A Comparative Study of Different Approaches to Modeling the Solar Wind

Sun, X. and Hoeksema, J. T., Stanford University

The WSA Model In Solar Wind Modeling:

1. Flux tube expansion factor (f_s)
2. Angular distance to the coronal hole edge (θ_b)

$$v = 265 + \frac{1.5}{(1+f_s)^{0.4}}[5.8 - 1.5\exp(1-(\frac{\theta_b}{2.5})^{2.0})]^{3.5}$$

Coronal Field Modeling:

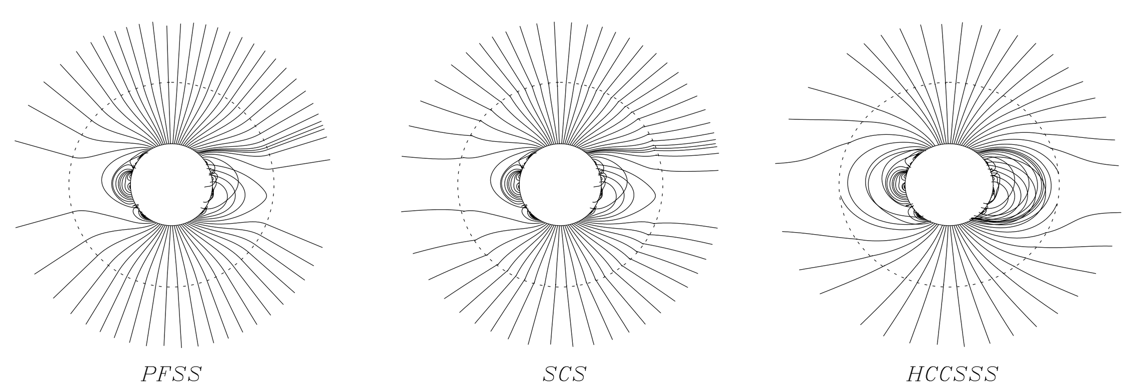

Fig1 Derived field configuration from 3 models CR1922

1. PFSS

Potential field (PF) everywhere; field becomes radial on the source surface (SS).

2. SCS

Potential field below SS; radial field at SS; current sheet (CS) above SS.

3. HCCSSS

SS near Alfven point; introduces cusp surface and streamer current sheet; introduces horizontal current (HC); field not necessarily radial at cusp surface.

Data Processing:

1. Input: MDI magetogram
   a. Correct the effect of solar *b* angle; convert LOS to radial map.
   b. Convert 3600x1080 sine-latitude map to 144x72 latitude map.
   c. Use well observed polar data and a time interpolation to fill in the polar field.
   d. Remove monopole.
2. Compute: Field line tracing
   a. Starting from a certain height, trace field lines downward.
   b. Compute expansion factor and angular distance; predict speed near the sun
   c. Propagate solar wind material to 1AU; compare the prediction with WIND

