SuperDARN2000 (La Trobe, May 2000)

Transient Plasma Flow Response to Solar Wind Dynamic Pressure Change as Observed by SuperDARN and Magnetometers

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Causes of Transient Plasma Flow

- Magnetospheric compression (rarefaction)
  SC/SI,
  TCV
- Magnetic reconnection
  FTE

Components of SC/SI

- SC/SI=DL+DP(PI)+DP(MI)
- DL:Chapman-Ferraro Currents
- DP(PI): Ionospheric currents caused by dusk-to-dawn electric fields generated by the compression of the sub-solar magnetopause.
- DP(MI): Ionospheric currents caused by dawn-to-dusk electric fields generated by the enhanced magnetospheric convection.

(Araki, 1994)

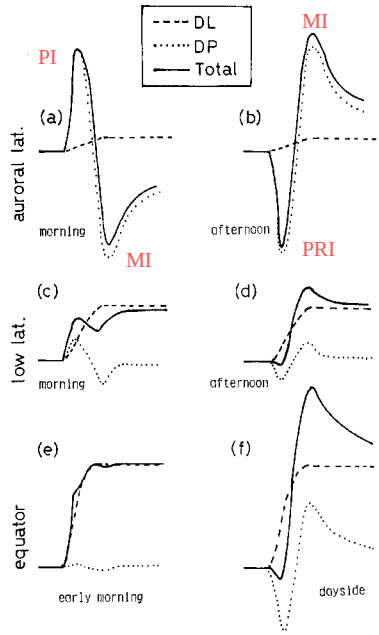


Fig. 11. Decomposition of the SC disturbance field into *DP*- and *DL*-sub-fields.

Equivalent Currents of SC/SI

Consist of DP2-type current vortices (Araki, 1994)

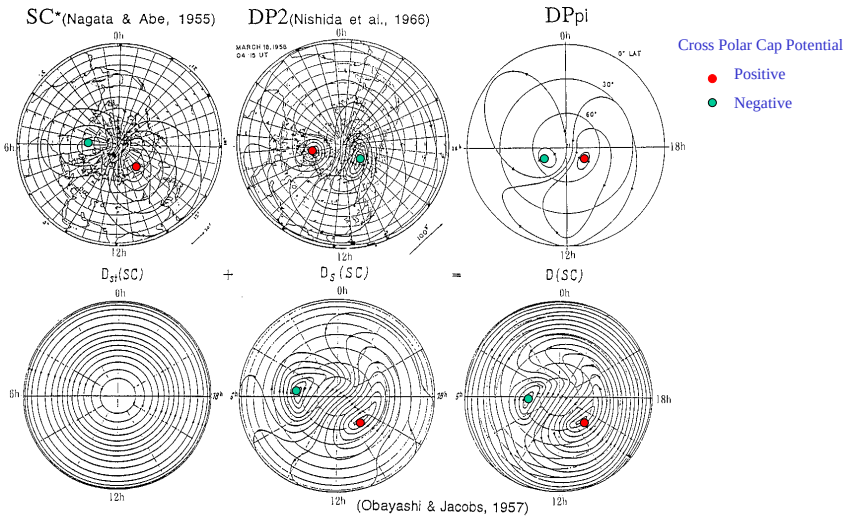
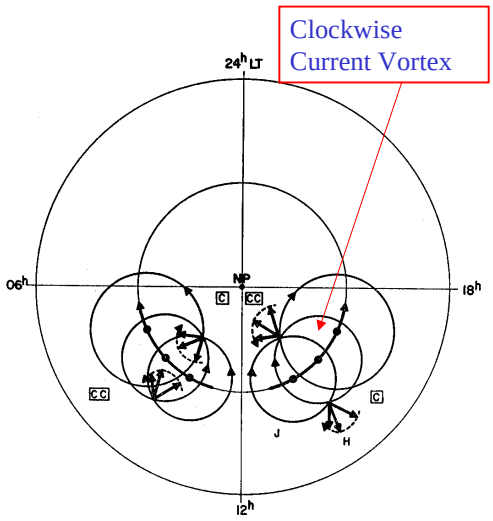


Fig. 10. Equivalent current systems for the PI of SC* [Nagata and Abe, 1955 and Araki et al., 1985], DP-2[Nishida et al., 1966], D_{st}(SC), D_s(SC) and D(SC) [Obayashi and Jacobs, 1957].

PRI Current Vortices

Equivalent currents of the PRI consist of a clockwise vortex in the afternoon and a counter-clockwise one in the morning sector. The vortices move slowly from the noon to the terminators.

