

Aziza Bounhir  
ISWI Coordinator



## ISWI in Morocco

Team of two professors and six Ph.D students  
Laboratory of High Energy Physics and Astronomy  
Cady Ayyad University; Marrakech

### Main purpose

Analyse the thermosphere/ionosphere coupling over African mid-latitude area.

### Data

- Thermospheric winds and temperature from Fabry-Perrot interferometer.
- Plasma irregularities occurrence and dynamics from wide angle viewing camera.
- Ionospheric TEC from five GPS stations in Morocco.
- Ionospheric and thermospheric satellite data.

## Annexure VII



**Oukaimeden Observatory (31.206°N,  
7.866°W, 22.84°N magnetic)**



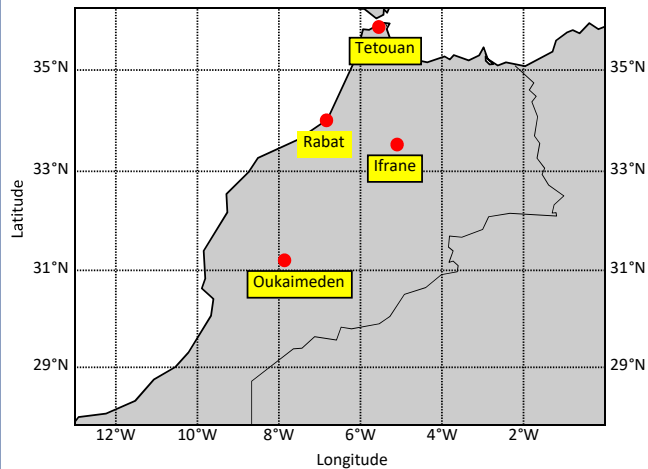
### **How we get involved.**

- In 2010 an ISWI delegation arrived to Morocco with proposed installations of observation instruments.
- In November 2013, the RENOIR "Remote Equatorial Nighttime Observatory of Ionospheric Region" experiment in collaboration with the University of Illinois has been deployed at Oukaimeden Observatory.
- In May 2014, International School on Space Weather at Cady Ayyad University.

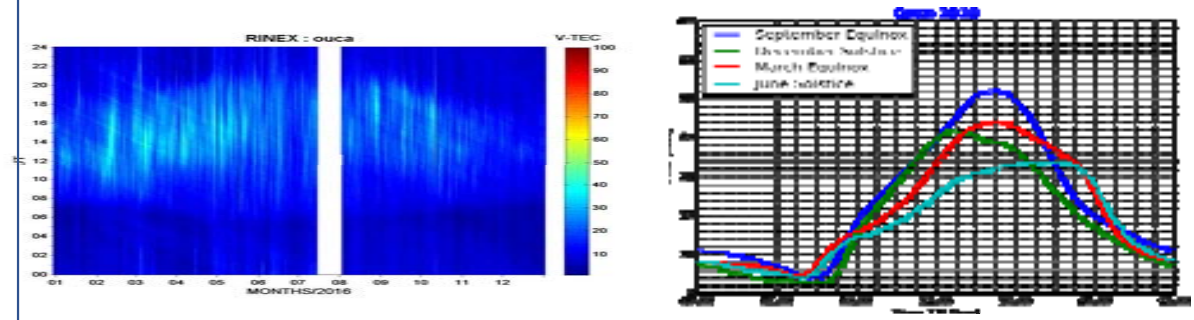
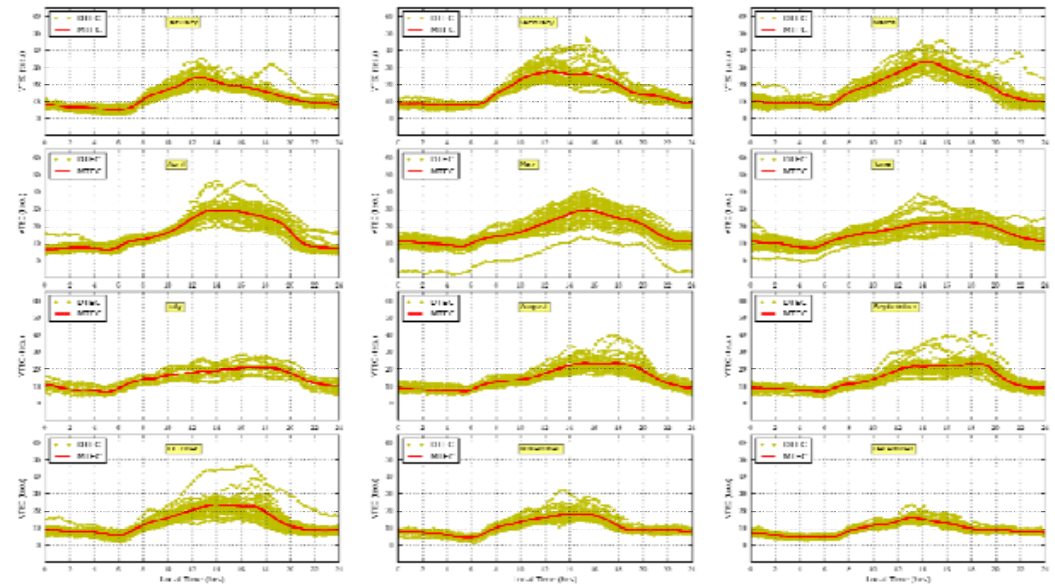
# Analyses of the TEC over Morocco

