

SuperDARN Radars in Space Science Research

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Outline

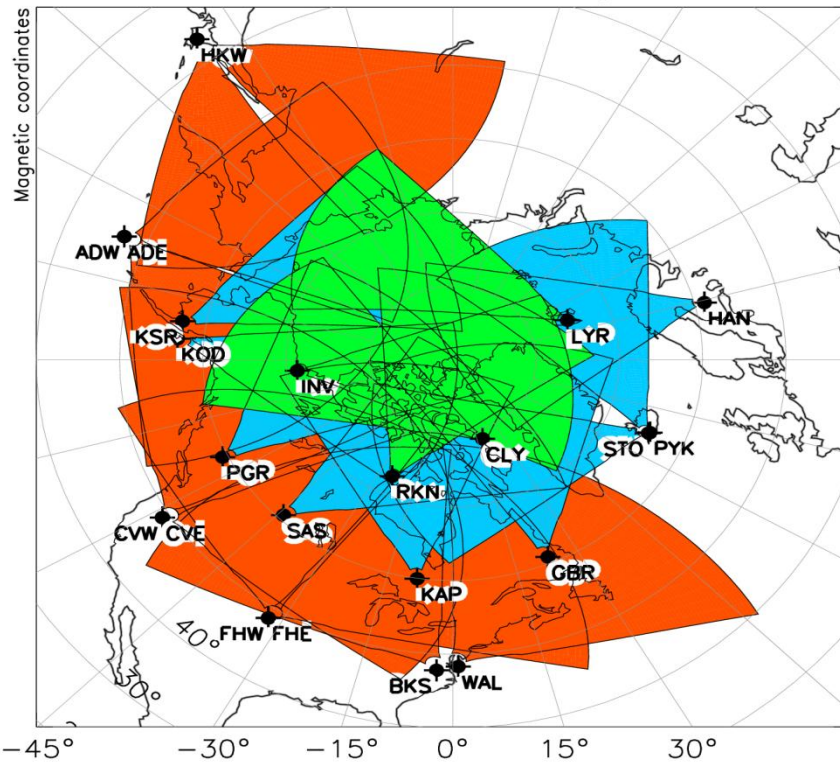
- ❑ Introduction to SuperDARN
- ❑ Accessing Data and Analysis Tools
- ❑ Studies on plasma dynamics & irregularities using SuperDARN radars
 - Shortwave Fadeout (SWF)
 - Polar Cap Dynamics
 - SAPS
 - SAIS
 - ULF Waves
- ❑ Conclusions

Overview & Introduction

Overview of SuperDARN

SuperDARN Radar Fields of View Coverage

Northern Hemisphere

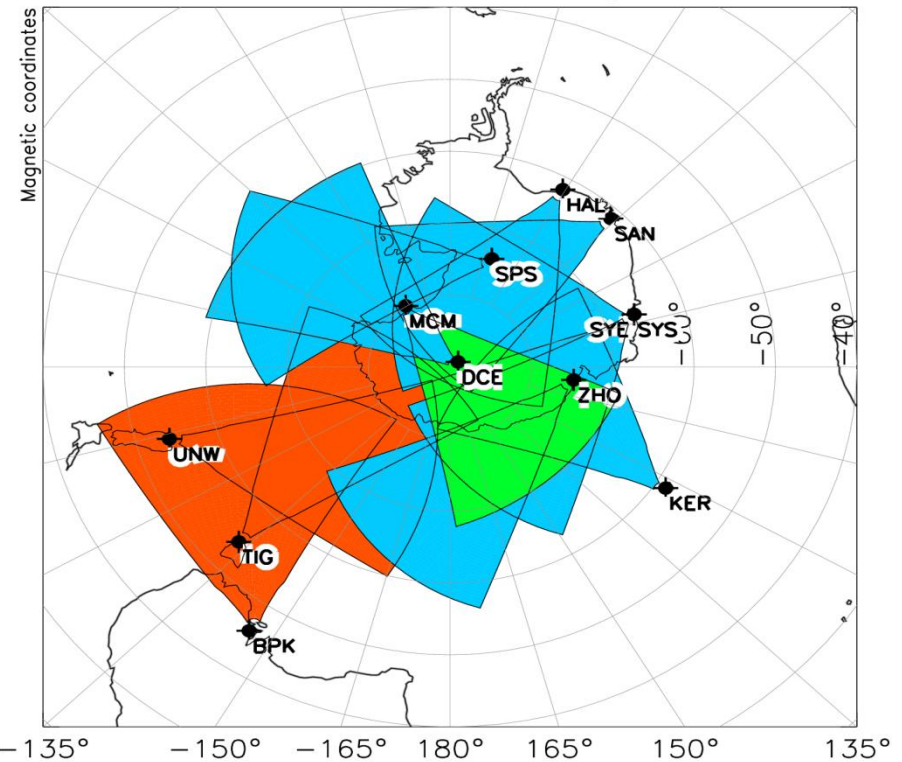


High-latitude

Mid-latitude

Polar cap

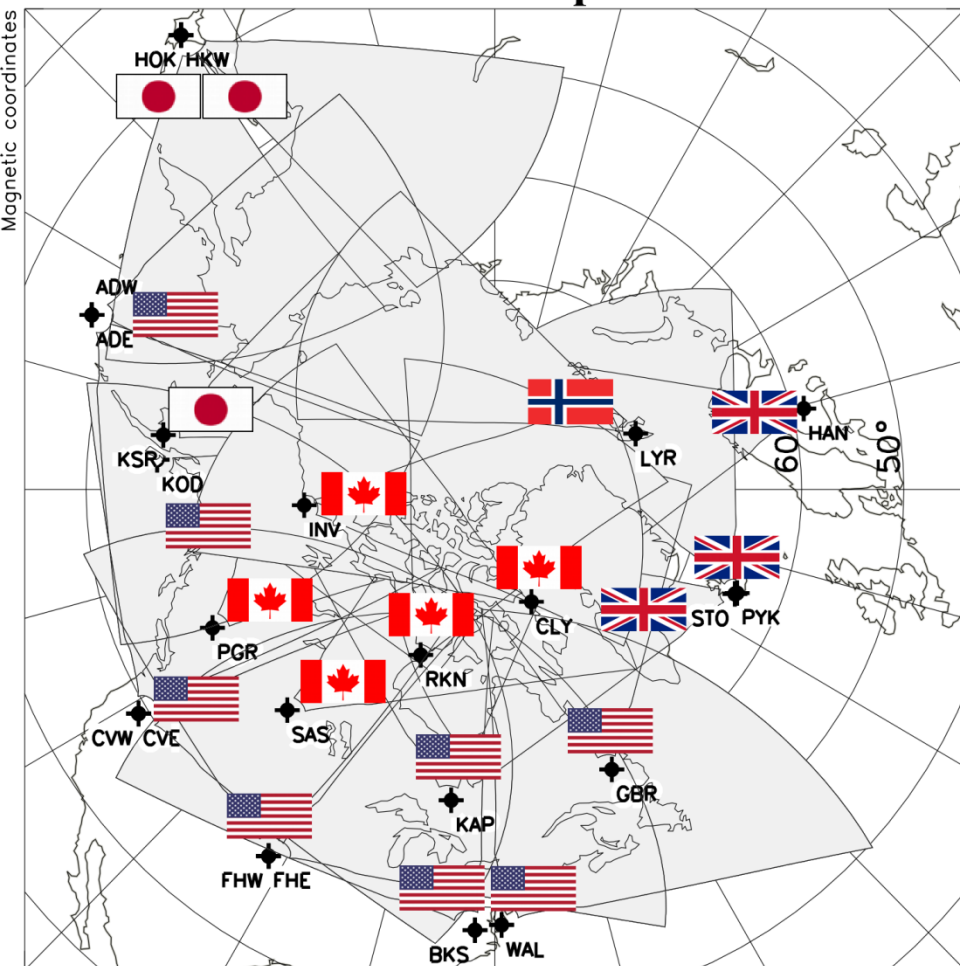
Southern Hemisphere



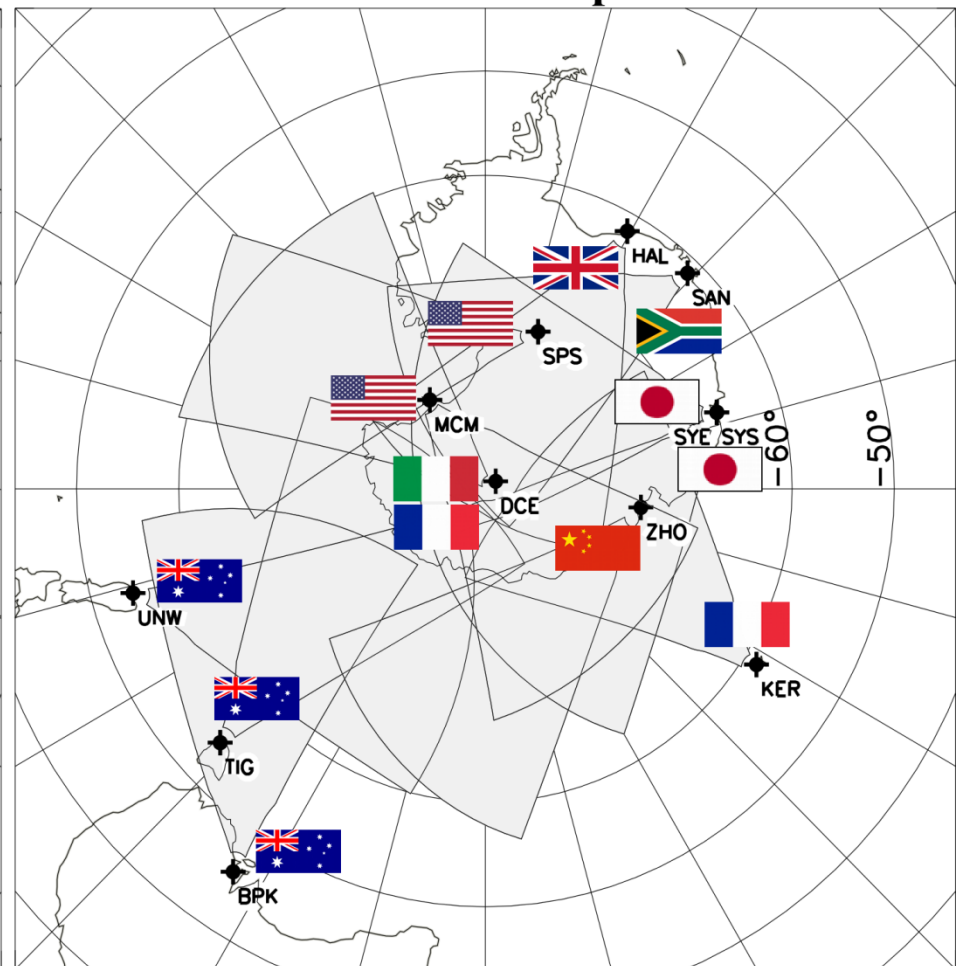
- Over the last ten years new chains of SuperDARN radars have been built to provide coverage over the polar cap and mid-latitude regions.

SuperDARN International Collaboration

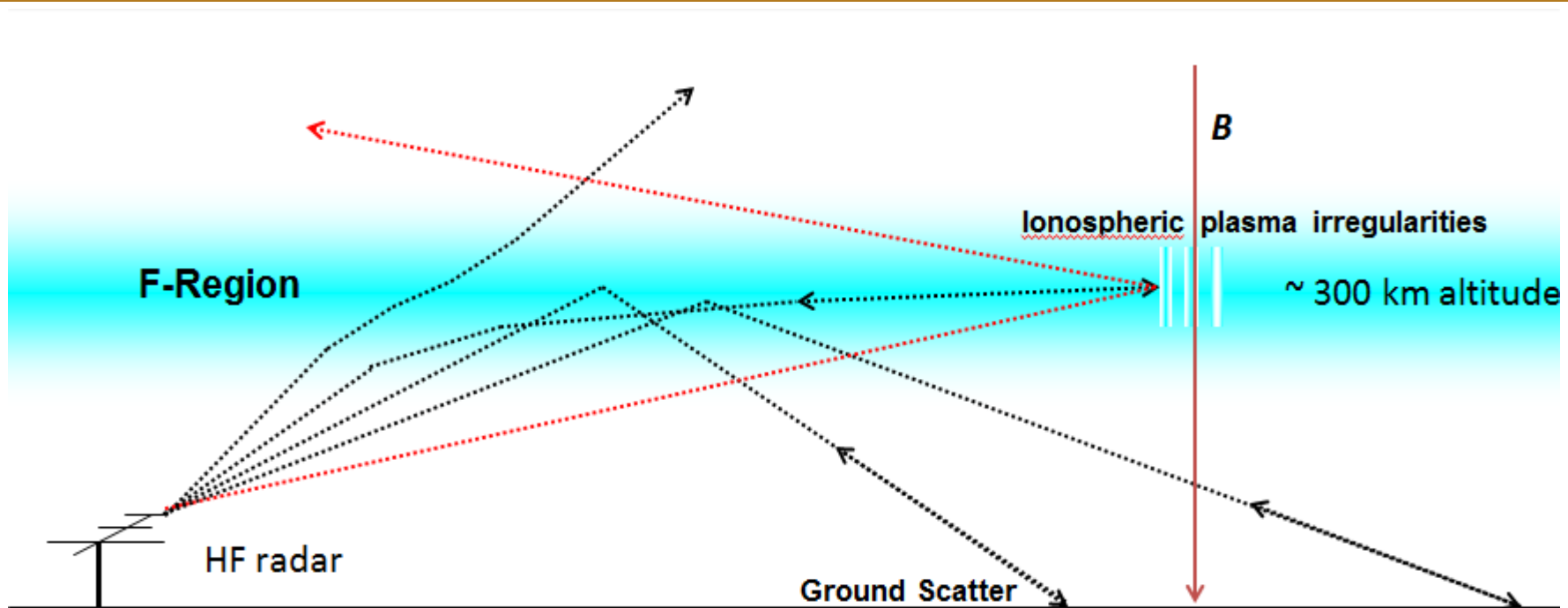
Northern Hemisphere



Southern Hemisphere



Propagation and Reflection of HF Signal



- ❑ HF rays are refracted in the ionosphere as they encounter gradients in electron density
- ❑ Transmitted signals can be reflected back to the radar by:
 - Ionospheric plasma irregularities
 - Earth's surface
- ❑ Information about the reflectors is carried in the returned signal, e.g., Doppler velocity

