Small-Scale Structures and Motions of Auroral Signatures as Observed From the Ground: A Planned Field Study Using Camera and Radar Observations


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Outline

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Abstract

As a continuation of the CASCADeS (the Changing Aurora: in Situ and Camera analysis of Electron precipitation Structures) sounding rocket campaign, a ground based study of auroral structures and motions will be conducted this coming winter from Poker Flat, AK. A major goal of this study is to examine the small-scale perpendicular motions of auroral features in the context of auroral poleward boundary activity associated with substorm breakup. The use of an all-sky camera and a narrow-field camera at Poker Flat will allow for a 2-D image of the auroral structures. The narrow-field camera has a 12 X 16 degree field of view and allows for viewing of sub-kilometer scale structures at 100 km altitude, and the all-sky camera provides a large scale auroral context. Ground magnetometers at Poker Flat, Fort Yukon, and Kaktovik provide a view of the 2-D equivalent horizontal current structures associated with the auroral intensification. The 30 MHz imaging radar located in Anchorage will be used to image the same area that is being observed with the narrow-field camera. The SuperDARN radar on Kodiak Island may also be used to view the larger scale auroral activity over AK. The AMISR that is currently being constructed at Poker Flat will give high time and space resolution information on the auroral plasma structures present.

Some of the science questions to be addressed with this array of instruments are: How intense are small-scale structures when viewed with high resolution? What differences are observed between the motions of adjacent light and dark auroral signatures, and what can this tell us about ionospheric electric fields and plasma density? Can large flow fields exist at very low altitudes on small scales due to ionospheric modification?

We are interested in getting feedback from other experimenters and modelers in terms of the relevance of the questions we are trying to address with the camera data as well as with AMISR and its capabilities.
Ground-Based Instrumentation

- **Imagers:**
  - All-sky
  - Narrow-field
  - Variable FOV camera from (M. Lessard)

- **Radars**
  - Anchorage 30 MHz coherent radar
  - Kodiak Island superDARN station
  - Poker AMISR
All-sky image from Kaktovik

Below about 30 degrees elevation the image gets too distorted; Can image about 3.5 degrees of latitude.

- Measure Mesoscale arc width distribution (Question #3)
- Motions of black auroral arcs along with discrete arcs (Question #4)
Example Narrow-Field Image

Field of view is about 20 x30 km at 100 km altitude (12 x 16 degree FOV)

- Measure small-scale arc width distribution (Question #3)
- Motions of small-scale black auroral arcs along with discrete arcs (Question #4)
30 MHz Radar image on all-sky image

- What are the irregularities that it is scattering off of? (Question #1)

- How do the returns differ in the discrete vs. the black aurora (Question #4)

Pixel size: 2.5 km in range, 3-5 km in az.
Integration time per image: 1 to 5 sec.  (Images the E-region)
Ground-Based Instrumentation
Radars AMISR

• AMISR: Allow high space and time resolution of the E-region. We want kilometer scale spatial resolution and sub-second time resolution.

• FOV: Zenith down to 30 degrees in the north and 30 degrees E-W of north.

• Perpendicular at E-region over Fort Yukon, so we may want to move a narrow-field camera there to get conjugate observations with AMISR.
Example of AMISR data

From the 16 panels in place at Gakona, AK. Data shows the decay of the enhanced plasma line from the HAARP ionospheric heater facility.

- Existence of localized large-scale structures (Question #1)
- Connect ion outflows to Alfvénic Aurora (Question #2)
- Compare flow velocities to speeds of auroral structures (Questions #1, 4)

From Brenton Watkins
Scientific Goals

• Literature review on auroral imaging with cameras and radars reveals many open questions, including:

--The existence or not of large amplitude structures in the lower ionosphere on small spatial and short time scales.

--Possible links between NEIAL, BBELF, ion outflows, and Alfvenic auroral rays.

--A gap in the occurrence of auroral arc widths of around 1 km in the camera data, which has not been confirmed to be a geophysical or a selection effect.

--Little is known about the morphology of the black aurora that occurs along with the discrete aurora, as opposed to the black aurora that is embedded in the diffuse aurora, which has been studied quantitatively.

A field campaign to Poker Flat this winter will gather data to address these open questions.
Open Question: Ionospheric Feedback

1: Do return current region structures cause significant modification of the lower ionosphere?

• Use AMISR to look for the existence of large amplitude structures in the lower ionosphere which may exist on small scales and/or for short times. (decreased density and conductivity, etc.

