Remote sensing of Arctic sea ice using the Super Dual Auroral Radar Network (SuperDARN)

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What is SuperDARN?

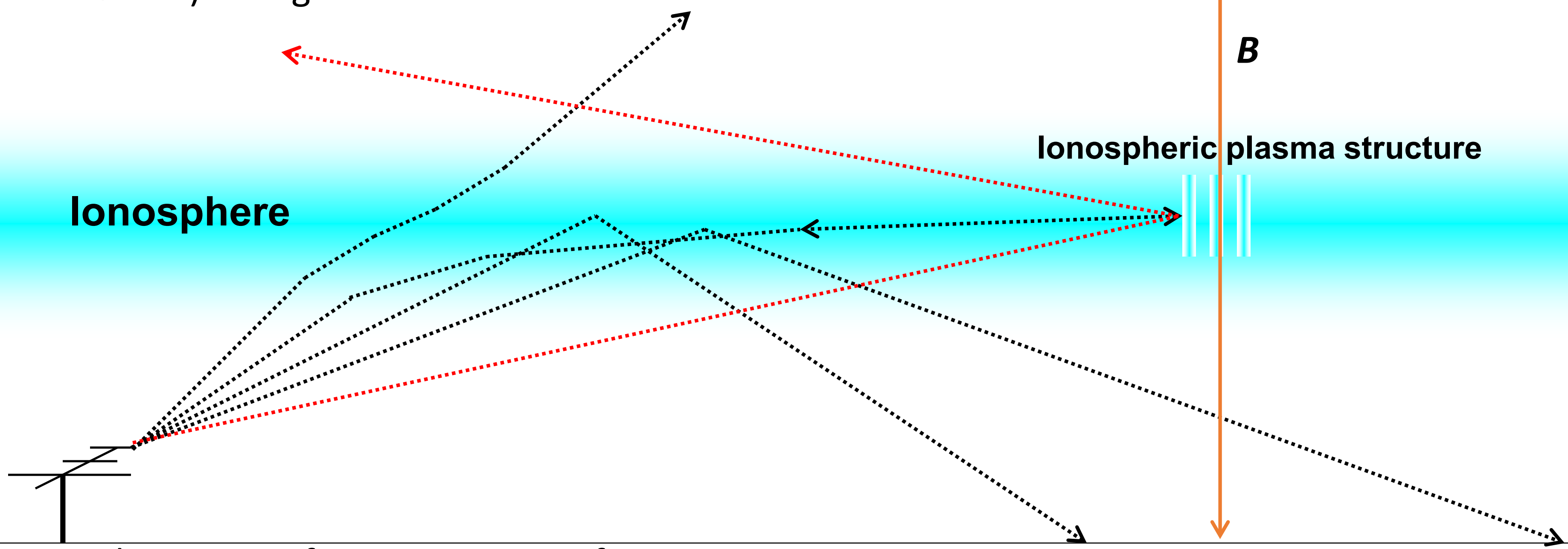
- The Super Dual Auroral Radar Network (SuperDARN) is an international network of ground-based, high-frequency (HF) space weather radars which have operated in the Arctic and Antarctic regions for more than 30 years

- Typical characteristics of a SuperDARN radar:
  - Operates between 8-20 MHz
  - Transmits ~10 kW peak power (low duty cycle)
  - 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?

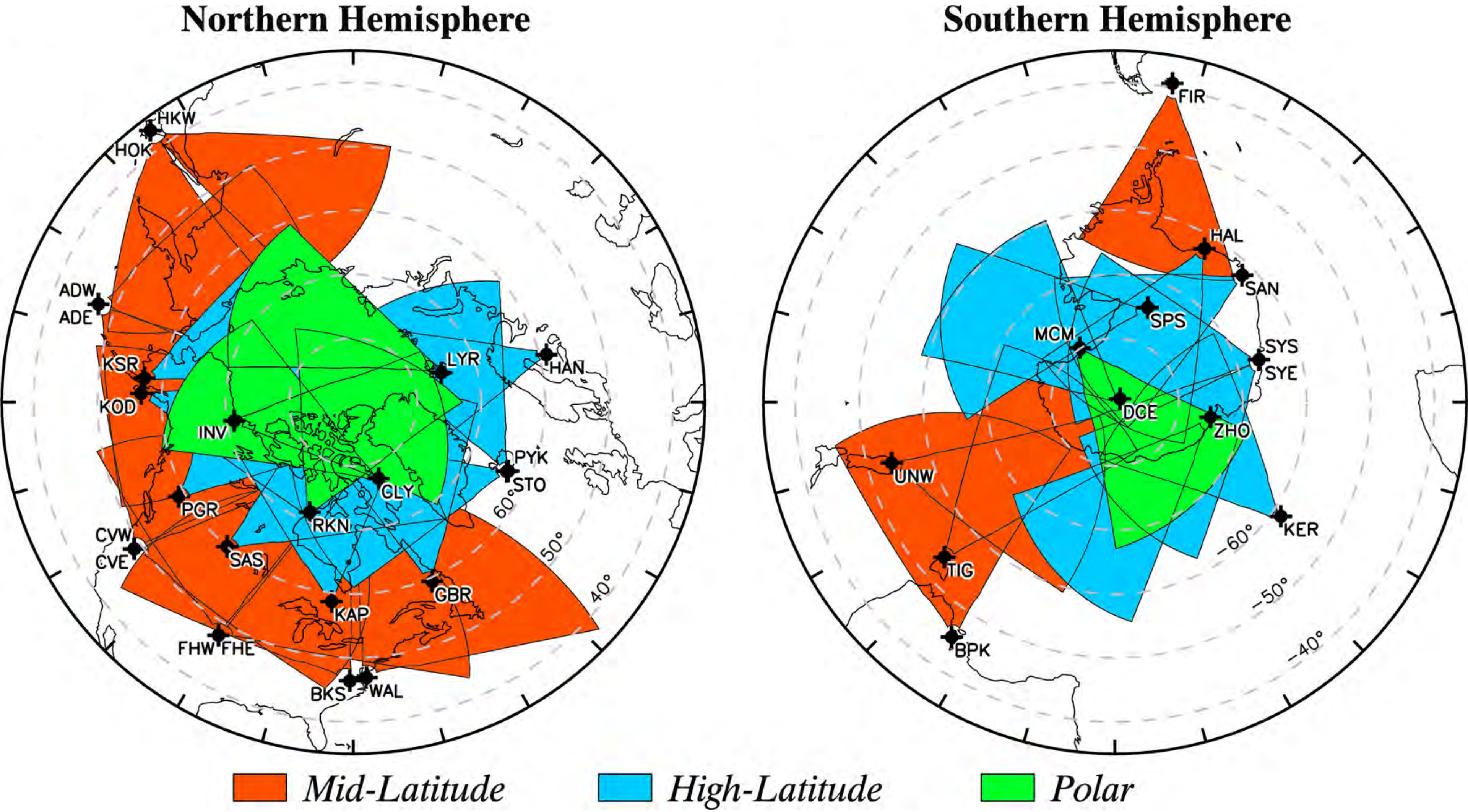
- HF radiation is refracted in the ionosphere as it traverses gradients in electron density.
- The transmitted signals can be reflected back to the radar by:
  1) Plasma irregularities if the ray is quasi-perpendicular to the magnetic field

