Evolution of convection vortices associated with sudden impulses observed by SuperDARN

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Introduction:
Sudden impulse of geomagnetic field(SI+, SI-)

SC: sudden commencement
SI: sudden impulse

Typically ~ tens of nT rise(SI+) or drop (SI-) on a time scale of ~ a few minutes

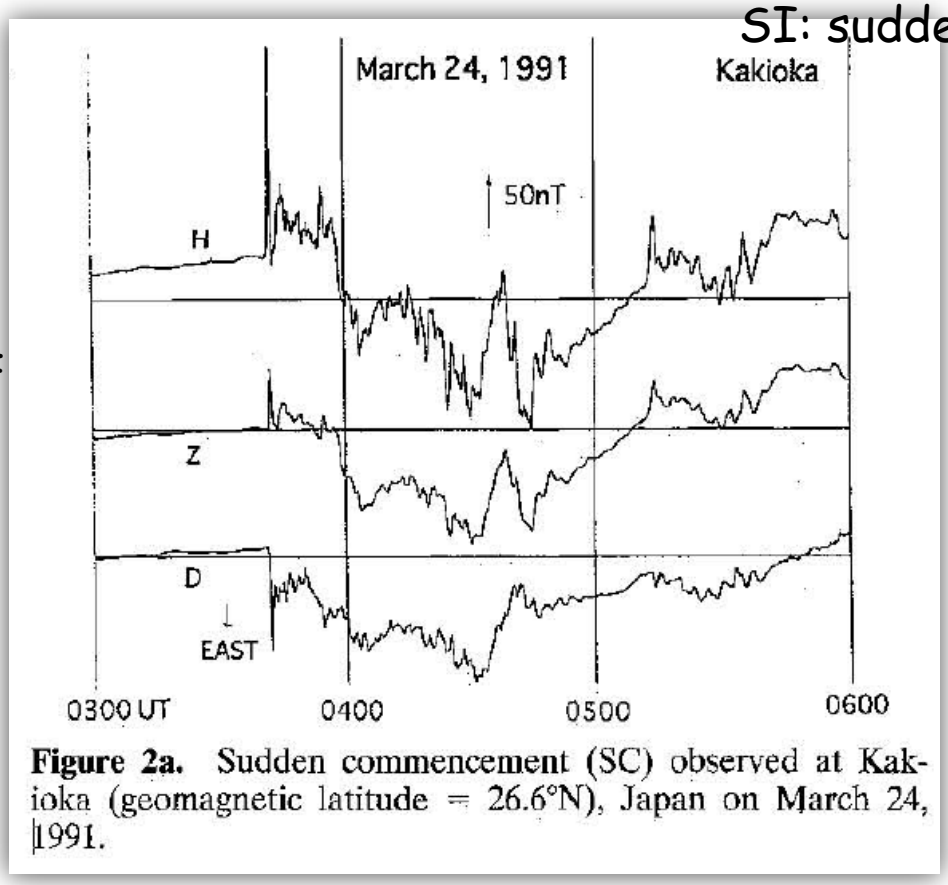
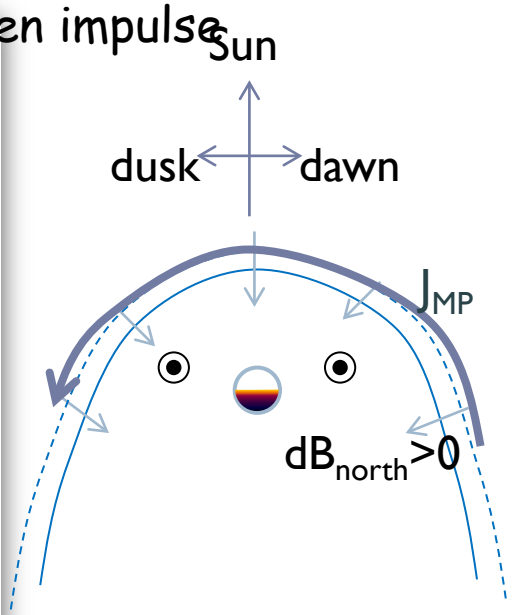