(Nagano et al., 1985)



Instantaneous Propagation of Polar Electric Fields (Observation)

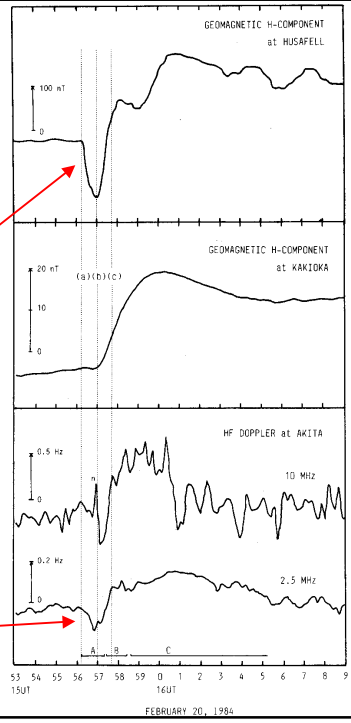
- PRI occurs simultaneously at afternoon high latitudes and dayside dip equator within 10 sec (Araki, 1977).
- PRI electric fields are observed at low latitudes within 10 sec by HF Doppler measurements (Kikuchi, 1986).
- DP2 (period=40 min) occurs coherently at high latitudes and the dayside dip equator within 25 sec (Kikuchi et al., 1996).

HF Doppler Observation of PRI Electric Fields at Night-time Low Latitudes

Kikuchi (1986)

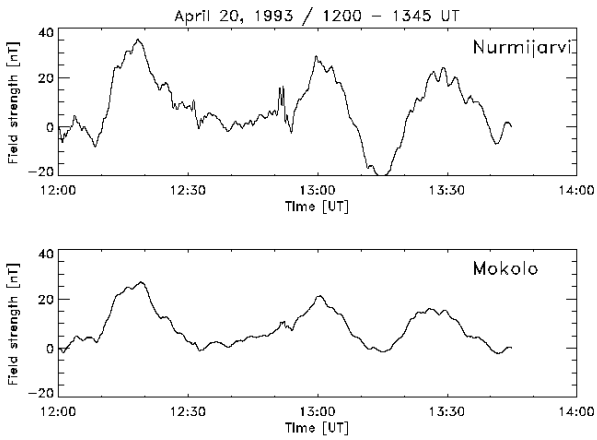
PRI at high latitude

Doppler frequency change due to dusk-to-dawn electric fields



Instantaneous Propagation of DP2 Electric Fields to the Equator

The DP2 fluctuations (period of 40 min) at Mokolo and Nurmijarvi are coherent with a correlation coefficient of 0.9. The time shift between the magnetic fluctuations is 25 sec, suggesting instantaneous propagation of auroral electric fields. (Kikuchi et al., 1996)



High Latitude

R = 0.9
T = 25 sec

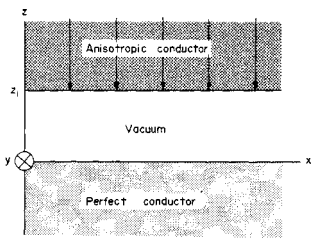
Equator

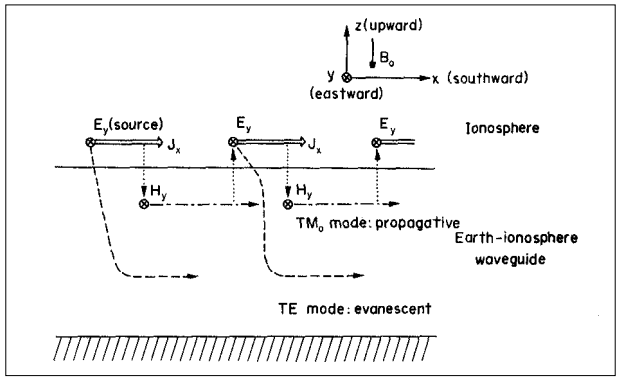
Theory of Instantaneous Horizontal Propagation

- F-region: severe attenuation or evanescent (Kikuchi and Araki, 1979a)
- E-region: severe attenuation
  (Kikuchi and Araki, 1979a)
- Earth-Ionosphere Waveguide: Zeroth-order TM mode propagation at a speed of light with no attenuation (Kikuchi and Araki, 1979b)

Earth-Ionosphere Waveguide Model for Instantaneous Propagation

TM0 mode waves propagate at a speed of light in the Earth-ionosphere waveguide with no propagation attenuation because of no cutoff frequency.
(Kikuchi et al., Nature 1978, p.650; Kikuchi and Araki, JATP 1979b, p.927)





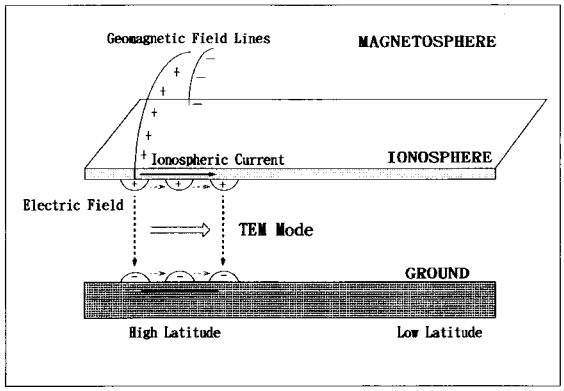
Transmission Line Model for Instantaneous Propagation of Polar Electric Fields

A parallel plane transmission line is composed of the ionosphere and the earth.