OR 2) The ground



Advantages of operation at HF frequencies:
1) Refraction of signals provides access to targets in the 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)

34 radars

18 institutions

10 countries

→ A truly international collaboration!

SuperDARN Radars


King Salmon, AK


Saskatoon, Sask.


Stokkseyri, Iceland


Kodiak, AK


Kapuskasing, Ont.

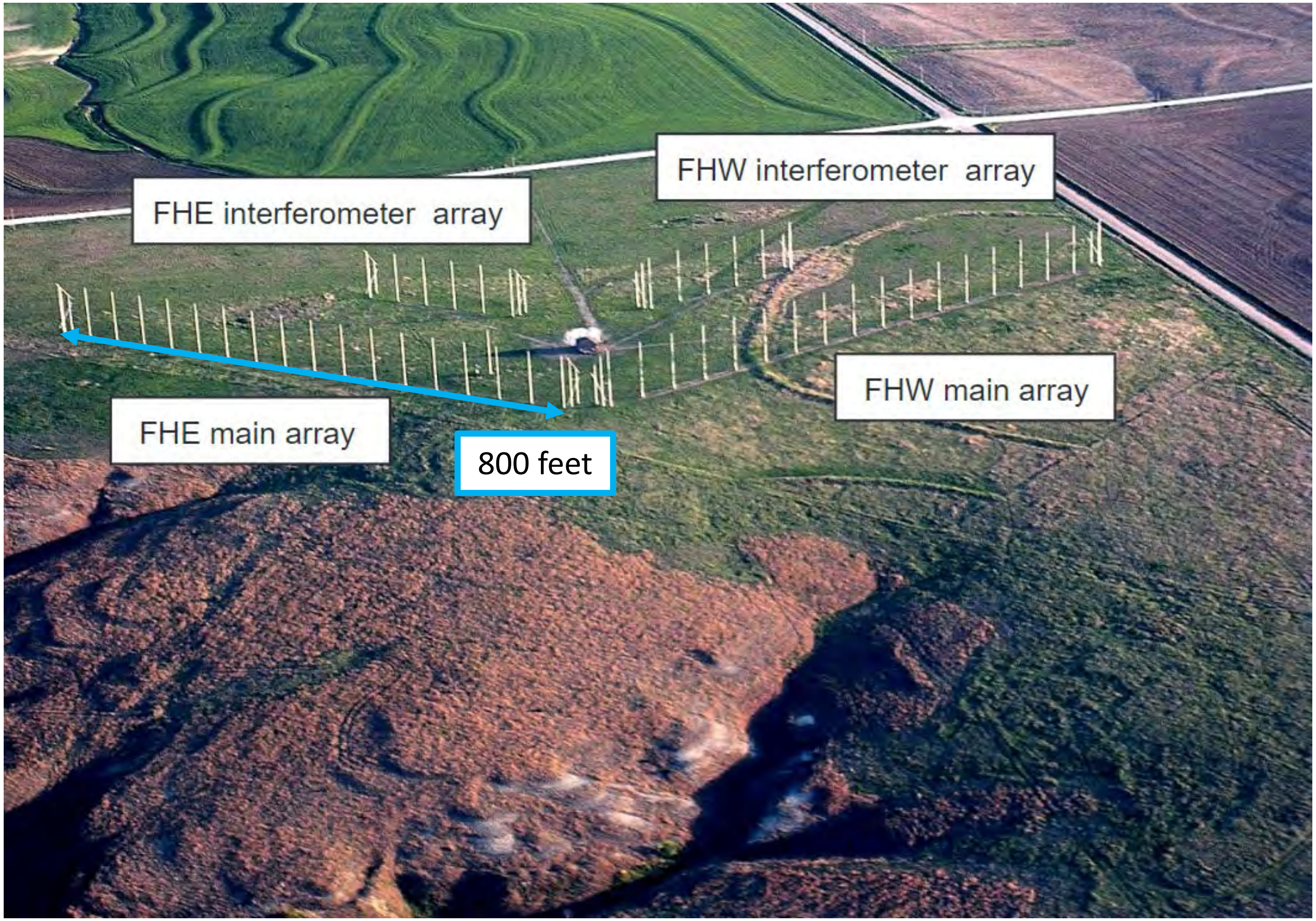

Pykkvibaer, Iceland


Prince George, B.C.


