SOLAR ERUPTION BRIGHTNESS FLUCTUATION AS MEASURED BY SOLAR DYNAMICS OBSERVATORY AND ITS EFFECT ON THE IONOSPHERE

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1. Abstract

Recent effects of solar eruptions on the ionosphere have been mild as the Dst index had not fallen much, which resulted in minor ionospheric disturbances since the launching of the Solar Dynamics Observatory. The low activity Sun provides an opportunity to study the asymmetrical entanglement of magnetic energy that has been ascribed to the Sun's rotation, as based on the high resolution images from Solar Dynamics Observatory. Using brightness fluctuation data on both sides of an eruption, the analysis suggests a general trend. At the site prior to an eruption, the fluctuation was observed to be greater in the leading edge as compare to the trailing edge. This asymmetry suggests that the magnetic lines are more tangled in the leading motion direction. Using brightness fluctuation analysis on the signal between two eruption peaks (Aug 1 2011 solar eruption 19 nm data, for example), the brightness coefficient of variation (CV) appears to reach saturation, consistent with the interpretation that energy release in the region between the two eruption peaks seems to stabilized. The Sunspot number as measured by the Wolf number could be analyzed as a random series exhibiting volatility, and the CV measure suggests that the Sun's recent relatively mild activity would not support an onset of another Maunder minimum-like period. The March 9 2011 (UT 23:30) solar eruption effect on the ionosphere TEC and the ionospheric disturbances triggered by the March 11 2011 (UTC 05:46) M9.0 Tohoku earthquake is discussed.

2. Introduction

The Solar Dynamics Observatory (SDO) was launched on February 11, 2010 and the observatory is part of the Living With a Star (LWS) program. In particular, the observations of the spectroscopic lines of Fe, such as 19.3 nm, etc., would yield high resolution images that could be used to track the spatial and temporal variations in the magnetic field. Presumably, the brightness fluctuations of the spectroscopic lines are related to the fluctuations in the density of the excited Fe atoms, which could serve as markers for the fluctuations in the magnetic structure.

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Fluctuation analysis via volatility, coefficient of variation CV, etc. has been a popular method for studying correlated randomness; and has been applied Solar Dynamics Observatory data. For example, the 19 nm data on Aug 1 2011 has been studied. Other fluctuations such as the sunspot number variations were studied as well. The ionospheric disturbance via TEC index was included in the study.

3. Data Sources

Synoptic Data and JPEG2000 download were done following the procedure listed on the AIA website. A solar eruption image is displayed in Figure 1 as an illustration. There were three solar eruption regions.

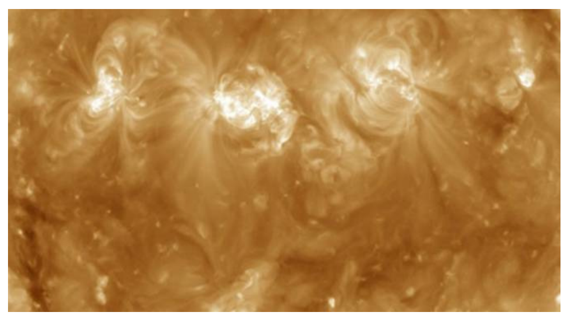

Figure 1: The SDO AIA 19.3 nm on Aug 1 2011 about 00:11 UT data

The AIA data was downloaded from
http://aia.lmsal.com/

The Dst data was downloaded from
http://wdc.kugi.kyoto-u.ac.jp/dst_realtime/

The total electron content TEC data was downloaded from http://iono.jpl.nasa.gov

4. Analysis and Discussion

Brightness profile was investigated via statistics (Fig. 2). The standard deviation calculations from the right side of the major peak were found to increase as the frame of the clip continues; which could indicate that there is more volatility. This could be due to the right-ward rotation of the sun itself (from the SDO image orientation). The fluctuation increases in the right-ward rotation direction and decreases in the trailing-behind edge of the rotation. This suggests that the magnetic energy lines are more tangled in the forwarded motion direction.

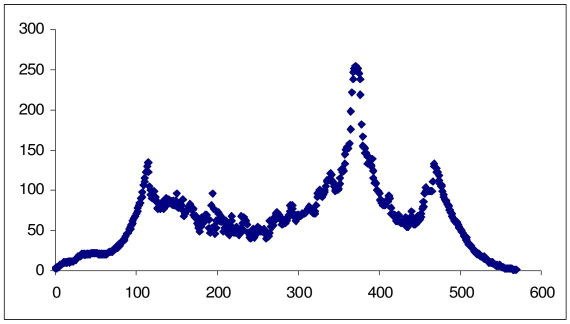

Figure 2: A brightness profile example of the Aug 1 2011 19.3 nm eruption data. The brightness is on the y-axis and the spatial coordinate is on the x-axis. The three eruption regions are clearly visible.

