Coordinated Radar-THEMIS Measurements of Region 2/Harang Reversal Dynamics

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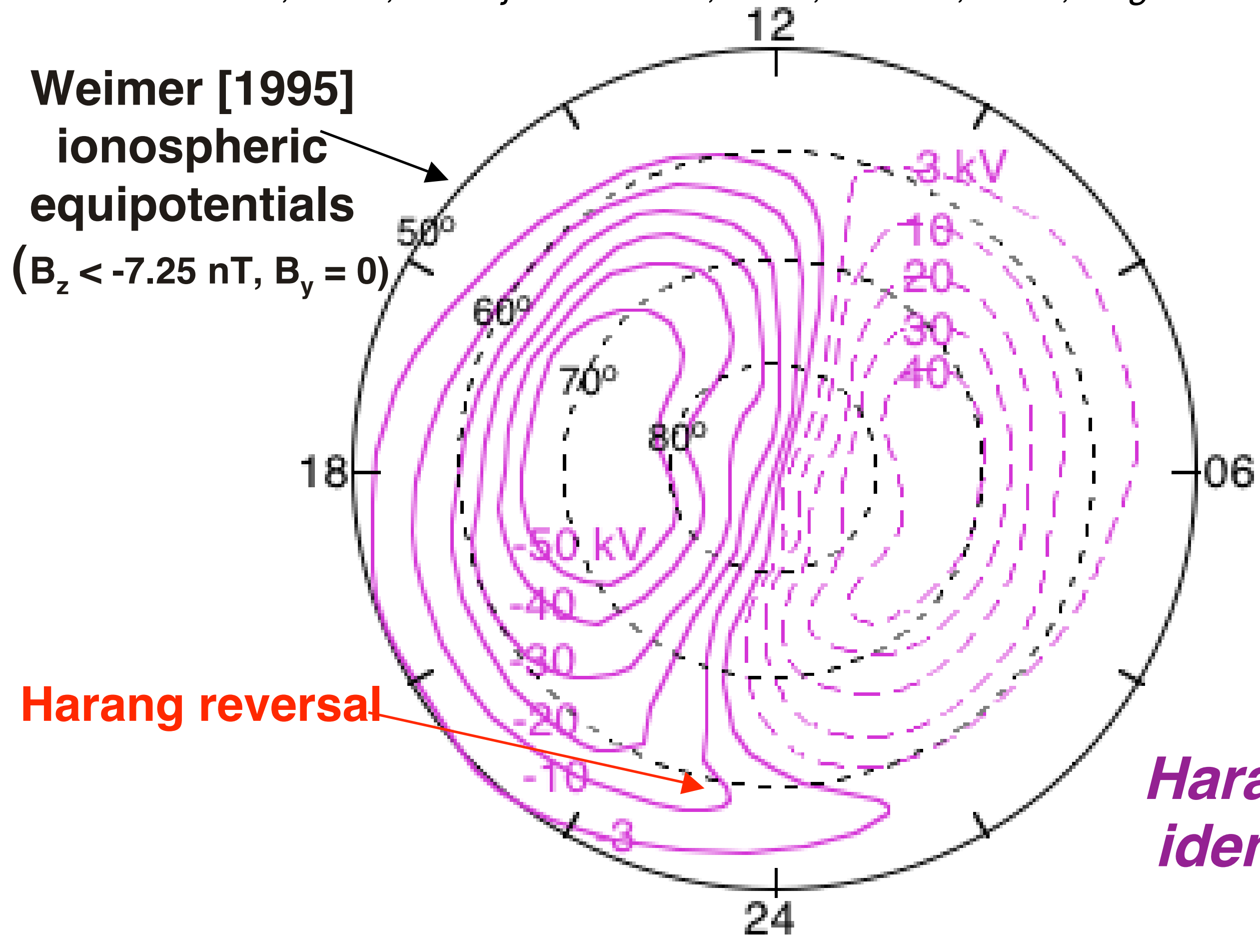
- **The Harang Reversal ("discontinuity"):**
  - **Fundamental component of Region 2 current system**
  - **Related to dayside convection, substorm growth phase & onset**
- **Unprecedented new capability** to measure Harang evolution
  - **With AMISR radar** in Poker Flat
  - **With SuperDARN radars** sufficiently equatorward to avoid absorption
  - **In relation to convection** (dayside Sondrestrom/Svalbard ISR; SuperDARN)
  - **In relation to disturbances** (Alaskan/THEMIS all-sky imagers, etc.)
- **Excellent azimuthal THEMIS-radar conjunctions**
  - **Plasma sheet azimuthal gradients:** Region II/Harang physics
  - **Evolution in relation to substorms** (also SMCs, etc.)
  - **Flow/flow burst azimuthal distribution** (substorms, PBIs -Zesta)

Substorm Auroral Activation in Ionosphere ($j_{||}$ up portion current wedge)

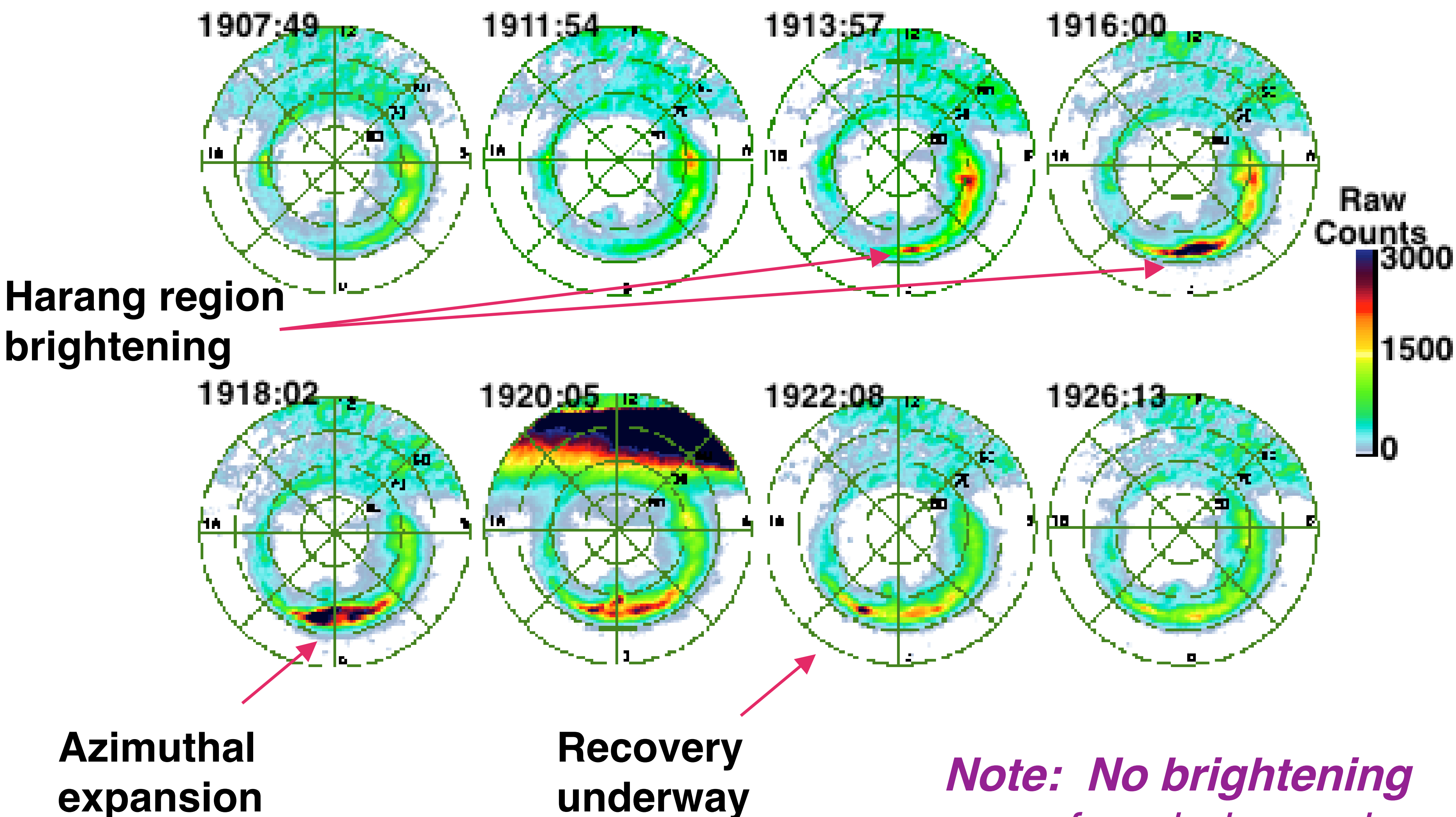
Equatorward portion of nightside auroral oval [*Samson et al.*, 1992]

In region of converging E know as Harang reversal![*Nielson & Greenwald*, 1979; *Baumjohann et al.*, 1981; *Nielson*, 1988; *Hughes & Bristow*, 2003; *Weygand et al., ICS-8*]