Goose Bay, Lab.

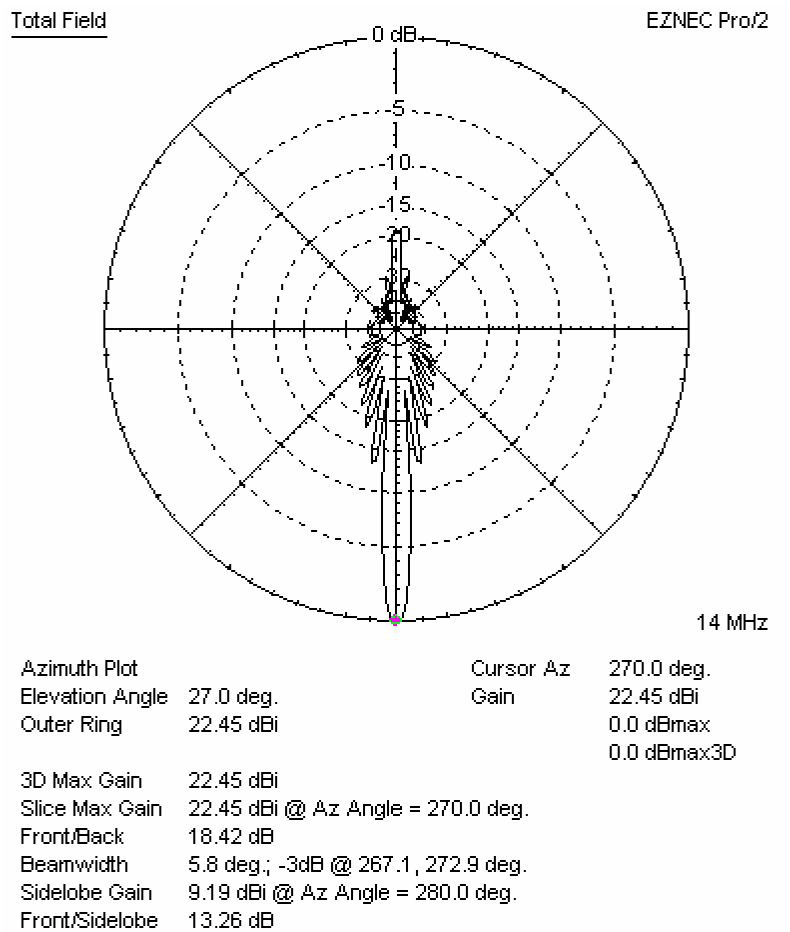

Hankasalmi, Finland

SuperDARN Radars

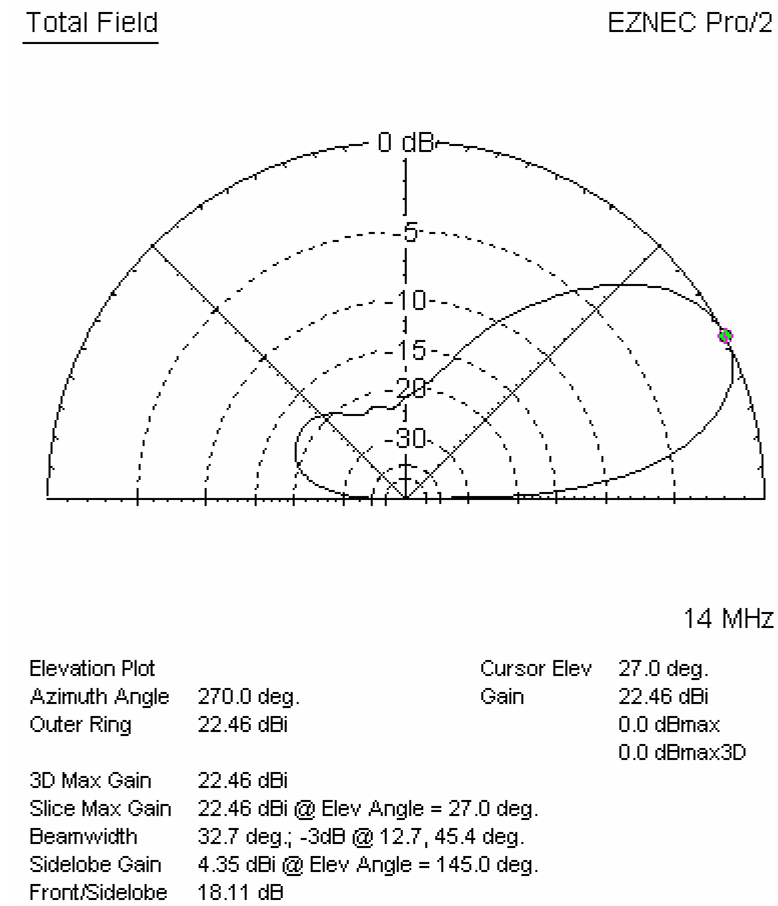


- Aerial photo of co-located Fort Hays East (FHE) and Fort Hays West (FHW) radars in Hays, KS