Data Products and Analysis Tools

Overview of SuperDARN Data Products and Analysis Tools

SuperDARN Data Products


□ Levels of SuperDARN data



- Raw line-of-sight velocity measurements (resolution of 45 km)
- Gridded line-of-sight velocity (square cells, resolution of ~ 150 km)
- Global electrostatic potential data (resolution of several hundreds of km, depending on the order of the fitting)

SuperDARN Interactive Web based Tools

□ Frequently used tools –

- Scan (f-o-v) Plot
- Range-Time Plot
- Map Velocity Plot
- Map Potential Plot
- GPS/TEC Plotting Tool
- Real-time Monitoring
- etc.


College of Engineering
Find Go

Optional Login:
Password:
Login
Forgot Login/Password? | Register

INTERACTIVE MAP POTENTIAL PLOTTING

Plot

Hemisphere	Year	Month	Day	Time	Window(?)
North ▾	2017 ▾	Jun ▾	16 ▾	12 ▾ : 00 ▾ UT	2-min ▾

Parameter	Range	
Velocity Vectors	Min Value: <input style="width: 50px;" type="text" value="0"/>	Max Value: <input style="width: 50px;" type="text" value="1000"/>

Velocity Model

Fit Velocities(?)
 True Velocities(?)
 Line-Of-Sight Velocities
 Merge Velocities(?)

Coordinates

MLT ▾
Lowest latitude for plotting:
Rotate Map by: deg. (clockwise)

Choose Lat/Lon limit to plot

Additional Options

Plot Original L-o-S velocities
 Remove IMF and Geomagnetic Indices
 Overlay DMSP SS/J/4 data(?)
 Overlay R1 oval(?)

Select All
 Remove names of radars
 Overlay DMSP SS/IES data(?)
 Overlay R2 oval(?)

Remove contour fill
 Overlay POES TED data(?)

Debug:

Plot

Virginia Tech Home
ECE Department
Space@VT
Calendar

▼ SuperDARN
News
SD Working Groups
SD Pub List
SD Documents
SD Tech News
SD-Van Allen Probes
Space Weather Portal

▼ VT SuperDARN
Personnel
Contact/Visit Us
VT Pub List
Tutorials
Student Opportunities
Group Meetings

▼ Radars
Maps/Tables/Links
Operating Schedule
Radar Coverage Tool
Conjugate FOV Tool
Radar Finder
Ray Tracing Tool

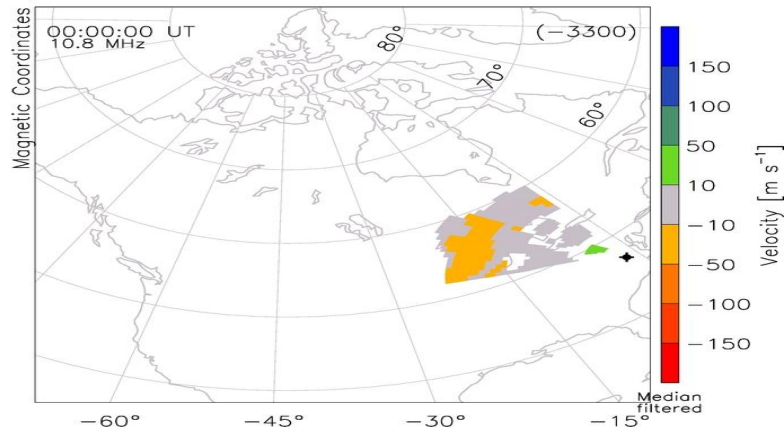
INTERACTIVE MAP POTENTIAL PLOTTING

WEB URLS: <http://vt.superdarn.org/tiki-index.php>
<http://superdarn.usask.ca/realtimedisplay.html>

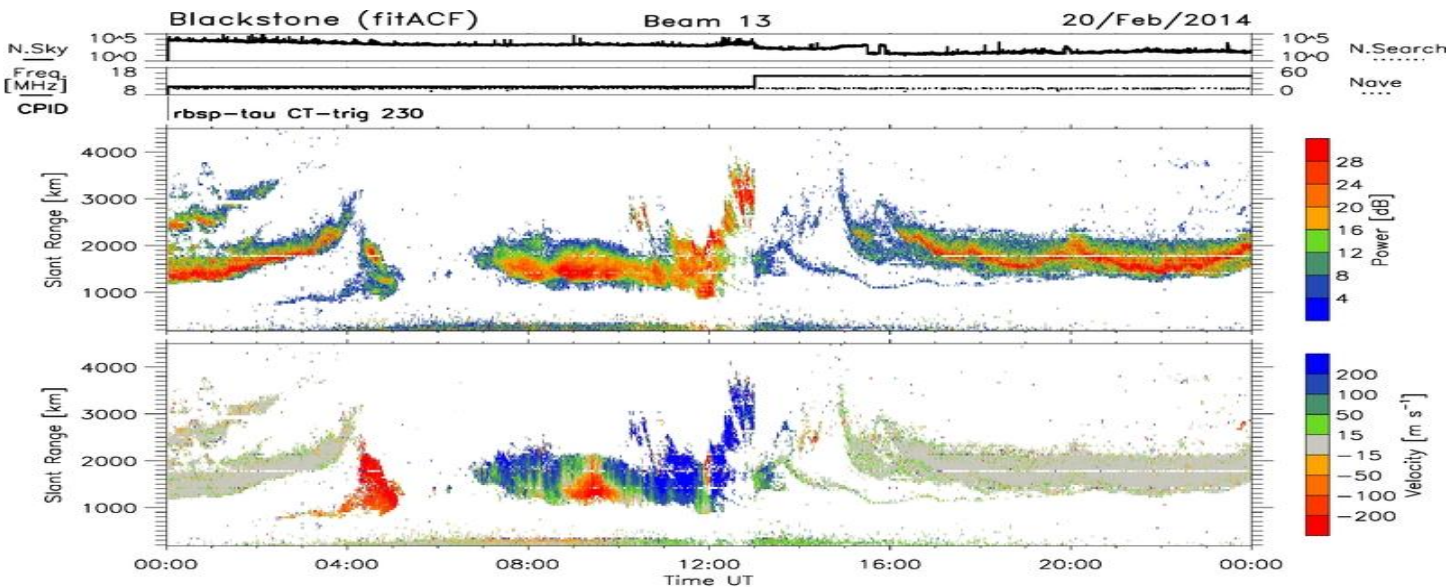
SuperDARN Interactive Web based Tools (Cont.)

Blackstone (fitACF) Ch A
g-s: v ± 10.0 m/s
Plot every 2 min

15/Jun/2016 00:00:00.0
to
15/Jun/2016 00:00:00.0

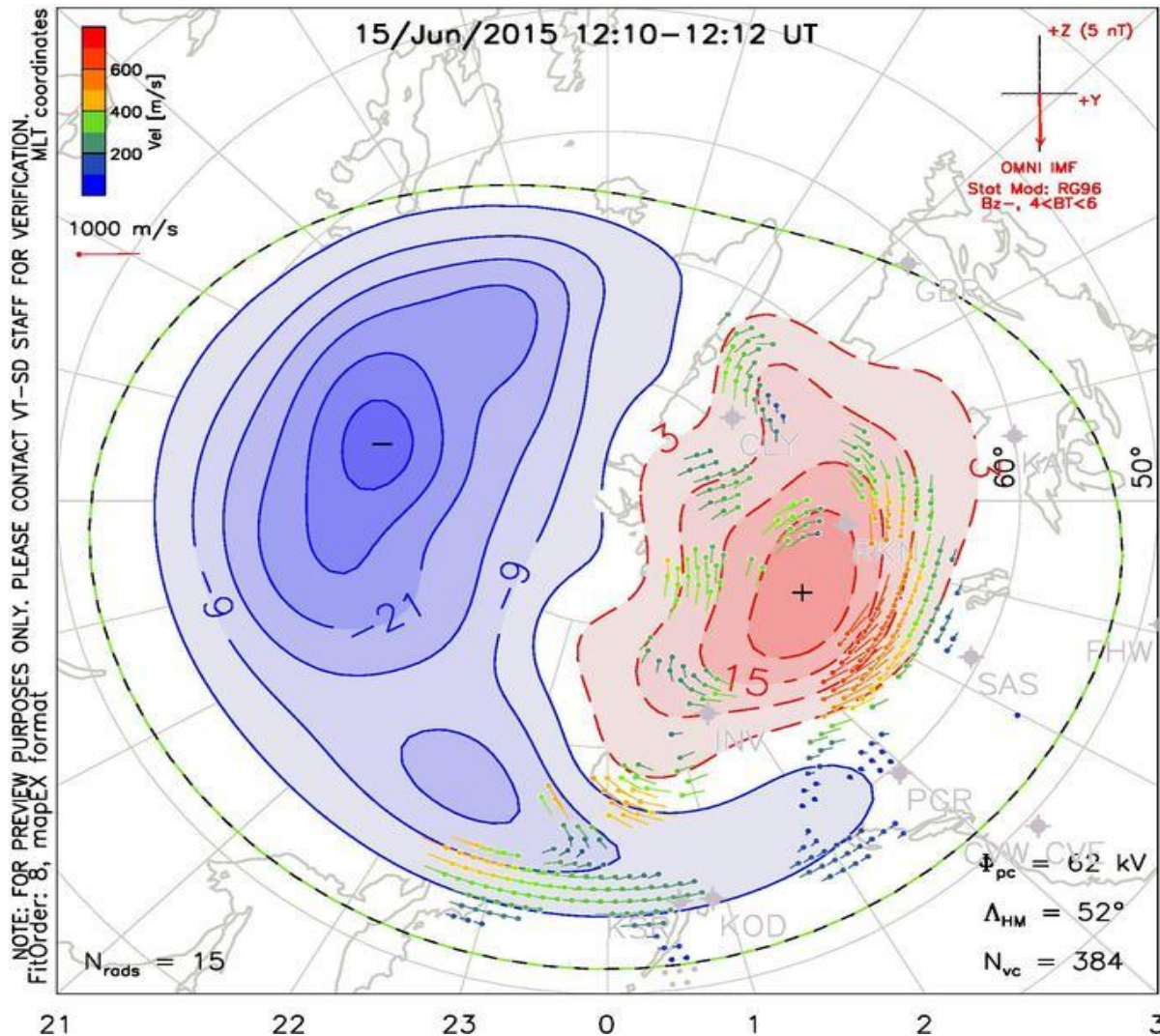


FOV Plot
(Data Level : Lowest)
Shows spatial distribution
of radar measurements at a
particular time



RTI Plot
(Data Level : Lowest)
Shows temporal
distribution of radar
measurements at a
specific radar look
direction

SuperDARN Interactive Web based Tools (Cont.)

