Evolution of negative SI-induced ionospheric flows observed by SuperDARN King Salmon HF radar

T. Hori[1], A. Shinbori[2], N. Nishitani[1], T. Kikuchi[1], S. Fujita[3],
T. Nagatsuma[4], O. Troshichev[5], K. Yumoto[6]

1. STEL, Nagoya Univ., 2. RISH, Kyoto Univ., 3. Meteorological College, 4. NICT,
5. AARI, Russia, 6. SERC, Kyushu Univ.

Contents

- Introduction
- Motivation and objectives
- Case study
  - Solar wind – IMF condition
  - Geomag.
    - Longitudinal evolution and local evolution around the radar
  - Ionospheric flows by SuperDARN King Salmon HF radar
- Discussion
- Conclusion
- Acknowledgments

1. Introduction
Ionospheric current for **negative sudden impulse (SI-)**

[Takeuchi et al., 2002]

SYM-H

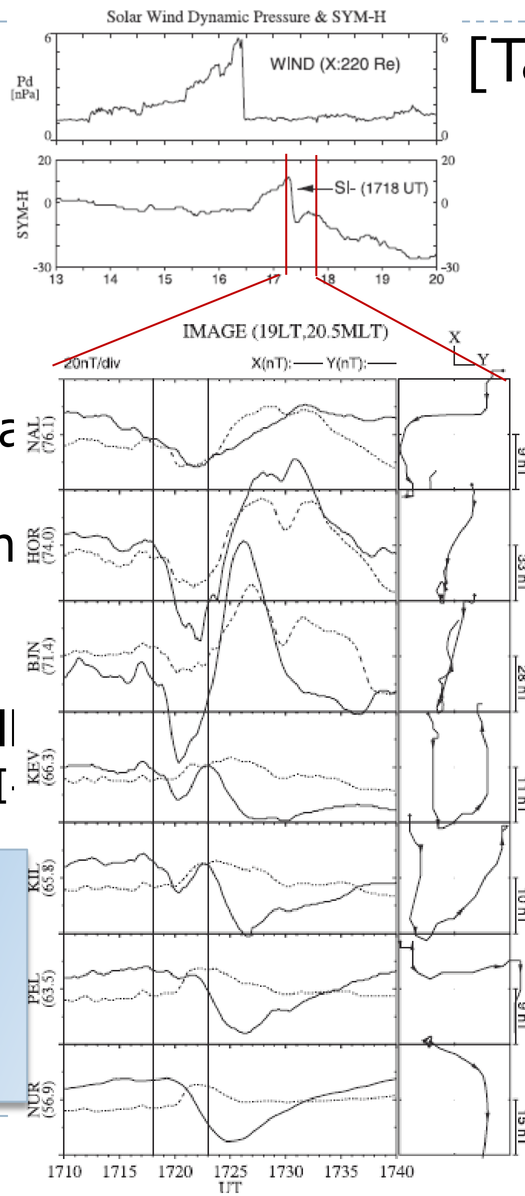
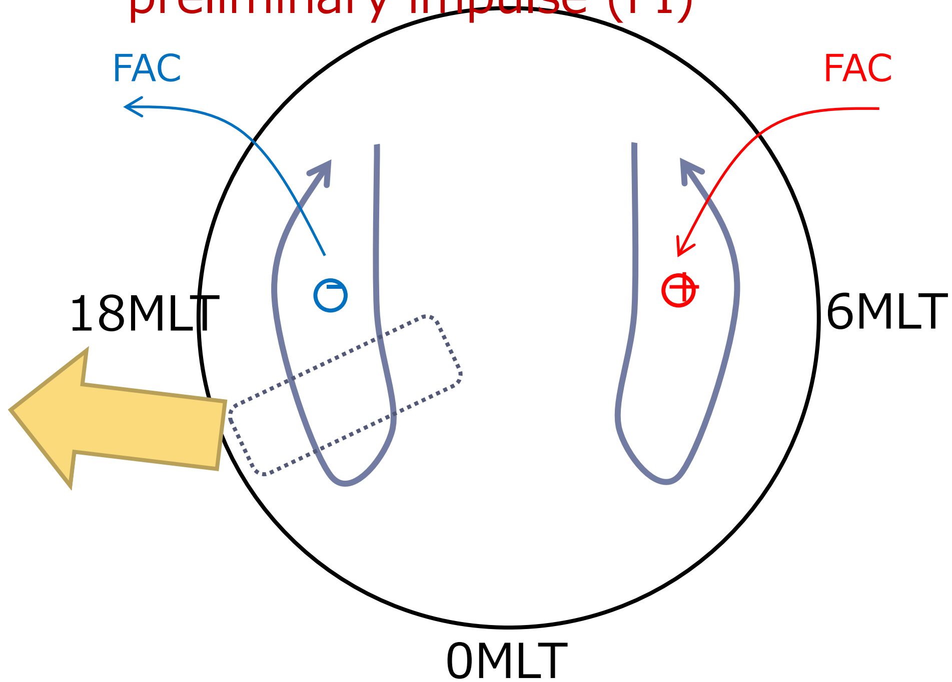


IMAGE geoma
MLT ~ 20.5h
(Solid: X-com

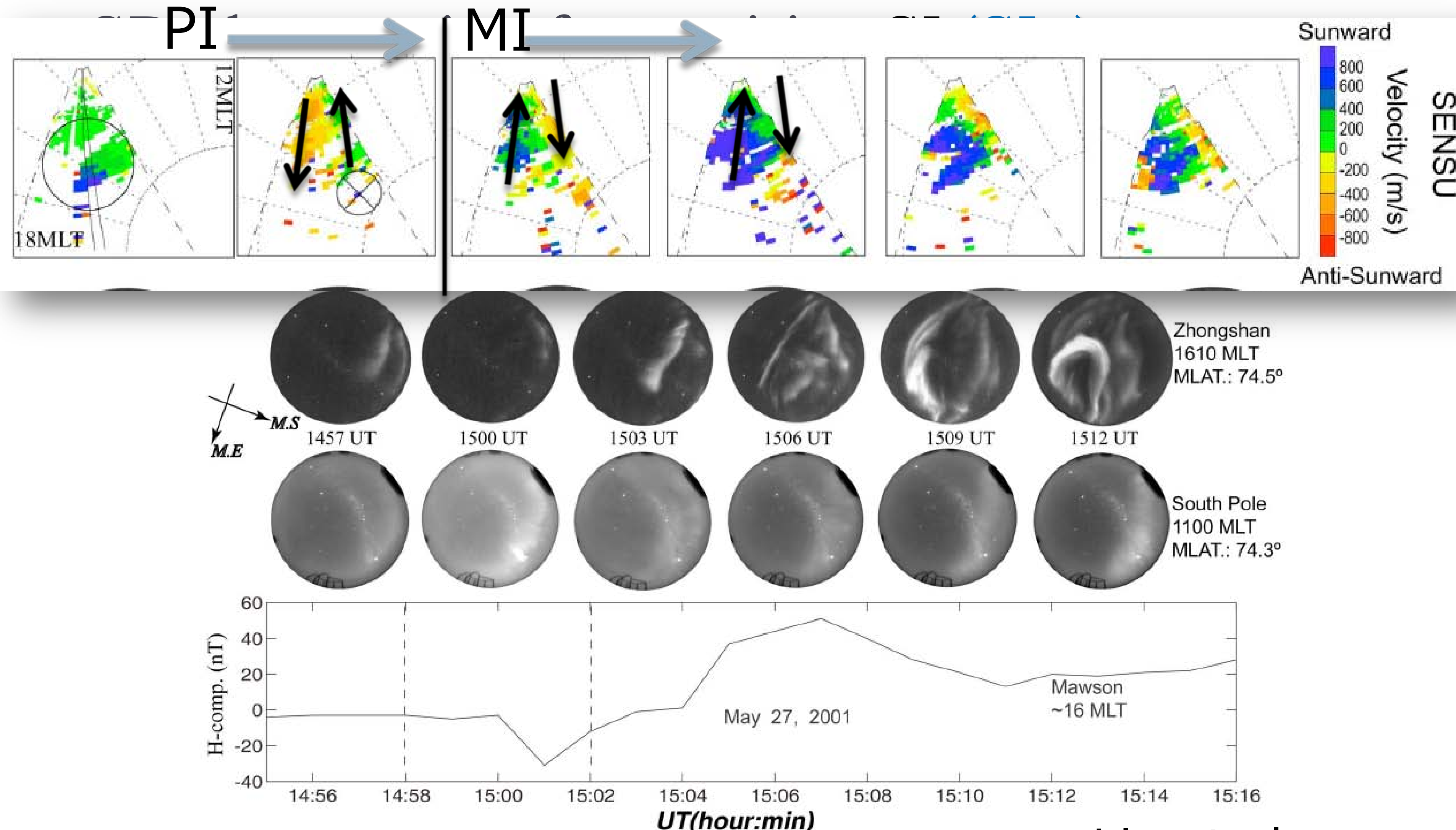
Transient convection cell on dusk for SI

A bipolar signature is observed at a fixed point.

