Statistical study of mid- and low-latitude electric field response corresponding to the CW structure during substorms

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Current systems during substorm

(1) SCW (Substorm Current Wedge)

- Formed at the beginning of substorm
- Connecting the nightside ionosphere to the magnetospheric tail

(2) R1, R2 type ionospheric current

- Reflect magnetospheric convection
- Developed before and during substorm

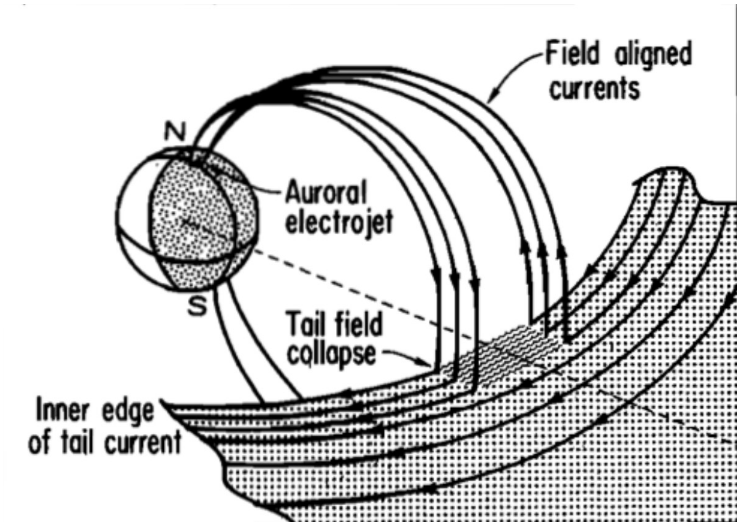
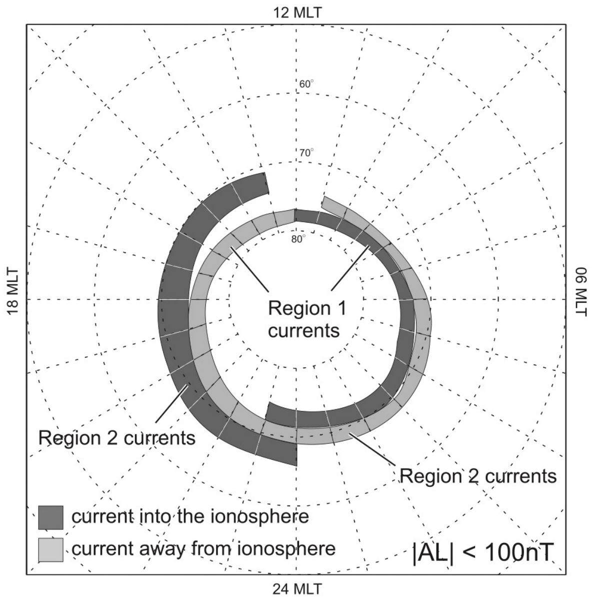


Fig.1. A perspective view of the substorm current wedge. [McPherron et al., 1973]



※ R1: Region 1
R2: Region 2

Fig.2. The amplitude distribution of field-aligned currents at northern high latitudes observed by Triad. [Iijima and Potemra, 1976]

How do these currents affect the magnetic and electric fields at mid and low latitudes?
How do these currents connect to the global current system?

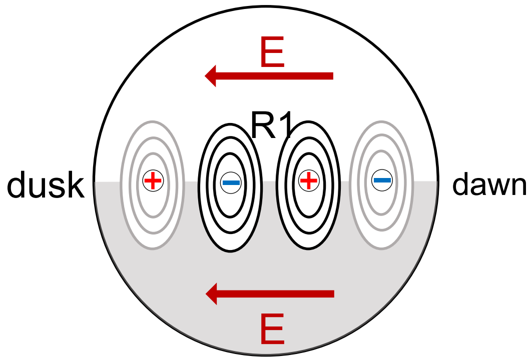
Electric field related to substorms

◆Growth phase

Magnetospheric convection grows (due to IMF Bz southward turning)

→**R1 type electric field** increases. It penetrate the mid and low latitudes[Kelley et al., 1979, Gonzales et al., 1979, Fejer et al., 1979]

< R1 type electric field >

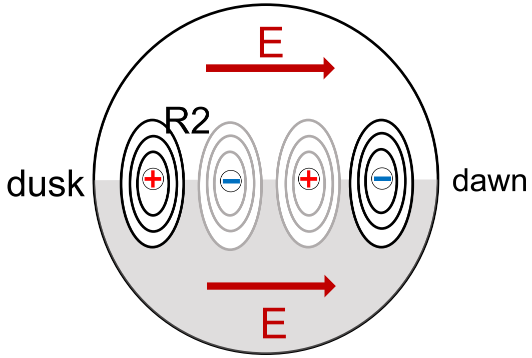


◆Expansion phase

Magnetospheric convection weakens (due to IMF Bz northward turning)

→R1 type electric field decreases and **R2 type electric field shields or exceeds R1 type electric field**. This also penetrates to mid and low latitudes[Somajajulu et al.,1987, Kikuchi et al., 2000, Peymirat et al., 2000]

< R2 type electric field >



◆Recovery phase

Magnetospheric convection weakens

→R1 type electric field decreases and **R2 type electric field shields or exceeds R1 type electric field.** [Hashimoto et al., 2017]

Motivation

◆Under the steady southward IMF condition

- The substorm onset provides **R1 type electric field** on the dayside [Huang et al., 2004, Huang, 2009]

- **Overshielding(R2 type electric field)** occurs with substorms [Hashimoto et al., 2011; Wei et al., 2009]

