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The December 2006 GLE Event as Seen from LARC, SVIRCO and OLC

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Abstract: During December 13, 2006 a Ground-Level Enhancement (GLE) was recorded by the world-wide network of neutron monitors. This paper describes the GLE prehistory and the response of three cosmic ray detectors characterized by different rigidity cutoffs: LARC (King George Island - Antarctica), SVIRCO (Rome - Italy) and OLC (Santiago of Chile).

Introduction

Ground Level Enhancement (GLE) events constitute an important subset of SEP (Solar Energetic Particle) events. During the last month of 2006, an enhanced solar activity interval was observed and an injection of solar relativistic particles in the terrestrial atmosphere occurred (GLE70/SEP; see Figure 1). The start of the event was identified during December 13 at $\sim$ 03 UT by the world-wide network of cosmic ray detectors. Since the mean free paths of GLE particles (mainly protons) are large and particles travel very nearly to the speed of light, the identification of the GLE onset is a good tool for Space Weather forecast. Indeed, solar high-energy particles need only $\sim$ 8 min to $\sim$ 20 min to travel from the solar source to the Earth. Hence, the GLE alert is relevant to furnish a space storm alarm [1, 2, 3].

In Cosmic Ray (CR) research field, the GLE modeling (for each one of those identified) help us to understand the acceleration/propagation mechanisms involved in the phenomenon ([4] and references therein). For this reason ground-based detectors have an outstanding role in the GLE identification and reconstruction of its main characteristics. The response of three CR detectors (characterized by different rigidity cutoffs: LARC, SVIRCO and OLC) is here presented.

Solar activity scenario during December 2006

In spite of the fact that solar cycle 23 was very close to its minimum, during December 2006, an enhanced rate of solar-terrestrial perturbations were revealed in the time variability of CR records.

From $\sim$ 8 to $\sim$ 23 December the registered nucleonic intensity was depressed from its previous level; an outstanding decrease occurred on 14 December ($>$ 8 % at polar regions). It was caused by the arrival at near Earth space of the interplanetary perturbation originated during the 13 December flare activity. The same activity had produced the GLE70 in the terrestrial records.

The time history of CR variability during $\sim$ 8 to $\sim$ 23 December is related to NOAA/USAF 10930 active region. It appears in the Eastern hemisphere of the Sun on December 4 and disappears from the visible hemisphere on December 18 (06° S - 90° W), after having produced 114 flares ranging from B (10^{-7} W/m^2) to X (10^{-4} W/m^2) flare classes. Table 1 summarizes for December 2006 the characteristics of the four big flares produced (upper part). Table 1 also reports all the Type II and Type IV radio emissions identified during the month in the spectral observations (central part) and the SSC occurrences (lower part). Data source: http://www.ngdc.noaa.gov/stp/SOLAR/.

Date	Start	Duration	Location	X Class	H_α Class
5 Dec.	10.18 UT	27 min	S07 E68	X9.0	2N
6 Dec.	18.29 UT	31 min	S05 E64	X6.5	3B
13 Dec.	02.14 UT	43 min	S06 W23	X3.4	4B
14 Dec.	21.07 UT	79 min	S06 W46	X1.5	SF
Date	**Start**	**Duration**	**Frequency (MHz)**	**Spectral Class**	**Remarks**
5 Dec.	10.28 UT	8 min	100-300	Type II (Herringbone)	Bleien/*
	10.33 UT	7 min	25-112	Type II (990 km/s)	Learmonth
	10.34 UT	5 min	38-73	Type II (836 km/s)	San Vito
		20 min	25-180	Type IV	San Vito
6 Dec.	8.15 UT	39 min	25-180	Type IV	San Vito
	8.30 UT	9 min	100-400	Type II	Bleien/*
	18.42 UT	17 min	25-180	Type II (827 km/s)	Palehua
	18.44 UT	18 min	30-180	Type IV	Sagamore Hill
	19.28 UT	32 min	84/U-180	Type IV	Palehua
12 Dec.	23.17 UT	152 min	25-900	Type IV	HIRA/*
13 Dec.	2.25 UT	136 min	150/U-1300	Type IV (Fine structure)	Culgora
	2.25 UT	99 min	25-2000	Type IV	HIRA/*
	2.26 UT	18 min	25-180	Type II (1534 km/s)	Learmonth
	2.27 UT	8 min	18-150	Type II/FN	Culgoora/*
		8 min	30-300	Type II/SH (1600 km/s)	Culgoora
		17 min	25-300	Type II	HIRA/*
	2.47 UT	385 min	25/U-180/U	Type IV	Learmonth
	6.27 UT	167 min	25-180	Type IV	San Vito
14 Dec.	22.07 UT	65 min	25-2000	Type IV	HIRA/*
	22.08 UT	62 min	180/U-1600	Type IV	Culgoora
	22.09 UT	4 min	25-180	Type II (1277 km/s)	Learmonth
		8 min	25-180	Type II (1140 km/s)	Learmonth
		9 min	25-180	Type II (918 km/s)	Palehua
		10 min	25-290	Type II	HIRA/*
	22.10 UT	3 min.	23-75	Type II/FN	Culgoora
		3 min.	50-140	Type II/SH (1500 km/s)	Culgoora
		9 min.	50-280	Type II/SH (850 km/s)	Culgoora
	22.12 UT	6 min.	30-60	Type II/FN	Culgoora
	22.20 UT	130 min	74-280	Type IV	Palehua
Date	**SSC Time**	**CR**	**A Quality**	**B Quality**	**C Quality**
8 Dec.	04.35 UT	Yes	4 Observ.	6 Observ.	2 Observ.
14 Dec.	14.44 UT	Yes	11 Observ.	5 Observ.	1 Observ.+3
16 Dec.	17.55 UT		1 Observ.	6 Observ.	4 Observ.
18 Dec.	10.14 UT			3 Observ.	1 Observ.
	16.36 UT		1 Observ.		3 Observ.
28 Dec.	19.13 UT			1 Observ.	3 Observ.

