# An examination of the impact of Strong Thermal Emission Velocity Enhancement (STEVE) on mid-latitude ionosphere

Veronica Romanek[1], Bharat Kunduri[1], J. Michael Ruohoniemi[1], Joseph Baker[1], Bea Gallardo-Lacourt[2,3]

[1]Virginia Tech, [2]Catholic University, [3]NASA Goddard

## ABSTRACT

Strong Thermal Emission Velocity Enhancement (STEVE) is a narrow, sub-auroral optical feature generally observed during the recovery phase of substorms. Unlike typical aurora, STEVE is not driven by significant particle precipitation but is often co-located with intense Sub-Auroral Ion Drifts (SAIDs) reaching several kilometers per second. In this study, we investigate the ionospheric response to STEVE using SuperDARN radar data from the Fort Hays West (FHW) radar alongside all-sky imager (ASI) observations. We analyze parameters such as Doppler velocity before, during, and after STEVE events. We hypothesize a lack of SuperDARN radar echoes co-located with STEVE, as its association with ionospheric density troughs—regions known to suppress radar backscatter—suggests a corresponding depletion of echoes during these events.

## INTRODUCTION

What are Strong Thermal Emission Velocity Enhancements (STEVEs)?

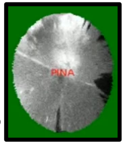
Fig 1

Source: [2]

- Long (thousands of km in lon) & narrow (tens of km in lat) mauve colored optical structure [1]
- Often (but not always) accompanied by green picket fence [1]
- Occurs mainly during recovery phase of geomagnetic substorms [2]
- Not associated with significant particle precipitation like typical aurora [1]
- Linked with intense Sub-Auroral Ion Drifts (SAIDs) reaching several km/s [2]

What observational tools are used to study STEVE and its ionospheric effects?

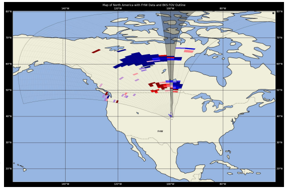
Fig 2




**All-Sky Imagers**

- Capture visible emissions like STEVE arcs and green picket fences
- Provide spatial and temporal context for optical auroral events

Fig 3



**SuperDARN Radars**

- Detect ionospheric plasma flows via HF backscatter
- Reveal flow structures and disturbances linked to STEVE

## METHODOLOGY

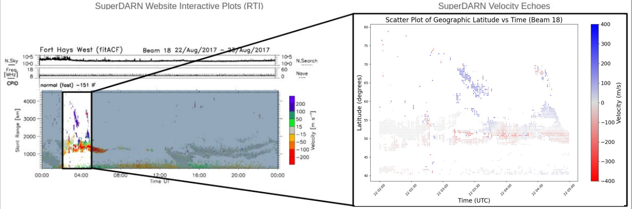



**Fig 4:** Comparison between a Range-Time-Intensity (RTI) plot from the SuperDARN website and a custom RTI plot generated from velocity echoes. This side-by-side comparison is used to validate the consistency and accuracy of the processed data.

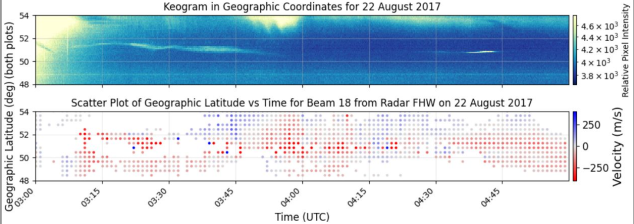



**Fig 5:** (Top) Keogram from the Pinawa (PINA) ASI; brighter yellow indicates stronger optical emissions. There is a clear STEVE feature ranging from 3 to 4 UT . (Bottom) SuperDARN FHW radar velocity echos at the same time and location, showing ionospheric flow patterns.

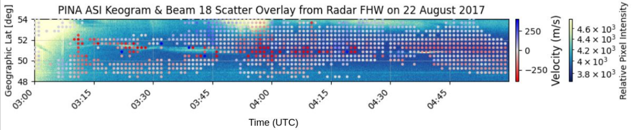



**Fig 6:** Overlaid ASI keogram and superDARN echoes from Fig 5. A clear gap in radar echoes aligns with the STEVE feature, followed by a narrow band or red ecoes- indicating strong westward plasma flows.

## RESULTS & CONCLUSIONS

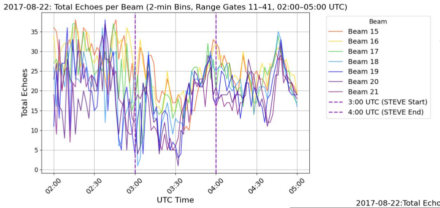



**Fig. 7:** Total FHW echo count for beams and range gates overlapping the PINA ASI FOV. Vertical lines mark STEVE onset and end. A sharp drop in echoes follows onset, requiring further investigation.

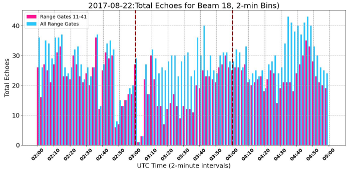



**Fig. 8:** Total echo count summed over all beams and range gates overlapping the PINA ASI FOV (blue), and for case study beam 18 only (pink), in 2-minute intervals. A clear drop in echoes immediately follows the STEVE onset. The general trends resemble those in Fig. 5, with beam 18 showing significant alignment.

## FUTURE WORK

A superposed epoch analysis will be conducted to identify consistent patterns in electrodynamic behavior surrounding STEVE onset. This will improve understanding of mid-latitude ionospheric responses and aid in characterizing STEVE as a distinct subauroral phenomenon.

## REFERENCES

[1] Gallardo-Lacourt, B, J Liang, et al. "On the Origin of STEVE: Particle Precipitation or Ionospheric Skyglow?" *AGU*, Geophysical Research Letters, 20 Aug. 2018

[2] Nishimura, Yukitoshi, Alan Dyer, et al. "Unsolved Problems in Strong Thermal Emission Velocity Enhancement (Steve) and the Picket Fence." Frontiers, Frontiers, 17 Jan. 2023

## ACKNOWLEDGEMENTS

This work was supported by NSF under award AGS-1935110. CGS is supported by NASA under award 80NSSC22M0163. 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. Data from the Pinawa All-Sky Imager was provided by the University of Calgary's Space Physics Group. We acknowledge the support of the Canadian Space Agency's Geospace Observatory (GO Canada) program.

vromanek@vt.edu

VIRGINIA TECH | CENTER FOR GEOSPACE STORMS | SuperDARN Workshop 2025