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)


THEMIS All-sky imagers

Streamer

Onset

Enhanced flow

Onset

RISR

THEMIS ASI

Magneto meters

UT, 2009-08-27

B (nT) - KUJJ

B (nT) - FCHU

ASI SNKQ
Possible resolution of the long-standing substorm argument

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
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

[Nishimura et al., 2010b]
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

Onsets from ASI images

Enhanced flow

RISR-SuperDARN combined

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

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

Enhanced flow

Onsets from ASI images

MLAT [deg]

RISR

SuperDARN

Enhanced polar cap flow prior to onset

- 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.

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