

We compare published results on flare-storm dependences and discuss possible sources of the discrepancy. We analyze following sources of difference: (1) different intervals of observations, (2) different statistics and (3) different methods of event identification and comparison. Our analysis shows that magnitude of geomagnetic storms is likely to be independent on X-ray class of solar flares.

**Key words.** Sun: Coronal mass ejections (CMEs), Sun: flares, Sun: solar-terrestrial relations

# Geomagnetic storm dependence on the solar flare class

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**Abstract.** Solar flares are often used as precursors of geomagnetic storms. In particular, Howard and Tappin (2005) recently published in A&A a dependence between X-ray class of solar flares and Ap and Dst indexes of geomagnetic storms which contradicts to early published results.

## 1. Introduction

One of the important aims of solar-terrestrial physics is investigation of possible causes of geomagnetic storms on the Sun and in the interplanetary space. Storms are primarily generated by large, long-duration southward component of interplanetary magnetic field (IMF) (Burton et al. 1975, Lyatsky and Tan 2003, Zhang et al. 2006) associated with interplanetary coronal mass ejections (ICME - magnetic clouds and ejecta) and corotating interaction regions (CIR) (see recent papers and reviews by Gopalswamy et al. 2005, Kane 2005, Meloni et al. 2005, Schwenn et al. 2005, Yermolaev et al. 2005, Yermolaev and Yermolaev 2006, and references therein).

Solar flares were one of the first strong disturbances discovered on the Sun and they were considered as the important source of almost all interplanetary and geomagnetic disturbances during long time. Later, in the beginning of 1970s, other powerful solar processes such as coronal mass ejections (CMEs) were discovered, and after the landmark paper by Gosling (1993) the situation has significantly changed, and now CME is considered almost as the unique cause of all interplanetary and geomagnetic disturbances (see recent reviews by Schwenn et al. 2005, Yermolaev et al. 2005 and references therein). Nevertheless the solar flares are often considered as a precursor of solar activity and used for prediction of interplanetary and geomagnetic disturbances (see recent papers by Park et al. 2002, Yermolaev et al. 2005 and references therein).

Recently a statistic study of interplanetary shocks and accompanying events on the Sun and in the magnetosphere for 1998-2004 was published by Howard and Tappin (2005). In particularly there is Fig.7 showing a dependence between class of solar flares (X-ray measurements on GOES satellites) and value of geomagnetic storms (Ap and Dst indexes) with statistics of 103 pairs of events. On the basis of these data the authors indicated "a tendency for large flares to be associated with very large storms". This is very strong contention because if it

would be true the class of solar flares could be used not only to predict an occurrence of magnetic storm but also to predict a magnitude of it. Unfortunately authors (Howard and Tappin 2005) did not compare this result with results of other papers. So, the aim of this paper is to compare this result with another published results on this topic.

## 2. Observations

Published results on flare-storm dependence are presented in the table. Shrivastava and Singh (2002) and Howard and Tappin (2005) initially selected CME-magnetosphere pairs of events and then analyzed relation between classes (respectively, optic class in 1st paper and X-ray class in 2nd paper) of accompanying flares and magnetospheric disturbances (Ap index in 1st paper and Ap and Dst indexes in 2nd paper). Howard and Tappin (2005) additionally selected events accompanied by interplanetary shocks. Although correlations between optic and X-ray classes of flares and between various geomagnetic indexes are sufficient low (Yermolaev and Yermolaev 2003b), these papers say in favor of existence dependence between flare class and storm magnitude.

Similar analysis of solar, interplanetary and magnetospheric events for 1976-2000 had been published by Yermolaev and Yermolaev (2003a) (see also preliminary publication by Yermolaev and Yermolaev 2002a) where the same dependence had been presented (see Fig.5 in paper by Yermolaev and Yermolaev 2003a). The dependence of magnitude of 325 storms on X-ray class ( $\geq M5$ ) of solar flares was presented on top panel of the figure 5 in the paper and the same dependence for 70 flares ( $\geq M0$ ) accompanied by Solar Particle Events (SPEs) - on bottom panel. In two panels the data have been selected with (1) location of solar flare on solar disc - west (open symbols) and east (closed), and (2) time delayed between flare and corresponding storm - 2 - 4 days (high probability of event relation, triangles), 1.5-2 and 4-5 days (intermediate probability, rhombs), and 1-1.5 and 5-6 days (low probability,

**Table 1.** Published results on correlation between solar flare class and magnetosphere disturbance

N	Statistics	Solar events	Magnetosphere events	Time intervals	Relation	Reference
1	144	Optic flare > 1 (F, N, B) + CME	Ap	1988-1993	Yes	Shrivastava & Singh, 2002
2	325	X-ray flare $\geq M5$	Dst	1976-2000	No	Yermolaev & Yermolaev, 2002a
3	325	X-ray flare $\geq M5$	Dst	1976-2000	No	Yermolaev & Yermolaev, 2003a
	70	X-ray flare $\geq M0 + S PE$			No	
4	103(?)	X-ray flare > C0 + CME + Shock	Ap, Dst	1998-2004	Yes	Howard & Tappin, 2005

circles). No tendency of increase in value of storms with increasing class of solar flares was observed.

