Sources of Large Scale Traveling Ionospheric Disturbances Observed using HamSCI Amateur Radio, SuperDARN, and GNSS TEC

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Traveling Ionospheric Disturbances

- TIDs are Quasi-periodic Variations of F Region Electron Density
- Medium Scale (MSTID)
  - $T \approx 15 – 60$ min
  - $v_H \approx 100 – 250$ m/s
  - $\lambda_H \approx$ Several Hundred km (< 1000 km)
  - May be associated with meteorological or auroral sources
- Large Scale (LSTID)
  - $\lambda_h >$ 1000 km
  - $30 < T$ [min] <180
  - Sources are typically attributed to Auroral Electrojet Enhancement, Particle Precipitation
- Both may be associated with Atmospheric Gravity Waves
- Identifying the actual source can be difficult

[Francis, 1975; Hunsucker 1982; Ogawa et al., 1967; Ding et al., 2012; Frissell et al., 2014; 2016]

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Data Sources

- **Amateur Radio**
  - Reverse Beacon Network
  - Weak Signal Propagation Reporting Network (WSPRNet)
  - PSKReporter
  - QRZ.com
- **SuperDARN**
- **Madrigal GPS Total Electron Content (TEC)**
- **NASA OMNI Data**
- **SuperMAG Data**

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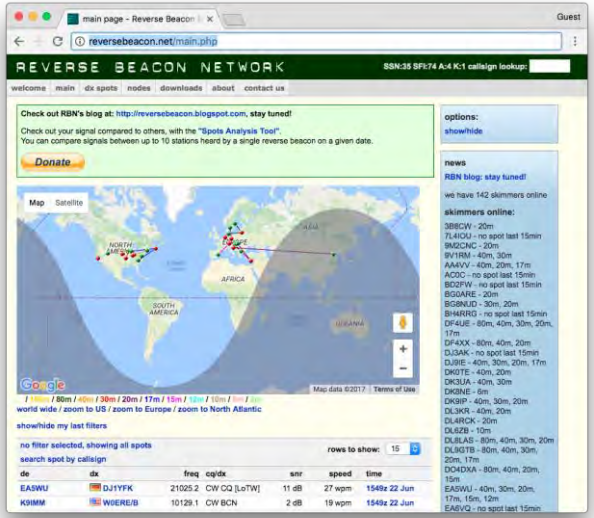
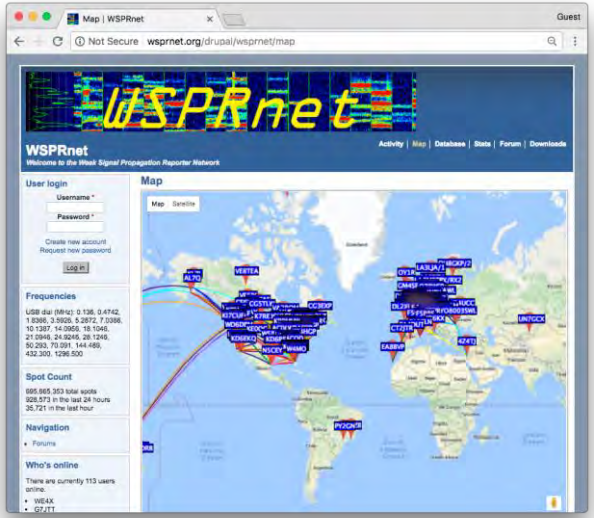
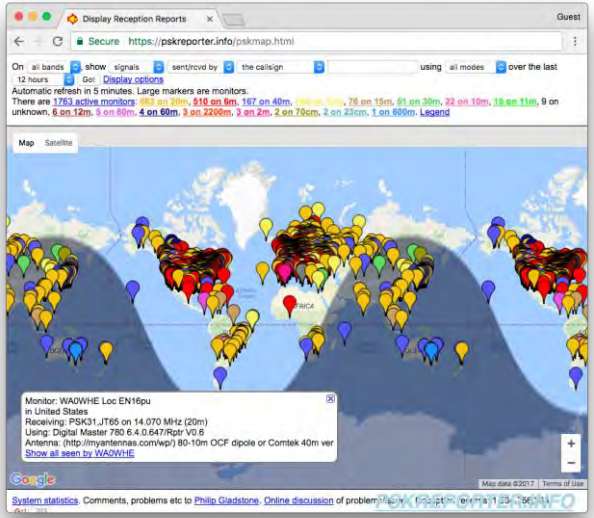
Amateur Radio Observation Networks



Reverse Beacon Network (RBN)
reversebeacon.net



WSPRNet
wsprnet.org



PSKReporter
pskreporter.info

- Quasi-Global
- Organic/Community Run
- Unique & Quasi-random geospatial sampling

- Data back to 2008 (A whole solar cycle!)
- Available in real-time!

