中緯度短波レーダー研究会（名古屋、2010.1.18）

中緯度電離圏電場の準周期変動と磁気圏電離圏電流系

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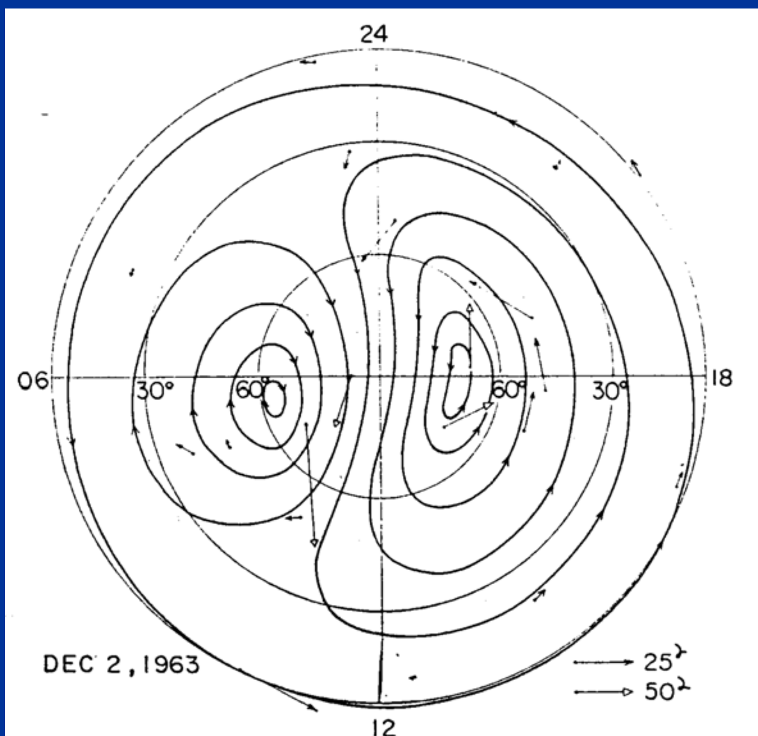
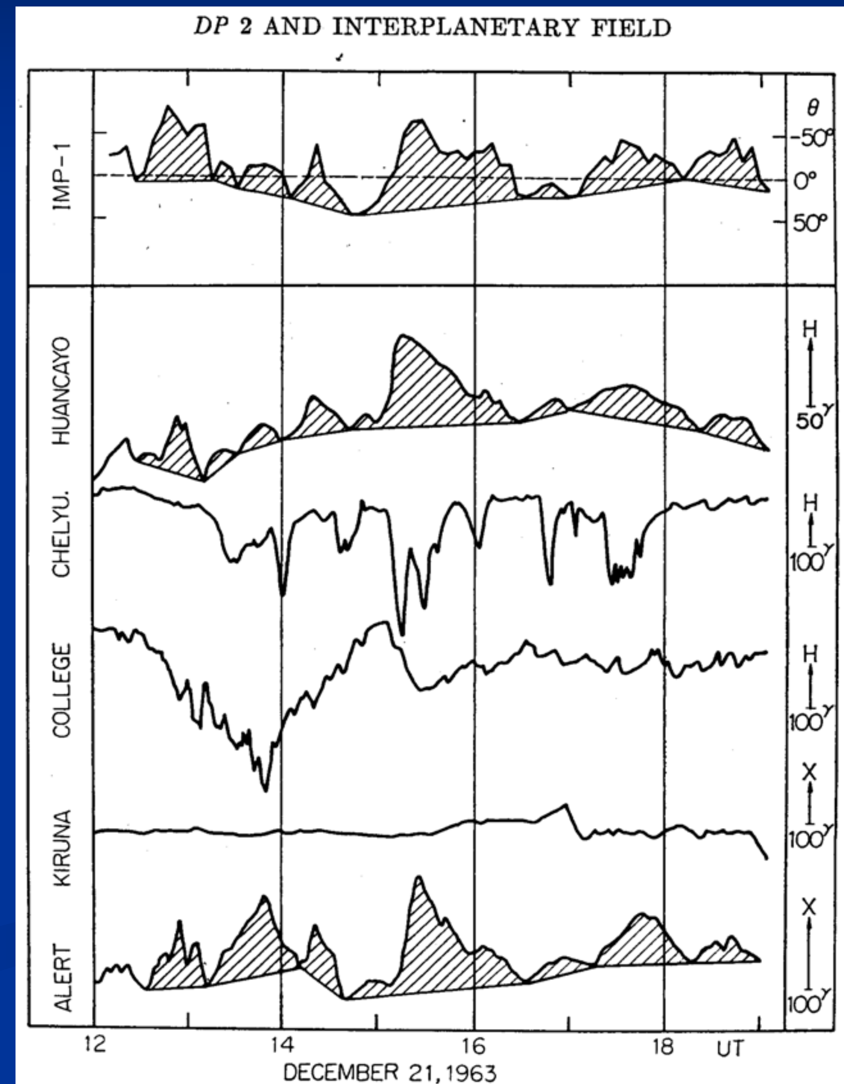
DP2 magnetic fluctuations and equivalent currents

Quasi-periodic DP2 magnetic fluctuations are caused by convection electric fields controlled by the IMF.

(Nishida, JGR 1968, p.5549)





DP2/DP1 currents at dayside high-mid latitudes during substorms

EISCAT

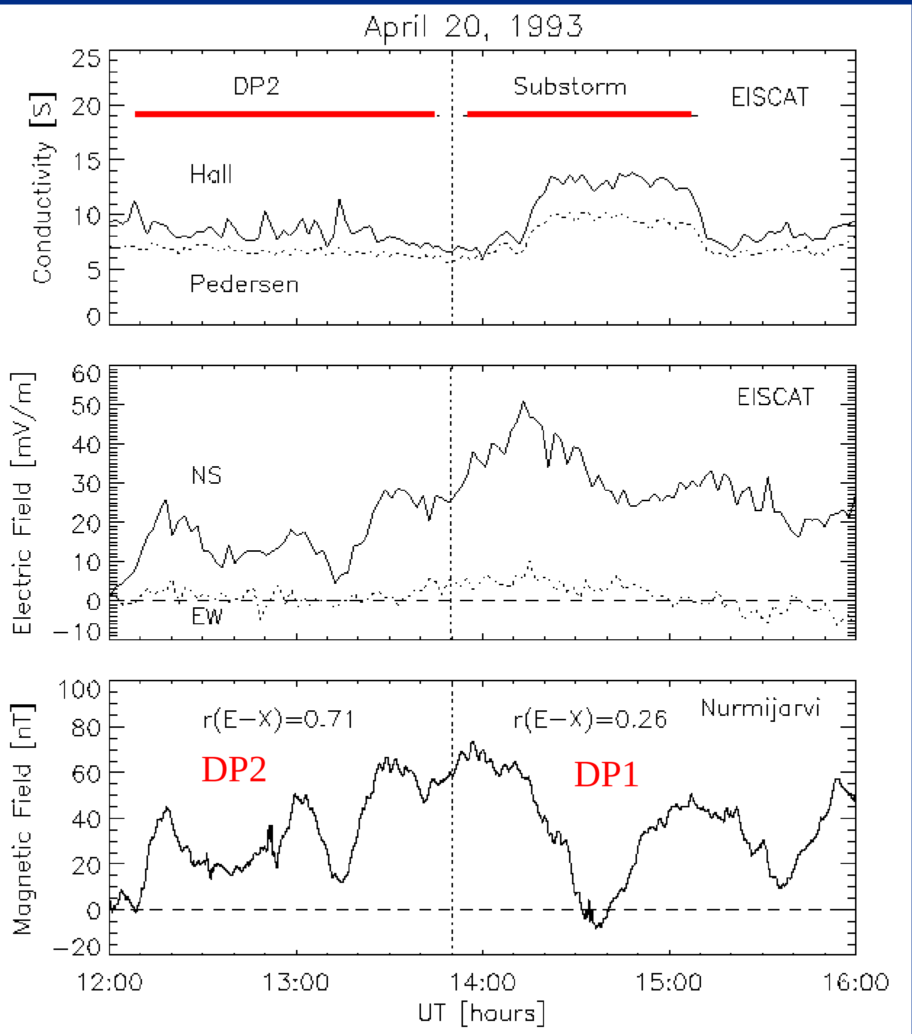
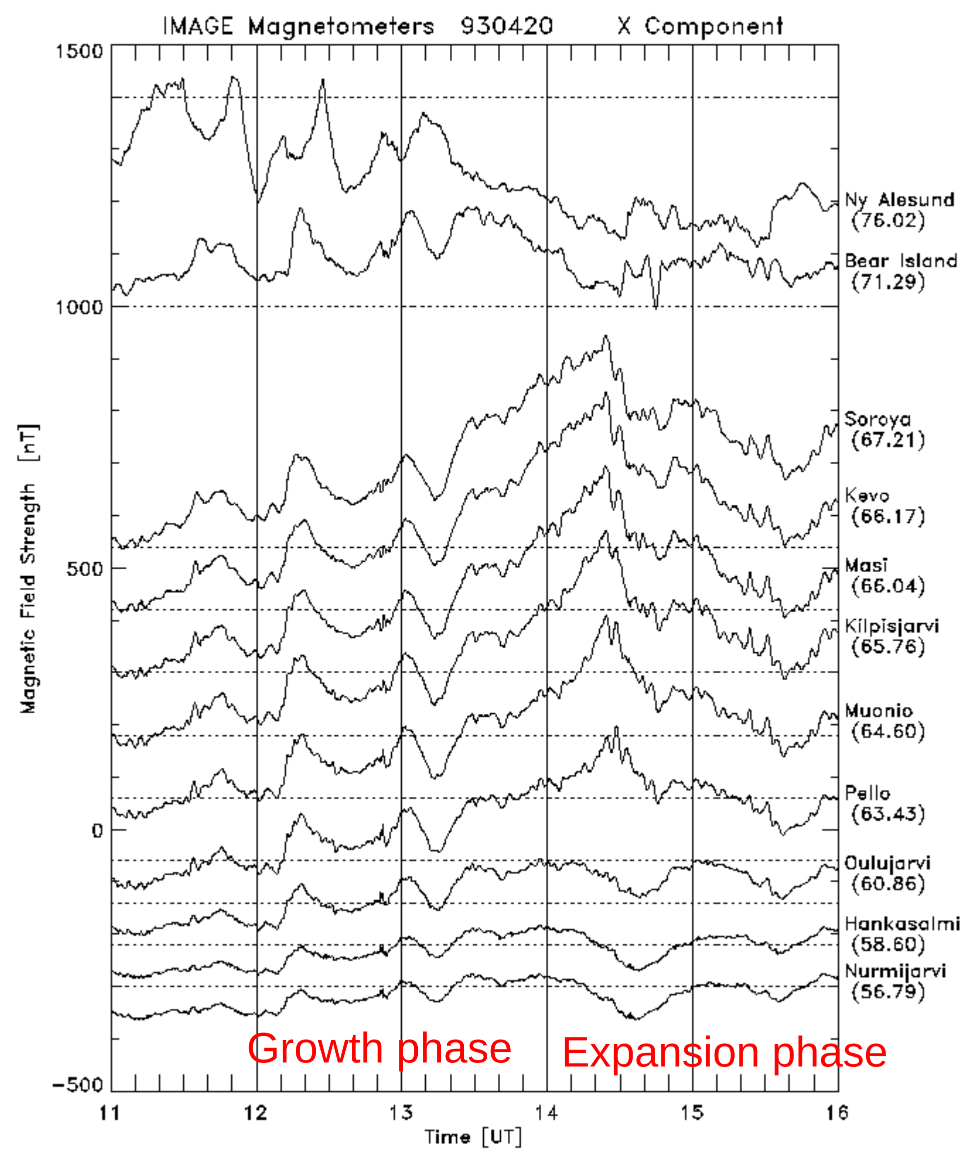
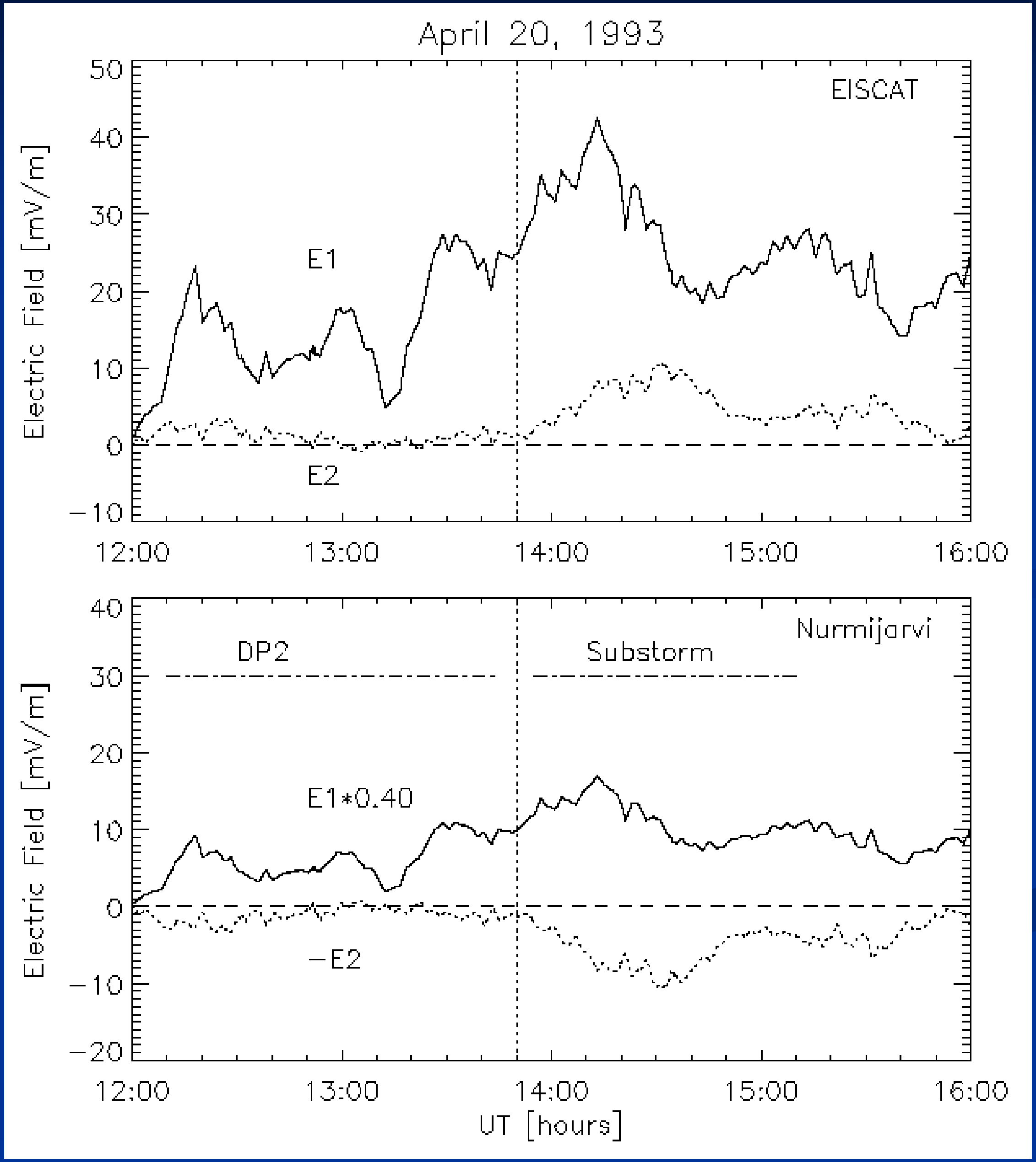