Comparison: CR1922

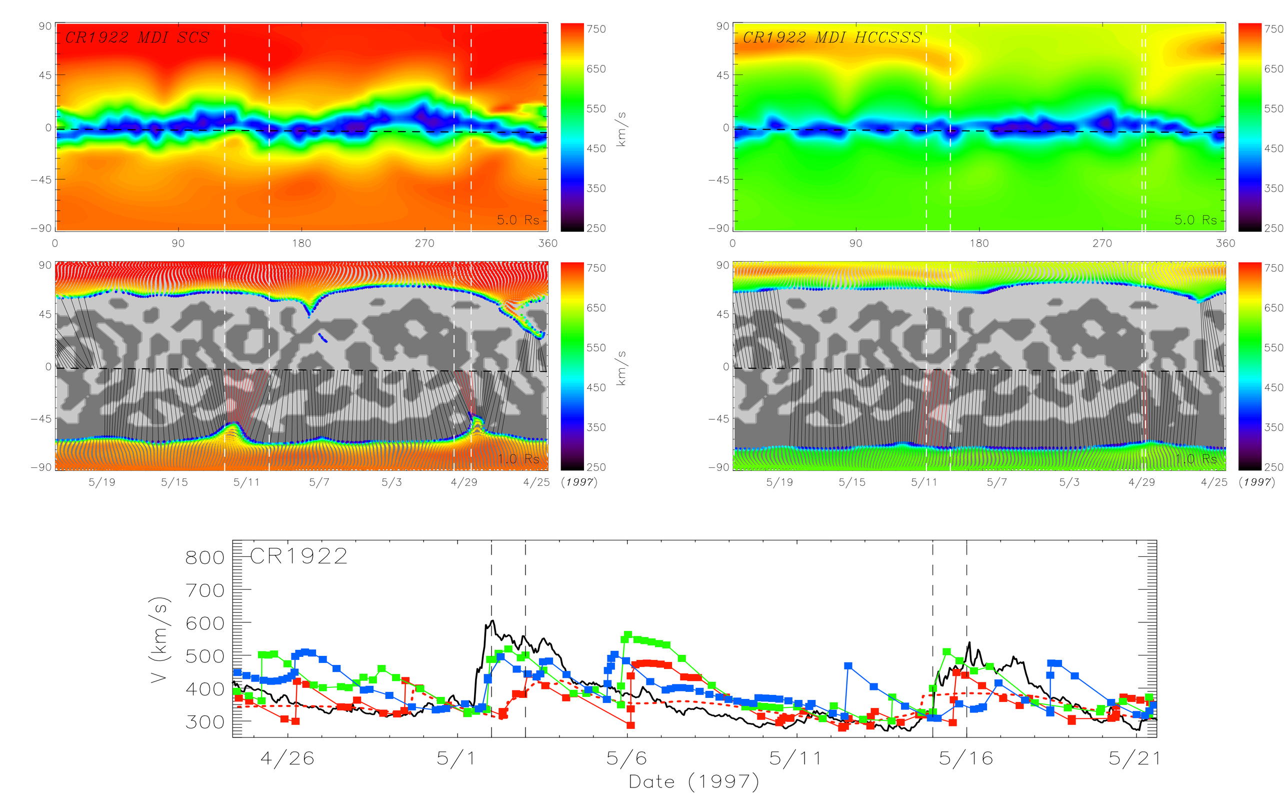

Fig2 Predictions from different models for CR1922

(Red: PFSS; Green; SCS; Blue: HCCSSS; Red dot: old WSA; Black: WIND)

