Space Weather Research Using ISOON, SOLIS and BBSO Observations

Forecasting and understanding "space weather" is extremely important for the Air Force. This is reflected in its leadership in two funded Multidisciplinary University Research Initiative (MURI) projects to probe space weather. Further, the Improved Solar Optical Observing Network (ISOON) is an extremely important Air Force task in which a series of optical telescopes is to be positioned around the world to monitor solar magnetic eruptions directed toward the earth, and even to predict them in advance. Such magnetic eruptions can have deleterious effects on satellites, military and civilian telecommunication and the power grid, just to name a few of the possible manifestations of space weather. Thus, it is critical to have the ability to provide reliable early warnings of solar storms coming our way. Although only one ISOON telescope is operational at this moment, the data analysis proposed here will be readily available when ISOON becomes the real network operation.

Very soon, the SOLIS system built by National Solar Observatory. SOLIS will provide unique data sets that are essential for space weather research: full-disk vector magnetograms, that are extremely important for the measuring and understanding the 3-D magnetic structure of active regions.

At Big Bear Solar Observatory (BBSO) we have been studying space weather for several years, and we are a member of one of the aforementioned MURI teams. Here we propose to expand our efforts in space weather, which will benefit the MURI projects and ISOON by expanding our capabilities and applying them to space weather issues. We plan to expand to provide unique, network-derived observational data as input to test and advance the models of the MURI teams, while providing unique complements to ISOON and SOLIS. BBSO's unique observation includes:

(1) BBSO, in collaboration with the University of Hawaii (UH), is upgrading BBSO by replacing its principal 65-cm aperture telescope with a modern, off-axis 1.6-m clear aperture instrument (NST). The new telescope offers a significant improvement in ground-based infrared and high angular resolution capabilities, and enhances our continuing program to understand photospheric and chromospheric dynamics.

(2) We have successfully established a five station Hα observing network at BBSO, Kanzelhöhe Solar Observatory in Austria, Catania Astronomical Observatory in Italy and the Yunnan and Huairou Observatories in China. All five stations use the same kind of 2k×2k pixel cameras, each with an image scale of $1''$/pixel and temporal resolution of 1 minute. This allows us to monitor solar activity round-the-clock, including real-time reports of all flux emergences, filament disappearances and flares – facilitating our predictions of flaring for each active region.

Combining ISOON, SOLIS and BBSO observation, we proposed the following three tasks for space weather monitoring and forecasting:

(1) Realtime Solar Activity Monitoring

We will use the technologies of image processing and pattern recognition, such as image morphology segmentation, Support Vector Machines (SVMs), and neural

networks to detect and characterize three important solar activities in real-time: filament eruptions, flares, and emerging flux regions (EFRs). Such detection methods will be applied to data obtained by ISOON and 5-station full-disk Global Hα Network which monitors solar activity continuously with a cadence of 1 minute and a pixel resolution of 1 arcsec.

(2) BBSO Activity Monitoring and Warnings:

Accurate predictions of solar activity are most important for the safety of satellites and the protection of power grids and communications systems.

At least once a day, BBSO now provides Solar Activity Reports, which are a visible light survey of active regions. When warranted, BBSO also issues a BBSO Solar Warning forecasting rapid development and/or energetic solar flares in individual sunspot groups. When we predict a flare, we are right more than 90% of the time, and we rarely miss a flare. We also provide daily activity reports to the operation centers of solar missions to optimize their solar targeting. BBSO is officially responsible for target selection of the Max Millennium observing program. In addition to posting the reports and warnings on our web site, the warnings are sent via electronic mail to about 400 people who have requested them. Recently, we have upgraded our space weather program to include the Active Region Monitor (ARM) and Flare Prediction System (FPS). They describe the real-time status of each active region. We will continue to improve this system by including more parameters, such as electric current maps and magnetic shear maps from SOLIS and NST vector magnetograms.

(3) Magnetic Topology of CME Initiating Active Regions and Interplanetary Magnetic Clouds

Large geomagnetic storms are usually caused by a structure in the solar wind having a specific feature – long duration, strong southward interplanetary magnetic fields (IMF) impinging on the earth's magnetosphere. There are two possible stages at which we can monitor geomagnetic storms:

(a) observing magnetic field fluctuations from a satellite, such as ACE or Wind and (b) measuring the Dst (degree of equatorial magnetic field deviation from ground stations), Ap and Kp indices.

While (a) can give a 1-2 hour warning of the arrival of geomagnetic storms, (b) is simply now-casting.

Our objective is to obtain some statistical results on filament eruptions/CMEs, magnetic clouds and geomagnetic disturbances. We have been studying about 20 halo CME events in detail (Yurchyshyn et al., 2001, 2003), and found that the overlying magnetic field structure above erupting filaments may provide a good indicator of the orientation of magnetic clouds. Our studies have been based on force-free extrapolations using MDI line-of-sight magnetograms. Vector magnetograms from SOLIS and BBSO will expect to provide more accurate estimation of force free fields. These extrapolations will aid real-time monitoring of solar active region fields and forecasting of field orientation of interplanetary magnetic clouds.

References

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