極域・中緯度SuperDARN研究集会（国立極地研究所、2016. 8. 9-10)

北海道レーダーとHFドップラーサウンダーによる中緯度電離圏電場の同時観測

Midlatitude ionospheric electric fields observed by the Hokkaido radar and HF Doppler sounders

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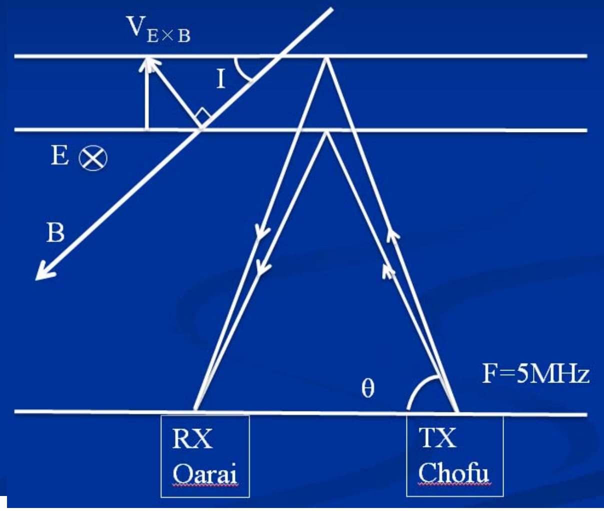
Observations of ionospheric electric field with the Hokkaido radar and HF Doppler sounder in midlatitudes and ionospheric currents with the magnetometer at the equator

$$\Delta f = -\frac{2f}{c}\frac{E}{B}\sin\theta\cos I$$

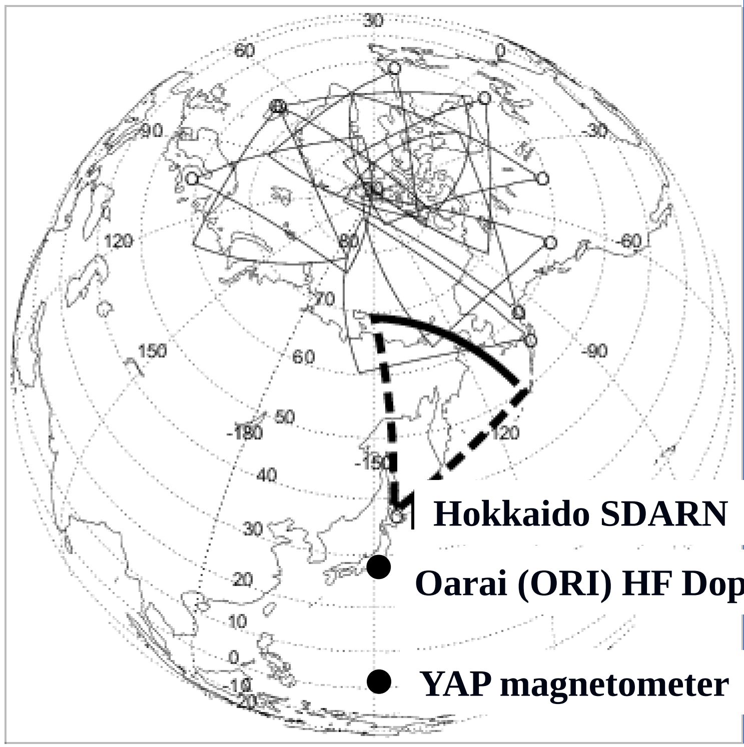
$f = 5$ [MHz], $\theta = 78.2°$, $I = 49°$, $B = 46000$ [nT],

distance = 120 [km], reflection height=300 [km]

$E = 2.15$ [mV/m] ($\Delta f = 1$ Hz)



HF Doppler (HFD) sounder in Tokyo

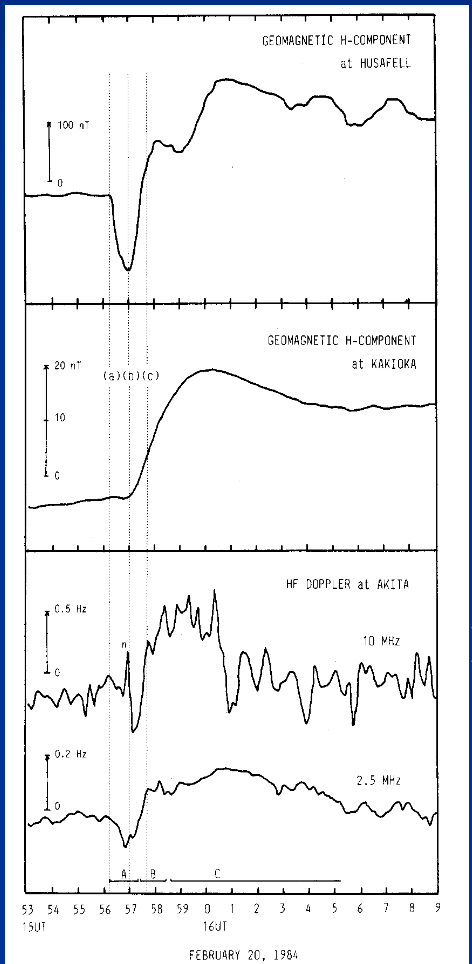


At the dayside equator, YAP, the SC/SI, PC5 and DP2 are amplified due to the ionospheric currents intensified by the Cowling effect.

Cowling conductivity: $\sigma_C = \sigma_P + \frac{\sigma_H^2}{\sigma_P}$

Instantaneous transmission of the electric field of the PI of SC to the low latitude on the day- and night-sides

Night-side



High latitude PI

Low latitude SC

Low latitude HFD

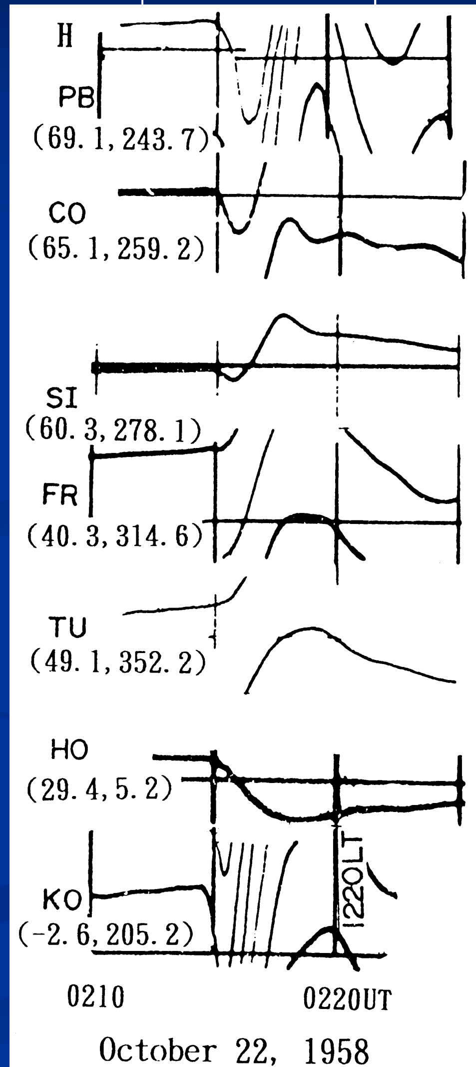
(Kikuchi, JGR 1986)

Day-side

High latitude PI

Low latitude SC

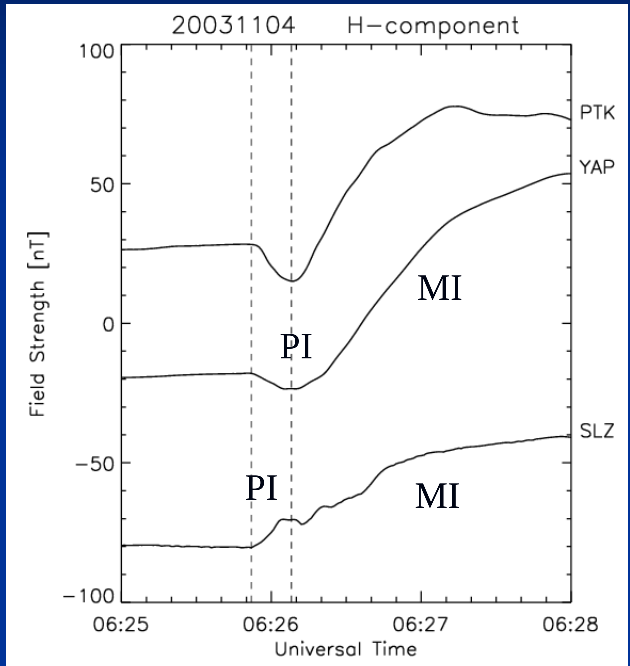
Equatorial PI



(Araki, PSS 1977)

