Super Dual Auroral Radar Network (SuperDARN) Tutorial

Evan G. Thomas

Thayer School of Engineering
Dartmouth College
Hanover, NH, USA

What is SuperDARN?

• The Super Dual Auroral Radar Network (SuperDARN) is an international network of high-frequency (HF) ground-based radars

• SuperDARN radars operate continuously to provide line-of-sight velocity and backscattered power measurements for the study of ionospheric plasma irregularities with 10 meter spatial scales

• Typical characteristics of a SuperDARN radar:
  ▪ Operates between 8-20 MHz
  ▪ Transmits ~10 kW peak power (~100 W average)
  ▪ Uses phased array steering to look in 16 or more beam directions
  ▪ Uses multi-pulse sequences to simultaneously determine range and Doppler shift
  ▪ Range and time resolution are typically 45 km and 1-2 minutes

Why Operate at HF?

- HF radiation is refracted in the ionosphere as it traverses gradients in electron density.
- The transmitted signals can be reflected back to the radar by:
  1) Plasma irregularities if the ray is quasi-perpendicular to the magnetic field

  OR 2) The ground
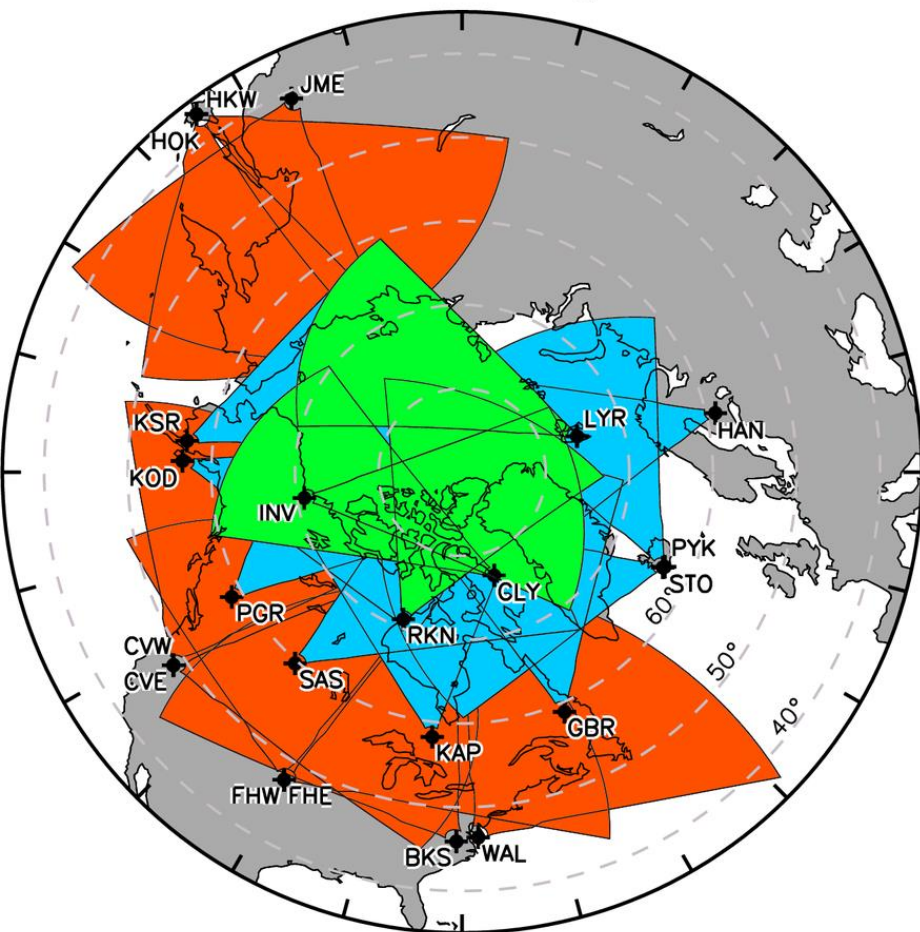
B

Ionospheric plasma structure
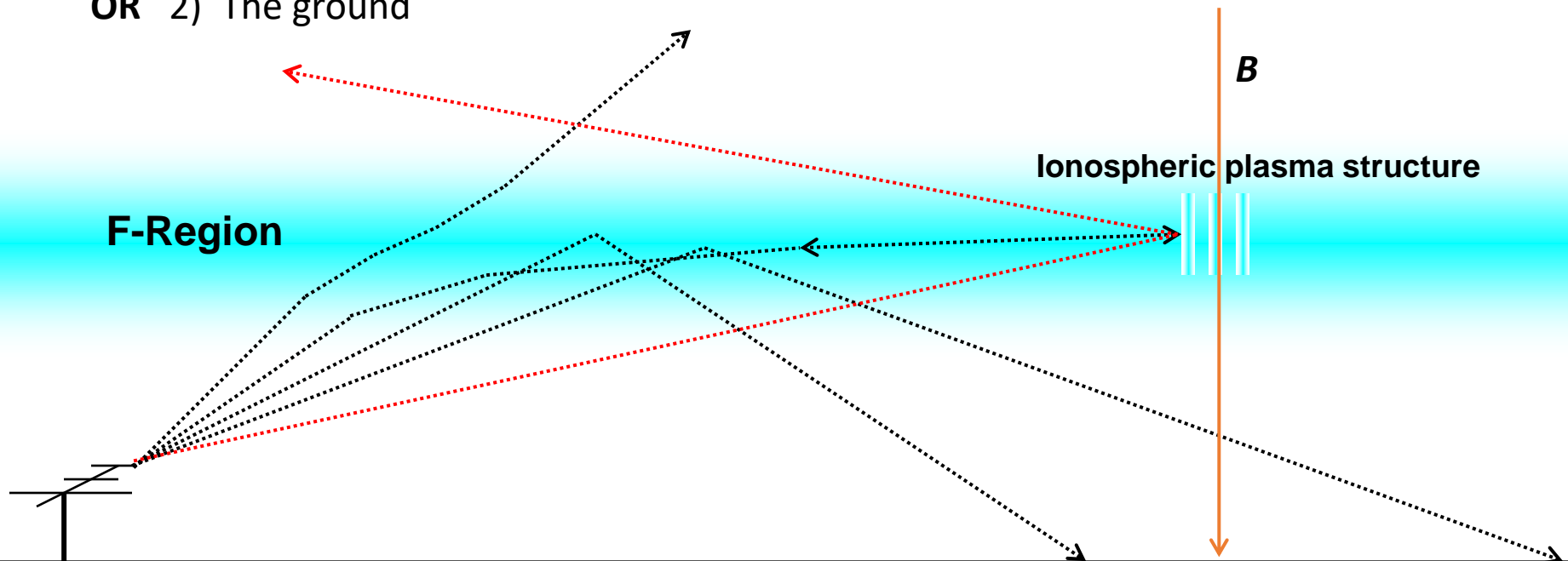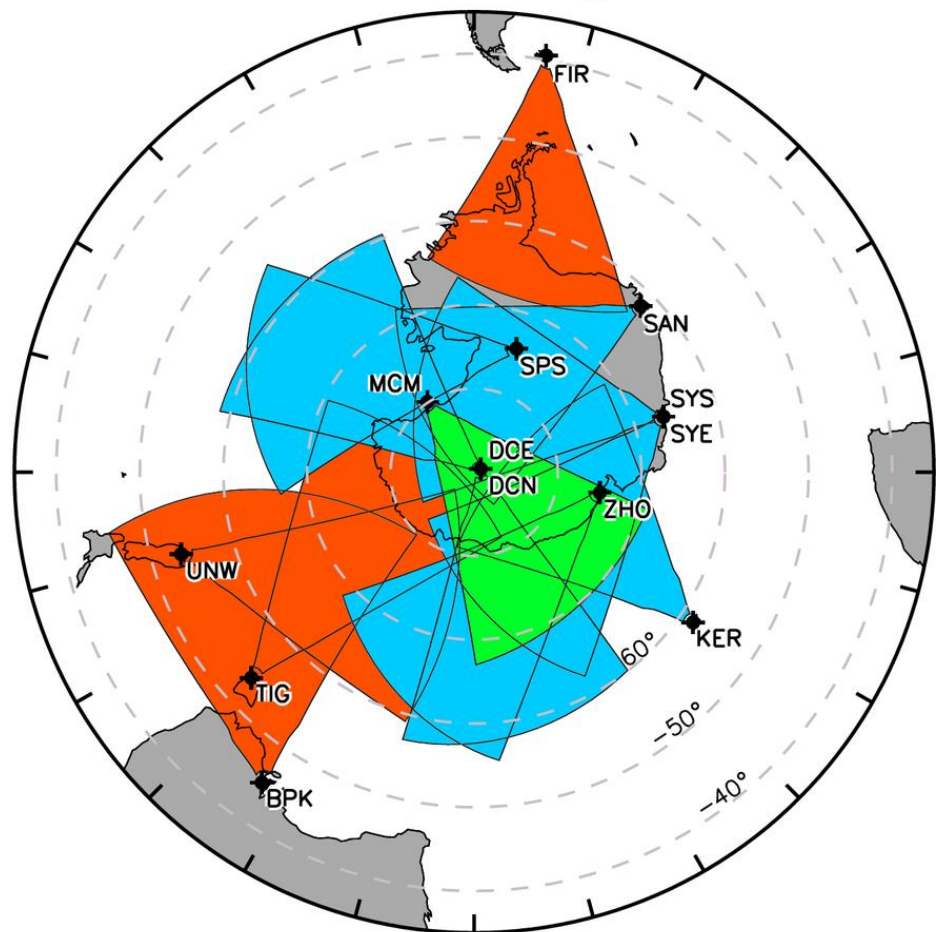
F-Region