IMAGE Magnetometer chain



Convection electric field (R1 FAC) and shielding electric field (R2 FAC) at auroral (EISCAT) and mid latitudes (Nurmijarvi) during the substorm



The R2 FAC electric field can overcome the R1 FAC electric field, when the R1 FACs decay rapidly.

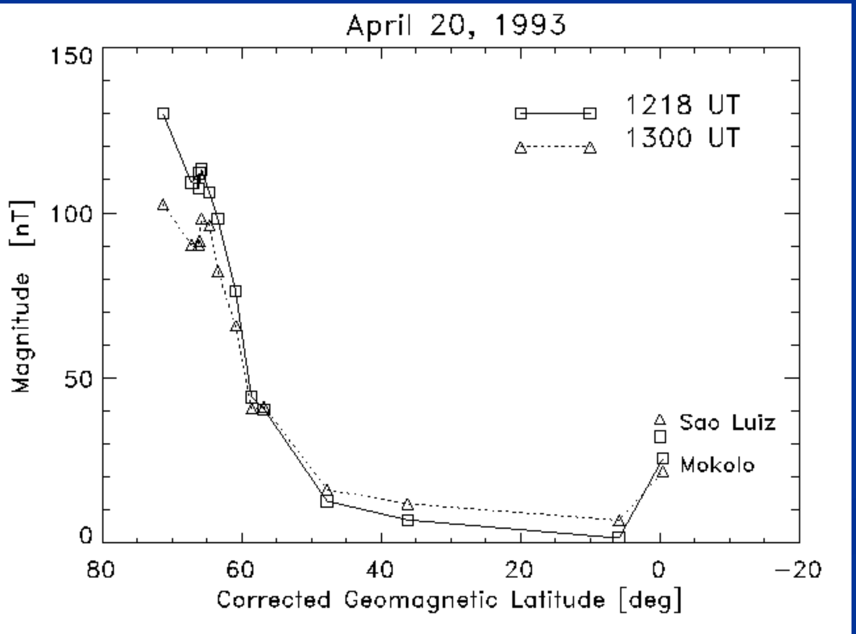
(Kikuchi et al., JGR 2000)

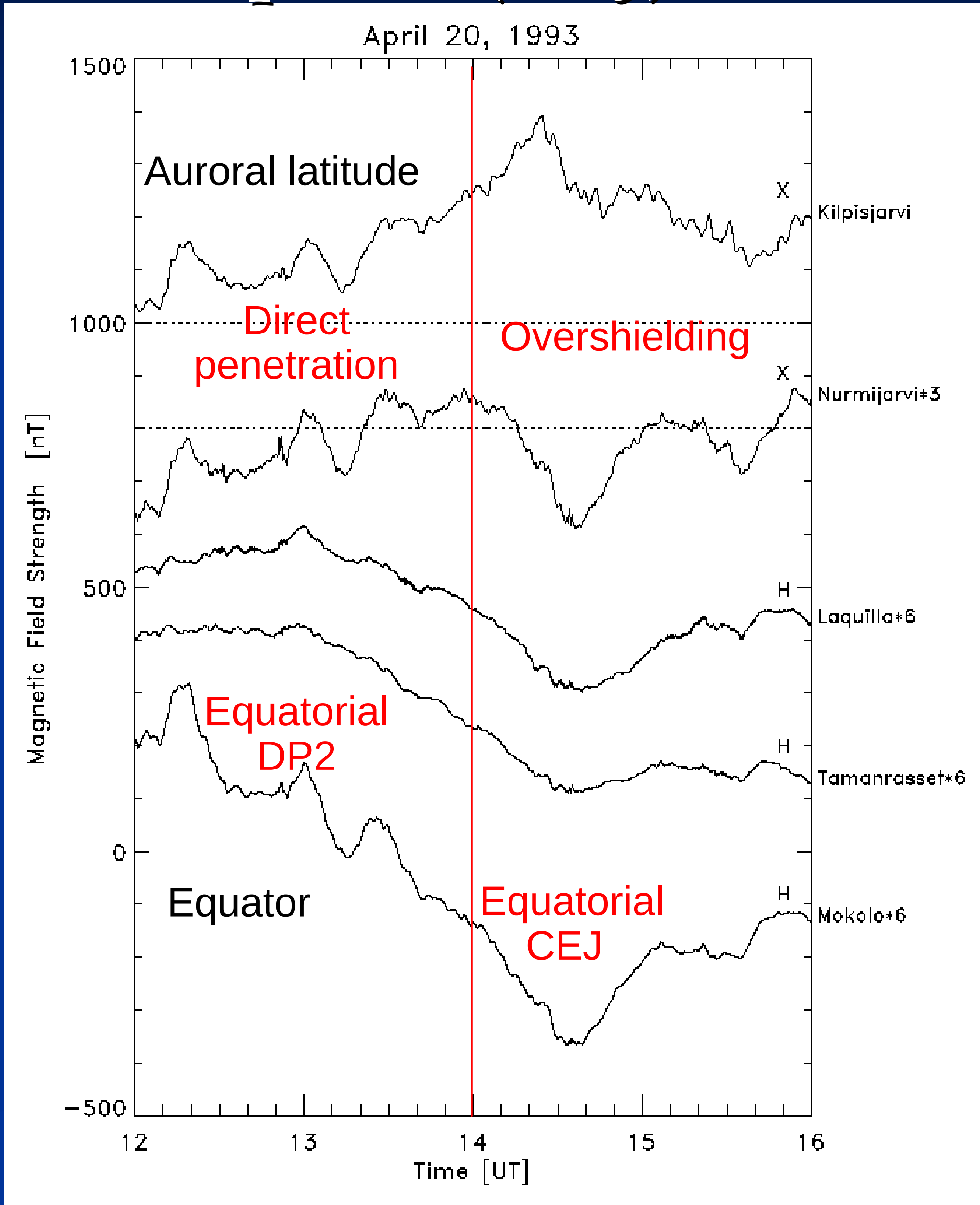
DP2 and overshielding at the geomagnetic equator (CEJ)

Magnetometer chain in the afternoon sector

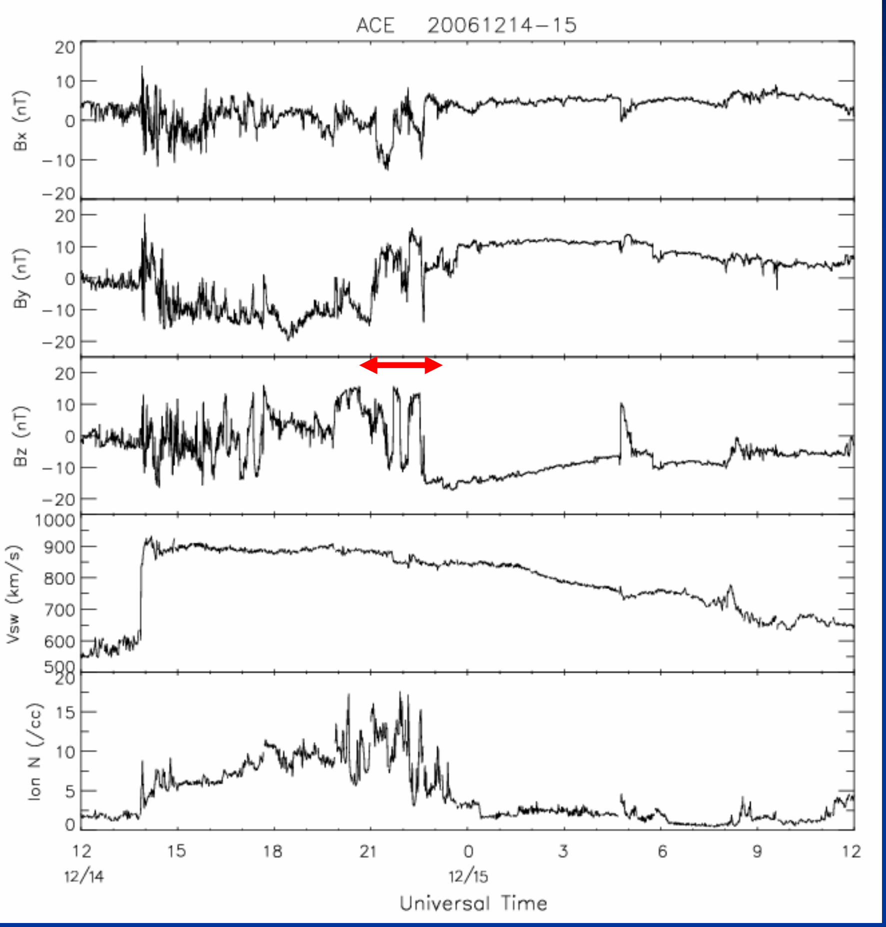
Kikuchi et al. (JGR 1996)

