

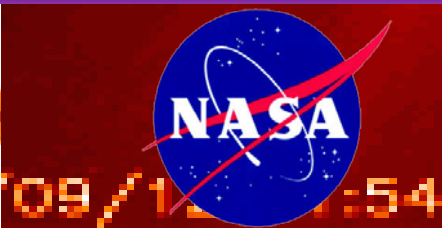
Longitudinal Variability of Equatorial Electrodynamics

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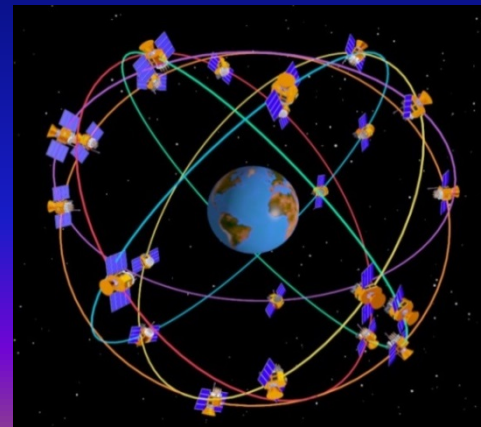
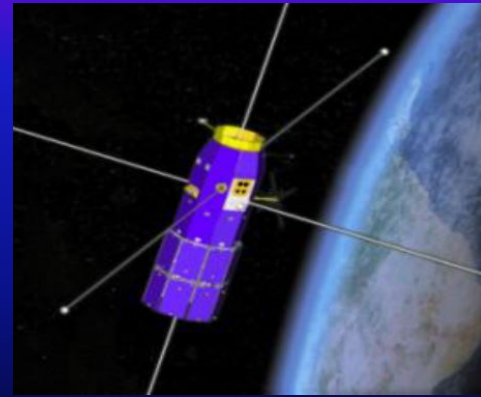
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Special Thanks: M. Magoun, M. Moldwin, E. Zesta, C. Valladares, and
AMBER, SCINDA, & C/NOFS teams



Outline

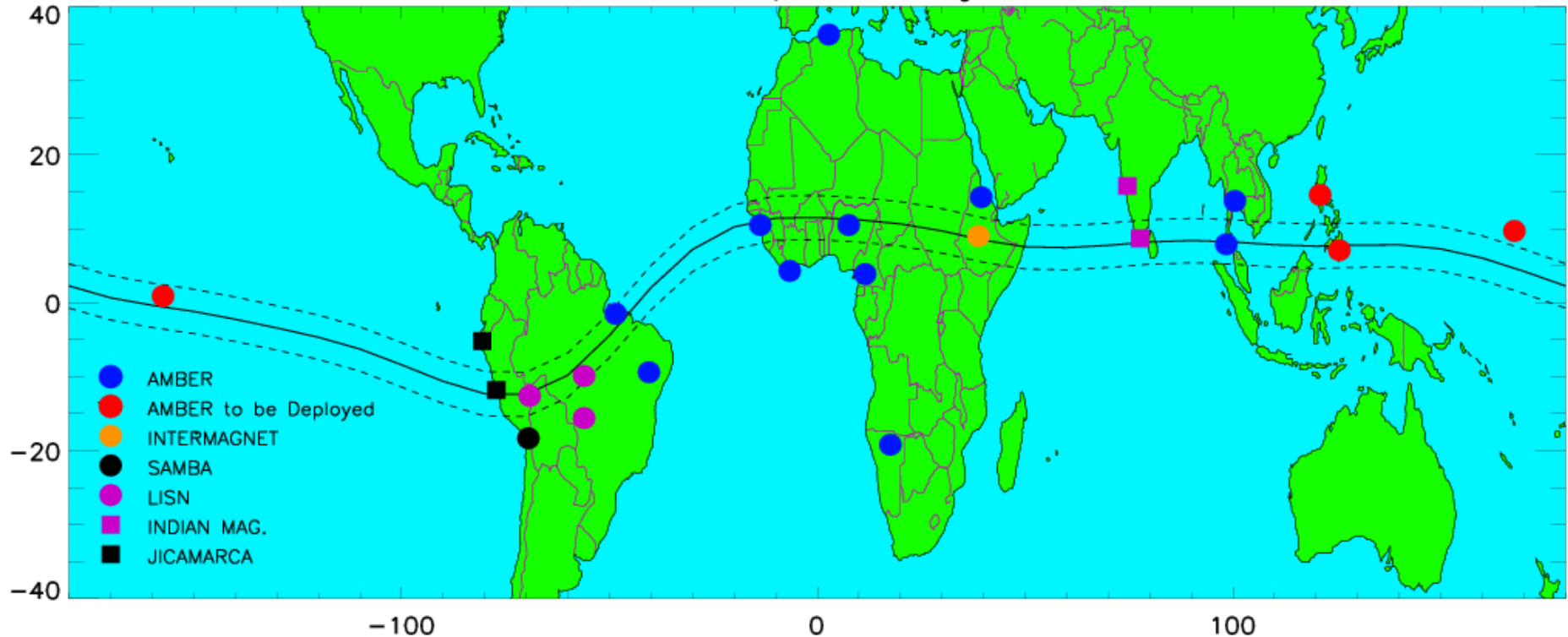
- AMBER instrument deployment status!
- The longitudinal dependence of EEJ/drift, ionospheric density and irregularity structures!
- Post midnight irregularities and its longitudinal dependences!
- Does the magnetospheric origin ULF wave cause ionospheric density modulation?



Status of AMBER network expansions

AMBER (African Meridian B-field Education and Research)

Global AMBER and other Equatorial Magnetometers Network

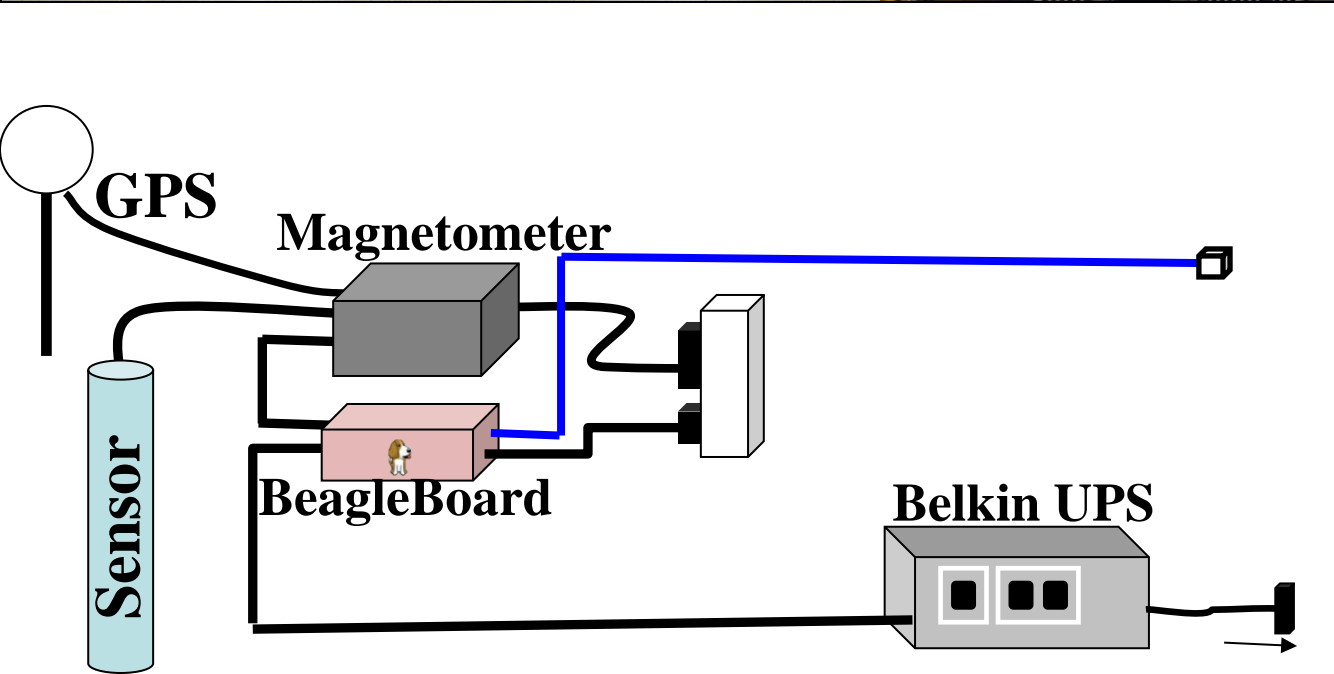


Team members: E. Yizengaw (PI, BC), M. Moldwin (Co-I, UM), E. Zesta (NASA), M. Magoun (BC)

Detail Information About AMBER can be found here:

<https://www2.bc.edu/~kassie/AMBER.html>

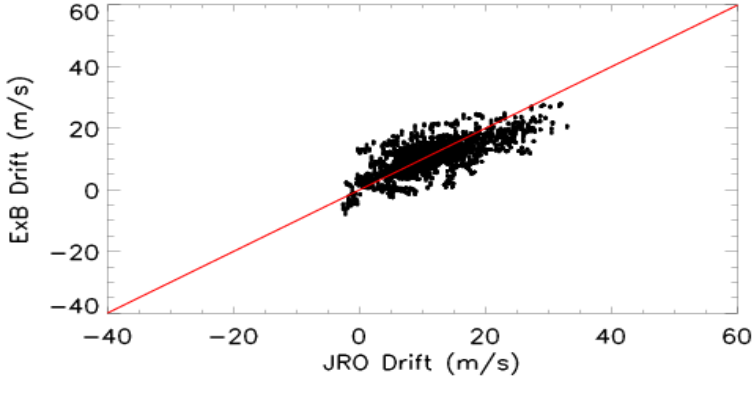
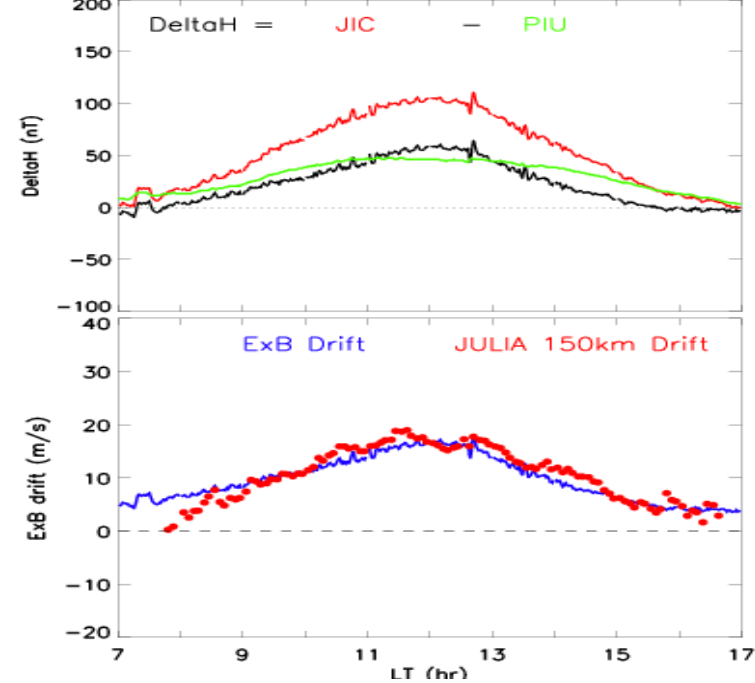
Instrument & its Setup at the site



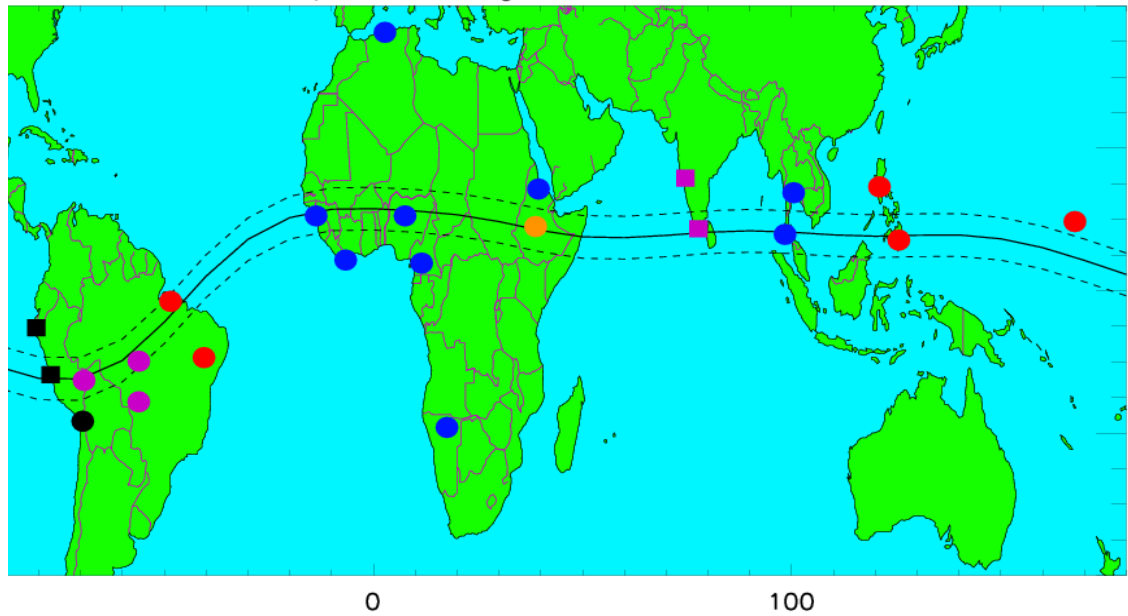
Sensitivity: **0.01 nT**
Resolution: **0.5 sec**

How to estimate drift from Mags. measurements?

