Storm-Time MSTIDs Observed Over Mid-Latitude North America

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Background

- Travelling Ionospheric Disturbances (TIDs) are wave like structures in the ionosphere, which are further classified into Medium Scale (MSTIDs) or Large Scale (LSTIDs).
- MSTIDs have been studied using TEC and SuperDARN.
- MSTIDs are generally assumed to be attributed to neutral atmospheric behavior, such as atmospheric gravity waves. This is especially true during the daytime and more geomagnetically active times.
- Nighttime MSTIDs have also been known to be driven by more complex electrodynamic processes, such as the Perkins instability. These MSTIDs are often westwards.
- These electrodynamic instabilities often involve polarization electric fields, which can act across field lines between layers of the ionosphere, and even to the point of geomagnetic conjugacy.
- MSTIDs are often under-studied, especially during storm times, due to concurrent LSTID behavior and the increased resolution needed to sense them.

Objective

- Use hi-resolution GNSS TEC and SuperDARN to examine MSTID signatures during the September 7th and 8th 2017 geomagnetic storm event.
- Examine the similarities between these datasets to enhance understanding of storm time MSTID behavior.
- Determine whether the MSTIDs are AGW driven or electrified.

Datasets: SuperDARN

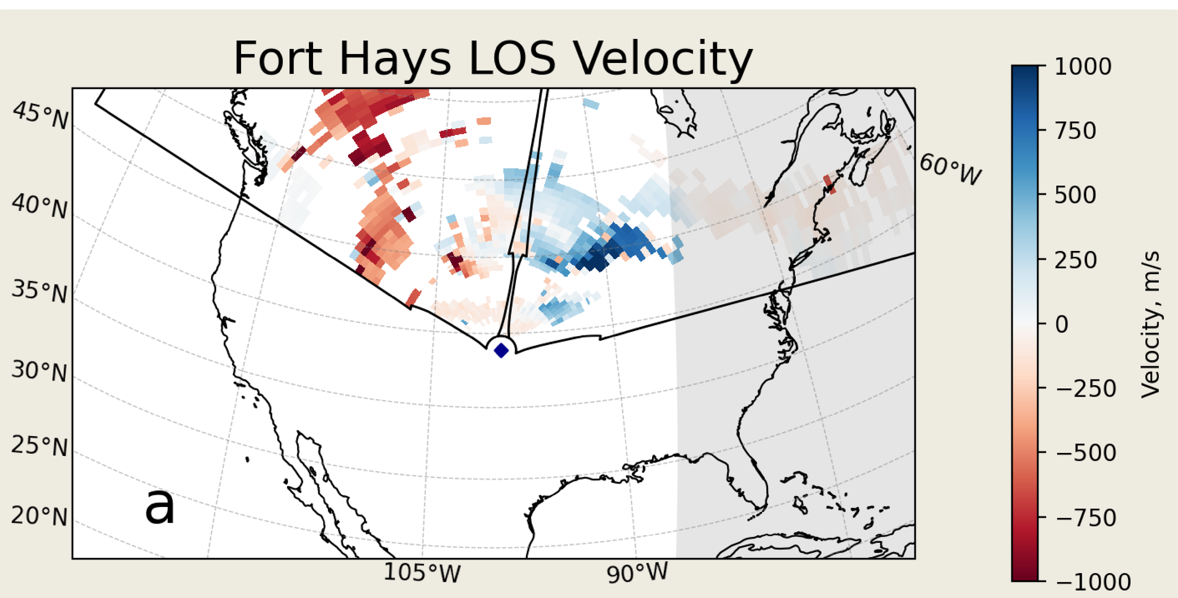

Figure 1: SuperDARN LOS velocity from Fort Hays Kansas East and West radars.

- Clear East to West plasma convection is present across the North American continent. The speeds are high, covering nearly 2km/s across the radars' azimuthal coverage.
- This supersonic plasma flow is suggestive of a northwards directed ionospheric electric field.

