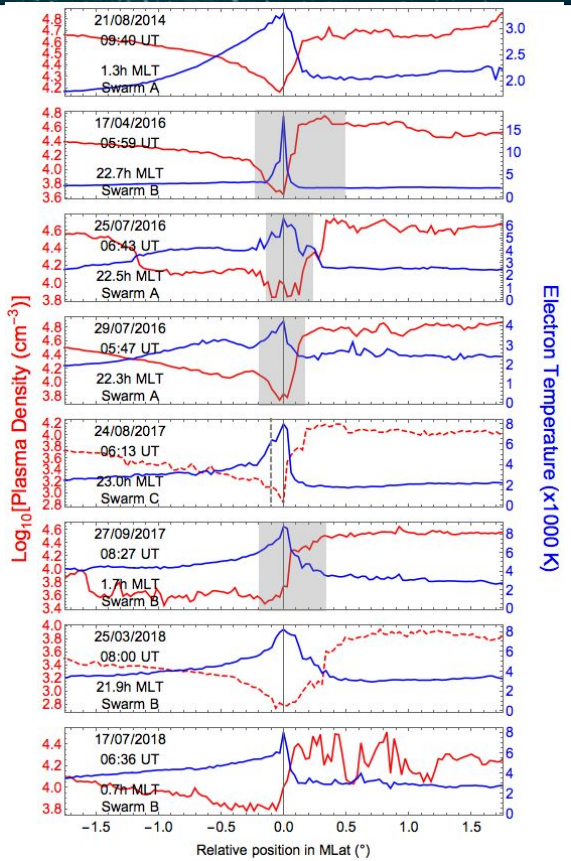
The ionospheric signature of auroral and subauroral fast flows

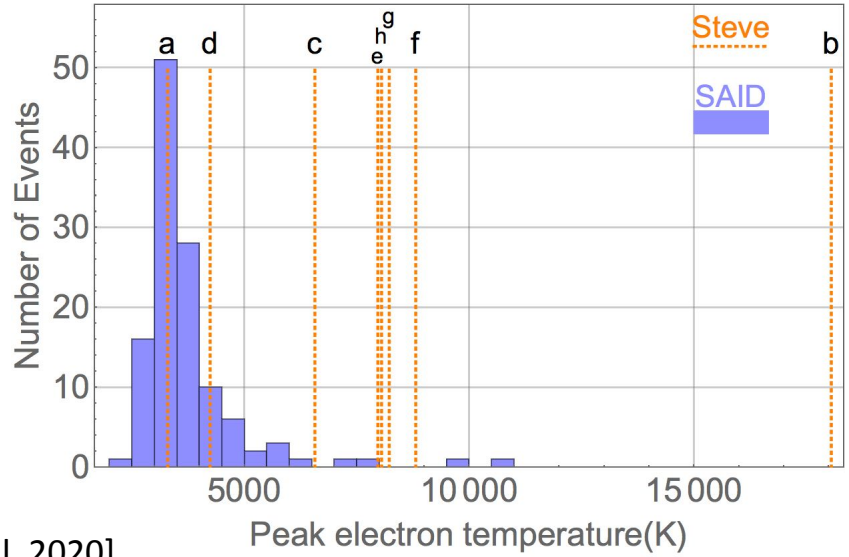
William Archer
University of Saskatchewan

