中緯度における磁気圏起源電場

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中緯度電離圏は内部磁気圏への入り口

Contents

1. **Magnetospheric potential electric field at mid latitudes**

- IS radar observation

  Convection (Mazaudier)

  Polarization jet (Huang)

- HF Doppler/FMCW sounder

  DP2 (Abdu)

  SC/Si, PC (Kikuchi, Motoba)

- Magnetometer observation

  DP2 (Kikuchi)

  DP1 (Kikuchi)

  SC/Si, PC (Kikuchi, Motoba)

磁気圏で生成されるポテンシャル電場がレーダー･磁力計網により中緯度で観測される。

磁気圏伝送線（沿磁力線電流）と地球電離層導波管によりポテンシャル電場が中緯度電離圏と内部磁気圏へ伝えられる。

2. **Transmission mechanism (Kikuchi and Araki)**

   Equatorward transmission (Earth-ionosphere waveguide)

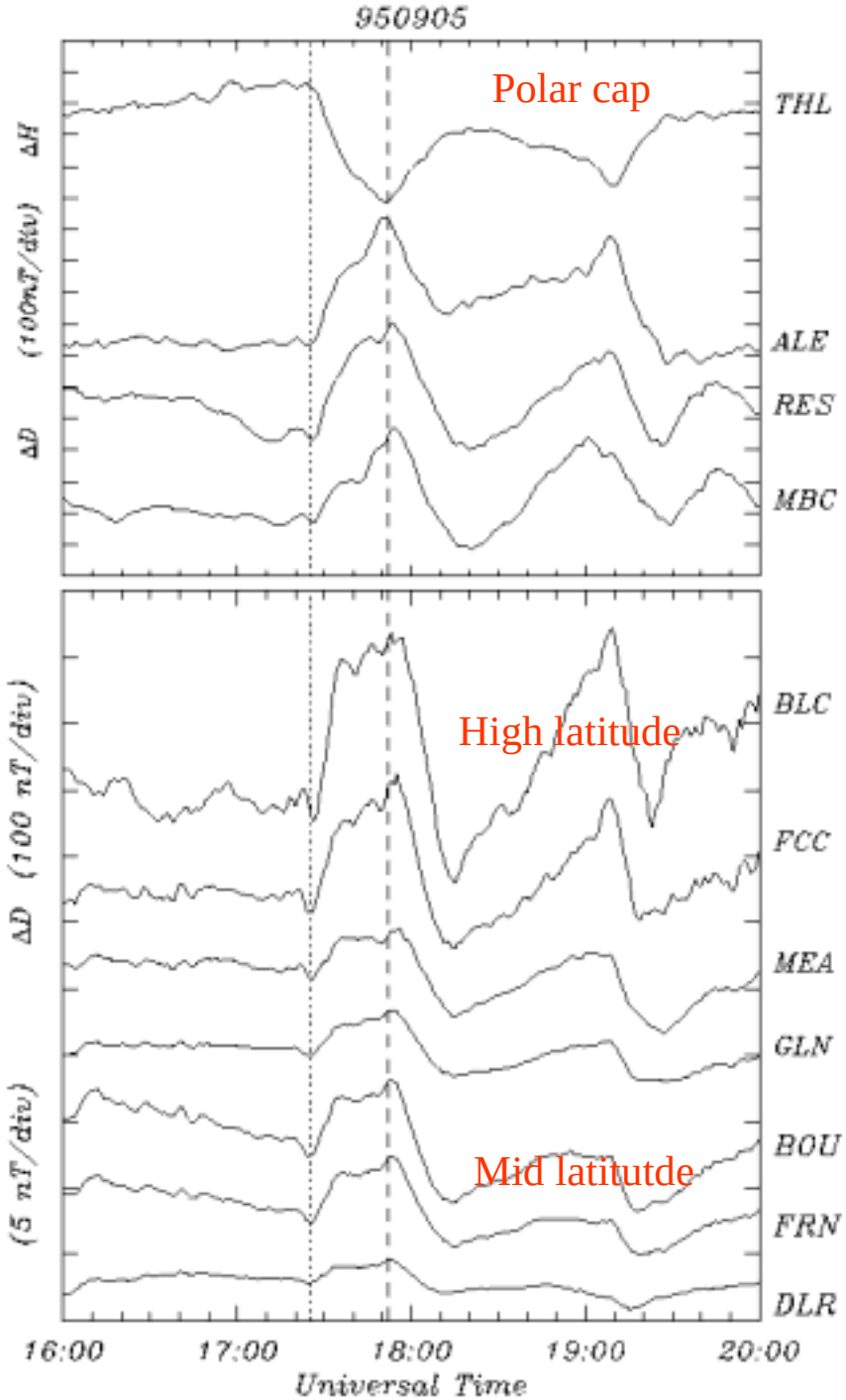
   Transmission from E to F-region

The convection electric field penetrated to mid and low latitudes as detected by magnetometers

Hashimoto et al. (JGR 2002)

極冠から中緯度までcoherentな磁場変動は対流電場の中緯度への侵入を示す。

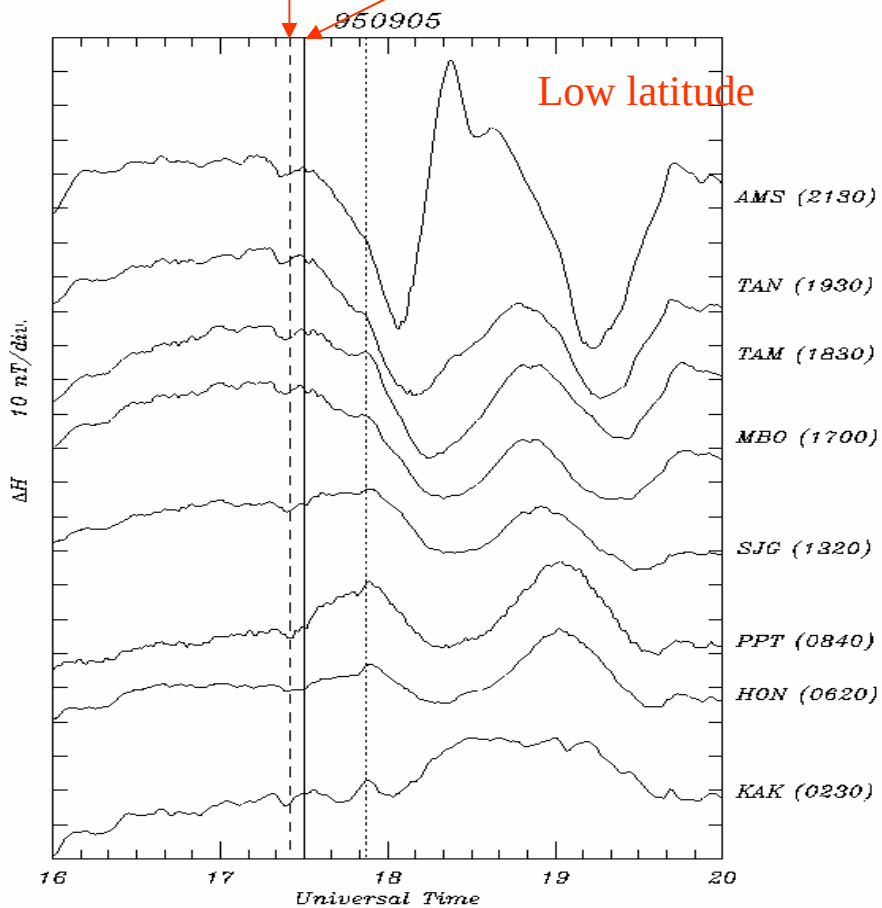
Baker Lake (BLC, 74.26 ° N, 326.55 ° E GM)
Fort Churchill (FCC, 69.25 ° N, 331.56 ° E GM),
Meanook (MEA, 62.28 ° N, 304.99 ° E GM),
Glenlea (GLN, 60.08 ° N, 328.53 ° E GM),
Boulder (BOU, 49.18 ° N, 319.15 ° E GM),
Fresno (FRN, 43.11 ° N, 303.24 ° E GM),
Del Rio (DLR, 38.93 ° N, 325.92 ° E GM).

