TOWARDS FORECASTING SPACE WEATHER

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Perhaps the main shortcoming of the present generation of *physics-based Sun-to-Earth space weather simulations* is their inability to *systematically refine* models using *observations*. At the heart of the problem is the fact that there are only a handful of spacecraft observing the Sun, the interplanetary medium, the magnetosphere and the upper atmosphere. This situation will not change in the next few decades; in fact, even a hundred spacecraft orbiting the Sun would not change the situation qualitatively. *In situ* (local) measurements provide information only about a single point in the vast space environment, while remote sensing observations of the space environment are obtained with very long line-of-sight (LOS) integrals, where the physical parameters vary over many orders of magnitude between the observer and the region where the optical depth becomes large. LOS images of the solar corona provide the most detailed information about the origin of space weather events. One of the largest available data sets that provides information about the upper atmosphere of the Earth is the collection of Total Electron Content (TEC) data, derived from GPS measurements. TEC measurements provide a spatially intermittent view of the ionized component of the upper atmosphere over North America, Japan, and Europe.

Given the severe sparsity of *in situ* data, and the limited availability of remote sensing data, it is not surprising that space weather models are not as mature as tropospheric weather or even climate models. It is extremely difficult to constrain the models with available data and by relying on present somewhat *ad hoc* methods for determining the dominant physical processes within various regions of space.

Presently magnetohydrodynamic (MHD) models represent the workhorse technology for simulating the space environment from the solar corona to the ionosphere. While these models are very successful in describing many important phenomena, they are based on a low-order moment approximation of the phase-space distribution function. In the last decade we developed the Space Weather Modeling Framework (SWMF) that efficiently couples together different models describing the interacting regions of the space environment. Many of these domain models (such as the global solar corona, the inner heliosphere or the global magnetosphere) are based on MHD and are represented by our multiphysics code, BATS-R-US.

This talk will describe the present status of physics-based space weather modeling and discuss the steps needed to achieve a true forecast capability.