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

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

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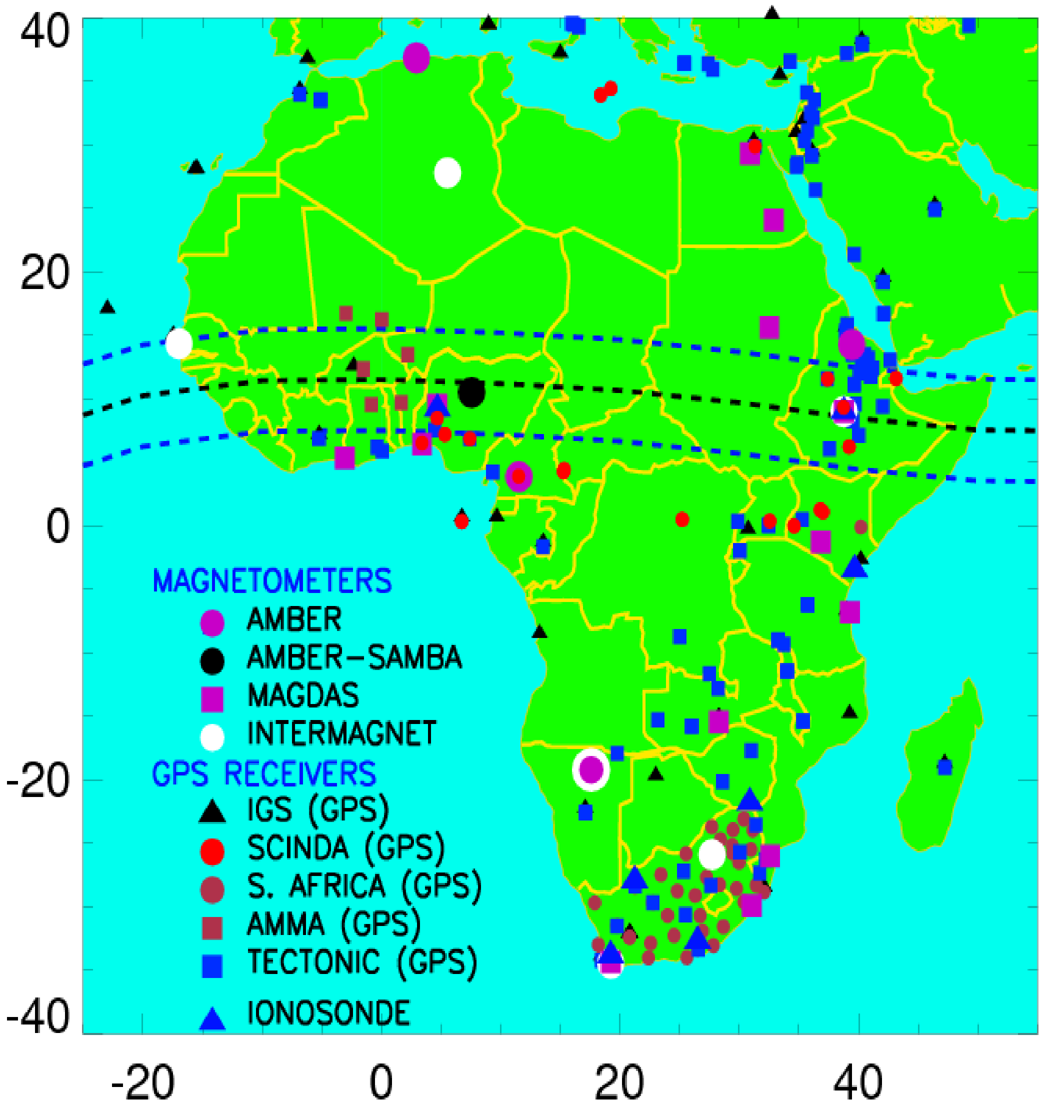
Outline

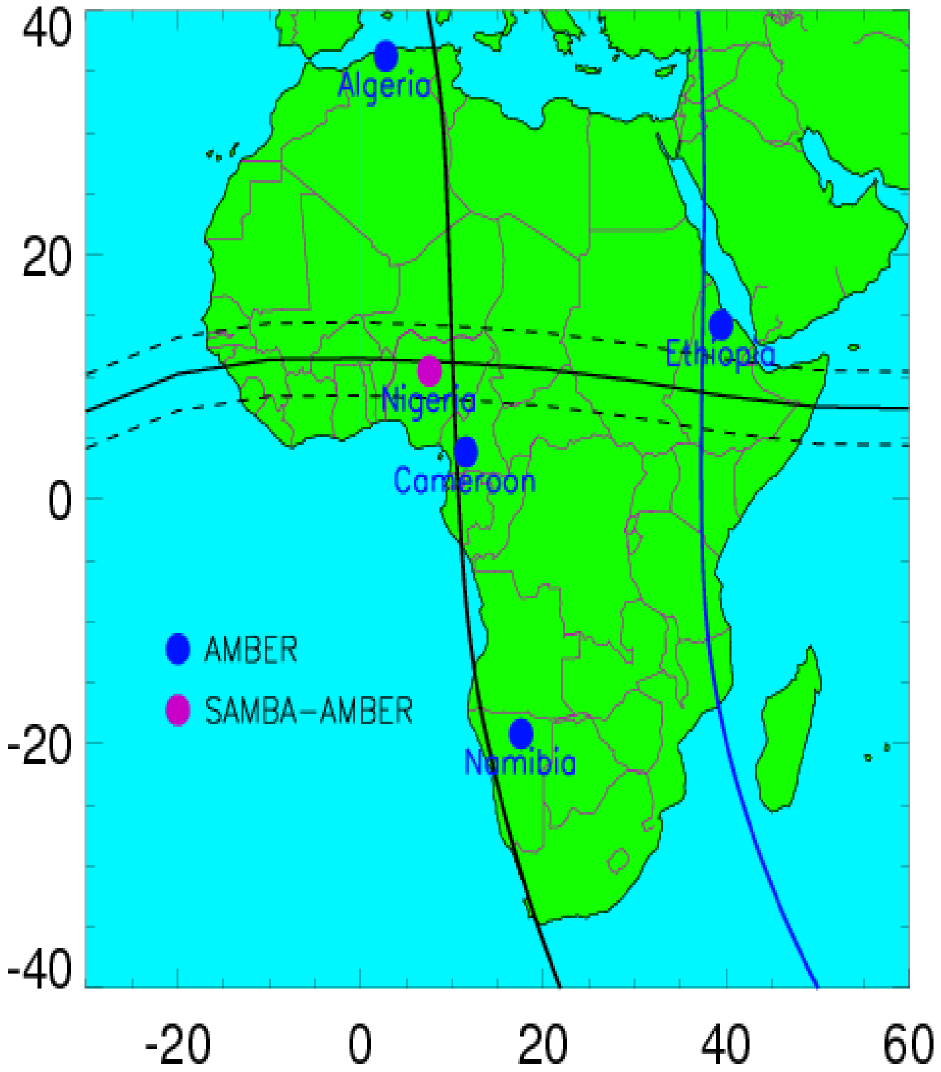
Instruments Network: Present



- Instrumentation in Africa: past and present
- AMBER magnetometer array
- EEJ (ExB drift) longitudinal difference
- Vertical density structures using tomography
- Day-to-day variability of the ionosphere
- Future direction

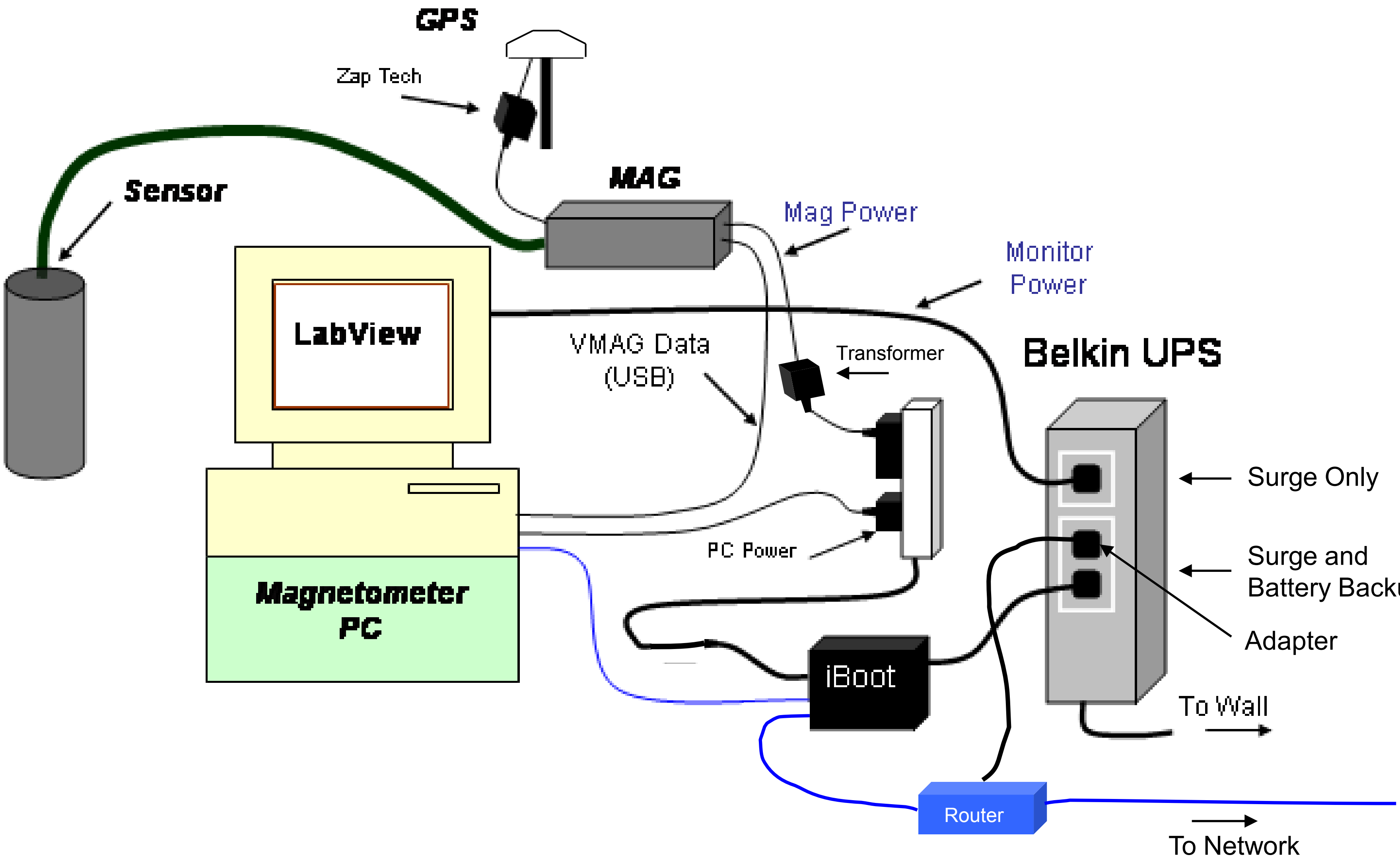
Objective of AMBER magnetometer Array

AMBER (African Meridian B-field Education and Research)

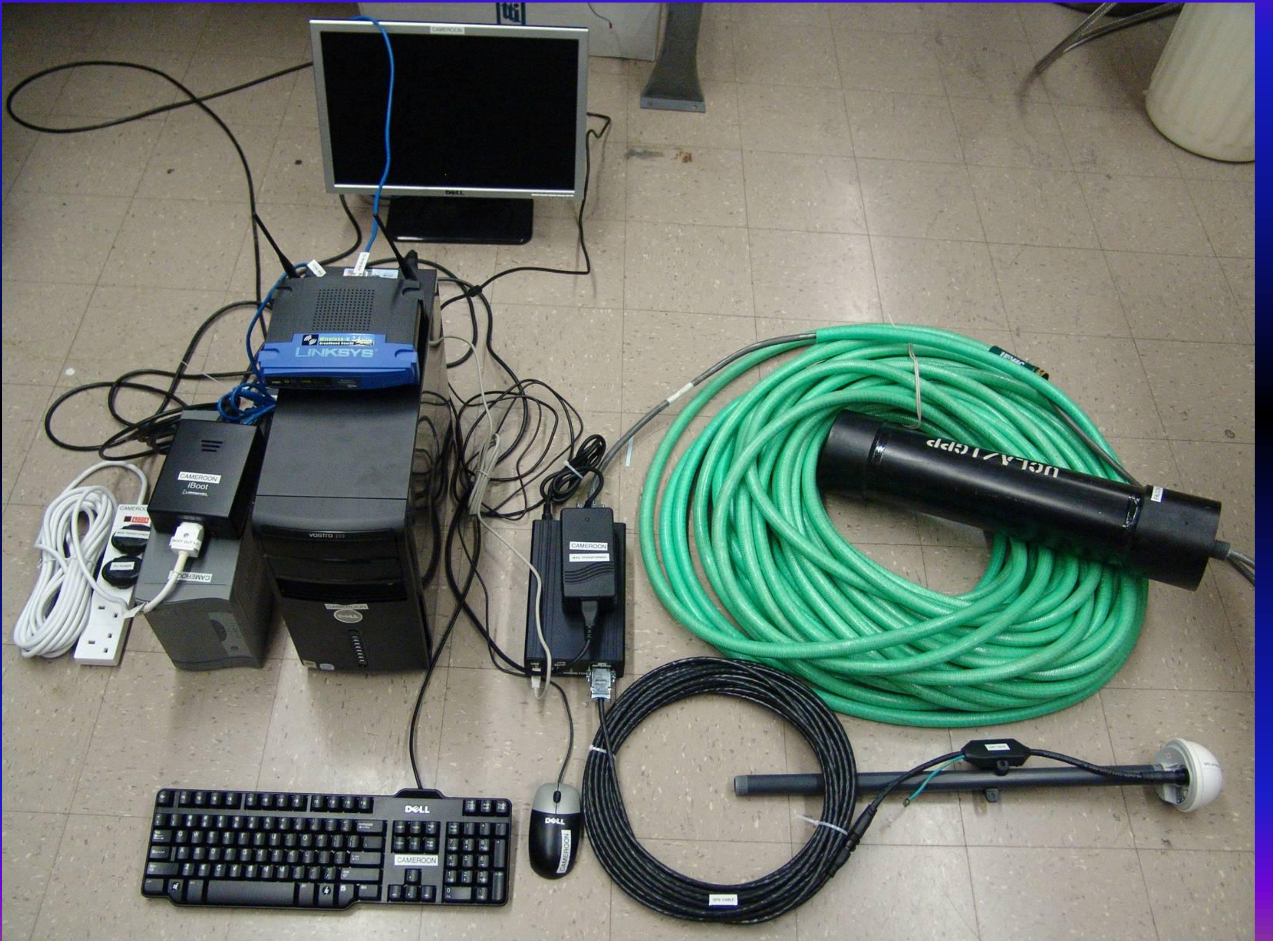


- the processes governing electrodynamics of the equatorial ionosphere as a function of local time, longitude, magnetic activity, and season, and
- ULF pulsation strength and its connection with equatorial electrojet strength at low/mid-latitude regions.

