Auroral Ionosphere: Combining Swarm Ion Flows and THEMIS Imagery with Machine Learning

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Objectives

- There is an abundance of ground-based observatory (GBO) all-sky auroral imagery available (THEMIS, REGO, Etc.)
- Coupled to this imagery, through magnetic field lines, are plasma flow and field measurements at spacecraft altitudes
- These measurements are provided by various satellites (SWARM, CASSIOPE, DMSP, etc.) but conjunctions with imagery are limited
- Can we train a machine learning (ML) algorithm to "remote sense" spacecraft altitude ionosphere with Swarm cross-track ion flow and THEMIS imagery as training samples
- Ultimately use GBO imagery with ML algorithm as a technique to probe plasma physics of auroral systems

Related Studies

- Clausen and Nickisch (2018) input 5824 manually labelled THEMIS all-sky images into a pretrained neural network providing classification of 6 different auroral types with an 82% accuracy. For a simpler classification of *aurora/no aurora* this accuracy bumped up to 96%.
- Archer et al. (2017) outline intense plasma flows related to auroral current sheets
- Lutz et al. (2019) use ML to improve remote sensing of lake water clarity using satellite imagery and citizen science data
- Vojinovic et al. (2013) use ML to estimate shallow water depths from optical satellite images and sonar measurements
- Wu et al. (2020) survey 530 conjunctions between Swarm and THEMIS images analyzing the relation between Alfvénic structures against FAC and auroral arcs.

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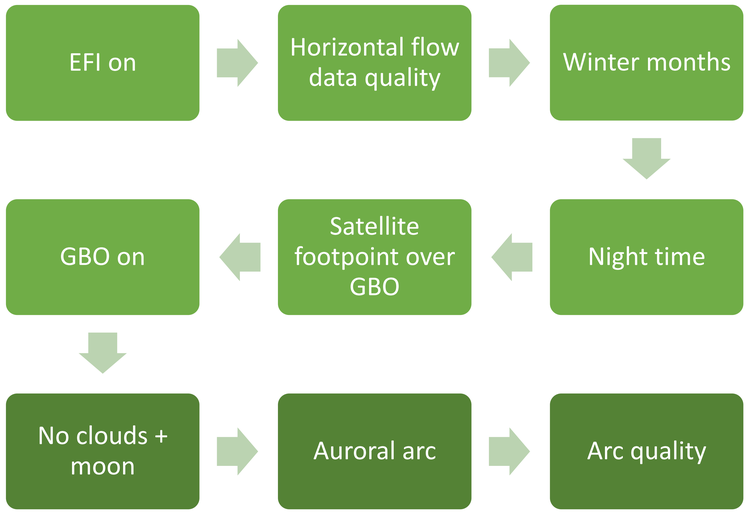
Data Collection

- Biggest hurdle: constructing a sizeable dataset
- Teach ML algorithm like you would a person (Matthew Argall, UNH)
- Ultimately use transfer learning due to limited data
- Data reduction procedure (Lighter shading indicates auto selection):



- Used online conjunction finder with Python script to automate conjunction gathering
- Found 108 conjunctions from 12/2013 to 12/2018 as of 06/2020:

