Long-wave propagation in the lower thermosphere and its response to the ionospheric F layer over Brazilian equatorial region

By
SOLOMON OTOO LOMOTEY
INPE
26th April 2018

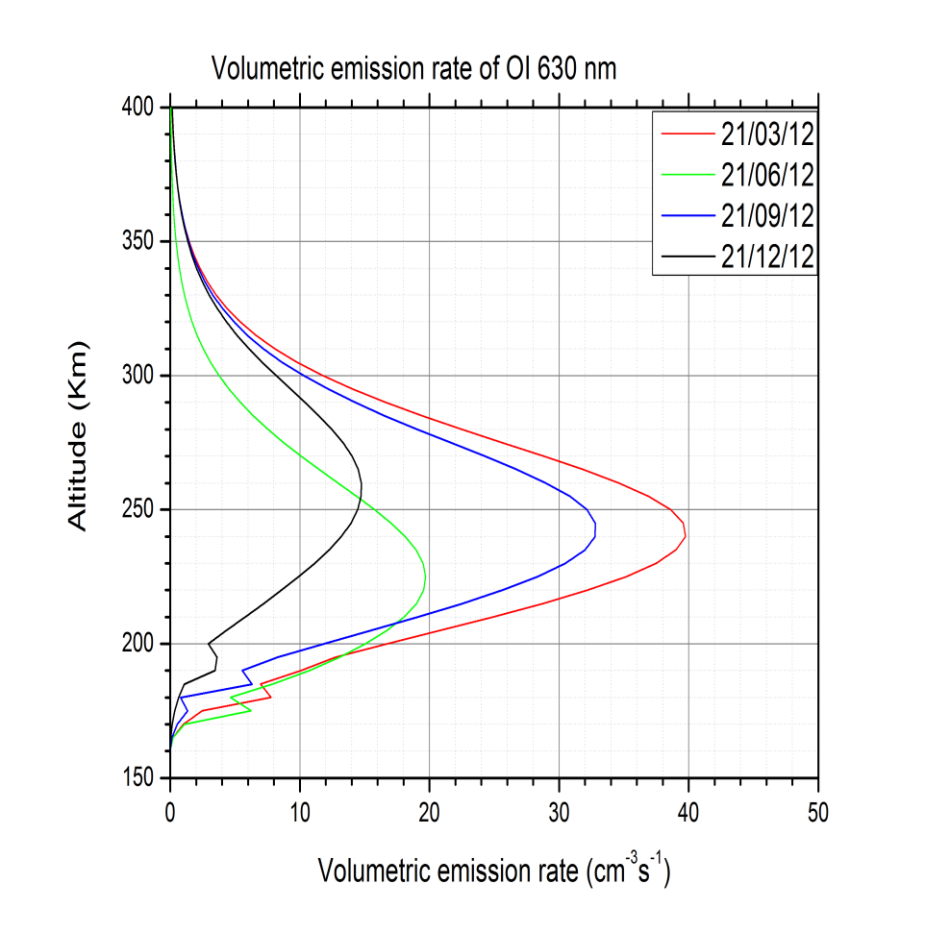
R. A. Buriti, I. Paulino, A. F. Medeiros, J. J. Makela, J. W. Meriwhether, D. Barros, C.M. Wrasse, H. Takahashi.

Affiliations: R.A.Buriti – UFCG, I.Paulino –UFCG , A.F. Medeiros –UFCG ,J. J. Makela - University of Illinois, J. W. Meriwhether - Clemson University , D. Barros - INPE

OUTLINE

- Introduction
  - planetary wave
- Objective
  - Determine the periodicities of the winds from FPI (i.e , temperature,Intensity ,Meridional and Zonal winds)
- Instrumentation/Methodology
- Results
- Summary

Thermosphere Nightglow Volume Emission Rates



Shows the profile volumetric emission rate of OI 630.0nm

O 6300 Å red line

The emission mechanism is known to be a dissociative recombination, which chemically is expressed by equation below and in which the photon emitted is in the red wavelength range .

