

# Ground-based Science Opportunities with the Radiation Belt Storm Probes Mission

**Harlan E. Spence**

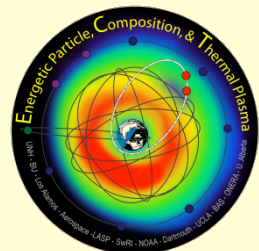
University of New Hampshire

*Institute for the Study of Earth, Oceans, and Space,  
Space Science Center*

*Acknowledgements: David Sibeck, S. Kanekal  
B. H. Mauk, N. Fox, and A. Ukhorskiy*

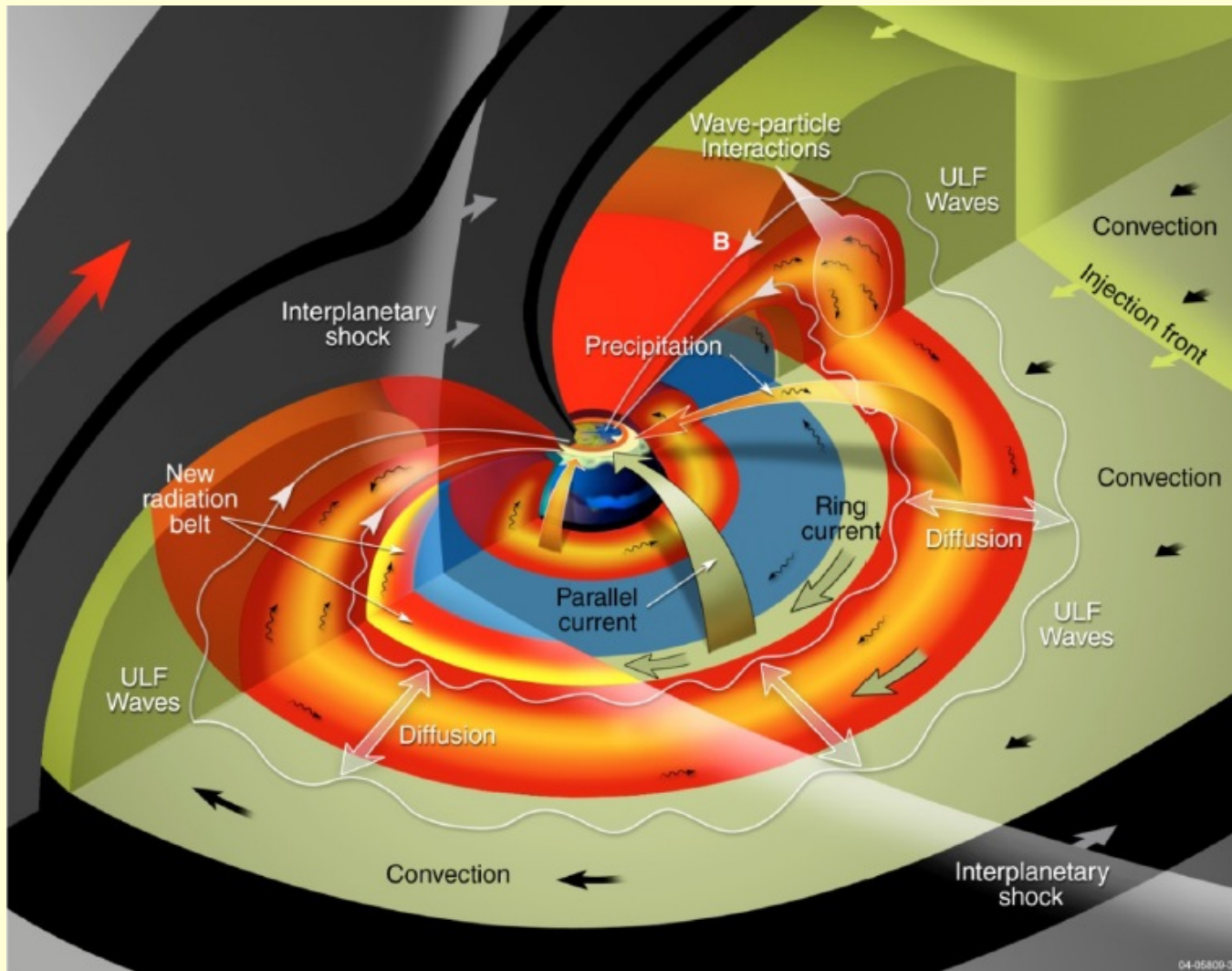


NSF CEDAR 2012 Summer Workshop

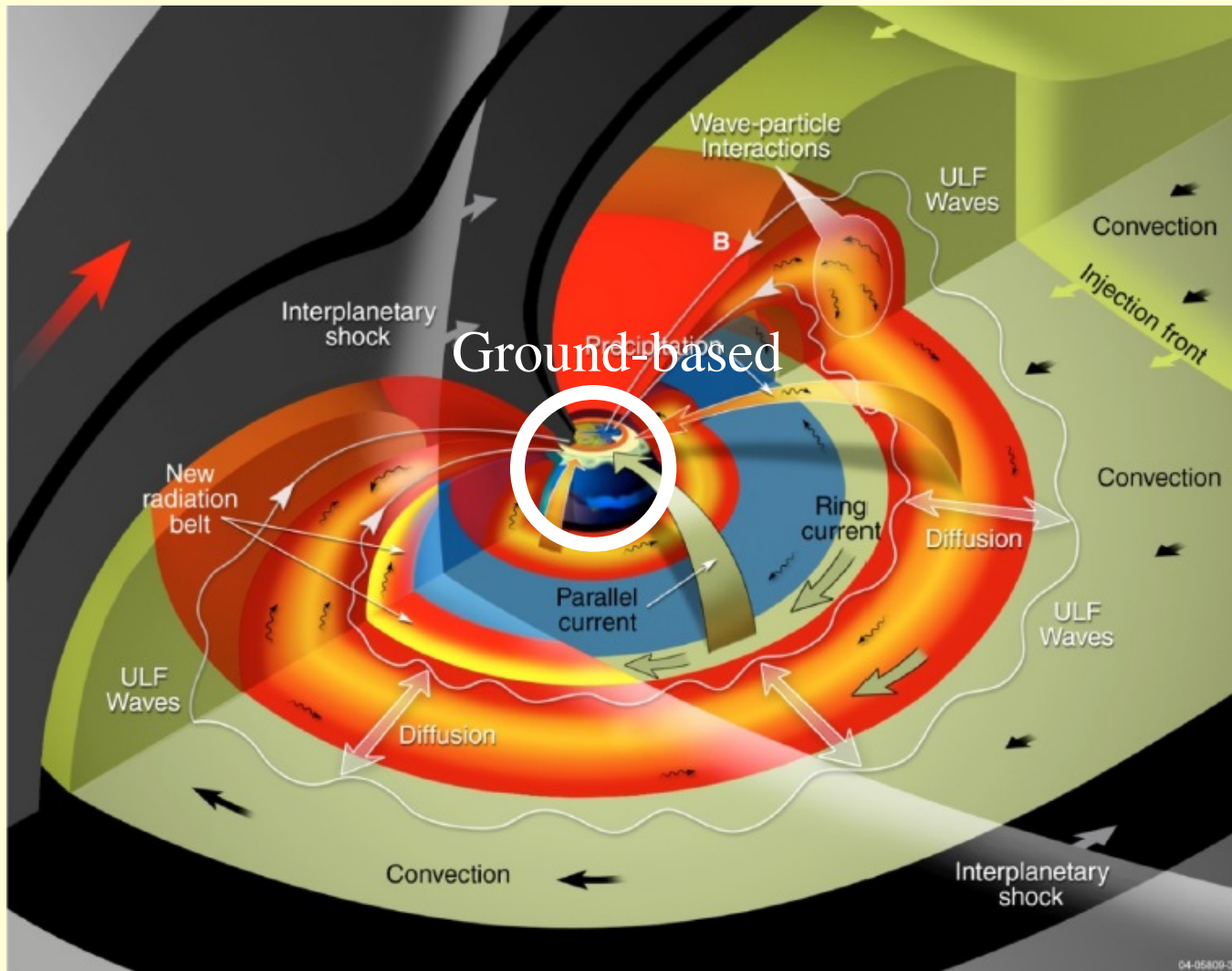


# Top-level RBSP Science Questions

- Which physical processes produce radiation belt enhancement events? (Local and Global)
- What are the dominant mechanisms for relativistic electron loss? (Local and Global)
- How do ring current and other geomagnetic processes affect radiation belt behavior?
- **RBSP is 2-s/c mission so not truly global; ground-based measurements powerfully complementary**



