Atmospheric Irregularities over the Equatorial and Low Latitude Region during geomagnetically disturbed and quiet time

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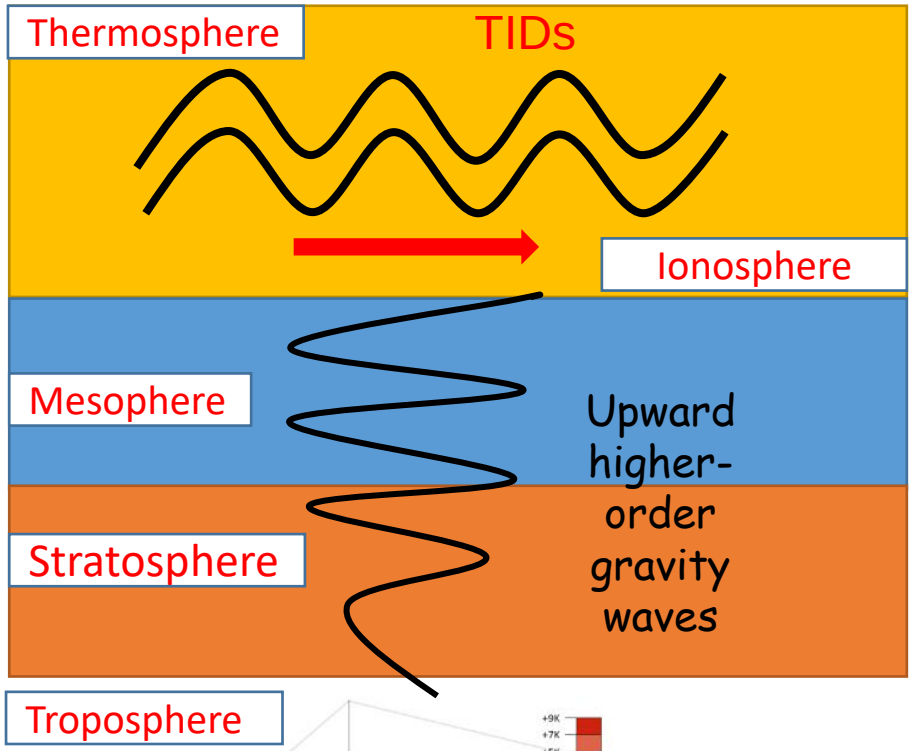
Outline

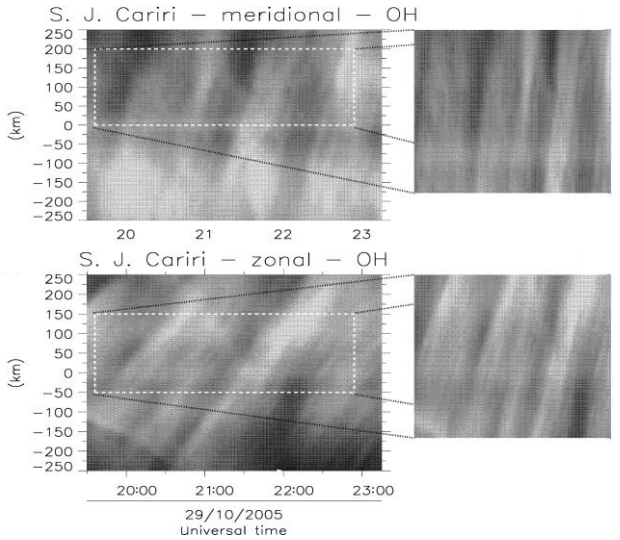
- Equatorial and Low latitude ionosphere
- Ionospheric Plasma Irregularity
- Dst Indices and vTEC
- Conclusion

Equatorial and low latitude ionosphere

- In the equatorial and low latitude ionosphere, there are specific variabilities that are important for the ionospheric weather
- The equatorial and low latitude regions are known to experience significant atmospheric irregularities, particularly in the ionosphere.
- These irregularities can impact communication and navigation systems.
    - Traveling Ionospheric Disturbances (TIDs)
    - Equatorial Plasma Bubbles (EPBs)
    - Equatorial Ionization Anomaly (EIA)
    - Equatorial Spread-F
    - Equatorial Electrojet
- Understanding these phenomena during both geomagnetically disturbed and quiet times is crucial for mitigating their effects.

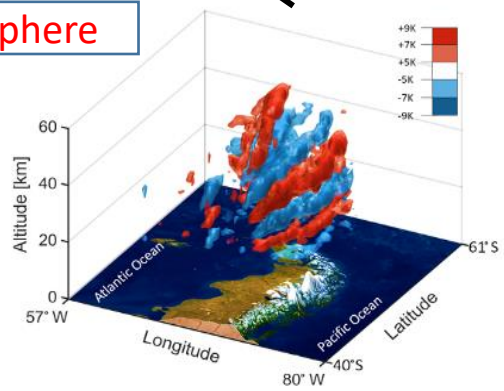
Traveling Ionospheric Disturbances (TIDs)





