Climatology of Traveling Ionospheric Disturbances Observed by HamSCI Amateur Radio with Connections to Geospace and Neutral Atmospheric Sources

Diego F. Sanchez KD2RLM1, Nathaniel A. Frissell W2NAF2, Gareth W. Perry KD2SAK1, William D. Engelke AB4EJ3, Anthea Coster4, Philip J. Erickson W1PJE4, J. Michael Ruohoniemi5, and Joseph Baker5, Lynn Harvey6, Carl Luetzelschwab K9LA

1New Jersey Institute of Technology  4MIT Haystack Observatory
2University of Scranton  5Virginia Tech
3University of Alabama  6University of Colorado Boulder
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
  - $30 < T \text{[min]} < 180$
  - 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;]
Data Sources

- **Ham Radio**
  - Reverse Beacon Network
  - Weak Signal Propagation Reporting Network (WSPRNet)
- **SuperDARN**
- **NASA OMNI Data**
- **MERRA-2**
Ham Radio TIDs

23 Nov 2017 - 24 Nov 2017
Ham Radio Networks
N Spots = 209145
RBN: 38%
WSPRNet: 62%

Date, number of spot data, and percentage of data source.

Location of the spot datums

Geomagnetic storm indices

Solar activity from GOES satellites

Ham radio spot data organized by propagation distance and time of day.

Quasi periodic wave TID structure.

White dotted line: Solar Zenith.

http://hamsci.org
TID Events

- 26 January 2017
- US
- 14 MHz

- 26 January 2017
- Europe
- 7 MHz

- 25 December 2017
- Europe
- 7 MHz

Well defined quasi periodic wave structures
TID Events

- 26 January 2017
- US
- 14 MHz

- 26 January 2017
- Europe
- 7 MHz

- 25 December 2017
- Europe
- 7 MHz

Highlighted yellow area: selected 1 hour time bins with noticeable potential TID activity.
Quiet Events

- 07 August 2017
- US
- 7 MHz

- 12 April 2017
- Europe
- 7 MHz

- 26 May 2017
- Europe
- 7 MHz

Smooth ham radio observations without any noticeable disturbances.
Quiet Events

- 07 August 2017
- US
- 7 MHz

- 12 April 2017
- Europe
- 7 MHz

- 26 May 2017
- Europe
- 7 MHz

Highlighted yellow area: selected 1 hour time bins with noticeably smooth ham radio observations.
Examples of events not included

- **Significant geomagnetic storm and solar activity**

- **Radio blackouts and disturbances likely caused by the geomagnetic storm and solar activity.**

- **Significant solar activity (solar flares)**

- **Radio blackouts and disturbances likely caused by solar flares.**
Total Spot Activity

Daily average number of total spots in Europe and the US for the year 2017.

- Relative consistency in the number of spots.
- No noticeable decrease in ham radio activity in the summer months.
Europe TID Climatology

Figure showing the total number of hours with TID activity by month observed within daily ham radio observation plots.

TID event = 1 hour with observable TID signature
US TID Climatology

Figure showing the total number of hours with TID activity by month observed within daily ham radio observation plots.

TID event = 1 hour with observable TID signature
SuperDARN Climatology Comparison

SuperDARN

Monthly Distribution of MSTID Events

- 629 MSTID Events
- [Frissell et al., 2014]

Monthly Distribution of Quiet Events

- 360 Quiet Events
- Lack of summertime ground scatter

Amateur Ham Radio

US TID Climatology 2017

- TID Events
- Quiet Events (no TIDs)
SuperDARN Max AE Comparison

**SuperDARN**

*Distribution of Max Kyoto AE for MSTID Events*

- 629 MSTID Events

*Distribution of Max Kyoto AE for Quiet Events*

- 360 Quiet Events

**Amateur Ham Radio**

*US Distribution of Max AE for TID Events*

- 729 TID Events

*US Distribution of Max AE for Quiet Events*

- 1548 Quiet Events

[Frissell et al., 2014]

- Enhanced Max AE values for TID events
- Lower Max AE values for quiet events
MERRA-2 60N Zonal Wind Speed Data

Northern Hemisphere Zonal Wind Speeds 2017

Altitude (Km)

Daily TID Events

60N Zonal Wind Speed (m/s)
Conclusions and Future Work

- TID activity more prominent starting in late fall and ending in early spring.
- Ham radio traffic not noticeably influenced by season.
- Exact mechanism is uncertain, currently looking at auroral and geomagnetic sources. Initial observations show:
  - Slightly enhanced max AE [nT] for times with TID events.
  - Large wind shifts appear to coincide with noticeable drops in TID activity.
  - Little to no TID activity when the 60N zonal winds are predominantly eastward.
- Develop Automated detection system for TID signatures within Ham radio data.
References


Acknowledgments

We are especially grateful to the amateur radio community who voluntarily produced and provided the HF radio observations used in this presentation, especially the operators of the Reverse Beacon Network (RBN, reversebeacon.net), the Weak Signal Propagation Reporting Network (WSPRNet, wspnnet.org), qrz.com, and hamcall.net. NAF gratefully acknowledges the support of NSF Grant AGS-2002278. We acknowledge the use of the Free Open-Source Software projects used in this analysis: Ubuntu Linux, python, matplotlib, NumPy, SciPy, pandas, xarray, iPython, and others.

GPS TEC data products and access through the Madrigal distributed data system are provided to the community by the Massachusetts Institute of Technology under support from US National Science Foundation grant AGS-1952737. Data for the TEC processing is provided from the following organizations: UNAVCO, Scripps Orbit and Permanent Array Center, Institut Geographique National, France, International GNSS Service, The Crustal Dynamics Data Information System (CDDIS), National Geodetic Survey, Instituto Brasileiro de Geografia e Estatística, RAMSAC CORS of Instituto Geográfico Nacional de la República Argentina, Arecibo Observatory, Low-Latitude Ionospheric Sensor Network (LISN), Topcon Positioning Systems, Inc., Canadian High Arctic Ionospheric Network, Institute of Geology and Geophysics, Chinese Academy of Sciences, China Meteorology Administration, Centro di Ricerche Sismologiche, Système d’Observation du Niveau des Eaux Littorales (SONEL), RENAG : REseau NAitonal GPS permanent, GeoNet - the official source of geological hazard information for New Zealand, GNSS Reference Networks, Finnish Meteorological Institute, SWEPOS - Sweden, Hartebeesthoek Radio Astronomy Observatory, TrigNet Web Application, South Africa, Australian Space Weather Services, RETE INTEGRATA NAZIONALE GPS, Estonian Land Board, and Virginia Tech Center for Space Science and Engineering Research.

The authors acknowledge the use of SuperDARN data. SuperDARN is a collection of radars funded by national scientific funding agencies of Australia, Canada, China, France, Italy, Japan, Norway, South Africa, United Kingdom and the United States of America.