Harang-region brightening identifies substorm onset

Typical Substorm: Dec. 9, 2000

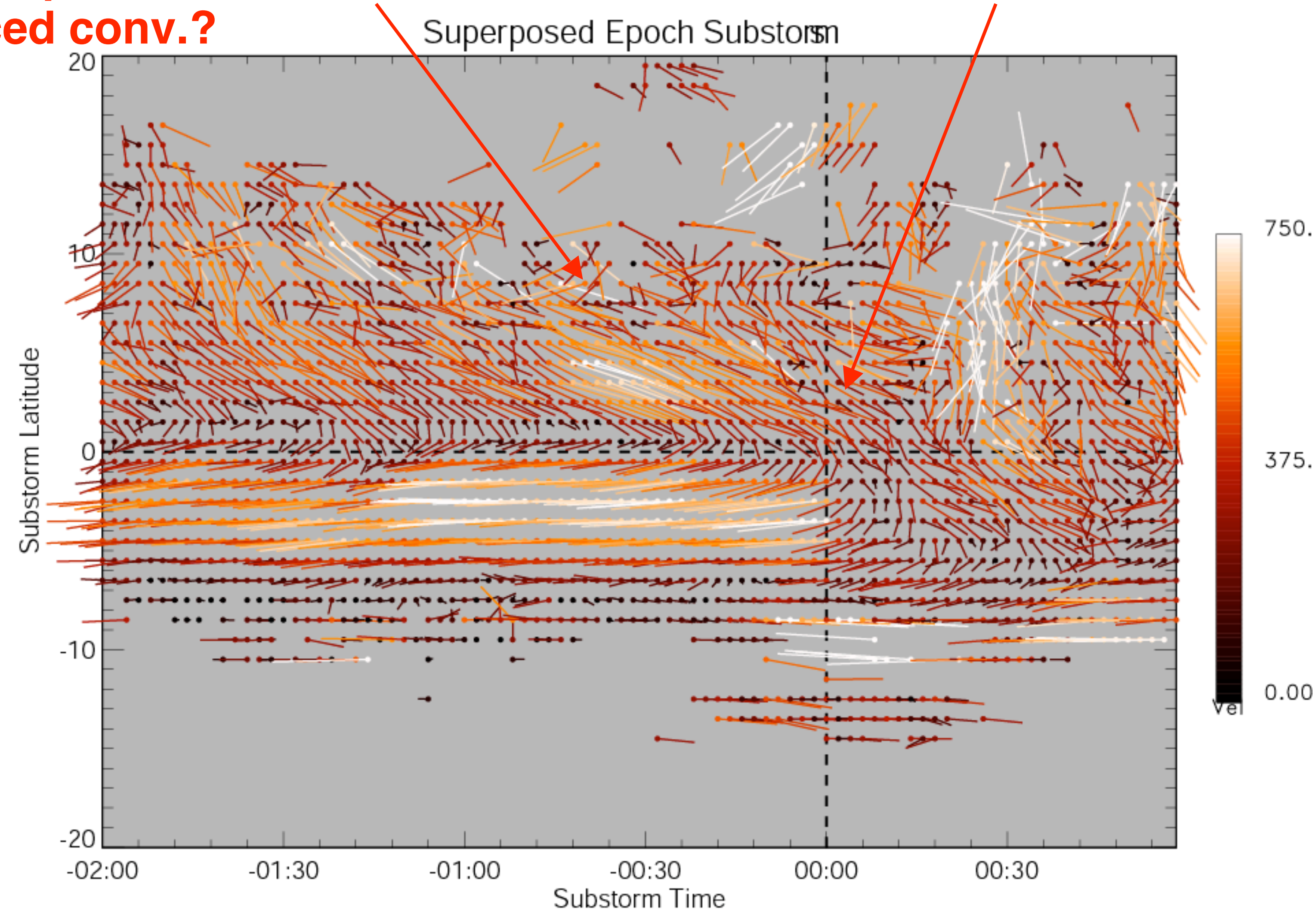


Note: No brightening
away from bulge region

Bristow (ICS-8, 2007): SuperDARN flows vs. lat. relative to substorm onset from 10 events

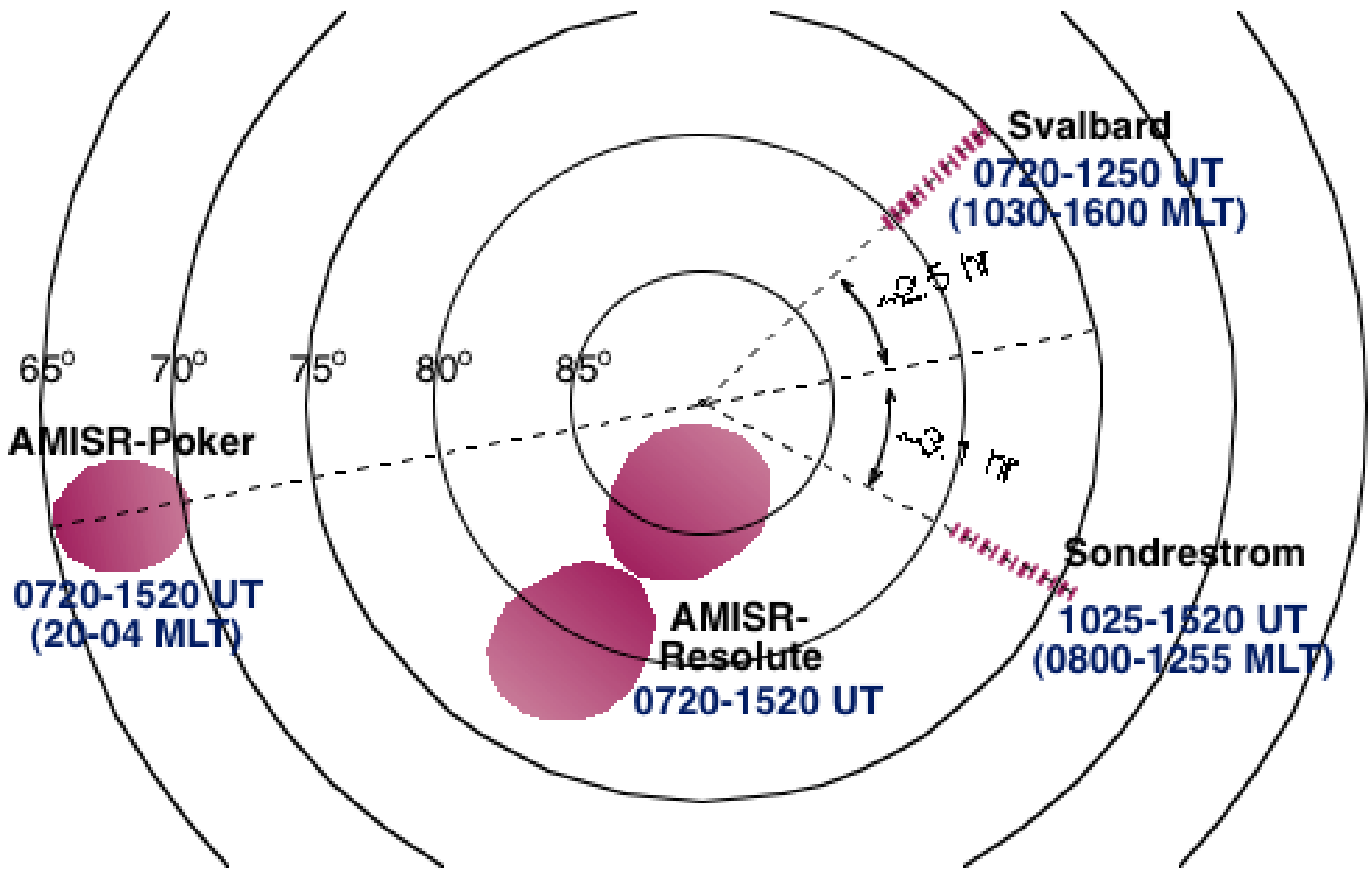
Enhancement of flow & shear prior to onset: Response to growth phase southward IMF, enhanced conv.?

Relaxation of shear and flow speed ~at onset: Response to convection reduction?



ISR Radar Operation Plan

- **AMISR-Poker, 20-04 MLT:** disturbance electrodynamics, connections to Harang
- **Sondrestrom and Svalbard:** connection to dayside convection
- **AMISR-Resolute Bay:** connection to polar-cap convection

