Possible Connection of Polar Cap Flows to Pre-Substorm Onset PBIs and Streamers and to Post-Onset Auroral Activity

Larry Lyons (given by Toshi Nishimura, UCLA)

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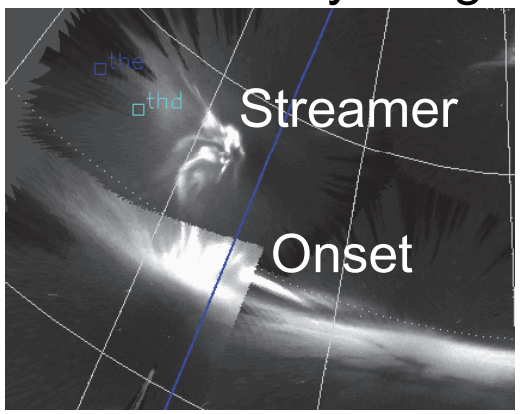
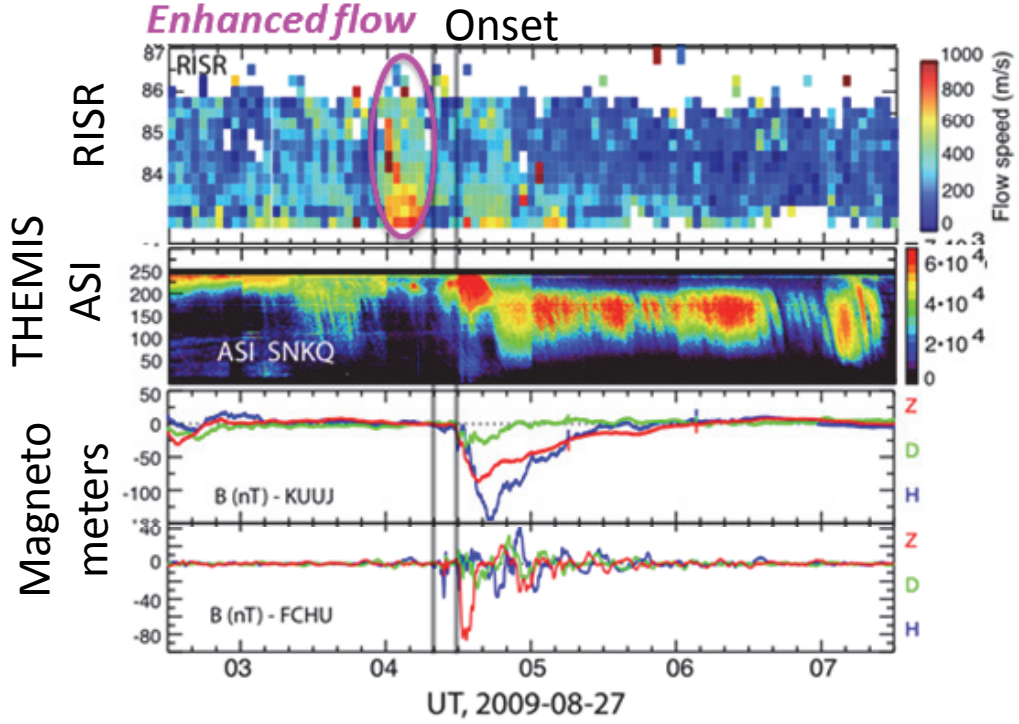
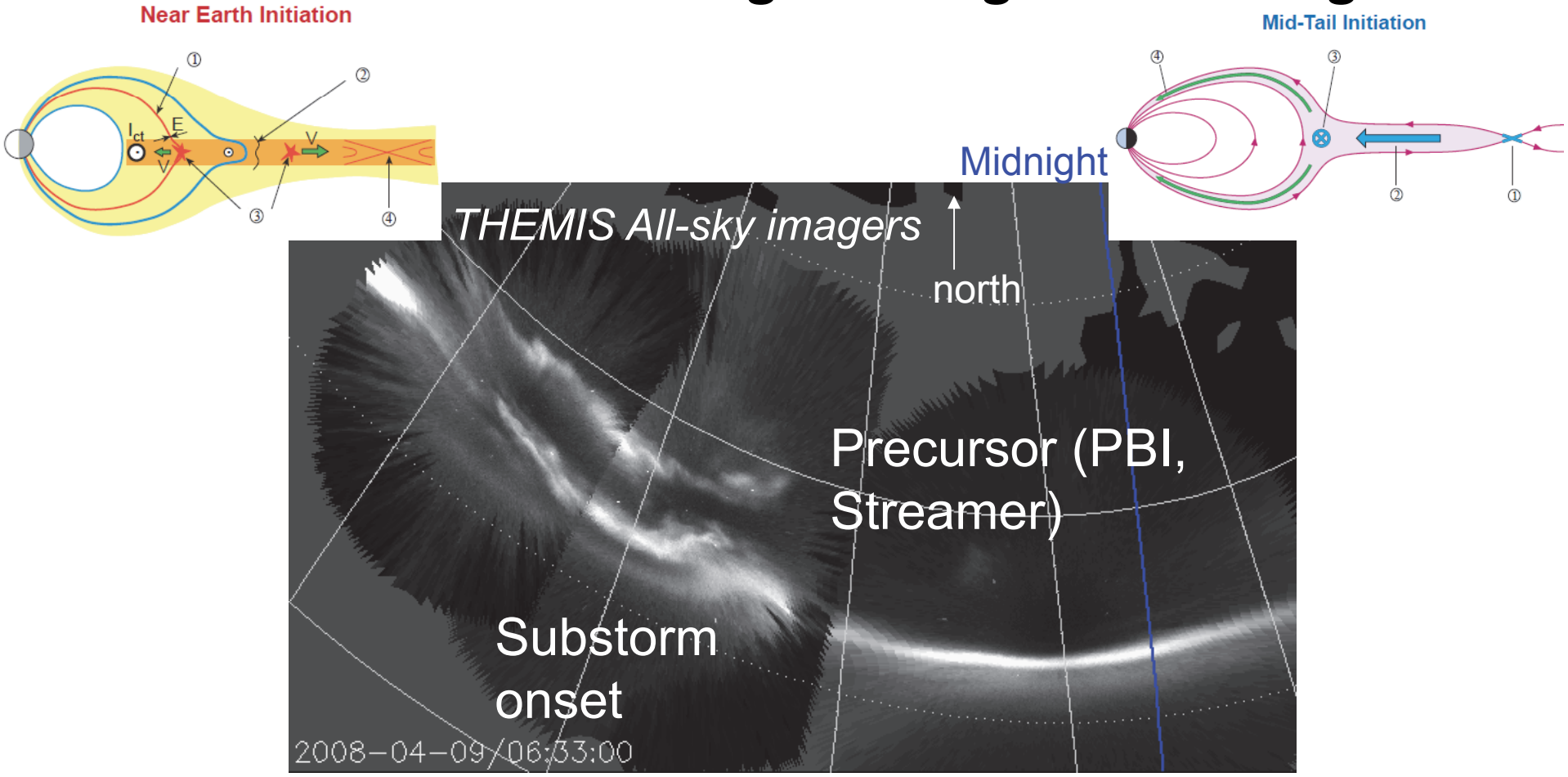
THEMIS All-sky imagers