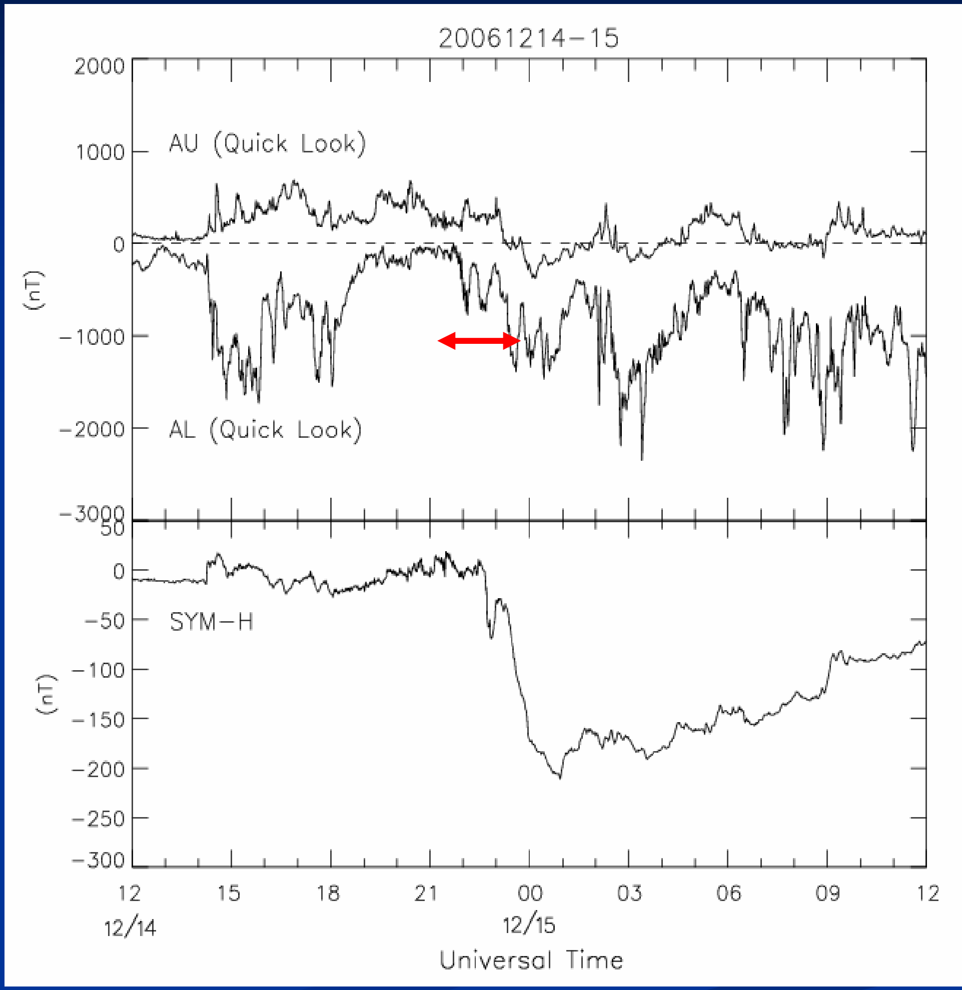
Latitudinal profile of the DP2 current





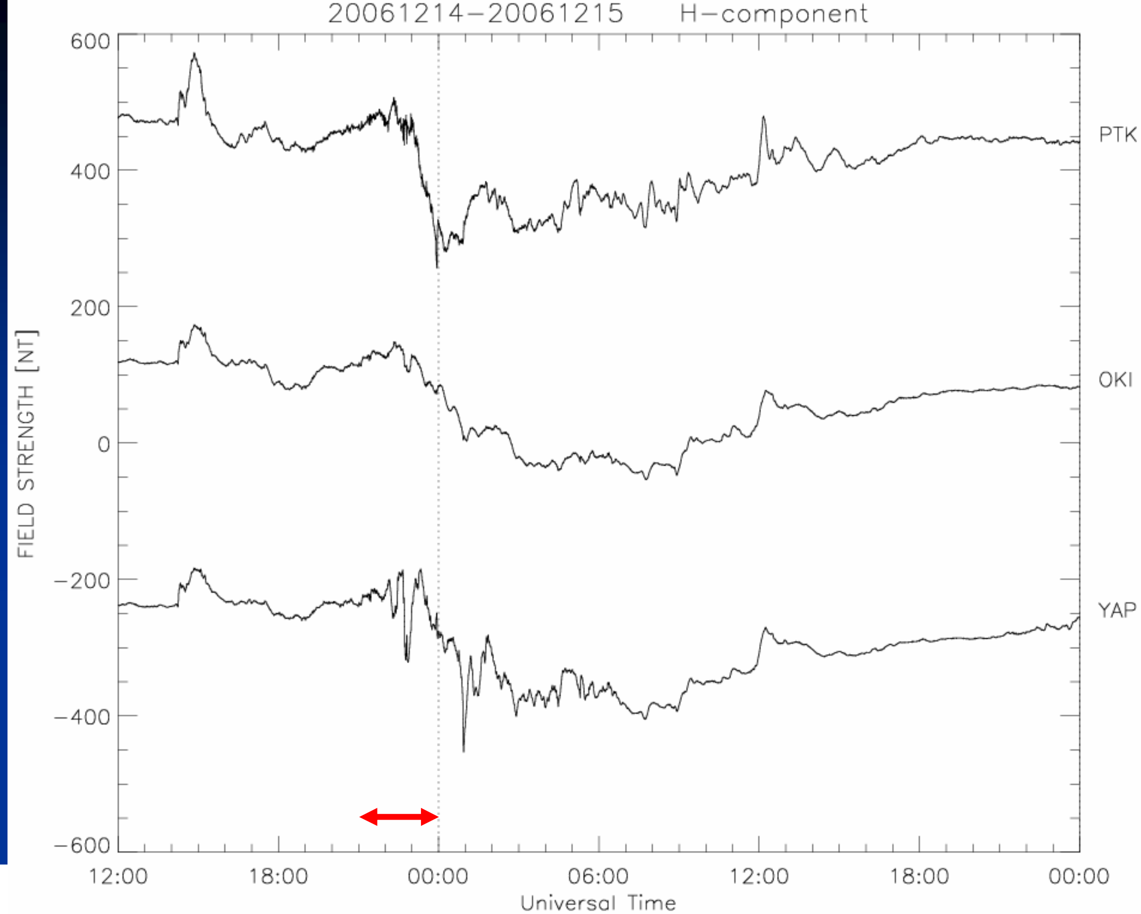
DP2 fluctuation event on December 14-15, 2006

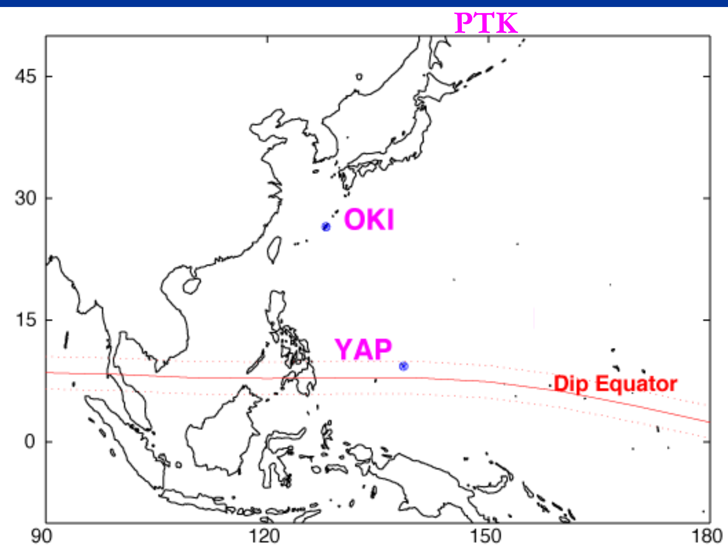




Quasi-periodic DP2 fluctuation event on December 14, 2006

The stations were located in the morning sector during the DP2 event.

