What can we learn from solar wind observations at L5?

Solar wind power input to the magnetosphere/unit area:

$$P = V_{sw} B_{IMF}^2 \mu_0 \sin^4(\theta/2)$$

Perreault and Akasofu 1978

Defines the energy available to drive plasma convection, create plasma waves, inject and energise ring current ions, heat electrons to relativisitic energies in the outer radiation belts, further ionise and heat the ionosphere…

Andrew Fazakerley, Dhiren Kataria, Chris Owen,

Jonny Rae, Robert Wicks,

Mullard Space Science Laboratory, University College London

Contribution of L5 data to Space Weather Forecasting

Interplanetary Coronal Mass Ejections (ICMEs)

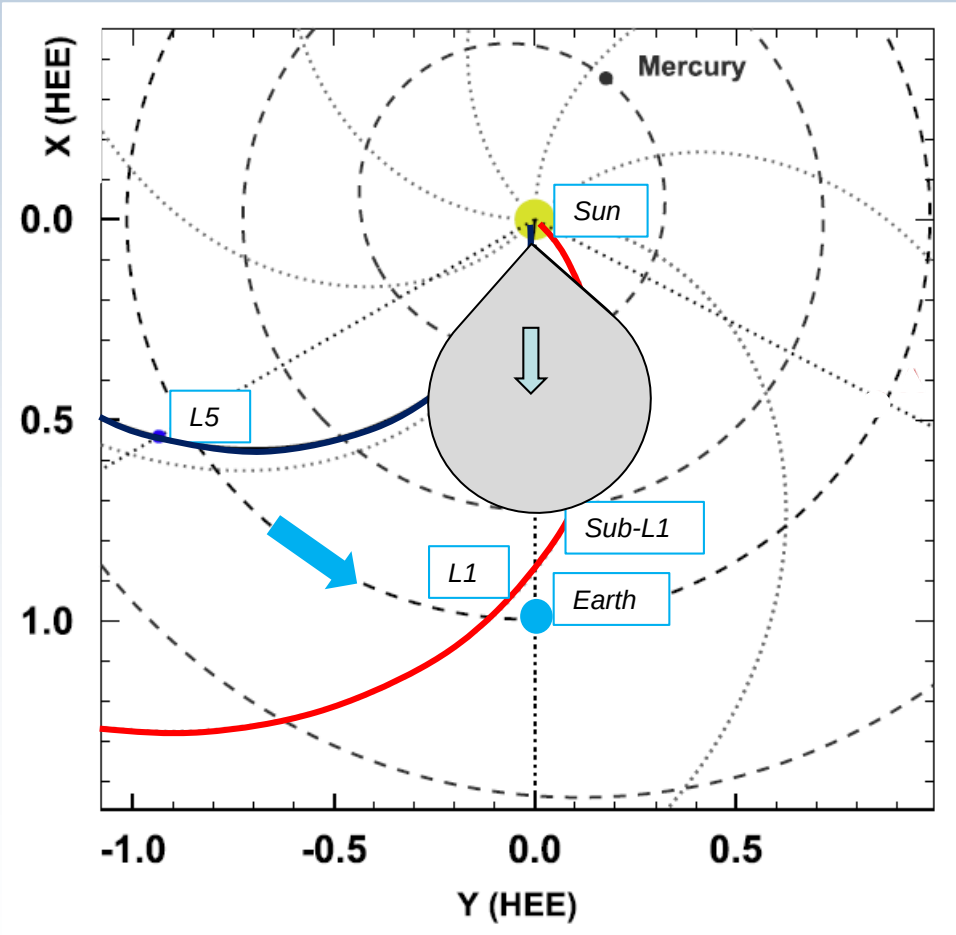
- Possibility of magnetic cloud, which may have prolonged geoeffective B
- ICME can drive geoeffective sheath
- SEPs often associated with sheath

Hazard Potential

- sudden magnetospheric compression
- possible prolonged geoeffective B
- radiation belt enhancements

Forecasting needs measurements at

- L5: active regions (caution)
- L5: Earthward ICME (**clear risk**)
- L1 or Sub-L1: n, V, B test for geoeffective plasma (**alert**)



Contribution of L5 data to Space Weather Forecasting

Stream Interaction Regions (SIR) and High Speed Streams (HSS)

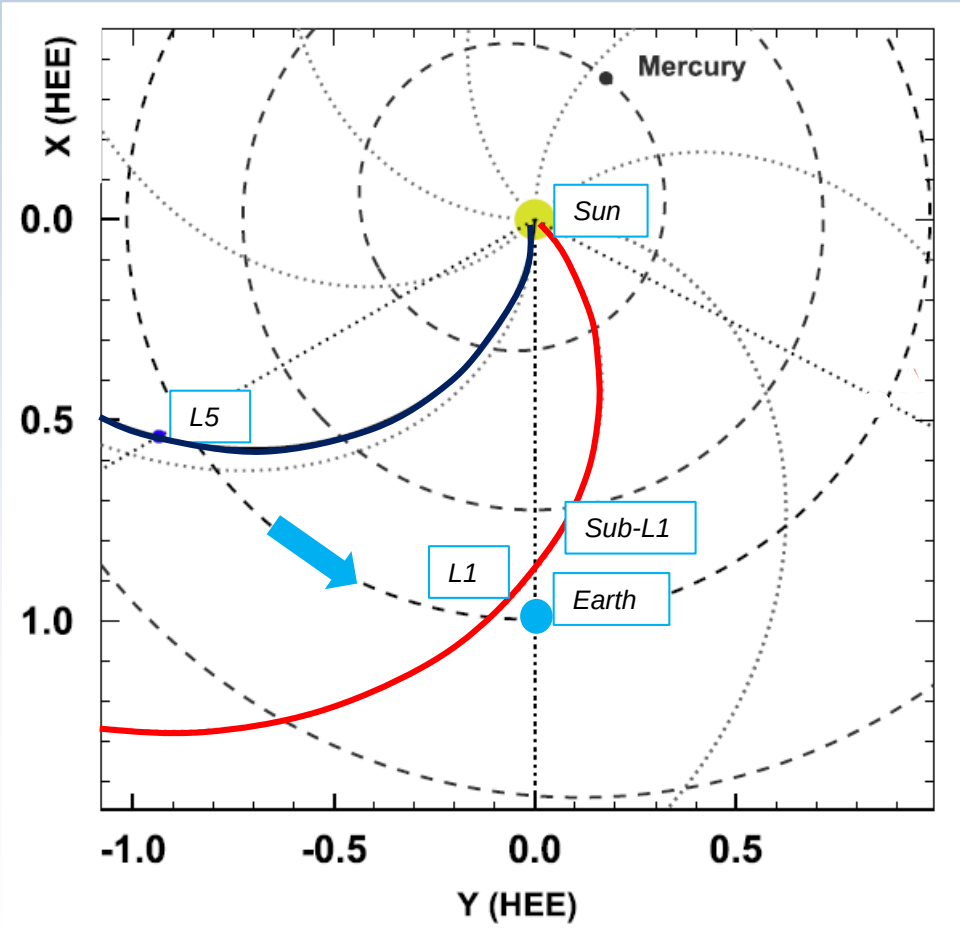
- Prolonged HSS related to radiation belt enhancements
- SIRs can be geoeffective