Antenna Radiation Pattern

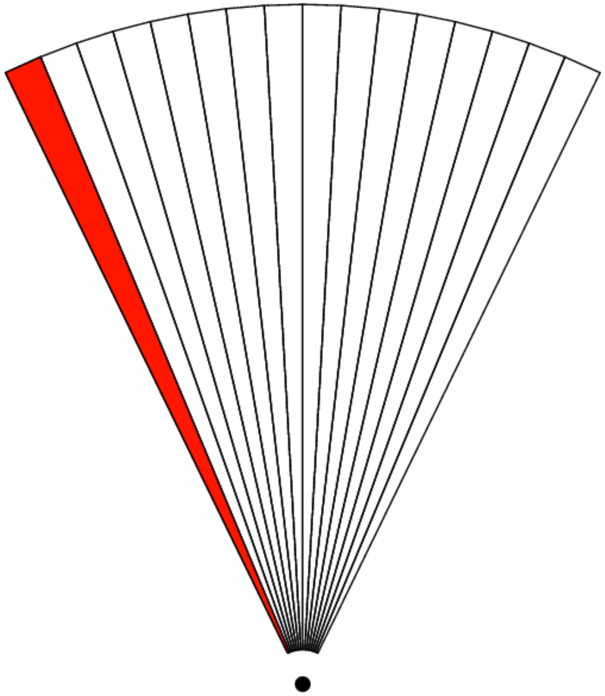


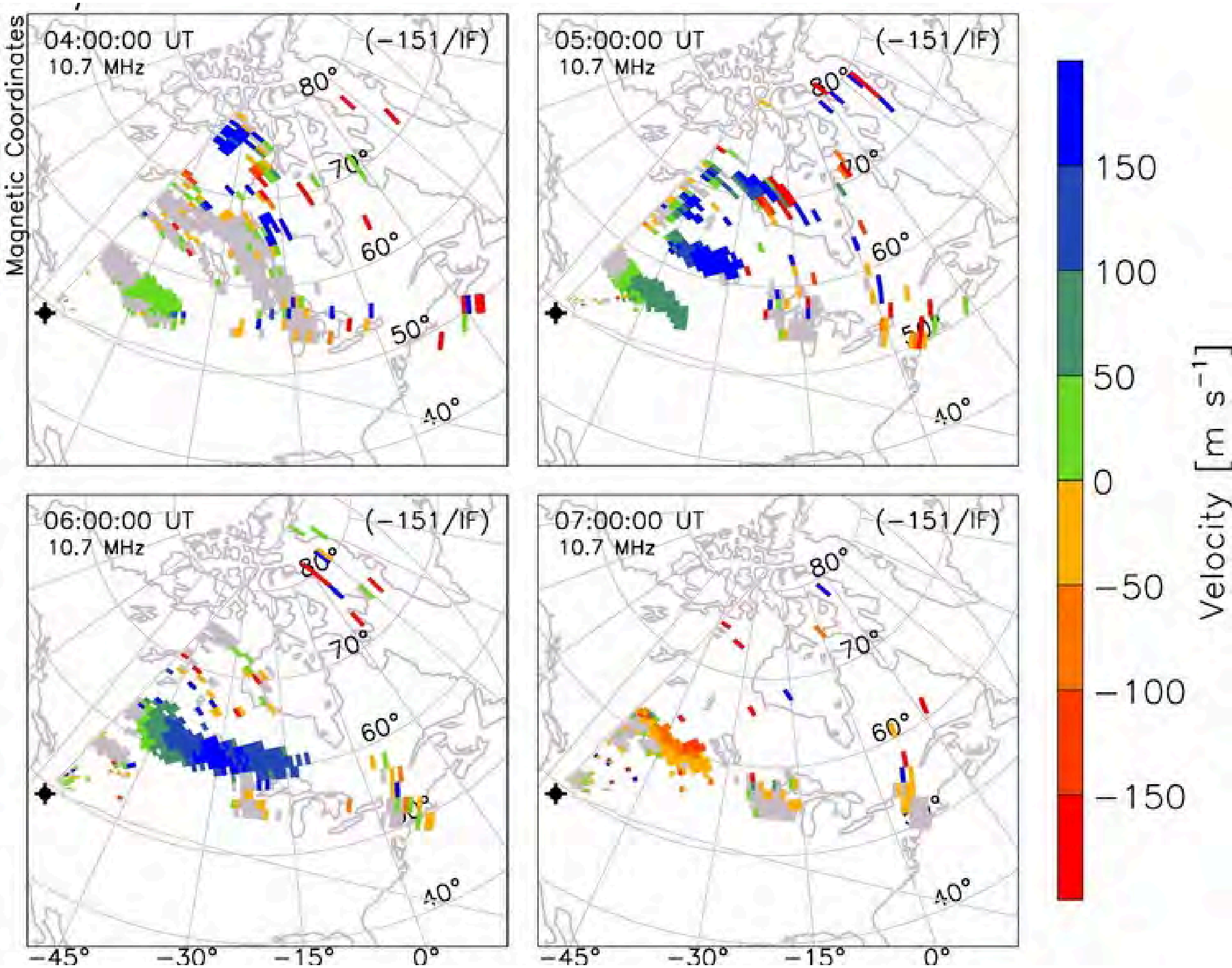
- Azimuth pattern at max gain elevation angle for TTFD array at 14 MHz