Table 1: Major flaring activity from NOAA/USAF 10930 active region (upper panel), type II/IV solar radio emission identification (middle panel) and SSC occurrence (lower panel). Symbols are: * for frequencies beyond the instrument range; U for uncertain frequency; FN for Fundamental emission; SH for Secondary harmonic emission; CR for nucleonic intensity decrease $>$ 2%.

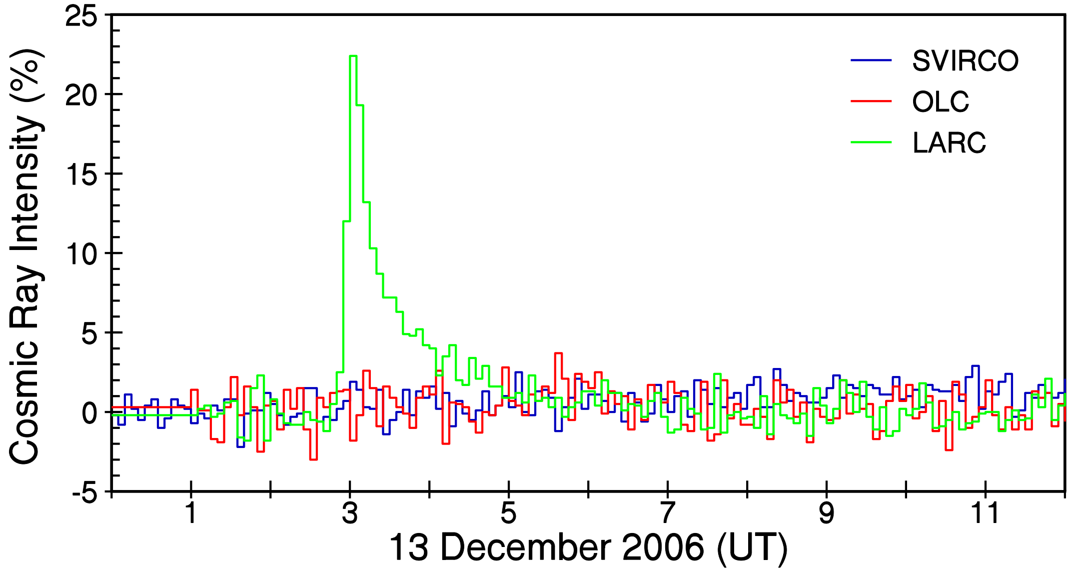

Figure 1: CR intensity registered on 5-min time base during the first half of December 13, 2006 by three neutron monitors: SVIRCO (Rome), OLC (Santiago of Chile) and LARC (Antarctica).

December 2006 GLE/SEP event

Four neutron monitors are running with IFSI-INAF partnership: ESO (6-NM-64, Mt. Hermon - Israel: 33.30° N - 35.78° E, 2020 m a.s.l, ∼ 11 GV), OLC (6-NM-64, Los Cerrillos/Santiago - Chile: 33.45° S - 289.40° E, 570 m a.s.l., ∼ 11 GV), SVIRCO (20-NM-64, Rome - Italy: 41.86° N - 12.47° E, s.l., ∼ 6 GV), LARC (6-NM-64, King George Island - Antarctica: 62.20° S - 301.04° E, 40 m a.s.l., ∼ 3 GV).

Figure 1 shows the detector response to GLE70 for LARC, SVIRCO and OLC, by using the 5-min time scale (the counting rate average for 01-02 UT was used as a pre-increase baseline [5, 6, 7]).

While the GLE profile is outstanding at the Antarctic latitude, there is not a clear evidence of solar proton particles at the Rome and Santiago of Chile locations.

