What controls the dayside reconnection rate?

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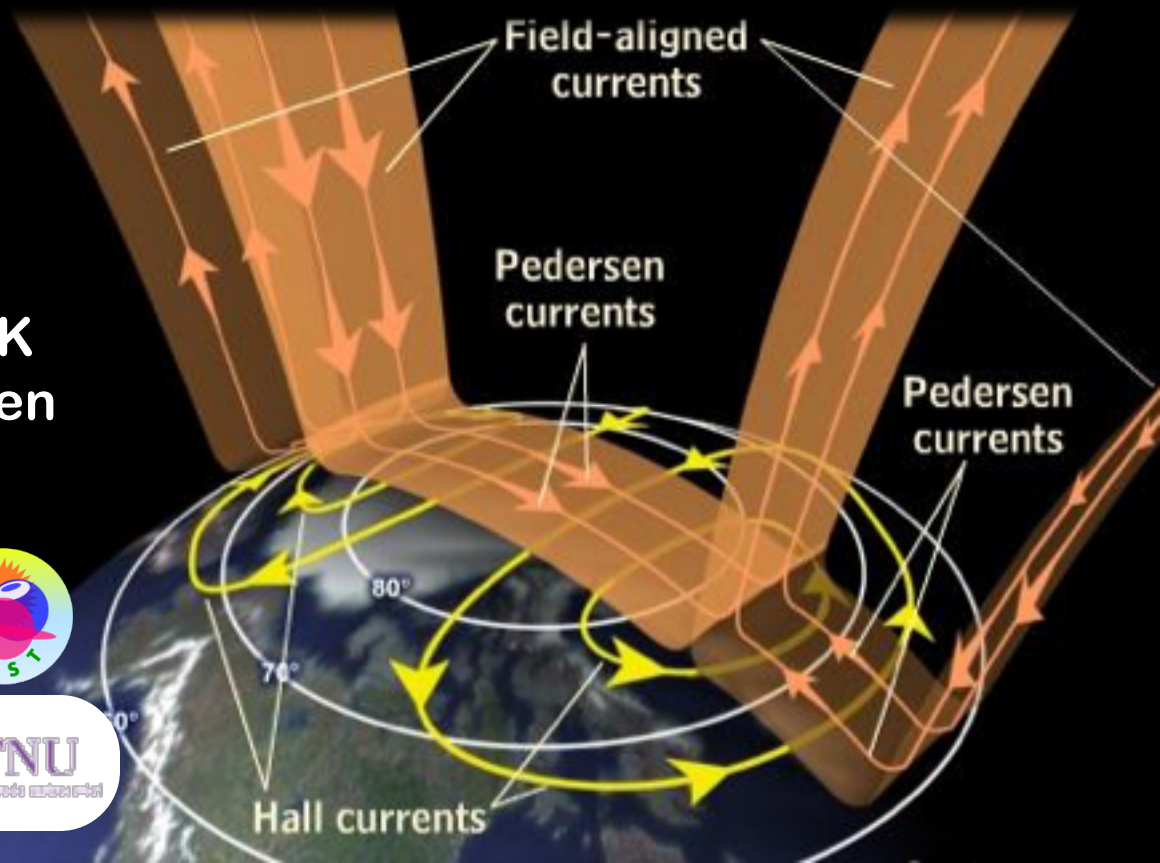

What is dayside reconnection?

How do we measure it?

Empirical coupling functions

Physics-based coupling functions

Temporal and spatial variability

Other complications

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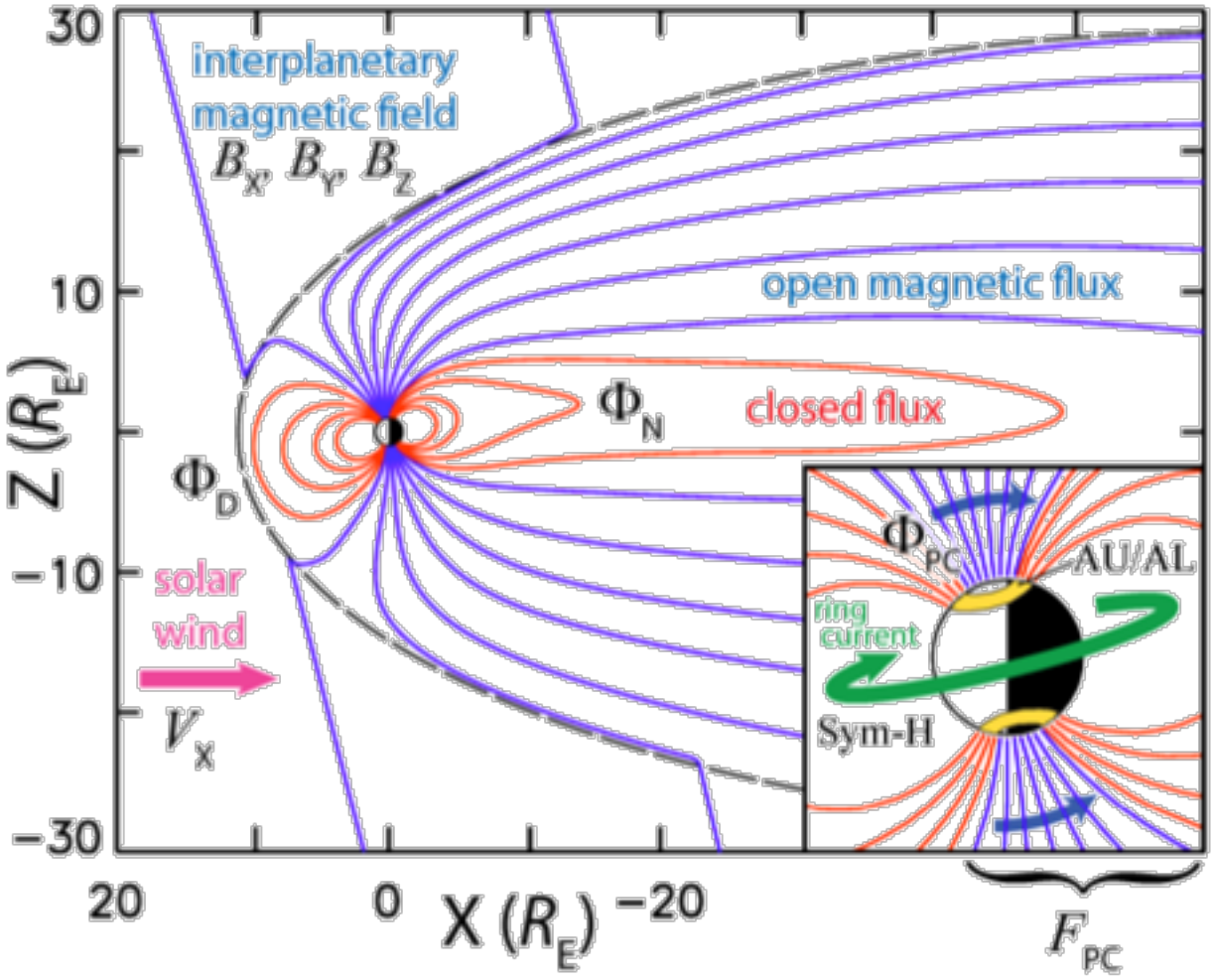
Φ_D – dayside reconnection rate (V)

F_{PC} – open magnetic flux (Wb)

Φ_N – nightside reconnection rate (V)

Φ_{PC} – transpolar voltage (V)



Milan et al. (2009)

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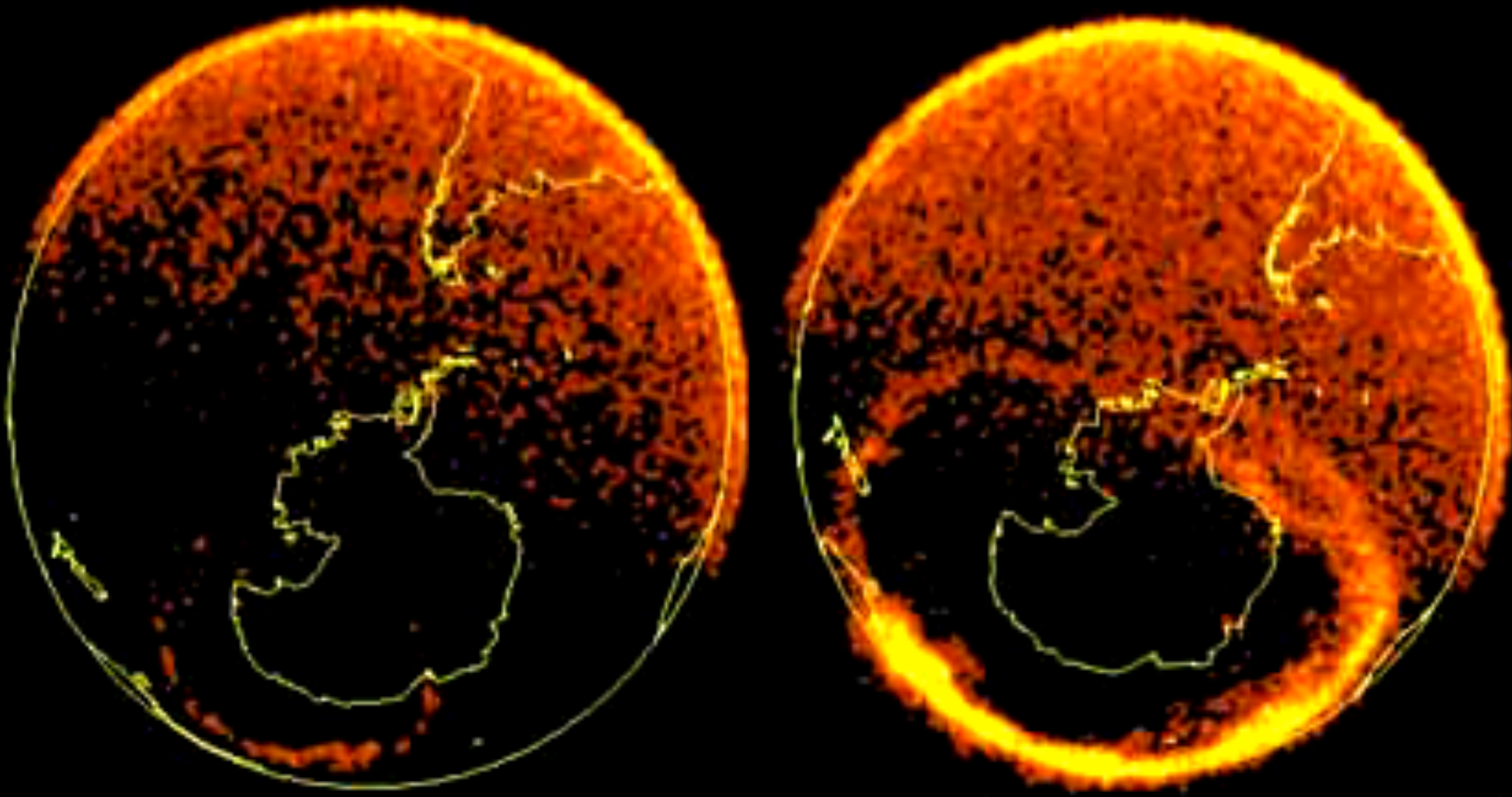
$F_{PC} \approx 0.2$ GWb (3%)

