Ionospheric Plasma Irregularities During Space Weather Events of Solar Cycle 24

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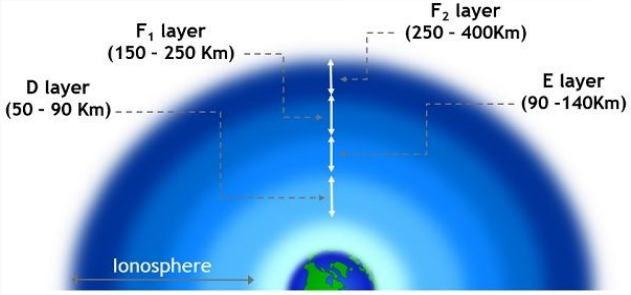
Outline

- Objectives
- An Overview: Formation and Composition of Ionosphere, Ionospheric Plasma irregularities and Space weather Phenomena
- Case Studies: Geomagnetic storms of Solar Cycle 24
- Observations: Ground/Space based instruments data
- Summary

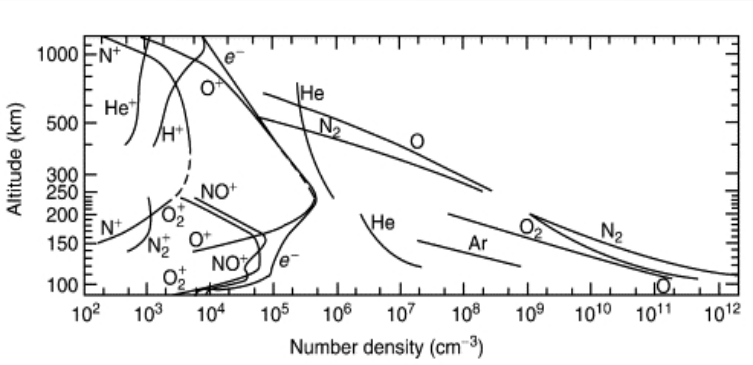
Objectives

- The most important objective of the space weather research program is to understand the connection between the ionospheric plasma irregularities and scintillation of the radio waves.
- In order to improve the space weather forecasting, it is important to study the ionospheric response over different regions.
- *The present work aims to understand the characteristics of the ionospheric plasma irregularities over low and middle latitudes during the space weather events of the solar cycle 24.*

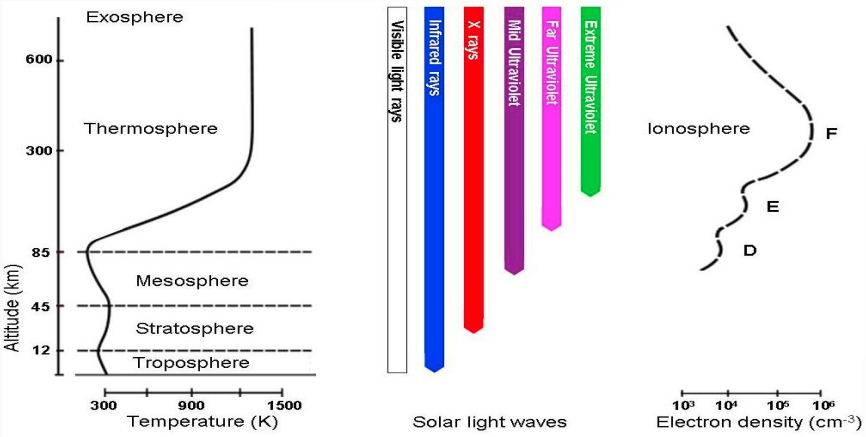
Ionosphere:Formation and Structure



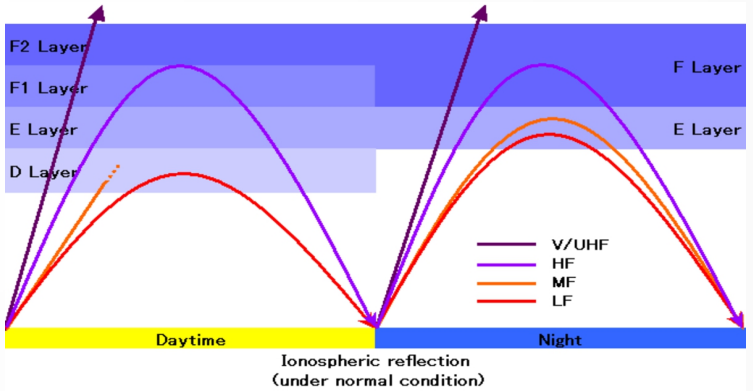
Structure of Ionosphere



Composition of Ionosphere



Formation of Ionospheric Layers



Reflection of radio waves depend on the Plasma Frequency $f_p=9(Ne)^{1/2}$.

