中緯度レーダー研究会名古屋大学グリーンサロン (2014. 11. 17)

Response of the midlatitude ionosphere to the compression/rarefaction of the magnetosphere during the geomagnetic sudden commencements

T. Kikuchi[1,6], K.K. Hashimoto[2], Y. Nishimura[3]Y. I.Tomizawa[4], T. Araki[5], A. Shinbori[6], T. Nagatsuma[7]

[1] Solar-Terrestrial Environment Laboratory, Nagoya University

[2] Kibi International University

[3] Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles

[4] University of Electro-Communications

[5] Geophysical Institute, Kyoto University

[6] Research Institute for Sustainable Humanosphere, Kyoto University

[7] National Institute of Information and Communications Technology

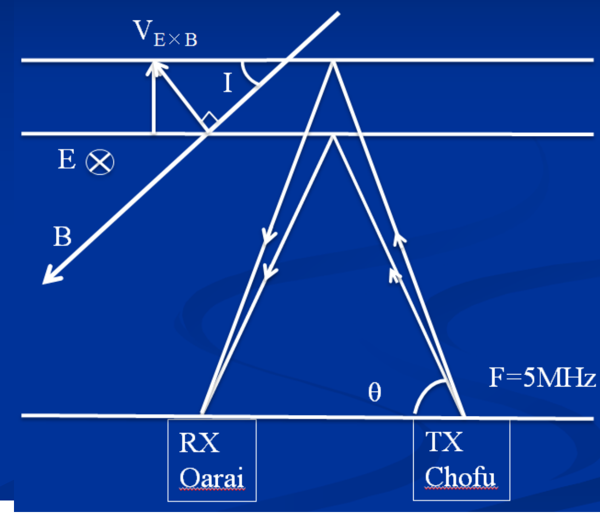
Observations of ionospheric electric field with the Hokkaido radar and HF Doppler sounder in midlatitudes and ionospheric currents with the magnetometer at the equator

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

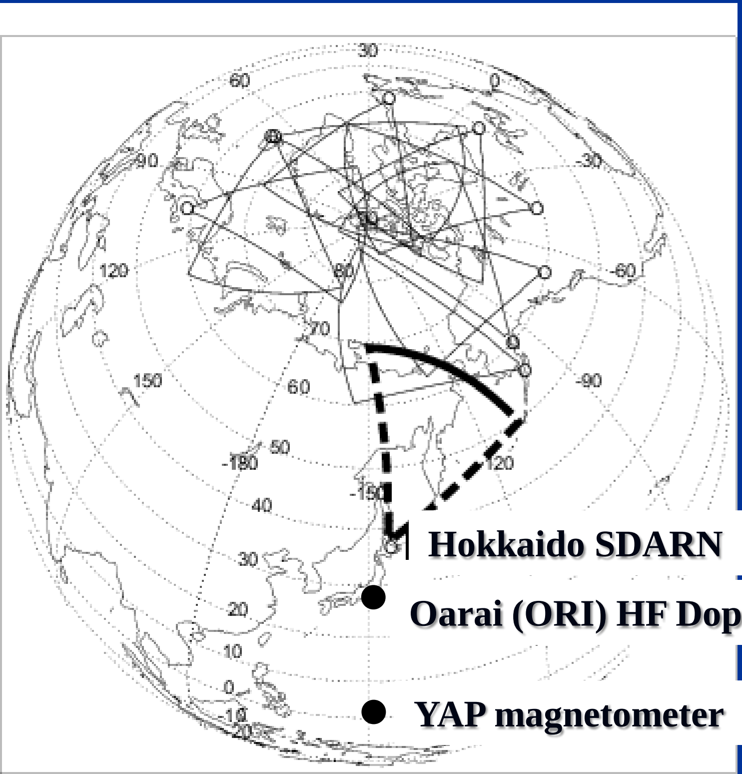
$f = 5$ [MHz], $\theta = 78.2°$, $I = 49°$, $B = 46000$ [nT],

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.

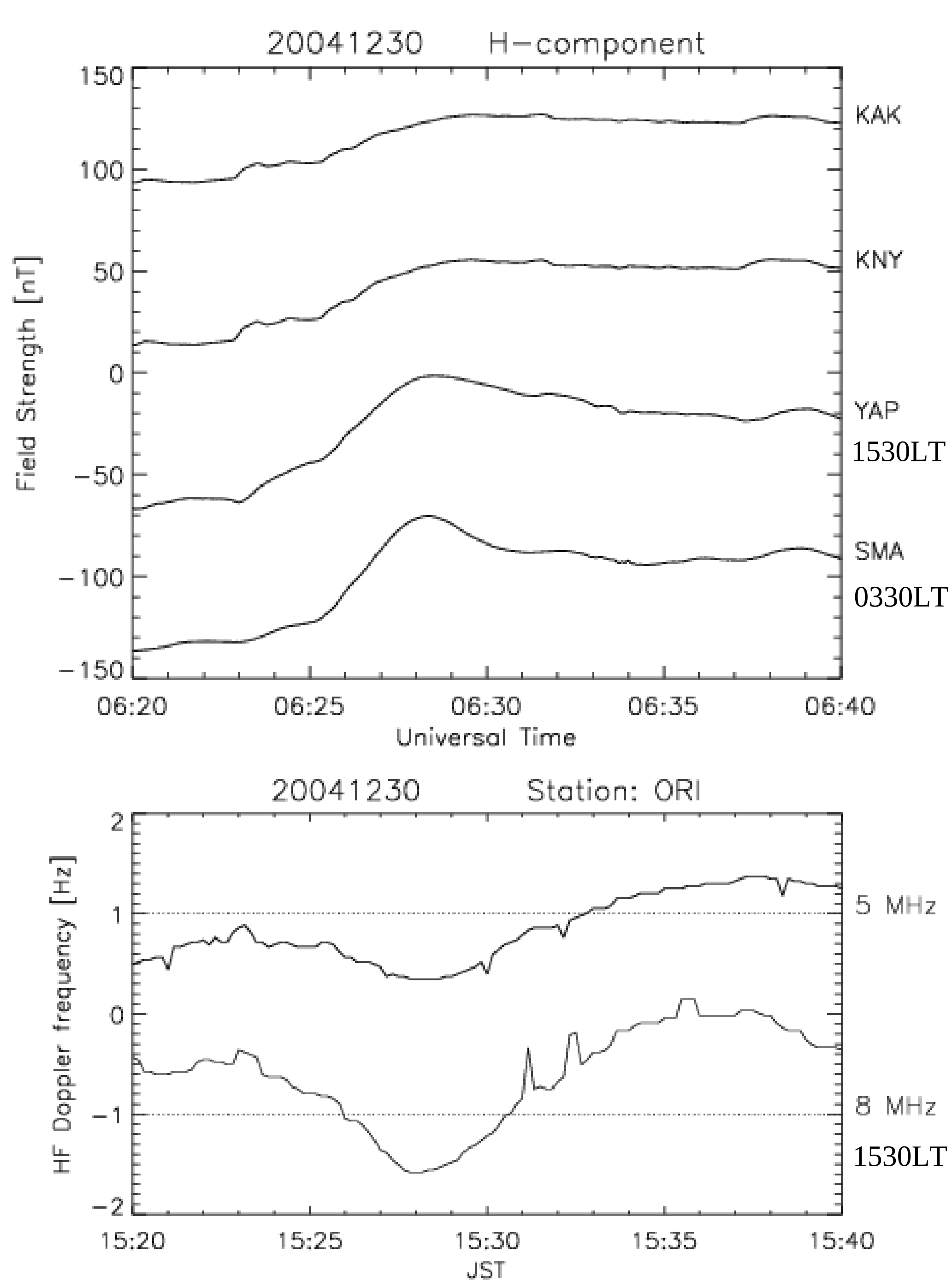
Cowling conductivity: $\sigma_C = \sigma_P + \frac{\sigma_H^2}{\sigma_P}$

Today's talk

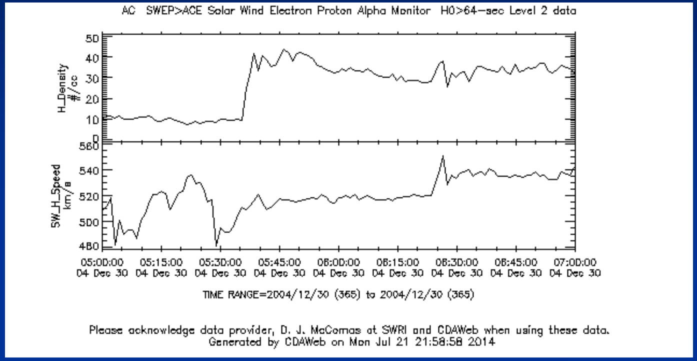
- Electric fields and currents during the geomagnetic sudden commencements (SC)

