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Variations of field-aligned currents on the nightside inferred from mid-latitude ground-based geomagnetic data: Relationships with the IMF and substorms

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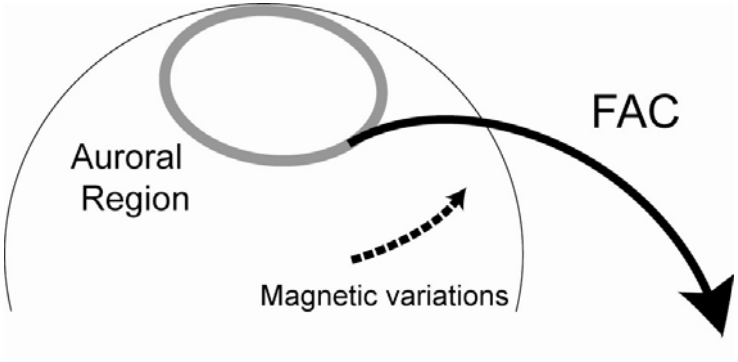
Introduction

- Our knowledge about field-aligned currents (FACs) has been mostly provided by statistical analyses of spacecraft data.
- However, it is difficult to observe the temporal variation of FACs by spacecraft.

→ We have little knowledge about the characteristics of temporal variation of FACs during disturbed times.

Introduction

- Mid-latitude east-west magnetic variations on the ground are mostly due to FACs, especially on the nightside.

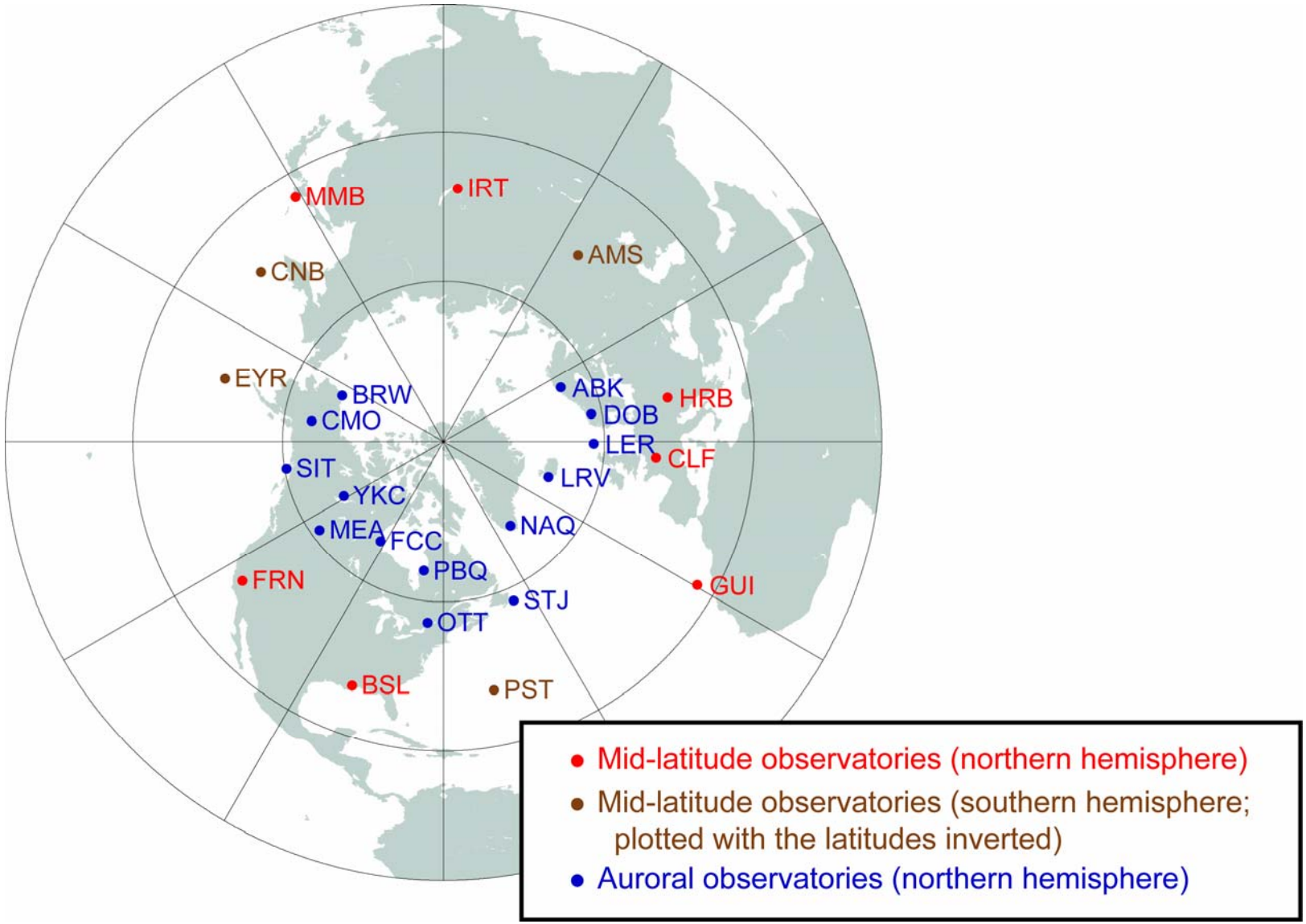


→ Mid-latitude magnetic data on the nightside enable us to obtain information about the temporal variation of FACs.

