - A high-resolution data display can be done by the user on the data server
  - The user can choose one or more of several instruments and represent the data from these instruments on the same plot.

Auxiliary data parameters

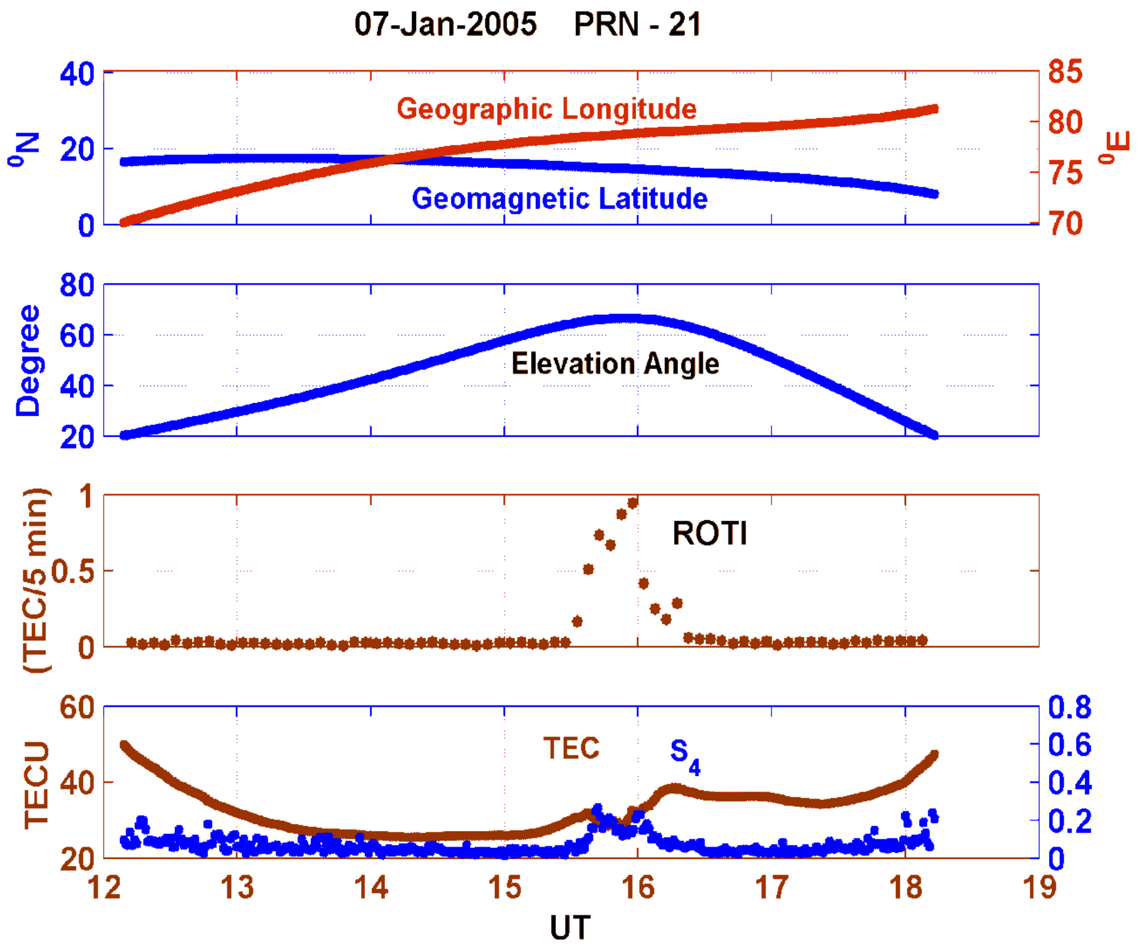
- Orbital parameters

- Attitude parameters

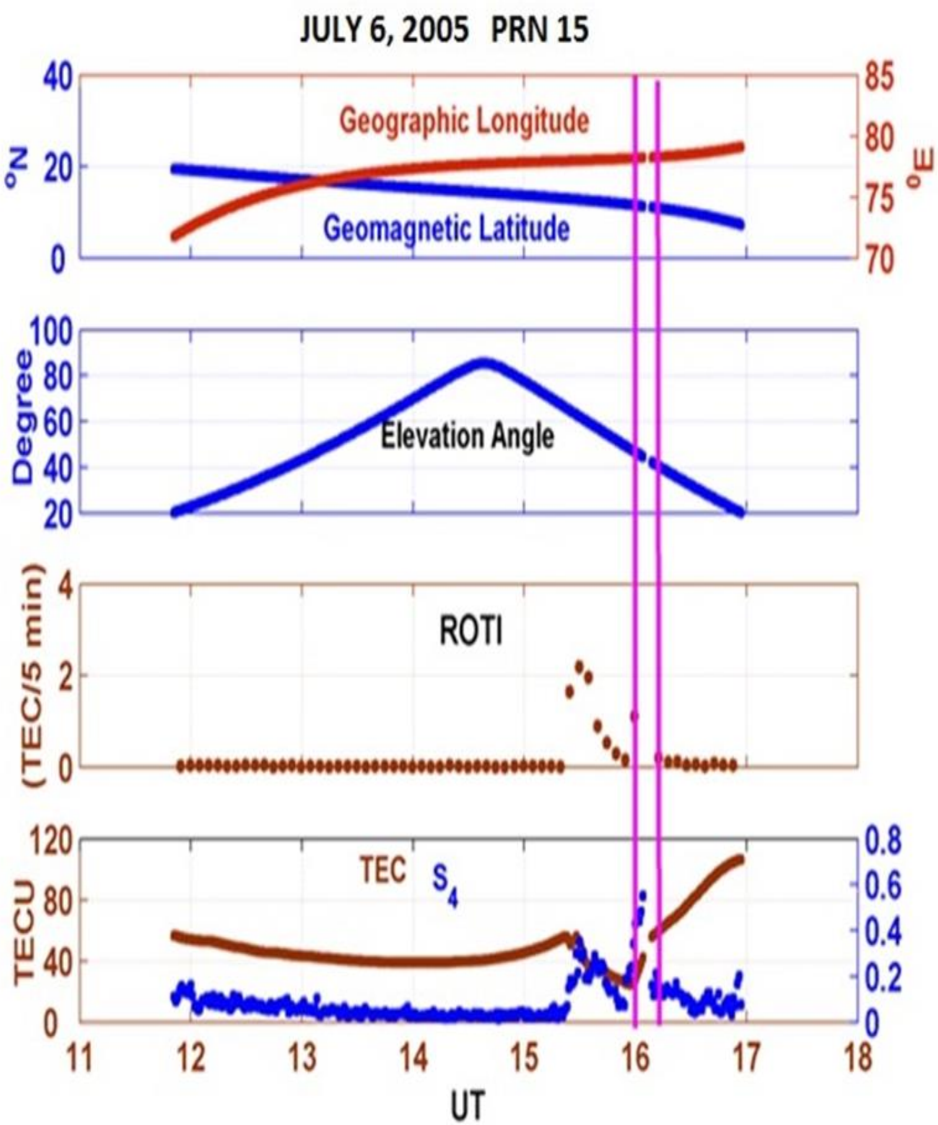
