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The online catalog of Wind/EPACT proton events

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Abstract

We present the newly compiled solar energetic particle catalog based on data from the Wind/EPACT instrument. The focus of this report is the online contents of the catalog's first version. We summarize the procedure employed to identify and analyze the proton events and their solar origin, which constitute the main ingredients of the online catalog. Planned future updates and improvements are also discussed.

Introduction

A solar energetic particle (SEP) is a generic term used to describe an elevated flux of non-thermal electrons, protons and ions observed in situ [1]. The particle profiles show velocity dispersion and follow in time eruptive phenomena that occurred on the Sun thus supporting the solar origin of the phenomena. Compared to all species, the solar protons are more frequently discussed and finally considered as the SEP events. Occasionally, an additional component in the particle profile can be identified, which is the contribution of accelerated articles in the interplanetary (IP) space due to shocks, co-rotating or/and streaming interaction regions, and not due to the primary acceleration process close to the Sun.

Irrelevant on their exact acceleration driver (flares and coronal mass ejections, CMEs) and mechanism, high energy protons and electrons can be harmful for satellite equipment and can expose humans to radiation, more severely during space travel and less during aircraft flights on polar orbits. Nowadays, SEPs are recognized as one of the major space weather agents [2].

The SEP data is eventually stored in databases and occasionally organized in catalogs. One such proton catalog is based on GOES data (http://umbra.nascom.nasa.gov/SEP/) and reports only events with proton intensity above a constant threshold level. Due to the long time coverage of this catalog (since 1976 to present) it is often used for academic research.

Recently, other proton catalogs based on IMP-8, SOHO and GOES proton data were released, namely Cane et al. proton list [3], SEPServer event list (http://server.sepserver.eu/index.php) [4] and the SEPEM reference proton list (http://dev.sepem.oma.be/help/event_ref.html). In contrast to the proton lists, a comprehensive electron event catalog is still lacking, since the only available electron list [5] is compiled for events with specific intensity profiles.

A comprehensive SEP catalog should provide information for the particle event (onset time, peak time, peak particle intensity, fluence, energy range, etc.), as well as the SEP solar origin (flare and CME characteristics). Usually, SEP catalogs are compiled manually after the actual observations were made. However, automatically produced flare and CME lists are already available.

In order to complement the GOES and SOHO proton catalogs and extend the event statistics, we compiled a comprehensive proton event list based on data from the Wind satellite [6]. This proton database is explored for the first time using visual and numerical methods. All proton events above the pre-event background level (i.e., no threshold applied) were identified and organized in a list. The aim of the present report is to describe the online version of this new proton catalog.

Data and Methods

For this catalog we use proton data from the Energetic Particle Acceleration, Composition and Transport (EPACT) instrument [6] aboard the Wind satellite during the time period 1996–2015. We used omni-directional data with time resolution of 92 seconds and in two energy channels (low: 19–28 MeV and high: 28–72 MeV), provided by the CDAWeb database (http://cdaweb.gsfc.nasa.gov).

First, using the web interface, we plotted the proton intensity over time period of several days for visual identification of the proton enhancements. When such an increase was visually confirmed, we collected and then analyzed the proton data using a routine, prepared by us under Python (https://www.python.org/) for the identification of: pre-event averaged intensity level (e.g., background level); onset time (defined as the time when the proton flux reaches 3 standard deviations (sigma) above the background level); peak intensity (the maximum value of the proton intensity identified in a specific, pre-selected time interval, and reported after subtraction of the background intensity level) and peak time (defined as the time when the intensity reaches its peak). In order to identify time and intensity markers, the proton data was initially averaged over 5 data points (denoted with blue color on all overview plots). The background and peak levels are identified based on time intervals manually selected by the observer during the data analysis.

An important part of the analysis is the correct separation of the locally accelerated proton component due to shock waves close to Earth from the SEP event. We excluded the shock-component by requiring the routine to search for the peak in a time interval chosen to precede the shock signature if present. The shock-signatures, which represent an additional increase on a (declining) SEP profile, can be easily identified by a visual inspection. We also used information about the shock arrival times at Earth from the Heliospheric Shock Database (http://www.ipshocks.fi/).