In this study...

- We examined temporal variations of the east-west component of mid-latitude geomagnetic field on the nightside, which is attributed to the FACs.
- In particular, we shall report the characteristics of mid-latitude east-west geomagnetic variations during the main phase of magnetic storms.

Geomagnetic observatories



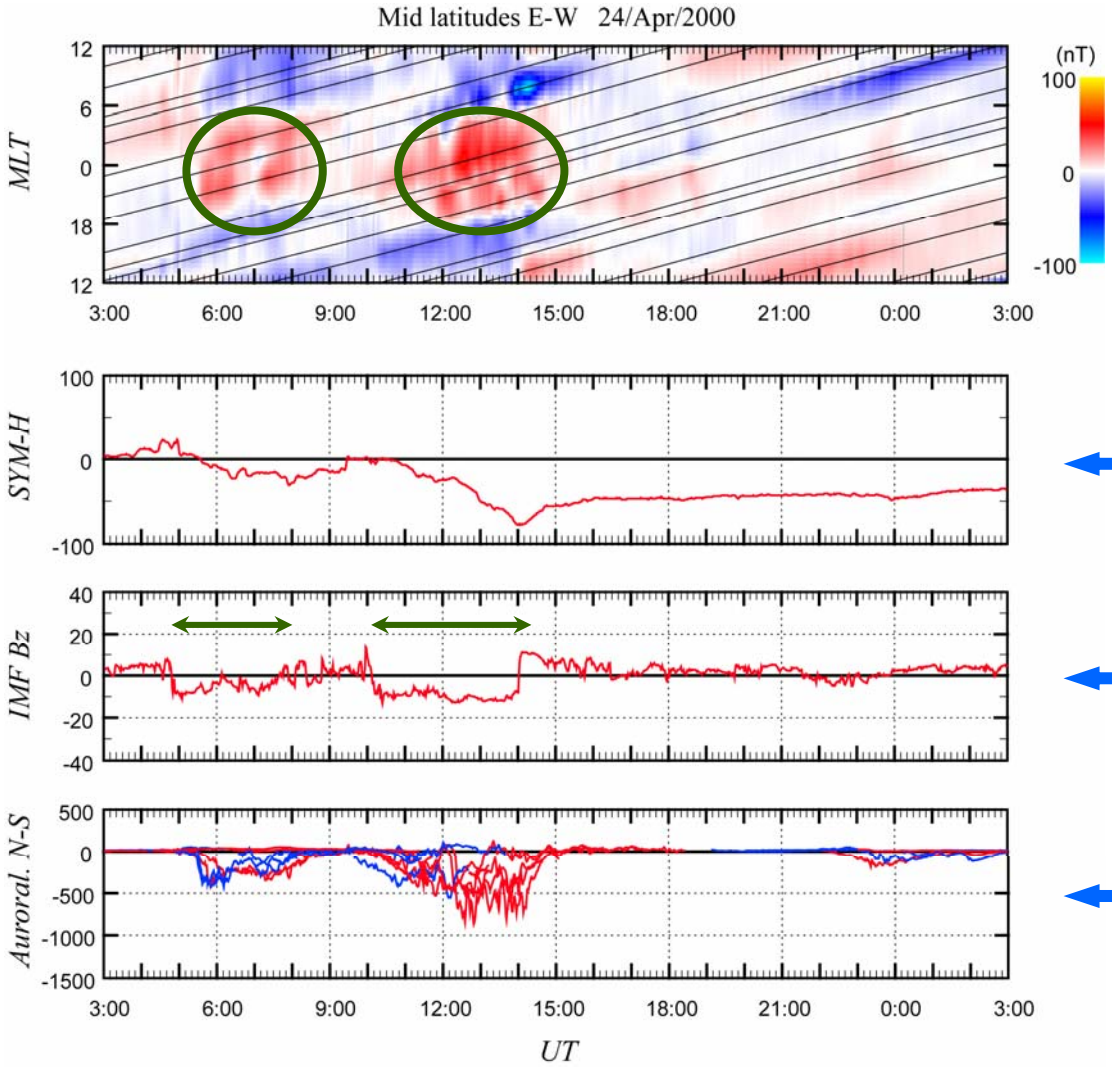
Data Processing

- We used the eastward component in the dipole coordinate system in order to avoid a mixing of the effect from the ring current etc. (Hereafter we denote the eastward component in the dipole coordinate system by "D"-component.)
- The signs of D for the observatories in the southern hemisphere were inverted.

  And we defined “positive” disturbances as the eastward/westward disturbances in the northern/southern hemisphere. Positive disturbances correspond to the effects of upward FACs at higher latitudes.

Data Processing

- The Sq field for each month was subtracted to obtain the eastward disturbance field, ΔD , for each mid-latitude observatories.
- Latitudinal dependence of magnetic effects of FAC was removed. (Here the ΔD for each observatory was normalized in order that its standard deviation obtained within 2100-0300 MLT is 10.0 nT.)
- Then the MLT profile of ΔD for each minute was derived by linear interpolation in MLT from the mid-latitude magnetic data.



