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Polar Geophysical Institute

SOLAR COSMIC RAY PROTON FLUXES IN THE EARTH'S ORBIT

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Abstract. A review on solar cosmic ray proton fluxes in the Earth's orbit outside its magnetosphere from 1956 till 2005 has been made. 338 solar proton events in which the fluence of protons of energies higher than 30 MeV had exceeded
10^5 cm^{-2} have been considered. The results of the analysis of proton event frequency and amplitude distribution and their energy spectra are presented. Essential irregularity of the proton flux source distribution on the Sun along the Carrington longitude and the longitude relative to the central meridian has been shown. The data on the decrease of solar proton event number and the total fluences of protons of various energies and the change of their spectra during the period of solar magnetic field sign change are presented.
The necessity of the permanent monitoring of various solar proton event parameters and the accompanying physical phenomena is pointed out.

General information

In this paper the data on solar cosmic ray proton fluxes in the Earth's orbit outside its magnetosphere in the period from 1956 till 2005 from various publications and Internet have been used (King J. H., 1974; Feynman J. et al., 1998, Akinyan S. T. et al., 1982; Bazilevskaya G. A. et al., 1990; Sladkova A. I. et al., 1998; http://nssdc.gsfc.nasa.gov/omniweb). 338 solar proton events, in which the fluence of protons of energies higher than 30 MeV had exceeded 10^5 cm^{-2} have been considered (Fig. 1).

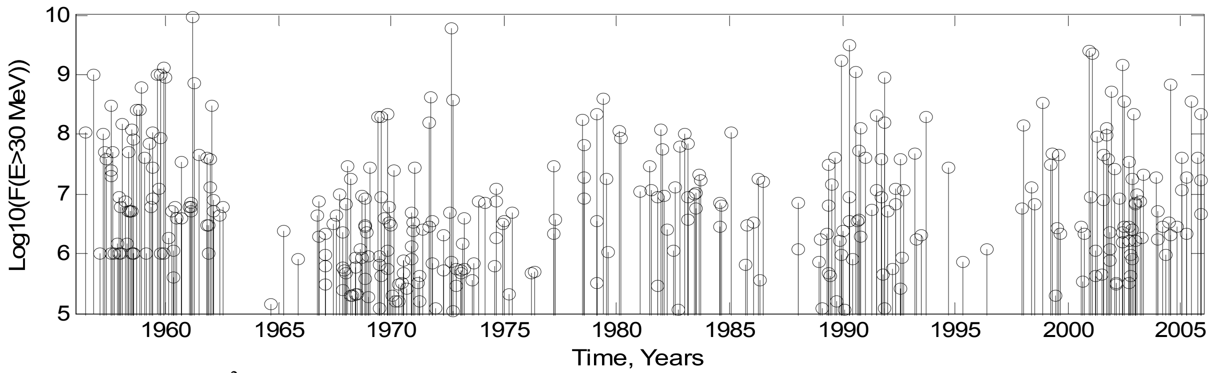

Fig. 1. Fluences (cm^{-2}) of protons of energies >30 MeV in 338 solar proton events in 19–23 solar cycles from 1956 till 2005 years.

Using these data proton fluences for the time intervals of 3 months, half a year, 1 year and above have been calculated, see Fig. 2 (Getselev I. V., Chuchkov E. A. et al., 2002; Getselev I. V., Okhlopkov V. P. et al., 2003).