Ionospheric Variability

Ionospheric variability exists on a broad range of scales, which affects the sky-wave propagation of the radio waves. It can be classified as:

I. Regular Variations (Cyclic)

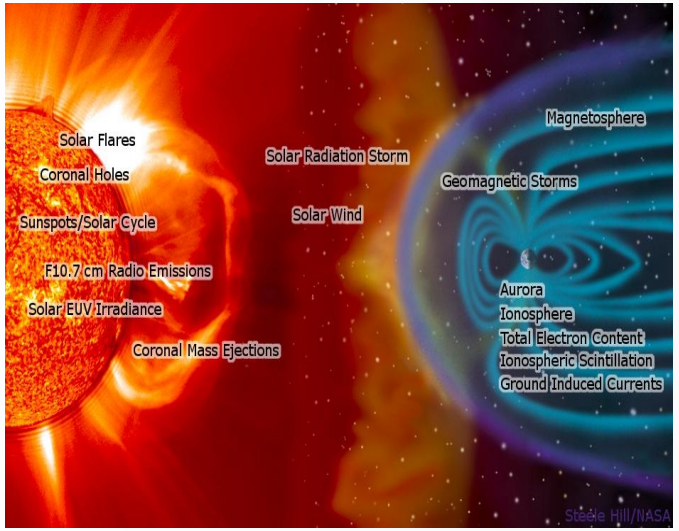
- Diurnal and Seasonal.
- Can be predicted in advance with reasonable accuracy.

II. Irregular Variations (Non Cyclic)

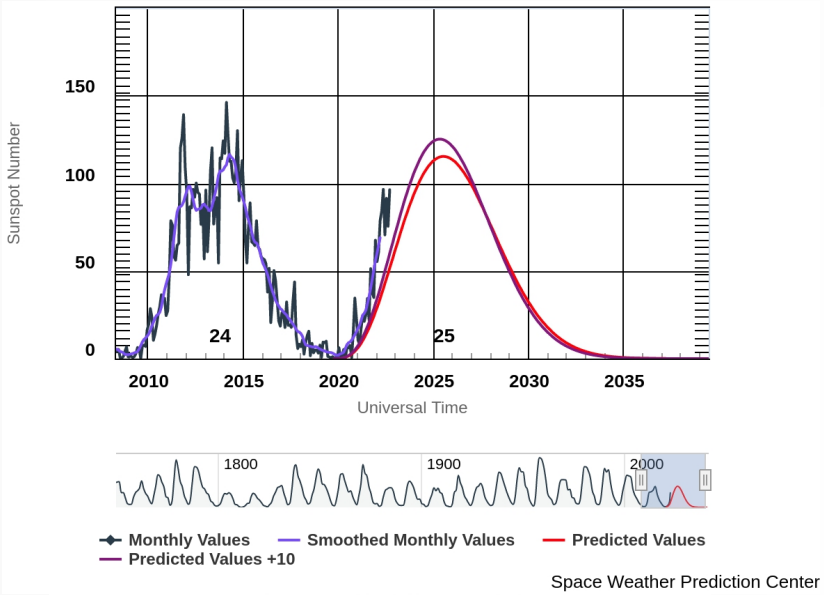
- Abnormal and cannot be predicted with accuracy.
- Triggered by space weather events (Solar flares, CMEs, HSSWs, geomagnetic storms, solar eclipse) and seismic events (Earthquakes, Explosions, Tsunamis).

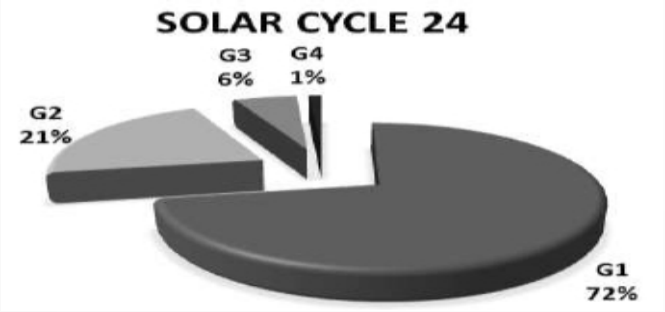
Space Weather Phenomena

- Space weather pheomena describes the variations between sun-Earth space environment.
- Geomagnetic storm is the temporary disturbance of the Earth's magnetosphere due to exchange of energy from the solar wind into Earth's magnetosphere. Drivers are:
  - Coronal Mass Ejection(CME)
  - High speed solar wind stream (HSSWs)
  - IMF Bz southward



Case Study: Geomagnetic Storms of SC 24





Coronal Mass Ejection(CME) driven:

- Intense with Dst < –100 nT
- Peaking at solar maximum

High Speed Solar Wind (HSS) driven:

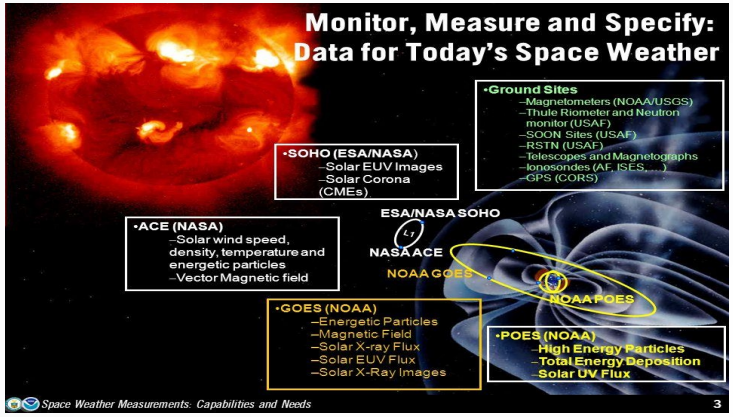
- Weak with –75< Dst < –35 nT
- Smaller solar cycle dependence
- Common in declining phase. Gonzalez et al. 1990

