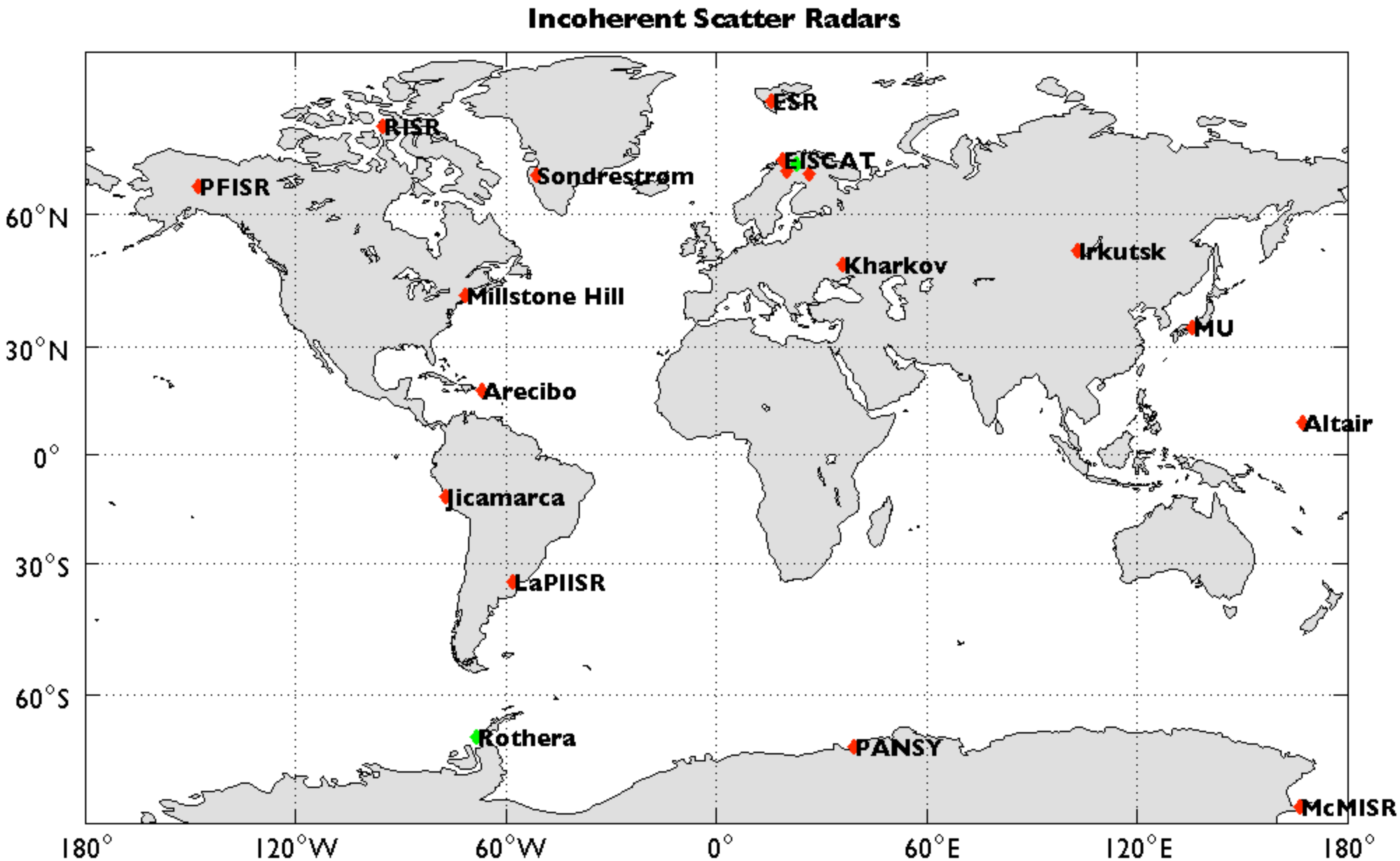
The US Incoherent Scatter Radars

Anja Strømme

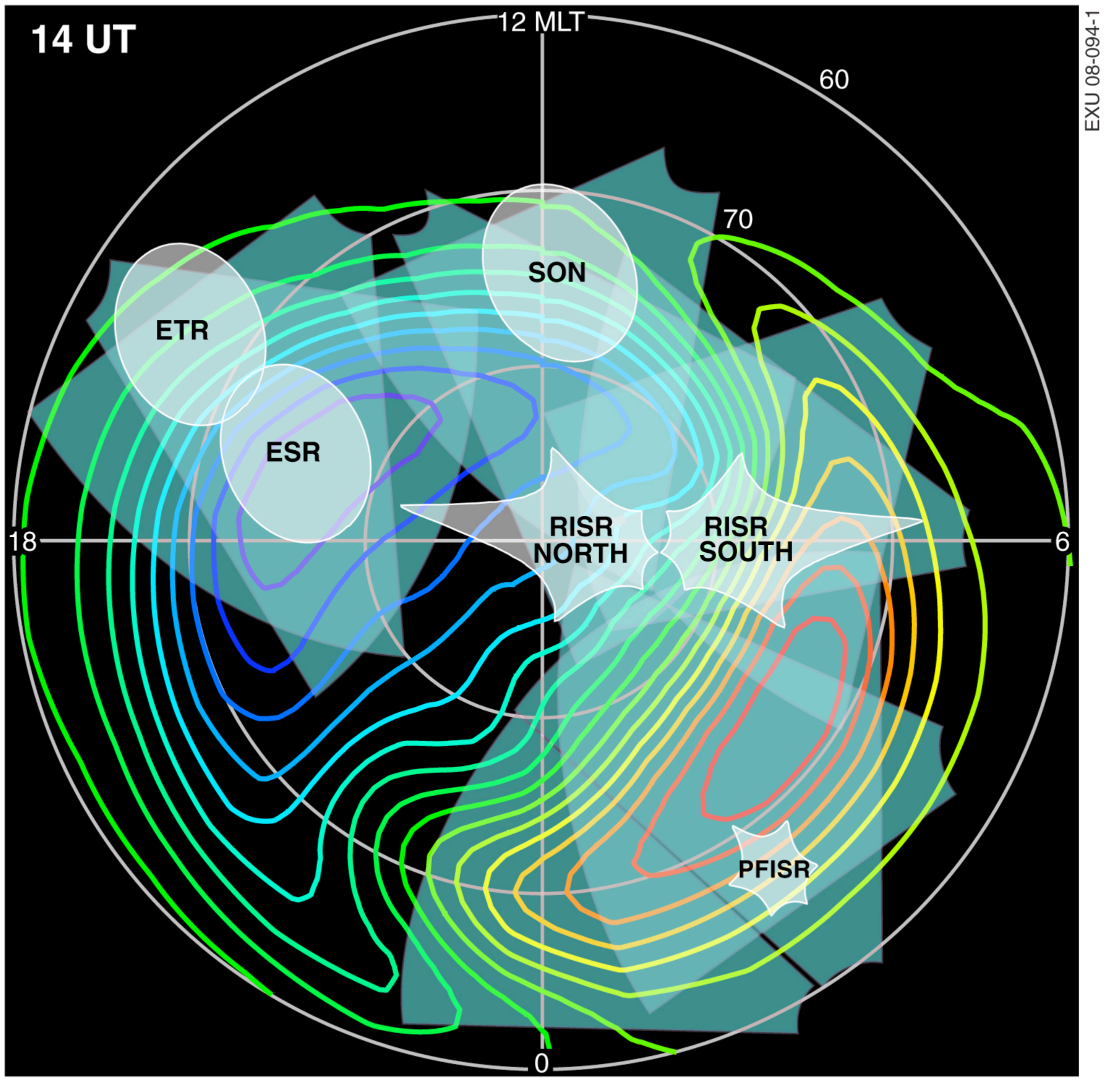
SRI International

With contributions from the other PIs

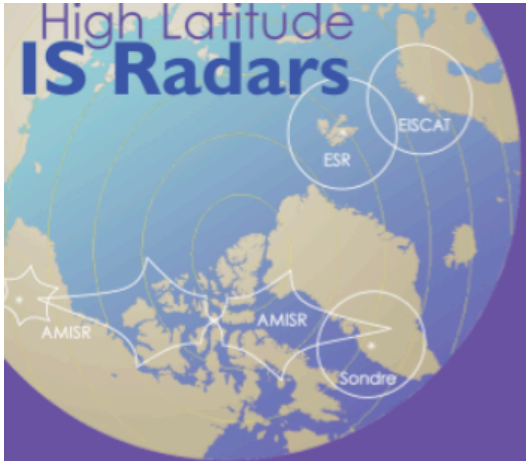


Map: Thomas Ulich

Map of the north…



High Latitude IS Radars



EISCAT2003

Useful Constants

$c_0 = 2.99792458 \times 10^8\ ms^{-1}$	$m_e = 9.10938188 \times 10^{-31}$ kg
$\mu_0 = 4\pi \times 10^{-7}\ NA^{-2}$	$e = 1.602176462 \times 10^{-19}$ C
$\varepsilon_0 = 1/\mu_0 c_0^2$	$r_e = 2.817940285 \times 10^{-15}$ m
$\varepsilon_0 = 8.854187817 \times 10^{-12}\ Fm^{-1}$	$1u = 1.66053873 \times 10^{-27}$ kg
$k_b = 1.3806503 \times 10^{-23}\ JK^{-1}$	$G = 6.673 \times 10^{-11}\ m^3 kg^{-1} s^{-2}$

Plasma frequency, $\omega_p = \left(\frac{n_e e^2}{\varepsilon_0 m e}\right)^{1/2} = 2\pi\sqrt{80.6 n_e}$

Debye length, $\lambda_D = \left(\frac{\varepsilon_0 k_B T_e}{n_e e^2}\right)^{1/2} = 69\sqrt{\frac{T_e}{n_e}}$

Electron thermal speed, $v_{the} = \left(\frac{2 k_b T_e}{m_e}\right)^{1/2} = 5500\sqrt{T_e}$

Ion thermal speed, $v_{thi} = \left(\frac{2 k_b T_i}{m_i}\right)^{1/2} = 128.4\sqrt{\frac{T_i}{W}}$

Ion-acoustic speed, $c_s = \left(\frac{k_b (T_e + T_i)}{m_i}\right)^{1/2} = 90.8\sqrt{\frac{T_e + T_i}{W}}$

Electron gyro frequency, $\Omega_e = \frac{eB}{me} = 1.759 \times 10^{11}$ B

Ion gyro frequency, $\Omega_i = \frac{eB}{mi} = 9575 \frac{B}{W}$

Electron gyroradius, $r_{Le} = \frac{v_{the}}{\Omega_e} = 3.13 \times 10^4 \frac{\sqrt{T_e}}{B_0}$

Ion gyroradius, $r_{Li} = \frac{v_{thi}}{\Omega_i} = r_{Le}\sqrt{\frac{1837\ W}{T_e/T_i}}$

W: molecular weight; $m_i = W \cdot u$

ESR

Geographic coord.	78° 09' 11" N 16° 1' 44" E
Geomag. dip angle	82° 06'
Invariant latitude	75° 10' 48" N
Local time	UT + 1 (UT + 2 summer)
Magnetic time	UT + 2:45
Elevation	445 m
Coverage	360° az., above, 30° elev.*

*No transmission below this elevation.

EISCAT

	Tromsø	Kiruna	Sodankylä
Geographic coord.	69° 35' 11" N 19° 13' 38" E	67° 51' 38" N 20° 26' 07" E	67° 21' 49" N 26° 37' 37" E
Geomag. dip angle	77° 30'	76° 48'	76° 43'
Invariant latitude	66° 12' N	64° 27' N	63° 34' N
Local time	UT+1 (UT + 2 summer)	UT + 1 (UT + 2 summer)	UT + 2 (UT + 3 summer)
Magnetic time	UT + 2:30	–	–
Elevation	86 m	418 m	197 m
Coverage	UHF: 360° az., above 20°–22° elev.* VHF: ±15° az., 30°–90° elev. (north only)	Fully steerable	Fully steerable

*Dependent on azimuth No transmission below this elevation.

AMISR

	Poker Flat*	Resolute Bay*
Geographic coord.	65° 7' 12" N 147° 25' 48" W	74° 43' 46" N, 94° 54' 16" E
Geomag. dip angle	77° 32'	88° 47'
Invariant latitude	66° 7' N	83° 37' N
Local time	UT – 9 (Alaska)	UT – 6 (central)
Magnetic time	–	UT – 7:45
Elevation	–	–
Coverage	±25°	±25°

*Initial locations. Poker Flat (one face) operational Spring 2005. Resolute Bay (two faces) operational Winter 2006. One face = 128 panels.

Sondrestrom

Geographic coord.	66° 59' 12" N 309° 03' 02" E
Geomag. dip angle	80° 24'
Invariant latitude	74° 11' 24" N
Local time	UT – 3 (UT – 2 summer)
Magnetic time	UT – 1:58
Elevation	177 m
Coverage	360° az., above 25°–30° elev.*

*Dependent on azimuth. No transmission below this elevation.

The Incoherent Scatter RADAR Equation:

Signal, $P_r = \frac{C c_0 G \lambda^2}{2} \frac{P_t \tau_P}{r^2} \frac{\sigma_e n_e(r)}{(1 + k\lambda_D^2)(1 + k\lambda_D^2 + T_r)}$

Noise, $P_n = P_n k_b T_{sys} \cdot BW$: BW – bandwidth

$\sigma_e = 4\pi r_e^2 = 9.98 \times 10^{-29}$ m ∴ Radar cross section of a free electron

C = Constant containing loss and antenna shape

ESR

Center transmit frequency, f	500 MHz
Wavenumber, k	$10.48\ m^{-1}$ ($2k = 20.96\ m^{-1}$)
Wavelength, λ	0.5996 m (λ/2 = 0.2998 m)
Peak power, P_t	1 MW
Max duty cycle	25%
Pulse length, τ_p	<1 – 2000 μs
Antenna size (dia.)	32 m / 42 m
Antenna gain, G	42.5 dBi / 45 dBi
Antenna beamwidth*	0.6°
System temperature, T_{sys}	55 – 65 K
Antenna type	Parabolic dish
Feed system	Cassegrain
Polarization	Circular

EISCAT

	Tromsø UHF	Kiruna UHF	Sodankylä UHF
Center transmit frequency, f	928.4 MHz	–	–
Wavenumber, k	$19.46\ m^{-1}$ ($2k = 38.92\ m^{-1}$)	220 km**, $2k \sin\theta = 36\ m^{-1}$	220 km**, $2k \sin\theta = 33\ m^{-1}$
Wavelength, λ	0.3229 m (λ/2 = 0.1615 m)	220 km**, λ/2 = 0.17 m	220 km**, λ/2 = 0.19m
Peak power, P_t	2 MW	–	–
Max duty cycle	10%	–	–
Pulse length, τ_p	1-2000 μs	–	–
Antenna size (dia.)	32 m	32 m	32 m
Antenna gain, G	48 dBi	48 dBi	48 dBi
Antenna beamwidth*	0.5°	0.5°	0.5°
System temperature, T_{sys}	70 – 80 K	30 – 35 K	30 – 35 K
Antenna type	Parabolic dish	Parabolic dish	Parabolic dish
Feed system	Cassegrain	Cassegrain	Cassegrain
Polarization	Circular	Any	Any

EISCAT VHF

Center transmit frequency, f	224 MHz
Wavenumber, k	$4.695\ m^{-1}$ ($2k = 9.389\ m^{-1}$)
Wavelength, λ	1.3384 m (λ/2 = 0.6692 m)
Peak power, P_t	2 x 1.5 MW
Max duty cycle	12.5%
Pulse length, τ_p	1 – 2000 μs
Antenna size	120 x 40 m (4 x (30 x 40 m))
Antenna gain, G	46 dBi
Antenna beamwidth*	Whole antenna: 0.6° EW x 1.7° NS; Half antenna: 1.2° EW x 1.7° NS
System temperature, T_{sys}	250 – 350 K
Antenna type	Offset parabolic cylinder
Feed system	Line feed
Polarization	Circular

AMISR

Center transmit frequency, f	449 MHz
Wavenumber, k	$9.4\ m^{-1}$ ($2k = 18.82\ m^{-1}$)
Wavelength, λ	0.6677 m (λ/2 = 0.3338 m)
Peak power, P_t	2 MW
Max duty cycle	10%
Pulse length, τ_p	1 – 2000 μs
Antenna size	128 x (1.5 x 3.5 m)
Antenna gain, G	43 dBi
Antenna beamwidth*	1°
System temperature, T_{sys}	120 K
Antenna type	Crossed dipole phased array
Feed system	Distributed amplifiers
Polarization	Circular

Sondrestrom

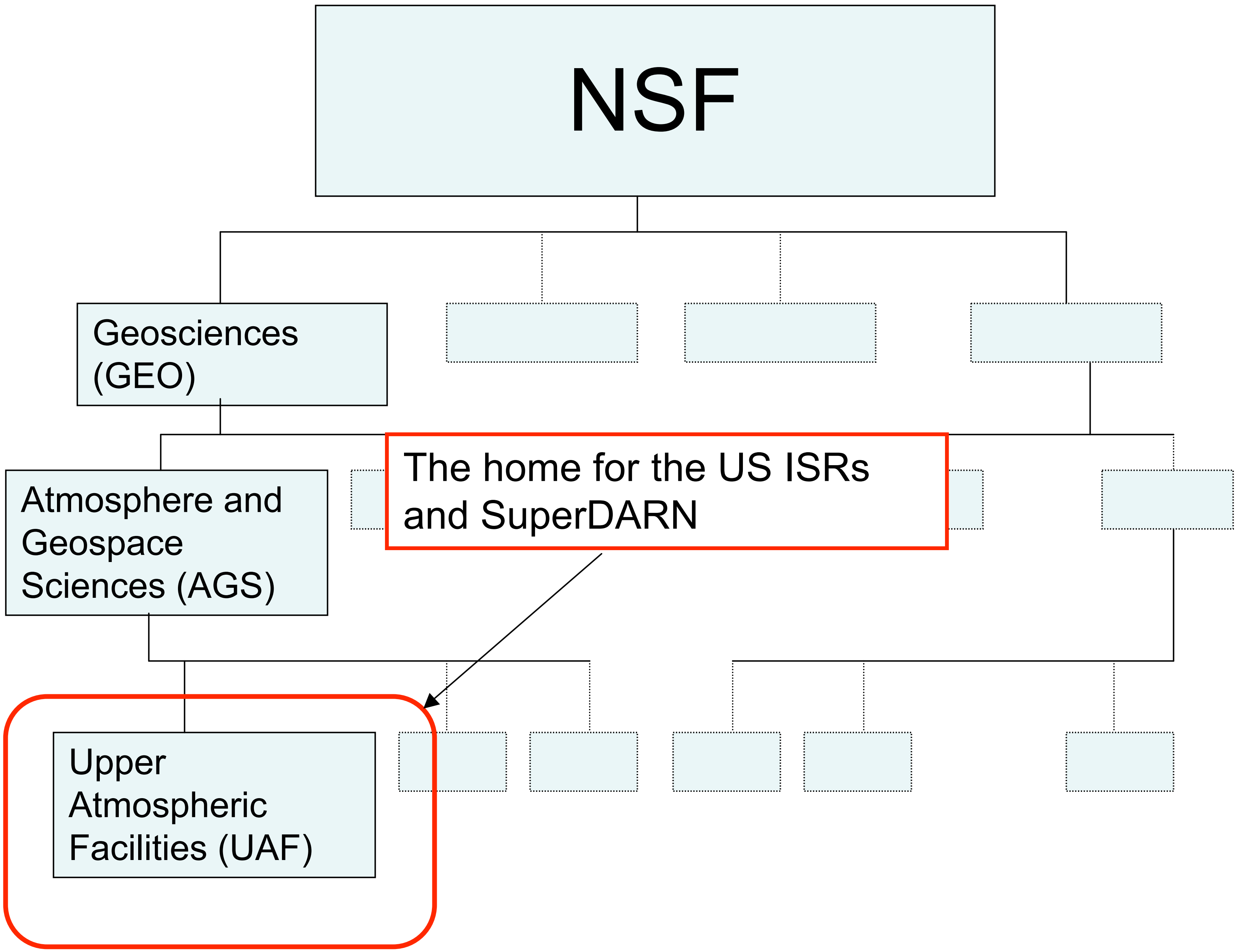
Center transmit frequency, f	1290 MHz
Wavenumber, k	$27.04\ m^{-1}$ ($2k = 54.07\ m^{-1}$)
Wavelength, λ	0.2323 m (λ/2=0.1162 m)
Peak power, P_t	3.5 MW
Max duty cycle	3%
Pulse length, τ_p	2 – 500 μs
Antenna size (dia.)	32 m
Antenna gain, G	49 dB
Antenna beamwidth*	0.5°
System temperature, T_{sys}	85 K
Antenna type	Parabolic dish
Feed system	Cassegrain
Polarization	Circular

* Full width, half power ** Tromsø field line

EISCAT2003

How it works - political

- All the US Incoherent Scatter Radars are funded by the National Science Foundation (NSF) and are governed under the Upper Atmosphere Facility (UAF) program.


NSF
Geosciences (GEO)
Atmosphere and Geospace Sciences (AGS)
The home for the US ISRs and SuperDARN
Upper Atmospheric Facilities (UAF)

How it works - political

- All the US Incoherent Scatter Radars are funded by the National Science Foundation (NSF) and are governed under the Upper Atmosphere Facility (UAF) program.
- The Operation and Maintenance (O&M) is done by a host institution through a cooperative agreement renewed every 5 years.

From South to North…

- Jicamarca - Cornell University (in collaboration with Instituto Geofísico del Perú)
- Arecibo - Cornell University (currently in the process of an open re-bid)
- Millstone Hill - MIT
- PFISR - SRI International
- Sondrestrom - SRI International
- RISR-N - SRI International

How it works - practically (1)

- The radars are available to all US users, and in reality to all users.
- Analyzed data is available in the madrigal database
  - http://jro.igp.gob.pe/madrigal/ (Jicamarca)
  - http://madrigal.naic.edu/ (Arecibo)
  - http://madrigal.haystack.mit.edu/madrigal/ (Millstone Hill)
  - http://isr.sri.com/madrigal/ (SRI International)
  - http://www.eiscat.se/madrigal/ (EISCAT)

Contact information Principal Investigator

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- Millstone Hill: Phil Erickson
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- PFISR: Mike Nicolls
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- RISR (+AMISR): Craig Heinselman
  craig.heinselman@sri.com
- Sondrestrom: Anja Strømme
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How it works - practically (2)

- There are annual “world days” coordinated between all the radars (653 hours in 2010).
- Otherwise scheduling is done individually for each radar (the SRI radars - Sondrestrom, PFISR and RISR - are scheduled together).
- We are working toward more coordinated scheduling and operation of all the UAF radars.

6 slide pre-AMISR history of the US radars (Bob Robinson):

1958-1959

Bill Gordon conceives of the idea of incoherent scatter and construction begins at Arecibo, Puerto Rico, with funding from the Defense Advanced Research Project Office (DARPA)

1961

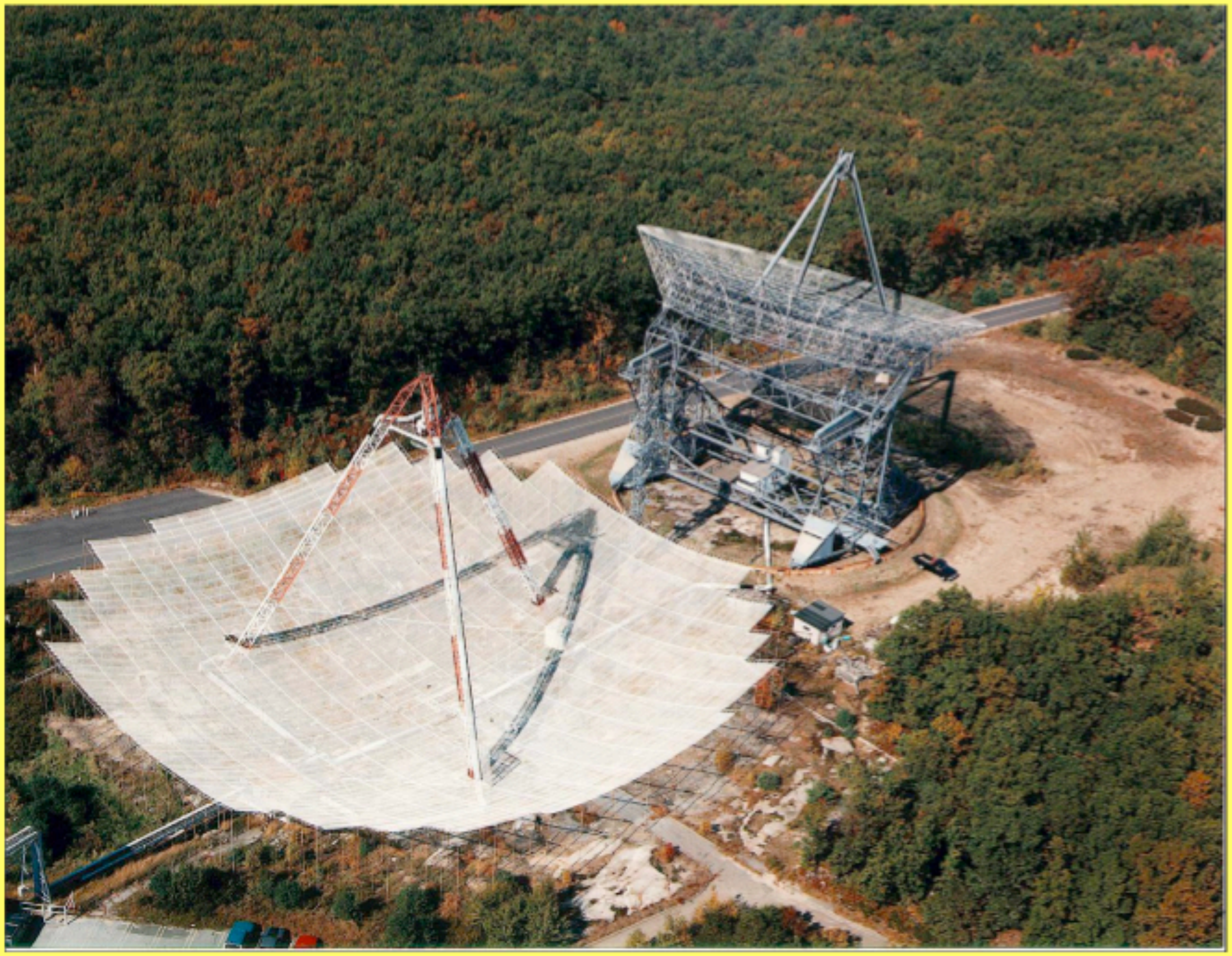
The Jicamarca Observatory is constructed near Lima, Peru, by the National Bureau of Standards.

1962

Construction of Arecibo is completed.

1963

The Millstone Hill zenith antenna is constructed by MIT Lincoln Laboratories at a site near Boston, MA



1971

The Chatanika Radar is moved from Stanford University to a new site near Fairbanks, Alaska.

1982

The Chatanika Radar is moved to a new location near Sondrestrom, Greenland,

1970 – 1980

The U. S. National Science Foundation takes over operation of four incoherent scatter radars

Sondrestrom

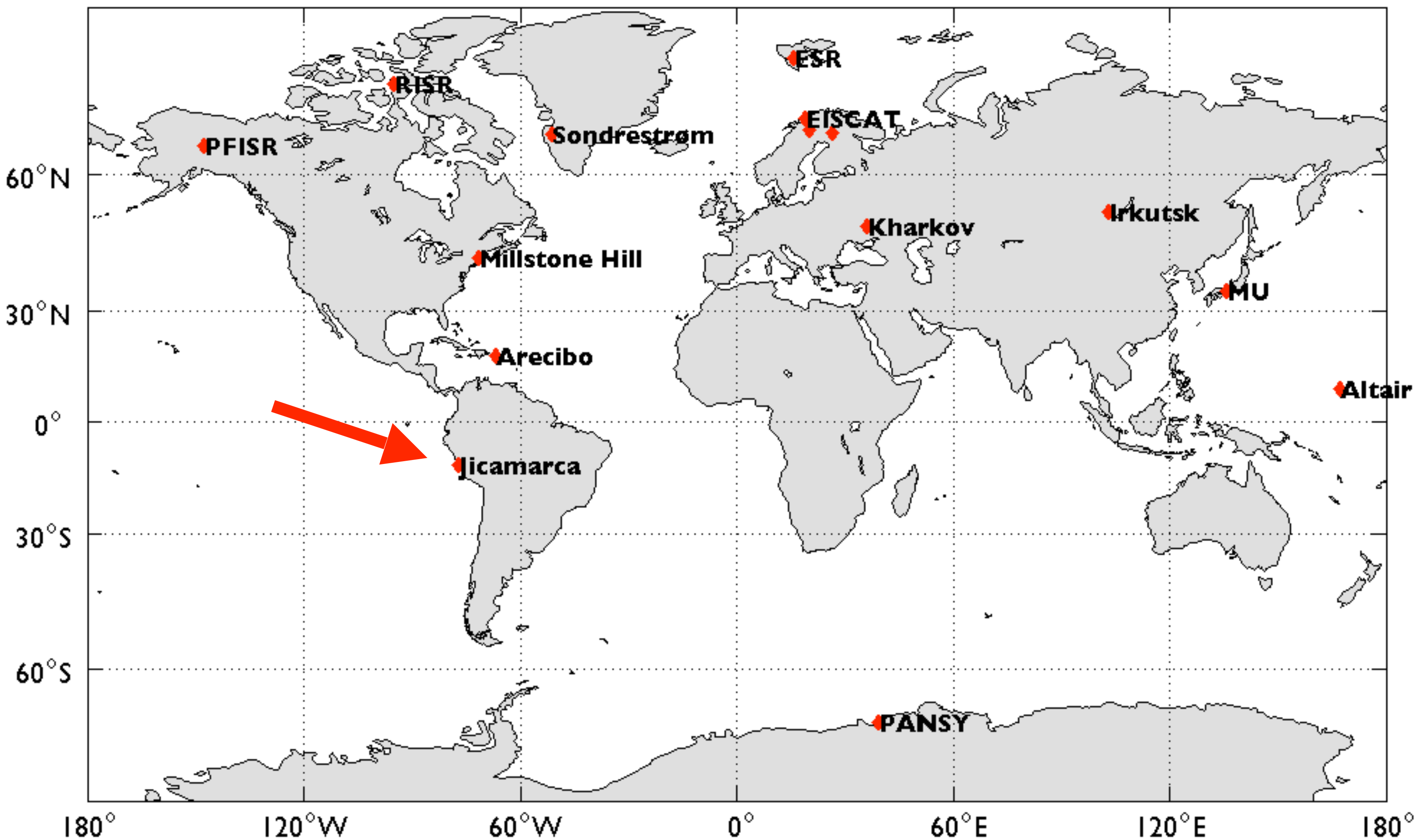
Millstone Hill

Jicamarca

Arecibo

The radars:

Incoherent Scatter Radars

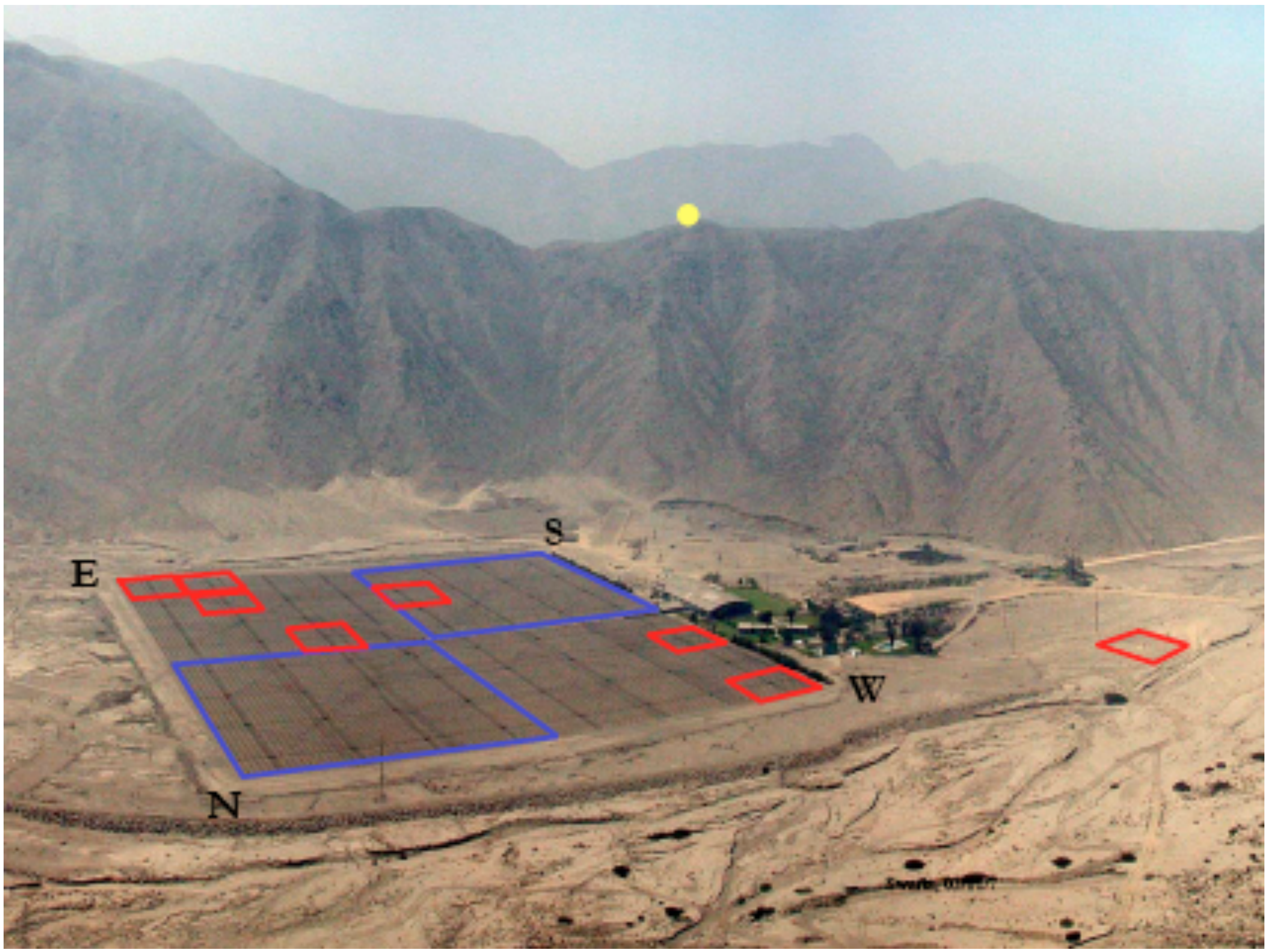


Map: Thomas Ulich

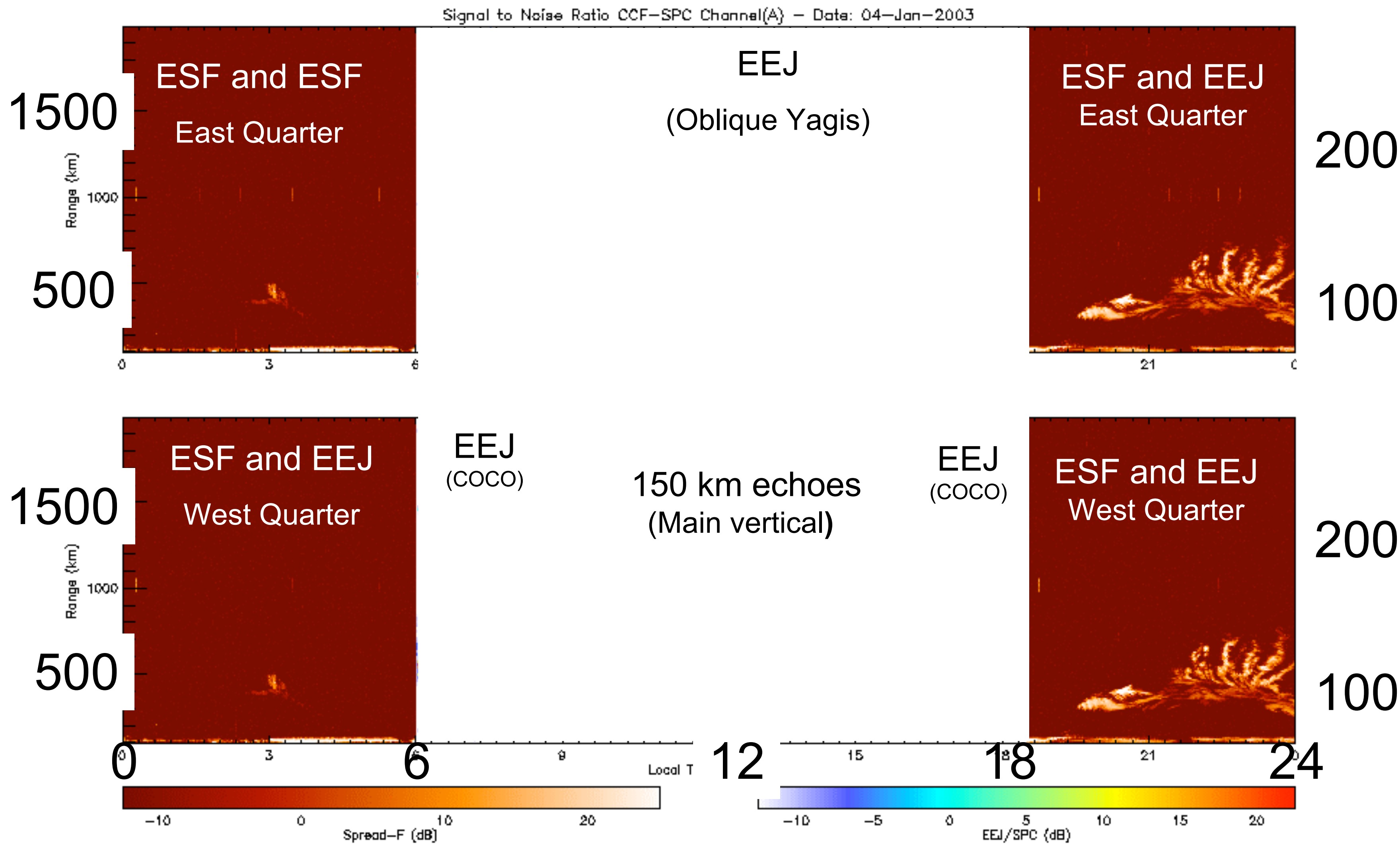
Low-Latitude Incoherent Scatter Radar - Jicamarca

- latitude 11.95° South, longitude 76.87° West
- 50 MHz
- 3 x 1.5 MW transmitters
- 18,432 dipole elements (64 sections of 12 x 12)
- 300 x 300 m main array (with a 12 x 12 array offset to the west for longer baseline interferometry)
- Close to magnetic equator (about 1° dip angle)
- Unique imaging/interferometric capabilities

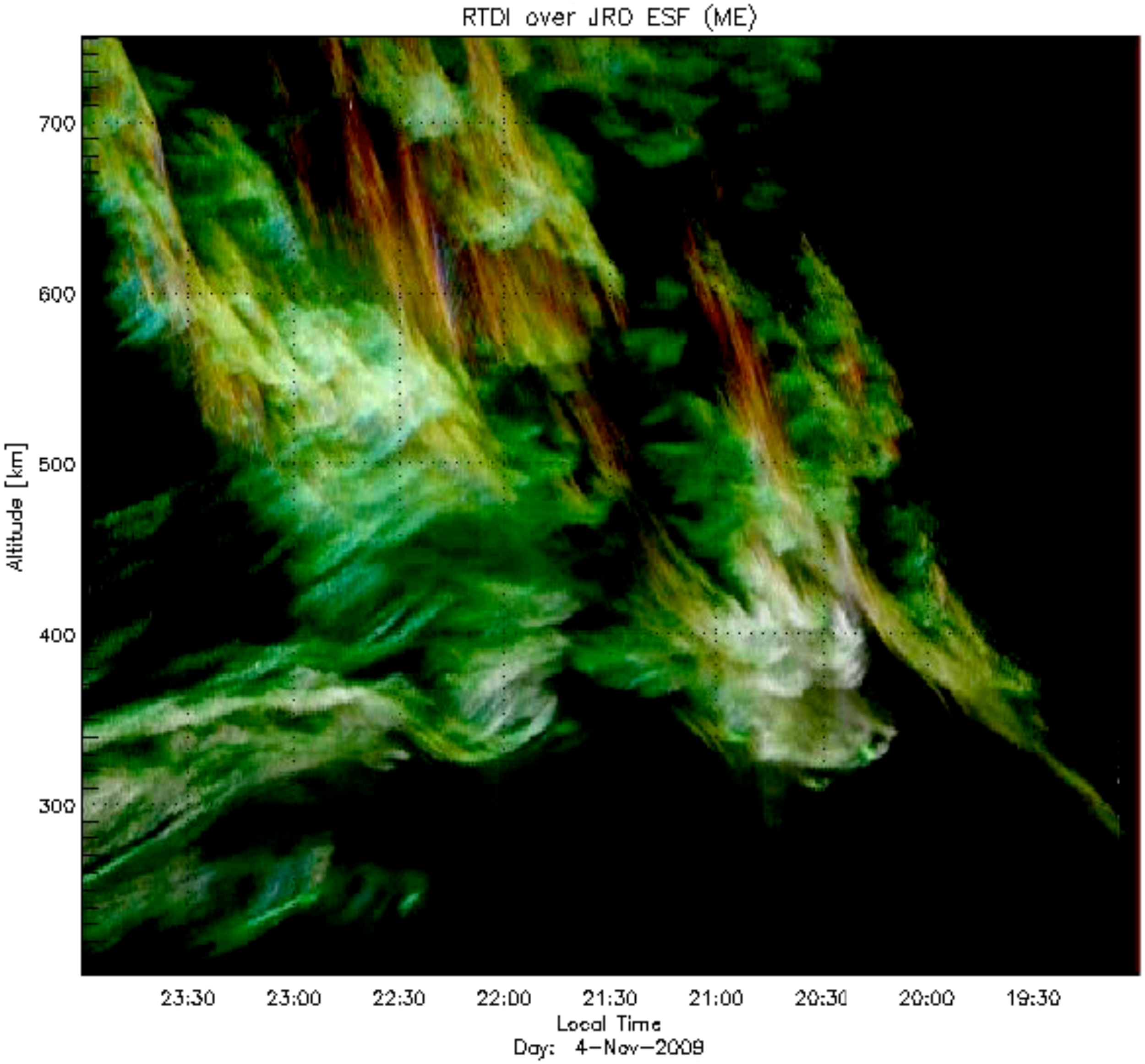
JULIA – Imaging (1)

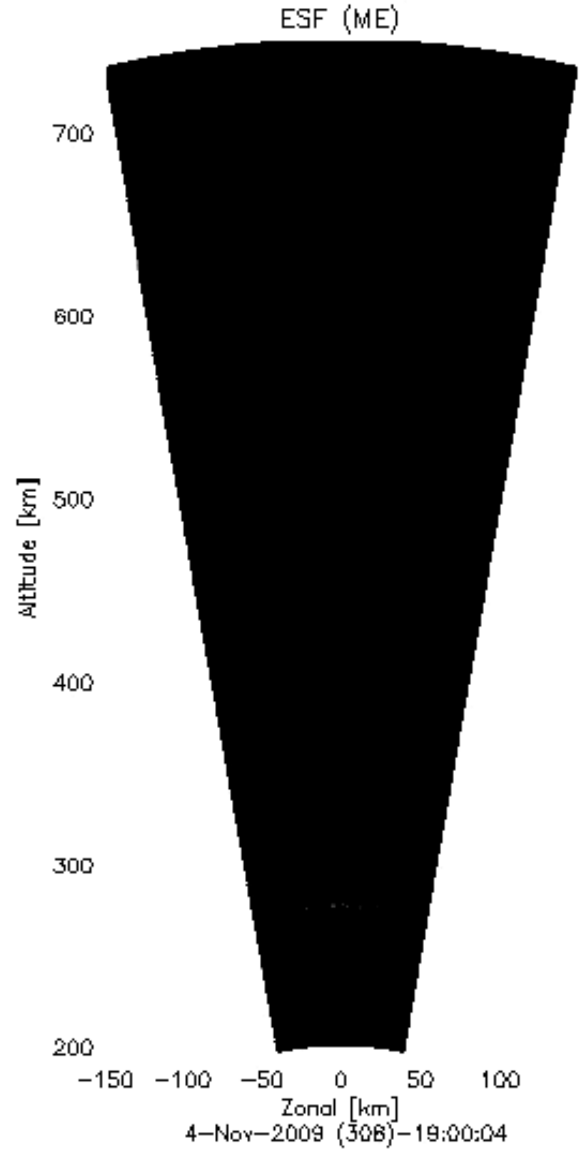


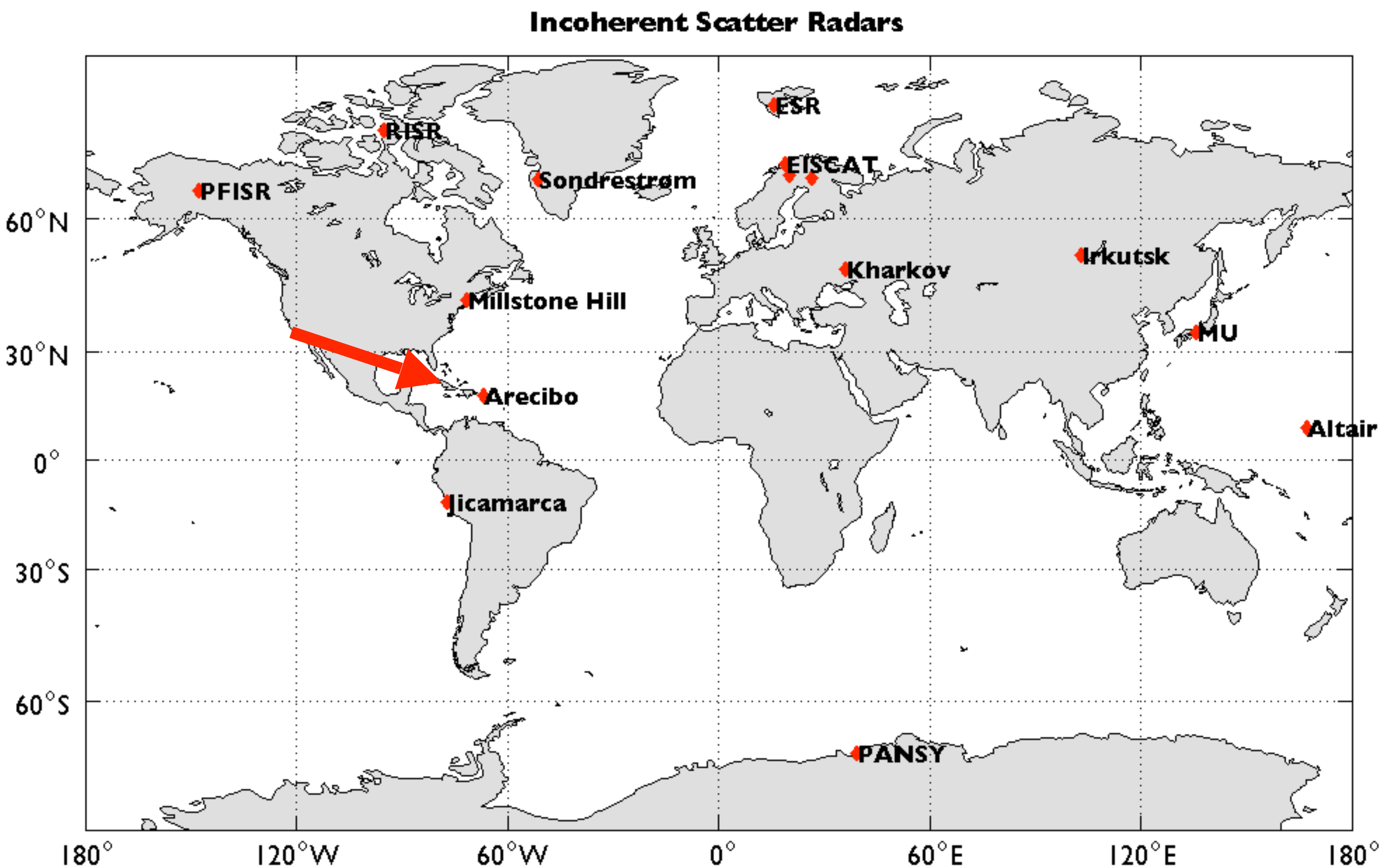
JULIA Observations



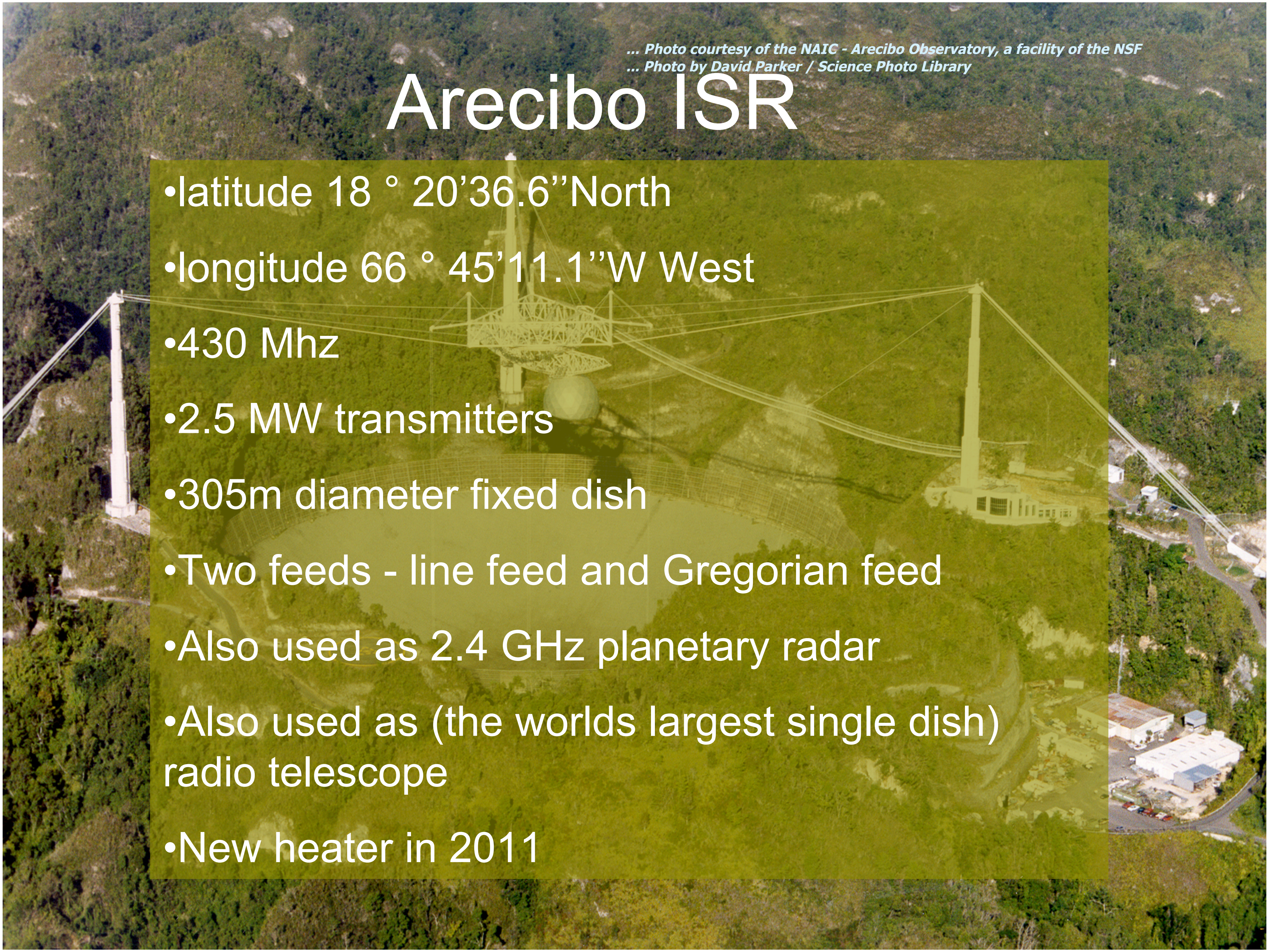
JULIA – Imaging (2)





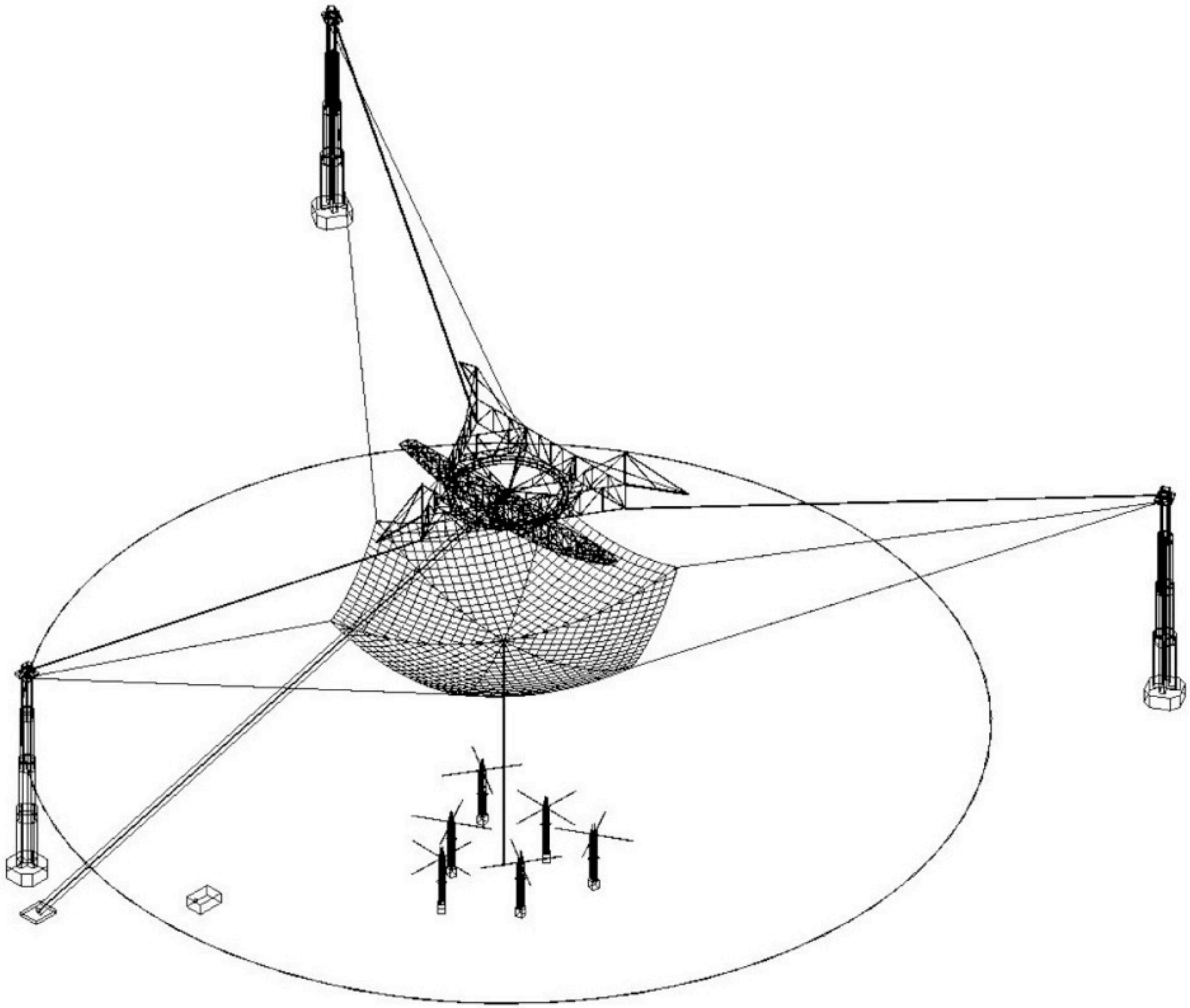


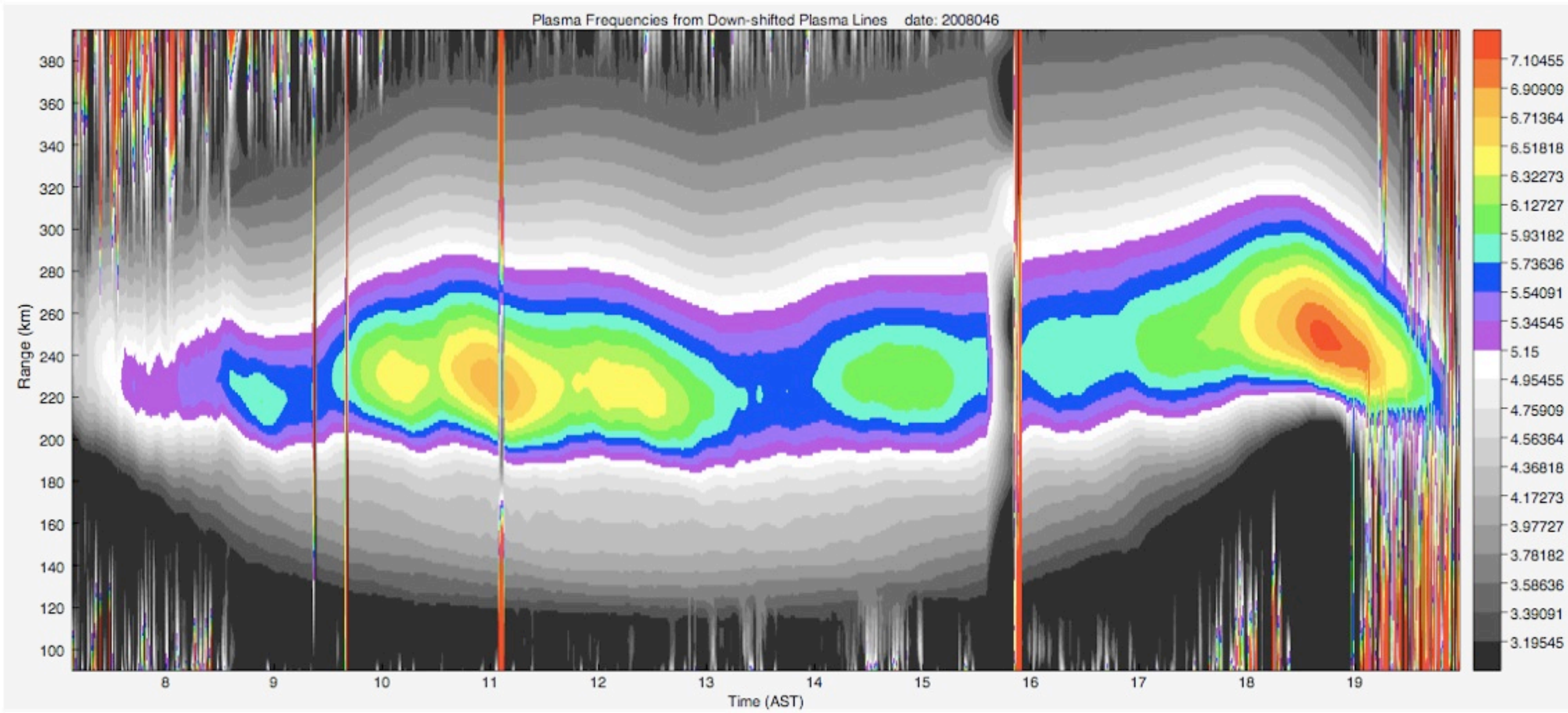
Map: Thomas Ulich



Arecibo ISR

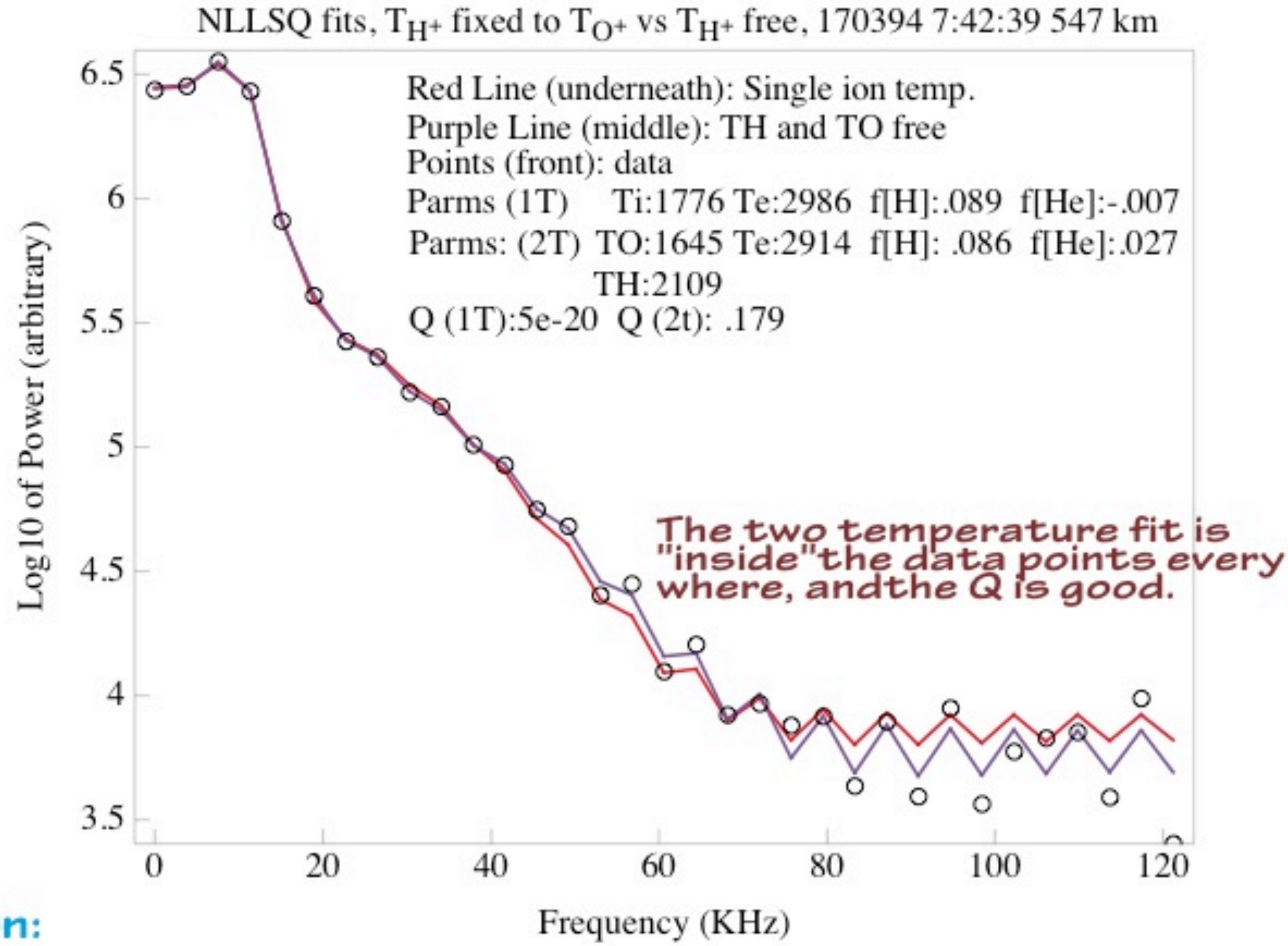
- latitude 18 ° 20’36.6’’North
- longitude 66 ° 45’11.1’’W West
- 430 Mhz
- 2.5 MW transmitters
- 305m diameter fixed dish
- Two feeds - line feed and Gregorian feed
- Also used as 2.4 GHz planetary radar
- Also used as (the worlds largest single dish) radio telescope
- New heater in 2011