- Seismic event

RESULTS

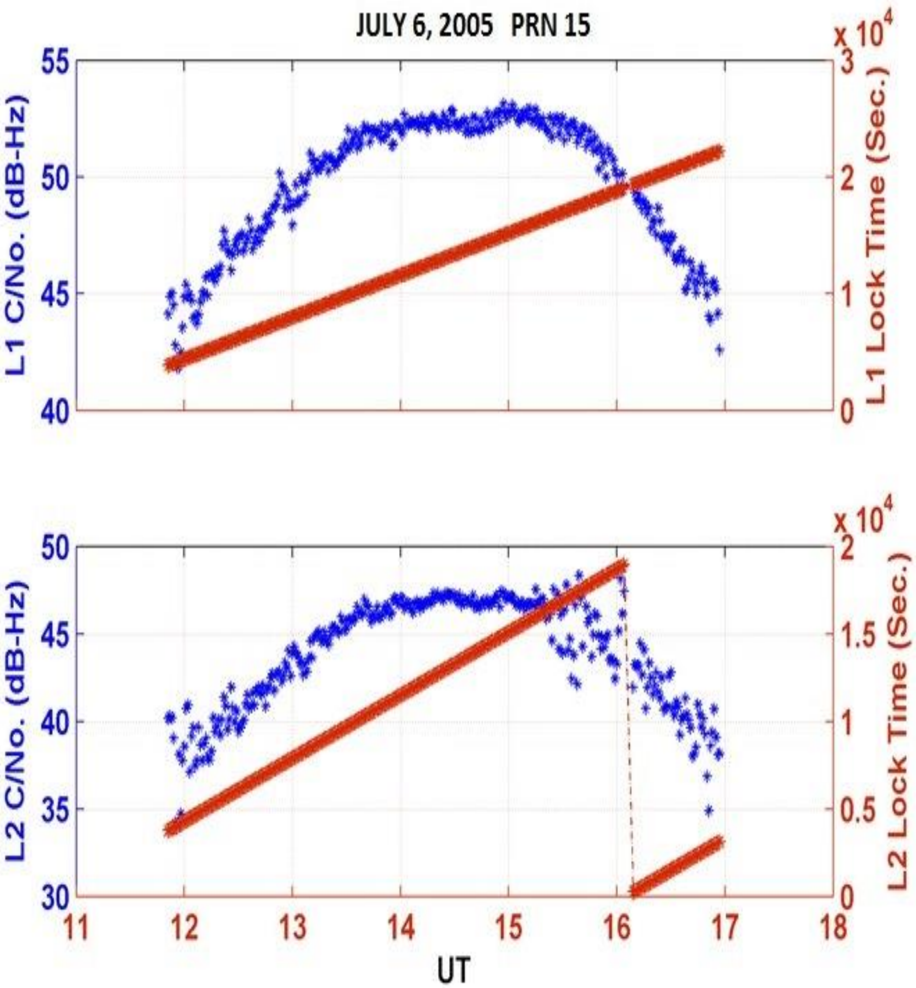
Observation of TEC depletion on 7 January 2005 for PRN-21

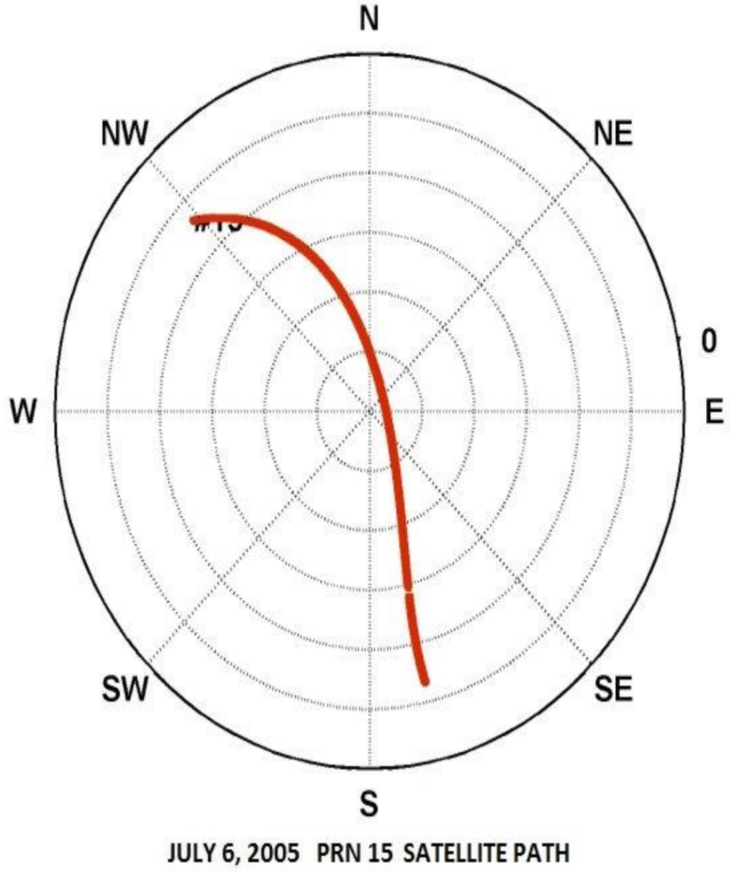


Observation of TEC depletion on July 6, 2005 for PRN-15

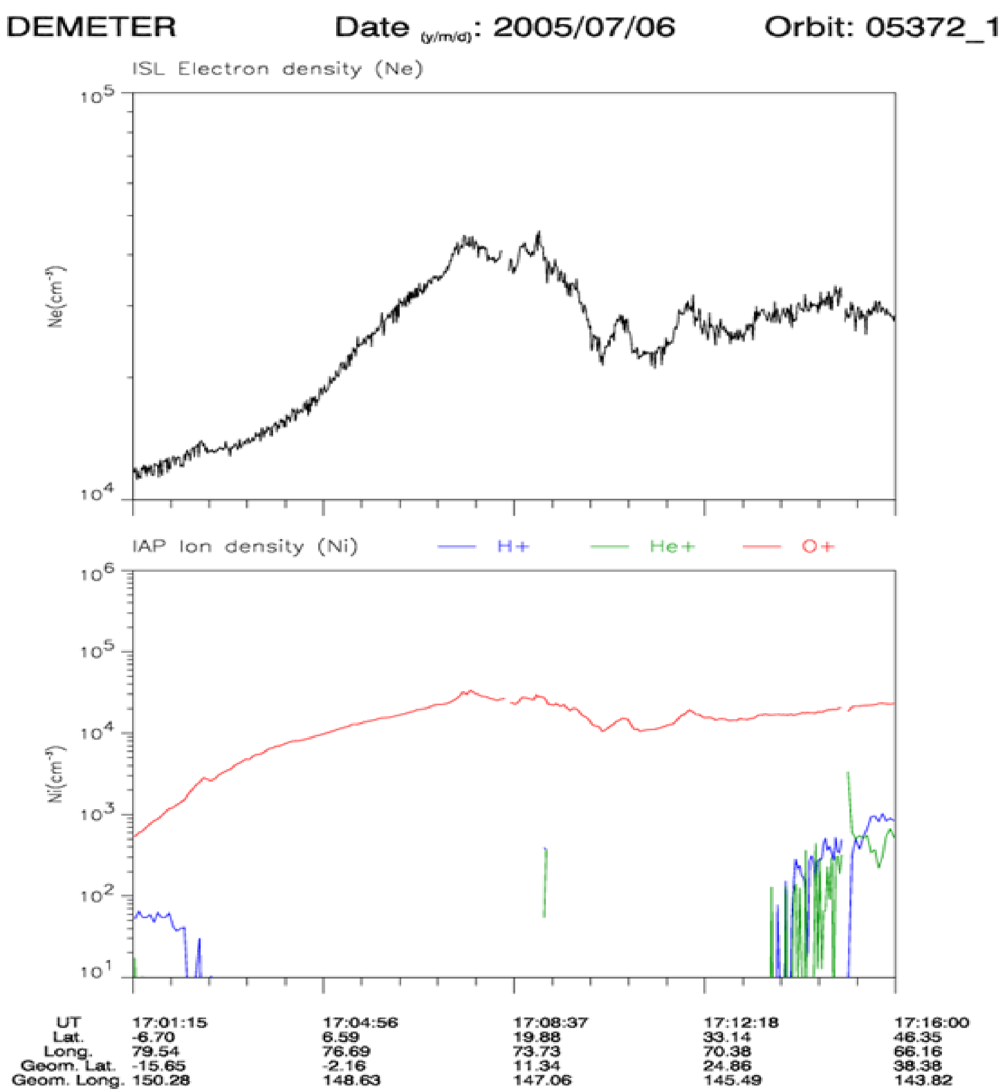


Loss of lock of L1 and L2 signals and L1 and L2 carrier to noise ratio and Sky plot of PRN-15