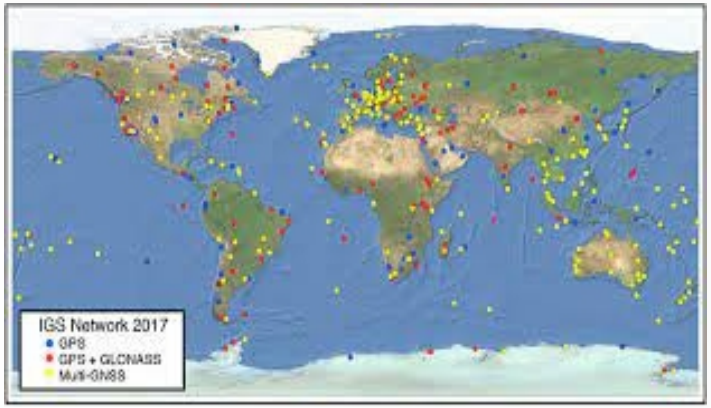
Events Under Consideration

Event #	Occurence	Kp	Category	Sudden Storm Commencement (SCC)
1	October 24-25, 2011	~7	Strong (G3), CME origin	24 October at 18:30 UT
2	February 18-20, 2014	~7	Strong (G3), CME origin	18 February at 14:00 UT
3	December 19-22, 2015	~7	Strong (G3), CME origin	19 December at 19:10 UT

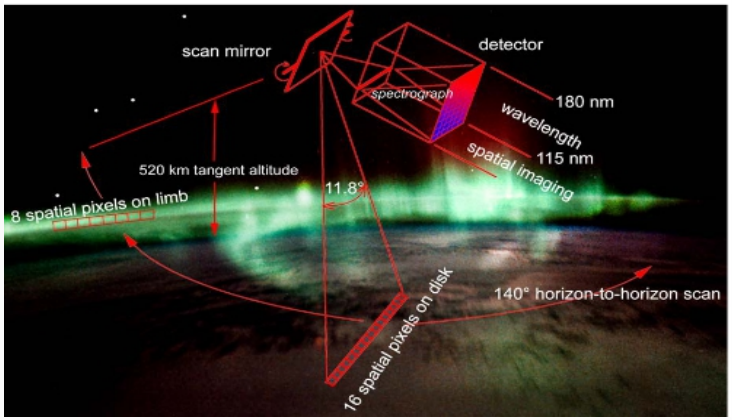
Methodology

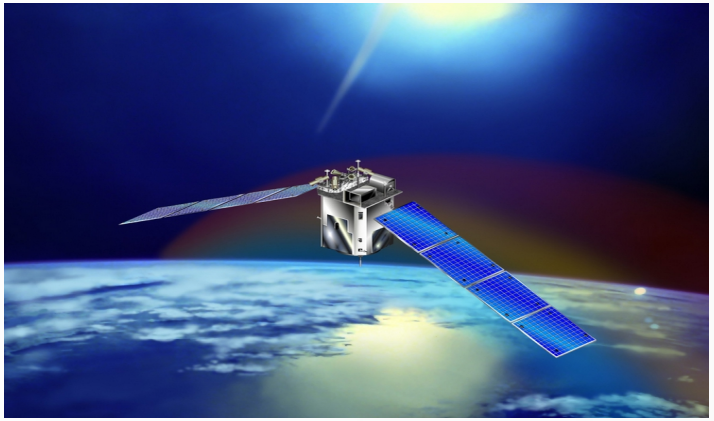
- Solar wind:The solar wind parameters such as Bz component of the IMF, the solar wind speed (Vsw), the proton number density and temperature (np/Tp), and the electric field (Ey) obtained from the OMNI database. The information about the geomagnetic indices is provided by the world data center for Geomagnetism (WDC);
- Ionospheric electron content: To analyze the storm-time response of the electron density, the Global Navigation Satellite System (GNSS) data from a cooperatively operated global network of ground tracking stations located in equatorial (0◦ : 10◦ N) to low latitude (10◦ : 30◦ N) in the three longitudes given as Asian (60◦ : 120◦ E), African (30◦ W: 60◦ E), and the American (120 : 30◦ W) is used.
- Plasma Bubbles Detection: Images of nightside Far Ultraviolet (FUV) emissions obtained from Special Sensor Ultraviolet Spectrographic Imager (SSUSI) are used to detect the ionospheric plasma bubbles.
- Thermospheric Neutral Composition: The O/N2 maps are obtained from Global Ultraviolet Spectrographic Imager onboard the satellite Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED/GUVI).