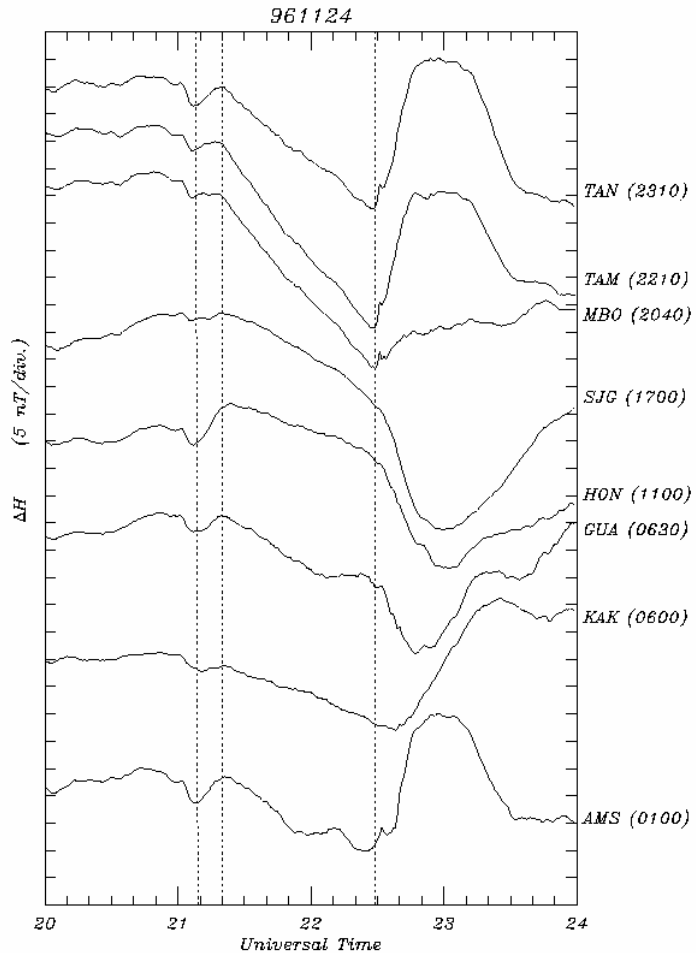


Prompt Development of Partial Ring Current

Onset of the increase in the polar cap potential

Onset of the partial ring current

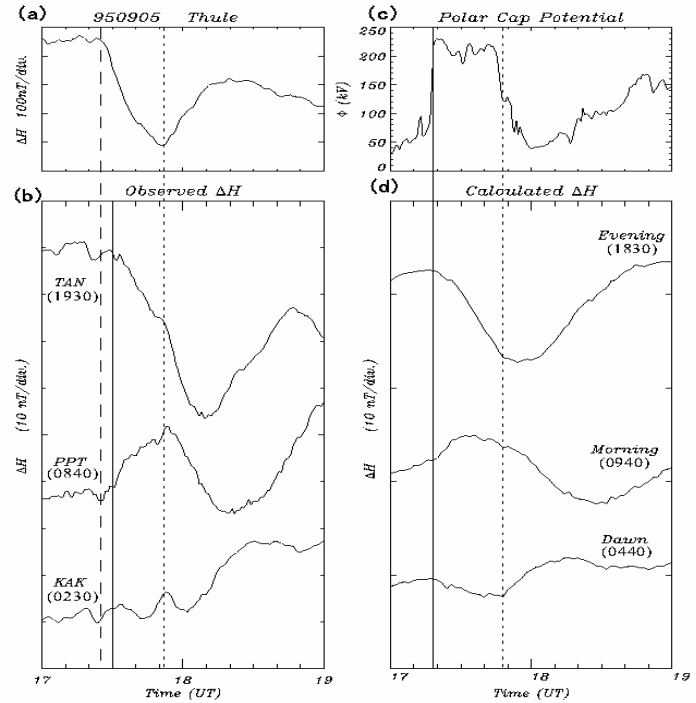


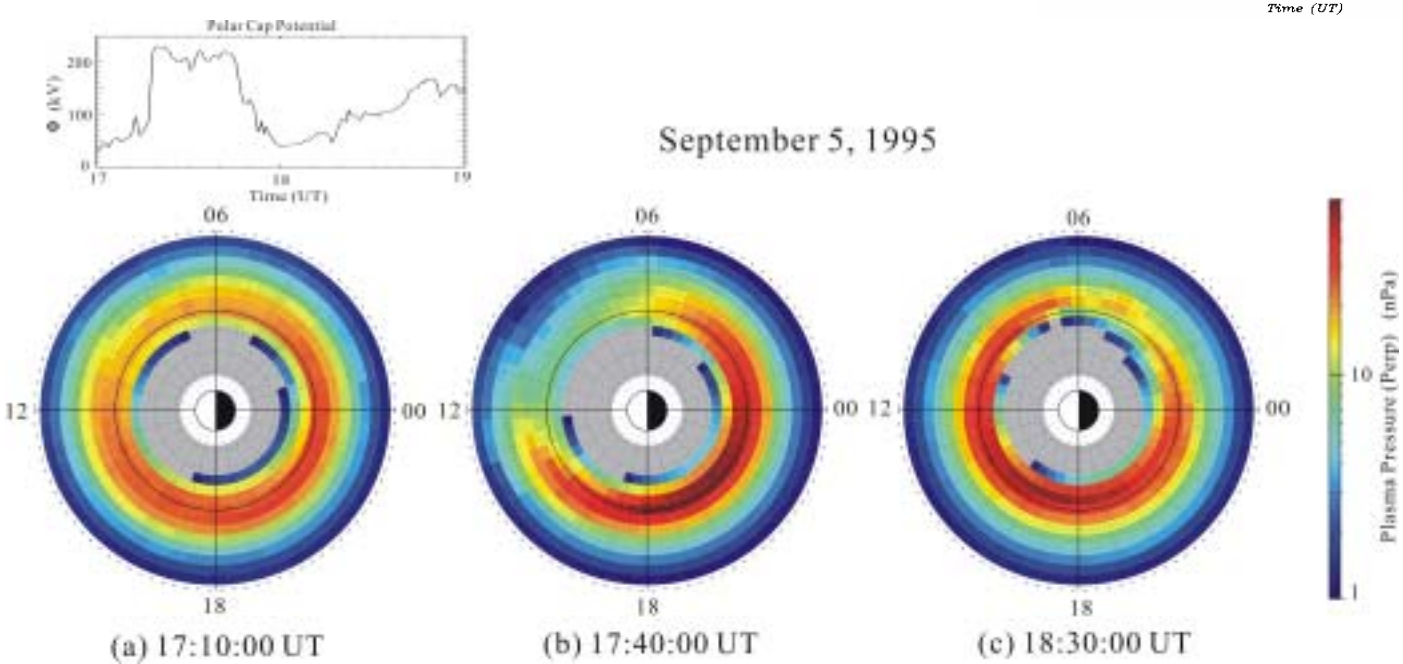


(Hashimoto et al., JGR 2002)

Asymmetric ring currents caused by the convection electric field in the inner magnetosphere