Hazard Potential

- Radiation belts
- sudden compression of magnetosphere

Forecasting needs measurements at

- L5: near-equatorial coronal holes and measure fast streams (caution)
- L1 or Sub-L1 : n, V, B test for geoeffective plasma (**alert**)

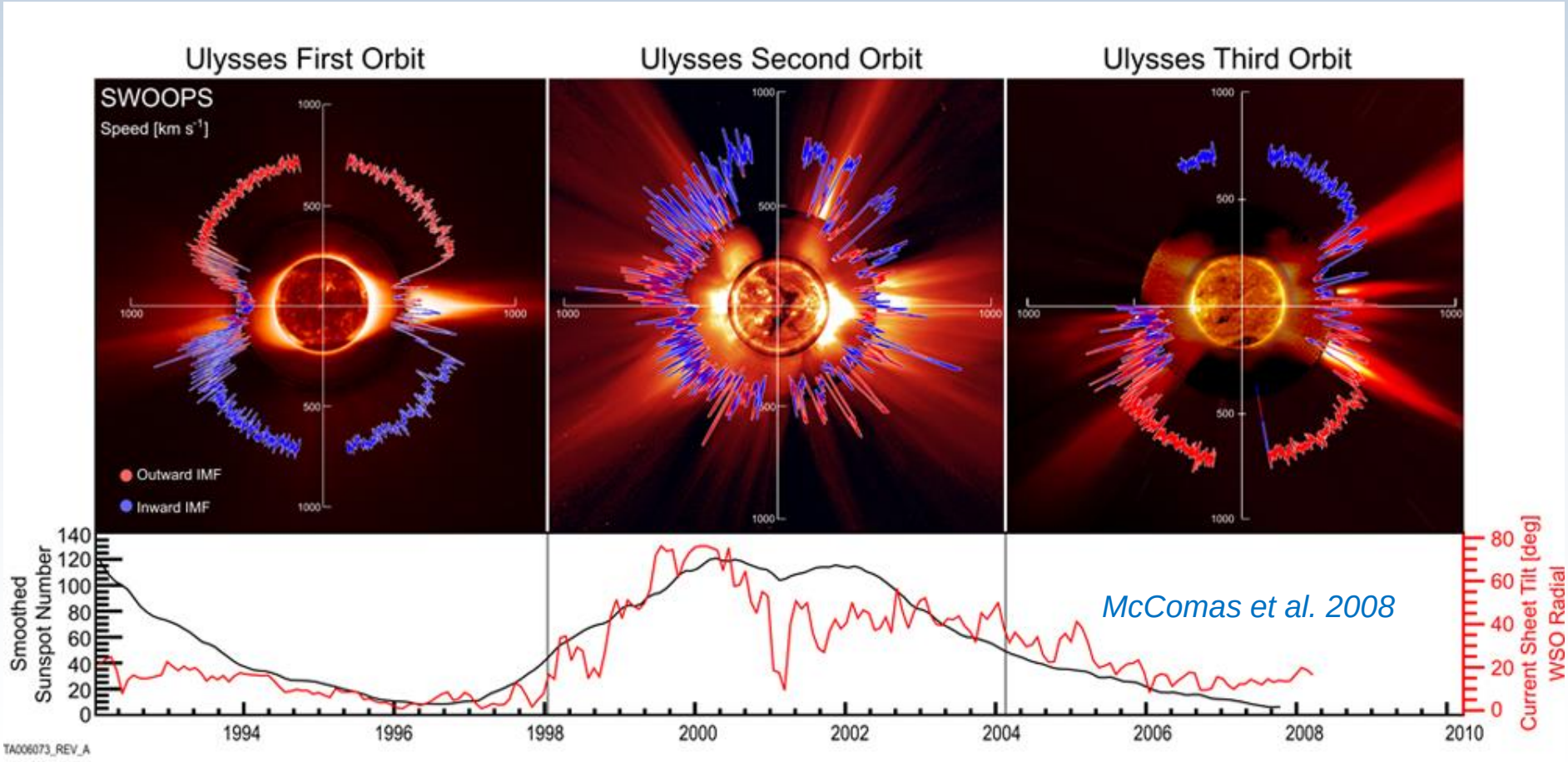


The Solar Wind

Fast wind from coronal holes (polar, equatorial)

Slow wind from various sources

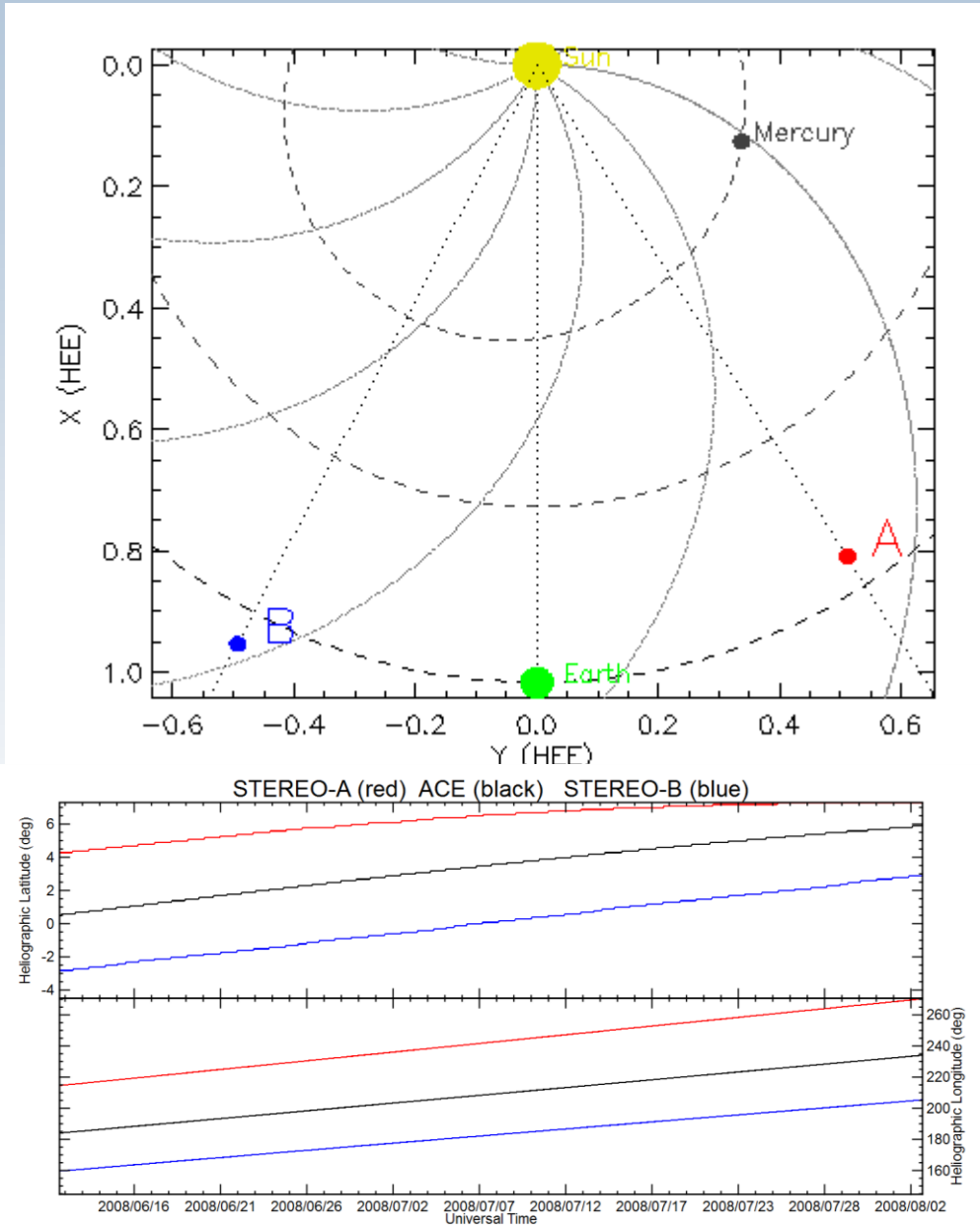
Solar magnetic field polarity reverses regularly (~11 year cycle)



