

Approach to Integrate Global-Sun Models of Magnetic Flux Emergence and Transport for Space Weather Studies,

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The Sun lies at the center of space weather and is the source of its variability. The primary input to coronal and solar wind models is the activity of the magnetic field in the solar photosphere. Recent advancements in solar observations and numerical simulations provide a basis for developing physics-based models for the dynamics of the magnetic field from the deep convection zone of the Sun to the corona with the goal of providing robust near real-time boundary conditions at the base of space weather forecast models. The goal is to develop new strategic capabilities that enable characterization and prediction of the magnetic field structure and flow dynamics of the Sun by assimilating data from helioseismology and magnetic field observations into physics-based realistic magnetohydrodynamics (MHD) simulations. The integration of first-principle modeling of solar magnetism and flow dynamics with real-time observational data via advanced data assimilation methods is a new, transformative step in space weather research and prediction. This approach will substantially enhance an existing model of magnetic flux distribution and transport developed by the Air Force Research Lab. The development plan is to use the Space Weather Modeling Framework (SWMF) to develop Coupled Models for Emerging flux Simulations (CMES) that couples three existing models: (1) an MHD formulation with the anelastic approximation to simulate the deep convection zone (FSAM code), (2) an MHD formulation with full compressible Navier-Stokes equations and a detailed description of radiative transfer and thermodynamics to simulate near-surface convection and the photosphere (Stagger code), and (3) an MHD formulation with full, compressible Navier-Stokes equations and an approximate description of radiative transfer and heating to simulate the corona (Module in BATS-R-US). CMES will enable simulations of the emergence of magnetic structures from the deep convection zone to the corona. Finally, a plan will be summarized on the development of a Flux Emergence Prediction Tool (FEPT) in which helioseismology-derived data and vector magnetic maps are assimilated into CMES that couples the dynamics of magnetic flux from the deep interior to the corona.

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