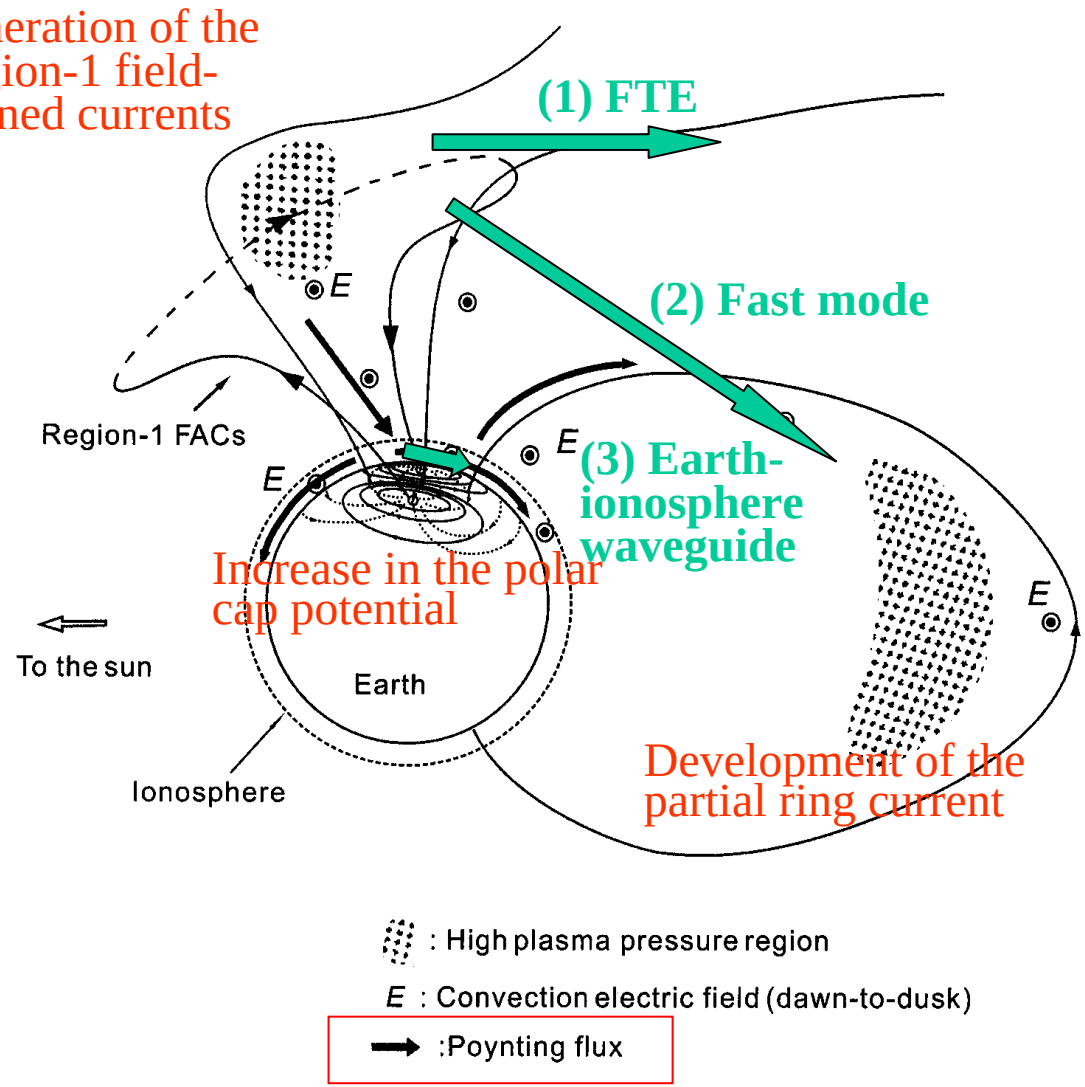
(Hashimoto et al., JGR 2002)





How was the convection electric field transmitted into the inner magnetosphere?

- The prompt development of the partial ring current suggests that the convection electric field is transmitted from the current generator in the cusp to the inner magnetosphere through the Earth-ionosphere waveguide.



Hashimoto et al. (JGR 2002)

FTE

1. It would take 15-30 min for the FTE to complete the ionospheric convection, inconsistent with the quick development of the nightside ionospheric convection (Ridley et al., 1998; Ruohoniemi and Greenwald, 1998) and of the partial ring current (Hashimoto et al., 2002).

Fast Mode in the magnetosphere

- The fast mode reduces an imbalance in the magnetic pressure distribution. It hardly drives rotational motion of plasma, except for the convection during the main phase of the SC.

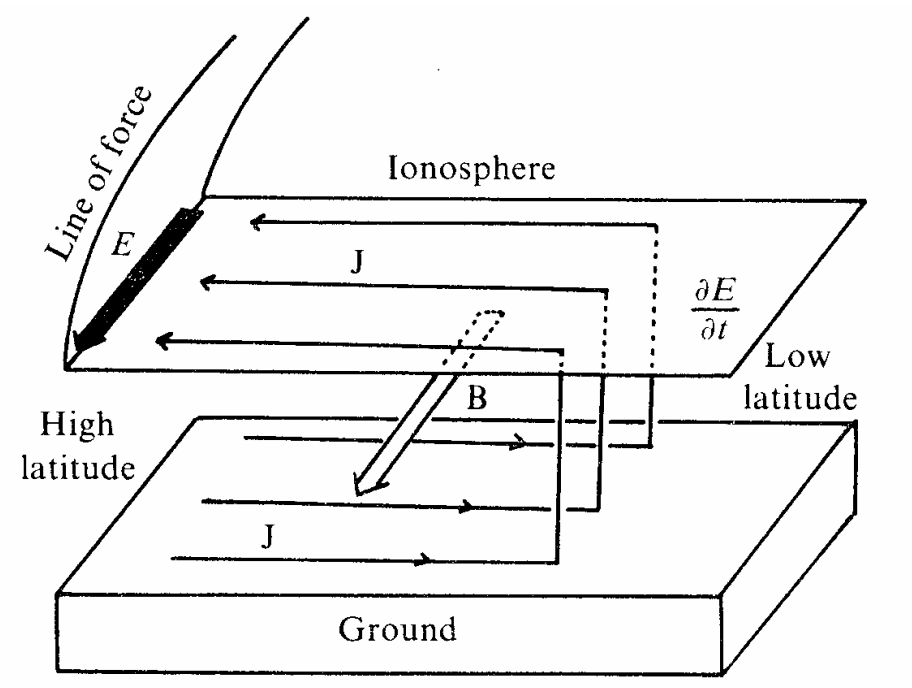
Possible propagation modes in the ionosphere

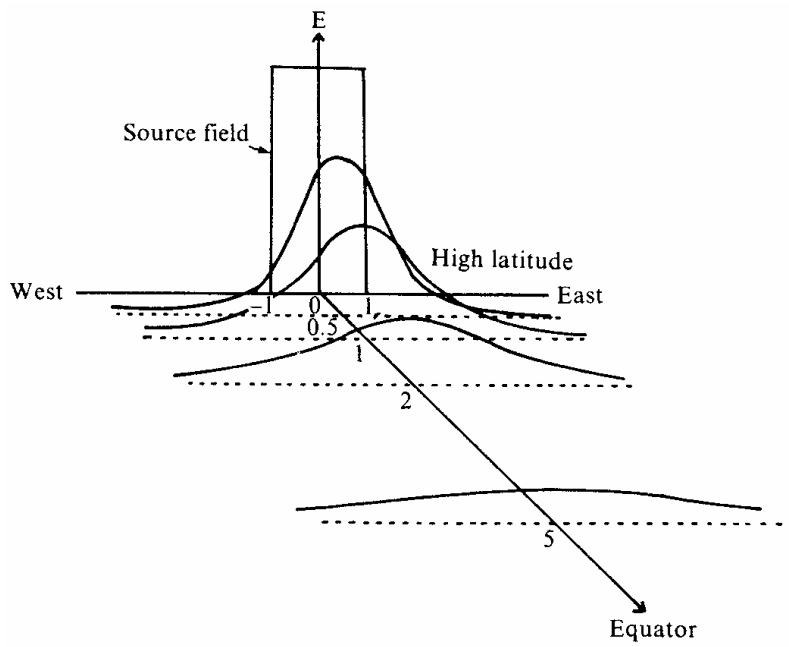
- F-region: Fast mode waves in the F-region waveguide are severely attenuated because of the cutoff frequency at about 1 Hz.
- E-region: Diffusion mode waves are severely attenuated.
- Earth-Ionosphere Waveguide: Zeroth-order TM mode waves propagate at the speed of light with no cutoff frequency.

(Kikuchi and Araki, JATP 1979a, JATP 1979b)

