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

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Presentation Outline

Outline

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

.. why it's important

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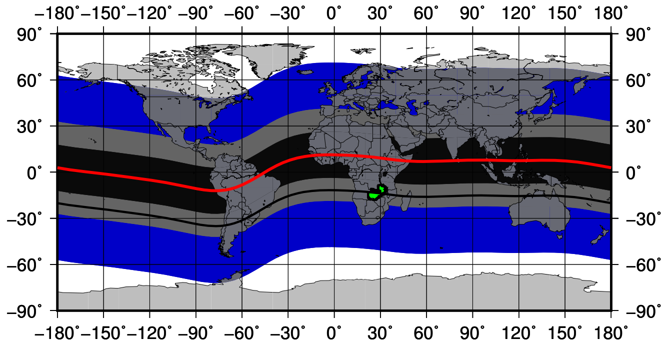
development of space weather models requires well defined & charecterised latitude regions

Model	Region	Data Base	Characteristics	Reference
ITS-79	Below *F2*	Ionosonde	Parabolic *E* and *F2* (Figure 6)	*Barghausen et al.* [*1969*]
RAL	Below *F2*	Ionosonde	Parabolic and linear segments, CCIR peaks (Figure 6)	*Bradley and Dudeny* [*1973*], *Dudeney* [*1978*]
IONCAP	Below *F2*	Ionosonde	Parabolic, linear, exp. segments, CCIR peaks (Figure 6)	*Teters et al.* [*1983*]
Rush - Miller	Full Profile	Ionosonde	Chapman, parabolic, hyperbolic secant, CCIR peaks	*Rush and Miller* [*1973*]
Bent	Full Profile	Ionosonde, Satellite (TS, In-situ)	Parabolic and exponential segments, CCIR peaks (Figure 5)	*Bent et al.* [*1972, 1976*], *Llewelyn and Bent* [*1973*]
ICED	Full Profile	Ionosonde, Satellite (TS)	Chapman profiles URSI-88 *foF2* model	*Tascione et al.* [*1988*]
RIBG	Full Profile	Composed of several models	ICED, *Bent, Gallagher et al.* [*1988*] models	*Reilly* [*1993*], *Reilly and Singh* [*2001*]
IRI	Full Profile	Ionosonde, Inc. Scatter Radar, Satellites (TS, in-situ), Absorp. Rockets,	Recommended by URSI and COSPAR for international use (Figure 7) ITU-R model	*Rawer et al.* [*1978, 1981*], *Bilitza* [*1990, 2001*]
DGR	Full Profile	Ionosonde	Epstein functions COST European model	*DiGiovanni and Radicella* [*1990*], *Radicella and Zhang* [*1995*]
NeQuick, COST prof, NeUoG-plas	Full Profile and Plasma-sphere	Ionosonde and VTEC	Epstein functions and plasmaspheric models COST European, ESA, and ITU-R models	*Hochegger et al.* [*2000*] *Radicella and Leitinger* [*2001*], *Leitinger et al.*, [*2002*]
Chiu	Full Profile	Ionosonde	Chapman layers, pheno-menological peak model	*Ching and Chiu* [*1973*], *Chiu* [*1975*]
Koehn-lein	Full Profile	Inc. Scat Radar, Satellites (in-situ)	Spherical harmonics	*Koehnlein* [*1989*]

Transition between latitude regions...



