Ionospheric electric field oscillation associated with Sudden Commencement seen by SuperDARN radars and ground magnetometers
大型短波レーダーや地上磁場で観測されるSudden Commencementに伴う電離圏対流変動

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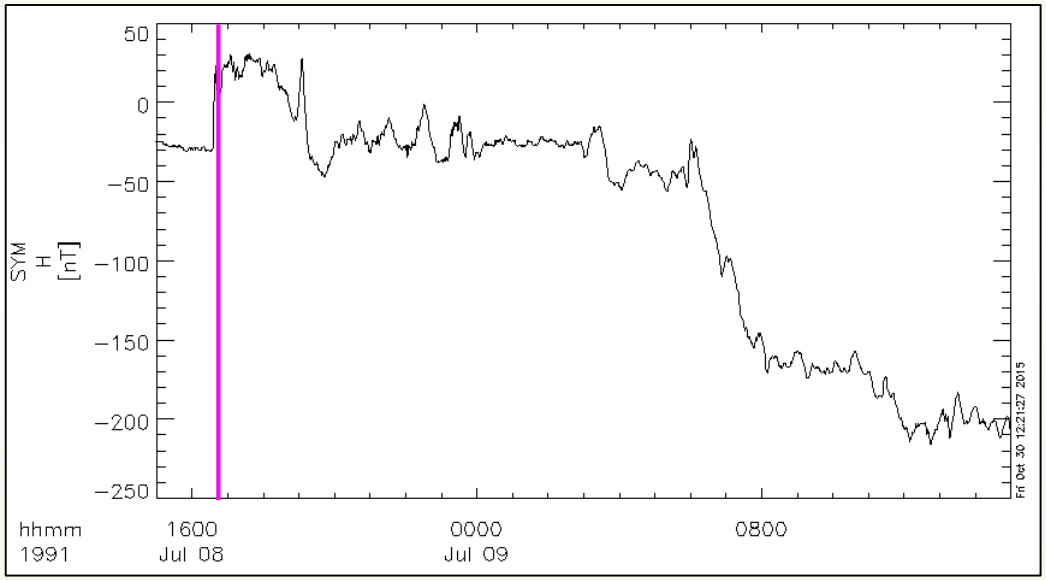
Sudden Commencement

quiet day

SC event day

Sudden Commencement (SC) is observed as a sudden increase of H-component often seen at low latitudes.



SYM-H index for July 8-9, 1991

Rapid compression of the magnetosphere caused by the passage of the interplanetary shock

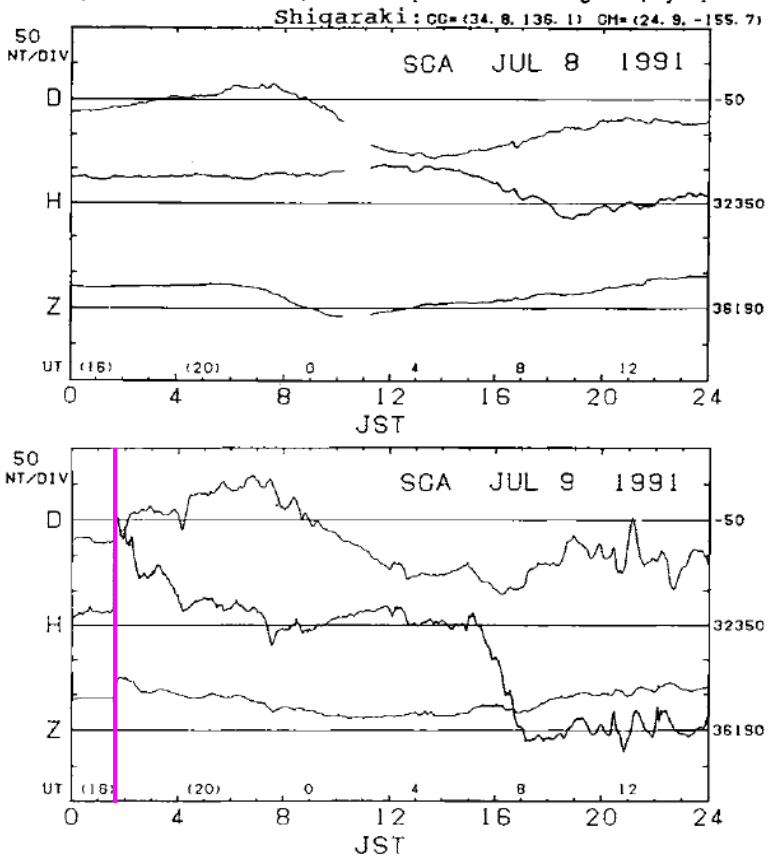
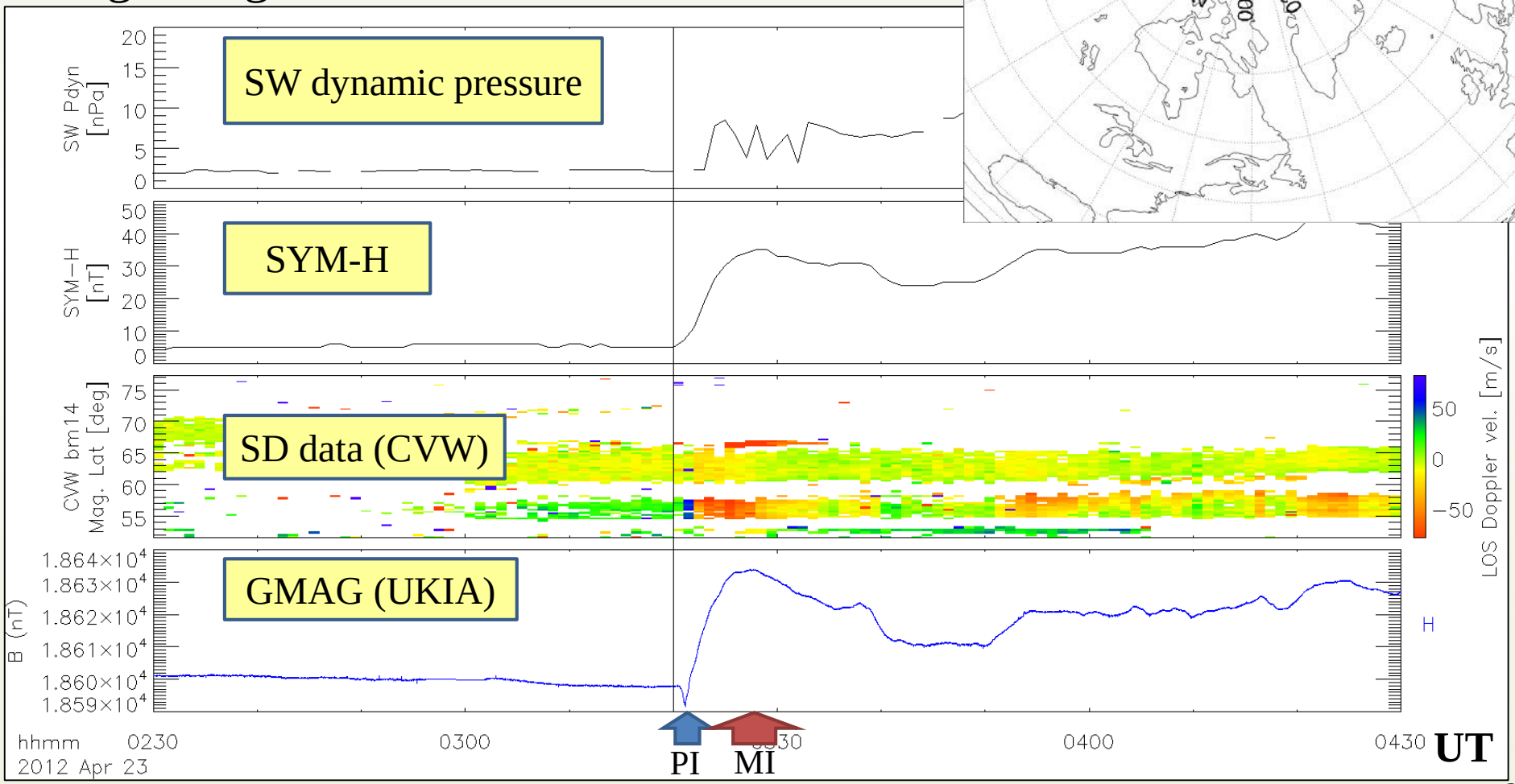