Meet Steve

Project 1: Steve and SAID

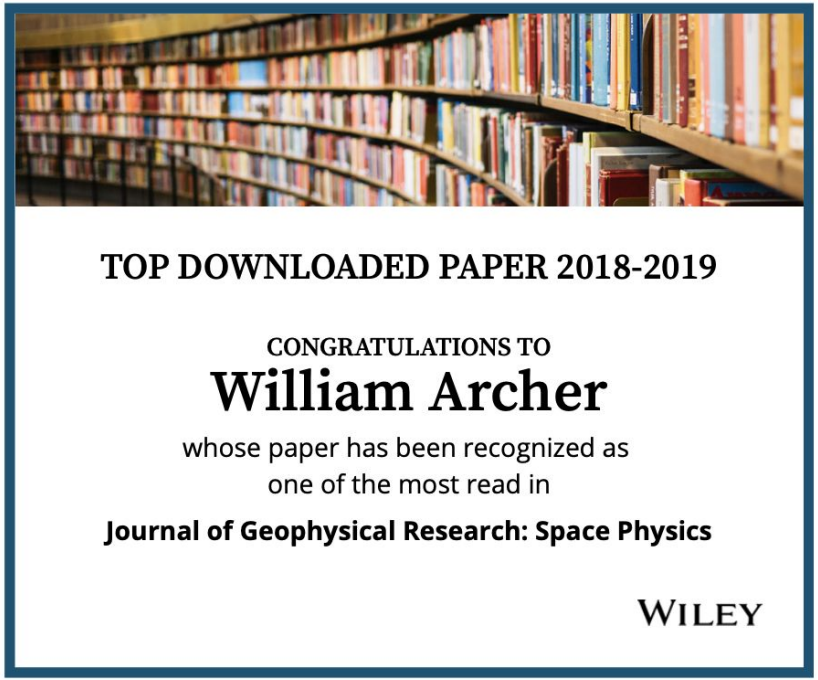


Extreme electron temperature, plasma density, and ion velocity associated with “Steve”.



[Archer et al. 2020]

Project 1: Steve and SAID



TOP DOWNLOADED PAPER 2018-2019

CONGRATULATIONS TO

William Archer

whose paper has been recognized as one of the most read in

Journal of Geophysical Research: Space Physics

WILEY

AGU100 ADVANCING EARTH AND SPACE SCIENCE

Geophysical Research Letters

RESEARCH LETTER
10.1029/2019GL082687

Steve: The Optical Signature of Intense Subauroral Ion Drifts

W. E. Archer[1], B. Gallardo-Lacourt[2], G. W. Perry[2,3], J. P. St.-Maurice[1,4], S. C. Buchert[4,5], and E. Donovan[2]

[1]Department of Physics and Engineering Physics, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, [2]Department of Physics and Astronomy, University of Calgary, Calgary, Alberta, Canada, [3]Center for Solar-Terrestrial Research, New Jersey Institute of Technology, Newark, NJ, USA, [4]Department of Physics and Astronomy, University of Western Ontario, London, Ontario, Canada, [5]Swedish Institute of Space Physics, Uppsala, Sweden

Abstract Little is currently known about the optical phenomenon known as Steve. The first scientific publication on the subject suggests that Steve is associated with an intense subauroral ion drift (SAID). However, additional inquiry is warranted as this suggested relationship as it is based on a single case study. Here we present eight occurrences of Steve with coincident or near-coincident measurements from the European Space Agency's Swarm satellites and show that Steve is consistently associated with SAID. When satellite observations coincident with Steve are compared to that of typical SAID, we find the SAID associated with Steve to have above average peak ion velocities and electron temperatures, as well as extremely low plasma densities.

Key Points:
- Eight Steve events were identified in all-sky imager measurements with coincident or near-coincident measurements from the Swarm satellites
- In all cases, evidence of subauroral ion drifts are observed in Swarm measurements
- All measurements of SAID overlapping with Steve have very fast ion flows, high electron temperatures, and extremely low plasma densities

Supporting Information:
- Supporting Information S1

Correspondence to:
W. E. Archer,
wea784@mail.usask.ca

Citation:
Archer, W. E., Gallardo-Lacourt, B., Perry, G. W., St.-Maurice, J.-P., Buchert, S. C., & Donovan, E. F. (2019). Steve: The optical signature of intense subauroral ion drifts. *Geophysical Research Letters*, *46*, 6279–6286. https://doi.org/10.1029/2019GL082687

Received 4 MAR 2019
Accepted 28 MAY 2019
Accepted article online 4 JUN 2019
Published online 26 JUN 2019

1. Introduction

A new optical phenomenon has recently been brought to the attention of the space physics community by auroral photographers. Steve is observed as a latitudinally narrow, longitudinally extended purple band of light equatorward of the auroral oval. MacDonald et al. (2018) presented the first scientific report of Steve, and investigated the phenomenon simultaneously with a ground-based all-sky imager (ASI), photographs taken by citizen scientists, and in situ measurements from the European Space Agency's Swarm A satellite. These observations showed the optical signature of Steve to be roughly colocated with a subauroral ion drift (SAID). Typical of SAID, this event was located at the equatorward edge of the premidnight region 2 (R2) downward current system in the midlatitude density trough. MacDonald et al. (2018) also reported that the SAID associated with Steve was unusually intense. These initial results show Steve to be a subauroral phenomenon, and as it was measured within a region of weak downward field-aligned current (FAC), unlikely to be caused by precipitating electrons. This result was supported by Gallardo-Lacourt et al. (2018) who present particle measurements from Polar Orbiting Environmental Satellite coincident with an occurrence of Steve identified in ASI measurements. They reported an absence of precipitating charged particles coincident with the optical signature of Steve. In these previous studies, the name "Steve" was presented as the acronym for Strong Thermal Emission Velocity Enhancement. As the physical mechanisms responsible for this phenomenon have not yet been established, in this study we will simply refer to it as Steve.