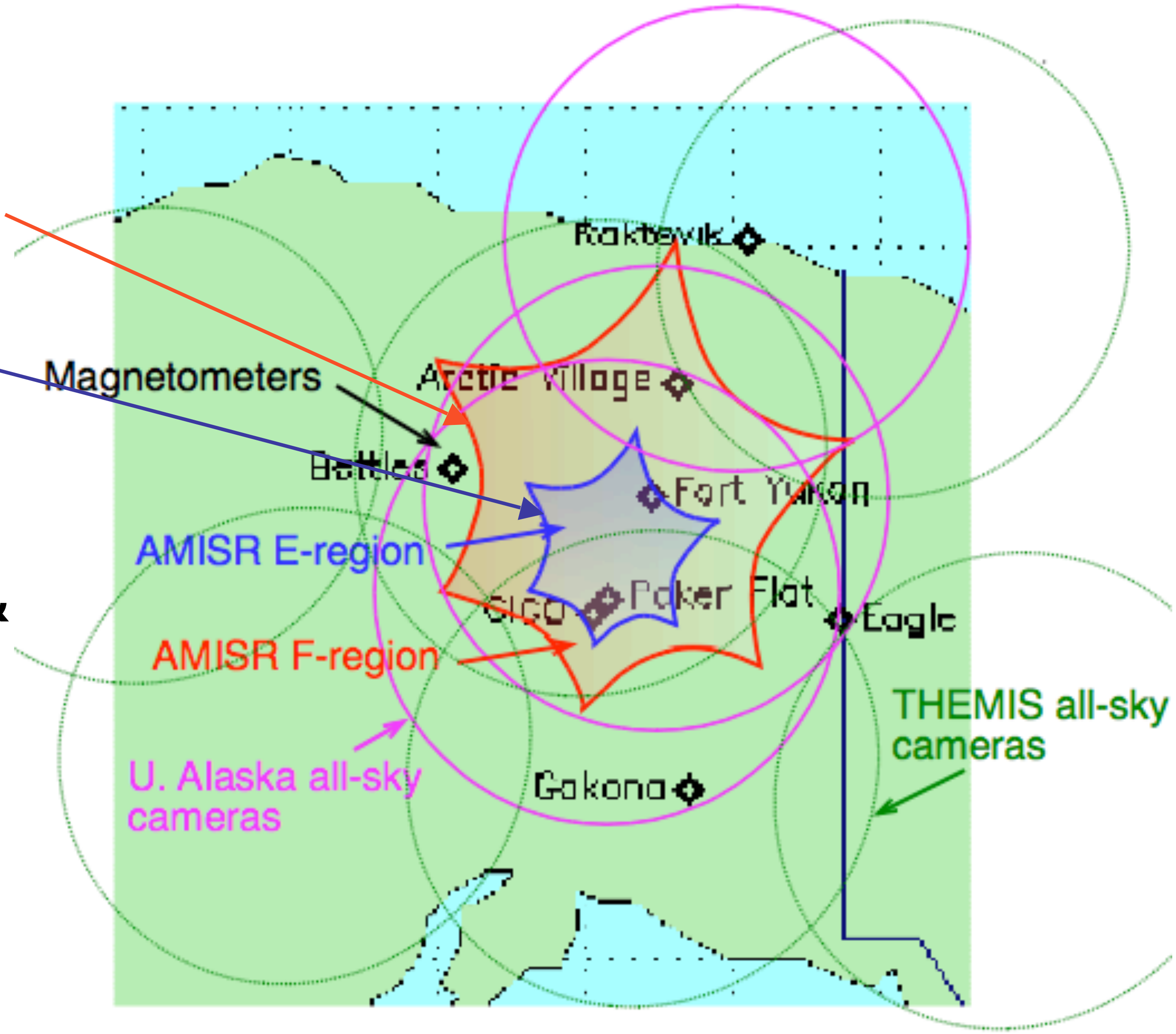


AMISR: F-region flows 8-10 faster than Sondrestr. [*C. Heinselman*].

- Good 2-D coverage of F-region flow vectors in 2 min.
- Simultaneous 2-D coverage of E-region densities vs altitude (conductivities) in 2 min feasible [*C. Heinselman*]

Excellent all-sky imager & magnetometer coverage

- Critical for disturbance identification

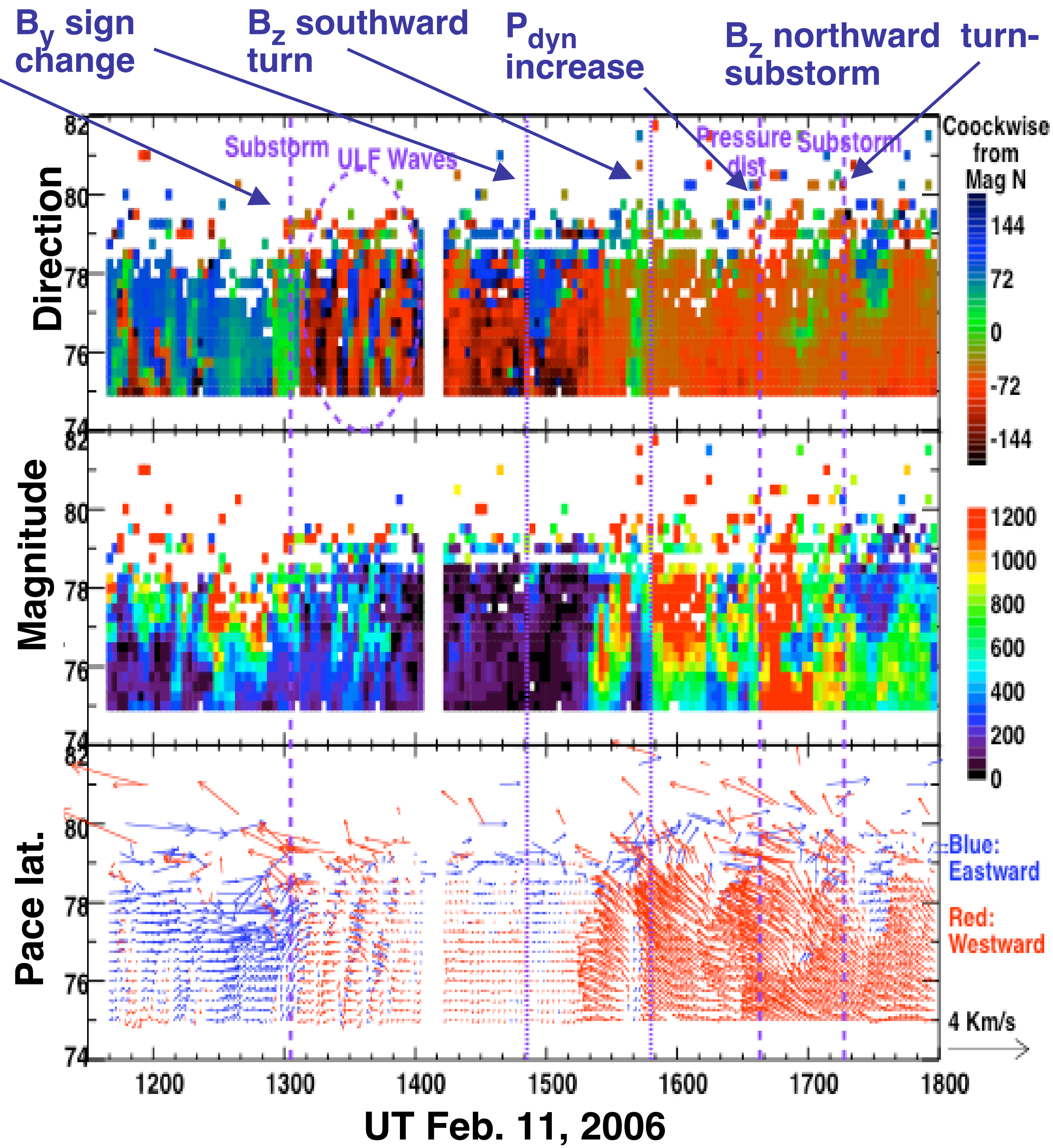


Spacecraft IMF/solar wind measurements

- ~5-30 min mapping errors
- Errors from spatial inhomogeniety
- Cannot use for timing studies

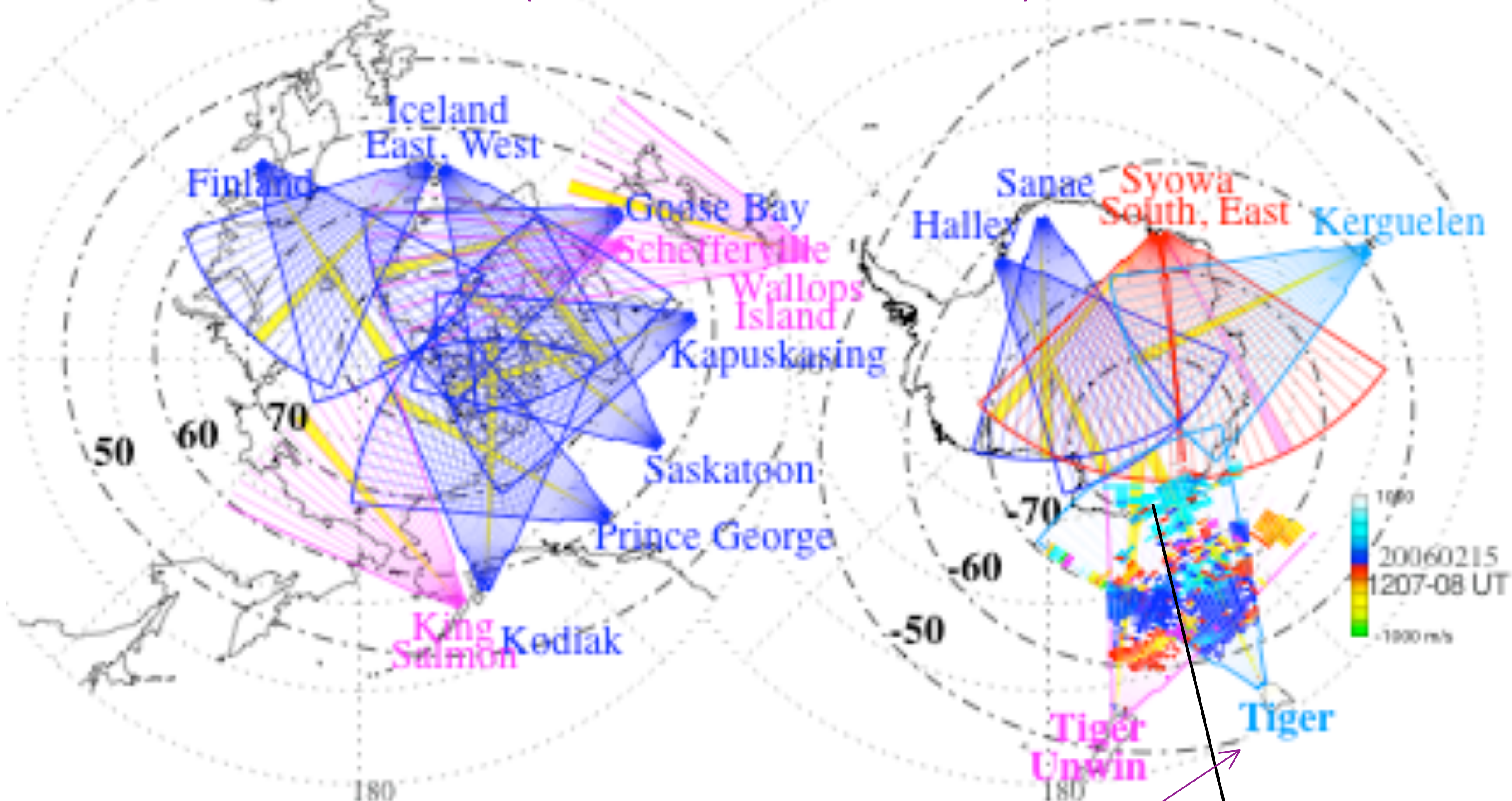
Campaign using Sondrestrom

- 2 min time resolution
- Flow response to P_{dyn}, B_y, B_z clear
- Can use for Harang, Substorm, triggering studies, including THEMIS conjunctions



SuperDARN Harang studies

Excellent dayside coverage
(also from Sonde, Sval.)