STEREO/ACE Summer 2008

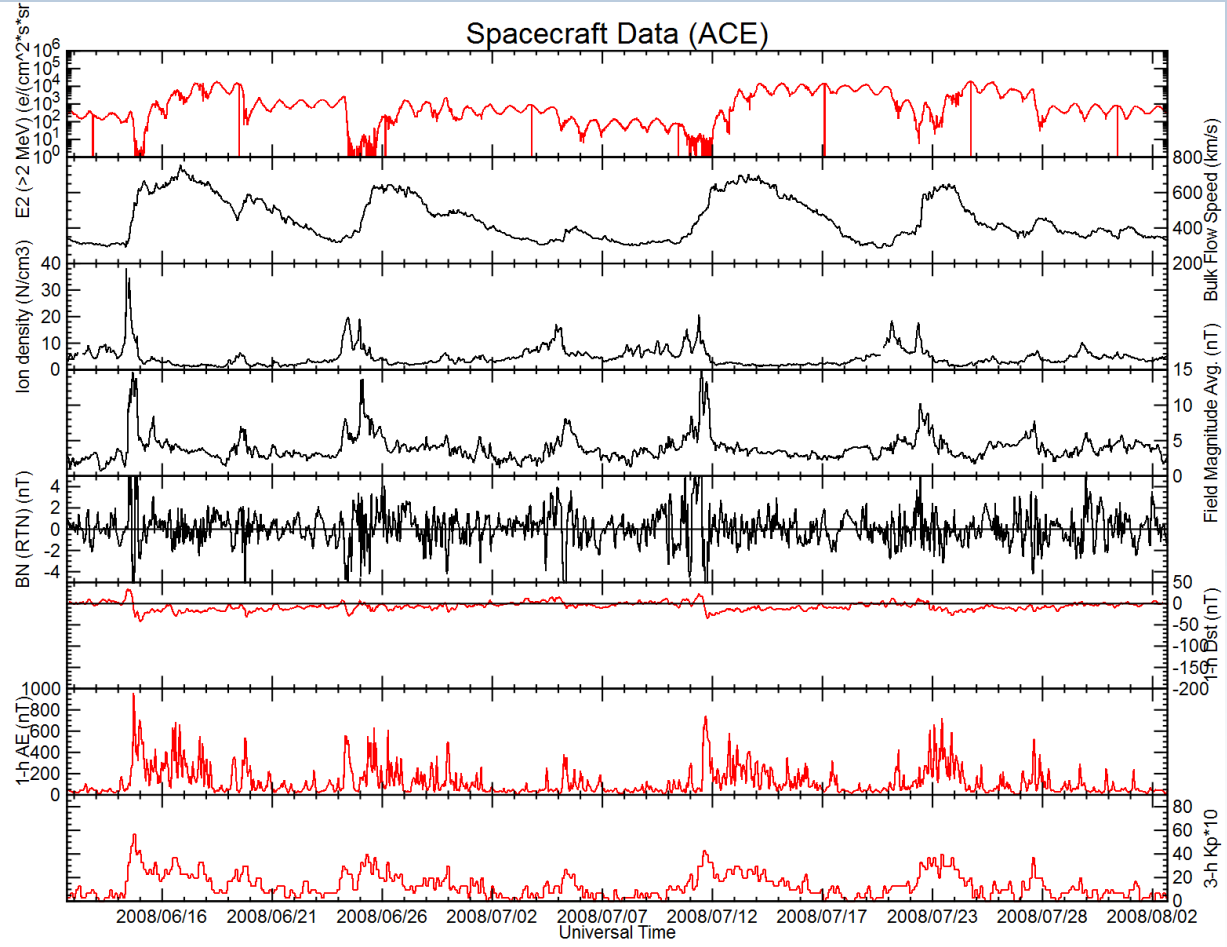
- Between 11 June 2008 – 03 Aug 2008, the helio-longitude separation of STEREO-B from STEREO-A increased from 55° to 65°
- ACE was between them.
- The spacecraft were also separated by a few degrees in helio-latitude

- (near solar minimum; see previous slide)



STEREO/ACE Summer 2008

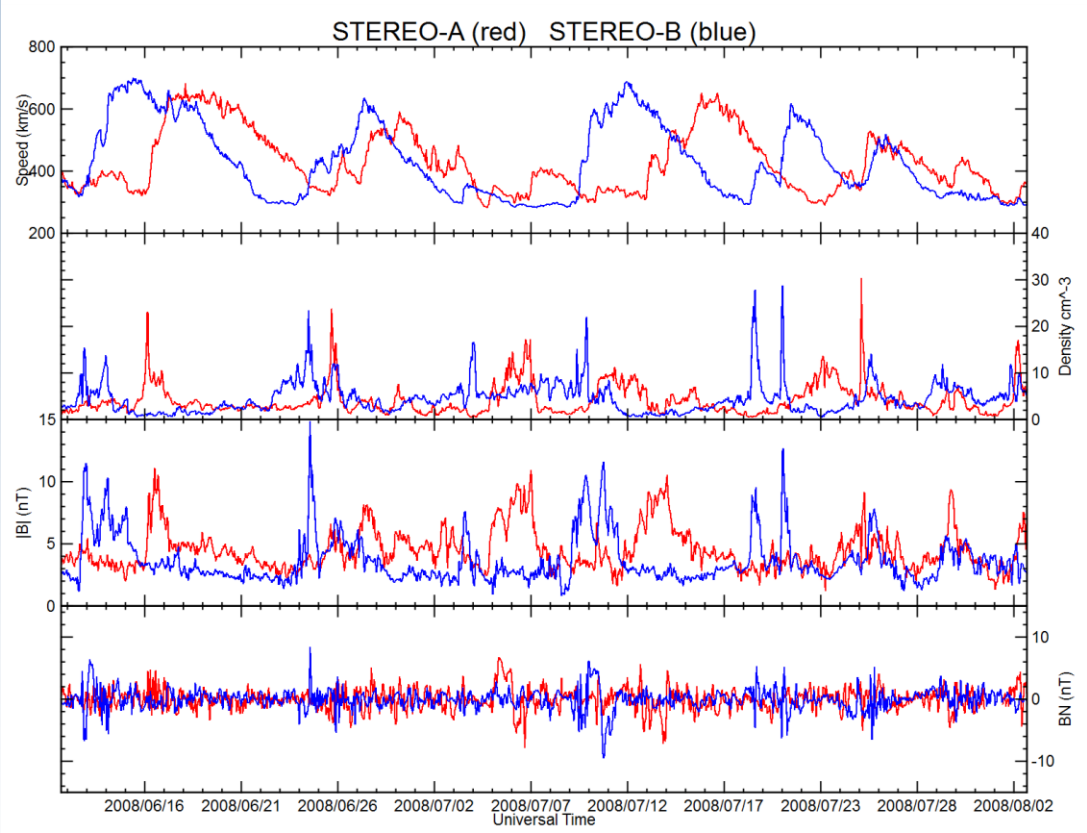
- No significant magnetic storms.
- Enhanced Kp and AE, and >2MeV electron fluxes at GEO tend to coincide with fast flow intervals
- Few ICMEs in the interval at ACE on 12, 14 June; 10, 16, 17 July (Jian list)
- SIRs in the interval at ACE on 14, 24 June; (04), 11, 22 July (Jian list)