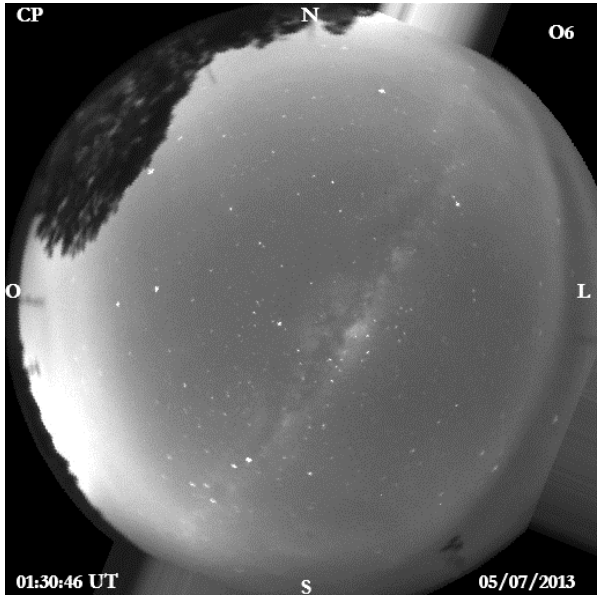
Essien et al., 2018

Source of gravity waves

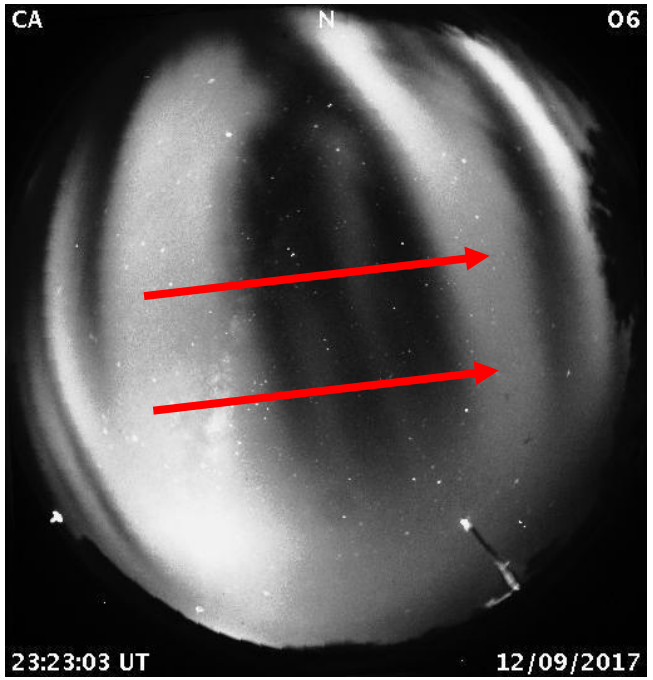


Perturbation Temperature from AIRS – AQUA satellite

Wright et al., 2017

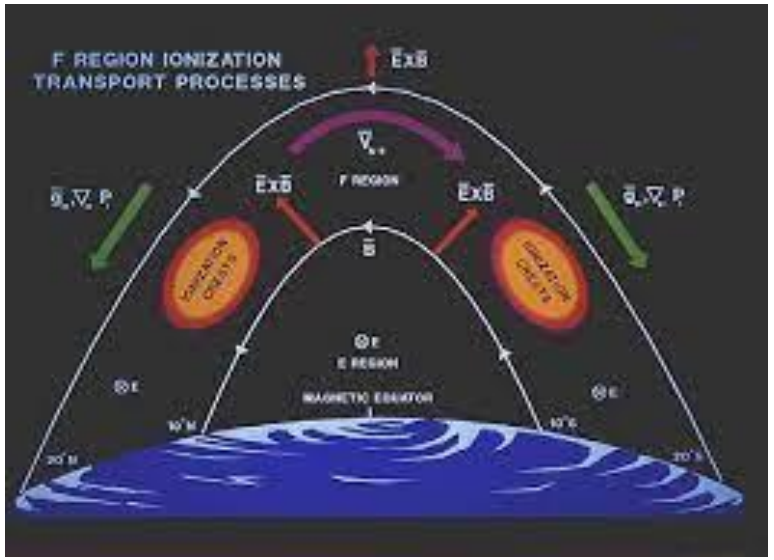


Equatorial Plasma Bubbles (EPBs)



- Plasma bubbles are large-scale irregularities characterized by regions of depleted plasma density in the equatorial and low latitude ionosphere.
- They predominantly occur at night during geomagnetically disturbed times (Abdu et al., 2010).
- Plasma bubbles are formed due to the Rayleigh-Taylor instability in the bottomside of the F-region, causing upward plasma movement and bubble-like structures (Woodman and La Hoz, 1976).
- These irregularities significantly impact radio wave propagation and scintillation effects (Fejer et al., 1999).

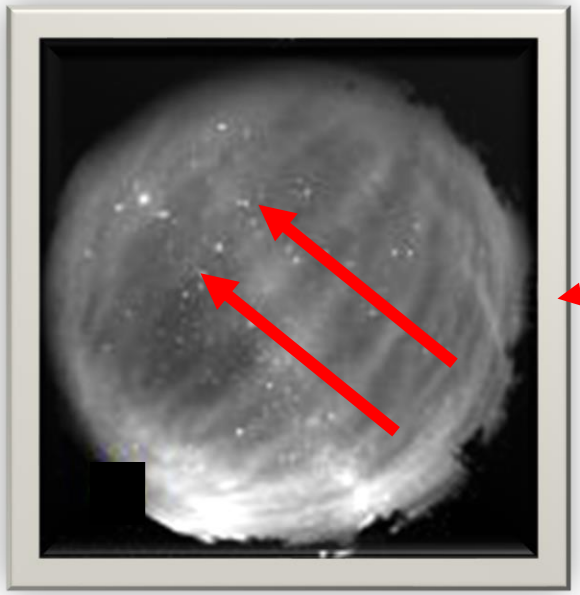
Equatorial Ionization Anomaly (EIA)

