DH CONSULTANCY BVBA

ESHIEM Technical Note 1B

IMP8/GME and GOES/EPS He Data Processing

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This is Technical Note 1B for the Improvement of Energetic Solar Heavy Ion Environment Models, ESA Contract No 4000107025/12/NL/AK.

Document information

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Change log

Issue	Date	Reason for change
1.0	30/04/2014	Description of data cleaning and gap filling.
1.1	09/05/2014	Comments by PT.
1.2	01/11/2014	SEPCALIB analysis.
1.3	16/02/2015	Separate energy channels per GOES spacecraft pair.
1.4	14/11/2018	Updated SEPCALIB calibration procedure. Background subtraction.
1.5	19/11/2018	Editorial corrections.

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1 References and acronyms

1.1 Applicable and reference documents

1.1.1 Applicable documents

[**AD 1**] "Improvement of Energetic Solar Heavy Ion Environment Models," Statement of Work, Appendix 1 to ESTEC/ITT AO/1-7131/12/NL/GLC, April 2012.

[**AD 2**] ESA Contract No 4000107025/12/NL/AK.

1.1.2 Reference documents

[**RD 1**] SEPEM Project: Final Report, ESA Contract No 20162/06/NL/JD, September 2011.

[**RD 2**] Crosby, N.B, Heynderickx, D., Aran, A., Sanahuja, B., SEPEM Post-Maintenance Final Report, CCN-4 to ESA Contract No 4200020162, July 2013.

[**RD 3**] SEPEM server: http://sepem.eu/.

[**RD 4**] A. Varotsou, A. Samaras, Creation of a cleaned ACE Heavy Ion database (WP 3100), ESHIEM Technical Note 1-A, April 2014.

[**RD 5**] D. Heynderickx, IPRAM DataSet Review V1.4, ESA Contract No 4000106133/12/NL/AF, August 2013.

[**RD 6**] R.N. Grubb, The SMS/GOES Space Environment Monitor Subsystem, NOAA Technical Memorandum ERL SEL-42, December 1975.

[**RD 7**] GOES I-M DataBook, DRL 101-08, Revision 1, August 1996; http://rsd.gsfc.nasa.gov/goes/text/goes.databook.html.

[**RD 8**] GOES N DataBook, CDRL PM—1-03, Rev B, February 2005; http://goes.gsfc.nasa.gov/text/goes.databookn.html.

[**RD 9**] SEPCALIB, Sandberg, I., "ESA SEPCALIB Project: Final Report," Ver. 1.2, ESA Contract No. 4000108377/13/NL/AK, 2014.

1.2 ACRONYMS AND ABBREVIATIONS

ACE	Advanced Composition Explorer
AD	Applicable Document
ASCII	American Standard Code for Information Interchange
BDDII	Burst Detector Dosimeter II
CDF	Common Data Format
ECSS	European Cooperation for Space Standardization
EPACT	Energetic Particle Acceleration, Composition, and Transport
EPEAD	Energetic Proton, Electron and Alpha Detector
EPS	Energetic Particles Sensor
ERNE	Energetic and Relativistic Nuclei and Electron
ESA	European Space Agency
ESHIEM	Improvement of Energetic Solar Heavy Ion Environment Models
FITS	Flexible Image Transport System
GEO	GEostationary Orbit
GME	Goddard Medium Energy
GOES	Geostationary Operational Environmental Satellite
GUI	Graphical User Interface
HEPAD	High Energy Proton and Alpha Detector
HDF	Hierarchical Data Format
IDL	Interactive Data Language
IMP	Interplanetary Monitoring Platform
LEMT	Low Energy Matrix Telescopes
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
ODI	Open Data Interface
RD	Reference Document
SEM	Space Environment Monitor
SEP	Solar Energetic Particle
SEPEM	Solar Energetic Particle Environment Modelling
SIS	Solar Isotope Spectrometer
SMS	Synchronous Meteorological Satellites
SOHO	SOlar and Heliospheric Observatory
SoW	Statement of Work
SPE	Solar Particle Event
SQL	Structured Query Language
TN	Technical Note

2 INTRODUCTION

This document is the *IMP8/GME and GOES/EPS He Data Processing* document, Technical Note 1B for the *Improvement of Energetic Solar Heavy Ion Environment Models*, ESA Contract No 4000107025/12/NL/AK.

2.1 CONTEXT

During the SEPEM main contract [RD 1] and the follow-up maintenance phase [RD 2], a reference SPE proton dataset was constructed and made available on the SEPEM server [RD 3]. One of the tasks in the ESHIEM project is the similar construction of a reference He dataset, which is the subject of this TN. The outline of this document is as follows:

1. Description of the datasets used (Section 3)
2. Data cleaning and gap filling procedures (Section 4)
3. Cross calibrations of the cleaned datasets (Section 0)
4. Dataset merging (Section 6)
5. Background subtraction (Section 7)

2.2 DATASET CHARACTERISTICS

Long term He measurements are available from the IMP8/GME and GOES/SEM/EPS series spacecraft instruments. These datasets were processed to constitute the reference He dataset for the project. The datasets were downloaded from internet data stores and ingested in the SEPEM database.

In addition, SOHO/ERNE H, He and heavy ion data, and Wind/EPACT/LEMT He and heavy ion data were downloaded and stored in the database for validation purposes. ACE/SIS He data processed by TRAD for selected events were ingested as well.

2.3 DATA CLEANING AND GAP FILLING

The IMP8/GME and GOES/EPS He datasets were manually checked for data records that exhibit spikes, saturation or any other defects that can be identified unambiguously. These values were replaced by NULL entries in the SEPEM database for the IMP8/GME dataset, and gap filled for the GOES/EPS datasets.

2.4 CROSS CALIBRATIONS OF HE DATA

The EPS instruments deployed on the GOES spacecraft are monitor type instruments with poorly defined energy channels and have not been rigorously calibrated. During the SEPEM contract [RD 1], the EPS proton data were cross calibrated with the GME data, which are of science quality (after removal of bad data records). During the current project, a similar cross calibration was applied to the He data from both instruments. The ACE/SIS He data were used as an independent validation source for the SPE periods for which the SIS data were processed.

The GOES cross calibration using the SEPEM method did not produce adequate results mainly due to the high background threshold in the higher energy EPS channels. The method developed during SEPCALIB [RD 9] was then applied in order to refine the energy bins of the EPS instruments.

2.5 Dataset merging

Once the GME and EPS datasets were cleaned and cross calibrated, they were re-binned to the SEPEM reference energy channels. The successive spacecraft datasets were then merged into a single contiguous reference He dataset.

2.6 Background subtraction

The GOES He data exhibit a relatively high instrumental background. Therefore, a background subtraction was performed on the merged dataset.

3 DATASET CHARACTERISTICS

The following datasets were used in the construction of the reference ion dataset:

- IMP8/GME He data
- SMS1-2/EPS and GOES01-13/EPS He data
- ACE/SIS He and heavy ion data

The ACE/SIS dataset and processing is described in TN 1-A [RD 4].

The virtual ion dataset is based on abundance ratios obtained from the ACE/SIS data analysis, and published ratios for the elements not in the ACE/SIS datasets. The abundance ratios are stored in the SEPEM database and applied on the fly to the He data when ion data are requested by an application.

3.1 IMP8/GME HE DATA

IMP8 (IMP-J) was launched by NASA on 26 Oct 1973 to measure the magnetic fields, plasmas, and energetic charged particles (e.g., cosmic rays) of the Earth's magnetotail and magnetosheath and of the near-Earth solar wind. IMP-8, the last of ten IMP (Interplanetary Monitoring Platform) or AIMP (Anchored-IMP) spacecraft launched in 10 years, operated for 33 years in its near-circular, 35 Earth radii, 12-day orbit. It was an important adjunct to the International Solar Terrestrial Physics program, provided in-ecliptic, one AU baseline data for the deep space Voyager and Ulysses missions, and accumulated a long time series database useful in understanding long-term solar processes.

IMP8 is a drum-shape spacecraft 135.6 cm across and 157.4 cm high. It originally had an elliptical orbit with apogee and perigee distances of about 45 and 25 Earth radii, respectively, but its eccentricity has decreased since it was launched. In 2007, it was about 160,000 miles away from Earth. The spacecraft has an inclination which has varied between 0° and 55° in a period of several years. The spacecraft spin axis is normal to the ecliptic plane, and the spin rate is 23 rpm. The spacecraft takes 12.5 days to orbit around the Earth--seven to eight days are spent in the solar wind, with the rest of the time in the magnetosheath and magnetosphere.

In October 2001, IMP8 was terminated as an independent mission. A more detailed description of the mission and instrument complement can be found in [RD 5].

The highest quality energetic particle dataset on IMP8 is the one collected by the Goddard Medium Energy (GME) instrument. This instrument was designed to measure fluxes as a function of energy and to make elemental identification for protons, alpha particles and heavier ions from <1 MeV/nuc to >400 MeV/nuc as well as to measure the flux of relativistic electrons between 3 and 18 MeV. The separation and identification of individual elements is accomplished by measurement of differential energy loss dE/dx and total energy E using multiple detector elements. The GME He energy channels are listed in Table 1.

TABLE 1 IMP8/GME HE CHANNEL DEFINITIONS

Channel	Energy Range (MeV/nuc)
Alpha_DIntn_1	1.14- 1.36
Alpha_DIntn_2	1.36- 1.88
Alpha_DIntn_3	1.88- 2.37
Alpha_DIntn_4	2.37- 3.06
Alpha_DIntn_5	3.06- 3.98
Alpha_DIntn_6	3.98- 4.94
Alpha_DIntn_7	4.94- 5.91
Alpha_DIntn_8	5.91- 7.26
Alpha_DIntn_9	7.26- 8.63
Alpha_DIntn_10	8.63-11.00
Alpha_DIntn_11	11.00-13.60
Alpha_DIntn_12	13.60-16.10
Alpha_DIntn_13	16.10-18.70
Alpha_DIntn_14	18.70-22.50
Alpha_DIntn_15	19.50-24.20
Alpha_DIntn_16	24.20-28.60
Alpha_DIntn_17	28.60-35.20
Alpha_DIntn_18	35.20-43.00
Alpha_DIntn_19	43.00-51.00
Alpha_DIntn_20	51.00-63.30
Alpha_DIntn_21	63.30-81.00

The 30 minute resolution data were obtained during the SEPEM project from ftp://spdf.gsfc.nasa.gov/pub/data/imp/imp8/particles_gme/gme_h0/ and ingested in the SEPEM database.

3.2 SMS1-2/EPS AND GOES05-13/EPS HE DATA

The Geostationary Operational Environmental Satellites (GOES) program, begun in 1974, is a program of the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce. GOES spacecraft operate as a two-satellite constellation in geosynchronous orbit above the equator and observe 60% of the Earth. Their instrument complement includes a suite of Space Environment Monitoring (SEM) instruments, which in turn includes Energetic Particles Sensors (EPS). A detailed description of the GOES programme and the SEM instruments can be found in [RD 5].

The EPS performs three integral measurements of electrons at >0.6, >2.0 and >4.0 MeV, a seven channel differential analysis of protons from 0.8 to 500 MeV (900 MeV for GOES13+), and a six channel differential analysis of alpha particles from 4 to 500 MeV. The EPS unit consists of a telescope subassembly, a dome subassembly and signal analyser unit/data processing unit. The EPS/HEPAD assembly for GOES13 is shown in Figure 1. Note that the GOES13-15 EPS assembly contains two EPEADs, one facing East and one facing West.

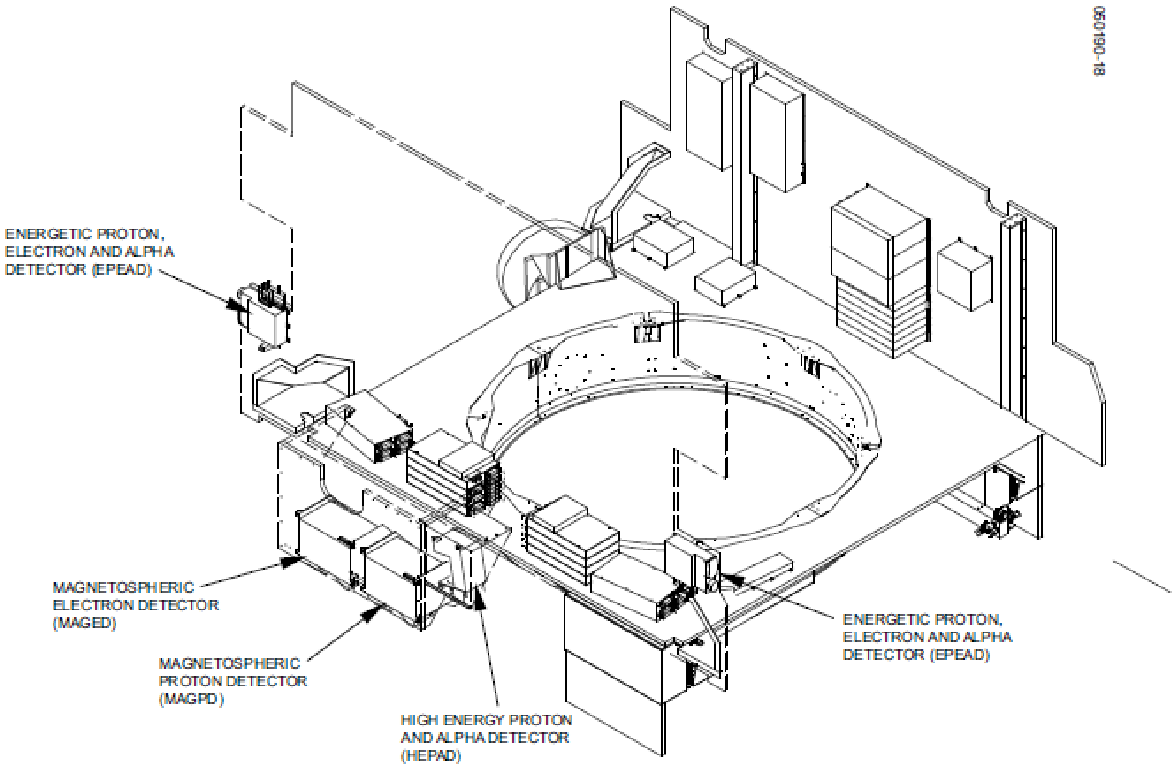

FIGURE 1 GOES13 EPS/HEPAD INSTRUMENT LOCATIONS (FROM [RD 8])

The EPS channel definitions have evolved over time with successive generations of GOES spacecraft. Table 2 summarizes the EPEAD He energy channels for each of them.

TABLE 2 NOMINAL EPEAD HE CHANNEL ENERGIES (MEV) FOR THE GOES SPACECRAFT USED IN THIS STUDY

Channel	SMS1-2, GOES01	GOES02-03	GOES05-07	GOES08-12	GOES13-15
A1	4.0- 10.0	3.2- 10.0	3.8- 9.9	4.0- 10.0	3.8- 9.9
A2	10.0- 16.0	10.0- 16.0	9.9- 21.3	10.0- 21.0	9.9- 20.5
A3	18.0- 56.0	16.0- 60.0	21.3- 61.0	21.0- 60.0	20.5- 61.0
A4	71.0-150.0	85.0-182.0	60.0-180.0	60.0-150.0	60.0-160.0
A5	167.0-245.0	156.0-228.0	160.0-260.0	150.0-250.0	160.0-260.0
A6	340.0-392.0	326.0-412.0	330.0-500.0	300.0-500.0	330.0-500.0

Data from the following GOES spacecraft were used in this study: 05, 07, 08, 11 and 13. The 5 minute ASCII A data files for all the GOES05-12 spacecraft were downloaded from ftp://satdat.ngdc.noaa.gov/sem/goes/data/avg/ and ingested in the SEPEM database. The 5 minute netCDF `epead_a16ew_5m` data files for GOES13 were downloaded from ftp://satdat.ngdc.noaa.gov/sem/goes/data/new_avg/. The IDL code used in the SEPEM maintenance phase to convert the corresponding proton NetCDF files to ASCII files was adapted for the He files.

During the SEPEM maintenance phase, the SMS and GOES FITS format files prior to 1986 were processed and converted into the same format as the 5 minute G and A files [RD 2]. The A files were added to the SEPEM database in ESHIEM, and were also used in this study.

Even though data from GOES06, GOES09-10 and GOES12 (with the exception of 19 days of data to bridge the gap between GOES08 and GOES11) were not used for the reference He dataset, they were downloaded and ingested in the SEPEM database for reference.

4 Data cleaning and gap filling

The newly ingested datasets used in the construction of the reference He dataset were visually checked for anomalies in the same way as the proton datasets were processed during the SEPEM contract.

4.1 IMP8/GME

The GME data are very sparse (i.e. fluxes are equal to zero or are set to the fill value) in quiet periods, i.e. when no SPE is in progress. Significant data dropouts also occur during SPE intervals, especially in the second half of the mission (see Appendix A for a summary of the fraction of valid records per channel). No attempt was made to fill these gaps, as they are in general too wide or occur during the rise and peak phases of events.

In addition, the GME instrument is subject to saturation and dead time effects. These manifest themselves as sudden drops in flux, often just before or after a data gap. The effect is illustrated in Figure 2 for the March 2001 SPE. The cleaned data for the same channels is shown in Figure 3.