Datasets: GNSS TEC

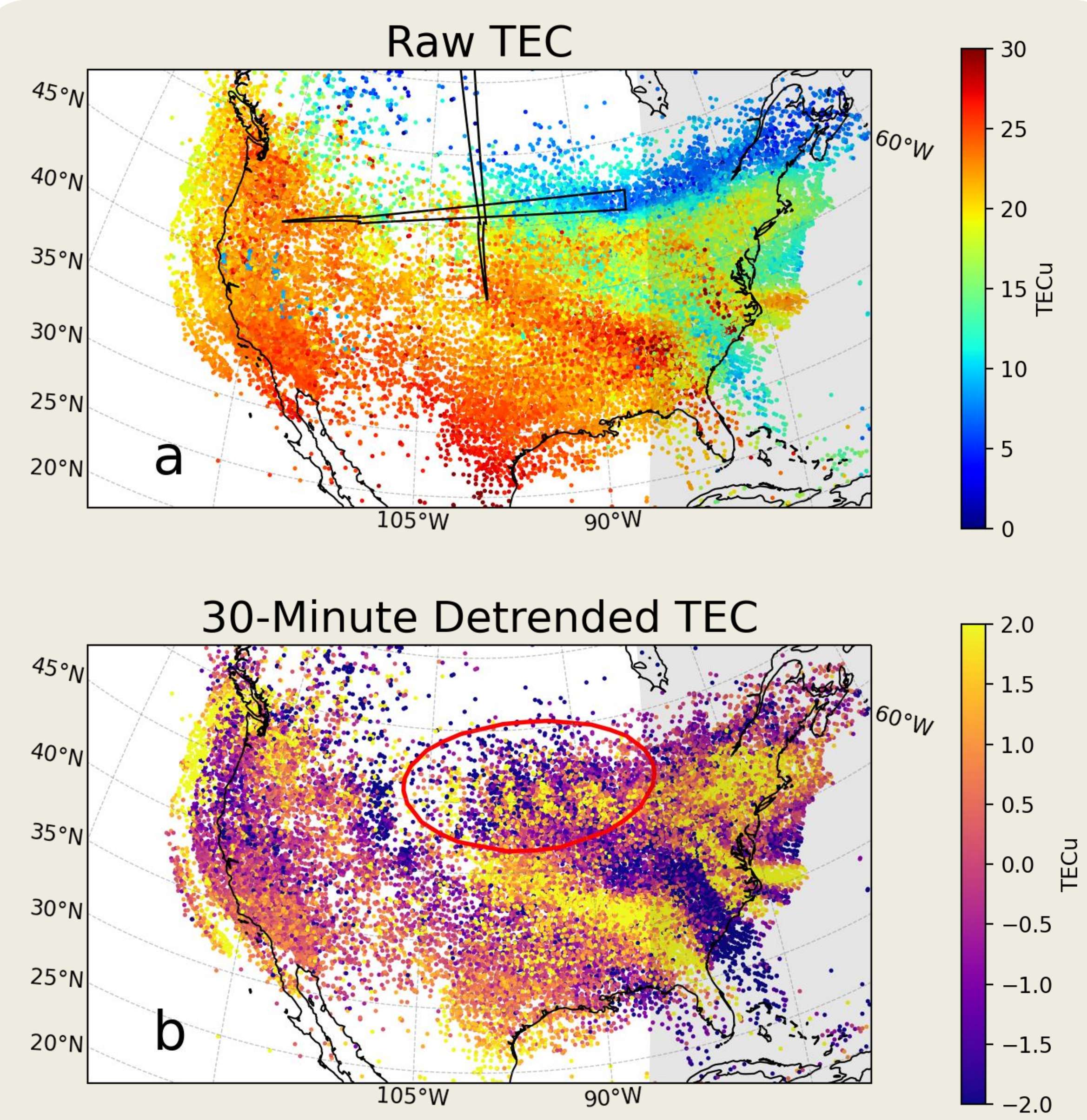

Figure 2: (a) Raw TEC shown with radar beams CVE 18 (left) and FHE 18 (right). (b) MSTIDs shown highlighted in the red oval after de-trending TEC data.

