Variable Electric Field-Conductance Response during Mesoscale Auroral Arc evolution observed by PFISR and PFDASC

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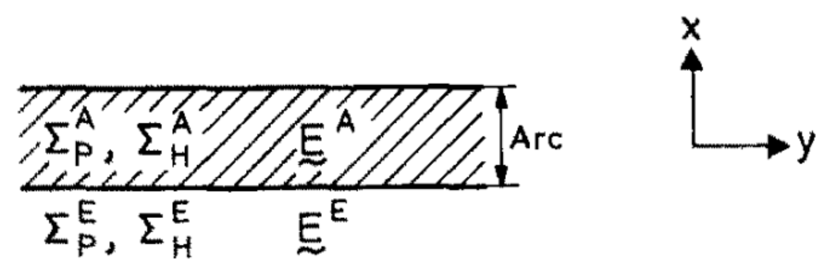
ABSTRACT

Mesoscale auroral arcs (structures spanning 10-500 km in spatial size with a temporal resolution of one to tens of minutes). This study combines Poker Flat Incoherent Scatter Radar (PFISR) 1D electric field and conductance measurements with 557.7 nm Poker Flat Digital All-Sky Camera (PFDASC) auroral imaging to examine one arc event on 24 November 2012. By comparing two stages of the same event, we find that the electric field-conductance response changes from anti-correlated to more correlated behavior. This suggests that the electrodynamic state of mesoscale auroral arcs can evolve over short time scales as precipitation, conductance, polarization electric fields, and current closure reorganize.

BACKGROUND

- Mesoscale auroral arcs are signatures of magnetosphere-ionosphere coupling.
- Auroral precipitation enhances ionospheric conductance and can modify local electric fields. How this relationship evolves during the dynamic evolution of auroral arcs remains unclear.



Auroral arc is treated as a 1D structure, where conductance and electric field vary mainly across the arc and are assumed nearly uniform along the arc, where x = across arc; y = along arc; Σ^A, E^A = inside arc; Σ^E, E^E = background. (Marklund,1983)

SCIENCE QUESTION

Does the electric field-conductance response remain constant during the evolution of a mesoscale auroral arc, or does it change between different arc stages?

OBJECTIVE

Compare two intervals of the same 24 November 2012 auroral arc event using PFISR electric field/conductance measurements and PFDASC auroral imaging to determine whether the electrodynamic response changes during arc evolution.

DATASETS and METHODOLOGY

Study uses coordinated **PFDASC 557.7 nm auroral imaging** and **PFISR radar measurements** to examine electric field-conductance coupling during a mesoscale auroral arc event on 24 November 2012.

PFDASC 557.7 nm ASI images

- Identified auroral arc location, morphology, and temporal evolution.
- Mapped to 150 km to project the 557.7 nm green-line auroral emission onto a geographic grid and align optical arc location with the PFISR sampling region.
- Keogram extracted along 212.52°E longitude (compare arc motion with PFISR electric-field and conductance variations)

PFISR LP data

- Derived PFISR F-region electric fields from Long Pulse velocity measurements.
- F-region electric fields are assumed to map along magnetic field lines to the E-region conductance layer.
- Electric field extracted near 150 km altitude using latitude-binned vector electric fields.
- Components: E_{east}, E_{north}, and |E|