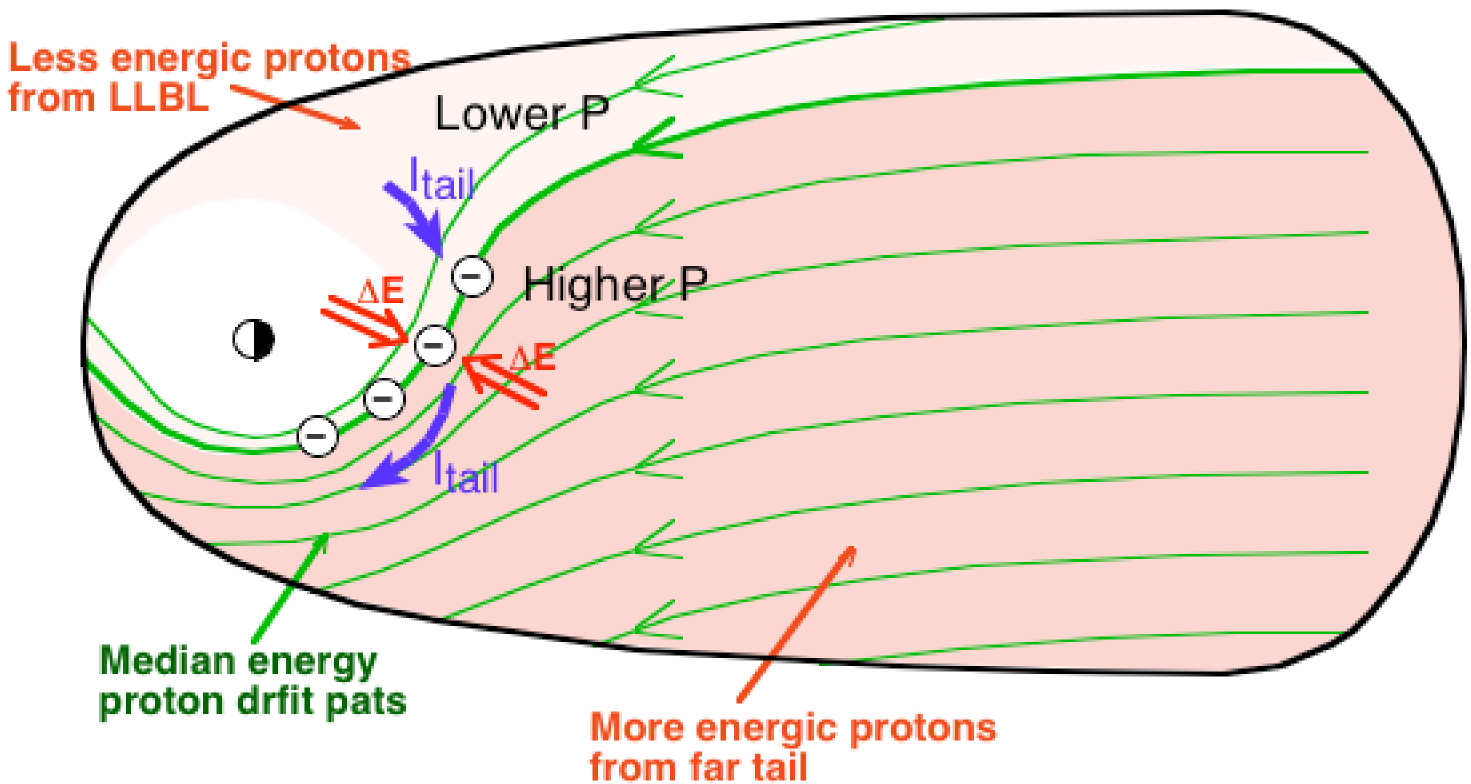


23 MLT @ 11 UT

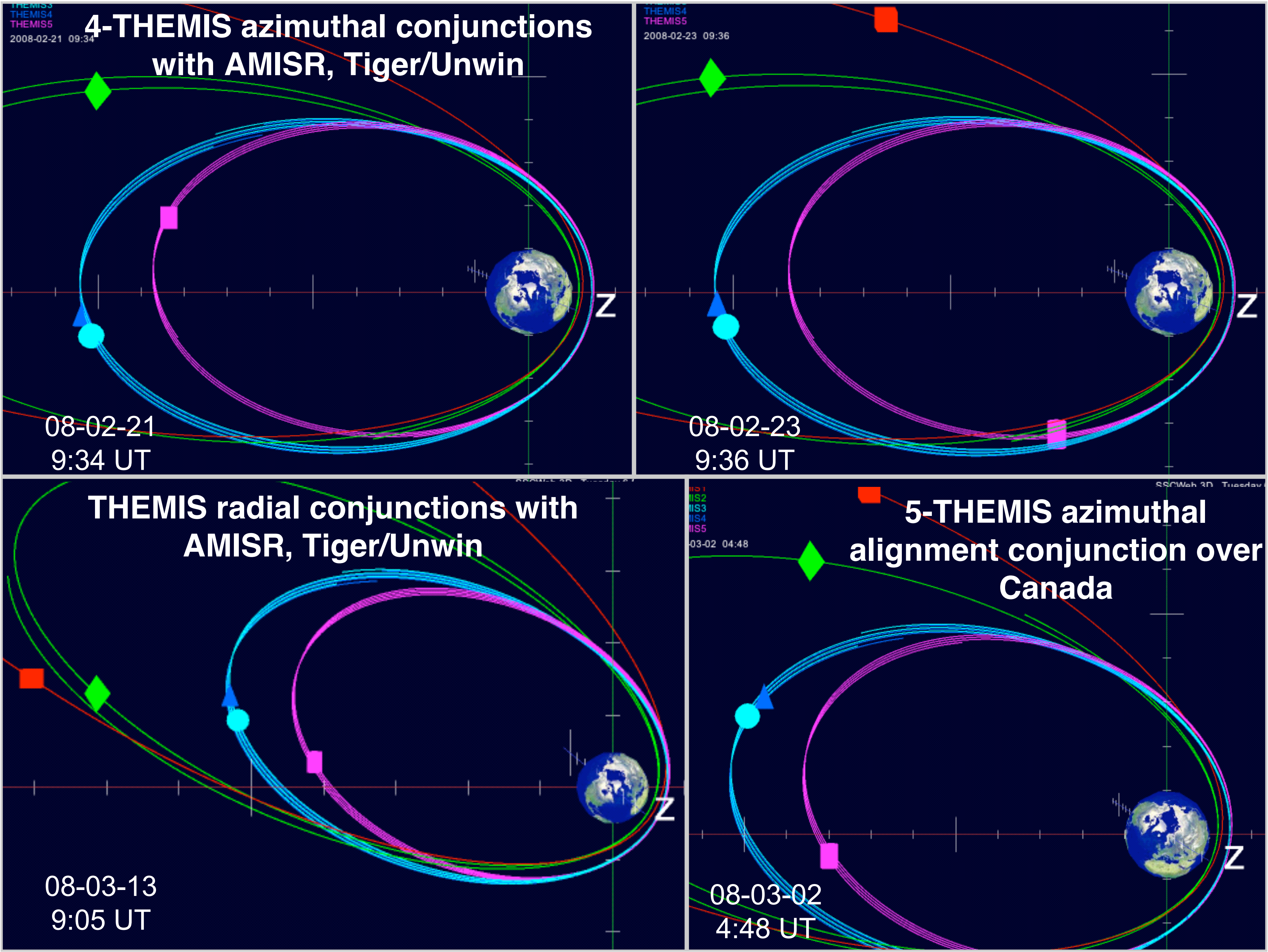
Tiger/Unwin pair excellent location: good substorm-Harang examples available

Development of Harang via Region II Physics

[Erickson et al. [1991]]



- Azimuthal ∇P due to mag. drift of particles from LLBL, deep tail
- Gives perp (cross-tail) current divergence, requiring $j_{||}$ from ionosphere
- Electric fields (ΔE) form to maintain ionospheric current continuity
- Azimuthal particle distribution, P gradients critical: *THEMIS can measure*!


