Overview of Space Weather studies using GNSS/NavIC

Dr. Nirvikar Dashora
National Atmospheric Research Laboratory
Department of Space, Govt. of India
Gadanki-517 112, India
Email - ndashora@narl.gov.in

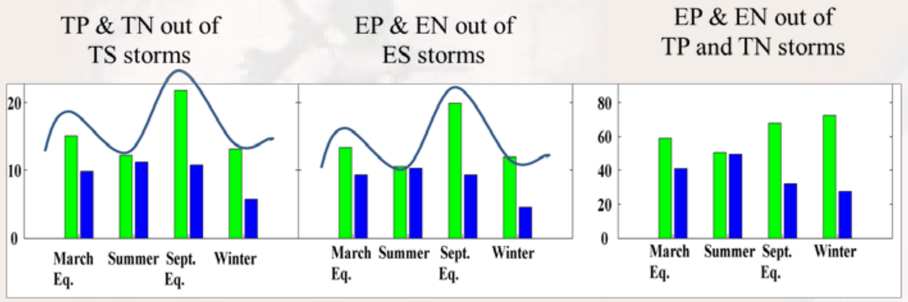
Outline

- Ionospheric storms in equatorial and low latitudes
  - GPS-TEC Network observations
  - NavIC-TEC observations
- Effect of scintillations on precise positioning
- NARL network of GNSS/NaVIC receivers
- Feed-back between research and applications as way forward

Ionospheric storms in equatorial and low latitudes

1. Climatology of Ionospheric response 1998-2018

Occurrence statistics show seasonal character in positive and negative responses



- ✓ Seasonal Background modulates the Storm effects.
  Russel-McPherron effect and semi-annual anomaly

- ✓ Mean amplitude of TEC perturbation varies

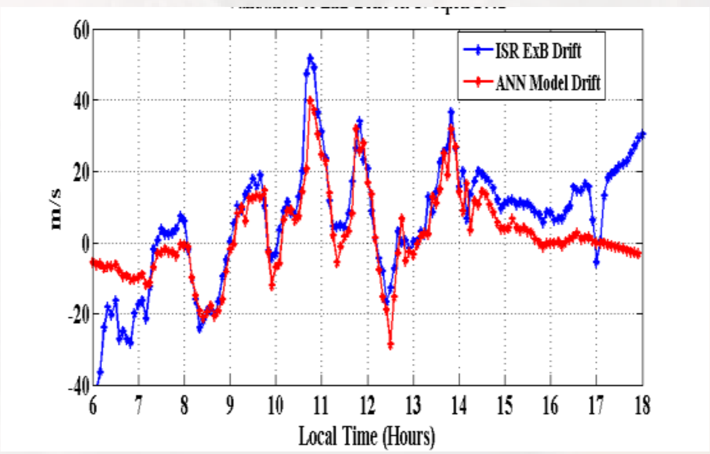
Major Storms	Dst<-200 nT	up to 25 TECu
Moderate storms	-100<Dst<-200 nT	up to 18 TECu
Minor storms	-50<Dst<-100 nT	up to 11 TECu

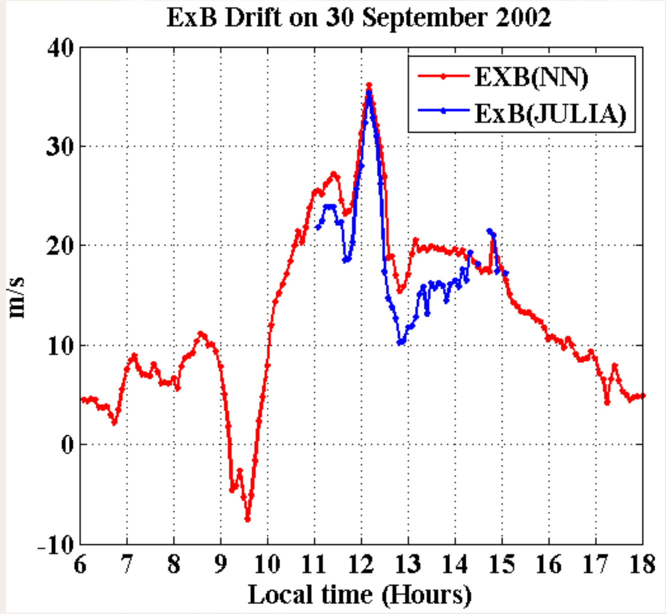
- ✓ Afternoon durations show more impact on ΔTEC in low latitudes

2. New Model for Equatorial vertical ExB drift

- ✓ Neural network model for ExB drift using 16 years of observations from Jicamarca radar, Peru and magnetometer observations
- ✓ The first model which works for Space Weather durations.

Validation of new ExB Drift Model





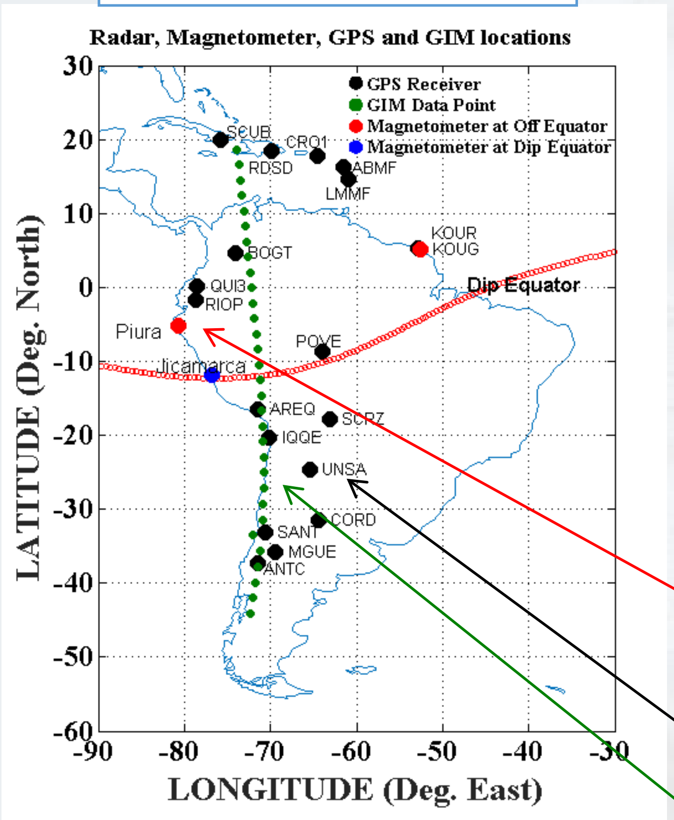
Dashora et al., 2019, JGR

- ✓ The model is able to reproduce the space weather effect in equatorial ionospheric plasma drift.
- ✓ Effect of prompt penetration electric field are used in later studies.