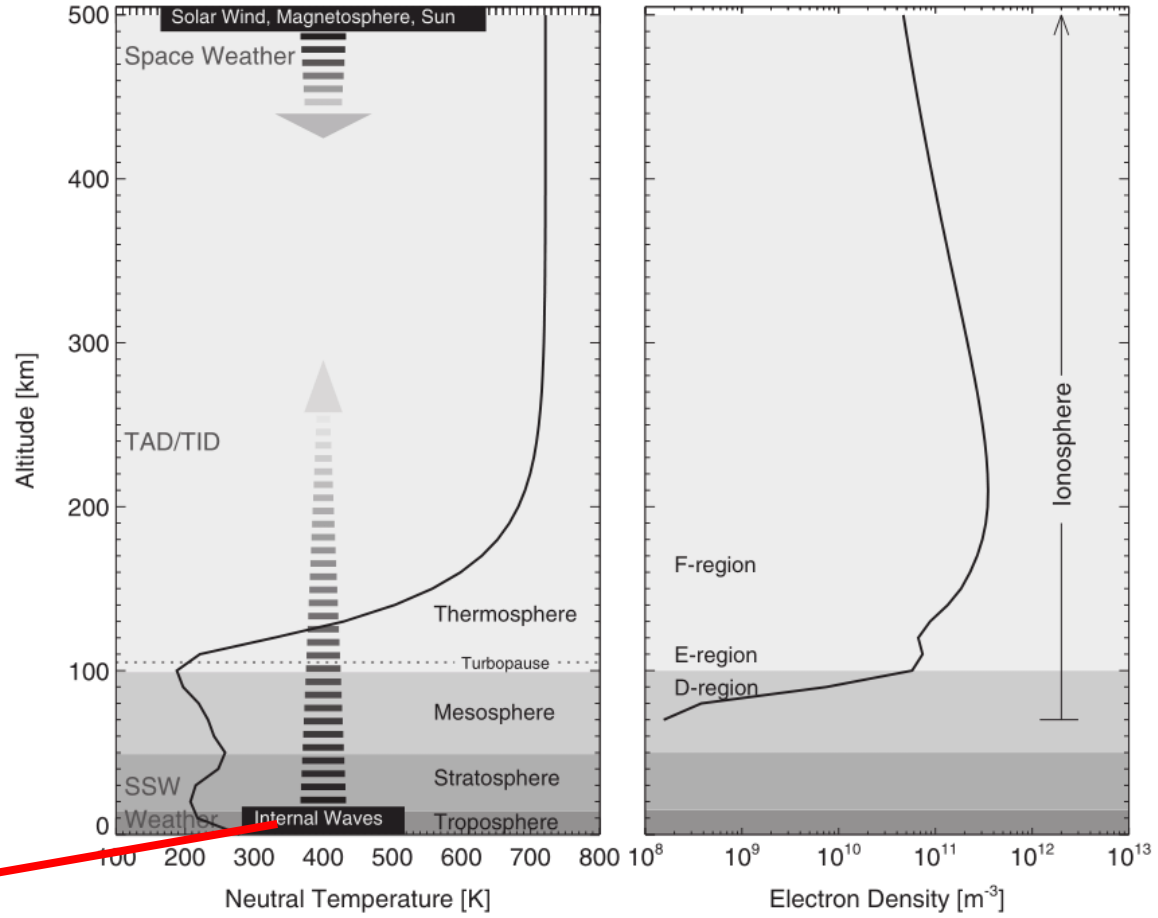


- The equatorial ionization anomaly is a localized enhancement of ionization near the magnetic equator, primarily observed during quiet times.
- It is influenced by the equatorial electrojet and neutral wind-driven ionospheric plasma drift (Kelley, 2009).
- The EIA leads to irregularities in the ionospheric electron density distribution, affecting radio wave propagation (Kelley et al., 2009).

Vertical structure of the atmosphere–ionosphere system

- The neutral atmospheric temperature is shown on the left and the electron density distribution on the right.
- Panels are produced using midlatitude data from MSISE-90 and IRI 2012 models for 1 January 2010 at noon.
- SSW and TAD/TID denote sudden stratospheric warming and traveling atmospheric/ionospheric disturbances, respectively.



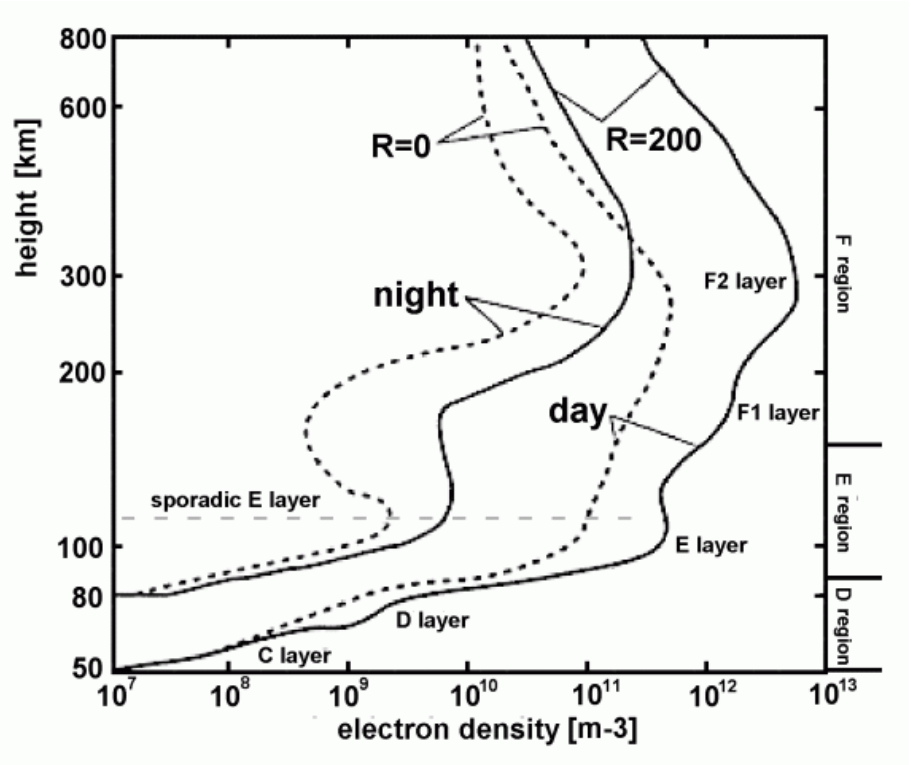


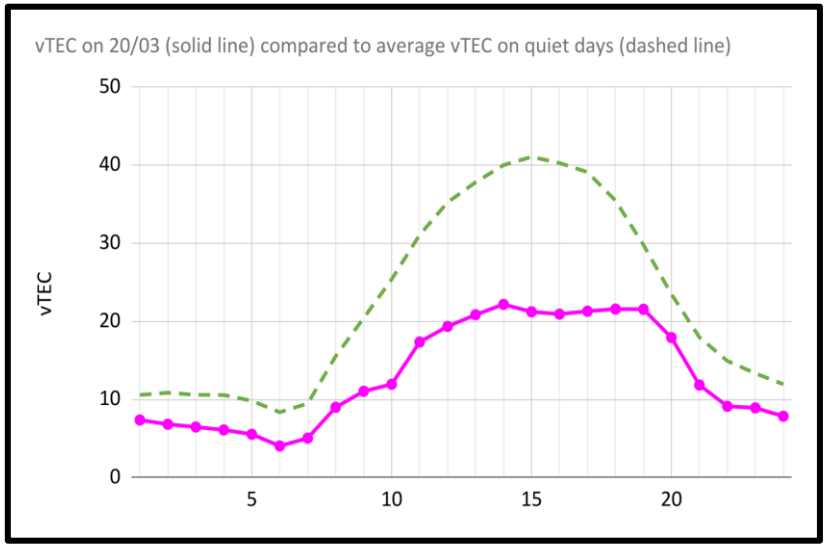
Erdal Yiğit 2015

The Ionosphere: a layered structure

Due to different ionization production and loss processes the electron density profile with altitude shows a layered structure that varies with:

- Time of day
- Day-to-Day
- Seasonal
- Location on Earth
- Solar activity and Space Weather conditions





METHOD

■GNSS TEC MAP

1. Total Electron Content (TEC) is calculated from dual-frequency GNSS data.

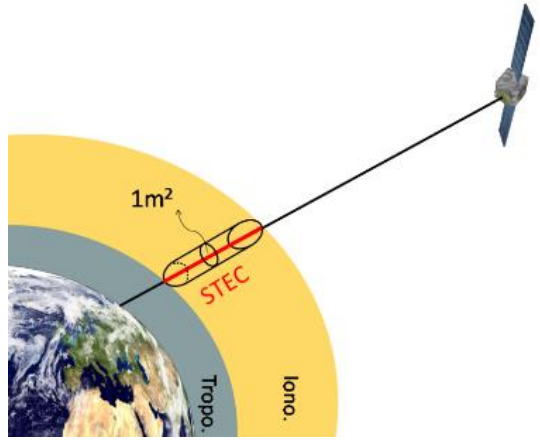
$$TEC = \int_r^s N_e ds$$

2. Slant TEC is converted to vertical TEC.

$$TEC_\Phi = \frac{1}{40.3} \frac{f_{1i}^2 f_{2j}^2}{\left(f_{1i}^2 - f_{2j}^2\right)} \left(\frac{L1}{f_{1i}} - \frac{L2}{f_{2j}}\right) c$$

3. 1-hour running average is subtracted from the original TEC to obtain perturbation component of TEC.

