INTERACTION OF MAGNETIC CLOUDS WITH THE TERRESTRIAL BOW SHOCK : IMPLICATIONS ON THEIR GEOEFFECTIVITY

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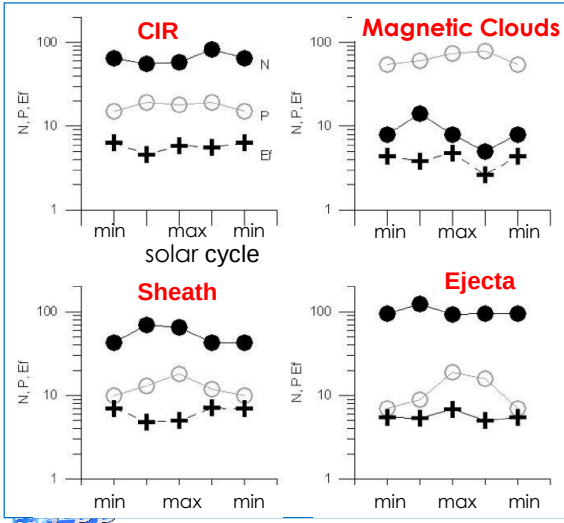
Geoeffectiveness of magnetic clouds

Statictics from OMNI database 1976 – 2000 at 1 AU

~ 800 events (Yermolaev et al., 2012)

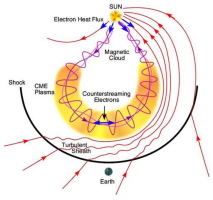


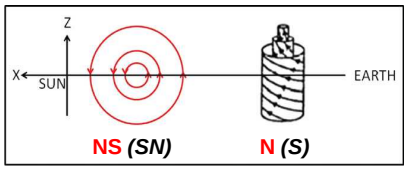
- Number of events
- Geoeffectiveness
  = probability of a relation between phenomena
  = % events causing storms with Dst < -50nT

+ Efficency of storm generation
  = ratio output/input
  output = Dst, Kp, AE, ….
  input= IMF Bz, Ey, Pressure, …

CIR:Corotating Interaction Regions
ICME: MC, Ejecta and their sheath

1. **Magnetic clouds** : huge structures described as flux ropes



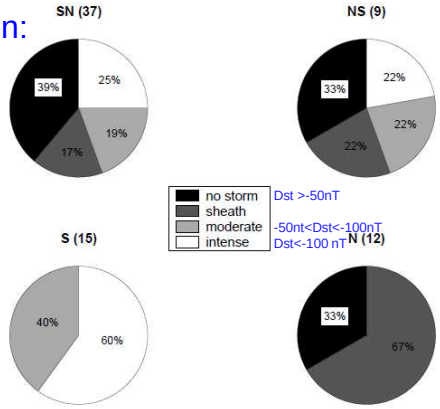


(Bothmer, Schwenn, 1998)

Geoeffectiveness versus orientation:

- storms for all S types:
  - IMF Bz < 0
  - favorable to geomagnetic activity
- but: storms for IMF Bz >0 (N)
  - role of the sheath ?
- but no storms for 33–40% NS - NS
  - role of shock on leading edge ?
  - role of fast wind on trailing edge (NS) ?

(Kilpua et al., 2012)

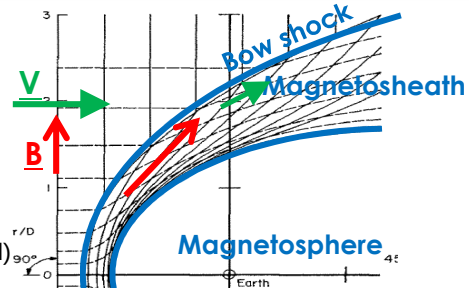


Question: Role of the Earth' bow shock ?

(Huttunen et al., 2005)

2. Role of the bow shock:

- decrease and deviation of the flow around the obstacle
- energy conversion

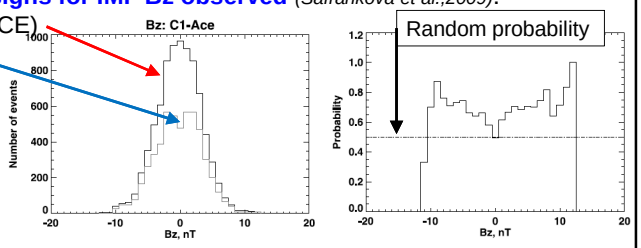


- **Consequences for geoeffectiveness:**
  Interaction of magnetosphere with magnetosheath plasma (not solar wind)