- Magnetosphere-ionosphere current circuits across the magnetic field lines in the equatorial plane and along the field lines and ionosphere

SC/SI-1



Solar wind density and speed



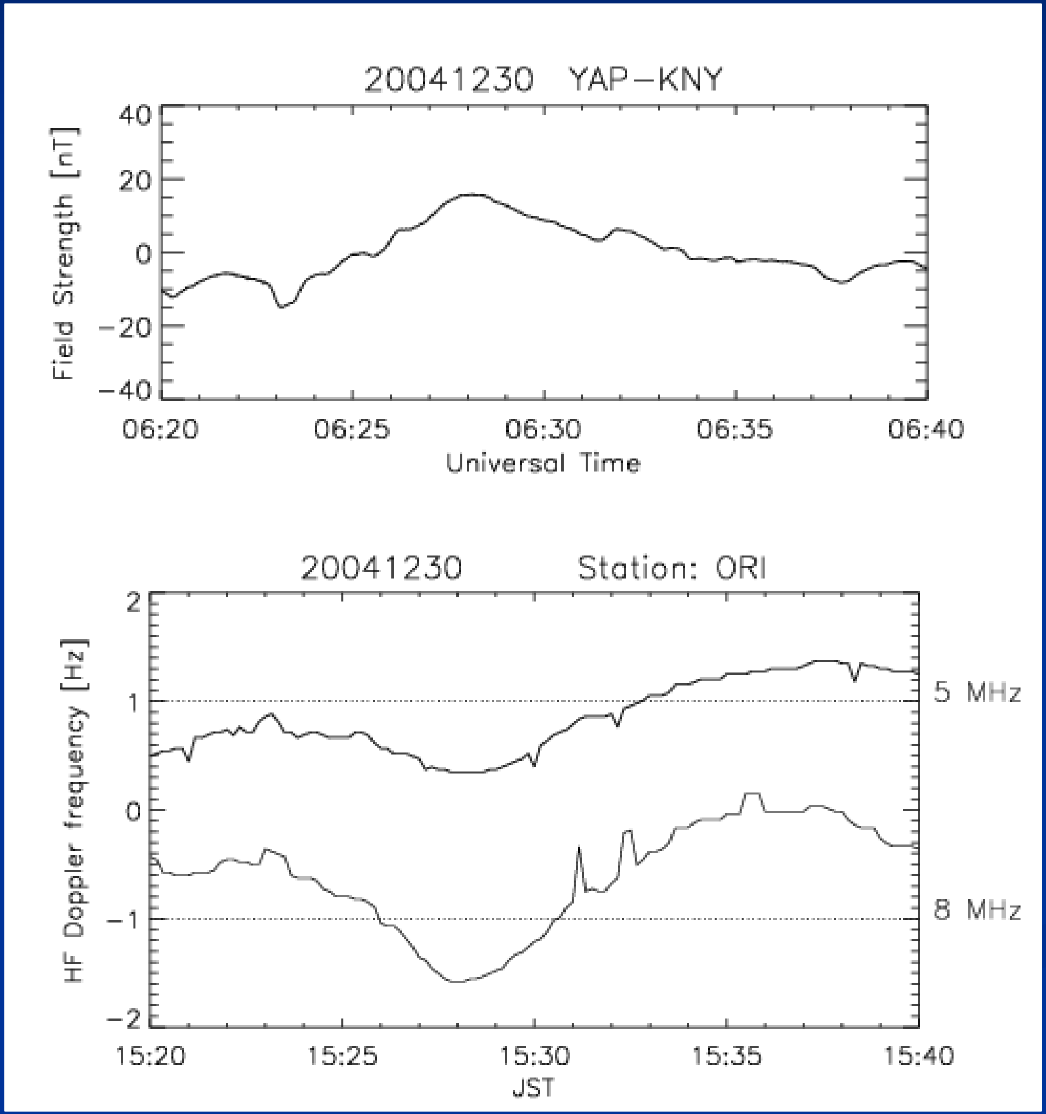
$\Delta H > 0$

Compression of the magnetosphere

$\Delta f < 0$

Upward motion of the ionosphere

SC/SI-1

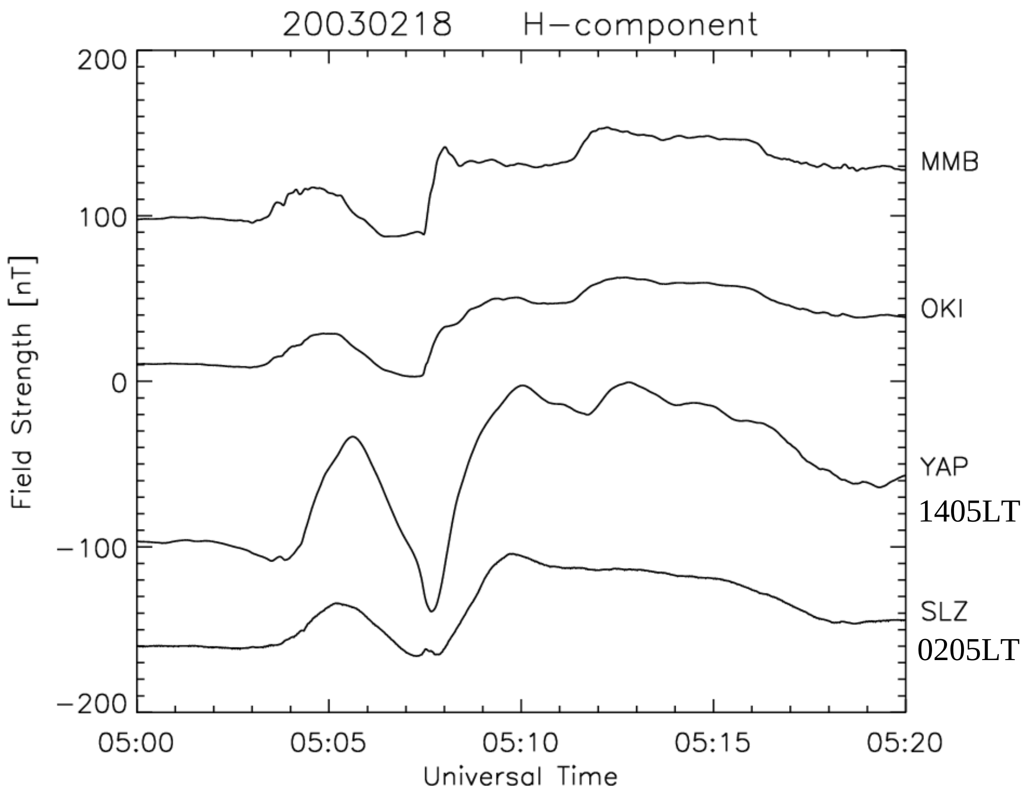


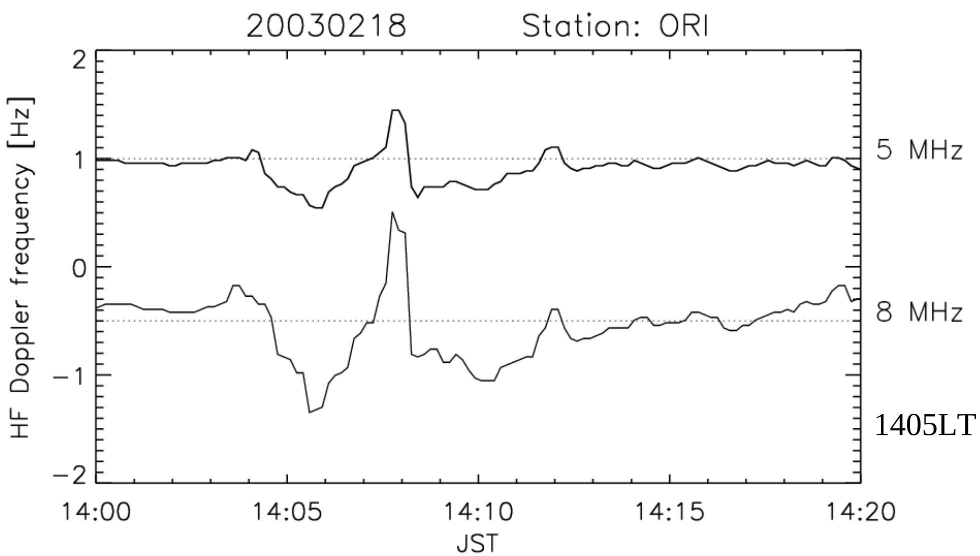
Equatorial ionospheric current intensification

