AGF-216

The Earth's Ionosphere & Radars on Svalbard

Katie Herlingshaw
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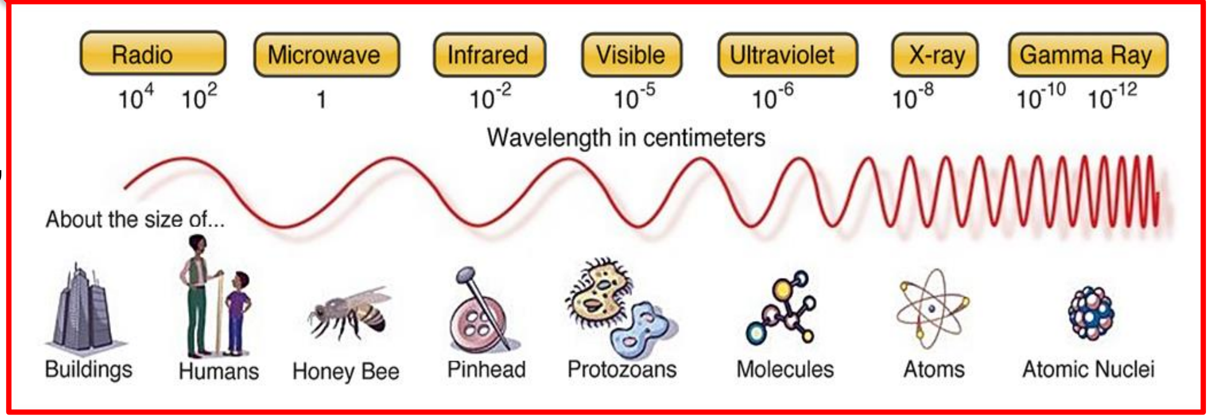
Overview

- Radar basics – what, how, where, why?
- How do we use radars on Svalbard?
- What is EISCAT and what does it measure?
- Let’s not forget about SuperDARN!

What is a RADAR?

- RAdio Detection And Ranging

Long wavelength,
Low frequency

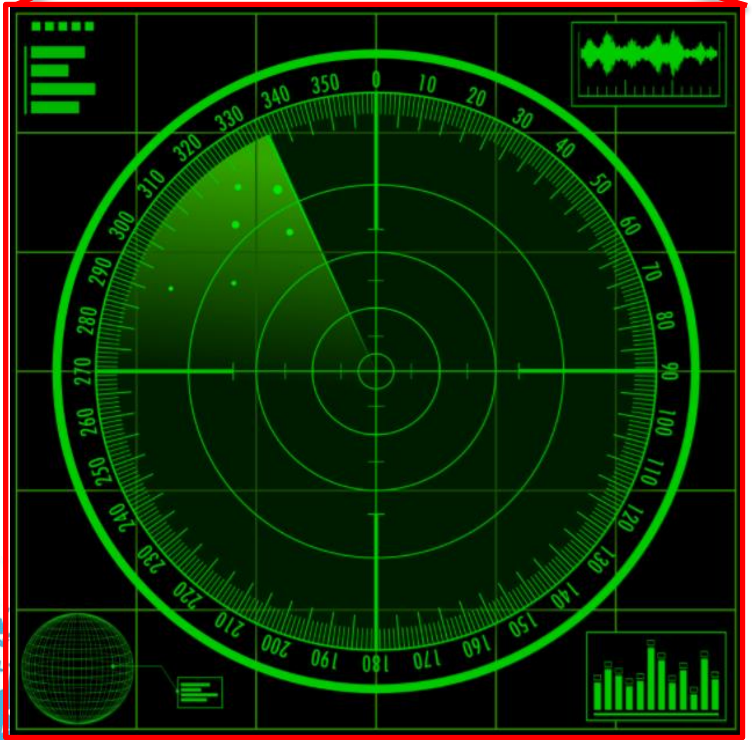


Short wavelength,
High frequency

- Radio waves are electromagnetic waves with a wavelength of cm to m
- Radars transmit and receive radio waves

What is a RADAR?

- RAdio Detection And Ranging



- The radio waves reflect off a target
- If we receive a signal back then there must be an obstacle in the direction that we sent the radio wave

What is a RADAR?

- RAdio Detection And Ranging

- Radars can measure the distance to the targets
- This is calculated by measuring the time between transmission and reception of the signal

What is a RADAR?

- RAdio Detection And Ranging

Visible light and our eyes

Radio waves and radars

The velocity of the target can also be measured by using the Doppler effect…

The Doppler Effect

It's the apparent change in the frequency of a wave caused by relative motion between the source of the wave and the observer.

The Doppler Effect: Stationary

For a stationary sound source:

- Waves are produced at a constant frequency and move outwards
- All observers hear the same frequency

The Doppler Effect: Moving Towards

For a moving sound source:

The sound waves gets compressed → the frequency sounds higher

The Doppler Effect: Moving Away

For a moving sound source:

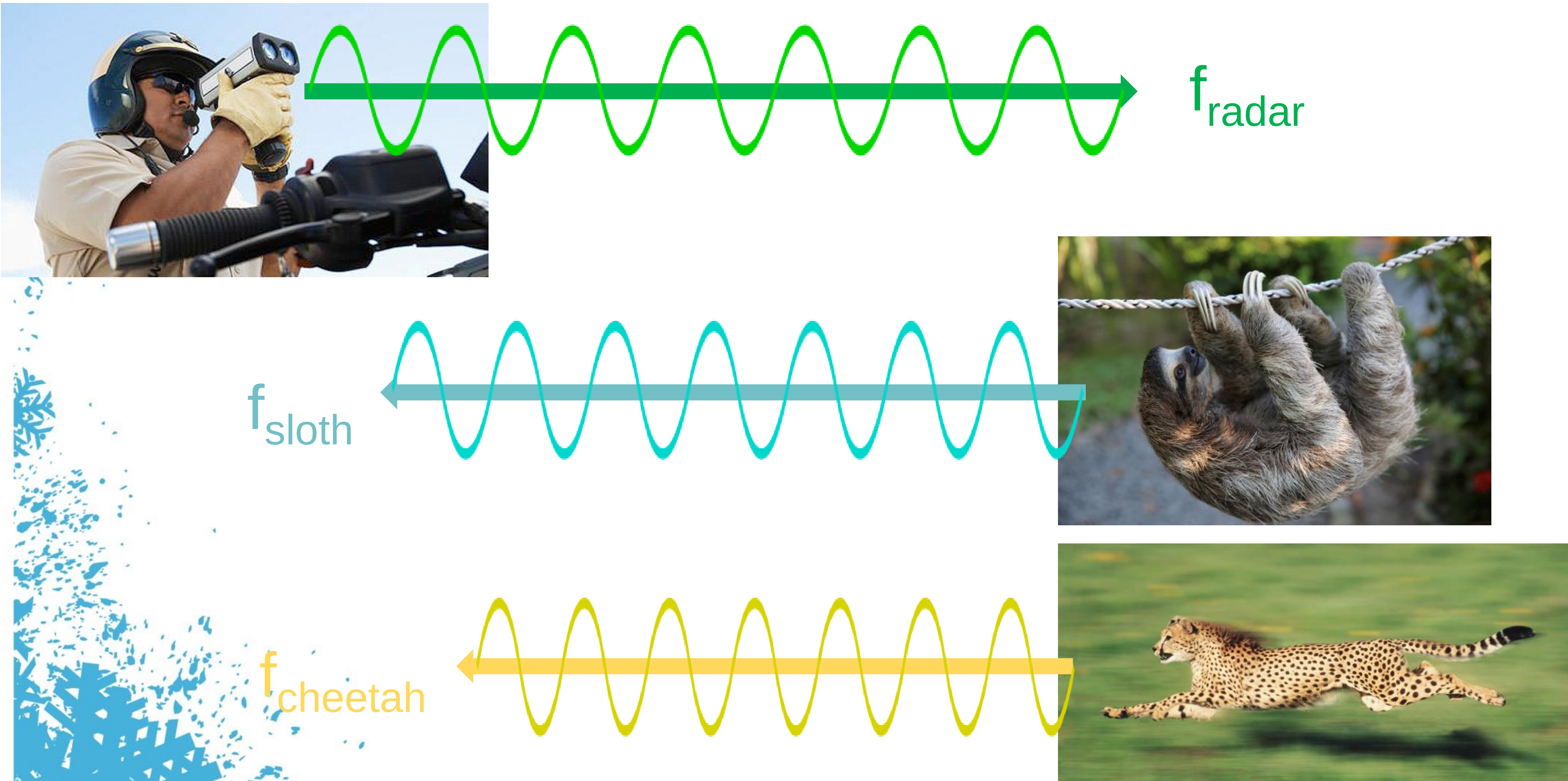
The sound waves gets stretched out → the frequency sounds lower

The Doppler Effect: Drive by

For a moving sound source:

Approaching car → higher frequency
Retreating car → lower frequency

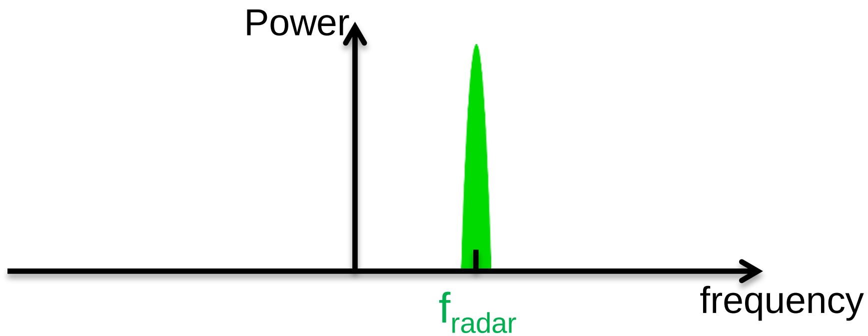
The Doppler Effect: Time Domain

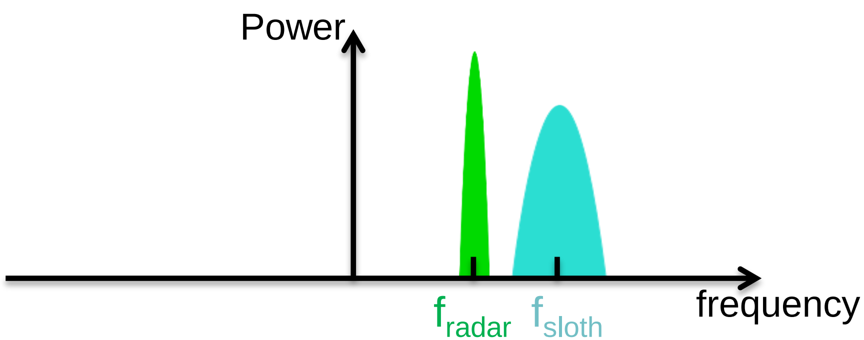


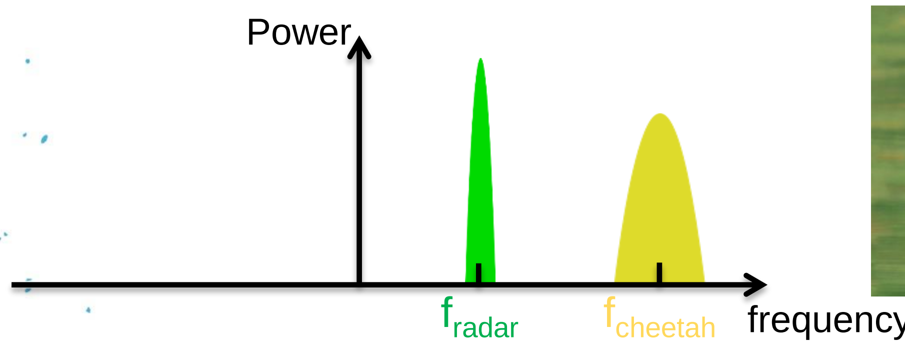
$f_{radar} < f_{sloth} < f_{cheetah}$ The animals move towards the radar, reflected wave is compressed

$f_{cheetah} > f_{sloth}$ The cheetah approaches faster than the sloth

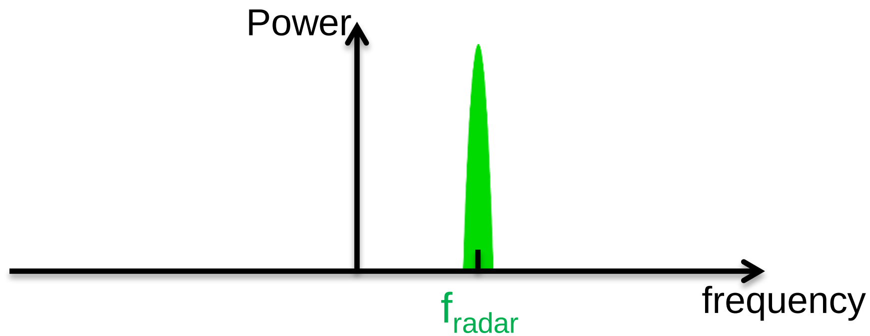
The Doppler Effect: Frequency Domain

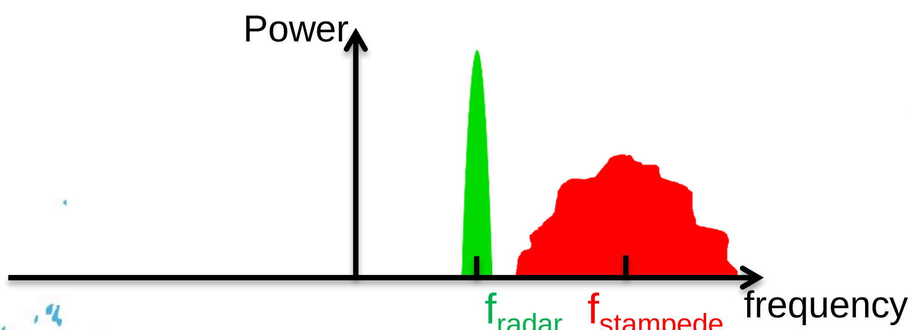


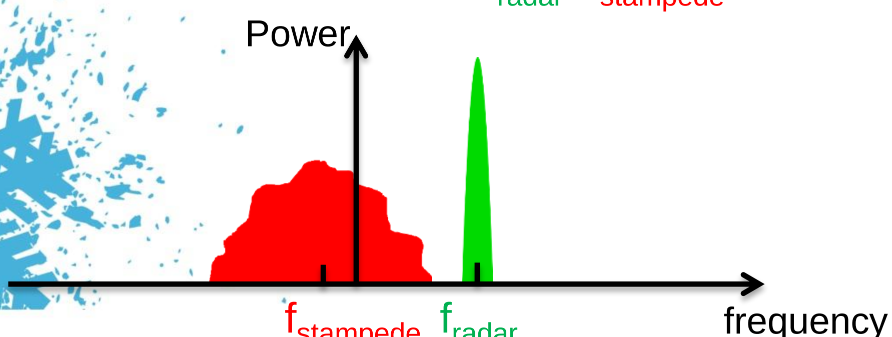




The Doppler Effect: Frequency Domain








So, how do we use radars
to measure the aurora?

The Ionosphere

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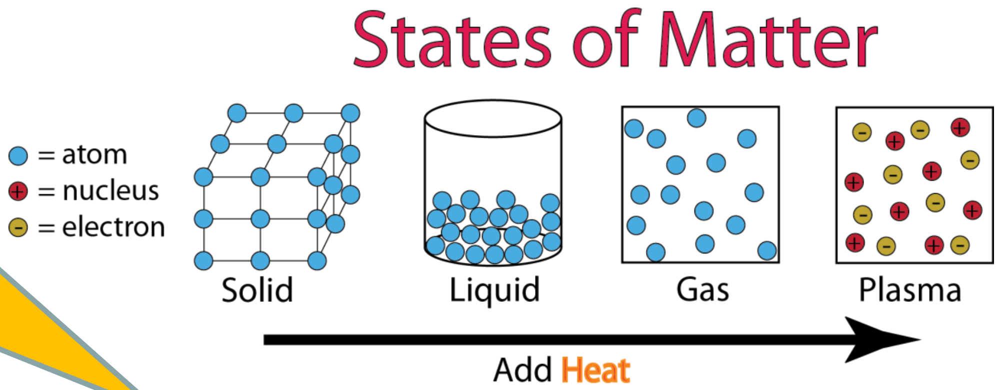
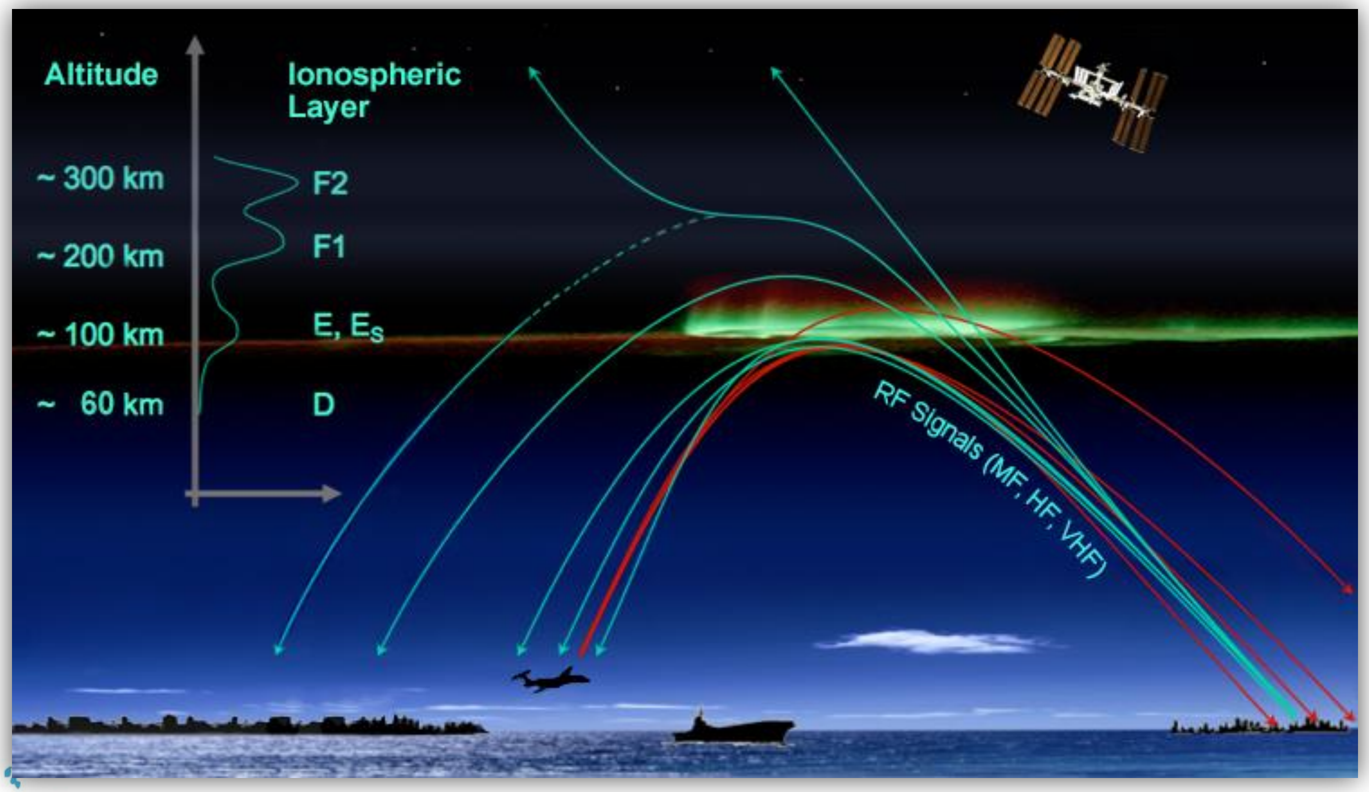
- Solar radiation ionizes the upper part of Earth's atmosphere (80 - 600 km)

- This creates a layer in the upper atmosphere made of plasma

99.9% of the observable universe is made of plasma!



