Current system and electric field associated with dipolarization front

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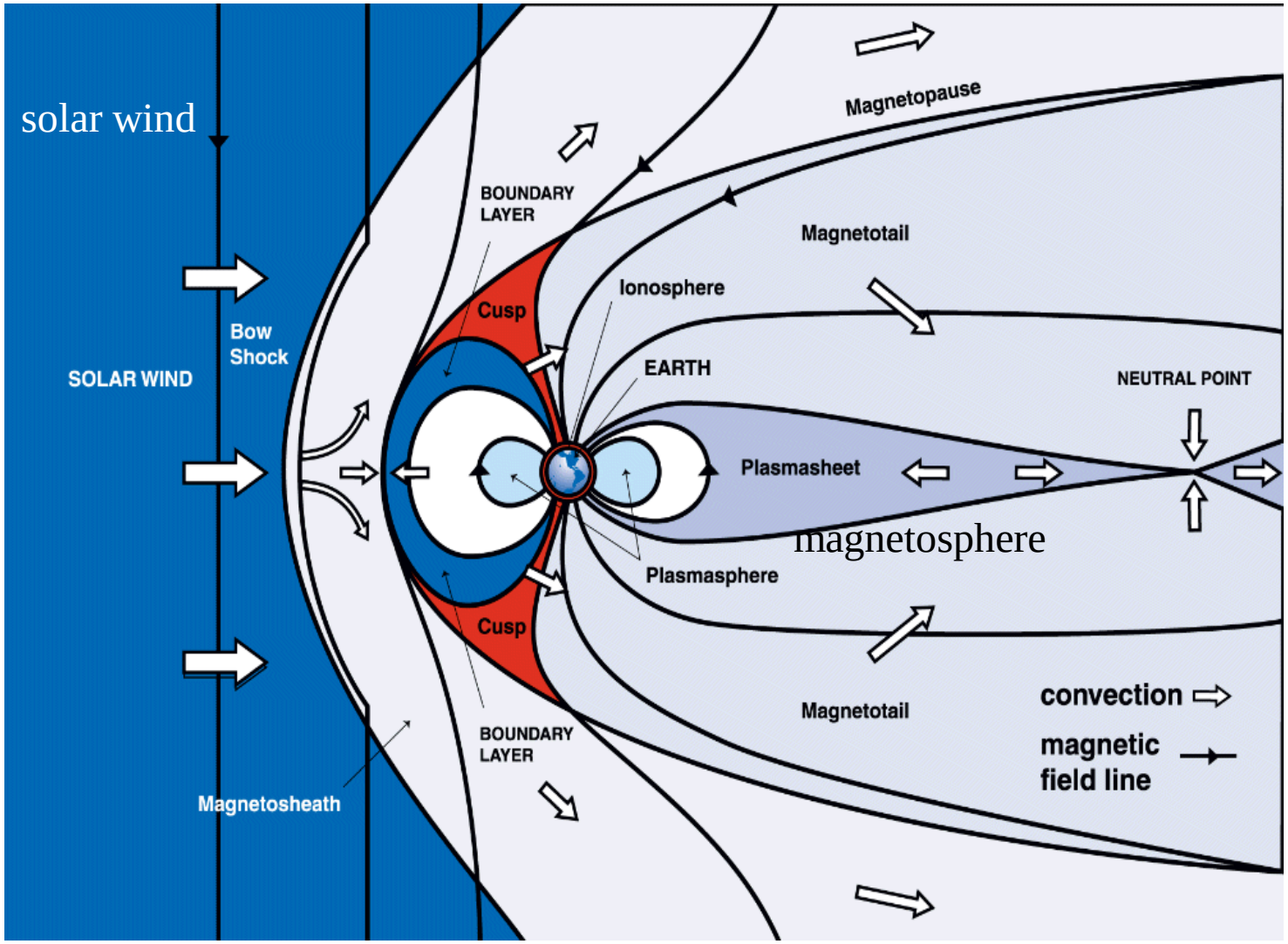
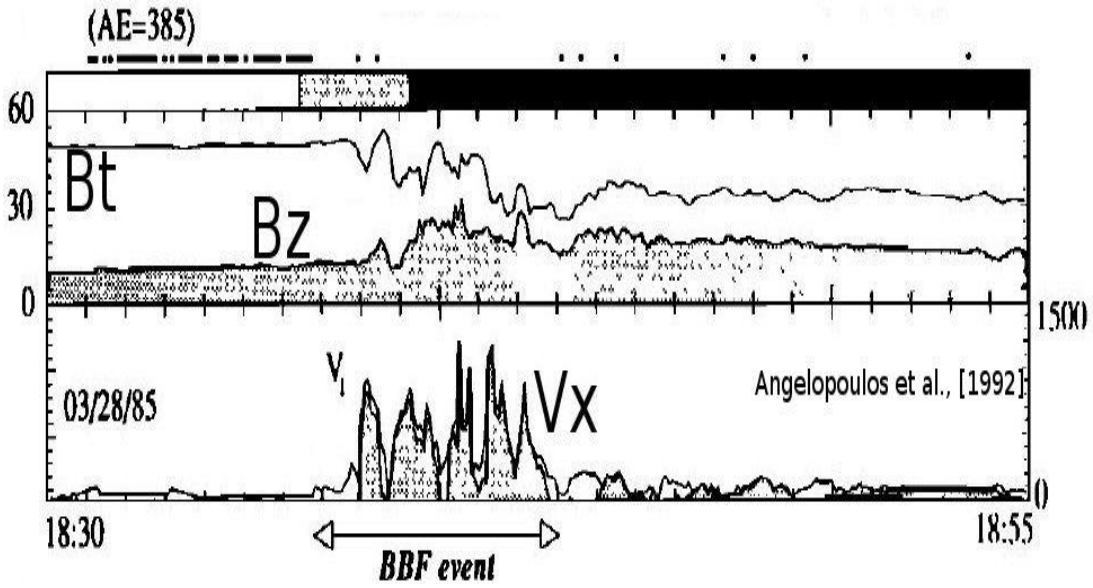
1. Introduction
2. Observations
   - Field-Aligned Currents (FACs) near DFs
   - Current closure around plasma bubble
   - Electric field associated with DFs
3. Summary