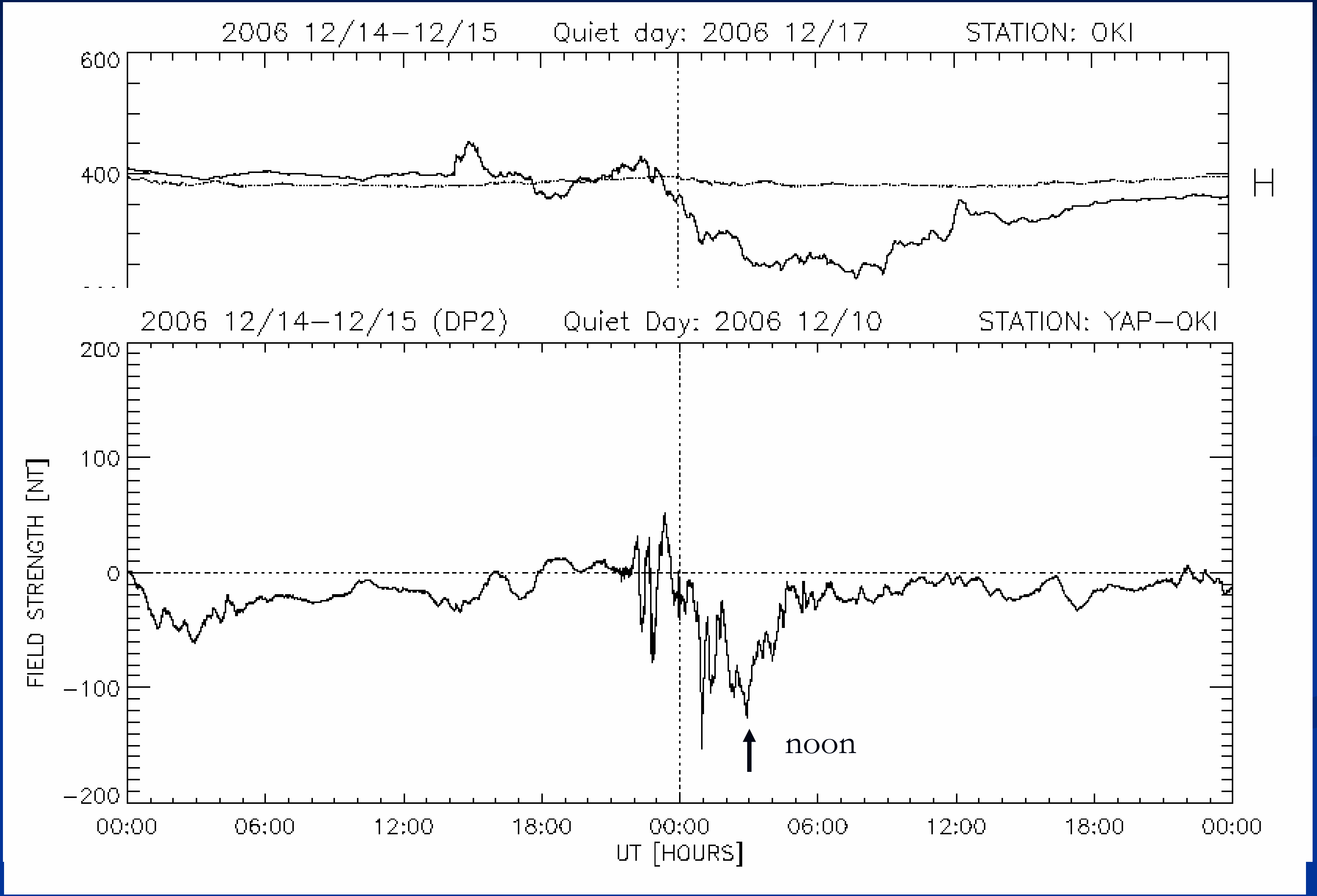




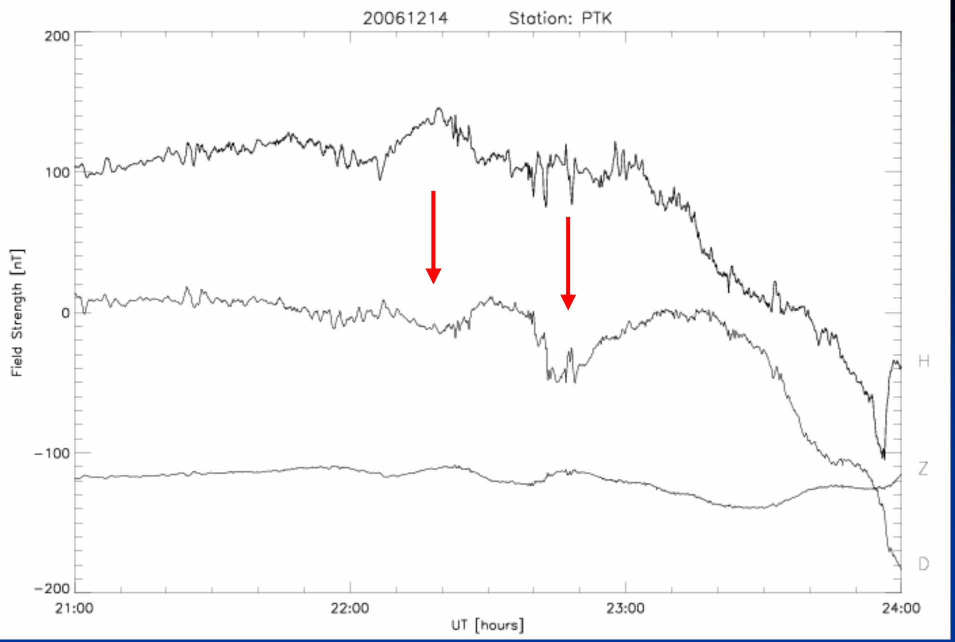
NICT space weather monitoring magnetometer stations

STATION		GEOGRAPHIC LAT	GEOGRAPHIC LON	GEOMAGNETIC LAT	GEOMAGNETIC LON	LT
PTK	Paratunka, Russia	52.94	158.25	45.58	221.13	UT+10.6
OKI	Okinawa, Japan	26.75	128.22	16.87	198.41	+8.4
YAP	Yap, Micronesia	9.49	138.09	0.38	209.21	+9.2

Magnetic perturbations due to ionospheric currents derived from YAP and OKI for the storm on Dec. 14-15, 2001 storm.

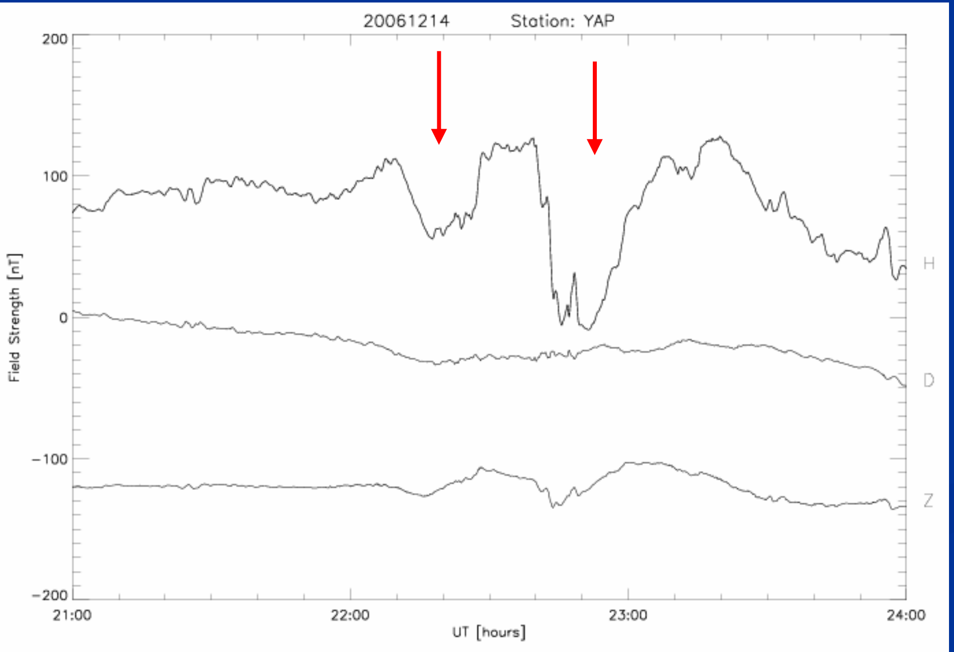


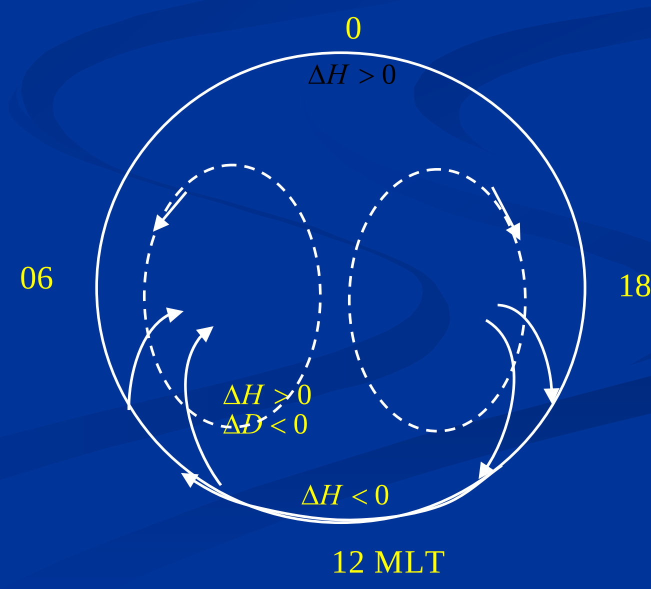
DP2 fluctuations at mid latitude (PTK) and at the geomagnetic equator (YAP)



The H (YAP) was negatively correlated with the H (PTK), while positively correlated with D (PTK).

The DP2 fluctuations were caused by ionospheric currents shown below.

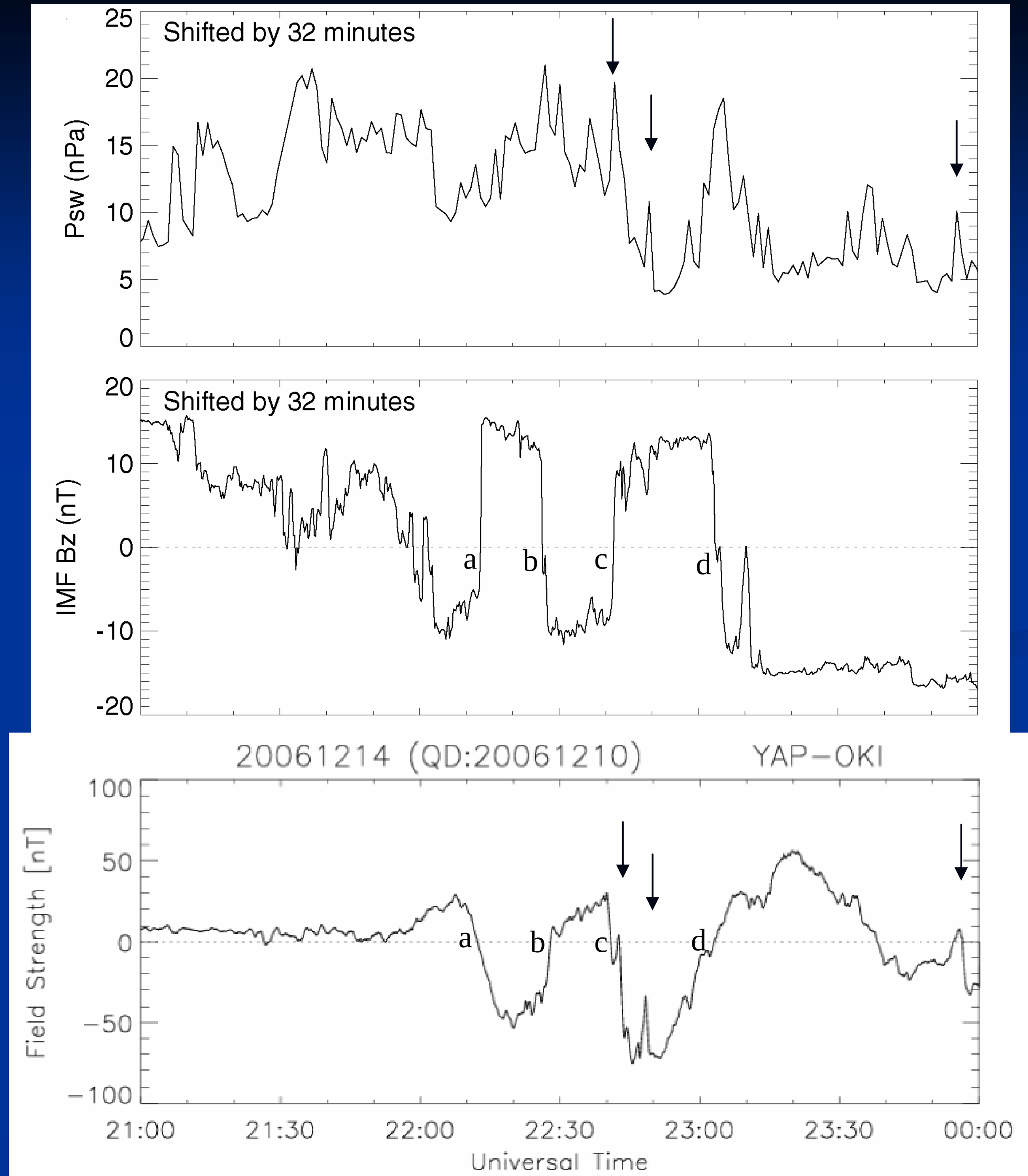




Correspondence between the IMF and DP2 fluctuations (32 min shifted)

We shifted the time axis of ACE by 32 min behind, then we see clear correspondence (1-2 min) between the DP2 and the IMF Bz.