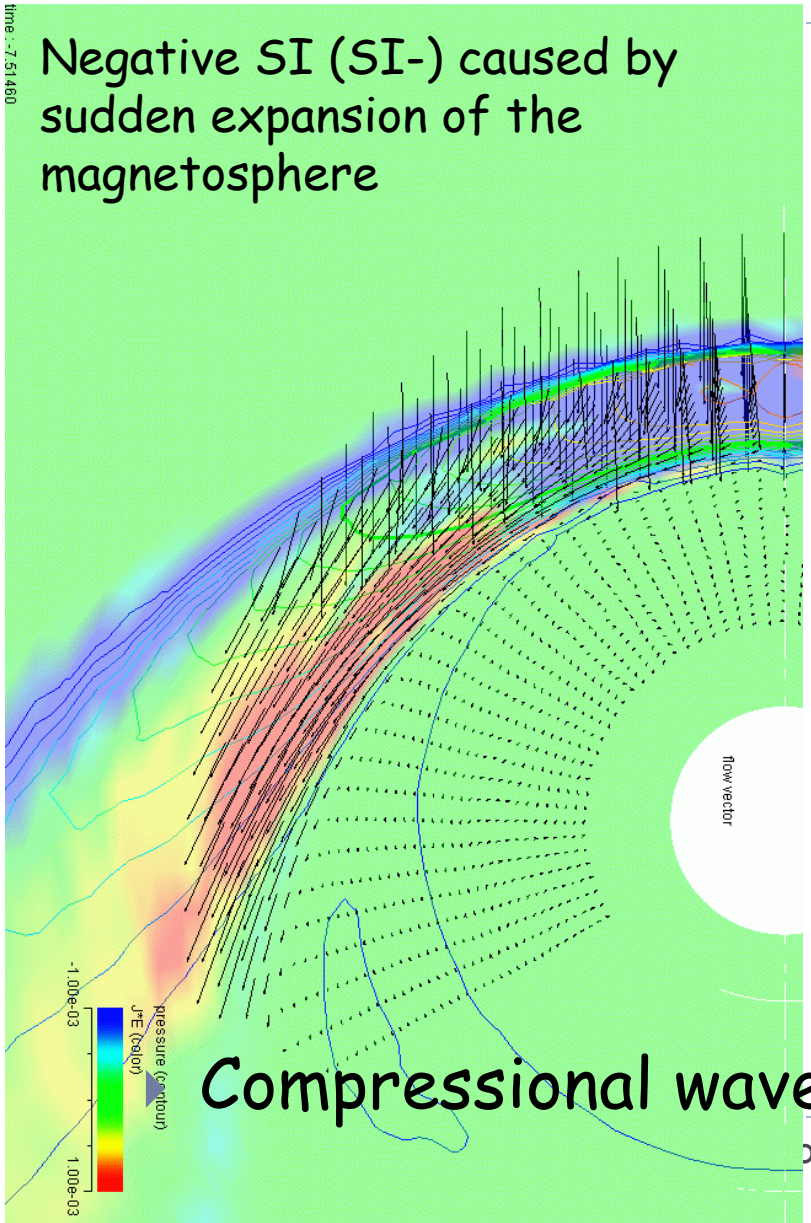
Figure 2a. Sudden commencement (SC) observed at Kakioka (geomagnetic latitude = 26.6°N), Japan on March 24, 1991.

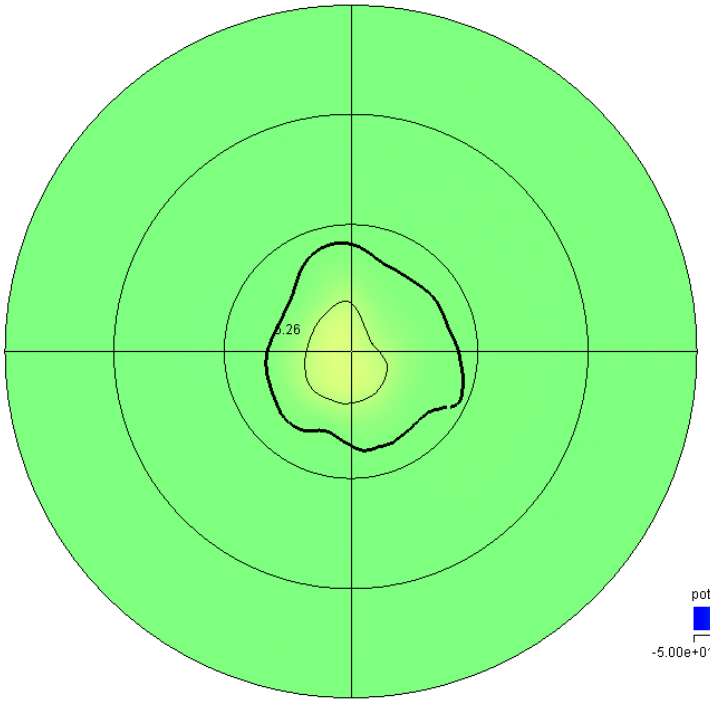


[Araki+1997]

- Rapid compression/expansion of the magnetosphere
  → sudden rise/drop of the horizontal geomagnetic field on ground

Introduction: Global MHD simulation of SI





Twin vortex-shaped transient convection in polar ionosphere

↑

Field-aligned currents

↑

Compressional wave →shear Alfven wave

[Fujita+2012]

Introduction:
Ionospheric current vortices from geomagnetic field observation

$$dB_{ground} = D_L + D_P + D_{FAC}$$

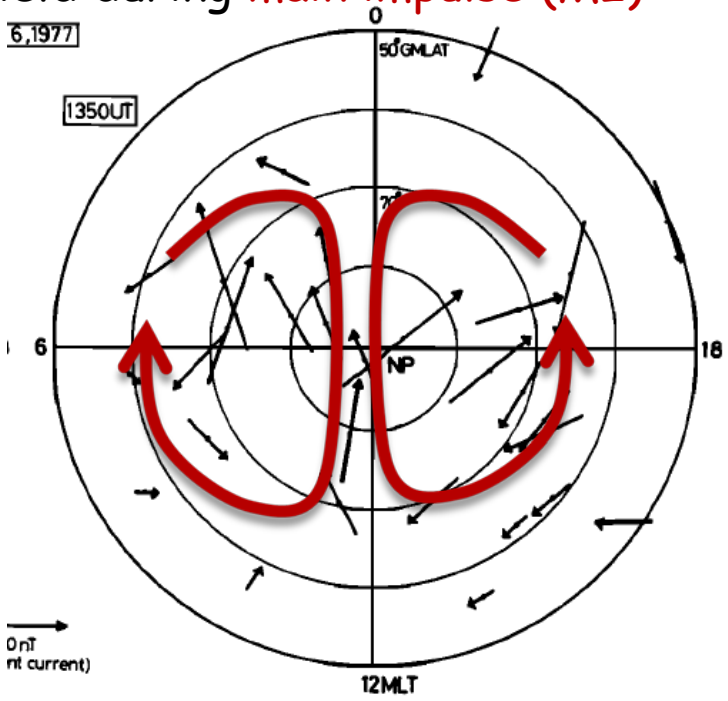
[Araki1994, modified]

