Curvature and Meridional Deflection Flows of Magnetic Clouds at Solar Minimum

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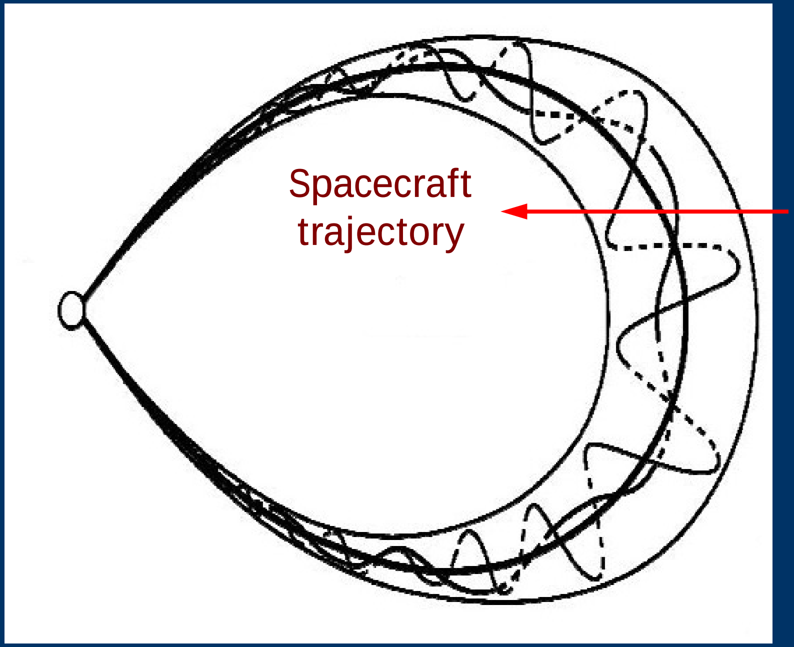
Global morphology of magnetic clouds

Generally accepted morphology



How do we know the distortion by the ambient solar wind?

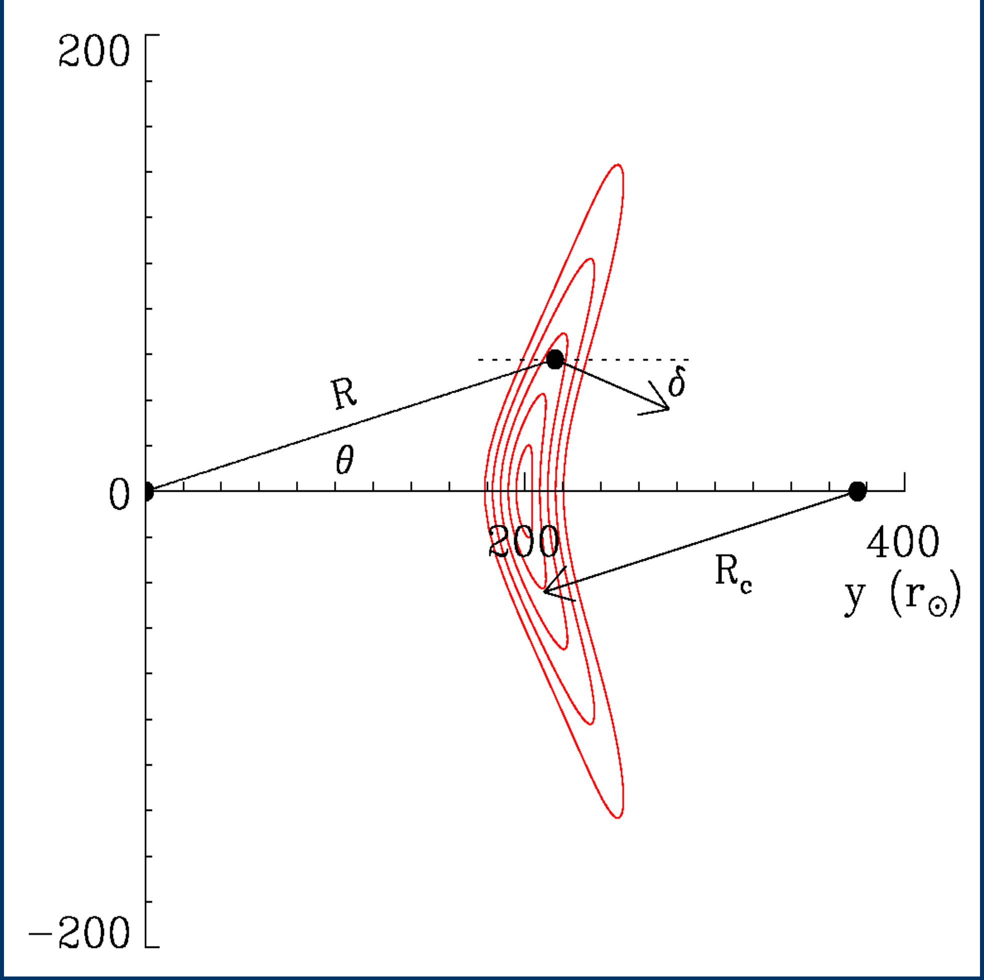
• Flux-rope fitting techniques? Involve with many free parameters and assumptions, and underestimate the true dimension.