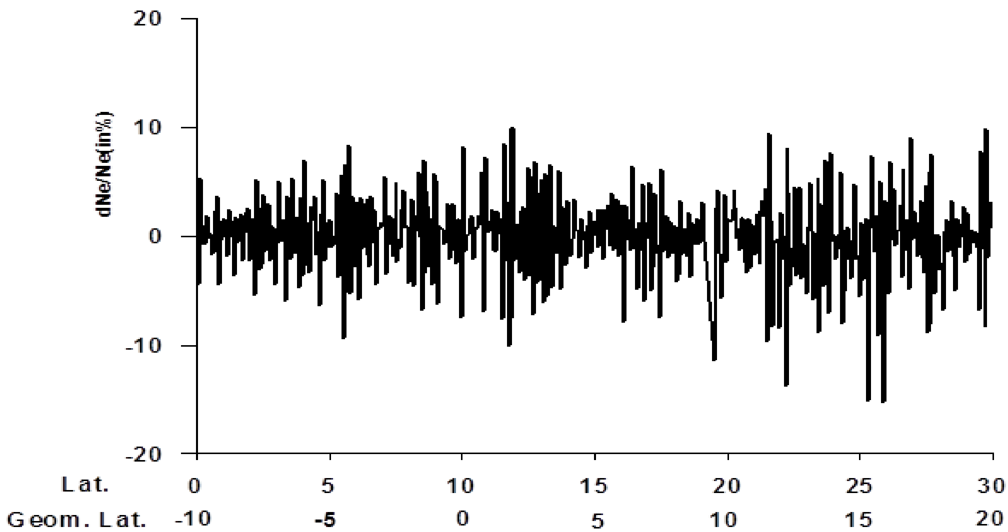


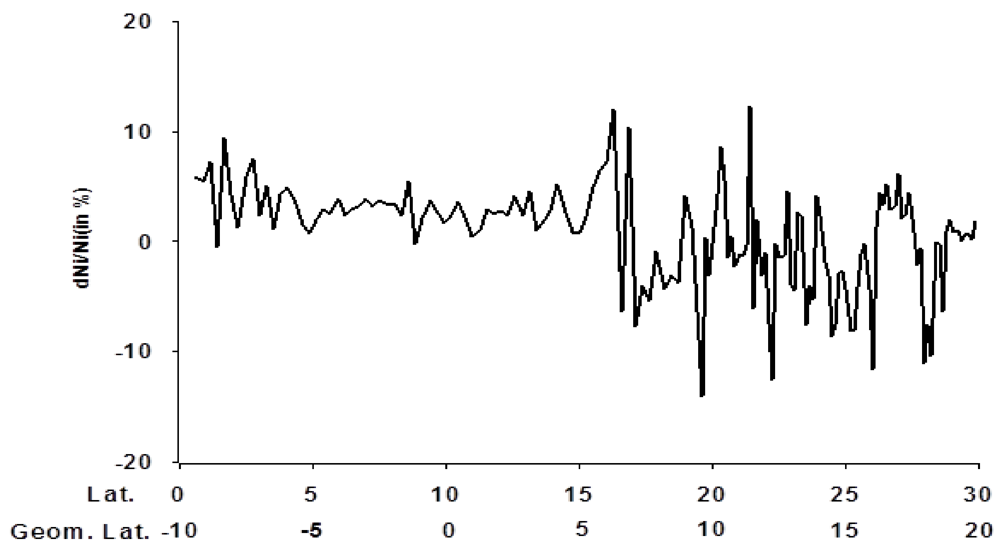


Data recorded by DEMETER along the orbit 5372.1

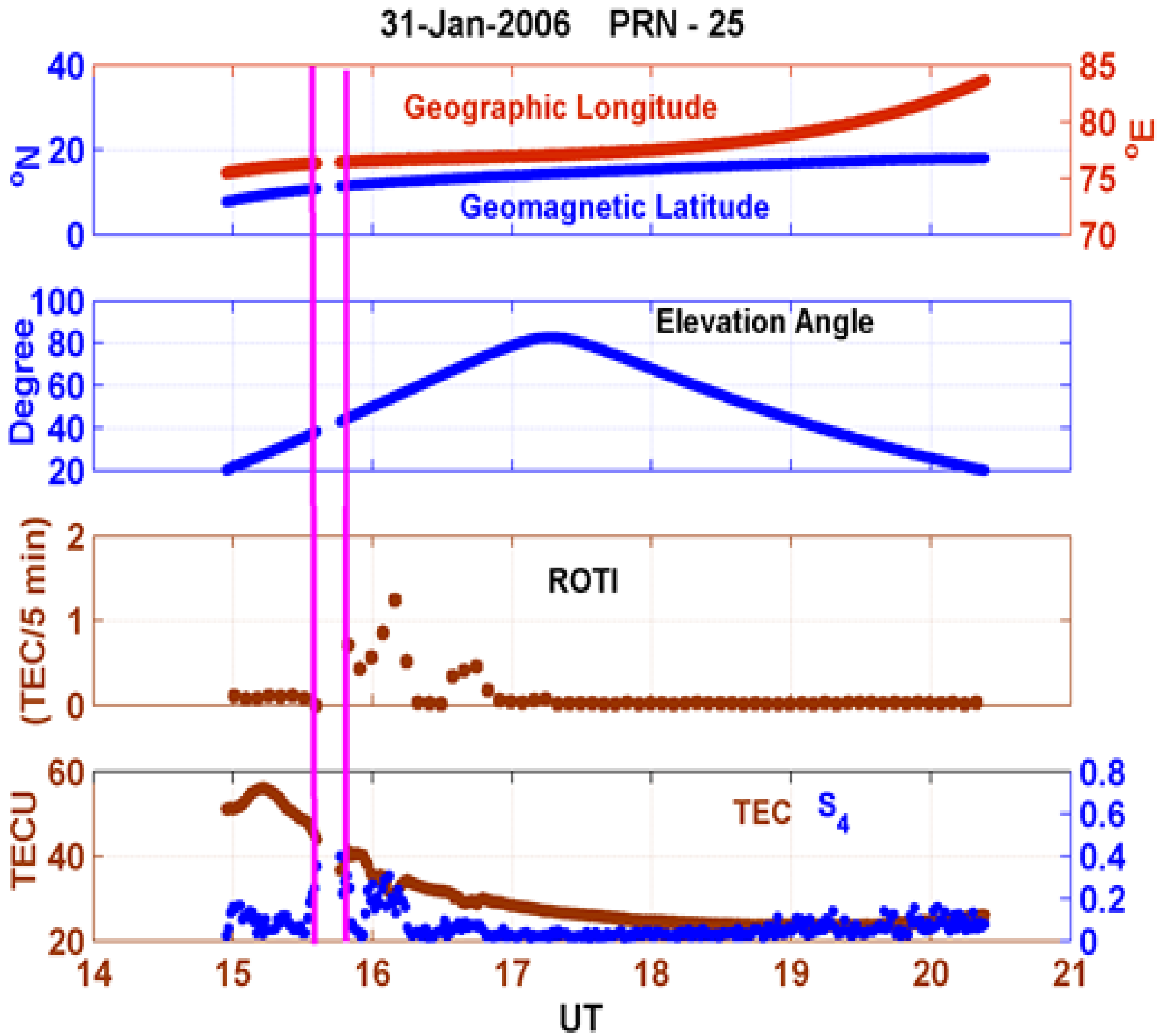


Normalized variation of the electron and ion density (O^+) as function of latitude for the orbit 5372.1