Ionospheric convection vortex (opposite to DP current assuming Hall current) for a preliminary impulse (PI)



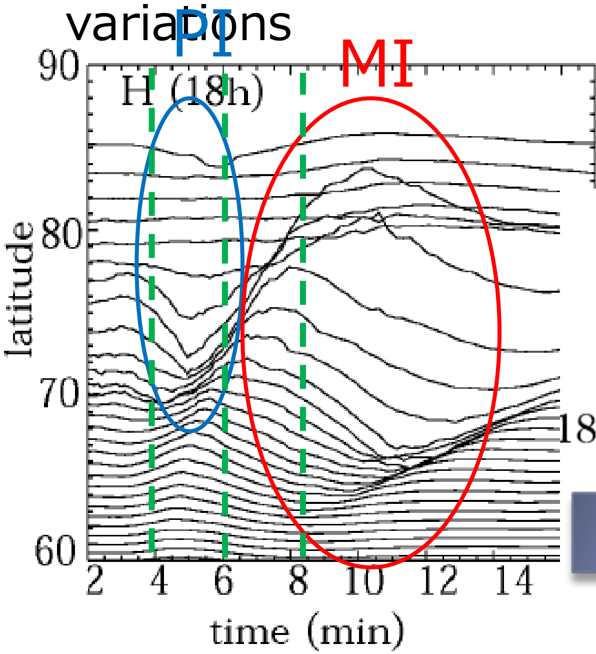
1. Introduction



- Liu et al. [2011]

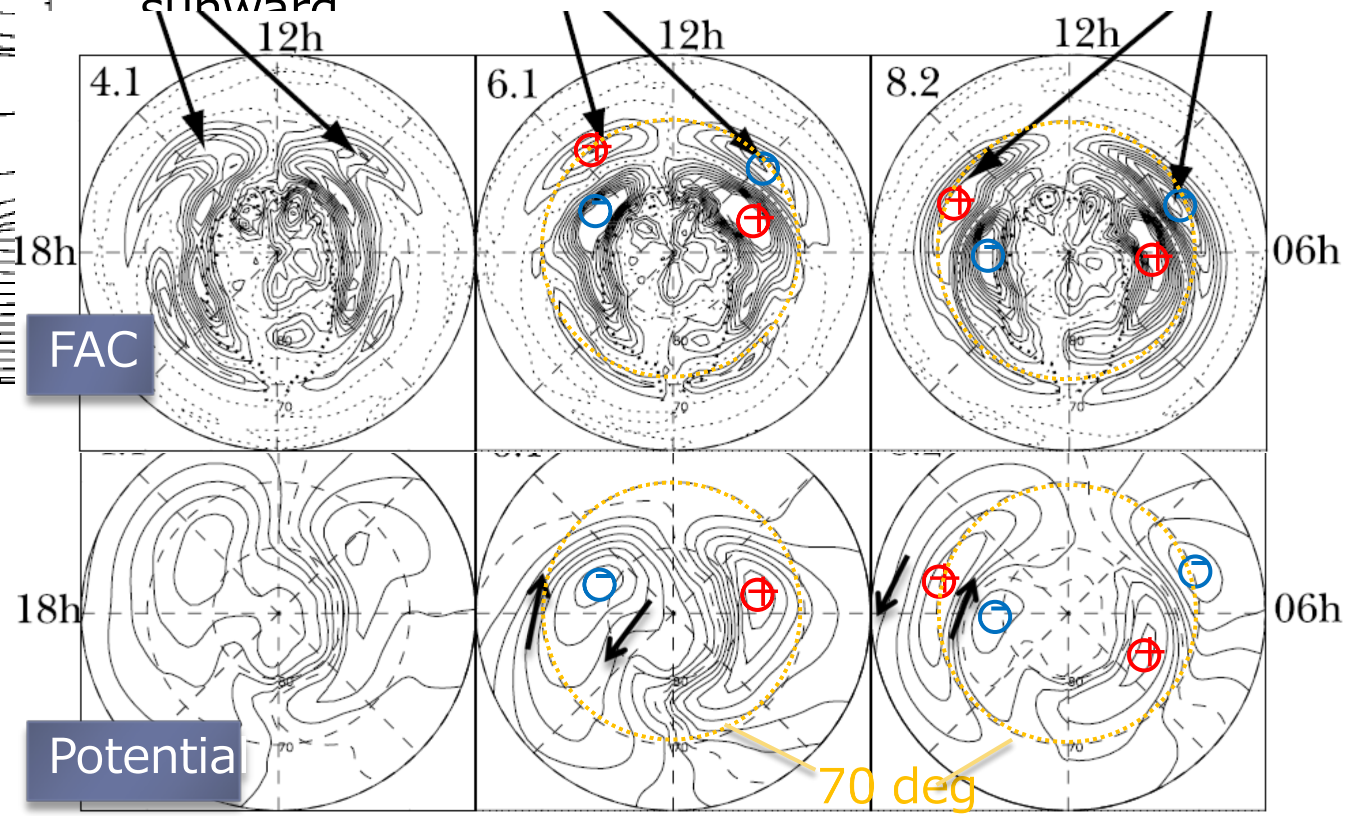
1. Introduction
Negative sudden impulse (SI-): MHD simulation

Simulated geomag. variations



Evolution of FAC in global MHD simulation

A pair of FACs with opposite senses are generated alternately and moves anti-sunward



Fujita et al. [2004]

1. Introduction
"Aftershock" following the 1st PI/MI?

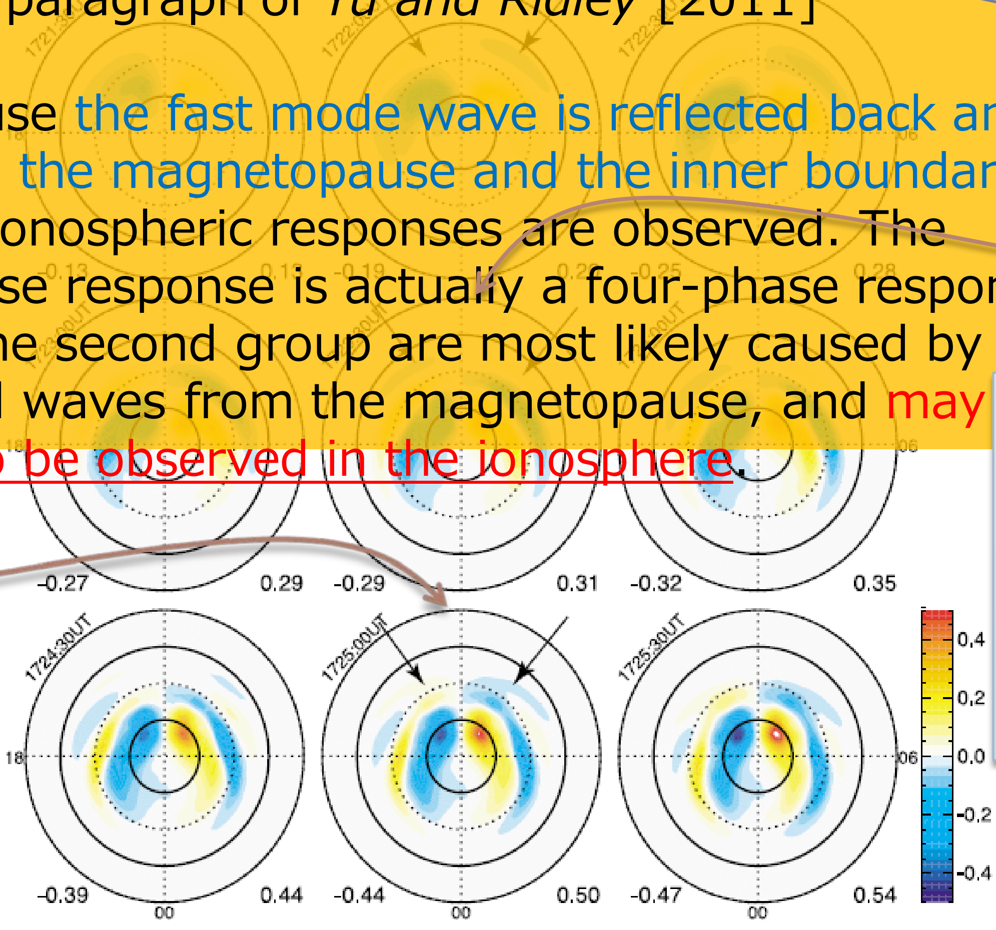
The last paragraph of *Yu and Ridley* [2011]
...
4. Because the fast mode wave is reflected back and forth between the magnetopause and the inner boundary, a train of ionospheric responses are observed. The two-phase response is actually a four-phase response, where the second group are most likely caused by the reflected waves from the magnetopause, and may subtle to be observed in the ionosphere.

