Global magnetic flux content of the magnetosphere during magnetic storms

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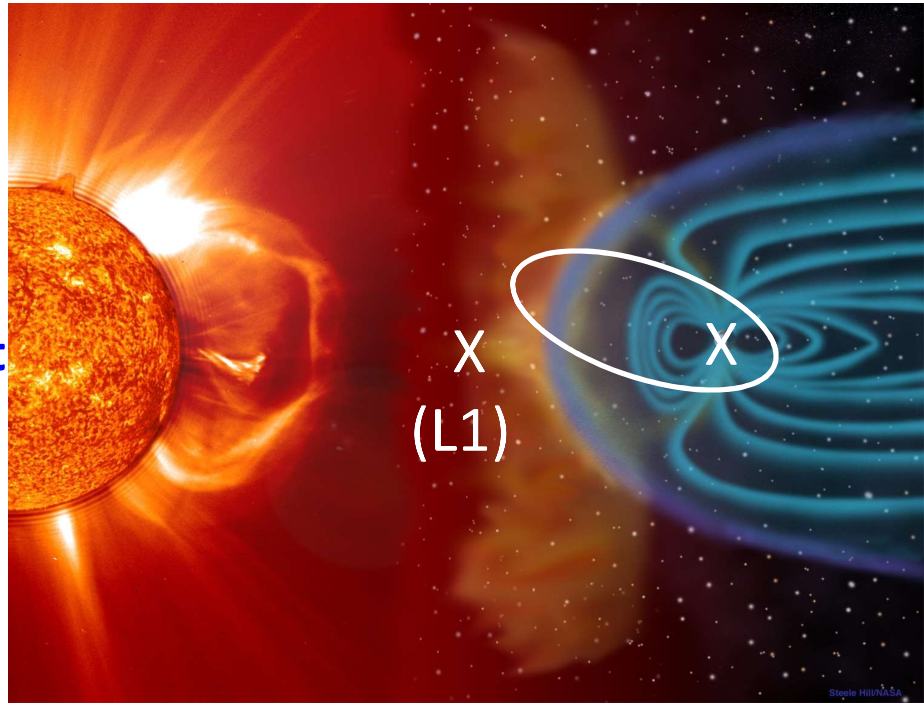
Impact of Solar Events



Solar wind & events : Continuous monitoring at L1:

(satellites ACE, WIND, …)

Magnetosphere : observations from orbiting spacecraft

(multi-spacecraft missions: Cluster THEMIS, MMS, …)

→ But no continuous coverage of crucial regions:

- boundaries: bow-shock, magnetopause
- magnetosheath plasma,
- magnetospheric plasma reservoirs: plasmasheet, ring current, …
- connections with the ionosphere: field-aligned currents, …

Impact on magnetosphere / ionosphere inferred from the only available monitoring :

→ Magnetic field variations from **ground-based magnetic stations**

→ Magnetic indices used as proxies for iono-/magnetospheric currents :

SYM-H[6] / Dst[4] : Disturbance Storm Time (equatorial currents)

< -50 nT: moderate storm

< -100 nT: intense storm

Other indices:

PC[2] (polar cap),

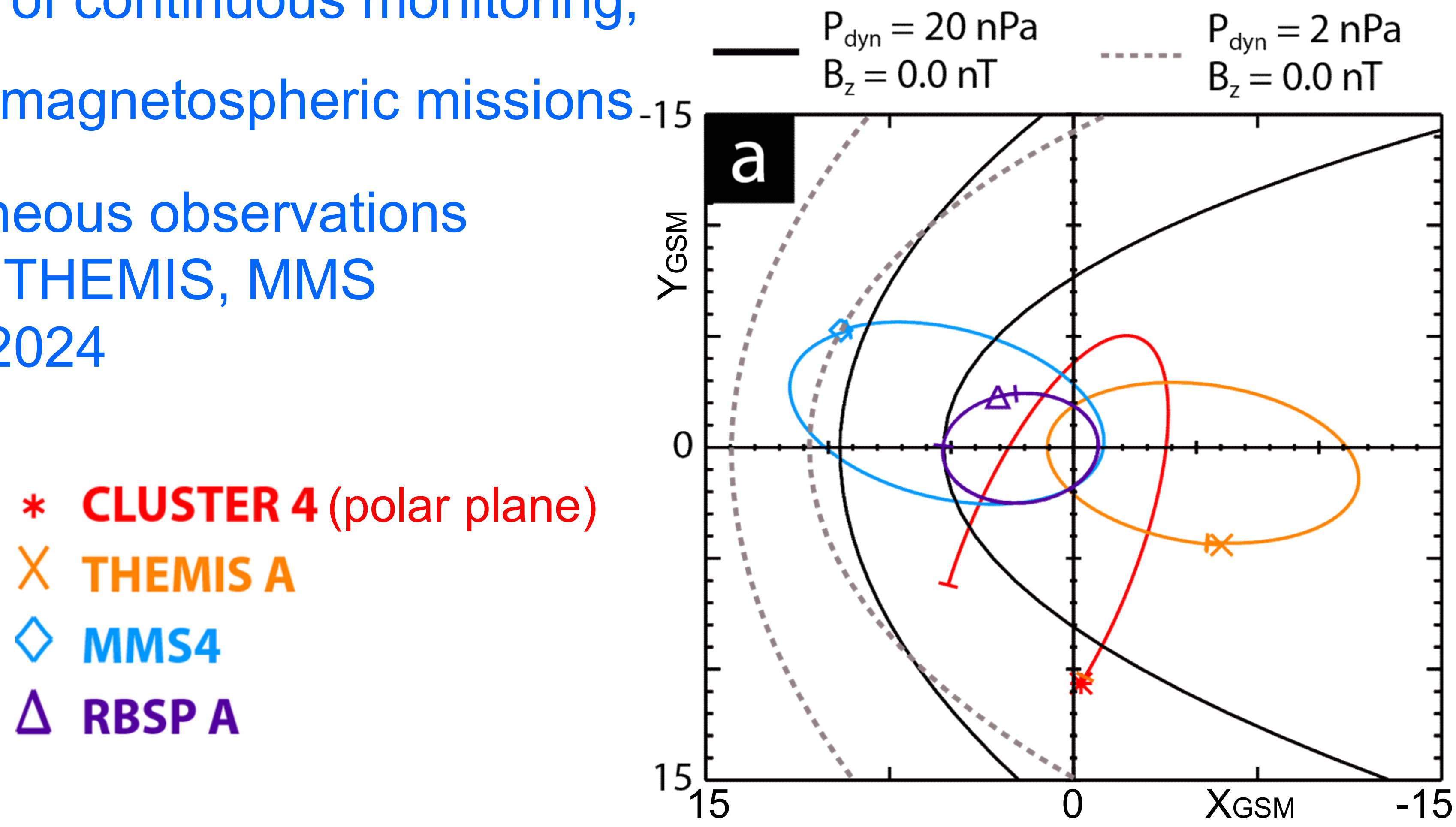
AE[12] (auroral electrojet),

Kp[13] (middle latitudes)

In absence of continuous monitoring,

→ Several magnetospheric missions

→ Simultaneous observations
Cluster, THEMIS, MMS
2015 - 2024



Equatorial plane

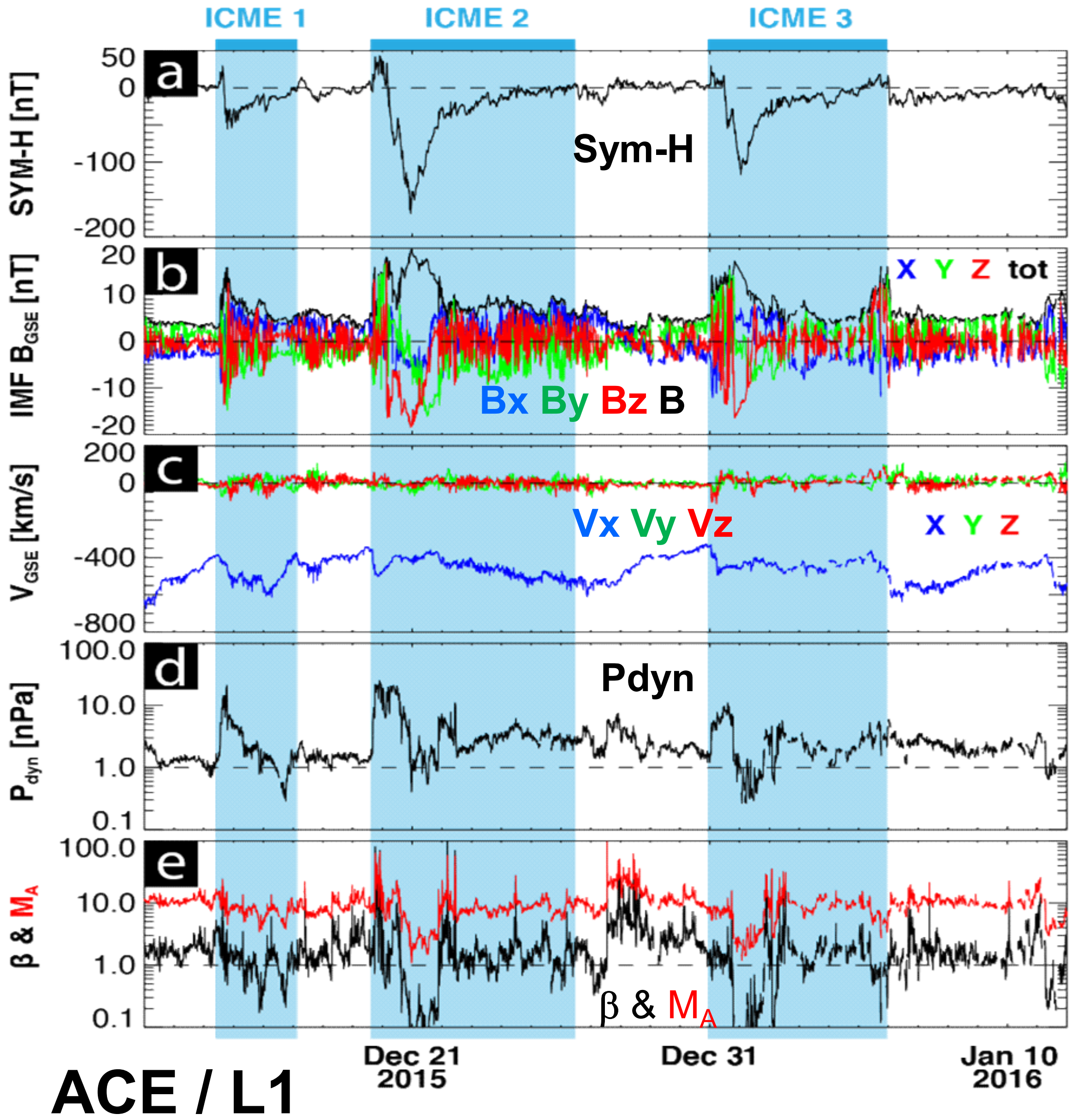
Case of intense magnetic storms :

minimum SYM-H < 100 nT

Triggered by Coronal Mass Ejections

(ACE observations)