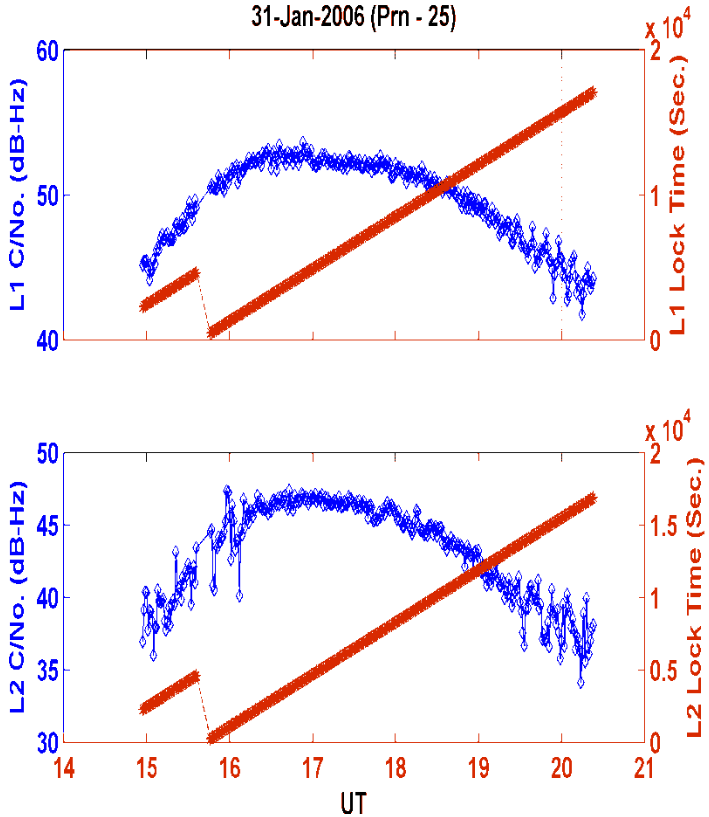


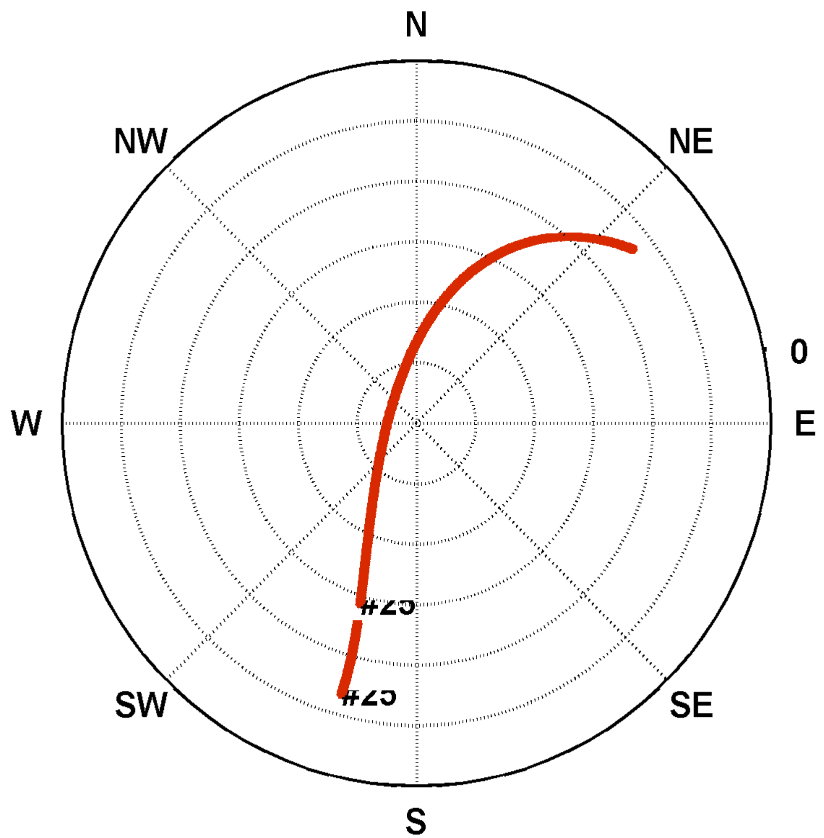


Observations of depletion in TEC on 31 January 2006 for PRN-25



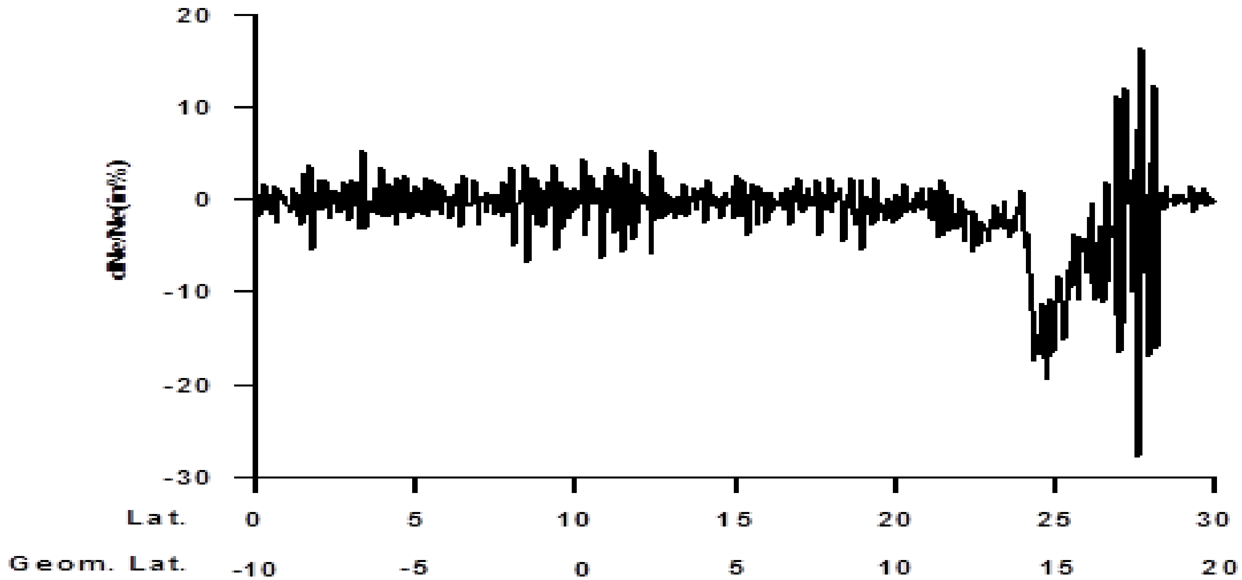
Loss of lock of L1 and L2 signals and L1 and L2 carrier to noise ratio (Left panel) and Sky plot (Right panel)

