A Swarm, SuperDARN, and ICEBEAR Collaboration – Turbulent E-region Aurora Measurements

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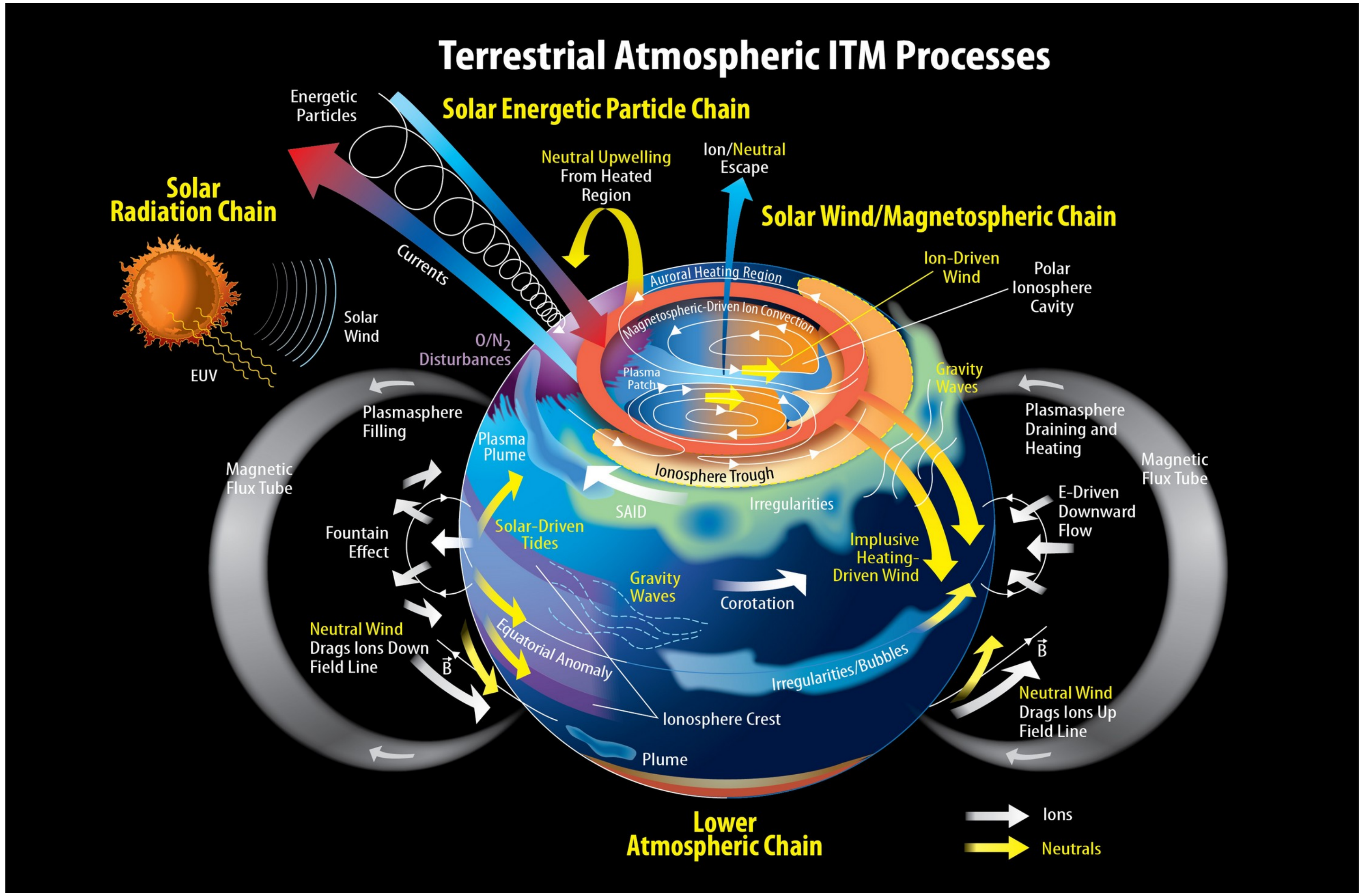
Introduction



(NASA's Goddard Space Flight Center/Mary Pat Hrybyk-Keith)

(https://svs.gsfc.nasa.gov/4641)

(Credit: ESA astronaut Samantha Cristoforetti)

(https://www.nasa.gov/content/aurora-borealis)