Advantages of operation at HF frequencies:
1) Refraction of signals provides access to targets in the F-region ionosphere
2) Refraction of signals extends the radar range to > 3500 km
3) Low power requirements allows for continuous operation

SuperDARN Fields of View

Operating (PI) Institutions

- Johns Hopkins University Applied Physics Laboratory, USA (1983)
- British Antarctic Survey, UK (1988)
- University of Saskatchewan, Canada (1993)
- National Center for Scientific Research, France (1994)
- National Institute for Polar Research, Japan (1995)
- University of Leicester, UK (1995)
- University of KwaZulu-Natal, South Africa (1997)
- University of Alaska, USA (2000)
- Communications Research Laboratory, Japan (2001)
- La Trobe University, Australia (2001)

- Nagoya University, Japan (2006)
- Virginia Tech, USA (2008)
- Dartmouth College, USA (2010)
- Polar Research Institute of China (2010)
- Institute for Space Astrophysics and Planetology, Italy (2013)
- Lancaster University, UK (2014)
- The University Center in Svalbard, Norway (2015)
- National Space Science Center, China (2017)

35 radars
18 institutions
10 countries
→ A truly international collaboration!

SuperDARN Radars

King Salmon, AK

Saskatoon, Sask.

Stokkseyri, Iceland

Kodiak, AK

Kapuskasing, Ont.

Pykkvibaer, Iceland
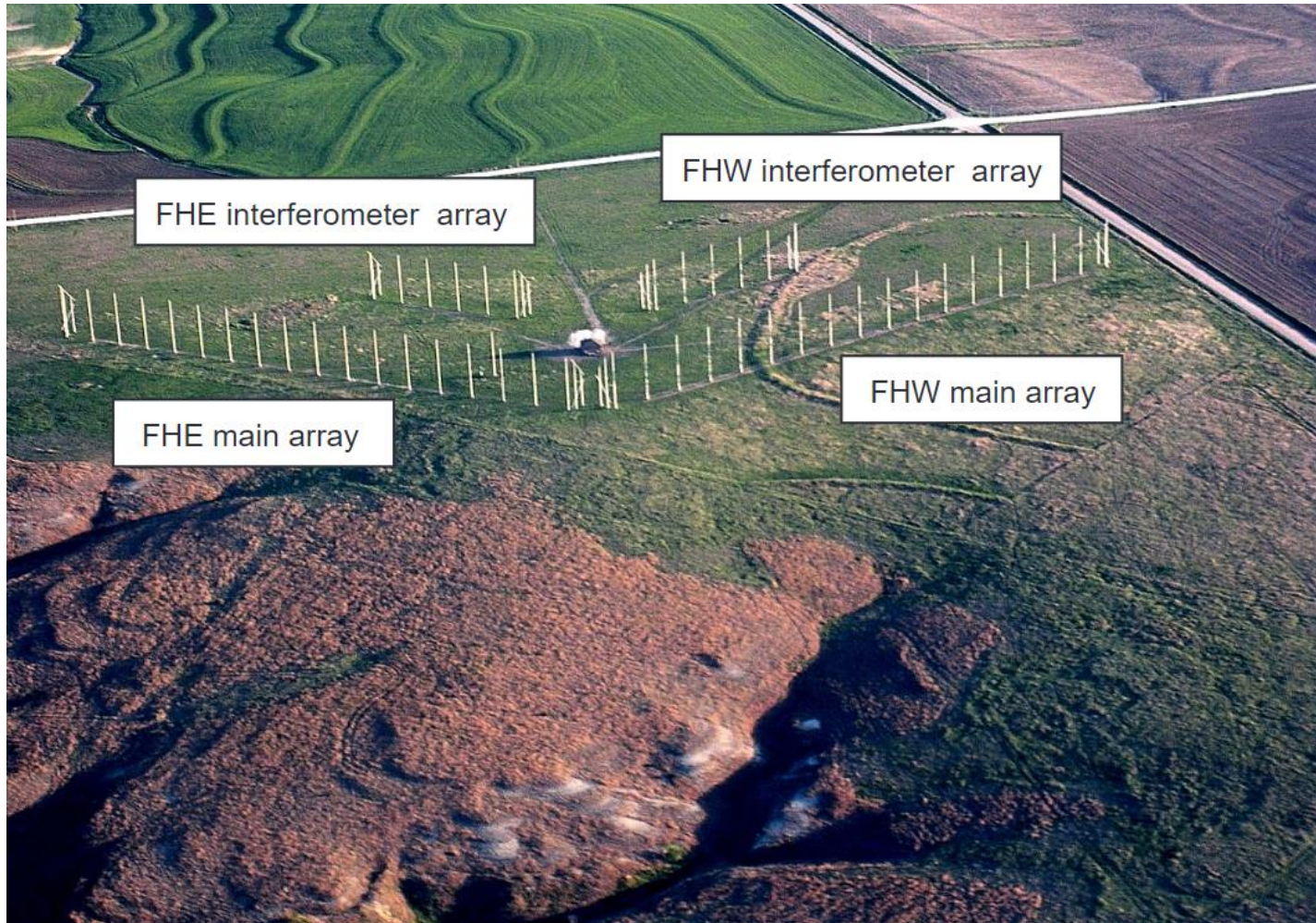
Prince George, B.C.