## Objectives:

- Analyses of the TEC from five GPS stations in Morocco (including Marrakech).
- Dynamics of the TEC in quiet and disturbed times.
- Regional attributes of the TEC over Morocco; 1) climatology, 2) seasonal behavior, 3) dependance on solar cycle
- Analyses of the thermosphere/ionosphere coupling.

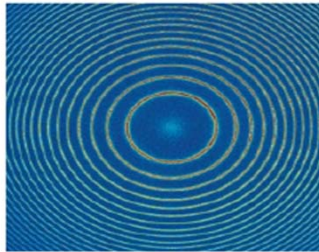
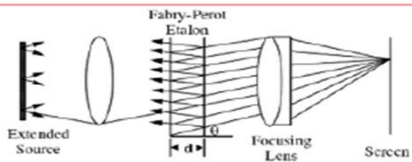


## Climatology of the TEC over Oukaimeden Observatory

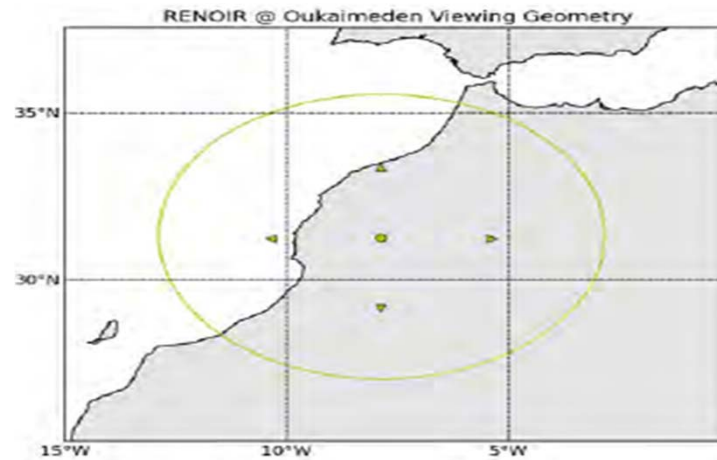
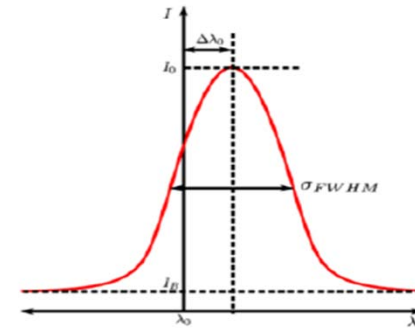