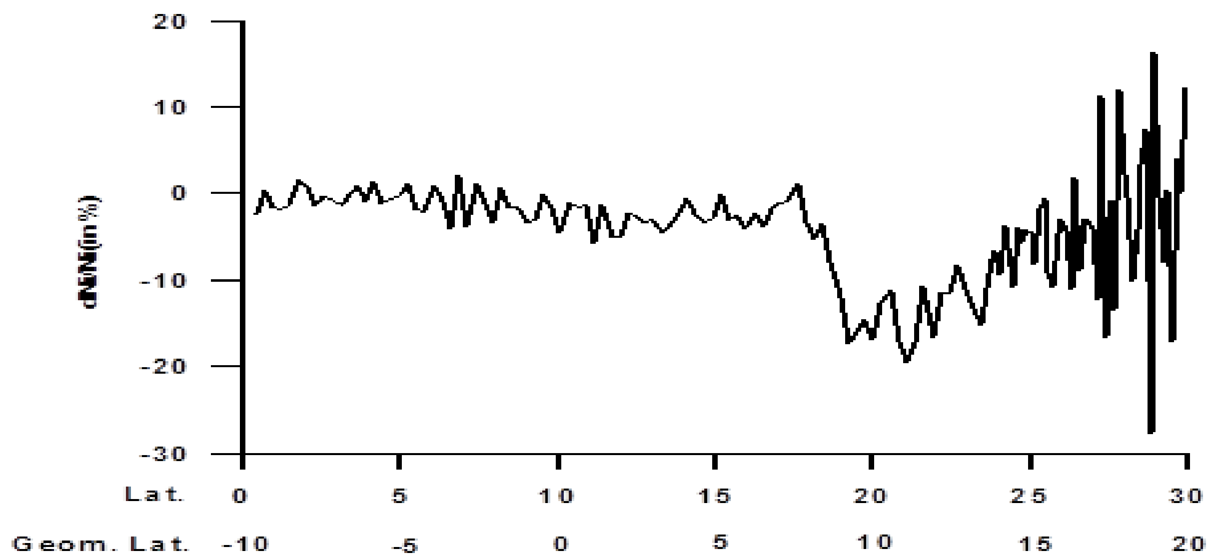




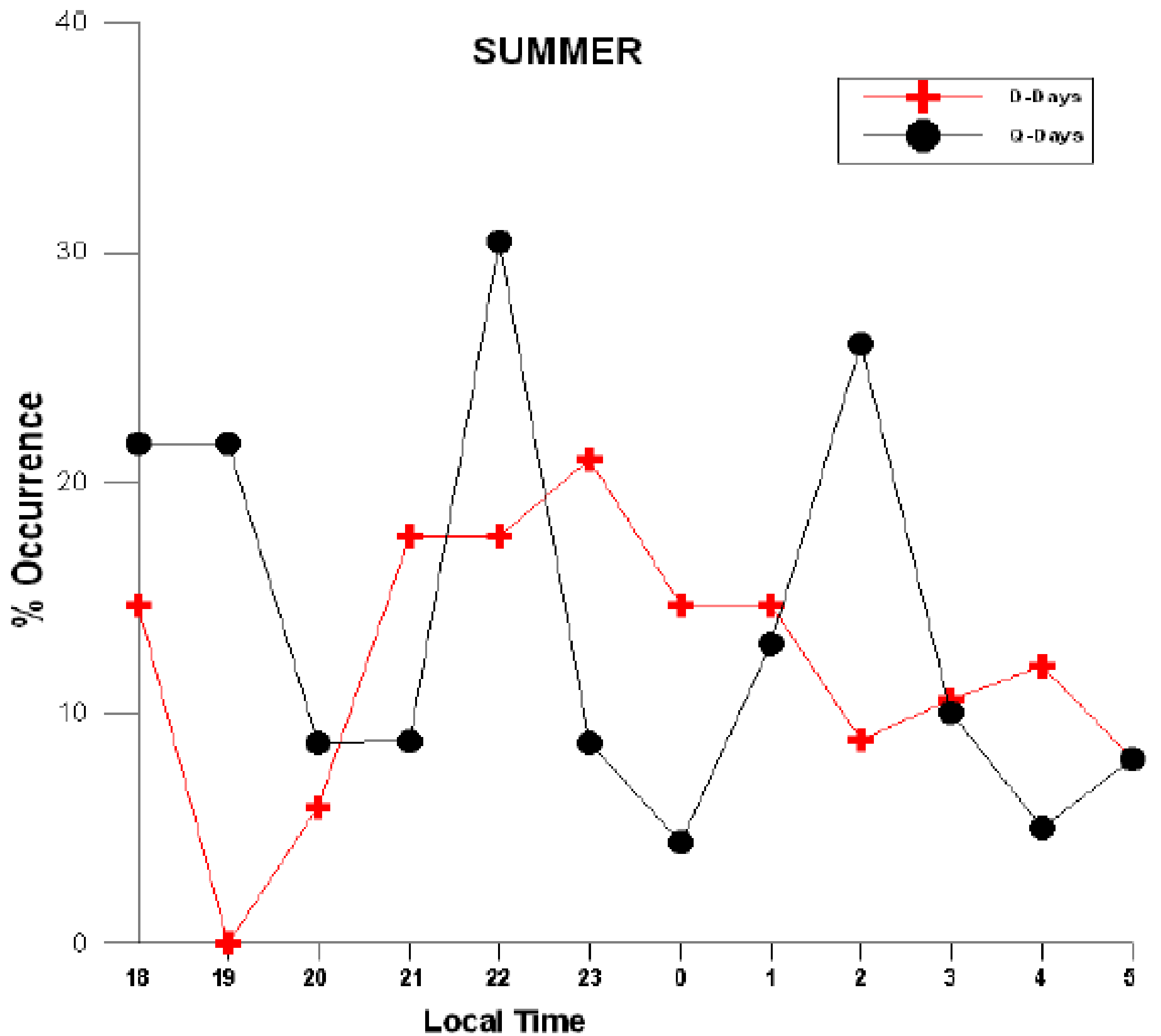
31-Jan-2006 Satellite Path of (Prn - 25)

Normalized variation of the electron and ion density (O^+) as function of latitude for 31Jan 2006 orbit 8421.1 (16UT)

