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On-line catalogs of solar energetic protons at SRTI-BAS

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Abstract.

We outline the status of the on-line catalogs of solar energetic particles supported by the Space Climate group at the Space Research and Technology, Bulgarian Academy of Sciences (SRTI-BAS). In addition to the already compiled proton catalog from Wind/EPACT instrument, in the current report we present preliminary results on the high energy SOHO/ERNE proton enhancement identifications as well as comparative analysis with two other proton lists. The future plans for the on-line catalogs are briefly summarized.

Introduction

The importance of solar energetic particles (SEPs: electrons, protons and heavy ions from keV up to GeV energies) in space weather research, in addition to flares and coronal mass ejections (CMEs), has already been recognized [*Schwenn* 2006; *Pulkkinen* 2007]. The risk for SEP produced radiation doses outside the terrestrial magnetosphere is regarded as a severe problem to be solved in order to secure the safety of humans during future space travel flights (https://oig.nasa.gov/audits/reports/FY16/IG-16-003.pdf).

Mitigating the negative effects of space weather drivers is the reason for the observational and theoretical efforts spent in understanding them. The forecasting SEP and flare events is the subject of numerous recently completed and ongoing EU-projects. Many of the forecasting schemes rely on long series of events in order to test and train the forecasting methods (e.g. by machine-learning techniques). This is one of the possible applications for the comprehensive SEP event lists prepared from data provided by different space-borne instruments, in addition to academic-oriented research.

Due to various reasons (e.g., service interruption, event detection threshold, magnetic field line connection, etc.) a single spacecraft is unable to provide a complete list of all SEP events observable at Earth. In a recent study, *Miteva et al*. [2017b] summarized a number of probable instrumental, positional and selection effects that may influence the completeness of a SEP catalog. The different instruments provide observations in several energy channels, particle species, and locations (geostationary orbit, around L1, along the Earth orbit).

In the present report we summarize the current status of the SEP cataloguing performed at the Space Climate group in the Space Research and Technology, Bulgarian Academy of Sciences (SRTI-BAS). The preparation of several catalogs is in progress and using proton data from Wind/EPACT [*von Rosenvinge et al*. 1995] and SOHO/ERNE [*Torsti et al*. 1995] instruments is now confirmed. The first version of the proton catalog based on Wind/EPACT data was announced by [*Miteva et al*. 2016], where the main guidelines for the proton identification were presented, as well as the on-line platform of the catalog. This preliminary version of the Wind/EPACT proton event catalog was used in a study by [*Miteva et al*. 2017a] to explore the solar cycle trends. The finalized version of the proton catalog is now completed and used for comparative and statistical studies [*Miteva et al*. 2017b,c]. At present, we continue with the analysis of proton enhancements above ~20 MeV from the SOHO/ERNE instrument. All particle catalogs (with information on their proton event characteristics – time and peak intensity, overview plots and solar origin – flares and CMEs) will be stored at the dedicated web-site: http://newserver.stil.bas.bg/SEPcatalog.

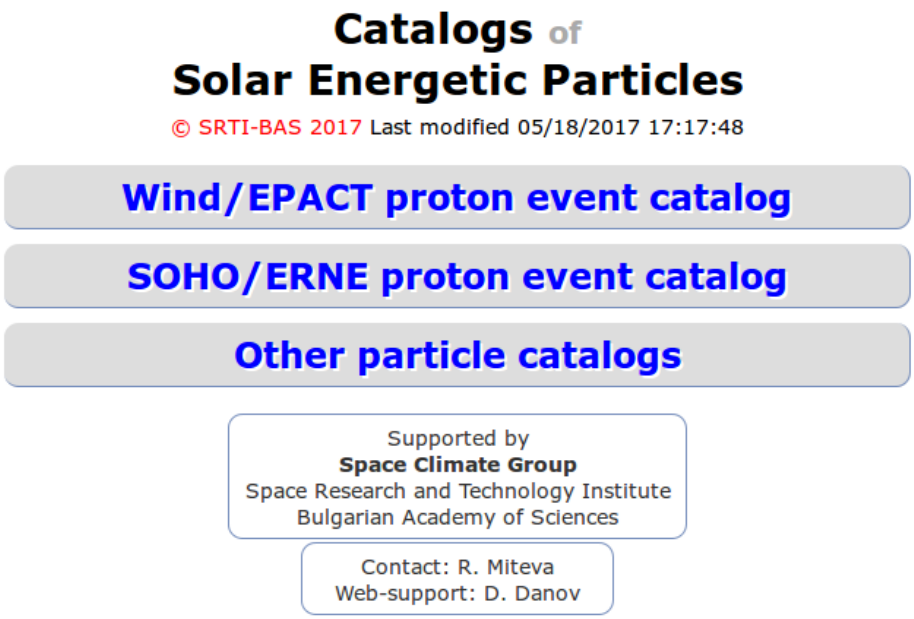

Fig. 1 Overview of the main page of the dedicated website (status: May 2017) hosting the catalogs: http://www.stil.bas.bg/SEPcatalog/ (http://newserver.stil.bas.bg/SEPcatalog).

