High latitude space weather effects from an Incoherent Scatter Radar (ISR) point of view

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What is Space Weather?

"The conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and endanger human life or health."

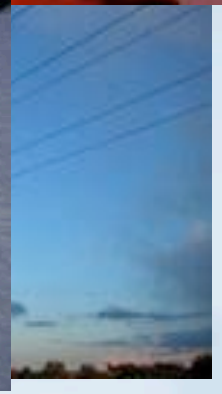
Impact of Space Weather on Human Activities

Satellites

Power grids

Humans in space

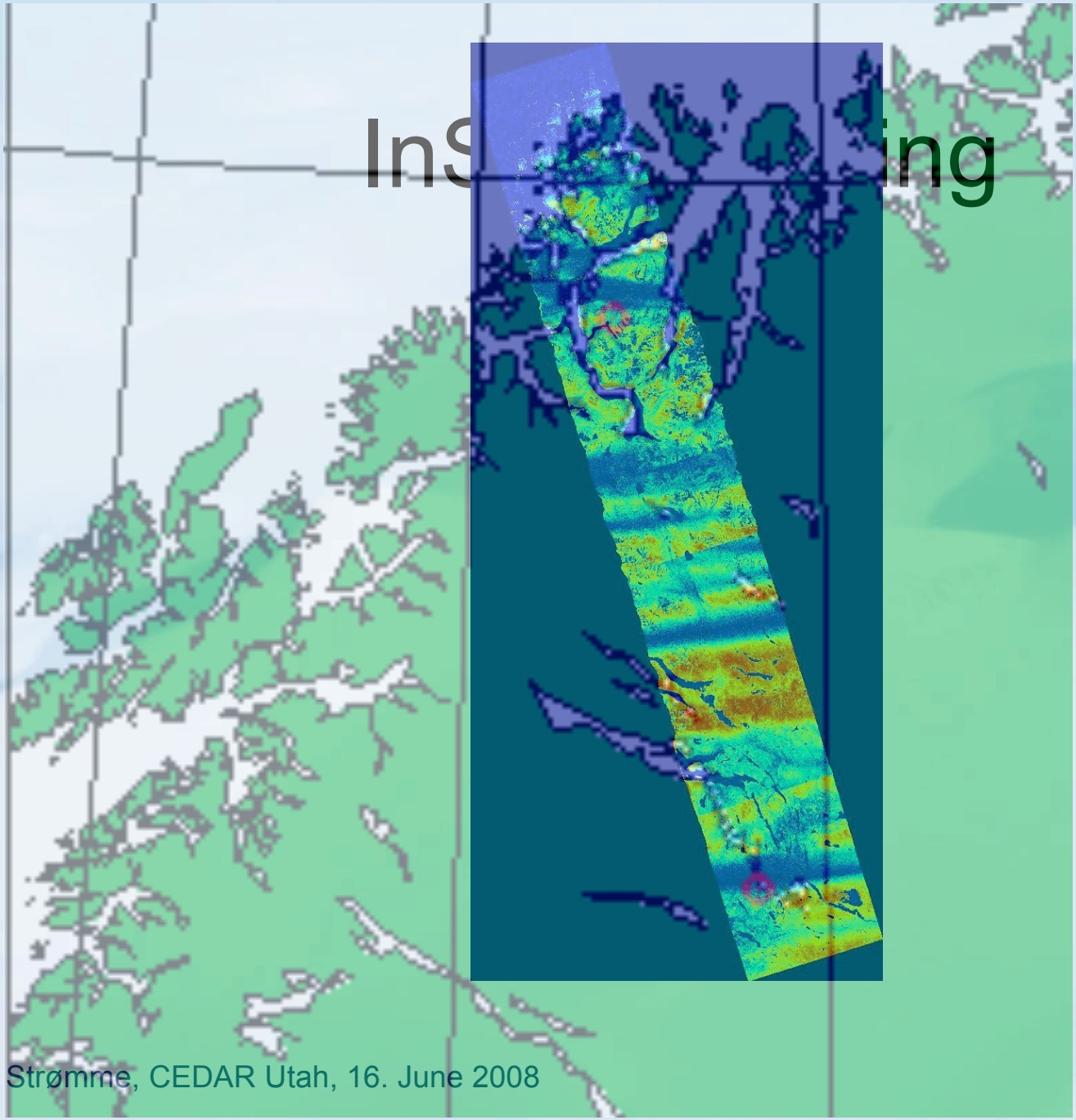
Radios



InSAR interferometry through a variable ionosphere

Anja Strømme,

InS ing



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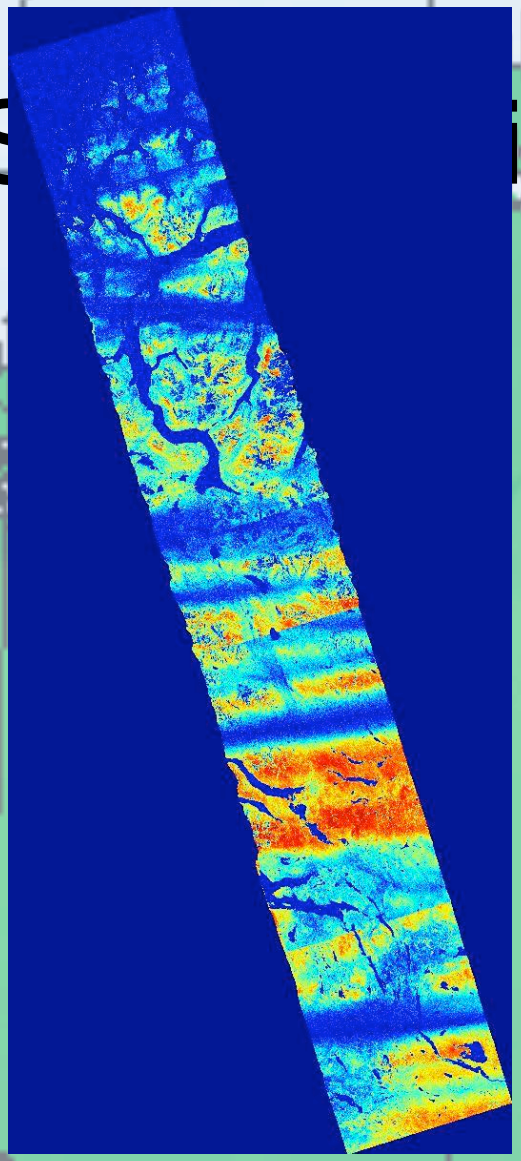
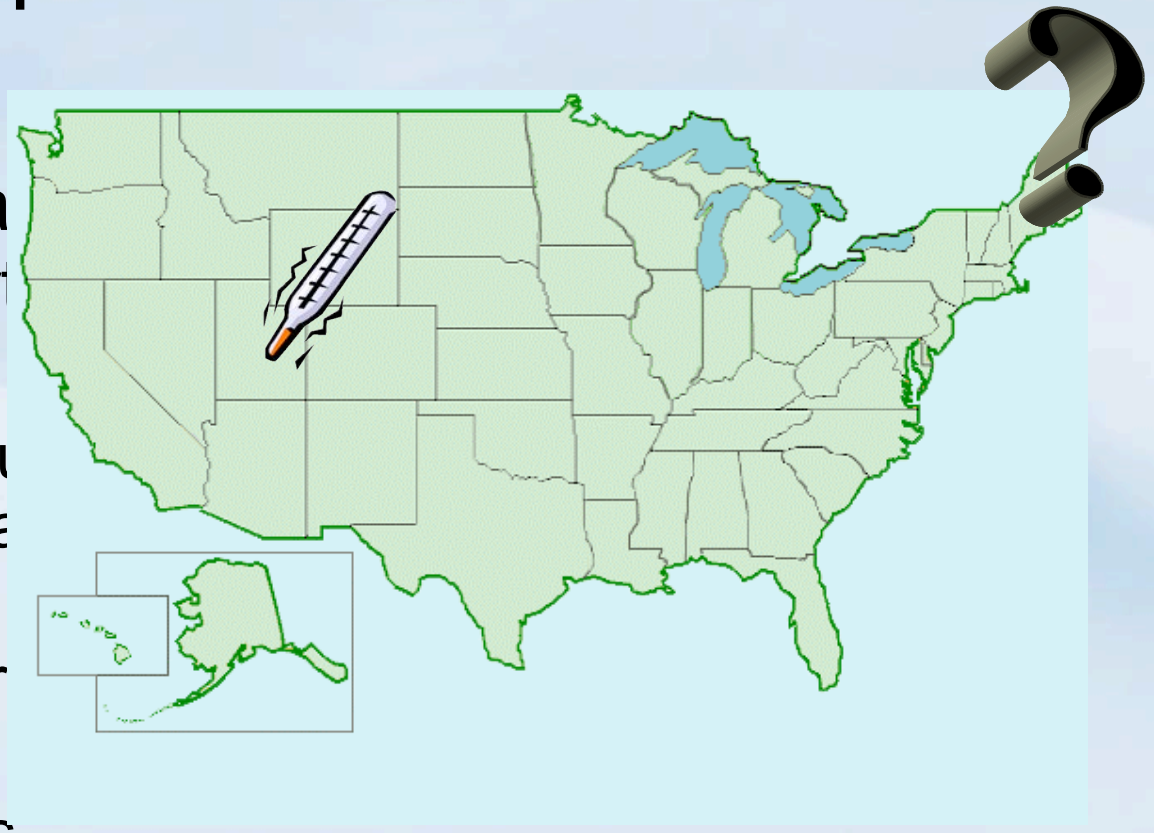


Ionospheric Space Weather Science

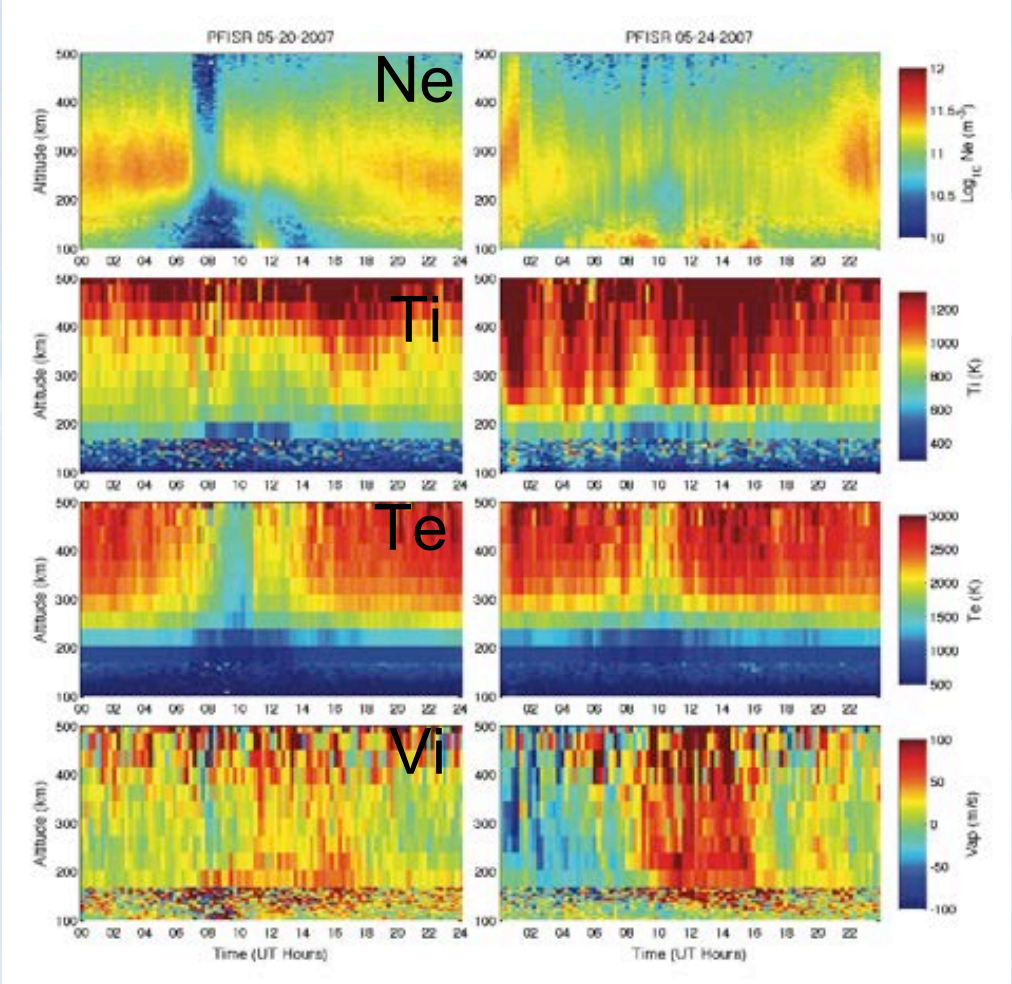


In order to nowca
in our near Ear
need:

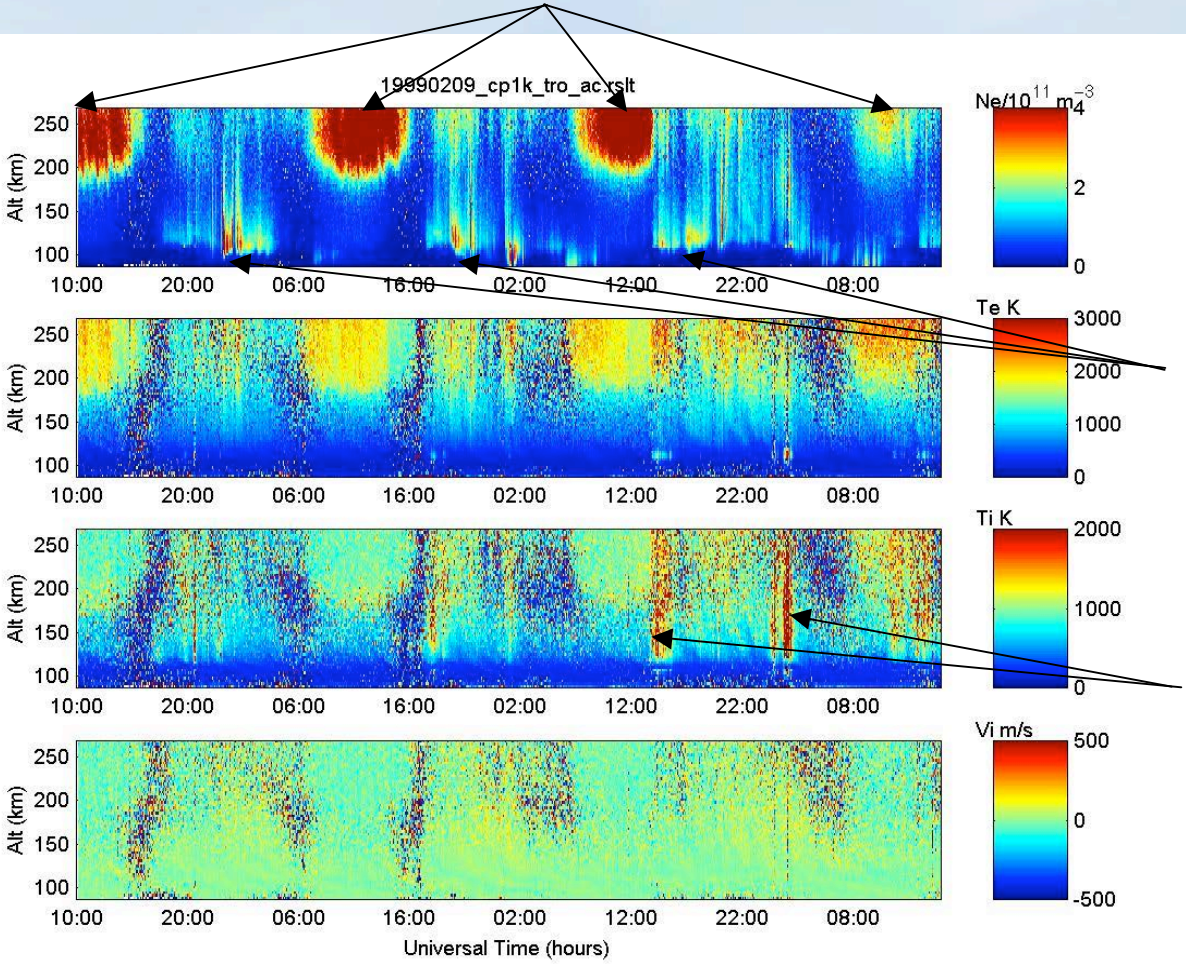
- Reliable and su
processes on a
periods.
- Accurate theor
together.
- Robust models.
- Lots of computing power.

Where does Incoherent Scatter Radars fit into this?

- High quality range resolved geophysical data.
- Measurements (almost) independent of weather, seasons and space weather conditions.
- Extended time series of high resolution data for small scale dynamics to long term trends.



