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

Nathaniel A. Frissell W2NAF[1], Diego F. Sanchez KD2RLM[2,3], Evan Markowitz KD2IZW[3], Gareth W. Perry KD2SAK[3], William D. Engelke AB4EJ[4], Anthea Coster[5], Philip J. Erickson W1PJE[5], J. Michael Ruohoniemi[6], and Joseph Baker[6]

[1]University of Scranton
[2]Essex County College
[3]New Jersey Institute of Technology
[4]University of Alabama
[5]MIT Haystack Observatory
[6]Virginia Tech

nathaniel.frissell@scranton.edu

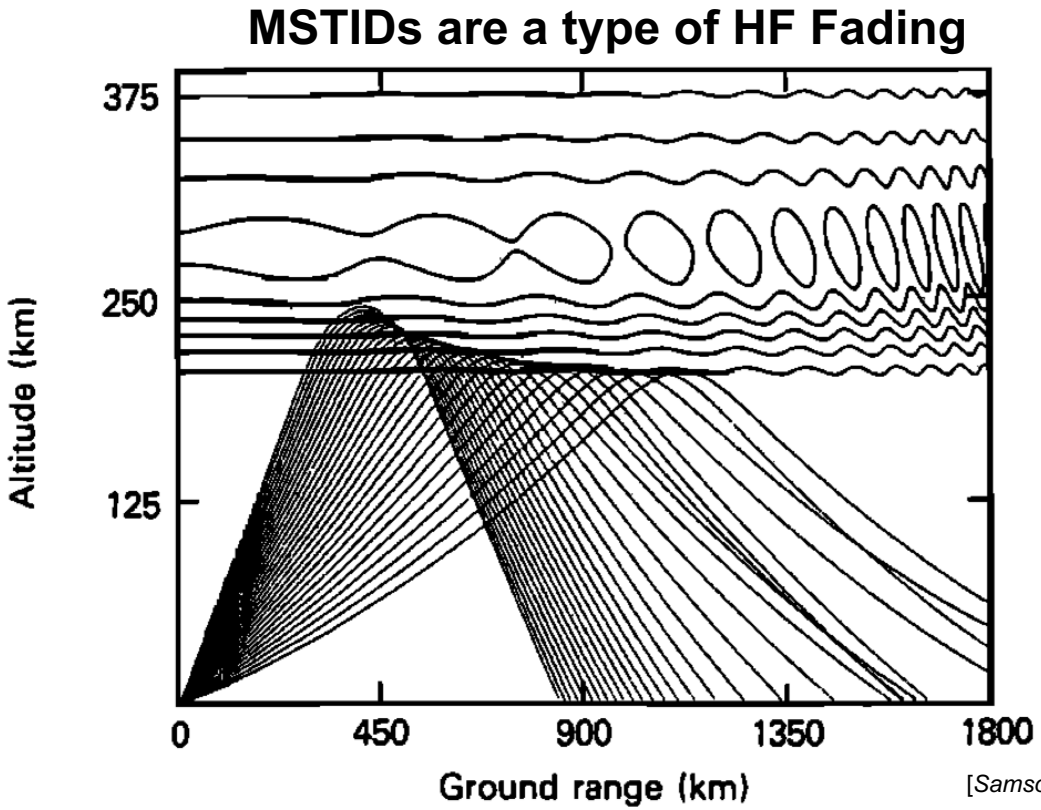
Traveling Ionospheric Disturbances

- **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)
  - Often Meteorological Sources
- **Large Scale (LSTID)**
  - $\lambda_h > 1000$ km
  - $30 < T$ [min] <180
  - Often Auroral Electrojet Enhancement, Particle Precipitation
- **Often associated with Atmospheric Gravity Waves**

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

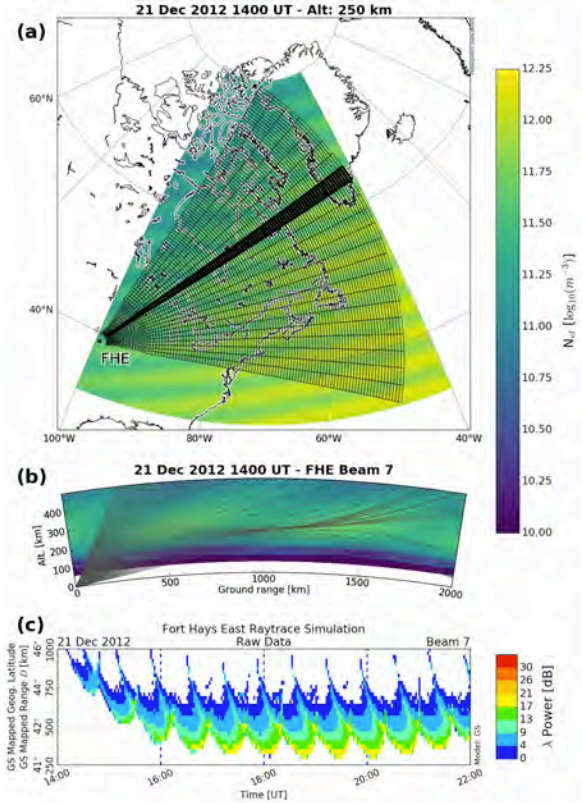
nathaniel.frissell@scranton.edu

Traveling Ionospheric Disturbances



[*Samson et al.*, 1990]