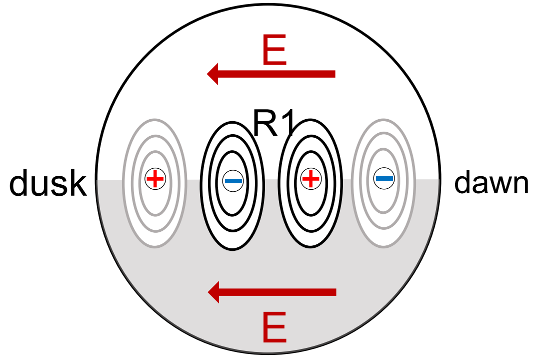
◆IMF change and substorms, electric field

- EEJ decreases within 1 min with IMF Bz southward turning(R2-type electric field effects)

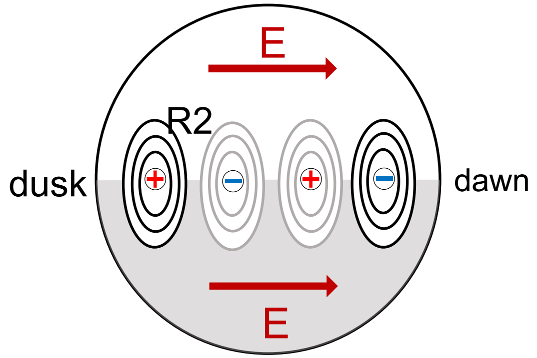
→ (if EEJ decrease is explained by substorm-related overshielding,) substorm onset is random for IMF Bz southward turning, but onset of EEJ decrease is often coincident with $\Delta t = 0$ [Ohtani et al,.2013]

There are still questions about the electric field at low latitudes during substorm

< R1 type electric field >



< R2 type electric field >



Purpose

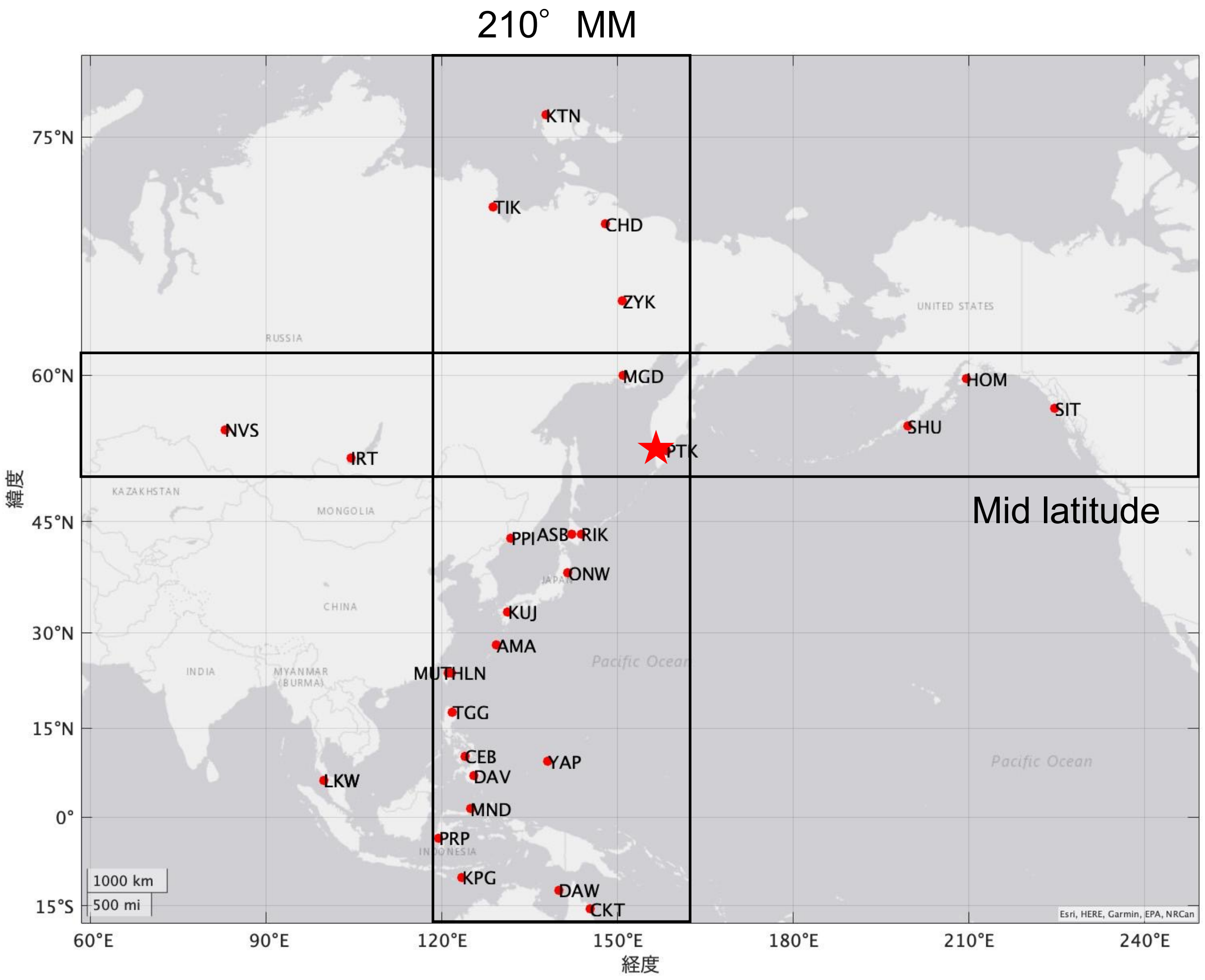
◆<u>Comprehensive understanding of electric field during substorms</u>

→For isolated substorm events, we analyze the

- Mid-latitude electric field variations using HF Doppler radar
- Global ground magnetic field
- Potential map plots and HF radar in Hokkaido(SuperDARN).

and investigate the global electromagnetic field response to current development in the polar regions.