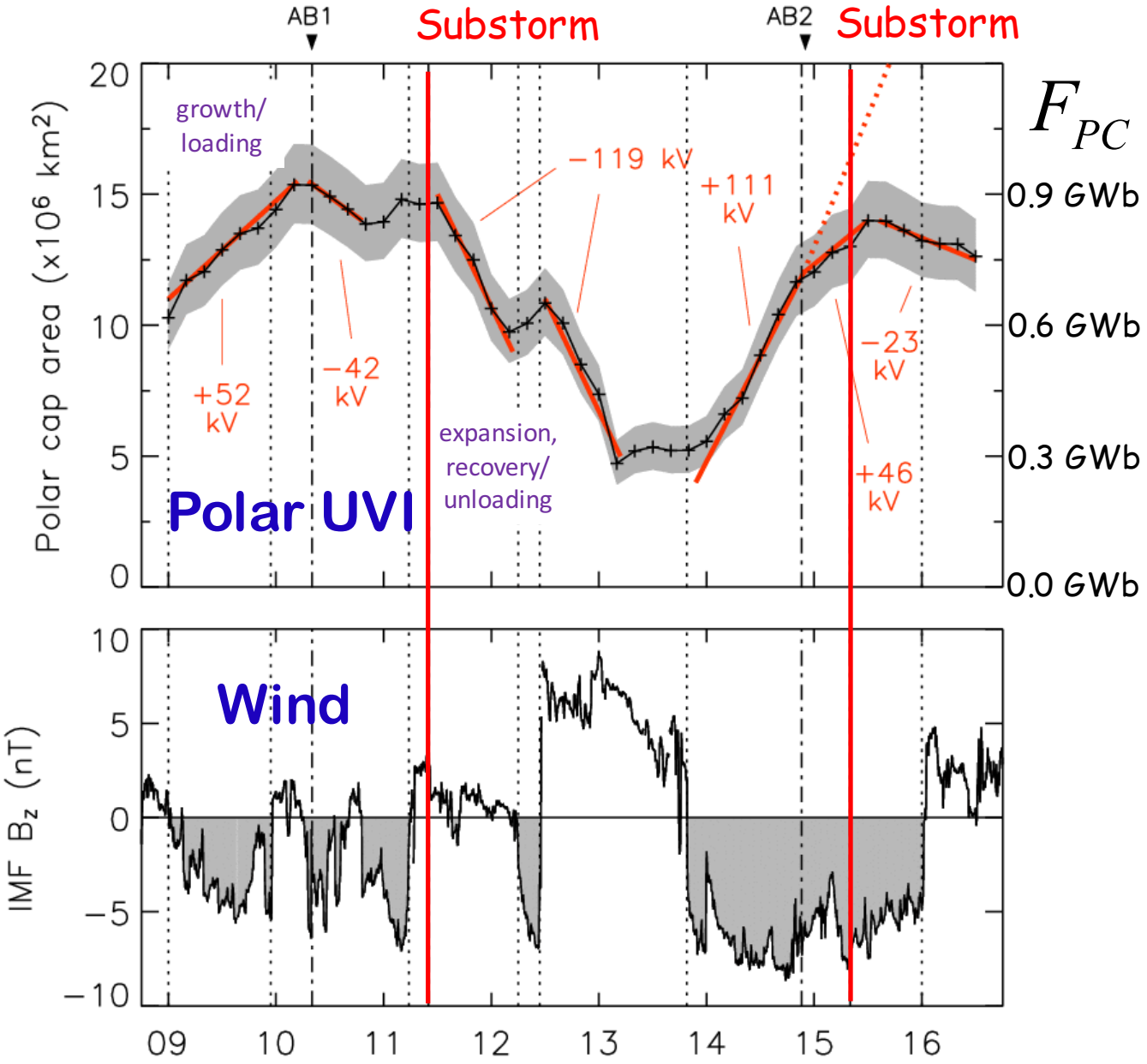
$F_{PC} \approx 1.2$ GWb (15%)



5 June 1998

Open flux

IMF B_Z



Milan et al. (2003)

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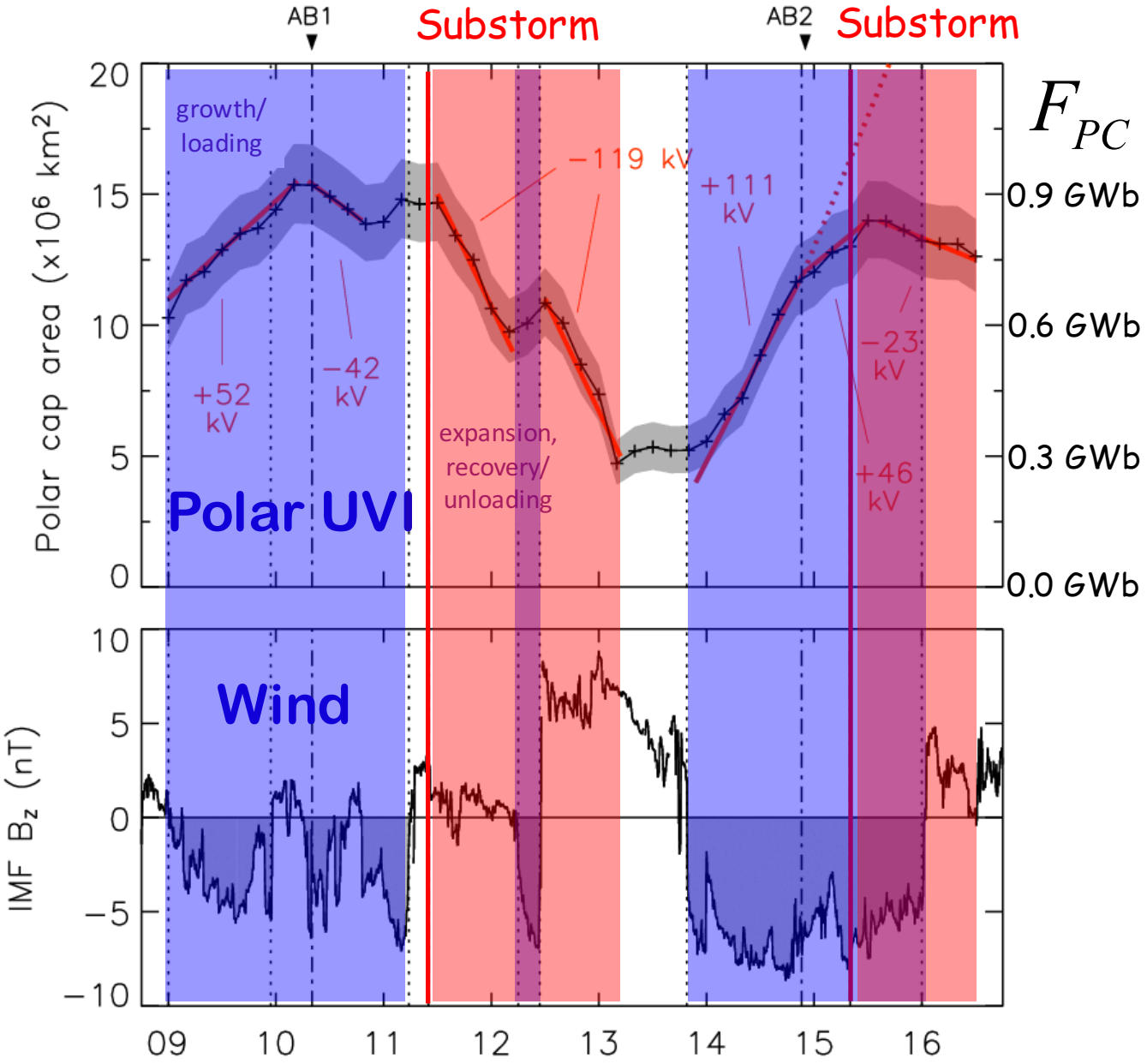
5 June 1998

Open flux

IMF B_Z



Milan et al. (2003)

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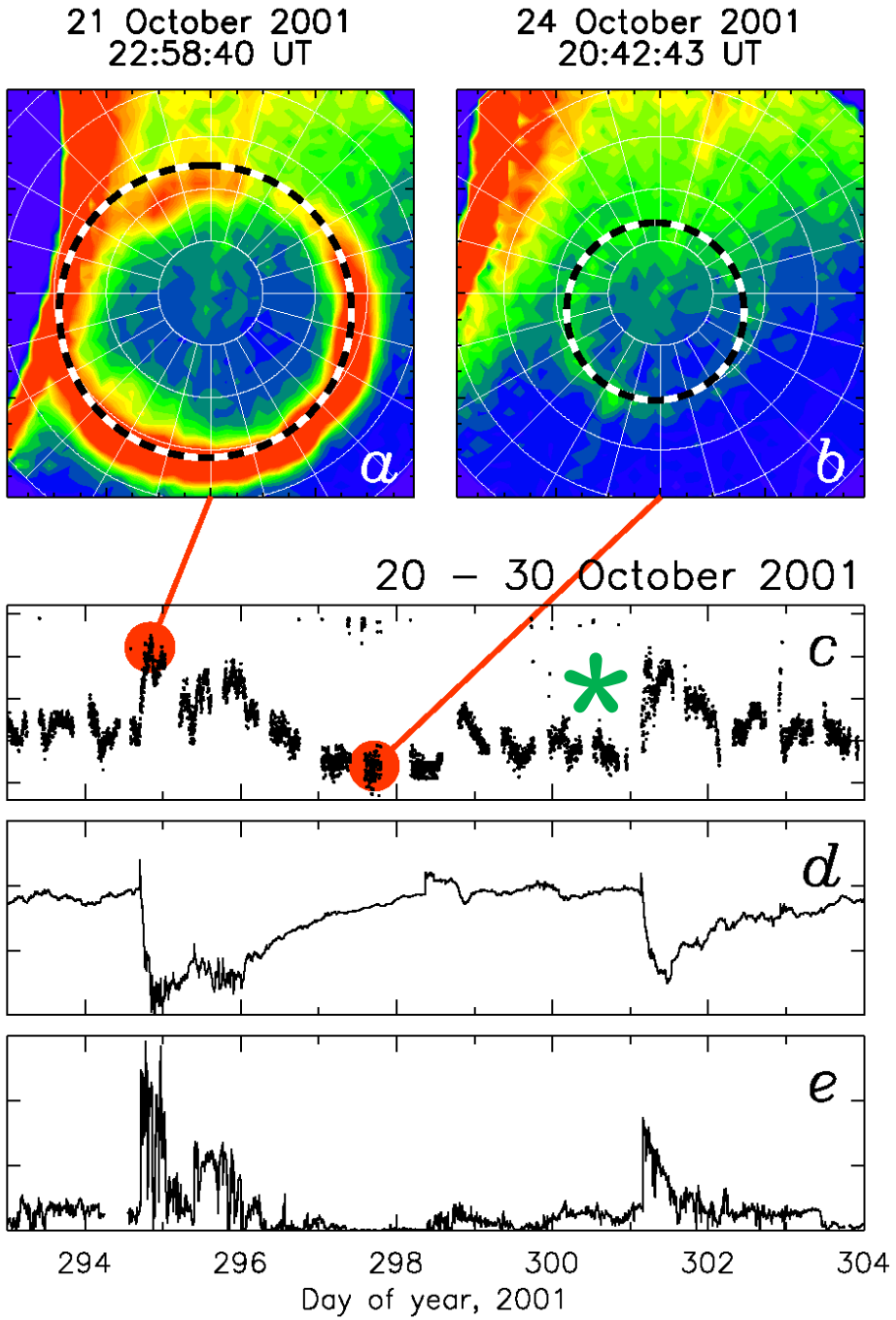
Ring current modulation of magnetospheric open flux content



Proxy for open flux content

Proxy for ring current intensity

* data gaps due to orbit of IMAGE

Milan (2009)

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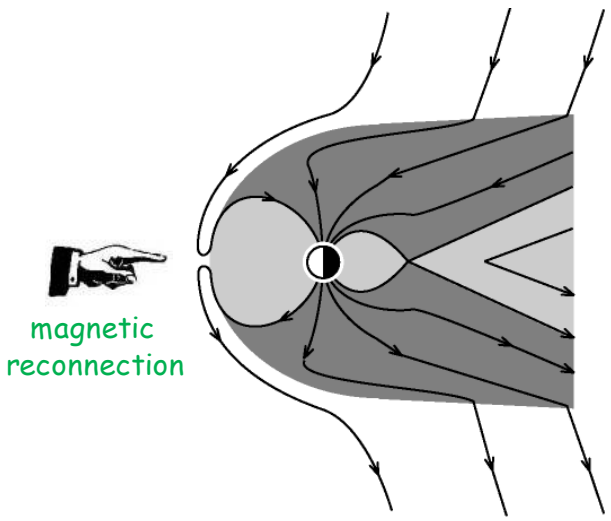
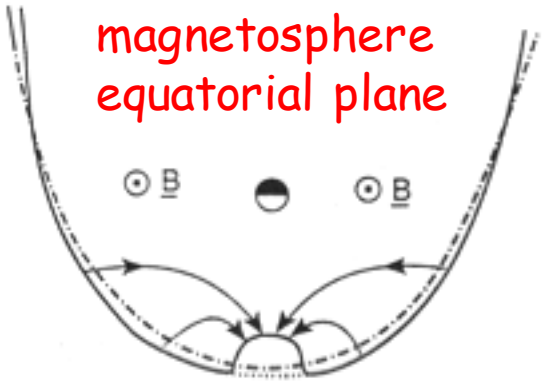
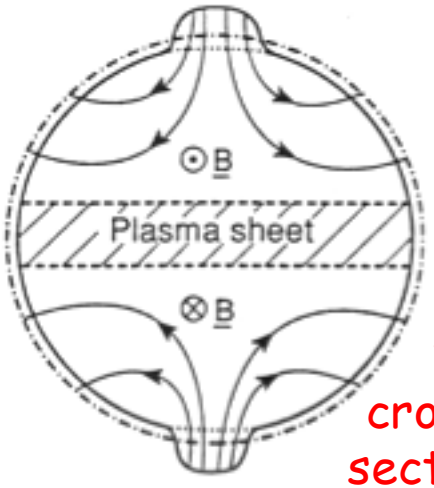
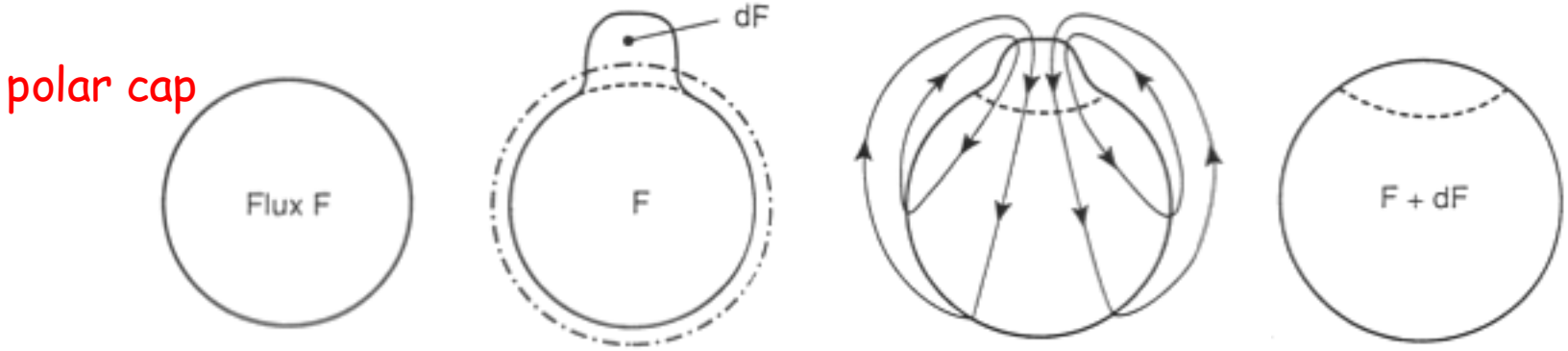
The response of the magnetosphere / ionosphere to a burst of low latitude magnetopause reconnection









after Cowley and Lockwood (1992)

