

Closing the Geophysical Data Gap: Recent Developments in Space Science studies in Zambia

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African School on Space Science: Related Applications and Awareness for Sustainable Development of the Region, Kigali - Rwanda, 30 June 2014 - 11 July 2014

We care

because ...

a growing dependence on space-based technology
applications e.g **communications and navigation systems**

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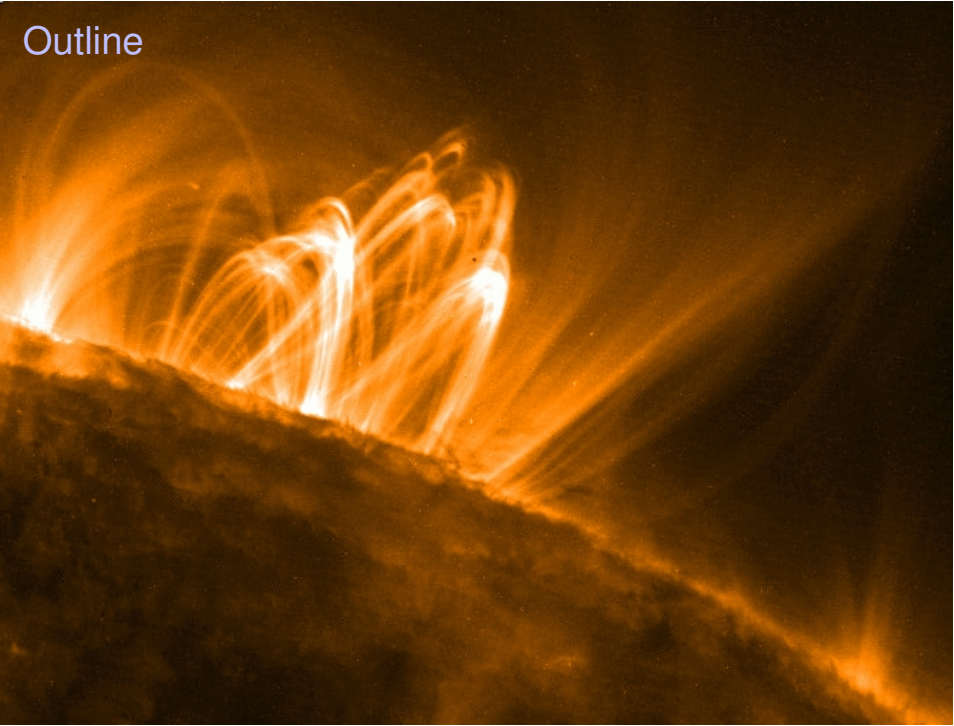
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Outline




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- Brief intro on space weather?


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- Summary - - -

... Space Weather

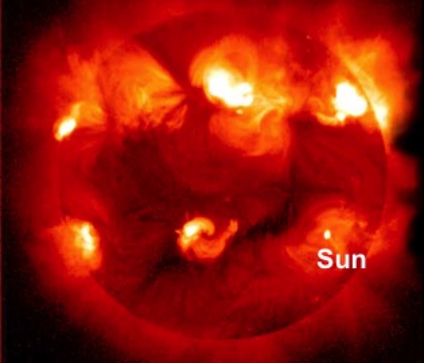
Space Weather happens when the Sun sends out **light, particles,** and **magnetic fields** that hit objects in the solar system



Space Weather:

What is it?

