Investigation of the Ionospheric Irregularities over the EIA region during intense space Weather events within the African sector

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Outline

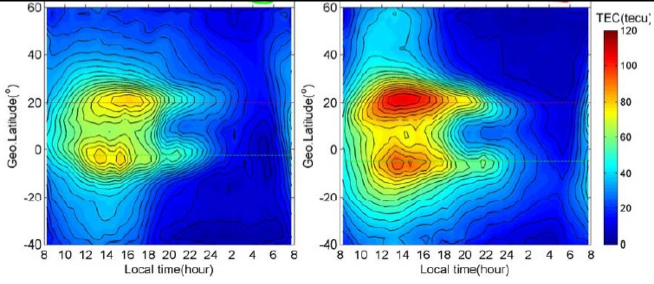
- Introduction
- The "Equatorial" region
- Some results and observations (model performance)
- Capacity building efforts
- Challenges and Summary

Introduction - the EIA

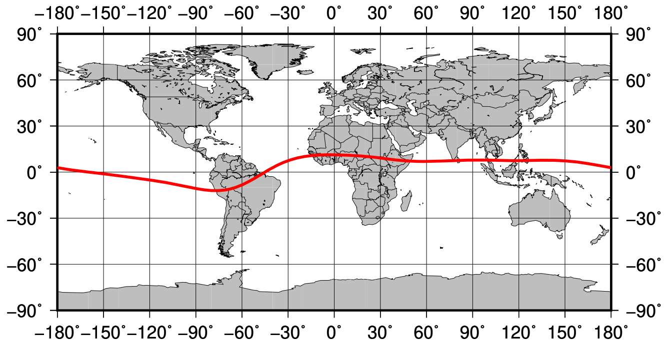
Investigation of the behavior of the ionospheric irregularities over the EIA

- electrodynamics of the ionosphere in the equatorial and low-latitude regions show dramatic changes especially during intense space weather conditions
- Equatorial ionization anomaly (EIA) - highly dependent on the daytime upward plasma fountain effect

The EIA - Biqiang Zhao *et. al., 2009*

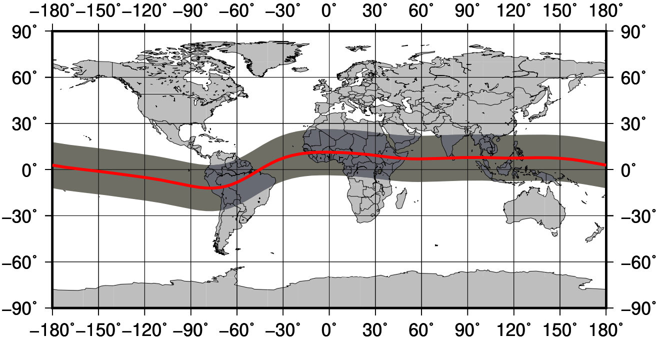


Uniqueness of the African sector - dip equator



- orientation with respect to the geographic equator compared to other longitude sectors
- ionisation influenced by zenith - respect to geographic equator
- magnetic field influence - distribution and propagation of the ionisation

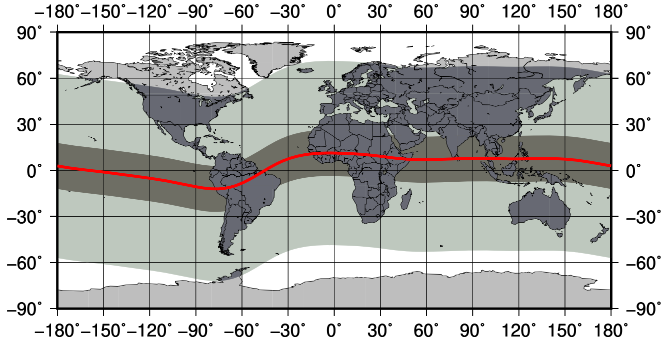
...different regions different phenomena