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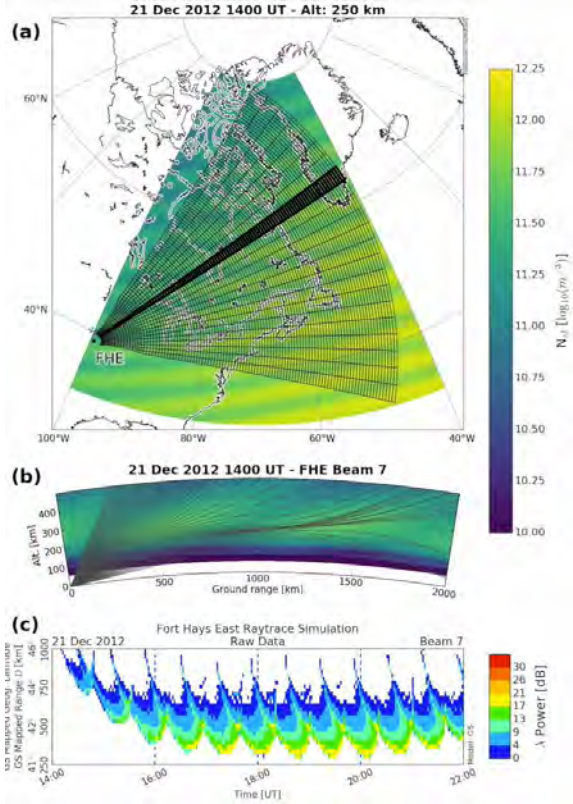
Traveling Ionospheric Disturbances



Ray trace simulation illustrating how SuperDARN HF radars observe MSTIDs.

(a) Fort Hays East (FHE) radar field of view superimposed on a 250 km altitude cut of a perturbed IRI. FHE Beam 7 is outlined in bold.

(b) Vertical profile of 14.5 MHz ray trace along FHE Beam 7. Background colors represent perturbed IRI electron densities. The areas where rays reach the ground are potential sources of backscatter.

(c) Simulated FHE Beam 7 radar data, color coded by radar backscatter power strength. Periodic, slanted traces with negative slopes are the signatures of MSTIDs moving toward the radar.

[Frissell et al., 2016]