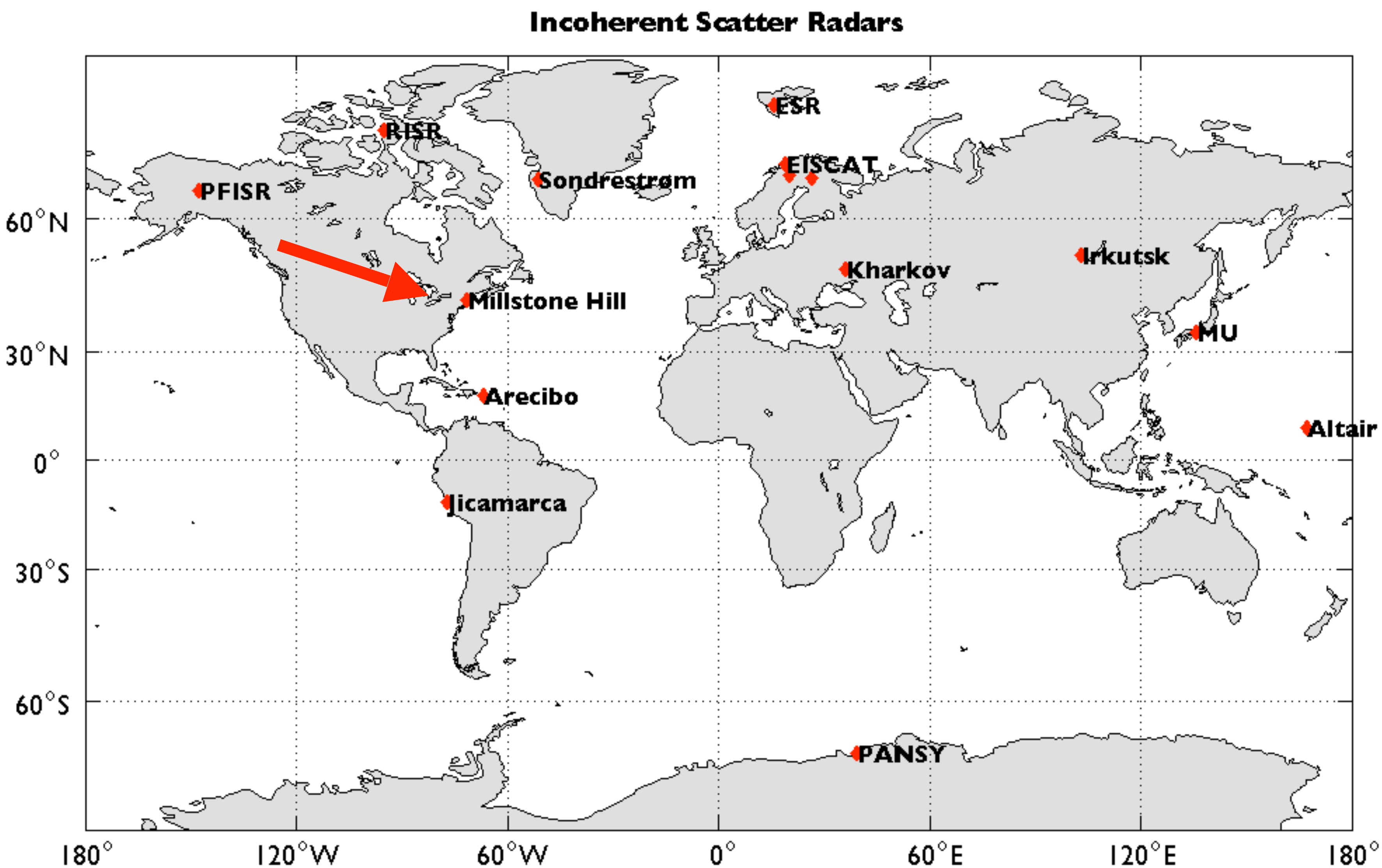
Plasma Frequencies from Down-shifted Plasma Lines date: 2008046
Range (km)
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
8
9
10
11
12
13
14
15
16
17
18
19
Time (AST)
7.10455
6.90909
6.71364
6.51818
6.32273
6.12727
5.93182
5.73636
5.54091
5.34545
5.15
4.95455
4.75909
4.56364
4.36818
4.17273
3.97727
3.78182
3.58636
3.39091
3.19545

A Model with More Freedom



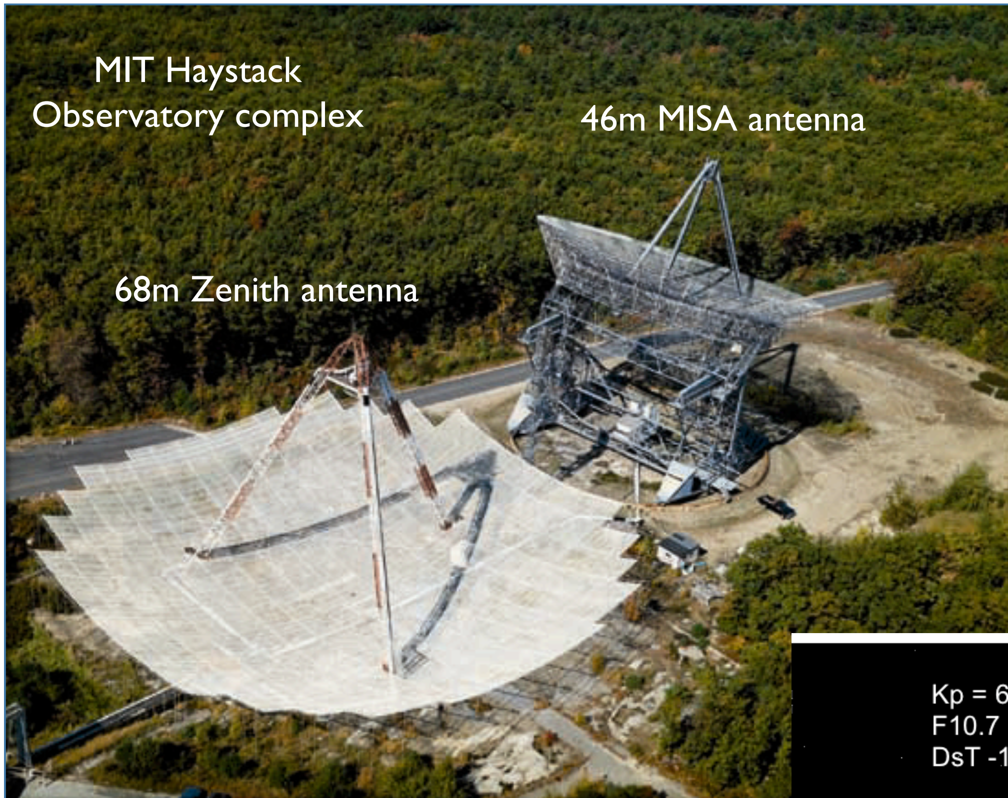
Conclusion:

Separate O^+ and H^+ temperatures are necessary and sufficient to obtain a good fit.



Map: Thomas Ulich


Millstone Hill Radar



Millstone Hill UHF Incoherent Scatter Radar
Westford, MA USA

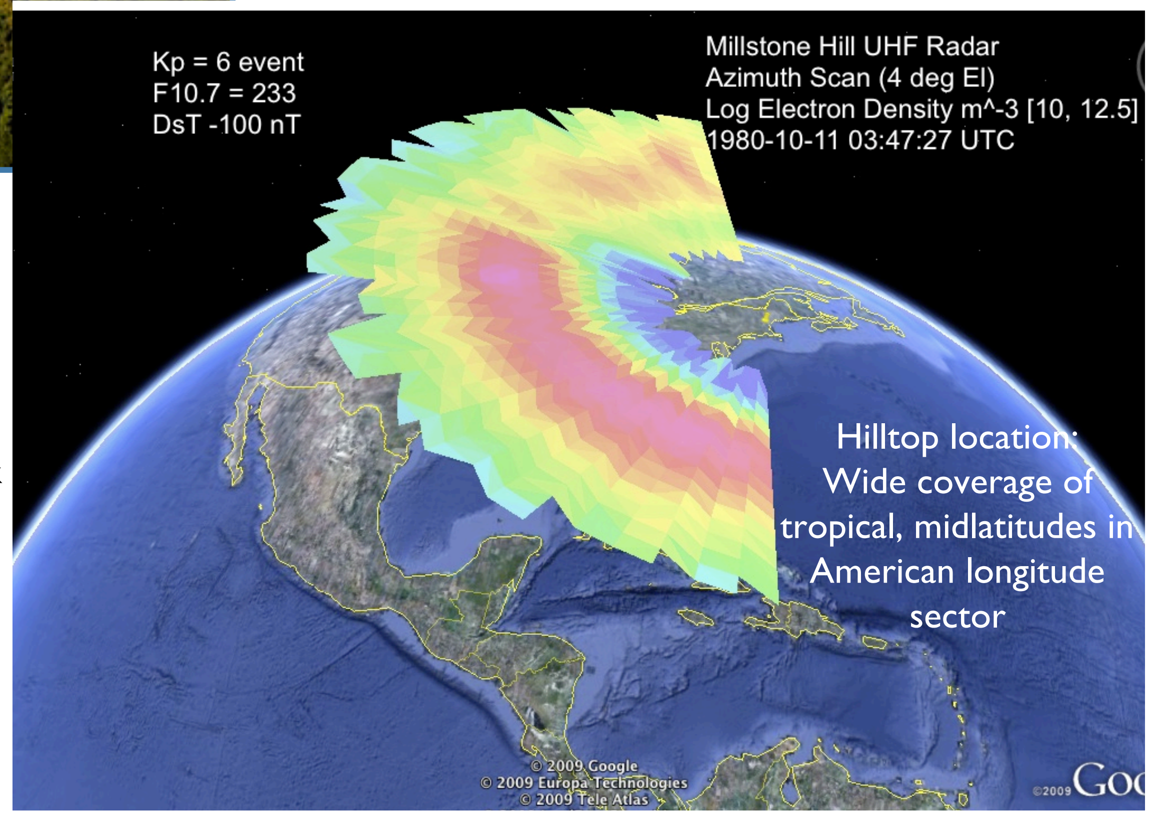
440.2 MHz frequency
2.5 MW peak TX
System temperature ~150-200 K overall

Fully steerable 46m antenna
68m zenith antenna

In operation since 1960

Litton 5773 UHF klystrons

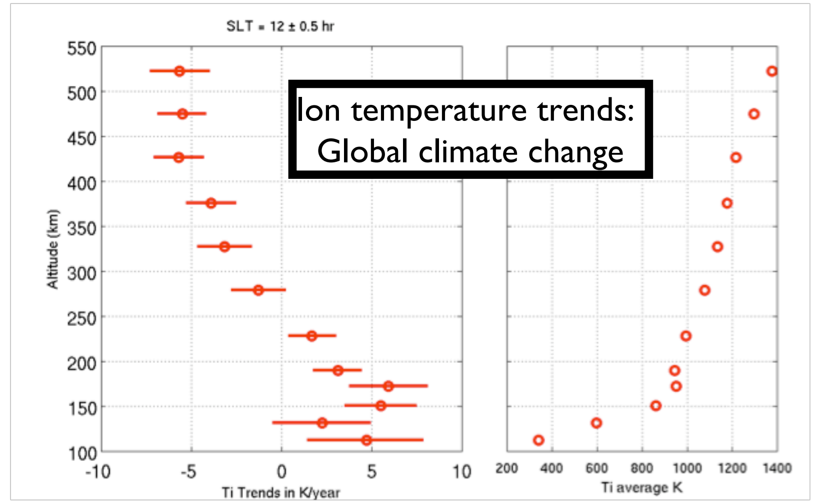
2 x 1.25 MW peak
6% max duty cycle



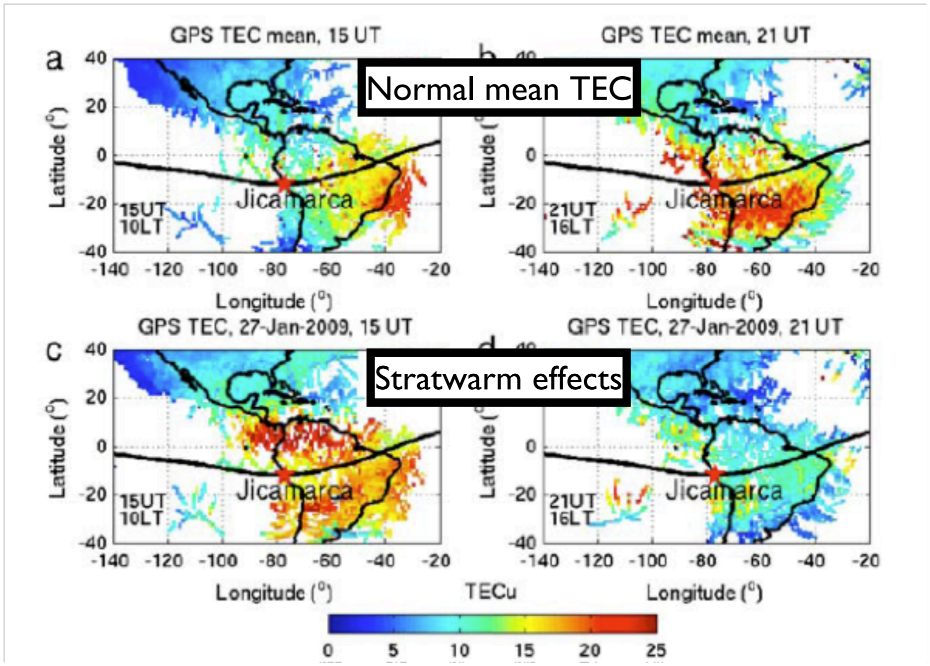
Millstone Hill
Geospace Science Center

- Modernized control, receiver area
- Displays for multiple instruments
- Smartboards for interactive teaching
- Community resource for coordinated campaigns, workshops
- Focus for North American Regional Distributed Arrays (DASI) activities

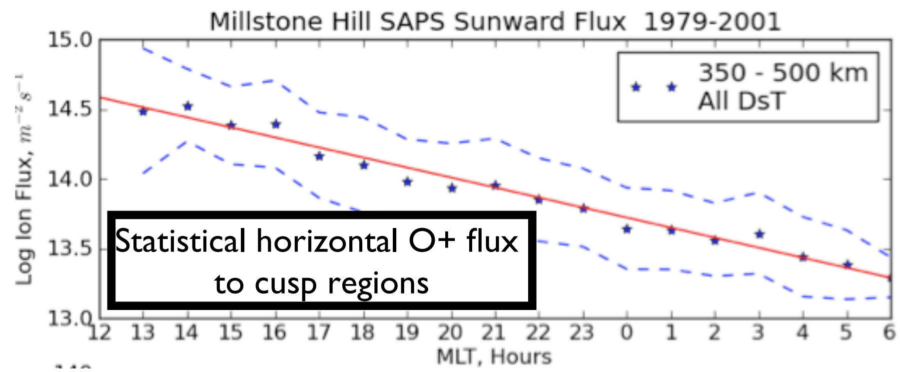
Millstone Hill research: Geospace System Science



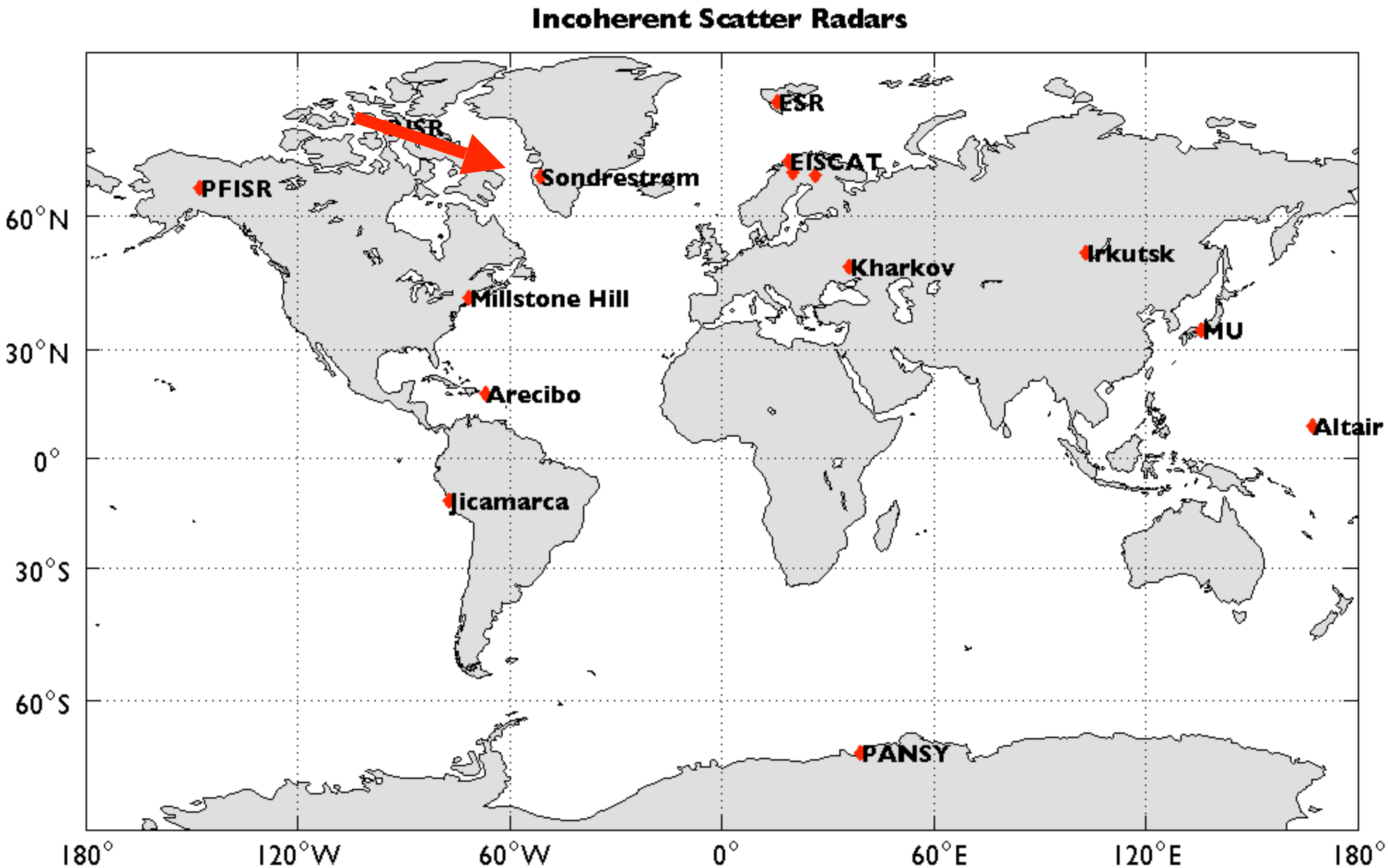
Long term ionospheric trend studies
Zhang, Holt



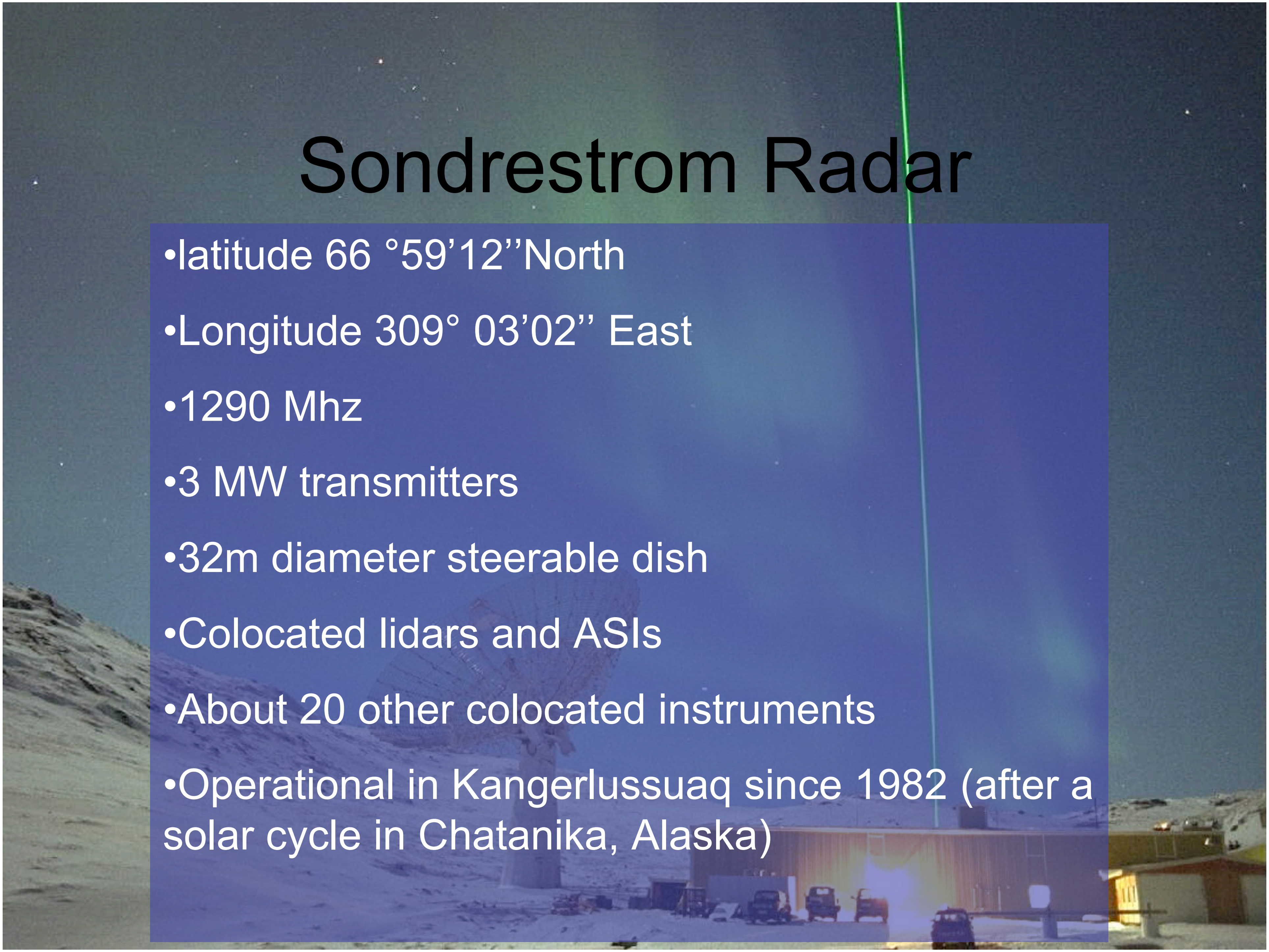
Lower/upper atmospheric coupling
[Stratospheric sudden warming]
and mesoscale effects on ionosphere, thermosphere
Goncharenko, Coster



Subauroral ionospheric redistribution
in SED/SAPS regions
Erickson, Foster, Coster



Map: Thomas Ulich



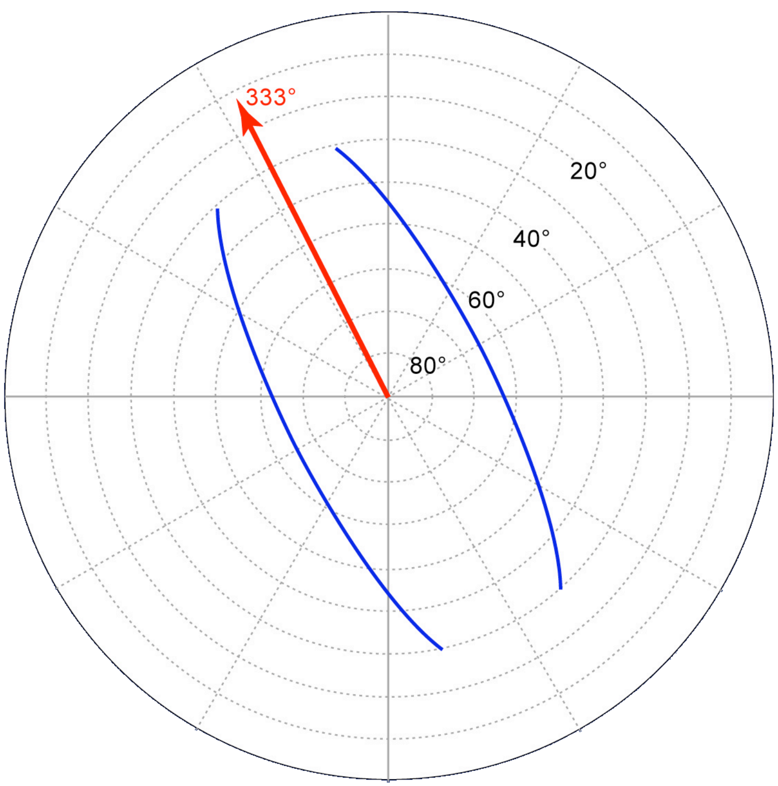
Sondrestrom Radar

- latitude 66 °59’12’’North
- Longitude 309° 03’02’’ East
- 1290 Mhz
- 3 MW transmitters
- 32m diameter steerable dish
- Colocated lidars and ASIs
- About 20 other colocated instruments
- Operational in Kangerlussuaq since 1982 (after a solar cycle in Chatanika, Alaska)

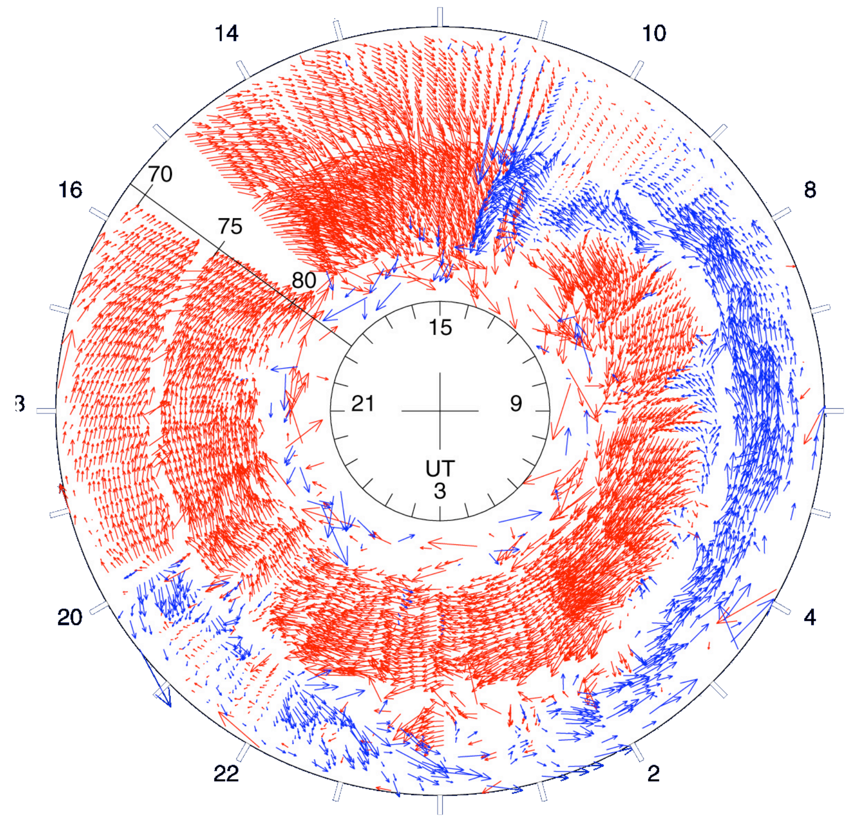

OR
BUST
XTRA


SØNDRESTRØM
OR
BUST

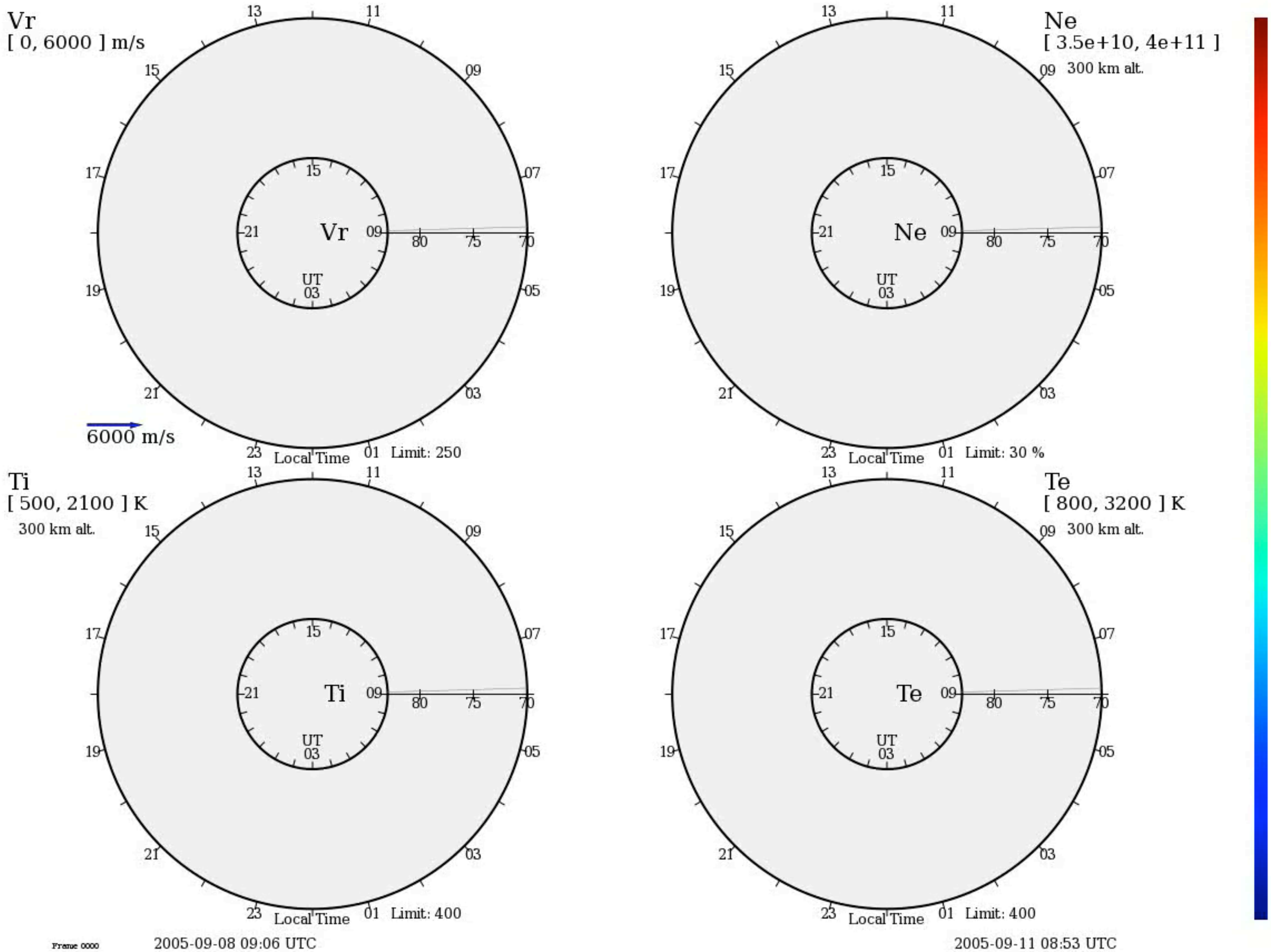
Ion Velocity (E-field) Maps



Composite Scans for
E-field Estimation

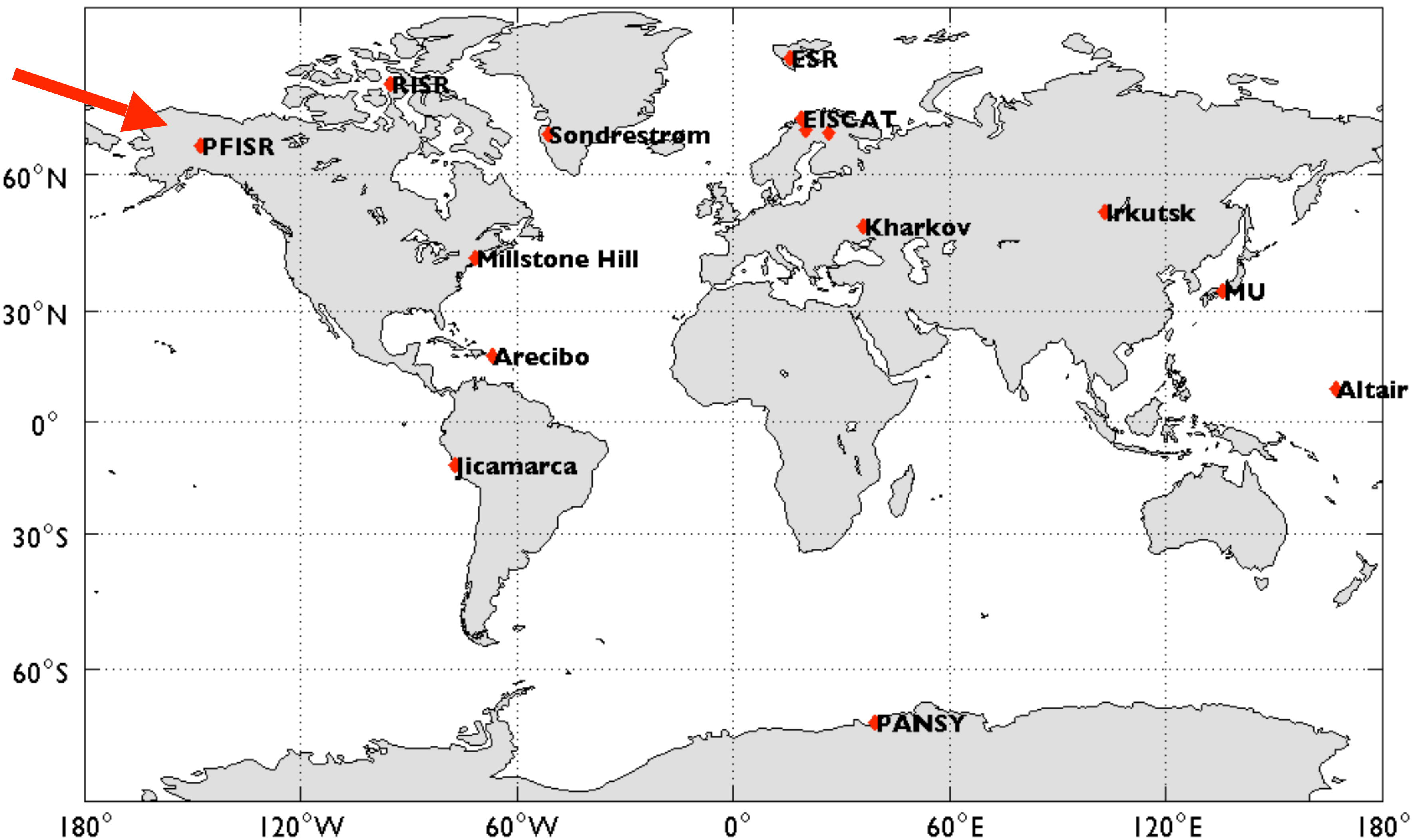


v9



Vr
[0, 6000] m/s
6000 m/s
Local Time
Limit: 250
UT
Ne
[3.5e+10, 4e+11]
300 km alt.
Limit: 30 %
Ti
[500, 2100] K
300 km alt.
Limit: 400
Te
[800, 3200] K
300 km alt.
Limit: 400
80
75
70
Frame 0000
2005-09-08 09:06 UTC
2005-09-11 08:53 UTC

Incoherent Scatter Radars



Map: Thomas Ulich

…but first some general words about AMISR…

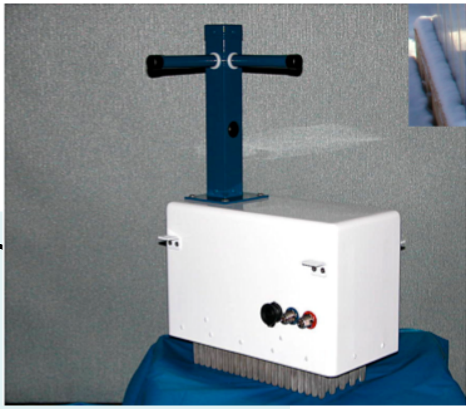
AMISR

- First US ISR designed under NSF funding for pure scientific research
- First modular pulse-to-pulse steerable Incoherent scatter radar

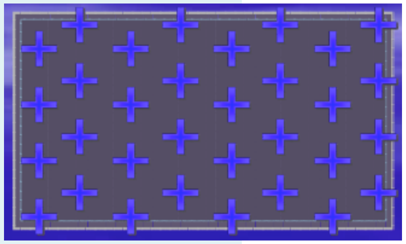
Abbriviations!!!!

