TEC disturbances caused by CME-triggered geomagnetic storm of September 6-9, 2017

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Introduction

Coronal Mass Ejections (CMEs) are significant expulsions of plasma and magnetic fields from the sun's corona that have a significant impact on the Earth's magnetosphere [1]. These solar phenomena can cause geomagnetic storms, which disrupt the Earth's magnetic field. The relationship between CMEs and geomagnetic storms is crucial, as they alter the distribution of Total Electron Content in the Earth's ionosphere, impacting communication, navigation, and power grid operations [2]. A September 2017 geomagnetic storm showed significant differences in TEC distribution, with middle latitude stations experiencing 8-10 TECU increases, while low latitude stations saw 15-16 TECU increases [3].

Data and methods

Data Sources:

- TEC data: Obtained from GPS stations at low, mid, and high latitudes.
- Geomagnetic Indices and Solar Wind Data: Retrieved from OMNIWeb (Dst, Kp, AE indices, IMF Bz, IEF Ey, and solar wind speed).
- Magnetic Field Data: Collected from INTERMAGNET.

Analysis Approach:

- TEC Variation: Computed as dTEC (difference between storm-time and quiet-time TEC), which is estimated using the relation:

$$dTEC = \frac{TEC_s - TEC_{median}}{TEC_{median}} \quad (1)$$

where TEC_s is the TEC during the storm period (September 6–9) and TEC_q is the median of the TEC during the quiet periods of the September month.

- Magnetic Field Response: ΔH is calculated to track geomagnetic disturbances. First, we computed H using,

$$H = \sqrt{X^2 + Y^2} \quad (2)$$

- From 2, the baseline value (the average of the night time (23:00-02:00 LT)) is computed as follows:

$$H_o = \frac{H_{23} + H_{24} + H_{01} + H_{02}}{4} \quad (3)$$

- Finally, ΔH is computed using,

$$\Delta H = H(t) - H_o \quad (4)$$

- PPEF: This ionospheric electric fields is obtained from IEF Real-time Model.

Geographical locations of the study

Code	Lat.	Long.	LT
ALIC	23.67°S	133.88°E	UT+9:00
MAW1	67.67°S	62.87°E	UT+4:00
CZTG	46.46°S	51.85°E	UT+3:00
DODM	6.18°S	35.74°E	UT+2:00
GNG	31.36°S	115.72°E	UT+9:00
KIRU	67.9°N	20.9°E	UT+1:00
HYDE	17.41°N	78.55°E	UT+5:00
SBL	43.93°N	299.99°E	UT+5:00
HNLC	21.30°N	157.87°W	UT-11:00
BOU	40.05°N	105.16°W	UT-7:00
CHUR	58.76°N	94.08°W	UT-6:00

Table 1. Geographical location of the selected stations.

Results

Geomagnetic indices variations:

- X9.3 flare on September 6 was the most intense. CME from this flare caused significant Earth's magnetosphere disturbance.

