

The philosophy that we promote by providing this material is that the space engineering community should standardize methods of creating and applying statistical models and approve reference data sets. Model details should be open so that methods and results can be reproduced. We hope that the current paper, which can be seen as a continuation of the pioneering work from Feynman et al.^{1,7} and which includes all details for reproducing the parameter estimate and the model generation, will contribute to raise interest for such an approach.

Furthermore, the method of error analysis, the data quality check procedure, and the list of events attached in the Appendices are general enough to be applicable to check other models like the ones from King,⁴ Nymmik,³ or Xapsos et al.⁵ The later model of cumulative fluence from Xapsos et al.⁵ should be less sensitive to data errors and to the structure of the events because it is based on yearly averaged fluence. A thorough analysis of this model is beyond the scope of the present paper but should be foreseen in the near future.

Appendix A: Solar Proton Events

Table A1 Solar proton events from 1 January 1974 to May 2002

Index	Start date (mm/dd/yy)	Stop date (mm/dd/yy)	Duration, days	Fluence >10 MeV, cm ⁻²	Reference
1	06/09/74	06/10/74	1	1.69e+06	IMP8/GME ^a
2	07/03/74	07/09/74	6	3.56e+08	IMP8/GME ^{a,b}
3	09/11/74	09/17/74	6	2.67e+08	IMP8/GME ^{a,b}
4	09/20/74	09/28/74	8	1.38e+08	IMP8/GME ^{a,b,c}
5	11/05/74	11/07/74	2	1.36e+07	IMP8/GME ^a
6	08/21/75	08/23/75	2	5.02e+06	IMP8/GME ^a
7	04/30/76	05/03/76	3	1.01e+08	IMP8/GME ^{a,b}
8	08/22/76	08/24/76	2	8.45e+06	IMP8/GME ^a
9	09/09/77	09/15/77	6	1.54e+07	IMP8/GME ^a
10	09/17/77	09/22/77	5	3.50e+08	IMP8/GME ^{a,b,c}
11	09/24/77	09/28/77	4	8.82e+07	IMP8/GME ^{a,b}
12	10/12/77	10/13/77	1	2.33e+06	IMP8/GME ^a
13	11/22/77	11/26/77	4	3.00e+08	IMP8/GME ^{a,b}
14	01/02/78	01/05/78	3	5.43e+06	IMP8/GME ^a
15	02/13/78	02/18/78	5	1.74e+09	IMP8/GME ^{a,b}