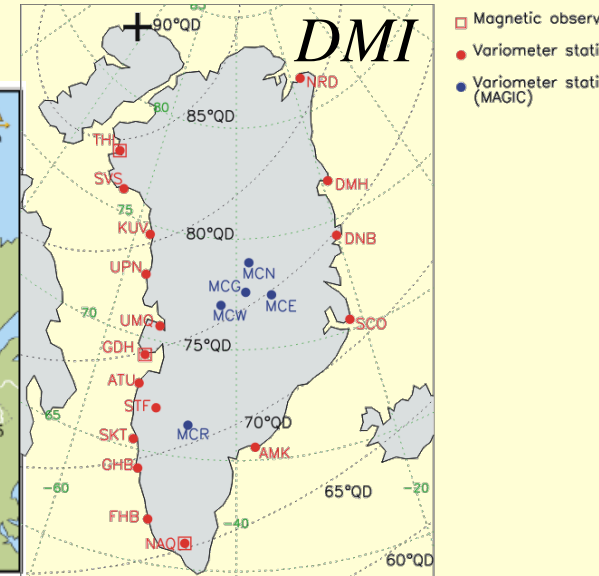
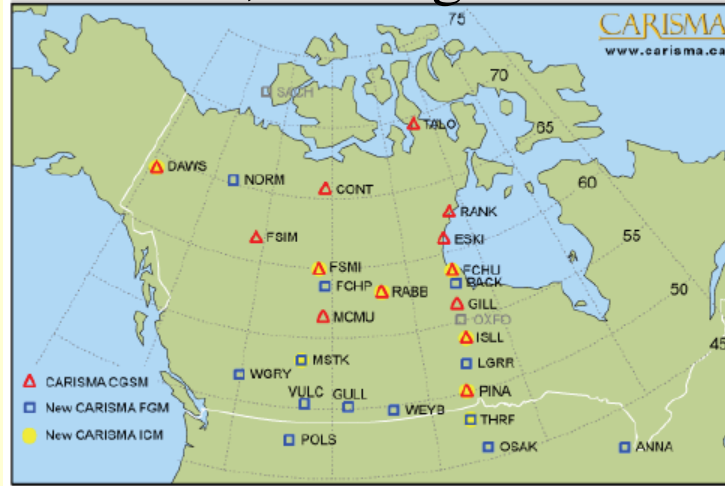
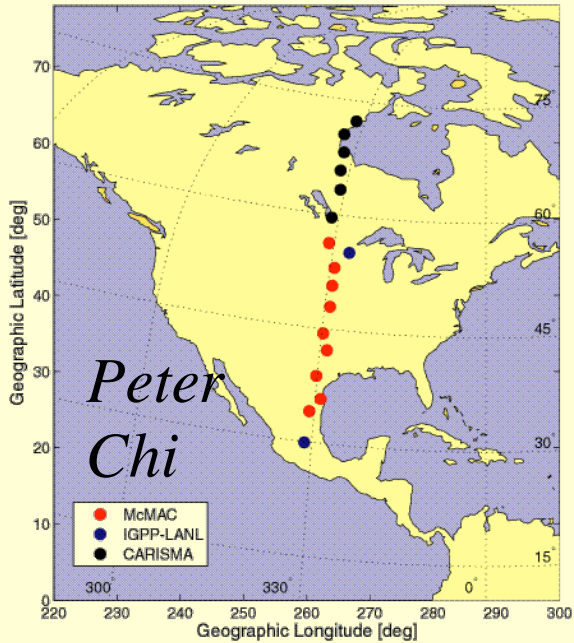
Many processes sculpt the inner magnetosphere:  
Correlative studies help quantify their importance as  
part of the geospace system



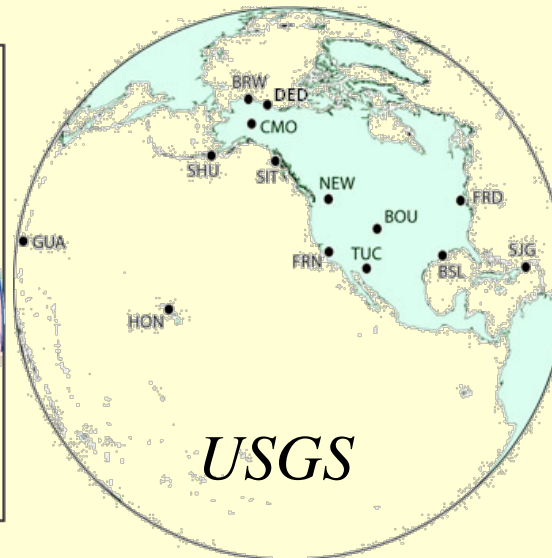
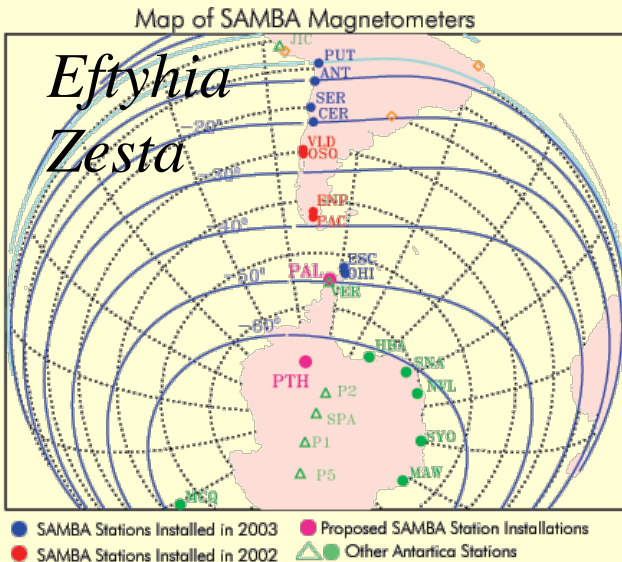
Ground-based observations (mid-latitude) at footpoints of inner magnetosphere B-field lines; fills in 2<sup>nd</sup> & 3<sup>rd</sup> dimension(s) along B and in MLT