1st MI FAC pair

2nd PI FAC pair

Damping M'pause oscillation
↓
Alternate launch of opposite-sense FAC pair

2nd MI FAC pair



(a) Residual Jr

Yu and Ridley [2011]

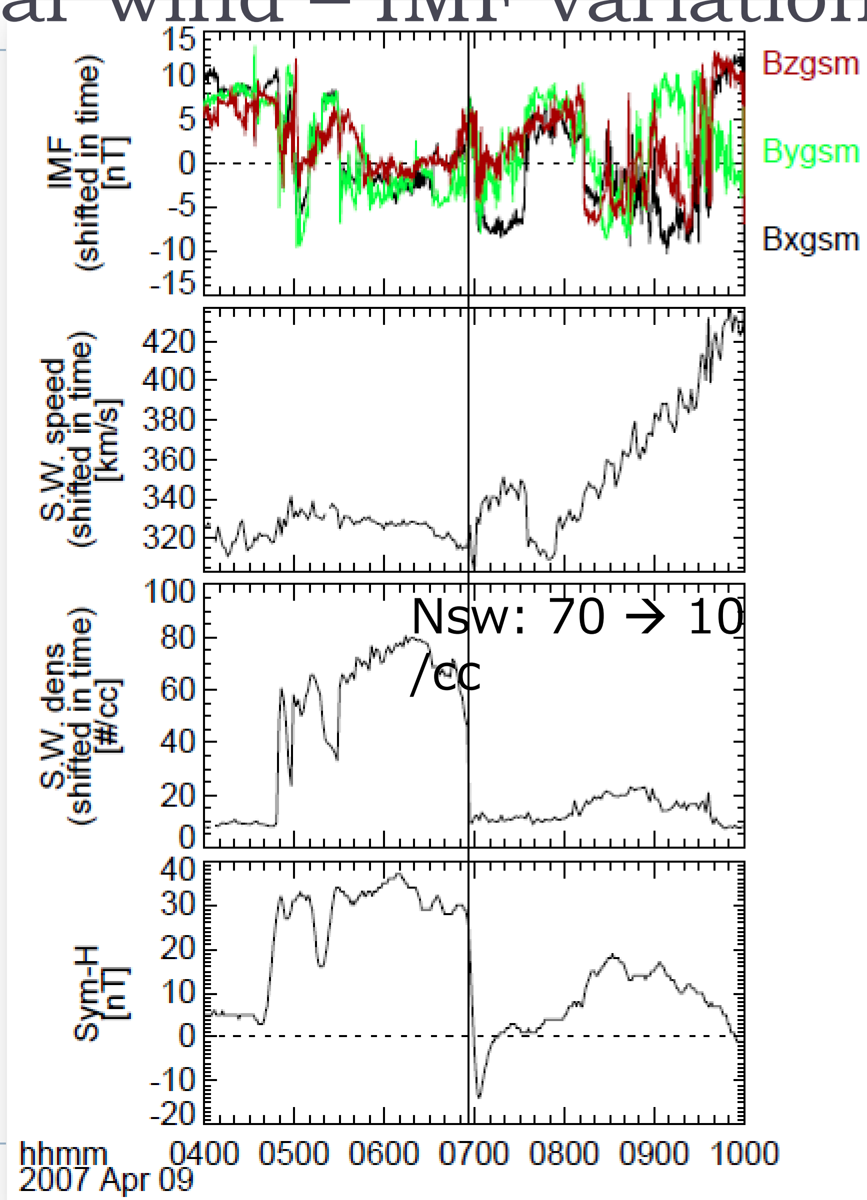
Motivation and objectives

- Evolution of 2-D ionospheric flow structures on dusk with a higher time resolution of 1 min associated with a large SI- is nicely captured by the King Salmon HF radar.
- Conjunction of the solar wind measurement, latitudinal/longitudinal chains of ground B-field, and simultaneous satellite observations are available.

Objectives

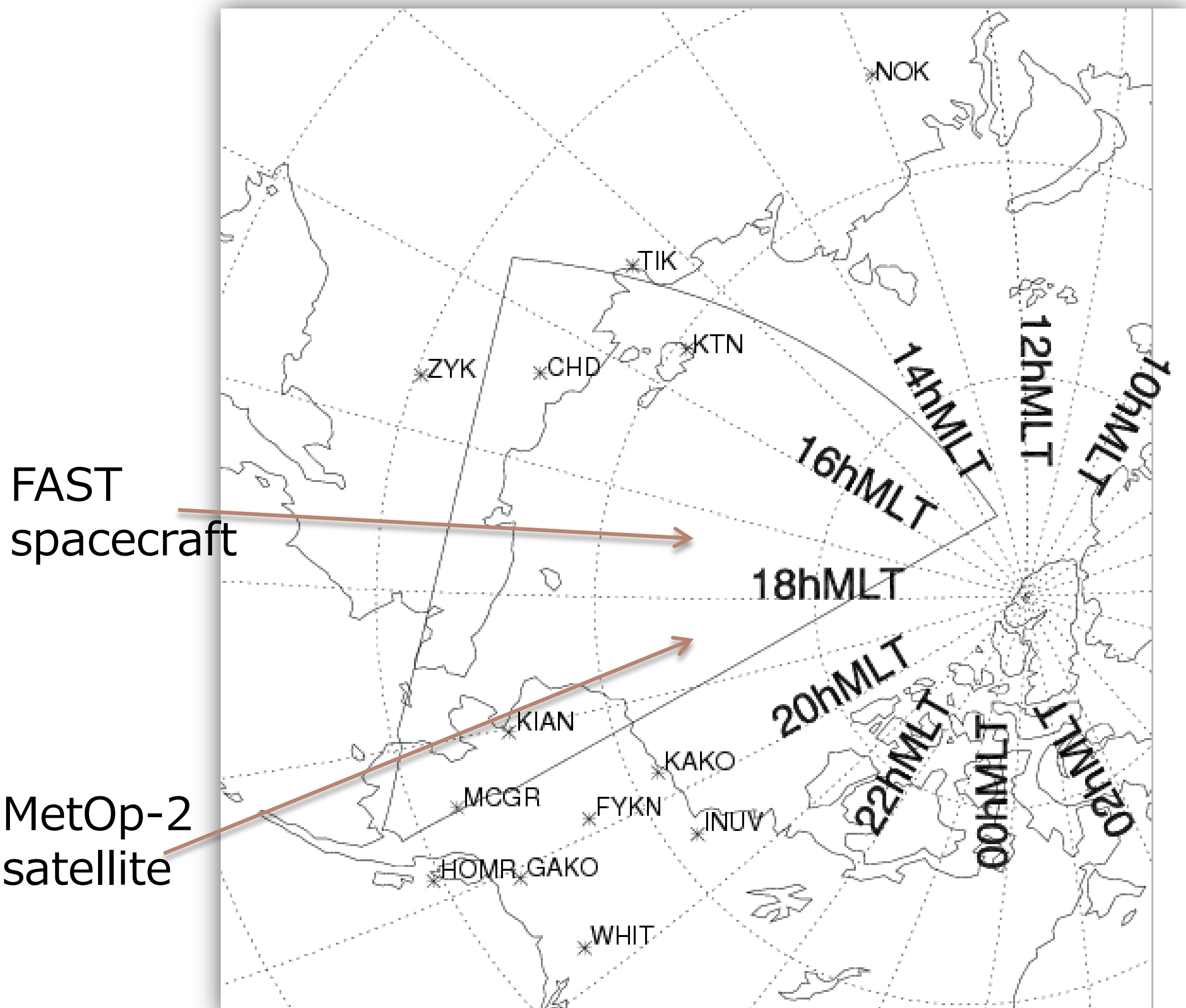
- Latitudinal structure of ionospheric E-field associated with a SI- and its temporal evolution
- Spatial/temporal properties of “aftershock” following the primary PI and MI sequence
- Quantitative comparison between ground B-field and ionospheric E-field

2. Case study
2.1 Solar wind – IMF variation



- A rapid decrease in the solar wind density (~70 → 10 /cc) caused a fairly large negative SI with Δsym-H ~ 40 nT near ~07:00 UT.