- Large and rotating magnetic fields (magnetic clouds)
- Large velocities: 400 → 600 km/s
- Enhanced pressure (magnetic sheaths)
- Low MA and low β

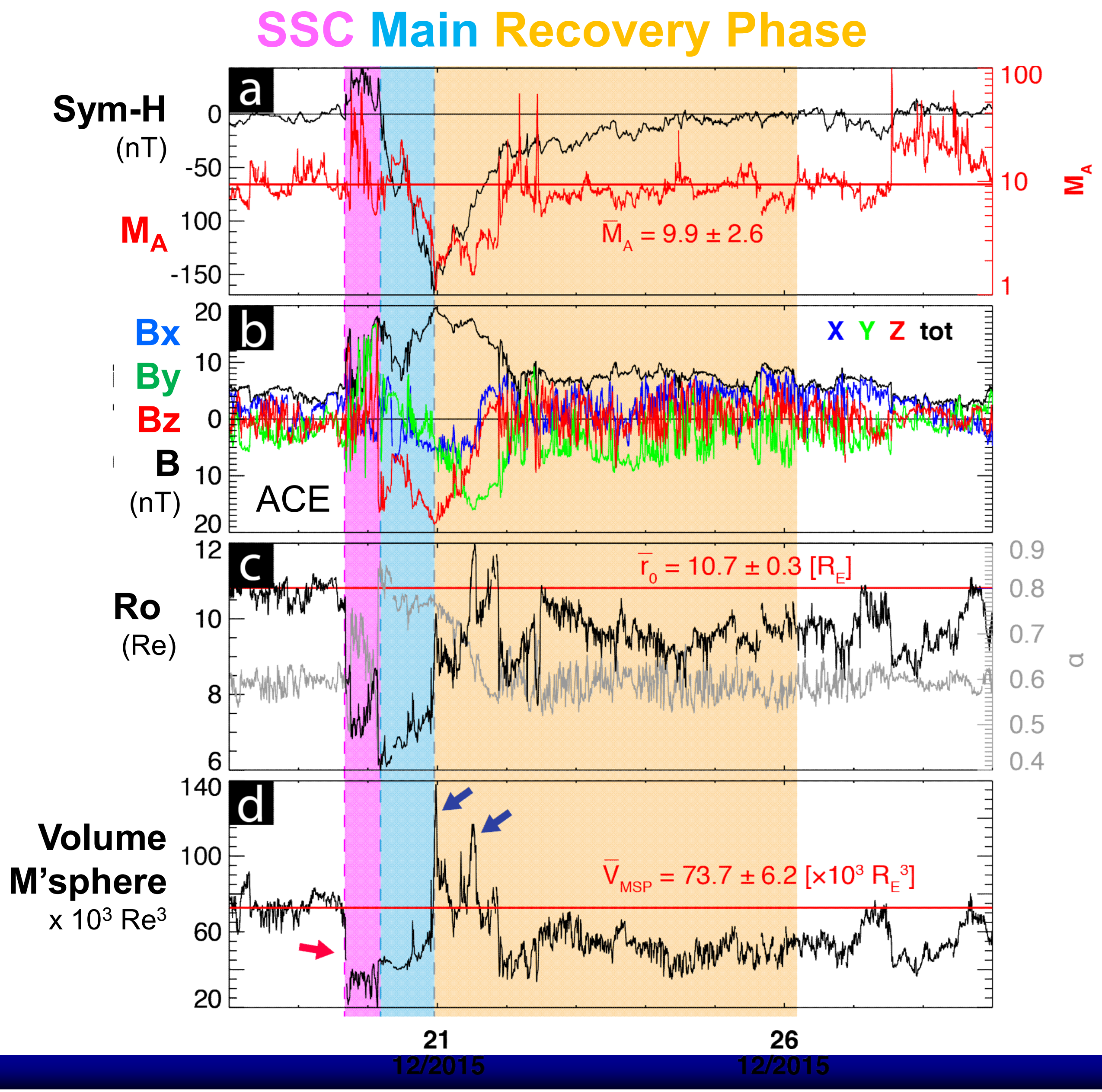


Impacts on the **dayside magnetosphere**

MMS, GOES, RBSP, Cluster

Subsolar magnetopause compressed from Ro ~11 Re to Ro ~ 6 - 7 Re during SSC & main phase at 10.8 Re/h for 10 min