THEMIS4
THEMIS5
2008-02-21 09:34
4-THEMIS azimuthal conjunctions with AMISR, Tiger/Unwin
Z
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THEMIS4
THEMIS5
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THEMIS radial conjunctions with AMISR, Tiger/Unwin
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5-THEMIS azimuthal alignment conjunction over Canada
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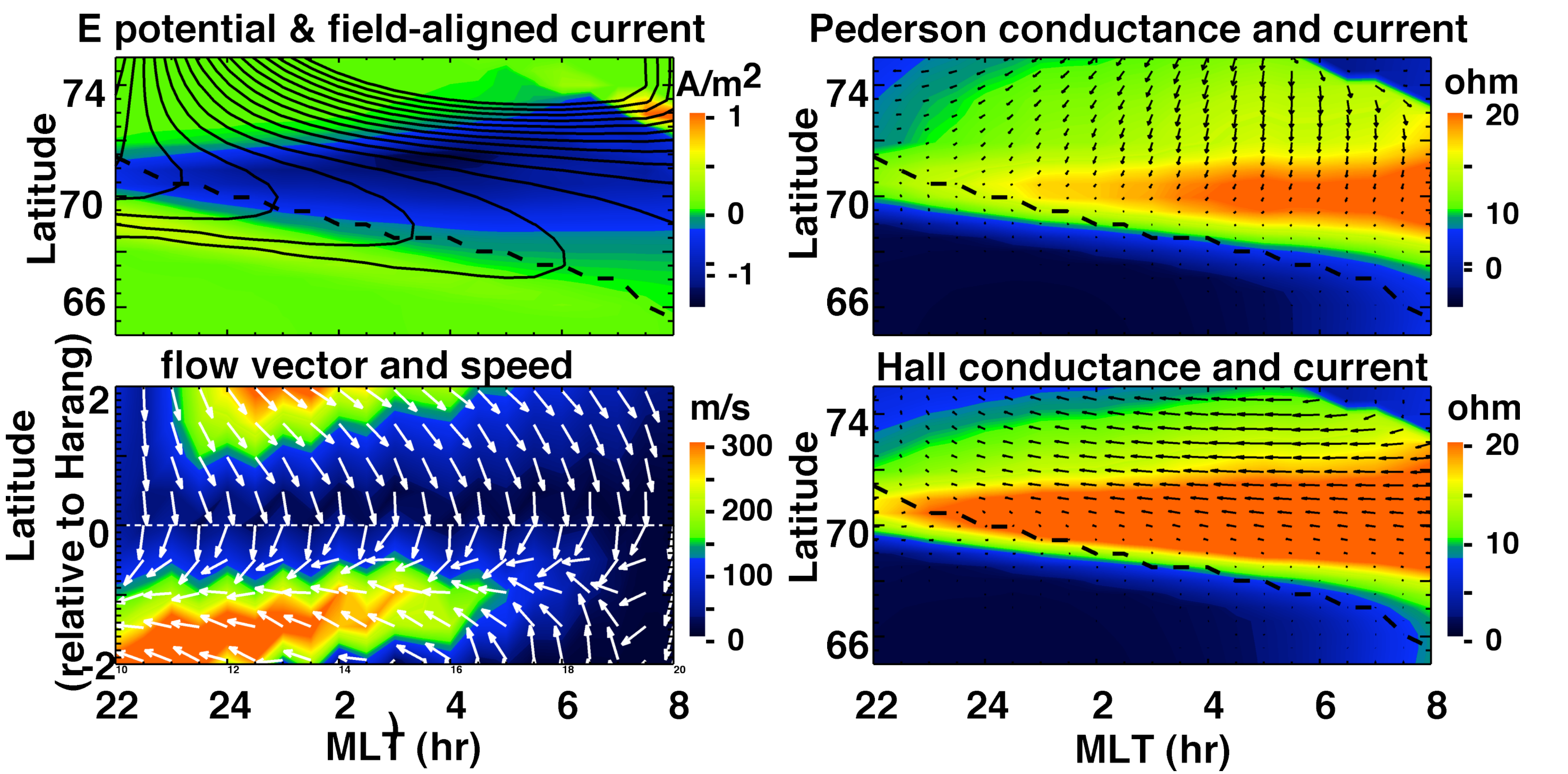
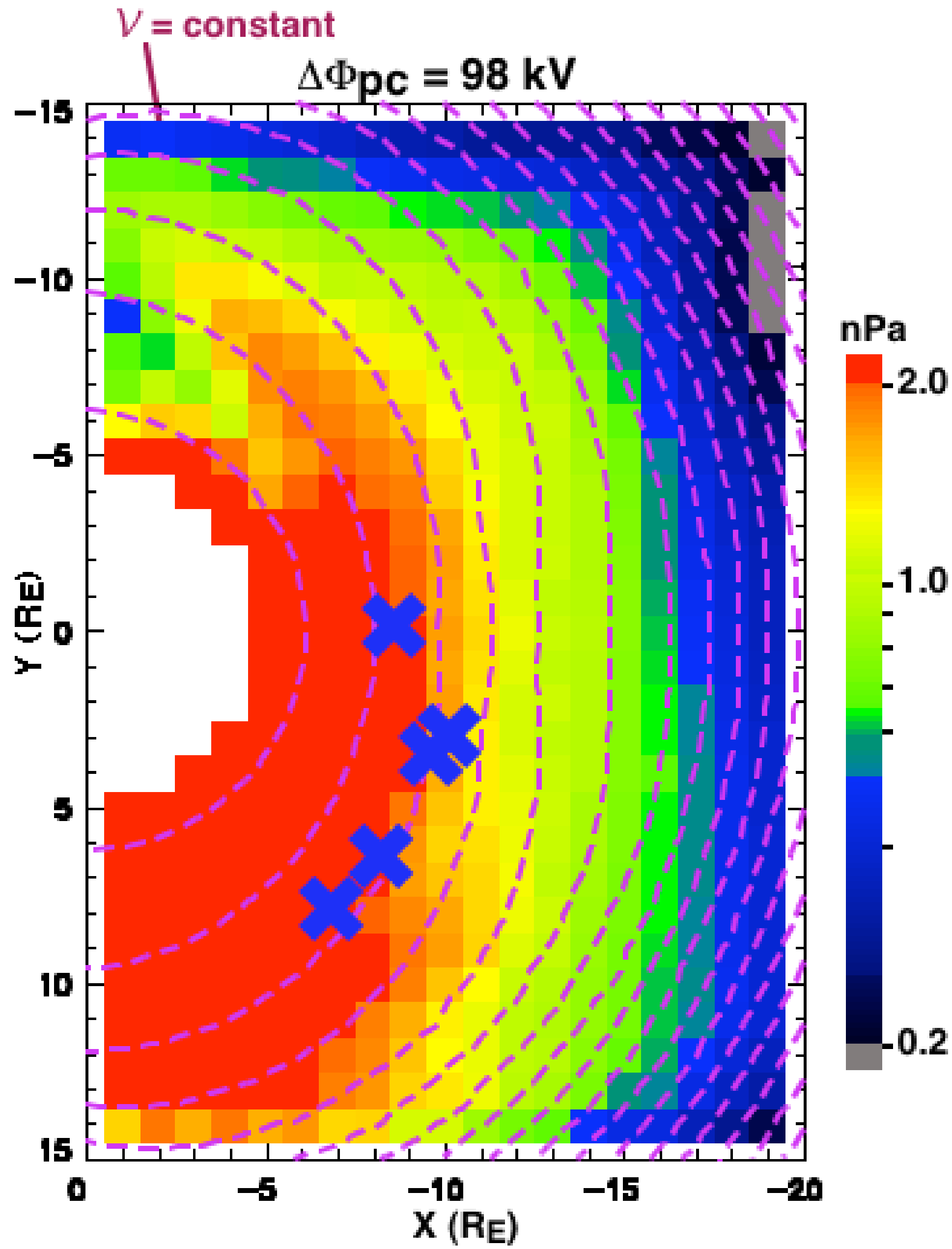
Comparisons with RCM model for growth phase, SMC events

(Model at UCLA, courtesy R. Wolf, R. Spiro)

- Only model with drift physics and electrical coupling to ionosphere, necessary for modeling the Harang
- Predicts quantities obtainable from AMISR, also plasma sheet particle dist, pressures observable by THEMIS



THEMIS azimuthal conjunction on RCM-like model pressures growth phase, SMC conditons [Wang et al.]



Summary

Schedule Poker AMISR

- For good THEMIS azimuthal conjunctions
- With dayside Sonde, Svalbard ISRs

SuperDARN always on

- Estimated useful radar data from both Tiger and Unwin for ~15-20% of onsets
- ~15-20% should apply for THEMIS events at ~07-14 UT.

Can get several (up to ~8 so far) Sonde runs/mo.

