Space Weather Prediction at BBSO

Haimin Wang
Big Bear Solar Observatory
New Jersey Institute of Technology
Newark, NJ 07102
phone: (973) 596-5781 fax: (973) 596-3617 email: haimin@flare.njit.edu
Award #: N000149711037

Co-PI: Phil Goode
Big Bear Solar Observatory
40386 North Shore Lane
Big Bear City, CA 92314
phone (909)-866-5791 fax: (909)-866-4240 email pgoode@bbso.njit.edu

http://bbso.njit.edu

LONG-TERM GOAL

Our long term goal is to understand the physics and relationship among flares, filament eruptions, Coronal Mass Ejections (CMEs) and interplanetary magnetic clouds; to understand their impact on the magnetosphere and ionosphere of the earth; and to predict them accurately.

OBJECTIVES

We concentrate on the study of filament eruptions, flares and Coronal Mass Ejections (CMEs), which are vitally important in predicting and understanding the space weather, particularly, the solar origins of geomagnetic disturbances. BBSO is establishing the possible relationship among filament eruptions, flares, CME and transient disturbances observed by WIND and ACE.

We also predict solar flares in our continuation of BBSO activity report and warnings, and geomagnetic storms.

APPROACH

In the past year, we have added two stations to our Global Halpha Network (GHN).The availability of full-disk, high-resolution Halpha images from Big Bear Solar Observatory (USA), Kanzelhohe Solar Observatory (Austria), Yunnan Astronomical Observatory (China), Huairou Solar Observing Station (China) and Catania Astrophysical Observatory (Italy) allows the continual monitoring of solar activity with unprecedented spatial and temporal resolution. Typically, our Global Halpha Network provides almost uninterrupted Halpha images with a cadence of 1-min and an image scale of 1” per pixel. This therefore facilitates automatic detection of flares, filament eruptions, and other energetic phenomena on a near real-time basis.

Every hour, GHN images are transferred to the web-based BBSO Active Region Monitor (ARM, www.bbso.njit.edu/arm), which includes the most recent full-disk EUV, soft X-ray, continuum, and

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE **Space Weather Prediction at BBSO**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Big Bear Solar Observatory,,New Jersey Institute of Technology,,Newark,,NJ, 07102**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Our long term goal is to understand the physics and relationship among flares, filament eruptions, Coronal Mass Ejections (CMEs) and interplanetary magnetic clouds; to understand their impact on the magnetosphere and ionosphere of the earth; and to predict them accurately.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT	b ABSTRACT	c THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

magnetogram data from the Solar and Heliospheric Observatory and Yohkoh. ARM also includes a variety of active region properties from the National Oceanic and Atmospheric Administration's Space Environment Center, such as up-to-date active region positions and flare identification.

Furthermore, we have developed a Flare Prediction System which estimates the probability for each region to produce C-, M-, or X-class flares based on nearly eight years of NOAA data from cycle 22. This, in addition to BBSO's daily solar activity reports, has proven a useful resource for activity forecasting.

We have developed an automatic filament detection program to report disappearances of solar filaments in real time. In addition, we study the evolution of magnetic fields associated with flares and CMEs to understand the fundamental physics of triggering these events.

WORK COMPLETED

The operation of GHN has been matured in the past year. Two stations (Italy and China) were added to the network. Daily full-disk movies from BBSO, and regional movies of M-class or above flares are now available on line right after each observing day. A data catalog from each station is available on line every day.

The Active Region Monitor (ARM) is a web-based solar activity monitoring tool which provides the most recent images from a variety of ground- and space-based solar observatories and can be found at www.bbso.njit.edu/arm. The software runs automatically every hour, taking approximately 15 min of CPU time on a 700 MHz PentiumIII processor, the majority of this run-time being occupied with data transfer. In the past year, the calculation of magnetic gradient was added to the ARM.

In addition to providing images from the photosphere, chromosphere, and corona, the ARM pages include tables of active region data from NOAA, including up-to-date active region positions. Furthermore, a developmental version of the Flare Prediction System (FPS) has been included, which provides a table of region names together with flaring probabilities.

Similarly to forecasters at NOAA's Space Environment Center, we have developed a flare prediction system based on the McIntosh active region classification scheme. Our system uses almost eight years of SEC flare occurrence and active region McIntosh classification data from November 1988 to June 1996, thus sampling the majority of activity in cycle 22. Probabilities are calculated based on tables of daily average flare rates.

