SOHO/ERNE proton event catalog: Progress results under the SEP origin project

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Abstract.

The focus of this report is to outline the current status of the multi-energy cataloging of solar energetic protons from the SOHO/ERNE instrument in solar cycles 23 and 24. Half of the energy channels provided by the high energy detector (HED) have been analyzed and the first results are presented here. The finalized event list (1996-2018) is planned to appear on-line as a freely accessible catalog supported by the Space Climate group at the Space Research and Technology Institute – Bulgarian Academy of Sciences (SRTI-BAS).

Introduction

Various proton catalogs already exist, either as freely available event lists or as part of publications. Without the ambition for completeness, we present some known to us proton catalogs.

Freely available proton event lists:

- NOAA preliminary listing (1976-present): https://umbra.nascom.nasa.gov/SEP/
- SEPEM reference event list (1973-2013): http://dev.sepem.oma.be/help/event_ref.html
- ERNE major proton events (1996-1999): https://srl.utu.fi/erne_data/events/proton/HED/eventlist.html
- SOHO/ERNE particle events (1996-2007): https://srl.utu.fi/SEPCatalog/index.php
- SEPserver event catalogs (several, 1997-2012/2015): http://server.sepserver.eu/
- Solar proton events (1970-2008): http://www.wdcb.ru/stp/online_data.en.html#ref113

Proton catalogs provided in recent publications, the primary instrument(s) and time coverage:

- Cane et al. (2010): IMP-8 (1996-2006)
- Miteva et al. (2013): GOES, Wind/EPACT, ACE/EPAM (1996-2006)
- Papaioanou et al. (2016): GOES (1984-2013)
- Kühl et al. (2017): SOHO/EPHIN (1997-2014)
- Paasilta et al. (2017): SOHO/ERNE (1997-2016)
- Miteva et al. (2018): Wind/EPACT (1996-2016)

For the purpose of the present catalog, proton data from SOHO/ERNE (Torsti et al. 1995) instrument is used, due to wide energy coverage provided (1.6 to 131 MeV). The instrument consists of two detectors:

- low energy detector (LED): (1) 1.6-1.8, (2) 1.8-2.2, (3) 2.2-2.7, (4) 2.7-3.3, (5) 3.3-4.1, (6) 4.1-5.1, (7) 5.1-6.4, (8) 6.4-8.1, (9) 8.1-10, (10) 10-13 MeV and
- high energy detector (HED): (1) 14-17, (2) 17-22, (3) 21-28, (4) 26-32, (5) 32-40, (6) 40-51, (7) 51-67, (8) 64-80, (9) 80-101, (10) 101-131 MeV.

As a reference channel is selected the second HED channel 17-22 (19.5) MeV, namely the visual identification of the proton enhancements is performed at this energy and all other events are in fact the high (or/and low) energy signatures of the ~20 MeV protons.

Despite that proton lists based on SOHO/ERNE data already exist, the aim of the current catalog is to provide information on proton peak intensity in all 10 HED energy channels individually (and in future also in selected LED channels) as well as additional information such as: calculation of the proton (onset-to-peak) fluences, completion of the solar origin association (solar flares and coronal mass ejections, CMEs), identification of related solar eruption phenomena (prominences, radio bursts, waves, etc.).

The need for a multi-energy catalog from the same instrument has been shown by Dierckxsens et al. (2015) and their energy dependent statistics. The results on correlation studies between proton intensity and flare class (increasing trend) or/and with CME speed (decreasing trend) as a function of the proton energy have not been challenged to date.

The first version of the on-line platform of the catalog was shown in Miteva and Danov (2017a). The first results in the ~20 MeV channel were reported by Miteva (2017b), where the main guidelines for the proton identification were already presented.

At present, we report on the preliminary statistical results in five out of the ten HED energy channels of SOHO/ERNE.

Current status of the on-line SOHO/ERNE catalog

The access point to the SOHO/ERNE catalog is through a web-based interface: http://newserver.stil.bas.bg/SEPcatalog as shown in Fig. 1. After selecting the relevant button, a new overview page is opened (Fig. 2) providing a concise description of the SOHO/ERNE catalog contents, the different abbreviation used, relevant links, contact information, etc.