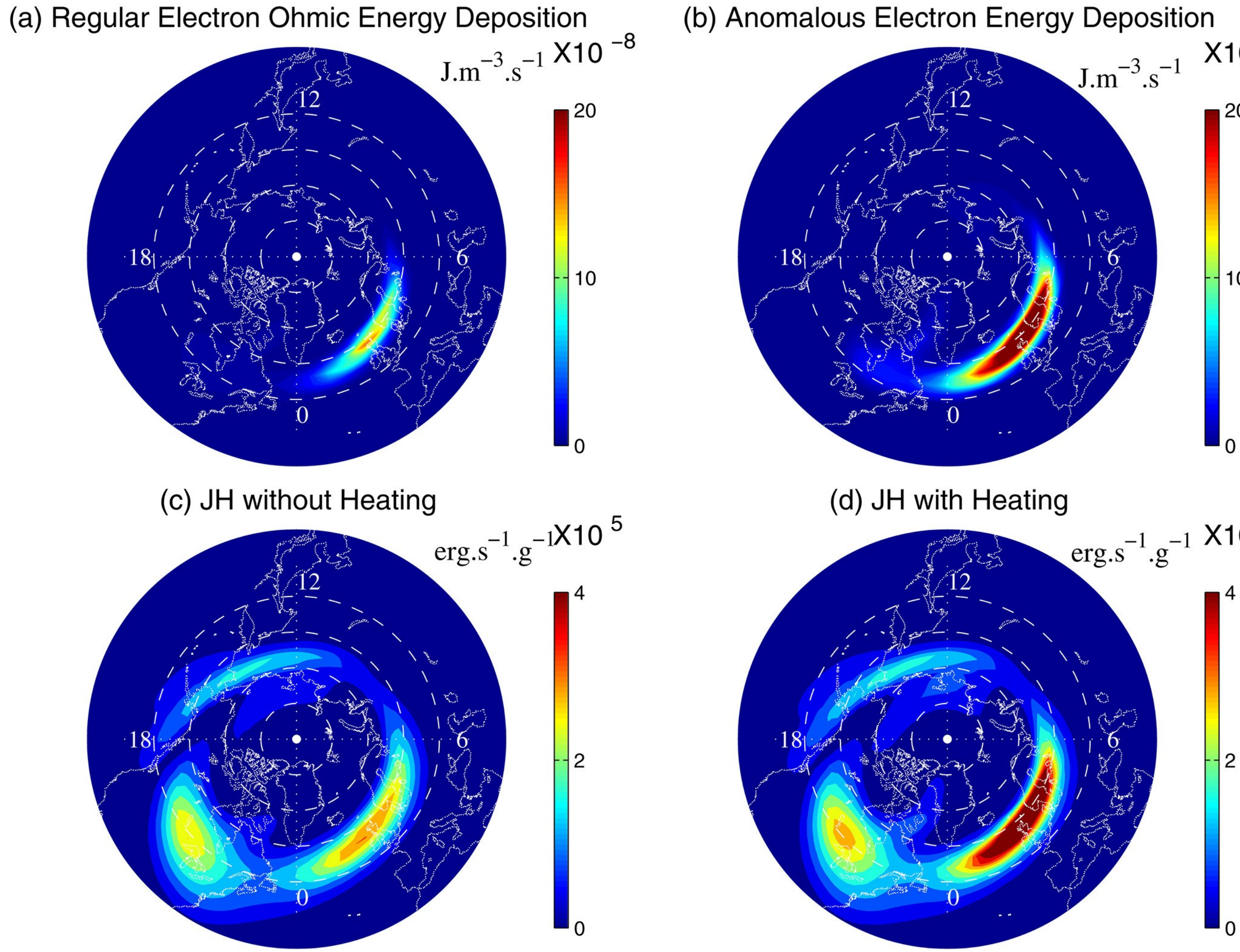
The Farley-Buneman Instability

E-region located at 90-150 km altitude

Different electron and ion motion in E-region gives rise to currents and the formation of plasma density instabilities

The Farley-Buneman, or two-stream, instability (Farley, 1963; Buneman, 1963) has positive growth when the electron motion exceeds the ions by at least the ion-acoustic speed

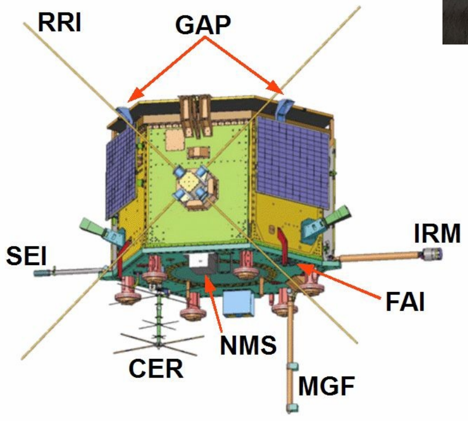
Generates plasma turbulence, creating localized fluctuations in the ionospheric plasma density which results in a fluctuating index of Refraction that RF signals can scatter from



(Liu et al., 2018)

Instruments Involved

(Credit: Ashton Reimer)



(https://epop.phys.ucalgary.ca/payload/)

(https://www.esa.int/Enabling_Support/Operations/Swarm_operations)

(ESA–P. Carril, 2013)

Swarm-E Fast Auroral Imager

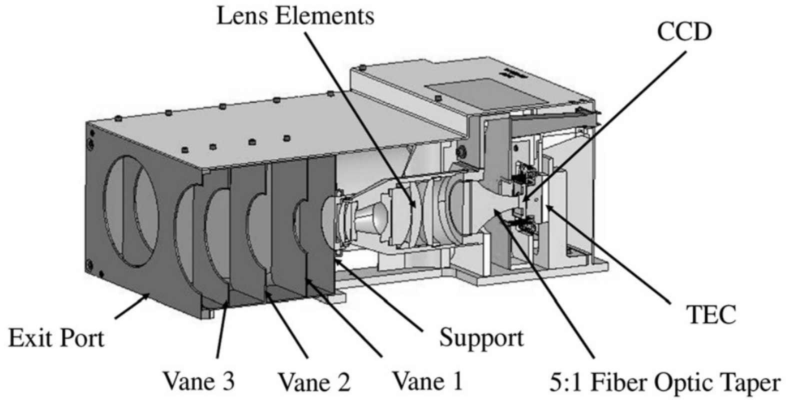
Swarm-E, aka ePOP, Fast Auroral Imager (FAI)