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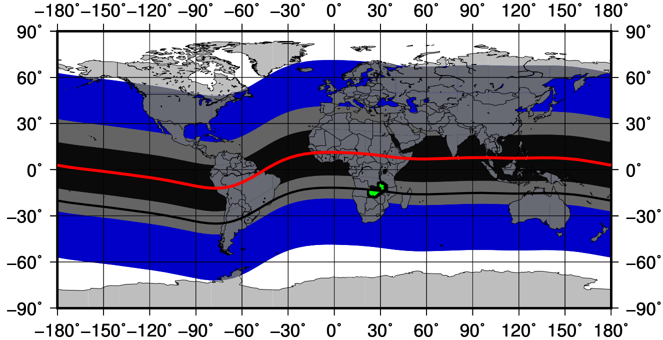
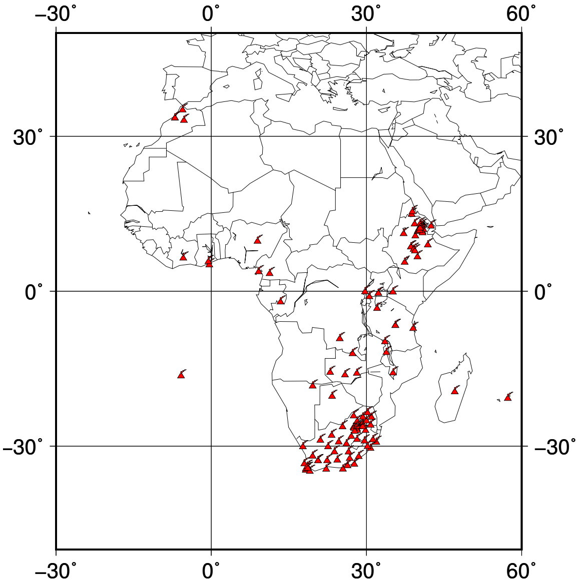


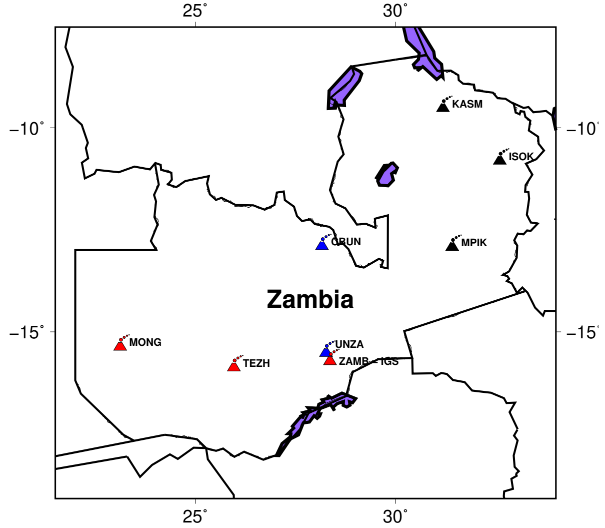
...different regions different phenomena

- 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

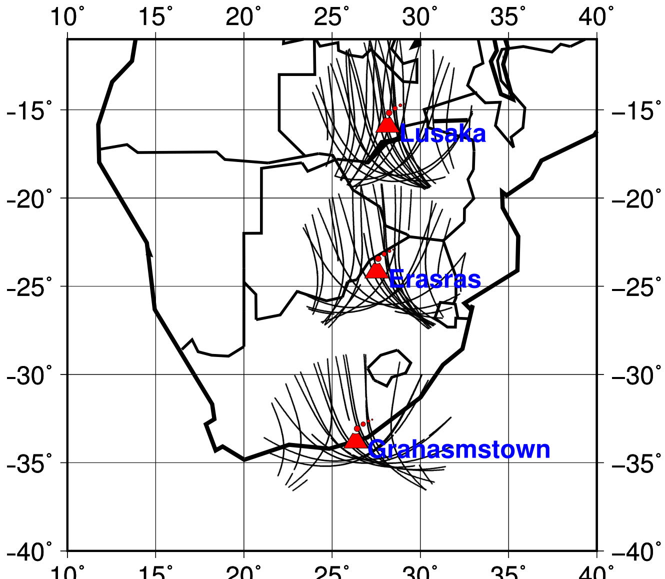
since 2007 - IHY campaign (UNACO & SA networks)