Possible resolution of the long-standing substorm argument

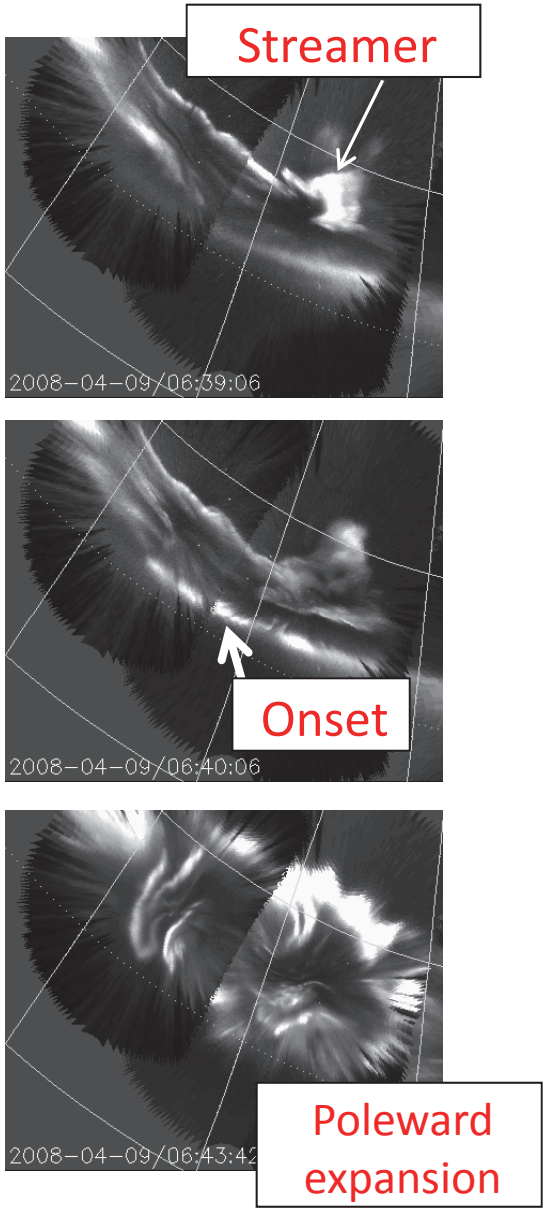


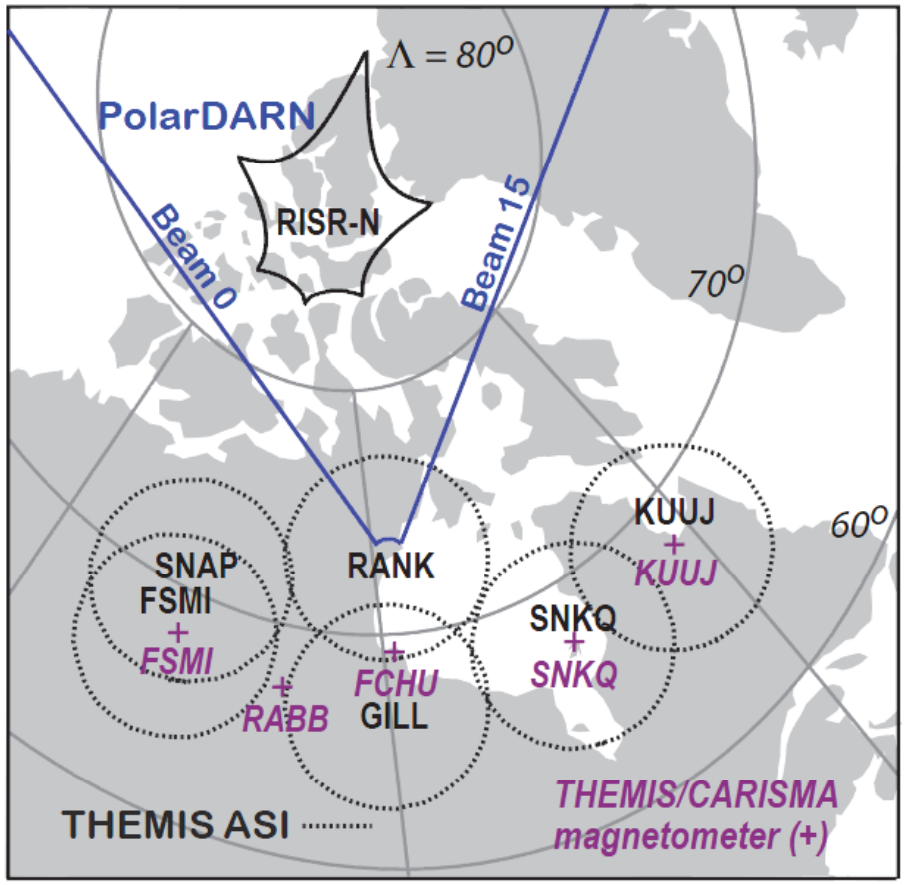
[Nishimura et al., 2010a]

PBI (reconnection)
→ Streamer (earthward flow)
→ Onset (near-Earth *instability*)

Supporting the pre-onset sequence by Angelopoulos et al. [2008], Kepko et al. [2009]

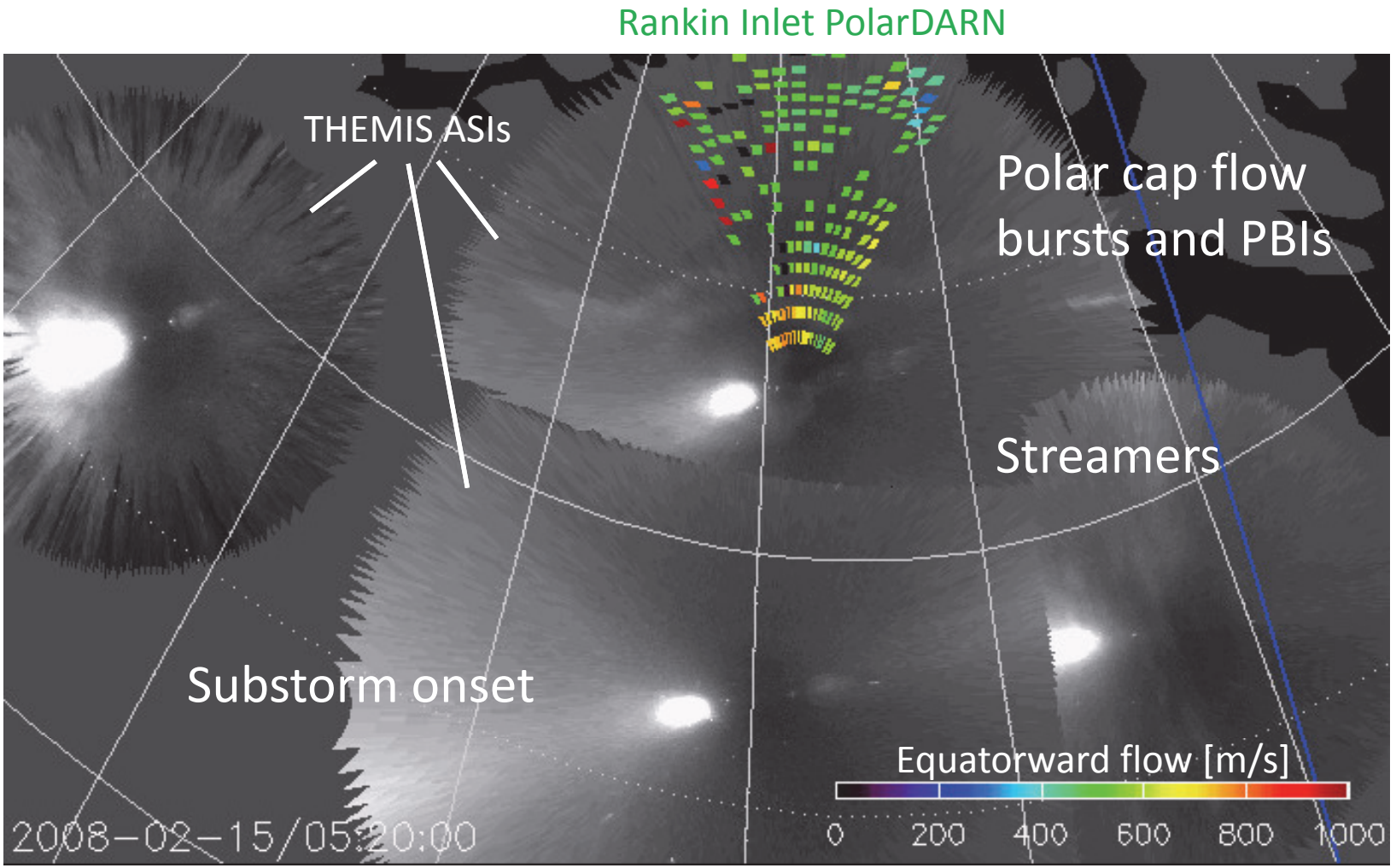
Unsolved issue: What does initiate the PBI/streamer?
→ What is a trigger of reconnection?



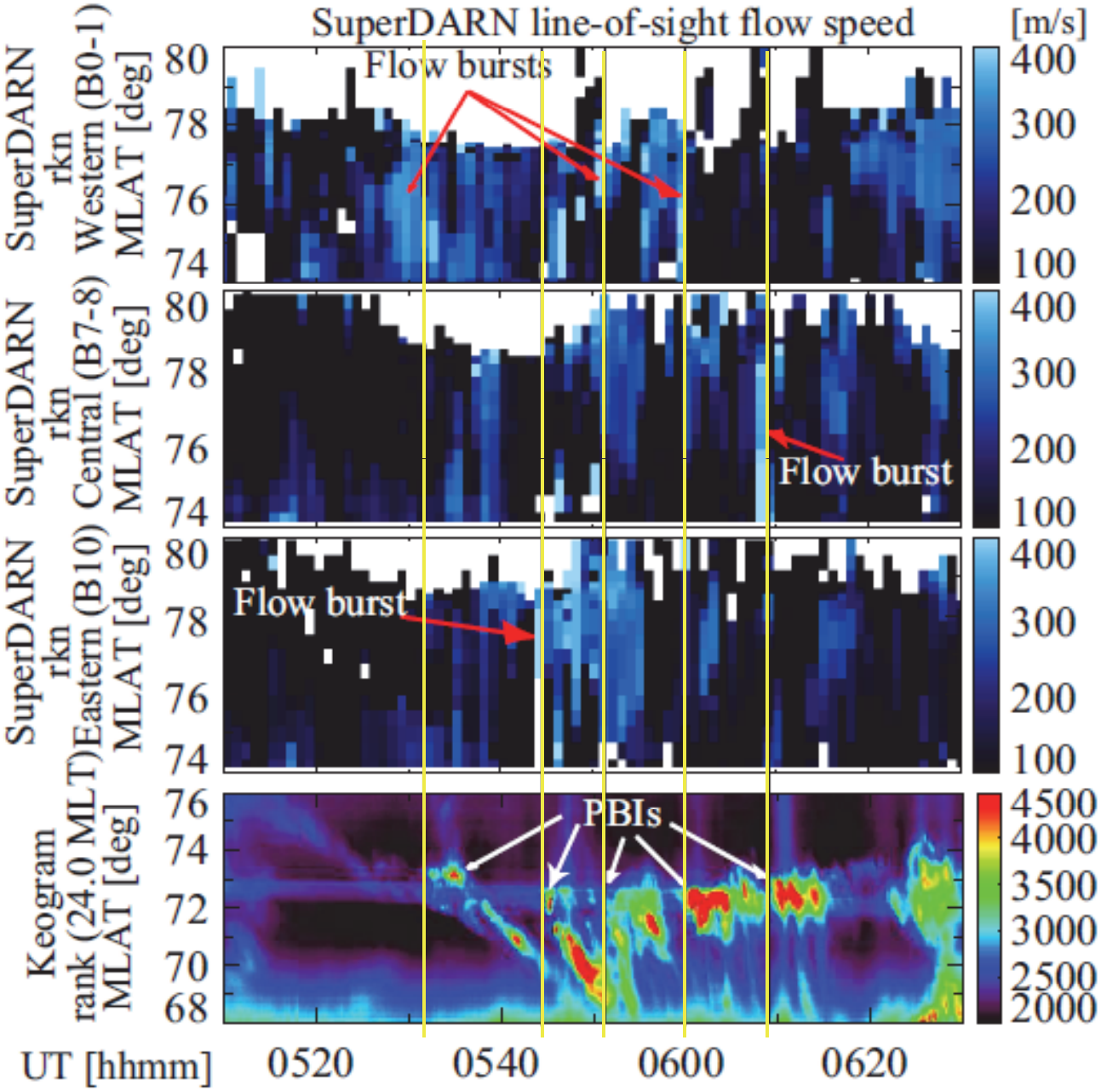


Our study investigates polar-cap flow observations to determine if convection on open field lines show a PBI precursor.