The Magnetosphere convection

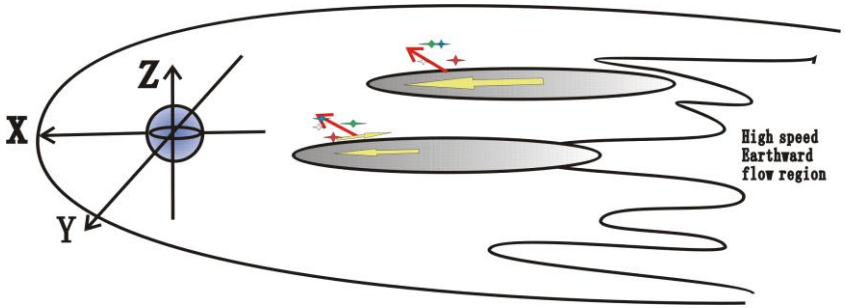


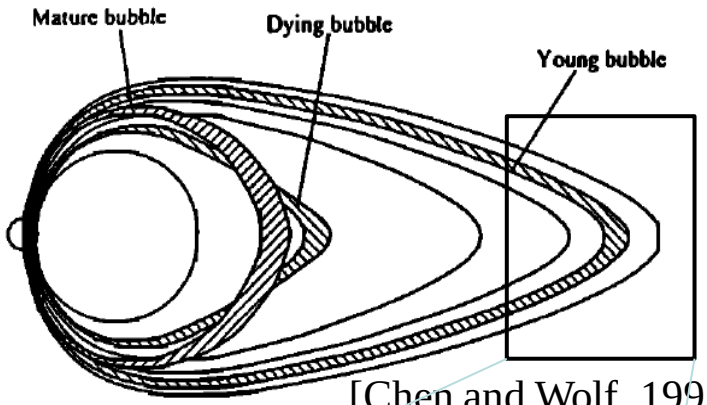
Bursty bulk flows



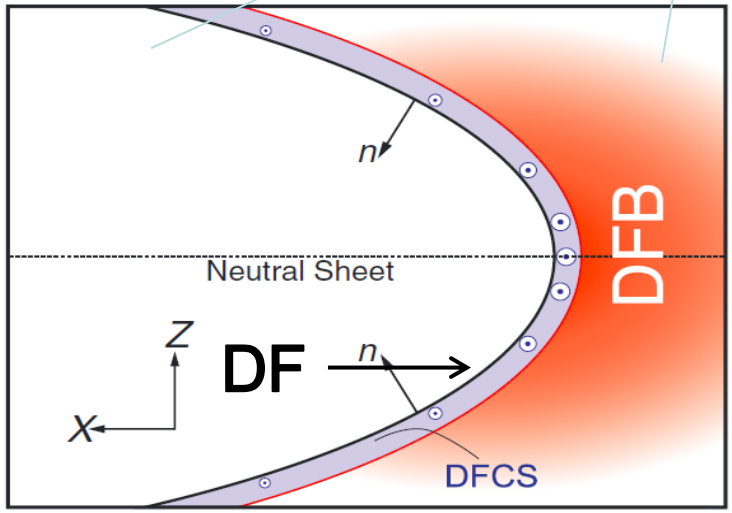
- The BBFs contribute more than 60% of the near-earth magnetotail transport [*Angelopoulos et al.*, 1994].

- ✓ Y ~2 – 3 R_E, Z ~ 1 – 2 R_E [*Nakamura et al.*, 2002].
- ✓ 10% - 15% observation time.



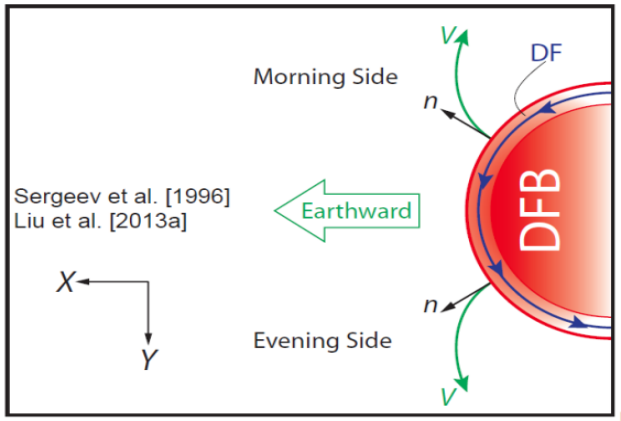


[Chen and Wolf, 1993]

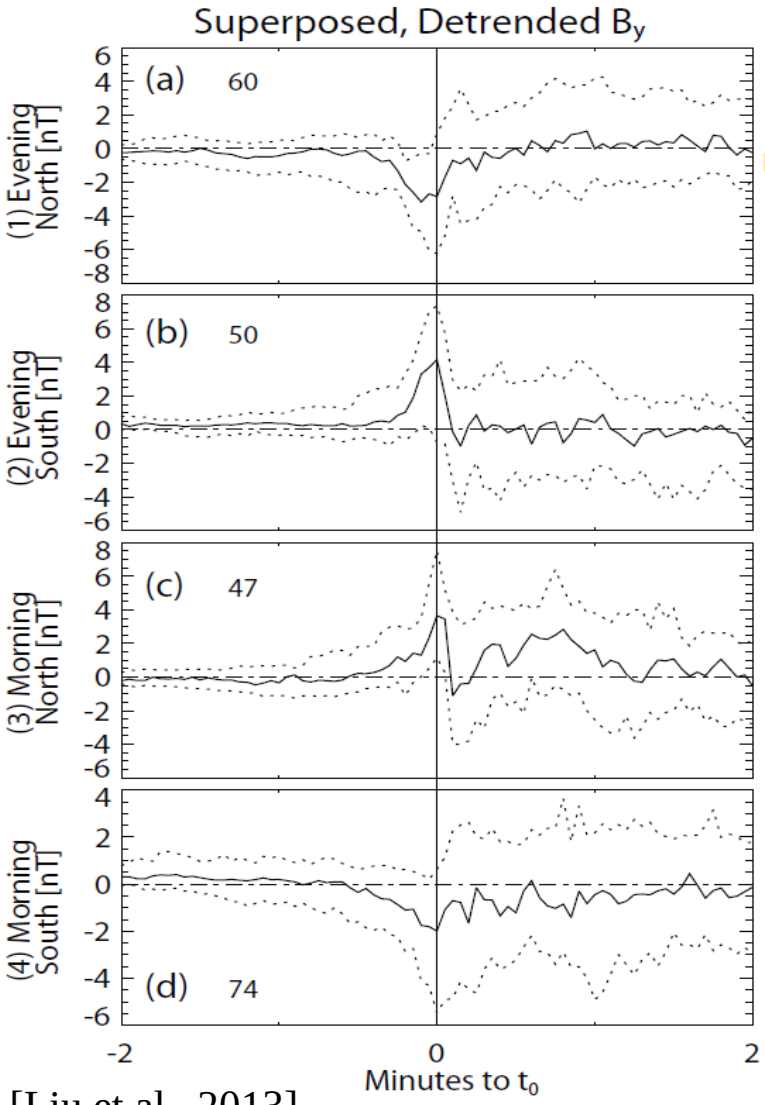


[Liu et al., 2013]

- A theoretical model for the BBFs is the "plasma bubble" [*Chen and Wolf*, 1997].
  - ✓Strong magnetic field
  - ✓Density depletion
  - ✓Usually accompanied by high speed flow
  - ✓Leading edge ~~ the DF

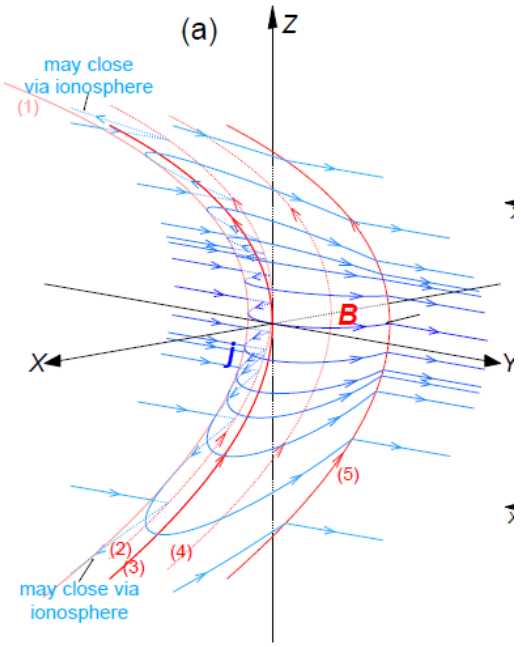


FACs in the near earth region



[Liu et al., 2013]

- From B_y variations:
  - region-2-sense FACs ahead of the DF;
  - region-1-sense FACs on the DF



– 9 R_E)

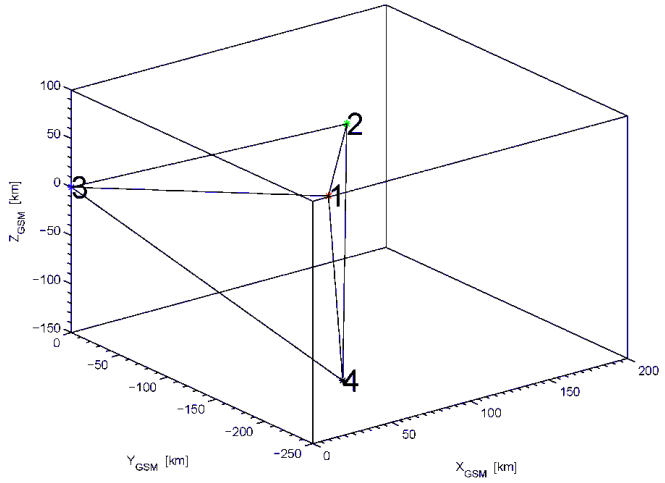
Cluster Event selection

Cluster 2003 (August 1st to October 1st)

