Studying Traveling Ionospheric Disturbances with Citizen Science: Modeling and Validation

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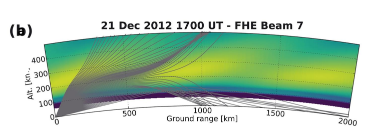
Introduction

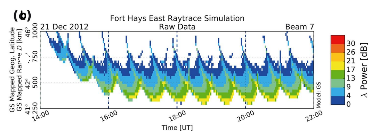
Traveling Ionospheric Disturbances (TIDs) are propagating variations in ionospheric electron densities that affect radio communications and can help with understanding energy transport throughout the coupled magnetosphere-ionosphere-neutral atmosphere system. TIDs may be generated by disturbances from space or from perturbations from the neutral atmosphere. TIDs often propagate over very large distances, making it difficult to identify their sources and track the evolution of their development, but they can be remotely sensed using ground-based radio instrumentation such as the Super Dual Auroral Radar Network (SuperDARN), a global network of high frequency (HF) radars; global position system (GPS), whose signals can be used to detect ionospheric electron density variations; and ionosondes. Recently, it has been shown that observations of amateur (ham) radio communications made by automated HF (3-30 MHz) receiving networks, voluntarily built and operated by the Ham radio community, can be used to measure ionospheric impacts of space weather events such as solar flares, geomagnetic storms, and solar eclipses. These observations present an unprecedented opportunity to use citizen science observations to advance our understanding of the geospace environment, thanks to the existence of large data sets generated by systems such as WSPRNet (Weak Signal Propagation Reporter Network) and RBN (Reverse Beacon Network) amateur radio networks.

Methodology

Ham radio data detects TIDs in a similar way to how SuperDARN, ionosondes, and other radio science instruments detect them. As the ionosphere becomes perturbed by a passing TID, the amount of refraction an HF signal experiences changes which results in a perceived fading in HF propagation. Radio frequency refraction is determined by the density of the ionosphere and since different frequencies refract at different ion densities, changes in the total electron content, caused by TIDs, are expected to show as dropping or growing numbers in total successful ham radio connections in the WSPRNet and RBN data and in the minimum estimated propagation distance of the signal. The Weak Signal Propagation Reporter Network is a group of amateur radio operators using K1JT's MEPT_JT digital mode to probe radio frequency propagation conditions using very low power (QRP/QRPp) transmissions while RBN is a network of stations listening to the bands and reporting what stations they hear, when and how well.

(a)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.
(b)Simulated SuperDARN Fort Hays East (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.



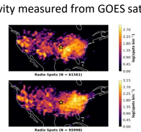


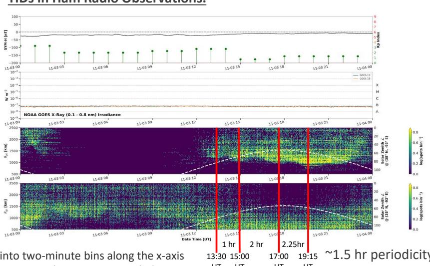
Results

TIDs in Ham Radio Observations.

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

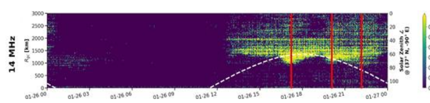
a) Geomagnetic activity from Kp Index.
b) Solar activity measured from GOES satellites.



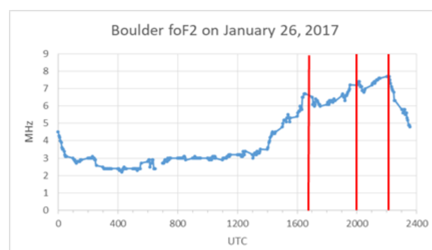


c) & d) The data in these histograms is separated into two-minute bins along the x-axis represented in UT hours, with the y-axis being the estimated propagation path distance of the radio communication and the colors representing the spot density of that particular bin for that propagation distance.

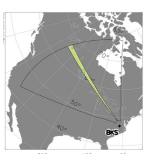
January 26, 2017 Ionosonde foF2 Comparison US



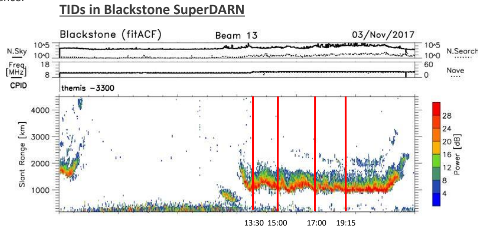
- The highest frequency that the ionosonde reflects is called foF2.
- The higher the frequency that is bounced back from the ionosphere, the higher the electron densities will be.
- More refraction at higher electron densities.
- Radio range is shortest at higher foF2 values.



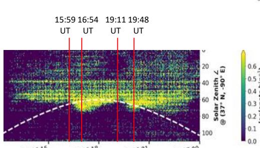
TIDs in Blackstone SuperDARN



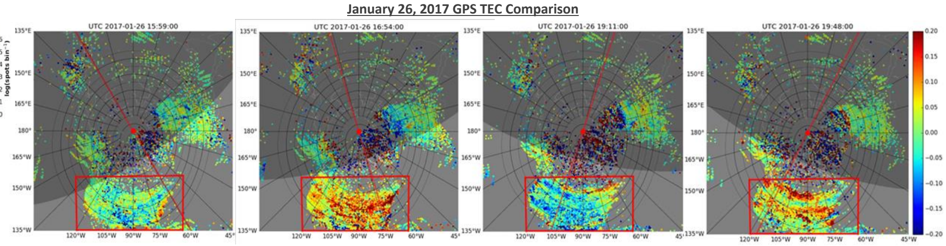
SuperDarn Beam 13 coverage.



January 26, 2017 GPS TEC Comparison



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



Conclusions

- **Ham Radio Disturbances seem likely to be LSTIDs.**
  - Appear coherent across Continental US .
  - Consistent with BKS SuperDARN Beam 13.
  - Consistent with GNSS TEC.
  - Consistent with Boulder (US) Ionosondes.
- **RBN and WSPRNet can serve as a tool for monitoring LSTIDs day and night.**
- **Less night observation capabilities using 14 MHz.**
- **Exact mechanism is uncertain, currently looking at auroral sources.**

Future Work

- Determine TID source.
  - Auroral? Geomagnetic Storm?
- **Develop automated mathematical approach to detect TIDs within ham radio data.**

References and/or Acknowledgements

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