Eastward electric field

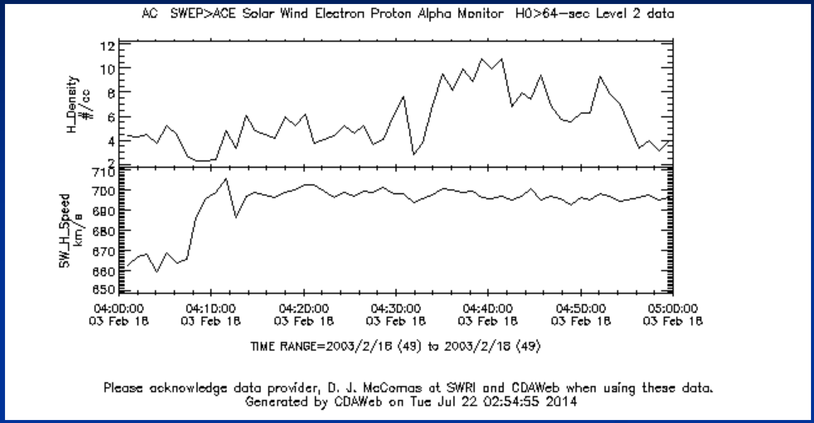
Upward motion of the ionosphere

SC/SI-2





Solar wind density and speed



$\Delta H > 0$

Compression of the magnetosphere

$\Delta H < 0$

Rarefaction of the magnetosphere

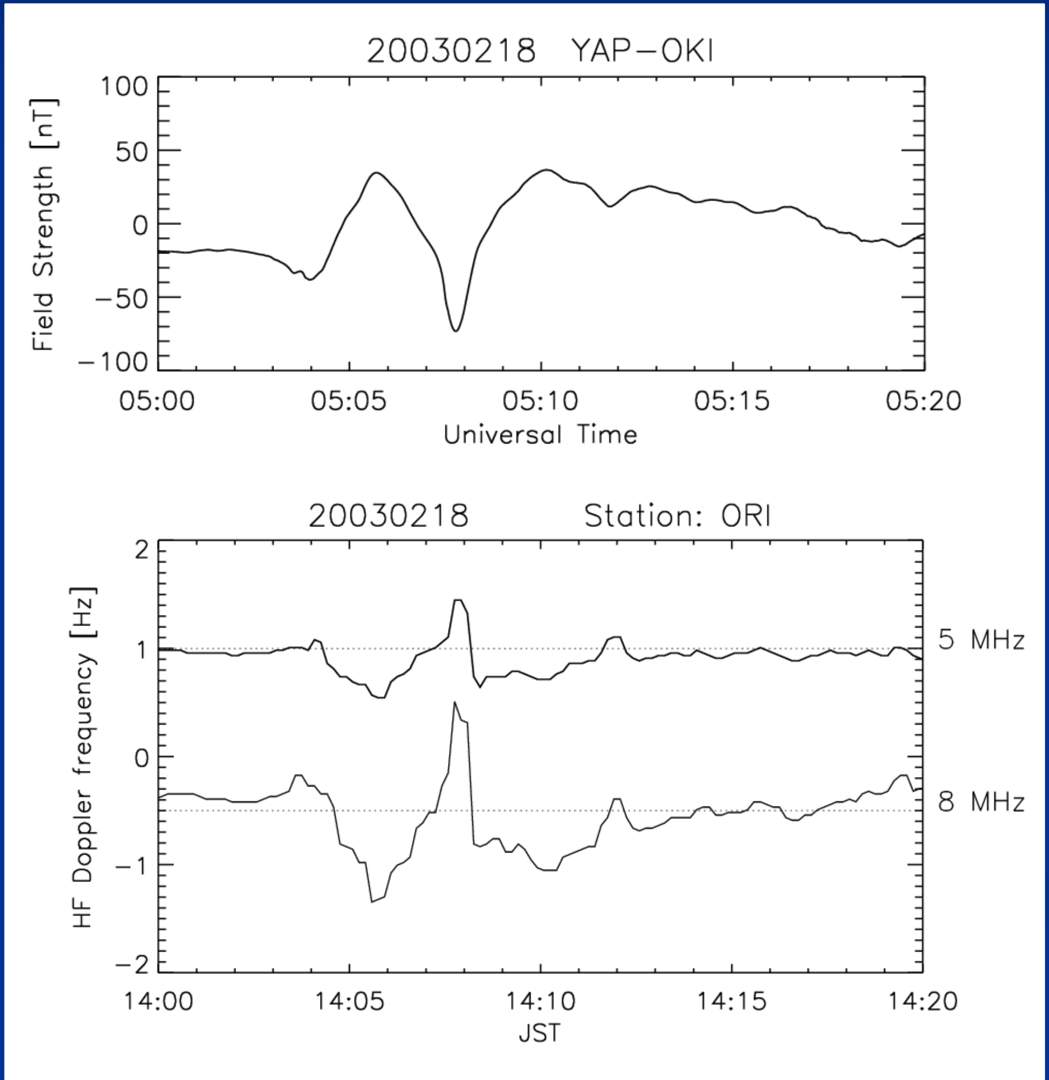
$\Delta f < 0$

Upward motion of the ionosphere

$\Delta f > 0$

Downward motion of the ionosphere

SC/SI-2



Eastward (westward) equatorial ionospheric currents

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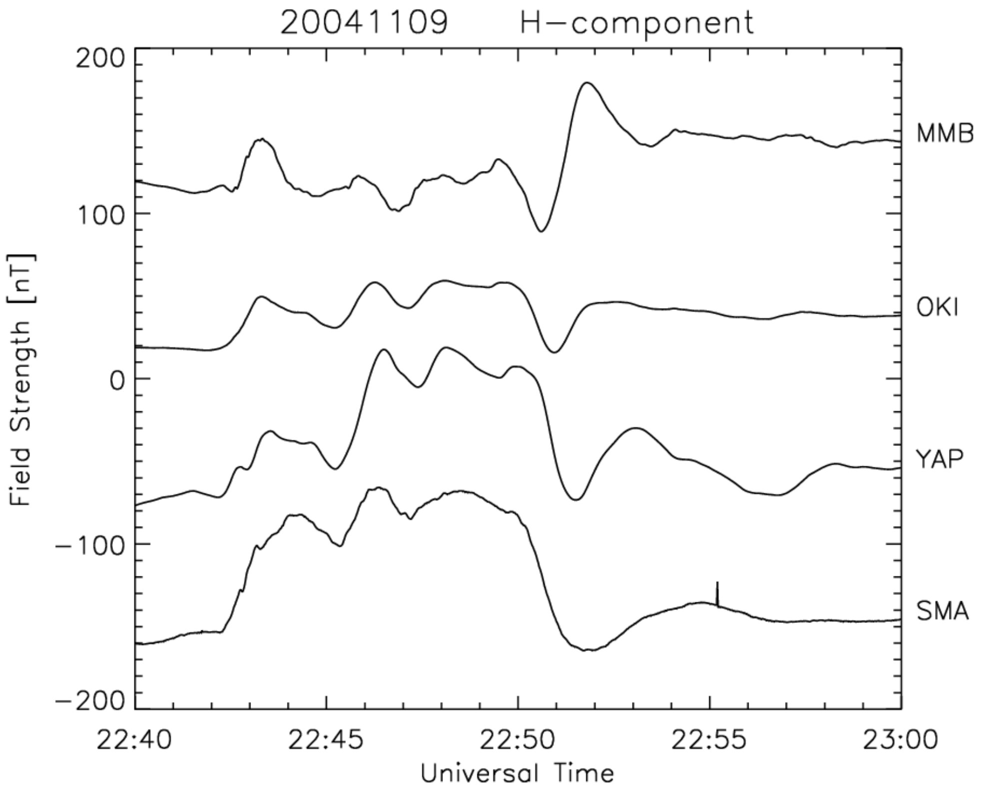
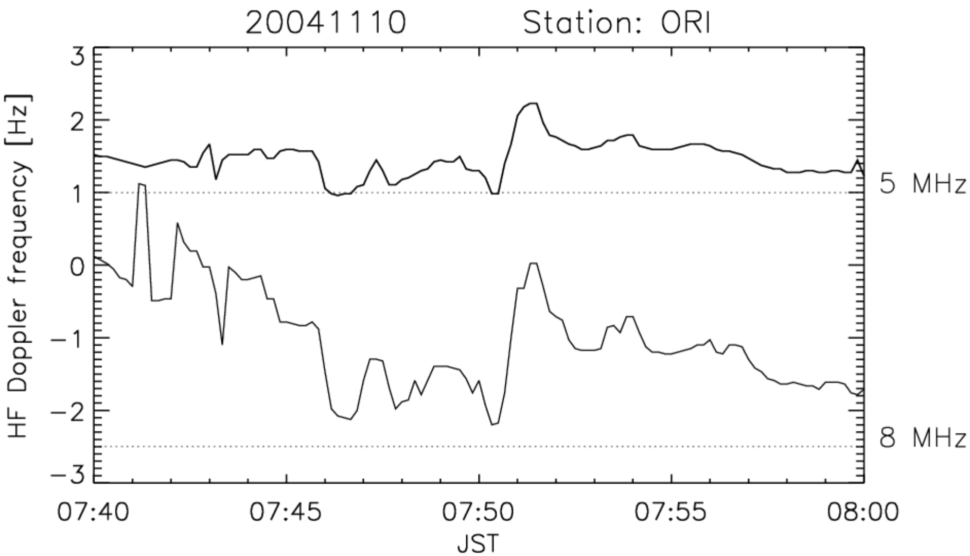
Eastward (westward) electric field