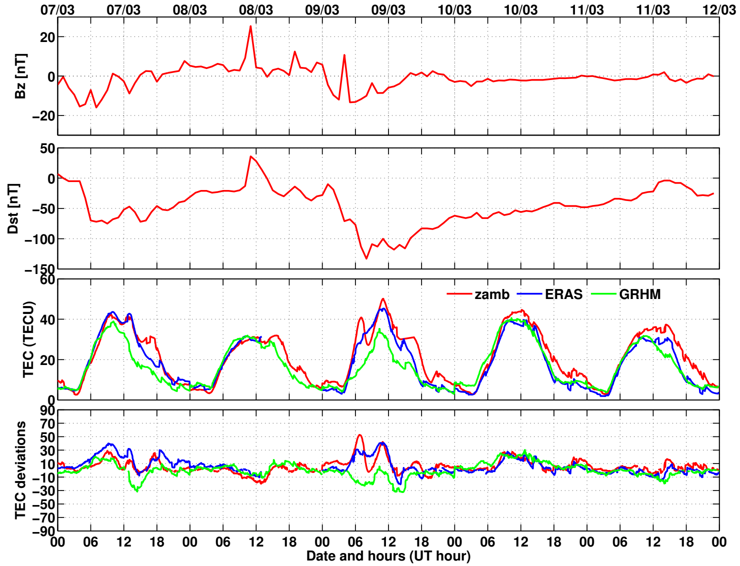
GNSS receivers in Zambia



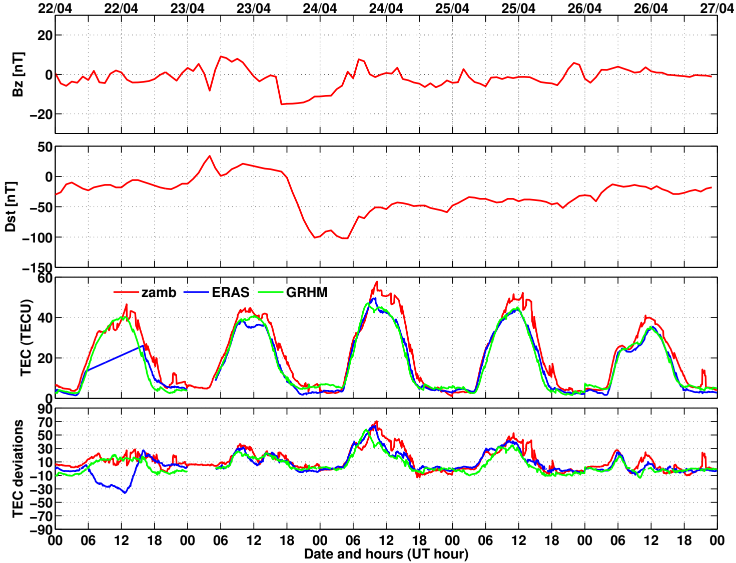
...with instruments along a selected meridian



March 07 - 13 storm



April 22 - 26 storm



representation of latitude regions in Models

..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

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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
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The main goal –>

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

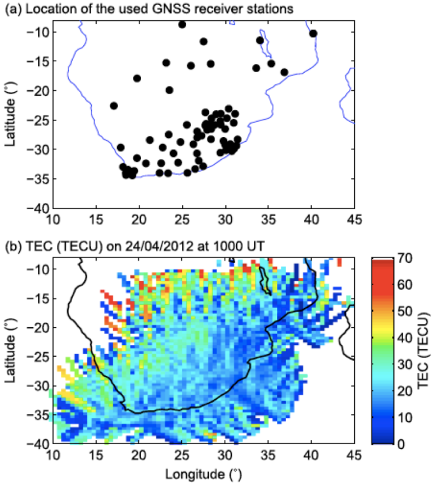
-> identifying the specific characteristics of the transition region between the two regions

Progress made - Project outcomes

...six (6) storms that occured in 2012

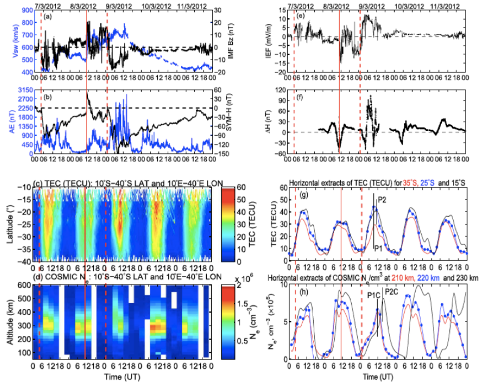
- analysis of a regional ionospheric response during six strong storms ($-200nT \leq Dst \leq -100$ nT)
- geographic latitudinal coverage of $10^{\circ}S - 40^{\circ}S$ within a longitude sector of $10^{\circ}E - 40^{\circ}E$.