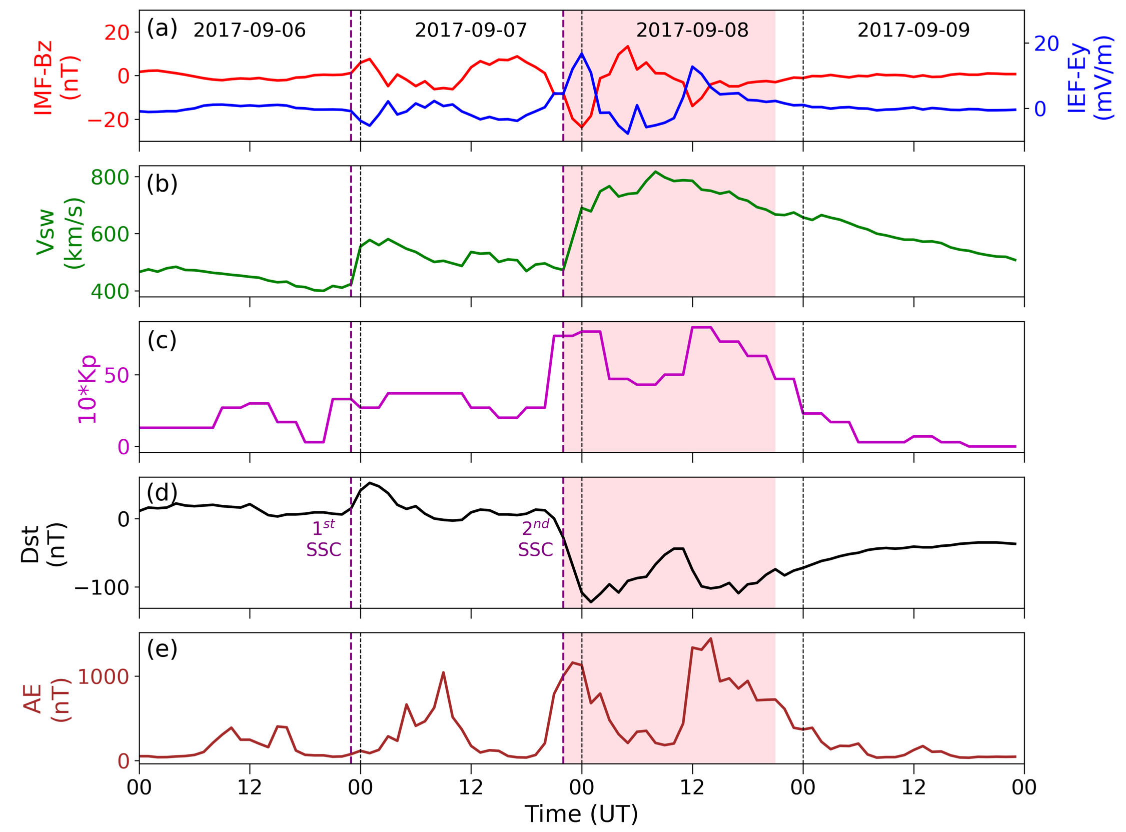

Figure 1. Variation on solar wind parameters and geomagnetic indices during the storm period of 6-9 September 2017. The top-to-bottom panels labeled from (a) to (e) represent IMF-Bz and IEF Ey, Vsw, Kp-index, Dst index, and AE index, respectively.

Variations of geomagnetic field component:

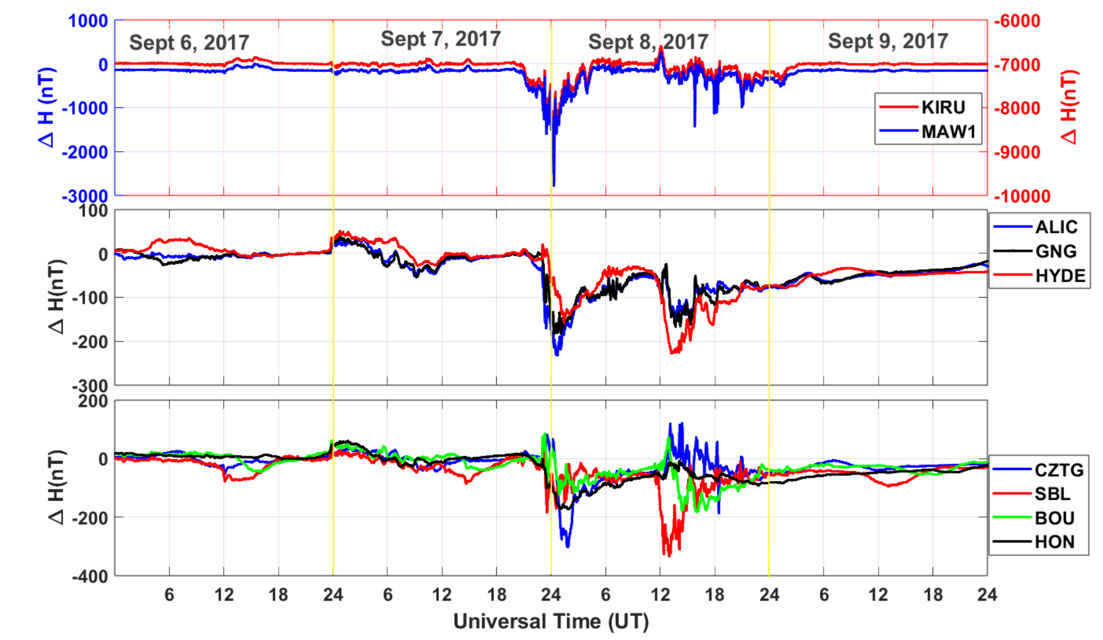

Figure 2. Variations of ΔH at different stations during September 6-9, 2017 geomagnetic storm.

- KIRU and MAW1 stations shows a drastic drop in ΔH exceeding -2000 nT at MAW1, whereas KIRU shows a simultaneous strong decrease, but with different amplitude.
- The middle and bottom panels show more localized variations, with stations experiencing disturbances with varying magnitudes but a common trend of sudden decrease followed by gradual recovery.
- These differences are expected due to geomagnetic latitude effects; high-latitude stations generally experience stronger disturbances due to direct interaction with geomagnetic currents.

Scan me!