# Fabry-Perot interferometer

- Light enters two parallel, partially-reflective glass plates after passing through the redline filter and is then focused onto a CCD
- Plate separation causes phase offsets that create interference on the imaging plane

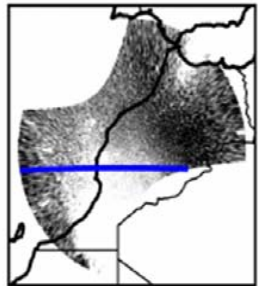


- Fit fringes to model and back out relevant airflow parameters through an inversion
- Background  $\sim I_B$
- Intensity  $\sim I_0 - I_B$
- Velocity  $\sim \Delta\lambda_0$
- Temperature  $\sim \sigma_{FWHM}$

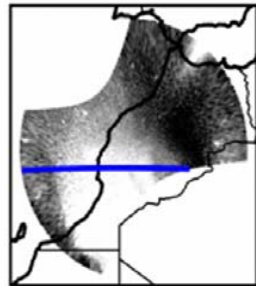


Airglow veiwing directions;  
North, South,  
East, West and Zenith  
With a laser reference.

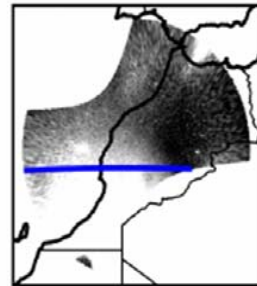
## Large angle viewing camera



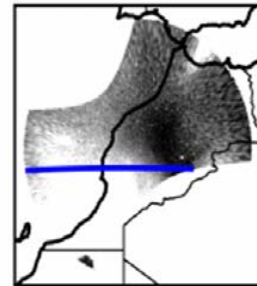
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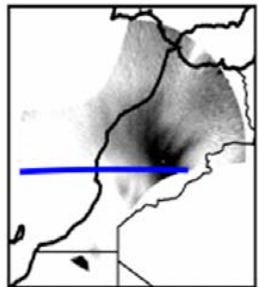
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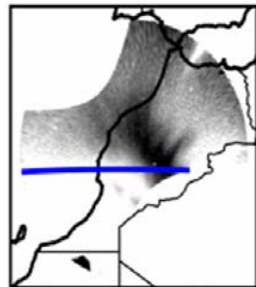
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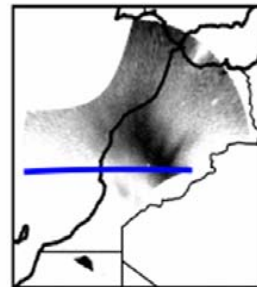
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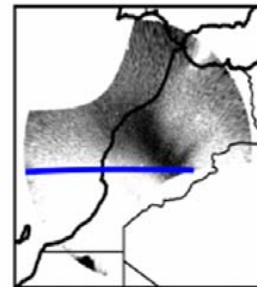
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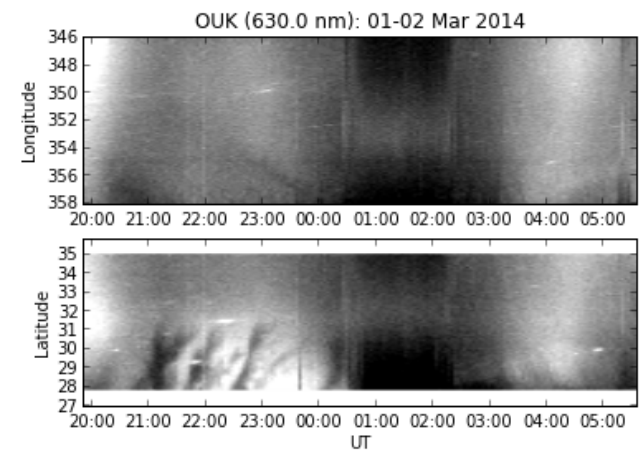