Dataset

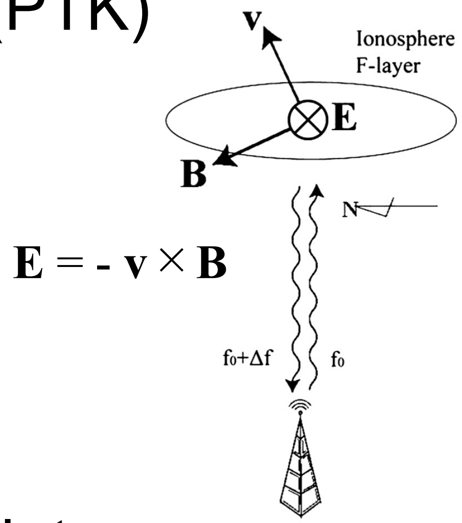


Electric field observed by HF Doppler

★Palatunka in Russia (PTK)

GMLat : 45.75

GMLon : 221.45



Ground magnetic field data

● 210°　MM, Mid latitude

Dataset

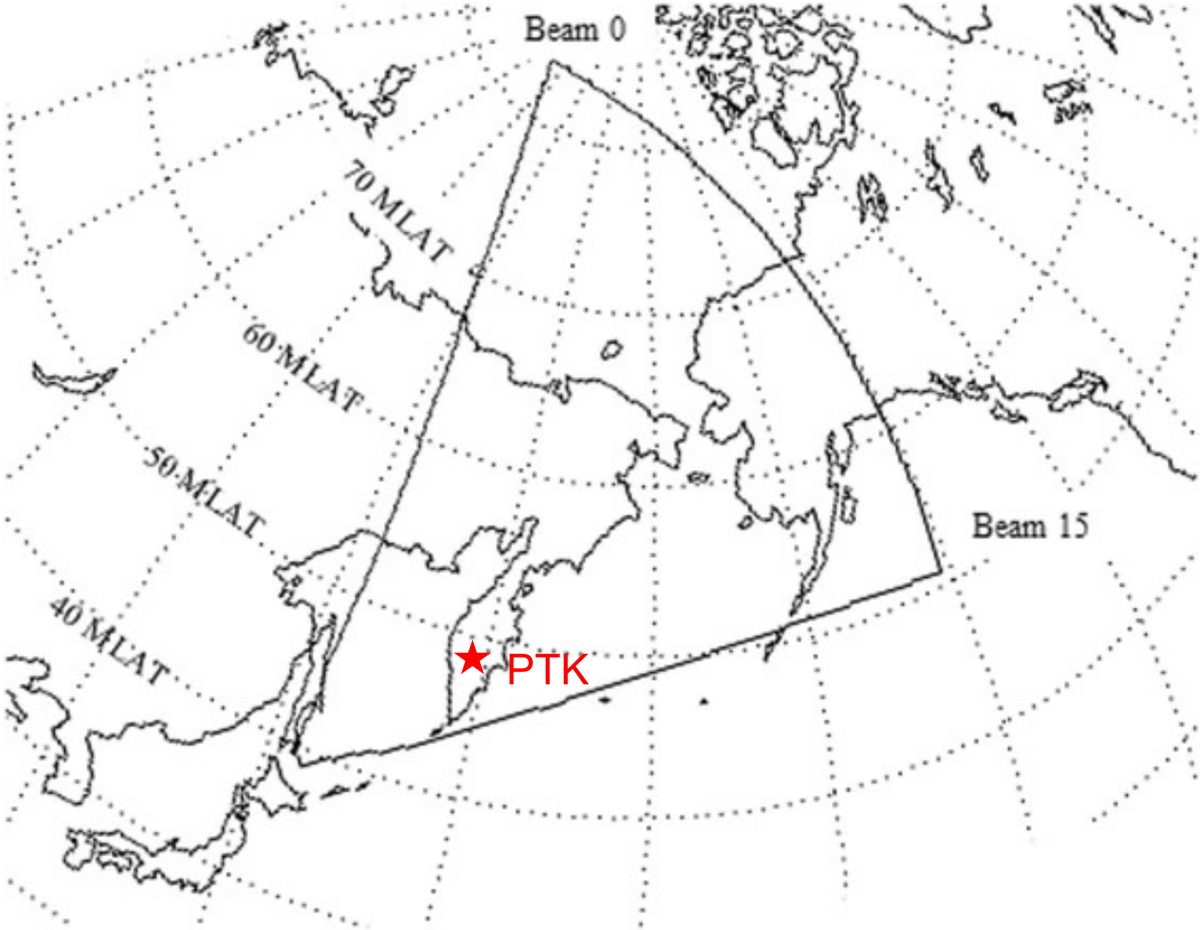
◆ FM-CW HF radar in Paratunka observes only vertical Doppler shift (East-West electric field)

+

◆ SuperDARN Hokkaido East Radar observes horizontal Doppler shift.

The electric field can be observed in 3D.