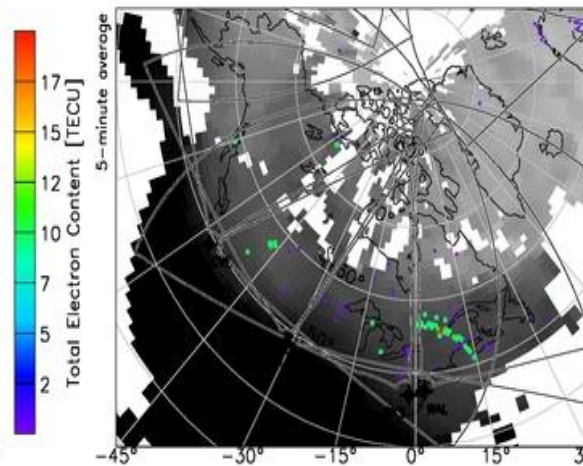
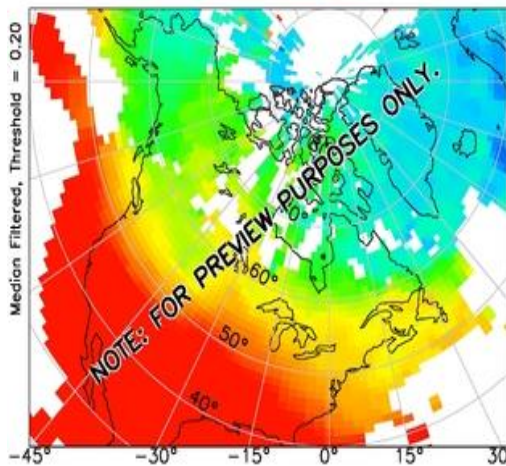
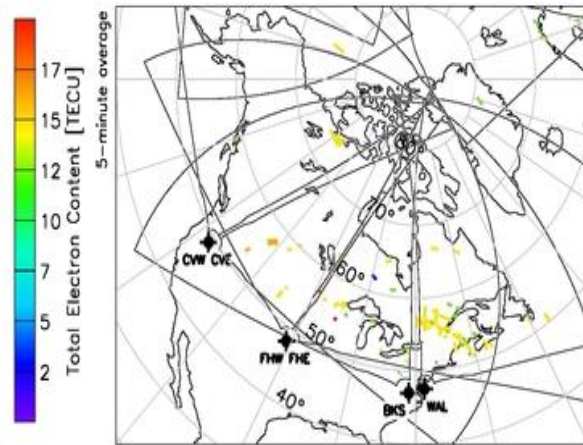
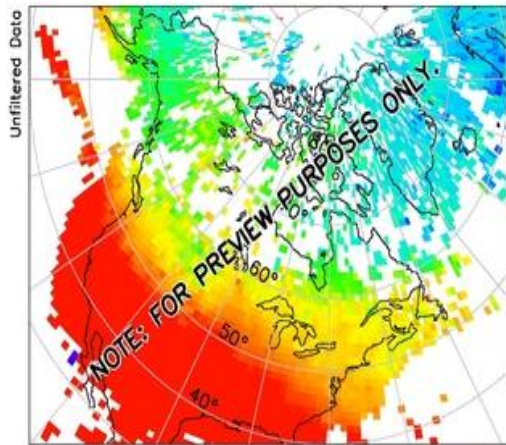


Map Potential Plot -
(Data Level : Highest)
Provides electric field measurements

SuperDARN Interactive Web based Tools (Cont.)

TEC Four Plot
GPS Receiver Network (Millstone Hill)

15/Jun/2016 00:00:00
to
15/Jun/2016 00:05:00



TEC Plotting Tool

Provides relation between TEC data and radar measurements

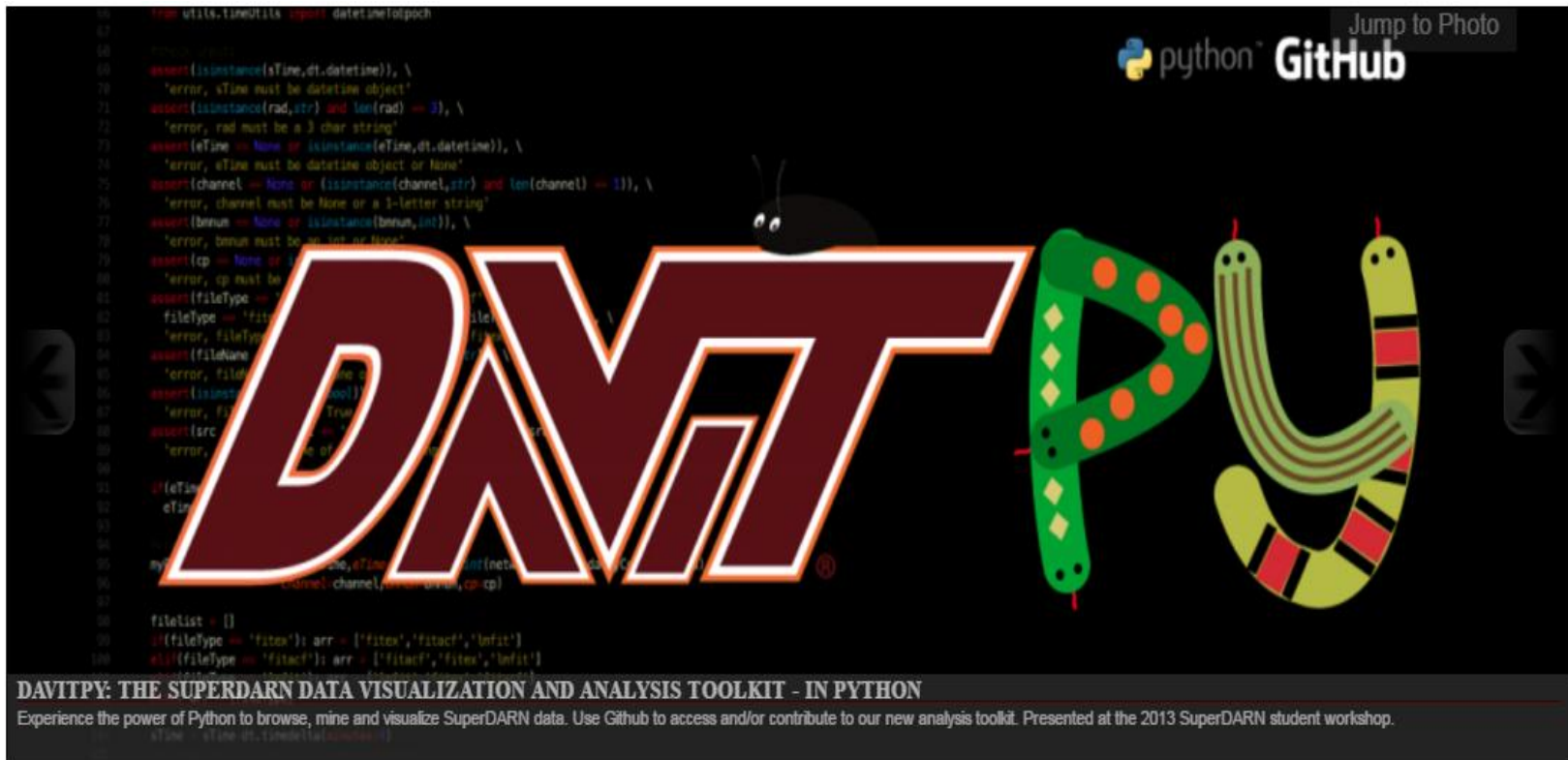
How to get SuperDARN data?

- ❑ Raw Data from website
 - Line-of-Sight data – ASCII format.
 - Electric Field Data – ASCII format.
- ❑ Contact with us if you need large amount of data.

```
#SuperDARN Data file.
#For North Vectors, positive means North and negative means South.
#For East Vectors, positive means East and negative means West.
#
d 2015-06-16/12:00:00
> Number of Measured Vectors (VCNUM): 100
> IMF Model: RG96 By+, 4<BT<6, Fit Order: 8
> OMNI IMF: Bx=-1 nT, By=4 nT, Bz=0 nT
> Potential: Drop=44 kV, Min=-28 kV, Max=15 kV
#
#Record Indices mlat          mlon          EField_north    EField_east     Fitted_Vel_North Fitted_Vel_East Potential
TimeStamp
#           [deg]           [deg]           [V/m]           [V/m]           [m/s]           [m/s]           [V]
[UT]
0          [1,1]           50.0000         0.00000         0.00000         0.00000         -0.00000         0.0000000
2015-06-16/12:00:00
0          [1,2]           50.0000         2.00000         0.00000         0.00000         -0.00000         0.0000000
2015-06-16/12:00:00
0          [1,3]           50.0000         4.00000         0.00000         0.00000         -0.00000         0.0000000
2015-06-16/12:00:00
0          [1,4]           50.0000         6.00000         0.00000         0.00000         -0.00000         0.0000000
2015-06-16/12:00:00
0          [1,5]           50.0000         8.00000         0.00000         0.00000         -0.00000         0.0000000
2015-06-16/12:00:00
0          [1,6]           50.0000        10.0000         0.00000         0.00000         -0.00000         0.0000000
2015-06-16/12:00:00
0          [1,7]           50.0000        12.0000         0.00000         0.00000         -0.00000         0.0000000
2015-06-16/12:00:00
```

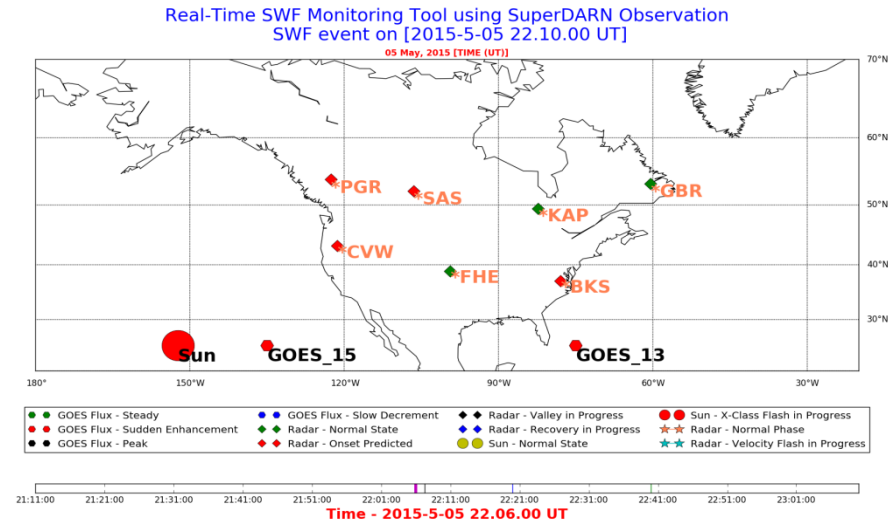
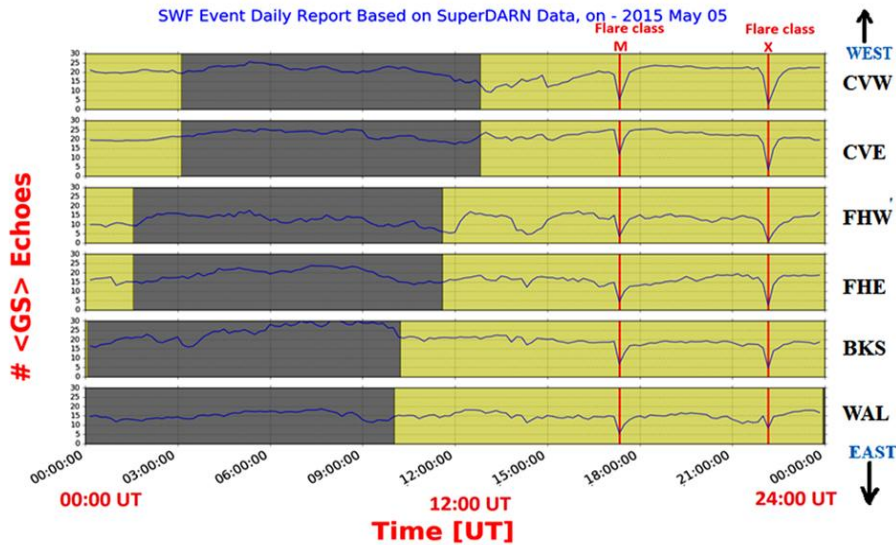
SuperDARN Software and Data

- ❑ Available Software to access SD Data –
 - Davitpy (python based, open source, available on our vtsuperdarn GitHub page - <https://github.com/vtsuperdarn/davitpy>)



DAVITPY: THE SUPERDARN DATA VISUALIZATION AND ANALYSIS TOOLKIT - IN PYTHON
Experience the power of Python to browse, mine and visualize SuperDARN data. Use Github to access and/or contribute to our new analysis toolkit. Presented at the 2013 SuperDARN student workshop.