Variability on a several day scale

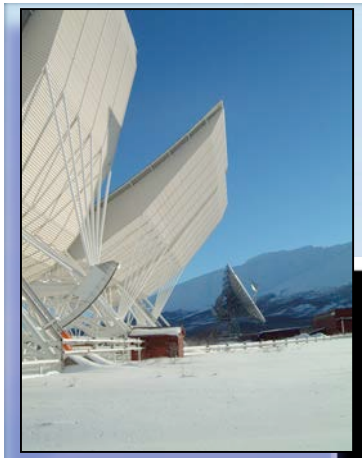


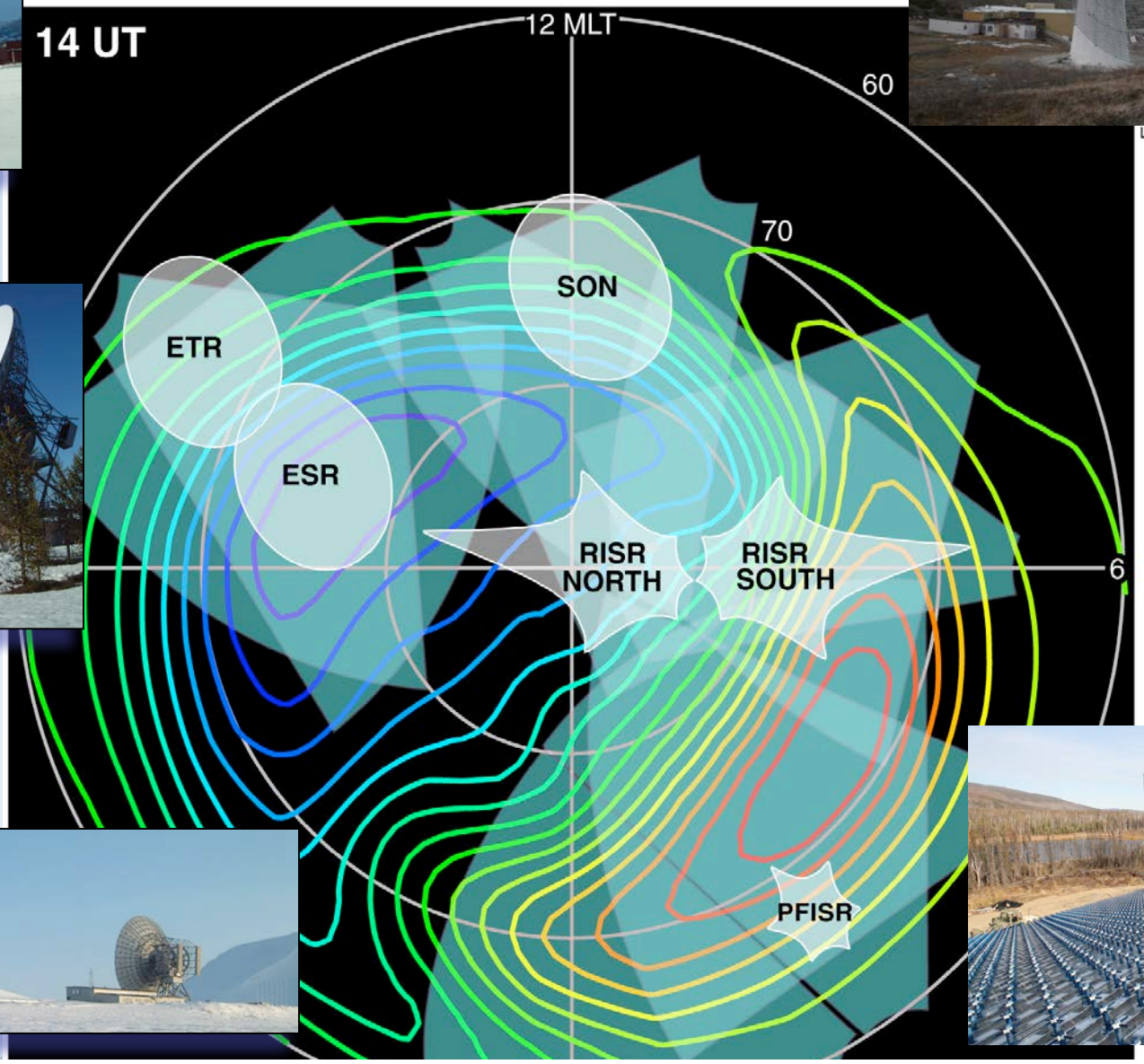
Note day-to-day variability in N_e

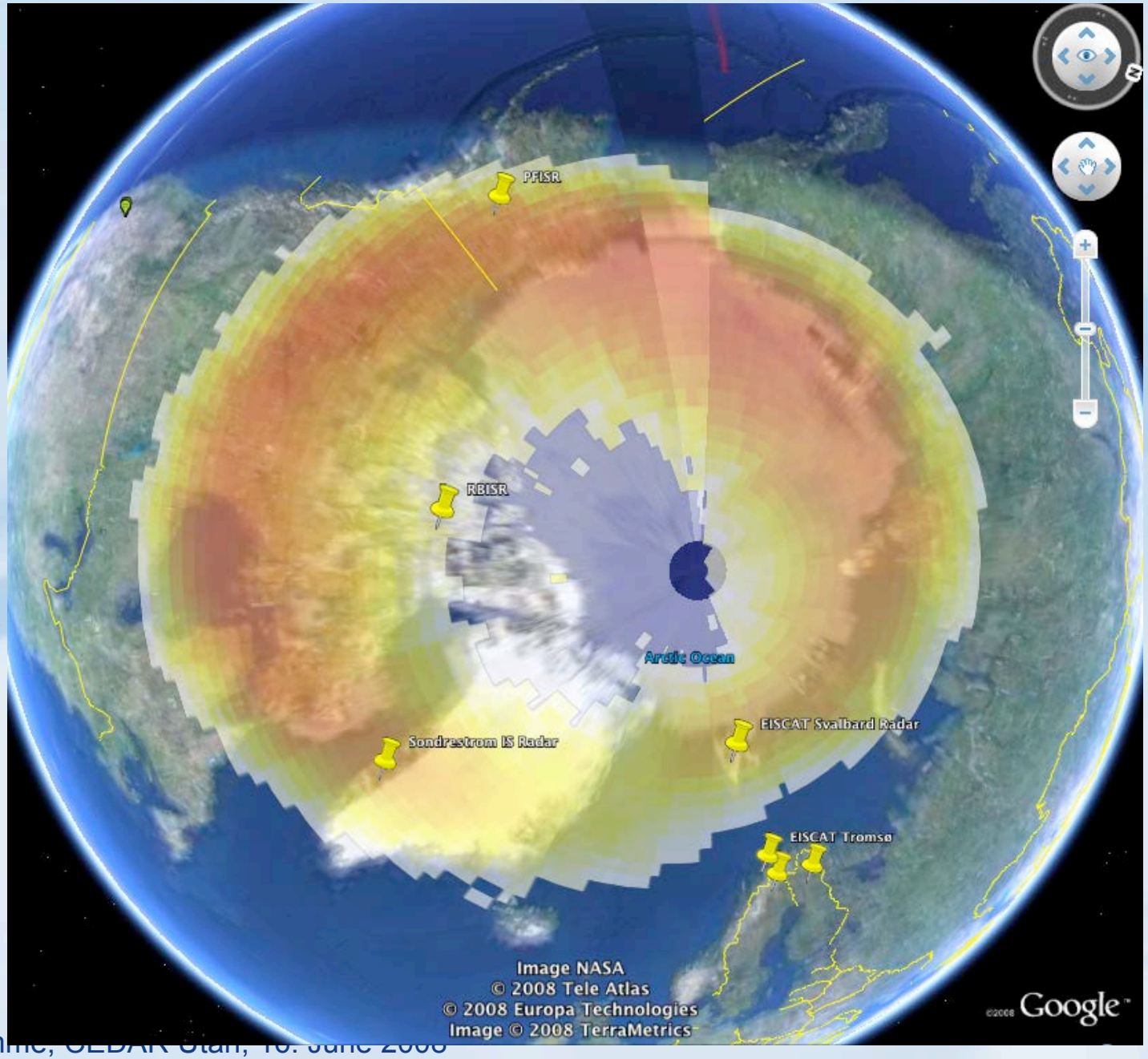
Precipitation effects

Ion heating events (Note T_i is almost independent of h at h > 130 km in events

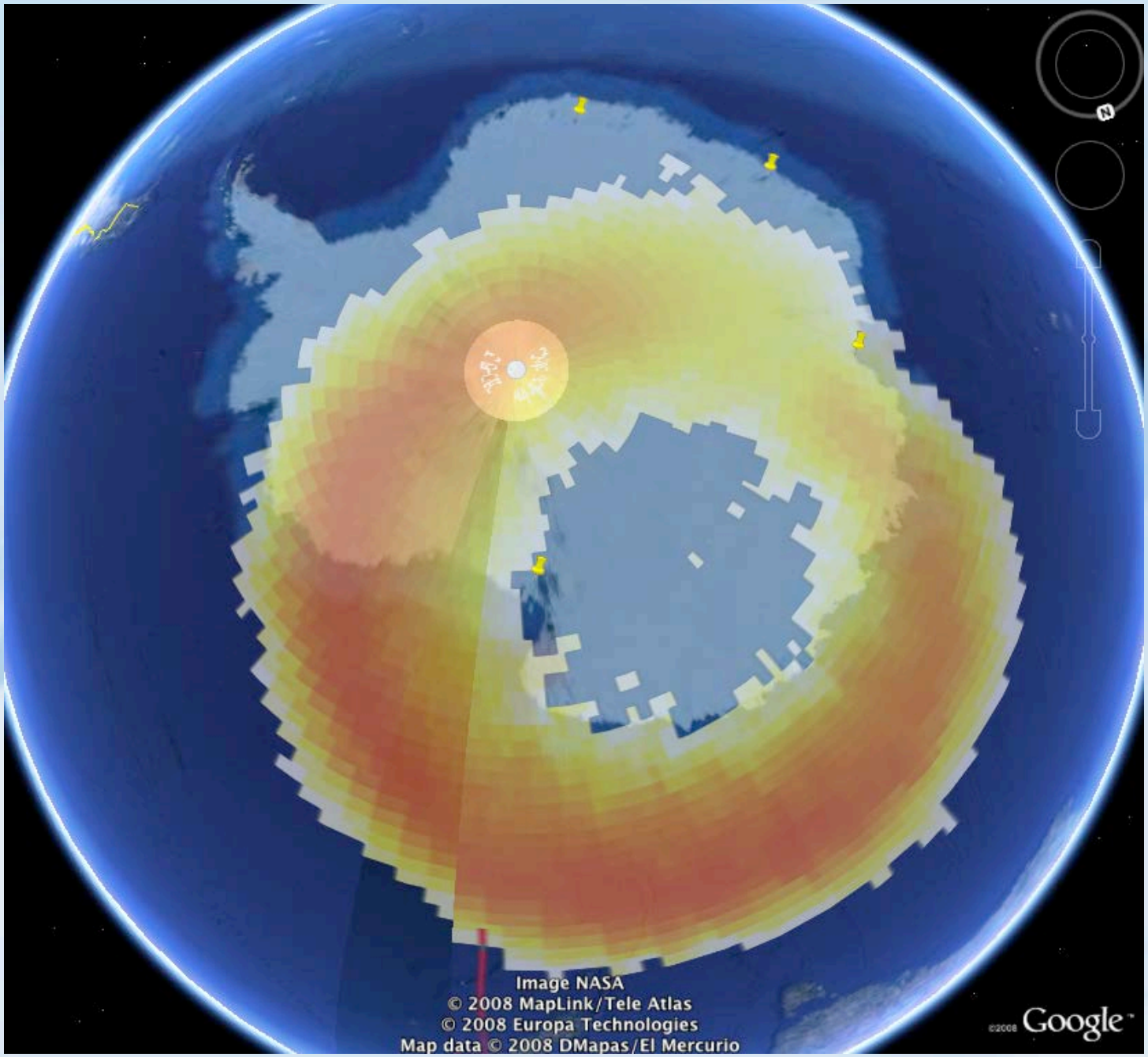
“Sufficient measurements” - Location of the high latitude ISRs







