Multi-Instrument Observations of MSTIDs/LSTIDs and Source Determination

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Goals and Motivation

- Use an incoherent scatter radar (ISR) to find medium/large-scale traveling ionospheric disturbances (MSTIDs/LSTIDs).
- Leverage high-density total electron content (TEC) datasets to detect same MSTIDs.
- Apply TEC datasets' horizontal geometry to better determine the source of the MSTIDs.

Medium/Large Scale Traveling Ionospheric Disturbances (MSTID/LSTID)

- Ionospheric waves that occur in the 100 km to 600 km altitude range, have approximately a 1 hour period, and have about a 200 km horizontal wavelength [1],[2].
- Can be seen in visible, radar, and GPS spectra all over the world—noise source for radars and GPS [3].
- Long-lasting waves with possible sources ranging from gravity waves to the magnetosphere [3],[4]

Incoherent Scatter Radar (ISR)

- Data taken at MIT Haystack Observatory's Millstone Hill ISR and two beams were used: Zenith (pointing vertically) and MISA (pointing along a magnetic field line, parallel to B).
- Quiet solar period during radar operation

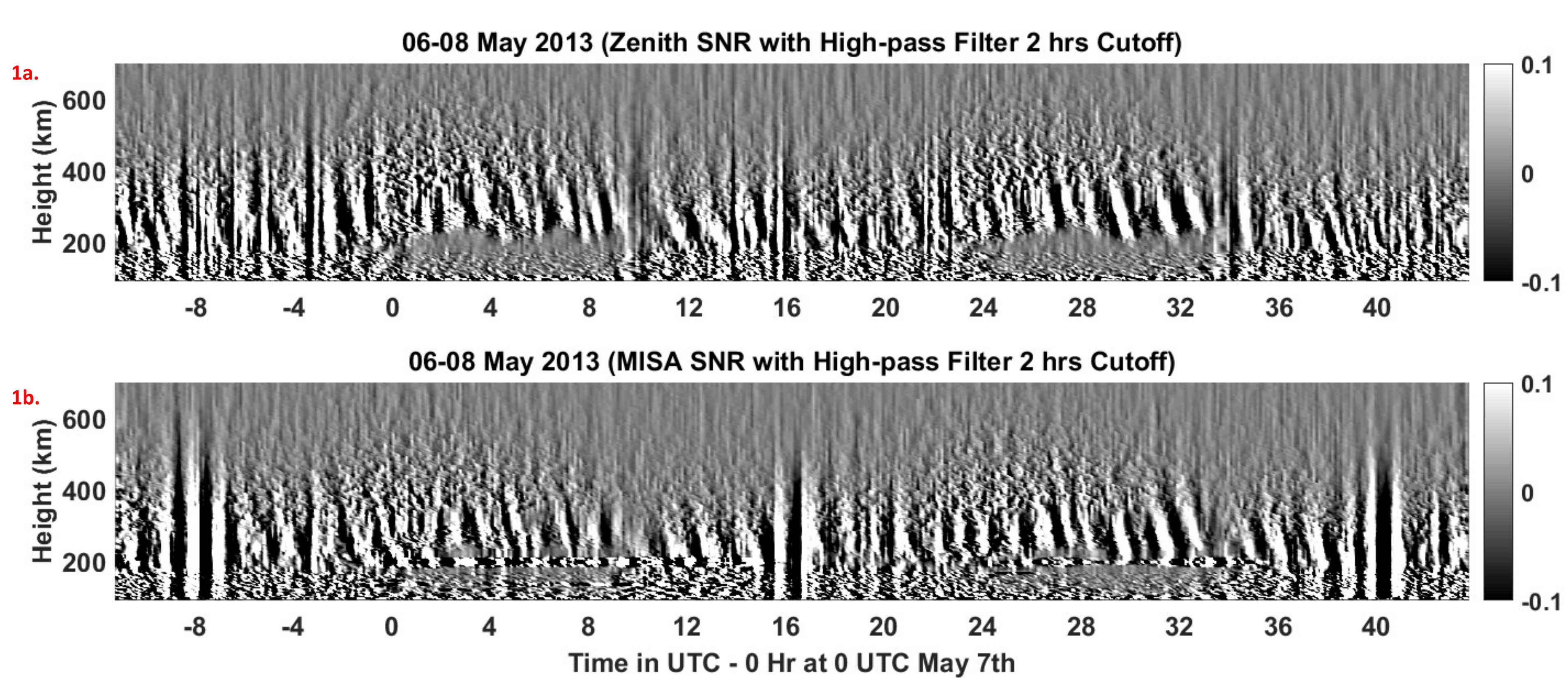

Figure 1 Above is a range-time-intensity (RTI) plot for the ISR's Zenith **(1a.)** and MISA beams **(1b.)**. The Zenith and MISA SNR has been high-pass filtered for each altitude band. The beams have a separation of 140 km at 300 km altitude. The Zenith beam is at an 88° angle and the MISA beam is at a 66° angle. The MISA beam has sun interference during -8, 16, and 40 hours.

