Nature of Prominences and their role in Space Weather
Proceedings IAU Symposium No. 300, 2013
B. Schmieder, J.-M. Malherbe & S. T. Wu, eds.

doi:10.1017/S1743921313011733

From solar eruption to transformer saturation: the space weather chain

Larisa Trichtchenko

Canadian Space Weather Forecast Centre, Natural Resources Canada, 2617 Anderson Rd., Ottawa ON, K1A 0E7, Canada
email: larisa.trichtchenko@nrcan-rncan.gc.ca

Abstract. Coronal mass ejections (CME) and associated interplanetary-propagated solar wind disturbances are the established causes of the geomagnetic storms which, in turn, create the most hazardous impacts on power grids. These impacts are due to the large geomagnetically induced currents (GIC) associated with variations of geomagnetic field during storms, which, flowing through the transformer windings, cause extra magnetisation. That can lead to transformer saturation and, in extreme cases, can result in power blackouts. Thus, it is of practical importance to study the solar causes of the large space weather events. This paper presents the example of the space weather chain for the event of 5-6 November 2001 and a table providing complete overview of the largest solar events during solar cycle 23 with their subsequent effects on interplanetary medium and on the ground. This compact overview can be used as guidance for investigations of the solar causes and their predictions, which has a practical importance in everyday life.

Keywords. Space Weather, Coronal Mass Ejections, Magnetic Storms, Geomagnetically Induced Currents

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The event, presented as a detailed example, started on November 4, 2001 with a halo CME and associated X-ray flare at about 16:20 UT (Fig. 1). Two days later the disturbance arrived at 1 AU as shown in variations of the solar wind magnetic field recorded by the ACE satellite (Fig. 1a). The southward (negative) component reached minimum value of 80 nT at $\sim$ 02:00 UT. On the same day, magnetic field variations in Western Canada (Fig. 1b) maximized at $\sim$ 04:00 UT and in Eastern Canada at $\sim$ 02:20 UT (Fig. 1d). Power grids in the West and East (Power site 1 and Power site 2) have responded with GIC maxima at $\sim$ 02:30 UT (site 1) and at $\sim$ 2:40 UT (site 2), as shown in Figs. 1c and 1e.

The complete overview of the most significant Space Weather Events of the Solar Cycle 23 is presented in Table 1 with their subsequent effects on geomagnetic field and power grids. The events were chosen based on the global index of geomagnetic activity $K_p > 8-$. The halo CME and location (approximate) of the source region, based on location of associated flare, are the key solar parameters. The southward interplanetary magnetic field has a controlling role in the interaction between the ICME and the Earth's magnetosphere. The effects on the ground magnetic field at specific region (eastern Canada) are defined by a peak local hourly range index of magnetic variations. Finally, the peak values of GIC recorded on the Nova Scotia Power system and by the Sunburst monitoring network (Electric Power Research Institute) at one of the power grids in the USA are shown. There were two short power outages during solar cycle 23 attributed to space weather impacts, in New Zealand (November 2001) and in Sweden(October 2003).

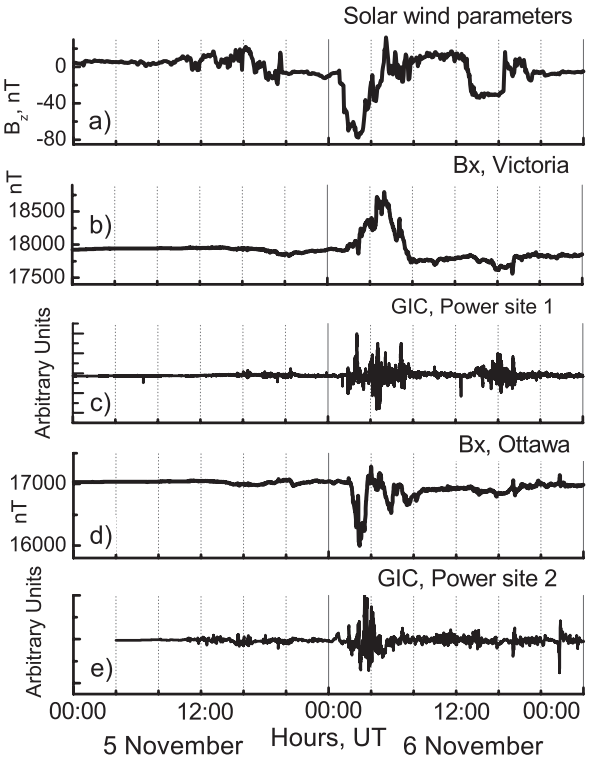

Figure 1. Magnetic field in the solar wind and on the ground and GIC on 5-6 November.

Table 1. Critical parameters of Space Weather Events from the Sun to the Earth.

Dates of events	CME	Flare (assoc.)	Location (possible)	IMF B_z nT	K_p	HR local nT	Site 1 Max GIC,A	Site 2 Max GIC,A
2-4 May 98	Halo	X1, M6	S17W15	-32	9-	898	70	74
23-25 Sep 98	N/A	M6.9	N18E09	-27	8+	1270	N/A	N/A
21-22 Oct 99	NE	M1	N/A	-30	8	908	47	N/A
4-7 Apr 00	Halo/DSF	C9	N16W66	-27	9-	807	96	80
14-16 Jul 00	Halo	X5	N22W07	-54	9	1729	92	76
17 Sep 00	Halo	M2	N13E09	-34	8+	875	62	N/A
31 Mar 01	Halo	X1.7	N20W19	-46	9	1236	100	76
11 Apr 01	Halo	X2	S23W09	-27	8	806	67	27
06 Nov 01	Halo	X1	N06W18	-68	9-	1020	50	64
24 Nov 01	Halo	M9.9	S15W34	-40	8	839	67	90
23 May 02	Halo/DSF	C5 LDF	S22W53	-43	8+	327	24	10
29-30 May 03	??	X1, X3	S07W17	-33	8+	915	40	60
29-31 Oct 03	2Halo	X17/X10	S16E08/ S15W02	-48/ -35	9	1500	100	75
20-21 Nov 03	Halo	M3	S01E18(?)	-53	9-	450	60	20
24-27 Jul 04	Halo	M1.2 LDE	N03W27	-21	9-	1422	N/A	50
7-8 Nov 04	Halo	M5/M9	N11E11/ N10E08	-48.5	9-	1561	N/A	78
9-10 Nov 04	Halo	X2/M9	N09W17/ N07W51	-25	9-	1317	N/A	80
15 May 05	Halo	M8	N12E12	-43	8-	1924	N/A	83
24 Aug 05	Halo	M2/M5 LDE	S08W50/ S12W60	-55	9-	662	N/A	55

DSF=Disappearing Solar Filament, LDE=Long Duration Event, N/A=data not available

https://doi.org/10.1017/S1743921313011733 Published online by Cambridge University Press