2. Case study
2.2 Magnetograms and KSR radar



- Rapidmag
- 210MM
- THEMIS/GMAG
- GIMA
- KSR radar

2. Case study
2.2 Magnetograms and KSR radar

SYM-H

MLT ~ 13h NOK

~ 15.3h TIK

~ 15.6h KTN

~ 16.4h CHD

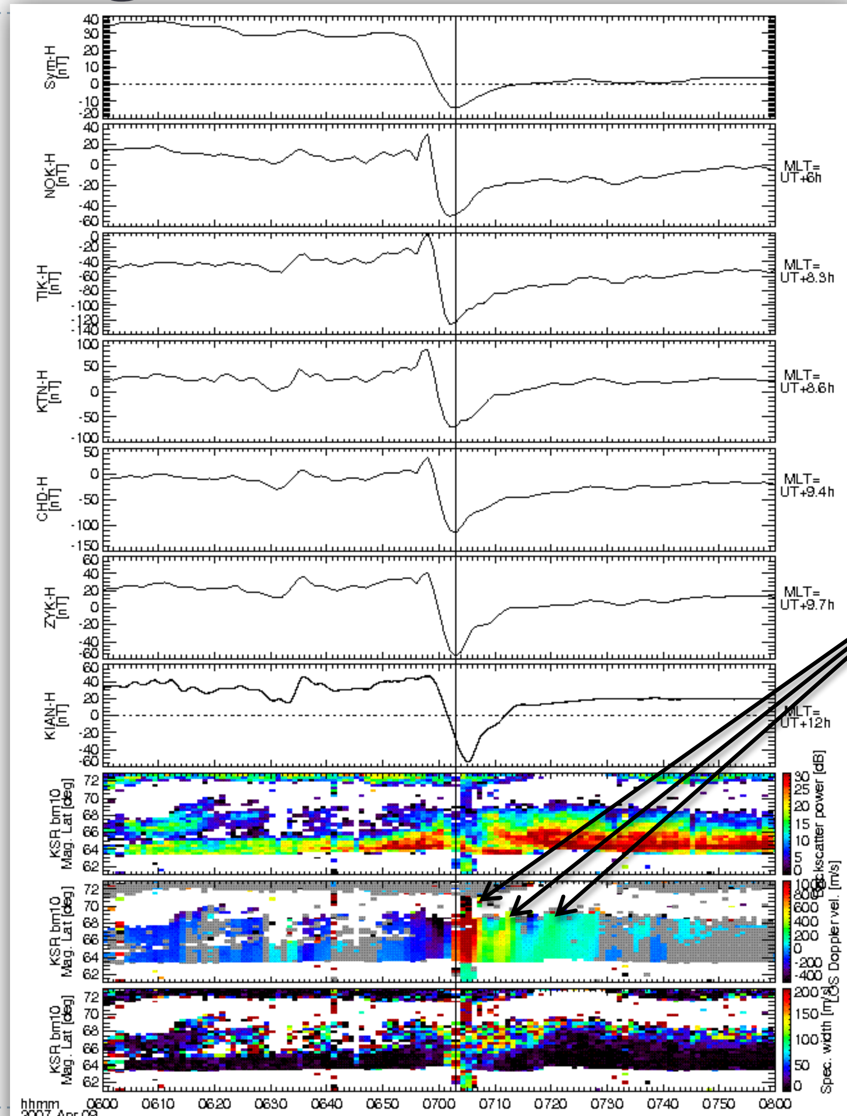
~ 16.7h ZYK

~ 19h KIAN

Echo power

L-o-S Velocity
(Mlat ~ 60– 72 deg)

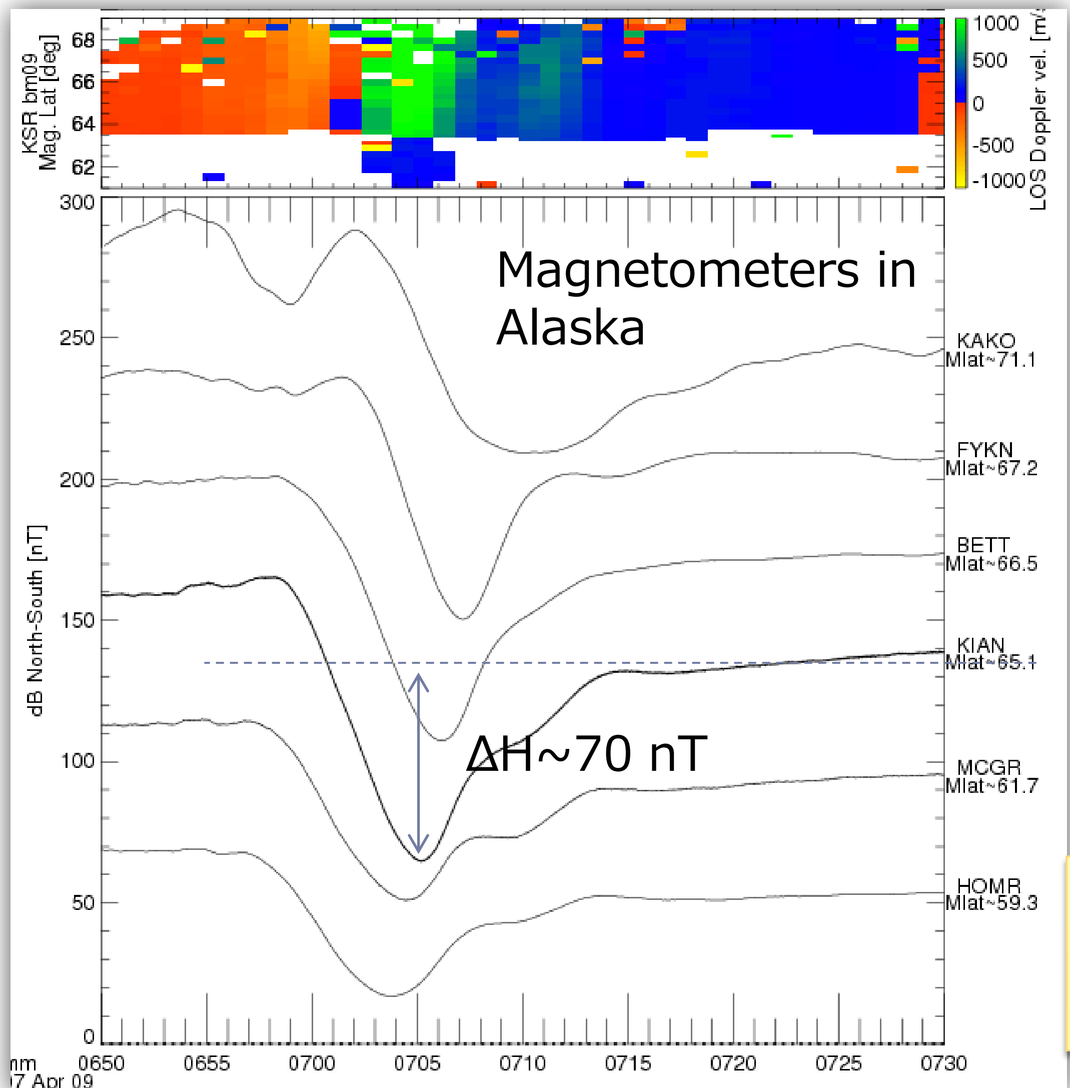
Spec. width



- A SI- signature propagated from dayside to MLT ~ 19h with a few minutes
- KSR saw enhancement of a away-from-radar flow followed by repeated enhancements of toward-radar flow at Mlat ~ 64–68 deg.

KSR beam10 passes right over KIAN

2. Case study
2.2 Magnetograms and KSR radar



From the radar obs.