Opposite direction of the SC electric fields on the day- and night-sides

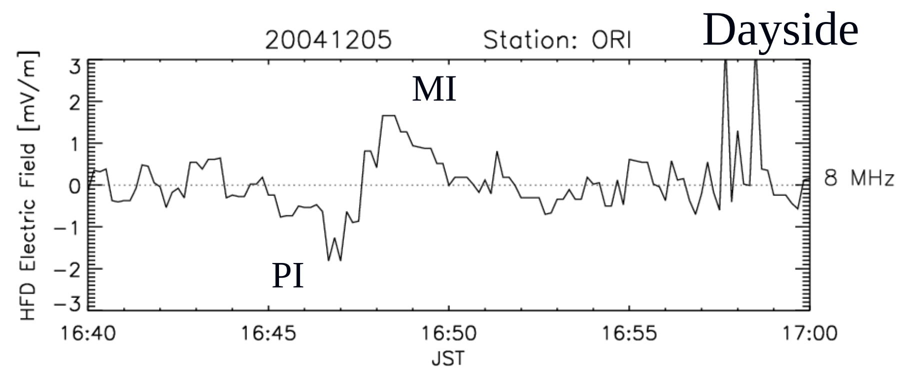
Magnetometers

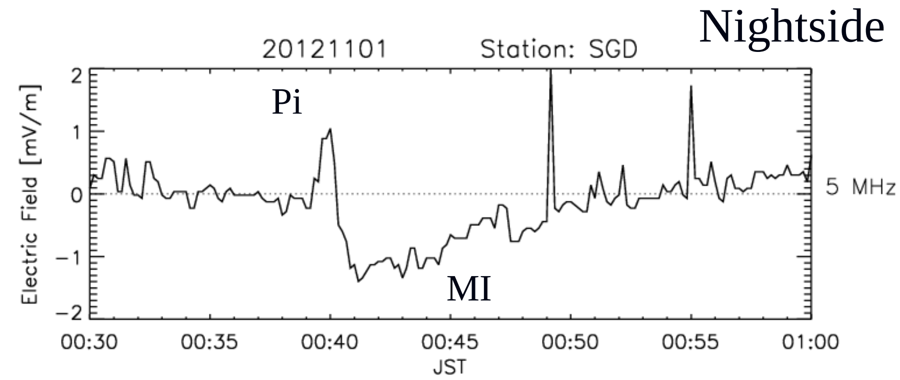


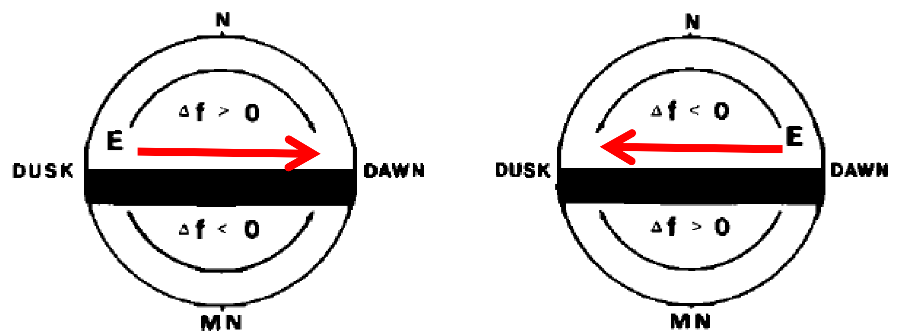
Dayside equator(YAP)

Nightside equator(SLZ)

HF Doppler sounders



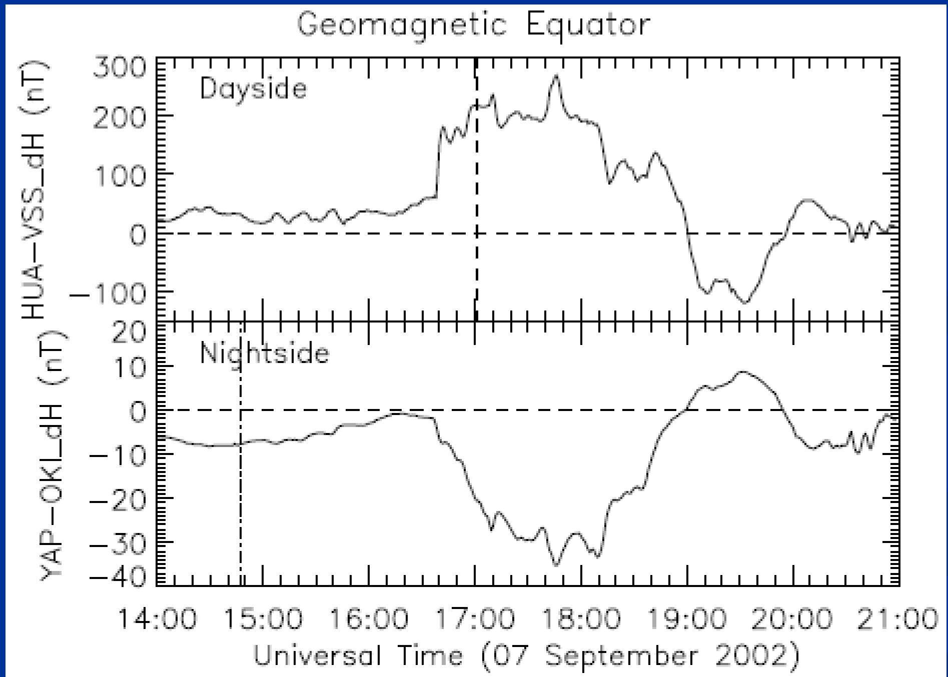




PI MI

Opposite direction of the stormtime electric fields on the day- and night-sides

Main phase EEJ/CEJ and recovery phase CEJ/EEJ on the day/night-side



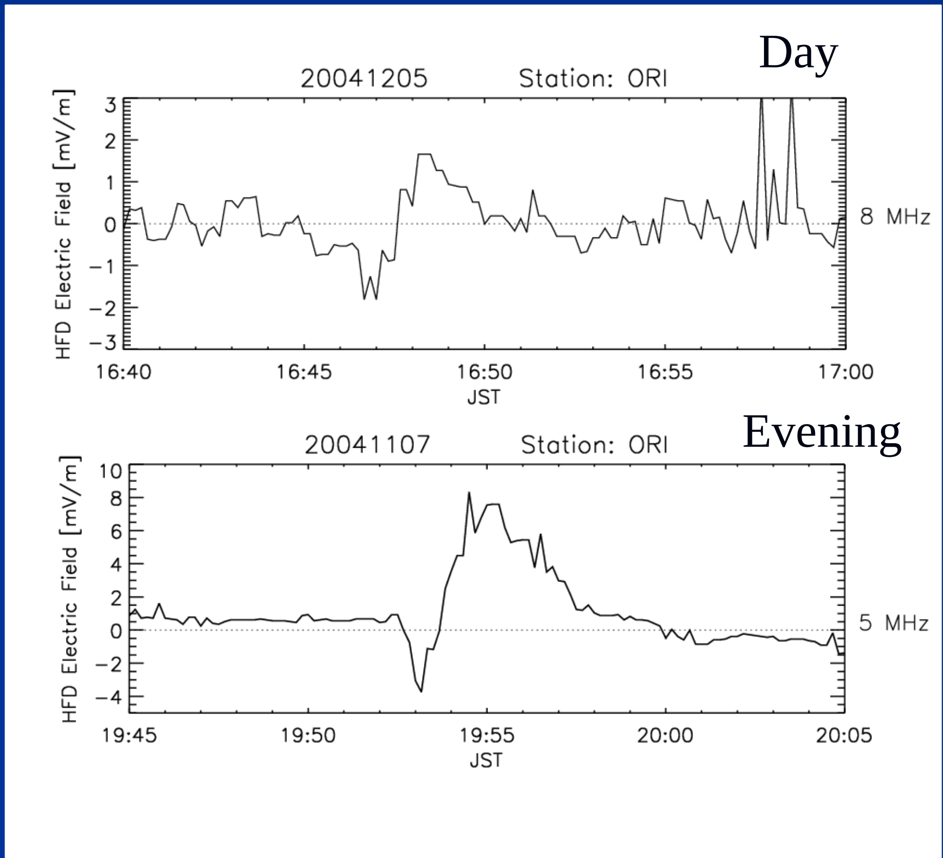
Tsuji et al., JGR 2012)

Evening anomaly of the SC electric fields

The PI and MI electric fields in the evening are in the same direction as in the day.

SCF(+ -) is observed from 06 to 22h in local time.

(Kikuchi et al., JGR 1985)



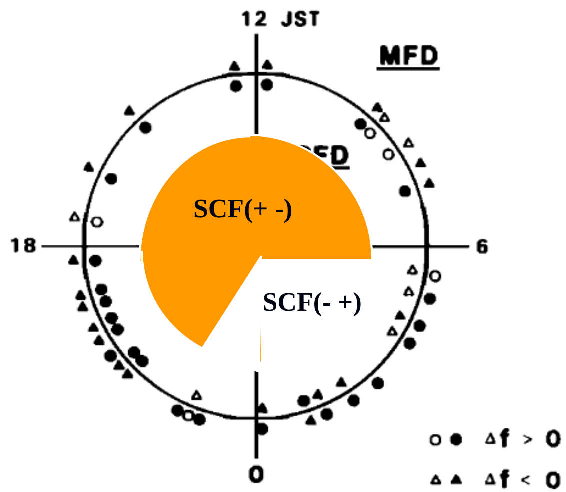


Fig. 5. Local time features of the signs of preliminary frequency deviations (PFD's) and main frequency deviations (MFD's) of SCF's. The SCF(+ −) appears in the daytime and evening sectors and the SCF(− +) in the nighttime sector. The solid circles and triangles indicate that the SCF was observed at more than two stations.