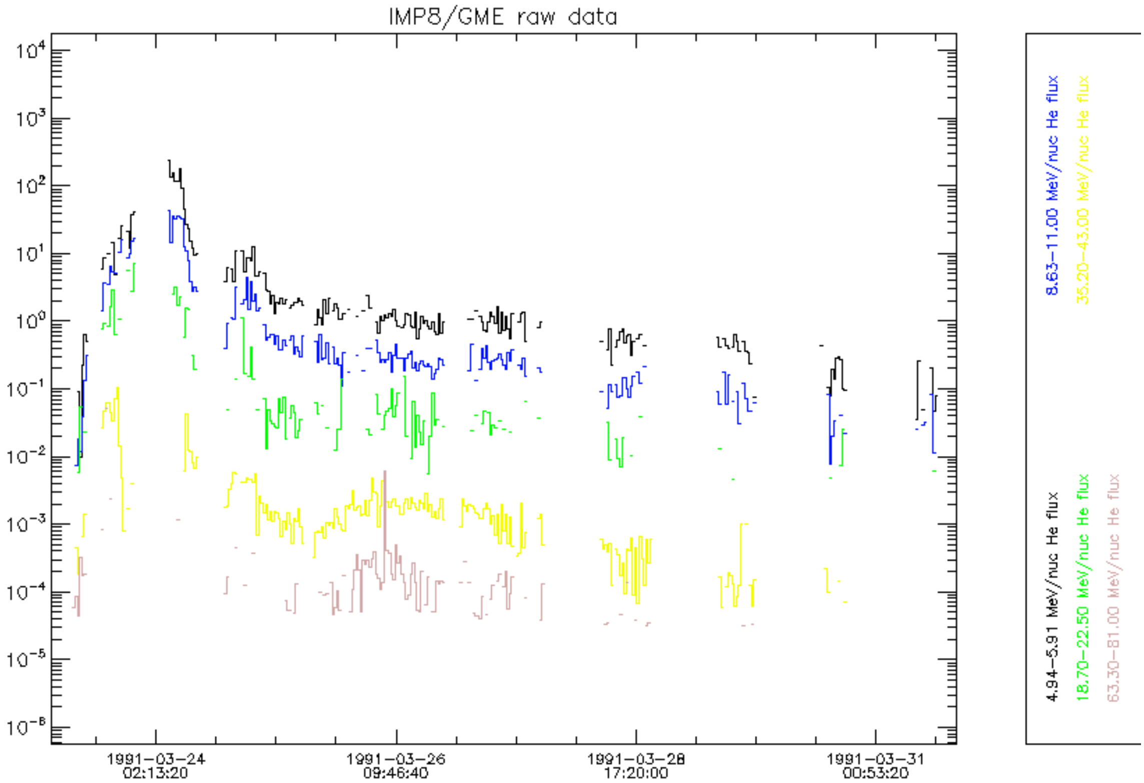

FIGURE 2 ILLUSTRATION OF GME SATURATION AND DEAD TIME EFFECTS DURING THE MARCH 2001 SPE

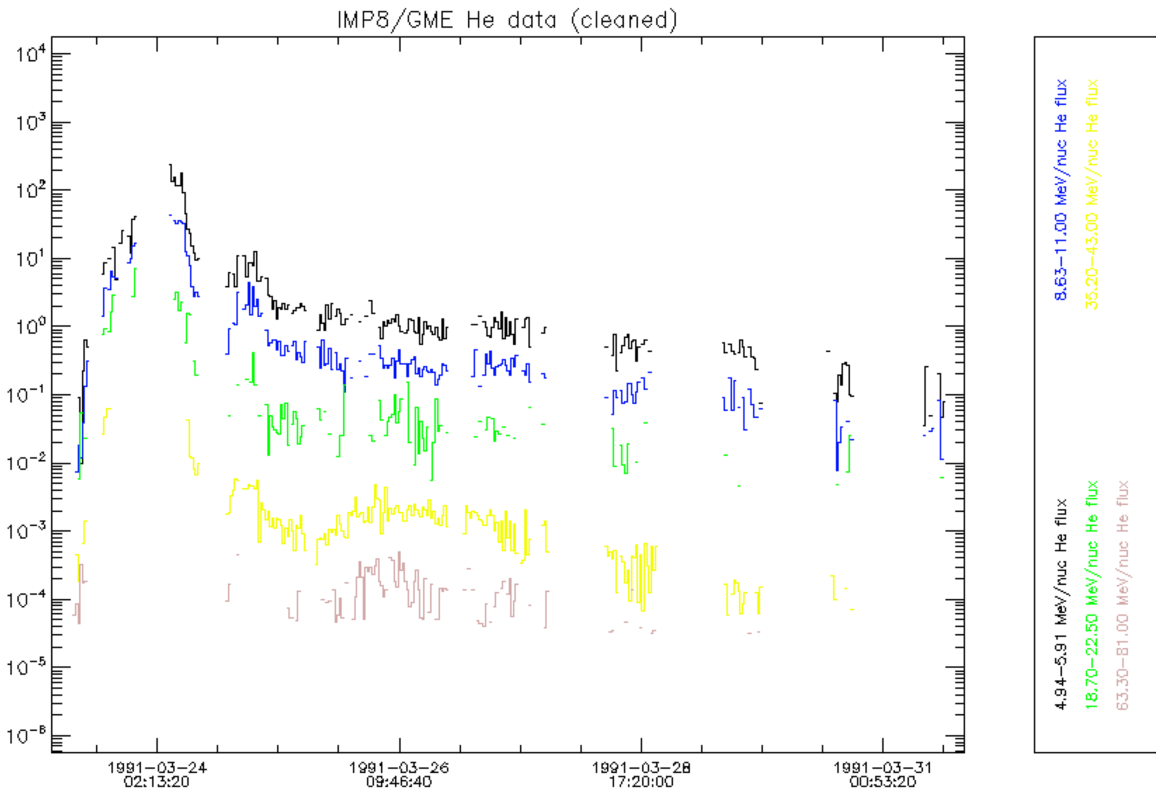

FIGURE 3 CLEANED GME HE CHANNELS FOR THE MARCH 2001 SPE

4.2 GOES/EPS

The EPS He data do not suffer from saturation or dead time effects. Also, data gaps during SPEs are very rare and very short, and can be gap filled with the manual cleaning tool. During quiet periods, data coverage is intermittent, but there is sufficient coverage to reliable gap fill the background data, so that contiguous datasets can be constructed.

The GOES data do exhibit data spikes of varying magnitude. The older datasets—SMS01-GOES07—are affected most, while in the GOES13 dataset, for instance, there are virtually no spikes. The worst affected datasets are from the SMS test spacecraft. Figure 4 shows the first week of SMS1 data (during which an event occurred) before cleaning. Although at first sight the data look quite unusable, after painstakingly removing the data spikes and performing gap filling, the resulting time series shown in Figure 5 illustrates that even these datasets can be recovered.

Figure 6 shows an example of a time period in the GOES05 dataset, manual cleaning and gap filling yields the time series shown in Figure 7. When longer time series are badly affected by spikes, the data from the secondary GOES satellite are checked to ensure that there were no SPEs. An example where this is required is shown in Figure 8 for GOES07: the A1 channel data is so badly affected that no cleaning is possible, so that the A1 data for this period was overwritten with the GOES06 data, as shown in Figure 9.

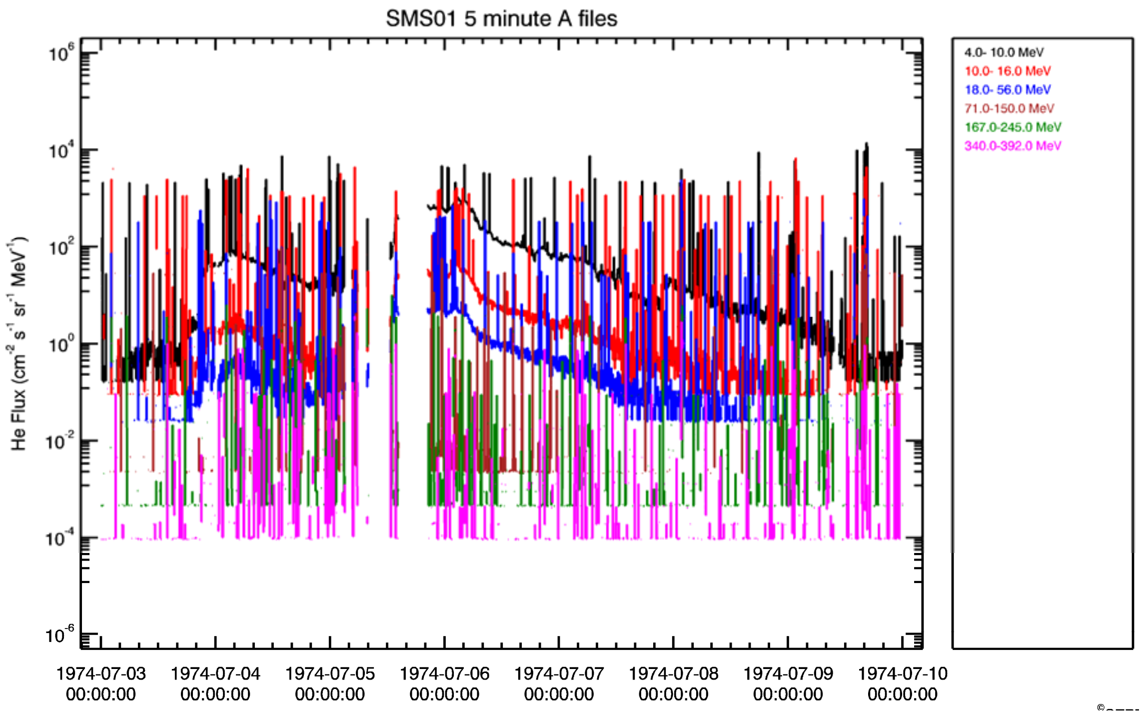

FIGURE 4 SAMPLE SMS1/EPS DATA EPISODE AFFECTED BY SPIKES WHICH CAN BE REMOVED AND GAP FILLED WITH THE SEPEM MANUAL CLEANING INTERFACE

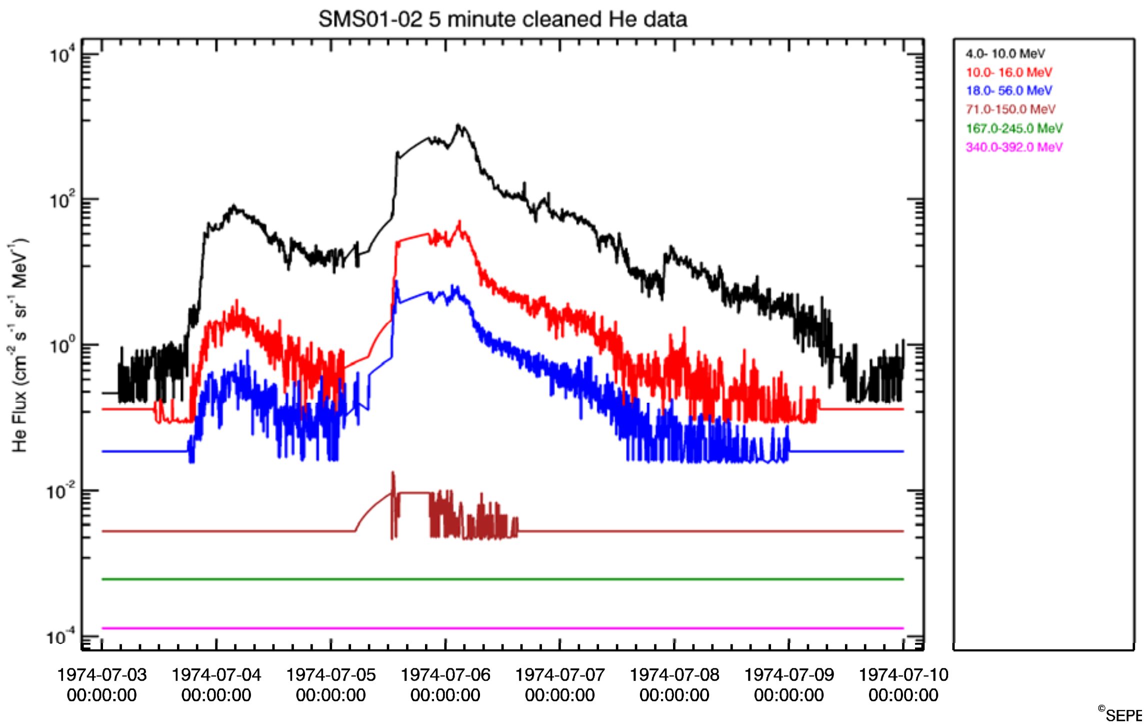

FIGURE 5 SMS1/EPS DATA FROM FIGURE 4 AFTER MANUAL CLEANING AND GAP FILLING

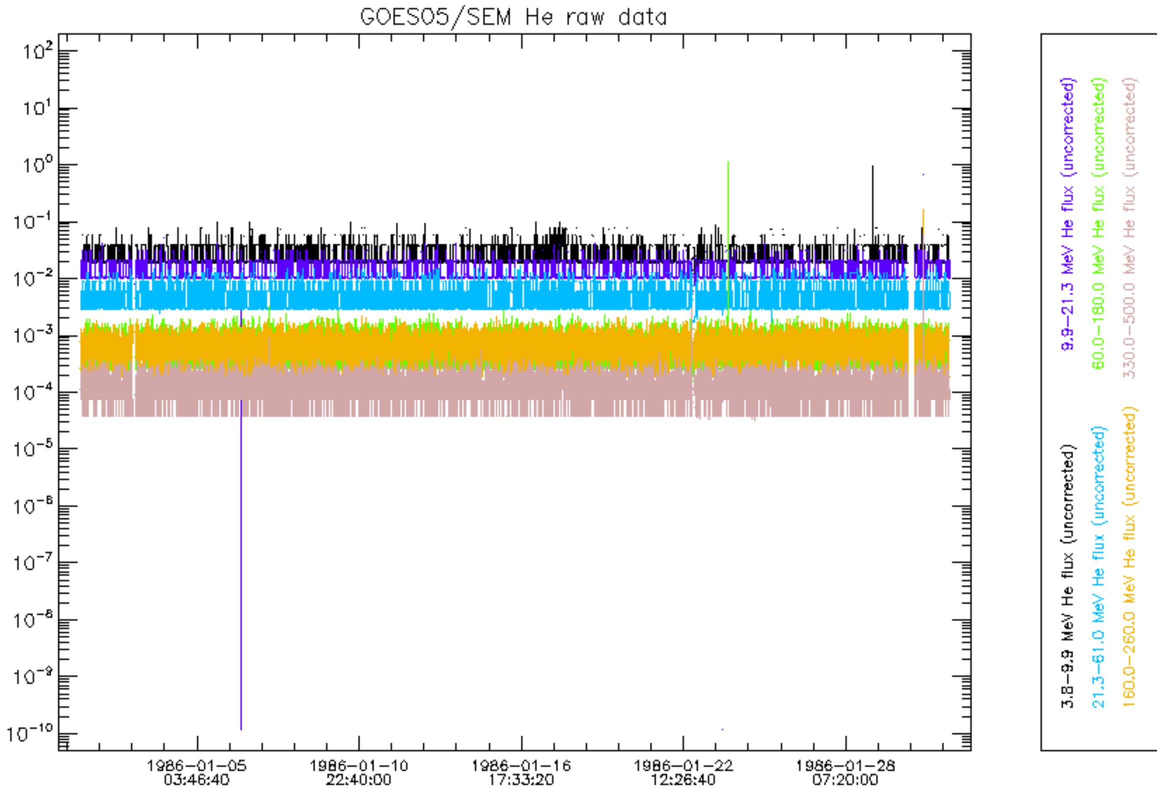

FIGURE 6 SAMPLE GOES05/EPS DATA EPISODE AFFECTED BY SPIKES WHICH CAN BE REMOVED AND GAP FILLED WITH THE SEPEM MANUAL CLEANING INTERFACE

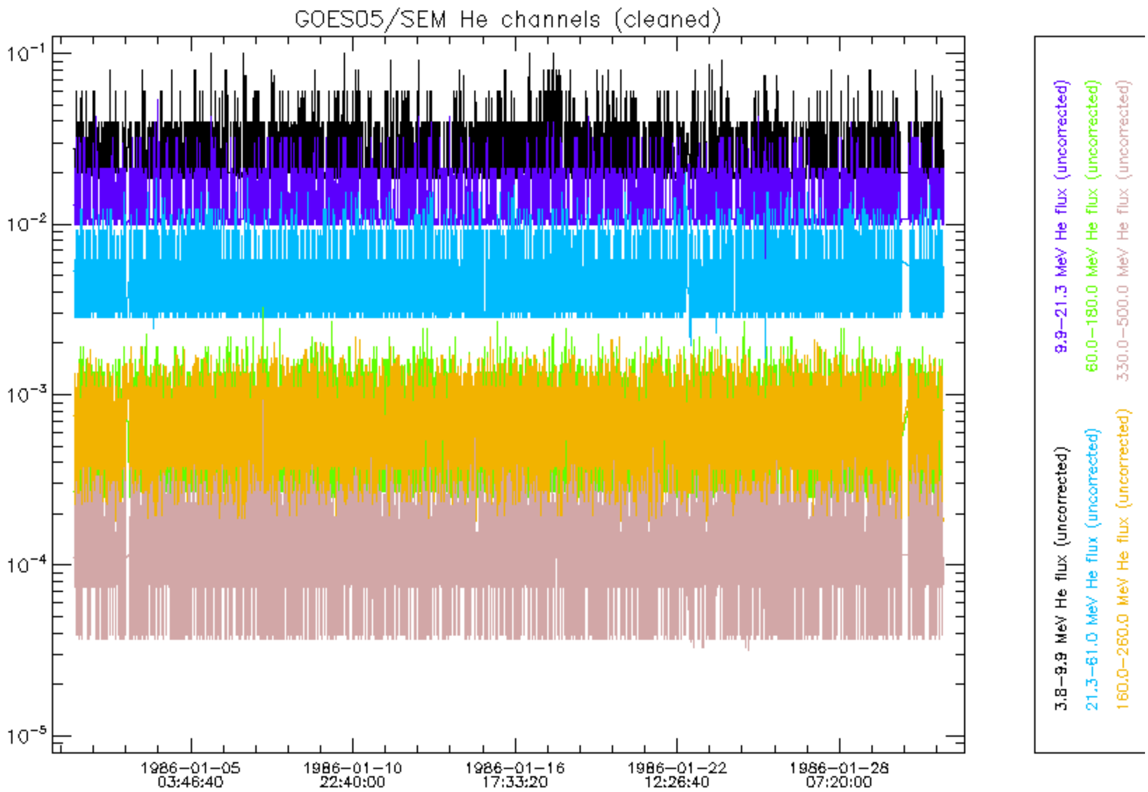

FIGURE 7 GOES05/EPS DATA FROM FIGURE 6 AFTER MANUAL CLEANING AND GAP FILLING

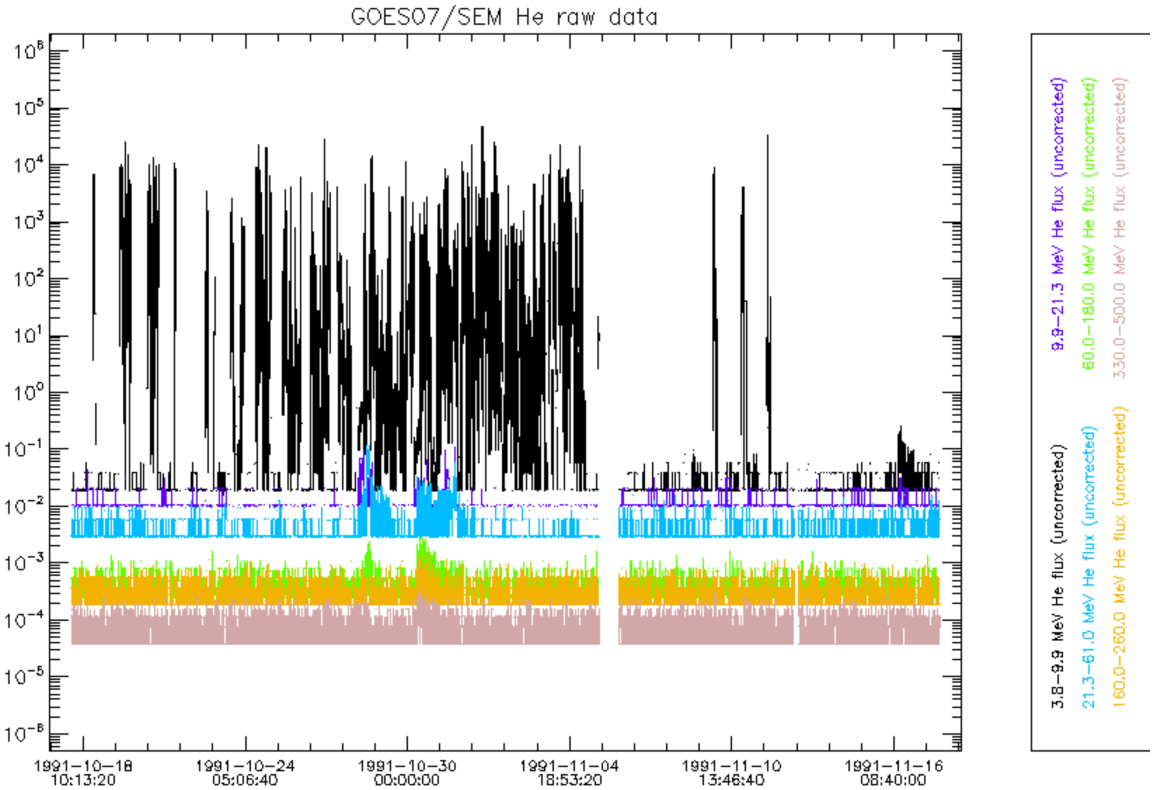

FIGURE 8 SAMPLE OF A GOES07/EPS DATA PERIOD BADLY AFFECTED BY DATA SPIKES

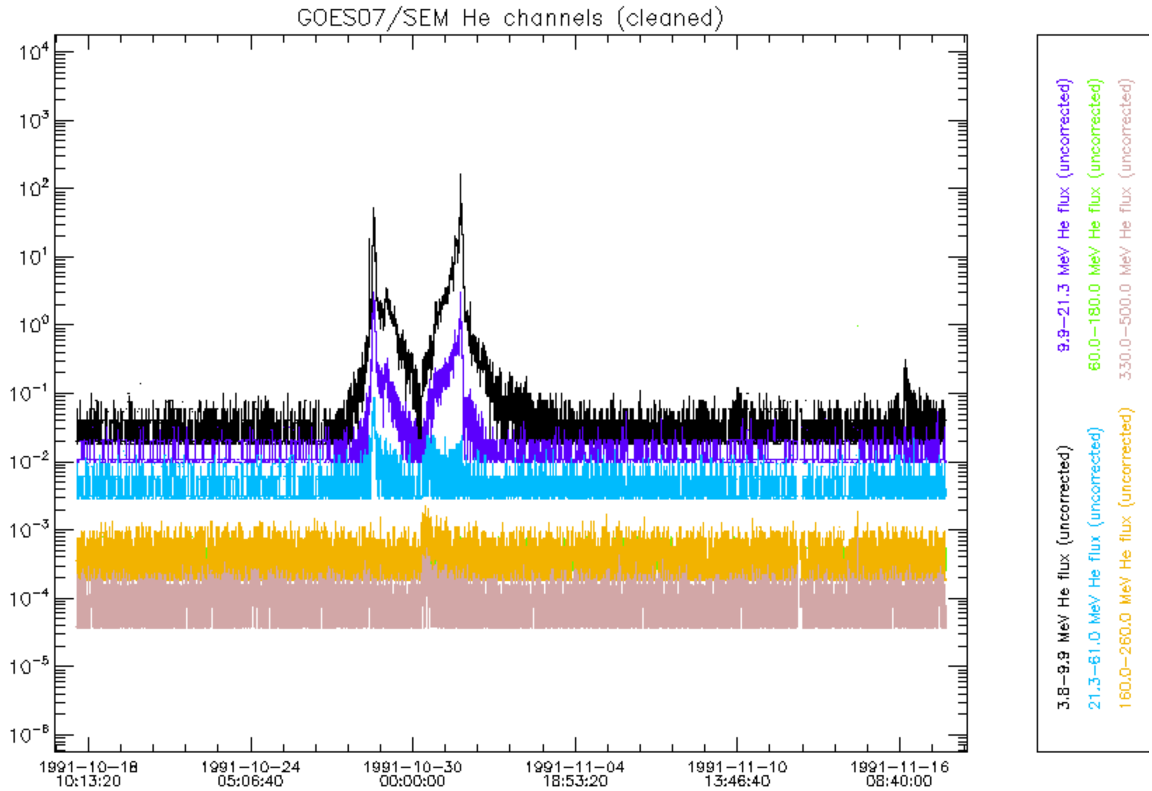

FIGURE 9 GOES07/EPS DATA SAMPLE FROM FIGURE 8 AFTER OVERWRITING THE A1 CHANNEL WITH GOES06 DATA

For GOES05, there is no data for December 1985. The GOES06 data for the same month, shown in Figure 10, demonstrate that there were no SPEs during this period. Hence, the time stamps of the GOES06 data were used to fill the Dec 85 coverage in GOES05, using the GOES05 channel background values just before and after the data gap (see Figure 11).