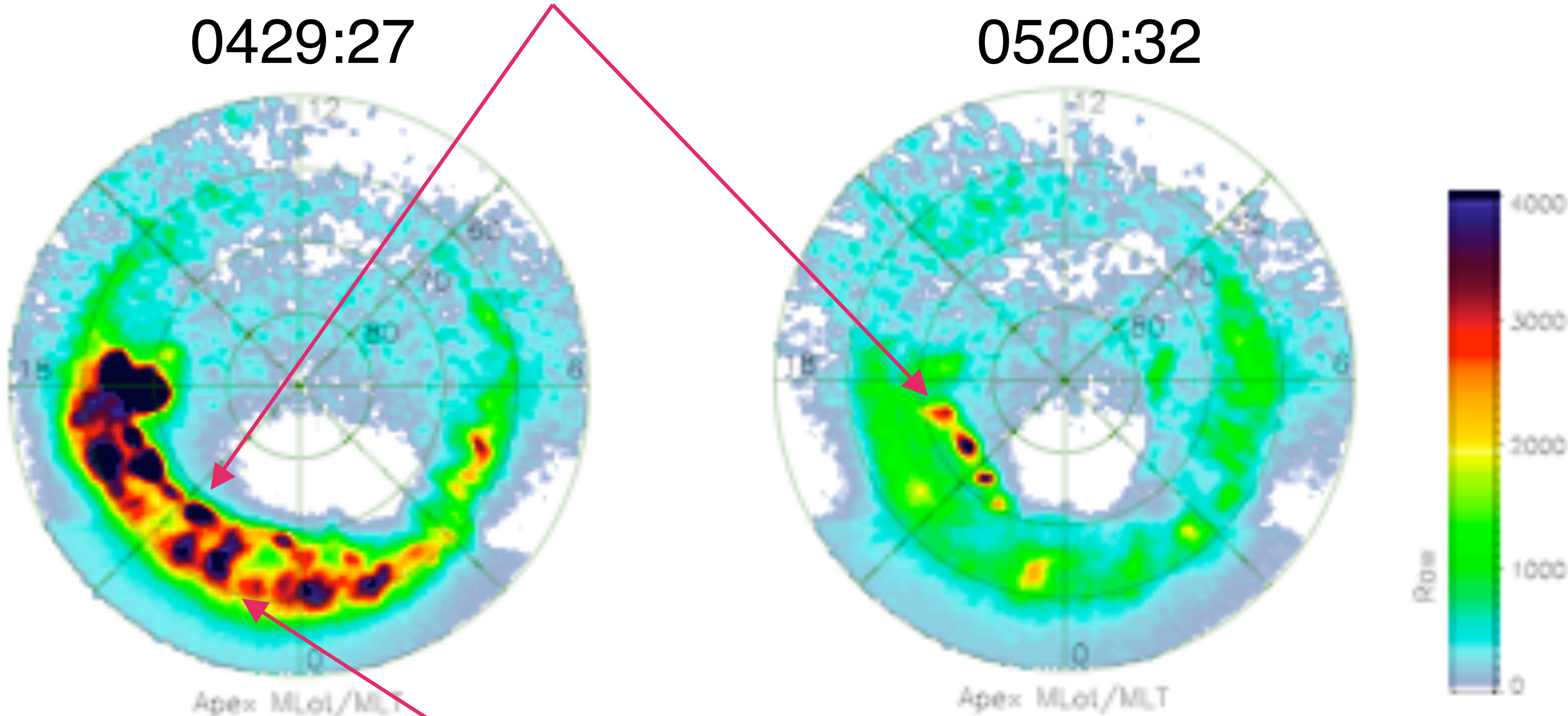
- Can schedule to provide dayside convection monitoring for many THEMIS nightside intervals at 1130-1830 UT.

RCM runs with self-consistent B, realistic deep tail and LLBL sources

- Excellent for comparison with THEMIS, coordinated radar-THEMIS observations.

August 11, 2000

PBIs

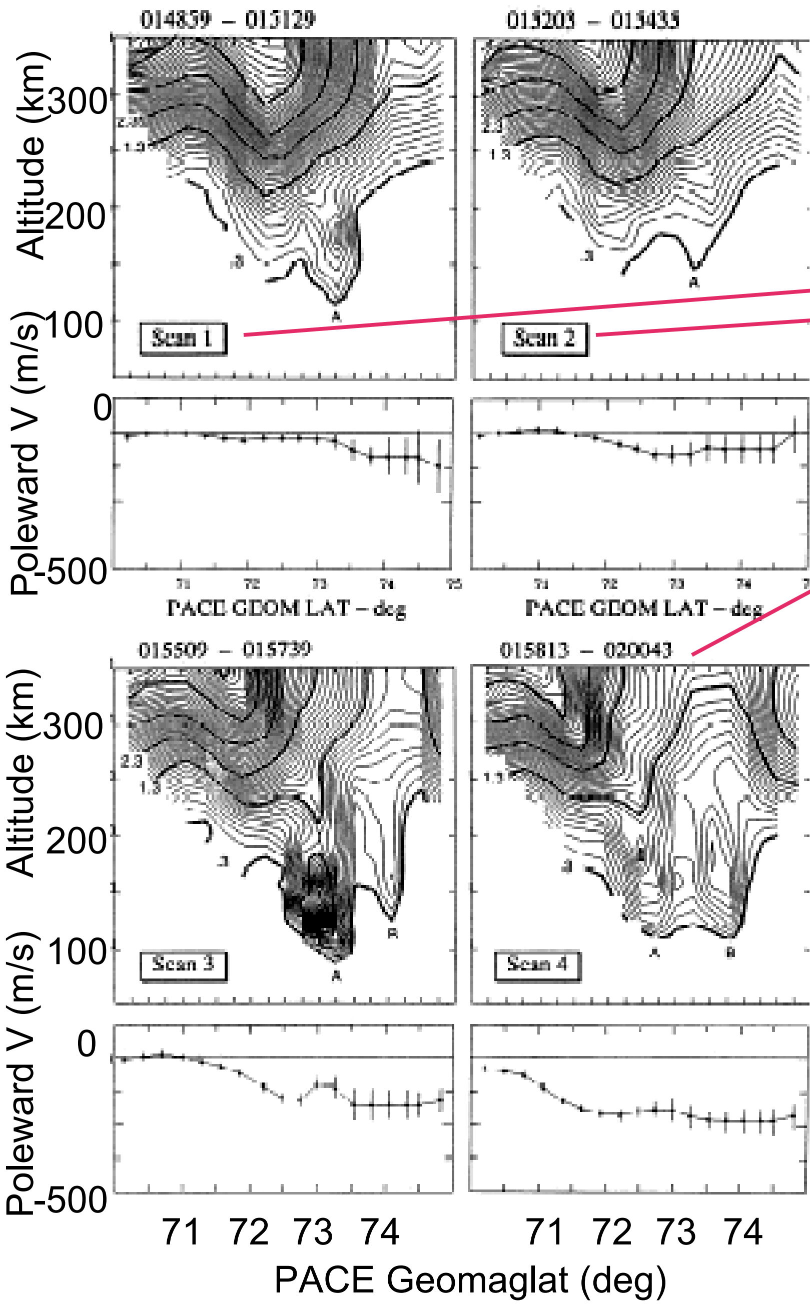


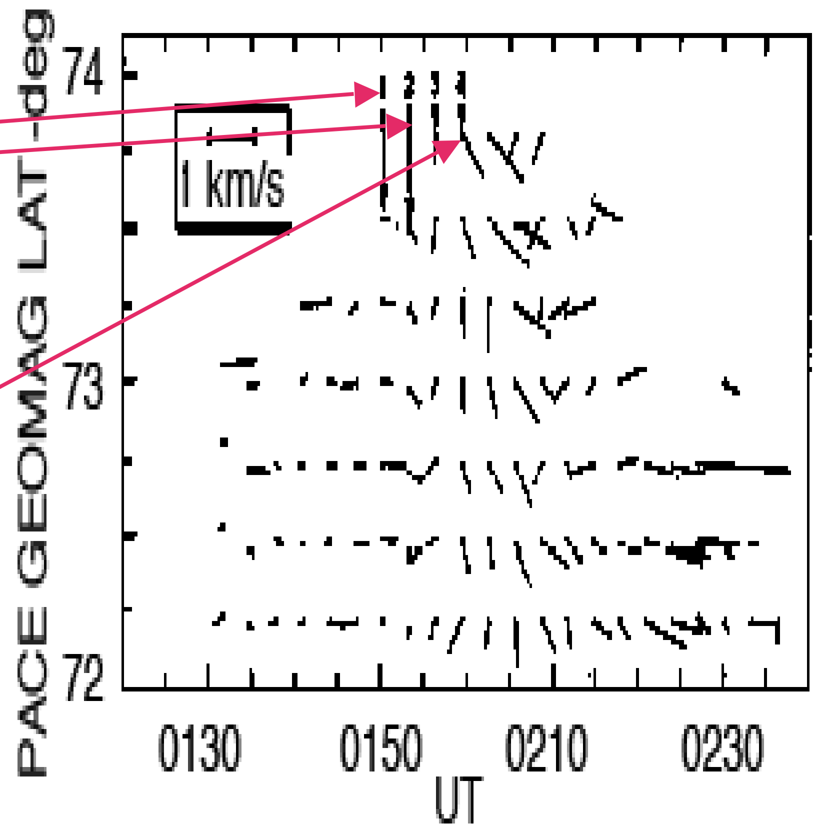
Can become N-S structures (auroral streamers)

PBIs, N-S structures associated with tail flow bursts, which map to auroral ionosphere

Sondrestrom measurement of PBI-flow burst relationship

[de la Beaujardiére et al., 1994]