In magnetosheath,

- **B** increases and rotates: → Bz sign crucial for geomagnetic activity
- **V**: direction & amplitude modified → generation of surface waves (KH) → activity
- Ey = - (**V** x **B**)y → magnetospheric transport
- Turbulence, Heating, particle accelerations, asymmetries

- **Statistics on coincident signs for IMF Bz observed** *(Safrankova et al.,2009)*:
  - upstream of bow shock (ACE)
  - downstream (CLUSTER) (time shifted)

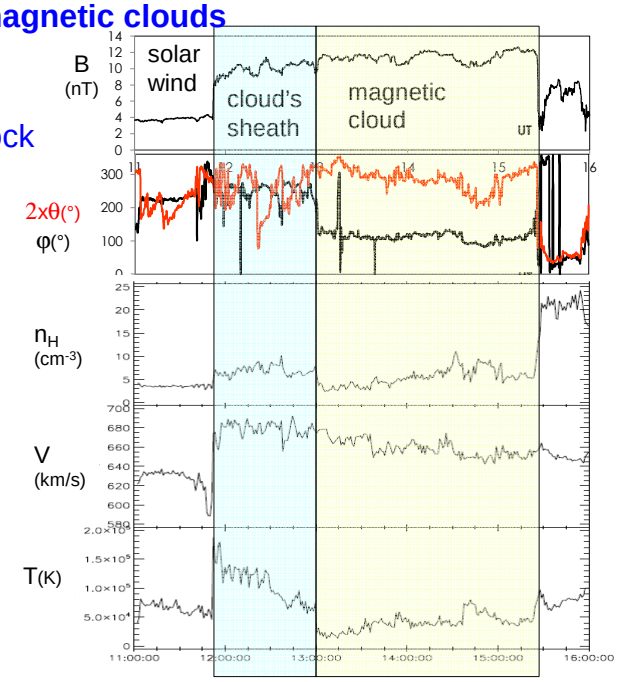


Probability between ~ 50 % and 80 %

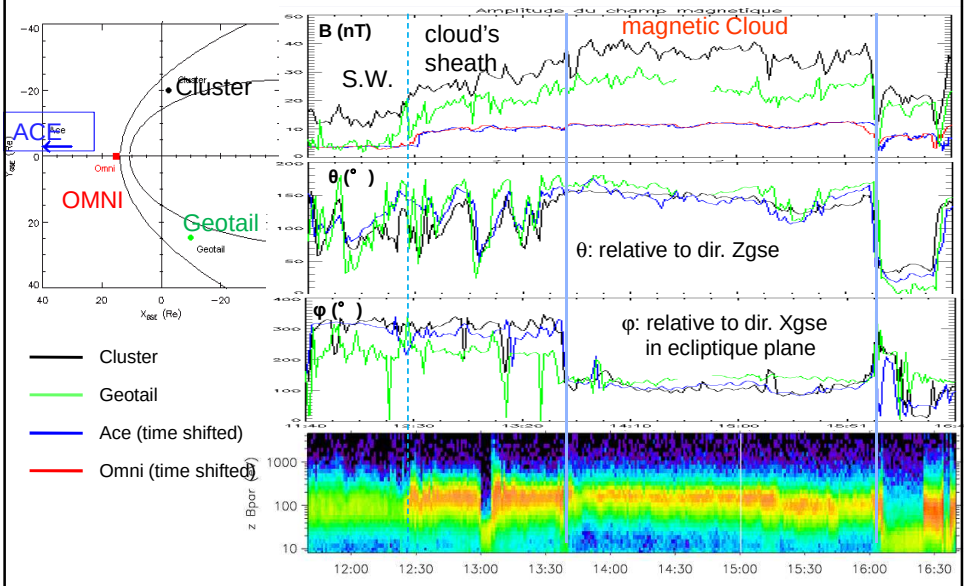
3. Observations of magnetic clouds

upstream of bow shock
(ACE: near L1)

- Enhanced magnetic field
- Smoothly rotating
- High speed
- Relatively weak n & T