- GNSS TEC data is available in 30 second line of sight (hi-resolution). Coverage is dense over and is available from http://www.openmadrigal.org.
- Coverage is high across the US, and a TEC depletion region covers an area around 45° N Geographic.
- De-trending involves subtracting a 30 minute rolling average from each individual satellite-receiver pair, of which nearly 30,000 are present during the event.
- After de-trending the hi-resolution TEC, MSTIDs are visible.
- Propagation is westwards with an equatorward component.

Geomagnetic Conditions

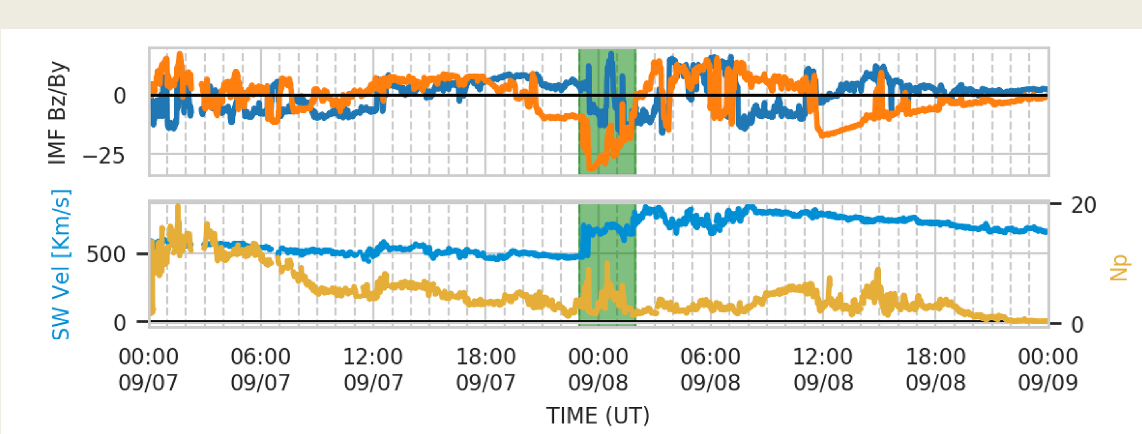

Figure 3: Geomagnetic conditions from 9/7/2017 to 9/9/2017. IMF BZ and By components are shown, as well as OMNI solar wind data. The period where MSTIDs are present is in green. Kp reached a peak value of 9 during this period which is the storm onset and peak.

