# Searching for STEVE in Incoherent Scatter Radar Data

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## Background

- STEVE (Strong Thermal Emission Velocity Enhancement) is a type of phenomenon that appears as a night-time mauve emission, equatorward of the auroral oval, during strong plasma flows.
- They extend thousands of kilometers in the east-west direction and only tens of kilometers in the north-south direction.

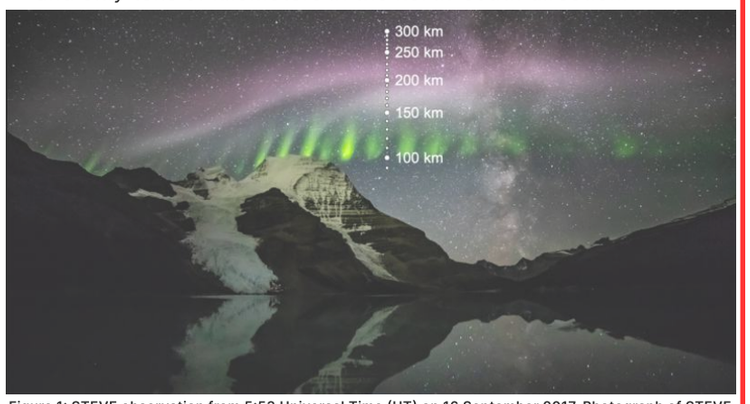


**Figure 1: STEVE observation from 5:53 Universal Time (UT) on 16 September 2017. Photograph of STEVE emissions and a greenpicket fence taken by Robert Downie at 53.12◦ north, 119.17◦ west, 3,400 m altitude. Values indicate the triangulated altitude. Figure taken from Archer et. al. (2019).**

- STEVE events lack a strong precipitation signature, but are associated with substorms, electron temperature enhancements, and SAIDs (SubAuroral Ion Drifts).
- The STEVE events identified in Gallardo-Lacourt et. al. (2018) are each associated with a substorm; however, not every substorm generates a STEVE event. While substorms occur several times per day, the frequency of reported STEVE events is of the order of several per year.
- It is speculated that STEVE associated flows are a source of intense frictional heating in the subauroral region.
- A STEVE “precursor” event has been observed with the Poker Flat Incoherent Scatter Radar (PFISR).

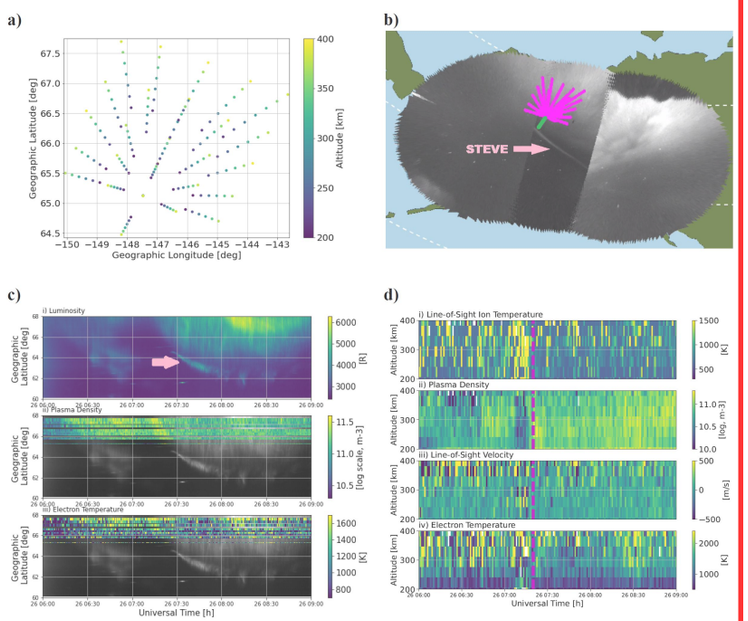


**Figure 2: 26 March 2008 STEVE event. a) PFISR beam pattern. b) The PFISR beam pattern superimposed on 7:27 UT imager observations from McGrath, Alaska; Gakona, Alaska; and Whitehorse, Yukon (left to right). The green beam is anti-parallel to the magnetic field. c) Keogram observations from the Gakona imager and PFISR observations between 200-250 km altitude: i) Gakona observations, ii) overlapping plasma density data, and iii) overlapping electron temperature data. d) PFISR plasma parameters anti-parallel to the magnetic field: i) line-of-sight ion temperature, ii) plasma density, iii) line-of-sight ion velocity, and iv) electron temperature. The purple dashed line indicates the beginning of the STEVE emissions in imager data**

- PFISR observations near a STEVE event show an ion temperature enhancement parallel to the magnetic field.
- This is consistent with our understanding of STEVE events and their relationship to SAIDs, as well as the time-scales behind ion-neutral frictional heating [Goodwin et al, 2014].
- **The motivation of this research is to find the unique characteristics of substorms associated with STEVE events.**
- To explore this possible connection even further, and find more STEVE events, we have designed an algorithm to detect plasma features typically associated with STEVE events.