Upcoming Tools



- Upcoming (WEB) Tools –
- SAIS Identification
 - SWF Detection and Real-Time Monitoring of SWF
 - ULF Wave Detection

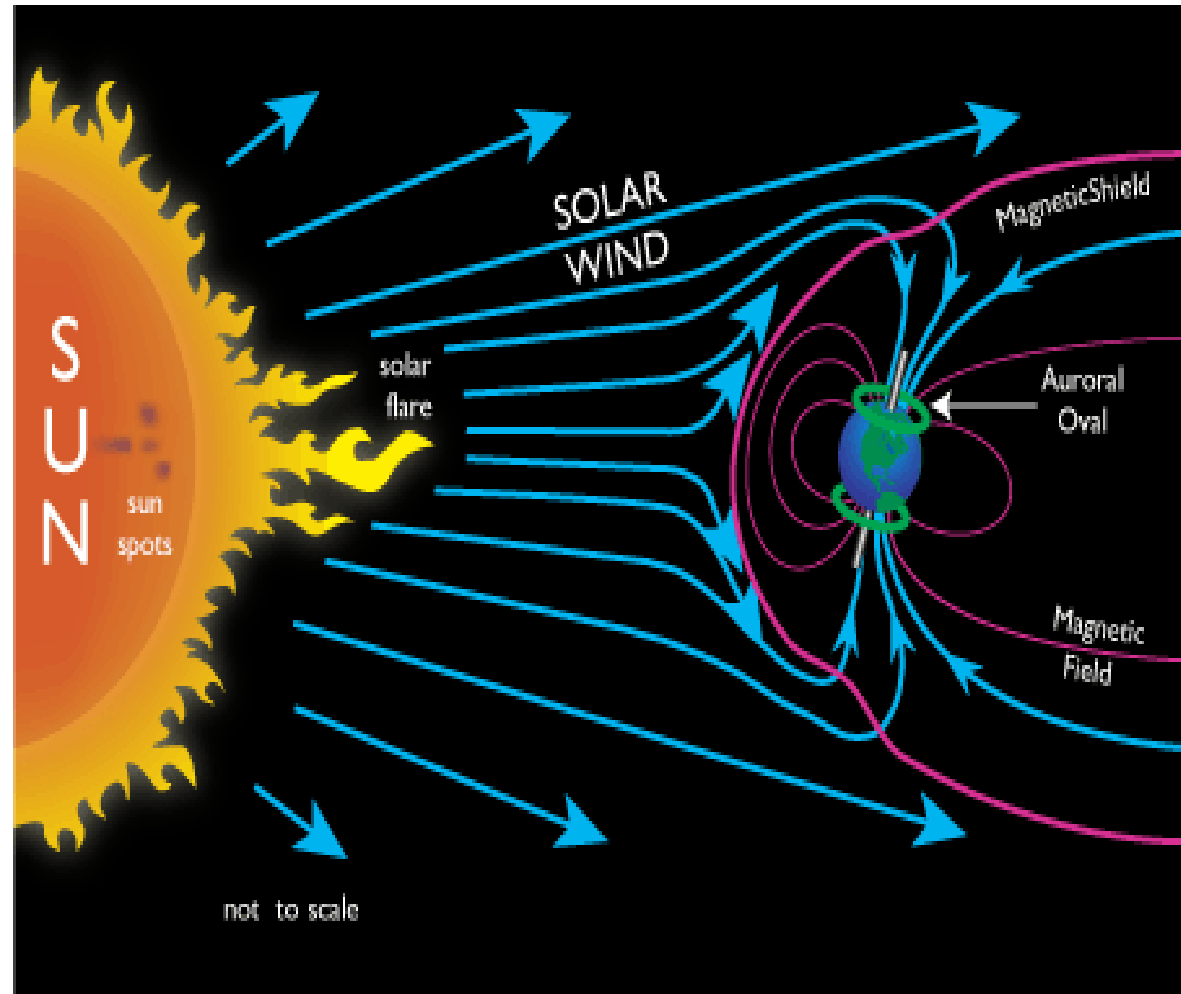
WEB URL : <http://vt.superdarn.org/tiki-index.php> [Stay Tuned]

Science

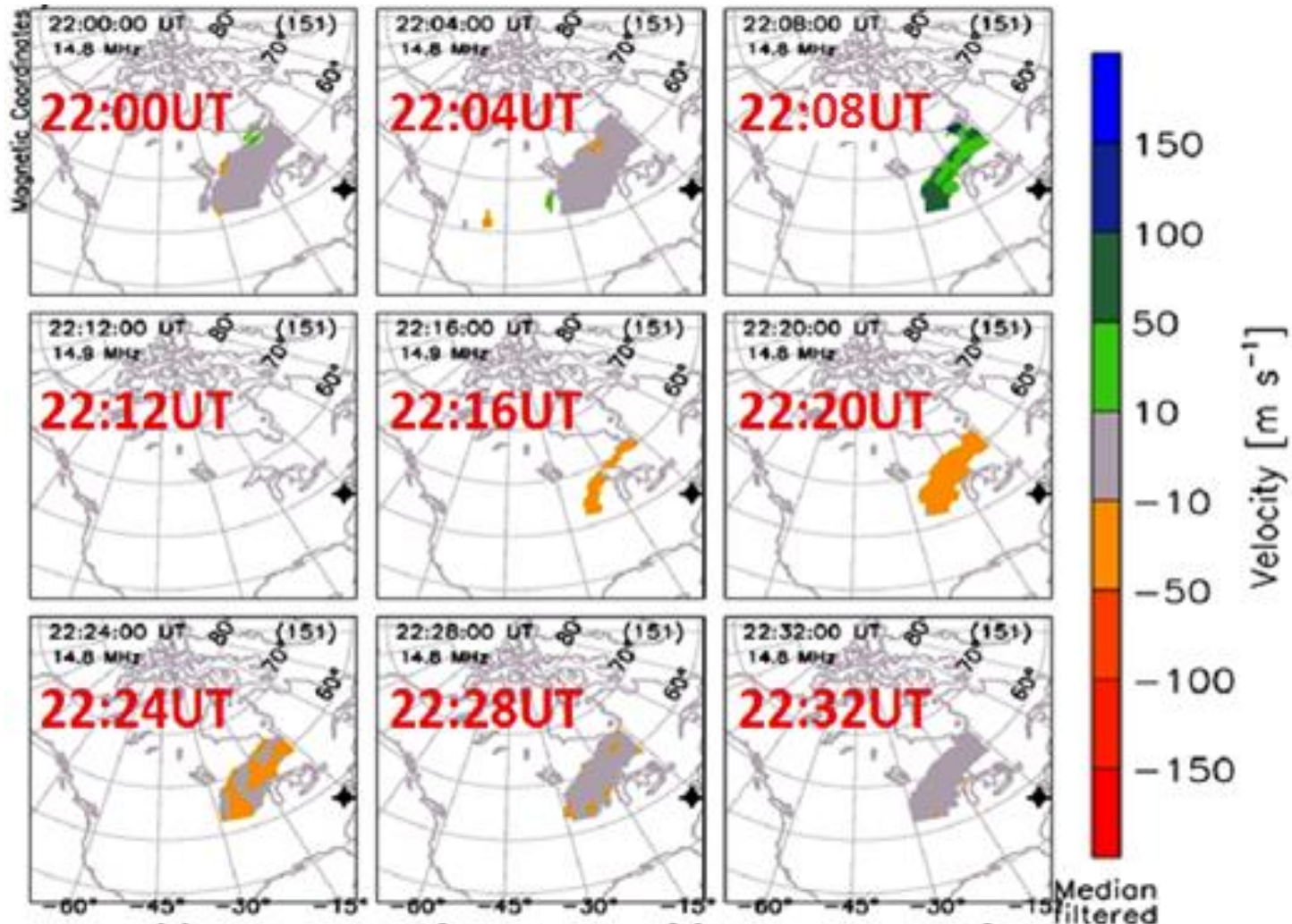
Addressing Research Topics using SuperDARN Radar Data

Prologue on Shortwave Fadeout (SWF)

- ❑ Solar flare produces intense ultraviolet (EUV) & x-ray radiation.
- ❑ Strikes the dayside of the Earth, creating anomalies and absorption in the travelling radio waves through ionosphere, known as ShortWave Fadeout (SWF).
- ❑ Represents earliest space weather effects of a flare, with only an 8 min delay.

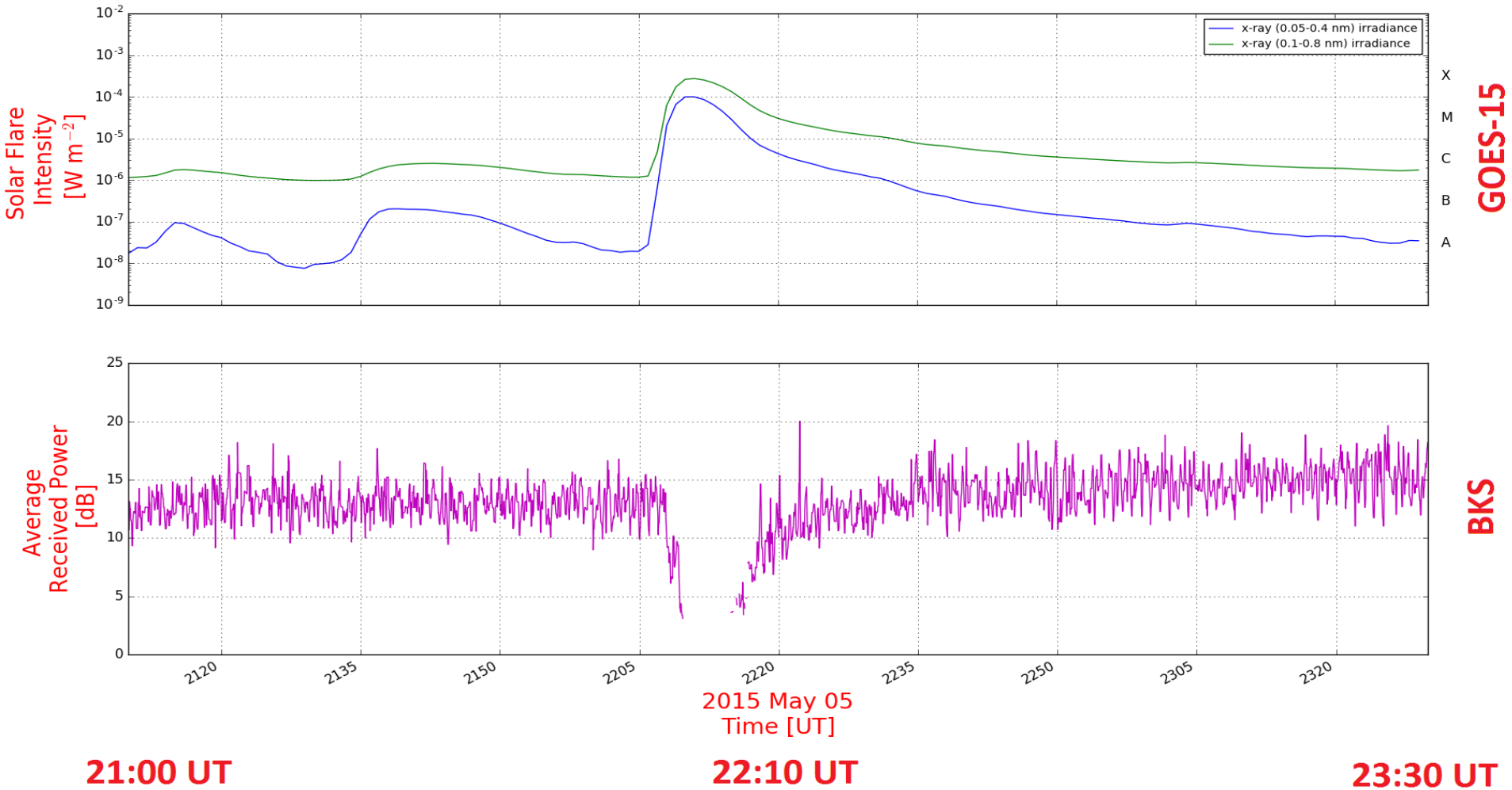


Effects of Shortwave Fadeout (SWF) on SuperDARN



GOES X-Ray Imager Data versus SuperDARN Measurements

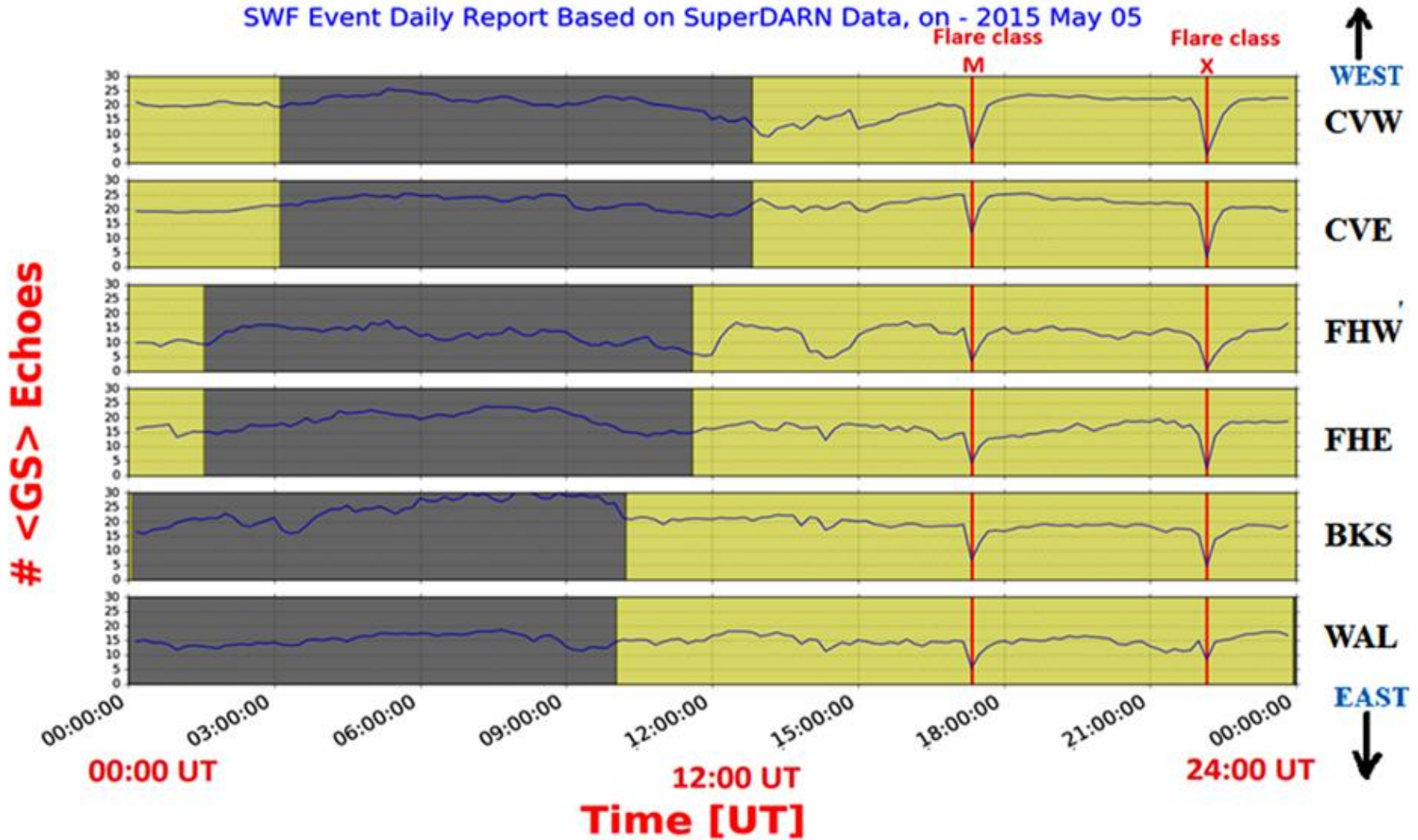
Timing comparison between solar flux recoded in GOES satellite and SWF seen in Radar- Blackstone on [2015-5-05 22.10.00]



