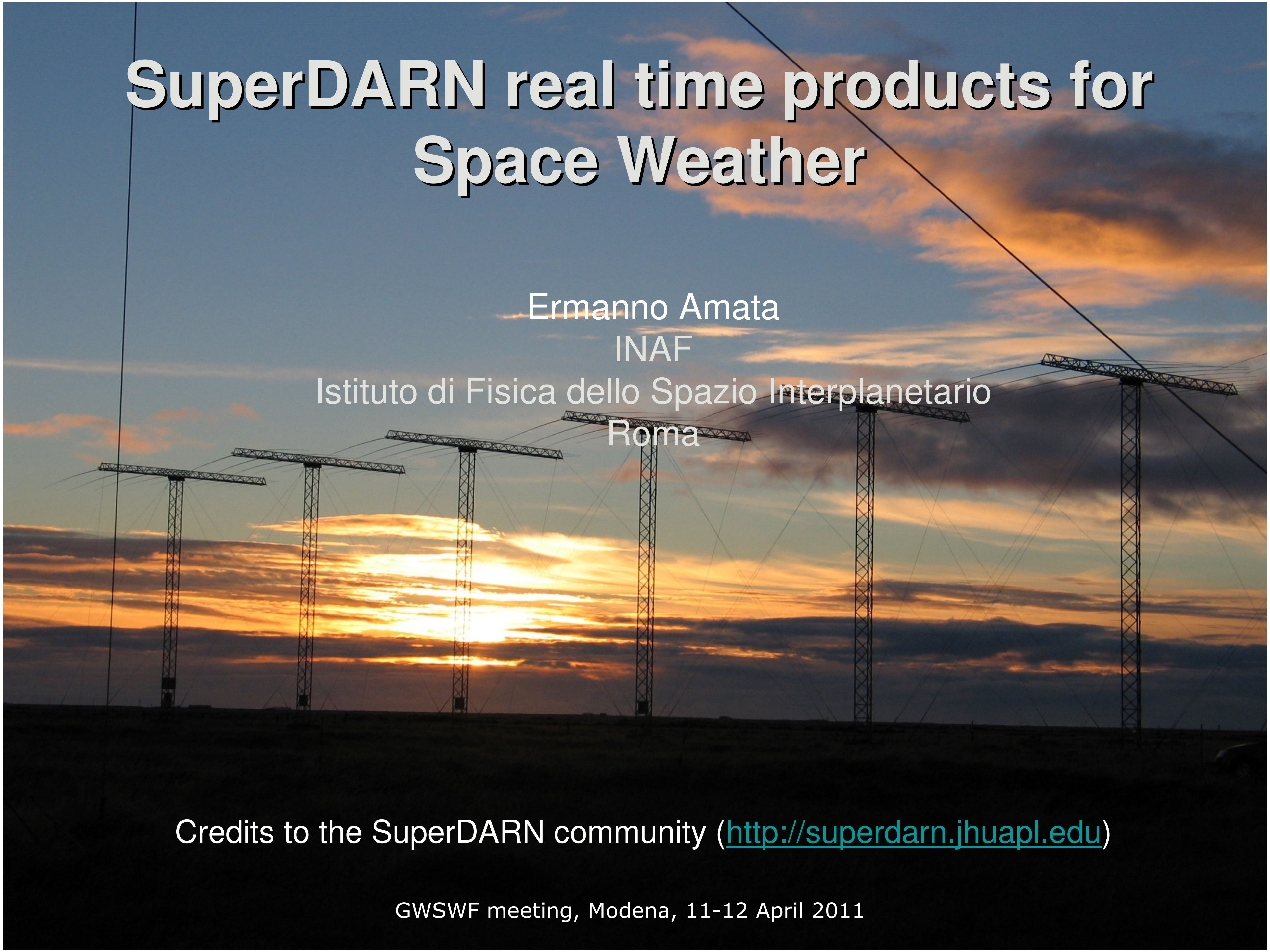


SuperDARN real time products for Space Weather

Ermanno Amata
INAF
Istituto di Fisica dello Spazio Interplanetario
Roma

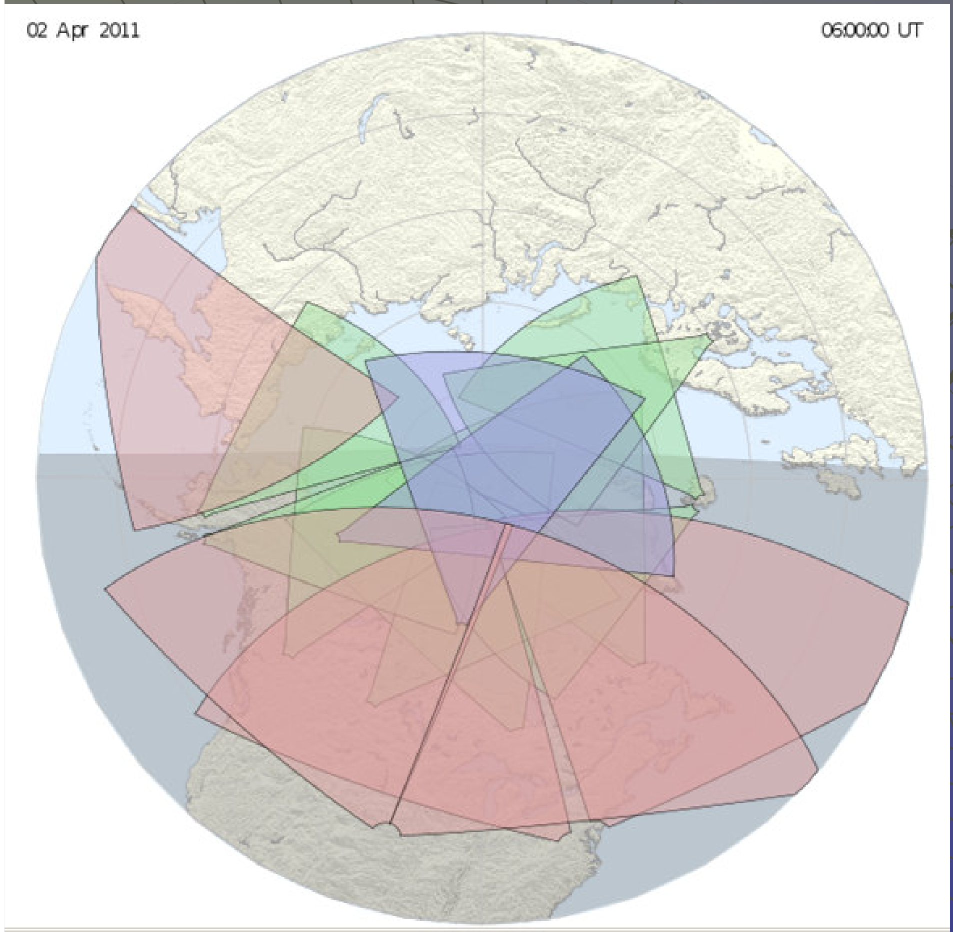
Credits to the SuperDARN community (http://superdarn.jhuapl.edu)

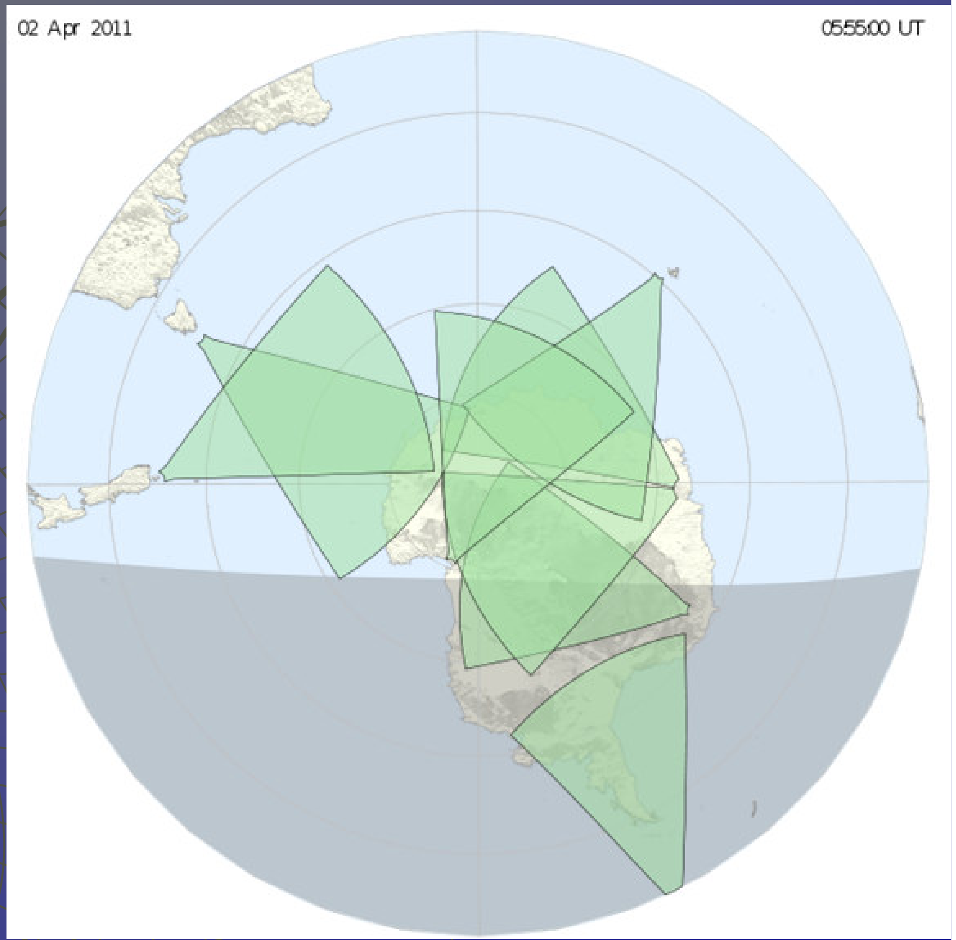
GWSWF meeting, Modena, 11-12 April 2011

Outline

- SuperDARN and its principle of operation
- Mesospheric winds product
- MUF and foF2 products
- Convection maps and transpolar potential drop (including the description of a couple of events)
- SD Space weather proxies