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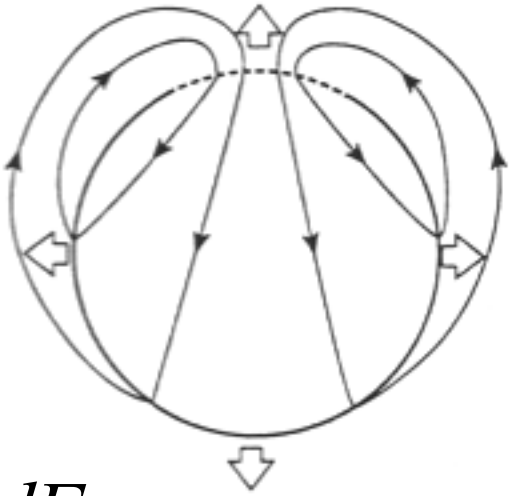
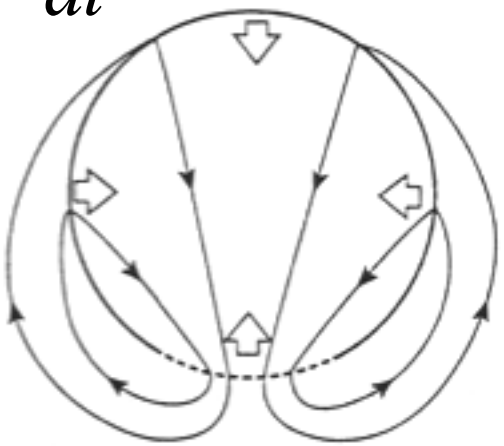
The expanding/contracting polar cap



$$\frac{dF_{PC}}{dt} = \Phi_D - \Phi_N$$



Faraday (1831)
Siscoe and Huang (1985)
Cowley and Lockwood (1992)

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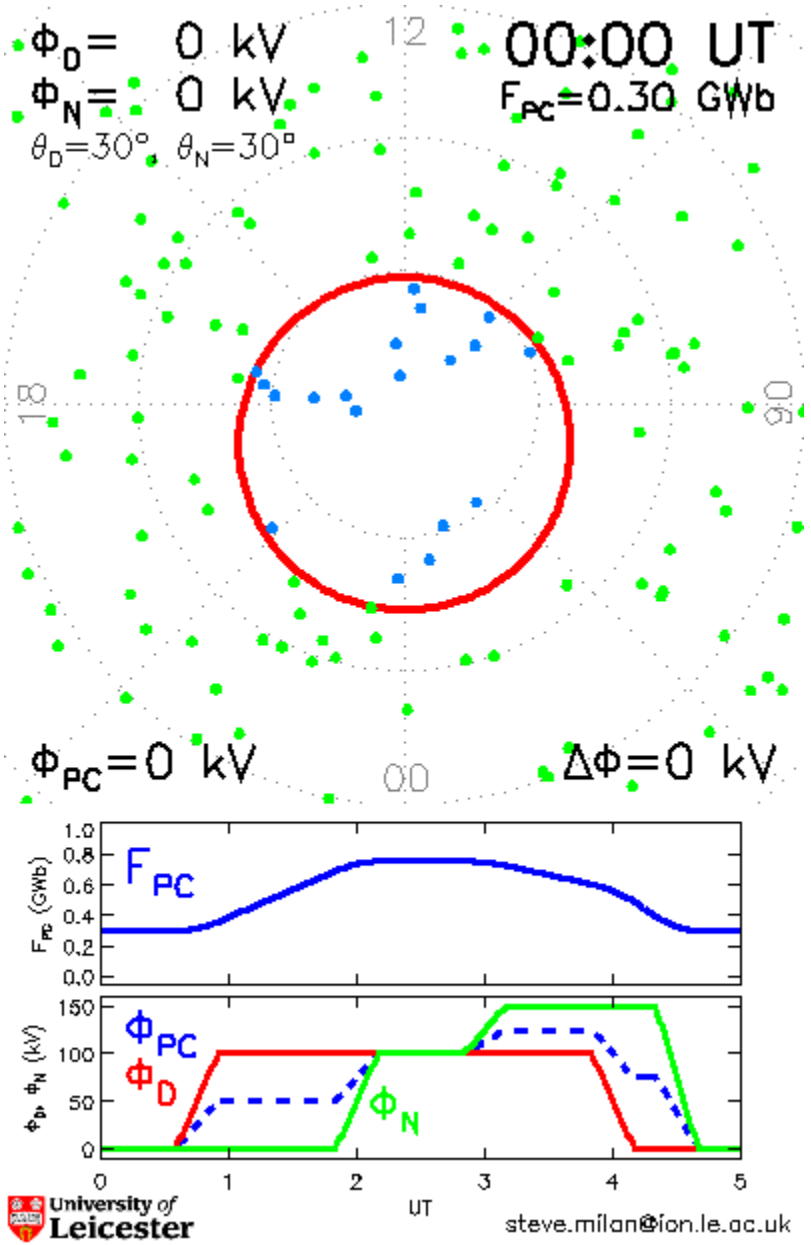
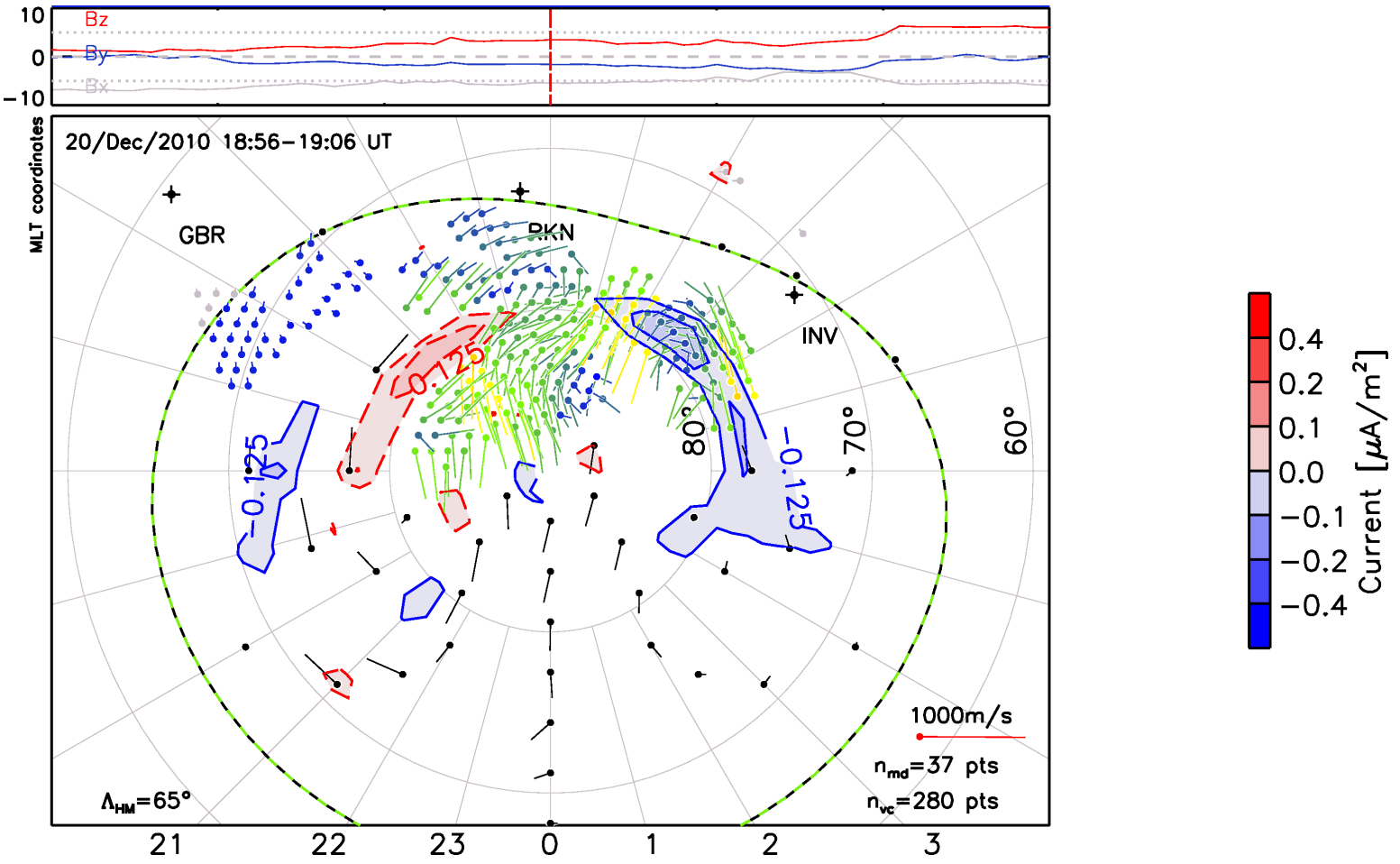


AMPERE and SuperDARN



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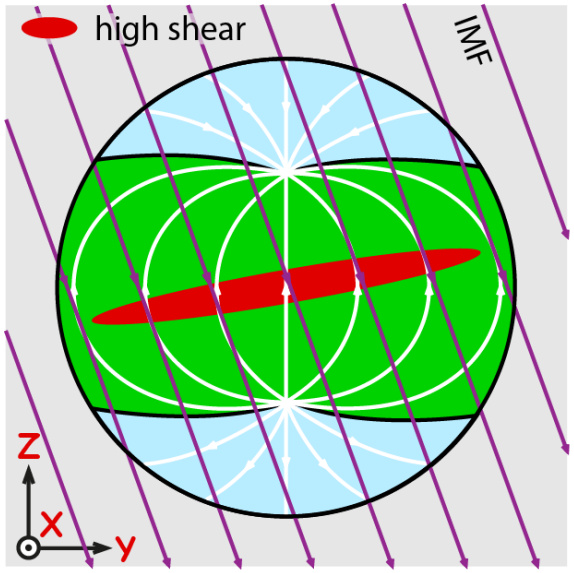
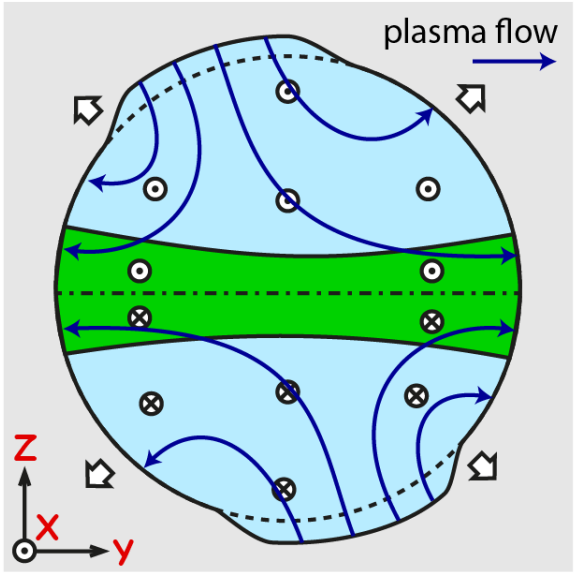
courtesy
Lasse Clausen