3. Study of 37 intense geomagnetic storms and equatorial and low latitude responses

Black arrow show sudden change in diurnal TEC due to storm processes

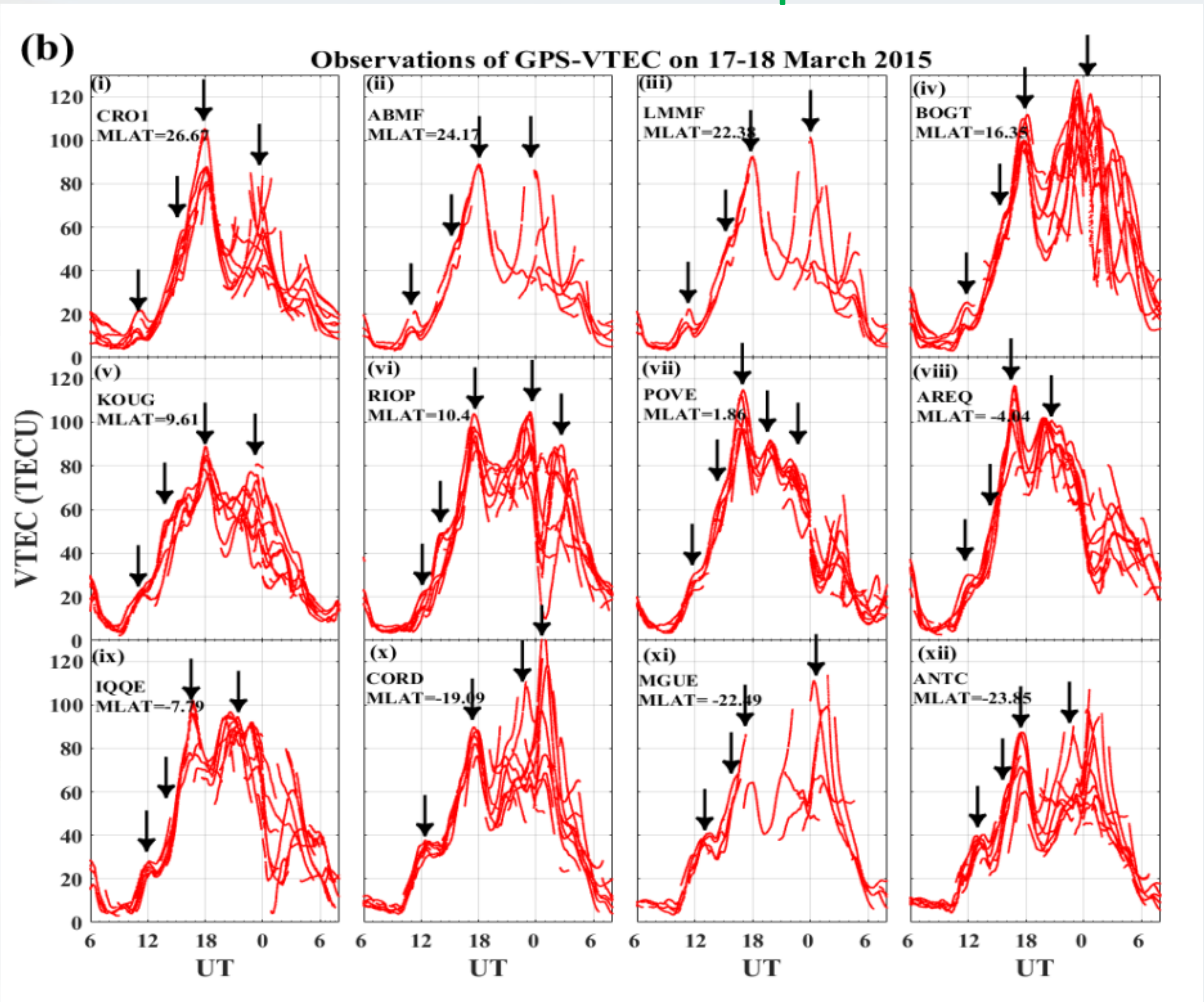
Data and Method



Simultaneous long term observations across the dip equator from the South American sector

From Years 2000 to 2018

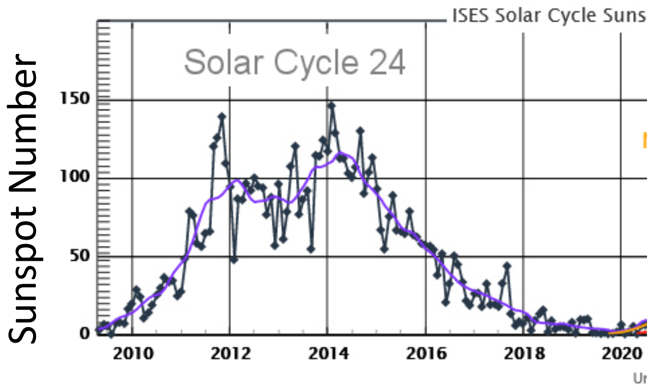
1. ACE Observations : IMF Bz and IEF Ey
2. SYM-H and ASYM-H indices
3. Vertical ExB drift from Jicamarca ISR and JULIA - DAYTIME
4. ANN model to derive ExB drift using Delta-H.
5. Delta-H from magnetometers at Jicamarca and Piura/Kourou
6. Observation of GPS – TEC (15-20 sites)
7. Global Ionospheric Maps - VTEC



Dashora et al., 2019, JGR

NavIC dual frequency receiver – Installed at Gadanki in 2016.

Space Weather events: Solar activity has been decreasing since 2016, yet a few intense storms have occurred.



Estimation of TEC using NavIC

L5 frequency = 1176.45 MHz

S-band frequency = 2492.02 MHz

(TEC=total electron content)

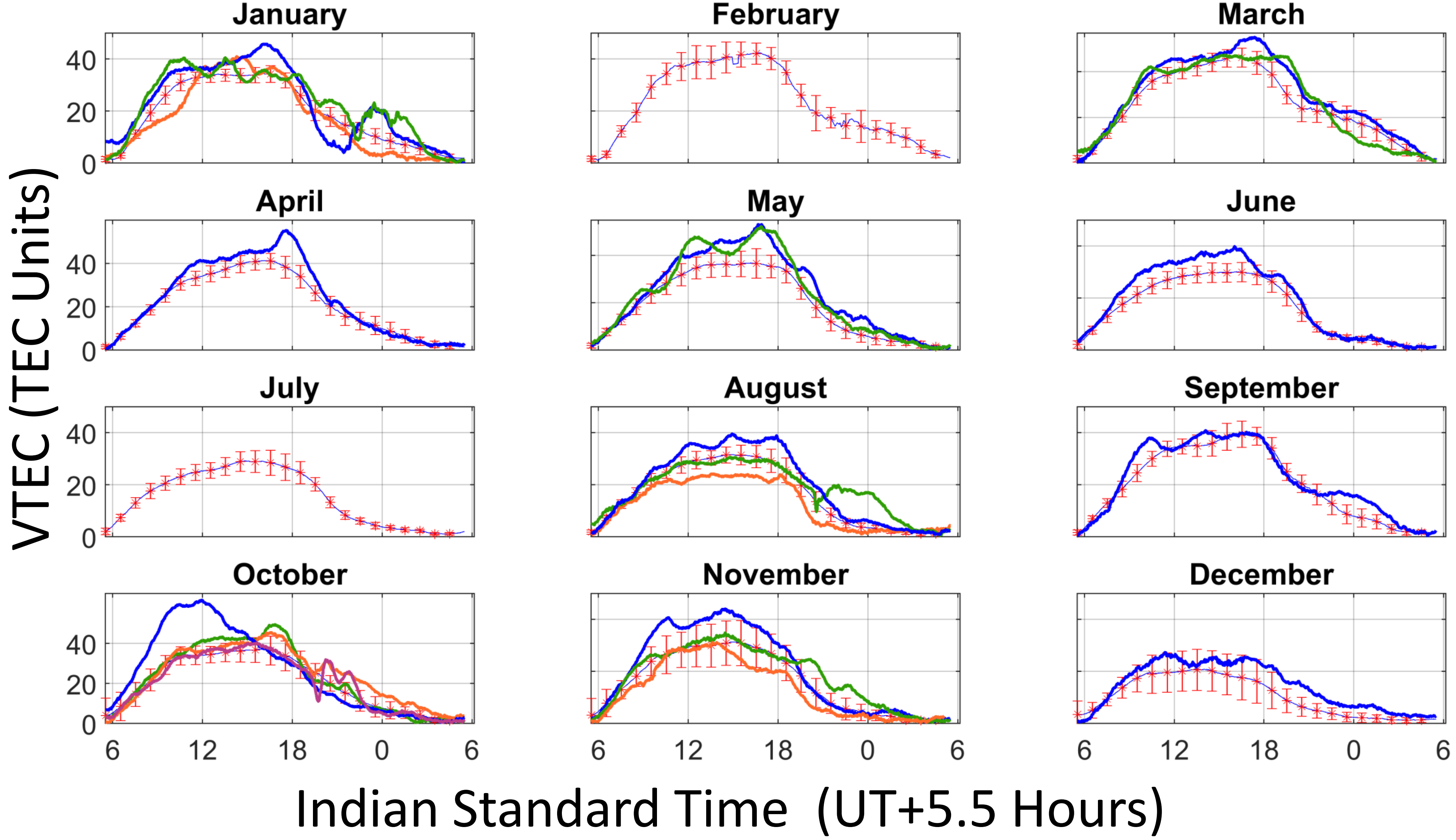
- TEC from both the CODE pseudorange and phase measurements is computed using ionospheric combination.
- The absolute TEC is obtain after leveling the Phase TEC and correcting for the differential code biases (DCB).
- Vertical TEC (VTEC) = Line of sight TEC x Mapping function (elevation, 350 km layer)