What then is known about the physical mechanisms for Steve? Gallardo-Lacourt et al. (2018) suggested an ionospheric source for the optical phenomenon, as opposed to magnetospheric precipitating particles responsible for aurora. The results of MacDonald et al. (2018) suggested an association between SAID and Steve. Some characteristics of SAID may be responsible for Steve, or these two phenomena may share a generation mechanism. However, MacDonald et al. (2018) presented a single case study. Therefore, we

Project 2: How Tall is Steve?

Project 2: How Tall is Steve?

AGU100 ADVANCING EARTH AND SPACE SCIENCE

Geophysical Research Letters

RESEARCH LETTER
10.1029/2019GL084473

The Vertical Distribution of the Optical Emissions of a Steve and Picket Fence Event

W. E. Archer[1], J.-P. St.- Maurice[1,2], B. Gallardo-Lacourt[3], G. W. Perry[4], C. M. Cully[5], E. Donovan[5], D. M. Gillies[5], R. Downie[6], J. Smith[6], and D. Eurich[6]

[1]Department of Physics and Engineering Physics, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, [2]Department of Physics and Astronomy, University of Western Ontario, London, Ontario, Canada, [3]NASA/GSFC, Greenbelt, MD, USA, [4]Center for Solar-Terrestrial Research, New Jersey Institute of Technology, Newark, NJ, USA, [5]Department of Physics and Astronomy, University of Calgary, Calgary, Alberta, Canada, [6]Alberta Aurora Chasers, Calgary, Alberta, Canada

Key Points:
- The optical emissions of Steve range from 130 to 270 km in altitude
- The optical emissions of the green Picket Fence range from 95 to 150 km in altitude
- Steve and the Picket Fence extend vertically along similar magnetic field lines

Supporting Information:
- Supporting Information S1

Correspondence to:
W. E. Archer,
wea784@usask.ca

Citation:
Archer, W. E., St.-Maurice, J.-P., Gallardo-Lacourt, B., Perry, G. W., Cully, C. M., & Donovan, E. et al. (2019). The vertical distribution of the optical emissions of a Steve and Picket Fence event. *Geophysical Research Letters, 46*, 10,719–10,725. https://doi.org/10.1029/2019GL084473

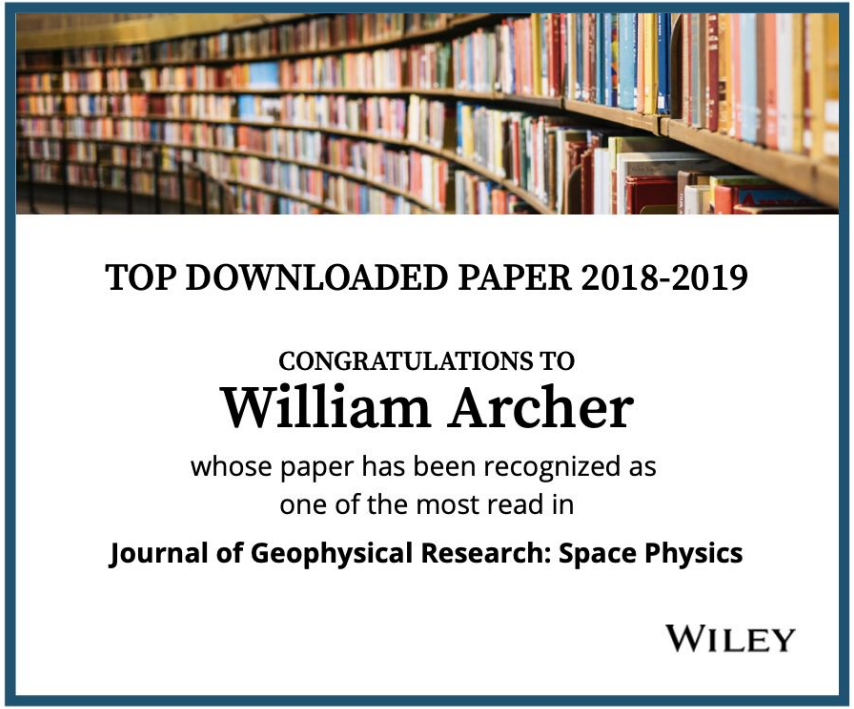
Received 8 JUL 2019
Accepted 29 AUG 2019
Accepted article online 3 SEP 2019
Published online 11 OCT 2019