# Ground Magnetometer Array Topics

I. Mann, M. Engebretson



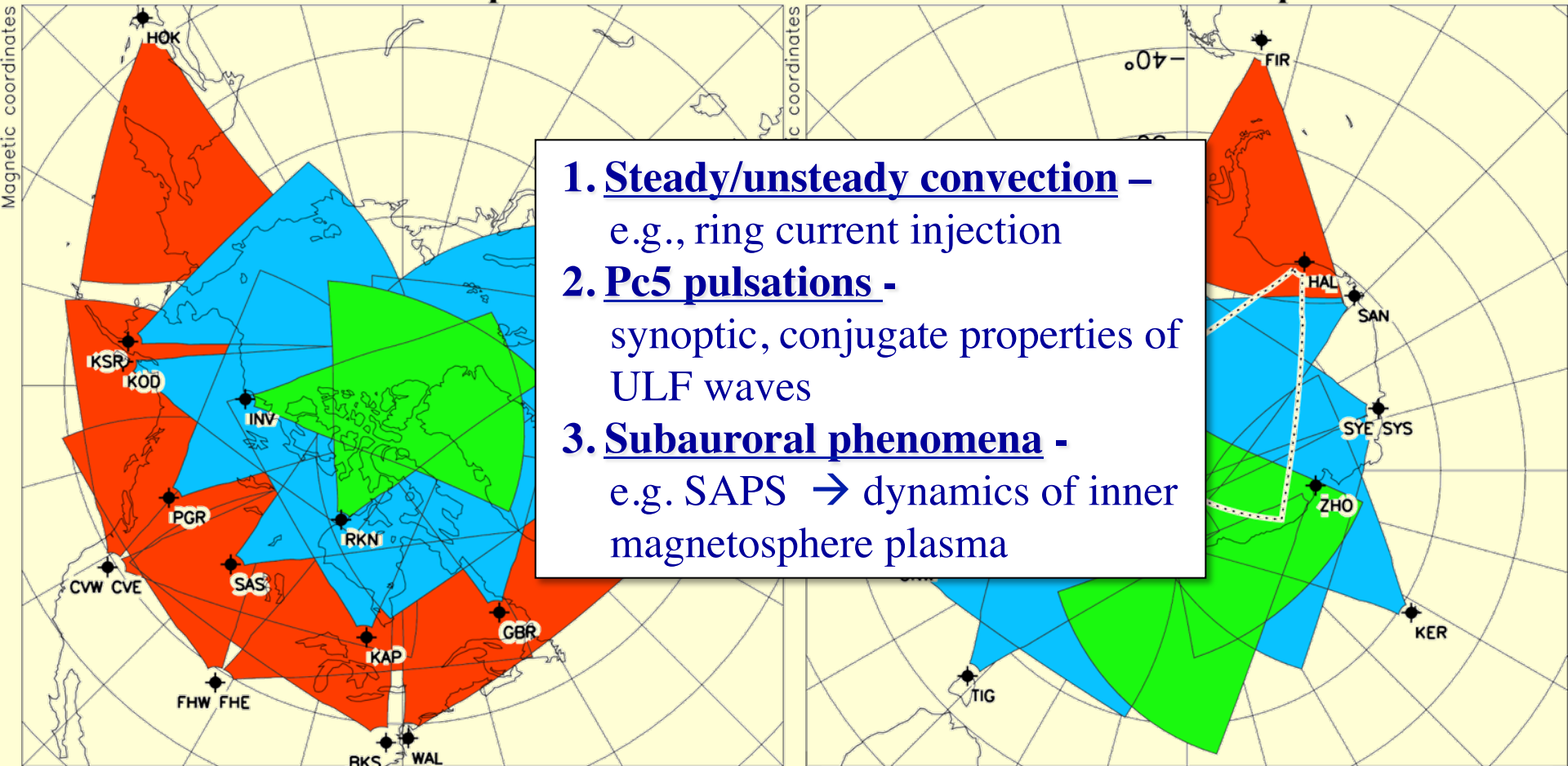
- Pc pulsation power – ULF resonance and WPI
- Substorm onset – outer zone e- seed population source
- Magnetoseismology - Use pairs of stations to determine  $m'$  sphere densities; needed for rad belt wave analysis



# SuperDARN Radar Convection Patterns Provide Global Context for RBSP Electric Field Measurements

Northern Hemisphere

Southern Hemisphere



■ Polar Cap ■ High-Latitude ■ Mid-Latitude ⋯ Out-of-Service

*Elsayed Talaat*

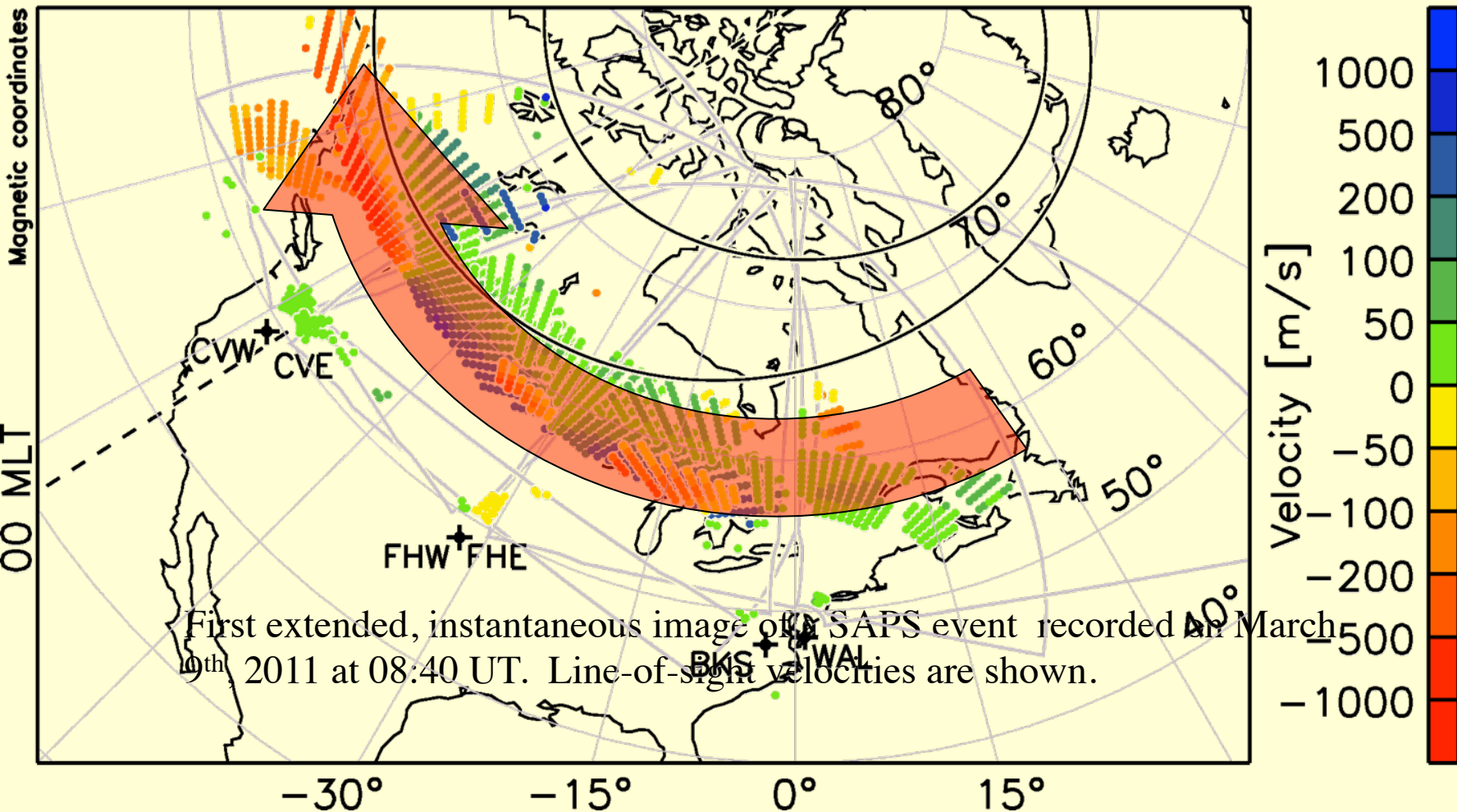


Christmas Valley, OR



Hays, KS

SuperDARN images SAPS  
 flow channel  $\rightarrow$  maps to strong  
 E at inner edge of dusk  
 ring current

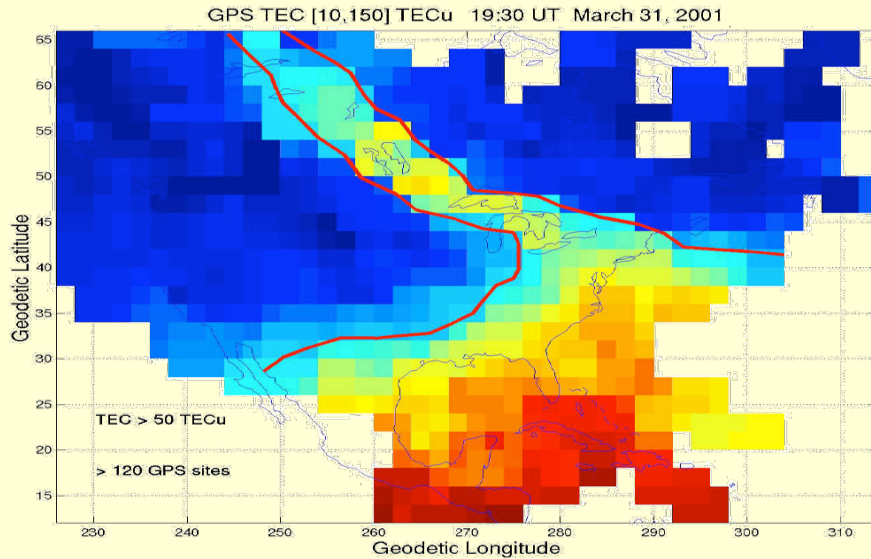


First extended, instantaneous image of a SAPS event recorded on March 9<sup>th</sup> 2011 at 08:40 UT. Line-of-sight velocities are shown.