There are large data gaps in the GOES11 data before 20 June 2003 (Figure 12 shows the GOES11 data for June 2003). The GOES08 datasets ends on 16 June 2003, which means there would a data gap in the reference dataset during which the 18 June 2003 SPE occurred. In order to fill the gap, GOES12 data were used for 1–19 June 2003. As there is no data for the GOES12 A6 channel due to a channel failure, the A6 values were set to background level. The patched data for June 2003 are shown in Figure 13.

GOES13 suffered an outage on 22–30 May 2013. The He data for that period were patched with GOES15 data, as shown in Figure 14.

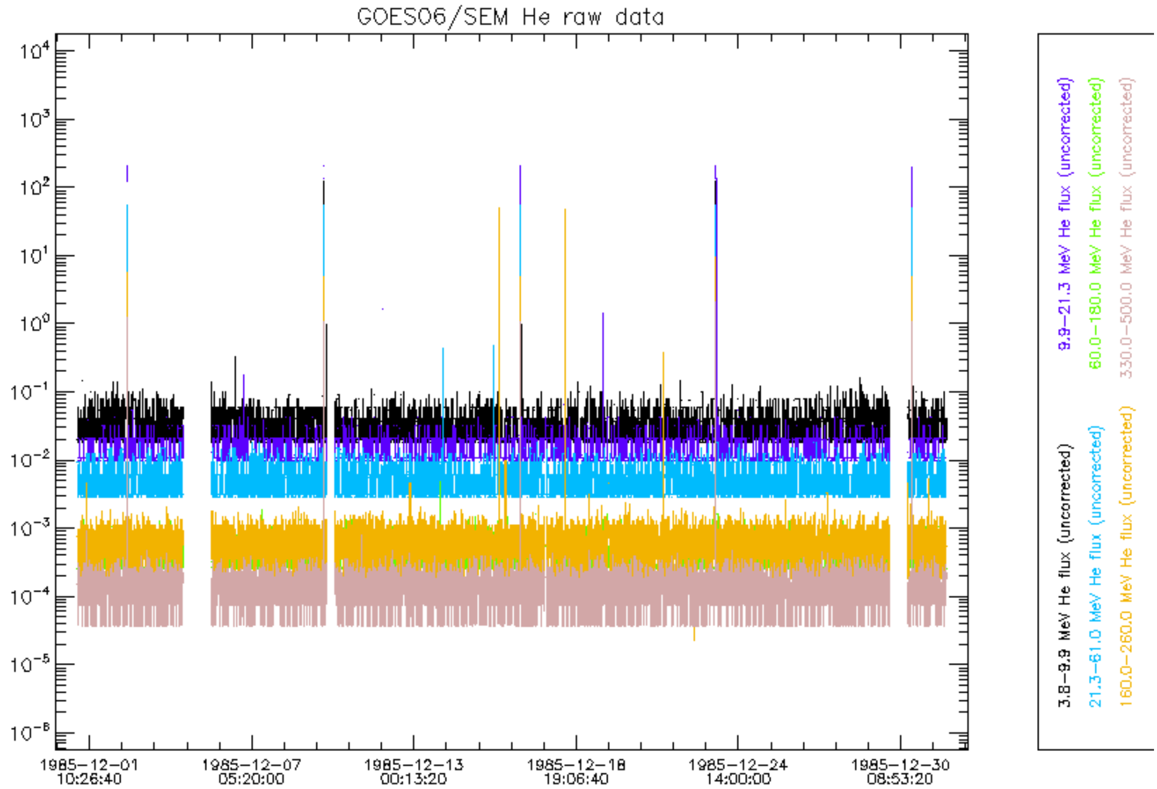

FIGURE 10 GOES06/EPS HE DATA FOR DECEMBER 1985

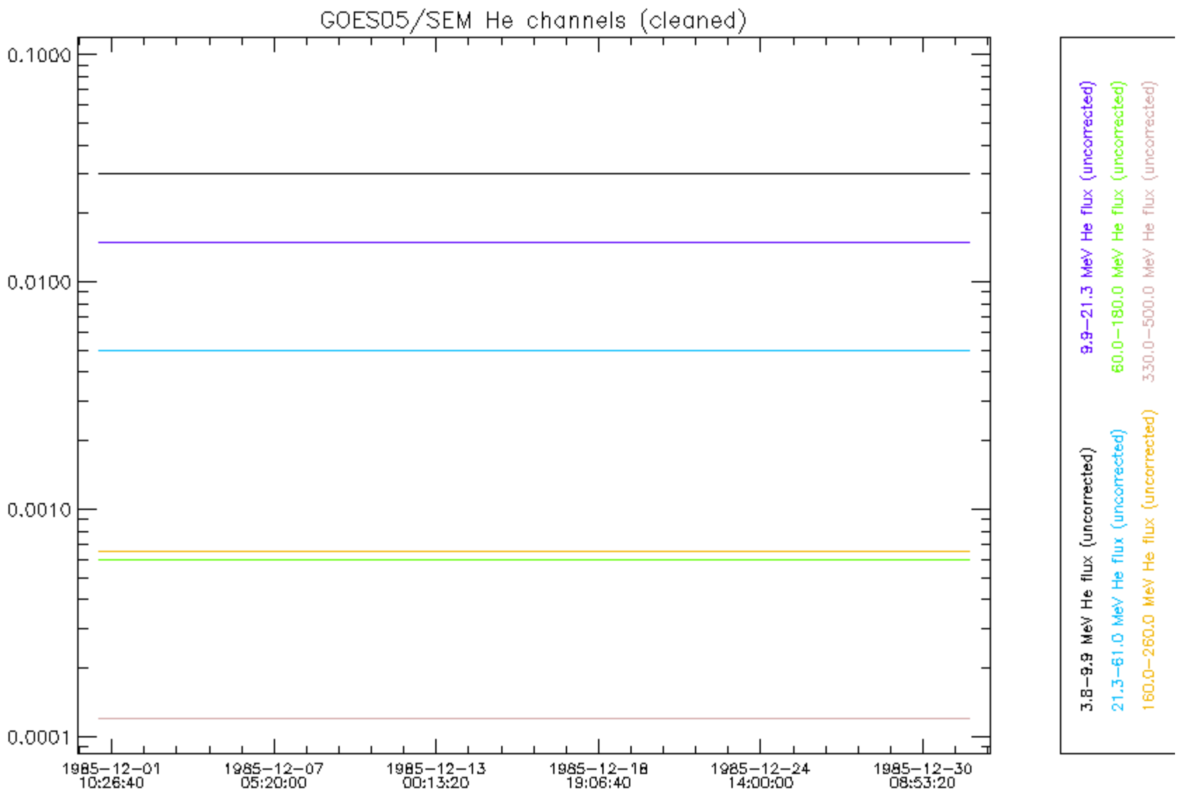

FIGURE 11 GOES05/EPS HE BACKGROUND VALUES INSERTED FOR DECEMBER 1985

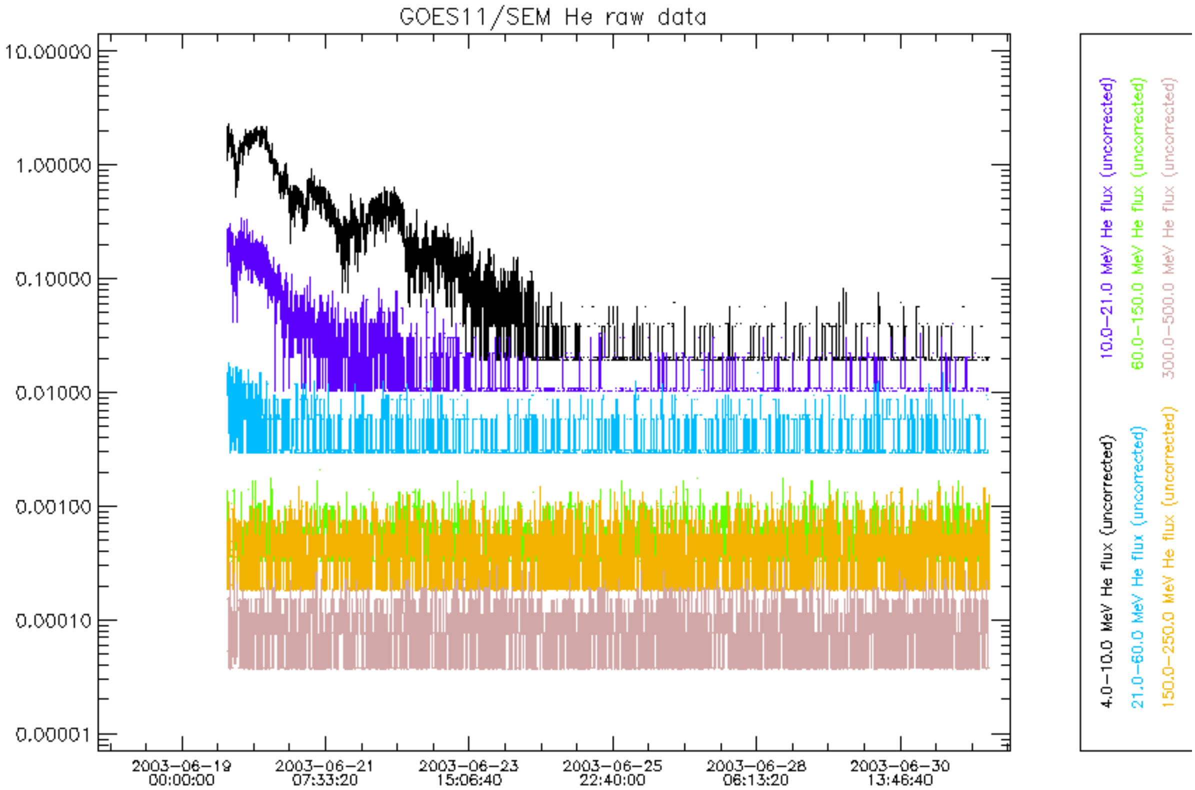

FIGURE 12 GOES11/EPS HE DATA FOR JUNE 2003, SHOWING THE DATA GAP BEFORE 20 JUNE

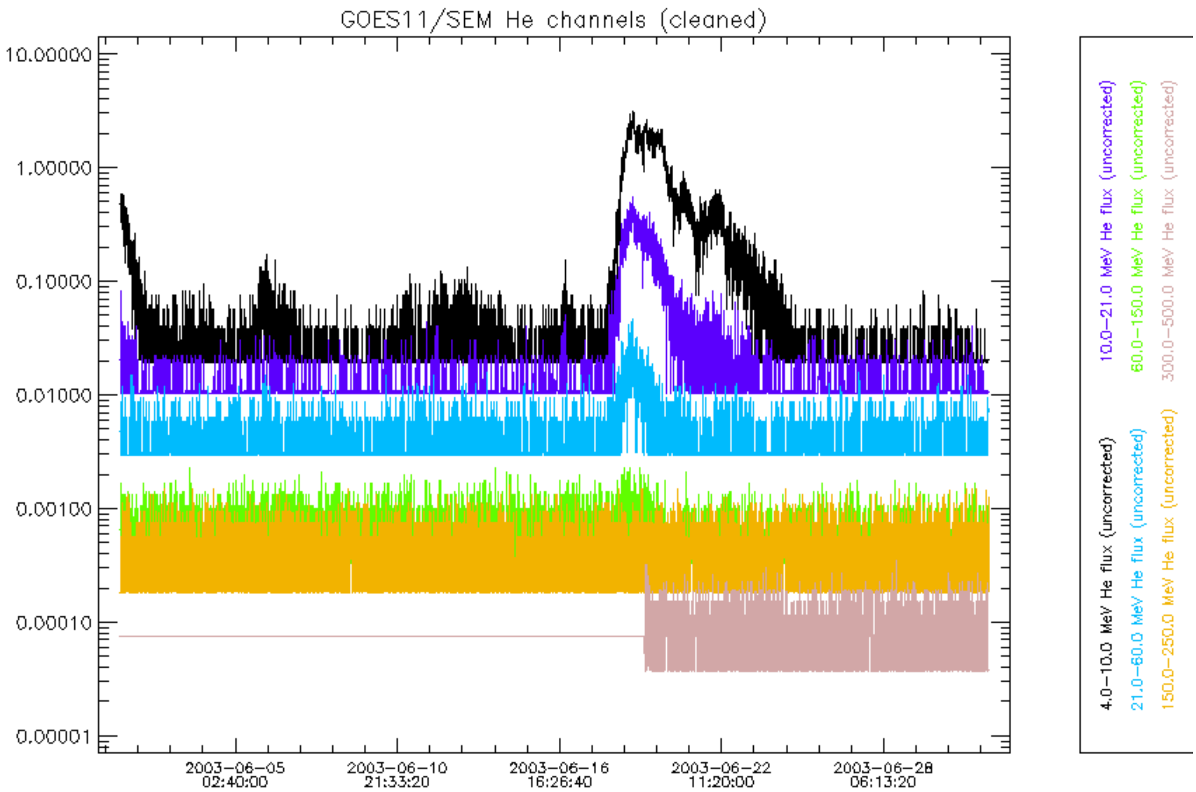

FIGURE 13 GOES11/EPS HE DATA FOR JUNE 2003 AFTER PATCHING WITH GOES12 DATA

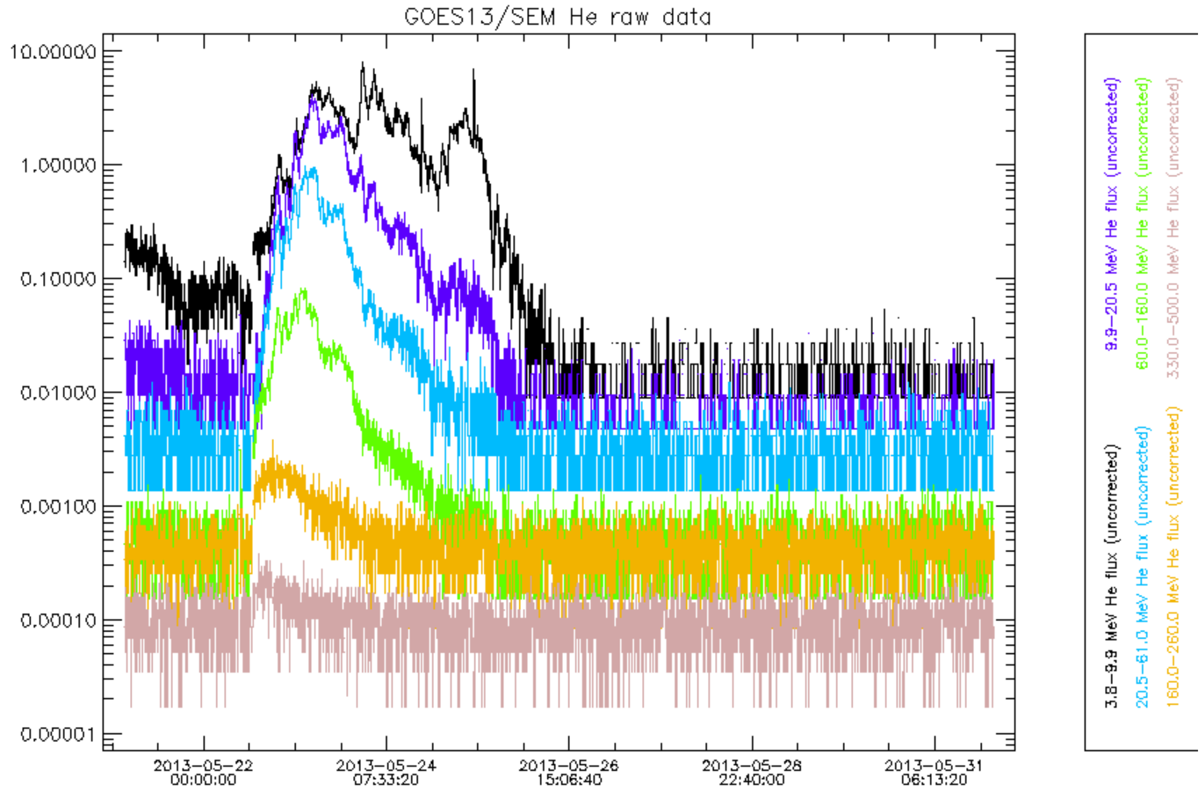

FIGURE 14 GOES13/EPS HE DATA FOR MAY 2013 PATCHED WITH GOES15 DATA

5 Cross calibrations of He data

During the SEPEM project, the GOES H data were cross-calibrated with the IMP8/GME H data using linear regression relations between flux values with the same time stamps. The regression analysis was performed after re-binning the energy channels for the various datasets into the SEPEM reference energy channels.

In this project, a different approach is used for the He data. In the SEPCALIB project [RD 9], a method was developed to determine the “true” energy centroids for the GOES channels by minimising the variance with respect to the GME data, re-binned into a fine grid of channels. Using these energy values, copies of the GOES He datasets were made with the new channel definitions. These new tables were then re-binned in energy into the SEPEM reference energy channels, listed in Table 3. In the current project, an extension of the energy range up to 300 MeV/nuc is required; hence a new channel (P11) was added which continues the logarithmic spacing. It should be noted that the GOES instrument only covers the first 8 channel energies, so that the reference He dataset only contains these 8 channels. However, SEPEM extrapolates event accumulated fluences or event peak fluxes to include the last three channels as well.

TABLE 3 SEPEM HE REFERENCE ENERGY CHANNELS (MEV/NUC)

Channel	E_l	E_u	E_c
P1	5.000	7.231	6.013
P2	7.231	10.46	8.695
P3	10.46	15.12	12.57
P4	15.12	21.87	18.18
P5	21.87	31.62	26.30
P6	31.62	45.73	38.03
P7	45.73	66.13	54.99
P8	66.13	95.64	79.53
P9	95.64	138.3	115.0
P10	138.3	200.0	166.3
P11	200.0	289.2	240.5

Due to the sparseness of the GME data, the SEPCALIB procedure proved problematic for a number of channels where almost no fluxes matching with GOES data were found above background levels for individual datasets. Therefore, it was decided to combine the fluxes from the individual datasets as follows: SMS1,2 + GOES01,02, GOES05,07 and GOES08,11. In addition, in order to match the 30 min time resolution of the IMP-8/GME data, the GOES data were averaged over 30 min time bins. Finally, a conversion factor of 4 was applied to the GOES data to convert from units of MeV^{-1} to units of $(\mathrm{MeV/nuc})^{-1}$.

