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COSMIC RAYS AND SOLAR-TERRESTRIAL RELATIONS

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Abstract. The semi-annual fluences of solar cosmic rays are suggested to use for the space weather and solar-terrestrial relations forecasting and analysis. For these purposes the statistical analysis of measured by satellites solar and galactic cosmic ray fluxes was performed. The temporal and energy distribution of semi-annual solar proton fluences and summary semi-annual solar and galactic proton fluences have been considered. Peculiarities of these distributions are discussed.

Introduction

It is well known the significant effect on the space and terrestrial weather of the high-energy charged particles entering the earth’s environment from interplanetary space. In a number of works this influence is studied during solar proton events or Forbush decreases of galactic cosmic rays. However in many cases essential difficulties in interpretation of the obtained results appear. As can be shown the cosmic ray effect on weather processes is more clearly seen with using the summary cosmic ray fluences on a base of sufficiently long period of time.

Initial data

The solar cosmic ray flux data for a period since 1956 till 2001 were used for analysis (Fig. 1). Data on the 19-th solar activity cycle were obtained by indirect way (balloons and riometeres) [1, 2], on the 20-th cycle, by the satellite-based equipment on various spacecrafts [2, 3], on 21–23 cycles, by the IMP-8 spacecraft [http://nssdc.gsfc.nasa.gov/space/.]. Data on fluences of protons of energies more than 30 MeV were chosen since we have the longest data set on them. Besides the data of IMP-8 on solar protons of energy more than 10 and 60 MeV were used in order to estimate the energy spectrums in the 21–23 solar cycles.

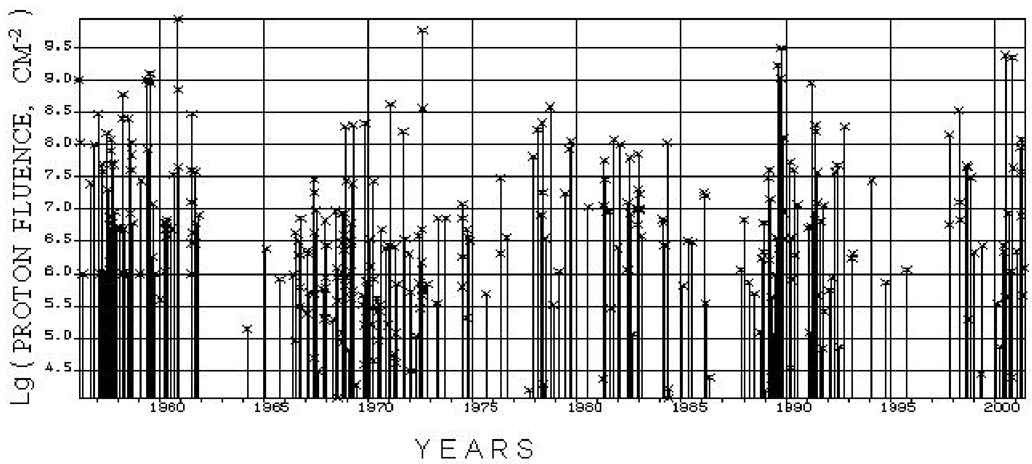

Fig. 1. Solar proton fluence variations during period of 1956–2001.

Results of calculations and discussion

Temporal distribution of semi-annual fluences of the protons of energies more than 30 MeV is shown in fig. 2. Contrary to Fig. 1 the certain correlation with the Wolf numbers (Fig.3) appears. In Fig.3 the half-year averaged daily Wolf numbers are shown.