PFISR AC data

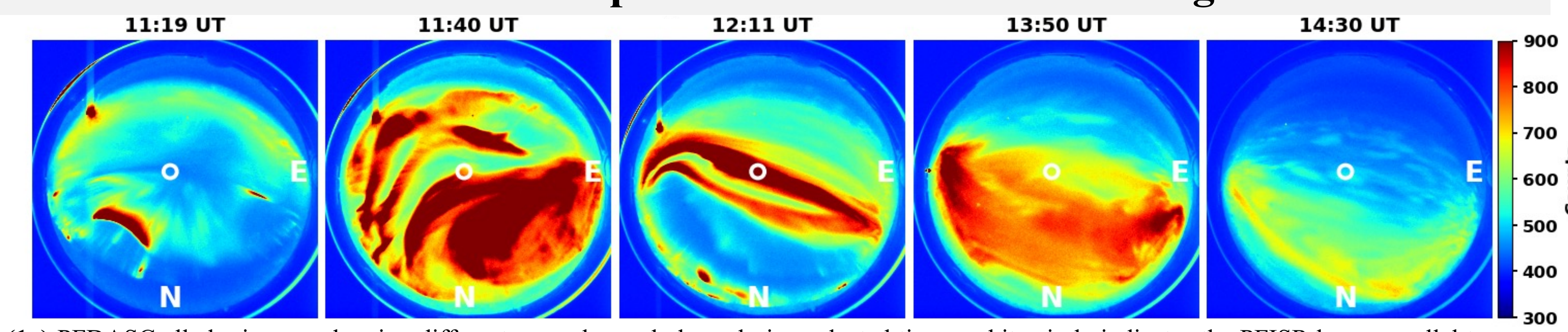
- Used PFISR Alternating Code E-region electron density and fitted plasma parameters.
- Calculated local σP and σH at each beam-range gate using B, ion composition, and collision frequencies.
- Binned valid measurements by actual latitude and altitude, then vertically integrated from 100-180 km to obtain ΣP and ΣH.

Analysis Procedure

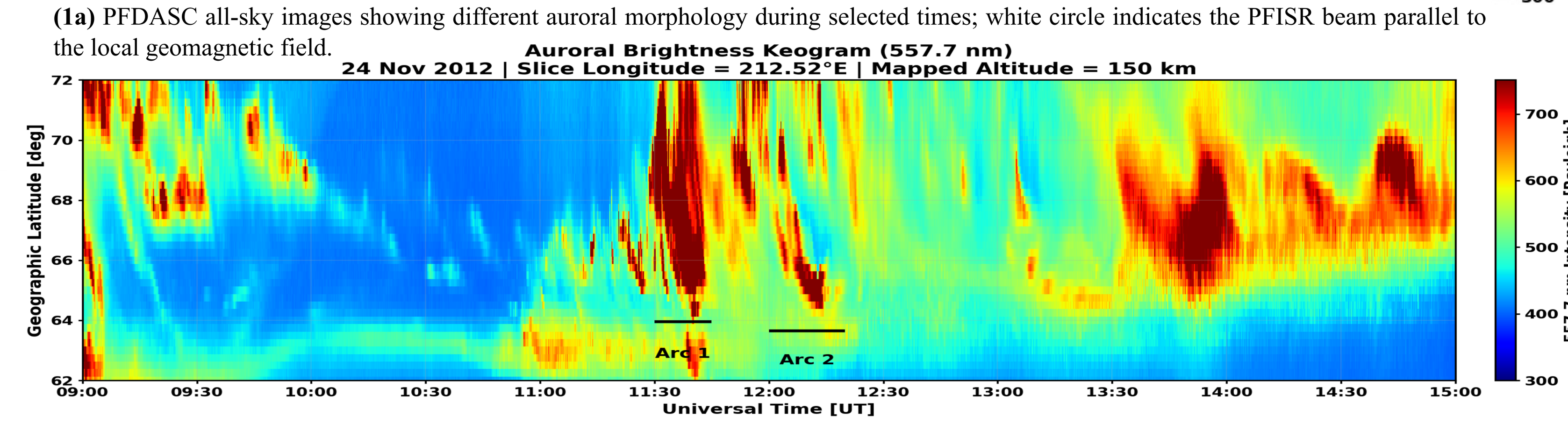
- Match ASI arc location with PFISR latitude region
- Selected two arc intervals:
  Arc 1: 11:30-11:45 UT
  Arc 2: 12:00-12:20 UT
- Compared electric field and conductance behavior in the same time-latitude region

