Explicit IMF By-dependence of magnetospheric energetic protons and the ring current

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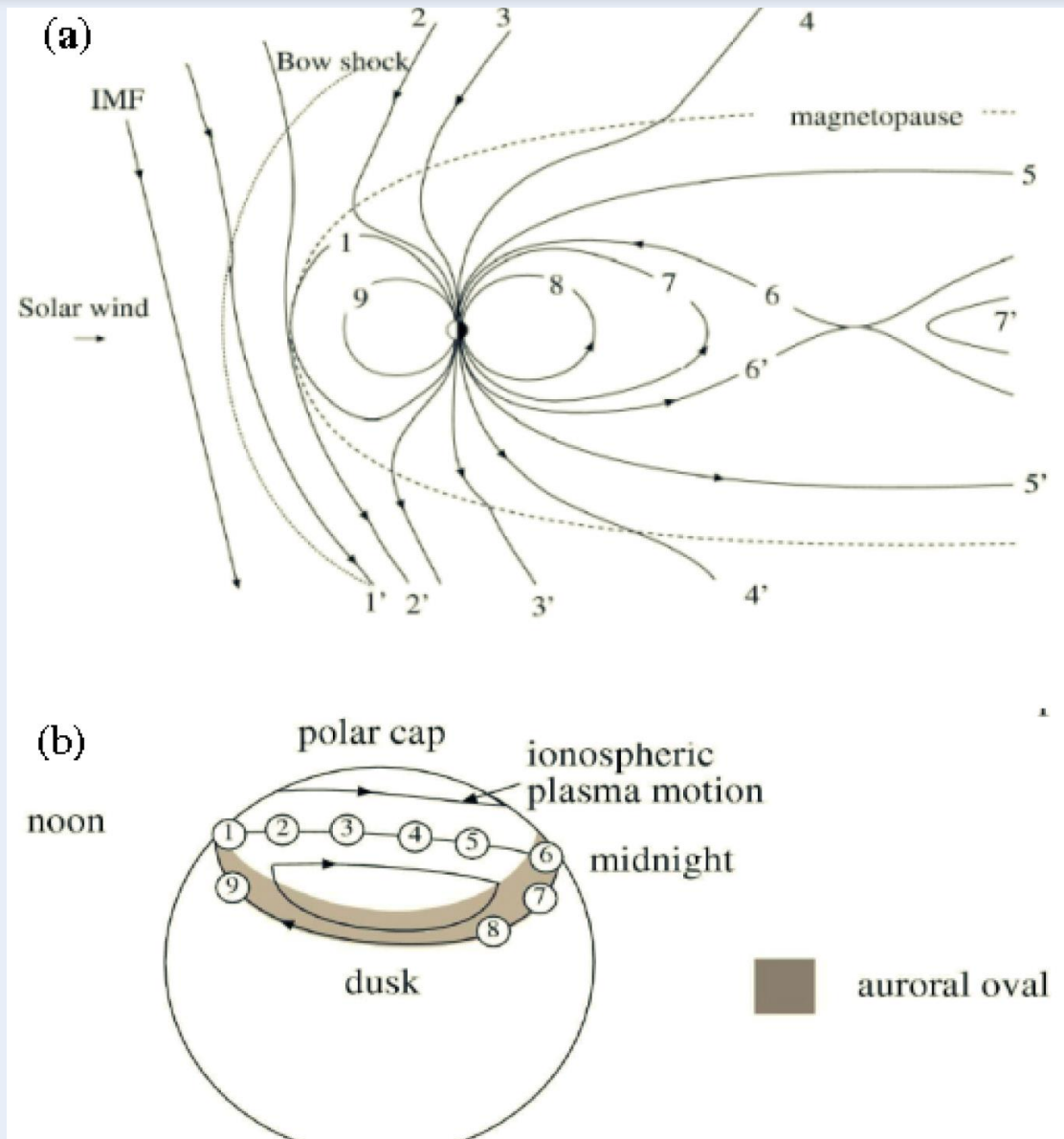
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- IMF B_z-component is the main driver of magnetic reconnection at the magnetopause