Evening enhancement of the SC electric fields

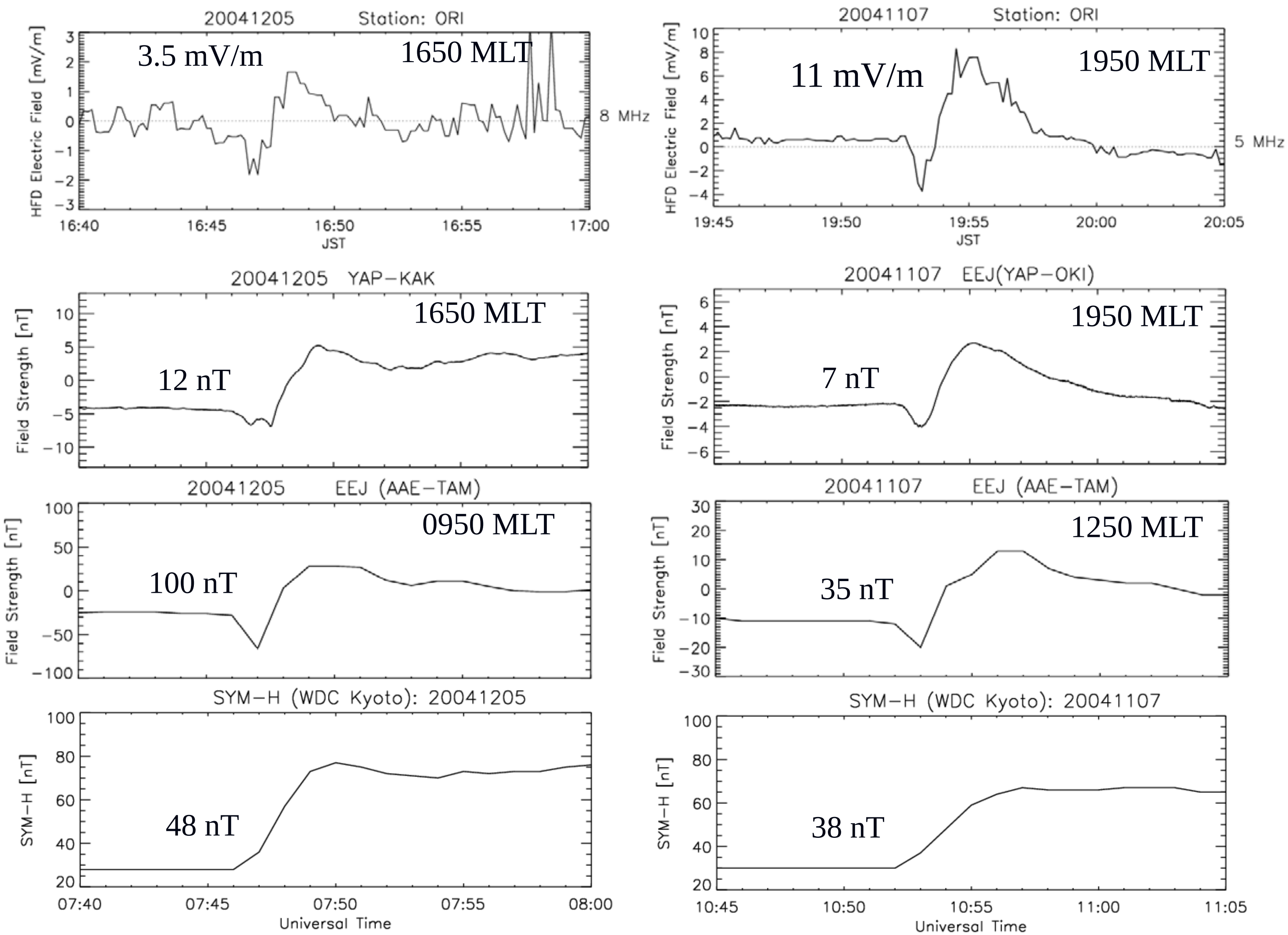
The electric field is 3 times stronger in the evening (11mV/m) than in the day (3.5 mV/m).

Electric field

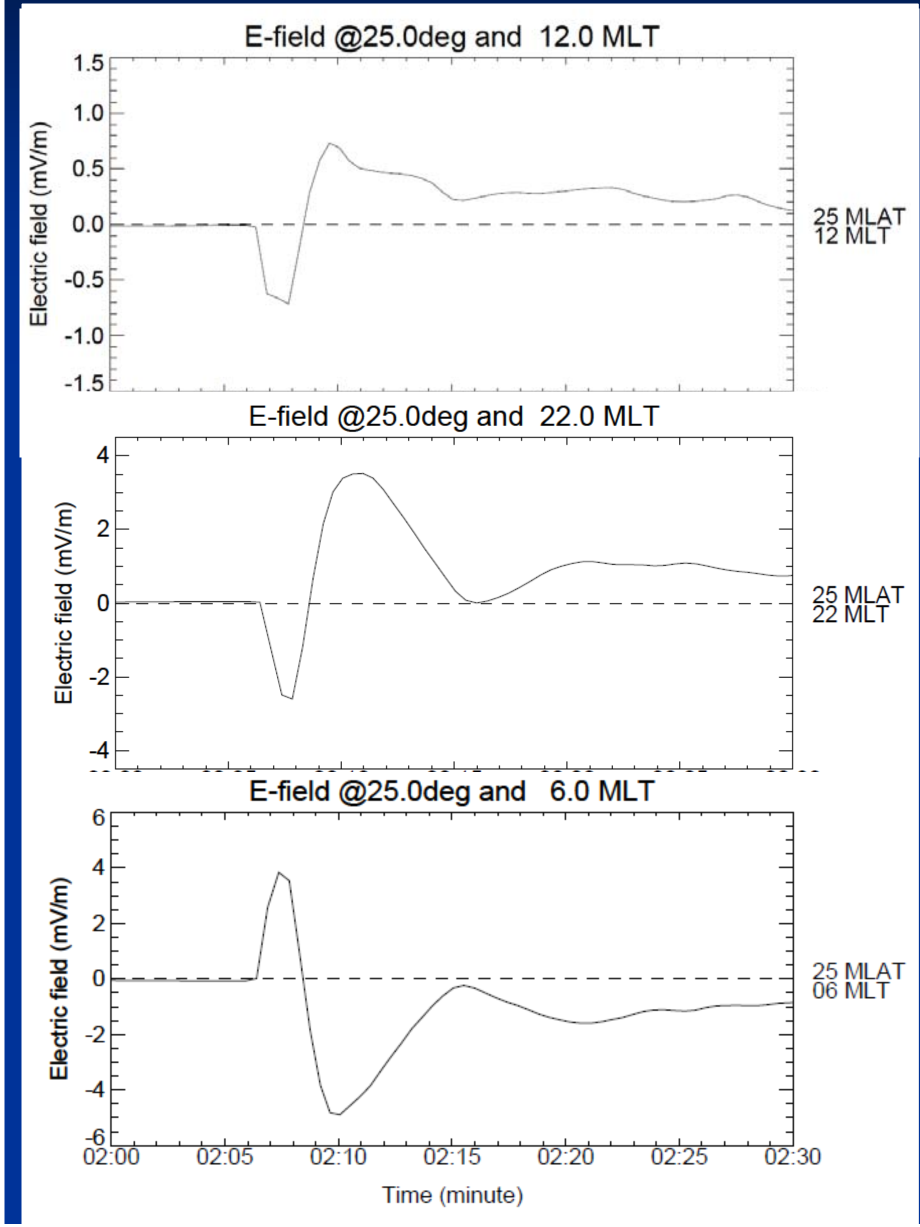
EEJ at YAP

EEJ at AAE

SYM-H



SC electric fields reproduced by Tanaka's global simulation

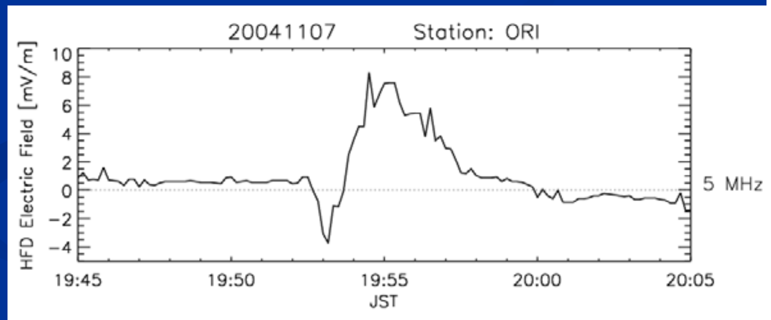


Day

Evening

Night

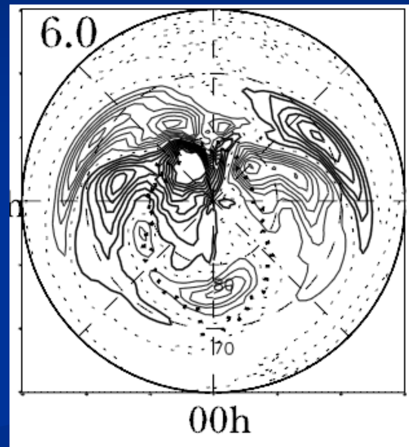
The PI and MI electric fields are reproduced with the evening anomaly.



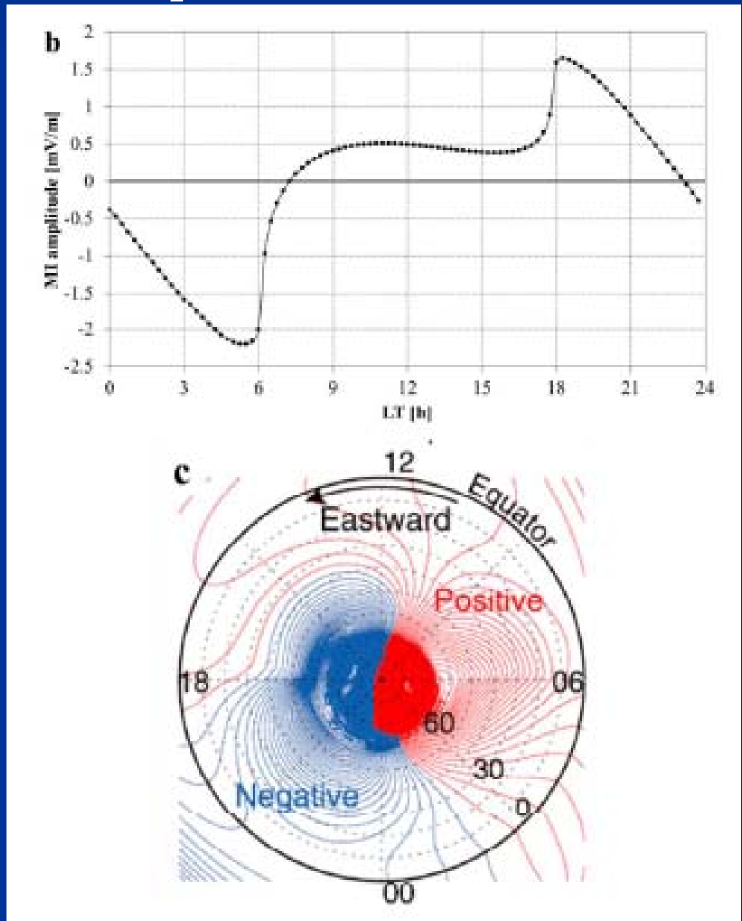
(Kikuchi et al., JGR 2016)

The evening anomaly is a unique feature of the electric potential in the global ionosphere.