Magnetosphere volume reduced by 40 %

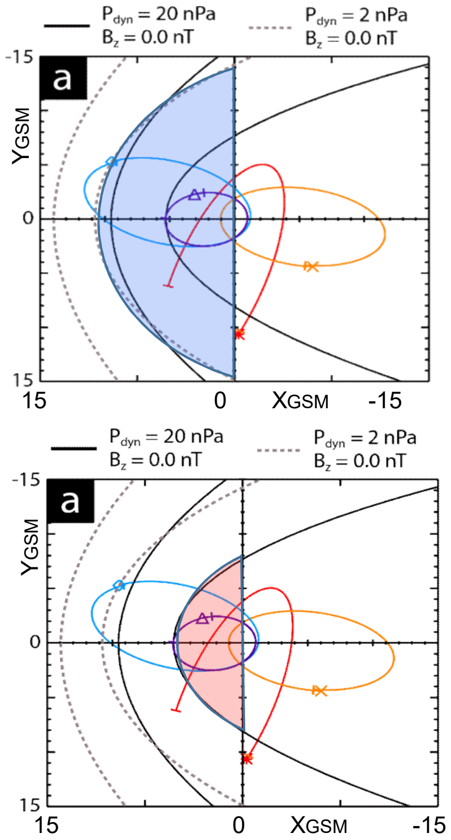


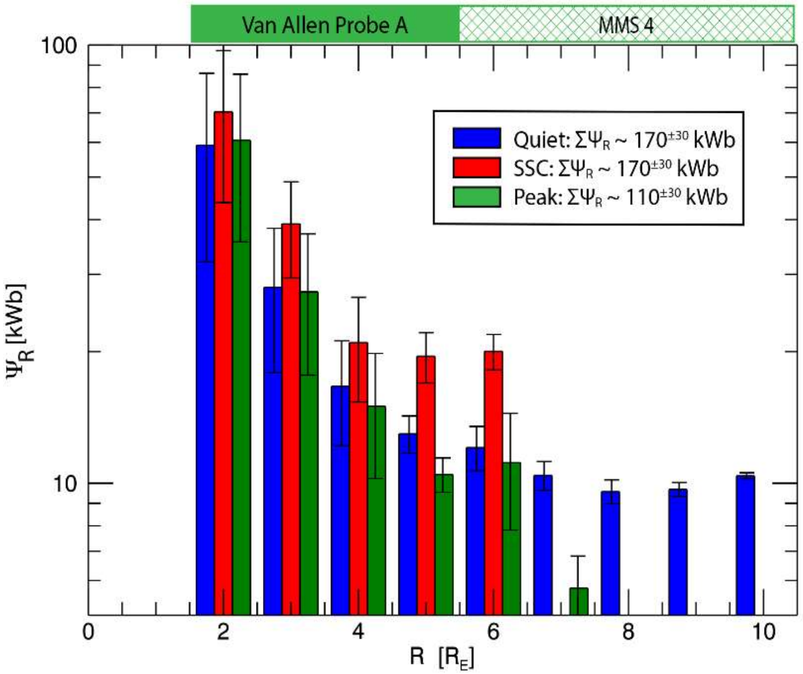
Variations of the magnetic flux content of dayside magnetosphere

$$\Phi = \iint \vec{B} . \overrightarrow{dS}$$

B = Bz in the equatorial plane
dS: equatorial surface of magnetic shells (~ circular rings on dayside)

- SSC: strong compression of the magnetosphere without magnetic flux loss
- Storm Peak (min SYM–H): magnetosphere still compressed but loss of magnetic flux





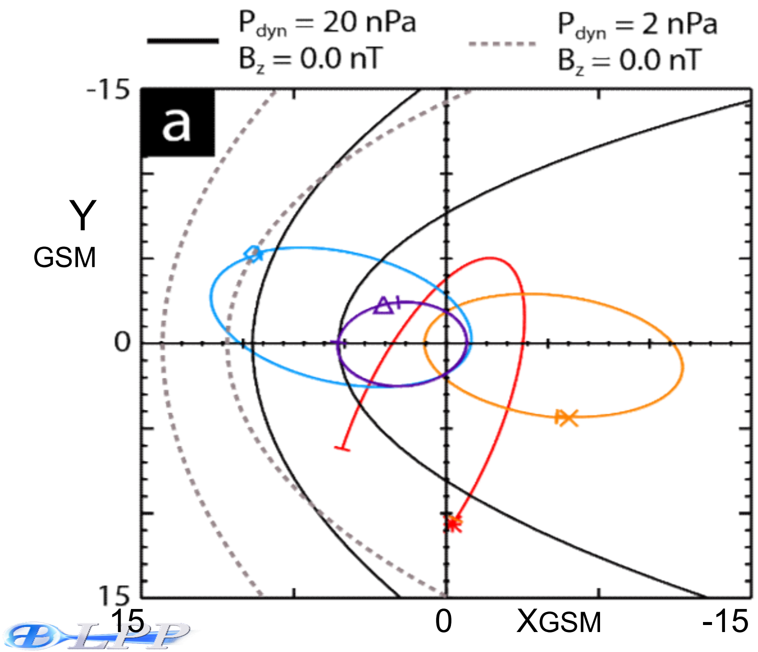
Suggestions:

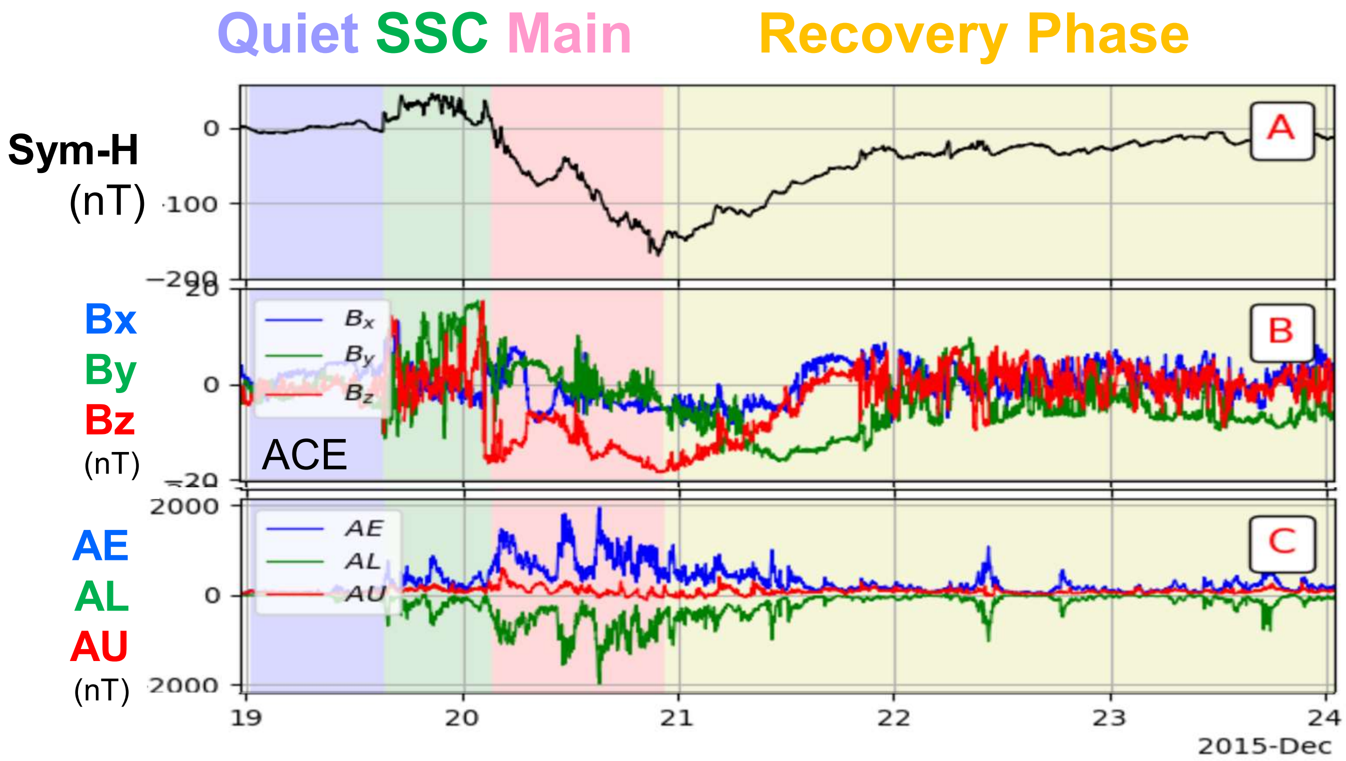
On-going reconnexion processes ?

