Project Details

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Project Title:
Using SDO/HMI data to investigate the energization of the coronal magnetic field

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Summary:
The energy to power solar energetic events must ultimately originate at or below the solar photosphere, and is likely to build up in the coronal magnetic field before release in an event. We propose here to use the unique properties of the data from SDO/HMI to follow the flux of free energy from below the photosphere into the corona, and out into the heliosphere, to try to understand the mechanism(s) which lead to the build up of magnetic free energy in the corona.

For this investigation, we will consider a small sample of active regions, on the order of 25. The data from the HMI instrument are new, and subject to artifacts whose influence on our analysis is not yet fully understood. By starting with a small number of active regions, we will be able to consider each in enough detail to determine how artifacts in the data influence the results, and how to correct or account for their effects in the analysis. Promising initial results would warrant a follow-up study of a statistically significant number of active regions, but that is beyond the scope of this investigation.

Our investigation will primarily utilize products produced by the HMI data analysis pipelines. To infer changes in the energy below the photosphere, we will use flow maps at a variety of shallow subsurface depths from local helioseismology, generated both by the pipeline running at Stanford University and the pipeline running at Max-Planck-Institut fuer Sonnensystemforschung.

To track the flow of free energy through the photosphere, we will use the vector magnetic field observations, combined with the flow at the surface obtained from DAVE4VM. These will be used to directly calculate the Poynting flux, to estimate the rate at which free energy is building up in the corona using a topological method, and to estimate the energy in the coronal magnetic field from the virial theorem. Finally, we will use nonlinear force-free extrapolations from the pipeline to estimate the coronal magnetic energy.

Each of these techniques is subject to a different set of assumptions, with different strengths and weakness, so one of the key issues in all of these approaches will be estimating how accurate the results are. In order to do this, we will compare the results of different methods of estimating the flow field close to the photosphere, and also compare the results of the different methods for estimating the free magnetic energy. In addition, we will estimate the uncertainties in the results of the methods.

Once we have the best available estimates of the flows and free energy flux, we will search for spatial and temporal associations between them. Specifically, we will look for whether upflows at different depths are consistently observed before or during the inflow of free energy, or whether predominantly horizontal flows are more closely linked to changes in free energy. These scenarios will be interpreted in the context of whether free energy enters the corona by the transport of nonpotential field from below the photosphere into the corona or if footpoint motions of a line-tied system energize an existing field. In addition, we will characterize how these associations evolve by examining active regions at different stages in their lives.

Finally, we will look for a temporal relationship between the injection of free energy and the occurrence of major flares. Is there a steady build-up of magnetic free energy, or are there episodes in which large amounts of energy are added comparatively quickly? We will attempt to characterize the distribution of time delays between free energy being introduced to the corona, and its release into the heliosphere.

Our investigation is likely to lead to new physical understanding of how the energy which powers solar energetic events is stored in the corona, and may lead to new tools for predicting the occurrence of such events.

Publication References:

Summary: no summary

Reference: Hayashi, K.; Liu, Y.; Sun, X.; Hoeksema, J. T.; Centeno, R.; Barnes, G.; Leka, K. D.; (2013), Making global map of the solar surface Br from the HMI vector magnetic field observations. Journal of Physics: Conference Series, Volume 440, Issue 1, article id. 012036, doi: 10.1088/1742-6596/440/1/012036

Summary: no summary

Reference: Hoeksema, J. Todd; Liu, Yang; Hayashi, Keiji; Sun, Xudong; Schou, Jesper; Couvidat, Sebastien; Norton, Aimee; Bobra, Monica; Centeno, Rebecca; Leka, K. D.; Barnes, Graham; Turmon, Michael; (2014), The Helioseismic and Magnetic Imager (HMI) Vector Magnetic Field Pipeline: Overview and Performance. Solar Physics, Volume 289, Issue 9, doi: 10.1007/s11207-014-0516-8

Summary: no summary

Reference: Centeno, R.; Schou, J.; Hayashi, K.; Norton, A.; Hoeksema, J. T.; Liu, Y.; Leka, K. D.; Barnes, G.; (2014), The Helioseismic and Magnetic Imager (HMI) Vector Magnetic Field Pipeline: Optimization of the Spectral Line Inversion Code. Solar Physics, Volume 289, Issue 9, doi: 10.1007/s11207-014-0497-7

Summary: no summary

Reference: Bobra, M. G.; Sun, X.; Hoeksema, J. T.; Turmon, M.; Liu, Y.; Hayashi, K.; Barnes, G.; Leka, K. D.; (2014), The Helioseismic and Magnetic Imager (HMI) Vector Magnetic Field Pipeline: SHARPs - Space-Weather HMI Active Region Patches. Solar Physics, Volume 289, Issue 9, doi: 10.1007/s11207-014-0529-3

Summary: no summary

Reference: Schuck, Peter W.; Antiochos, S. K.; Leka, K. D.; Barnes, Graham; (2016), Achieving Consistent Doppler Measurements from SDO/HMI Vector Field Inversions, The Astrophysical Journal, Volume 823, Issue 2, article id. 101, 22 pp, doi: 10.3847/0004-637X/823/2/101