- The entire ISR dataset has constant MSTID occurrence. The ubiquitous MSTIDs have about an hourly period. They occupy the F-region, at ~300 km, where the bulk of GPS TEC measurements originate [1].

References

[1] Livneh, D. J., I. Seker, F. T. Djuth, and J. D. Mathews (2009), Omnipresent vertically coherent fluctuations in the ionosphere with a possible worldwide-midlatitude extent, J. Geophys. Res., 114, A06303, doi:10.1029/2008JA013999.

[2] Nicolls, M. J., S. L. Vadas, N. Aponte, and M. P. Sulzer (2014), Horizontal parameters of daytime thermospheric gravity waves and E region neutral winds over Puerto Rico, J. Geophys. Res. Space Physics, 119, 575–600, doi:10.1002/2013JA018988.

[3] Seker, I., S. F. Fung, and J. D. Mathews (2011), The relation between magnetospheric state parameters and the occurrence of plasma depletion events in the night-time mid-latitude F-region, J. Geophys. Res., 116, A04323, doi:10.1029/2010JA015521.

[4] Djuth, F. T., L. D. Zhang, D. J. Livneh, I. Seker, S. M. Smith, M. P. Sulzer, J. D. Mathews, and R. L. Walterscheid (2010), Arecibo's thermospheric gravity waves and the case for an ocean source, J. Geophys. Res., 115, A08305, doi:10.1029/2009JA014799.

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GPS Total Electron Content (TEC)

- GPS TEC data was processed and de-biased to delta-slant-TEC (ΔsTEC). ΔsTEC is the change in the line-of-sight total electron content.

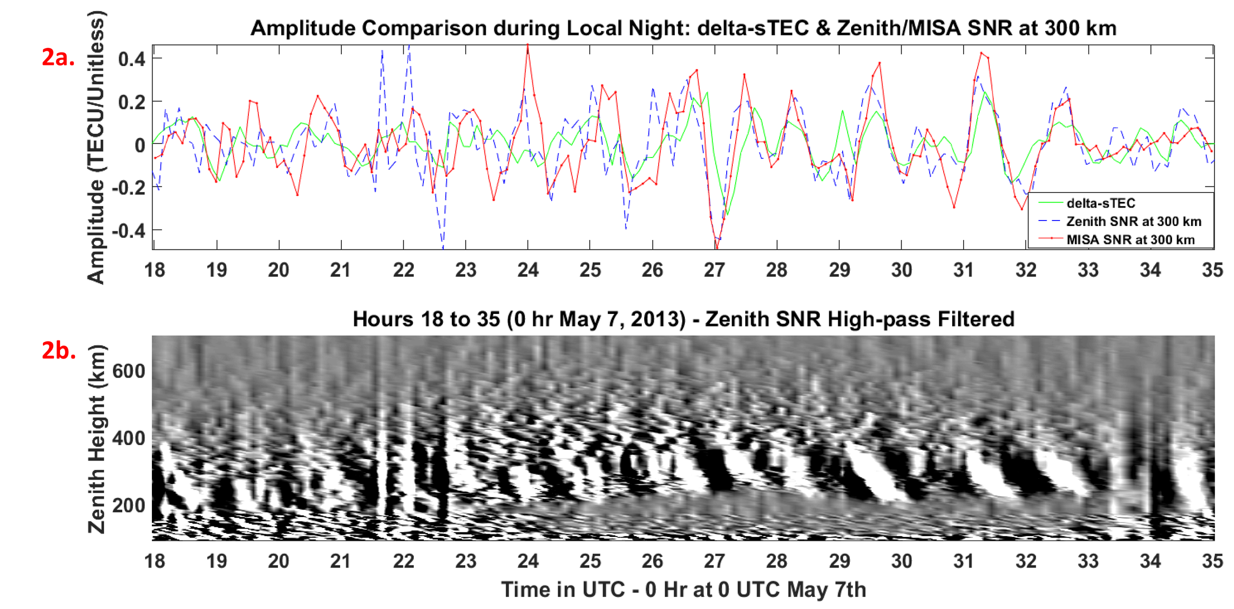

Figure 2 **(2a.)** shows ΔsTEC on the ISR data interval as well as the ISR's Zenith and MISA filtered SNR at 300 km (averaged +/-25 km in altitude) on the same plot. The adjustments make the datasets more equivalent. **(2b.)** is the Zenith ISR filtered SNR for reference. The time period chosen includes local night time, when the F-region peak is relatively high.