1400 m/s ~ 70 mV/m

J_H ~ 70 mV/m * 1.0[S] ~ 70 mA/m

→ $\Delta H \sim 4 \times 10^1$ nT

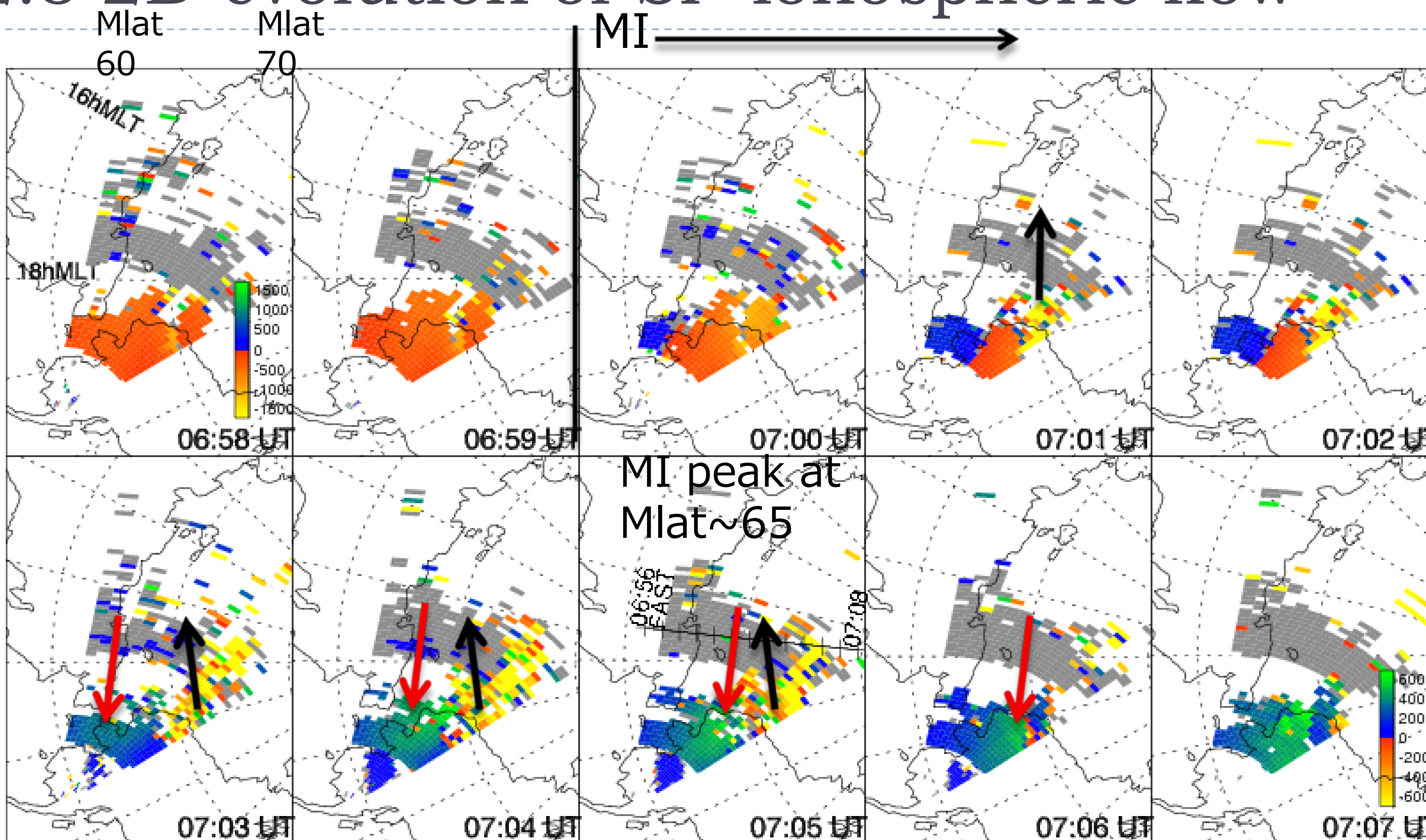
From the magnetogram

$\Delta H_{obs} \sim 70$ nT

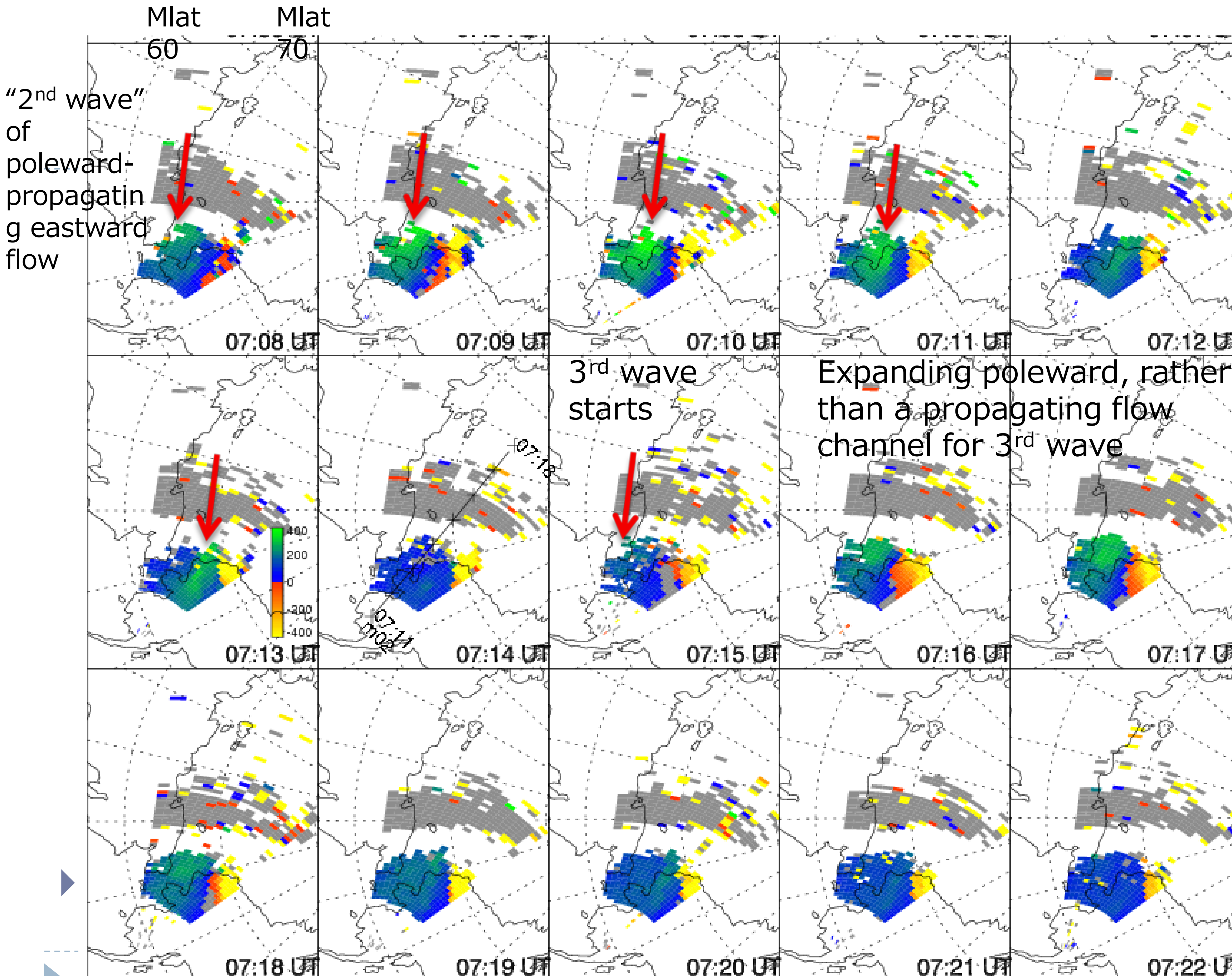
→ $\Delta H_{iono\_current} \sim 46$ nT

The MI variation in ground B-field can be explained by the Hall current equivalent to the fast eastward flow

2. Case study
2.3 2D evolution of SI- ionospheric flow

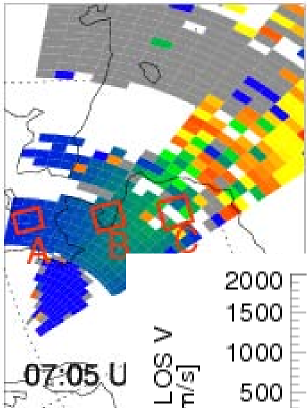


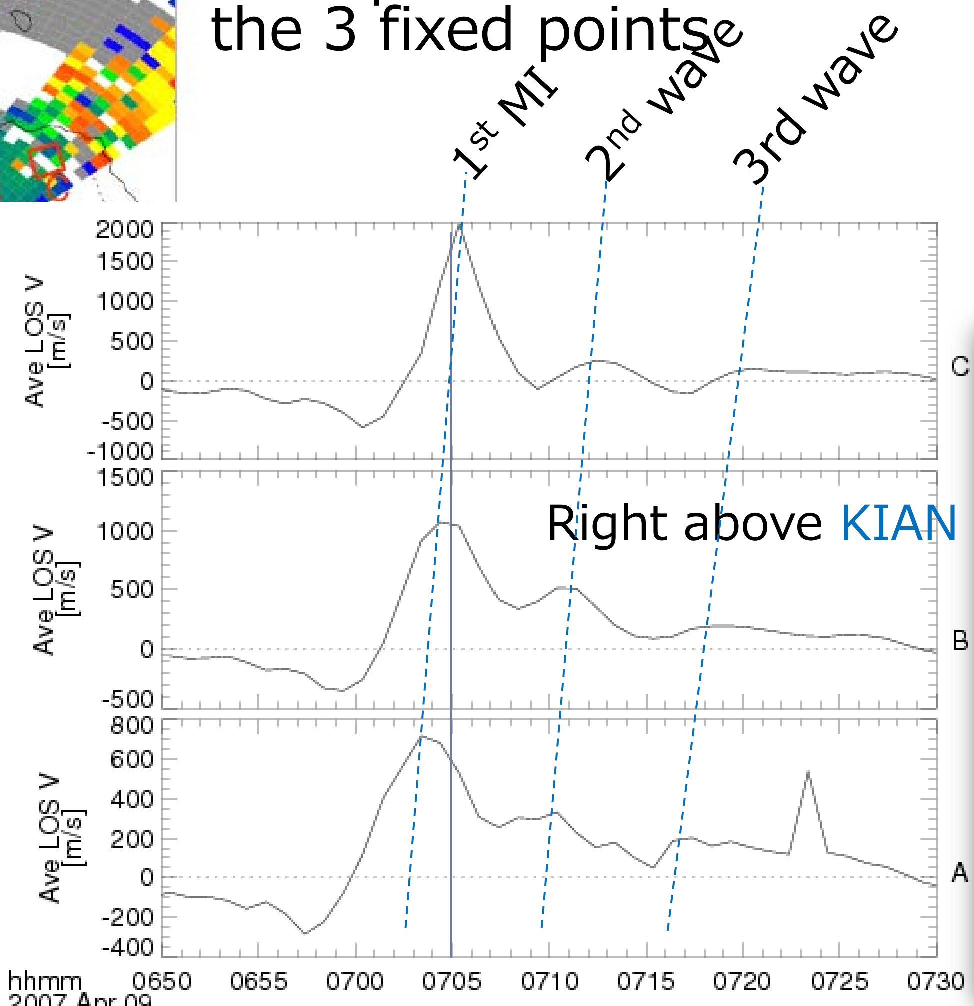
- A fast eastward flow channel ( ) propagates poleward during MI, while a westward flow enhances at higher lat. ( )