• Any other methods?

This morphology is not quite right since it omits the distortion by the solar wind.

Liu et al., JGR, 2006

Curvature at solar minimum

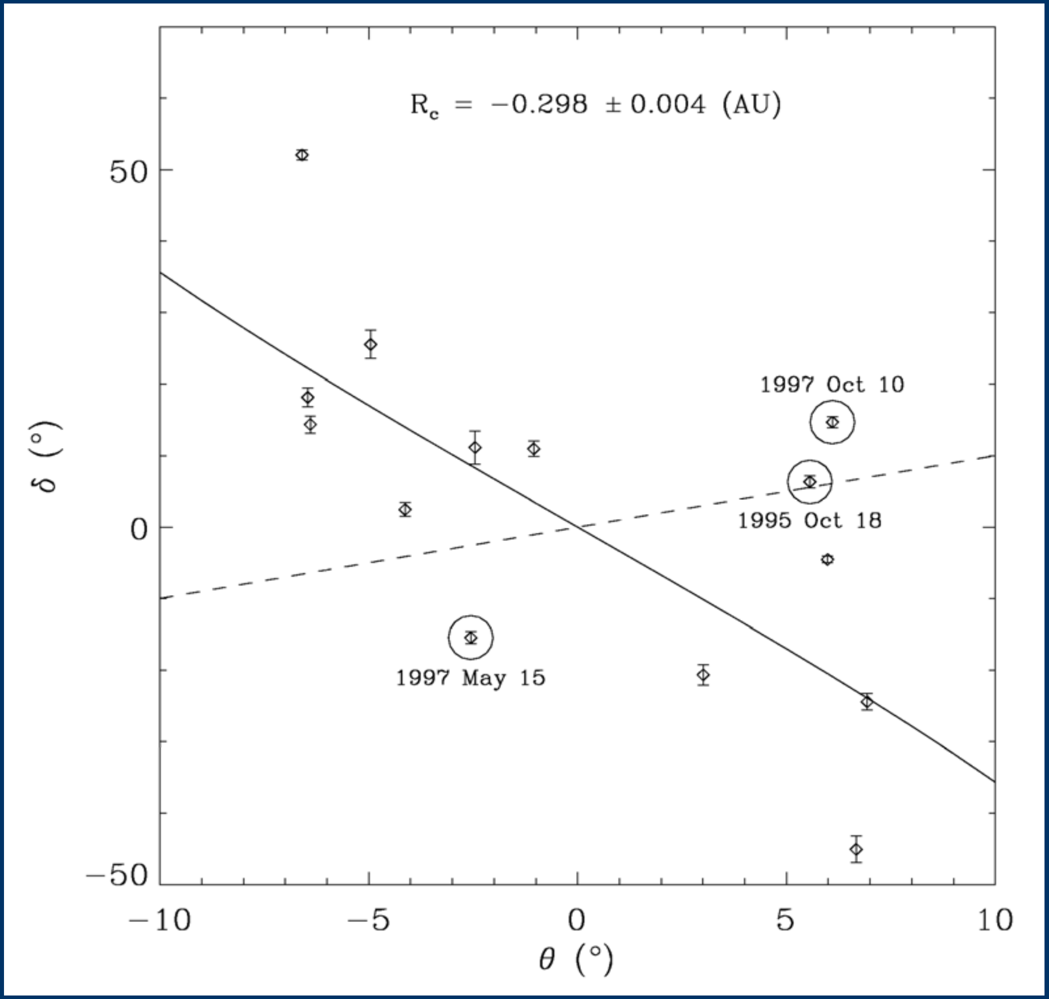


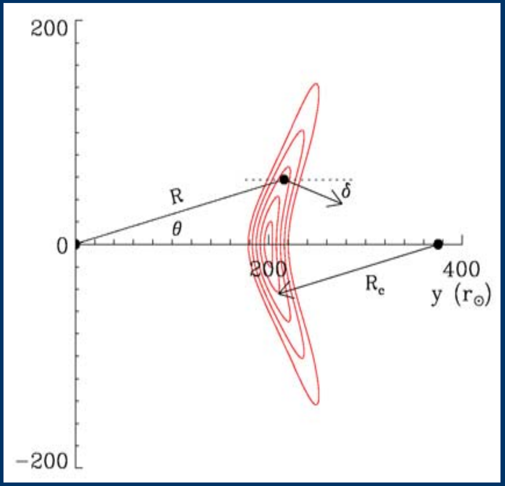
Near solar minimum, the solar wind is well ordered with fast wind from polar coronal holes and slow wind near equatorial plane. Expect to see a concave-outward curvature at solar minimum,