Goose Bay, Lab.

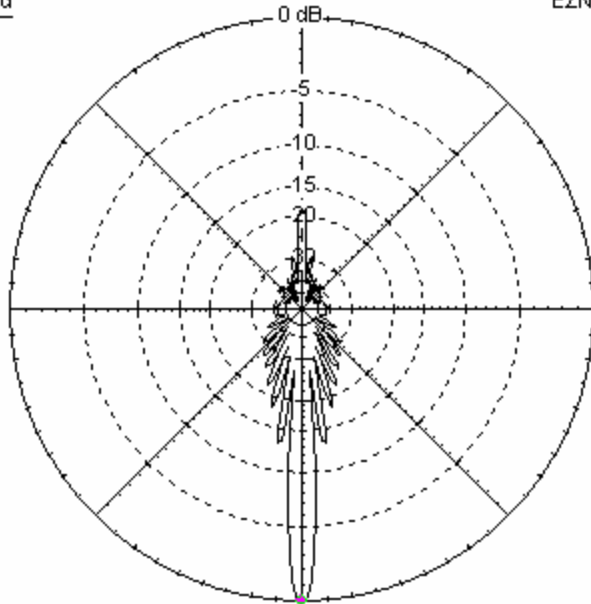Hankasalmi, Finland

SuperDARN Radars

- Aerial photo of co-located Fort Hays East (FHE) and Fort Hays West (FHW) radars in Hays, KS

Antenna Radiation Pattern

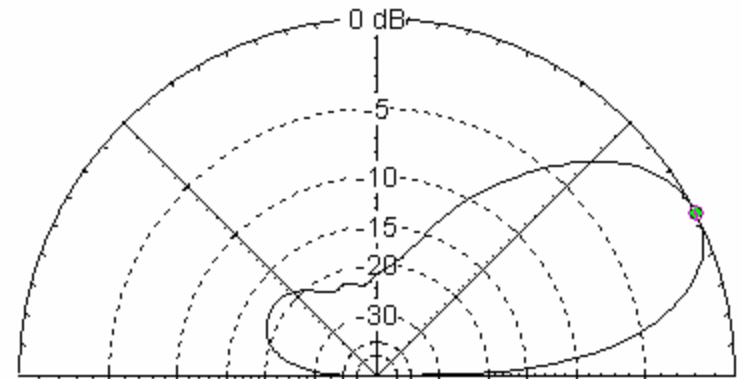- Azimuth pattern at max gain elevation angle for TTFD array at 14 MHz

- Elevation pattern of array of TTFD antennas at 14 MHz [*Sterne*, 2010]

SuperDARN Radars

- The standard radar operating mode scans sequentially across 16-24 azimuthal beam directions, completing a full scan in 1- or 2-minutes

- Each radar beam is separated by 3.24° in azimuth and sampled in 45 km range gates, out to a maximum distance of ~3500-5000 km

- Radars operate continuously (24 hours per day, 365 days per year) to monitor upper atmosphere space weather phenomena