Monthly mean VTEC for each satellite is computed

VTEC on Stormy days is plotted.

NavIC Observations from NARL, Gadanki, India : 2016 to 2021

Year 2016



1 meter = 4.09 TECU for L5 and S-band diff. delay

Continuous observations Year 2016. Background mean VTEC changes with season

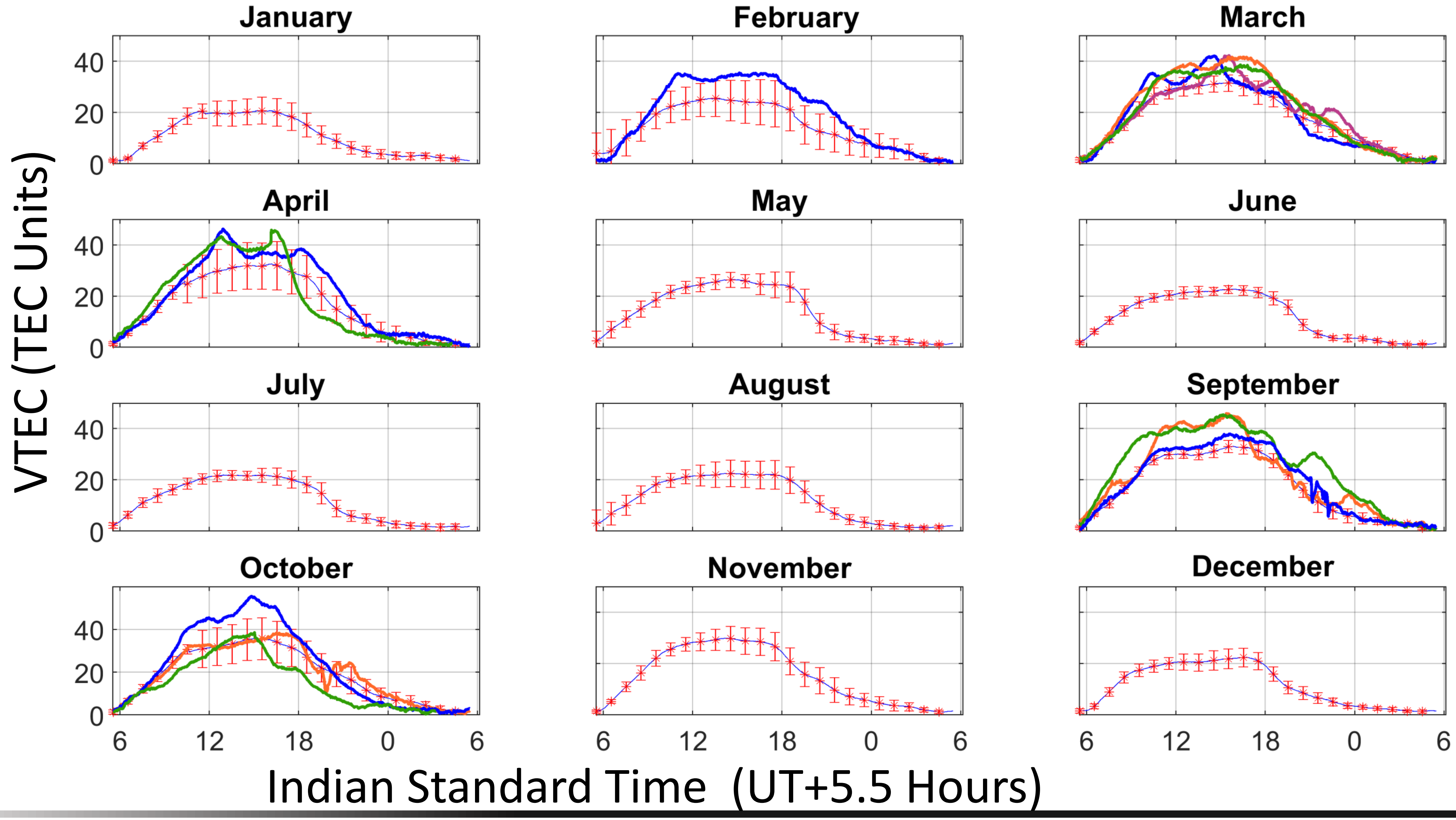
VTEC on the days of Geomagnetic storms is plotted in each month.

ΔTEC in low latitudes Each storm show different impact.