Map of Line-of-Sight Velocities for 08:40 UT, March 9<sup>th</sup>, 2011

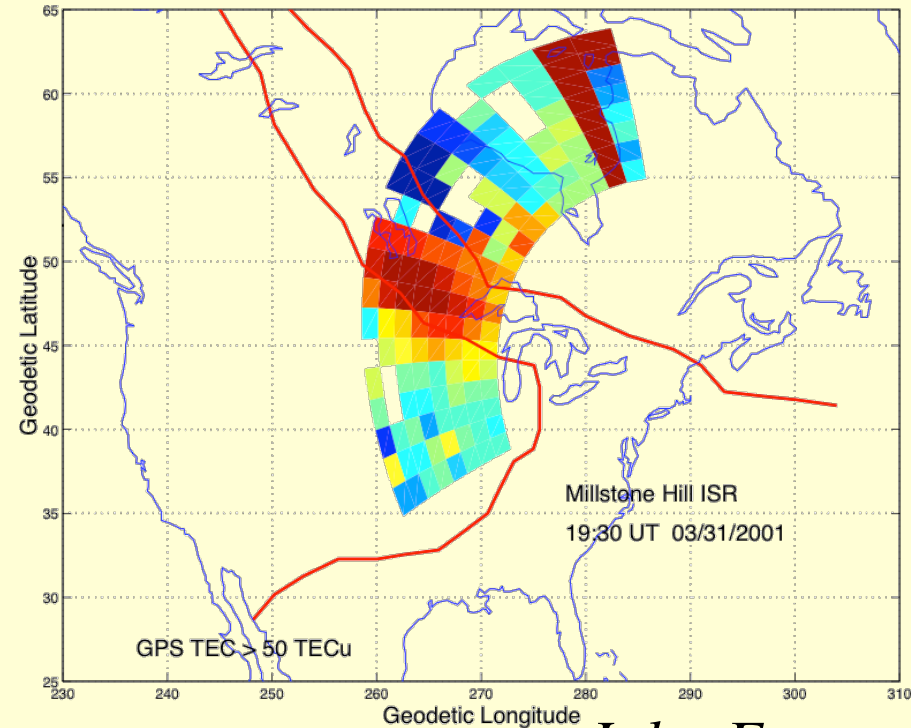
# GPS and Incoherent Scatter Radars

GPS Observations of Plasma Plume



*Tony Manucci*

ISR Observation of Plasma Plume

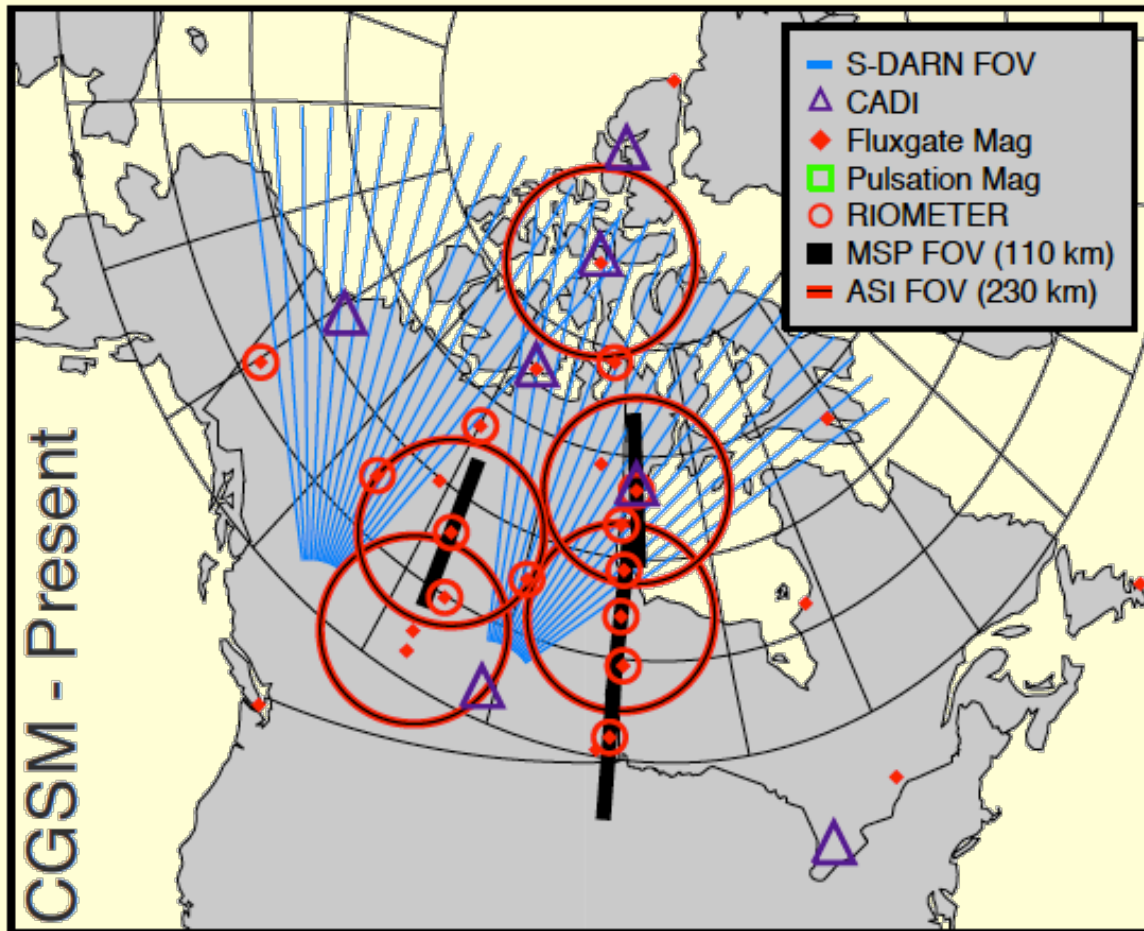


*John Foster*

**Dayside plasmaspheric plume →  
EMIC/hiss waves →  
inner magnetosphere particle loss**



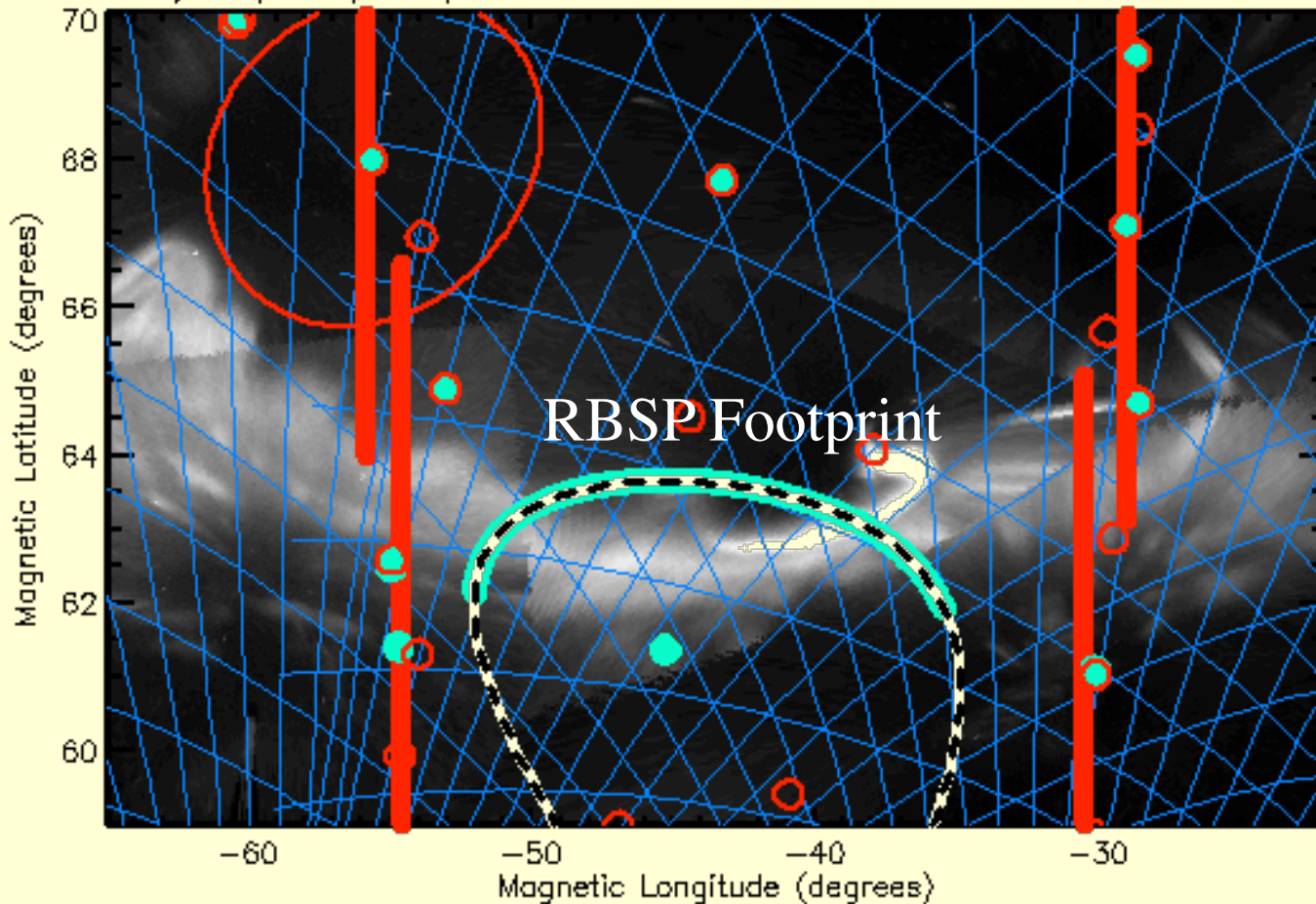
# Canadian Geospace Monitoring (CGSM) Array



- 1. Radar** → steady and transient convection
- 2. Riometer** → precipitation of 10's keV electron injections and loss at  $L = 4.2, 5.5, 6.7 \dots$
- 3. MSP/ASI** → substorm auroral activity extent and intensity
- 4. CADI Ionosonde**

# Footprint of RBSP lies Well within CGSM Field of View

THEMIS ASI  
FSMI, GILL, ATHA, TPAS, PINA



