Research Article

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An alternative classification of solar particle events that reach the earth ground level

Abstract

There is currently a controversy in the literature about the denomination of Energetic Solar Protons, which are usually designated as Ground Level Enhancements (GLE), Sub-GLE or simply Solar Energetic Particles (SEP). Such classifications depend on the nature of a given event behavior. There is some criteria discrepancy among different authors that we have pointed out in the first part of this work. In order to unify criteria, here we carry out an analysis of several data bases and different catalogs of particle events. We observe that there is some discrepancy in the conceptualization of events in the specialized literature, and we hereby propose a reconceptualization in the sense that all GLE fulfill the criteria given in the literature to be considered as GLE, even those that have been classified recently as Sub-GLE/GLE for the particular case of the present cycle 24 To discern the kind of solar particle enhancements occurring during the present Solar Cycle, we base our work on different database of NM, data from the SOHO satellite catalogue and SEP catalogs. This leads us to recommend a reconceptualization of the kind of involved events. Our proposal is to name the event according to its date of occurrence, which leads us to avoid renumbering in case of detecting an intermediate event between two others already officially numbered, in the specific case of GLE. We propose, for instance, the following nomenclature: GLE dd/mm/yyyy. Another option is to consider all events that reach the terrestrial level simply as GLE with the first nomenclature just given above, which obviously includes GLE and Sub-GLE.

Keywords: ground level enhancements, sub-gles–seps, diurnal variation

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Abbreviations: GLE, ground level enhancements; SEP, solar energetic particles; SA, solar activity; GCR, galactic cosmic rays

Introduction

GLE of relativistic solar protons are sporadic phenomena associated with solar flares and are assumed to be of a quasi-random nature. These energetic particles span over most of the earth´s latitudes. To a certain extent they follow the time behavior of the 11-year cycle of solar activity (SA); however, they do not follow the intensity of the SA: for instance, solar cycle 22 was much more intense than cycle 23, but the latter had more GLE than cycle 22: there were 13 GLE in the period from July 1989 to June 1991, and not a single event from the end of December of 2006 up until 2012. In principle, only 72 GLE have been officially recorded: the first measurement was on February 28, 1942 (GLE01) and the last one on September 10, 2017 (GLE72). Though the average occurrence rate is ~1.05 $year^{-1}$, their occurrence may stretch at times for almost six years, as was the case between GLE70 and GLE71. GLE are measured at ground level by the worldwide network of Neutron Monitor (MN) detectors spanning over most latitudes and altitudes (from sea level up to high mountains).

The original definition of a GLE is basically the detection of a statistically significant increases of particles of solar origin in counting rates, in common times, and at least in two neutron monitor stations located in different places, at high latitudes, and one/two low or middle latitudinal stations. This definition is accepted by quite a number of scientists, however, since the decade of the 70s. In fact, all GLE since 1942 have had significant increases in some stations at sea level (<300m).

This definition was proposed by the community of cosmic rays in the 1970s, when there was only one station at high latitudes and altitudes (South Pole). With the installation of another station at high latitudes and altitudes (DOMC/DOMB), for weak events, the conditions of the original definition could be given without requiring any station at sea level to detect the increase. According Miroshnichenko[1] if particles are recorded by spacecrafts in the Earth's orbit, with no clear evidence of penetration at the earth ground level, these are conventionally designated as SEP (Solar Energetic Particles) events.

In the current solar cycle there were a great number of notably weak events, which caused great confusion in designating them as GLE, thus giving them a suitable nomenclature. Recently, a new kind of GLE has been defined, the so called *Sub-GLE* events[2,3] which differ from the GLE definition in that no statistically significant enhancement in the count rates of NM at the sea level (>300 m) is required, in which case the count rate must be registered by at least two different located high-altitude NM station.