Measures 650-1100 nm wavelengths

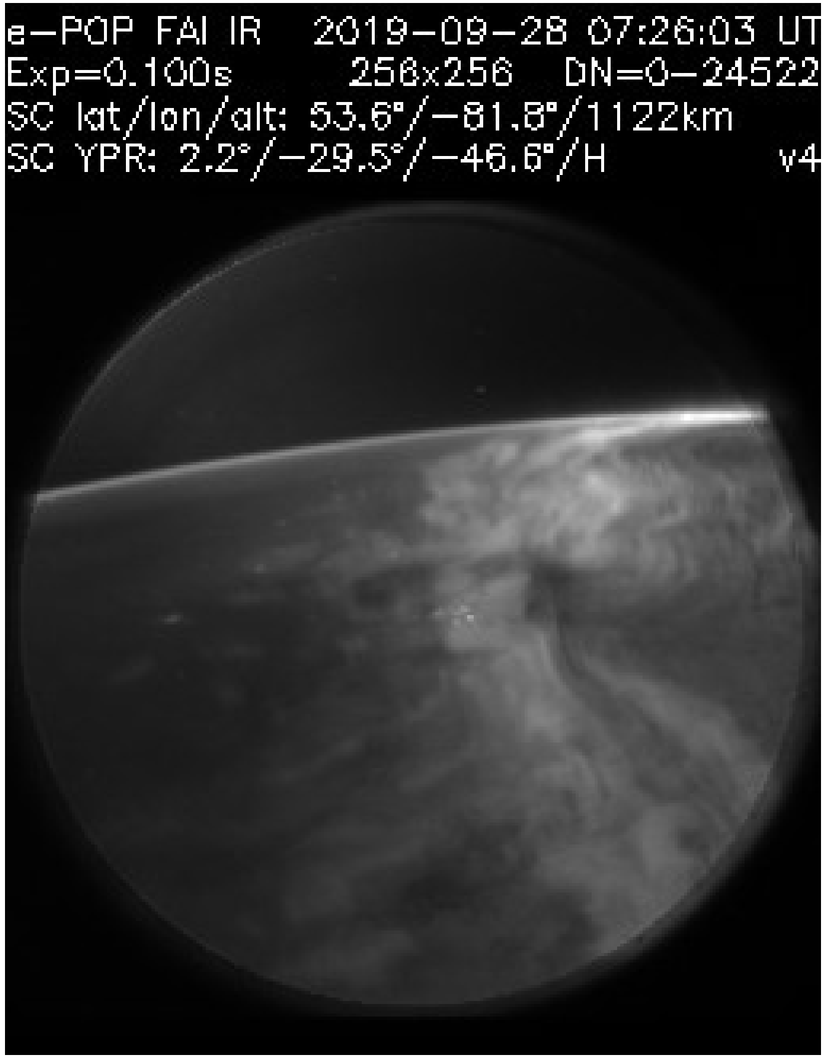
Dominant emission species in this range are N_2, O_2, N_2^+

Instrument can be pointed to a region for extended measurement periods

Resolution of 0.5 s per image



(Cogger et al., 2015)



(https://epop-data.phys.ucalgary.ca/)