DL: due to magnetopause current,

D_P: due to ionospheric current

D_{FAC}: due to field-aligned current

DP field during main impulse (MI)



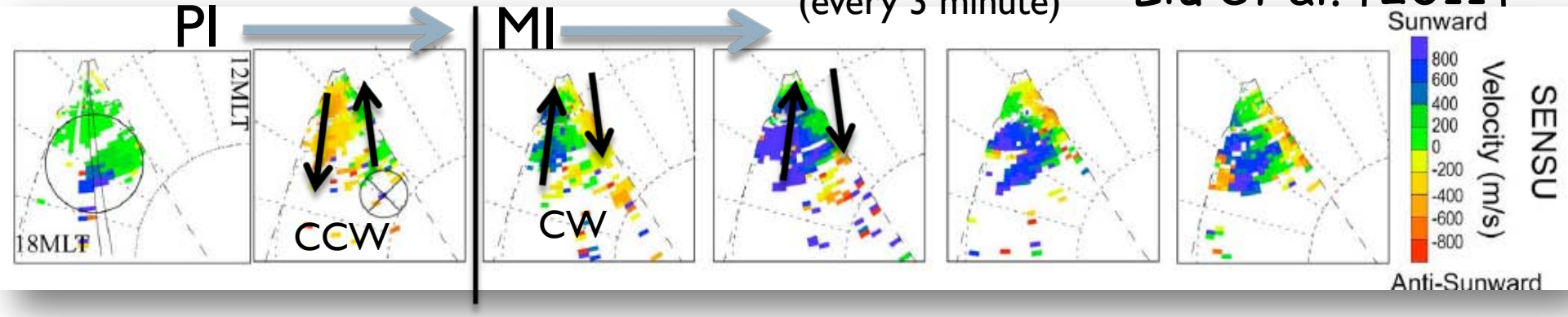
6MLT

18MLT

12MLT

[Araki and Nagano, 1989]

Introduction:
SI-induced vortex seen by SuperDARN



[e.g., Lyatsky+1999; Thorolfsson+2001; Vontrat-Rbeberac+2002; Coco+2008; Huang+2008; Kane+2010; Liu+2011; Hori+2012; Liu+2013]

Previous works by SD

- Covered only limited portions of vortices on dayside or dusk.
- Just examined the vortex polarity on the basis of event study.

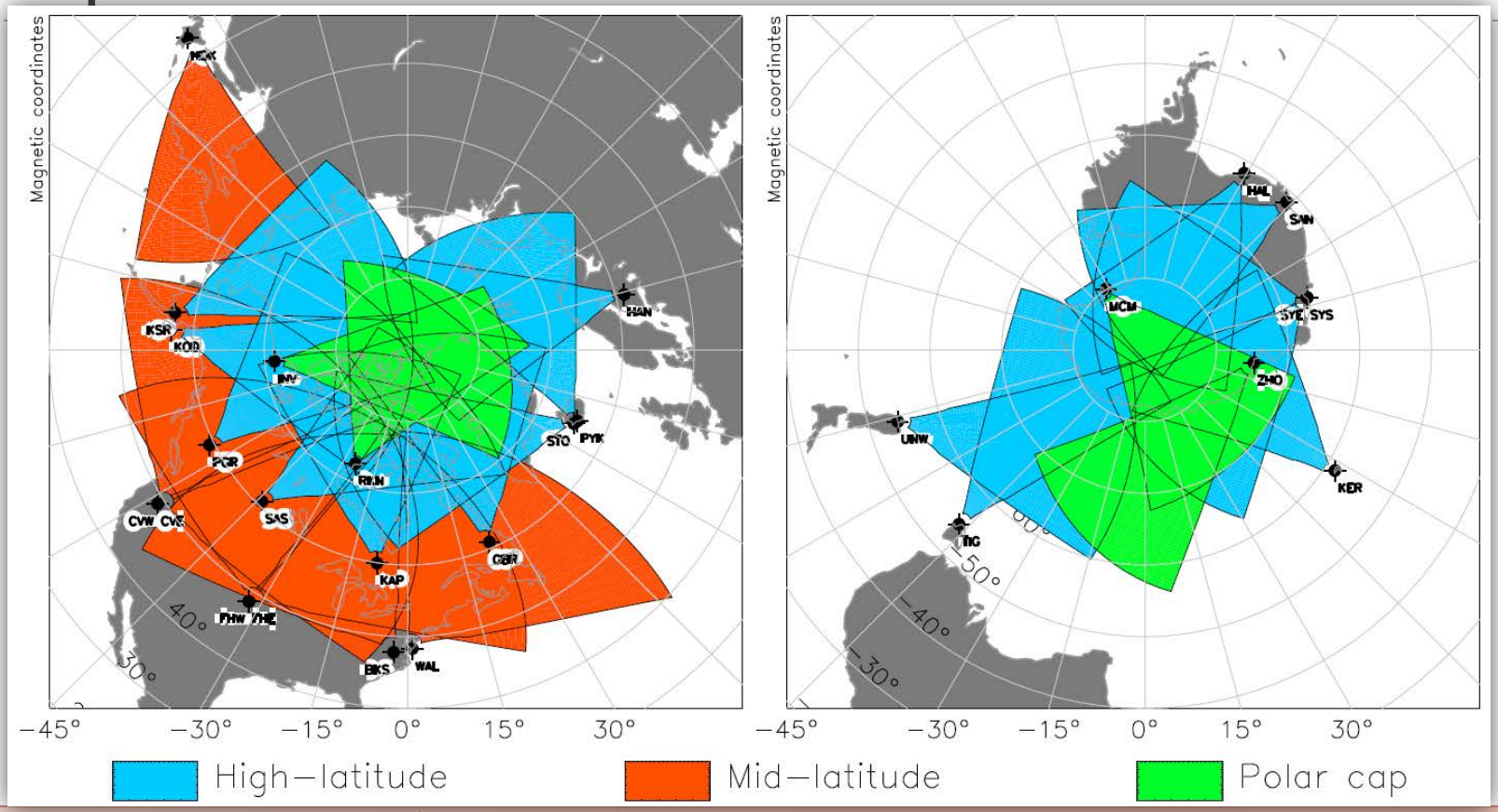
- No study so far on the global structure, especially the night side transient convection.