THEMIS ASI-SuperDARN observation



- Highly structured and variable polar cap convection
- Polar cap flow bursts preceding PBIs
- Connection from the polar cap to the substorm onset area

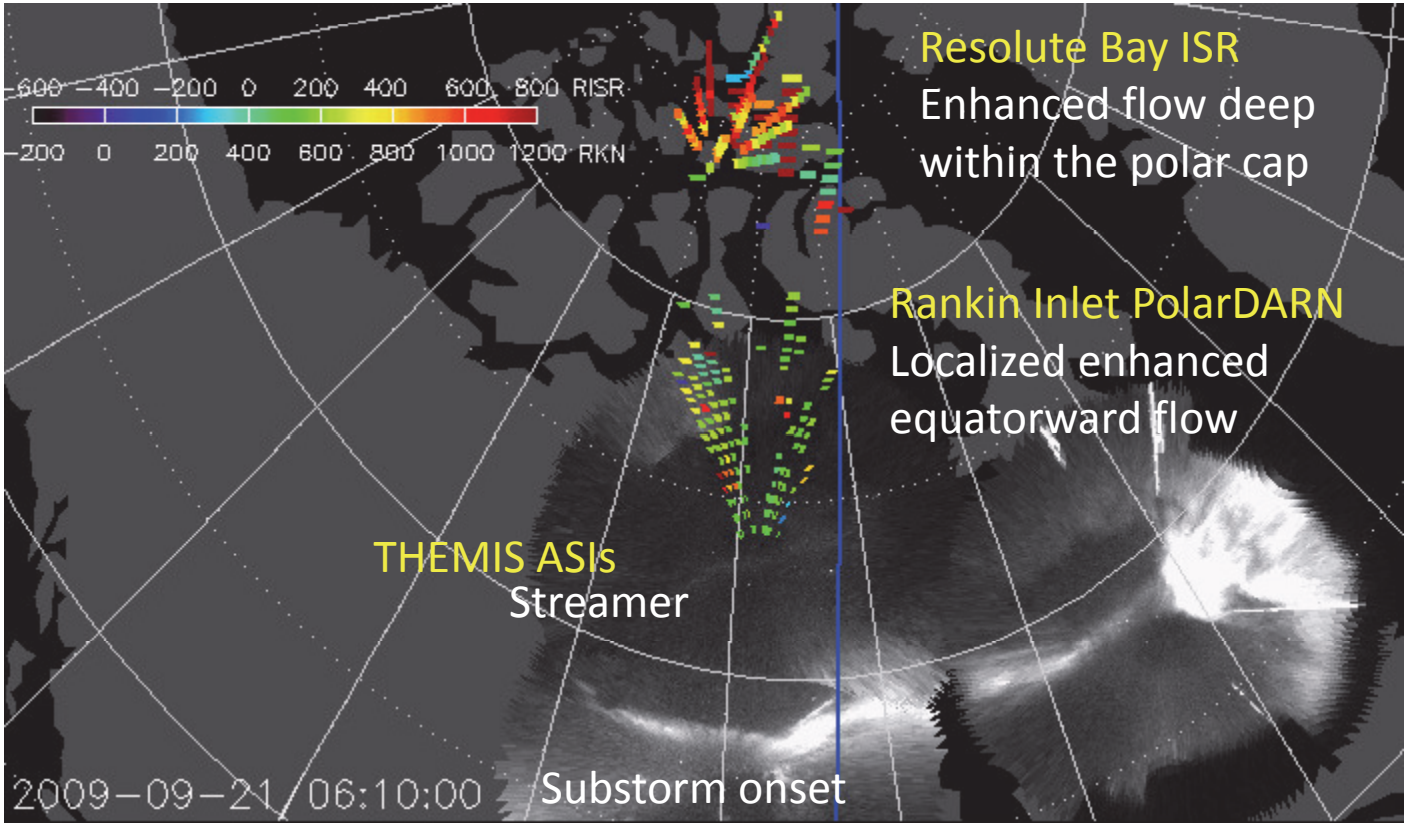


[Nishimura et al., 2010b]

Rankin Inlet ASI keogram and PolarDARN equatorward l-o-s flows : 3 beams

- *Narrow equatorward flow burst just before each PBI*
- *Flows from well within polar cap, head towards polar cap boundary*

2009 Sept 21, 0626:30 UT onset

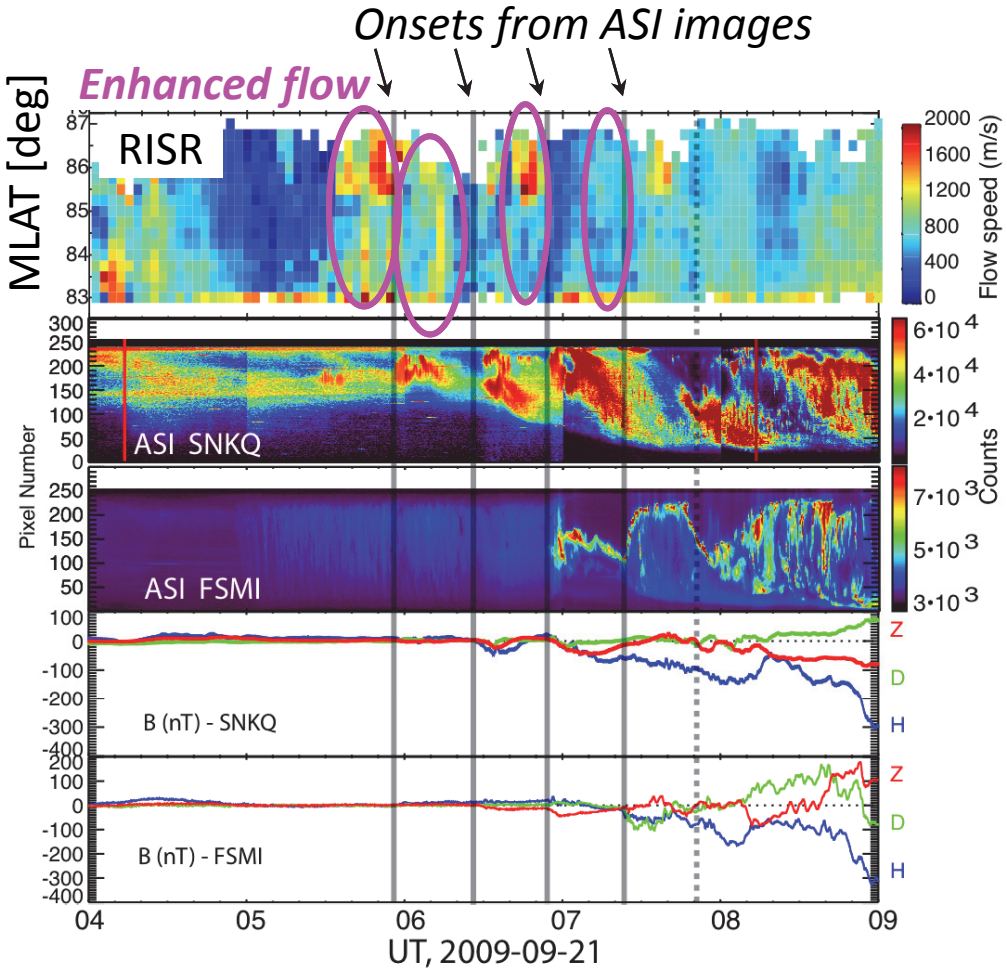


Pre-onset sequence extending from the polar cap

1. Enhanced, localized flow in the polar cap/lobe
2. PBI/reconnection
3. Streamer/BBF
4. Auroral breakup/onset instability

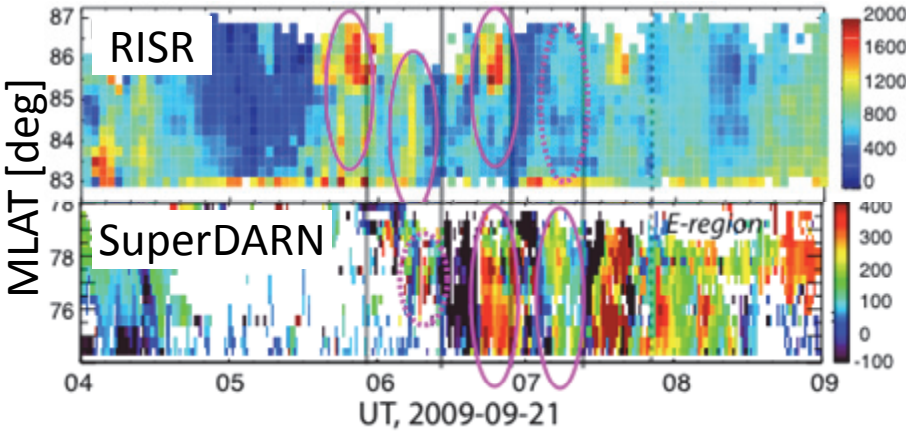
[Lyons et al., submitted to JGR, 2011]

Longer time span



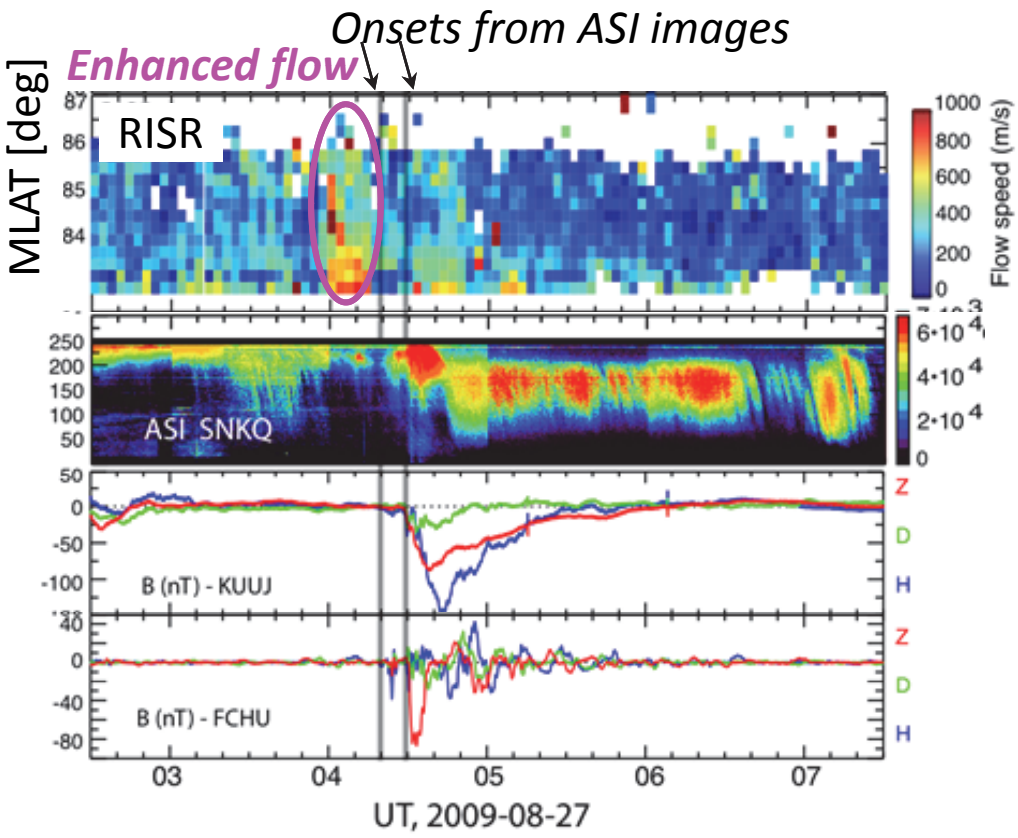
4 polar cap flow enhancements preceding 4 substorms by ~10 min