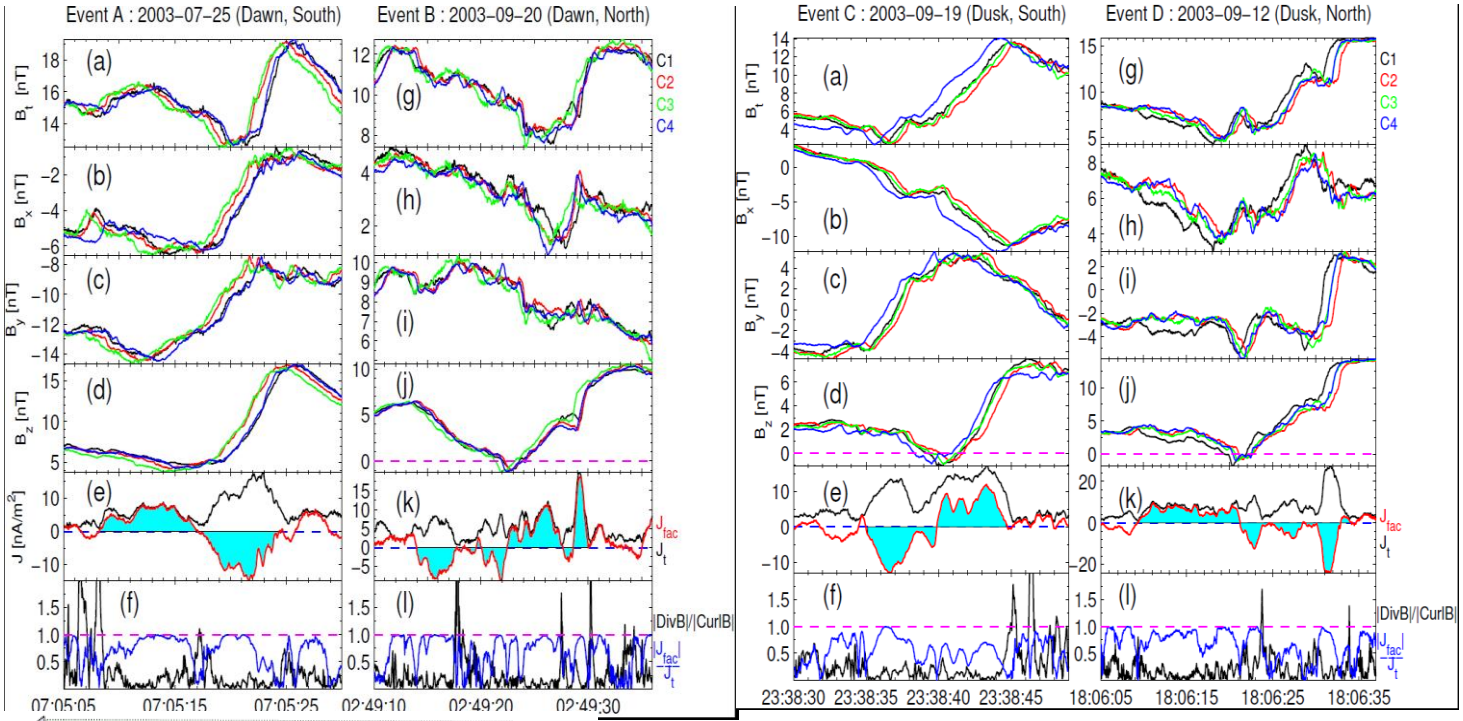
- Separation ~ 100 – 300km, forming regular tetrahedron

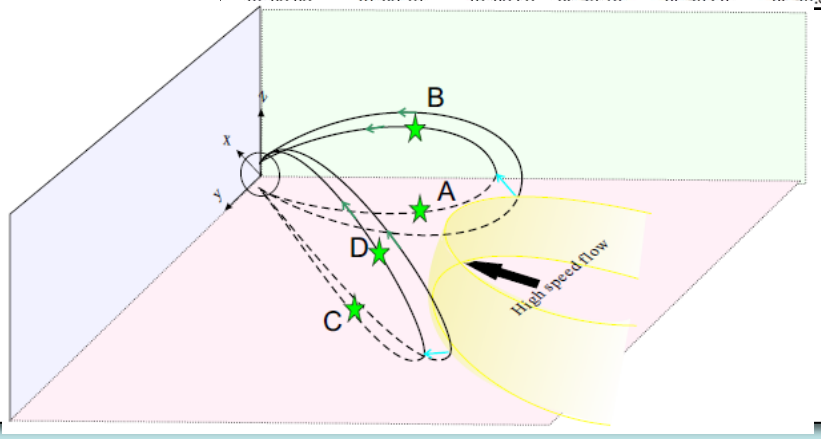
Event selection criteria:

- ✓ Plasma β > 0.5
- ✓ Bz must increase more than 4 nT within 20s
- ✓ Maximum elevation angle of magnetic field > 45°
  increase more than 10° in 20s
- ✓ Embedded in earthward plasma flow