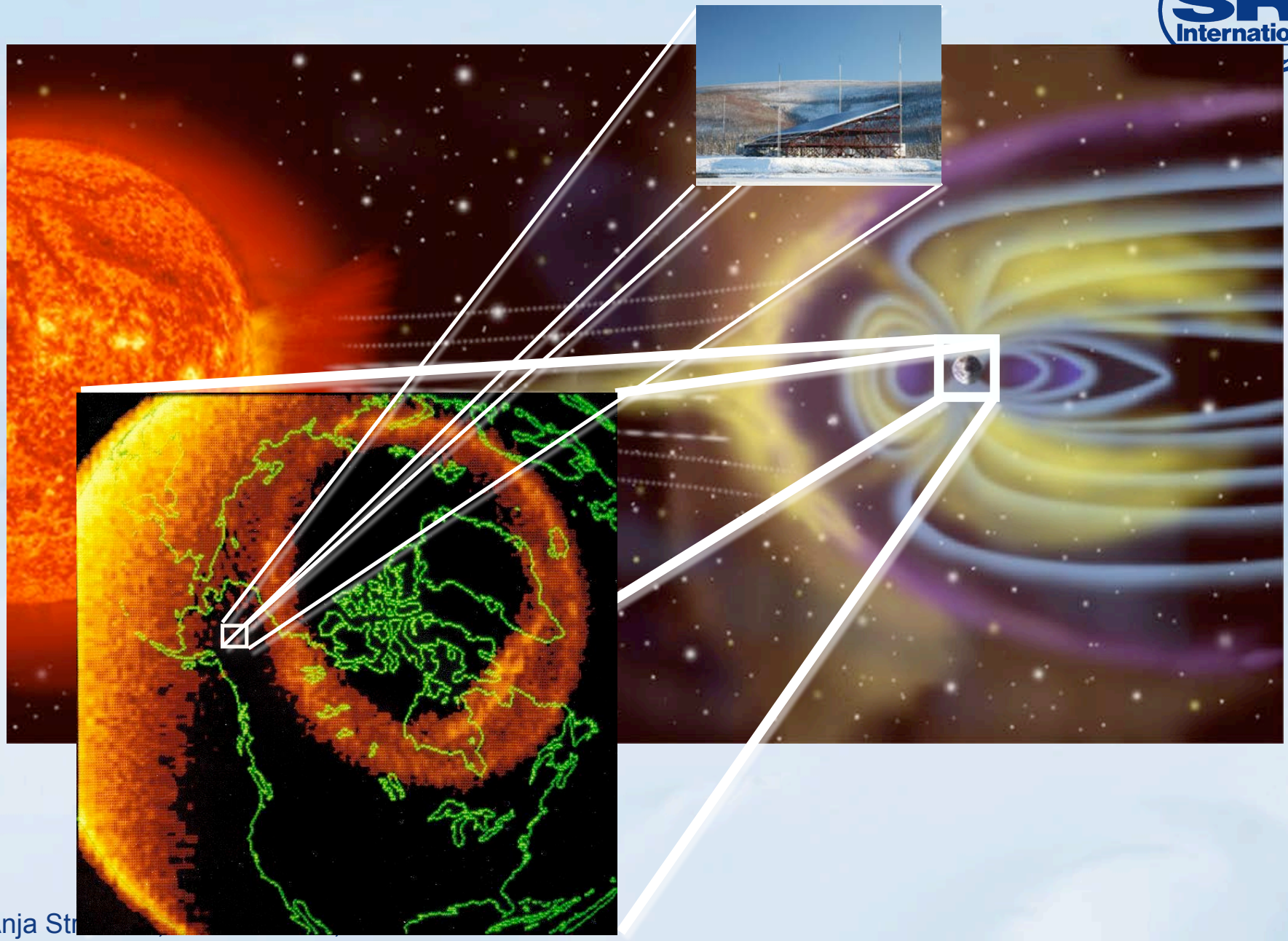
2008 06 16 12:30 UT

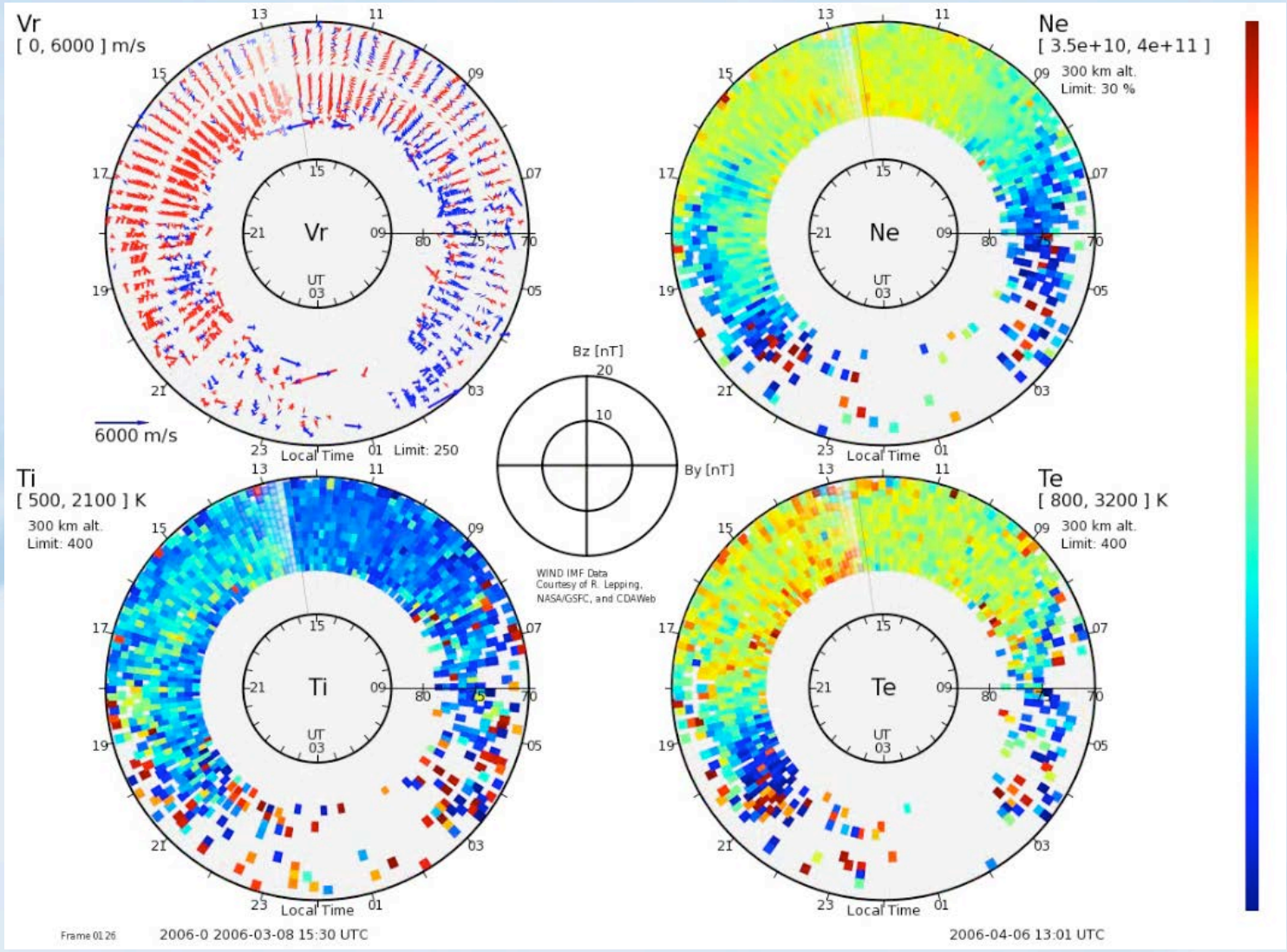


Anja Strømme, CEDAR Utah, 16. June 2008

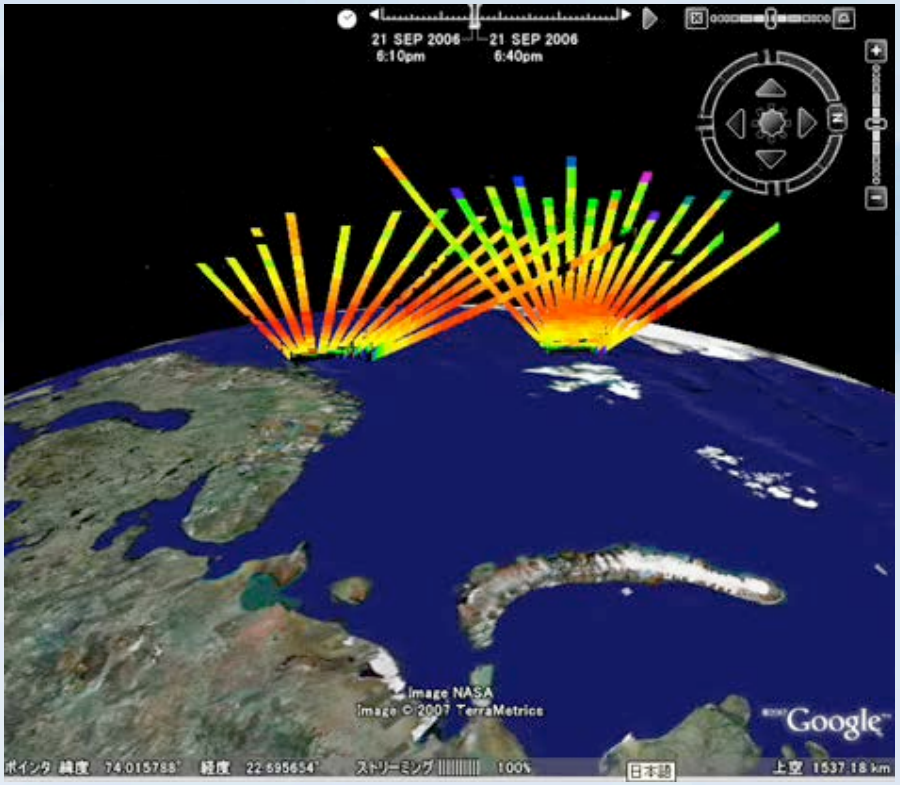
2008 06 16 12:30 UT

~1° beam width (a few km)





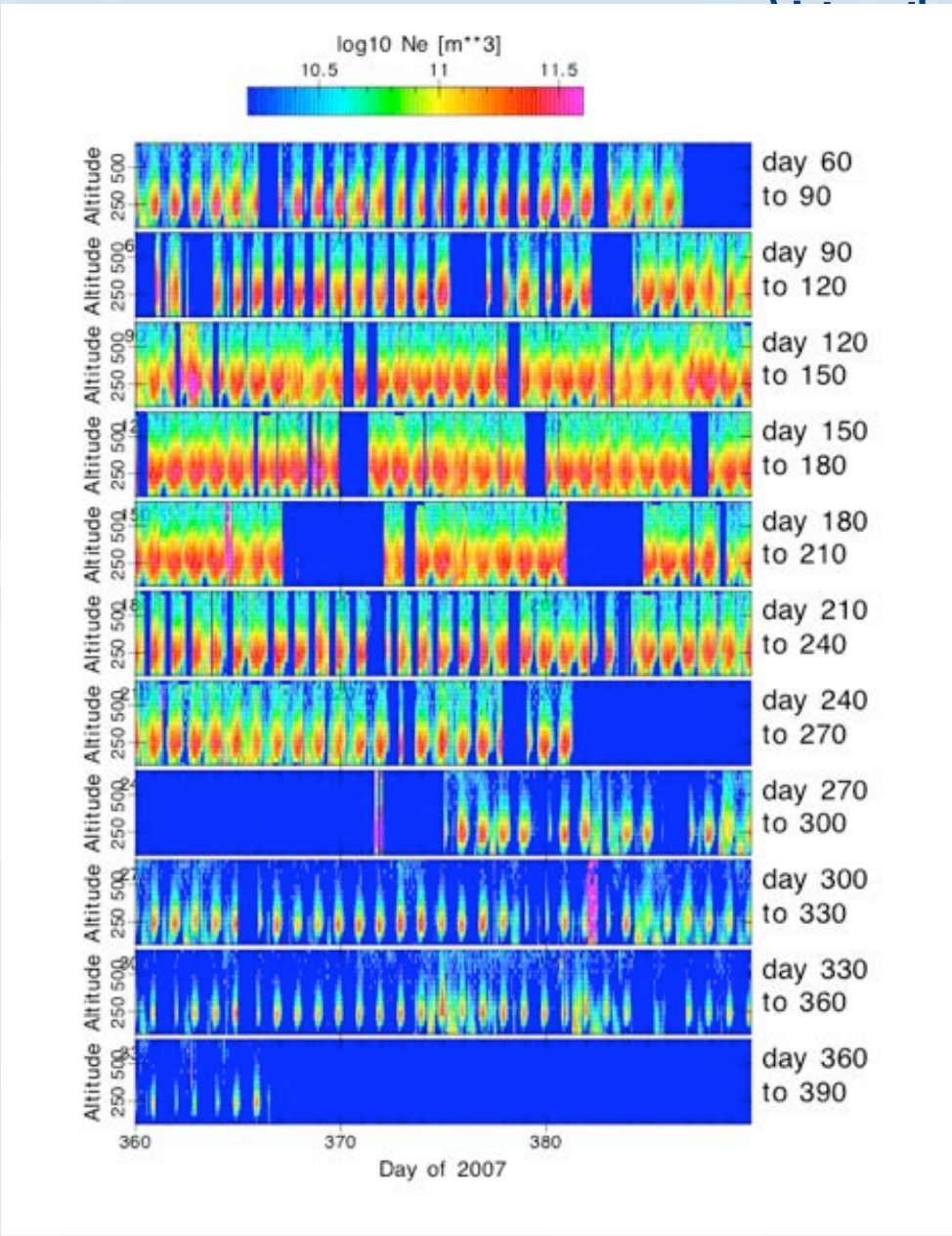
Anja Strømme, CEDAR Utah, 16. June 2008



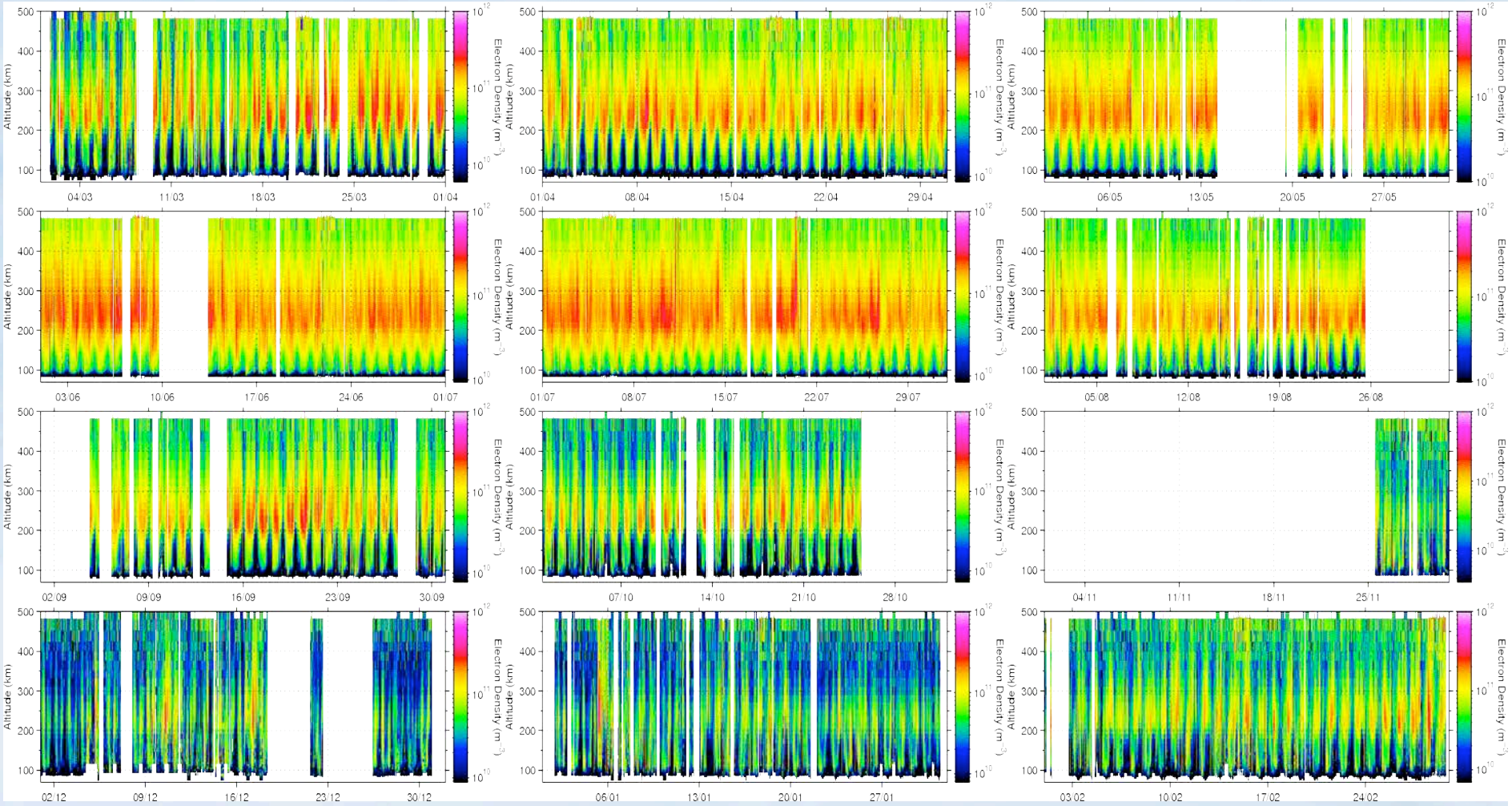
Anja Strømme, CEDAR Utah, 16. June 2008

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



Spring, Summer, Autumn, Winter



EISCAT Svalbard Radar IPY data

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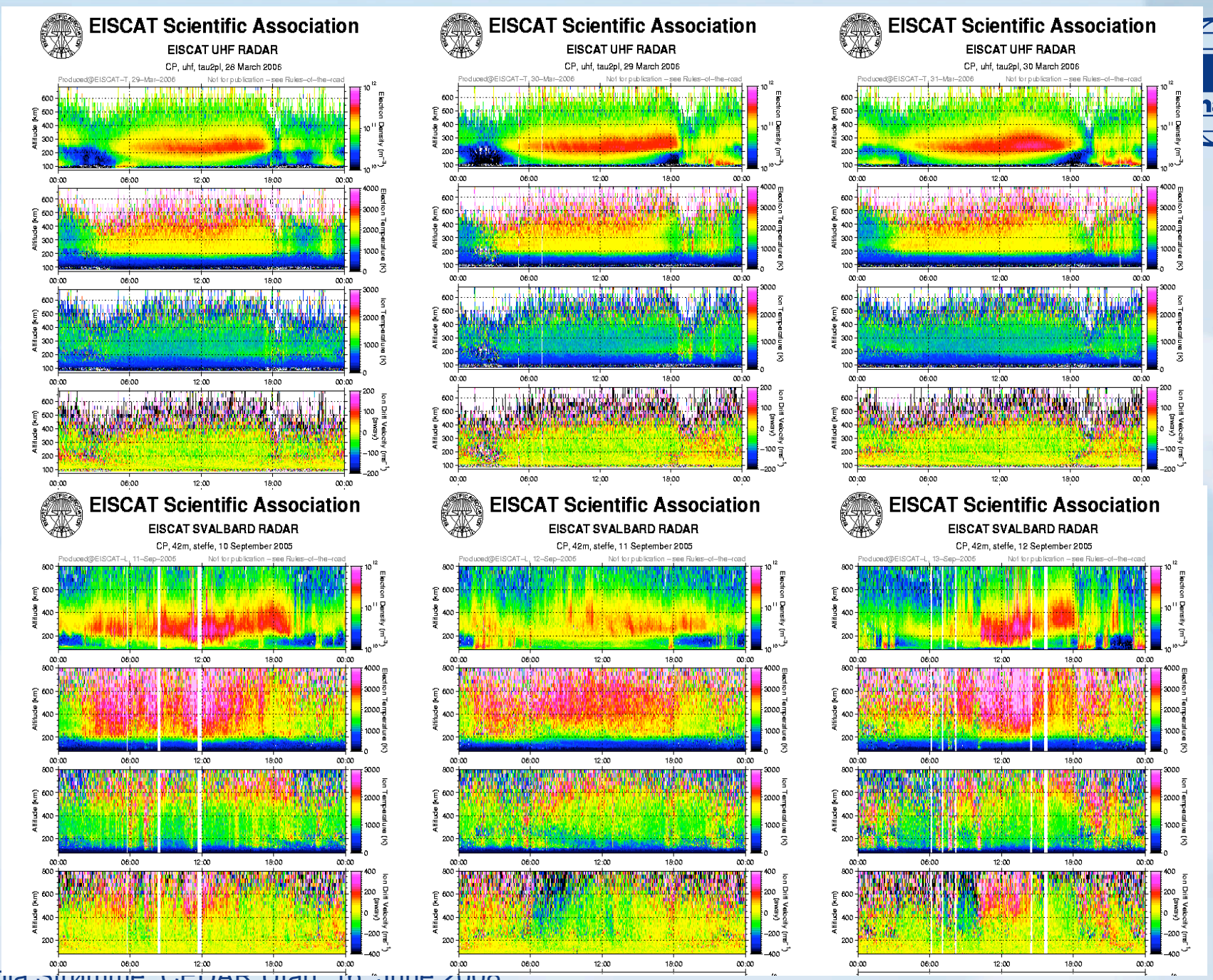
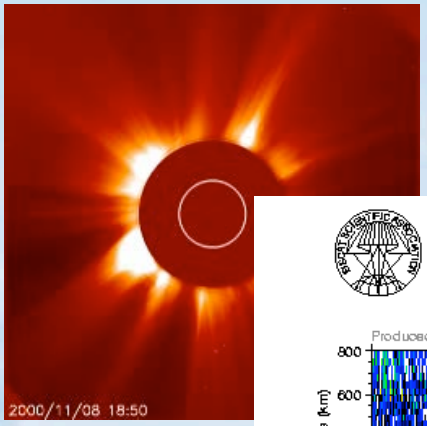