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]

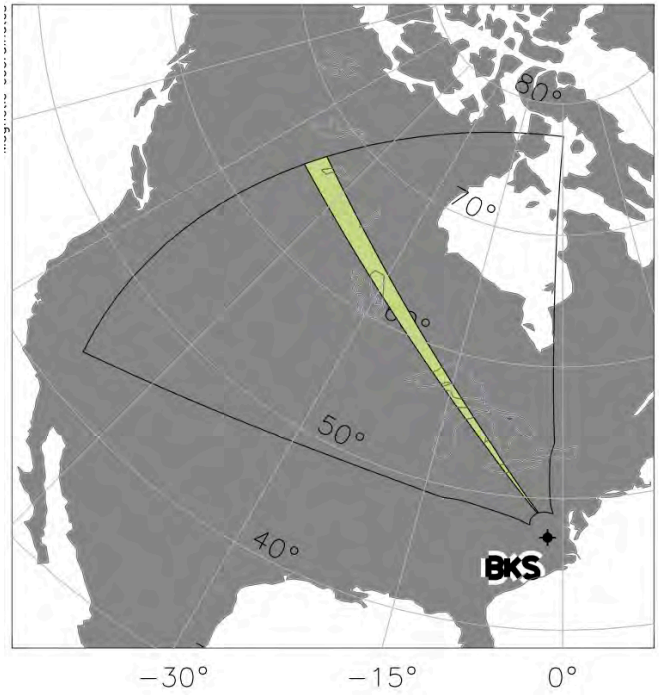
nathaniel.frissell@scranton.edu

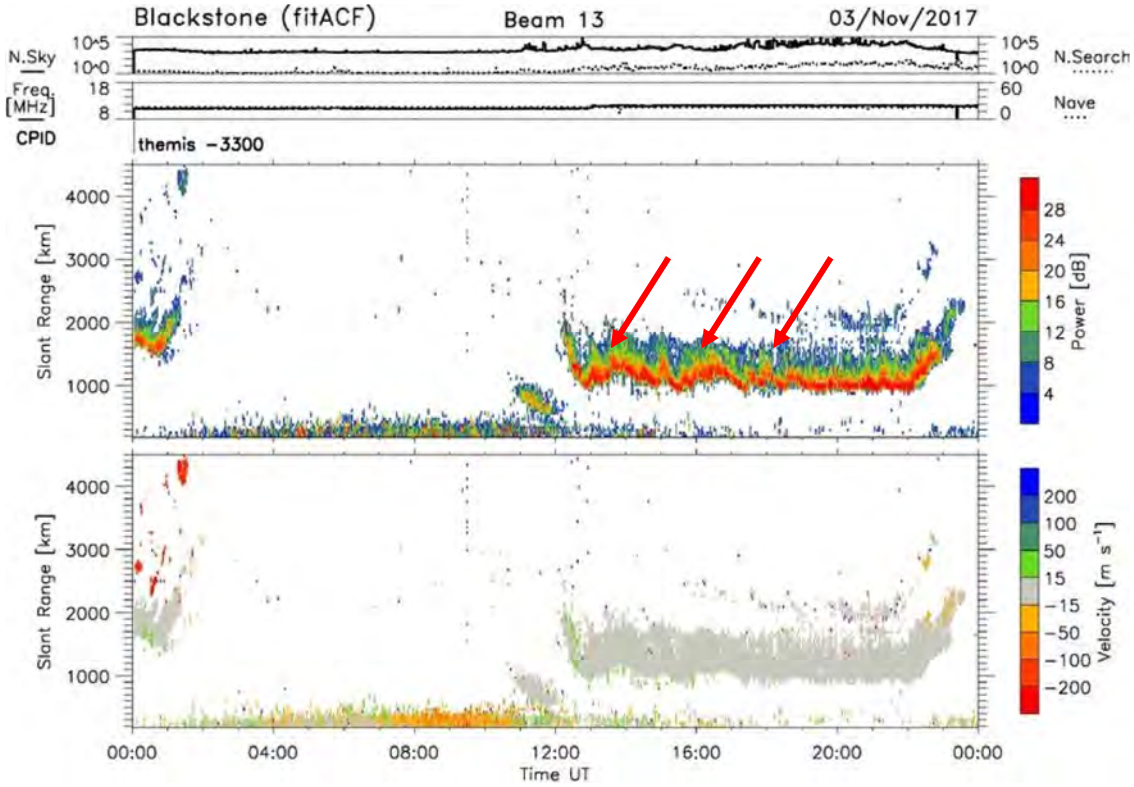
Data Sources

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

nathaniel.frissell@scranton.edu

TIDs in Blackstone SuperDARN