ExB drift in West-America on 02 January 2010



AMBER & other Equatorial Magnetometers Network



➡ Magnetometer at off the equator

$$\mathbf{B}_{\text{Obs}} = \mathbf{B}_{\text{main}} + \mathbf{B}_{\text{SQ}} + \mathbf{B}_{\text{FAC}} + \mathbf{B}_{\text{RC}} + \mathbf{B}_{\text{MP}}$$

➡ Magnetometer at the equator

$$\mathbf{B}_{\text{Obs}} = \mathbf{B}_{\text{main}} + \mathbf{B}_{\text{SQ}} + \mathbf{B}_{\text{FAC}} + \mathbf{B}_{\text{RC}} + \mathbf{B}_{\text{EJ}} + \mathbf{B}_{\text{MP}}$$

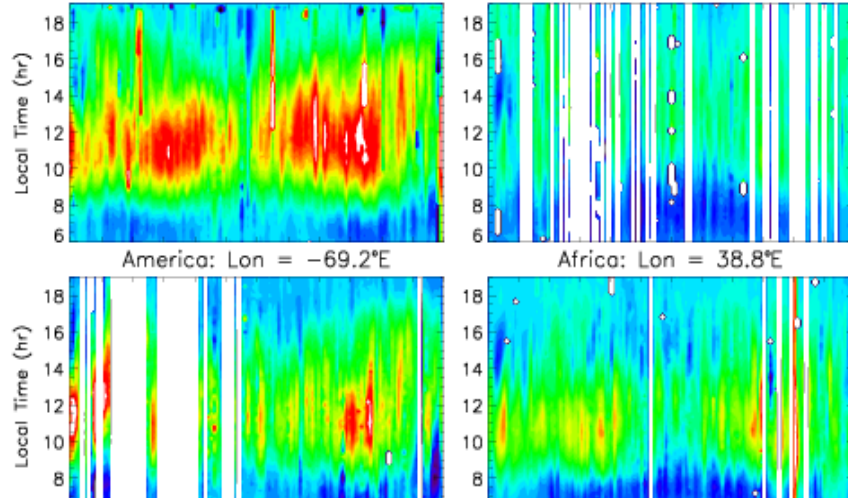
EEJ, which is generated by Hall and Pederson conductivities at the vicinity of geomagnetic equator ($\pm 3^\circ$), is proportional to vertical drifts.

Longitudinal variability of EEJ & drift

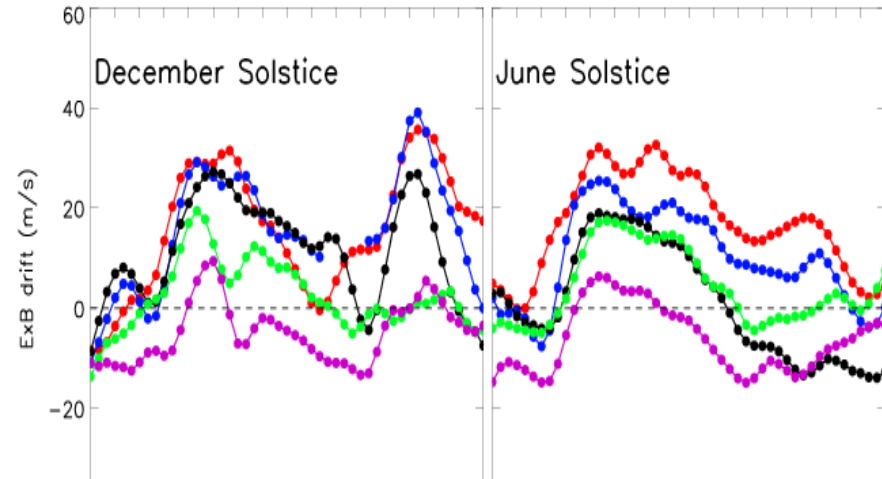
Statistical night side EEJ Longitudinal Dependence (2011–2014)