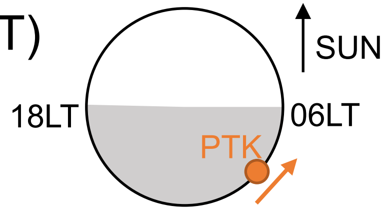
SuperDARN Hokkaido East Radar



[Nagano et al., 2015]

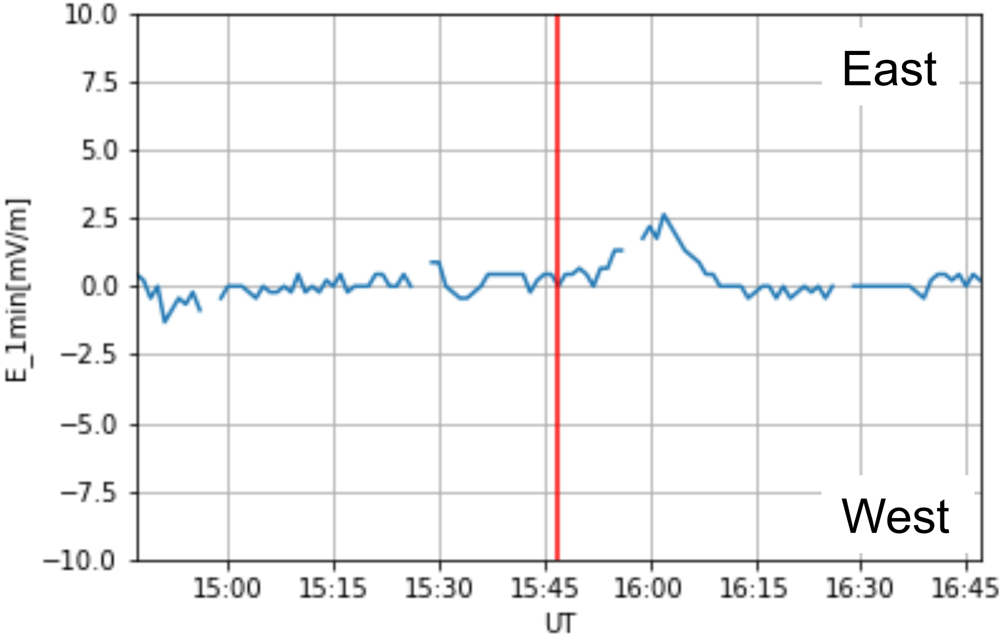
Results (Electric field, solar wind, AL index)

2011/01/04 15:47UT(03LT)

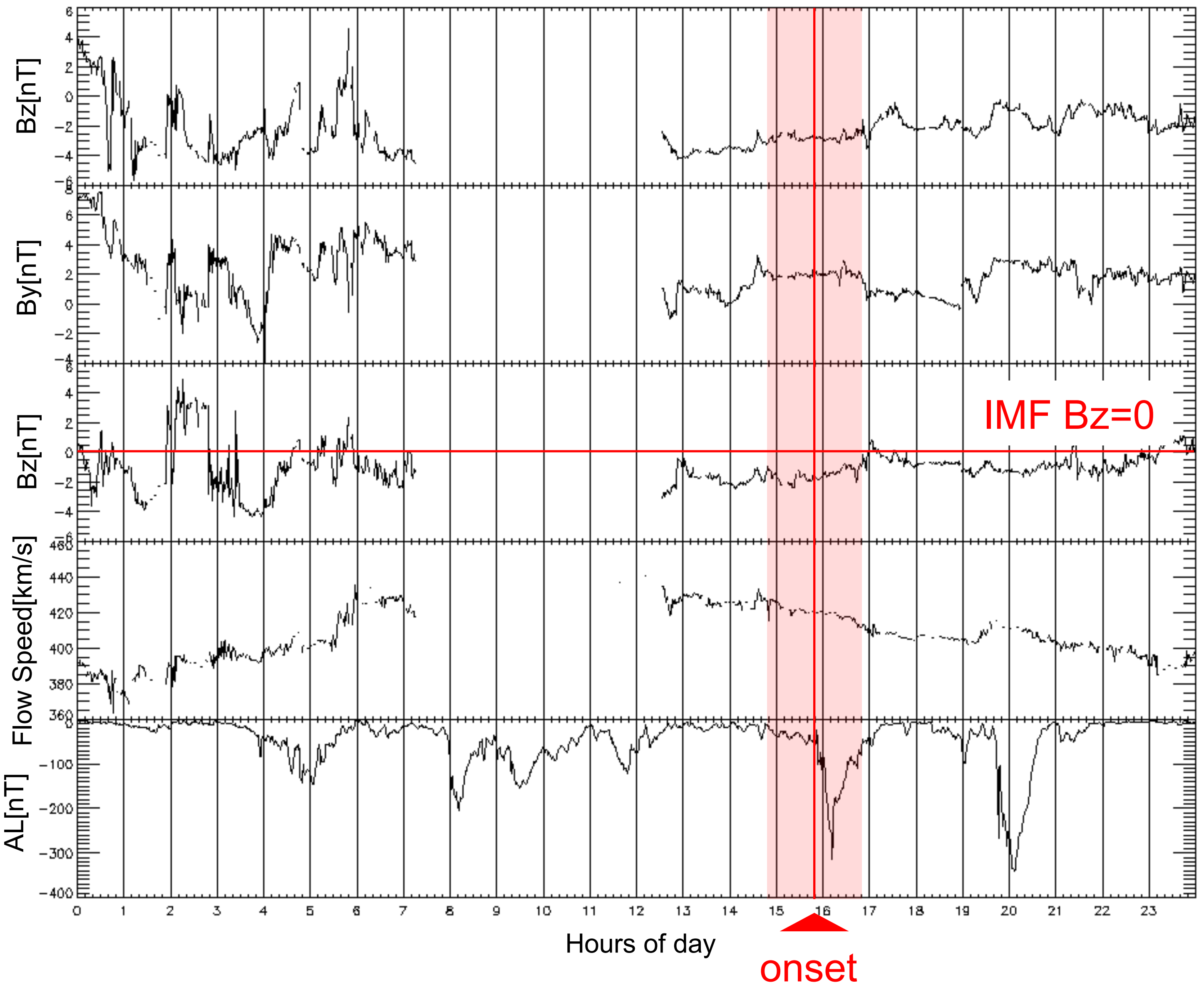


- After the onset, eastward electric field was observed for 30 minutes.
- IMF Bz was southward until the substorm.