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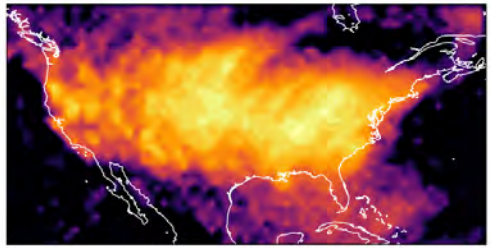
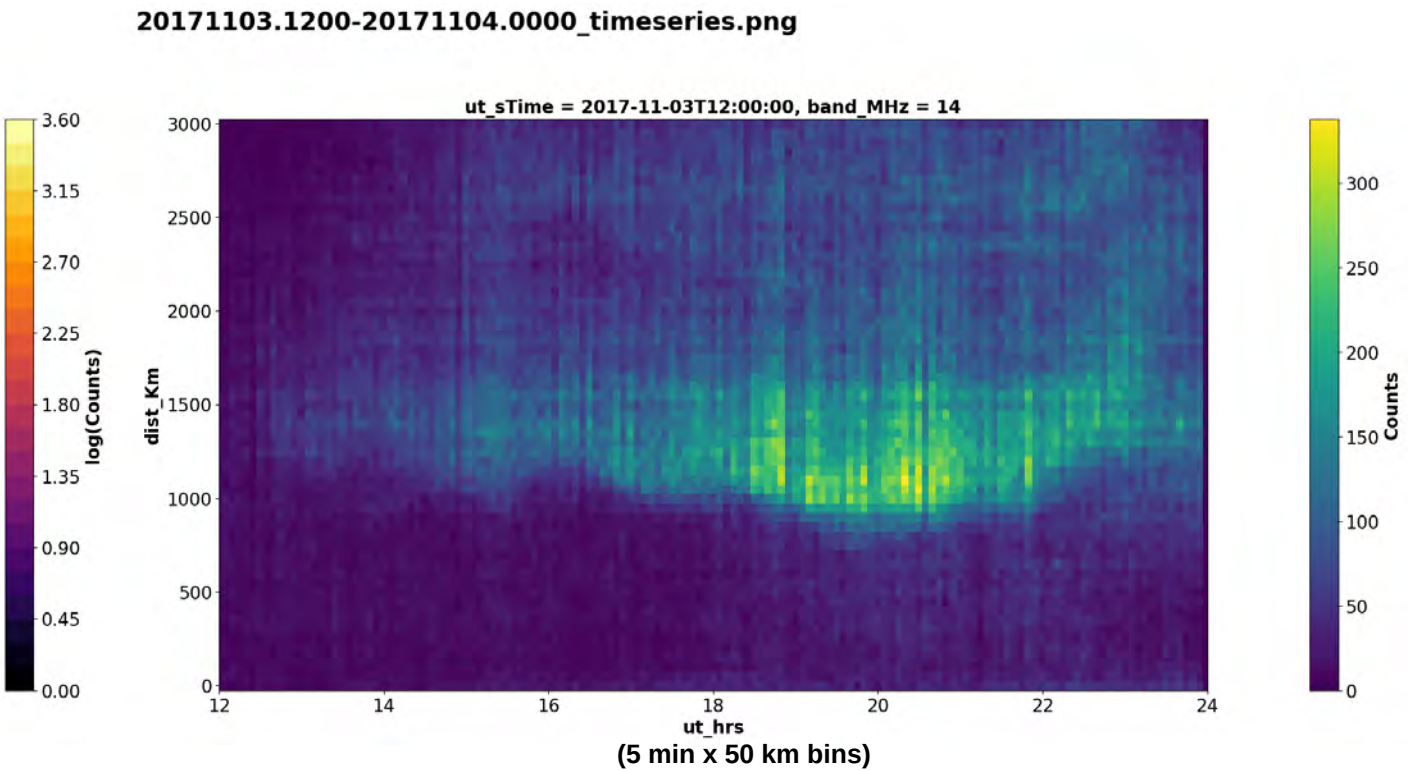
November 3, 2017



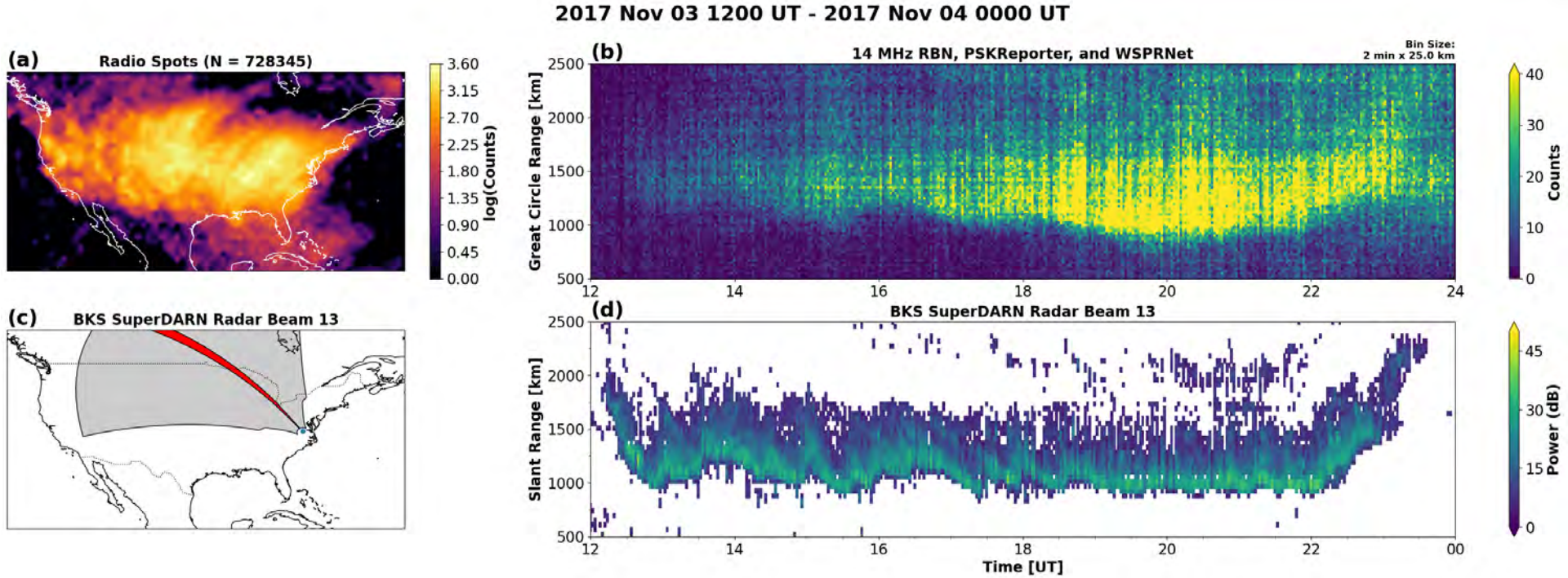
Radio Spots (N = 728345)