Open questions to be addressed by the present study

- How do SI transient flows evolve in polar ionosphere?
  - How and to what extent do they migrate to the night side?
- Any difference between SI+ and SI-? Are they just a mirror image of each other?

Present study addresses these issues with a statistical study using SuperDARN data.

Data: SuperDARN



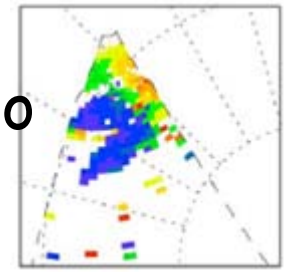
- International network of HF radars
- Measure a light-of-sight velocity of the horizontal ExB drift of ionospheric plasma over ~1000x1000 km^2 area

Analysis:
Identification of SI and SI-associated flow

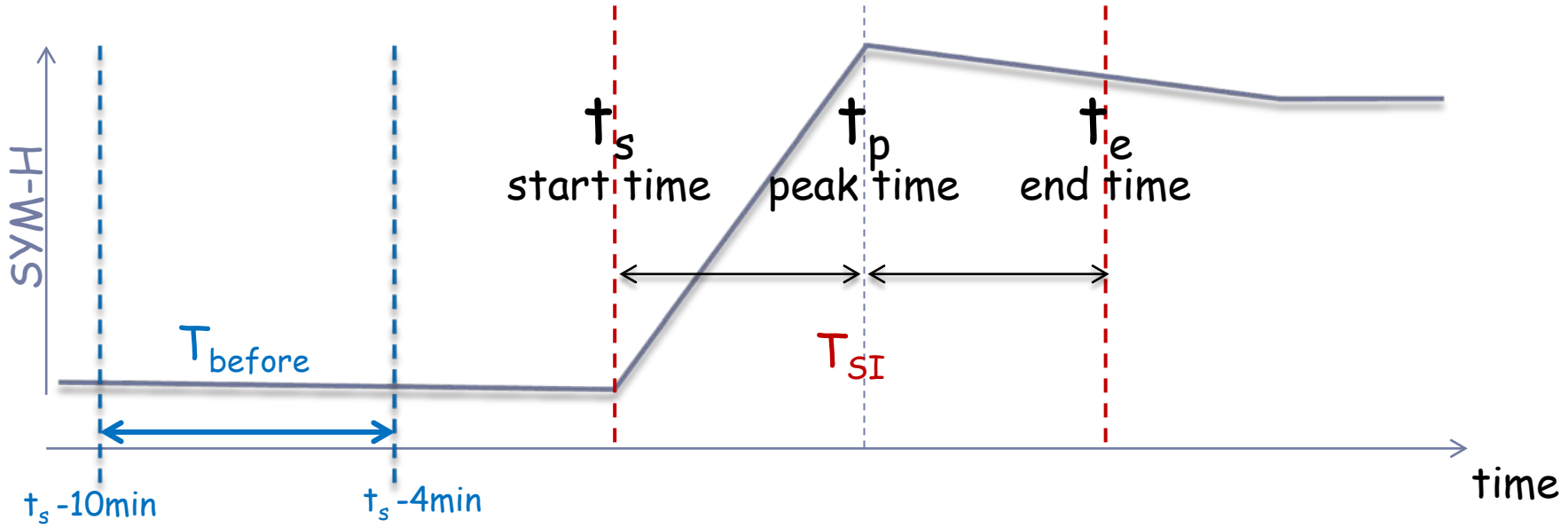
- SI+ and SI- events were identified by the following criteria:
  - ΔSym-H > 5 nT , accompanied by a Pdyn jump in solar wind
  - d(Sym-H)/dt > 0.025 nT/sec (~15 nT / 10 min)
  - d(Sym-H)/dt < 0.015 nT/sec during preceding 40 min
  - Sym-H > -40 nT, AE < 200 nT (Quiet condition)

  → **482 SI events** for Mar2007-Aug2012
  (SI+:256, SI-: 226)

- Doppler velocity of ionospheric echo obtained by all northern hemisphere SD radars are statistically analyzed.
- Original data smoothed spatially to 8x25 pixels to smear out random spikes.