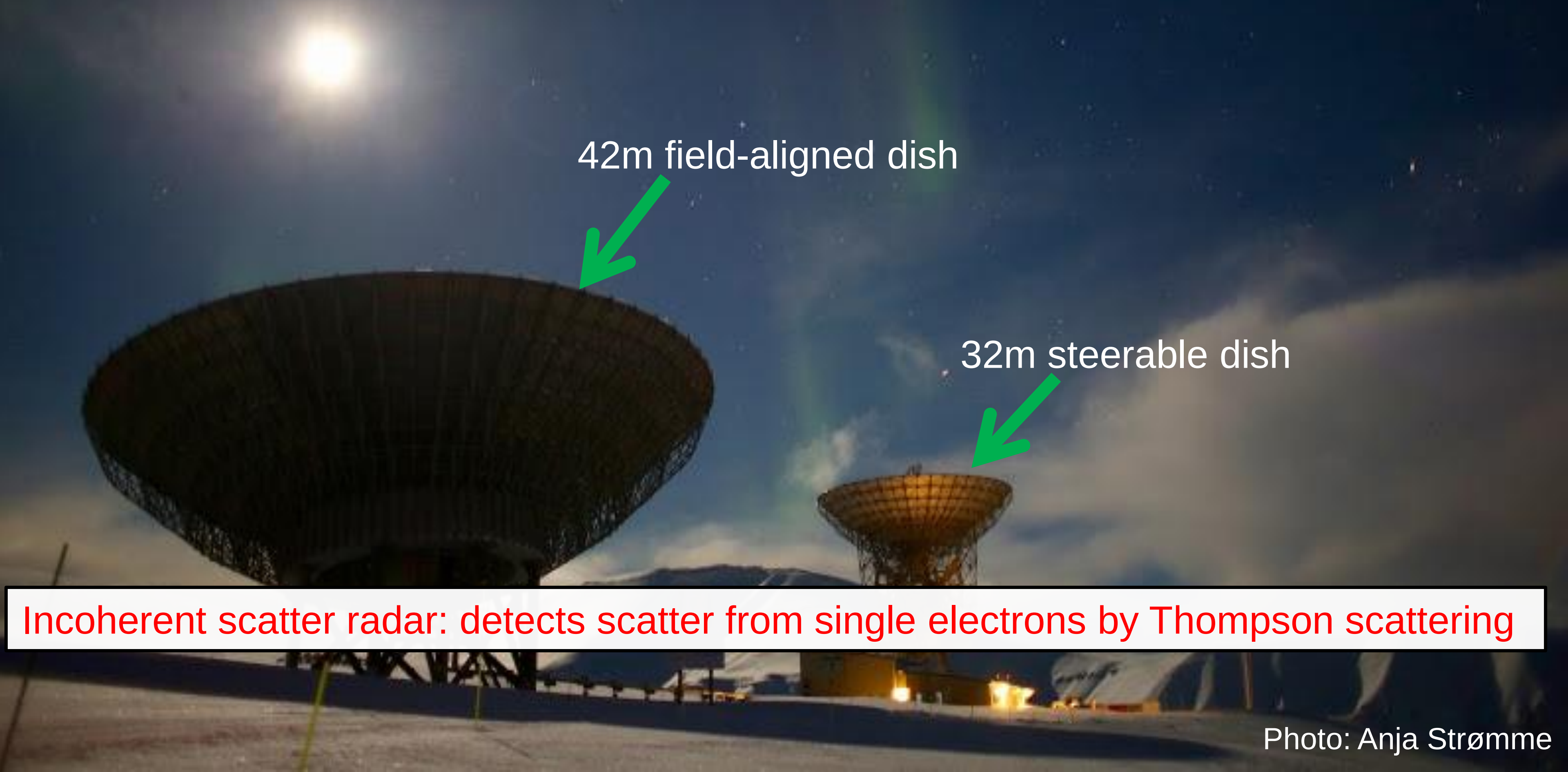
Electron density profile



- We have an altitude dependent electron density profile
- A complex balance between the ionization and recombination
- Marconi first proved this ionosphere existed by using it for radio communication in 1901 to transmit the first transatlantic wireless communications

EISCAT Svalbard Radar

- Transmission frequency 500 MHz
- Peak transmission power of 1 MW
- 2x parabolic dish antenna: uses a curved surface to direct radio waves



Incoherent scatter radar: detects scatter from single electrons by Thompson scattering

Photo: Anja Strømme

Thompson Scattering

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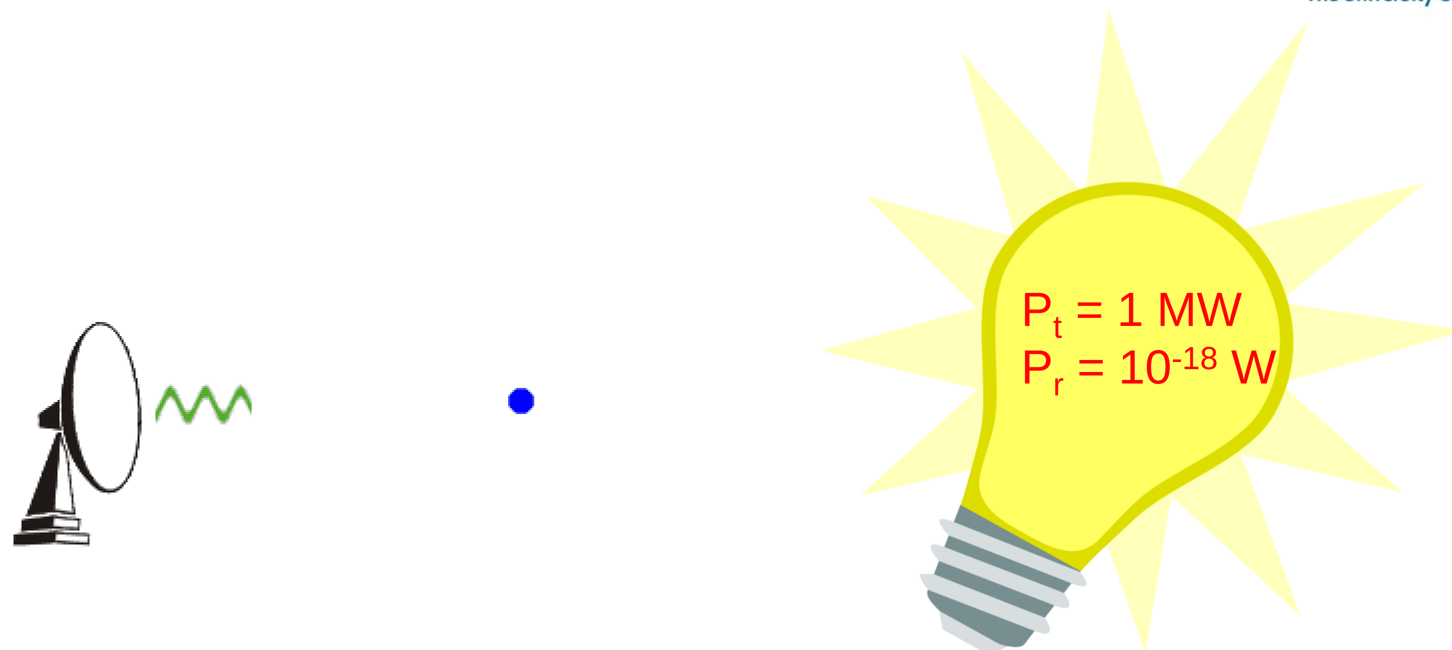

- The radar transmits a radio wave
- This hits the ionospheric free electrons, which are in random thermal motion
- The radio wave causes the electrons to oscillate
- They then emit their own radio waves in all directions
- Only a small fraction of the energy returns back to the radar