In the course of solar cycle 24, only two GLE have been "formally" recognized; one is that of May, 17 2012, the so called GLE71,[4–19] and the second one is the GLE of September 10, 2017, that has been "formally" designated as GLE72 by many authors Tassev et al.,[20–22] However, there are some authors who claim that the GLE72 corresponds to the 06 January, 2014 event Augusto et al.,[23–26] as can be observed in Table 1 there is a high discrepancy in the nomenclature assigned to the same event. For instance, Augusto et al.,[27] have designated GLE73 the event of October 29, 2015. Table 1 shows the high dispersion in the classification of different authors for a given event. In view of such a discrepancy of nomenclatures as can be seen in Table 1, our goal in this work is to attempt to elucidate the real nature of each event and to propose a more easily manageable reclassification on the basis of specific conditions.

Methodology

As can be seen in Table 1, there is a wide conception of a given event according to the different authors. In view of these discrepancies, an exhaustive analysis was made of all the events treated in the literature for the solar cycle 24, Table 1. This implies a reclassification of the concept of a GLE. Such a reclassification considers to some extent some of the conditions previously established in the literature:[3,16]

I. A GLE event is registered when there are near-time coincident and statistically significant enhancements of the count rates of at least two differently located neutron monitors including at least one neutron monitor near sea level and a corresponding enhancement in the proton flux measured by a space-borne instrument(s).

II. A sub-GLE event is registered when there are near-time coincident and statistically significant enhancements of the count rates of at least two differently located high-elevation neutron monitors and a corresponding enhancement in the proton flux measured by a space-borne instrument(s), but no statistically significant enhancement in the count rates of neutron monitors near sea level.

We begin for analyzing which of the studied events coincided with an appreciable overlap effect of Diurnal Variation during one or two days before the beginning of each event. This was done on basis to the database www.mndb.eu. We found that only two events where all stations were strongly affected by the Diurnal Variation March 13, 2012, and the event of 18 April 2018. Consequently, no increment at ground level can be perceived; though some authors claim to have perceived them as a possible Sub-GLE/GLE.[28,19]

Table 1 Events of cycle 24, and their classification according different authors

Event	Author or database	Observations
January 23, 2012	Bazilevskaya, et al.,[32] Gopalswamy et al.,[26] Li et al.,[13] Makhumoto et al., 2013	SEP
	This work based in www.nmdb.eu	No discernible enhancement
January 27-28, 2012	Bazilevskaya, et al.,[35] Gopalswamy et at.,[34] Li et al.[12,13]	SEP
	Augusto et al.,[23]	"almost" GLE
	Belov et al.,[28]	possible GLE
	Velinov et al.,[29]	Contender for GLE
	GLE database University of Oulu	Sub-GLE
	This work based in www.nmdb.eu (Figure 1a: INVK, NAIN, THUL, SOPO, SOPB, MRNY, TERA, MCMU, MXCO, NEWK. FSMT)	Discernible enhancement
March 7, 2012	Augusto et al.,[27] Bazilevskaya, et al.,[35] Gopalswamy et al.,[26] Li et al.,[12,13] Ding et al.,[33]	SEP
	Belov et al.,[28]	possible GLE
	Velinov et al.,[29]	Contender for GLE
	GLE database University of Oulu: Mishev et al.,[16]	Sub-GLE
	This work based in www.nmdb.eu (Figure 1b; KERG: APTY, SOPB, SOPO, TERA, MCMU, MXCO, ARNM, NANM, AATB, ROME, BKSN, JUNG1, LMKS, IRKS, IRKT, MOSC, KIEL, KIEL2. YKTK)	Discernible enhancement
March 13, 2012	Bazilevskaya et al.,[32] Gopalswamy et al.,[26] Li et al.,[13]	SEP
	Belov et al.,[28]	possible GLE
	Velinov et al.,[29]	Contender for GLE
	This work based in www.nmdb.eu (Figure 1 c: THUL, SOPB, SOPO, TERA, MCMU, MXCO, NEWK, FSMT, NAIN, INVK)	Discernible enhancement
May 17, 2012	Augusto et al., 2013, Asvestari et al.,[4] Balabin et al.,[6,24] Berrilli et al., 2014 Firoz et al.,[8] Gopalswamy et al.,[9,25,26] Krastova and Sdobnov et al.,[10] Li et al., 2013, 2015, 2016 Mishev et al.,[15,16] Papaioannou et al.,[17] Perez-Peraza et al., 2018, Plainaki et al.,[18] Thakur et al.,[26] Velinov et al.,[29] The IceCube Collaboration et al.,[19] Kühl et al., 2015 GLE database University of Oulu; This work based in www.nmdb.eu	GLE 71
	Bazilevskaya et at.,[32]	SEP
	Belov et al.,[28] Ding et al.,[33] Thakur et al.,[26]	GLE
July 23, 2012	Gopalswamy et at.,[9]	Small GLE
	This work based in www.nmdb.eu	No discernible enhancement
May 22, 2013	Gopalswamy et al.,[26]; Li et al.,[16]	SEP
	This work based in www.nmdb.eu	No discernible enhancement