Swarm Instruments

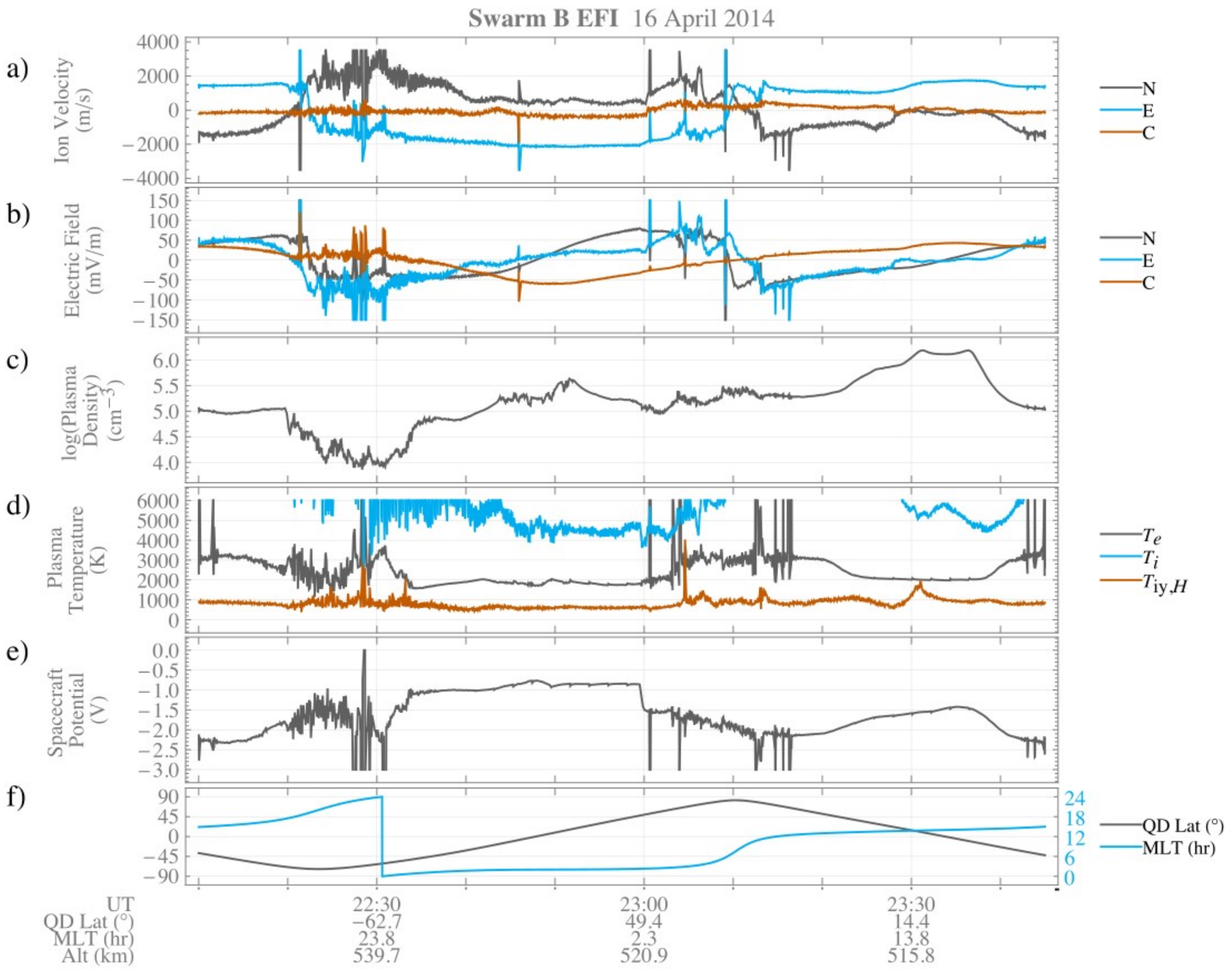
Each of Swarm A, B, C have an Electric Field Instrument (EFI) and Magnetometer

Magnetometers operate at 50 Hz

EFI obtains measurements at 16 Hz

EFI measures plasma temperature, density, and ion Velocity

Orbits of satellites in F-region, though E-region ionosphere properties along magnetic field lines can be inferred from higher altitudes



(Knudsen et al., 2017)

ICEBEAR

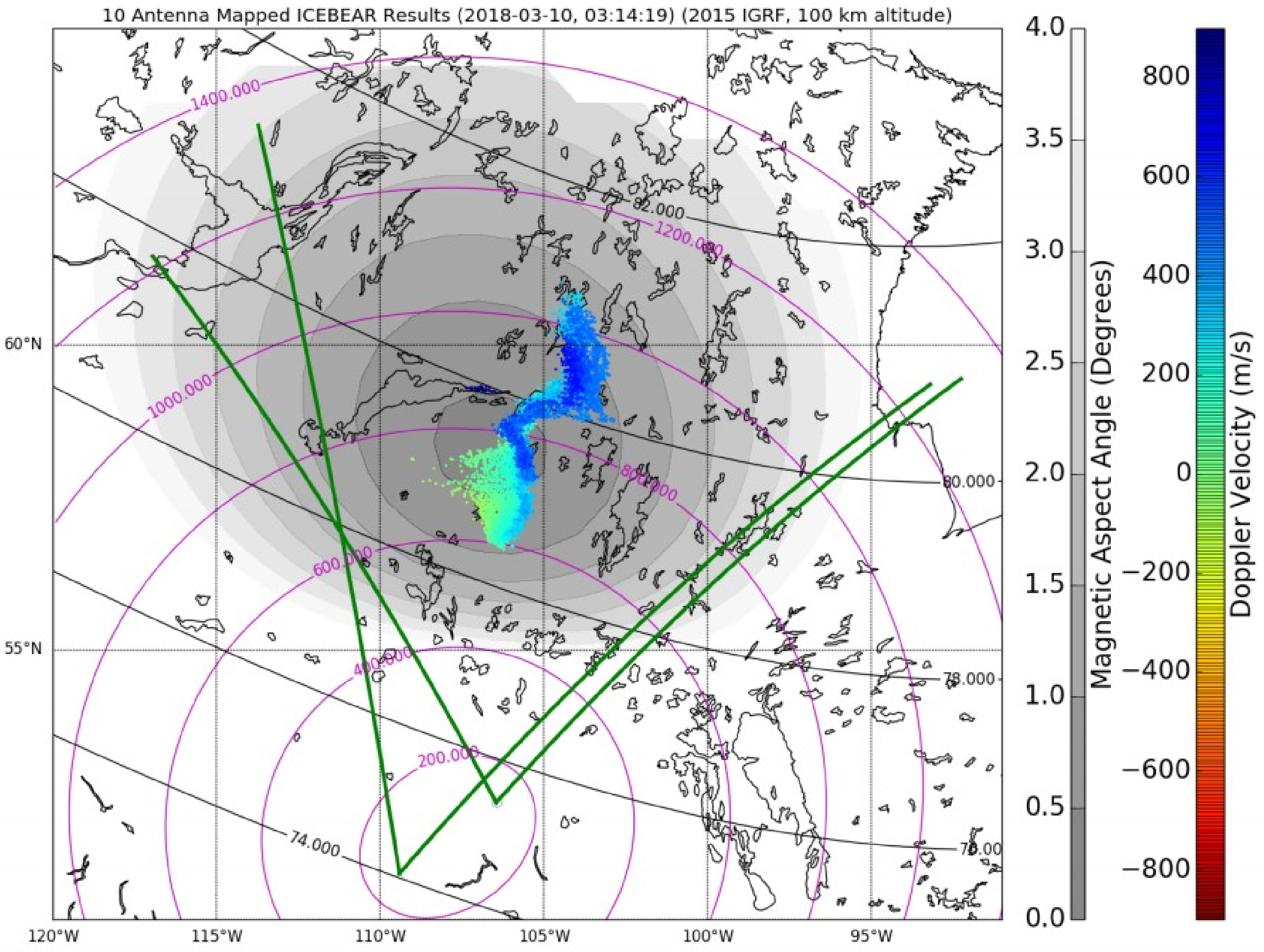
Ionospheric Continuous-wave E-region Bistatic Experimental Auroral Radar