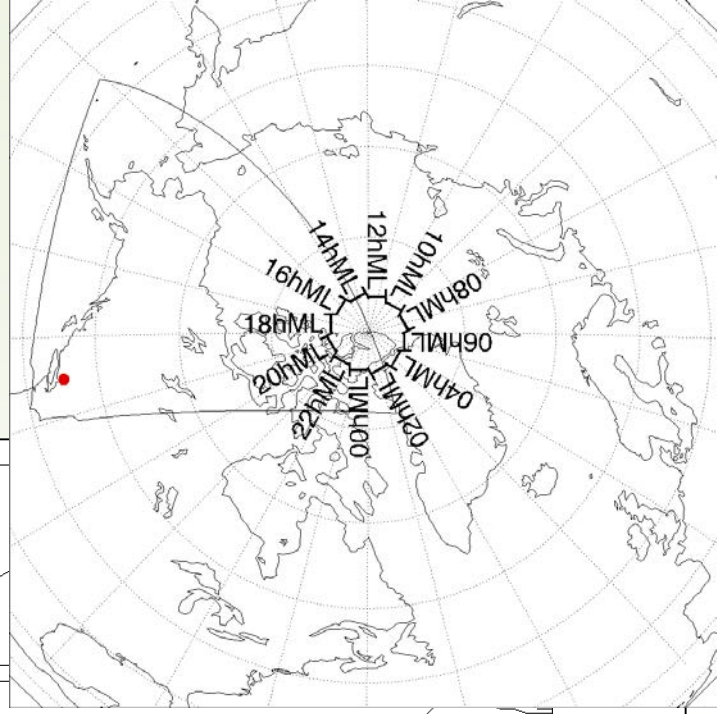
Fig. 1. Lower panel: The ground magnetogram for July 9, 1991 at Shigaraki (geomag. lat. : 24.9°), Japan. An SC occurred at 0130 UT and is followed by a geomagnetic storm. Upper panel: The magnetogram for the previous quiet day for reference.

[Araki, 1994]

- The typical reaction of SCs in the auroral and mid-latitudes

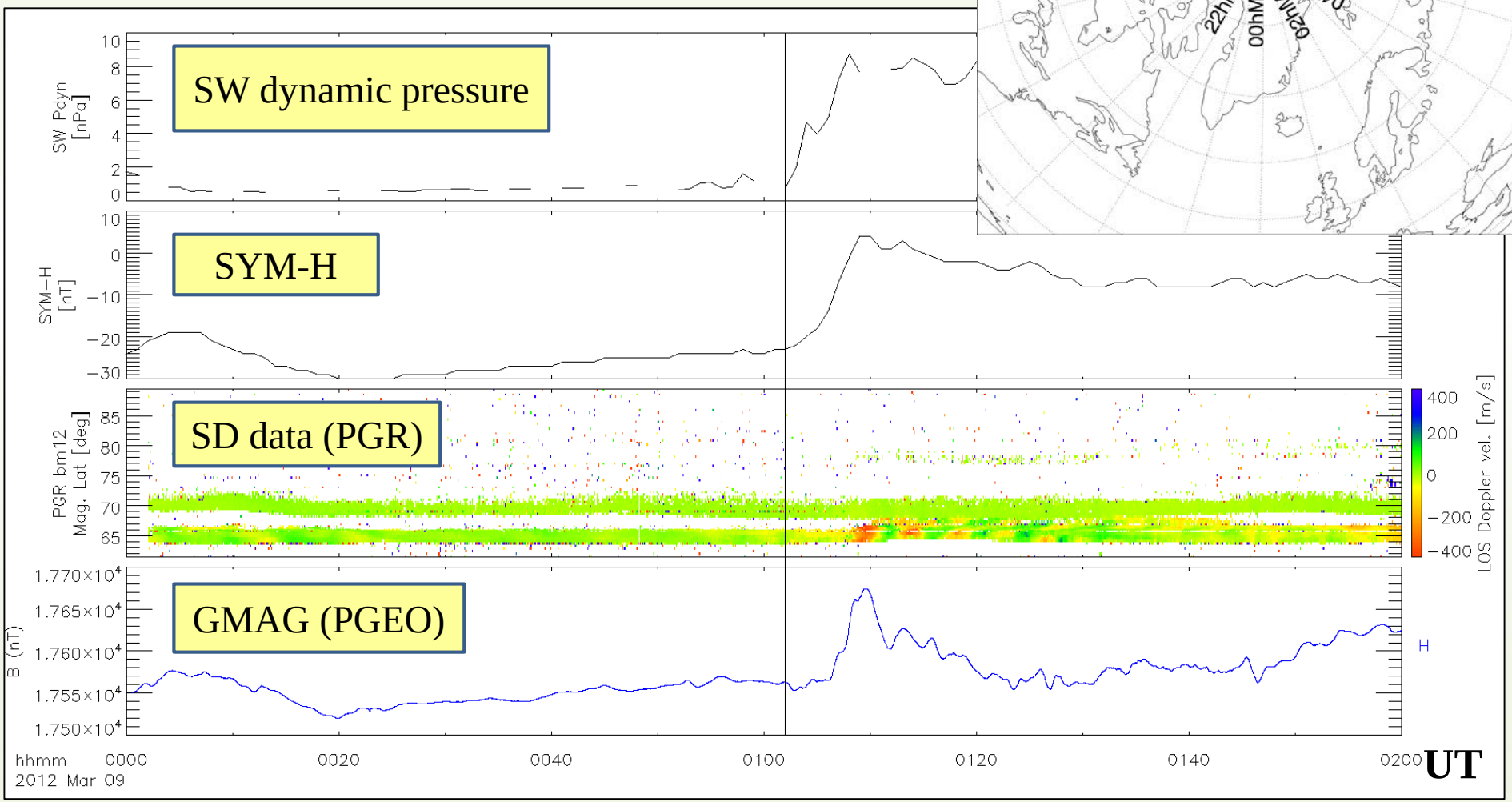
Most of SCs consist of (PI) and MI signatures in the ionospheric electric field, in agreement with geomag. observations.