(top panel is > 2MeV electrons on GOES-11)
Data courtesy CDAWeb

STEREO/ACE Summer 2008

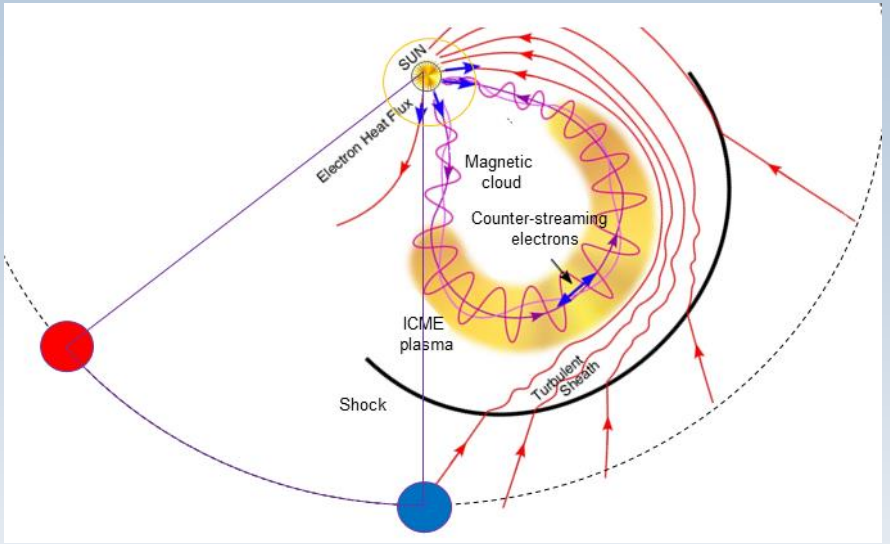
- Plasma and magnetic parameters at the times of observation on each spacecraft
- Little evidence of seeing the same ICME at both – would expect a signature at roughly the same time

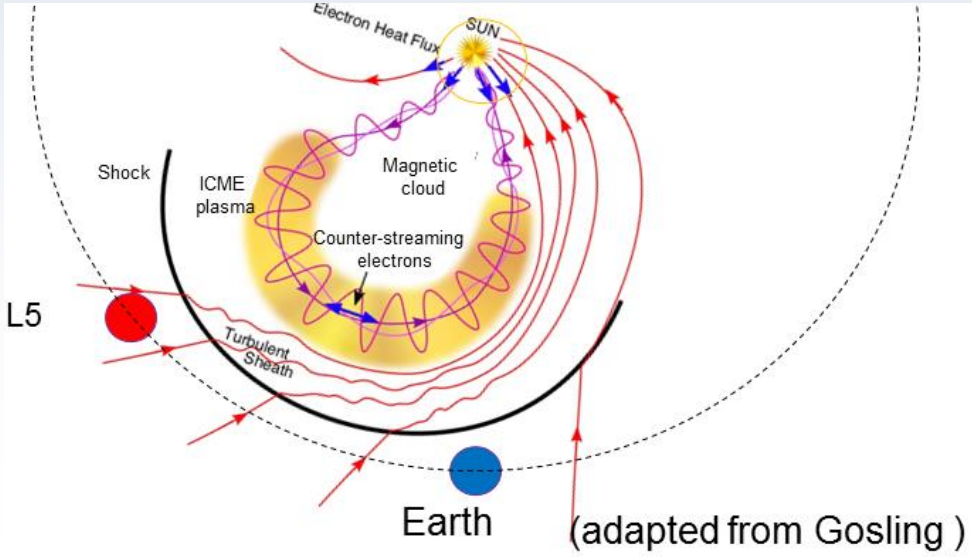


Data courtesy CDAWeb

STEREO/ACE Summer 2008

- Plasma and magnetic parameters at the times of observation on each spacecraft
- Little evidence of seeing the same ICME at both
- Perhaps not surprising given 3D distribution of ICME directions