Equatorial/Low latitudes region

- Broadly taken to be in the range (-30 to 30°)
- two crests of the EIA on both sides of the geomagnetic equator
- EIA crest magnitudes (± 11.5) - geomagnetically conjugate

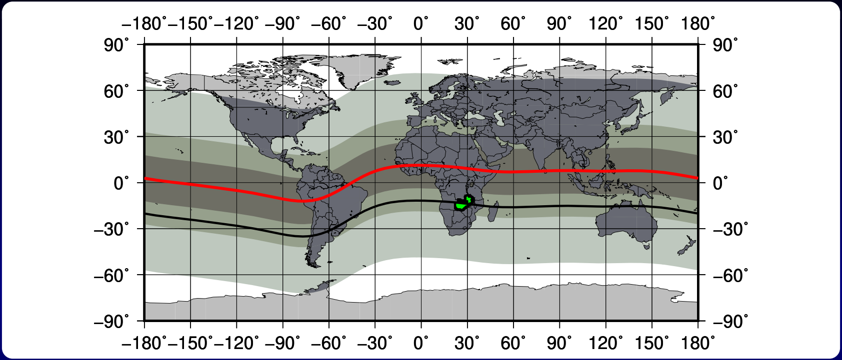
...different regions different phenomena



Mid latitudes

- considered to lie ($\pm 15/20/30$ to 55°) latitudes
- no complicated physics, easy to study, model and reproduce

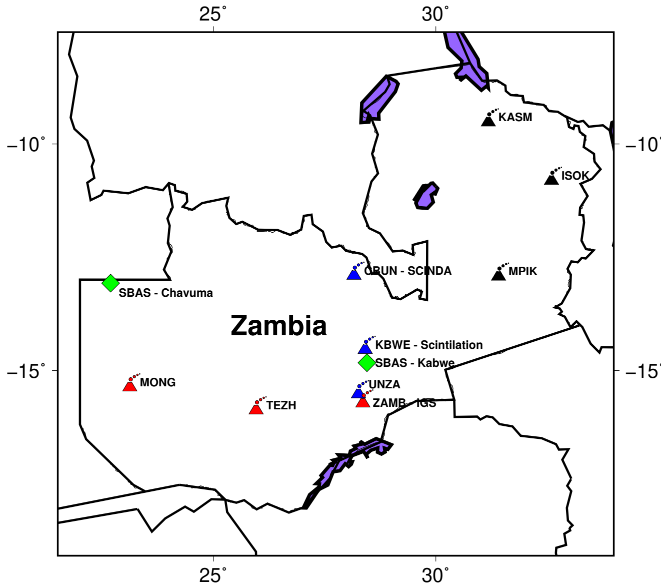
Zambia - $\sim 21^\circ$S



Minimun low lat -to- max low lat

- "another region" - extreme ends of the low latitude (± 15 to $\pm 30^\circ$)
- mixing of the low latitude and high latitude originating phenomena
- the physics of this regions mostly mis-represented

Space weather instruments in Zambia



How well do Models capture phenomena in the different latitude regions

..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

currently in most models - e.g. IRI

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

- the ionosphere exhibits distinct electron density gradients across the different latitude regions
- need for models to distinctly represent the phenomena in the different latitude regions during both quiet and disturbed conditions

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The main goal –>

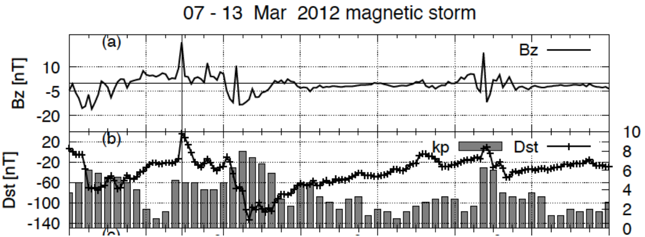
to characterise the ionospheric variations over the low and the mid latitude regions thereby

-> identifying the specific characteristics of the region between the low and the midlatitude regions

Investigation of the Ionospheric Irregularities over the EIA region within the African sector

...Tow (2) intense storms in 2012

- regional ionospheric response to selected intense storms ($Dst \leq -100$ nT)
- geographic latitudinal coverage of $10^\circ S - 40^\circ S$ within a longitude sector of $10^\circ E - 40^\circ E$.