$$\delta = \arcsin\left(\frac{R}{R_c}\sin\,\theta\right)$$

Curvature at solar minimum

Wind Observations 1995 - 1997





An inverse correlation between δ and θ is largely observed. Radius of curvature is ~0.2 – 0.3 AU (negative).

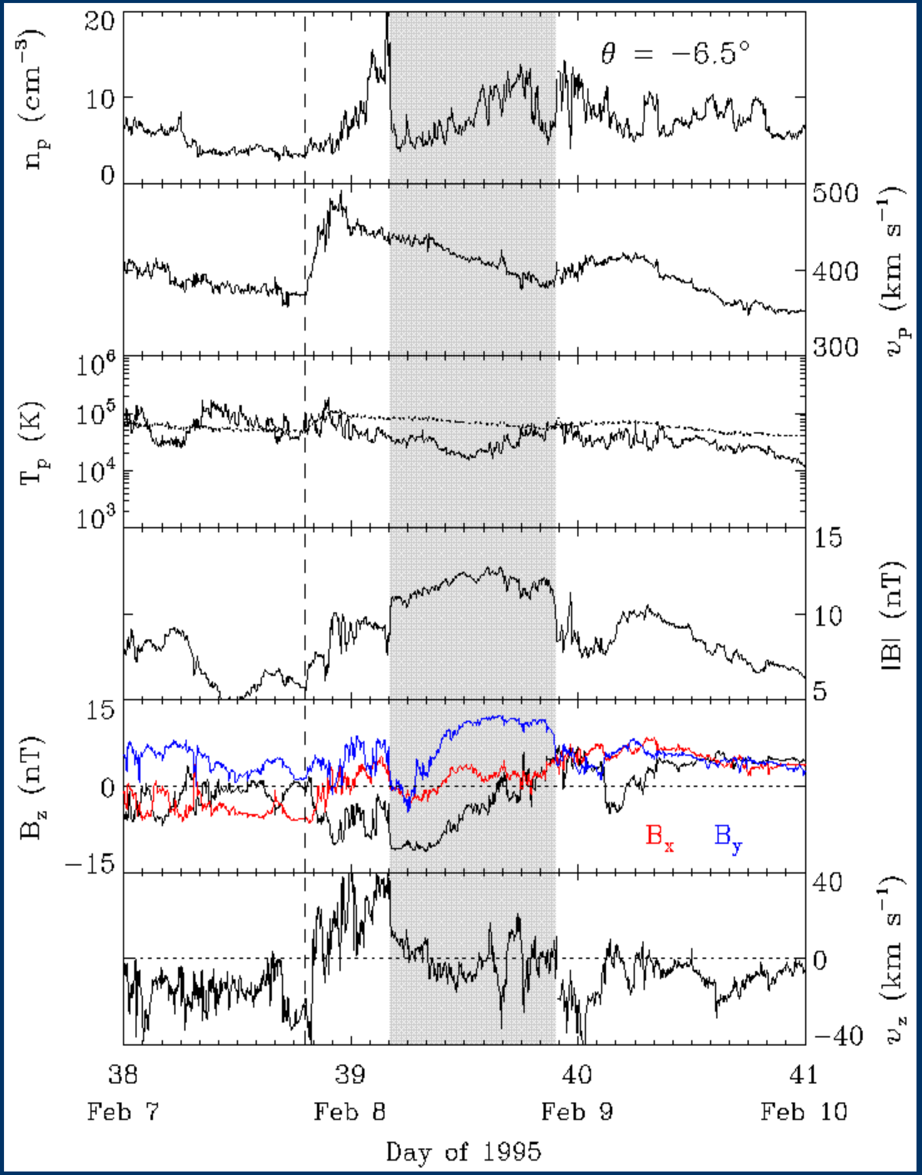
Meridional deflection flows

An MC with axis (-7, 285) deg:

• observe a positive meridional flow (~40 km/s) close to the MC at latitude = -6.5 deg, so the flow is deflected toward solar equatorial plane;

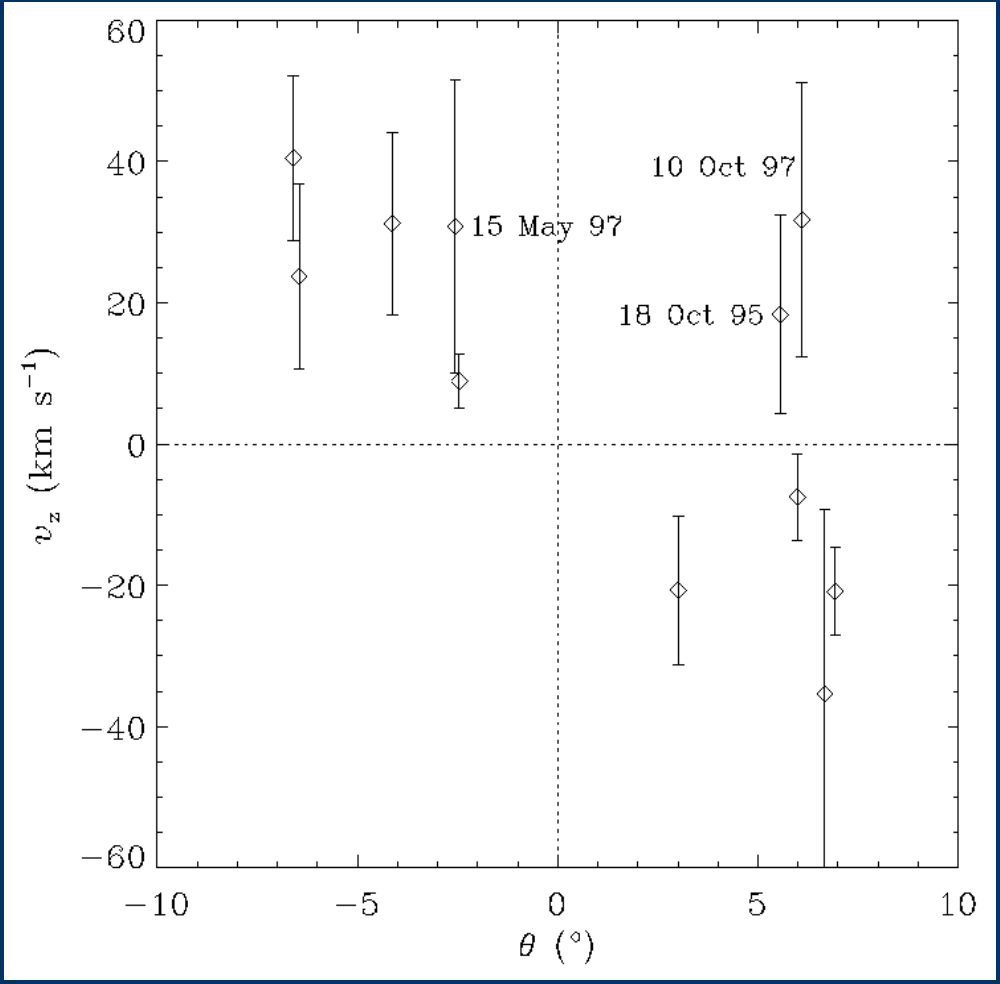
• a southward field is induced by the meridional flow;

• deflection flow reverses direction at the shock.