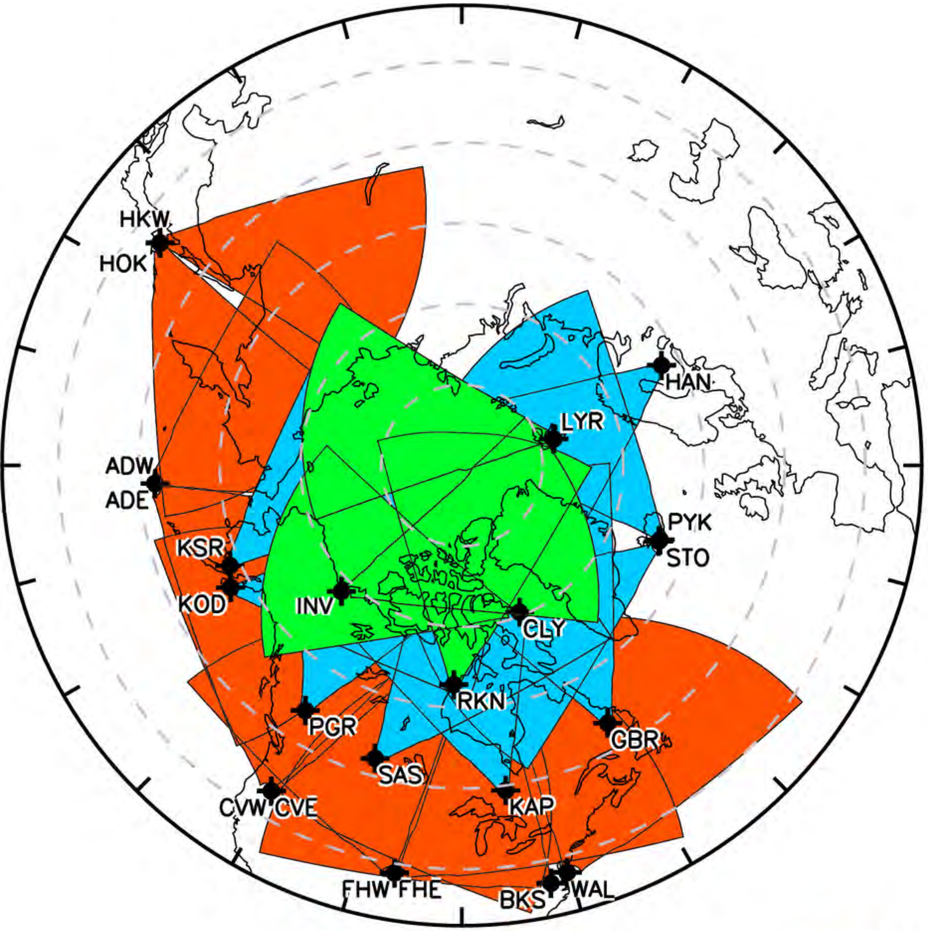
- Elevation pattern of array of TTFD antennas at 14 MHz [*Sterne*, 2010]