↓

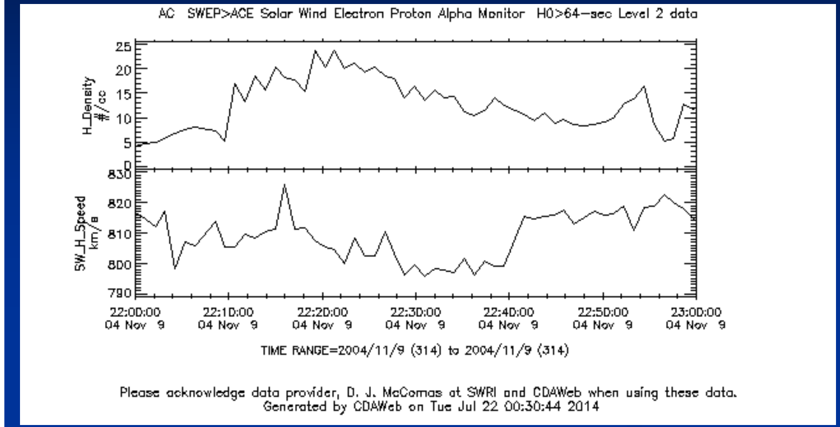
Upward (downward) motion of the ionosphere

SC/SI-3





Solar wind density and speed



$\Delta H > 0$

Compression of the magnetosphere

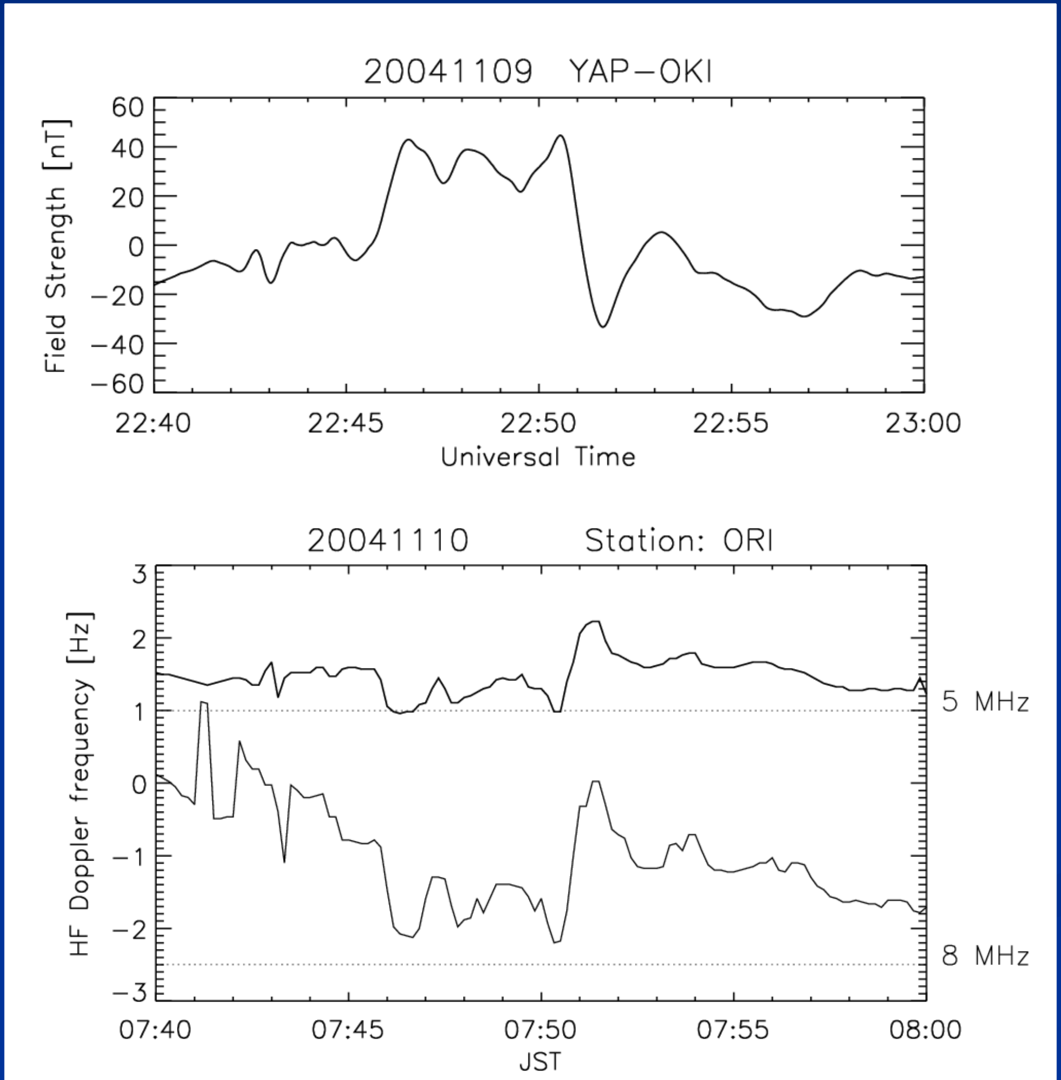
$\Delta f = 0$

$\Delta f < 0$

No response

Upward motion of the ionosphere

SC/SI-3

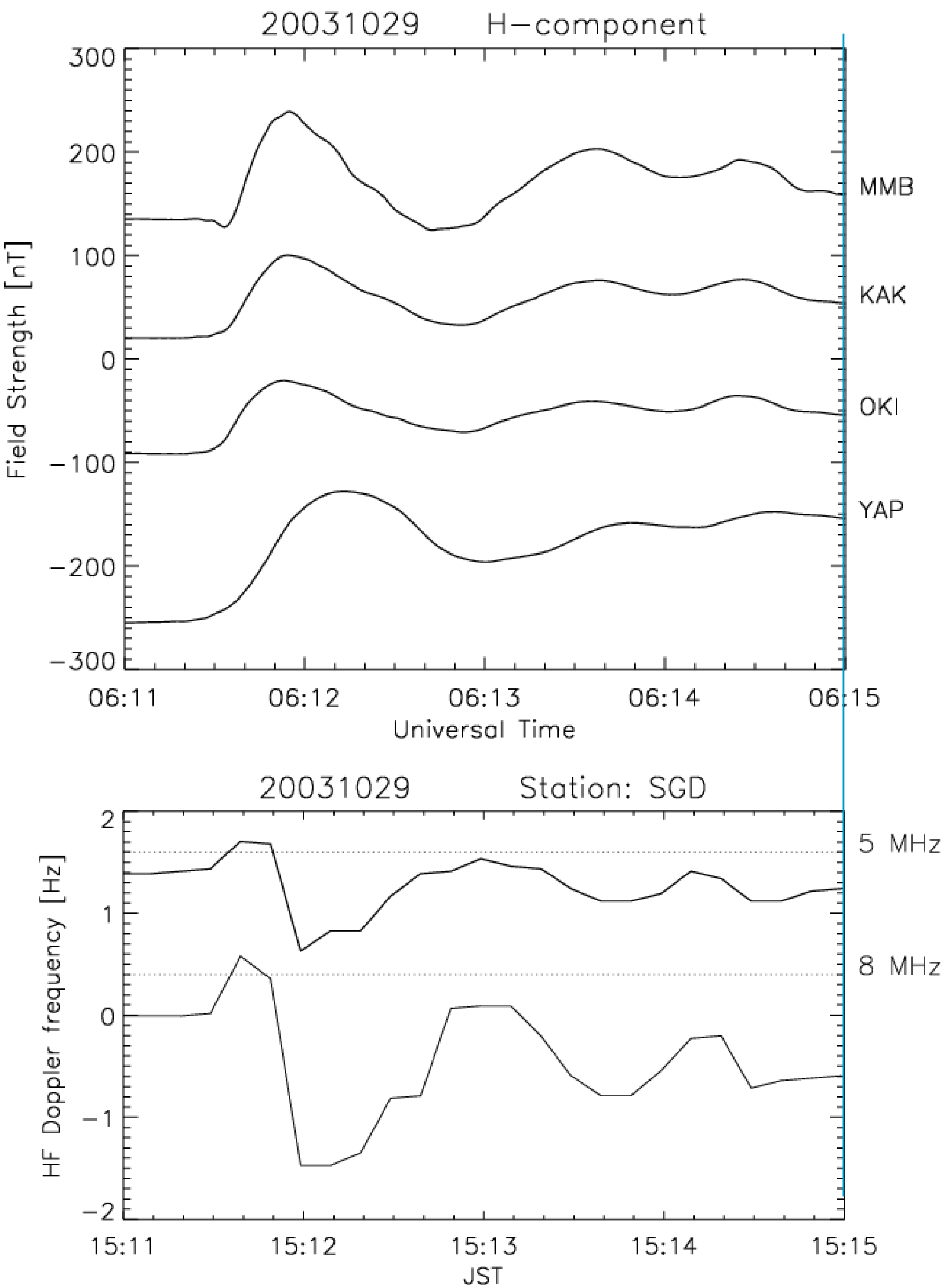


Equatorial ionospheric current intensification

Eastward electric field

Upward motion of the ionosphere

SC/SI-4



Inductive electric field?