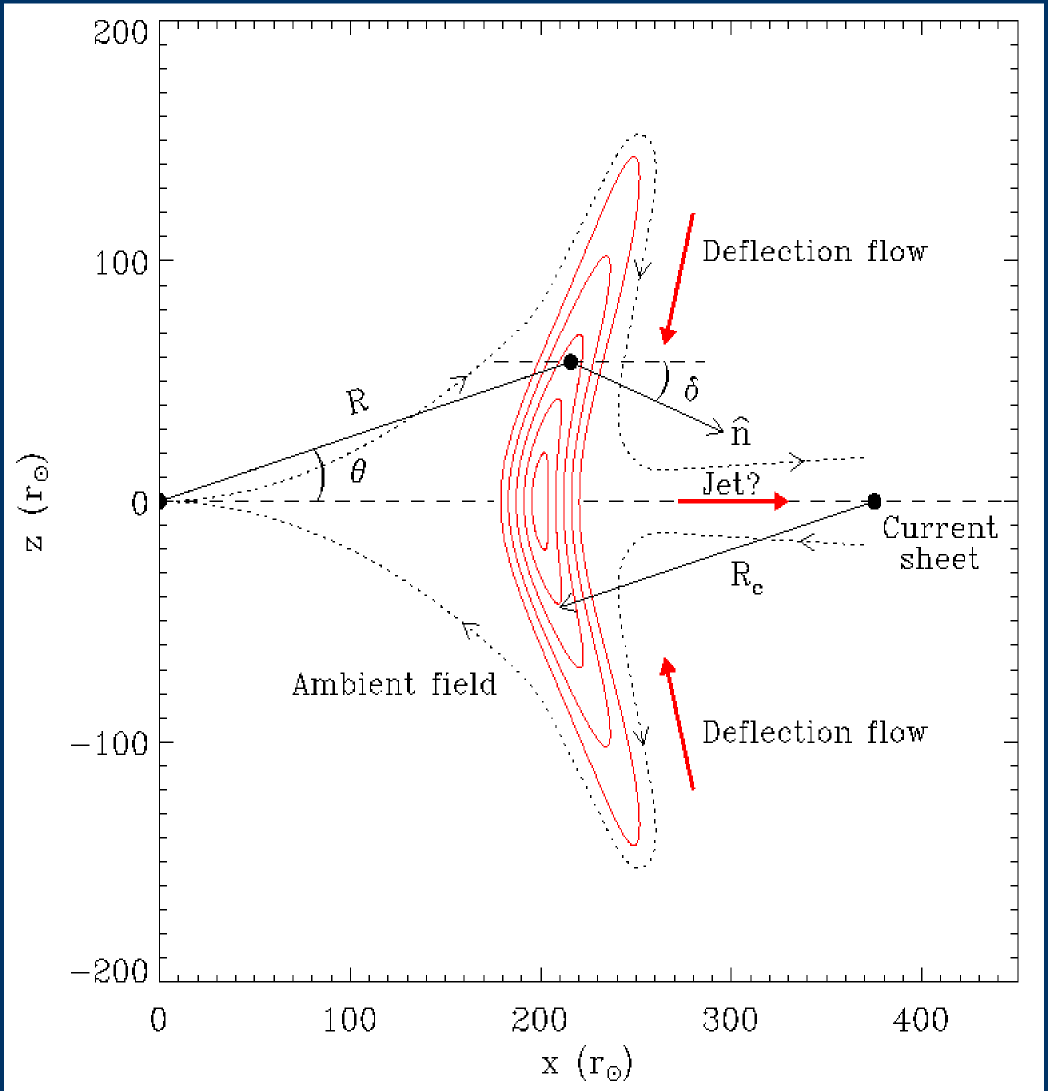
Meridional deflection flows

Wind Observations 1995 - 1997



- For concave-outward MCs, observe an inverse correlation between spacecraft latitude and meridional deflection flows, so the flow tend to move toward the equatorial plane;
- For convex-outward MCs, upstream plasma tends to be deflected to high latitude.

Curvature and deflection flows



Implications for STEREO observations:

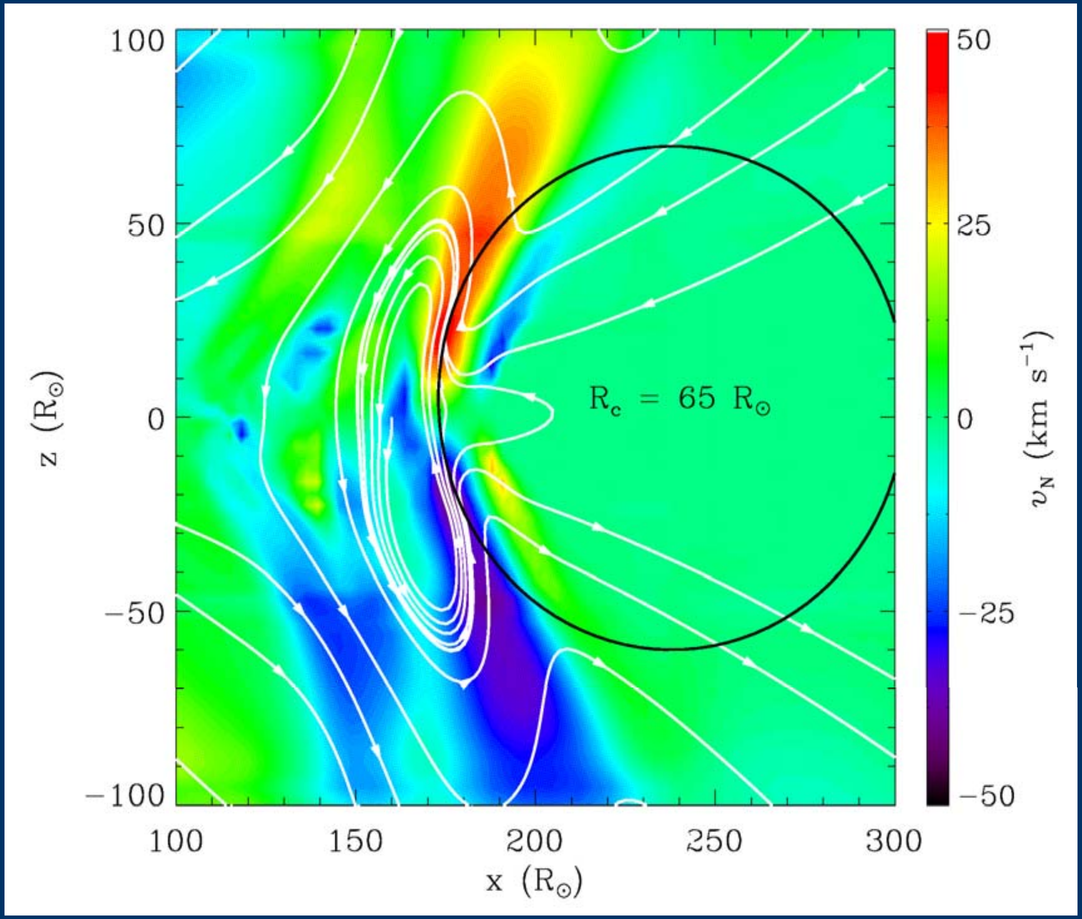
- A concave-outward plow deflects the upstream plasma toward the equatorial plane?
- A reconnection jet is driven by the deflection inflows?
- The reconnection jet should form a 2D disk. Stereo A and B, widely separated in longitude, could show if the jet exists.

Comparison with MHD simulations

• Simulations show the radius of curvature is larger than the MC radial width;

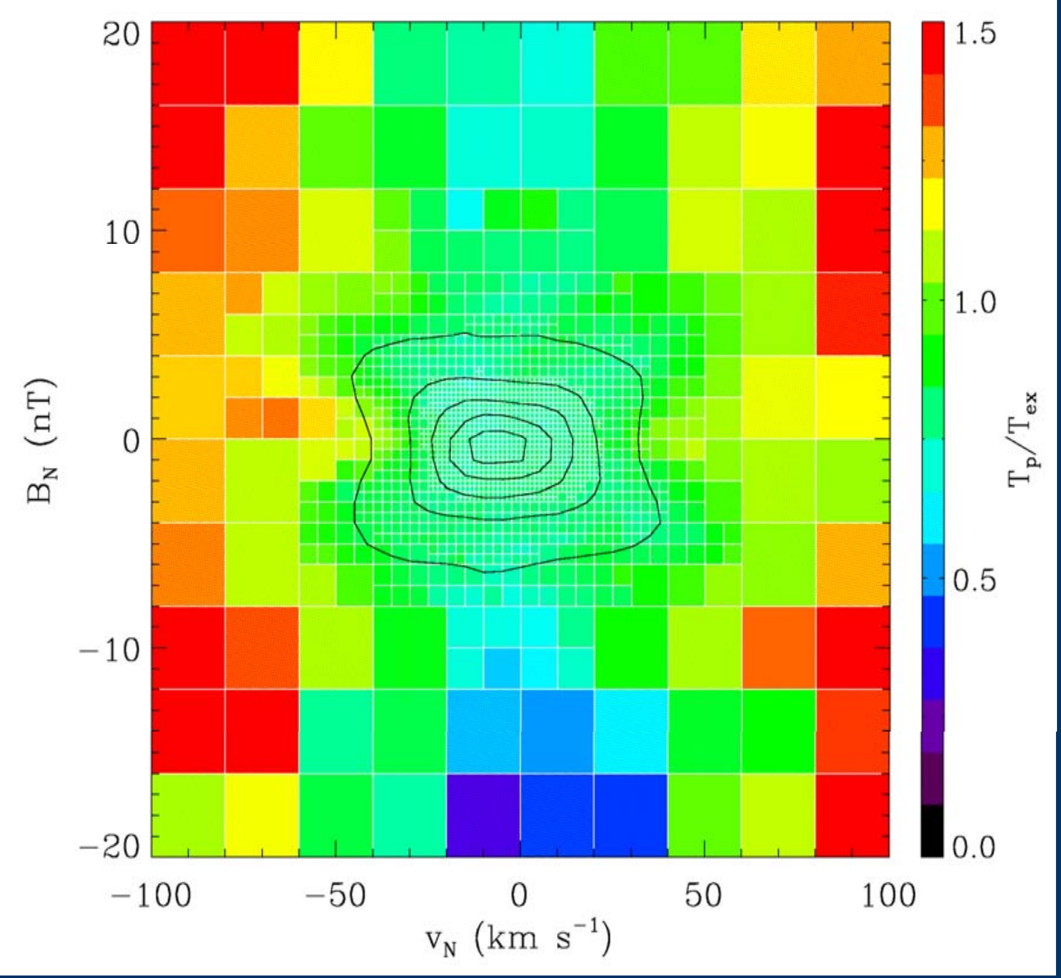
• Simulations also show the upstream plasma is deflected to high latitude, not the equatorial plane.