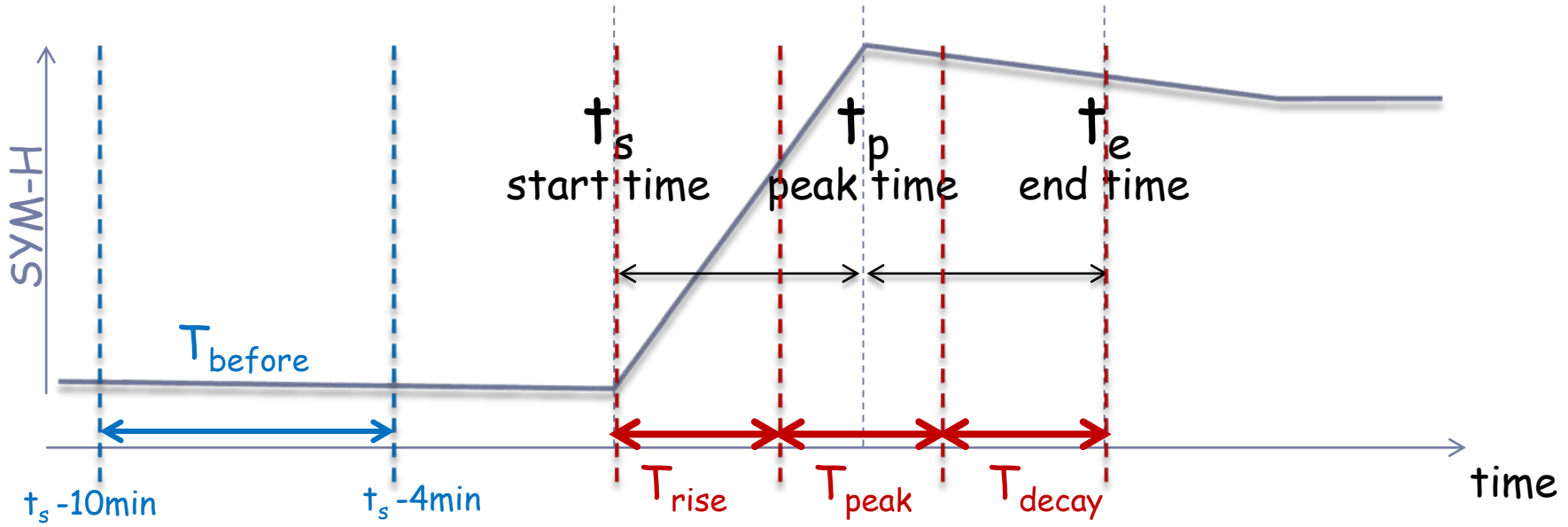


Analysis:
Time binning of SI period for statistics



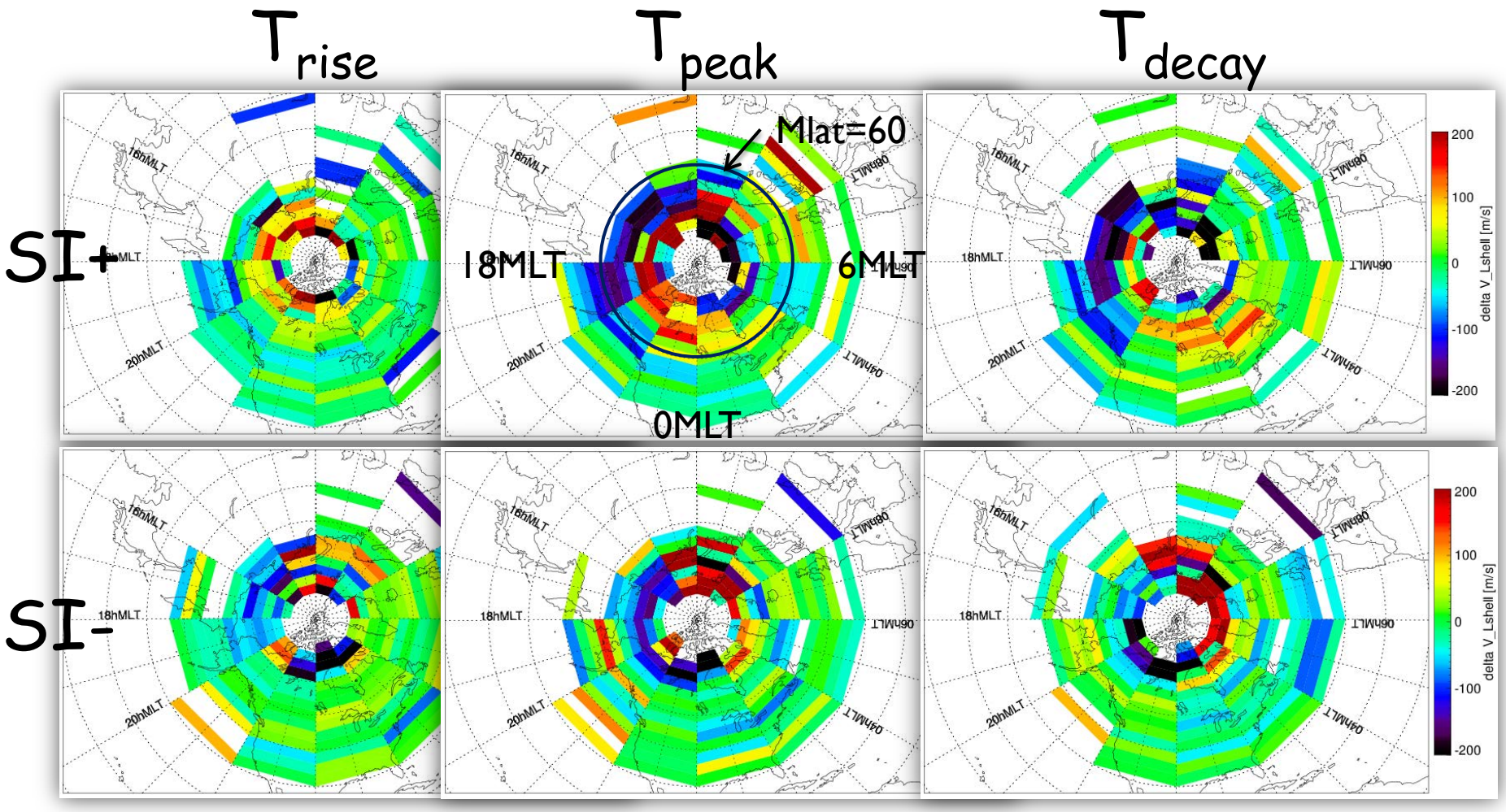
- Define T_{before}, T_{SI}, for each SI event