Abstract So-called "Steve" subauroral purple emissions have recently been uncovered by auroral photographers and have rapidly become an intense subject of debate as to their origin. In some events, nearby periodic green emissions have also been uncovered and given the name "picket fence," owing to their appearance. The present paper advances our understanding of these phenomena by narrowing down the altitude extent of the Steve and picket fence emissions. Our determination is based on the event of 16 September 2017, which was simultaneously observed from two vantage points, allowing for a determination of the height range of Steve and picket fence through triangulation. We show that the picket fence extend between 95- and 150-km altitude and is aligned with the geomagnetic field, while the Steve altitude spread is between 130 and 270 km. We also show the two phenomena to be on nearby or perhaps the same magnetic field lines.

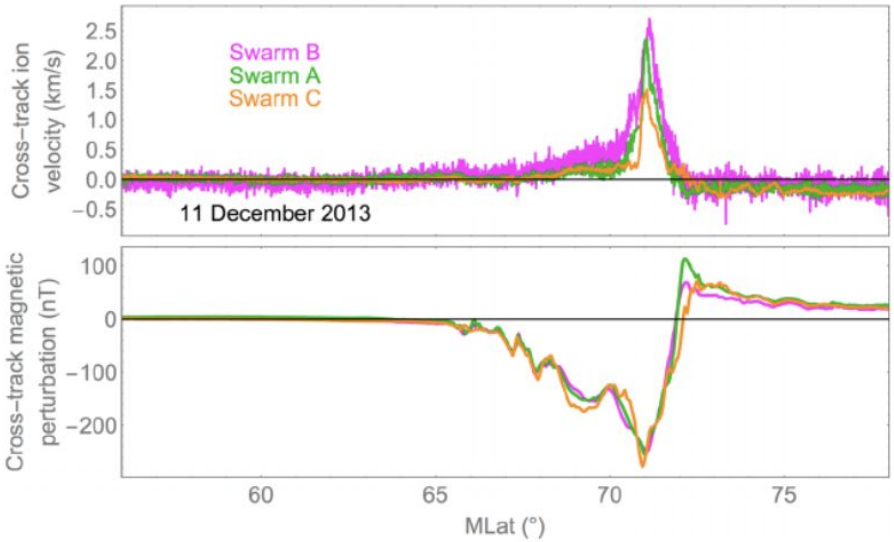
1. Introduction

The scientific community has recently reported on a nighttime optical phenomenon called Steve. Steve is described as a purple band of light observed equatorward of aurora, spanning only tens of kilometers in latitude but thousands of kilometers in longitude (Gallardo-Lacourt, Nishimura, et al., 2018). Archer et al. (2019) were able to find eight occurrences of Steve with near-coincident satellite measurements, and they show Steve to be consistently associated with intense subauroral ion drifts (SAID). The notion of Steve as an optical signature of SAID was put forward by MacDonald et al. (2018). Typical of SAID, these events were near the ionospheric projection of the plasmapause, with either near-zero or downward field-aligned current, which suggests that Steve is not caused by precipitating electrons. Particle measurements from the Polar Operational Environmental Satellites coincident with an occurrence of Steve shows there is insufficient particle precipitation to cause the optical signature of the phenomenon (Gallardo-Lacourt, Liang, et al., 2018). These studies suggest that Steve may be related to the plasma heating present in very intense SAID.

