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

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Abstract

Traveling Ionospheric Disturbances (TIDs) are propagating variations in ionospheric electron densities that affect radio communications and can help with understanding energy transport throughout the coupled magnetosphere-ionosphere-neutral atmosphere system. Large scale TIDs (LSTIDs) have periods T [?]30-180 min, horizontal phase velocities vH[?]100-250 m/s, and horizontal wavelengths H>1000 km and are believed to be generated either by geomagnetic activity or lower atmospheric sources. TIDs create concavities in the ionospheric electron density profile that move horizontally with the TID and cause skip-distance focusing effects for high frequency (HF, 3-30 MHz) radio signals propagating through the ionosphere. The signature of this phenomena is manifest as quasi-periodic variations in contact ranges in HF amateur radio communication reports recorded by automated monitoring systems such as the Weak Signal Propagation Reporting Network (WSPRNet) and the Reverse Beacon Network (RBN). In this study, members of the Ham Radio Science Citizen Investigation (HamSCI) present a climatology of LSTID activity using RBN and WSPRNet observations on the 1.8, 3.5, 7, 14, 21, and 28 MHz amateur radio bands from 2017. Results will be organized as a function observation frequency, longitudinal sector (North America and Europe), season, and geomagnetic activity level. Connections to geospace are explored via SYM-H and Auroral Electrojet indexes, while neutral atmospheric sources are explored using NASA's Modern-Era Retrospective Analysis for Research and Applications Version 2 (MERRA-2).

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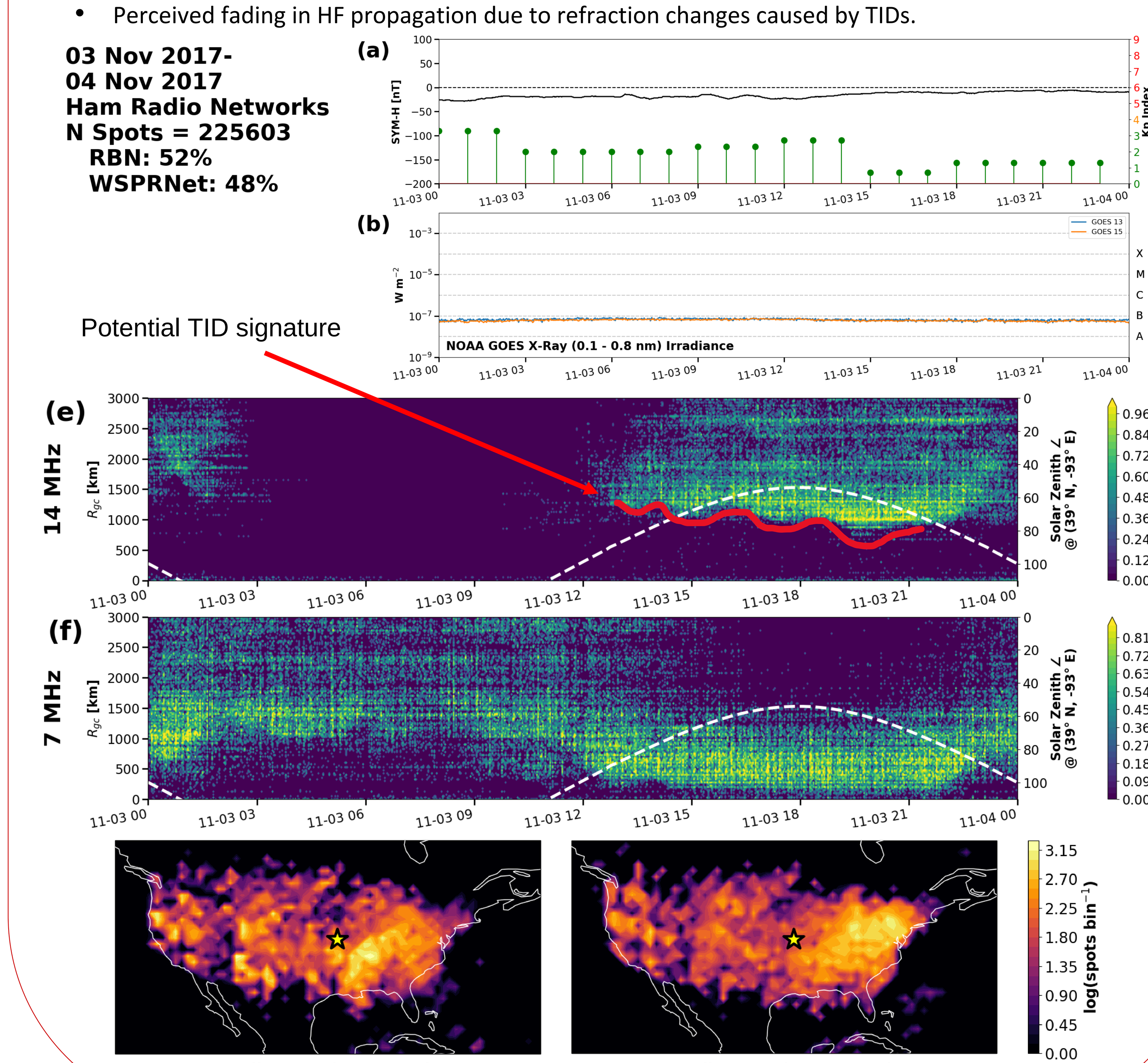
Introduction