Figure 15 – Figure 20 show the SEPCALIB analysis summaries for the 6 channels of the combined SMS1,2 + GOES01,02 dataset, Figure 21 – Figure 26 for the combined GOES05,07 dataset, and Figure 27 – Figure 32 for the combined GOES08,11 dataset, respectively. The red lines in the bottom panels represent the relation $\log Y = \log X$, the green curves represent the linear fit shown in the captions.

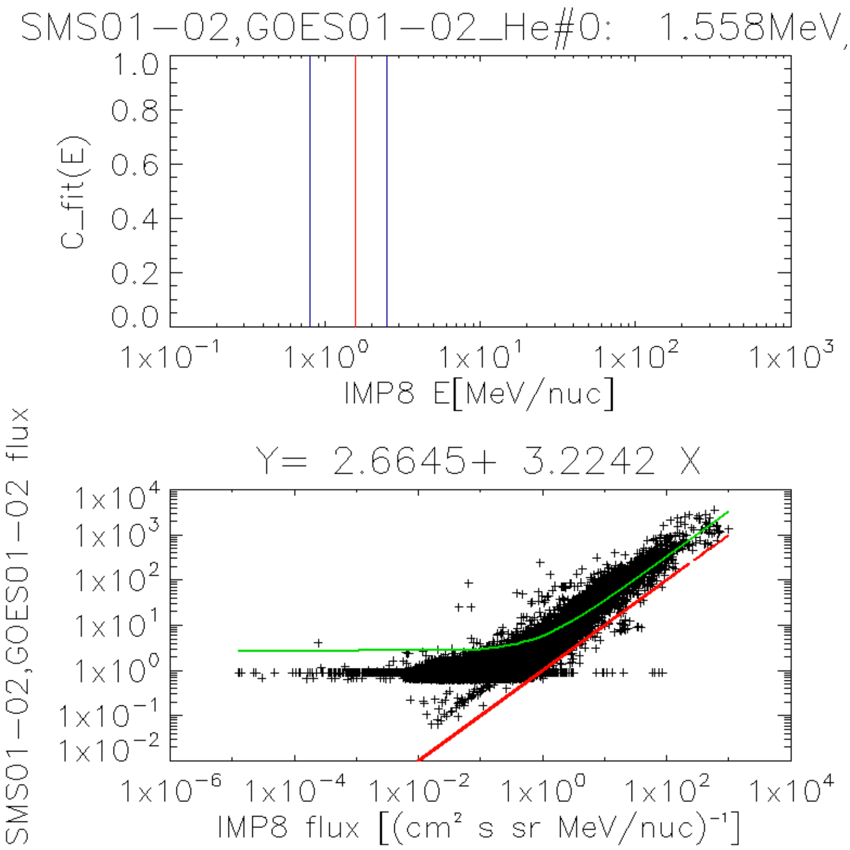

FIGURE 15 SEPCALIB ANALYSIS FOR SMS1,2 + GOES01,02 CHANNEL A1

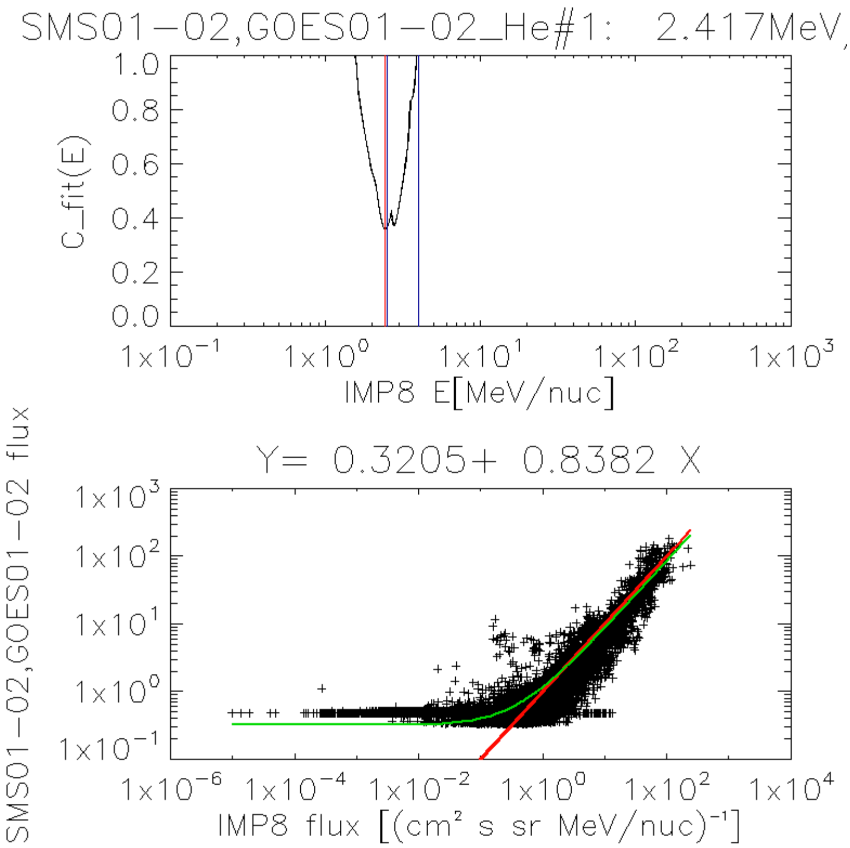

FIGURE 16 SEPCALIB ANALYSIS FOR SMS1,2 + GOES01,02 CHANNEL A2

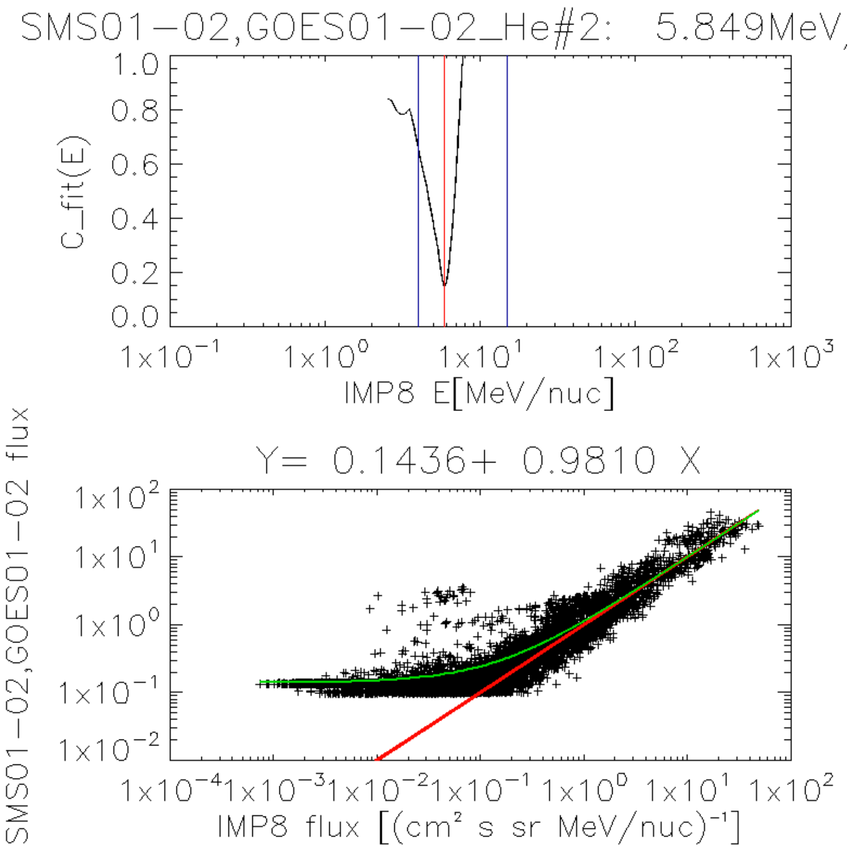

FIGURE 17 SEPCALIB ANALYSIS FOR SMS1,2 + GOES01,02 CHANNEL A3

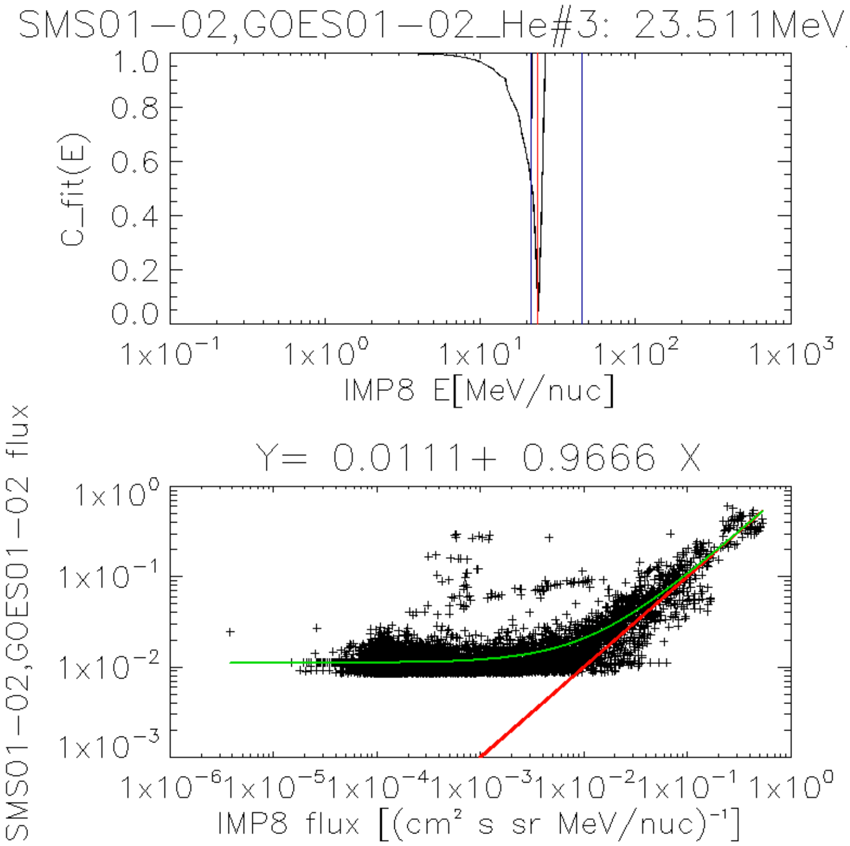

FIGURE 18 SEPCALIB ANALYSIS FOR SMS1,2 + GOES01,02 CHANNEL A4

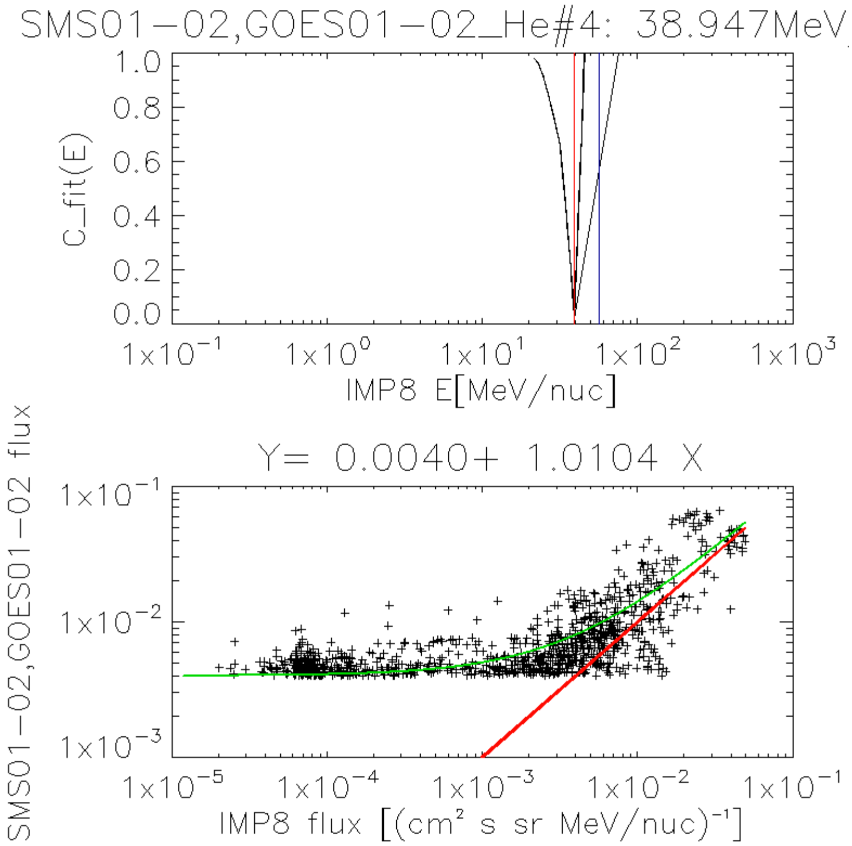

FIGURE 19 SEPCALIB ANALYSIS FOR SMS1,2 + GOES01,02 CHANNEL A5

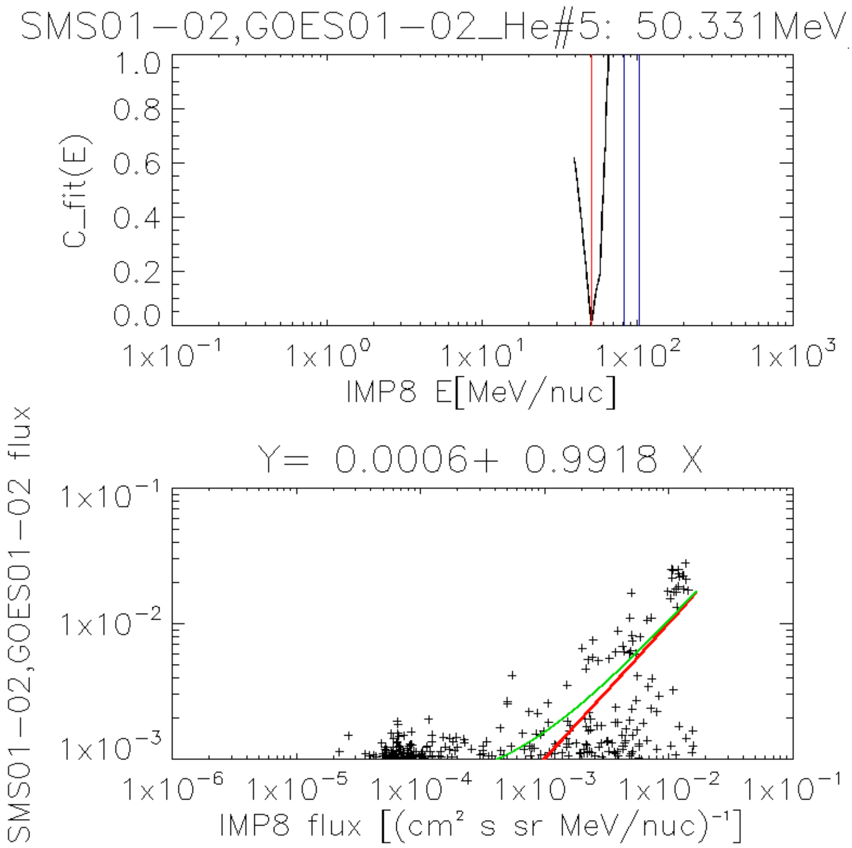

FIGURE 20 SEPCALIB ANALYSIS FOR SMS1,2 + GOES01,02 CHANNEL A6

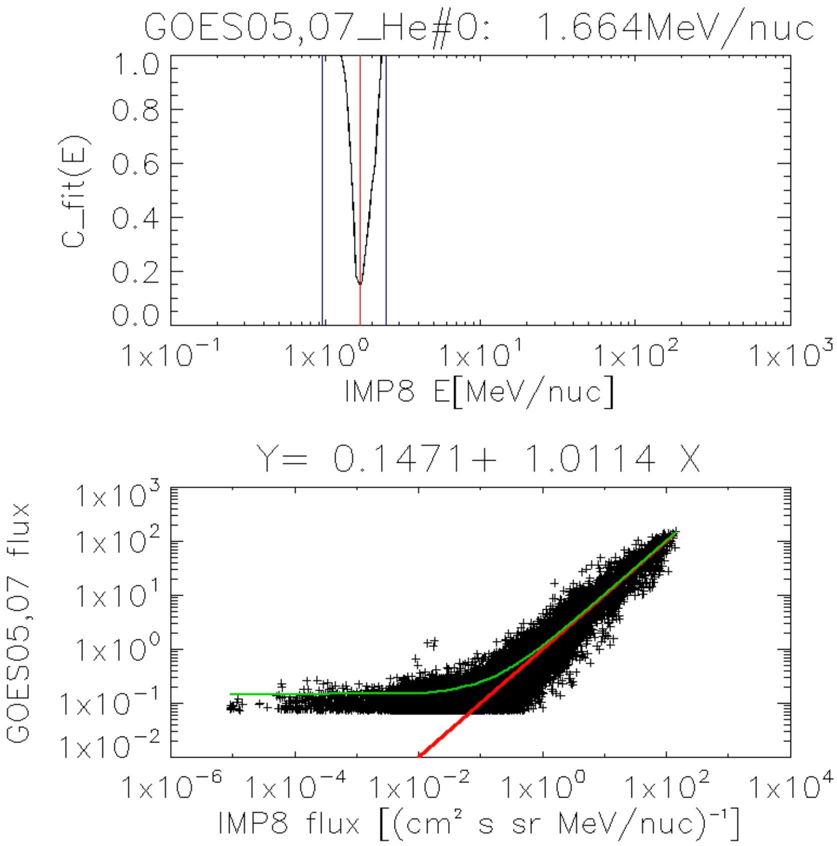

FIGURE 21 SEPCALIB ANALYSIS FOR GOES05,07 CHANNEL A1

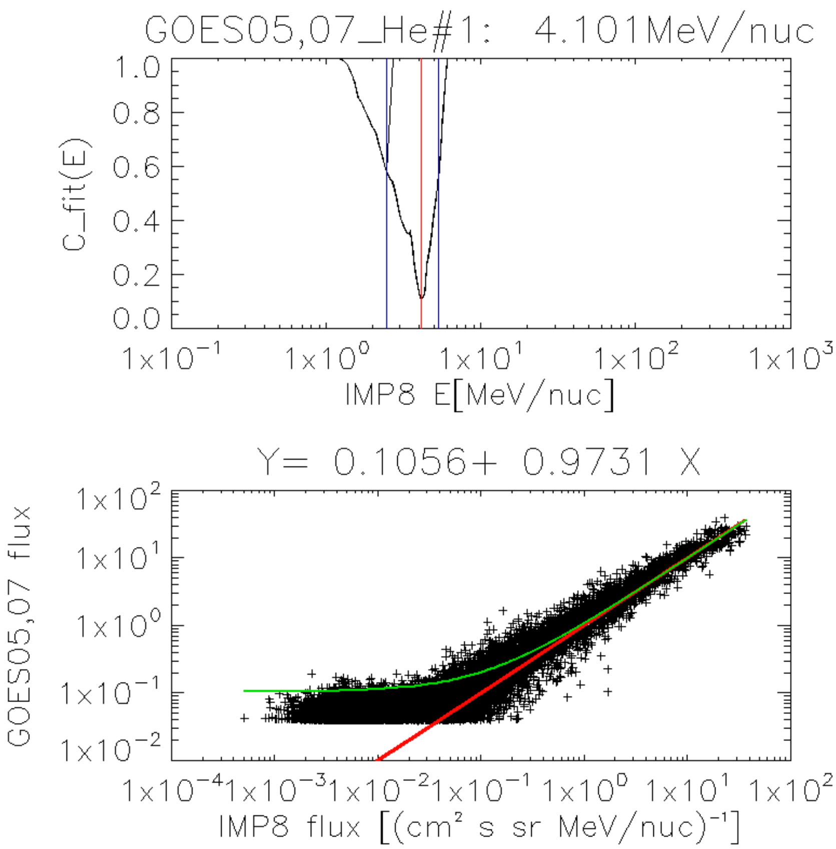

FIGURE 22 SEPCALIB ANALYSIS FOR GOES05,07 CHANNEL A2

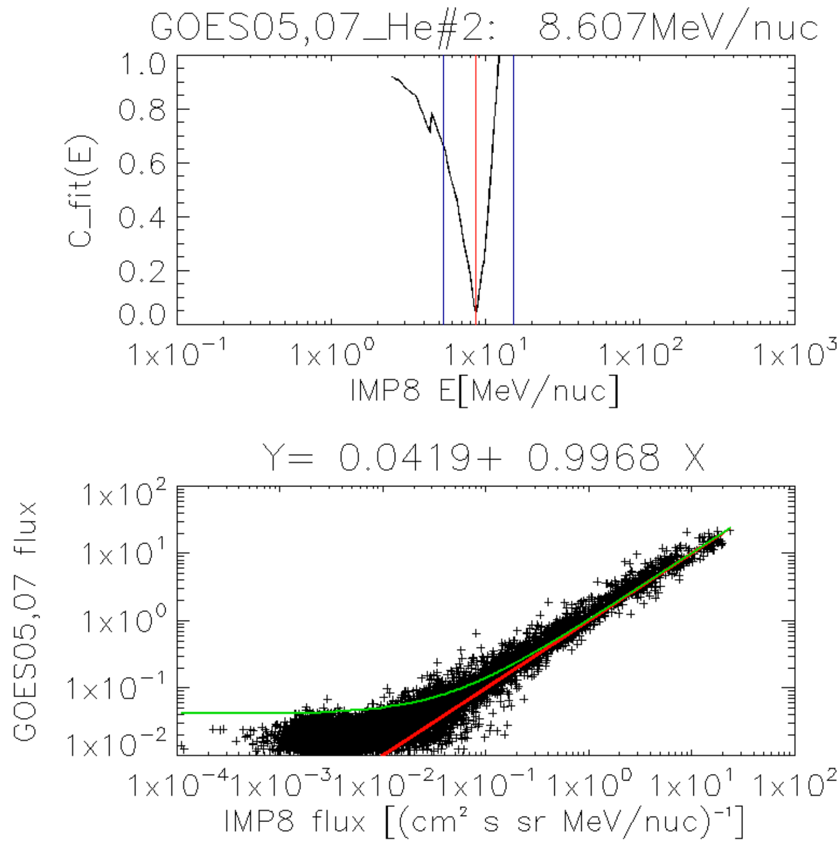

FIGURE 23 SEPCALIB ANALYSIS FOR GOES05,07 CHANNEL A3

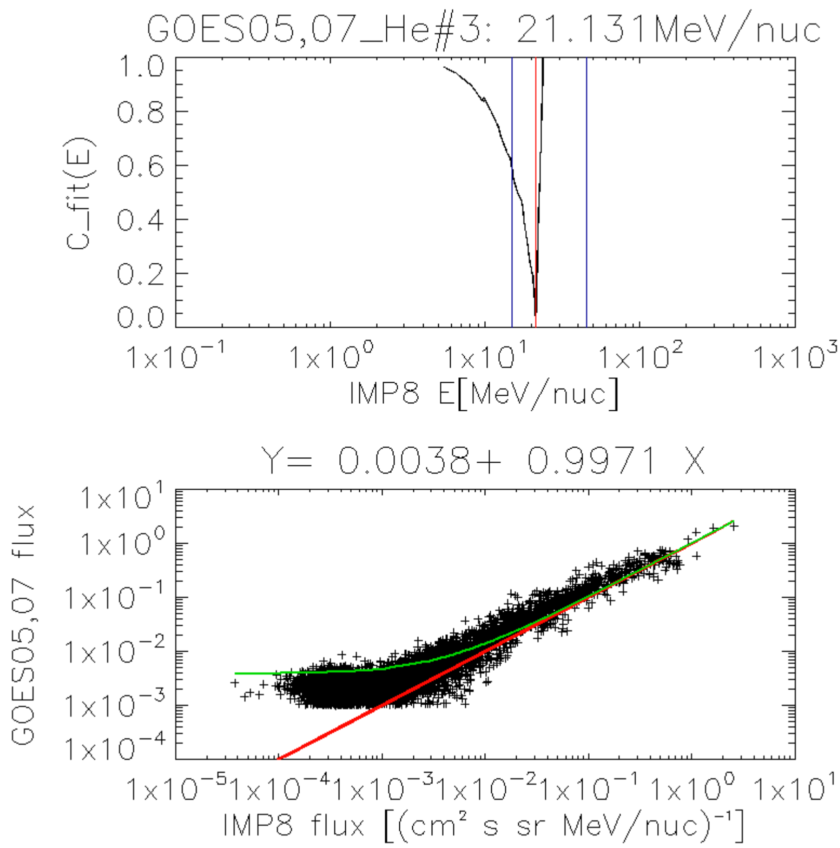

FIGURE 24 SEPCALIB ANALYSIS FOR GOES05,07 CHANNEL A4

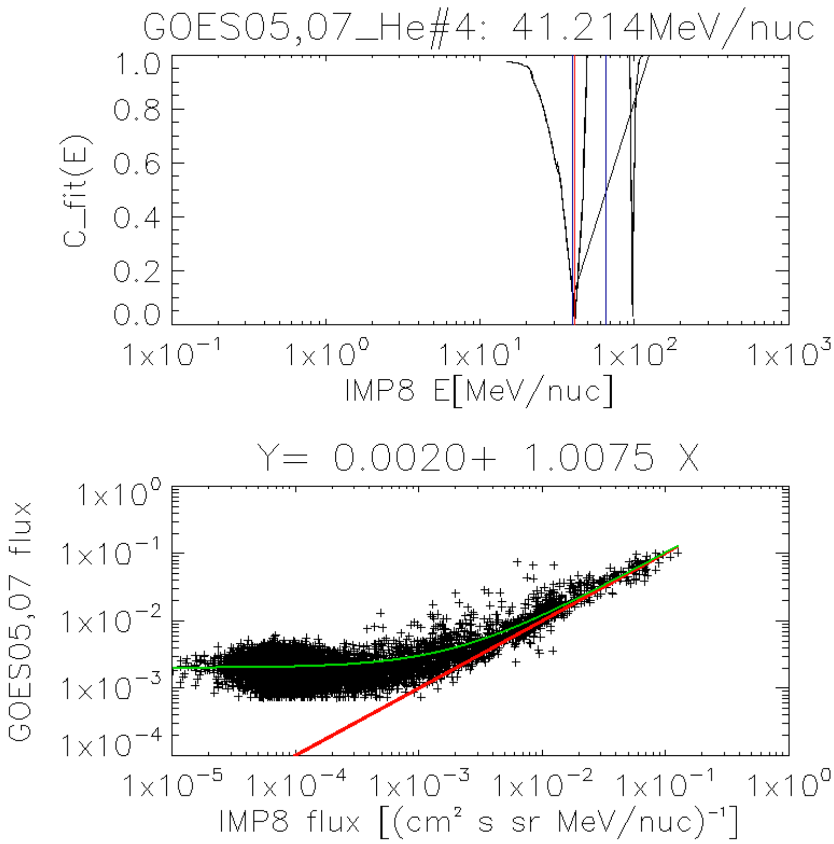

FIGURE 25 SEPCALIB ANALYSIS FOR GOES05,07 CHANNEL A5

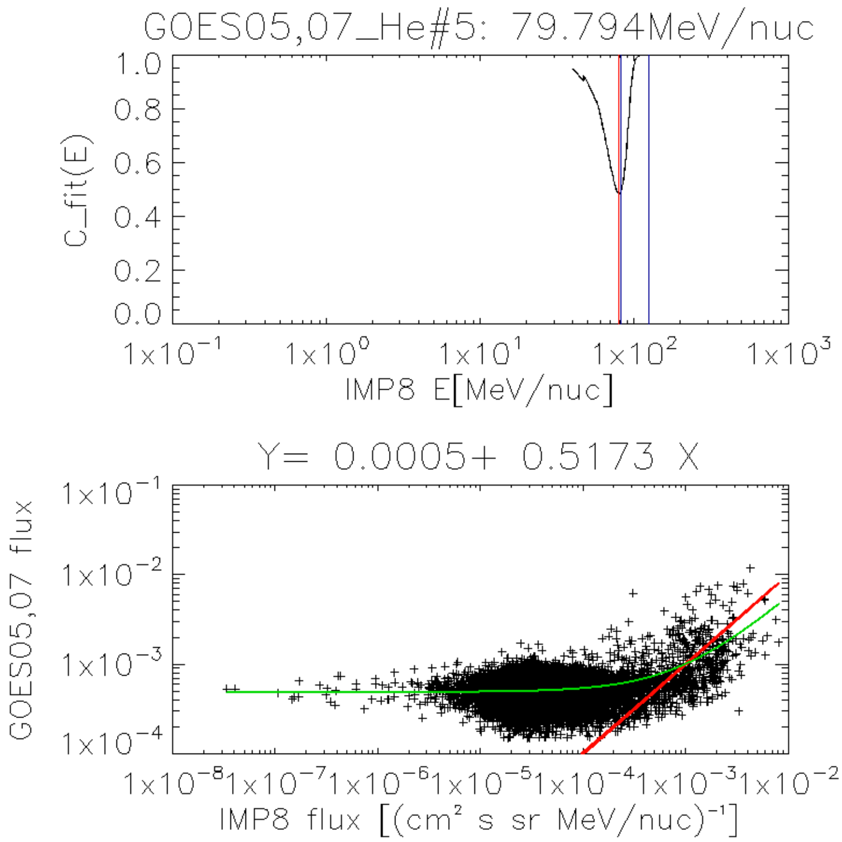

FIGURE 26 SEPCALIB ANALYSIS FOR GOES05,07 CHANNEL A6

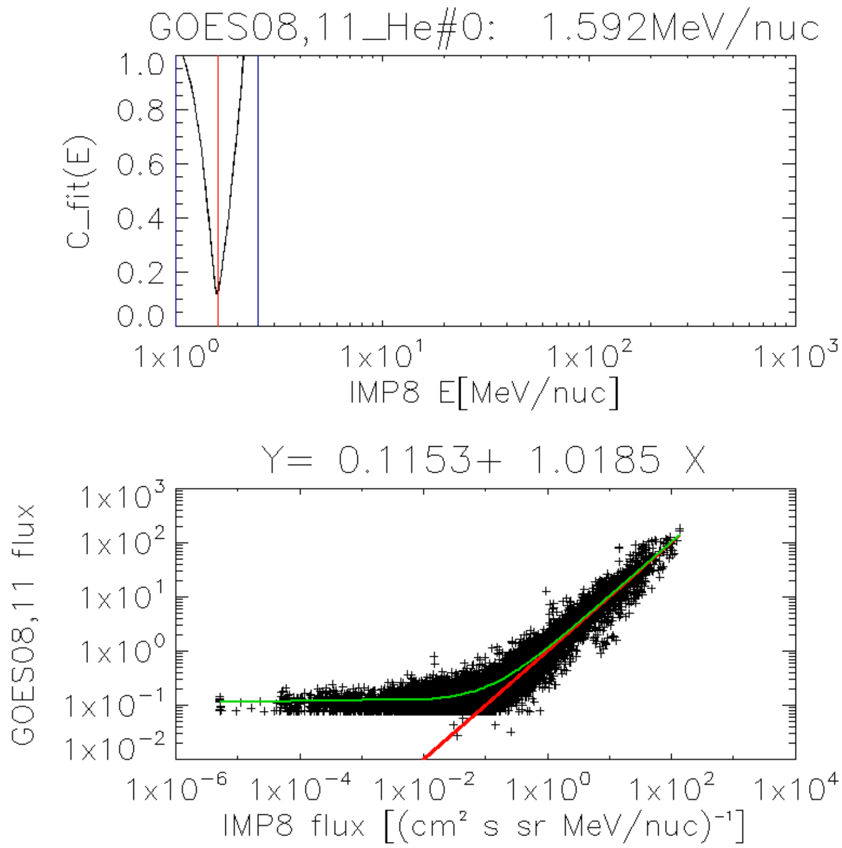

FIGURE 27 SEPCALIB ANALYSIS FOR GOES08,11 CHANNEL A1

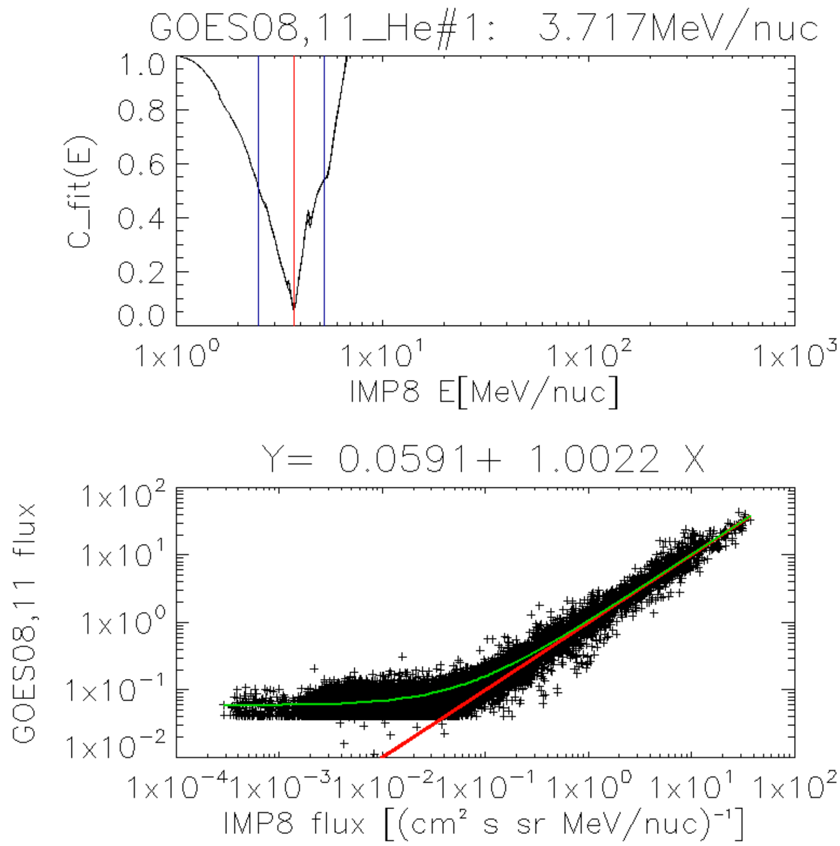