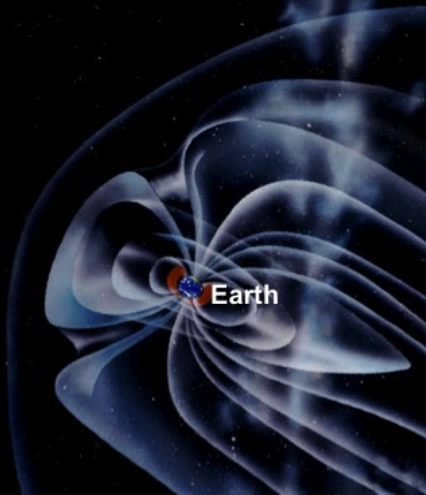
Space Weather refers to changes in the space environment near Earth



Sun

Sun:

- Energy released in the form of...
 - Light
 - Particles (electrons and protons)
 - Magnetic Field
- Activity Cycles
 - 11 years
 - 22 years
 - 88 years
 - 208 years

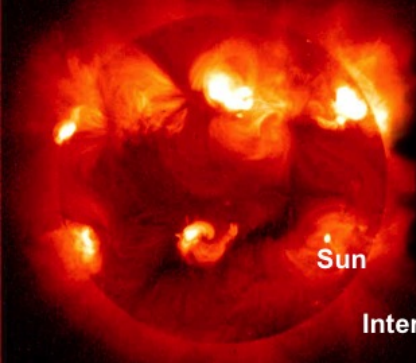


Earth

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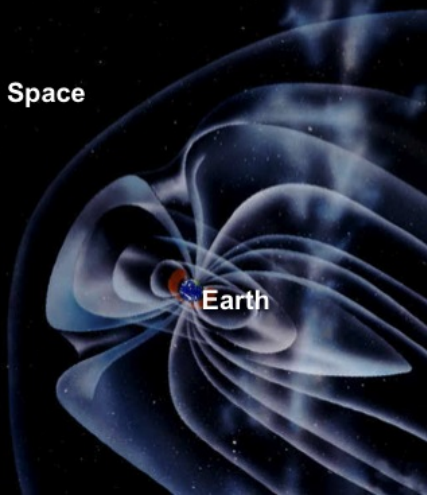
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Sun

Interplanetary Space



Earth

Interplanetary Space:

- Not quite a vacuum
- Solar Wind
 - Electrons and protons
 - Magnetic field
- Disturbances from the Sun make waves in the solar wind

Space Weather:

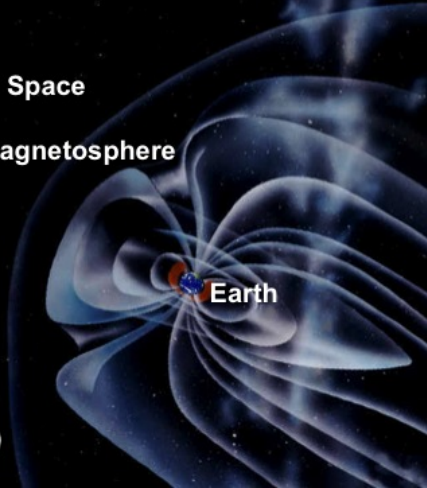
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Magnetosphere

Earth

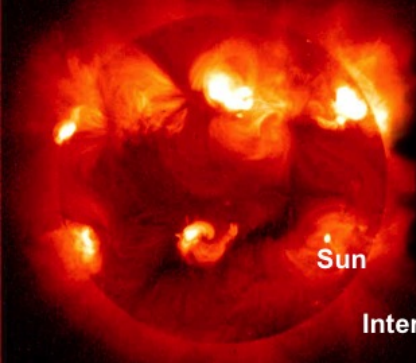
Magnetosphere:

- Created by Earth's magnetic field
- Deformed by the Solar Wind
 - Not Quite a Vacuum
 - Particles (electrons and protons) trapped on magnetic field lines

Space Weather:

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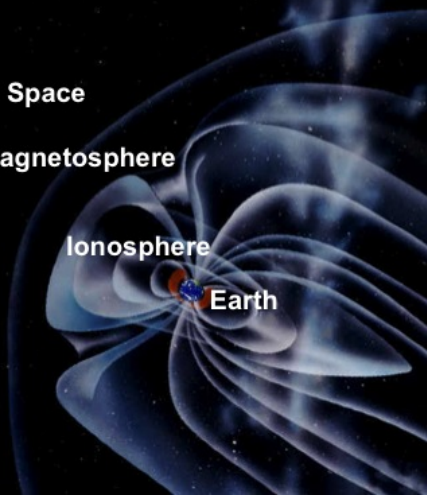
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Magnetosphere