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### Keogram of plasma bubbles



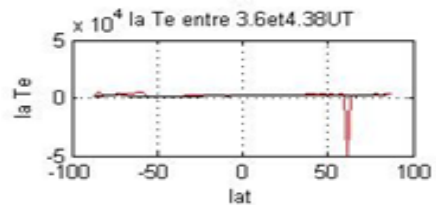
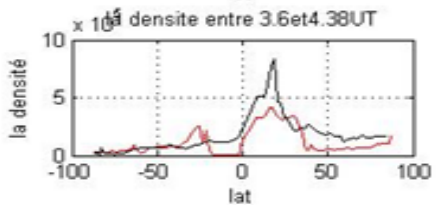
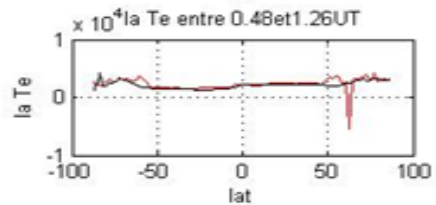
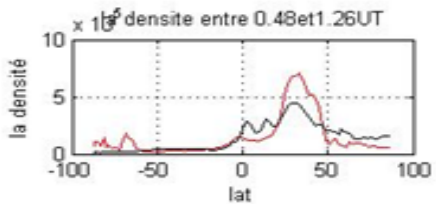
- Tracking of the ionospheric structures taking place over the studied area.
- Occurrence of Equatorial plasma bubbles.
- Occurrence of Traveling ionospheric disturbances and MSTID.
- Effect of storm time on plasma drift velocity and irregularities occurrence.

# Swarm data to study storm time

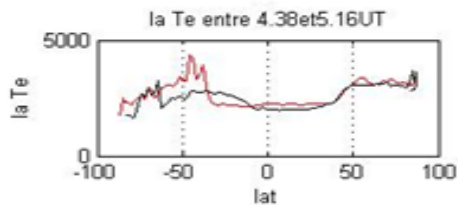
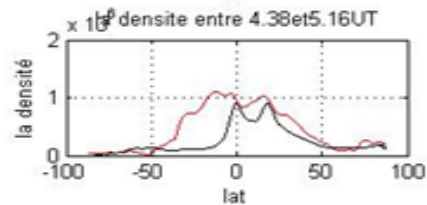
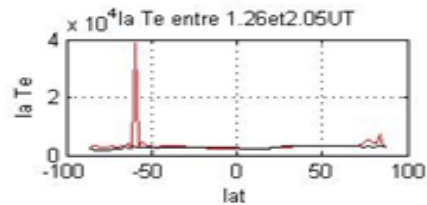
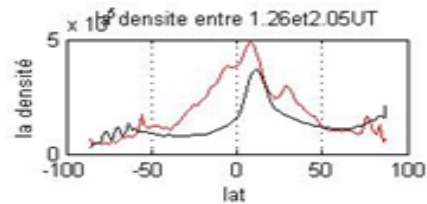
— Jour calme

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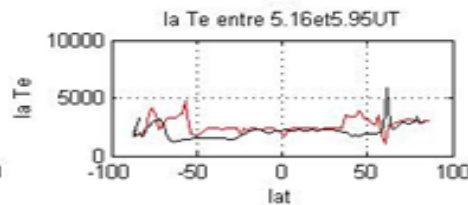
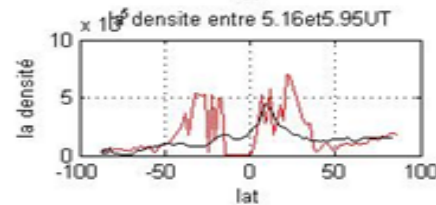
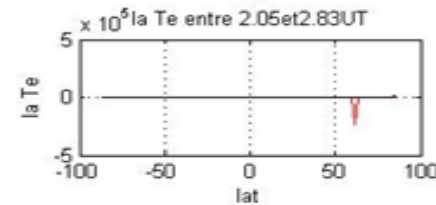
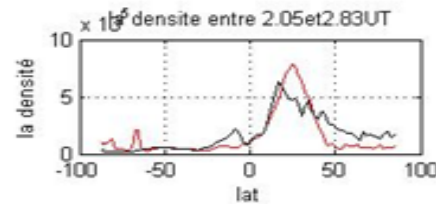
Coté nuit