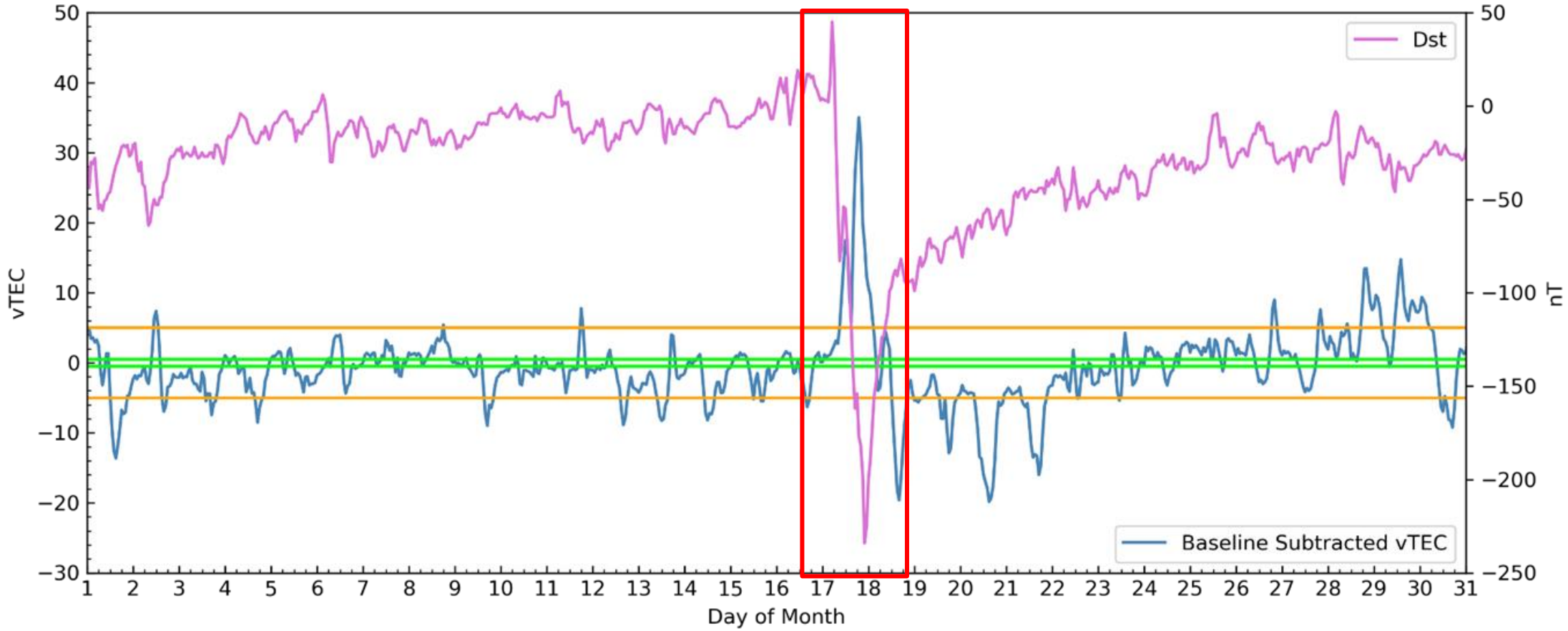
$$dTEC(t) = TEC(t) - \langle TEC(t \pm 30\ \text{min}) \rangle .$$



- The ionospheric delay (I) on GPS signals can be described in terms of TEC, inversely proportional to a square of frequency