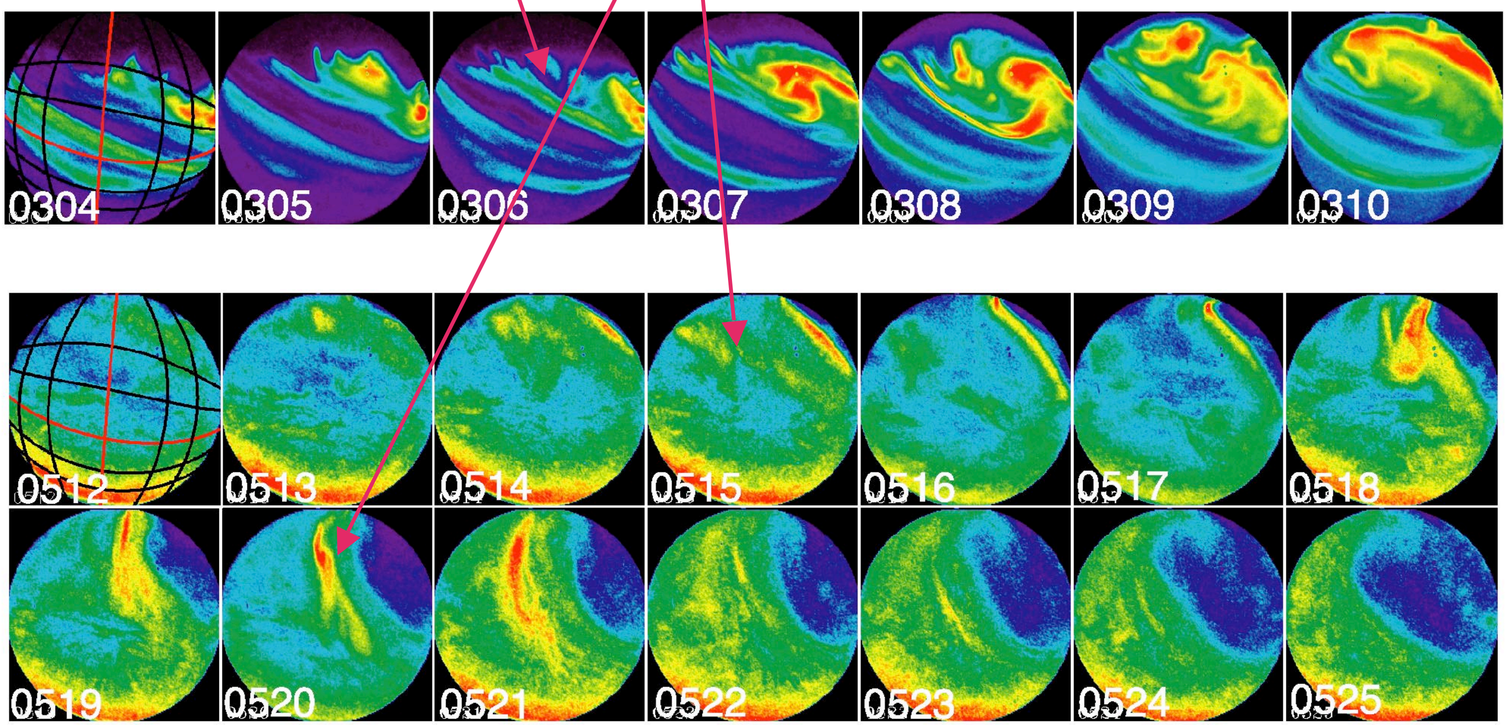




- **Flow bursts every ~10-20 min, propagate westward**
- **PBIs on westward edge of bursts**
- ***Relation to flow-burst for equatorward extending PBIs (i.e., N-S auroras)?***

Gillam all-sky imager at ~Poker latitude

Substorm surge, PBI/N-S aurora, readily distinguishable in ground images



(based on *Zesta et al., 2000*)

AMISR: Distinguish Alfvénic and inverted-V aurora

Tall arcs: Narrow, enhanced n_e ~120 km to >300 km.

Precipitation enhancements over broad energy range, as within Alfvénic acceleration regions.

Reflects dynamic rayed aurora features, each far more narrow and dynamic than resolvable by radar [*Robinson and Vondrak, 1990*].

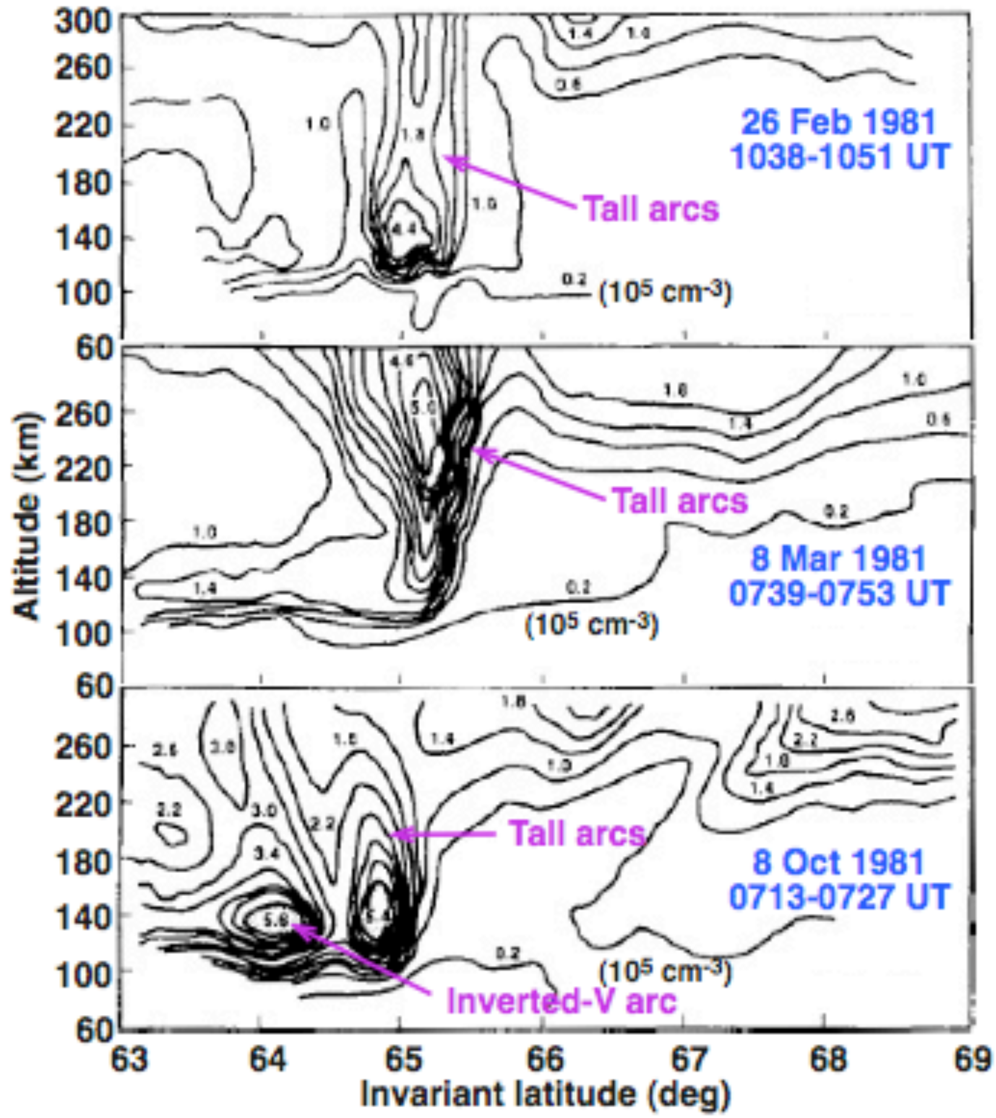
Inverted-V aurora: Enhanced n_e primarily in E-region

Electron energy flux concentrated in relatively narrow energy range, typically >1 keV

Far less dynamic that Alfvénic aurora

Chatanika radar observations of substorm related aurora

[*Robinson and Vondrak*, 1990]



Other Fundamental Questions

Pseudo substorms (breakups): terminate before full expansion

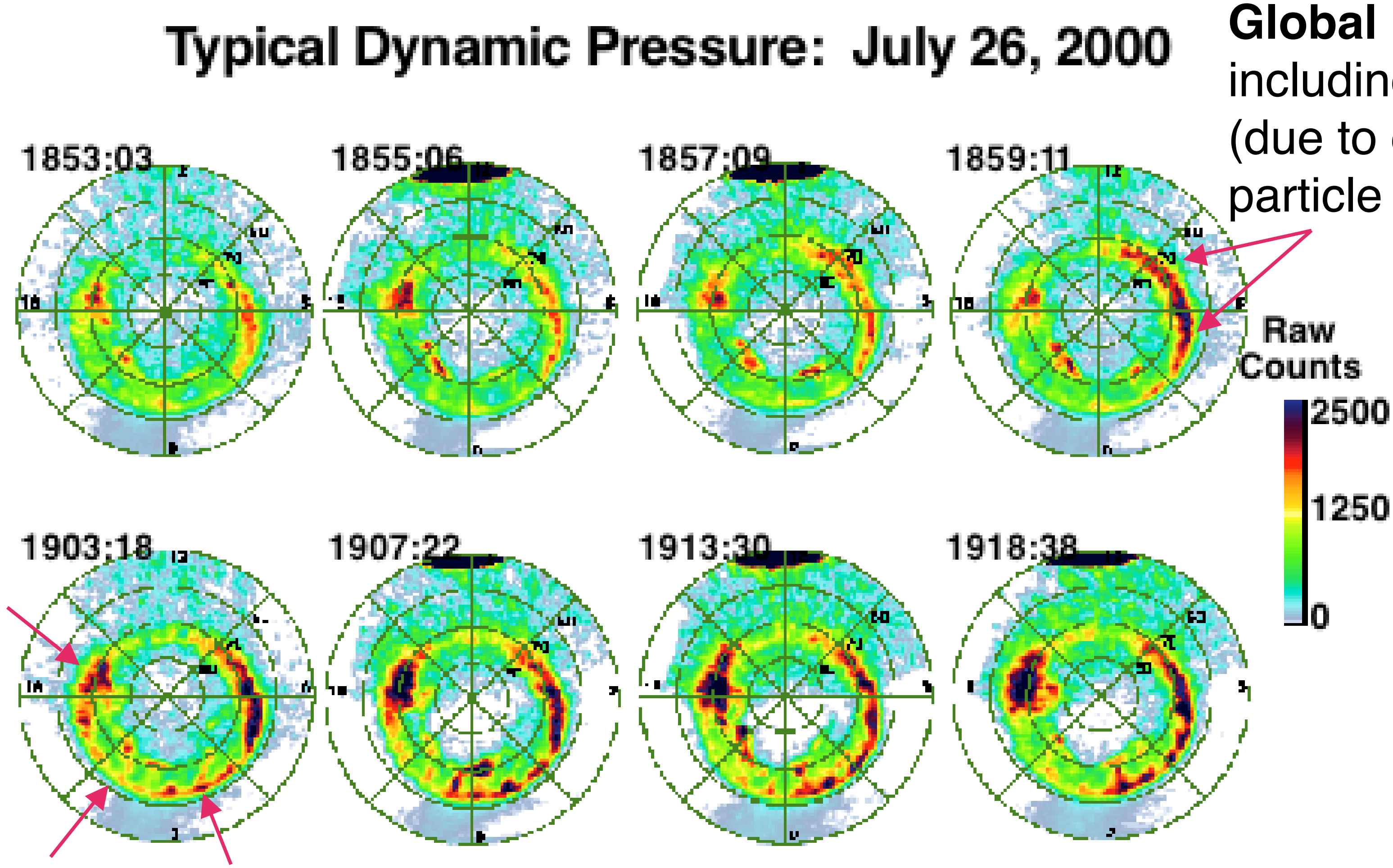
- Start as normal substorm in association with convection reduction?
- Terminates when convection increases within ~10 min of onset?
- Harang reversal start to weaken, then strengthen when expansion terminates?