$\Delta H > 0$

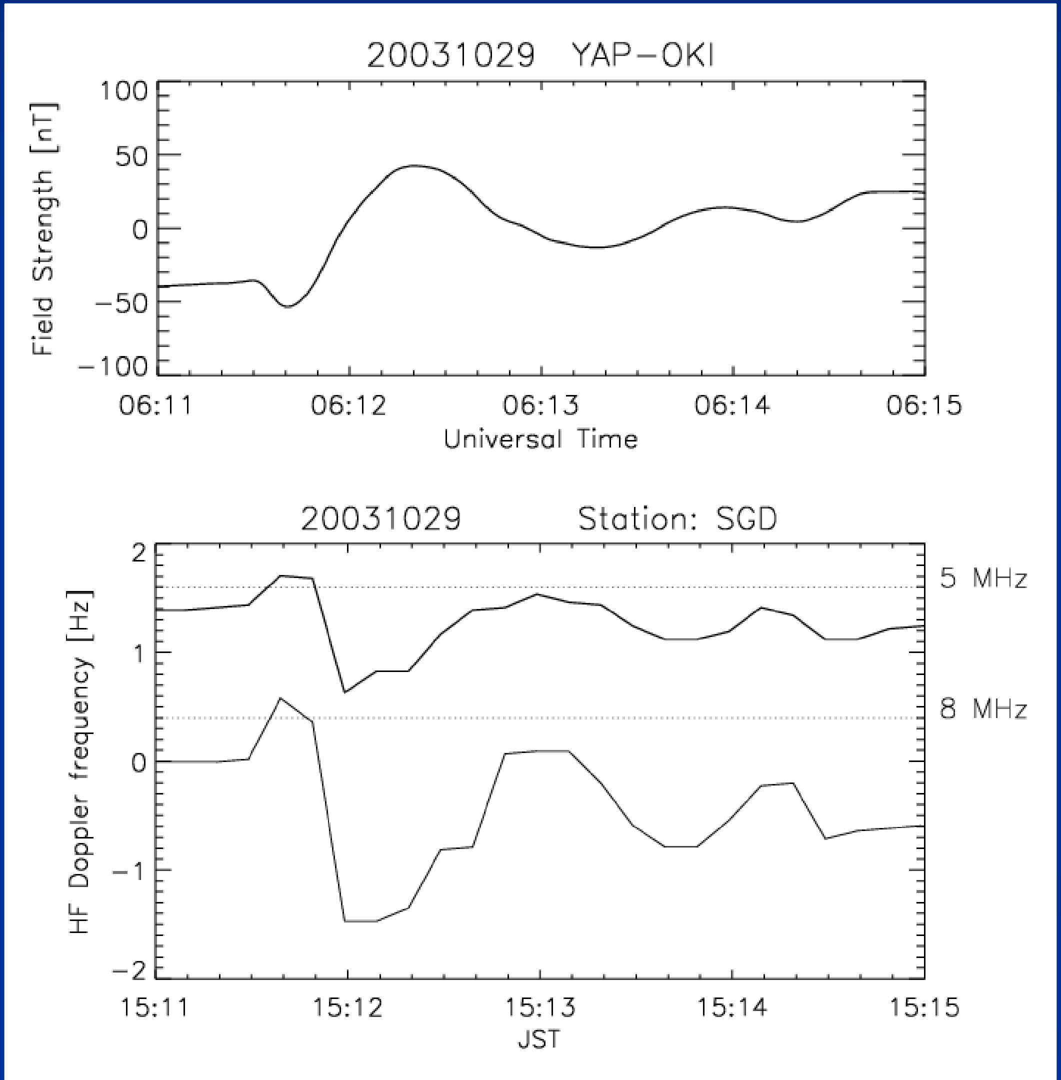
Compression of the magnetosphere

$\Delta f > 0$

Downward motion of the ionosphere

SC/SI-4

SC with pulsations

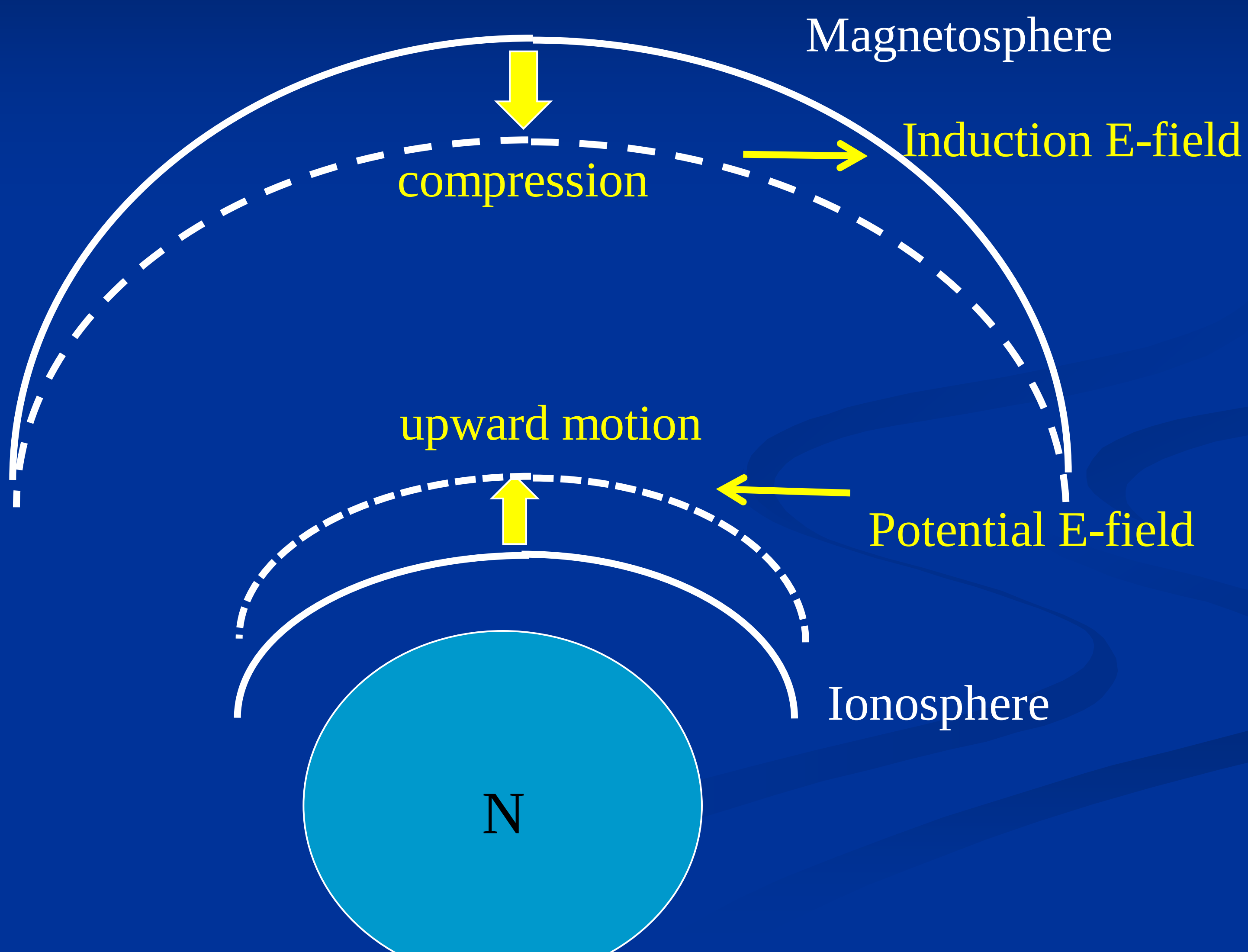


Equatorial ionospheric current intensification

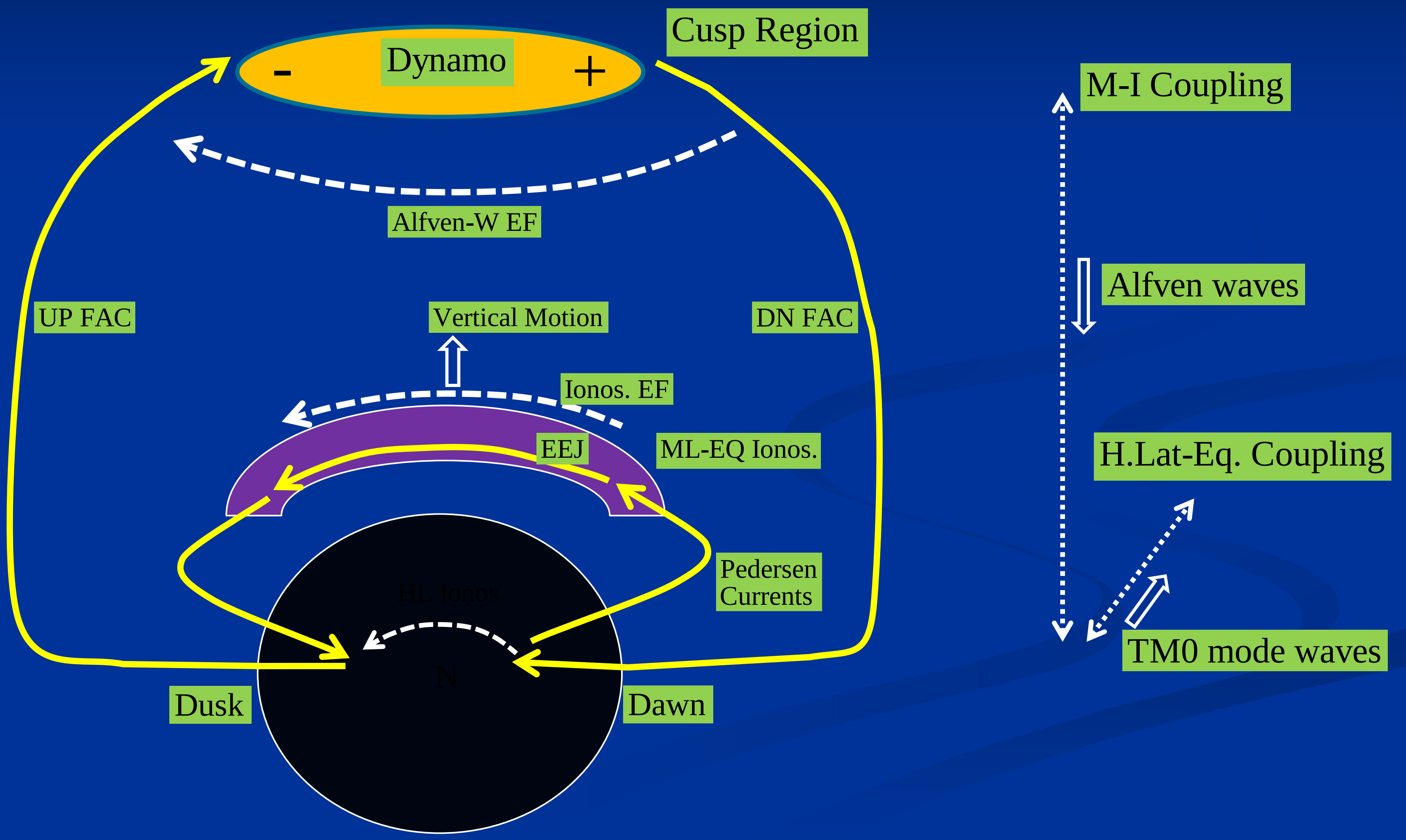
Westward PI electric field