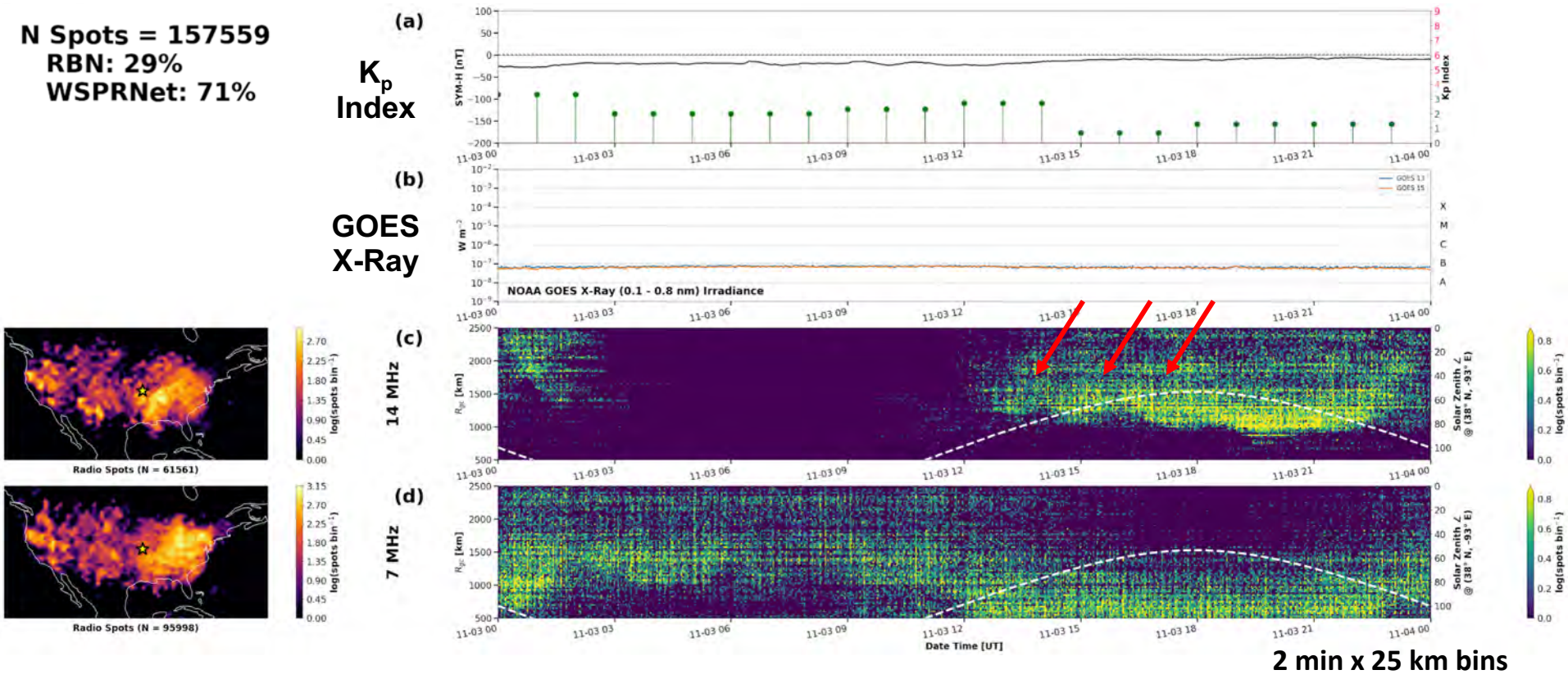




nathaniel.frissell@scranton.edu

Ham Radio TIDs

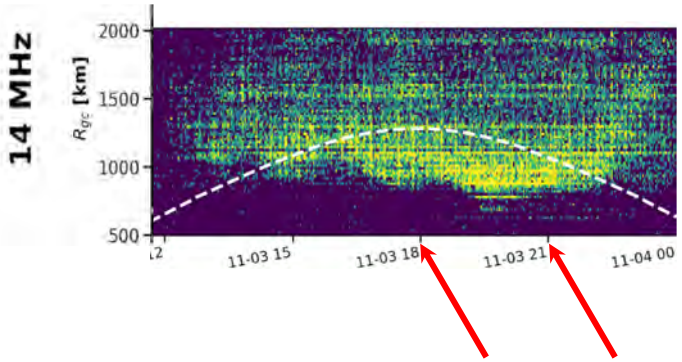
N Spots = 157559
RBN: 29%
WSPRNet: 71%



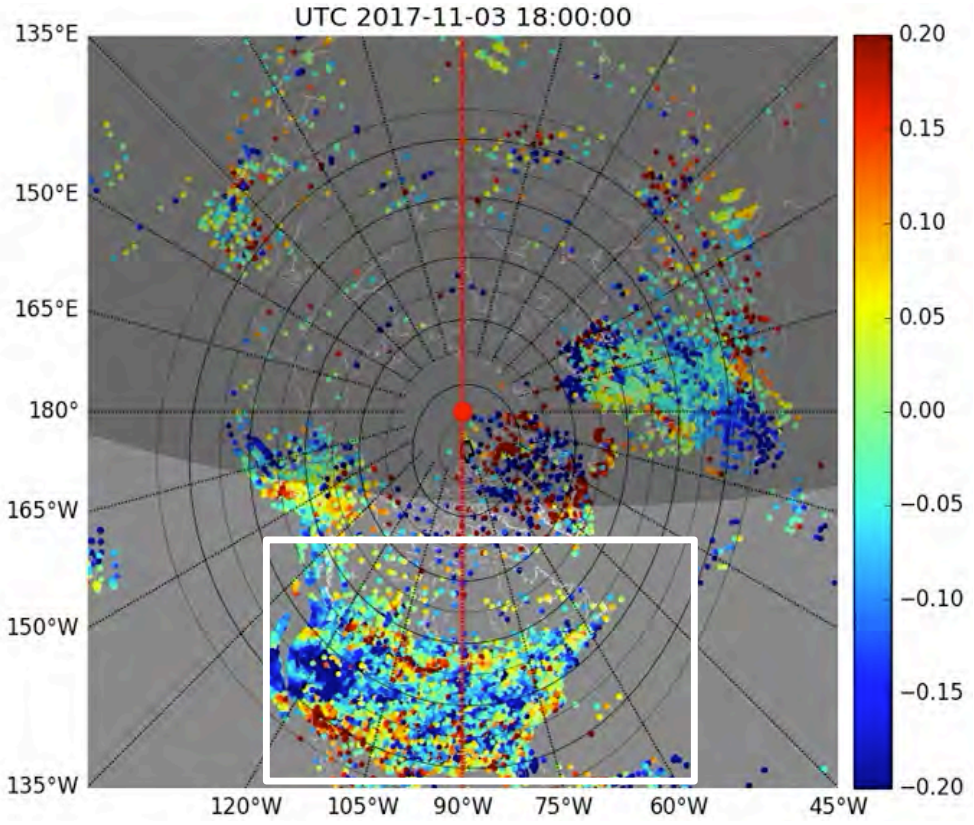
2 min x 25 km bins

nathaniel.frissell@scranton.edu