In this study, we are searching for TID sources by analyzing observations from distributed passive radio receiver networks and amateur ham radio transmissions. We determine TID parameters visually finding quasi-periodic variations in the minimum HF signal distance within WSPRNet and RBN ham radio observations. This is then applied to a statistical study of TIDs observed by ham radio data for 2017 and compared to similar studies using SuperDARN radars. Seasonal dependencies are identified in the observed TIDs.

Data and Methodology

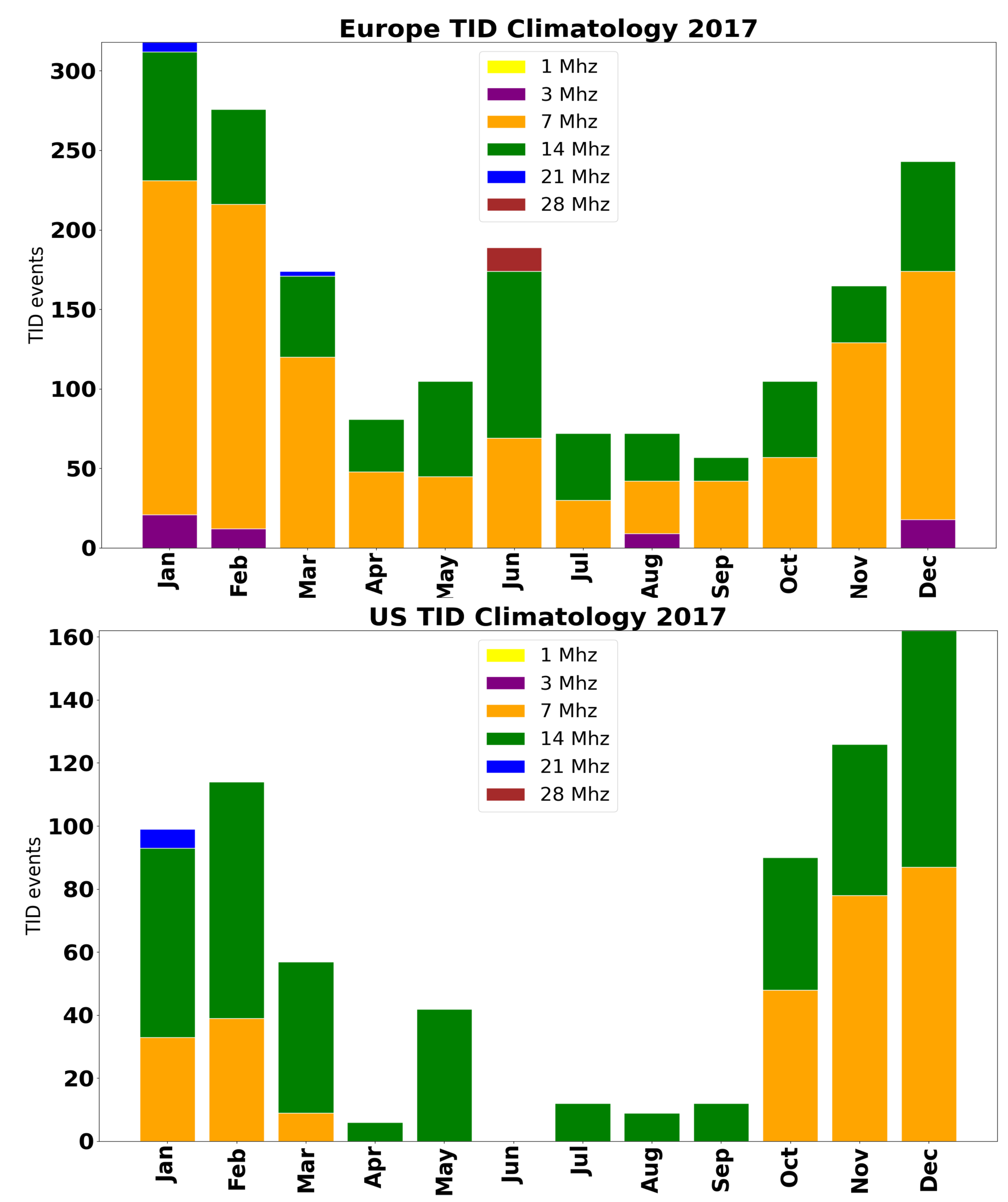
WSPRNet and RBN are automated communication observation networks that are voluntarily operated by amateur radio operators that can monitor and log radio signals. Each datum ("spot") includes information on the transmitter, receiver, time, and frequency. Using data from these networks, two dimensional histograms were created that show:

- Density of spots (from RBN and WSPRNet) per distance (between transmitter and receiver).
- Geomagnetic activity from NASA MNIWeb (SYM-H and Kp Index) • Solar activity from GOES satellites.
- Maps of selected geographic location showing midpoint location of the spot data.
- Perceived fading in HF propagation due to refraction changes caused by TIDs.



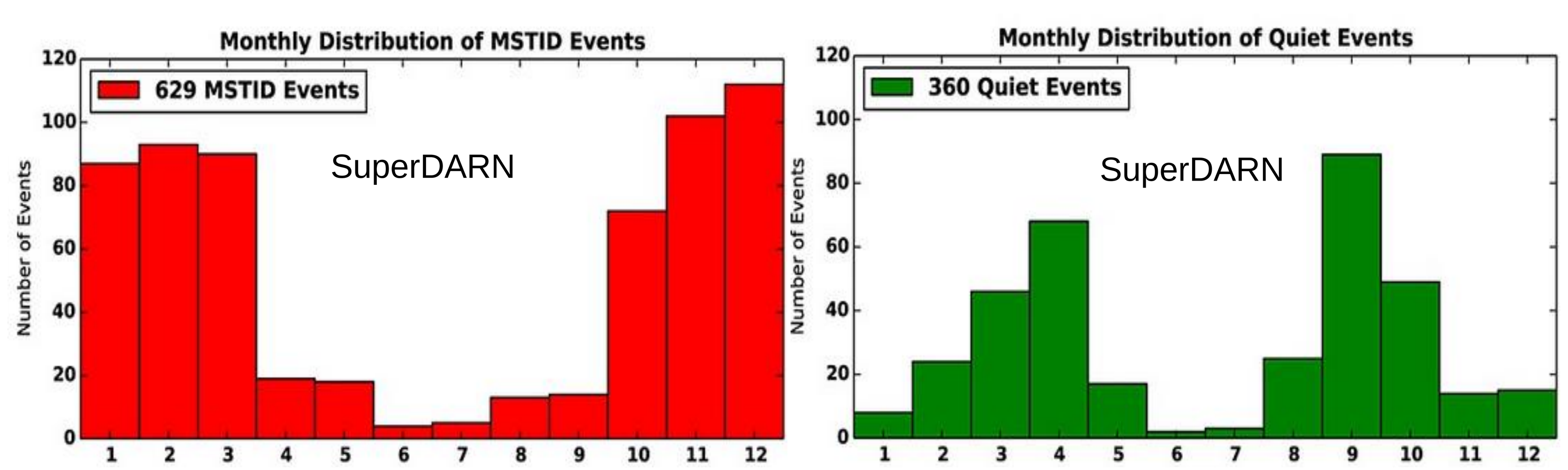
Climatology

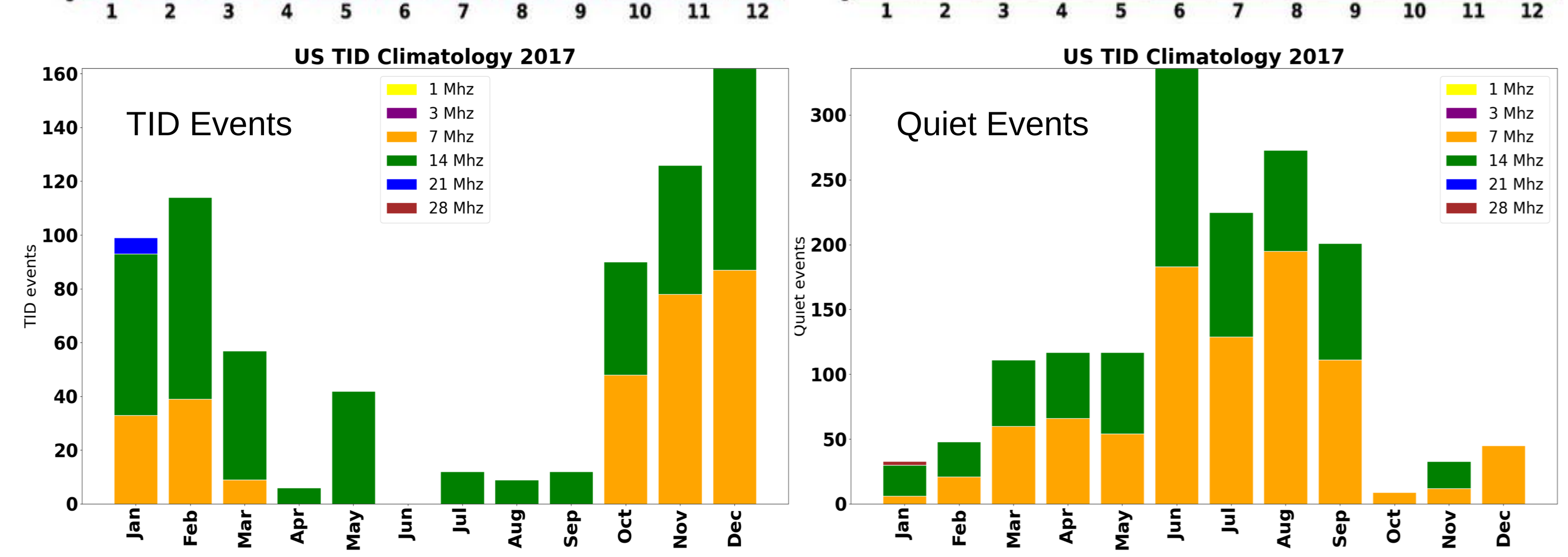
Daily ham radio WSPRNet and RBN plots were generated for the year 2017, for both Europe and the US, and were then searched manually for TID signatures.



- The ham radio histograms were divided into 1-hour bins where bins with observable wave structures were chosen as TID events.
- TID event = 1 hour with observable TID signature.
- Figure showing the total number of hours with TID activity by month observed within daily ham radio observation plots.
- TID activity was much more prominent in the late fall and early spring.
- Fewer observations were made in the summer months in general, except for June in Europe and May in the US.