FACs associated with DFs





Morning side

On the DF layers: FACs are downward

Magnetic dip region: FACs are upward

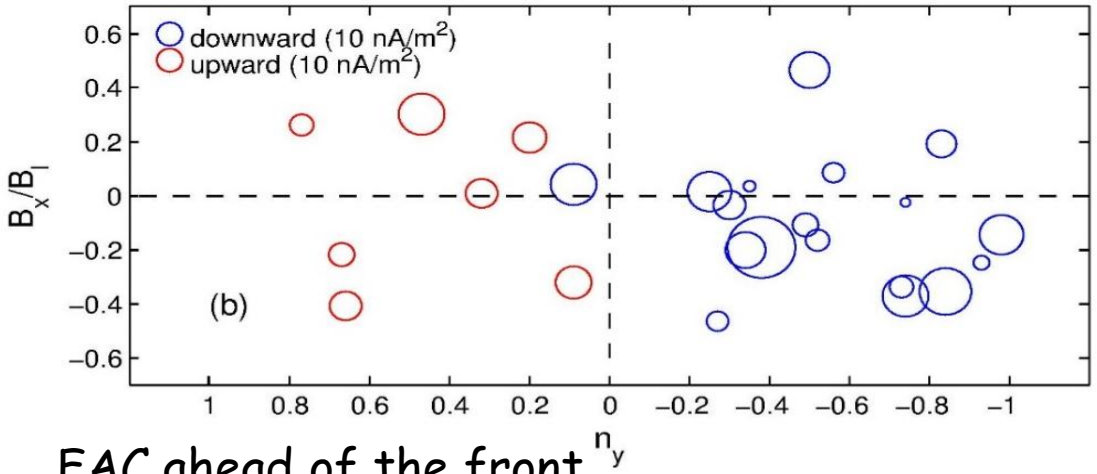
Dusk Side

On the DF layers: FACs are upward

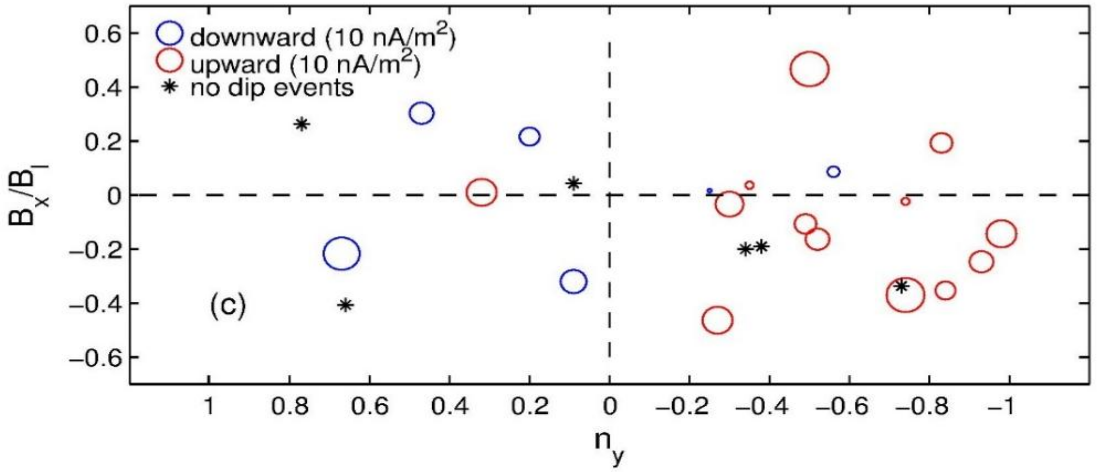
Magnetic dip region: FACs are downward

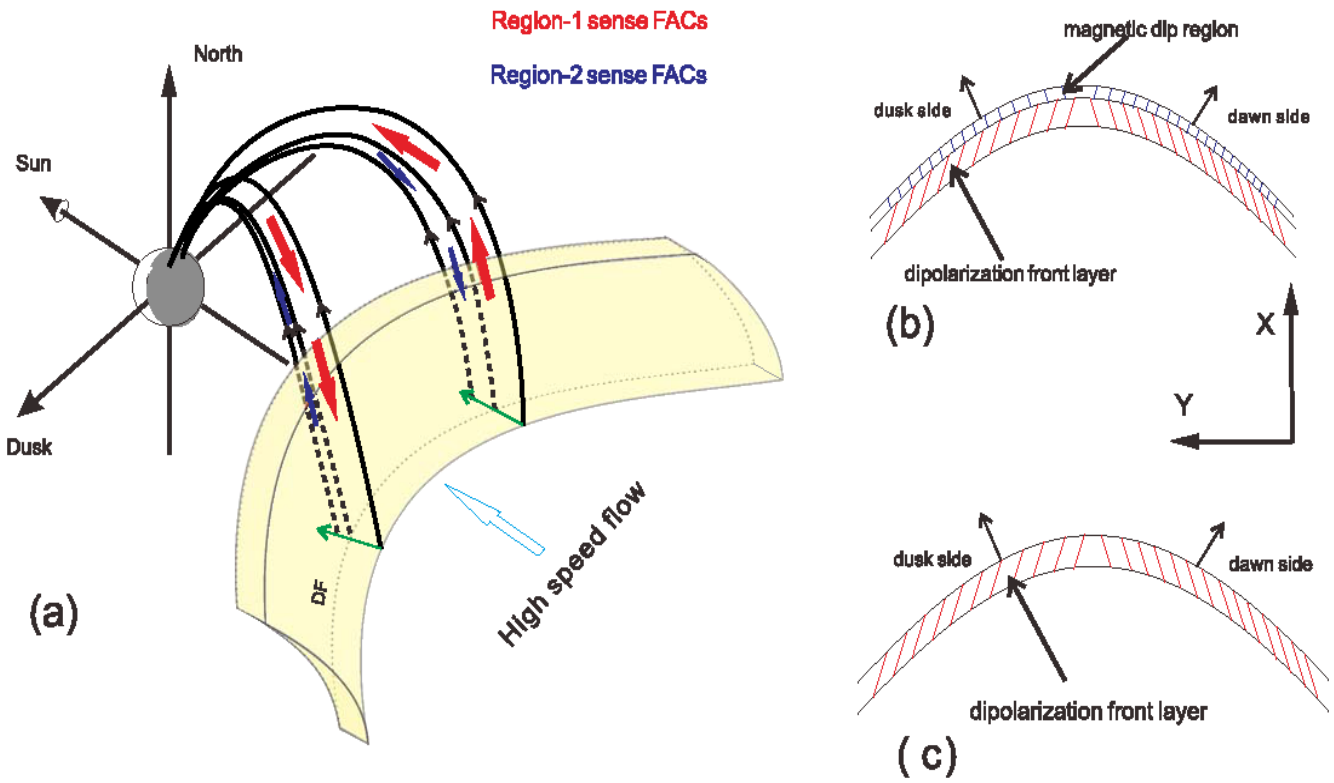
FAC near the dipolarization front

FAC at the front



FAC ahead of the front

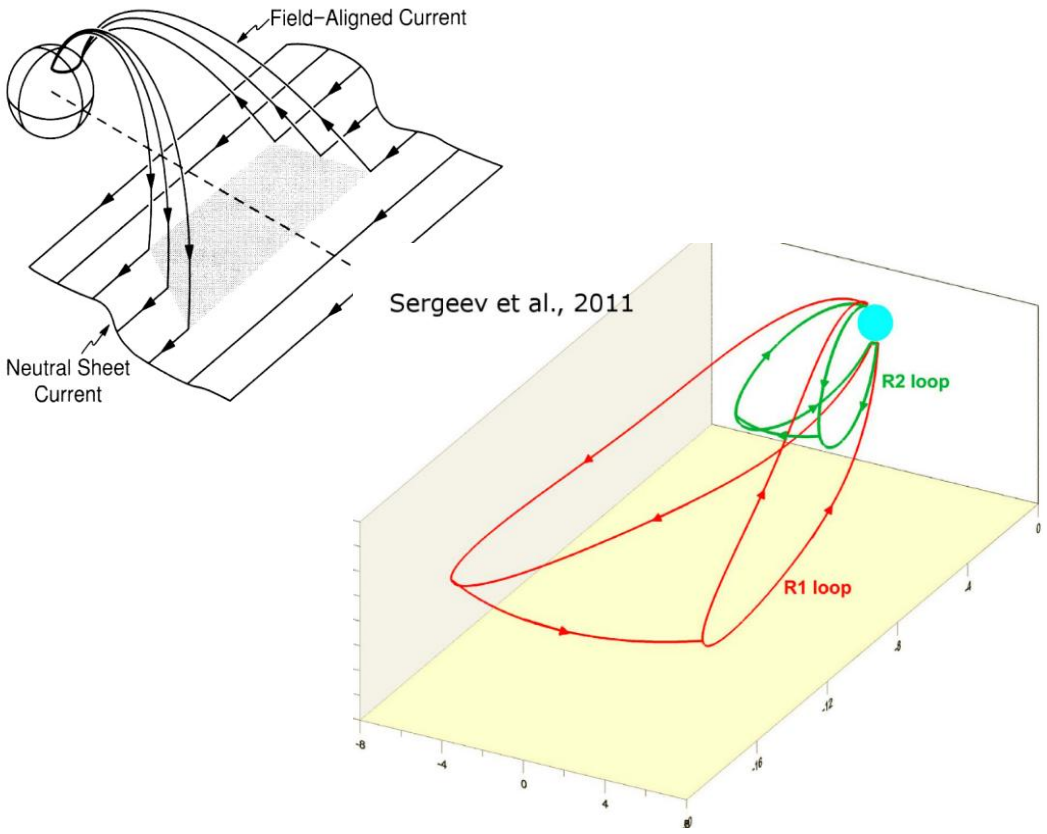




Sun, et al., GRL 2013

Yao, et al., GRL 2013

- Mainly field-aligned component only occur in the dip region ahead of the front with a scale of 500 km.
- Parallel and perpendicular components in the front with scale of 1000km.



The FACs in the DF region resembles the substorm current wedge [Sergeev et al., 2011] that connects the ionosphere and magnetosphere.

- ✓ Ritter and Lühr [2008], suggested that an additional azimuthal current loop of Region 2 polarity in the low-latitude nightside ionosphere
- ✓ Amm and Fujii [2008] showed that a significant part of the upward current in auroral spirals can be closed via surrounding distributed FACs with opposite polarity, whereas only a third of its current was closed via a Cowling current system.