GNSS TEC Comparison 18:00 - 21:00



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



nathaniel.frissell@scranton.edu

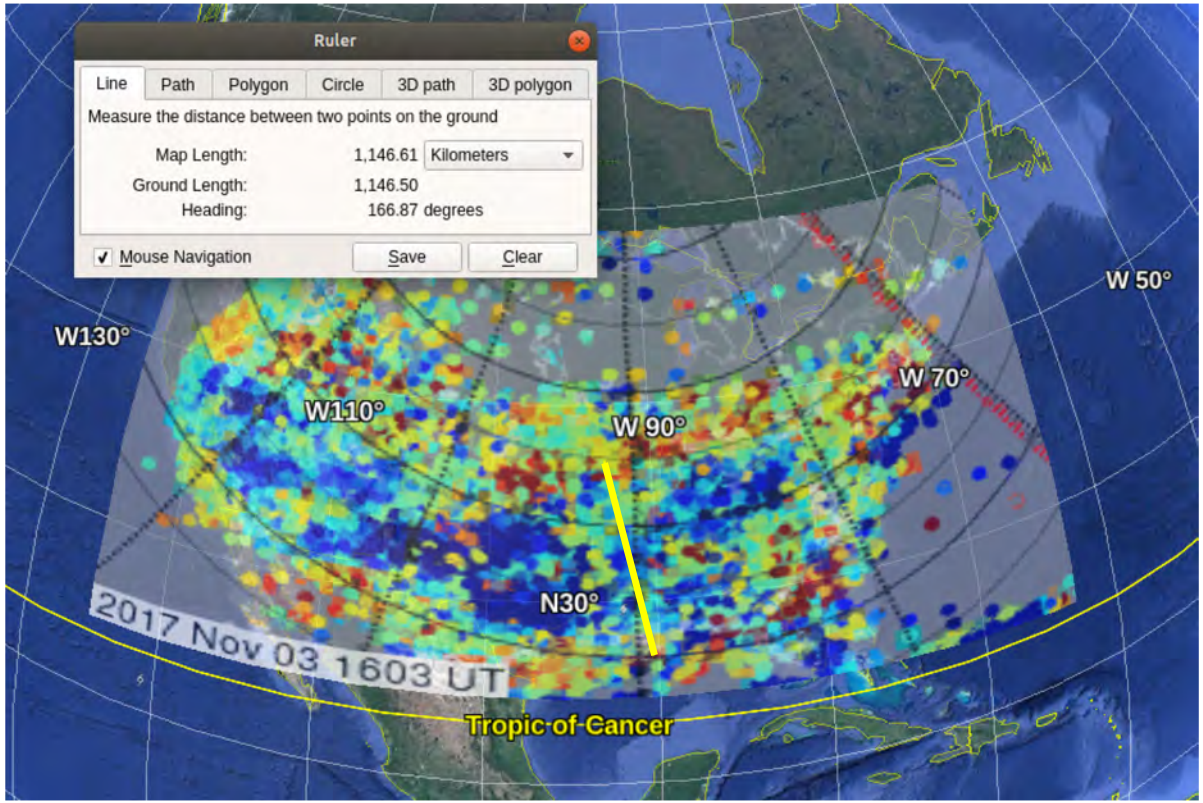
Estimated GNSS TEC LSTID Parameters

$\lambda_h \approx 1{,}100$ km

$v_p \approx 950$ km/hr

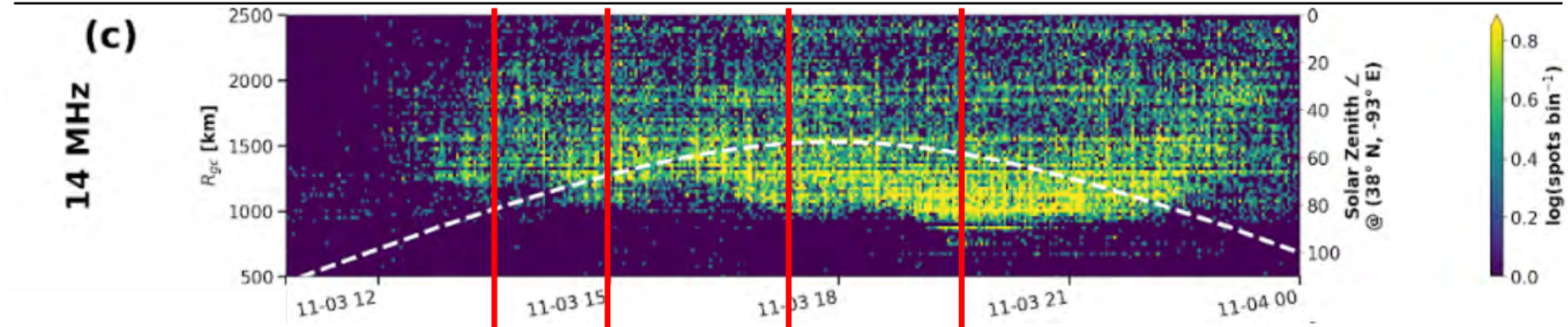
