The AMISR

ISR Capabilities

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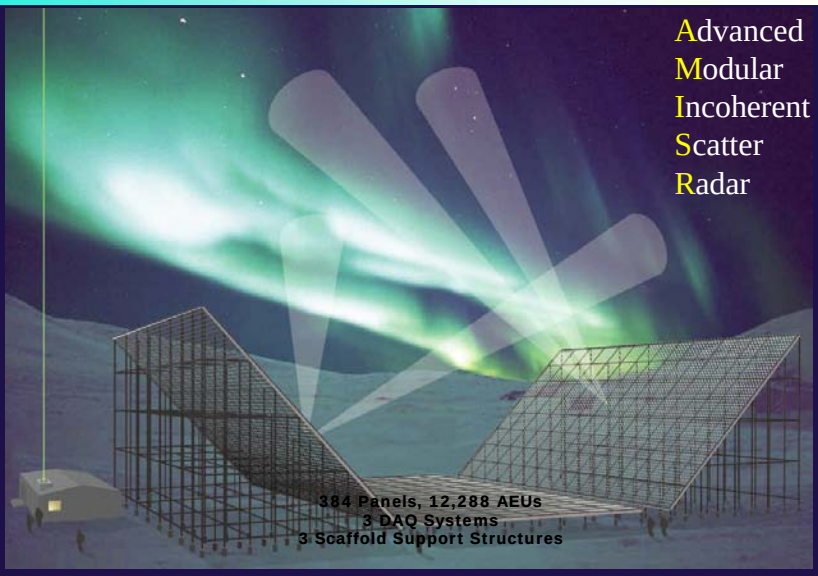
SRI International

CEDAR, 28 June 2004

AMISR



Advanced
Modular
Incoherent
Scatter
Radar

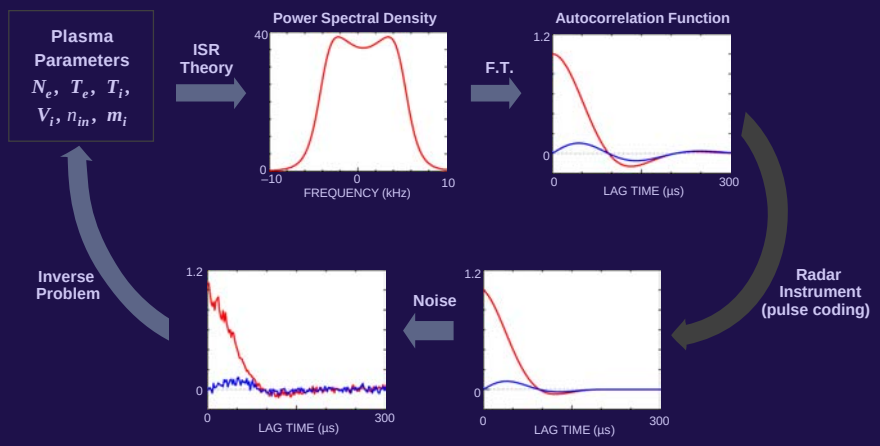
2

Topics

- Incoherent Scatter Radar Review
- AMISR Measurements – new IS Radar capabilities
- Sensitivity and Coverage
- Future Configurations
- Brief Status

3

Incoherent Scatter Radar

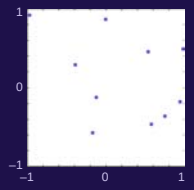


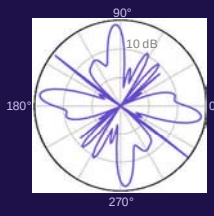
v3

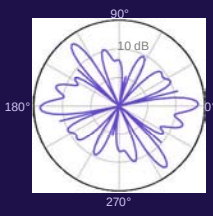
4

Incoherent Scatter

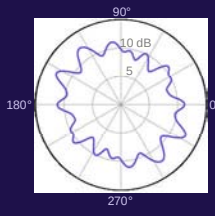
Noise-Like Signal

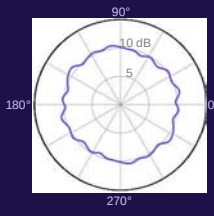


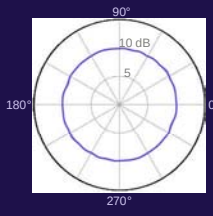




Incoherent Integration







10 Pulses | **100 Pulses** | **1000 Pulses**

vv4

5

ISR Signal Strength

Differential received power

$$dP_r = \frac{P_T L l^2 G_{TX}(q,f) G_{RX}(q',f') n_e(q,f,r) s}{(4p)^3 r^4} dV$$

Assuming a narrow antenna beam and sufficiently short pulse

$$dV = \left(\frac{ct_P}{2}\right) r dq \cdot r \sin q \cdot df$$

$$P_r(r) \approx \frac{P_T L l^2 c t_P n_e(r) s}{2(4p)^2 r^2} \frac{1}{4p} \iint G^2(q,f) \sin q \cdot dq \cdot df$$

Defining the mean squared gain (backscatter gain) as

$$G_{BS} = \frac{1}{4p} \iint G^2(q,f) \sin q \cdot dq \cdot df$$

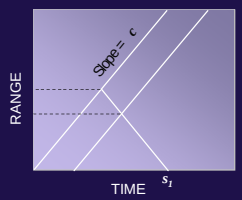
and from Hagen and Baumgartner (1996)

$$G_{BS} \approx C_{BS} \frac{4p A_{eff}}{l^2}$$

$$P_r(r) \approx \frac{P_T L c t_P C_{BS} A_{eff} n_e(r) s}{2(4p) r^2}$$

$$P_r(r) \approx \frac{P_T L c t_P C_{BS} A_{eff}}{8p r^2} \frac{n_e(r) s_e}{\left(1 + k^2 l_D^2\right)\left(1 + k^2 l_D^2 + T_r\right)}$$

$$P_n = k_B T_{sys} BW$$



P_T = transmitter peak power
L = transmit feed line losses
c = speed of light
t_P = transmit pulse duration
C_{BS} = backscatter gain constant
A_{eff} = antenna effective aperture
n_e = electron number density
s_e = electron radar cross-section
$k = 2p/l$ = radar wave number
l_D = plasma debye length
T_r = electron to ion temperature ratio
k_B = Boltzmann constant
T_{sys} = system noise temperature
BW = receiver bandwidth

v5A

6

ISR Signal Strength

Signal-to-noise ratio

$$SNR = \frac{P_r}{P_n} = \frac{(P_T L)(C_{BS} A_{eff})\, t_P}{T_{sys} BW} \cdot \frac{c}{8\pi r^2 k_B} \frac{n_e(r)\, s_e}{(1+k^2 l_D^2)(1+k^2 l_D^2 + T_r)}$$

$$std\left(\frac{\hat{P}_r}{P_r}\right) \propto \frac{1}{\sqrt{K_{meas}}}\left(\frac{P_r + P_n}{P_r}\right) = \frac{1}{\sqrt{K_{meas}}}\left(1 + \frac{1}{SNR}\right)$$

To obtain an $SNR = 1$ with the following parameters

$L = 1$ (no feed line losses) $C_{BS} = 0.4$

$t_P = 300$ μsec (45 km range resolution) $n_e = 10^{11}$ m^{-3}

$T_{sys} = 100$ K $BW = 50$ kHz

$k^2 l_D^2 = 0$ (sufficiently high n_e) $T_r = 1$

we need

$P_T A_{eff} = 8.7 \times 10^8$ Wm^2

for $A_{eff} = 400$ m^2

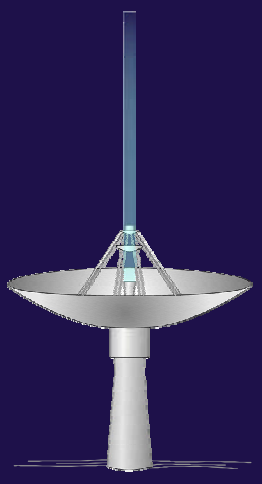
$P_T = 2.2$ MW

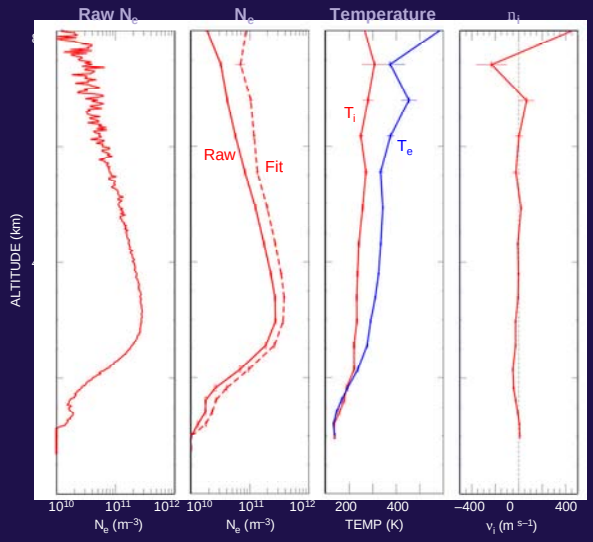
$$FOM = \frac{P_T A_{eff}}{T_{sys}} \sqrt{d_{rf}}$$

v5B

7

Plasma Parameter Profile

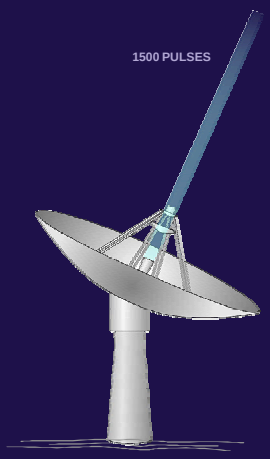


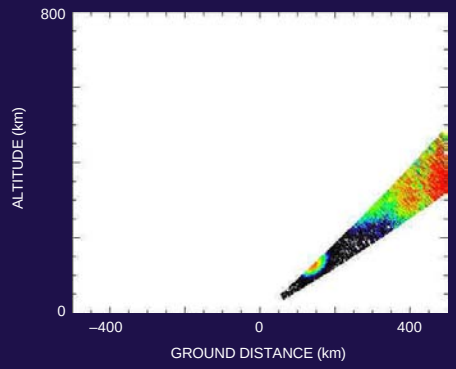


v6

8

Plasma Parameter Maps

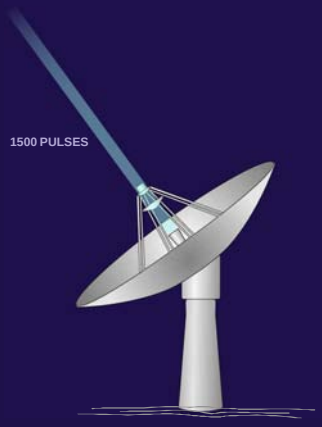


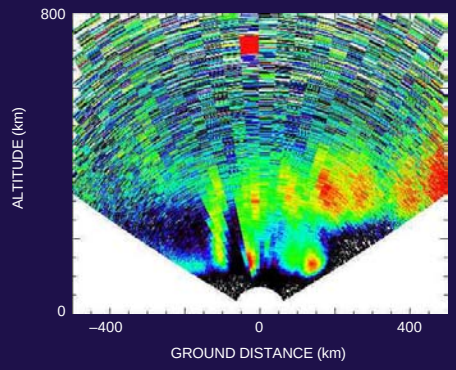


V7-2

9

Plasma Parameter Maps

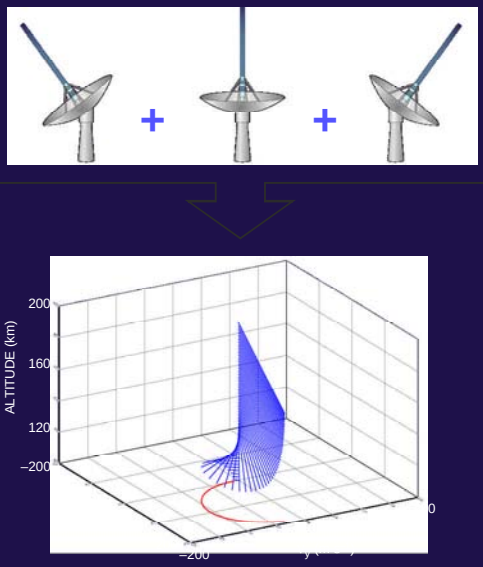




V7-6 END

10

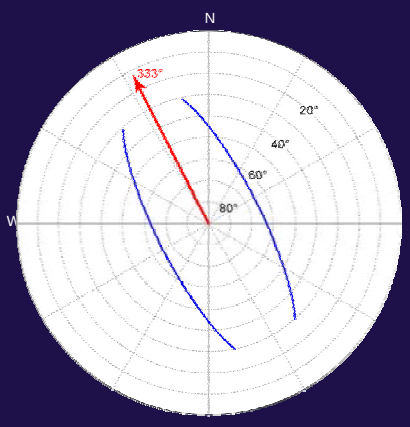
Ion Velocity Estimation



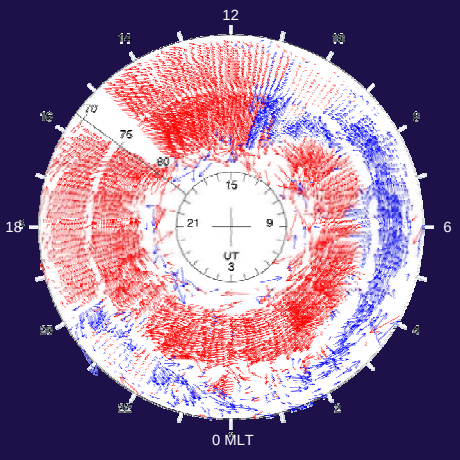
V8

11

Ion Velocity (E-field) Maps



Composite Scans for
E-field Estimation

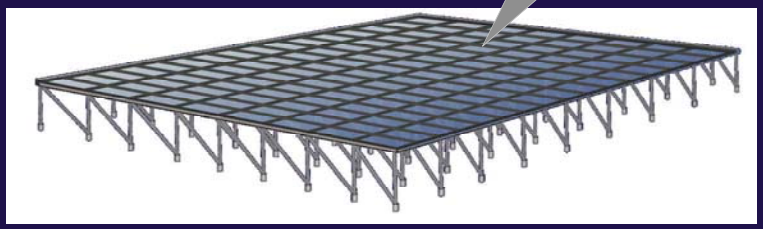


v9

12

AMISR

- Three new IS radars
- Modular/transportable/reconfigurable
- Phased array/rapid steering
- Solid state / no warm-up
- Heavily networked/graceful degradation



v10

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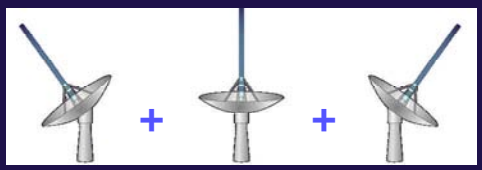
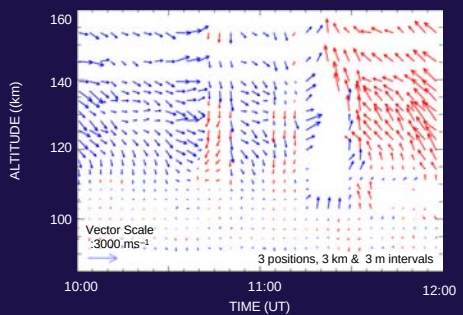
Ion Velocity Estimation

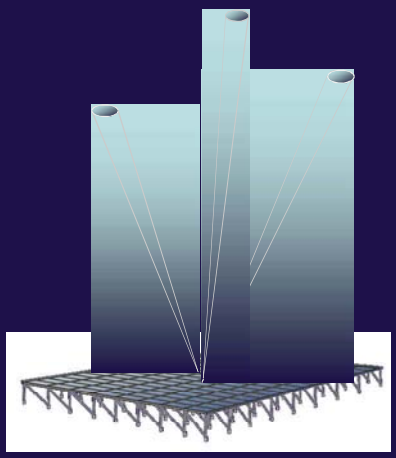


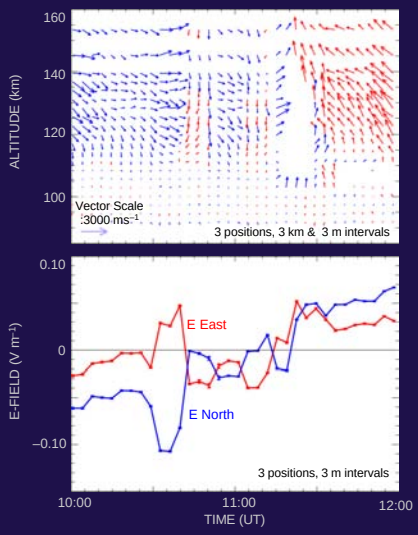


V8

14

AMISR Ion Velocity Estimation





v12

15

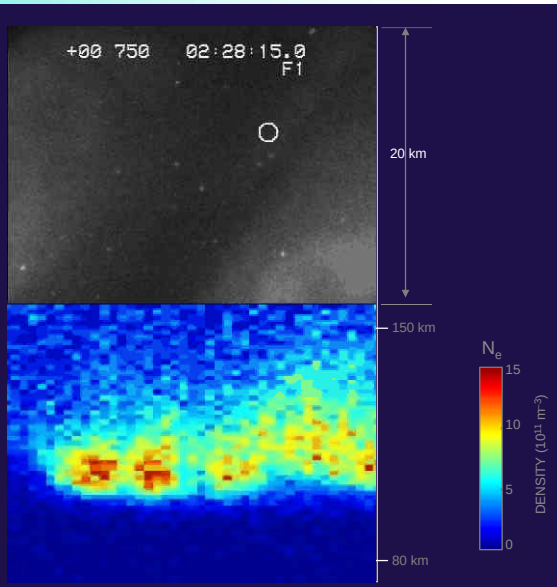
AMISR – Resolving Temporal/Spatial Ambiguities

High Speed Intensified Auroral Imaging

- **Narrow-field camera**
  25 frames/sec
  > 640 nm
  21 x 26 km at 110 km

- **Sondrestrom IS radar**
  Electron density
  1 km x 1.2 sec

J. Semeter



v13A

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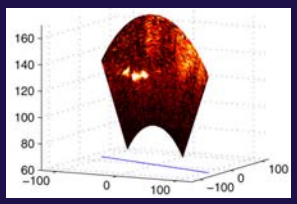
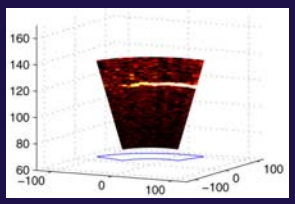
AMISR – Imaging Plasma Structures

Sporadic E Evolution

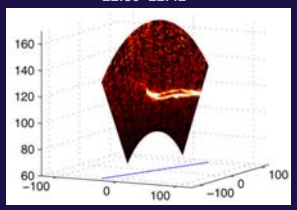
21:29–21:34



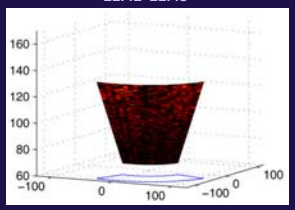
21:34–21:36



21:36–21:41



21:41–21:43



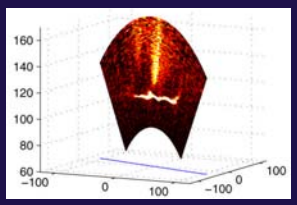
v14

17

AMISR – Imaging Plasma Structures

Sporadic E Evolution

21:43–21:48



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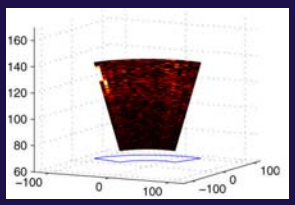
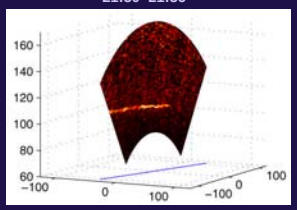
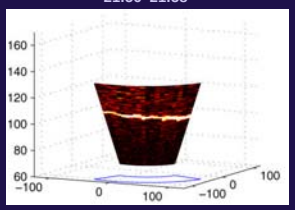


21:50–21:56



21:56–21:58



v15

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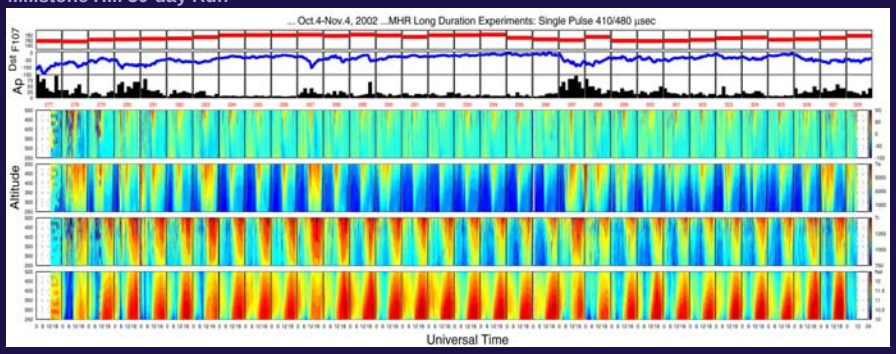
AMISR Synoptic Measurements

Millstone Hill 30-day Run



- AMISR is well equipped for frequent short-duration experiments
- No moving parts – simplifies personnel safety
- Computer control
- 4 min every half hour ~ 100 hours/month

v16

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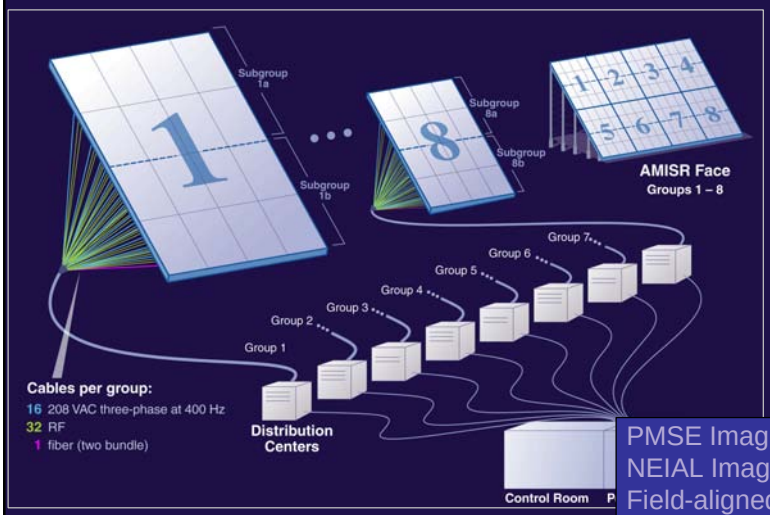
AMCSR – Advanced Modular Coherent Scatter Radar (Interferometry)

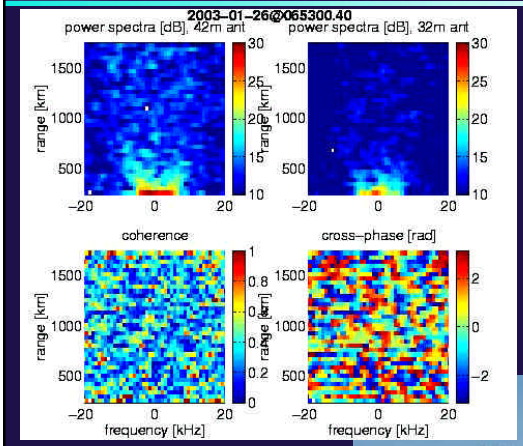


PMSE Imaging
NEIAL Imaging
Field-aligned irregularities
Meteor head echoes

v17B

20

AMCSR – Advanced Modular Coherent Scatter Radar (Interferometry)

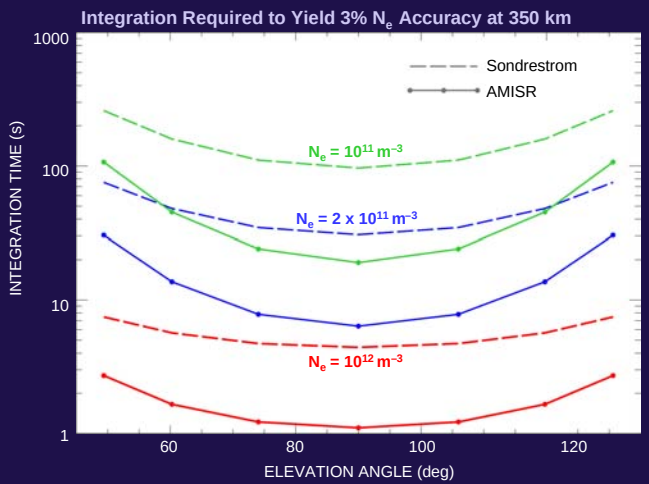


T. Grydeland, 2004

NEIAL Interferometry ESR

v17

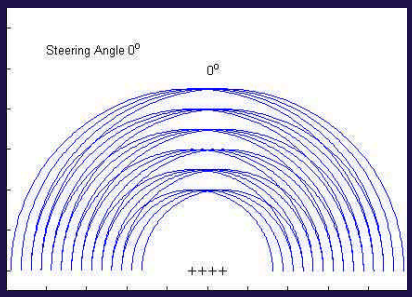
AMISR Sensitivity – Vertical Face



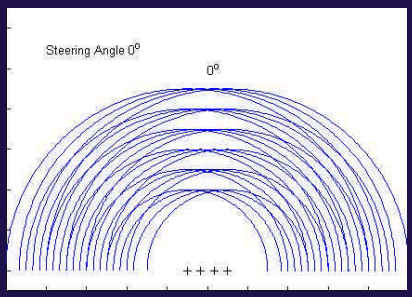
v18

AMISR Coverage – Grating Lobes

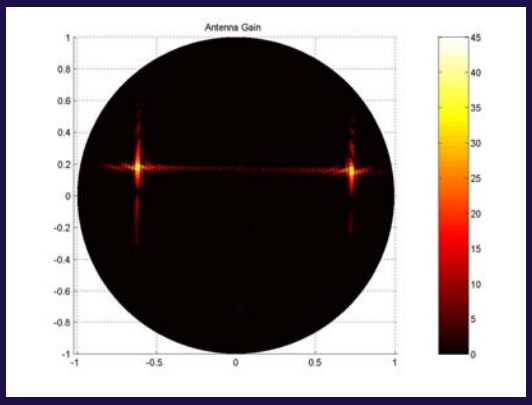
Element Spacing 0.50λ

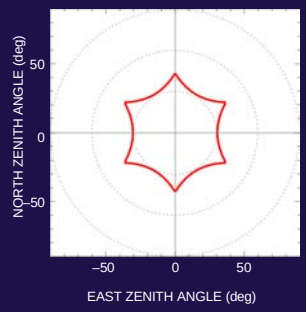


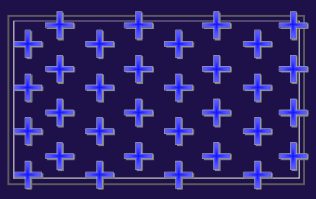
Element Spacing 0.67λ



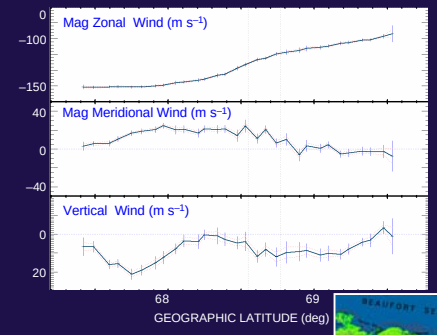
AMISR Coverage – Grating Lobes



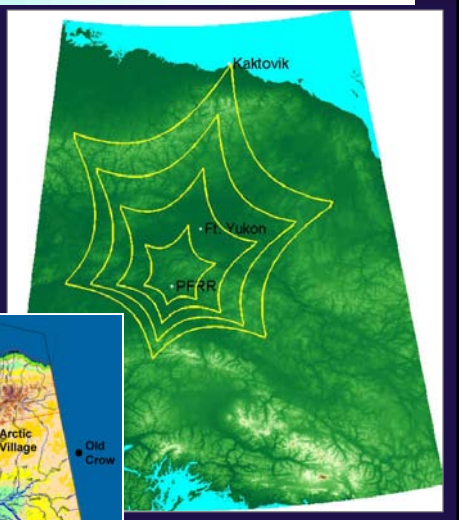




AMISR Coverage – Poker Flat



HEX Rocket Experiment
M. Conde, et. al



v20

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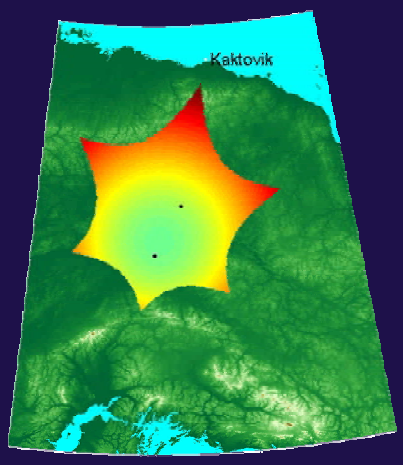
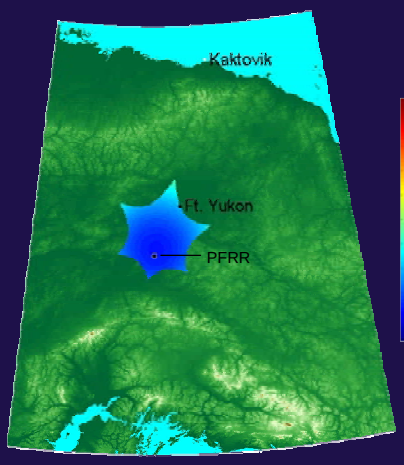
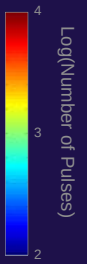
AMISR Coverage – Poker Flat

350 km, 1 x 10^{11}, 10%



150 km, 1 x 10^{11}, 10%





v21

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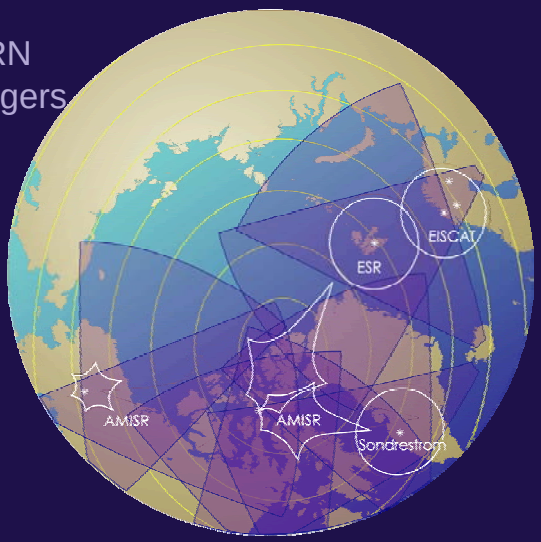
AMISR Coverage – Global Context

ISRs
SuperDARN
Allsky Imagers
Satellites



v21B

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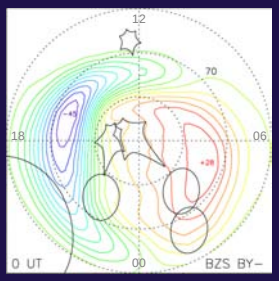
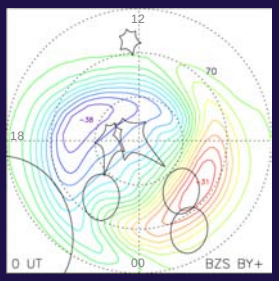
AMISR Coverage – Resolute Bay