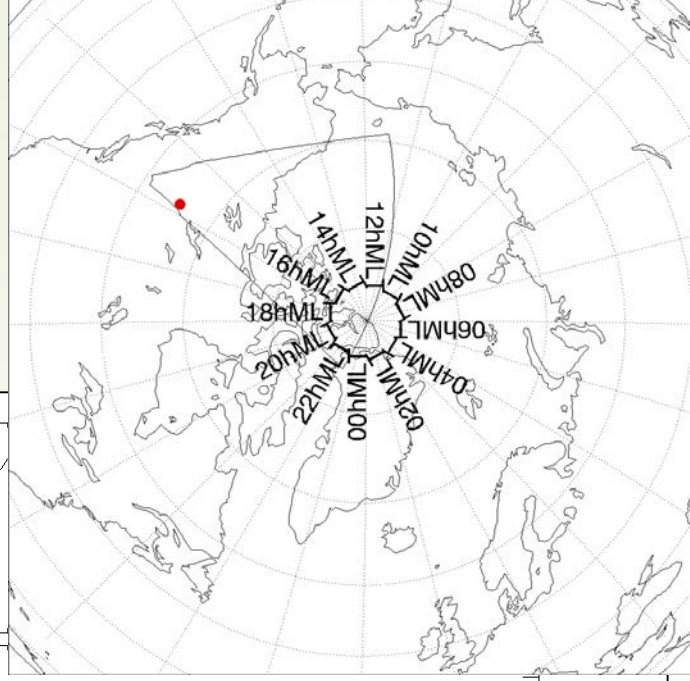




Ionospheric E oscillation associated with SCs

Some SC events are occasionally accompanied by oscillations of the ionospheric electric field.





Purpose of this study

- Previous studies report that oscillations associated with SC are seen by not only geomagnetic observations, but also SuperDARN radar observations in the ionosphere. [Thorolfsson+2001; Hori+2012; Liu+2013]

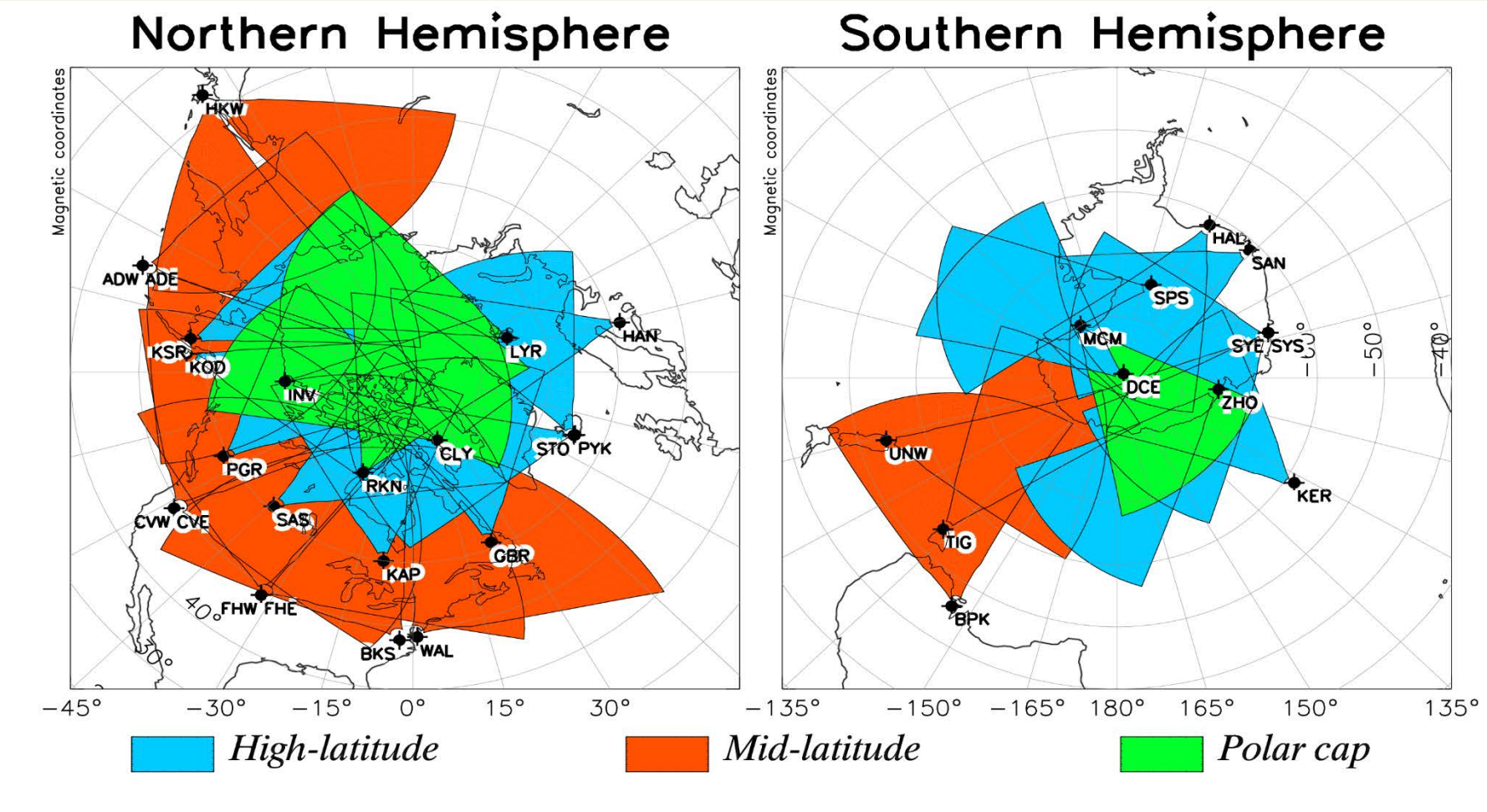
- Two types of SC event :
  - those followed or not followed by oscillations

- But triggering condition(s) of the difference has not been understood well.
  - There are few studies focusing on the triggering condition of the E-field oscillation.