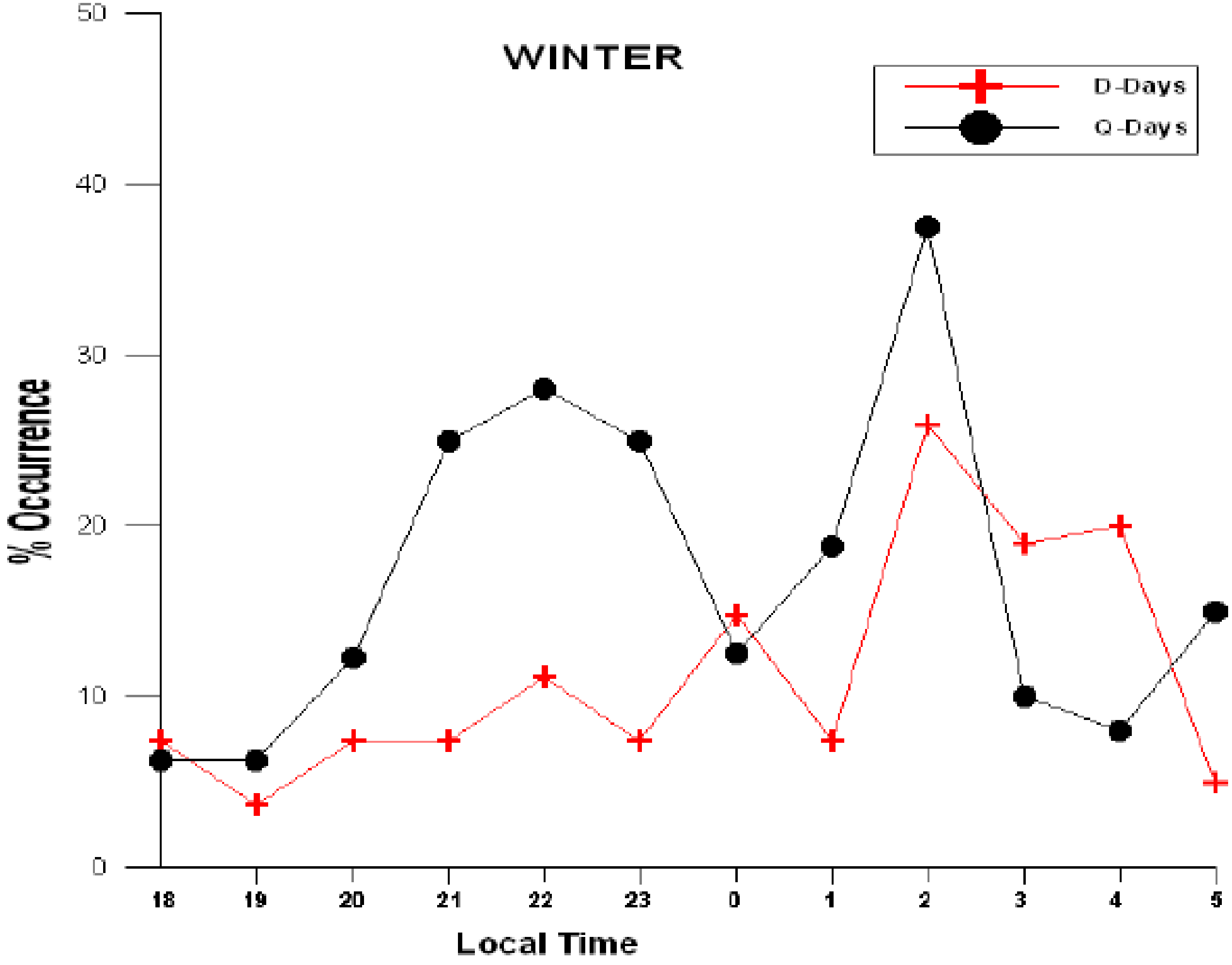




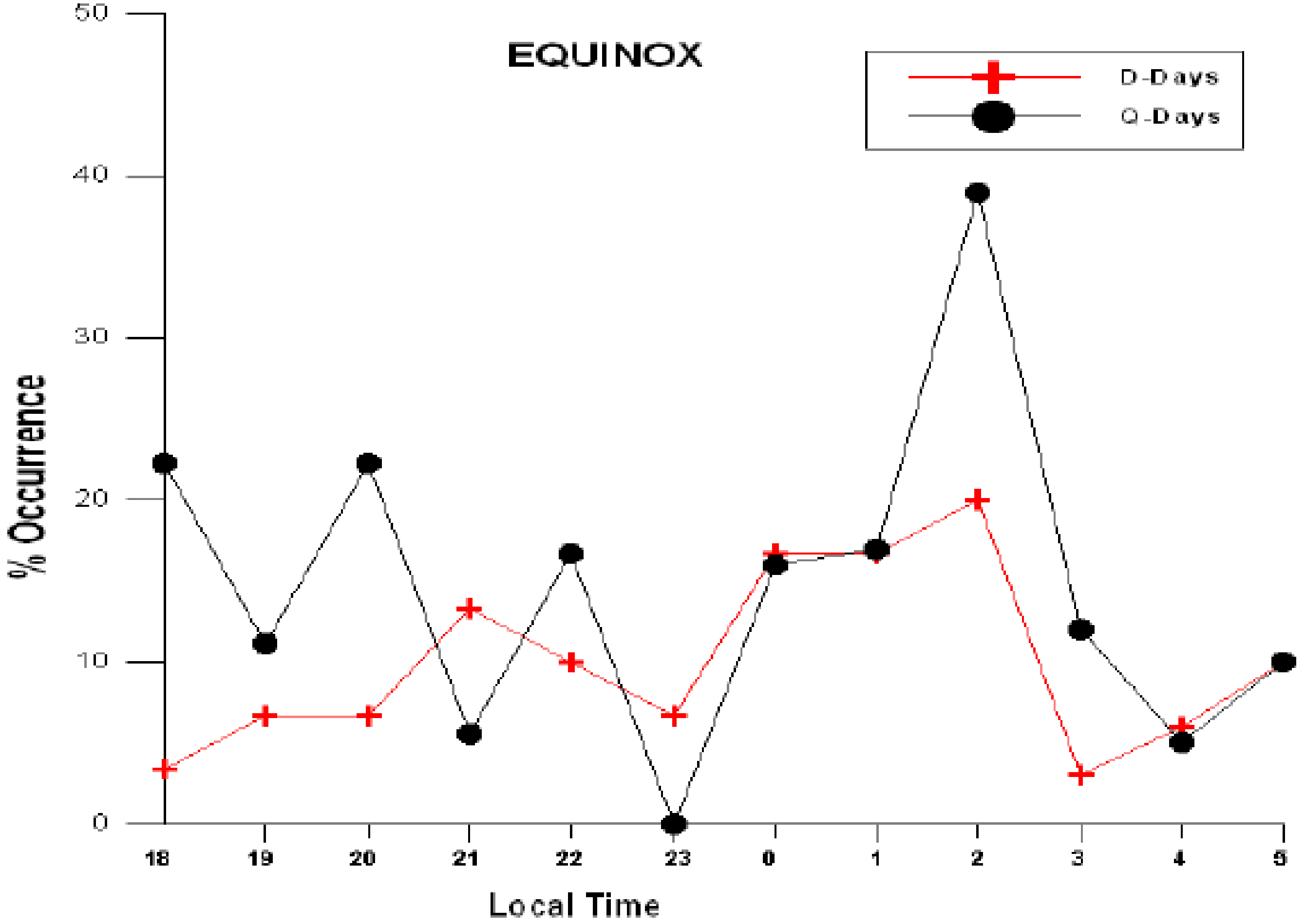
Percentage occurrence of nighttime TEC depletions for summer months during 2005-06



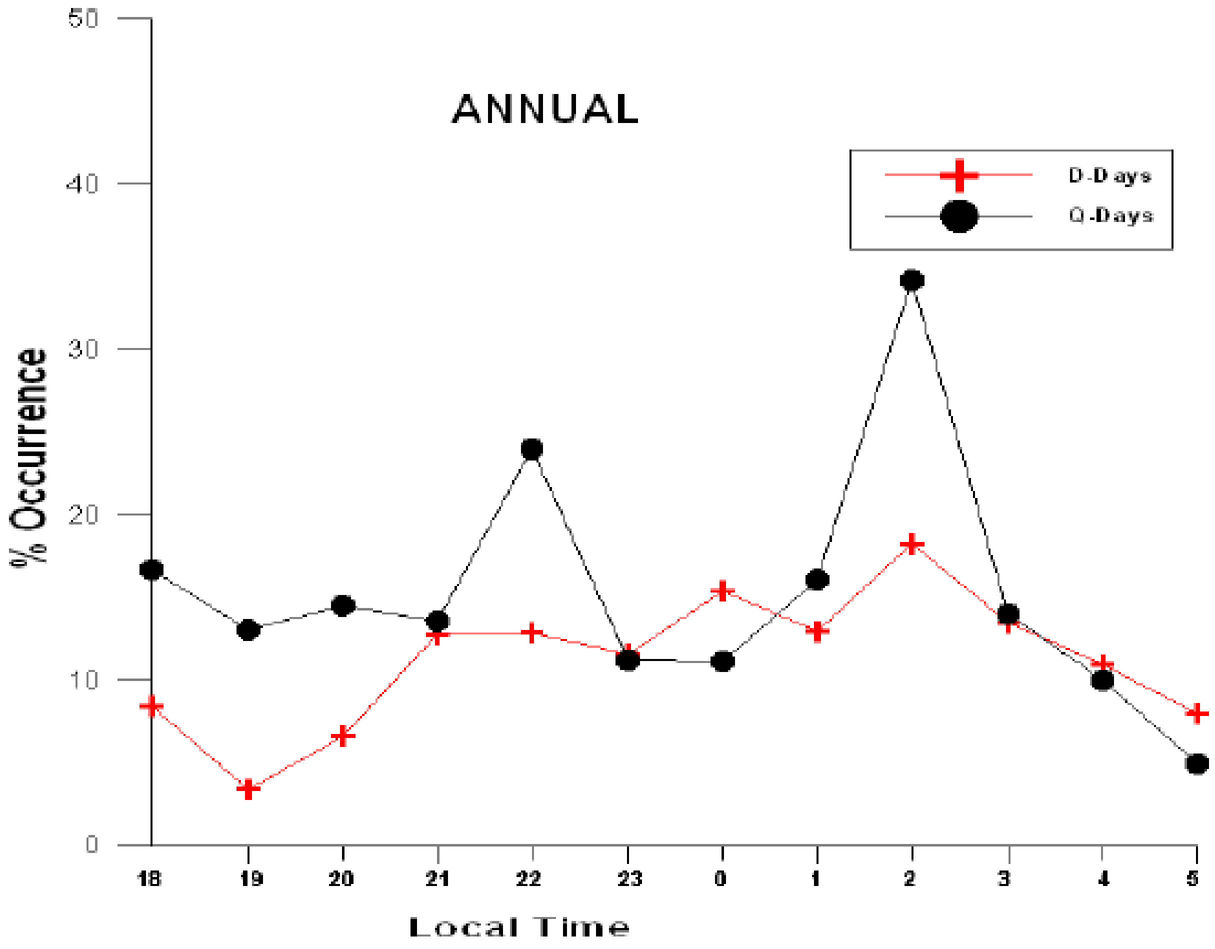
Percentage occurrence of nighttime TEC depletions for winter months during 2005-06