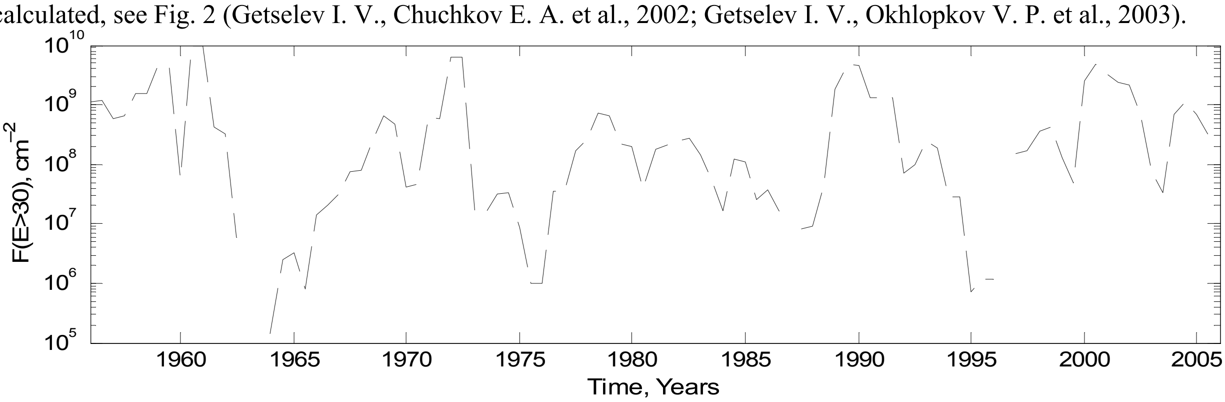

Fig. 2. Time dependence of 1-year fluences (cm^{-2}; calculated with a half-year time shift) of solar protons of energies >30 MeV in 19–23 solar cycles from 1956 till 2005 years.

Energy spectra

Energy distributions of the calculated solar proton fluences were considered. (Getselev I. V., Okhlopkov V. P., Chuchkov. E. A., 2005). They were found to be well approximated by the power functions. For example in Fig. 3 solar proton energy spectra for various 3-month time intervals corresponding to different solar cycles are presented (in brackets after the year the months are given, for which the calculations have been made). The value of the spectra exponent γ changes in the interval from –0.8 till –2.4.

The computations showed that γ experienced 11-year variations; its variation interval decreased and its value tended to constant equal to about –1 with the increase of the time interval, for which the fluences had been calculated.

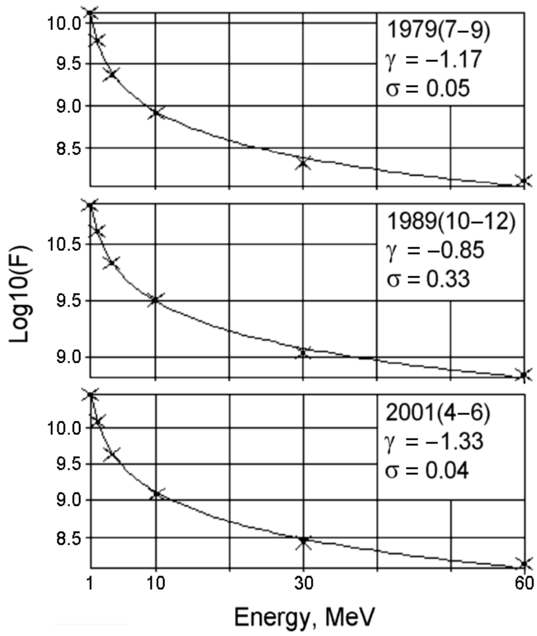

Fig. 3. Examples of 3-month proton fluence energy spectra approximation by the power functions.

Solar proton event source heliolongitude distributions

The solar proton event number and fluence heliolongitude distribution in each of the last 5 solar cycles and total for 19–23 cycles have been considered (Getselev I. V., Okhlopkov V. P., Chuchkov E. A., 2003). In Fig. 4 solar proton event number and fluence distributions for the energies >30 MeV over their source longitude relative to the central meridian are shown. Fluence values are normalized to the total value for the whole range of longitudes. In both plots peaks of the distributions are located in the longitude range near 0° relative to the central meridian.

