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Global MHD Modeling of the Solar Corona and Inner Heliosphere for the Whole Heliosphere Interval

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Abstract. With the goal of understanding the three-dimensional structure of the solar corona and inner heliosphere during the "Whole Heliosphere Interval" (WHI), we have developed a global MHD solution for CR 2068. Our model, which includes energy transport processes, such as coronal heating, conduction of heat parallel to the magnetic field, radiative losses, and the effects of Alfvén waves, is capable of producing significantly better estimates of the plasma temperature and density in the corona than have been possible in the past. With such a model, we can compute emission in extreme ultraviolet (EUV) and X-ray wavelengths, as well as scattering in polarized white light. Additionally, from our heliospheric solutions, we can deduce magnetic field and plasma parameters along specific spacecraft trajectories. We have made detailed comparisons of both remote solar and *in situ* observations with the model results, allowing us to: (1) Connect these disparate sets of observations; (2) Infer the global structure of the inner heliosphere; and (3) Provide support for (or against) assumptions in the MHD model, such as the empirically-based coronal heating profiles.

Keywords. Sun: corona, Sun: evolution, Sun: magnetic fields, Sun: solar wind, interplanetary medium

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1. Introduction

Whole Heliosphere Interval (WHI), which ran from March 20 through April 16, 2008, and coincided with Carrington Rotation (CR) 2068, is providing a unique opportunity for both observers and modelers to collaborate in an effort to understand the three-dimensional structure and evolution of the solar corona and inner heliosphere. It builds on the previous Whole Sun Month (WSM) interval, which proved to be exceptionally successful. WHI occurred on the way to the current solar minimum, which has, thus far, been unique in a number of ways. For example, the polar photospheric flux is lower than the previous minimum by $\sim 40\%$ (Svalgaard and Cliver 2007) and the coronal holes are noticeably smaller (Kirk et al. 2009). Measurements by *in situ* spacecraft show substantial differences between the current minimum and the previous three. As of late 2008, Ulysses polar observations, in particular, suggested that: (1) The interplanetary magnetic field (IMF) was $\sim 36\%$ lower than the previous minimum (Smith and Balogh 2008); (2) The scaled number density was $\sim 17\%$ lower (McComas et al. 2008); and (3) The scaled temperature was $\sim 14\%$ lower (McComas et al. 2008). It was also determined that the bulk solar wind speed was $\sim 3\%$ lower, although this may not represent a statistically significant change. The profiles of high-speed streams upstream of Earth also seem to be unique, being stronger, longer in duration, and more recurrent than the previous minimum (Gibson et al. 2009).

To understand the three-dimensional structure during the WHI, and, more generally, the unique features of the current solar minimum, we have undertaken a detailed investigation involving magnetohydrodynamic (MHD) modeling of the global structure of

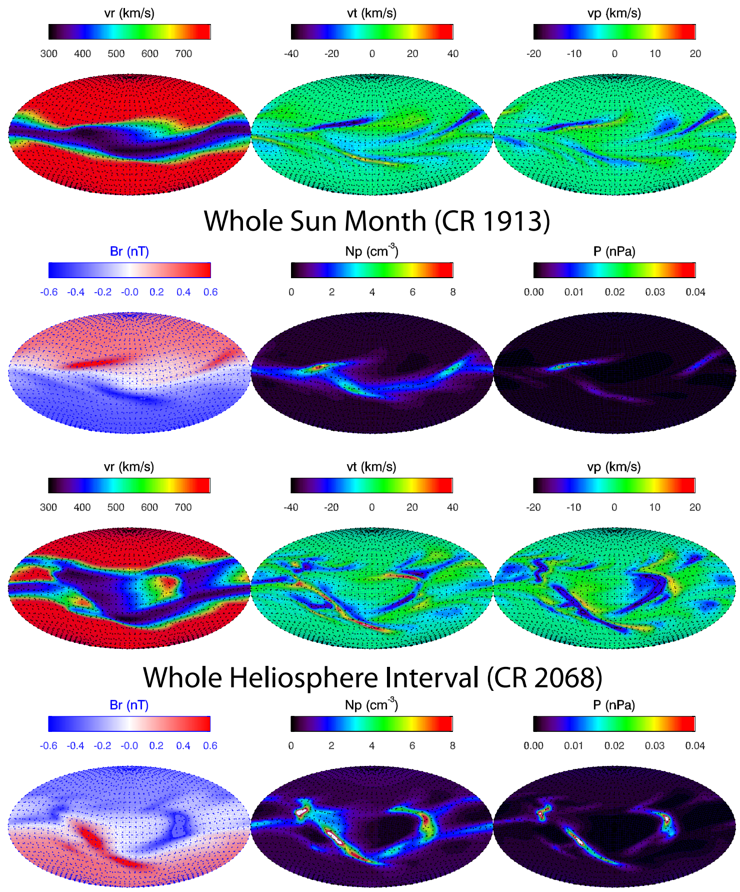

Figure 1. Mollweide projection maps of radial speed (v_r), meridional speed (v_r), azimuthal speed (v_p), radial magnetic field (B_r), number density (N_p), and thermal pressure (P) for Carrington rotation 1913 (Top), corresponding to the Whole Sun Month (WSM) interval, and 2068 (Bottom), corresponding to the Whole Heliosphere Interval (WHI).

the corona and inner heliosphere, analysis of remote solar and *in situ* measurements, and interpretation and connection of the data using the simulation results. Our model results allow us to explore the physical connections between the various phenomena and synthesize these diverse observations into a coherent picture. In this brief report, we highlight one specific aspect of this study: A comparison of the large-scale three-dimensional structure of the inner heliosphere during WSM and WHI.

2. Modeling the Large-Scale Structure of the Heliosphere during WSM and WHI

MHD models have proven highly successful in interpreting and understanding a wide array of solar and heliospheric phenomena. They provide a global context for connecting diverse datasets and understanding the physical interrelationship between often dissimilar phenomena (Riley et al. 1996, 2001a,b, 2002, 2003; Riley 2007). Our group has studied the properties of the ambient solar wind for a number of years, and found that, in general, our model can reproduce the essential large-scale features of the solar wind. While these past comparisons demonstrate the success of the MHD model, the simplified polytropic approximation used has limitations. In the current study, we have developed coupled global thermodynamic MHD simulations driven by observed photospheric magnetic fields to study the large-scale, quasi-stationary properties of the WHI and understand the differences between the current solar minimum and the previous one, as characterized by the Whole Sun Month (WSM) interval (August/September, 1996).

In Figure 1, we show the three components of speed, together with the radial magnetic field strength, number density, and thermal pressure for WSM and WHI. The differences are quite remarkable. First, the "band of solar wind variability," that is, the region of typically slower, but more variable solar wind, and roughly centered about the helio-equator, extends to significantly higher latitudes during WHI. Second, the polar speeds are essentially the same for the two minima (confirmed by Ulysses observations). Third, a significant source of fast solar wind in the ecliptic plane derives from equatorial coronal holes during WHI. Fourth, the structure of CIRs is more complex during WHI: The systematic, opposed tilts observed during the declining phase of solar cycle 22 (Gosling et al. 1995; Riley et al. 1996, 2001a,b) are not nearly as well defined during WHI; the equatorial coronal holes producing more localised "U" shaped interaction regions (Riley et al. 2003).

3. Closing Remarks

In this brief report, we have summarized one aspect of our modeling effort to support the goals of the WHI Campaign. Model results will be contributed to the WHI repository (http://ihy2007.org/WHI/obs_models.shtml) and will be made available through Predictive Science's website (http://www.predsci.com).

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