RESULTS and DISCUSSION

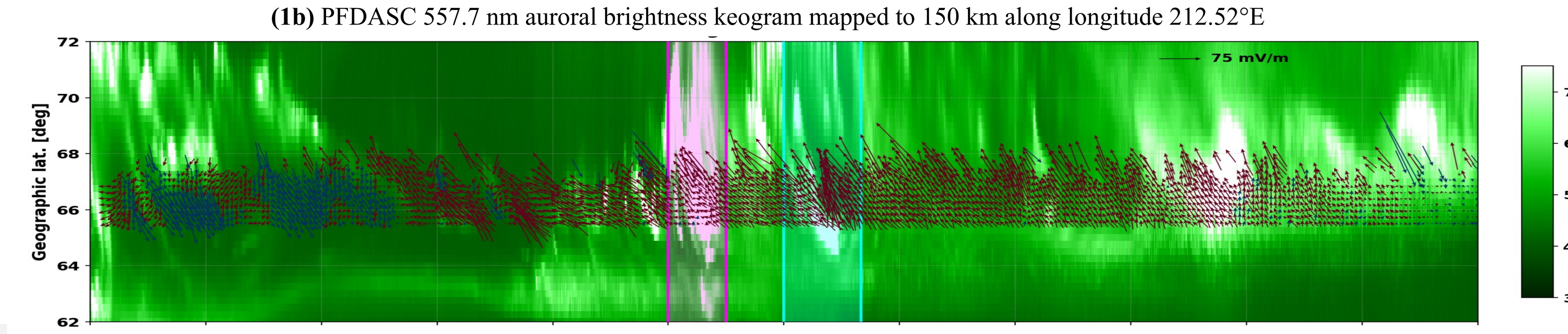
Same auroral event was separated into two arc stages to test whether the electric field-conductance response remains constant during arc evolution.



(1a) PFDASC all-sky images showing different auroral morphology during selected times; white circle indicates the PFISR beam parallel to the local geomagnetic field.



(1b) PFDASC 557.7 nm auroral brightness keogram mapped to 150 km along longitude 212.52°E



(1c) Keogram overlaid with PFISR 1D electric field vectors. Red = eastward electric field; Blue = westward electric field ; 75 mV/m= reference vector length

