How Good are Potential Field Source Surface Models? What the MHD Modelers Don't Want you to Know

At SAIC, we have also been studying the ambient global structure of the solar corona and solar wind. The large-scale, steady-state magnetic field configuration of the solar corona is typically computed using boundary conditions derived from photospheric observations. Two popular approaches in use today are: (1) potential field, source surface (PFSS) models; and (2) magnetohydrodynamic (MHD) models. The former have the advantage that they are: simple to develop and implement; require relatively modest computer resources; and can resolve global structure on spatial scales beyond those that can be handled by current MHD models. On the other hand, they have been criticized because their basic assumptions (that the field is potential and that a single, spherical source surface exists) are seldom, if ever, met. In addition, PFSS models cannot directly incorporate time dependent phenomena, such as magnetic reconnection, and, moreover, do not include plasma or its effects. We have assessed how well PFSS models can reproduce the large-scale quasi-static magnetic structure of the corona by making detailed comparisons with MHD solutions at different phases in the solar activity cycle. In particular, we: (1) computed the shape of the source surface as inferred from the MHD solutions to assess deviations from sphericity; (2) compared the coronal hole boundaries as determined using the two models; and (3) compared the open flux determined from the two models with the magnetic flux observed at 1 AU.

As an illustration of this study, in Figure 1 we summarize the 3-D coronal field structure for CR1910, which occurred shortly before the minimum of the solar activity cycle using the MHD model (left) and PFSS model (right). The solar surface is colored according to the radial component of the magnetic field at the photosphere. Field lines have been assigned random colors for ease of identification, and the same starting points at the photosphere were used in tracing the field lines. Considering CR1910 first, comparison between the two panels suggests that, to a first approximation, the PFSS and the MHD model match in a number of respects. The coronal holes (which appear as the bundles of open field lines above the north and south polar regions), for example, are qualitatively the same. The larger closed loops connecting the northern and southern mid latitudes as well as the smaller loops associated with the active regions are qualitatively similar. However, there are several notable differences. First, the PFSS model does not reproduce the cusp like features of the streamer belt, which merge into the heliospheric current sheet in the MHD solution. The PFSS model also appears to underestimate the amount of flux opened up to the heliosphere (as inferred from the total number of open field lines. And finally, closed field lines in the PFSS model are, in general, shorter than their MHD counterparts. These comparisons hold to a greater of lesser degree for CR1969.

Our results suggest that, with caveats, the PFSS solutions yield surprisingly good matches to the MHD solutions for configurations based on untwisted coronal fields, i.e., when driven by line-of-sight magnetograms. It remains an open question as to how well they can perform when vector magnetograms are used as boundary conditions for the MHD models. This will be addressed in the near future when vector data from SOLIS and Solar-B can be incorporated into the MHD models.

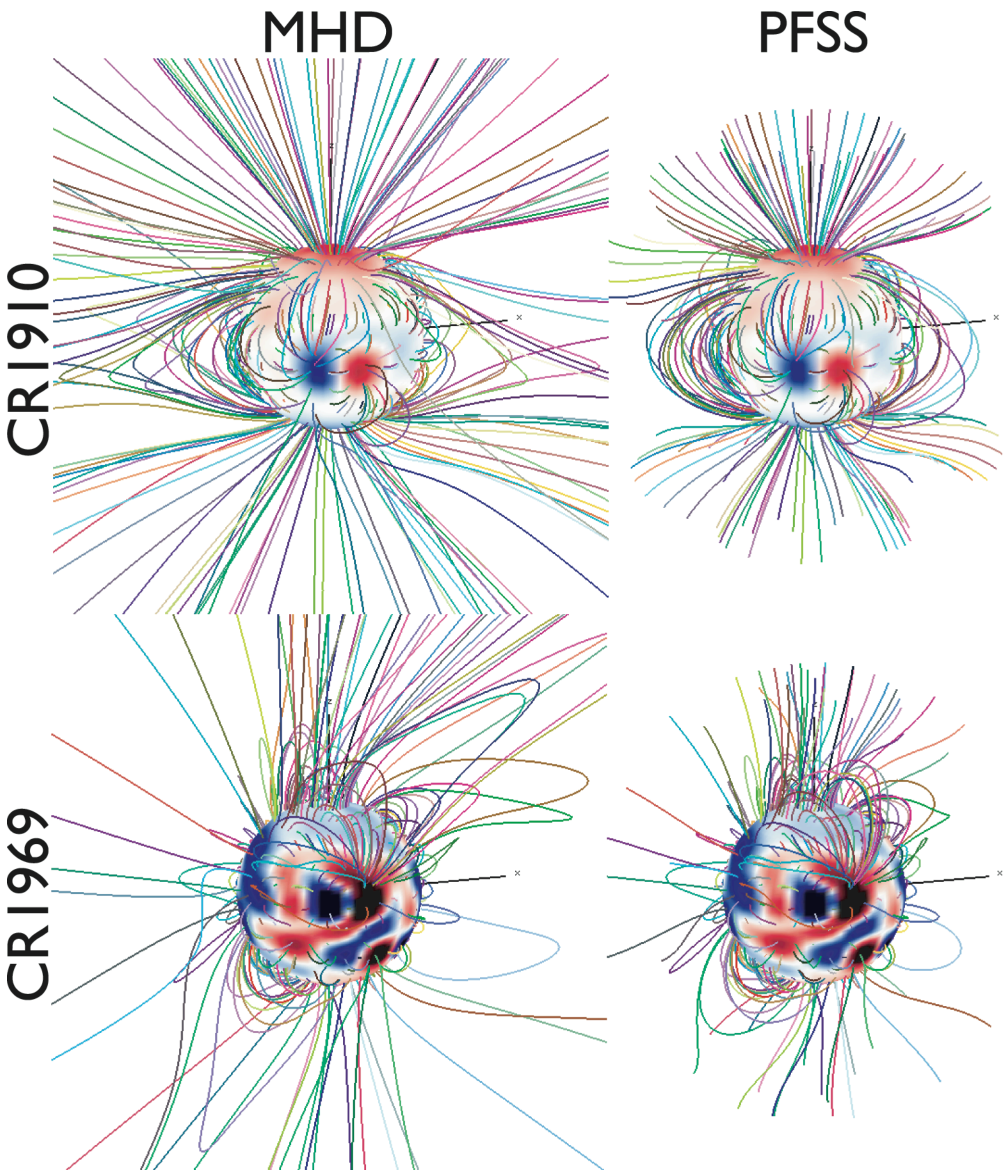

Figure 1. Comparison of PSFF Model (left) with MHD solution (right) for Carrington rotations 1910 (top) and 1969 (bottom). The solar surface is colored according to the radial component of the magnetic field at the photosphere. Field lines have been assigned arbitrary colors for ease of identification; however, the same starting points at the photosphere were used in tracing the field lines in all panels, allowing a direct comparison between the PFSS and MHD solutions.