Quantitative estimates of the magnetic flux variations in the inner magnetosphere during an intense storm

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Motivations

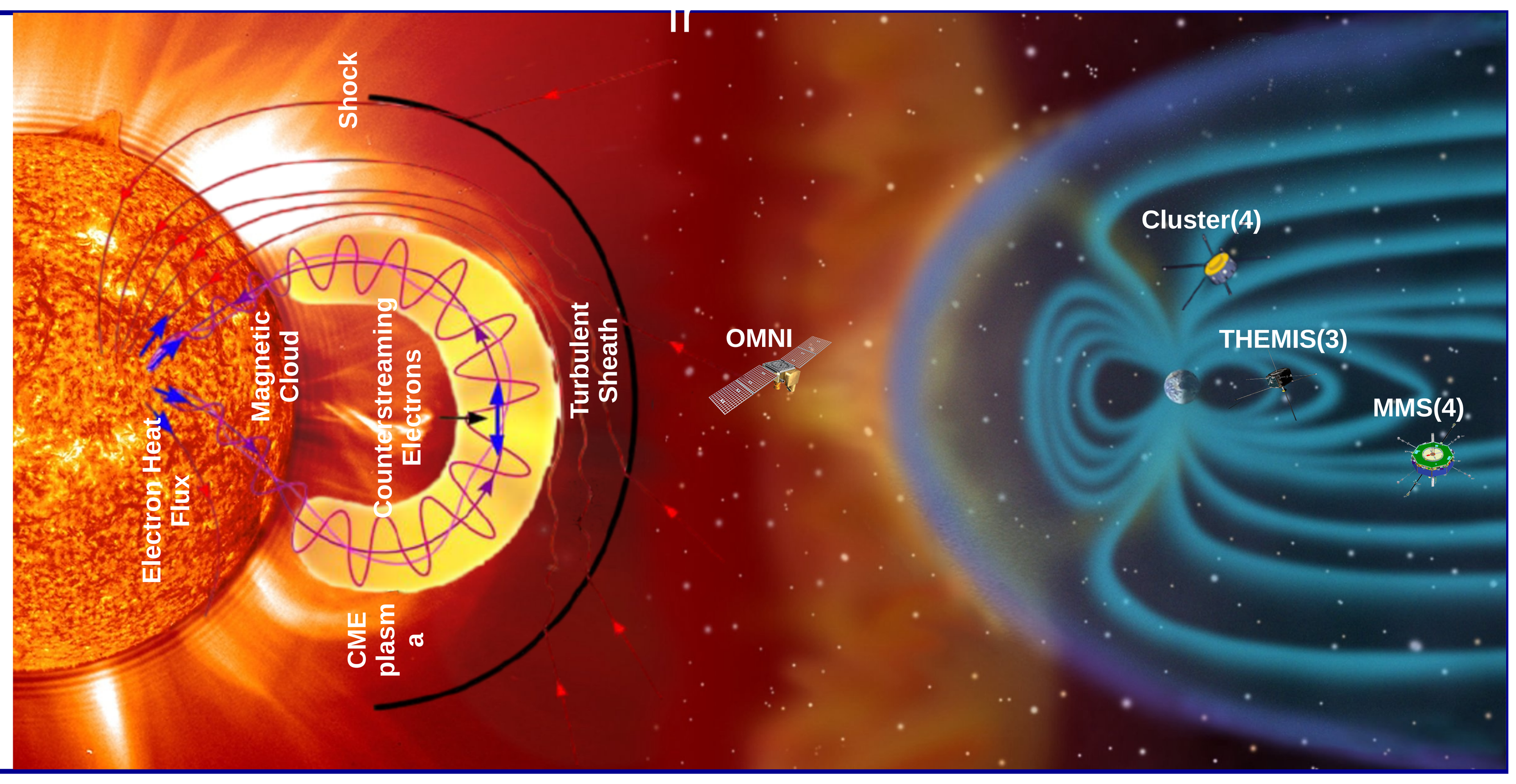
- Solar storms disturb the magnetosphere and menace satellites and communications.
- Their impact on the different parts of the Sun-Earth system is poorly understood and in particular on the different regions the magnetosphere.