Beam 0

Beam 15
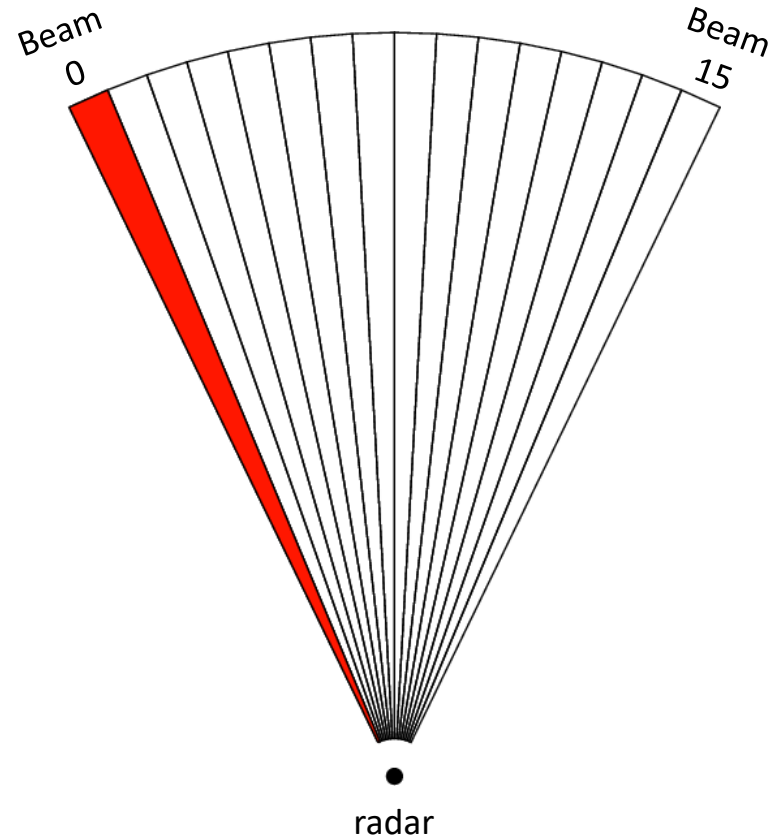
radar

SuperDARN Radars

Multi-Radar Doppler Map

11 Jan 2001

01:10:00 - 01:12:00 UT

2000
2000 m/s
0 m/s