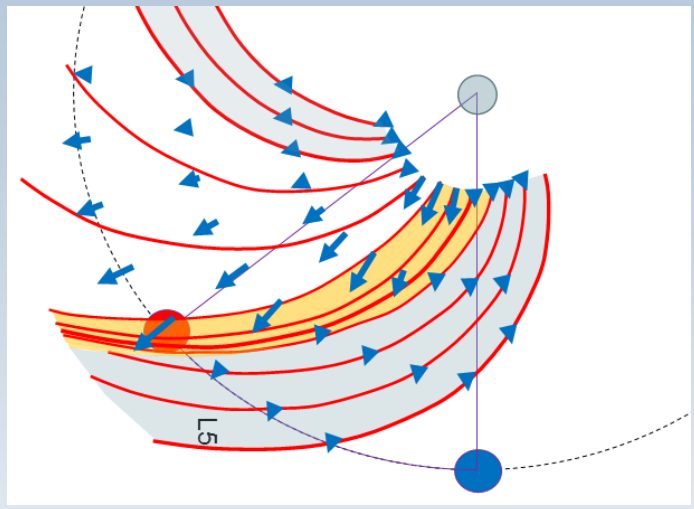


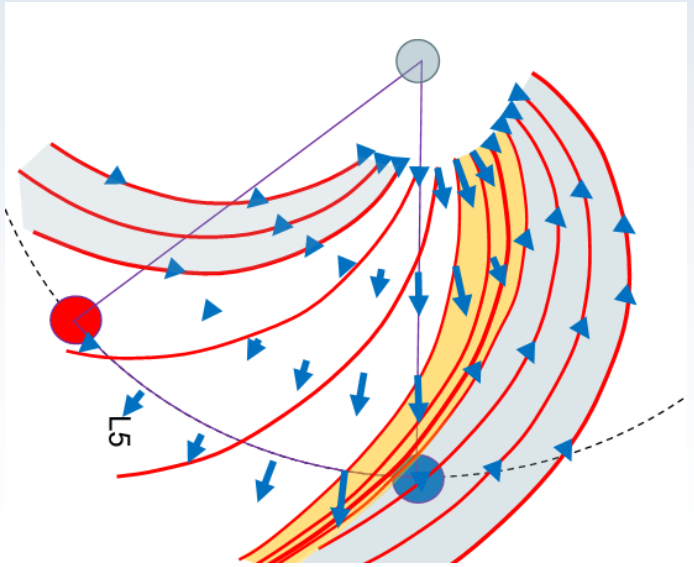


STEREO/ACE Summer 2008

Corotating/Stream interaction regions

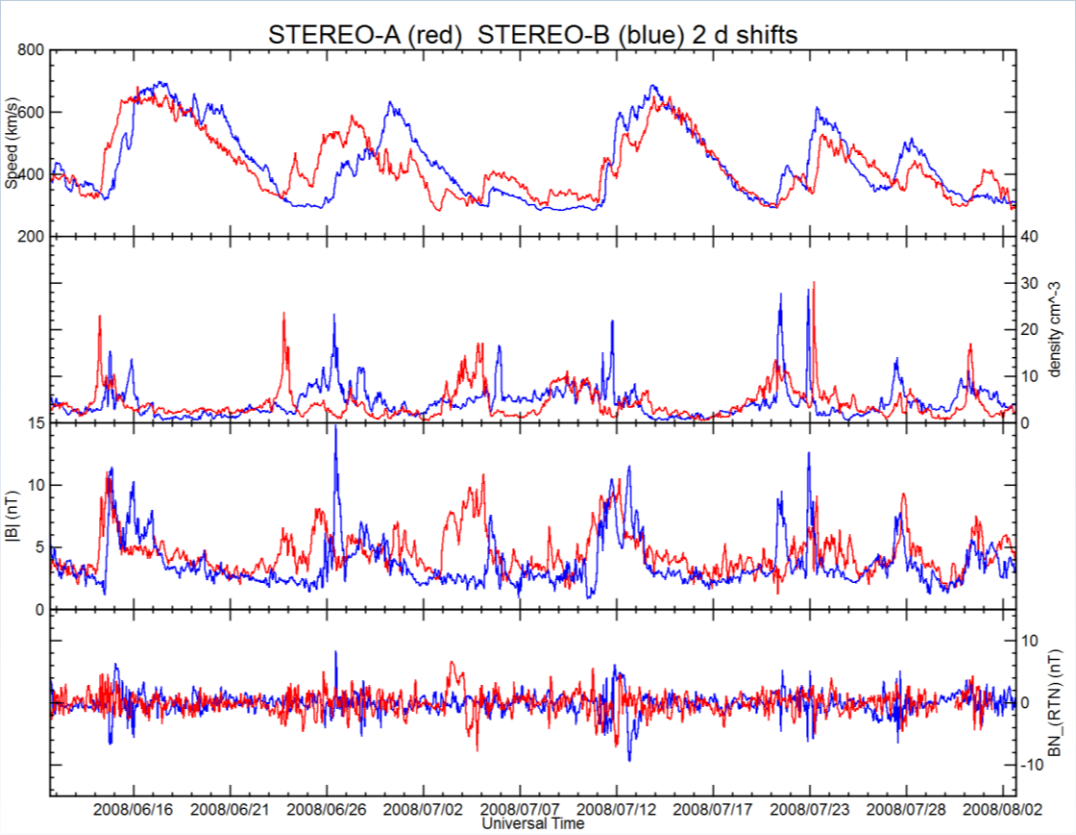
- 2D sketch ignores possible 3D structure
- 2D sketch ignores possible time evolution





STEREO/ACE Summer 2008

- Plasma and magnetic parameters after adding a 2 day interval to STEREO-B data and subtracting a 2 day interval from STEREO-B data. (ACE is unaltered)
- Note that good alignment of the plasma flow time series is possible, although it is not perfect, particularly during the second fast flow interval