Steady magnetospheric convection events (SMCs)

- Harang evolution - to an approximately steady configuration?
- Harang reversal associated with auroral arcs such as during growth phase and with equatorward extending PBIs?

Equatorward extending PBIs

- Precise association with flow enhancements?
- Have upward $J_{||}$'s that balance converging height-integrated ionospheric currents?
- As with Alfvénic, as seen by FAST near polar cap boundary)?
- Does occurrence relate to strength of dayside/polar cap convection and of Harang reversal?



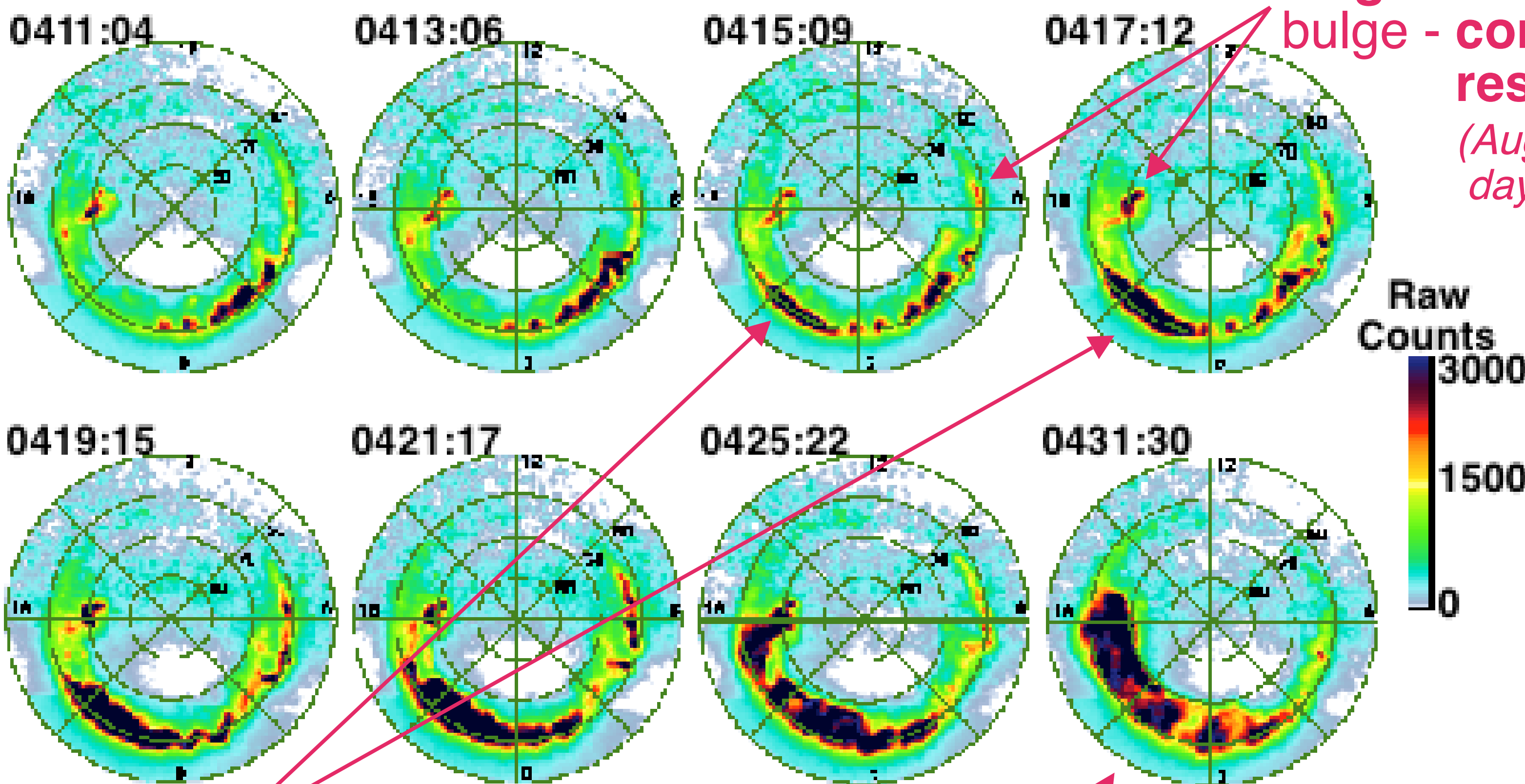
Global brightening, including dayside (due to compressive particle energization)

No Harang region onset or bulge formation

No recovery within 21 min

Not a substorm

Strong South IMF Dynamic Pressure: Aug. 11, 2000



Brightening away from bulge - **compressive response**,

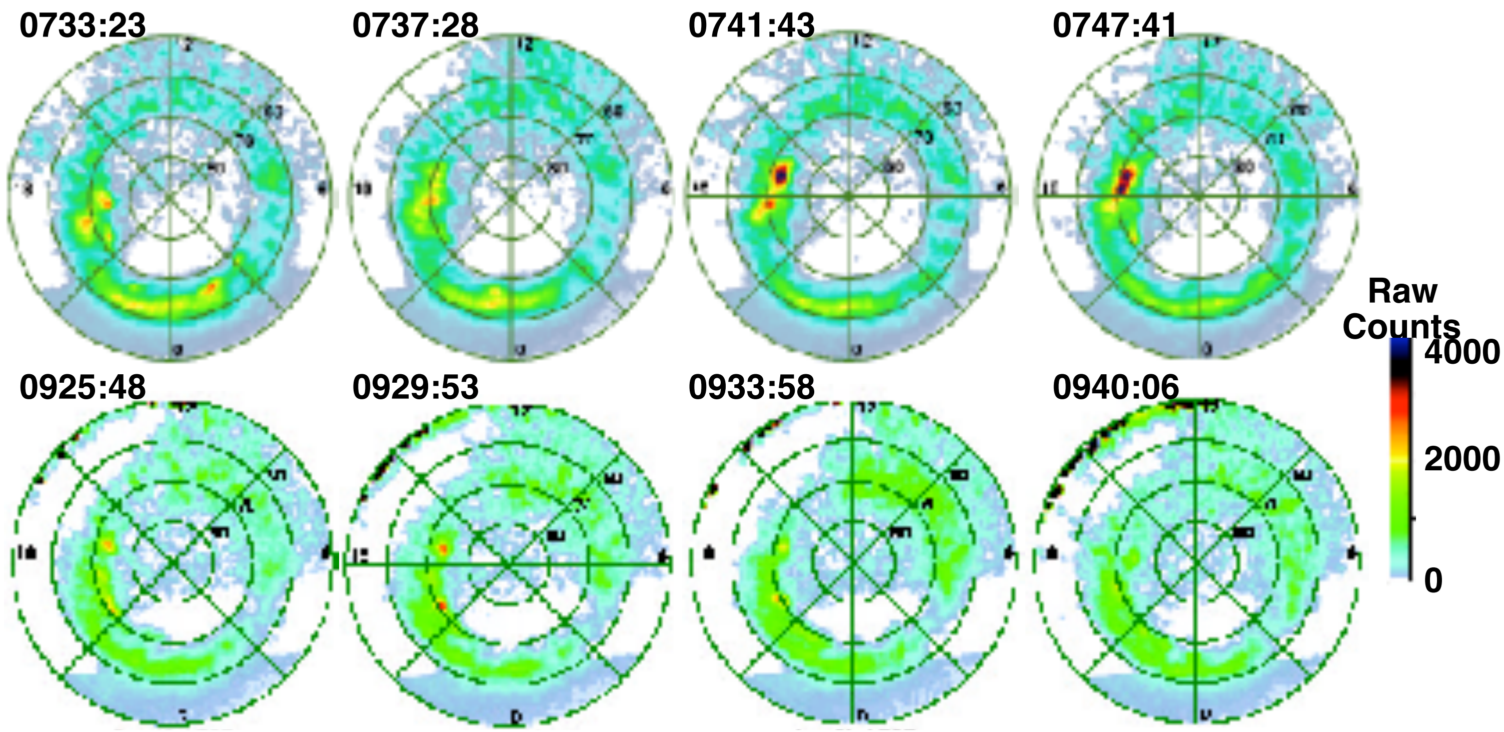
(August, thus poor dayside viewing)

Harang region brightening

Brightening expands to ~10-14 hr MLT (merger of substorms and compressive responses)

Null events: Aug 11, 2000

1. *B_z northward turning with P_{dyn} decrease*
2. *P_{dyn} increase with B_z further southward turning*



No Harang region brightening

Will use coordinated measurements to evaluate Harang-convection for P_{dyn} dist, P_{dyn} substorms, and null events