$T \approx 70$ min

$\Phi_{Azm} \approx 135°$



nathaniel.frissell@scranton.edu

Periods get longer...



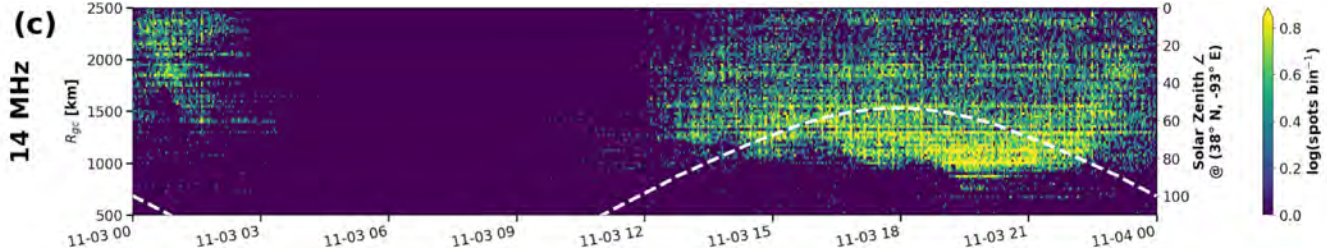
1 hr 2 hr 2.25hr

13:30 UT 15:00 UT 17:00 UT 19:15 UT

Range	Est. Time
min	13:30
max	14:00
min	15:00
max	16:15
min	17:00
max	18:30
min	19:15