Electric charges carried along the magnetic field lines induce vertical electric fields below the ionosphere, exciting a TEM mode in the transmission line.

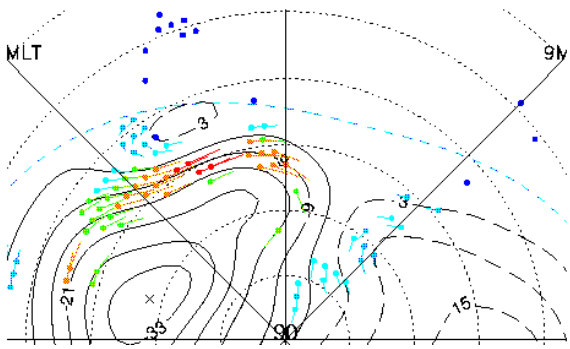
This enables instantaneous propagation of polar electric fields to lower latitudes at a speed of light.

(Kikuchi et al., JGR 1996, p.17161)



In this Paper

- We show SuperDARN observations of a counter-clockwise flow vortex centered at 72 degs in 14 MLT meridian during the PRI of SC on April 21, 1997.

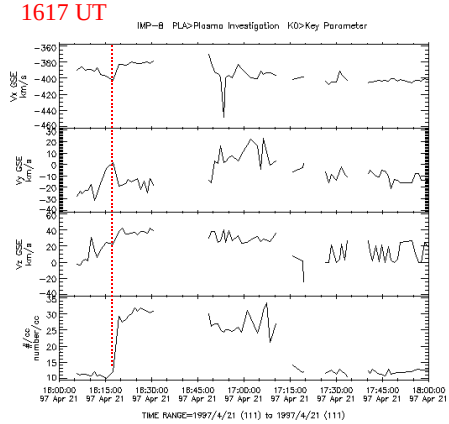


SC on April 21, 1997

IMP-8 (7.2, 36.7, -1.6 Re)

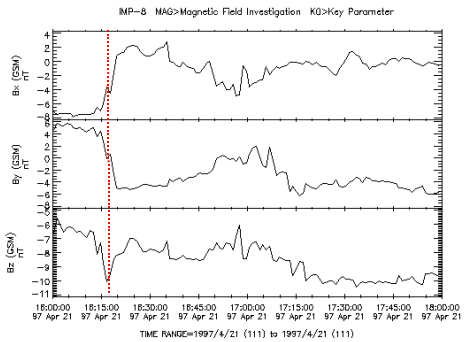
Nsw = 30/cc (←12/cc)

1617 UT



Bz = - 8 nT

Apr.21, 1997



Global Features of SC

The PRI (Preliminary Reverse Impulse) occurred at 1618 UT at afternoon high latitudes (NUR, YOR) and at the dayside dip equator (ANC, GLP).

The global PRI is explained by DP2-type ionospheric currents caused by dusk-to-dawn electric fields extending to the equator.