STEREO will give the answer.



Deflection leading to geo-effectiveness

ACE data 1998 - 2005



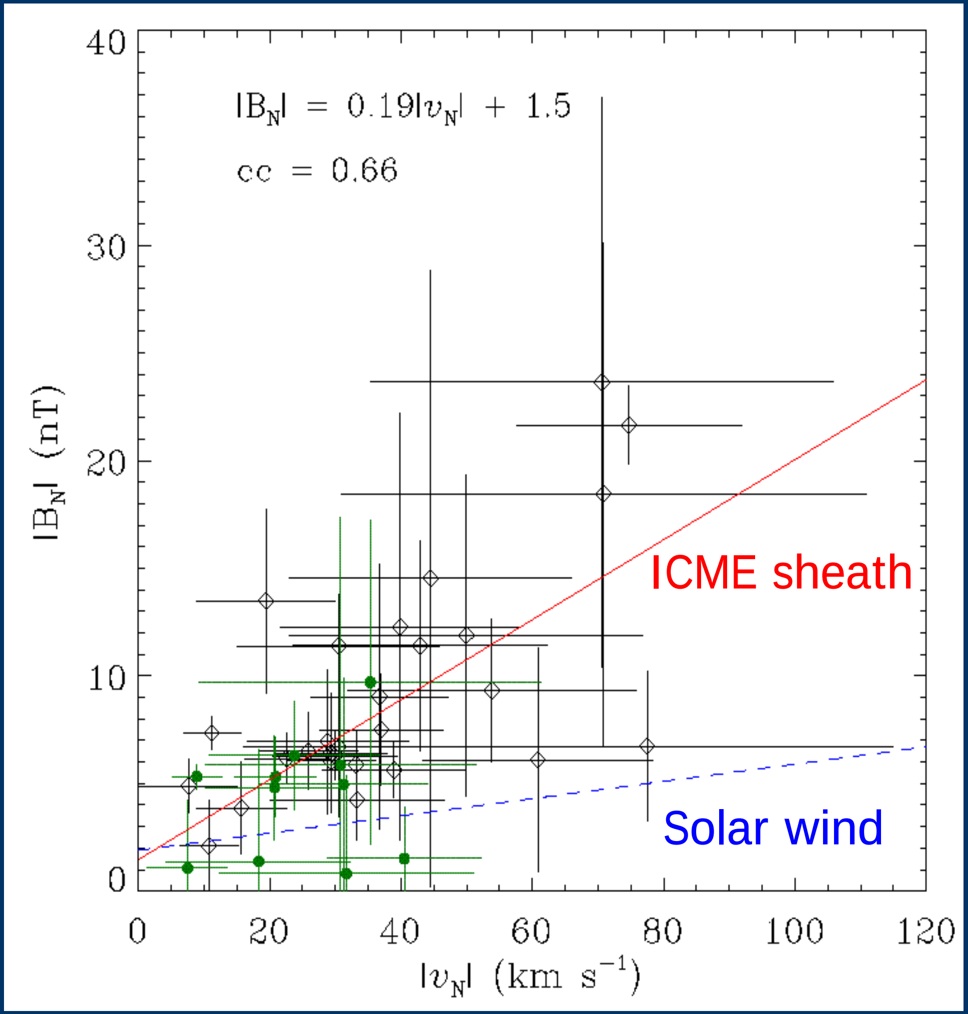
- B_N increases with v_N;
- Hot plasma (at corners) is associated with large v_N and B_N, so stream interactions are geo-effective;
- ICME plasma (low T) has small v_N but large B_N, so large B_N is intrinsic to ICMEs;
- ICMEs seem to favor a southward field during this period.