Steve is at times accompanied by green bands of light called the "picket fence." It is currently unknown if these two phenomena are causally linked. While Steve has been reported on several occasions in the absences of the picket fence, the picket fence has not yet been reported in isolation. Nishimura et al. (2019) presented measurements from the Defense Meteorological Satellite Program coincident with two different Steve events, one with picket fence and one without. They report a region of kiloelectron volts precipitating particles roughly coincident with the event including a picket fence, detached from the auroral oval. Based on these observations, Nishimura et al. (2019) suggest that while plasma heating may contribute to Steve, the picket fence seems to be caused by precipitating electrons



Project 3: Neutral Density and BCBF

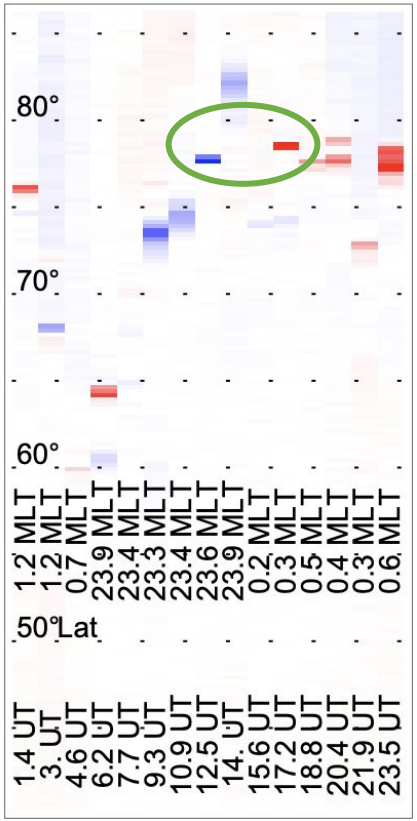


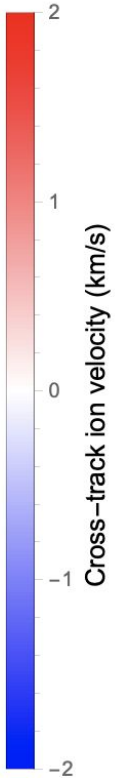
[Archer et al. 2016]

What are Birkeland Current Boundary Flows?

- Auroral phenomena that occur during:
  - Night-time
  - Winter
  - Geomagnetically-quiet
- Fast (>1 km/s) and narrow (<100 km) flow channels resulting from
  - Birkeland currents closing through Pedersen currents
  - Extreme conductivity gradients during quiet and stable conditions
- Strong candidate when looking for density enhancements

Project 3: Neutral Density and BCBF



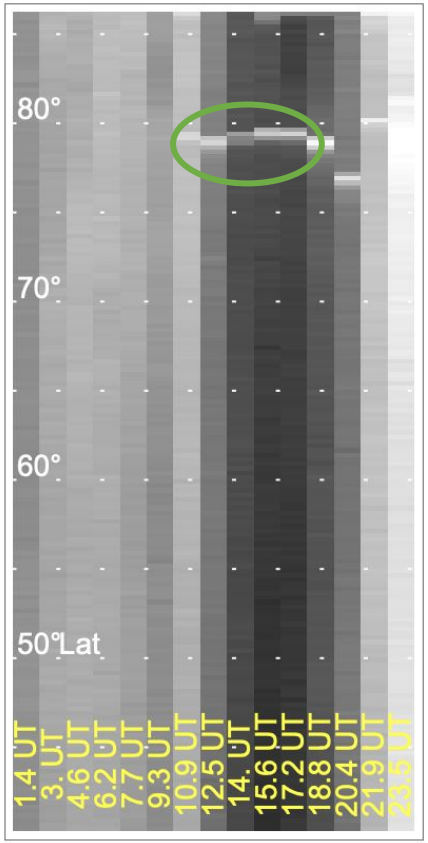


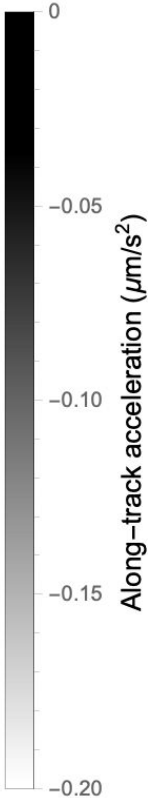
Previously identified ~150 BCBF events in December 2013 Swarm measurements