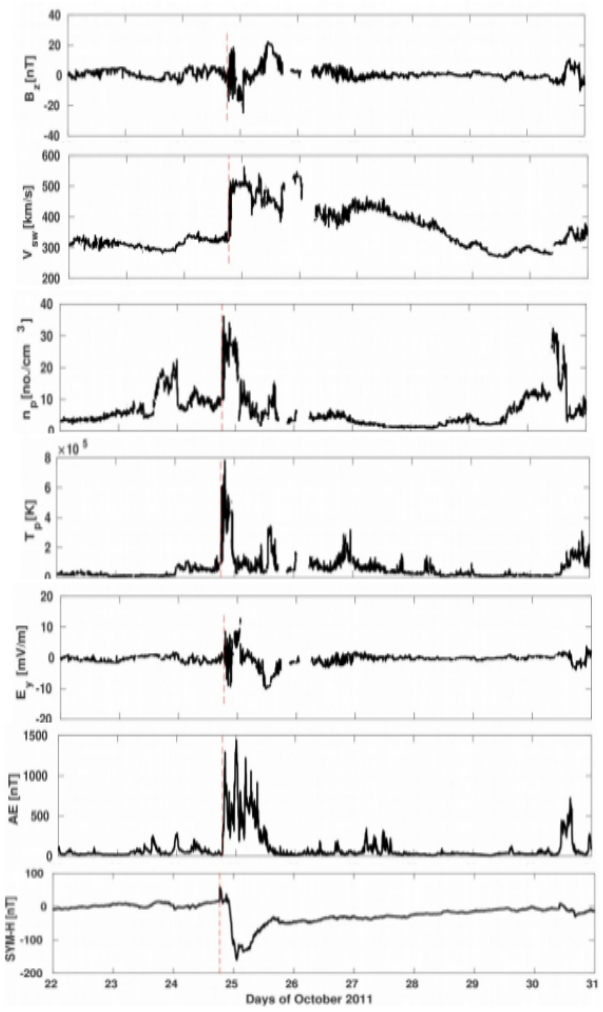


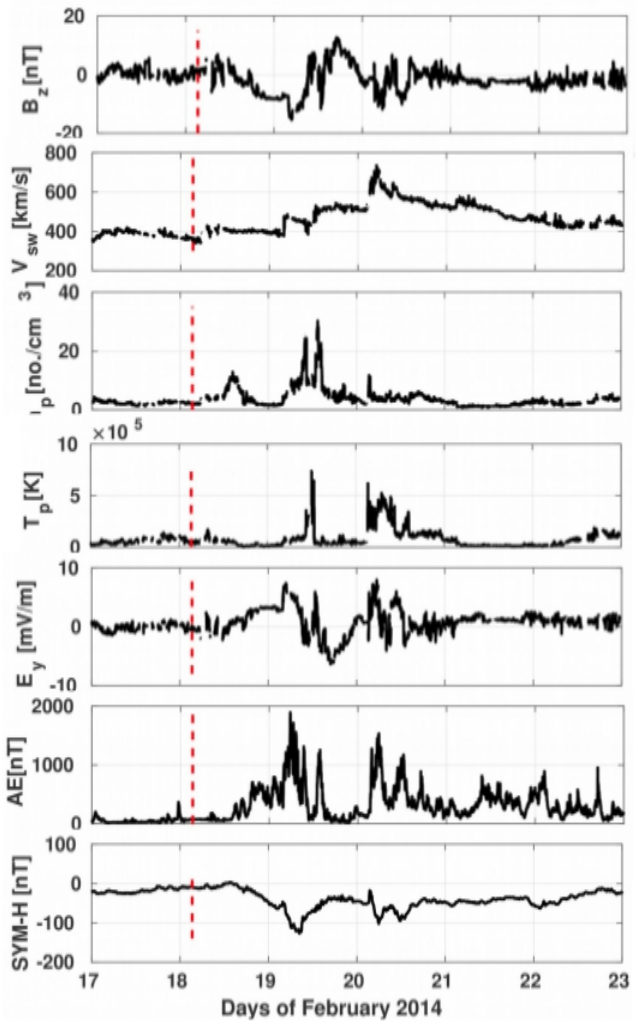
OBSERVATIONS

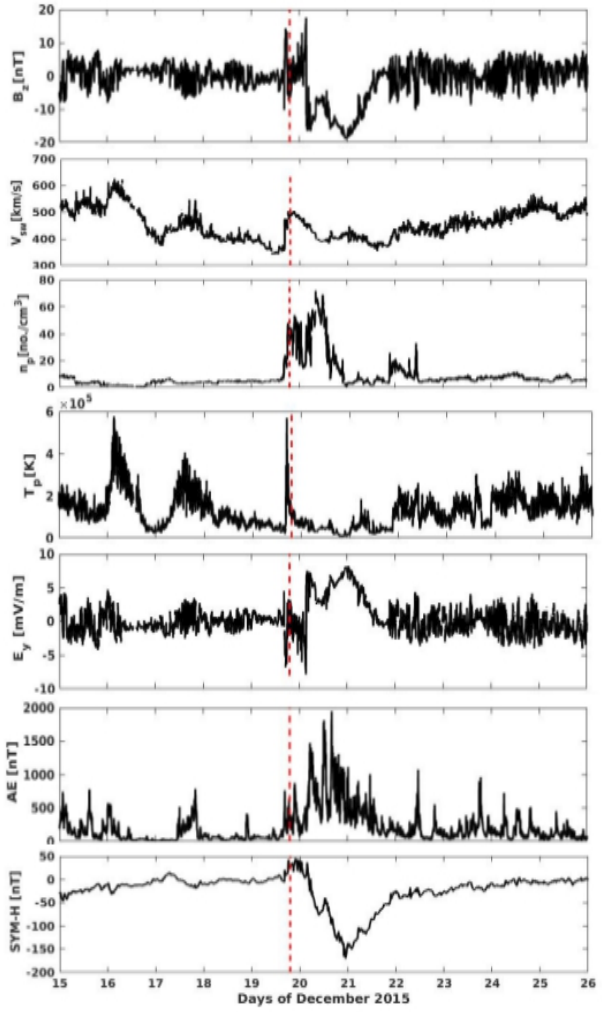




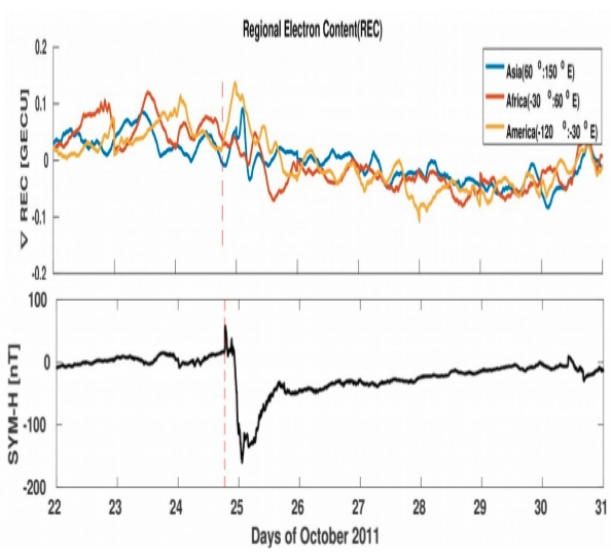
Solar Wind Parameters



