11- AND 22-YEAR VARIATIONS OF THE COSMIC RAY DENSITY AND OF THE SOLAR WIND SPEED

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ABSTRACT

Cosmic ray density variations for 17-21 solar activity cycles and the solar wind speed for 20-21 ones are investigated. The 22-year solar wind speed recurrence was found in even and odd cycles which allows to forecast it. The 22-year variations of cosmic ray density opposite to the solar wind speed and solar activity were found. The account of solar wind speed in 11-year variations significantly decreases the modulation region of cosmic rays with E = 10-20 GeV.

1. Introduction. Many authors [1-4] to investigate the nature of 11-year variations of cosmic ray density use solar activity and obtain the large sizes of modulation region. But according to the equation of transfer the agent modulating cosmic rays should be proportional to the solar wind speed. If the latter is not proportional to the solar activity then the conclusions on large sizes of cosmic ray modulation region will be incorrect.

2. Results. To study the regularities of the solar wind speed the geomagnetic activity (aa-index) was used taking into account their close relationship [5,6]. The averaged picture of geomagnetic and solar activities is presented in Fig.1 [7] where data for 1868-1977 were used. In the left the odd solar cycles, in the right the even ones are shown. From Fig.1 it is seen that on the average in odd cycles a close correlation with solar activity is observed and in even cycles - a bad one. Both in even and odd cycles the two maxima of geomagnetic activity are observed. The first maximum coincides with the solar activity maximum, the second one delays by 1 year in odd cycles and by 4 years in even ones. The solar wind speed should have the similar regularity which in 20 and 21 solar cycles was observed [8,9]. The second maximum of geomagnetic activity has 22-year recurrence either in even or odd cycles which allows to forecast it [6,7]. The next second maxima of geomagnetic activity and solar wind speed should be observed in 1996 and 2004.
Presented in Fig.1 picture of behaviour of geomagnetic activity and solar wind speed should significantly complicate the 11-year variation of cosmic ray density as it is was observed [10].

Here we continue the investigation of [10] for more

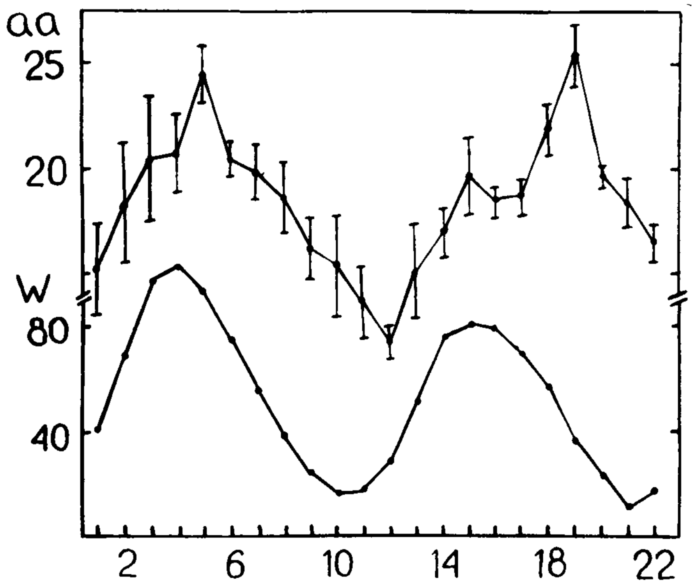

Fig.1. 22-year averaged data of aa-index and of Wolf numbers for 1868-1977

extend energy range of the observed cosmic ray variations. The ionization chamber data for 17-21 solar cycles and the neutron and balloon data for 19-21 ones were used. Correlation and regression coefficients a,b in the equations of type

$$\Delta I = a\Delta W + b\Delta aa,$$

where ΔI, ΔW, Δaa are deviations from mean values and are presented in the Table. The values of a total correlation coefficient R and values of

$$\sigma = \sqrt{\Sigma(\Delta I_{obs} - \Delta I_{cal})^2/n}$$

are also presented. From the Table it is clear that the account of the solar wind speed significantly improves the relationship. The correlation coefficient is 0.89 - 0.96. The calculated and observed values of I are shown in Fig.2 from which their good agreement is evident. As it is seen from the Table σ for ionization chamber is 0.2 - 0.4%, for neutron monitors $\sigma = 1.3$ - 2.7%, for balloons $\sigma = 3.7$ - 5.9% which is better by several times than obtained by other methods.

Table

Cycle	$r_{I,W}$	$r_{I,aa}$	$r_{W,aa}$	R	a	b	σ
			Ionization chamber, ΔI^k				
17	-0.88±0.08	-0.34±0.32	-0.03	0.95	-0.014	-0.083	0.2
18	-0.84±0.09	-0.66±0.17	0.39±0.26	0.92	-0.014	-0.098	0.4
19	-0.91±0.05	-0.93±0.04	0.85±0.08	0.96	-0.006	-0.107	0.3
20	-0.82±0.09	-0.35±0.25	-0.15±0.28	0.95	-0.012	-0.056	0.2
21	-0.79±0.14	-0.54±0.24	0.09	0.92	-0.010	-0.073	0.3
			Neutron monitor, ΔI^m				
19	-0.84±0.09	-0.91±0.05	-	0.92	-0.024	-0.865	2.7
20	-0.92±0.04	0.05	-	0.93	-0.090	-0.081	1.3
21	-0.70±0.14	-0.56±0.28	-	0.89	-0.066	-0.607	2.4
			Balloons, ΔI^c				
19	-0.95±0.04	-0.92±0.05	-	0.97	-0.096	-0.051	5.1
20	-0.91±0.05	0.06	-	0.92	-0.254	-0.249	3.7
21	-0.78±0.14	-0.45±0.28	-	0.89	-0.182	-1.222	5.9