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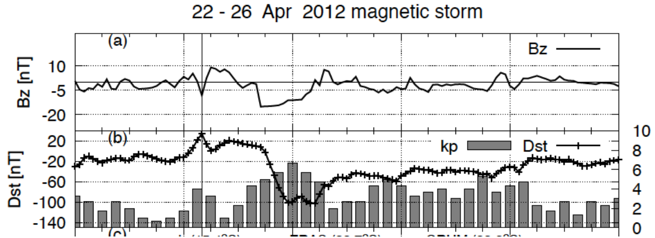
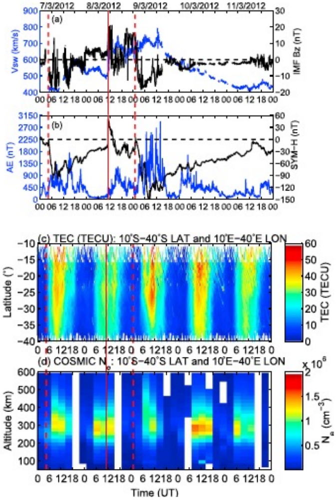
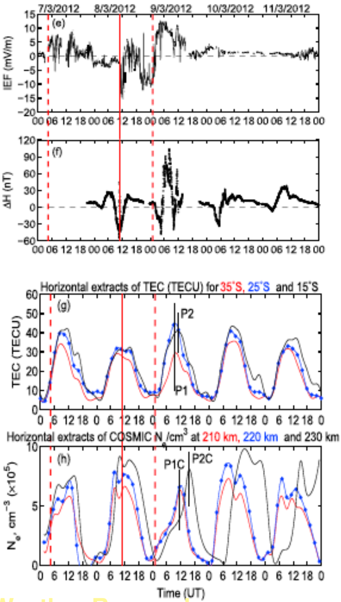


7 - 13 March storm



- 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
- dashed - main phase: 0420 UT and 0100 UT
- solid - shock time (11:03 UT) - led to the 9 Mar storm

7 - 13 March storm



- 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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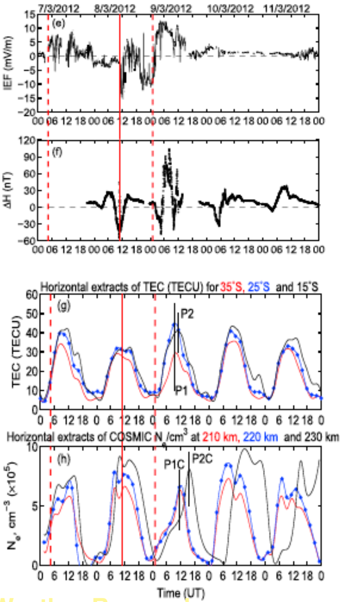


Fig c

- 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
- Both 7 and 9 March 2012 storms caused positive storm phase
- COSMIC data show enhanced N_e with altitude during daytime on 9 March