The MLT-UT map of east-west disturbances ΔD

← *Dst* field (*SYM-H* index)

← The *z* component of the IMF observed by ACE

← ΔH in the auroral region 22-1 MLT and 1-6 MLT

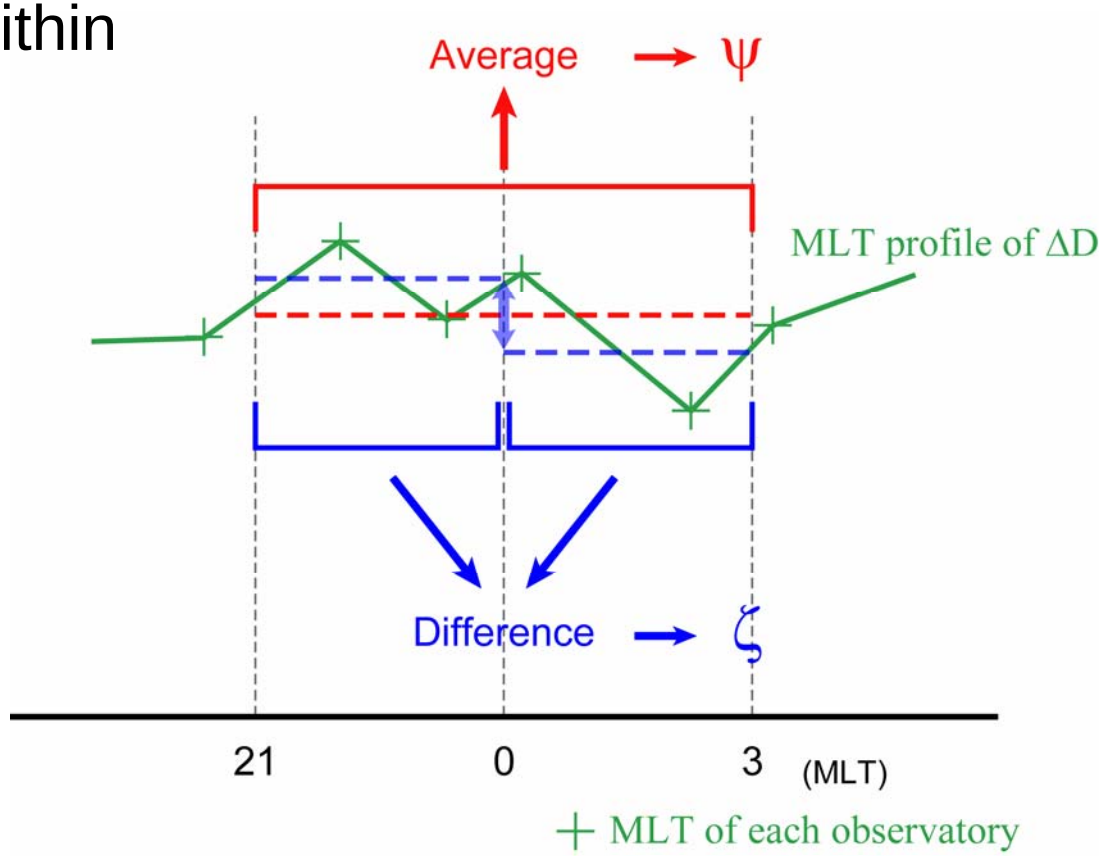
When the IMF is southward, positive east-west disturbances due to upward FAC are observed on the almost entire nightside.