Electron impact

$$O + e \rightarrow O(^1D) + e$$

Dissociative recombination

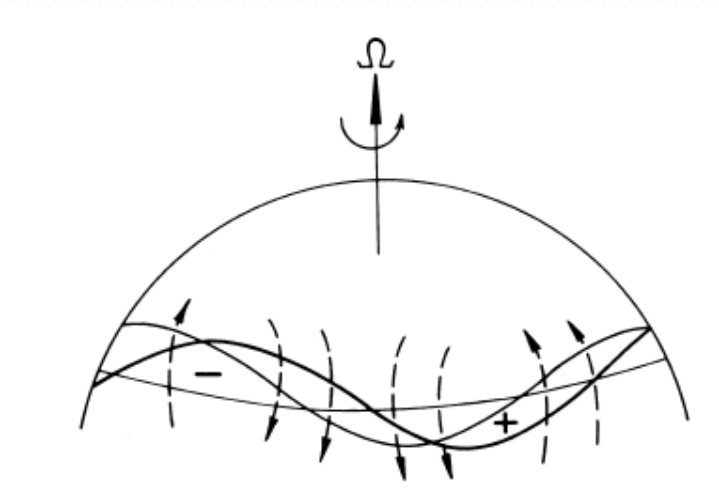
$$O_2^+ + e \rightarrow O + O(^1D)$$

Photodissociation of O2

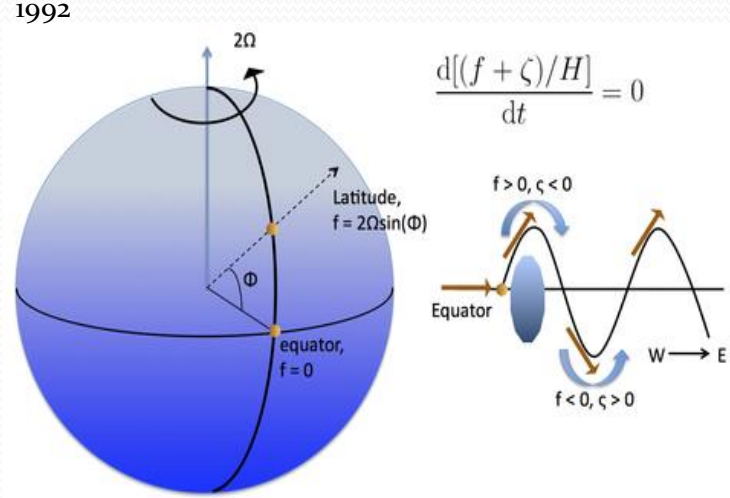
$$O_2 + h\nu \rightarrow O + O(^1D)$$

Planetary (Rosbby) wave

- **Rossby wave** is an absolute vorticity (Rotation) -conserving motion that owes its existence to atmospheric oscillations: the variation of the Coriolis parameter with latitude. [Holton.R.James].
- **Planetary waves** are generated by irregular thermal or mechanical forcing
- Propagate
  - **MOMENTUM**
  - **ENERGY**
  - **HEAT**



Perturbation vorticity field and induced velocity field (dashed arrows) for a meridionally displaced chain of fluid parcels. Heavy wavy line shows original perturbation position; light line shows westward displacement of the pattern due to advection by the induced velocity. Holton 1992



Theory

Dynamics Equations:

$$\frac{Du}{Dt} - (f + \frac{u\tan\phi}{a})v + \frac{\Phi_\lambda}{a\cos\phi} = X,$$

$$\frac{Dv}{Dt} + (f + \frac{u\tan\phi}{a})u + \frac{\Phi_\phi}{a} = Y,$$

$$\Phi_z = H^{-1}R\theta e^{-\kappa z/H},$$

$$\frac{[u_\lambda + (v\cos\phi)_\phi]}{a\cos\phi} + \frac{(\rho_0 w)_z}{\rho_0} = 0,$$

$$\frac{D\theta}{Dt} = Q,$$

$H = RT/g$ is the scale height,

a is the earth radius,

Φ is the geopotential,

$\theta = T(p_s/p)^\kappa$ $(\kappa = R/c_p \approx 2/7)$ is the potential temperature,

ρ_0 is the density

$\Omega = 2\pi/T_{day}$

$f = 2\Omega\sin\phi$

(λ, ϕ) = (longitude, latitude)

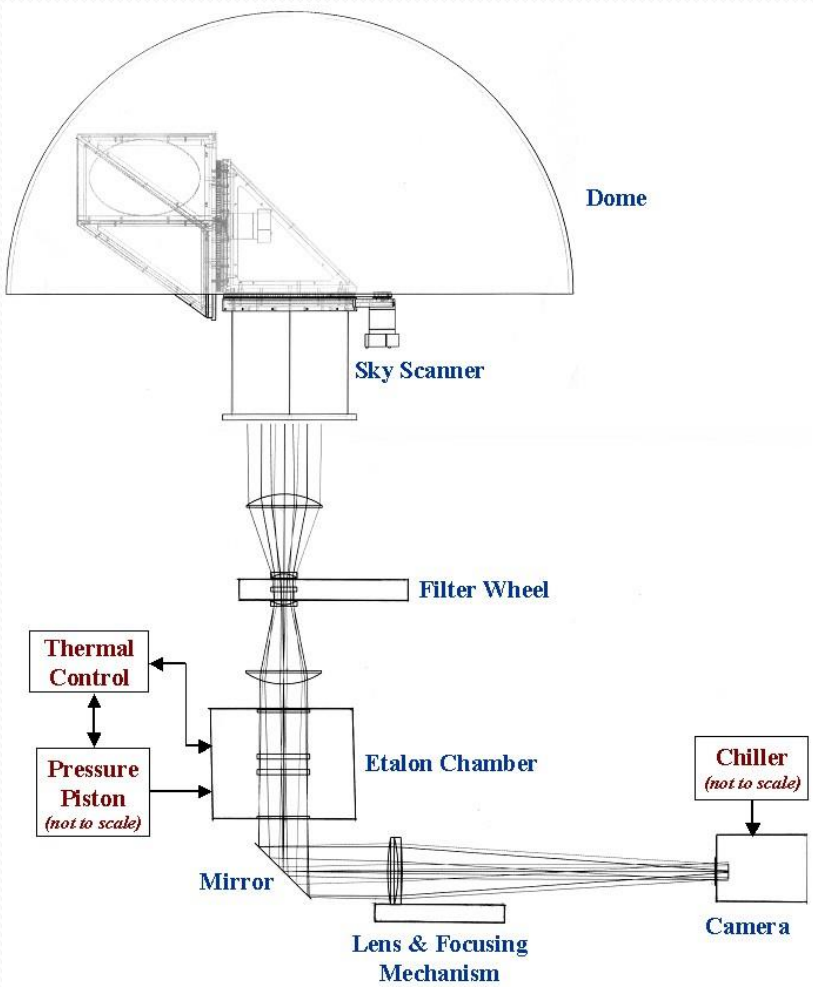
(u, v, w), velocity in zonal, meridional, and vertical directions

$$\frac{D}{Dt} = \frac{\partial}{\partial t} + \frac{u}{a\cos\phi}\frac{\partial}{\partial\lambda} + \frac{v}{a}\frac{\partial}{\partial\phi} + w\frac{\partial}{\partial z}$$