EISCAT Scientific Association
EISCAT UHF RADAR
CP, uhf, tau2pl, 28 March 2006
CP, uhf, tau2pl, 29 March 2006
CP, uhf, tau2pl, 30 March 2006
EISCAT SVALBARD RADAR
CP, 42m, steffe, 10 September 2005
CP, 42m, steffe, 11 September 2005
CP, 42m, steffe, 12 September 2005
Not for publication – see Rules-of-the-road
Altitude (km)
Electron Density (m⁻³)
Electron Temperature (K)
Ion Temperature (K)
Ion Drift Velocity (ms⁻¹)

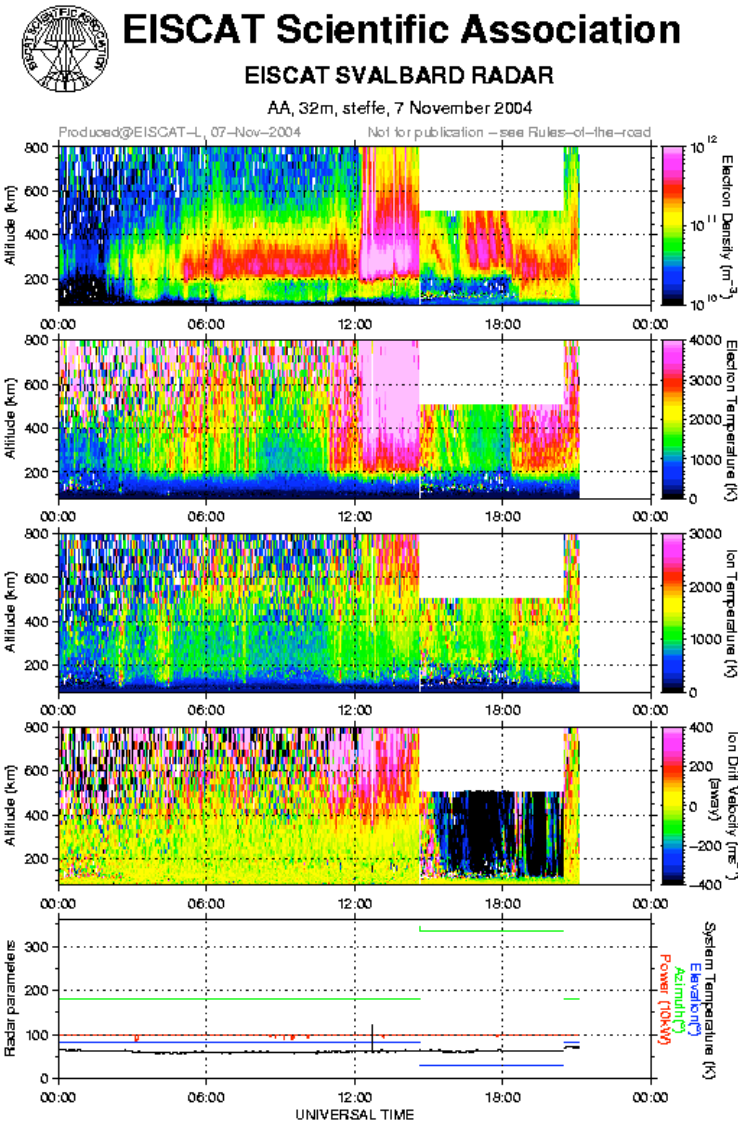
The Future of Space Science: Coordinated Measurements

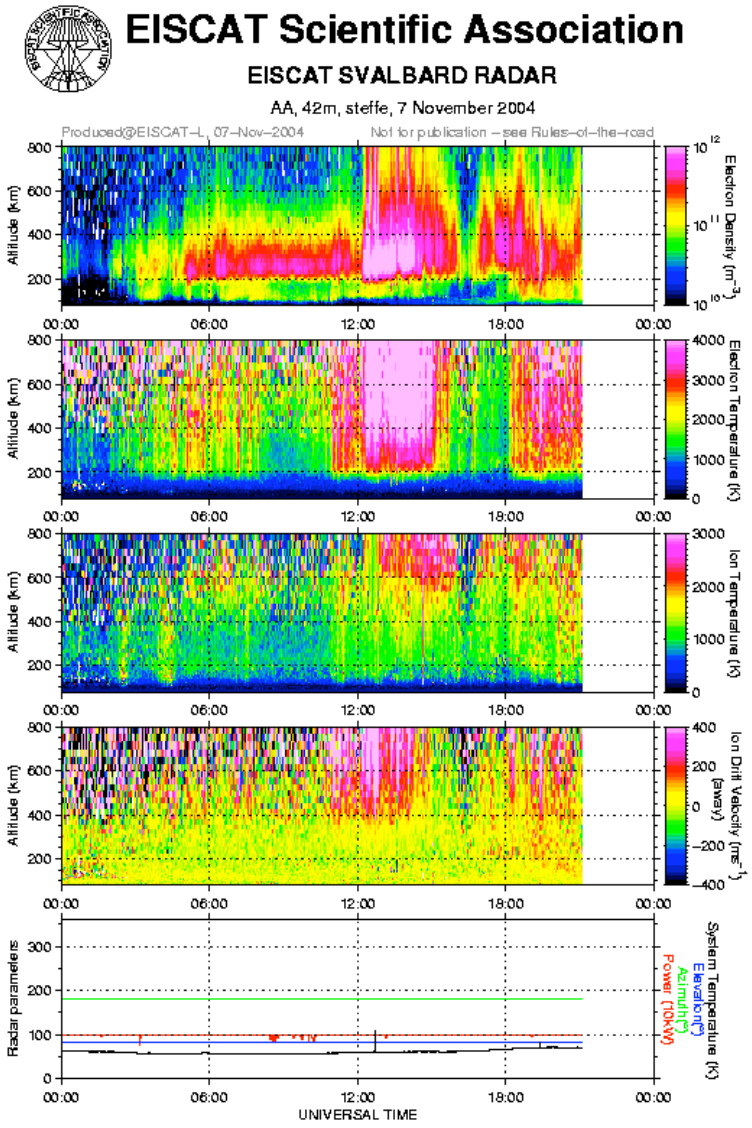
- **Long term climate and weather (Long Time Scales)**
  - International Polar Year (IPY)
- **Ionosphere-Magnetosphere coupling (Large Spatial Scales)**
  - Energy transfer to the ionosphere and atmosphere
  - Substorm triggering, etc.
- **Plasma structuring (Small Spatial and Short Time Scales)**
  - Auroral physics
  - Instabilities
  - Sporadic layers
- **Atmosphere-Ionosphere coupling (All Scales)**
  - Gravity waves, tides, forcing from below
  - Mesospheric phenomena



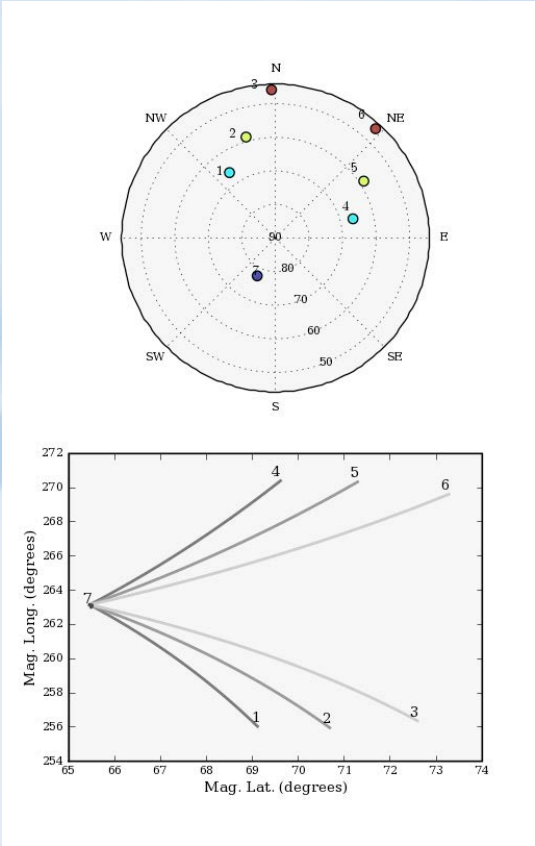
DOY .vs. Multiple Variables

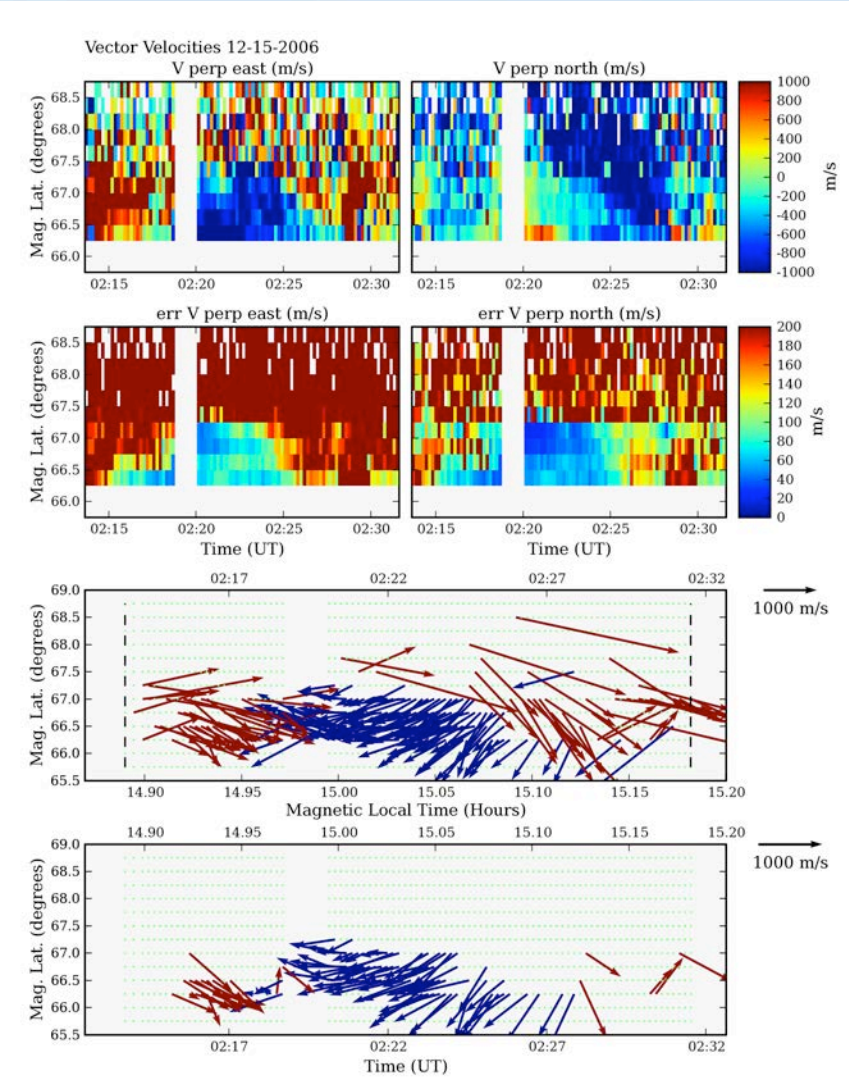
64-sec Averages -- Plot created Jun 16 2008