We examine statistically the cause of the oscillation of SC events, using SuperDARN data.

Super Dual Auroral Radar Network

Operates between 8-20MHz



Number of operating HF radars: 35 (23 in the northern and 12 in the southern hemispheres) as of Oct. 20, 2016

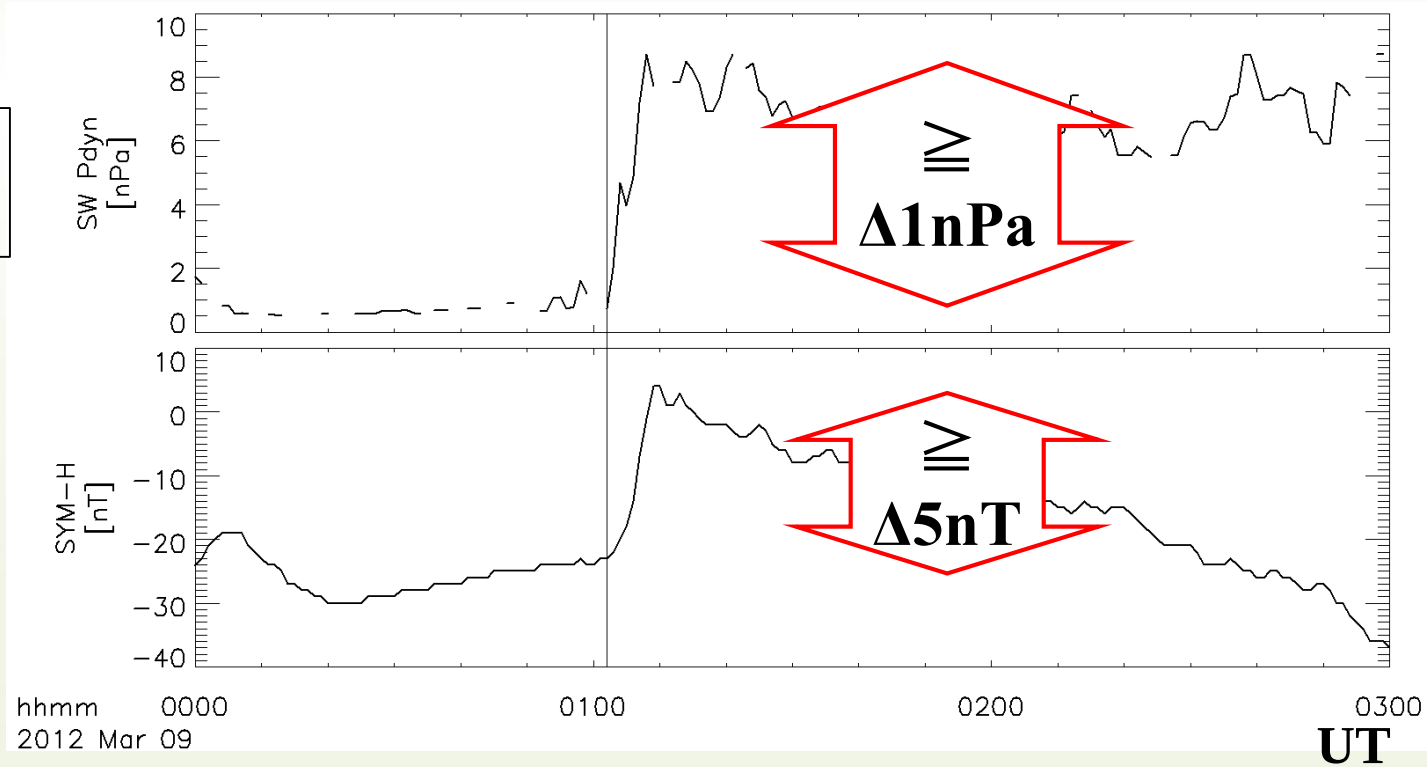
Standard temporal resolution: 1-2 min

Identification of Sudden Commencement

- Criteria
  - Check both sudden increase of the solar wind dynamic pressure and SYM-H
  - Rise time less than 10 minutes

