Characteristics of Storm-time TEC variations observed over the Equatorward-end of the Mid-latitude regions

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Presentation Outline

- Background
- Progress - instrument deployment in Zambia
- Project objectives
- Results and - outcomes
- Observations and Summary

development of space weather models requires well defined & characterised latitude regions
.. why it’s important

Outline

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Development of space weather models requires well defined & characterised latitude regions
Transition between latitude regions...

-180˚ −180˚ −150˚ −150˚ −120˚ −120˚ −90˚ −90˚ −60˚ −60˚ −30˚ −30˚ 0˚ 0˚ 30˚ 30˚ 60˚ 60˚ 90˚ 90˚ 120˚ 120˚ 150˚ 150˚ 180˚ 180˚

Different regions: different phenomena broadly categorized as high (±55 to 60˚), mid (±30 to 55˚), and low latitudes (−30 to 30˚ or −15 to 15˚). The physics of each region is different.

Instruments deployed over the African sector since 2007.
Transition between latitude regions...

...different regions different phenomena

- Broadly categorised as high (±55 to 60°), mid (±30 to 55°) and low latitudes (−30 to 30° or −15 to 15°) ??
- the physics of each region is different
- instruments deployed over the African sector since 2007
since 2007 - IHY campaign (UNACO & SA networks)
GNSS receivers in Zambia
...with instruments along a selected meridian
March 07 - 13 storm

![Graph showing Bz, Dst, TEC (TECU), and TEC deviations over time.](image)

- The graph displays the magnetic field strength (Bz) in nT, the Dst index in nT, TEC (TECU) values, and TEC deviations.
- The data is represented over a period from March 07 to 13, with UT hours from 00 to 00.

**Graph elements:**
- **Bz [nT]**
- **Dst [nT]**
- **TEC (TECU)**
- **TEC deviations**

**Legend:**
- zamb
- ERAS
- GRHM

**Date and hours (UT hour):**
- 07/03
- 07/03
- 08/03
- 08/03
- 09/03
- 09/03
- 10/03
- 10/03
- 11/03
- 11/03
- 12/03

**TEC deviations:**
- -20
- 0
- 20

**Note:**
- The graph provides a visual representation of the changes in magnetic field strength and other parameters during the March 07 - 13 storm.
global ionospheric models

- need to represent the various phenomena occurring in the different regions
- well defined transition from one geomagnetic latitude region to the other
representation of latitude regions in Models

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how is it done? is it just a line as boundary between latitude regions? geomagnetic regions tend to overlap - e.g. in during geomagnetic storms,
Project - objectives

Problem statement

- because the ionosphere exhibits different electron density gradients across the different latitude regions
- models need to be able to make the clear distinction between the different latitude regions during both quiet and disturbed conditions
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The main goal —>

to characterise the ionospheric variations over the low and the mid latitude regions thereby

- identifying the specific characteristics of the transition region between the two regions
...six (6) storms that occurred in 2012

- Analysis of a regional ionospheric response during six strong storms ($-200 \text{ nT} \leq Dst \leq -100 \text{ nT}$)
- Geographic latitudinal coverage of $10^\circ S - 40^\circ S$ within a longitude sector of $10^\circ E - 40^\circ E$. 
the GNSS data

- GNSS receivers used in this study
- example of TEC coverage at the IPP (April 24th) at 1000 UT averaged within 0.5° × 0.5° latitude-longitude bins.
April 7 - 13 storm

- IMF Bz (nT), SYM-H (nT) and AE indices;
- TEC (TECU) within 10 – 40°E longitude and 10 – 40°S latitude
- COSMIC $N_e$ distribution - altitude (50–600 km) for same geog location
- IEF (mV/m), equatorial $\Delta H$, TEC extracts at lats 35°, 25°, & 15°S
- COSMIC $N_e$ extracts at altitudes 210, 220, and 230 km
April 7 - 13 storm

- red dashed - main phase on set times 0420 UT and 0100 UT
- red solid - the shock time (11:03 UT) which led to the 9 March storm
- P1 and P2 peak occurrences in TEC at lats 35°, 25°, & 15°S
- P1C and P2C COSMIC $N_e$ at altitudes 210, 220, and 230 km
April 7 - 13 storm

Both 7 and 9 March 2012 storms caused positive storm phase

COSMIC data show enhanced $N_e$ with altitude during daytime on 9 March
April 7 - 13 storm

Fig 2d

- an enhancement of the eastward electric field (2f from about 0600 UT to 0900 UT) increased plasma uplift and further aided the expansion of the EIA toward midlatitudes thus contributing to the observed increased TEC values as far as 20°S geog lat
April 7 - 13 storm

Fig 2g

- A time shift in TEC peak occurrences at different selected latitudes on 9 March (about 08:57 UT at 35° & 25°S and later at 10:59 UT for 15°S) linked to passage of TIDs.
- COSMIC data revealed similar shift in Ne peak occurrences with respect to altitude.
April 7 - 13 storm

Fig 2g

- computed a TID velocity of $428 \pm 26$ m/s between 10:00 and 11:00 UT with a period of 1 h, gives $\lambda = 1540$ km

- calculated by tracking the TID wave front within a latitude range of $36^\circ - 22^\circ S$ over 1 h interval.
March 22 - 26 storm
A positive storm phase is observed on 24 April 2012 - TEC & $N_e$ remained enhanced during the main and recovery phases

an enhancement of COSMIC $N_e$ from lower regions (100 km) to over 550 km (Fig. 4d)
Global COSMIC $N_e$ and TEC maps (0000–1800 UT within altitude range of 250–450 km) for 25–26 April 2012.

Ionospheric map (IONEX) data (at 0800 UT, IPP of 450 km)
both show an increase on 25 April (compared to 26 April) over the region of interest

EIA expansion on 25 April 2012 beyond 15°S from the geomagnetic equator is clearly visible - reaching 30°S

General observations - summary

- Storms occurred during the same solar activity period and were all coronal mass ejection driven.
- Their impacts and associated features on the ionosphere found to be different due to different contributing factors to their driving mechanisms.
- All but one, characterized by positive storm effects during the main and (or) recovery phases.
- Common to all the analyzed storms - the presence of large-scale TIDs during the storm main phases.
- An attempt to use GNSS TEC and COSMIC RO $N_e$ to investigate meridional and vertical propagation of TIDs simultaneously during the strong storms.
- Shown that it's possible to identify vertical motion of TIDs using RO data in cases when equatorward TIDs, as revealed by GNSS total electron content data, are present.
Thank you

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Refs

- Habarulema *et al* 2016