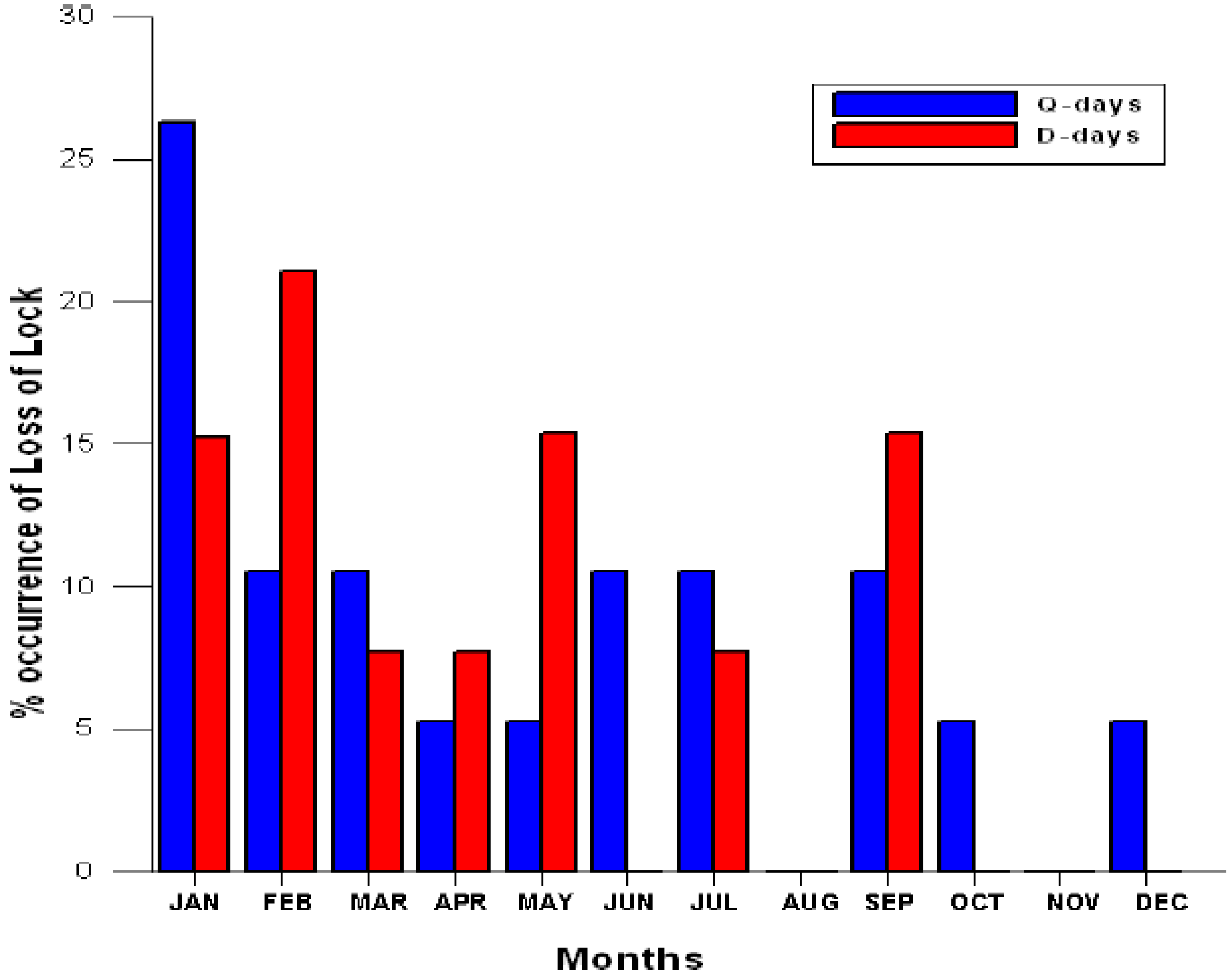
Percentage occurrence of nighttime TEC depletions for equinox months during 2005-06