America: Lon = -76.9°E

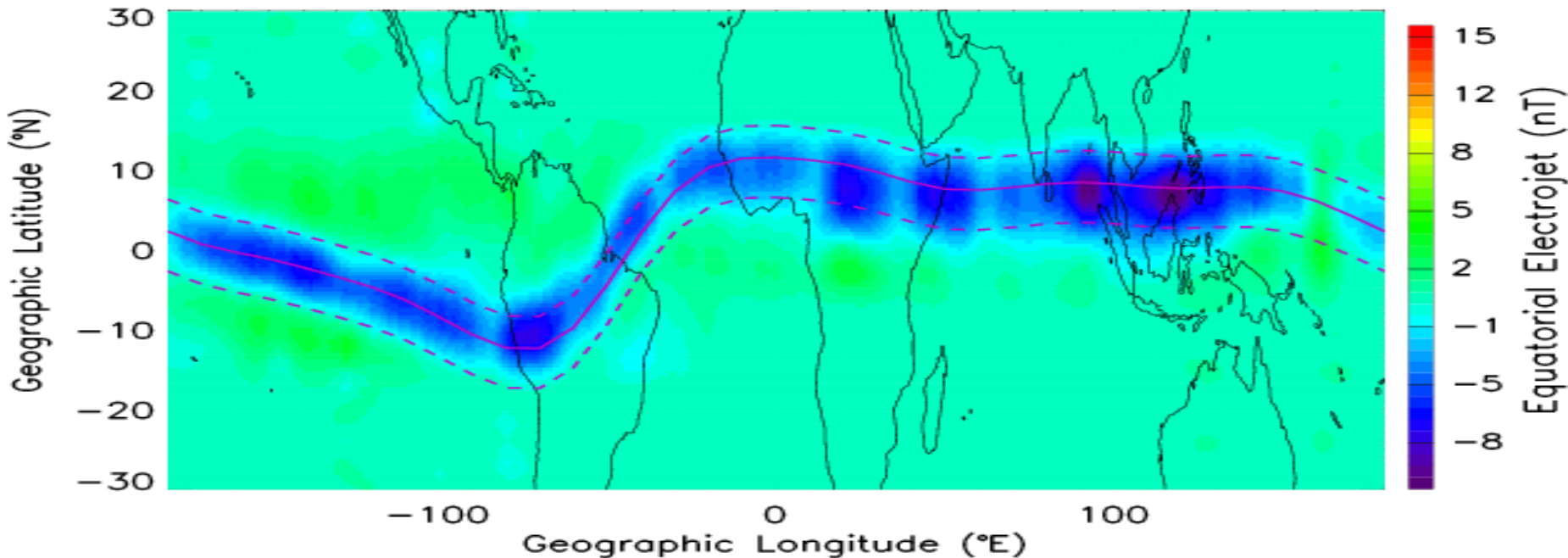
Africa: Lon = 7.6°E



-76.9°E -69.2°E -56.1°E 7.6°E 38.8°E

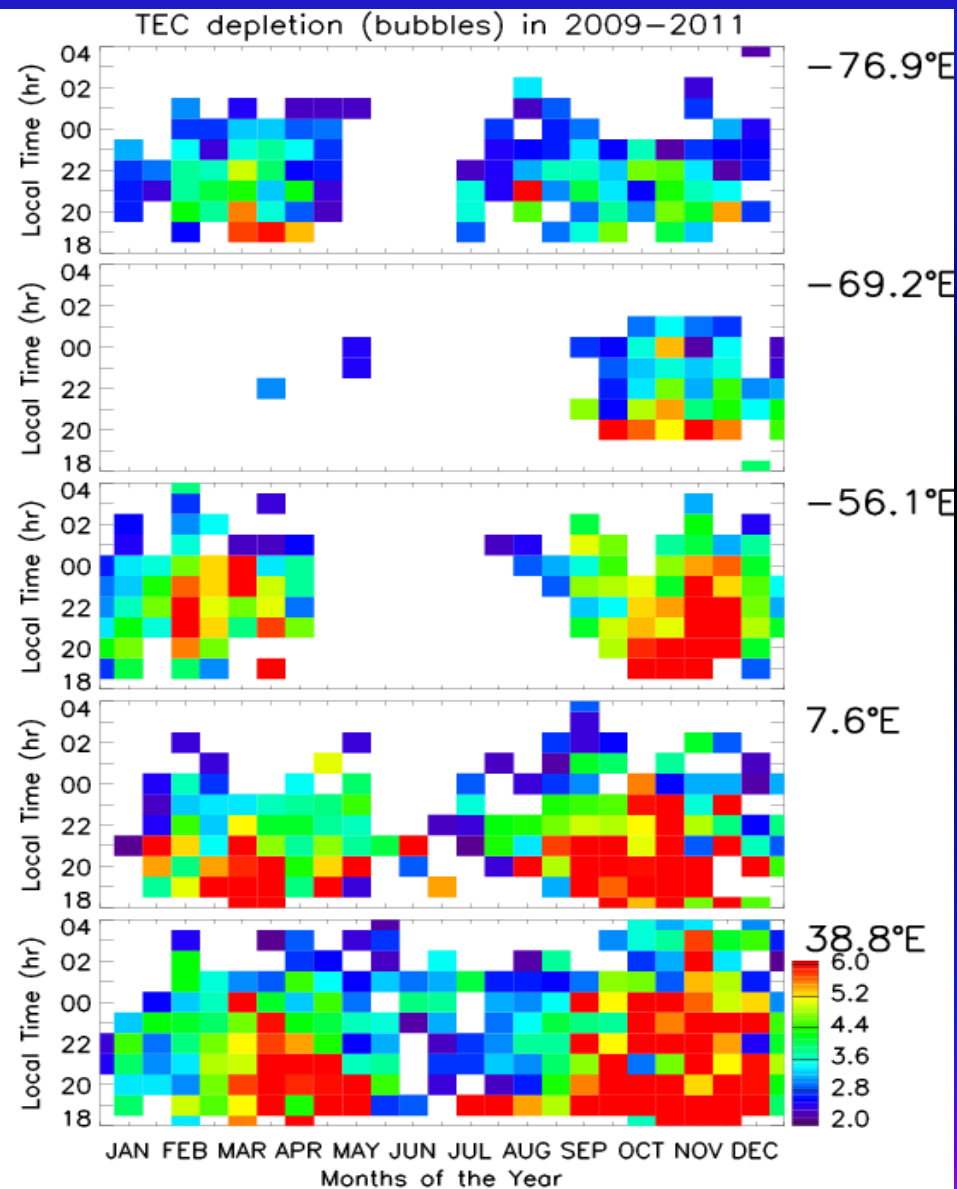


EEJ from SWARM-A,B&C in January–February 2014
from 10:00 to 11:00 LT

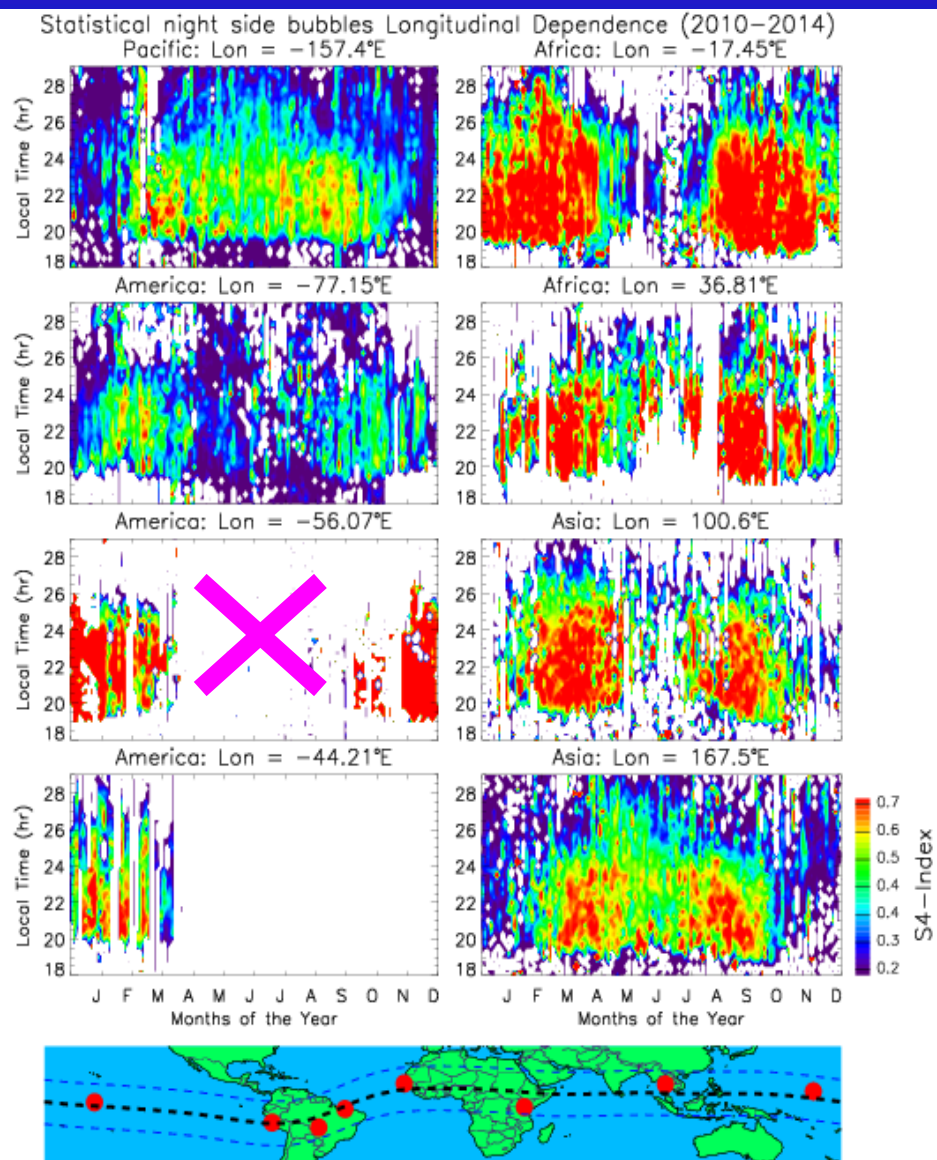


Does ESF has the same longitudinal dependence?

Bubbles from GPS TEC (2009-2012)



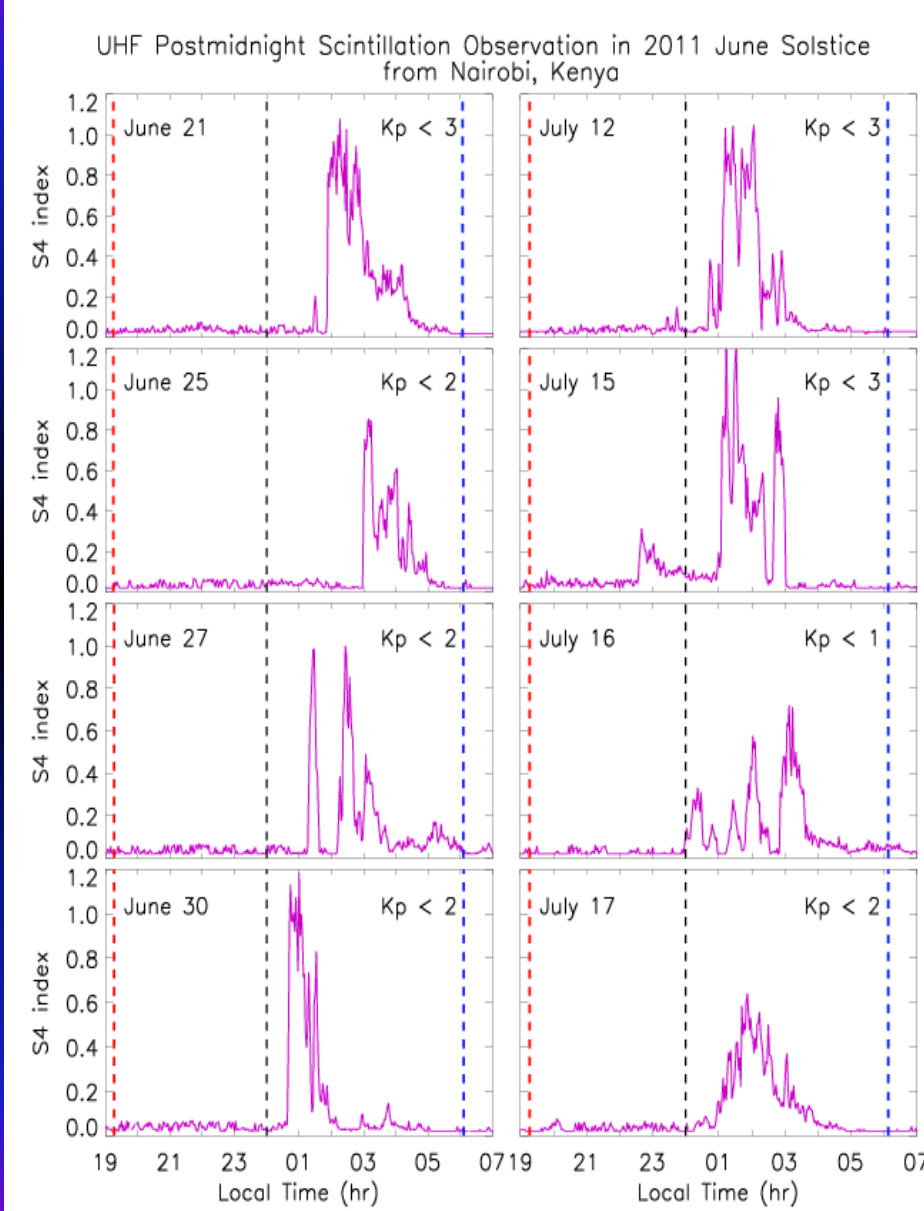
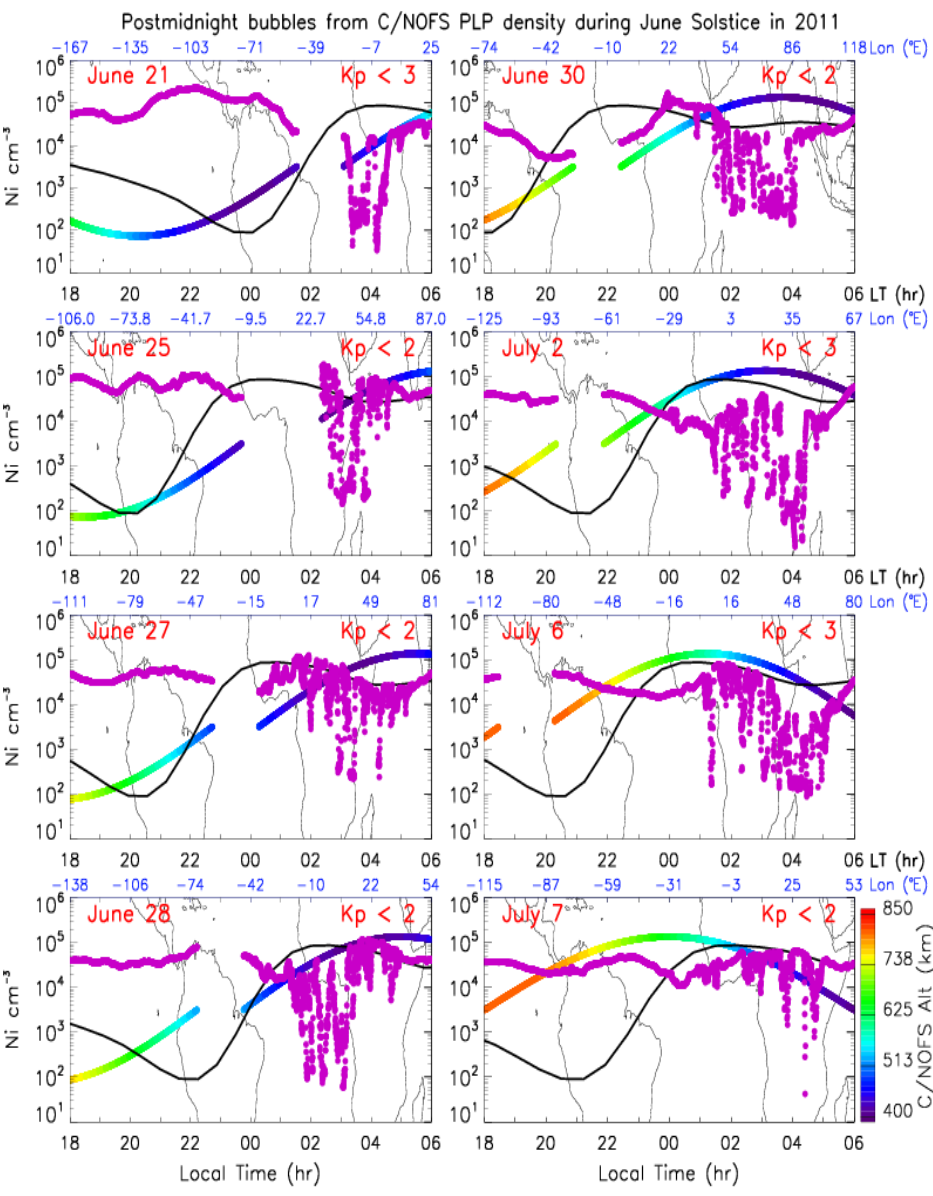
Scintillation from UHF data (2010-2014)



Post-midnight irregularities and its longitudinal dependences

2000/09/12 11:54

Is the ionosphere calm during post-midnight?



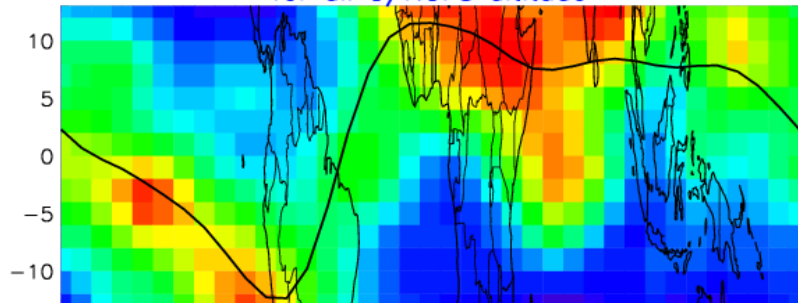
Yizengaw et al., GRL, 2013

How about long term observation?