Mag/Sensor Setup Diagram



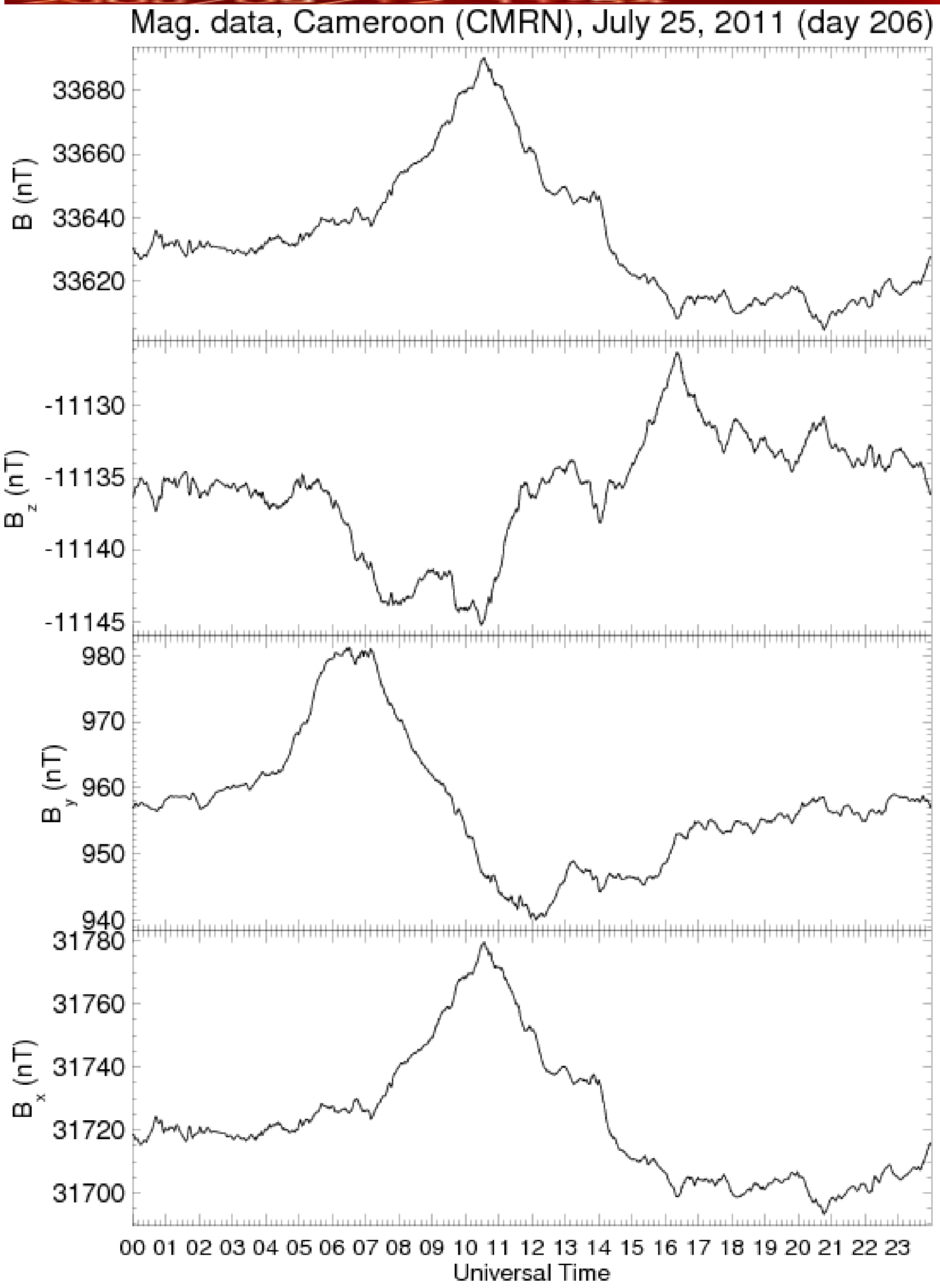
Full Setup

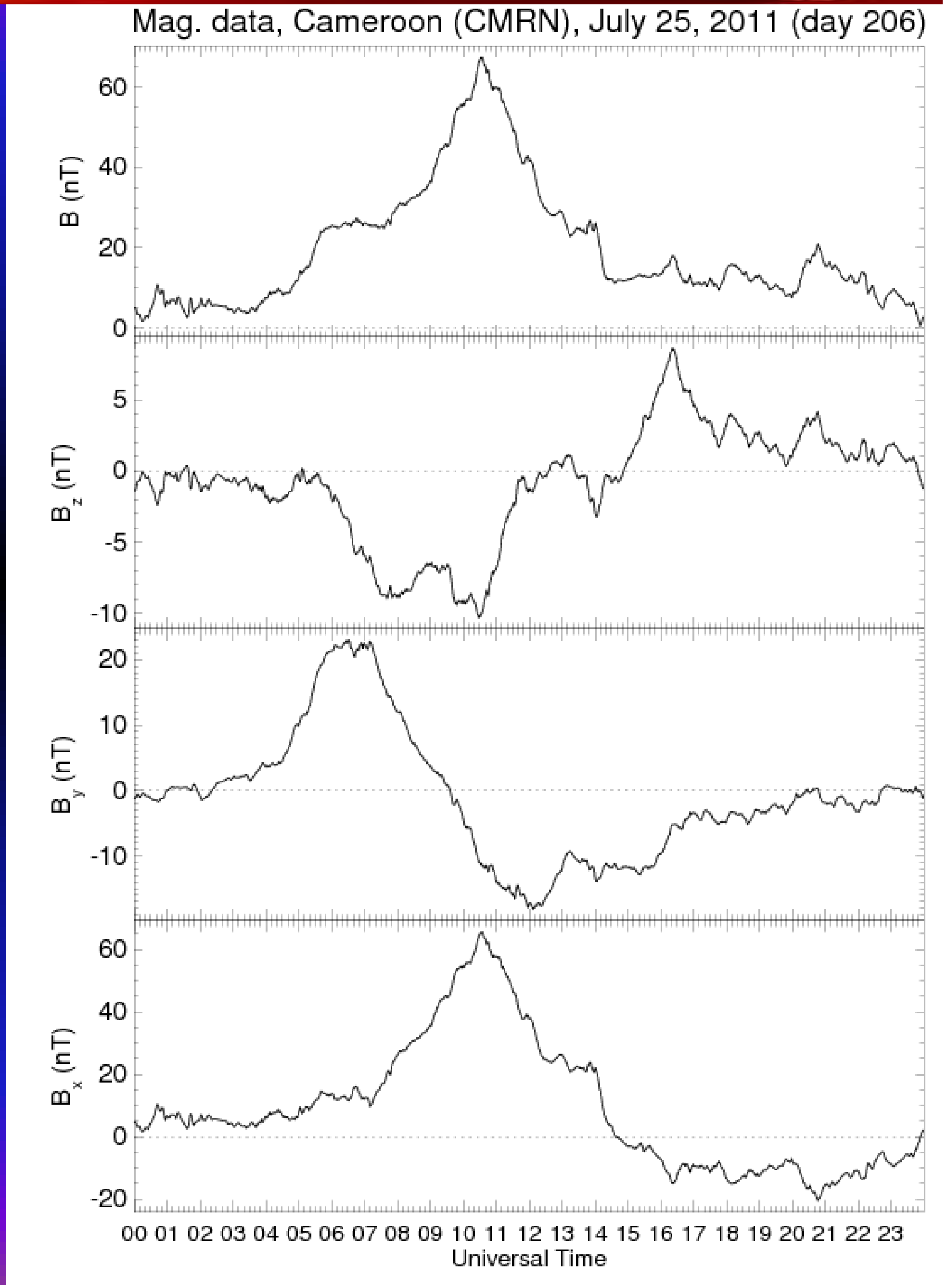


Setup at the Site

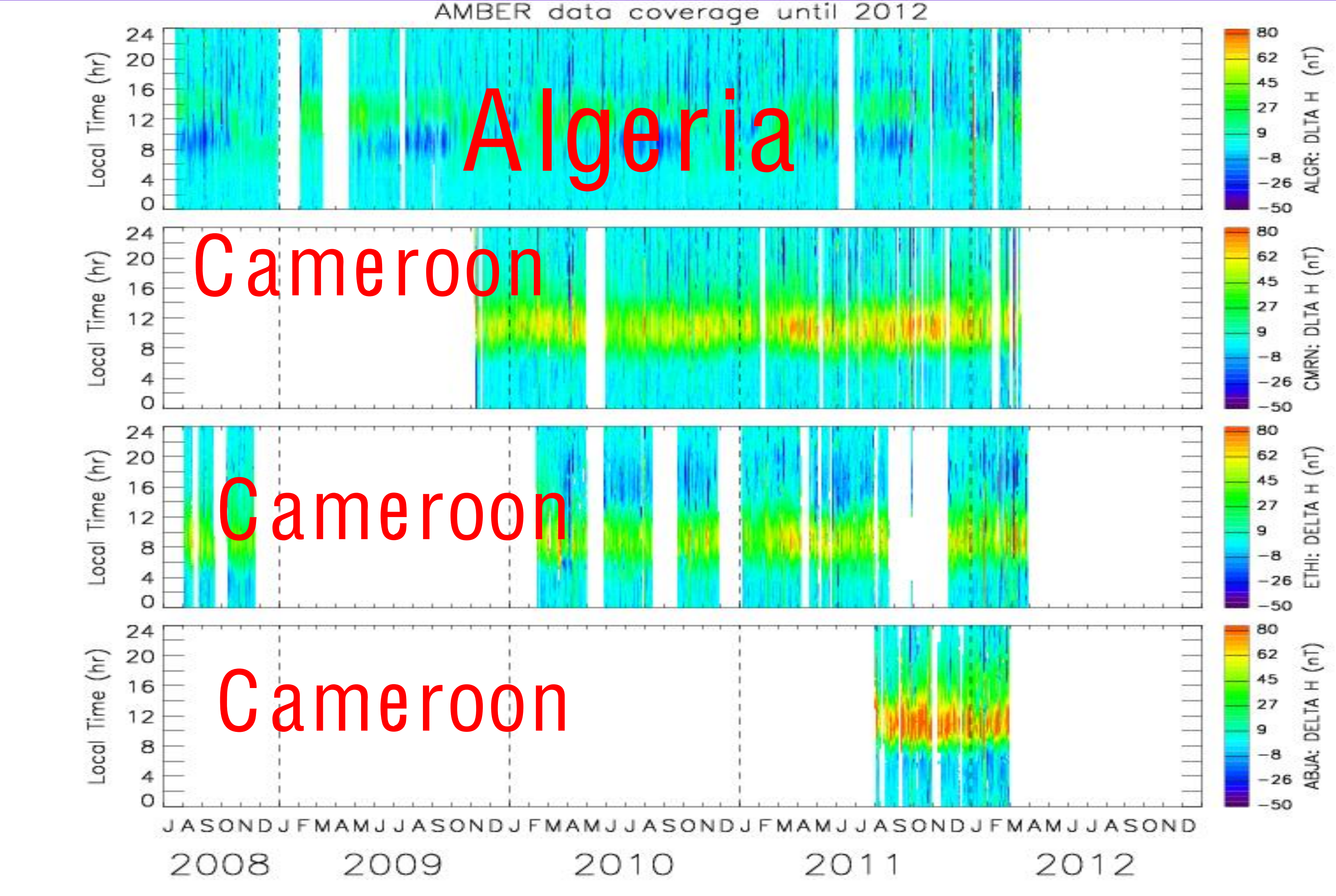
- Sensitivity: 0.01 nT
- Time resolution: 0.5 sec

What does the magnetometer Observes?



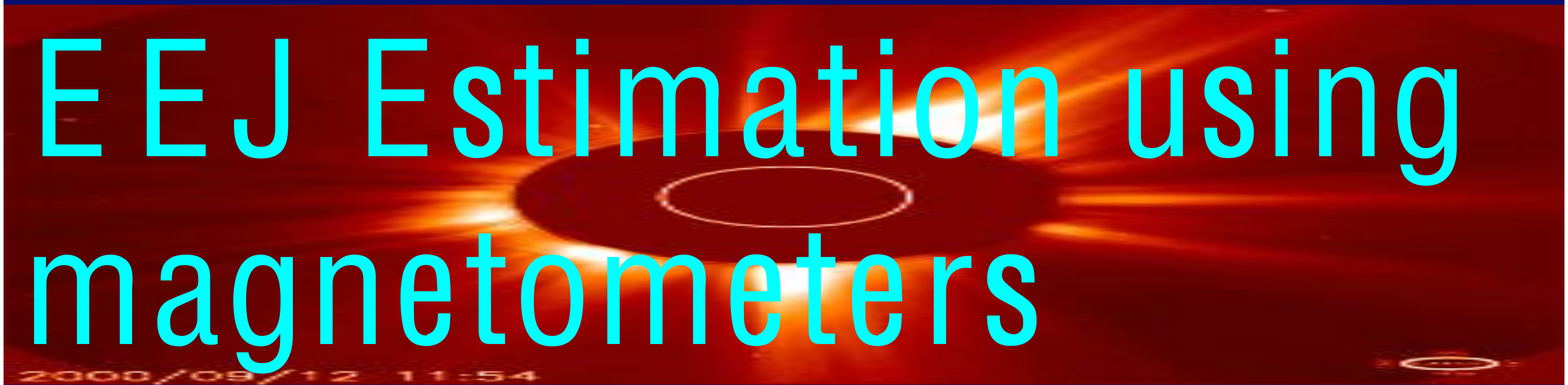


Examples of AMBER data coverage

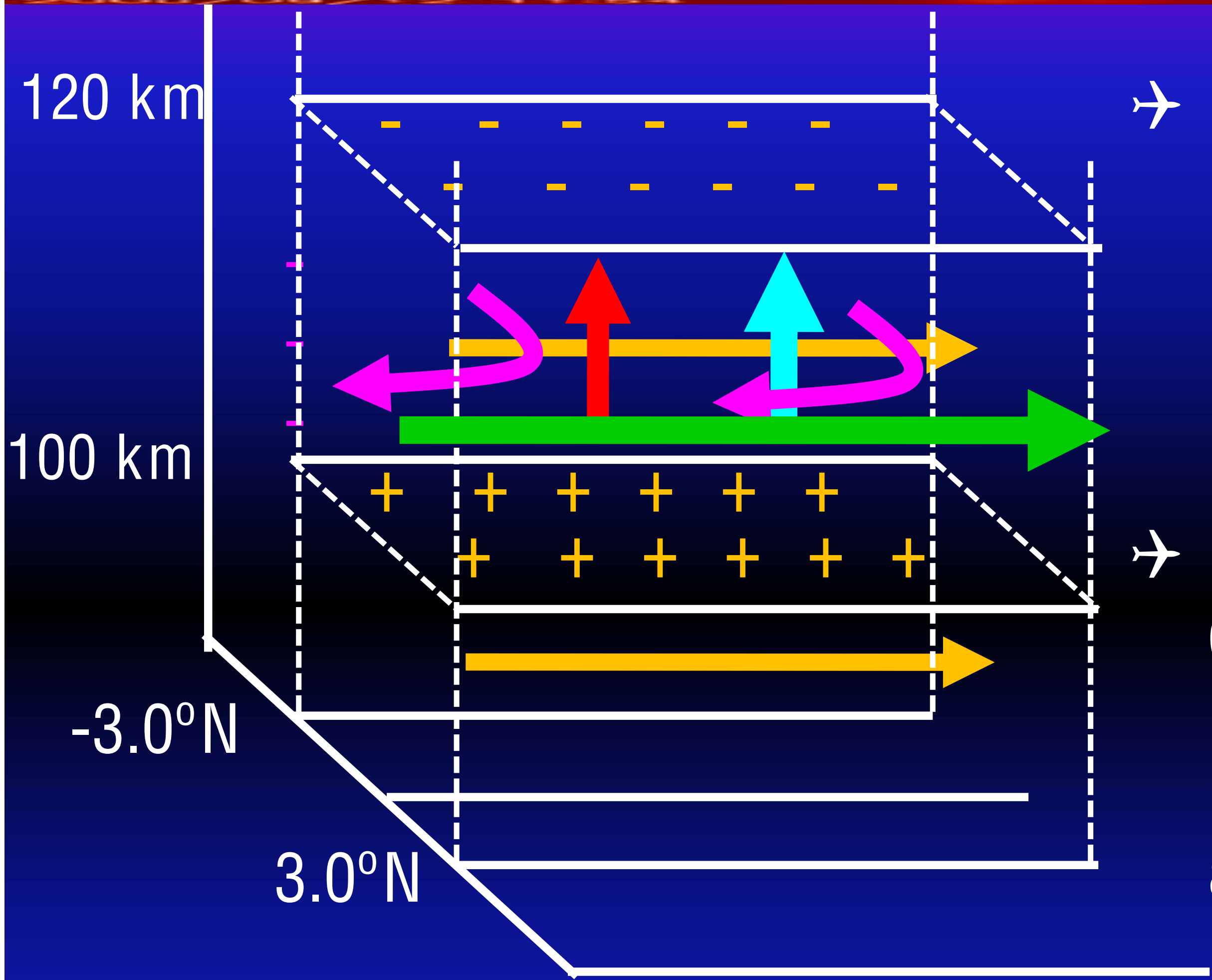


Real time data flow from Africa and South America

EEJ Estimation using magnetometers

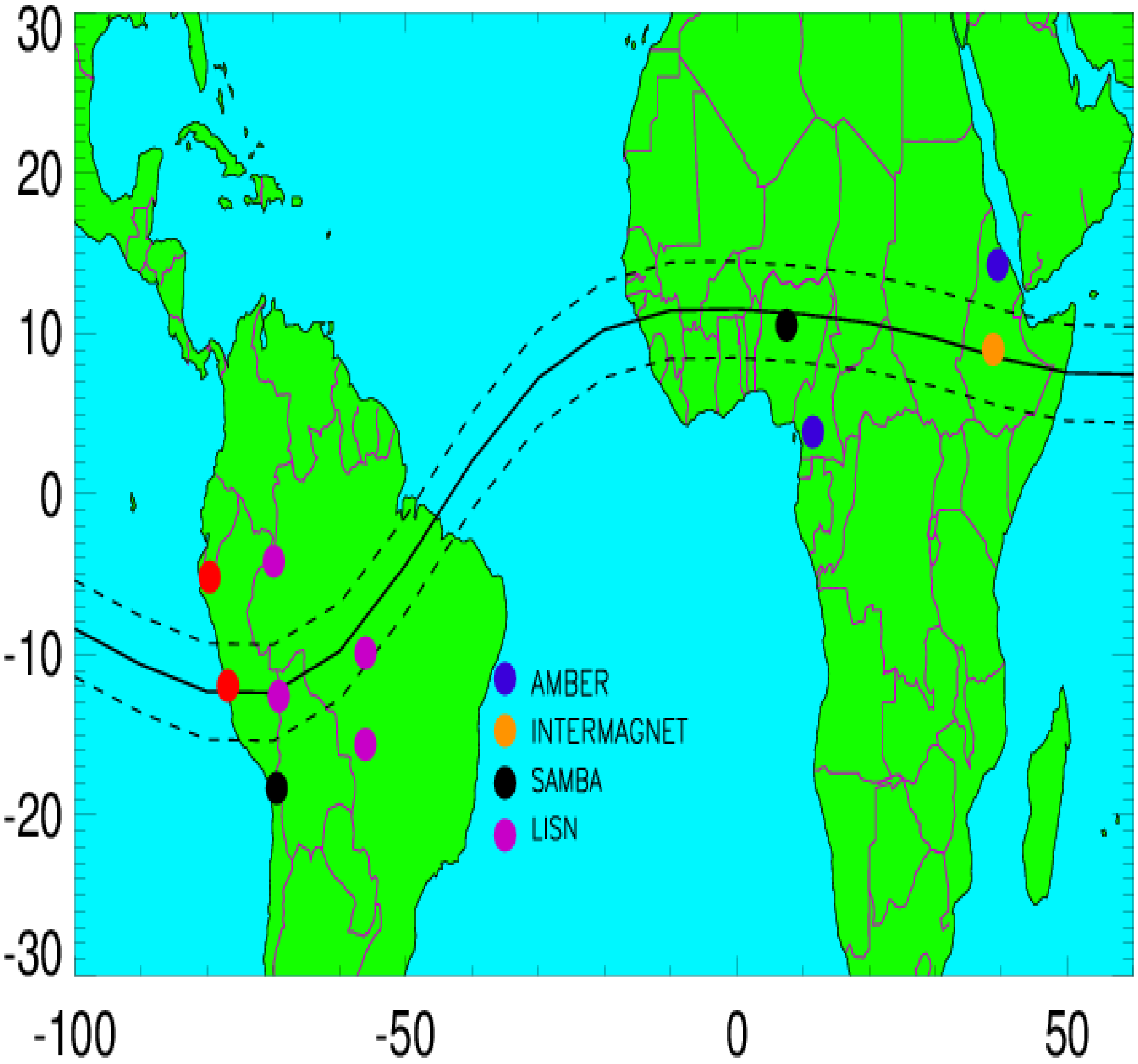


Equatorial Electrojet (EEJ) formation



- 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 3.0º of the magnetic equator, which is called the Equatorial Electrojet (EEJ)

Longitudinal EEJ Variations



- Disturbances due to geomagnetic impact

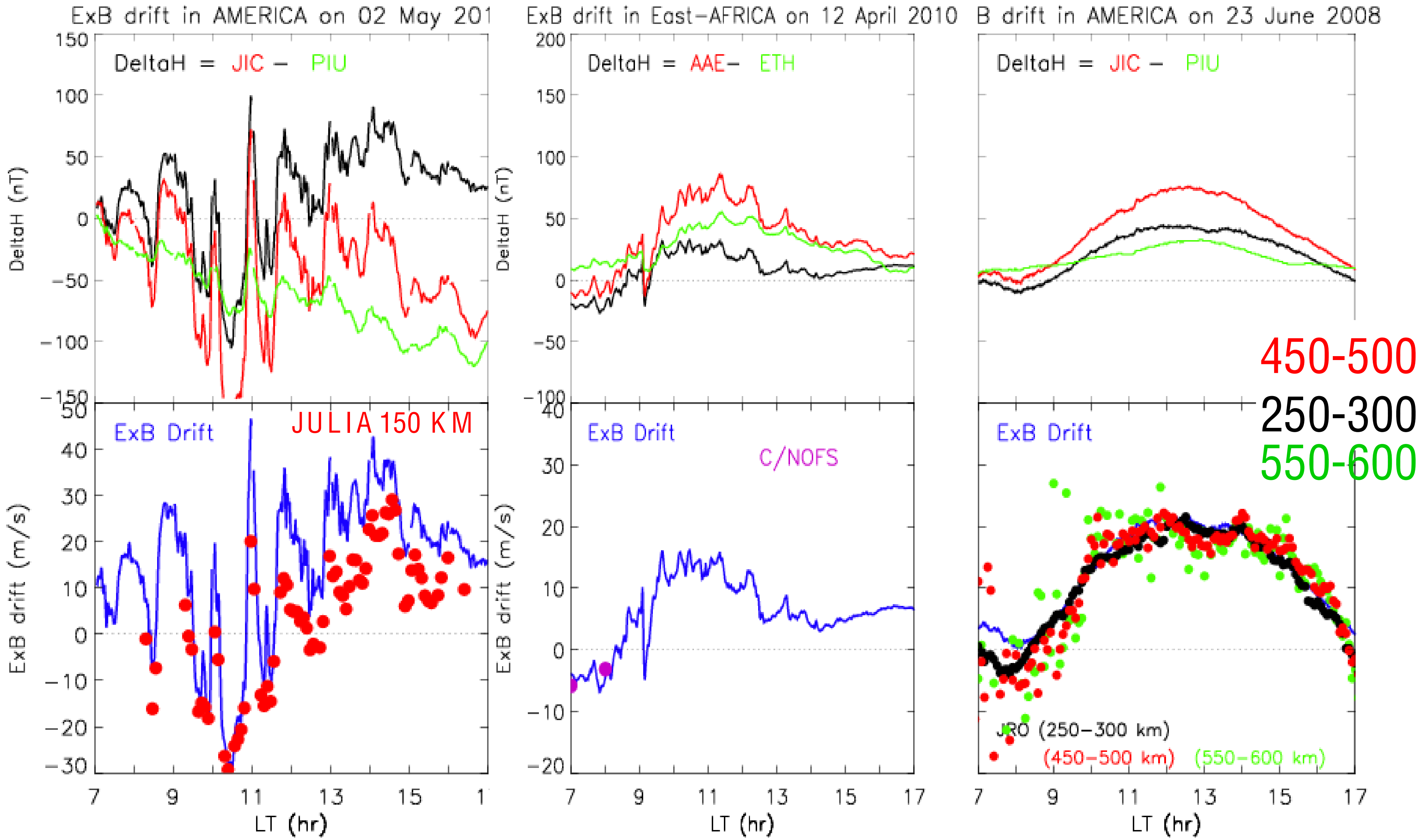
  On H-components at the equator and off the equator