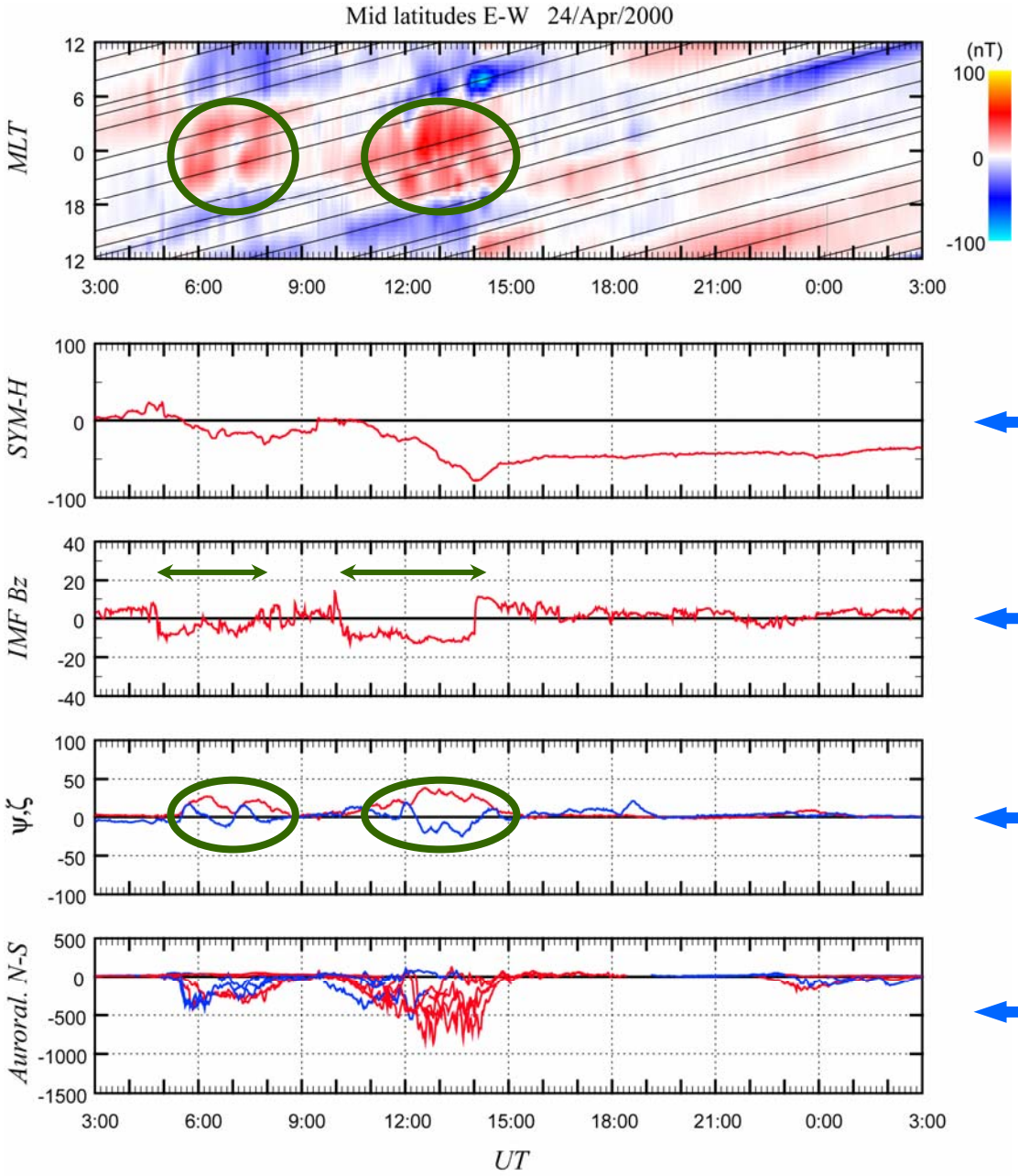
→ We shall refer to this disturbances as NPED (Nightside Positive East-west Disturbance) in the following.

To summarize the phenomena, we defined two parameters:

ψ: The average of ΔD within 2100<MLT<0300.

ζ: The average of ΔD within 2100<MLT<0000 minus the average of that within 0000<MLT<0300





The MLT-UT map of east-west disturbances ΔD

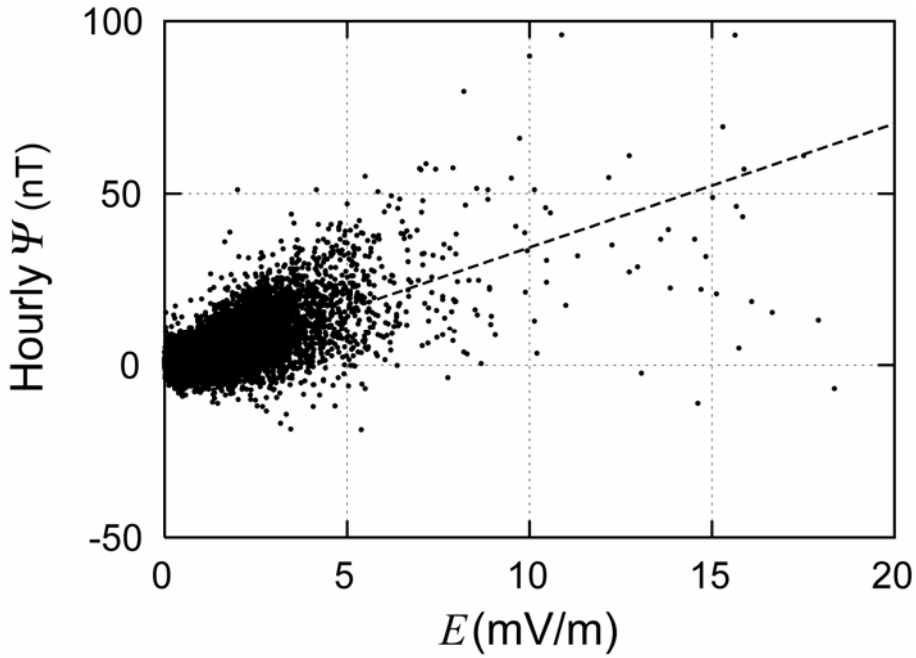
← *Dst* field (*SYM-H* index)