SuperDARN Fields of View





HF propagation

Refraction

Back-scattering

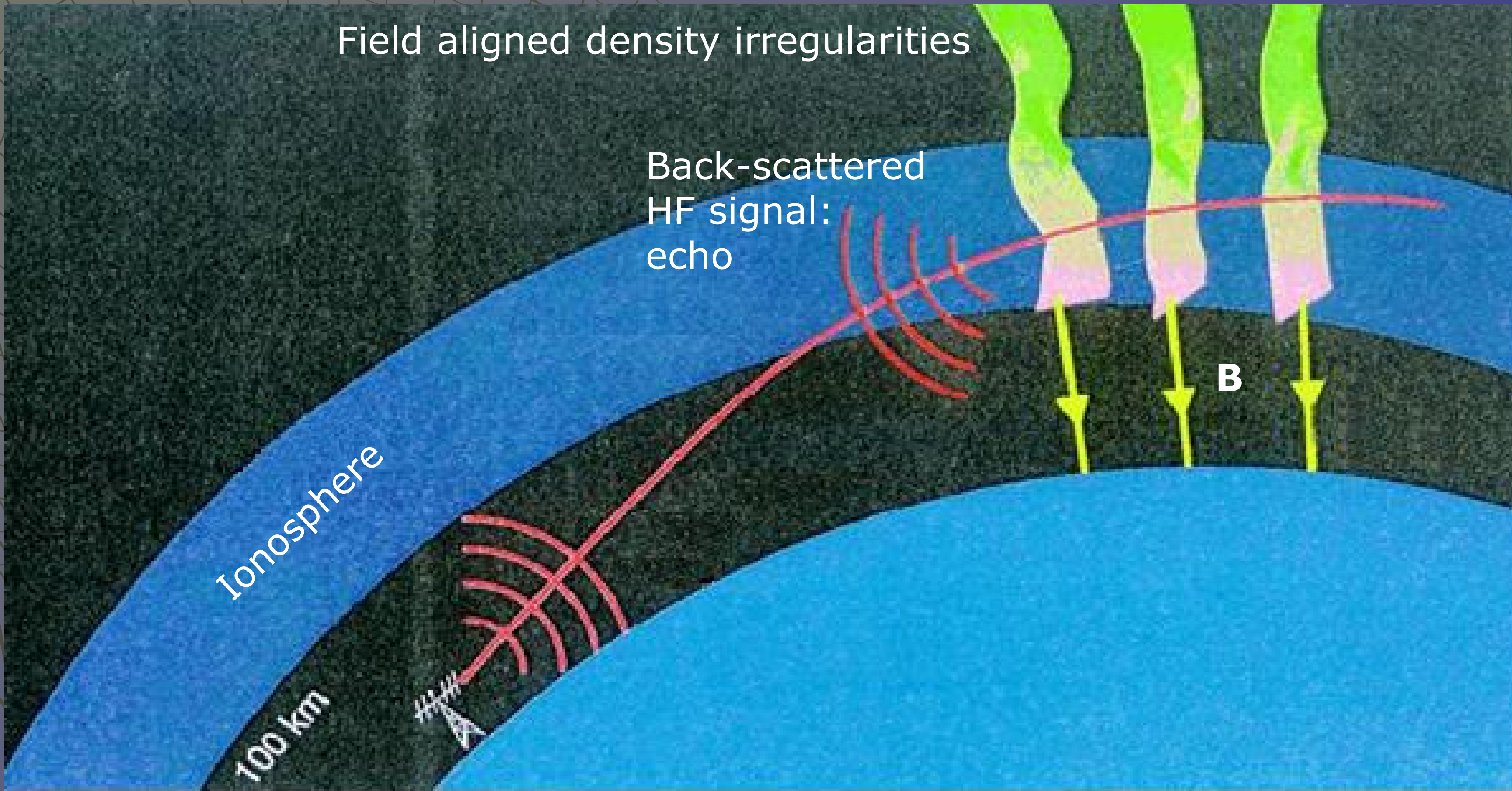
Doppler shift

Principle of operation of SuperDARN

Absorption

Phase and amplitude fluctuations

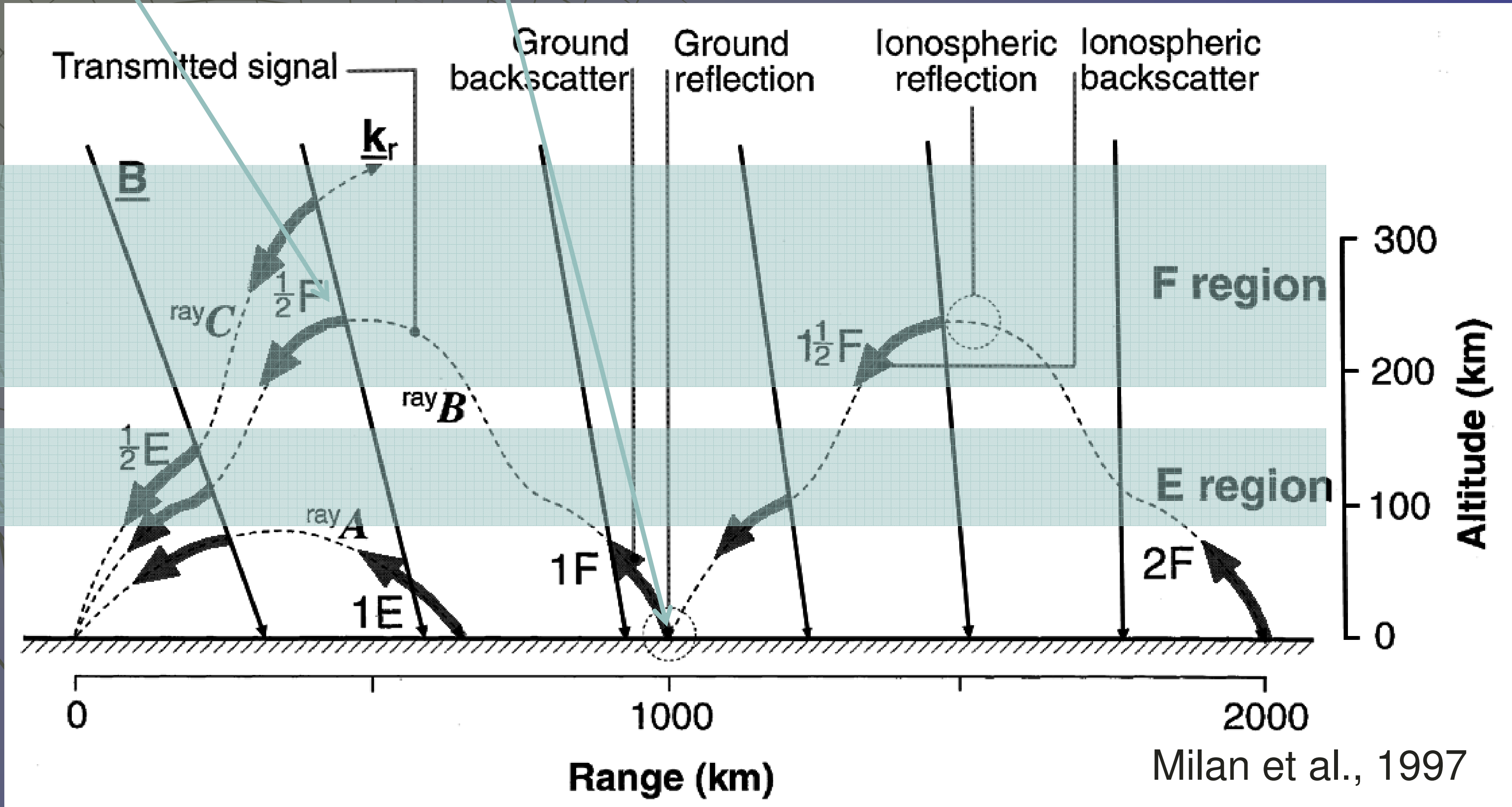
SuperDARN principle of operation



Two kinds of scatter, i.e from:

ionosphere ground

Both kinds can be used: for different purposes.
Even the absence of scatter could be used.



Milan et al., 1997

SuperDARN facts

Almost all radars form pairs covering roughly the same area from different directions.

16 azimuthal bins covering 52°.

75 range gates, 45 km each.

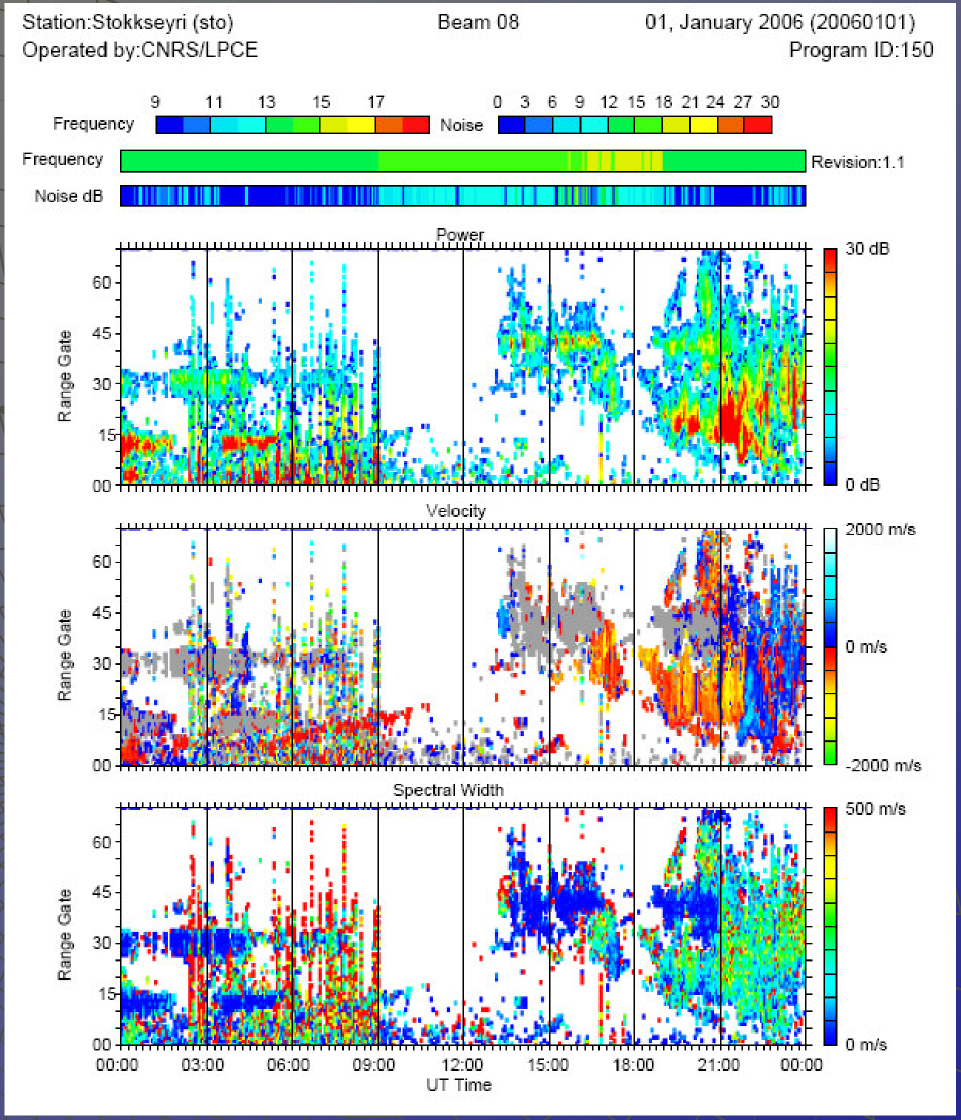
Time for full azimuth-range scan: 1-2 min.

