Solar activity and its impact on the mid-latitude trough during geomagnetic storms

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ABSTRACT

Mid-latitude trough (MIT) is the distinct structure of depleted plasma density observed in Earth's ionosphere at high latitudes especially at the nighttimes. The phenomenon is observed at both hemispheres. As it resides at the topside ionosphere in the sub-auroral region, its behaviour and properties are highly sensitive to the solar and geomagnetic activity. Generally as the geomagnetic activity is more pronounced the MIT is observed at lower latitudes, it also deepens and becomes much more distinct in comparison to the low magnetic activity periods. MIT responds as well to the rapid changes in geomagnetic conditions, as are the geomagnetic storms, mainly caused by the CMEs. Based on the observations gathered by DEMETER data between 2005 and 2010 years we present a set of geomagnetic storm cases and how the MIT properties have been changing as the storm evolved. We also discuss how it corresponds to the current solar activity and their evolutionary history described by a set of different parameters.

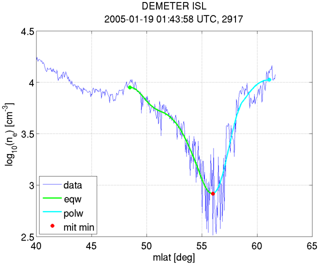

Figure 1: MIT and it's parameters: blue line represents observational data, electron density in log10 scale plotted against the magnetic latitude presented in degrees. Green line is a smoothed line of an equatorial wall with the green circle marking its beginning-edge. Cyan line is a smoothed line of a polar wall with its edge marked with cyan circle. Red circle is the position of the MIT minimum.

MIT VS GENERAL MAGNETIC CONDITIONS

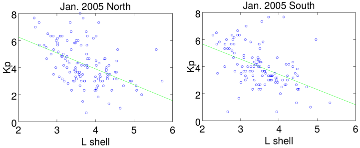

Figure 2: Correlation between the MIT position (represented by the L shell value - magnetic field line) and Kp index values (left: Northern hemisphere, right: Southern hemisphere). Data from January 2005, DEMETER ISL experiment.

MIT location depends mainly on the geomagnetic activity and magnetic local time.

For the fixed local time, the correlation between MIT position and geomagnetic activity is still positive. Kp index, which reflects daily mean magnetic field deviations, is a good representation of the general magnetic activity conditions. For quiet conditions Kp index is small, whereas for active periods Kp index increases. Figure 2 shows the relation between the trough position in the L shell and the Kp index.

For low Kp values (quiet conditions) MIT is observed at larger L shell values (higher latitudes) and with increasing geomagnetic activity moves to lower L shell values (equatorward, or lower latitudes).

MIT DURING GEOMAGNETIC STORM I

The trough properties change accordingly to the geomagnetic storm phase. In particular it moves equatorward with the storm onset, and as the storm develops it narrows and deepens. This is because during the geomagnetic storm, the entire magnetosphere gets compressed by the increased pressure of the Solar Wind. Regions with increased ionization from auroral areas move equatorward filling the trough, which in effect becomes narrower. In September 2017 complex geomagnetic event has been observed. The main phase started around 23 UTC on 7th September, followed by the second peak around 10 UTC on 8th September. Then two Dst minima occurred at 01 UTC -142 nT on 8th September and at 17 UTC on 8th September -122 nT.

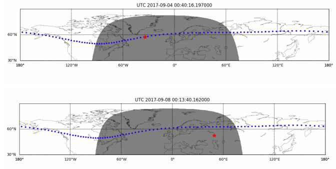

Figure 3: MIT position on 04.09.2017 and during the storm on 08.09.2017. Data obtained from Swarm mission.
(animation works in Adobe Reader)

Another example of the storm occurred in 2005 between 7th and 11th of January, when Dst reached its minimum value of -93nT on 8th January. Gradients on both hemispheres get visibly steeper during the main phase of the storm, and their values fluctuate in the recovery phase.

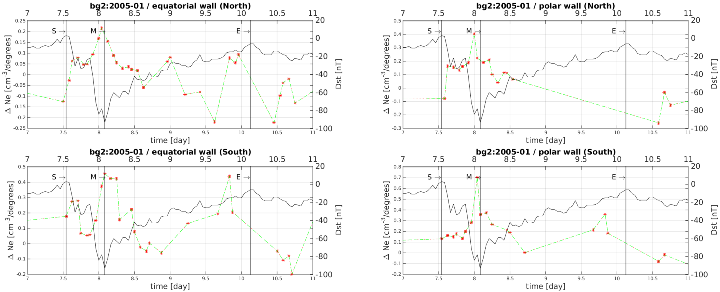

Figure 4: Gradients on the MIT walls during the storm observed on both hemispheres.