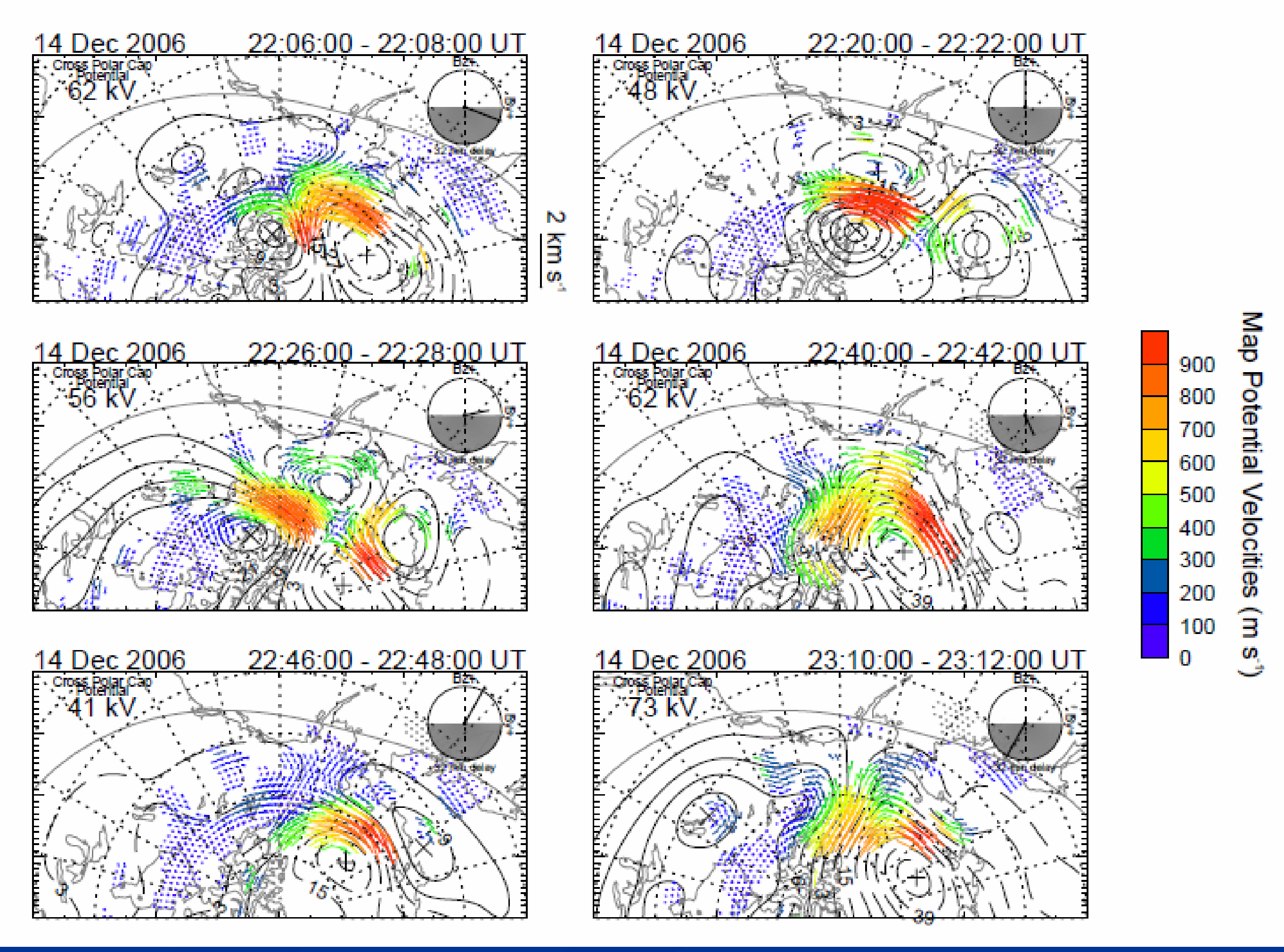
The southward IMF caused the eastward electrojet, while the northward IMF caused the westward electrojet.



Convection maps during the DP2 fluctuation event

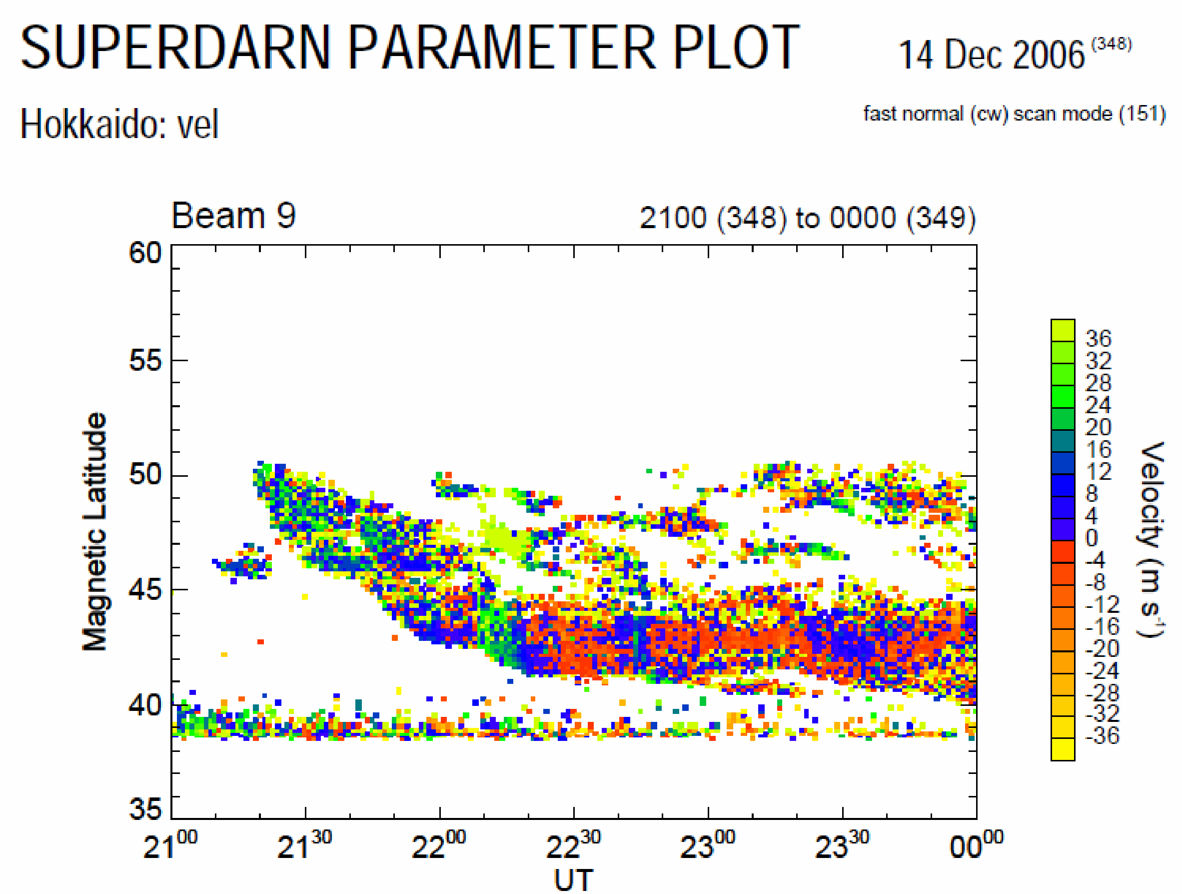
The convection is in two-cell pattern for southward IMF (Figures (1), (4), (6)). The electric field associated with the two-cell pattern penetrated to the equatorial ionosphere, and caused the e-EJ.

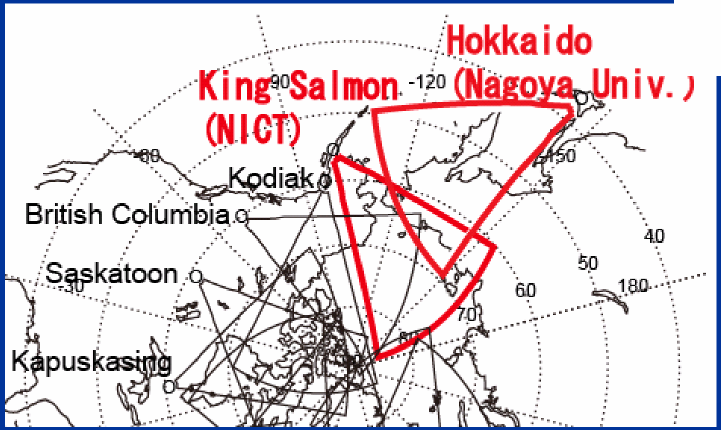
Reversed flow vortices appeared equatorward of the two-cell convection vortices for norhward IMF (Figures (2), (3), (5)). The reverse vortices must be associated with the R2 FACs that would cause a westward electric field responsible for the w-EJ at the equator.

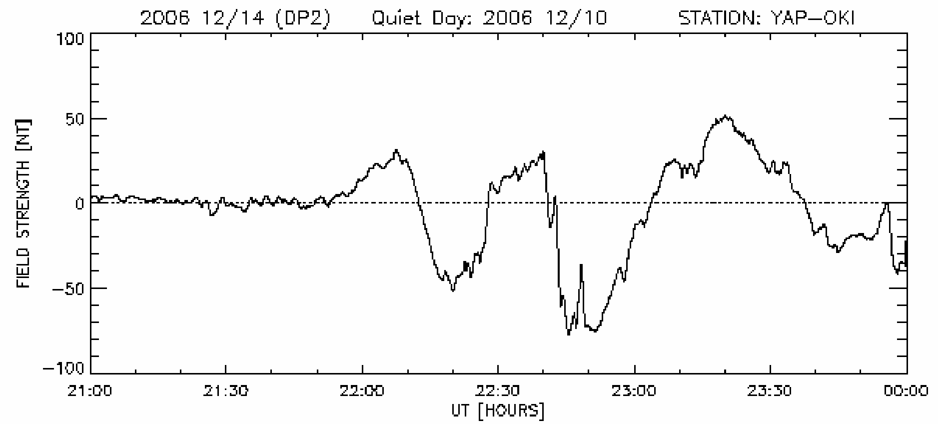


Line of sight velocity from the Hokkaido HF radar

Hokkaido radar detected poleward and equatorward flows during the DP2 fluctuation event, corresponding to the two-cell pattern and the reverse vortex in the morning sector





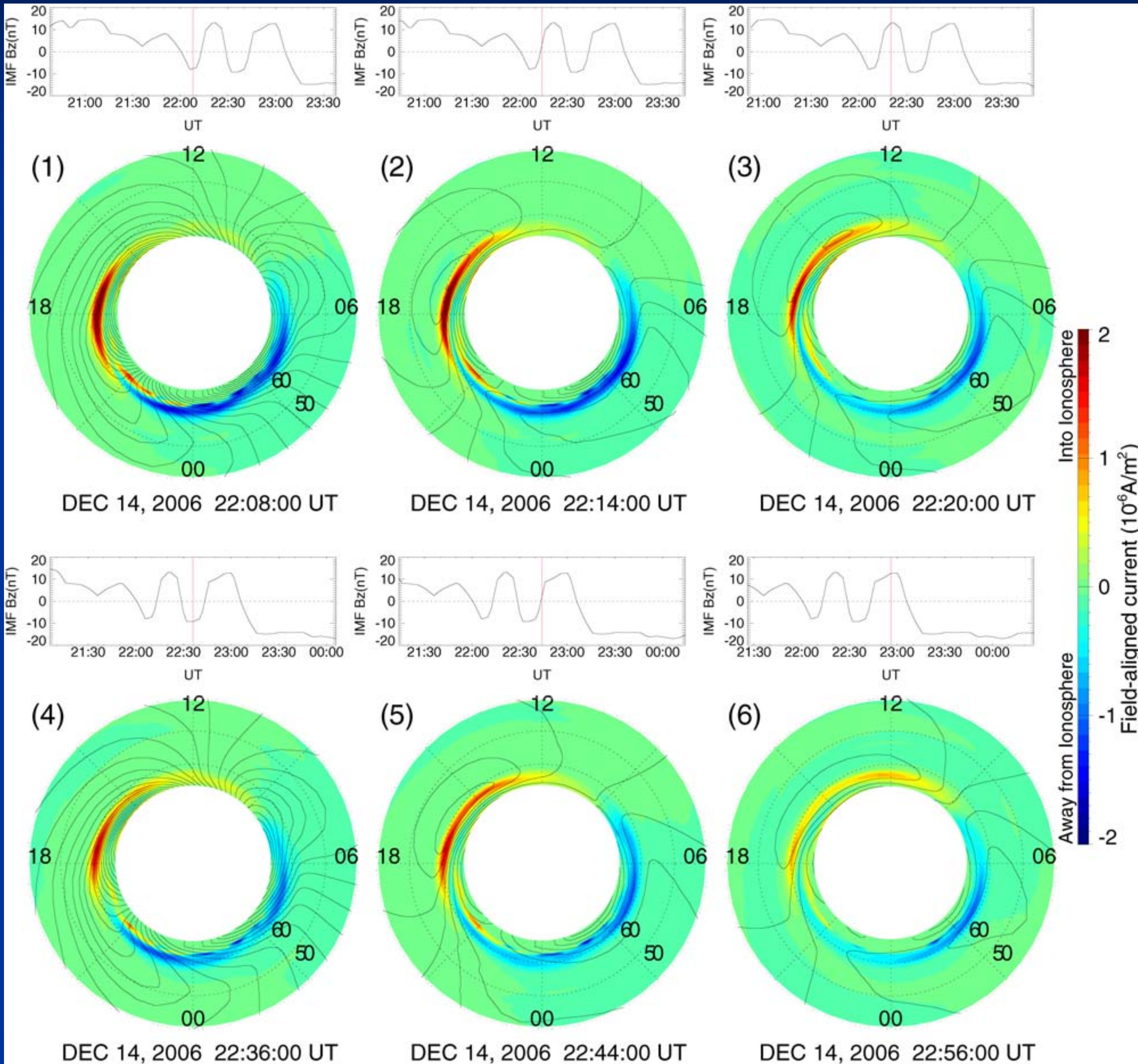


Electric potential patterns calculated with the CRCM

(ACE data is shifted in time by 32 min)

The R2 FACs are indicated with warm/cool color for downward/upward currents, and the contours describe the equi-potentials associated with the R1 and R2 FACs.