RISR-SuperDARN combined

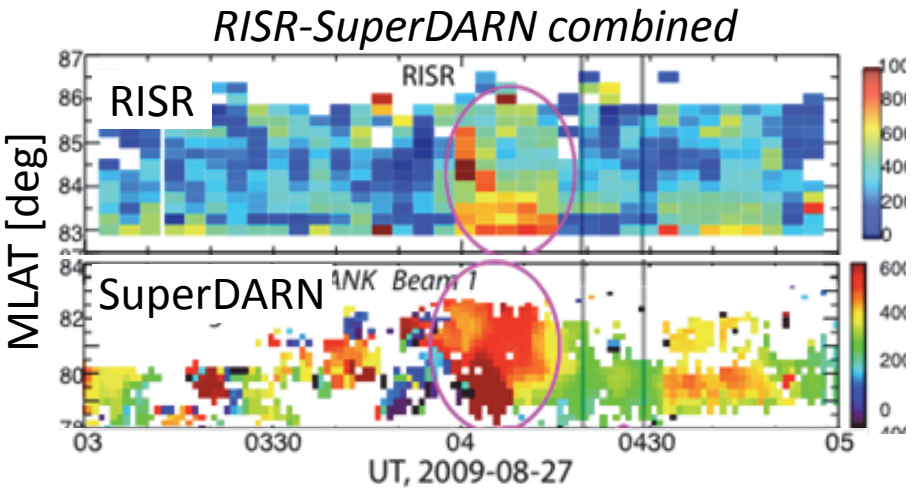


The localized flow channel extends from the magnetic pole to the nightside open-closed boundary.

Another event



Enhanced polar cap flow prior to onset

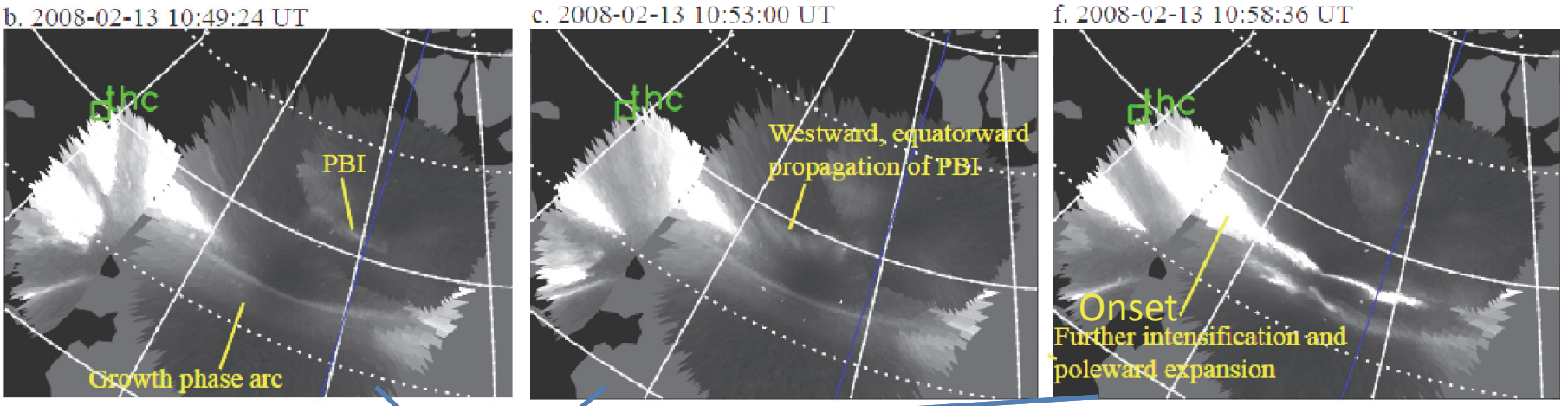


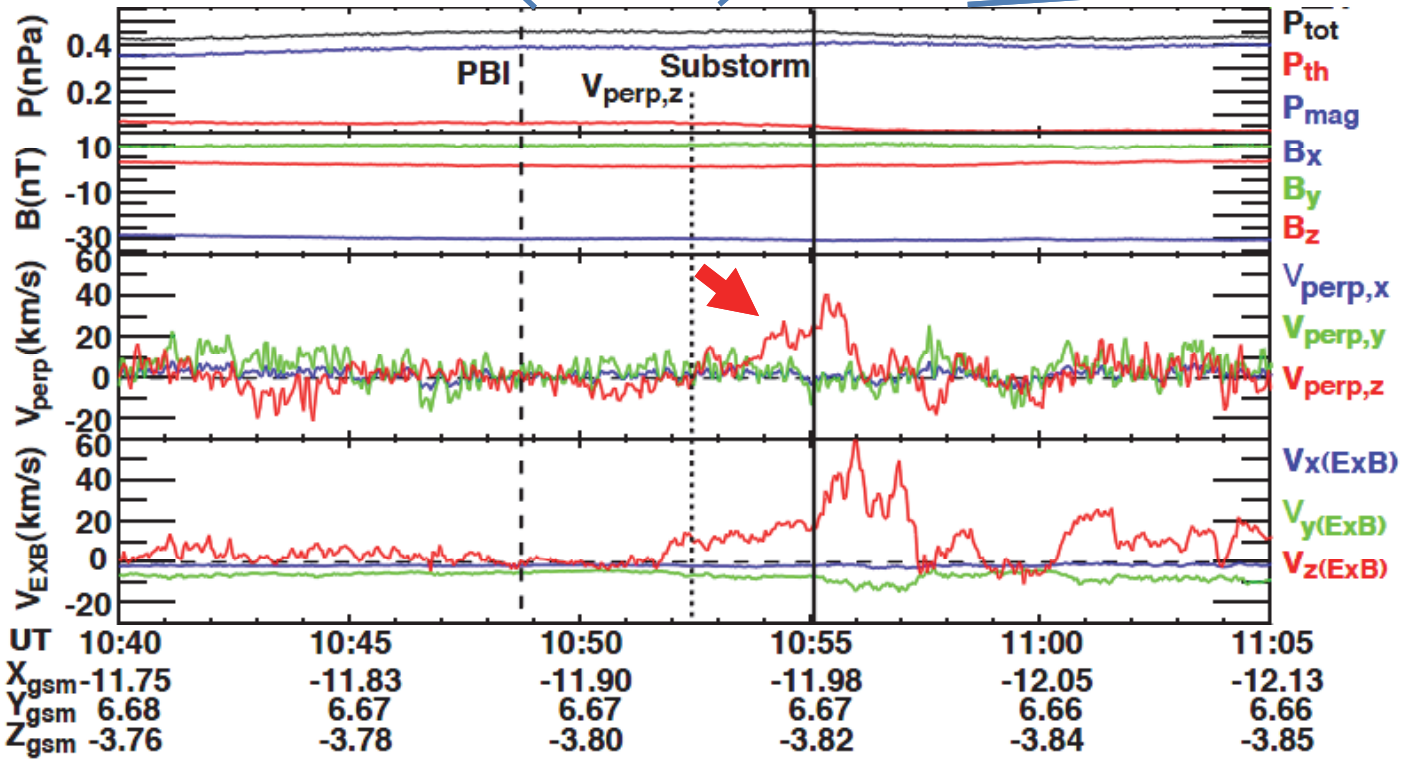
The localized flow channel extends from the magnetic pole to the nightside open-closed boundary.

- An enhanced flow in the polar cap triggers a PBI, ensuring streamer, and substorm onset.
- It suggests that reconnection is triggered by enhanced lobe flow.