Special modes allowed: e.g. one fixed beam with 3 s resolution.

Some radars operate in the STEREO mode (Leicester Un., UK), which allows to sound the f-o-v at two different frequencies: e.g. full 2D scan at $f_{1;}$ 3s resolution along a single beam at f_2.

Monthly planning approved by all PI's.

One day of SuperDARN echoes



SuperDARN and Space Weather

Space Weather Science

- Solar wind – magnetosphere coupling
- Location of magnetospheric boundaries (Cusps, OCB, X-line, auroral oval)
- Occurrence of radar echoes in relation with SW conditions

Space Weather Real-time data products

- Normal echoes → Convection maps and polar cap potential (in operation)
- Ground scatter → HF propagation conditions (not in operation)
- Near range echoes → Mesospheric winds (not in operation)

Outline

SuperDARN and its principle of operation

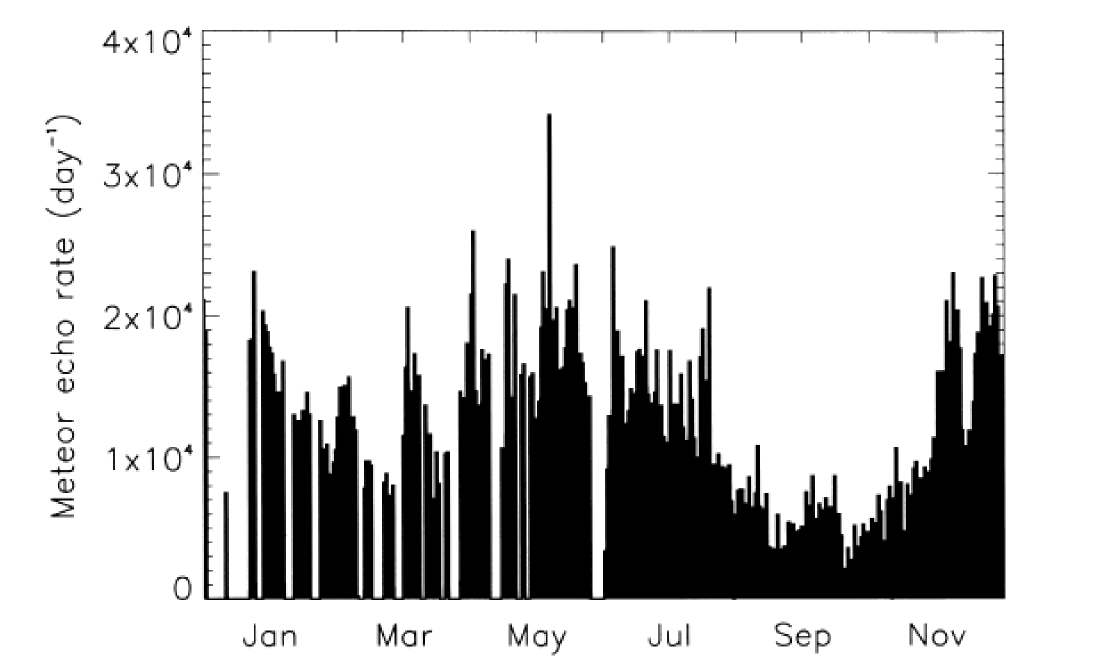
Mesospheric winds product

MUF and foF2 products

Convection maps and transpolar potential drop (including the description of a couple of events)

SD Space weather proxies

Mesospheric wind measurements from SuperDARN low range echoes



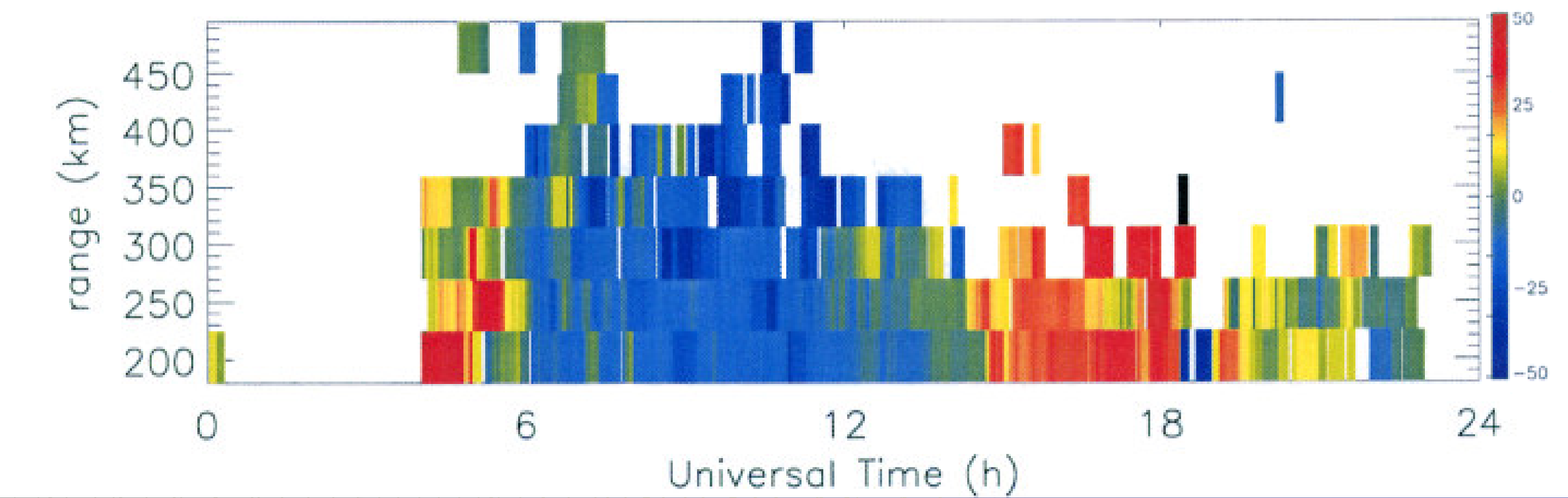
Meteor echoes daily rate at Halley radar in 1996

400 meteor echoes/hour

Echoes are classed as meteor echoes if:
- the spectral width is less than 50 m s^{-1} and greater than 1 m s^{-1},
- the range is less than 500 km,
- the backscattered power is greater than 3 dB above the background.

From the selected data SD can provide:
- l-o-s-v as a function of azimuth, beam and time;
- average meridional and zonal velocities as a function of time.

Mesospheric wind velocity (23 Dec 1997, beam 3 of Halley radar)



Jenkins and Jarvis, Earth Planets Space, ***51, 685–689, 1999***

This service is not in operation.
An archive is available at BAS (http://dabs.nerc-bas.ac.uk/dabs/).

Outline

SuperDARN and its principle of operation

Mesospheric winds product

MUF and foF2 products

Convection maps and transpolar potential drop (including the description of a couple of events)

SD Space weather proxies

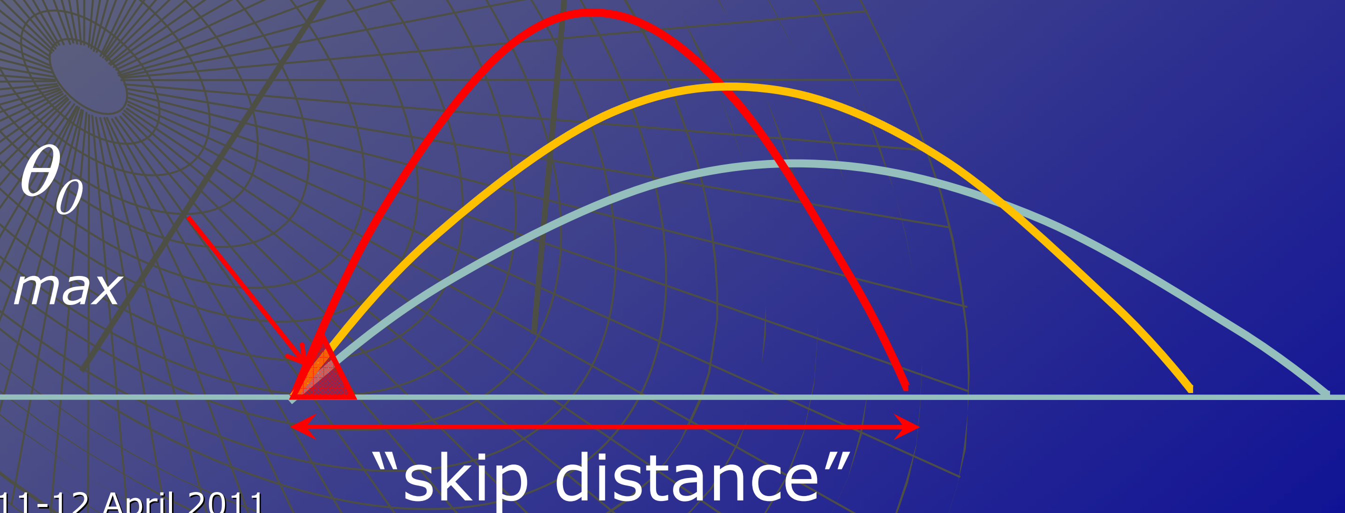
MUF product

Simple case: radiowave propagating in an unmagnetized, horizontally stratified, single layer ionosphere. Rays at a frequency f_0 will be reflected towards ground if

$$\theta_0 \leq \cos^{-1}(1 - f_c^2/f_0^2)^{\frac{1}{2}}$$

where θ_0 is the takeoff angle measured from the horizontal and f_c is the ionospheric critical frequency.

As θ_0 increases, the distance reached by the signal after refraction decreases until a minimum distance is reached: ***f_0* is the MUF at that distance.**



MUF product

During SuperDARN scans there are 12 s per min during which no data are collected.