Given the similarities between how TIDs are observed in SuperDARN radars and Amateur ham radio data explained during the previous talk by Dr. Nathaniel Frissell, the ham radio climatology results were compared with Dr. Frissells results from his 2014 paper Climatology of medium-scale traveling ionospheric disturbances observed by the midlatitude Blackstone SuperDARN radar.

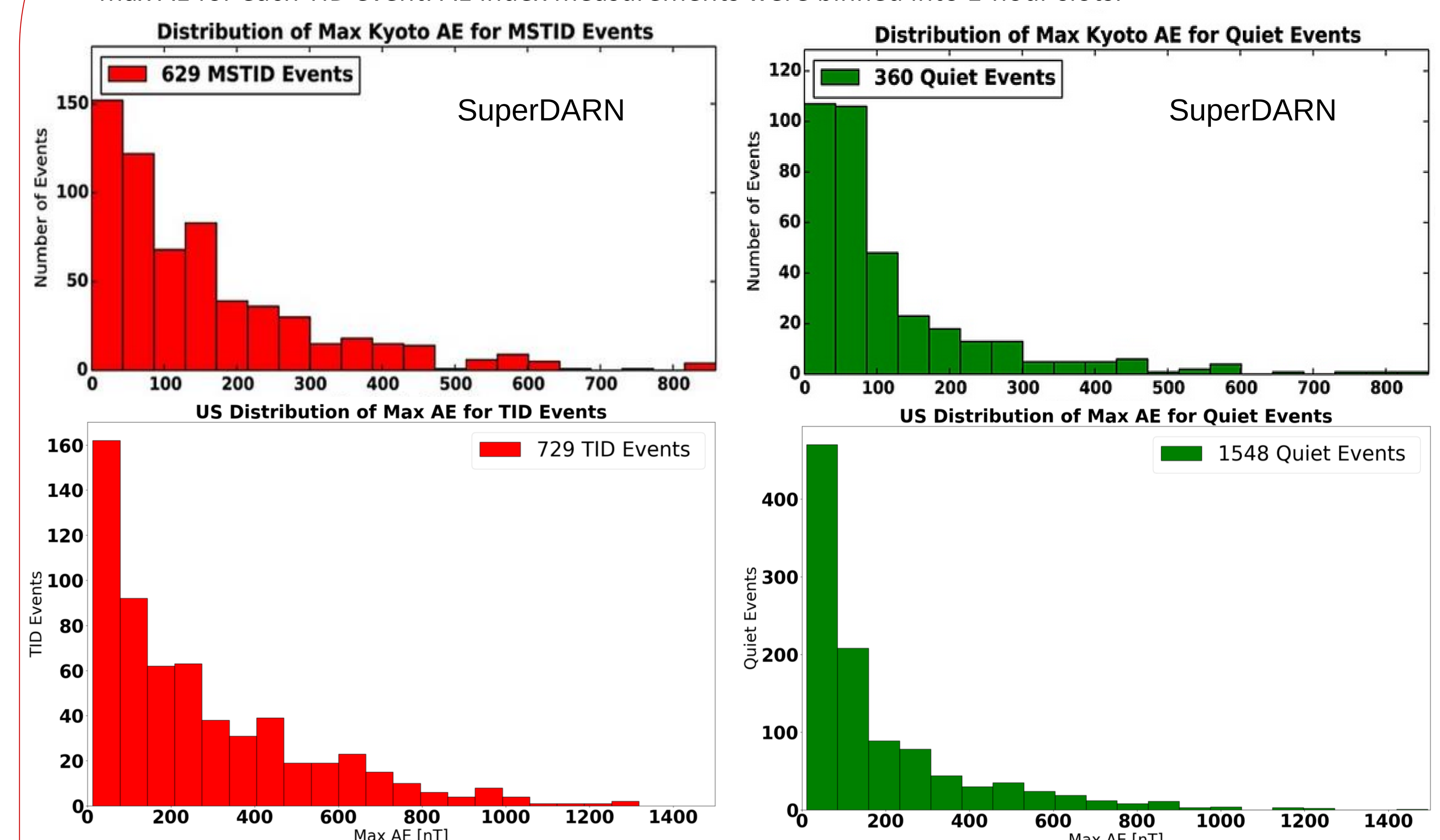




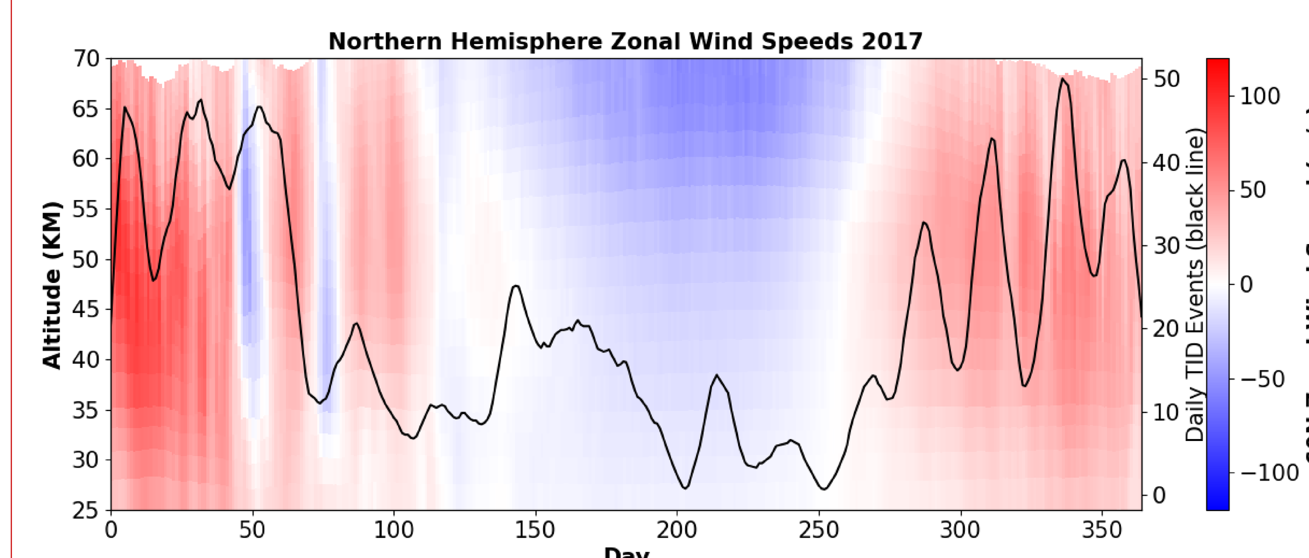
Only the US climatology data was used for this comparison given that the location of the SuperDARN blackstone beams is closer in coverage to the ham radio data from the continental US. Both appear to be consistent with one another, showing more TID activity during the winter months. SuperDARN is unable to have any observations in the summer months due to the lack of ground scatter, an issue not present in the ham radio data.

Geospace and Neutral Atmospheric Sources

Using the same data from the yearly distribution and NASA Omni data, we found the average hourly max AE for each TID event. AE index measurements were binned into 1-hour slots.



The results show slightly enhanced values of Max AE during TID events as opposed to quiet events. These results were then compared again to the results from Frissell et al., 2014 and found consistent.



We explored neutral atmospheric sources next. Zonal wind speed data from MERRA-2 for the year 2017 was plotted along with the daily ham radio observed TID event data on the second vertical axis.

It is suspected that large changes in wind direction and speed may affect how TIDs propagate. Initial conclusions from this plot are that significant decreases in TID activity appear to align well with large and abrupt changes in wind speed or direction.

Summary and Conclusions

- RBN and WSPRNet can serve as a tool for monitoring LSTIDs day and night.
  - LSTIDs are detectable in RBN and WSPRNet observations when data is binned into 2D histograms with 2 min x 25 km bins over the United States and Europe.
  - LSTIDs affect available ham radio communication path lengths.
- Fewer night observation capabilities using 14 MHz.
- 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, continuing work with auroral, geomagnetic sources. Initial observations show:

  Slightly enhanced max AE [nT] and large wind direction changes for times with TID events.

References and Acknowledgments

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