X, Y forcing term

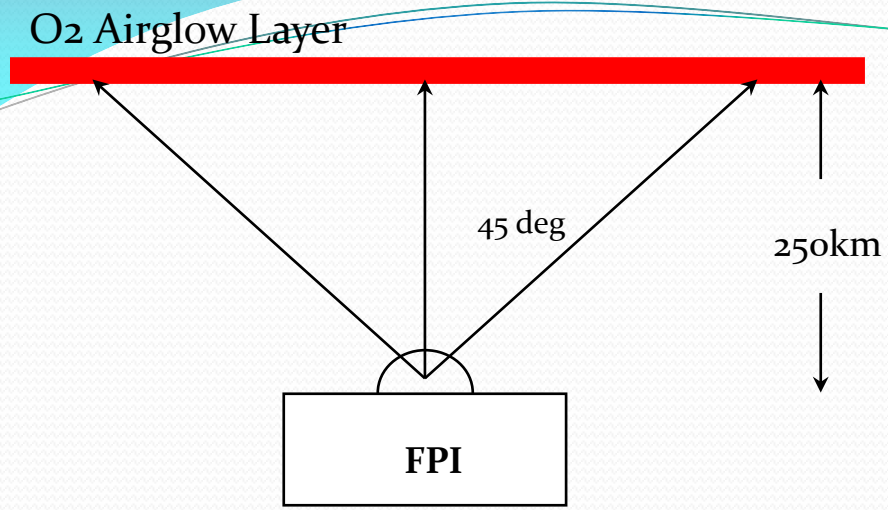
Q heating source

SCHEMATIC-FABRY-PEROT INTERFEROMETER

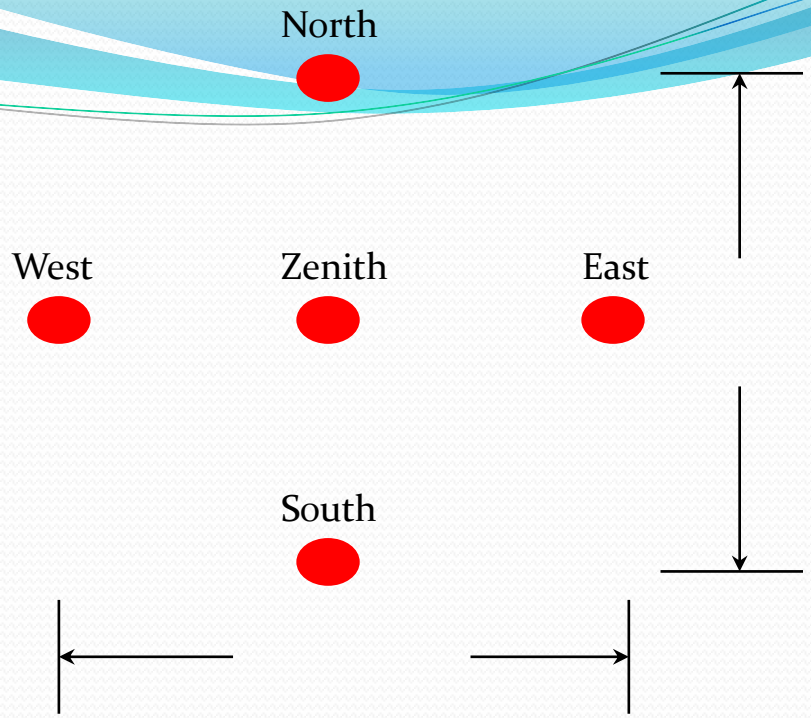


Meriwether et al.,2011

- The FPI which measures the atomic oxygen red line emission at 630.0 nm, which has peak intensity ~250 km altitudes.
- The FPI infers the neutral wind and temperature from the Doppler shift and thermal Doppler broadening of naturally occurring airglow emissions in the upper atmosphere.
- The design of the Fabry-Perot instrument used for the thermospheric wind and temperature observations combines a 50 mm diameter interference filter with a 42 mm diameter etalon having a fixed-gap spacing of 1.5 cm.
- The reflectivity of the etalon coating was specified to be 77% to enhance the transmission of the 630.0 nm emission without much loss of spectral resolution.
- The exposure time used for each 630.0 nm sky measurement was 300 s.

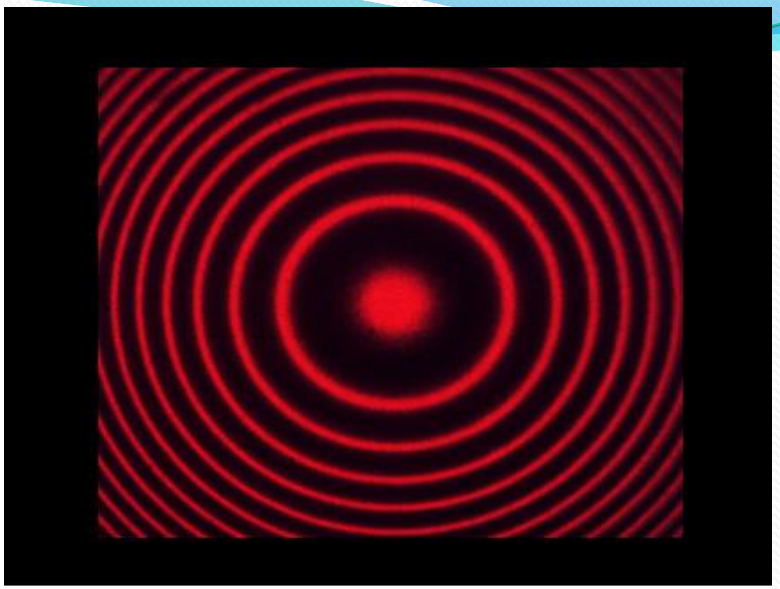


(a)



(b)

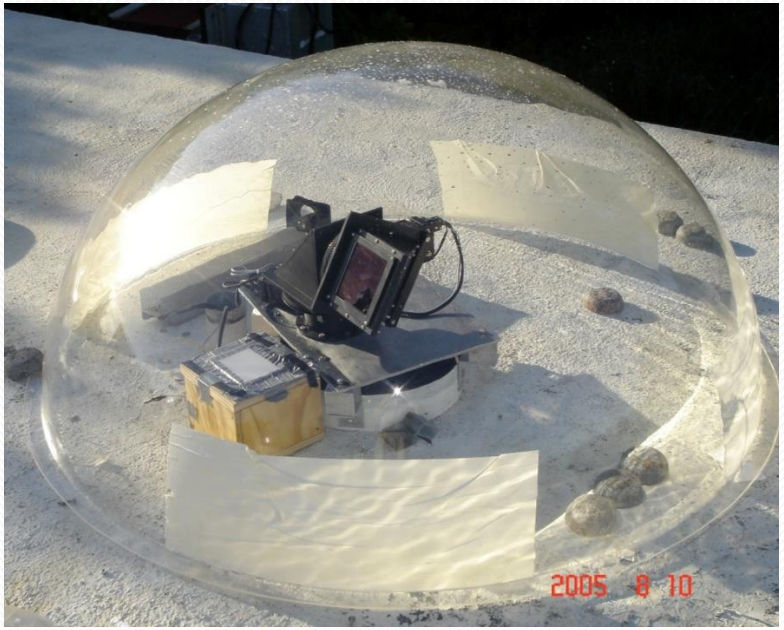
- For the measurements reported here, one observing cycle including measurements to the zenith followed by the four cardinal directions (N, E, S, W) and a laser calibration image.