Dashora and Sethi, Under review, 2021

NavIC Ionospheric TEC during storms

Year 2017



Intense storms of Following days in months of

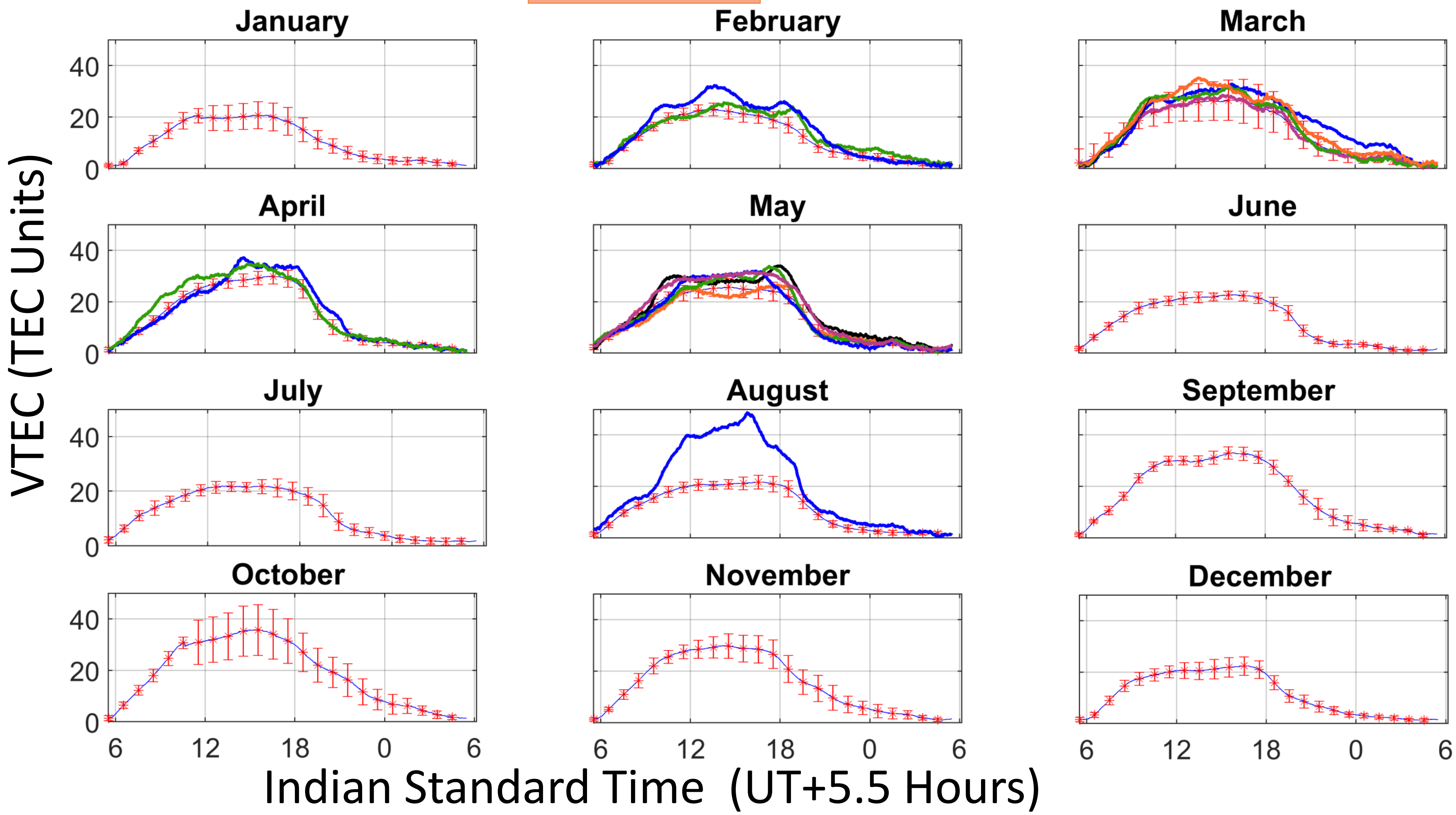
March (1, 27, 28)
April (5, 19)
September (8,9, 27)
October (11,24,26)

Enhancement and Decrements are observed and analyzed for each storm.

Dashora and Sethi, Under review, 2021

NavIC Ionospheric TEC Observations

Year 2018



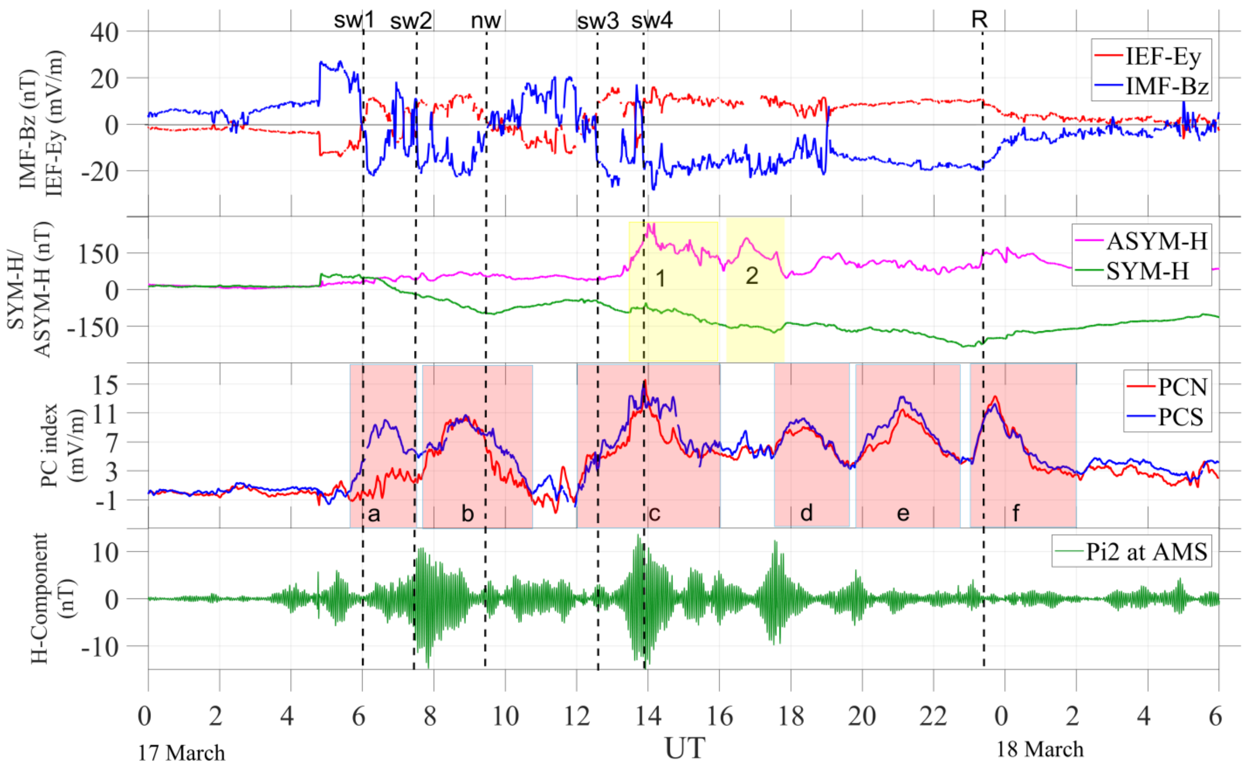
Intense storms of Following days in months of

February (27)
March (10,15, 18)
April (20,21)
May (5,6,7)
August (26)