- AMISR - Advanced Modular Incoherent Scatter Radar
  - Refers to the technology and the overall kind of radar
- PFISR - Poker Flat Incoherent Scatter Radar
  - An AMISR radar located in Poker Flat, Alaska
- RISR-N - Resolute Bay Incoherent Scatter Radar - North (toward ESR!)
  - An AMISR Radar in Resolute Bay, Canada. Pointing northward
- RISR-S/RISR-C - Resolute Bay Incoherent Scatter Radar - South/Canada
  - An AMISR radar under construction in Resolute Bay, Canada. Pointing South. Funded (and owned) by Canada. Official name RISR-C

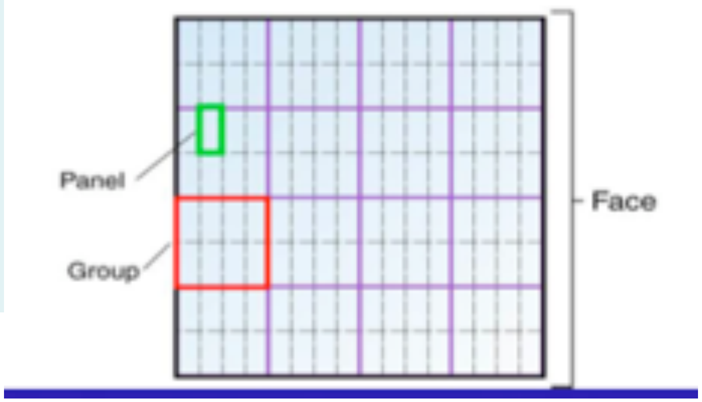
The lego set



- AMISR: Advanced Modular Incoherent Scatter Radar
- AEU: Antenna element unit (4096 per radar)



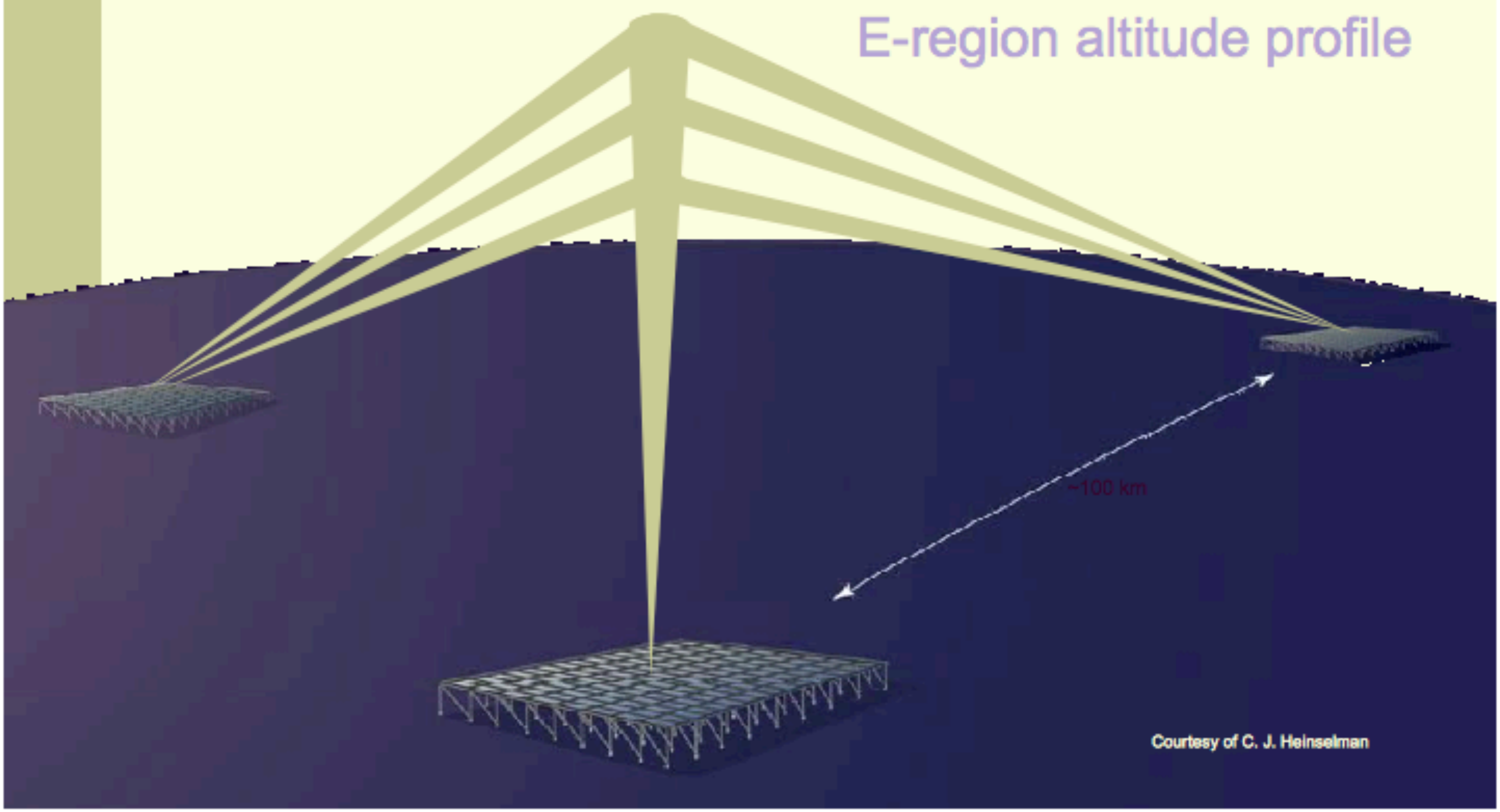
- Panel: smallest “lego” piece (consist of 32 AEU)
- Group: Set of Panels (consist of 8 panels)
- Face: Set of groups (one complete radar (“Face”) consist of 16 groups, 128 panels, 4096 AEU...)



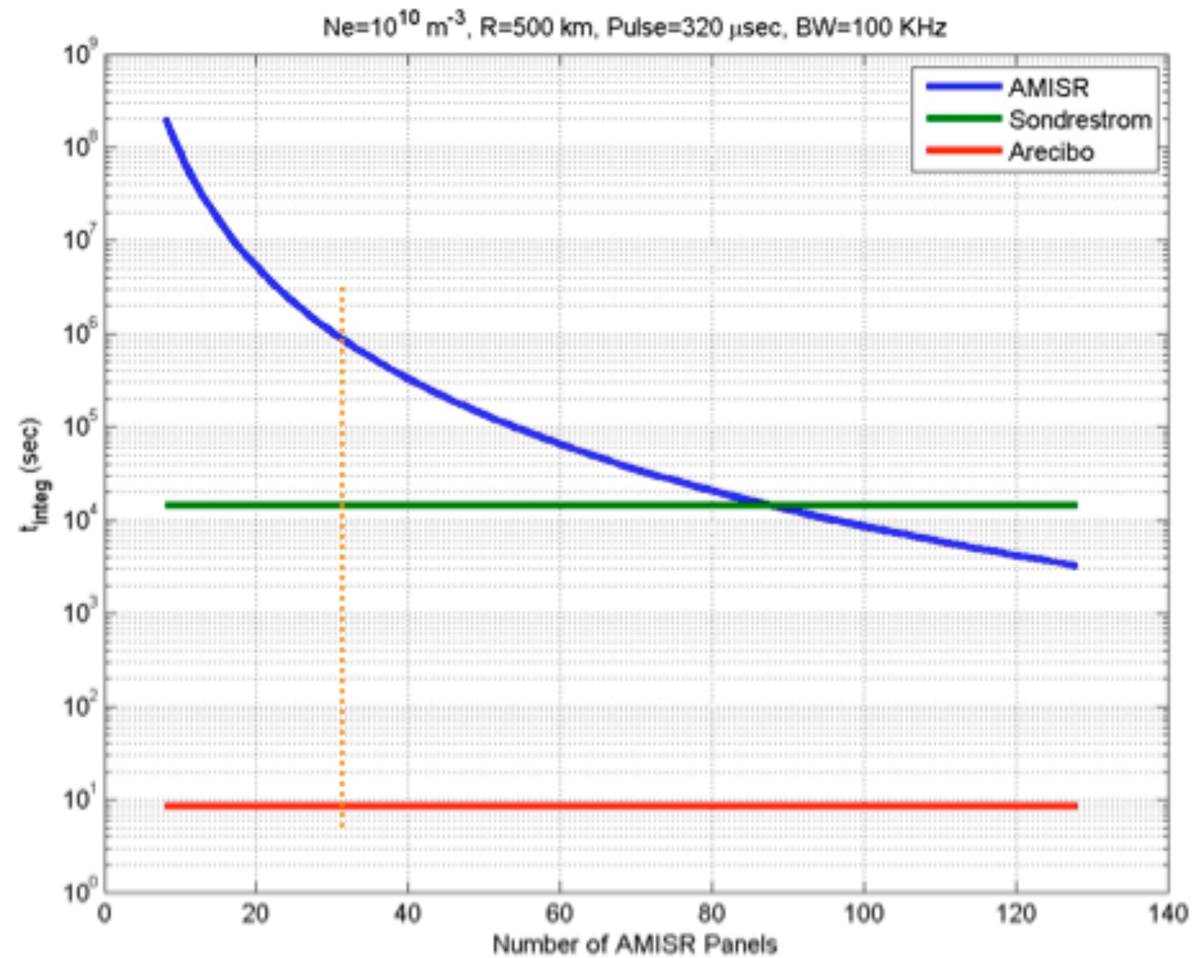
More about the “current” AMISR

- NSF originally funded 3 full faces. Funding was sufficient to two (and a bit)
  - One operational since January 2007 in Poker Flat, Alaska (PFISR)
  - Second operational since Dec 2009 in Resolute Bay, Canada (RISR-N)
  - A collaboration with Canada will lead to the completion of the third face of the original AMISR plan (RISR-S now RISR-C).
- Modular/Transportable/Reconfigurable
- Phased array - pulse-to-pulse steering
- Solid state
  - No moving parts, can hence be remotelly controlled
- Gentle degrade
- 430-450 MHz TX frequency
- ~2 MW peak power per radar (10% duty cycle)
- 1 μs to 2 ms pulses

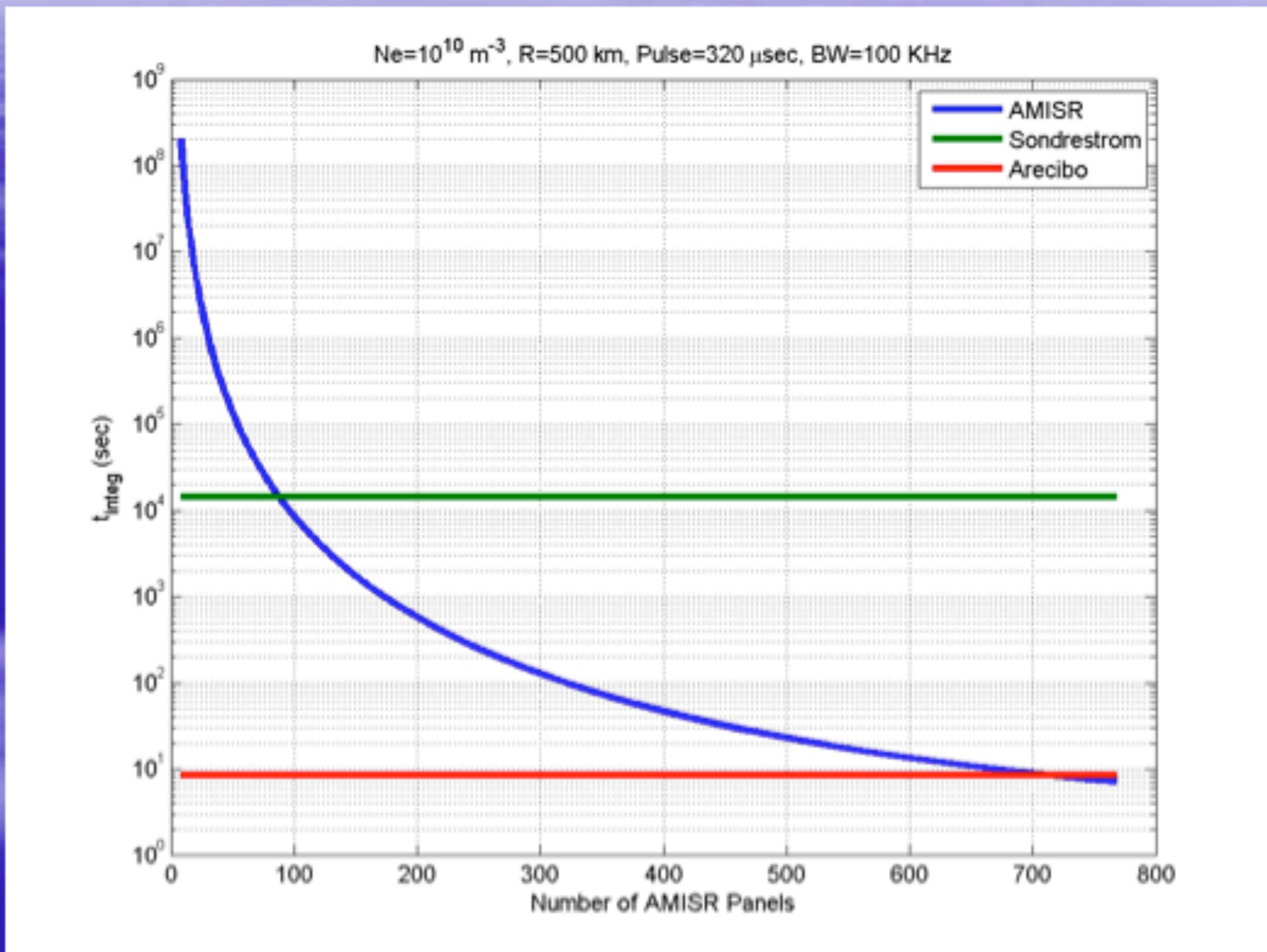
Tristatic Configuration



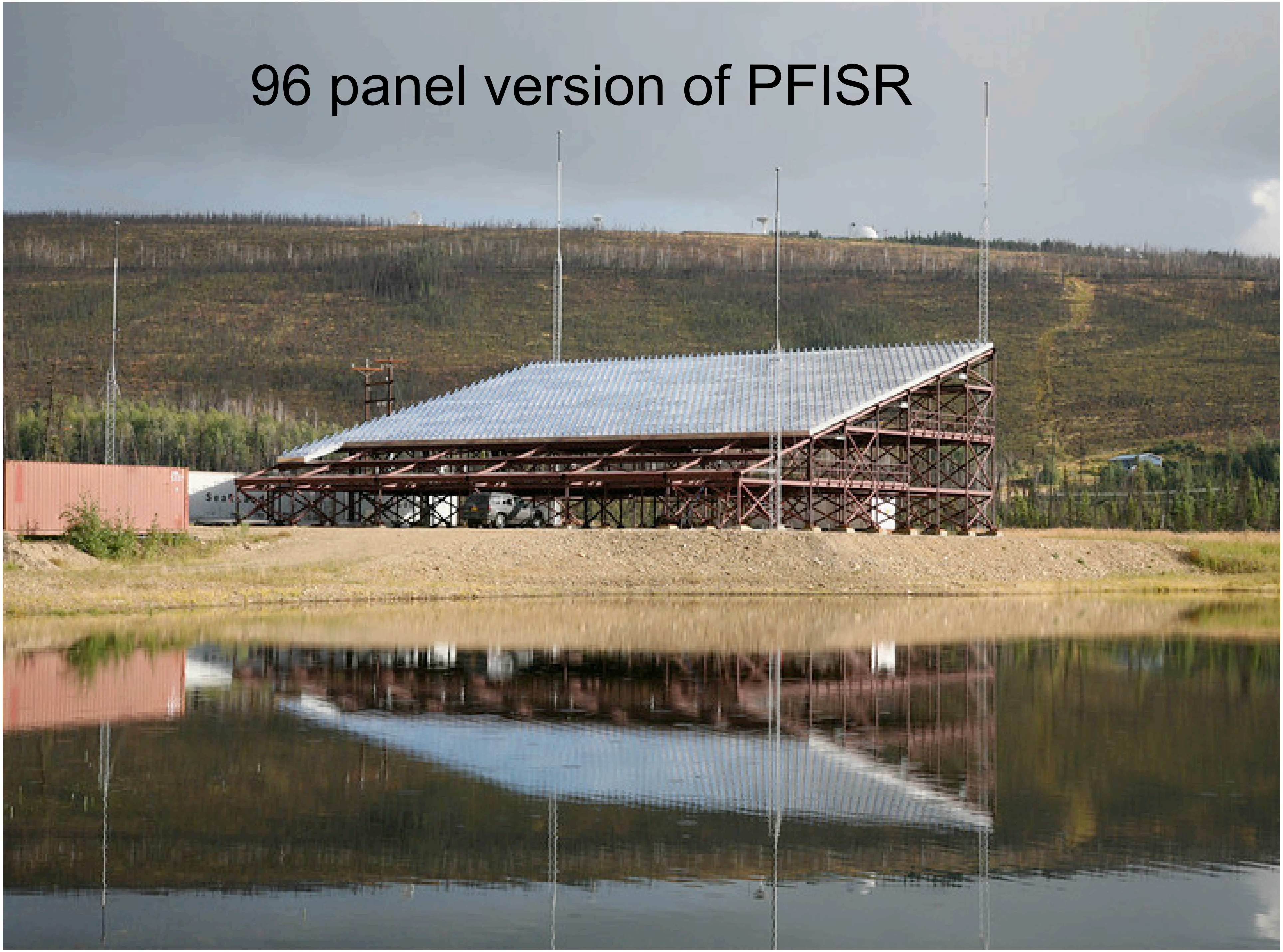
AMISR Sensitivity vs. Size



AMISR Sensitivity vs. Size

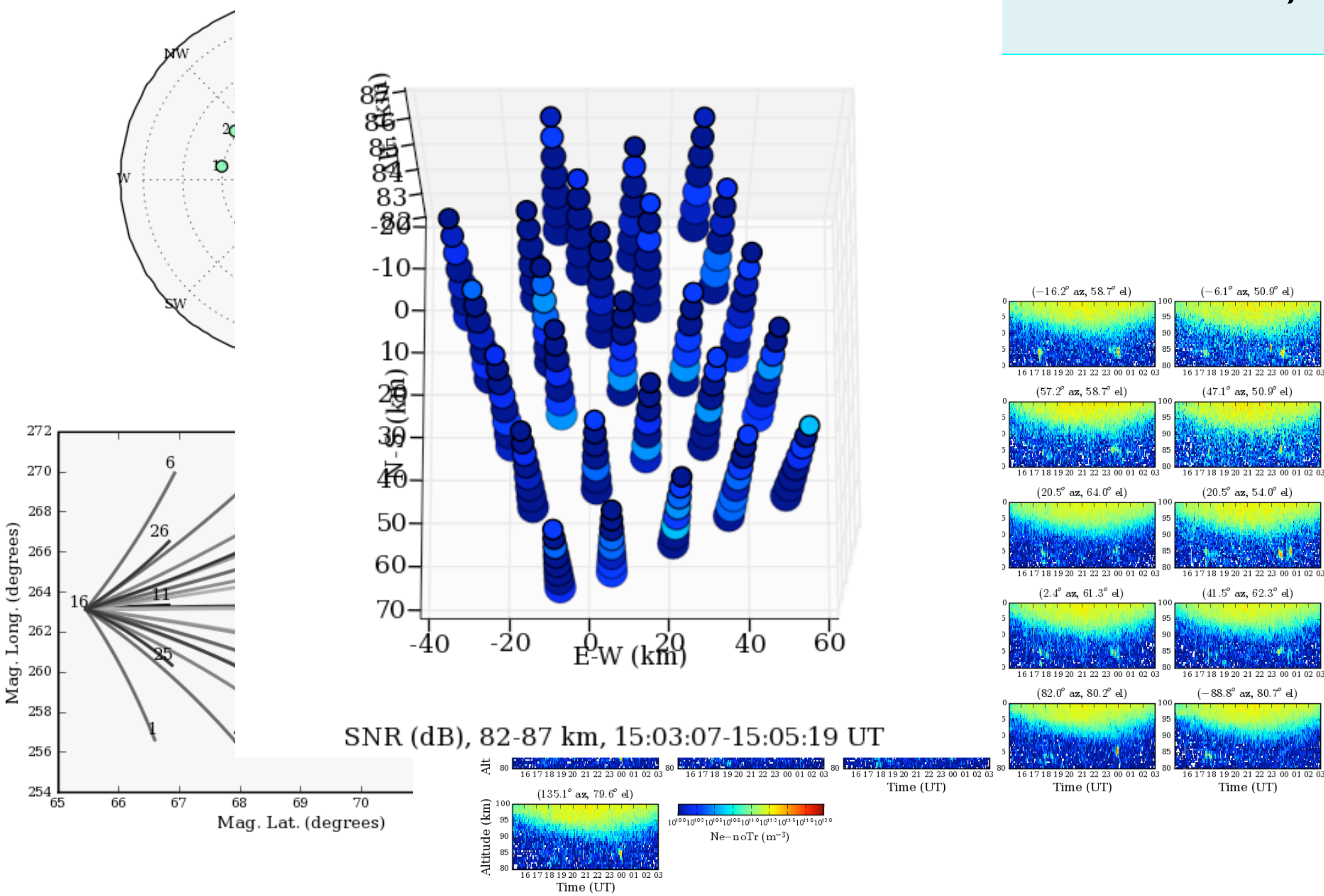


96 panel version of PFISR

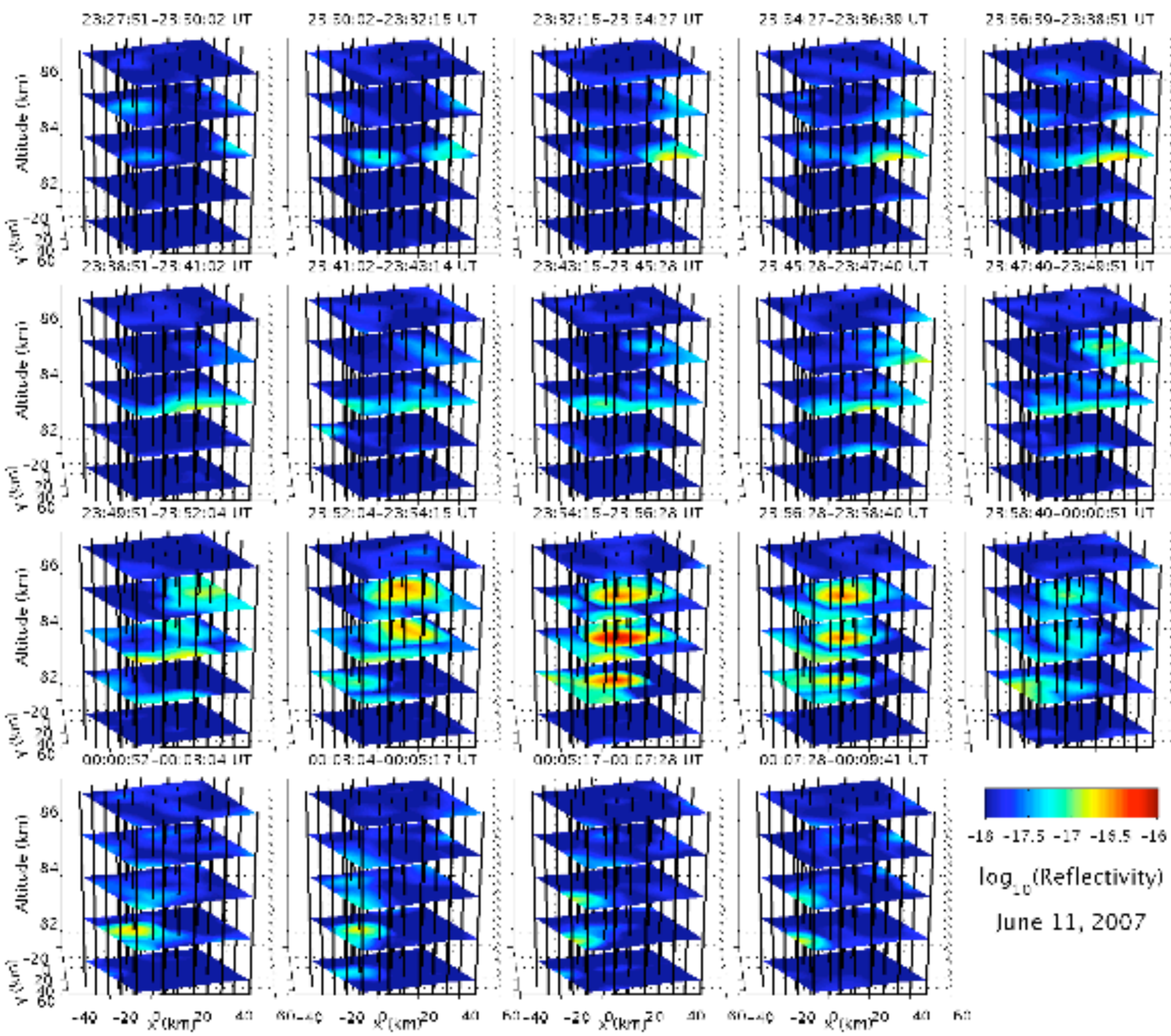


PFISR

ospheric Summer Echoes)