- Disturbances due to EEJ

  Only on H-component at the equator

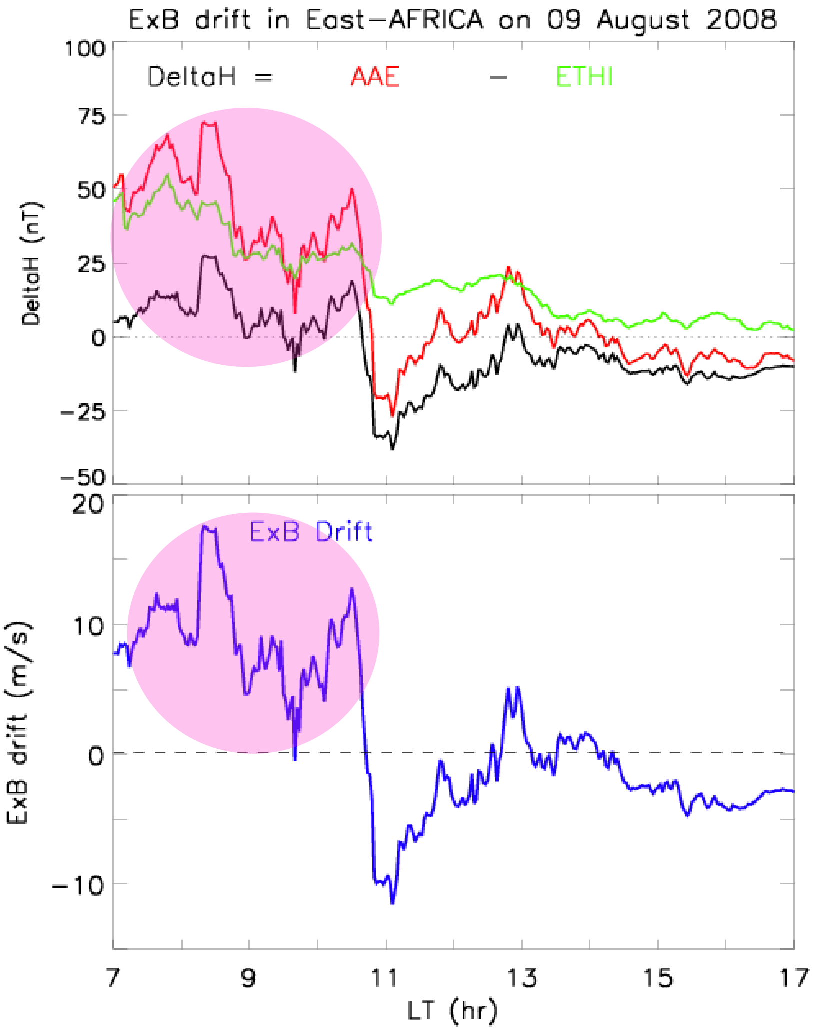
Comparison with other observations

with JULIA C/NOFS - Africa C/NOFS - America

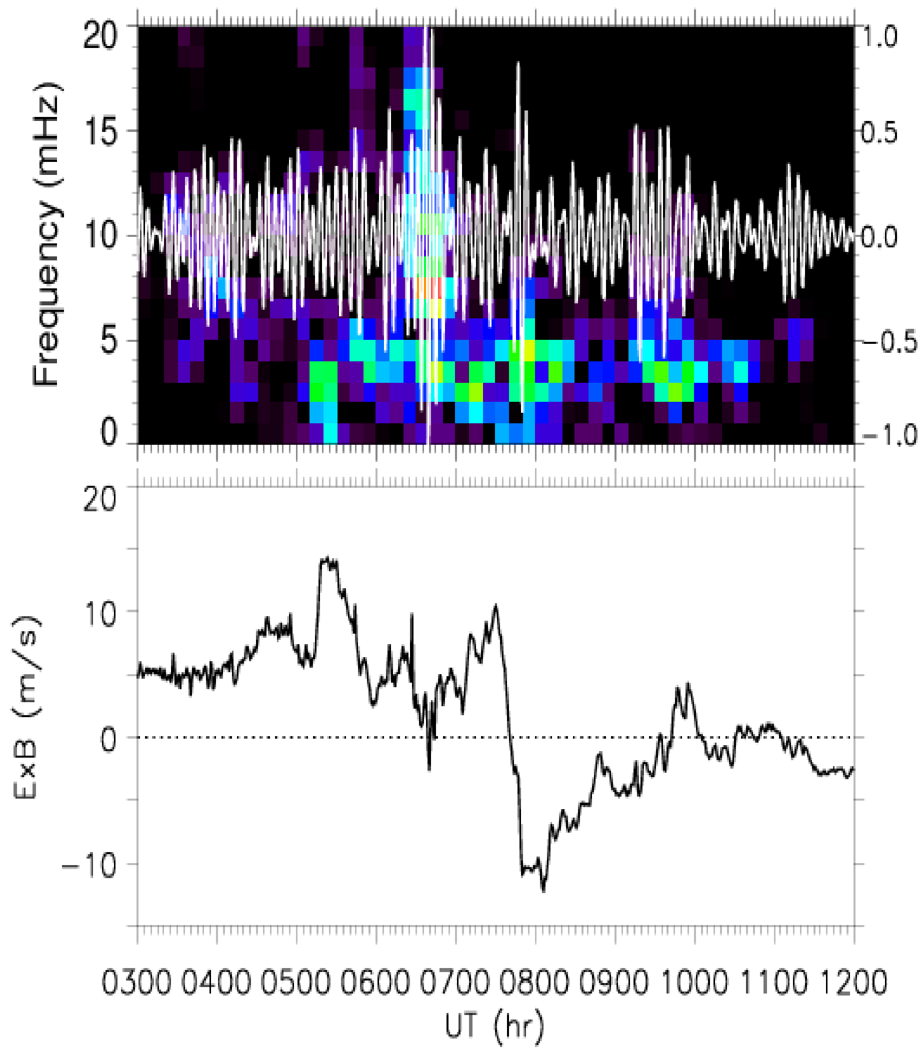


ULF wave related equatorial vertical drift and density fluctuation study

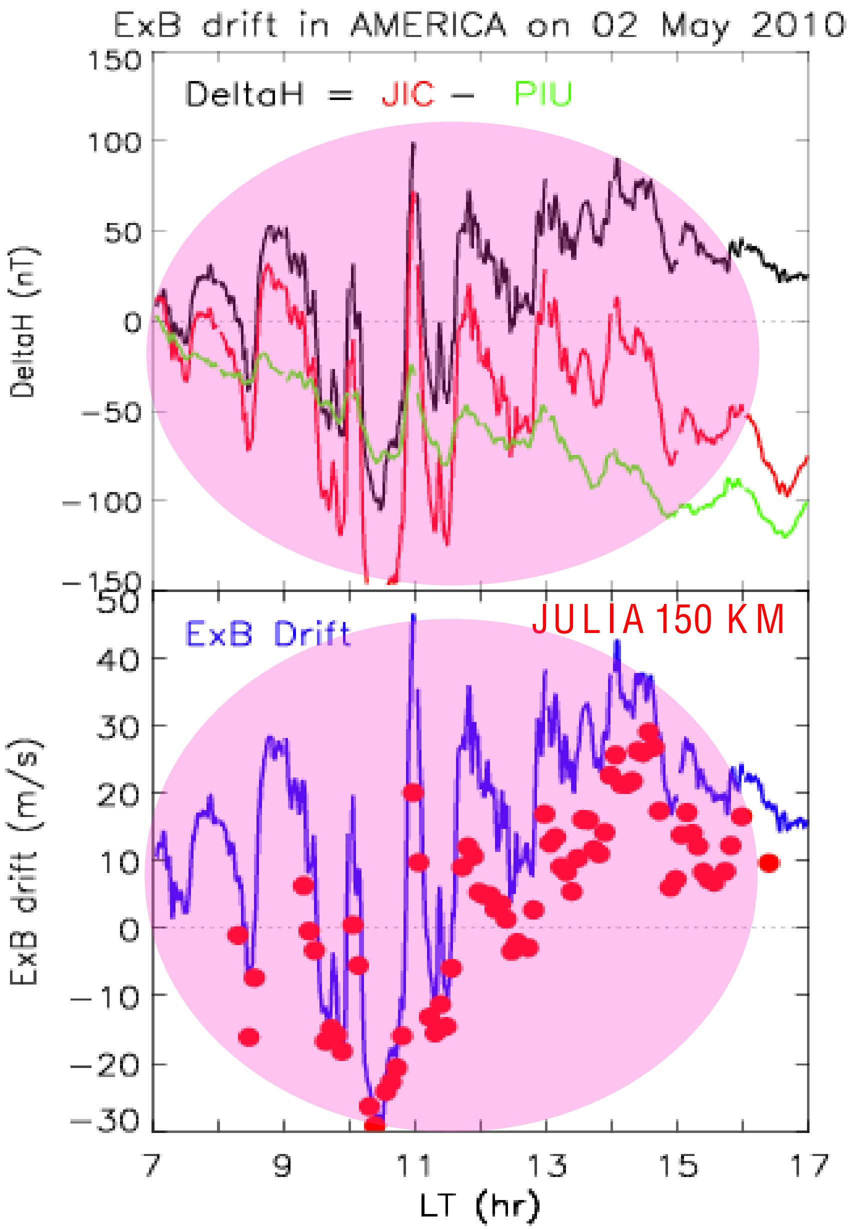
African sector

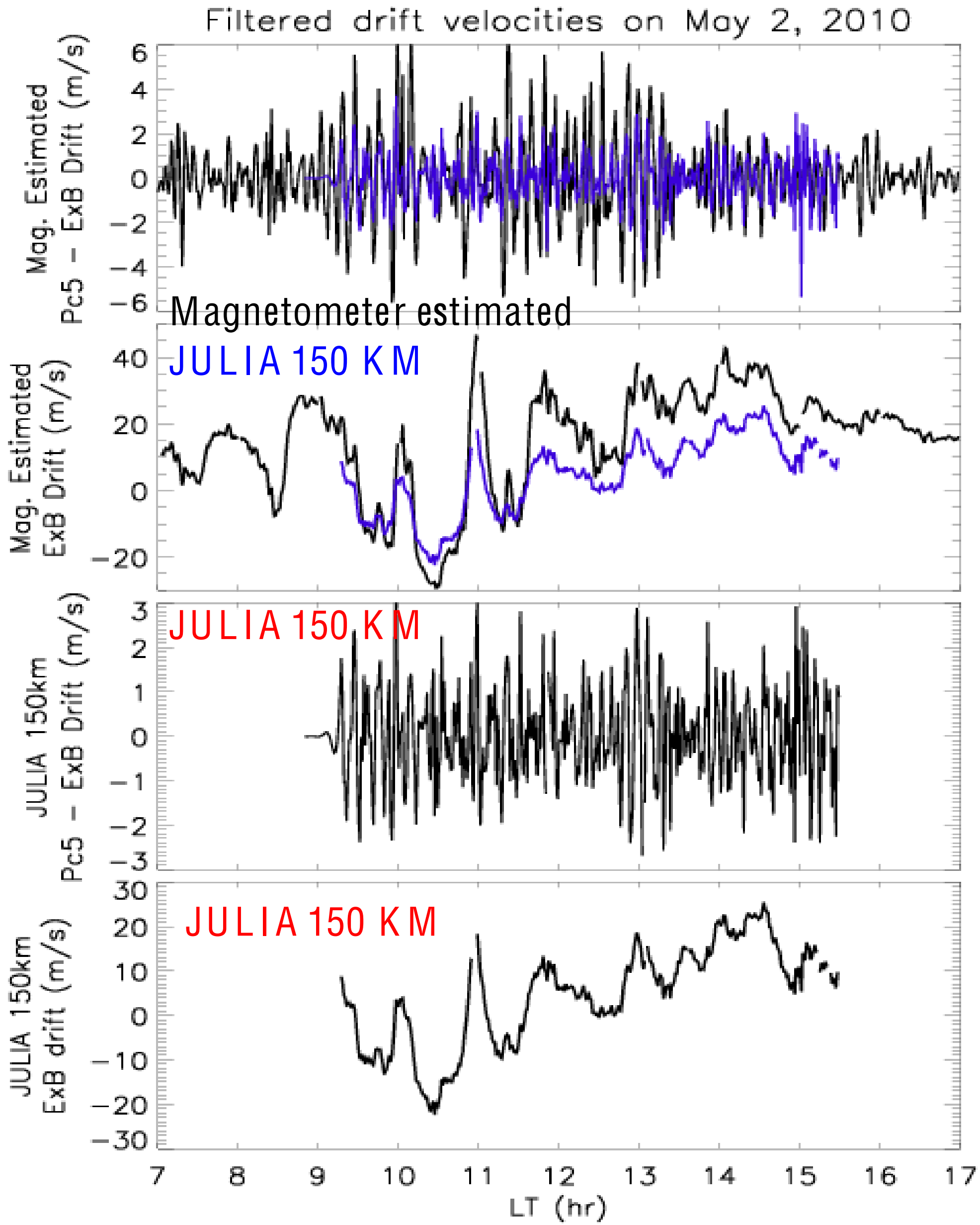


Band-pass filtered drift shows ULF wave