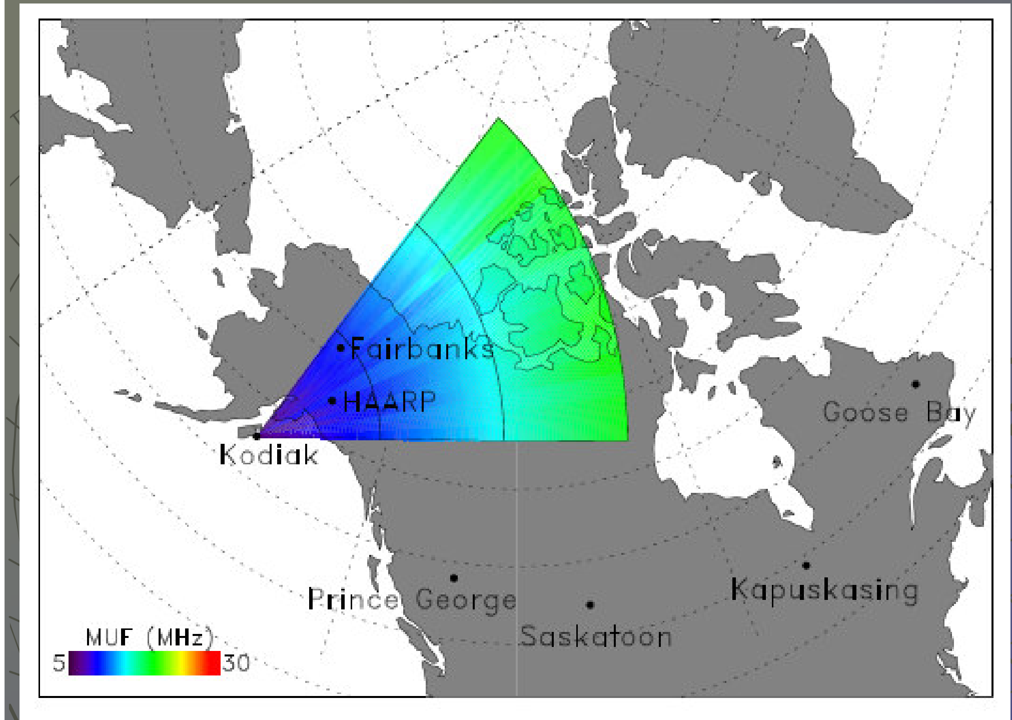
Hughes et al. (2002) developed an operating mode known as the "sounding mode" that makes use of these 12 s to collect data useful for space weather studies.

For each radar operating in the sounding mode, a table of frequencies is defined that typically consists of approximately 8 entries equally spaced between 10 and 18 MHz.

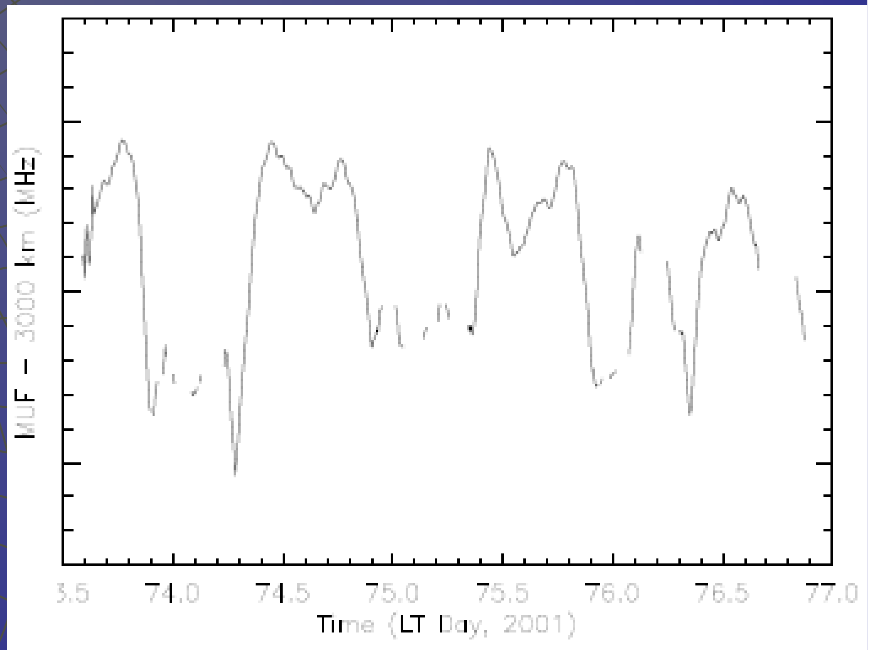
During the time available between azimuth scans, the sounding mode steps through this frequency table for each beam direction using 1 s integration periods.

The amount of time required to record a full sounding mode scan varies with the number of frequencies but is typically in the range 5-15 min.

MUF for the Kodiak radar on 23 June 2001 (22:39-22:55 UT)



$$\theta_0 \leq \cos^{-1}(1 - f_c^2 / f_0^2)^{\frac{1}{2}}$$

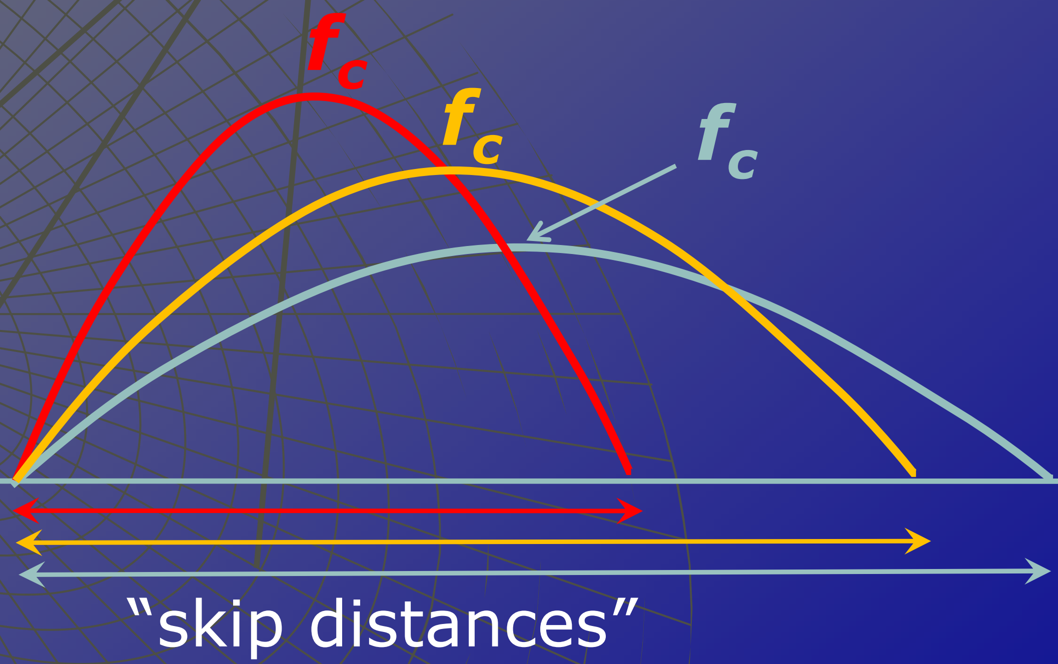


MUF at 3000 km for the Kodiak radar, averaged over all beams, for 3.5 days in 2001

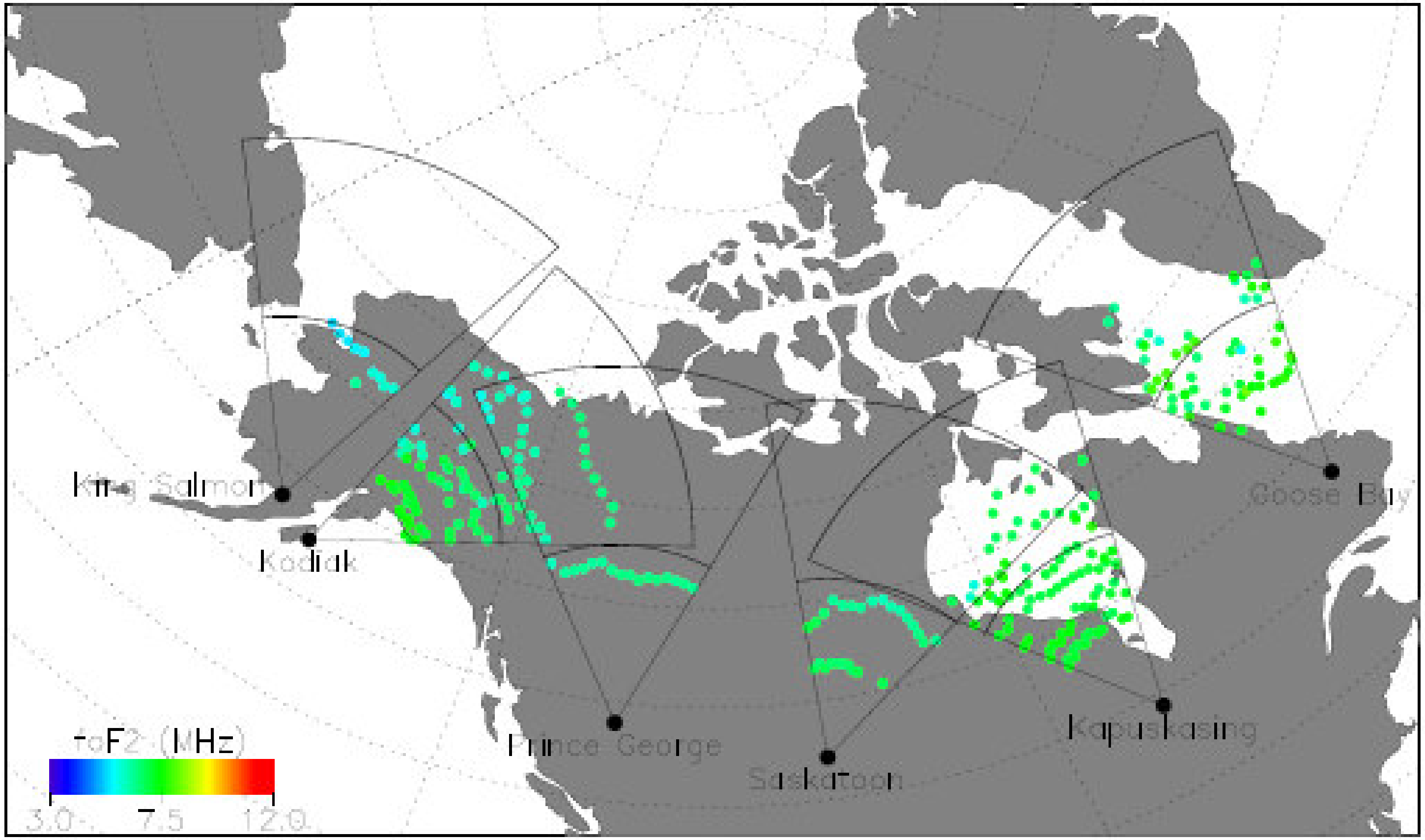
foF2 product

We recall that $\theta_0 \leq \cos^{-1}(1 - f_c^2/f_0^2)^{\frac{1}{2}}$

As SuperDARN allows to measure *θ*, the determination of the skip distance at various frequencies yields the vertical incidence critical frequency **foF2** in the ionosphere above the point at half the skip distance.