Combined velocities





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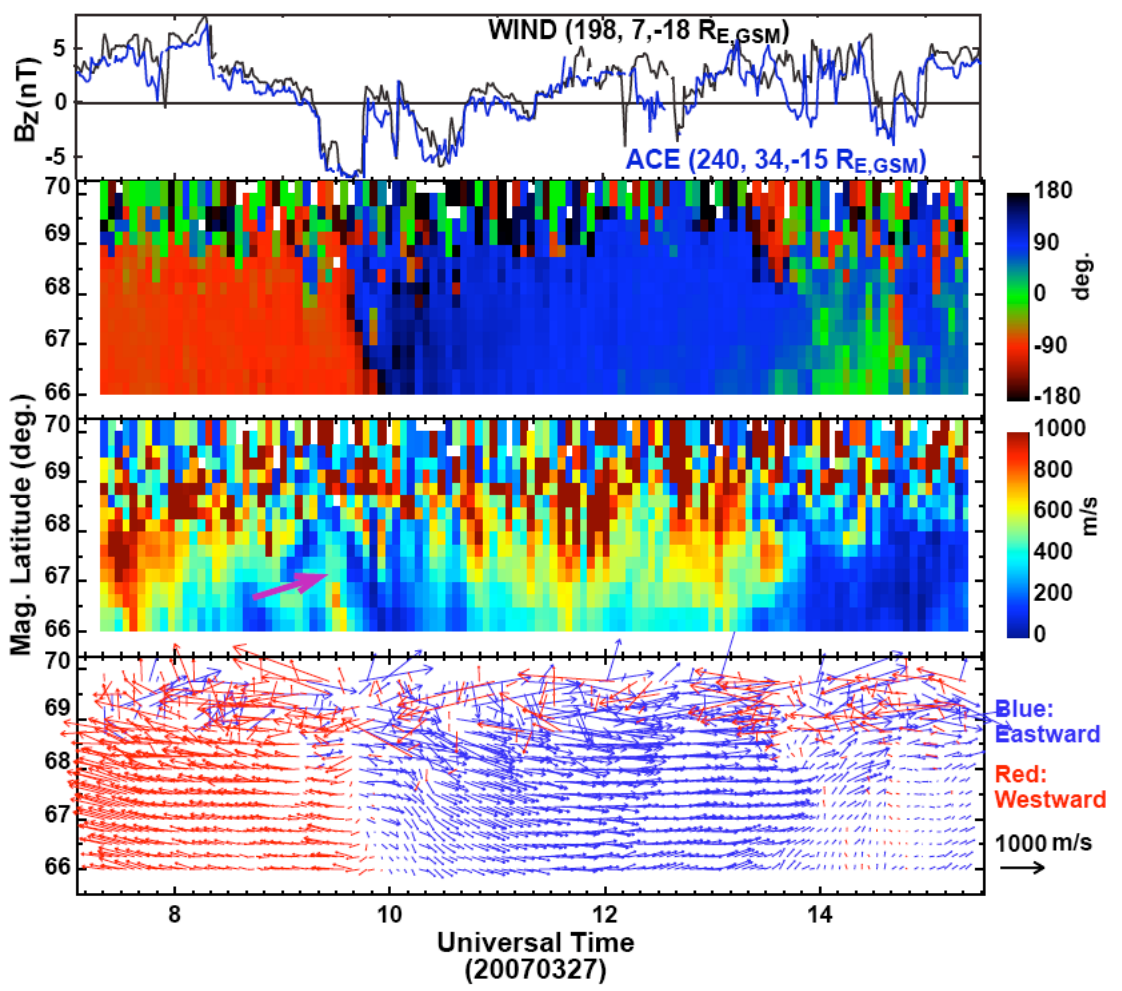
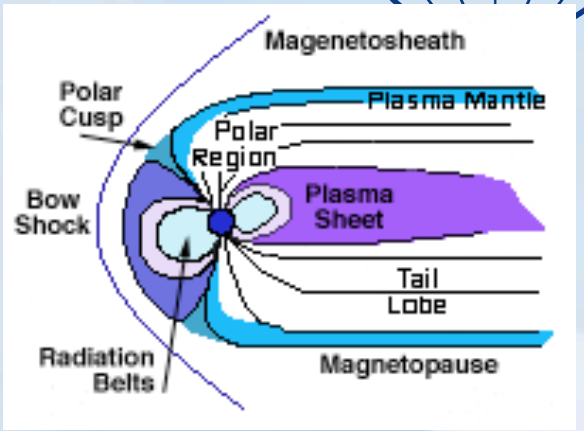
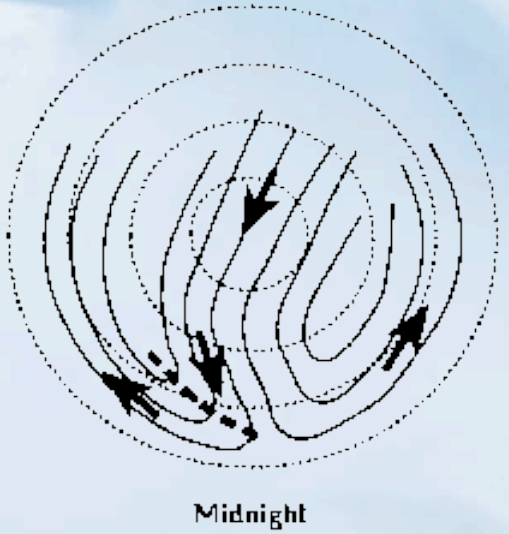
MI Coupling - Motion of the Plasma Sheet

- Equatorward moving region of enhanced flows with enhanced plasma sheet convection - SAPS

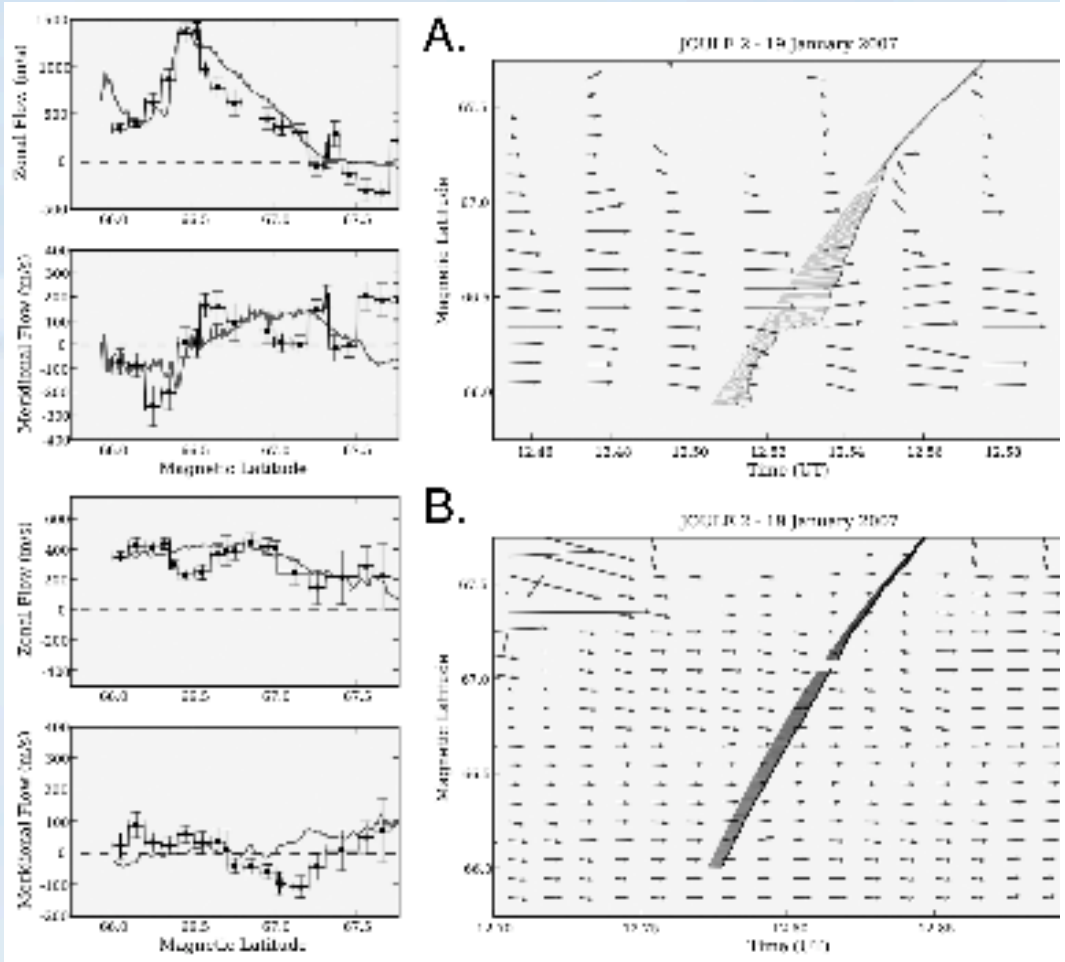






Lyons et al. [2008]