FIGURE 28 SEPCALIB ANALYSIS FOR GOES08,11 CHANNEL A2

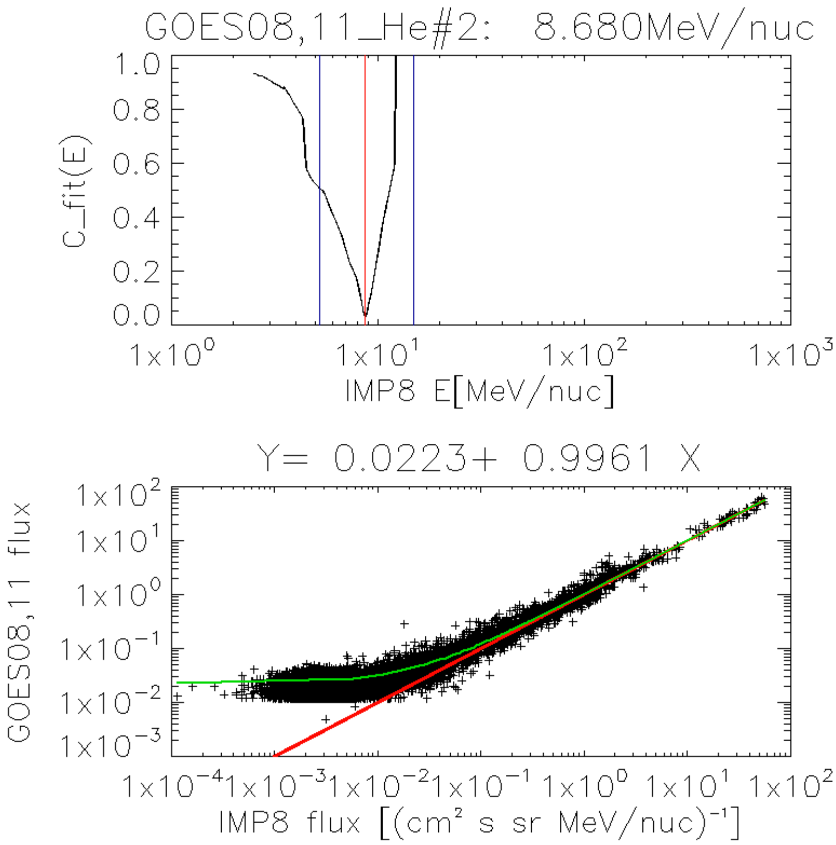

FIGURE 29 SEPCALIB ANALYSIS FOR GOES08,11 CHANNEL A3

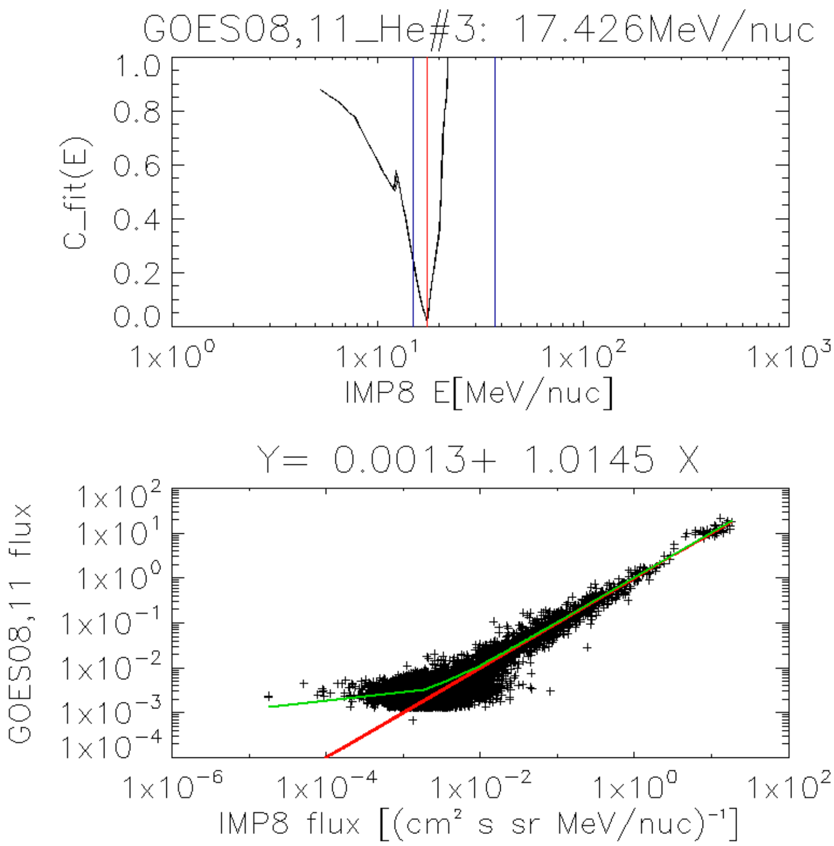

FIGURE 30 SEPCALIB ANALYSIS FOR GOES08,11 CHANNEL A4

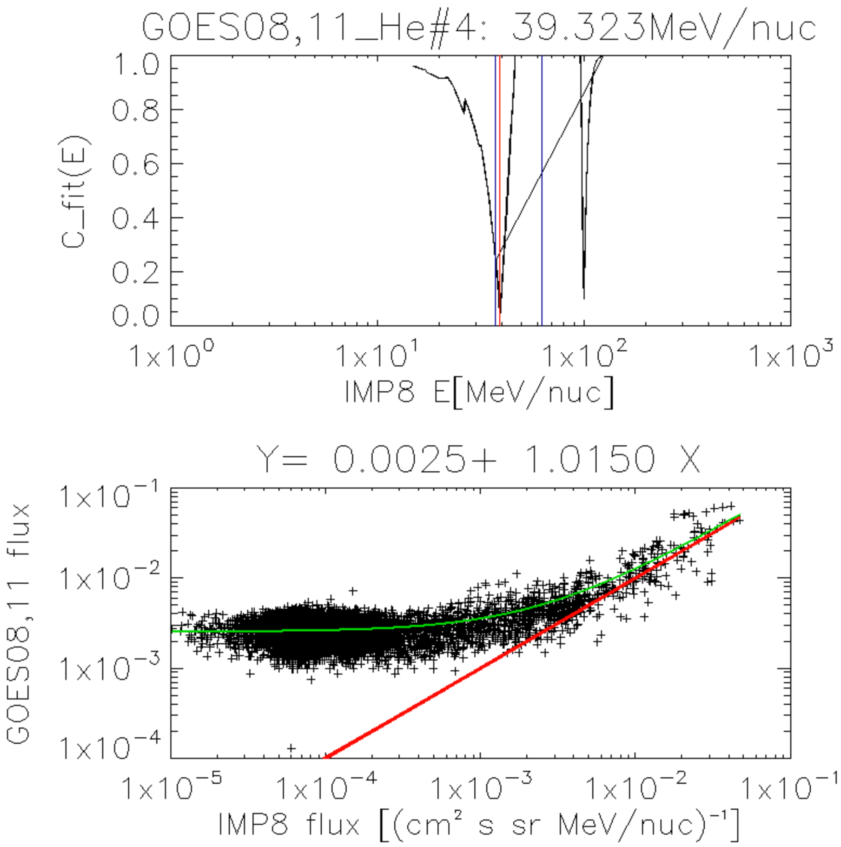

FIGURE 31 SEPCALIB ANALYSIS FOR GOES08,11 CHANNEL A5

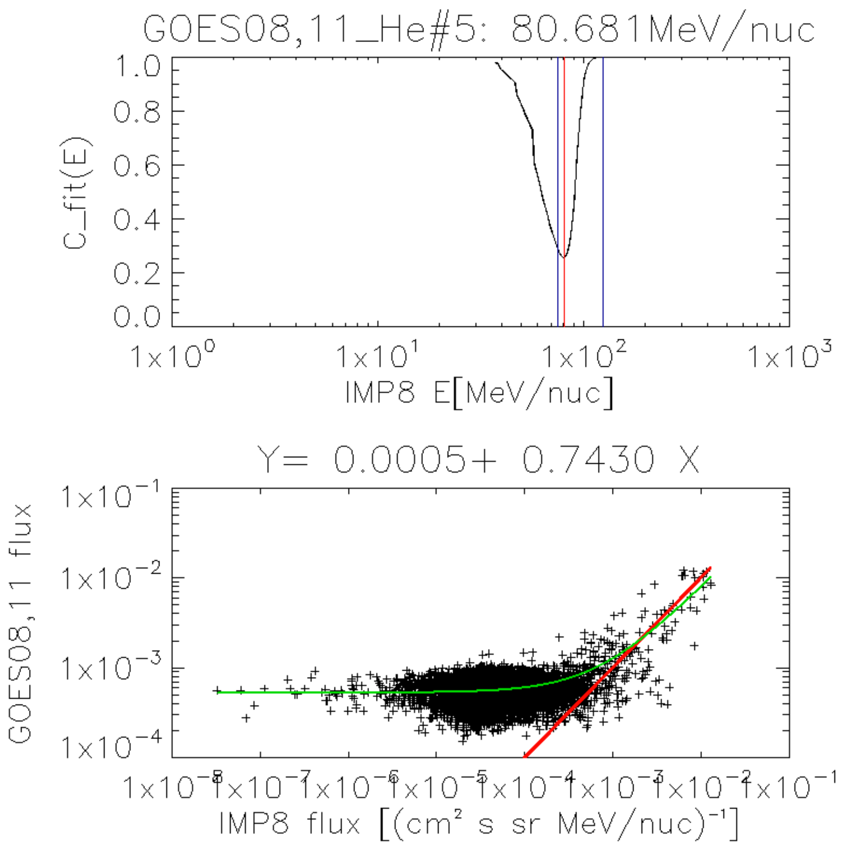

FIGURE 32 SEPCALIB ANALYSIS FOR GOES08,11 CHANNEL A6

The total mission fluence spectra for the combined datasets are shown in Figure 33 – Figure 35. The black lines and symbols represent the uncalibrated fluences, the red lines and symbols are the same fluences at the new energies obtained with the SEPCALIB procedure.

Figure 36 – Figure 38 show the SEPCALIB goodness of fit parameter as a function of energy for the respective combined datasets.

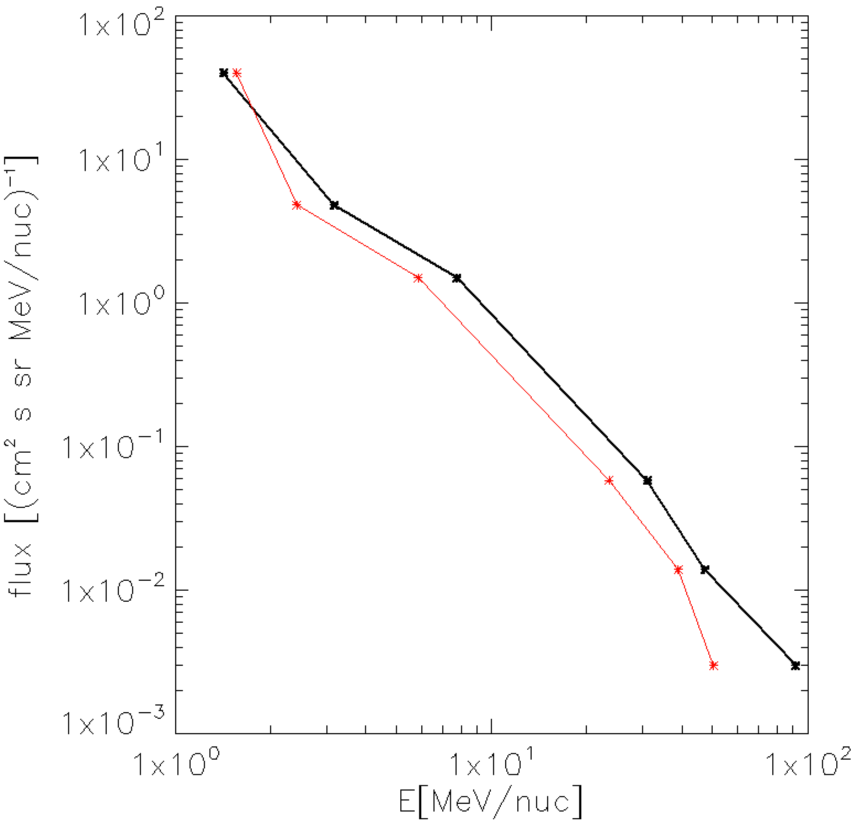

FIGURE 33 TOTAL HE FLUENCE SPECTRA FOR THE COMBINED SMS1,2 + GOES01,02 DATASET

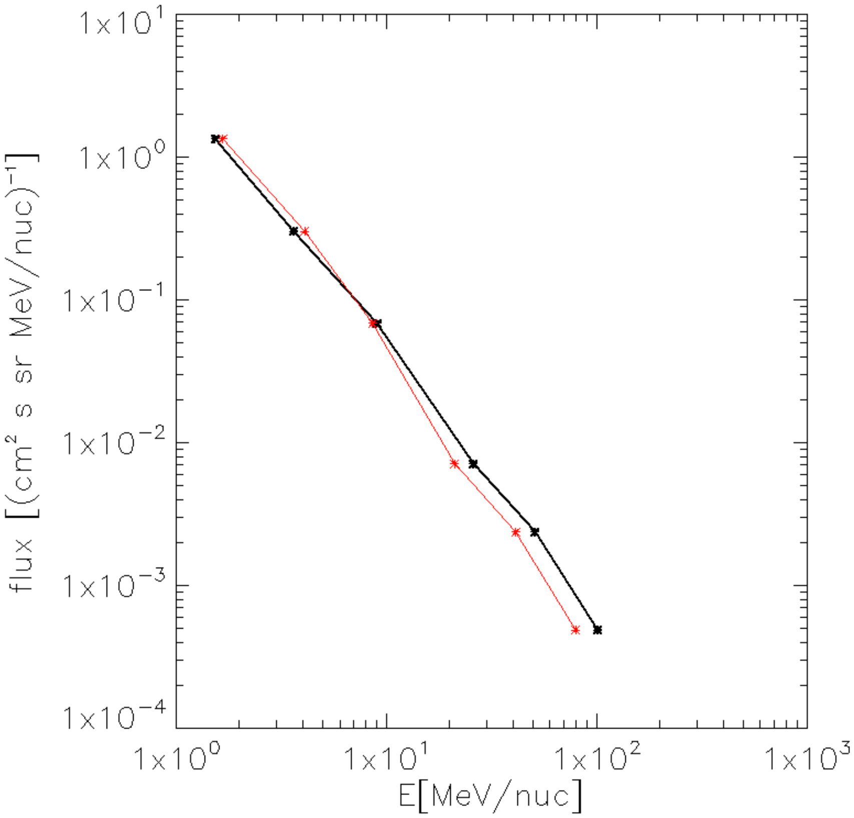

FIGURE 34 TOTAL HE FLUENCE SPECTRA FOR THE COMBINED GOES05,07 DATASET

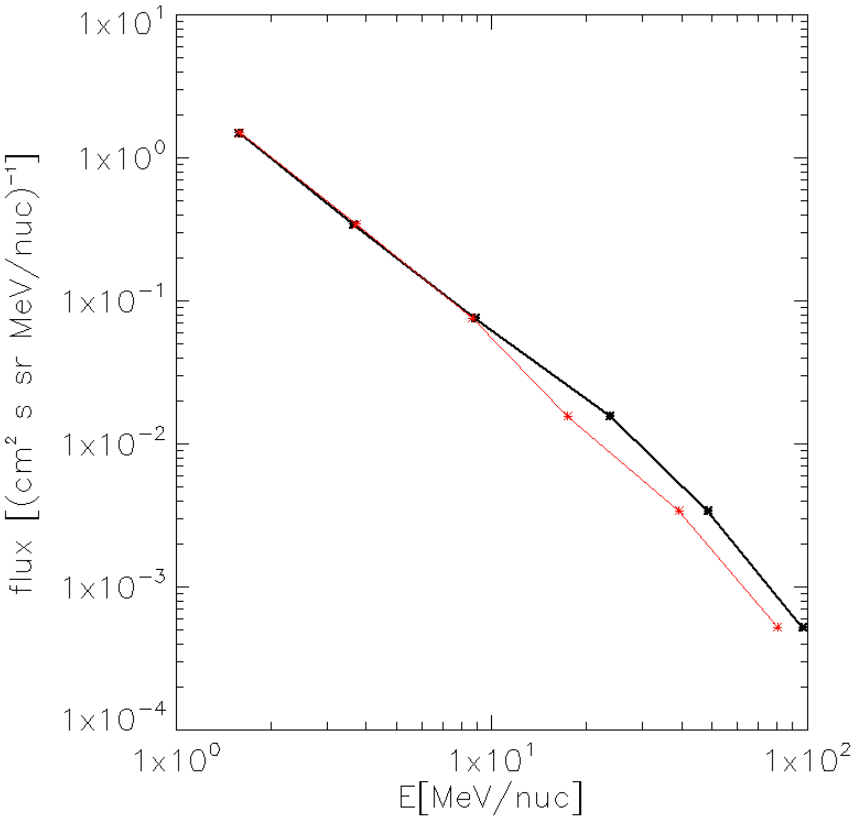

FIGURE 35 TOTAL HE FLUENCE SPECTRA FOR THE COMBINED GOES08,11 DATASET

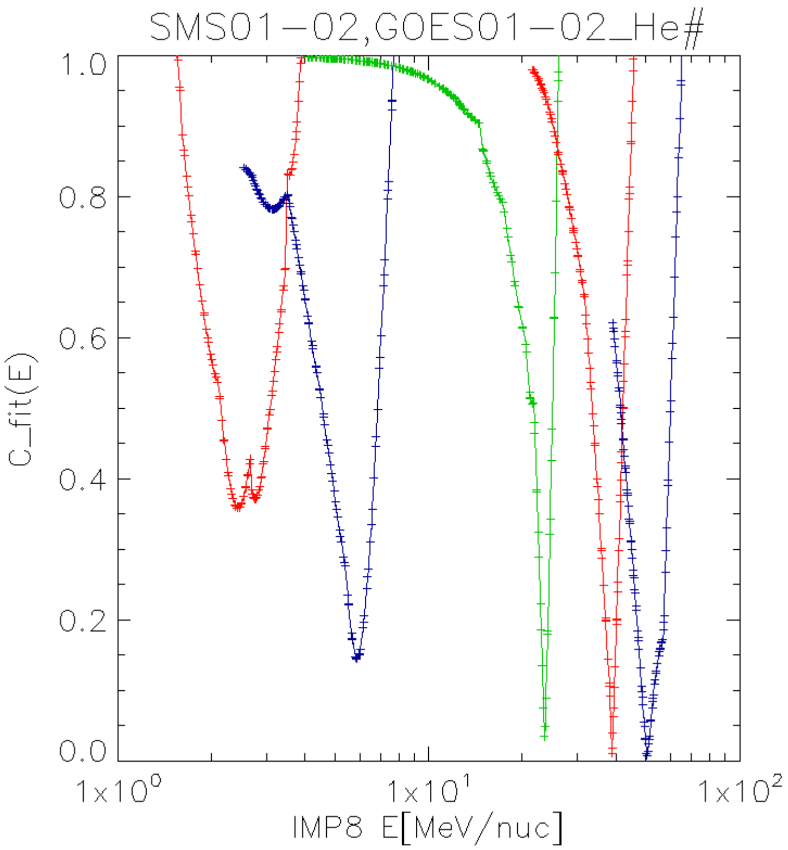

FIGURE 36 SEPCALIB GOODNESS OF FIT PARAMETER AS A FUNCTION OF ENERGY FOR SMS1,2 + GOES01,02

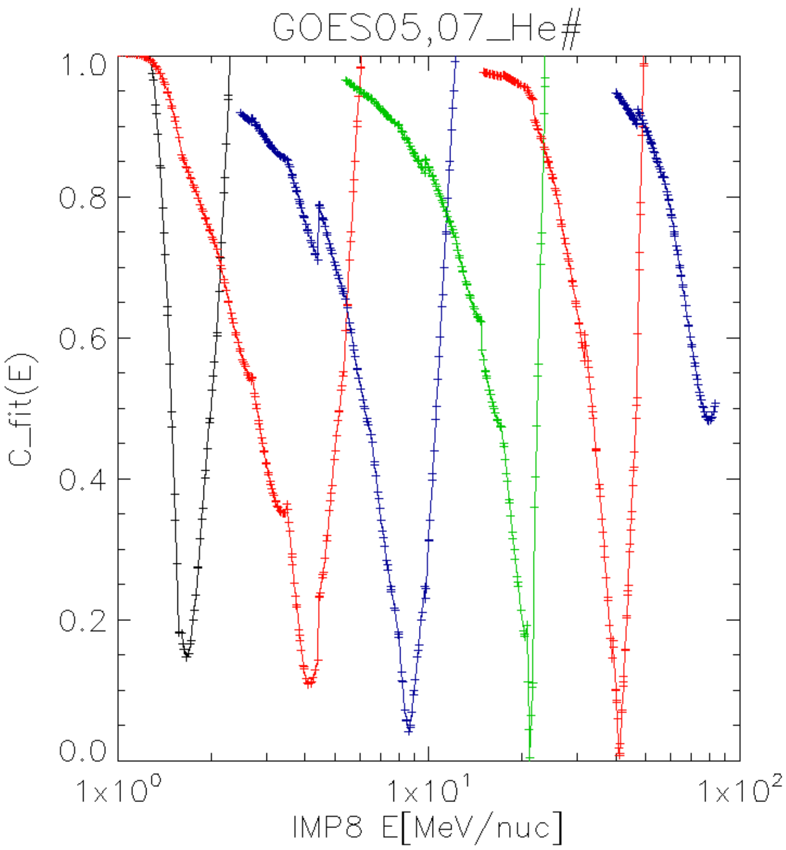

FIGURE 37 SEPCALIB GOODNESS OF FIT PARAMETER AS A FUNCTION OF ENERGY FOR GOES05,07

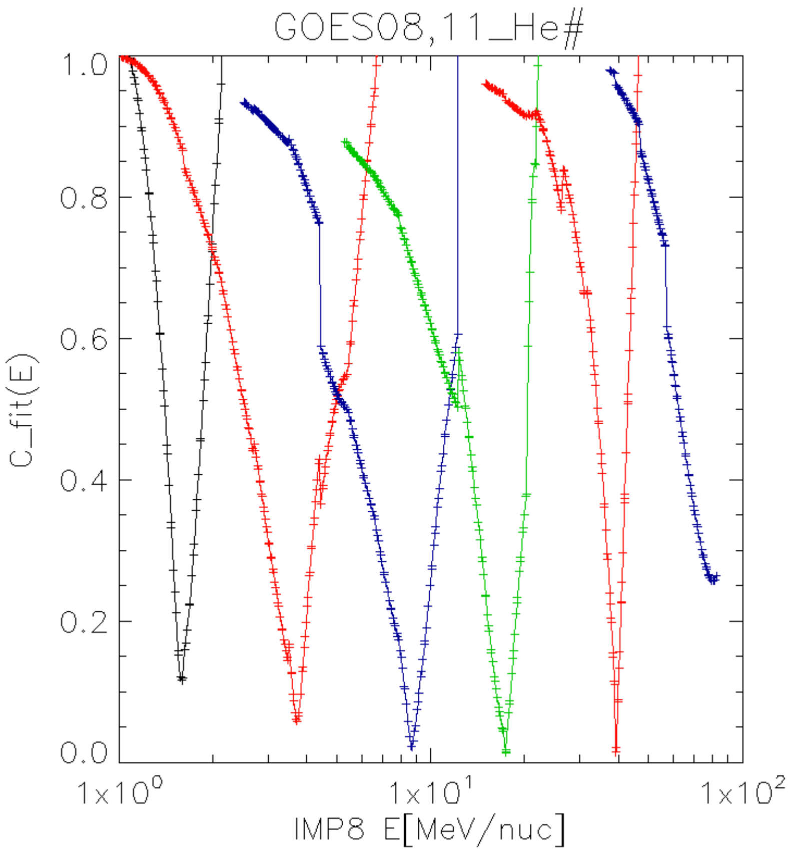

FIGURE 38 SEPCALIB GOODNESS OF FIT PARAMETER AS A FUNCTION OF ENERGY FOR GOES08,11