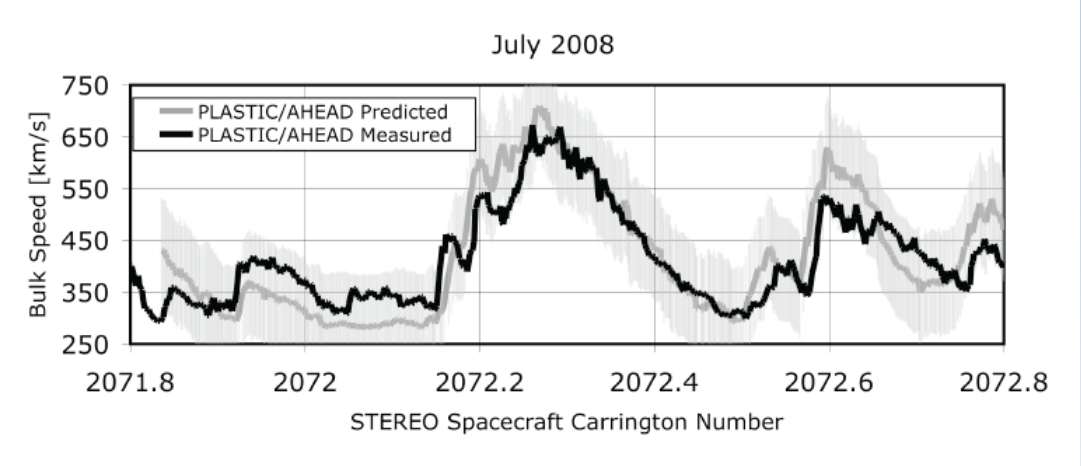
Data courtesy CDAWeb

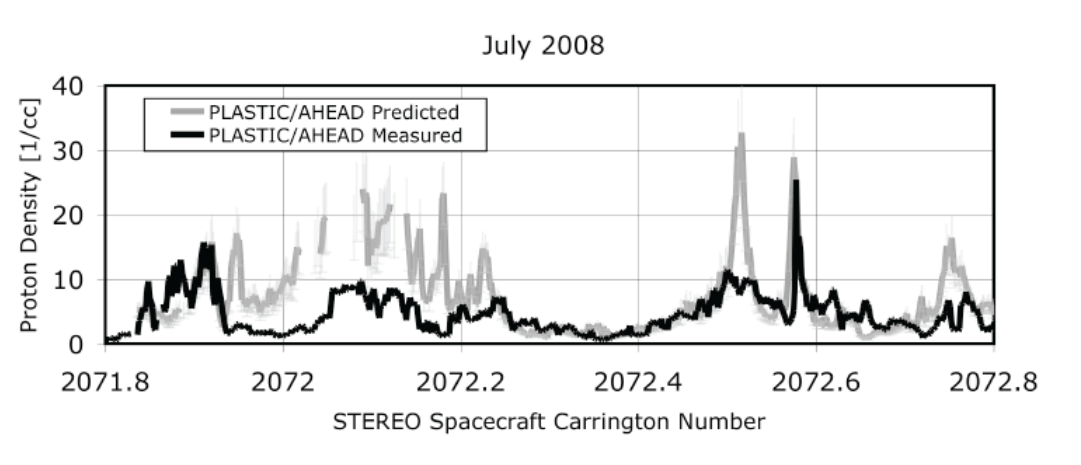
STEREO/ACE Summer 2008

- Expected Carrington Longitude for STEREO-A to see a stream seen by STEREO-B is

$$\varphi_{C\_A} = \varphi_{C\_B} - \Omega_{sun}\,(R_B - R_A)/V_{sw\_B}$$

- Agreement is good in July 2008





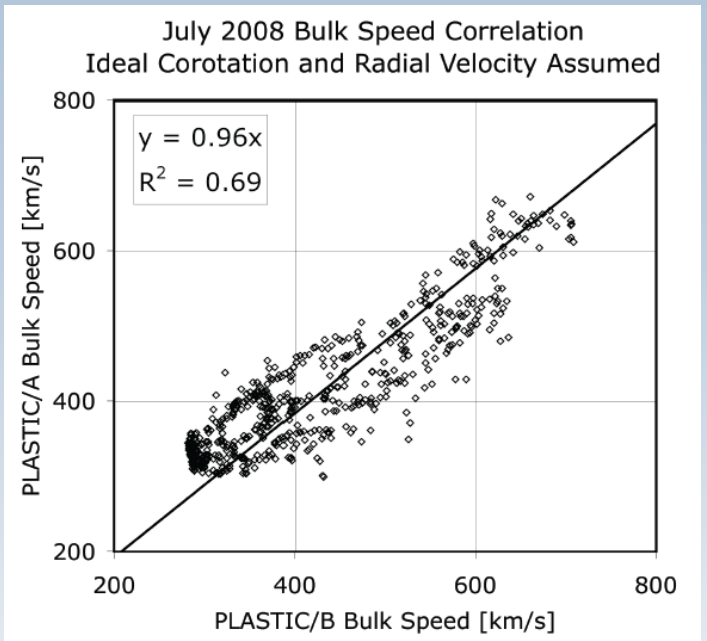
Simunac et al., Ann. Geo., 2009

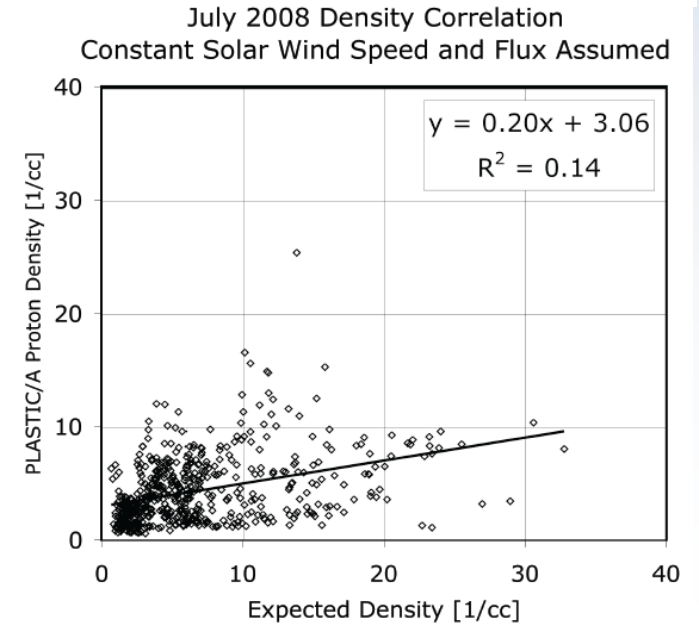
STEREO/ACE Summer 2008

- Expected Carrington Longitude for STEREO-A to see a stream seen by STEREO-B is

$$\varphi_{C\_A} = \varphi_{C\_B} - \Omega_{sun} (R_B - R_A) / V_{sw\_B}$$

- Speed profiles similar despite separations of spacecraft of ~5° in latitude and ~60° in longitude
- Arrival time could be predicted within 10% of the corotation time between the spacecraft
- (Some work needed to understand the behaviour of the preceding stream in early July)