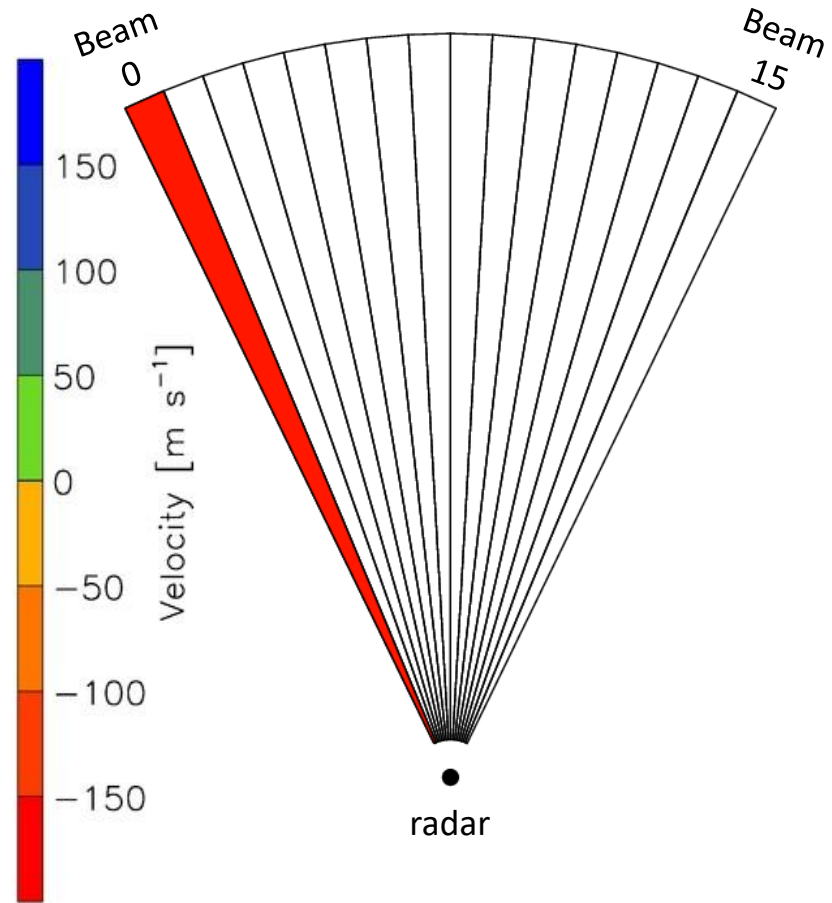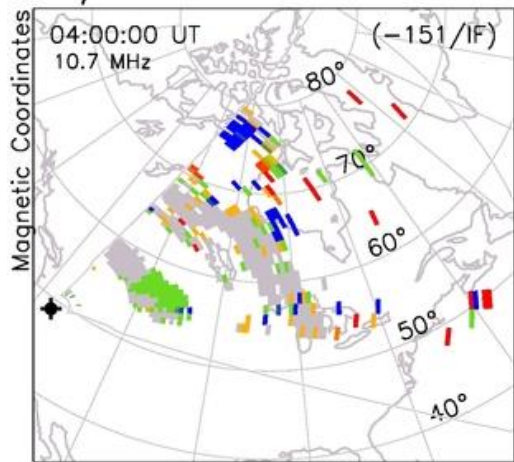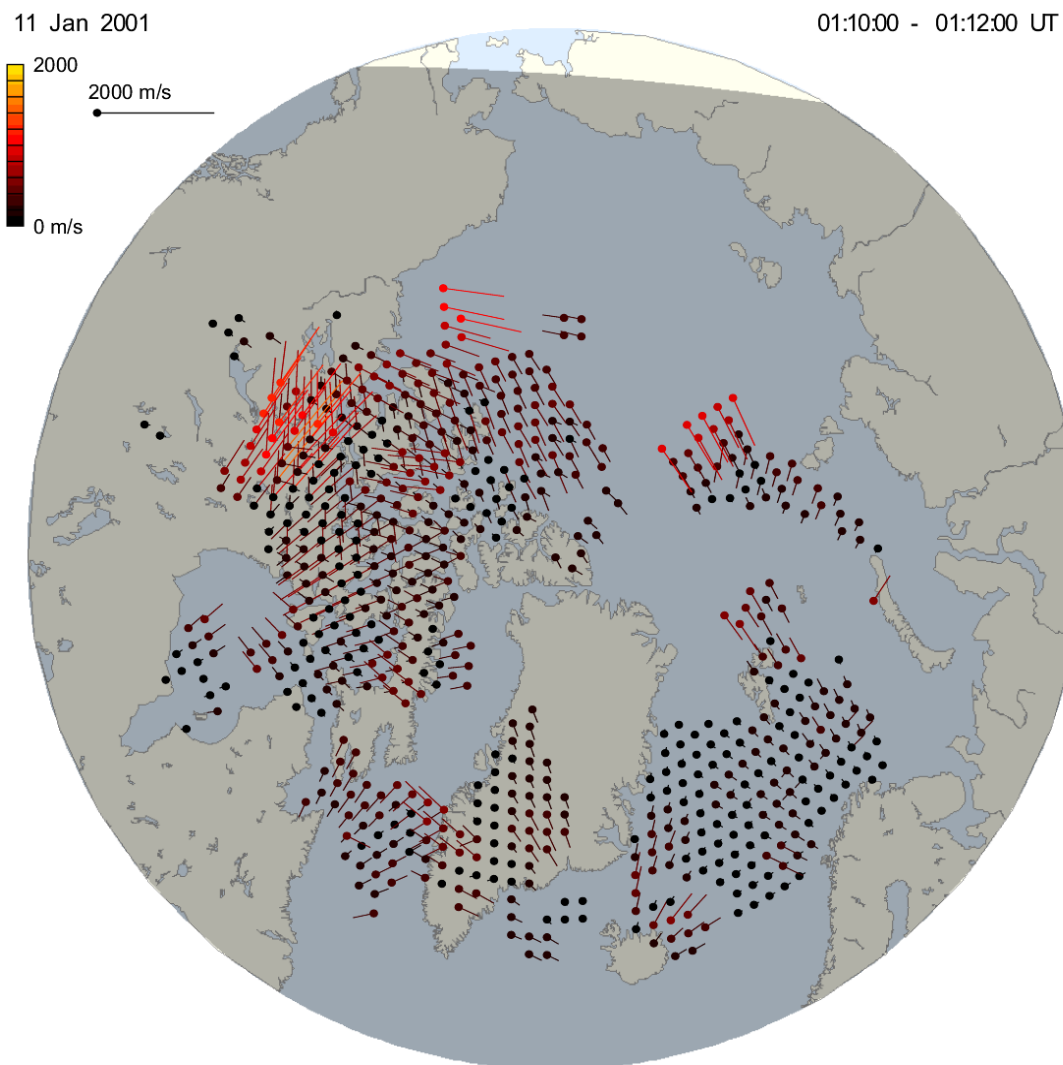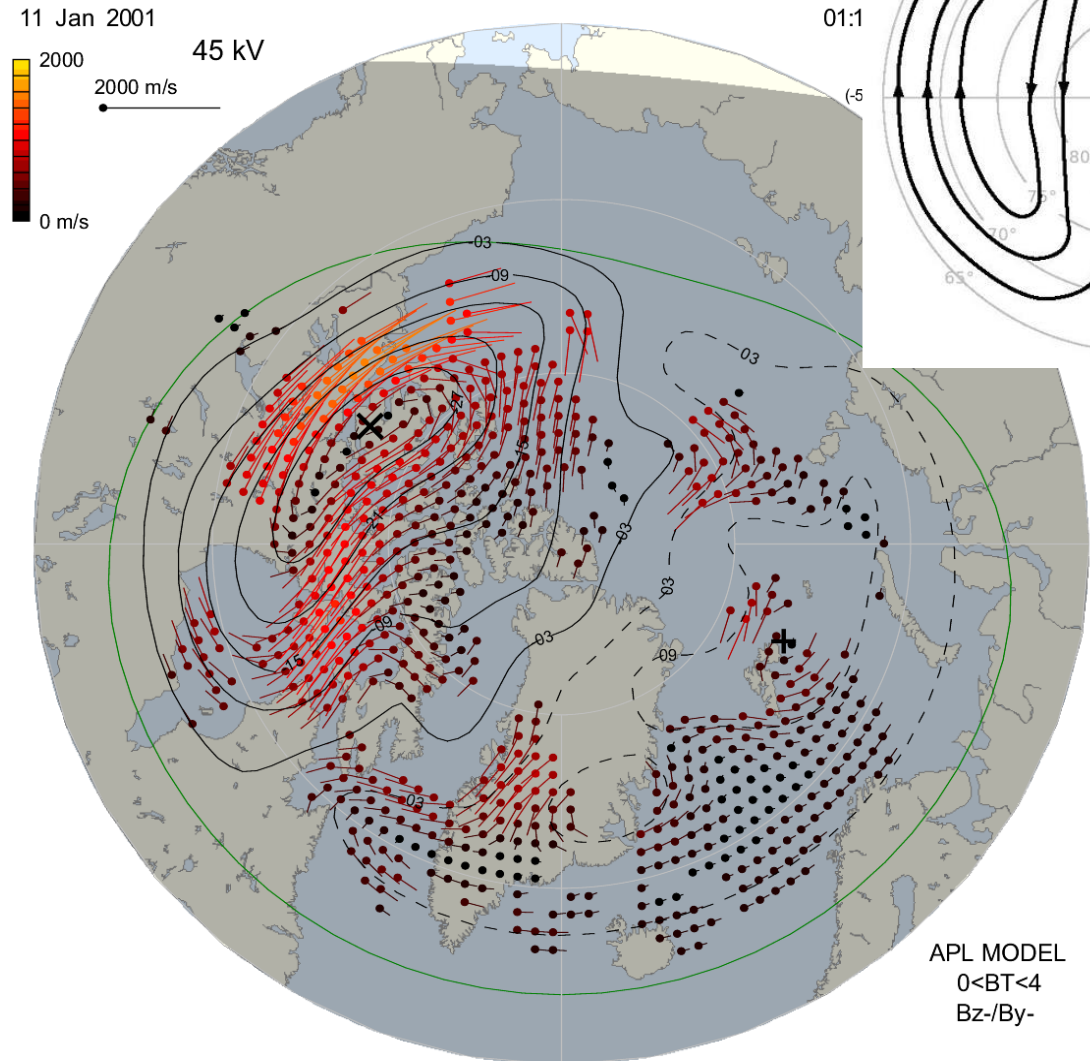
Convection Map

