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 v3.2 Data files

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The processed data set is composed of 2 CSV (.csv) files, for which:

- The starting point is the RDS v3.1 Data Files

- Based on the calculated effective and bow-tie energies, the proton spectral data from RDS v3.1 were interpolated to the SEPEM energy channels (see below).

- Data were then merged into a single data set for protons

- For proton data prior to 1983-05-20 where no very high energy fluxes are available from HEPAD a power law extrapolation with particle rigidity has been applied to approximate these data

- Integral fluxes for protons were derived for the full data set and the output stored in the first CSV file

- Based on the calculated effective energies, the helium (alpha) spectral data from RDS v3.1 were interpolated to the SEPEM energy channels (see below).

- Data were then merged into a single data set for alpha particles

- For all alpha particle data the higher energies (>100 MeV/nuc) have been derived for each timestamp based on the relationship between the He and H abundance ratio

- Integral fluxes for alpha particles were derived for the full data set and the output stored in the second CSV file

The data are separated into individual files identified by particle species. The file name format is RDS3.2\_F<x>DO\_F<x>IO.csv where x either P (protons) or A (alpha particles).

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 2-15 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 mean energies given below.

Columns 16-22 contain the integral fluxes [cm-2.s-1.sr-1] of the H/He channels with channel definitions and threshold 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 FPIO (Flux of Protons Integral in energy and Omnidirectional), and FADO (Flux of Alpha particles Differential in energy and Omnidirectional) and FAIO (Flux of Alpha particles Integral in energy and Omnidirectional)

Timespan of data sets

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The resulting merged proton and alpha particle datasets have the following identical start and end times:

FPDO\_FPIO: 1974-07-01 to 2017-12-31

FADO\_FAIO: 1974-07-01 to 2017-12-31

All data files are contiguous in time, for details on pre-existing data gaps and the treatment. See the readme files for RDS v3.0 and RDS v3.1 for details.

Energy channels for the SEPEM Reference Data set (RDS) v3.2

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H differential channels (MeV)

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Channel Mean Energy Nominal Energy Bin

fpdo\_1 6.01 5.00-7.23

fpdo\_2 8.70 7.23-10.46

fpdo\_3 12.57 10.46-15.12

fpdo\_4 18.18 15.12-21.87

fpdo\_5 26.30 21.87-31.62

fpdo\_6 38.03 31.62-45.73

fpdo\_7 54.99 45.73-66.13

fpdo\_8 79.53 66.13-95.64

fpdo\_9 115.01 95.64-138.3

fpdo\_10 166.31 138.3-200.0

fpdo\_11 240.51 200.0-289.2

fpdo\_12 347.81 289.2-418.3

fpdo\_13 502.97 418.3-604.9

fpdo\_14 727.36 604.9-874.7

H integral channels (MeV)

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Channel Threshold Energy

fpio\_1 > 5

fpio\_2 > 10

fpio\_3 > 30

fpio\_4 > 50

fpio\_5 > 100

fpio\_6 > 300

fpio\_7 > 500

He differential channels (MeV/nuc)

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Channel Mean Energy Nominal Energy Bin

fado\_1 6.01 5.00-7.23

fado\_2 8.70 7.23-10.46

fado\_3 12.57 10.46-15.12

fado\_4 18.18 15.12-21.87

fado\_5 26.30 21.87-31.62

fado\_6 38.03 31.62-45.73

fado\_7 54.99 45.73-66.13

fado\_8 79.53 66.13-95.64

fado\_9 115.01 95.64-138.3

fado\_10 166.31 138.3-200.0

fado\_11 240.51 200.0-289.2

fado\_12 347.81 289.2-418.3

fado\_13 502.97 418.3-604.9

fado\_14 727.36 604.9-874.7

He integral channels (MeV/nuc)

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Channel Threshold Energy

faio\_1 > 5

faio\_2 > 10

faio\_3 > 30

faio\_4 > 50

faio\_5 > 100

faio\_6 > 300

faio\_7 > 500