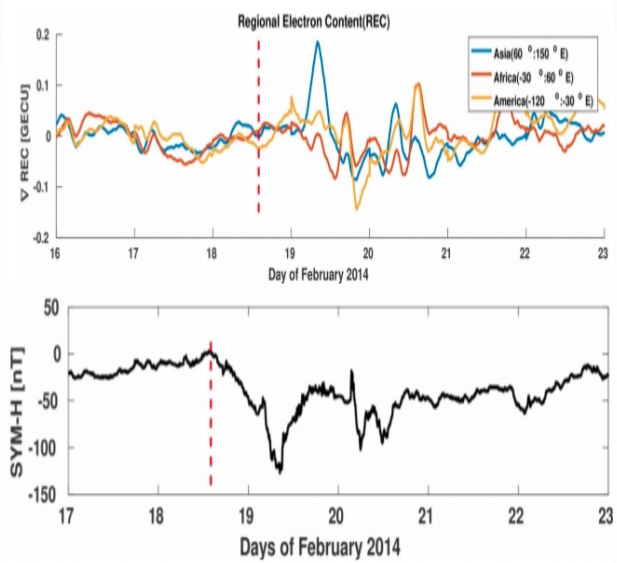




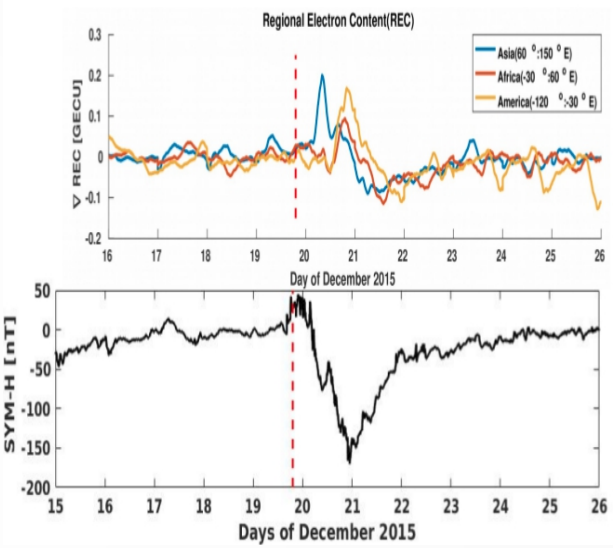
Regional Electron Content



SCC: October 24, 2011 at 18:30 UT
America=morning sector
Africa=evening sector
Asia=mid-night sector