7 - 13 March storm

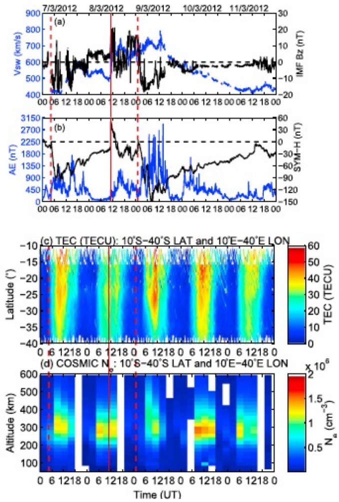


Fig d

- 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$^\circ S$ geog lat

7 - 13 March storm

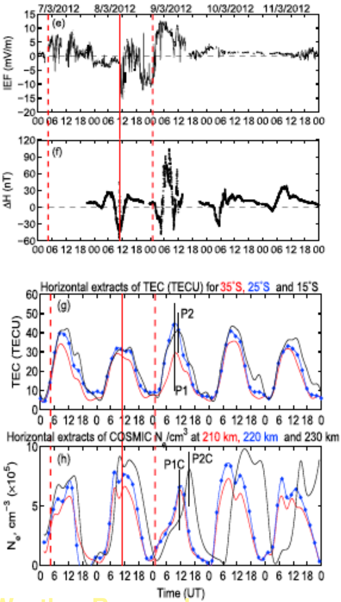


Fig g

- 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.

7 - 13 March storm

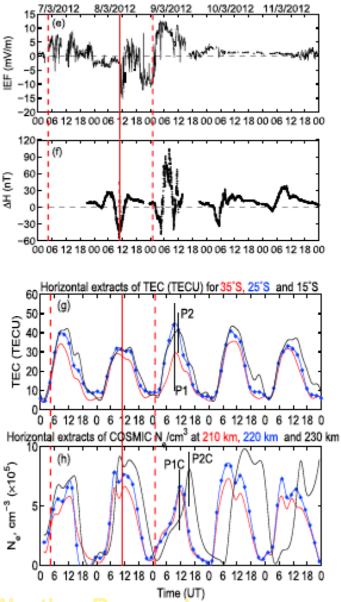
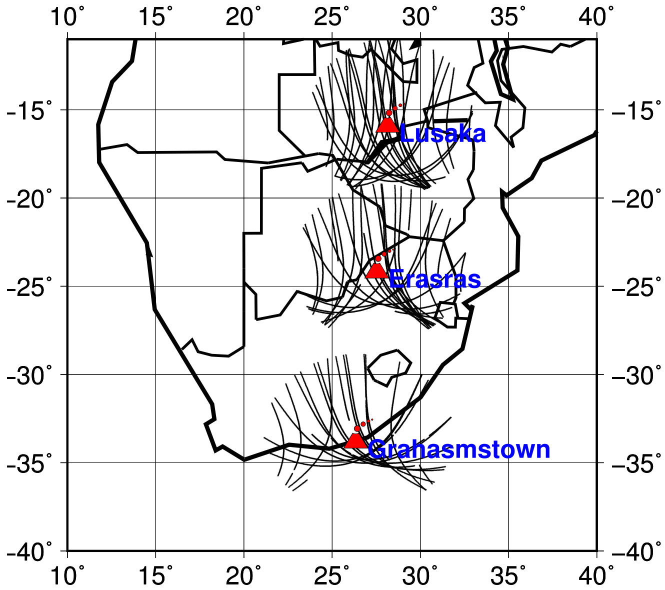


Fig g

- 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° $-$ 22°S over 1 h interval.

...with instruments along a selected meridian



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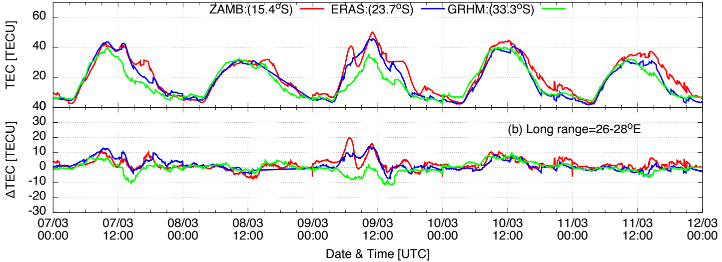