The brightness standard deviation versus time is displayed in Figure 3. It appears that fluctuation as measured by standard deviation is increasing as eruption progresses.

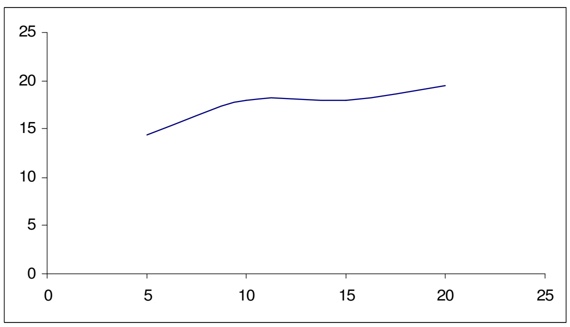

Figure 3: Brightness standard deviation (y-axis) versus time (x-axis arb unit) for the studied Aug 1 2011 19.3 nm data.

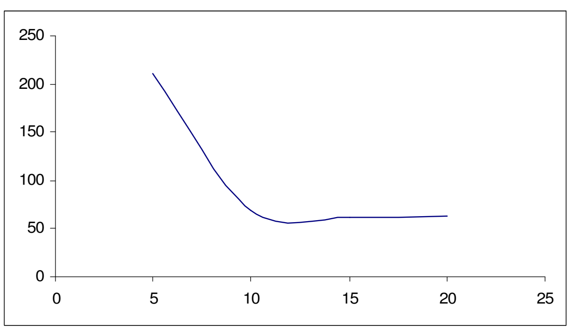

Figure 4: Brightness average (y-axis) versus time (x-axis arb unit) for the studied Aug 1 2011 19.3 nm data.

The average brightness versus time is displayed in Figure 4. It appears that the average brightness values approaches a minimum as eruption progresses

The Coefficient of Variation CV (standard deviation/average) versus time is displayed in Figure 5. It appears the fluctuation as measured by the CV parameter in statistics would approach saturation.

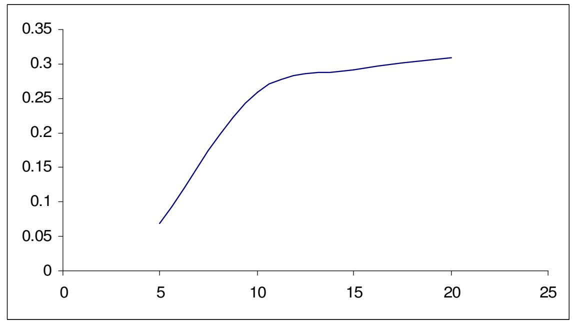

Figure 5: Coefficient of variation CV (y-axis) versus time (x-axis arb. unit) for the studied Aug 1 2011 19.3 nm data.

The brightness variation has been applied to study the recently reported solar tornado event (Figure 6). The histogram CV measure of the region of interest (Figure 7) was found to be 0.099; and 0.118 as the solar disk rotated to about 14:44 UT.

Figure 6: The SDO AIA 19.3 nm data on Feb 8 2012 about 2:14 UT.

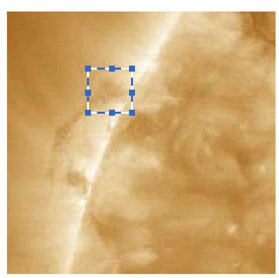

Figure 7: Region of interest in Figure 6.

The histogram CV values of the studied regions also were found to have a correlation to the image fractal dimension. For example, the fractal dimension was found to be 1.12 at about 2:14 UT and became 1.17 at about 14:44 UT.

The brightness fluctuation analysis results would impose constraints on solar dynamo equation solutions as described by Kapyla, Nandy, Tobias and others. The detailed correlation of brightness with the density of excited Fe atoms in the solar magnetic structure would need further study, however.

Similar analysis has been performed for the study of sunspot number variations. Sunspot numbers (Wolf number) are grouped every 5-year (Start 1749 Jan – May 2011) and the analysis results are displayed in Figure 8. The CV parameter-measure would suggest that the Sun's recent relatively mild activity would not support an onset of another Maunder minimum-like period

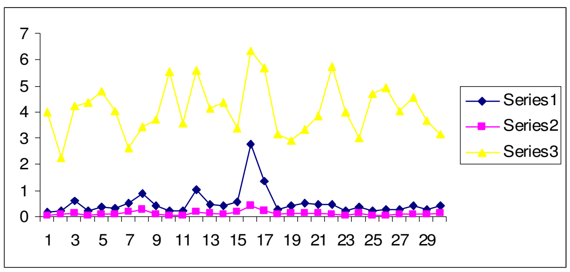

Figure 8: Sunspot number average statistics for each 5-year period are displayed. The average is displayed as square (Series 1). The volatility (standard deviation) is displayed as diamond (Series 2). The CV trend is displayed as triangles (Series 3). The Wolf number data was downloaded from http://solarscience.msfc.nasa.gov/greenwch/spot_num.txt

The effect of the solar eruption on Earth has been studied. For example the effect from on the flare on March 9 2011 23:30 UT was studied.

