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

Project Title:
Active Region Dynamics and the Variability of Meridional and Zonal Flows

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Project Information:
Using helioseismic data analysis and numerical modeling we will assess the properties of flows related to magnetic fields on the Sun, including plage and active regions across a wide range of magnetic flux, and their contribution to the meridional and zonal components of global solar flows. Motivated by the recent discovery of high-latitude flow features, which may indicate convective giant cells, another component of our observing program is to explore in higher resolution the nature of high-latitude flows, their relation (if any) with magnetic fields, and their contribution to global dynamics.

Primary tasks include carrying out a high-resolution holography survey of flows around magnetic regions using HMI observations from the Solar Dynamics Observatory. We will use spatially coaligned ensemble-averages of near-surface calibrated flows, measured using helioseismic holography, to characterize the flows associated with active regions as a function of magnetic flux (from small regions with 10^20 Mx flux, to the largest observed in the current solar cycle), and as the regions evolve with time. A smaller survey of giant-cell candidates will also be performed. We will employ forward and inverse modeling of these averages, designed to maximize the signal-to-noise, to infer the depth variation of these flows. The contribution of these local flows to contemporary global meridional and zonal measurements, such as the torsional oscillations, will be assessed as a function of time for the duration of solar cycle 24. This is facilitated by identifying and accounting for the flows from active regions from daily synchronic magnetograms and employing our catalog of ensemble-averaged flows to perform high signal-to-noise longitudinal averages. The result will enable a separate characterization of the global, time-varying, dynamics and the local active-region flows, both of which are necessary as inputs to flux transport models and as constraints on solar dynamo and interior modeling. Validating the reliability of both surface and deeper inferences of the flows is achieved using synthetic data derived from state-of-the-art numerical MHD simulations of waves in the vicinity of magnetic regions. A portion of these simulations will have sufficient temporal duration to enable the examination of the physics of the flows, which may result from thermal winds under geostrophic conditions.

The identification and characterization of local active-region flows and giant-cells and their contribution to global dynamics, is critical to the goal of Focus Science Topic (FST) #4 in enabling a data-driven model for solar magnetic flux production to enable forecasting of active latitude and longitude regions over times scales of years or more. Specific to this goal is the establishment of a consensus set of observational constraints of surface and interior flows, with the latitudinal and temporal variation of meridional and zonal flows specifically called out. Our effort contributes directly to three of the suggested investigation types of FST #4, including "observational studies of the spatial structure of internal and surface solar flows," "inversion techniques," and "theory and modeling of large-scale flows."

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Citations: