Reconstruction of magnetic clouds with two spacecraft: Examples from WIND-ACE and STEREO-WIND

C. Möstl1,2, C. J. Farrugia3, A. Galvin3, K.E.J. Huttunen4, J.G. Luhmann4, K. W. Ogilvie5, and H.K. Biernt1,2

1Institute of Physics, University of Graz, Universitätsplatz 2, A-8010 Graz, Austria
2Space Science Center and Dept. of Physics, University of New Hampshire, Durham, NH 03824, USA
3NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
4Space Research Institute, Austrian Academy of Sciences, Schmiedlstr. 6, A-8042 Graz, Austria
5Space Sciences Laboratory, University of California, Berkeley, 7 Gauss Way, Berkeley, CA, USA

EGU General Assembly Vienna 2008

ABSTRACT

We reconstruct magnetic clouds (MCs), the core flux rope of Coronal Mass Ejections at 1 AU, focusing on combining measurements from two spacecraft to optimize the magnetic field map, thus doing in the interplanetary medium what other authors have done in the context of transfer events at the magnetopause.

- Three magnetic clouds are selected, of different sizes, seen by both WIND and ACE, when their separations were largest (1998, 2001). We undertake a quantitative comparison with results from with minimum variance (MV) analysis and linear force-free fitting (FF).

- We then optimize this field map by checking for consistency with observations by WIND and STEREO-B.

We find a shape of the magnetic cloud’s cross-section slightly elongated perpendicular to the direction of motion (“flattening”).

METHOD

We numerically solve the Grad-Shafranov equation, based on MHD theory:

\[
\nabla \cdot \mathbf{B} = 0, \quad \nabla \times \mathbf{A} = \mathbf{B}, \quad \mathbf{V} = 0, \quad \mathbf{B} \cdot \mathbf{V} = 0.
\]

We first look at the magnetic cloud on May 22, 2007, seen by WIND and STEREO-B. A magnetic field map is obtained from STEREO-B plasma and magnetic field observations, delivered by the PLASTIC and IMPACT instruments. We then optimize this field map by checking for consistency with observations by WIND.

Three features:

- 1/2-dimensional (invariant but not cylindrical). Magnetic field maps are generated, with spacecraft observations as initial values; thus no preconceptions on geometry.
- Self-consistent, non-force-free, number of flux tubes not prescribed.
- Invariant axis where \(P(A)\) displays minimal scatter (i.e. \(P(A)\) is single-valued).


- Marging of individual magnetic field maps into one combined map.
- Invariant axis found by coefficient correlations between predicted and observed magnetic field components (consistency check).

Advantages:

- Independent test of magnetic flux rope topology, flexibility.
- Optimization of the invariant axis and shape of the structure through correlation coefficients, not only from constraint that \(P(A)\) is single-valued.
- Magnetic fluxes, orientations etc. are more robust, important in relation magnetic clouds to their associated flares and CMEs (e.g. Leamon et al. 2004; Qiu et al., 2007; Longcope et al., 2007; Möstl et al., 2008).

Conclusions

- New method based on multi-spacecraft information is capable of retrieving robust orientations, shapes and magnetic fluxes for large spacecraft separation; results comparable to other methods.
- Variety of shapes of cross-sections possible, depending on size? small MCs circular, large flat?
- First step to infer full 3D structure of magnetic clouds (future HELEX and Solar Orbiter observations).

References

- Huttunen et al., 2008.
- Riley et al. (5).
- WIND observations (upper Wind, lower ACE).
- Figure 8 (from Huttunen et al., GRL, submitted, 2008).
- Plasma data (protons) (format as Fig. 4).

Acknowledgements

- M. C. is supported by the young researchers fund of the Austrian Academy of Sciences, SFB-A03 and the Austrian Funds for the Promotion of Research in the Sciences of the Future (project 16A05-316).
- C. J. F. is a Core on STEREO/PLASTIC. This work is supported by NASA WIND/ACE and MIT group NNG05SG77G, NNG05G041H, and ANS00101G.