FACs (Fujita et al. 2003)



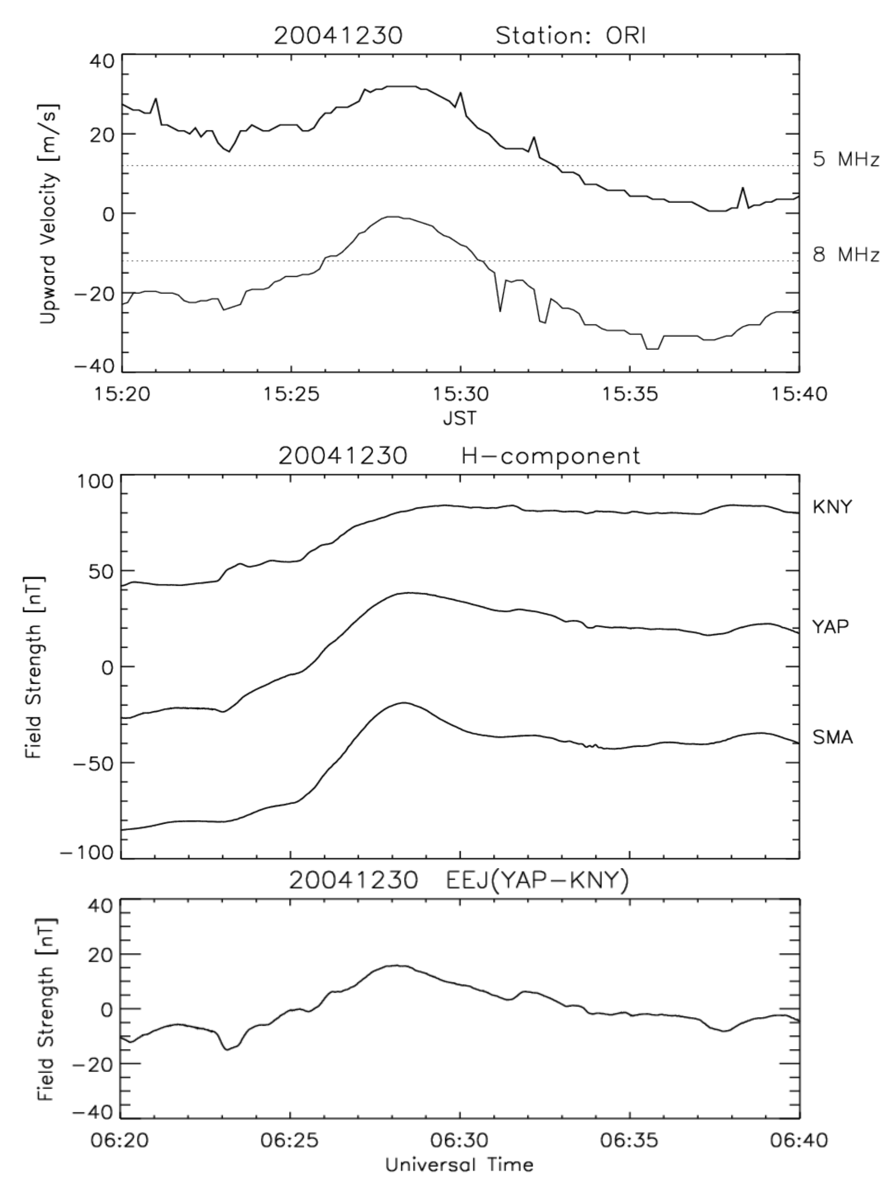
Equatorial electric field



$$\nabla \cdot \sigma \nabla \phi_I = J_{\parallel}$$

Electric potential

(Ebihara et al. 2014)



The potential electric field causes upward motion of the ionosphere during the compression of the magnetosphere

$V_{vert} > 0$

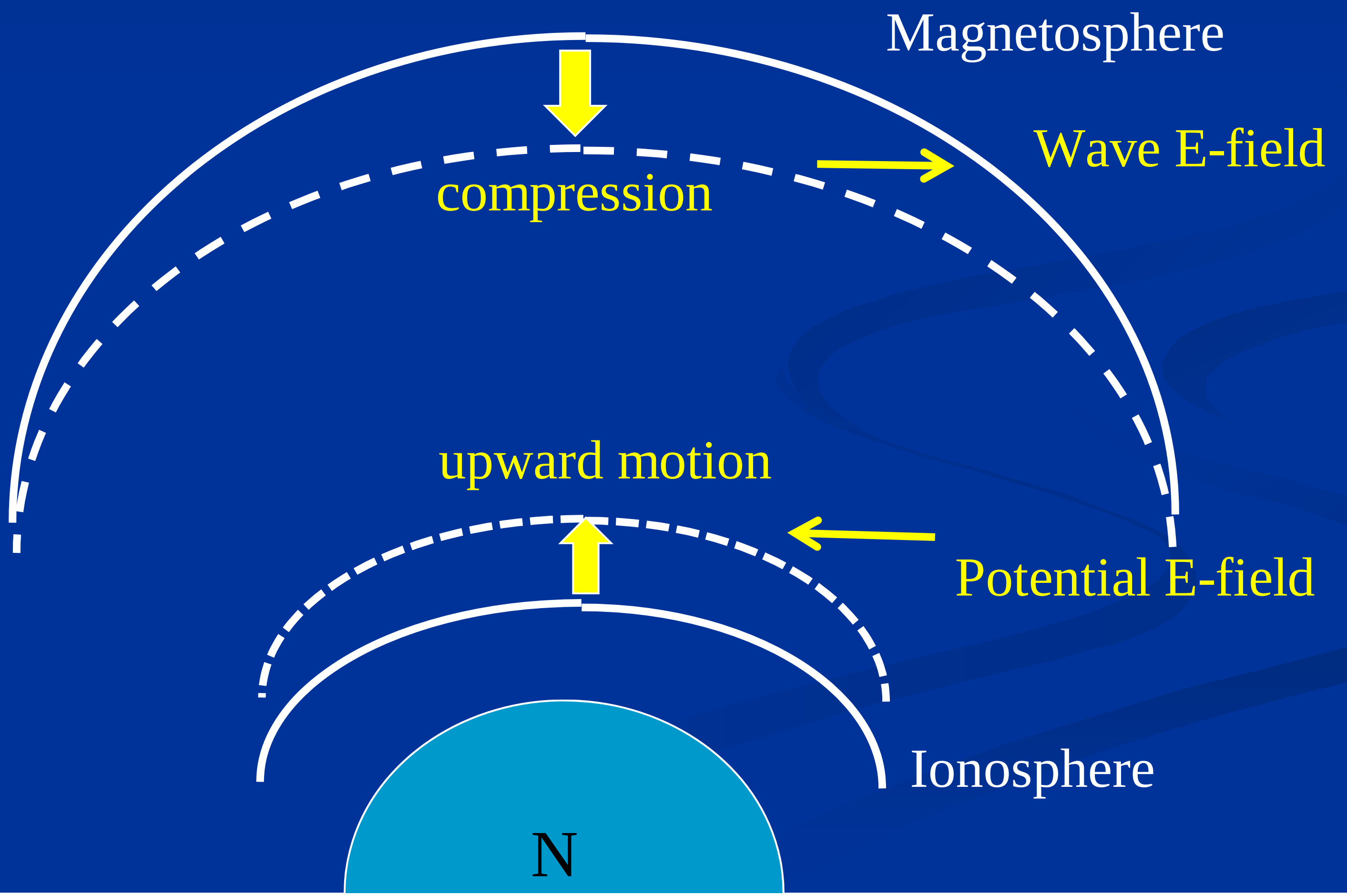
The ionosphere moves upward.