foF2 product

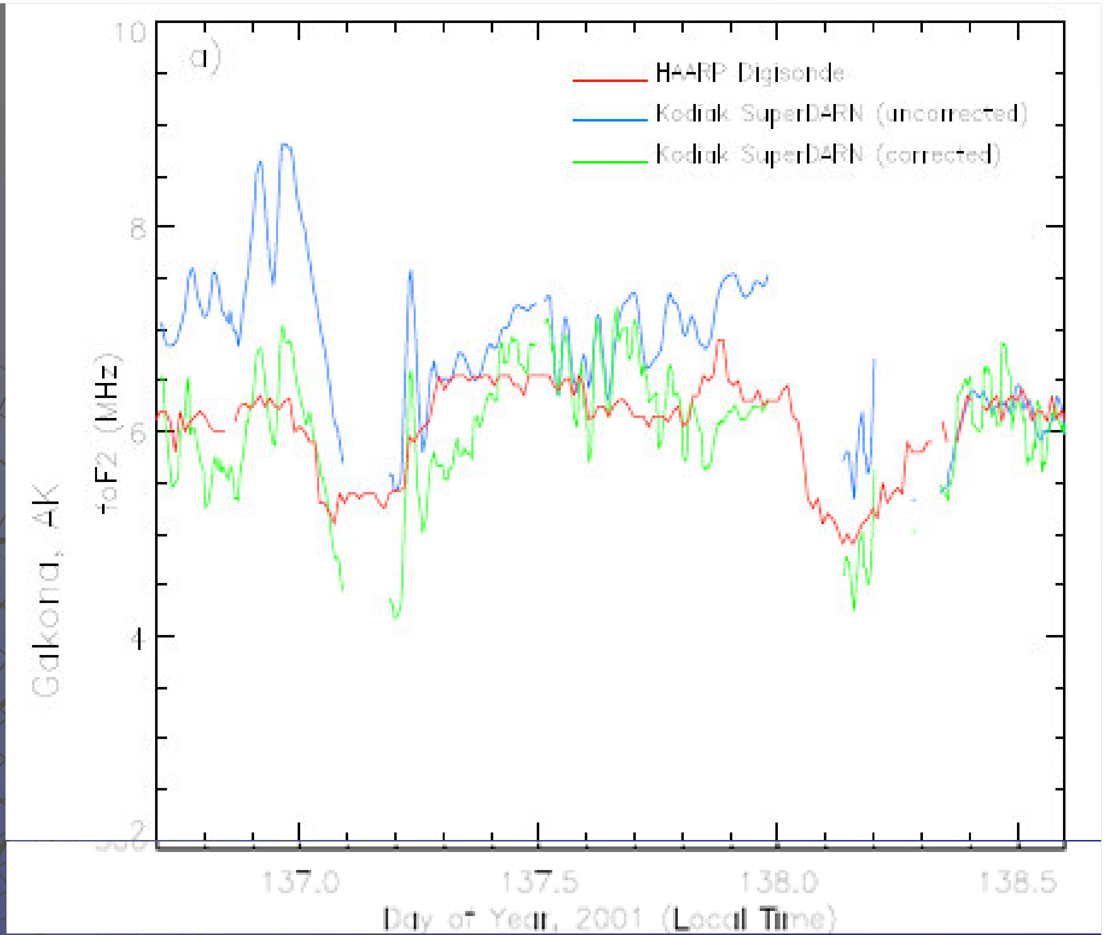


Scan period: 00:05:41 – 00:20:49 UT
Number of data points:295

foF2 product

Gakona, Alaska

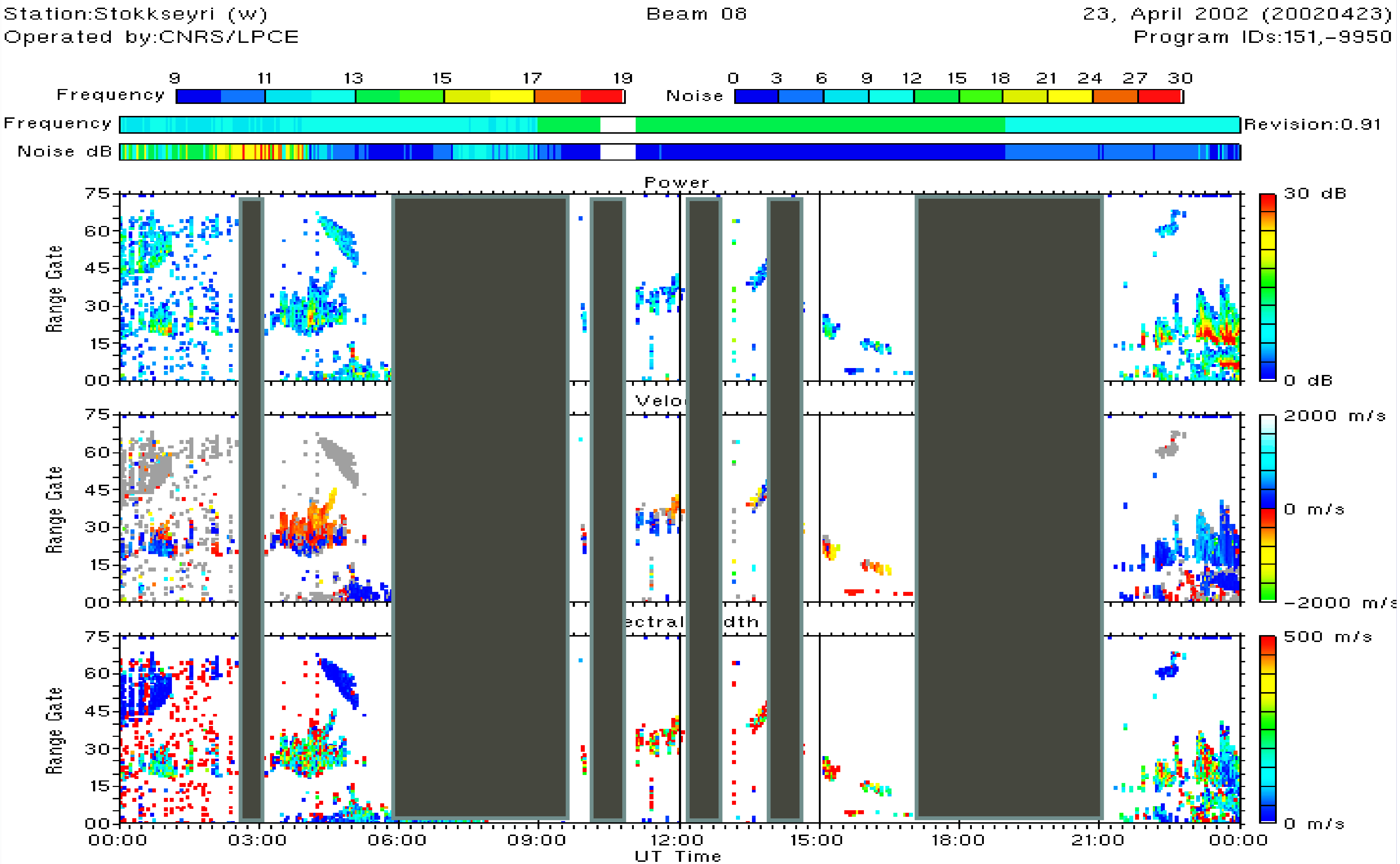
Red: foF2 from the HAARP digisonde.
Blue: foF2 from real time Kodiak data
Green: foF2 from Kodiak using the correct virtual height



This service was in operation a few years ago. Not operating now.

Hughes et al., *Annales Geophysicae , 20, 1023–1030, 2002)*

Radio blackout due to absorption (possible future product)



Outline

SuperDARN and its principle of operation

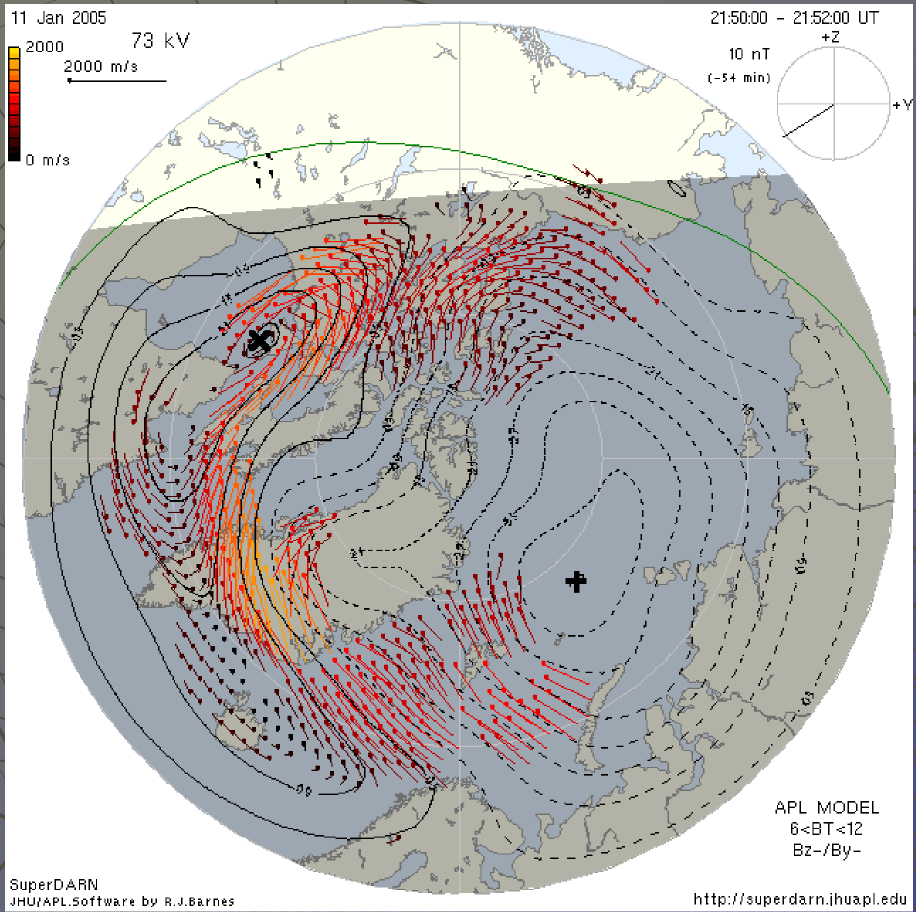
Mesospheric winds product

MUF and foF2 products

Convection maps and transpolar potential drop (including the description of a couple of events)