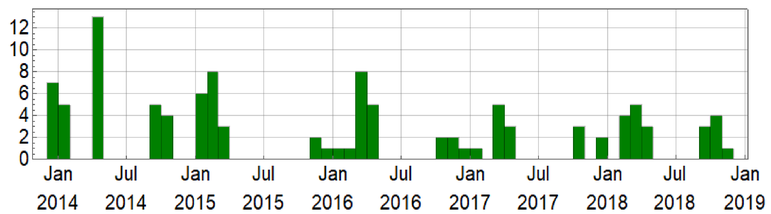


Figure 1: Distribution of 108 events

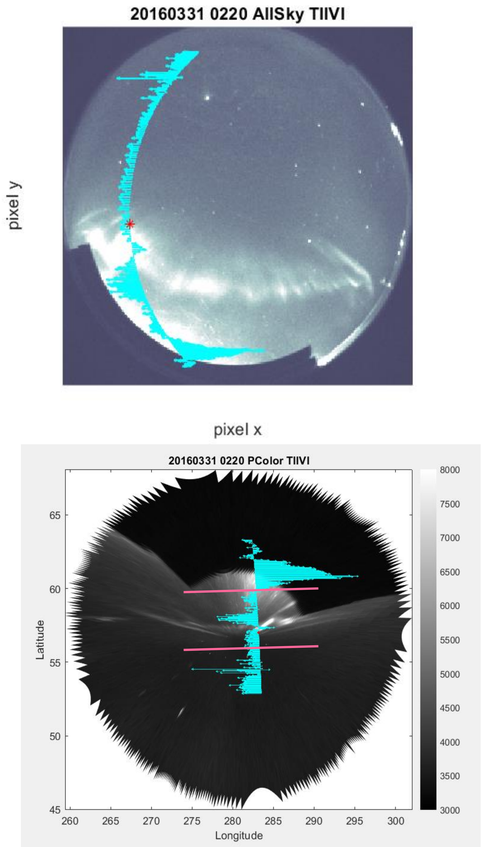


Figure 2: Horizontal ion flow velocity superimposed onto GBO image in pixel coordinates (top) and geographic coordinates (bottom). For the pixel coordinates top is south.

Refining data criteria

- Always need more data which could mean loosening certain criteria:
- Swarm data quality flag: is 1 okay based on statistics-based machine learning algorithm?
- Refining winter and night-time: what's dark enough?
- GBO has a ~30° FOV, but we want to avoid edges. Or do we? By how much? Will it hurt when using ML?
- Do we ignore arc quality altogether or do we want only clean sheet-like aurora?
- Use Clausen and Nickisch classification neural network to filter auroral images?

Next steps

- Build a ML MatLab structure database with all 108 events
- Train ML algorithm to recreate horizontal ion velocity plots given an image
- Test algorithm's accuracy with a validation dataset
- Use image with each single trajectory and expand to hypothetical trajectories across the image to create a 2D flow map (See Clayton et al. (2019))
- Train with time history at a footpoint vs. spatial distribution of brightness around footpoint

Results

- Limit data to events surrounding, ignore edges of the image
- Important to focus on auroral signatures and avoid potential edge brightness/unrelated brightness

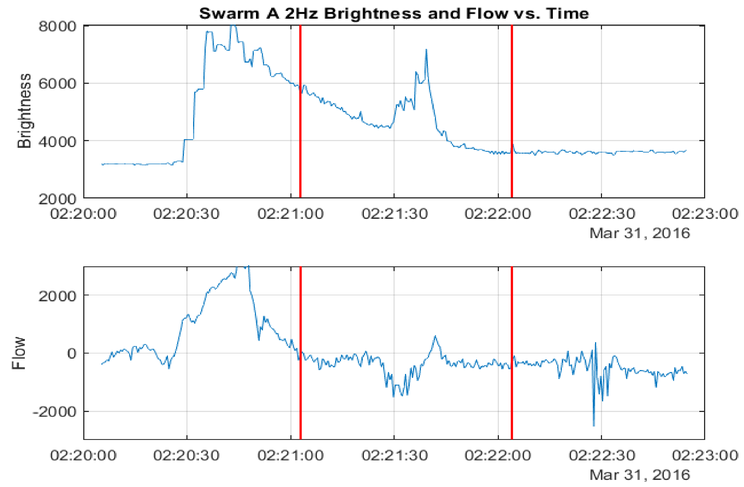


Figure 3: Plots of Sanikiluaq image brightness along the path of the satellite (top) and horizontal ion velocity along the path of the satellite (bottom). Red lines span auroral arc event. Positive values are westward.

Acknowledgments

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References

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Potential Adjacent Study

- Planet is a commercial provider of daily, high resolution satellite imagery
- Currently they do not take images at night
- Potential study: Convince people involved to take images of aurora
- Great set-up for conjugacy studies