16	04/08/78	04/09/78	1	1.09e+06	IMP8/GME ^a
17	04/11/78	04/14/78	3	4.81e+07	IMP8/GME ^{a,b,c}
18	04/17/78	05/10/78	23	2.35e+09	IMP8/GME ^{a,b,d}
19	05/31/78	06/03/78	3	1.44e+07	IMP8/GME ^{a,b}
20	06/23/78	06/26/78	3	5.17e+07	IMP8/GME ^a
21	07/12/78	07/16/78	4	2.08e+07	IMP8/GME ^{a,b}
22	09/08/78	09/09/78	1	1.54e+06	IMP8/GME ^a
23	09/23/78	09/29/78	6	3.32e+09	IMP8/GME ^{a,b}
24	10/09/78	10/11/78	2	7.82e+06	IMP8/GME ^a
25	11/10/78	11/13/78	3	1.79e+07	IMP8/GME ^{a,b}
26	12/12/78	12/14/78	2	2.58e+06	IMP8/GME ^a
27	02/17/79	02/20/79	3	1.20e+07	IMP8/GME ^a
28	03/03/79	03/06/79	3	8.56e+06	IMP8/GME ^a
29	04/03/79	04/06/79	3	2.04e+07	IMP8/GME ^{a,b}
30	06/06/79	06/10/79	4	2.96e+08	IMP8/GME ^{a,b}
31	07/06/79	07/09/79	3	1.83e+07	IMP8/GME ^{a,b}
32	08/07/79	08/08/79	1	1.18e+06	IMP8/GME ^a
33	08/19/79	08/30/79	11	6.40e+08	IMP8/GME ^{a,b}
34	09/09/79	09/13/79	4	5.26e+06	IMP8/GME ^a
35	09/15/79	09/29/79	14	3.11e+08	IMP8/GME ^{a,b,c}
36	11/16/79	11/18/79	2	4.16e+07	IMP8/GME ^{a,b}
37	01/11/80	01/12/80	1	1.22e+06	IMP8/GME ^a
38	02/07/80	02/08/80	1	1.31e+06	IMP8/GME ^a
39	04/04/80	04/06/80	2	5.36e+06	IMP8/GME ^a
40	07/18/80	07/26/80	8	1.48e+08	IMP8/GME ^{a,b}
41	08/07/80	08/08/80	1	1.62e+06	IMP8/GME
42	10/15/80	10/21/80	6	2.95e+07	IMP8/GME ^{a,b}
43	11/15/80	11/18/80	3	4.37e+06	IMP8/GME ^a
44	11/24/80	11/25/80	1	4.87e+06	IMP8/GME ^a
45	11/30/80	12/01/80	1	1.83e+06	IMP8/GME ^{a,c}
46	03/30/81	04/06/81	7	7.56e+08	IMP8/GME ^{a,b}
47	04/10/81	04/13/81	3	6.42e+07	IMP8/GME ^{a,b}
48	04/15/81	04/19/81	4	1.17e+07	IMP8/GME ^{a,b,c}
49	04/24/81	05/21/81	27	1.06e+09	IMP8/GME ^{a,b,d}
50	07/20/81	07/26/81	6	8.41e+07	IMP8/GME ^{a,b}
51	08/09/81	08/11/81	2	9.57e+06	IMP8/GME ^{a,b}
52	09/07/81	09/09/81	2	7.03e+06	IMP8/GME ^a
53	09/19/81	09/25/81	6	1.18e+07	IMP8/GME ^{a,b}
54	10/08/81	10/21/81	13	1.85e+09	IMP8/GME ^{a,b}
55	11/11/81	11/12/81	1	1.57e+06	IMP8/GME ^a
56	12/06/81	12/08/81	2	4.73e+06	IMP8/GME ^a
57	12/10/81	12/12/81	2	6.95e+07	IMP8/GME ^{a,b,c}