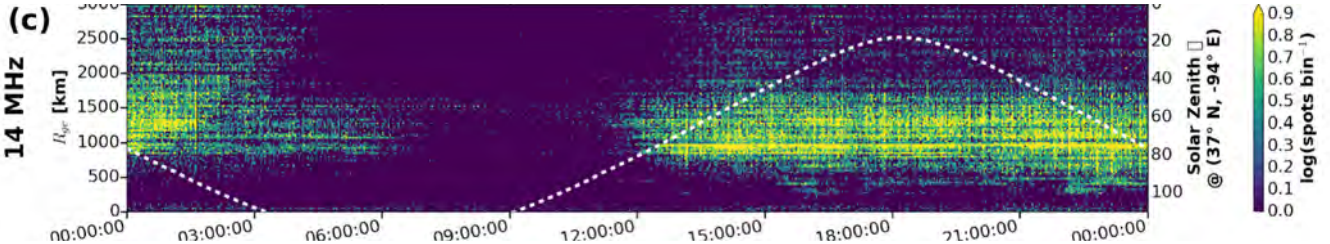
14 MHz Plot Comparisons

03 Nov 2017-
04 Nov 2017
Ham Radio Networks
N Spots = 157559
RBN: 29%
WSPRNet: 71%



3 Nov 2017 **4 Nov 2017**

16 May 2017-
17 May 2017
Ham Radio Networks
N Spots = 169822
RBN: 12%
WSPRNet: 88%



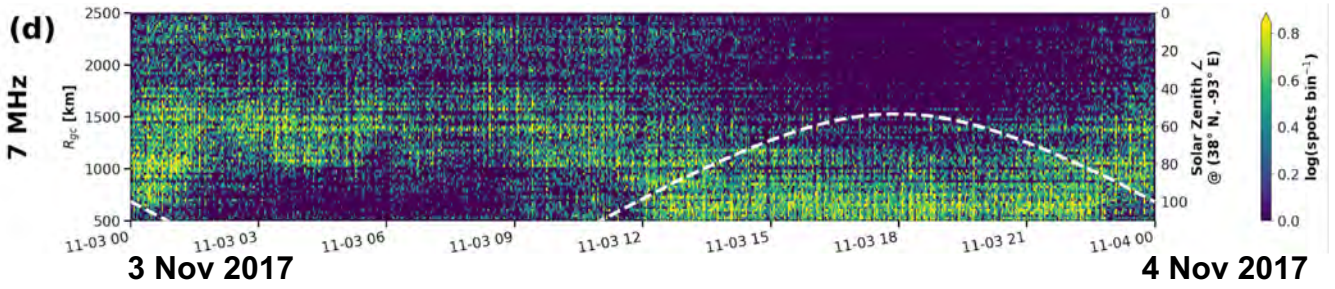
16 May 2017 **17 May 2017**

2 min x 25 km bins

nathaniel.frissell@scranton.edu

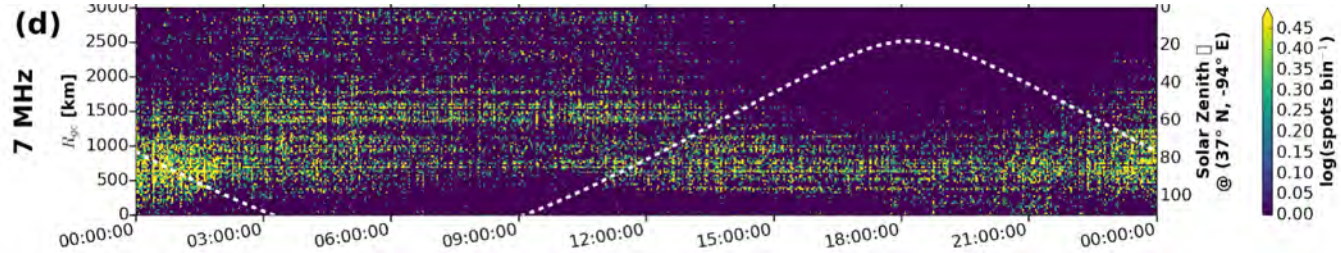