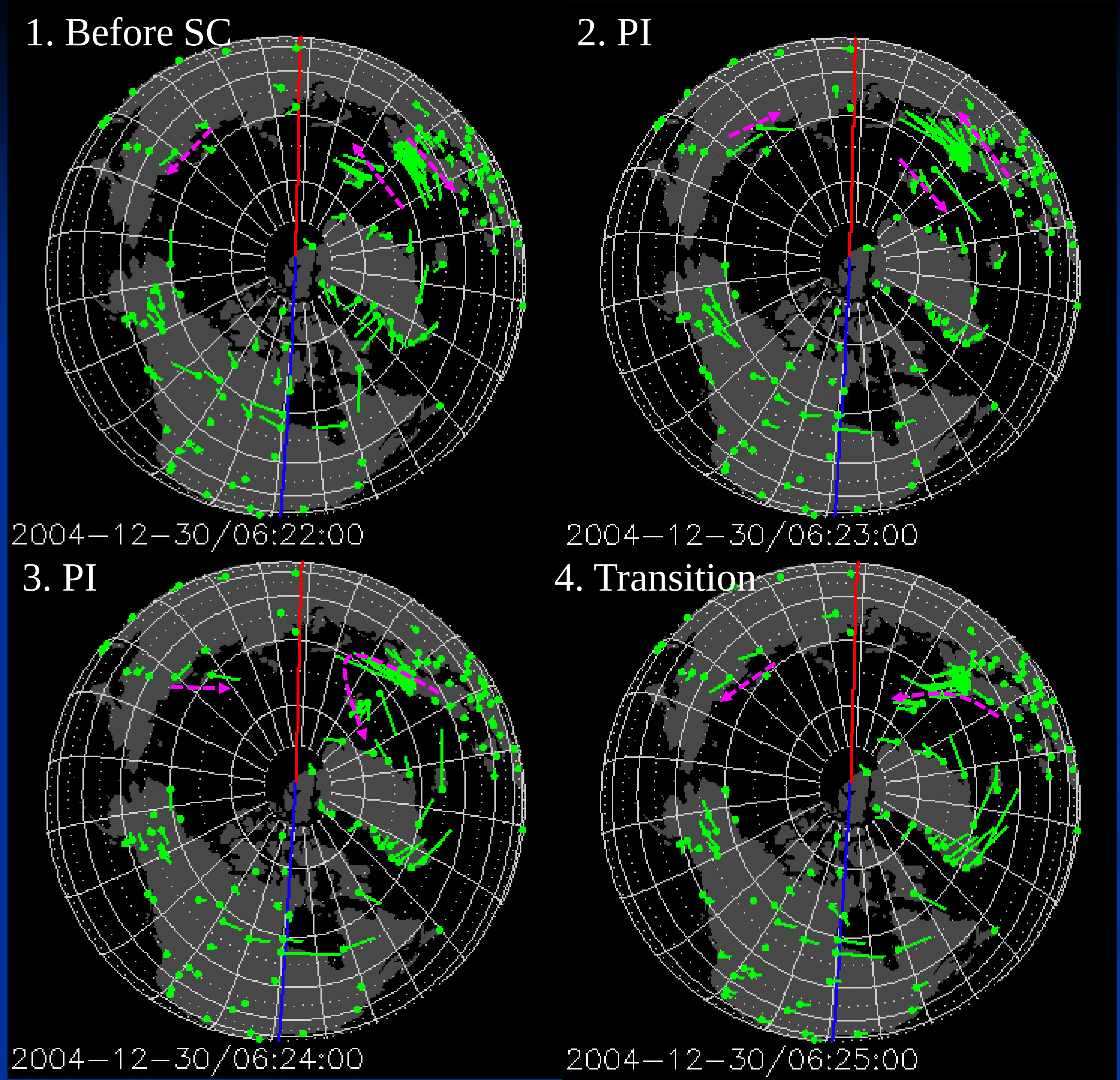
downward motion of the ionosphere

Response of the ionosphere to the compression of the magnetosphere during SC/SIs



How is the potential electric field transmitted to the mid-equatorial latitude ionosphere? (Magnetosphere-ionosphere-ground transmission line)