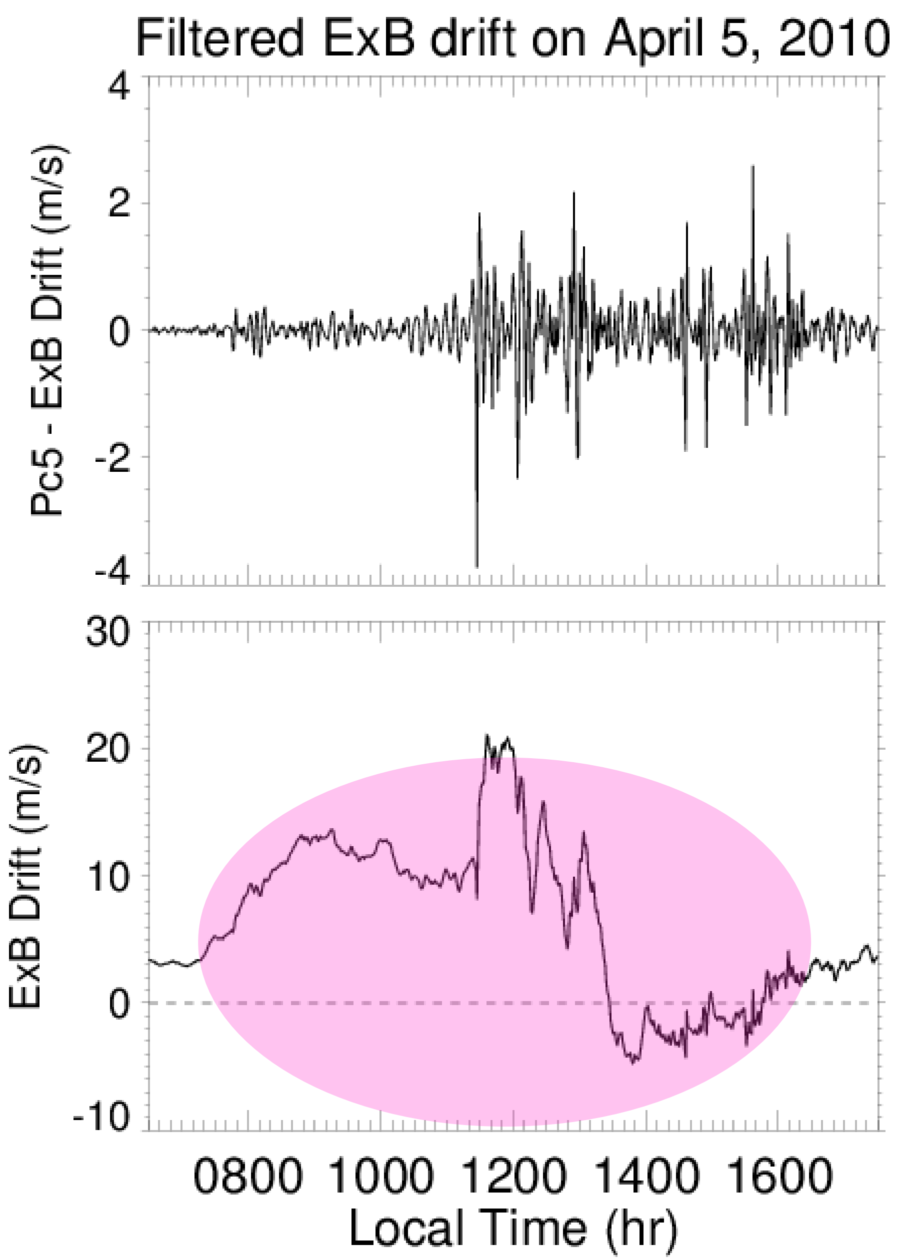
Vertical Drift and Density Fluctuation



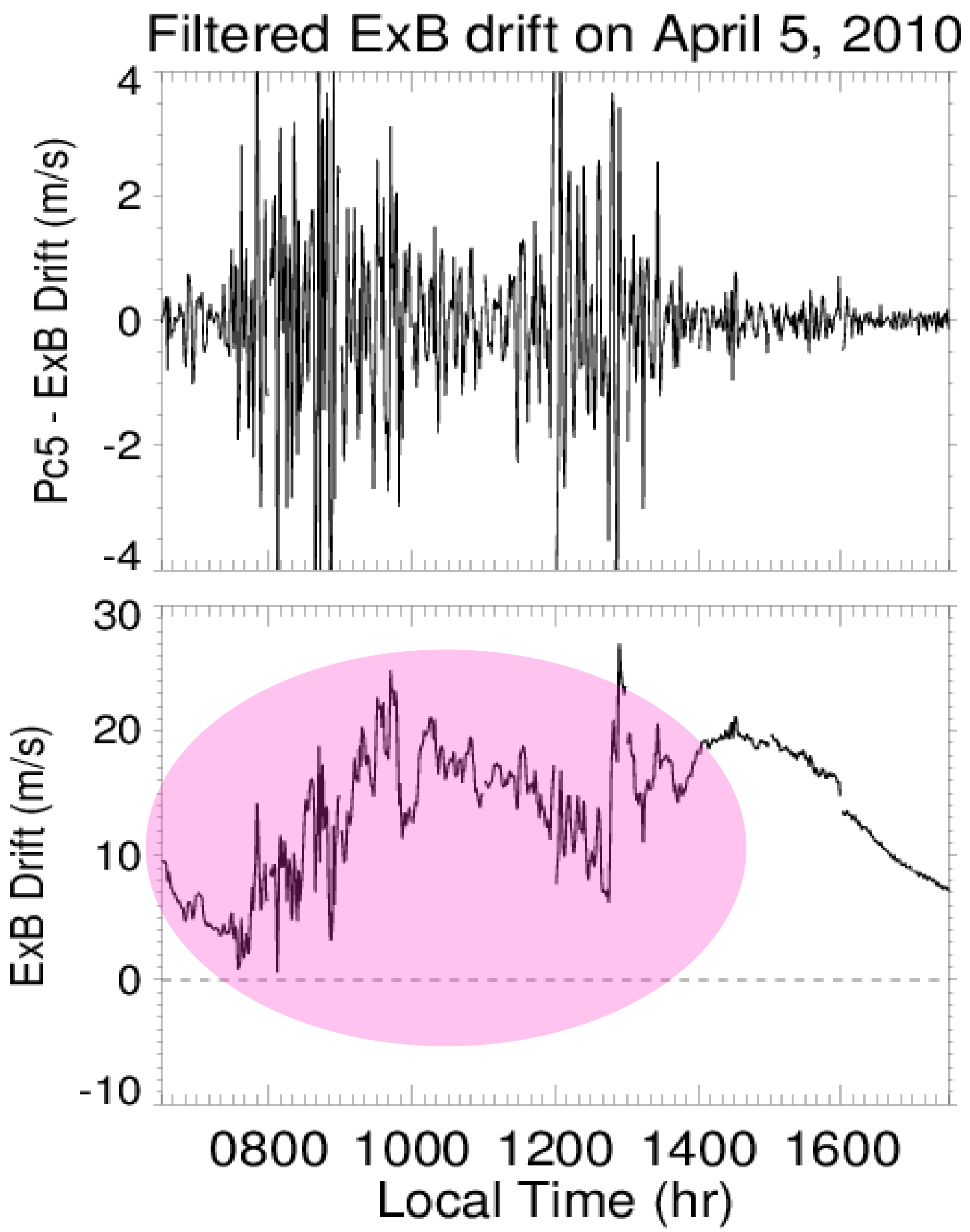


Equatorial Vertical Drift Fluctuation

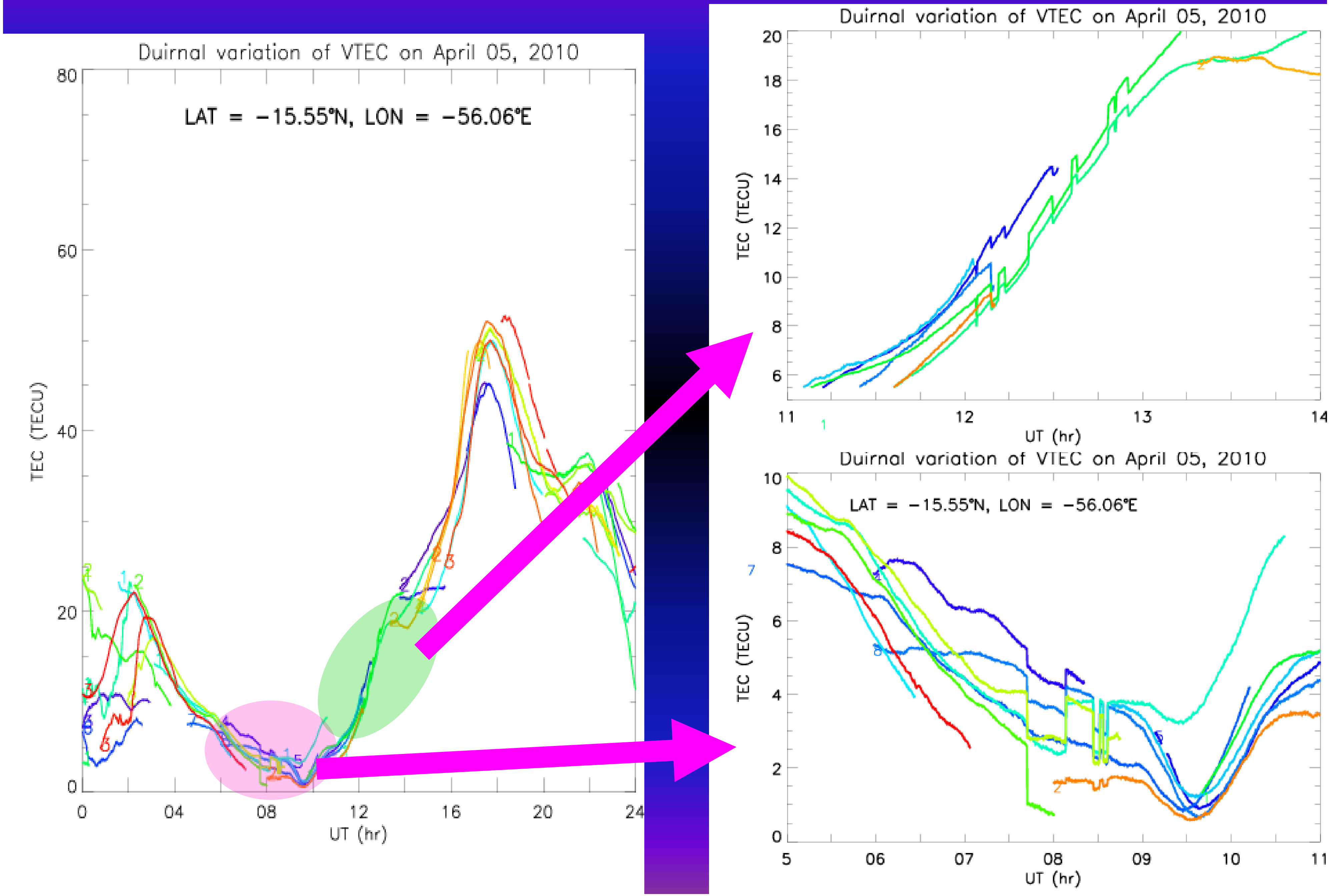
East Africa



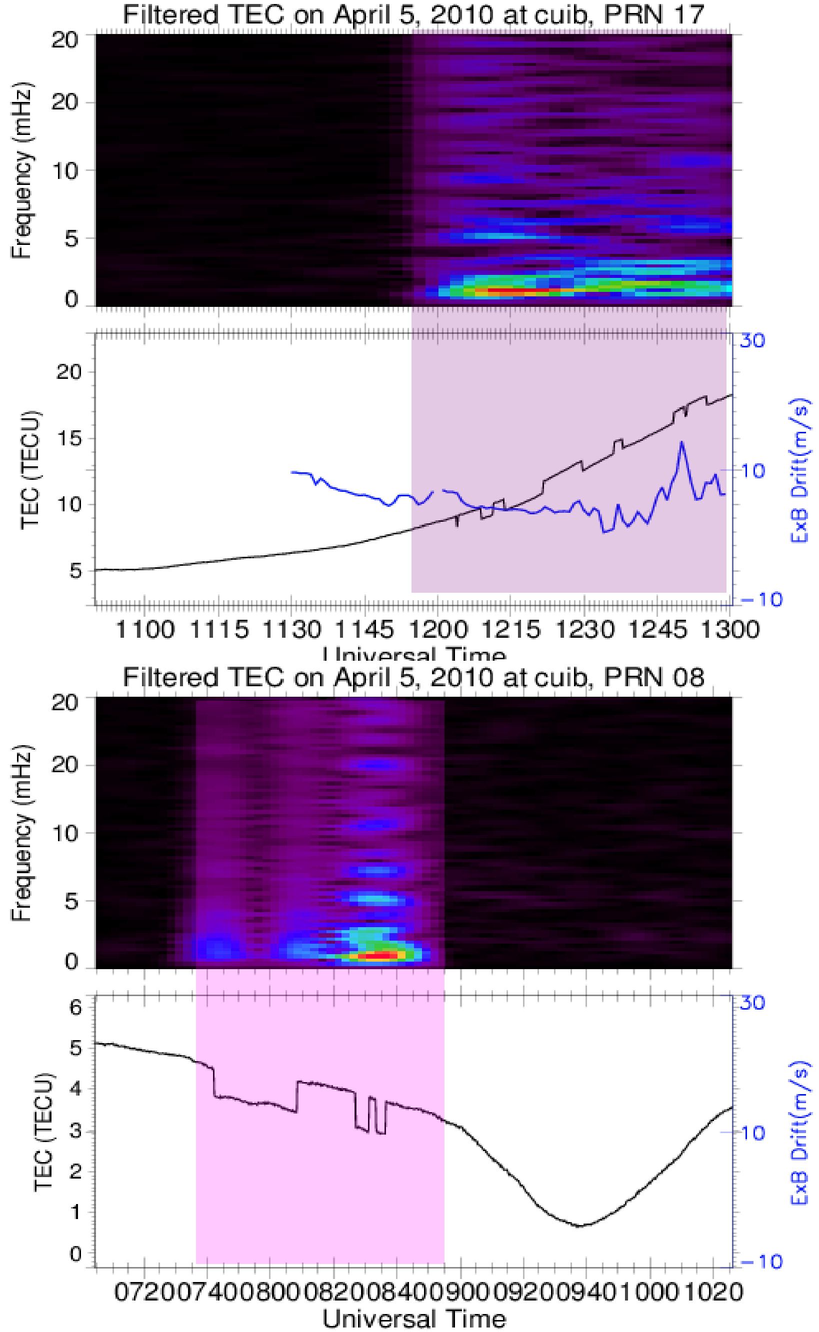
West America

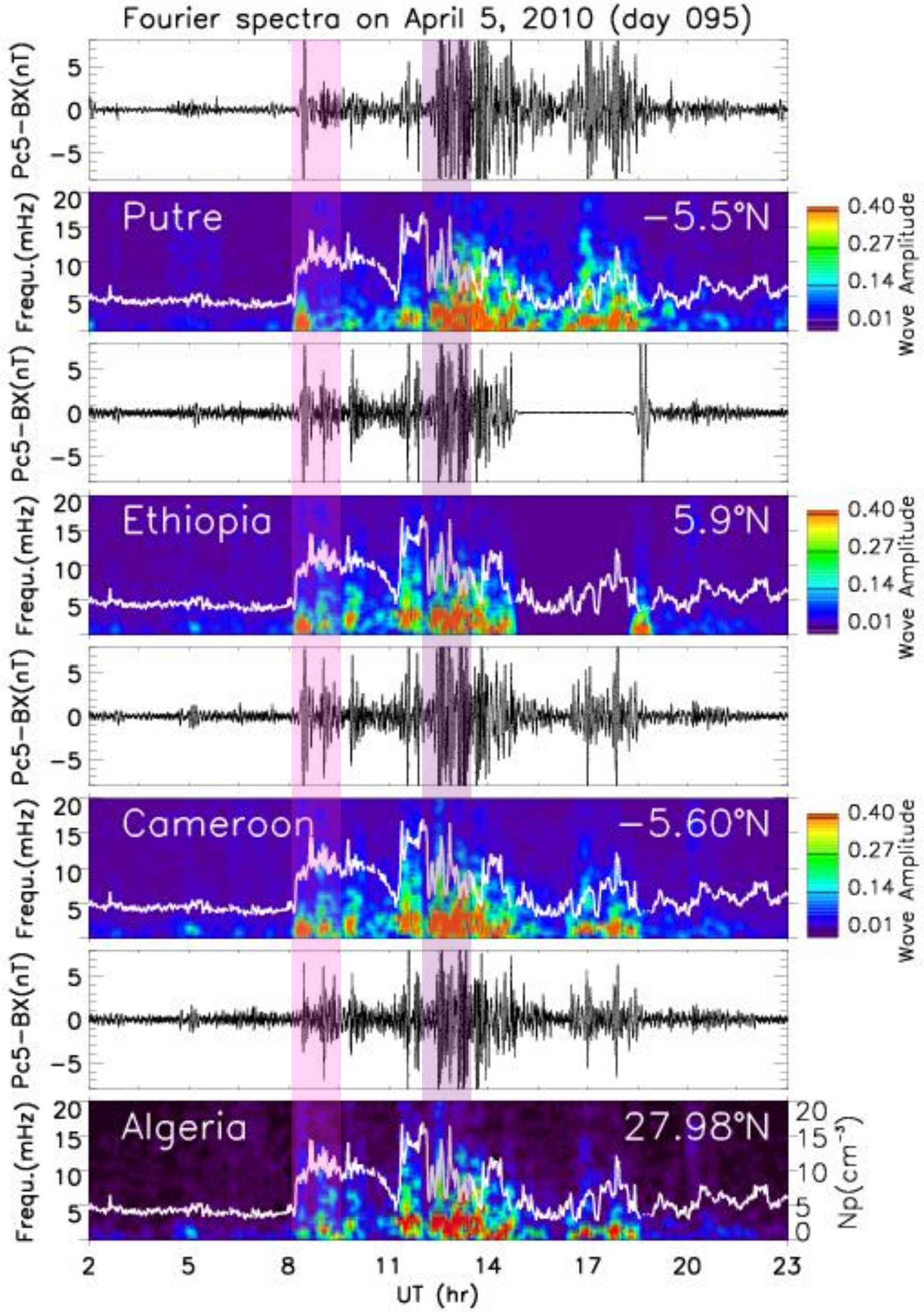


Equatorial drift and Density fluctuation



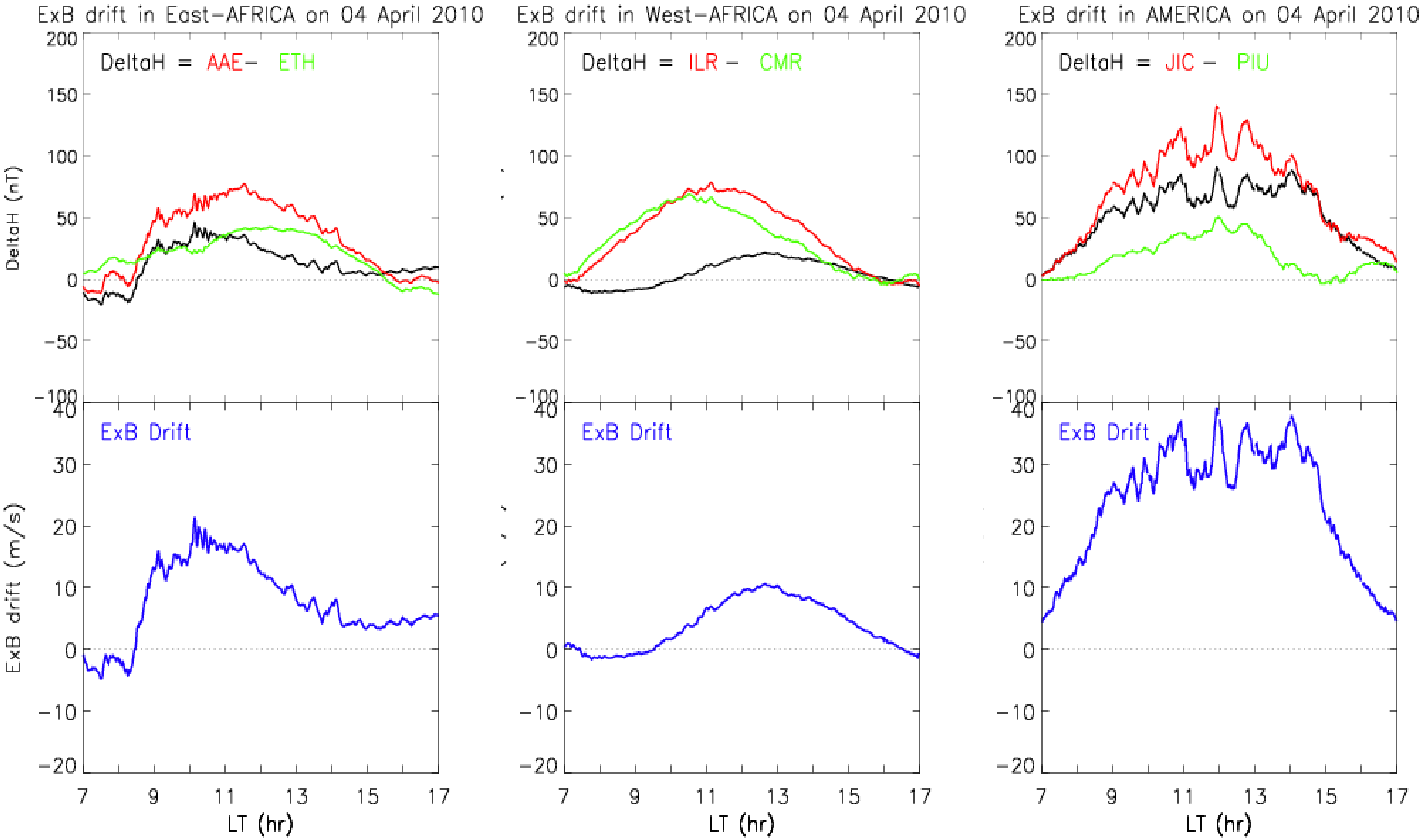
Equatorial drift and Density fluctuation