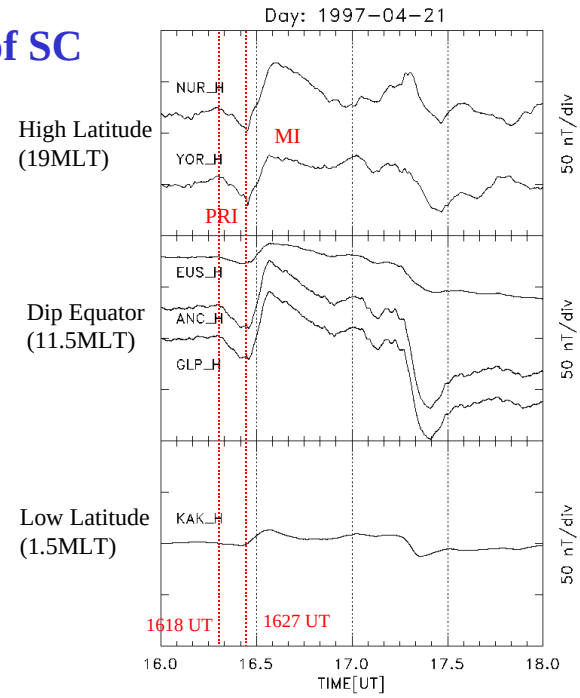
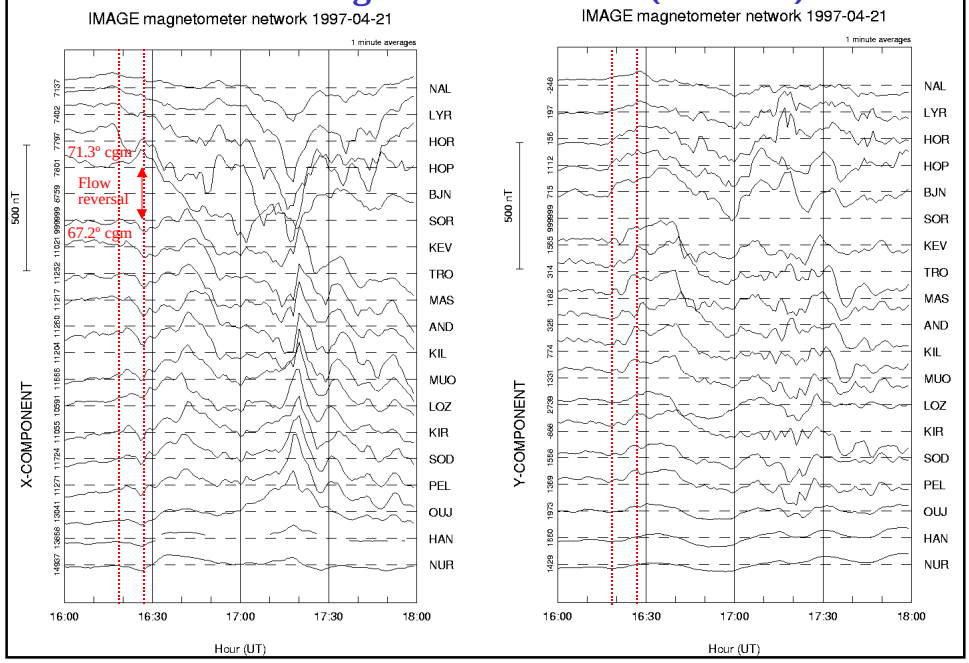
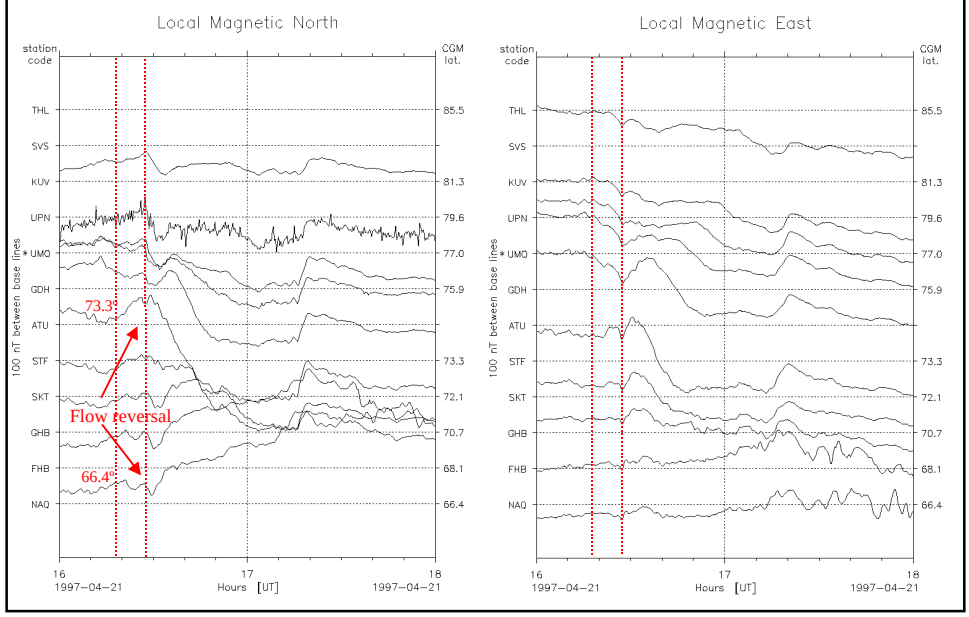


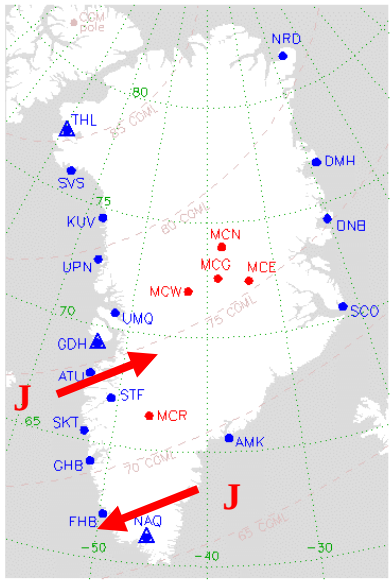
IMAGE Magnetometer Chain (19 MLT)



Greenland Magnetometers (14.5 MLT)