A 30 cm focal length lens images the 11.7 rings of the interference pattern onto an Andor Technology DU-434 CCD camera using a 1024 × 1024 CCD chip with each pixel 13.0 mm in width

Fabry-Perot trailer at São João do Cariri

Fabry-Perot trailer at Cajazeiras



Sky Scanner Observatory

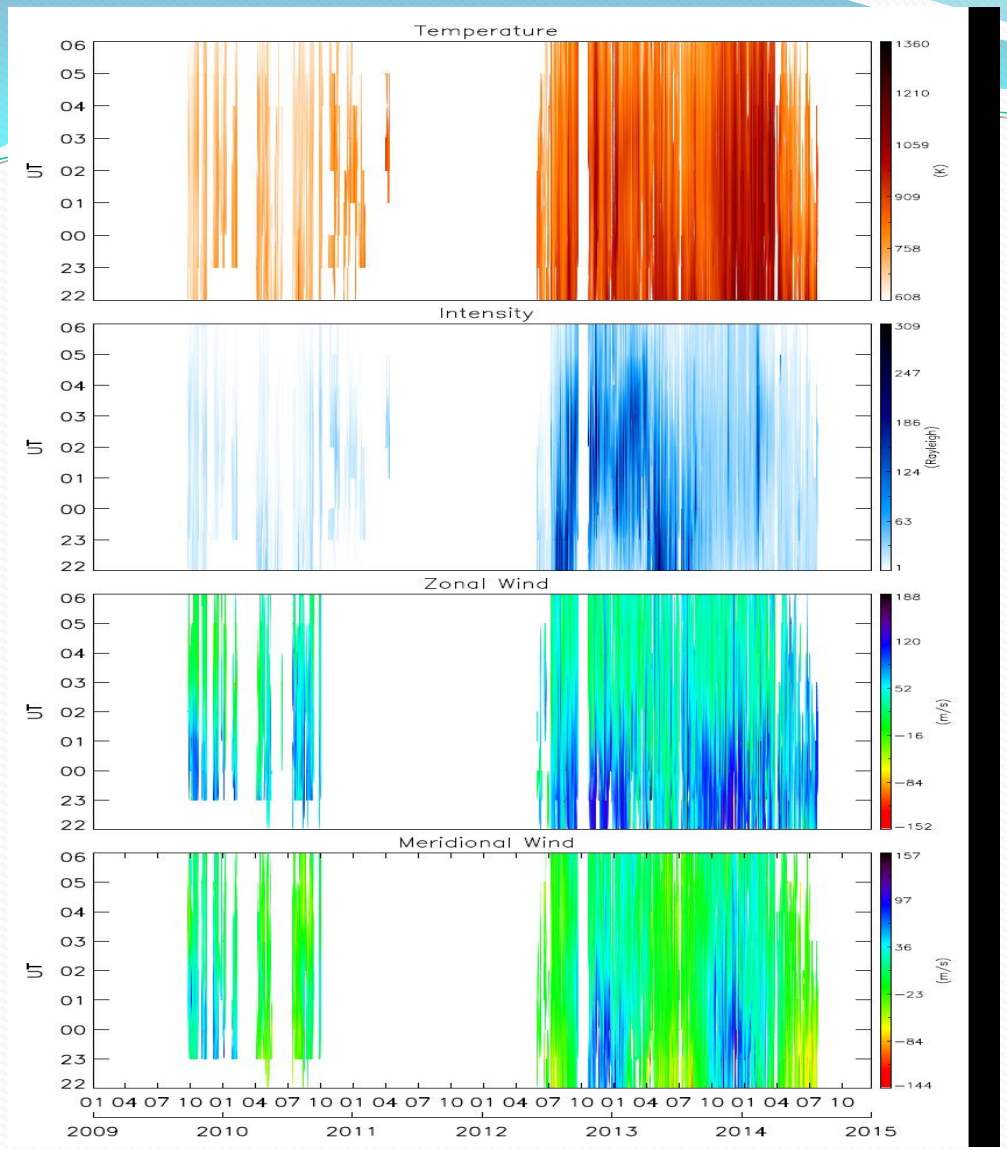


Figure 1: Nighttime variability of data observed by FPI as function month, from the top is Temperature, Intensity, Zonal and Meridional , from 2009 to 2015

- From the plot, considering the meridional wind during the period of 2010, it could be seen that the wind blows towards the north during the time (22:00 UT) of observation to 02:00 UT and to the south (03:00 UT-06:00 UT) during the month of November, 2010.

- During the period of July, 2013 to July, 2015, it can be seen clearly that the wind blows towards south and changes direction to the North and this sudden changes in the direction of the meridional wind could be attributed to general wind circulation.

- For the zonal wind, it could be seen that during the hours of 23:00 UT to 03:00 UT, the wind blows towards the east and suddenly changes directions to the west from 03:00 UT to 06:00 UT.

- And also considering intensity and temperature, it could be seen that during the same hours of observing this strong changes in direction of the meridional and zonal winds, a high intensity and temperature were recorded during and after the observations.