Table Continues...

Event	Author or database	Observations
January 6, 2014	Augusto et al.,[23] Balabin et al., 2015 Gopalswamy et al.,[25,26] Krastsova and Sdobnov, 2017; Kühl et al., 2015;Velinov et al., 2016 The IceCube Collaboration et al.,[19]	GLE 72
	Li et al.,[16] Thakur et al.,[25,26]	GLE 72 (Small OLE)
	Belov et al., 2015	GLE
	GLE database University of Oulu: Mishev et al.,[3]	Sub-GLE
	This work based in www.nmdb.eu (Figure 1 d): APTY,SOPB, SOPO, MCMU, OULU, MWSN	Discernible enhancement
January 7, 2014	Li et al.,[16]	SEP
	This work based in www.nmdb.eu	No discernible enhancement
April 18, 2014	Augusto et al.,[23]	Favorable conditions for the formation of a GLE
	This work based in www.nmdb.eu (Figure le: MXCO, NEWK, PWNK, MWSN, SOPO, SOPB, NAIN)	Discernible enhancement
November 1, 2014	Augusto et at.,[31]	Signals at ground level of relativistic solar particles
	This work based in www.nmdb.eu (Figure 1f SOPO, SOPB. MCMU. NAM. PWNK)	Discernible enhancement
June 07, 2015	Gil et al.,[30]	ACRE (Anisotropic Cosmic-Ray Enhancement)
	GLE database University of Oulu	Sub-GLE
	This work based in www.nmdb.eu (Figure 1g: SOPB, SOPO, TERA, MCMU, NEWK, PWNK)	Discernible enhancement
October 29, 2015	Augusto et al.,[23] The IceCube Collaboration et al.,[19]	GLE 73 –
	Velinov et al.,[29]	Contender for GLE
	GLE database University of Oulu; Mishev et al.,[3]	Sub-GLE
	This work based in www.nmdb.eu (Figure lb: JUNG, KERG, TXBY, MWSN, SOPB, SOPO, KIEL)	Discernible enhancement
September 10, 2017	Augusto et at.,[21] Kurt et al., 2018 Tassev et al.,[20]; GLE database University of Oulu; This work based in www.nmdb.eu	GLE 72
August 26, 2018	GLE database University of Oulu	Sub-GLE
	Gil et al., 2018	Possible ACRE
	This work based in www.nmdb.eu (Figure 2: TSMB, HRMS, MOSC, ICEFtG, OULU, APTY, NAIN, THUL, SOPB, SOPO, MRNY, MEN, AATB, ROME, BKSN, JUNGT, LMKS.IRKT)	Discernible enhancement

Results

In the case of events of 27 January, 2012, 07 March, 2012, 6 January 2014, 1, November, 2014 and 29 October, 2015, a number of stations were not totally masked by the Diurnal Variation, as we will mention later. These events that were partially affected by Diurnal Variation. For all these events we analyzed the relative increase of particles with respect to the Background of Galactic Cosmic Rays (GCR), two hours before the events were detected, as indicated in Table 2 and Figure 1. Also, as we mention before we consider the information two days before the event in order to determine the intensity of the Diurnal Variation. An interesting analysis of the event of 07 June 2015 indicates that this is an anisotropic cosmic ray enhancements of the type ACRE.[30] They also argue that the event of 26 August, 2018 is most probably also an ACRE. Obviously, in these cases there are not associated flares nor increases of particles in the satellites detectors (Figure 1g).