Mlat 60
Mlat 70
"2nd wave" of poleward-propagating eastward flow
3rd wave starts
Expanding poleward, rather than a propagating flow channel for 3rd wave
400
200
0
-200
-400
07:18
07:11
07:02
07:08 UT
07:09 UT
07:10 UT
07:11 UT
07:12 UT
07:13 UT
07:14 UT
07:15 UT
07:16 UT
07:17 UT
07:18 UT
07:19 UT
07:20 UT
07:21 UT
07:22 UT

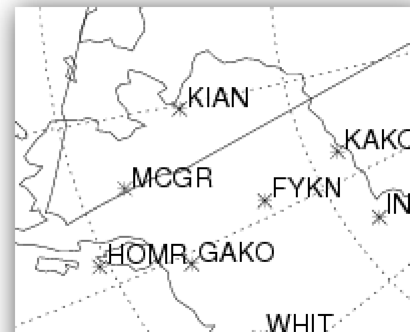
2. Case study
2.4 Latitudinal propagation of eastward flows

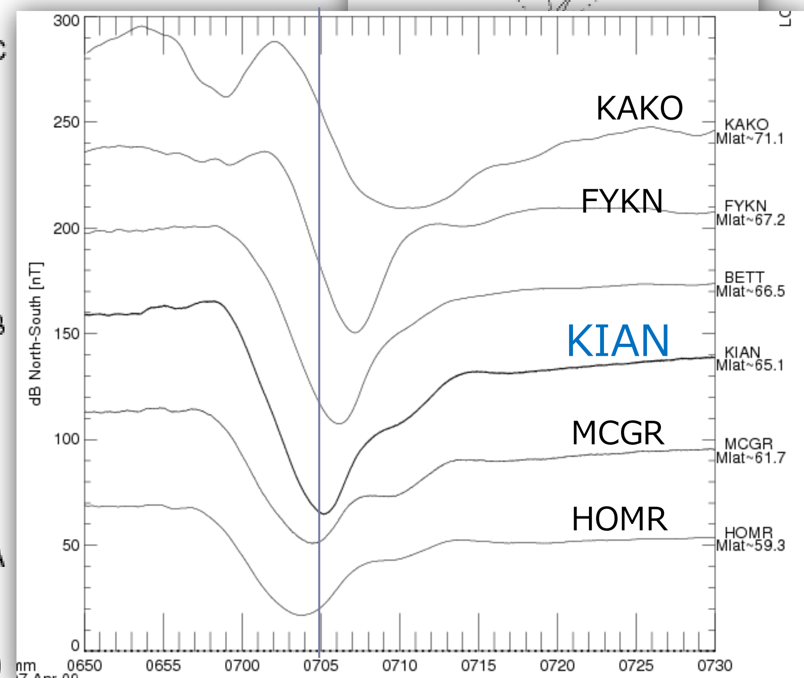
Ionospheric flows at the 3 fixed points



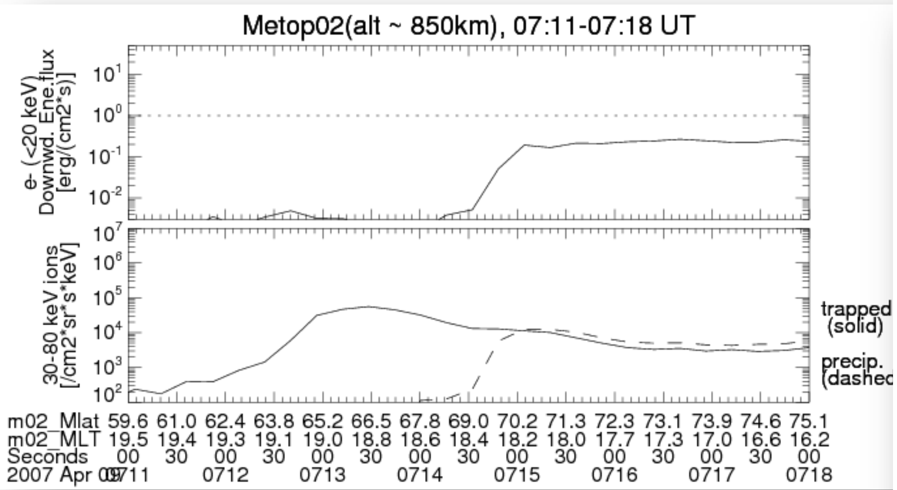


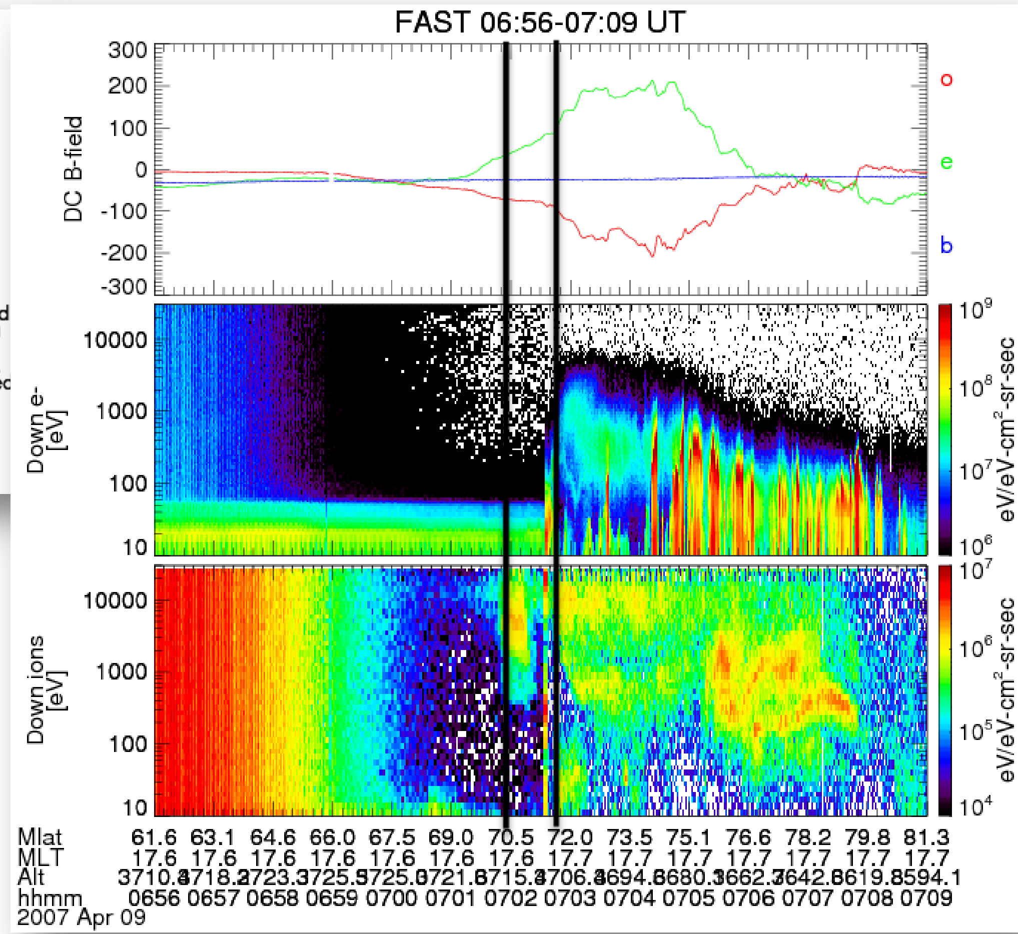
THEMIS GMAG at Alaska





2. Case study
2.5 Simultaneous satellite observations



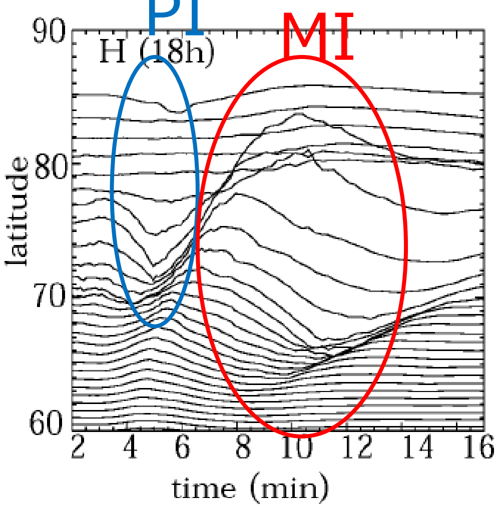


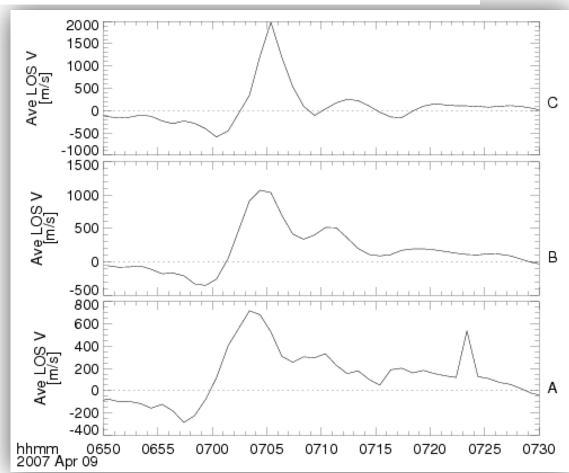
- For both passes, the oval is located at latitudes higher than ~70 deg