Ionosphere

Earth



Ionosphere:

- Layer of electrons & ions at the top of the atmosphere (50 – 400 km & up)
- Formed when extreme ultraviolet light from the Sun hits Earth's Atmosphere
- Critical in the reflection and transmission of radio waves

SUN

convection zone
radiative zone
core

surface
atmosphere

sunspot
plage
coronal mass ejection

Active Region on the Sun Erupts

1. Solar Flare (x-ray)
2. Shock (energetic particles)
3. Coronal Mass Ejection (particles and fields)

- X-rays reach Earth in 8 minutes (speed of light)
- Energetic Particles reach Earth in 15 min to 24 hours
- Coronal Mass Ejection reaches Earth in 1-4 Days

EARTH

particles and
magnetic fields

photons

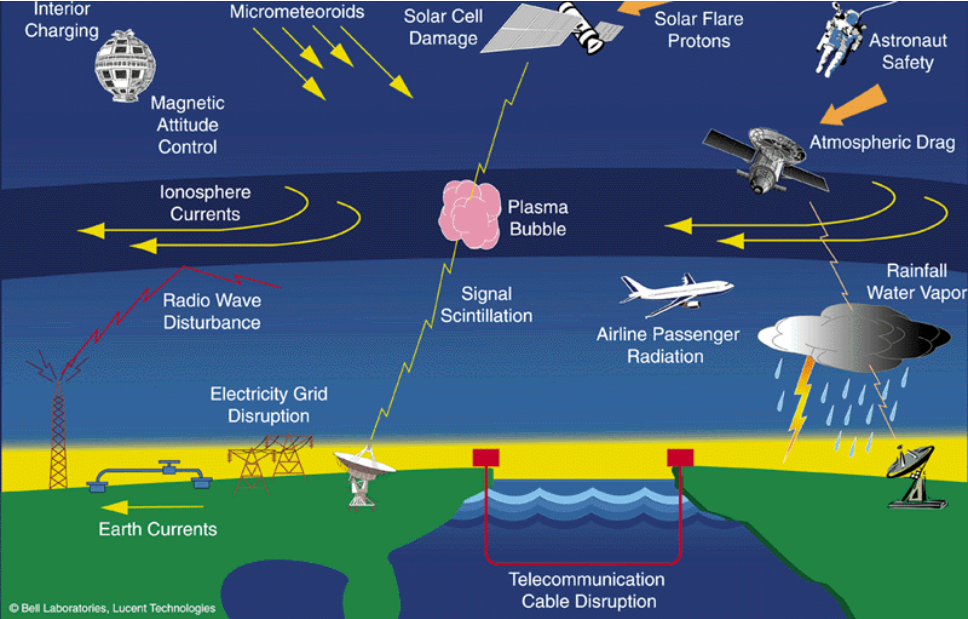
bow
shock

solar wind

heliosphere

surface
ionosphere
plasmasphere
magnetosphere

not to scale



Many technologies are affected by Space Weather

Zambia & space weather studies??

As we have noted ...

- Complex temporal and spatial changes within the Earth's space environment can limit and degrade the performance of earth to satellite systems.

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we care because ...

- With the increasing importance of space weather aspects on the technologies, it is important to provide industry and other users with the means to access space weather data and services.

Zambia's participation in Space Weather studies...

Africa is poorly represented in space sciences

- While space science & technology is advancing at an increasing pace, yet Zambia and **most** African countries lack the

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The changing situation - in Zambia

in the recent past ...

- There is growing realization that Space Science is an important tool for development
 - significant progress in introducing Space Science -related activities

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- It was viewed by most as a subject for developed countries with capabilities in space technology.

A brief history of space science in Zambia...