the GNSS data



- GNSS receivers used in this study
- example of TEC coverage at the IPP (April 24th) at 1000 UT averaged within $0.5^\circ \times 0.5^\circ$ 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 $\triangle H$, TEC extracts at lats 35°, 25°, & 15°S
- COSMIC N_e extracts at altitudes 210, 220, and 230 km

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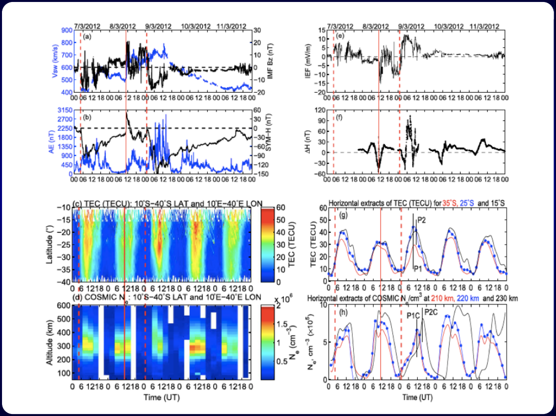


- red dashed - main phase on set times 0420 UT and 0100 UT
- red solid - the shock time (11:03 UT) which led to the 9 March storm
- P1 and P2 peak occurrences in TEC at lats 35°, 25°, & 15°S
- P1C and P2C COSMIC N_e at altitudes 210, 220, and 230 km

April 7 - 13 storm

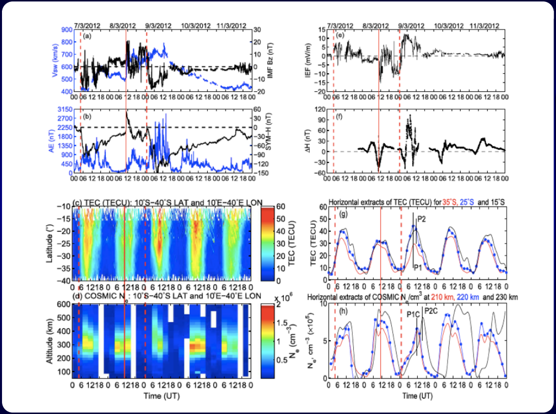


Fig 2c

- 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

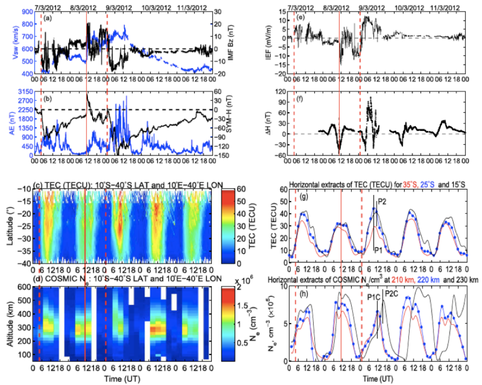


Fig 2d

- 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

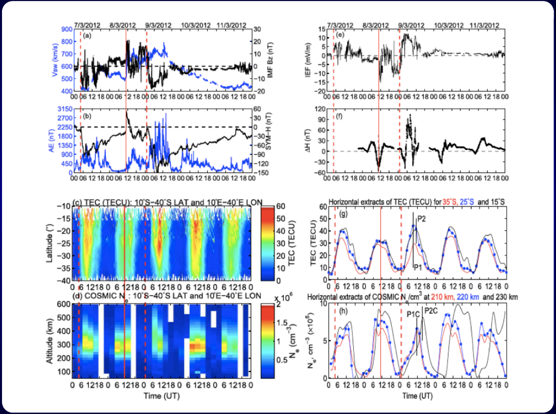


Fig 2g

- 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 N_e peak occurrences with respect to altitude.

