3.4 TERRESTRIAL WEATHER AND SPACE WEATHER FUSION AS AN OPERATIONAL TOOL

Stephen S. Carr*
Edward E. Hume

Johns Hopkins University Applied Physics Laboratory (JHU/APL), Laurel MD, USA

To be effective, space and terrestrial weather forecasts and observations must add value to operational missions. A detailed and fully integrated picture of the battlespace environment is key for planning and executing military operations, along with the ability to predict changes in conditions that will impact the effectiveness of weapons systems and personnel. Satellite observations and sophisticated numerical forecast models for simulating regional scale environments provide critical information needed to construct this common operating picture, and both observations and models can provide key inputs to many tactical decision aids. The space weather community has lagged the terrestrial weather community in this area for decades. However, with current and near-future space environment sensors on research and operational satellites, the space environment community will rapidly approach the levels of maturity found in the terrestrial weather community. *

The Johns Hopkins University Applied Physics Laboratory (JHU/APL) is transforming the current concept of intelligence preparation of the battlefield (IPB) into a more effective predictive battlespace awareness (PBA) process by fusing terrestrial and space weather forecasts into a useful "mud-to-sun" operational forecast tool so operators can successfully use the complete environmental picture as a force-mulitplier. Our innovative architecture will merge our forecasts for coronal mass ejections, geoeffective interplanetary shocks, geomagnetic storms, meteor showers, auroral oval intensity, radar/communications outages and high altitude heating and radiation dosages, into operationally significant space environment forecasts in which we create products that show the user which systems and/or operations may be impacted by the space environment. This* space environment predictive architecture will complement our comprehensive terrestrial weather forecasting toolset--which includes a dust storm model used by the DOD during Operation Iraqi Freedom (see the 1 April 2003 *New York Times* article, page D1)--to make our mud-to-sun architecture operationally functional.

Our effort will leverage the large investment by NASA and JHU/APL over the past decade in state of the art remote sensing technology (multi- and hyper-spectral), geophysical algorithm development and validation and data processing and distribution systems to provide new and innovative tools for the warfighter that will revolutionize PBA.

Solar physicists have studied the relevant solar observables (i.e. coronal mass ejections, solar wind fields, the interplanetary magnetic field (IMF), etc.) and have a decent understanding of their concomitant geophysical consequences (i.e. enhanced ionospheric densities, thermospheric heating, penetrating radiation, etc.) and resulting areas of operational concerns (satellite drag, communications outages, navigation degradations, etc). Many space weather forecasts in the past relied on persistence or climatology. Now, similar to terrestrial weather, we have prognostic space weather capabilities out to seven days that show improved validated and verified predictive

* *Corresponding author address:* Stephen S. Carr, 11100 Johns Hopkins Rd, MP3-E109, Laurel MD 20723; email: stephen.carr@jhuapl.edu

skill scores. For example, we have pattern recognition software that distinguishes "sigmoids", characteristic patterns observed in X-ray images on the sun that give us a 3-7 day leadtime of coronal mass ejections (CMEs) that can disrupt space assets. We have propagation models that can follow CME shockwaves through the interplanetary medium that eventually produce geoeffective events such as aurora and ionospheric scintillations which can both affect dual-frequency GPS. We use neural networks to make better estimates of geomagnetic indices, which in turn are fed into thermospheric heating models to produce more accurate satellite drag calculations. One DOD agency is using our real-time auroral oval product that spatially maps the aurora (and its energy levels) to help predict HF communications and intercept problems.

The *first phase* of our effort will involve conducting a limited number of pilot projects to demonstrate the value added to warfighter capabilities by exploiting in-house data, products and models, and other data from operational military and civilian research satellites. The focus here will be on developing products that are meaningful to the warfighter user in an operational environment. The primary pilot in this first phase will be a web-based space environment impact chart designed to coincide with operationally significant events, such as theater-wide Air Tasking Orders (ATOs). The chart will highlight which system and/or operation (such as HF communication outages) may be a "go" or a "no-go" due to the space environment and/or the terrestrial environment. The chart will be a "drill-down" display so the user can click on a box and mine additional information, such as noting that dual frequency GPS-guided munitions will be a "no-go" due to solar-flare induced extreme ionospheric scintillations near the target.

The *second phase* will be devoted to methodologies and techniques for integrating these products into information systems accessible to the warfighter. Emphasis here will be on timely data acquisition and processing, integration with other data sources, bandwidth limitations of dissemination systems, and ingesting products into tactical decision aids. For example, we shall overlay radio communication or radar propagation outages over a theater using 3-D graphics capabilities. As in the first phase, these products will be "drill-down" displays so the user can click on the area of interest to mine more information, such as why communications are down in that area (it may be due to meteorological conditions from rain attenuation or it may be due to a geomagnetic storm at high latitudes). We plan on using modeling and simulation techniques to horizontally fuse all of our appropriate terrestrial and space weather products into an environmental predictive battlespace awareness (ePBA) tool that will help military decision makers exploit the environment for battle in realtime.