Questions

- What is the impact of solar storms on the inner magnetosphere?
- How could it be quantified for space weather predictions?

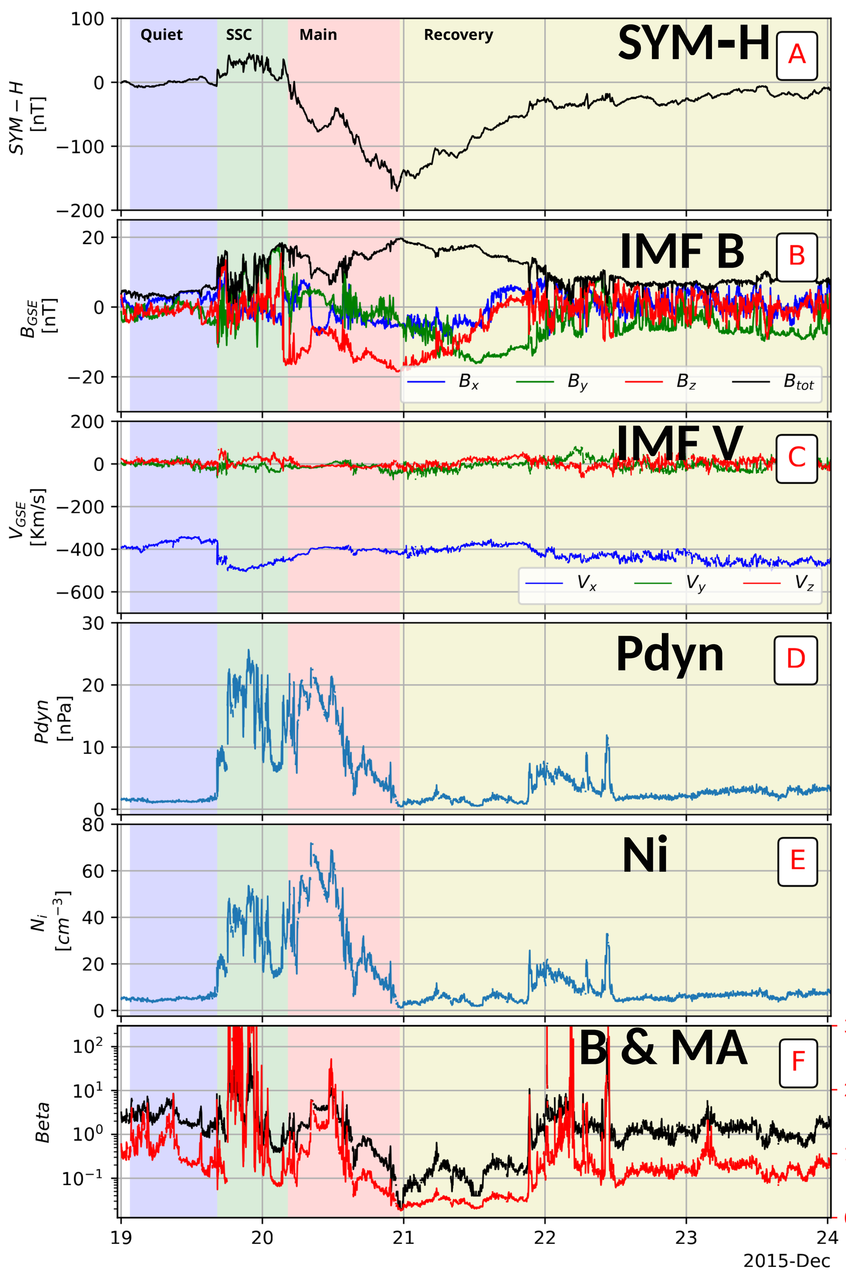
Goals

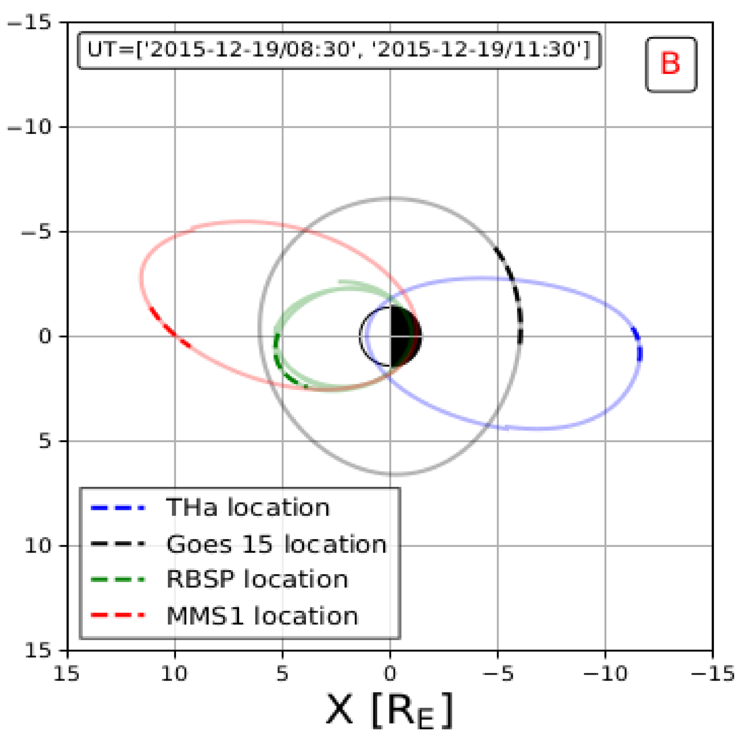
- Estimate the magnetic flux content in the inner magnetosphere and its variations during an intense magnetic storm triggered by an interplanetary mass ejection.