Based on the above archived information, BBSO is now in charge of target selection for major solar missions.

RESULTS

1. BBSO's new Digital Vector MagnetoGraph (DVMG) system has shown its power in studies of the evolution of magnetic fields at high resolution and cadence. One significant paper, Spirock et al. (2002), demonstrated a rapid/permanent increase of the limb-ward magnetic flux after a flare. This was explained by the emergence of very inclined magnetic flux.

To follow up this work, Wang et al. (2002) presented results of studies of six X-class flares, all of which show rapid and permanent changes in line-of-sight magnetic fields immediately after flares. All the events showed an increase in the magnetic flux of the leading polarity of a few times 10^{20} Mx; three of them showed some degree of decrease in the following polarity flux. The increases are impulsive (while the time scale for the overall change in the flux ranged from 10 to 110 min) and permanent. However, no satisfactory explanation has been found for this curious and provocative phenomenon.

Figure 1 shows the magnetic field change associated with the flare of the October 19, 2001 event. The amount of flux increase in the leading polarity (positive) was 3.0×10^{20} Mx while the following (negative) flux decreased by 0.4×10^{20} Mx, over the time scale of 60 min. We found that the decrease of the following flux is primarily due to the cancellation of the newly formed positive flux with the previously existing negative flux around the leading spot.

For this event, the increase in the transverse field has the same trend as that of the line-of-sight field. The mean value of the transverse field in the calculation box increased by 90 Gauss. The weighted mean shear angle increased by almost 10 degrees. The increase of the shear angle occurred during a period of 15 minutes, which was much more rapid than that of the change in the line-of-sight and transverse field strength. In the bottom panel of Figure 1, we plot the mean intensity of the box. The mean photospheric value is defined as 1.0. Therefore, the decreasing intensity indicates the appearance of new sunspot area.

2. In recent study by Yurchyshyn et al. (2002), we found the relationship between the projection speed of CMEs, measured from SOHO/LASCO images, and hours averaged magnitude of sourthwardly directed magnetic field Bz, as measured by ACE magnetometer. We also developed a method to predict the time and magnitude of geomagnetic storms. So far, the prediction is 100% accurate based on 17 events. Our basic tools so far for this part of the research are high resolution Halpha full disk observations, MDI magnetograms and the vectormagnetograph data from BBSO and HSO. The vector magnetograms are utilized for more comprehensive field extrapolation, as we have a good estimate of the sign and size of the alpha to start with. We have to guess the alpha constant, if we do the extrapolation from line-of-sight fields only. Furthermore, evaluation of alpha over the whole field of view would give us some idea if the LFFF could have a good representation of the magnetic field in a given active region.

IMPACT/APPLICATION

The prediction of solar activity is so important in many areas since magnetic eruptions can have deleterious effects on satellites, upper atmosphere communications and even the North American power grid. Thus, it is critical to have the most reliable early warning system possible. For the Navy, the important factor appears to be their effects on VLF communication and on satellites, such as those involved in communication, surveillance and the global positioning system.