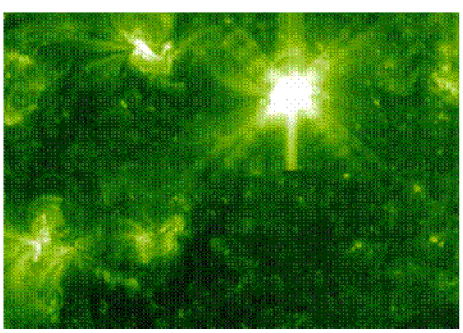

Figure 9: The SDO AIA 9.4 nm on March 9 2011 about 23:30 UT data

The Dst response is displayed in Figure 10.

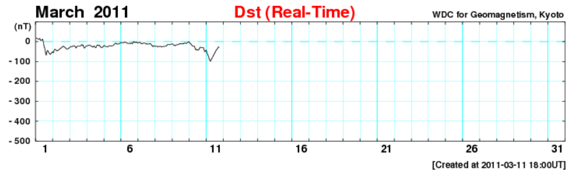

Figure 10: The Dst dip is due to a solar eruption at March 9 2011 (UT 23:30)

An ionospheric TEC response map is displayed on Figures 11 and the TEC continued growth is displayed in Figure 12.

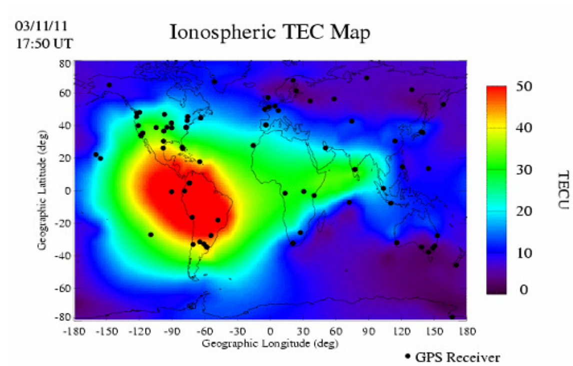

Figure 11: The growth of high TEC region Mar 11 2011 17:50 UT

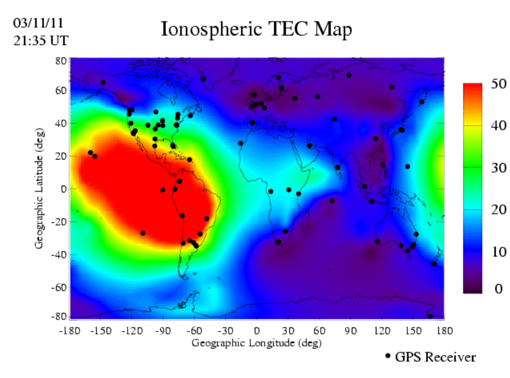

Figure 12: The continued growth of high TEC region on March 11 2011 21:35 UT

The transit effect of the ionospheric disturbance triggered by the March 11 2011 (UTC 05:46) M9.0 Tohoku earthquake as reported by Liu at al. appears to be small as compared to the disturbance caused by the flare on March 9 2011 23:30 UT as illustrated in Figure 7.

5. Conclusions

Brightness fluctuation study would be a valuable tool to study energy transfer issues on the solar disk. Future studies could include analysis of other eruptions to confirm this exploratory study. Extension to the study of the correlation of brightness with the density of excited Fe atoms would shed light to the solar dynamo magnetic field equation.

6. Acknowledgements

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7. References:

Liu, J.-Y., C.-H. Chen, C.-H. Lin, H.-F. Tsai, C.-H. Chen, and M. Kamogawa (2011), Ionospheric disturbances triggered by the 11 March 2011 M9.0 Tohoku earthquake, J. Geophys. Res., 116, A06319, doi:10.1029/2011JA016761.

Kapyla, P.J. (2011) On global solar dynamo simulations. Astron. Nachr. 332, 43-50.

Nandy, D. (2012) Dynamo models of the solar cycle: current trends and future prospects. To appear in the Bulletin of the Astron Soc India, Proc First Asia Pacific Solar Physics Meeting

Tobias, S.M. (2002) The Solar Dynamo. Phil. Trans. R. Soc. Lond. A , Vol 360, 2741-2756