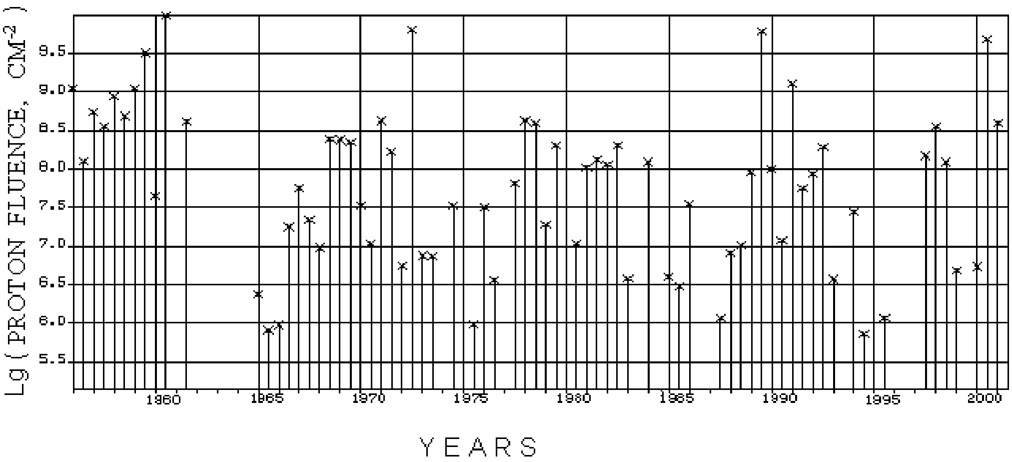

Fig. 2. Semi-annual fluences of protons of energy more than 30 MeV in 1956–2001.

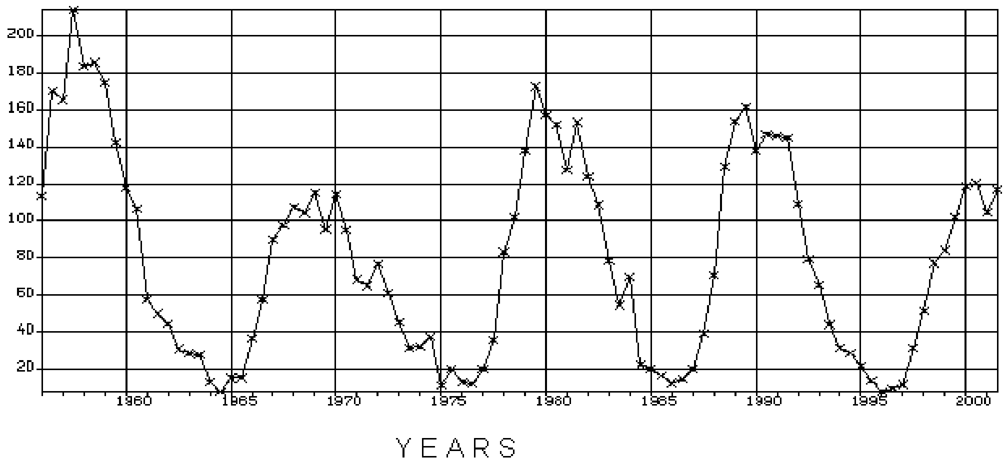

Fig. 3. Semi-annual means of sunspot numbers in 1956–2001.

In Fig. 4 the summary semi-annual fluences of solar and galactic protons of energies more than 30 MeV entered the near-earth's environment since 1956 till 2001 are shown. By shading the solar cosmic ray proton fluences are marked.

One can see that minimal fluence value is about 10^7 protons*cm^{-2} and solar cosmic rays enhance it up to about 10^{10}. The shown in Fig. 4 data confirm the expediency of using the summary fluences for analyzing the effect of solar and galactic cosmic rays on the weather. For example, considering only solar cosmic ray data we won't take into account fluences of almost $2*10^7$ protons*cm^{-2}.

It is rather important for our purposes to consider the frequency power spectrum of the proton fluence temporal distribution. The spectra were obtained by the Fourier transform method (Fig. 5 and 6). As can be seen the 11-year cycle is clearly seen (10.4 year peak on the spectra) both for the sum of galactic and solar cosmic ray fluences (Fig.5) and solar cosmic ray fluences only (Fig.6). Besides the 3–4 year cycles could be distinguished in fig.5 and 6 too. The 90 and 95% confidence levels are shown in Fig. 5 and 6. It should be mentioned that in our earlier study using another method of analysis the periods close to the indicated in Fig. 5 and 6 were found too.