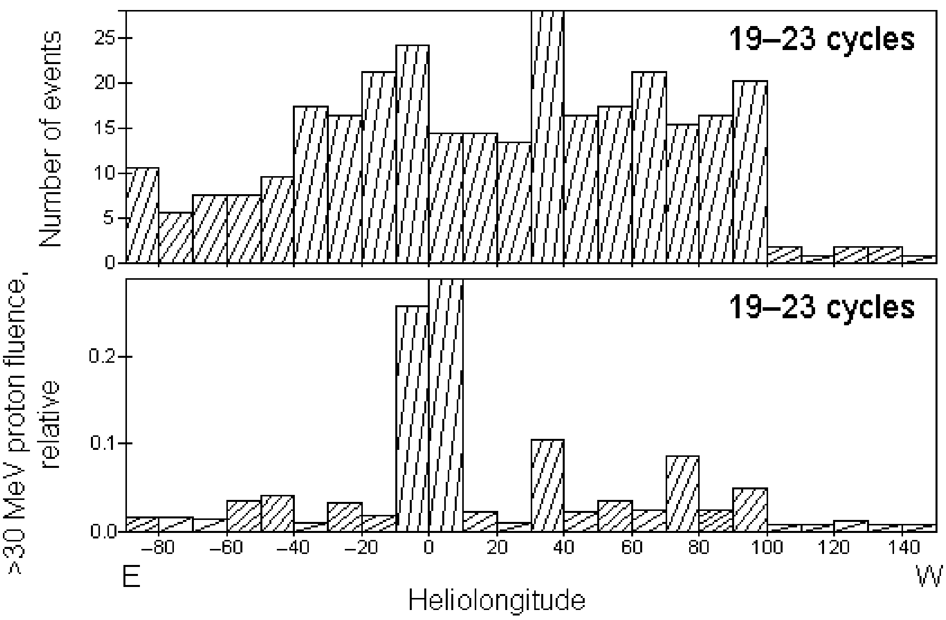

Fig. 4. Solar proton event number (upper graphic) and fluence (lower graphic) distribution for the energies >30 MeV over their source longitude relative to the central meridian in 19–23 solar cycles.

In Fig. 5 distributions of fluences of solar protons of energies >30 MeV in 19–23 solar cycles along the Carrington longitude are shown. The irregularity of distributions can be clearly seen. The location of active longitudes changes from cycle to cycle. There exists an extensive in terms of time (all 5 solar cycles) and the longitude range (80°–170°) interval of passive longitudes.

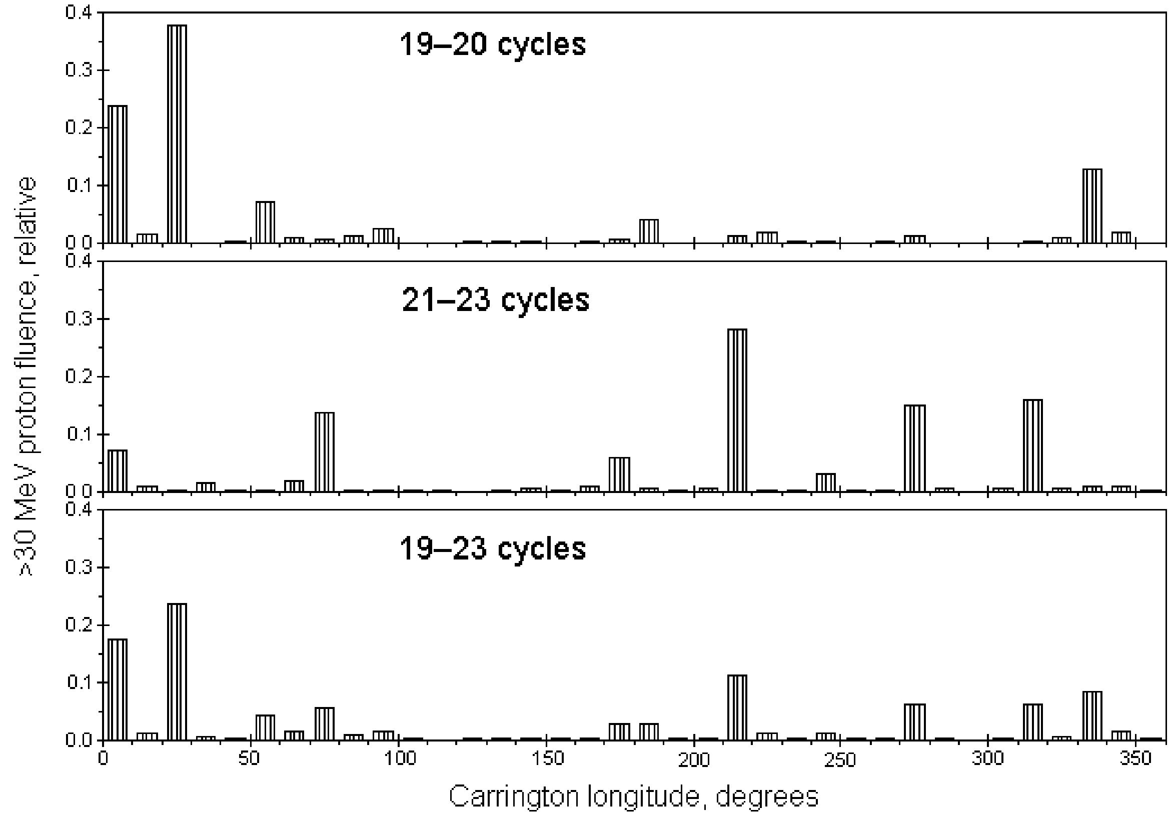

Fig. 5. Distributions of fluences of solar protons of energies >30 MeV along the Carrington longitude in 19–20, 21–23 and total for 19–23 solar cycles.