Influence of IMF B_Y

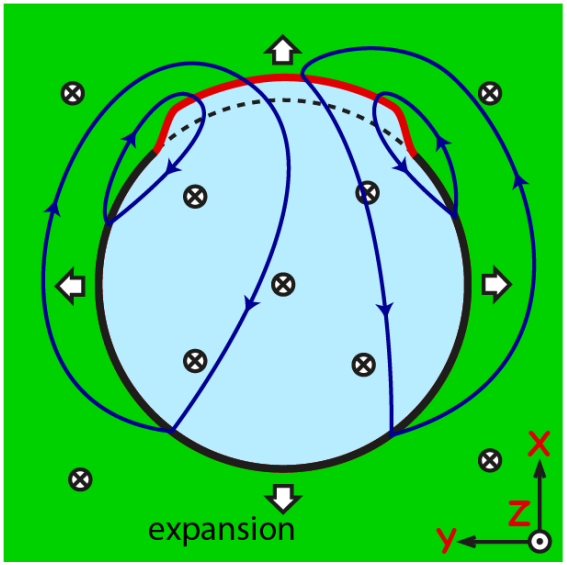
Dayside magnetopause



Magnetotail cross-section



Ionosphere



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The ECPC explains the relationship between open magnetic flux, reconnection voltages, and magnetic flux transport voltage

but

it does not specify what the reconnection voltages should be

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Anatomy of a coupling function

Poynting flux in solar wind

$$\varepsilon \approx \underbrace{L^2}_{\text{cross-sectional area of dayside magnetopause}} \overbrace{V_X B^2} \underbrace{\sin^4 \frac{\theta}{2}}_{\text{reconnection efficiency due to geometry}}$$

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Anatomy of a coupling function

solar wind electric field or
transport of magnetic flux

$$\Phi_D = L_{eff}\, V_X B_{YZ}\, \sin^2\frac{\theta}{2}$$

width of channel in
solar wind that
impacts magnetopause

reconnection efficiency
due to geometry

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Anatomy of a coupling function

$$\frac{d\Phi_{MP}}{dt} = V_X^{4/3} \; B_{YZ}^{2/3} \; \sin^{8/3}\frac{\theta}{2}$$

Newell et al. (2007)

Determined by cross-correlation
with (averaged) geomagnetic indices

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Event selection

- interval of $B_Z > 0$ nT
- southward turning, $B_Z < 0$ nT
- growth phase with no nightside activity
- end at substorm onset

Identified 26 intervals

$$\Phi_D = \frac{dF_{PC}}{dt}$$

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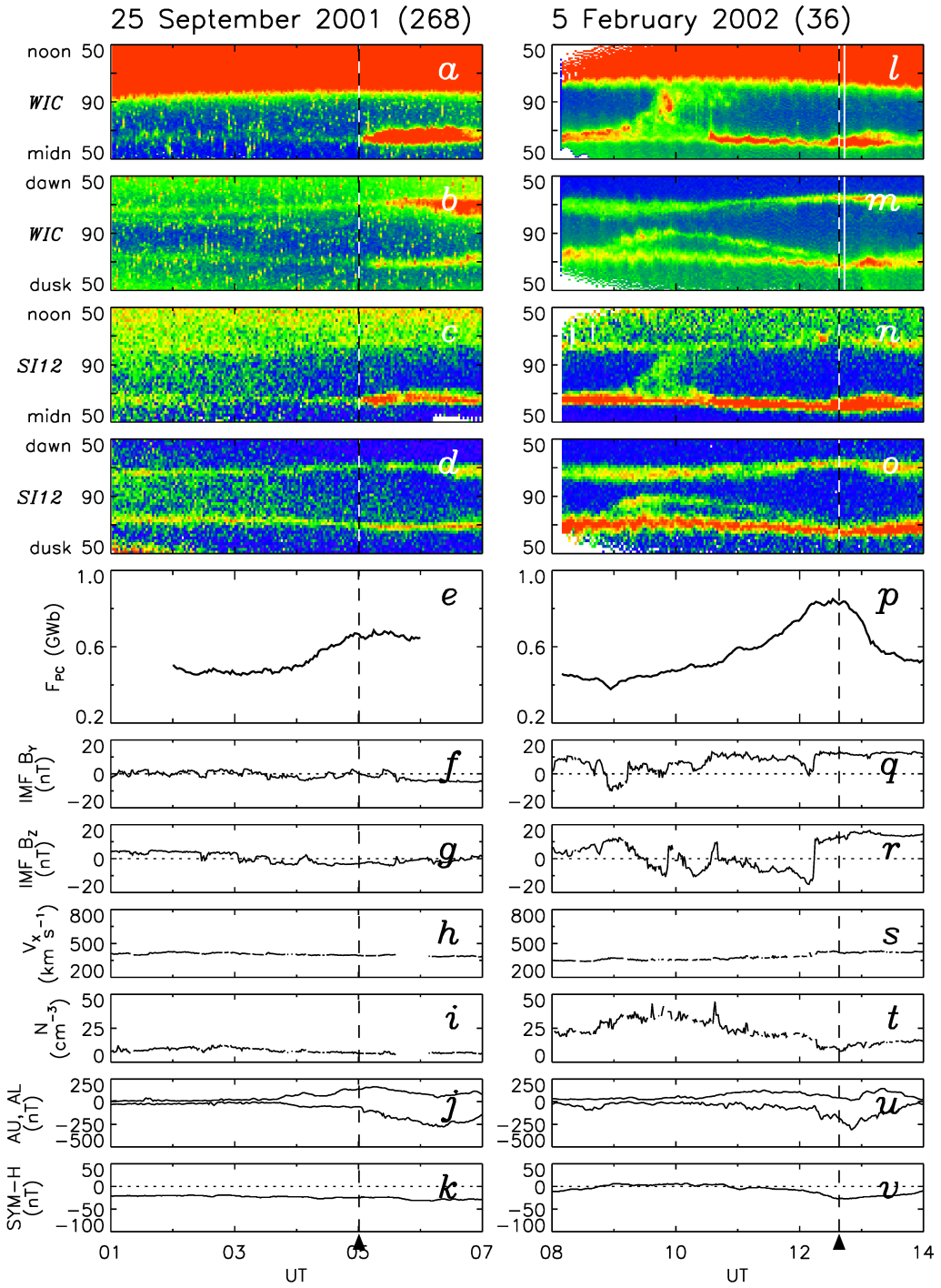

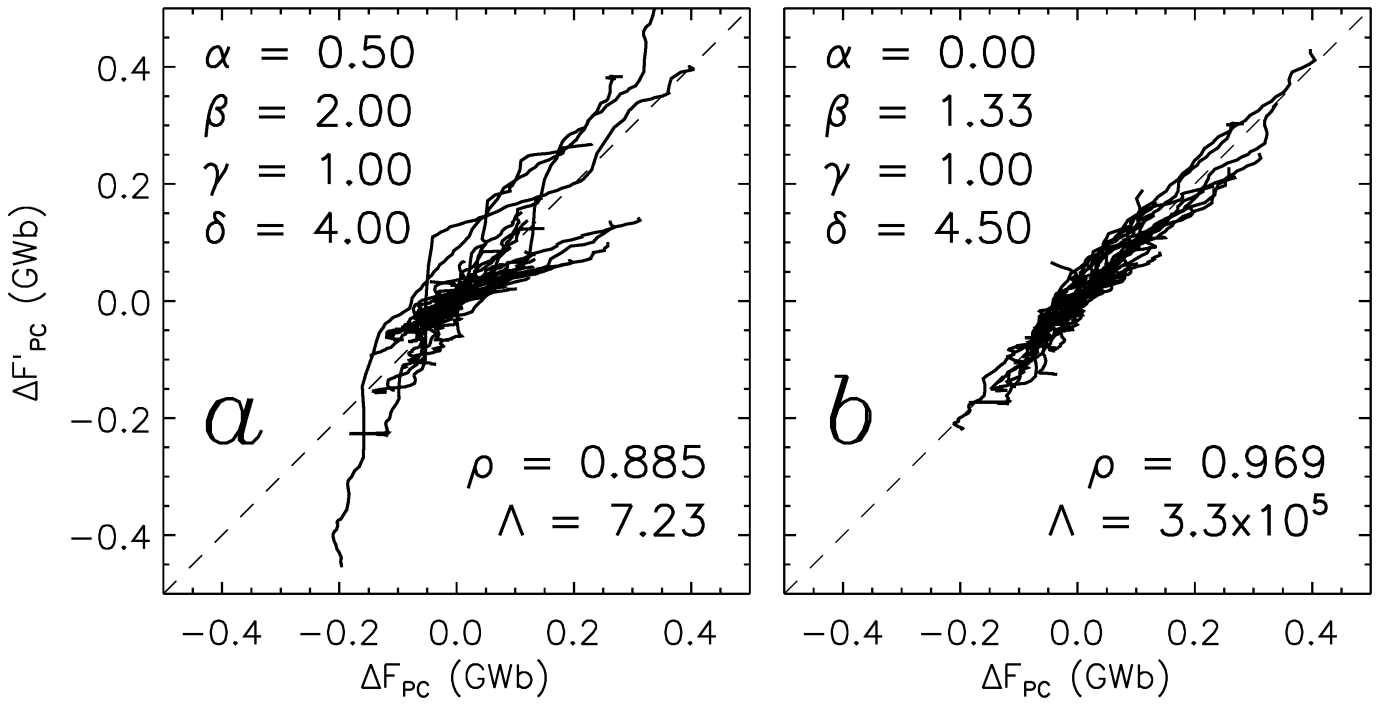

$$\Phi_D = \Lambda N^{\alpha} V_X^{\beta} B_{YZ}^{\gamma} \sin^{\delta} \frac{1}{2}\theta$$

$$F'_{PC}(t) = \int_{t_1}^{t_2} \Phi_D(\alpha, \beta, \gamma, \delta; t)\, dt$$

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26 substorm growth phases

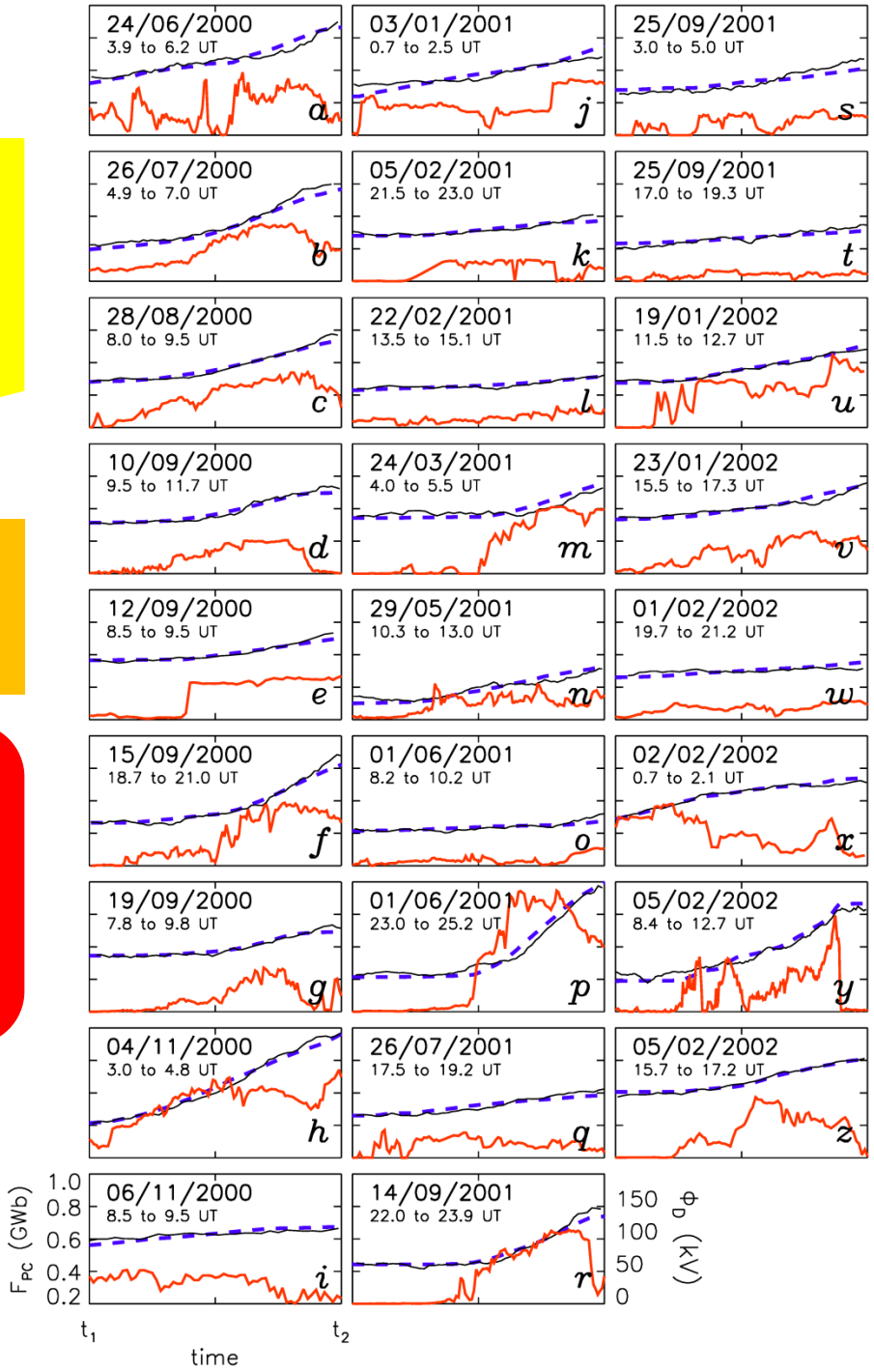
Solar wind control of dayside reconnection rate

