A New Source Surface Radius in Potential Field Modeling During the Current Weak Solar Minimum?

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Introduction

• The potential-field source-surface (PFSS) model is widely used to extrapolate field in corona from the photosphere. It is very useful for describing large-scale coronal structures.
• A 2.5 solar radii source surface (Hoeksema et al., 1983) successfully reproduces the interplanetary magnetic field (IMF) polarity at 1AU. It gives a good description of the streamer belt topology and coronal hole location too for the last minimum.
• The current minimum shows an overall weaker field (fig 1). A smaller source surface is needed (Ludlam et al., 2009) to produce the observed coronal structures and to keep the model self-consistent in terms of open flux.

Estimating the Source Surface Radius:

• During the current weak minimum, the current sheet is more warped; there are more large mid-latitude coronal holes; the photospheric field and IMF are both weaker than the last but by a different factor. A source surface of about 1.8 solar radii yields a better result.

Modeling Heliospheric Current Sheet

• Bright stripes in LASCO C2 and STEREO COR coronagraphs show the streamer belt structure. The helmet streamer structures whose core at the source surface define the base of the heliospheric current sheet. The zero isosurface of radial field in PFSS model describes the inferred location of the current sheet.
• For the last minimum, a 2.5 solar radii source surface produces a relatively flat current sheet and fits observation well. For the current minimum where the current sheet looks more warped, a source surface of 1.8 solar radii seems better (fig 2).
• However, for modeled IMF polarity where solar wind stream interactions are involved, the 2.5 solar radii source surface yields better result for both periods (fig 3).

Modeling Coronal Hole Location

• Dark regions in EIT and STEREO SECCHI EUVI 195A observations indicate open field structures, in the lower corona, which show the location of coronal holes. In PFSS, we can specify the open field foot points by field line tracing.
• During the previous minimum, there are few mid-low latitude coronal holes, and a 2.5 solar radii source surface correctly shows that most open flux comes from the polar region. For the current minimum, we see more large middle and low latitude coronal holes. The 2.5R source surface fails to reproduce them, while a source surface of about 1.8 solar radii works better (fig 4).

HCCSSS: An Improved Approach

• The PFSS model assumes that field lines are radial outside the source surface, which does not fit the observations well. It also assumes there is no current flowing in the corona. Therefore, inferred coronal field at low latitude are significantly lower than high latitude, causing a false latitudinal field gradient (fig 5).
• By introducing a horizontal current sheet (Schatten, 1971), the flux is more uniformly distributed over latitude. The horizontal-current sheet-source-surface (HCCSSS) model (Zhao and Hoeksema, 1995) introduces horizontal current to the system, while also satisfying the magnetostatic equations (Dogiel and Lueft, 1996). It gives a more realistic description of the corona, while predicts IMF strength at higher accuracy (fig 6).

Conclusions

• The PFSS model with a 2.5 solar radii source surface models the coronal structures well during the last minimum.
• During the current weak minimum, the current sheet is more warped; there are more large mid-latitude coronal holes; the photospheric field and IMF are both weaker than the last but by a different factor. A source surface of about 1.8 solar radii yields a better result.
• The current sheet sector structure at 1AU, however, is better reproduced by the 2.5 solar radii source surface in both minimum.

References

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Fig 1 Sunspot number (top), IMF Bx component from WSO (bottom), and Solar Geophysical Data (not in this work) over the last three cycle. Streaked lines show the polarity changes. A decision in value is plotted for all three panels into this composite with the box.

Fig 2 Magnetic latitude map from LASCO C2 coronal hole at 1.8R and 2.5R (OMNI data, and from 2005/05/01 to 2005/06/30) on blue box (n=820). North hemisphere are zero isosurface of ± 2.5 R as current stream interactions, computed from PFSS with different source surface radii.

Fig 3 Heliospheric current sheet from OMNI data, daily averaged, shaded by a 7-day period time filtered in show the heliographic sector and coronal hole structures. (Middle) Modelled current sheet, 2.5R source surface, assuming magnetic field at 2.5R source surface. (Right) modelled current sheet with 1.8R source surface, computed from PFSS with different source surface radii.

Fig 4 Illustration of how to determine source surface radius in terms of open flux. Radial open flux from different flux base lines. Vertical axis shows the difference to the flat IMF case. Horizontal lines show the observed IMF. If 2.5R is used for last minimum, 1.8R is needed for the current one.

Fig 5 Illustration of how to determine source surface radius in terms of open flux. Radial open flux from different flux base lines. Vertical axis shows the difference to the flat IMF case. Horizontal lines show the observed IMF. If 2.5R is used for last minimum, 1.8R is needed for the current one.

Fig 6 Illustration of how to determine source surface radius in terms of open flux. Radial open flux from different flux base lines. Vertical axis shows the difference to the flat IMF case. Horizontal lines show the observed IMF. If 2.5R is used for last minimum, 1.8R is needed for the current one.

Fig 7 Open flux from dipole field and PFSS, on source surface radii from two minima.