-- Not seen by radars before because they would get integrated out in time and/or space.  
-- Large amplitude (~ 1 V/m) electric fields are seen by the Freja satellite at about 1400 km altitude, which occur on small scales, but it is not known if they map to the lower ionosphere.
-- Very fast motions observed to exist for short times in auroral features. Does this velocity correspond to $E \times B$ velocity, which would mean large electric fields (V/m) in the lower ionosphere?

-- Implications: Ionosphere may play a significant role in the active feedback mechanism to the magnetosphere.

[Streltsov and Lotko, 2003]
[Hwang, et. al., 2005]
[Lysak, 1991]
Open Question: Precipitation Driven Ion Outflows

2: What wave mode causes ion outflows?
• Establish a connection between the NEIAL (Naturally Enhanced Ion-Acoustic Lines), BBELF and ion outflows associated with Alfvenic auroral rays.

--(Ground) NEIAL has been observed to be associated with ion outflows using ISRs.
--(In Situ) Ion outflows and BBELF are observed to occur together using rocket and satellite measurements.

--(Link) Alfvenic auroral rays have recently been associated with NEIAL, but a larger data set is needed.

--Can a connection be made between the ion outflows using AMISR and the Alfvenic auroral rays associated with soft electron precipitation.

--Implication: Morphology of ion outflow on larger scales

[Forme and Fontaine, 1999]
[Blixt, et. al., 2005]
[Lynch, et. al., 2002]
Open Question: Mesoscale Arc Distribution

3: What is the distribution of auroral arc scale sizes?
• Examine the existence of an apparent gap in the occurrence of auroral arc widths of around 1 km, by optimizing the FOV of the camera to this range.

-- Maggs and Davis [1968] observed a distribution of arc widths which was rising toward the instrumental cutoff of 70 m.

-- Knudsen, et al. [2001] used all-sky images and found a distribution of arc widths peaked at about 10 km with a sharp cutoff around 7 km.

-- Chaston, et al. [2003] model of Alfvén wave/ionosphere interactions predict a distribution peaked around 1 km for Alfvénic aurora.

-- We will have access to a variable FOV camera from M. Lessard, which we will optimize to match the data gap.
Open Question: Discrete Black Aurora Morphology

4: What is the morphology of black aurora in the discrete regions?

• Examine the differences between the light and dark auroral features and infer how the return current region may be affecting the ionosphere, density holes, decreased conductivity, etc.

--Most work has been done quantifying the black aurora that occurs in the diffuse aurora.

--Little attention has been paid to the black aurora that occurs alongside the discrete white aurora. This black aurora could have influence on the behavior and evolution of the aurora since it is likely to contain density, and conductivity depletions, and therefore large electric fields.

--These observations can be compared to in situ observations of the return current region (from FAST) and its relation to the discrete aurora.
Questions for Discussion

Some of the questions which arose from our literature search are listed here as items we may address with this winter’s campaign:

a) A connection between Alfvenic auroral rays and enhanced ion outflows through NEIAL/BBELF?
b) Existence of large-amplitude, transient, small-scale structures in the lower ionosphere?
c) What are the irregularities that 30 MHz radar scatters from?
d) Causal relationship between auroral luminosity and 30 MHz radar returns?
e) Optimize camera viewing in 1-10 km range, existence of data gap, to test Alfvenic aurora theory?
f) Correlating arc thicknesses to other arc parameters?
g) How black aurora (w/discrete aurora) forms and evolves in time?
h) Quantify motion of black aurora with respect to plasma through diffuse aurora with radar?
i) Any periodic variations of auroral intensity on the order of minutes to test Goertz and Boswell?
j) Time evolution of auroral arcs: large to small, or small to large, or neither?
k) Determine altitudes of quiet arcs from all-sky data?
l) Electric field spectral index as a function of time, compare to theory?
m) Time evolution of formation and breakup of small-scale structures?
n) Are auroral folds associated with auroral curls?
o) Density holes in downward current region exist with black aurora?
p) Radii of curvature of arcs compared to thicknesses of arcs?
q) Linear black structures have faster motions than curved ones?
r) Proper motions of arcs and predictions of fracture model?

Suggestions welcome for other things to look for, or other questions to address
Plans and Scheduling

• Optical measurements during a two-week field campaign this coming winter at Poker Flat, AK.
• Collect AMISR and coherent radar data whenever it is possible to be conjugate with the camera data.

• Use this data to address:
  --Small-scale large amplitude structures in the lower ionosphere.
  --NEIAL, BBELF and ion outflow connections
  --Measuring distribution of arc widths.
  --Morphology of return current region black aurora.