$$\Delta^{iono} = \frac{40.3}{f^2} TEC$$

Dst and vTEC of Mar 2015



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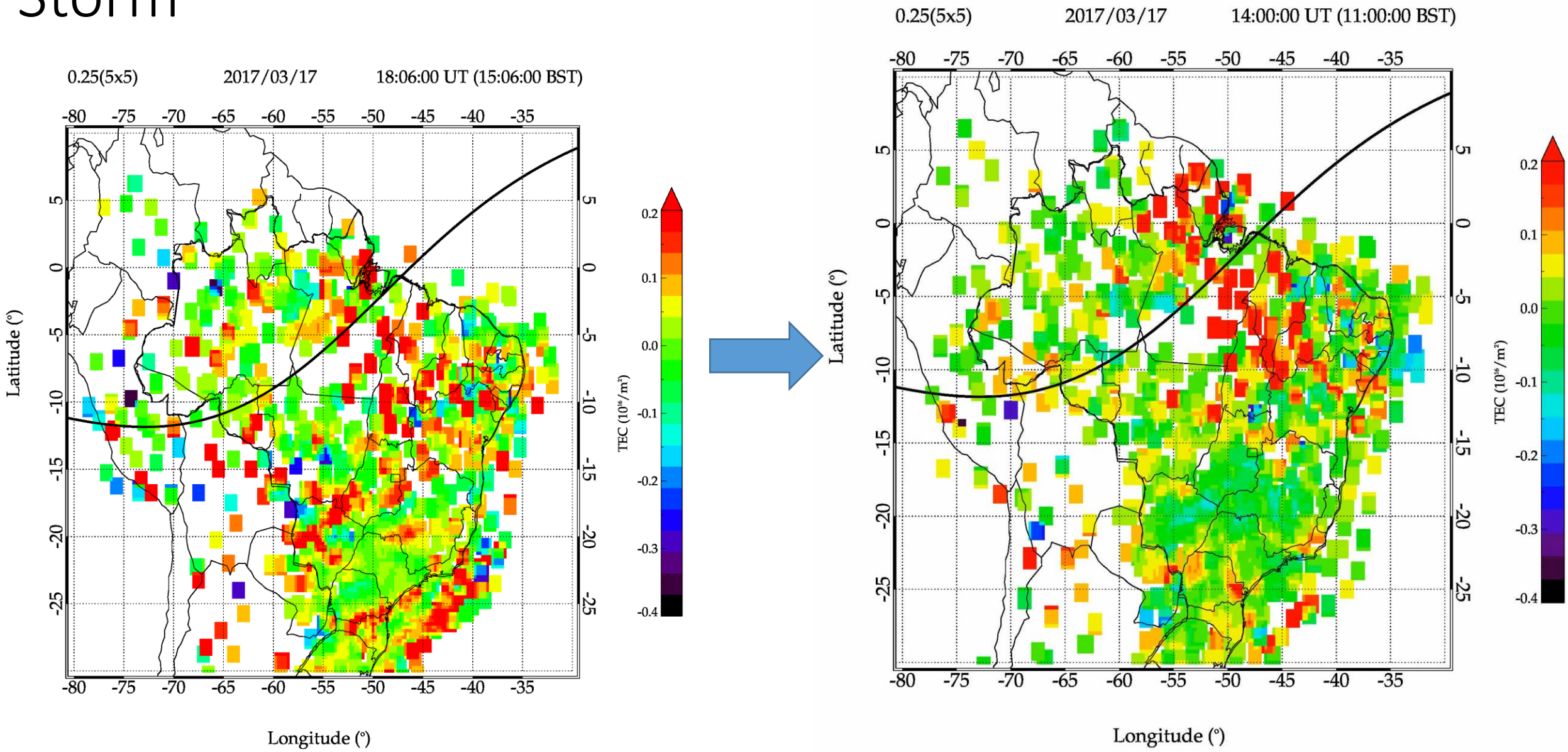
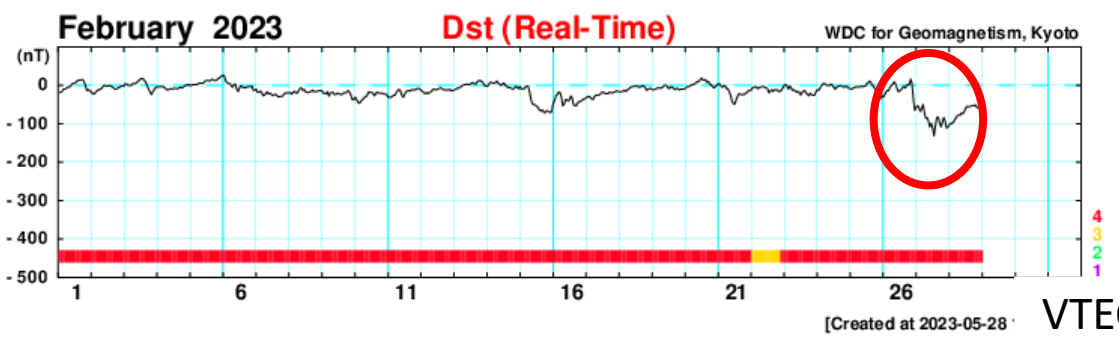
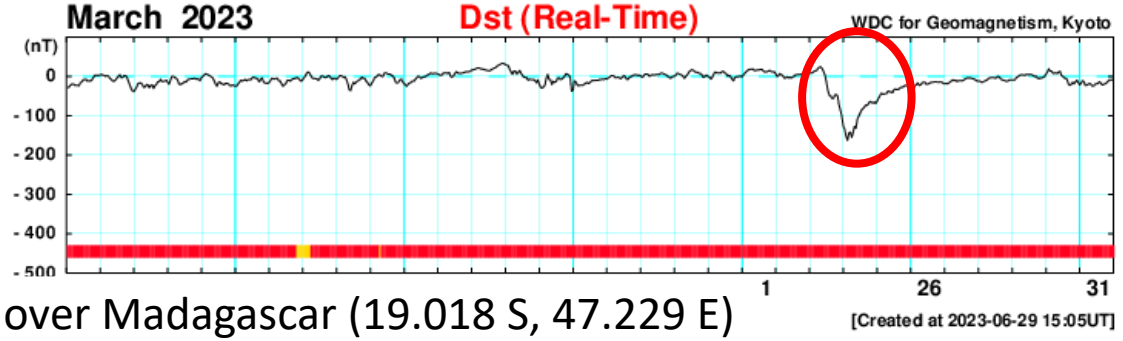
TIDs generated during 2015 St. Patricks day Geomagnetic Storm