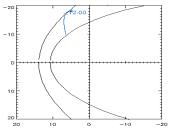


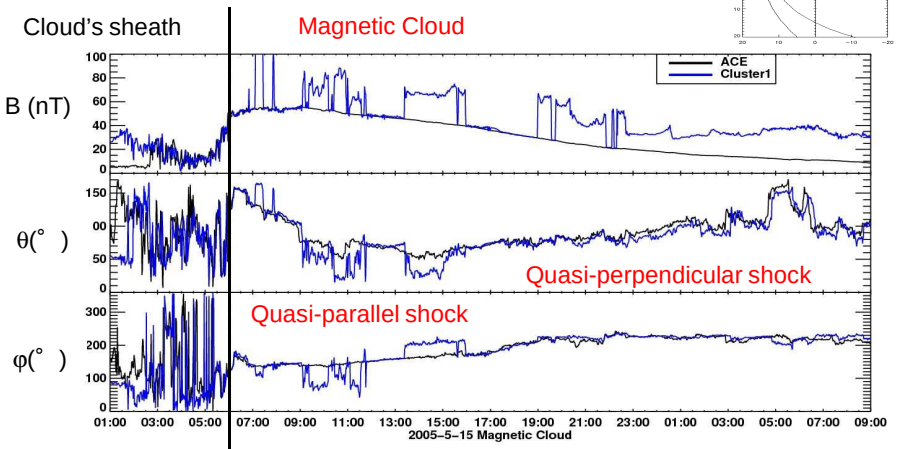
Comparison of cloud's structure up- and down- stream of bow shock



→ Cloud's magnetic structure almost unchanged downstream of the shock

Other events:





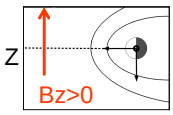
Multiple shock crossings:
Conditions at the shock from analysis of the shock normal (M.V.A. analysis)

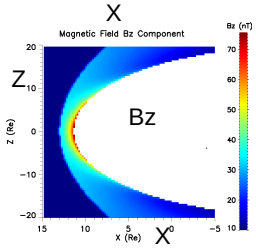
Quasi-perpendicular shock: cloud's structure almost unchanged