Unbalanced flux replenishment due to the time lag of convection cycle ?

(Akhavan-Tafti et al., 2020, 2023)

Nightside Magnetosphere ?



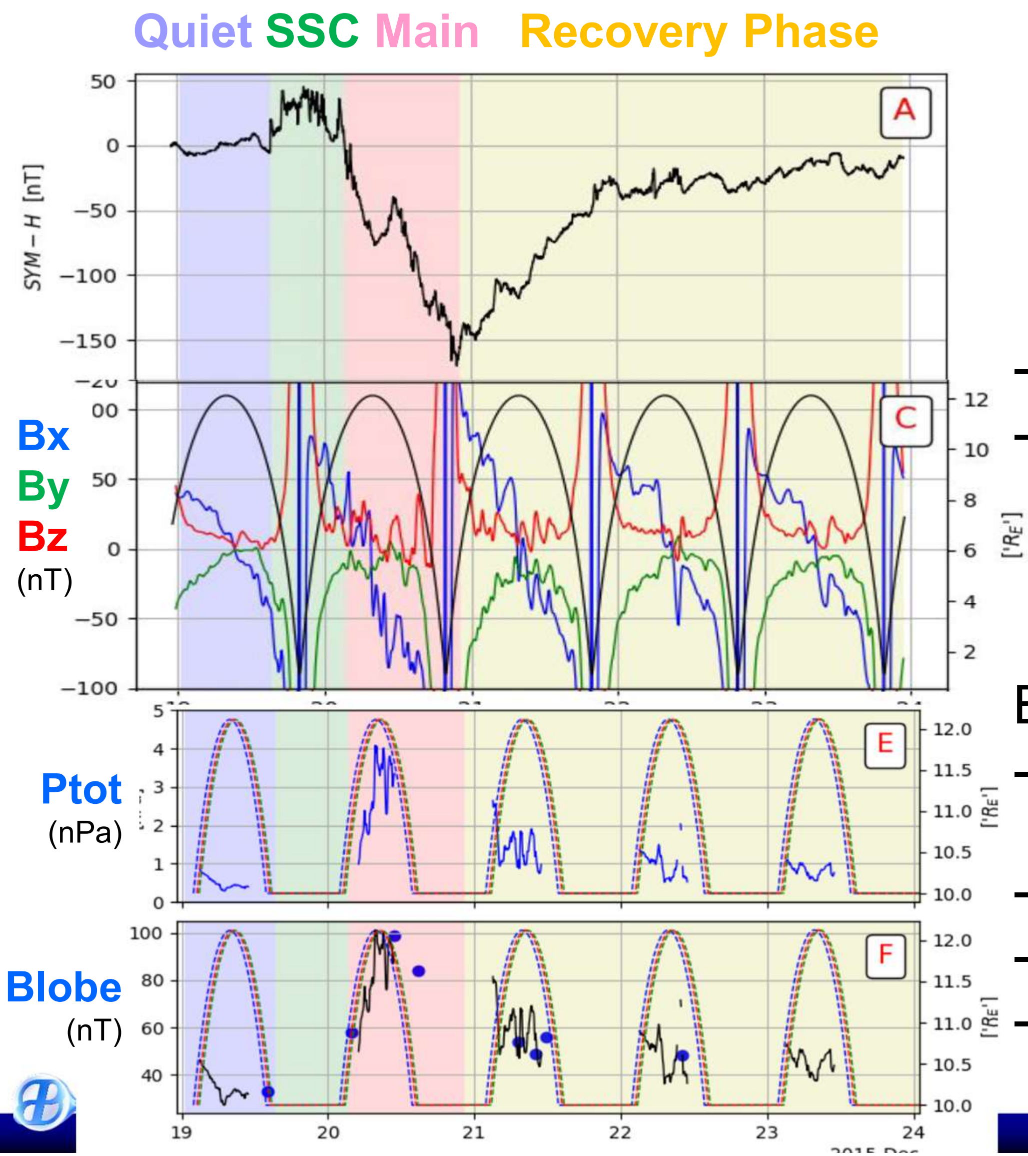


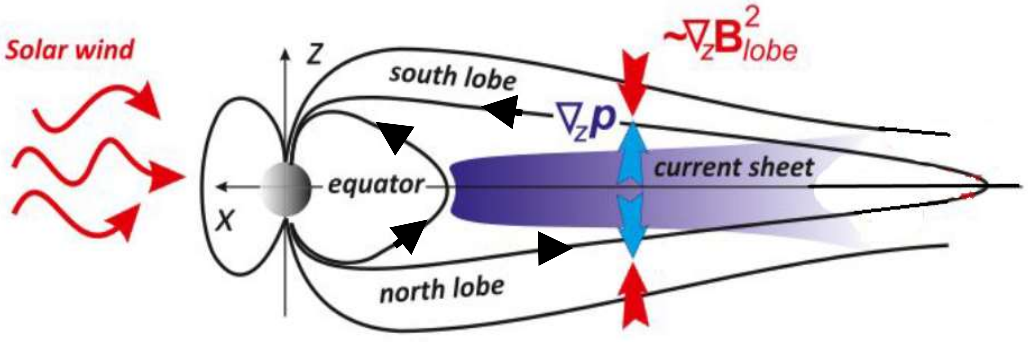
Peaks in auroral indices :

→ Geomagnetic activity, substorms in plasmasheet, main magnetospheric plasma reservoir

→ THEMIS Observations

Nightside plasmasheet from THEMIS data





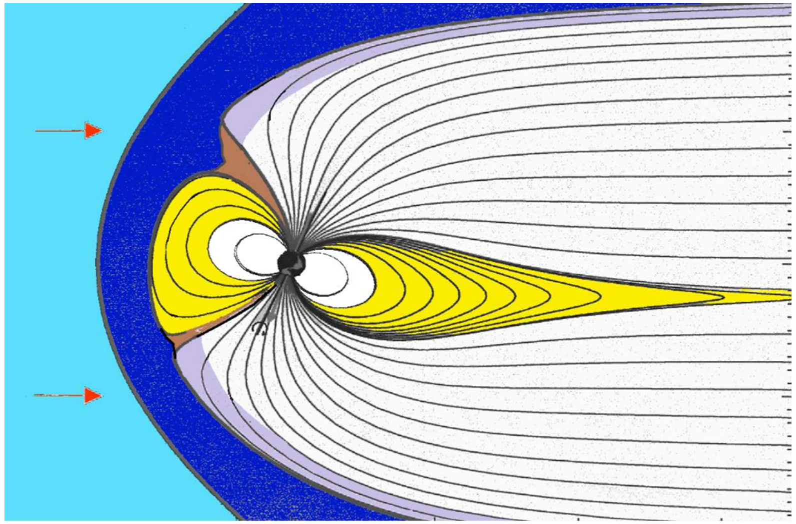