April 7 - 13 storm

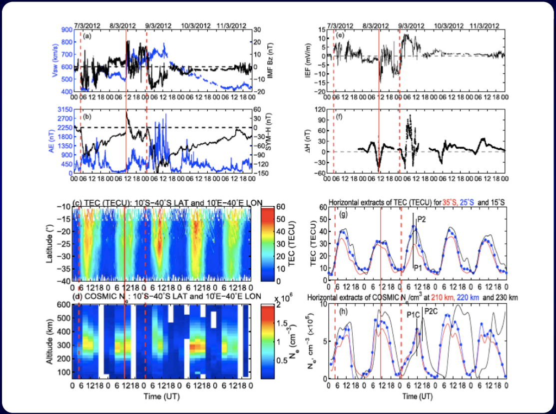
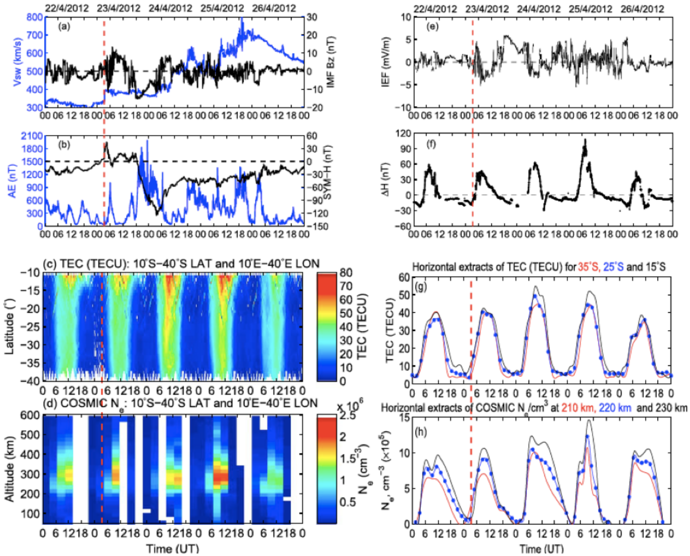


Fig 2g

- computed a TID velocity of 428 ± 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

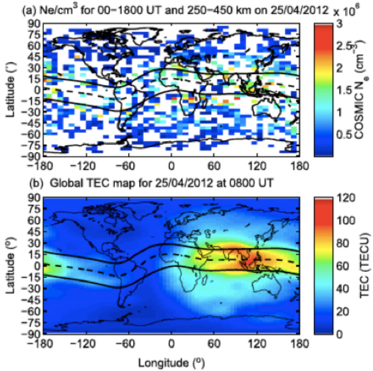


Mar 22 - 26 storm

...specific observations

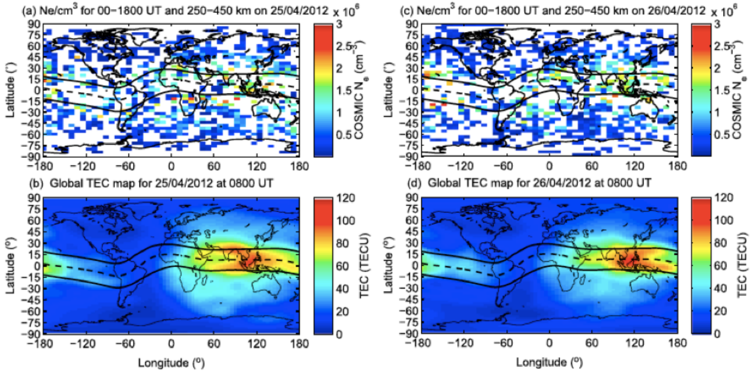
- A positive storm phase is observed on 24 April 2012 - TEC & N_e remained enhanced during the main and recovery phases
- an enhancement of COSMIC N_e from lower regions (100 km) to over 550 km (Fig. 4d)

the global picture



- 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)

the global picture



- 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

Special thanks to:

- The organisers of the workshop and cooperating partners for the support

Refs

- Habarulema *et al* 2016