Automatic SWF Event detection tool – Daily Report

[For details visit Poster IRRI-01]

SWF Event Daily Report Based on SuperDARN Data, on - 2015 May 05

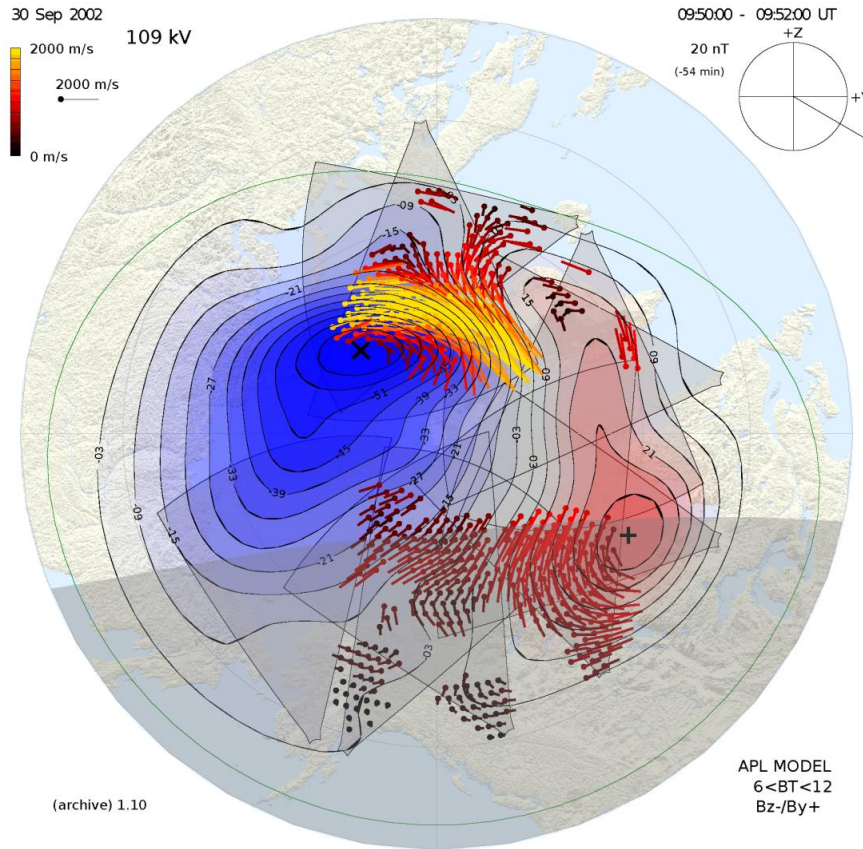


Summary of Shortwave Fadeout

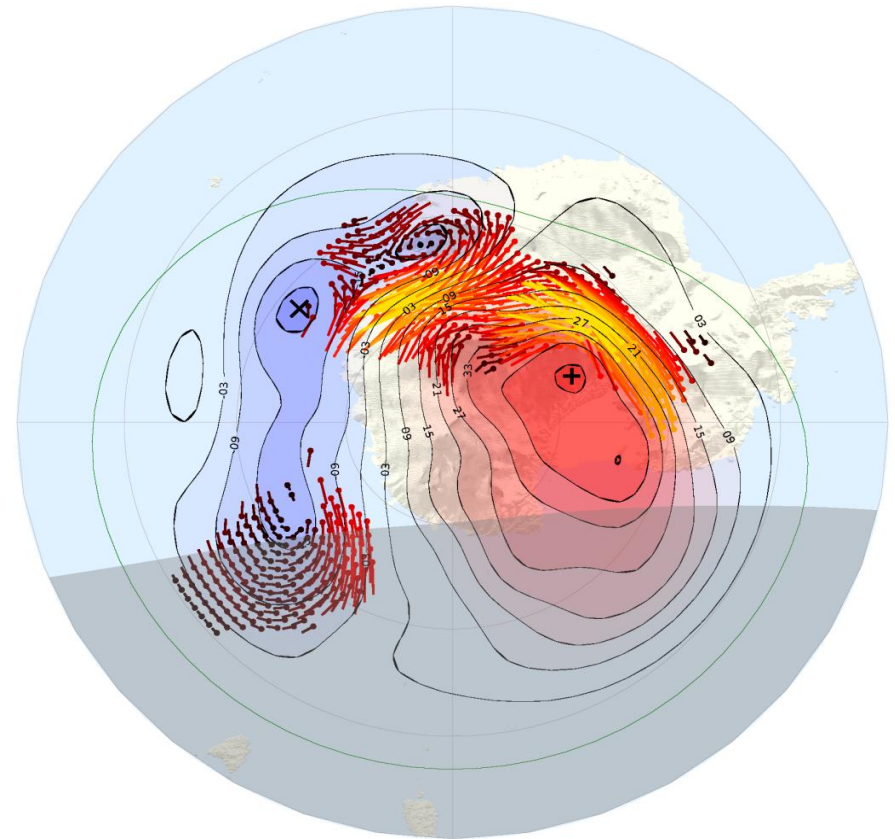
- ❑ Daytime SuperDARN ground-scatter echoes get suppressed by the SWF events. It is one of the most significant effects seen in any HF communication system during SWF.
- ❑ We can identify multiple phases of SWF in ground-scatter measurements from SuperDARN radars.
- ❑ We can use historical SuperDRAN data to detect SWF events, which will be very useful for statistical studies.

Large-Scale Mapping of Ionospheric Plasma Motion

September 30, 2002: 09:50 – 09:52 UT



Northern Hemisphere



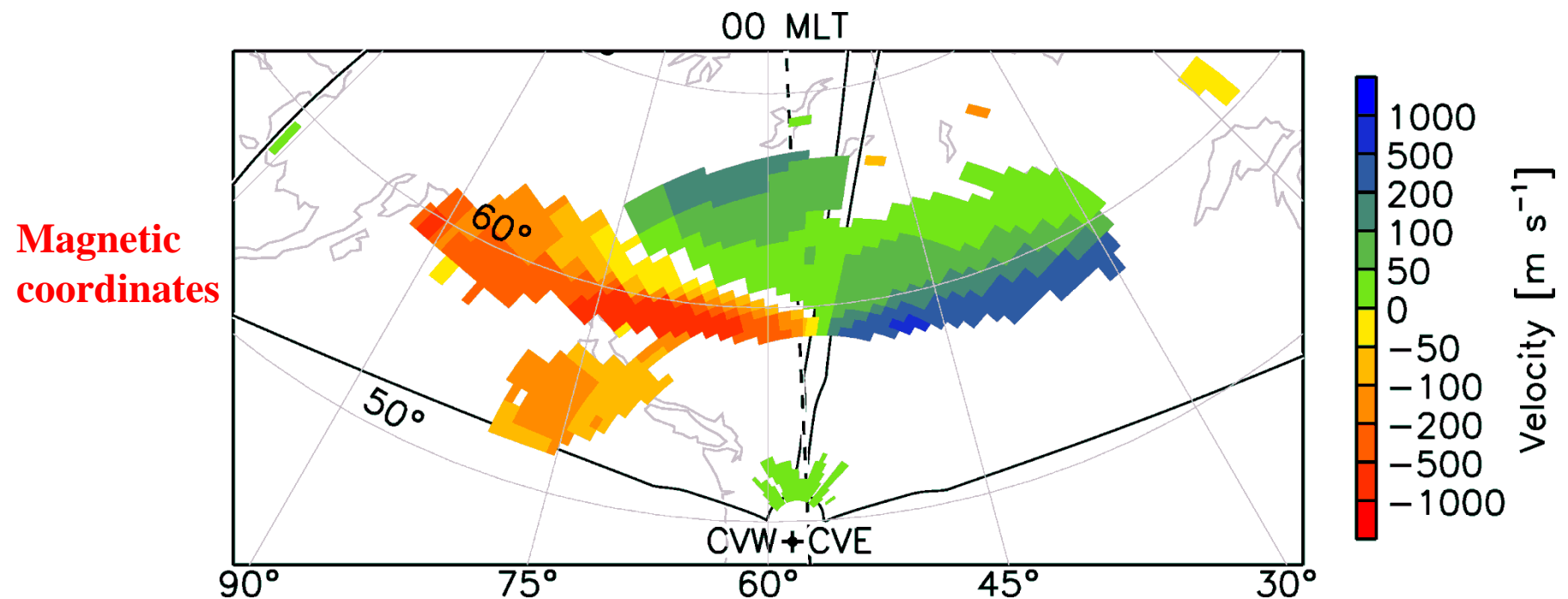
Southern Hemisphere

Mid-Latitude Anomalies and Disturbances

- ❑ For the past 10 years, SuperDARN has been expanded to the mid-latitude regions to image the storm expansion

- ❑ Surprised to observe extensive subauroral ionosphere scatter (SAIS) on the night-side during quiet time, e.g., Ribeiro et al. [2012]

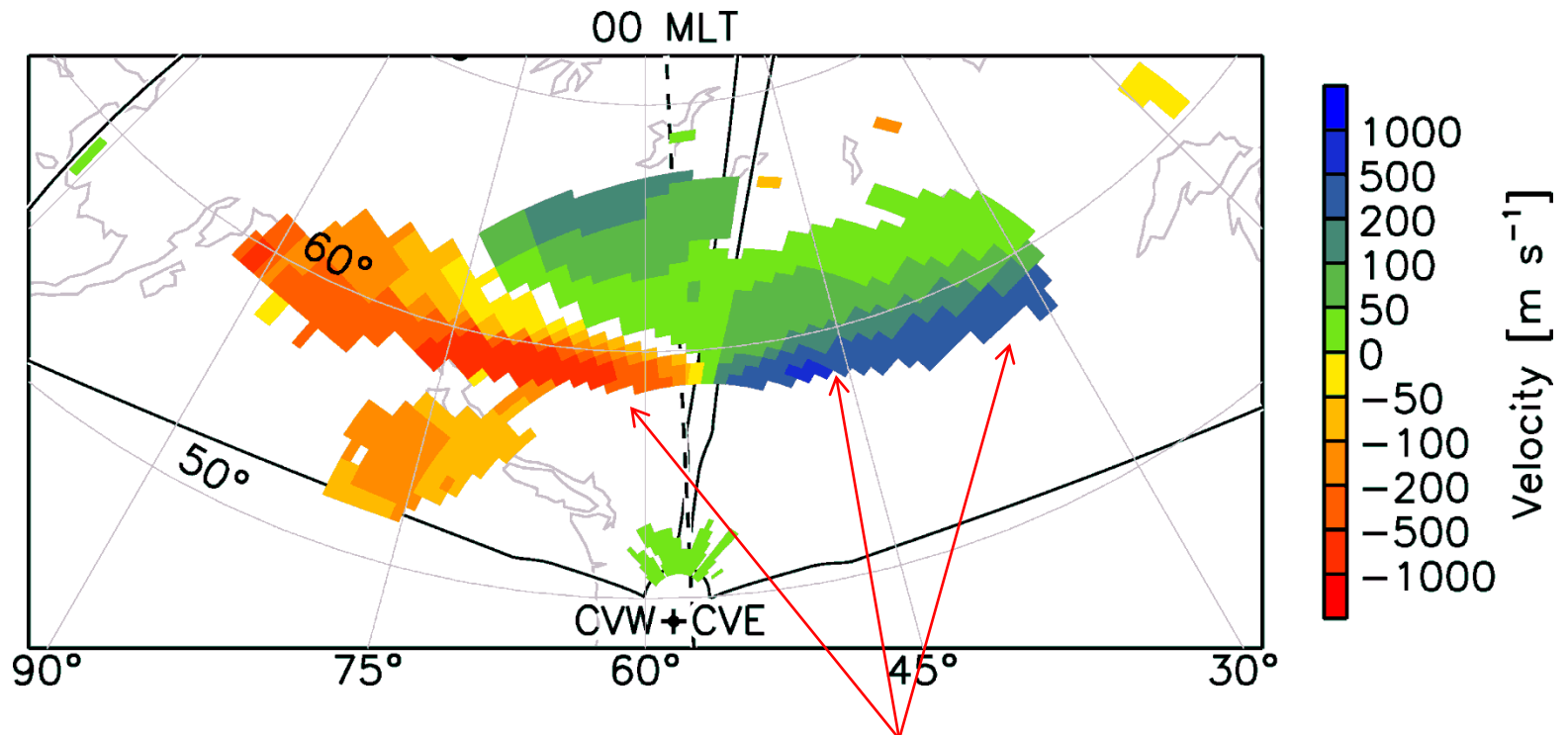
- ❑ With the mid-latitude chain, it has become possible to map the flows of the subauroral polarization stream (SAPS) instantaneously over many hours of MLT, e.g., Clausen et al. [2012]