Observations

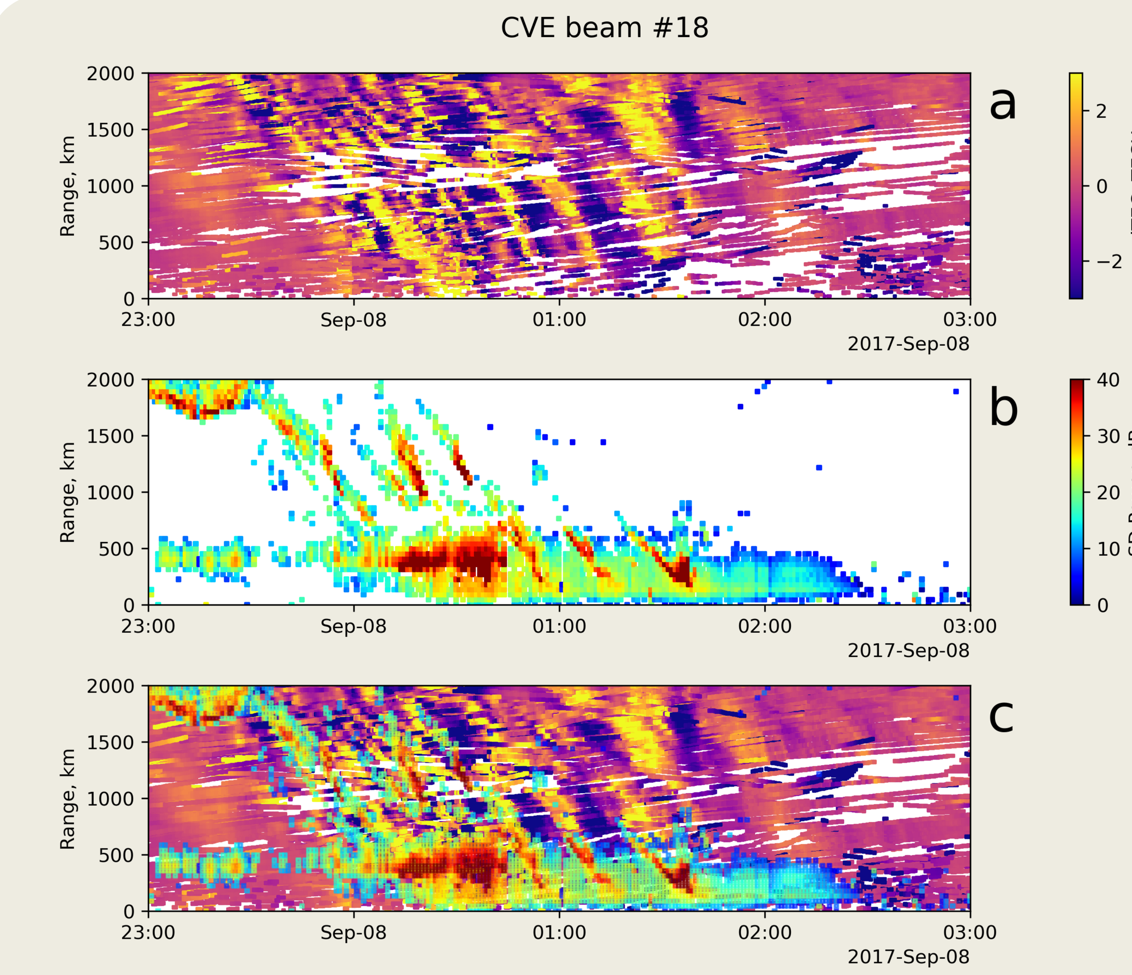

Figure 4: (a) 30 minute detrended GNSS TEC values taken within the footprint of CVE Beam #18. (b) CVE Beam #18 Power levels. (c) Direct comparison of both datasets.