7 MHz Plot Comparisons

03 Nov 2017-
04 Nov 2017
Ham Radio Networks
N Spots = 157559
RBN: 29%
WSPRNet: 71%



3 Nov 2017 **4 Nov 2017**

16 May 2017-
17 May 2017
Ham Radio Networks
N Spots = 169822
RBN: 12%
WSPRNet: 88%



16 May 2017 **17 May 2017**

2 min x 25 km bins

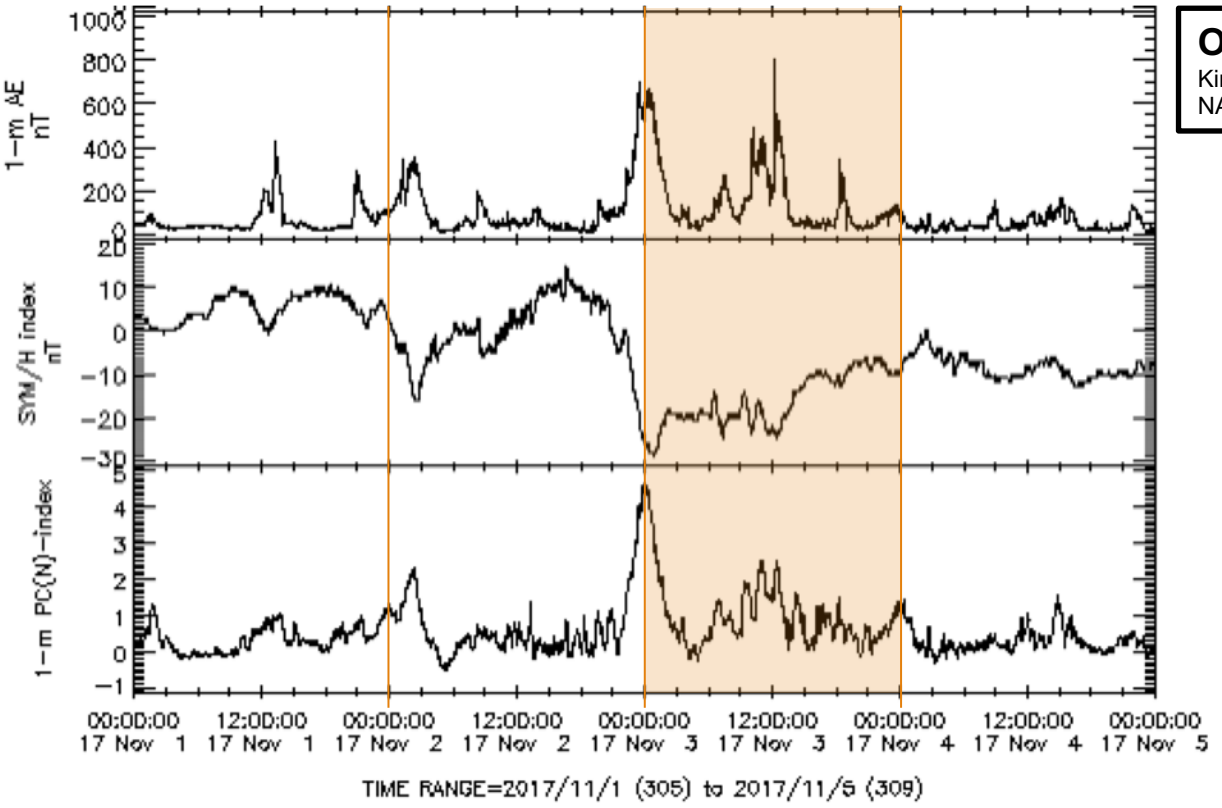
nathaniel.frissell@scranton.edu

Geomagnetic Environment: 1-5 Nov 2017

Auroral Electrojet

Sym-H
(Geomagnetic Storm Index)