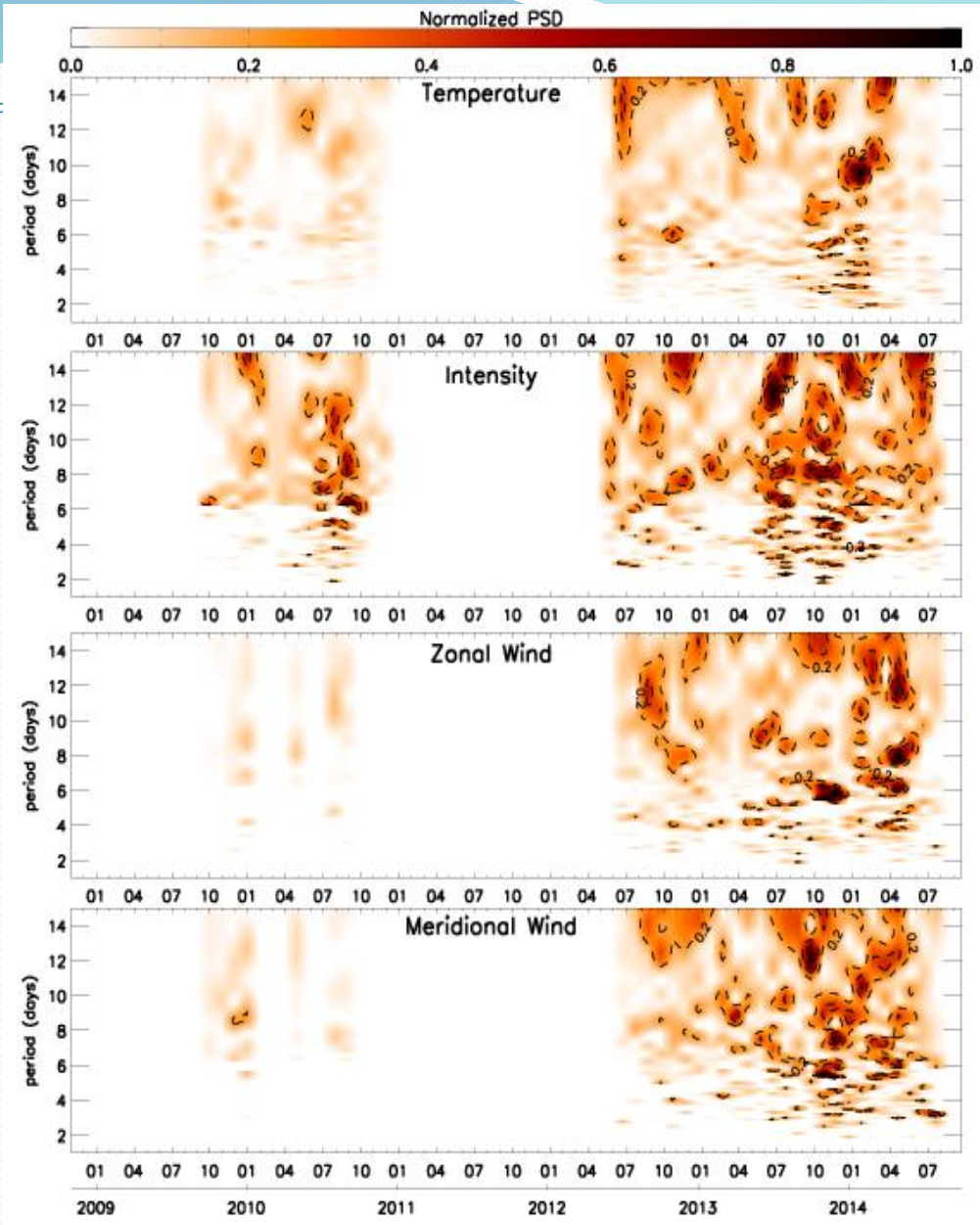
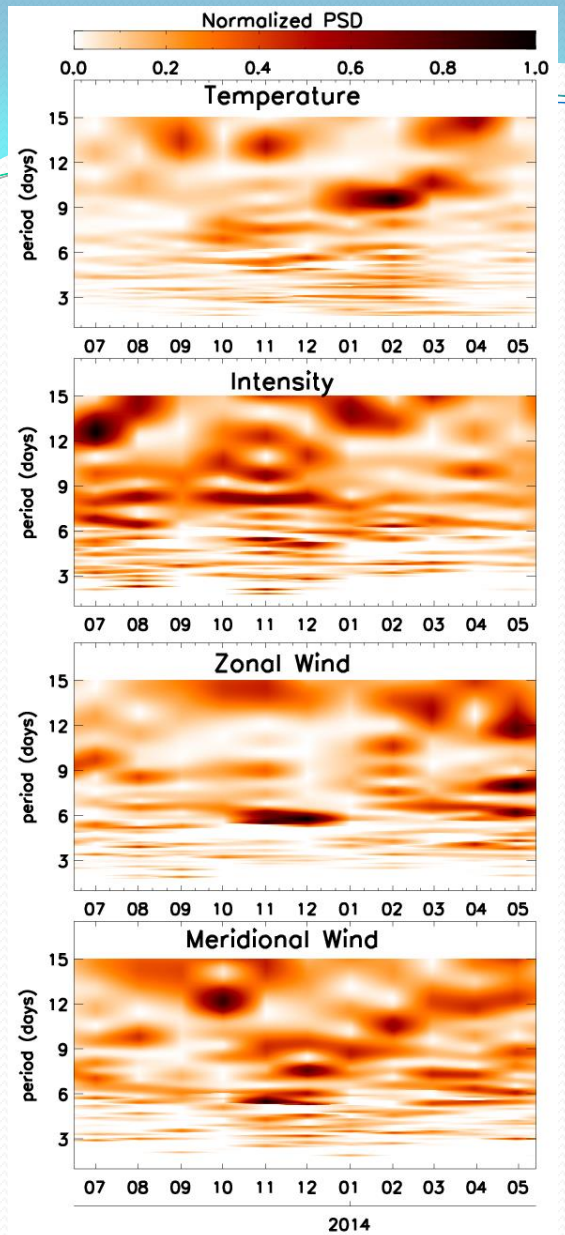


Figure 2: Lomb-Scargle periodogram spectrum (period in days) as a function month of the year (2009-2014), from the top is temperature, intensity, zonal and meridional wind components.



