Evaluation of the mid-latitude ionospheric trough using high-resolution IGS GIMs maps

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Motivation and Background

The ionospheric mid-latitude trough (MIT) is a phenomenon characterized by a depletion in electron density in the F-layer of the ionosphere within the sub-auroral zone. MIT typically occurs at geomagnetic latitudes of 50–70° during the nighttime from 18:00 to 6:00 local magnetic time. Solar activity, longitude, geomagnetic activity, and magnetic local time also influence the position of MIT. The trough's latitudinal width varies between 5° and 17°. MIT is typically observed at higher latitudes during the afternoon and moves closer to the equator as local time progresses. Additionally, it is more prominent during the December solstices and equinoxes compared to the June solstices. In this study, we identify and describe the mid-latitude ionospheric trough using high - resolution IGS (International GNSS Services) GIMs Maps– UQRG, which provide temporal resolutions as fine as 15 minutes. Our study is based on an extensive database obtained by detecting troughs between 1998 and 2023, covering two complete solar cycles, cycles 23 and 24.

Database

➤ high-resolution IGS GIMs maps – UQRG (every 15 minutes with a 5 ° longitude and 2.5° latitude spatial resolution)
➤ period of 26 years (1998 -2023, two complete solar cycles)
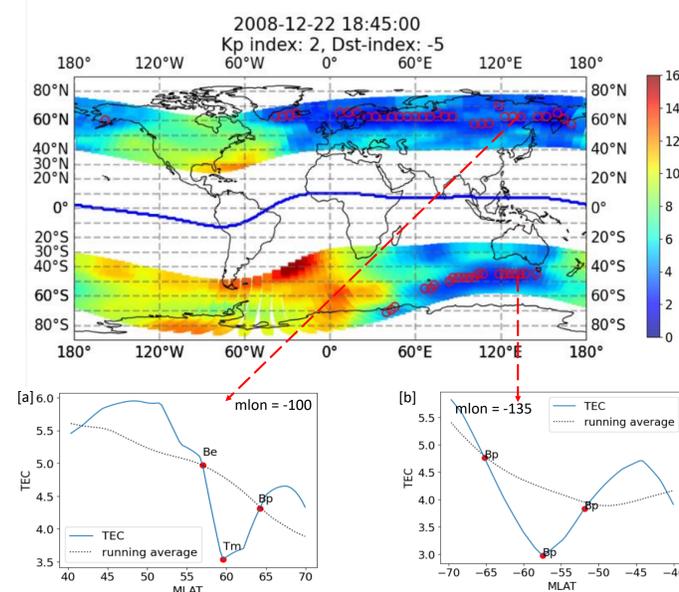
Figure 1. Examples of IGS TEC map with area between 40 and 70 magnetic latitudes for the Northern and Southern hemisphere. The blue line correspond to magnetic equator. The red circles determine the detected trough position.

Figure 2. Examples of IGS TEC profiles for Northern hemisphere [a] and for Southern hemisphere [b].

Method

The detection algorithm comprises the following steps:

1. TEC profile data are taken within the magnetic latitudes of 40°–70° in both hemispheres and interpolated with a step of 0.37°.
2. The background TEC is calculated as a running average of the TEC in a sliding window of 48 data points.
3. We considered a threshold value of –0.1 detrended log_{10} (TEC)
4. Detection of MIT characteristic points: Tm, Be, Bp, He, Hp.
5. Applying a trough width filter (1° to 17°)
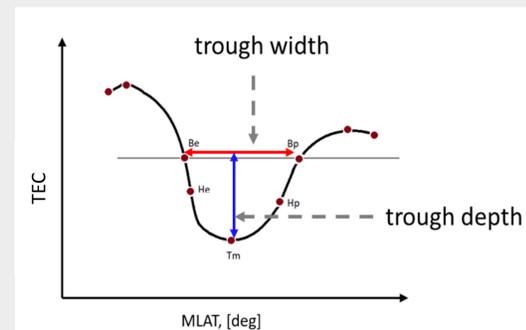
20 million profiles are detected with MIT signature with parameters such as trough minimum, trough width and trough depth.

Figure 3. Schematic diagram of the MIT characteristic points.