solar wind dynamic pressure

SYM-H

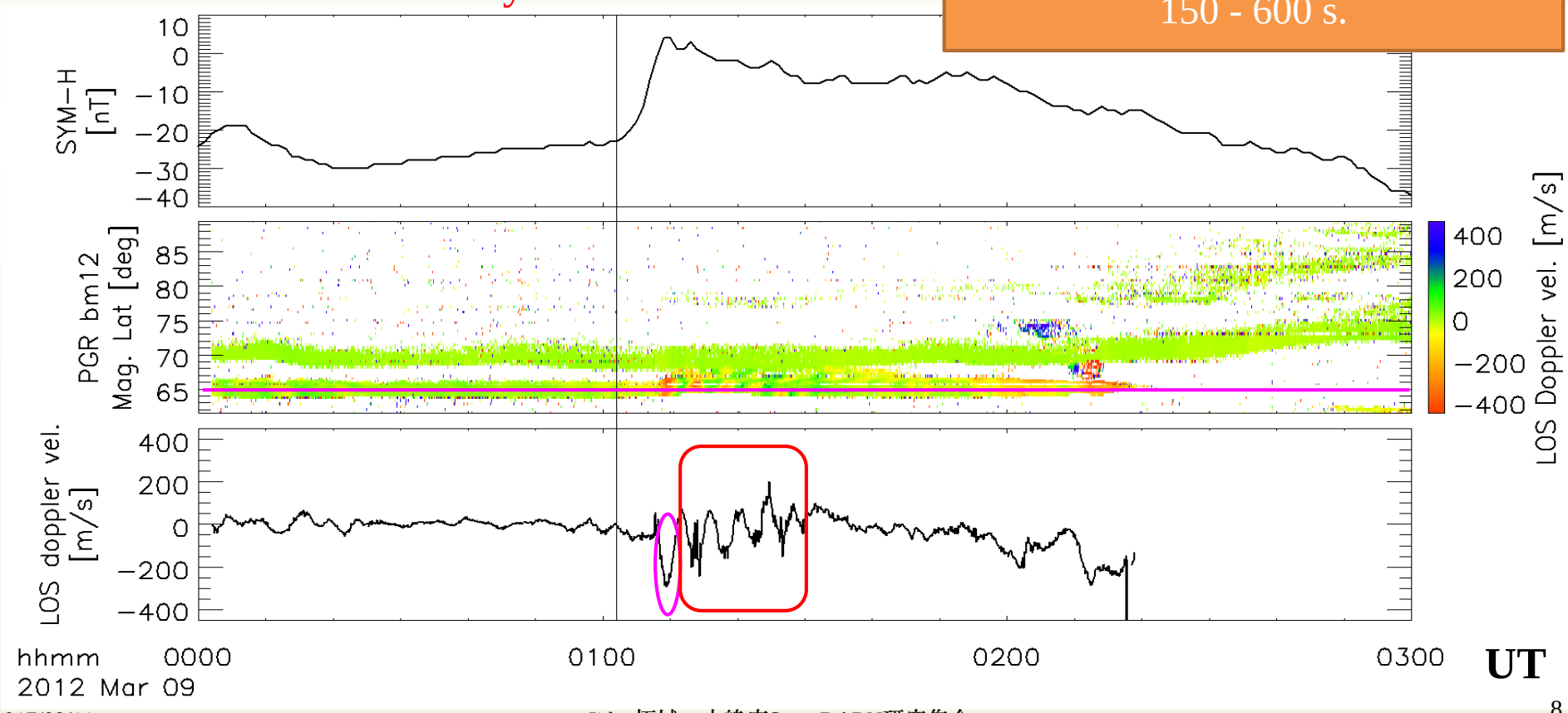


Identification of the ionospheric electric field oscillation seen by SuperDARN radar

- Criteria
  - Line-of-Sight Doppler Velocity
    - Oscillation amplitude > $\frac{1}{5} \times$ MI's amplitude
  - Needs at least two cycles of oscillation

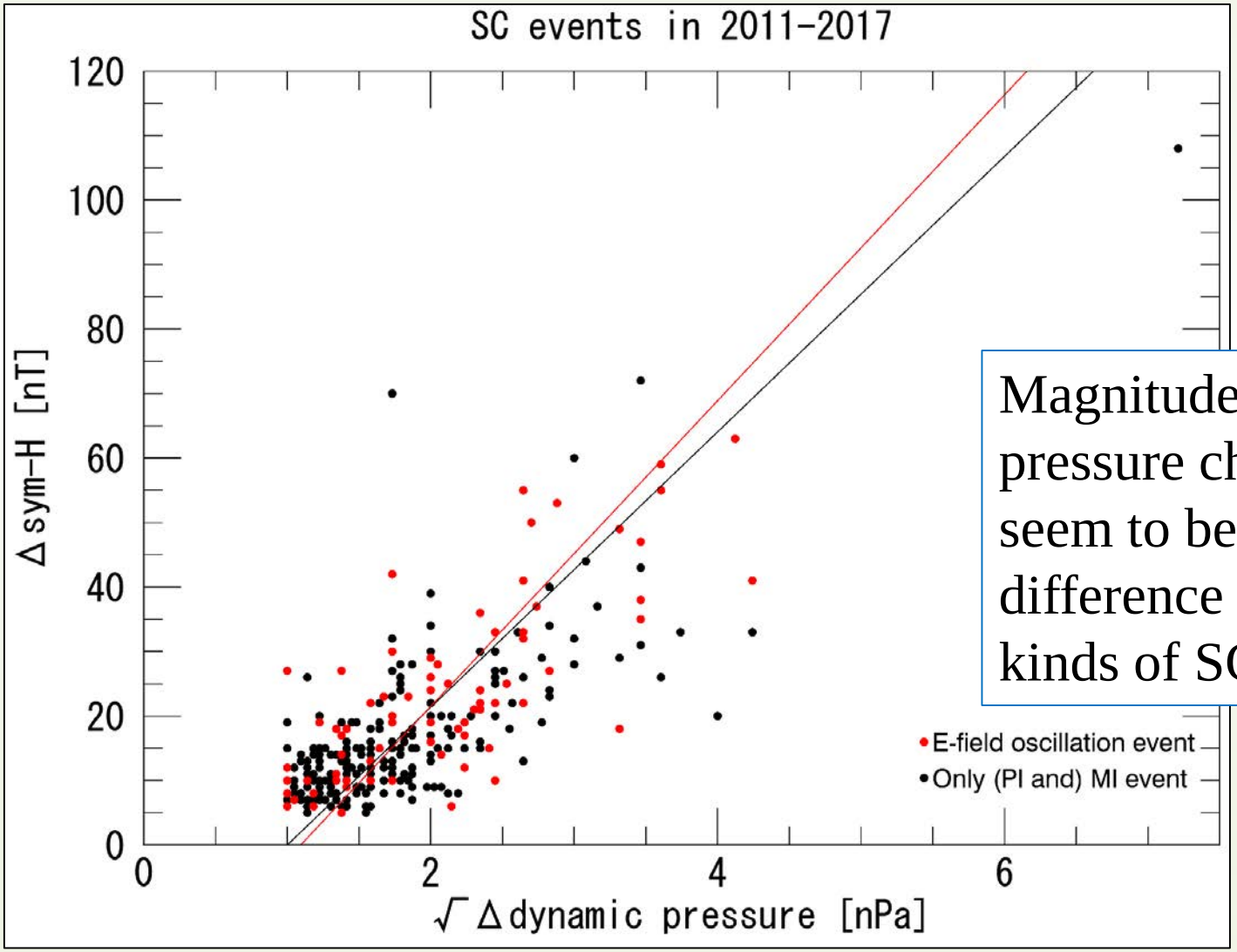
We call this type of SC "SC oscillation event" identified separately for each radar.

E-field oscillation period is mainly 150 - 600 s.