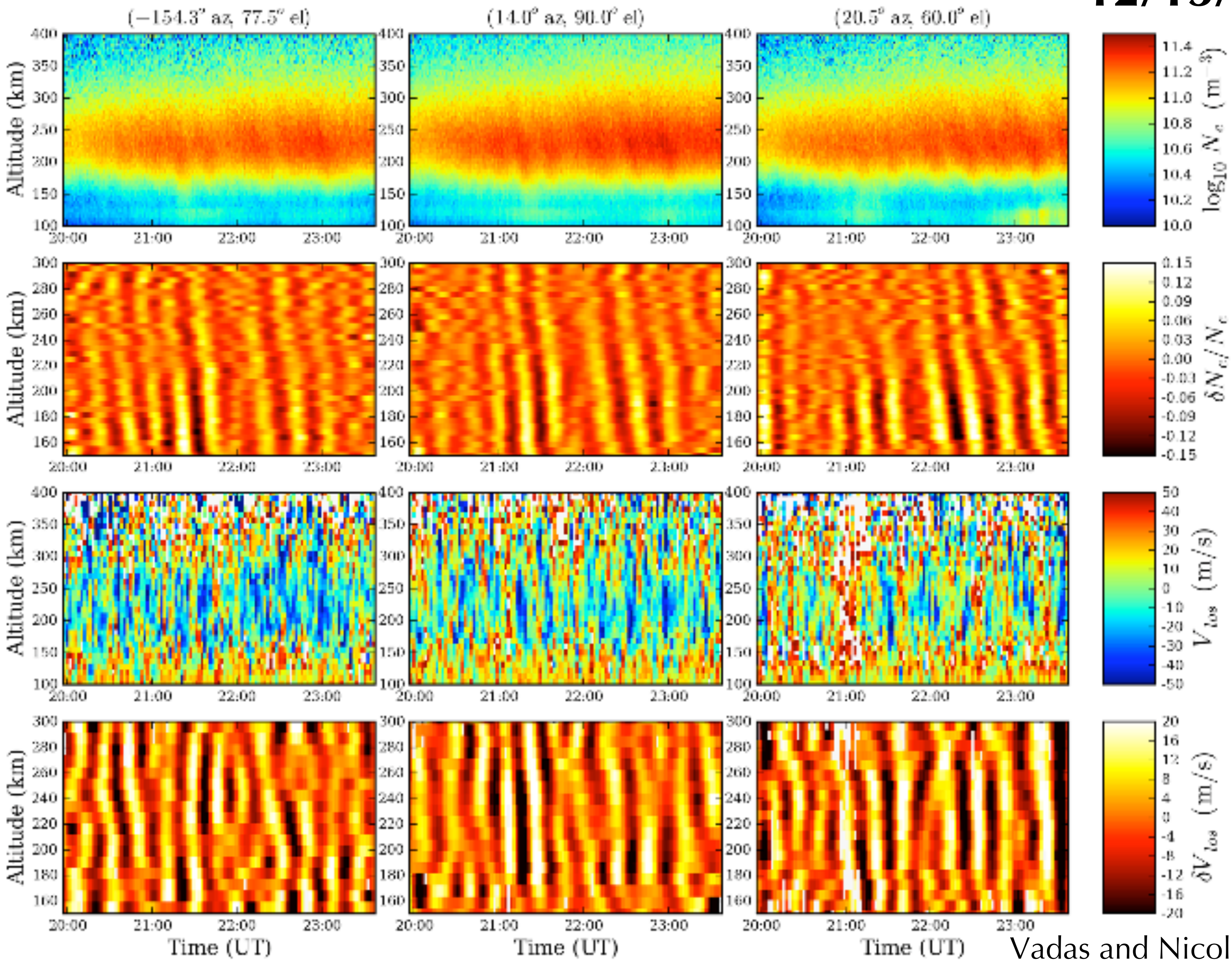


Imaging PMSE over Poker Flat



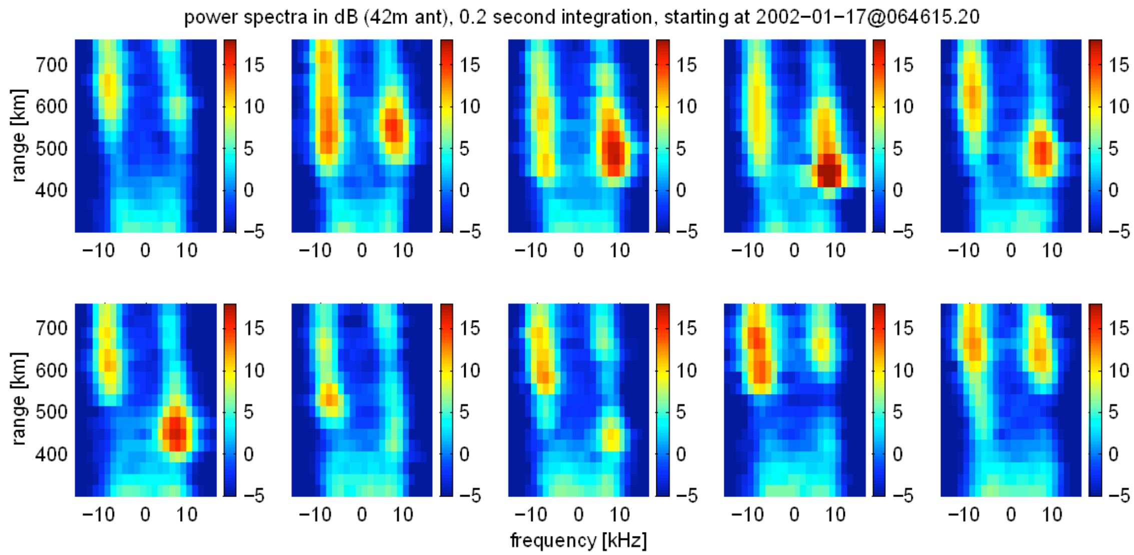
Ionospheric-Atmospheric Coupling

12/13/2006



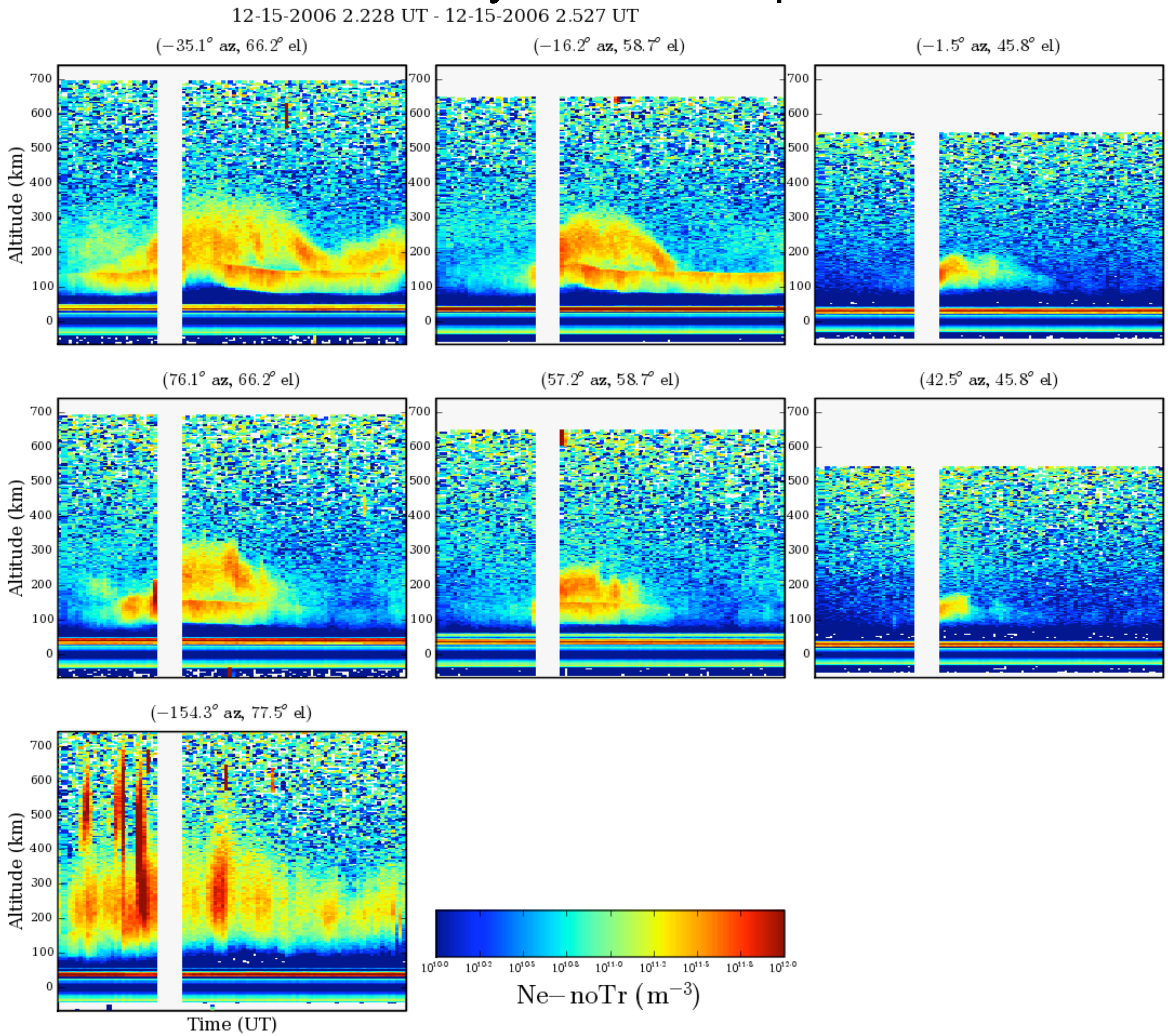
Vadas and Nicolls (2007)

Naturally enhanced ion-acoustic lines (NEIAL):

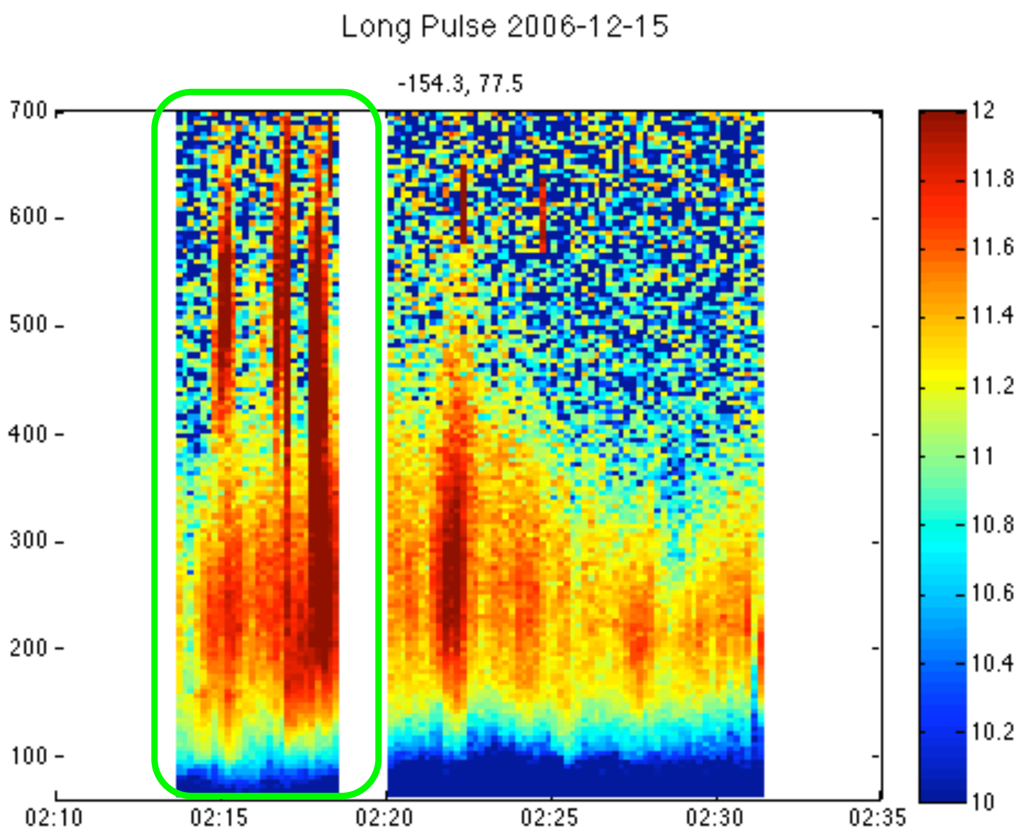


- Order of magnitude enhancement in either or both ion-acoustic lines.
- Over extended altitude range (300 km and up).
- Aligned with the geomagnetic field.
- Rapidly varying in time.

Raw density in all the 7 positions

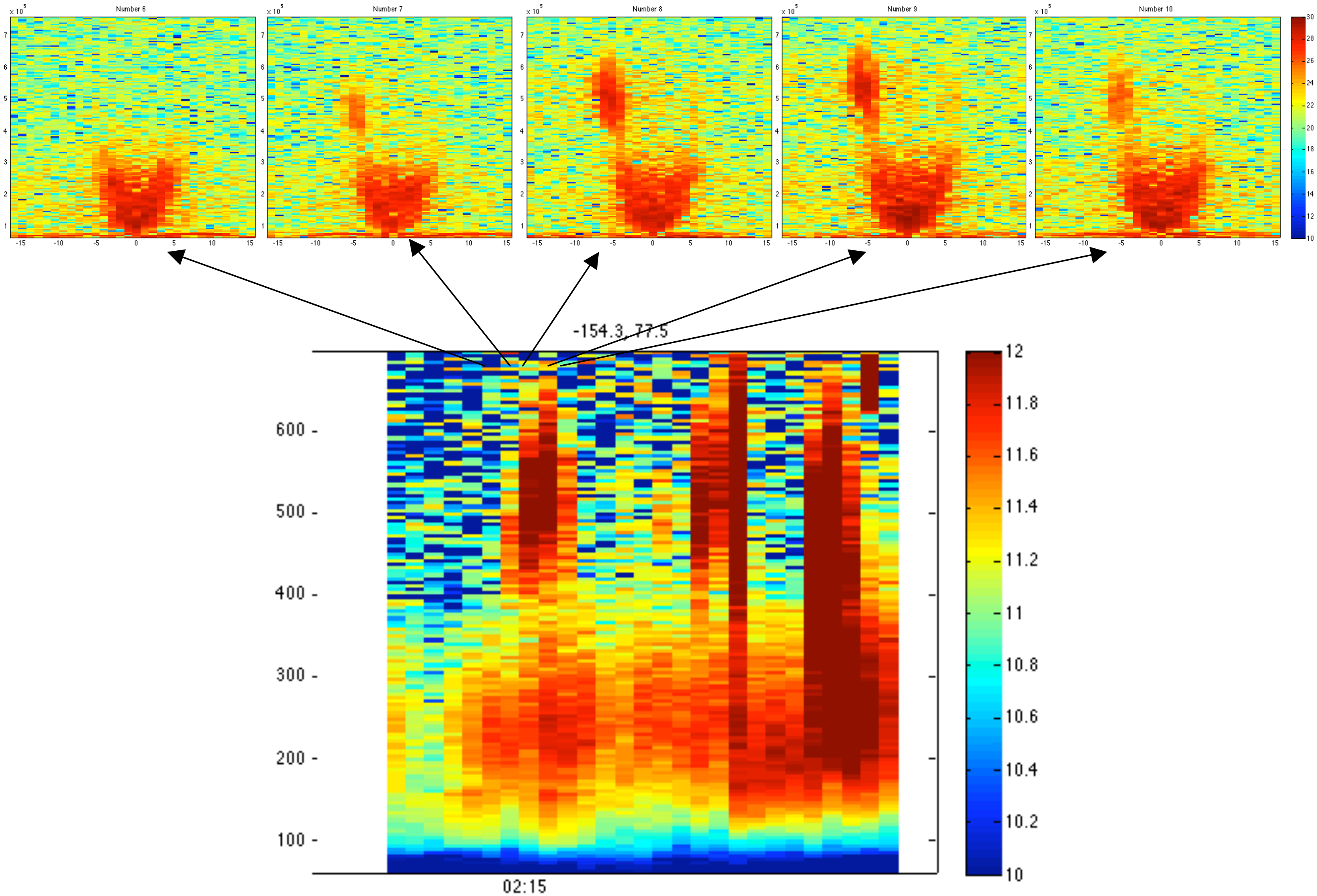


Strong Coherent Elongated Structures in the upper F-region

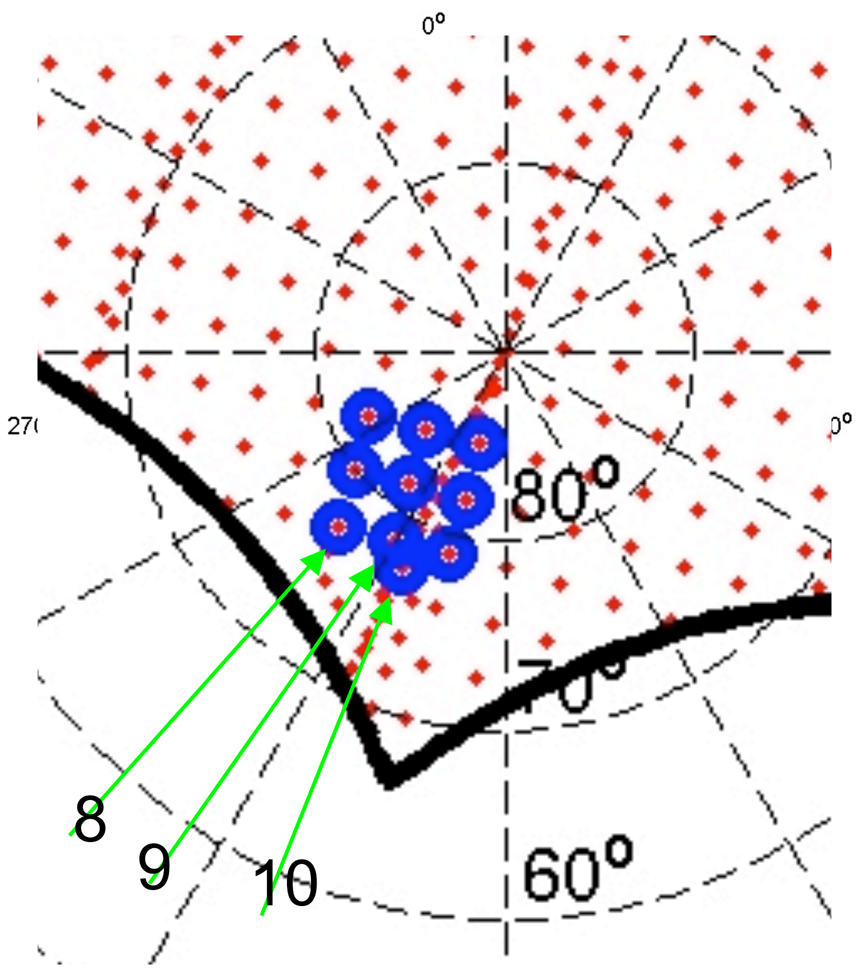


PFISR raw electron densities 15. Dec 2006

The Ion Line Spectra are Enhanced and Asymmetric



The Experiment Stromme01

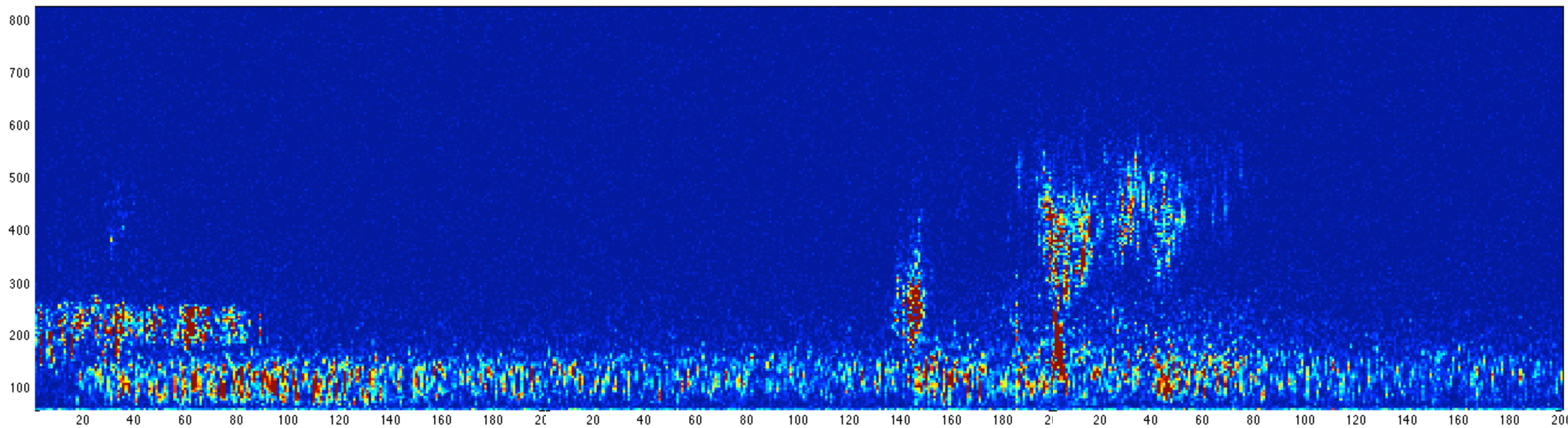


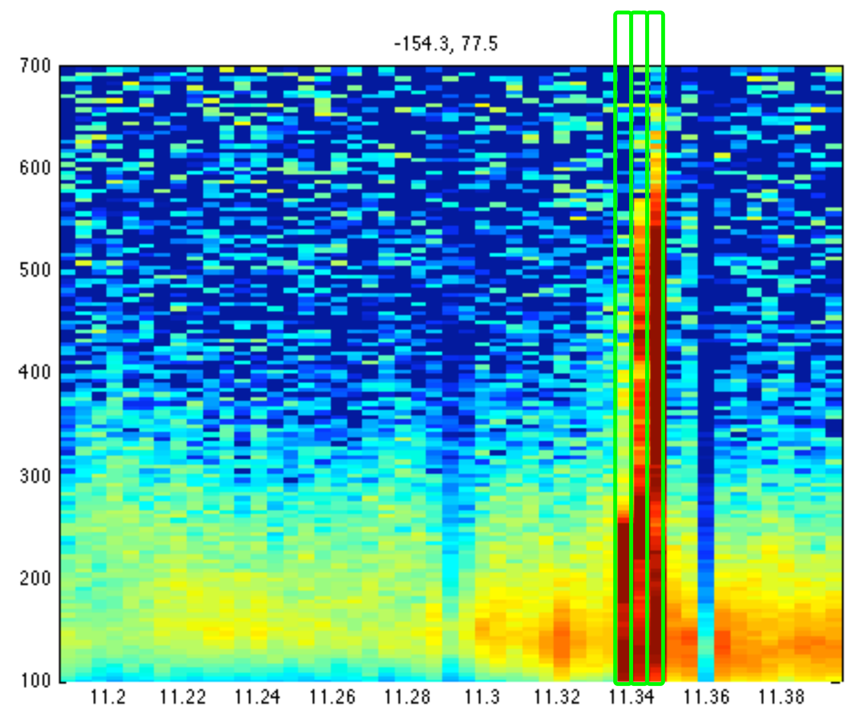
- 9 positions in 3 degree grid
- 10th position up B
- 480 μs pulses (72 km range)
- Raw voltage sampling
- Plasma line data

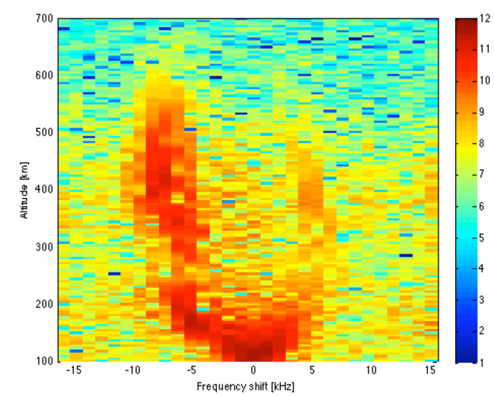
We cycle through the 10 pulses in a fixed order

- 7.5 ms between pulses
- 75 ms between pulses in same direction

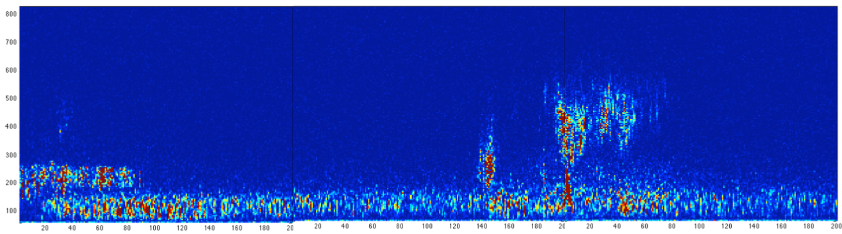
Voltage level data -> pulse-to-pulse time resolution

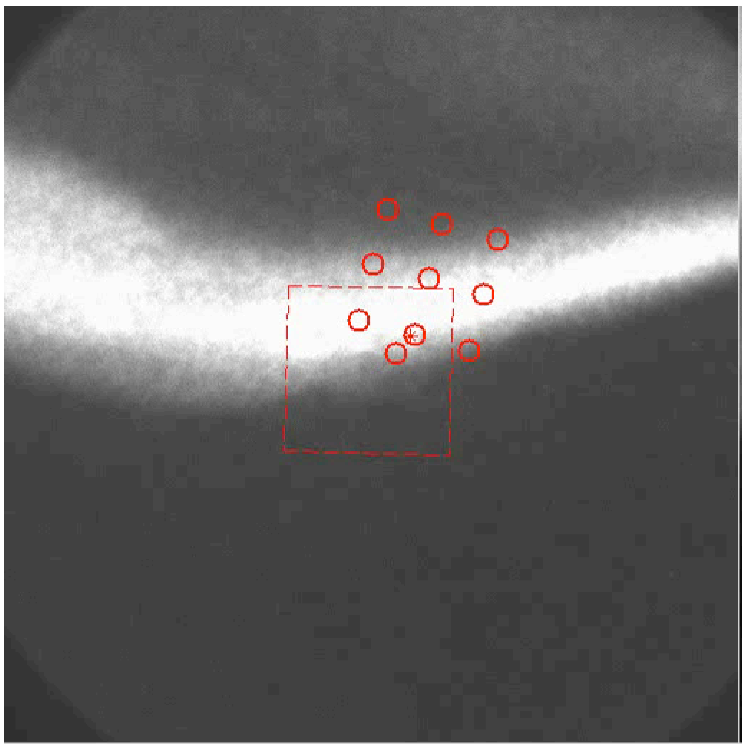


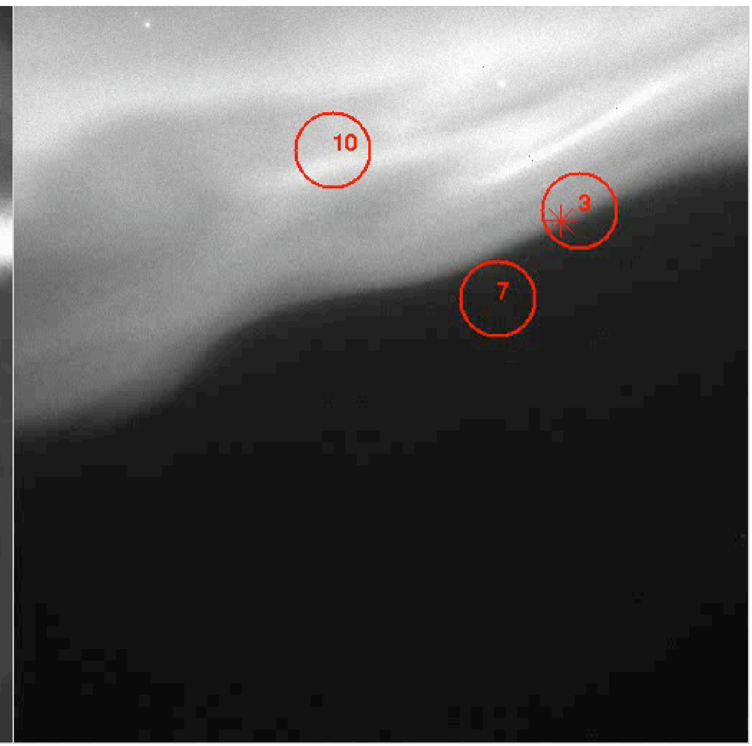




High Resolution PFISR data and narrow field of view imagers 2007-03-23

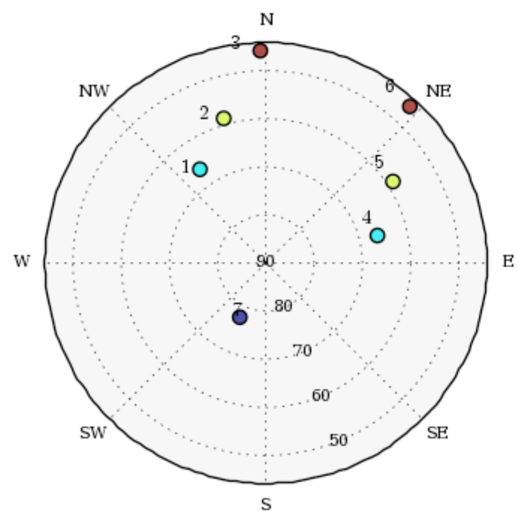


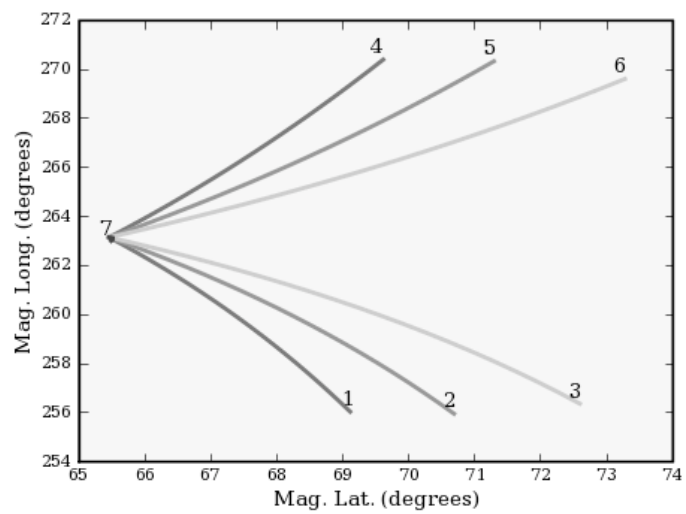




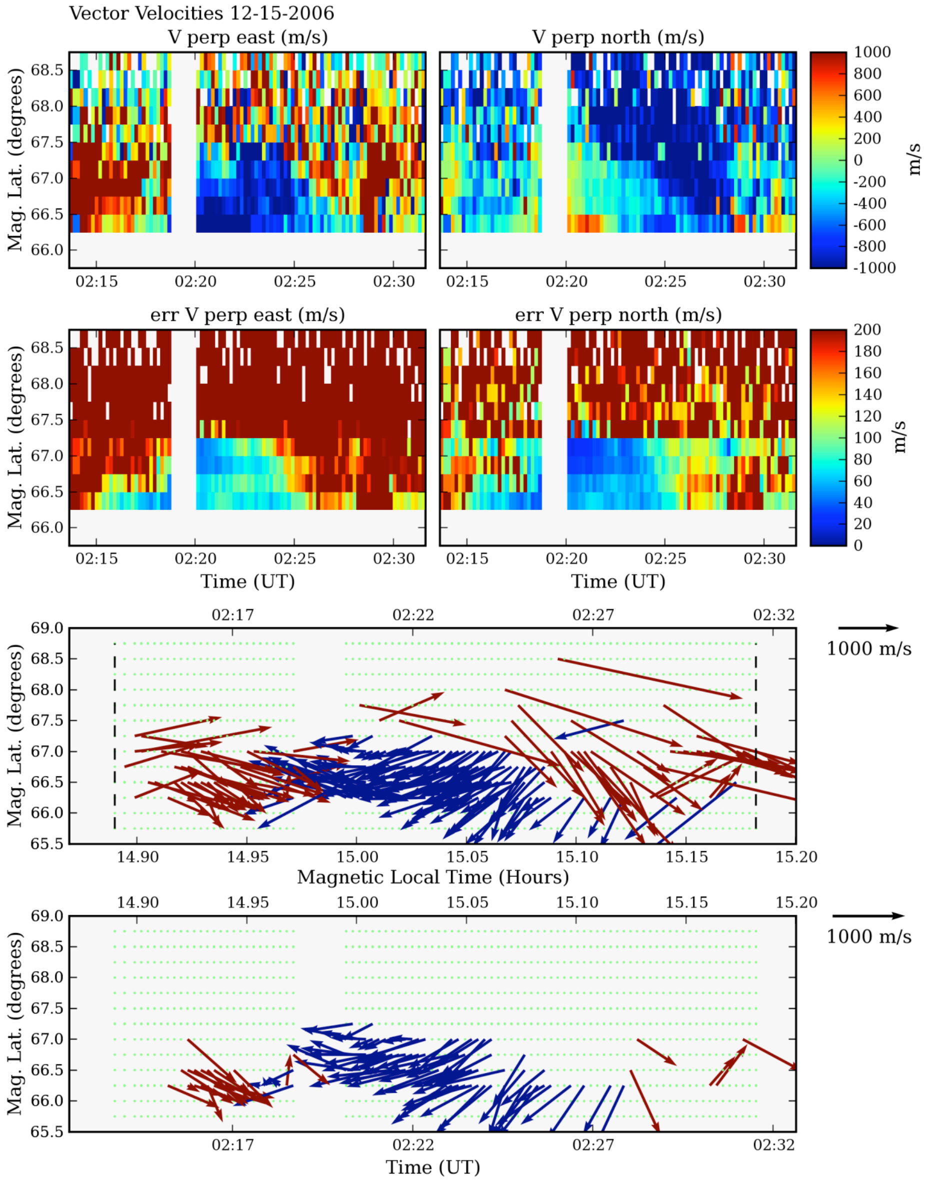
Courtesy of Joshua Semeter

E-fields with AMISR



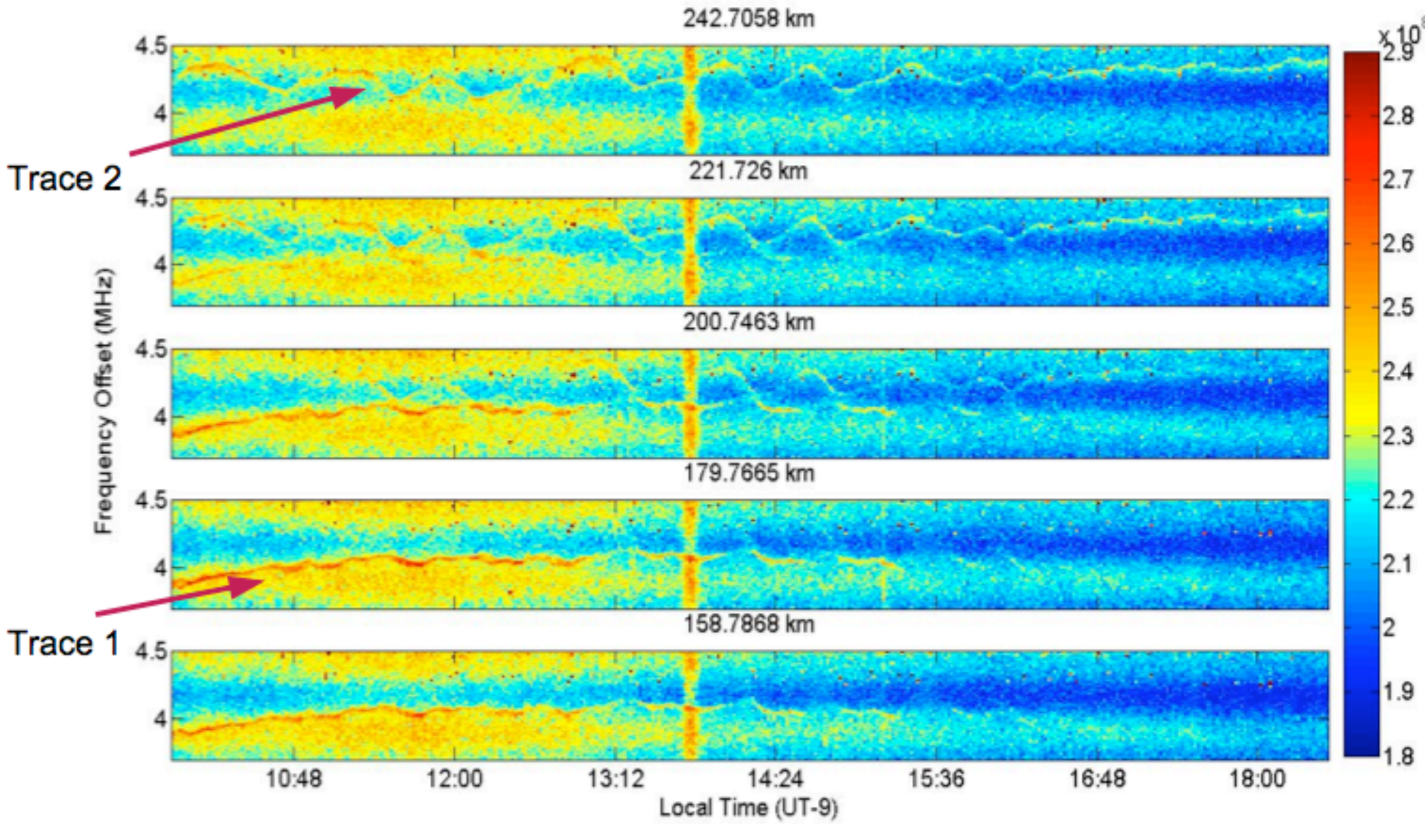


Combined velocities



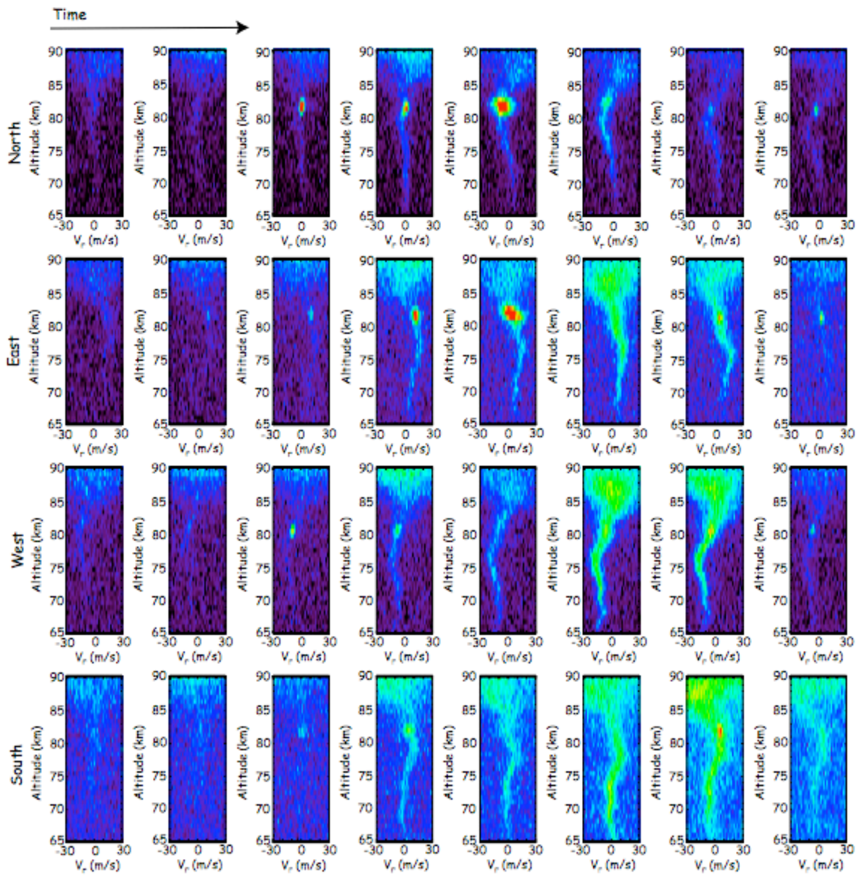
Plasma lines

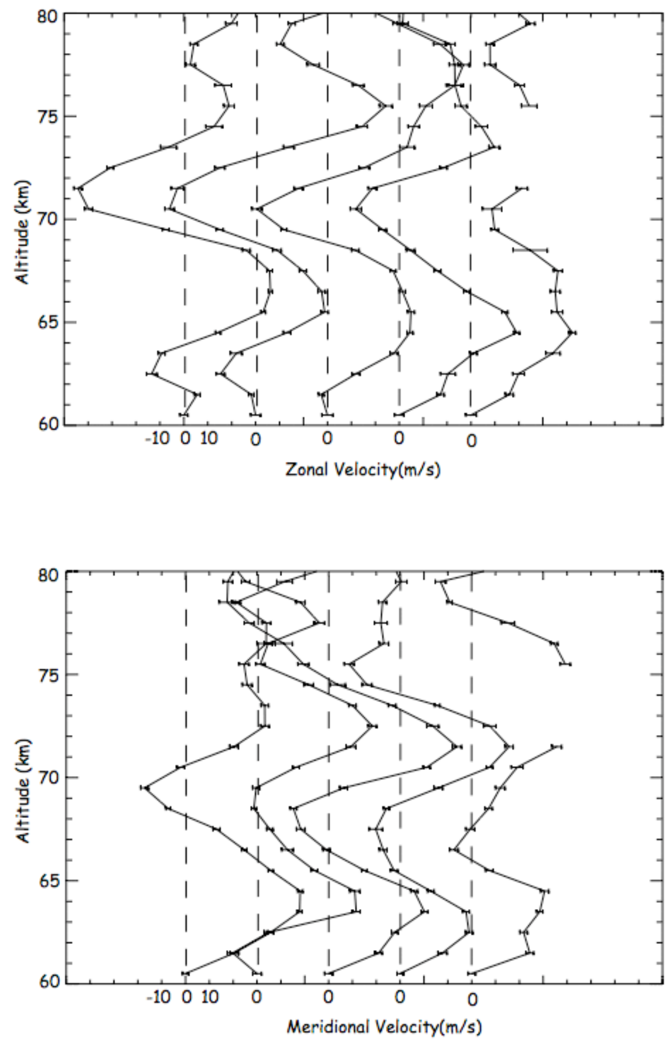
Plasma line observations



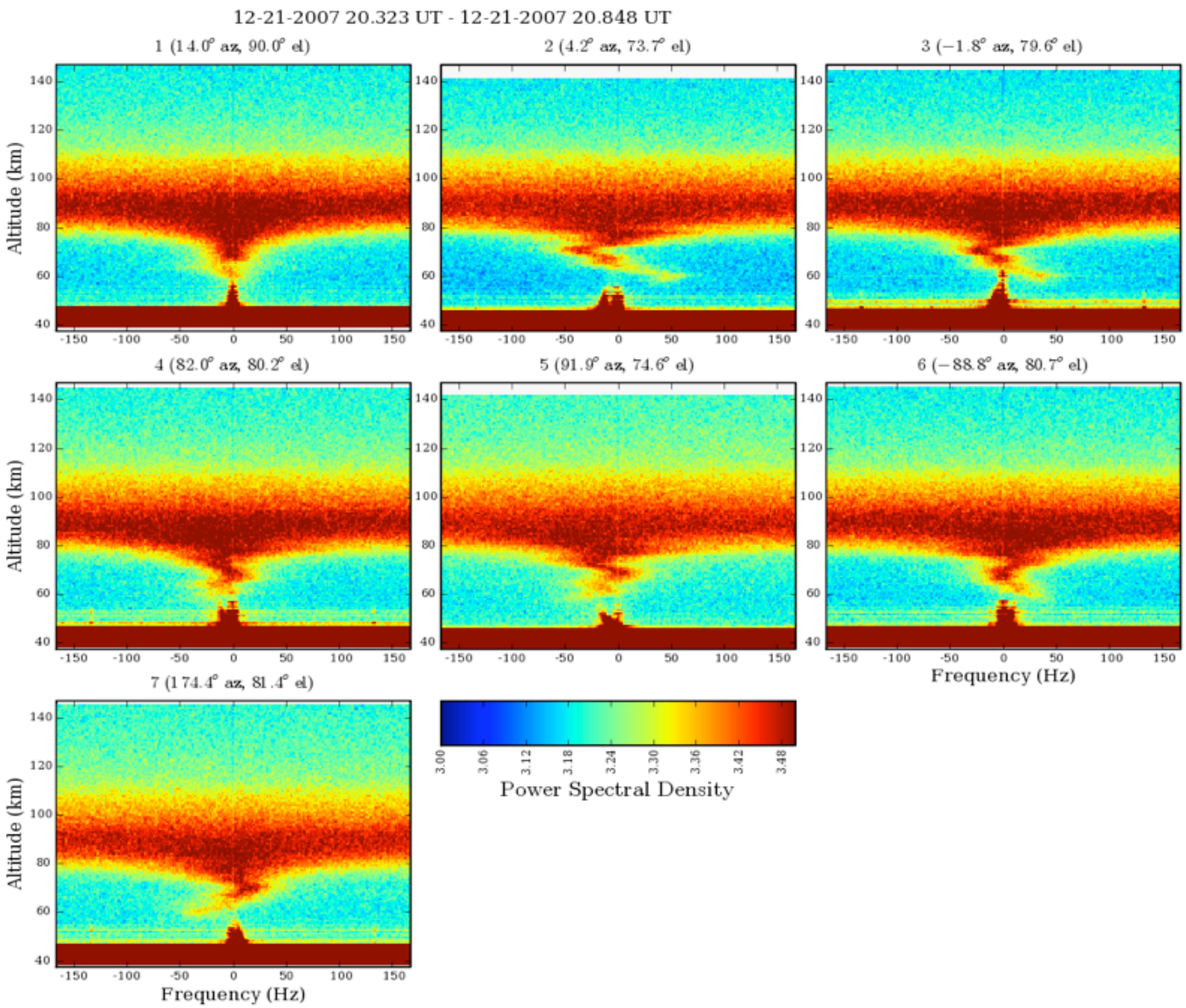
Asti Bhatt 2008

D region



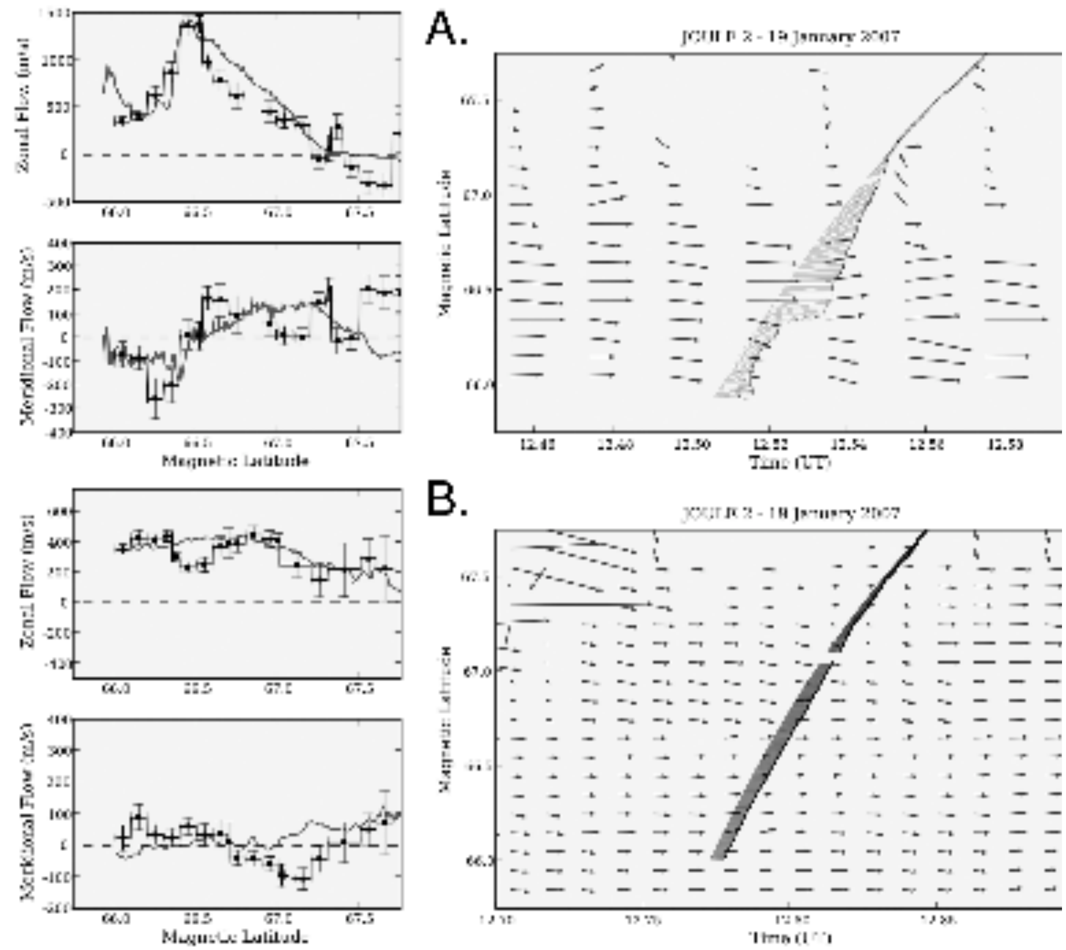


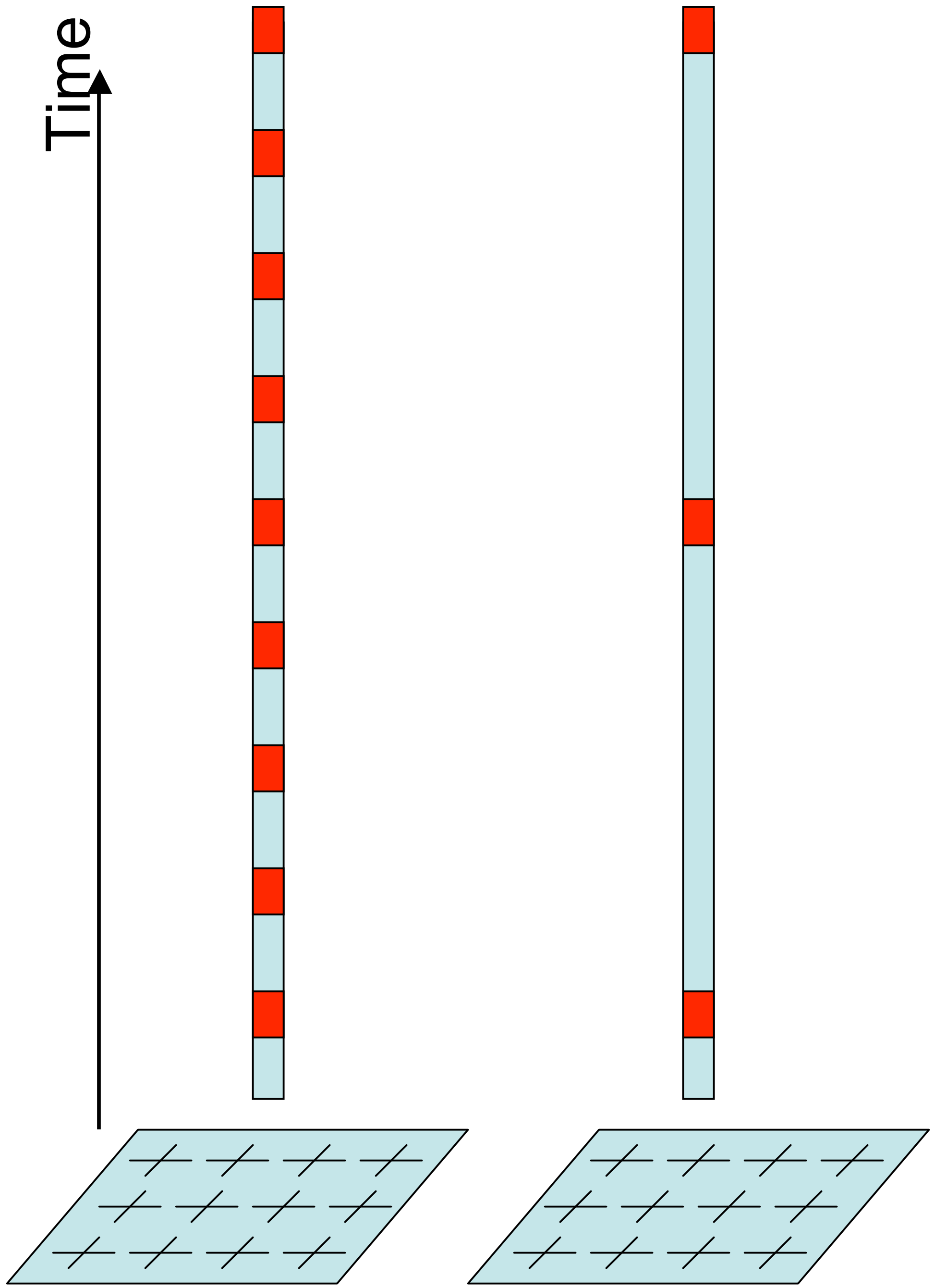
Janches et al 2009



12-21-2007 20.323 UT - 12-21-2007 20.848 UT
1 (14.0° az, 90.0° el)
2 (4.2° az, 73.7° el)
3 (−1.8° az, 79.6° el)
4 (82.0° az, 80.2° el)
5 (91.9° az, 74.6° el)
6 (−88.8° az, 80.7° el)
7 (174.4° az, 81.4° el)
Altitude (km)
Frequency (Hz)
Power Spectral Density

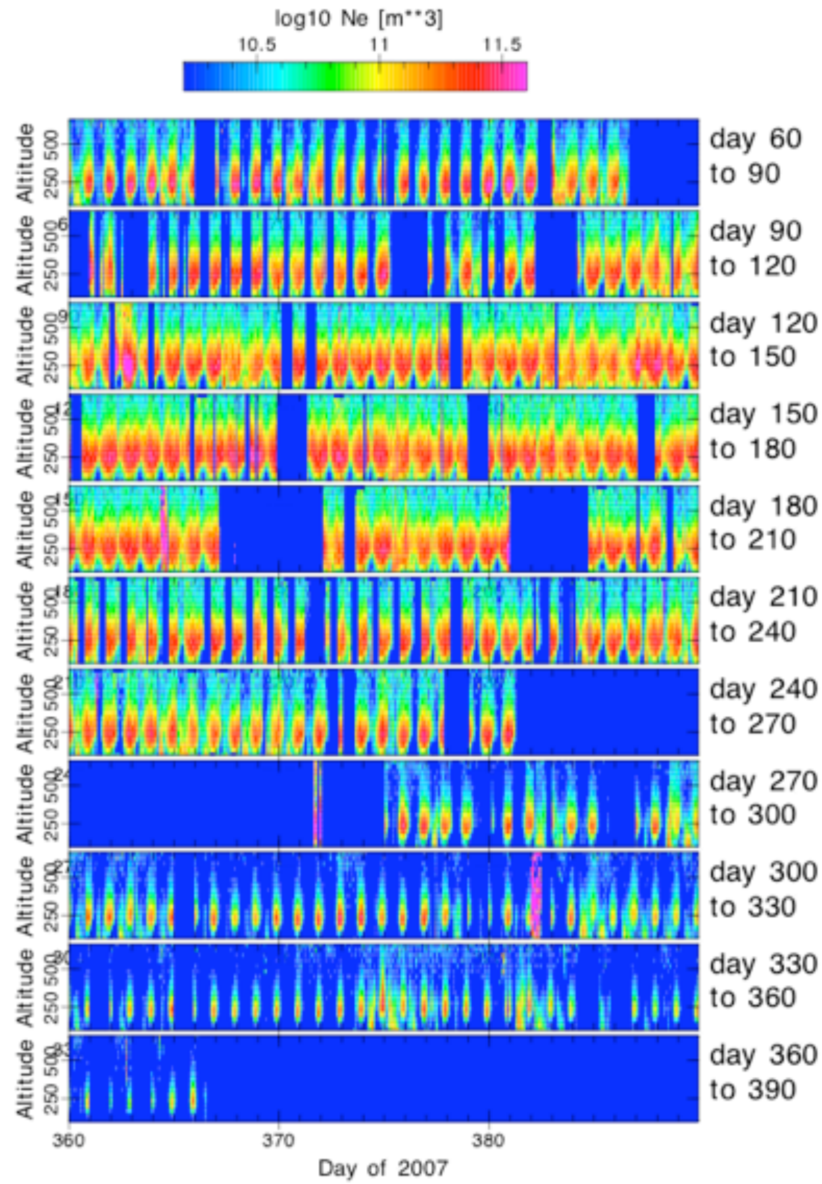
Joule 2 and PFISR

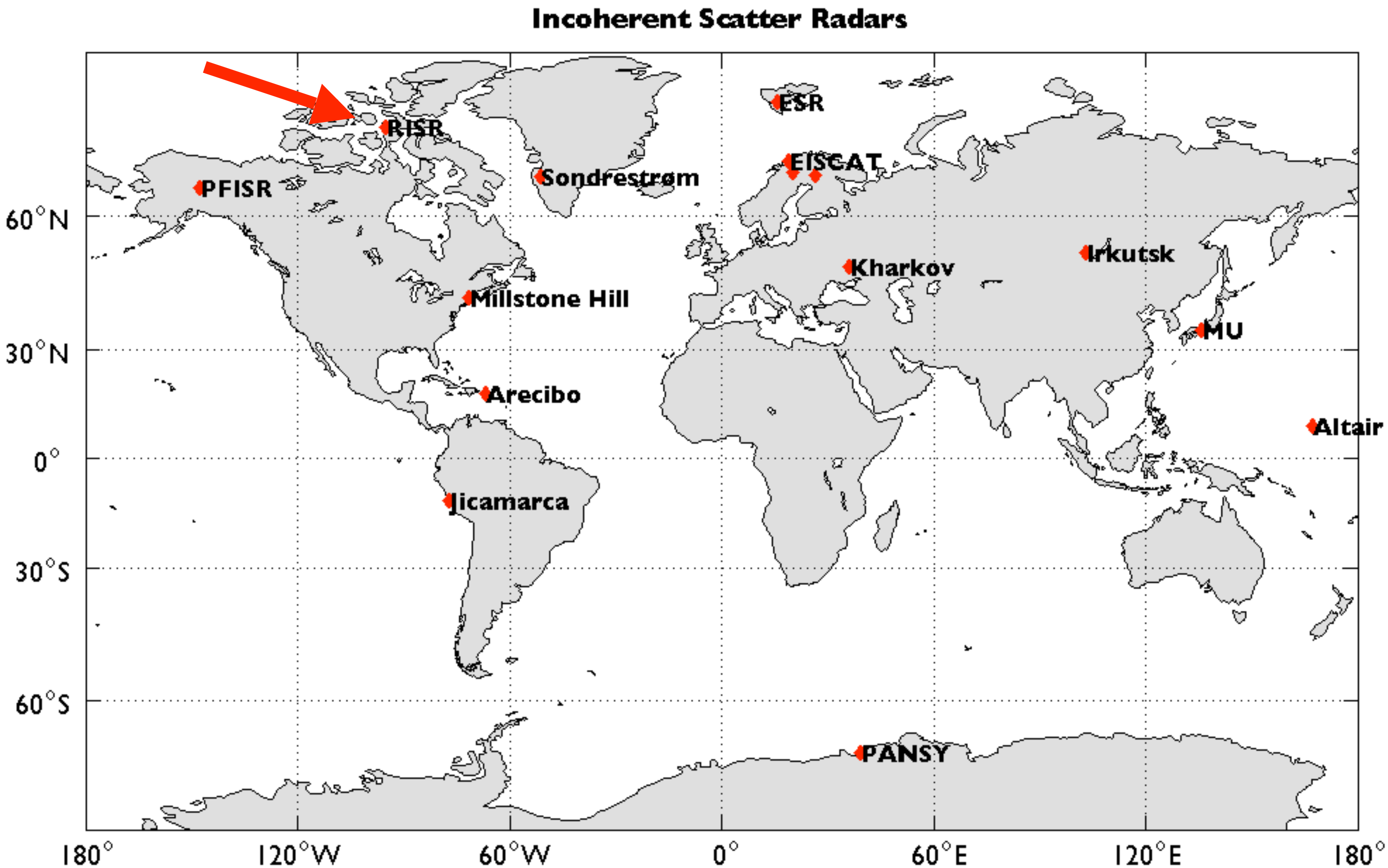



Time

International Polar Year Support

- EISCAT Svalbard Radar and PFISR are operating 24 hours per day in support of the IPY
- Low duty-cycle, single beam mode at PFISR (some augmentation)
- Longest *ever* IS ionospheric dataset
- Supposed to emphasize “quiet time variability” - coupling from below