Comparison: over a Solar Cycle

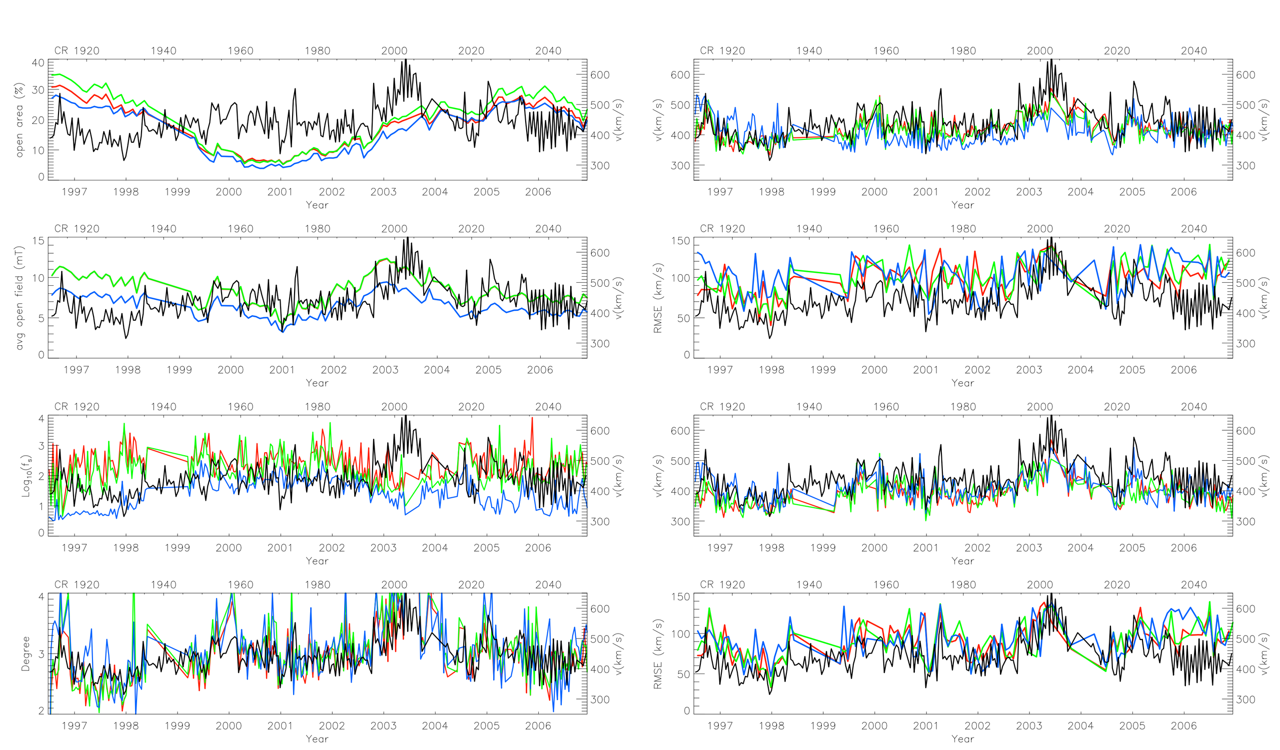

Fig3 Left: area of open flux; averaged absolute Br; expansion factor; angular distance

Right: prediction and RMSE with a single function; with empirical function fitted for each CR

Discussion & Conclusion:

1. HCCSSS model generally predicts a more uniform speed. Unlike other two models, there is no radial constraint on the field at 2.5 solar radii. The polar field expands more, resulting in a more uniform field. The area of open flux region and the total absolute flux from HCCSSS is smaller, too.