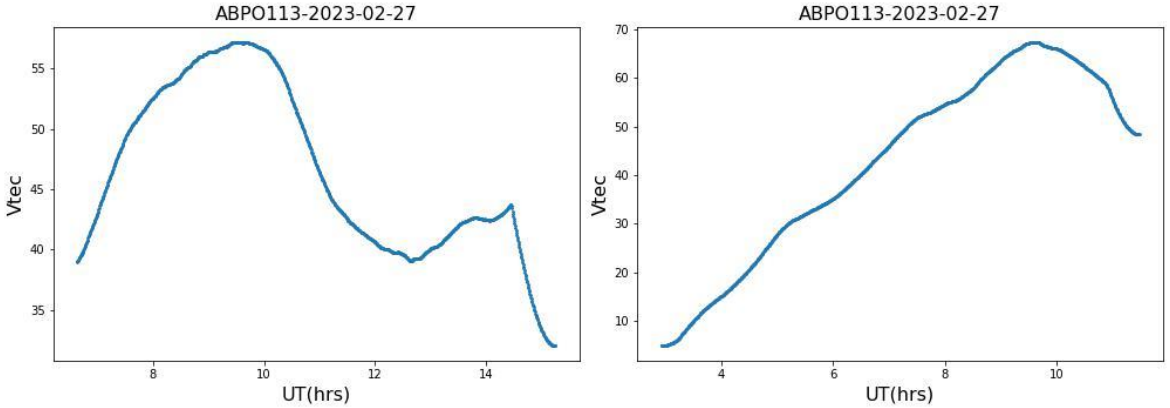


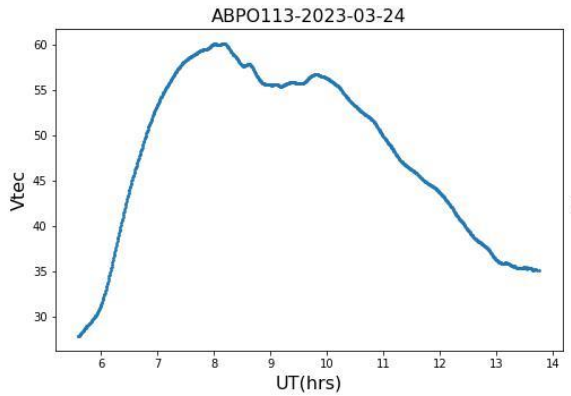
Dst Indices and vTEC over Africa

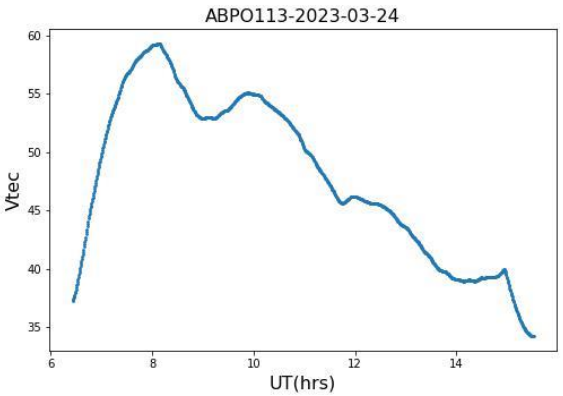


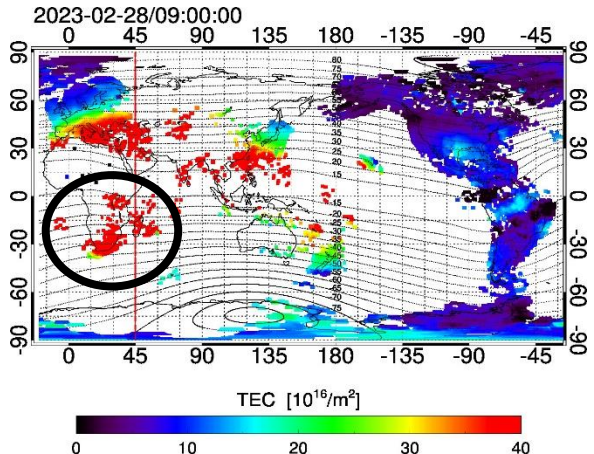


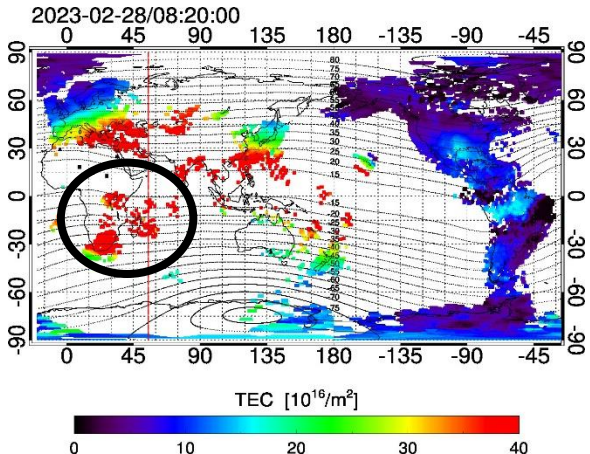
VTEC observed over Madagascar (19.018 S, 47.229 E)