Storms, substorms, and pulsating aurora/chorus studies

# Summary – Yes! Please Collaborate!

- Ground-based measurements will contribute significantly to many radiation belt science questions.
- RBSP welcomes your participation in the mission. More information: <http://rbsp.jhuapl.edu/>
- RBSP data, ephemeris, and analysis tools will be available for correlative, collaborative ground-based studies
- Please ask for white paper describing detailed science plans as a function of RBSP mission phase (send email to [harlan.spence@unh.edu](mailto:harlan.spence@unh.edu) if interested)
- Thank you! Questions?

# Back-up Slides

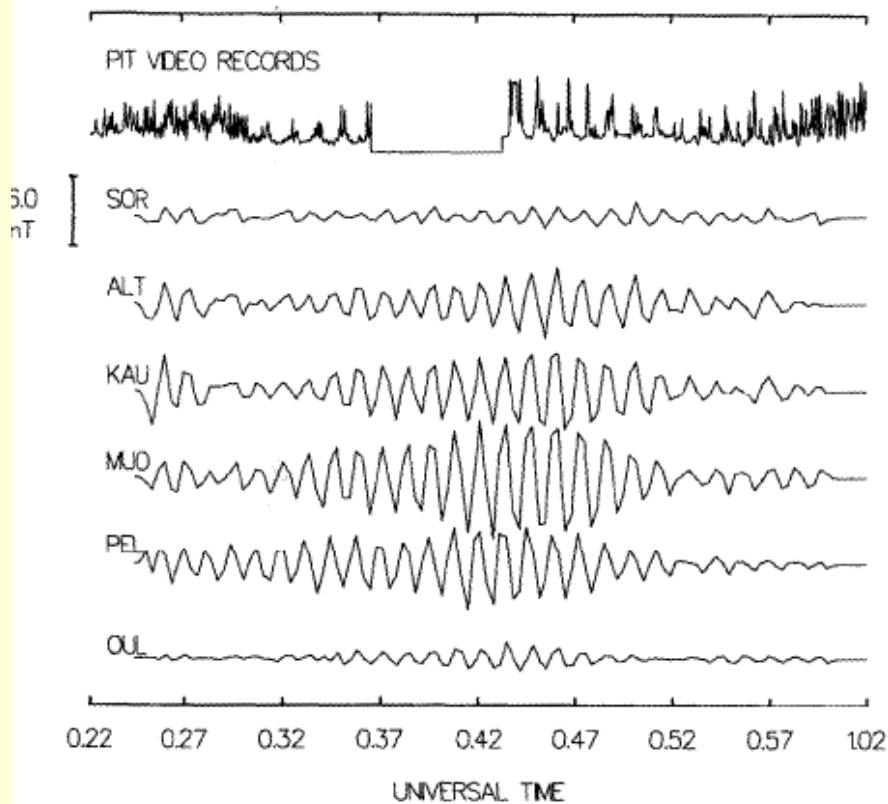
# Poloidal Pulsations:

Symmetric low 'm' scatter, energize electrons

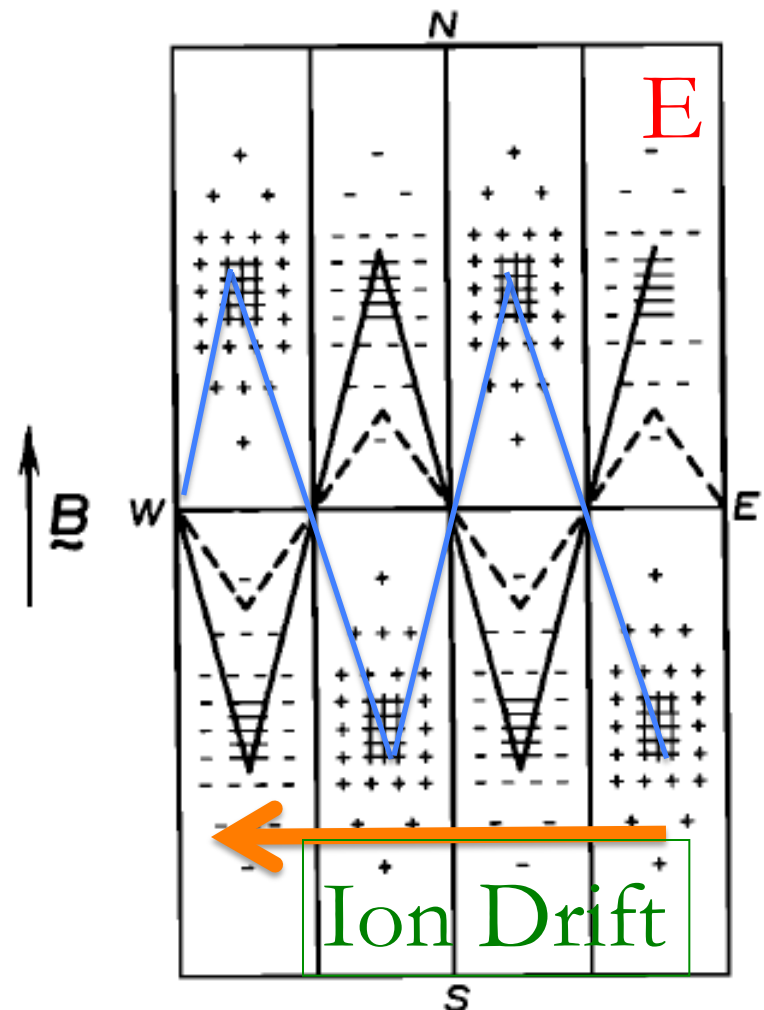
Antisymmetric high 'm' energize ions

Southwood and Kivelson [1982]