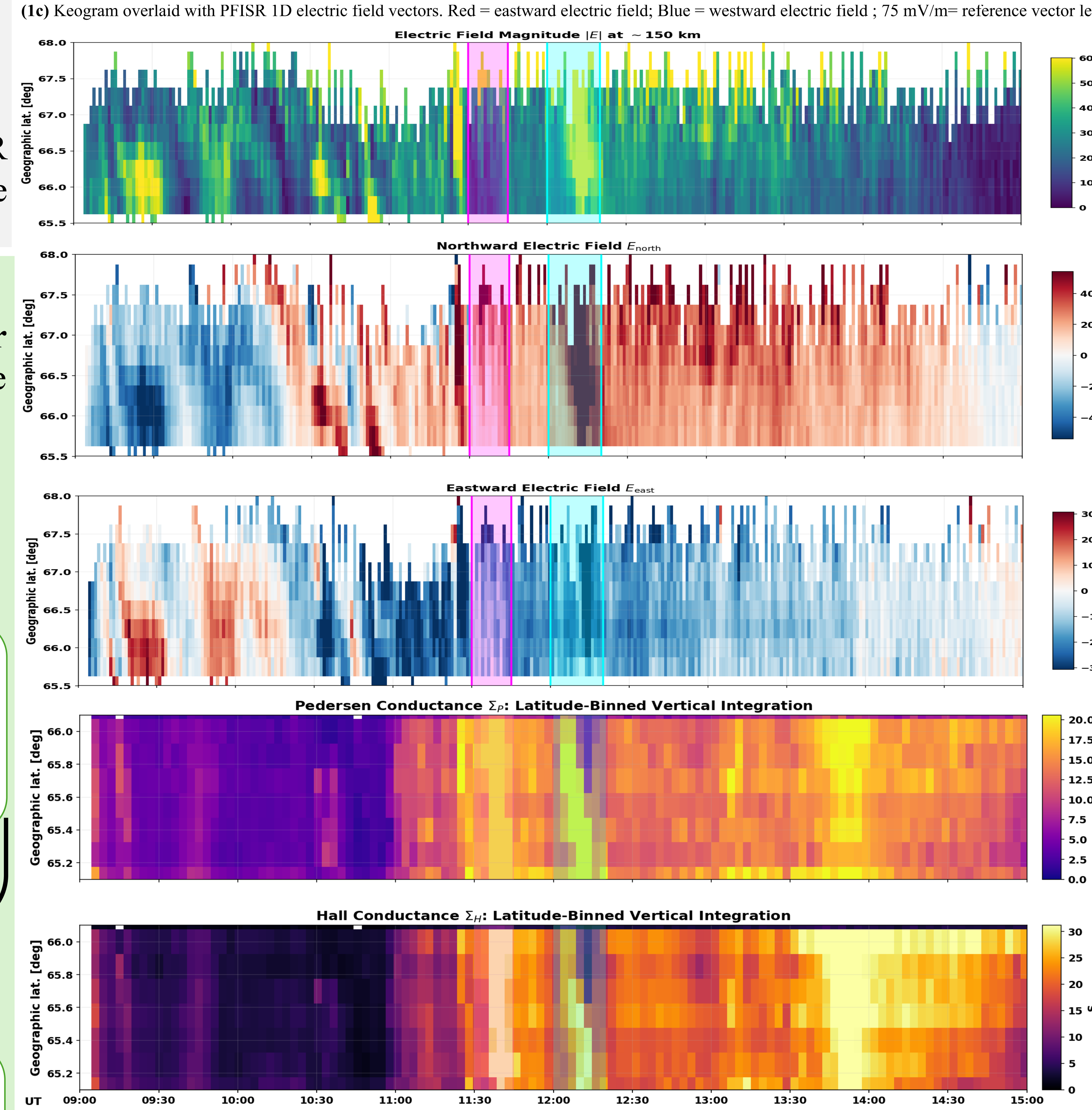


Figure 1: PFDASC 557.7 nm and PFISR observations on 24 November 2012.

(1d) Electric field magnitude |E|
(1e) Northward electric field E_{north} : (+) = northward electric field (-) = southward electric field.
(1f) Eastward electric field E_{east} :(+) = eastward electric field; (-) = westward electric field
(1g) Pedersen conductance ΣP
(1h) Hall conductance ΣH

Highlighted intervals mark Arc 1 and Arc 2

Arc 1 (11:30-11:45 UT)	Arc 2 (12:00-12:20 UT)
Conductance enhanced, but electric field response is not aligned with the arc	Electric field and conductance more organized with arc
Indicates anticorrelated coupling between auroral precipitation, ionospheric conductance, and the local electric field	Indicates stronger coupling

INTERPRETATION

DASC images show that the auroral morphology changes during the same event, while PFISR measurements show that the electric field-conductance response also changes between arc stages. This suggests that mesoscale auroral arcs do not have a single fixed electrodynamic response. Instead, their response may depend on the evolving arc morphology, precipitation structure, and current-closure conditions.