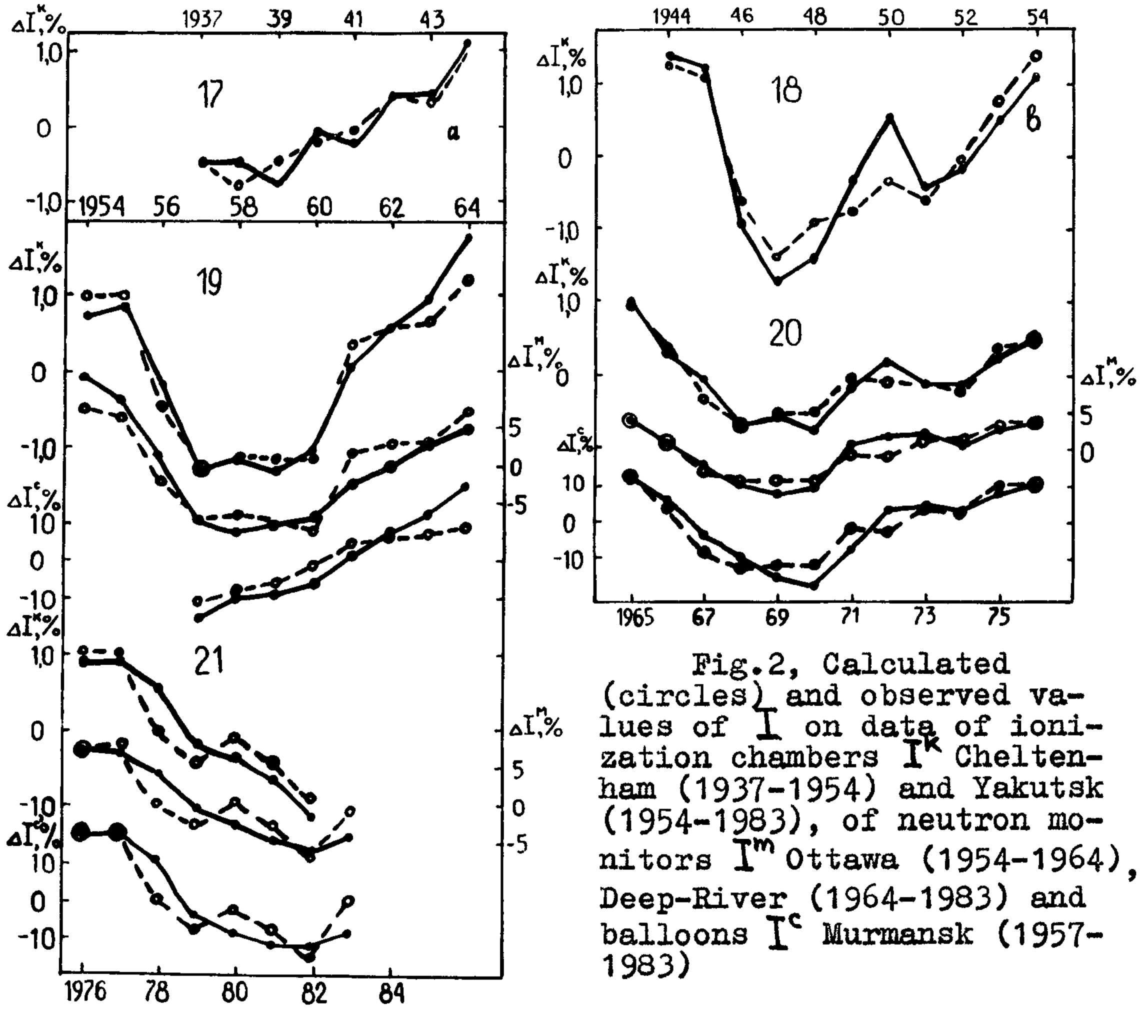

Fig.2, Calculated (circles) and observed values of I on data of ionization chambers I^k Cheltenham (1937-1954) and Yakutsk (1954-1983), of neutron monitors I^m Ottawa (1954-1964), Deep-River (1964-1983) and balloons I^c Murmansk (1957-1983)

The solar wind enhancement at solar activity decrease caused the delay of recovery of cosmic ray intensity by 1-2 years in 19 cycle and by 3 years in 21 cycle caused also the repeated decreases of I in 18 and 20 cycles in 4-5 years after the solar activity maximum.

A good agreement (within 6 months) of calculated and observed values ΔI allows to estimate the sizes of cosmic ray modulation region ~ 30 AU. The use of monthly values of smoothed for a year I, W and aa-index allows to decrease the sizes of modulation region up to $\leq$ 10 AU.

In [11] the 22-year variations of solar and geomagnetic activities were found. The even and odd cycles being closely related than odd and even ones. The similar dependence was found in [12] for cosmic ray density and it is expected in solar wind speed. The 22-year variations of cosmic ray density are opposite to 22-year variations of solar activity and of solar wind speed.

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