On-line catalogs

The dedicated web-site for the particle catalogs has been recently updated. The overall structure is enhanced to include two new sections designed for other SEP catalogs, as shown in Fig. 1.

a) Wind/EPACT proton event catalog

The Wind/EPACT proton event catalog lists the in situ proton enhancements in two energy channels, as ~25 and ~50 MeV. The on-line structure of the catalog has been described in an earlier contribution [*Miteva et al*. 2016] with event sample ranging from over 350 low energy protons to over 300 high energy protons. The first version of the proton catalog (1996÷2015) with the purpose to do a research study was used in *Miteva et al*. [2017a] for investigating the solar cycle trends of the energetic protons, using ~360 low energy and ~340 high energy protons. In a subsequent data analysis completed recently, the complex proton event profiles were re-examined and all conspicuous proton enhancements were identified as individual events. Thus the number of events in the final event list is increased. These modifications of the proton catalog were used in two follow-up studies covering the period 1996÷2016. The first study focuses only over solar cycle (SC) 23 [*Miteva et al*. 2017b] using 280 low and 262 high energy Wind/EPACT protons and presents a comparative analysis between several proton catalogs. The second study presents in a consistent way the Wind/EPACT proton event catalog [*Miteva et al*. 2017c] in the period 1996–2016, namely the event identification, comparison with other event lists as well as statistical analysis, based on the finalized event list of 429 low energy and 397 high energy protons. The full details can be found in the dedicated publications. The release of the catalog (open access) is scheduled before the end of 2017. Information on proton event identifications after 2016 is planned to be provided on yearly basis, namely early in the subsequent year, since the proton data is not delivered in real time.

Fig. 2 Preliminary structure of the on-line version of the SOHO/ERNE proton event catalog.

b) SOHO/ERNE proton event catalog

The new upgrade of the on-line catalog includes analysis of proton enhancements from the SOHO/ERNE instrument (Fig. 2), accessed from the main web-page (Fig. 1).

We explore the proton data recorded by the SOHO/ERNE high energy detector (HED) above 17 MeV. A recent work by *Paassilta et al*. [2017] describes the instrument and presents a proton catalog over the energy range 55–80 MeV. We completed a preliminary analysis on the highest energy channel, 101–131 MeV (mean value of 116 MeV), using 5-min data smoothing and proton onset time determination when the proton flux reaches three standard deviations above a pre-event background level. The event number in the period 1996–2015 is 68 events. For illustrative purpose we present here the results as a comparison between the occurrences of protons at similar and higher energies. Namely, in Fig. 3 we present the scatter plots between the ~116 MeV SOHO/ERNE protons and protons detected by the GOES >100 MeV as reported by [*Papaioannou et al*. 2016], left plot, and SOHO/EPHIN >500 MeV as given by [*Kühl et al* 2017], right plot. The $\log_{10}$–$\log_{10}$ Pearson correlation coefficients and the bootstrapping uncertainty (based on 1000 calculations) are also given on each plot. A better correlation of 0.76±0.06 is obtained for the SOHO/ERNE and GOES data despite the fact that the satellites are different and at different location. Lower correlation is obtained with the higher energy protons from SOHO/EPHIN is 0.56±0.11. For comparison, the calculated cross-correlation correlation between GOES and SOHO/EPHIN protons is very high, 0.92±0.04.

The analysis of the SOHO/ERNE proton events in the remaining eight high energy channels is in progress and all results will be reported in a dedicated publication. The new proton catalog will be finally released as on-line table (Fig. 2).

c) Other particle catalogs

Additional particle data (proton and/or electron) are under consideration. The finally selected data and the details on the particle enhancements will be given at the web-site.

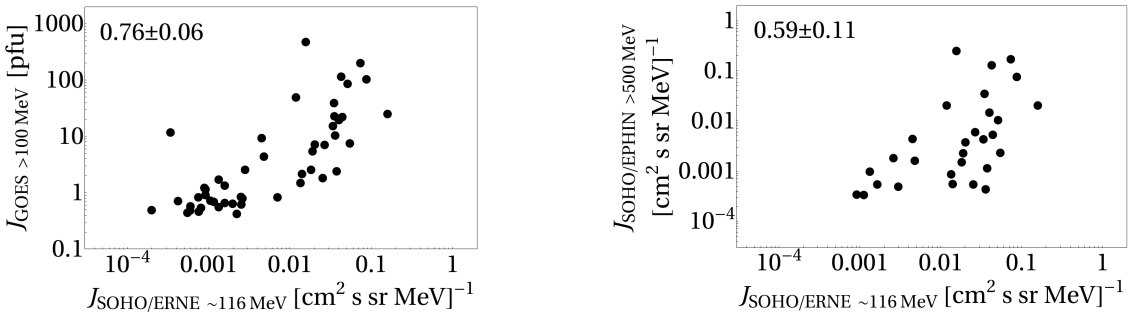

Fig. 3 Scatter plots between the peak proton intensity from SOHO/ERNE ~116 MeV with GOES >100 MeV (left) or with SOHO/EPHIN >500 MeV protons (right), respectively. The log_{10}÷log_{10} Pearson correlation coefficient and its uncertainty are given on each plot.

Conclusions

1. The proton catalog from Wind/EPACT instrument is now completed: proton onset and peak time, peak proton intensity, onset-to-peak proton fluence in the two available energy channels and the associated solar origin are identified. Overview plots are provided. The catalog release is scheduled following the publication of a dedicated paper.
2. The data analysis on the proton enhancements from SOHO/ERNE in nine energy channels (17–131 MeV) is in progress under the Bulgarian–Russian project for collaborative research: "On the origin of solar energetic particles: solar flares vs. coronal mass ejections".

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