The new central energies for the channels of the combined datasets, re-binned to 30 minute intervals, are listed in Table 4. The current version of the SEPEM system still uses the previous set of energies (shown in Table 5), which was derived using the same GOES data but without re-binning in time. For most of the channels, the calibrated energies have not changed between versions or only by a very small fraction; the largest change is for channel A6 in the combined GOES08,11 dataset (77.79 -> 80.68, which actually brings it closer to the value for the combined GOES08,11 dataset). With the new procedure, the centroid energy for channel A6 in the combined SMS1,2 + GOES01,02 dataset changes from 75.00 to 50.33; this is not realistic and probably due to the small number of above background fluxes in the time binned dataset (the regression line in Figure 20 lies below the above background fluxes), therefore, the original value of 75.00 is retained (marked in blue). The values in Table 5 should be used in the next update of the He reference dataset (energies which have changed between versions have been marked in red).

TABLE 4 GOES HE CHANNEL CENTROID ENERGIES (MEV/NUC) OBTAINED WITH THE COMBINED SEPCALIB ANALYSES (WITHOUT RE-BINNING IN TIME)

Channel	SMS1,2 GOES01,02	GOES05-07	GOES08-13
A1	1.558	1.664	1.598
A2	2.417	4.173	3.717
A3	5.849	8.607	8.680
A4	23.76	21.13	17.45
A5	38.95	41.21	39.32
A6	75.00	79.79	77.79

TABLE 5 GOES HE CHANNEL CENTROID ENERGIES (MEV/NUC) OBTAINED WITH THE COMBINED SEPCALIB ANALYSES (AFTER RE-BINNING IN 30 MINUTE TIME INTERVALS)

Channel	SMS1,2 GOES01,02	GOES05-07	GOES08-13
A1	1.558	1.664	1.592
A2	2.417	4.101	3.717
A3	5.849	8.607	8.680
A4	23.51	21.13	17.43
A5	38.95	41.21	39.32
A6	75.00	79.79	80.68

6 DATASET MERGING

The cleaned and re-binned SMS and GOES datasets were merged into a single table (`sepem_rds_2_1_he`, after background subtraction, see Section 7). The data time periods used for each spacecraft are listed in Table 6.