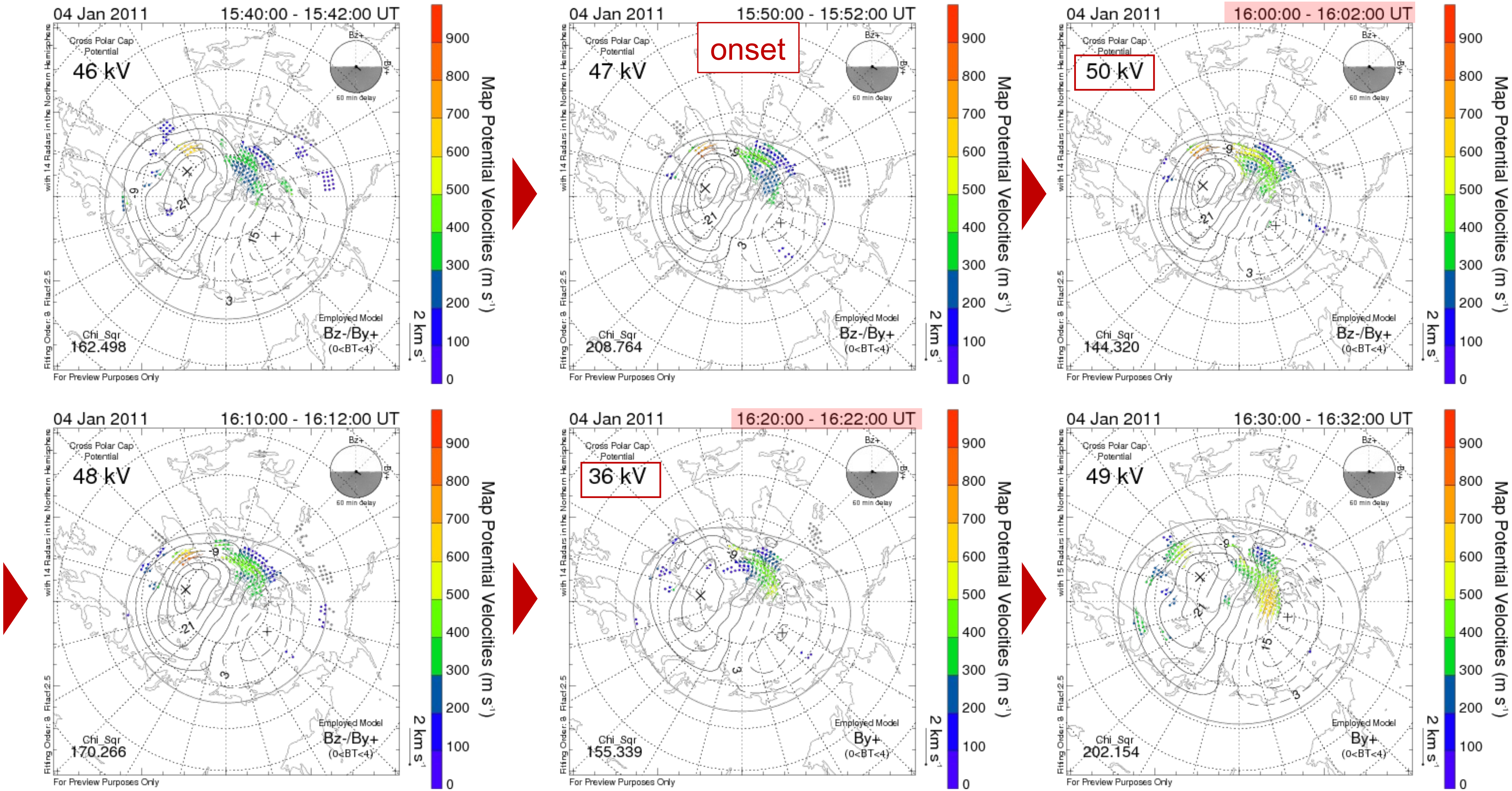
Electric Field @ Palatunka



solar wind data(OMNI) and AL

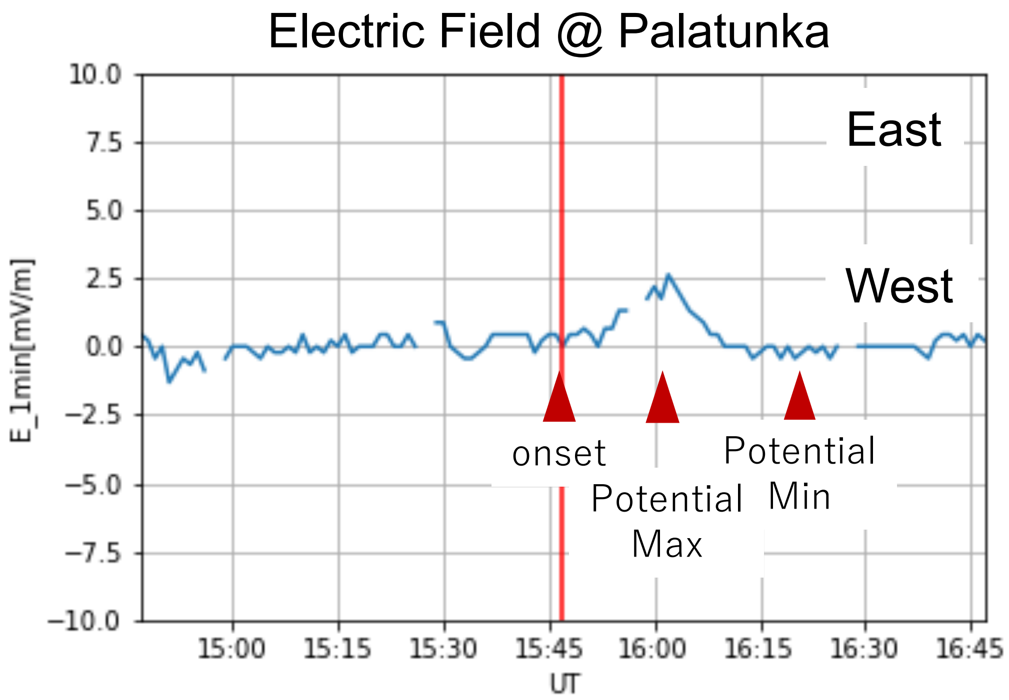


Results (Potential Map Plot)



Relation between electric field and potential

Is the eastward electric field due to shielding from reduced convection?



