Overview of Space Weather studies using GNSS/NavIC

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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
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 \( \text{Dst} < -200 \text{ nT} \) up to 25 TECu
  - Moderate storms \( -100 < \text{Dst} < -200 \text{ nT} \) up to 18 TECu
  - Minor storms \( -50 < \text{Dst} < -100 \text{ nT} \) up to 11 TECu
- Afternoon durations show more impact on \( \Delta \text{TEC} \) 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

- 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.

Dashora et al., 2019, JGR
Ionospheric storms in equatorial and low latitudes

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

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

Black arrow show sudden change in diurnal TEC due to storm processes
NavIC Observations from NARL, Gadanki, India: 2016 to 2021

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 obtained 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

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

VTEC (TEC Units)

Year 2016

January
February
March
April
May
June
July
August
September
October
November
December

Indian Standard Time (UT+5.5 Hours)

1 meter = 4.09 TECU for L5 and S-band diff. delay
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 Decrement 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
The most severe geomagnetic storm of Solar cycle 24 with min. Dst index of ~ -223 nT.

Kader, Dashora et al., Under review, 2021
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

18 March 2015
• Daytime enhancement persisted only over the African region
• Day time depletions traversed westward in afternoon sector.

Kader, Dashora et al., Under review, 2021
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
Scintillation Monitoring
ISMR Receivers
Novatel GSV4004B +
Septentrio Polarx S

Present Status and Plan
NARL Network

IRNSS
GPS
GNSS

Ajmer (2014)
Hyderabad (2013)
(2012)

Nagpur (2016)
Hyderabad (2012)
Tirupati (2014)
Mangaluru (2015)
Cochin (2015)
Gadanki (2016)
VIT, Chennai (2016)

Nainital (2016)
Raipur (2016)
Nagpur (2016)
Hyderabad (2012)
Tirupati (2014)
SDSC-SHAR (2011)

2012
2014
2016
2021-22
This works as a positive feedback loop for Science and Navigation applications that demand precise positioning.
Thank You