To further examine how the electrodynamic response changes between two arc stages

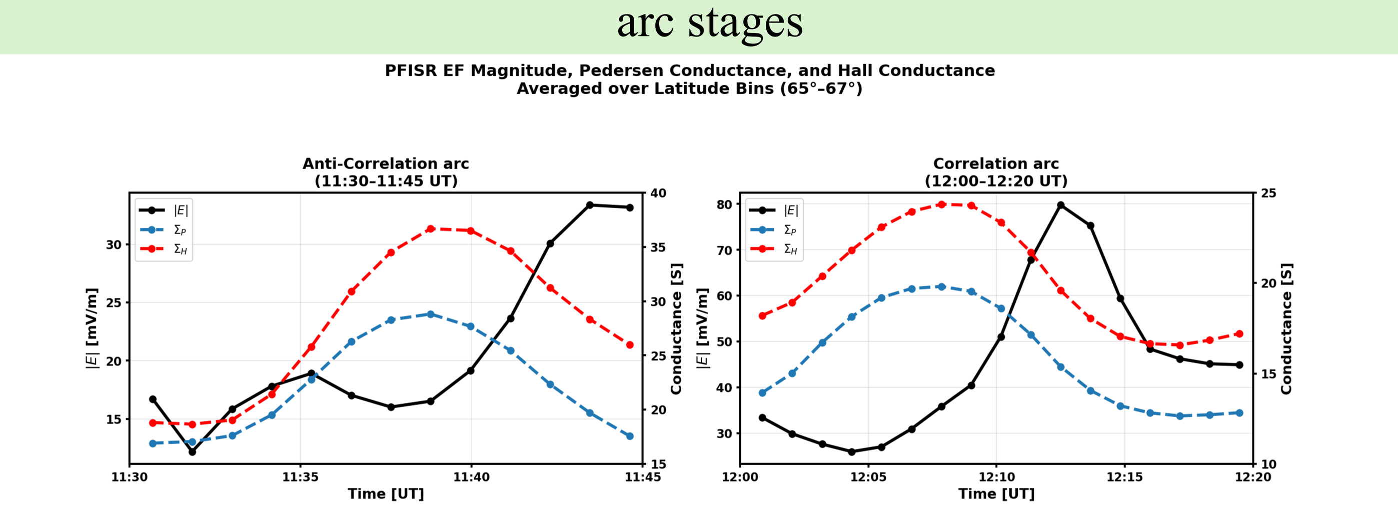


Figure 2: Latitude-averaged electric field magnitude |E|, Pedersen conductance ΣP, and Hall conductance ΣH for two auroral arc intervals

Arc 1: Anti-correlated behavior (11:30-11:45 UT):

Pedersen and Hall conductance increases while |E| remains low.
After the conductance peaks and begins to decrease, |E| increases strongly, showing an opposite electric field-conductance response.

Arc 2: Correlated behavior (12:00-12:20 UT):

|E|, ΣP, and ΣH vary more consistently during arc evolution.
Electric field enhancement occurs close to the conductance enhancement, indicating stronger arc-related electrodynamic coupling.

CONCLUSION

- We found that electric field-conductance behavior is not constant during a mesoscale auroral arc event.
- Arc 1 shows anti-correlated behavior, where conductance is enhanced, but the electric field is weaker inside the arc. Arc 2 shows more correlated behavior, where electric field and conductance increase more consistently together.
- This transition suggests that the dominant electrodynamic response changes as the arc evolves, likely due to changes in precipitation, polarization, and current closure.

FUTURE WORK

- Extend this PFISR-PFDASC electric field-conductance analysis from one mesoscale arc event to a larger event database.
- Combine electrodynamic properties with ML-based PFDASC auroral morphology classification.
- Collaborators: Dr. Dogacan Su Ozturk will support auroral morphology interpretation, and Dr. Jeremiah Johnson will support ML-based image classification.
- Build an **Aurora Almanac** linking visual auroral structures with electric field, conductance, and current-closure behavior.

REFERENCE

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3. Kaeppler, S. R., Hampton, D. L., Nicolls, M. J., Strømme, A., Solomon, S. C., Hecht, J. H., & Conde, M. G. (2015). An investigation comparing ground-based techniques that quantify auroral electron flux and conductance. Journal of Geophysical Research: Space Physics.