Project Details

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Topic: Understanding Global-scale Solar Processes and their Implications for the Solar Interior

Project Title:
Improving Long Term Forecasts of Solar Variability with the Advective Flux Transport Model

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Summary:
The photospheric magnetic field drives the solar wind and produces space weather events such as solar flares and CMEs. The Advective Flux Transport (AFT) model combines data assimilation with the observed surface flows to accurately reproduce the evolution of the field. AFT uses an evolving convection pattern to produce realistic surface magnetic field maps (including a magnetic network). AFT can also incorporate synthetic Active Region (AR) data to perform experiments and make reliable predictions of the magnitude and timing of solar cycle properties.
Goals and Objectives
- Perform feature tracking of magnetic data to obtain surface flows and their residuals.
- Perform feature tracking on faculae to measure flow velocities of these features.
- Compare the measured flow velocities to access the uncertainty and improve estimates of the surface flows, particularly at latitudes above 75 degrees.
- Investigate relationships between the long-lived convective cells and the magnetic field.
- Provide an ensemble of predictions for Solar Cycle 25.

Methodology
We will use two distinct codes to measure the surface flows. Rightmire-Upton et al. tracked the magnetic patterns in SDO/HMI magnetograms to measure the axisymmetric Differential Rotation (DR) & Meridional Flow (MF). Recent improvements allow the code to more accurately measure the surface flows, particularly at high latitudes. We will use this improved code to measure the surface flows and their residuals (e.g. the torsional oscillations) for the entire MDI and HMI time periods.
Recently, the SWAMIS magnetic feature tracking code was used to measure DR & MF of individual magnetic features. We will adapt SWAMIS to track faculae in HMI continuum images. Faculae are magnetic structures that have increased visibility near the limb. We will compare the flows obtained where magnetic features and faculae overlap to develop an understanding of the uncertainty present in measurements of the faculae-derived flows.
Measurements of the surface flows explicitly include measurements of uncertainty both in the measured flow and in the fit parameters. We will quantify any systematic differences among our methods, and incorporate that knowledge into our reports of the measured flows.
Large-scale cellular flows (giant cells) are signatures of the internal dynamics of the the Sun s convection zone. They have been detected using the motion of supergranules and also with helioseismology. The detected structures are large, long-lived, and have the expected kinetic helicity and R large structures, axisymmetric flows, and the magnetic field.
AFT is a robust surface flux transport model that incorporates magnetic sources by manually inserting ARs or by assimilating magnetograms. Manual insertion allows AFT to investigate flows and make predictions, while assimilation produces accurate synchronic maps of the entire Sun. We will use AFT in assimilation mode to provide near-real time maps of the entire solar surface. We will use AFT in predictive mode to create multiple realizations of the Cycle 25 evolution and predict the timing of the polar field reversals and Cycle 25 maximum.
Proposed Contributions to the Focus Team Effort
Our study is relevant to the FST scientific objectives. We will provide improved forecasts of the photospheric magnetic field on timescales from months to years. Our contributions include Novel data analysis techniques; Use of feature finding algorithms; Observational studies of the spatial and temporal structure of solar surface flows; and Studies to develop assimilative methods. Our metrics of success will be a) the degree to which our high-latitude results are self-consistent, and agree with the internal & surface flows derived by other teams using helioseismology; b) the degree to which previous solar cycles (and Cycle 25) can be predicted.

Publication References:

no references