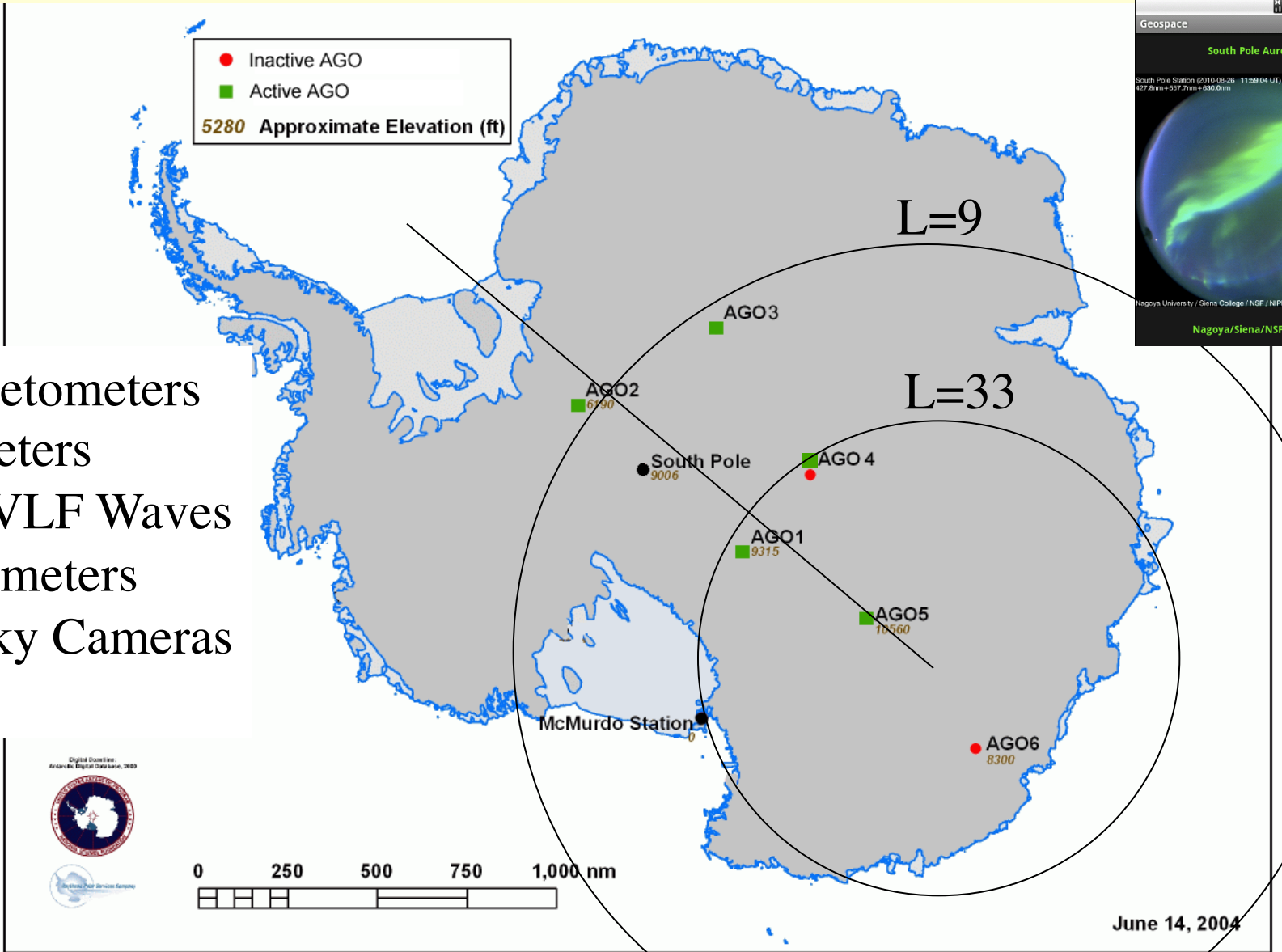
Chisham et al. [1990]



$m = 2\pi R/\lambda$ , where  $R$  = radius,  
 $\lambda$  = wavelength

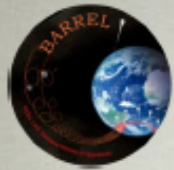


# Antarctic Ground-based Support for RBSP



Magnetometers  
Riometers  
ELF/VLF Waves  
Photometers  
All Sky Cameras

<http://antarcticgeospace.org>  
Allan Weatherwax



# BARREL Project Overview

Robyn Millan, Dartmouth

BARREL is a multiple-balloon experiment designed to study relativistic electron precipitation

. Two Antarctic Science Campaigns during RBSP Mission

- 20 small balloon payloads in each campaign in 2013 and 2014
- Launched successively to set up slowly drifting array
- Long duration balloon flights => 30 day campaign
- >3000 hours of data in radiation belt region ( $L < 7$ )
- Launch sites planned: Halley Bay and South African Antarctic station (SANAE)

Observe brehmsstrahlung generated by electron-neutral collisions resulting from precipitating MeV electrons

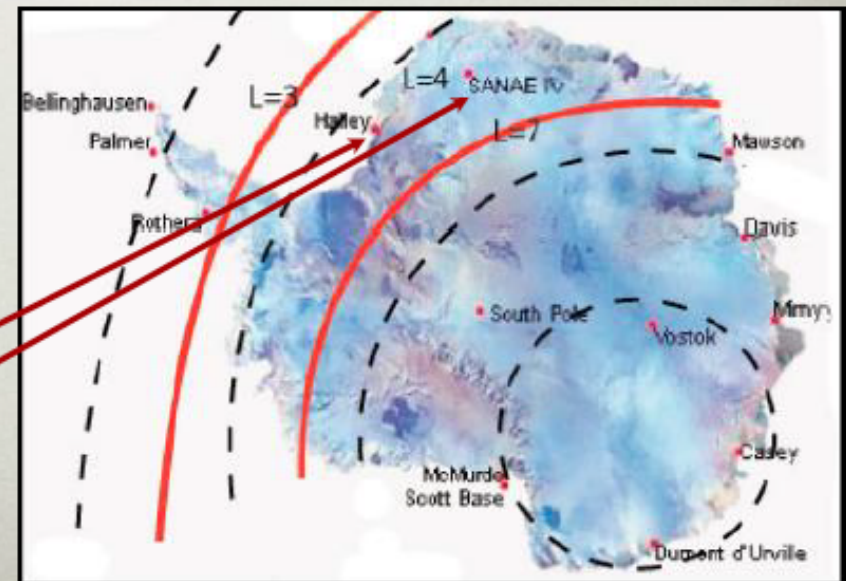


# Platform - Balloon Array



- BARREL uses an array of balloons to achieve its science
  - 4-5 balloons aloft simultaneously
  - separation 1-2 hours of MLT
  - flight durations ~7 days
  - 20 balloons per campaign

- Two launch sites:
  - Halley Bay
  - SANAE





# Geosynchronous GOES-13/15 (Separation: 4 Hrs LT)

Magnetometer

0.5s time resolution

Magnetospheric Electron Detector (MAGED):

9 look directions for (5 azimuth and 5 elevation with shared center)

5 energy channels in each look direction: **30 keV – 600 keV**

Magnetospheric Proton Detector (MAGPD):

9 look directions for (5 azimuth and 5 elevation with shared center)

5 energy channels in each look direction: **80 keV – 800 keV**

Energetic Proton Electron and Alpha Detector (EPEAD):

2 look directions (East and West)

3 electron energy channels: **> 0.8 MeV, > 2 MeV, > 4 MeV**

7 proton energy channels: **0.7 – 900 MeV**

6 alpha particle energy channels: **4 – 500 MeV**

High Energy Proton and Alpha Detector (HEPAD):