EISCAT: P_t = Power Transmitted P_r = Power received

EISCAT measurements

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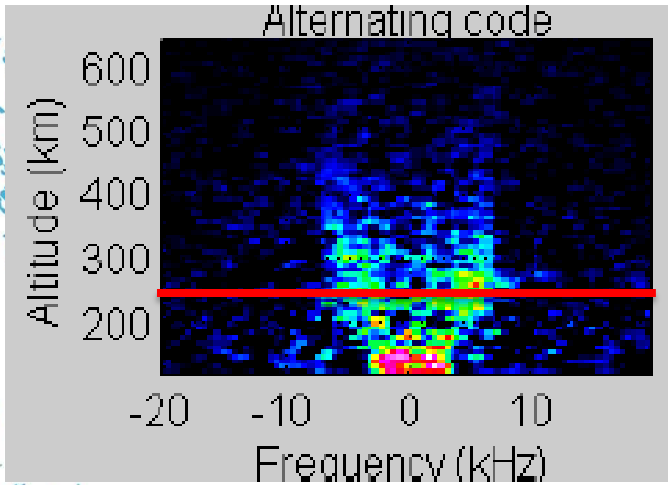
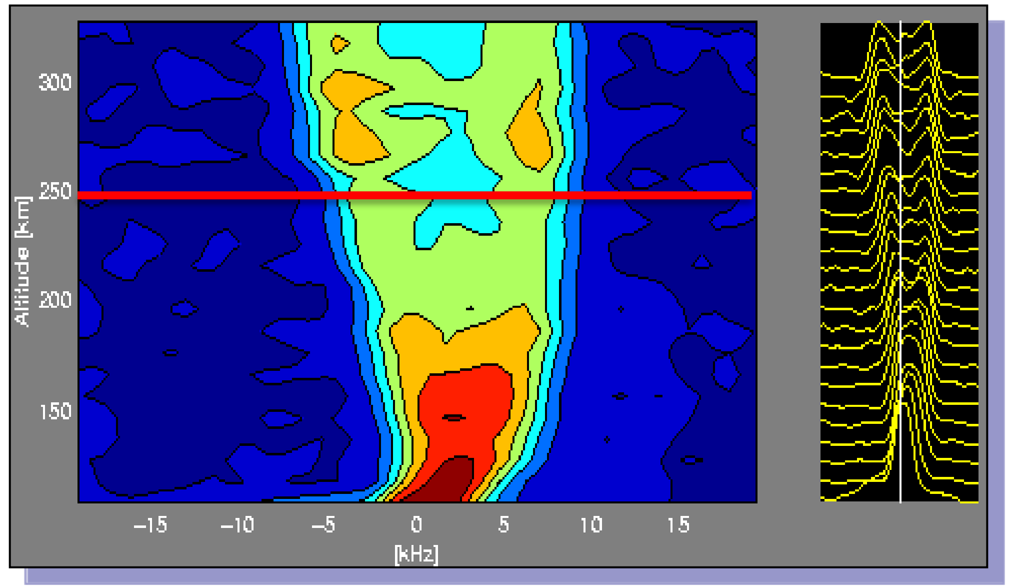
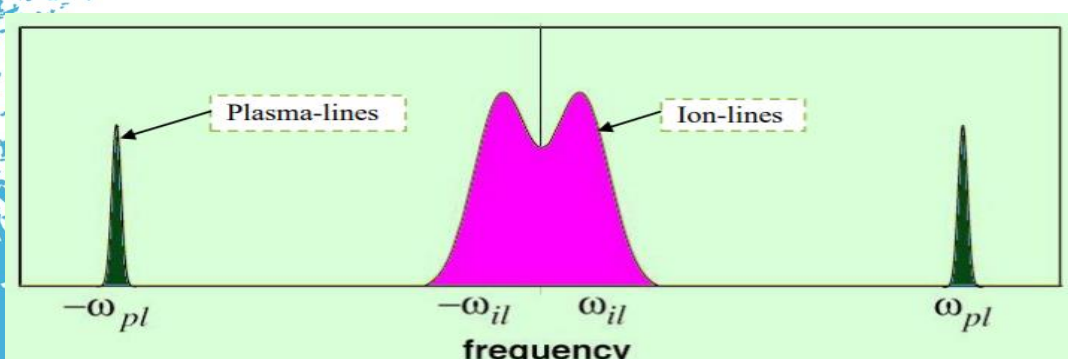
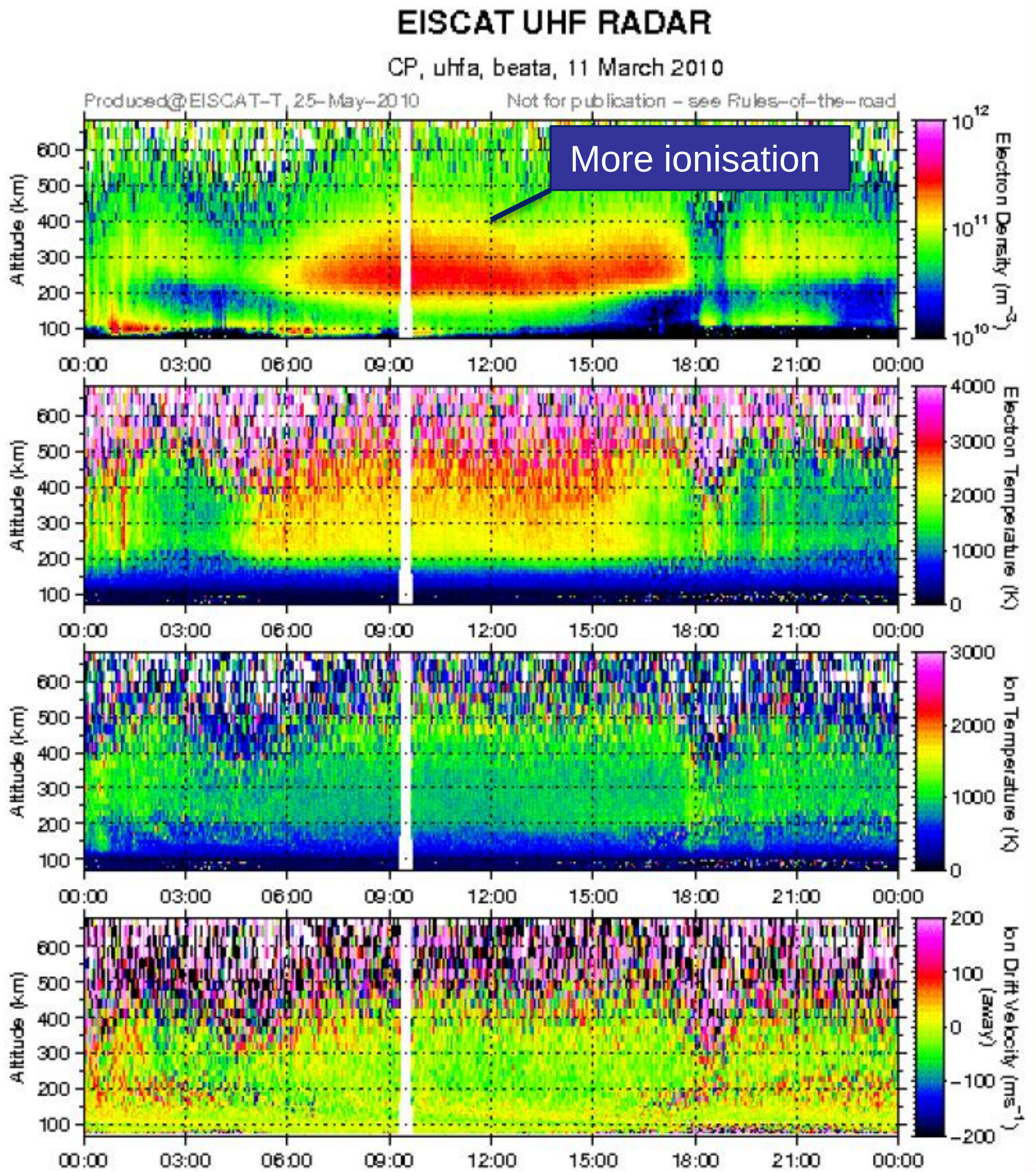






Incoherent scatter spectrum

Data: Typical Day



- Use measurements with a model to calculate electron density and temperature and ion temperature and velocity
- We always get measurements, even we have daylight or clouds!
- During the daytime, when the ionosphere is sunlit there is a higher electron density and temperature

All Seasons

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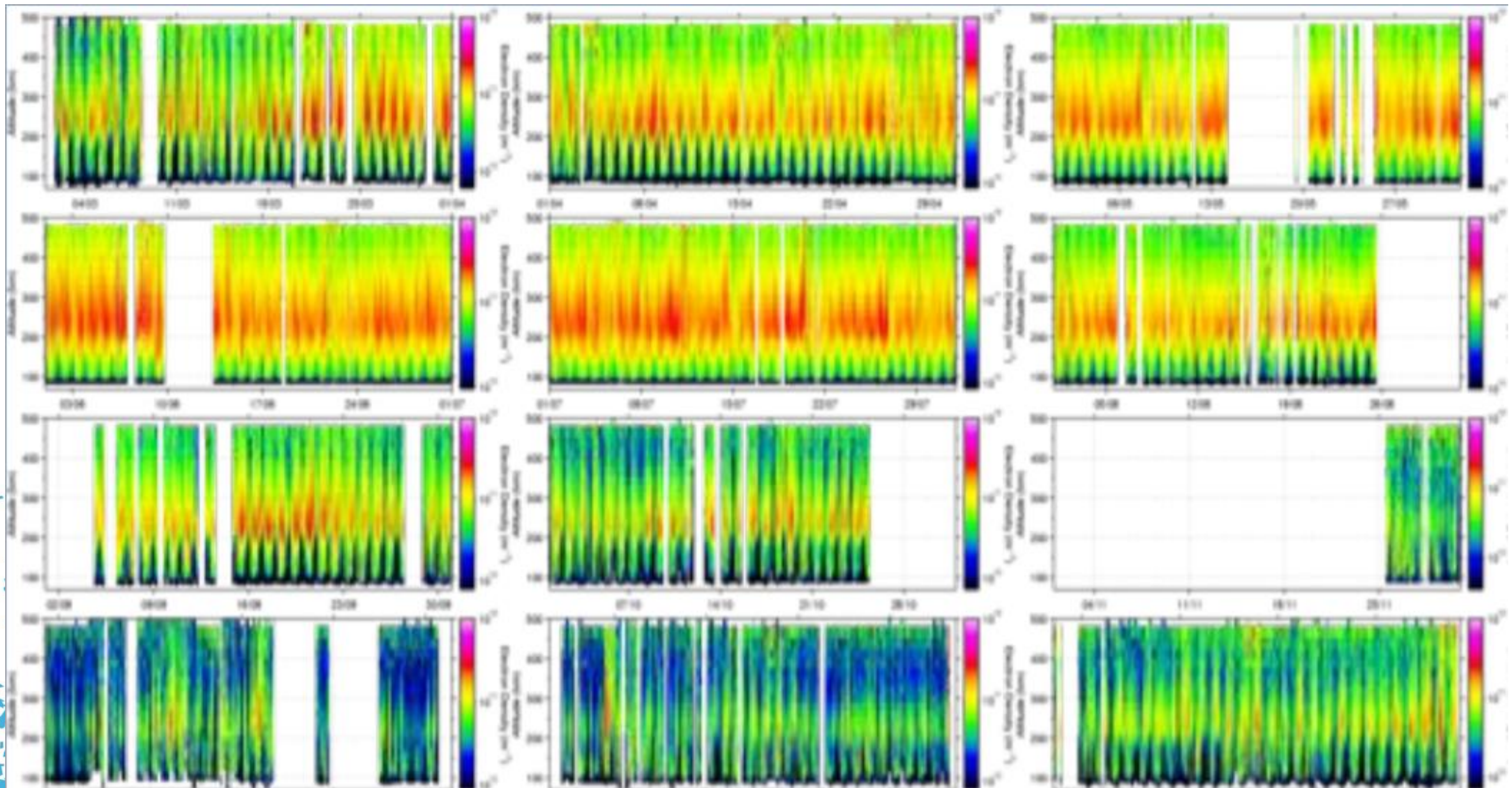