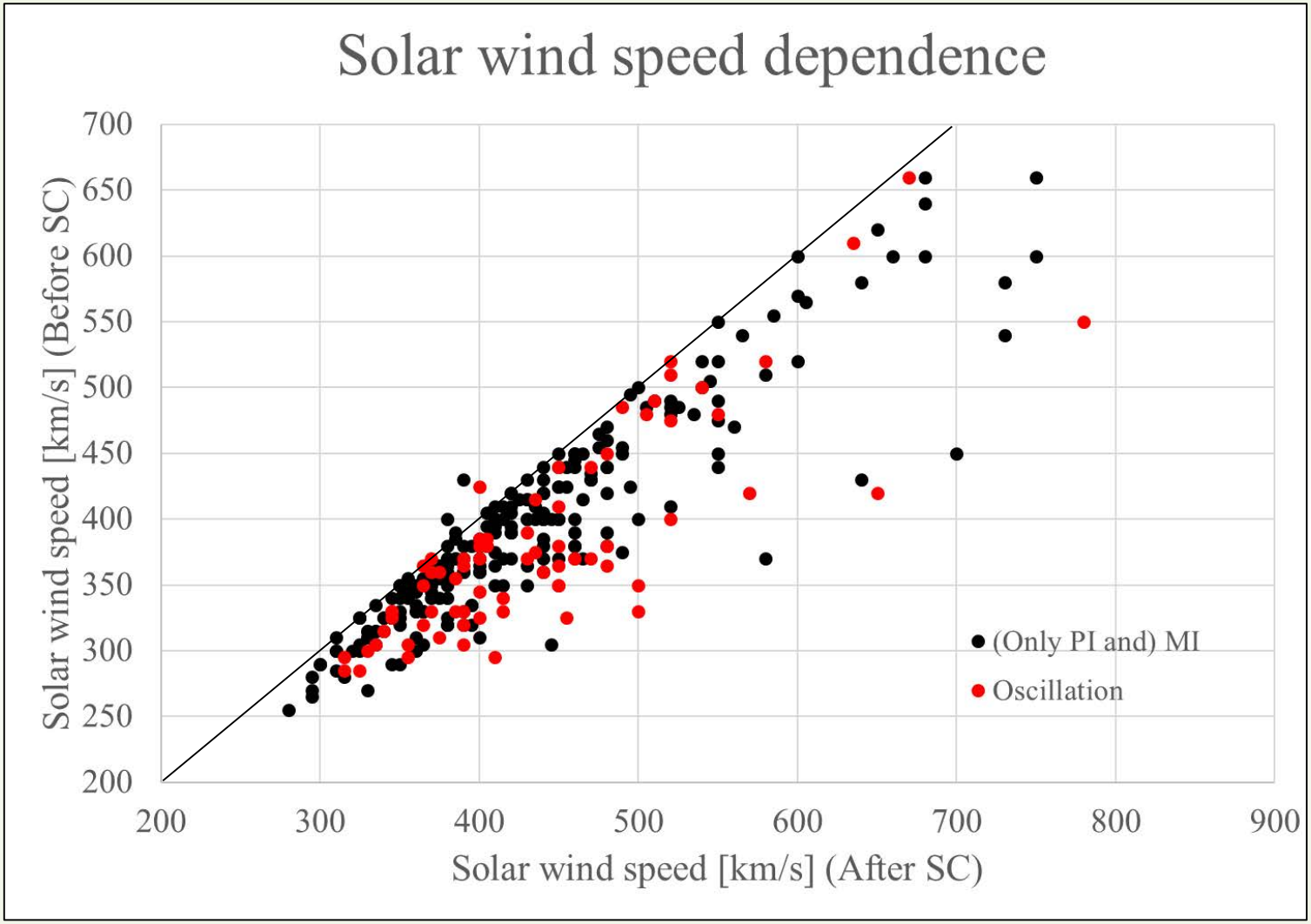
SC events from Jan. 1, 2011 to Jun. 30, 2017 (309 events)

- The relation between ΔSYM-H and the square root of Δ(solar wind dynamic pressure)



Magnitude of dynamic pressure change does not seem to be the cause of the difference between two kinds of SC events.

Solar wind speed dependence



Average of SW speed (Before SC)
- 394.1 [km/s]
- 382.8 [km/s]

Average of SW speed (After SC)
- 429.8 [km/s]
- 438.6 [km/s]

Average of ΔSW speed
- 35.7 [km/s]
- 55.8 [km/s]

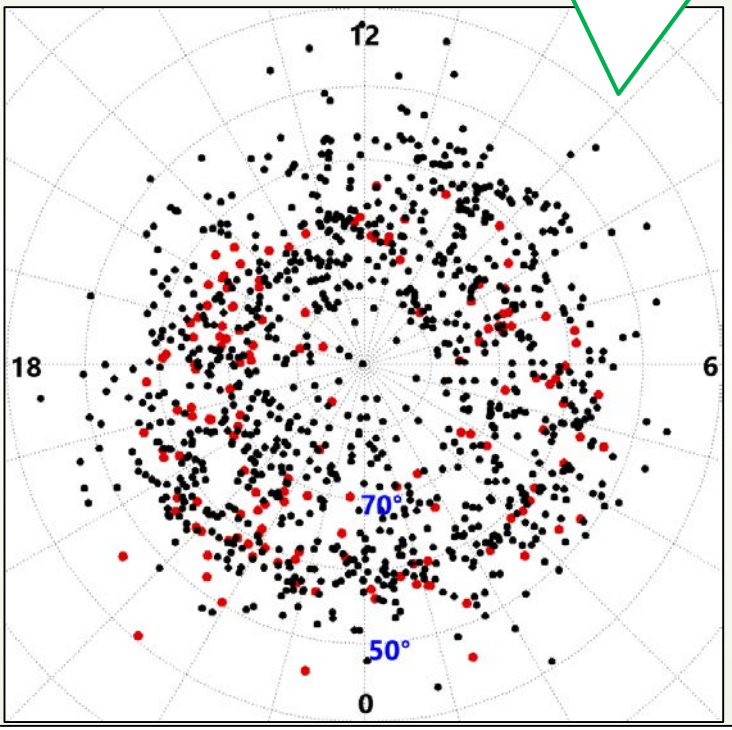
- Result of the t-test
  - ΔSW speed difference was statistically significant.