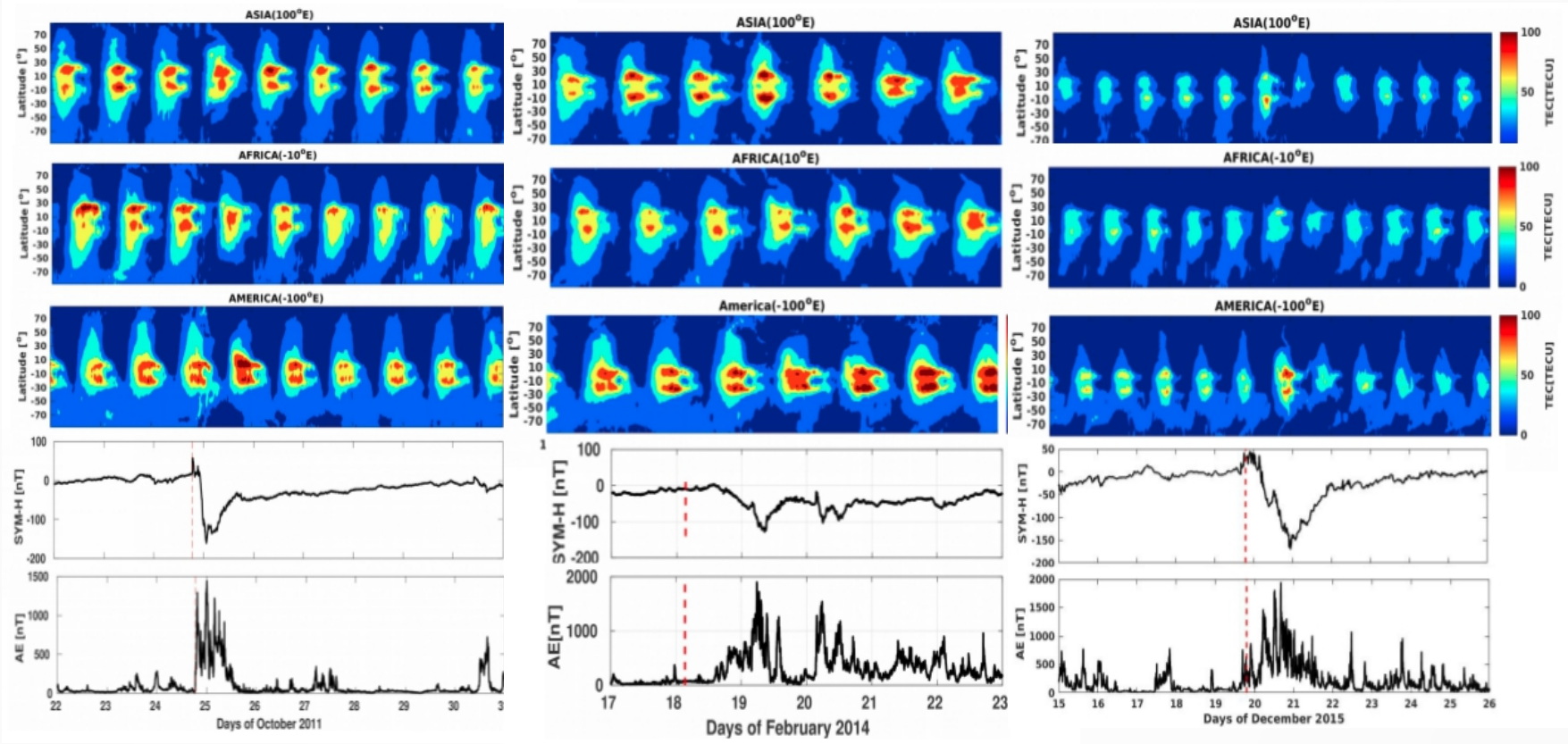


SCC: February 18, 2014 at 14:00 UT
America=morning sector
Africa=noon sector
Asia=night sector