TABLE 6 DATA SELECTION FOR THE REFERENCE HE DATASET

Dataset	Original Time Span	Time Span of Selected Data	Comments
SMS1/EPS	01/07/1974–31/10/1975	01/07/1974–31/10/1975	
SMS2/EPS	01/02/1975–31/03/1978	01/11/1975–31/03/1977	
GOES01/EPS	01/01/1976–31/05/1978	01/04/1977–31/07/1977	
GOES02/EPS	01/08/1977–31/05/1983	01/08/1977–19/05/1983	
GOES03/EPS	01/07/1978–31/12/1979		Not used.
GOES05/EPS	01/01/1984-25/03/1987	01/01/1984-05/03/1987	Missing data for Dec 1985 were patched with background values.
GOES06/EPS	01/05/1983–31/12/1994	20/05/1983–31/12/1983	
GOES07/EPS	06/03/1987-31/08/1996	06/03/1987-31/12/1994	
GOES08/EPS	01/01/1995-17/06/2003	01/01/1995-16/06/2003	Data missing for days 24/06/1995 and 04/07/1995. Patched with background levels.
GOES09/EPS	01/04/1996–31/08/1998		Not used.
GOES10/EPS	01/07/1998–31/12/2009		Not used.
GOES11/EPS	01/07/2000-28/02/2011	17/06/2003-31/01/2011	Due to large data gaps, data prior to 21/06/2003 are only used for cross-calibration. Data from GOES12 were used for 1–19/06/2003.
GOES12/EPS	01/01/2003–30/09/2010	01/06/2003–19/06/2003	
GOES13/EPEAD	01/05/2010-31/12/2017	01/02/2011-31/12/2017	Data for 22/04/2013–03/05/2013 were patched with GOES15 data.

7 BACKGROUND SUBTRACTION

Due to the high instrument background in the GOES He channels, a background subtraction needs to be performed to the cross calibrated and merged SEPEM He dataset. The background subtraction algorithm consists of the following steps (per energy channel):

1. Use an event list to identify quiet and active periods.
2. For each day in the dataset, calculate the average flux over the three days centred on the day, if all three days fall in a contiguous quiet period. If not, find the closest three day contiguous quiet periods before and after the event (this can result in merging event periods which are separated by less than 3 days). This procedure sets the background level for each day in the dataset.
3. For each day in the dataset, find the minimum non-zero flux value.
4. For each day in the dataset, subtract the daily background flux from all fluxes.
5. If the background subtracted flux value is below the original minimum flux for the day, set it to zero.

At first, the SEPEM reference event list was used for step 1. However, this list was built using a mixture of IMP-8/GME and GOES/EPS data (the original reference H dataset). In addition, due to the data noise, the event start and stop times are not always correctly defined (typically, event durations tend to be too short as the data noise makes the flux dip below the end threshold flux prematurely). Therefore, a new event list was built using the new H reference dataset, after re-binning in 1 hour time intervals to remove the data noise. For each successive spacecraft era, the start and end event threshold values were set to best reflect the data background levels.

Figure 39 – Figure 46 show the final reference He dataset flux (i.e. including background subtraction) for the individual reference energy channels as daily averages.