When the eastward electric field is maximum, the potential is also maximum.

→ The reason for the eastward electric field is **not a convection reduction**.

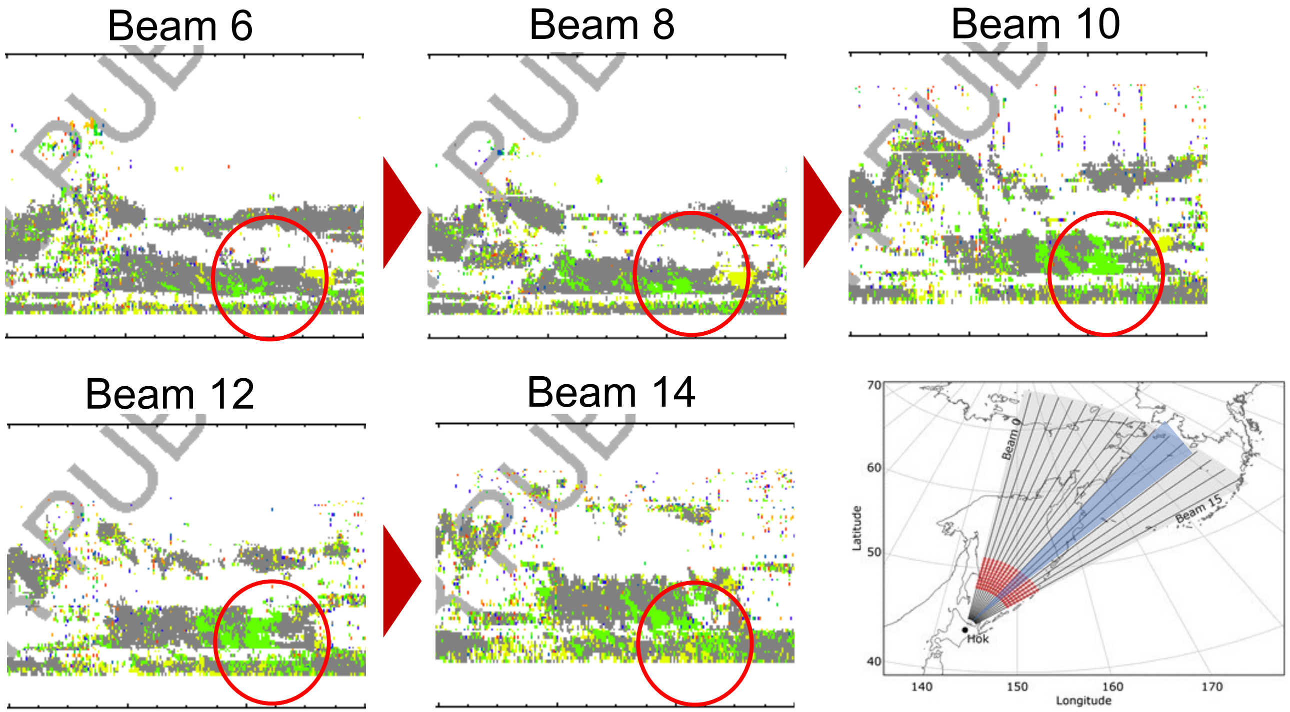
Results (SuperDARN Hokkaido East Radar)