Joule 2 and PFISR



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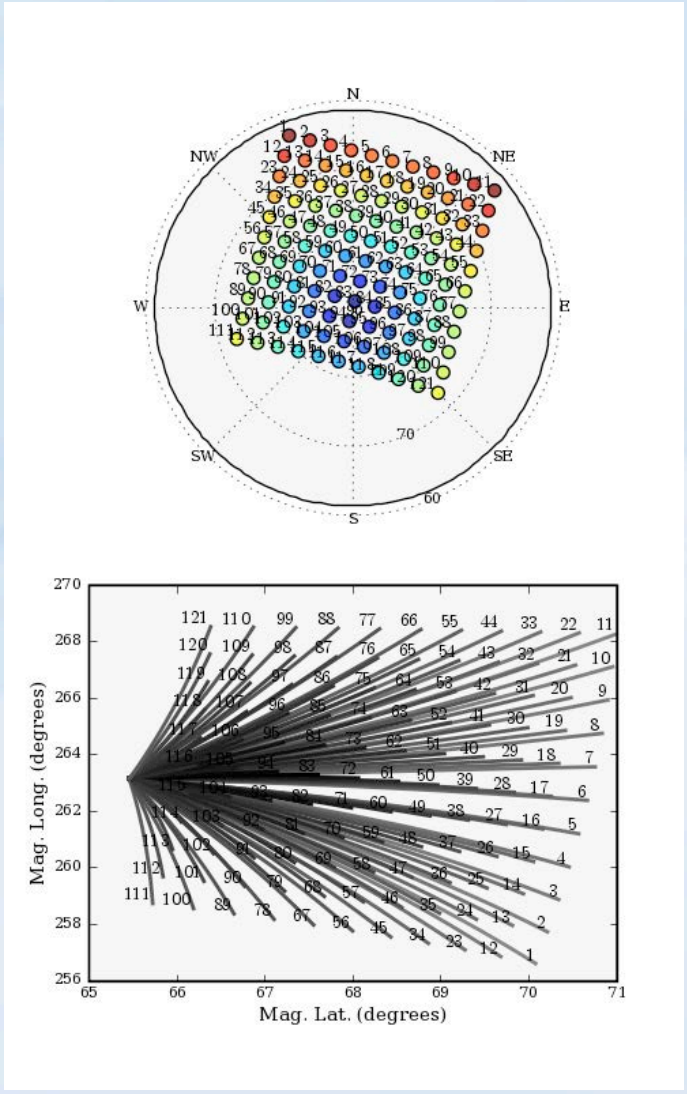
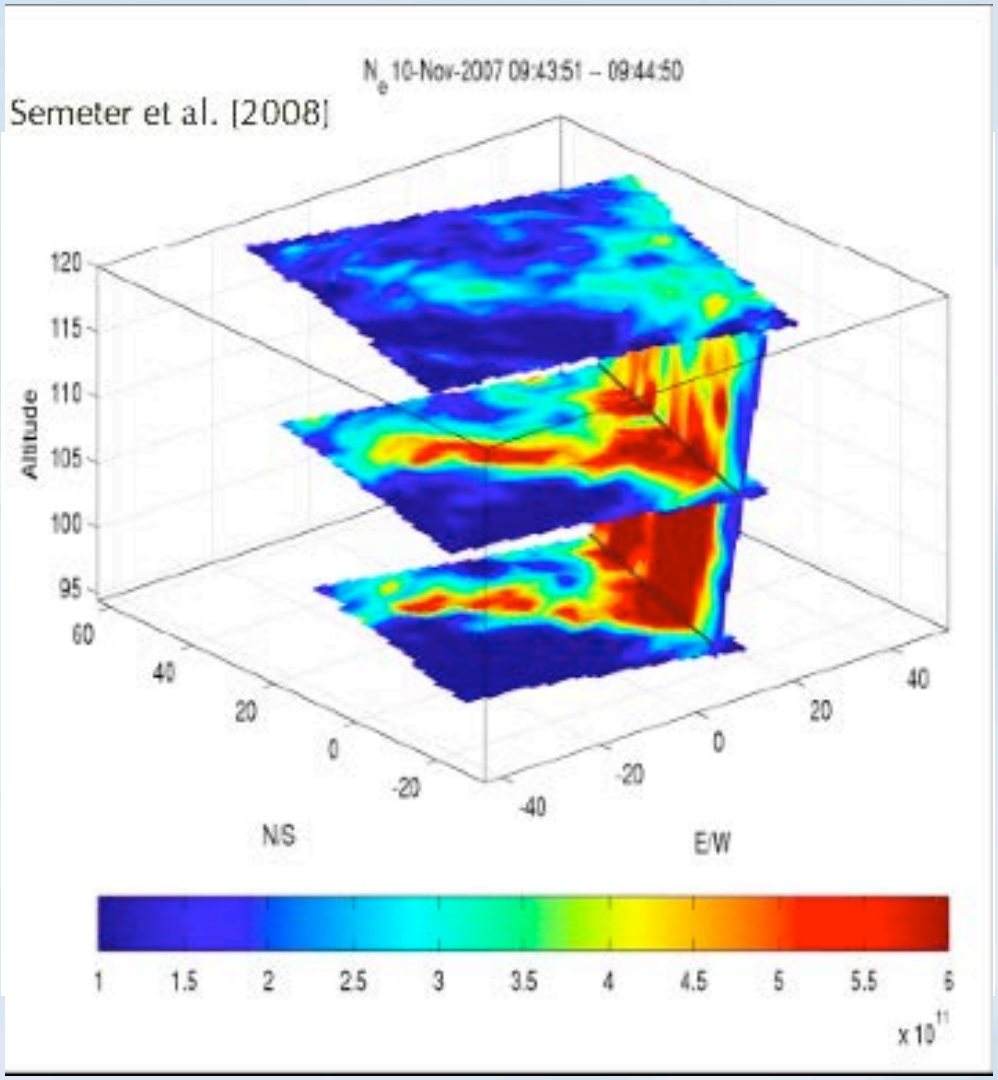
Imaging the aurora with PFISR





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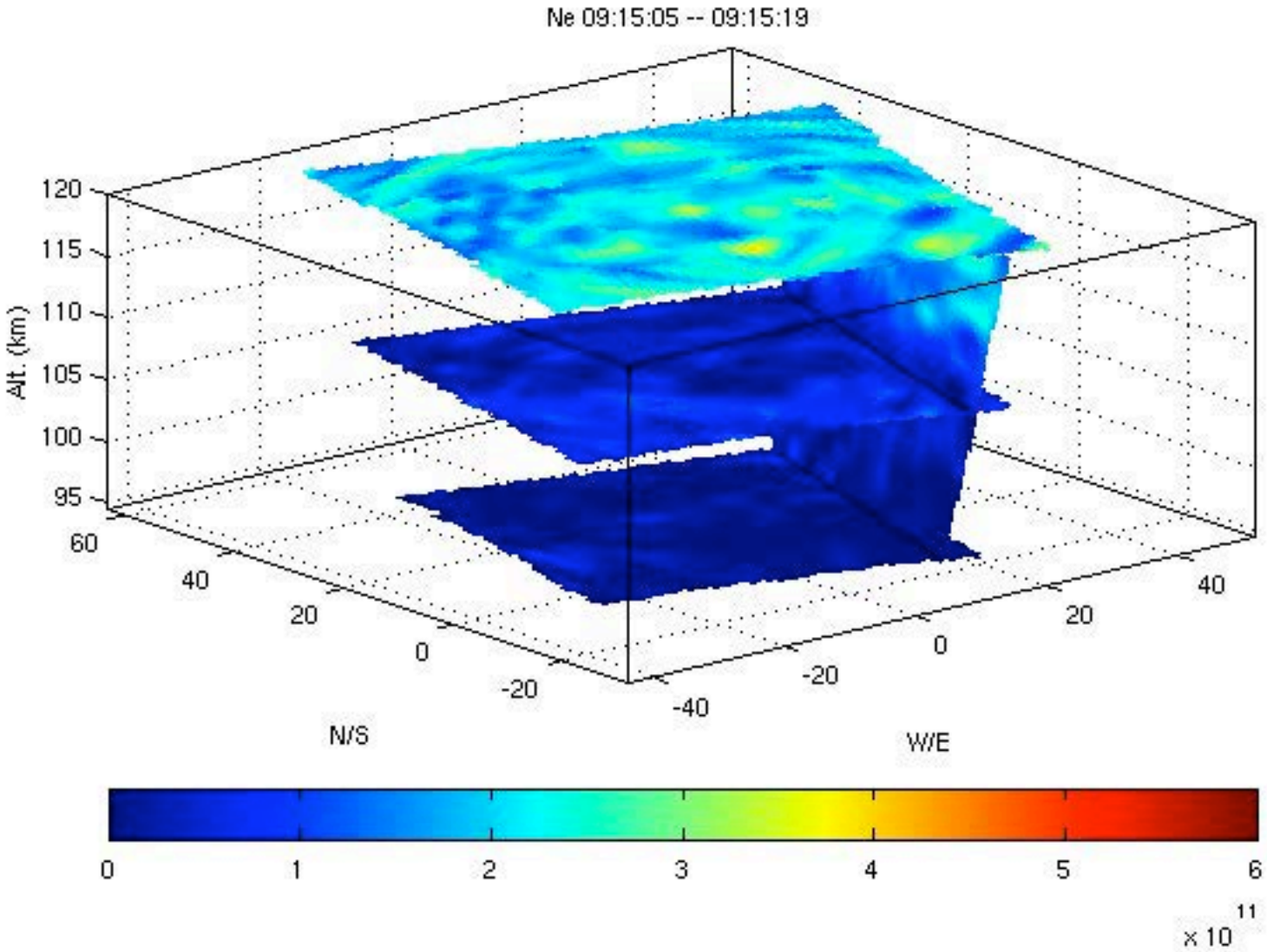
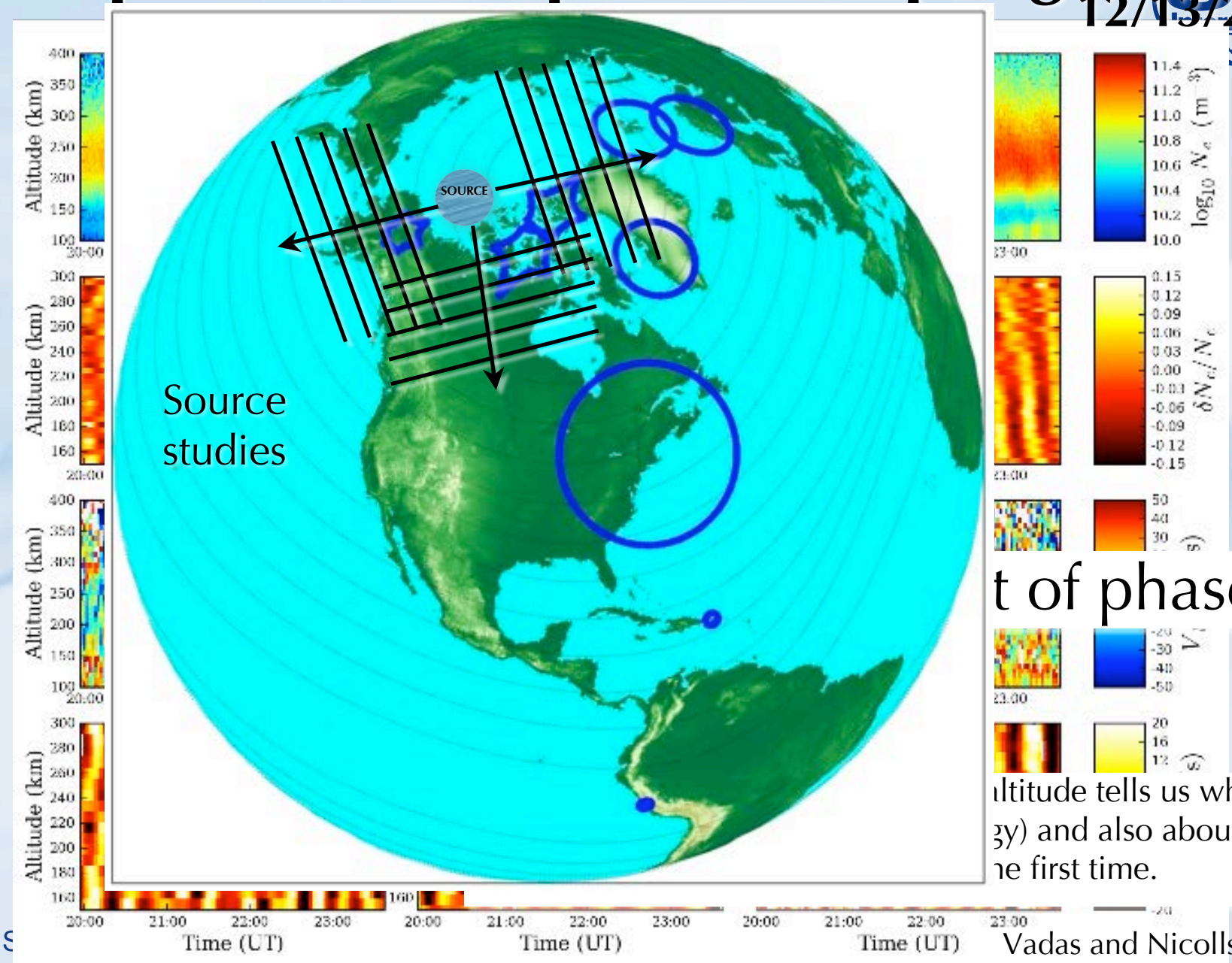