As derived from Table 1, the main characteristics of the GLE70/SEP are associated to the particle emission from 06° S - 23° W. It is interesting to observe from Table 1 that although the X-class of the big flares produced by the involved active region decreases from X9.0 to X1.5, the H_α-class increases from 2N to 4B (GLE70/SEP) and close with SF. Moreover, GLE 70 is preceded by another SEP occurring during 6 December and related to the big flare of 5 December.

We believe that the build-up of the GLE prehistory of solar activity may be useful to GLE forecast. The idea is to collect each GLE prehistory for the current solar activity cycle and to search for common features. It is an event-oriented method proposed by Storini [8] to obtain a learning (scenario) for the development of a GLE forecast code (see Figure 2, for the main steps).

Conclusion

The sporadic emission of solar relativistic charged particles causes GLEs in the terrestrial cosmic ray records (which are good alerts for several Space Weather issues). Nowadays, we are able to model many GLE aspects (by using different available techniques), but to our knowledge there is no way to forecast the GLE occurrence during the solar activity cycle. Here preliminary work to build-up GLE70 scenario is described.

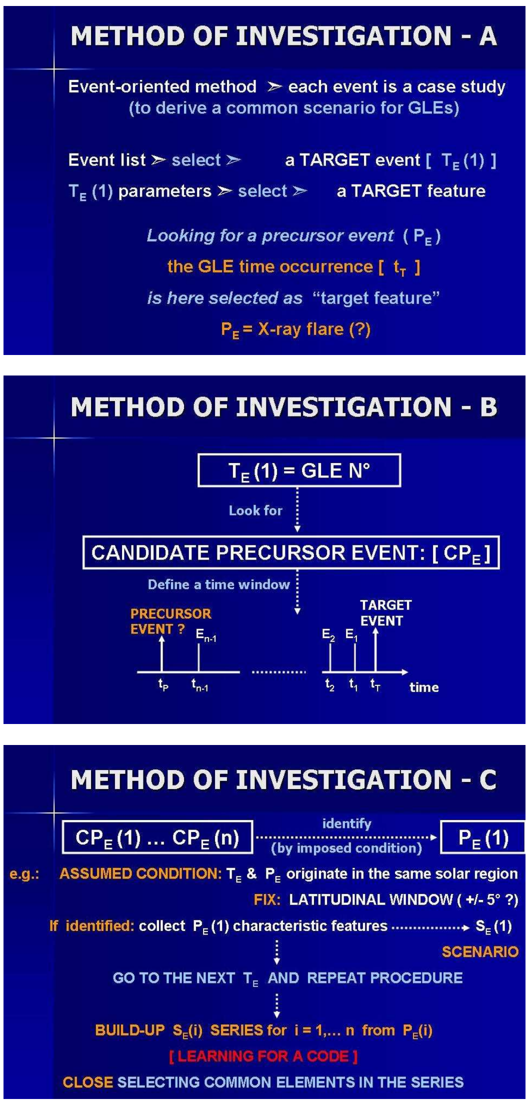

Figure 2: Sketch of the event-oriented method proposed by Storini [8] to build-up each GLE Scenario (learning for a code; see the text).

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References

[1] T. Kuwabara, J. W. Bieber, J. Clem, P. Evenson, R. Pyle, Development of a ground level enhancement alarm system based upon neutron monitors, Space Weather 4 (2006) 1–9.

[2] L. I. Dorman, Space weather and dangerous phenomena on the Earth: principles of great geomagnetic storms forecasting by online cosmic ray data, Annales Geophysicae 23 (2005) 2997–3002.

[3] H. Mavromichalaki, G. Souvatzoglou, C. Sarlanis, G. Mariatos, M. Gerontidou, A. Papaioannou, C. Planaki, S. Tatsis, A. Belov, E. Eroshenko, V. Yanke, The new Athens center on data processing from the neutron monitor network in real time, Annales Geophysicae 23 (2005) 3103–3110.

[4] C. Plainaki, A. Belov, E. Eroshenko, H. Mavromichalaki, V. Yanke, Modelling ground level enhancement: Event of 20 January 2005, Journal of Geophysical Research 112 (2007) 1–16.

[5] E. F. Olivares, M. Storini, E. G. Cordaro, LARC response to GLE 70, Report INAF/IFSI-2007-2.

[6] F. Signoretti, F. Re, M. Storini, SVIRCO Prompt Report, Report INAF/IFSI-2007-1.

[7] E. F. Olivares, M. Storini, E. G. Cordaro, OLC Data to GLE 70, Report INAF/IFSI-2007-3.

[8] M. Storini, SEP/X-ray flare relation for GLEs (Search for), in: COST 724 MM and Scientific Event, Sofia, Bulgaria, May 21-25, 2007.