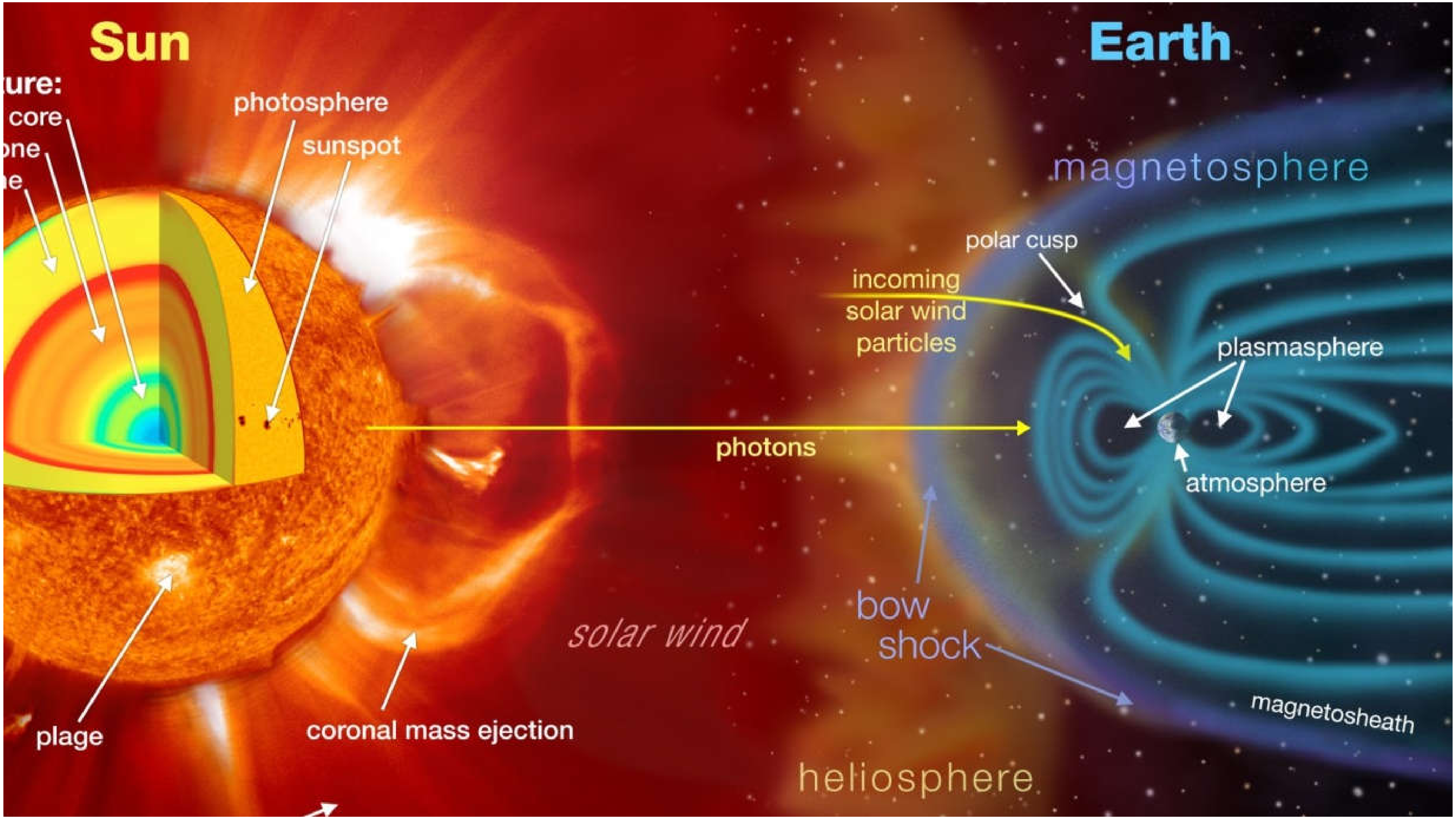
Geosphere Storms



Sun
ure:
core
one
e
photosphere
sunspot
plage
coronal mass ejection
solar wind
photons
Earth
magnetosphere
polar cusp
incoming
solar wind
particles
plasmasphere
atmosphere
bow
shock
magnetosheath
heliosphere

Solar wind energy input

- There is a strong correlation between the solar wind Ey = v Bz and magnetospheric activity.
- An empirical indicator of solar wind energy input going into substorm development is the Akasofu epsilon parameter ε
  - $\varepsilon > 10^{11}$ W, a substorm can occur;
  - $\varepsilon > 10^{13}$ W is indicative of a big storm

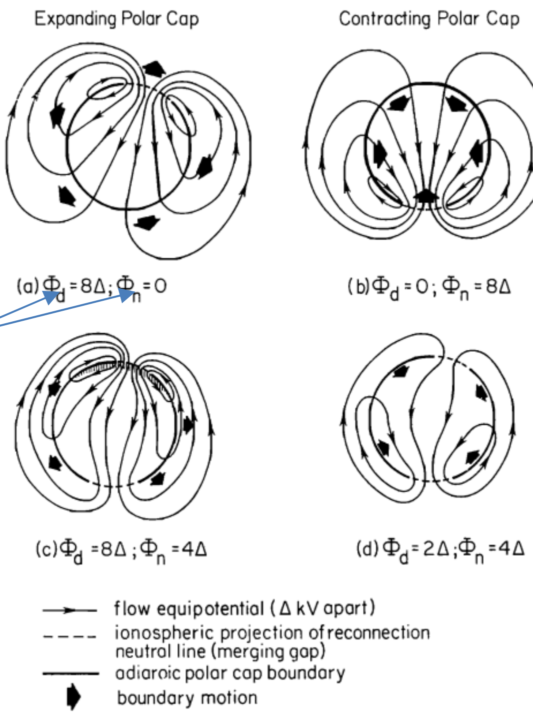
$$\varepsilon = \frac{4\pi}{\mu_0} L_0^2 V_X B^2 \sin^4 \frac{1}{2}\theta$$

- L_0 = 7 RE, and empirical scaling parameter.
- B is the IMF magnitude,
- θ is the clock angle of the IMF relative to the Earth's magnetic dipole axis
- v = solar wind speed.

Milan+ (2012, https://doi.org/10.1029/2011JA017082)

Imbalance of ΦD and ΦN

Voltage at dayside and nightside reconnection neutral lines



- The amount of open magnetic flux in the magnetosphere governs the location of the OCB
- when there is more open magnetic flux, the boundary is farther from the pole, and therefore the size of the polar cap is increased.
- Faraday's law: the rate of change of polar cap magnetic flux within OCB must be equal to the electric field integrated around the OCB (sum of voltages ΦD and ΦN)

$$\frac{\mathrm{d}F_{\mathrm{PC}}}{\mathrm{d}t} = \Phi_D - \Phi_N$$

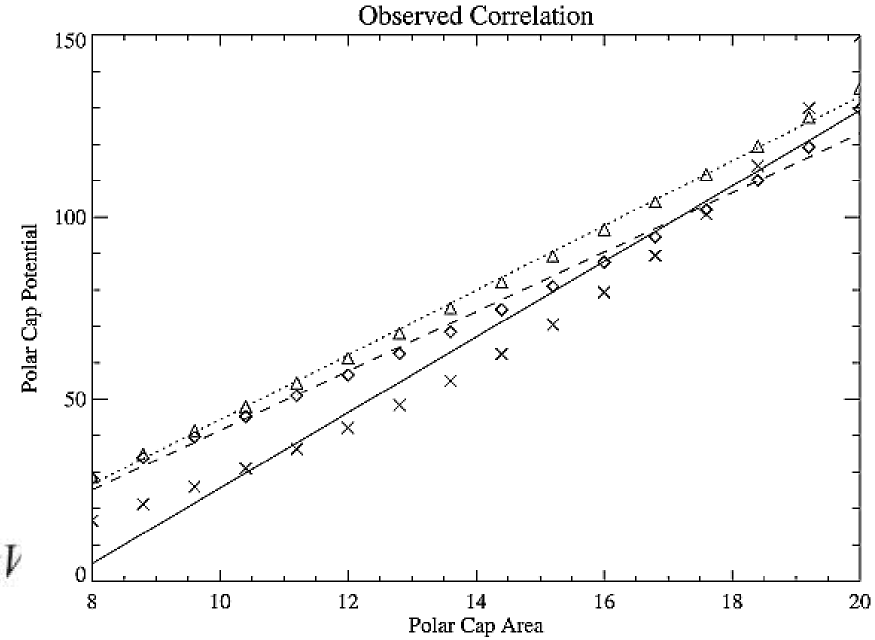
Lockwood+(1990, http://dx.doi.org/10.1029/JA095iA06p07961)

Polar Cap Potential

- Empirical formulas of polar cap size and polar cap potential relationships refit with a linear formula.

Merging electric field (Kahn&Lee, 1979) $E_m = vB_T \sin^2\left(\frac{\theta}{2}\right)$

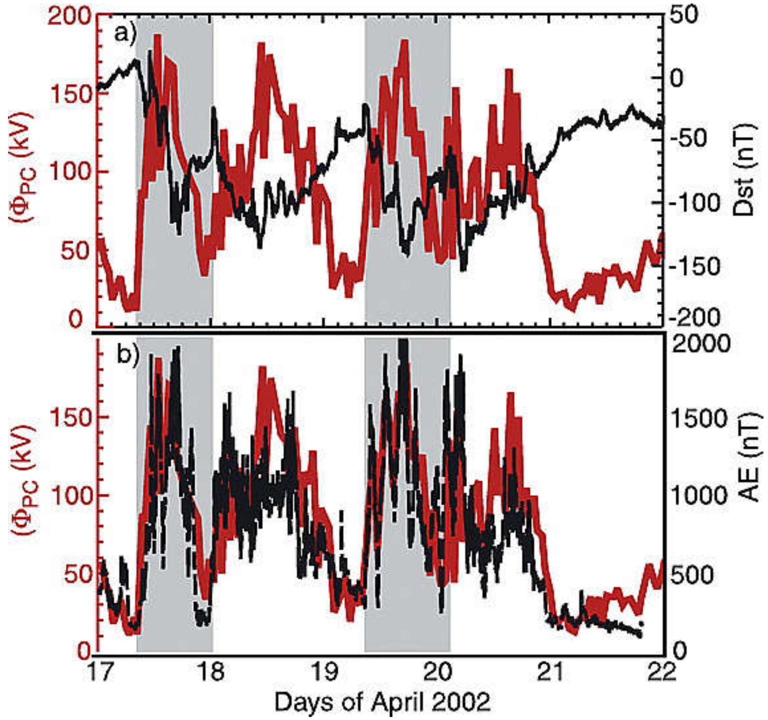
Polar cap potential $\Phi_{pc} = 33.4 + 24.0E_m\,(kV$

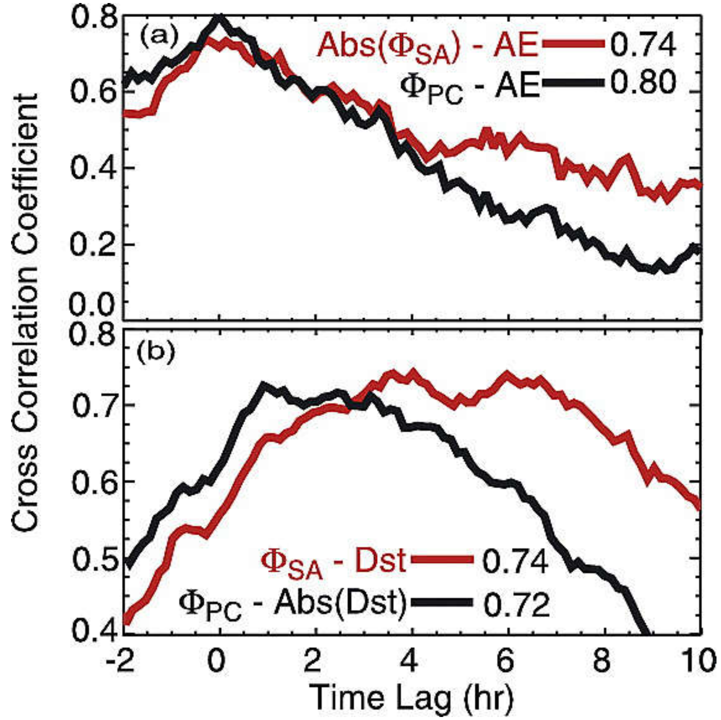


http://dx.doi.org/10.5140/JASS.2012.29.3.259

Liu, 2007
https://doi.org/10.1029/2007JA012392

Increase of Magnetosphere Convection Electric Field





Magnetosphere Perturbations

Two basic dynamic event types

Rising level of geomagnetic activity

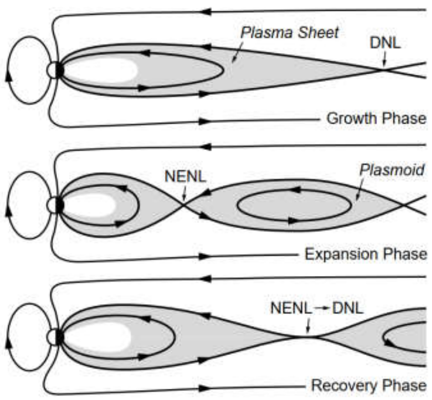


Fig. 5.10. Reconfi guration of the plasma sheet during a substorm.