Deflection leading to geo-effectiveness

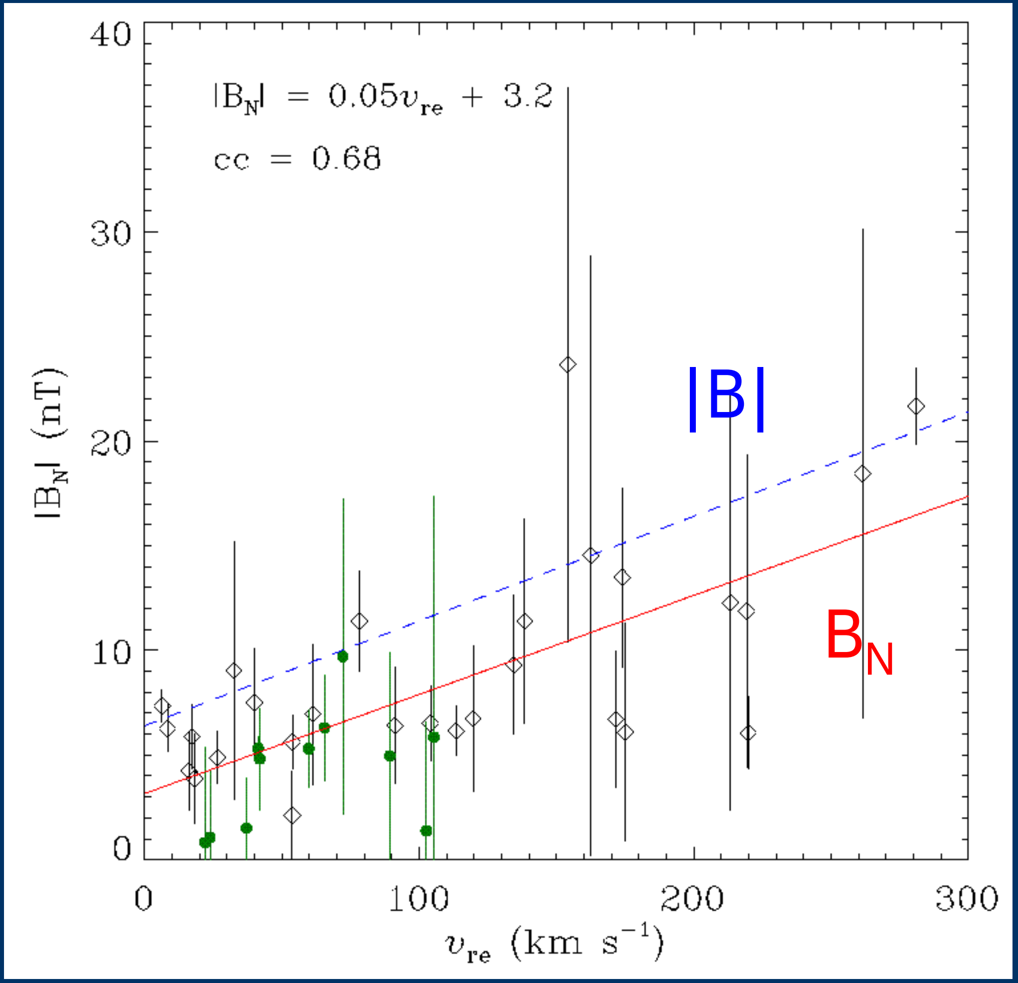
Due to the frozen-in nature of the field:

• Meridional flows produce field components along the north-south direction;

• B_N in ICME sheaths is larger than the solar wind level, probably due to shock compression.



Deflection leading to geo-effectiveness



- The faster the ICME, the larger the meridional field;
- Similar correlation for the total field in ICME sheaths.

The magnetic field in ICME sheaths may be predictable based on the observed CME speed, useful for space weather forecasting.

Summary

- At solar minimum, MCs are concave outward with a radius of curvature ~0.2 – 0.3 AU at 1 AU;
- Upstream deflection flows tend to move toward the solar equatorial plane;
- Meridional deflection flows give rise to meridional magnetic fields, which can be predicted given the observed CME speed.