Map: Thomas Ulich

Photo: John Kelly


Photo: John Kelly

Photo: John Kelly


VOLVO
Photo: John Kelly

Photo: John Kelly

Photo: John Kelly


Photo: John Kelly

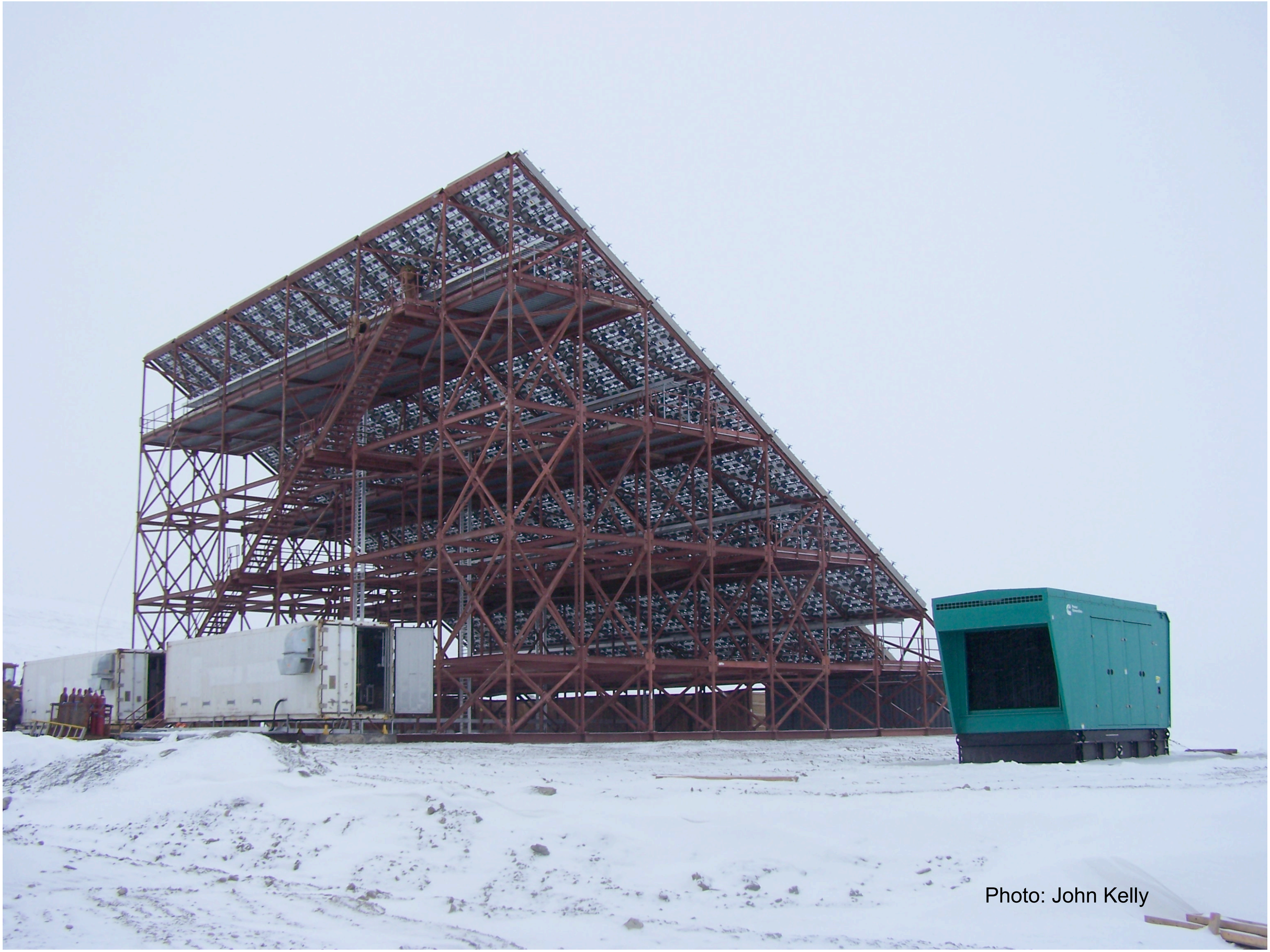


Photo: John Kelly

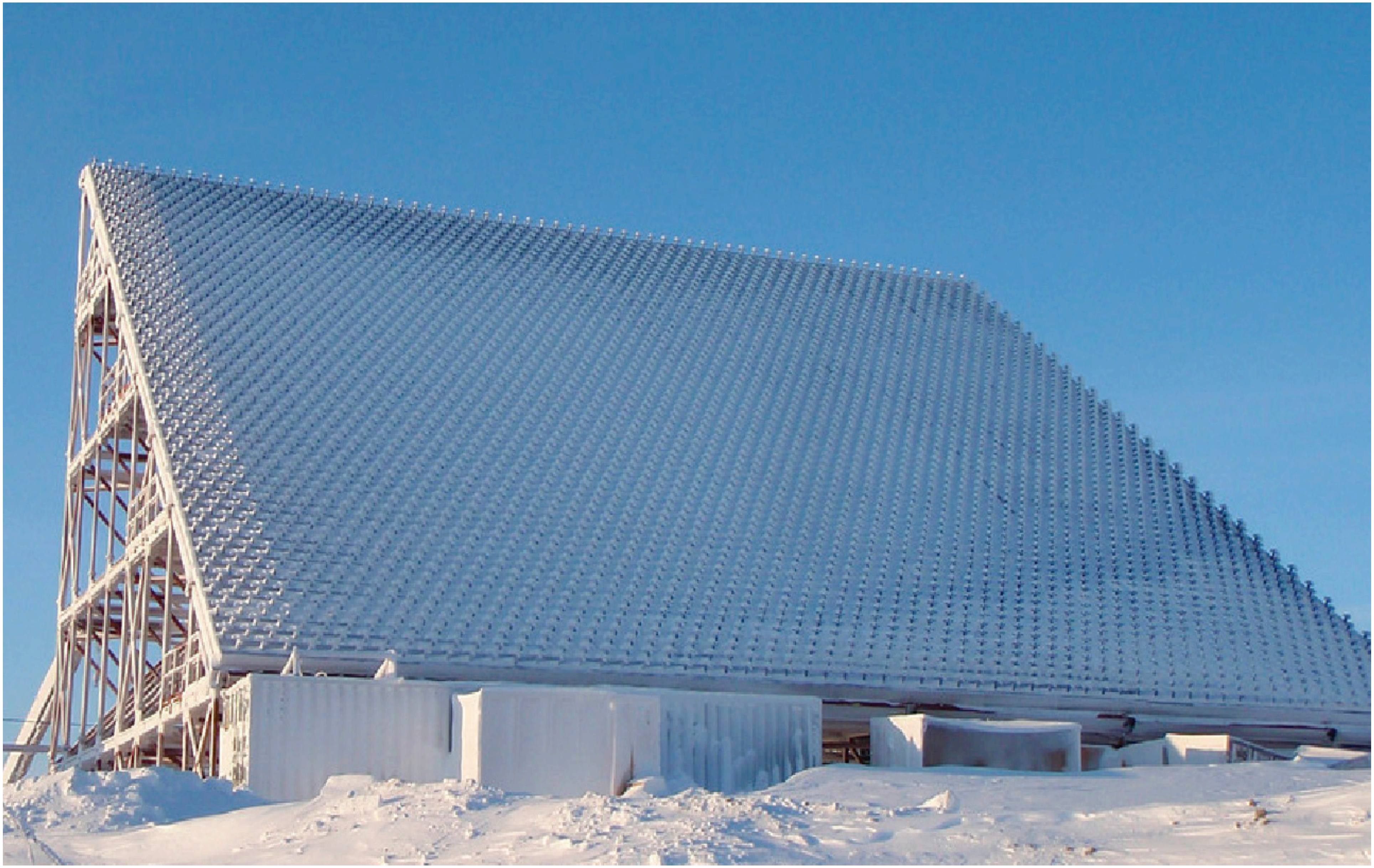


Photo: Craig Heinselman


Photo: Craig Heinselman

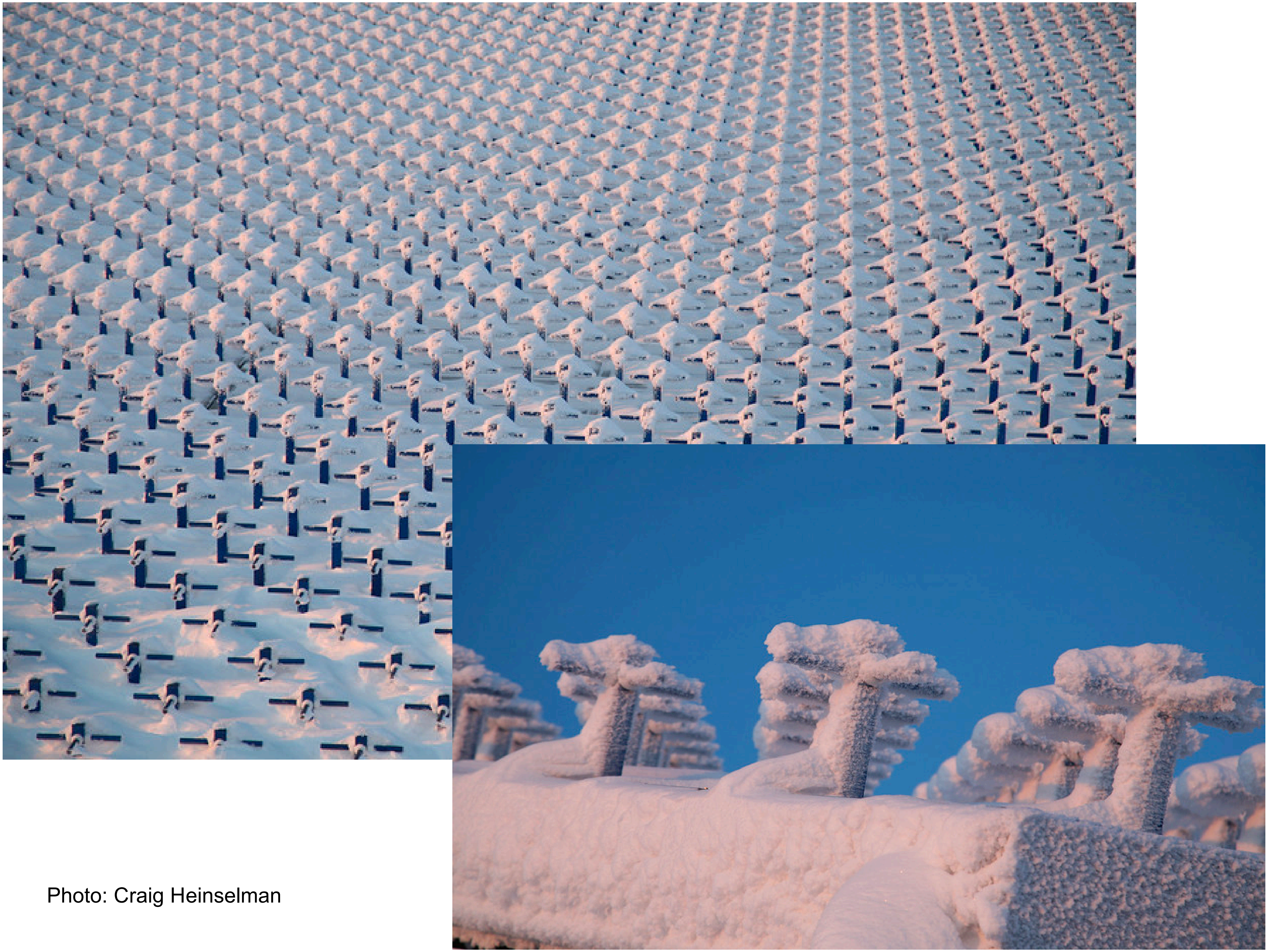
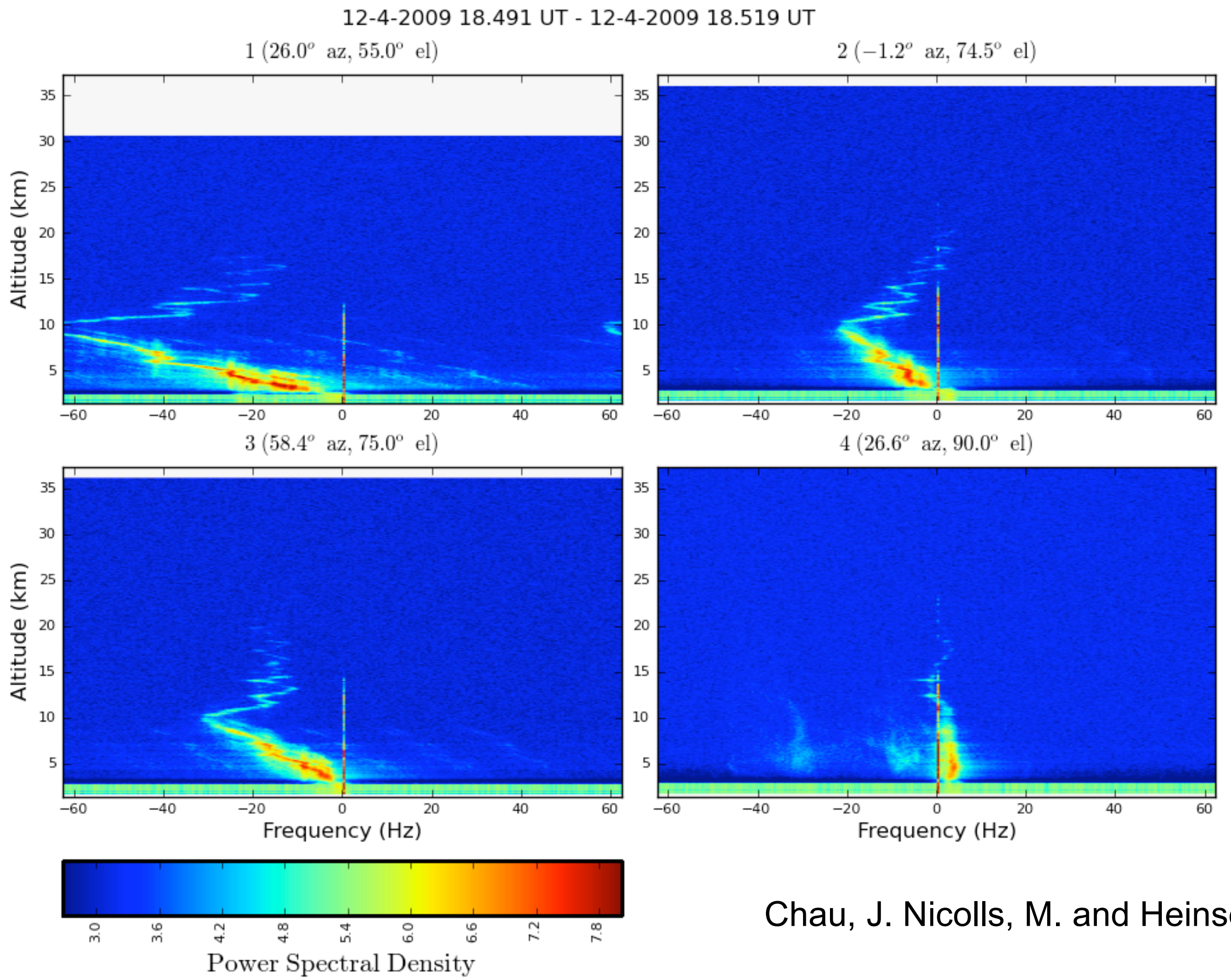


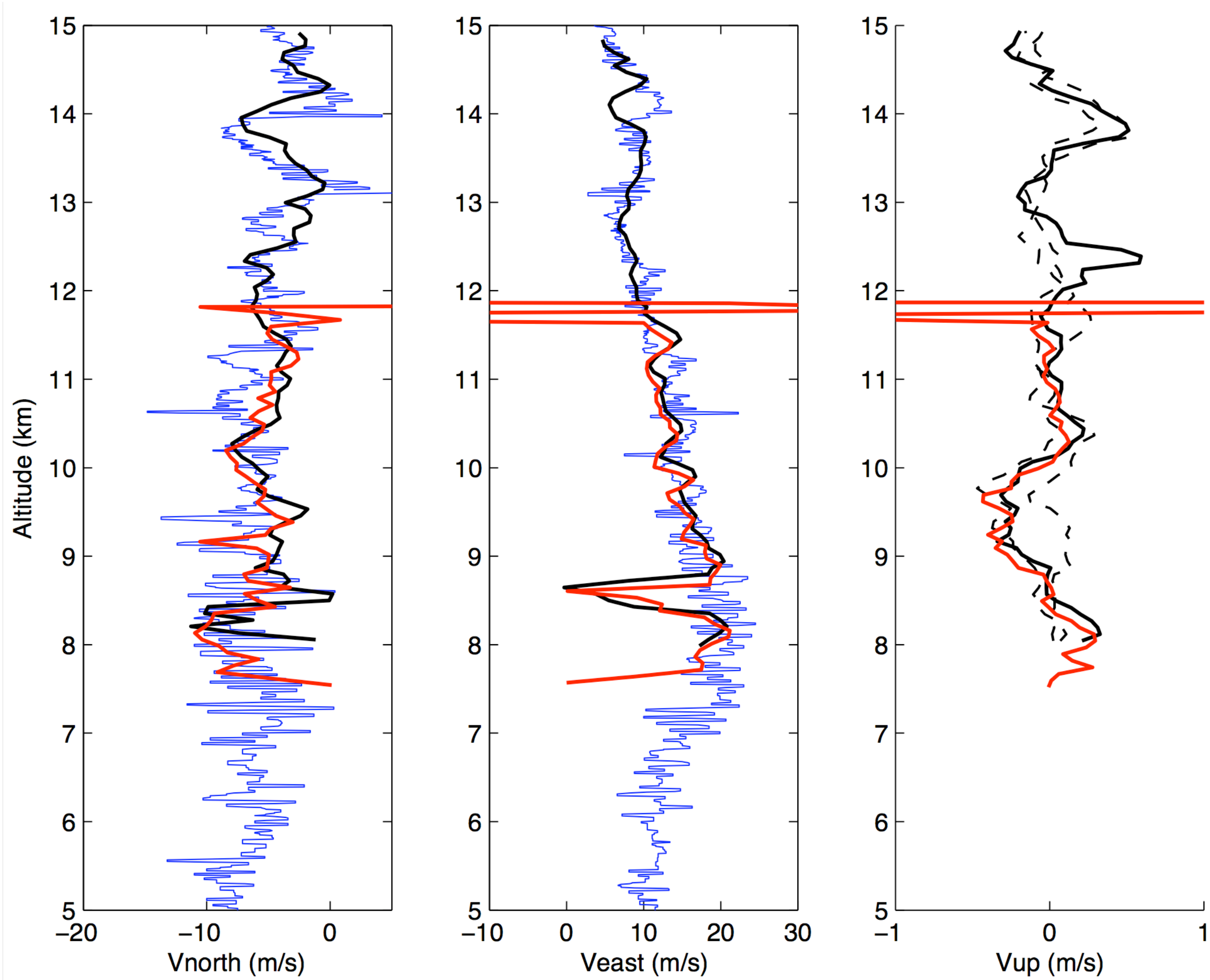
Photo: Craig Heinselman

Pulse to Pulse Spectra at RISR

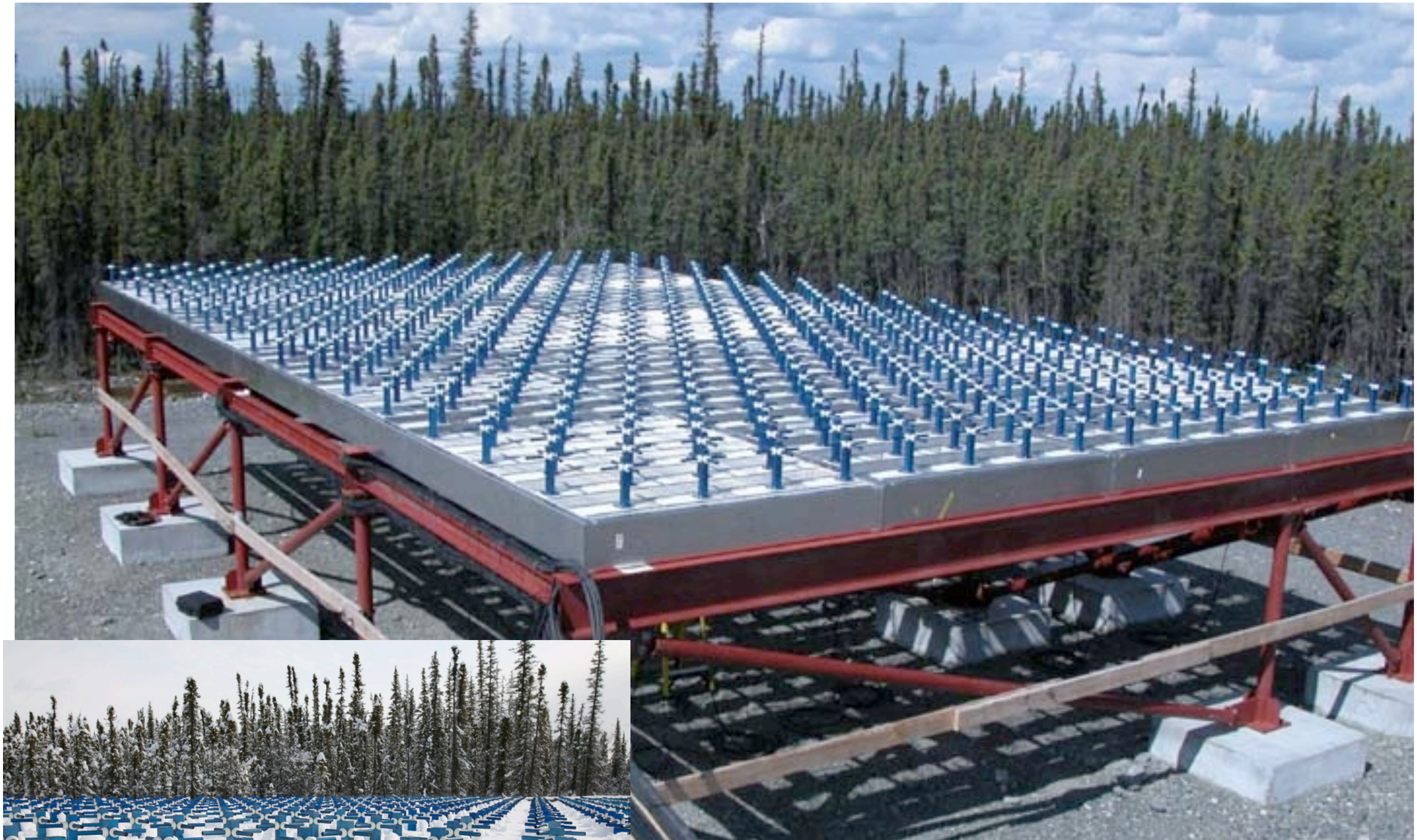


Chau, J. Nicolls, M. and Heinselman, C.

Resolved winds at PFISR (black and red)
Comparison to balloons (blue)
Note we get vertical velocity – balloon does not



Other AMISRs…



MUIR - at the HAARP
facility in Gakona, Alaska

AMISR at Jicamarca

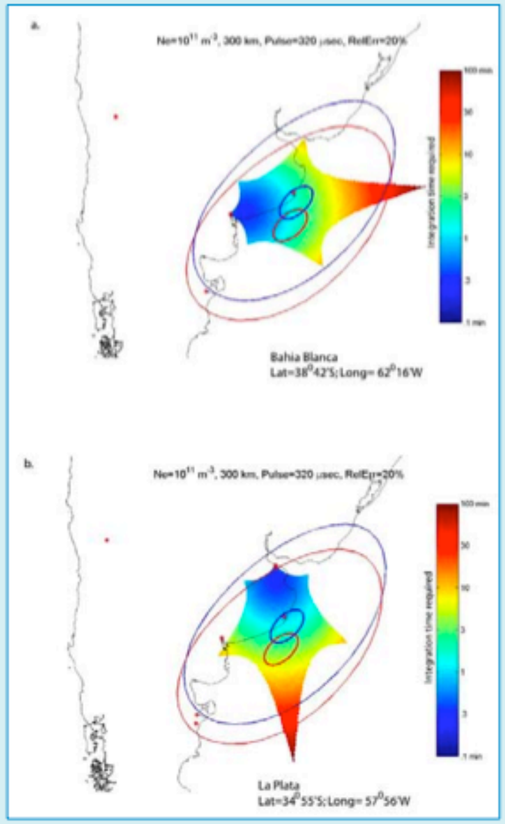

ALTAIR ISR

AMISRs to be…

Report on the

Concept Development for an Upper Atmospheric Research Facility at the Arecibo Geomagnetic Conjugate Point in Argentina

NAIC Arecibo Observatory • April 17-19, 2006

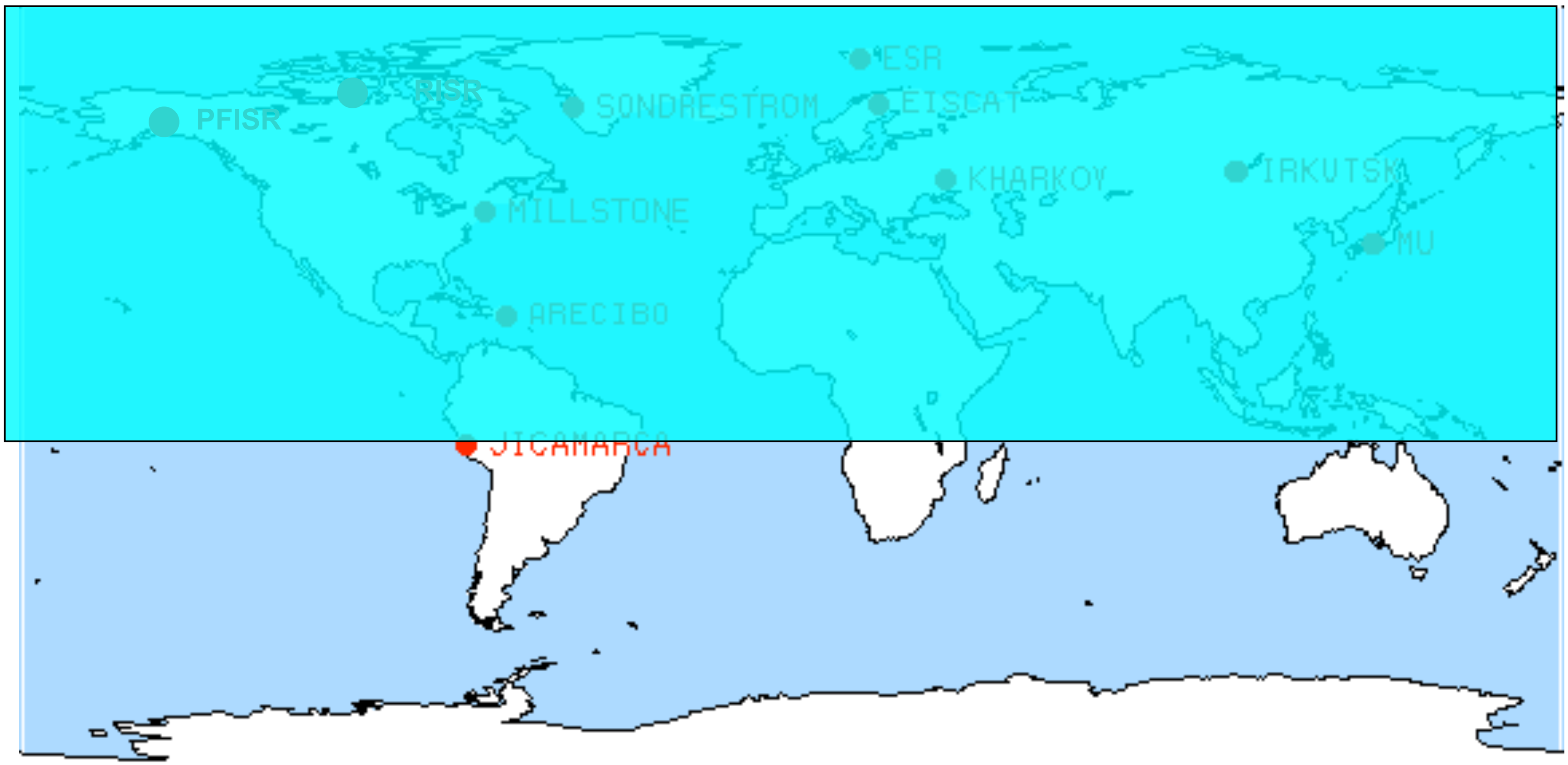


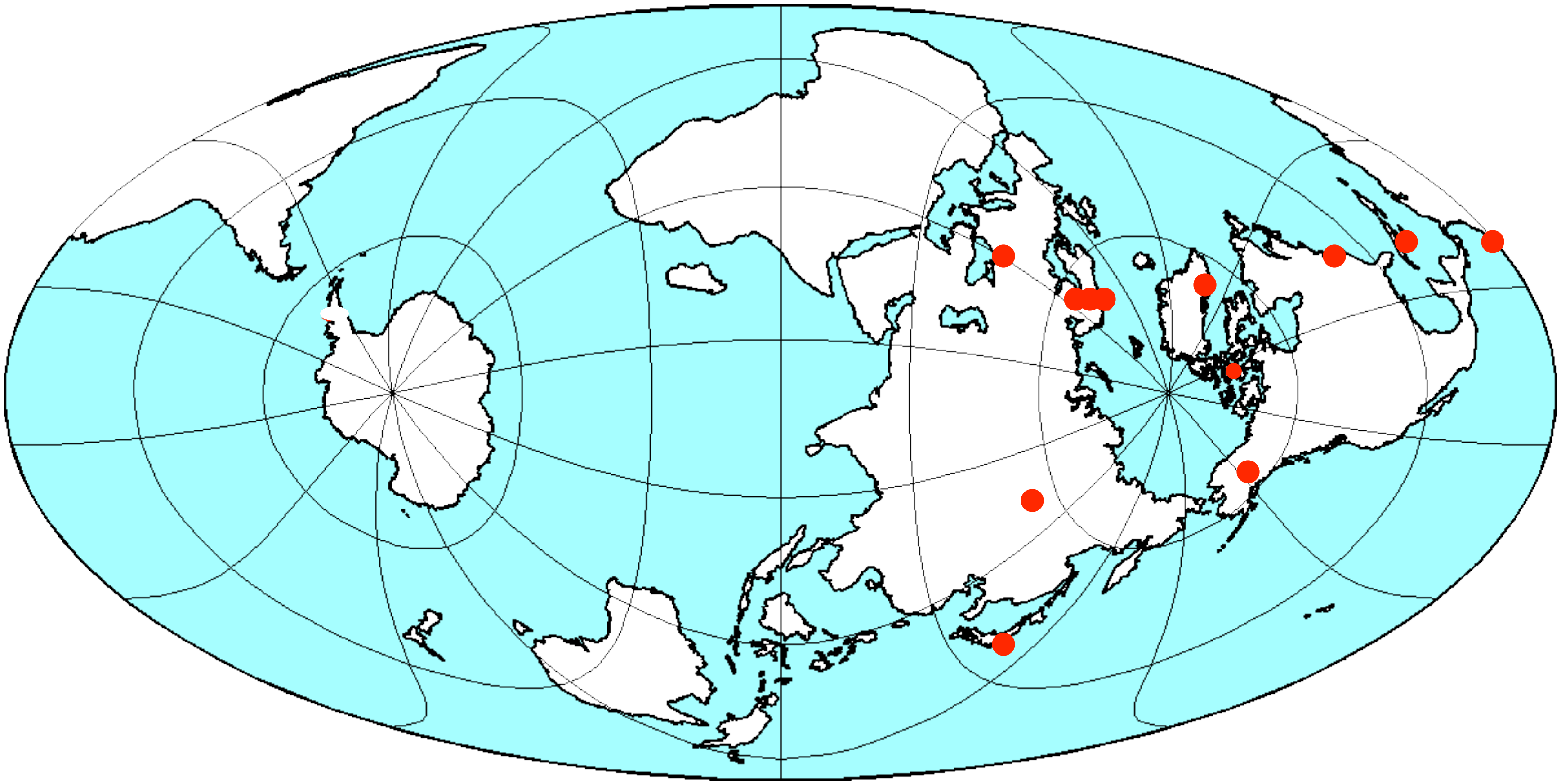
Edited By

Dr. Diego Janches, Northwest Research Associates

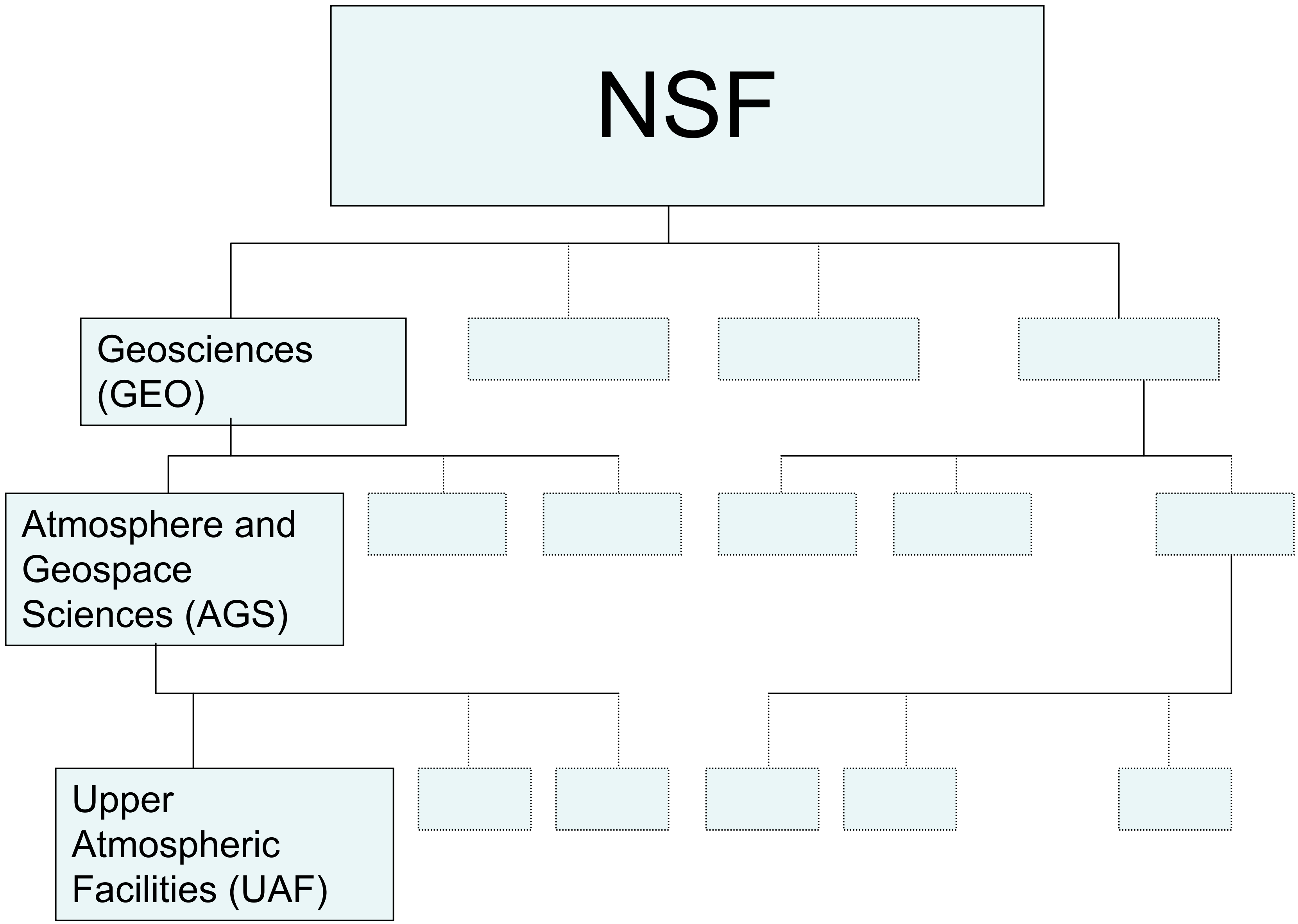
Dr. Robert L. Brown, National Astronomy and Ionosphere Center

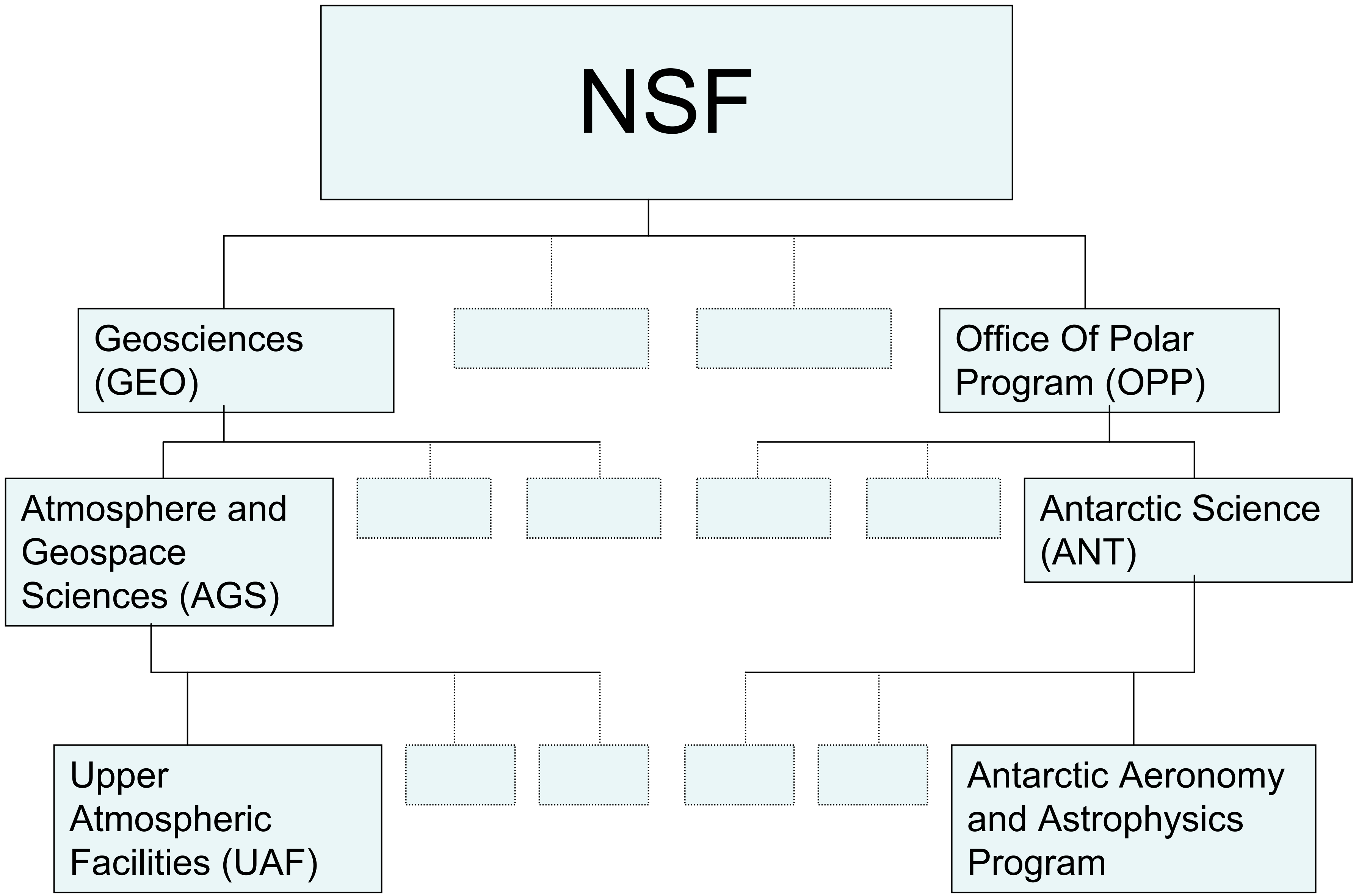
Incoherent Scatter Radars of the World



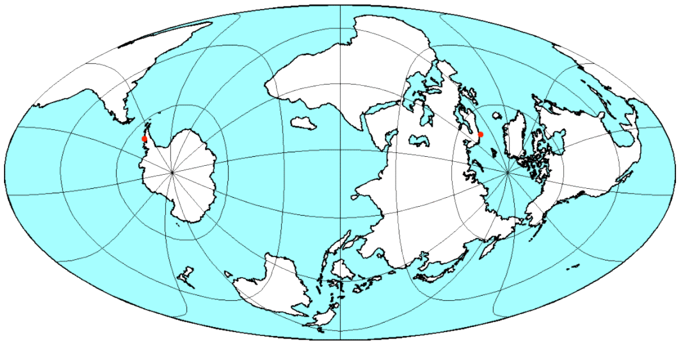


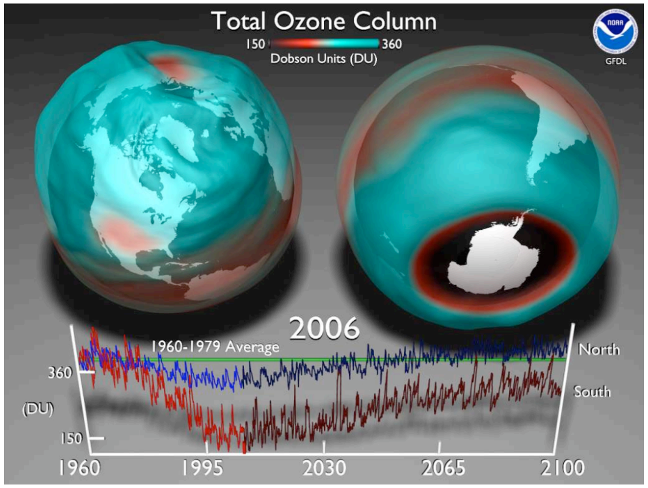
ftp://isr.sri.com/pub/Antarctic-ISR/Antarctic_ISR_Workshop_2008.pdf