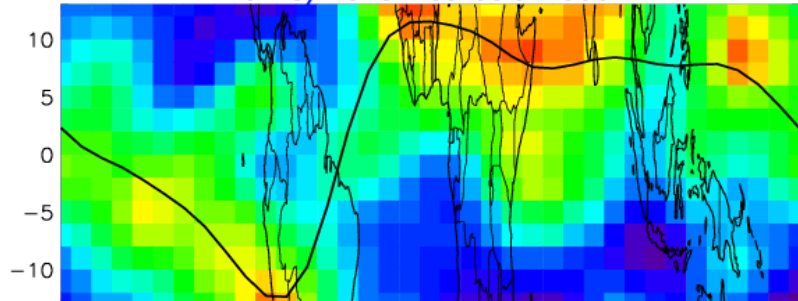
Post-midnight bubbles longitudinal dependence

Dawn sector (0000–0600 LT) C/NOFS bubble occurrence during 2009–2012

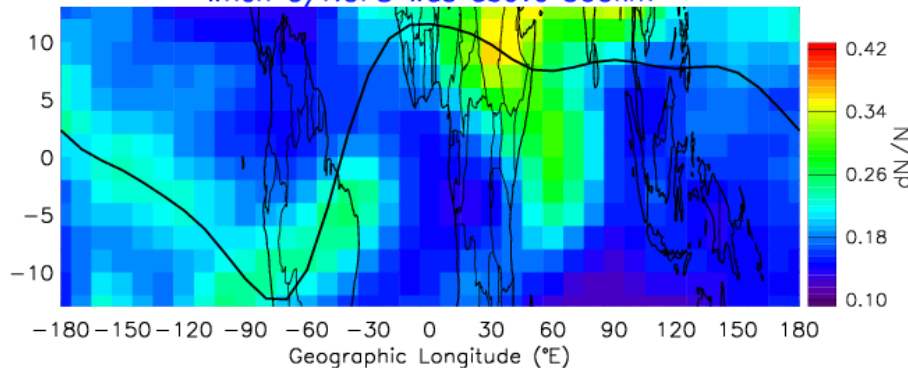
for all C/NOFS altitude



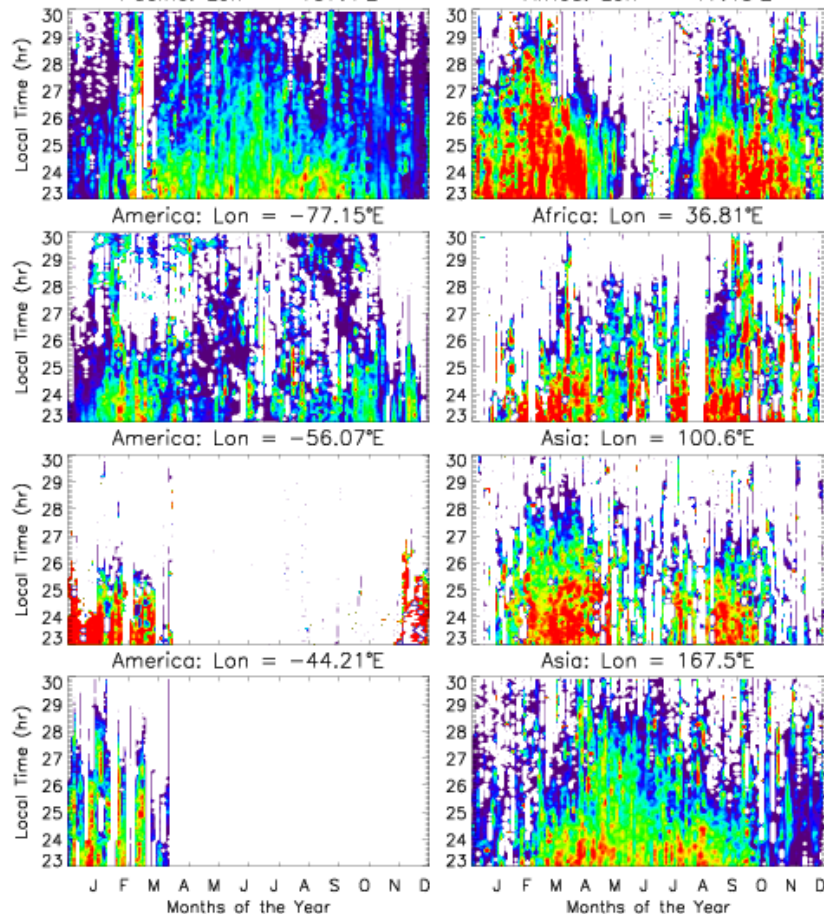
when C/NOFS was below 500km



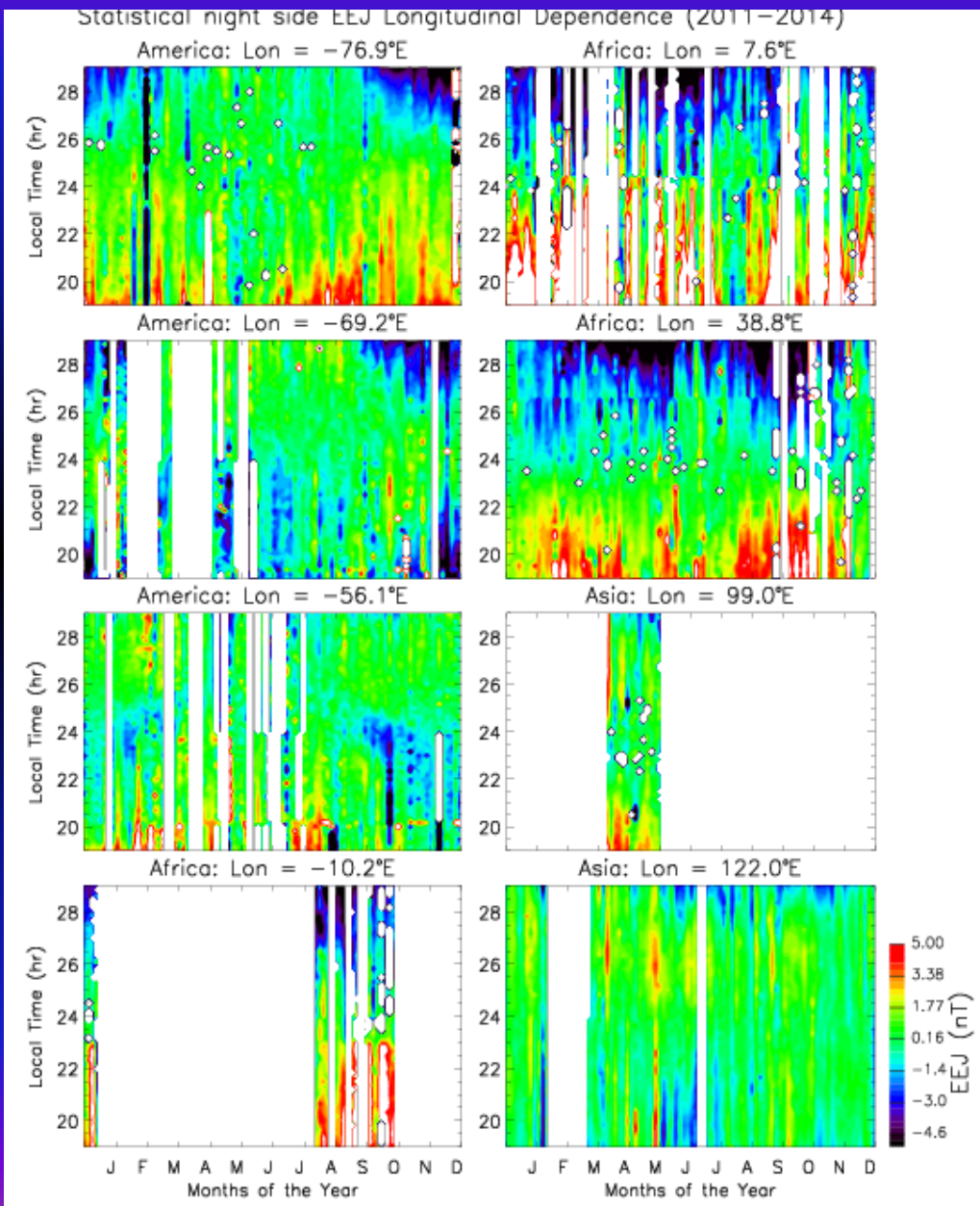
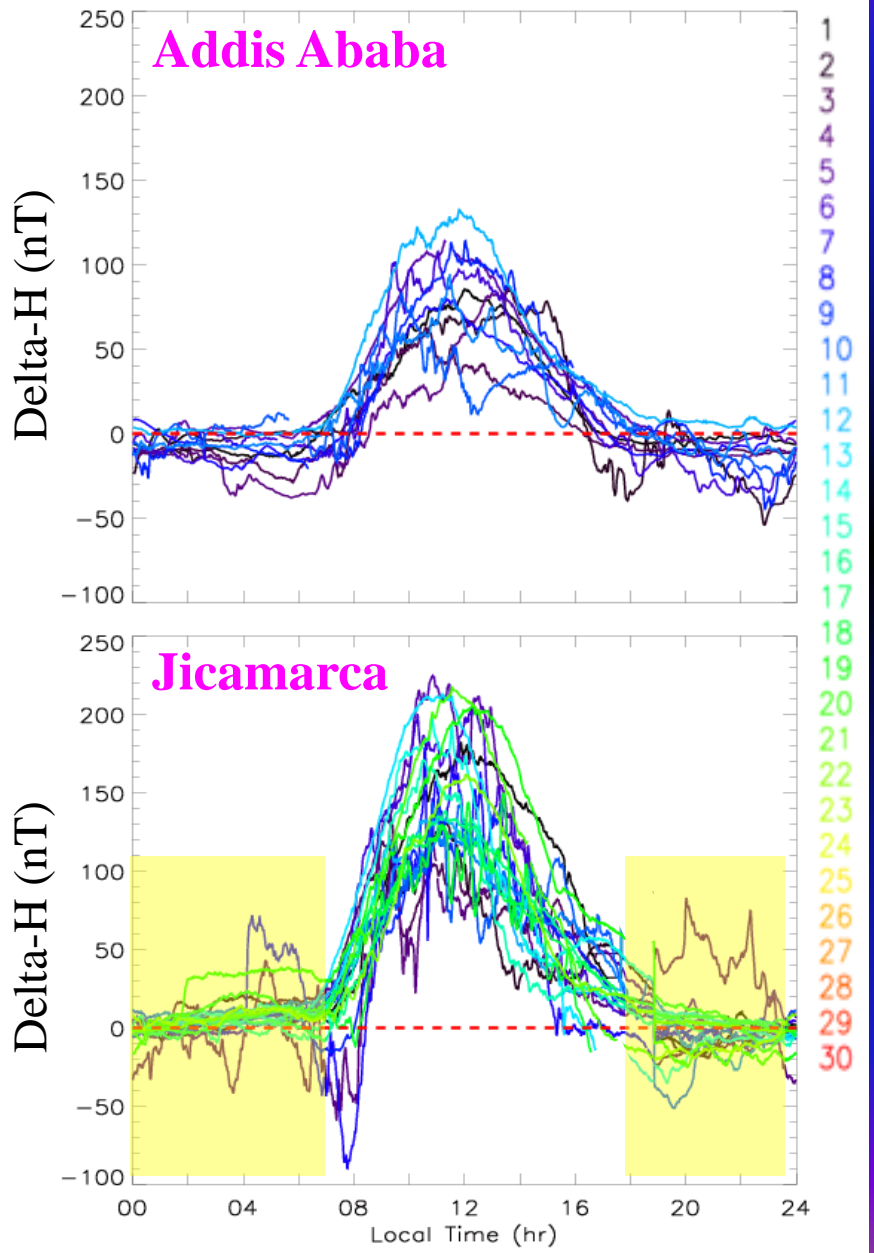
when C/NOFS was above 500km




Statistical post-midnight bubbles Longitudinal Dependence (2010–2014)



Does Mag data useful for post-midnight bubbles?