Supporting THEMIS spacecraft observation

(Different event)





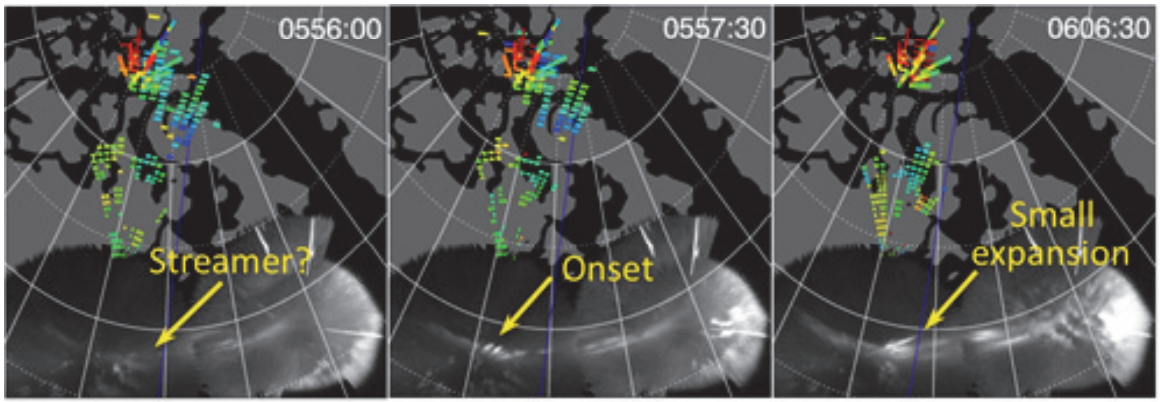
- Enhanced plasma flow crossing the O-C boundary, 3 min before onset
- Consistent with the radar observations of the polar cap flow

[Lyons et al., 2010]

Post onset activity and polar cap flow

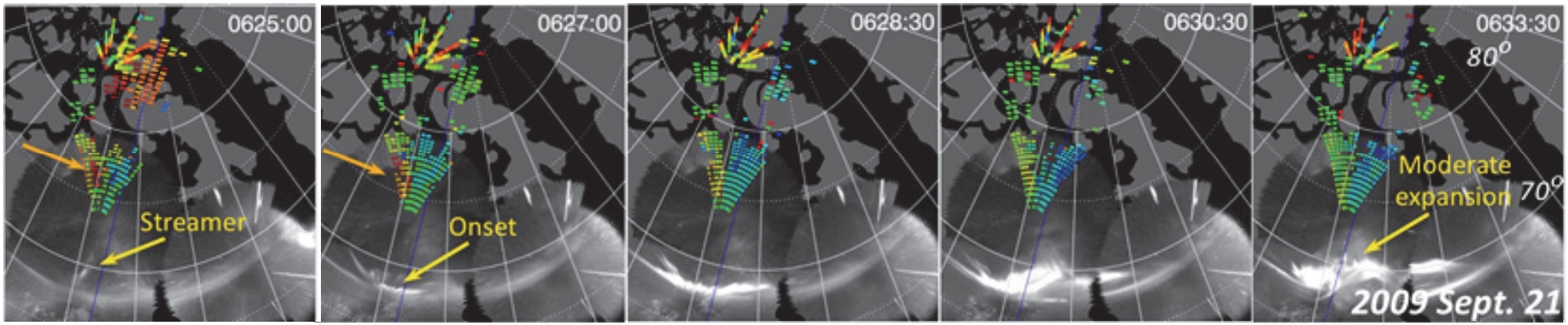
- Small expansion events

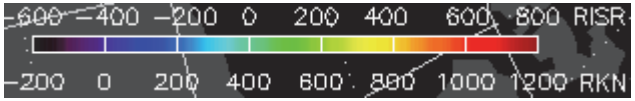
Event 1



- ***Small, short duration expansion***
- ***Weaker post-onset flows in the polar cap***

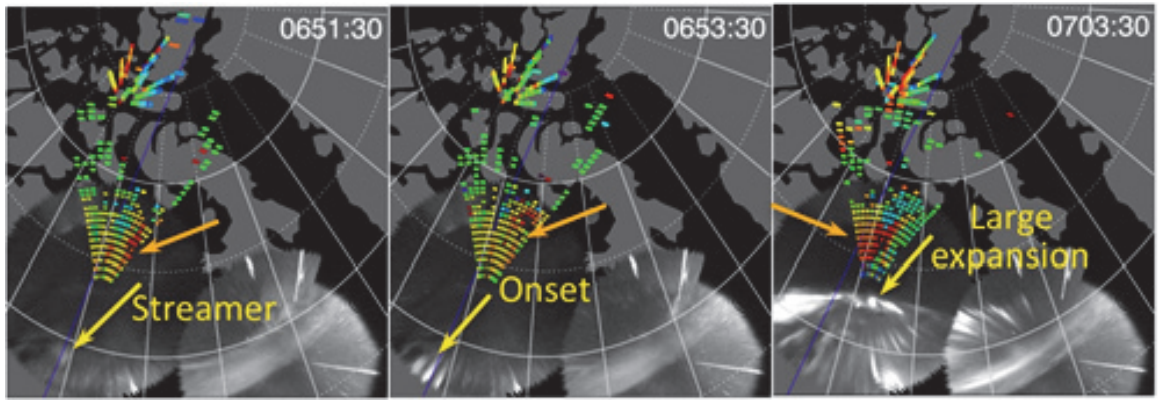
Event 2

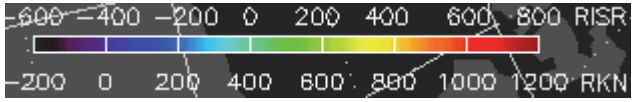




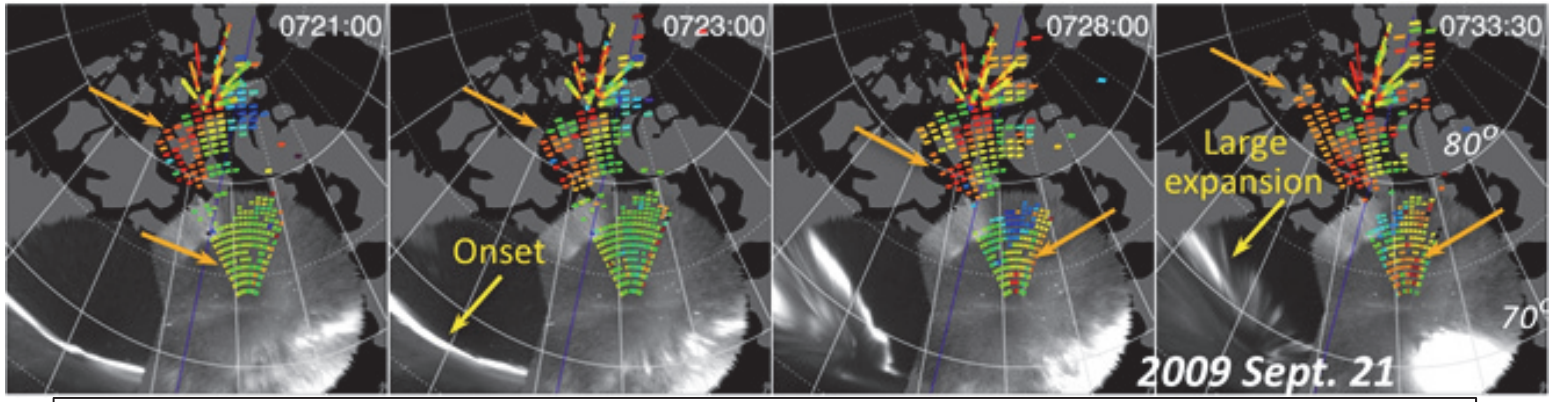
- Large expansion events

Event 3





Event 4



- ***Large, long duration expansion***
- ***Stronger post-onset flows in the polar cap***

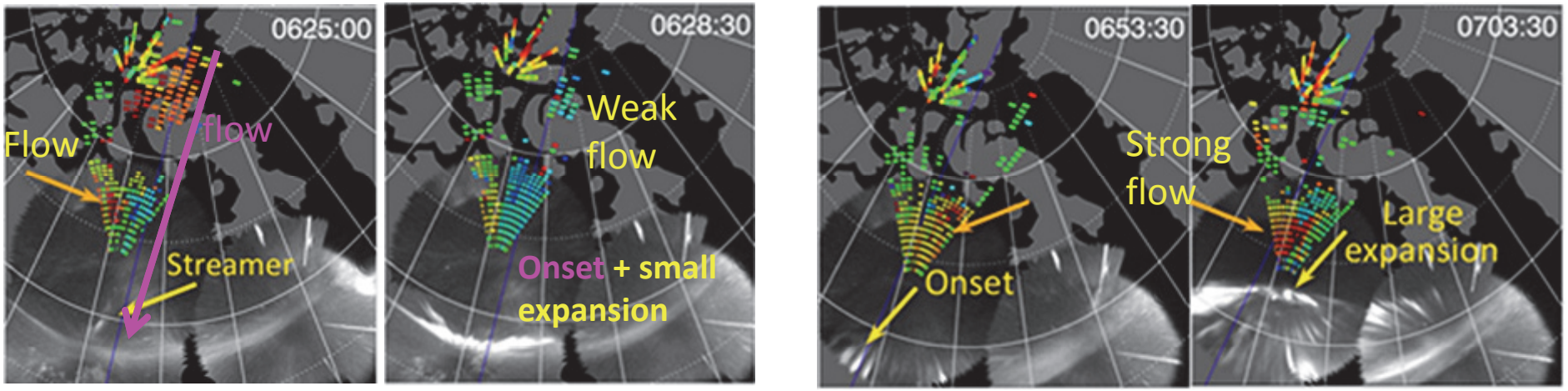
Although the causality should be examined further carefully…

The polar cap flow intensity is suggested to control the substorm expansion phase activity.

