Project Details

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Project Title:
Integrated Global-Sun Model of Magnetic Flux Emergence and Transport

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Summary:

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. We propose to develop 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 proposal addresses new strategic capabilities that enable characterizing and predicting 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 proposed 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. The primary deliverables will be three analysis tools that produce: (i) enhanced solar synoptic maps at the photosphere, (ii) first-principles-based models for the rise of magnetic structures from the deep interior to the corona, and (iii) local maps forecasting the location and emergence of active regions. The tools will result in substantial improvement in modeling and prediction of space weather.

The effort includes a substantial enhancement to an existing model of magnetic flux distribution and transport developed by the Air Force. The Air Force Photospheric Flux Transport, ADAPT, model is expected to be incorporated, during fall 2012, by the National Weather Service (NWS) Space Weather Prediction Center (SWPC) to approximate the magnetic flux at the base of the solar wind model (WSA-Enlil). We will develop an enhanced model under this proposal that will enable data assimilation of near-surface flow dynamics from helioseismology and vector magnetic data from the Solar Dynamics Observatory - Helioseismic and Magnetic Imager (HMI).

In addition to enhancing the data input and global magnetic modeling of ADAPT, we will 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, we will develop 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. This new simulation tool will be implemented within the SWMF, and we expect it to become part of the CCMC toolset of available community software.

Publication References:

Summary: no summary

Reference: Hartlep, T.; Zhao, J.; Kosovichev, A. G.; Mansour, N. N.; (2013), Solar Wave-field Simulation for Testing Prospects of Helioseismic Measurements of Deep Meridional Flows, The Astrophysical Journal, Volume 762, Issue 2, article id. 132, 7 pp, doi: 10.1088/0004-637X/762/2/132

Summary: no summary

Reference: Kitiashvili, I. N.; Kosovichev, A. G.; Mansour, N. N.; Wray, A. A.; (2015), Realistic Modeling of Local Dynamo Processes on the Sun, The Astrophysical Journal, Volume 809, Issue 1, article id. 84, 18 pp, doi: 10.1088/0004-637X/809/1/84

Summary: no summary

Reference: Guerrero, G.; Smolarkiewicz, P. K.; de Gouveia Dal Pino, E. M.; Kosovichev, A. G.; Mansour, N. N.; (2016), Understanding Solar Torsional Oscillations from Global Dynamo Models, The Astrophysical Journal Letters, Volume 828, Issue 1, article id. L3, 7 pp, doi: 10.3847/2041-8205/828/1/L3