**Does the magnetospheric
origin ULF wave cause
ionospheric density
modulation?**

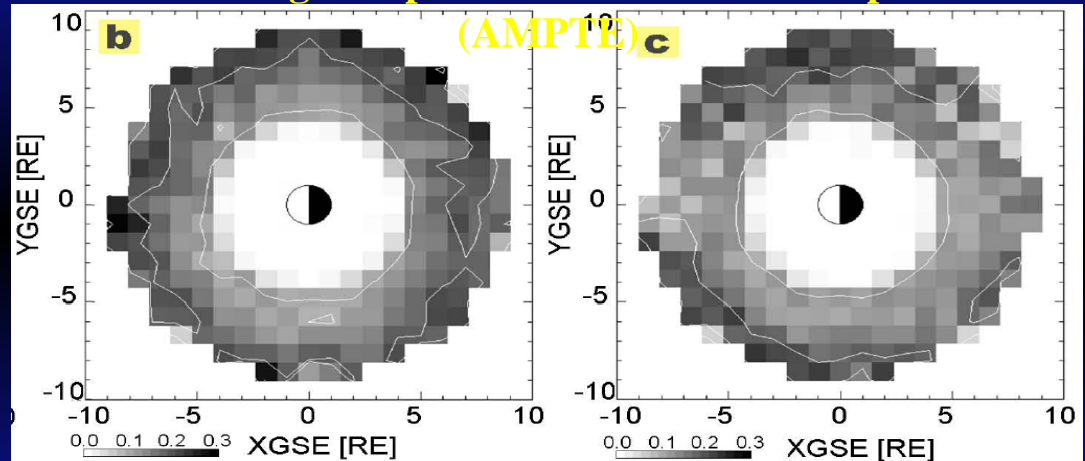
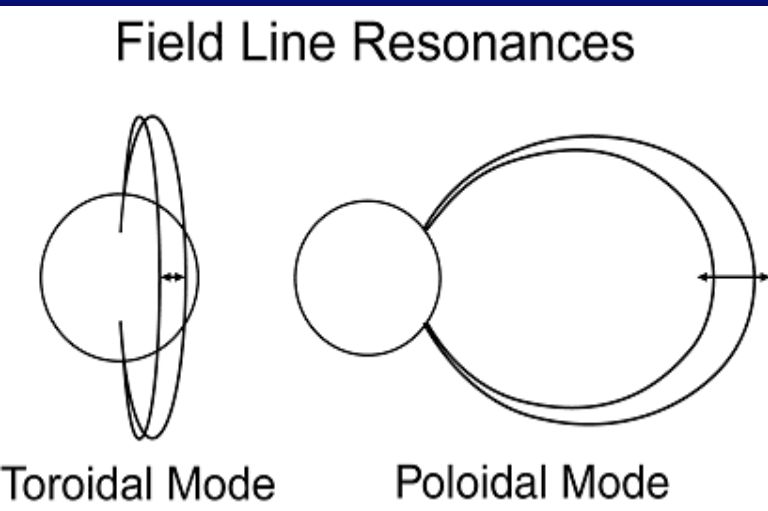
2000/09/12 11:54



ULF wave generation mechanisms

- The periodic SW dynamic pressure oscillations slowly alter the size of the magnetospheric cavity, causing the generation of poloidal ULF wave.
- The change in SW azimuthal flow direction (usually accompanying shocks) can excite Kelvin-Helmholtz (KH) instabilities at the magnetopause, which in turn causes the generation of Toroidal mode ULF wave.

Active Magnetospheric Particle Tracer Explorers

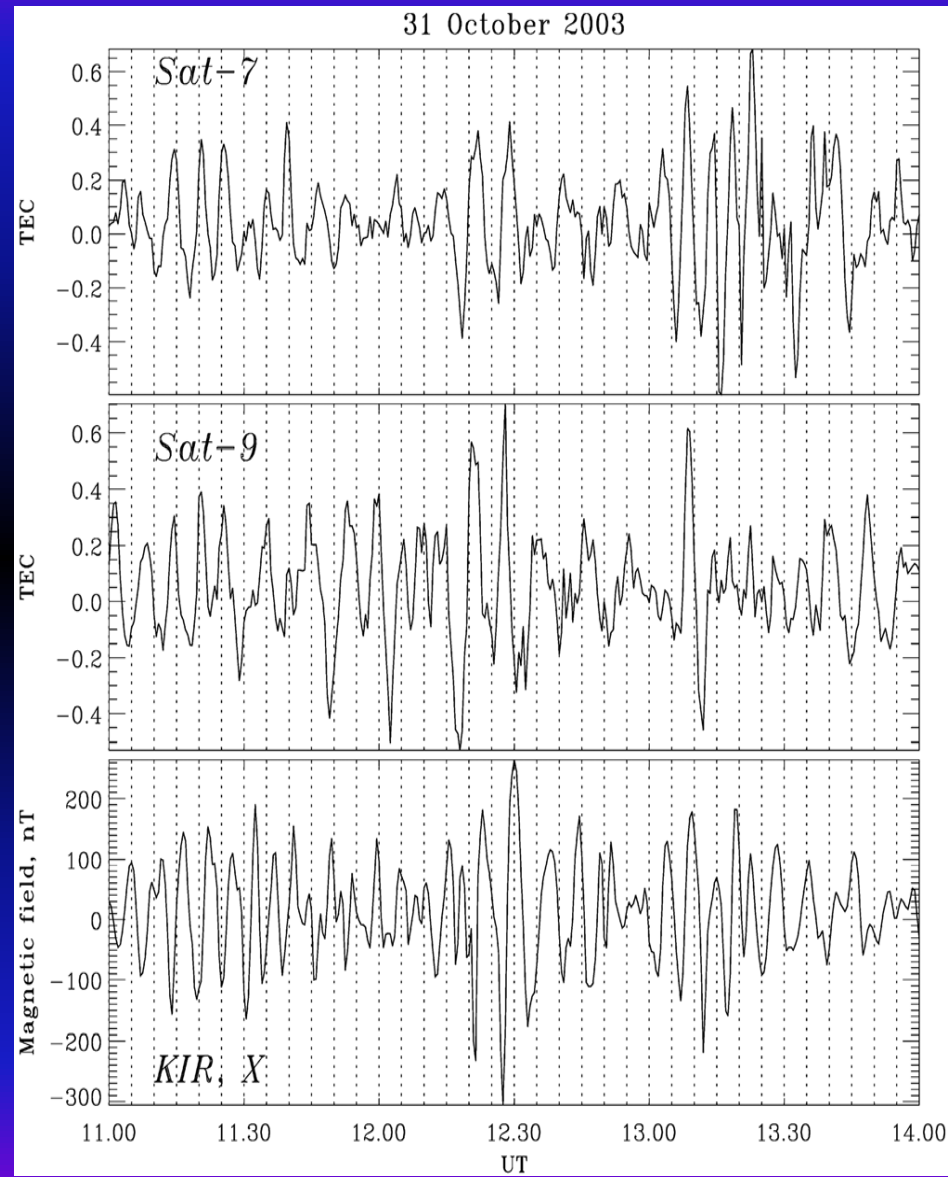
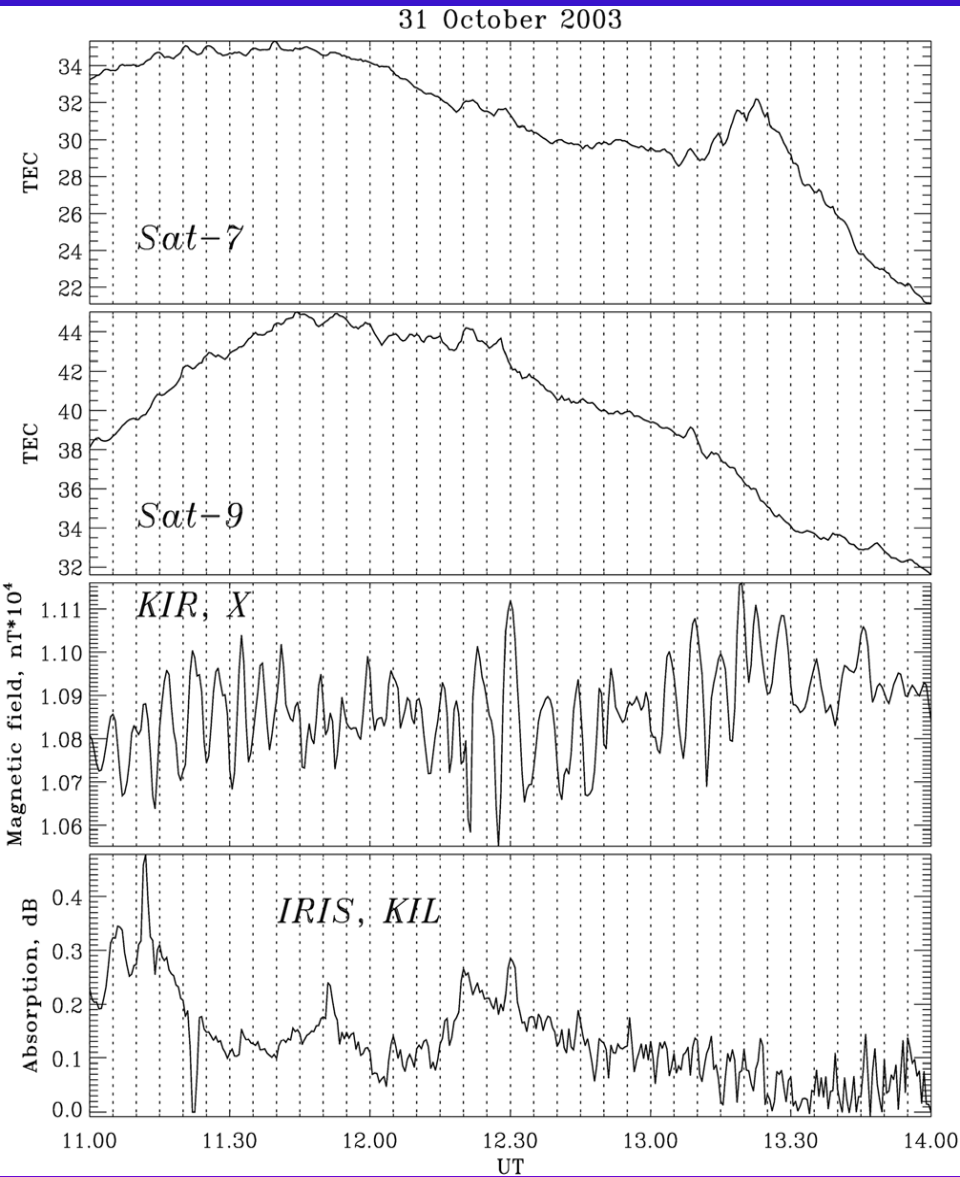


Poloidal Pc5 & Toroidal Pc5

wave occurrence rates [Agapitov & Cheremnykh, 2013]

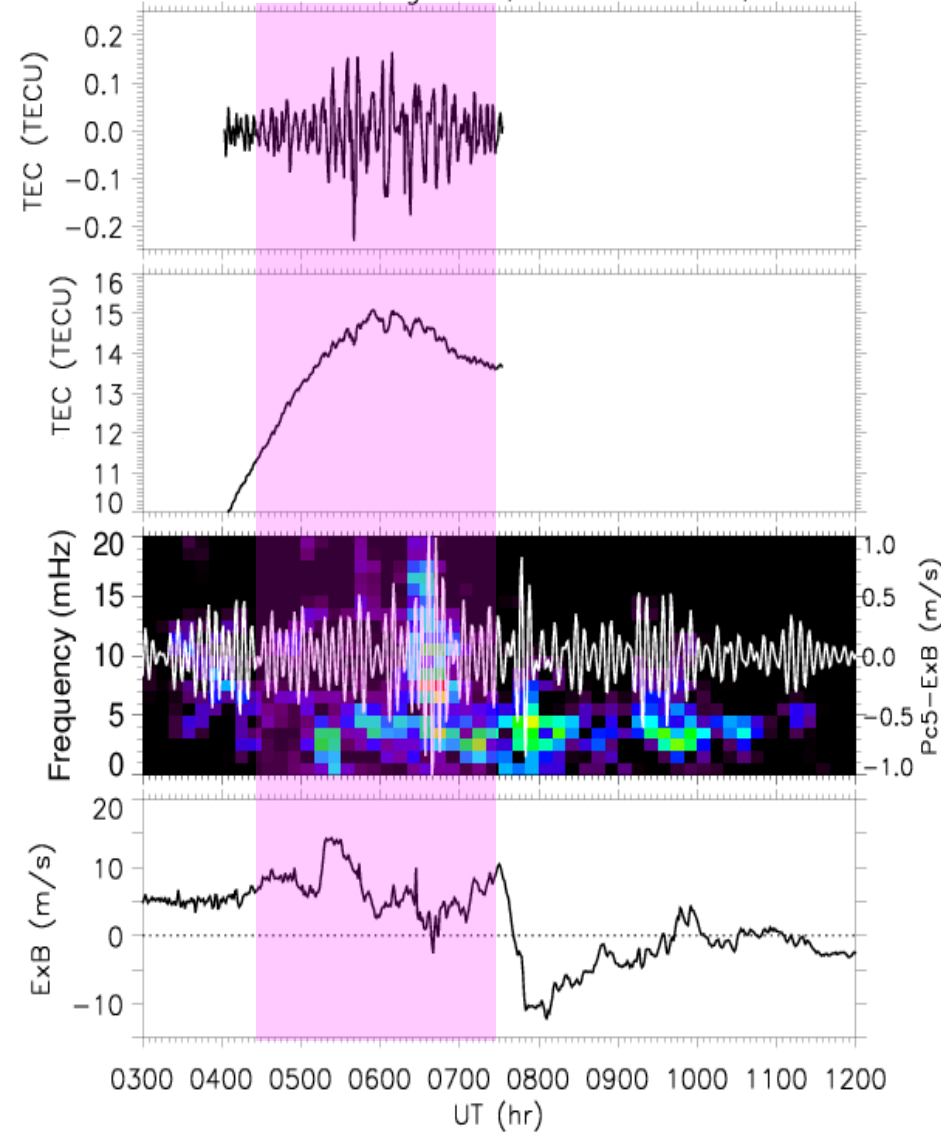
The ULF wave fields drive perturbations in the ionosphere, like FLR on radio sounders at low [Menket *al.*, *GRL*, 2007] and high latitudes [Mthembu *et al.*, *AG*, 2009], electric field oscillations [Cosgrove *et al.*, *AG*, 2010], GPS TEC modulation [Yizengaw *et al.*, 2013; Pilipenko *et al.*, *JGR*, 2014], generation of kilometer scale waves in the ionosphere [Cosgrove *et al.*, *AG*, 2010], etc