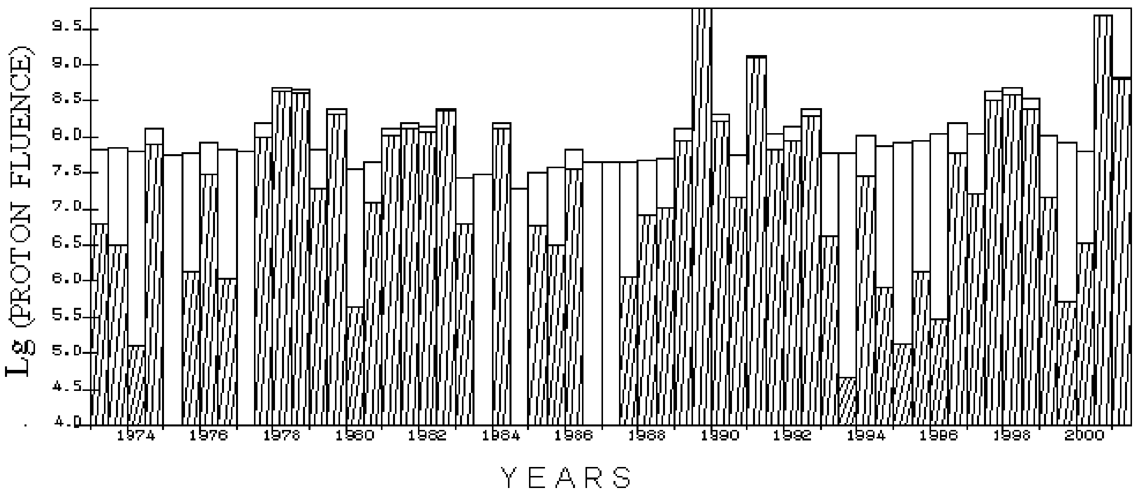

Fig. 4 Semi-annual fluences of protons of energy > 30 MeV in 1956–2001. Top level is the sum of solar and galactic proton fluences; shading marks the solar proton fluences only.

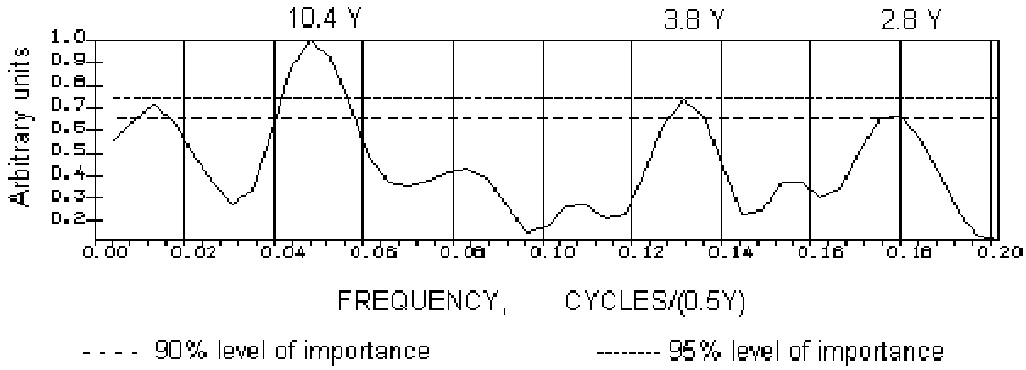

Fig. 5. Frequency spectra of the solar and galactic proton fluence of energy > 30 MeV.

None of the less importance is the study of proton fluence energy distribution. In Fig. 7 the exponents of the integral energetic spectra approximated by the power law are shown for protons of energies >10 MeV. The data in Fig. 7 illustrate strong averaging of the proton energy spectrum for semi-annual fluences. Thus while the power spectrum exponent for the separate solar proton events may be as high as 5 ÷ 6, for the semi-annual fluences it varies only within the range of 0.8 –1.8. The impact of galactic cosmic ray protons makes the spectrum slightly harder. As seen in Fig.7 the summary proton fluence spectral exponent lays within the range from –0.1 to –1.4.