- Many and large B fluctuations
- Occasional exits outside of the plasmasheet
  - → disturbed situation,
  - → instabilities, plasmasheet thinning
  - → triggering of substorms

Estimation of :

- Total plasmasheet pressure
  (enhanced by a factor of 5 during main phase)
- Lobe magnetic pressure exerted on plasmasheet
- Lobe magnetic field,
- Plasmasheet thickness, …

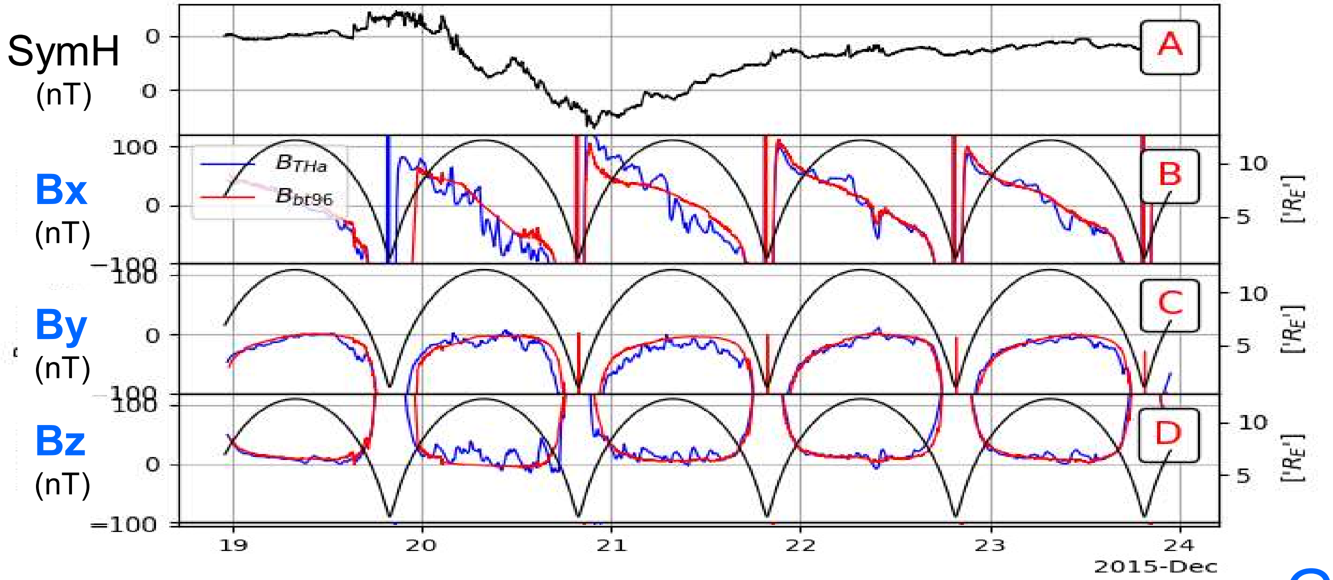
→ See poster by S. Alqeeq et al.