TEC modulation by ULF waves

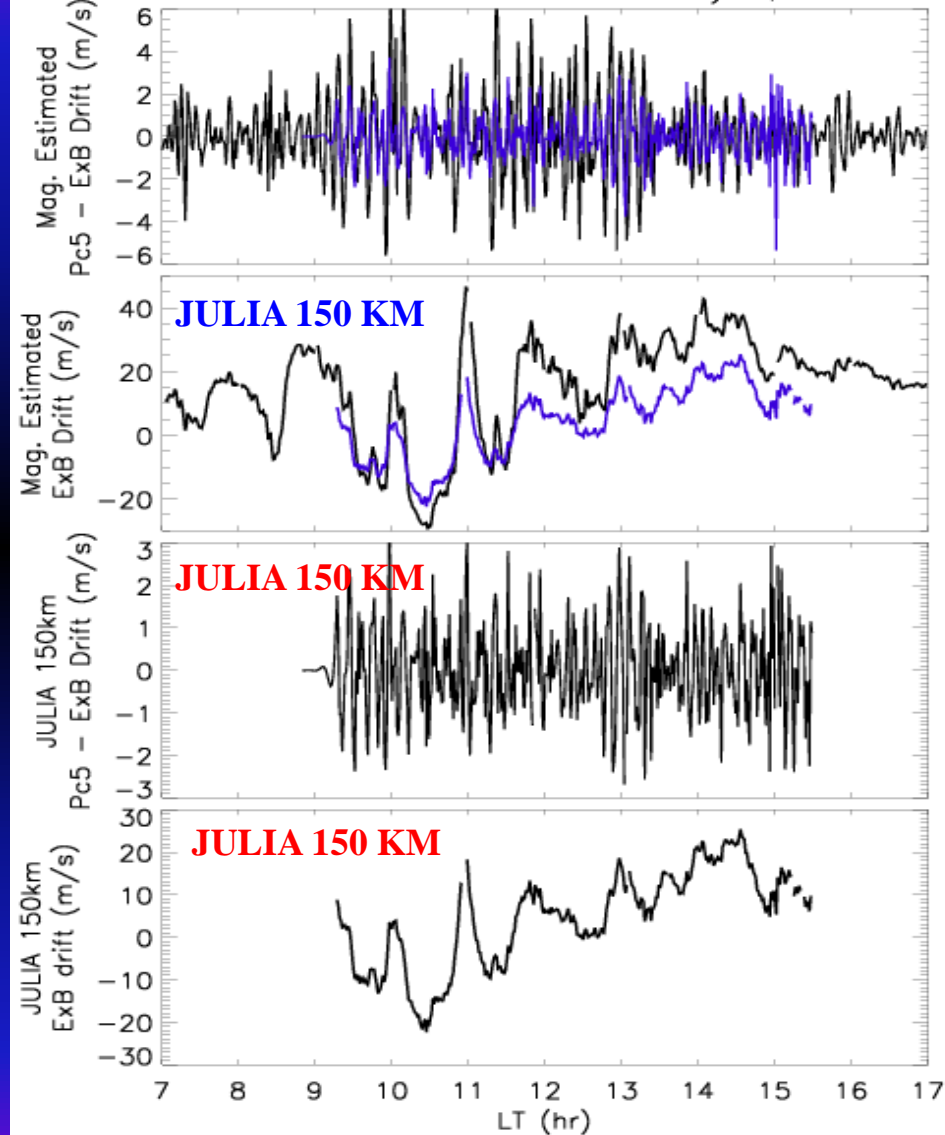


ULF wave related EEJ fluctuation

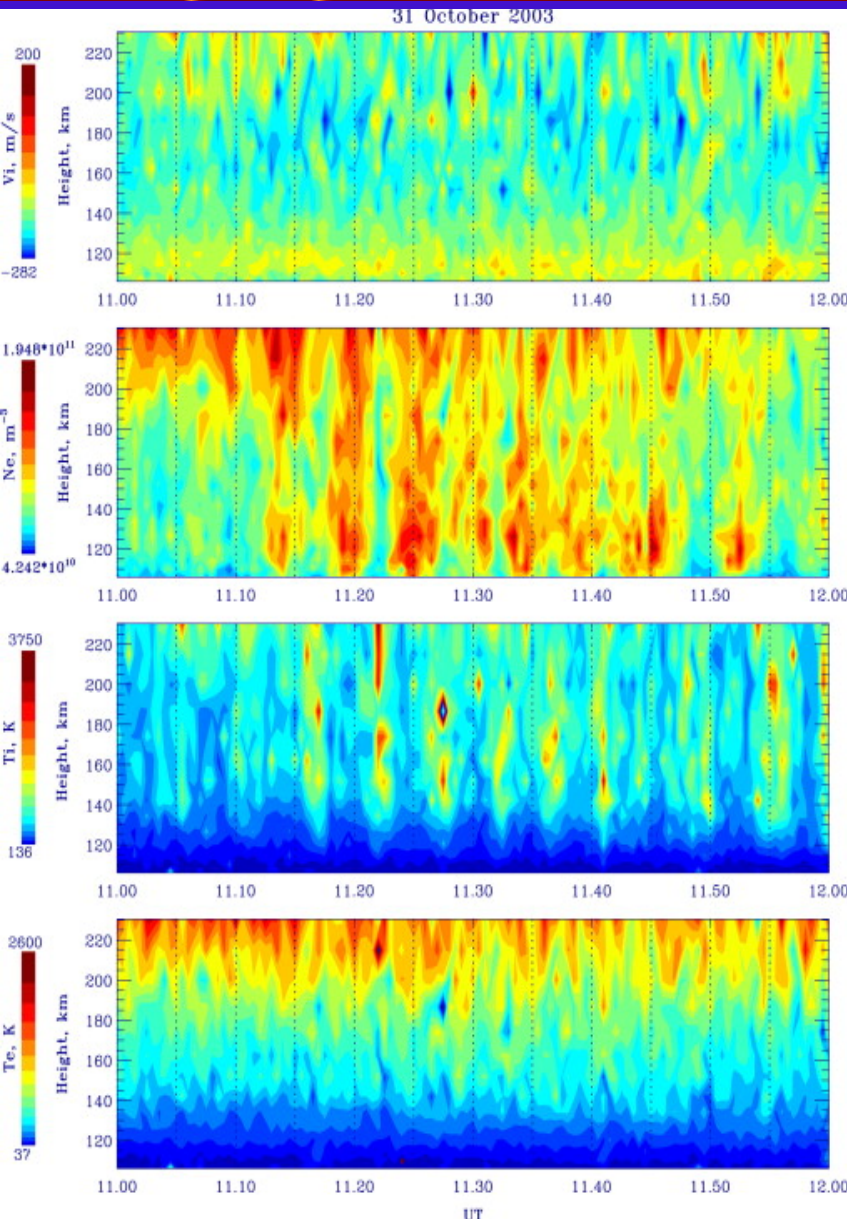
Filtered TEC on August 9, 2008 at MALI, PRN 20



Filtered drift velocities on May 2, 2010



How ULF wave modulate density?

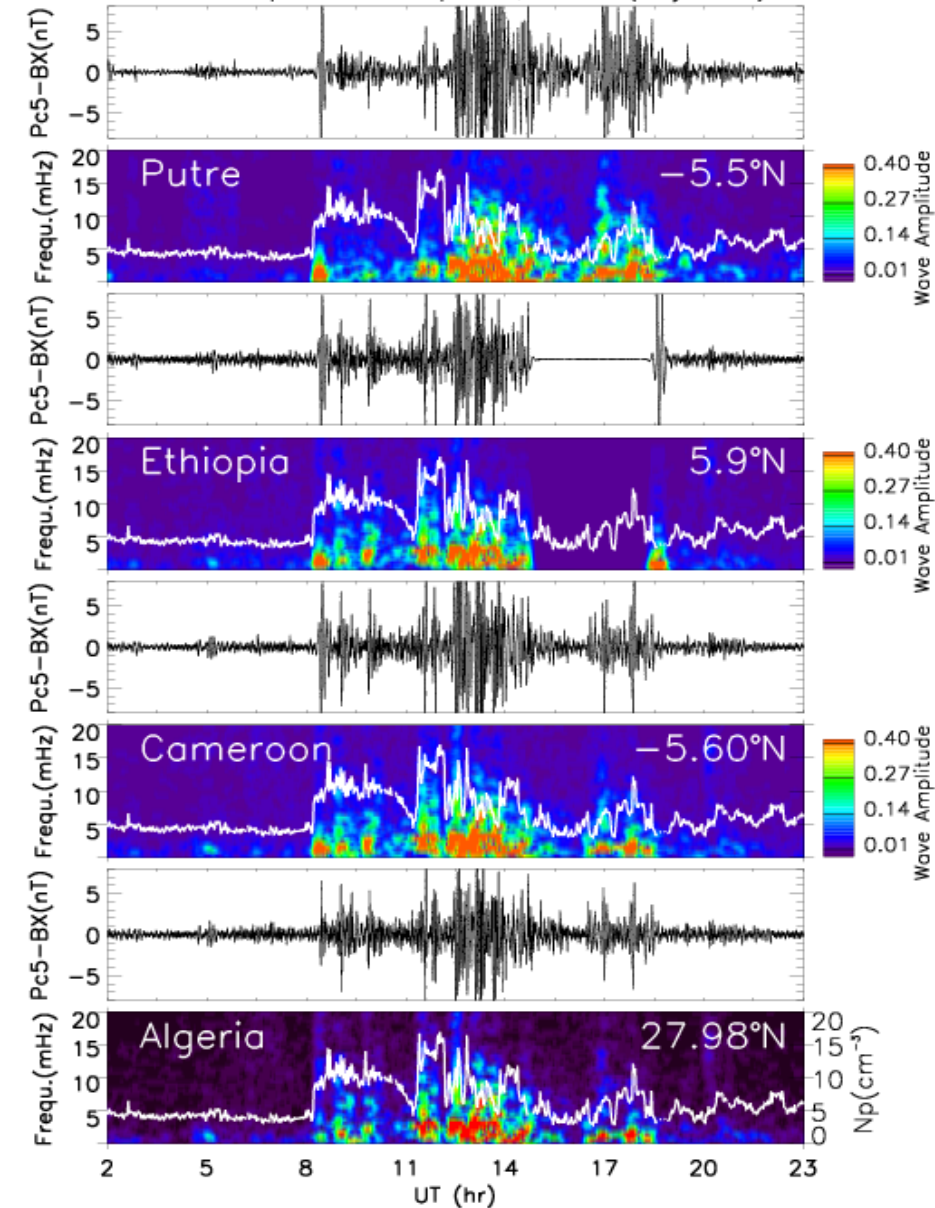


ULF waves in the Pc5 range are very much intense enough to generate fluctuation in the ion temperature.