(Continued)

Table A1 Solar proton events from 1 January 1974 to May 2002 (continued)

Index	Start date (mm/dd/yy)	Stop date (mm/dd/yy)	Duration, days	Fluence > 10 MeV, cm ⁻²	Reference
58	12/28/81	12/30/81	2	5.12e+06	IMP8/GME ^a
59	01/31/82	02/09/82	9	1.03e+09	IMP8/GME ^{a,b}
60	03/07/82	03/09/82	2	8.92e+06	IMP8/GME ^{a,b}
61	06/07/82	06/17/82	10	5.21e+07	IMP8/GME ^a
62	06/28/82	06/29/82	1	2.42e+06	IMP8/GME
63	07/11/82	07/20/82	9	1.52e+09	IMP8/GME ^{a,b}
64	07/22/82	07/26/82	4	1.15e+08	IMP8/GME ^{a,b}
65	09/05/82	09/07/82	2	1.45e+07	IMP8/GME ^{a,b}
66	11/22/82	12/22/82	30	1.08e+09	IMP8/GME ^{a,b,d}
67	12/26/82	12/31/82	5	2.39e+08	IMP8/GME ^{a,b}
68	02/03/83	02/06/83	3	8.29e+07	IMP8/GME ^{a,b}
69	06/15/83	06/18/83	3	1.45e+07	IMP8/GME ^{a,b}
70	02/01/84	02/02/84	1	1.24e+06	IMP8/GME ^a
71	02/16/84	02/24/84	8	1.43e+08	IMP8/GME ^{a,b,d}
72	03/13/84	03/17/84	4	2.82e+07	IMP8/GME ^{a,b}
73	04/25/84	05/07/84	12	1.03e+09	IMP8/GME ^{a,b,d}
74	05/24/84	05/25/84	1	2.72e+06	IMP8/GME
75	01/22/85	01/24/85	2	5.86e+06	IMP8/GME ^a
76	04/24/85	04/28/85	4	7.95e+07	IMP8/GME ^{a,b}
77	07/09/85	07/10/85	1	1.53e+07	IMP8/GME ^{a,b}
78	02/05/86	02/12/86	7	1.29e+08	IMP8/GME ^b
79	02/14/86	02/19/86	5	1.76e+08	IMP8/GME ^b
80	03/06/86	03/08/86	2	3.97e+06	IMP8/GME
81	11/08/87	11/10/87	2	2.81e+07	GOES7 ^e
82	12/30/87	01/01/88	2	5.46e+06	GOES7
83	01/03/88	01/07/88	4	8.78e+07	GOES7
84	03/26/88	03/27/88	1	2.80e+06	GOES7
85	06/30/88	07/01/88	1	3.27e+06	GOES7
86	08/25/88	08/31/88	6	1.41e+07	GOES7
87	10/05/88	10/06/88	1	1.18e+06	GOES7
88	10/12/88	10/13/88	1	2.13e+06	GOES7
89	11/08/88	11/11/88	3	7.18e+06	GOES7
90	11/14/88	11/15/88	1	1.98e+06	GOES7
91	12/15/88	12/20/88	5	1.88e+07	GOES7
92	01/05/89	01/06/89	1	2.40e+06	GOES7
93	03/08/89	03/21/89	13	1.05e+09	GOES7 ^e
94	03/23/89	03/25/89	2	1.00e+07	GOES7
95	04/11/89	04/17/89	6	2.01e+08	GOES7 ^e
96	04/23/89	04/24/89	1	2.62e+06	GOES7
97	05/01/89	05/09/89	8	4.05e+07	GOES7 ^e
98	05/22/89	05/29/89	7	2.20e+07	GOES7
99	06/18/89	06/20/89	2	3.58e+06	GOES7
100	06/30/89	07/02/89	2	4.21e+06	GOES7
101	07/25/89	07/27/89	2	1.59e+07	GOES7
102	08/12/89	09/06/89	25	7.84e+09	GOES7 ^e
103	09/12/89	09/17/89	5	2.81e+07	GOES7
104	09/29/89	10/13/89	14	3.86e+09	GOES7 ^e
105	10/19/89	11/10/89	22	1.91e+10	GOES7 ^e
106	11/15/89	11/17/89	2	1.25e+07	GOES7
107	11/27/89	12/05/89	8	2.20e+09	GOES7 ^e
108	03/19/90	03/22/90	3	7.24e+08	GOES7 ^e
109	03/29/90	03/30/90	1	3.31e+06	GOES7
110	04/07/90	04/10/90	3	2.00e+07	GOES7
111	04/12/90	04/13/90	1	1.21e+06	GOES7
112	04/16/90	04/23/90	7	3.29e+07	GOES7
113	04/28/90	04/30/90	2	7.23e+07	GOES7 ^e
114	05/08/90	05/10/90	2	2.74e+06	GOES7
115	05/16/90	06/01/90	16	3.60e+08	GOES7 ^e
116	06/12/90	06/14/90	2	3.60e+07	GOES7
117	07/26/90	08/06/90	11	1.98e+08	GOES7 ^e
118	08/13/90	08/15/90	2	3.56e+06	GOES7
119	01/28/91	02/02/91	5	8.70e+07	GOES7 ^e
120	02/08/91	02/10/91	2	4.55e+06	GOES7
121	02/25/91	02/27/91	2	4.47e+06	GOES7
122	03/13/91	03/16/91	3	1.21e+07	GOES7
123	03/23/91	04/09/91	17	9.11e+09	GOES7 ^e
124	04/23/91	04/24/91	1	2.52e+06	GOES7
125	05/10/91	05/15/91	5	1.37e+08	GOES7 ^e
126	05/19/91	05/28/91	9	2.47e+07	GOES7
127	05/31/91	06/21/91	21	3.20e+09	GOES7 ^e
128	06/30/91	07/13/91	13	1.16e+09	GOES7 ^e
129	08/26/91	08/31/91	5	1.25e+08	GOES7 ^e
130	09/07/91	09/08/91	1	1.30e+06	GOES7

(Continued)

Table A1 Solar proton events from 1 January 1974 to May 2002 (continued)