Earth-Ionosphere Waveguide Model
TM0 Mode Propagation

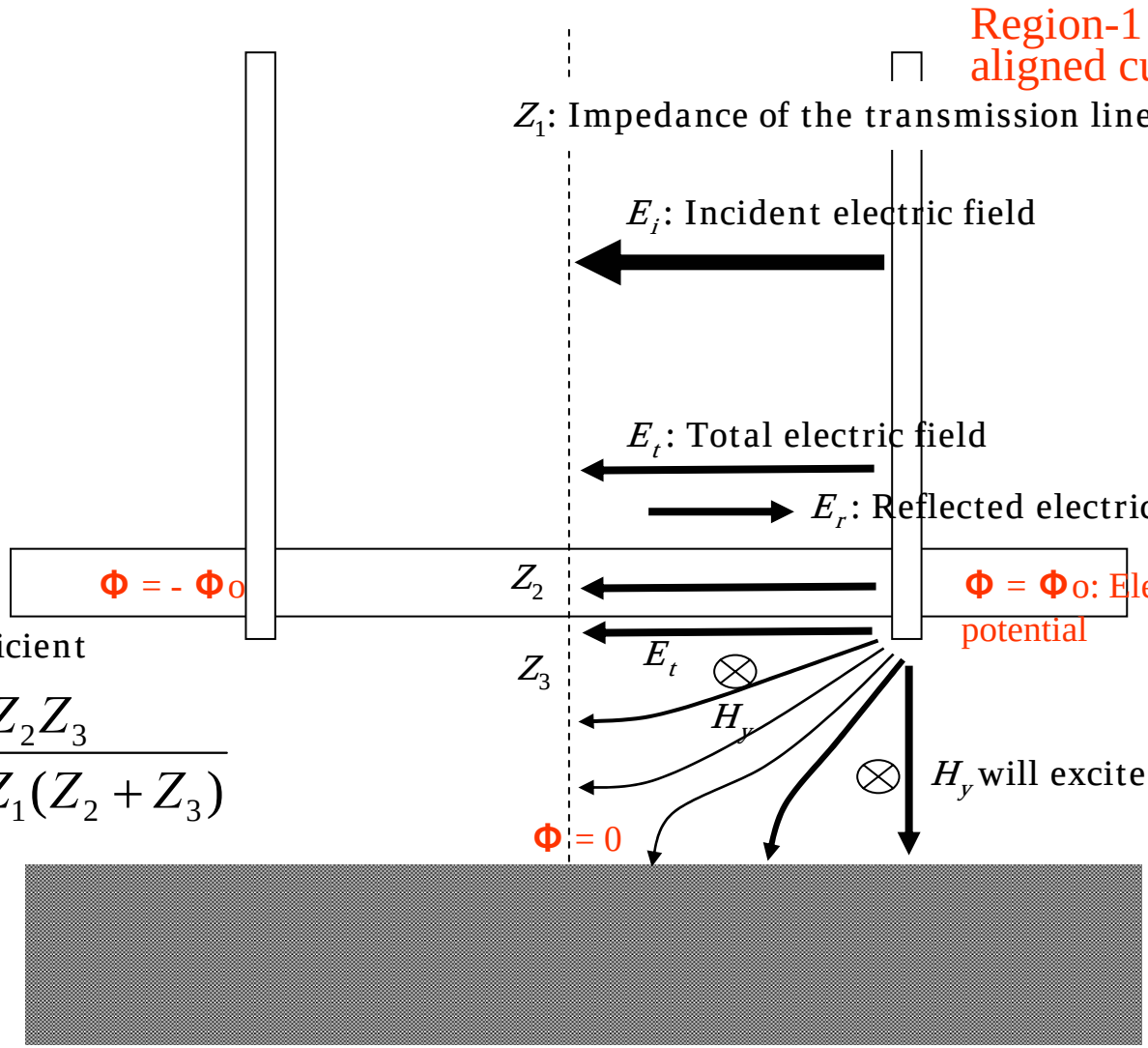
Kikuchi et al., (Nature 1978, p.650)





Excitation of the TM0 mode

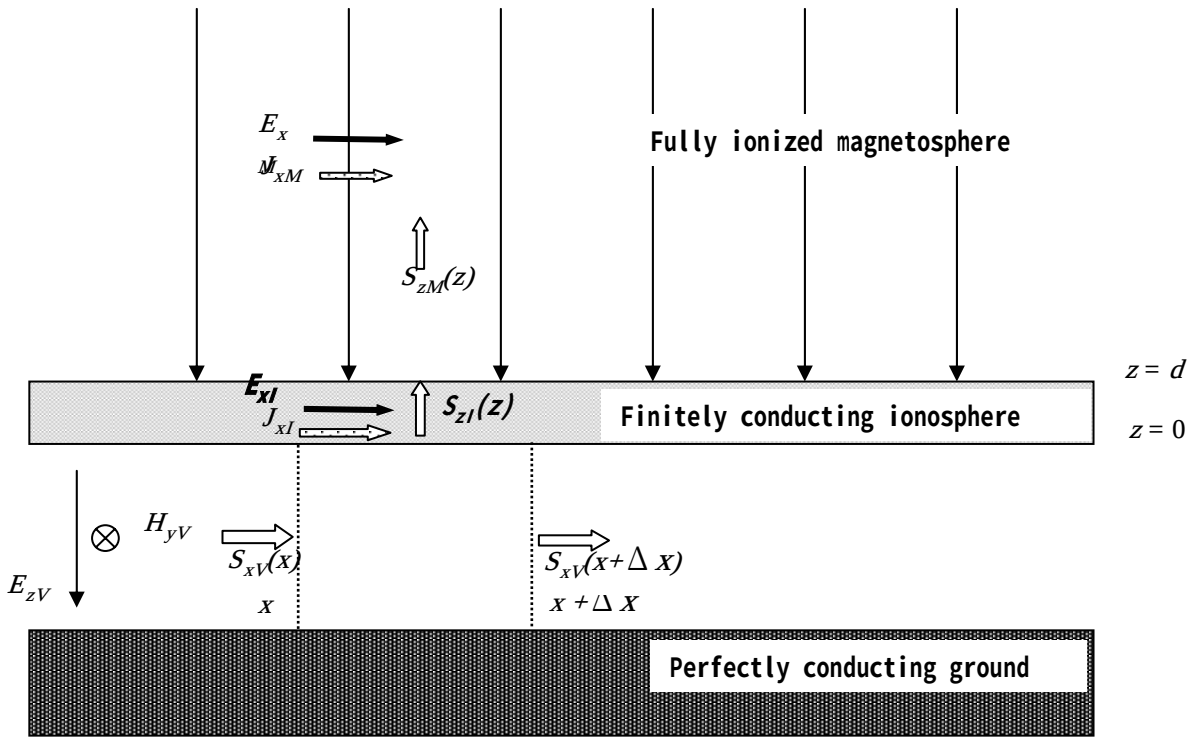
Transmission of EM energy into the Earth-ionosphere waveguide



Transmission coefficient

$$t = \frac{2Z_2Z_3}{Z_2Z_3 + Z_1(Z_2 + Z_3)}$$

Three-layered Earth-ionosphere waveguide



Electric and magnetic fields in the three-layered Earth-ionosphere waveguide

In the magnetosphere

$$H_{yM}(x) = \frac{\Sigma_A}{\Sigma_A + \Sigma_I} H_{yV}(x) \cdot U\left(t - \frac{z}{V_a}\right)$$

$$E_{xM}(x) = \frac{1}{\Sigma_A + \Sigma_I} H_{yV}(x) \cdot U\left(t - \frac{z}{V_a}\right)$$

$$\Sigma_A = \frac{1}{\mu_0 V_a}$$

$$\Sigma_I = \sigma \cdot d$$

In the ionosphere

$$H_{yI}(x) = \left(1 - \frac{\sigma z}{\Sigma_A + \Sigma_I}\right) H_{yV}(x)$$

$$E_{xI}(x) = \frac{1}{\Sigma_A + \Sigma_I} H_{yV}(x)$$

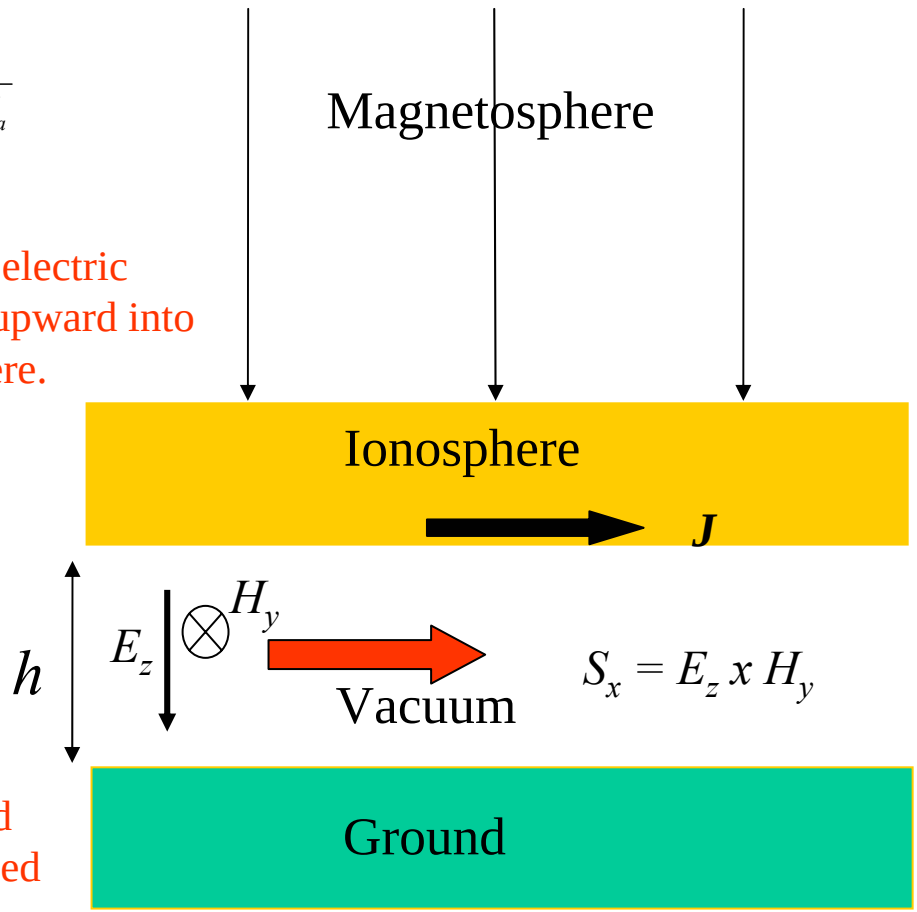
The ionospheric electric field is mapped upward into the magnetosphere.