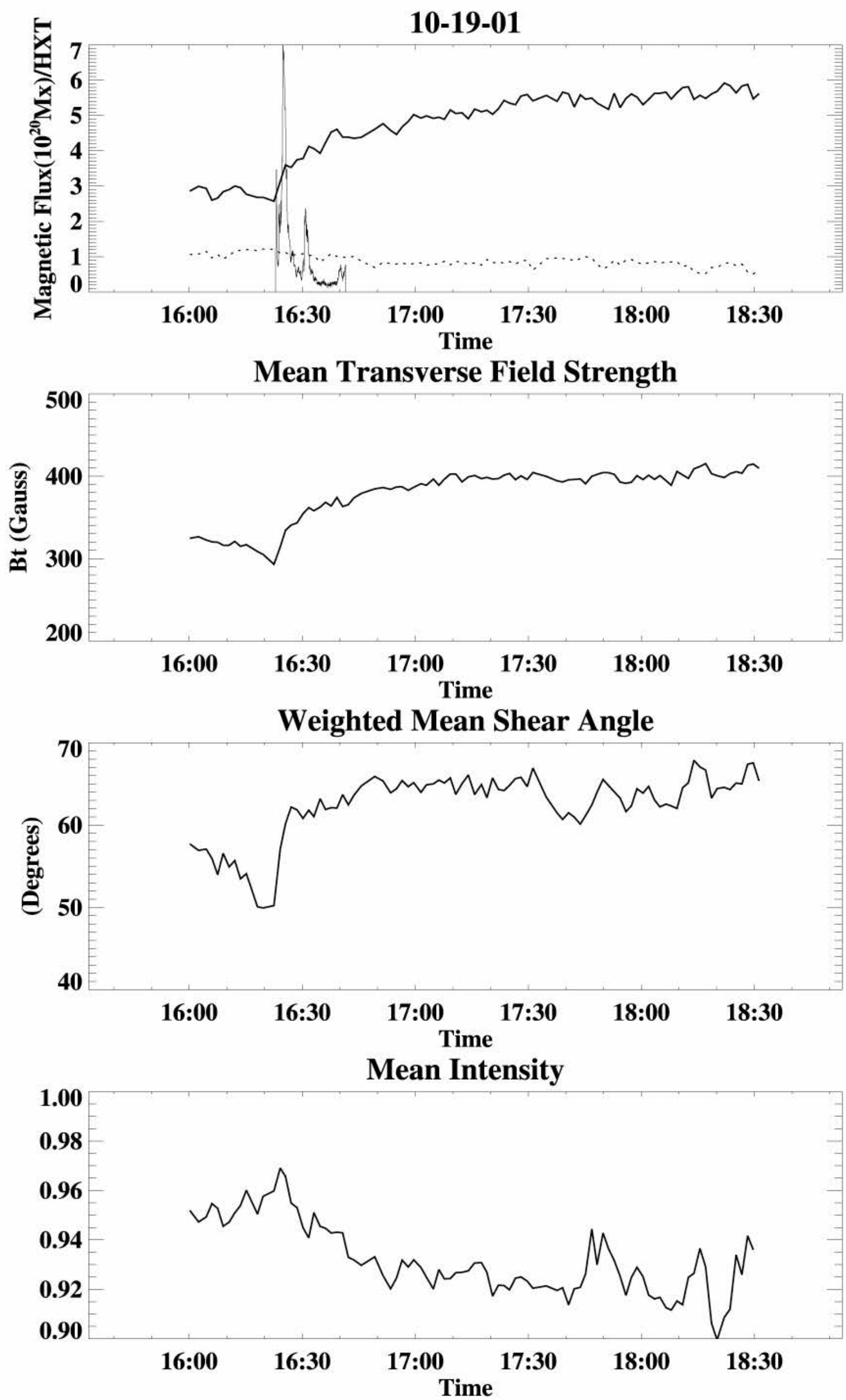

Figure 1: Evolution of magnetic fields as a function of time. Top panel: line-of sight magnetic field. 2nd panel: Transverse field; 3rd panel: weighted mean shear angle; bottom panel: mean intensity indicating sunspot area.

TRANSITIONS

Our data on the World Wide Web has been used wide in the world to monitor solar activity. Our BBSO activity report and warnings, active region monitoring and flare prediction system have been highly regarded in the community.

RELATED PROJECTS

The PI has been awarded a grant by NSF, which provided the hardware to establish the Halpha network.

PUBLICATIONS

Gao, J., Zhou, M. and Wang, H., 2002, Development of an Automatic Filament Disappearance Detection System, Solar Physics, 205, 93

Wang, H., Yurchyshyn, Y., Chae, J., Yang, G., Steinegger, M. and Goode, P.R., 2001, Inter-Active Region Connection of Sympathetic Flaring on 2000 February 17, Ap. J., 559, 1171

Wang, H., Spirock, T., Qiu, J., Ji, H., Yurchyshyn, V., Moon, Y., Denker, C., and Goode, P.R., 2002, Rapid Changes of Magnetic Fields Associated with Six X-Class Flares, Ap. J., 576, 497

Wang, H., Gallagher, P., Yurchyshyn, V., Yang, G. and Goode, P. R., 2002, Core and Large-Scale Structure of the 2000 November 24 X-Class Flare and Coronal Mass Ejection, Ap. J., 569, 1026

Spirock, T., Yurchyshyn, V. and Wang, H., 2002, Rapid Changes in the Longitudinal Magnetic Field Related to the 2001 April 2 X20 Flare, Ap. J., 572, 1072

Yurchyshyn, V., Wang, H., Goode, P.R. and Deng, Y., 2001, Orientation of the Magnetic Fields in Interplanetary Flux Ropes and Solar Filaments Ap. J., 563, 381

Yurchyshyn, V., Wang, H. and Abramenko, V., 2002, Correlation Between Speeds of CMEs and Geomagnetic Storms, GRL, submitted