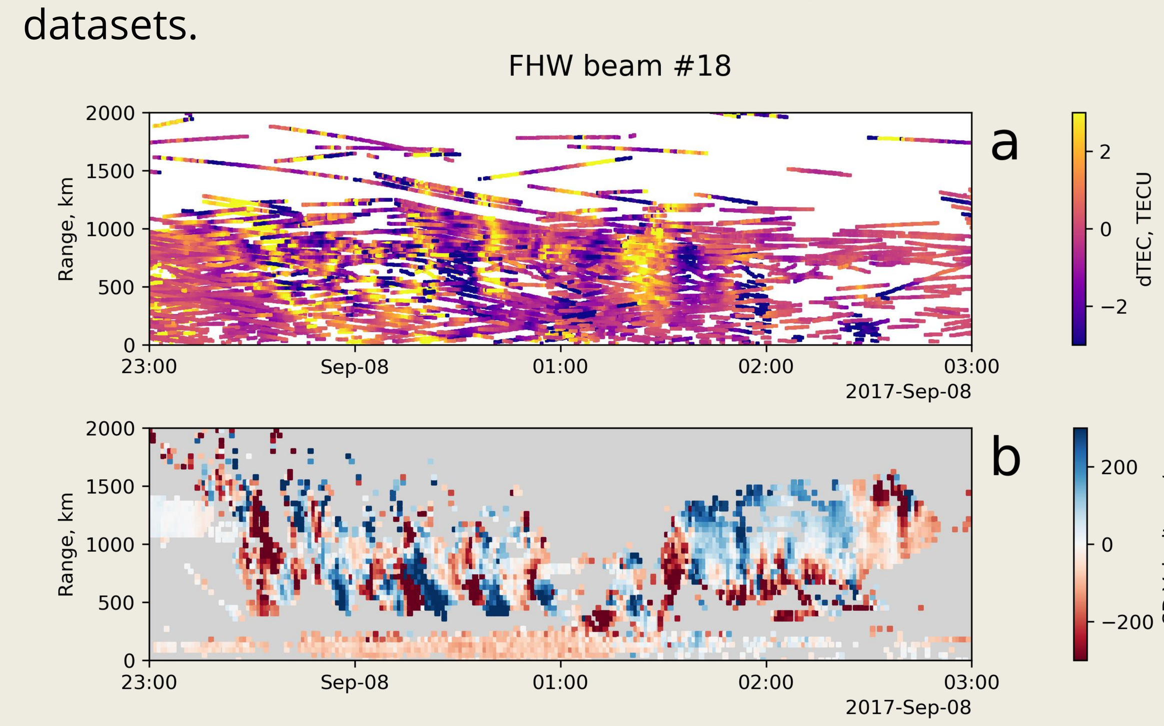

Figure 5: (a) 30 minute detrended GNSS TEC values taken within the footprint of FHW Beam #18. (b) FHW Beam #18 LOS velocities.

- Despite being completely separate datasets, MSTID striations are present and well correlated between TEC and SuperDARN. This implies that ionospheric plasma irregularities sensed by SuperDARN within the MSTID structure are more likely in areas of higher TEC.
- In beams that look parallel to MSTID propagation, such as CVE Beam #18, characteristics such as phase speed (~550 m/s) period (15-20 mins) and wavelength (600 km) can be identified. These values are similar to those reported by Zhang et al. (2019) which examined the same MSTIDs during this event
- Strong Velocity oscillations are present in beams which view MSTIDs obliquely, such as FHW Beam #18. In these beams, positive (towards the radar) velocities are correlated to regions of increased TEC / electron density, and vice versa.

