Characteristics of Medium-Scale Traveling Ionospheric Disturbances over the South American Equatorial Region during Solar Cycle 24

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Abstract

Using data collected by GNSS dual frequency receivers network, TEC perturbation maps were generated to identify the presence of MSTIDs over the South American equatorial region during solar cycle 24 (2014 to 2019). The MSTIDs were predominantly observed in winter solstices and equinoxes during daytime. The number of MSTIDs observed decreased with the solar cycle phase from maximum, descending and minimum phase. The horizontal wavelengths of the MSTIDs were concentrated between 300 and 1400 km, with the mean value of 667±131 km. The observed periods were ranging from 20 to 60 min with the mean value of 36±7 min. The observed horizontal phase speeds were distributed around 100 to 700 m/s, with the corresponding mean of 301±75 m/s. The MSTIDs in winter solstice and equinoctial months predominantly tend to propagate northeastward and northwestward. Meanwhile, during summer solstice they propagated in all directions. The anisotropy of their propagation directions could be as result of the source regions and generation mechanism. Atmospheric gravity waves from strong convective sources originated from Amazon region could be a precursor of the northeastward and northwestward propagating MSTIDs during summer solstice and equinoxes. Strong cold front emanating from low latitude could be the precursor of the northeastward and northwestward MSTIDs during winter solstice. In all the seasons, we noted that some oscillations of MSTIDs propagated toward southeast, which could be associated with the Intertropical Convergence Zone (ITCZ) activity.

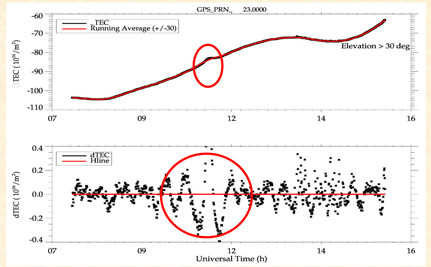
Introduction

- Medium-scale traveling ionospheric disturbances (MSTIDs) are plasma density fluctuations that propagate as waves through the ionosphere at a wide range of velocities and frequencies.
- They havehorizontal phase velocities of hundreds of meters per second (m/s), periods of less than 1 hour, and wavelengths of several hundred of kilometers.
- MSTIDs constitute a specific type of space weather and geophysical phenomenon that can be driven by processes from the solar terminator, geomagnetic storms, tropospheric convection, hurricanes and tornado among others.
- This work aims to characterize day-to-day MSTIDs that propagated over South American equatorial region during solar cycle 24 (2014 to 2019) using GPS and GLONASS TEC perturbation maps.

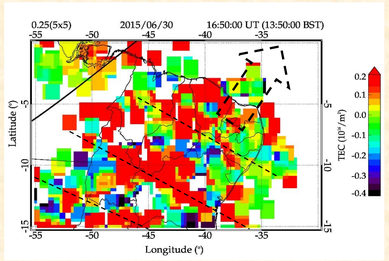
Calculating detrendnd TEC

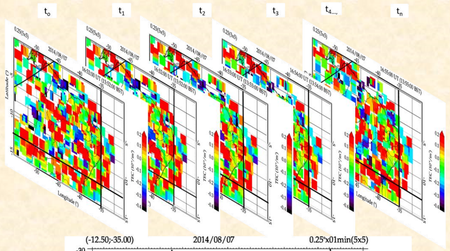
- The perturbation components of TEC (dTEC) were calculated by subtracting the 1 hour running average of TEC(t) from the original TEC(t).