Persistent accelerometer signature seen 18-12-2013

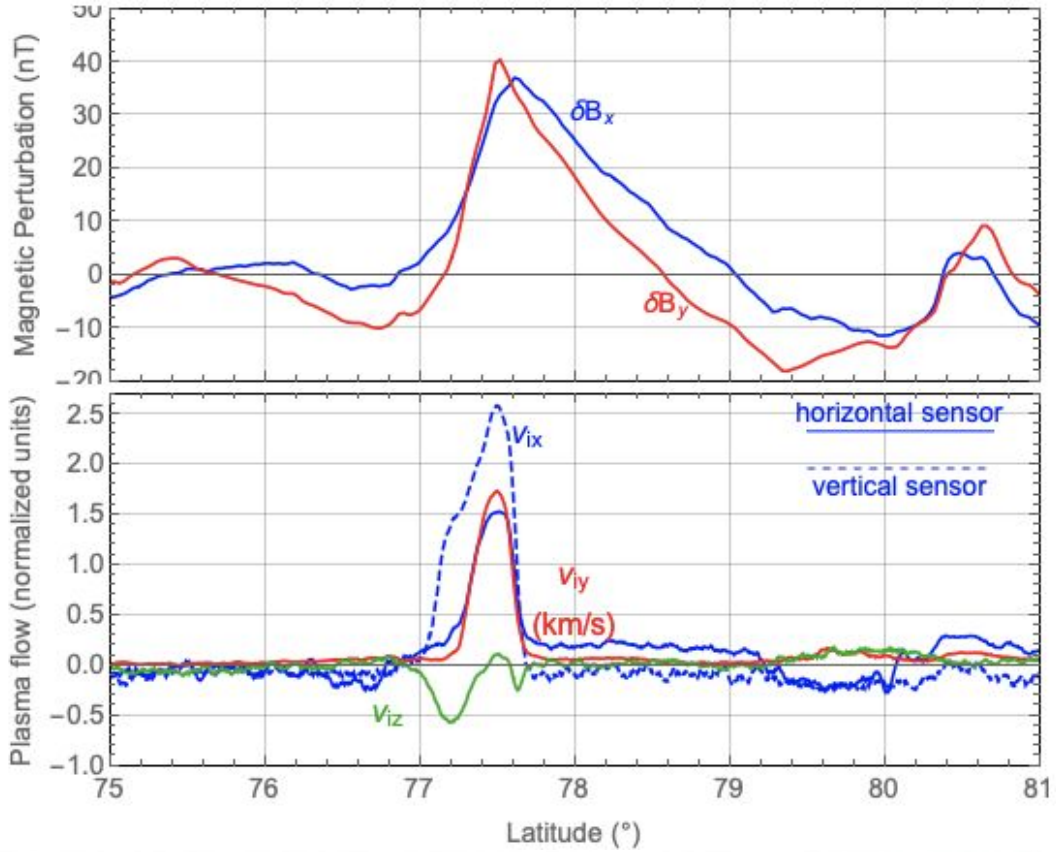
Consistent with narrow density enhancement

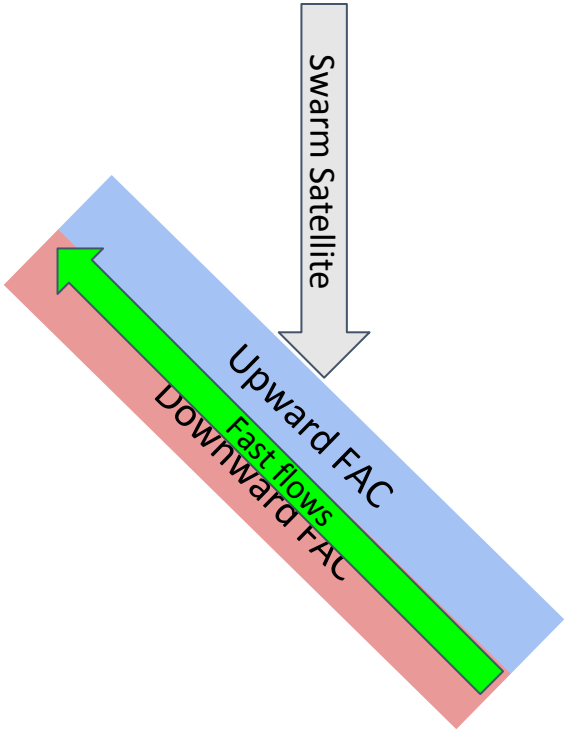
Accelerometer and E-field signatures nearly coincident