Quasi-parallel shock: large deviations

4. Simplified modelling of magnetosheath plasma

Turc, Fontaine et al., 2014 ; Turc, PhD thesis

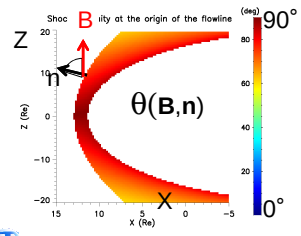


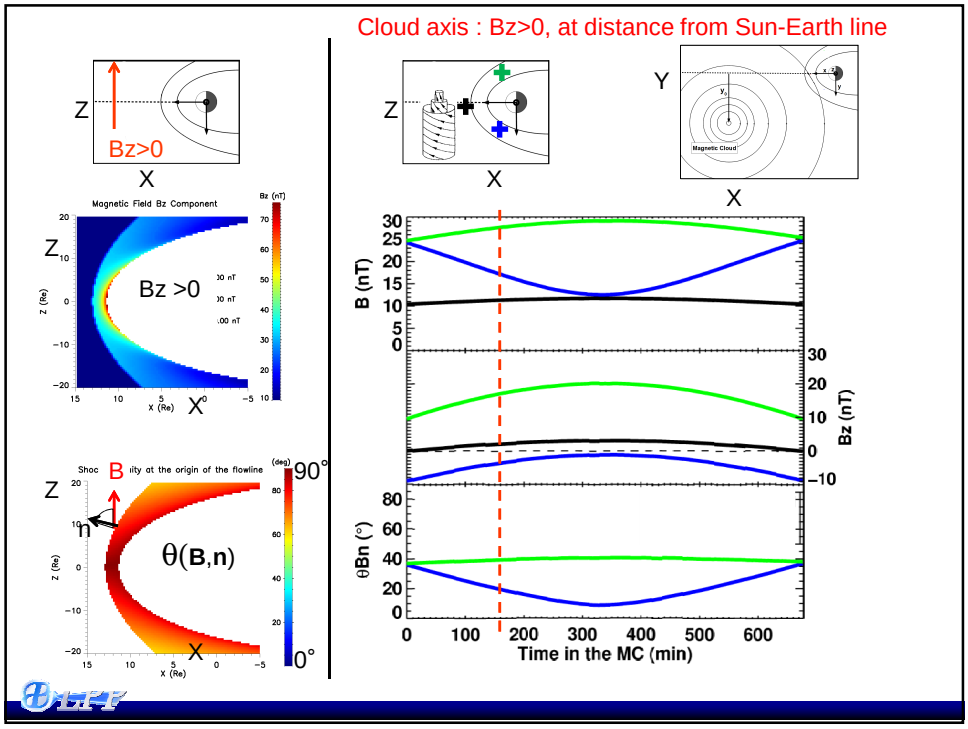


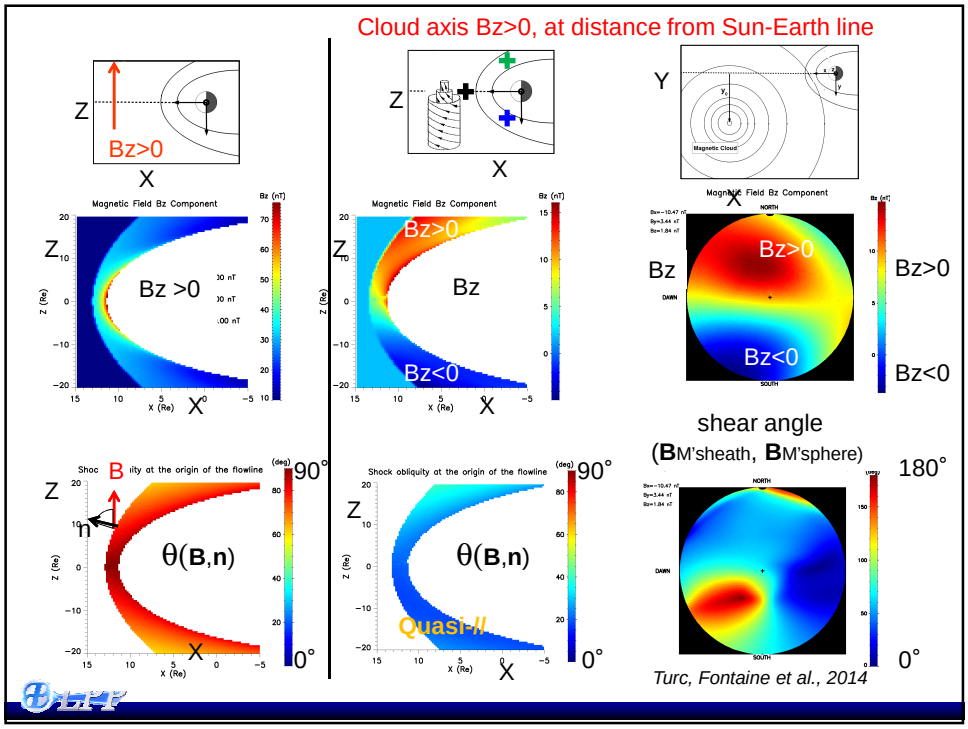
Magnetosheath flow model:
From Génot et al. 2011, Soucek et al., 2012

Propagation of **B** along flow lines from MHD

Case of standard solar wind

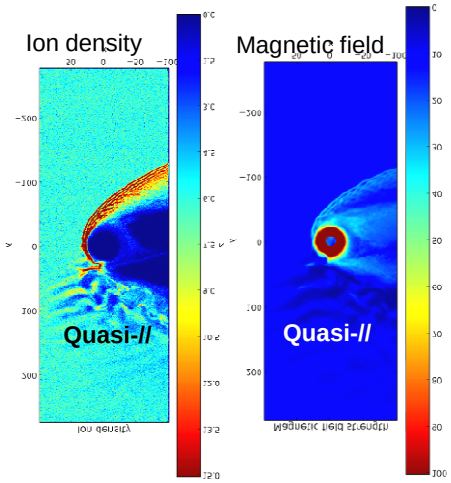



Cloud axis : Bz>0, at distance from Sun-Earth line
Z
Bz>0
X
Magnetic Field Bz Component
Bz >0
Z
X
Y
Magnetic Cloud
B (nT)
Bz (nT)
θBn (°)
Time in the MC (min)
θ(B,n)
90°
0°


Cloud axis Bz>0, at distance from Sun-Earth line
Z
Bz>0
X
Magnetic Field Bz Component
Bz >0
Bz
Bz>0
Bz<0
shear angle
(BM'sheath, BM'sphere)
180°
0°
θ(B,n)
Quasi-//
90°
0°
Turc, Fontaine et al., 2014

5. Hybrid simulations

Snapshot during the cloud's crossing



→ Describe more accurately the ion disturbances due to quasi-parallel conditions
→ Confirm the presence of a highly asymmetric magnetosheath and large modifications of the cloud's structure relative to the solar wind
→ Confirm the rotation of these asymmetries with the cloud's crossing

Summary:

- Magnetic clouds are very geoefficent structures but geoeffectiveness not fully understood: ex: variable geoeffectiveness for comparable orientation,
  → role of surrounding winds of bow shock ?

- Cluster observations / modelling / simulations show :

- Importance of configuration at shock:
  Cloud's structure almost unchanged in case of quasi-perp. configuration
  Large modifications in case of quasi-parallel configuration
- Asymetries in magnetosheath : ex: Bz may reverse in part of it
  Ex: clouds far from Sun-Earth axis, highly tilted axis relative to ecliptic plane, …
- Role of Bx component
  → more complex interaction with magnetosphere
  → and geoefficiency modified relative to predictions from solar wind