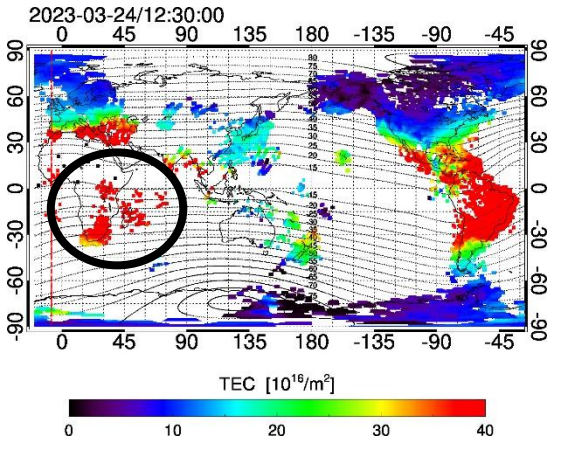


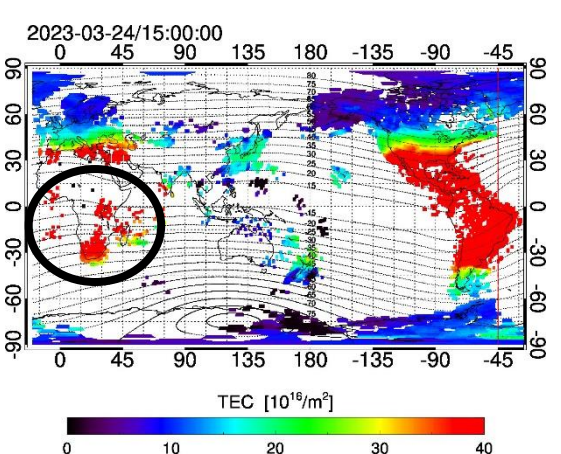




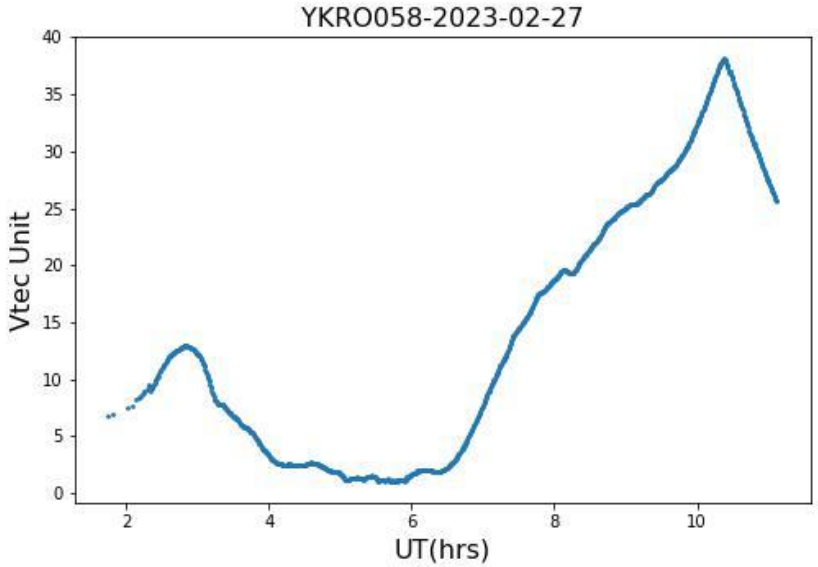


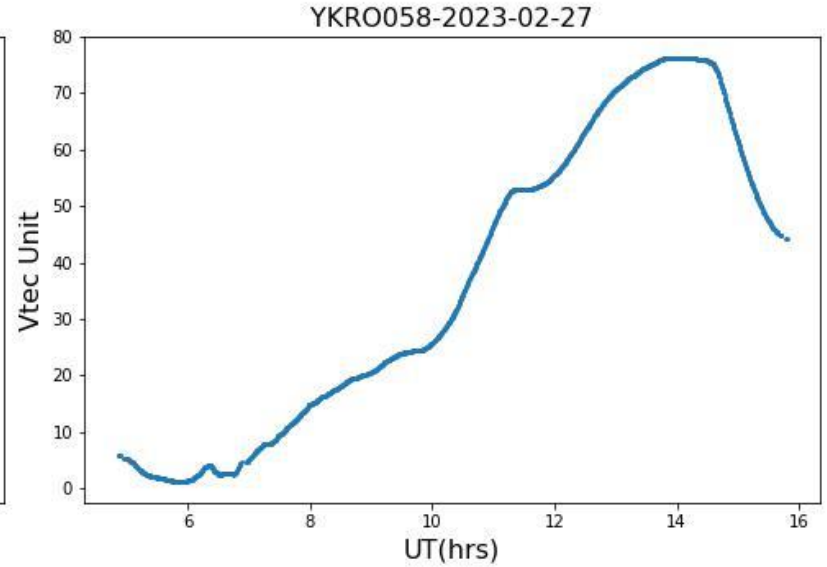


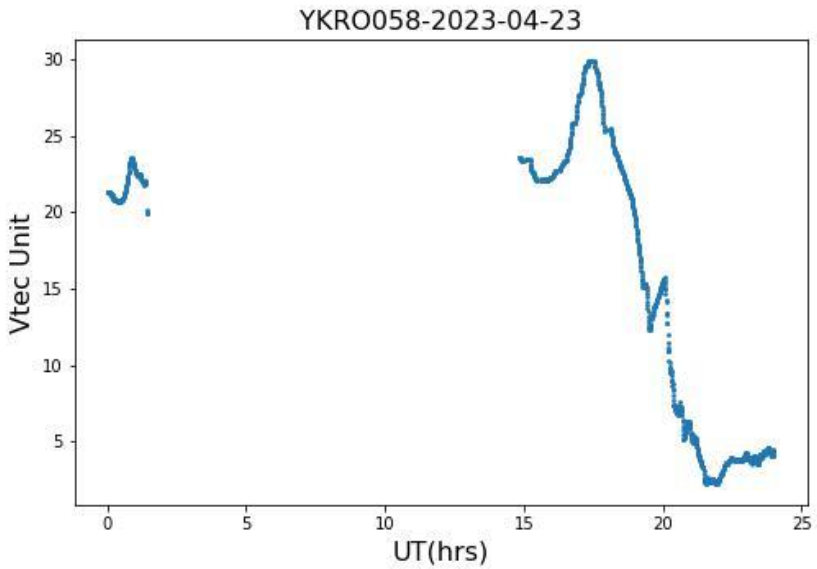


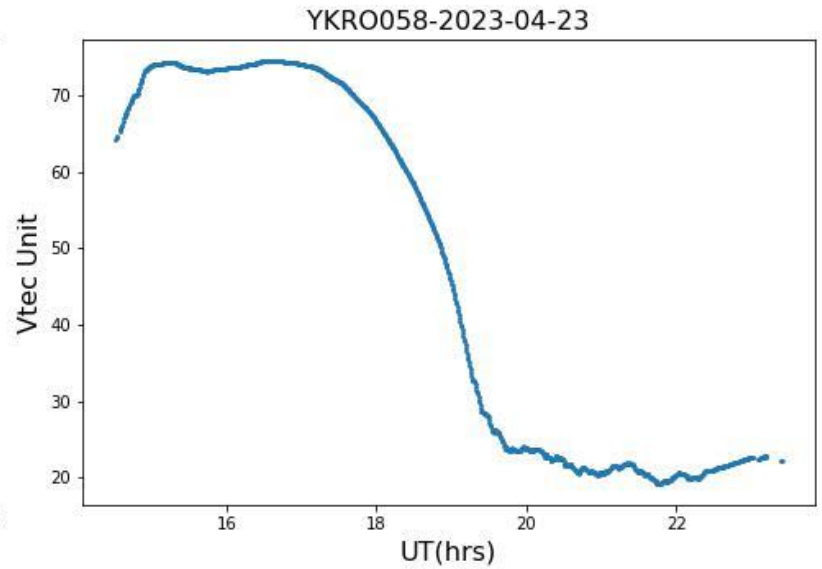


vTEC Profile over Cote d'Ivoire (6.87N, 5.75S)









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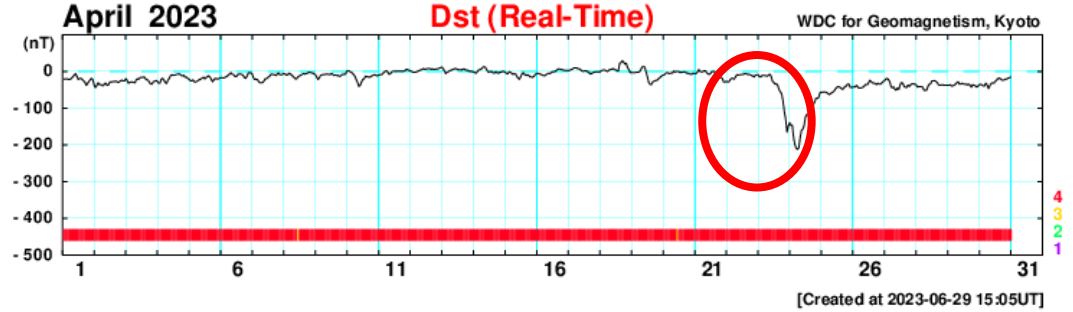