Solar protons during the periods of solar magnetic field sign change

Solar proton fluences, proton event number and energy spectra exponent before, during and after the solar magnetic field sign change have been considered (Getselev I. V., Okhlopkov V. P., Chuchkov E. A., 2004). Proton fluences and the number of solar proton events during the periods of solar magnetic field inversion are lower and their spectra are softer, then during the equal periods of time before and after that (see Table 1).

Table 1. The fluences of solar protons of energies >10 and >30 MeV, solar proton event number and energy spectra exponent γ before, during and after the periods of solar magnetic field sign change.

Cycles		Before		**During**		After	
21	Time	01.10.1978–30.11.1979		**01.12.1979–31.01.1981**		01.02.1981–31.03.1982	
	No of events, γ	8	–1.44	**2**	**–1.79**	11	–1.37
	F(>10, >30)	$0.11 \cdot 10^{10}$	$0.22 \cdot 10^{9}$	**$0.14 \cdot 10^{9}$**	**$0.12 \cdot 10^{8}$**	$0.18 \cdot 10^{10}$	$0.33 \cdot 10^{9}$
22	Time	01.04.1989–28.02.1990		**01.03.1990–31.01.1991**		01.02.1991–31.12.1991	
	No of events, γ	19	–0.87	**12**	**–1.33**	16	–1.13
	F(>10, >30)	$0.19 \cdot 10^{11}$	0.61E$\cdot 10^{10}$	**$0.11 \cdot 10^{10}$**	**$0.18 \cdot 10^{9}$**	$0.54 \cdot 10^{10}$	$0.13 \cdot 10^{10}$
23	Time	01.04.1999–31.10.1999		**01.11.1999–31.05.2000**		01.06.2000–31.12.2000	
	No of events, γ	4	–1.62	**2**	**–2.15**	11	–0.9
	F(>10, >30)	$0.88 \cdot 10^{8}$	$0.77 \cdot 10^{7}$	**$0.20 \cdot 10^{8}$**	**$0.47 \cdot 10^{6}$**	$0.15 \cdot 10^{11}$	$0.48 \cdot 10^{10}$
Total	No of events	31		**16**		38	
	F(>10, >30)	$0.2 \cdot 10^{11}$	$0.63 \cdot 10^{10}$	**$0.13 \cdot 10^{10}$**	**$0.19 \cdot 10^{9}$**	$0.22 \cdot 10^{11}$	$0.64 \cdot 10^{10}$

Solar proton fluence dependence from the solar cycle phase

1-year solar proton fluences relative to the solar cycle maximum were considered (Podzolko M. V., Getselev I. V., 2005). From Fig. 6 it follows that inside the interval of (–2; +4) years relative to the solar maximum the fluences are basically higher, and outside this interval – lower than the threshold value, corresponding to the mean of the fluence logarithms during the whole period of observations.

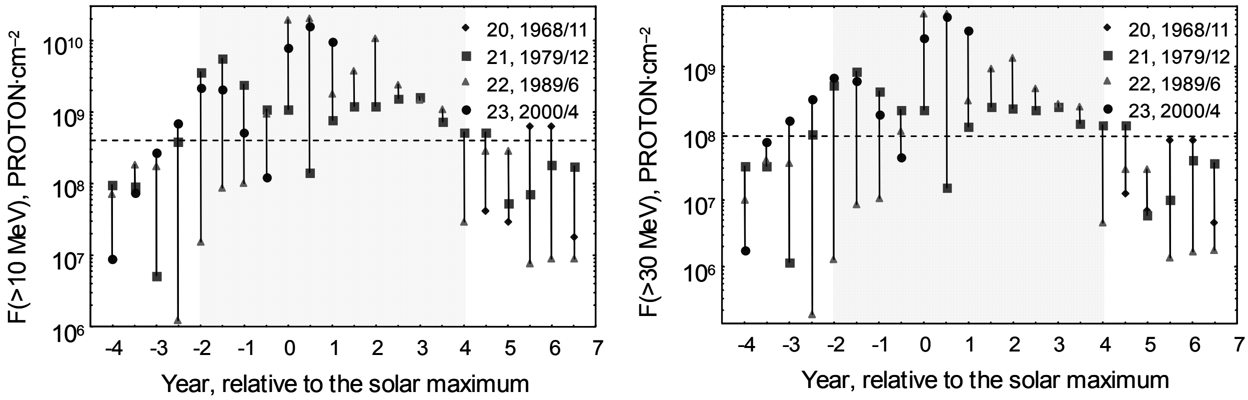

Fig. 6. 1-year fluences of solar protons of energies >10 and >30 MeV calculated with a half-year time shift relative to the solar cycle maximum in 20–23 solar cycles.

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