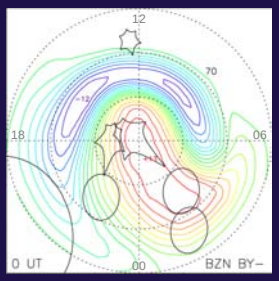
BZS By–
4 kV contours
00 UT

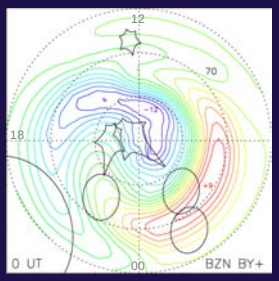




BZS By+
4 kV contours
00 UT

BZN By–
1 kV contours
00 UT





BZN By+
1 kV contours
00 UT

350 km ionospheric footprint

Heppner Maynard Convection Pattern

v22

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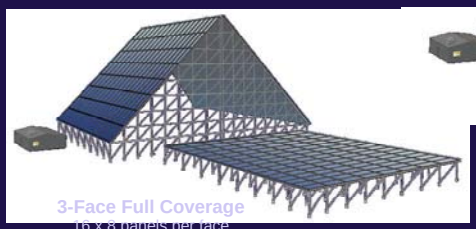
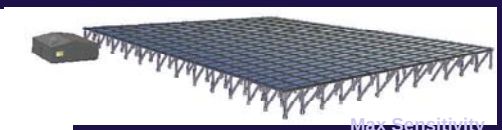
Future Configurations



3-Face Full Coverage
16 x 8 panels per face



Max Sensitivity
12 x 24 panels

Equatorial
32 x 1 panel

PMSE Radar/ Wind Profiler
2 x 4 panel

v24

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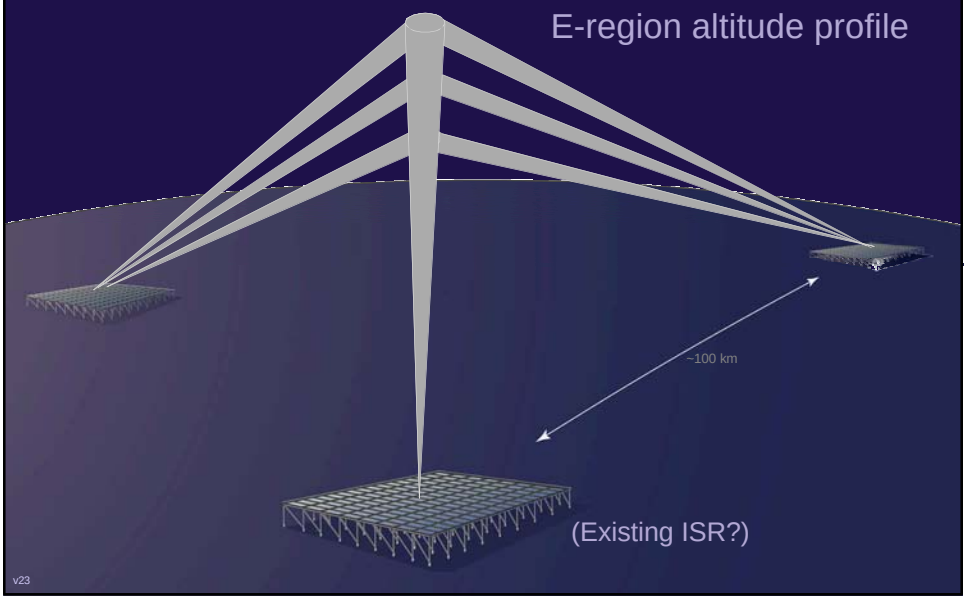
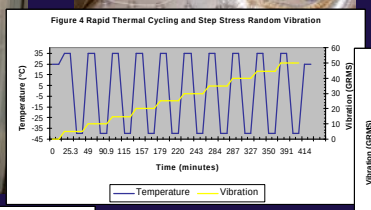
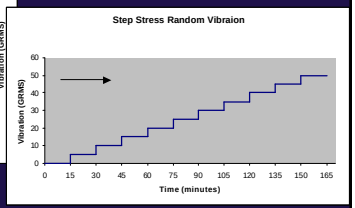
Tristatic Configuration

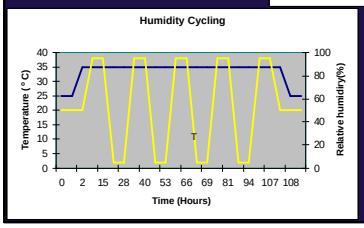


v23

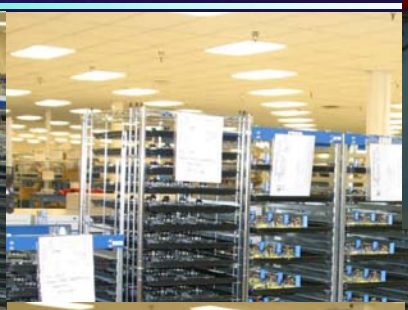
Status - Design Verification Test Complete (Shake ‘n Bake)

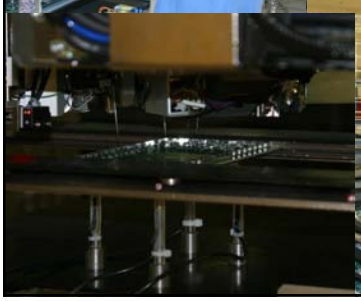






Status – Production Started





Status

Time to start planning your first AMISR experiments from Poker Flat!