VHF radar, uses CW phase modulated signal

Makes coherent scatter measurements of E-region - signatures of plasma density Turbulence

1.5 km, 1 s resolution images of full field of view

Operated on a campaign basis - recently received funding to operate every evening 0:00-14:00 UT



(Huyghebaert et al., 2019)

SuperDARN

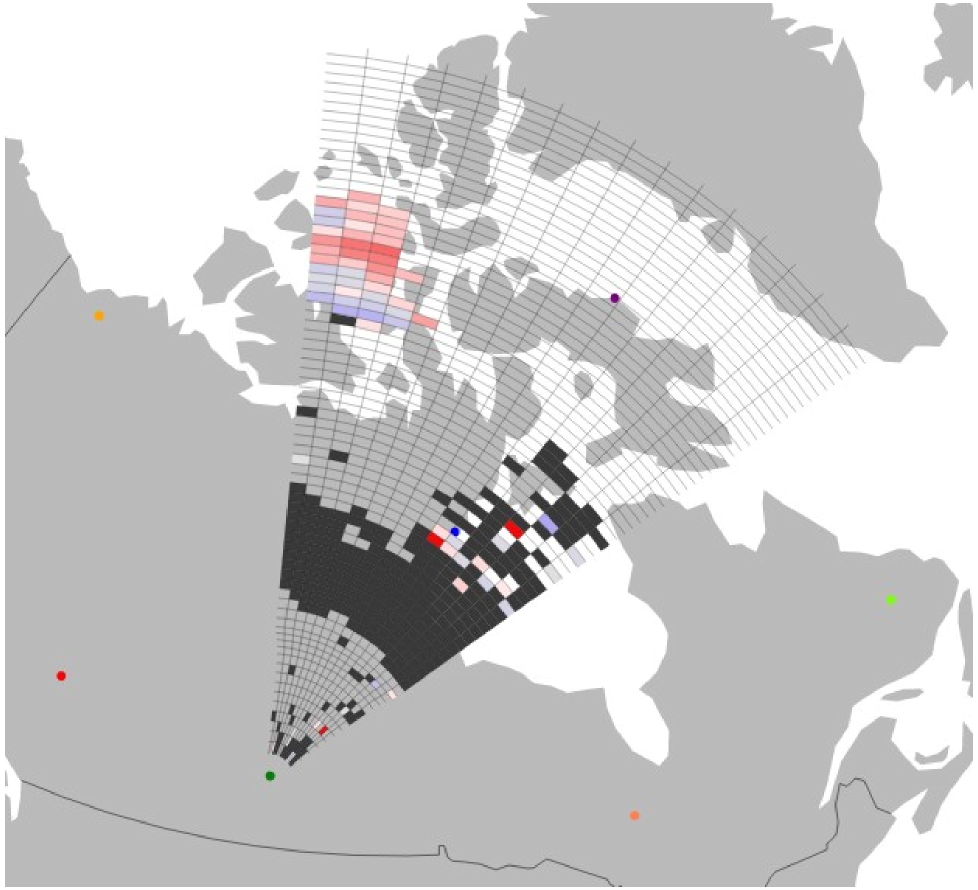
The Super Dual Auroral Radar Network (SuperDARN) is a global network of HF coherent scatter radars that measure the ionosphere using coherent scatter

Resolution of 45 km during common mode, with ≈ 3 s per beam integration time. Specialized modes can be implemented for improved resolution but decreased SNR

Full field-of-view measurement every minute

Saskatoon SuperDARN site overlaps with ICEBEAR data, providing opportunity for multi-frequency coherent scatter measurements