The same as Fig. 2, but from the month of July 2013 to May 2014.

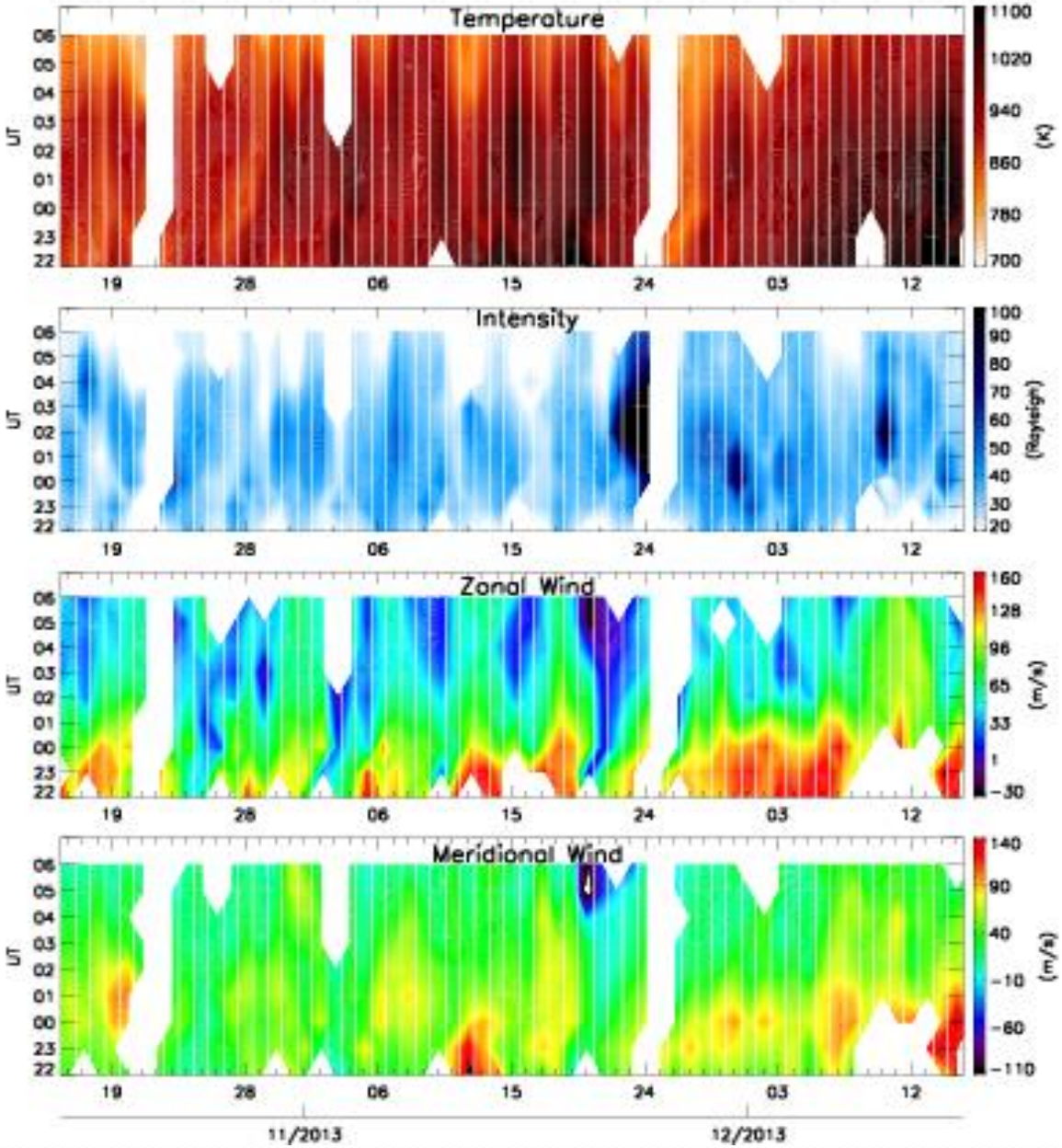
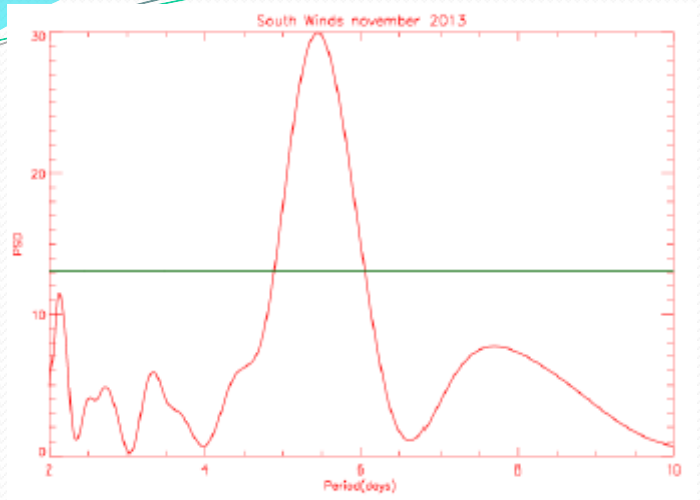
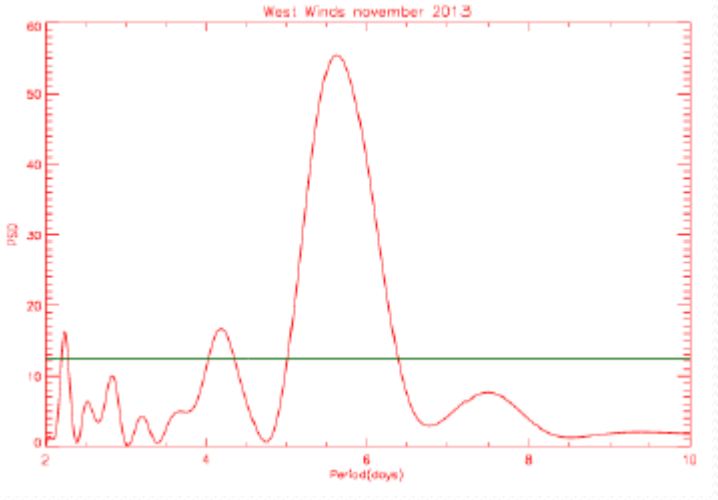
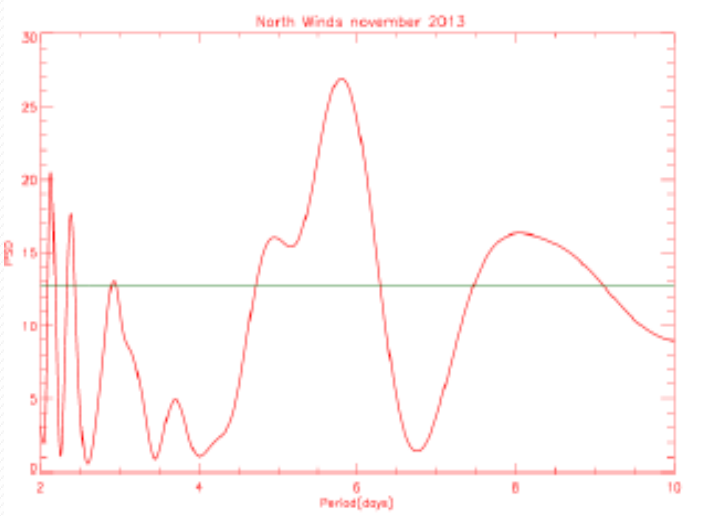
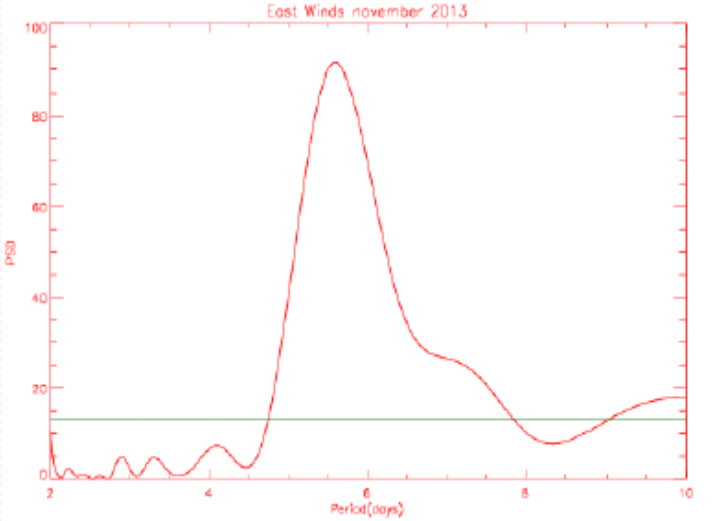