1 years worth of data shows daily and seasonal variations

Svalbard's Position

- Svalbard at 78°N has a unique position underneath the dayside auroral oval
- Great for measuring dayside aurora! Also possible to measure nightside aurora.
- It is dark in the daytime during winter, which is good for optical measurements

Data: Auroral Substorm (Nightside)

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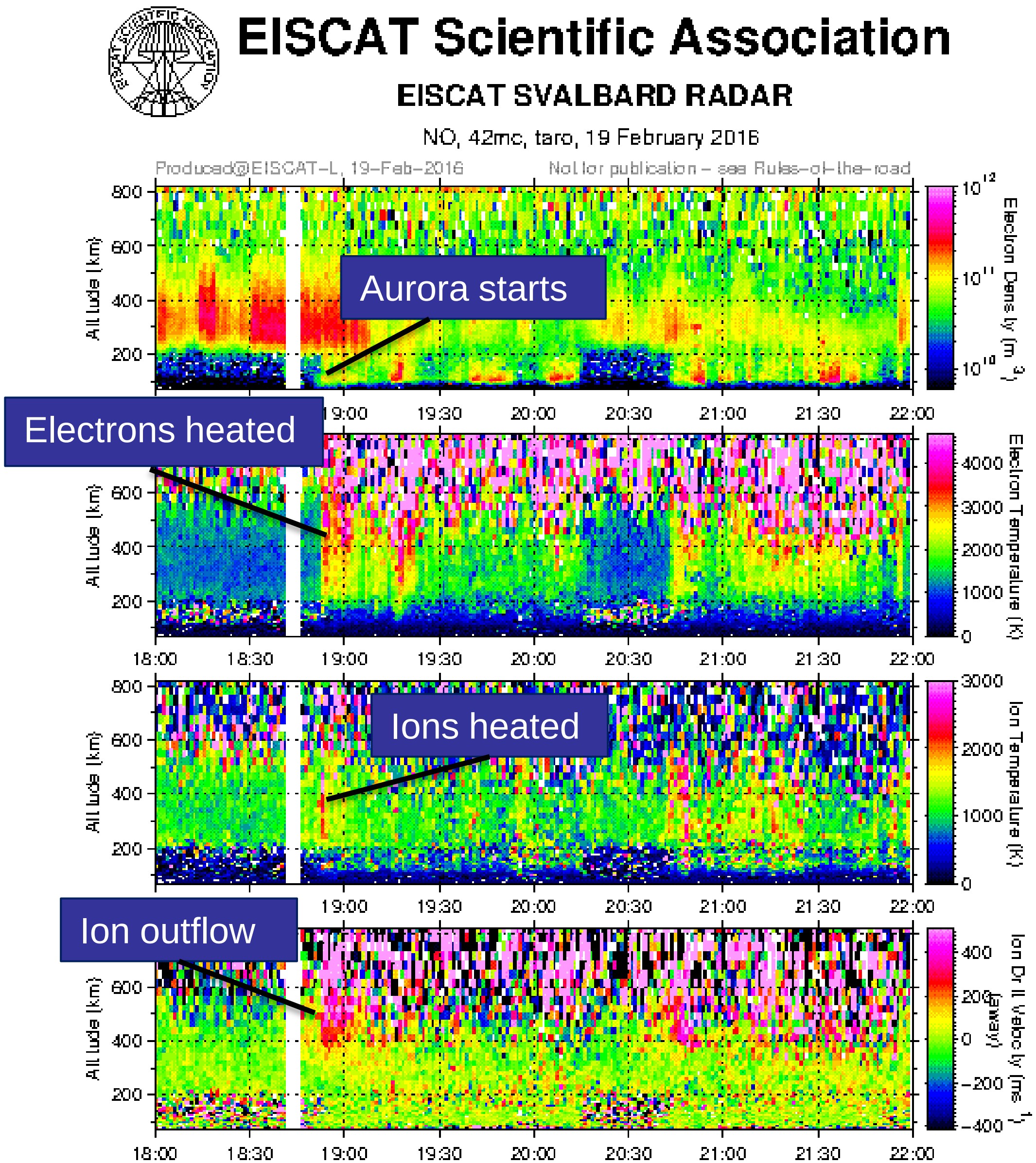
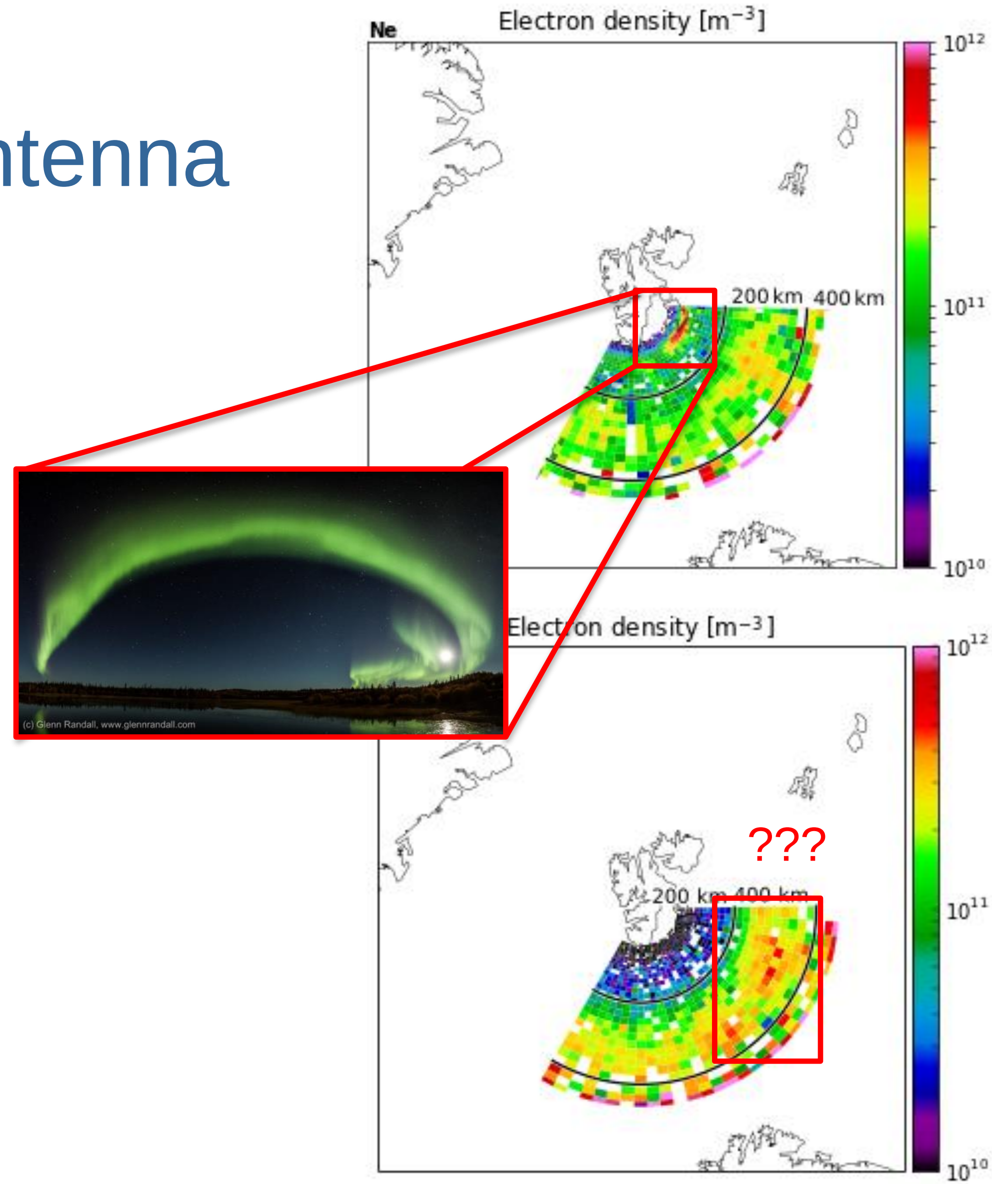