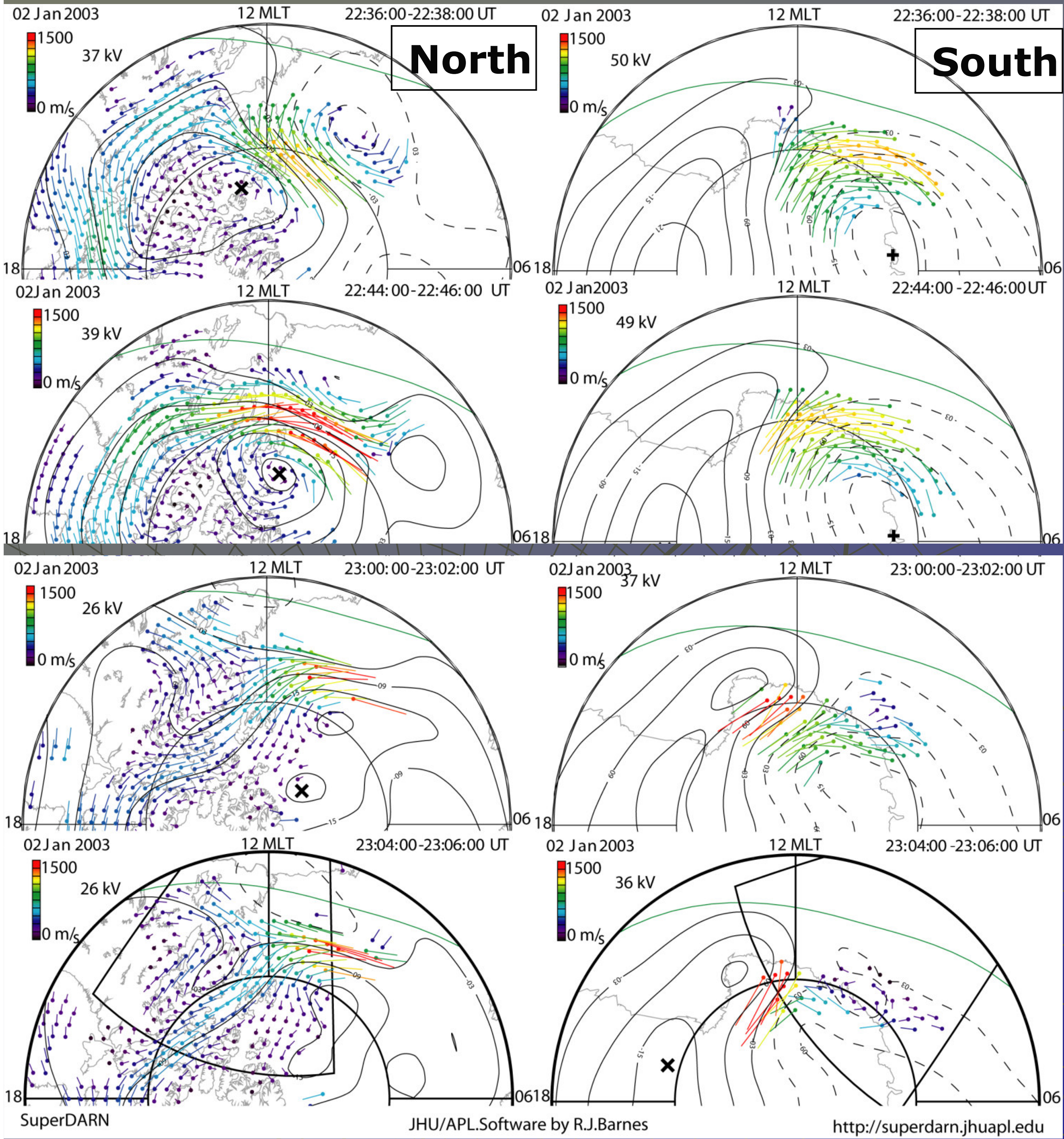
SD Space weather proxies

Convection maps



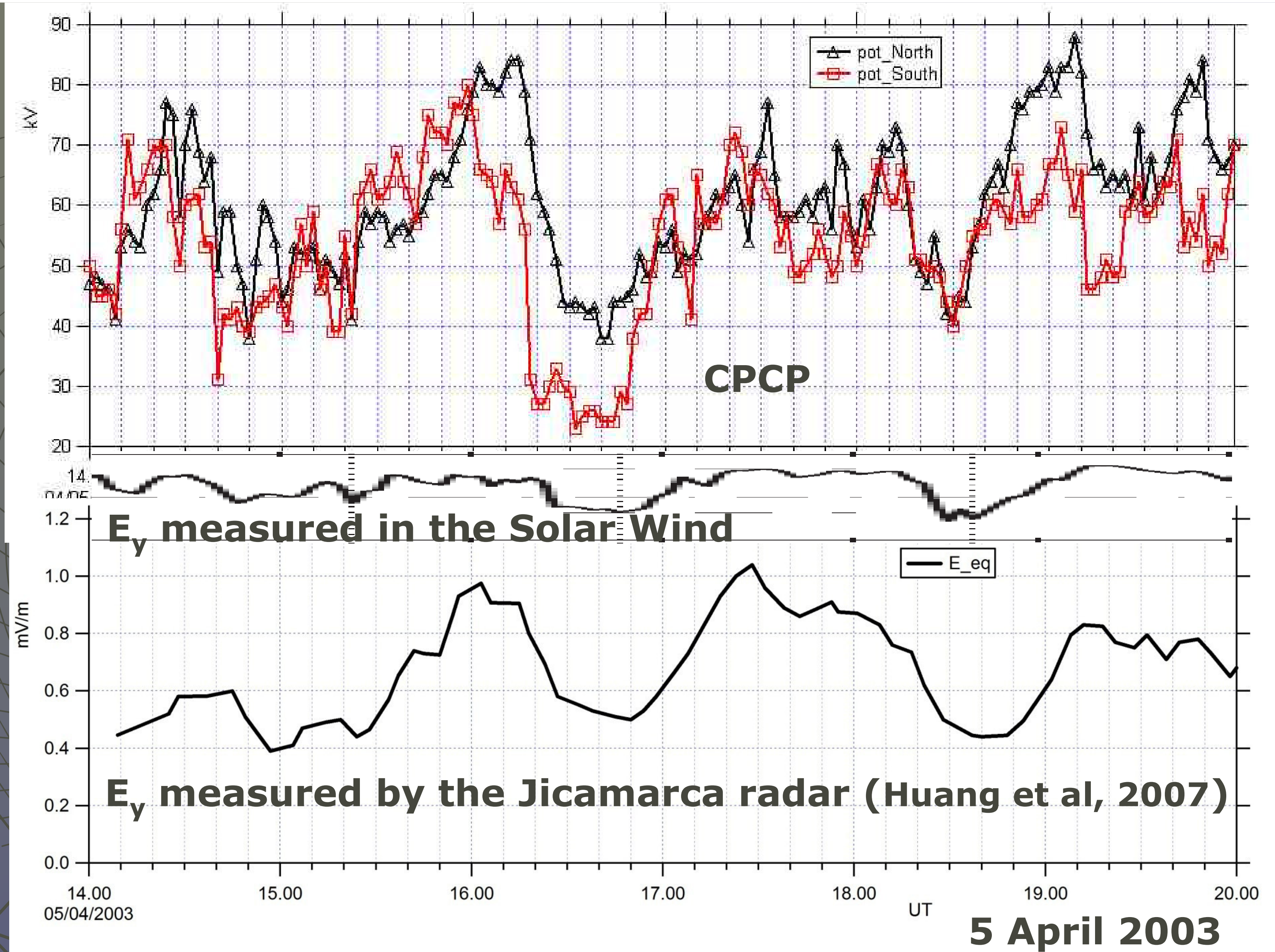
- Basic SD data product
- Available in real time with 2-min resolution
- Derivation from line of sight velocities
- Fit data to IMF-dependent statistical model
- Grid of E-field value
- Polar cap potential

http://superdarn.jhuapl.edu/rt/map/movie/index.html



22:45 UT: IMF rotation.

In this case, the northern and southern ionospheres have different response times.



Higher equatorial E in general corresponds to higher CPCP.

Lower equatorial E in general corresponds to lower high latitude CPCP.

	SuperDARN	Real Time AMIE	LiMIE
+	Large area of coverage	Large area of coverage	Only needs SW data
	Short delay (~10 min)	Magnetometer data almost always available	
	Direct measurement of V	Short delay (~10 min)	
	Large scale of coverage	Provides Joule heating and B-aligned currents	
-	Often not a lot of scatter	Needs Σ model (V not directly measured)	Statistical model: not a real measurement
	Not all MLT's are covered	Not all MLT sectors are covered	
	Polar cap may expand equatorwarsd of fov's		

Outline

SuperDARN and its principle of operation

Mesospheric winds product

MUF and foF2 products

Convection maps and transpolar potential drop (including the description of a couple of events)

SD Space weather proxies

What is the best SuperDARN proxy for Space Weather activity ?

- polar cap potential ?
  - similar values from northern and southern hemispheres data (same model)
  - lack of data during large storms
  - derived mainly from model during these periods
  - validation needed (PC index)

- number of echoes ?
  - related to HF propagation and absorption
  - role of polar cap expansion
  - differences between northern and southern hemispheres data

Outline

SuperDARN and its principle of operation

Mesospheric winds product

MUF and foF2 products

Convection maps and transpolar potential drop (including the description of a couple of events)

SD Space weather proxies

Final considerations

SuperDARN and space facilities

- Potential science that can be achieved by co-ordinating space and ground-based facilities is huge
- Recent missions which have related to SuperDARN include Polar, Geotail, Cluster, IMAGE, TIMED, THEMIS.
- Science from these missions with SuperDARN cover nearly all the science that can be achieved by SuperDARN.
- There are a number of future missions which could provide added value to the SuperDARN science