Quiet Magnetosphere

Substorm

- **Initiated by enhancement of ΦD**
- **Phases: Growth, (Onset,) Expansion, (Westward Surge,) Recovery**

Steady Magnetosphere Convection

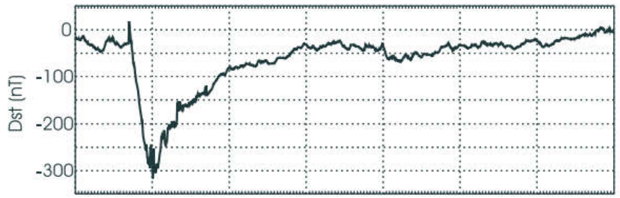
- Steady southward IMF conditions (several hours)
- No substorm occur at all
- Accompanied by continuous auroral activity without substorm characteristics

Sawtooth Event

- Enough energy is deposited in the magnetosphere that substorms are required to dissipate the energy stored in the tail
- Rapid repeated substorms

Geomagnetic Storm

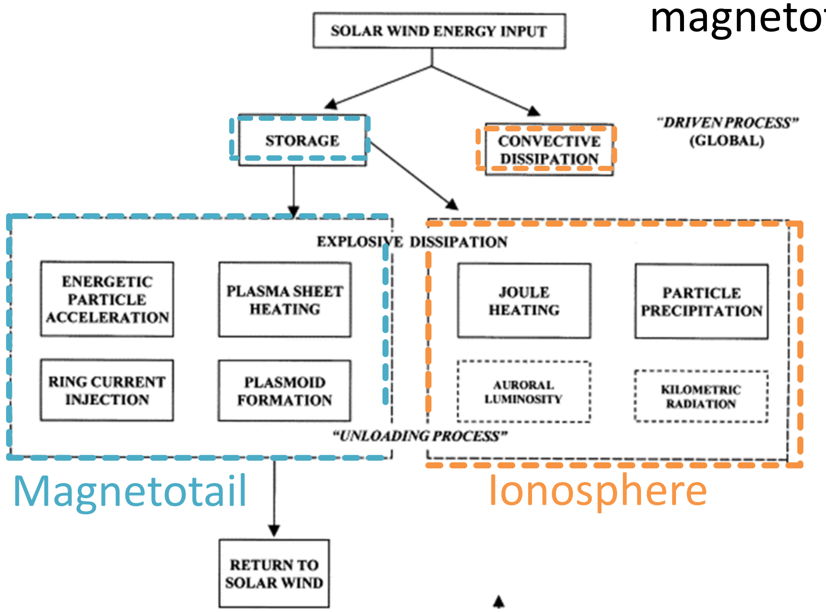
- **Sufficiently increasing ring current**
- **Phases: initial, main, recovery**



Role of Magnetotail

Substorm phenomena related to the magnetotail

- Clear role of energy storage
- **Growth**: storage
- **Expansion**: explosive dissipation/ „unloading“



Baker+, 1997, JGR, https://doi.org/10.1029/96JA03961

Energy Budgets

- Solar wind energy transformed into thermal and kinetic energy

Table 1. Geospace Energy Budgets

Entry rates	
Incident solar wind	10^{13}-10^{14} W
Coupled to magnetosphere	10^{11}-10^{12}
Storage (energy)	
Magnetotail	10^{15}-10^{16} J
Ring current	10^{15}-10^{16}
Transport and loss rates	
Ring current injection	10^{11}-10^{12} W
Ionospheric Joule heating	10^{10}-10^{11}
Auroral precipitation	10^{9}-10^{10}
Auroral luminosity	10^{8}-10^{9}
Auroral kilometric radiation	10^{7}-10^{9}
Plasmoids	10^{11}-10^{12}
Total energy dissipation	
Substorms	~3 x 10^{15} J
Major storms	>8 x 10^{16} J

Baker+, 1997, JGR, https://doi.org/10.1029/96JA03961

Intensivication of Currents

- different sources of the geomagnetic field have widely different response and decay times
- storm-time symmetric ring current requires at least several hours to build up and decays on the timescale of at least one or two days
- magnetotail current varies much faster (only a few minutes for SW pressure pulses)