For each event, the relative increase with respect to the GCR background was obtained, considering a range of two hours prior to the event. It can have been observed in Figure 1 that the start of the associated SEP event to the ground level enhancement is substantially similar with the start of particle enhancement at the level of satellite data, (Table 3) and (Figure 1). In view that the determination of the start of the GLE is not easy, mainly when there is an overlapping Diurnal wave we have considered the associated SEP start time. Note that Figure 1 refers to the satellite-level count which excludes Diurnal Variation, while Figure 2 refers to the count rate at the terrestrial level where sometimes the Diurnal Variation is intense enough to mask small increments of particles solar, of the type that took place in Solar Cycle 24, as the events that occurred on March 13, 2012 and April 18, 2014 (Table 2).

Taking into a count the ample discrepancy in the classification and the corresponding dates as exposed in Table 1, we proceeded to a new reclassification on the basis of the existing database. For the events of January 27, 2012, March, 2012, 6 January 2014, 1, November, 2014 and 29 October, 2015 (Figure 2) we have the following analysis: for each event, the relative increase with respect to the GCR background was analyzed, considering a range of two hours prior to the event (Figure 1). The five selected events, (Table 2), were chosen because they meet the above mentioned criteria 2.I.

Table 2 Summary of stations that distinguished particle increment in spite of the Diurnal Variation

Event	Station that distinguished the event
27/01/2012	THUL, SOPB, SOPO, FSMT
07/03/2012	KERG, SOPB, SOPO, MCMU, MXCO, BKSN
13/03/2012	All stations were affected by the diurnal wave
06/01/2014	SOPB, SOPO, OULU, MWSN
18/04/2014	All stations were affected by the diurnal wave
01/11/2014	SOPB, SOPO
07/06/2015	ACRE[30]
29/10/2015	TXBY, SOPB, SOPO
26/08/2018	Possible ACRE[30]

(https://www.ngdc.noaa.gov/stp/satellite/goes/doc/SPE.txt; https://umbra.nascom.nasa.gov/SEP/)

Table 3 SEP corresponding to selected events from Table 2

Year	Particle event			Associated CME, FLARE, and active region				
	Start (Day /UT)	Maximum (Day/UT)	Proton Flux (pfu @ >10 MeV)	CME	Maximum (Day/UT)	Importance (X ray/Opt)	Location	NOAA SEC Region No.
2012	Jan 27/1905	Jan 28/0205	796	Halo NW/27 1827	Jan 27/1837	X1/1F long duration	N27W71	11402
2012	Mar 07/0510	Mar 08/1115	6530	Halo NF/07 0036	Mar 07/0024	X5/3B	N17E15	11429
2012	Mar 13/1810	Mar 13/2045	469	Halo NW/13 1736	Mar 13/1741	M7	N18W62	11429
2014	Jan 06/0915	Jan 09/0340	1033	Asymm. Partial Halo SW/07 1824	Jan 07/1832	X1/2N	S15W11	11944
2014	Apr 18/1525	Apr 19/0105	58	CME (C3)/181325	18/1303	M7	S16W41	12036
2014	Nov 01/1400	N/A	N/A	N/A	N/A	C2.7-class flare	southeastern region	N/A
2015	Oct 29/0550	Oct 29/1000	23	Far-sided on W limb, S11/29 0236	(Farside)	N/A	N/A	12434