Greenland Magnetometer Network



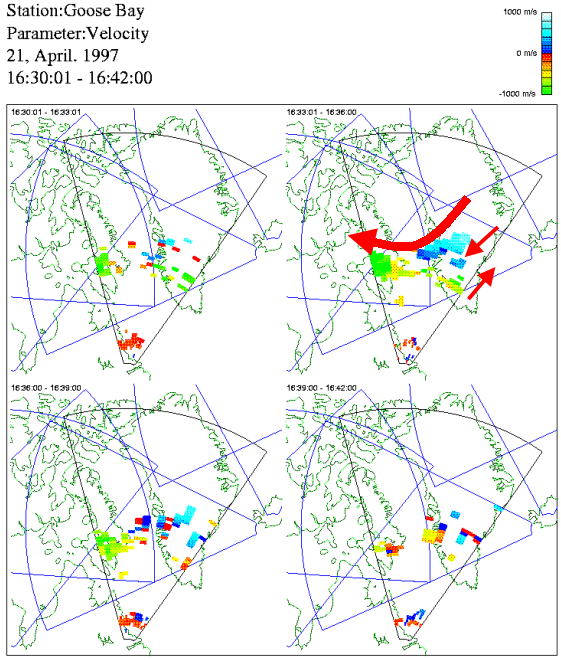
△ Geomagnetic observatory (operated by DMI)

● DMI magnetometer site

● MAGIC site

Pace Map of LOS Flow Speed

Station:Goose Bay
Parameter:Velocity
21, April. 1997
16:30:01 - 16:42:00



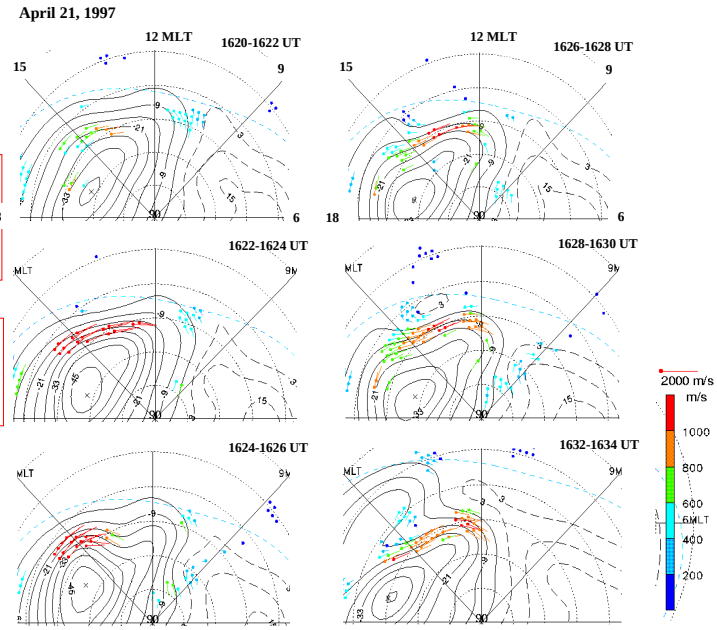
→ Plasma Flow

PRI

(Preliminary Reverse Impulse)

Small-scale counter-clockwise vortex centered at 72 degs in the 14 MLT sector

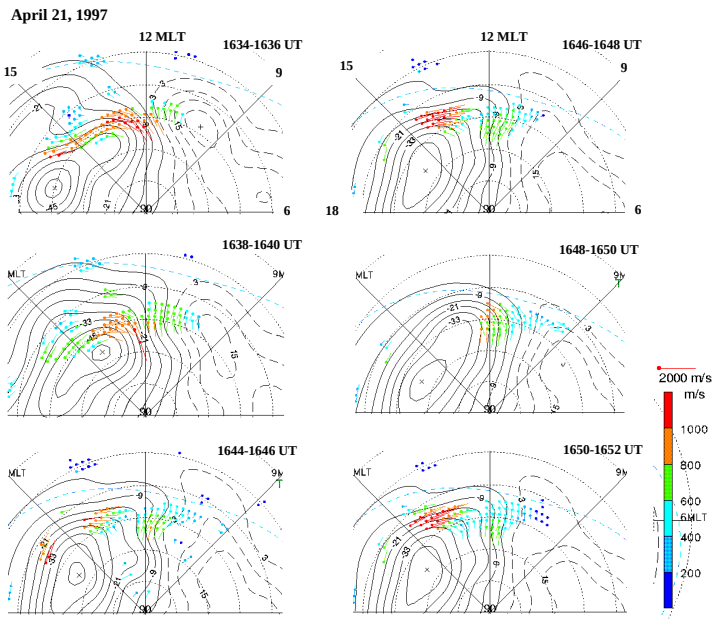
Large-scale clockwise convection vortex centered at 79 degs in the 17 MLT sector



MI

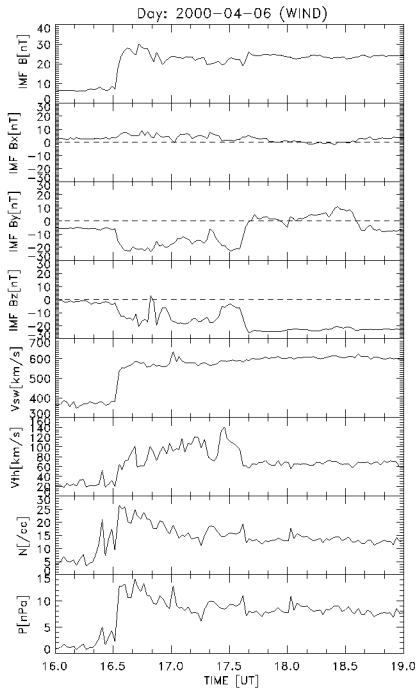
(Main Impulse)