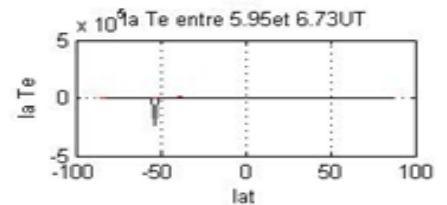
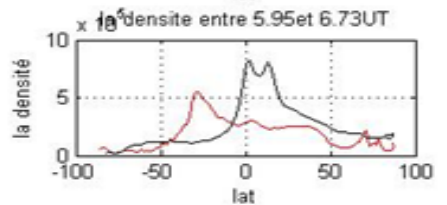
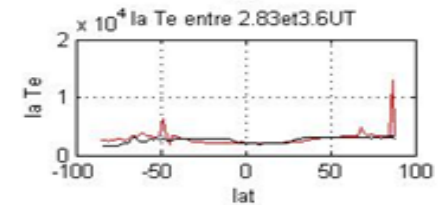
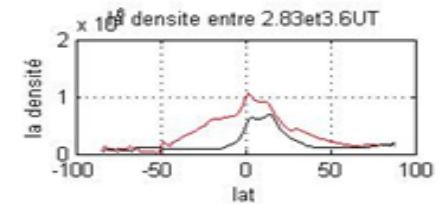
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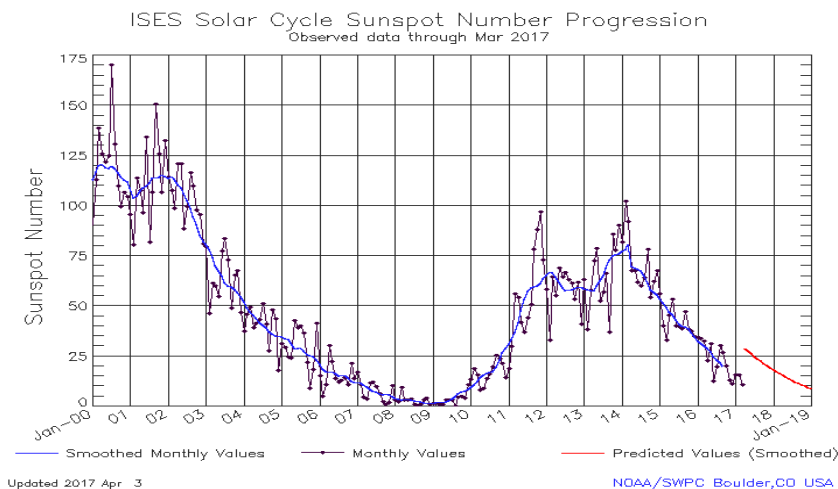
Coté jour



# Thermosphere Dynamics in quiet and disturbed conditions

**Data** = Zonal and meridional winds + Temperature; 2014, 2015 and 2016.

- Establish the climatology of the zonal and meridional winds.
- Comparison with HWM14 model.
- Illustrate the wind and temperature variations with seasons.
- Illustrate the wind and temperature variations with the solar cycle.
- Illustrate the variations in quiet and disturbed geomagnetic conditions.
- Case study of a geomagnetic storms; 27 February 2014 (FPI, Camera and TEC), 2015 St Patrick day (FPI network, GPS TEC, SWARM data), 03 Nov 2003 storm.



**Study of the data from FPI;  
Questions to answer**

Identification and occurrence of the different type of tides .

Identification and occurrence of the MTM phenomena.

Identification and occurrence of gravity waves.