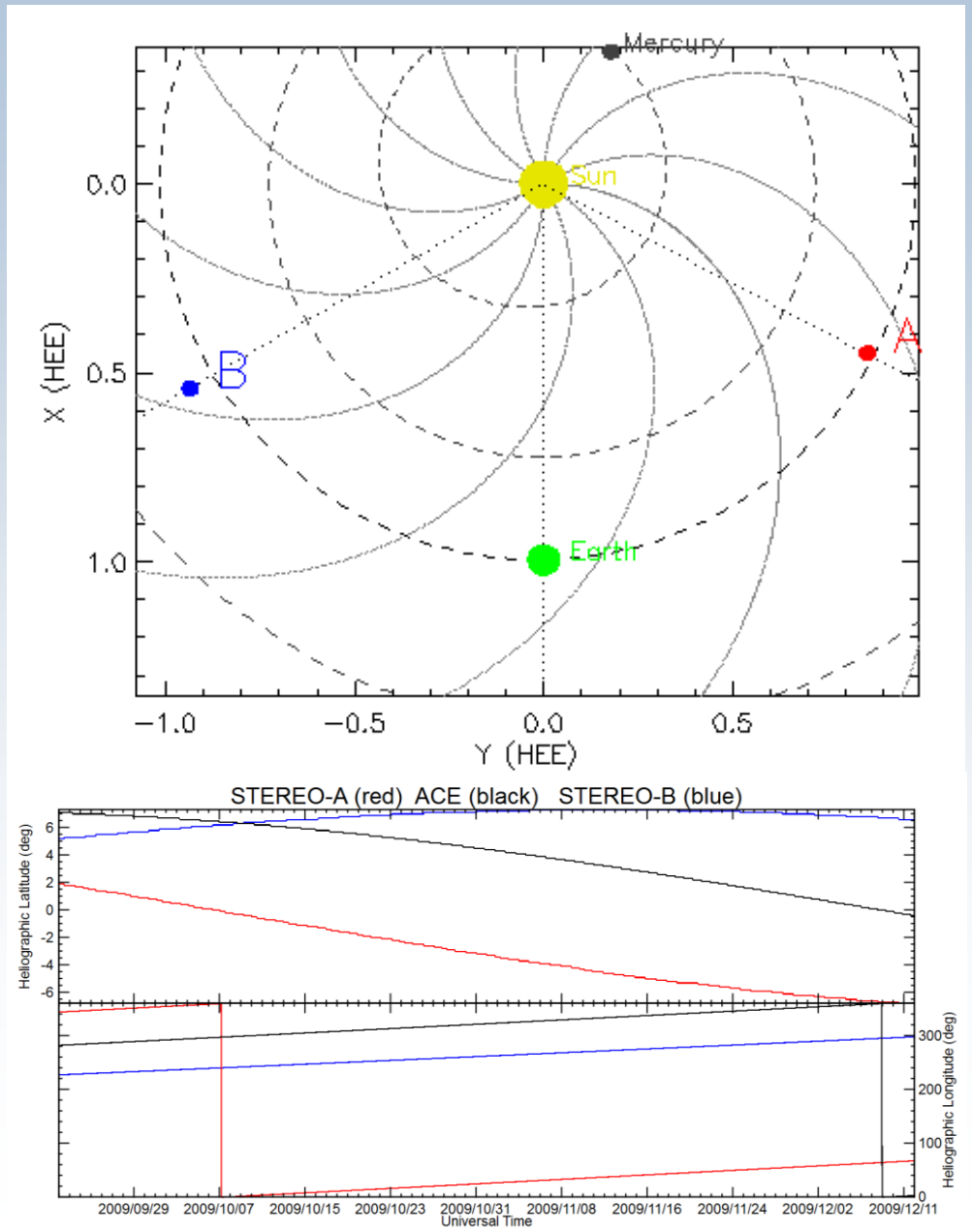




Simunac et al., Ann. Geo., 2009

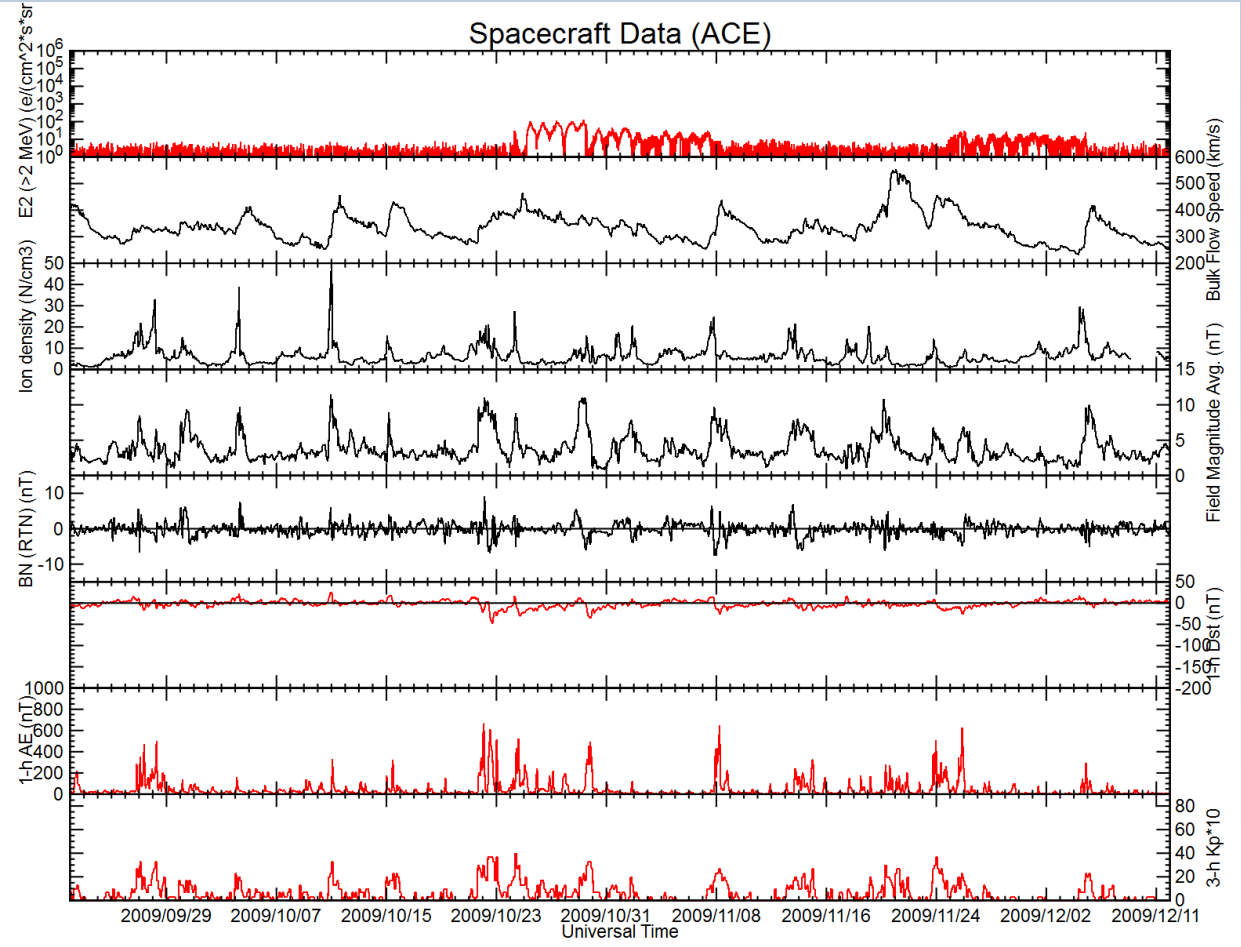
STEREO/ACE Autumn 2009

- Between 22 Sep 2009 – 12 Dec 2009, the helio-longitude separation of STEREO-B from ACE, and also from ACE to STEREO-A was about 60°.
- The spacecraft were also separated by a few degrees in helio-latitude



STEREO/ACE Autumn 2009

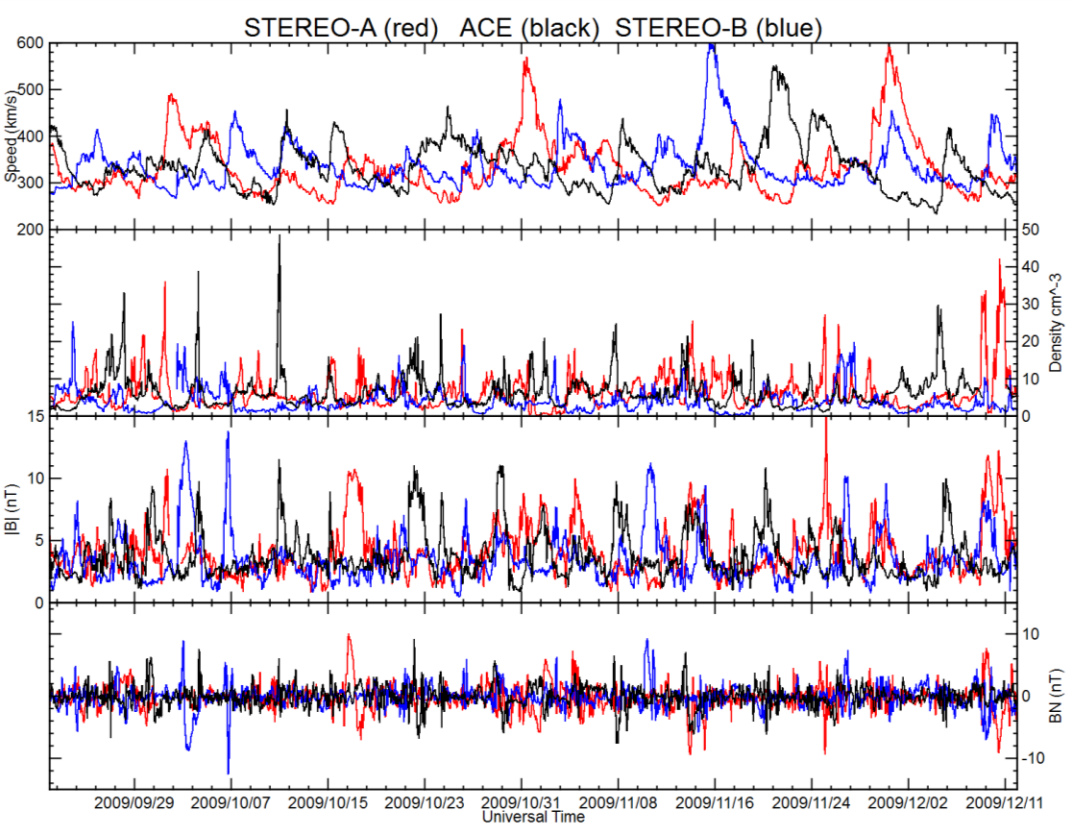
- No significant magnetic storms.
- Enhanced Kp and AE tend to coincide with fast flow intervals
- Few ICMEs in the interval: 30 Sept; 16, 17, 29 Oct; 13 Nov (Jian list)
- SIRs in the interval 20 Sept; 04, 10, 15, 21, 24 Oct; 07, 20, 24 Nov; 05 Dec (Jian list)