$\Delta H > 0$

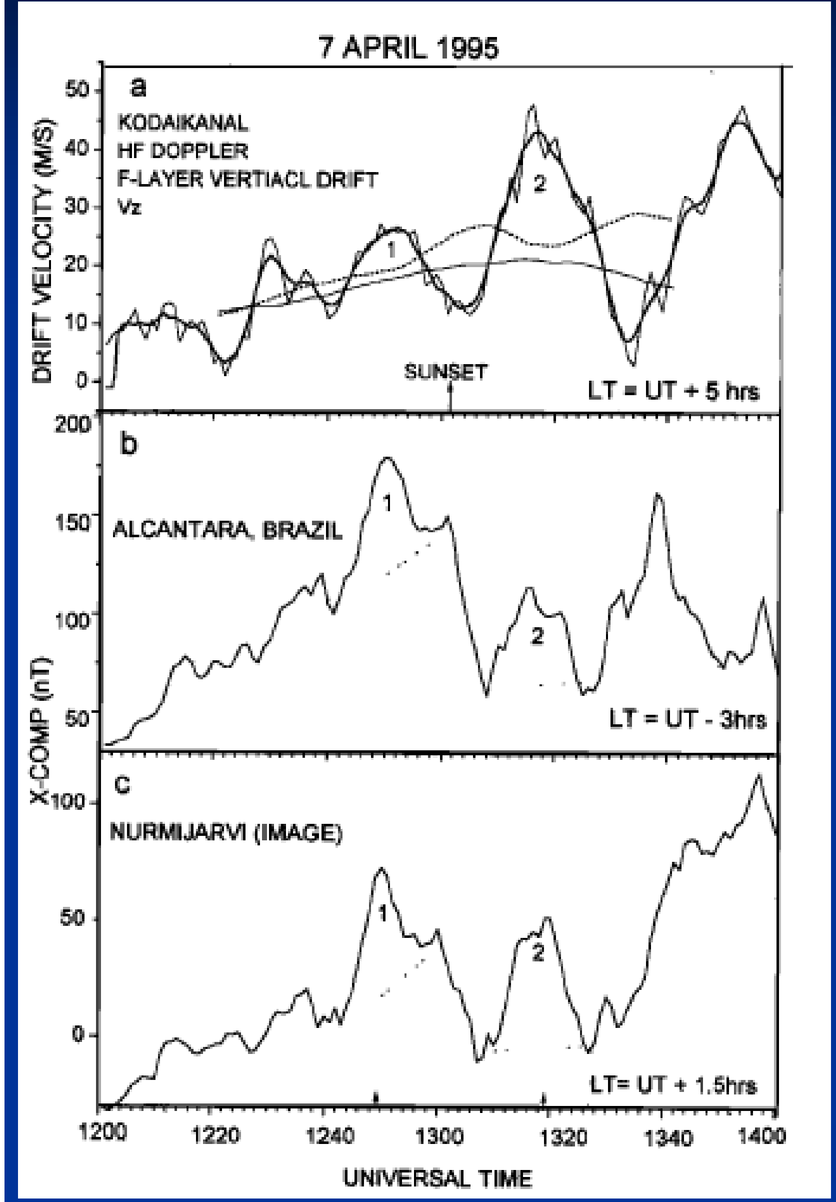
The magnetosphere is compressed,

The upward motion is well correlated with the EEJ.

The compressional MHD waves do not compress the dayside ionosphere. The ionosphere is moved by the potential electric field associated with the ionospheric currents.



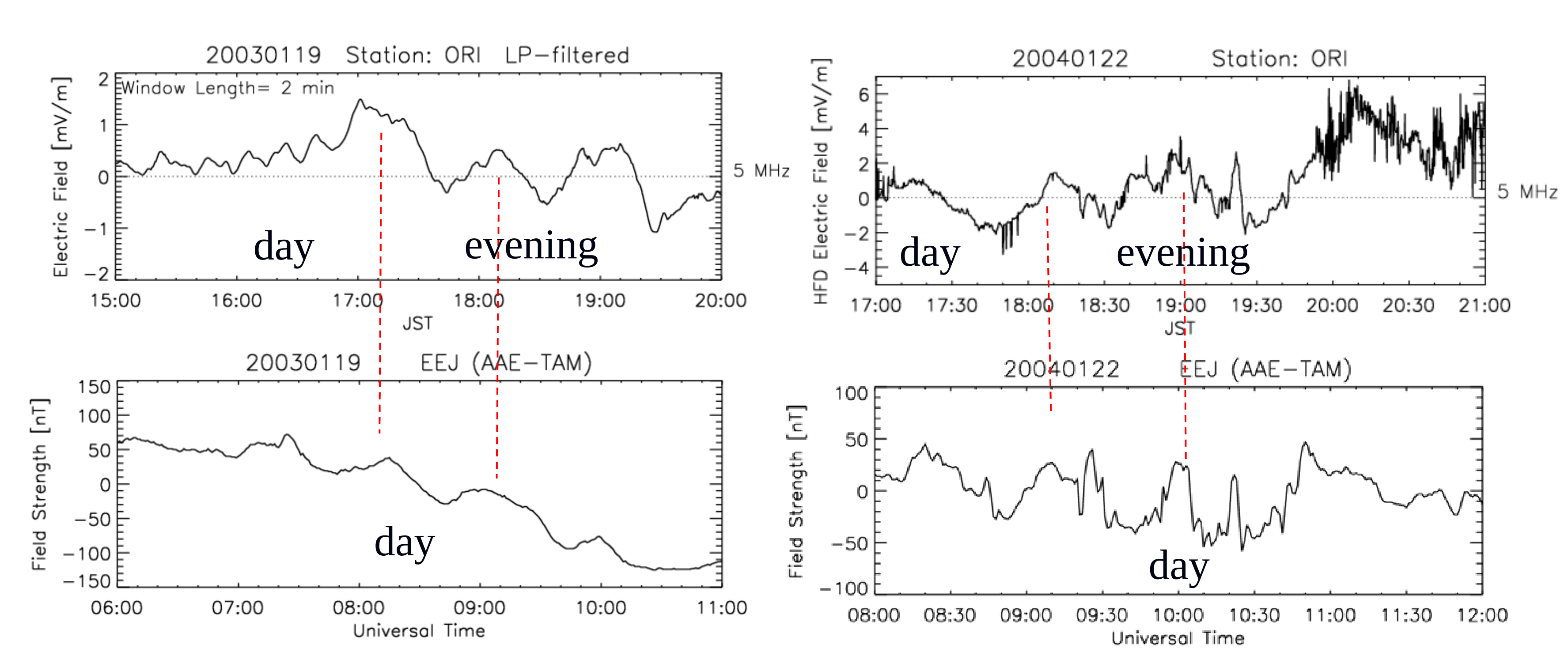
Evening anomaly of the DP2 electric field at the equator



The DP2 electric field detected with the HF Doppler sounder in the evening is directed in the same direction as the DP2 currents in the dayside equatorial ionosphere. The electric field is enhanced in the evening. (Abdu et al., GRL 1998)

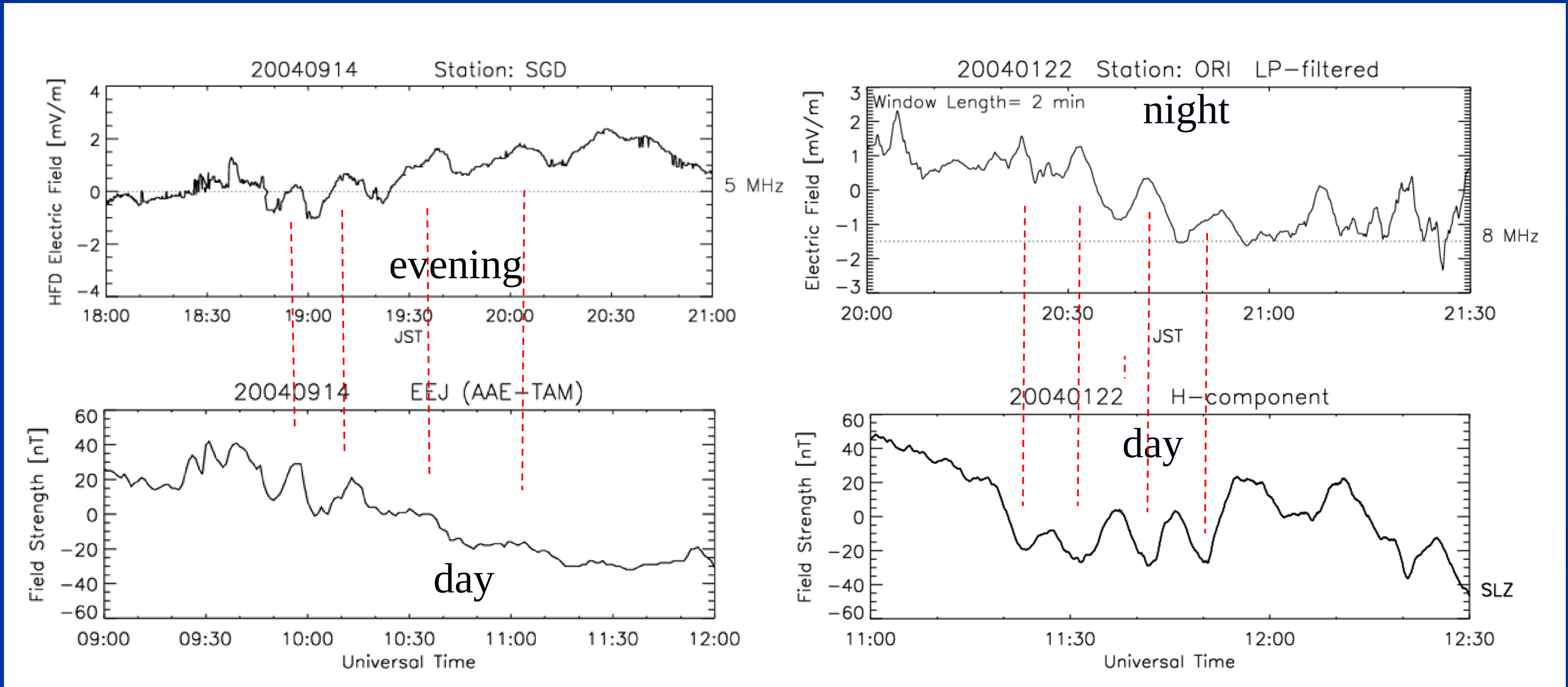
Evening anomaly of the DP2 electric field at midlatitudes

The eveningtime electric field of the quasi-periodic DP2 (period=1 hour) is in the same direction as the daytime EEJ.