## Methodology

- To find a ion temperature enhancement, our algorithm searches for points that are bigger in value when compared to the preceding and subsequent points. It then filters out enhancements that are not larger than the collective standard deviation multiplied by a factor of 3.5 .

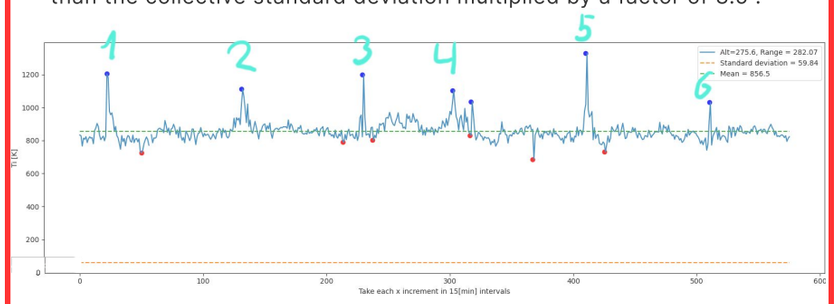


**Figure 3: Example of “ion temperature enhancements” on an arbitrary dataset.**

- To filter out possible enhancements due to noise, enhancements must be observed at both 240 and 275 km altitude.
- These enhancements are then filtered by looking for the presence of “STEVE-like” structures in Swarm spacecraft data (see poster MDIT-3)
- This algorithm is applied to PFISR ion temperature data spanning between the years of 2014-2016.