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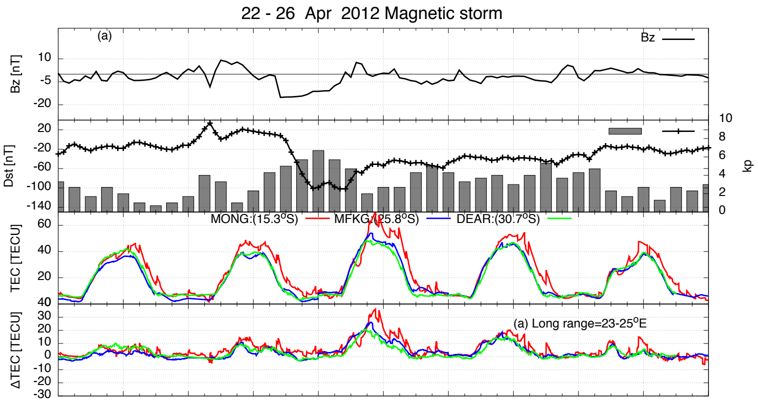


General observations - summary

- mexpansion of the EIA toward midlatitudes thus contributing to the observed increased TEC values as far as $20^{\circ}S$ geog lat - was due to enhancement of the eastward electric field increased plasma uplift
- storms analysed were coronal mass ejection driven occurred during the same solar activity period
- characterized by positive storm effects during the main and (or) recovery phases
- presence of large-scale TIDs during the storm main phase
- use of GNSS TEC and COSMIC RO N_e to investigate meridional and vertical propagation of TIDs simultaneously during the strong storms
- possible to identify vertical motion of TIDs using RO data in cases when equatorward TIDs are present, as revealed by GNSS TEC data,

Progress - scientific & non scientific research outputs

Capacity building and skills development include

- building human capacity to carry out high level scientific research
- skills development and creating interest in the field (especially on the Zambian side)
- developing collaboration networks across Africa SANSA
- Some Good will from the government - Venturing into space technology
- Hosting the ISWI School(26 - 30 Sept), and the 6th AGS conference (2 - 4th Oct)

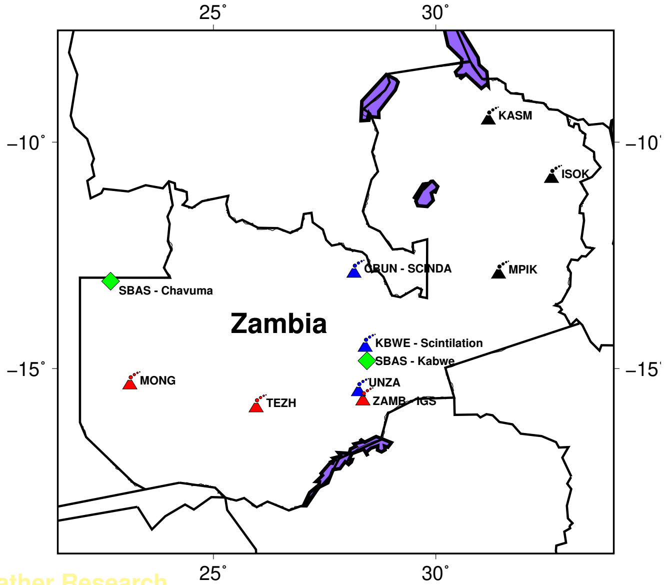
Challenges and Summary

Challenges

- Lack of postgraduate funding instrument leading to slow progress
- Brain drain due to limited opportunities -
- Declining number of students taking up careers in science

Space weather instruments in Zambia

Call for collaboration and support



Up Coming Events in Lusaka, Zambia

- International Space Weather Initiative (ISWI) School
  - September 26th to 30th 2023
  - Open to students/postdocs/early career at African institutions
  - Limited travel support available - Apply
- African Geophysical Society Conference
  - October 2nd to 4th 2023
  - Open to all Earth and Space science students and scientists
  - Limited travel support available - Apply

https://afgps.org/conference

Thank you

Special thanks to:

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