- **IMF B_y** is included in coupling functions, but **its effect does not depend on its sign**

$$\frac{d\Phi_{MP}}{dt} = v^{4/3} B_T^{2/3} \sin\left(\frac{\theta}{2}\right)^{8/3},$$

$$B_T = \sqrt{B_z^2 + B_y^2}$$

$$\theta = \arctan\left(\frac{B_y}{B_z}\right)$$

- **Does the sign of B_y matter? Yes, during a significant dipole tilt!**
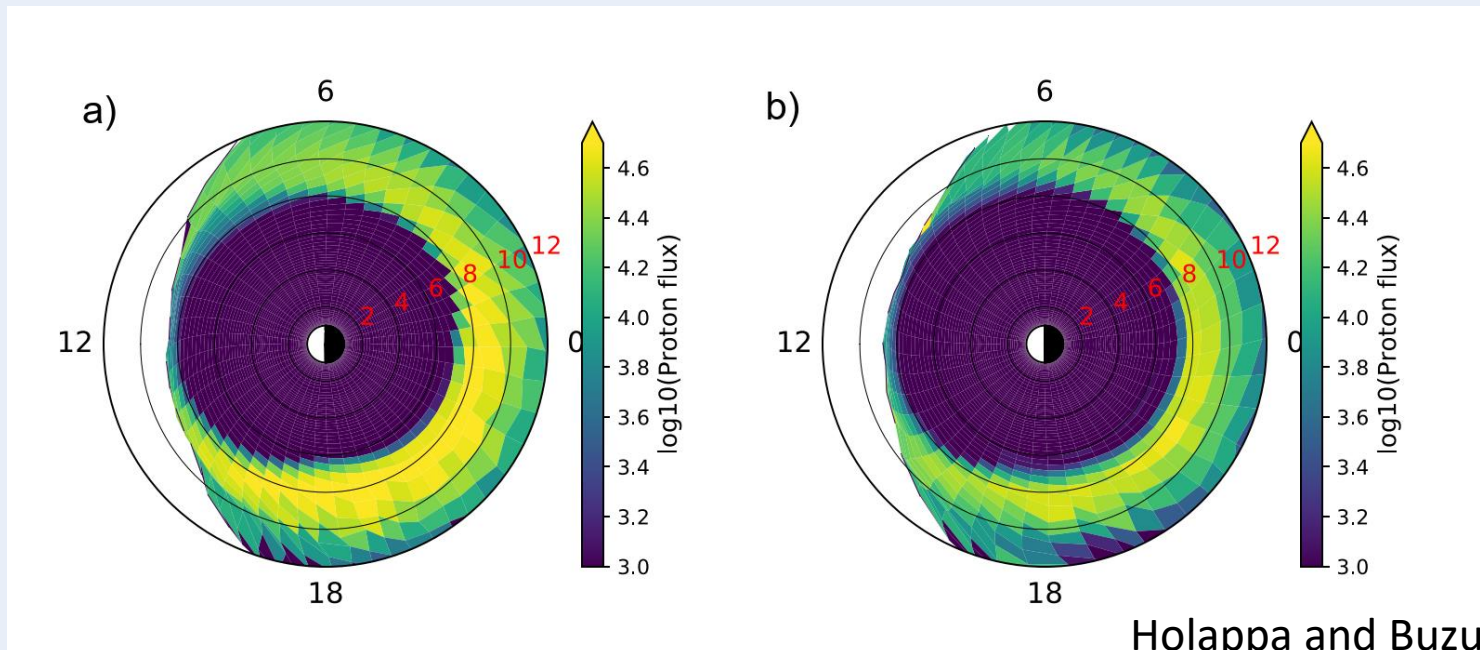
- Two runs with SWMF including the Comprehensive Inner Magnetosphere-Ionosphere (CIMI) model for NH summer (**positive dipole tilt, +20 degrees**)

a) Bz = -5 nT, By =-5 nT
b) Bz = -5 nT, By = +5 nT

Greater Equatorial (omnidirectional) fluxes of 56 keV protons for negative By
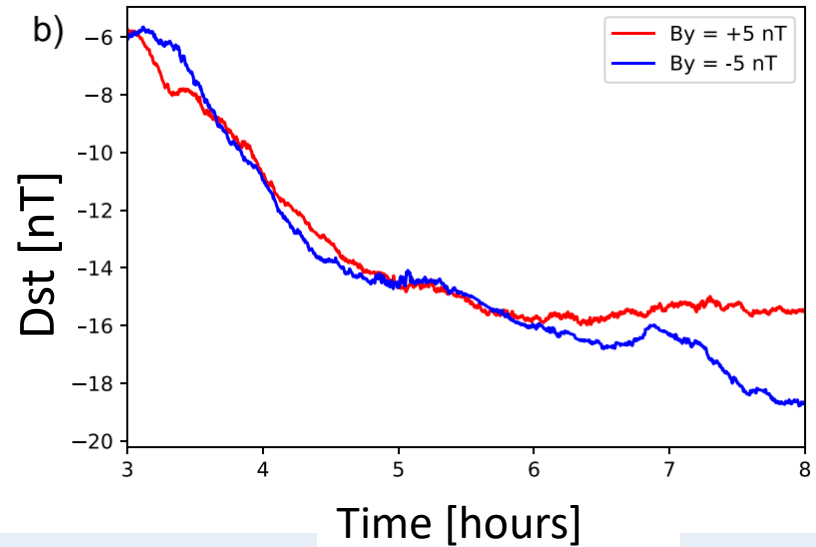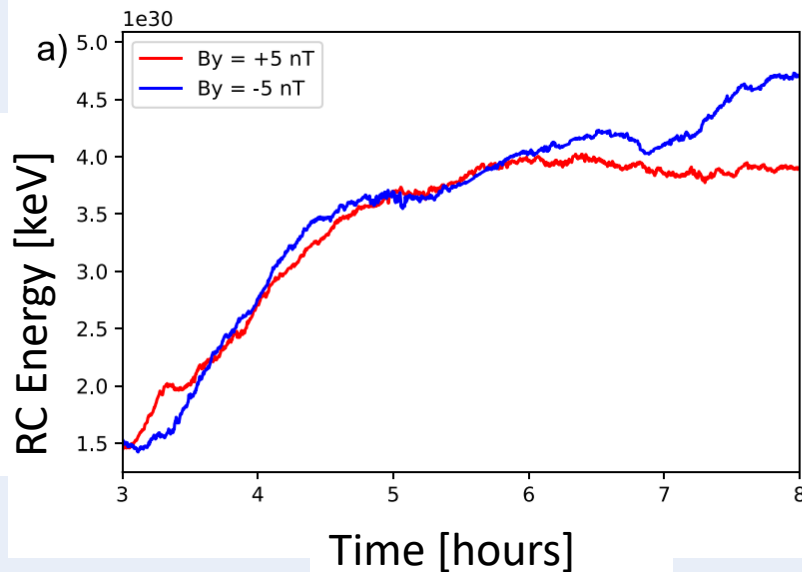

Holappa and Buzulukova (2022)

- Two runs with SWMF including the CIMI inner magnetosphere model for NH summer (**positive dipole tilt, +20 degrees**)

a) Bz = -5 nT, By = -5 nT

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Greater ring current energy and modeled Dst for negative By

Holappa and Buzulukova (2022)

Dipole tilt > +20°

- IMF By modulates the flux of energetic (>30keV) protons and electrons precipitating into ionosphere.

- Larger electron NOAA POES particle fluxes in the midnight and dawn sectors for **By<0 and positive dipole tilt**.

- The explicit By-dependence can be "removed" by a simple analytic modification of the coupling function

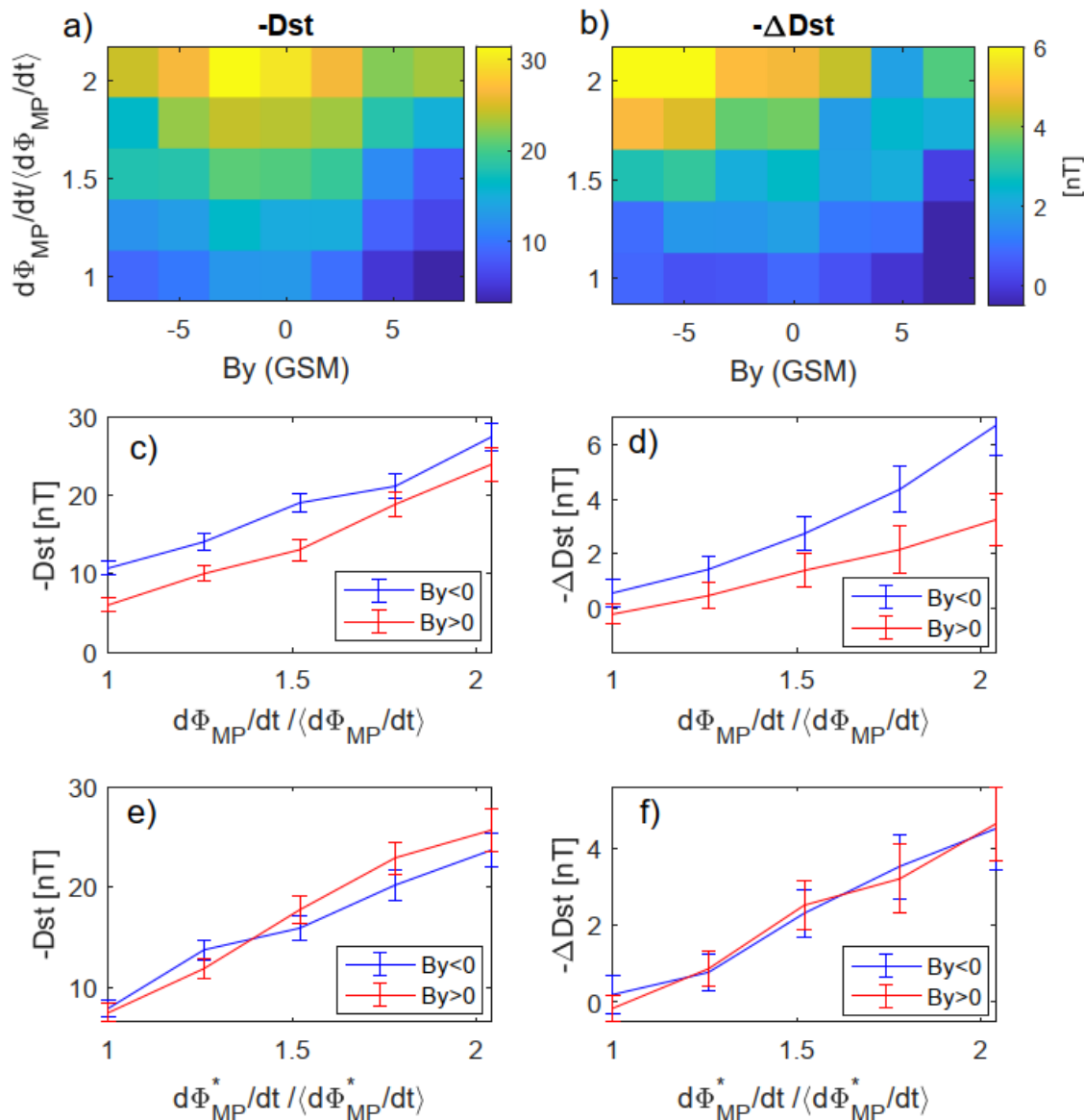$$\frac{d\Phi^*_{MP}}{dt} = (1 - 0.04\tan(\psi)\,\text{By}) \cdot \frac{d\Phi_{MP}}{dt}$$

where ψ is the dipole tilt angle.
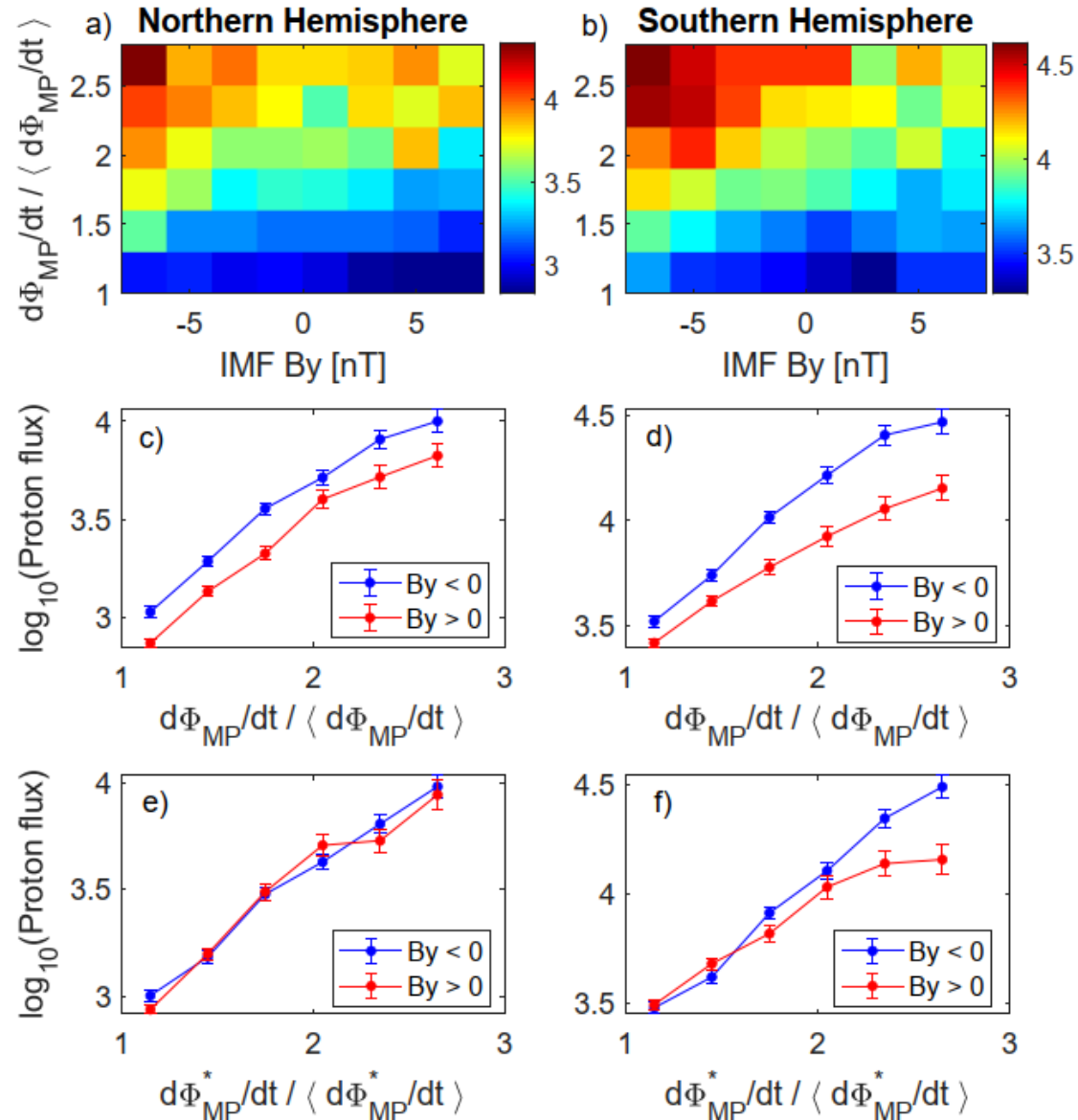
- The Dst index shows a very similar By-dependence as the POES particle fluxes

- By-dependence is clear in the time derivative of Dst (ΔDst), change of Dst during a 3-hour window

- RC growth faster for negative By during positive tilt

- The modified coupling function removes the By-dependence

Dipole tilt > +20°

Dipole tilt < −20°

- By-dependence is reversed during negative dipole tilt.