Index	Start date (mm/dd/yy)	Stop date (mm/dd/yy)	Duration, days	Fluence > 10 MeV, cm ⁻²	Reference
131	09/30/91	10/03/91	3	1.33e+07	GOES7
132	10/28/91	11/01/91	4	2.94e+07	GOES7
133	12/29/91	12/30/91	1	1.09e+06	GOES7
134	02/07/92	02/09/92	2	4.72e+07	GOES7
135	02/27/92	02/28/92	1	1.90e+06	GOES7
136	03/08/92	03/09/92	1	2.62e+06	GOES7
137	03/15/92	03/18/92	3	8.83e+06	GOES7
138	05/09/92	05/14/92	5	5.84e+08	GOES7 ^e
139	05/24/92	05/25/92	1	1.13e+06	GOES7
140	06/25/92	07/02/92	7	2.85e+08	GOES7 ^e
141	08/06/92	08/08/92	2	6.99e+06	GOES7
142	10/30/92	11/08/92	9	3.47e+09	GOES7 ^e
143	11/29/92	11/30/92	1	2.10e+06	GOES7
144	03/04/93	03/09/93	5	1.46e+07	GOES7
145	03/12/93	03/15/93	3	2.17e+07	GOES7
146	06/07/93	06/08/93	1	1.49e+06	GOES7
147	02/20/94	02/23/94	3	8.01e+08	GOES7 ^e
148	10/20/94	10/21/94	1	1.34e+07	GOES7
149	08/12/95	08/13/95	1	1.32e+06	GOES7
150	10/20/95	10/22/95	2	2.29e+07	GOES8
151	11/04/97	11/11/97	7	4.89e+08	GOES8 ^{d,f}
152	04/20/98	04/27/98	7	1.62e+09	GOES8 ^f
153	04/30/98	05/11/98	11	1.00e+08	GOES8 ^{d,f}
154	06/17/98	06/19/98	2	2.55e+06	GOES8
155	08/23/98	09/01/98	9	5.69e+08	GOES8
156	09/24/98	09/26/98	2	4.30e+06	GOES8
157	09/30/98	10/04/98	4	5.60e+08	GOES8
158	10/19/98	10/20/98	1	1.85e+06	GOES8
159	11/06/98	11/09/98	3	8.39e+06	GOES8
160	11/14/98	11/18/98	4	1.37e+08	GOES8
161	01/21/99	01/25/99	4	1.67e+07	GOES8
162	04/24/99	04/27/99	3	1.90e+07	GOES8 ^f
163	05/05/99	05/08/99	3	1.24e+07	GOES8 ^f
164	05/27/99	05/28/99	1	2.15e+06	GOES8
165	06/02/99	06/08/99	6	9.06e+07	GOES8 ^{d,f}
166	02/18/00	02/20/00	2	5.10e+06	GOES8 ^f
167	04/04/00	04/07/00	3	3.61e+07	GOES8 ^f
168	06/07/00	06/13/00	6	8.27e+07	GOES8 ^{d,f}
169	06/26/00	06/27/00	1	1.21e+06	GOES8
170	07/13/00	07/24/00	11	1.65e+10	GOES8 ^{d,f}
171	07/28/00	07/30/00	2	6.37e+06	GOES8 ^f
172	09/12/00	09/18/00	6	2.66e+08	GOES8 ^f
173	10/16/00	10/19/00	3	1.56e+07	GOES8 ^f
174	10/25/00	10/28/00	3	1.20e+07	GOES8 ^f
175	10/31/00	11/02/00	2	3.74e+06	GOES8
176	11/09/00	11/20/00	11	1.08e+10	GOES8
177	11/24/00	12/04/00	10	4.75e+08	GOES8 ^{d,f}
178	01/22/01	01/24/01	2	3.26e+06	GOES8
179	01/28/01	01/31/01	3	3.34e+07	GOES8 ^f
180	03/27/01	04/22/01	26	1.65e+09	GOES8 ^{d,f}
181	04/27/01	04/29/01	2	4.47e+06	GOES8 ^f
182	05/07/01	05/10/01	3	2.34e+07	GOES8 ^f
183	05/20/01	05/22/01	2	4.99e+06	GOES8
184	06/15/01	06/18/01	3	2.18e+07	GOES8 ^f
185	08/10/01	08/11/01	1	6.05e+06	GOES8 ^f
186	08/16/01	08/26/01	10	2.77e+08	GOES8 ^f
187	09/15/01	09/16/01	1	2.52e+06	GOES8 ^f
188	09/24/01	10/12/01	18	8.21e+09	GOES8 ^{d,f}
189	10/19/01	10/26/01	7	2.73e+07	GOES8 ^{d,f}
190	11/04/01	11/13/01	9	1.50e+10	GOES8 ^f
191	11/18/01	12/01/01	13	7.89e+09	GOES8 ^{d,f}
192	12/26/01	01/08/02	13	6.29e+08	GOES8 ^f
193	01/10/02	01/19/02	9	1.42e+08	GOES8
194	01/27/02	01/28/02	1	2.07e+06	GOES8
195	02/20/02	02/21/02	1	1.76e+06	GOES8
196	03/16/02	03/24/02	8	6.23e+07	GOES8
197	04/17/02	04/29/02	12	2.85e+09	GOES8
198	05/01/02	05/02/02	1	1.45e+09	GOES8
199	05/22/02	05/25/02	3	9.29e+07	GOES8

^aAlso identified by Feynman et al.⁷ ^bAlso identified by Goswami et al.¹⁵ ^cIncluded in the preceding event in the reference. ^dDivided into several events in the reference. ^eAlso identified by Sauer (private communication, 1995). ^fAlso identified by CDAW.