Polar Cap Index



OMNI Data
King and Papatashivilli
NASA GSFC CDAWeb

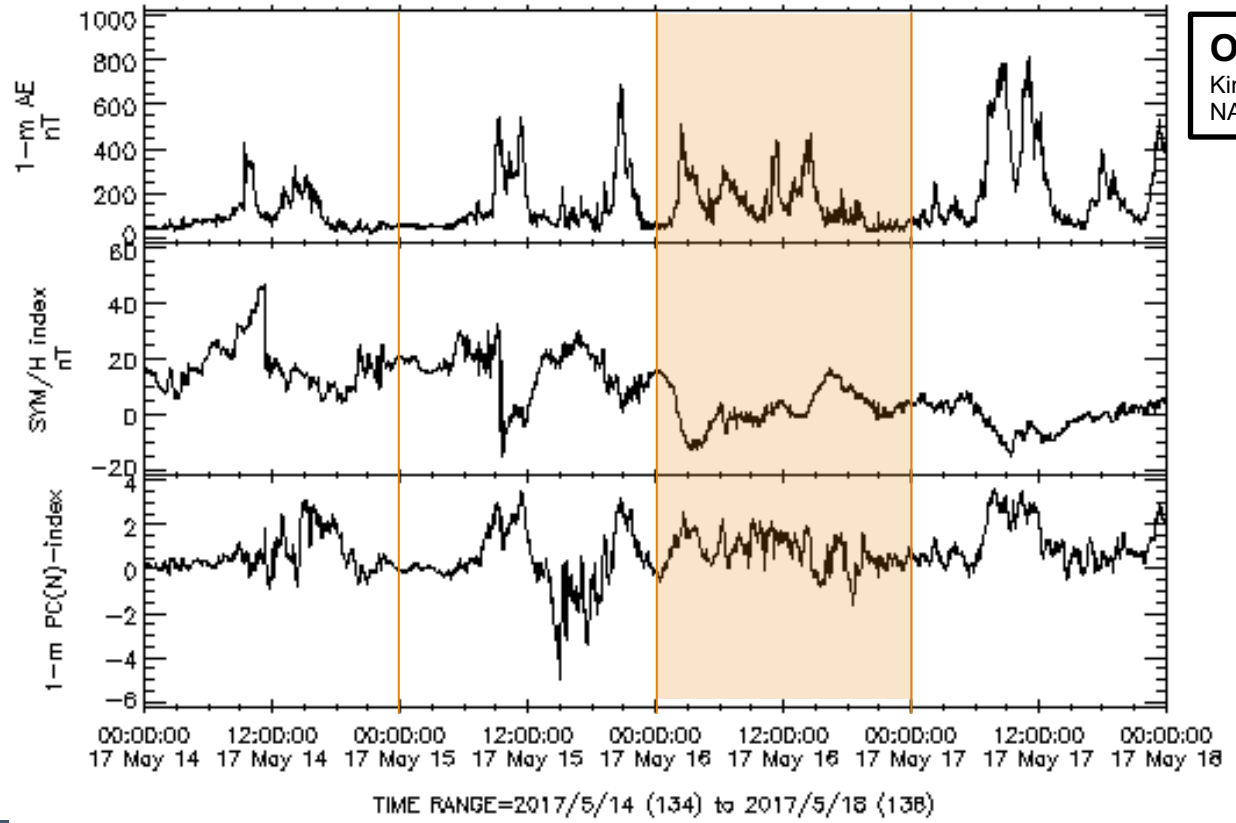
nathaniel.frissell@scranton.edu

Geomagnetic Environment: 14-18 May 2017

Auroral Electrojet

Sym-H
(Geomagnetic Storm Index)

Polar Cap Index



OMNI Data
King and Papatashvilli
NASA GSFC CDAWeb

nathaniel.frissell@scranton.edu

Conclusions

- **Ham Radio Disturbance Seems likely that it is a LSTID**
  - ~1.5 hr periodicity
  - Appears coherent across Continental US
  - Consistent with BKS SuperDARN Beam 13
  - GNSS dTEC Wave Parameter Estimate
    - $\lambda_h \approx 1100$ km, $v_p \approx 950$ km/hr, $T \approx 70$ min, $\Phi_{Azm} \approx 135°$
- **Geomagnetic Environment**
  - AE Spikes to ~700 nT @ 00 and 12 UT on 3 Nov 2017
  - Kp < 3
  - -25 < Sym-H < 0 nT
  - Flat GOES X-Ray Flux (No Flares)
- **Exact source mechanism is uncertain**
- **RBN and WSPR can serve as a tool for monitoring LSTIDs day and night**

nathaniel.frissell@scranton.edu

References

Ding, F., Wan, W., Ning, B., Zhao, B., Li, Q., Zhang, R., Xiong, B., and Song, Q. (2012), Two-dimensional imaging of large-scale traveling ionospheric disturbances over China based on GPS data, J. Geophys. Res., 117, A08318, doi:10.1029/2012JA017546.

Francis, S. H. (1975), Global propagation of atmospheric gravity waves: A review, J. Atmos. Terr. Phys., 37, 1011–1054, doi:10.1016/0021-9169(75)90012-4.

Frissell, N. A., Baker, J. B. H., Ruohoniemi, J. M., Gerrard, A. J., Miller, E. S., Marini, J. P., West, M. L., and Bristow, W. A. (2014), Climatology of medium-scale traveling ionospheric disturbances observed by the midlatitude Blackstone SuperDARN radar, J. Geophys. Res. Space Physics, 119, 7679– 7697, doi:10.1002/2014JA019870.

Frissell, N. A., Baker, J. B. H., Ruohoniemi, J. M., Greenwald, R. A., Gerrard, A. J., Miller, E. S., and West, M. L. (2016), Sources and characteristics of medium-scale traveling ionospheric disturbances observed by high-frequency radars in the North American sector, J. Geophys. Res. Space Physics, 121, 3722– 3739, doi:10.1002/2015JA022168.

Chimonas, G. (1970), The equatorial electrojet as a source of long period traveling ionospheric disturbances, Planet. Space Sci., 18(4), 583–589, doi:10.1016/0032-0633(70)90133-9.

Vadas, S. L., and H. Liu (2009), Generation of large-scale gravity waves and neutral winds in the thermosphere from the dissipation of convectively generated gravity waves, J. Geophys. Res., 114, A10310, doi:10.1029/2009JA014108.

nathaniel.frissell@scranton.edu