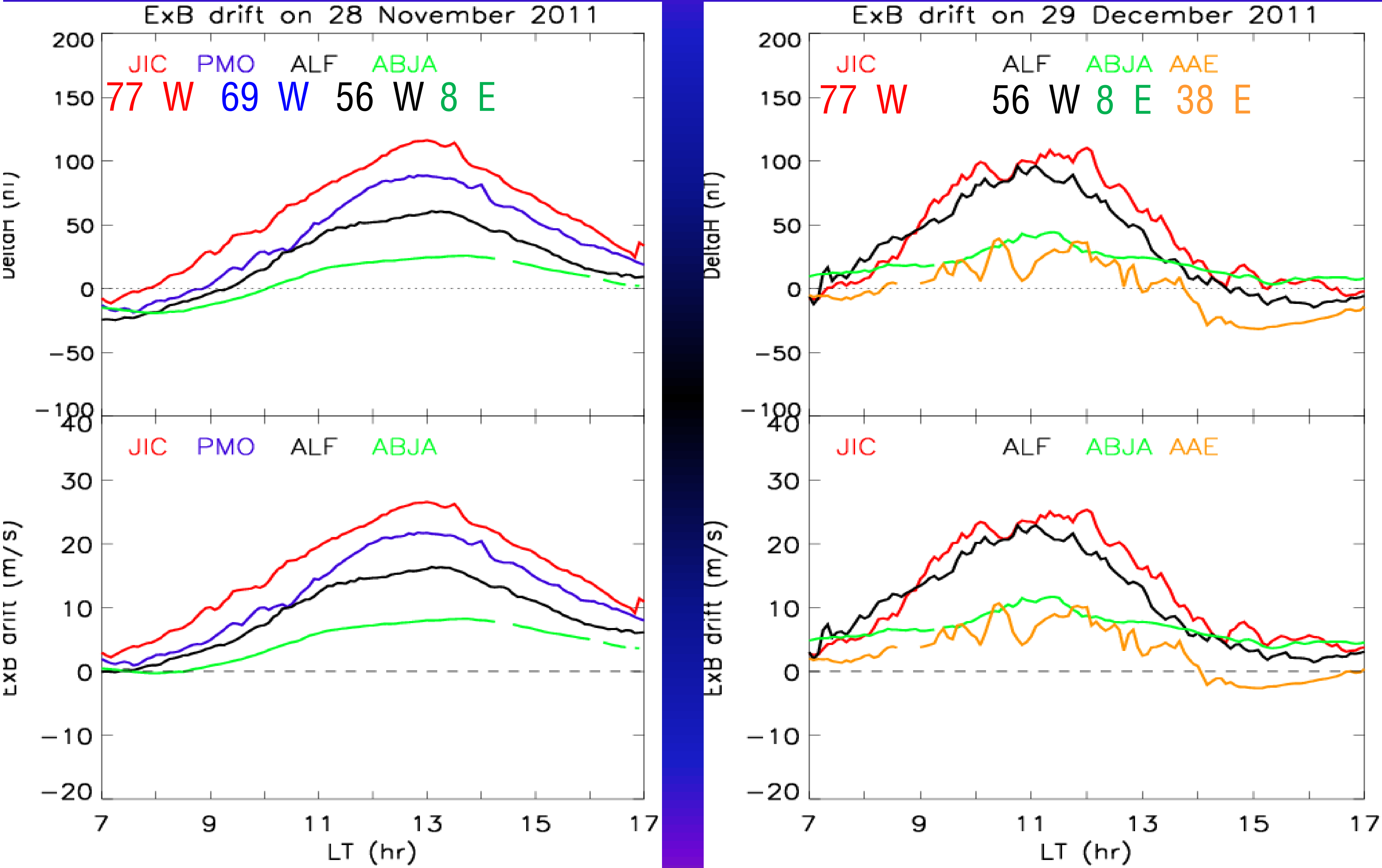


Longitudinal EEJ Variations

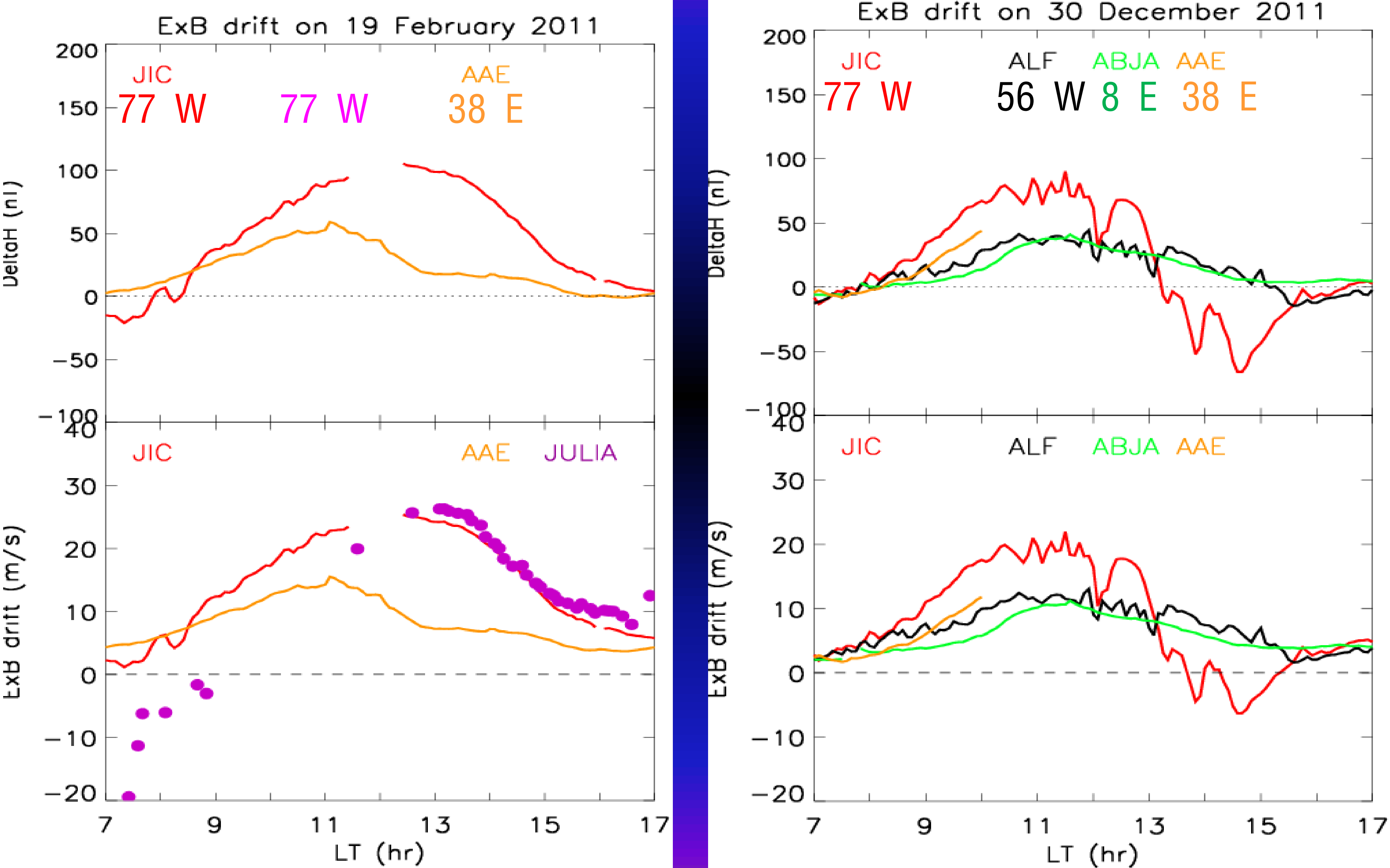
East Africa	West Africa	West America



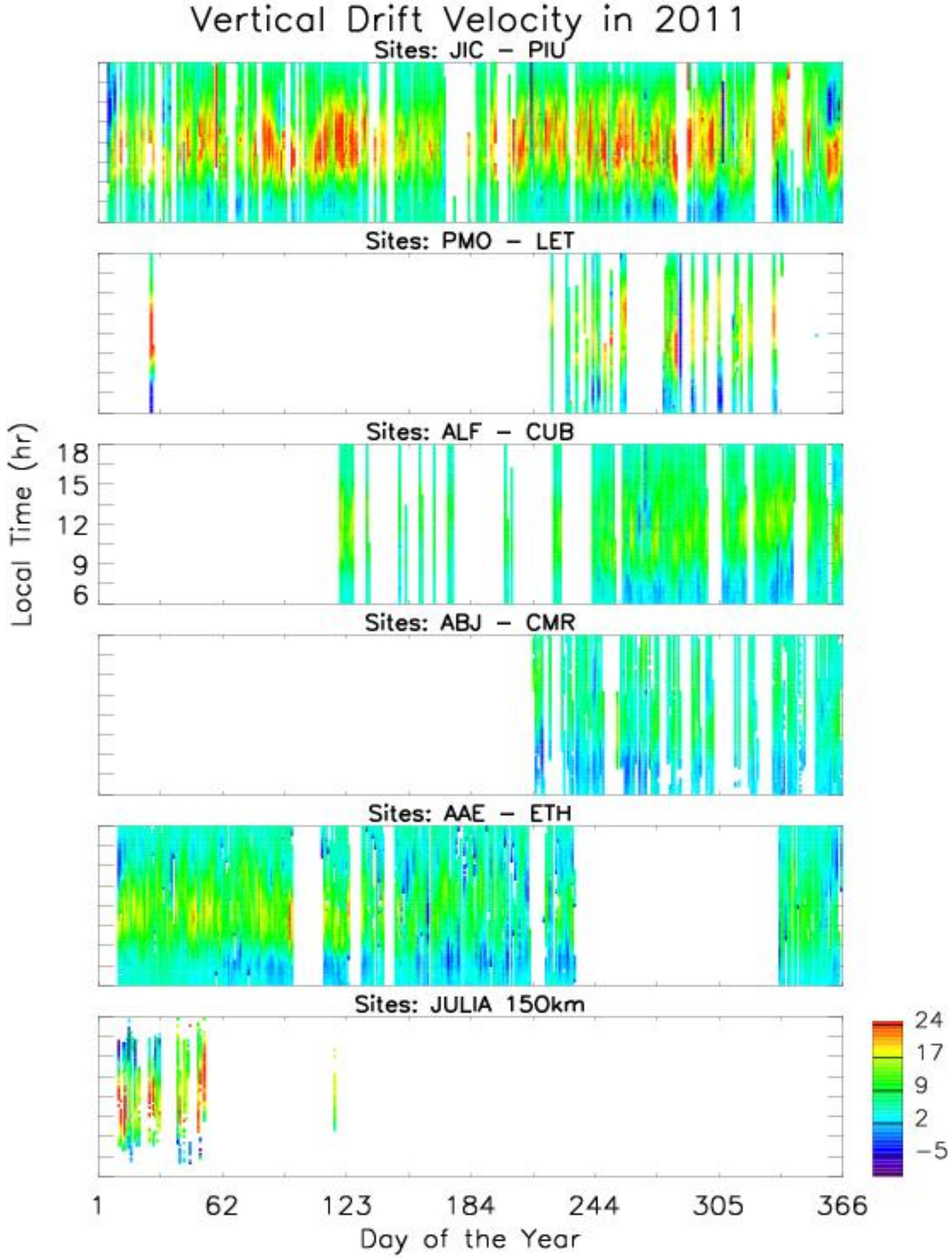
Longitudinal EEJ Variations

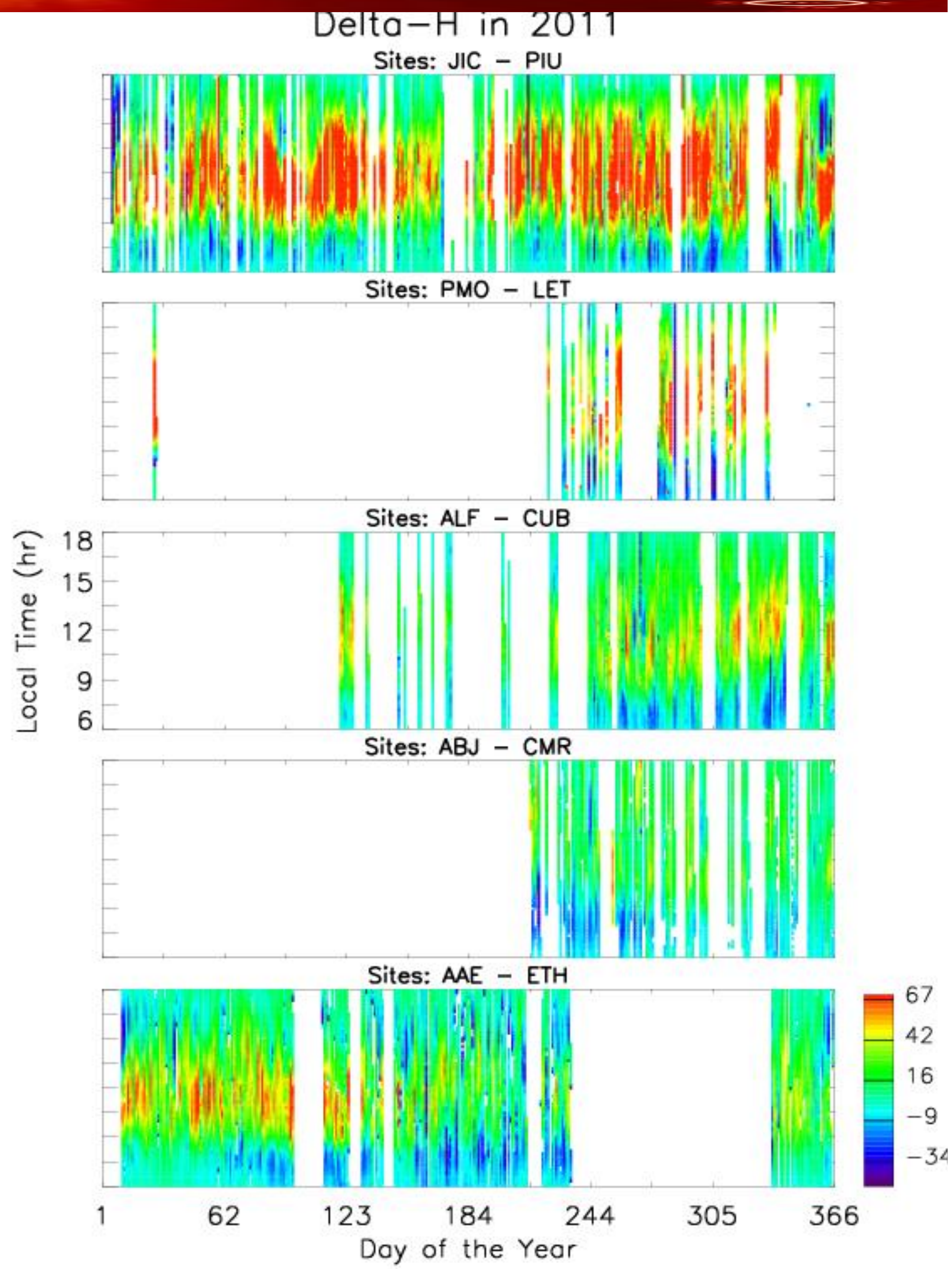


Longitudinal EEJ Variations



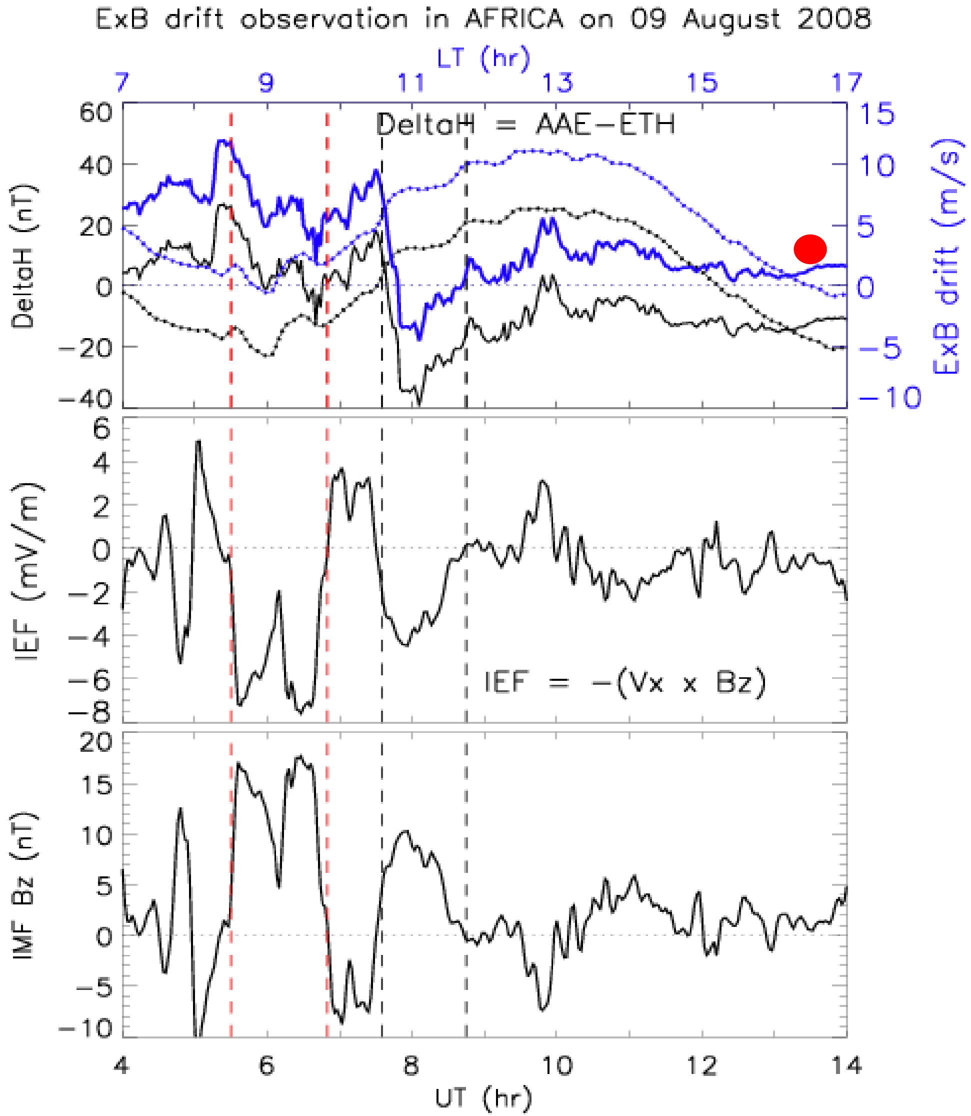
Longitudinal EEJ Variations

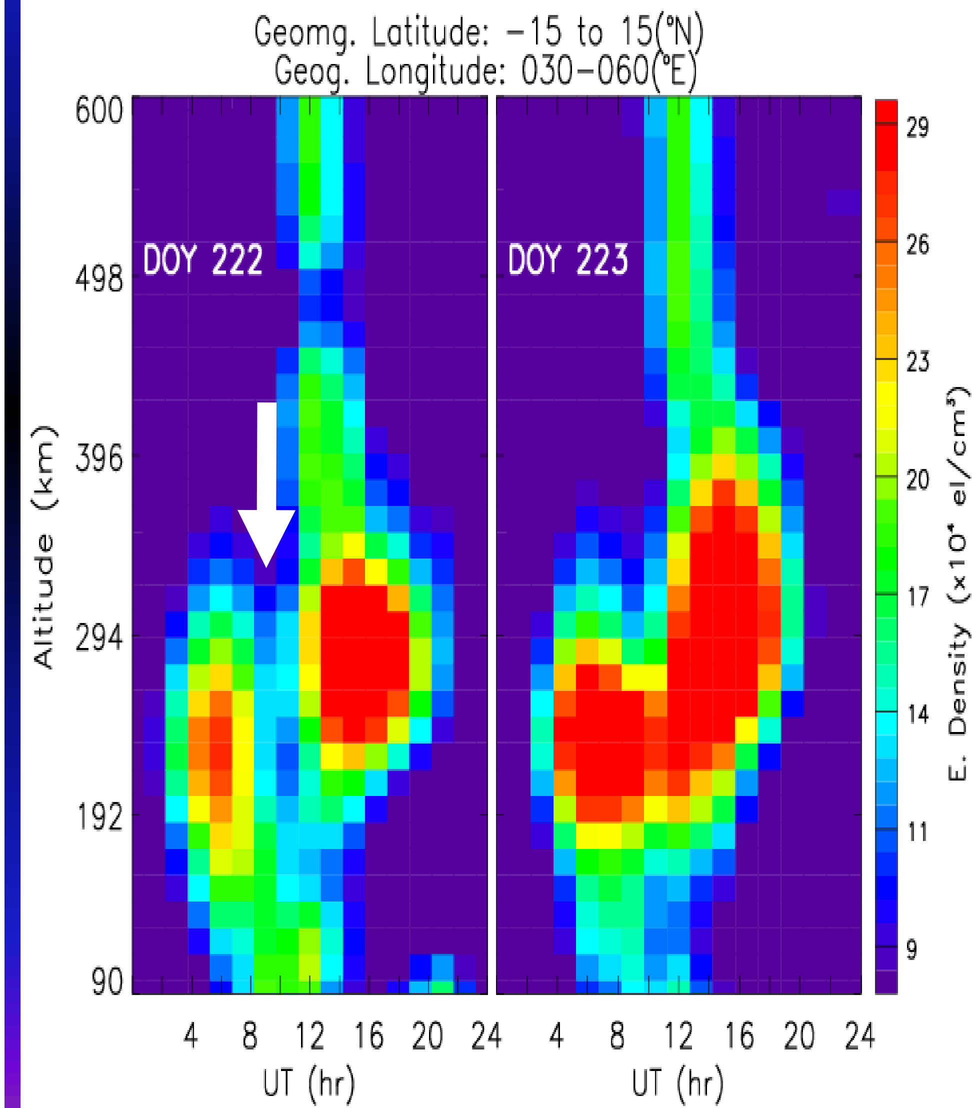




How does the ionospheric density respond to such drift differences?

Storm time electrojet and TEC & Occultation Density profile response

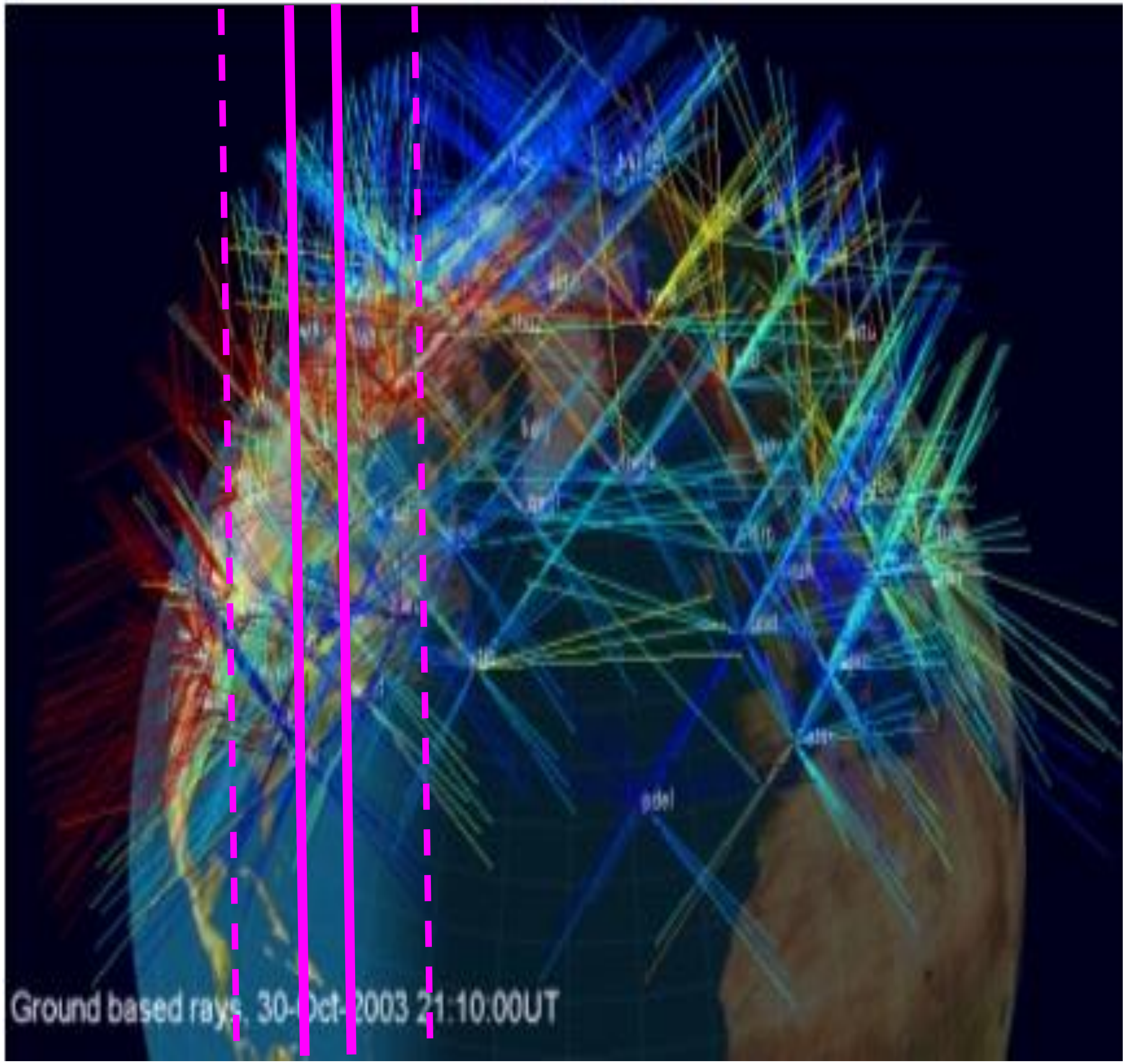




Computerized Ionospheric Tomography (CIT)