Courtesy of Thomas Butler

Ionospheric-Atmospheric Coupling

12/13/2006

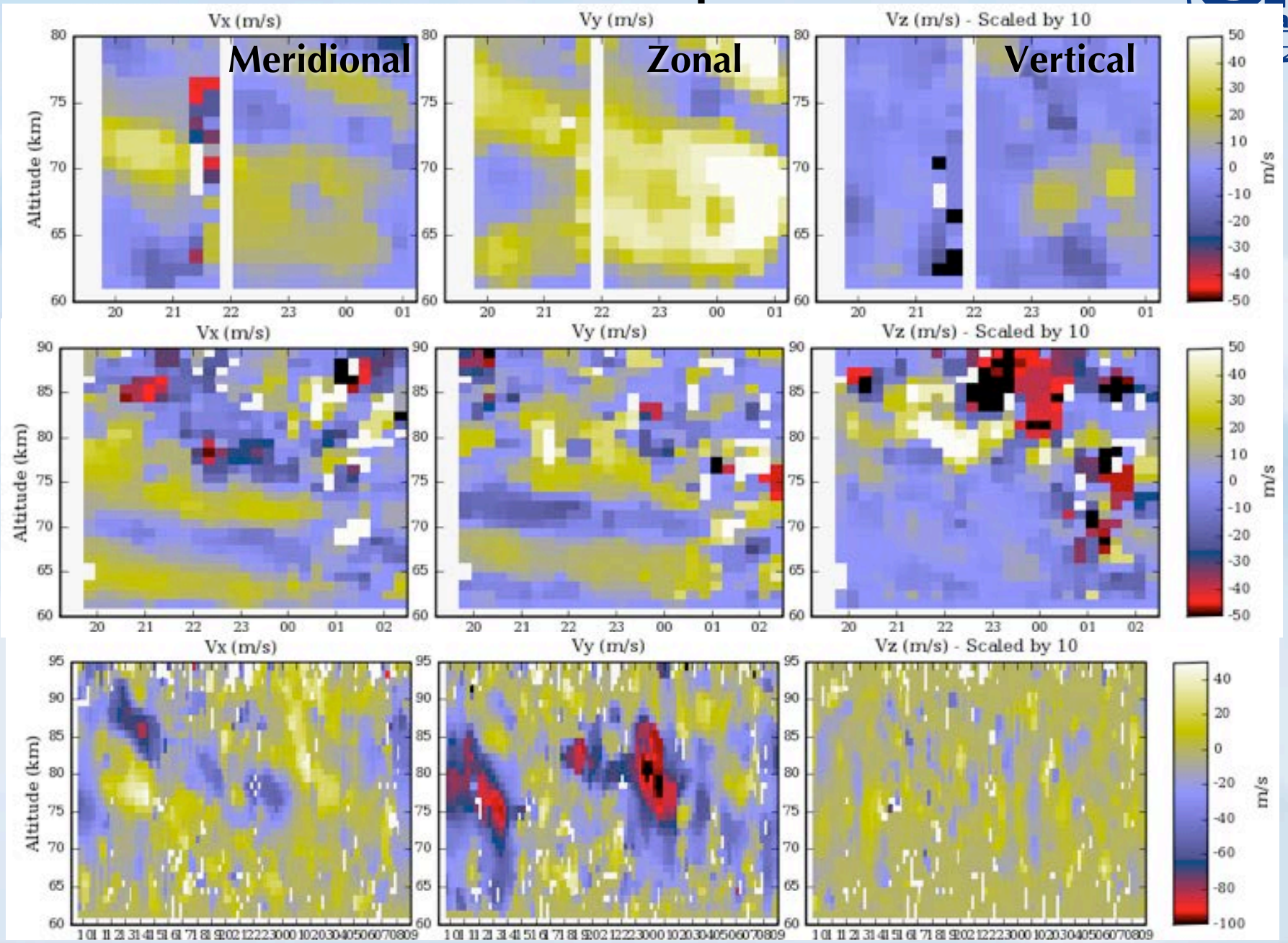


t of phase

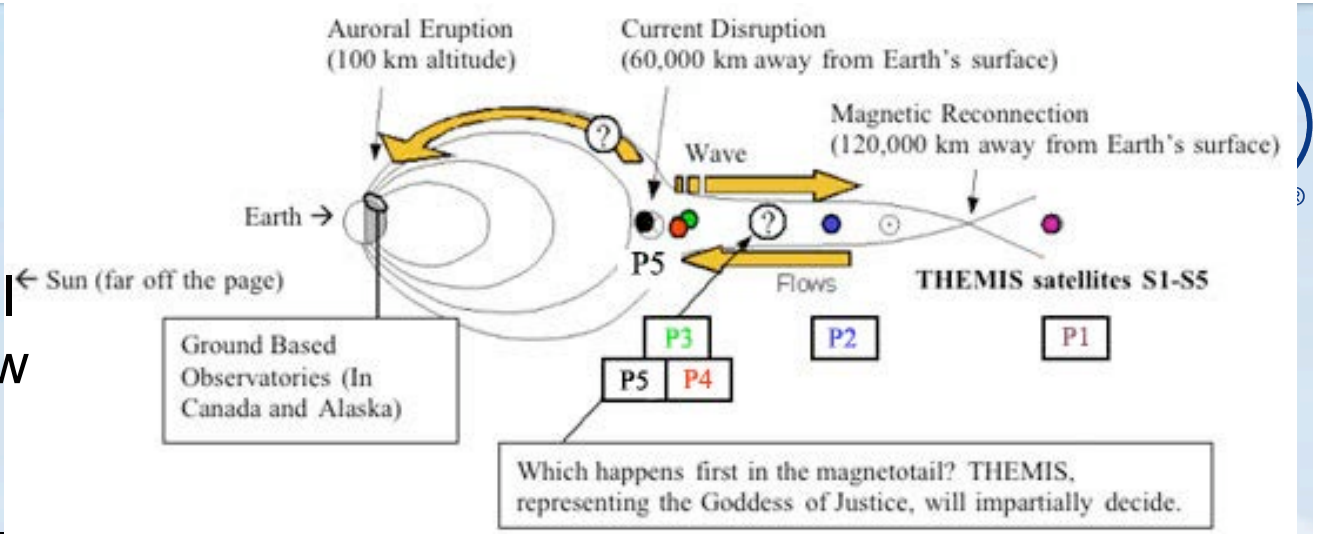
ltitude tells us where the
gy) and also about the
ne first time.

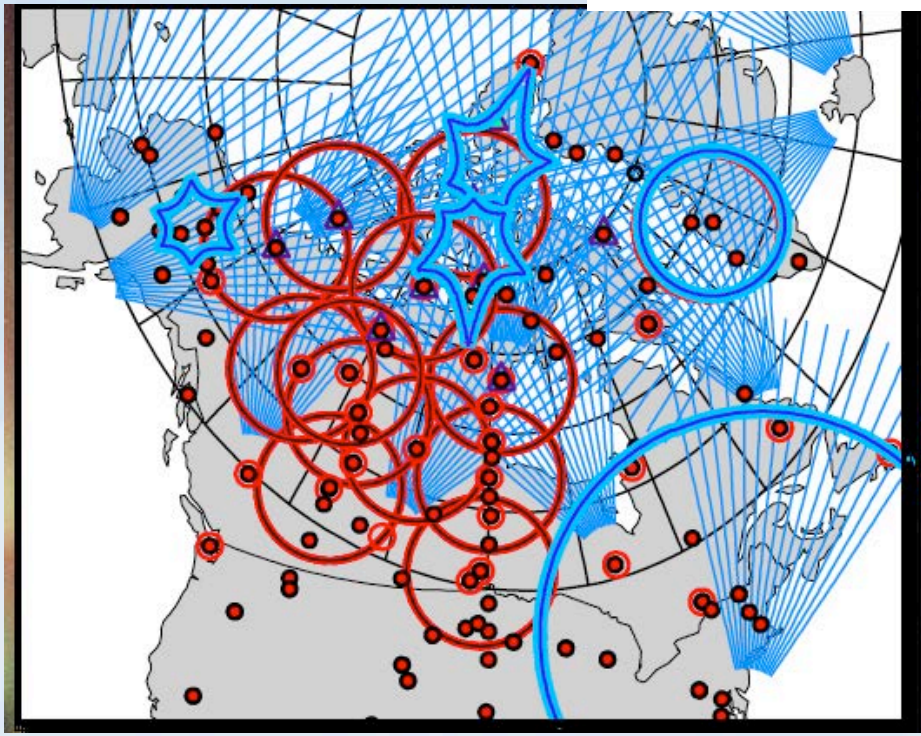
Vadas and Nicolls (2007)

atmosphere

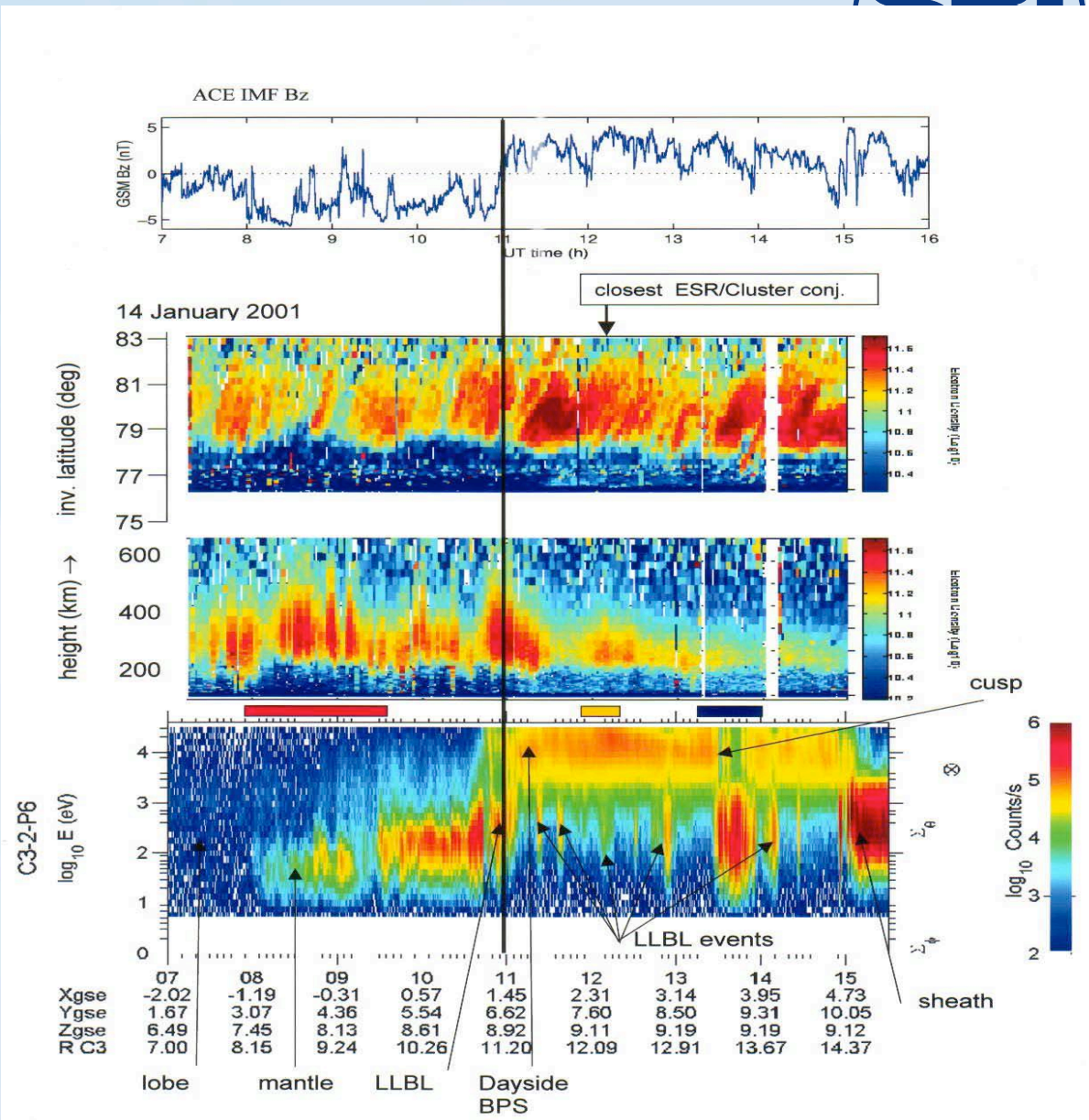

Vx (m/s)
Vy (m/s)
Vz (m/s) - Scaled by 10
Meridional
Zonal
Vertical
Altitude (km)
m/s

Coordinated THEMIS observations will be critical for identifying MI coupling issues like flow bursts, substorm initiations, etc.





Extensive THEMIS ground network


ACE IMF Bz
GSM Bz (nT)
UT time (h)
closest ESR/Cluster conj.
14 January 2001
inv. latitude (deg)
height (km) →
C3-2-P6
log10 E (eV)
cusp
LLBL events
sheath
log10 Counts/s
07 08 09 10 11 12 13 14 15
Xgse -2.02 -1.19 -0.31 0.57 1.45 2.31 3.14 3.95 4.73
Ygse 1.67 3.07 4.36 5.54 6.62 7.60 8.50 9.31 10.05
Zgse 6.49 7.45 8.13 8.61 8.92 9.11 9.19 9.19 9.12
R C3 7.00 8.15 9.24 10.26 11.20 12.09 12.91 13.67 14.37
lobe
mantle
LLBL
Dayside BPS

Summary

- In order to predict space weather we have to be able to describe the current state ("nowcasting").
- IS radars are very important contributors in providing high quality ionospheric data on a varaity of scales.
- Space weather effects are truly global - as must our approach to understand it be.