Identification and occurrence of other type of waves.

Energy budget of the subsequent heating of the thermosphere.

Storm time interference with the background wind.

Storm time circulation and MTM phenomena.

Transport of the energy from high to low latitudes.

Seasonal reaction of the thermosphere to the storm.

Thermosphere/Ionosphere coupling during quiet and disturbed times.

- Effect of tides (waves) on the ionosphere.
- Effect of storms on the ionosphere.

Comparison with different physics based models to understand the step  
By step mechanisms .....

## Main production

Fisher, Daniel J.; Makela, Jonathan J.; Meriwether, John W.; Buriti, Ricardo A.; Benkhaldoun, Zouhair; Kaab, Mohamed; Lagheryeb, Amine; Climatologies of nighttime thermospheric winds and temperatures from Fabry-Perot interferometer measurements: From solar minimum to solar maximum, *Journal of Geophysical Research: Space Physics*, Volume 120, Issue 8, pp. 6679-6693.

Kaab, Mohamed; Benkhaldoun, Zouhair; Fisher, Daniel J.; Harding, Brian; Bounhir, Aziza; Makela, Jonathan J.; Laghriyeb, Amine; Malki, Khalifa; Daassou, Ahmed; Lazrek, Mohamed; Climatology of thermospheric neutral winds over Oukaïmeden Observatory in Morocco, *Annales Geophysicae*, Volume 35, Issue 1, 2017, pp.161-170.

Fisher, D. J.; Benkhaldoun, Z.; Buriti, R.; Castelaz, M.; Ciocca, M.; Harding, B. J.; Makela, J. J.; Meriwether, J. W.; Mesquita, R.; Ridley, A. J.; Sanders, S; The Dependencies of Annular Variations in the Nighttime Thermospheric Neutral Winds, *American Geophysical Union, Fall General Assembly 2016*, abstract id.SA53A-2439.

Bounhir, Aziza; Benkhaldoun, Zouhair; Kaab, Mohamed; Makela, Jonathan J.; Harding, Brian; Fisher, Daniel J.; Lagheryeb, Amine; Khalifa, Malki; Lazrek, Mohamed; Daassou, Ahmed; Thermospheric nighttime wind and temperature analysis from some 2014 stormy nights monitored at Oukaimeden Observatory by RENOIR instrument, *2015 American Astronomical Society, 2015IAUGA..2251702B*.

Khalifa, Malki; Benkhaldoun, Zouhair; Vilmer, Nicole; Bounhir, Aziza; Makela, Jonathan J.; Kaab, Mohamed; Lagheryeb, Amine; Ionospheric and thermospheric response to the 27-28 February 2014 geomagnetic storm, *2015 American Astronomical Society, 2015IAUGA..2251685K*.

Kaab, Mohamed; Benkhaldoun, Zouhair; Fisher, Daniel J.; Harding, Brian; Makela, Jonathan J.; Bounhir, Aziza; Lazrek, Mohamed; Lagheryeb, Amine; Daassou, Ahmed; Khalifa, Malki; First Thermospheric Winds and Neutral Temperatures statistics Over Oukaimeden Observatory, *2015 American Astronomical Society, 2015IAUGA..2229535K*.

Benkhaldoun, Zouhair; Makela, Jonathan J.; Meriwether, John W; Solar initiative at Oukaimeden Observatory, *Solar and Astrophysical Dynamos and Magnetic Activity, Proceedings of the International Astronomical Union, IAU Symposium, Volume 294, pp. 479-480*.

Lagheryeb, Amine; Benkhaldoun, Zouhair; Makela, Jonathan J.; Harding, Brian; Kaab, Mohamed; Lazrek, Mohamed; Fisher, Daniel J.; Duly, Timothy M.; Bounhir, Aziza; Daassou, Ahmed; Measuring the equatorial plasma bubble drift velocities over Morocco, *2015 IAU General Assembly, Meeting #29, id.2251778*.