In the vacuum

$$H_{yV} = H_{y0}\, \mathrm{U}(t - \frac{x}{c})$$

$$E_{zV} = -Z_0 H_{y0}\, \mathrm{U}\left(t - \frac{x}{c}\right)$$

The electric potential, $V=E_{zV} \cdot h$, is transmitted horizontally at the speed of light.



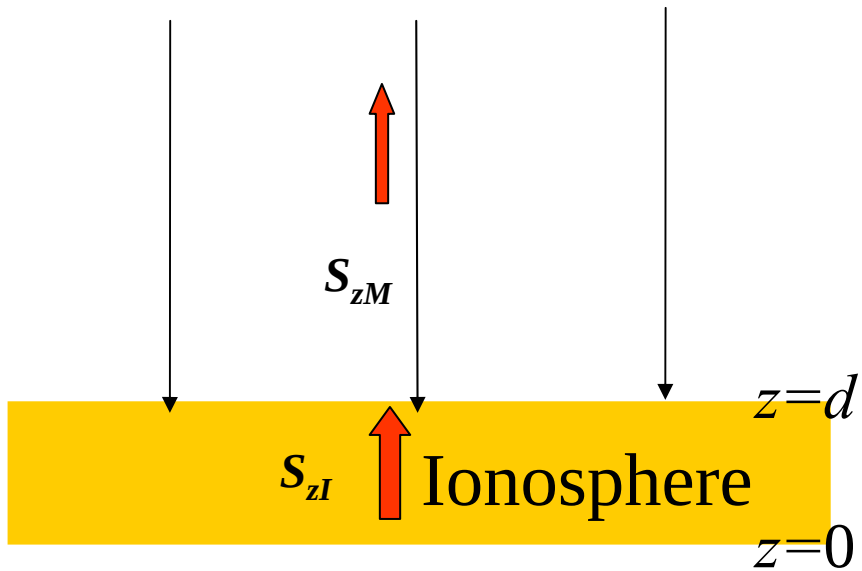
Poynting flux in the three regions

Upward Poynting flux in the magnetosphere (leakage from the ionosphere)

$$S_{z,M}(x,z) = \frac{\Sigma_A}{(\Sigma_A + \Sigma_I)^2} H_{yV}^2(x) \cdot U\left(t - \frac{z}{V_a}\right)$$

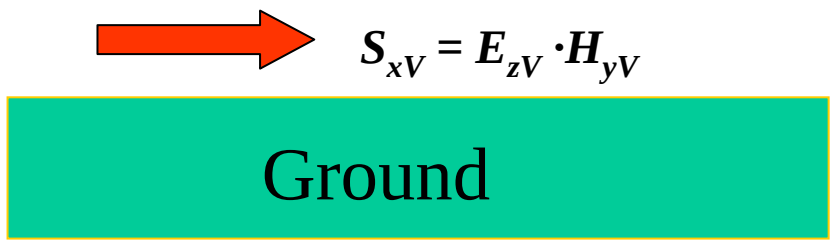
Upward Poynting flux in the ionosphere

$$S_{zI}(x,z) = \frac{\Sigma_A + \Sigma_I - \sigma \cdot z}{(\Sigma_A + \Sigma_I)^2} H_{yV}^2(x)$$



Horizontal Poynting flux in the waveguide

$$S_{xV}(x) = Z_0 H_{yV}{}^2(x) = E_{zV}{}^2(x) / Z_0$$



The ionosphere drives the convection in the inner magnetosphere

$$E_{xM}(x) = E_{xI}(x) \cdot U\left(t - \frac{z}{V_a}\right)$$

$$E_{xI}(x) = \frac{1}{\Sigma_A + \Sigma_I} H_{yV}(x)$$

$$\Sigma_A = \frac{1}{\mu_0 V_a} = \frac{1}{B_0}\sqrt{\frac{\rho}{\mu_0}}$$

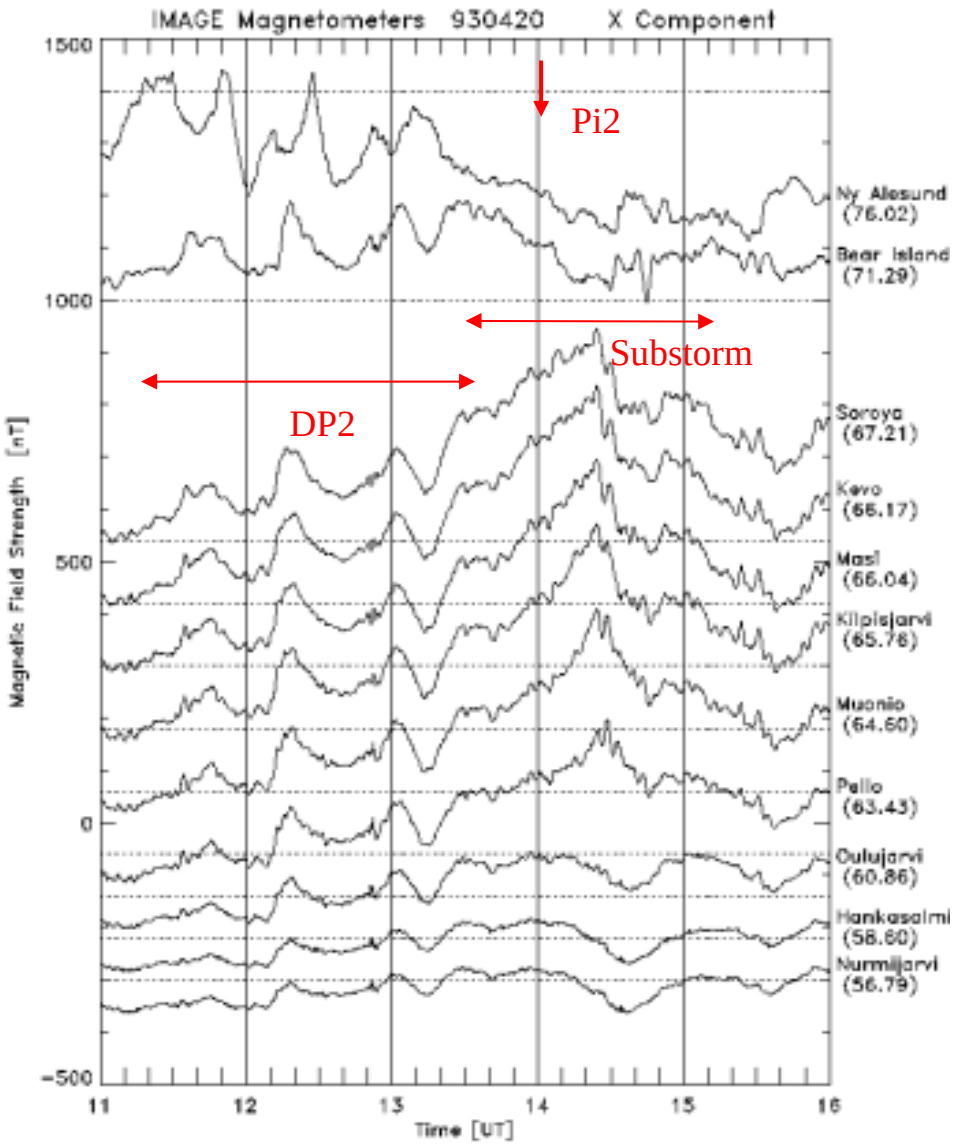
電離圏電場が磁力線沿いに内部磁気圏へ伝送され、対流を駆動する

The convection electric field in the inner magnetosphere depends on the ionospheric conductance and the plasma density of the inner magnetosphere.