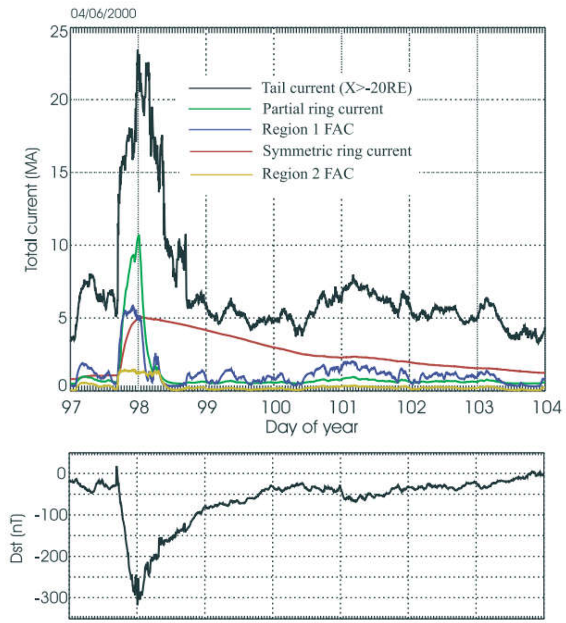


Figure 1. (top) Variation of the total current in the five principal current systems during the storm of 6–10 April 2000. (bottom) Concurrent variation of the *Dst* index during the event.

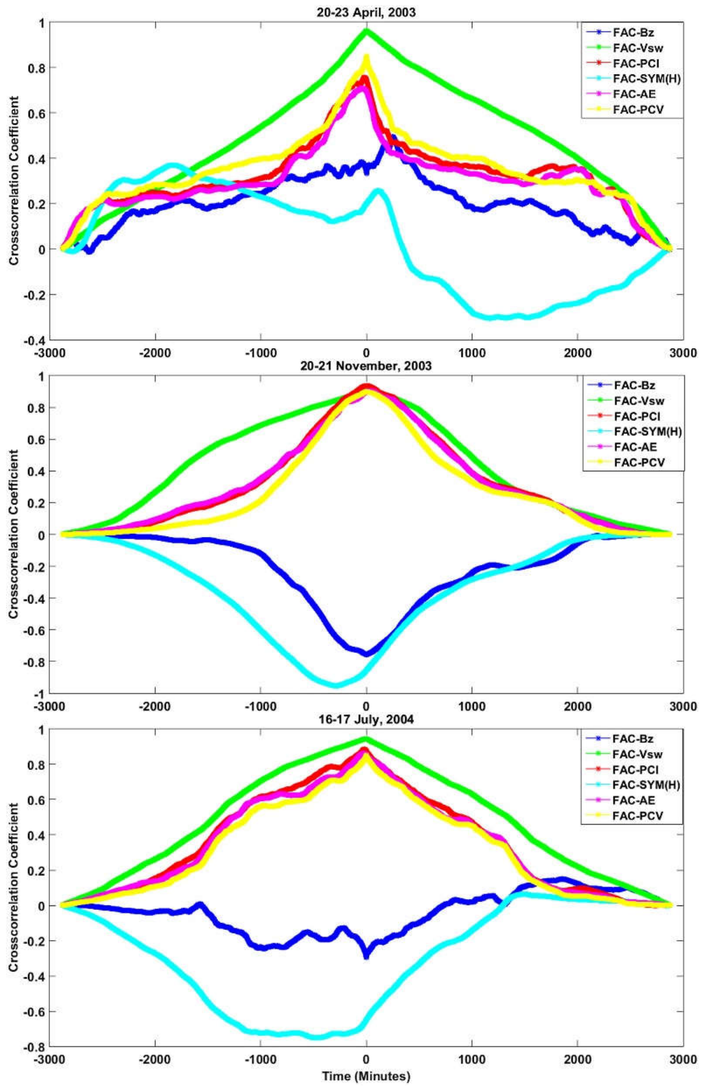
Tsyganenko & Sitnov (2005, doi:10.1029/2004JA010798)

FAC intensification

- Whenever the solar wind electrons are accelerated downward or upward in the polar cap there must be distinct variation of FAC and PCV accordingly. →high and positive correlation between FAC and PCV (yellow)

$$\mathrm{PCV} = \left[V_{sw} B_t \sin^2\frac{\theta}{2} \times 7\mathbb{R}e\right]\ (\mathrm{mV/m})$$

$$\mathrm{FAC} = 0.328\left[np^{\frac{1}{2}} V_{sw} B_T \sin\left(\frac{\theta}{2}\right)\right]^{\frac{1}{2}} + 1.4.$$



[Adhikari+ (2018) https://doi.org/10.1029/2018EA000392](https://doi.org/10.1029/2018EA000392)