## Results

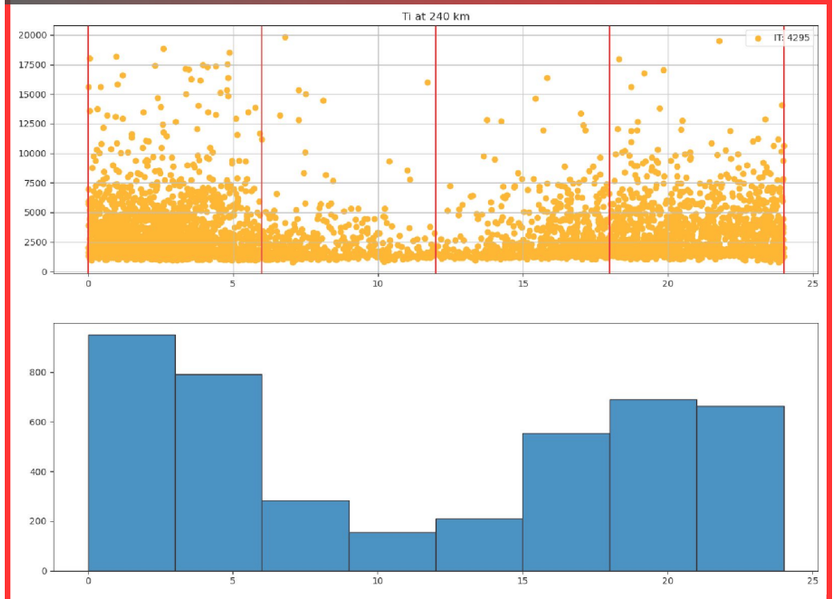


**Figure 4: Magnetic Local Time (MLT) graph of Ion temperature enhancements at the altitude of 240 km**

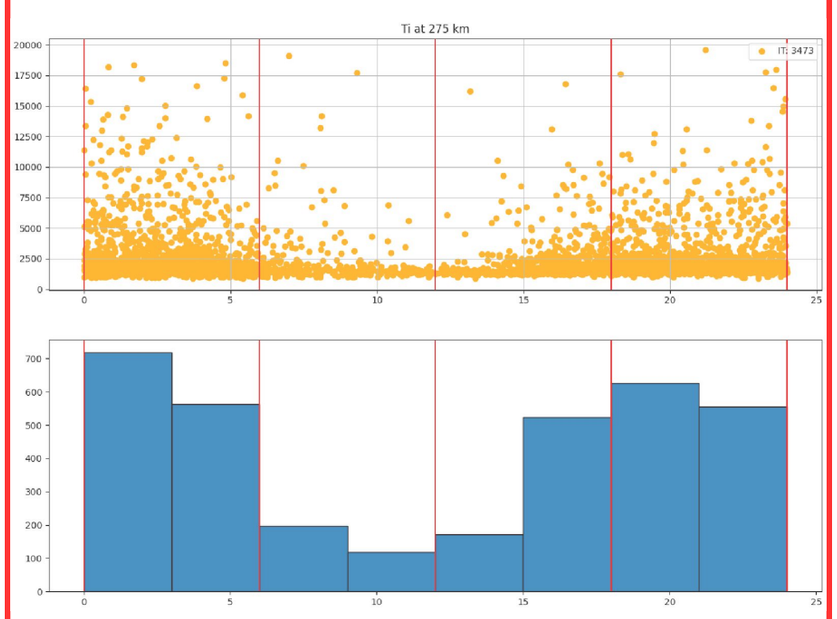


**Figure 5: MLT graph of Ion temperature enhancements at the altitude of 275 km.**

## Results Continued

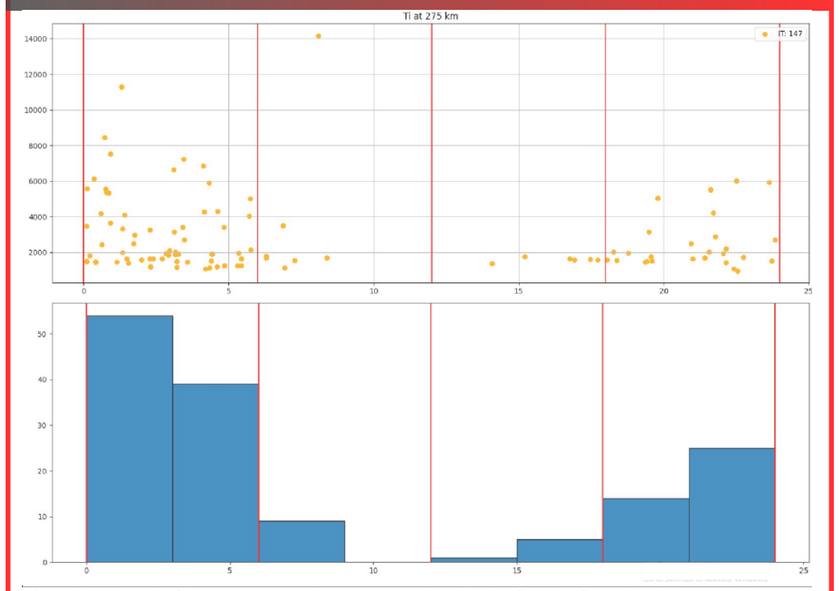


**Figure 6: MLT graph of ion temperature enhancements at the altitude of 275 km filtered out by SWARM electron spikes (similar plot at 240 km has been omitted).**

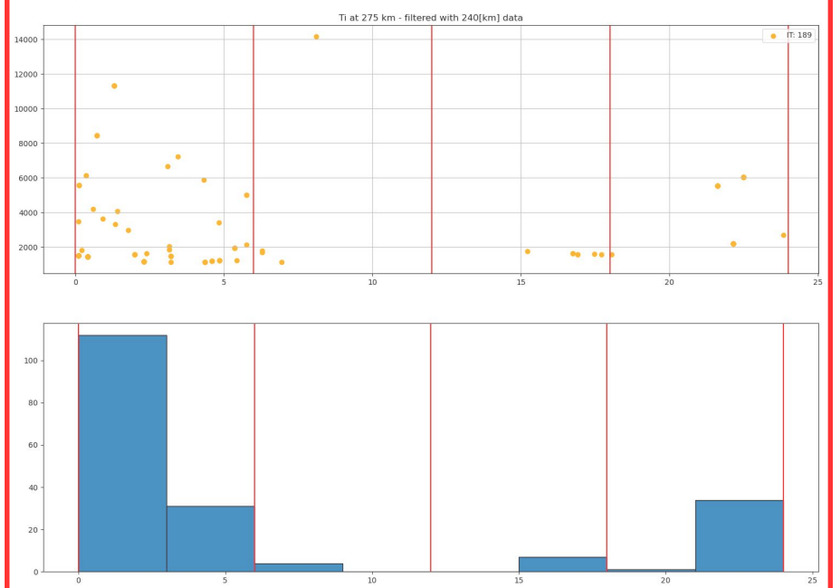


**Figure 7: MLT graph of ion temperature enhancements at both 240 km and 275 km altitudes, further filtered by Swarm spacecraft observations of “STEVE-like” plasma parameters.**

## Summary

- In this work, an algorithm to find ion temperature enhancements in ISR data has been developed and coupled with Swarm data to search for STEVE events.
- Preliminary results show that the occurrence of ion temperature spikes and STEVE plasma conditions are most common at night. However, they are most typically post-midnight, which is inconsistent with our current understanding of STEVE optical emissions.

**Future Work:**

- Times with “STEVE-like” plasma conditions are being examined using optical all-sky camera data, to see if STEVE events are observed.
- Better tune our algorithm using plasma density depletions.
- Once more STEVE events and STEVE-like events are found, couple these with spacecrafft observations in the magnetosphere to find the drivers behind STEVE events.

**Reference:**

- Archer, W. E., Gallardo-Lacourt, B., Perry, G. W., St.-Maurice, J. P., Buchert, S. C., & Donovan, E. (2019). Steve: The optical signature of intense subauroral ion drifts. *Geophysical Research Letters*, 46(12), 6279-6286.
- Gallardo-Lacourt, B., Nishimura, Y., Donovan, E., Gillies, D. M., Perry, G. W., Archer, W. E., ... & Spanswick, E. L. (2018). A statistical analysis of STEVE. *Journal of Geophysical Research: Space Physics*, 123(11), 9893-9905.
- Goodwin, L., St.-Maurice, J. P., Richards, P., Nicolls, M., & Hairston, M. (2014). F region dusk ion temperature spikes at the equatorward edge of the high-latitude convection pattern. Geophysical Research Letters, 41(2), 300-307.

**Acknowledgments:**

This research is funded by the NSF - GEM (Award Number 2225972). PFISR observations are sourced from SRI International (https://amisr.com/amisr/).