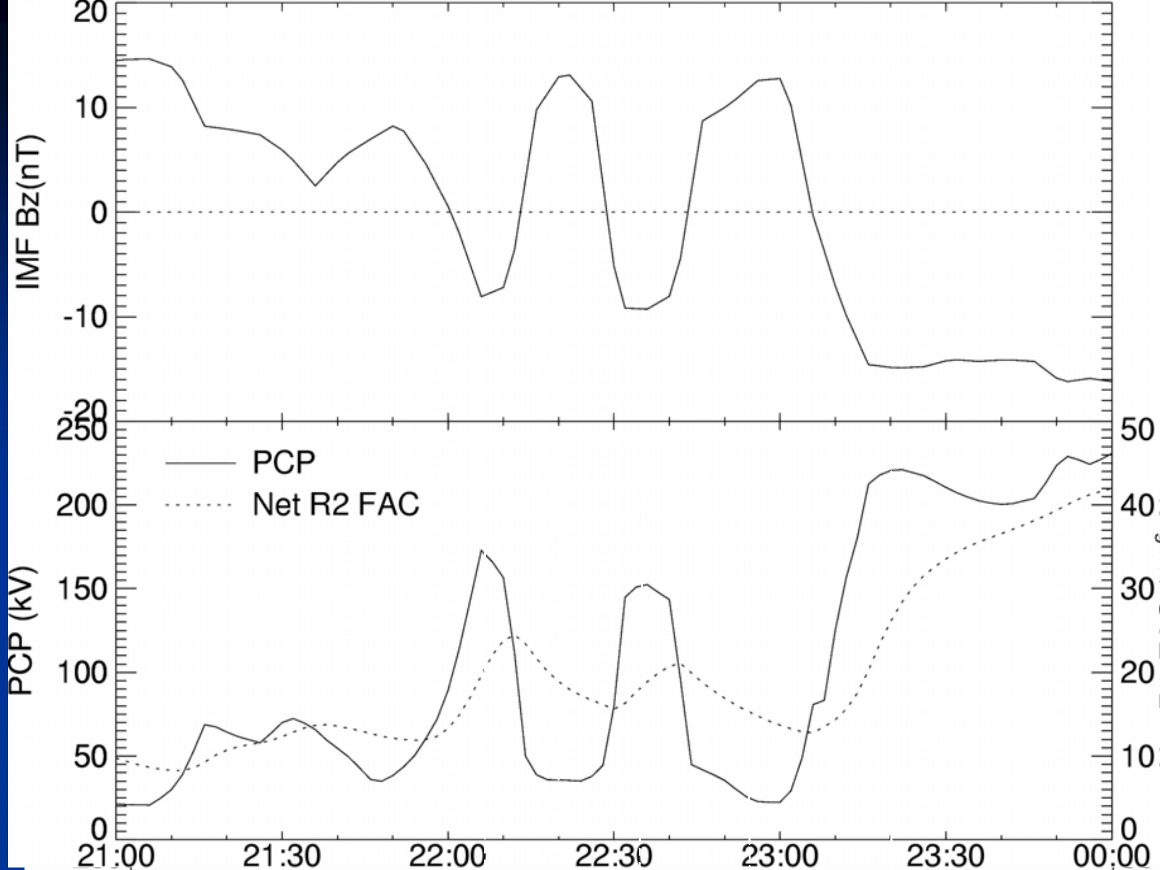
The contours are in two-cell pattern during the southward IMF (1, 4), but was dominated by the R2 FACs, when the IMF was northward (3, 6).

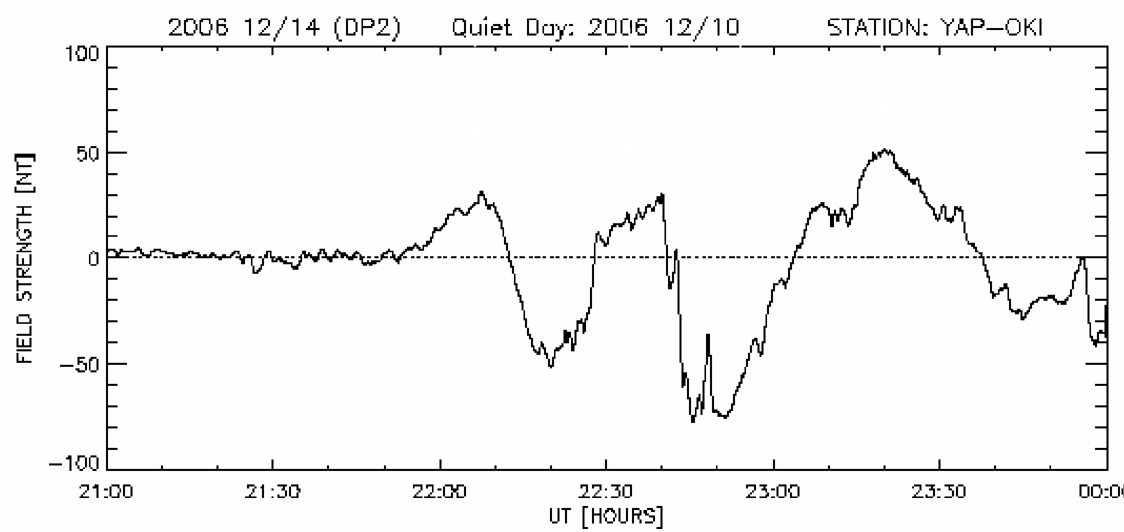


Temporal variation of PCP and net R2 FACs (solid and dotted curves in the middle panel)

The R2 FACs grow and decay slowly, even when the polar cap potential (PCP) changes rapidly.

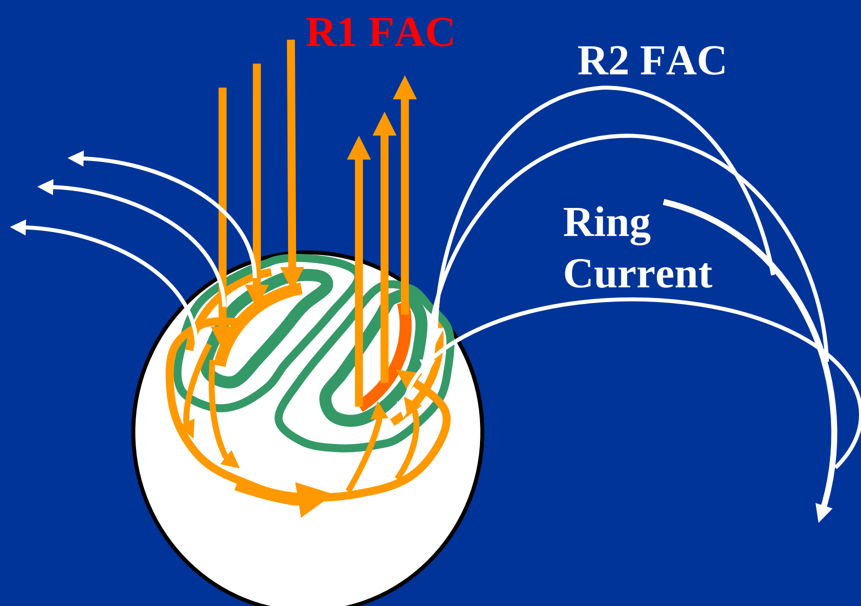
As a result, an electric field associated with the R2 FACs becomes dominant, when the PCP decreases substantially due to the northward IMF.