*SAPS Disturbance – April 9, 2011***Line-of-sight velocity measurements**

Fields of view of the Christmas Valley West and East radars (Oregon)

SAPS Disturbance – April 9, 2011

Line-of-sight velocity measurements 0840 UT



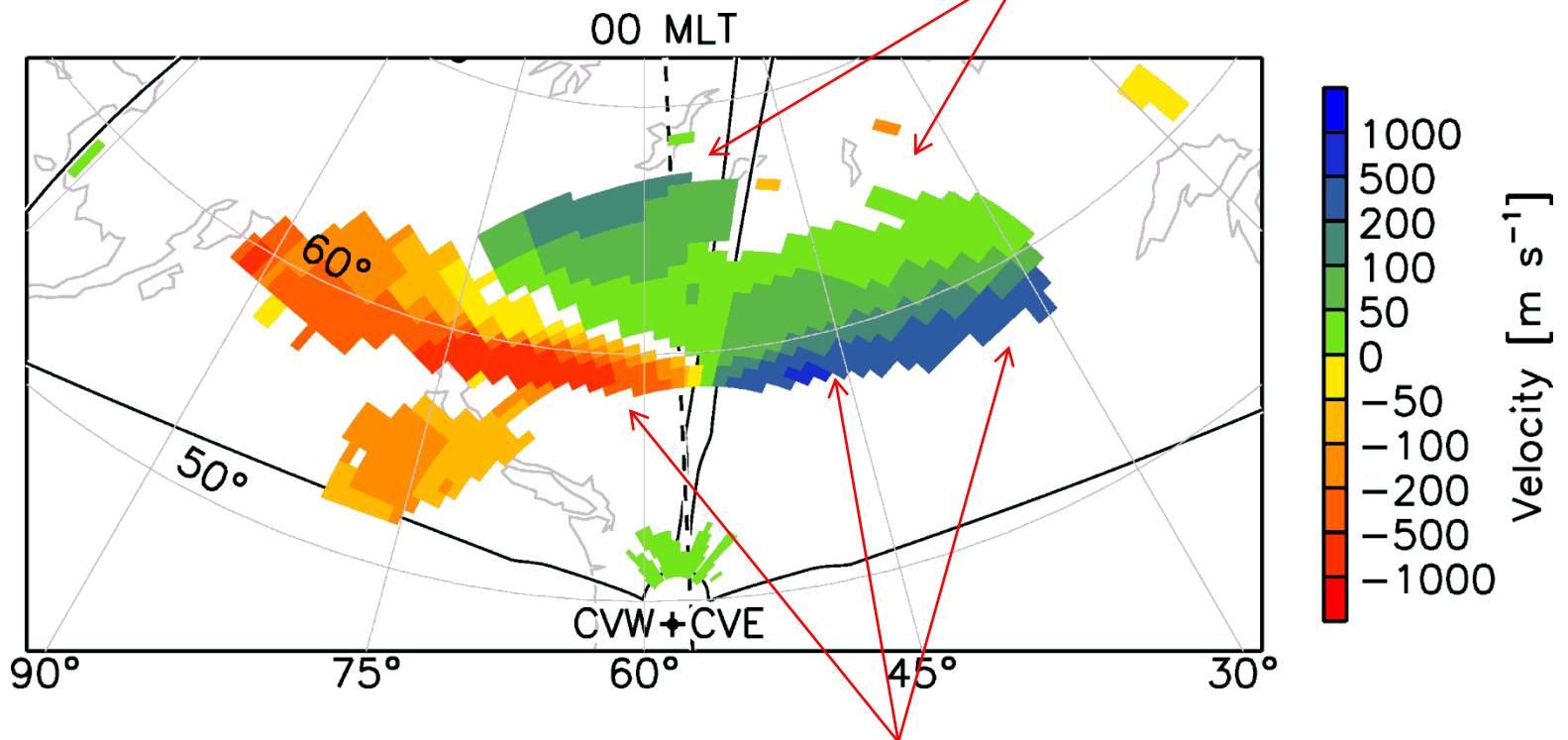
SAPS Channel (Oksavik et al. [2006])

SAPS Disturbance – April 9, 2011

Line-of-sight velocity measurements

0840 UT

Auroral Oval



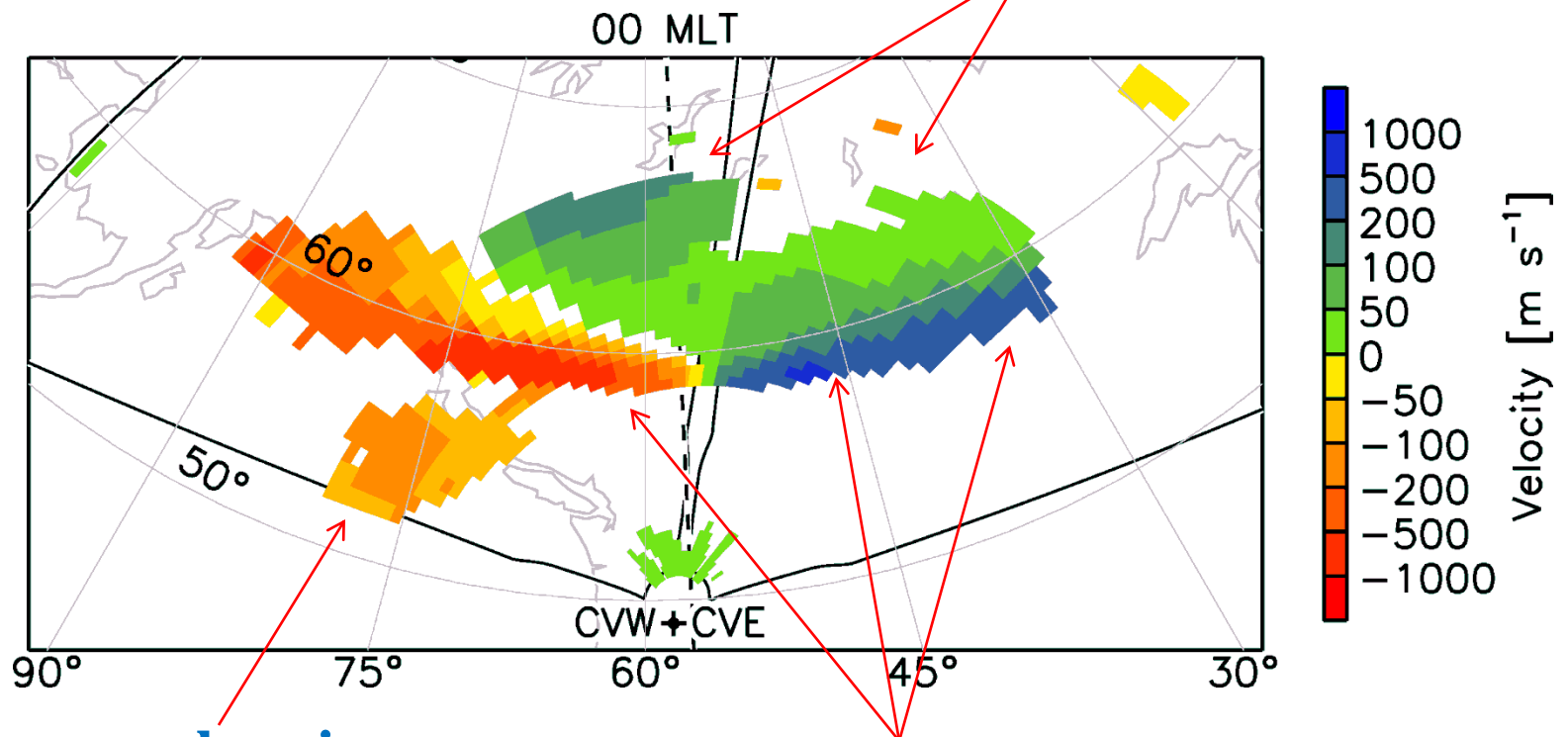
SAPS Channel (Oksavik et al. [2006])

SAPS Disturbance – April 9, 2011

Line-of-sight velocity measurements

0840 UT

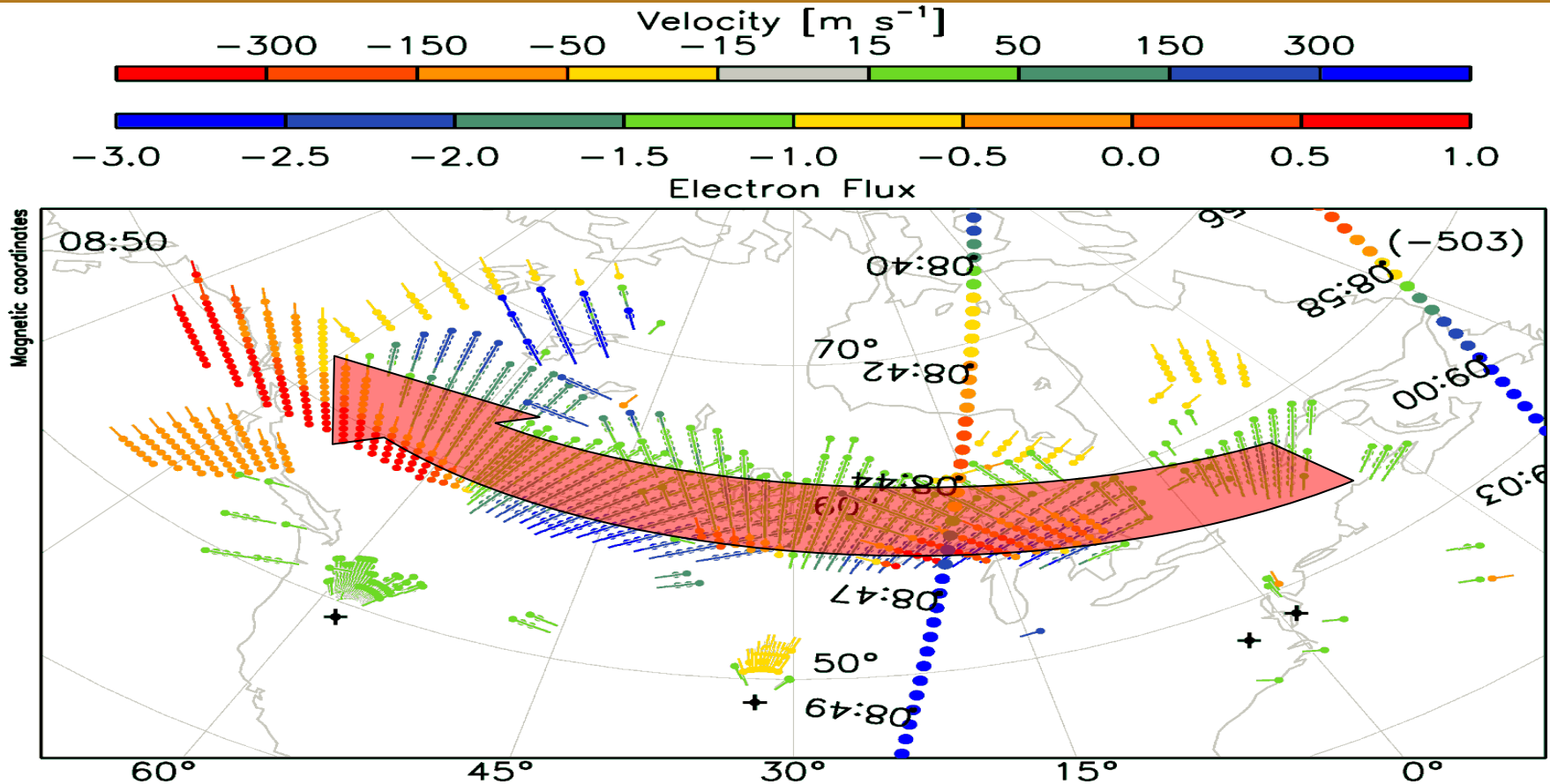
Auroral Oval



Subauroral region
(Riberio et al. [2012])

SAPS Channel (Oksavik et al. [2006])