Deviation TEC variation

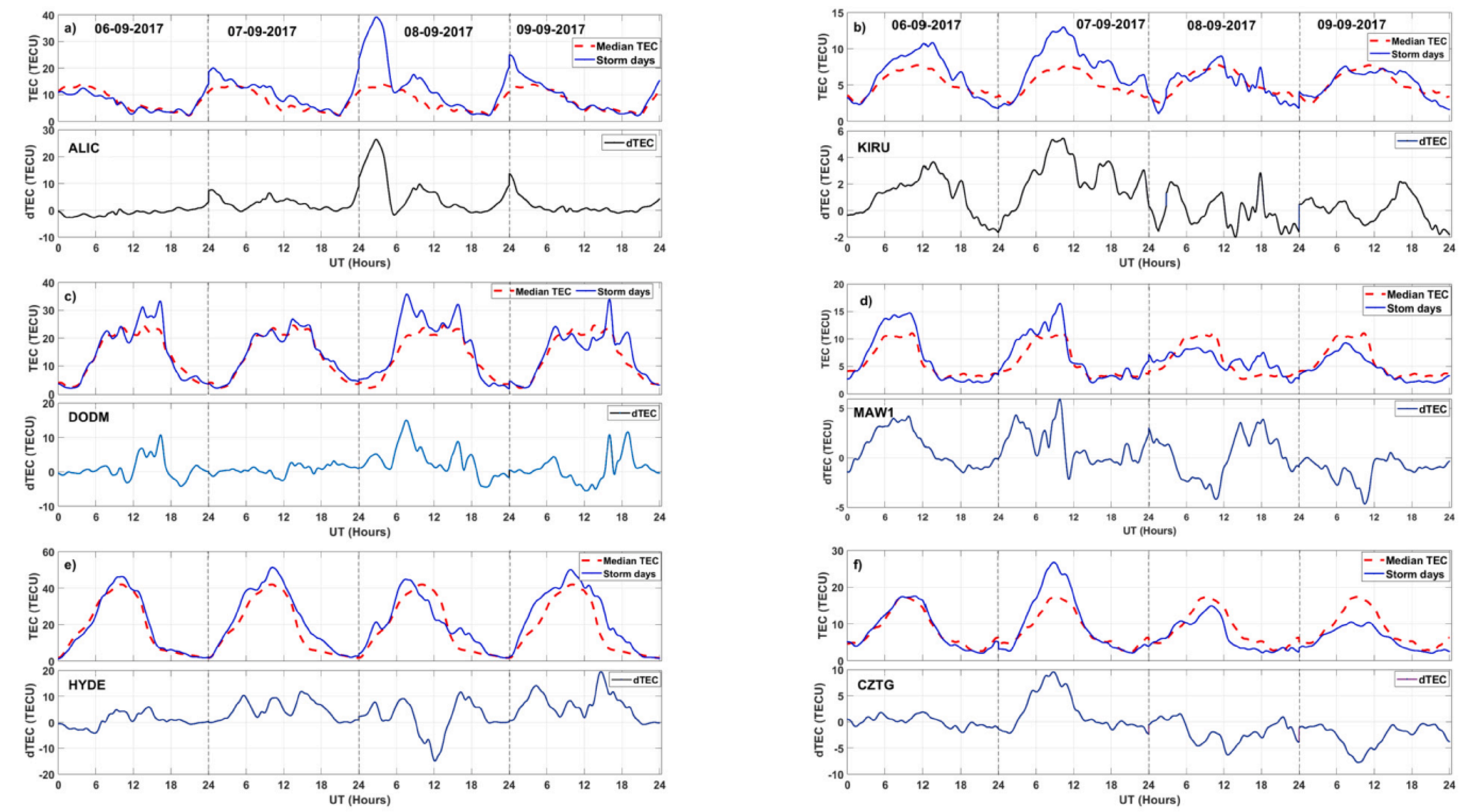

Figure 3. Variations of TEC during the normal days (dotted red line) and TEC during the event days (solid blue line) from September 6-9, 2017 with corresponding dTEC over different stations.

- On September 8, 2017, a significant increase in TEC is observed across most stations, followed by a rapid drop. This trend aligns with geomagnetic storm-driven ionospheric disturbances, likely due to energy input from solar activity.
- The largest deviations from the median TEC occur around local noon to evening hours, which may be linked to enhanced ionization effects or storm-driven plasma redistribution.

Conclusions

- A major drop in ΔH is observed across all stations, with the most substantial decrease at the beginning of September 8, 2017, UT.
- This indicates a strong geomagnetic storm, likely caused by a CMEs or solar wind interaction with Earth's magnetosphere.
- The magnitude of disturbance varies between stations, reflecting differences in geomagnetic latitude and local conditions [4].
- The geomagnetic storm, primarily driven by solar activity, caused significant TEC perturbations during September 6-9, 2017. These disturbances, influenced by electric field penetration, disturbance dynamo effects, and plasma redistribution, have significant implications for satellite communications, navigation, and space weather forecasting [5].

Selected References

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