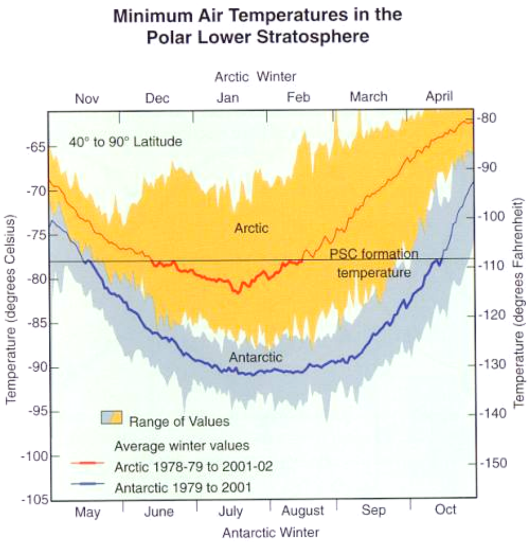

NSF
Geosciences (GEO)
Atmosphere and Geospace Sciences (AGS)
Upper Atmospheric Facilities (UAF)

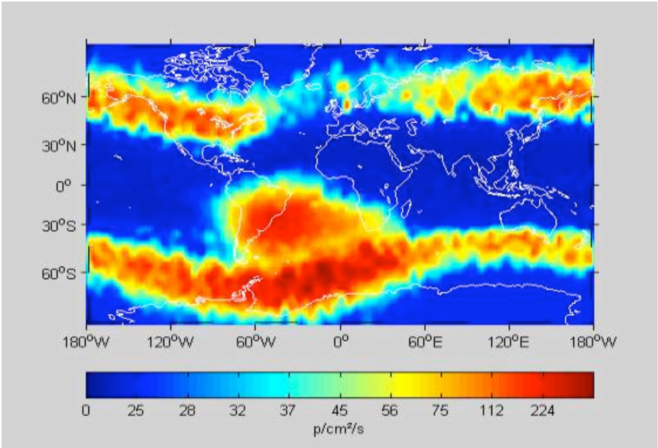

NSF
Geosciences (GEO)
Office Of Polar Program (OPP)
Atmosphere and Geospace Sciences (AGS)
Antarctic Science (ANT)
Upper Atmospheric Facilities (UAF)
Antarctic Aeronomy and Astrophysics Program

Antarctica is different

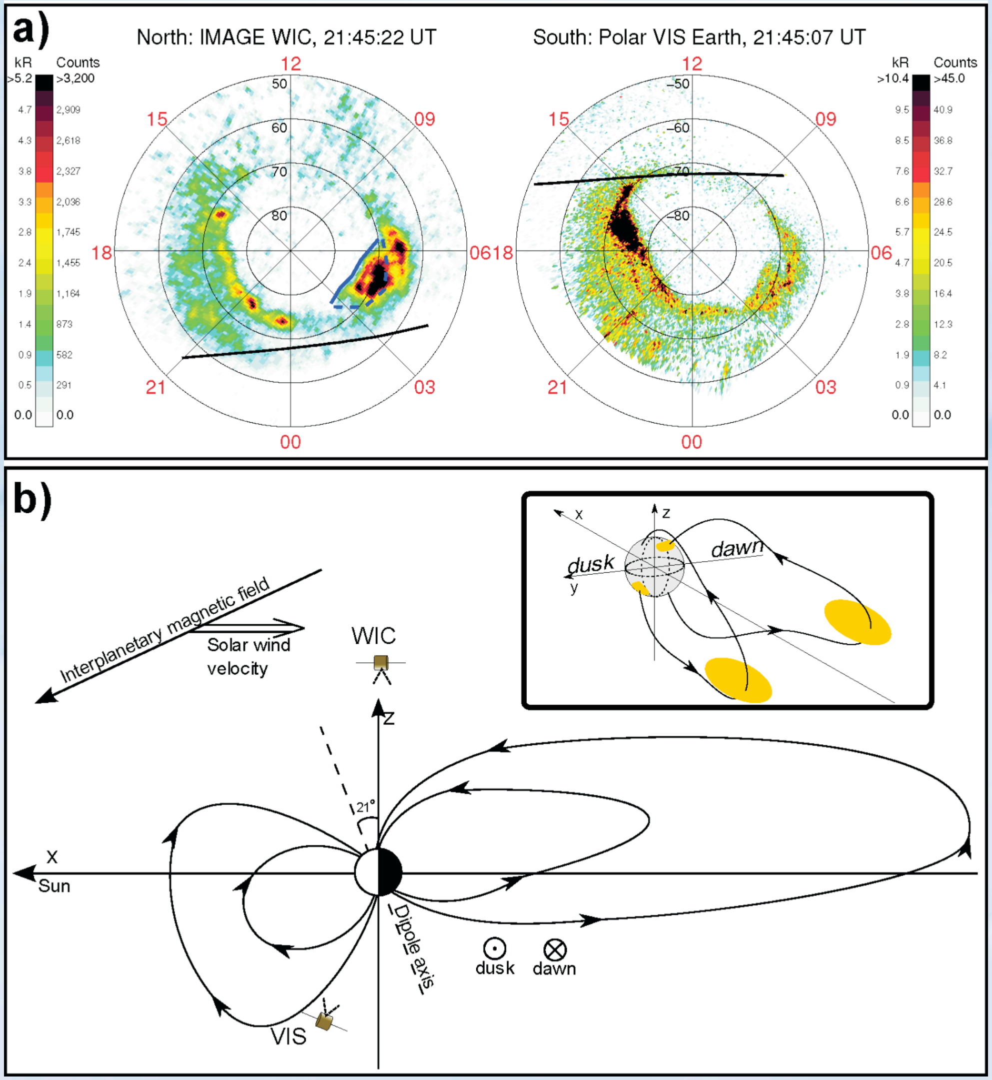






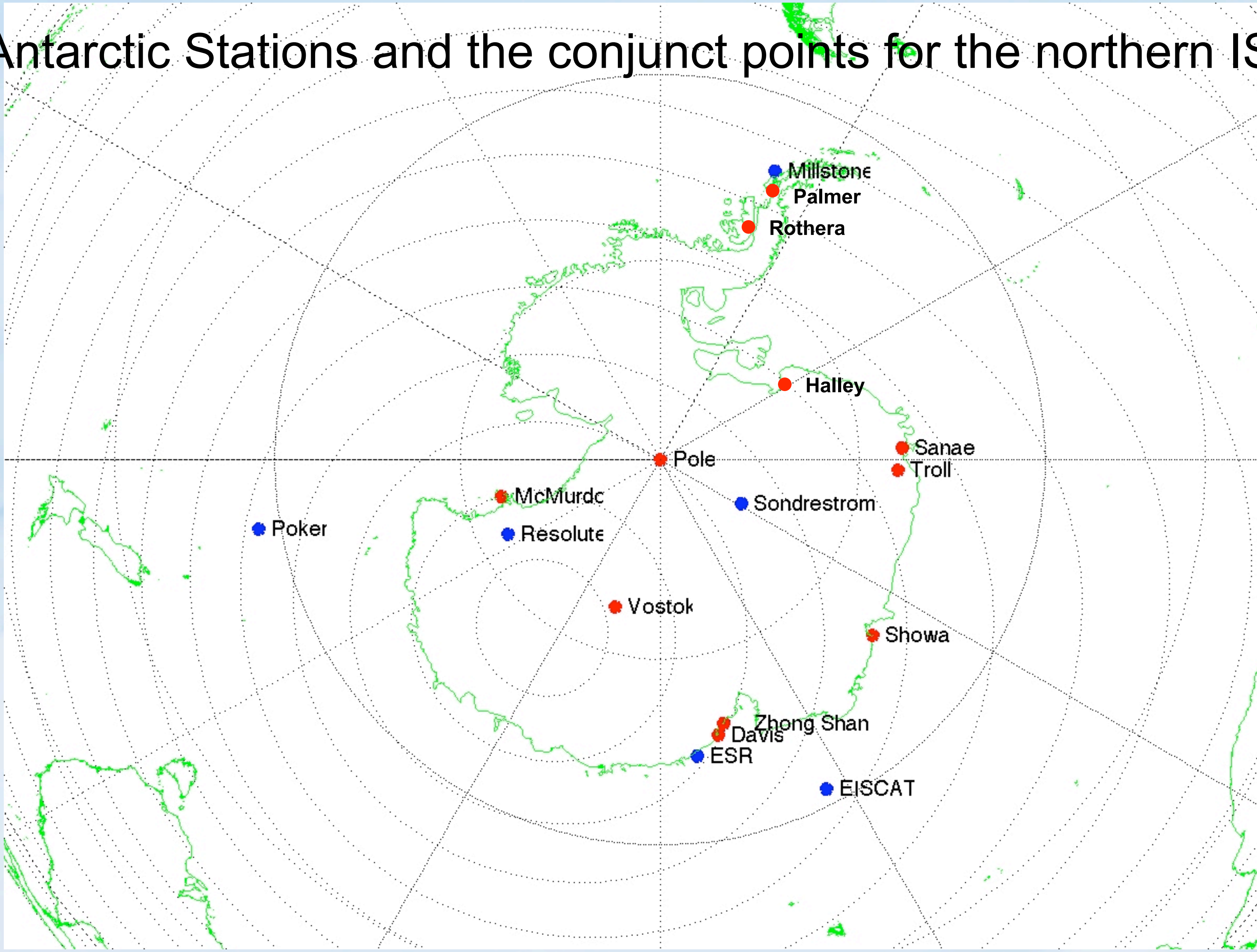


Antarctica is different



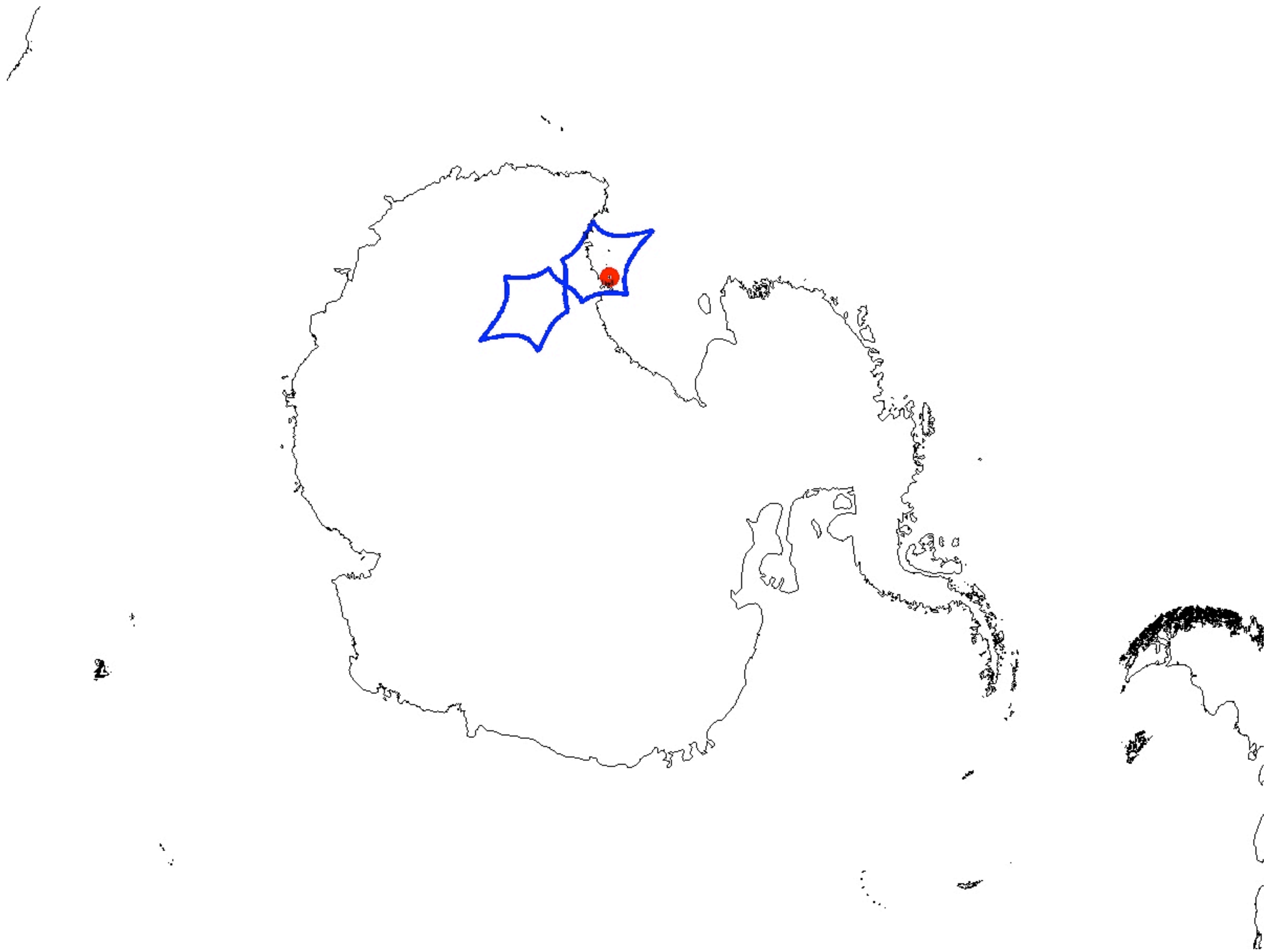
From Laundal and Østgaard 2009

Antarctic Stations and the conjunct points for the northern ISRs

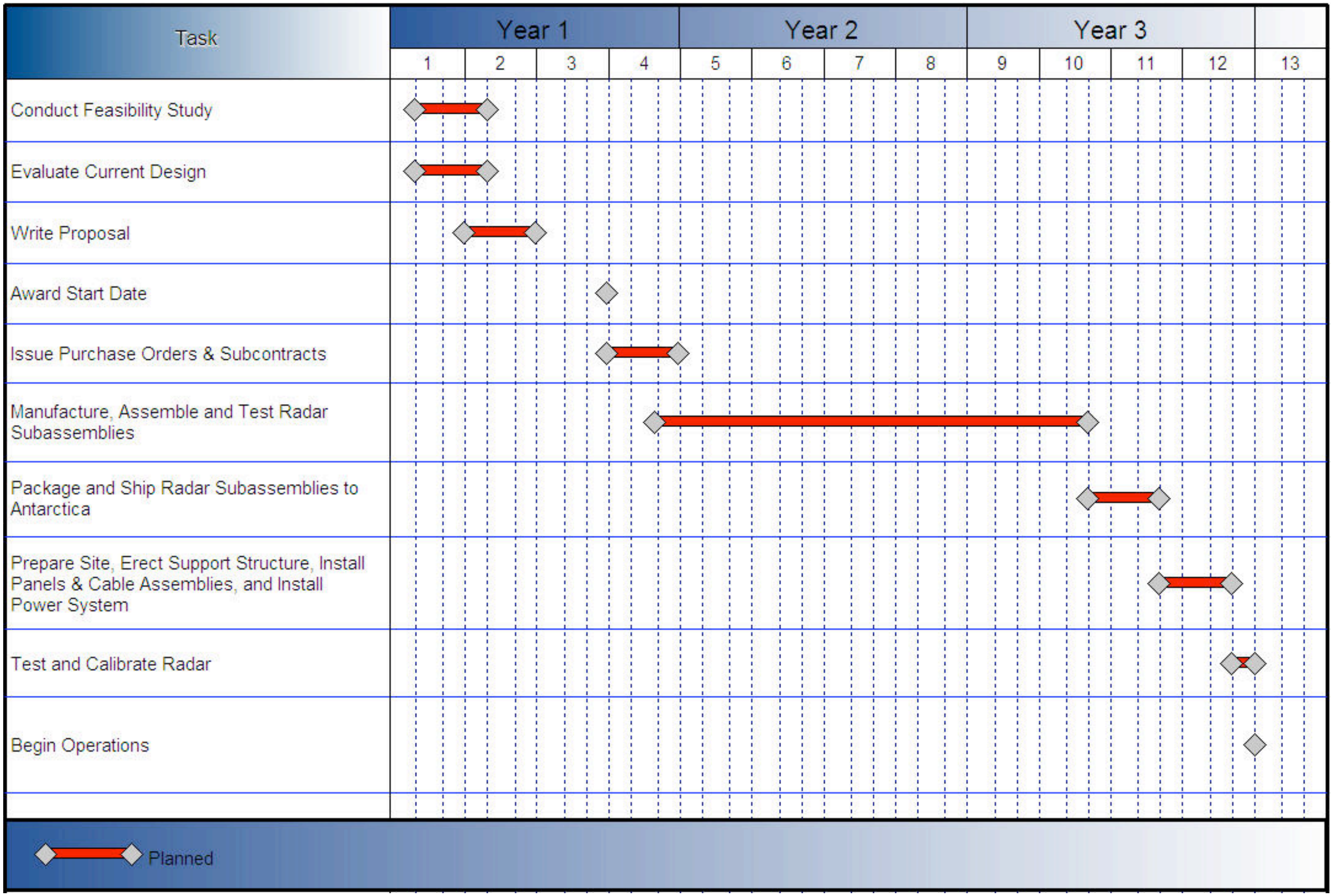


Some possible locations

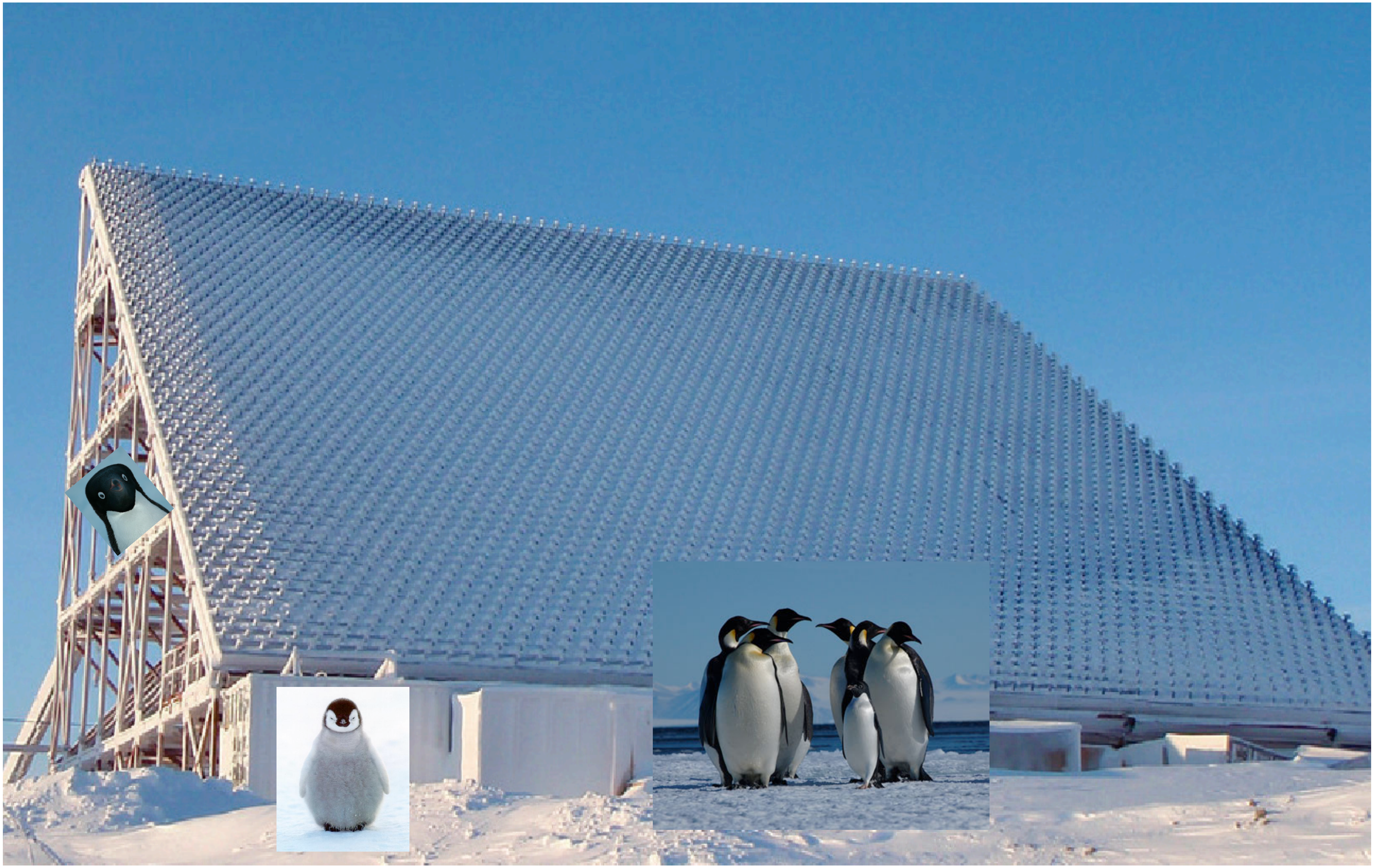
Conjugate pair	Geographic lat & lon		Geomagnetic lat & lon	
Syowa	-69.0,	39.6	-70.4,	83.6
Leirvogur (Iceland)	64.2,	338.3	69.3,	71.1
McMurdo	-77.9,	166.7	-79.0,	290.1
Resolute	74.7,	265.1	82.9,	303.0
Davis	-68.6,	78.0	-76.5,	128.2
Zhonshan	-69.4,	76.4	-74.6,	96.5
Longyeabyen	78.2,	15.8	75.3,	112.1



Timeline:

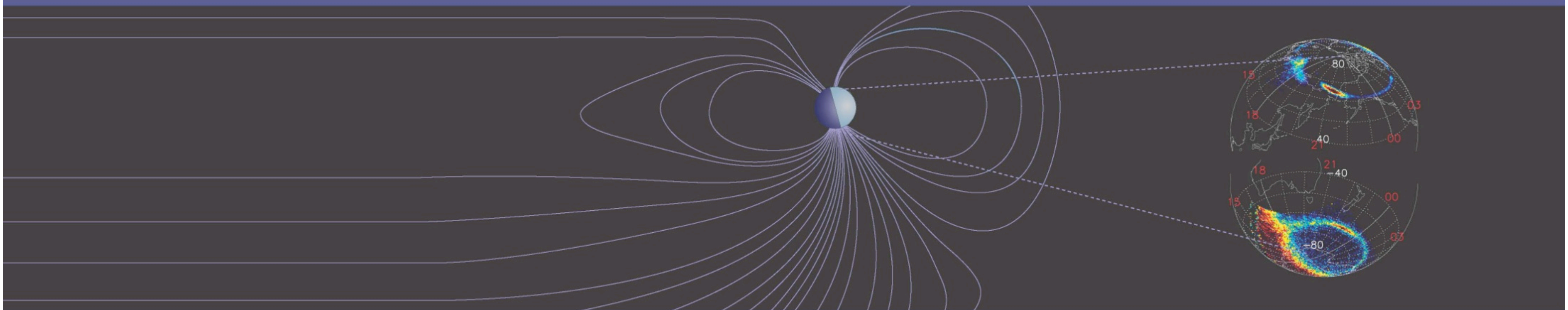


Task
Year 1
Year 2
Year 3
1
2
3
4
5
6
7
8
9
10
11
12
13
Conduct Feasibility Study
Evaluate Current Design
Write Proposal
Award Start Date
Issue Purchase Orders & Subcontracts
Manufacture, Assemble and Test Radar Subassemblies
Package and Ship Radar Subassemblies to Antarctica
Prepare Site, Erect Support Structure, Install Panels & Cable Assemblies, and Install Power System
Test and Calibrate Radar
Begin Operations
Planned



THE
Antarctic Incoherent Scatter Radar Facility

Transformational Solar-Terrestrial Research In the High South

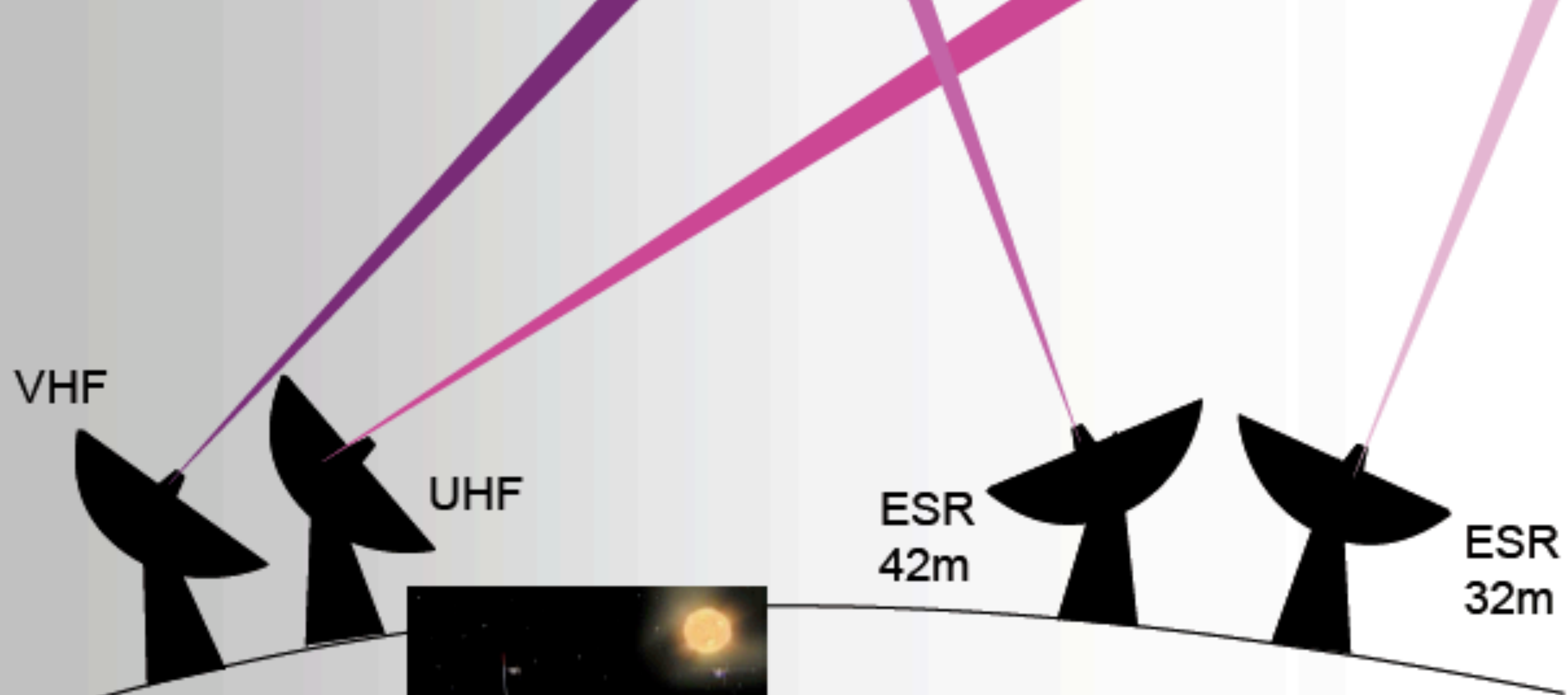


ftp://isr.sri.com/pub/Antarctic-ISR/Antarctic_ISR_Workshop_2008.pdf

Antarctic ISR Workshop
8–9 AUGUST 2008

Multiple Radar use

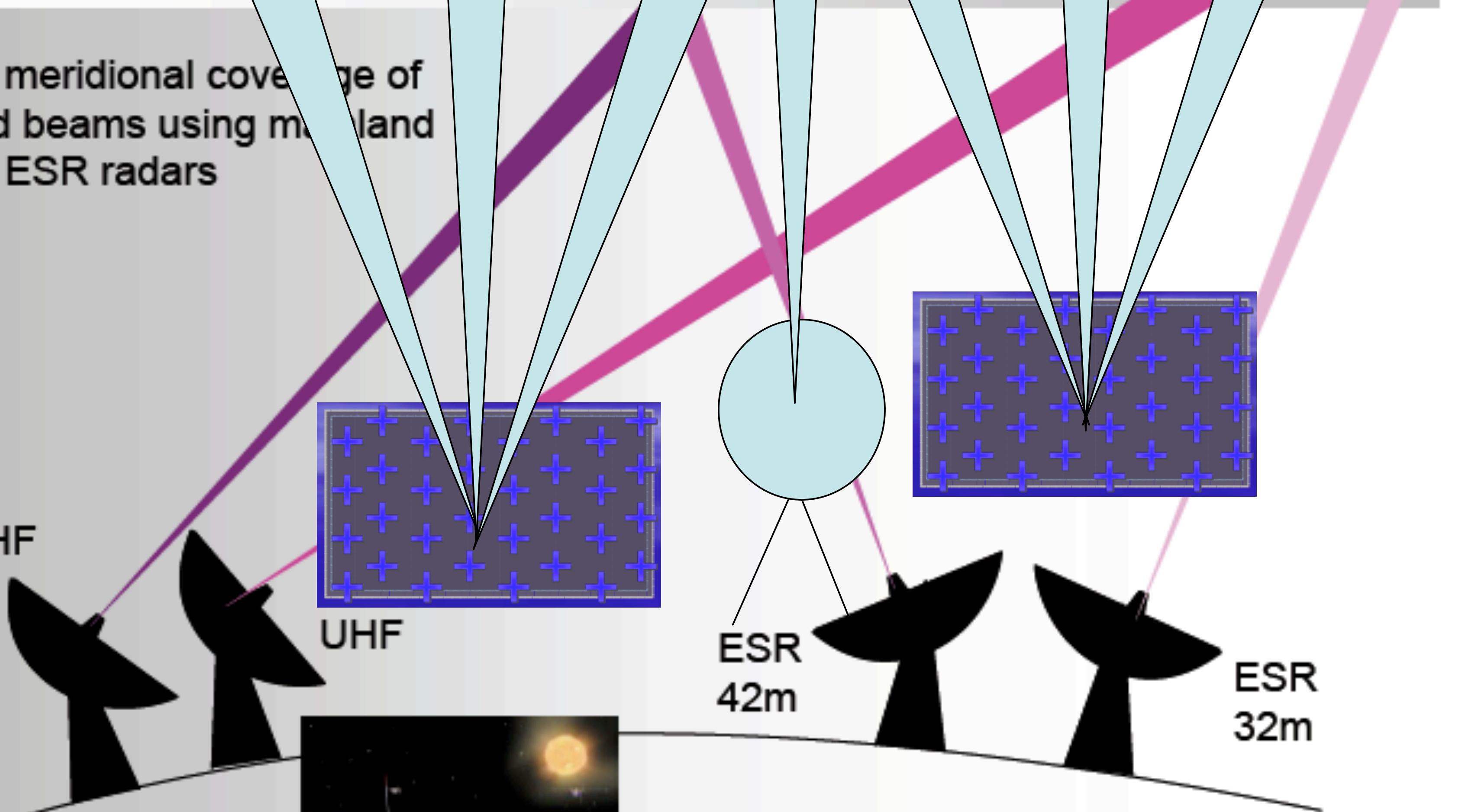
e.g. meridional coverage of fixed beams using mainland and ESR radars

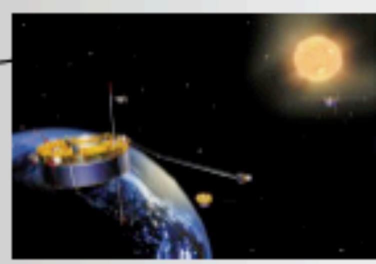


Plus you have Cluster & Doublestar, TIMED, DMSP, Fast .....

Multiple Radar u

e.g. meridional cove ge of fixed beams using m land and ESR radars





Plus you have Cluster & Doublestar, TIMED, DMSP, Fast .....

“Summary”

- As scientists we should focus more on the science and processes then on the instruments
- There are no (national or institutional) borders in space!

Photo: Craig Heinselman