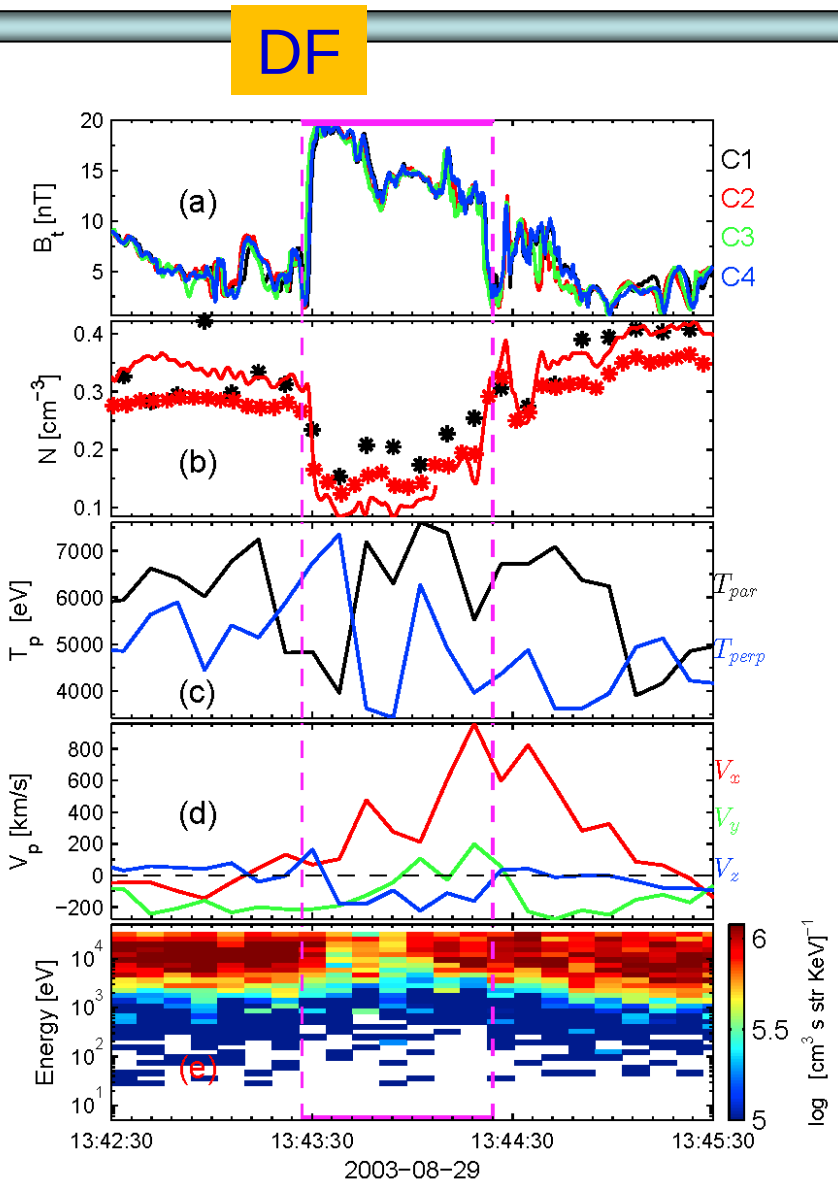
Current around plasma bubble

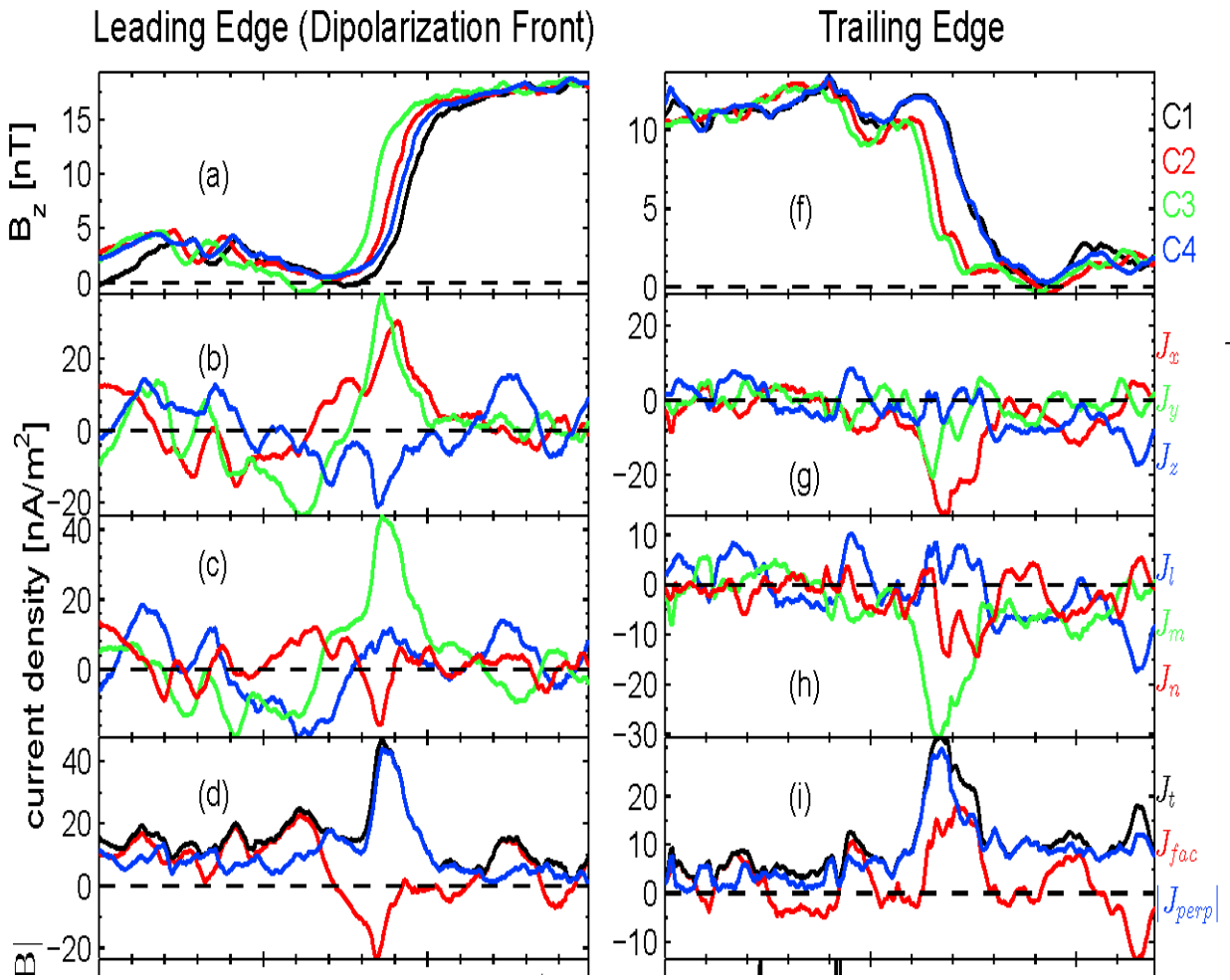
Plasma bubble

- ✓ Strong magnetic field
- ✓ Density depletion
- ✓ Usually accompanied by high speed flow

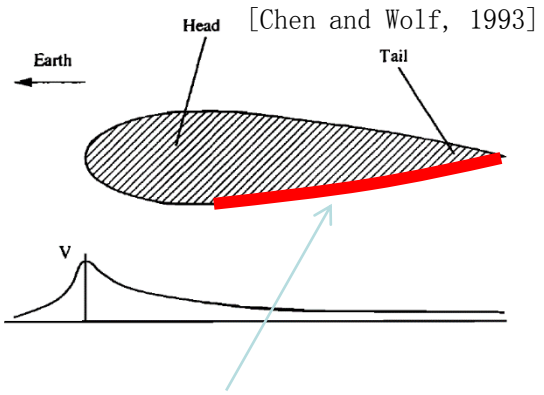
Dipolarization front (DF)

- ✓ Sharp increase of Bz
- ✓ Scale: ion inertial / gyro-radius length (~ 1000 km);