Discussion

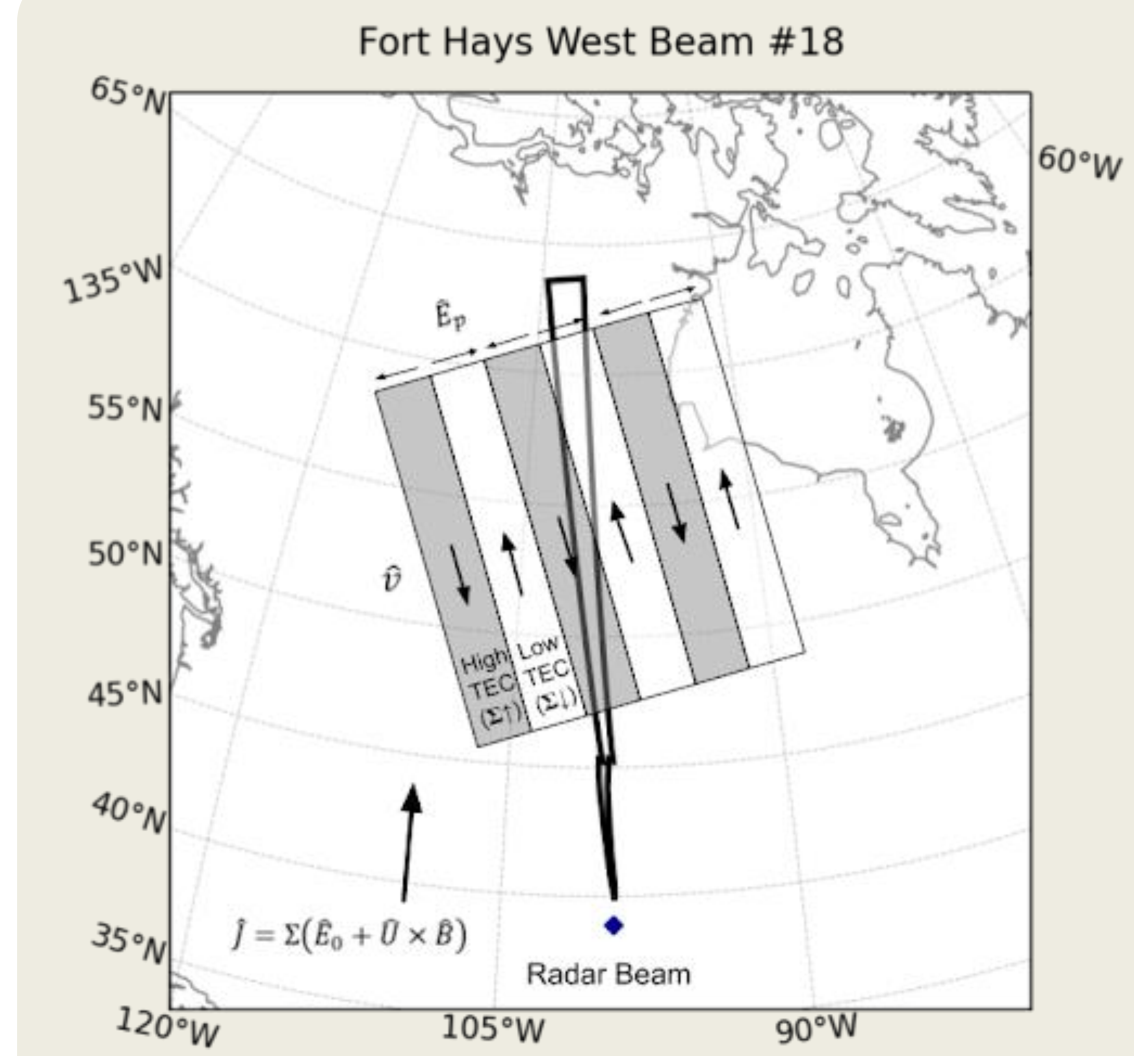

Figure 6: Schematic representation similar to Ogawa et al. (2009) of MSTID behavior as observed by Fort Hays West, Beam 18.

- MSTID phase fronts are presented as discontinuous structures. Based on westwards flow, ionospheric electric field is assumed to be northwards. MSTID phase velocity is westwards with an equatorward component. Current continuity must be maintained, so polarization electric fields are induced orthogonal to phase fronts. These polarization fields act against the direction of propagation in areas of increased conductivity and electron density. Based on these electric fields, plasma motion follows the $E \times B$ convention and plasma velocities oscillate accordingly.

Summary & Conclusions

- This study analyzed MSTID signatures over North America during a Kp=9 geomagnetic storm.
- GNSS TEC enhancements are correlated to SuperDARN Power enhancments, when plotted in radar beams.
- SuperDARN doppler velocity polarity was in line with enhancements and depletions in MSTID amplitude, suggesting polarization electric fields indicative of electrified MSTID behavior.

References

- Zhang, S. R., Erickson, P. J., Coster, A. J., Rideout, W., Vierinen, J., Jonah, O., & Goncharenko, L. P. (2019, 12). Subauroral and Polar Traveling Ionospheric Disturbances during the 7–9 September 2017 Storms. Space Weather , 17 , 1748-1764. doi:10.1029/2019SW002325
- Ogawa, T., Nishitani, N., Otsuka, Y., Shiokawa, K., Tsugawa, T., & Hosokawa, K.. (2009, 3). Medium-scale traveling ionospheric disturbances observed with the Superdarn Hokkaido radar, all-sky imager, and GPS network and their relation to concurrent sporadic e irregularities. Journal of Geophysical Research: Space Physics, 114 , 3316. doi: 10.1029/2008JA013893

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