→ The poleward-propagating fast eastward flows are in the sub-auroral region

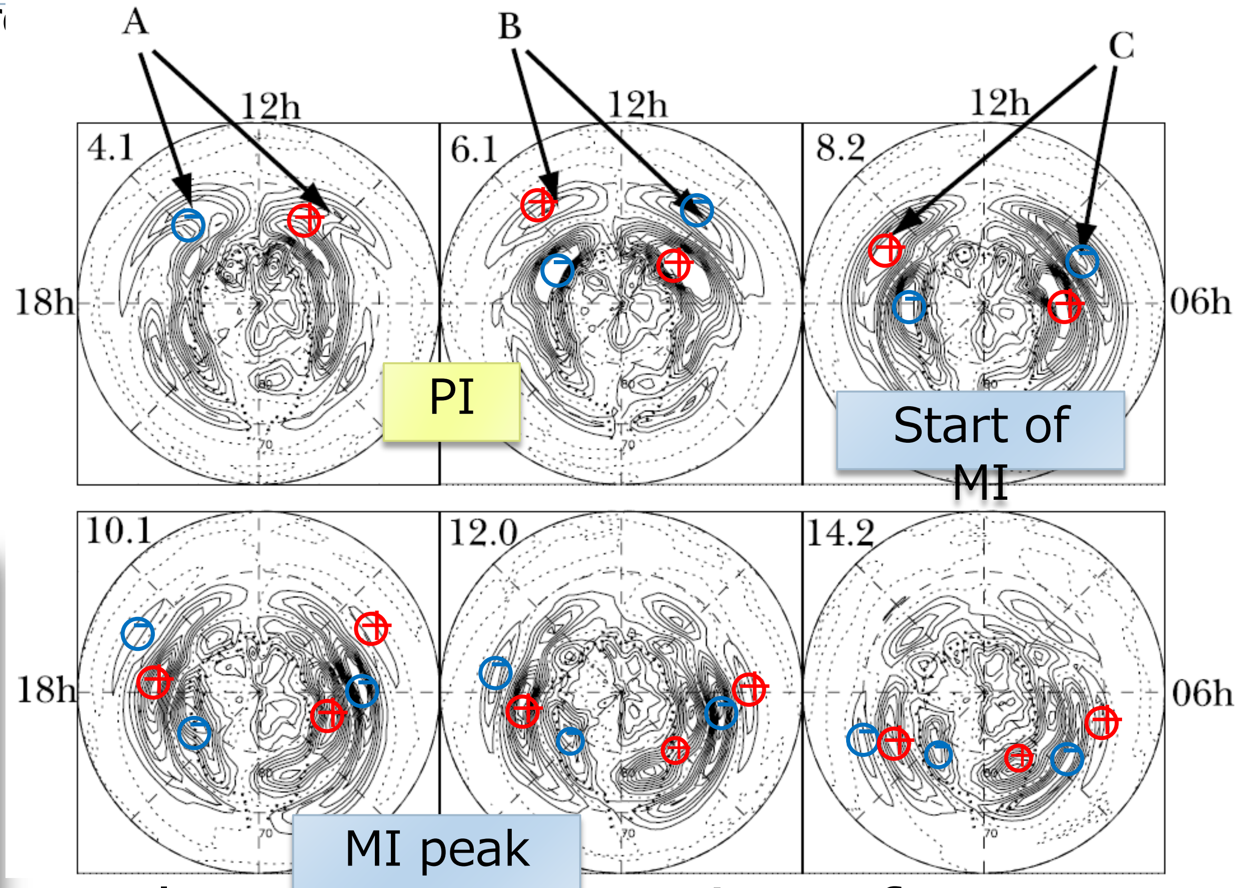
3. Discussion
Poleward-moving flow channel