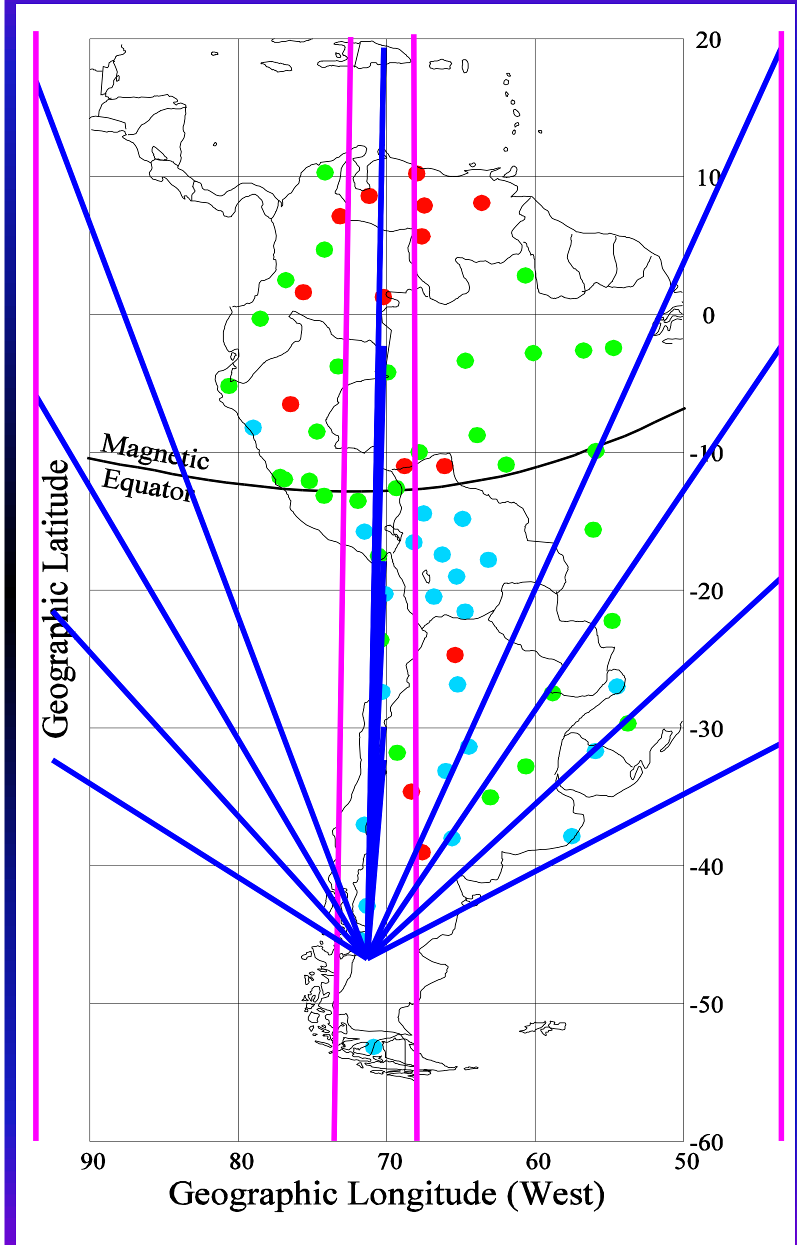
- Use radio signals from satellites
- Needs a chain of ground stations
- Use line integral of electron density (TEC) as input ingredients
- Invert data sets based on linear mathematical inversion technique
- Obtain 2D image of electron density
- Large-scale spatial structure of ionosphere

Resource for Tomography



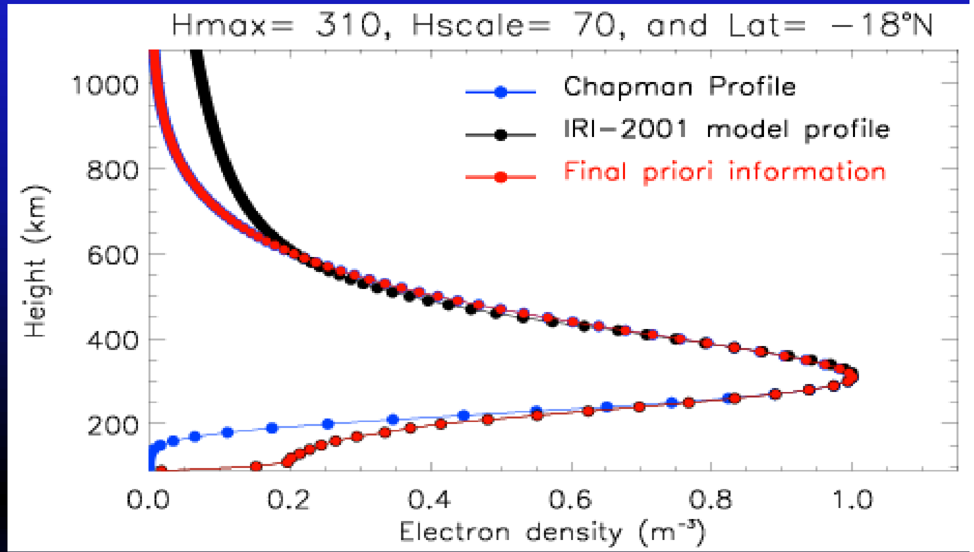
Background profiles

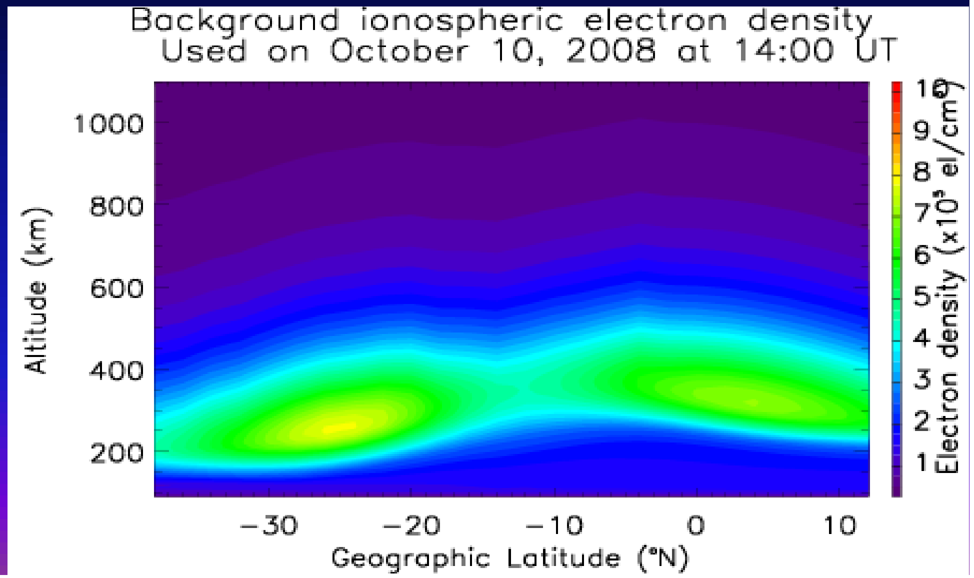
Resource for Tomography



Courtesy to Valladares

Harmonic background profiles





CIT Inversion technique

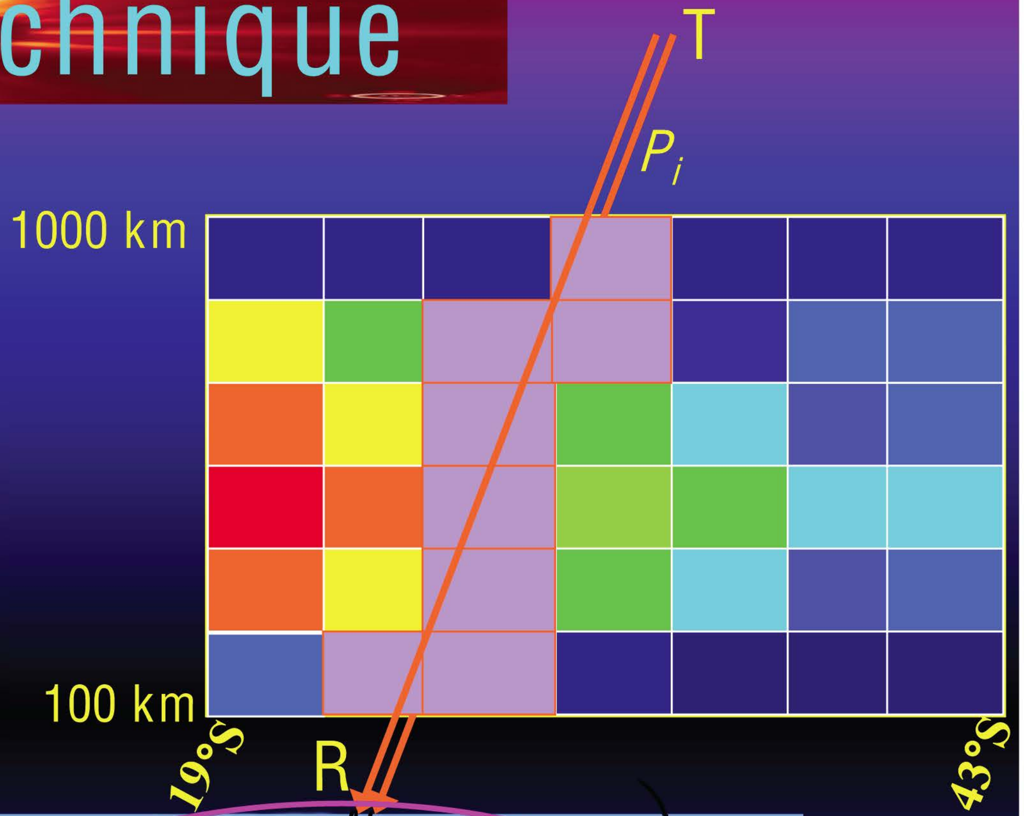
- Divide the imaging region in to number of pixels

- Fill each pixel with initial electron density guess, which can be obtained from model profiles.

- Calculate TEC for the current raypaths through initial guess.

- Using an iterative fashion, the vertical electron density profile then can be calculated as:

CIT Inversion technique



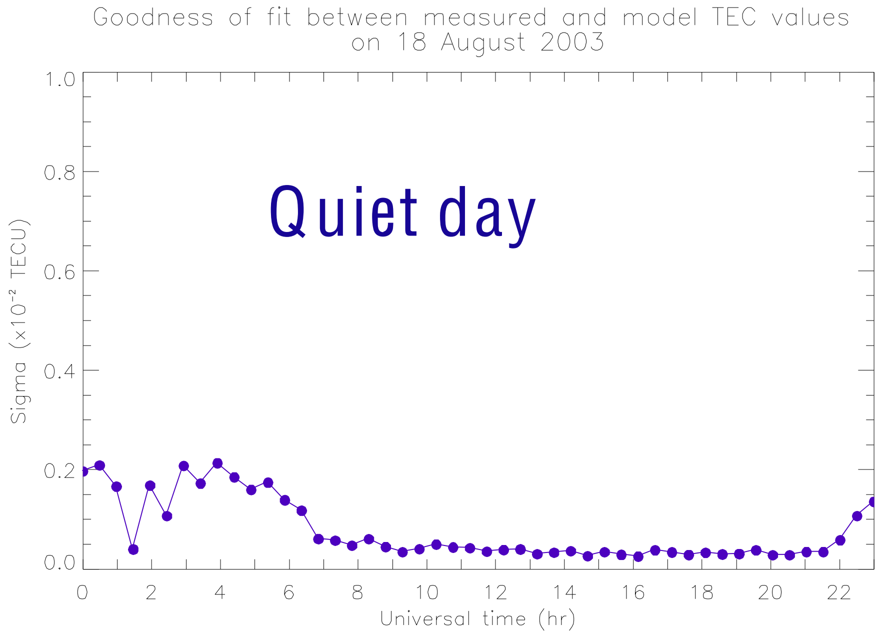
$$TEC_i = \int_{p_i} N_e ds = \sum_{j=1}^{N} d_{ij} n_j + E$$

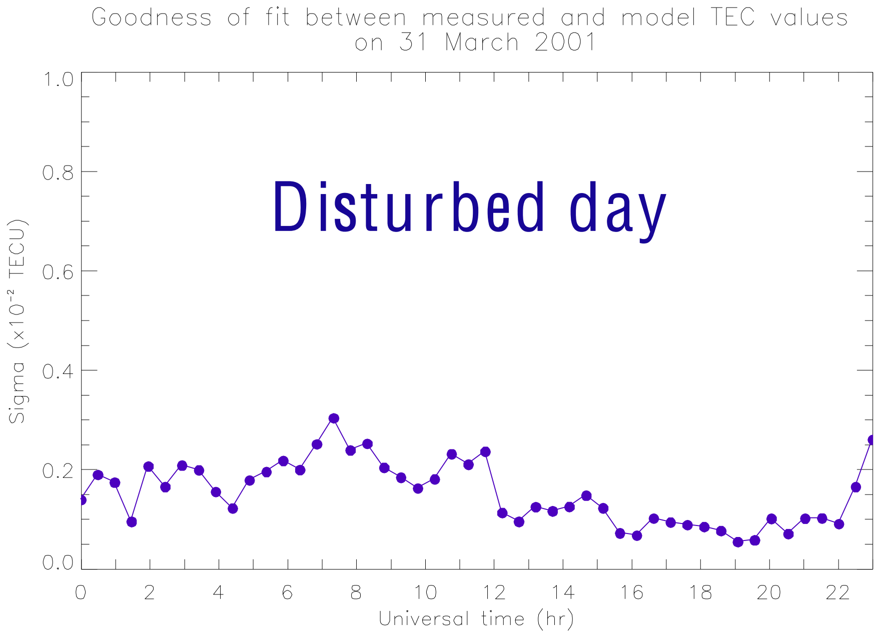
$$TEC_{guess} = \sum_{j=1}^{N} d_{ij} (n_{gs})_j$$

$$N_e^{k+1} = N_e^k + \lambda_k \left(\frac{TEC_i - \sum_{j=1}^{N} d_{ij} n_j^k}{\sum_{j=1}^{N} d_{ij} d_{ij}} \right) D_i$$

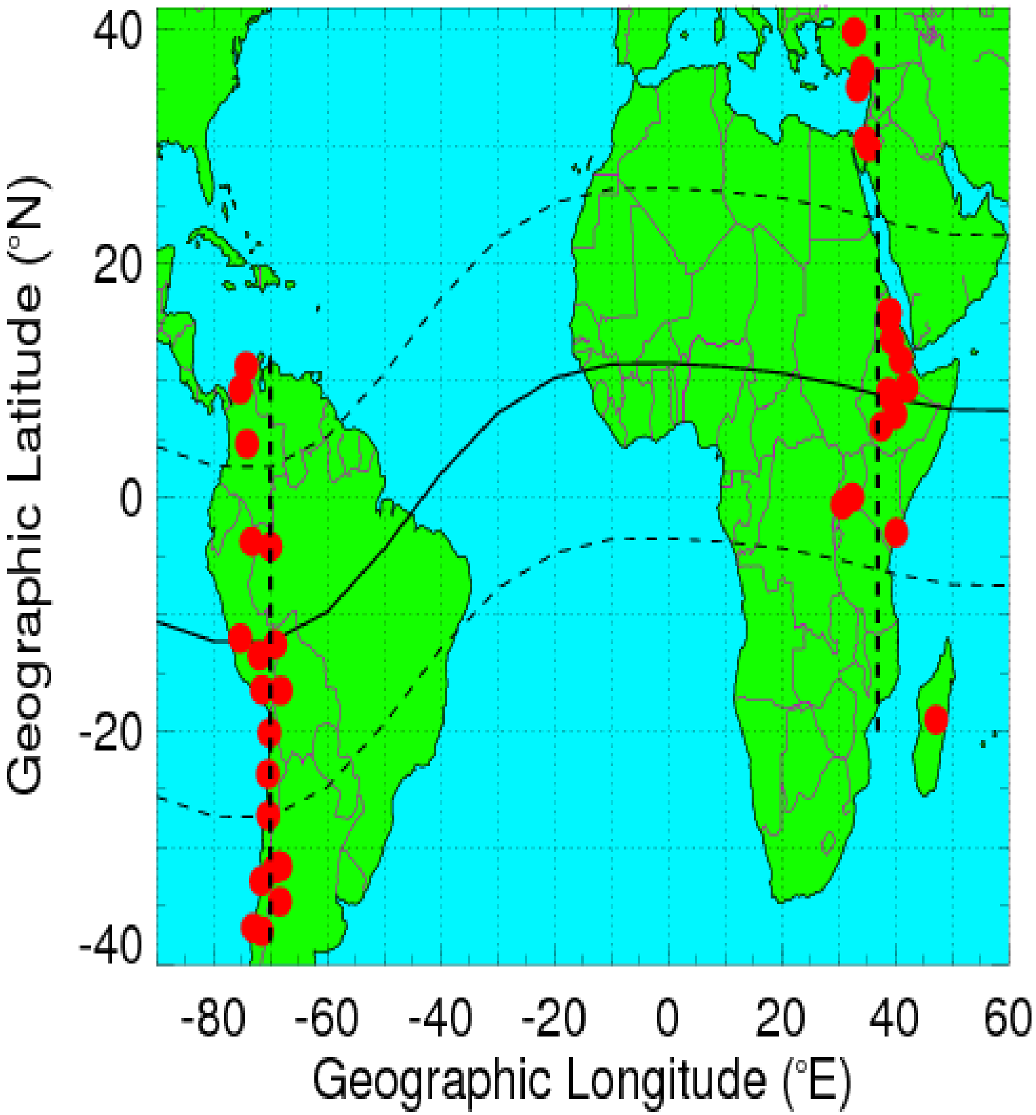
Which ensures that the correction remains stable

CIT Inversion technique





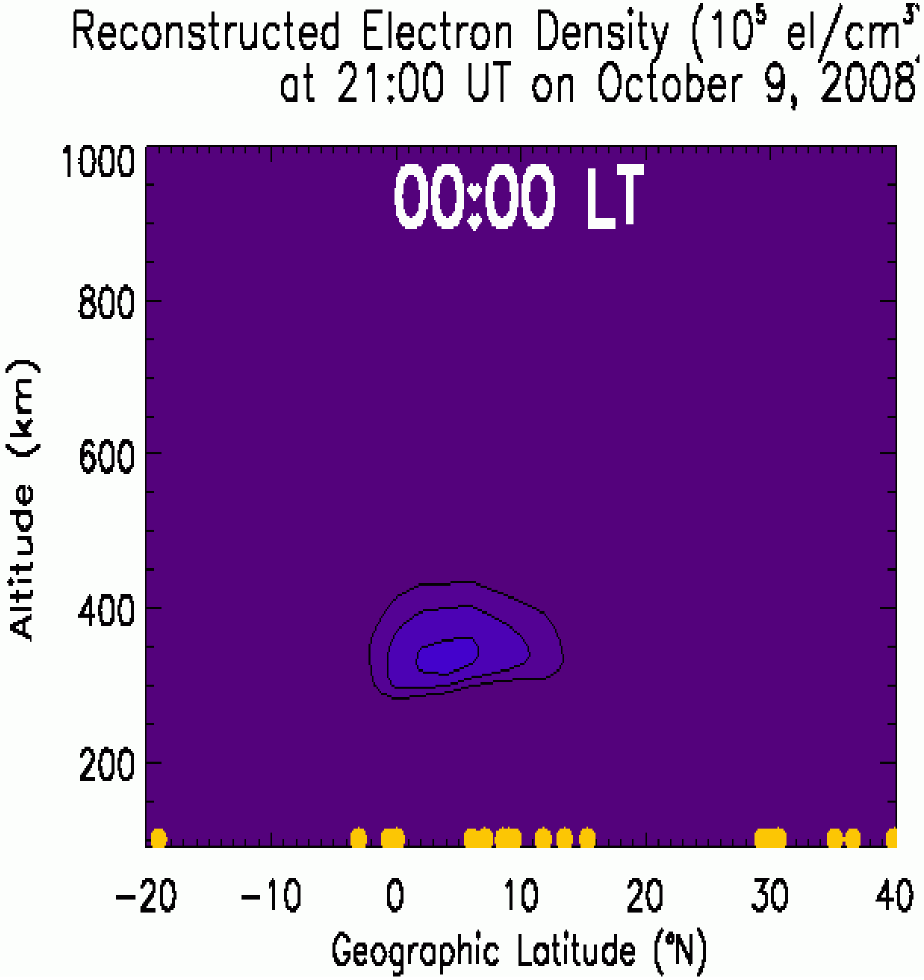
Computerized Ionospheric Tomography (CIT)