← The *z* component of the IMF observed by ACE

← Mid-latitude geomagnetic activity
ψ: NPED
ζ: Positive - R1 sense

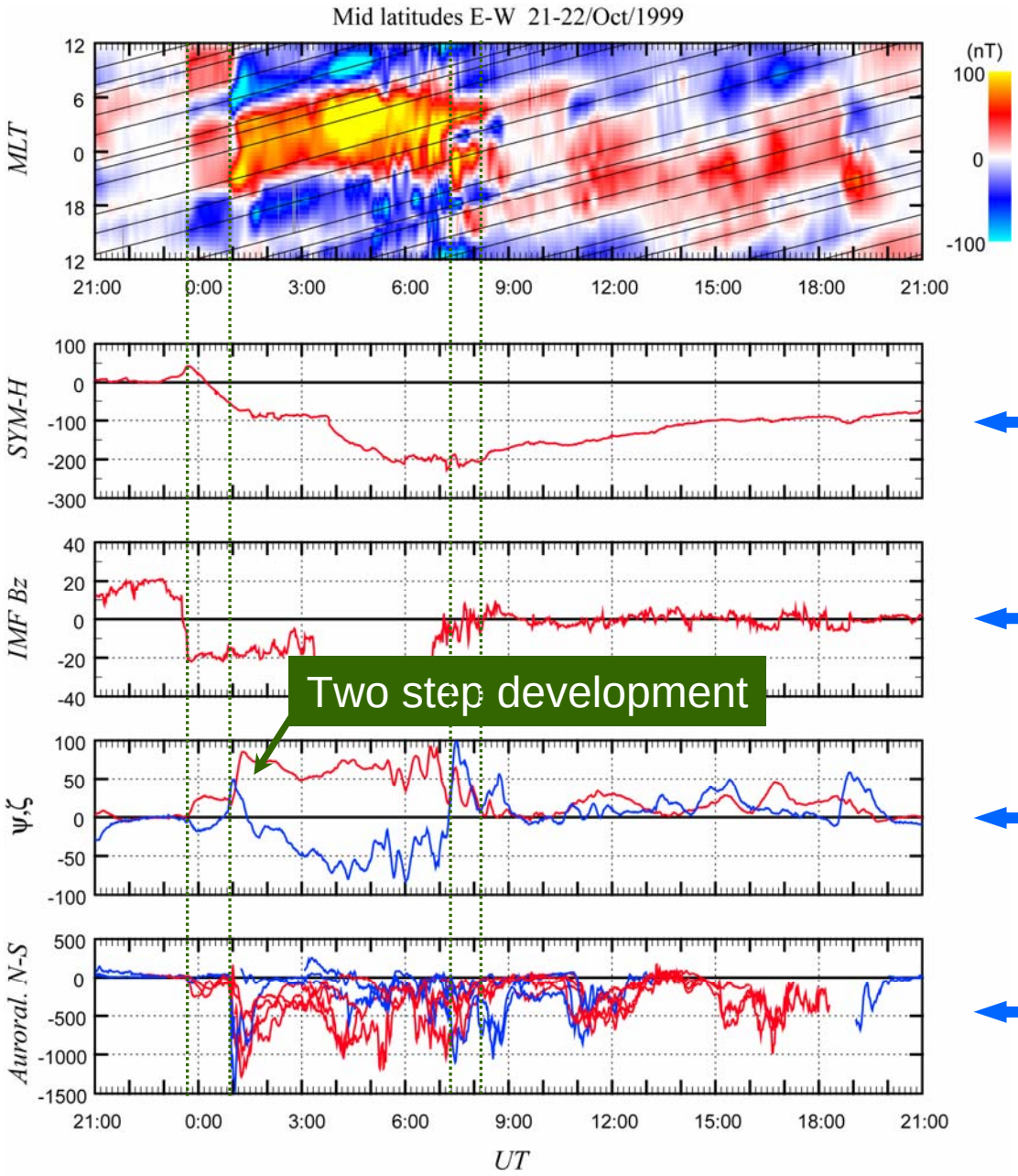
← ΔH in the auroral region
22-1 MLT and 1-6 MLT

Comparison between ψ and the merging electric field



Corr. = 0.67

The merging electric field was calculated from OMNI solar wind data by using the equation $E = vB_T \sin^2\left(\frac{\theta}{2}\right)$ (Kan and Lee [1979]).