Evolution of the magnetic flux content in magnetic shells during the crossing of solar events



Nightside, magnetic shells cannot be approximated by circular rings

Complementary inputs from magnetic field models ?

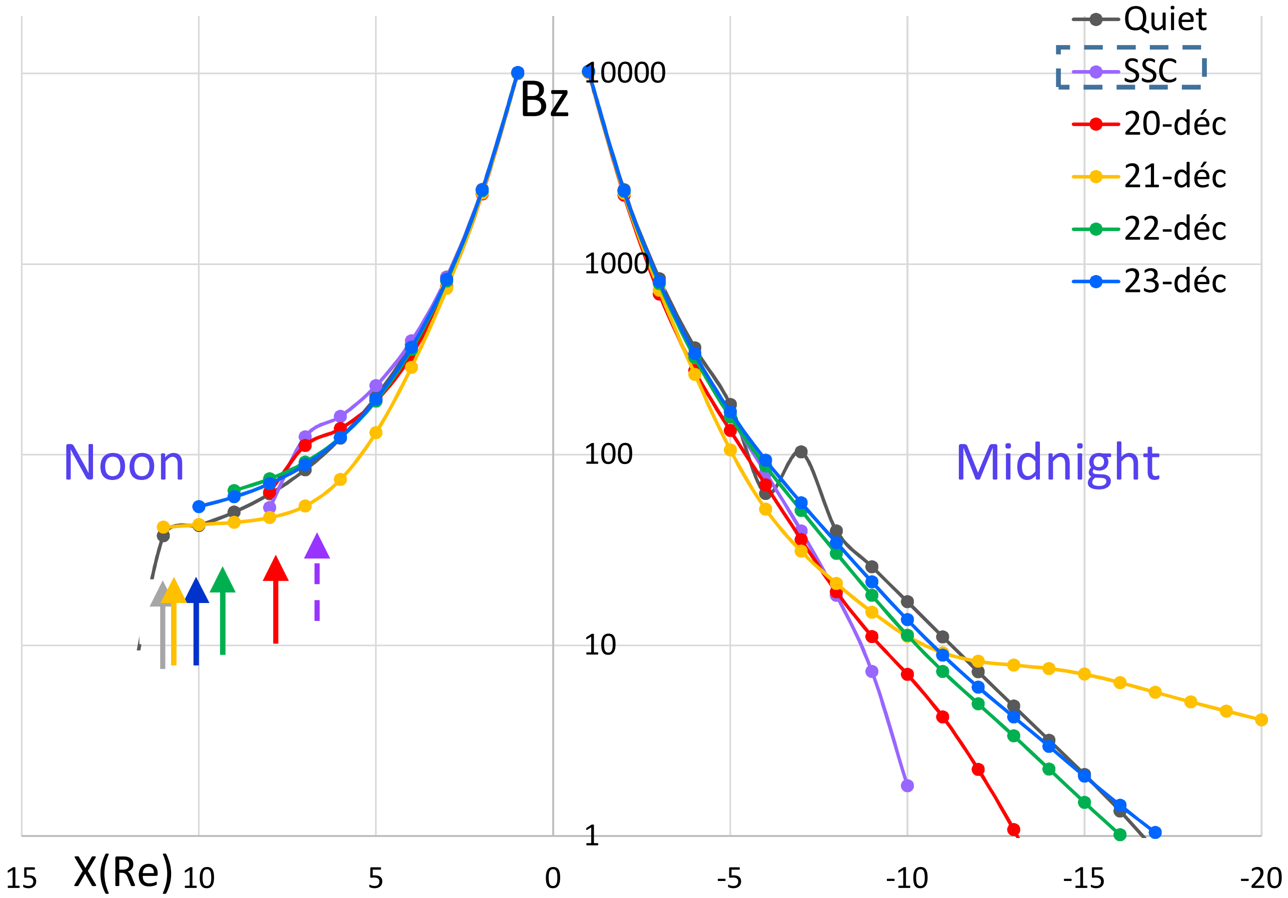


___ THEMIS A magnetic field

___ Tsyganenko model (T96) [Psw, Dst, IMF (By,Bz)]

Good agreement data / model !

Magnetic field model (T96) averaged over 3h (around THEMIS apogee)