$$\Phi_D = \Lambda V_X^{4/3} B_{YZ} \sin^{9/2} \tfrac{1}{2}\theta$$

$$\Phi_D = L_{eff}\, V_X B_{YZ} \sin^{9/2} \tfrac{1}{2}\theta$$

$$L_{eff} \propto V_X^{1/3}$$

No dependence on N; efficiency dependent on V_X



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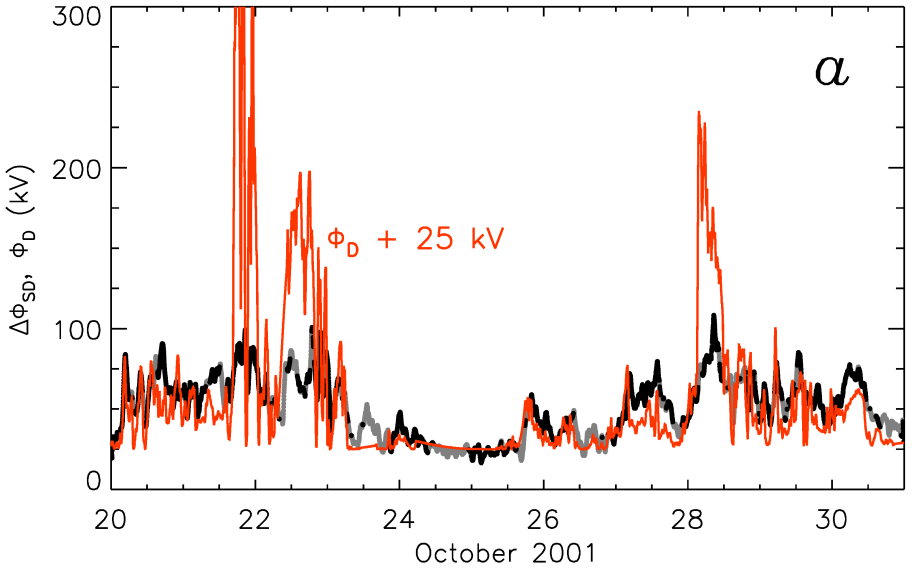
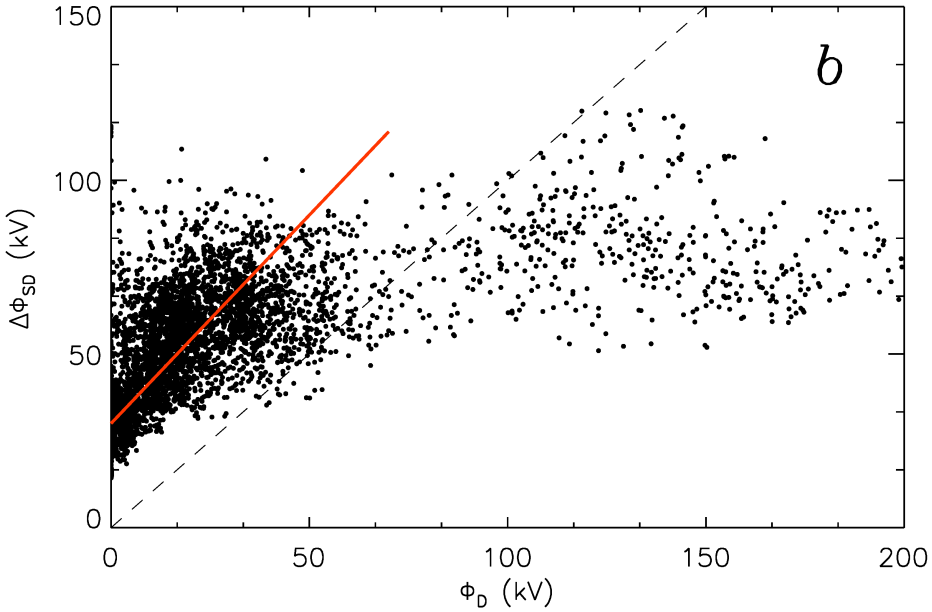
Milan et al. (2012)

Comparison with SuperDARN

During non-storm intervals we find a good comparison with SuperDARN measurements of $\Delta\Phi$, with a coefficient of proportionality of 1.4 and an offset of 25 kV





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Physics-based coupling functions

The solar wind electric field does not control the dayside reconnection rate *Borovksy (2014)*

Dayside reconnection rate is determined by conditions local to the magnetopause which depend on the condition of the magnetosheath, which in turn is a complicated and spatially-varying function of solar wind parameters

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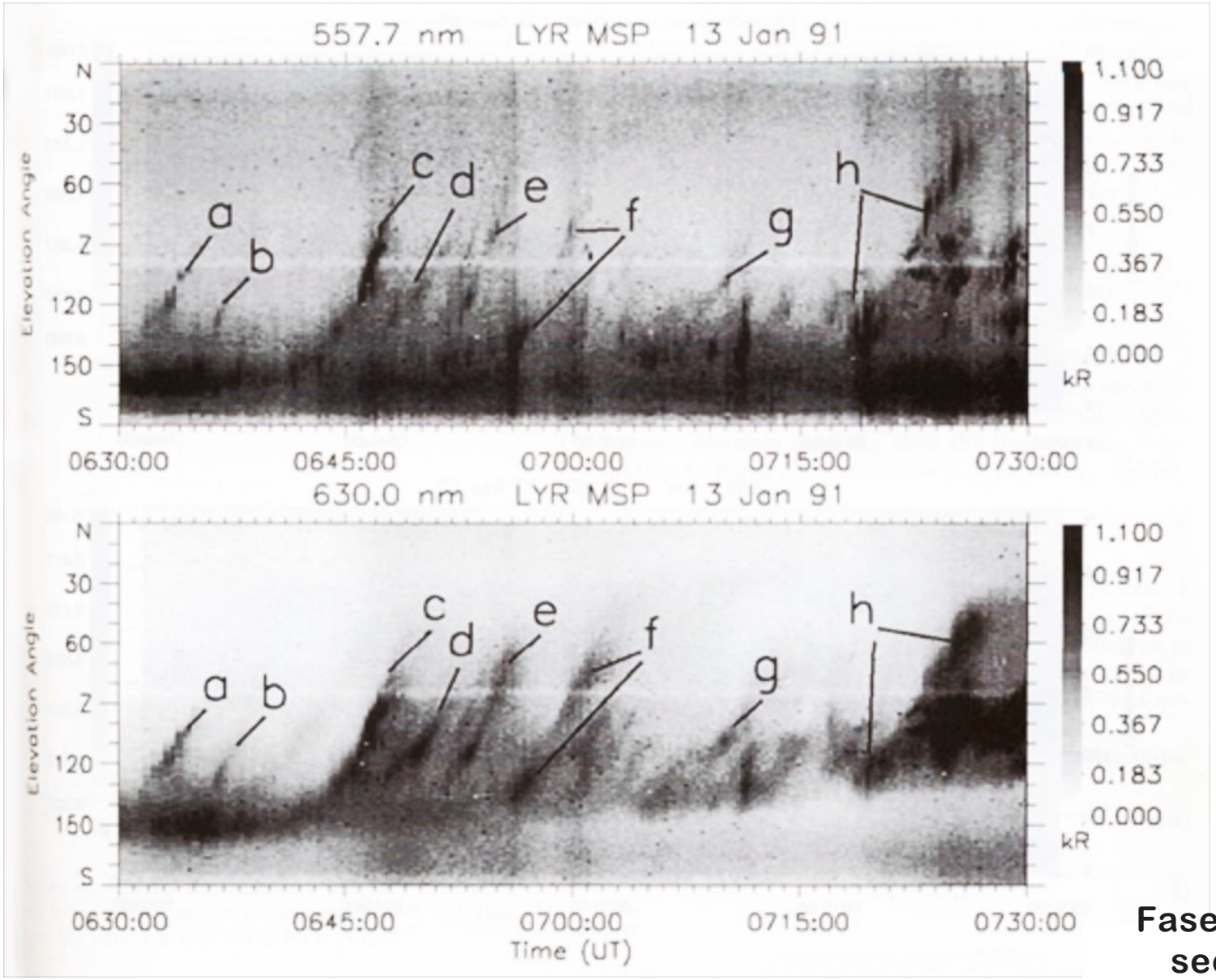
Episodic reconnection – flux transfer events



Fasel (1995)
see also
Sandholt, Moen

Flux transfer events

Poleward-moving auroral forms (PMAFs) have radar flow (PIFs) and backscatter (PMRAFs) counterparts

SuperDARN:

Pulsed ionospheric flows (PIFs)

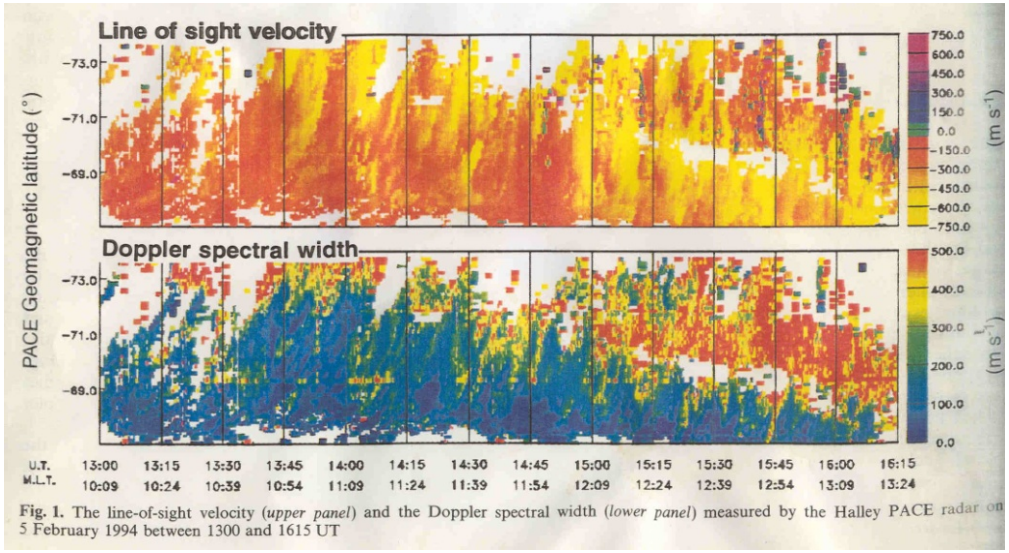
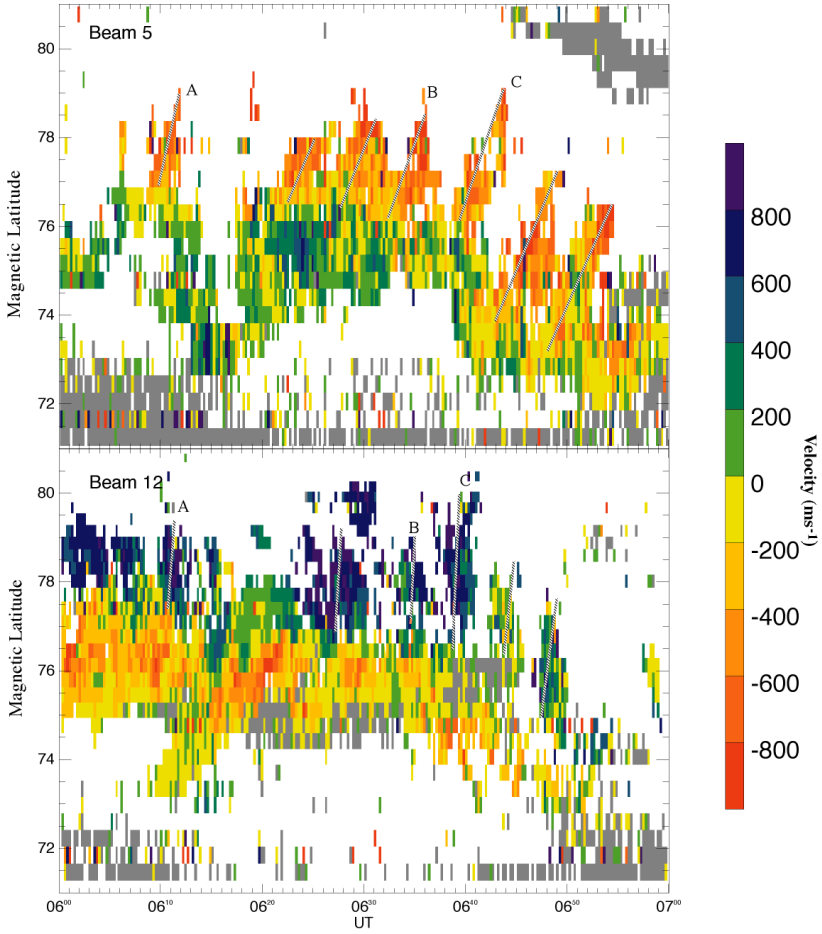