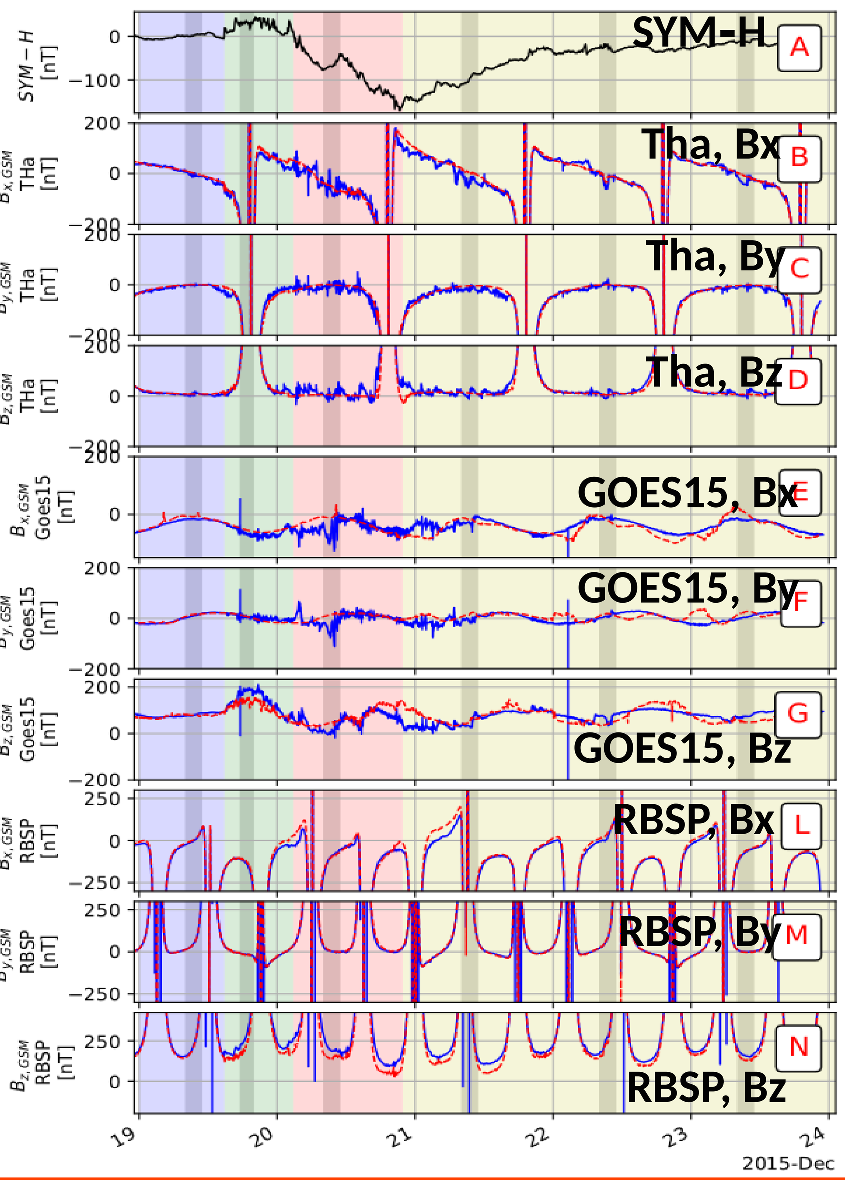
Observations

- ICME, 19-24/12/2015
- OMNI, IMF B ~20 nT
- OMNI, Pdyn ~20 nPa, Ni ~70 cm^3
- SYM-H is magnetic index computed from ground based stations.
- Intense Storm SYM-H<-150 nT
- The storm intervals are marked with the quiet region, Storm Sudden Commencements (SSC), main phase, and recovery phase shades.
- THEMIS (A, E, and D), in the tail.



