Project Details

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Program Element: Focused Science Topic

Topic: Understanding The Onset of Major Solar Eruptions

Project Title:
Modeling the Causes and Consequences of Solar Eruptive Events that Drive Major Coronal Mass Ejections

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Summary:
A central goal of NASA's Living With a Star (LWS) Program is to develop the scientific capabilities necessary to understand and predict significant changes in the near-Earth space environment. The large solar flares and coronal mass ejections (CMEs) that produce the most severe space weather disturbances are powered by the rapid release of energy stored in the coronal magnetic field. Energy buildup and release in the low corona are driven both by the emergence of new flux through the solar photosphere, by the changes of the distribution of already-emerged magnetic flux, and the corresponding coronal evolution.

We propose a comprehensive series of data-inspired and data-driven numerical MHD simulations of energized active regions (ARs) that are observed to erupt with large flares that result in energetic coronal mass ejections. The aim of our simulations and analysis will be to obtain quantitative measures of the causes and consequences of solar eruptive events to answer the main scientific question: How do energized active region fields erupt?

Our simulations will be designed to address the following specific science questions:

(1.) What is the role of the photospheric boundary flows and vector magnetic field evolution in triggering the CME initiation?

(2.) What is the role of the adjacent and overlying AR and larger global-scale magnetic field in facilitating or inhibiting the CME initiation and eruption?

(3.) What are the roles of flux-cancellation and flux emergence in the energization and destabilization of AR configurations?

We will perform a set of 3D spherical MHD simulations with the RADMHD code based on a set of initial, energized magnetic field states obtained by the magneto-frictional (MF) modeling of a handful of eruptive ARs obtained via the Coronal Global Evolutionary Model (CGEM) framework. We propose to investigate the MHD response of these ARs and their surrounding flux systems to both idealized and observed boundary flows by leveraging the CGEM-MF capabilities to generate data-driven, energized magnetic field configurations observed by the Solar Dynamics Observatory.

The RADMHD boundary flows will be calculated via the PDFI electric field methods pioneered by our group in the development of the CGEM project. These energizing flows will generate Poynting flux, increase the free magnetic energy, inject relative

magnetic helicity, and evolve the spatial distribution of magnetic energy density throughout the simulation volume. We will test various flow and field evolution driving on the same CGEM-MF configurations in RADMHD computational domains of varying sizes to investigate: the contributions of the driving and subsequent evolution of the energized and overlying flux distributions; how much external, breakout-like reconnection or flux-cancellation/tether-cutting reconnection contributes to the AR destabilization and eruption; and how much flux emergence contributes to the energization and subsequent eruption.

Our multidisciplinary data analysis and data-driven modeling project directly supports the LWS FST Understanding the Onset of Major Solar Eruptions. Our proposed work will contribute to the FST by calculating the relevant physical observables associated with the energization and eruption of CME-producing ARs in both observations and our corresponding simulation data. We will explore the parameter space of energized AR systems right at the onset of their loss-of-equilibrium by modeling the full MHD evolution of these systems under different driving conditions and flux evolution scenarios.

Additionally, the proposed work addresses a number of the science goals identified in the Solar and Space Physics Decadal Survey, such as "determine the origins of the Sun's activity and predict the variations of the space environment," "determine the interaction of the Sun with the solar system," and "to discover and characterize fundamental processes that occur within the heliosphere."

Publication References:

no references