Solar Activity and its Magnetic Origin
Proceedings IAU Symposium No. 233, 2006
V. Bothmer & A. A. Hady, eds.

doi:10.1017/S1743921306001529

On forecasting the onset of Solar Proton Events

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Abstract. A major problem for predicting the onset of Solar Proton Events is the detection of the magnetic connection between the flare and the earth. If there is a magnetic connection, the particles accelerated by a large solar event may impact the earth and produce the onset of a solar energetic proton event. Current physical models cannot predict the onset of a SPE mainly because of the chaotic conditions within the IMF structure. Kiplinger (1995) reported a high correlation between the existence of 10 MeV protons at Earth and a characteristic pattern of X-ray spectral evolution for several associated flares. We propose a practical approach that tries to detect the time intervals of this correlation. Our assumption is that a high correlation betwewn X-ray and protons at Earth is an important symptom of a magnetic connection and may help to prevent Solar Proton Events.

Keywords. Sun: solar-terrestrial relations magnetic fields, methods: data analysis

1. Introduction

It seems quite clear that the protons are accelerated at the CME-driven shock [Reames (2003)]. The apparent correlation between X-ray properties and proton events does not imply that protons are accelerated on post-flare loops where the X-rays originate. A possibility for a correlation between X-ray and proton at Earth seems to be that flares that accompany powerful CMEs occur in a unique configuration of the magnetic field [Tylka, Boberg, Cohen, *et al.* (2002); Reames (2003)]. Our approach searches for time intervals in which there is a strong correlation between X-ray peaks (from small/large flares) and small peaks in any of the proton fluxes. If there is a sequence of X-ray peaks and a similar sequence of peaks in any of the proton channels later, one may assume a cause-effect relation due to a magnetic connection.

Most of the current statistical-based correlation/dependence techniques cannot be used for this purpose, because of the existence of changing dependences between the time series. For these reasons a new dependence technique was developed to deal with this problem. This approach ignores the majority of the fluctuations of X-ray and Proton signals. It concentrates only on 5% of rare fluctuations, that is, in extreme fluctuations of X-ray and proton channels signals. The main assumption in our approach is that an extreme fluctuation in the X-ray flux (Rx) might sometimes cause an extreme fluctuation in a proton channel (Px) within a posterior time interval window. The estimate of Rx➡Px dependence at a given time t is proportional to the number of hypothetical "cause-effect" peaks found in the immediate past of t and inversely proportional to the standard deviation of the temporal distance between both correlated peaks, that is, the separation of the peaks. If there is a high Rx➡Px dependence, then there is a great chance that this causality pattern is due to a magnetic connection. Experimentation with data from 2002–2005 showed that before the arrival of several SPEs, extreme-value Rx➡Px dependences would have been detected by our approach several minutes/hours before the SPE event.

Table 1. Summary of EWS performance on X-ray and Proton channels data from January 2002 to December 2005

	Number of SPEs	Number of SPEs which EWS could have warned against (succesful cases)	Number of SPEs which EWS could have NOT warned against	Number of false alarms (EWS warnings with no posterior SPE)
2002	14	6 (42% of SPEs)	8 (57% of SPEs)	15 (71% of EWS warnings)
2003	8	5 (63% of SPEs)	3 (38% of SPEs)	8 (62% of EWS warnings)
2004	6	3 (50% of SPEs)	3 (50% of SPEs)	19 (86% of EWS warnings)
2005	7	6 (85% of SPEs)	1 (14% of SPEs)	19 (76% of EWS warnings)

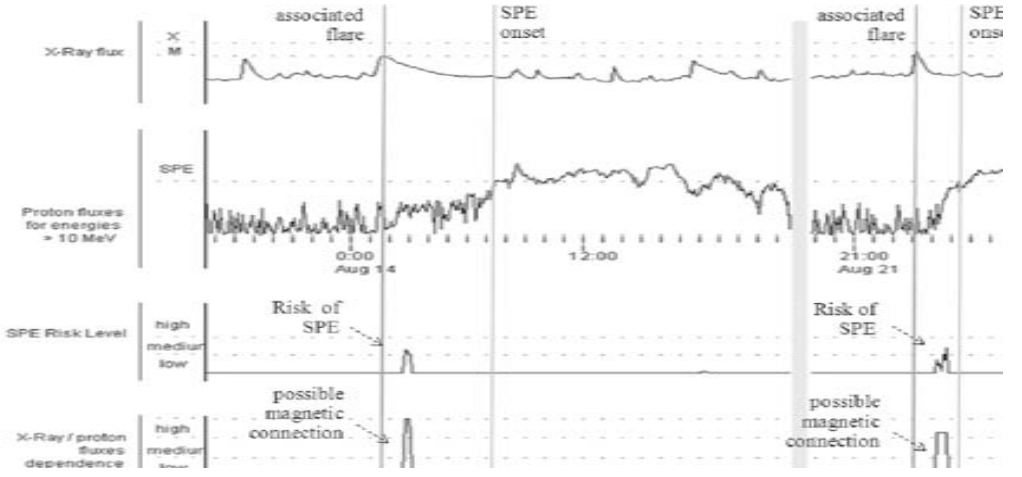

Figure 1. Two successful cases: three solar proton events occurred during August 2002.

When a magnetic connection is detected, the EWS also discovers the average delay between the correlated X-ray and proton peaks, which is combined with the X-ray datum, occurred some time before (the delay time) and the flare helio-longitude to produce an estimation of risk level of SPE.

2. Experimentation

Table 1 presents the results of this approach for the period 2002–2005. This table shows the proportion of succesful cases and false warnings that our approach would have produced for the analyzed period. Figure 1 shows the magnetic connection level (botton time series) and on it, it shows the SPE risk level for two situations occurred during August 2002, when some large SPEs occurred. Our approach would have estimated strong magnetic connections immediately after the associated two flares. In the first case, our approach would have given a warning 4.5 hours before the SPE onset. In the second case, our approach would have warned 1.5 hours before the onset.

References

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https://doi.org/10.1017/S1743921306001529 Published online by Cambridge University Press