Late 90's - first efforts to initiate space related activities

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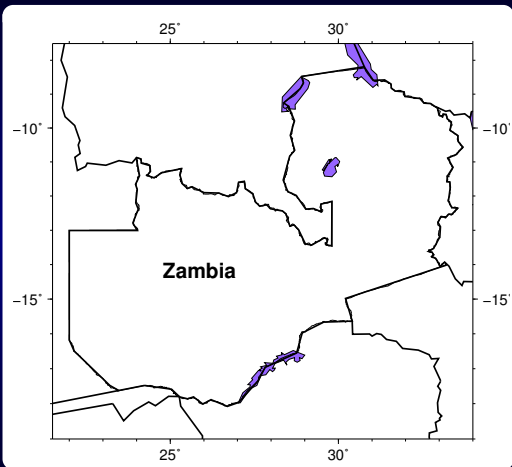
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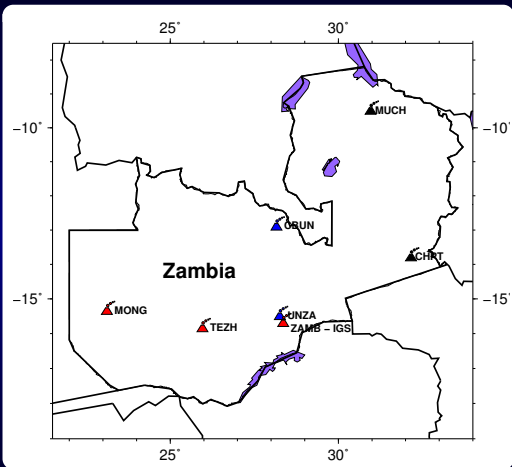
- An upsurge of interest in Space Science at the University of Zambia
- IHY was a platform to establish strong links with International institutions and individual scientists with wide experience in space science and technology.

Status of ionospheric monitoring in Zambia

- ...before 2009



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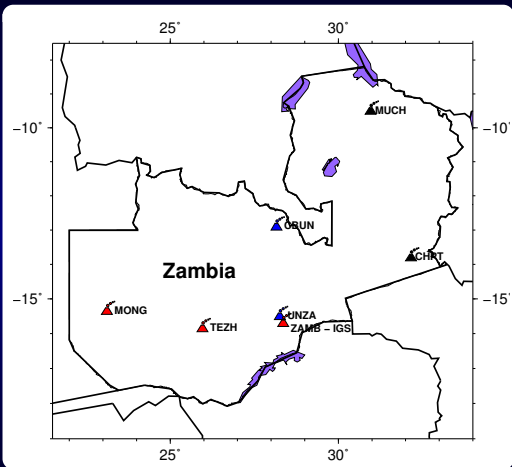


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We have....

- 6 active GNSS receivers
- 1 scintillation monitor
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Human capacity dev

- new space science program at the UNZA.
- building a research team

Capacity building and skills development

Through international collaborations

- Two **Zambians with PhDs in Space Science**
- One member of the Phys. Dept. at UNZA currently pursuing his PhD in space science
- Members of the Phys. Dept. at UNZA have at occasions visited SANSa, CHPC and SAAO
- This has enabled high level access for Zambian scientists to high-tech astronomical and Space Science facilities
 - **Knowledge and technology transfer has been the focal point of the collaboration**

Progress - through international collaborations

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established cooperation between UNZA Phys. Dept. & the
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MAGDAS magnetometer - collaboration with the Japanese

Zambian GNSS data base to date

| Station | Available date | Comments |
|---------|---------------------|----------------------|
| ZAMB | Jun-2002 - May-2008 | reactivated Jan 2012 |
| MONG | Aug-2010 - present | active |
| TEZH | Aug-2010 - present | active |
| UNZA | Aug-2011 - present | active |
| CBUZ | Dec-2012 - present | active |
| MUCH | Sep-2013 - present | active |
| CHPT | Sep-2012 - present | active |

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by nature ...

Space weather research and related ionospheric studies require **broad international collaboration** in **sharing databases**, developing analysis software and models and **providing services**.