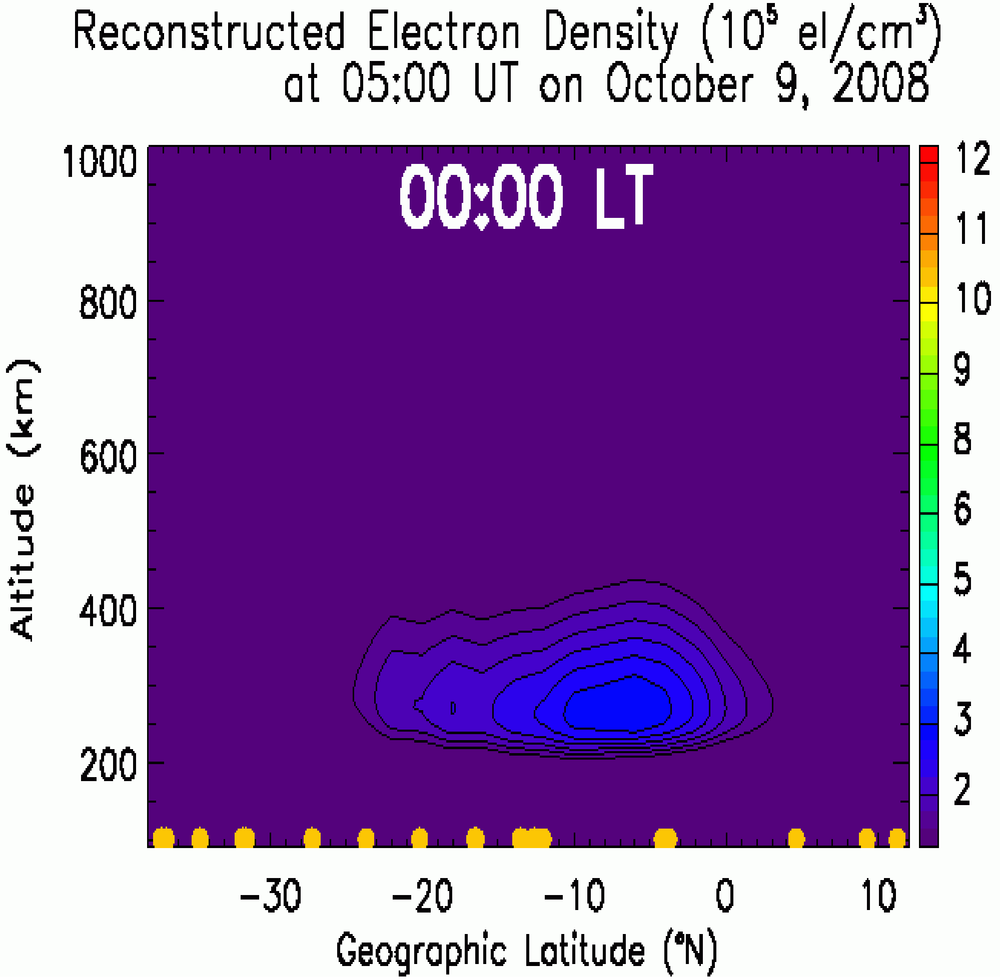
- Use radio signals from satellites
- Needs a chain of ground stations
- Use line integral of electron density (TEC) as input ingredients
- Invert data sets based on linear mathematical inversion technique
- Obtain vertical structure of electron density
- Large-scale spatial structure of ionosphere

Tomographically reconstructed density profiles

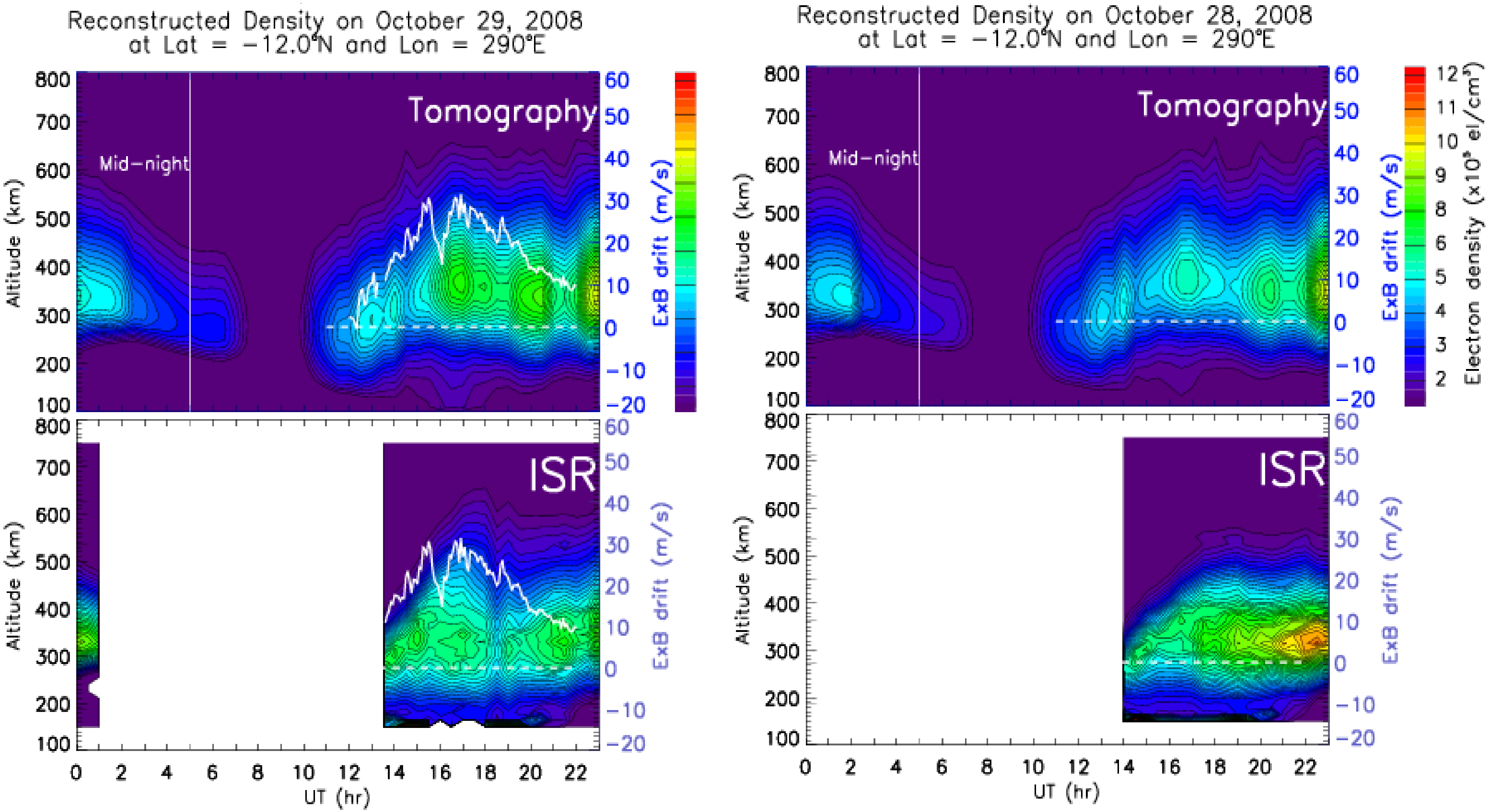
East Africa



West America

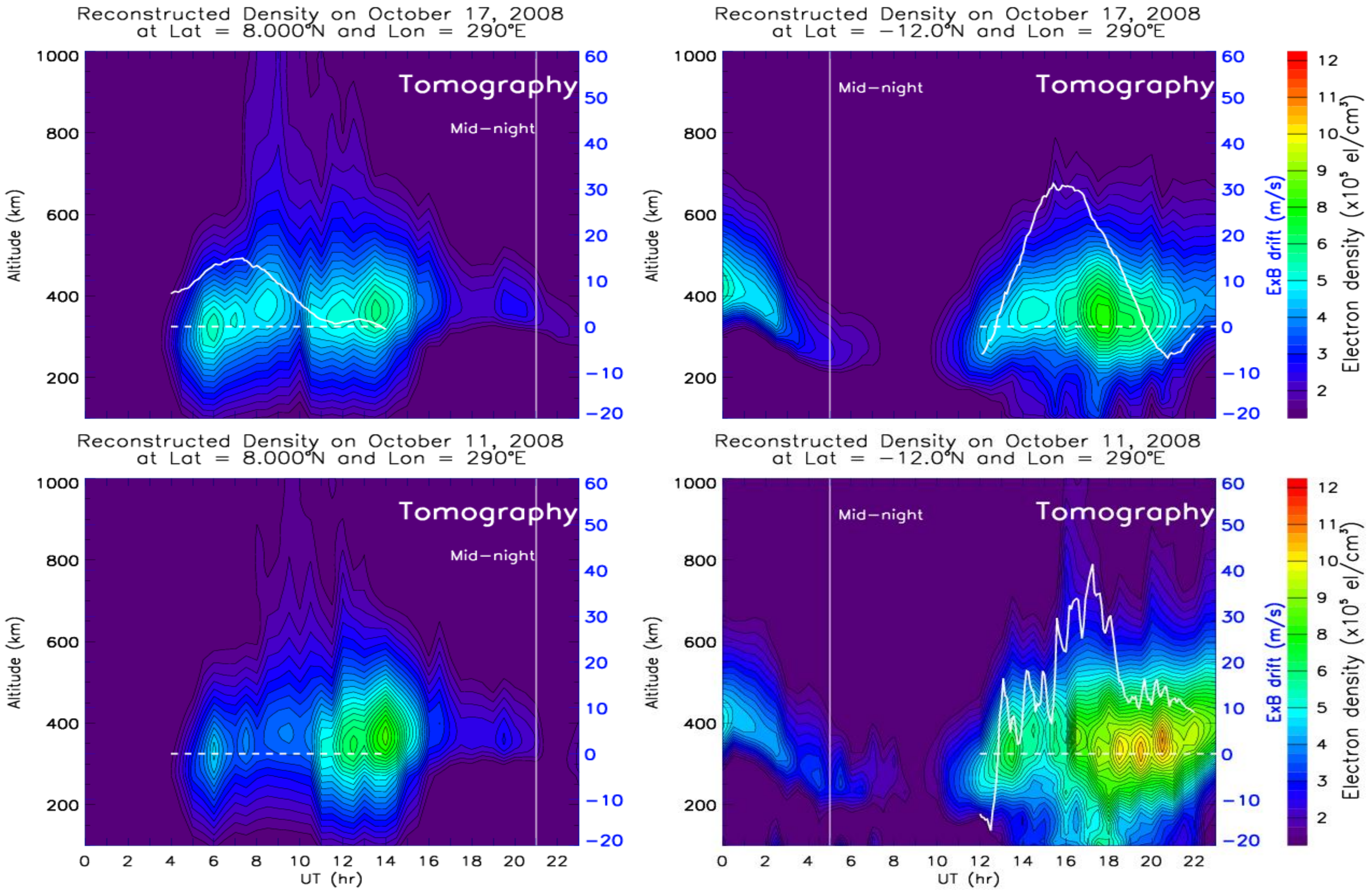


Tomography and ISR Density profiles comparison



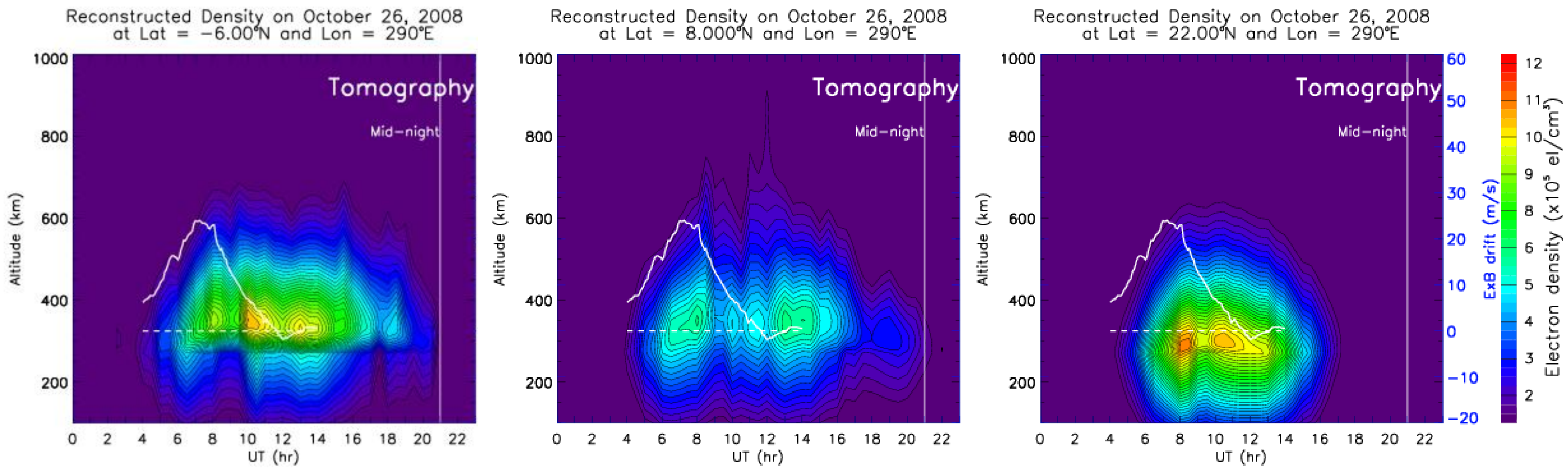
Longitudinal Density profiles differences

East Africa | West America

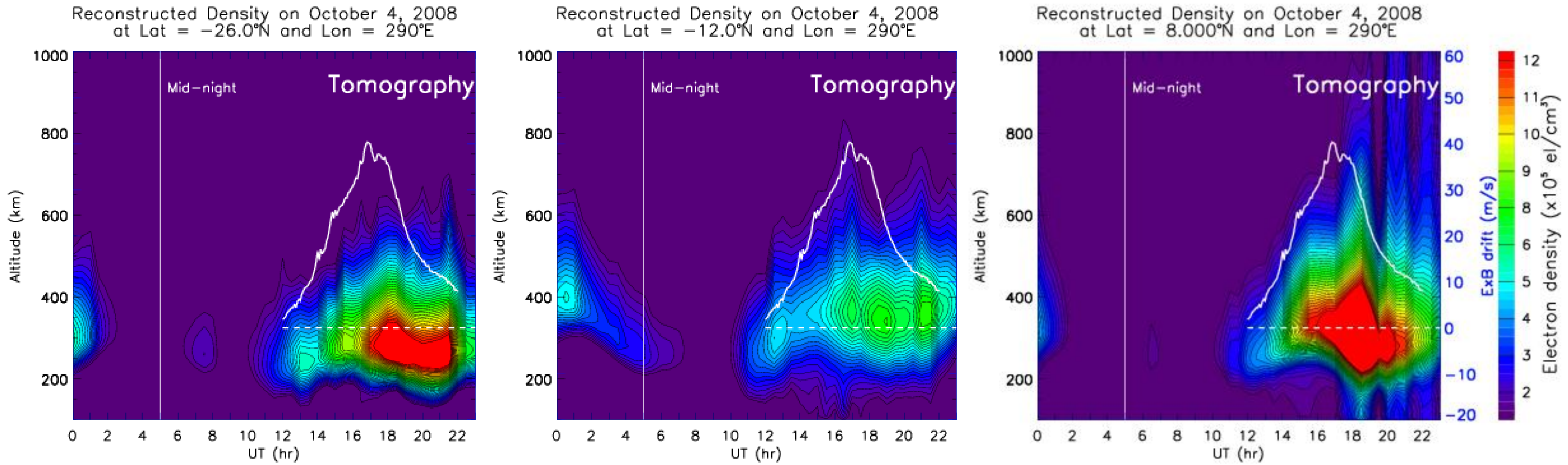


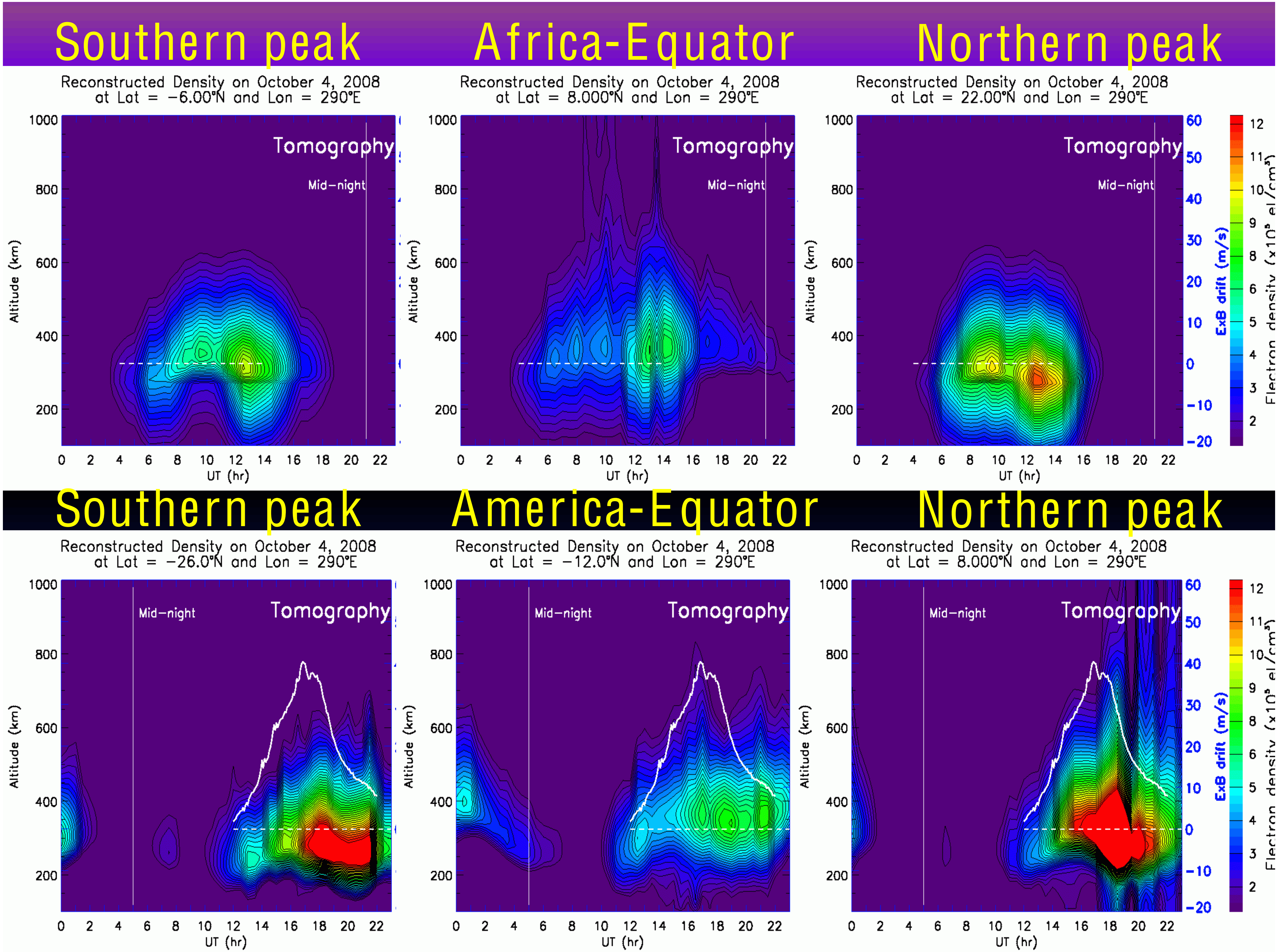
Longitudinal Density profiles differences