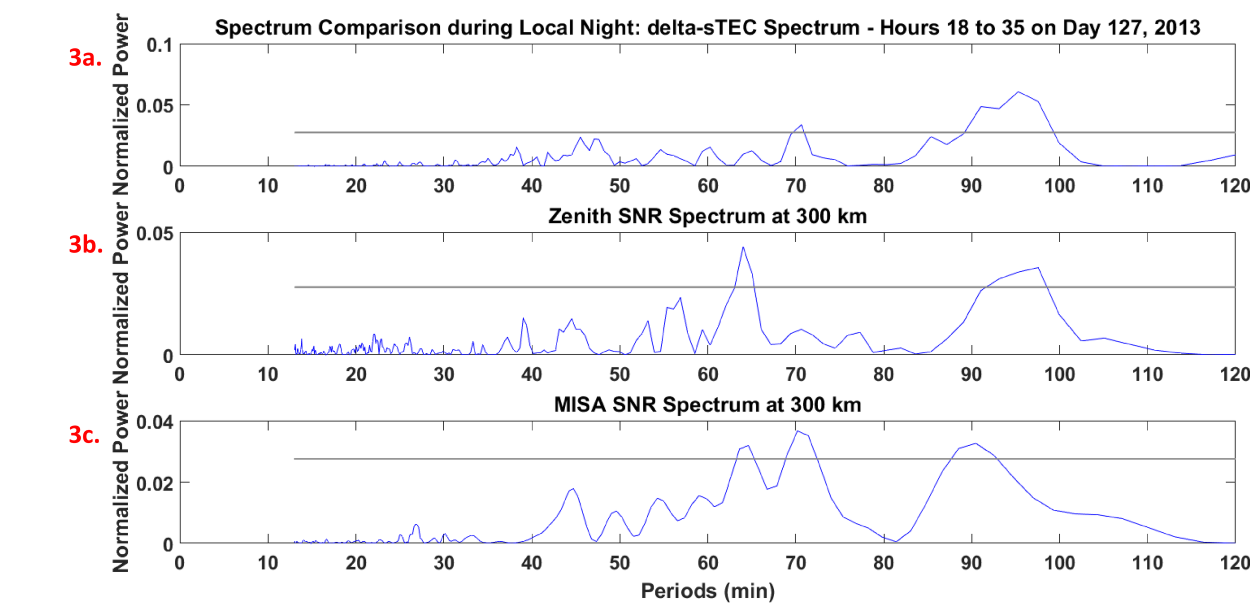

Figure 3 The spectra for Figure 2 are seen here. **(3a.)** shows the ΔsTEC which shares an approximately 90 and 70 minute peak with the Zenith spectrum in **(3b.)** and the MISA spectrum in **(3c.)**. The ΔsTEC data is from a 50 km radius around the Zenith ISR location. The noise floor is denoted by the horizontal line.

- Figures 2 and 3 show TEC can detect the same MSTIDs seen in the ISR data in amplitude and frequency at the most correlated times.