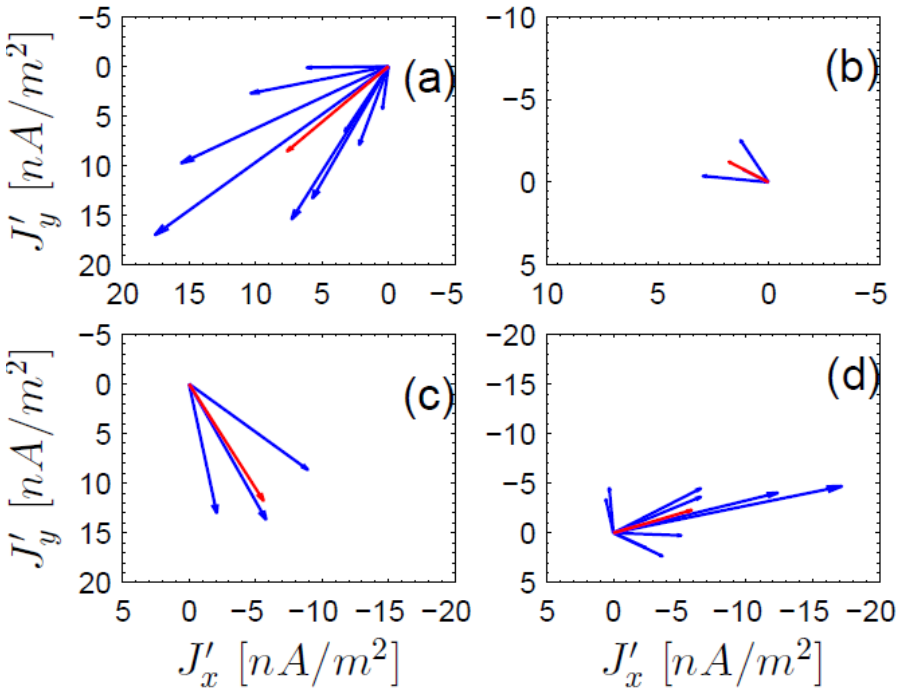


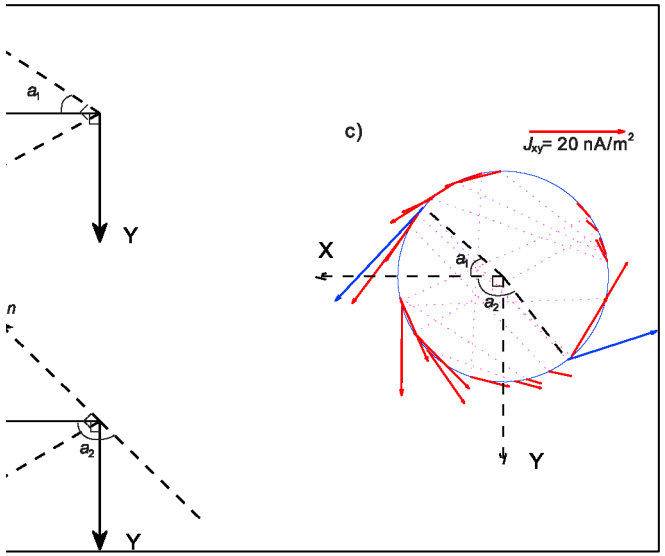
B_x < 0, in the Southern Hemisphere



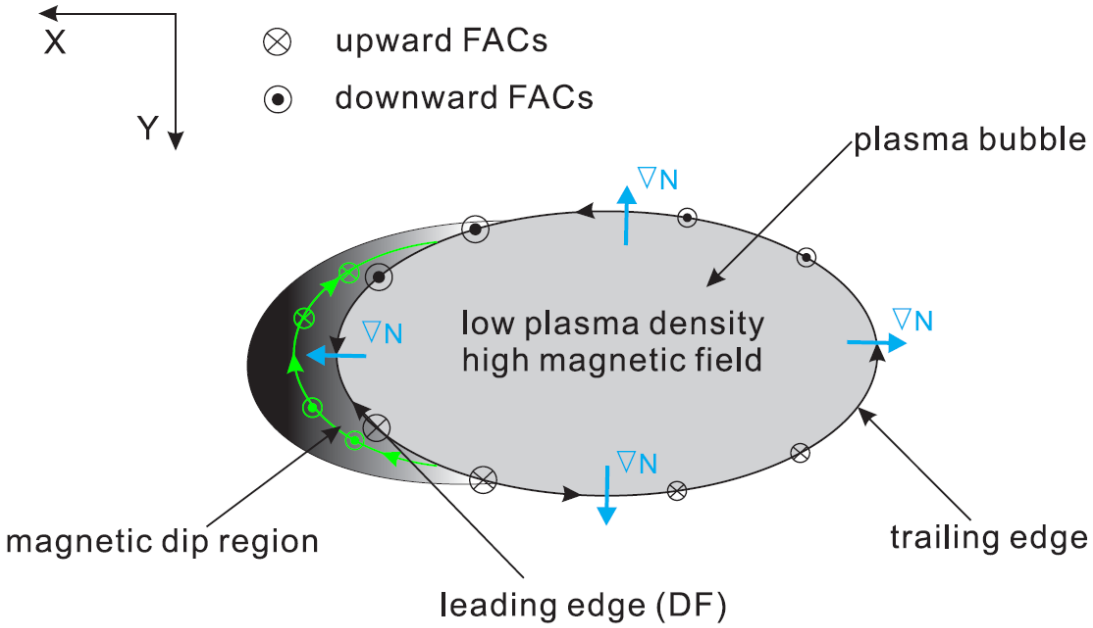
[Chen and Wolf, 1993]

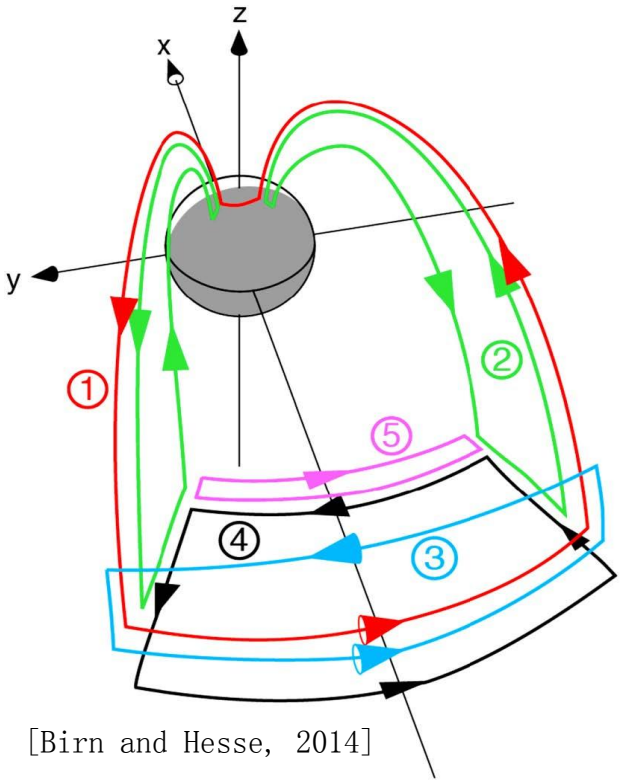
FACs in the trailing edge is upward, region-1 sense





- ✓ J_{par} in the DF is larger than the trailing edge.
- ✓ J_{perp} between two edges is comparable.