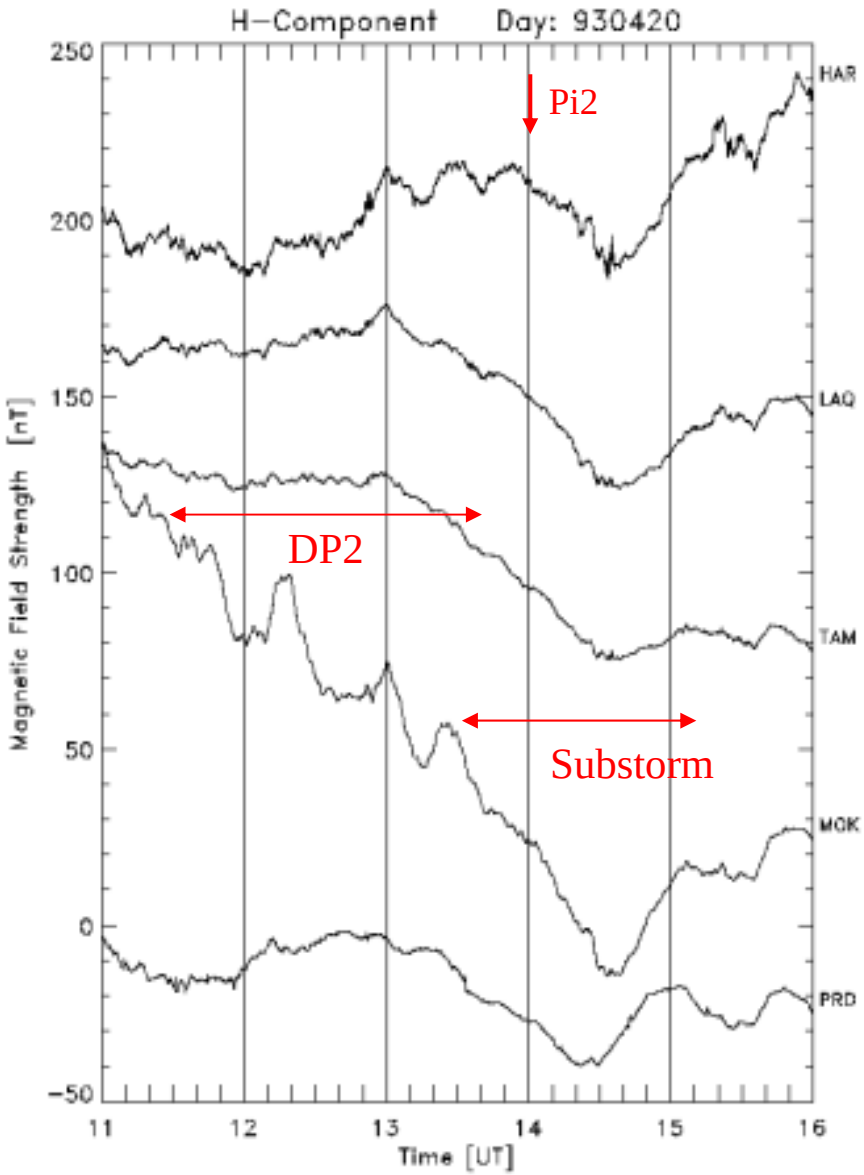
The velocity of the convection decreases with increasing ionospheric conductance and magnetospheric plasma density.

Equatorial enhancement of DP2 and DP1 (substorm)

Kikuchi et al. (JGR 2000, p.17161)