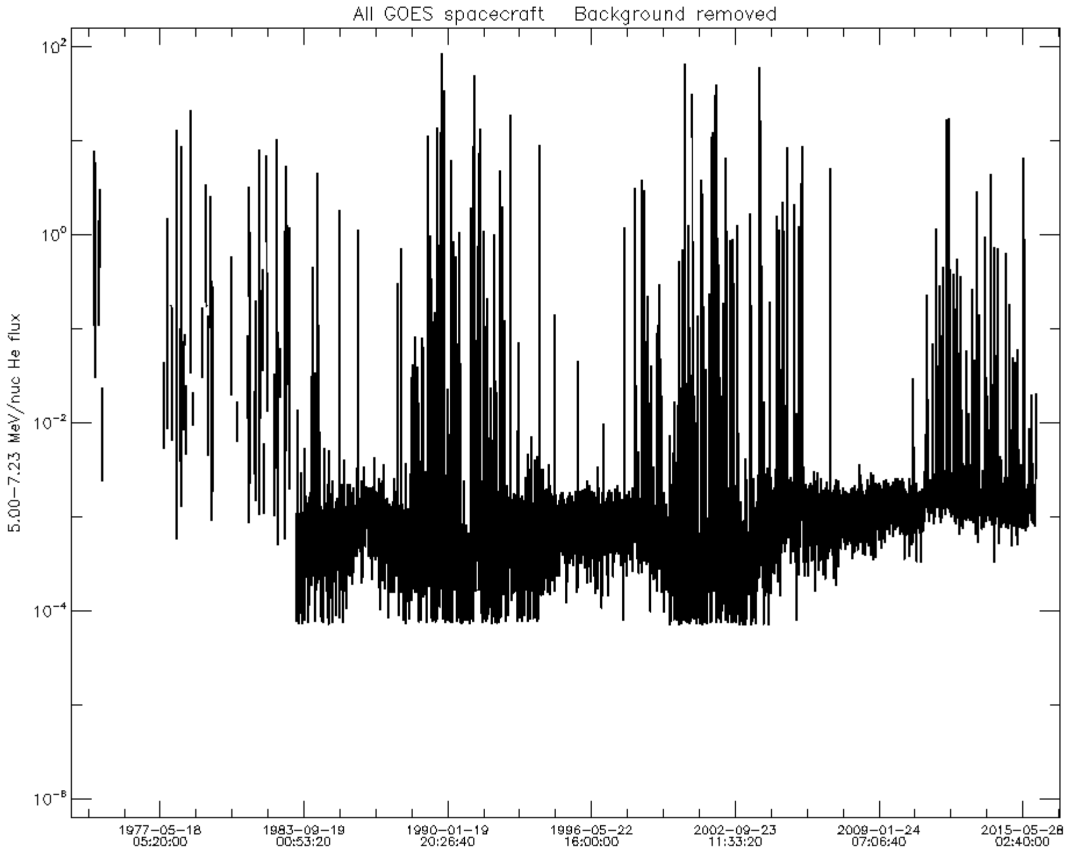

FIGURE 39 DAILY AVERAGE FLUX FOR CHANNEL 1 OF THE HE REFERENCE DATASET

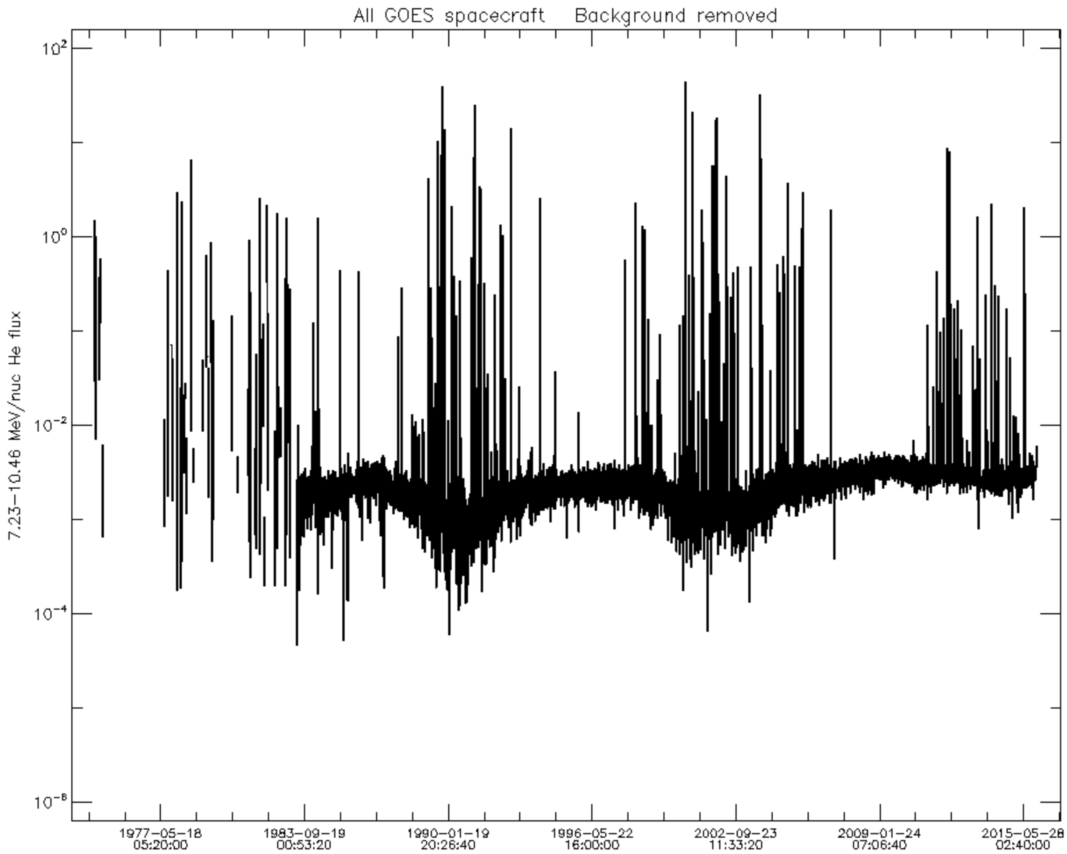

FIGURE 40 DAILY AVERAGE FLUX FOR CHANNEL 2 OF THE HE REFERENCE DATASET

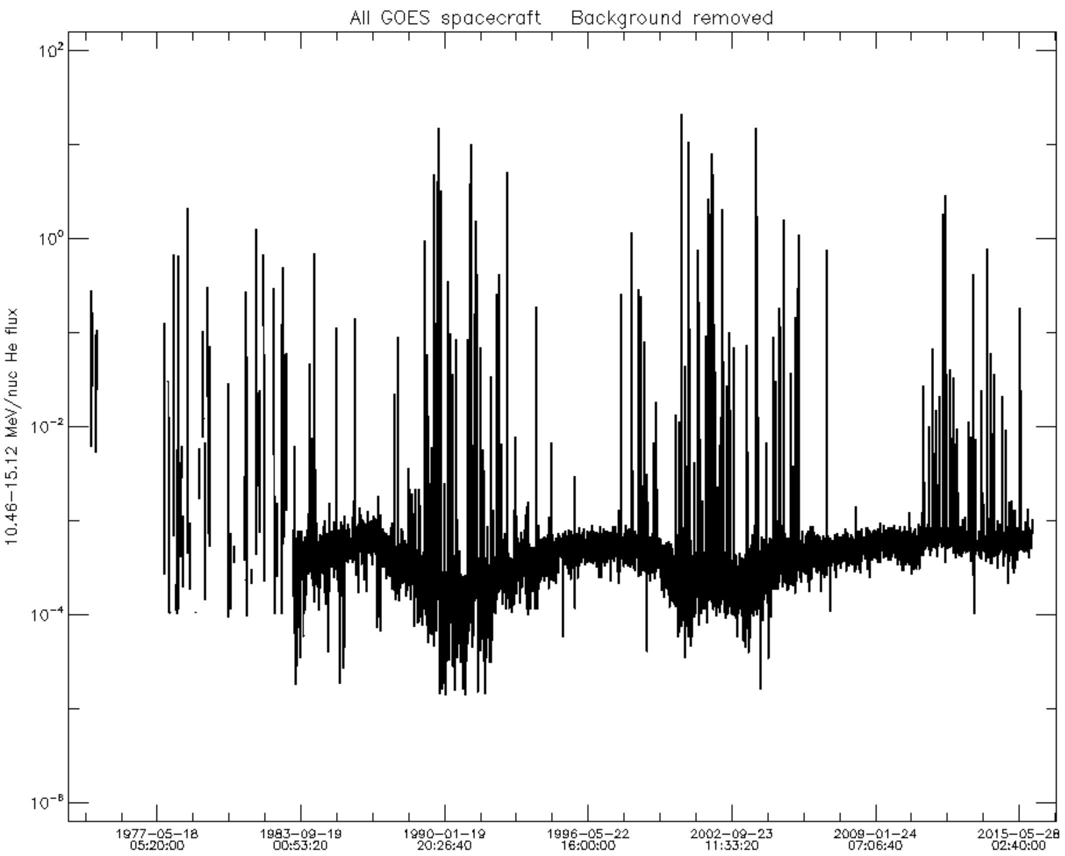

FIGURE 41 DAILY AVERAGE FLUX FOR CHANNEL 3 OF THE HE REFERENCE DATASET

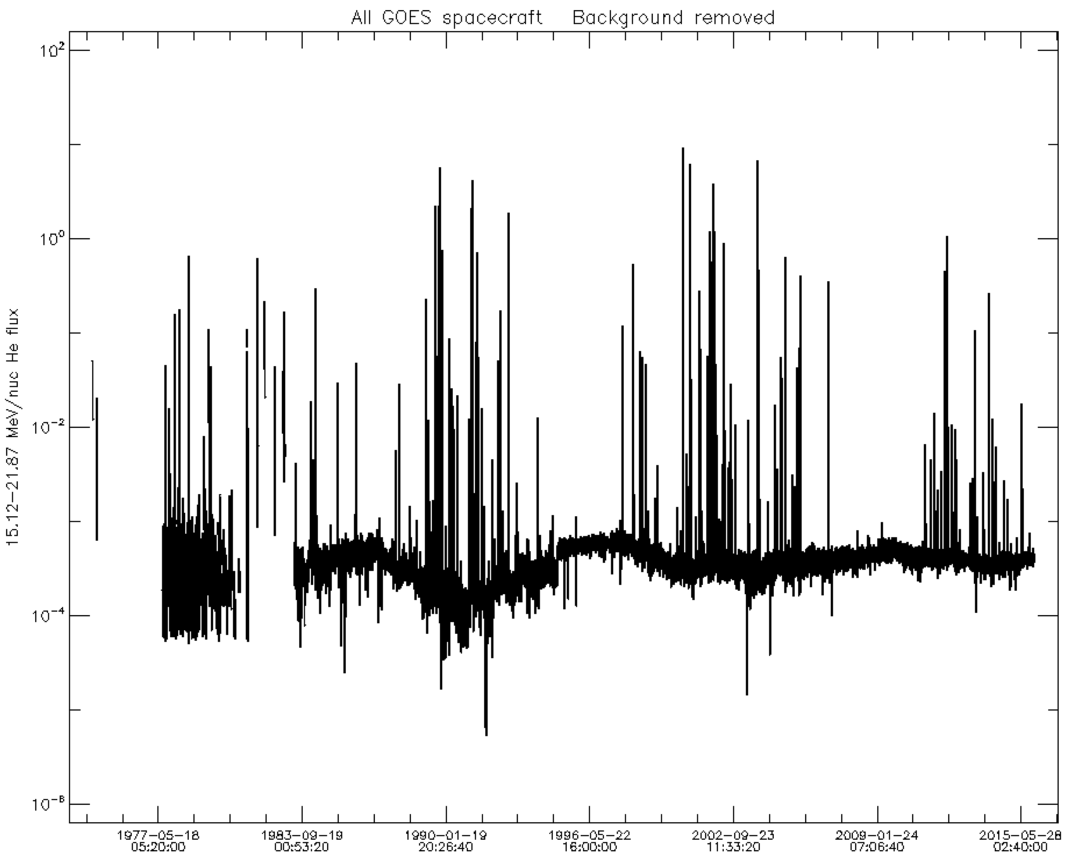

FIGURE 42 DAILY AVERAGE FLUX FOR CHANNEL 4 OF THE HE REFERENCE DATASET

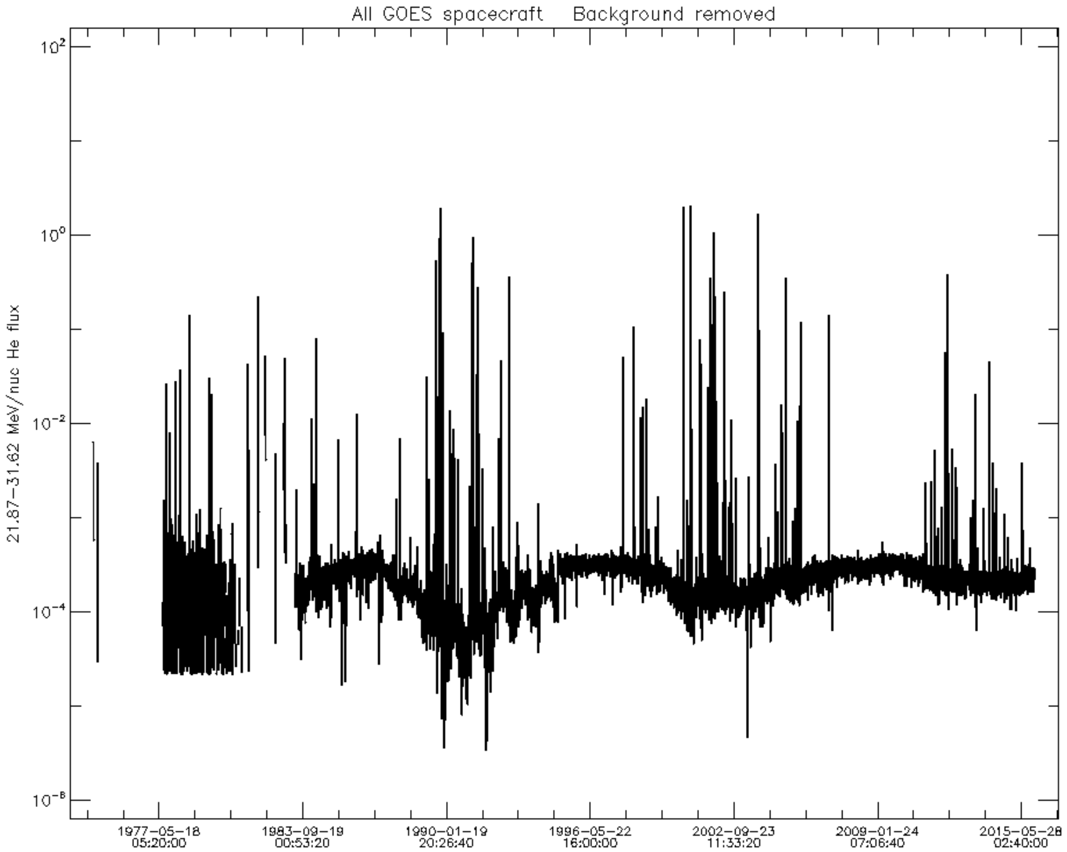

FIGURE 43 DAILY AVERAGE FLUX FOR CHANNEL 5 OF THE HE REFERENCE DATASET

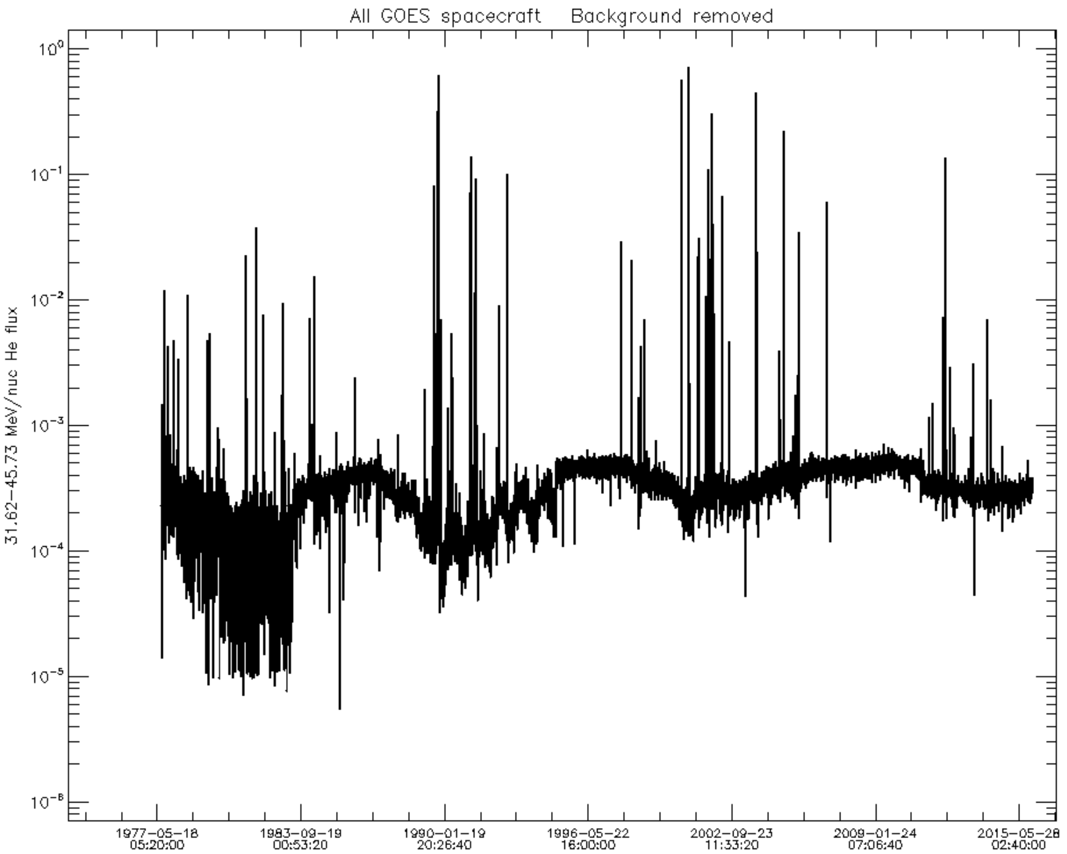

FIGURE 44 DAILY AVERAGE FLUX FOR CHANNEL 6 OF THE HE REFERENCE DATASET

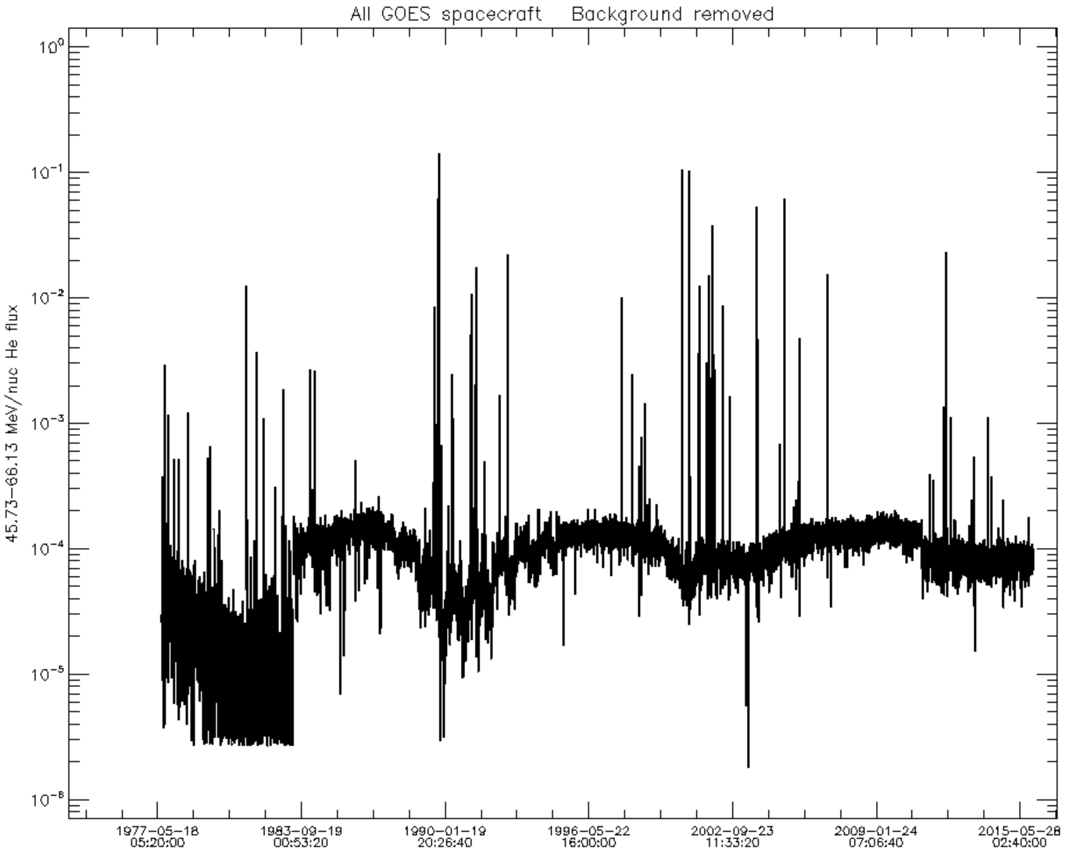

FIGURE 45 DAILY AVERAGE FLUX FOR CHANNEL 7 OF THE HE REFERENCE DATASET

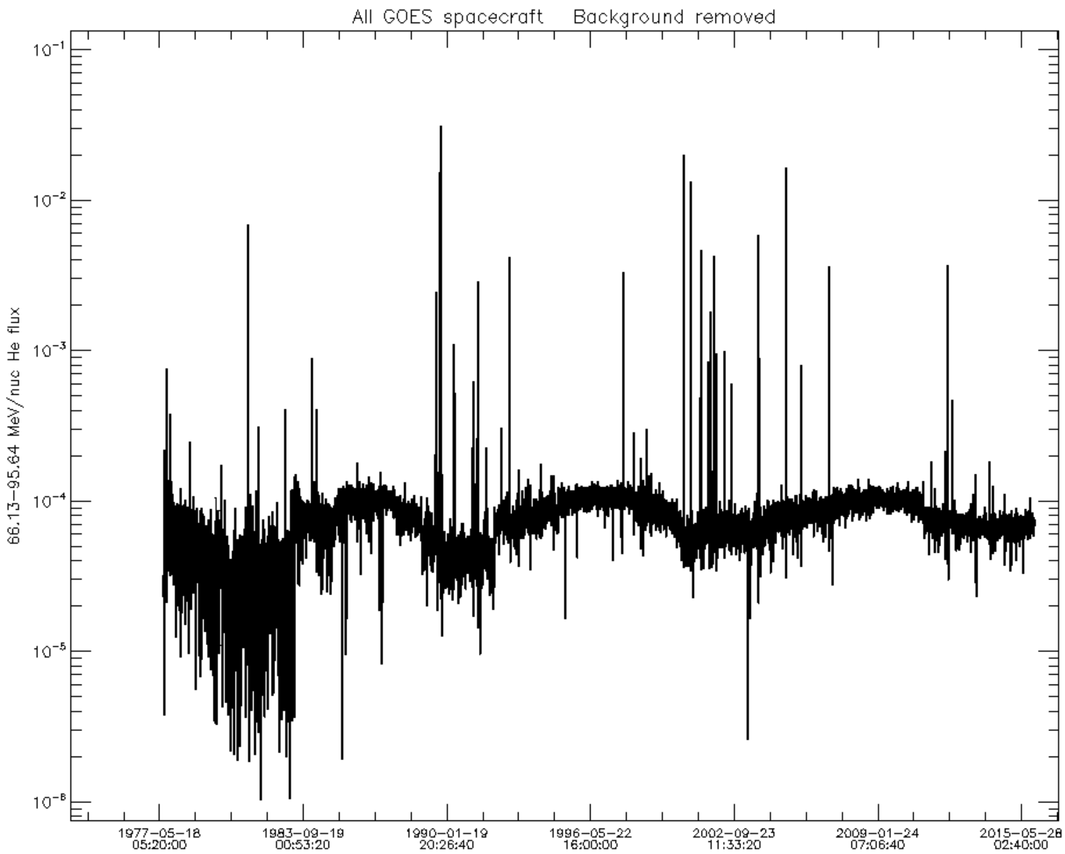

FIGURE 46 DAILY AVERAGE FLUX FOR CHANNEL 8 OF THE HE REFERENCE DATASET

In hindsight, it appears that steps 3–5 in the procedure outlined above tend to remove too many non-background fluxes in the descending phase of some events. This is illustrated in Figure 47, which shows the He reference data for the August 1998 event (the effect is more clearly seen in the H data, which are shown in Figure 48).

An improved procedure consists of replacing steps 3–5 by the following rule: if a flux value at least 20% above the background level, subtract the background flux level; in all other cases, set the flux to zero. Figure 49 and Figure 50 show the He and H data, respectively, obtained with the updated background subtraction procedure for the August 1998 event. The original, very evident gaps in the H data have now disappeared, and the He data in the descending phase are now better populated. It is recommended to use the updated procedure for the next release of the reference datasets.

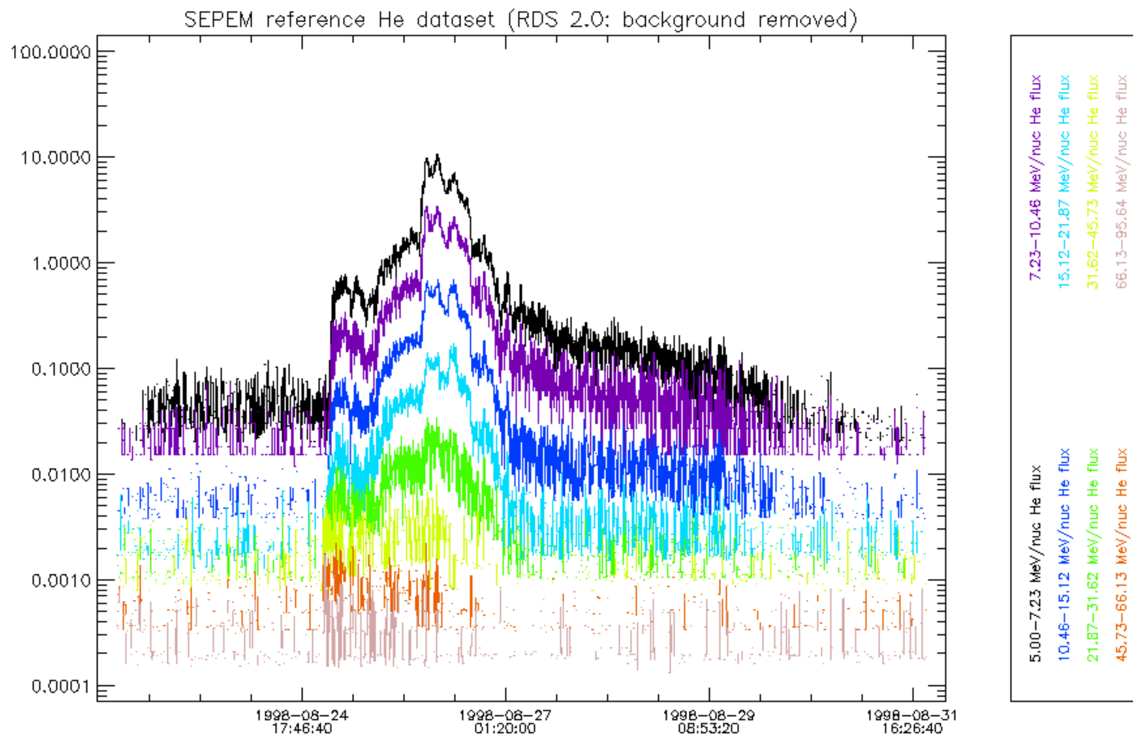

FIGURE 47 HE REFERENCE DATASET FOR THE AUG 1998 EVENT, USING THE CURRENT BACKGROUND SUBTRACTION PROCEDURE

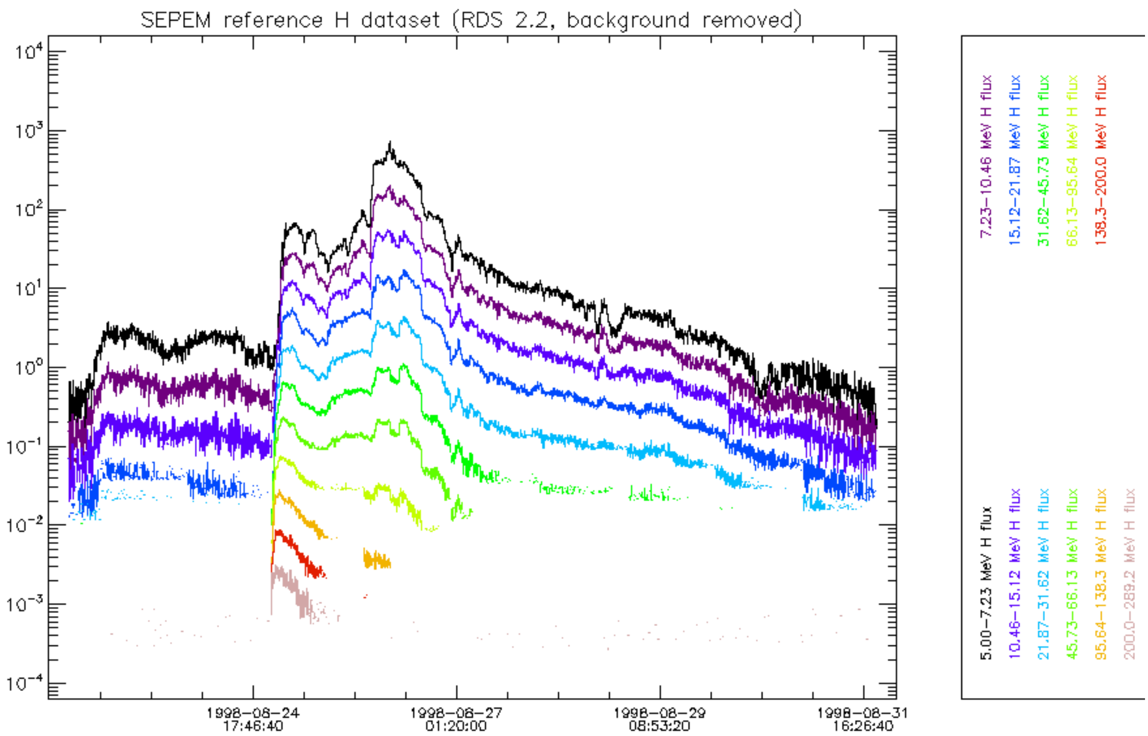

FIGURE 48 H REFERENCE DATASET FOR THE AUG 1998 EVENT, USING THE CURRENT BACKGROUND SUBTRACTION PROCEDURE

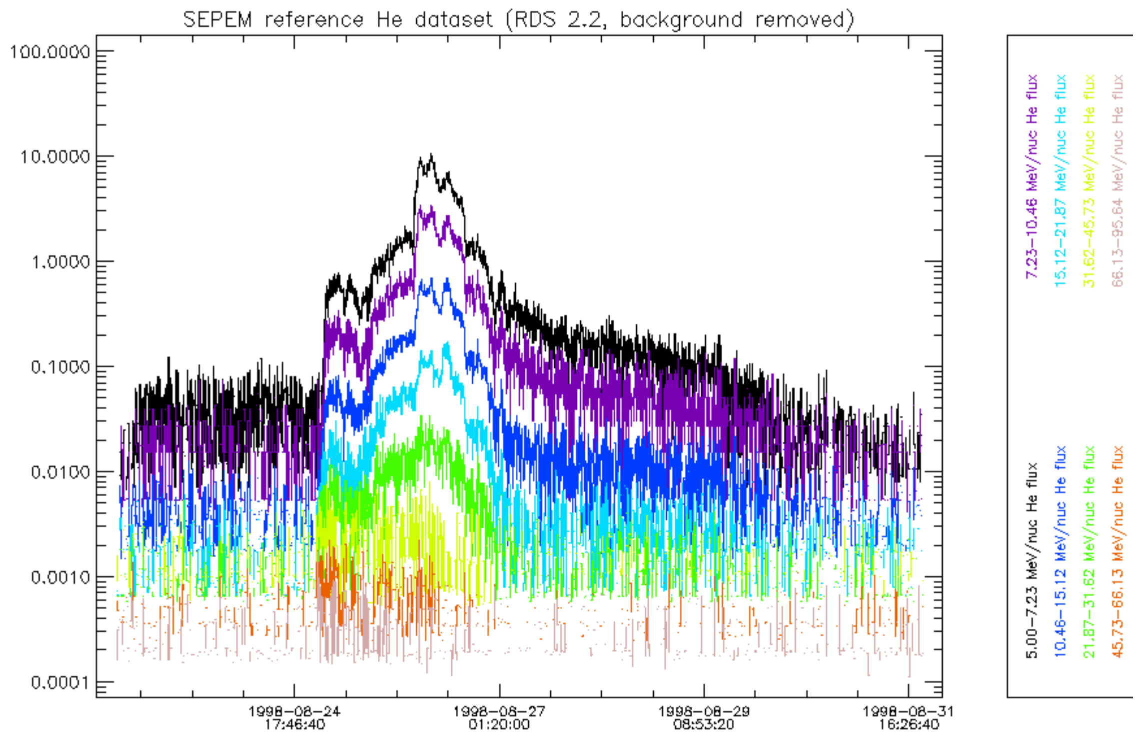

FIGURE 49 HE REFERENCE DATASET FOR THE AUG 1998 EVENT, USING THE UPDATED BACKGROUND SUBTRACTION PROCEDURE

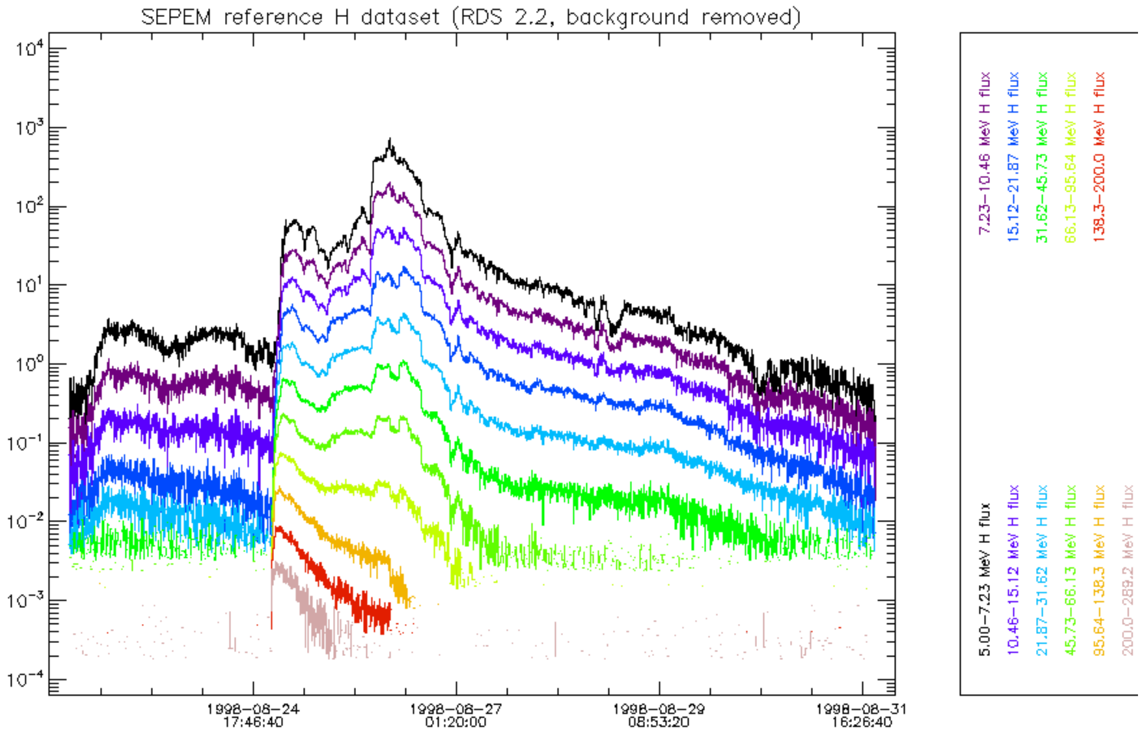

FIGURE 50 H REFERENCE DATASET FOR THE AUG 1998 EVENT, USING THE UPDATED BACKGROUND SUBTRACTION PROCEDURE

Appendix A Fraction of NULL values in the IMP8/GME He dataset

The table in this appendix contains a list of the events in the SEPEM reference event list and the number of NULL and non-NULL entries for each He channel in the IMP8/GME dataset (see Table 1). The fraction of the NULL entries with respect to the total number of entries per channel is also listed (in pct).