Upgrading SuperDARN

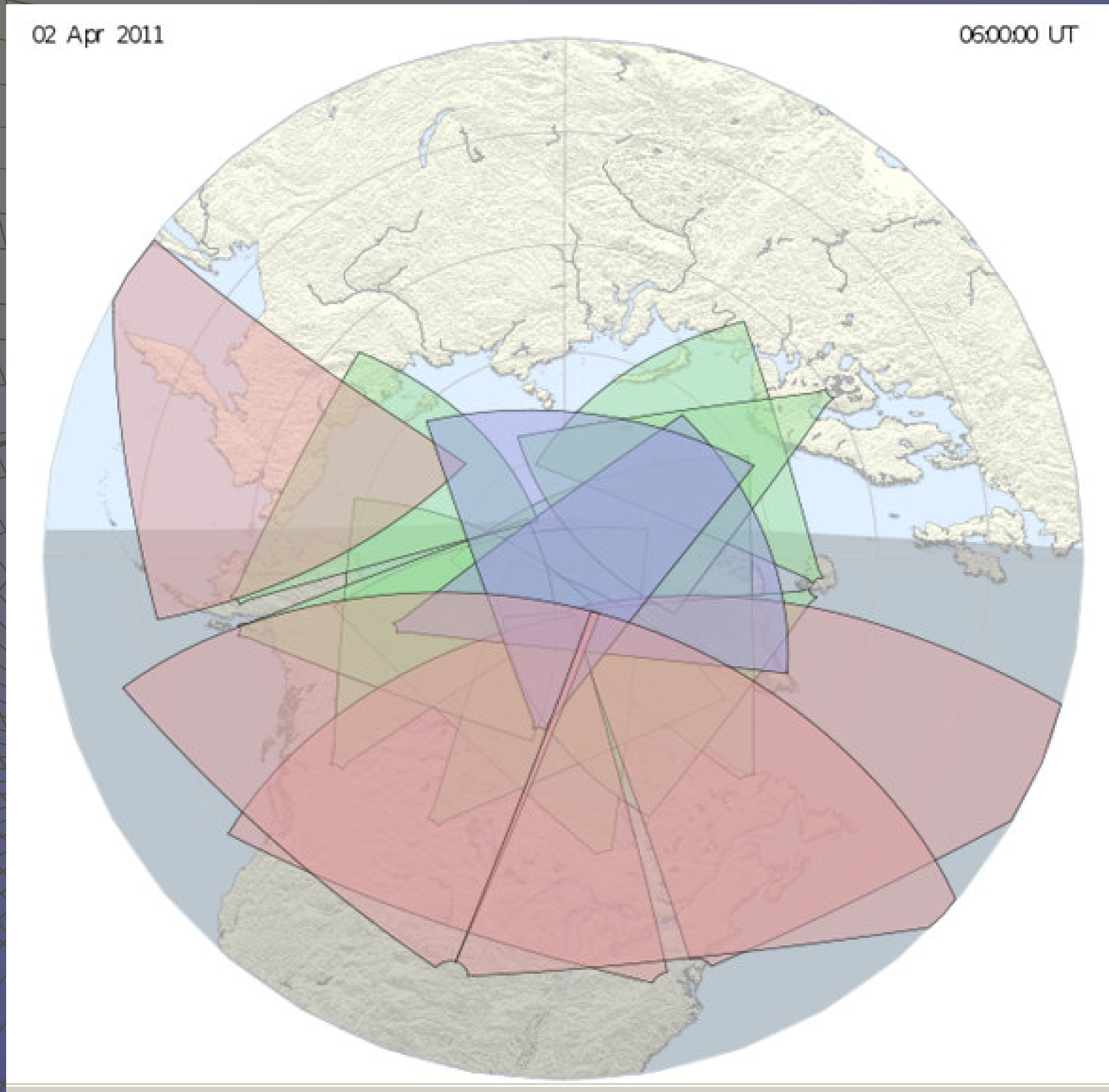
The capability of SD observations are influenced (and limited) by:

- global radar coverage (Siberian gap)
- daily variation of echo distribution (cusp)
- changes in ionospheric electron density
- increase of HF radio absorption (blackout)
- polar cap expansion

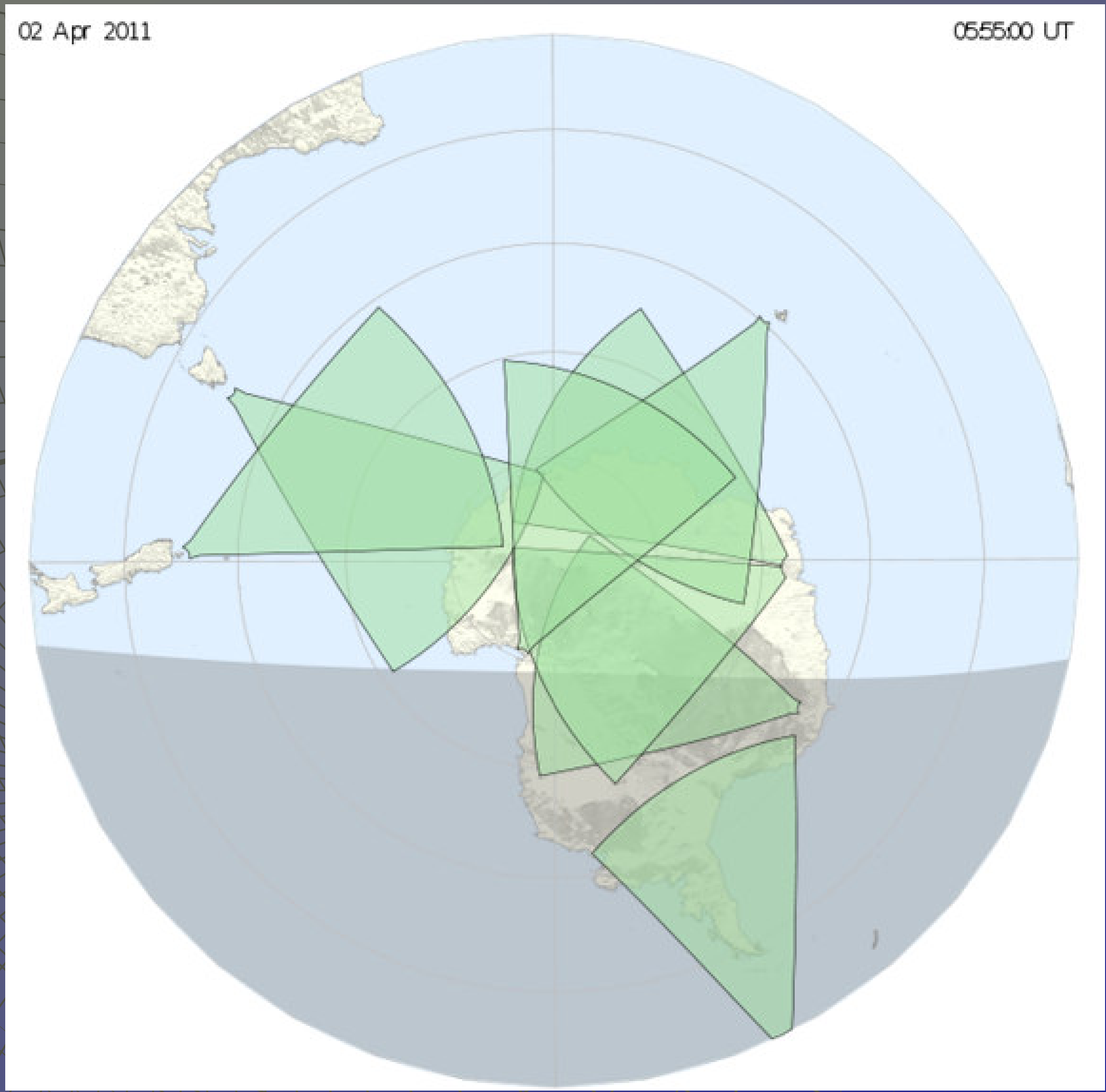
Solutions:

- extension of network towards mid-latitudes
- installation of several radars in Siberia
- fill the southern hemisphere gaps