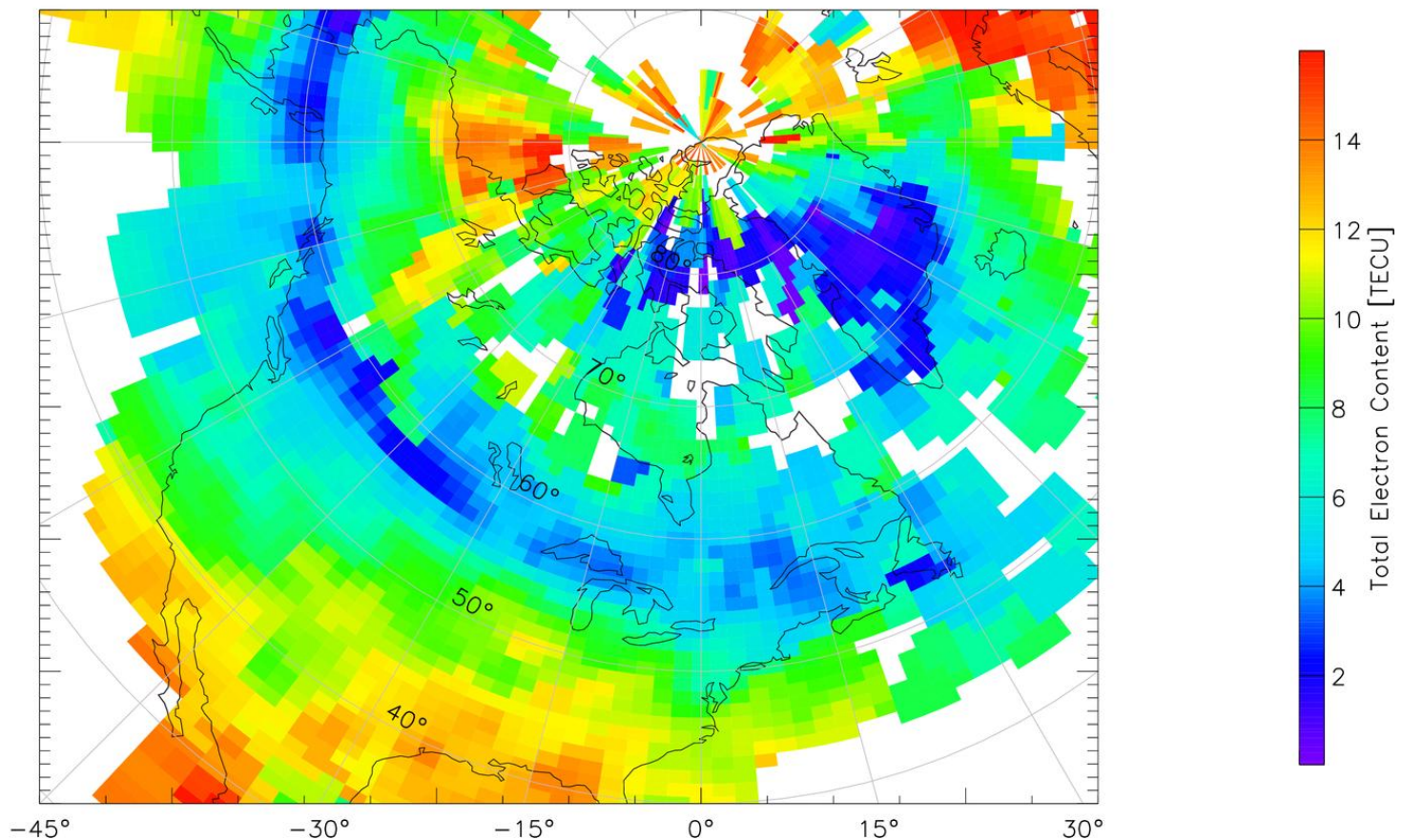
An Example of SAPS



□ The new mid-latitude array of SuperDARN radars images the large-scale evolution of storm-time features such as SAPS.

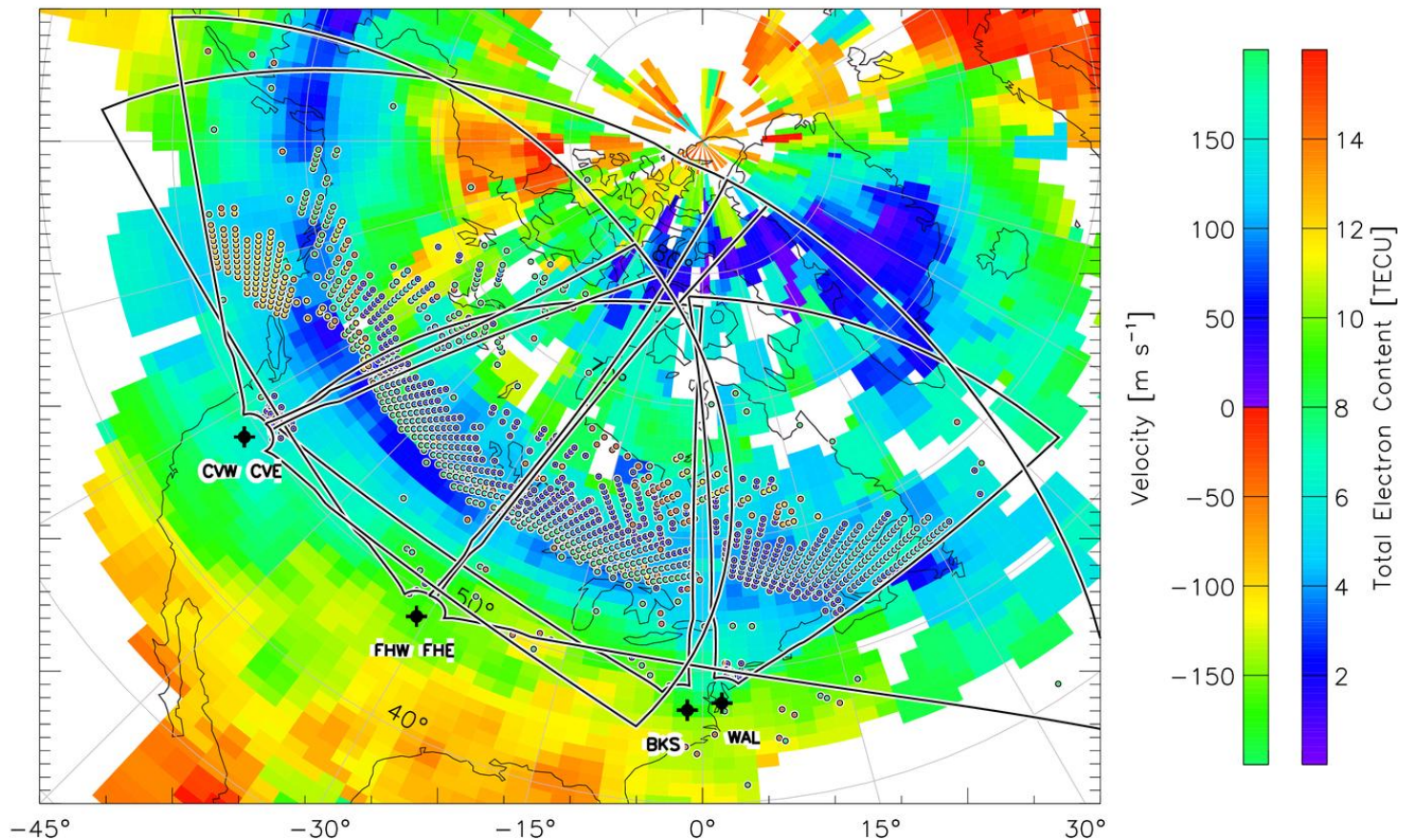
Mid-Latitude Disturbance: SAPS and TEC Trough

TOTAL ELECTRON CONTENT 09/Apr/2011 08:00:00.0
Median Filtered, Threshold = 0.01 to
09/Apr/2011 08:05:00.0

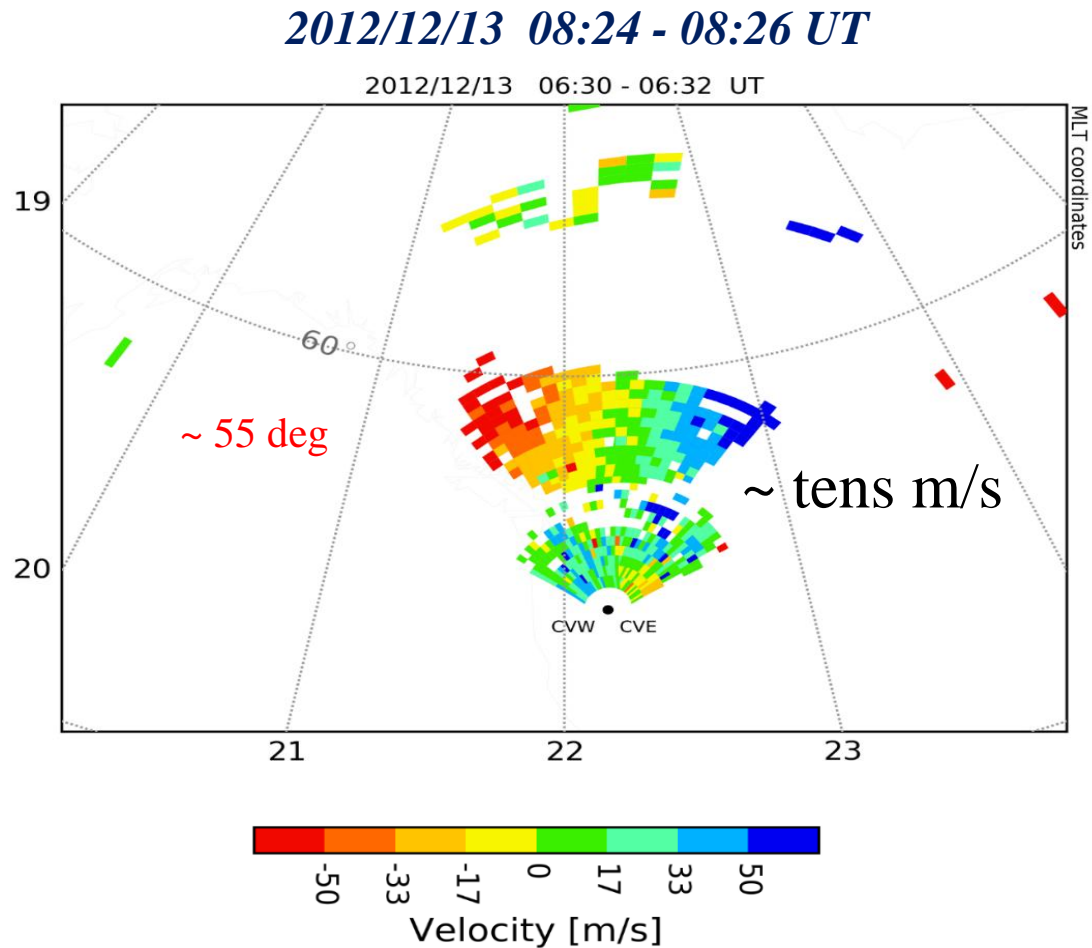


Mid-Latitude Disturbance: SAPS and TEC Trough

TOTAL ELECTRON CONTENT 09/Apr/2011 08:00:00.0
Median Filtered, Threshold = 0.01 to
09/Apr/2011 08:05:00.0



Example of SAIS (Blackstone) – February 5, 2012

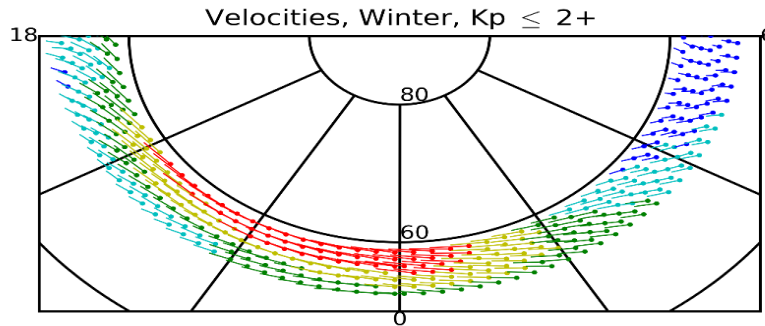


Scan plot of SAIS showing azimuthal sense of velocity variation

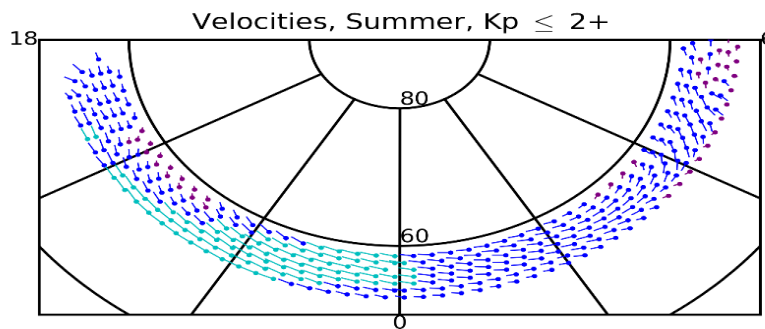
Subauroral Convection Patterns

[For details visit Poster MDIT-06]