SuperDARN Data

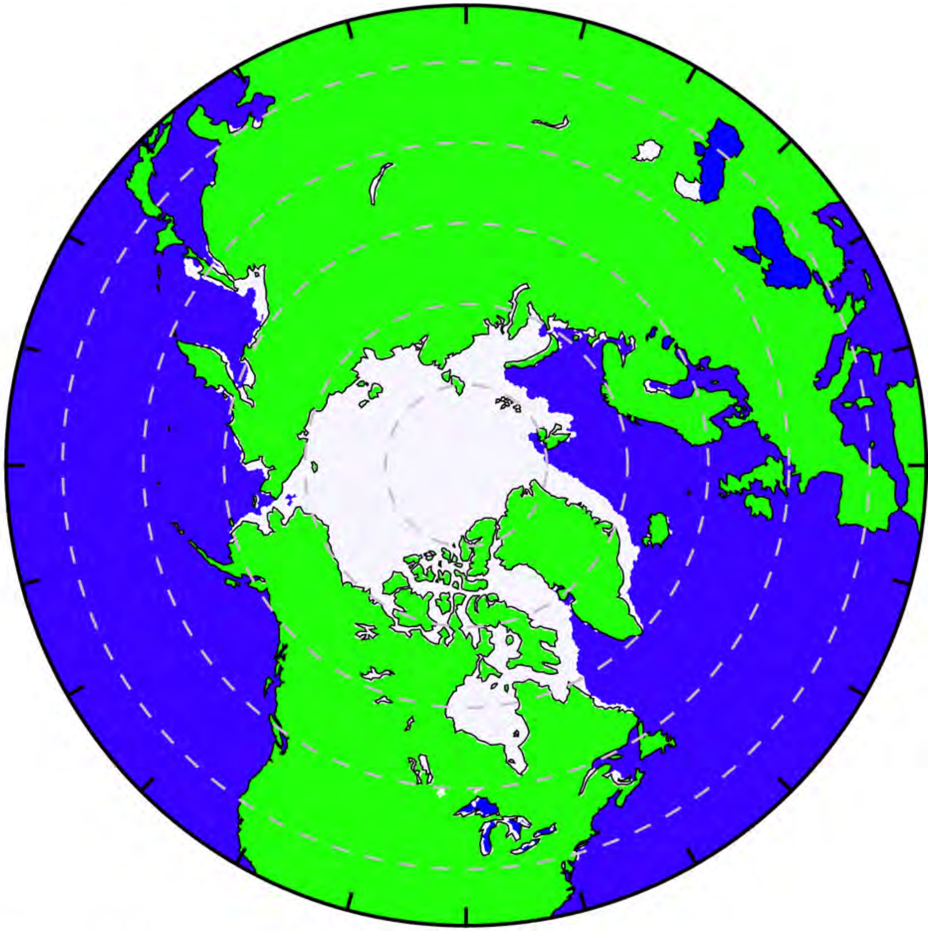




Northern Hemisphere
SuperDARN FOVs



IMS Daily 24 km Sea Ice
Extent on 01 Jan 2018



Mid-Latitude *High-Latitude* *Polar*

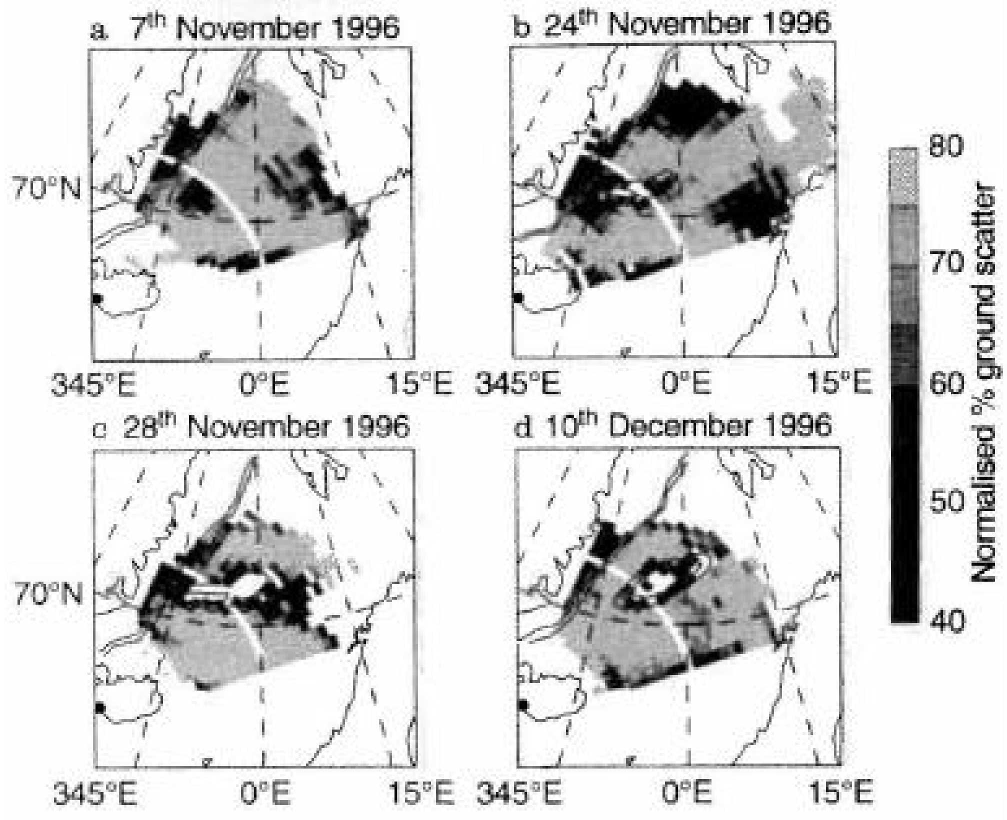
Previous Work

• *Shand et al.* [1998] studied the dynamics of the Greenland glacier tongue (Odden) using ground scatter measurements from the Pykkvibaer SuperDARN radar in Iceland