SC/SI-1

Counter-clockwise current vortex in the morning

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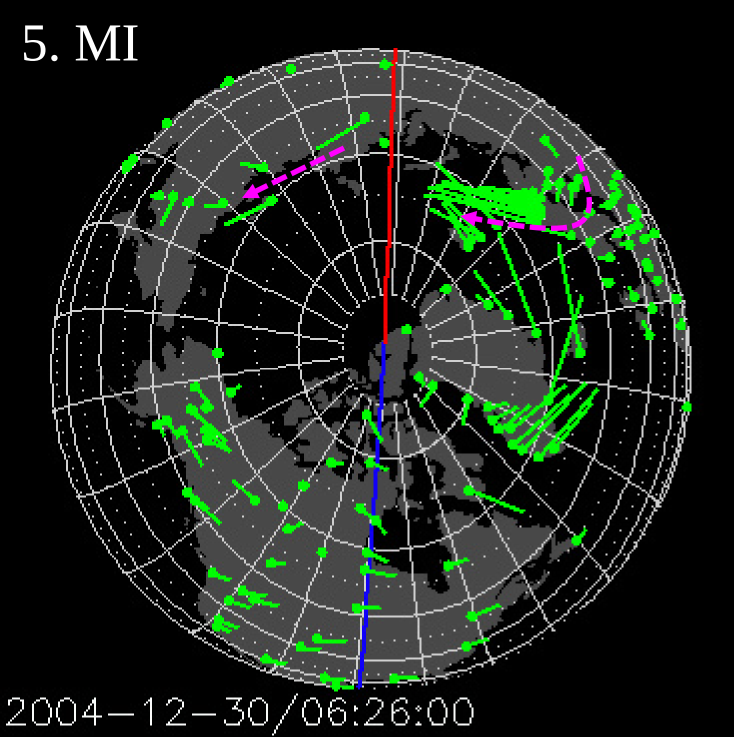
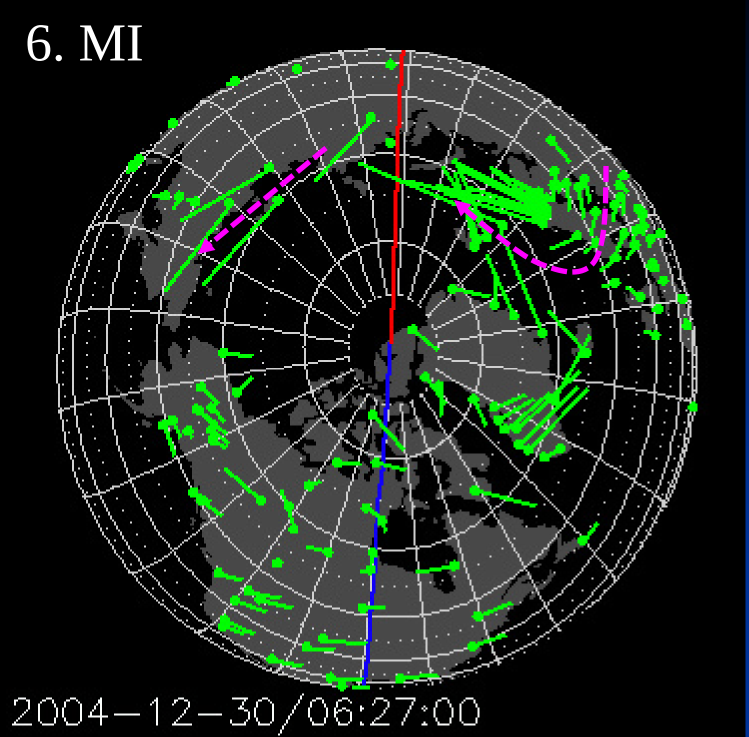
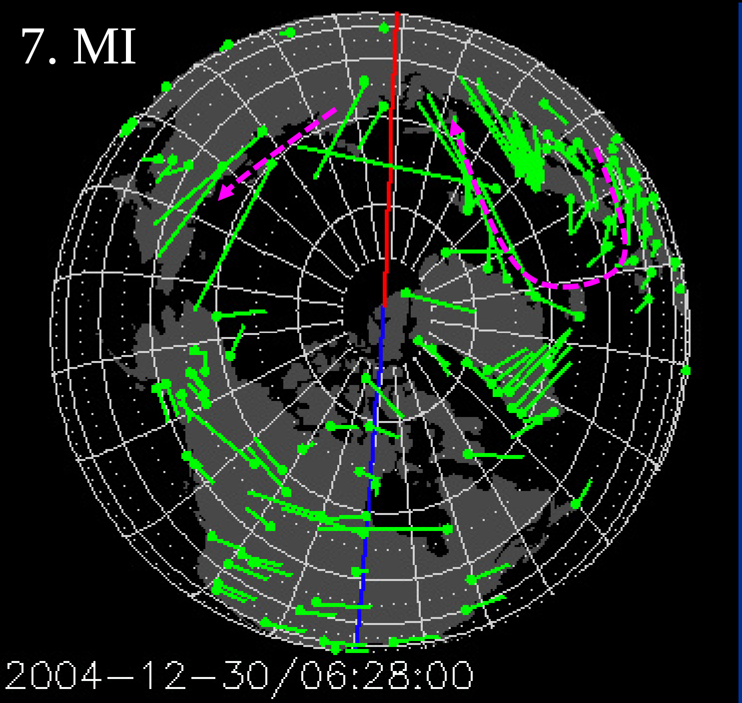
Upward FAC of PI