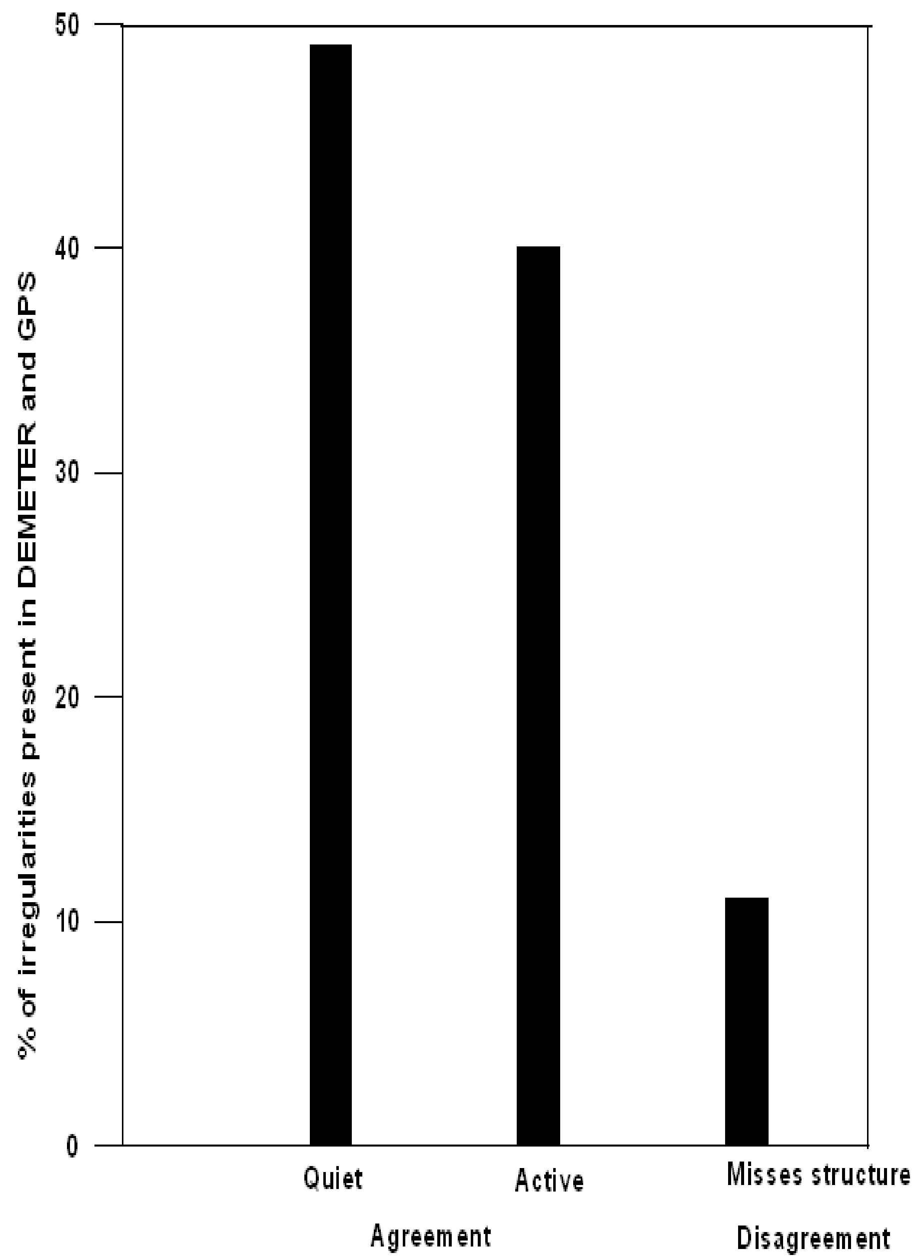


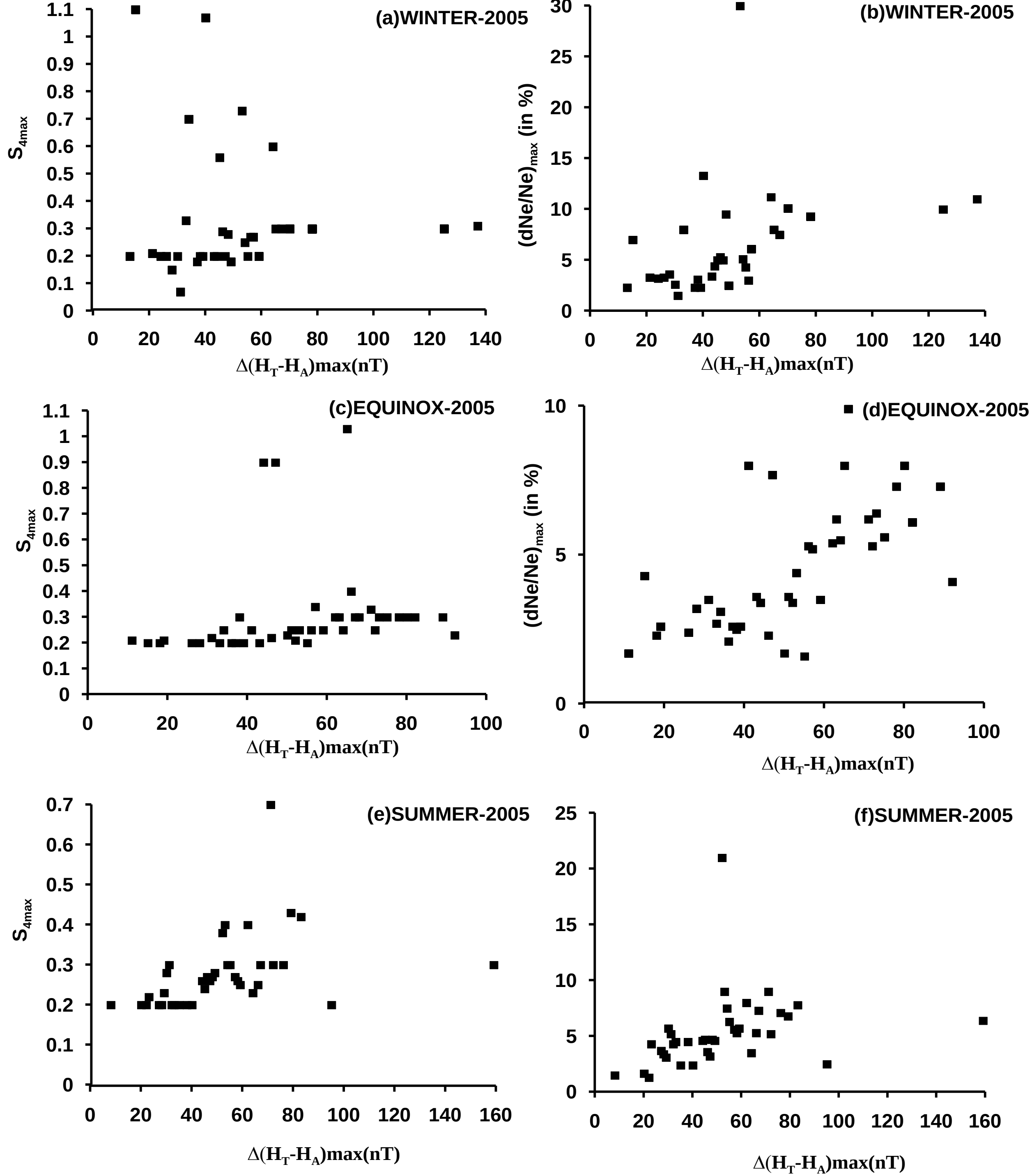
Annual variation of percentage occurrence of nighttime TEC depletion with local time for the year 2005-06



Percentage occurrence of Losses of lock occurred during 2005-06




% of irregularities present in DEMETER and GPS
50
40
30
20
10
0
Quiet
Active
Misses structure
Agreement
Disagreement



(a)WINTER-2005
S_{4max}
$\Delta(H_T-H_A)max(nT)$
(b)WINTER-2005
$(dNe/Ne)_{max}$ (in %)
$\Delta(H_T-H_A)max(nT)$
(c)EQUINOX-2005
S_{4max}
$\Delta(H_T-H_A)max(nT)$
(d)EQUINOX-2005
$(dNe/Ne)_{max}$ (in %)
$\Delta(H_T-H_A)max(nT)$
(e)SUMMER-2005
S_{4max}
$\Delta(H_T-H_A)max(nT)$
(f)SUMMER-2005
$\Delta(H_T-H_A)max(nT)$

Variation of S4 max and $dNe/Ne)_{max}$ with diurnal maximum value of $\Delta(H_T\text{-}H_A)$

$\Delta(H_T\text{-}H_A)_{max}$	MONTH	S4≥3	$(dNe/Ne)_{max}$ ≥5%
40nT	winter months	46% of nights	46% cases
<40nT	winter months	34% of the nights	8% cases
≥50 nT	equinox months	50% of nights	47% of the nights
<50 nT	equinox months	4% nights	8% of the nights
≥50 nT	summer months	50% of nights	66% of the nights
<50 nT	summer months	3% of the nights	6% of the nights

Results and Discussion (1/4)

- The presence of large depletions (plasma bubbles) is always accompanied with very fast increase in the S4 index (S4).
- The ROTI value shows the strength of irregularity this is confirmed by the sudden TEC depletion and increase in the S4 value.
- Hence ROTI can alone be used as the irregularity index.
- The losses of lock occur during the encounter of the irregularity and the signal strength degrades during the passes of the irregularity.

Results and Discussion (2/4)

- It is confirmed that north-south satellite trajectories show scintillations over a long period with transition from intense scintillation to no scintillations corresponding to crossing over the northern edge of the irregularity cloud
- The occurrence of depletion in TEC is found maximum in winter and minimum in summer.
- DEMETER observations show that irregularities extend from the trough to crest region with sharp gradients
- The scintillation events corresponded well with irregularity structures present on the DEMETER observations and can be attributed to plasma bubble activity.

Results and Discussion (3/4)

- During the low solar activity the ambient ionization is low and also the overall strength of the irregularities would be low. DEMETER satellite, too, at the height of 710 km has detected many irregularity structures during the solar minimum. Percentage occurrence of these irregularities along with L band scintillations is found to be 40% for the low solar activity year.
- The percentage occurrence of density irregularities and scintillation shows a good correspondence with EEJ strength however this varies with different seasons with maximum correspondence in summer (up to 66%) followed by equinox (up to 50%) and winter (up to 46%).

Results and Discussion (4/4)

- Also, there is a threshold value of EEJ strength to produce density irregularities ($(dNe/Ne)_{max} \geq 5\%$) and for moderate to strong scintillations ($S4 \geq 0.3$) to occur. In winter this value is around 40nT whereas for equinox and summer this value is around 50 nT.

Conclusion

- In conclusion, in situ satellite measurements can provide a huge data base for scintillation study with its global coverage and high sampling rate. GPS scintillation measurements have long been used to study the irregularity characteristics in different regions. In situ measurements help to study the F-region irregularities at the apex height of 700-800 km in different longitude regions.

Acknowledgements

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THANK YOU