Plasma flow is enhanced in the cusp and expands poleward

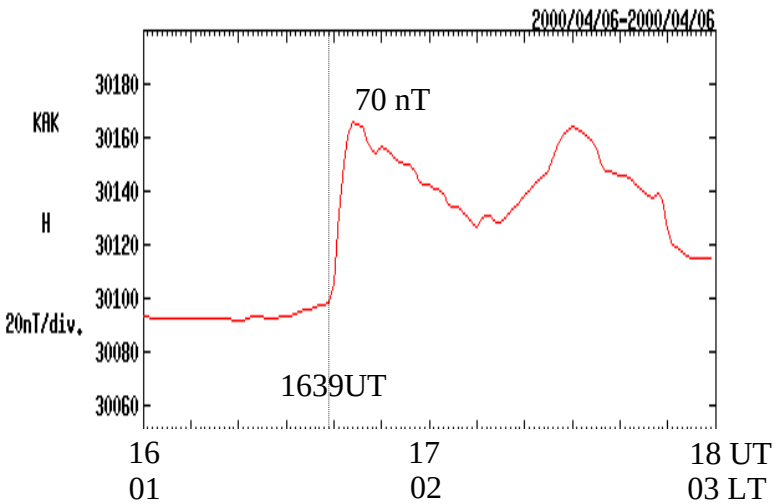


April 6, 2000/1639
SC Event

WIND



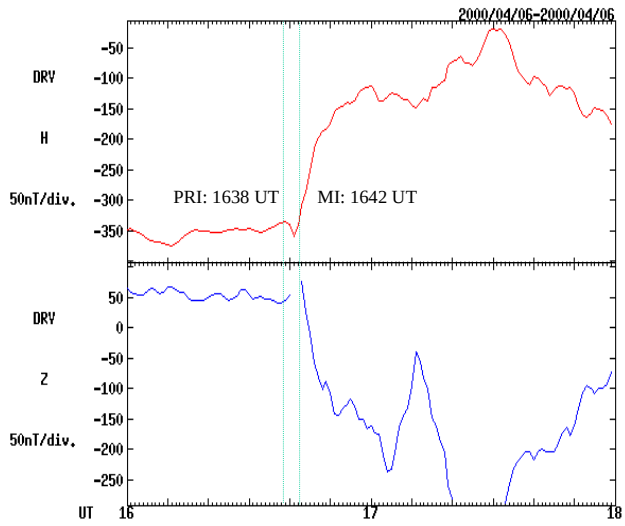
Kakioka



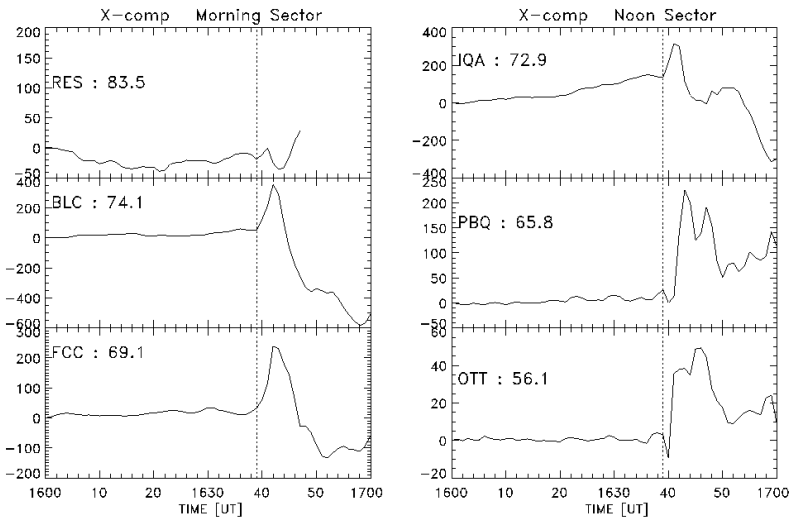
DumontDurville (INTERMAGNET)