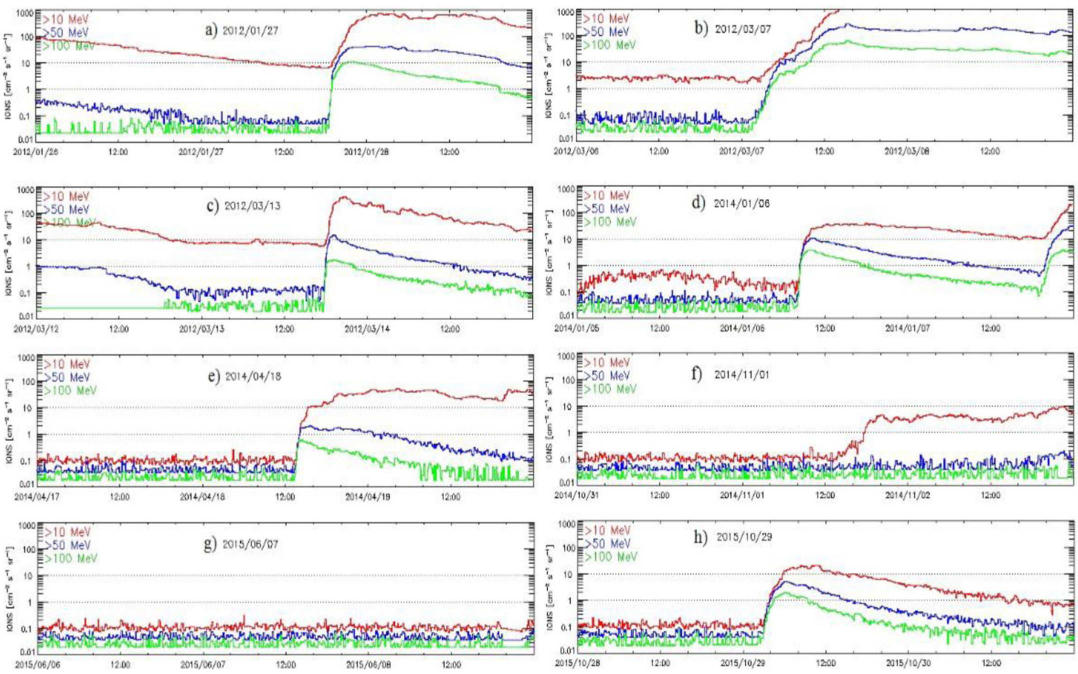

Figure 1 Integral Flux for each event (SOHO LASCO CME CATALOG: https://cdaw.gsfc.nasa.gov/CME_list/).

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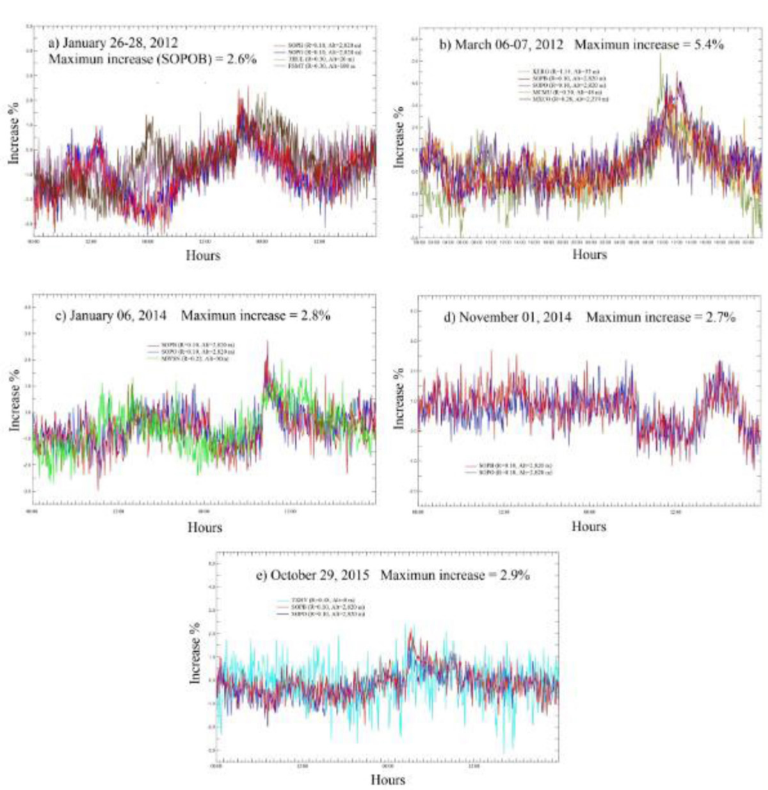