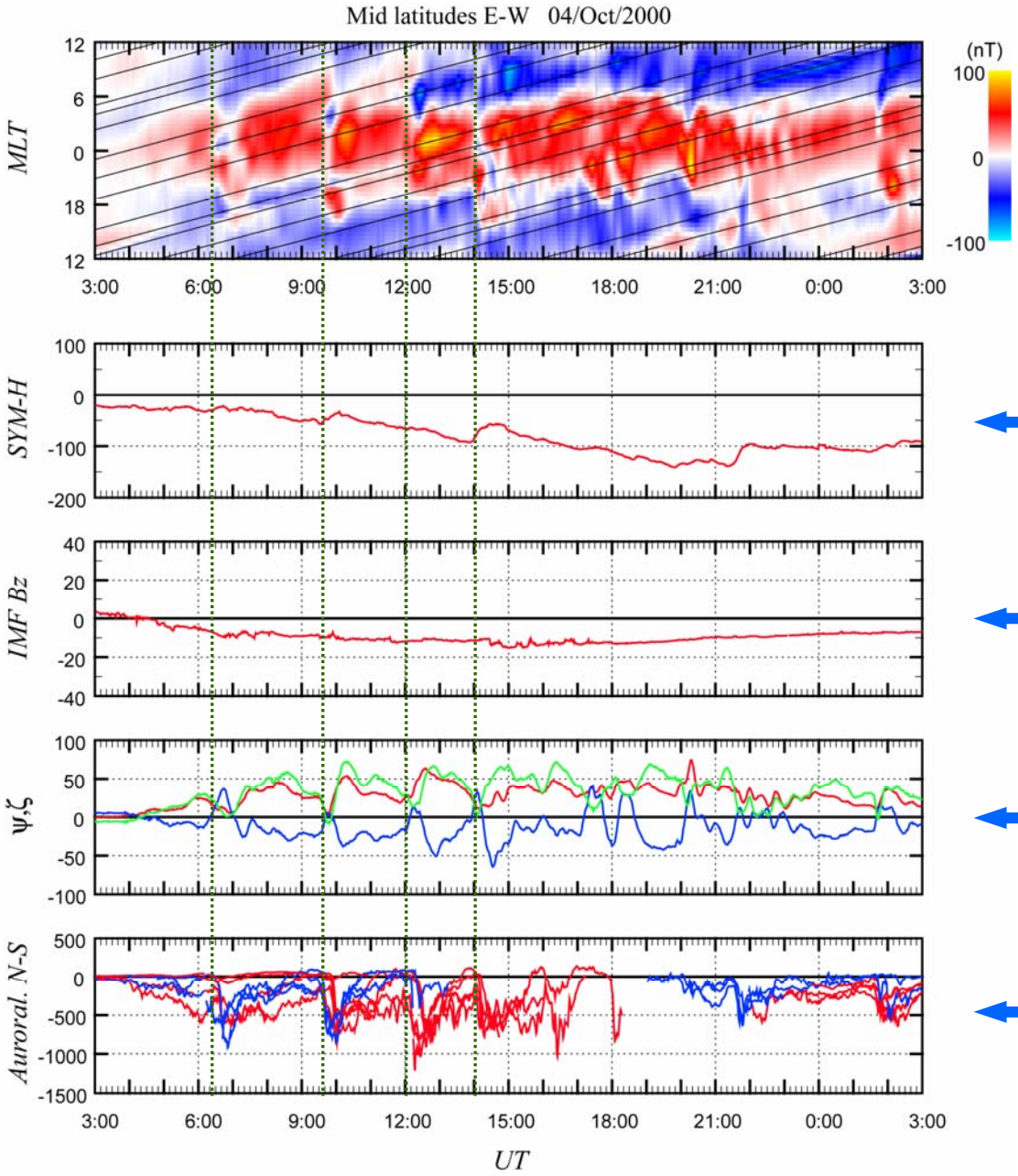
The MLT-UT map of east-west disturbances ΔD

← *Dst* field (*SYM-H* index)

← The *z* component of the IMF observed by ACE

← Mid-latitude geomagnetic activity
ψ: NPED
ζ: Positive - R1 sense

← ΔH in the auroral region
22-1 MLT and 1-6 MLT



The MLT-UT map of east-west disturbances ΔD

Dst field (*SYM-H* index)