Example plots of the proton intensity–time profile in the low and high energy channels are given in Figure 1. The onsets and peaks are marked by different symbols in all overview plots. There are more than 350 proton events in the low energy and more than 300 events in the high energy channel which are listed in the online catalog.

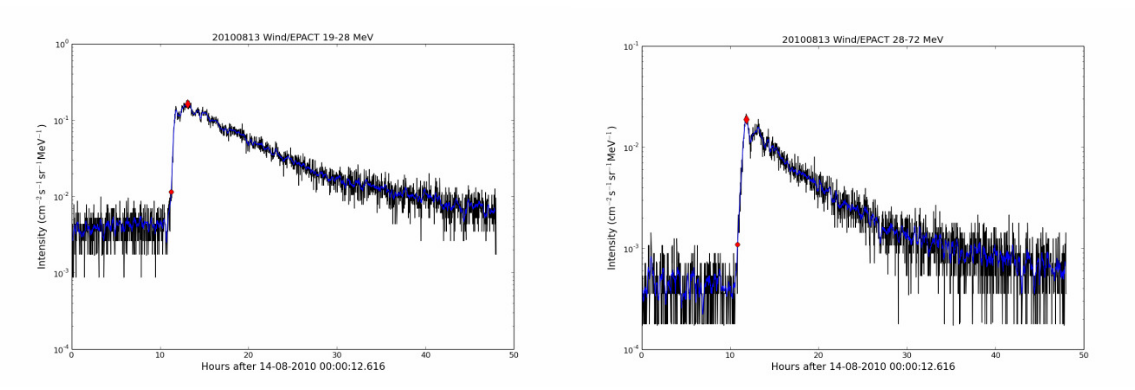

Fig.1. Example intensity–time plots in the low (19–28 MeV) and high (28–72 MeV) energy channel of Wind/EPACT instrument.

Each SEP event is related to activity phenomena observed at the Sun, regarded as the SEP origin. The well-known agents giving rise to accelerated particles are the solar flares and CMEs. We used timing and location criteria to relate each SEP event to its most probable solar driver and often we could identify a pair of flare and CME. The reason when a flare could not be identified, in the majority of cases, was that a flare has occurred behind the solar limb, as evidenced by occulted radio emission signatures. Alternatively, no association of SEP-related CMEs was primarily due to SOHO data gaps.

The parameters of solar flares are collected from the GOES soft X-ray (SXR) instrument reports as provided online: ftp://ftp.ngdc.noaa.gov/STP/space-weather/solar-data/solar-features/solar-flares/x-rays/goes/ and from www.SolarMonitor.org.

The properties of the CMEs are taken from the SOHO/LASCO CME catalog [7]: http://cdaw.gsfc.nasa.gov/CME_list/

Online Catalog

The present structure of the catalog is shown in Figure 2. This is a snapshot of the web-based interface dedicated to the catalog: **http://newserver.stil.bas.bg/SEPcatalog/index.html**

Catalog
of
solar energetic particles

from Wind/EPACT instrument

Solar cycle 23: 1996-2008   Solar cycle 24: 2009-present

Event date	19-28 MeV			28-72 MeV	Flare	CME	Comment
yyyy-mm-dd	onset time (UT)	peak time (UT)	J_p $(cm^2\ s\ sr\ MeV)^{-1}$	J_p $(cm^2\ s\ sr\ MeV)^{-1}$	SXR class/ onset time (UT)/ location	time (UT)/ speed (km s^{-1})/ width (deg)	
2009	-	-	-	-	-	-	no SEP events
2010-06-12	04:04	08:39	0.0123	0.002	M2.0/00:30/N23W43	01:32/489/119	
2010-08-03	15:13	18:25	0.0478	0.0014	u	u	
2010-08-07	22:45	01:43[nd]	0.0111	0.0014	M1.0/17:55/N11E34	18:36/871/360	
2010-08-14	11:15	13:05	0.158	0.0184	C4.4/09:38/N17W52	10:12/1205/360	
2010-08-18	08:01	12:18	0.0486	0.0034	C4.5/04:45/N17W95	05:48/1471/184	
2010-09-09	03:02	04:25	0.0071	0.0007	C3.3/23:05/N19W91	23:27/818/147	

Fig.2. Snapshot of the first online version of the proton catalog.

The catalog consists of two identical in contents web-pages, dedicated to events in solar cycle (SC) 23 and 24, respectively. The default page gives the recent proton event list, namely in SC24. The catalog is organized as an electron table, where each row is designed for a specific proton event and its solar origin. Links to the overview plots (as in Figure 1) in both energy channels are available. The details are given in separate columns with overhead titles, as described below.

Column 1: yyyy-mm-dd

The first column gives the event date, abbreviated as year (yyyy), month (mm) and day (dd).

Column 2: onset time (UT)

The time of 3-sigma increase of the proton profile in the low energy channel (19-28 MeV) is reported here in universal time (UT) units, in standard format (hh:mm).

Column 3: peak time (UT)

The peak time of the proton event in the low energy channel is given in UT.

Column 4: J_p $(cm^2\ s\ sr\ MeV)^{-1}$

This column presents the peak proton intensity in the low energy channel.

Column 5: J_p $(cm^2\ s\ sr\ MeV)^{-1}$

Peak proton intensity in the high energy channel (28–72 MeV) is shown here.

Column 6: Flare

This column lists the flare soft X-ray (SXR) class, onset time in UT and location on the solar surface.

Column 7: CME

Here, we provide the time of first appearance of the CME in UT, its projected speed (in km/s) and angular width (in degrees).

Column 8: Comment

This column is dedicated for additional information about the proton event or related phenomena.

Below the table, we provide links to the Wind/EPACT data and instrument, a concise summary on the proton data analysis, a list of the abbreviations used in the catalog, the reference paper(s), and contact information.

Summary

At present the proton data analysis and solar origin are completed by the end of 2015. A dedicated publication (under completion) will present the statistical results based on SEP observations over nearly two solar cycles. Several planned improvements in the online catalog are considered, such as search and sort options in order to improve the visibility of the catalog contents. Yearly updates of the catalog are scheduled and will be completed in the beginning of the following year in order to account for delays in the proton/flare/CME data release. This online catalog will be further supported by the Space Climate group in the Space Research and Technology Institute, Bulgarian Academy of Sciences.

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References

[1] Gloeckler, G. In situ detection of energetic particles. // Heliophysics: Space Storms and Radiation: Causes and Effects, eds. C. J. Schrijver and G. L. Siscoe, Cambridge University Press – 2010 – P:43-77.

[2] Schwenn, R. Space Weather: The Solar Perspective. // Living Reviews in Solar Physics. – 2006. – 3(2).

[3] Cane, H. V., Richardson, I. G., von Rosenvinge, T. T. A study of solar energetic particle events of 1997-2006: Their composition and associations. // Journal of Geophysical Research. – 2010. – 115(A8). – CiteID A08101.

[4] Vainio, R., Valtonen, E., Heber, B. et al. The first SEPServer event catalogue ~68-MeV solar proton events observed at 1 AU in 1996-2010. // Journal of Space Weather and Space Climate. – 2013. – 3. – id.A12.

[5] Haggerty, D. K.; Roelof, E. C. Impulsive Near-relativistic Solar Electron Events: Delayed Injection with Respect to Solar Electromagnetic Emission. // The Astrophysical Journal. – 2002. – 579(2). – P:841-853.

[6] von Rosenvinge, T. T, Barbier, L. M., Karsch, J. et al. The Energetic Particles: Acceleration, Composition, and Transport (EPACT) investigation on the WIND spacecraft. // Space Science Reviews. – 71(1-4). – P:155-206.

[7] Gopalswamy, N, Yashiro, S., Michalek, G., Stenborg, G., Vourlidas, A., Freeland, S., Howard, R. The SOHO/LASCO CME Catalog. // Earth, Moon, and Planets. – 2009. – 104(1-4). – P:295-313.