Figure 2 Increments obtained for potential GLEs or Sub-GLEs selected from table 1, based on the data of the worldwide network of Neutron Monitors (www.nmdb.eu).

January 27, 2012

Figure 2a shows the relative rate of increase from the count to every 5 minutes of the SOPB, SOPO, THUL and FSMT stations for the days 26-28 January 2012, normalized to the count interval from 5:00 to 7:00 UT of the GCR background of January 27, 2012 (Table 2) and (Figure 1a), which indicate the start of the event. As we observed in Figure 2a, in these stations a certain effect of Diurnal variability is observed, however, it is possible to clearly distinguish the relative increment of the event. Applying the criteria indicated in:[3,16]

I. The event was detected by spatial instruments at 19:05 UT from the flare of class X1/1F (N27W71) (Table 2).

II. The event was detected at the South Pole station (SOPB and SOPO) of high latitude and altitude.

III. The event has been seen at the THUL and FSMT stations, both of high latitude, but of altitude at mean sea level (<300 m mid-level sea).

IV. Due to these criteria this event is classified as a **GLE** (According to 2.I).

March 7, 2012

Figure 2b shows the relative rate of increase from the count to every 5 minutes of the SOPB, SOPO, KERG, MCMU and MXCO stations for the days 06-07 March 2012, normalized to the counting interval of 03:00 – 05:00 UT of the GCR background of March 7, 2012 (Table 2) and (Figure 1b), which indicate the start of the event. As we observe in Figure 2b in these stations, no effect of Diurnal variability is observed and it is clearly distinguished the relative increase of the event without any doubt. Applying the criteria indicated in: Poluianov et al.,[3,16]

I. The event was detected by spatial instruments at 05:10 UT from the flare class X5 / 3B (N17E15) (see Table 2).

II. The event was detected at the South Pole station (SOPB and SOPO) of high latitude and altitude.

III. The event has been seen at the KERG and MCMU stations, both at altitude at mean sea level (<300 m mid-level sea).

IV. The event was detected at the low latitude and high altitude MXCO station.

V. Due to these criteria this event is classified as **GLE** (According to 2.I).

January 6, 2014

Figure 2c shows the relative rate of increase from the count to every 5 minutes of the SOPB, SOPO and MWSN stations for the days 05-06 January 2014, normalized to the counting interval of 07: 00-09: 00 UT of the GCR background of January 06, 2014 (Table 2) and (Figure 1d), which indicate the start of the event. As we observe in the Figure in these stations a slight effect of daytime variability is observed from the day before the event, however, it is possible to clearly distinguish the relative increase of the event without any doubt. Applying the criteria indicated in: Poluianov et al.,[3,16]

I. The event was detected by spatial instruments at 09:15 UT from the flare class X1/2N (S15W11) (Figure 1d) and (Table 2).

II. The event was detected at the South Pole station (SOPB and SOPO) of high latitude and altitude.

III. The event has been seen at the MWSN station, of high latitude, but of altitude at mean sea level (<300 m mid-level sea).

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IV. Due to these criteria this event would be classified as **GLE** (According to 2.I).