New hardware has recently been implemented and allows enhanced resolution modes - currently under development



(https://superdarn.ca/real-time)

Software Development

To compare the different data sets, software is being developed

Python used for the software language due to popularity

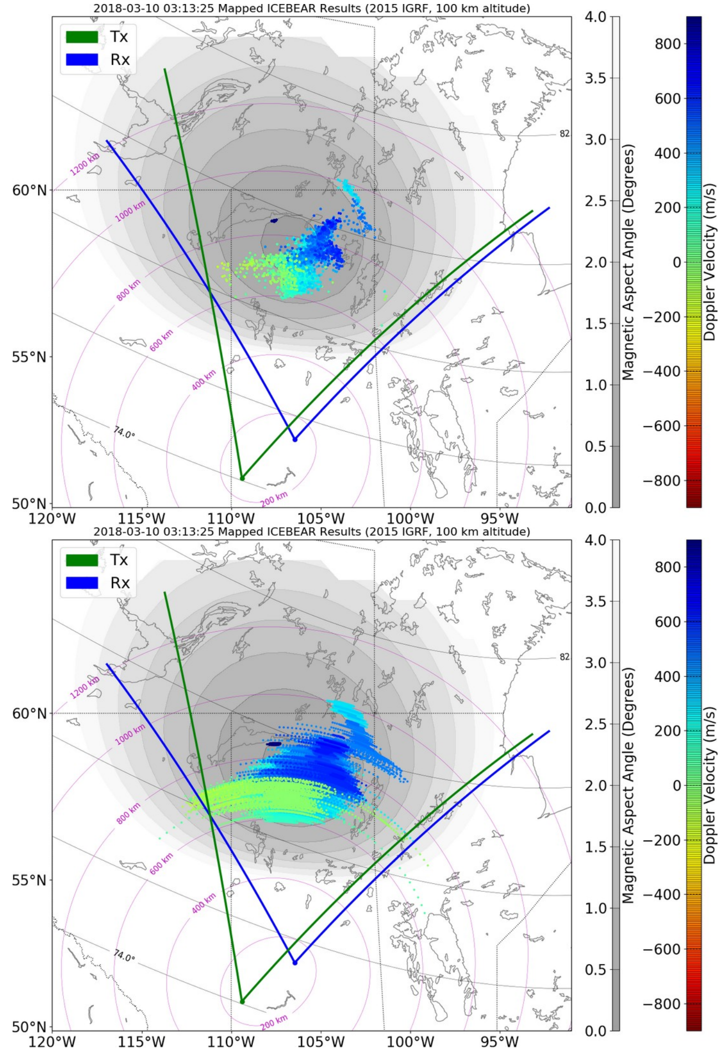
Swarm-E FAI is mapped to a latitude/longitude grid

Swarm A, B, C data is mapped along magnetic field line to
E-region altitudes
(AACGM library – Burrell et al.,2020; Shepherd, 2014)

ICEBEAR data required to be accurately mapped to field-of-view

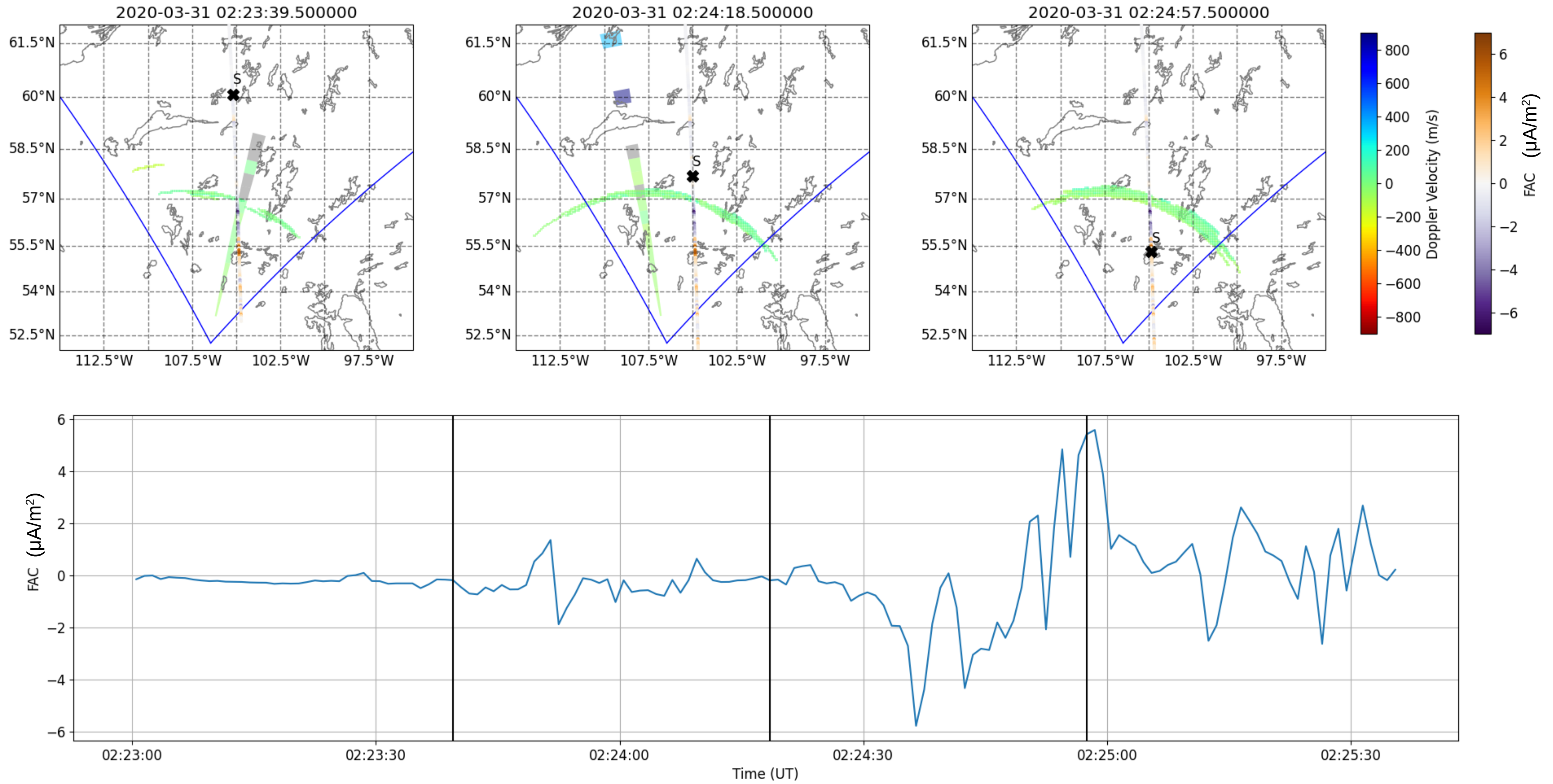
Recent publication submitted addresses the ICEBEAR mapping