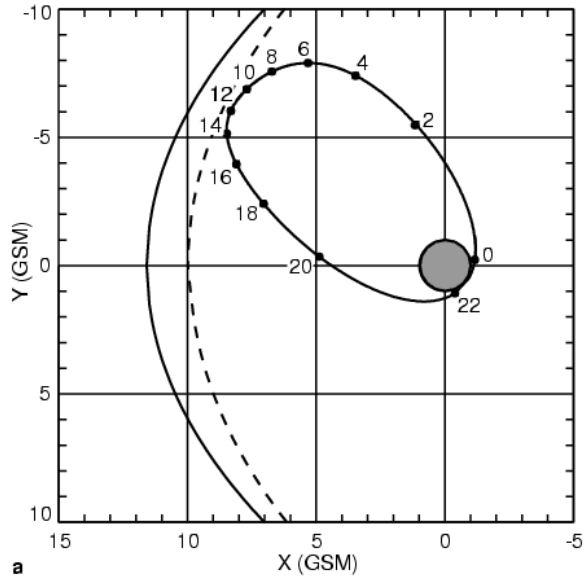
Fig. 1. The line-of-sight velocity (*upper panel*) and the Doppler spectral width (*lower panel*) measured by the Halley PACE radar on 5 February 1994 between 1300 and 1615 UT

Pinnock et al. (1995)

Poleward-moving radar auroral forms (PMRAFs)



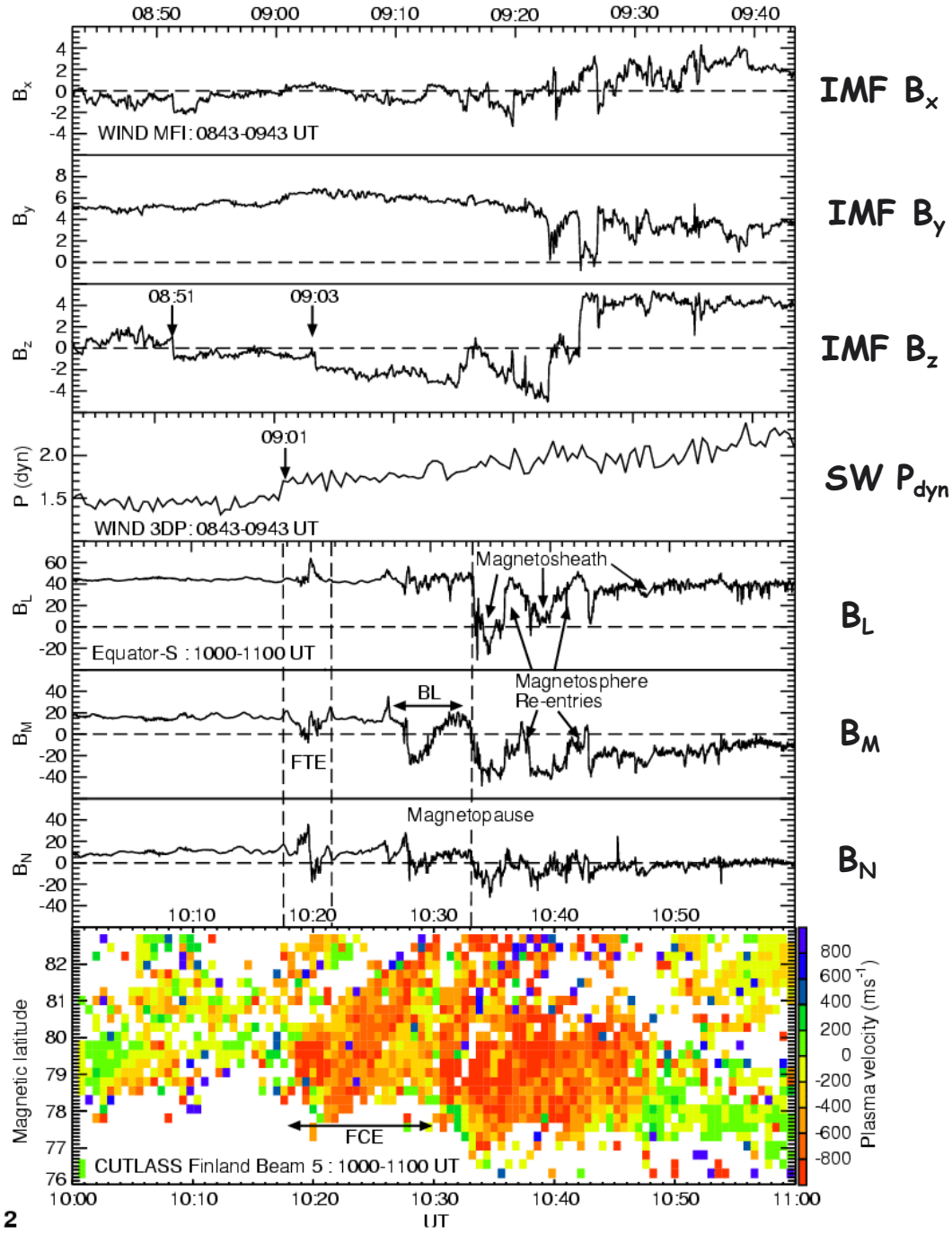
Provan et al. (1998)

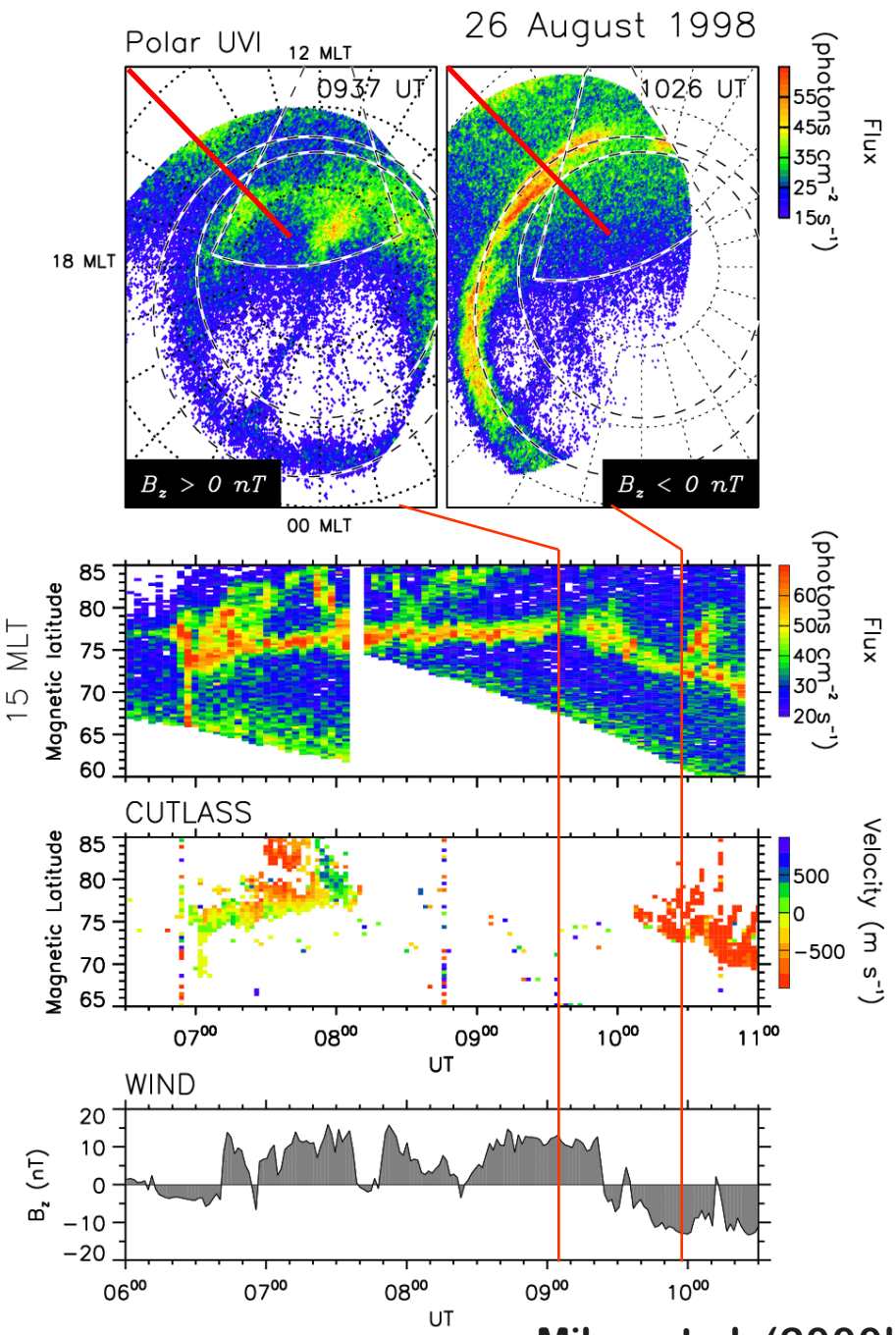


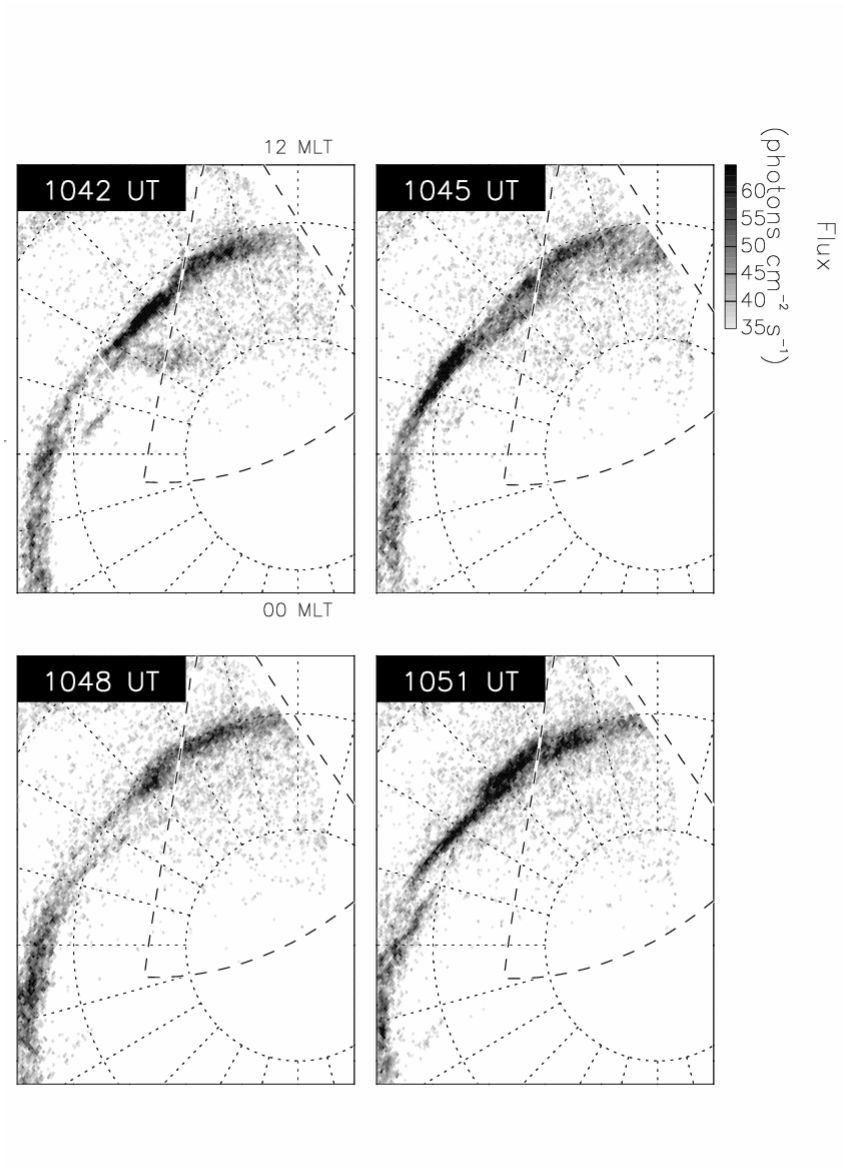
Flux transfer events

An association has been found between magnetopause FTEs and radar PIFs and PMRAFs