Real-Time Convection
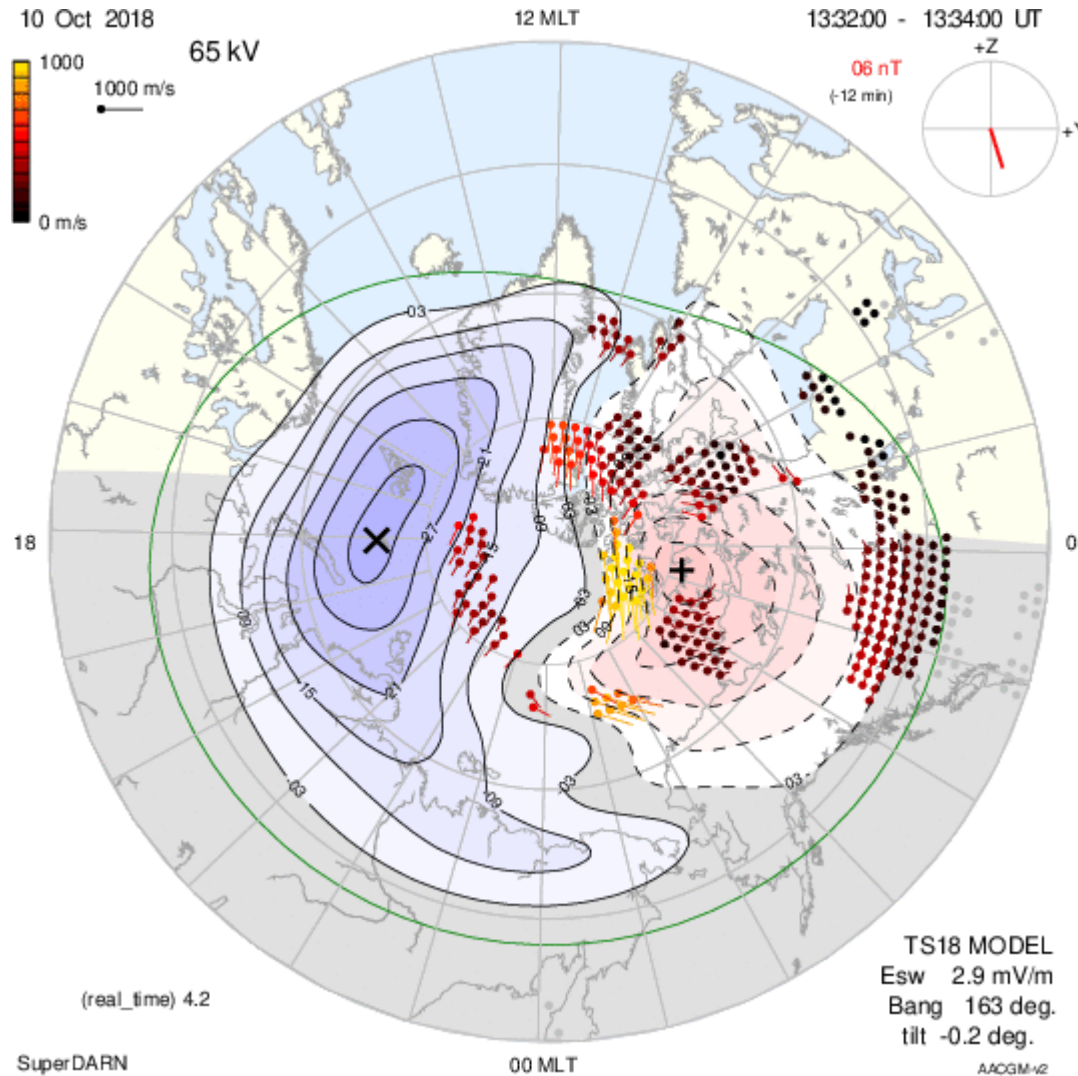
SuperDARN Data Access