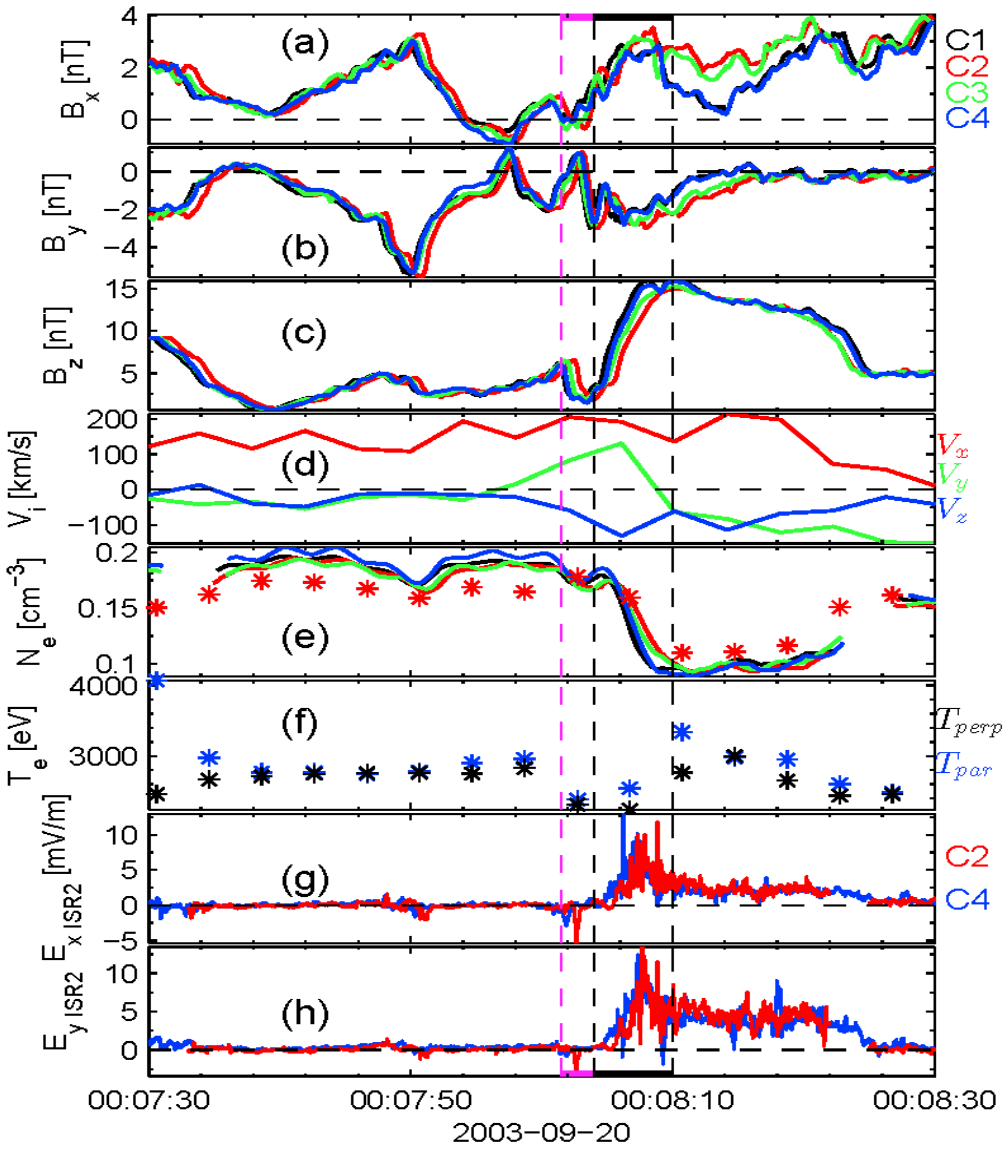




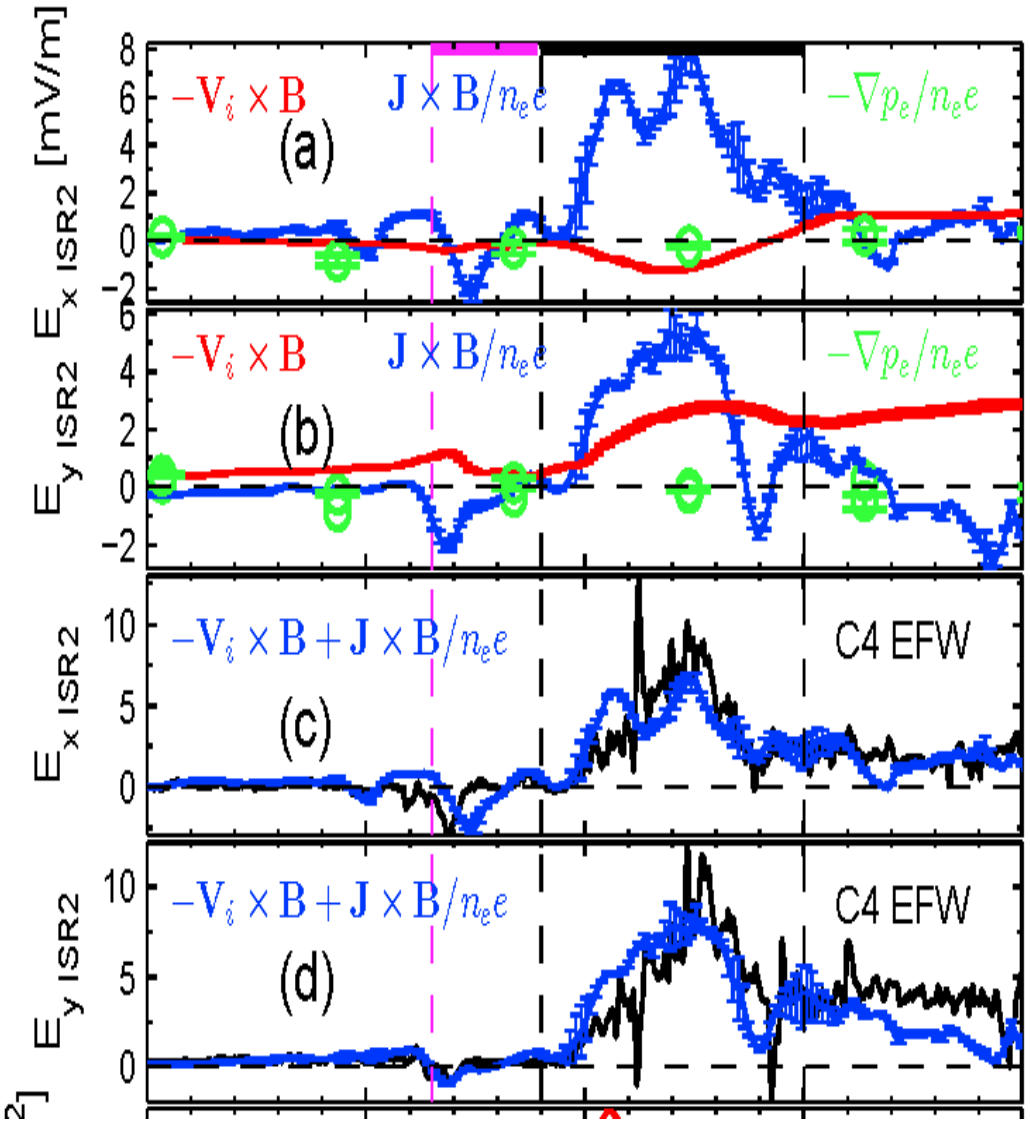
[Birn and Hesse, 2014]

- Region-1-sense FACs on the boundary;
- Dawnward current in the magnetic dip region with region-2-sense field-aligned component.
- A partial closed current around plasma bubble;

E field near DF



- ✓ The electric field inside the DF was balanced by the three terms, with Hall term being dominates [see Fu et al., 2012; Lu et al., 2012].
- ✓ Electric field is in opposite directions in the dip region and DF layer.