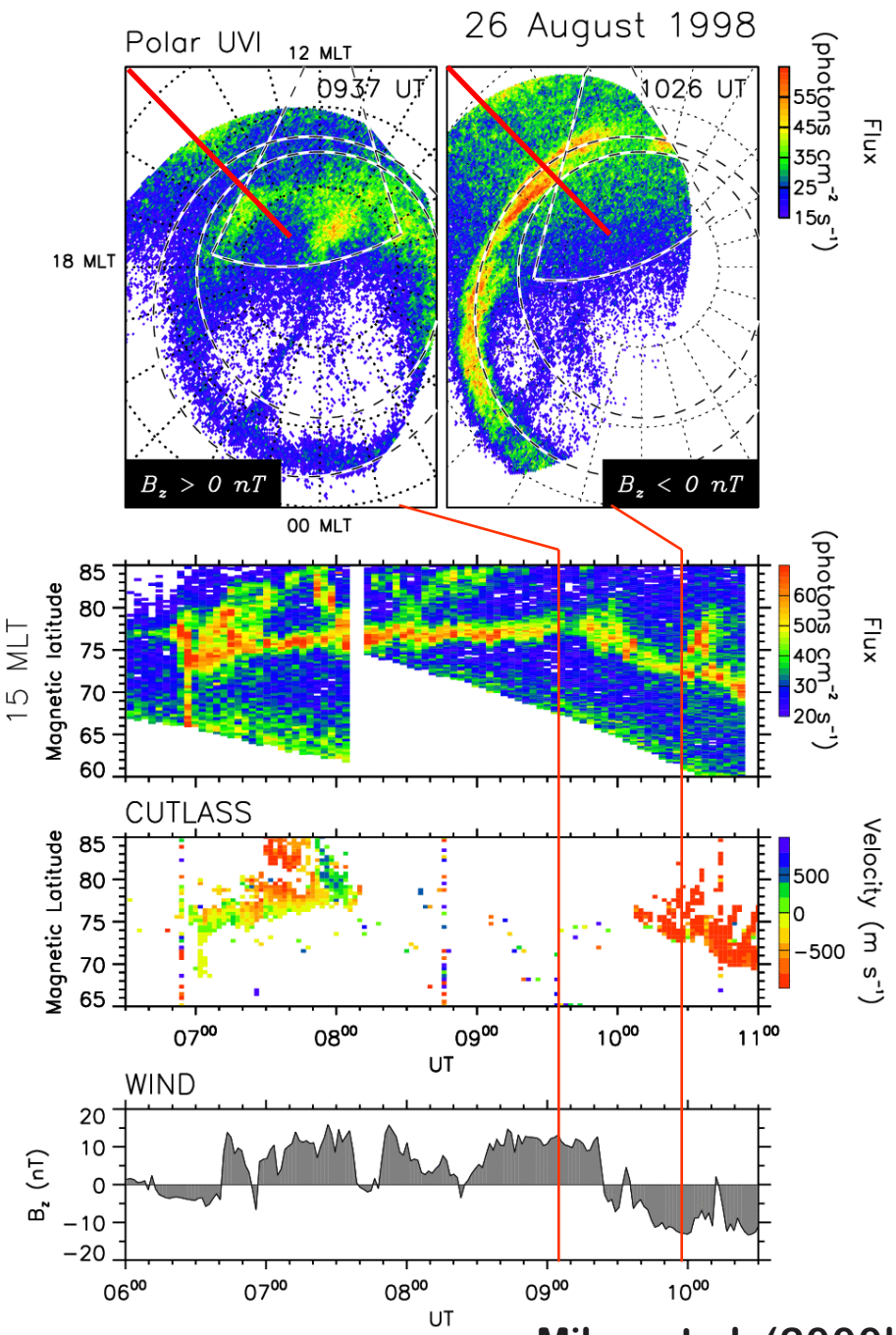
Neudegg et al. (1999)

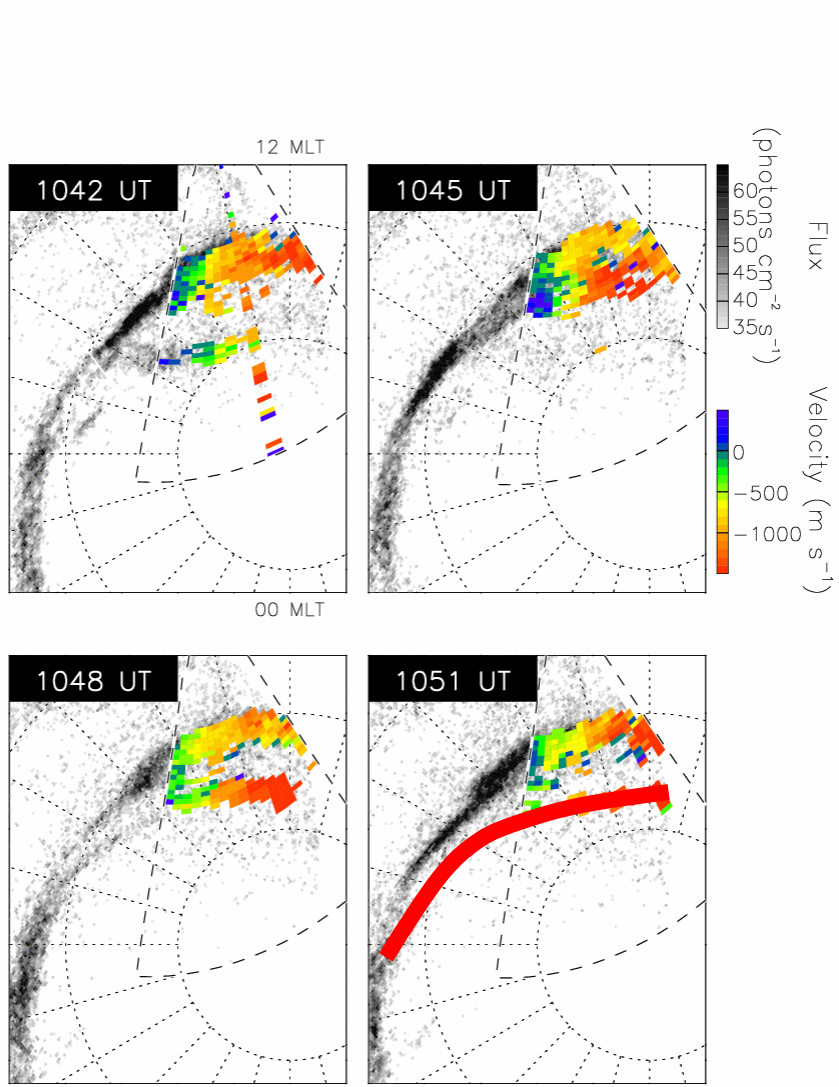




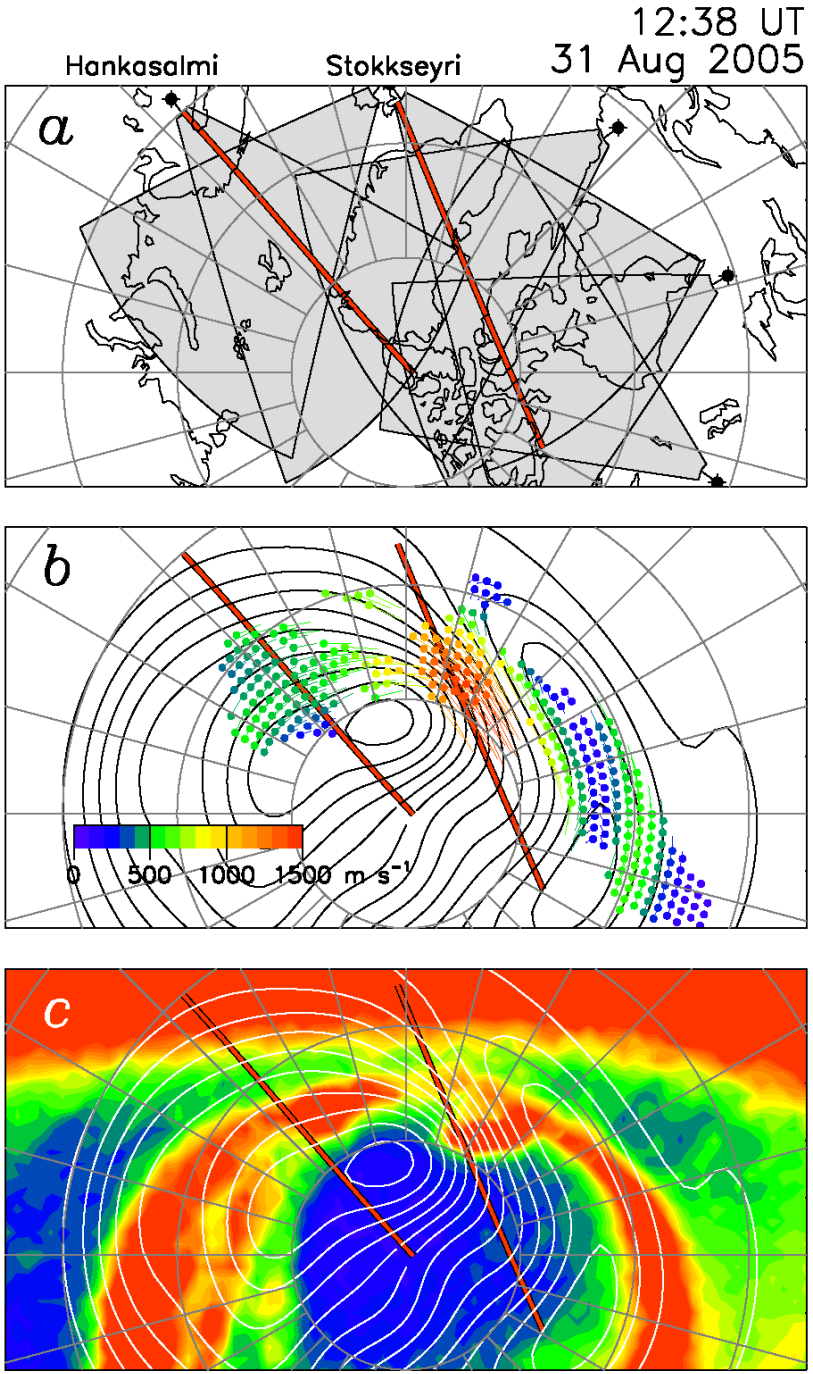


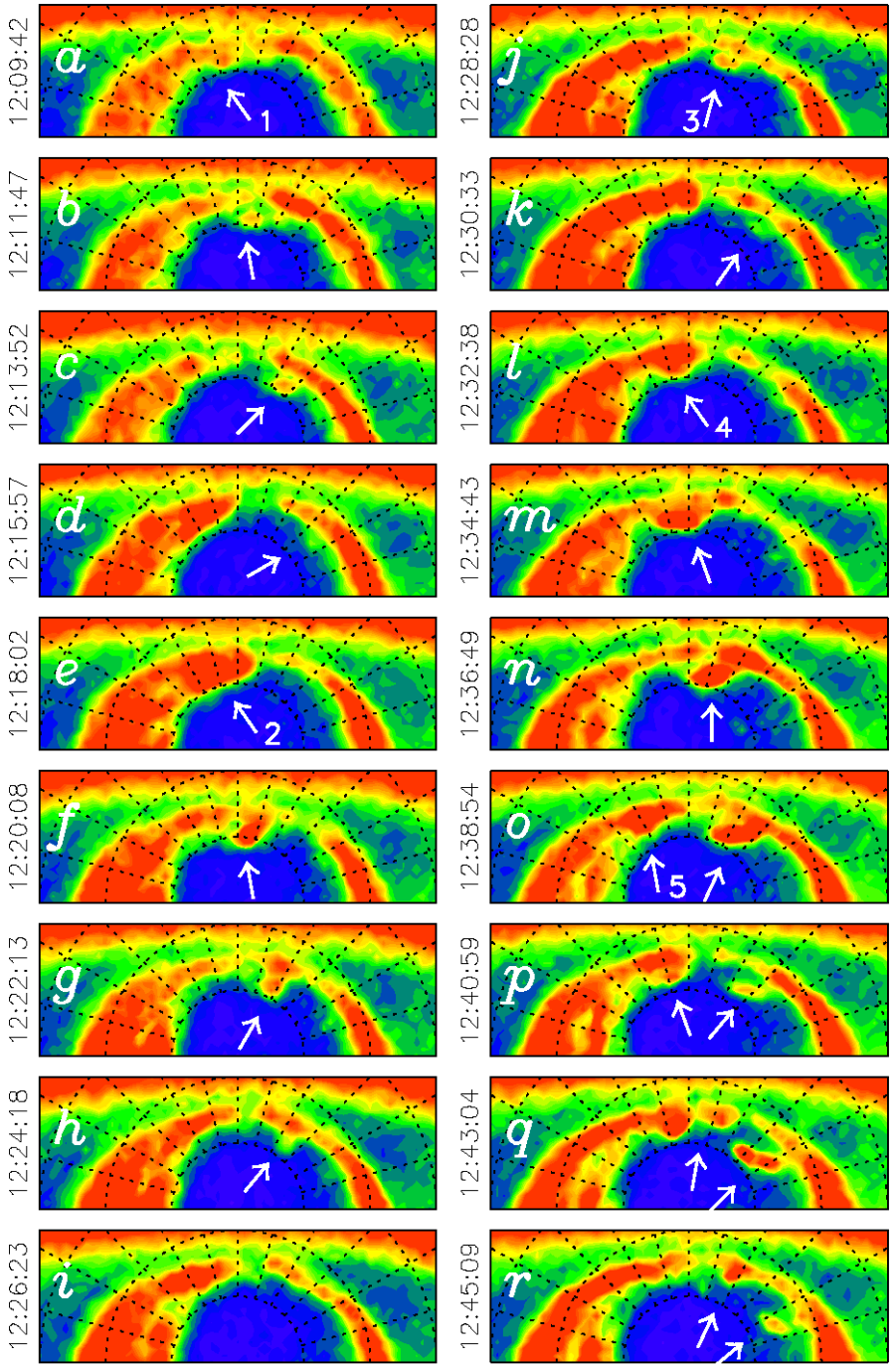
Milan et al. (2000b)