1 look direction

4 proton energy channels: **330 – >700 MeV**

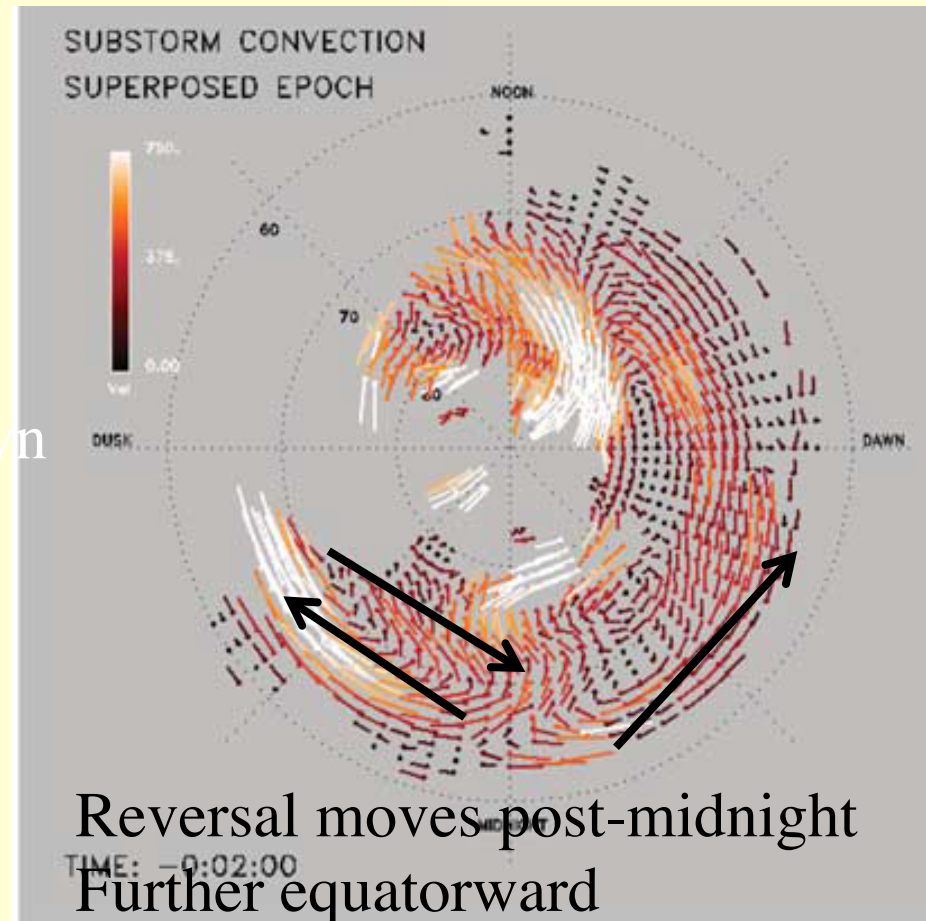
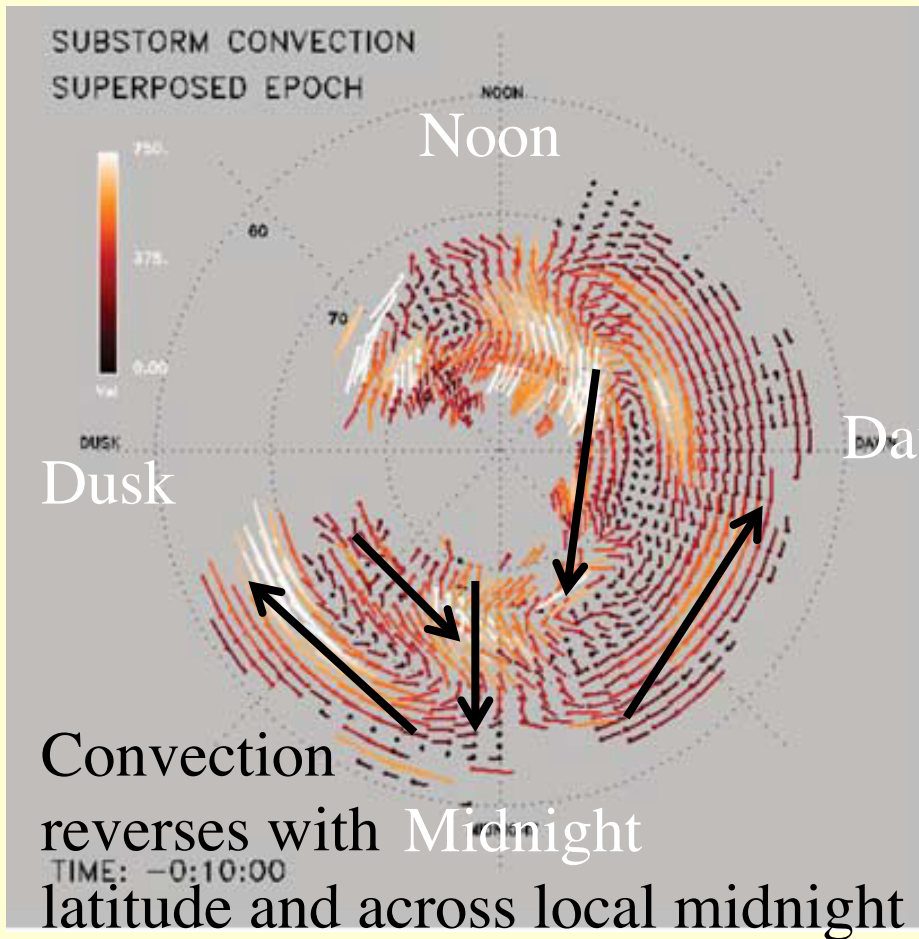
2 alpha particle channels: **2560 – >3400 MeV**