$$-\frac{\nabla p_e}{ne} \ll -\mathbf{V}_i \times \mathbf{B}$$

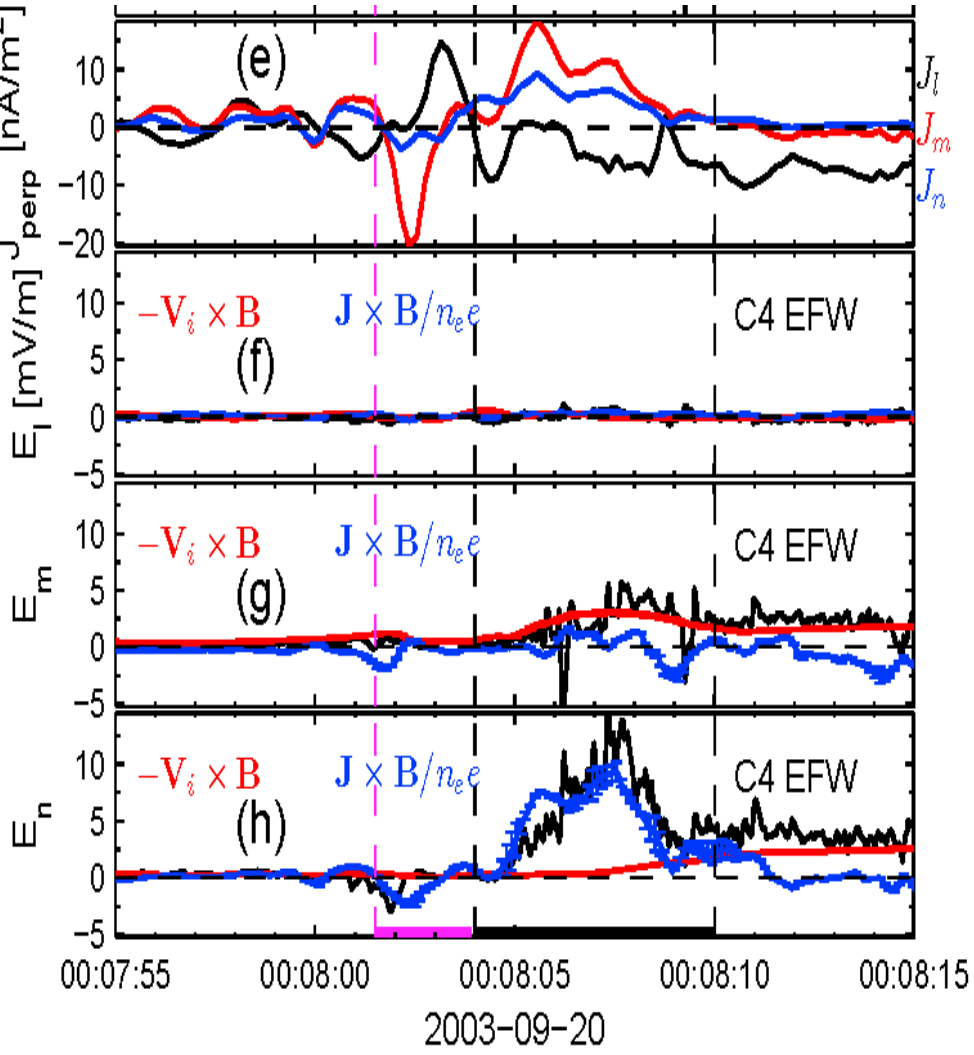
$$-\frac{\nabla p_e}{ne} \ll -\frac{\mathbf{J} \times \mathbf{B}}{ne}$$

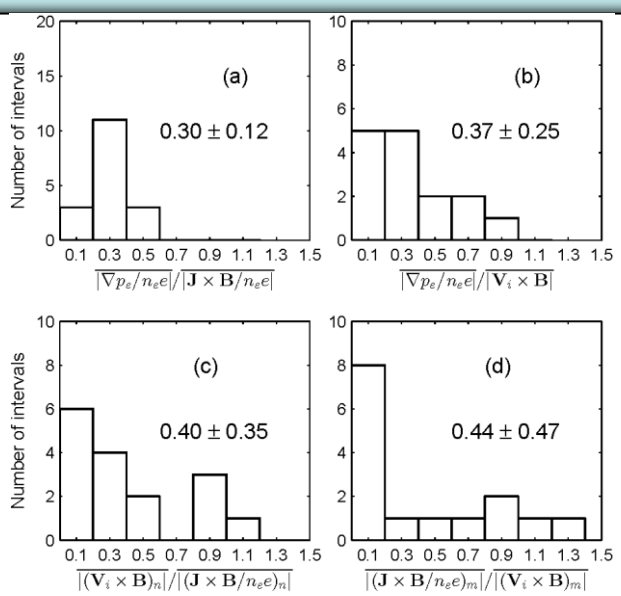
frozen-in for proton is broken;

$(\mathbf{E} + \mathbf{V}_i \times \mathbf{B} \neq 0)$

electron is still frozen-in

$(\mathbf{E} + \mathbf{V}_e \times \mathbf{B} = \nabla p_e / n_e e)$

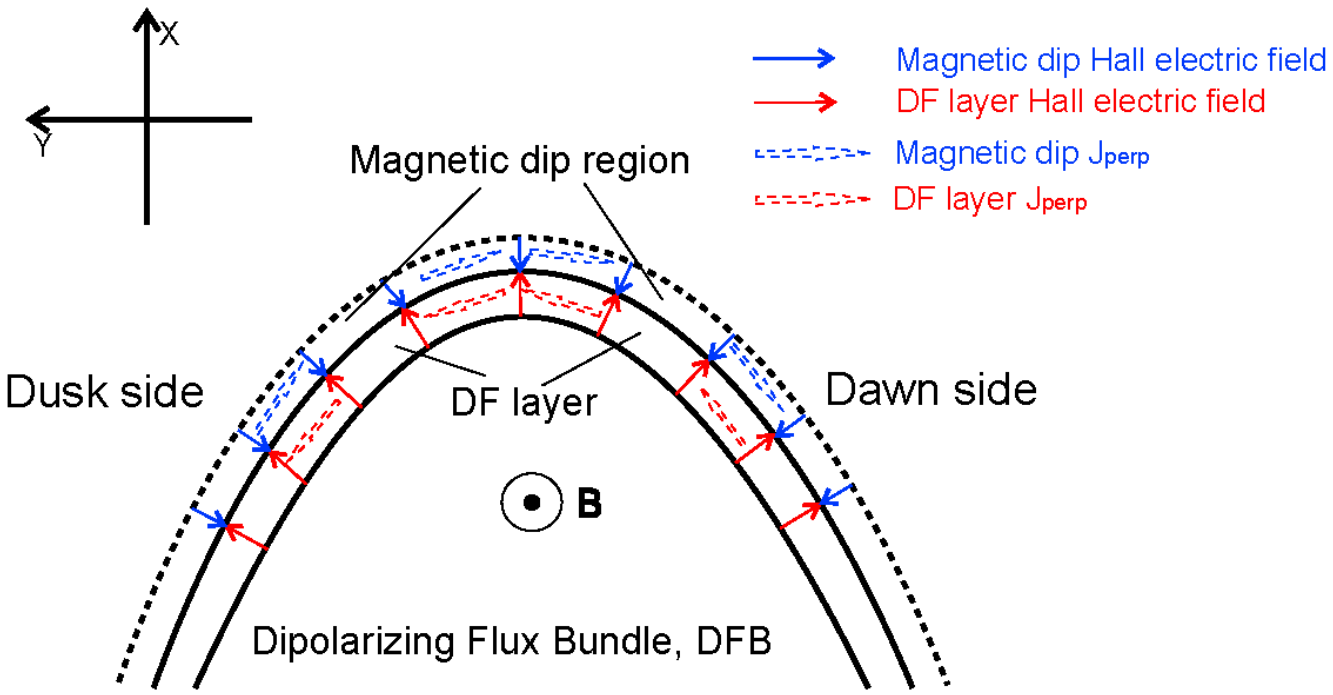




- ✓ Electron pressure gradient is smaller than other two terms.
- ✓ Dawn-dusk electric field is mainly from convection term;

$$E_m \approx -\mathbf{V}_i \times \mathbf{B}$$

- ✓ Normal electric field is mainly from Hall term. $E_n \approx \dfrac{\mathbf{J}\times\mathbf{B}}{ne}$



- The Hall electric fields in the DF layer and magnetic dip region are opposite to each other.

Sun, et al., JGR, 2014

Summary

- The FACs with region-1 current sense flowing inside the boundary of plasma bubble and region-2 sense just in the magnetic dips. A partial closed current flows in the boundary of plasma bubble.

- Normal electric field in the DF layer is mainly contributed from Hall term, and dawn-dusk electric field from convection term. Hall electric fields in the DF layer and magnetic dip region is opposite to each other.

- The ions is decoupled from the magnetic field in the DF layer and dip region, whereas electrons remain frozen-in.

Thank You!