More than 100% change is also observed

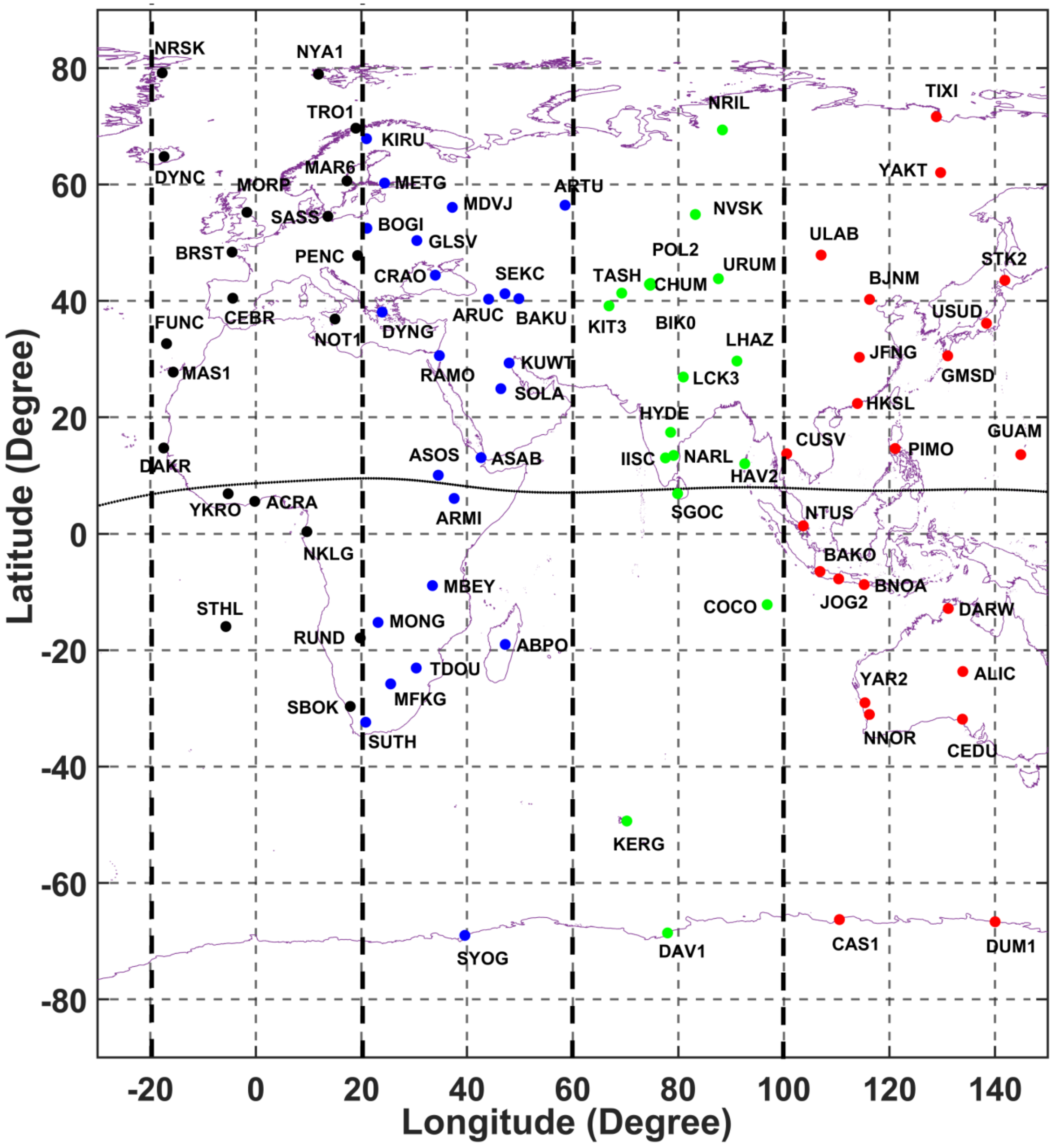
Dashora and Sethi, Under review, 2021

St Patrick's Day storm of 17-18 March 2015
Regional and global effects



The most severe geomagnetic storm of Solar cycle 24 with min. Dst index of ~ -223 nT.

