Improving Space Weather Predictions with Data-driven Models of the Solar Atmosphere and Inner Heliosphere

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The solar wind (SW) emerging from the Sun is the main driving mechanism of solar events which may lead to geomagnetic storms that are the primary causes of space weather disturbances that affectthe magnetic environment of Earth and may have hazardous effects on the space-borne and ground-based technological systems as well as human health. Accurate modeling of the SW is a necessary part of space weather forecasting. We describe our efforts in the development of a new, publicly available, data-driven, time-dependent model of the solar corona and inner heliosphere aimed to predict the SW properties at Earths orbit and beyond. The new models provide more accurate solutions and are all scalable on massively parallel systems. This allows the user community to easily experiment with these tools and combine them with other models to produce more advanced space weather modeling capabilities.The suite of codes includes new versions of the (1) flux transport model (Open Flux surface Transport, OFT); (2) finite-difference potential field solver (POT3D), and (3) Reynolds-averaged MHD SW model based on modern computational methods. Component 1 primarily requires the solution of an advection-diffusion equation on the sphere and produces the magnetic field data on the full Sun. Component 2 requires the solution of Laplaces equation. Finally, component 3 requires solution of the MHD and turbulence transport equations with boundaries specified on the inner surface. The coronal simulations are based on the empirical

Wang-Sheeley-Arge model, which allows us to perform ensemble modeling of the SW with quantified uncertainties. The model of the inner heliosphere ensures the fourth order of accuracy in space and time on adaptive grids a feature of substantial importance for space weather simulations - and uses grids based on cubed spheres. The application of such grids makes it possible to get rid of the restriction on the computational time step imposed by the mathematical singularity on the z-axis, intrinsic to spherical grids. Special attention is paid to modeling of coronal mass ejections (CMEs) based on the derivation of their properties from multi-viewpoint images and remote observations.

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