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Space Weather over Africa Project - OBJECTIVES

The primary **objective of the initiative** is to establish an ionospheric monitoring network over Zambia that will link the corresponding instruments in operation in the neighboring countries.

Closing the big Gap over Africa

- This emerging space science capacity in Zambia, and its growing scientific linkages with other countries in the region,
 - highlights the need for improved coordination of current and future activities in order to maximize the scientific and societal benefits of space science.

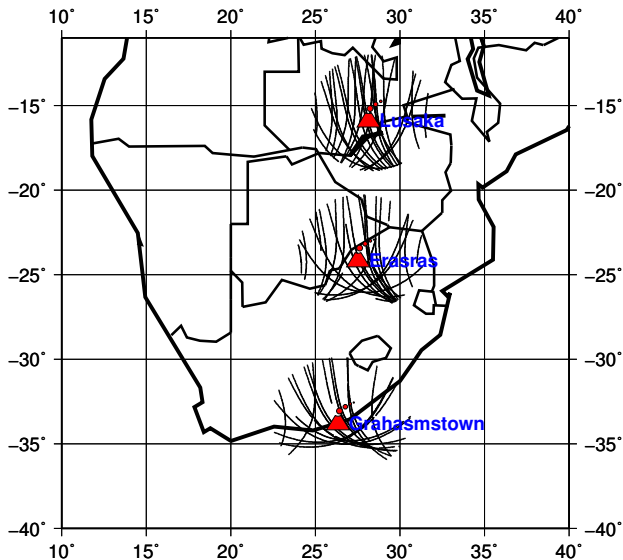
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the new GNSS receiver network

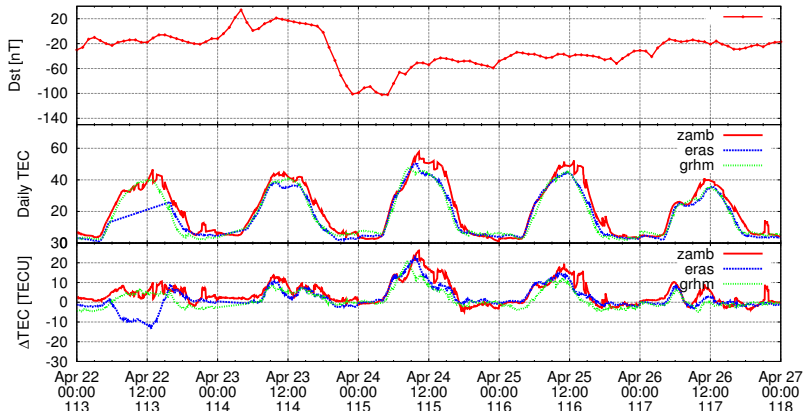
- allows for permanent monitoring of the ionospheric state in this region and in particular
- closing this gap - is now enabling us to identify & trace space weather effects from high to mid latitudes

The recent TIDs study.....



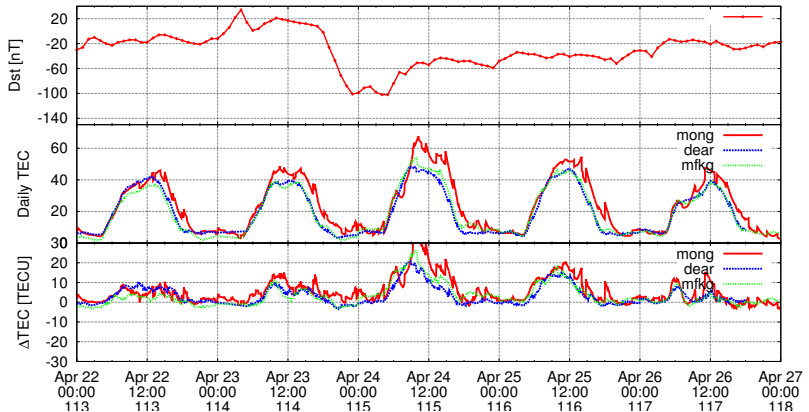
TEC perturbations observed at three stations.....

Array 1 ~ 28°E



TEC perturbations observed at three stations.....

Array 2 ~ 23° E



TEC perturbations observed from three stations.....

Mid-latitudes - - science questions

Fundamental ionospheric perturbation phenomena covering quite different scales in time and space can be investigated

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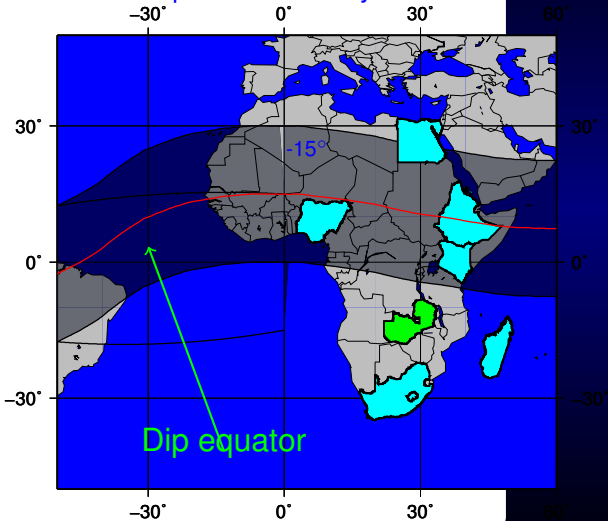
Fundamental ionospheric perturbation phenomena covering quite different scales in time and space can be investigated

- large-scale perturbation processes characterized by moving ionization fronts
- wave-like traveling ionospheric disturbances

should also be able to participate in studies of small-scale irregularities causing radio scintillation

Zambia - location - - mid-low latitude region

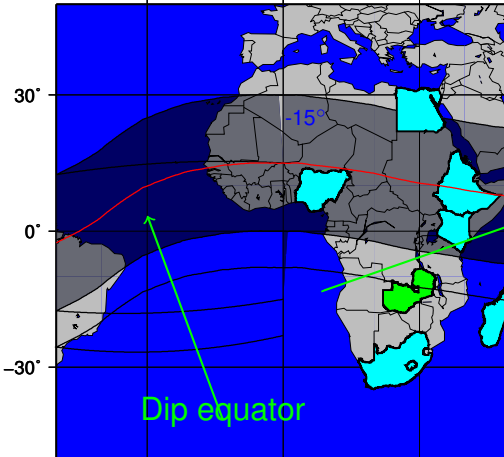
$\pm 15^\circ$ boundary
of the equatorial anomaly



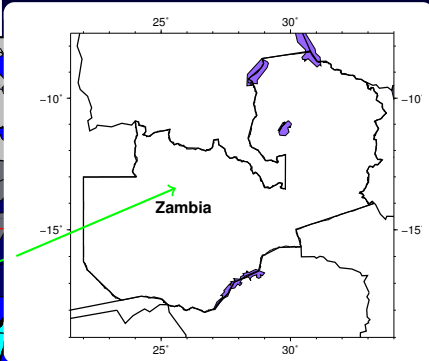
Zambia - location - - mid-low latitude region

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-30° 0° 30°



Zambia located
-23° dip-latitude



mid-latitude ionospheric
characterization

-30° 0° 30°

TEC - - ionospheric characterization

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total electron content (TEC) from GPS

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- carries information on time and position variability of the ionosphere - - useful as a sensor of ionospheric climatology

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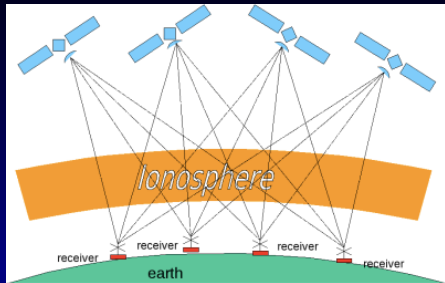
total electron content (TEC) from GPS

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- carries information on time and position variability of the ionosphere - - useful as a sensor of ionospheric climatology
- Can be derived from GNSS observation

Able to do ionospheric tomography

through tomography...

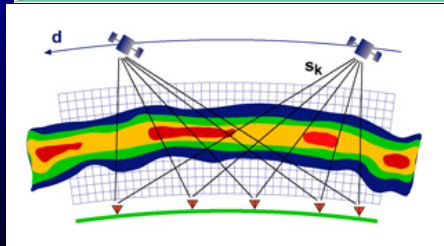
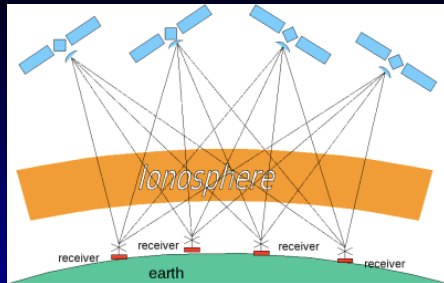
- a vertical cross section through ionospheric electron density can be imaged



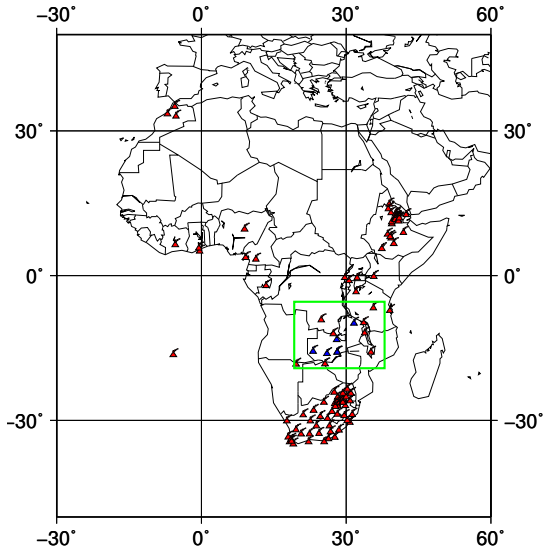
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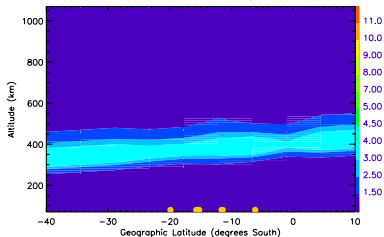
- a vertical cross section through ionospheric electron density can be imaged
- where tomographic reconstruction algorithms and calculated TEC values are used together to reconstruct ionosphere electron density image for a given scenario



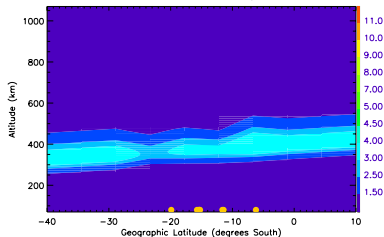
region of interest....



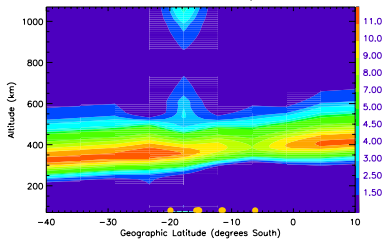
Reconstructed Electron Density (10^5 e l/cm^3)
00:00–00:25 UT on on 21 September 2012



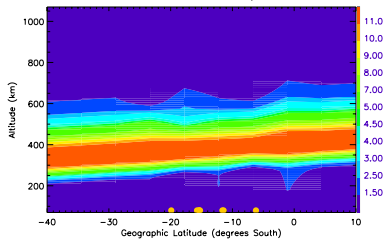
Reconstructed Electron Density (10^5 e l/cm^3)
03:00–03:25 UT on on 21 September 2012



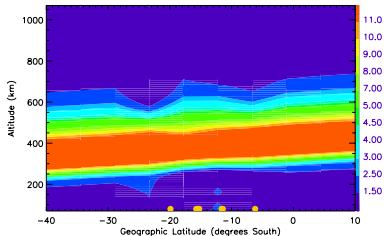
Reconstructed Electron Density (10^5 e l/cm^3)
06:00–06:25 UT on on 21 September 2012



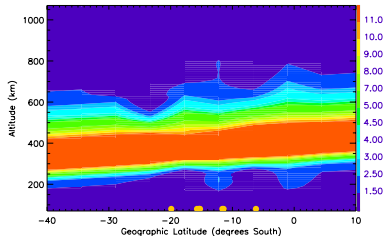
Reconstructed Electron Density (10^5 e l/cm^3)
09:00–09:25 UT on on 21 September 2012



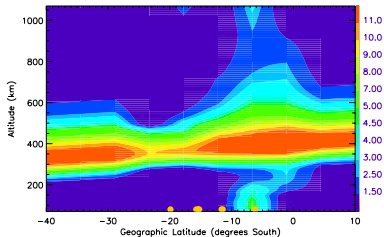
Reconstructed Electron Density (10^5 el/cm³)
13:00–01:25 UT on on 21 September 2012



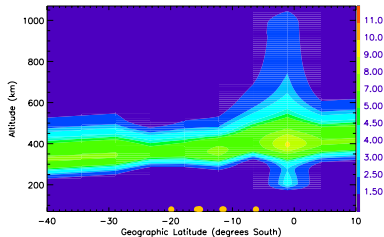
Reconstructed Electron Density (10^5 el/cm³)
15:00–01:25 UT on on 21 September 2012



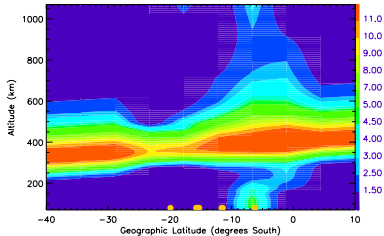
Reconstructed Electron Density (10^5 el/cm³)
18:00–01:25 UT on on 21 September 2012



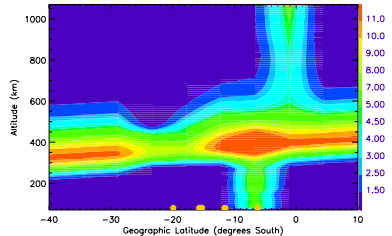
Reconstructed Electron Density (10^5 el/cm³)
21:00–02:25 UT on on 21 September 2012



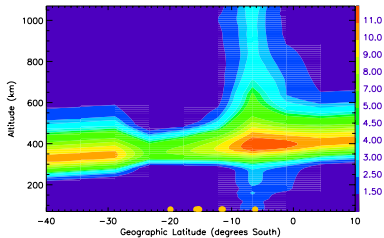
Reconstructed Electron Density (10^5 el/cm³)
18:00–01:25 UT on on 21 September 2012



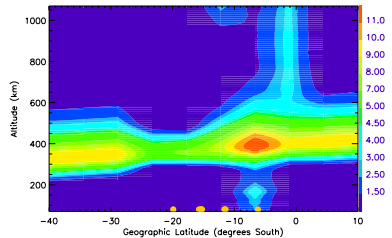
Reconstructed Electron Density (10^5 el/cm³)
18:30–01:55 UT on on 21 September 2012



Reconstructed Electron Density (10^5 el/cm³)
19:30–01:55 UT on on 21 September 2012



Reconstructed Electron Density (10^5 el/cm³)
20:00–02:25 UT on on 21 September 2012



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GPS receiver network in Zambia

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Strategic partnership with our NRSC - joint project on

- Mapping (Geographical information system - GIS)

Societal benefits

Student training...

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student learning project; developed our own FORTRAN code to compute TEC with bias estimation and correction - will soon be ready for public release

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 - ability to track the upper atmospheric changes across longitude
 - how different/similar are these phenomenon when observed from the different locations (African/American sectors)
 - quantify the sizes of the ionospheric disturbances - time-scales, length scales etc
 - acquire greater knowledge of the science drivers of these phenomenon

Thank you