Simulated eastward curr

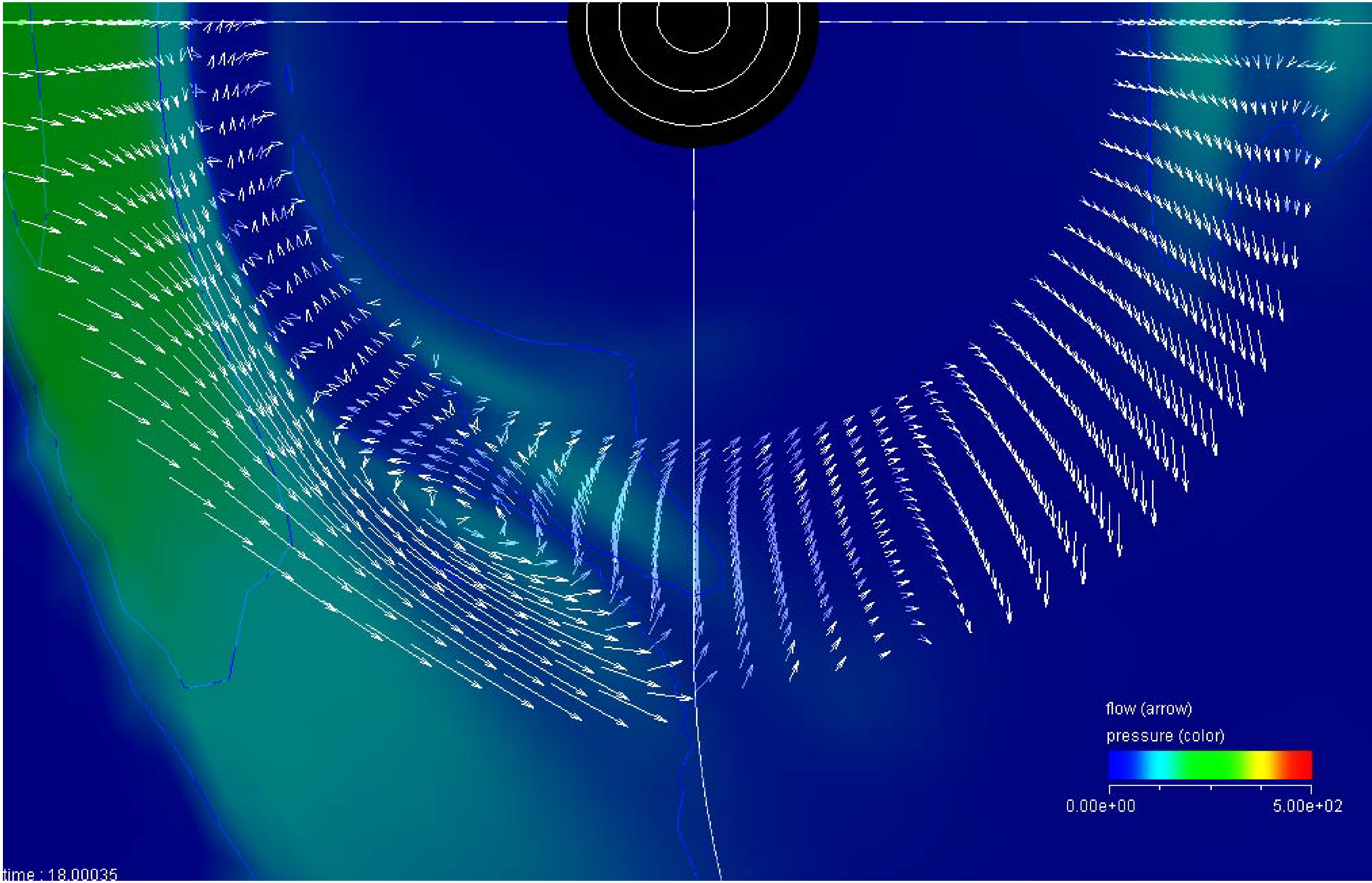




Observed eastward flow

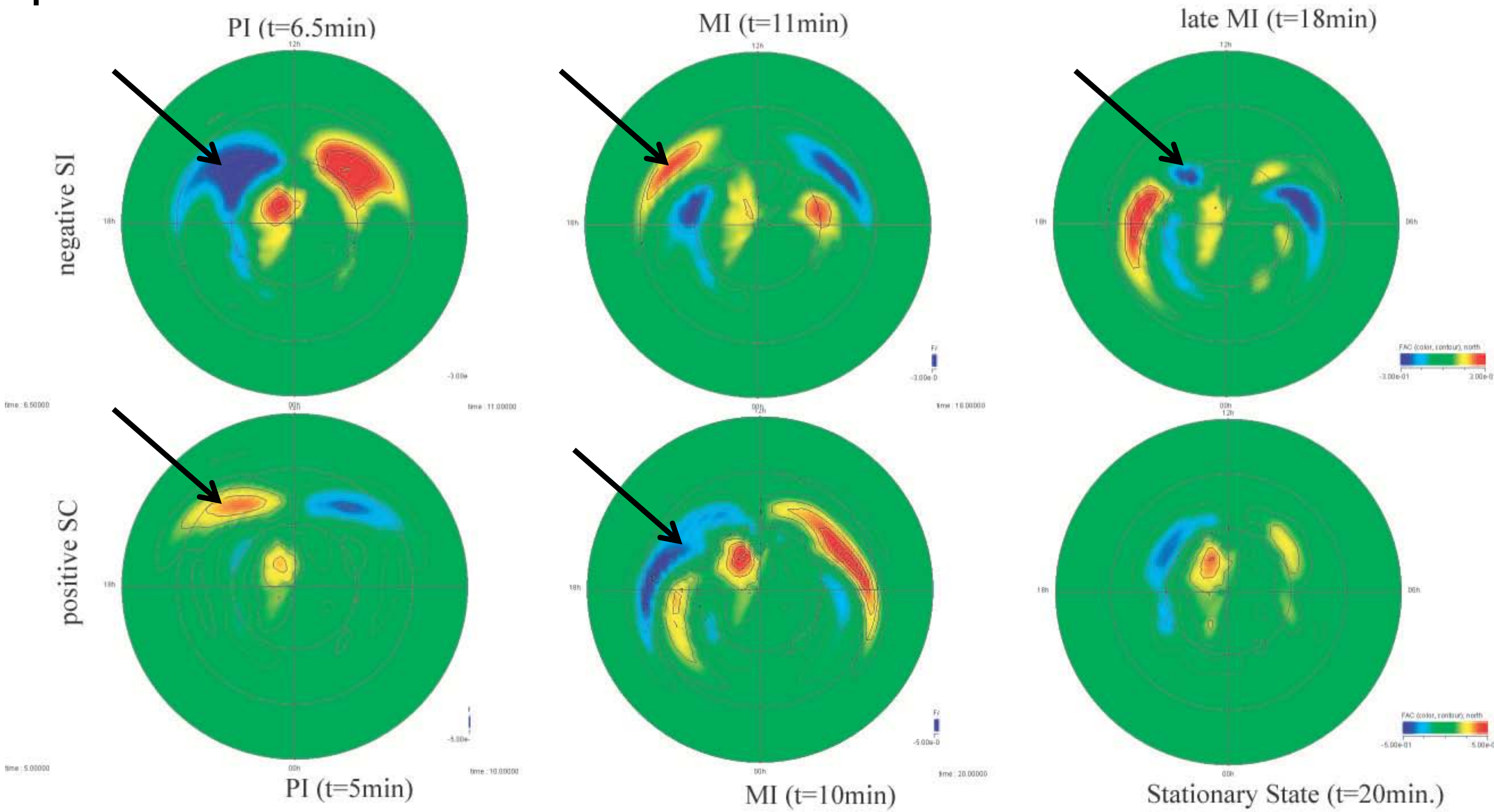


- Poleward propagation of eastward flow, consistent with MHD simulation



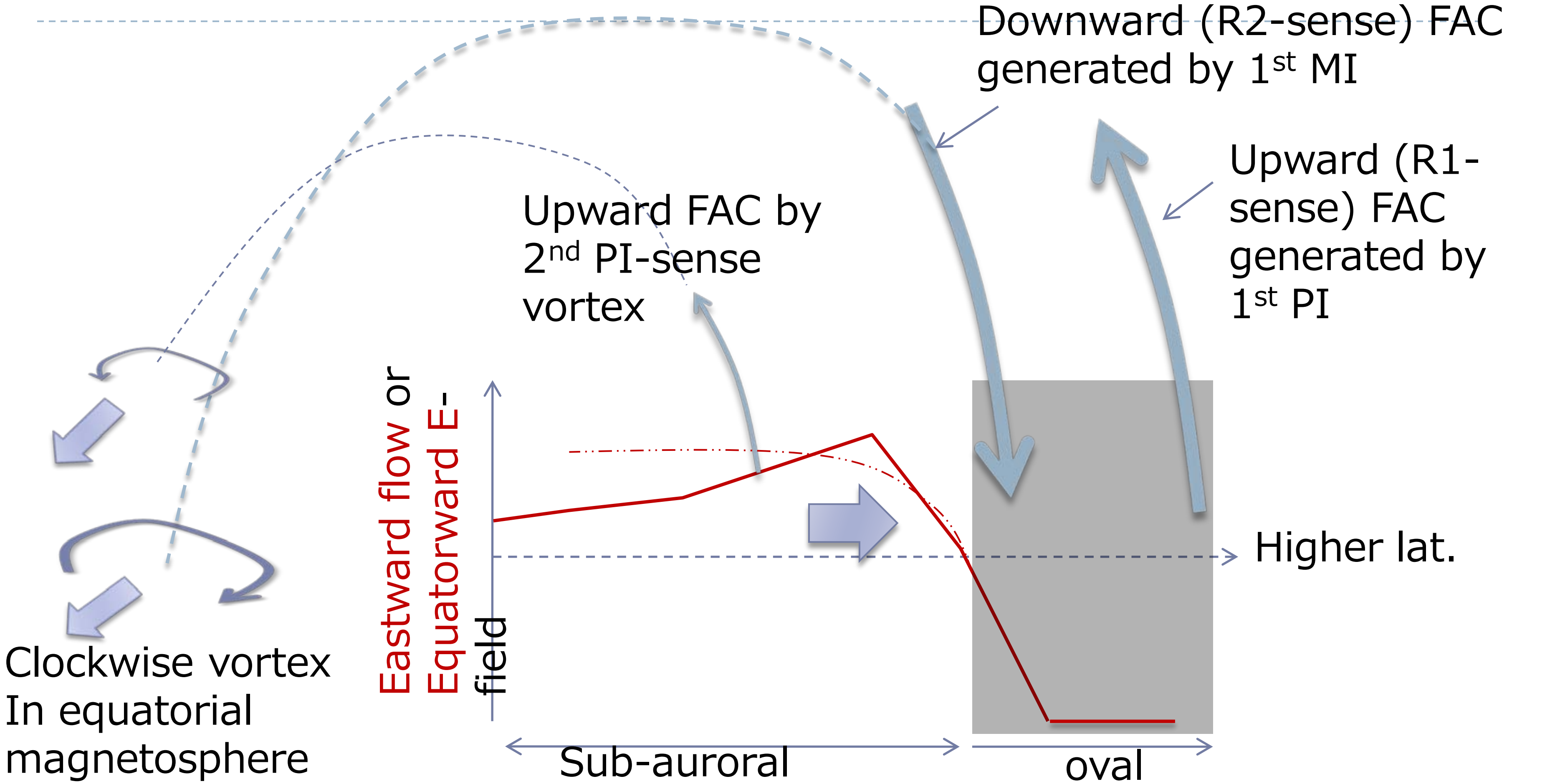
[Fujita et al., 2011, in preparation]

Aftershocks occur only with negative SI, not with positive SI?



[Fujita et al., 2011, in preparation]

3. Discussion



$$J_\parallel = \Sigma_P \mathbf{B} \cdot \boxed{\nabla \times \mathbf{v}} - \mathbf{E} \cdot \nabla\Sigma_P + \mathbf{B}\,\mathbf{v} \cdot \nabla\Sigma_H$$

Sofko et al. [19

~ dV_eastward /

4. Conclusion

A good conjunction between ground magnetograms and SuperDARN during a large SI- event reveals:

- Geomagnetic variations of a MI in the subauroral region on dusk is associated with a poleward-propagating fast eastward flow channel.
- Subsequent 2nd and possibly 3rd eastward flow channels follow, causing variations in H in the same fashion as the MI but with a much smaller amplitude. Each flow channel could be associated with a pair of upward and downward FACs.
- Such aftershocks following the primary PI and MI are likely to be caused by the decaying expansion-compression of the dayside magnetopause.

Acknowledgments

The Wind SWE and MFI data were provided by the CDAWeb. The sym-H index were provided by WDC/Kyoto. The NOAA/POES data were obtained from NOAA/NGDC. We acknowledge Dr. C. T. Russell for providing THEMIS/GBO GMAG data.