Institute for Space Weather Sciences Colloquium

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Towards Data-Driven MHD Simulations of Solar Coronal Mass Ejection Events

Large scale solar eruptions such as solar flares and coronal mass ejections are manifestations of the explosive release of magnetic energy stored in the non-potential, current carrying coronal magnetic fields. Determining the realistic 3D coronal magnetic field evolution of the solar eruptive events are essential to understanding the physical mechanisms that have led to the eruptions and advancing the capability of predicting their space weather impact. In recent years, MHD simulations using observed data for constructing the initial and boundary conditions, called "data-constrained" and "data-driven" simulations, have seen significant development and played an increasingly important role in studying real solar eruptive events with complex magnetic structures. In this talk, I present the results of MHD simulations of two well-observed CME events from strong active regions using boundary driving electric fields derived from observations. In the simulation of the 2006 December 13 CME event from NOAA active region 10930, we drive at the lower boundary the emergence of a twisted magnetic flux rope based on the observe flux emergence pattern, and in addition a random electric field that represents the effect of turbulent convection. We find that the simulated pre-eruption magnetic field with the buildup of a twisted magnetic flux rope produces synthetic soft X-ray emission that shows qualitatively similar morphology as that observed by the Hinode/XRT for both the ambient coronal loops of the active region and the central inverse S-shaped "sigmoid" that sharpens just before the onset of the eruption. The synthetic post flare loop brightening also shows similar morphology to that seen in the Hinode/XRT image during the impulsive phase of the eruption. In the second simulation of the 2011 February 15 CME event of NOAA active region 11158, we devised a new lower boundary driving electric field that is computed directly from the evolution of the normal magnetic field and the vertical electric current from the HMI vector magnetograms. The simulation shows the build-up of a pre-eruption coronal magnetic field close to that obtained from the nonlinear force-free field extrapolation just before the onset of the observed X-class flare, and it subsequently develops multiple eruptions. The morphology of the current-carrying field lines shows good qualitative agreement with the brightening loops of the SDO/AIA hot channel images. In this case it is found that the pre-eruption sigmoidal fields are strongly sheared fields with no dipped field lines, until the onset of the eruption where an erupting magnetic flux rope containing dipped field lines forms because of the tether-cutting reconnection. Our simulation results suggest that the derived electric field based on the observed vertical electric current is a promising way to drive MHD simulations to establish the realistic pre-eruption coronal magnetic field and model its transition to dynamic eruption.

Dr. Yuhong Fan is a Senior Scientist at the High Altitude Observatory (HAO) at the National Center for Atmospheric Research (NCAR). She received a B.Sc. in Space Physics from Peking University, China, in 1989, and a Ph.D in Astronomy from the Institute for Astronomy at the University of Hawaii in 1993. Dr. Fan did her postdoctoral research at the National Solar Observatory (NSO) in Tucson, and at the Joint Institute of Laboratory Astrophysics (JILA), University of Colorado at Boulder. She joined the scientific staff of HAO/NCAR in 1998 and has been there ever since.

Dr. Yuhong Fan's research interest is in solar magneto-hydrodynamics. She has carried out MHD modeling of the solar convective dynamo, magnetic flux emergence from the solar interior into the corona, and the initiation of solar eruptions such as coronal mass ejections and the associated prominence eruptions.