AMBER Magnetometers Network and Longitudinal Differences of Equatorial Electrodynamics and Ionospheric Vertical Density Distribution

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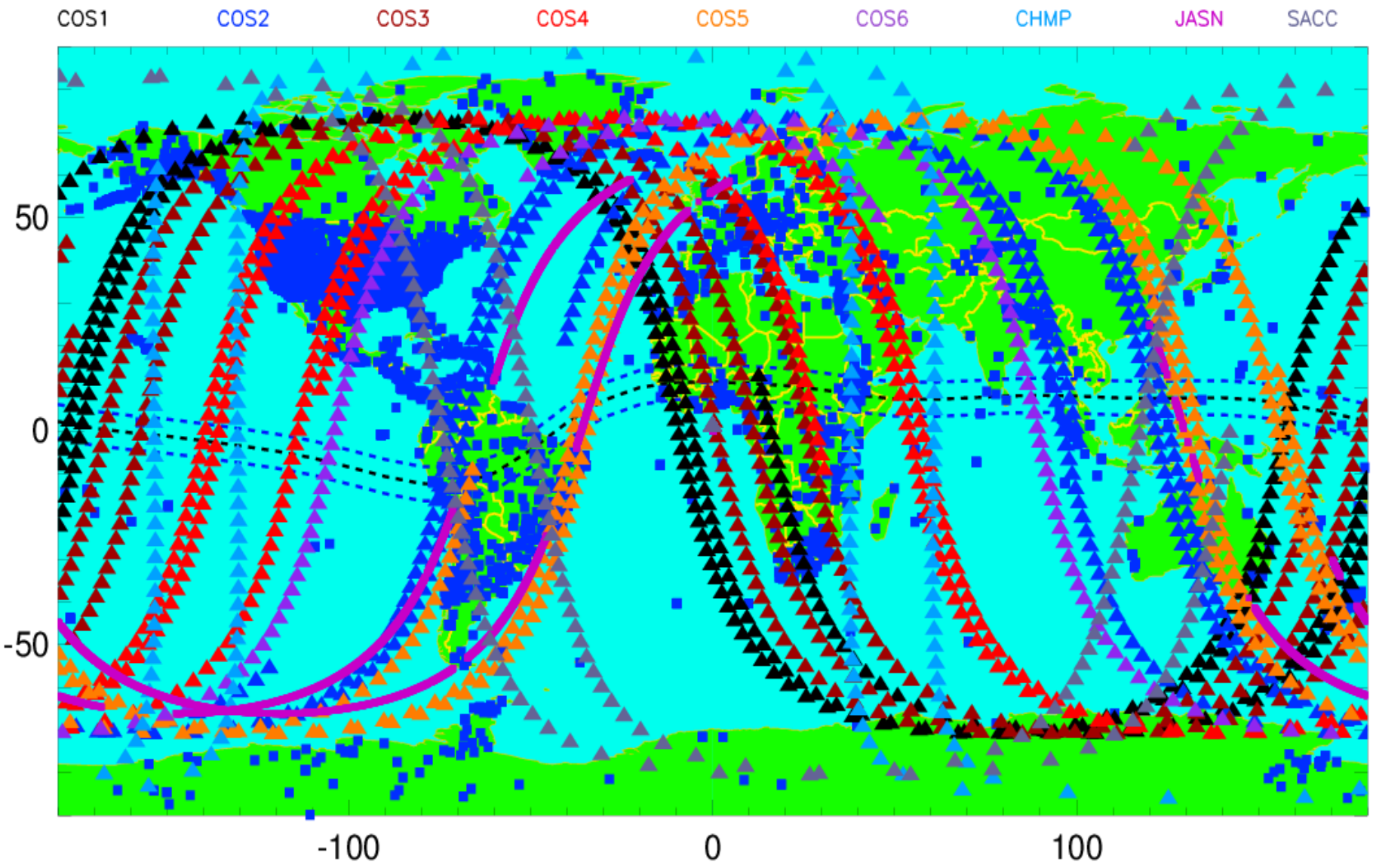
Outline

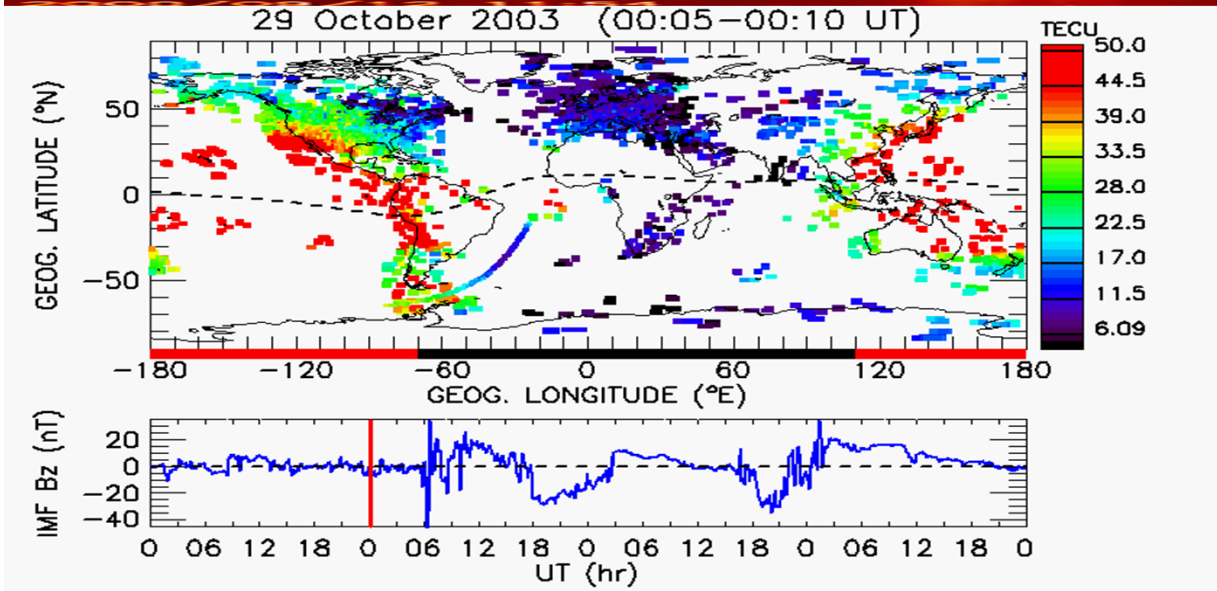
AMBER Network Logo

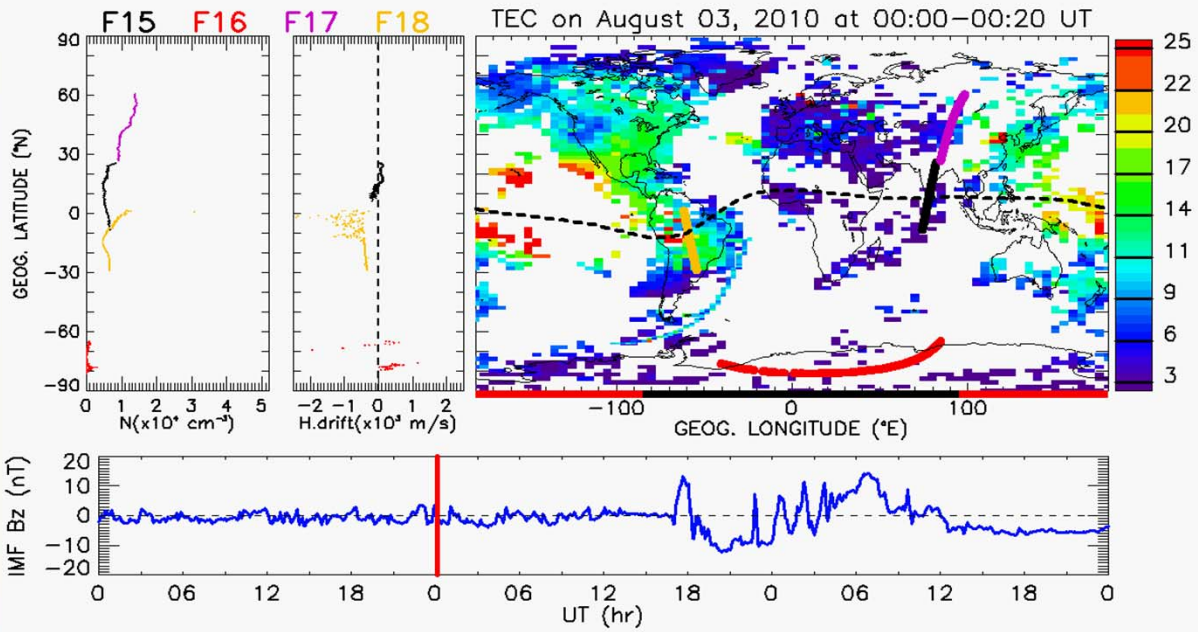
- Global ionospheric density distribution
- AMBER magnetometer array
- EEJ (ExB drift) longitudinal difference
- Vertical density structures using tomography
- Is the vertical drift the main driver RT instability?
- Post-midnight bubbles
- **Conclusion**

GNSS receivers network expansion



Ionosphere is boiling like ---?

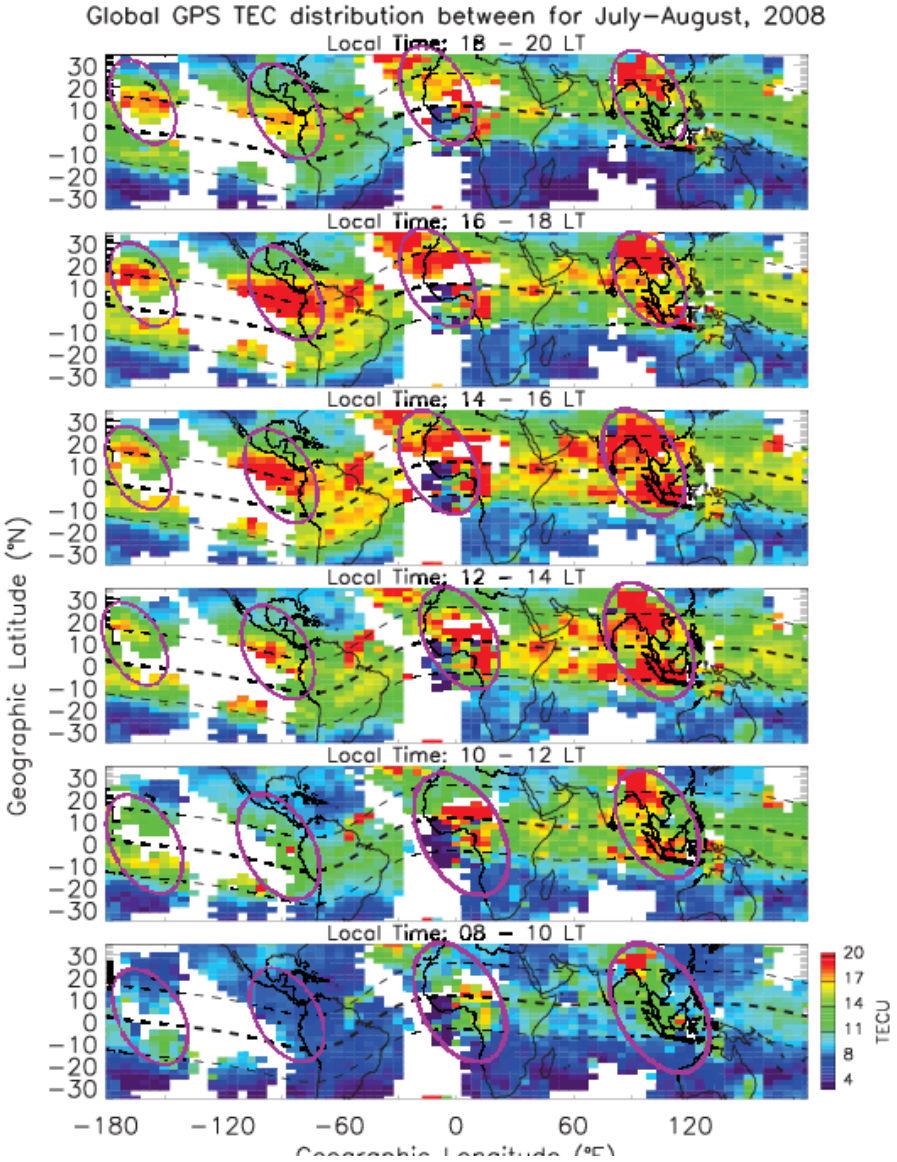


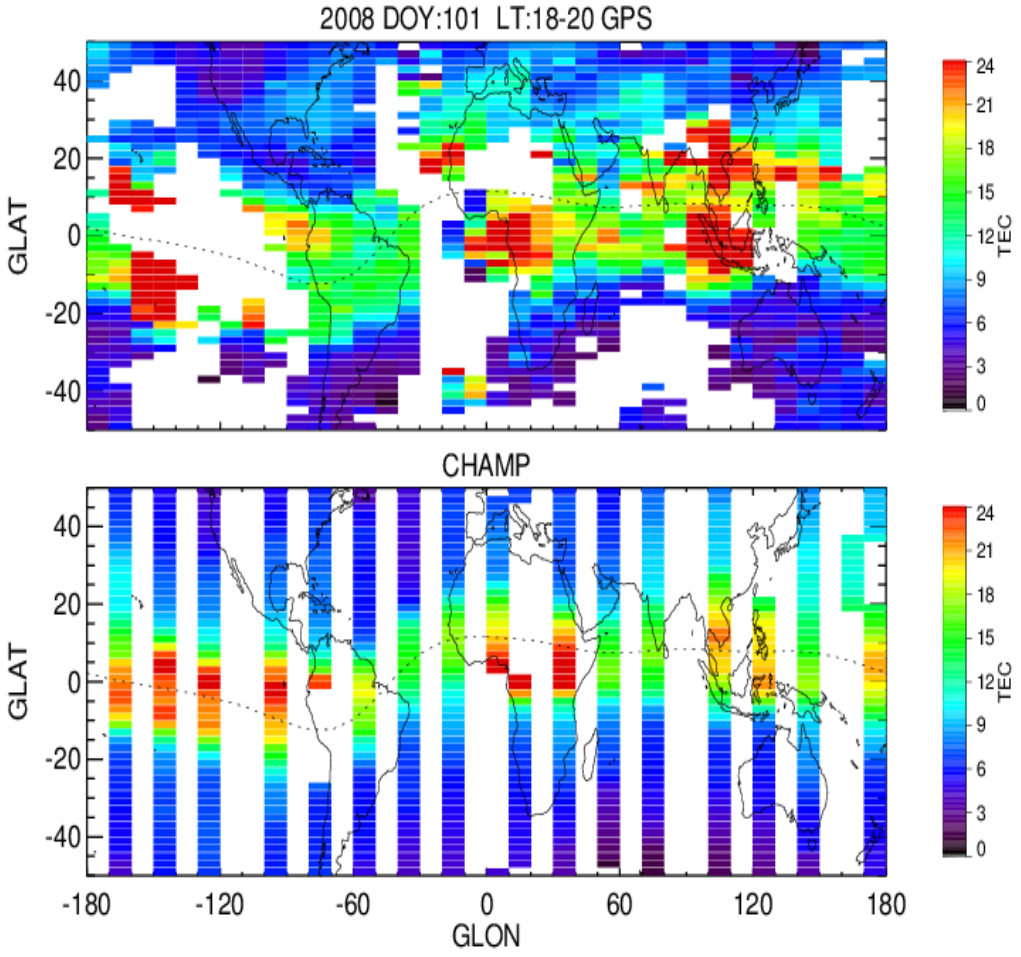


GNSS and LEO coverage: a decade ago

GNSS and LEO coverage: three years ago

4-cell structure from ground and space based Global TEC map





Yizengaw, IJG, 2012

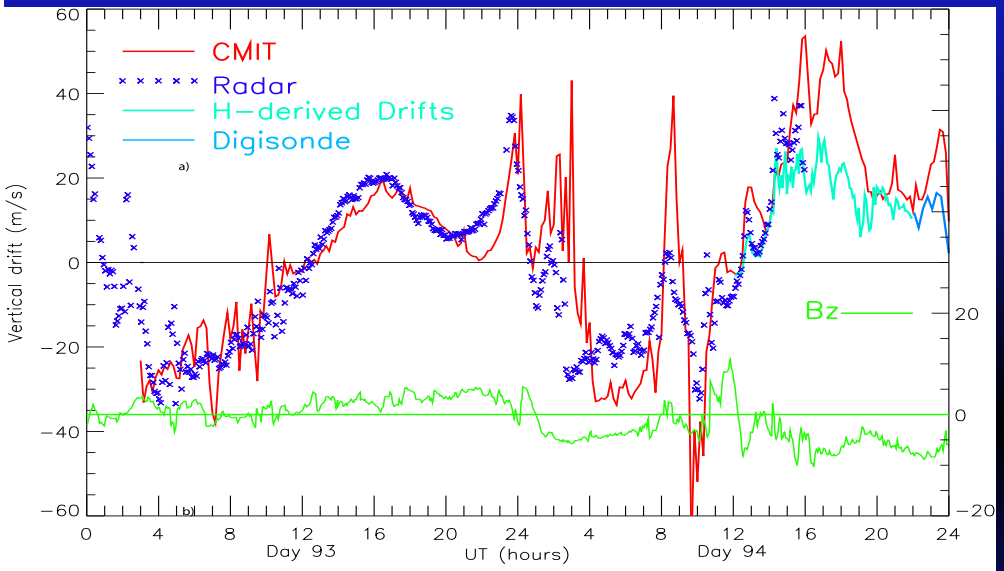
Why the ionosphere behaves differently at different longitudes?

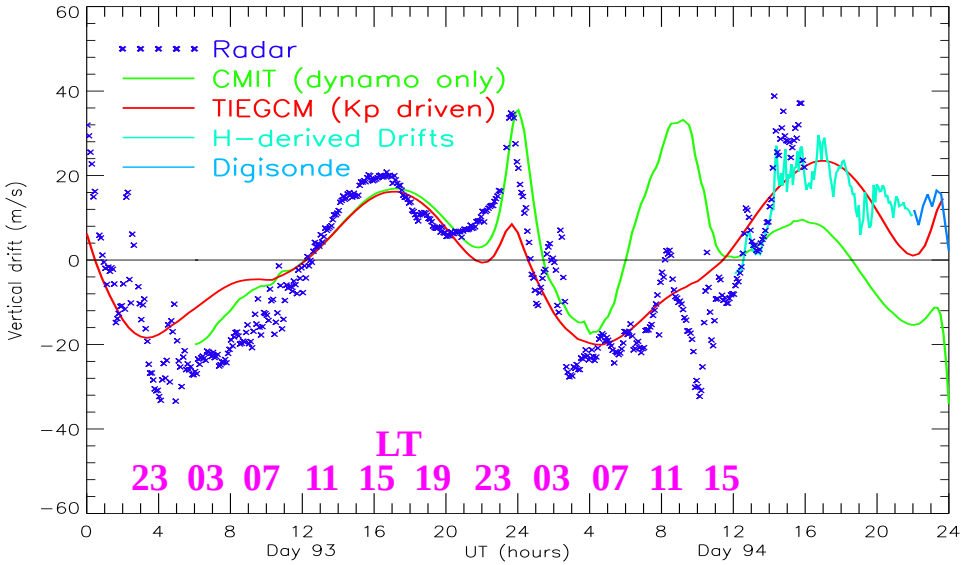
Electrodynamics different

What is responsible for this difference?

- Magnetic declination
- Neutral winds
- latent heat release difference (tidal force difference)
- Magnetic field magnitude difference
- Dust concentration difference

Do we have facilities to measure electrodynamics?



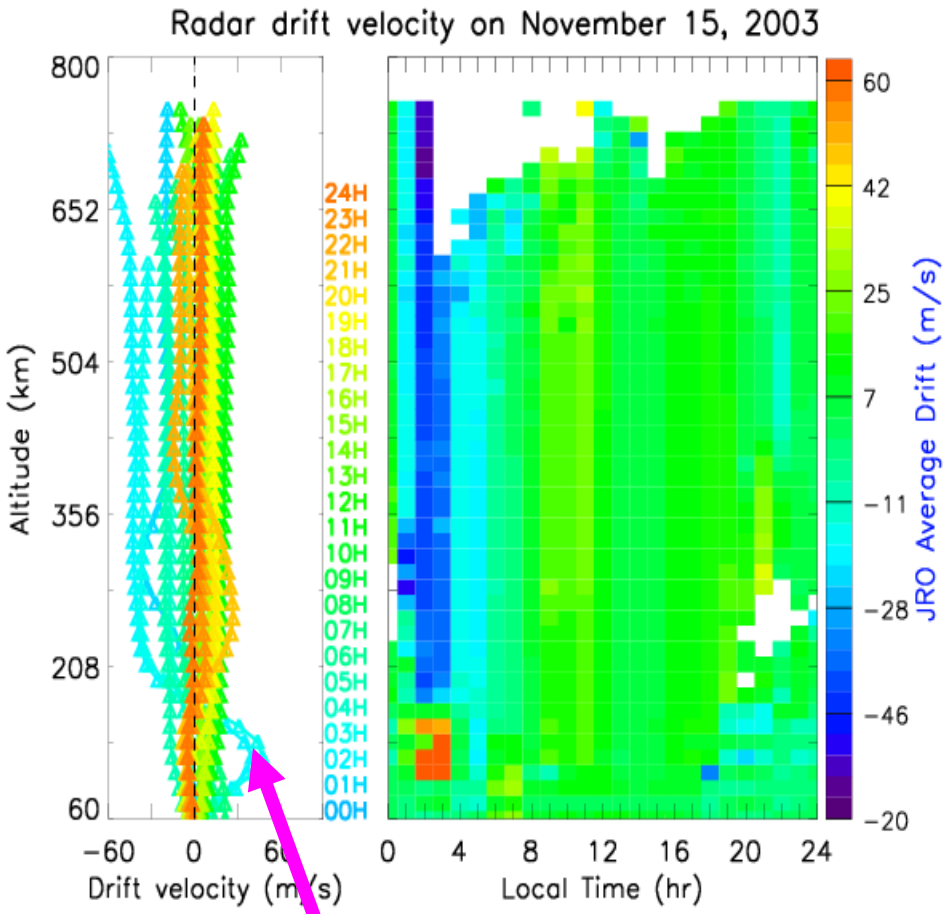


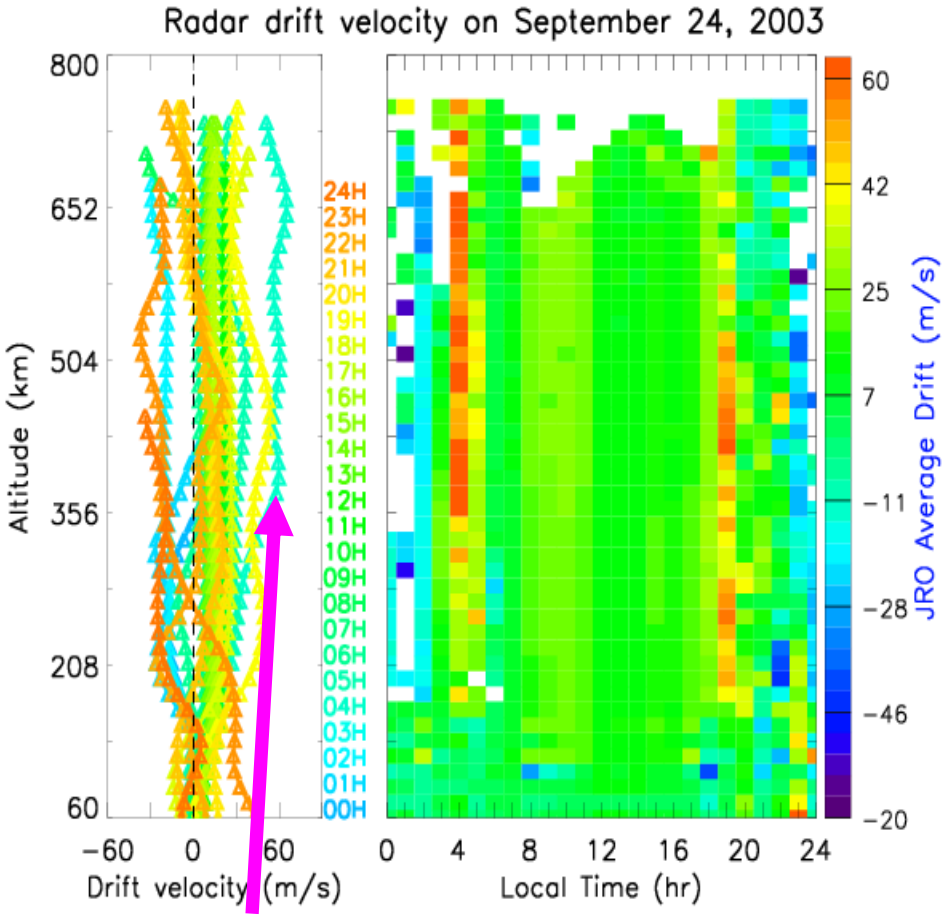
Ion vertical drift velocities

- ✈ **Jicamarca radar**
- ✈ **Models**
- ✈ **Ionosonde**
- ✈ **Magnetometers**

Wang, W. et al., GRL, 2008

Jicamarca ISR vertical drift observation





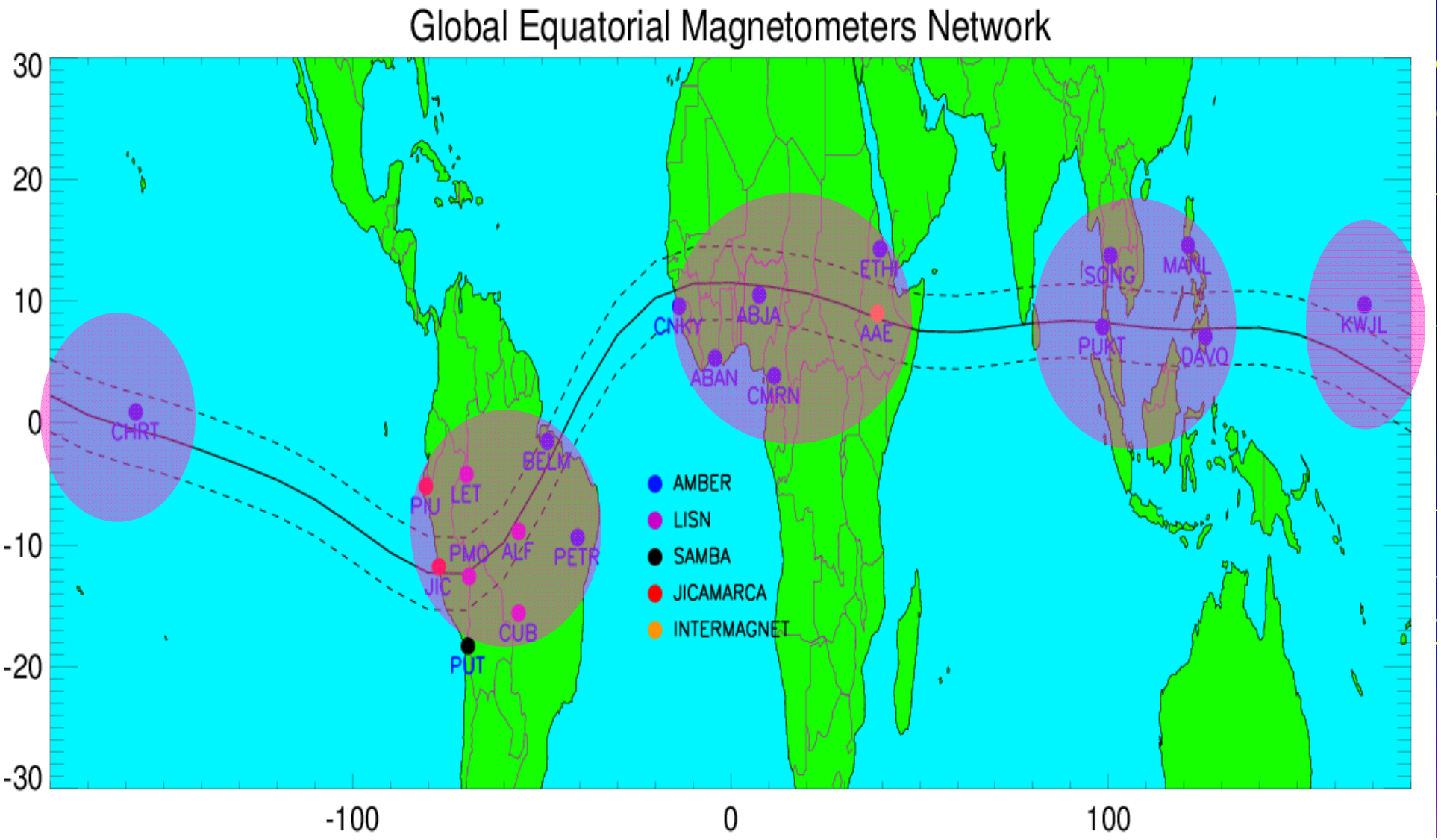
E-region upward drift in the post-midnight sector

F-region upward drift in the post-midnight sector

Is there a cheaper way to estimate electrodynamics at different longitudes?

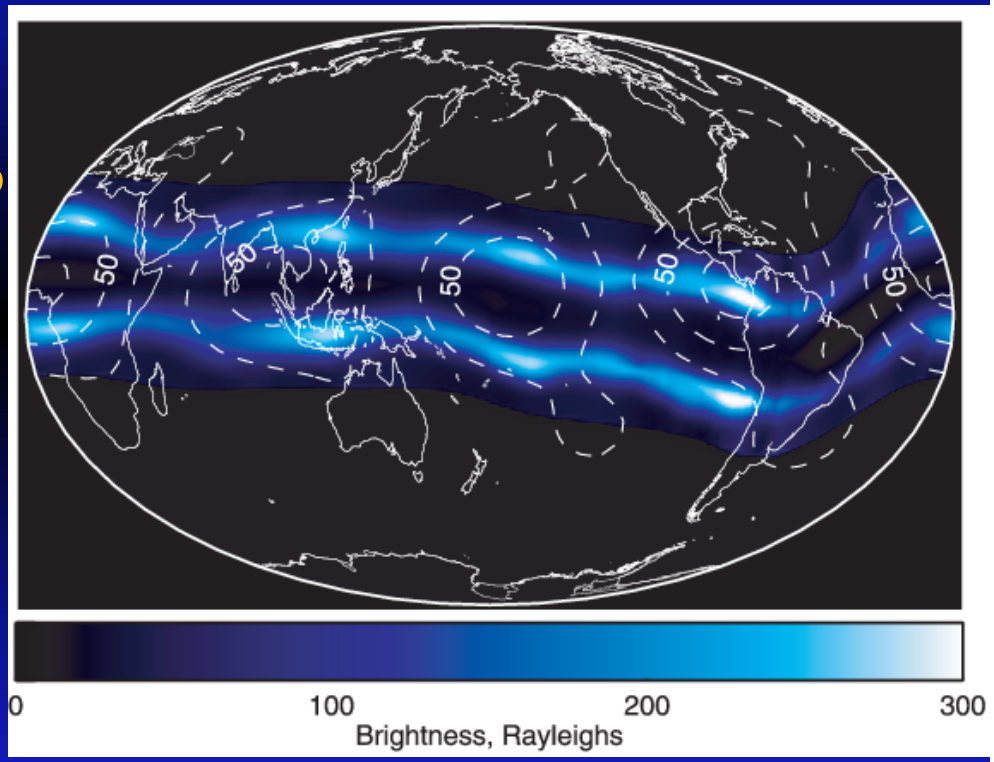
AMBER magnetometer Array

AMBER (African Meridian B-field Education and Research)



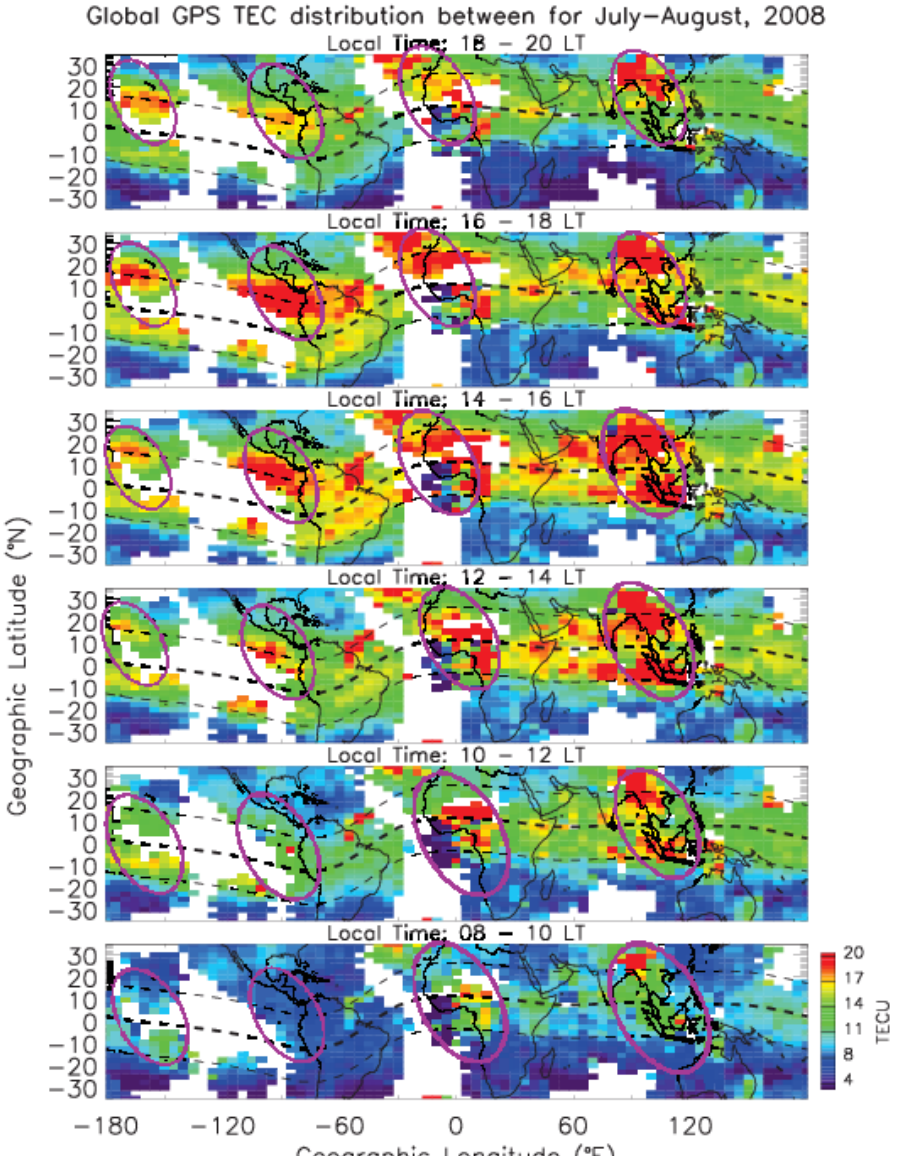
What is the physics behind ionospheric Wn-4 structure?

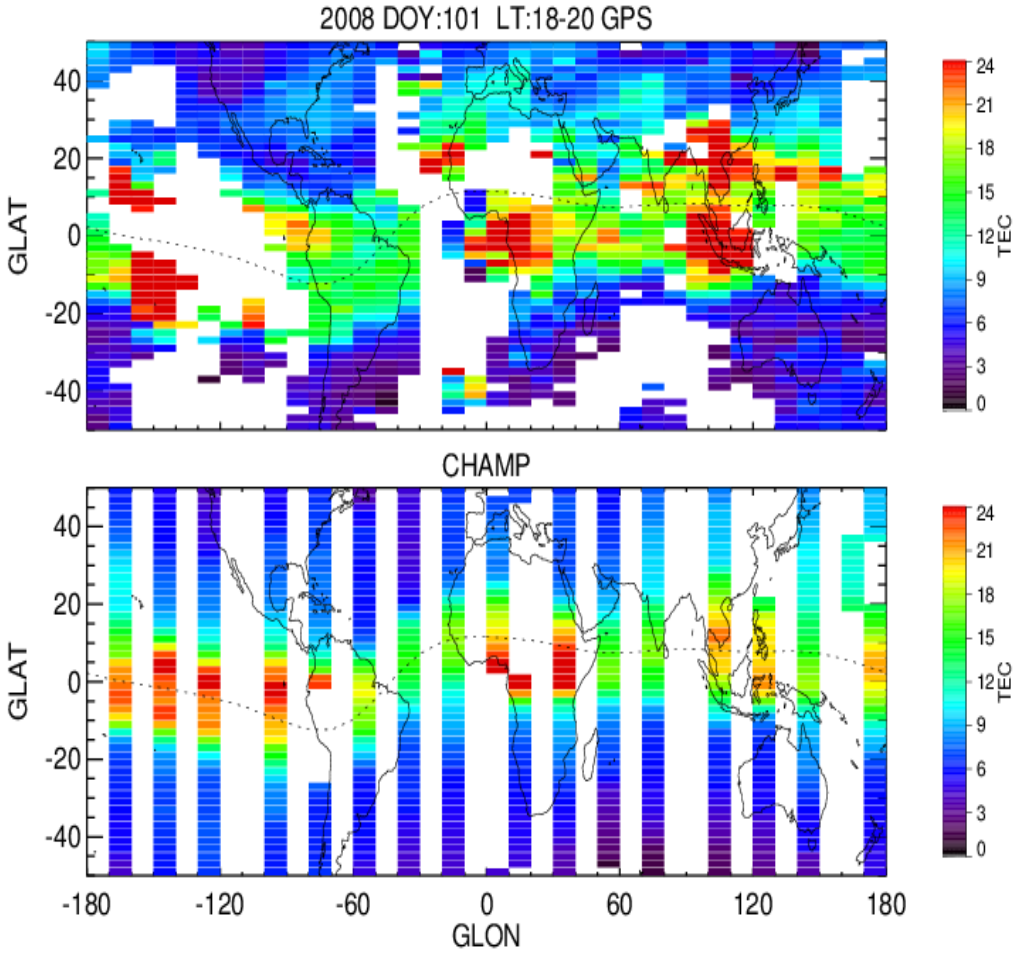
- What is its day-to-day occurrence probability?
- Is there specific local time sector that favor its formation?
- What is the possible driving mechanism?



Immel et al., GRL, 2006

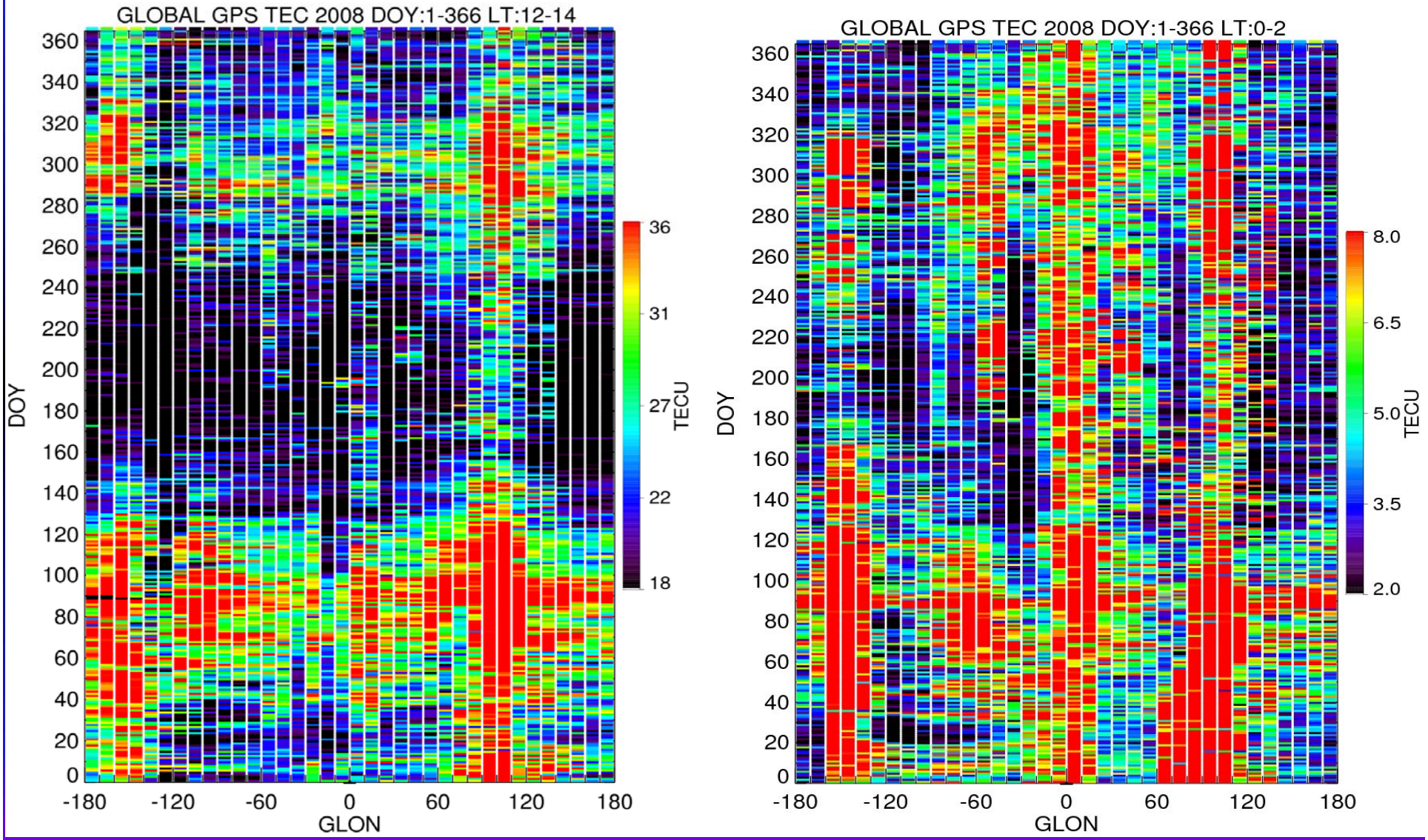
4-cell structure from ground and space based Global TEC map





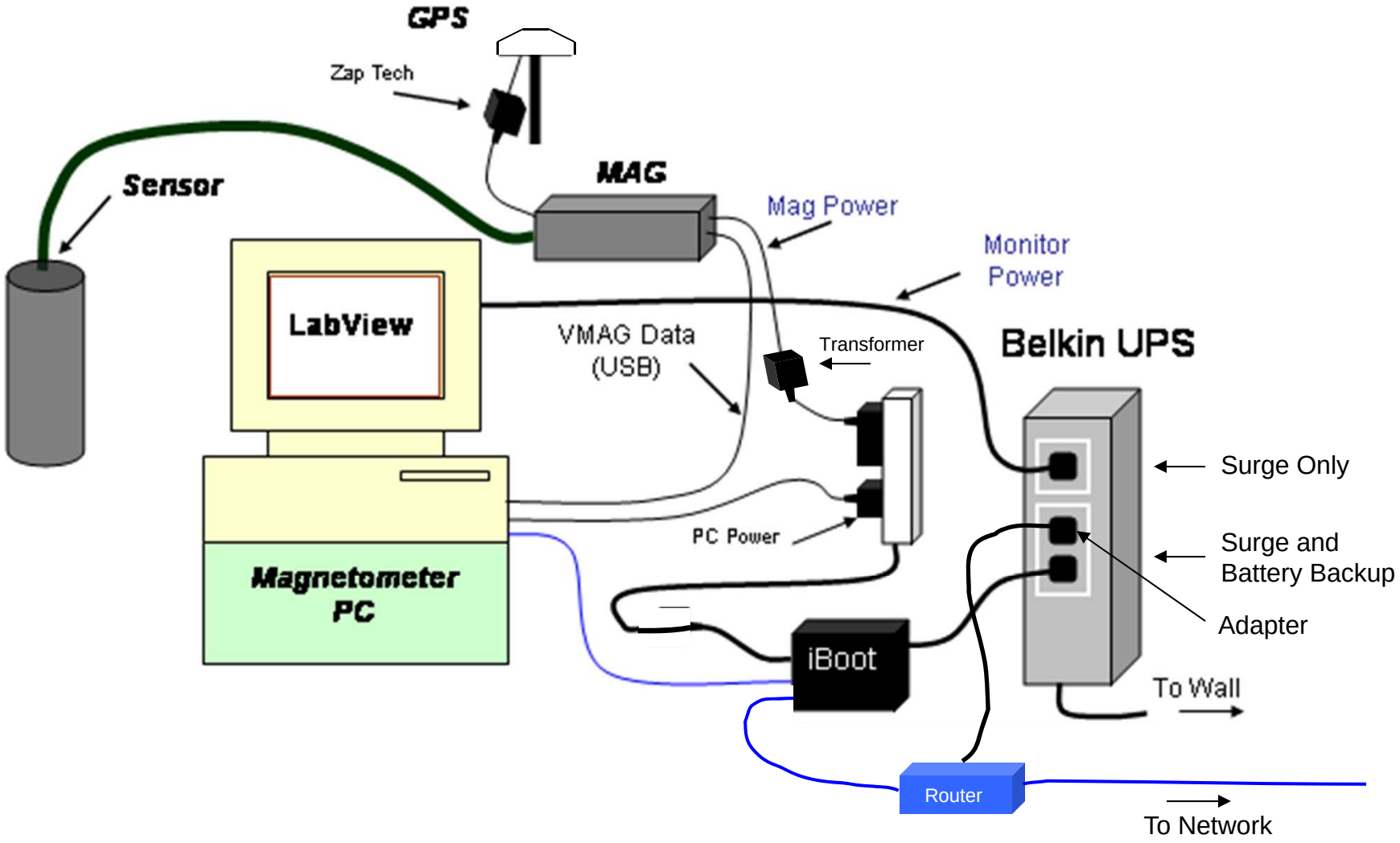
Yizengaw, IJG, 2012

Day-to-day wave number-4 structure at different local time



Pacheco and Yizengaw, JGR, 2013

Mag/Sensor Setup Diagram

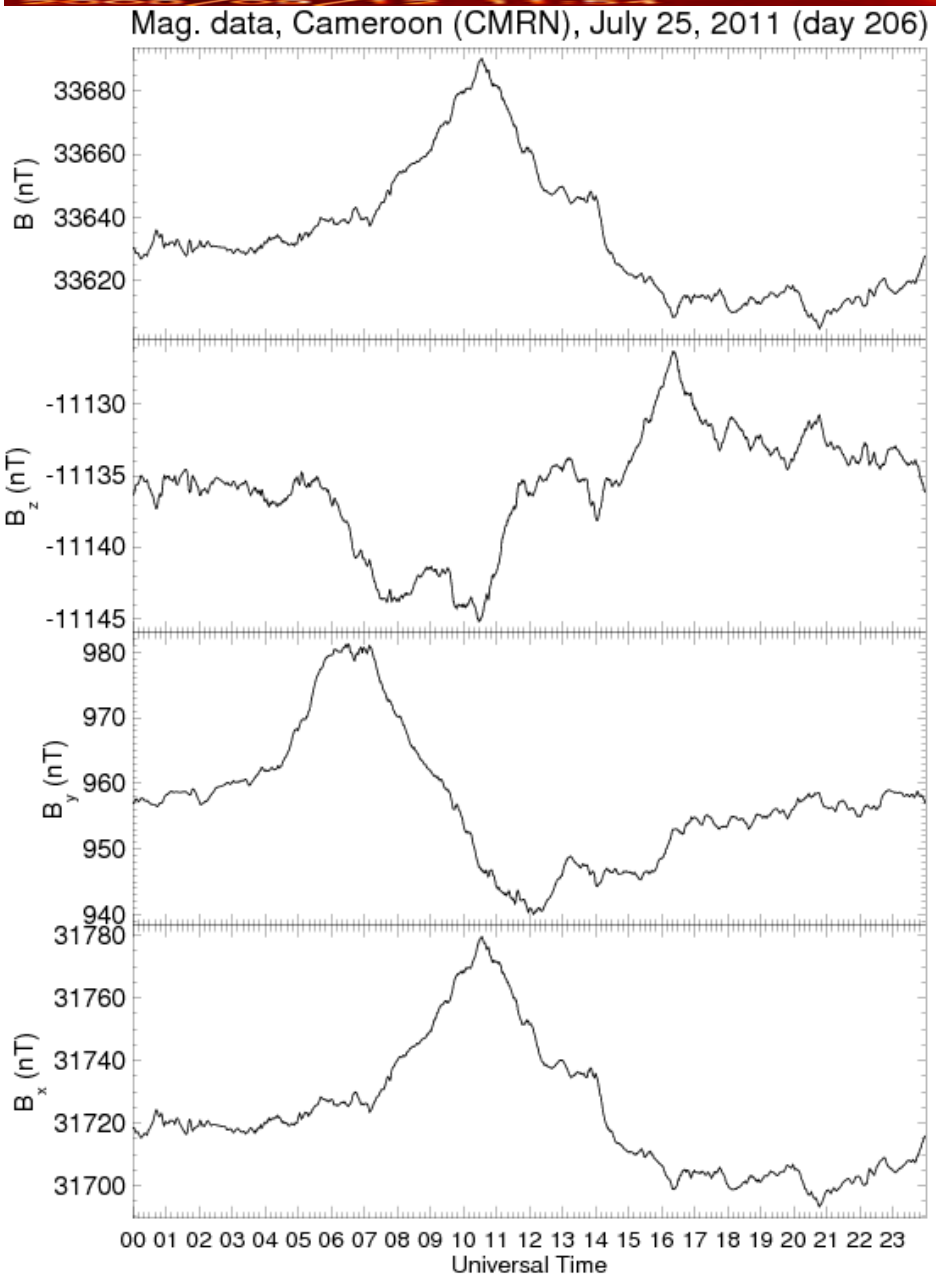


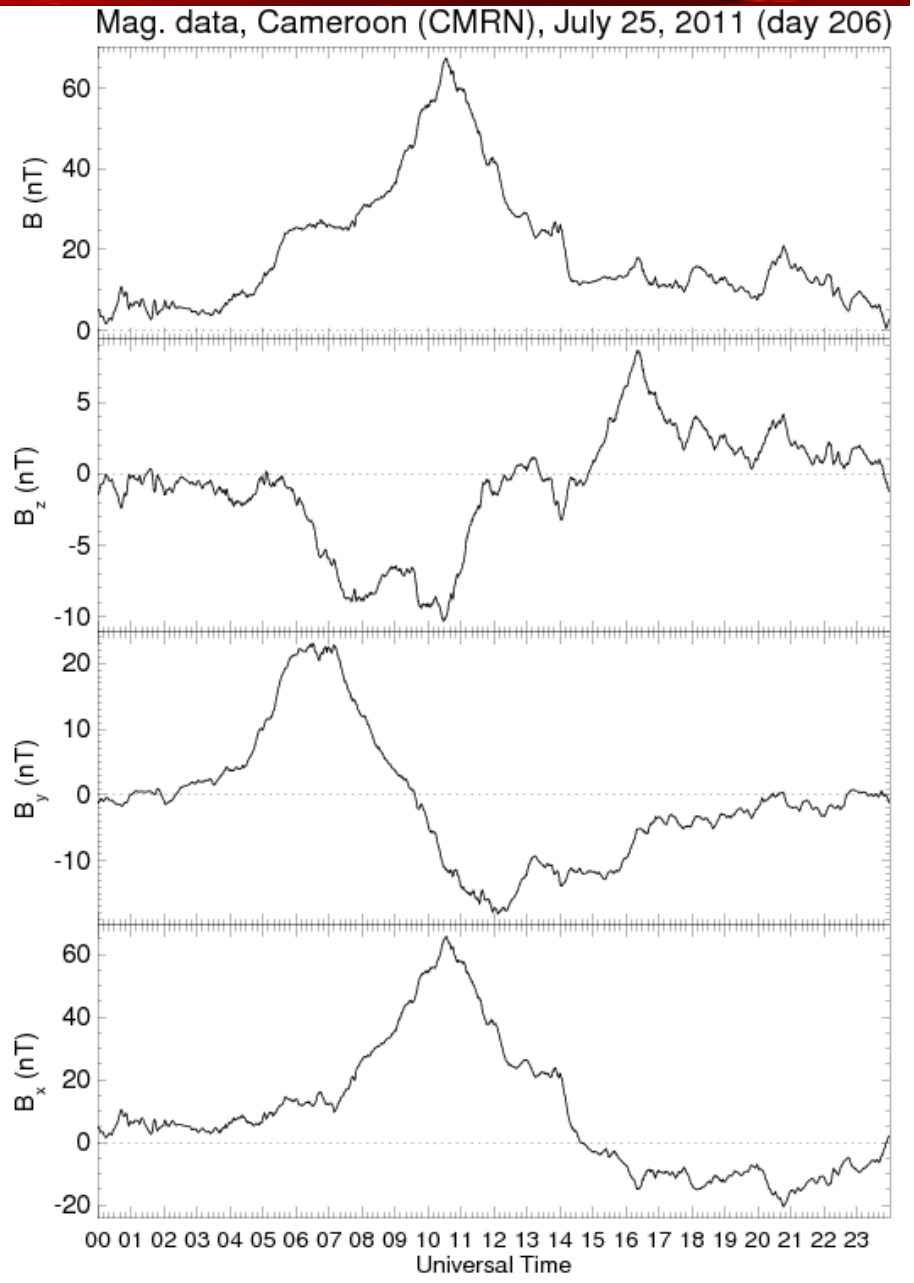
Full Setup

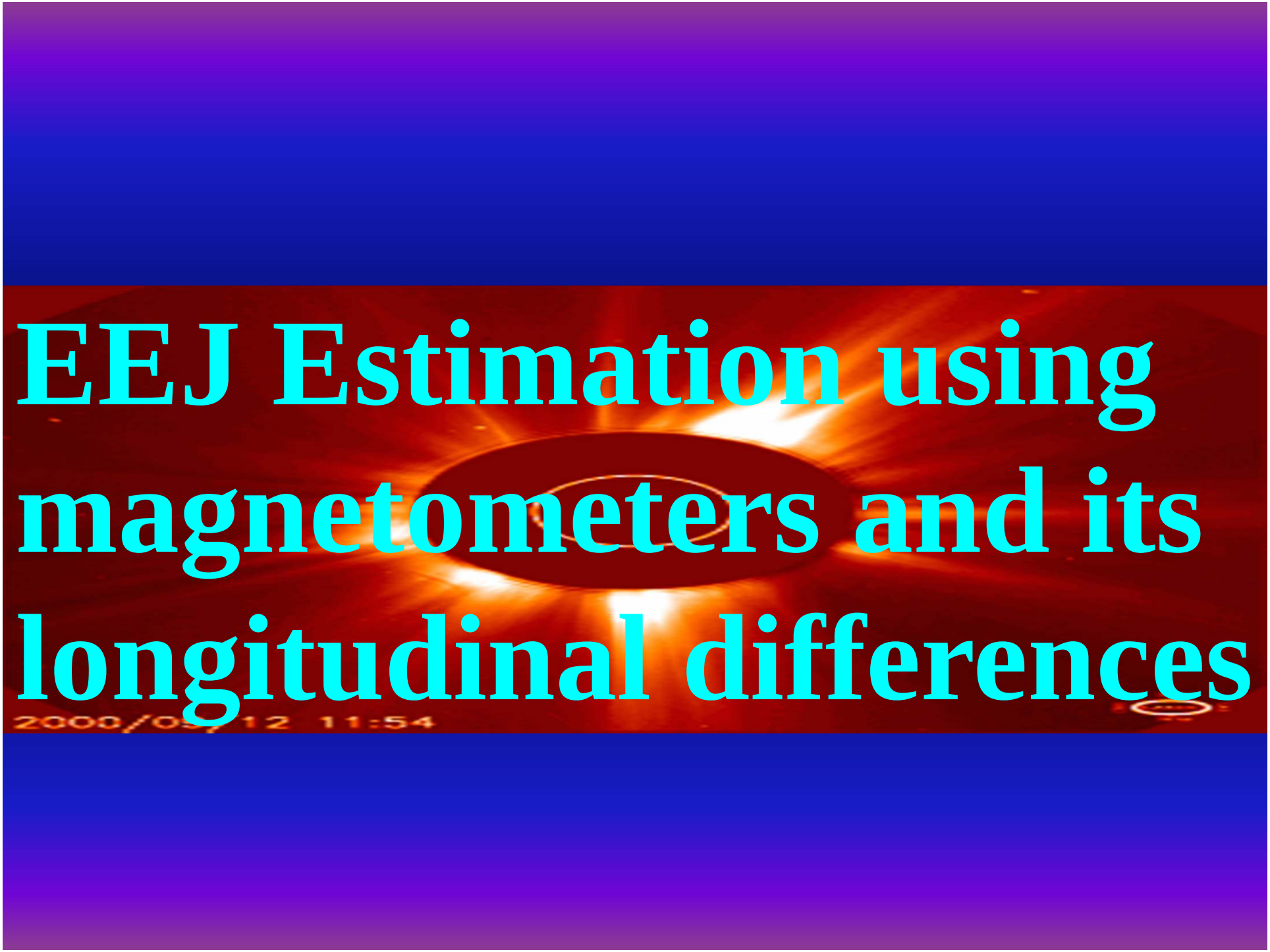
Setup at the Site

- Sensitivity: **0.01 nT**
- Time resolution: **0.5 sec**

What does the magnetometer Observes?

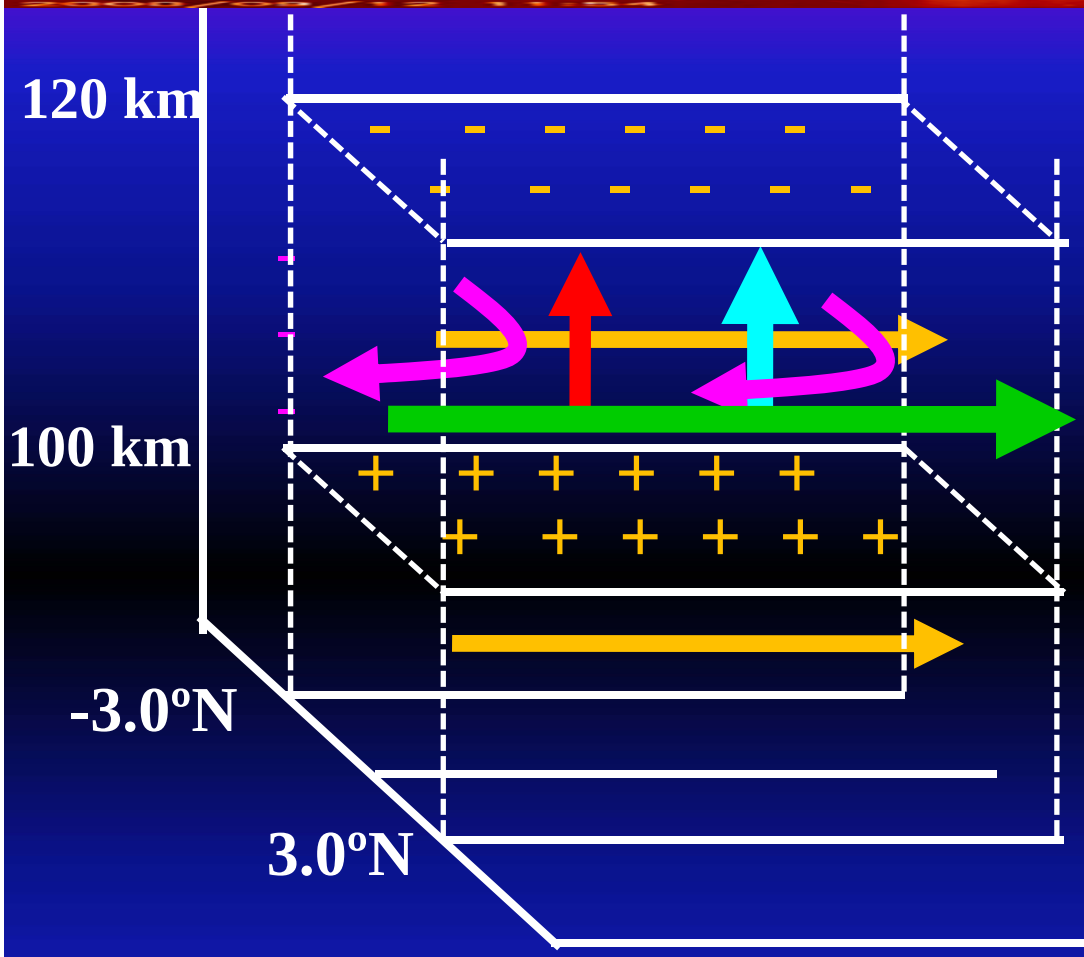






EEJ Estimation using magnetometers and its longitudinal differences

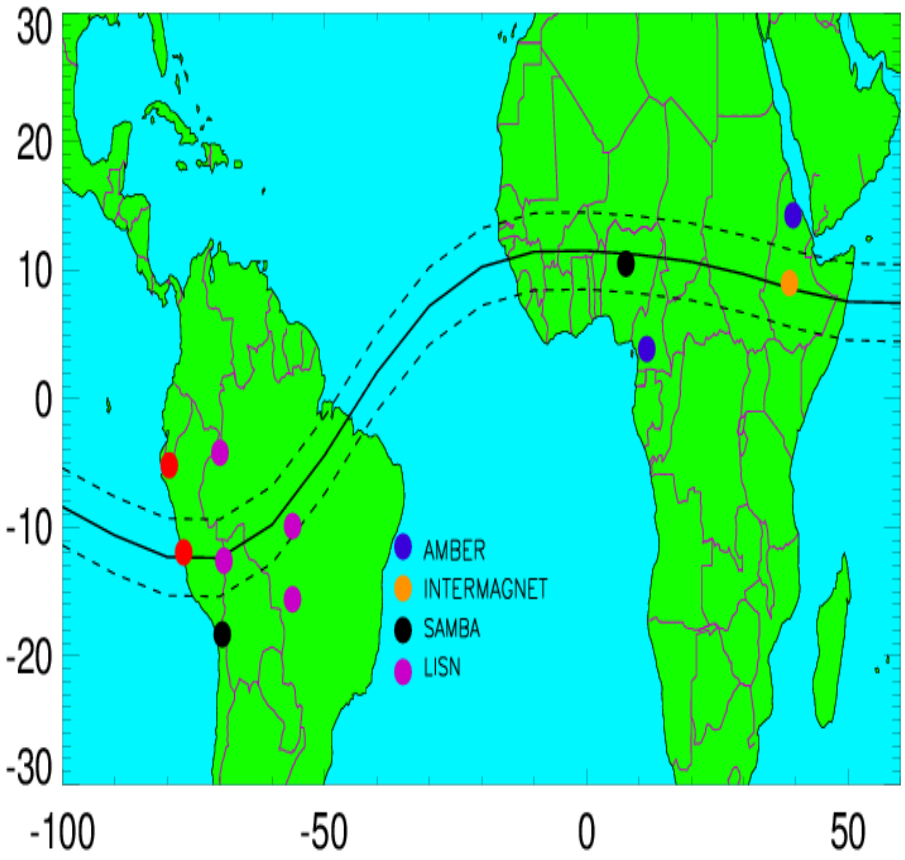
Equatorial Electrojet (EEJ) formation



- The solar-driven neutral wind results Sq current system and then **east-west polarization E-field** in the E-region.
- At the magnetic dip equator, the resulting **upward E x B drift** moves **negative** charge at the top and a **positive** at the bottom of the E-region.
- The **resulting E-field** prevents electrons to be drifted further upward, instead, they are **propelled westward** by the **eastward E-field**. This forms an **eastward electric current flow** within ±3.0° of the magnetic equator, which is called the Equatorial Electrojet (EEJ)

Can we estimate EEJ?

Only for Dayside



- Magnetometer at off the equator

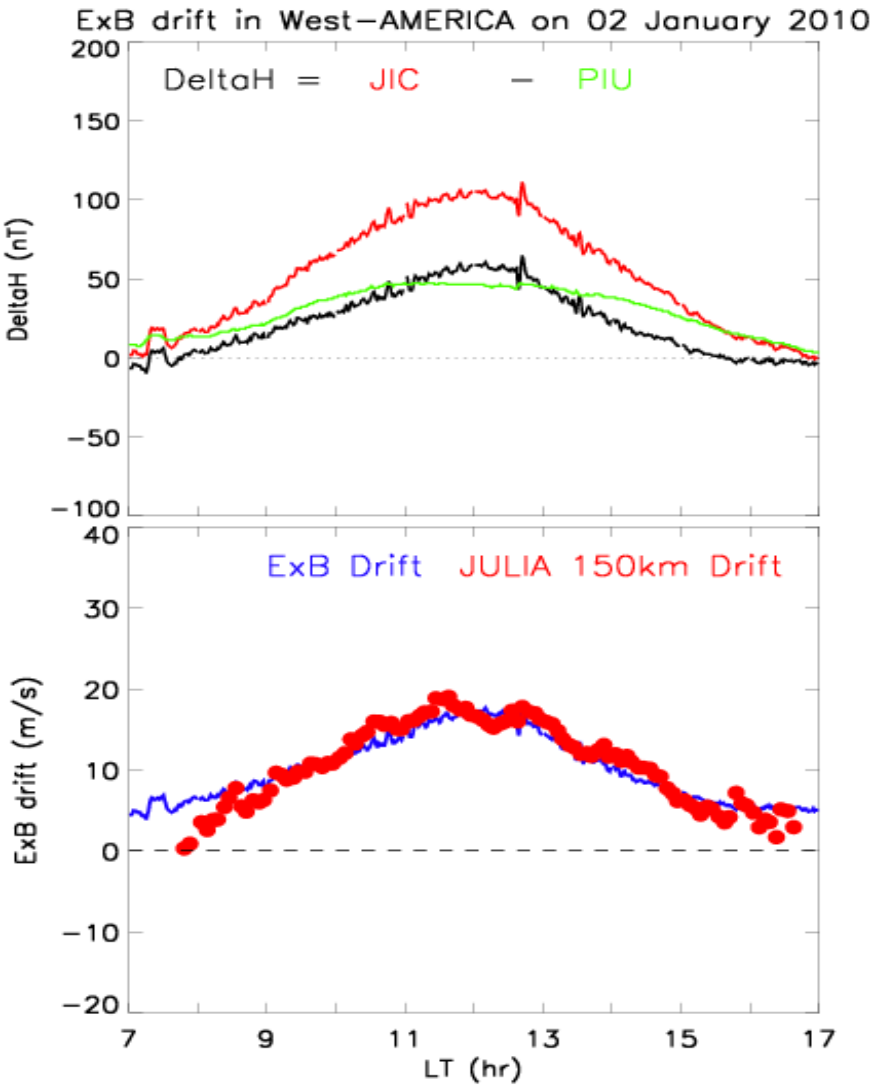
$$B_{Obs} = B_{main}+B_{SQ}+B_{FAC}+B_{RC}+B_{MP}$$

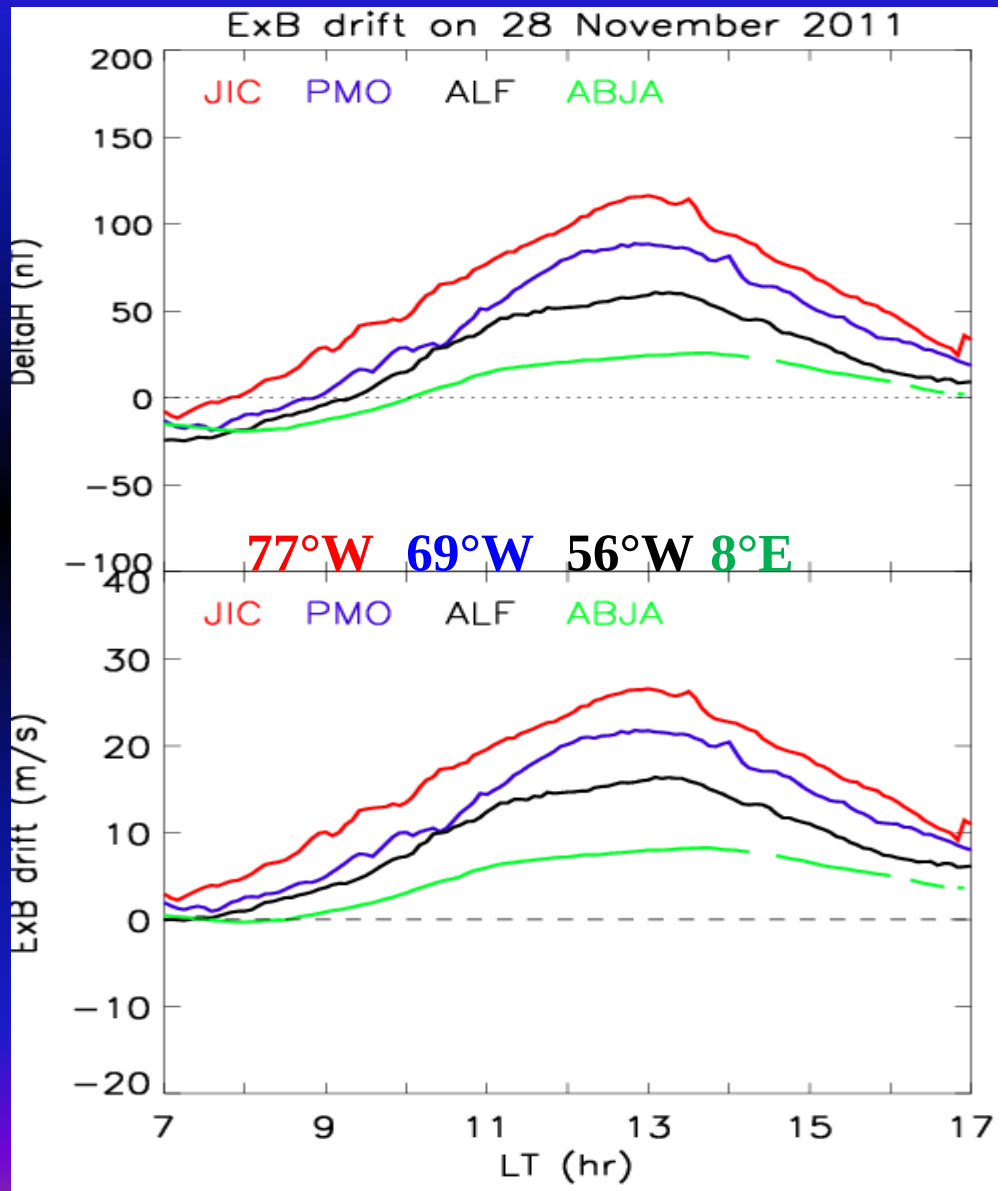
- Magnetometer at the equator

$$B_{Obs} = B_{main}+B_{SQ}+B_{FAC}+B_{RC}+B_{EJ}+B_{MP}$$

EEJ estimation technique

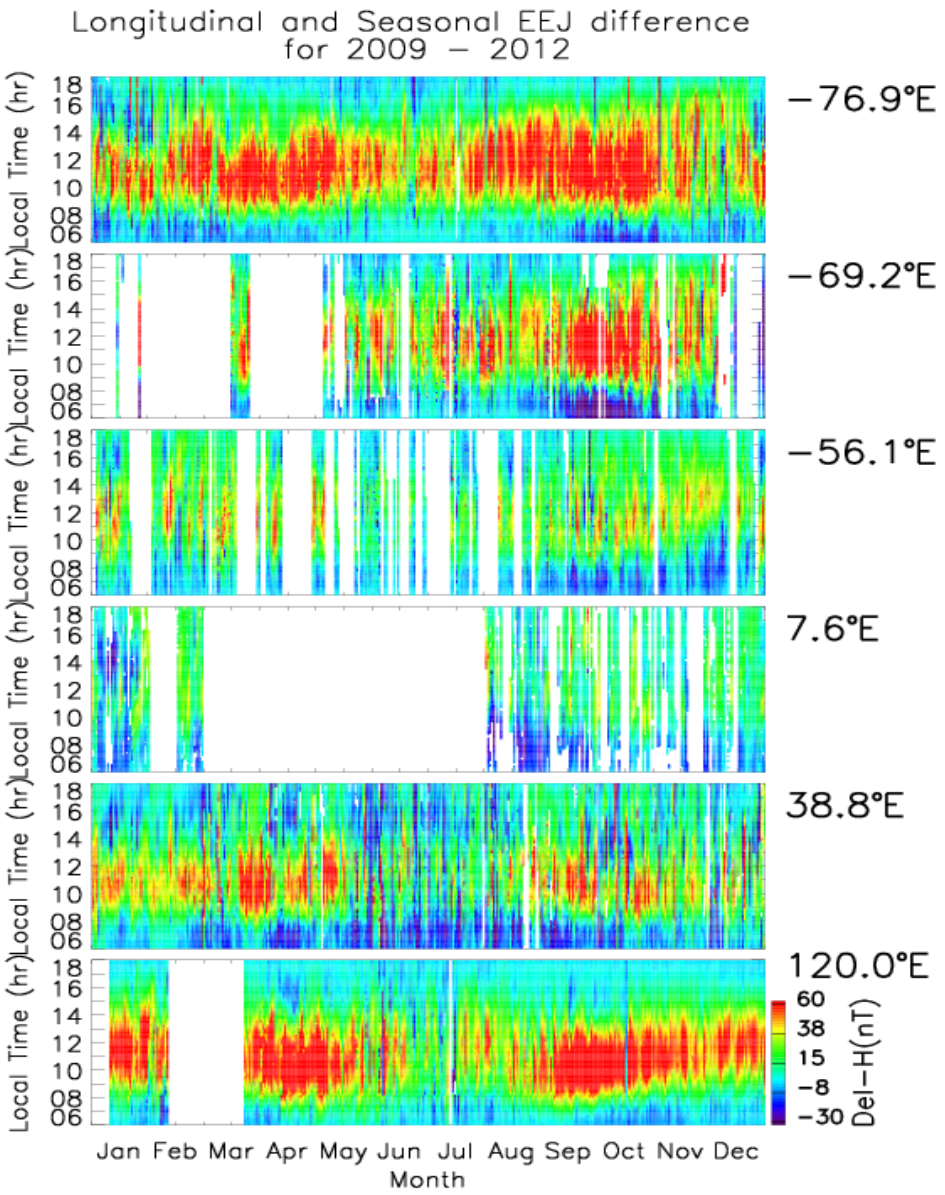
Only for Dayside



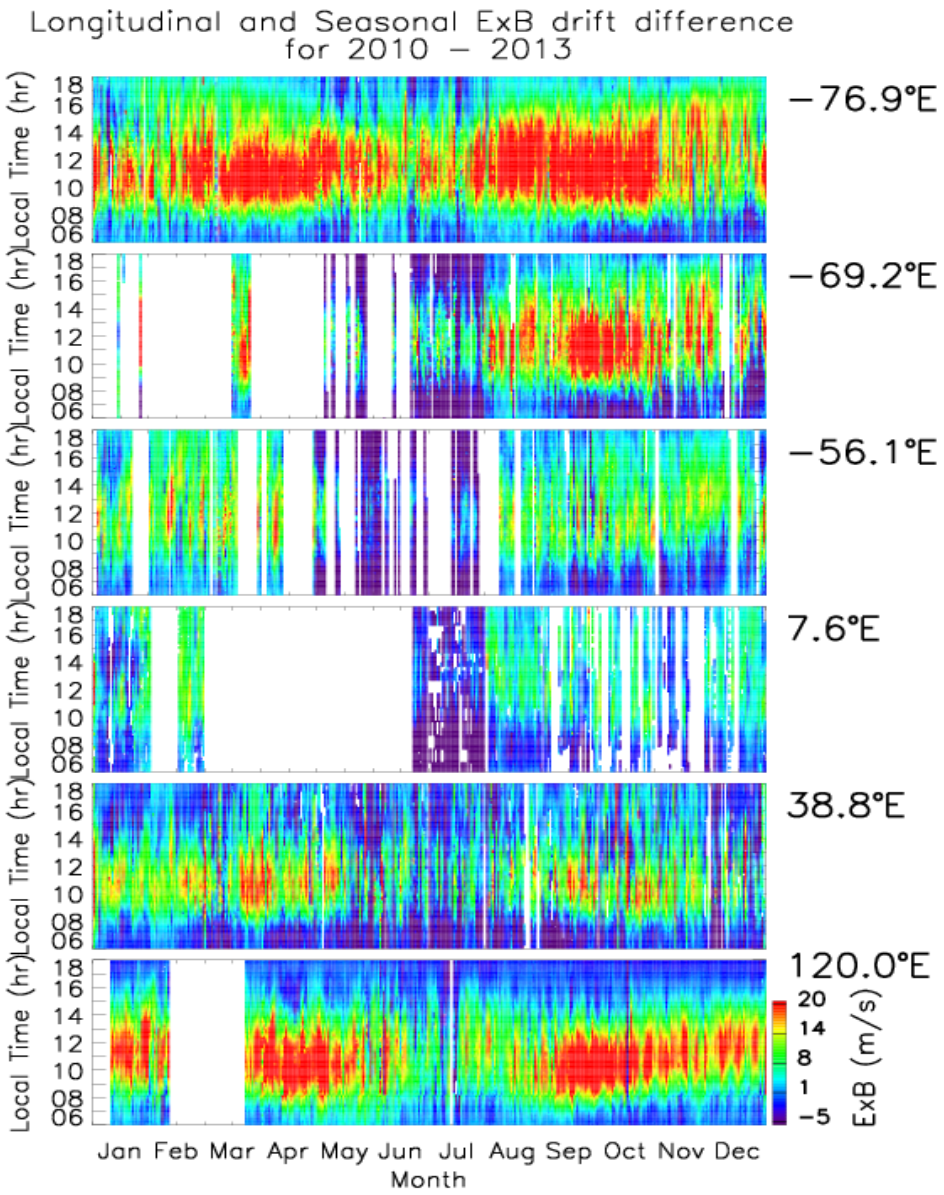


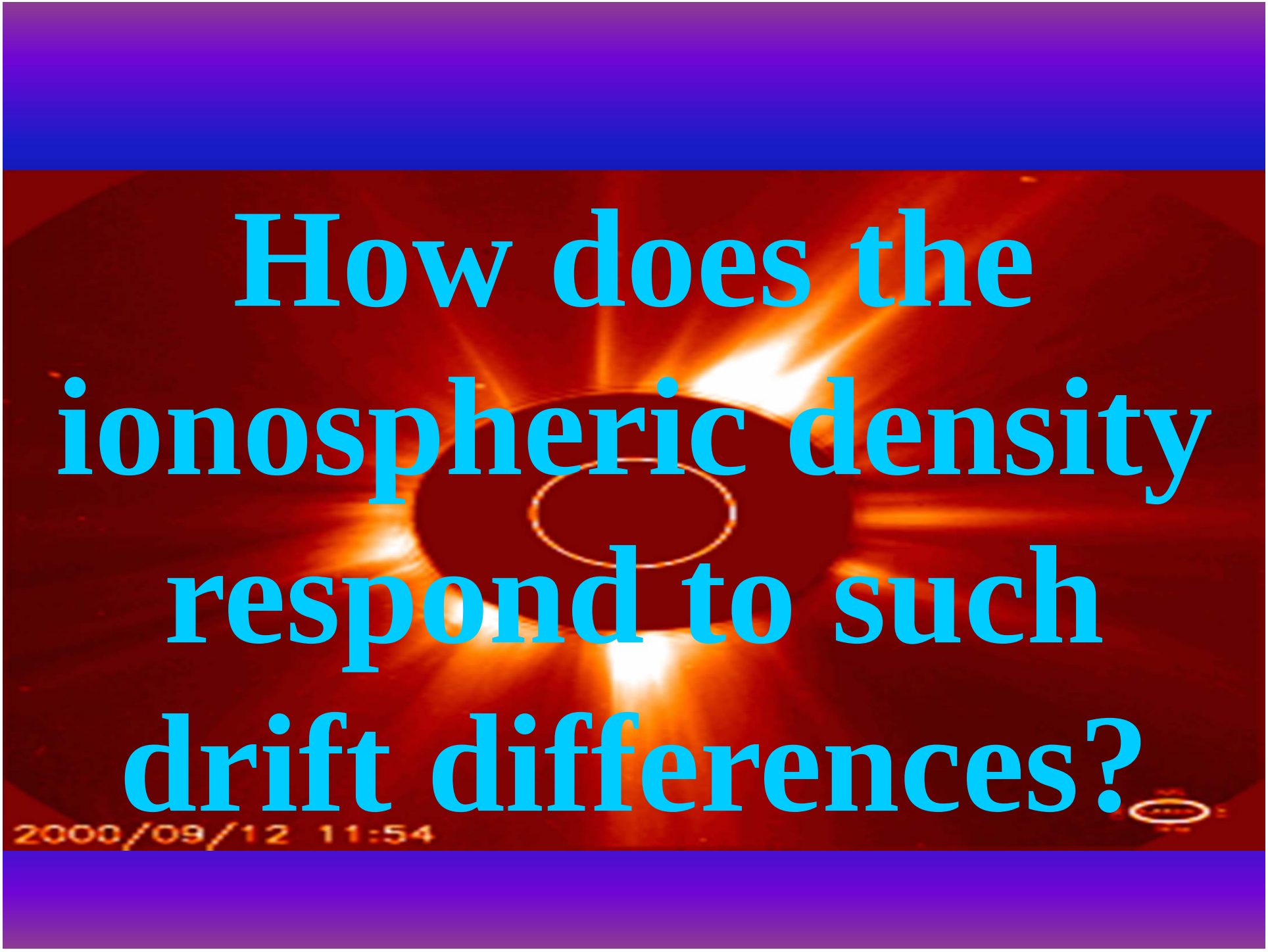
Longitudinal variability of EEJ & drift

EEJ



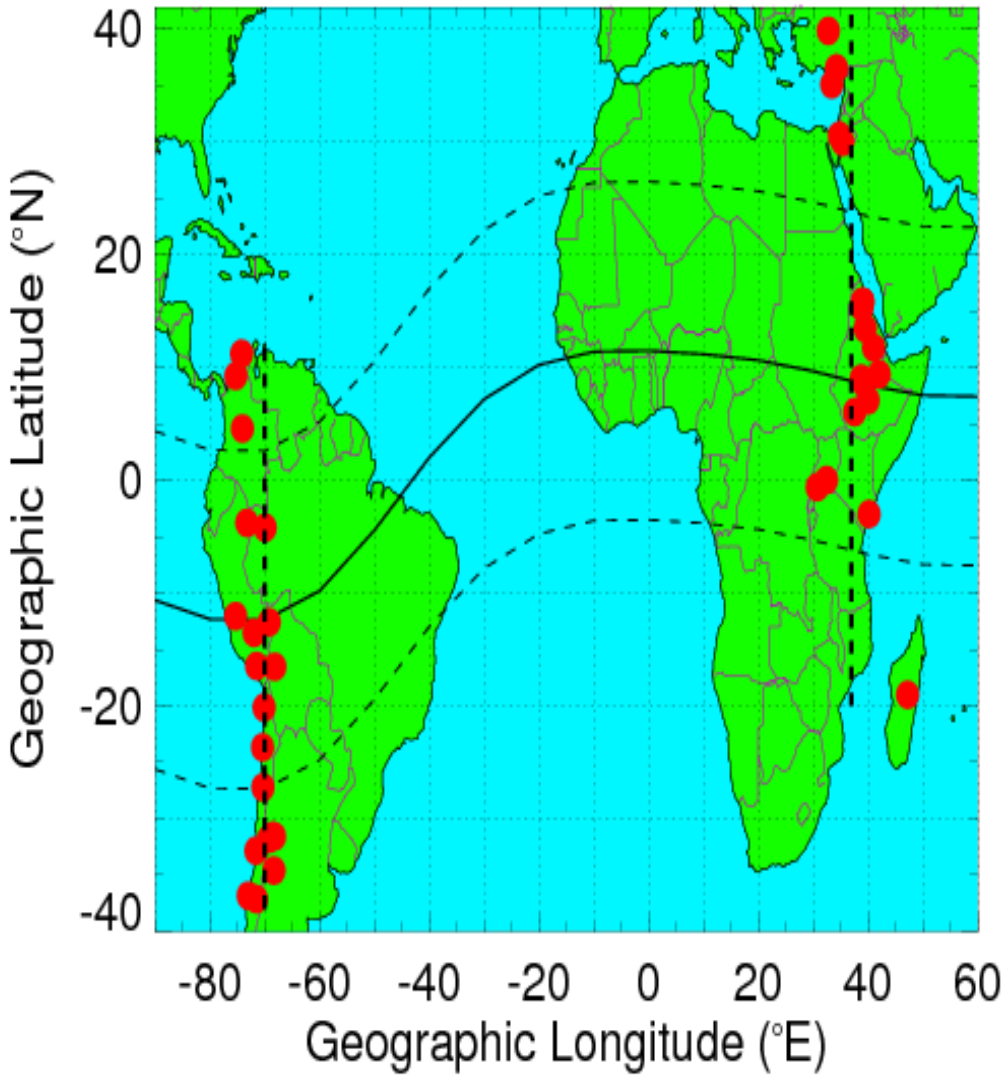
ExB Drift





How does the ionospheric density respond to such drift differences?

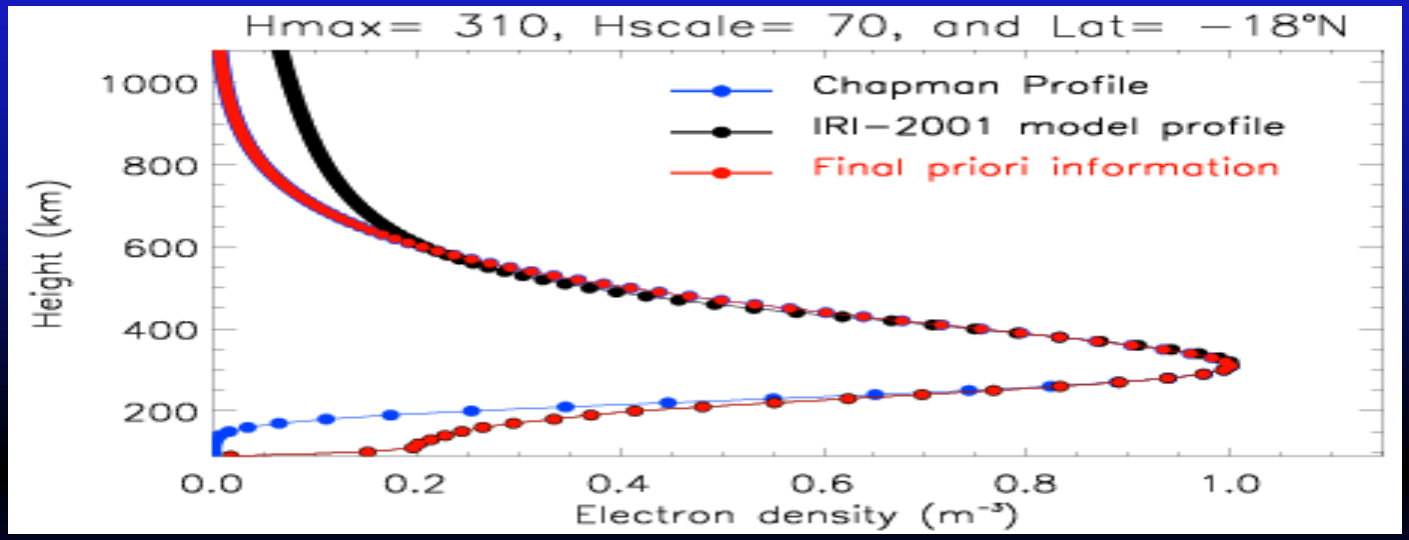
Computerized Ionospheric Tomography (CIT)



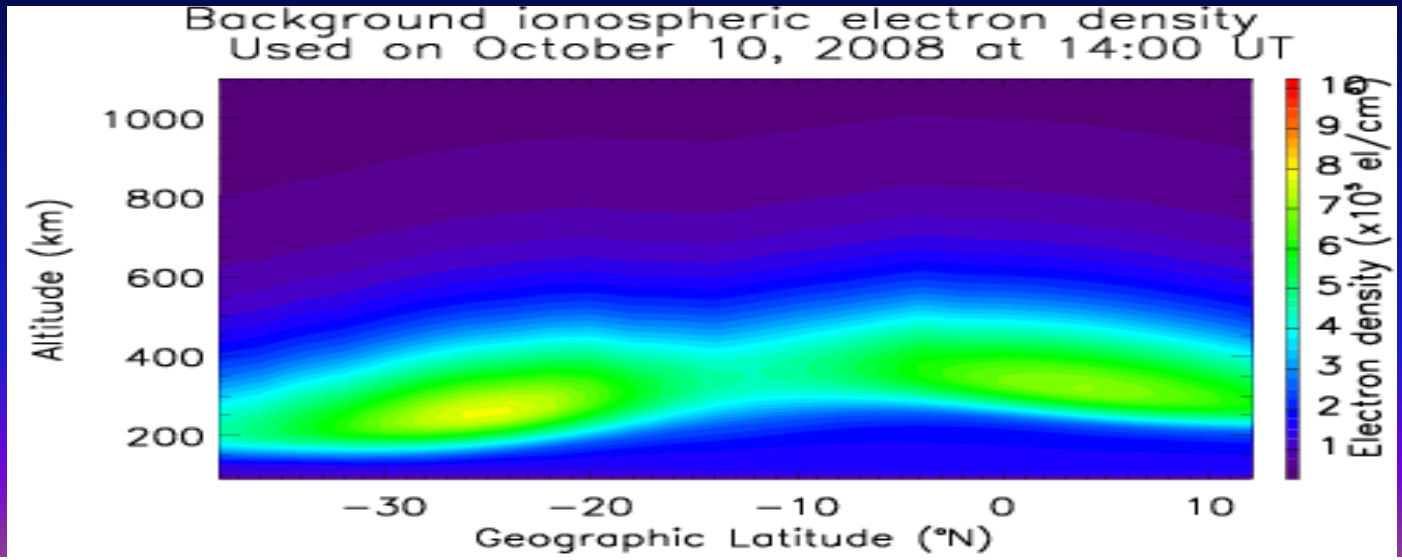
- Use radio signals from satellites
- Needs a chain of ground stations
- Use line integral of electron density (TEC) as input ingredients
- Invert data sets based on linear mathematical inversion technique
- Obtain vertical structure of electron density
- Large-scale spatial structure of ionosphere

Resource for Tomography

Harmonic background profiles

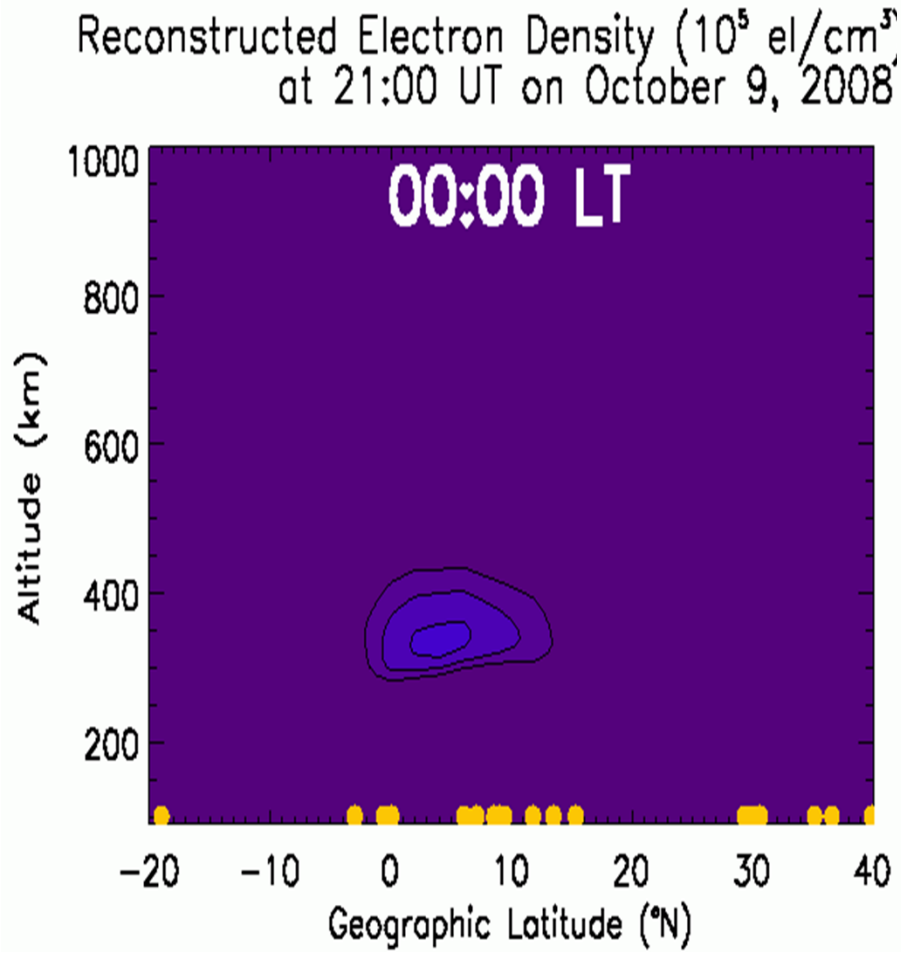


Background profiles

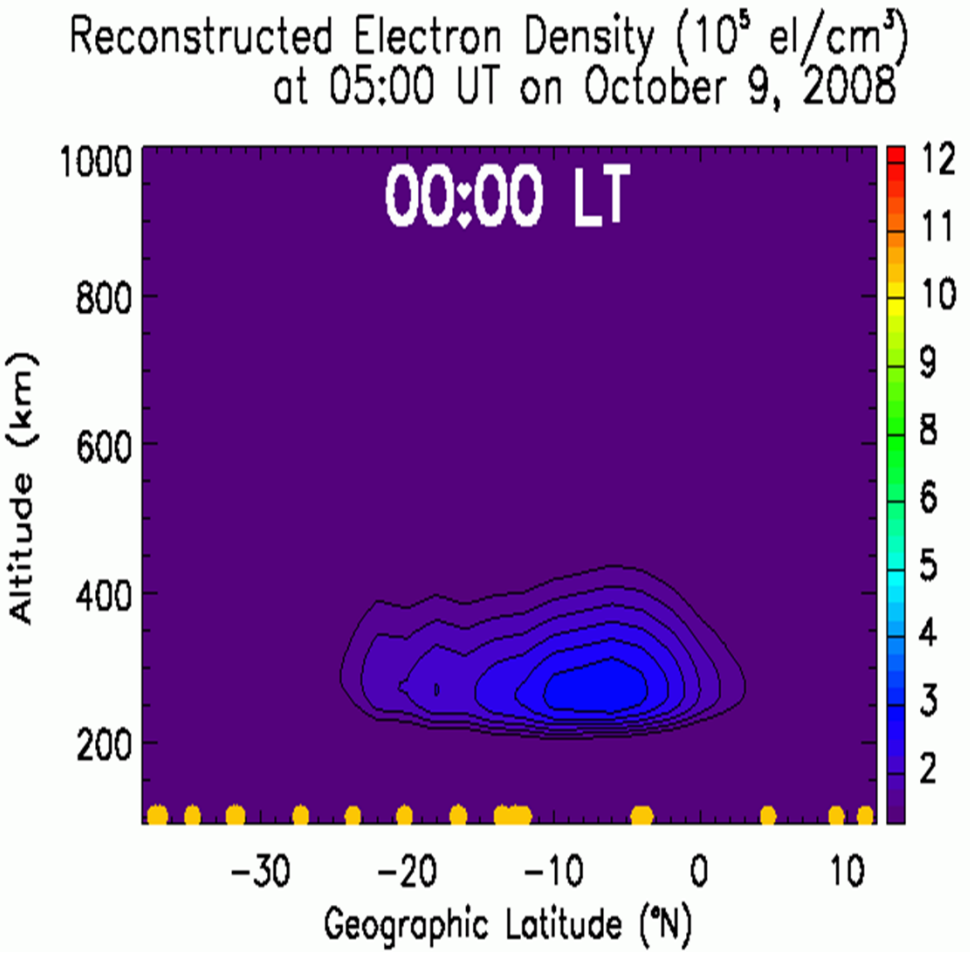


Tomographically reconstructed density profiles

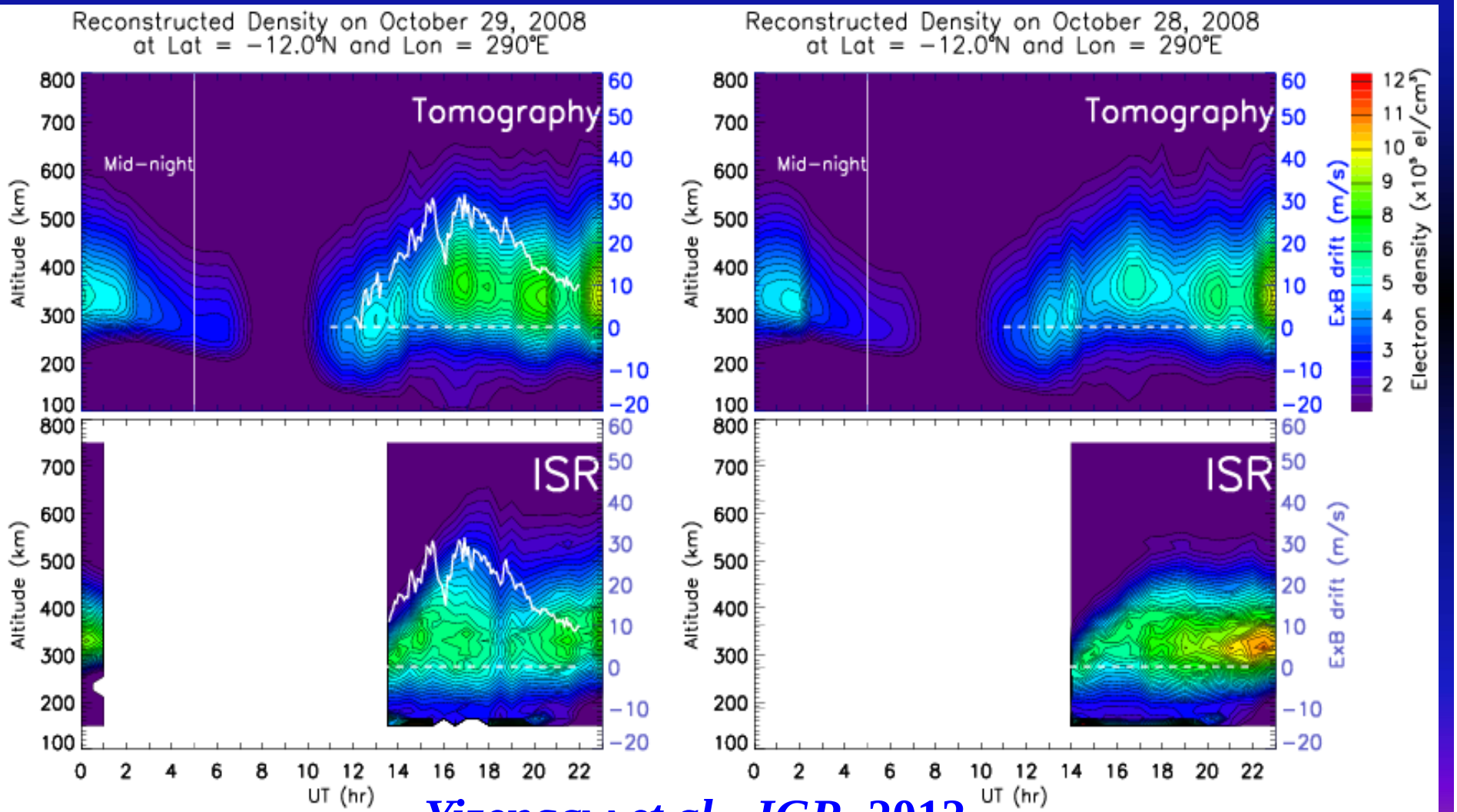
East Africa



West America



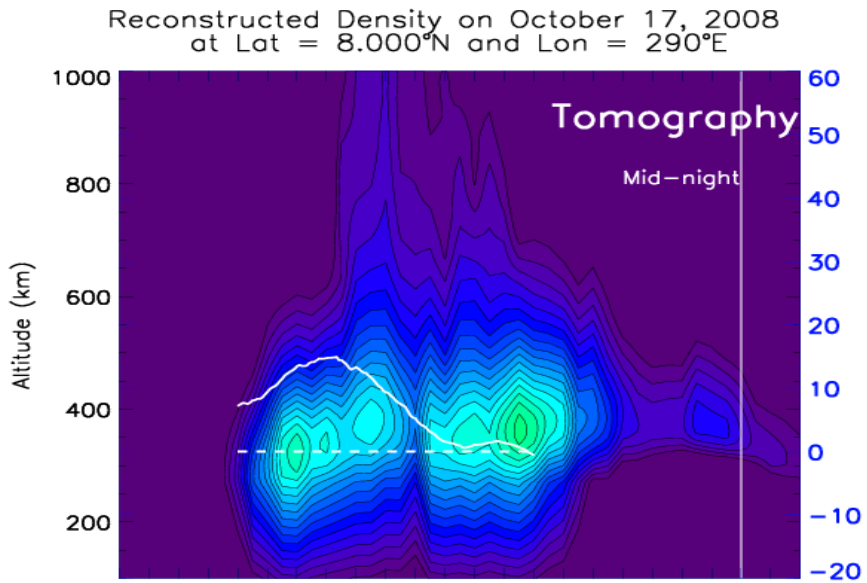
Tomography and ISR Density profiles comparison

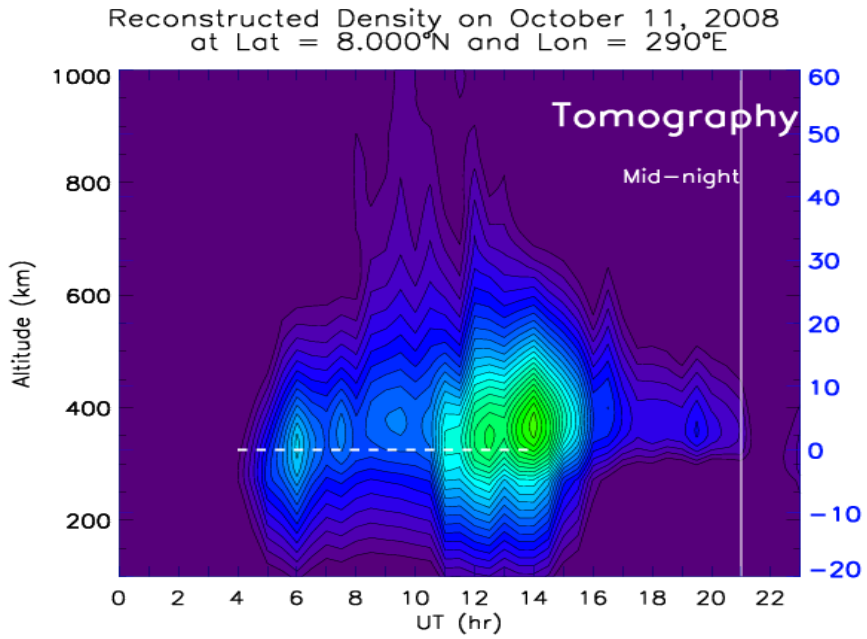


Yizengaw et al., JGR, 2012

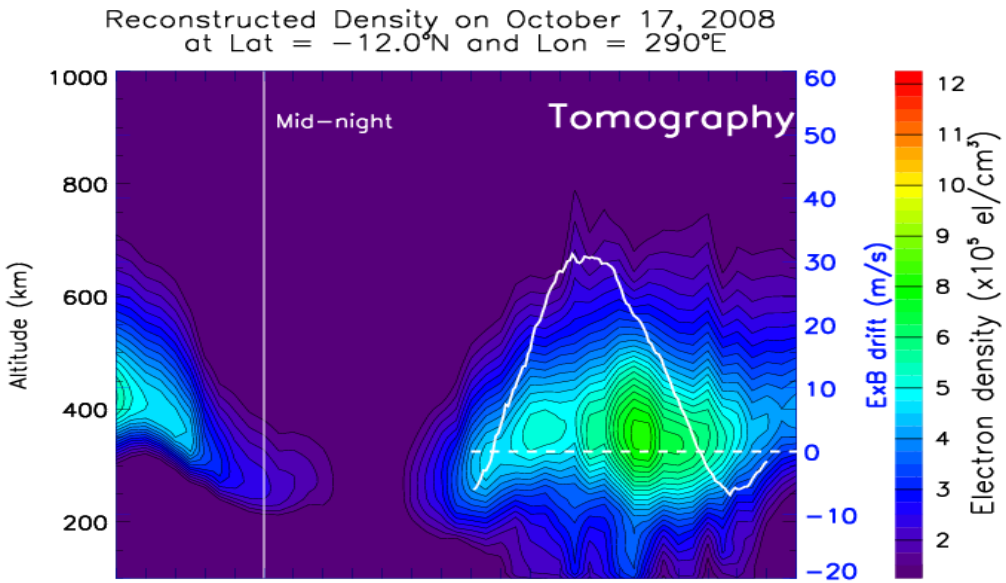
Longitudinal Density profiles differences

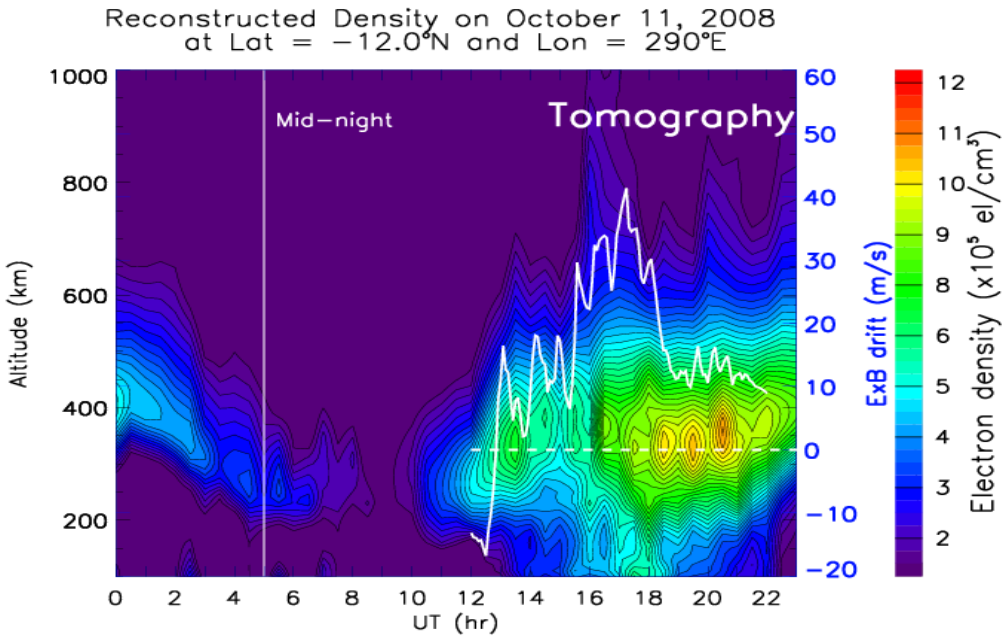
East Africa





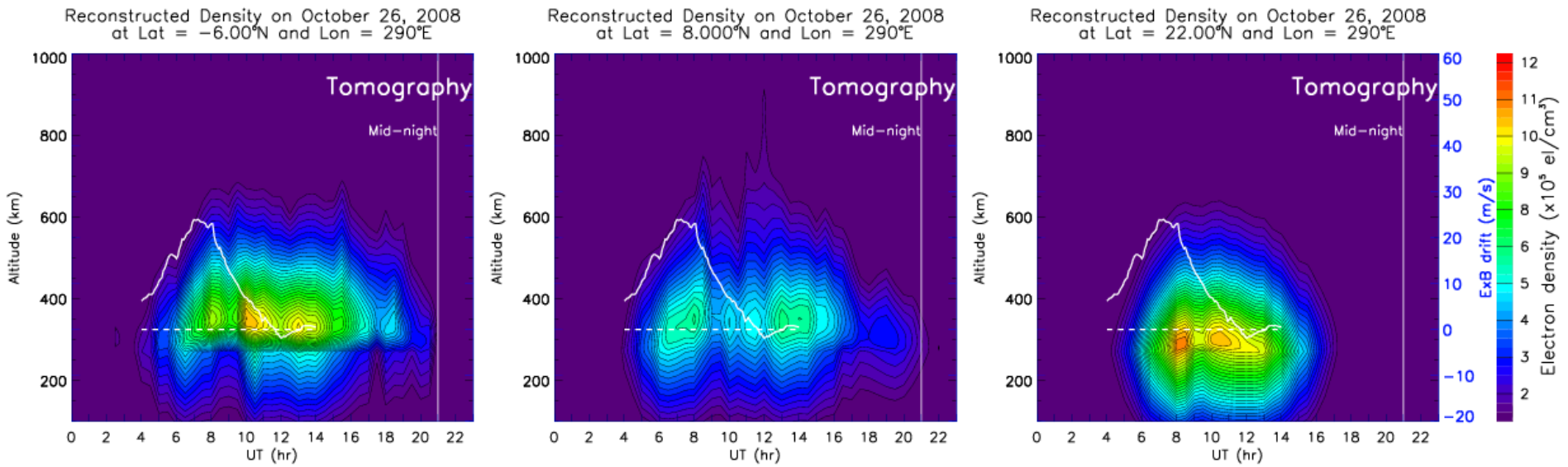
West America



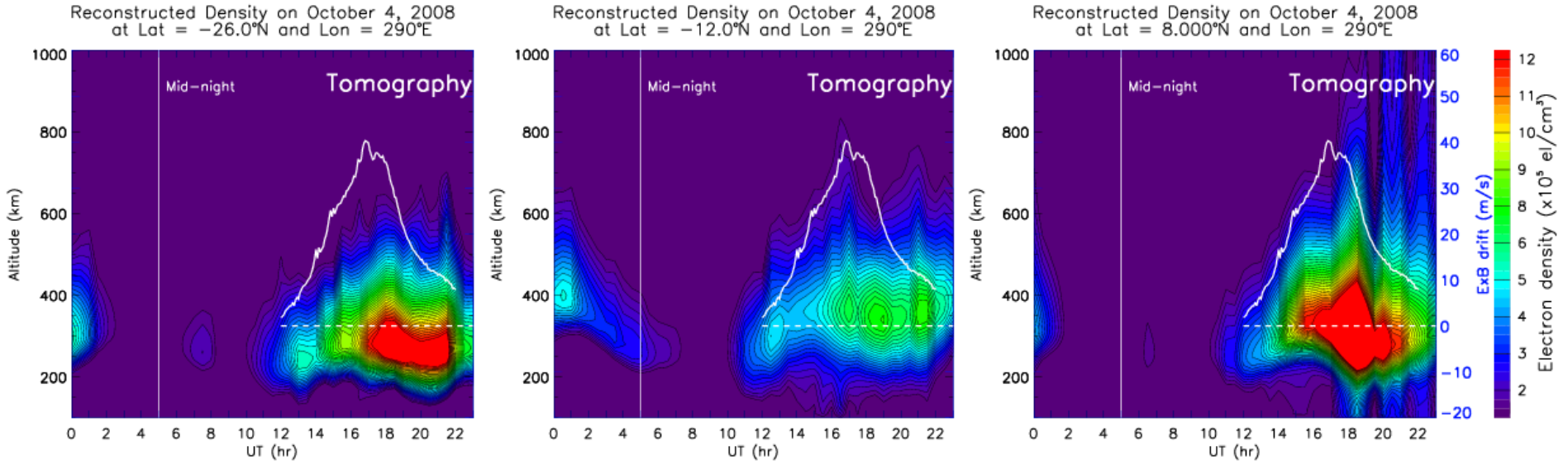


Longitudinal Density profiles differences

Southern peak Africa-Equator Northern peak



Southern peak America-Equator Northern peak



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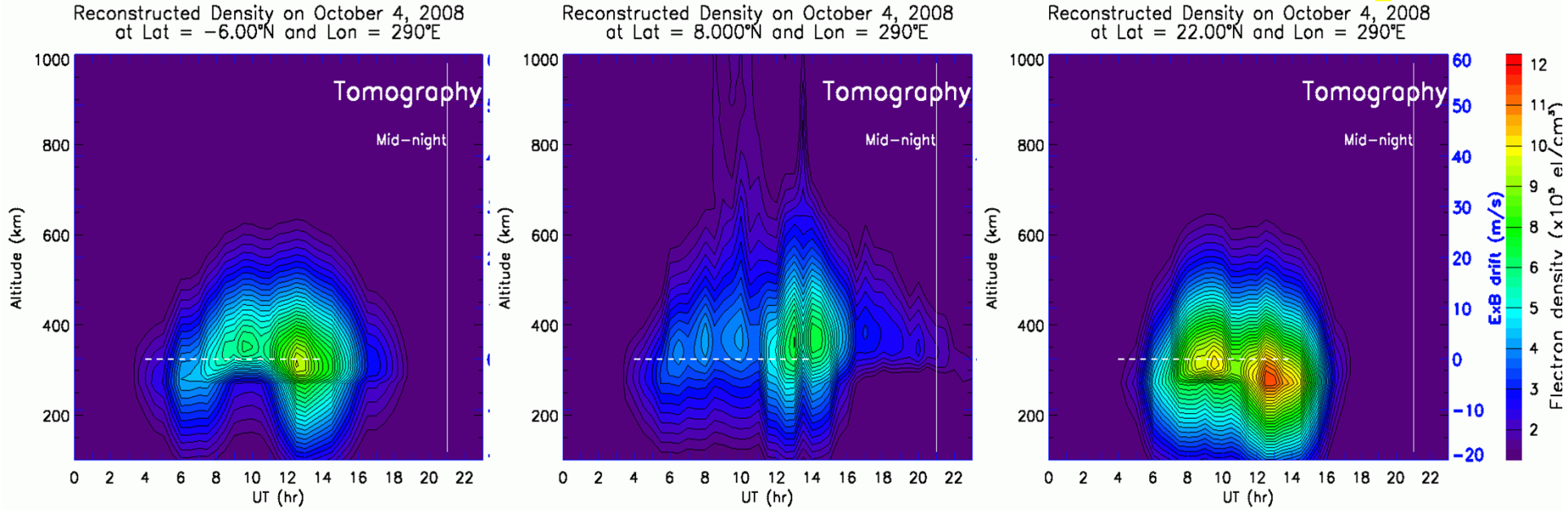
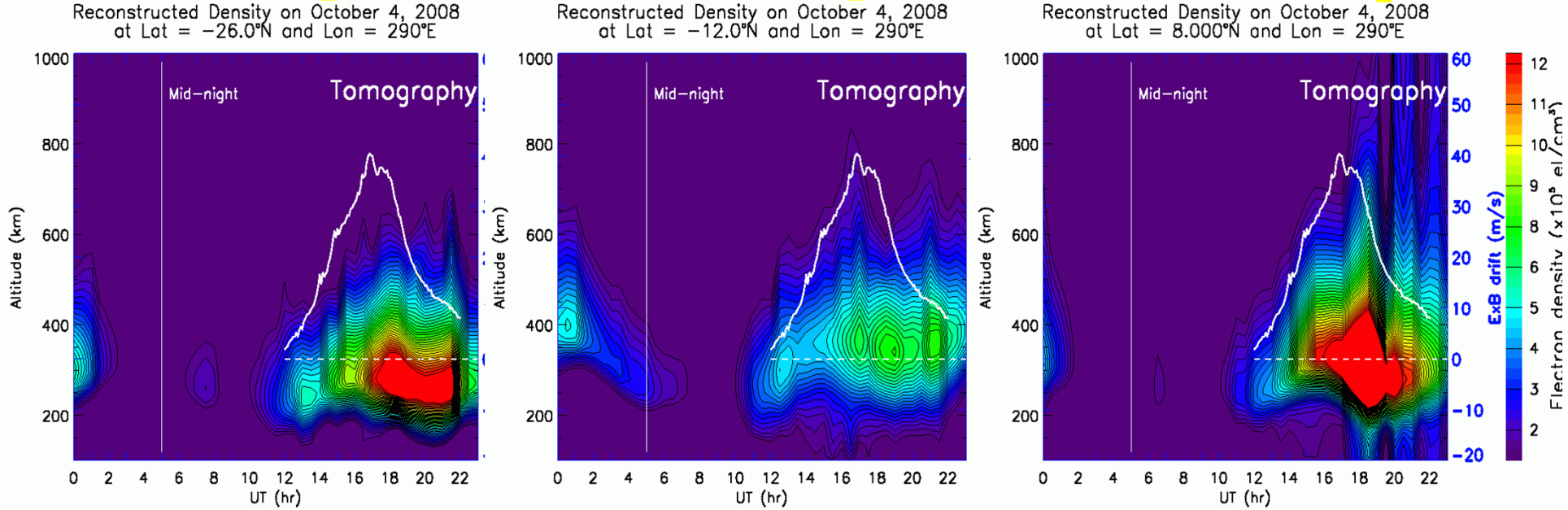


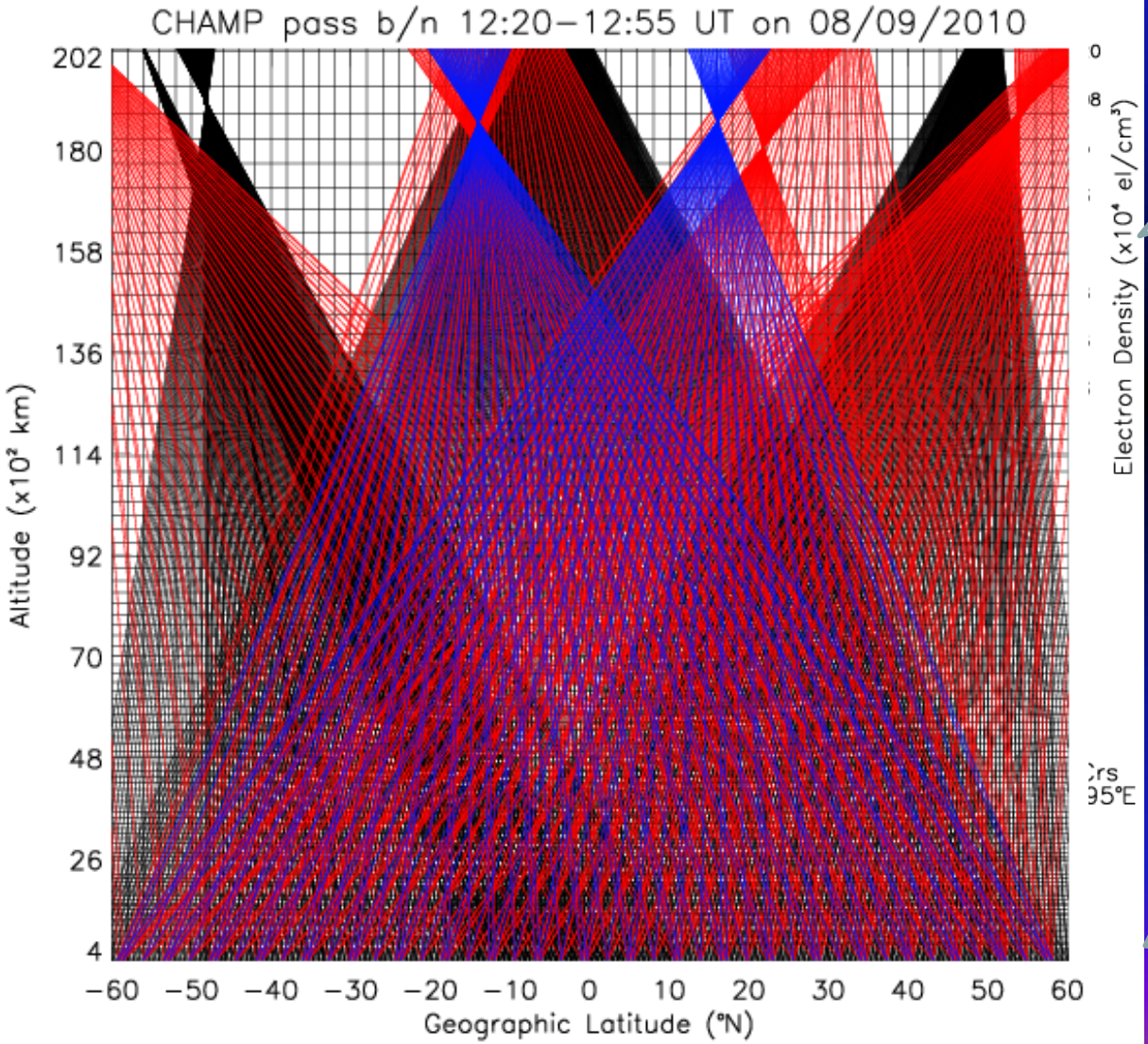
Southern peak America-Equator Northern peak



Clear EIA from topside ionospheric structure

Vertical density profiles

Horizontal density profiles



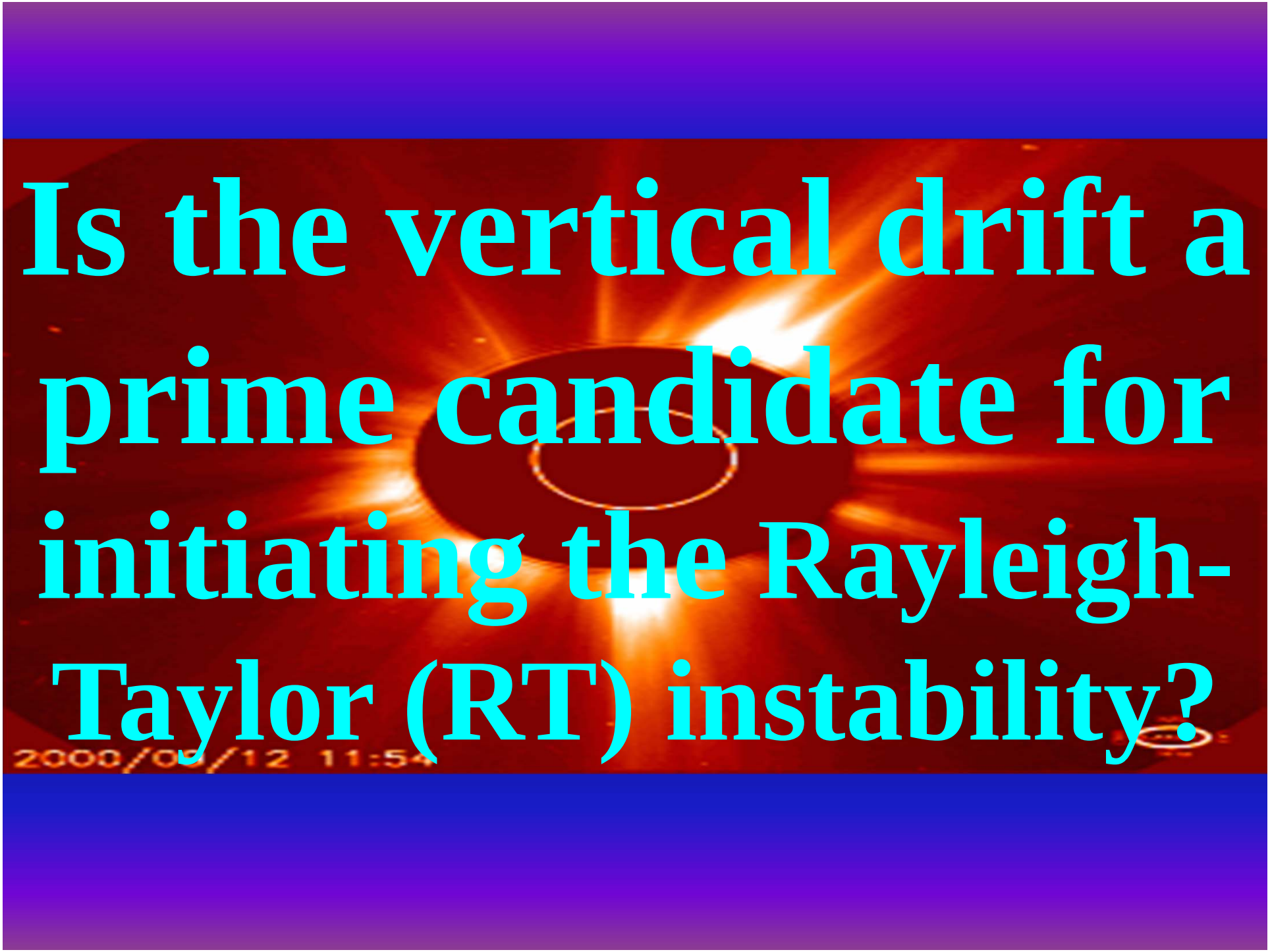
Density profile

GPS

GPS+GLON

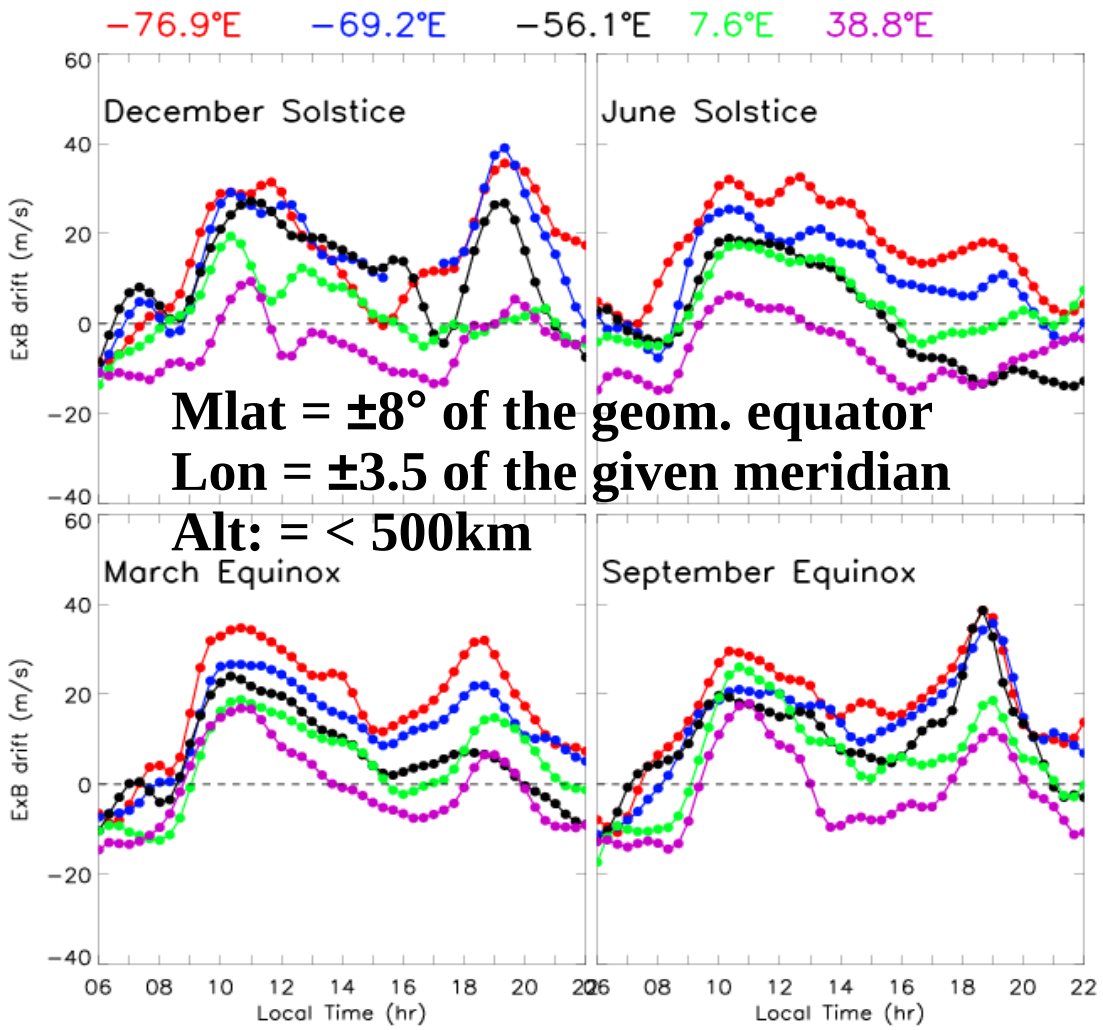
GPS+GLON +GAL

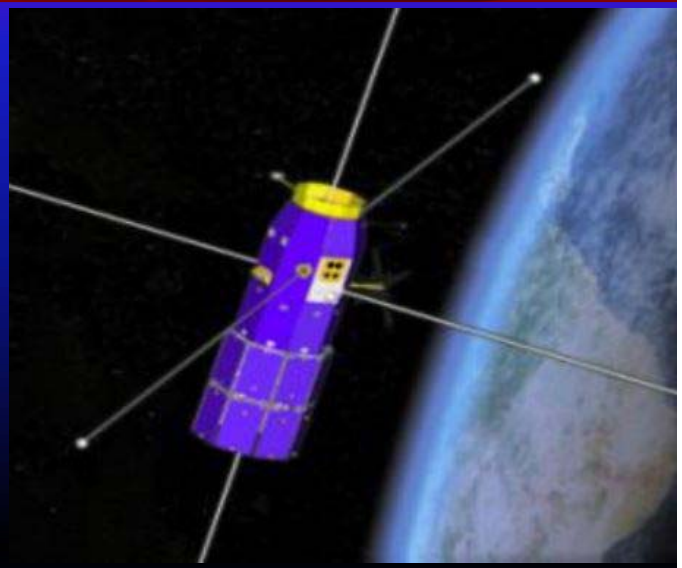
Comparison with TOPEX altimeter TEC


Is the vertical drift a prime candidate for initiating the Rayleigh-Taylor (RT) instability?
2000/05/12 11:54

Longitudinal drift Variations

IVM drift average (2009-2013)





Incl.: 13°
Alt.: 400 – 850km
Instruments: PLP, IVM, VEFI, magnetometer, GPS, and lightening detector

The drift in general decrease in magnitude as we go east.

Yizengaw et al., AG, 2013 (submitted)

What cause the enhancement of Rayleigh-Taylor instability growth rate?

$$\gamma = \frac{\Sigma_F}{\Sigma_F + \Sigma_E}\left(V_{dr} - U_{\perp} - \frac{g}{\nu_{eff}}\right)\frac{1}{N_e}\frac{dN_e}{dh}$$

Σ_F & Σ_E :- *F- and E-region Pederson conductivities*

V_{dr} :- *Vertical drift*

$U_{\perp}$:- *Perpendicular neutral wind component*

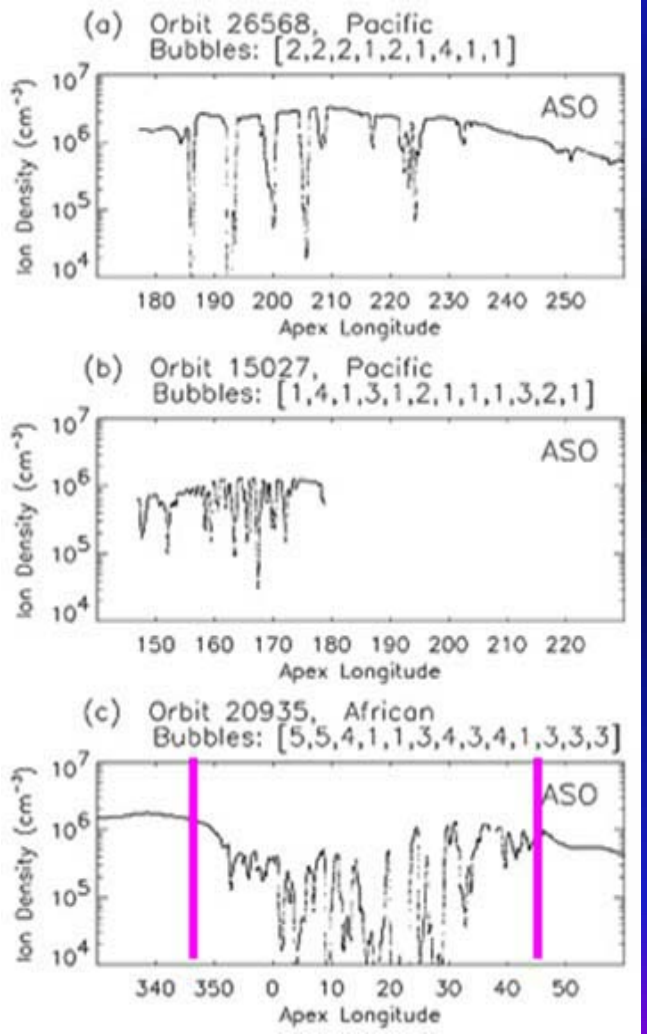
g :- *Gravity*

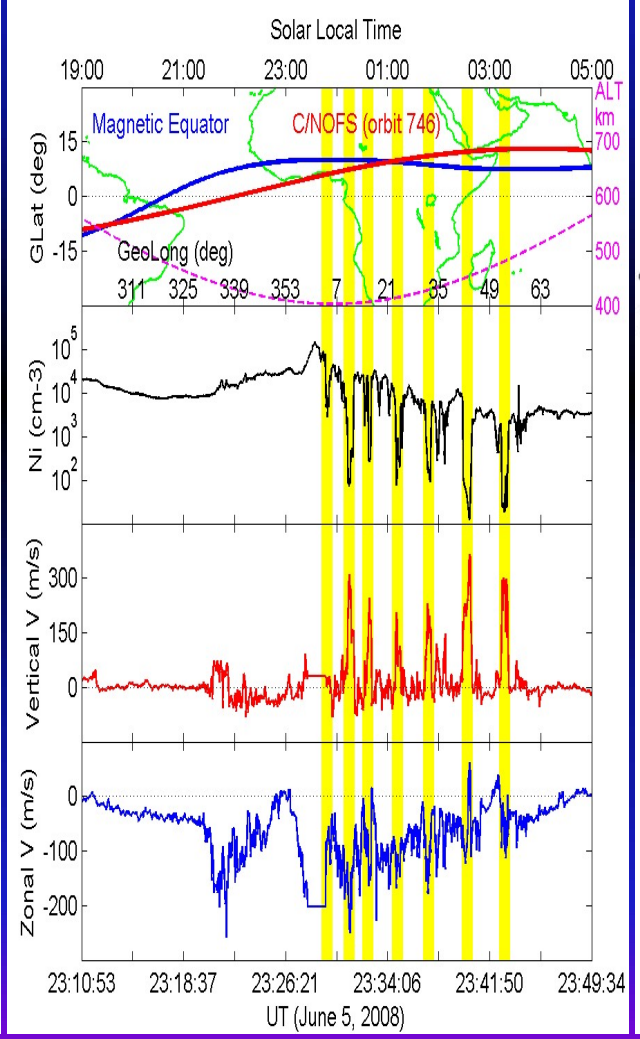
ν_{eff} :- *Collision frequency*

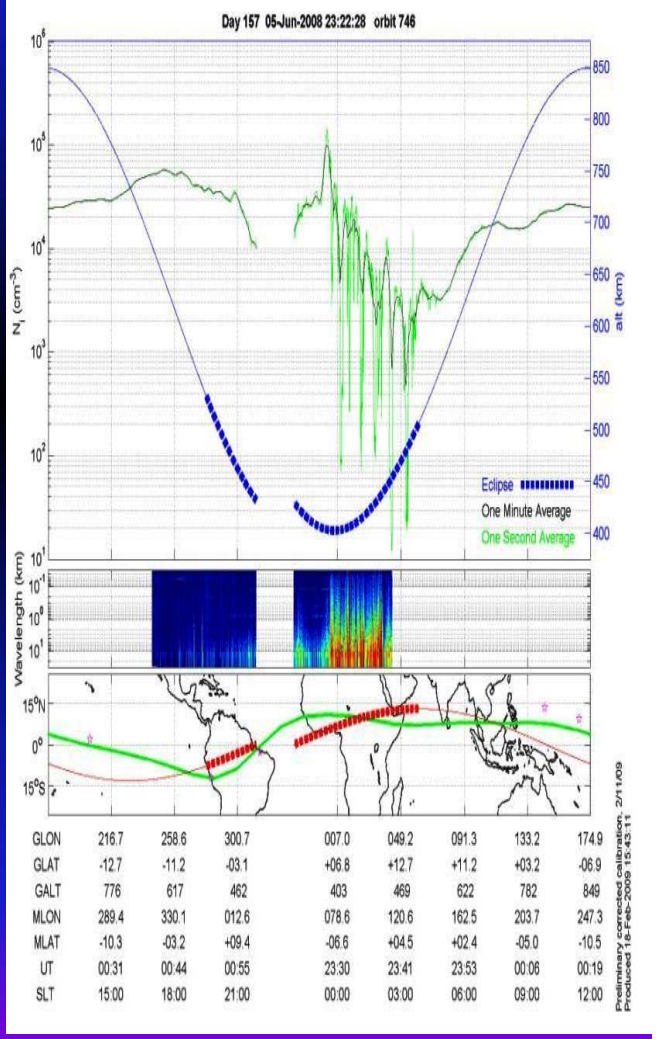
N_e :- *Electron density*

$\frac{dN_e}{dh}$:- *Density gradient!*

Then why the bubble distributions show the other way around?



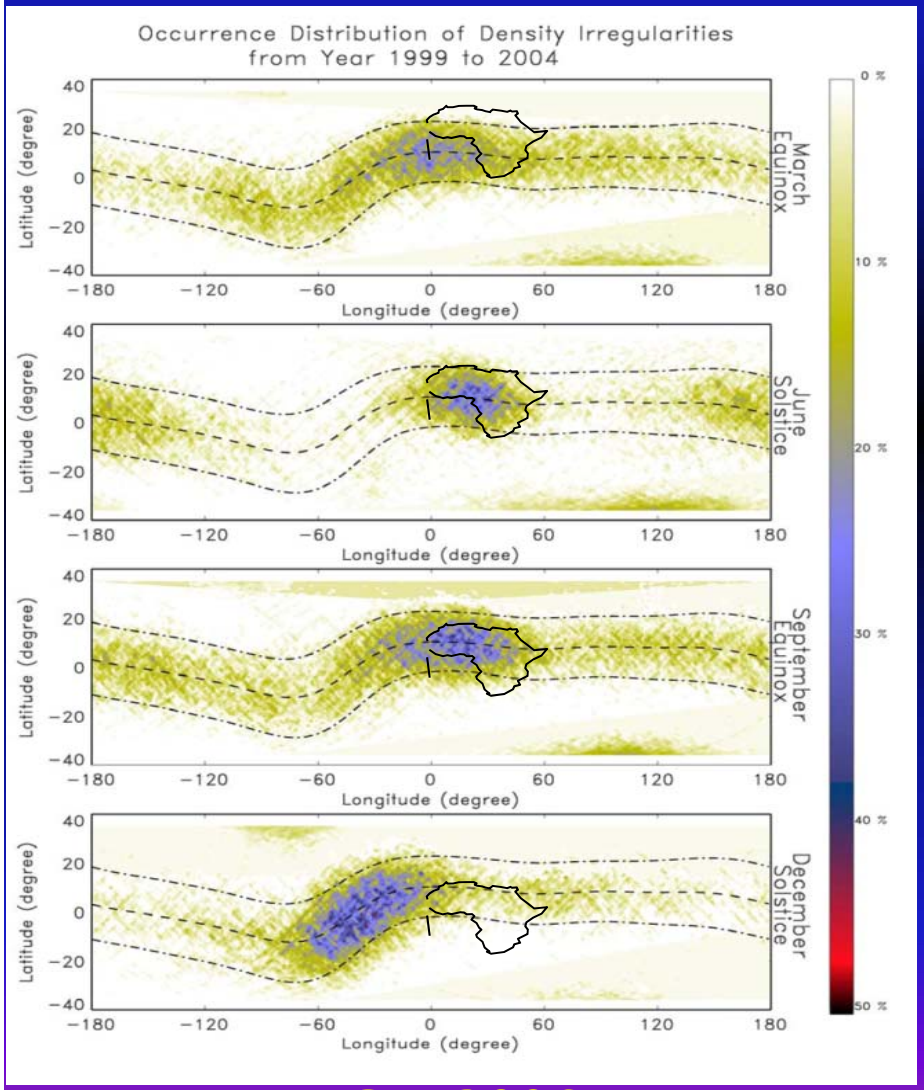




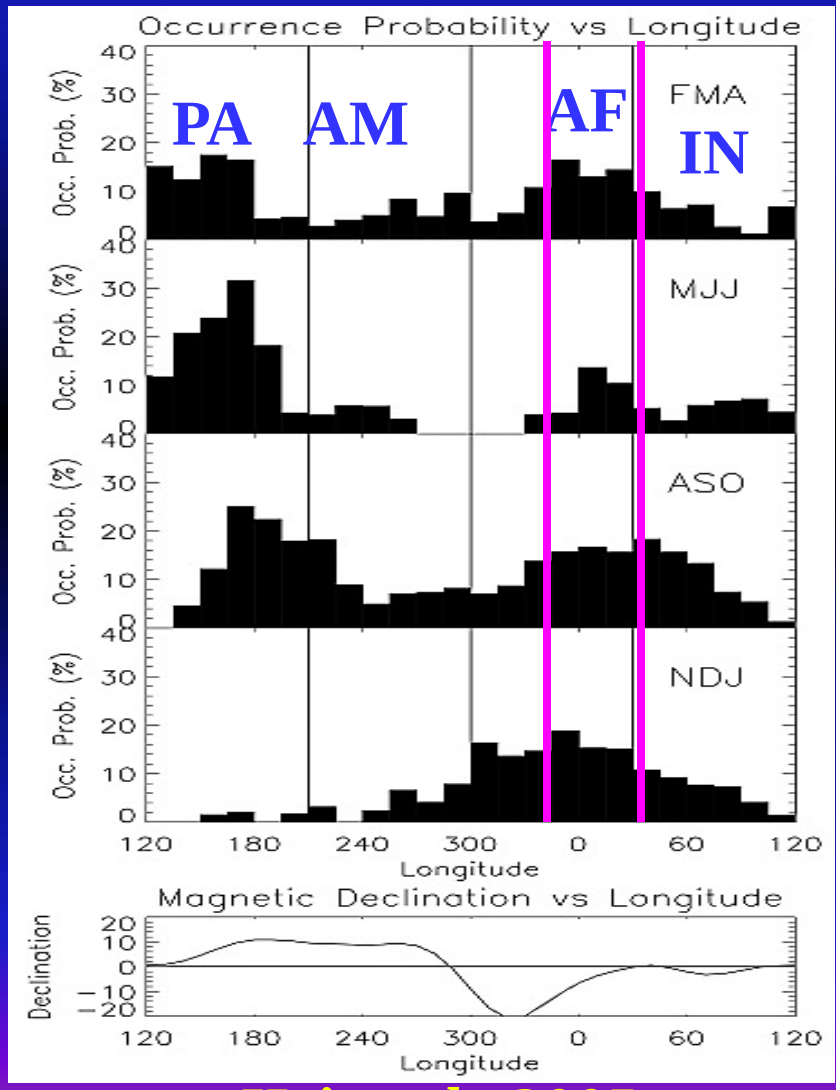
Hei et al., 2005

Courtesy of Odile

Then why the bubbles distribution show the other way around?



Su, 2006



Hei et al., 2005

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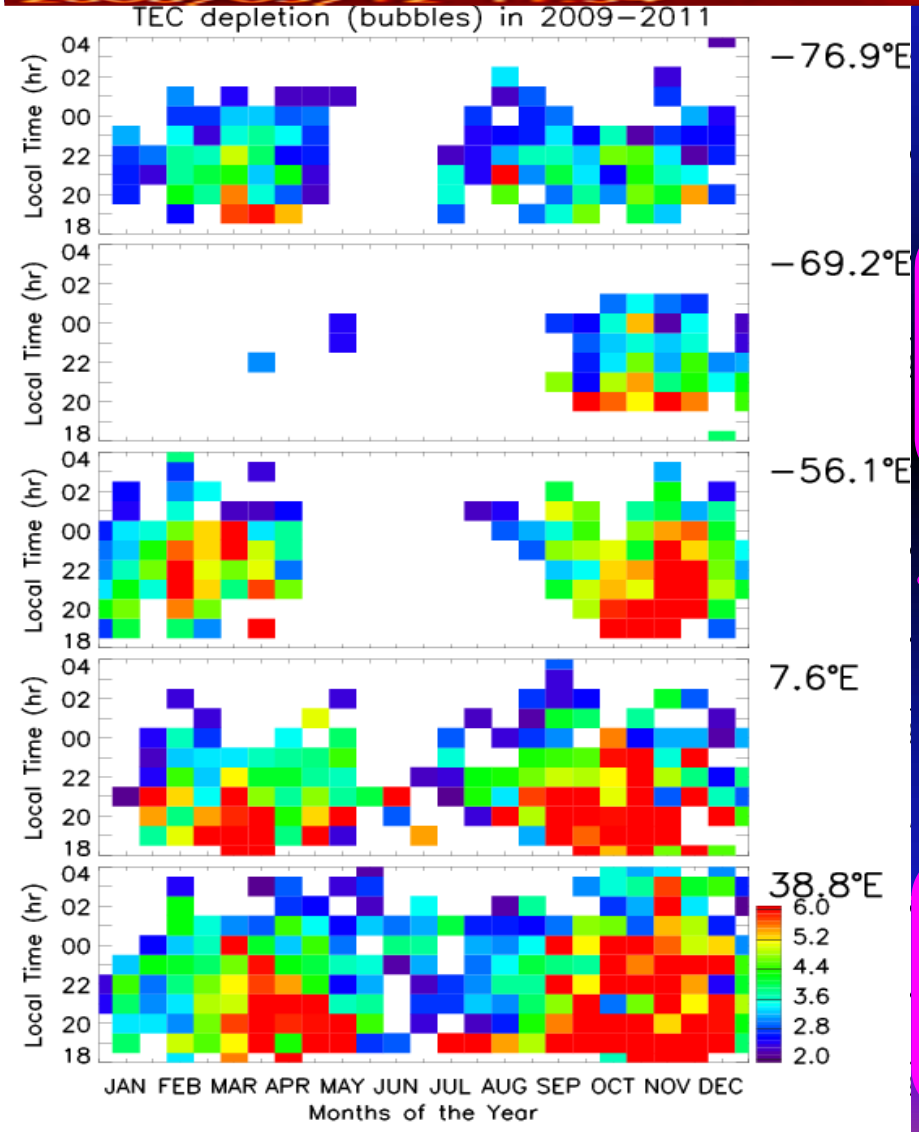
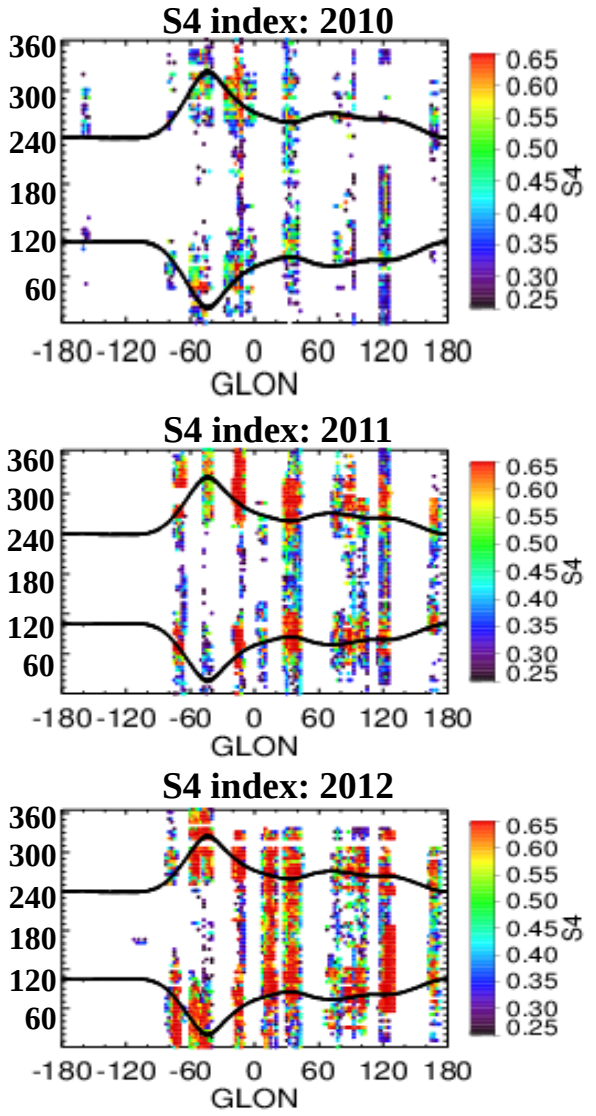


Bubbles from ground-based GPS TEC

S4 index from ground-based GPS TEC



Then why the bubbles' distribution show the other way around?

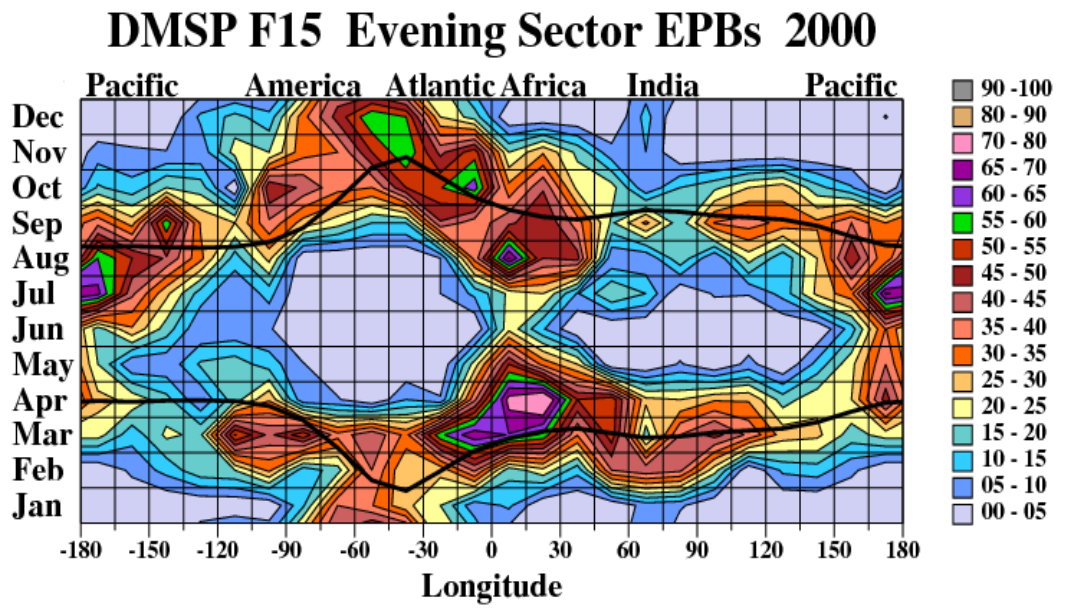
DMSP Observations:

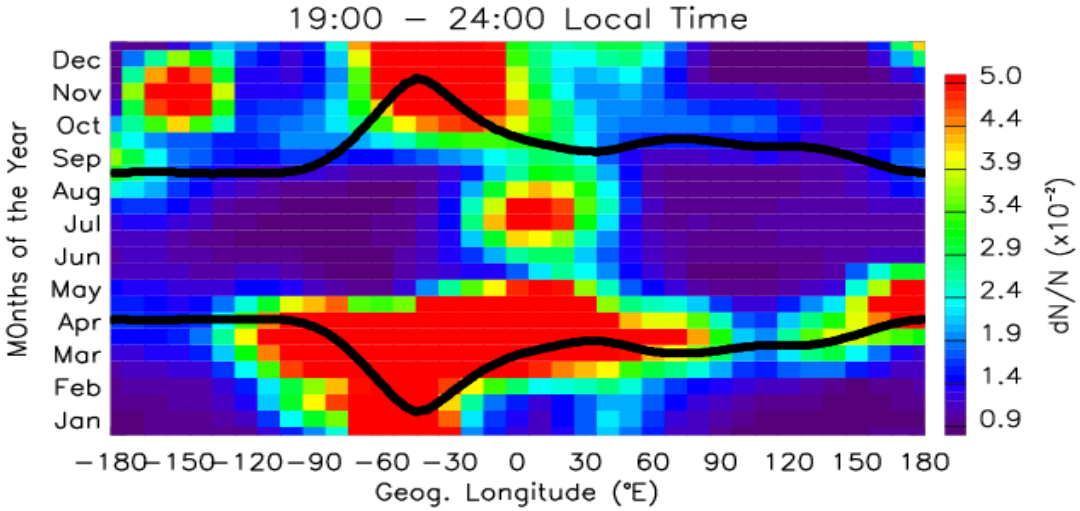
Gentile et al., 2011

In Africa (Long ~ -20° to 52°) dusk sector irregularities are active almost all seasons during solar max.

C/NOFS Observations

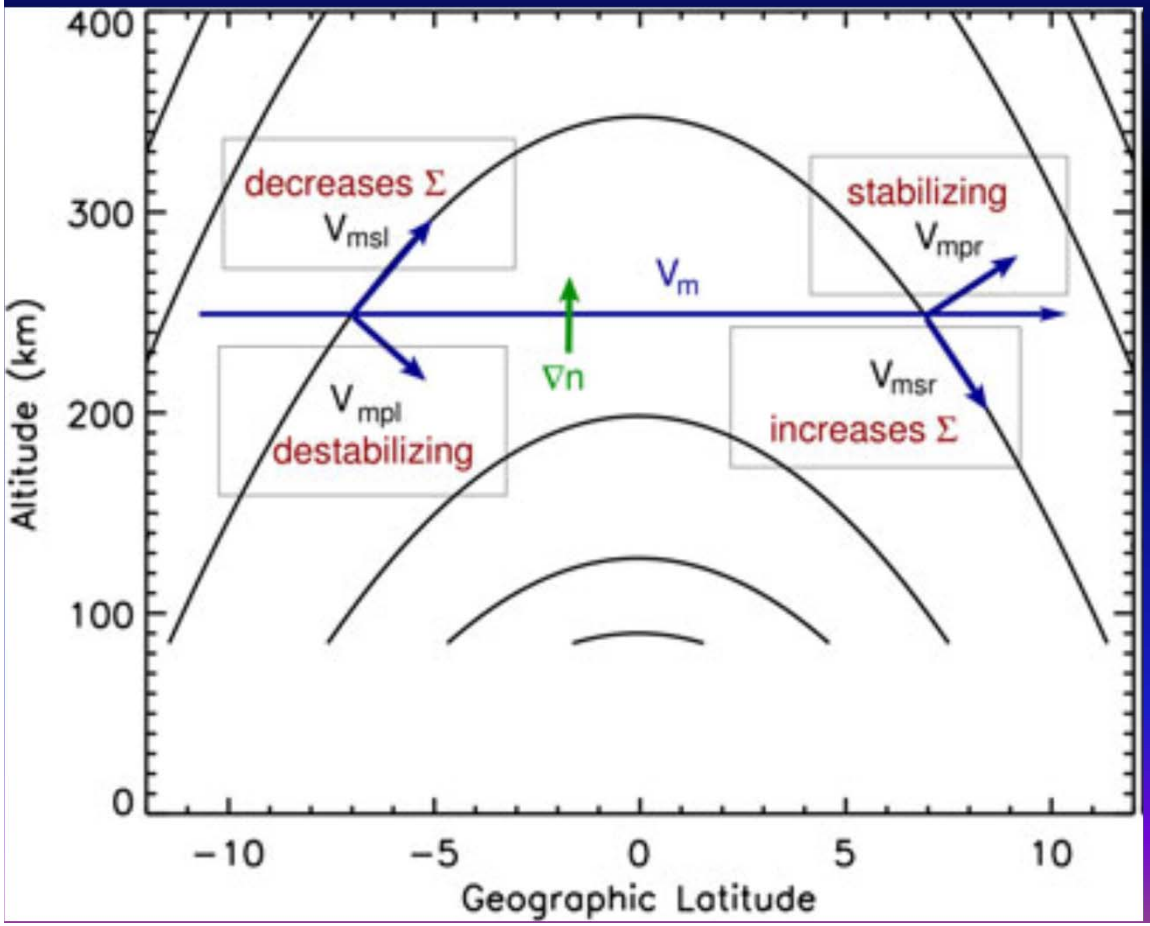
Yizengaw et al.





Potential questions?

- If not the drift, then what could it be? Would it be the neutral winds that cause the long lasting bubbles in Africa? If it is the neutral wind, why the orientation and magnitude of the wind in the African sector is unique compared to other longitudes?

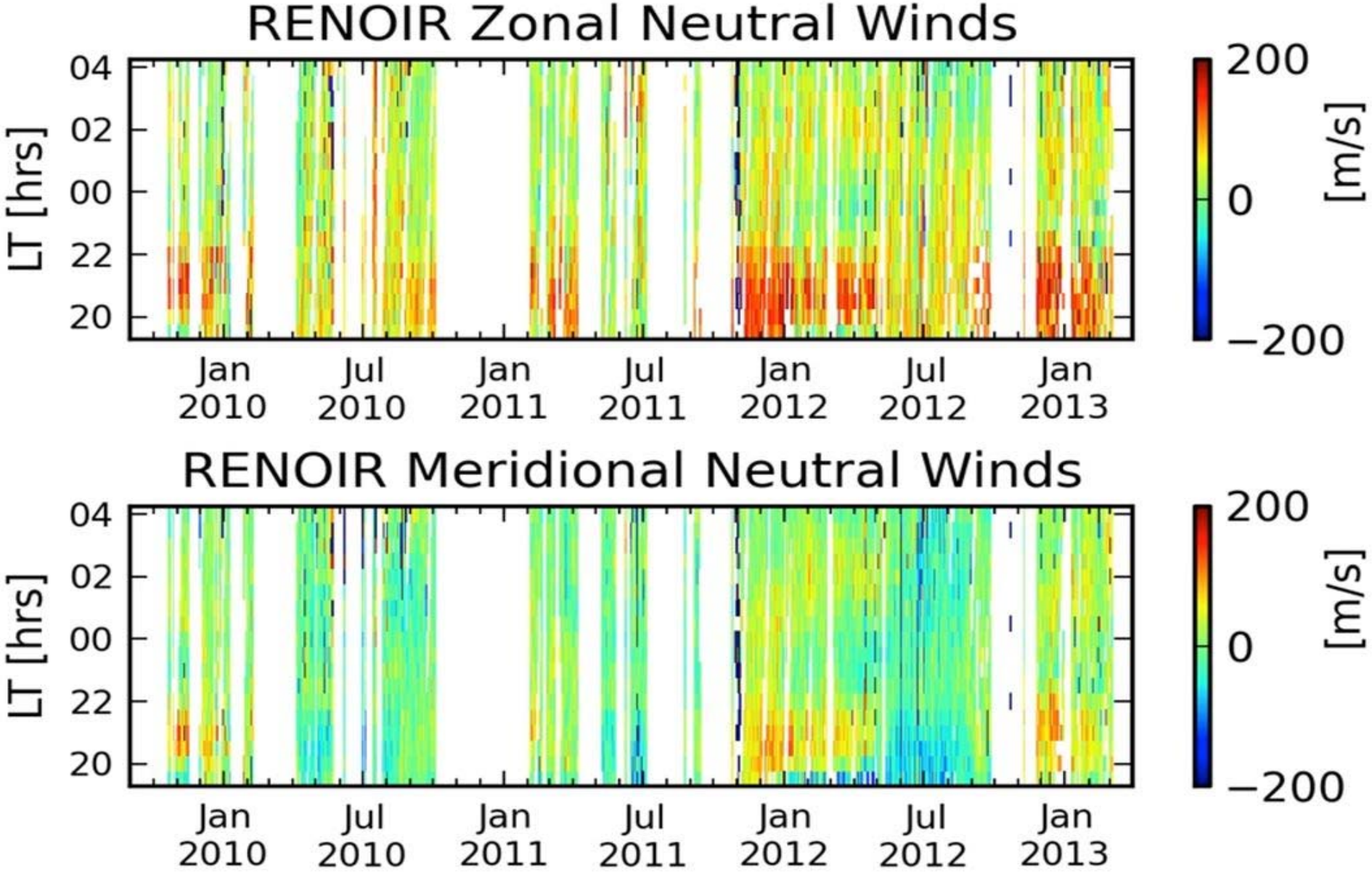


- Equator ward meridional wind decrease conductivity and increase RTI growth rate

- Pole ward meridional wind increase conductivity and decrease RTI growth rate

Huba and Krall, GRL, 2013

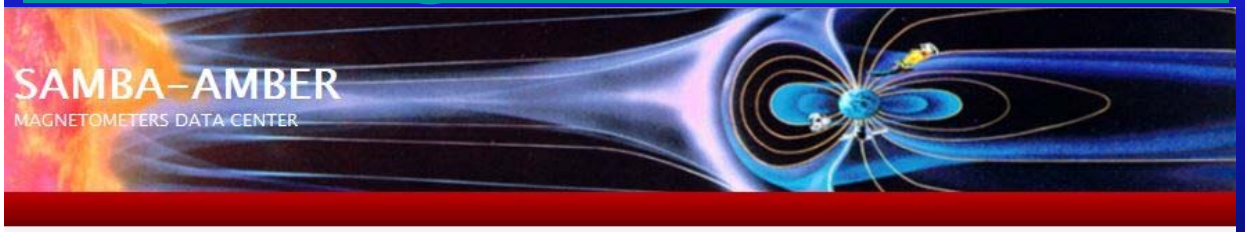
Upcoming FPI instruments in Africa



Courtesy of Meriwether

Our Database

http://magnetometers.bc.edu/



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SAMBA–AMBER MAGNETOMETERS DATA CENTER

The **SAMBA** and **AMBER** magnetometer B–Field networks provide data characterizing the earth's magnetic field in the southern hemisphere, utilizing parallel chains of meridional sensor stations in South America and Africa.

The "South American Meridional B–Field Array" (SAMBA) stretches from Putre, Chile to Escudero, O'Higgins and Palmer Stations, Antarctica.

The "African Meridian B–Field Education and Research" (AMBER) array ranges from Medea, Algeria south to Tsumeb, Namibia in two parallel lines. Additional stations are planned for installations along the magnetic equator from Brazil to the Philippines.

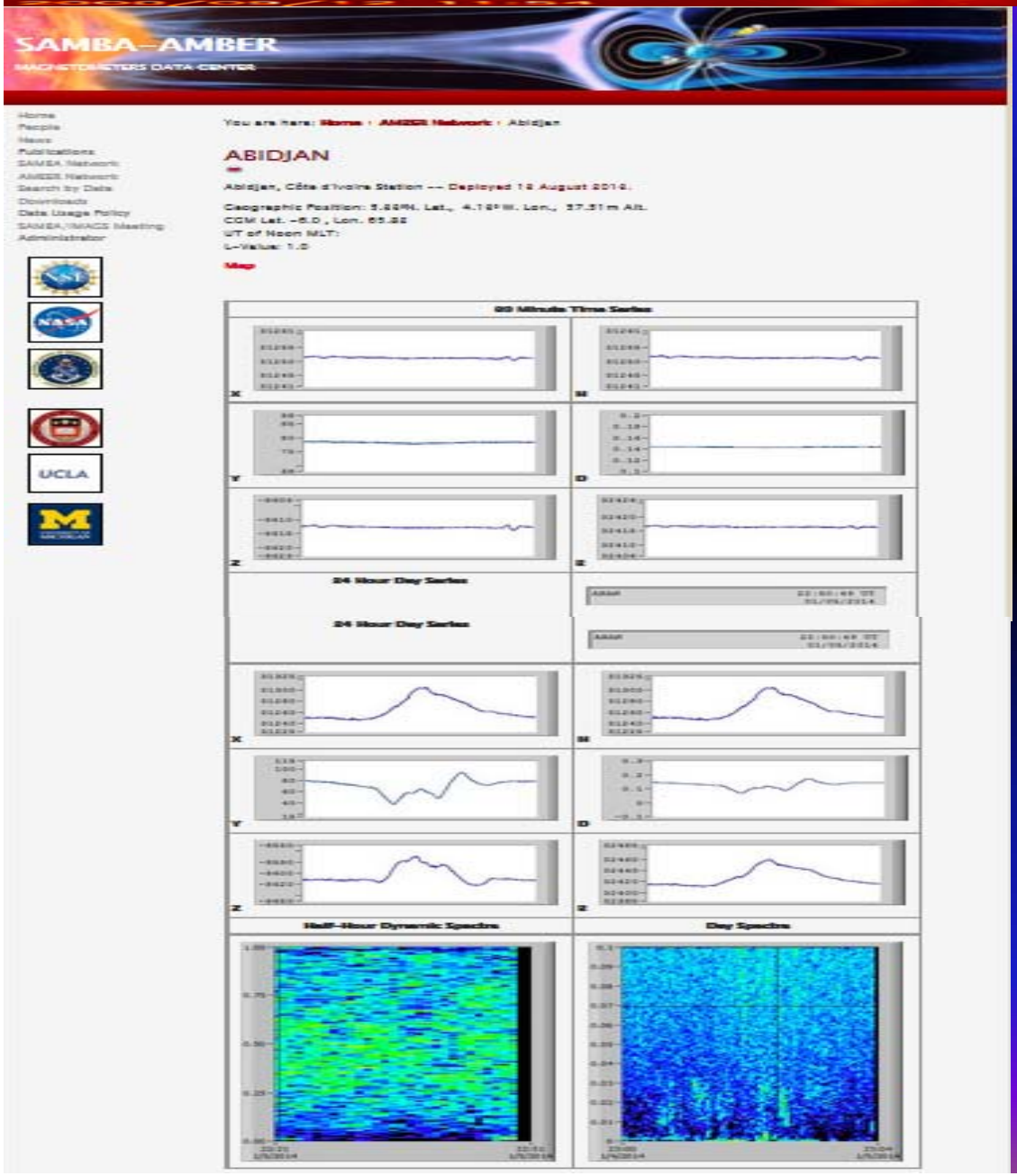
These networks and this data center are sponsored by funds from the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), and the U.S. Air Force Office of Scientific Research (AFOSR). Leading participants include Boston College and the University of California Los Angeles. Host organizations for the sensors are identified in the Station pages of the sensor networks.

Sensor data on this site are stored in ascii daily data tables and as PostScript® daily plot files. Users can browse the stored file tree via the Downloads menu item or by searching for a particular day and station. Table data have been de–spiked during processing, prior to plot generation.

PostScript® is a registered trademark of Adobe Systems, Inc.

- You can search by days, by station
- You can download ASCII data (1 min, 1 sec, and half sec resolution)
- You can download summary plots for a quick look!

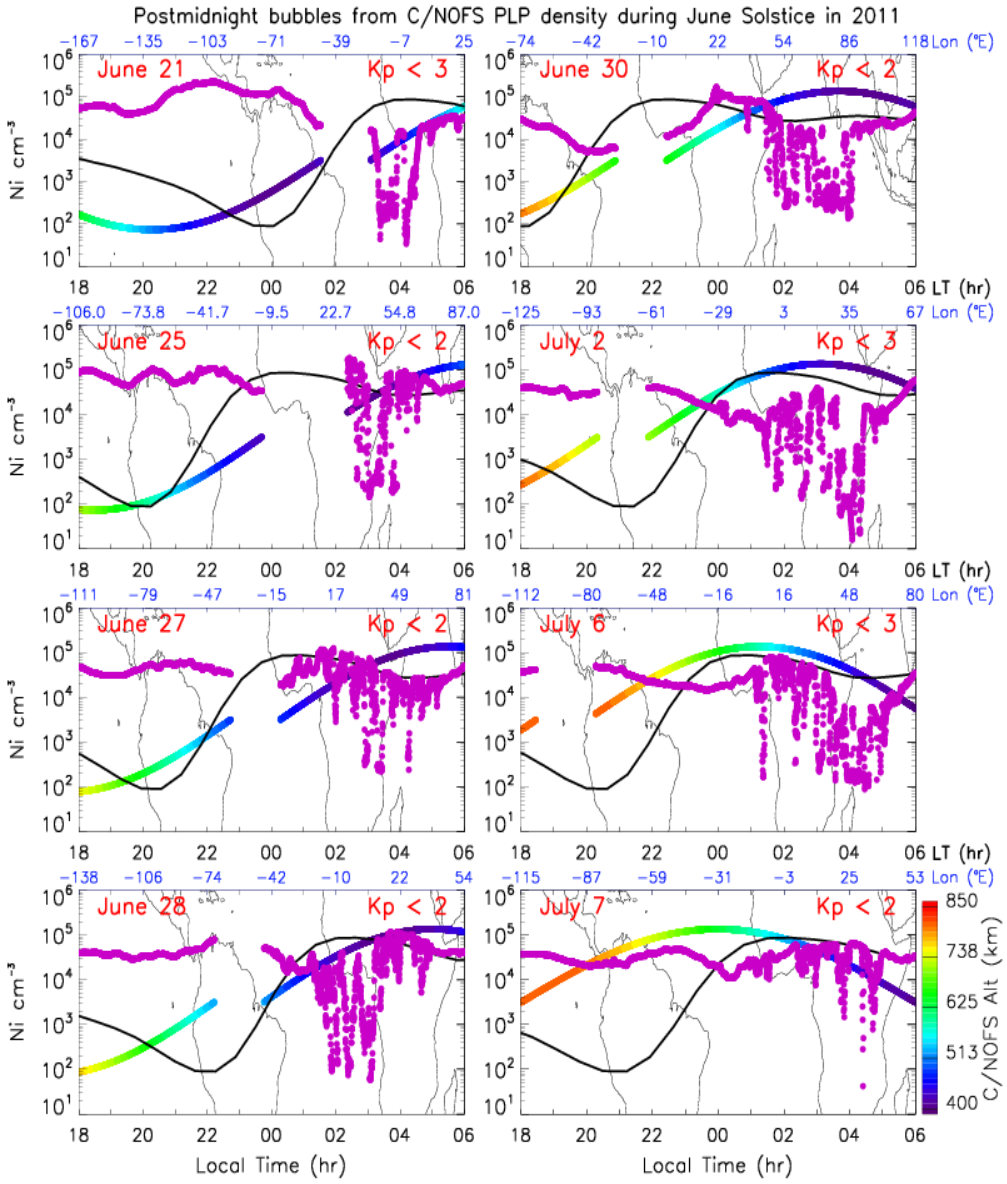
Real Time Database!

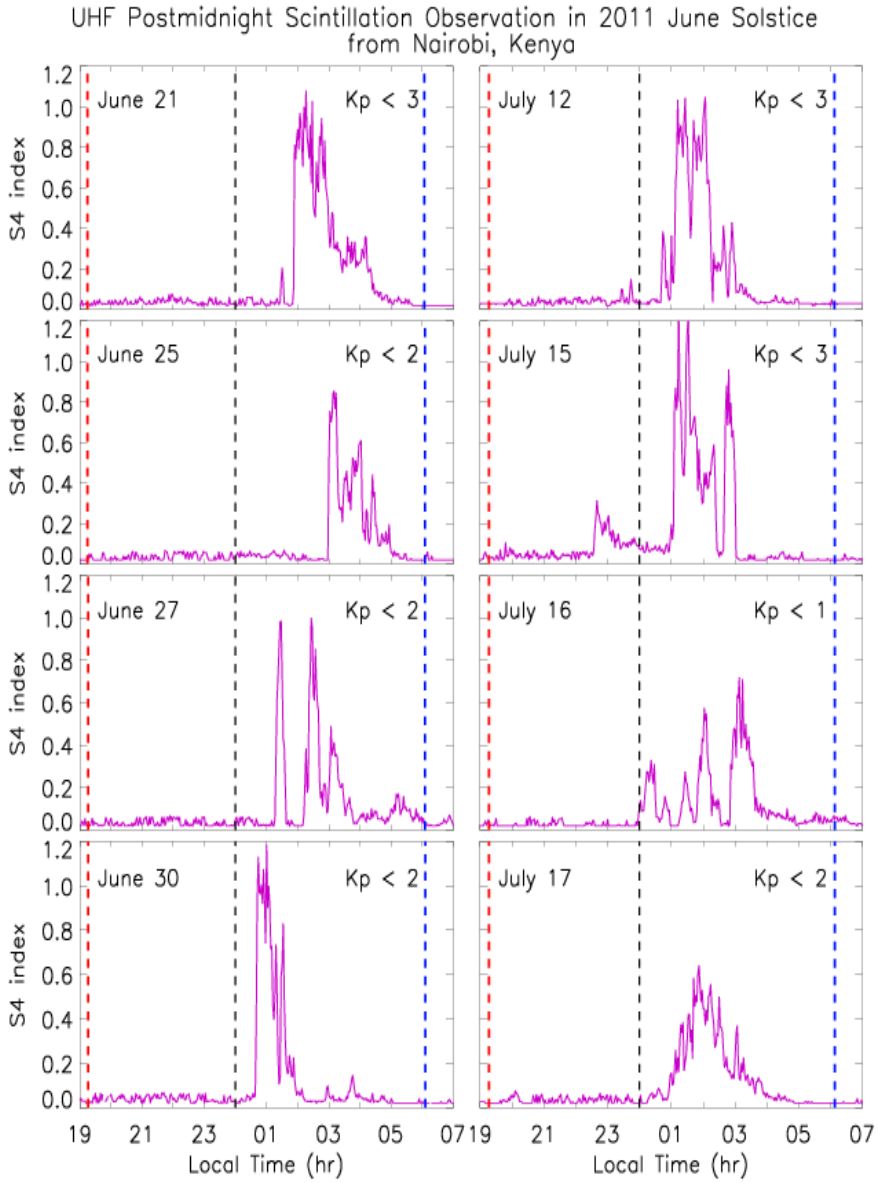


- 30 minute plots
- 24 minute hours plots
- 30 minute and 24 hours dynamic spectra.

Thank you!

Is the ionosphere calm during quiet time?

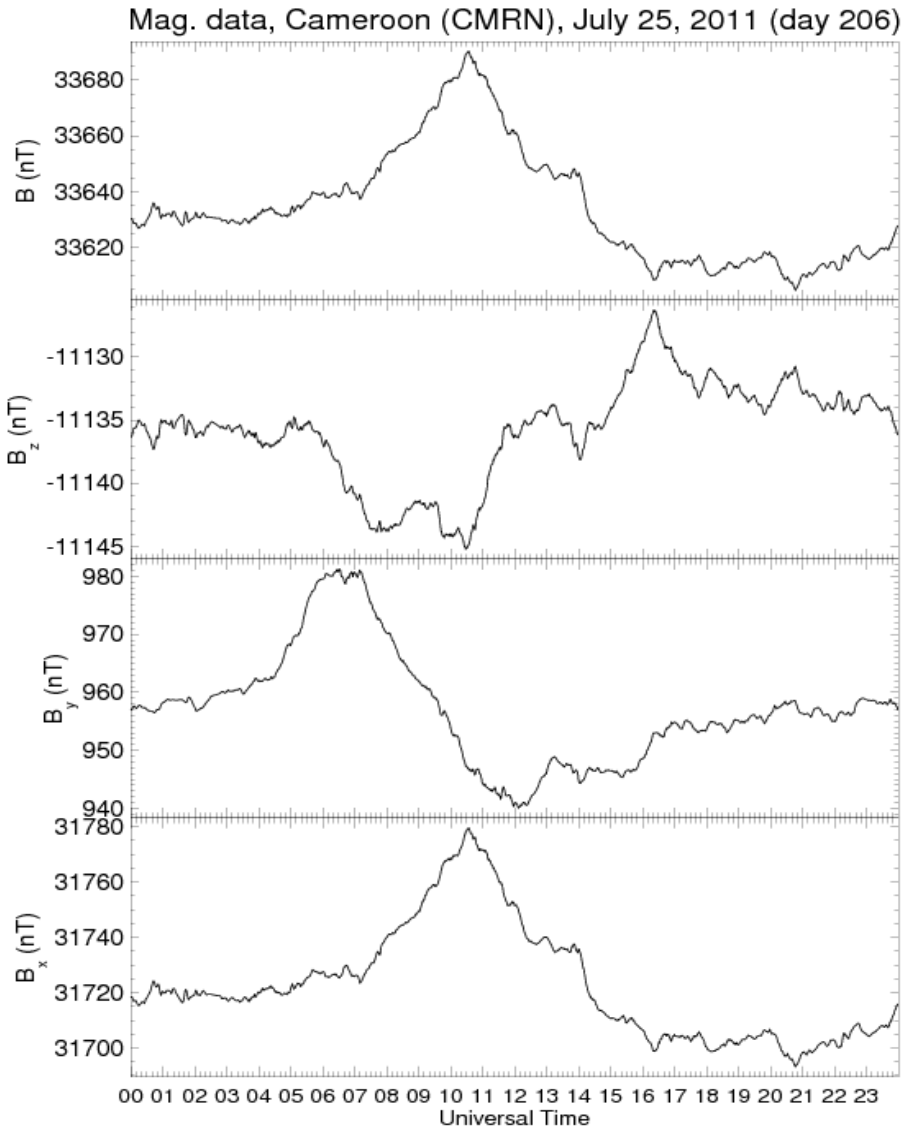




Yizengaw et al., GRL, 2013 (submitted)

Where do I get AMBER data?

You welcome to get me here



- Average the X-component night time (2230 – 0300 LT) values, and subtract it from the measurement data.

EEJ to ExB drift!

TR1=0.0222*F107 Daily observed F10.7

TR2=0.0282*F107A Daily adjusted F10.7

TR3=0.0589*KP(hr) Kp value

TR4=0.1661*LT Local time

TR5=0.1892*DH(hr) Delta H

TR6=0.00028*(DH(hr))^2 Delta H

TR7=0.0000023*(DH(hr))^3 Delta H

ExB=K-TR1-TR2-TR3-TR4+TR5+TR6-TR7

Can you run your IDL program please