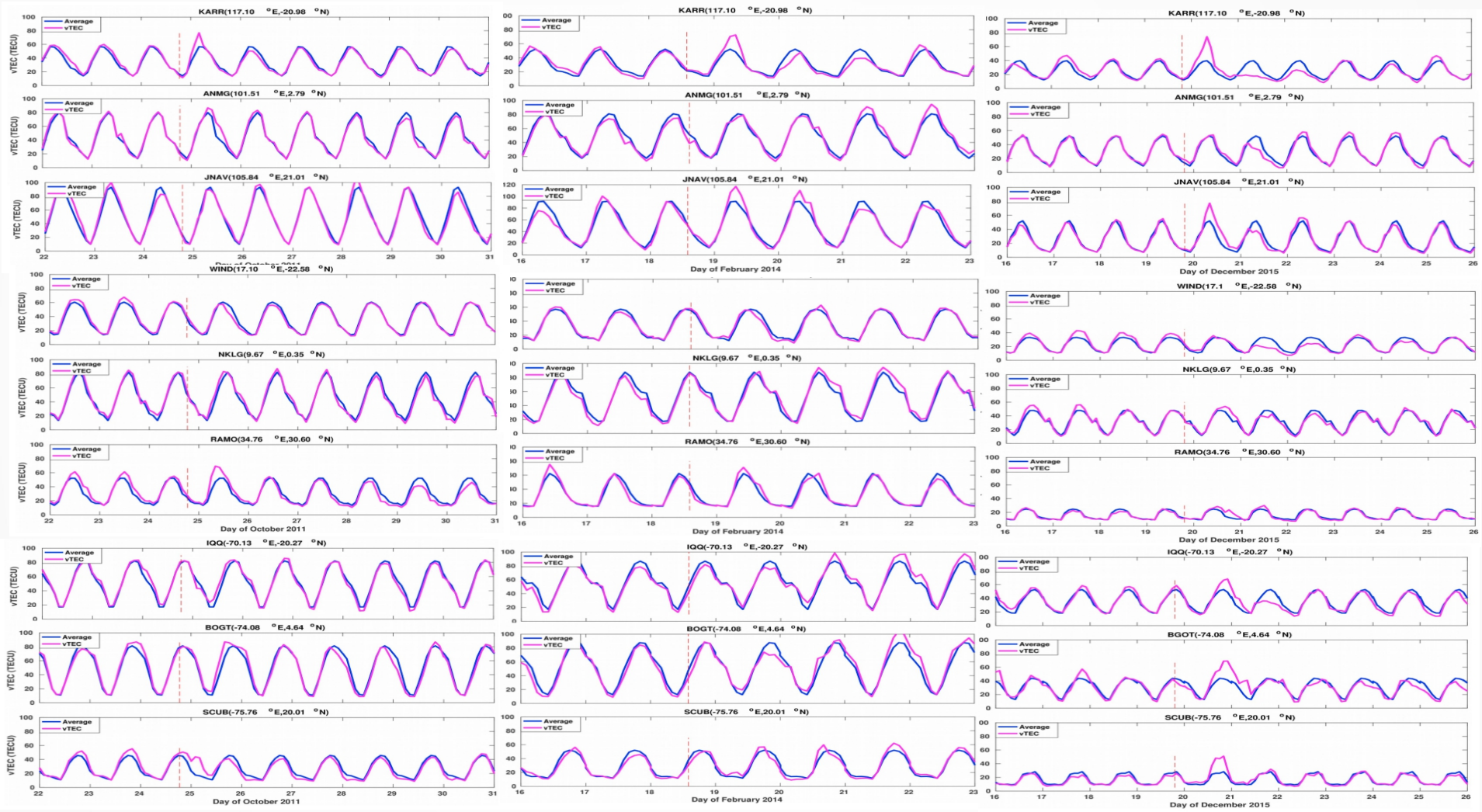


SCC: December 19, 2015 at 16:16 UT
America=morning sector
Africa=noon sector
Asia=night sector