Milan et al. (2000b)


12:38 UT
31 Aug 2005
Hankasalmi
Stokkseyri
a
b
0 500 1000 1500 m s-1
c


12:09:42
a
1
12:11:47
b
12:13:52
c
12:15:57
d
12:18:02
e
2
12:20:08
f
12:22:13
g
12:24:18
h
12:26:23
i
12:28:28
j
3
12:30:33
k
12:32:38
l
4
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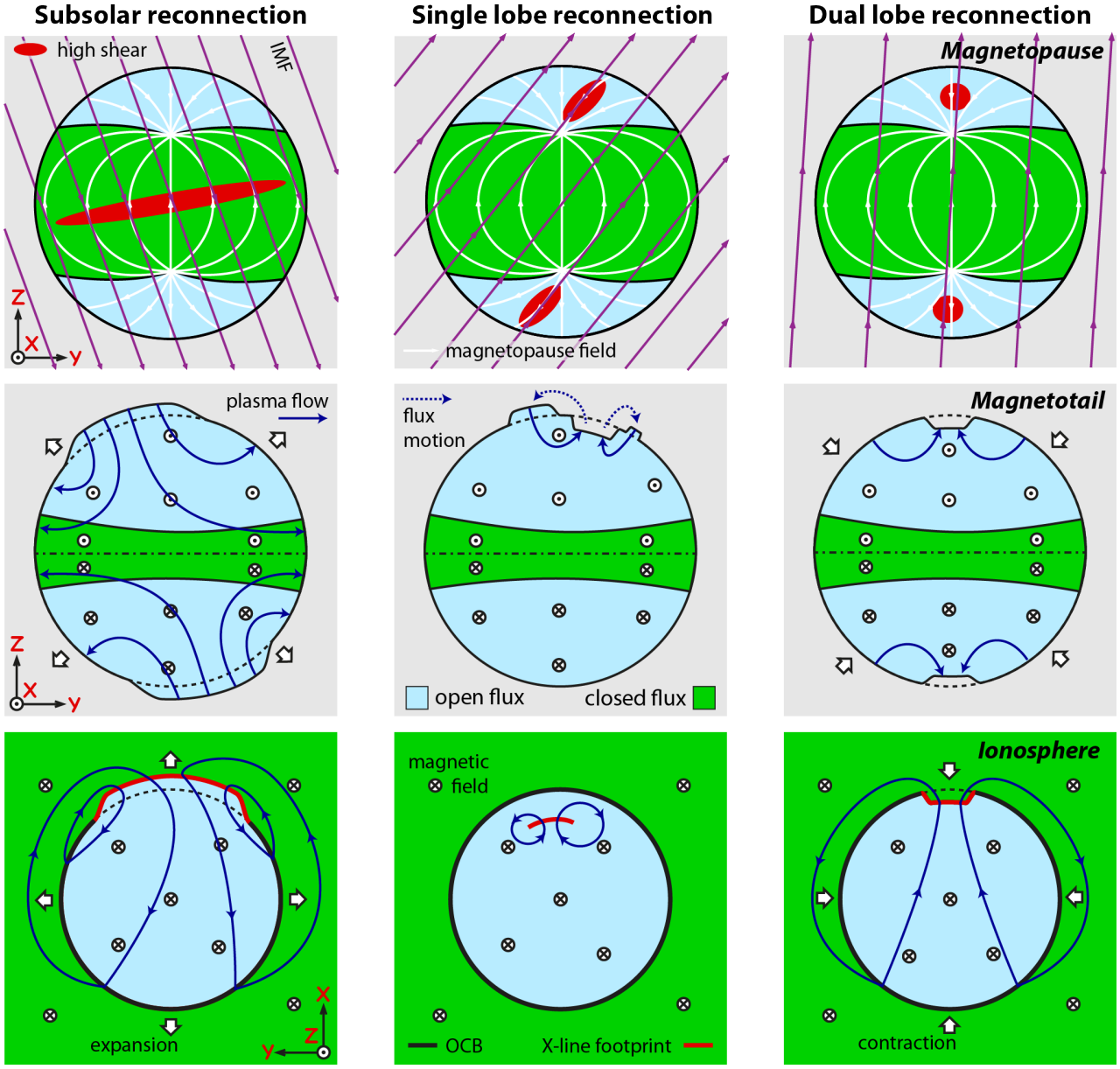
12:40:59
p
12:43:04
q
12:45:09
r



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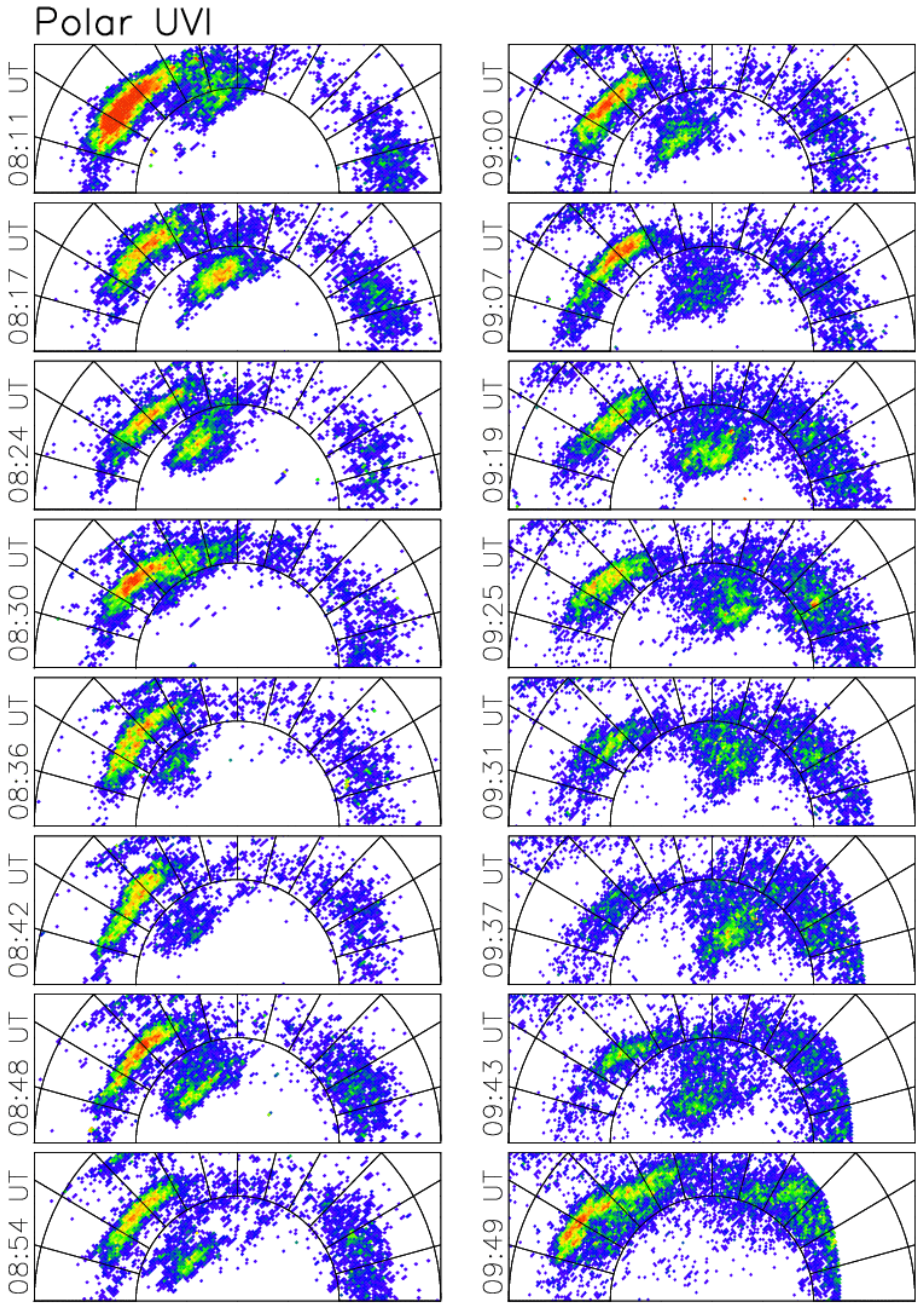
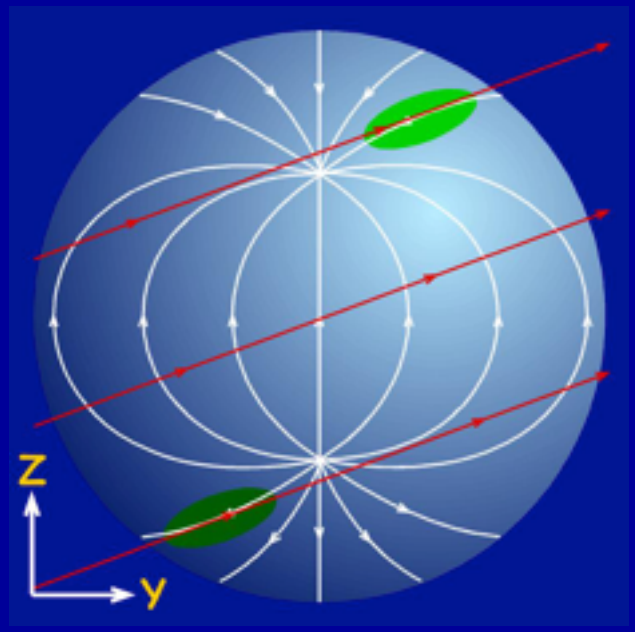
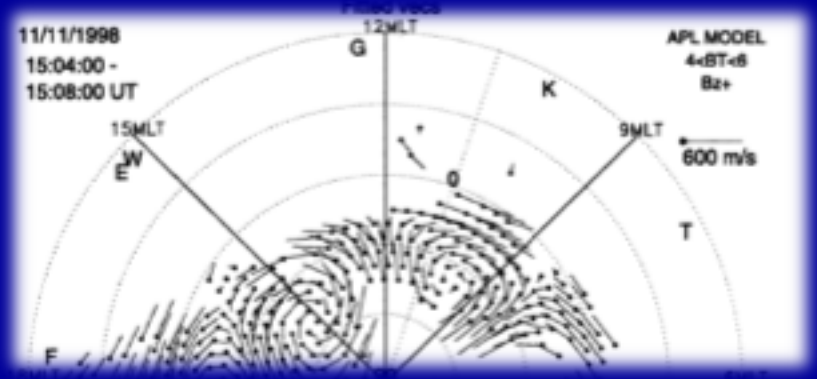


Milan et al. (2000a); Chisham et al. (2004)

A "cusp spot" forms when the IMF is directed northwards





Questions

- Why can we predict the reconnection rate from upstream parameters?
- How does the magnetosheath organise itself to process the solar wind?
- What is the local time distribution of reconnection?
- Why is reconnection patchy and bursty?
- Why does the patchiness and burstiness display a range of scales?
- How do we reconcile magnetopause and ionospheric signatures of FTEs?
- What role does mass-loading from the magnetosphere play?

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