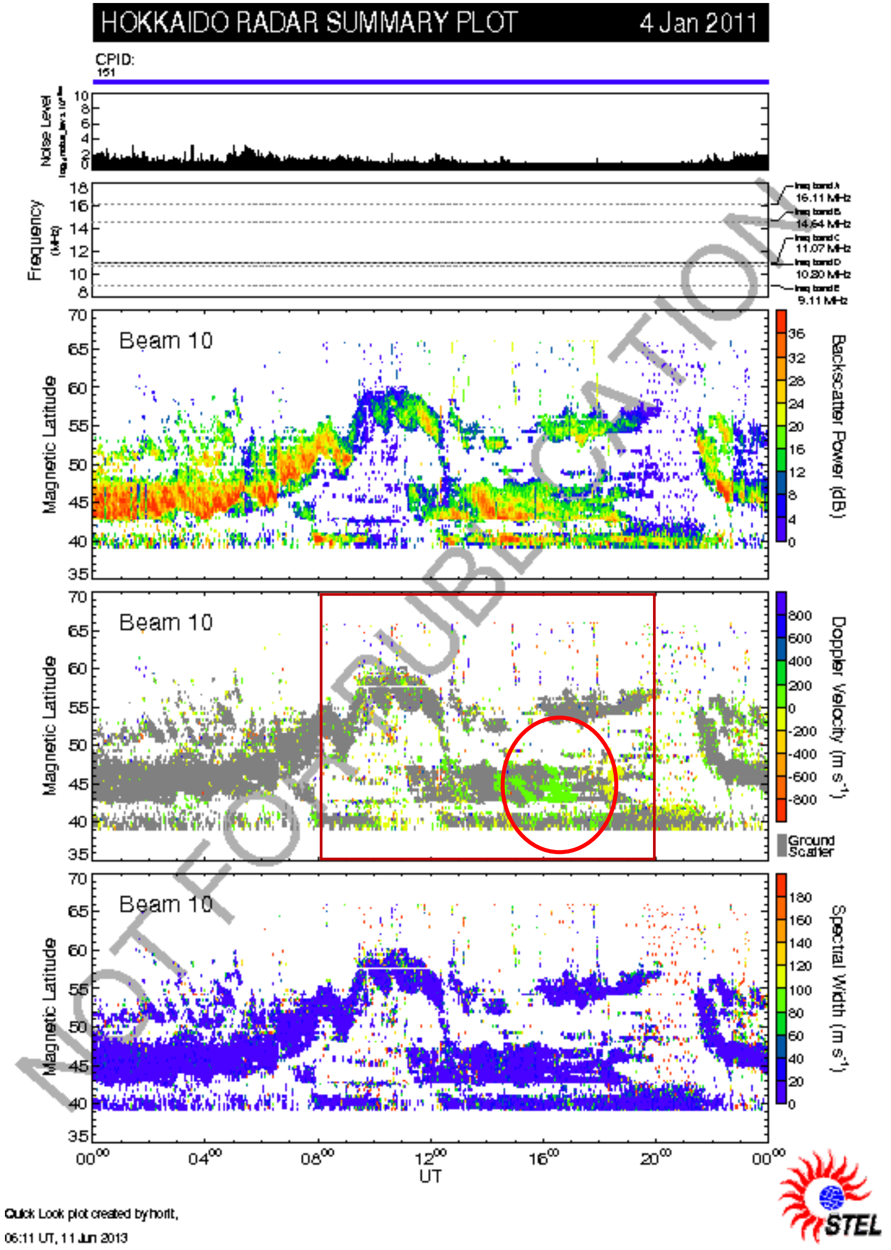
- Doppler Velocity
  - During the substorm (16:00-17:00 UT), about 200 km/s toward flow appears at 43~48 MLat.
  - The flow was particularly clear in Beam8-12

- Collaboration with PTK's HF radar

  (Ex, Ey, Ez) = (-5.8, 6.2, 3.0)[mV/m]

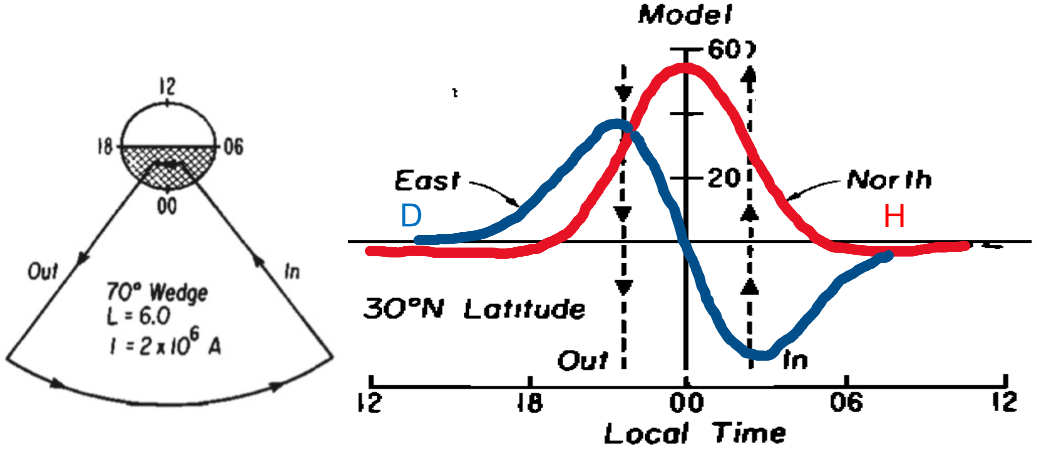
  (southwest direction)



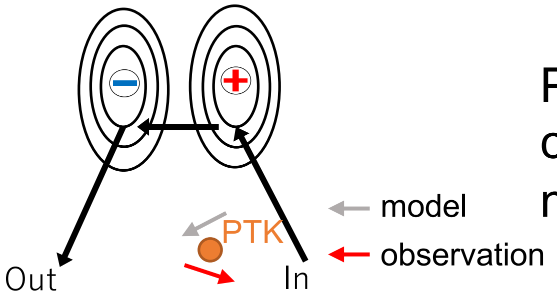


Results (Geomagnetic data @210MM)

- H component increases from high latitudes to low latitudes (positive bay)
- D component increases and then decreases at high latitudes