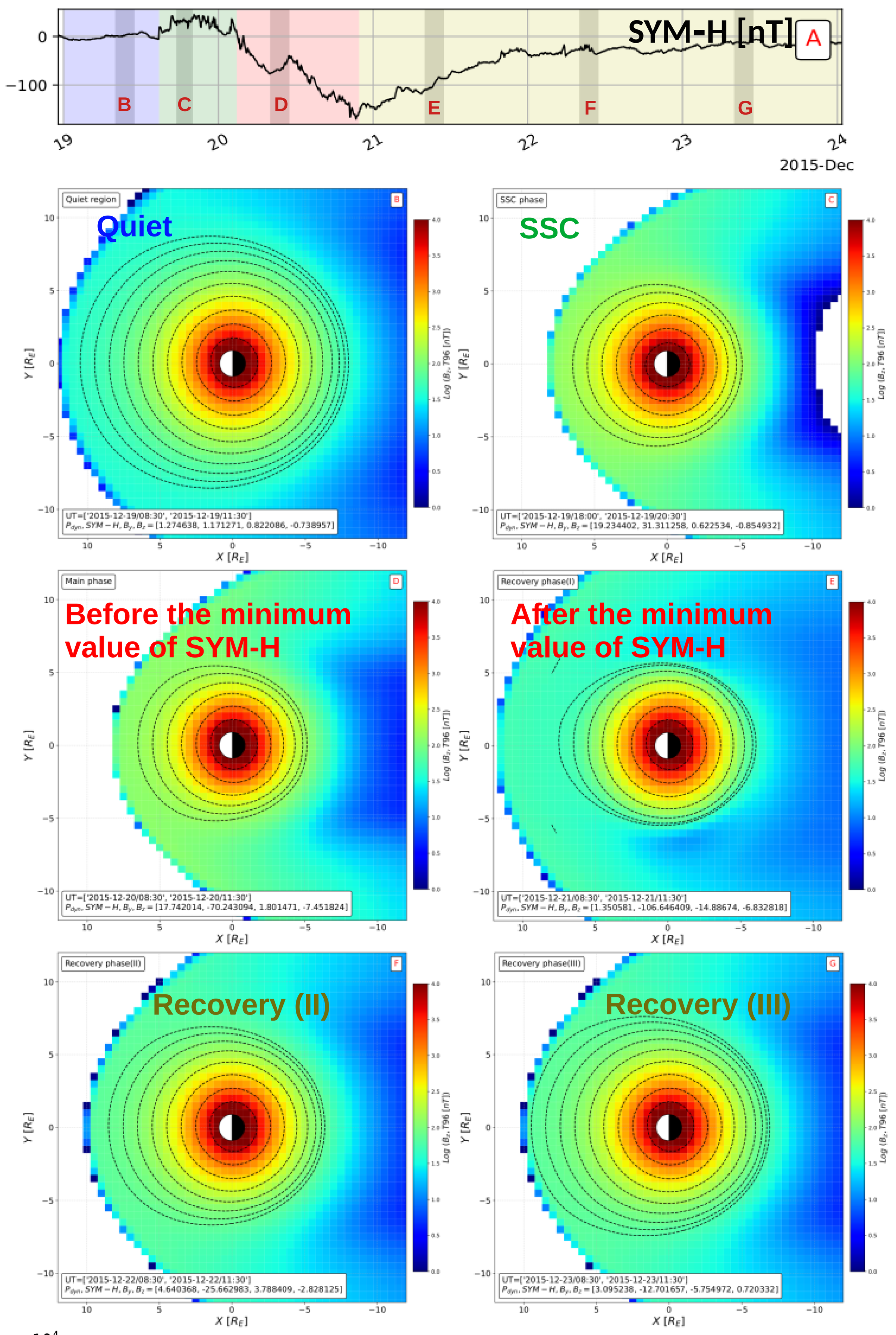


- The different spacecraft (THEMIS, GOES, Van Allen Probes, MMS) cover a large area in the magnetosphere.
- A comparison of the observed magnetic field components from THEMIS A, GOES 15, and RBSP (blue) with the Tsyganenko T96 model field (red) demonstrates good agreement for all components and all spacecraft.