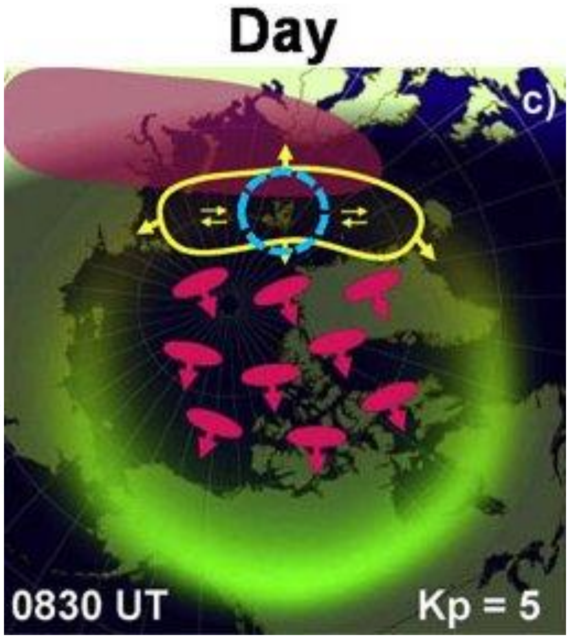
- We can see signatures of aurora. The incoming energetic auroral particles collide with the atmospheric particles
- There is more ionisation and heating due to these collisions
- Ions also flow outwards into space

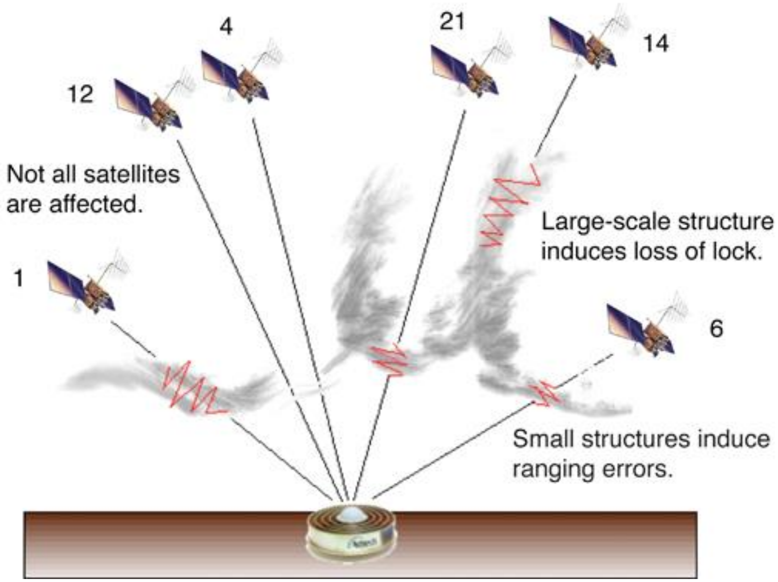
Scans: The 32m Antenna



- The 32m dish can be used to scan in lots of different patterns
- Can be useful if you're interested in the size, structure or evolution of features

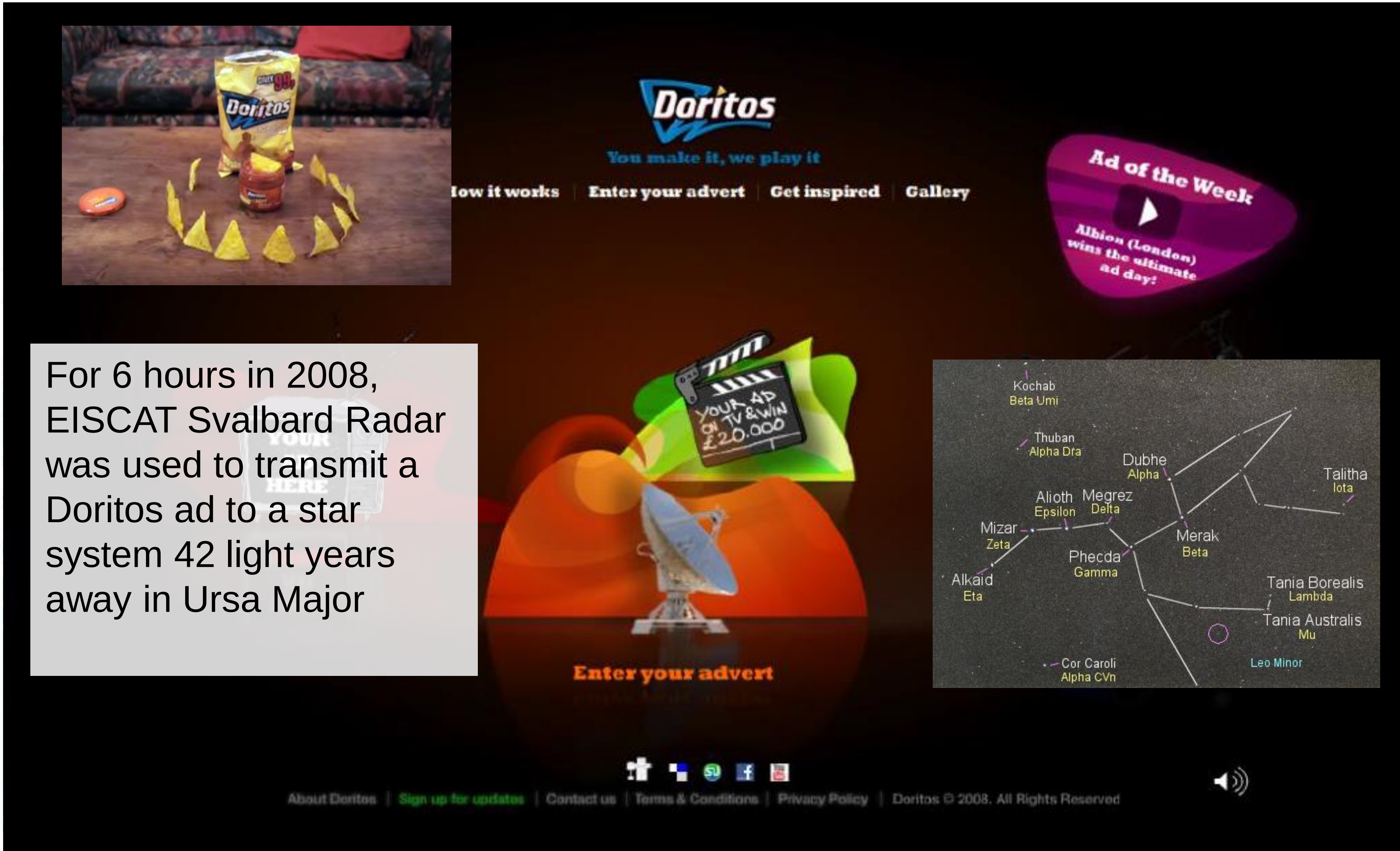
Data: Polar Cap Patches





- Islands of enhanced plasma density in the F region (200-500km altitude)
- Due to ionisation on the sunlit, dayside ionosphere
- Drift across the polar cap at speeds of 300-1000 m/s
- They are then destroyed in the nightside auroral region
- Can cause positional errors and loss of signal in GPS

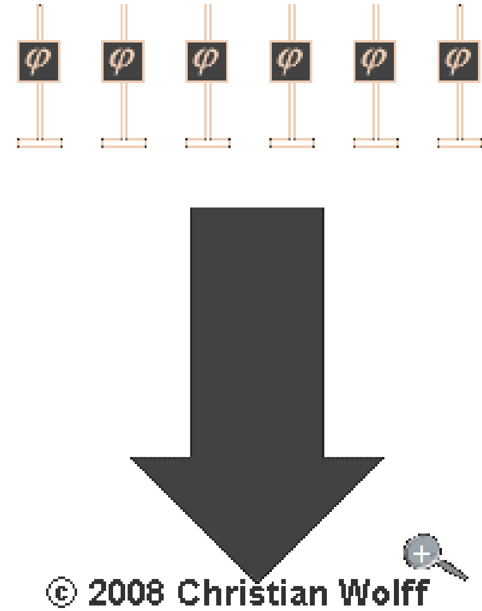
EISCAT: Snacks for Aliens



For 6 hours in 2008, EISCAT Svalbard Radar was used to transmit a Doritos ad to a star system 42 light years away in Ursa Major

The Svalbard SuperDARN Radar

SuperDARN: Super Dual Auroral Network



Phased array:

- A collection of radio antennae connected together to form a single antenna.
- The direction that the radar looks can be moved across the sky by adjusting the timing of the signals.