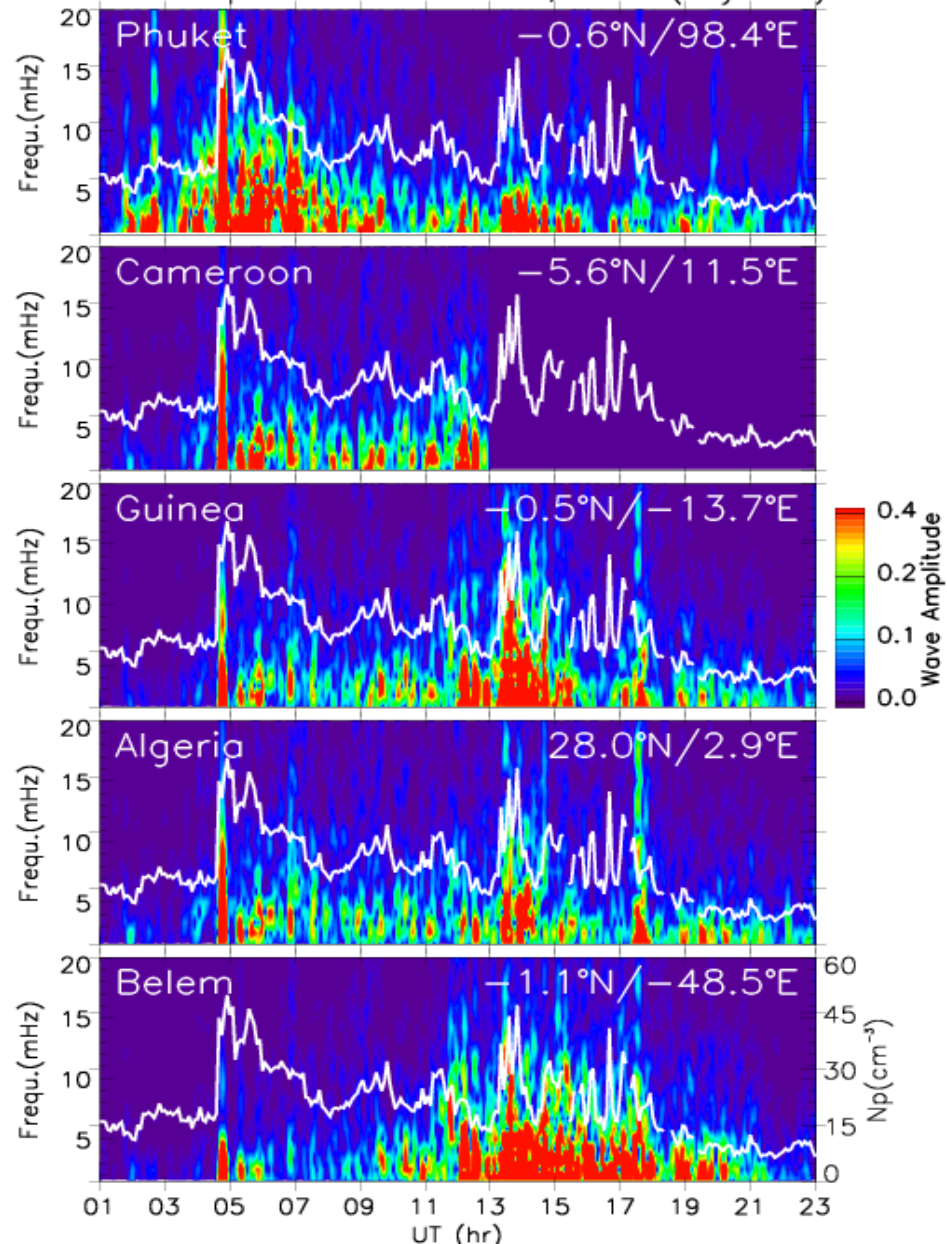
For example; any typical Pc5 wave of $f = 3mHz$ at $\Delta\beta = 0.1mHz \rightarrow \Delta T_i = 300K$, may cause $\Delta N/N \sim 0.8\%$ fluctuation (Pilipenko *et al.*, *JGR*, 2014).

Longitude independence of ULF wave

Fourier spectra on April 5, 2010 (day 095)



Fourier spectra on March 17, 2015 (day 076)

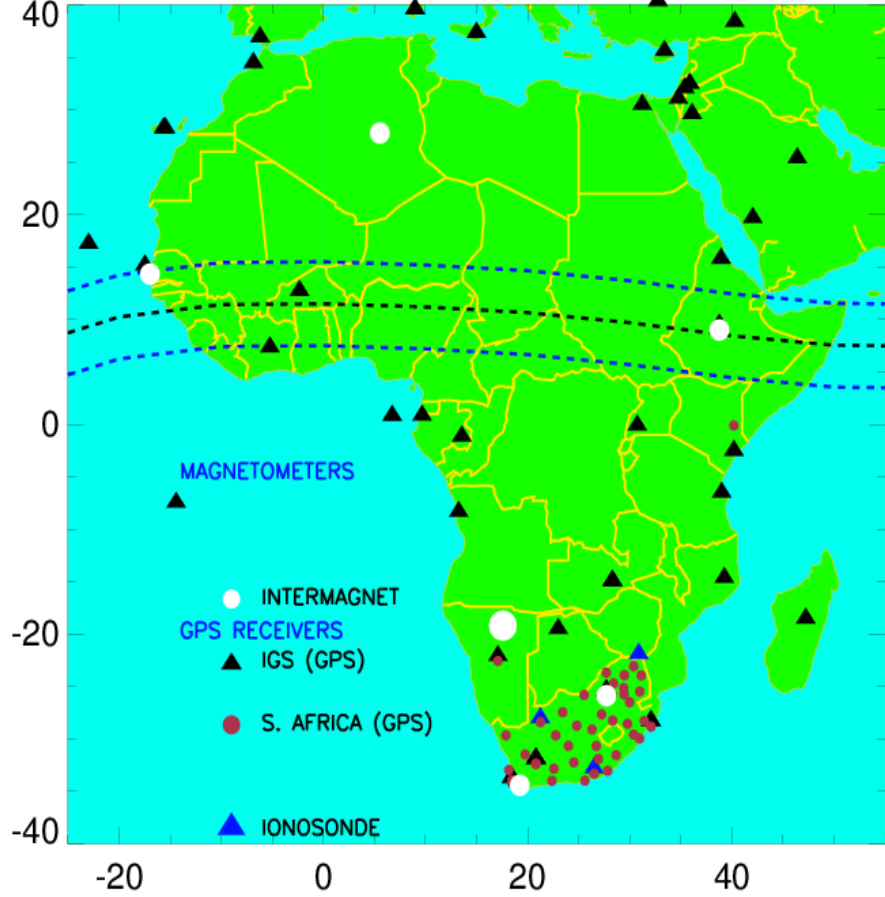


Summary with lots of open questions!

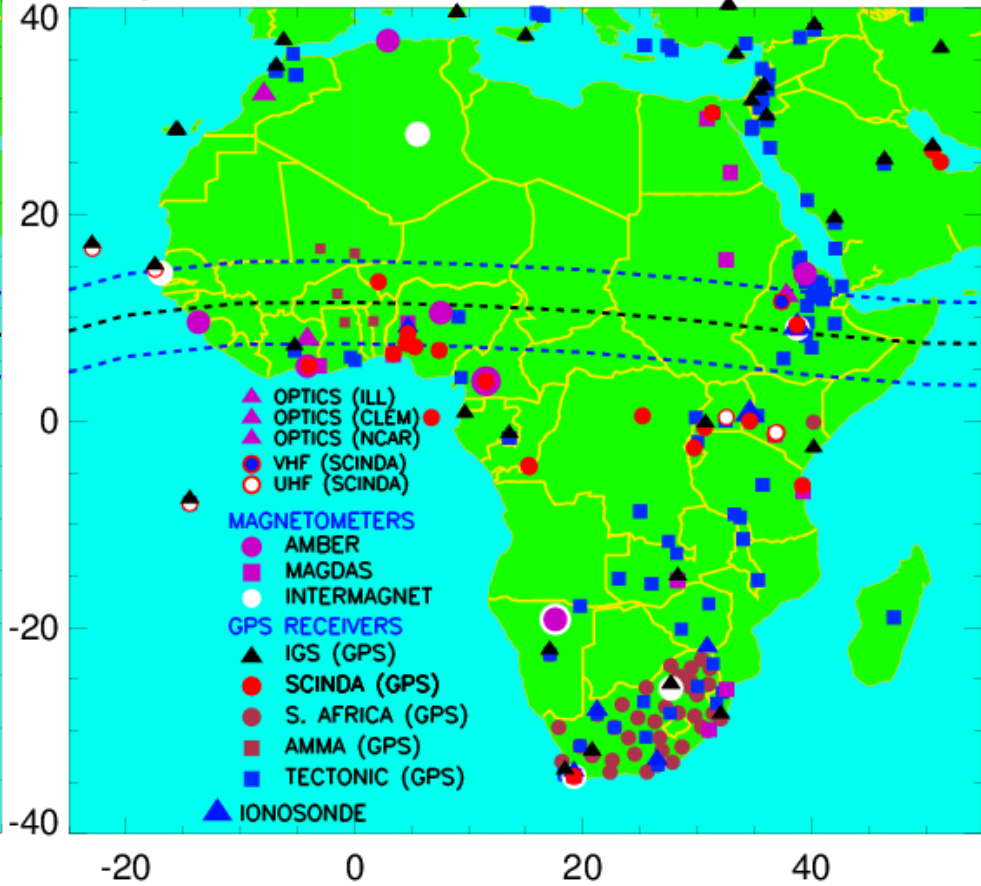
- The magnitude & direction of the vertical drift (both dayside and evening sector) show significant longitudinal differences, stronger in the American and Asian than African sectors, what cause this longitudinal differences? Is it due to tides or something else?
- Both ground- and space-based observations show clear longitudinal and seasonal variability of bubbles/irregularities structures, stronger in the African sector, which is opposite to the vertical drift longitudinal variability trend. If not the drift that cause the longitudinal bubbles distribution difference, then what could it be? Would it be the neutral winds that cause the long lasting bubbles in Africa?
- Both ground- and space-based observations show clear longitudinal and seasonal variability of the discrete post-midnight bubbles, stronger in the African sectors. The question is what cause such strong discrete post-midnight bubbles?
- It has been unambiguously proven that the Pc5 ULF waves can penetrate to the our atmosphere and drive perturbations in the ionosphere, modulating the magnetic and electric fields and density. The question is, can ULF wave produce strong density fluctuation that may cause at least HF propagation?

General Instrumentation in Africa

Space Science Instruments in Africa: 5 years ago



Space Science Instruments in Africa: Now



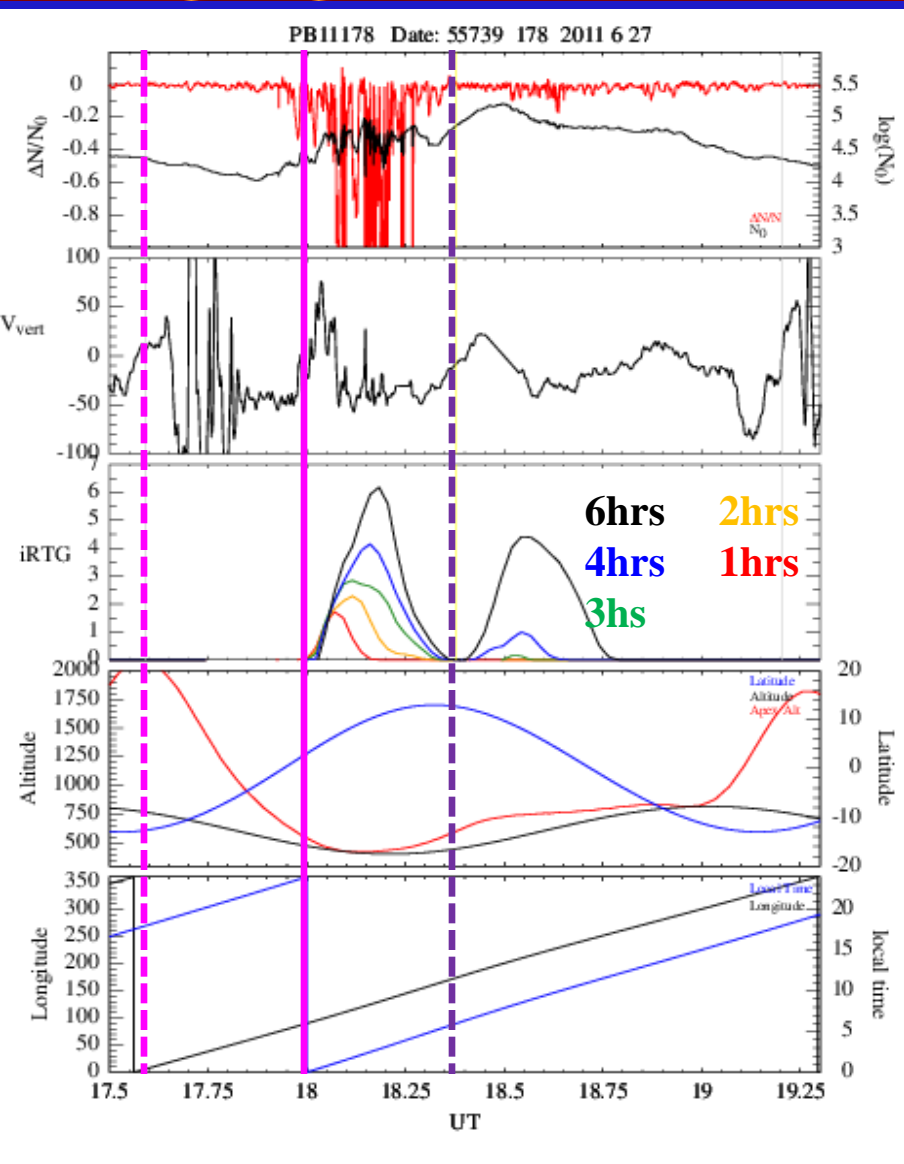
Seven Years ago

This Now!

