Description

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The data files in this archive contain aggregated and partially processed Solar Energetic Particle (SEP) H and He data derived from space-based measurements.

This Reference Data Set (RDS) may be freely used and modified but any publication or website making use of these data should include the following citation:

SEPEM Reference Data Set version 3.0, European Space Agency (2022).

This work has been carried out as part of successive contracts issued by the European Space Agency (ESA) aimed at building a system for plotting data, building and validating environmental models and derivation of effects pertaining to Solar Energetic Particles (SEPs), all of which were initiatives of the Space Environment and Effects section of ESA based at the European Space Research and Technology Centre (ESTEC) in the Netherlands: <https://space-env.esa.int/>

[Contract Numbers: 20162/06/NL/JD; 4000108377/12/NL/AK; 4000107025/12/NL/AK; 4000115930/15/NL/HK, 4000127129/19/NL/HK, 4000127282/19/NL/IB/gg]

The present Solar Energetic Particle Environment Modelling (SEPEM) system is operated by the Royal Belgian Institute for Space Aeronomy and available for registration and use by registered users here:

<http://sepem.eu/>

Or may alternatively be accessed via the ESA Space Weather Service Network portal:

<https://swe.ssa.esa.int/>

A description of the system and its functionalities is available in a peer-reviewed journal article [Crosby, N., et al. (2015), SEPEM: A tool for statistical modeling the solar energetic particle environment, Space Weather, 13, 406–426, doi:10.1002/2013SW001008].

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Data has been processed from the NOAA Energetic Particles Sensor (EPS) (latterly named Energetic Proton, Electron and Alpha Detector (EPEAD)) and the High Energy Proton and Alpha Particles Detector (HEPAD), part of the Space Environment Monitor (SEM) package on-board GOES and earlier SMS satellites. The original NOAA data is available for download from here:

<https://www.ngdc.noaa.gov/stp/satellite/goes/dataaccess.html>

Data from the EPS(EPEAD) have been cross-calibrated to find the effective (mean) energy of each energy channel using data from the Goddard Medium Energy (GME) instrument on-board the IMP-8 spacecraft:

<http://spdf.gsfc.nasa.gov/imp8_GME/GME_home.html>

A description of this cross-calibration, and necessary corrections for spurious behaviour in the GME measurements, is available in a peer-reviewed research letters article [Sandberg, I., P. Jiggens, D. Heynderickx, and I. A. Daglis (2014), Cross calibration of NOAA GOES solar proton detectors using corrected NASA IMP-8/GME data, Geophys. Res. Lett., 41, doi:10.1002/2014GL060469].

Data from the HEPAD have been assessed in terms of the energy dependence of the geometric factor to derive the bow-tie (mean) energy for each energy channel. A description of this bow-tie analysis is included in the Appendix available in a peer-reviewed journal article [Raukunen, O. et al. (2020), Very high energy proton peak flux model, Journal of Space Weather and Space Climate, 10, 24, doi: 10.1051/swsc/2020024].

The time range for Version 3.1 of the data set is from 1974-07-01 until 2017-12-31.

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RDS v3.1 Data files

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The processed data set is composed of 14 text (.csv) files, for which:

- The starting point for the data processing was the RDSv3.0 Data files.

- The time-varying background of the dataset was defined as the value that maximizes the number of the crossings of the raw measurements.

- This approach is insensitive to SPE enhancements (i.e. requires no list) - as long as the selected time window is large compared to typical SPE durations.

- The “signal”, i.e. the coherent measurements above the background attributed to SEPs is extracted by setting conditions that involve the time-varying background and the width/spread of the background fluctuations.

- Only the “signal” values are retained, and the time-varying background is subtracted from these points.

- Mean energy values are provided for each energy channel (given below), these are unchanged from the RDSv3.0 values

The P2-P10 H channels (P1 was not considered in the analysis) and the A1-A6 He channels into individual files identified by particle species and GOES spacecraft identifier. Data from EPS/EPEAD and HEPAD have been combined.

The file name format is RDS3.1\_<species>\_<spacecraft>.csv. There are:

- 7 H files (note that the spacecraft names separated by an underscore indicate first the EPS/EPEAD detector spacecraft and then the HEPAD detector spacecraft)

- 7 He files

(note that a hyphen between SMS 1 and 2 and GOES 1 and 2 indicates where data were merged)

The file format for both sets is the same with a header line followed by data records (always in 5-minute time resolution):

Column 1 contains the date and time in ISO format (yyyy-mm-dd HH:MM:SS) of the start of a measurement time bin

Columns 2-6(2-7)(2-9) contain the differential fluxes [cm-2.s-1.sr-1.MeV-1 or cm-2.s-1.sr-1.(MeV/nuc)-1] of the H/He channels with channel definitions and effective (mean) energies given below.

All data are comma-separated.

A separate JSON file (metadata.json) provides the channel information and units for FPDO (Flux of Protons Differential in energy and Omnidirectional) and FADO (Flux of Alpha particles Differential in energy and Omnidirectional)

Timespan of data sets

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In order to build a contiguous time series of data, the following datasets were processed:

SMS01-02 (EPS): 1974-07-01 to 1977-03-31

GOES01-02 (EPS): 1977-04-01 to 1983-05-19

GOES05\_GOES06 (EPS+HEPAD): 1983-05-20 to 1987-03-05

GOES07\_GOES06 (EPS+HEPAD): 1987-03-06 to 1994-12-31

GOES08 (EPS+HEPAD): 1995-01-01 to 2003-06-16

GOES11 (EPS+HEPAD): 2003-06-17 to 2011-01-31

GOES13 (EPEAD+HEPAD): 2011-02-01 to 2017-12-31

The P4 channel in the GOES01-02 data is corrupted, so this channel is excluded from that file.