Analysis:
Time binning of SI period for statistics



- Define T_{before}, T_{rise}, T_{peak}, T_{decay} for each SI event
- We average the difference in flow (T_{rise}, T_{peak}, T_{decay}) from the pre-SI flows (T_{before}) for each SI event enables us to squeeze out MI-associated evolution.

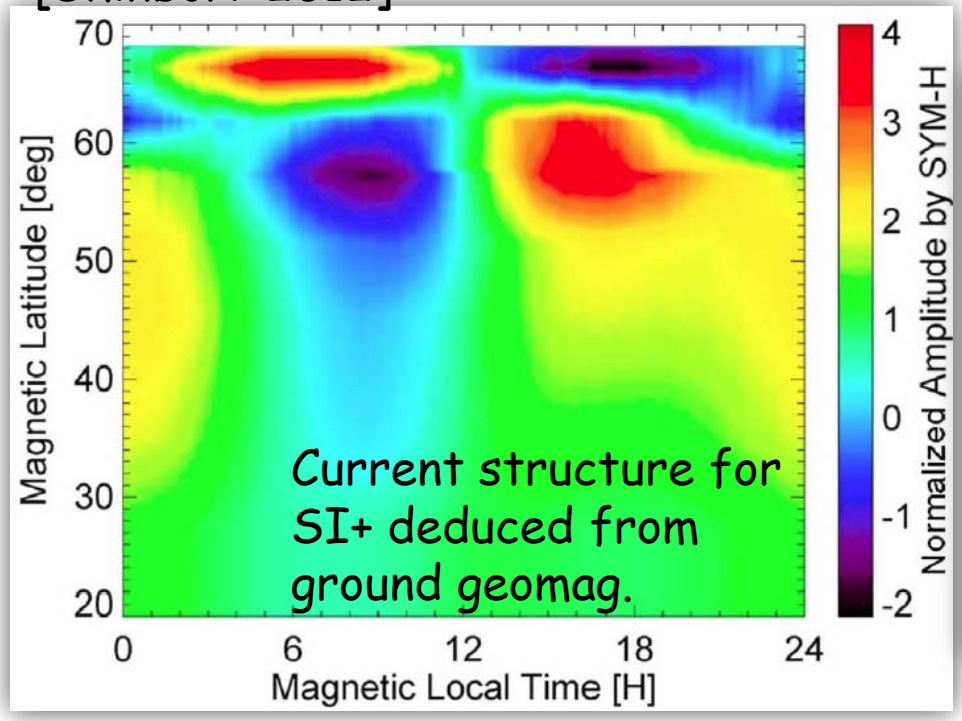
Results:
Evolution of SI flow during main impulse (MI)



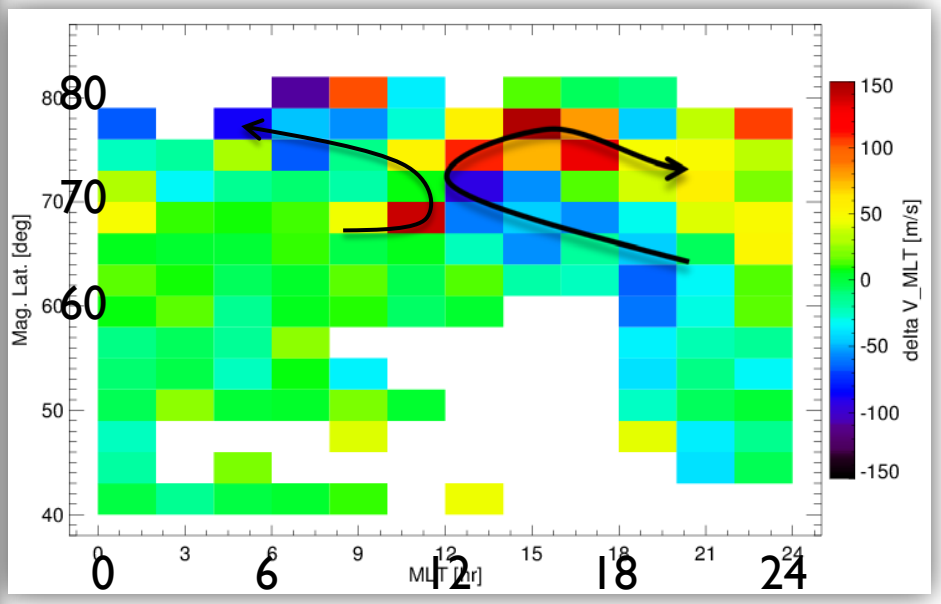
- Difference in convection structure between SI+ and SI- peak

Discussion: Comparison with geomagnetic observations

[Shinbori+2012]