Thank you!

What cause these quiet time post-midnight bubbles?

Is there RT instability during this local time?



Yizengaw et al., GRL, 2013

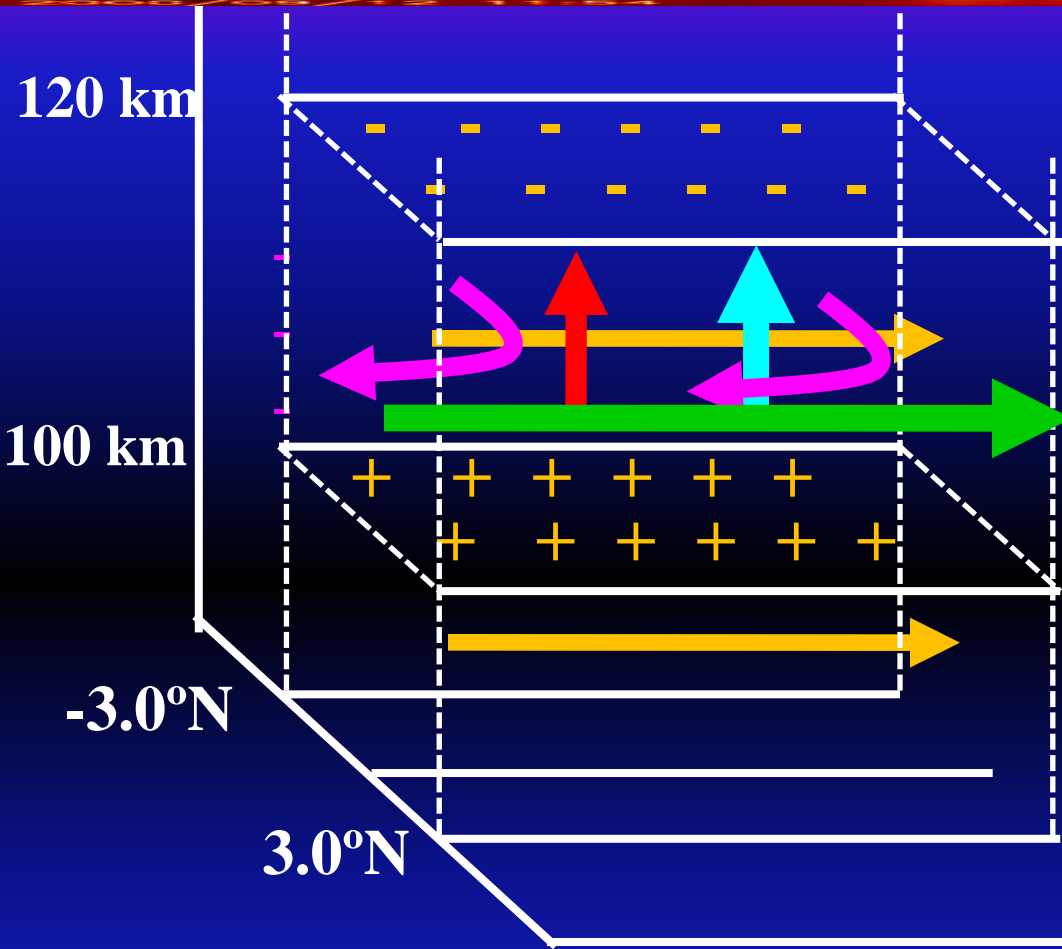
PBMOD run RT instability
growth rate

What cause the vertical drift
velocity to be reversed at this local
time sector and during quiet
periods?

Sporadic E-layer presence! If so
what is the primary mechanism
for the formation of Es layer?

- ♣ Charged dust particles due to strong gusty winds,
 - ♣ meteors that can cause ionization, and
- polarized electric field associated with the MSTID

Equatorial Electrojet (EEJ) formation



→ The solar-driven neutral wind results Sq current system and then **east-west polarization E-field** in the E-region.

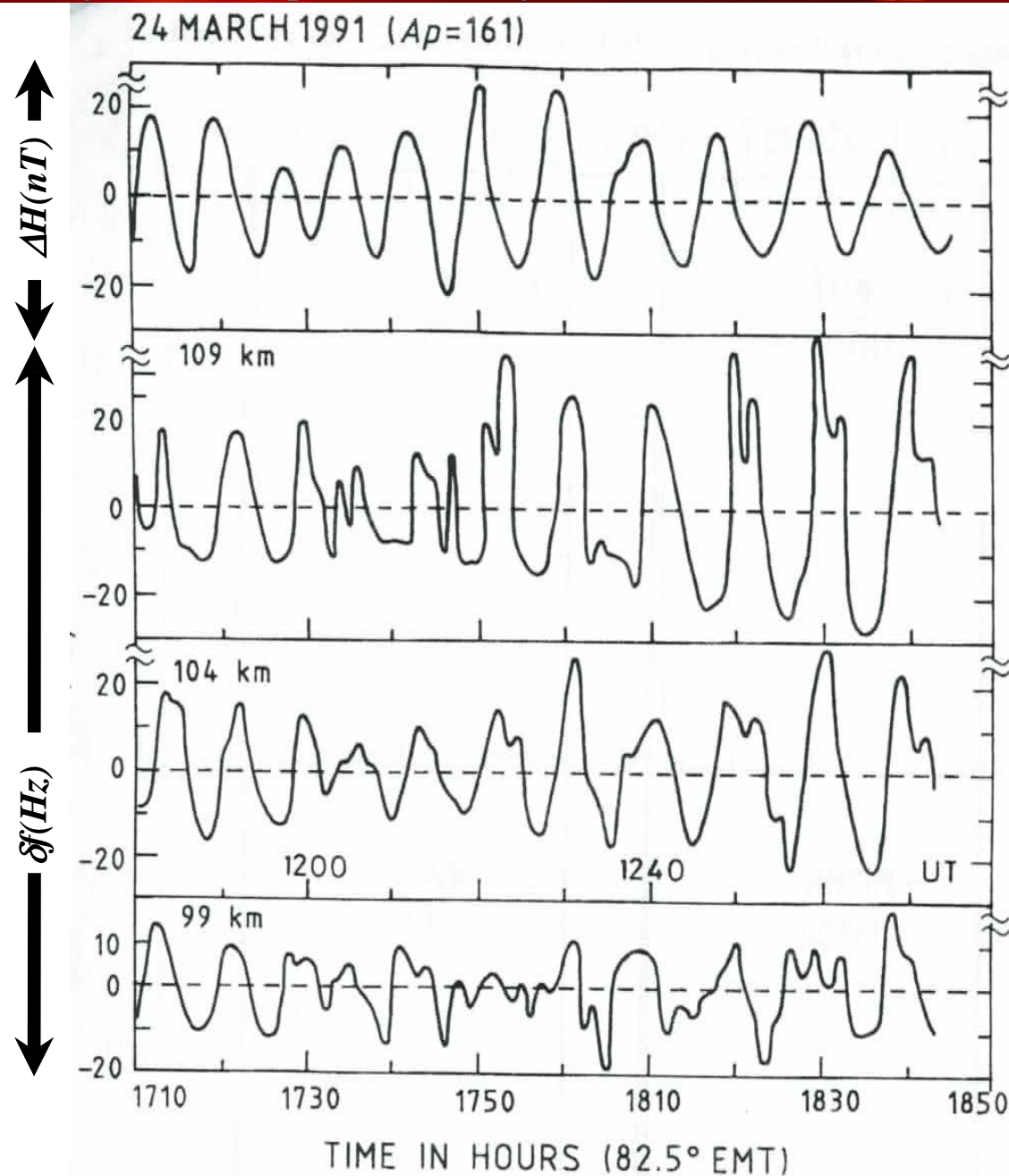
→ At the magnetic dip equator, the resulting **upward $E \times B$ drift** moves **negative** charge at the top and a **positive** at the bottom of the E-region.

→ 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 $\pm 3.0^\circ$ of the magnetic equator, which is called the Equatorial Electrojet (EEJ)

ULF wave and density irregularity correlation

Time series of Doppler frequency variation at three different altitudes, observed by 54.95 MHz coherent backscatter radar!

(Reddy et al., AG, 1994)



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

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

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

V_{dr} :- *Vertical drift*

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

g :- *Gravity*

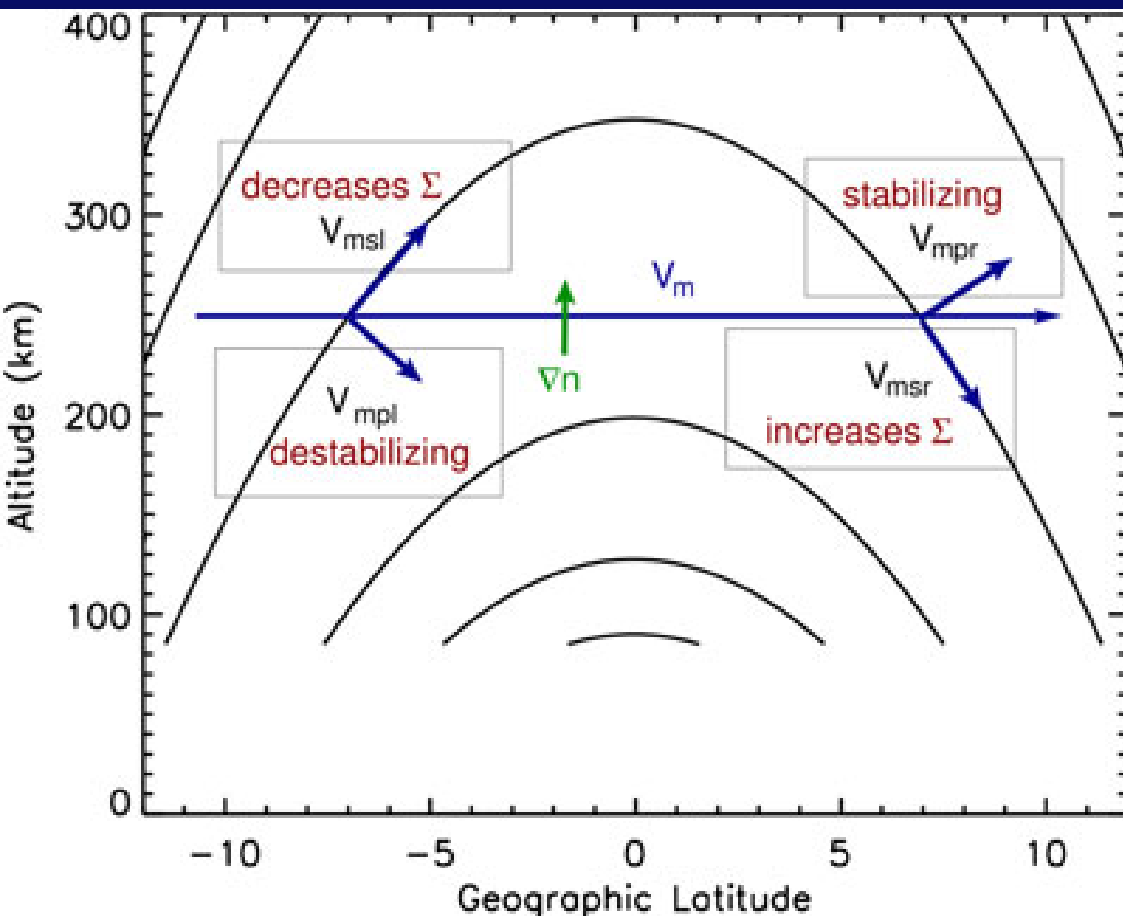
v_{eff} :- *Collision frequency*

N_e :- *Electron density*

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

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