(1°x1° bins)



(5 min x 50 km bins)

November 3, 2017



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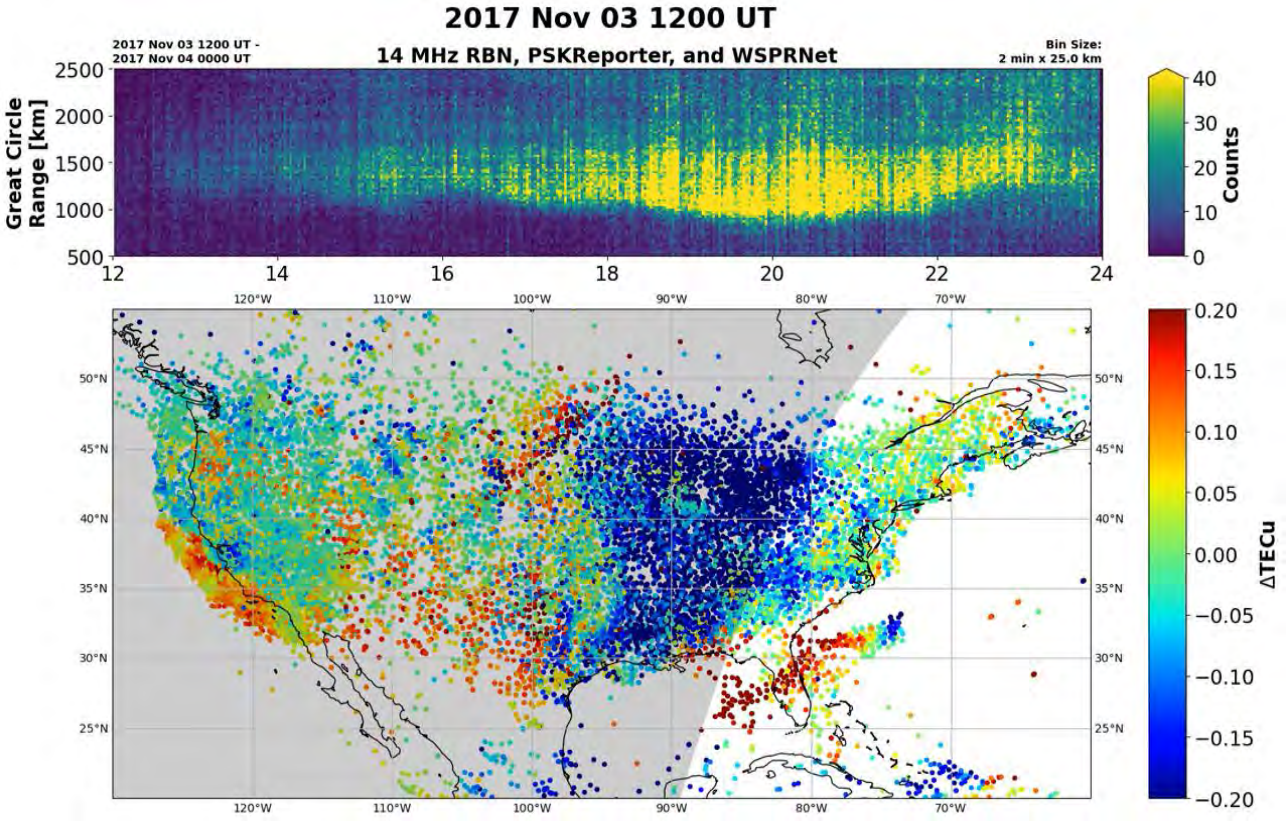
Amateur Radio Compared with GNSS dTEC