Kader, Dashora et al., Under review, 2021

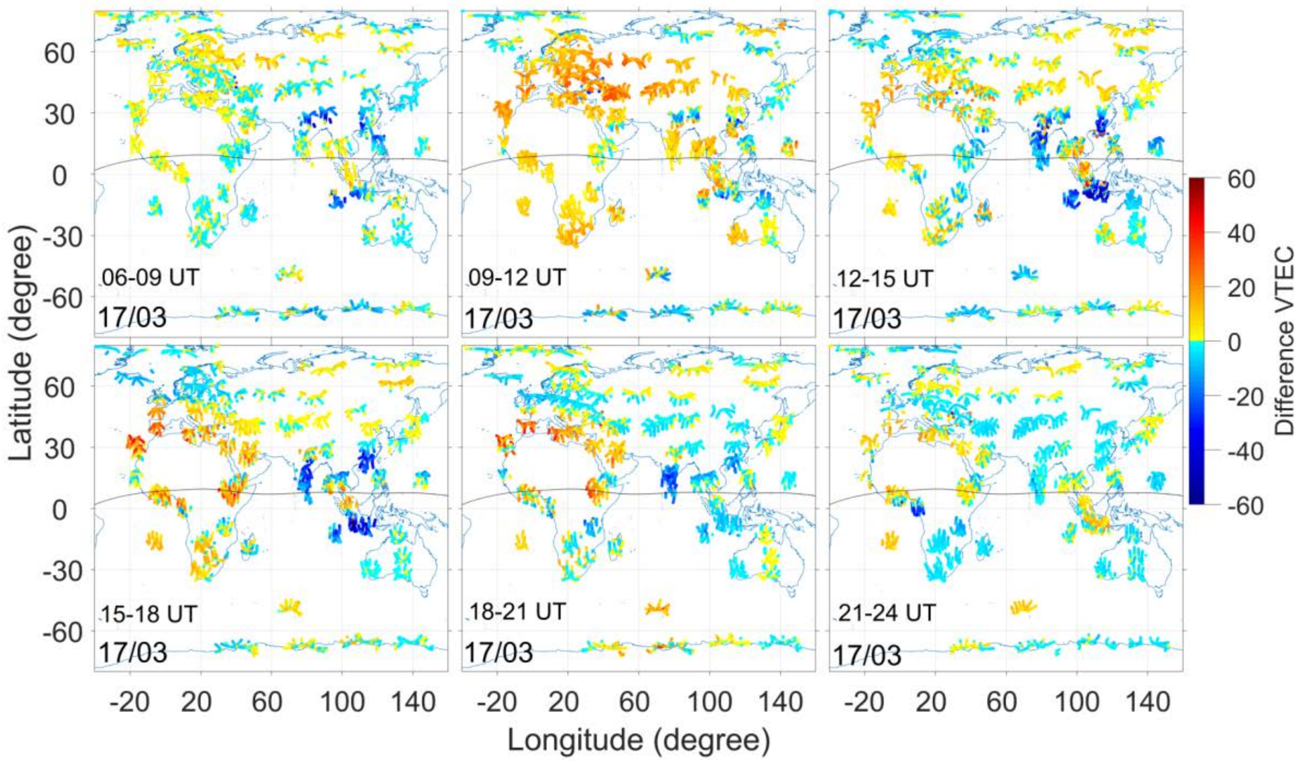


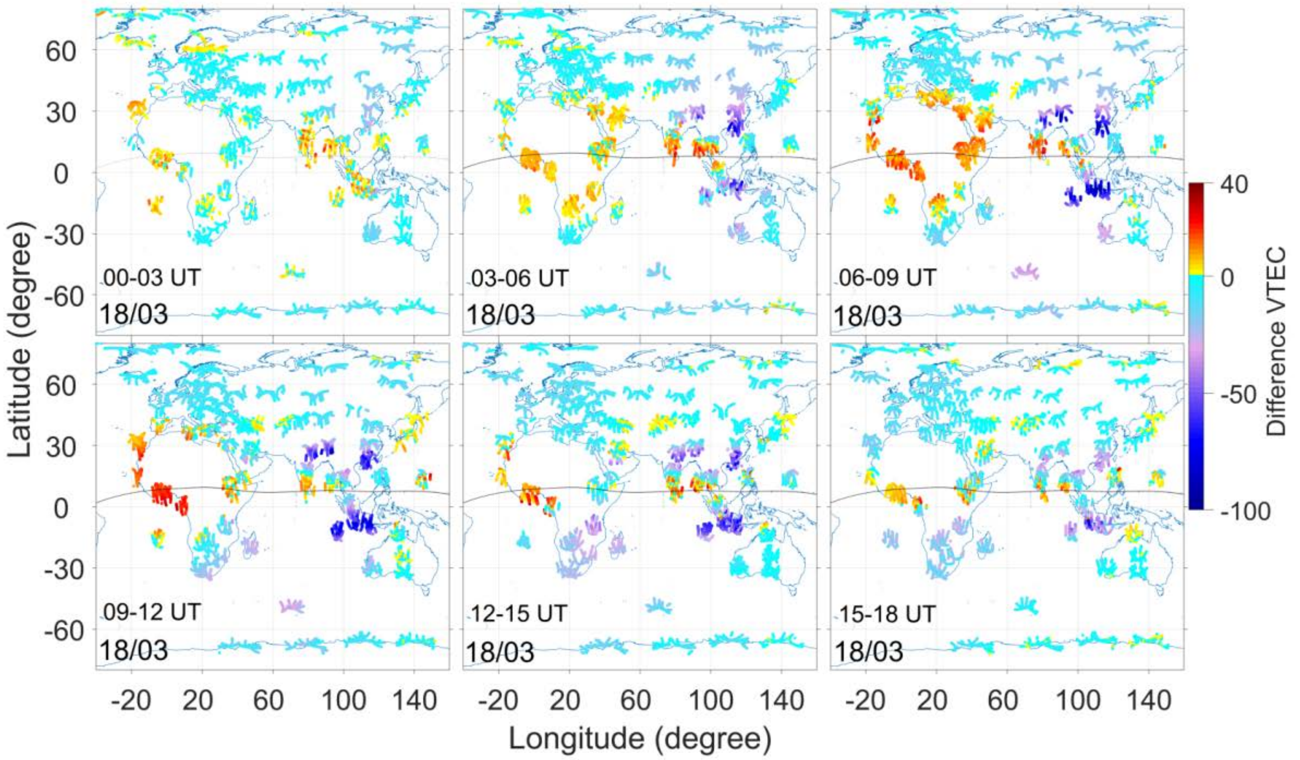
85 GPS stations

Asian
European

ΔTEC from GPS along with other satellite observations is analyzed.

St Patrick's Day storm of 17-18 March 2015
Regional and global effects





17 March 2015

- Daytime enhancement over the European and the African regions
- Night time depletions only over dip equator the Indian region

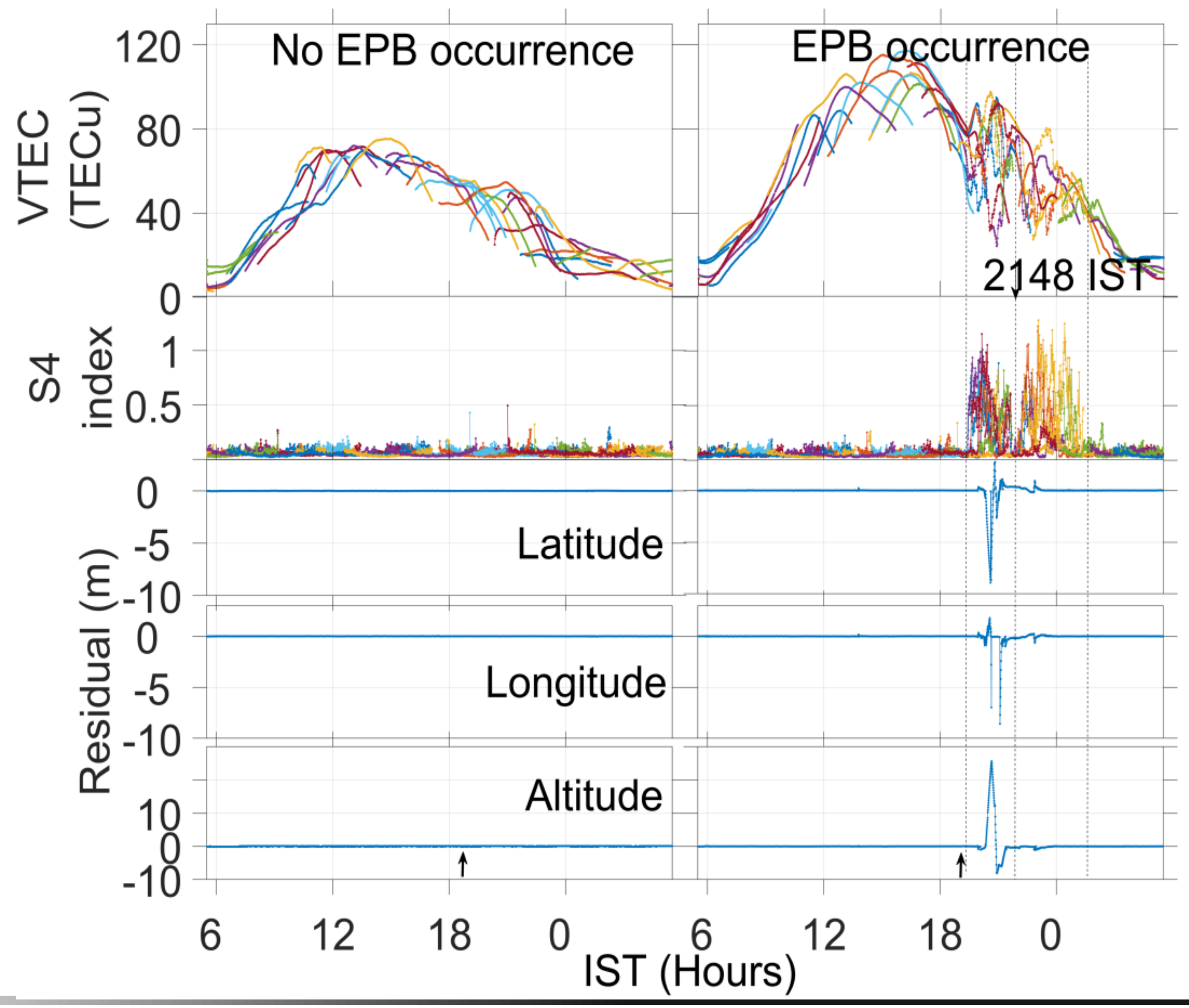
Kader, Dashora et al., Under review, 2021

18 March 2015

- Daytime enhancement persisted only over the African region
- Day time depletions traversed westward in afternoon sector.

