Project Details

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Topic: Advances Toward a Near Real Time Description of the Solar Atmosphere and Inner Heliosphere

Project Title:
Data-Optimized Modeling of ICMEs with Internal Magnetic Structure

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Summary:
If we are ever to predict the magnetic orientations and hence space-weather impact of interplanetary coronal mass ejections (ICMEs), we need to understand how they evolve from Sun to Earth. Progress hinges on being able to answer key questions such as:

* How does internal magnetic structure, including magnetic flux, topology, and orientation, affect ICME evolution during propagation, including distortion and shock formation, deflection and rotation, and magnetic reconnection/erosion?

* What is the role of ICME/solar-wind interactions in these processes, and what is their dependency on variation in properties of the background solar wind, such as magnetic field (strength and structure), dynamic pressure, and velocity distribution?

These questions, central to Heliophysics, cannot be answered by models or observations alone.

Our overarching goal is to develop a new method for incorporating solar and heliophysics data into models to describe and interpret ICME propagation and evolution in the solar wind in (near)-real time.

Our objectives are:

- to couple solar-heliospheric models in order to analyze physical processes driving ICME evolution and the role of internal magnetic structure and ICME/solar-wind interactions

- to compare model predictions to observations in a climatological study to understand when, where, and to what degree these physical processes occur

- to develop a data assimilation approach that uses event-specific solar and heliospheric data along with climatological constraints to forecast ICME properties at 1 AU.

Our methodology includes:

- Parameterized model examining how variations in ICME magnetic structure and the ambient solar wind affect evolution and propagation. We evaluate Gibson & Low (GL) self-similarly erupting CMEs at 20 Rs , insert them into Wang-Sheeley-Arge (WSA) corona/solar-wind models driven by ADAPT photospheric boundaries, and use the Lyon-Fedder-Mobarry heliospheric model extension (LFM-helio) to propagate the resulting ICMEs out to 1 AU.

- Posterior predictive distributions of model parameters conditional on observed solar and heliospheric climatology, for four phases of the solar cycle. We employ Bayesian statistics and the ROAM optimizer; climatological data include SOHO and STEREO solar/coronal observations, STEREO heliospheric imaging, and in-situ data as catalogued by OMNIWeb.

- Event studies yielding probabilistic forecasts of ICME properties. We test the method with synthetic data in Observing System Simulation Experiments (OSSEs), undertaking sensitivity studies for a range of observations and viewpoints (e.g. L5). We then apply it to real data for cases with good coronal/heliospheric/in-situ coverage and time-evolving ADAPT boundaries.

This study directly addresses the Heliophysics Decadal Survey goal to predict the variations in the space environment. Our contribution to the Focused Science Team effort will be a statistical, data-assimilative framework for (near) real-time prediction of properties of ICMEs at 1 AU, based on well-established models and climatological and event-specific observations from NASA spacecraft. We will apply this method to a particular analytic-numerical ICME/solar-wind model coupling, but it is broadly applicable. We will use both solar and heliospheric observations, including EUV, white-light, solar-wind HI and in-situ data. Through the OSSE, we will do a sensitivity study of all these observations, and also consider observations currently not available, e.g., from the L5 viewpoint. Uncertainty analysis, including propagation of errors, is built into the Bayesian statistical approach.

Publication References:

no references