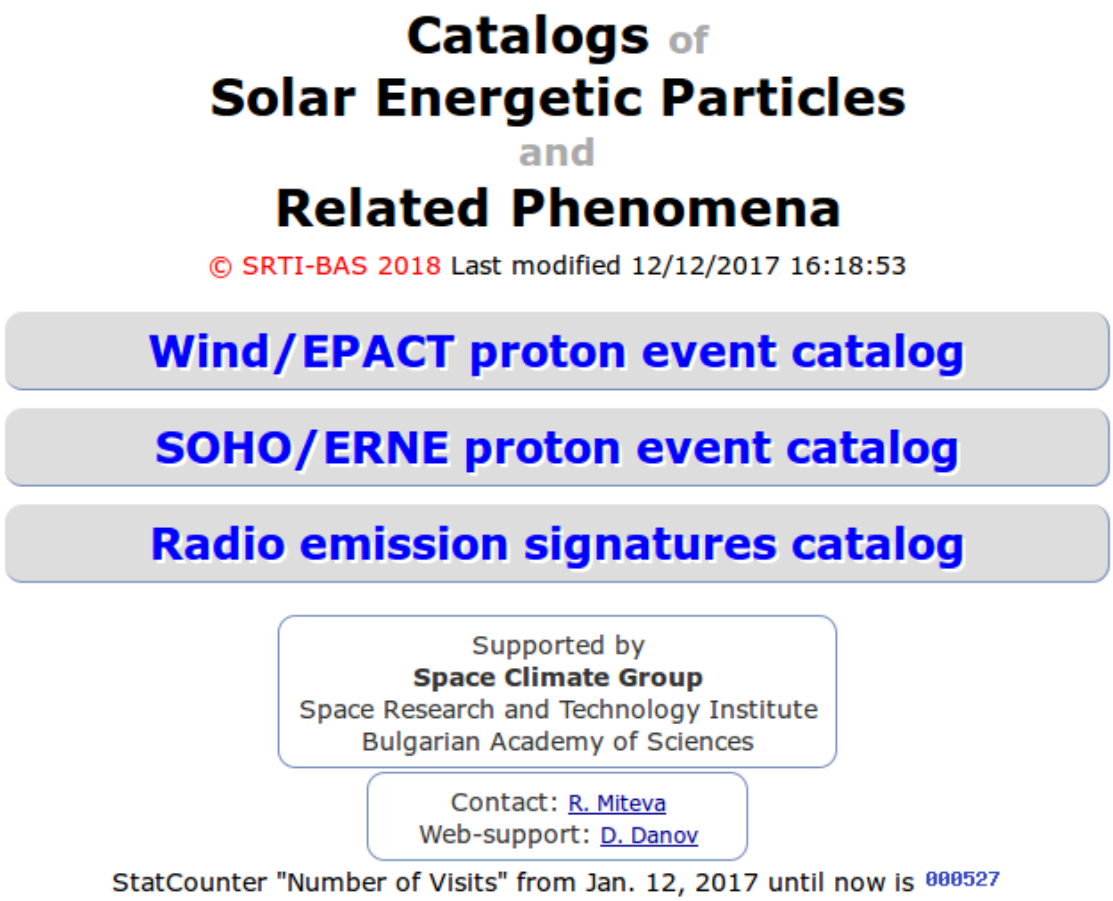

Fig. 1 Home page of the dedicated website hosting three different catalogs: http://newserver.stil.bas.bg/SEPcatalog.

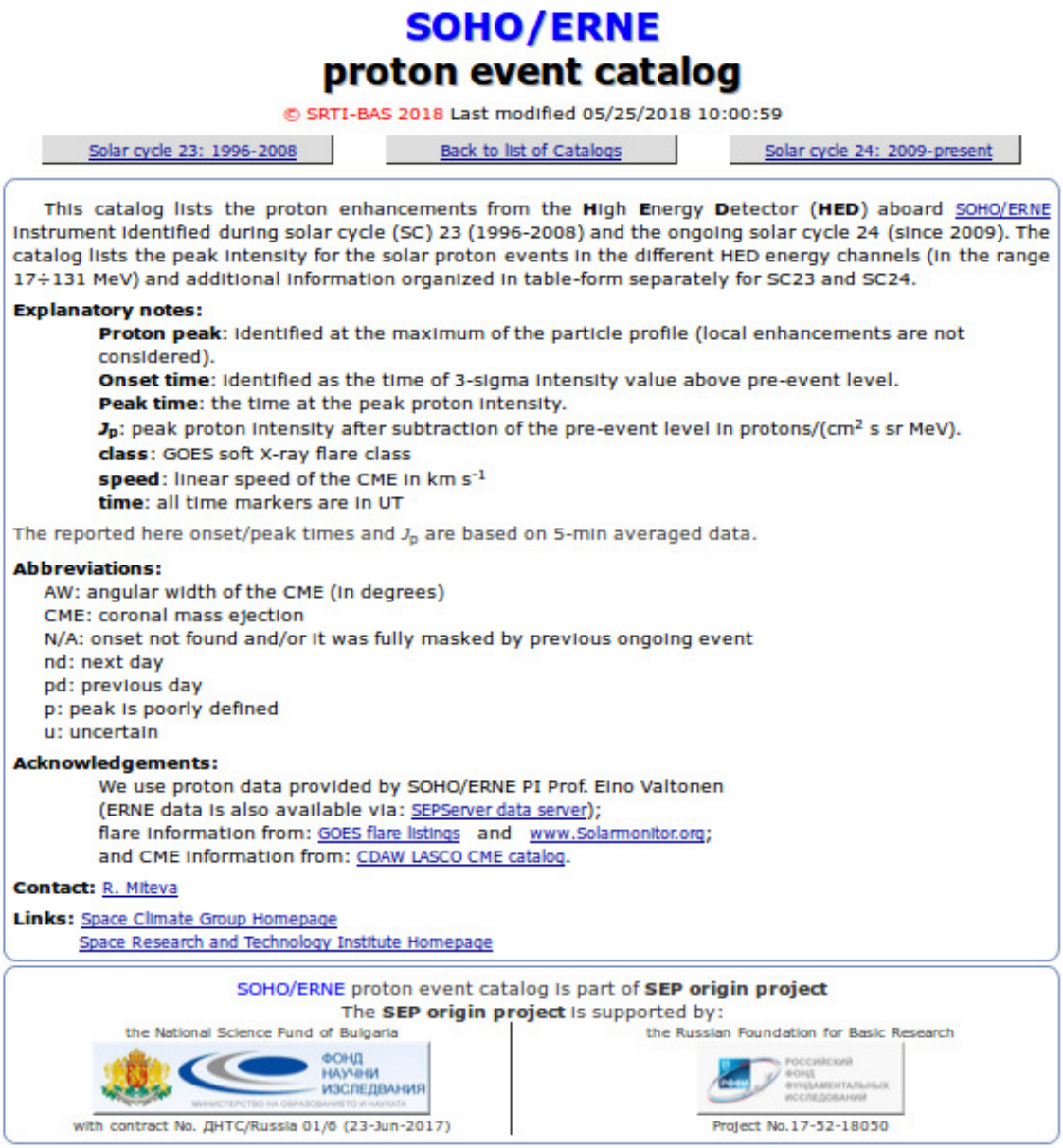

Fig. 2 Description of the SOHO/ERNE proton event catalog.

The final web-level is accessed via the two buttons at the top of the page designed to contain the information separately on solar cycle (SC) 23 and 24. Each of these new pages (see Fig. 3) is structured as a table containing information about the proton events and their solar origin. Complete information (onset, peak time and peak proton intensity, J_p) is planned to be provided only for the reference energy channel. There, the value for J_p will be linked to an overview plot over two-day period (see Fig. 1 in Miteva 2017b), where two different symbols will depict the onset time (with a cross) and the peak intensity and time (with a diamond). The remaining columns will contain only the evaluated peak proton intensity for each proton enhancement in the specific energy. In many of the energy channels, no particle enhancement is identified (denoted by '-' for no event). Flare and CME information is provided in separate columns.

SOHO/ERNE
proton event catalog
Solar cycle 23: 1996-2008
© SRTI-BAS 2018 Last modified 03/26/2018 16:52:12

Back to list of Catalogs | Back to SOHO/ERNE | Solar cycle 24: 2009-present

Event date	14-17 MeV	17-22 MeV			21-28 MeV	26-32 MeV	32-40 MeV	40-51 MeV	51-67 MeV	64-80 MeV	80-101 MeV	101-131 MeV	Flare	
yyyy-mm-dd	J_p	onset time	peak time	J_p	J_p	J_p	J_p	J_p	J_p	J_p	J_p	J_p	class/onset/location	tim
1996-07-09		10:03	10:50	0.0016		0.0004		-		-		-	X2.6/09:05/S10W30	
1996-08-13		17:53	22:05	0.0038		0.0012		0.0005		-		-	uncertain	16:
1996-11-27		00:18	02:37	0.0004		-		-		-		-	B9.0/20:48^{pd}/u	21:
1996-11-27		14:22	15:20	0.0005		-		-		-		-	uncertain	
1996-11-28		19:53	22:09	0.0034		0.0007		-		-		-	C1.3/15:35/u	16:
1996-11-29		04:43	13:49	0.0015		0.0003		-		-		-	uncertain	
1996-11-30		06:23	07:14	0.0101		0.0022		0.0002		-		-	uncertain	
1996-12-01		22:05	01:33nd	0.0005		-		-		-		-	M1.0/20:16/S06W47	
1996-12-24		14:59	18:21	0.0050		0.0014		0.0003		-		-	C2.1/13:03/N05W95	13
1997														
1998														
1999														
2000														
2001														

Back to list of Catalogs | Back to SOHO/ERNE | Solar cycle 24: 2009-present

SOHO/ERNE
proton event catalog
Solar cycle 24: 2009-present
© SRTI-BAS 2018 Last modified 03/20/2018 19:49:11

Back to list of Catalogs | Back to SOHO/ERNE | Solar cycle 23: 1996-2008

Event date	14-17 MeV	17-22 MeV			21-28 MeV	26-32 MeV	32-40 MeV	40-51 MeV	51-67 MeV	64-80 MeV	80-101 MeV	101-131 MeV	Flare	
yyyy-mm-dd	J_p	onset time	peak time	J_p	J_p	J_p	J_p	J_p	J_p	J_p	J_p	J_p	class/onset/location	tim
2009-12-22		07:33	13:18	0.0011		0.0004		0.00022		-		-	C7.2/04:50/S26W46	
2010-02-12		17:20	22:19	0.0007		0.0003		-		-		-	M8.3/11:19/N23E11	
2010-04-04		10:23	11:06	0.0002		-		-		-		-	uncertain	
2010-06-12		02:32	07:02	0.0207		0.0061		0.0023		-		-	M2.0/00:30/N43W23	01:
2010-08-03		N/A	23:06^{u}	0.0326		0.0025		-		-		-	uncertain	
2010-08-07		20:09	01:33nd	0.0042		0.0042		0.0011		-		-	M1.0/17:55/N11E34	18:
2010-08-14		10:53	12:48	0.6267		0.1852		0.0512		-		-	C4.4/09:38/N17W52	10:
2010-08-18		07:18	11:52	0.1170		0.0190		0.0037		-		-	C4.5/04:45/N18W88	05:
2010-08-31		23:28	04:20nd	0.0191		0.0046		0.0010		-		-	uncertain	21:
2010-09-09		01:02	04:38	0.0135		0.0024		0.0006		-		-	C3.3/23:05/N21W87	23:
2010-12-31		05:58	06:57	0.0004		-		-		-		-	C1.3/04:18/N12W57	05
2011														
2012														
2013														

Back to list of Catalogs | Back to SOHO/ERNE | Solar cycle 23: 1996-2008

Fig. 3 Contents of the SOHO/ERNE proton event catalog (status end July 2018) for solar cycle 23 (upper) and solar cycle 24 (lower plot).

Preliminary results of the multi-energy analysis

The yearly distribution (1996-2016) of the proton event in two energy channels (~20 and ~116 MeV) is shown in Fig. 4. The solar cyclicity is evident, as well as the weaker, also in proton number, SC24.

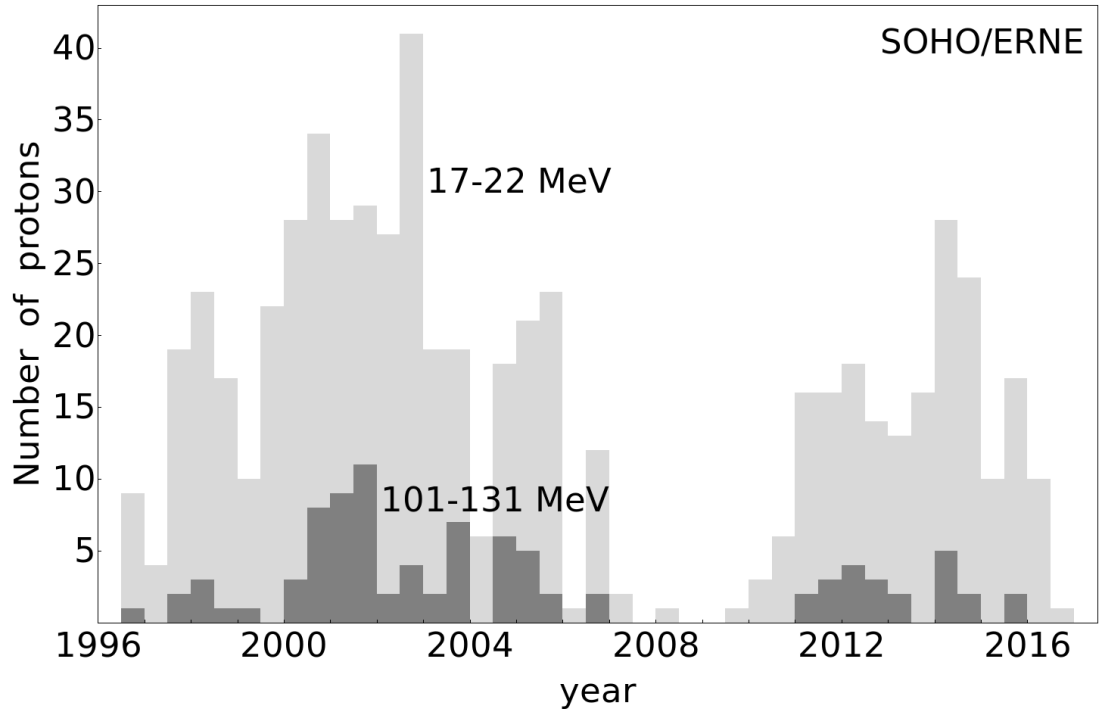

Fig. 4 The yearly distribution of proton events in the reference ~20 MeV and the highest, ~116 MeV, HED energy channel.

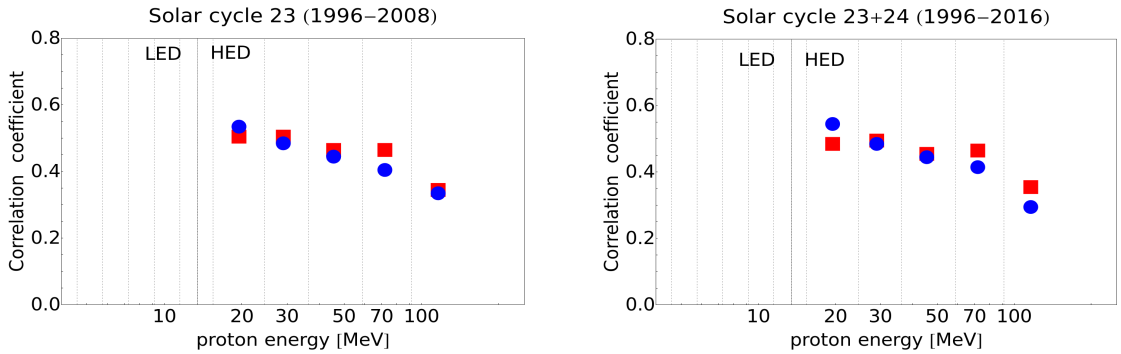

Fig. 5 The log_{10}–log_{10} Pearson correlation coefficient with flare class (red squares) and CME speed (blue circles) for two time periods, as denoted at the top of the plot. LED and HED energy coverage is separated by solid vertical line.

The aim of the analysis over the available energy channels is to investigate the correlation behavior as a function of energy. Once the proton peak intensity in each energy channel is evaluated, the Pearson correlation coefficients with flare class and CME speed can be calculated. At present, the preliminary results over five energy channels is shown in Fig. 5, namely for HED channels (2), (4), (6), (8) and (10). The dotted vertical lines denote the channels under completion. Five LED energy channels are considered at present for further evaluation, namely for a better energy coverage over the entire range, namely (6)-(10). The range can be further extended at lower energies (down to 1.6 MeV) if necessary.

The first energy dependent statistical results are shown in Fig. 5, separately for data in SC23 (1996-2008) and for the entire evaluated period SC23+24 (1996-2016). There are no statistical differences between the results in the two period of interest.

The preliminary results show a steady declining trend of the correlation coefficients between the peak proton intensity and, both, flare class (opposite to the results in Dierckxsens et al. 2015 over SC23) and CME speed (confirming the results there). When the finalized evaluation of the proton intensity is completed, these calculations will be repeated in order to avoid differenced due to erroneous particle identifications.

Nevertheless, SOHO/ERNE instrument is subject to saturation when the proton flux surpasses certain intensity threshold (of about 10 flux units, as shown in Fig. 2 in Miteva (2017b), by comparing ~20 MeV SOHO/ERNE and ~25 MeV Wind/EPACT protons). This effect needs to be investigated at the different energy channels. Without suitable correction factor, the flux level of large proton events is underestimated. This effect could be responsible for a drop in the correlation trend, however such possibility needs to be carefully verified.

The complete catalog and energy dependent statistical results will be reported elsewhere. Finally, the catalog contents will be released on-line, covering the last two solar cycles (1996-2018) and beyond if SOHO/ERNE data is also been provided.

Acknowledgement

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