Fig. 2, Nighttime of November to December 2013.

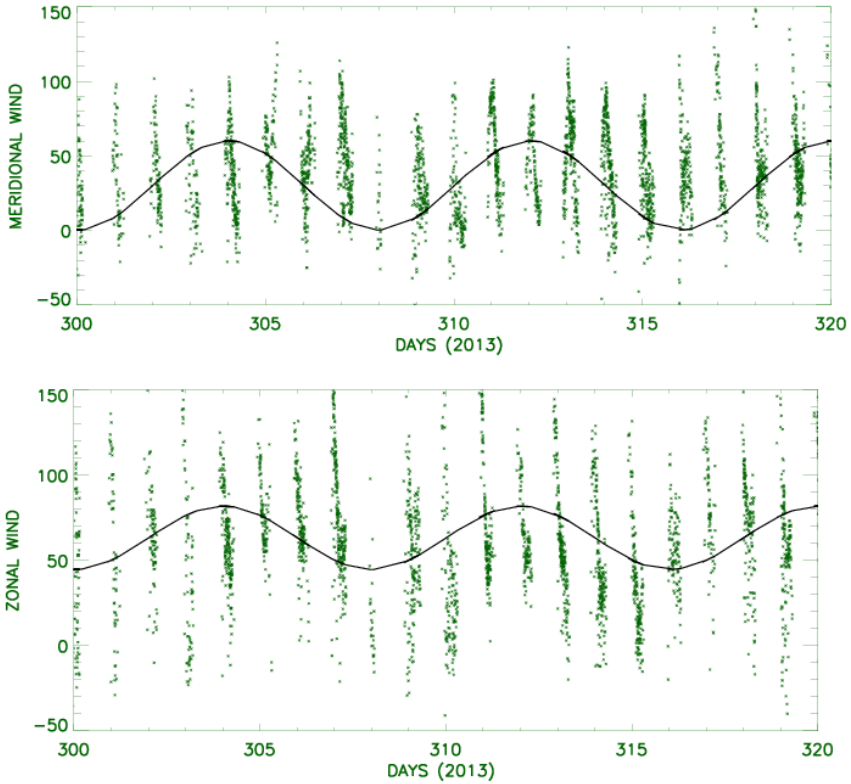




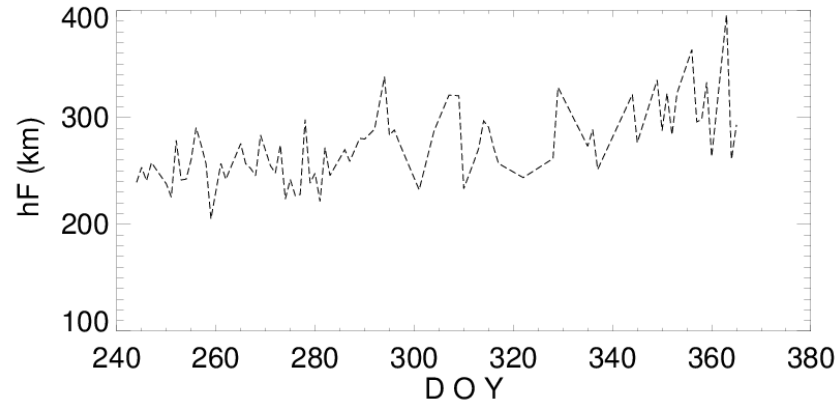


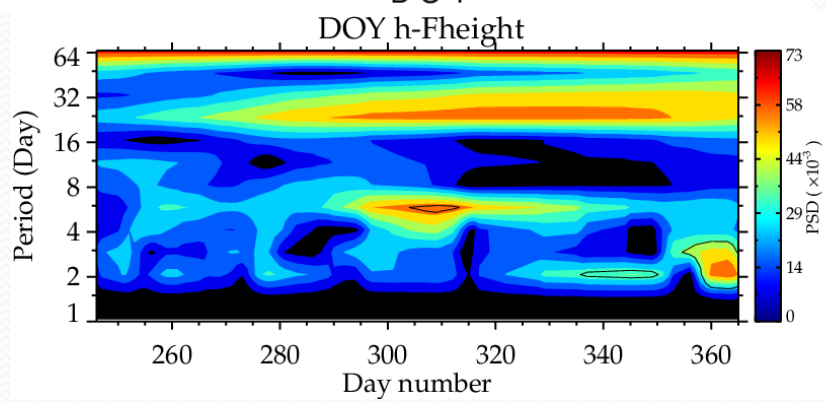


Lomb-Scargle plot for the South, North, West and East directions, November , 2013



Amplitude (m/s) and phase (day of maximum) the wave oscillation as a function of the day in number (October to November, 2013) for Zonal and Meridional winds

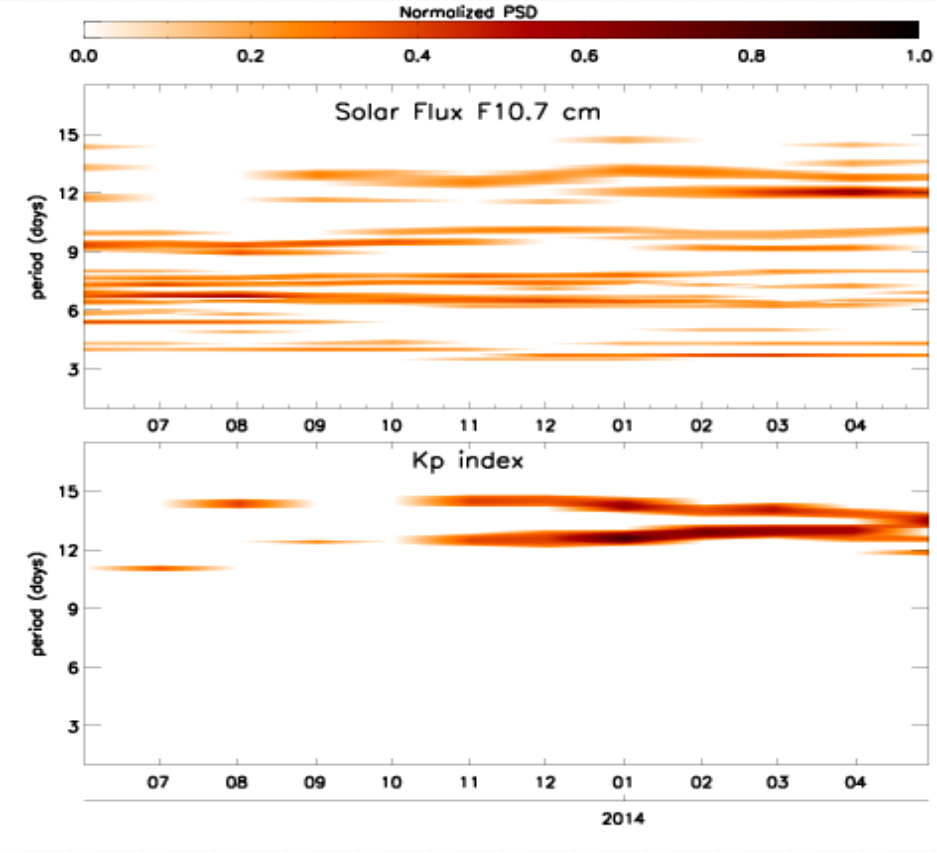




Ionospheric F-layer hoF time series at 23:00 UT (20:00 LT) observed at Fortaleza and Wavelet power spectra (below) of the ionospheric h'F day-to-day variation parameter at 23:00 UT at Fortaleza.

- PWTOs propagating into the lower thermosphere is known to be caused by the activities such as solar and magnetic activities, (e.g., Meyer, 1999; Pancheva et al., 1994, 2002; Altadil and Apostolov, 2003).

- PWTOs observed in the lower thermosphere could also be excited by planetary type oscillations in the neutral atmosphere but not necessarily caused by solar and geomagnetic activities, (Pancheva et al., 1989; Pancheva and Lastovicka, 1989).



A plot showing periods *versus* month of the year of the geomagnetic activity, index (*kp*) and solar activity (F10.7 cm) from July 2013-April 2014

Summary and conclusion

- Fabry-Perot interferometer is an effective instrument for upper atmosphere dynamics studies.
- A period of 6 day wave oscillation was observed in both winds and simultaneously in the ionospheric virtual height parameter .
- This periods observed could be influenced by meteorological process in the lower atmosphere .
- The dynamic coupling is not well understood.
- A 6-8 day oscillation has been observed simultaneously in the minimum ionospheric virtual height and the MLT zonal wind in the equatorial regions (Takahashi et al., 2006).
- The source of the 6-day periodic wave oscillation observed from FPI could be a wave propagating upwards from the stratosphere to the mesosphere and lower thermosphere, or via the wave modulation on the neutral wind and dynamo electric fields in the ionosphere E region.

THANK YOU ALL FOR YOUR ATTENTION !!