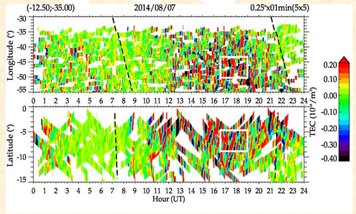
$$\text{dTEC} = TECt - \langle TEC(t \pm 30min) \rangle$$



dTEC map and FFT Spectral Analysis of Keograms



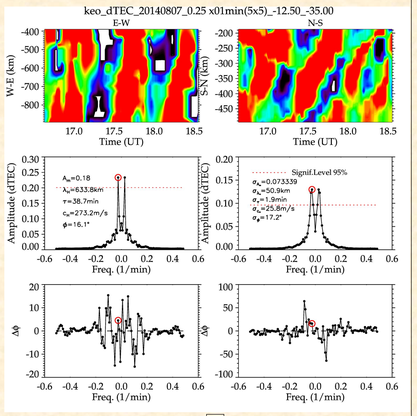




- Series of maps used to produce keogram at longitude 35.0 west and latitude 12.5 south

- TEC perturbation maps in the South American equatorial region.
- The red and the blue colors shows crest and trough of the MSTIDs respectively.
- The MSTID is propagating to northeasward as shown by the arrow .
- The dTEC maps are generate in every one minute at a grid of 0.5 ° and smoothing 0.25°.

FFT spectral analysis of keogram

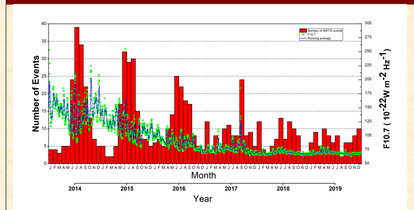


Result

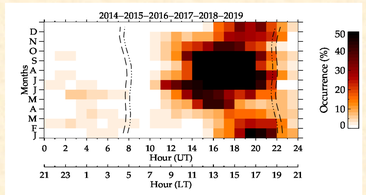
Am =0.18, λ_H = 633.8 km, τ=38.7 min, C_H =273.2 m/s
Φ=16.1°

Where Am= amplitude, λ_H= wavelength, τ= period
C_H= phase velocity and Φ= azumuth

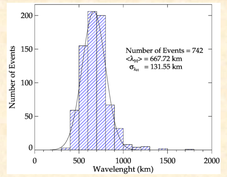
Results



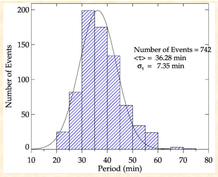
- Solar Cycle 24 dependence on the occurrence rate of MSTIDs over South America equatorial region from January 2014 to December 2019.
- The monthly occurrence rate is indicated with red histogram while the green represent the solar cycle numbers with blue as it's running average of 6 months.



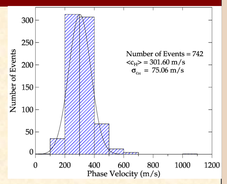
- Time dependence of the observed MSTID.
- .The months are represented by their initials and the dawn and dusk solar terminator are shown at the altitude of 100 km (dotted lines) and 300 km (broken line).



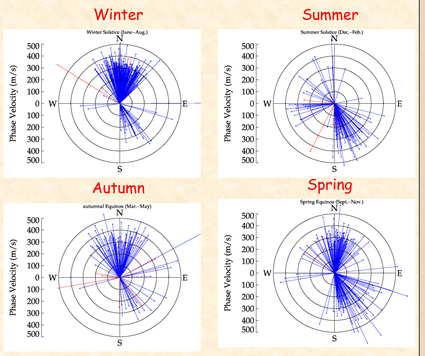
Wavelengths of the MSTIDs



Periods of the MSTIDs



Phase velocities of the MSTIDs



Seasonal variation of the propagation direction of the observed MSTIDs

Summary

- Total number of 742 MSTIDs were observed from January 2014 to December 2019 with ~70%, 25% and 5% of the events occurred during the daytime, dusk and nighttime.
- The daytime MSTID activities decrease with the solar cycle.
- The winter, summer, autumn and spring events are 329, 106, 125 and 182.
- High MSTIDs activity in winter during daytime and almost disappears during summer.
- The wavelenght ranges from 300-1400km with mean of 667±131 km, phase velocity between 300-700 m/s with mean of 298±69 m/s and the period ranges from 20-60 min with mean of τ = 36±7min
- Possible sources mechanisms: Intertropical Convergence Zone (ITCZ) for Southward, Cold front for the Northward, northeastward, northwestward during winter, and convection in summer, autumn and spring.
- We recommend thorough work into ITCZ and MSTID relation including ray tracing.