Magnetic local time dependence

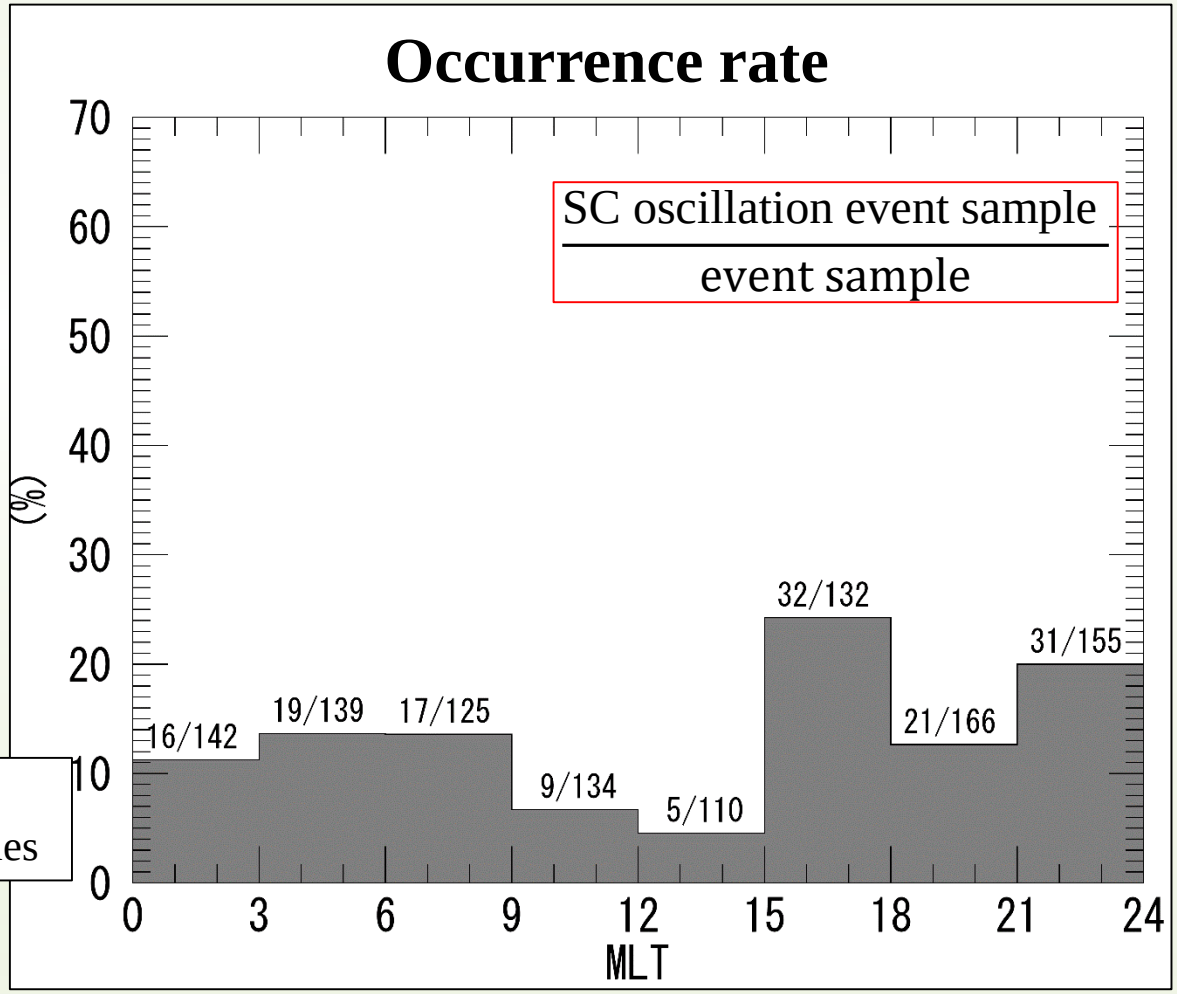
SC-associated E oscillations do not have very strong dependence on MLT.

1103 samples in 2011-17

Disturbance location



Red dots : SC oscillation event samples
Black dots : Only (PI and) MI event samples