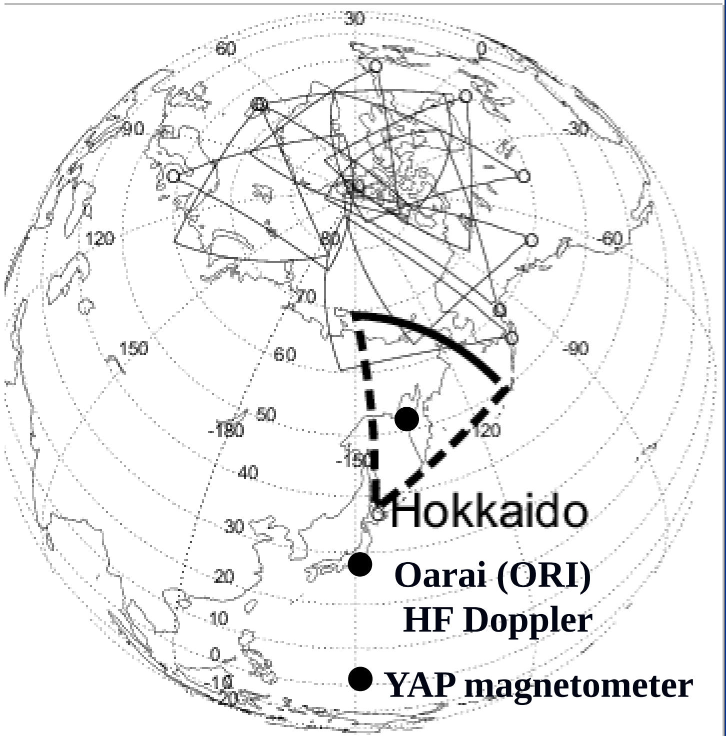


Evening anomaly of the DP2 electric field at midlatitudes

The eveningtime electric field of the quasi-periodic DP2 (period=10-30min) is in the same direction as the daytime EEJ, while the nighttime electric field is in opposite direction to the daytime EEJ.