Summary

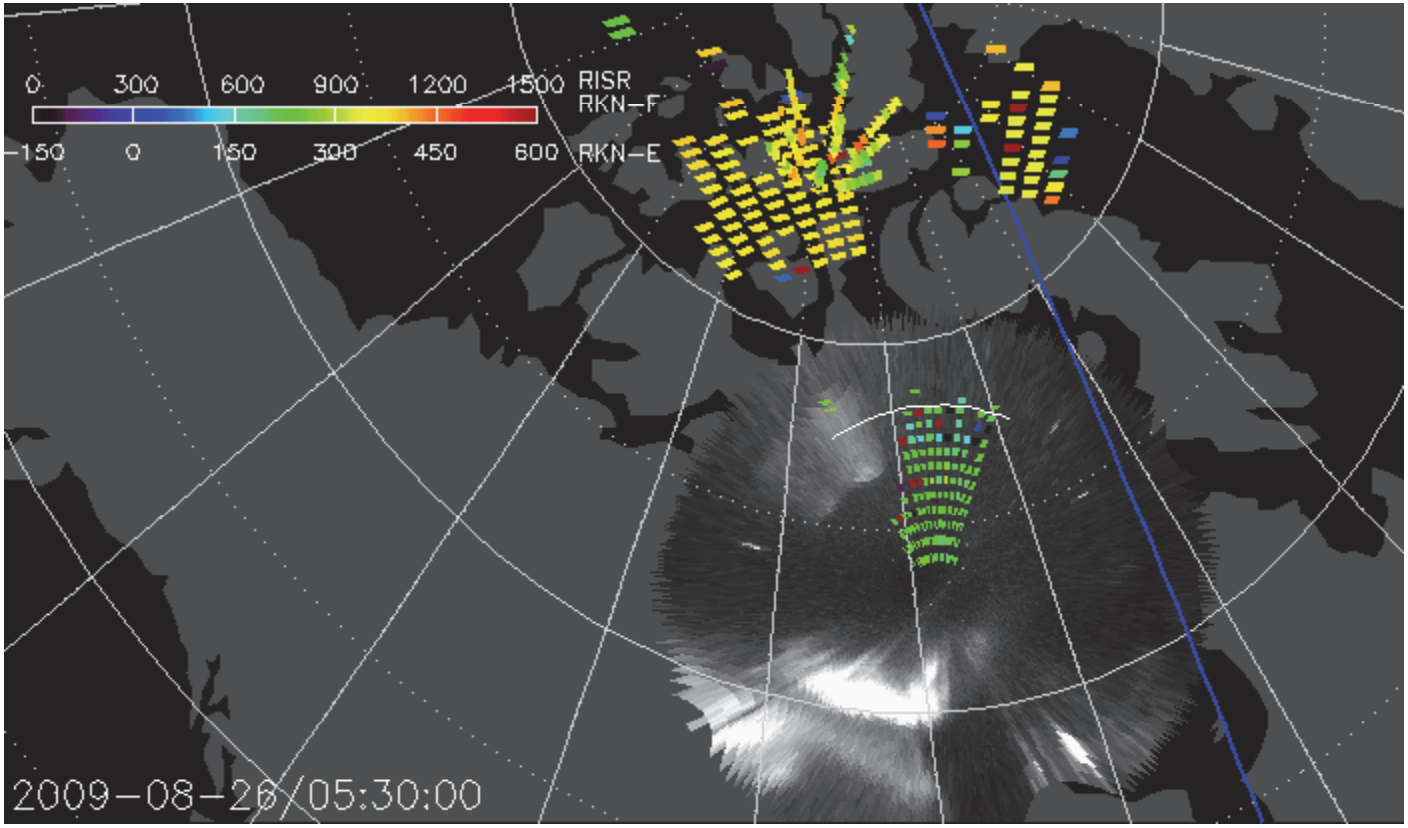
1. Evidence that polar cap V structure:
   - **Leads to longitudinally localized flow channels** toward the polar cap boundary

2. Evidence that flow channels from polar cap
   - **Lead to PBIs, streamers,** including those leading to substorm onset
   - **Persistence** after onset enhances post-onset **auroral poleward expansion and activity**

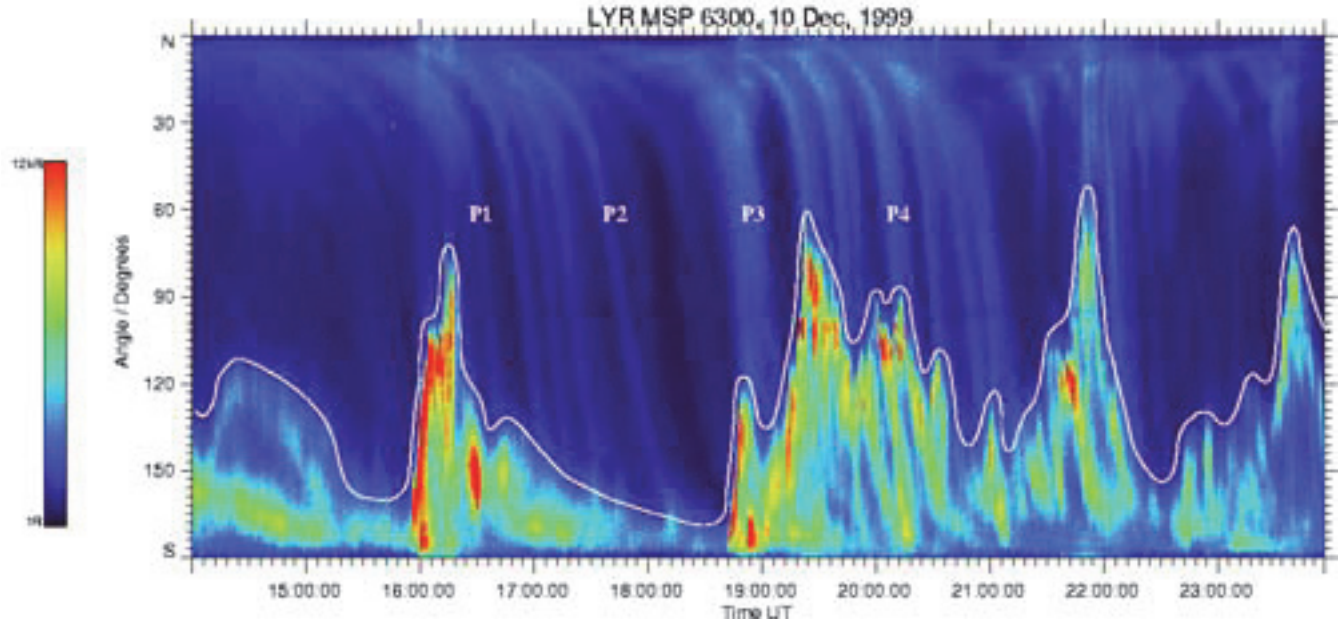


These ideas should be further tested with lobe flow observations with THEMIS. Comparisons with reconnection simulations are also desired.

2009 Aug 26 onsets



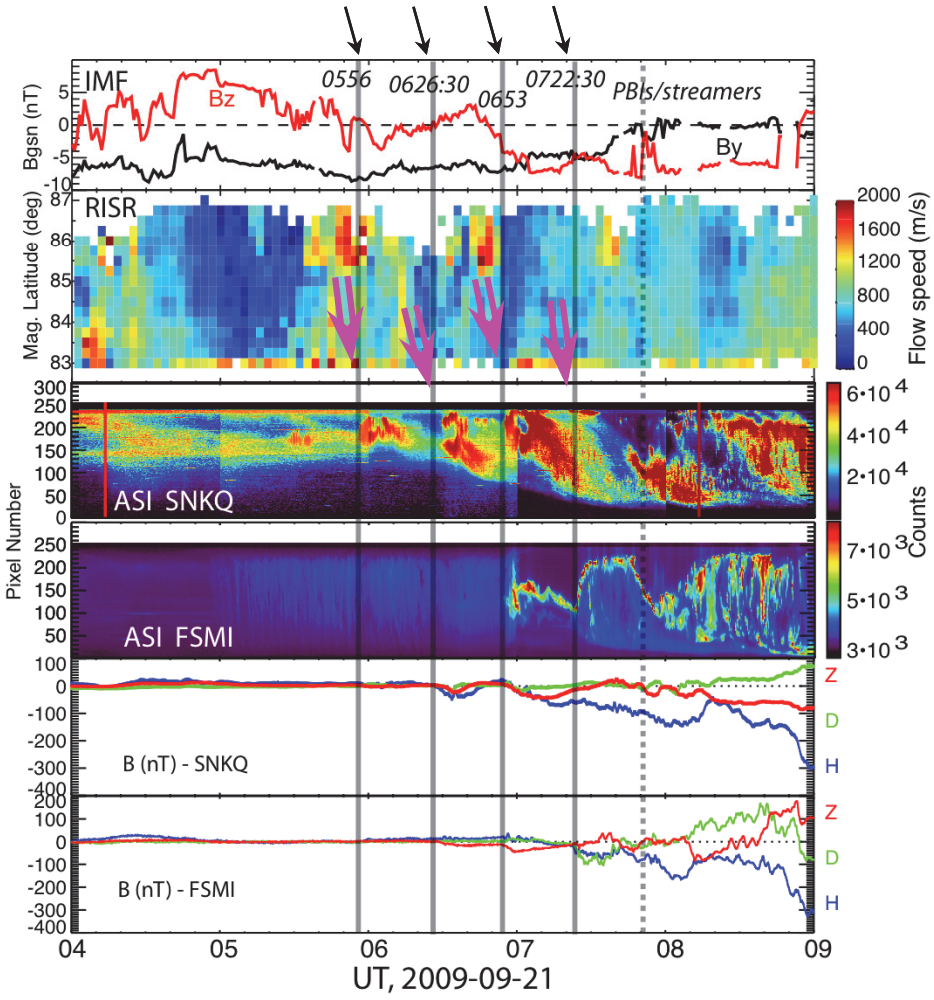
D. A. Lorentzen, N. Shumilov, and J. Moen, GRL [2004]



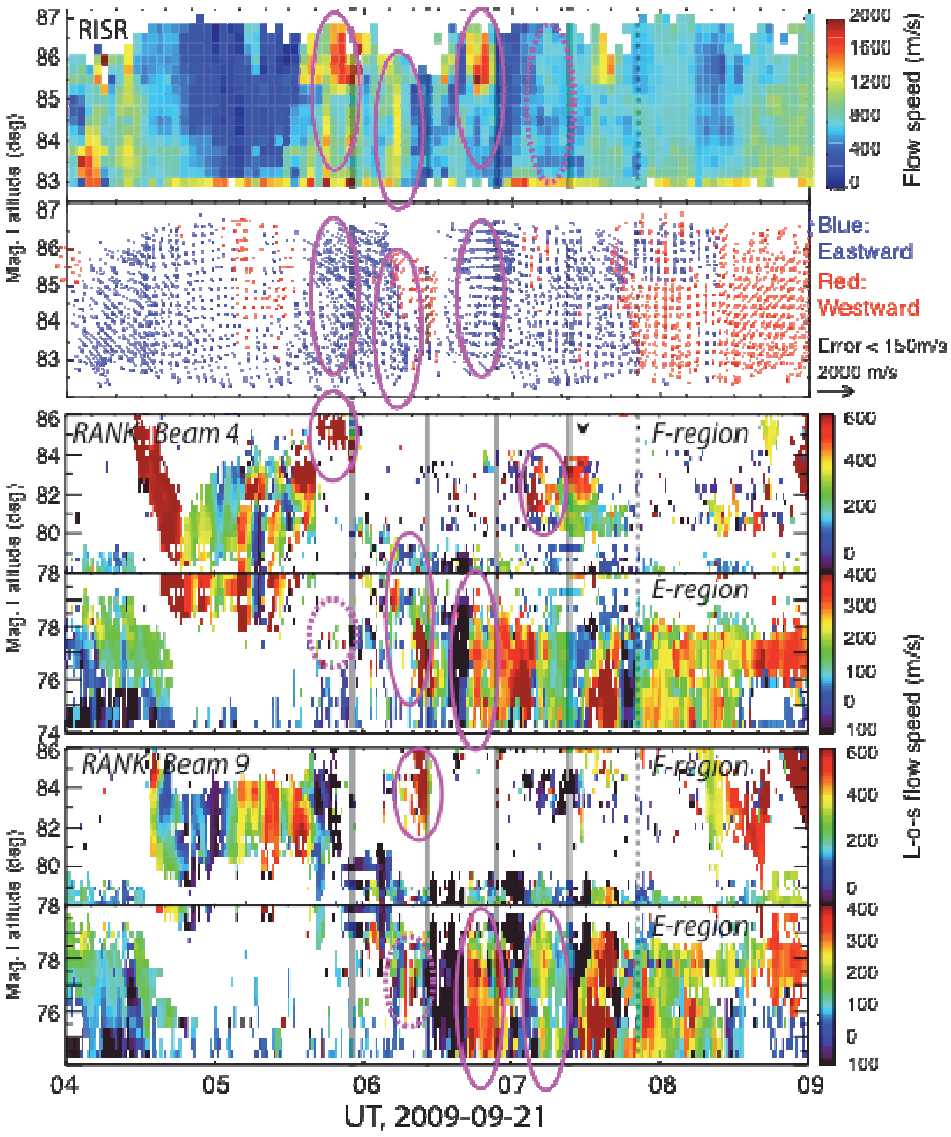
Study results:

1. **Drifting airglow patches** can sometimes be **measured by the MSP** in the evening/nightside MLT region (IMF BZ negative and IMF BX and BY positive conditions.
2. Meridional drift speeds from 350 to 1000 m/s observed.
3. Using triangulation, **altitude of the patches ~ 315 km** (F-region).
4. **All patches drift into the open/closed field line boundary**, with a subsequent brightening of the **6300 A ° boundary** (PBI).
5. This is taken as a unique signature of tail reconnection bursts, occurring even in the growth phase of an auroral substorm

Onsets from 2-D ASI images



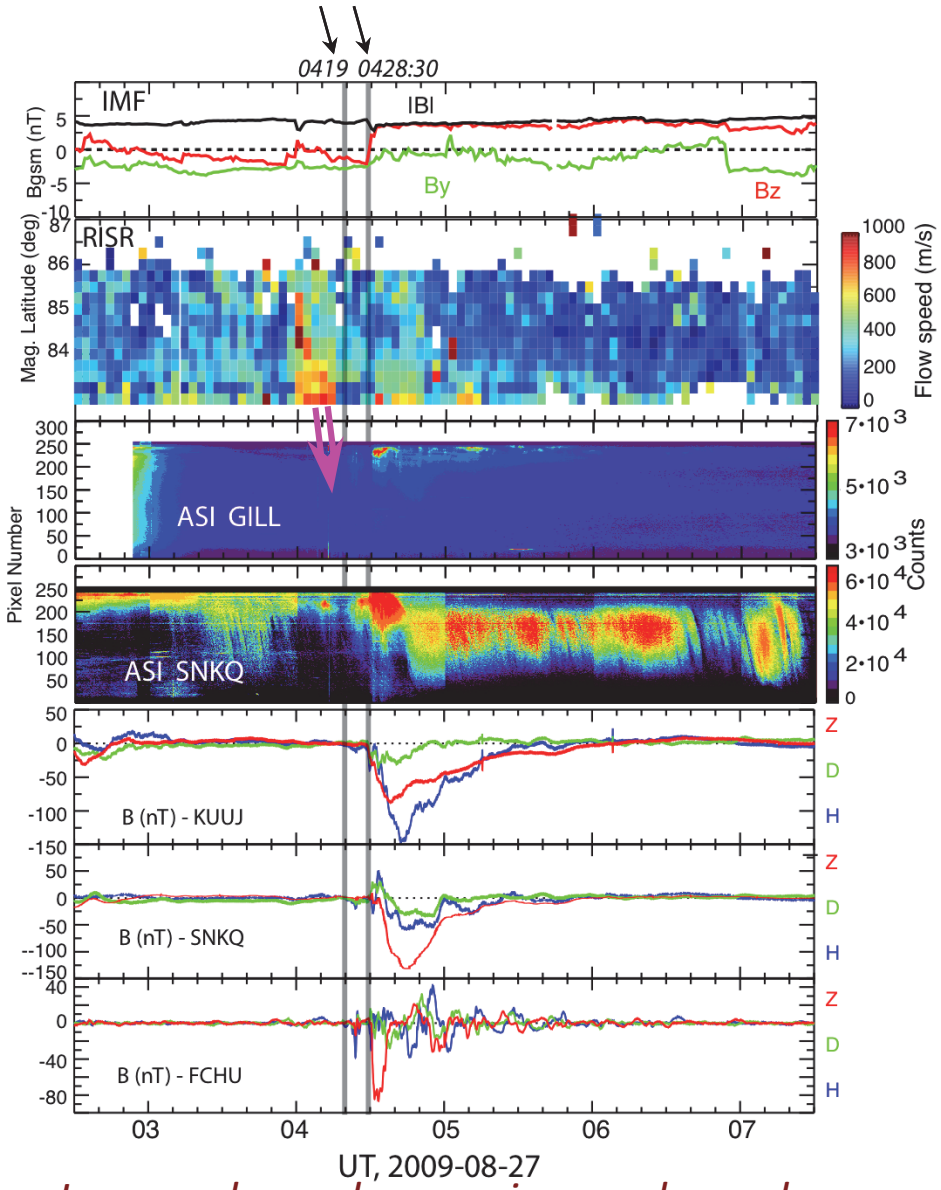
RISR obs. suggest some flows may come from near center of polar cap



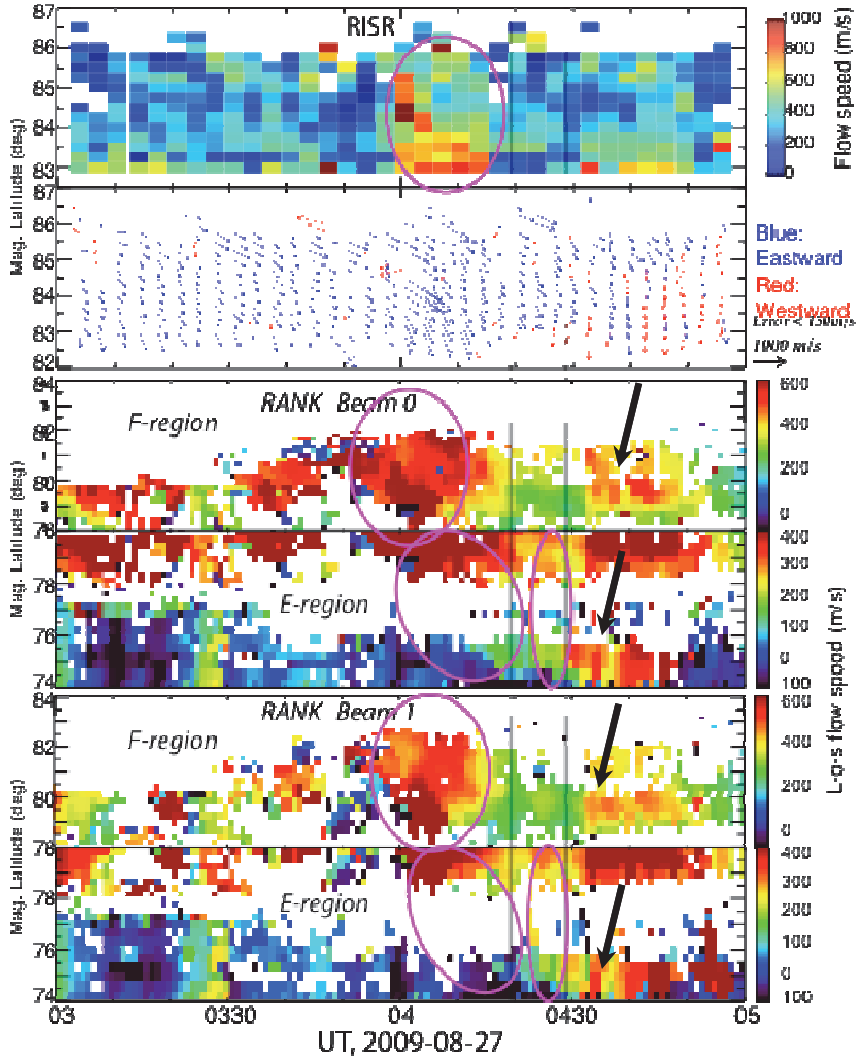
Rankin PolarDARN obs. support suggestion