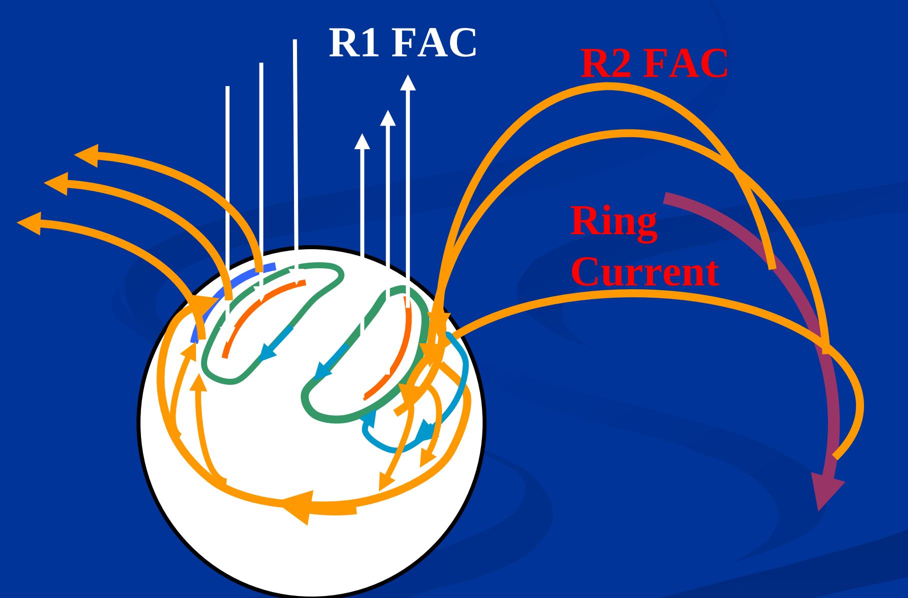


Current system of the quasi-periodic DP2 fluctuation

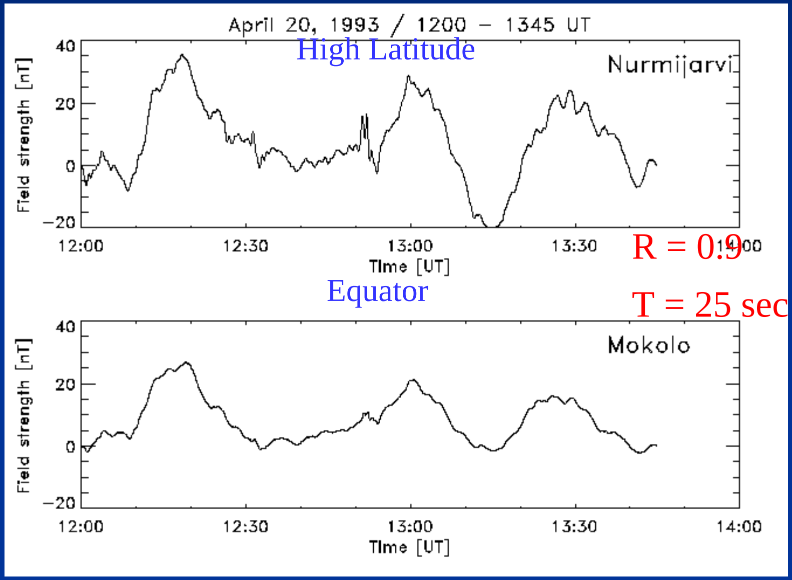
R1 FAC - e-EJ
current circuit



R2 FAC - w-EJ
current circuit

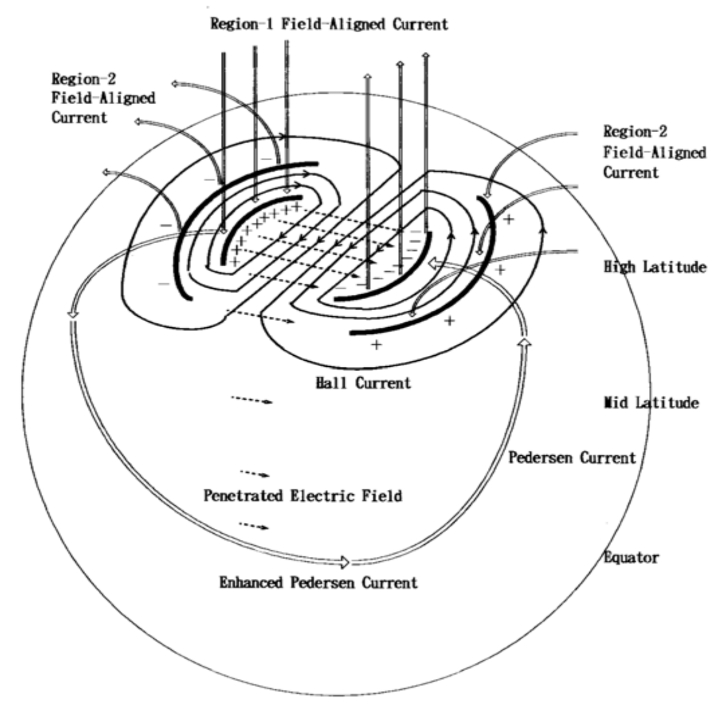


Coherency of the DP2 fluctuations at high latitude and equator
(R1 FAC - DP2 current circuit)



The excellent correlation between the high latitude and equatorial DP2 suggests instantaneous transmission of the electric field and current to the equator.

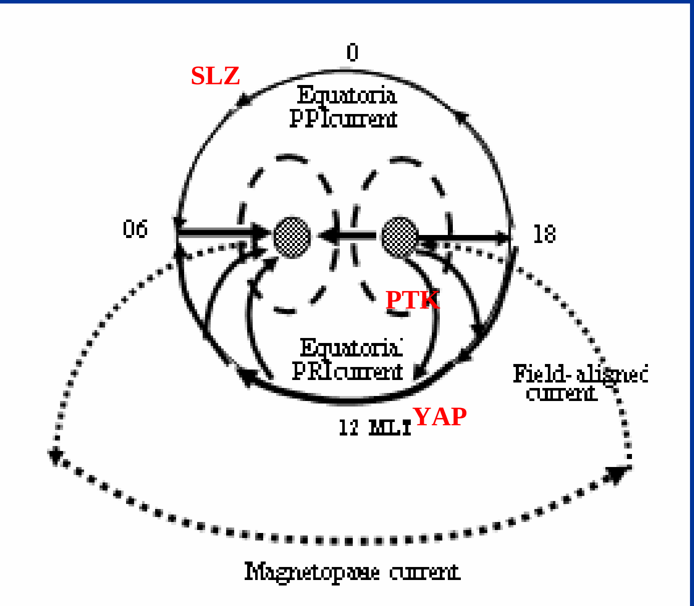
A current circuit is completed between the R1 FACs and the equatorial currents.

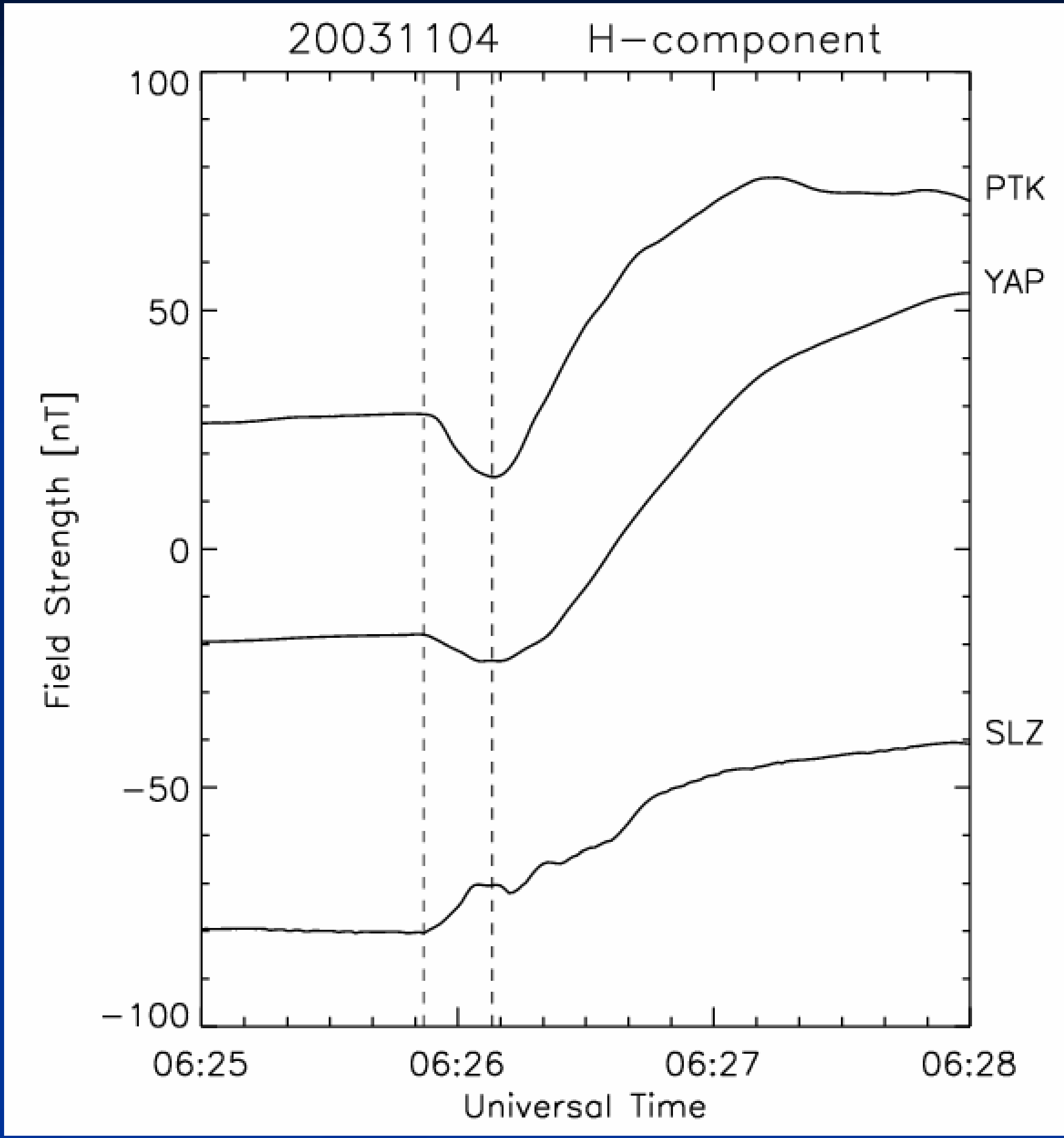


(Kikuchi et al., JGR 1996)

Simultaneous onset of the preliminary impulse (PRI/PPI) at the mid latitude and equator

(within a few seconds !)



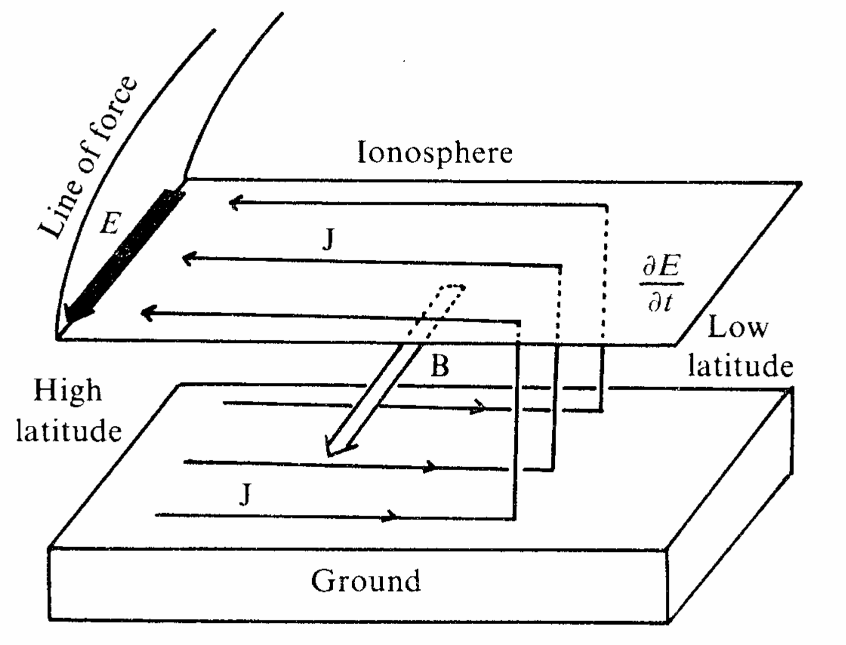


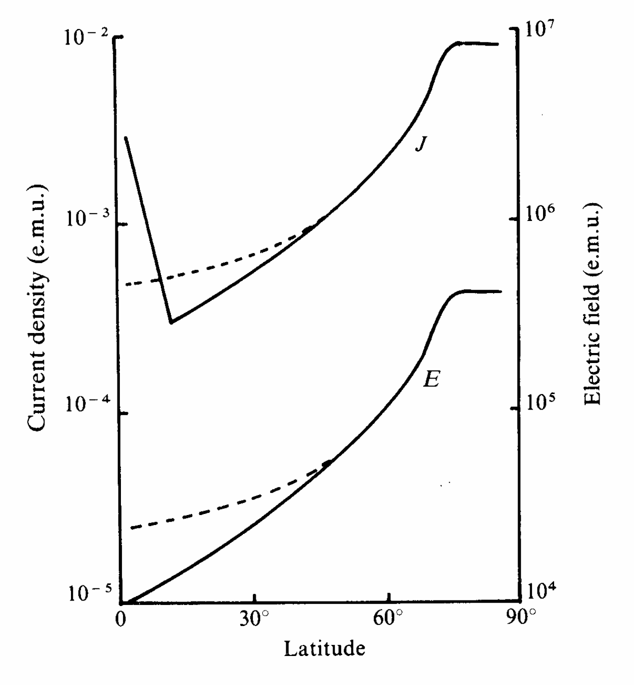
Earth-ionosphere waveguide (transmission line) model for the near-instantaneous transmission of the ionospheric current from the polar ionosphere to the equator

The TM0 (TEM) mode waves in the Earth-ionosphere waveguide transport electric currents in the ionosphere and at the surface of the ground, which are connected by the wave front current of the TM0 mode waves.

The transmitted electric field suffers from geometrical attenuation, but the induced currents are enhanced at the dayside equator by the Cowling effect.

(Kikuchi et al., 1978; Kikuchi and Araki, 1979)





How can the electric field be transmitted to the F-region ionosphere?