Results
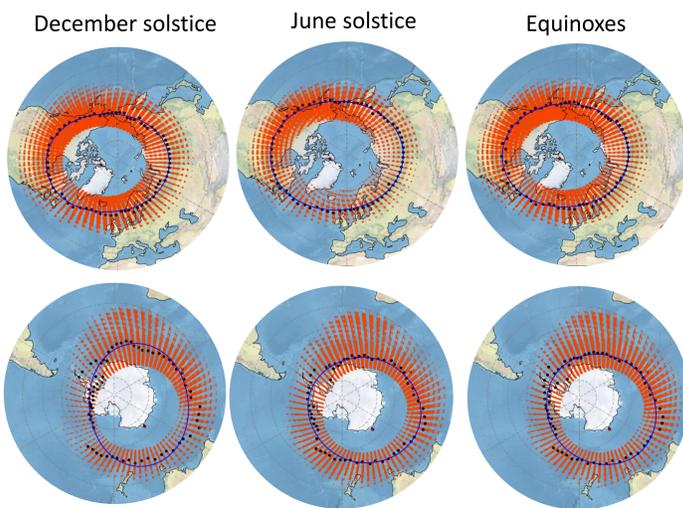
Figure 4. Ellipse distribution of the mean position of trough minimum
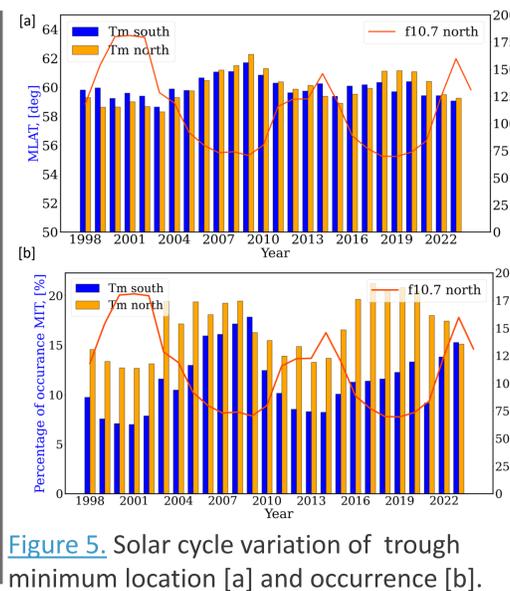
Figure 5. Solar cycle variation of trough minimum location [a] and occurrence [b].
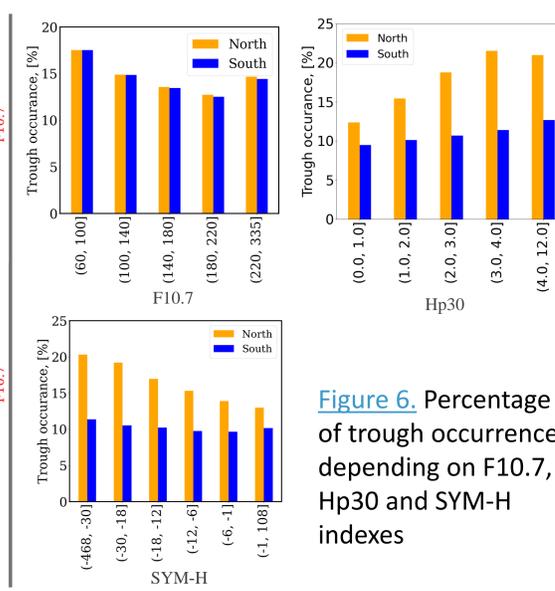
Figure 6. Percentage of trough occurrence depending on F10.7, Hp30 and SYM-H indexes
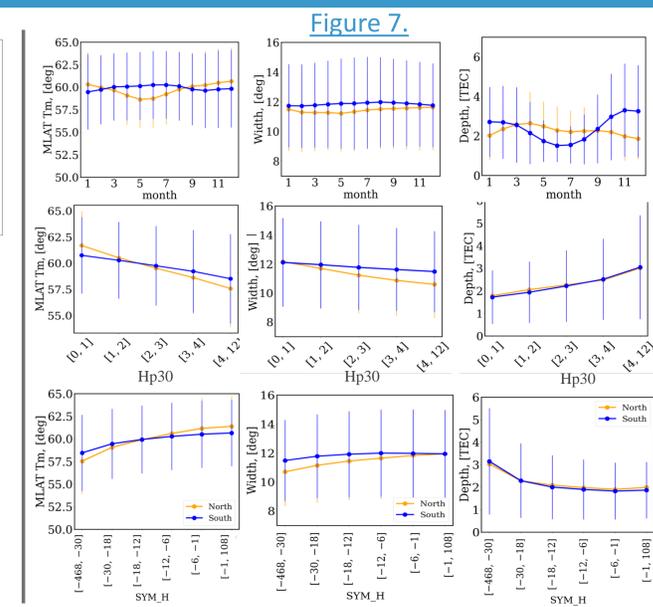
Figure 7.

Conclusion

Our analysis confirms previous MIT studies and contributes to the current state of knowledge about the dependence of MIT on geophysical conditions. The MIT model validation process and the creation of new MIT models can benefit from the knowledge gathered in this study regarding MIT dependence and occurrence probability.

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