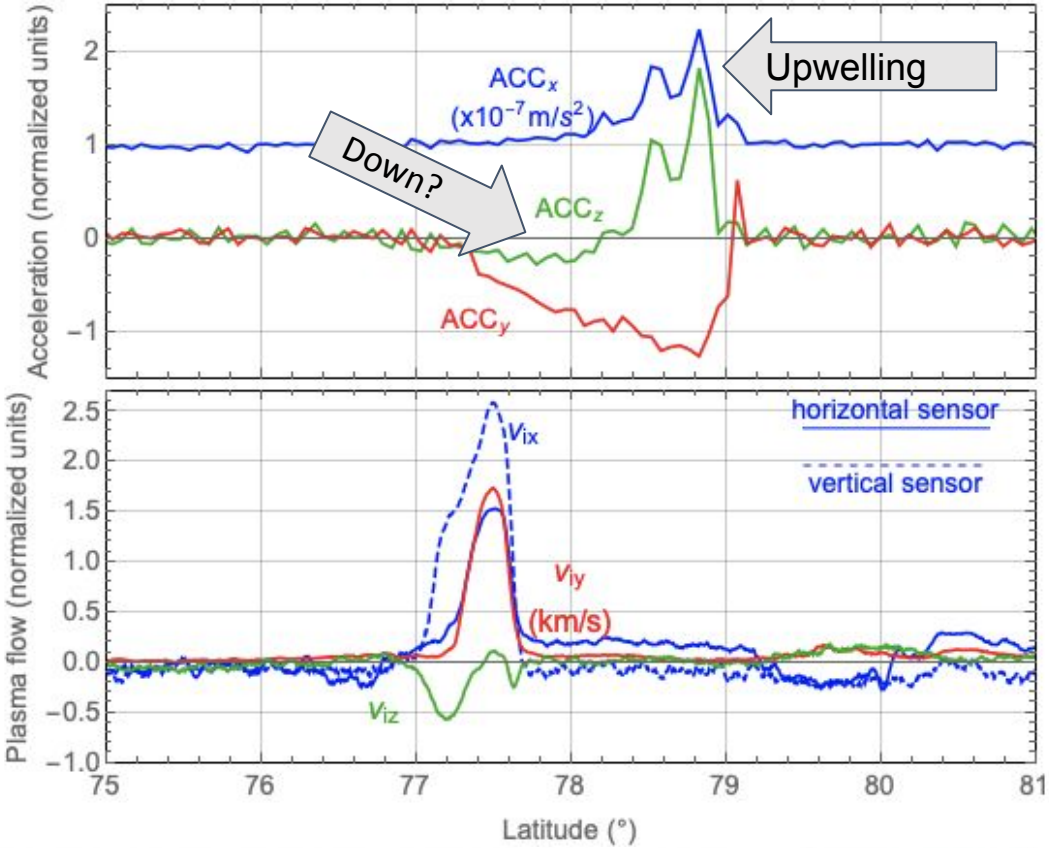


Project 3: Neutral Density and BCBF

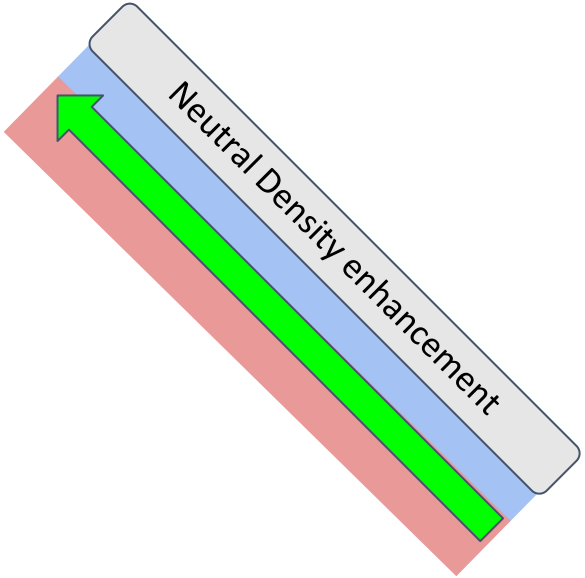




Project 3: Neutral Density and BCBF

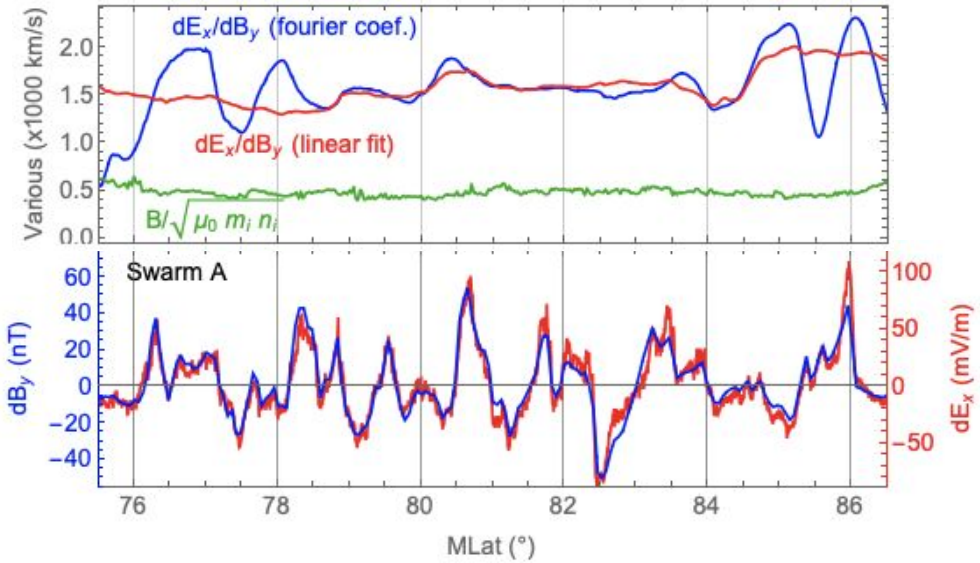


Work still to be done to carefully interpret accelerometer measurements.



Project 4: Highly correlated E and B fields

Stable current system?



Under “standard” assumptions:

$$dB_y \propto \int_z J_x$$

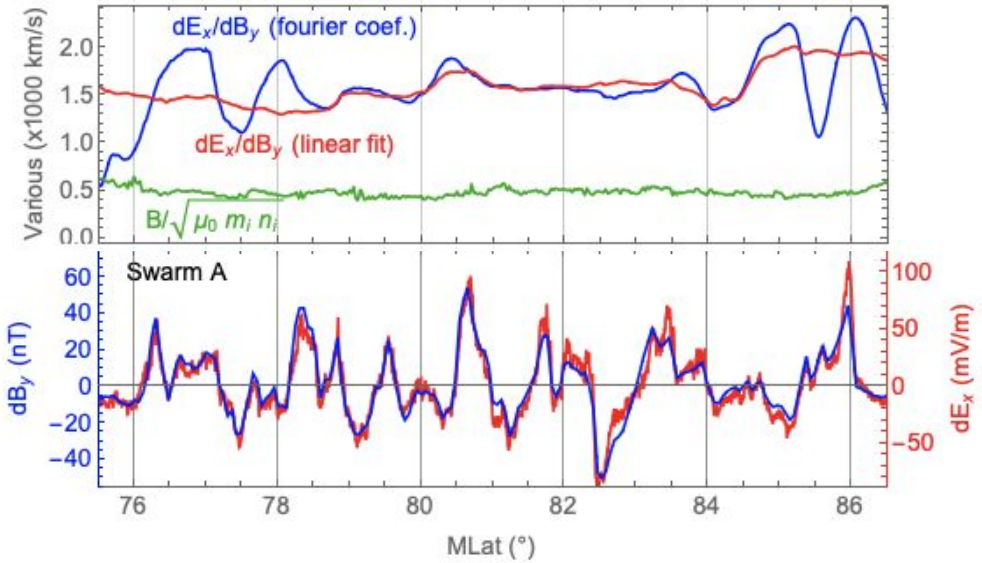
$\therefore$ dEx/dBy $\propto$ height integrated resistivity

(V/I = R)

Constant conductivity through a dynamic region?

Project 4: Highly correlated E and B fields

Alfven Waves?



- Negligible dB$_z$
- Dominant Fourier coefficient near 150 km
- ~10 minute oscillations from ground mag.
- Local plasma Alfven speed significantly lower...

Question?

Thank you for your attention

Archer, W.E., St.-Maurice, J.P., Gallardo-Lacourt, B., Perry, G.W., Cully, C.M., Donovan, E., Gillies, D.M., Downie, R., Smith, J. and Eurich, D., (2019). “The vertical distribution of the optical emissions of a Steve and Picket Fence event.” Geophysical Research Letters

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

Fenrich, F. R., Rankin, R.,Sydorenko, D., Archer, W. E., Knudsen, D. J. (2020) “Birkeland Current Boundary Flows Associated with Field Line Resonances.” Submitted for publication

Billett, D., Perry, G.W., Clausen, L.B.N., Archer, W.E., McWilliams, K.A, “The Relationship Between Large Scale Thermospheric Density Enhancements and the Spatial Distribution of Poynting Flux”, Submitted for publication