PRI : 1638 - 1642 UT

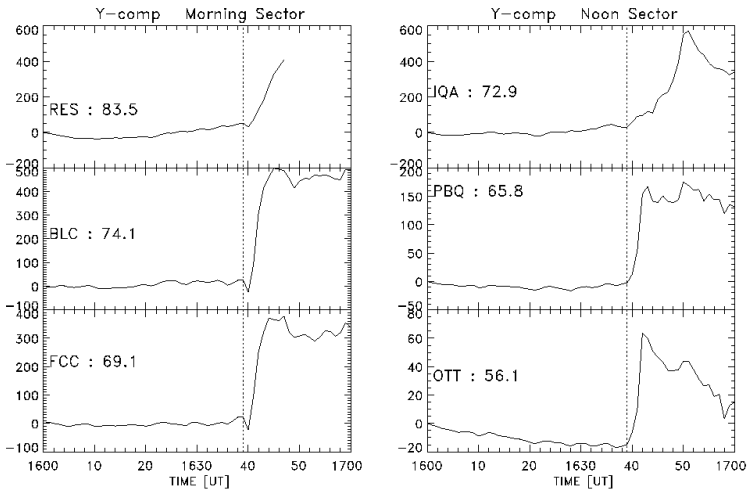
80.6S CGM
0330 MLT



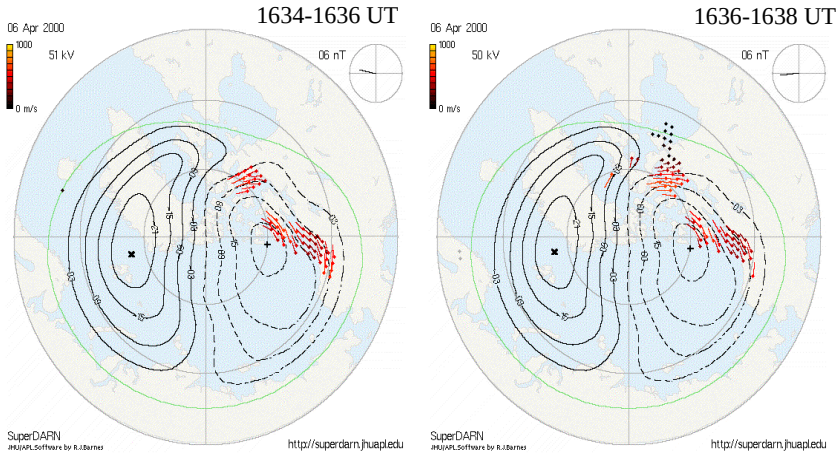
CANOPUS Magnetometers



CANOPUS Magnetometers



Pre-SC



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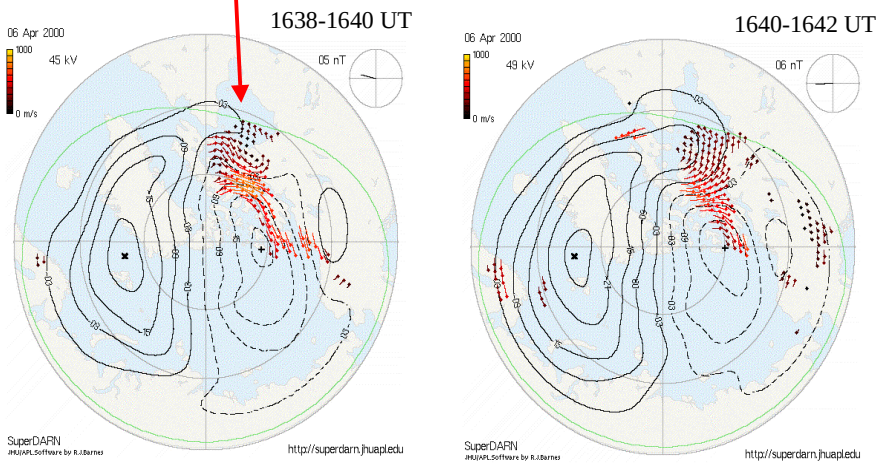
Onset of SC (PRI)

Clockwise vortex centered at 74 degs, 10 MLT



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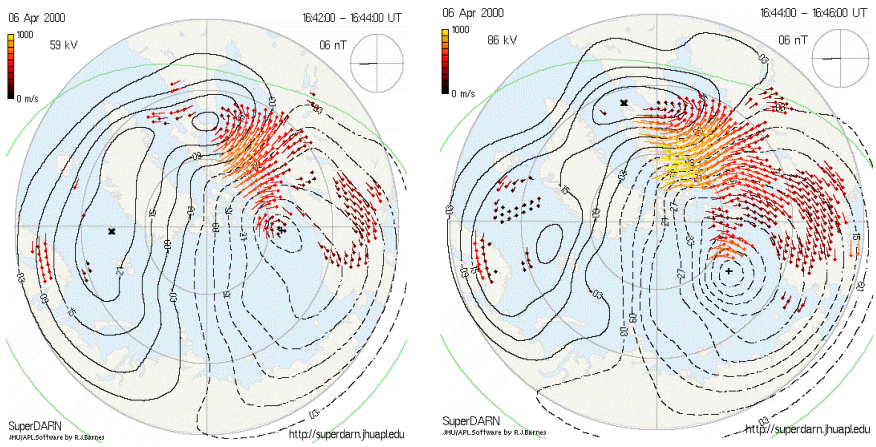
MI of SC