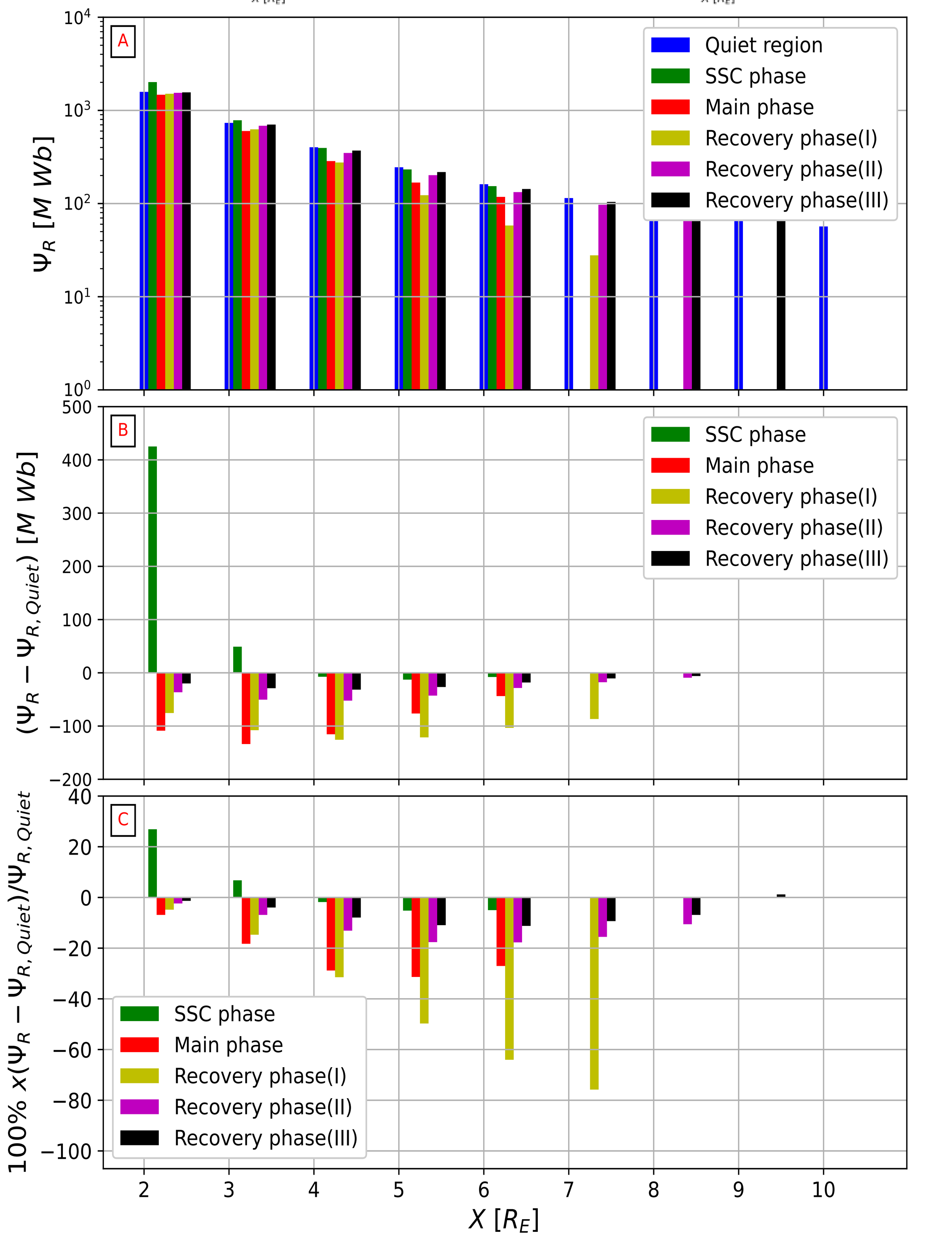
Equatorial cross section of the magnetic shells lines

- These maps represent the intensity of the vertical component of the magnetic field (Bz) from the T96 model. The drift shells of equatorial energetic particles have been superimposed onto these maps to illustrate their evolution during the different phases of the geomagnetic storm from 19 to 24 December 2015.
- Relative to the quiet phase, these panels show a strong compression of the magnetosphere during the SSC and main phase which progressively expands again during the recovery days.



The total Magnetic Flux Content (MFC) variations in closed magnetic shells

- The magnetic flux content (MFC) Ψ_R values for each ring, defined with a width of 1 RE between successive drift shells, are presented as a function of the average geocentric distance along the Xgsm-axis at local noon.
- For all phases, the magnetic flux content decreases with the distance from about 1.6 GWb at the first ring at 2 R_E by a factor of about 30 to less than 60 MWb at the last ring at 10 R_E at noon.



Conclusion

- Contribution of **in-situ measurements** in addition of magnetic indices deduced from **ground-based** stations and commonly used for **Space Weather** studies.
- we got a very good case of observations of the magnetospheric impacts of a magnetic storm with different spacecraft in different regions of the magnetosphere. Good agreement data (**THEMIS, GOES, Van Allen Probes**) with **Tsyganenko model (T96)** model, so that we used it to described the whole inner magnetosphere.
- During the **SSC**, the magnetosphere experienced a **sudden compression** from a high-pressure solar event, causing a large MFC **increase** of ~425 MWb (27%) at the innermost region (2 R_E).
- In the main and recovery phases, the flux **decreased** significantly, reaching -134 MWb and -125 MWb (33% and 76%) at 5 R_E and 7 RE, likely due to intensified cross-tail currents in the nightside plasma sheet penetrating inward to 4–5 R_E.
- Good agreement with **previous studies focused on the dayside** (Atilaw et al., 2024; Akhavan Tafti et al., 2023, 2020).