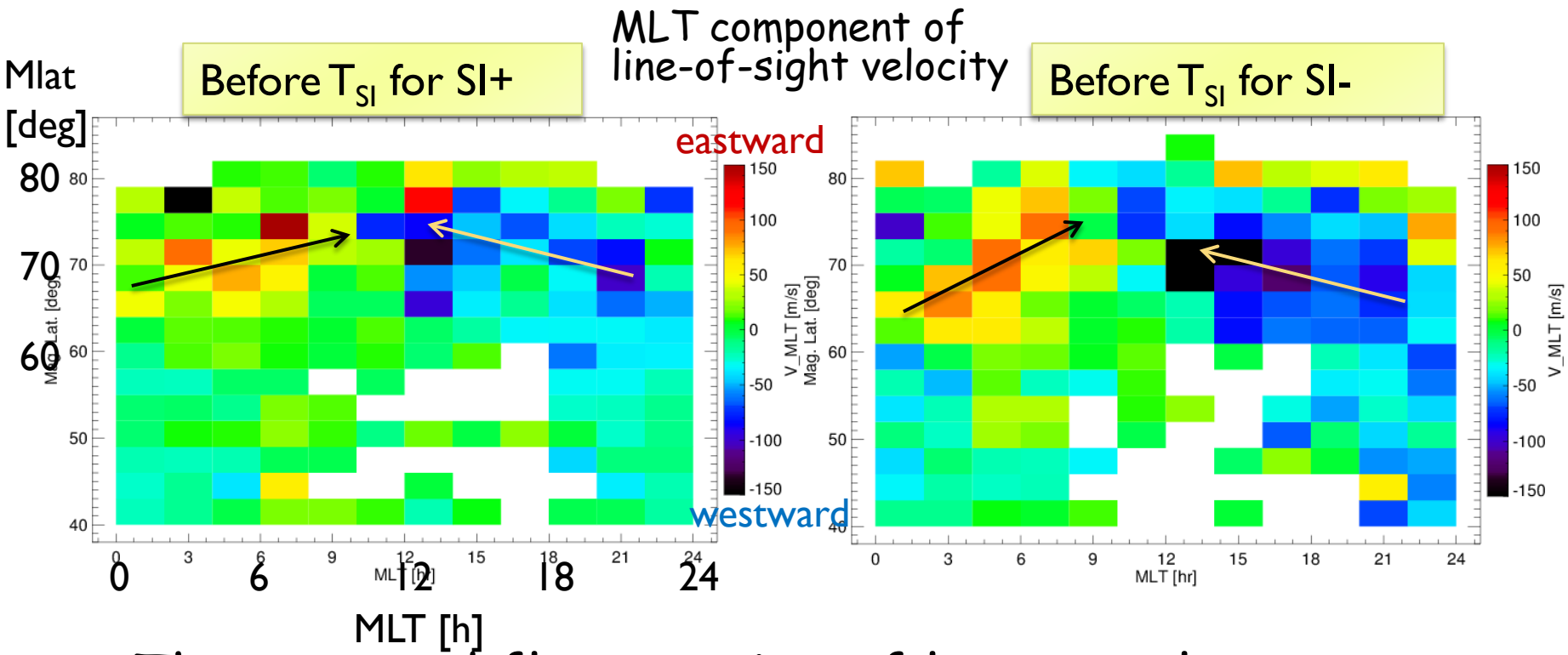
Present result for SI+



MLT [h]

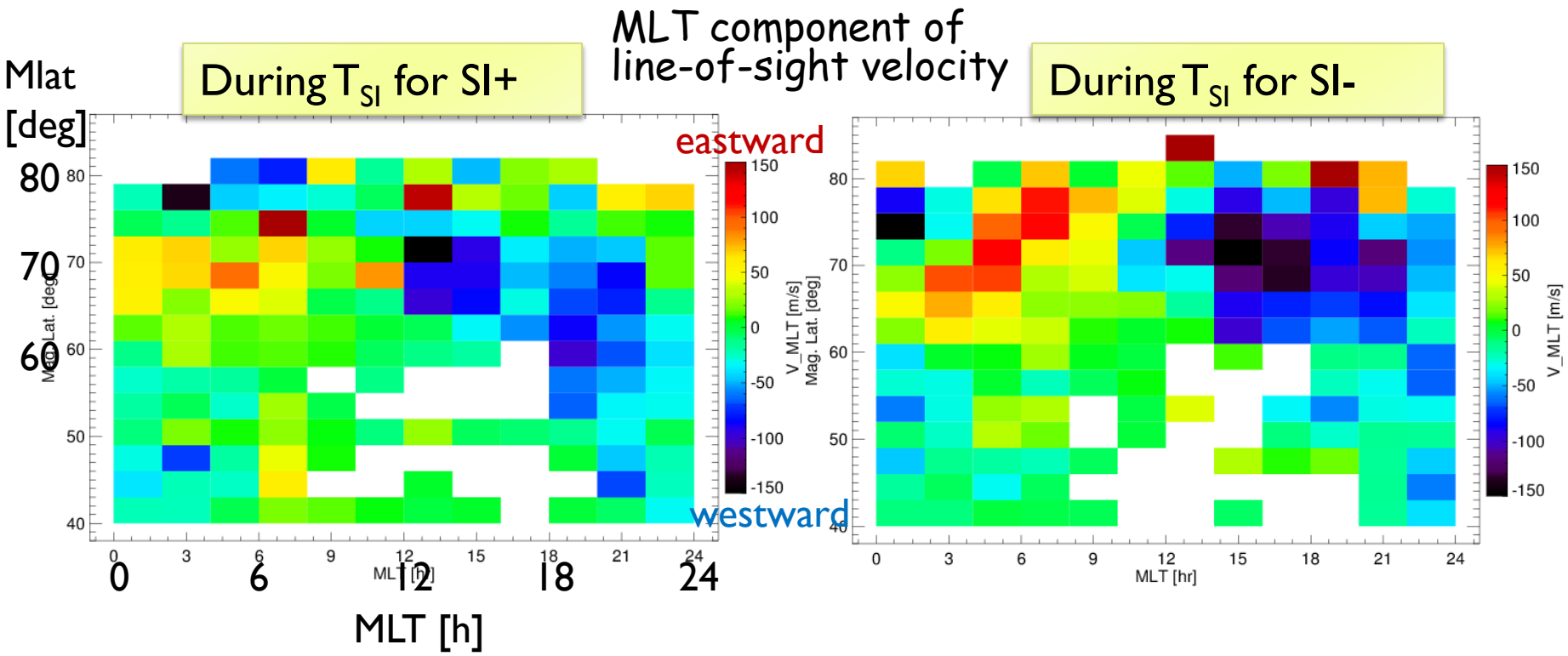
- Overall vortex polarity is consistent.
- Lower lat. flow on dusk by radar extends equatorward across the terminator.
- Lower lat. flow on dawn is missing on radar.
- Discrepancy in latitude