The *z* component of the IMF observed by ACE

Mid-latitude geomagnetic activity

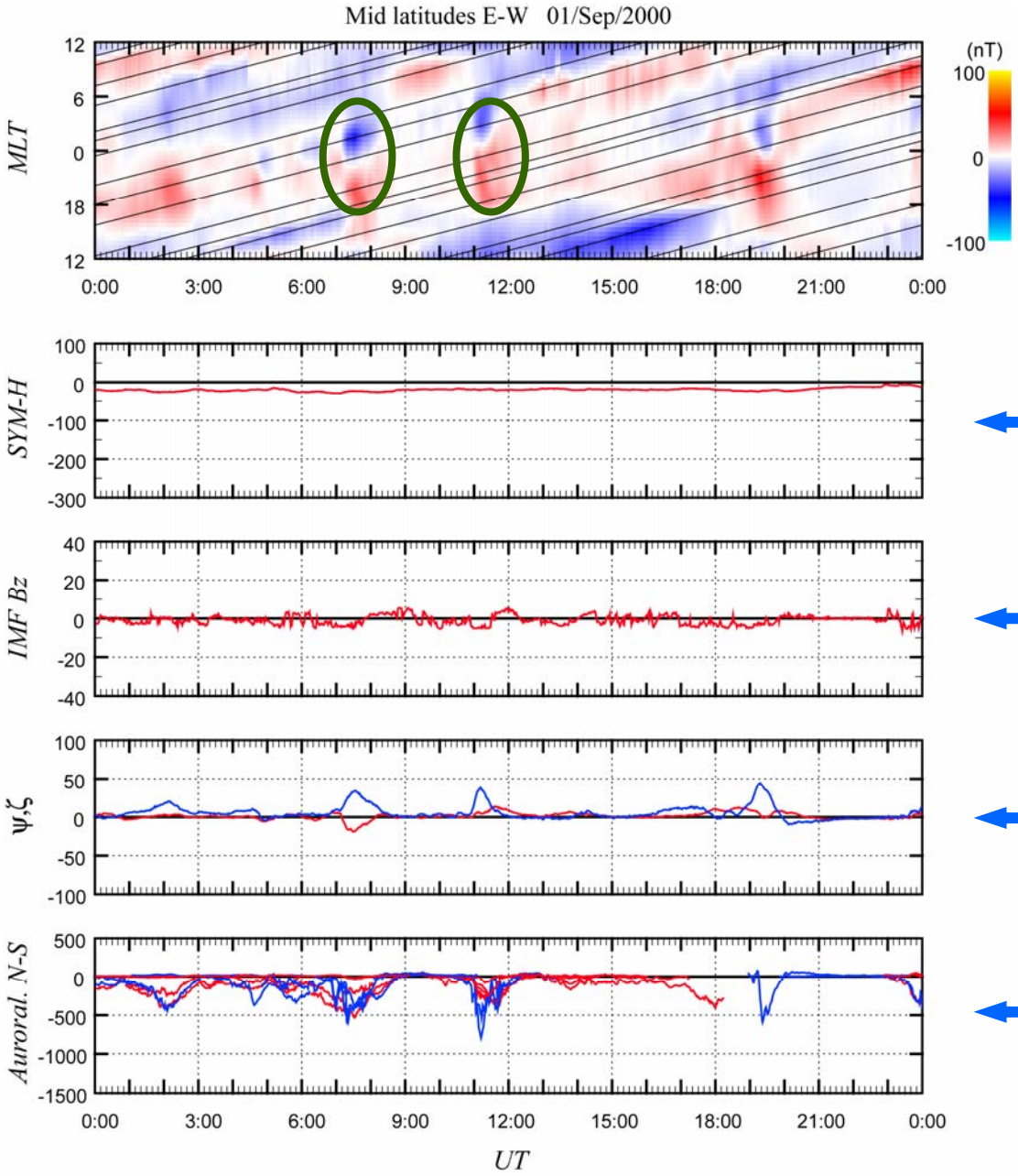
ψ: NPED

ζ: Positive - R1 sense

Green: ΔD at 0230 MLT

ΔH in the auroral region

22-1 MLT and 1-6 MLT



The MLT-UT map of east-west disturbances ΔD

← *Dst* field (*SYM-H* index)

← The *z* component of the IMF observed by ACE

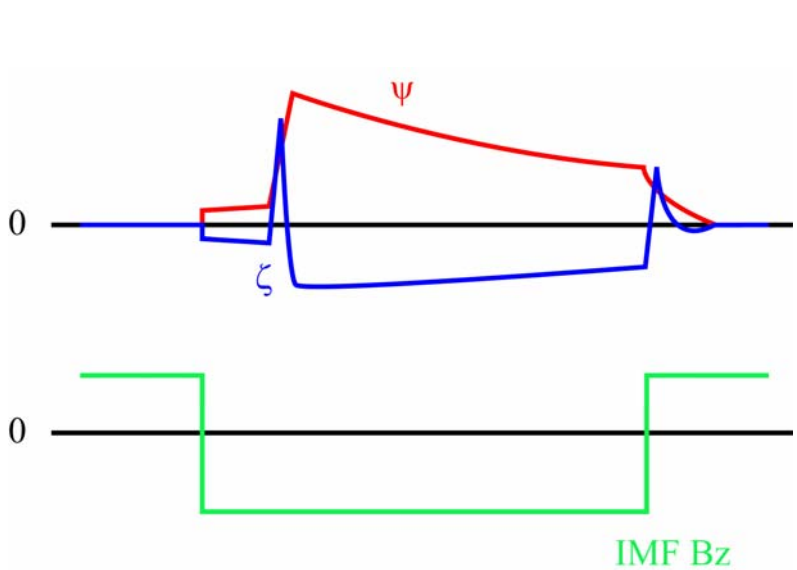
← Mid-latitude geomagnetic activity
ψ: NPED
ζ: Positive - R1 sense

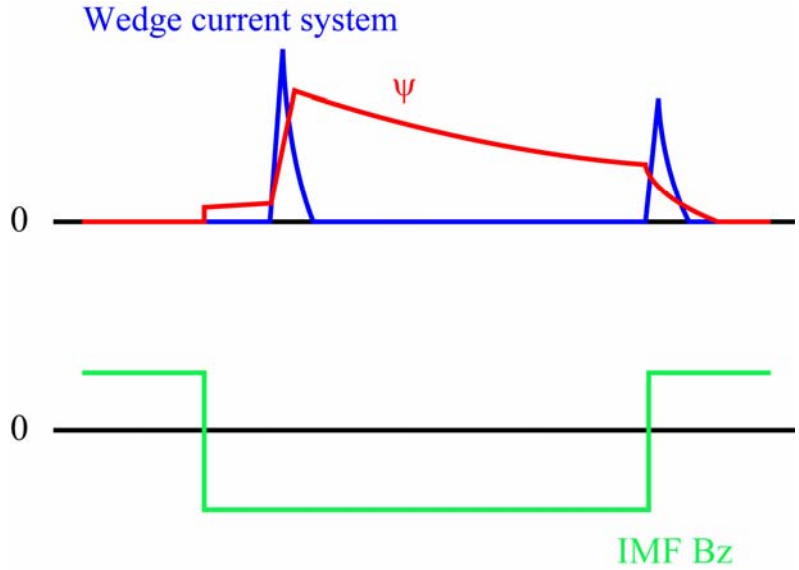
← ΔH in the auroral region
22-1 MLT and 1-6 MLT