Impact of Ionospheric Scintillations on Kinematic Precise Point Positioning (KPPP)

January 31, 2014 March 25, 2014



Observations using a

1. IGS reference station at Hyderabad , India ('HYDE' site)

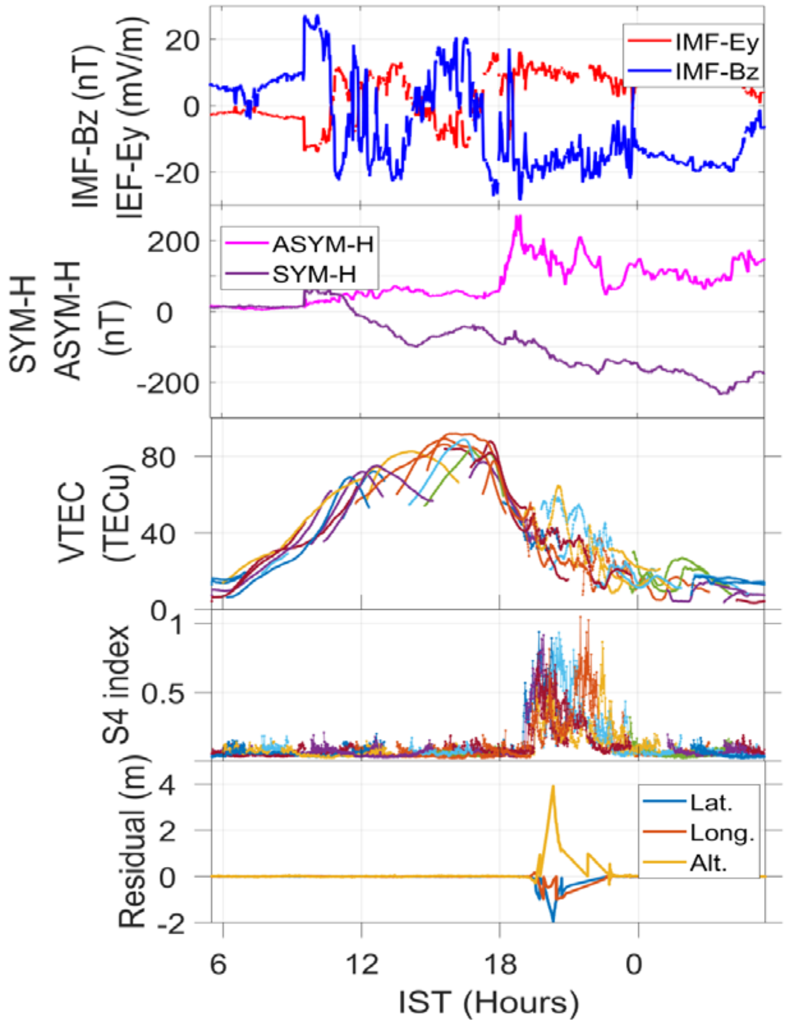
2. Scintillation monitoring receiver at Hyderabad (VBIT College)

No Scintillation night shows no impact on KPPP and residuals show mm accuracy

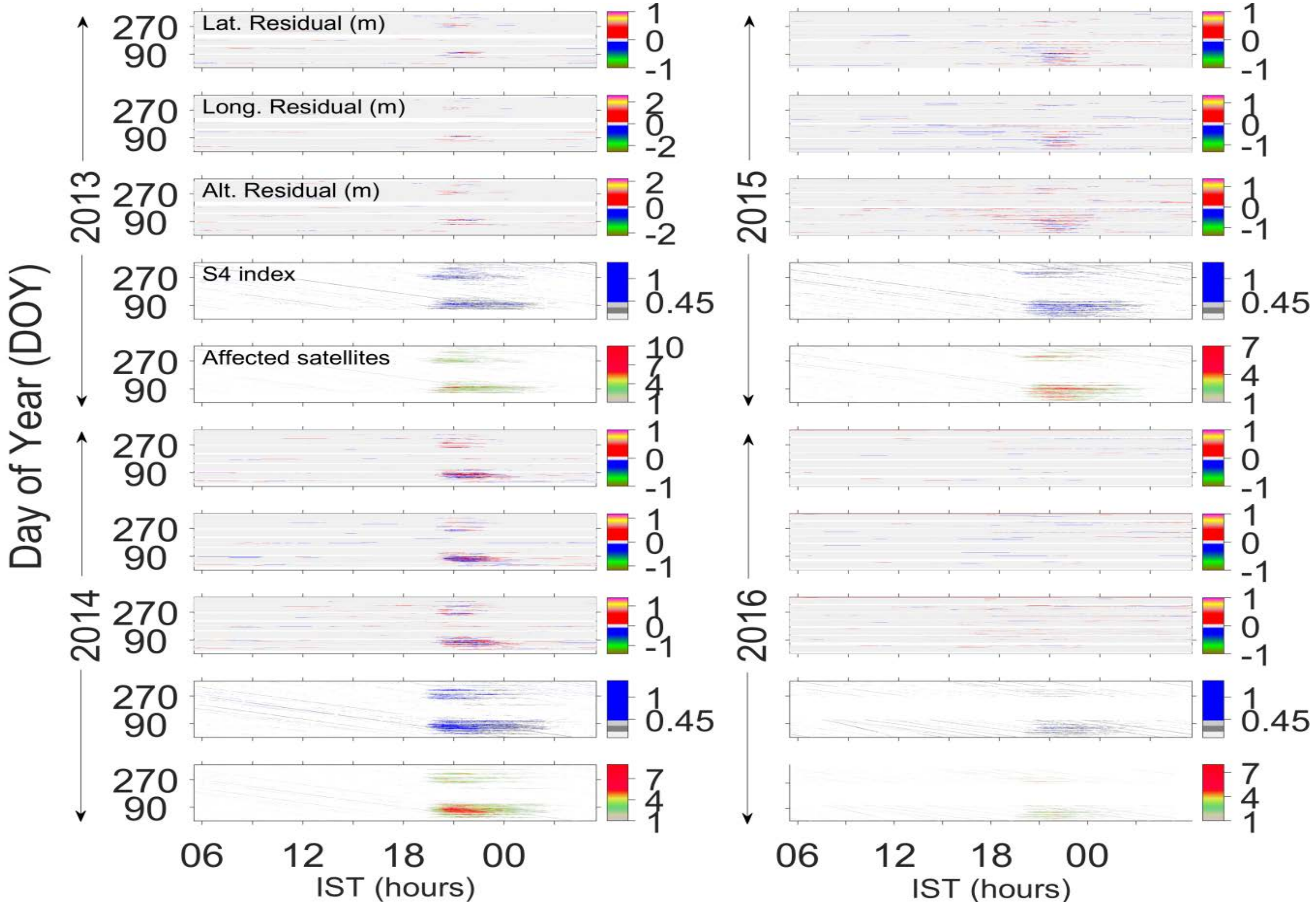
Scintillation night (post sunset) shows major impact on the KPPP residuals

Space weather and Solar cycle effect on Kinematic Precise Point Positioning (KPPP)