Global Ionospheric Maps

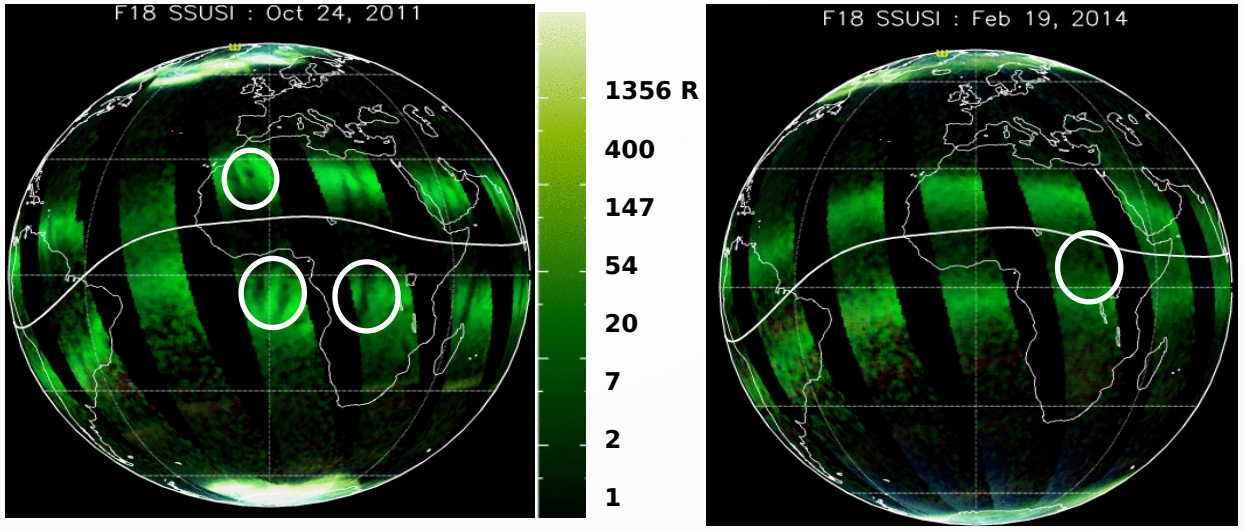


vTEC

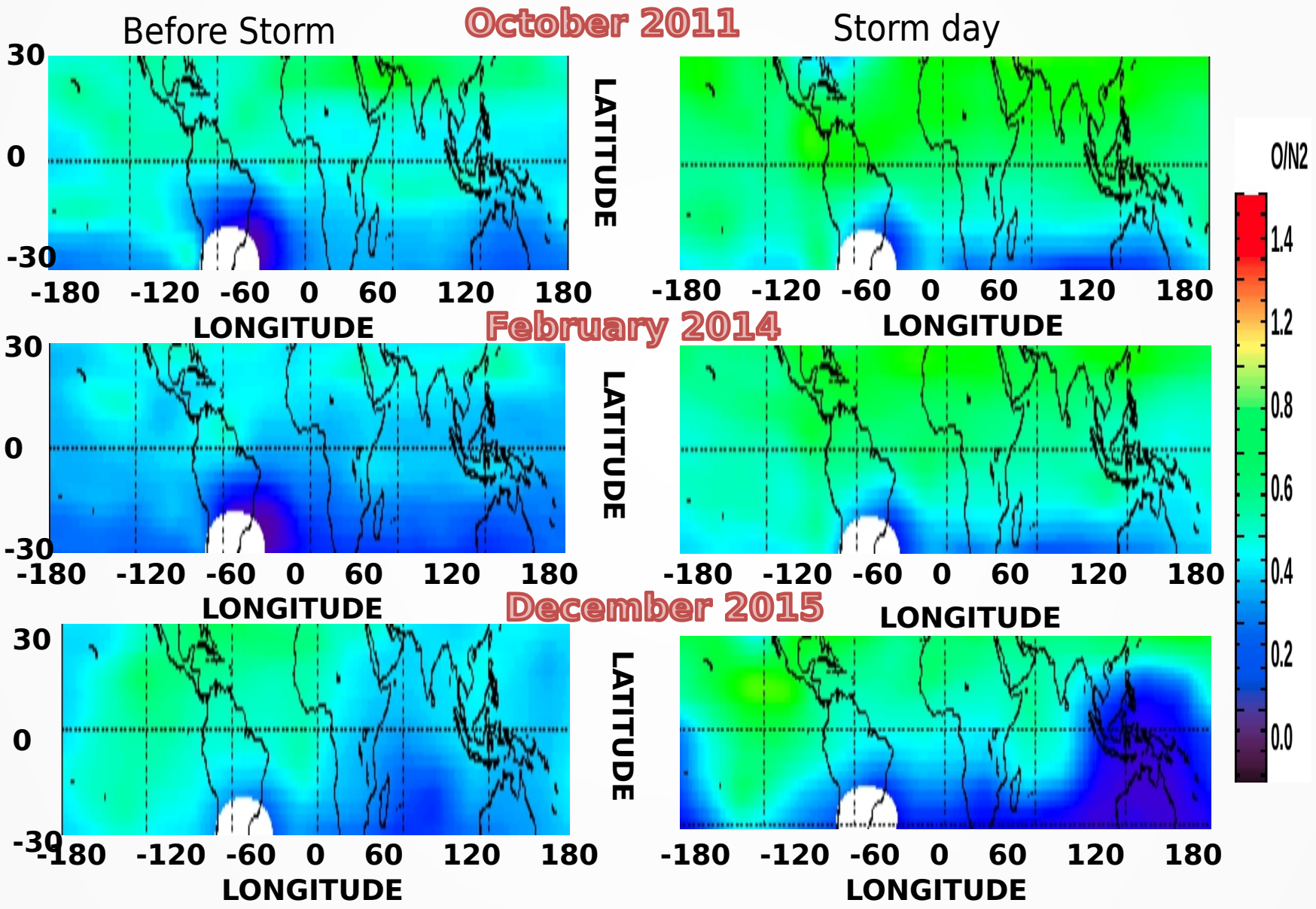

KARR(117.10 °E,-20.98 °N)
ANMG(101.51 °E,2.79 °N)
JNAV(105.84 °E,21.01 °N)
WIND(17.10 °E,-22.58 °N)
NKLG(9.67 °E,0.35 °N)
RAMO(34.76 °E,30.60 °N)
IQQ(-70.13 °E,-20.27 °N)
BOGT(-74.08 °E,4.64 °N)
SCUB(-75.76 °E,20.01 °N)
Average
vTEC
vTEC (TECU)
Day of October 2011
Day of February 2014
Day of December 2015

Plasma Bubble Detection

- EPBs are plasma irregularities that originate in the equatorial ionosphere due to Rayleigh–Taylor instability (RTI) and can propagate to higher latitude ranges (Kelley, 2009).
- Plasma depletion occurs in the form of geomagnetic field-aligned irregularities.
- EPBs also change the local ionospheric electrical conductivity.



O/N2 Composition



Summary

- Multi-instruments observations of the Ionospheric palsma irregularities due to 3 space weather events of the solar Cycle 24 have been presented.
- Both positive and negative storm effects can be seen during these storms.
- Ionospheric electrodynamics and storm thermospheric winds play important role in the storm time effects.

- Future work:
  - Analysis of more space weather events solar cycle 24.
  - ROTI index Analysis
  - Ionosonde Data Analysis
  - Magnetometers Data Analysis for Equatorial Electrojet(EEJ)

Data Sources

- https://omniweb.gsfc.nasa.gov/
- https://igs.org
- https://intermagnet.github.io
- https://ssusi.jhuapl.edu/
- http://guvitimed.jhuapl.edu/

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THANK YOU!