All data files are contiguous in time, i.e. there are no data gaps. In the period from 2003-06-01 until 2003-06-21 GOES11 data are missing. Therefore from 2003-06-17 until 2003-06-21 data in the GOES11 data files for EPS comes from the GOES12 satellite. It should be noted that background levels were used for the highest 2 energy EPS channels (P6 and P7) during this period due to missing channels in GOES12 data, the 3rd highest channel is also at background during this period, giving confidence this is valid. Accordingly, HEPAD energy channel fluxes can also be assumed to be at background throughout this time period and gaps in both GOES8 and GOES11 data sets have been filled with background values. The final helium channel (A6) is also filled with background levels during this time period.

Data Availability

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The data files (H and He) were ingested into a MySQL database; all subsequent analysis and processing was performed using the database tools available on the SEPEM server. The resulting individual data sets are accessible following the Heliophysics API (HAPI) specification through ESA’s Open Data Interface (ODI) at:

<https://spitfire.estec.esa.int/hapi/>.

More information on ODI is available via the user guide:

<https://spitfire.estec.esa.int/trac/ODI/>

and the client software may be downloaded from:

<https://essr.esa.int/project/odi-open-data-interface-client>

Original energy channels for the individual GOES data files

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H EPS/EPEAD channels (MeV)

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Spacecraft P2 P3 P4 P5 P6 P7

SMS01-02 4.0-6.0 6.0-10.0 18.0-38.0 40.0-500.0 84.0-150.0 150.0-500.0

GOES01-02 4.0-6.0 6.0-10.0 18.0-38.0 40.0-500.0 84.0-150.0 150.0-500.0

GOES05 4.2-8.7 8.7-14.5 15.0-44.0 39.0-82.0 84.0-200.0 110.0-500.0

GOES07 4.2-8.7 8.7-14.5 15.0-44.0 39.0-82.0 84.0-200.0 110.0-500.0

GOES08 4.0-9.0 9.0-15.0 15.0-40.0 40.0-80.0 80.0-165.0 165.0-500.0

GOES11 4.0-9.0 9.0-15.0 15.0-40.0 40.0-80.0 80.0-165.0 165.0-500.0

GOES13 4.2-8.7 8.7-14.5 15.0-40.0 38.0-82.0 84.0-200.0 110.0-900.0

H HEPAD channels (MeV)

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Spacecraft P8 P9 P10

GOES06 330–420 420–510 510–700

GOES08 330–420 420–510 510–700

GOES11 330–420 420–510 510–700

GOES13 330–420 420–510 510–700

He EPS/EPEAD channels (MeV/nuc)

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Spacecraft A1 A2 A3 A4 A5 A6

SMS01-02 4.0-10.0 10.0-16.0 18.0-56.0 71.0-150.0 167.0-245.0 340.0-392.0

GOES01-02 4.0-10.0 10.0-16.0 18.0-56.0 71.0-150.0 167.0-245.0 340.0-392.0

GOES05 3.8- 9.9 9.9-21.3 21.3-61.0 60.0-180.0 160.0-260.0 330.0-500.0

GOES07 3.8- 9.9 9.9-21.3 21.3-61.0 60.0-180.0 160.0-260.0 330.0-500.0

GOES08 4.0-10.0 10.0-21.0 21.0-60.0 60.0-150.0 150.0-250.0 300.0-500.0

GOES11 4.0-10.0 10.0-21.0 21.0-60.0 60.0-150.0 150.0-250.0 300.0-500.0

GOES13 3.8- 9.9 9.9-20.5 20.5-61.0 60.0-160.0 160.0-260.0 330.0-500.0

Effective energies obtained from cross calibration

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H EPS/EPEAD channels (MeV)

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Spacecraft P2 P3 P4 P5 P6 P7

SMS01-02 4.282 6.561 29.59 52.96 150.7 440.8

GOES01-02 4.347 7.233 - 34.20 78.29 278.5

GOES05 6.348 11.01 17.56 46.54 103.8 213.6

GOES07 6.591 11.15 21.54 49.98 102.4 214.4

GOES08 6.214 10.74 18.65 47.82 105.6 152.9

GOES11-13 6.643 12.61 20.55 46.62 103.7 154.6

H HEPAD channels (MeV)

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Spacecraft P8 P9 P10

GOES06 405 473 622

GOES08 406 457 583

GOES11 406 457 583

GOES13 406 457 583

He EPS/EPEAD channels (MeV/nuc)

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Spacecraft A1 A2 A3 A4 A5 A6

SMS01-02 1.558 2.417 5.849 23.76 38.95 75.00

GOES01-02 1.558 2.417 5.849 23.76 38.95 75.00

GOES05 1.664 4.173 8.607 21.13 41.21 79.79

GOES07 1.664 4.173 8.607 21.13 41.21 79.79

GOES08 1.598 3.717 8.680 17.45 39.32 77.79

GOES11 1.598 3.717 8.680 17.45 39.32 77.79

GOES13 1.598 3.717 8.680 17.45 39.32 77.79