Southern peak | Africa-Equator | Northern peak



Southern peak | America-Equator | Northern peak

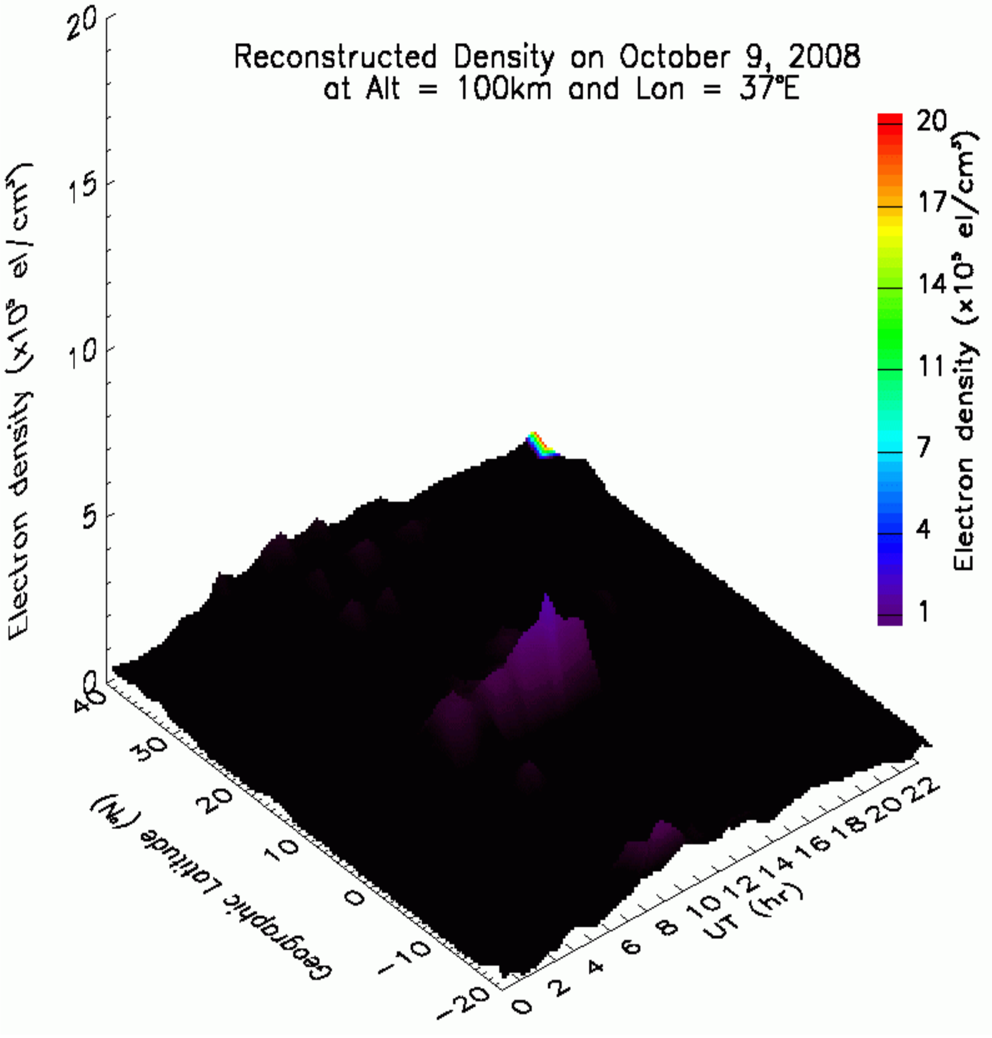




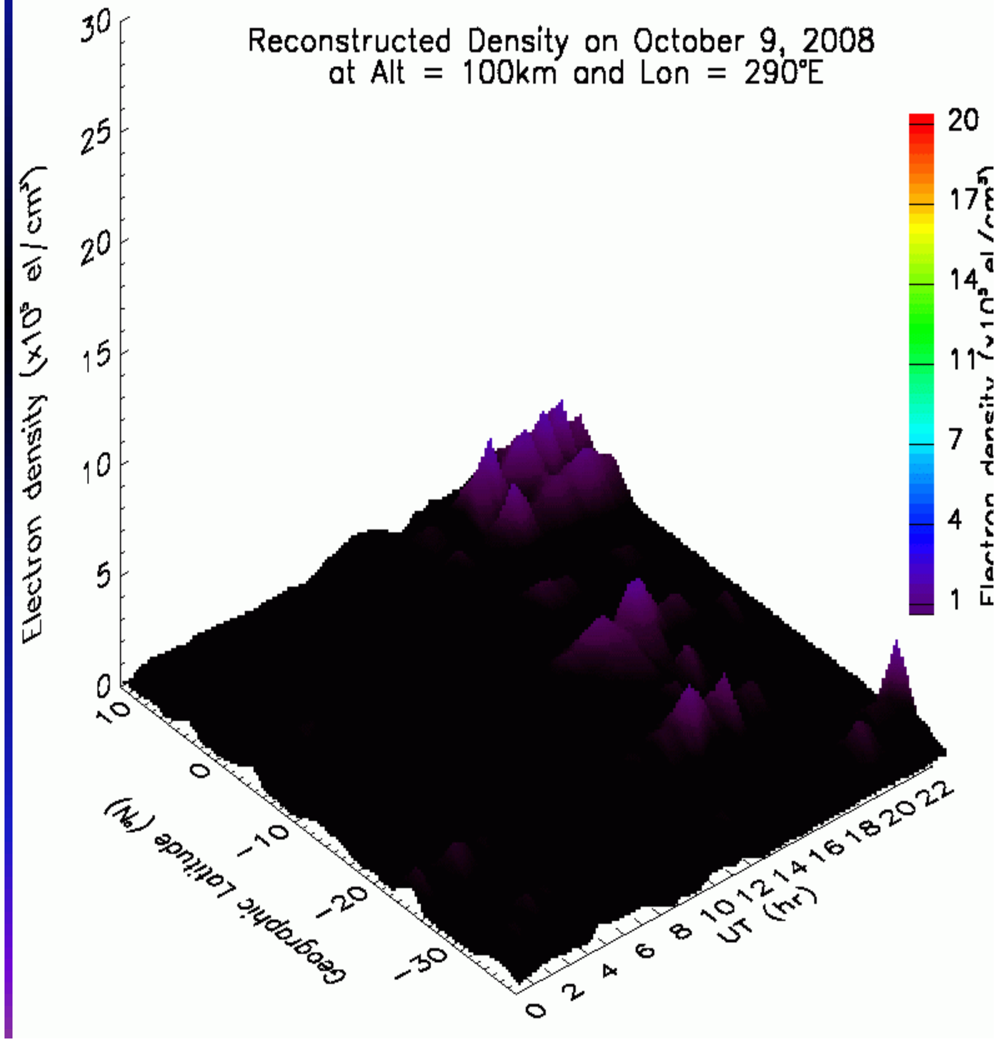
Southern peak
Africa-Equator
Northern peak
Reconstructed Density on October 4, 2008 at Lat = −6.00°N and Lon = 290°E
Reconstructed Density on October 4, 2008 at Lat = 8.000°N and Lon = 290°E
Reconstructed Density on October 4, 2008 at Lat = 22.00°N and Lon = 290°E
Tomography
Mid−night
Altitude (km)
UT (hr)
ExB drift (m/s)
Electron density (x10⁵ el/cm³)
Southern peak
America-Equator
Northern peak
Reconstructed Density on October 4, 2008 at Lat = −26.0°N and Lon = 290°E
Reconstructed Density on October 4, 2008 at Lat = −12.0°N and Lon = 290°E
Reconstructed Density on October 4, 2008 at Lat = 8.000°N and Lon = 290°E

Electron Density structure at different altitudes

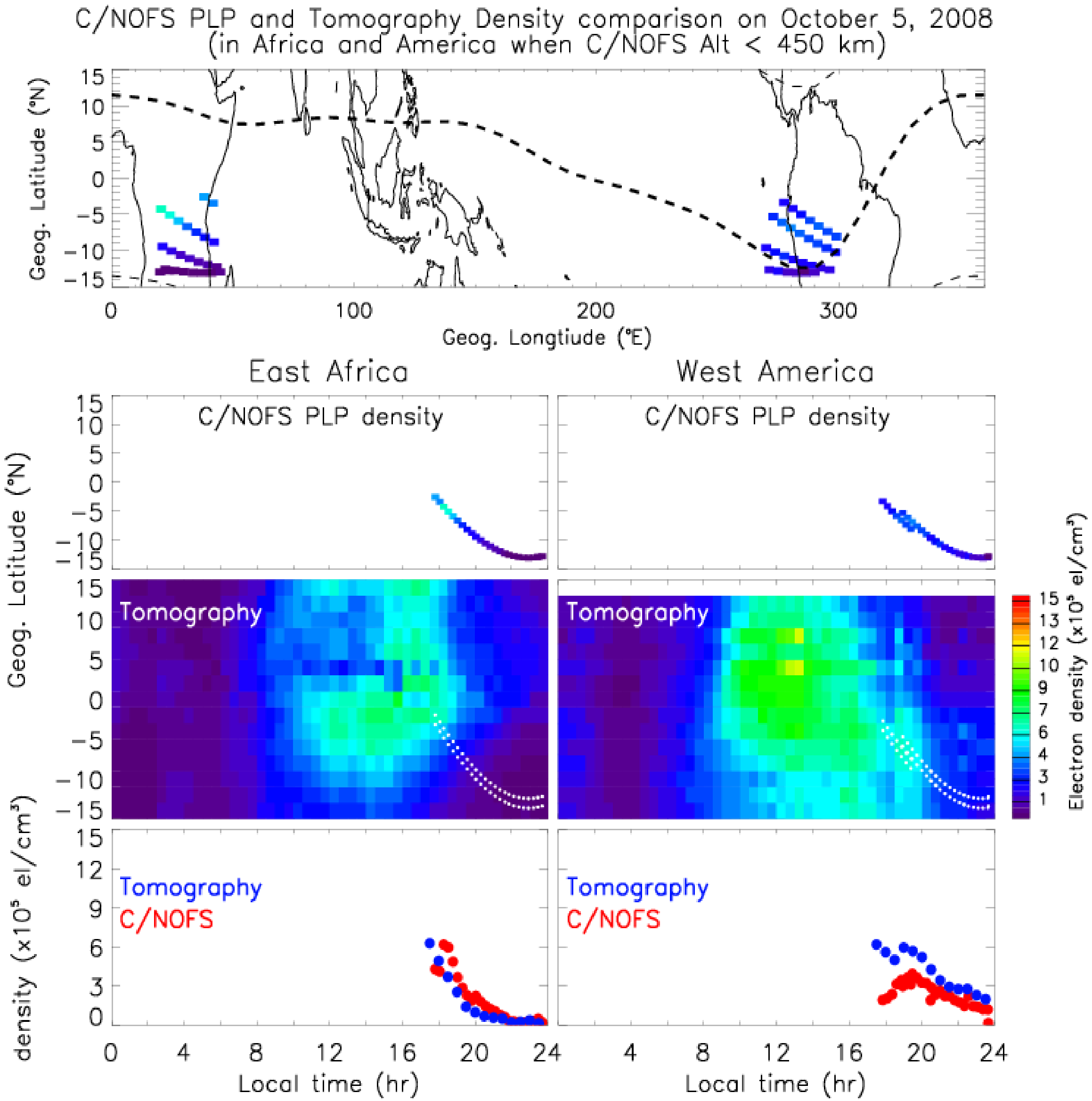
East Africa



West America



C/NOFS PLP and tomography density comparison



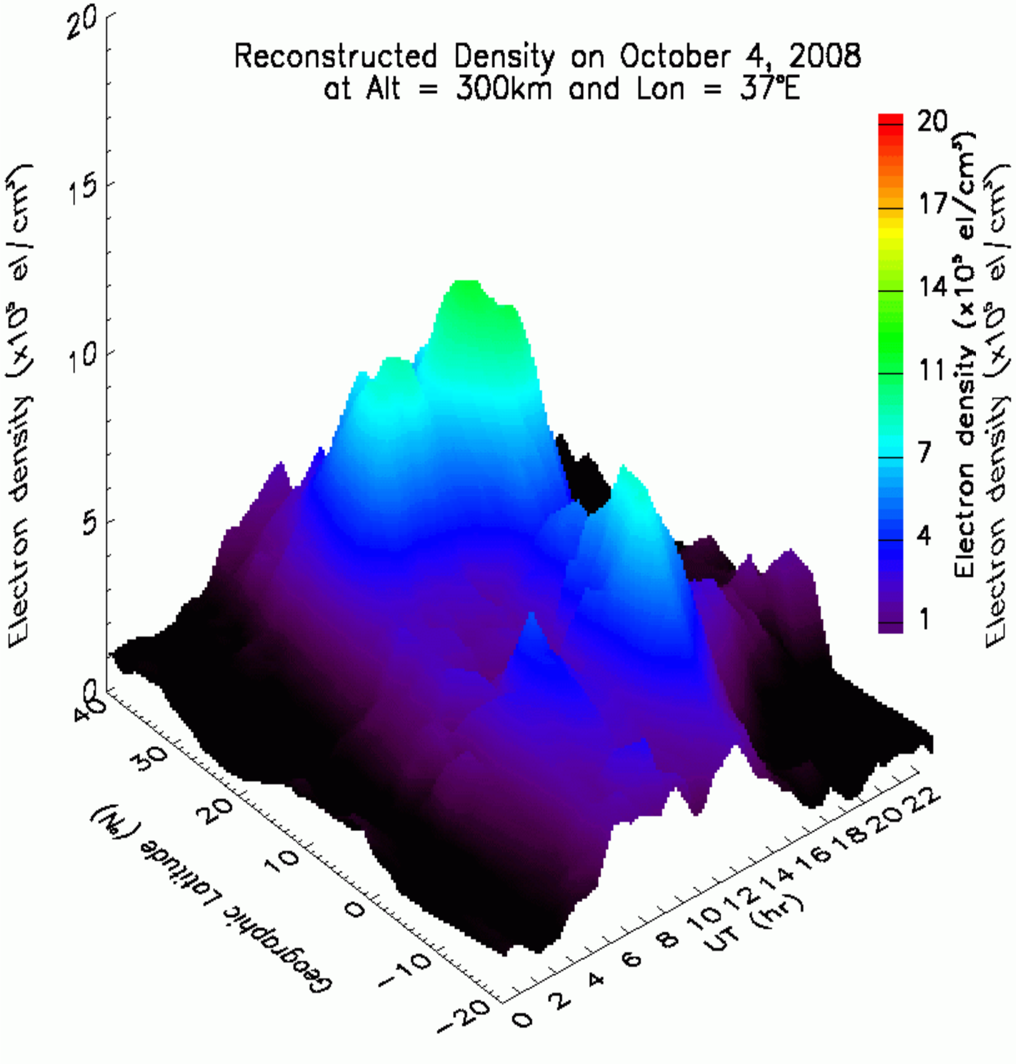
C/NOFS density distribution on October 5, 2008

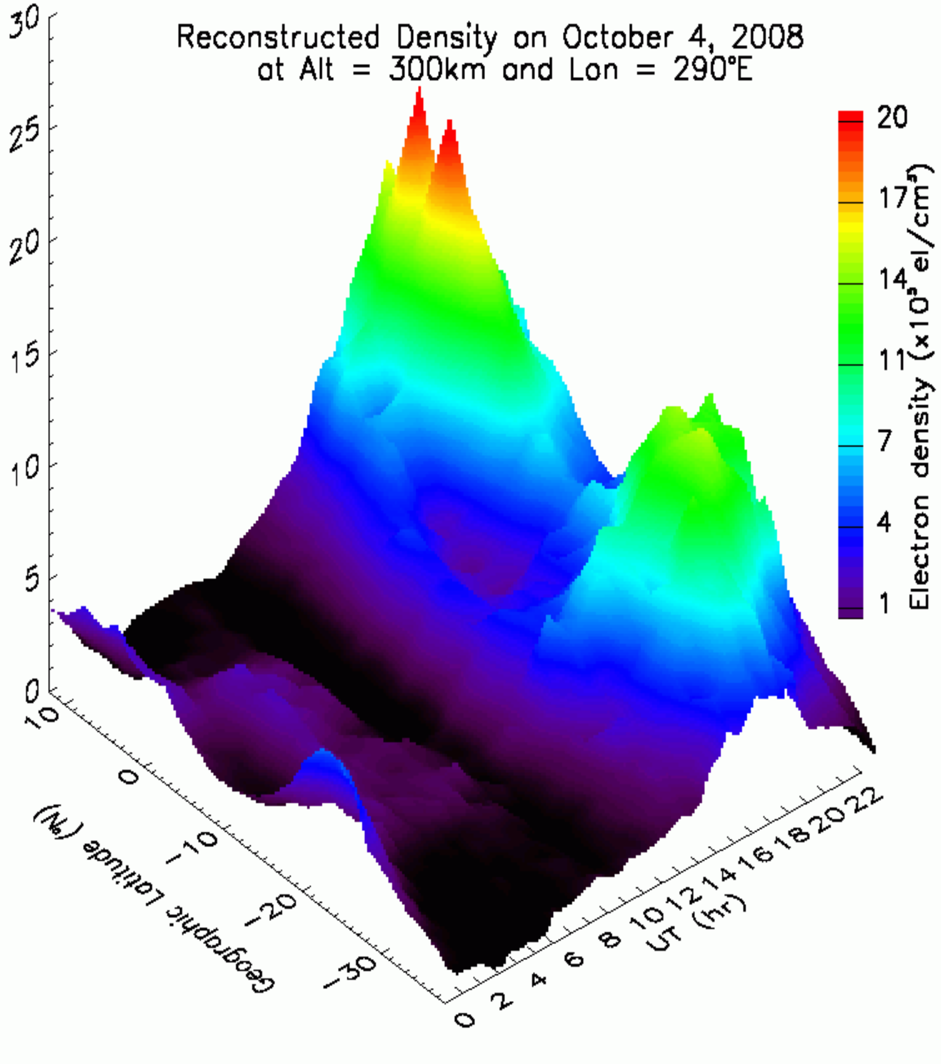
Local-time distribution of C/NOFS density

Tomography density at 420 km

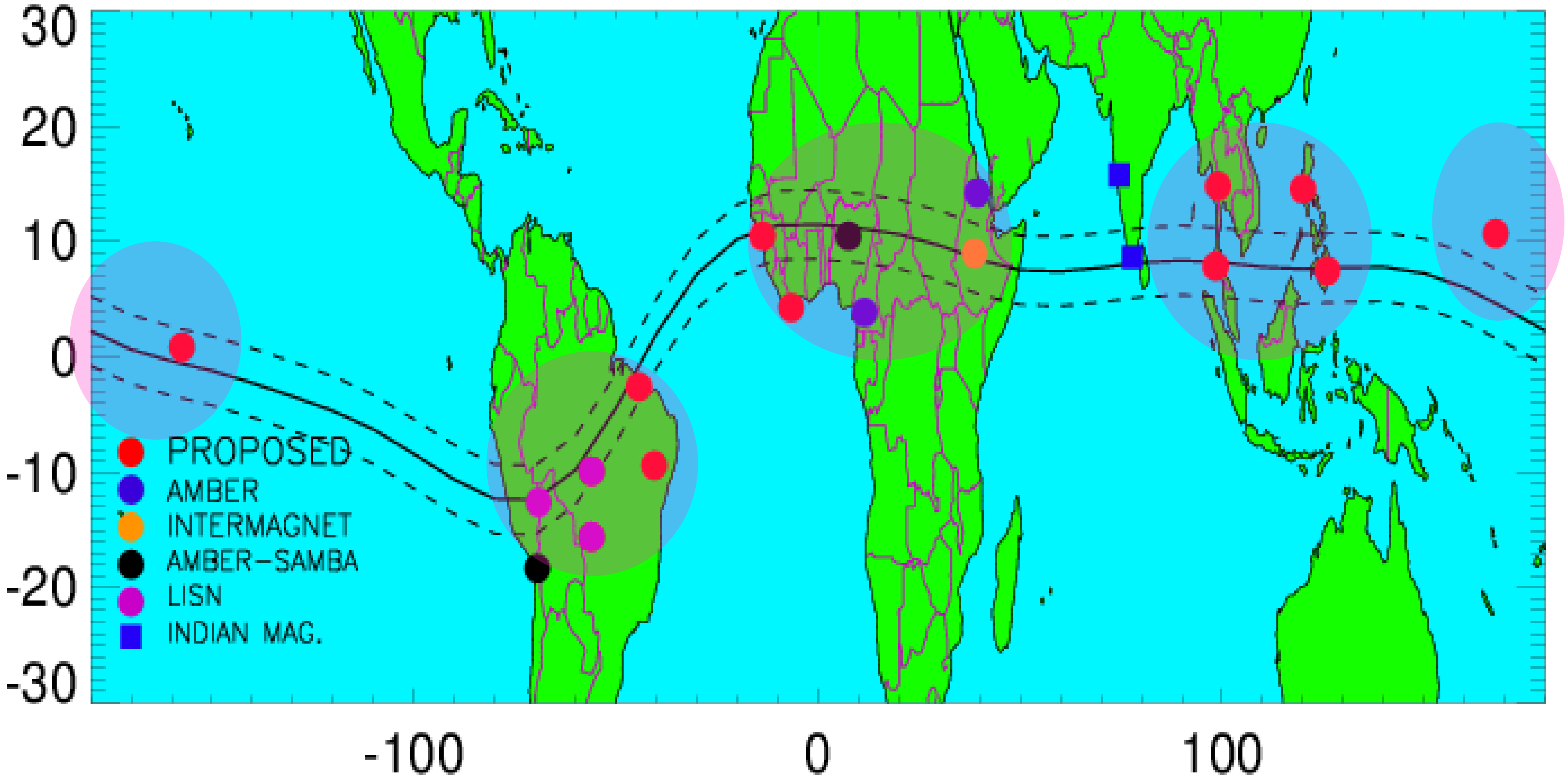
F-region (at 300km) Electron Density day-to-day variability

East Africa | West America





Future direction



✈ Such ground-based magnetometer distribution will allow us to understand the physics behind the longitudinal variation of the EEJ and thus ionospheric irregularities.

Conclusion

- The magnitude and direction of the vertical drift shows significant difference at different longitudinal sectors.
- The ionospheric density also responded differently at different longitudinal sectors, lower density in the east African sector than west American sector.
- The tomographically inverted density is important to monitor the day-to-day variability of the density at different altitudes, as well as for validation of the in-situ density observations onboard LEO satellites.

Thank you!