Janet  
Green

# Radars and Substorms

Growth Phase: Two Cell Pattern

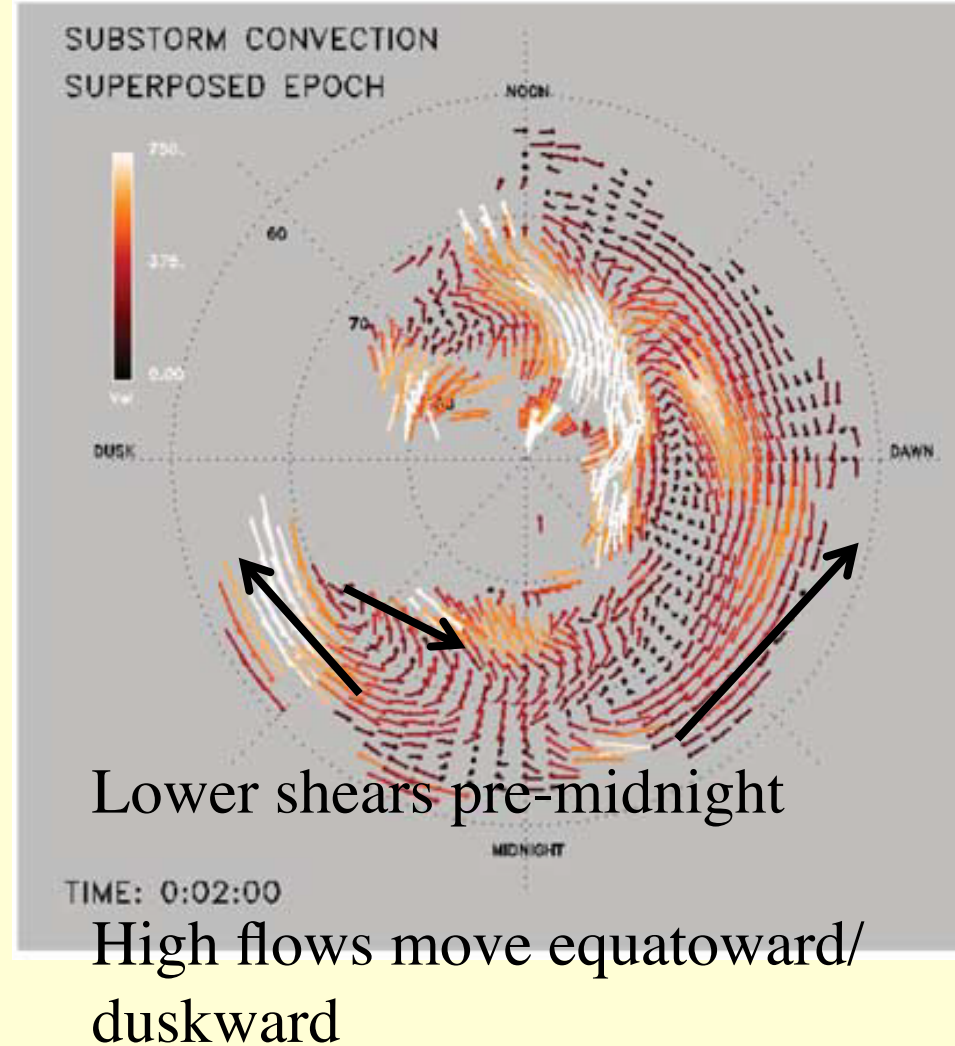
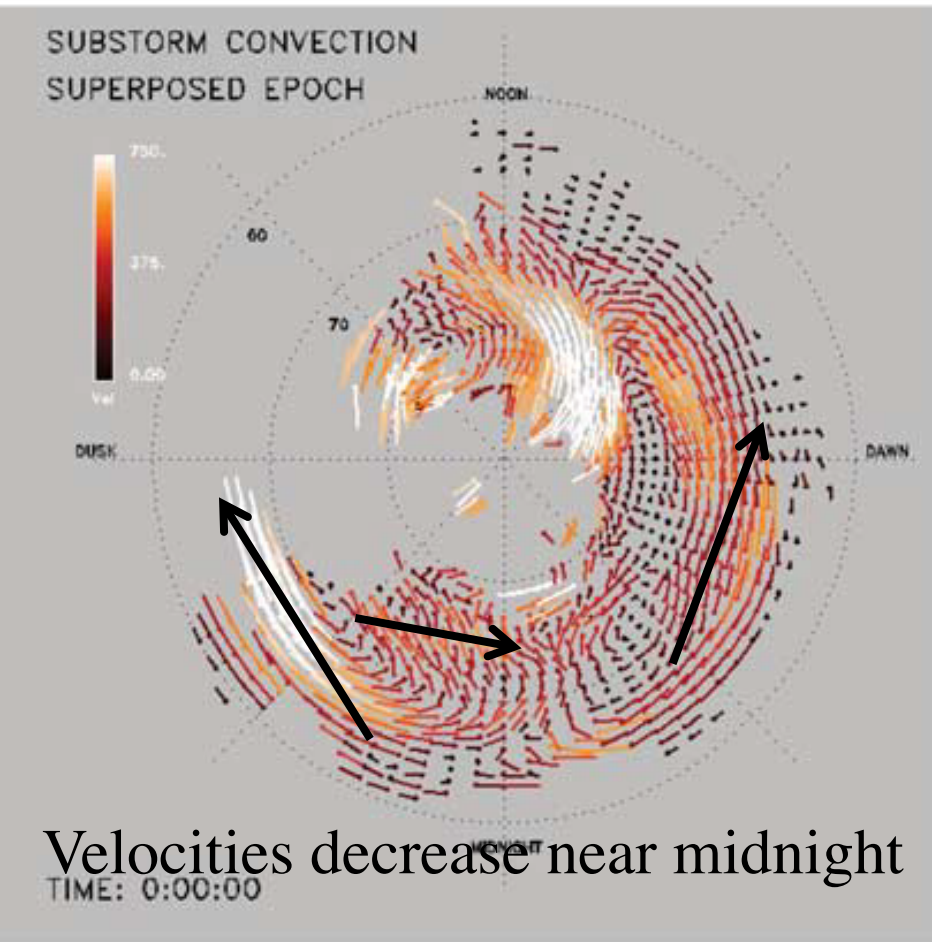
Just Prior to Onset



# Radars and Substorms

Onset

Onset + 2 min



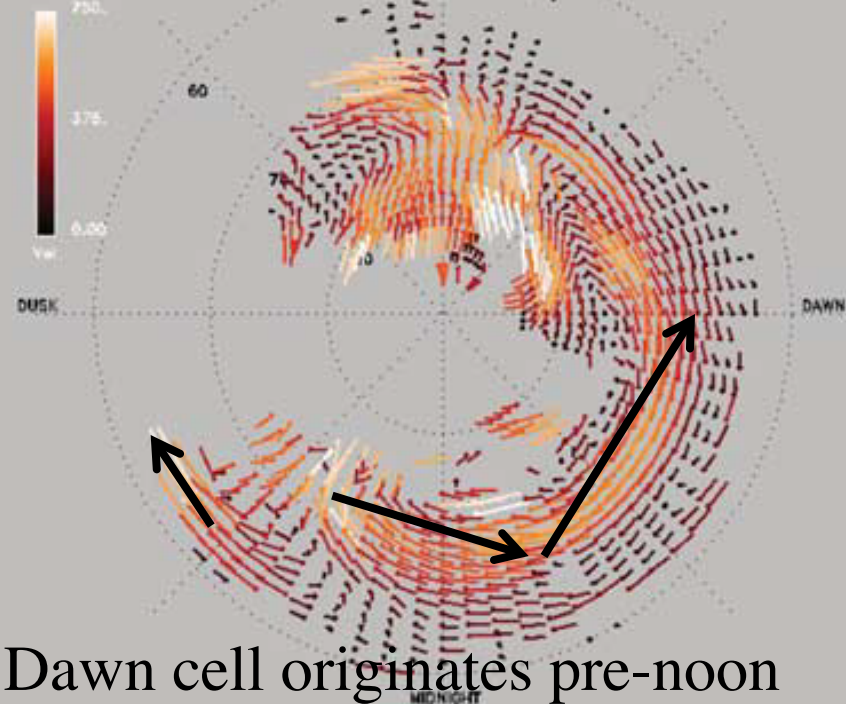
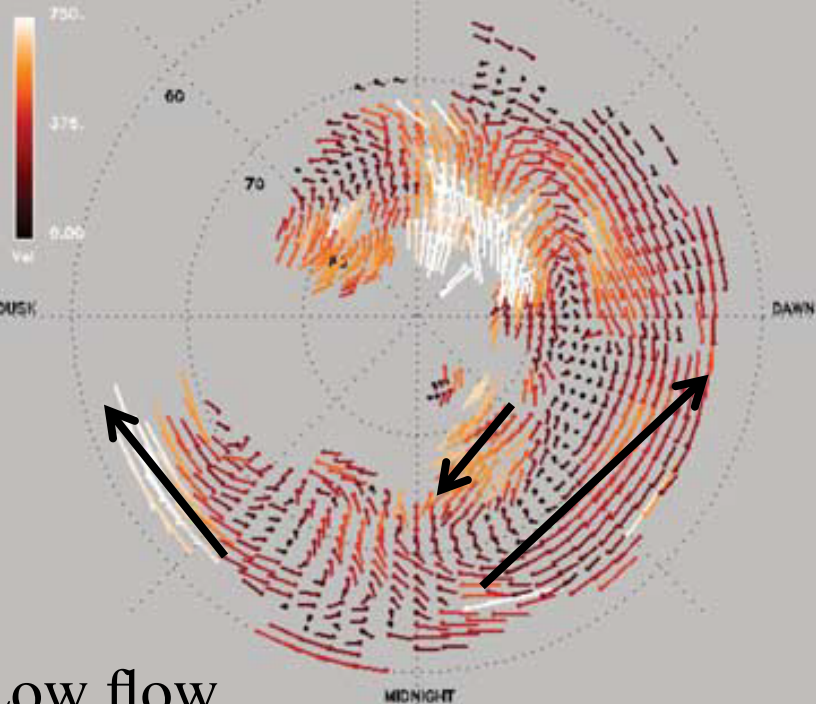
# Radars and Substorms

Onset + 10 min

Onset + 30 min

SUBSTORM CONVECTION  
SUPERPOSED EPOCH

SUBSTORM CONVECTION  
SUPERPOSED EPOCH



Low flow  
TIME: 0:10:00  
Pre-midnight

Dawn cell originates pre-noon  
TIME: 0:30:00

Bristow et al. [2007]

# Summary

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- The radiation belt is an area still ripe for discovery, despite its 50+ year history of study
- Radiation belt dynamics are scientifically compelling, universally relevant, and important to variety of user communities
- Transformational measurements made by RBSP will achieve outstanding science objectives
- Modeling opportunities abound – both local and global processes require a variety of models and techniques - students encouraged to participate