November 1, 2014

Figure 2d shows the relative increase rate from the count to every 5 minutes of the SOPB, SOPO stations for the days 10-11 November 2014, normalized to the counting interval of 11:00-13:00 UT of the background of GCR of November 01, 2014 according to Table 2 and Figure 1f, which indicate the start of the event. As we observe in the figure in these stations no effect of Diurnal variability is observed, however, there is a systematic drop in the count approximately at 07 UT on November 1, later it is possible to distinguish the relative increase of the event. Applying the criteria indicated in: Poluianov et al.,[3,16]

I. The event was detected by spatial instruments at 14:00 UT from the flare class C2.7 (Southeastern region) (Figure 1f) and (Table 2)

II. The event was detected at the South Pole station (SOPB and SOPO) of high latitude and altitude.

III. The event was not detected by any other station.

IV. Since both monitors (SOPB and SOPO) are in the same station, the criteria for classifying the event as a possible GLE (as assumed by Augusto et al.,[31]) are not met, whereas according to this work only can be classified as a **SEP**.

October 29, 2015

Figure 2E shows the relative increase rate from the count to every 5 minutes of the SOPB, SOPO and TXBY stations for the days 28-29 October 2015, normalized to the counting interval from 04: 00-05: 00 UT of the GCR background of October 1, 2015 according to Table 2 and Figure 1H, which indicate the beginning of the event. The noise behavior of the TXBY station could indicate probable affectation due to the daytime variability, while the monitors of the South Pole station do not show this affectation. Applying the criteria indicated in: Poluianov et al.,[3,16]

I. The event was detected by spatial instruments at 05:50 UT whose source was apparently a CME (Figure 1H) and (Table 2).

II. The event was detected at the South Pole station (SOPB and SOPO) of high latitude and altitude.

III. The event has been seen at the TXBY station, of altitude at the mean sea level (<300 m mid-level sea).

IV. In our opinion these events can be classified as **GLE** (According to 2.I).[32–36]

Conclusion

On the basis to criteria popular in the scientific community we have made an analysis of all Solar Particle events (of any kind) that have taken place during cycle 24 as is shown in Table 1. Basically, what we have done in the present work consists of an exhaustive revision of all the events that have been reported in the literature related to the solar cycle 24. We have found 15 events which appear in Table 1: the first column contains the date of the studied event, the second column displays the data source, and/or the corresponding authors, and finally the third column indicates the kind of event, as has been assigned by each of the authors. It is precisely in these two columns where the conflict in the classification of the events as reported by the different authors, can be appreciated. In virtue of this, we have proceeded to carefully examine the information regarding the particle counting rate in the available data basis existing for this purpose: (www.nmdb.eu, GLE Database University of OULU and Databases of neutron monitors of McMurdo, Mirny and Kiel; data from the SOHO satellite catalogue and SEP catalogs).

Basically, our study consists in making sure that a ground level enhancement really existed. Of the above, procedure we have selected nine events that presumable have shown a possible increment (Table 2). Among these nine events, two of them are not solar particle enhancements (the so called ACRE) and other two are indiscernible due to the effect of Diurnal Variation. After confirming the enhancements of the other five events, we proceed to identify the generator SEP of each event (Figure 1) and (Table 3) in order to reclassify each one of the five selected events (Table 4) on basis to the criteria established in section 2 Poluianov et al.,[3,16] According to our results (Table 4), it can be observed that we are demonstrating that there are two GLE events which occurred between the officially accepted GLE70 and GLE71 (January 27, 2012 and March 13, 2012), as well as two between the GLE71 and the GLE72 (January 6, 2014 and October 29, 2015); which comply with the established criteria to be considered as GLE, which leads us to claim that the nomenclature of GLE events carried out to date, based on consecutive numbering is not adequate. This was made clear by the significant number of relatively weak events that occurred in the mentioned solar cycle between GLE70 and GLE72.