• Location of the boundary of the sea ice was found using the passive Special Sensor Microwave/Imager (SSM/I) instrument onboard DMSP spacecraft

• The ice tongue can be seen forming off the east coast of Greenland in early November then detaching and drifting away over a period of 33 days

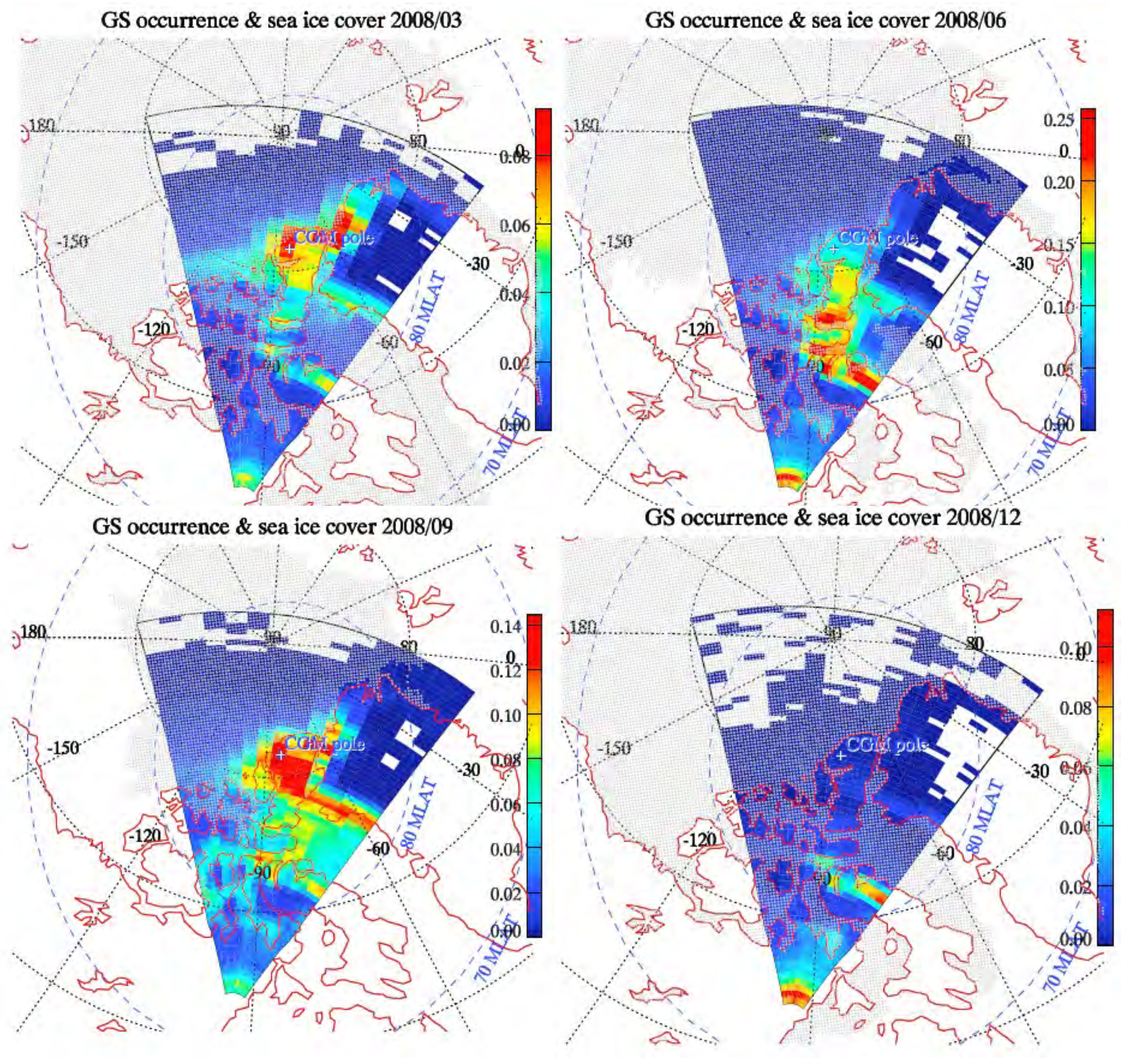
• Sea ice is altering the radar scattering mechanisms in regions where no radar ground scatter is observed, resulting in a loss of returns



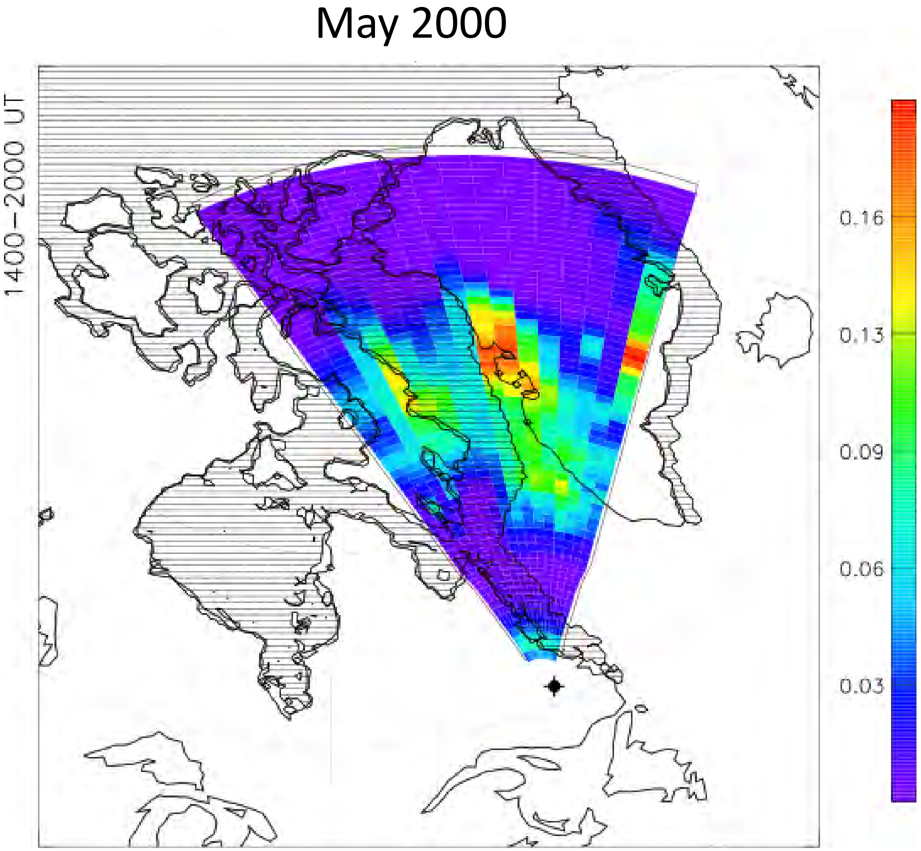
Previous Work

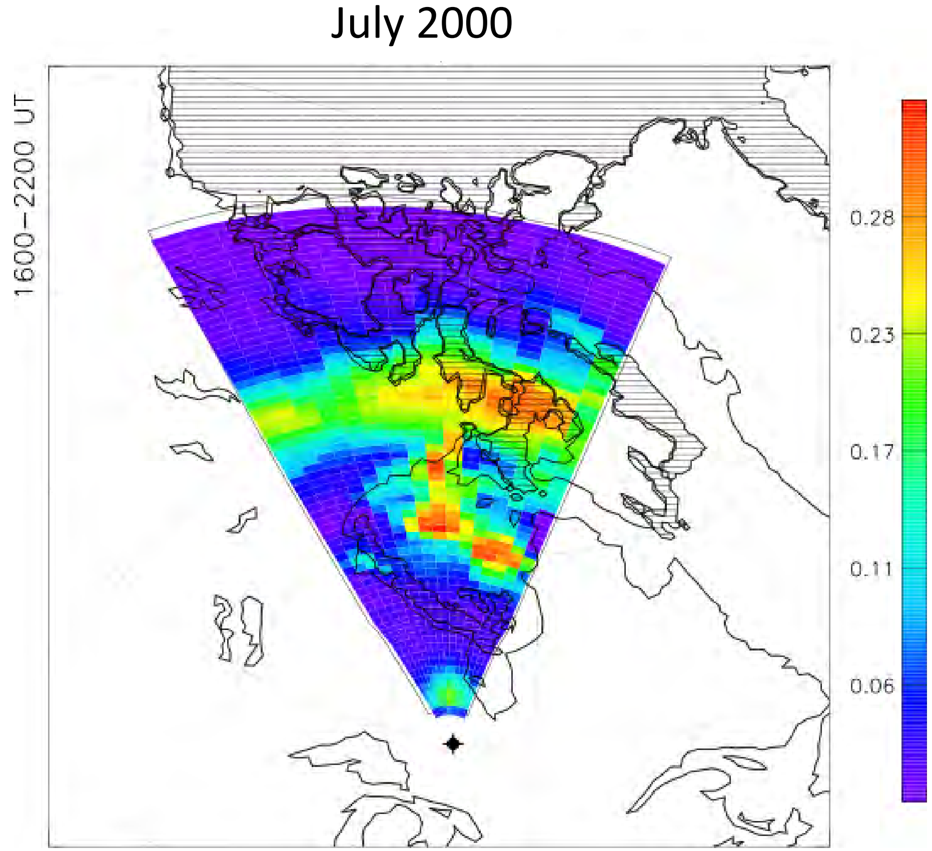
• *Ponomarenko et al.* [2010] examined monthly ground scatter occurrence rates over from the Rankin Inlet radar in Canada, reaching three major conclusions:

1) Ice sheets rarely produce detectable backscatter
2) Mountain ranges were the primary source of ground scatter
3) Sea surface becomes a significant source of ground scatter once the Artic sea ice melted away



Previous Work

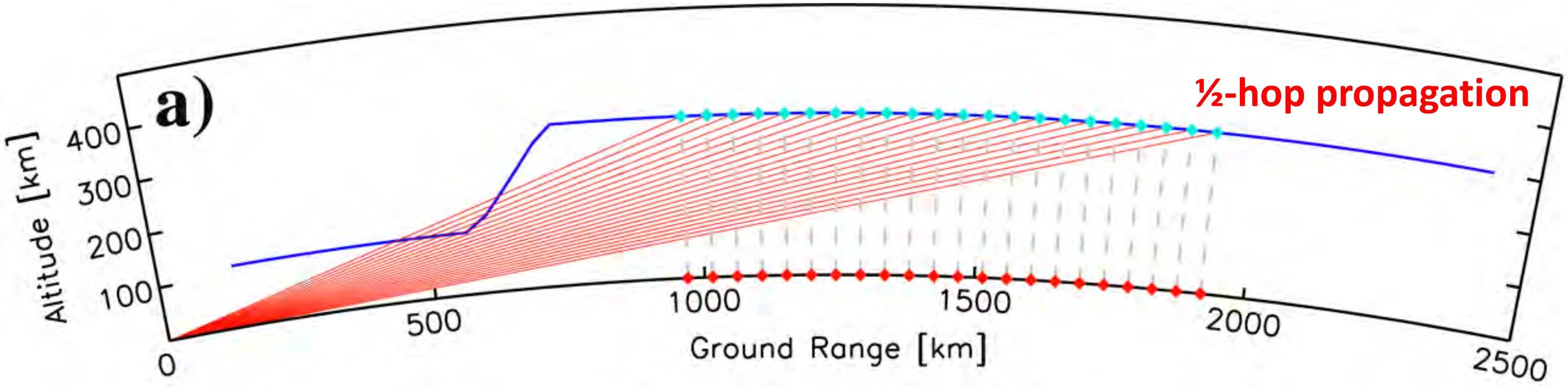




- As part of a Masters thesis project, *Thomas* [2012] examined monthly ground scatter occurrence rates from 4 NH radars, finding similar qualitative agreement between the presence of Arctic sea ice and a reduction in ground backscatter

Current Project

- Our goal is to extract sea ice parameters from the 25+ years of SuperDARN HF radar observations in a manner beneficial to the Arctic research community
- This project is the first dedicated effort to perform a multi-year, multi-radar analysis of SuperDARN ground scatter echoes to examine features on the Earth's surface
- Results will be compared against space-based remote sensing observations of sea ice characteristics such as concentration, extent, and thickness
- As part of the Arctic Observing Network (AON), any operational sea ice products will be submitted to the Arctic Data Center to ensure long-term accessibility for the broader scientific community



½-hop propagation

1-hop propagation

Ground range error

Thank You!

References:

- Ponomarenko, P. V., J.-P. St. Maurice, G. C. Hussey, and A. V. Koustov (2010), HF ground scatter from the polar cap: Ionospheric propagation and ground surface effects, *J. Geophys. Res.*, *115*, A10310, doi:10.1029/2010JA015828.
- Shand, B. A., S. E. Milan, T. K. Yeoman, P. J. Chapman, D. M. Wright, T. B. Jones, and L. T. Pederson (1998), CUTLASS HF radar observations of the Odden ice tongue, *Ann. Geophys.*, *16*, 280–282.
- Sterne, K. T. (2010), Testing the Re-designed SuperDARN HF Radar and Modeling of a Twin Terminated Folded Dipole Array, M. S. thesis, Virginia Tech, Blacksburg, VA, USA.
- Thomas, E. G. (2012), Dynamics of the geomagnetically disturbed ionosphere as measured by GPS receivers and SuperDARN HF radars, M.S. thesis, Virginia Tech, Blacksburg, VA, USA.

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