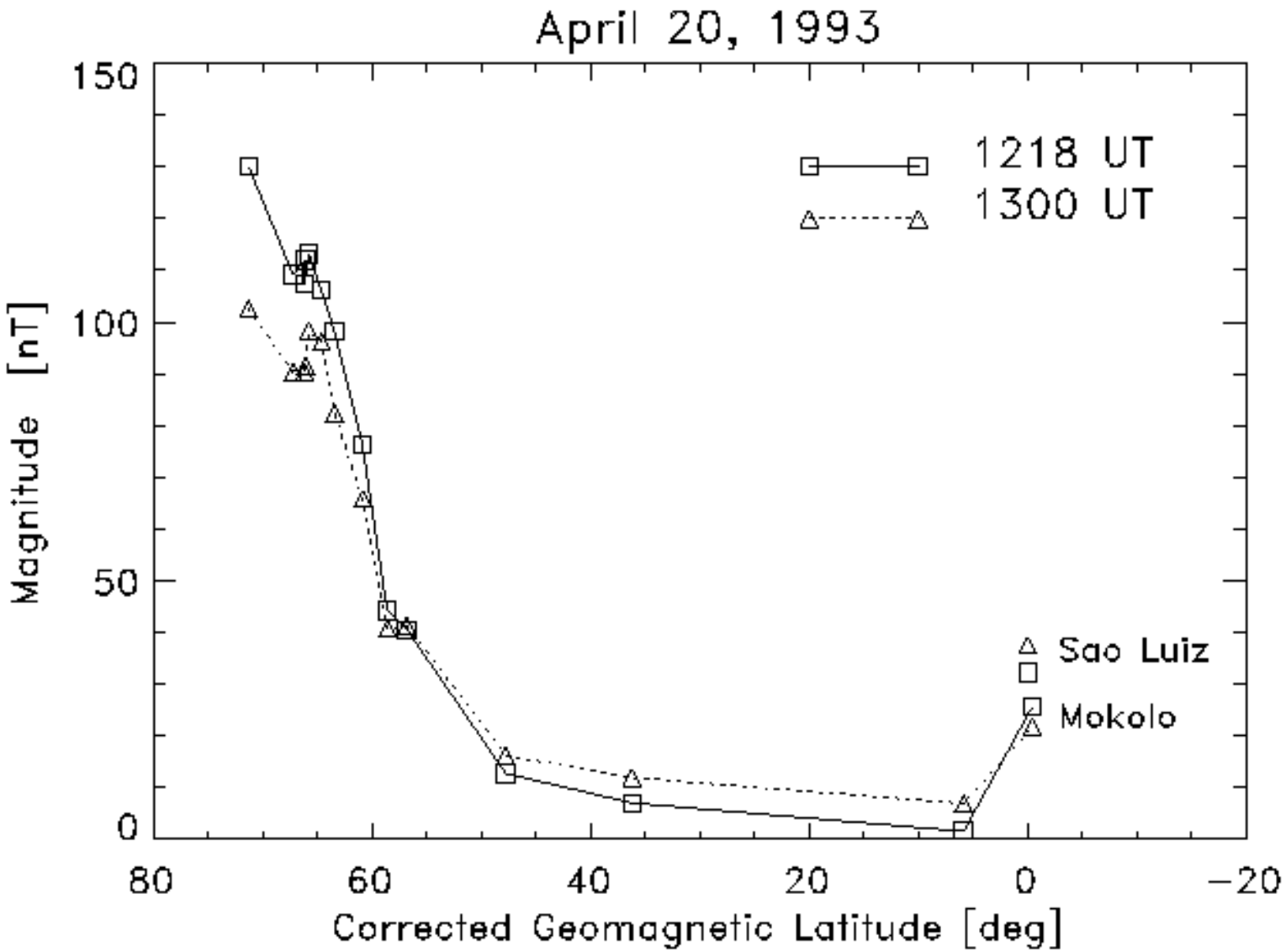


17 MLT

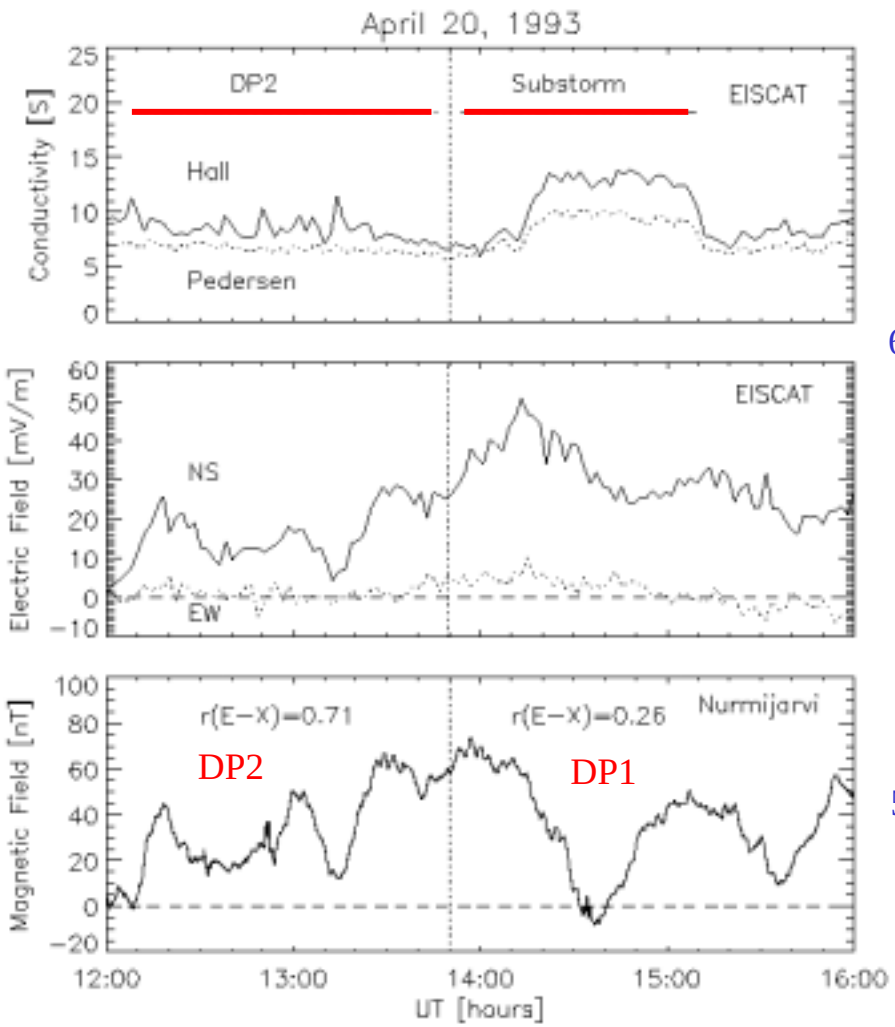


15 MLT

Latitudinal Profile of the DP2



Correlation between the auroral electric field and midlatitude magnetic fluctuations during the DP2 and substorm events