- Radio range is shortest when TEC is red (higher TEC)
- Higher electron densities → More HF refraction, communication range decreases

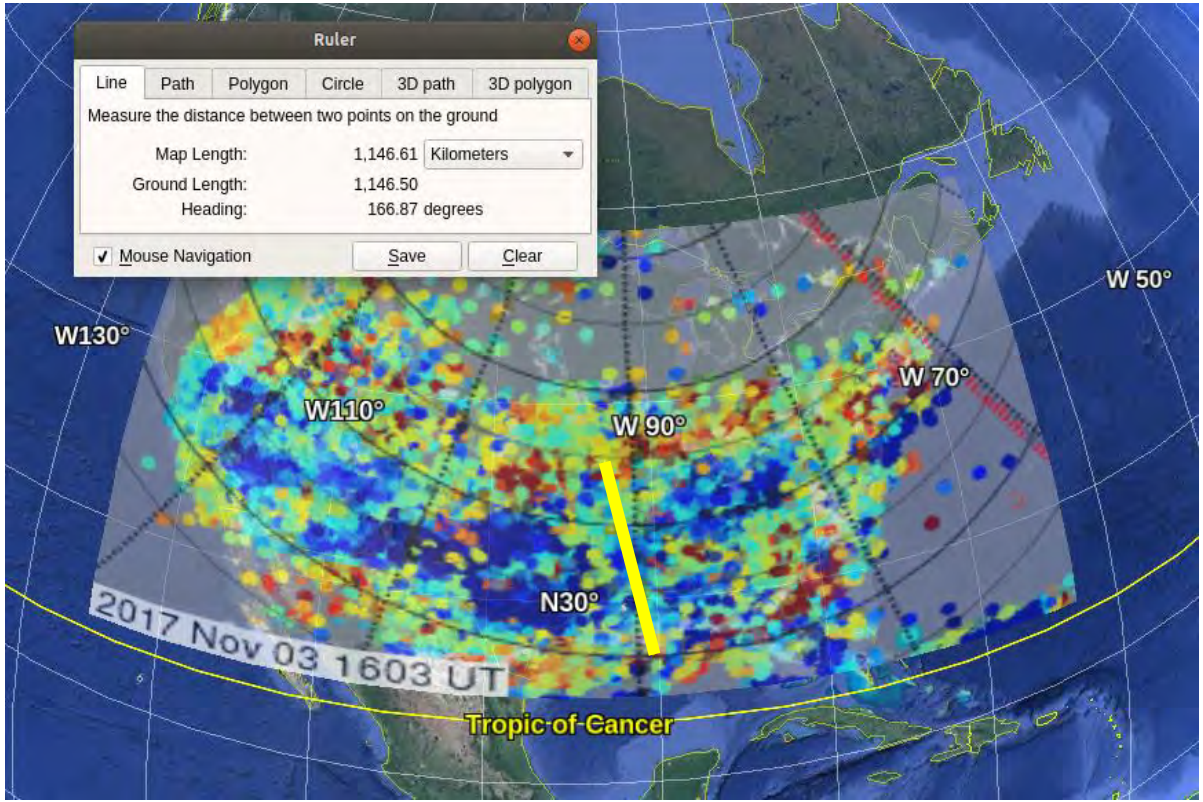
Estimated GNSS TEC LSTID Parameters

$\lambda_h \approx 1{,}136$ km

$v_p \approx 1280$ km/hr

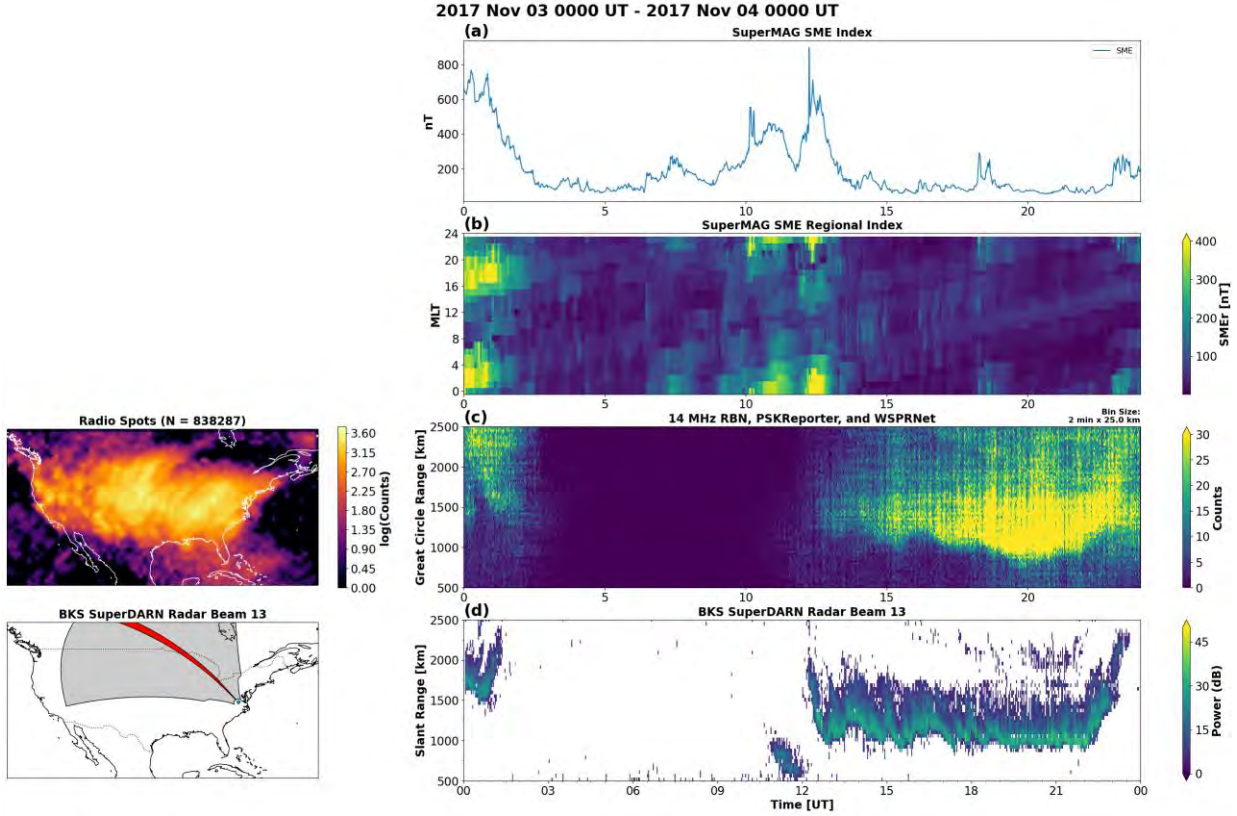
$T \approx 53$ min

$\Phi_{Azm} \approx 167°$



TEC MUSIC Analysis by E. G. Thomas.
For algorithm description, see
Bristow et al. (1994) and
Frissell et al. (2014).

November 3, 2017



Conclusions

- LSTID Observed on 3 Nov 2017 starting at ~12 UT
  - ~1.5 hr periodicity
  - Observed with Amateur Radio, BKS SuperDARN Beam 13 and GNSS dTEC
  - GNSS dTEC Wave Parameter Estimate (using MUSIC)
    - $\lambda_h \approx 1136$ km, $v_p \approx 1280$ km/hr, $T \approx 53$ min, $\Phi_{Azm} \approx 167°$
- Auroral electrojet activity occurring about 3 hours prior to the observation of TIDs is a likely candidate for the LSTIDs observed on this day.

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Acknowledgments

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- PyDARN Analysis Toolkit made available by the SuperDARN Data Analysis Working Group, Schmidt, M.T., Billett, D.D., Martin, C.J., Huyghebaert, D., Bland, E.C., … Sterne, K.T. (2021, February 23). SuperDARN/pydarn: pyDARNio v2.0.1 (Version v2.0.1). Zenodo. http://doi.org/10.5281/zenodo.4558130.
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Thank you!

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