Space Weather Extreme Scintillations 17 March 2015



Solar cycle variation in error in KPPP



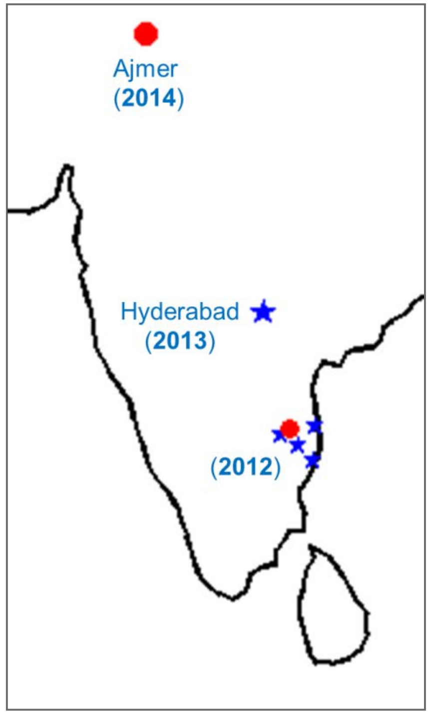
Yousuf, Dashora et al., Under Review, GPS Sol., 2021

NARL GNSS/NavIC Network

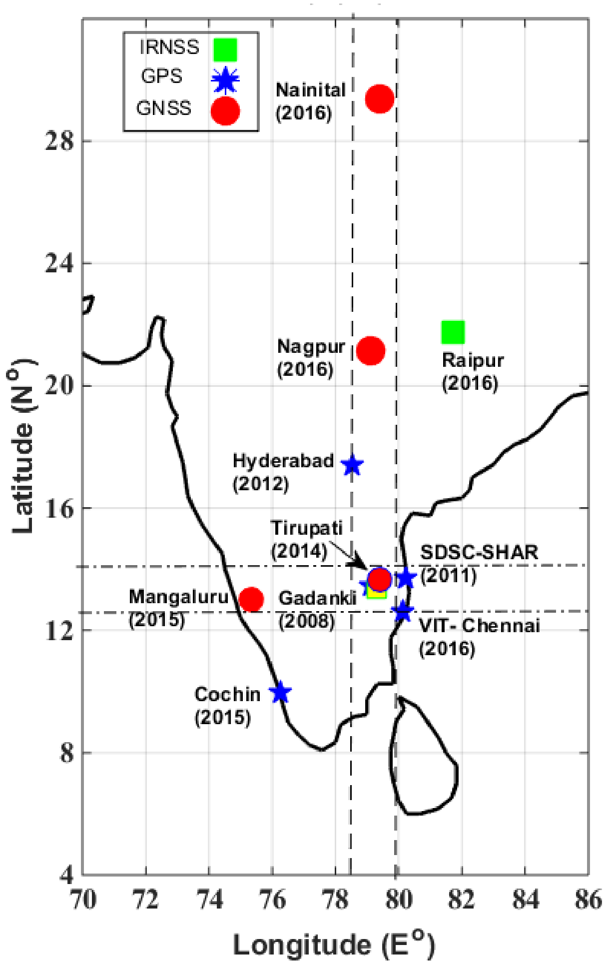
Scintillation Monitoring
ISMR Receivers
Novatel GSV4004B +
Septentrio Polarx S

Present Status and Plan
NARL Network

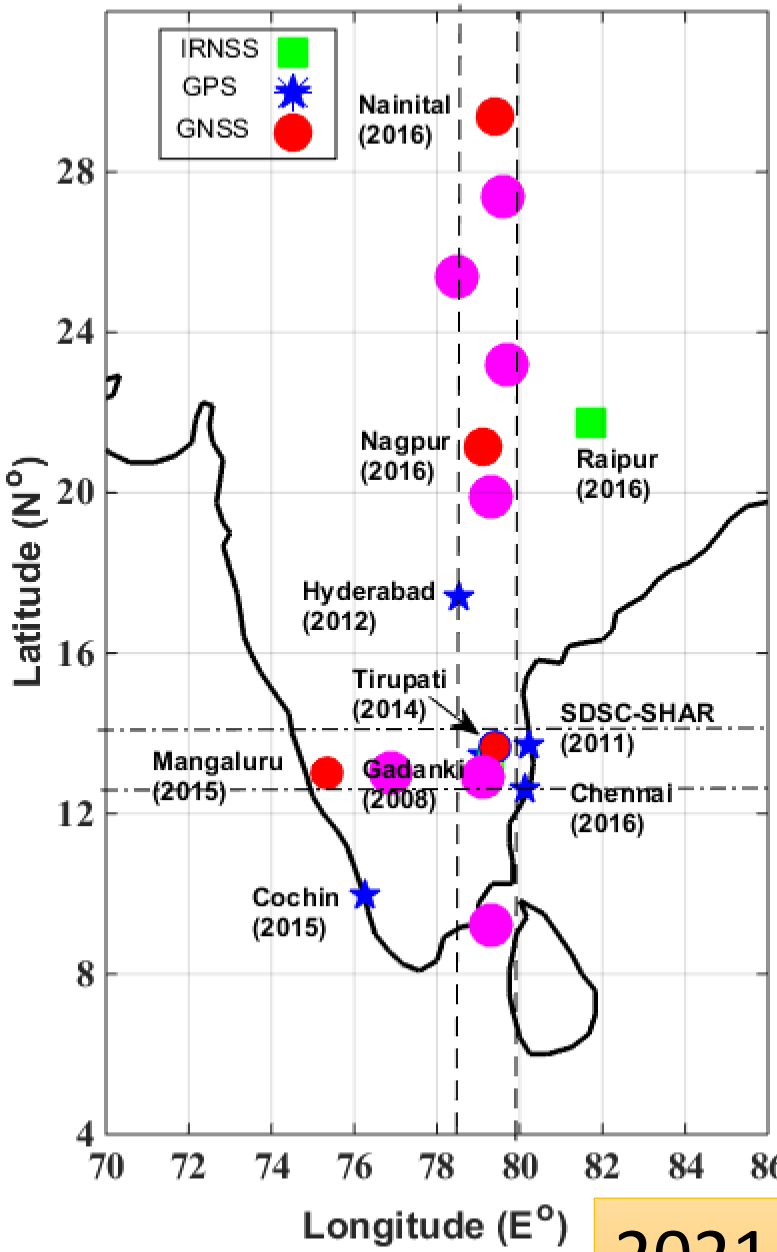
2012



2014



2016



2021-22

Positive Feed back loop

This works as a positive feedback loop for Science and Navigation applications that demand precise positioning

Science/Research

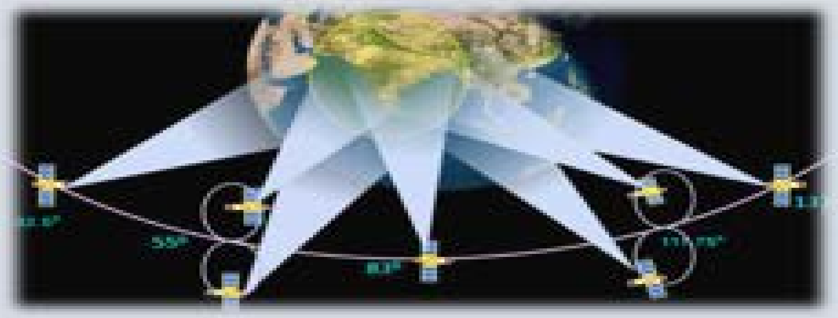
- Earth Sciences
- RS-GIS
- High resolution imaging of
  1. Ionosphere Plasma
  2. Tropospheric Water vapor

DATA/Observations

Raw data
Quality Checks
Processed data
Algorithms and Techniques

Applications

Satellite Navigation,
Geodesy,Surveying and
so many more ….


Thank You