2009 Aug 26 onsets

Onsets from 2-D ASI images



Large poleward expansion, prolonged activity after second onset



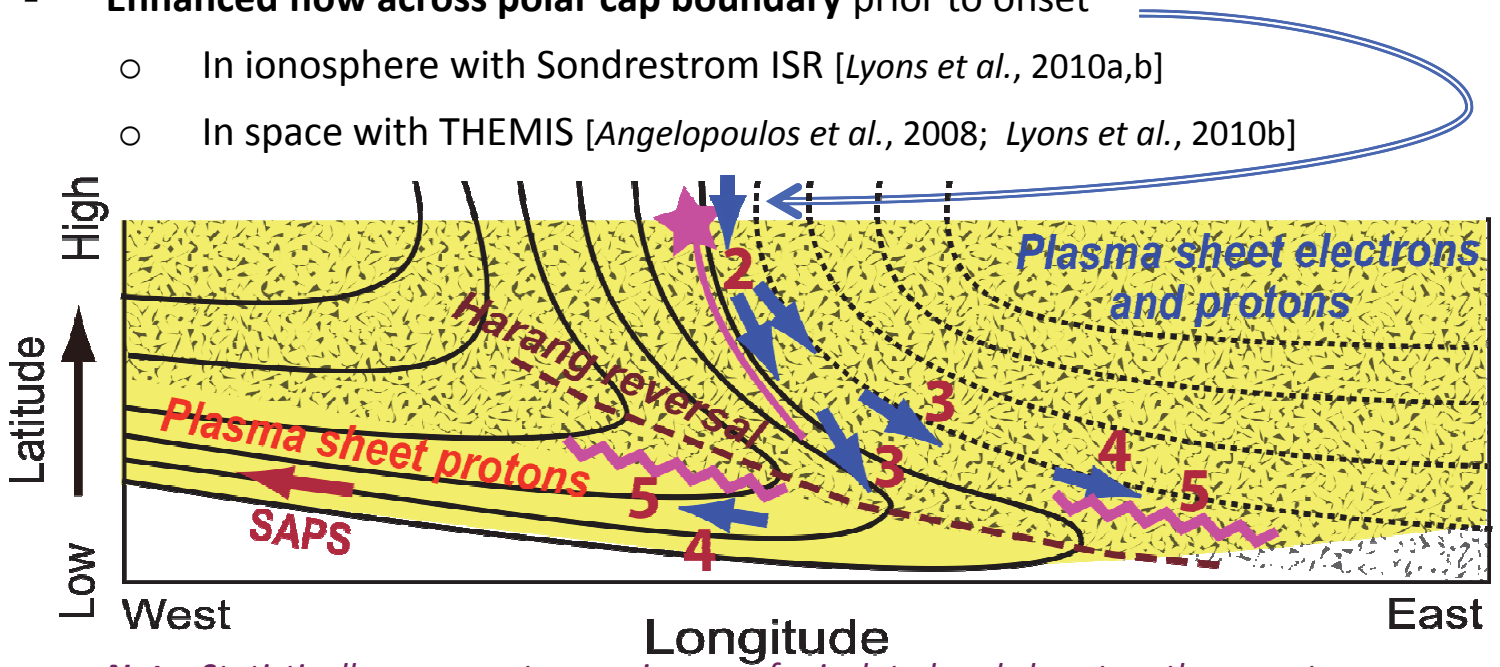
Rankin PolarDARN obs.:

- *Support polar cap flows leading to onset*
- *Enhanced post-onset polar-cap flows after second onset*

Discuss possible connection of polar cap flow channels to pre-onset PBIs and streamers and to post-onset auroral expansion and activity [*Lyons et al., 2011*]
(have not yet examined connection of polar cap flow channels to PBIs in general)

Nishimura et al. [2010] pre-onset sequence

- **Enhanced flow across polar cap boundary** prior to onset
  - In ionosphere with Sondrestrom ISR [*Lyons et al.*, 2010a,b]
  - In space with THEMIS [*Angelopoulos et al.*, 2008; *Lyons et al.*, 2010b]

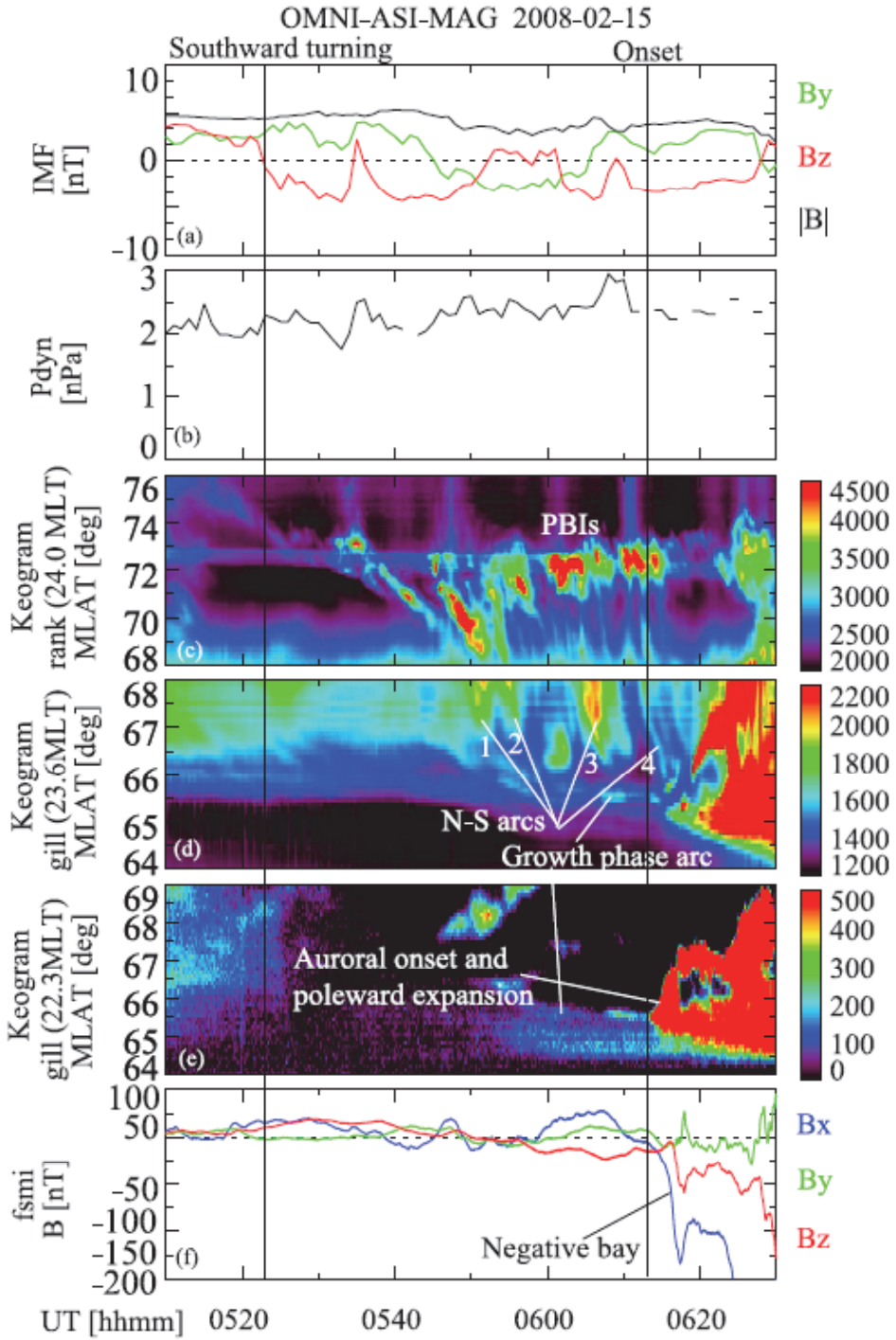


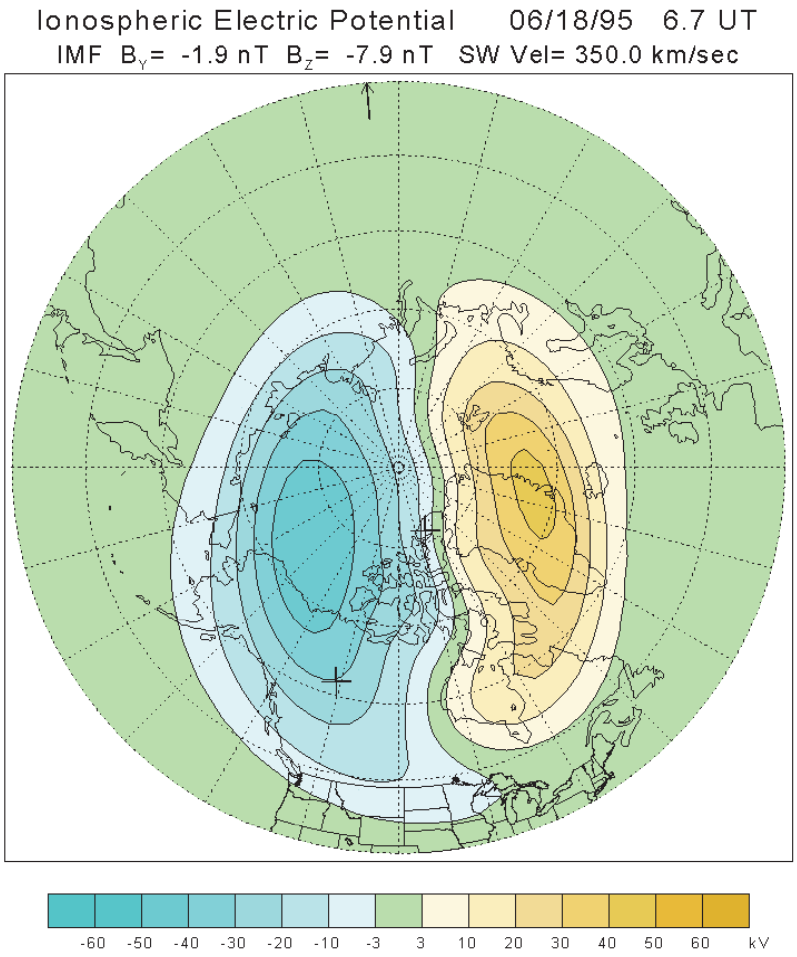
Note: *Statistically, pre-onset scenario same for isolated and close together onsets.*

- ***Physical process same****: streamer flows leads to near-Earth instability*

Present unexpected evidence that

- **Flow channels leading to onset** are result of longitudinally localized enhanced flow structures from deep within polar cap impinging on polar cap boundary
- **Persistence of such flow channels** enhances post-onset auroral poleward expansion and activity


OMNI-ASI-MAG 2008-02-15
Southward turning
Onset
IMF [nT]
By
Bz
|B|
(a)
Pdyn [nPa]
(b)
Keogram rank (24.0 MLT) MLAT [deg]
PBIs
(c)
Keogram gill (23.6MLT) MLAT [deg]
1
2
3
4
N-S arcs
Growth phase arc
(d)
Keogram gill (22.3MLT) MLAT [deg]
Auroral onset and poleward expansion
(e)
fsmi B [nT]
Bx
By
Bz
Negative bay
(f)
UT [hhmm]
0520
0540
0600
0620



from *Weimer* potential model

Polar Cap Convection as seen by statistical models:

- Smooth
- Characterized by large-scale, two-cell shape, $\Delta\phi_{pc}$

In-situ and radar observations:

- Structured ionospheric flows with Sondrestrom ISR [Lyons et al., 2010a,b]
- Structured and highly variable flows (BBFs) [Angelopoulos et al., 2008; Lyons et al., 2010b]

<<2009.08.27-03 2009.08.27-05>>