Results

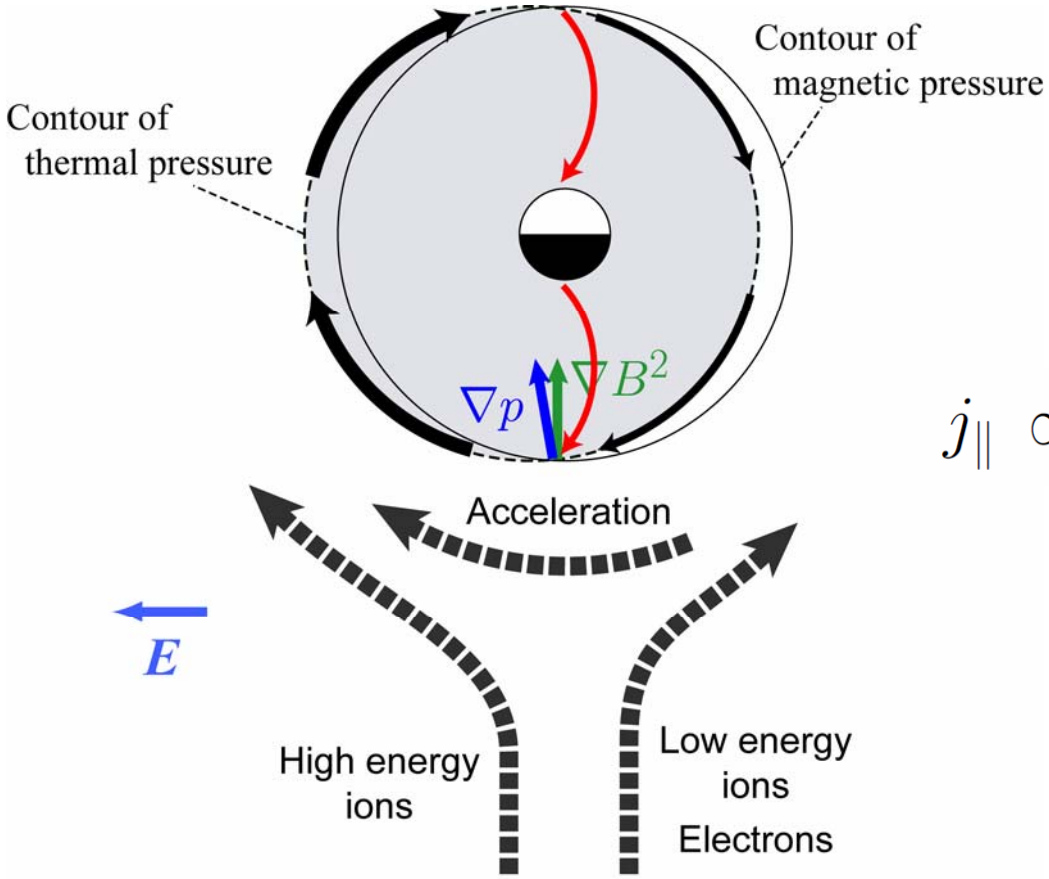
- When the IMF is southward, positive east-west disturbances due to upward FACs are observed on the nightside.
- While the nightside positive east-west disturbances (NPED) are principally associated with the southward IMF, they can also be intensified by substorm expansions especially in the post-midnight if the IMF is southward. This suggests that substorms can result in the development of the upward currents in the post-midnight.

  (The positive disturbances after substorm onsets exhibit essentially different behavior from the current wedge signature.)





Effect of the development of magnetospheric convection



$$j_{\parallel} \propto \nabla p \times \nabla B^2$$

(e.g. Vasyliunas 1972)

Effect of substorms

What causes the development of the upward FACs on the nightside at substorm onsets?

- The NPEDs continue even after the decay of the current wedge as long as the IMF is directed southward.

→ This fact should be interpreted to indicate that the development of the upward FACs is not a transient phenomenon such as the formation of the wedge current system.

But it suggests that a change of the magnetospheric and ionospheric conditions would cause the development of the upward FACs.

Effect of substorms

What causes the development of the upward FACs on the nightside at substorm onsets?

- The injection of energetic particles into the inner magnetosphere is one of possible crucial changes causing the development of the upward FACs at substorm onsets.

However, the electric and magnetic fields would highly change in the inner magnetosphere in a substorm expansion phase. This could complicate the mechanism of the generation of the upward FACs.

Summary

- We examined temporal variations of the east-west geomagnetic field at mid-latitudes. The results are summarized as follows:
  - When the IMF is southward, positive east-west disturbances due to upward FACs are observed on the nightside. However, the positive disturbances are also often intensified by a substorm expansion especially in the post-midnight if the IMF is southward.
  - The positive disturbances after substorm onsets exhibits essentially different behavior from the current wedge signature.
  - These fact suggests that the upward Region 2 currents in the post-midnight are mainly controlled by the convection electric field and that they can be also intensified by a substorm expansion.
  - The development of the upward currents at substorm onsets possibly results from the injection of energetic particles from the magnetospheric to the inner magnetosphere.

Acknowledgements

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