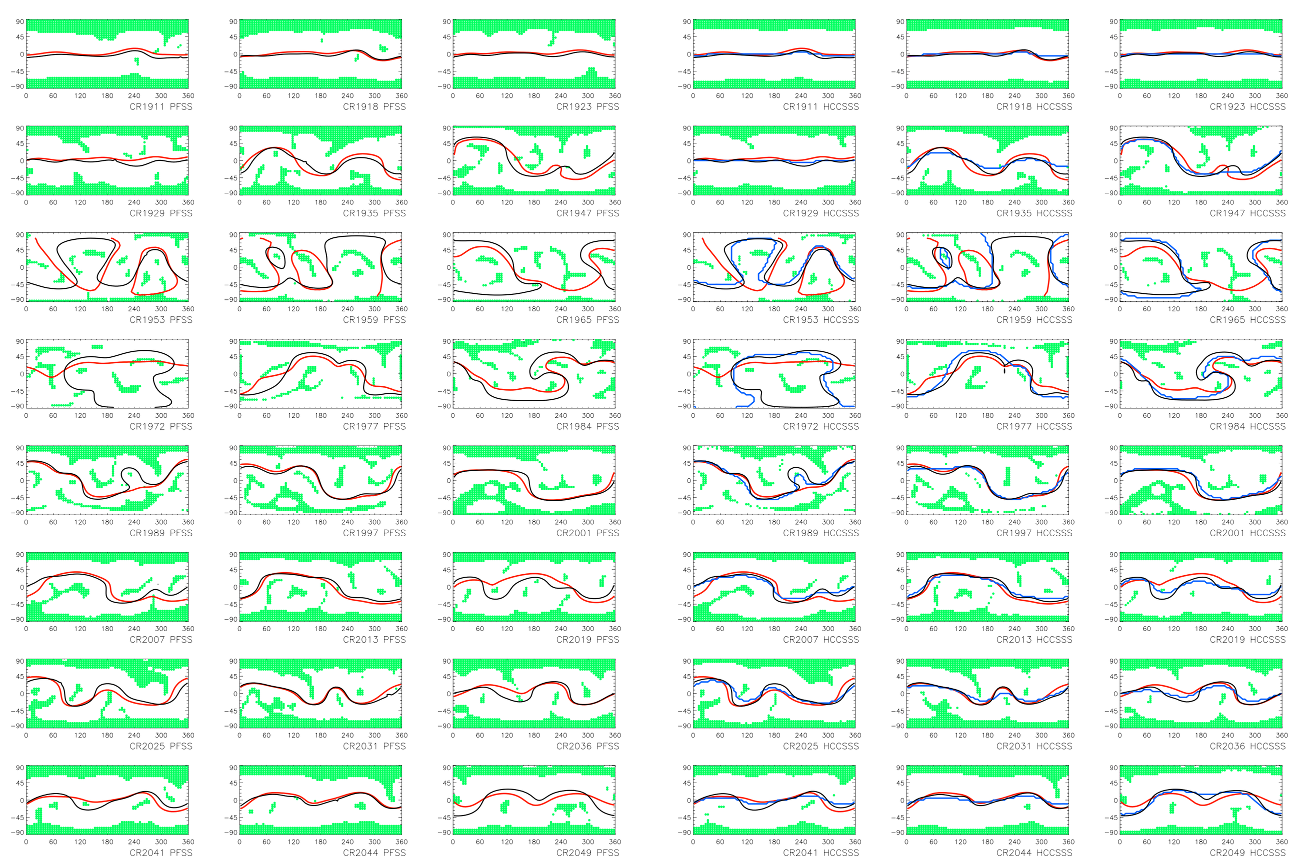

Fig4 Foot points and neutral lines derived from SCS and HCCSSS

Neutral lines with Black: 2.5$R_\odot$; Blue: 15$R_\odot$; Red: WSO 2.5$R_\odot$

2. If we use a single function over a solar cycle, the performance of three models varies systematically. Amongst the three, SCS works the best. However, by optimizing the empirical function for each prediction, there's no obvious evidence to choose one over the others. By fitting the empirical function objectively over time, we may be able to find a unique scheme for each model.

3. Data processing is essential to speed prediction, and the polar field correction is the most important step. Our current scheme works well in many ways, yet There is still a north-south asymmetry that needs to be worked on.

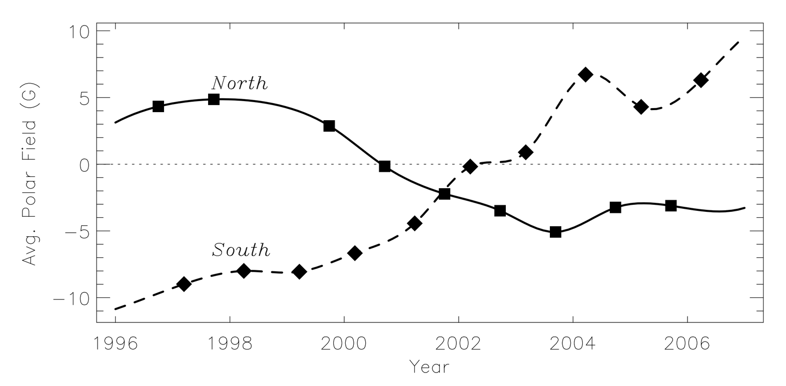

Fig5 Interpolated averaged polar field

References:

Wang, Y.-M. & Sheeley Jr., N. R., 1990, ApJ, 355, 726.
Arge, C. N. et al., 2003, Solar Wind Ten, CP679.
Schatten, K. H., 1971, Cosmic Electrodynamics, 2, 232.
Zhao, X. & Hoeksema, T., 1994, Solar Physics, 151, 91.
Bala, P. & Zhao, X., 2004, J. Geo. Res., 109, A08102.
Richardson, I. G. & Cane, H. V., 1995, J. Geo. Res., 100, 23297
Liu, Y. et al., 2007, AAS/AAPT Joint Meeting, #24.05