SuperDARN data can be mapped with pre-existing PyDARN
software, though additions and modifications are required



(Huyghebaert et al., submitted to Radio Science)

Software Development



Software Development

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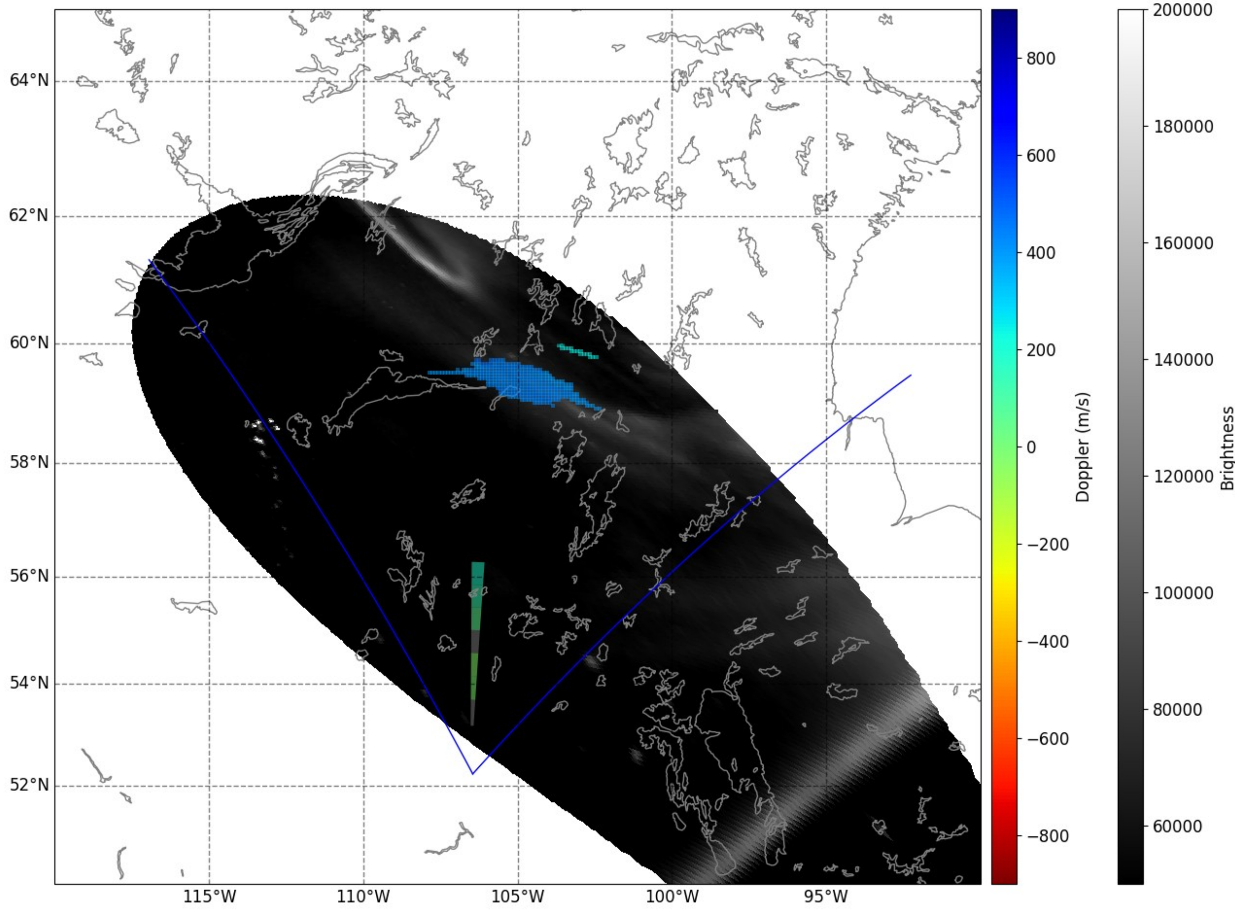

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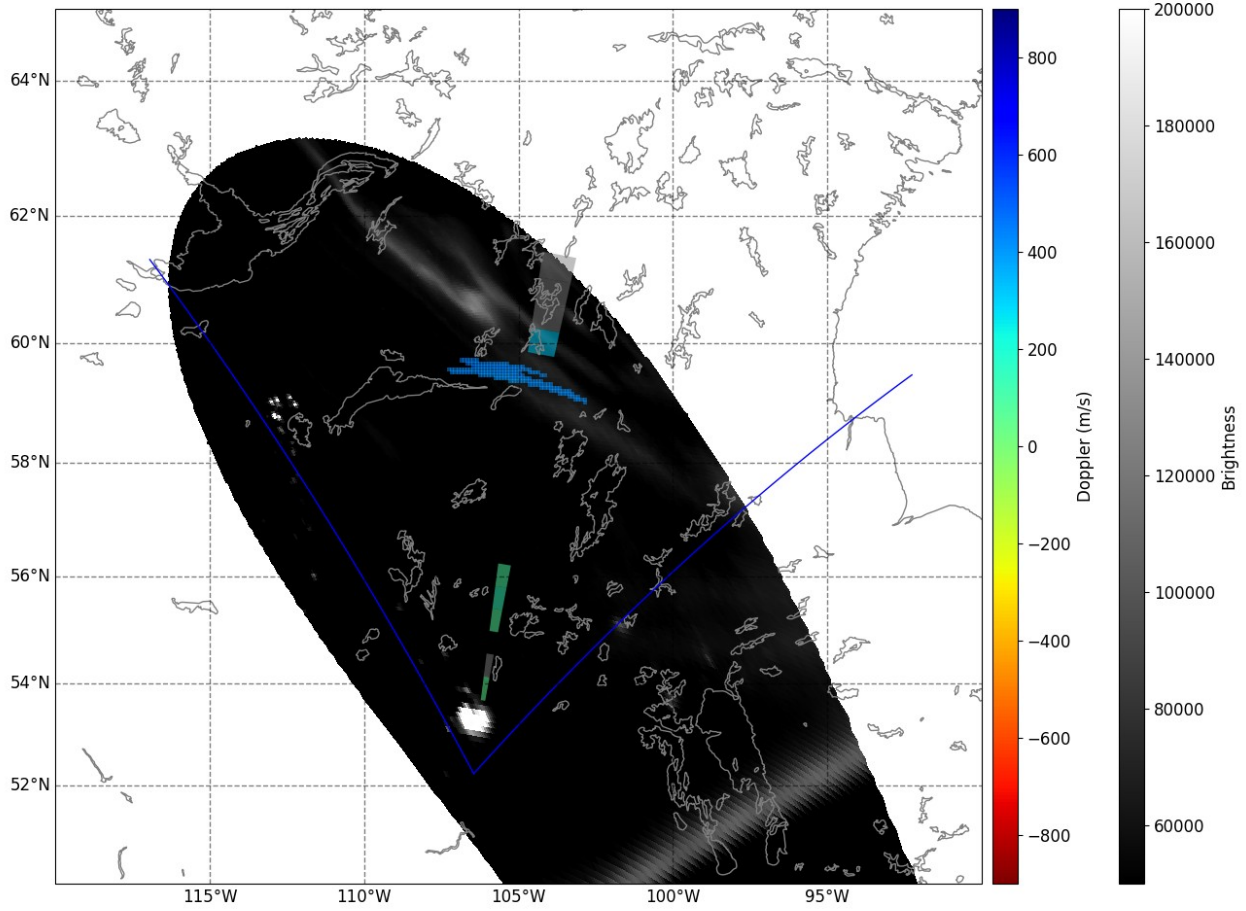

Note: These are preliminary results – data locations could change based on modifications to mapping software

Summary

SSIC-TEAM project aims to investigate plasma density turbulence in the E-region ionosphere

Software under development to map and compare data from Swarm, SuperDARN, and ICEBEAR

Studies underway to compare Swarm measurements with coherent scatter

Outstanding questions to be investigated:

1. How does E-region plasma density turbulence correspond to emissions in the 650–1100 nm band?

2. What are the conditions for E-region plasma density turbulence to occur with respect to field-aligned currents, electric fields and plasma density? How do these characteristics of the ionosphere/magnetosphere correspond to the properties of the E-region plasma density turbulence measured by coherent scatter radars?

3. Are there other factors that correspond to E-region plasma density turbulence, such as Alfvèn waves and/or ion upflow?

Thank You

Questions?

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References

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