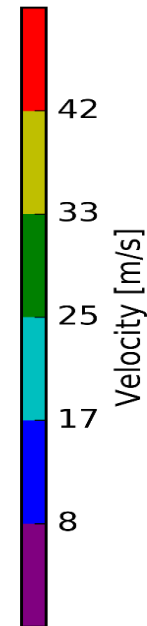
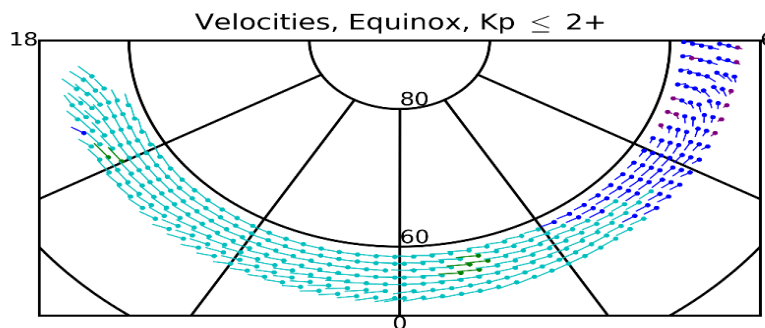
Winter



Summer



Equinox

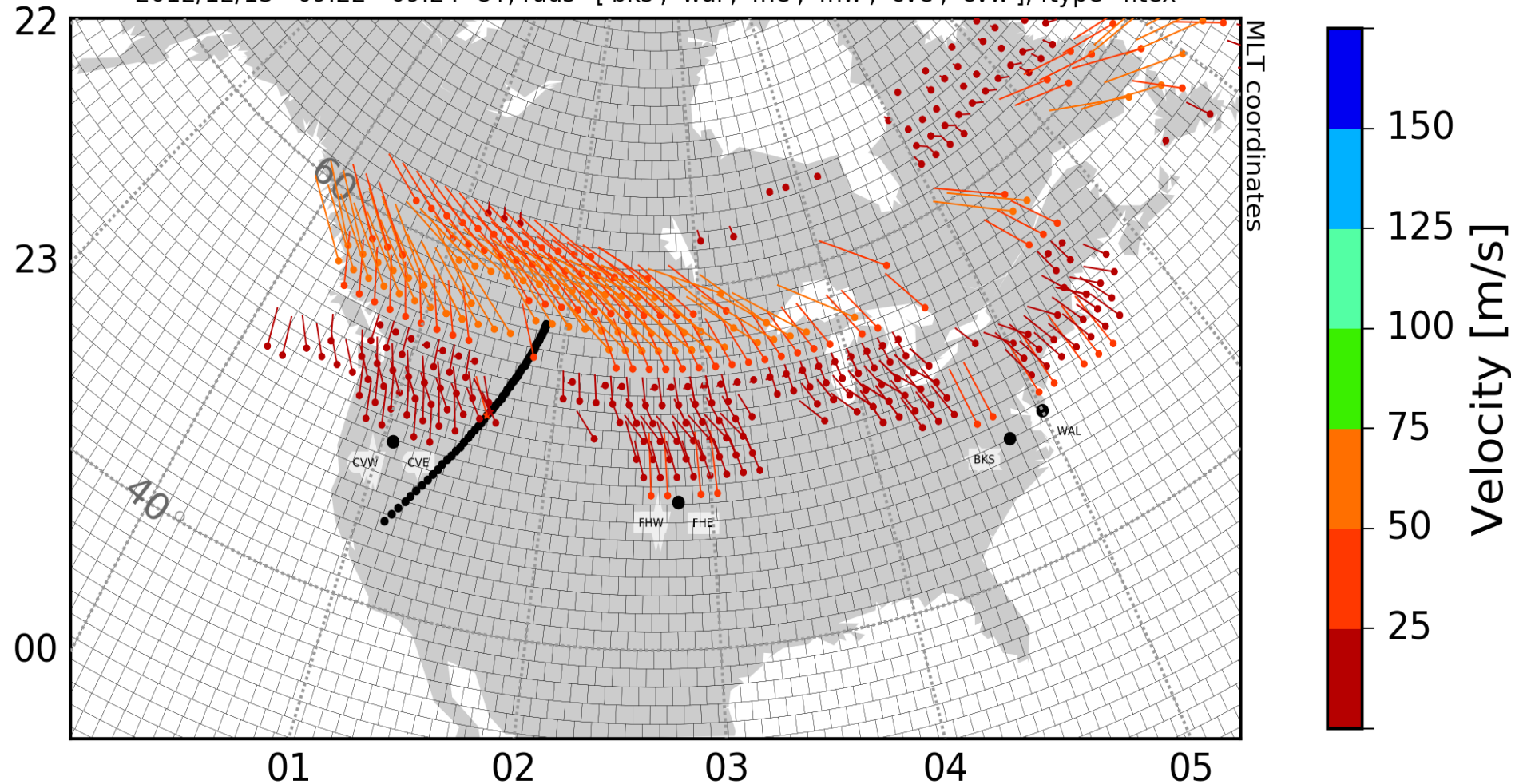


- Data are split into three seasons; Winter (Nov-Feb, Summer (May-Aug) and Equinox (Mar-Apr, Sep-Oct)

- Flows are mainly westward across the night-side

SAIS Observation in Conjunction with Van Allen Probe

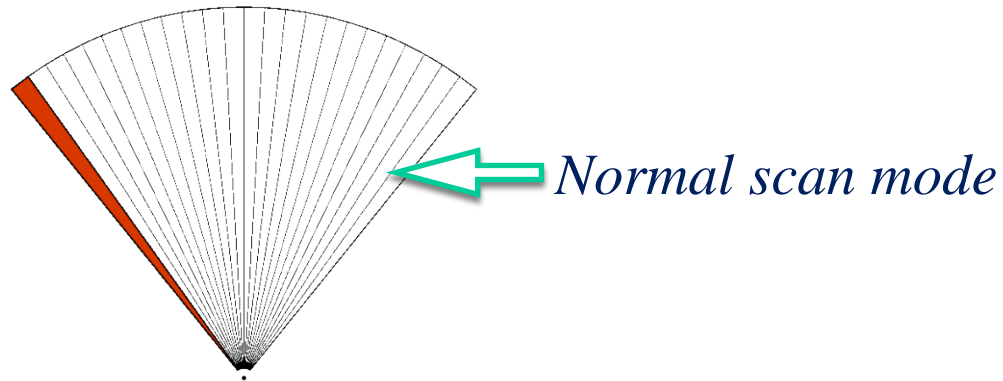
2012/12/13 09:22 - 09:24 UT, rads=['bks', 'wal', 'fhe', 'fhw', 'cve', 'cvw'], ftype=fitex



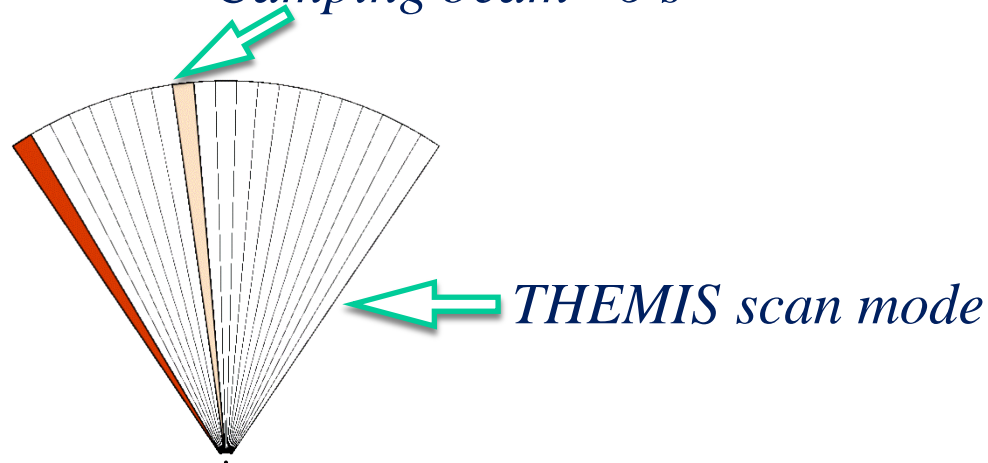
Summary of Mid-Latitude Disturbances

- ❑ Original concept of ‘StormDARN’ is realized with expanded mapping of storm time convection
- ❑ Subauroral ionospheric scatter (SAIS) gives views of plasma flows and electric fields conjugate to the inner magnetosphere
- ❑ Extensive observations of SAPS provides a testbed for modelling storm-time dynamics and coupling to the inner magnetosphere
- ❑ Strong correlations observed between SAPS and global distribution of TEC

SuperDARN THEMIS Mode for ULF Wave Study



Camping beam ~6 s

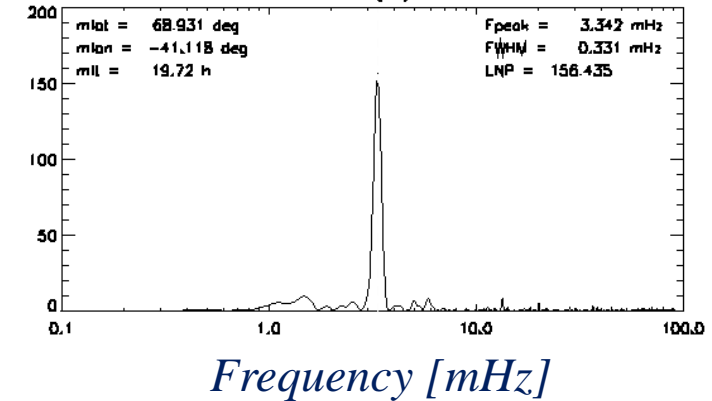
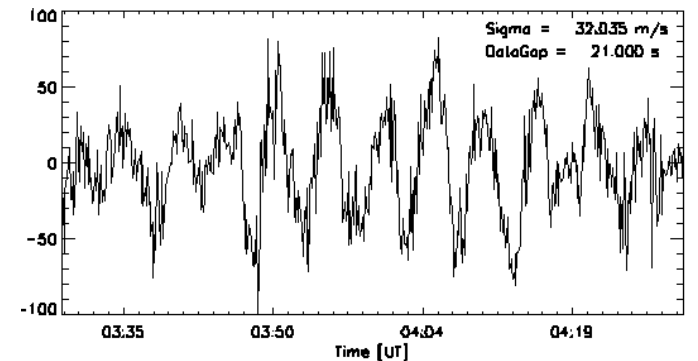
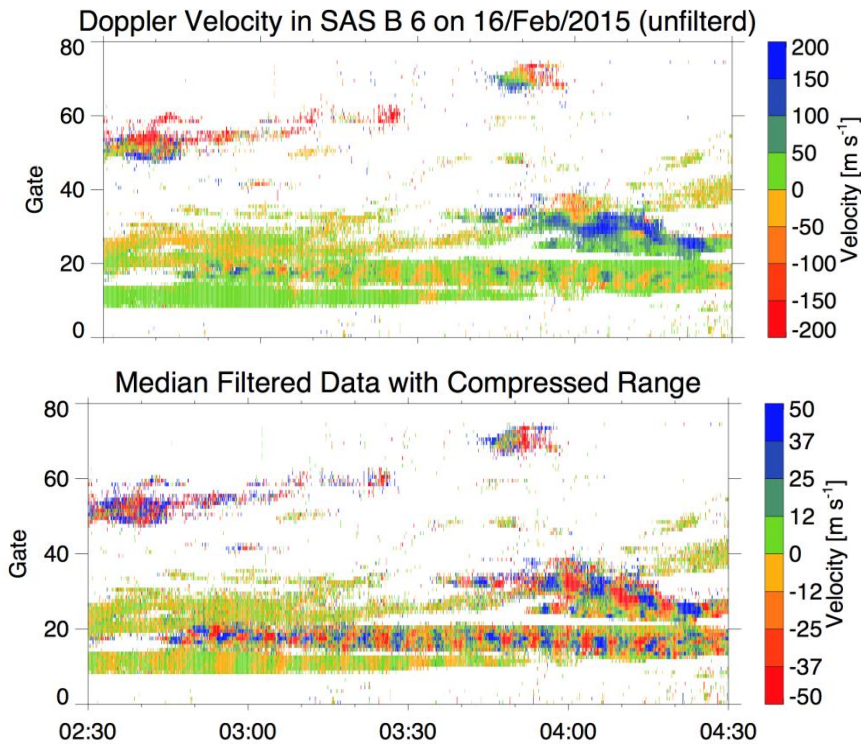


ULF Example Waveform Plot using THEMIS Mode Data

- Ultra-low frequency (ULF) Waves:
 - MHD plasma wave at 1mHz ~ a few Hz;
 - ULF wave electric field results in oscillations in drift velocities in the ionosphere.

*Doppler Velocity in SAS
Beam 6 Gate 16 on
16/Feb/2015*

$$\vec{E} \times \vec{B}$$



Other Science Topics

- Magnetic Reconnection
- Storms and Substorms
- Ionospheric Plasma Irregularities
- MHD Waves and ULF Waves
- Gravity Waves and Traveling Ionospheric Disturbance
- The Neutral Atmosphere

QUESTIONS?

THANK YOU !!!