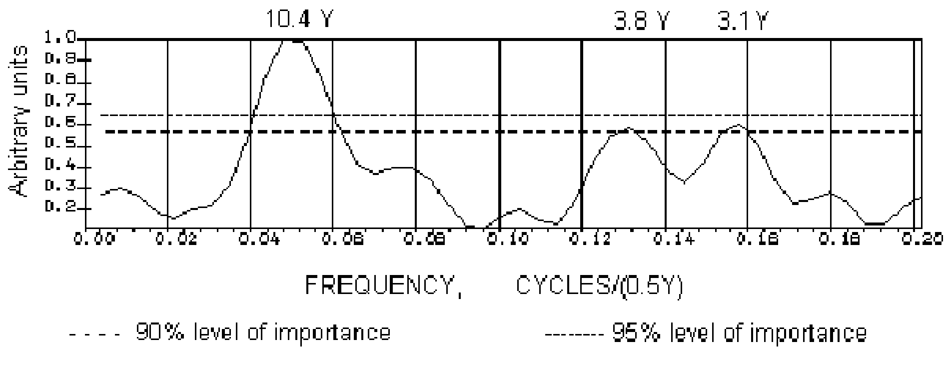

Fig. 6. Frequency spectra of solar proton fluence of energy > 30 MeV.

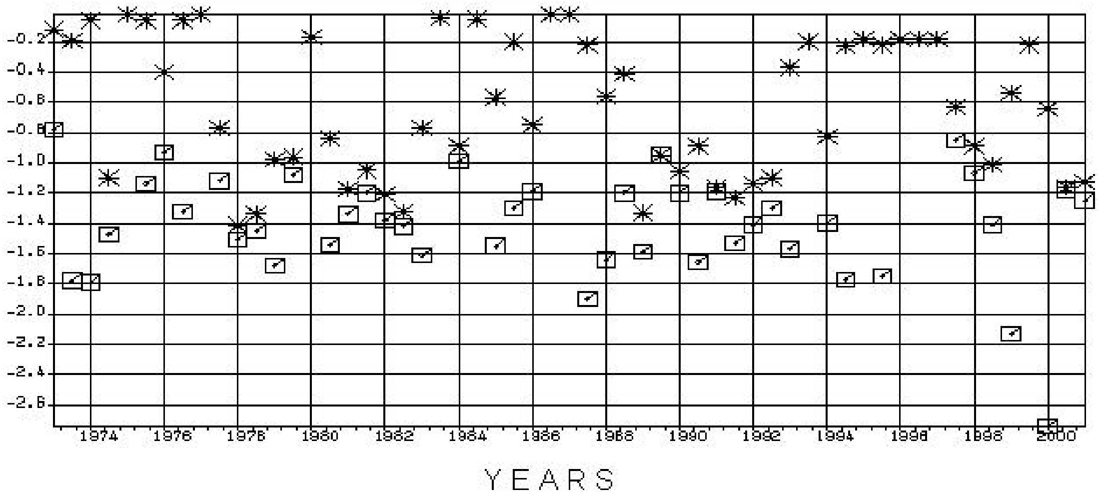

Fig. 7. The exponent of the integral energetic proton spectrum of energies > 10 MeV. Starlets are the sum of solar and galactic protons; squares are solar protons only.

Conclusions

1. For the study of cosmic ray effect on the space and terrestrial weather we suggest to use the summary solar and galactic cosmic ray fluences integrated over the long enough period of time (half a year and more).
2. The minimal value of semi-annual fluence during 1973–2001 was of order of 10^7 and the maximum is about 10^{10}.
3. The periods of 11 and 3-4 year long can be distinguished in the frequency power spectrum of the cosmic ray proton fluence temporal variations.
4. The energetic spectral exponent of summary semi-annual proton fluence (solar and galactic cosmic rays) lays within the range of –0.1 to –1.4, that is sufficiently less than the spectral exponent range for individual solar proton events.

We are concerned about continuing the study of protons of energies more than 100 MeV annual fluences.

References

1. Getselev I.V., Tkachenko V.I. Probability Estimation of the Solar Cosmic Ray Fluxes Observation on Earth's Orbit, "*Geomagnetism i aeronomia*", 1973, V. 13, ? 2, P. 208–211.
2. Feynman J., Armstrong T.P., Dao-Gibner L. and Silverman S.A. New Interplanetary Proton Fluence Model, "Journal of Spacecraft and Rockets", 1990, V. 4, P. 403.
3. Getselev I.V., Zubarev A.I., Podzolko M.V. Long-term Forecast of Solar Cosmic Rays, Memoirs of International Conference "Modern Problems of Solar Cyclicity, Main Astrophysical Observatory, Saint-Petersburg, Russia, 1997.