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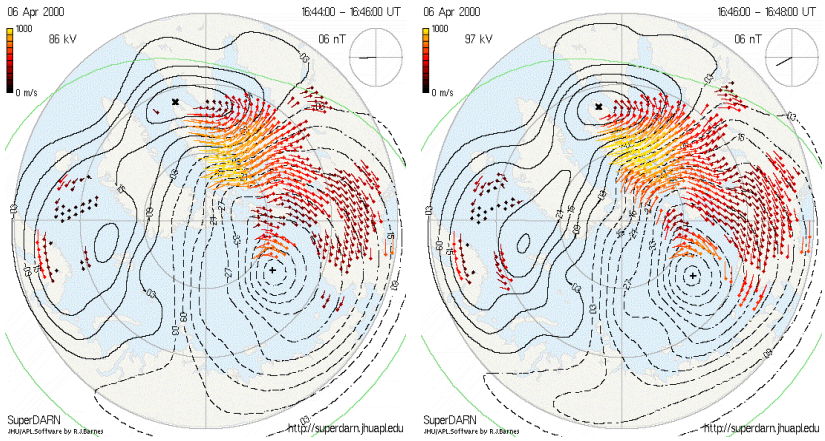
MI of SC (continued)



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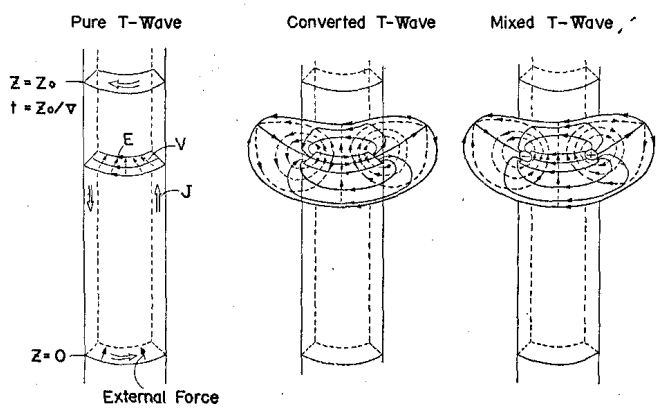
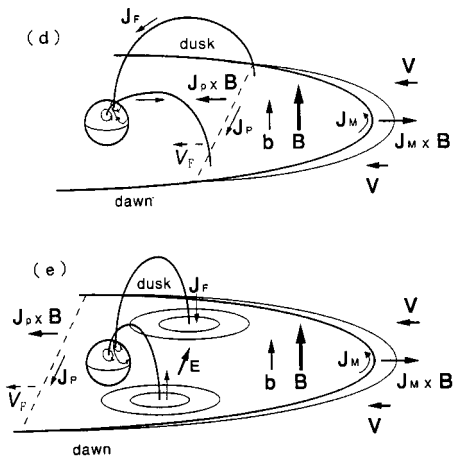
PRI Model (Tamao, 1964)

- Vortical motion of the magnetospheric plasma is produced in the dayside magnetosphere.

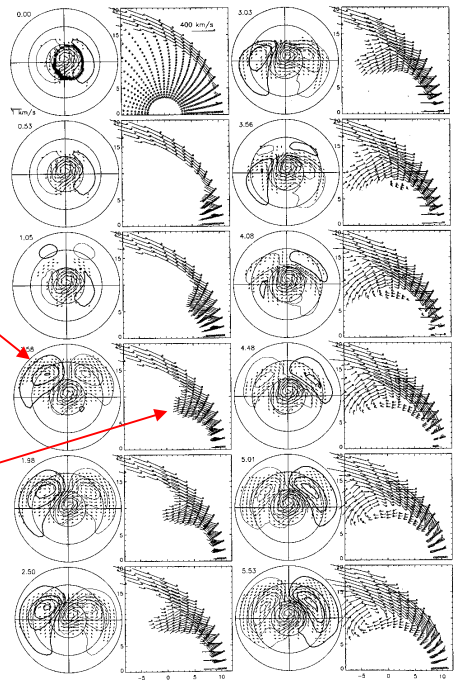


SC/SI Model (Araki, 1994)

- **SC/SI=DL+DP(PRI)+DP(MI)**
- DL:Chapman-Ferraro Currents
- DP(PRI):Ionospheric currents caused by dusk-to-dawn electric fields associated with field-aligned currents generated by the compression of the sub-solar magnetopause.
- DP(MI):Ionospheric currents caused by dawn-to-dusk electric fields associated with field-aligned currents generated by the enhanced magnetospheric convection.



MHD Simulation (Slinker et al., 1999)



FAC

Flow vector in the equatorial plane

Summary

- We have found clockwise and counter-clockwise plasma flow vortices in the morning and afternoon sectors respectively during PRIs of SC/SI.
- The vortices are located at 72-74 degs, 7 degs lower than the latitude of CRB. The appearance of the vortices deep inside the closed field lines may be due to dynamical processes rather than by reconnection.
- Dusk-to-dawn electric fields associated with the vortices propagate instantaneously to the global ionosphere as detected by an equatorial magnetometer.
- The vortices may be caused by FACs associated with transient Alfvén waves propagating from the dayside magnetosphere, agreeing with the PRI model by Tamao (1964) and simulation results by Slinker et al. (1999).