Upward Poynting flux in the fully ionized ionosphere

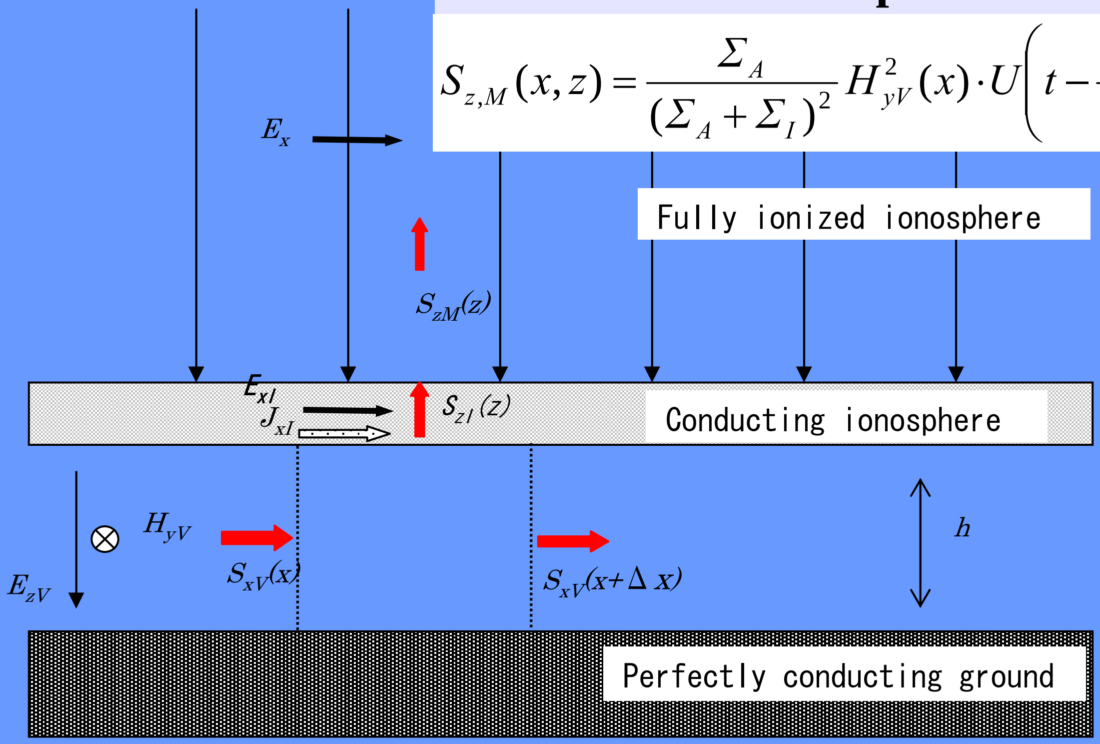
$$S_{z,M}(x,z)=\frac{\Sigma_A}{(\Sigma_A+\Sigma_I)^2}H^2_{yV}(x)\cdot U\left(t-\frac{z}{V_a}\right)$$

Upward Poynting flux in the conducting ionosphere

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

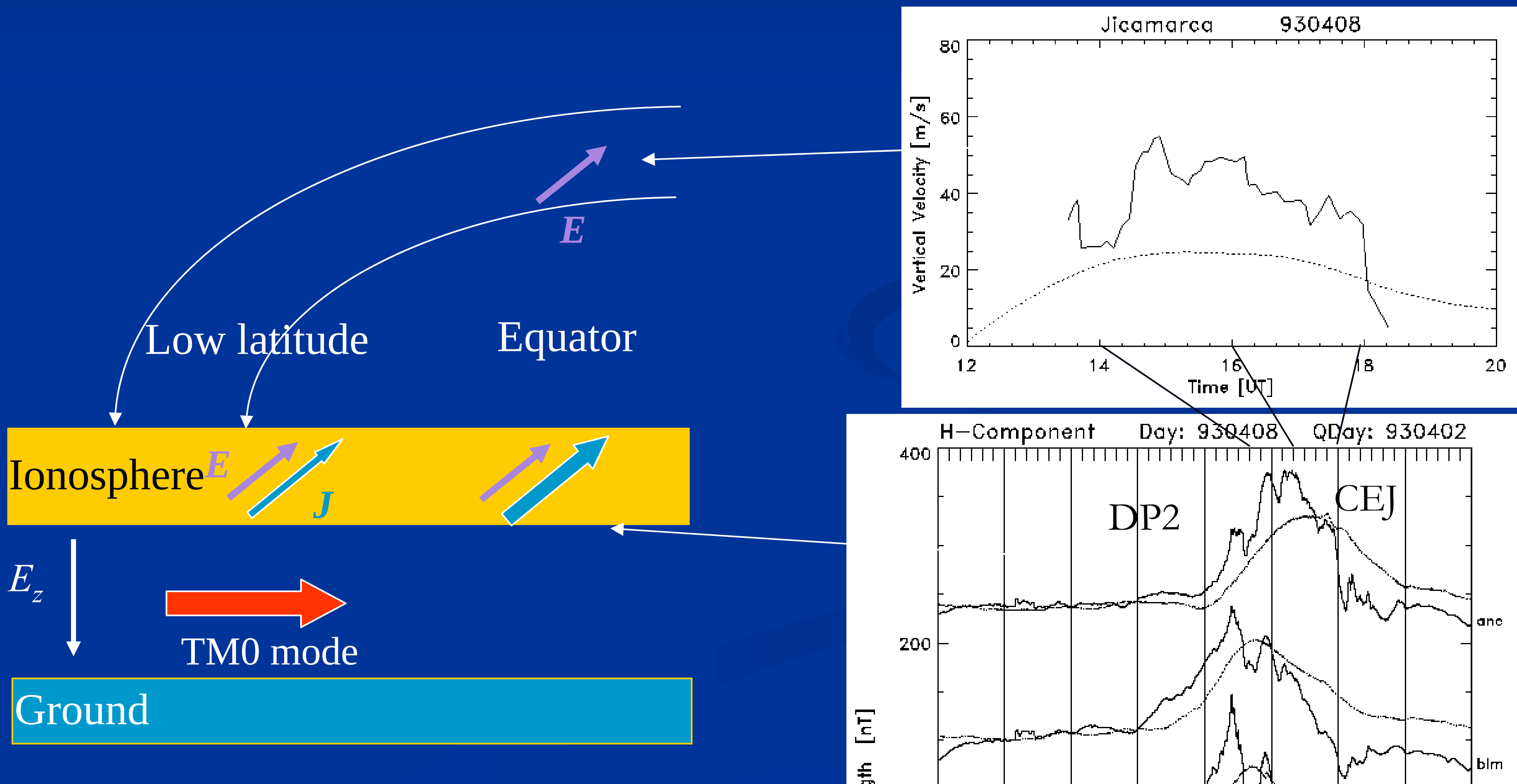
Horizontal Poynting flux in the waveguide

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



Coherent electric field and current at the Equator

The TM0 mode waves transport ionospheric currents to low latitude and equator. The electric field is further transmitted from the low latitude E-region to the equatorial F-region, causing the plasma motion as observed by the incoherent scatter radar. The electric currents are intensified in the highly conductive equatorial E-region, causing the equatorial DP2.

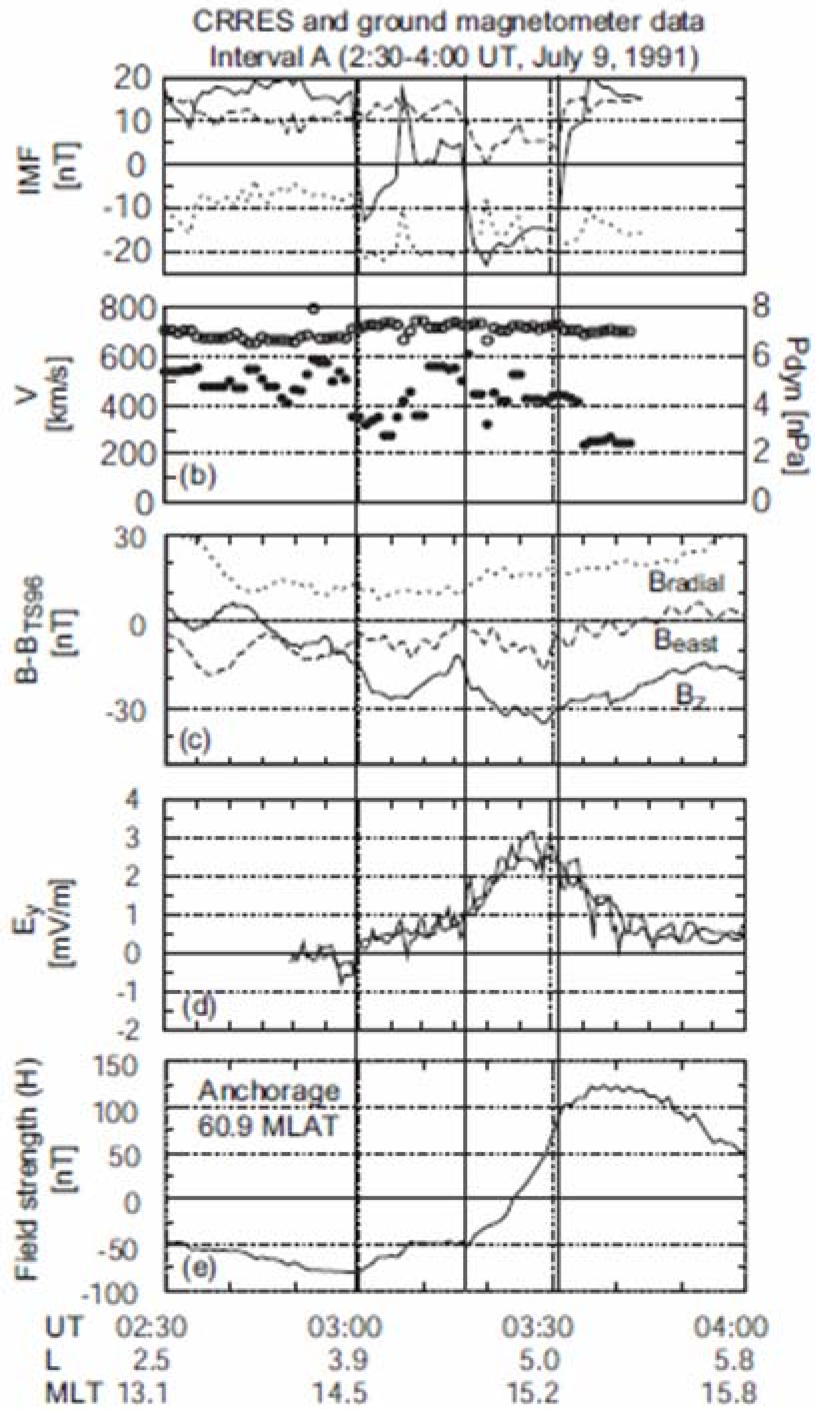


Quick response of the electric field in the inner magnetosphere (L=4-5)

Nishimura et al. (JGR 2009)

Upward Poynting flux was observed in the inner magnetosphere

(Nishimura et al. in preparation)



Conclusion

- During the quasi-periodic (period = 30 min) magnetic fluctuation event on December 14, 2006, SuperDARN detected the large-scale two-cell convection during the period of southward IMF, indicating development of the Region 1 field-aligned currents (R1 FACs).
- The King Salmon and Hokkaido radars detected reversed convections equatorward of the two-cell convections during the period of northward IMF, indicating development of the R2 FACs and overshielding electric field at mid latitude.
- The convection electric field caused the eastward electrojet at the dayside equator, while the overshielding electric field caused the counterelectrojet, which should be connected with the R1 and R2 FACs, respectively.
- The ring current simulation with CRCM shows that the electric field associated with the R2 FAC develops with a time lag (7 min), resulting in the dominant appearance of the overshielding electric field when the R1 FACs decreased rapidly.
- Prompt propagation of the electric field to the midlatitude F-region ionosphere is explained by means of the TM0 mode wave propagating at the speed of light in the Earth-ionosphere waveguide.