- SuperDARN raw data mirror access (ssh, rsync) at British Antarctic Survey (BAS)

  - https://www.bas.ac.uk/project/superdarn/#data

- SuperDARN raw data archive (with DOIs) at Federated Research Data Repository (FRDR)

  - https://www.frdr-dfdr.ca/repo/collection/superdarn

- While SuperDARN has an open data use policy, i.e., prior permission to access and analyze the data is not required, the data user is strongly encouraged to establish early contact with any principal investigator (PI) group whose data are involved in the project to discuss the intended usage and collaboration.

SuperDARN Software

- The Radar Software Toolkit (RST) is an open-source C and IDL software package for SuperDARN data processing and analysis

  - https://doi.org/10.5281/zenodo.801458   (Zenodo)

  - https://github.com/SuperDARN/rst   (GitHub)

- Documentation for installing the RST and using it to process raw data files into fitted line-of-sight and global convection data can be found here:

  - https://radar-software-toolkit-rst.readthedocs.io/en/latest/

- Documentation for the C libraries and command-line routines can be found here:

  - https://superdarn.github.io/rst/

SuperDARN Software

- pyDARNio is a python IO library for SuperDARN data
    - https://doi.org/10.5281/zenodo.4009470   (Zenodo)
    - https://github.com/SuperDARN/pyDARNio   (GitHub)
    - https://pydarnio.readthedocs.io/en/latest   (Documentation)

- pyDARN is a python visualization library for SuperDARN data
    - https://doi.org/10.5281/zenodo.3727269   (Zenodo)
    - https://github.com/SuperDARN/pydarn   (GitHub)
    - https://pydarn.readthedocs.io/en/latest/   (Documentation)

SuperDARN Links

- https://github.com/SuperDARN　　　　(SuperDARN GitHub)

- https://zenodo.org/communities/superdarn (Zenodo Community)

- http://superdarn.thayer.dartmouth.edu/　(Dartmouth College)

- https://superdarn.jhuapl.edu/　　　　(JHU/APL)

- https://superdarn.met.psu.edu/　　　　(Penn State)

- http://vt.superdarn.org/tiki-index.php　　(Virginia Tech)

- https://superdarn.ca/　　　　　　(SuperDARN Canada)

- http://polaris.nipr.ac.jp/~SD/sdjapan/　(SuperDARN Japan)

- http://www.tiger.latrobe.edu.au/　　(La Trobe University)

Questions?