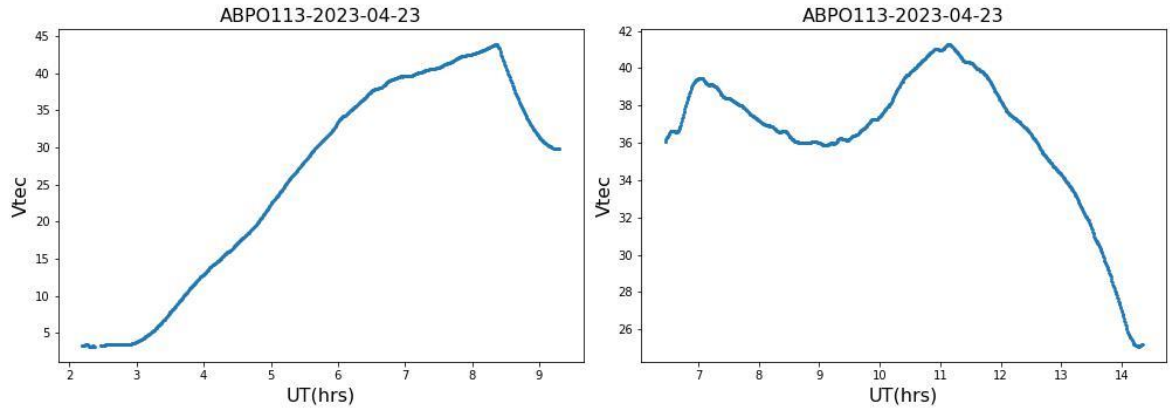

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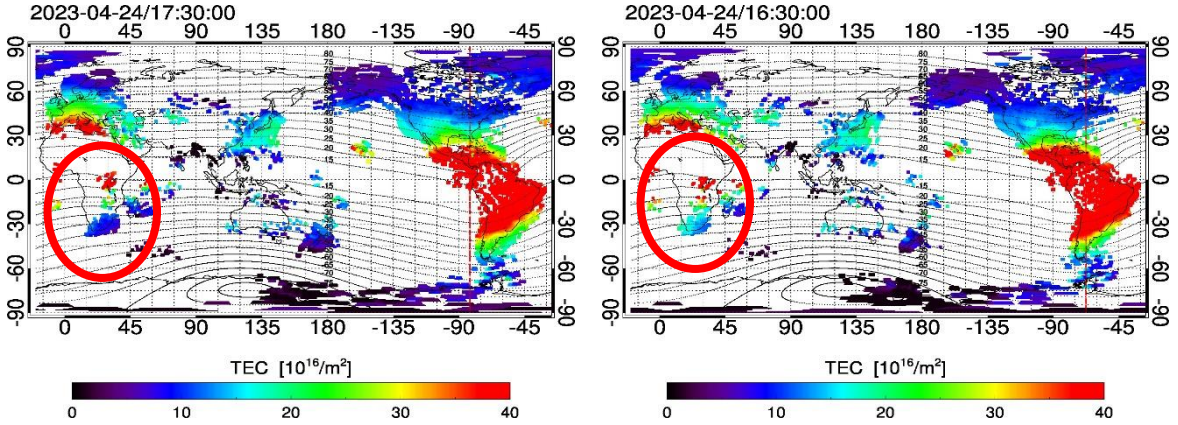
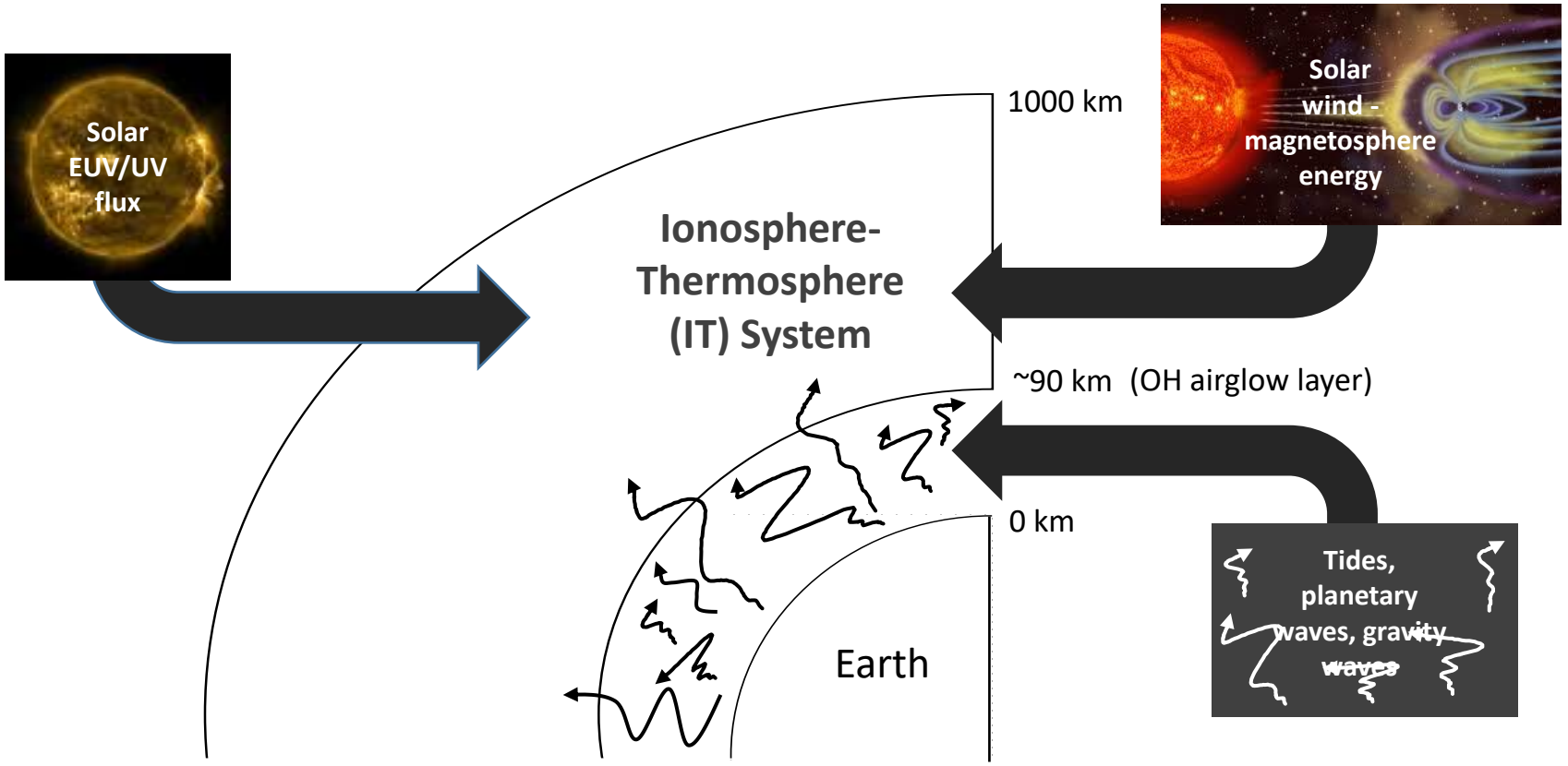


https://stdb2.isee.nagoya-u.ac.jp/GPS/GPS-TEC/GLOBAL/MAP/2023/057/index.html

Drivers of Ionosphere Thermosphere Weather



Courtesy J. Forbes

Conclusion

- High concentration of TEC during geomagnetic storms.
- Ionospheric plasma fluctuations are pronounced during geomagnetic storms.

Acknoweledgement

- ISEE, Nagoya University, Japan for the TEC map.

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