SC/SI-1







Clockwise current vortex in the morning

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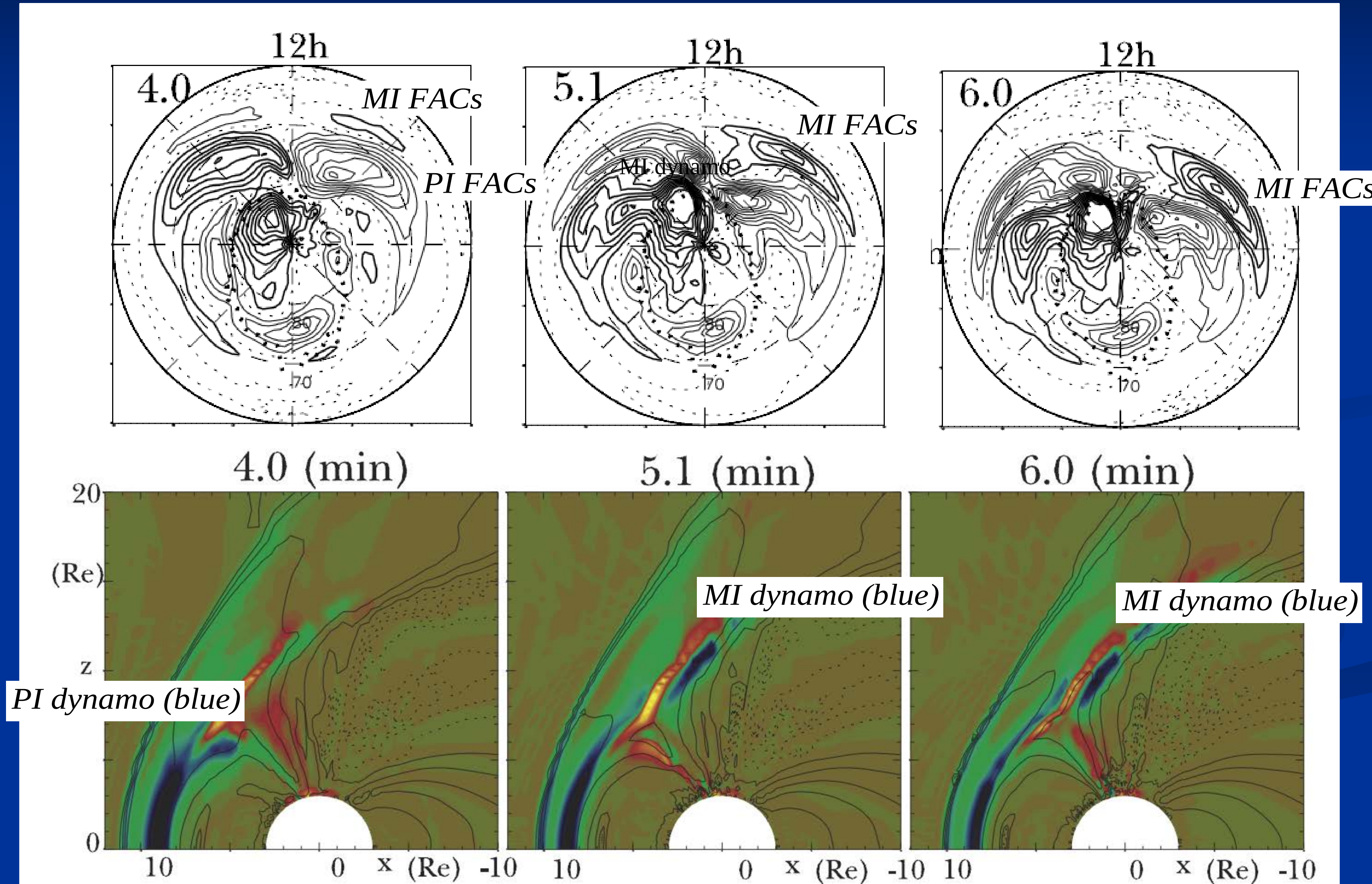
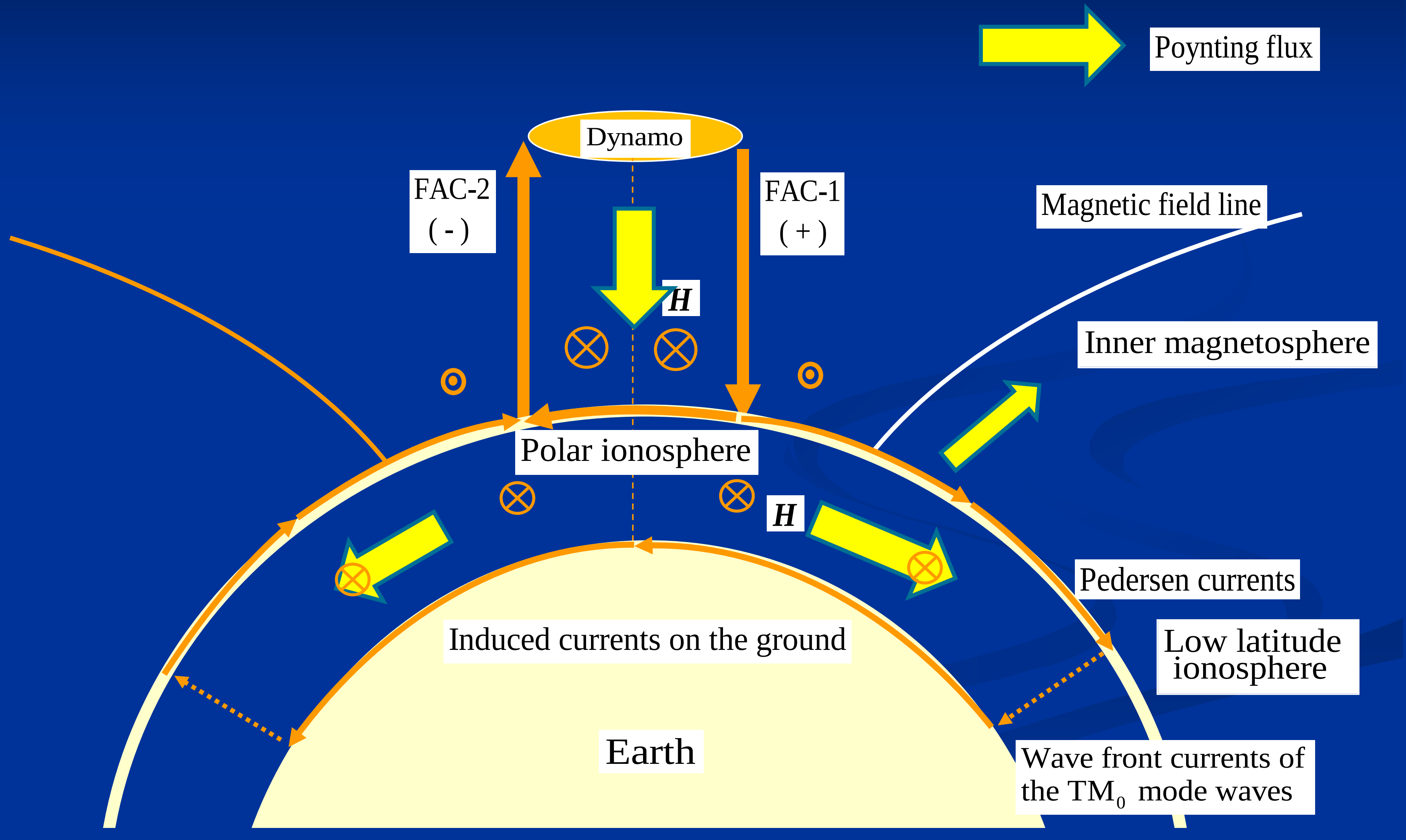
Downward FAC of MI

MHD simulation of the PI and MI field-aligned currents and their dynamos

From Fujita et al. [2003]



Magnetosphere-ionosphere-ground (MIG) transmission line [Kikuchi, 2014]



Magnetosphere-ionosphere-ground (MIG) transmission line

Transmission line parameters

$d_1 = 80{,}000$ km (length of the FAC transmission line)
$d_2 = 8{,}000$ km (length of the EIG transmission line)
$w = 2{,}000$ km (width of the FAC and EIG transmission lines)
$l = 2{,}000$ km (separation of the FAC transmission line)
$h = 100$ km (separation of the EIG transmission line)

$V_A = 1{,}000$ km (Alfven speed)
$\Sigma_1 = 8$ mho (height-integrated conductivity of the polar ionosphere)
$\Sigma_2 = 0.2$ - 30 mho (height-integrated ionospheric conductivity of the EIG)

Intrinsic impedance

$$Z_{01} = \mu_0 V_A = 1.26 \text{ ohm}$$

$$Z_{02} = \mu_0 c = 376.7 \text{ ohm}$$

Characteristic impedance

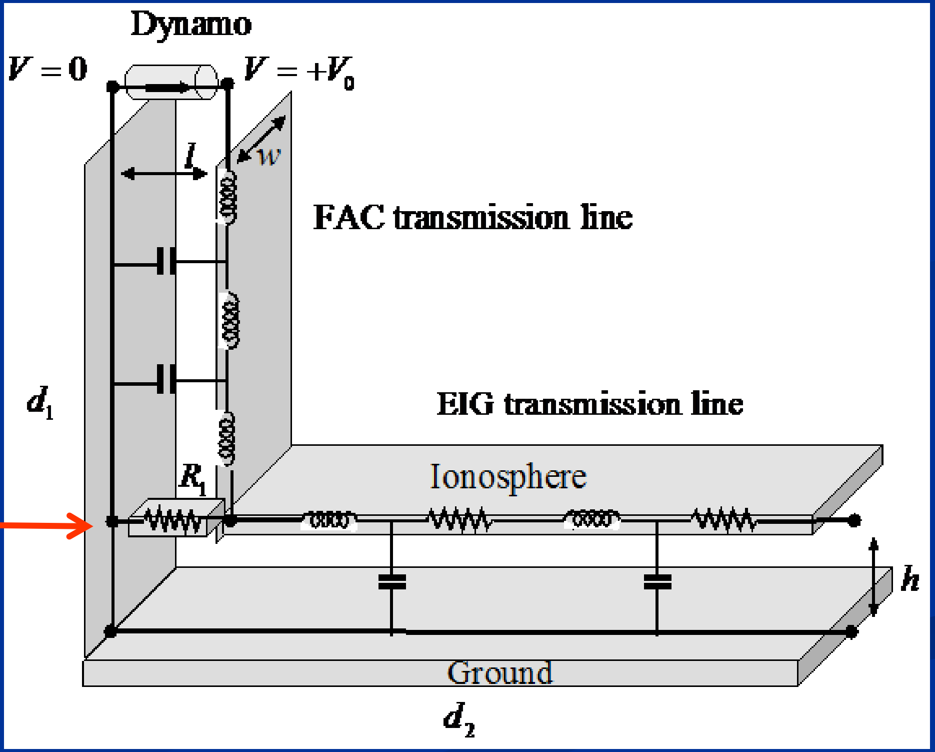
$$Z_1 = \mu_0 V_A = 1.26 \text{ ohm}$$

$$Z_2 = 376.7 \frac{h}{w} = 18.8 \text{ ohm}$$

Reflection and transmission coefficients

$$C_r = \frac{R_1 Z_2 - Z_1 (R_1 + Z_2)}{R_1 Z_2 + Z_1 (R_1 + Z_2)} = -0.821$$

$$C_t = \frac{2 R_1 Z_2}{R_1 Z_2 + Z_1 (R_1 + Z_2)} = 0.179$$



The transmitted electric and magnetic fields excite the TM0 mode wave.

Summary

- During the SC, the dayside midlatitude ionosphere moves upward when the magnetosphere is compressed and moves downward when the magnetosphere is rarefied.
- The ionospheric motion is well correlated with the ionospheric currents which are intensified at the equator.
- The electric field responsible for the ionospheric motion is a potential field in the ionospheric currents transmitted from the magnetosphere via the polar ionosphere.
- The Alfven-TM0 mode wave combination enables the electric potentials to be transmitted to the midlatitude ionosphere.