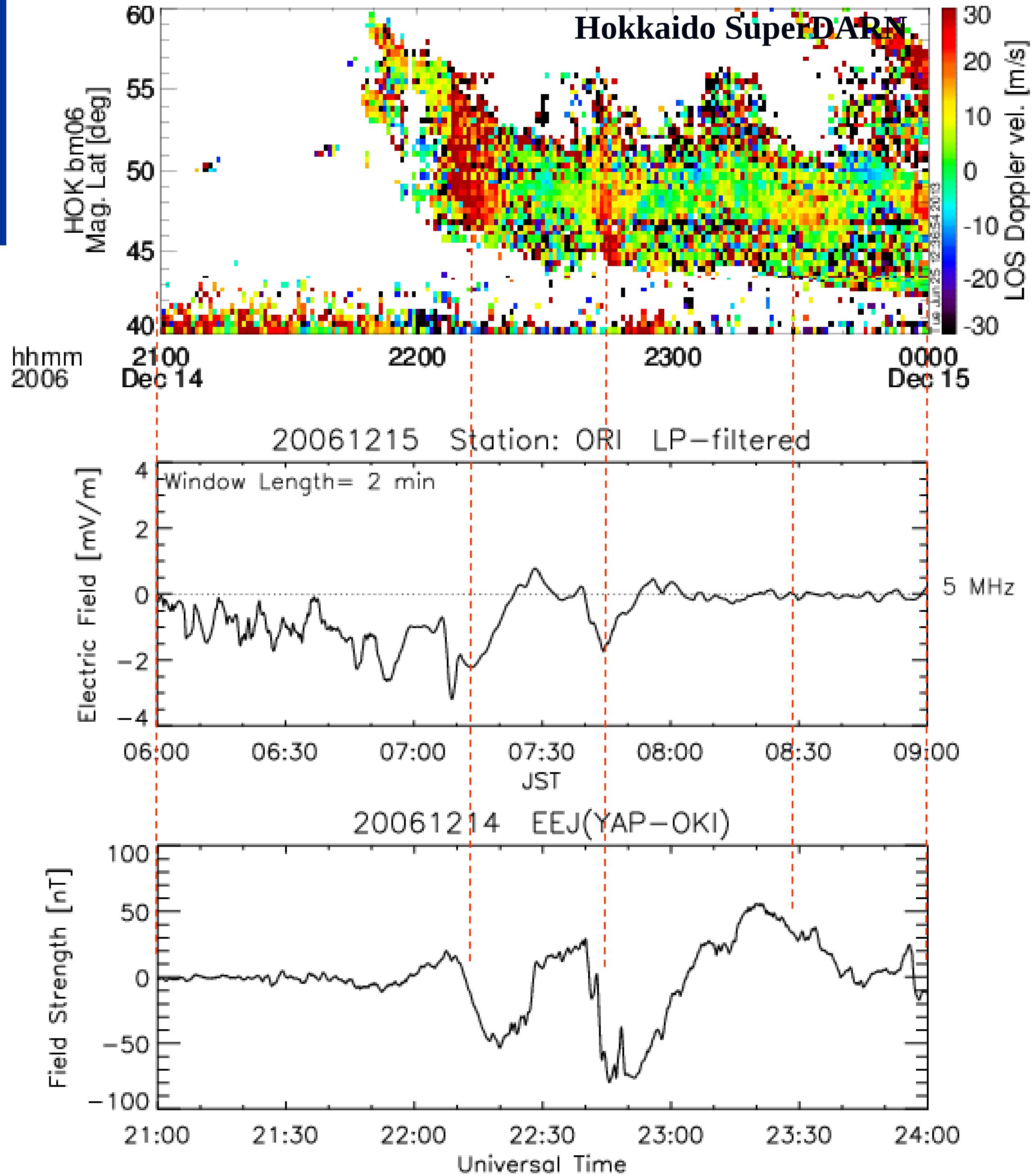


Hokkaido SuperDARN and HF Doppler sounder observations of the DP2 electric field

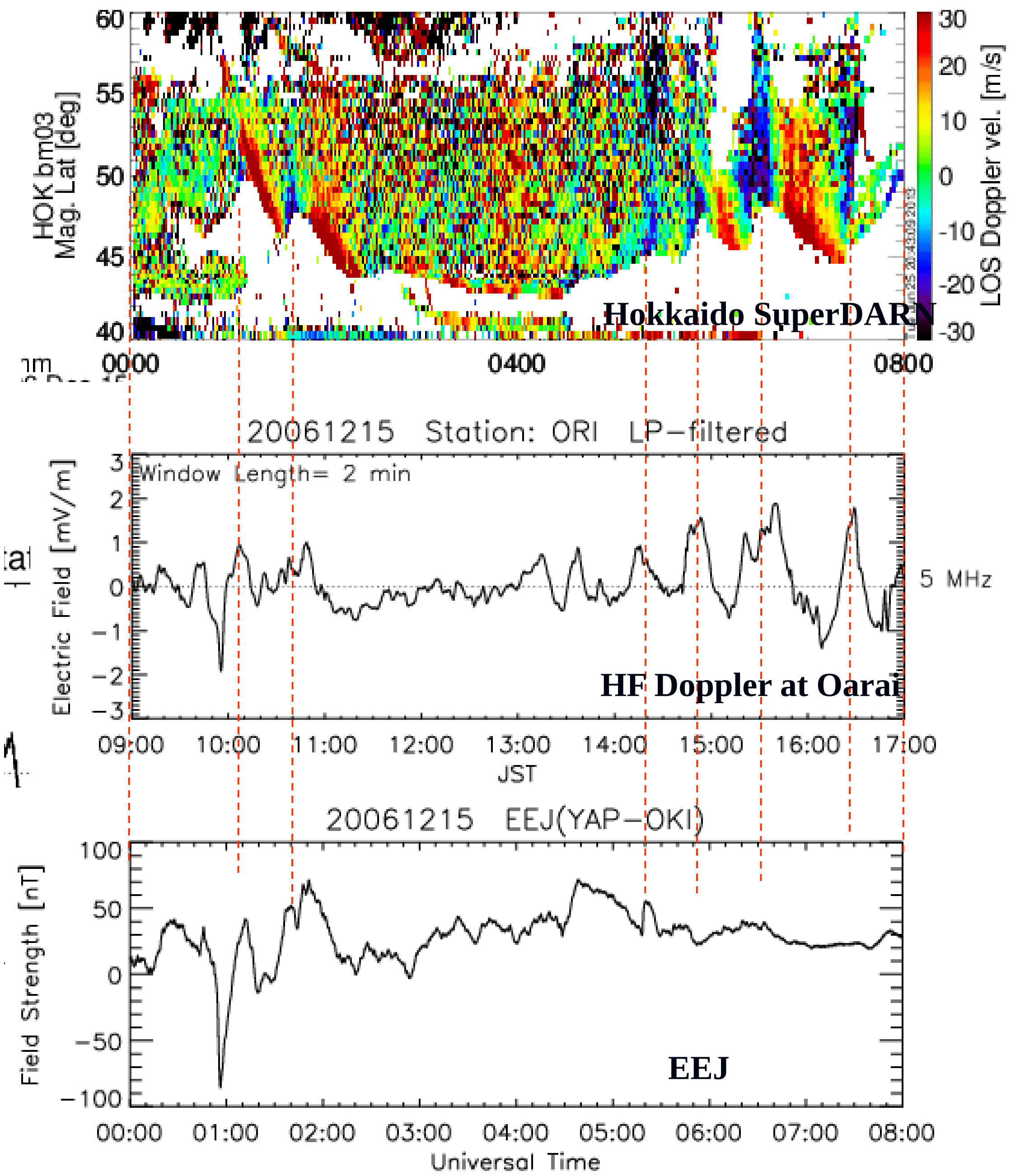


Electric field from HF Doppler

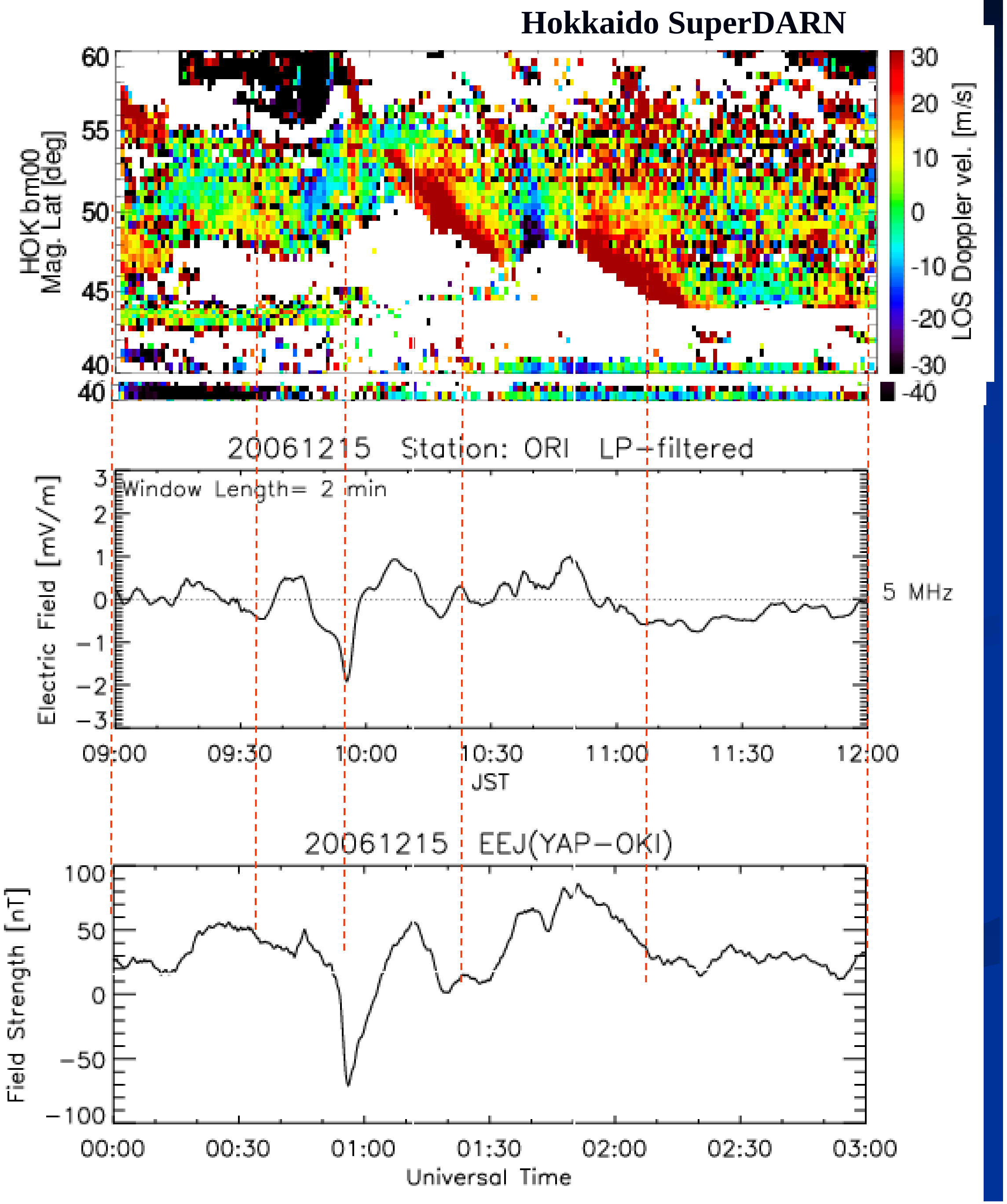
$E = 2.15$ [mV/m] ($\Delta f = 1$ Hz)



Stormtime electric fields detected by the Hokkaido SuperDARN radar and HF Doppler sounder



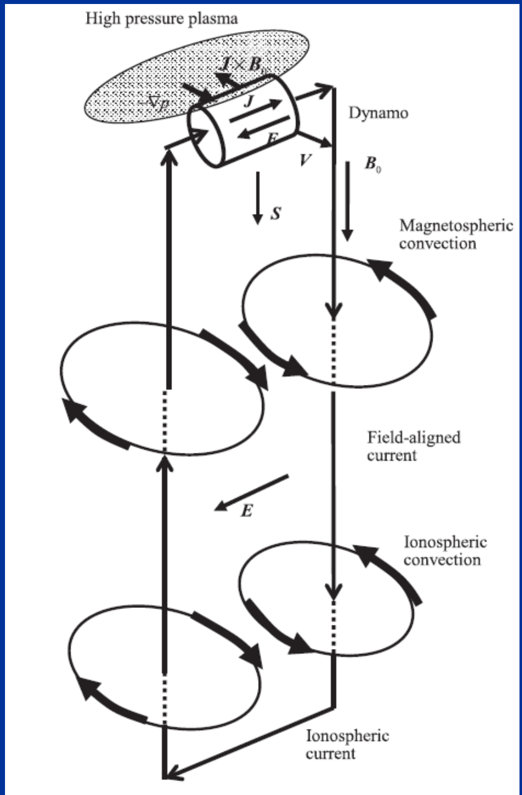
Hokkaido SuperDARN and HF Doppler observations of the electric fields at mid and low latitudes



The electric fields observed by the Hokkaido SuperDARN radar and HF Doppler sounder are westward during intense CEJs and eastward during weak CEJs. It is suggested that the long-lasting weak CEJs are caused by the disturbance dynamo, while the overshielding electric field intensify the CEJs.

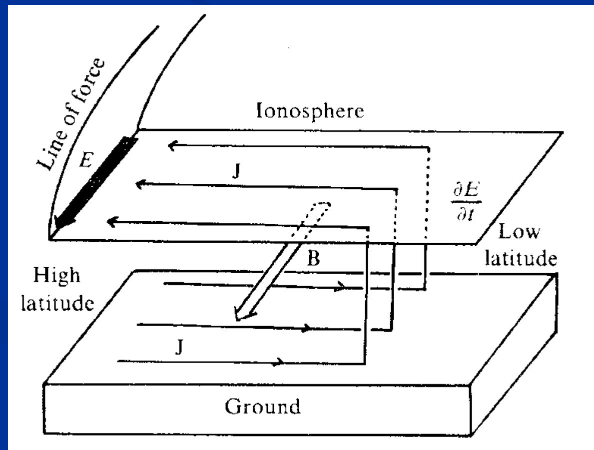
How are the potential electric field and currents transmitted from the magnetosphere to the equatorial ionosphere?

Field-aligned currents



+

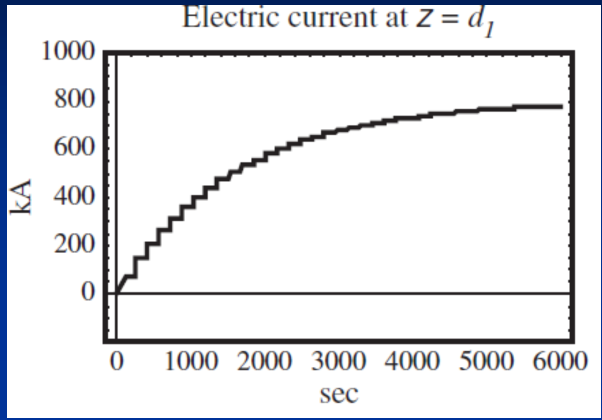
TM0 mode waves in the Earth-ionosphere waveguide (Kikuchi et al., 1978)

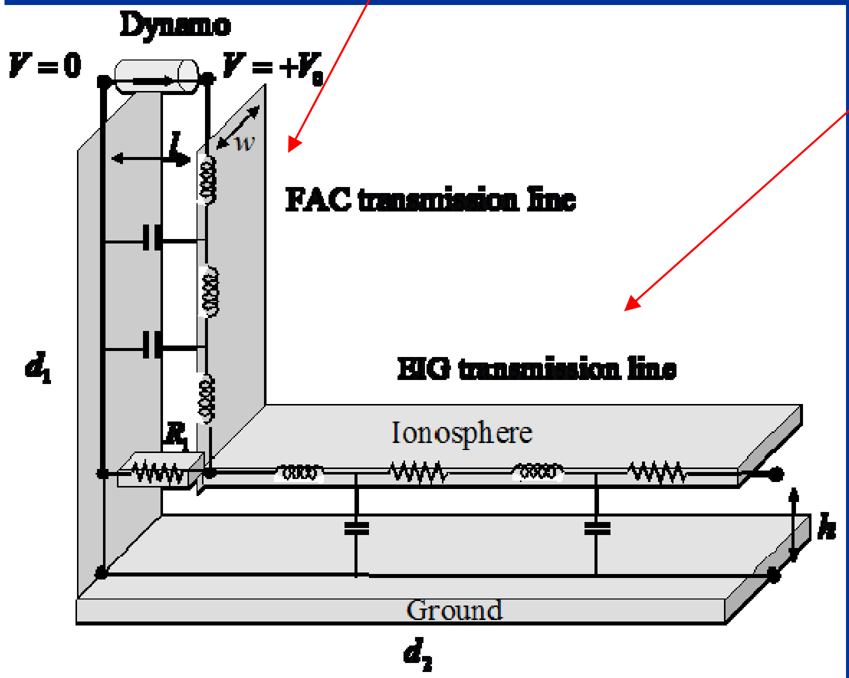


Magnetosphere-ionosphere-ground (MIG) transmission line

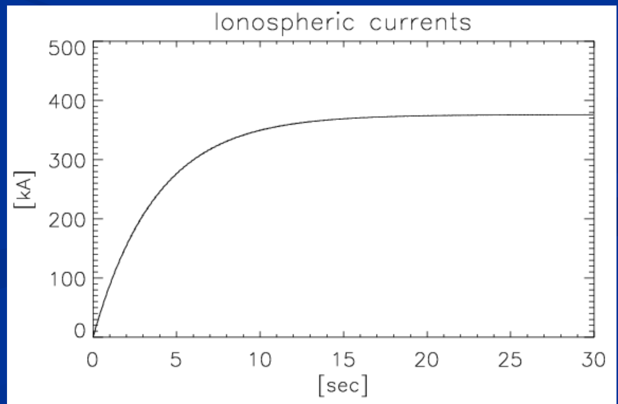
[Kikuchi, JGR 2014]

[MI transmission line]
The ionospheric currents increase gradually with time constants (10s of min) depending on the length of the filed lines and ionospheric conductivity.