- RC growth faster for positive By during negative tilt
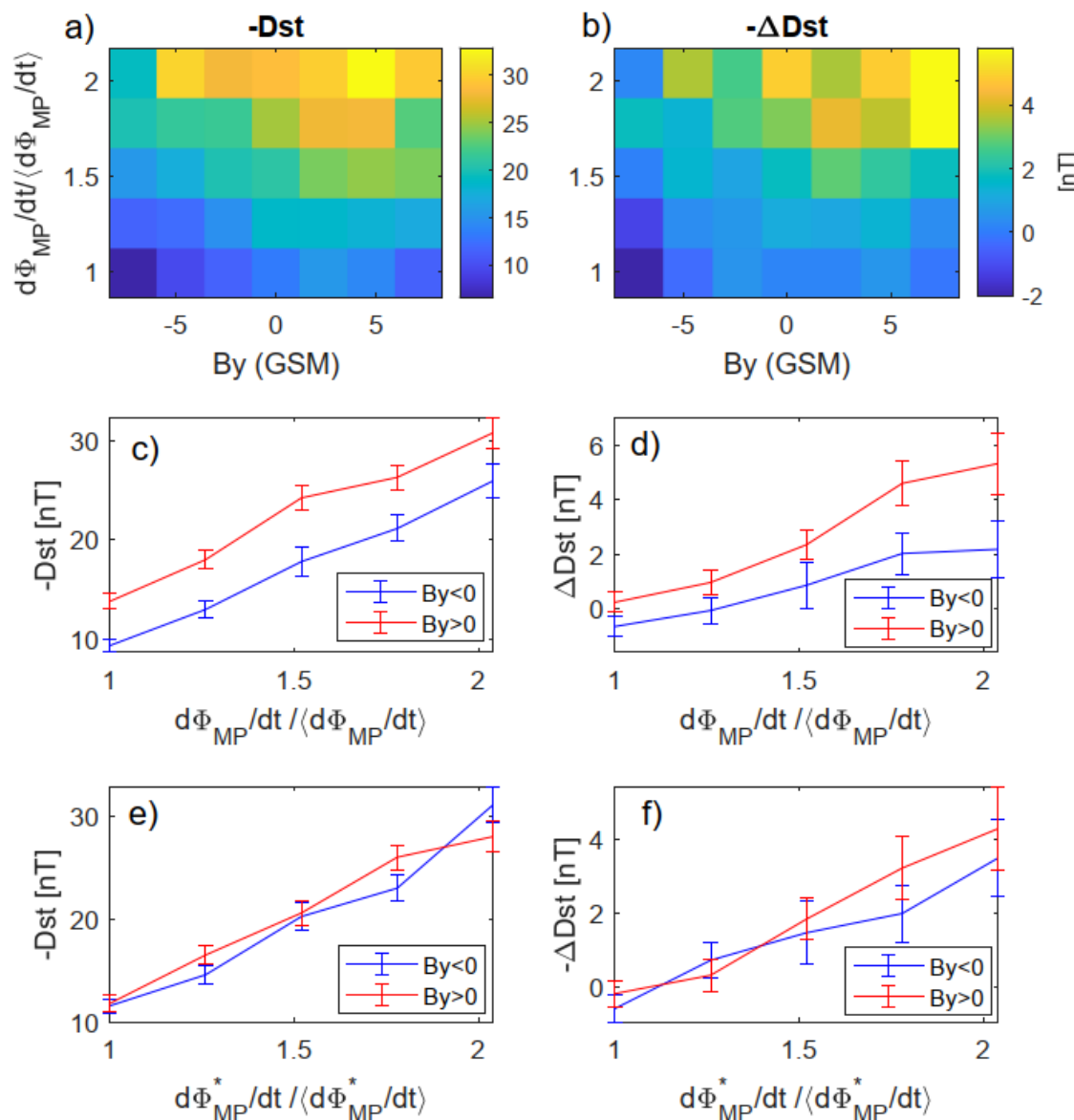
- IMF By modulates the fluxes of energetic protons and the ring current in the inner magnetosphere

- Larger fluxes of protons and stronger ring current growth for By < 0, when the dipole tilt is positive (NH summer).

- The By dependence is reversed for negative tilt (NH winter)

- The underlying physical mechanism is not fully understood, but the global BATS-R-US/CIMI model captures the By-dependence.

- Similar By-dependence found earlier in the westward electrojet and substorm activity

References

Holappa, L. and N. Buzulukova, Explicit IMF B_y-Dependence of Energetic Protons and the Ring Current, GRL, 2022.

https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2022GL098031