Project Details

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Project Title:
The Coronal Global Evolutionary Model (CGEM)

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Summary:
Coronal mass ejections (CMEs) and large solar flares produce the strongest space weather disturbances, and are driven by the release of stored magnetic energy low in the solar corona. Since the build up of coronal magnetic energy is induced by magnetic evolution at the photosphere, the ability to use observations of the evolving photospheric magnetic field to drive a time-dependent model of the coronal magnetic field has long been a goal of both NASA's Living With a Star (LWS) Program and the multi-agency National Space Weather Program (NSWP), with the aims of both understanding how CMEs and flares work and predicting such events. Here, we --- a collaborative team from UC Berkeley, Stanford, and Lockheed-Martin --- demonstrate precisely this ability, using sequences of vector magnetograms and Dopplergrams from the Helioseismic and Magnetic Imager (HMI) instrument aboard the LWS program's Solar Dynamics Observatory to drive a magnetofrictional (MF) model of the coronal magnetic field in AR 11158, which produced an X2.2 flare. During a three-day simulation run, magnetic energy in the model field increased steadily, and the model field erupted at a time in the data sequence coincident with the actual flare. We propose to implement this MF model in spherical coordinates, to enable real-time, long-term modeling of the non-potential coronal magnetic field, both globally and for active region (ARs). The model's Earth- facing hemisphere will be driven using electric fields derived from the observed evolution of photospheric line-of-sight magnetic fields and electric currents. Far-side data inputs will be from an existing flux transport code, combined with HMI far-side observations of new active regions, with empirical parametrizations of orientation and flux. Because this model includes large-scale coronal electric currents, it is a substantial improvement over existing real-time global coronal models, which assume potential fields. Data products available from the model include: 1) the evolving photospheric electric field, Poynting flux, and helicity flux; 2) estimates of coronal free energy and non-potential geometry and topology; 3) initial and time-dependent boundary conditions for MHD modeling of active regions; and 4) time-dependent boundary conditions and flux tube expansion factors for MHD and empirical solar wind models. Unstable configurations found from MF models will be dynamically evolved with local and global MHD codes. Modules used to derive surface electric fields from magnetic evolution will be incorporated into the HMI data pipeline, and data products will be distributed through the JSOC and directly to space weather forecasters and users. The electric field and MF codes will be delivered to the CCMC for science analysis and use with other models.

Intellectual Merit: By including electric currents in modeling long-term coronal evolution driven by photospheric evolution, our magnetofrictional model will improve our capability to study both how the coronal magnetic field responds to conditions at the solar surface, and how and where magnetic energy is stored in the corona.

Broader Impacts: This model will represent an improved fidelity over existing potential- field global solar models, and will result in an improved ability to model and predict space-weather events and conditions, and thereby lead to better space-weather forecasting.

Publication References:

Summary: no summary

Reference: Hudson, H. S.; Fletcher, L.; Fisher, G. H.; Abbett, W. P.; Russell, A.; (2012), Momentum Distribution in Solar Flare Processes, Solar Physics, Volume 277, Issue 1, pp.77-88, doi: 10.1007/s11207-011-9836-0

Summary: no summary

Reference:
Sun, Xudong; Bobra, Monica G.; Hoeksema, J. Todd; Liu, Yang; Li, Yan; Shen, Chenglong; Couvidat, Sebastien; Norton, Aimee

A.; Fisher, George H.; (2015), Why Is the Great Solar Active Region 12192 Flare-rich but CME-poor?, The Astrophysical Journal Letters, Volume 804, Issue 2, article id. L28, 6 pp, doi: 10.1088/2041-8205/804/2/L28