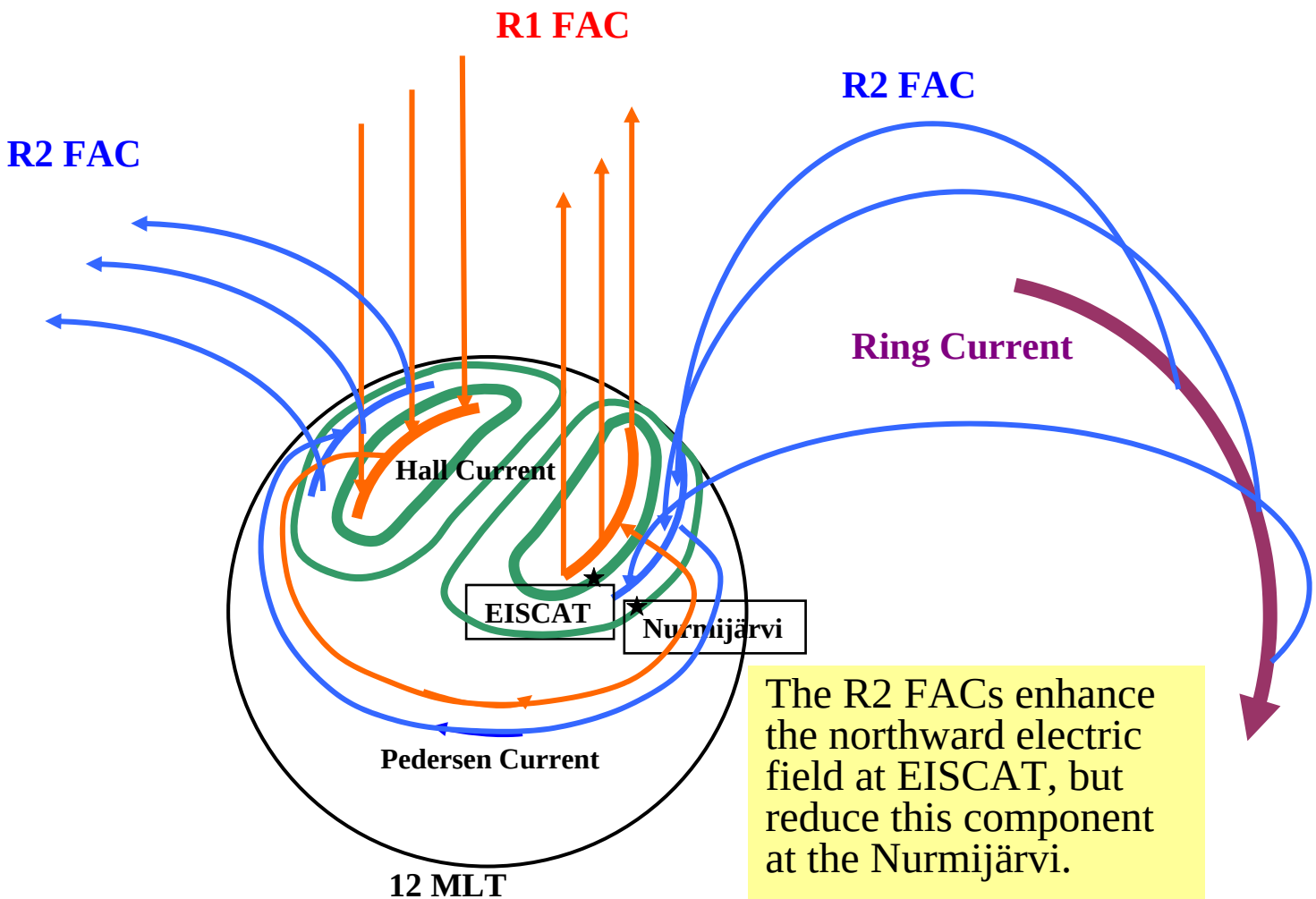
66 º CGML

56 º CGML

E/X = 0.15 mV/m/nT at Nurmijärvi

中緯度で、高緯度とcoherentなDP2電場、coherentでないDP1電場が観測される

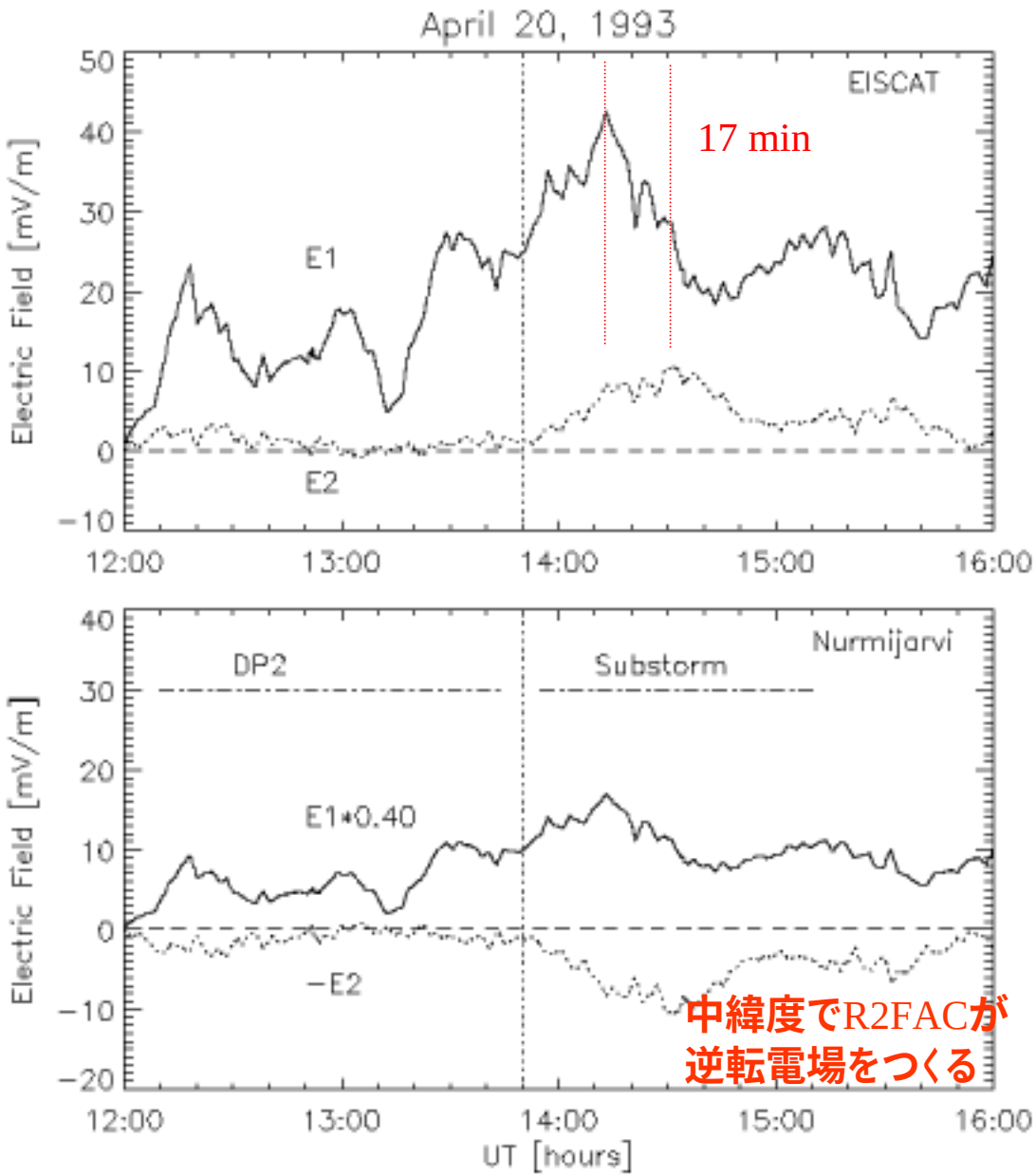
R1- and R2-FACs Electric Fields



The R2 FACs enhance the northward electric field at EISCAT, but reduce this component at the Nurmijärvi.

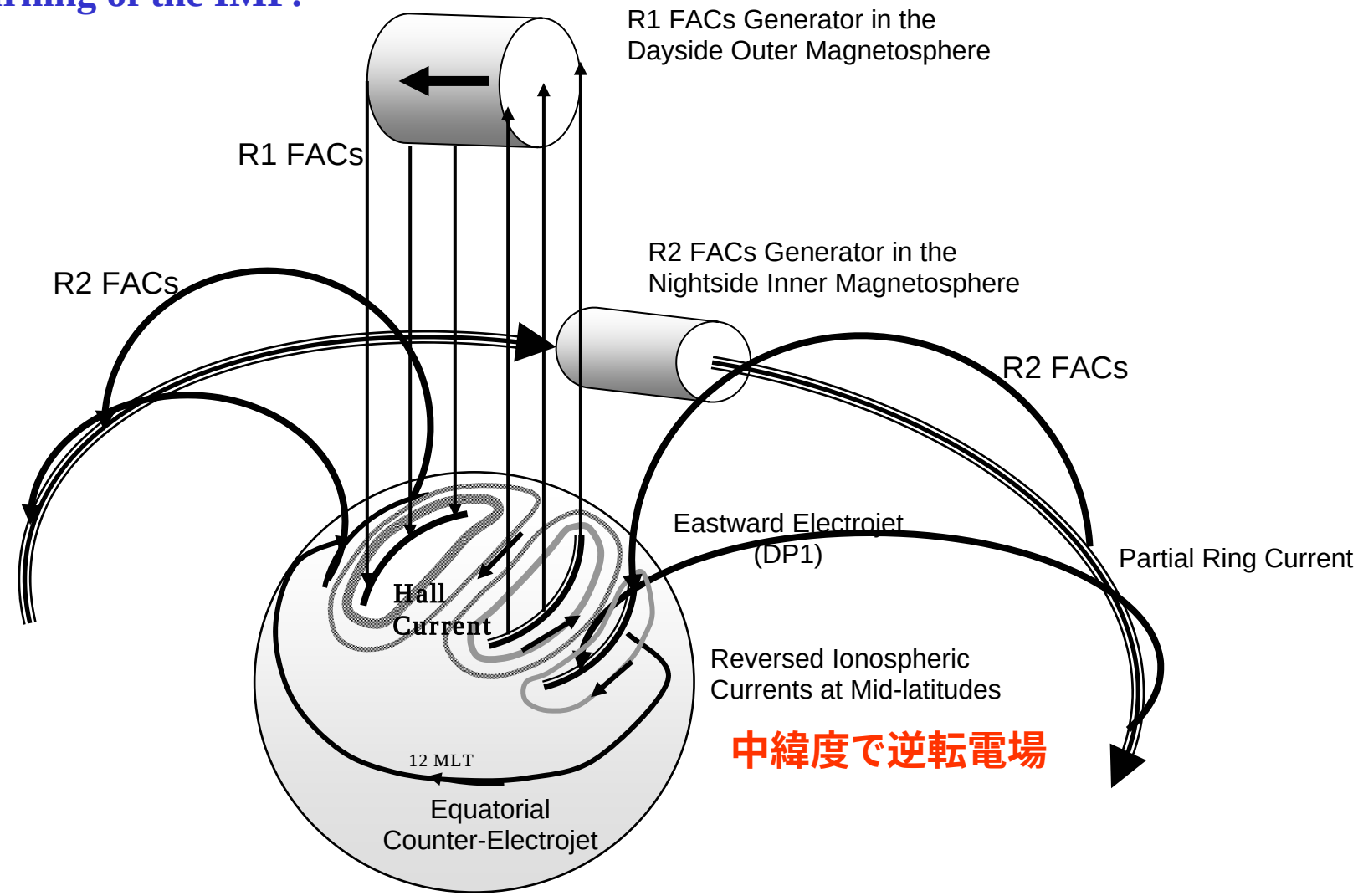
Estimated electric fields associated with the R1 and R2 FACs at auroral and mid latitudes

- The shielding electric field, E_2 develops in response to the convection electric field, E_1, but is delayed by 17 min.
- The shielding electric field is smaller than the convection electric field at EISCAT, but comparable to that at Nurmijärvi, which results in the shielding or over-shielding effects at lower latitudes.



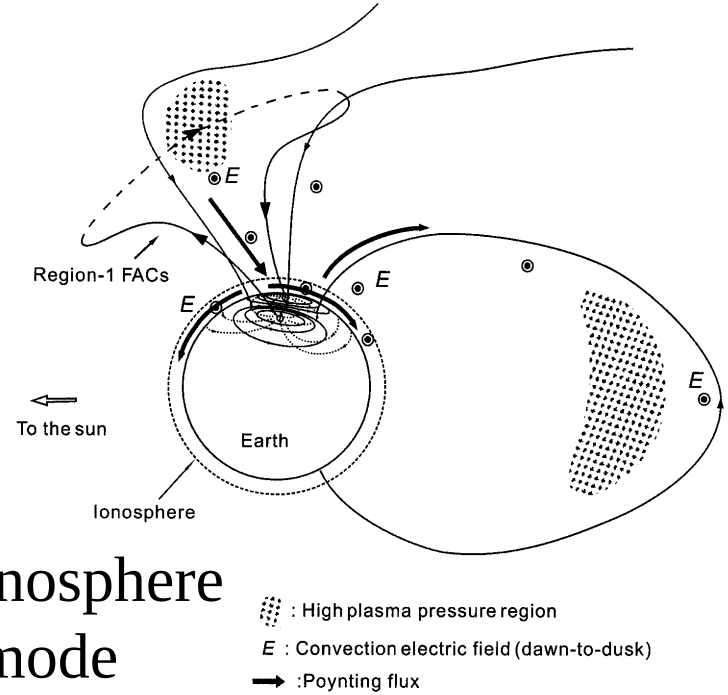
DP1 Current System

Magnetosphere-ionosphere current system is composed of the R1 and R2 FACs and ionospheric currents. The equatorial CEJ connects with the R2 FACs, which become dominant when the R1 FACs decay rapidly because of the northward turning of the IMF.



Conclusion

中緯度レーダーで
内部磁気圏研究



1. The potential difference between the ionosphere and ground is transmitted by the TM0 mode in the Earth-ionosphere waveguide.

2. A fraction of the energy of the TM0 mode penetrates into the magnetosphere, but the attenuation of the TM0 mode is much less than the geometrical attenuation due to the finite size of the polar cap potential difference.

3. The upward transmitted electric field will drive the convection in the inner magnetosphere.