Thus two different results were obtained in different studies. Possible causes of this difference will be discussed in next section of paper.

### 3. Discussion

Two papers, which indicate the existence of flare-storm relation (Shrivastava and Singh 2002 and Howard and Tappin 2005), have common feature in method of data selection (This feature is absent in papers by Yermolaev and Yermolaev 2002a, 2003a): initial selection of CME-magnetosphere pairs of events and consequent analyses of relation between classes of accompanying flare and magnetospheric disturbances. So, necessary condition of existence of flare-storm relation is likely to be existence of CME-storm relation. This condition is not clearly stated in papers by Shrivastava and Singh (2002) and Howard and Tappin (2005) and this hypothesis requires further investigations.

It is difficult to compare results of papers by Shrivastava and Singh (2002) and Yermolaev and Yermolaev (2002a, 2003a) because they were obtained with use of absolutely different methods of event definition and classification. Nevertheless, several considerations, which will be applied below to comparison of results in papers by Howard and Tappin (2005) and Yermolaev and Yermolaev (2002a, 2003a), may be of interest in future data analyses.

In addition to mentioned above methodical difference (initial selection of CME-magnetosphere pairs of events) in papers by Shrivastava and Singh (2002) and Yermolaev and Yermolaev, (2002a, 2003a) there are three main possible causes of discrepancy: (1) different intervals of analysis, (2) different statistics and (3) different methods of event identification and comparison. Yermolaev and Yermolaev (2003a) studied 25-year interval (more than 2 solar cycles from 1976 up to 2000) while Howard and Tappin (2005) investigated only 7-year interval near maximum of 23-rd solar cycle (1998-2004). As well known, the magnetic storms are generated by different types of solar wind disturbances (magnetic clouds, MC, or corotating interaction regions, CIR, which are generated by CME or fast streams from coronal hole, respectively) during different phases of solar cycle (see, for instance, Fig. 6 in paper by Yermolaev and Yermolaev 2002b). It is possible to suggest that averaging data over solar cycle could mask indicated dependence but this hypothesis requires further investigations.

The higher statistics in paper by Yermolaev and Yermolaev (2003a) indicate in favour of absence of storm dependence on class of flare. For instance, extremely strong geomagnetic storm on March, 1989 (Dst = -589 nT) can be associated with large (but not extremely large) flares with class X1-X5 and this event does not agree with suggested flare-storm relation.

As has been shown (Yermolaev et al., 2005, Yermolaev and Yermolaev 2003a, 2006) result of comparison of different events on the Sun, in the interplanetary space and in the geomagnetosphere strongly depends on methods of event identification and comparison procedures. Unfortunately methodical problems related to dependence under study are very schematically discussed in paper by Howard and Tappin (2005) and it makes impossible to search for cause of result discrepancy in features of methods.

Available data allow us to discuss only problem of selection of flares with various classes for comparison with magnetic storms. Howard and Tappin (2005) included C-class flares in the analysis. As well known CMEs (not flares) generated interplanetary disturbances and then magnetic storms (Gosling 1993), and flares can be used only as indicator of solar activity which can result in CMEs and interplanetary disturbances. On the other hand, association flares and CMEs decreases with decreasing class of flares (Kahler et al. 1989). In recent paper by Yashiro et al. (2005) 15% and 30% flare-CME associations were obtained respectively for disc and limb flares with class range of C3-M1. So, C-class flares, included by Howard and Tappin (2005) in analysis, could not improve correlation between class of flares and Dst index during magnetic storms.

### 4. Conclusions

Thus, our analysis of published results allows one to make preliminary conclusions.

1. There is no any correlation between X-ray class of solar flares and magnitude of corresponding geomagnetic storms.
2. If one selects initially CMEs and corresponding geomagnetic storm and then solar flares accompanying CMEs, for solar flares obtained by this way a slight positive correlation between these parameters is likely to be observed.

Such a correlation would be very important for space weather prediction and reliability of it requests further investigations.

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