Coherent Scatter Radar: detects plasma structures by Bragg scattering

The Svalbard SuperDARN Radar

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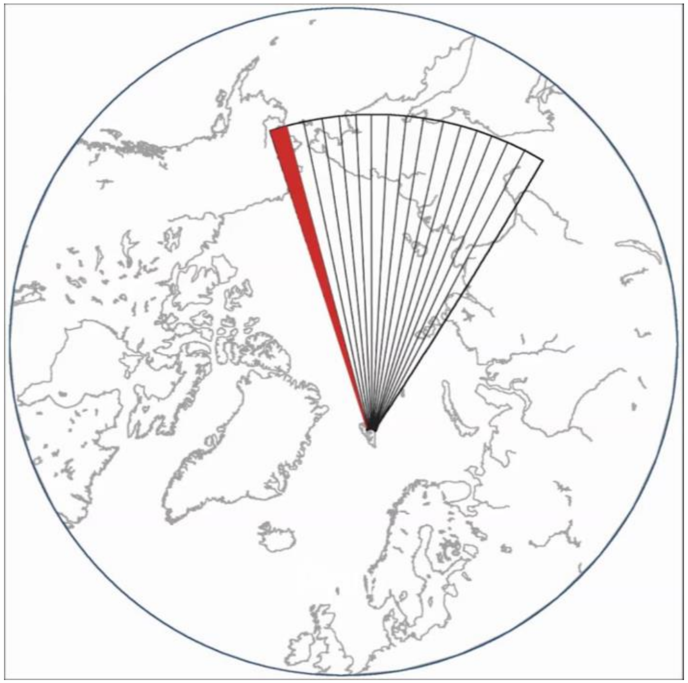
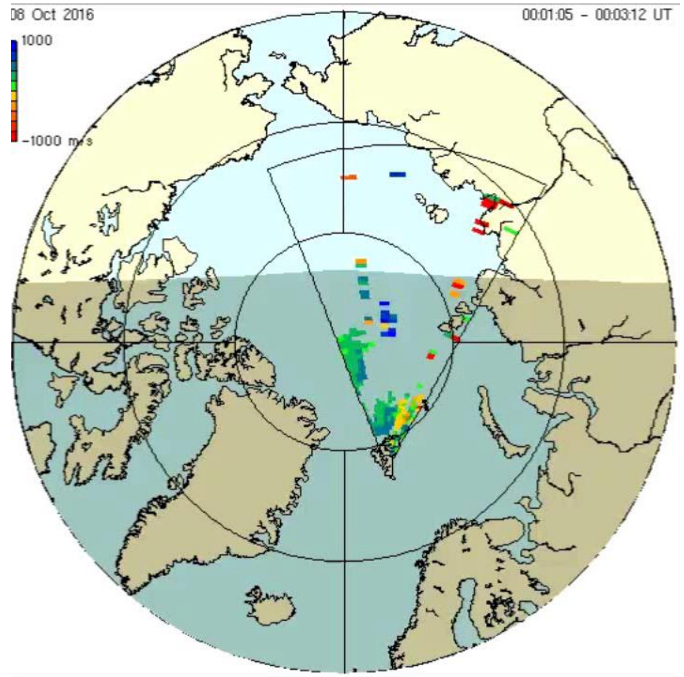




- Operates between 9-20 MHz
- Range resolution 15-45km
- Transmits 10kW of power over 16 'beam' directions

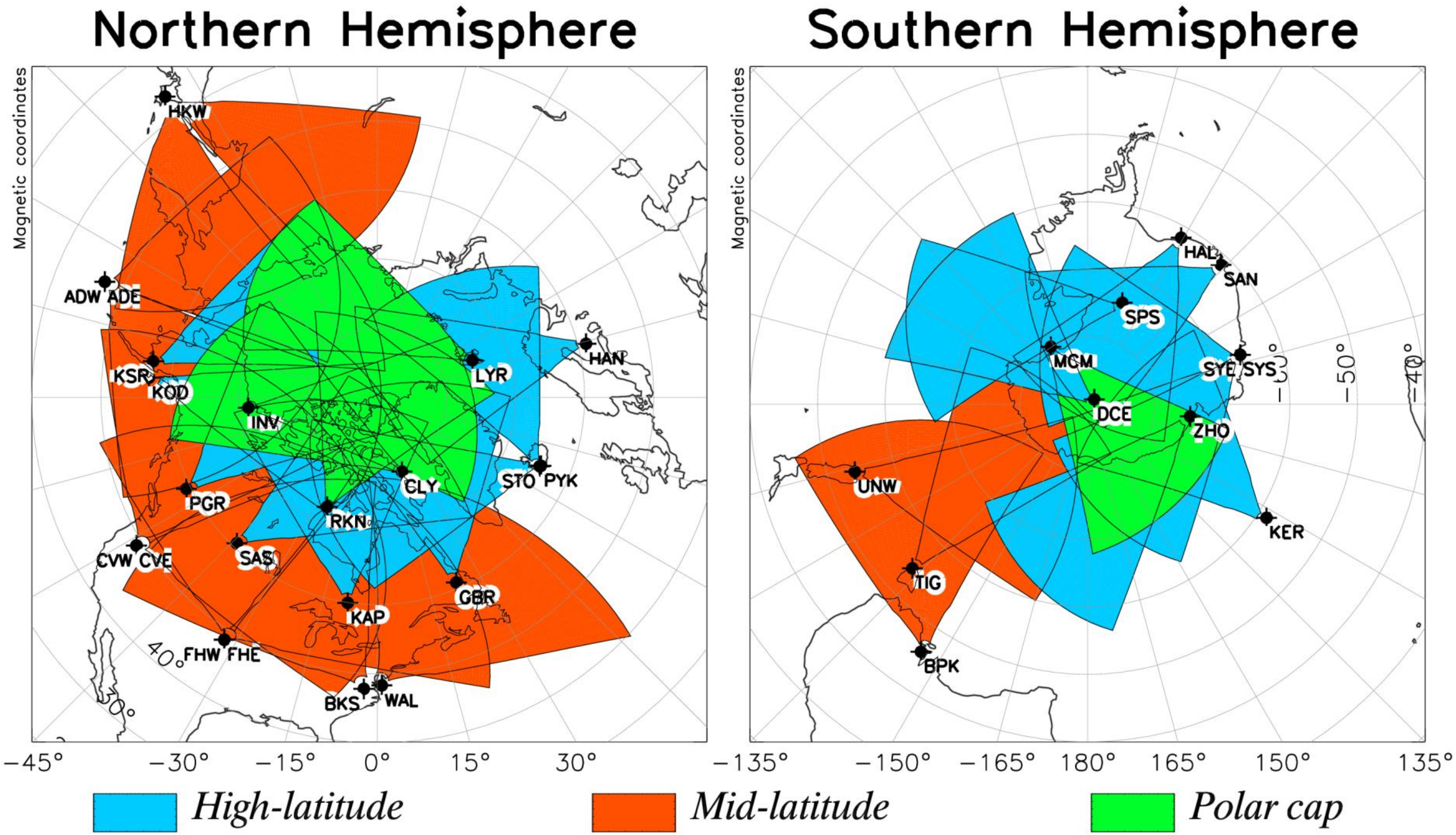
SuperDARNit….

SuperDARNit….

- Very specific temperatures, snow and wind caused severe icing
- ~2km of rope with diameter of 1cm
- Ice formed on rope with ~5cm diameter
- ~20,000kg of extra weight

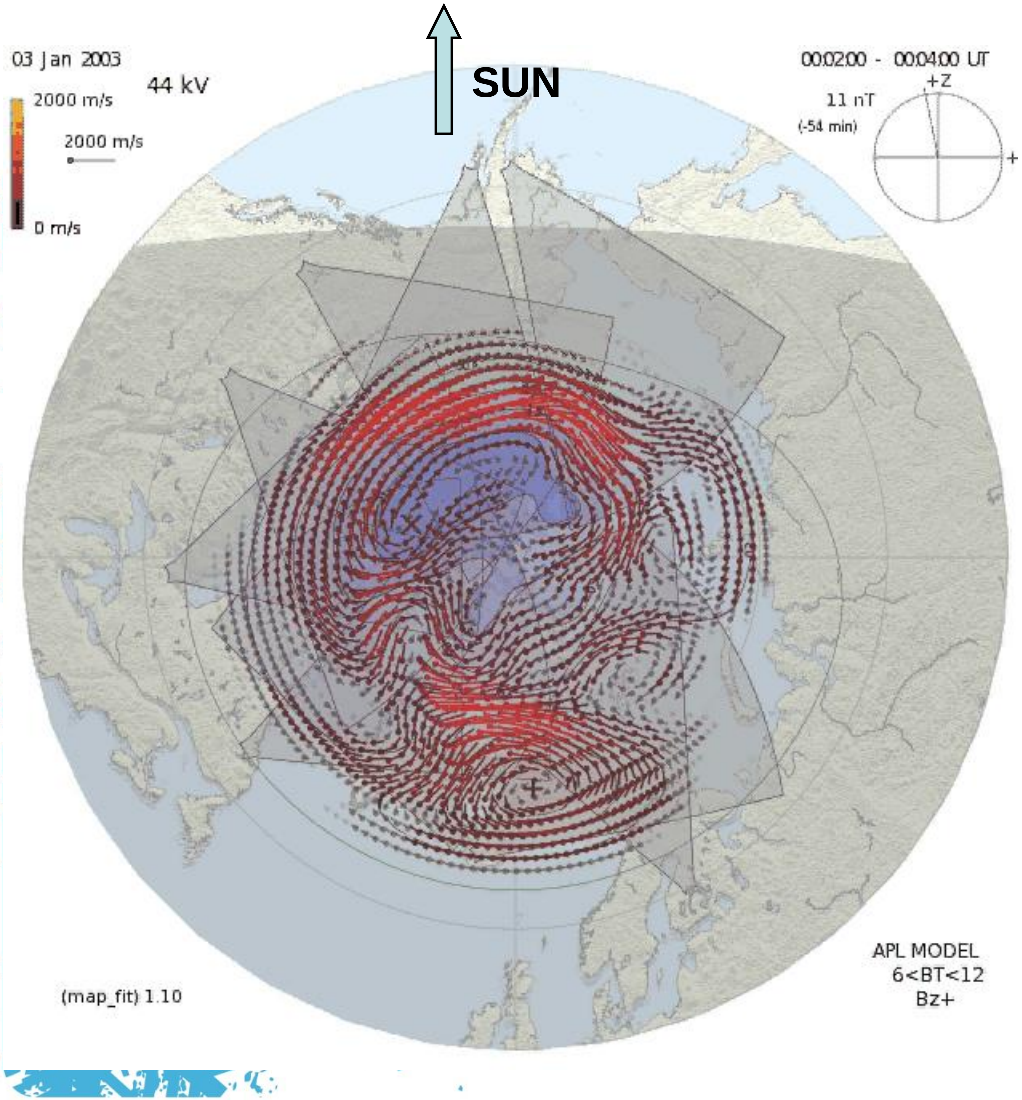
SuperDARN Network

24 radars | 12 radars



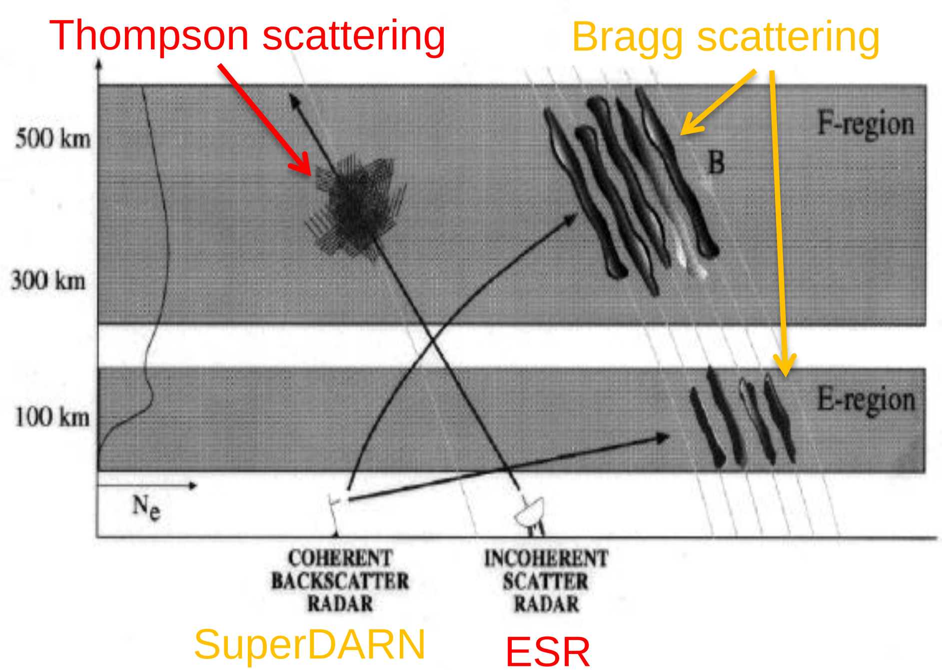
We can combine all of these measurements to make global maps….

SuperDARN Combined Measurements



- Data is taken from all the radars and fitted to a model
- From this we can build a map of how the plasma is moving over large areas
- Helps us to get a global picture of plasma circulation

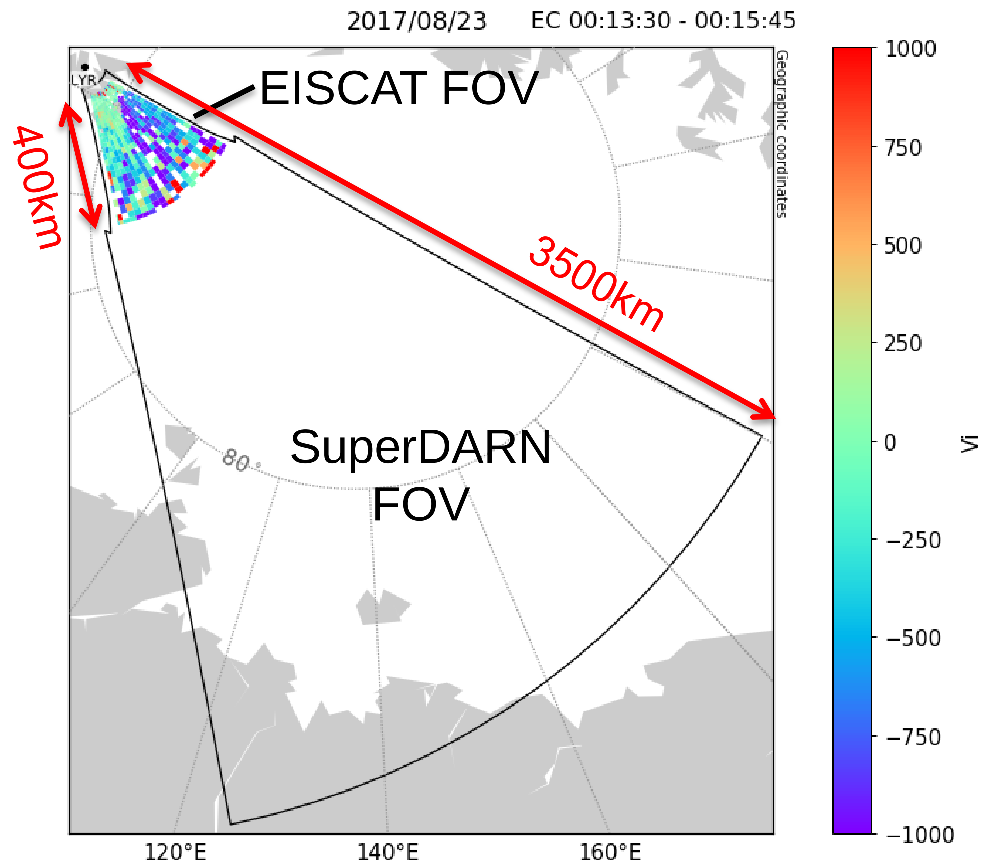
EISCAT vs SuperDARN



Radar	EISCAT	SuperDARN
Scatter type	Incoherent (Thompson)	Coherent (Bragg)
Frequency	Fixed (500 MHz)	Variable (9-20 MHz)
Range resolution	~100m-10km	15-45 km
Field of view	Narrow	Wide

- ISRs see smaller structures in any direction using Thompson scattering
- CSRs see bigger structures aligned with the magnetic field using Bragg scattering

EISCAT vs SuperDARN



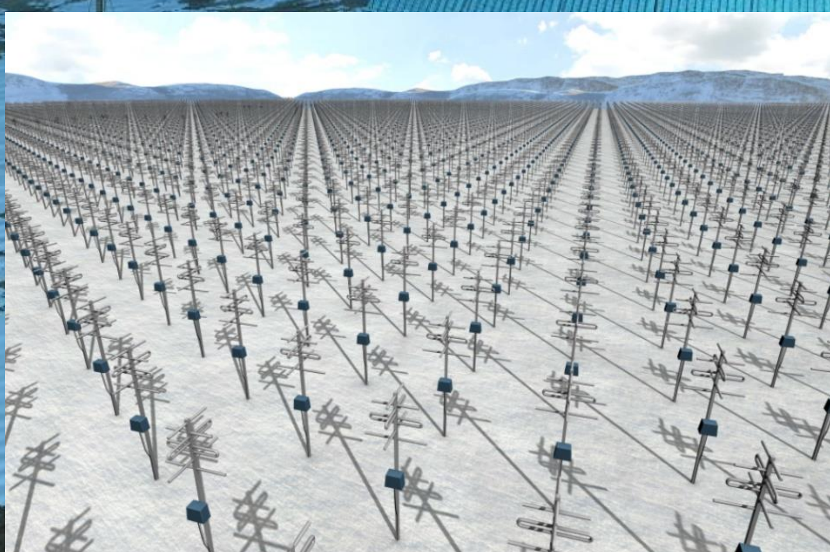
- EISCAT: narrow FOV, high spatial resolution, low time resolution
- SuperDARN: wide FOV, lower spatial resolution, higher time resolution
- Which radar is better depends what you want to look at!

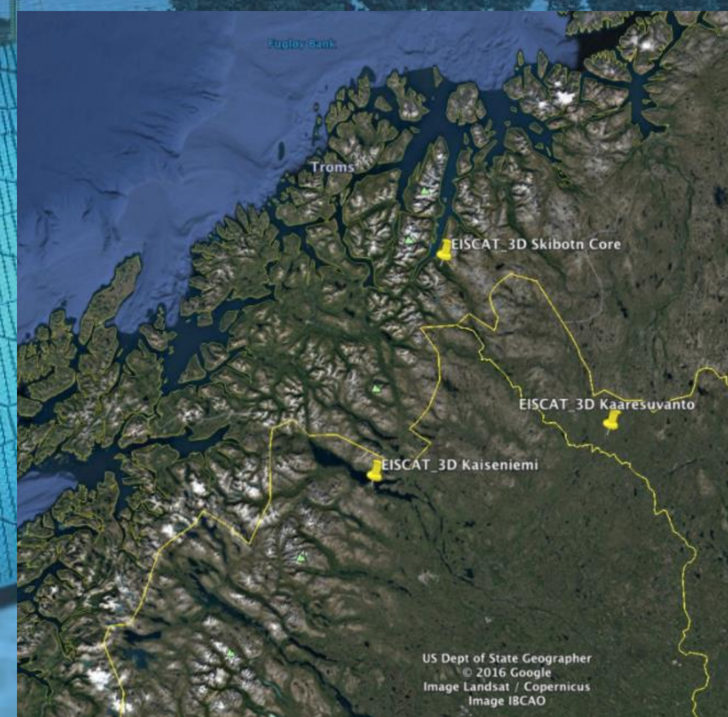
FOV = Field of View

The Future: EISCAT 3D

- Will be the largest and most advanced radar system ever built
- Phased array with 3 sites - over 50,000 antenna in total!
- Started to build in 2017, operational in 2021
- Looks at large parts of the sky simultaneously and can scan extremely fast (ms)

Will measure an entire 3D volume of the ionosphere in unprecedented detail!





Summary

- Radar stands for RAdio Detection and Ranging
- They send out radio waves and listen for the echo from ionospheric plasma
- The Doppler effect allows us to determine the speed of the plasma
- EISCAT is an incoherent scatter radar working by Thompson scattering
- SuperDARN is a coherent scatter radar working by Bragg scattering
- Radars are important as they help us understand about aurora, polar cap patches, transport of plasma in the ionosphere
- Crucial in applications such as space weather forecasting, communications and navigation
- SuperDARN LYR will make a comeback & EISCAT 3D is exciting!

Thanks for listening!
Questions? ☺