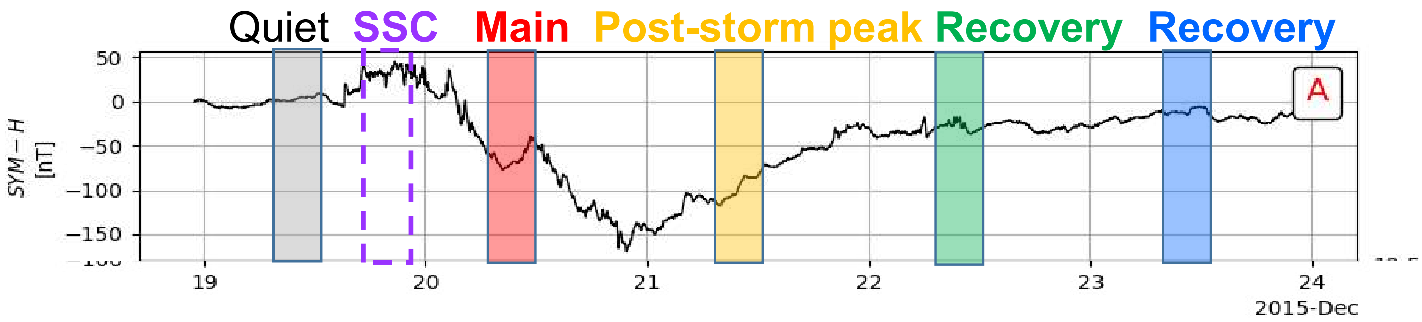
On the **dayside:**

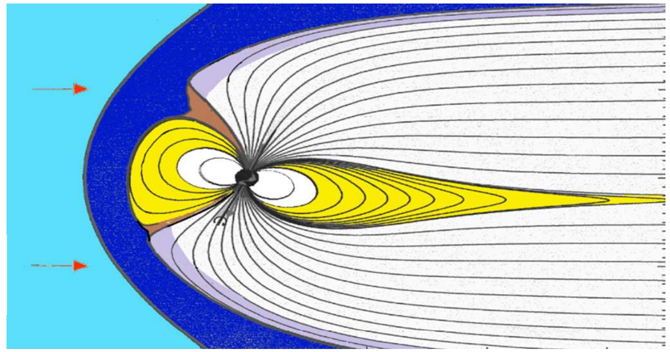
- Compression of the dayside magnetosphere to shorter distances: 11 Re → 6-8 Re
- Higher Bz

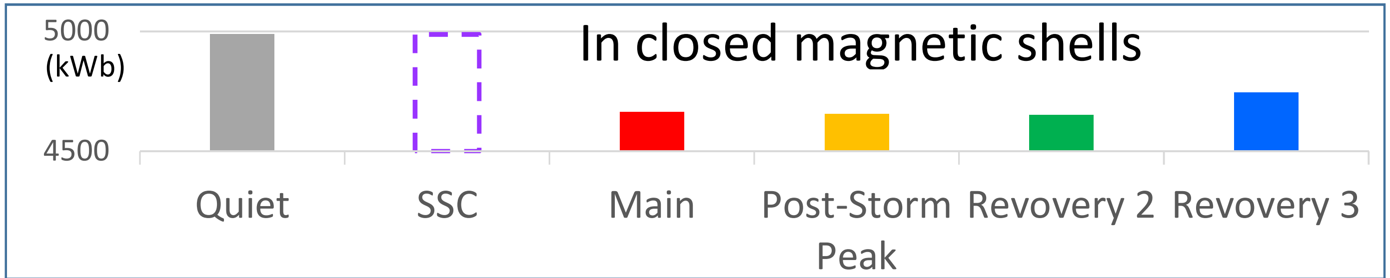
On the **night-side**:

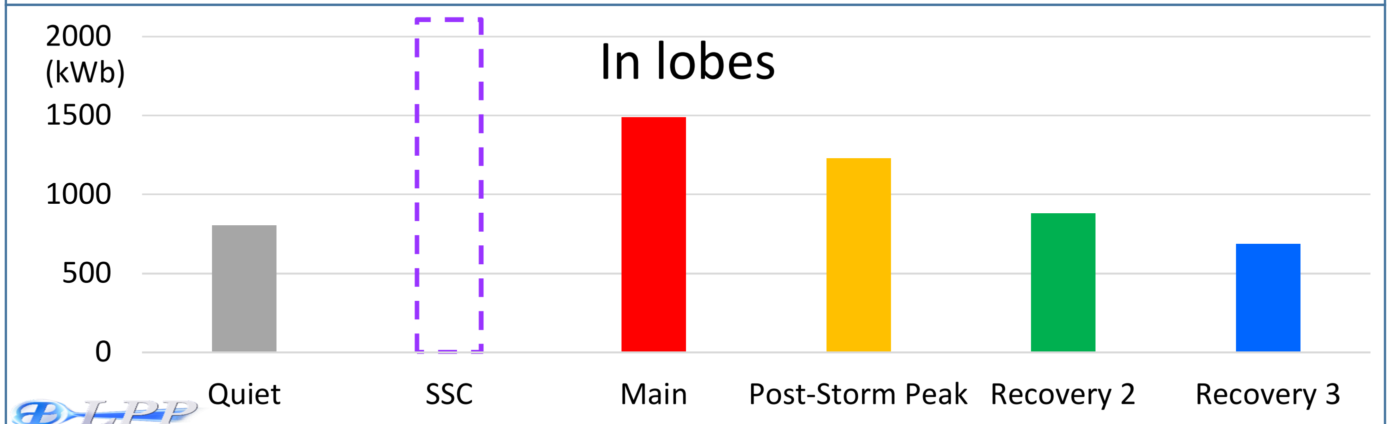
- Steeper Bz decrease due to cross-tail currents
- Closed magnetic shells closer to Earth

First estimates of the magnetic flux content during magnetic storm (TBC)









Closed magnetic shells:

- Large magnetic flux content (inner field)
- No variation at SSC
- Small flux loss afterwards

Lobes (open field lines):

- Small flux content at quiet time
- Large increase at SSC and Main
- Flux loss afterwards

Magnetospheric dynamics during magnetic storms

Contribution of *in-situ* measurements in addition of magnetic indices deduced from ground-based stations and commonly used for Space Weather studies.

Several missions (Cluster, THEMIS, MMS,…) in the magnetosphere (2015 – 2024)

→ Good opportunity to have one mission in a crucial region during events

→ Focus on the case of intense magnetic storms, triggered by ICMEs

→ Characterization of the boundary motions and plasmasheet dynamics

Plasmasheet compression and estimation of the lobe magnetic field

Estimation of the plasmasheet thickness, …. → *see poster by S. Alqeeq et al.*

→ Estimation of the variation of the magnetic flux content during the storms (study in progress)

- In closed magnetic shells: compression of magnetic shells
  loss of magnetic flux content from main phase
- In the lobes: large enhancement of magnetic flux content from the storm beginning
  regular decrease afterwards

→ Extend to more cases (to be done)