Table 4 Reclassification of the category of events

Event	Author or database	Previous class	Station [R(GV),ALT(m)]	Reclassification
January 27-28, 2012	Bazilevskaya et al.,[32] Gopalswamy et al.,[26] Li et al.,[12,13]	SEP	SOPB(R=0.10,Alt=2820m), SOPO(R=0.10,Alt=2820m), THUL(R=0.30,Alt 26m), FSMT(R=0.30,Alt=180m)	GLE
	Augusto et al.,[23]	"almost" GLE		
	Belov et al.,[28]	possible GLE		
	Velinov et al., 2016	Contender for GLE		
	GLE database University of Oulu	Sub-GLE		
	This work based in www.nmdb.eu (Figure la)	Discernible enhancement		

Table Continues...

Event	Author or database	Previous class	Station [R(GV),ALT(m)]	Reclassification
March 7, 2012	Augusto et al.,[23] Bazilevskaya, et al., 2013 Goplswamy et al.,[26] Li et al.,[12,13] Ding et al.,[33]	SEP	KERG(R=1.14,Alt=33m), SOPB(R=0.10,Alt=2820m), SOPO(R=0.41.10,Alt=2820m), MCMU(R=0.30,Alt=48m) MXCO(R=8.28,Alt=2274m)	GLE
	Belov et al.,[28]	possible GLE		
	Velinov et al., 2016	Contender for GLE		
	GLE database University of Oulu; Mishev et al.,[3]	(R41•30 A1r=48m), Sub-GLE		
	This work based in www.nmdb.eu (Figure lb)	Discernible enhancement		
January 6, 2014	Augusto et al.,[23] Balabin et al., 2015 Gopalswamy et al.,[25,26] Kratsova and Sdobnov, 2017; Kühl et al., 2015; Velinov et al., 2016 The IceCube Collaboration at al.,[19]	GLE 72	SOPB(R=0.10,Alt=2820m), SOPO(R=0.10,Alt=2820m), MWSN(R=0.22,Alt=30m)	GLE
	Li et al.,[12] Thakur et al.,[25,26]	GLE 72 (Small GLE)		
	Belov et al.,[28]	GLE		
	GLE database University of Oulu; Mishev et al.,[3]	Sub-GLE		
	This work based in www.nmdb.eu (Figure 1c)	Discernible enhancement		
November 1, 2014	Augusto et al.,[31]	Signals at ground level of relativistic solar particles	SOPB(R=0.10,Alt=2820m), SOPO(R=0.10,A1I=2820m)	SEP
	This work based in www.nmdb.eu (Figure Id)	Discernible enhancement		
October 29, 2015	Augusto et al.,[23] The IceCube Collaboration et al.,[19]	GLE 73	TXBY(R=0.48,A1I--0m), SOPB(R=0.10,Alt=2820m), SOPO(R=0.10,Alt=2820m)	GLE
	Velinov et al., 2016	Contender for GLE		
	GLE database University of Oulu; Mishev et al.,[3]	Sub-GLE		
	This work based in www.nmdb.eu (Figure le)	Discernible enhancement		

In our detailed analysis of all solar particle events of solar cycle 24, we observe the confusion existing between different authors; which generates a great discrepancy regarding the consideration of such events as GLE or not, as well as their nomenclature. In this paper we classify, based on precise criteria (Section 2), 4 events as GLE, which leads us to indicate that the consecutive numbering method for GLE events is not adequate. Our proposal is to name the event according to its date of occurrence, which leads us to avoid renumbering in case of detecting an intermediate event between two others already officially numbered, in the specific case of GLE. We propose, for instance, the following nomenclature: GLE dd/mm/yyyy. Another option is to consider all events that reach the terrestrial level simply as GLE with the first nomenclature just given above, which obviously includes GLE and Sub-GLE; entailing that the Sub-GLE can not necessarily be seen by stations near sea level; while a 100% of the GLE up to now have been registered at least by one station near sea level (including the four GLE of Table 4 that have been seen in at least one station at the sea level). On the other hand, in view that both of these two types have a SEP counterpart, in reality there is not a sharp distinction between them. In summary, according to our study, small and intensive events that come to earth could be considered all them as GLE.

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Conflicts of interest

The auhtor declares there is no conflict of interest.

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