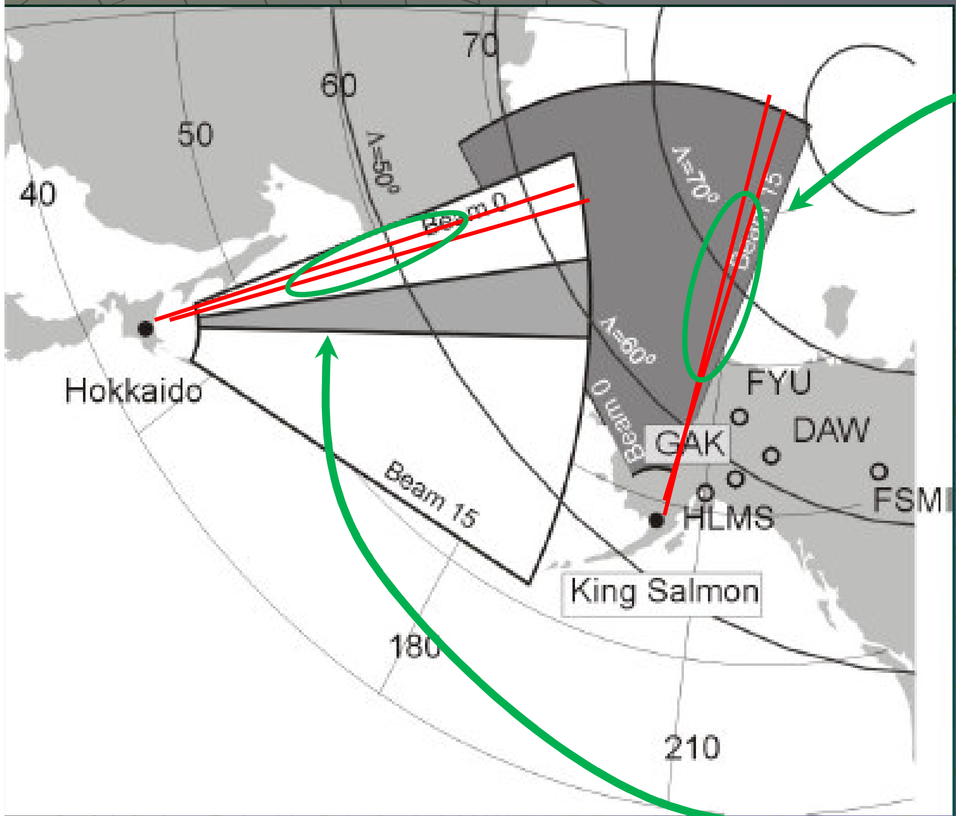
Upgrading SuperDARN

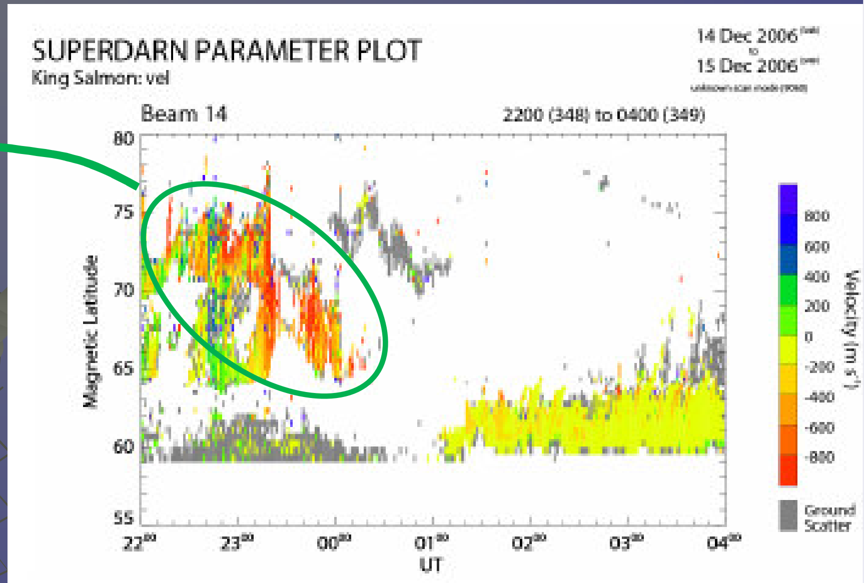


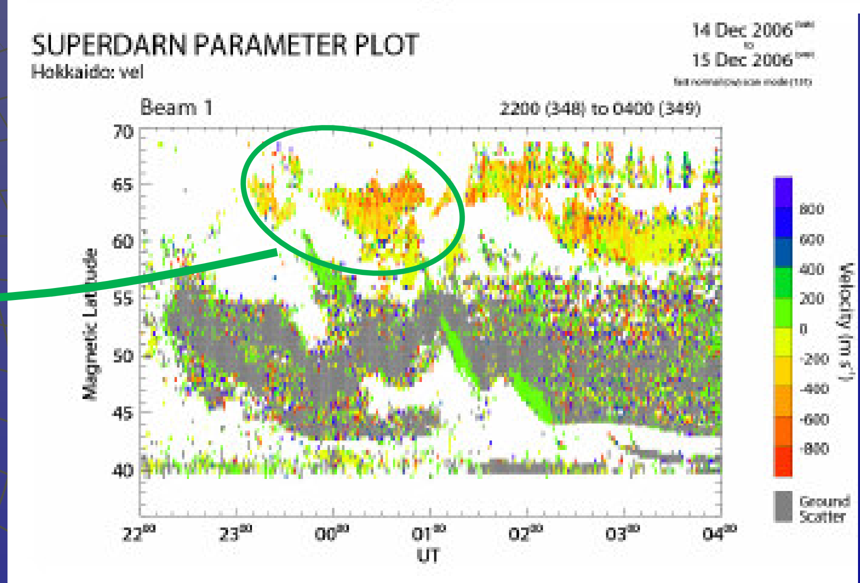
Upgrading SuperDARN



Example of how mid-latitude radars enhance the SuperDARN capabilities

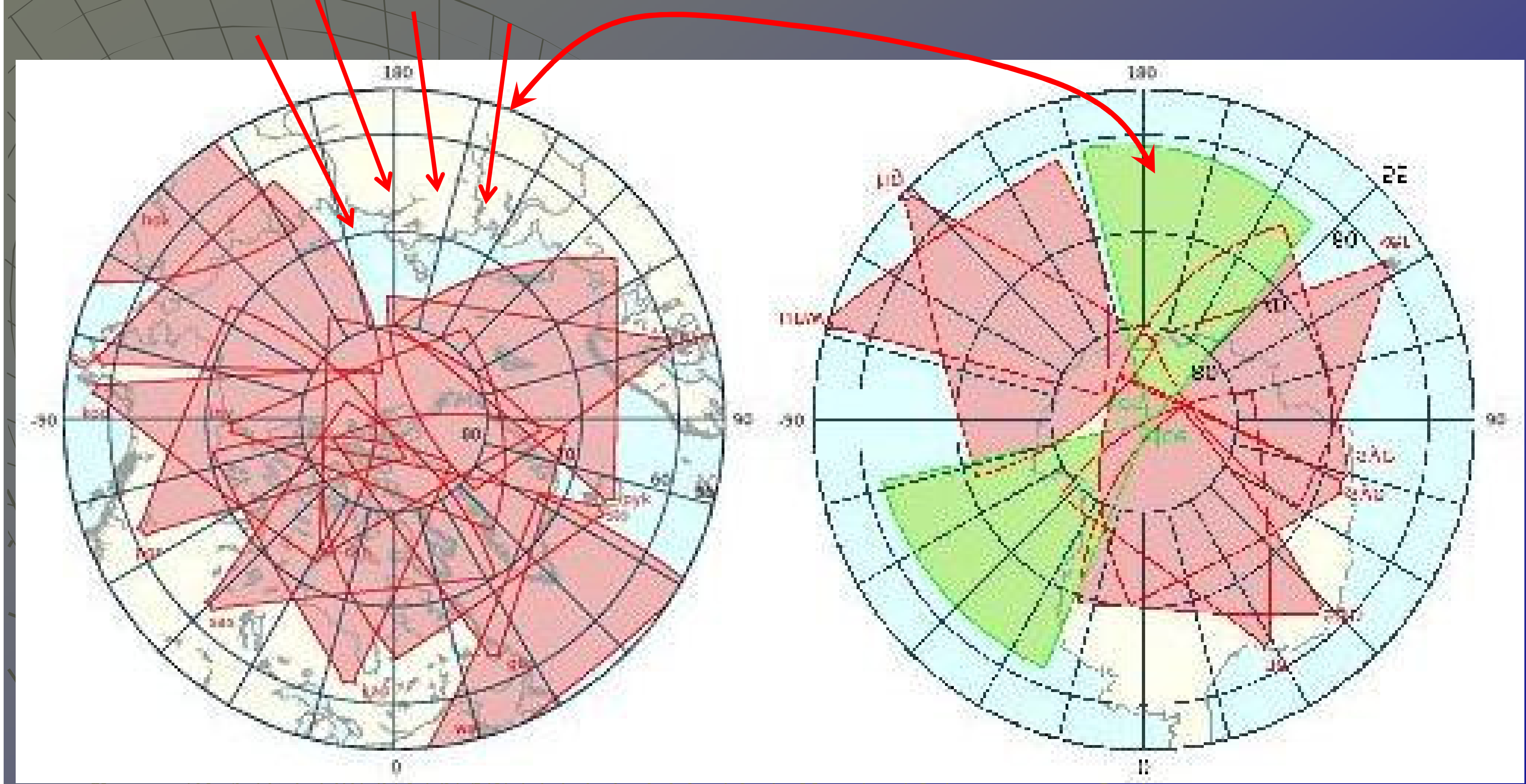




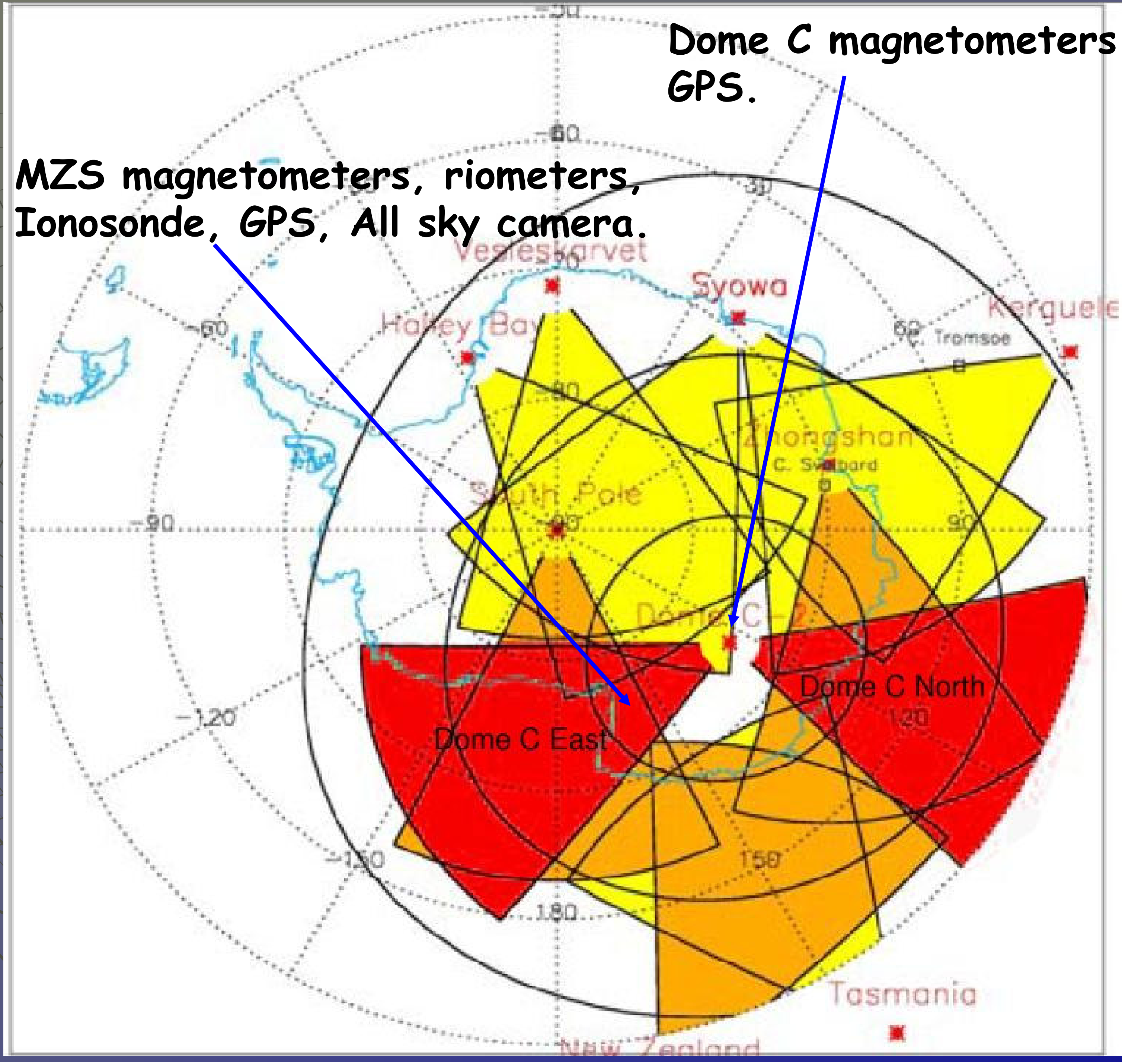


Equatorward motion of poleward flows down to 55° Mlat associated with IMF southward turning.

Siberian radars >2012 | Dome C radars 2012



http://superdarn.jhuapl.edu


Dome C magnetometers
GPS.
MZS magnetometers, riometers,
Ionosonde, GPS, All sky camera.
Vesleskarvet
Syowa
Halley Bay
Kerguele
Tromsoe
Zhongshan
South Pole
Dome C-2
Dome C North
Dome C East
Tasmania
New Zealand
-60
30
60
-90
90
-120
120
-150
150
180

Kerguelen Radar antennae

Wallops Island Radar antennae

Thank you