Analysis:
SI transient flow in MLT-Mlat plane



- The sunward flow portion of large-scale convection is obtained as a background.

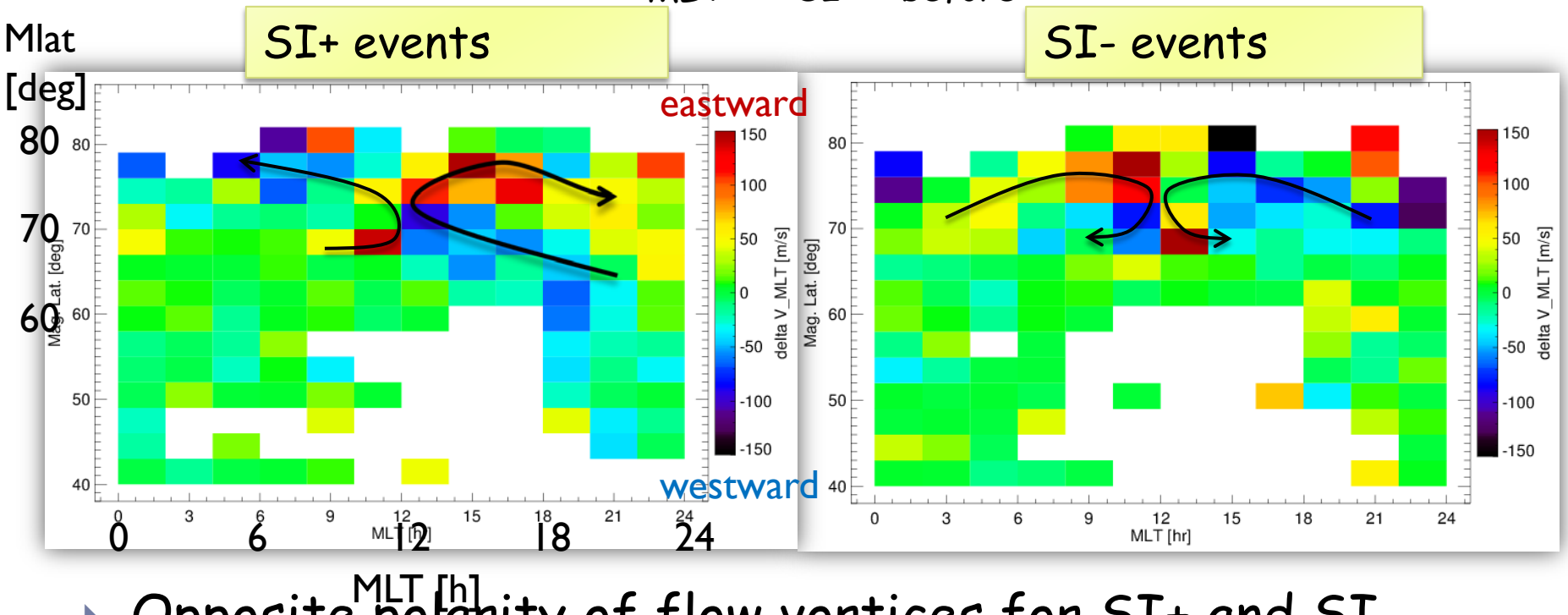
Analysis:
SI transient flow in MLT-Mlat plane



- Roughly similar to the pre-SI flow structure, but …
- Significant enhancement/displacement in the flow structure

Results:
SI transient flow in MLT-Mlat plane

$\Delta V_{MLT}\,(T_{SI}-T_{before})$



- Opposite polarity of flow vortices for SI+ and SI-, consistent with the past geomagnetic obs.
- The higher latitude flow portion extends smoothly to nightside without gaps.

Summary & Conclusion

The SuperDARN data were statistically analyzed to deduce the large-scale structure of transient convection vortices associated with SI.

- The radar observation of flow polarity is consistent with that obtained by the past studies based on ground geomagnetic fields.
- The evolution toward nightside is faster for SI+ than SI- by referring to SYM-H variation.
- The lower lat. portion of vortices are unclear except for SI+ dusk.
- SI+ and SI- do not give a mirror image of flow structure for each other.

- Future works
  - Dependence on Solar wind-IMF conditions
  - Seasonal variations