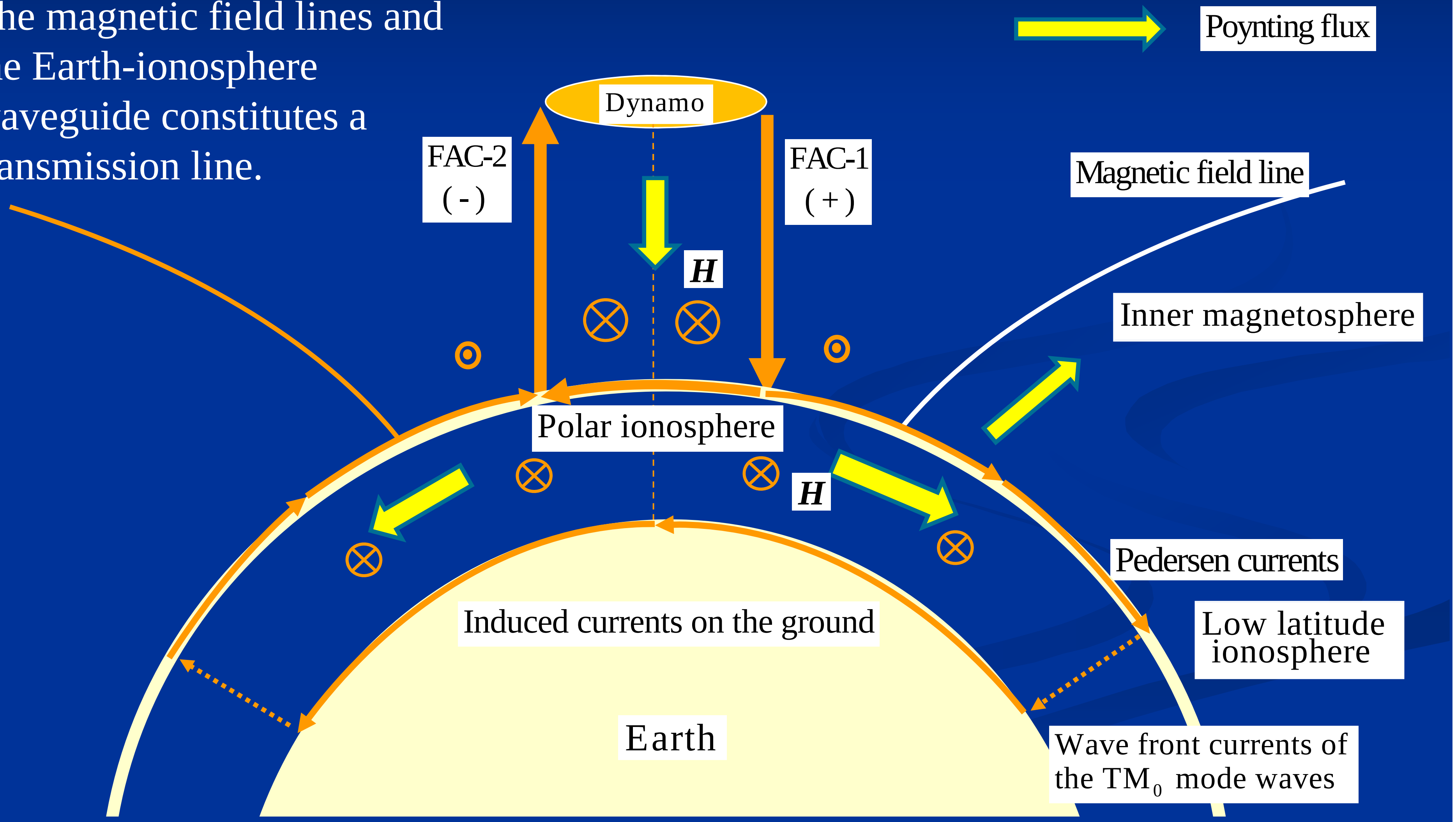


IG transmission line]
The ionospheric currents increase gradually with time constants (a few seconds) dependin on the ionospheric conductivity.



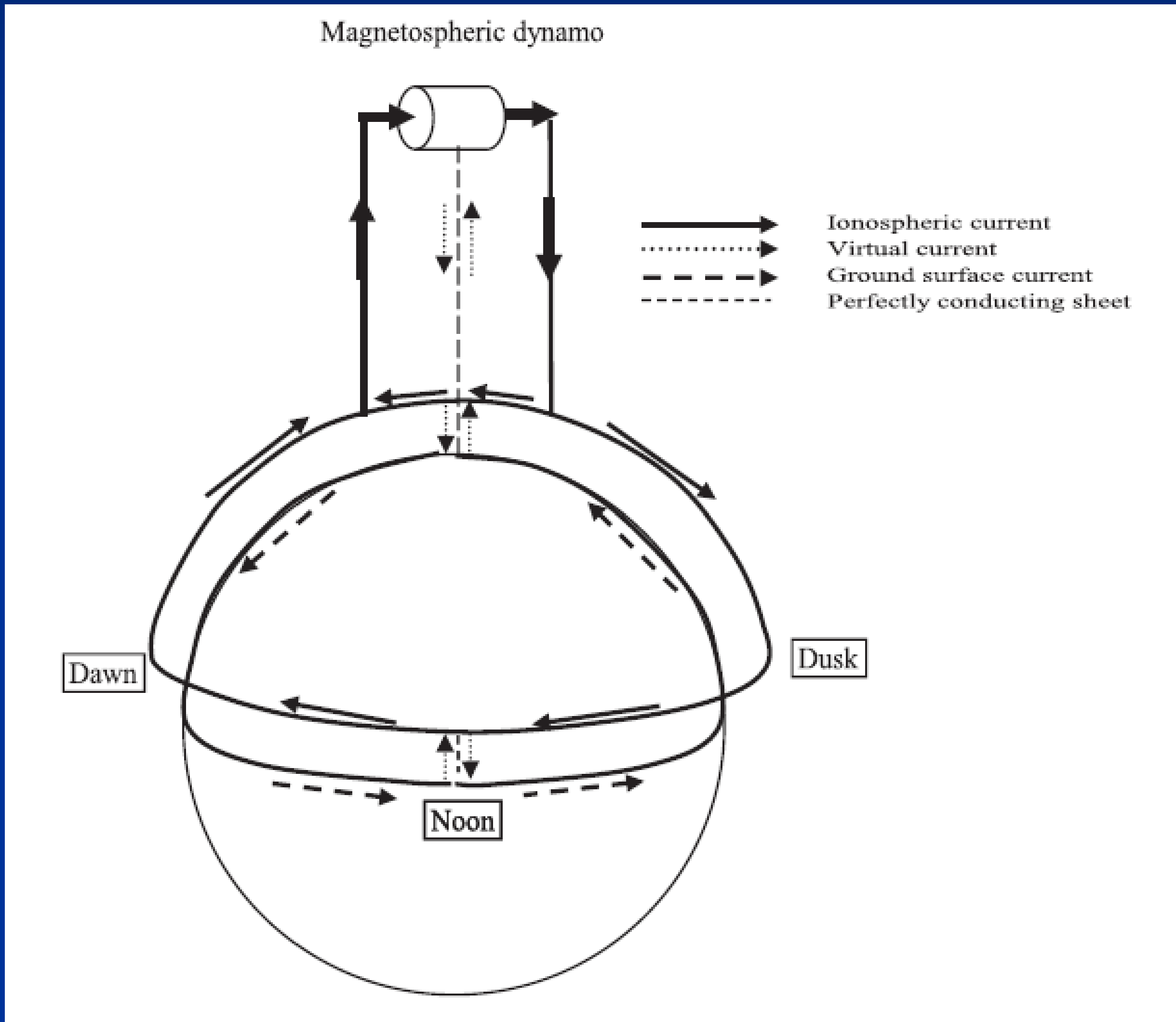
The Poynting flux is transmitted to the equatorial ionosphere down the field lines and through the Earth-ionosphere waveguide.

The magnetic field lines and the Earth-ionosphere waveguide constitutes a transmission line.



Magnetosphere-Ionosphere-Ground current circuit

磁気圏電離圏地面電流回路



(Kikuchi, JGR 2014)

Summary

- The midlatitude electric fields on the day are opposite in direction to those on the nightside for the period range from 10 sec to hours.
- The midlatitude electric field is well correlated with ionospheric currents, indicating that the electric field is a potential filed transmitted from the polar ionosphere where the electric potentials are supplied by the field-aligned currents.
- The evening anomaly of the midlatitude electric field is a unique feature of the electric potential in the global ionosphere.
- The electric potential is transmitted from the dynamo in the magnetosphere by the Alfven waves in the magnetosphere and TM0 mode electromagnetic waves in the Earth-ionosphere waveguide.