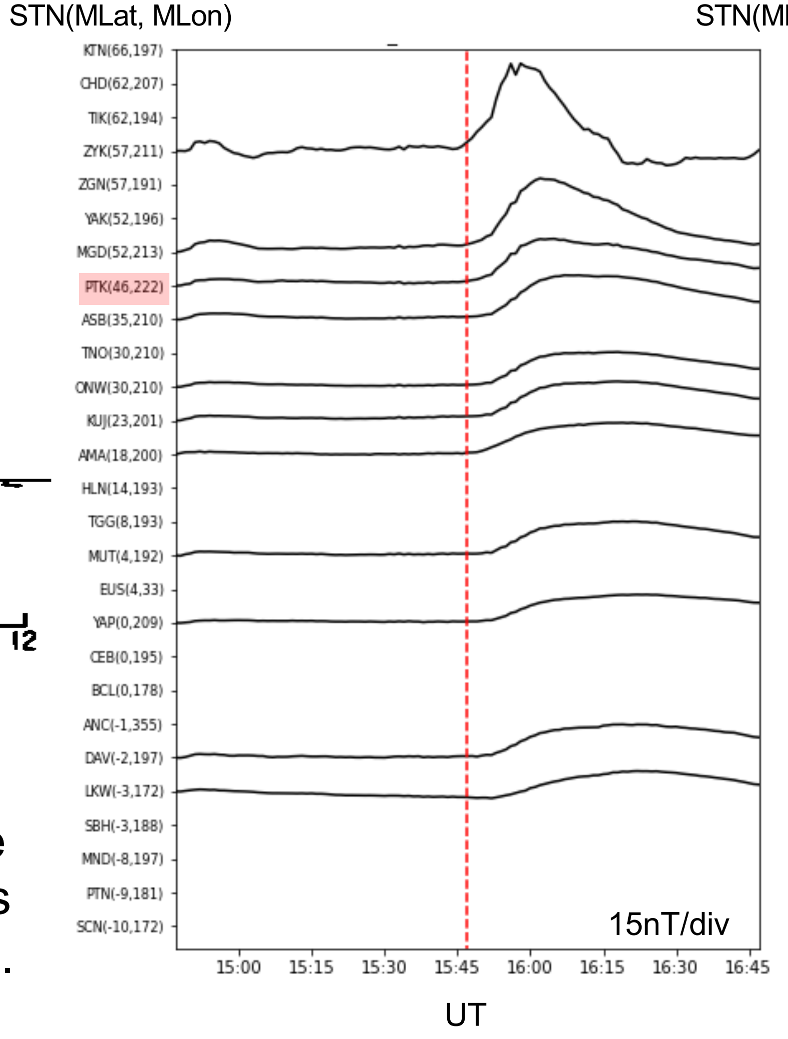


[Clauer and McPherron, 1974]

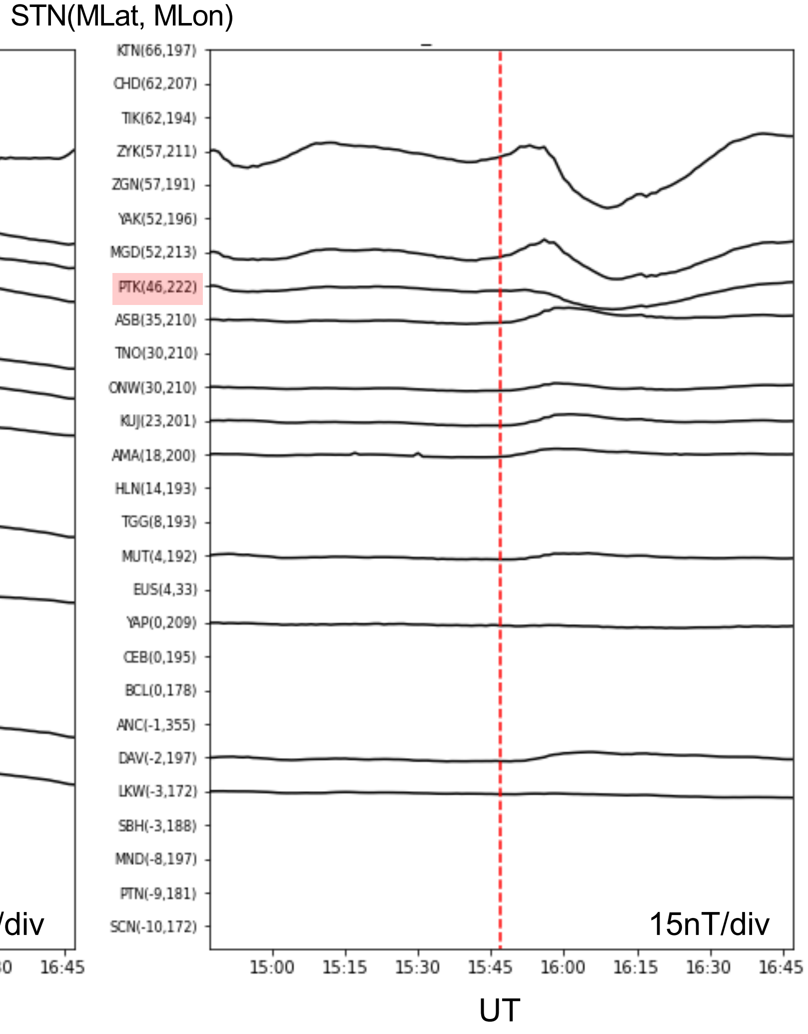


PTK is located in the current wedge and is near downward FAC.

H-component



D-component



Discussion & Summery

A 30-minute eastward electric field was observed by HF radar in PTK in the explosion phase of the substorm.

- Over shielding due to reduced convection? [e.g. Kikuchi et al. 2020].

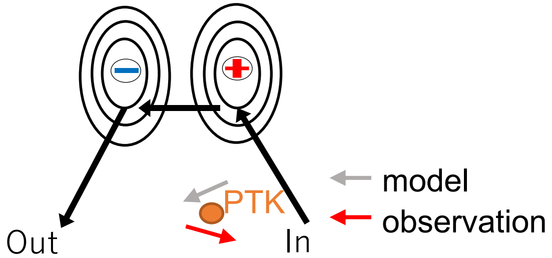
  →Convection is enhanced.

>>More detailed (locally)

There is flow at 43~48 MLat, generating an electric field in the southwest direction

- Is the electric field related to R1 and R2 type ionospheric currents and substorm current wedges[CW]?

  →If the CW creates a zero-order potential, then the directions of the electric fields do not match.



Future work

- On 2011/01/04, an eastward electric field occurred with the onset of the explosion phase, but analysis of other events shows that the timing, timescale, and direction of the electric field variations are different.

- Combining SuperDARN, geomagnetic, and electric field data, we will closely examine the development of the current system during the substorm and the development of the electric field.