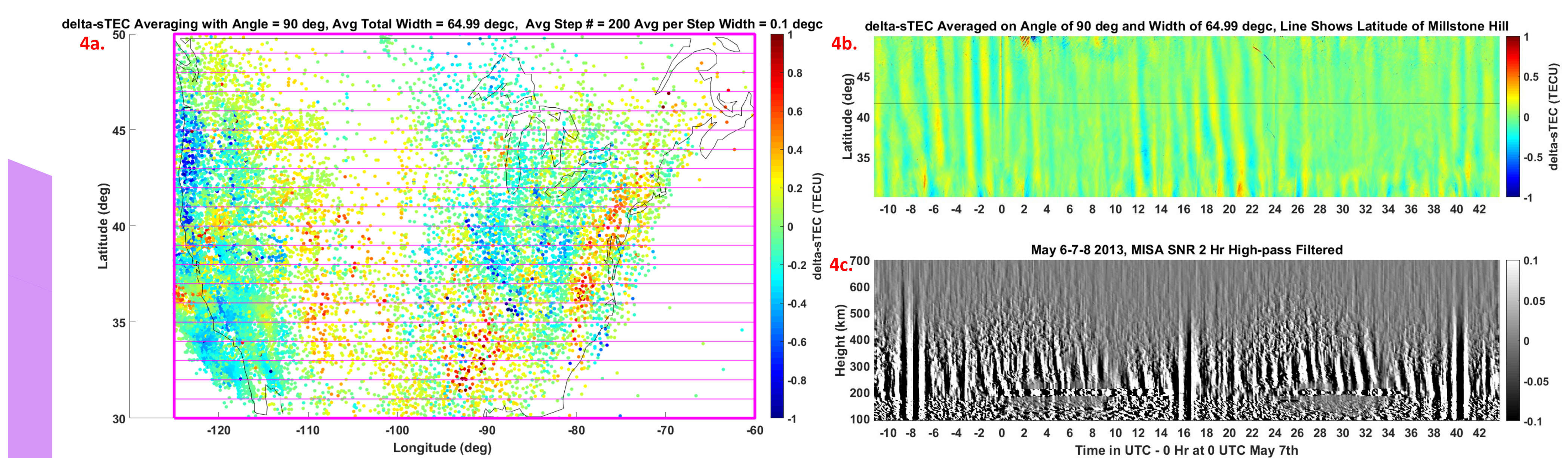

Figure 4 **(4a.)** shows how averaging the ΔsTEC in horizontal bands across the entire United States is applied. All ΔsTEC within a band is averaged to one value at one time to make a pixel in **(4b.)**. Actual averaging bands are smaller than the visualization shows. A blue asterisk in Massachusetts represents the ISR location.

(4b.) shows the results of that averaging system with latitude vs. time. Coherency occurs despite the large averaging range. The black line shows the MISA ISR latitude.

(4c.) shows the ISR MISA RTI plot for reference.

- Figure 4's **(4b.)** ΔsTEC periodicity corresponds with **(4c.)**'s ISR periodicity despite the very different geometries (horizontal vs. vertical).
- Averaging **(4a.)** in the perpendicular direction yields a very similar plot to **(4b.)**, which shows no directionality on a country-wide scale.

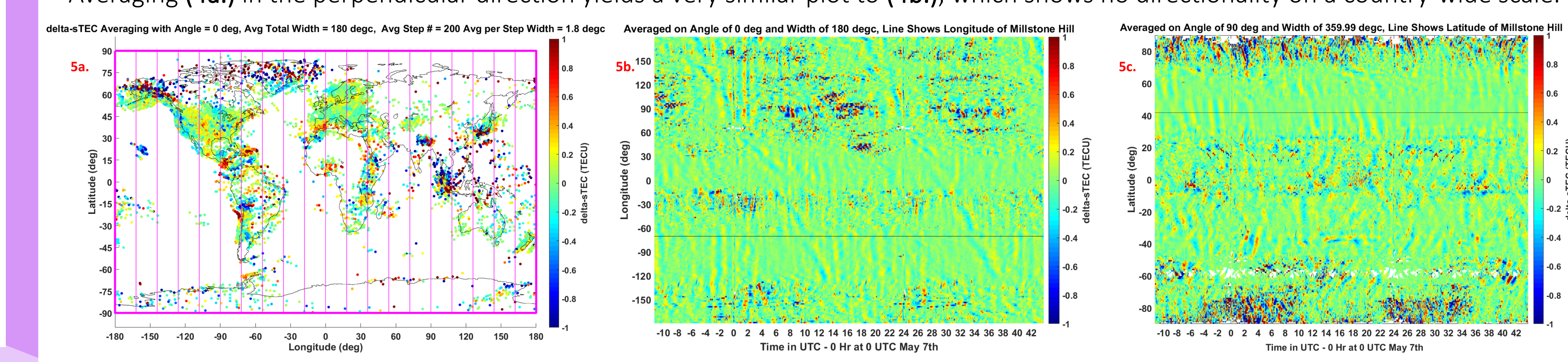

Figure 5 **(5a.)** shows the ΔsTEC averaging system applied to the world. **(5b.)** shows the results of that averaging method with resulting axes of longitude vs. time. **(5c.)** shows the results of averaging perpendicular to **(5a.)** with resulting axes of latitude vs. time. **(5a.)** averages all latitudes per each longitude and shows the day/night cycle at this scale, which is the continuous diagonal feature seen in **(5b.)**. The day/night cycle washes out of **(5c.)** due to the all longitude per each latitude averaging method.

- On the scale of the Earth, the ΔsTEC averaging method shows large-scale structures spanning hours in **(5b.)** and **(5c.)**.
- **(5b.)** shows no movement longitudinally for the vertical pulsing structures. In **(5c.)**, the vertical structures have a slant that indicates the structures are moving from the high latitude polar region towards the equator along the magnetic field lines.

Conclusions

- Large-scale, coherent, and ubiquitous ionospheric pulsing structures manifest as MSTID-like waves over the Millstone Hill ISR beams.
- Process may be magnetospheric in origin [3] due to the direction of travel and scale. Origin due to ocean, etc. [4] seems less likely.