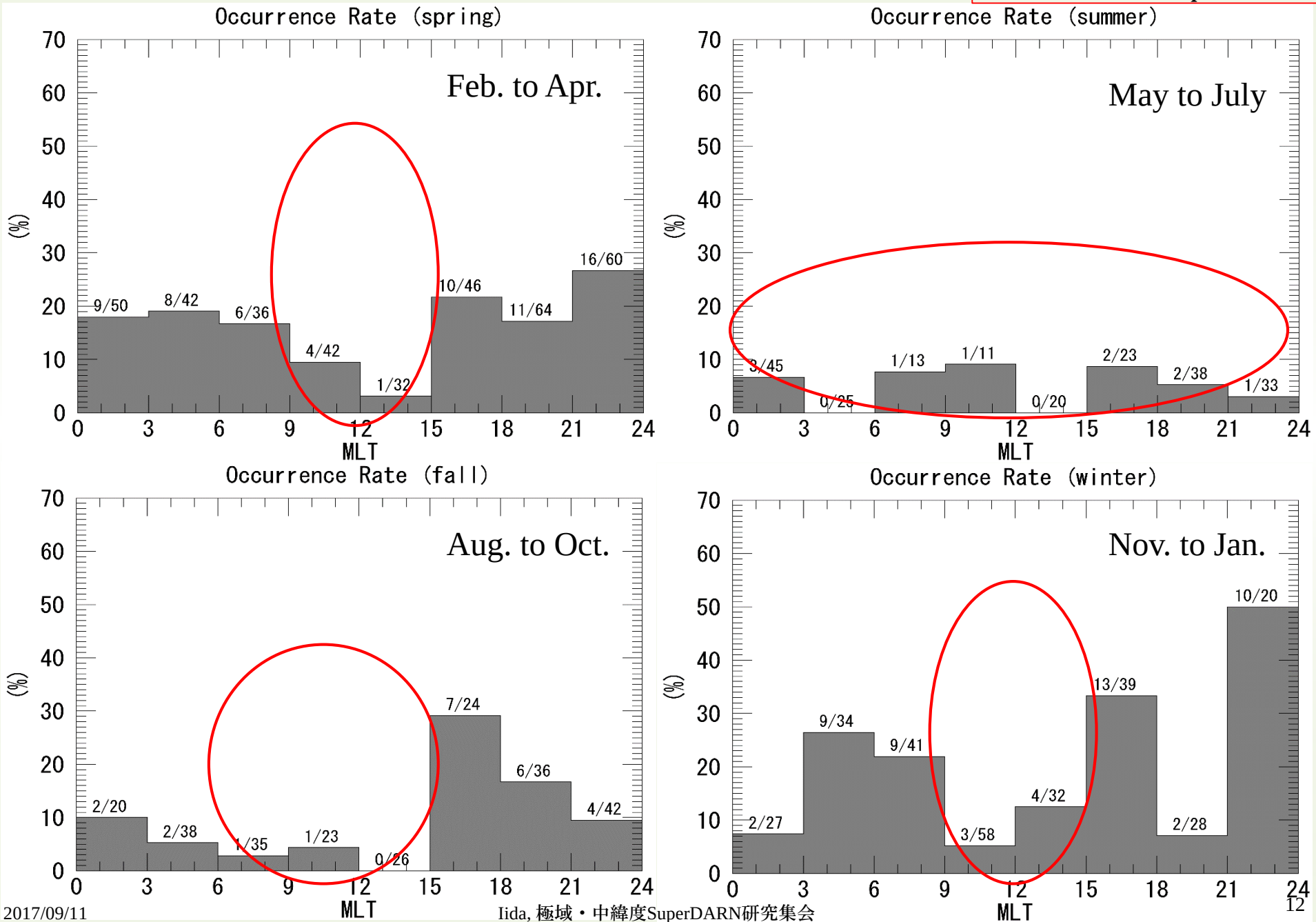


including ground scatter events

geomagnetic coordinates

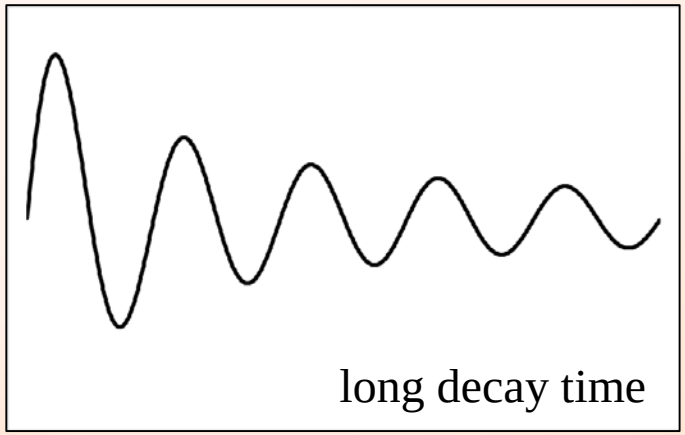
Seasonal Variation

$$\frac{\text{SC oscillation event sample}}{\text{event sample}}$$



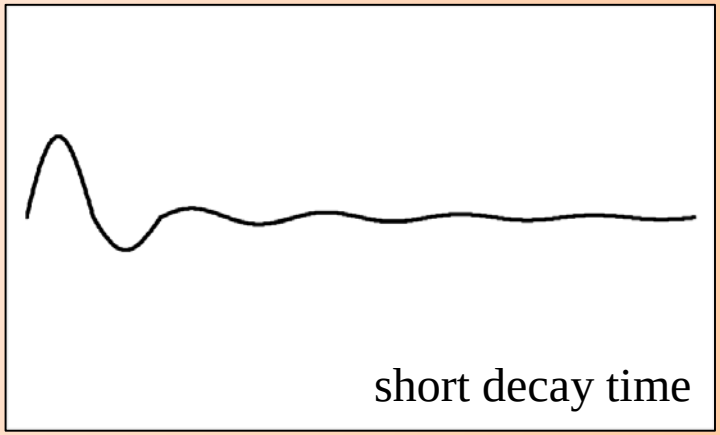
Why is the occurrence rate lower in the summer ?

low Joule heating



E-field

high Joule heating



Joule heating is high
(→Power consumption is large)

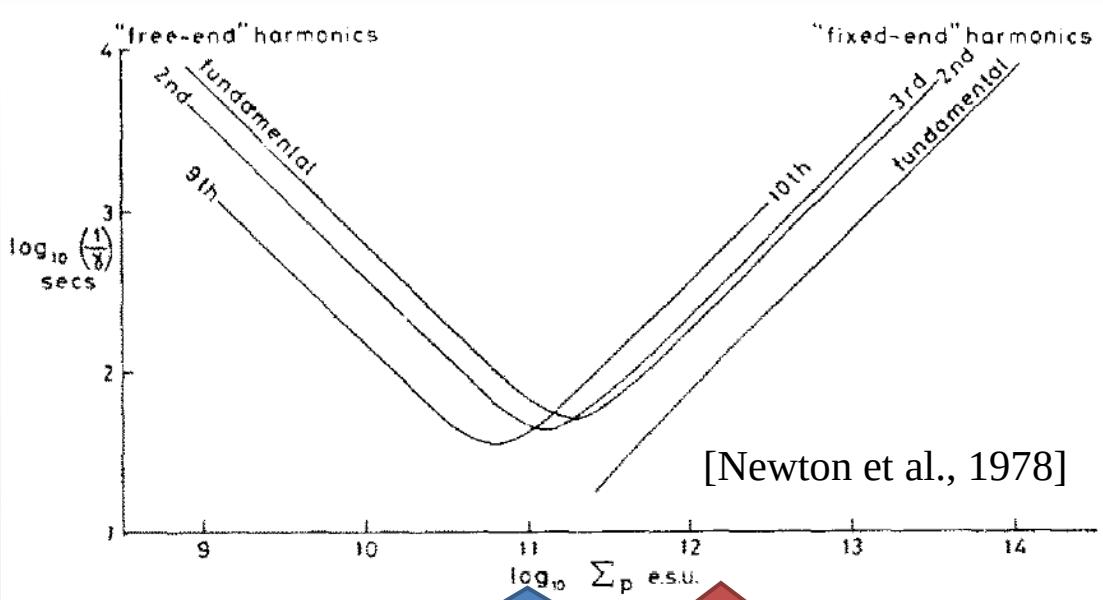
→ The damping rate is high

- In the northern hemisphere, the daytime hours in summer are longer than in winter. Also, the electron density in the dayside sector is higher than the nightside sector.

The Pedersen conductivity → high (dayside, summer)
The Pedersen conductivity → low (nightside, winter)

Why is the occurrence rate lower in the summer ?

- Newton et al. [1978] reported that the damping rate of the oscillation in the dayside ionosphere is inversely proportional to the Pedersen conductivity in the ionosphere. ($\Sigma_p > 10^{12}$)
- Also, in the nightside, the typical height integrated ionospheric Pedersen conductivity is $\Sigma_p \sim 10^{11}$.



[Newton et al., 1978]

nightside dayside

This tendency of the damping rate is opposite to our study.

Summary

- We analyzed statistically SC-associated electric field oscillations observed by the SuperDARN radars from Jan. 1, 2011 to Jun. 30, 2017.

- The difference of the solar wind speed before and after SC is about 20 km/s, and the result of t-test is statistically significant.
- The occurrence rate of the electric field oscillation is higher in the night sector than in the dayside sector. Also, the occurrence rate of seasonal variation is higher in the winter than in the summer.
  - If the Joule heating is high, the electricity consumption in the ionosphere is large. Then the decay time of the oscillation is shorter.

→But the previous study of the damping rate is opposite to our study.

Future work

- To analyze the difference between global oscillation events and local oscillation events
- To examine the E-field oscillation event in detail