(top panel is > 2MeV electrons on GOES-11, quality tbc)
Data courtesy CDAWeb

STEREO/ACE Autumn 2009

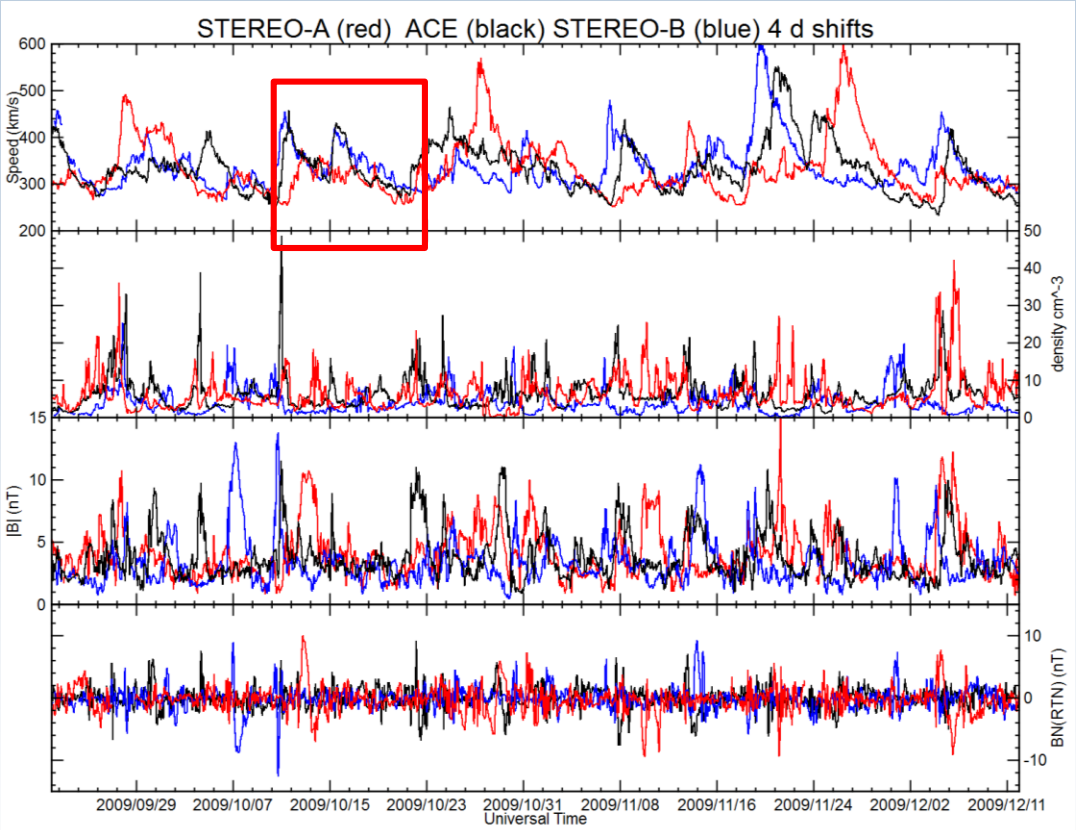
- Plasma and magnetic parameters
- Few features align, as might be expected for ICMEs intersecting two or three spacecraft



Data courtesy CDAWeb

STEREO/ACE Autumn 2009

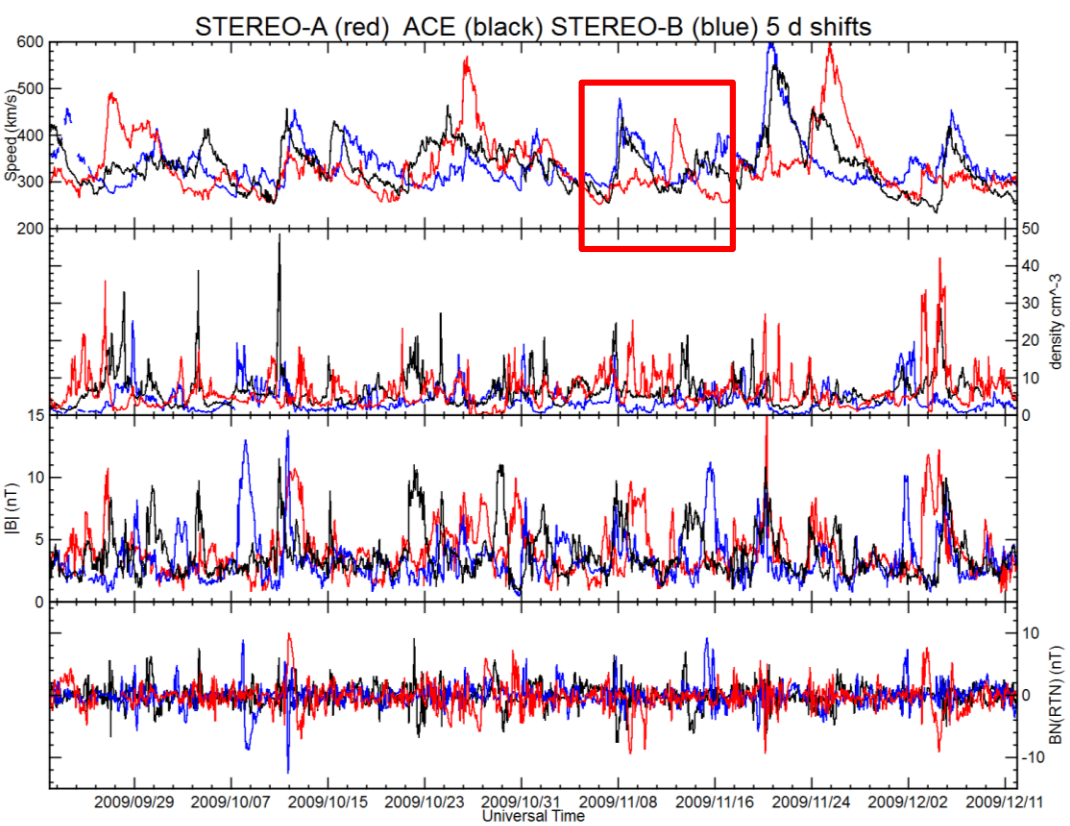
- Plasma and magnetic parameters after adding a 4 day interval to STEREO-B data and subtracting a 4 day interval from STEREO-B data
- Flows agree well between STEREO-B and ACE ~Oct 10-20, but not so well at STEREO-A
- Is this due to SIR evolution, or spacecraft latitude differences, or another cause?
- Most of the enhanced |B| and n events are ICMEs or SIRs



Data courtesy CDAWeb

STEREO/ACE Autumn 2009

- Plasma and magnetic parameters after adding a 5 day interval to STEREO-B data and subtracting a 4 day interval from STEREO-B data
- Flows agree well between STEREO-B and ACE ~Nov 08-24, (and some other times) but again not so well at STEREO-A
- Is this due to SIR evolution, or spacecraft latitude differences, or another cause?



- Most of the enhanced |B| and n events are ICMEs or SIRs

Data courtesy CDAWeb

Summary

- Plasma flow speed and density are essential parameters for estimating geo-effectiveness of the solar wind

- Observations from pairs of spacecraft 60˚ apart in longitude are available using STEREO and ACE in summer 2008 and autumn 2009; proxies for L5-Earth comparisons
- This was a period of relatively low solar activity, things would be more complex at more active times
- Work is in progress assessing predictive value
  - ICMEs are rarely seen (in this quiet period) at two spacecraft separated by 60˚
  - SIRs are more commonly seen at both spacecraft, but not all events show simple corotating speed profiles.
- An L5 mission would enable advances in modelling of the solar wind and interplanetary magnetic field in the inner heliosphere

Postscript: a paper is in preparation based on this work