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Variations of the interplanetary magnetic field, cosmic rays and solar activity

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Abstract. In the paper the different periodical variations of the interplanetary magnetic field intensity, green coronal line intensity and cosmic rays intensity are investigated. It was shown by the method of mathematical filter that seasonal, 2-, 11- 22- years variations of considered quantities is observed and considerable correlation between these variations takes place. The possible interpretation of observed effects is given.

1. Introduction

In the paper the variations with different periods of the interplanetary magnetic field intensity, green coronal line intensity and cosmic radiation intensity are investigated. The seasonal 1-, 2-, 11- and 22- year variations of the considered quantities with the high power of the confidence by method of the mathematical filter are calculated. It is shown that between this variations the considerable correlation is observed. The interpretation of the observed effects is given.

2. Results

In the paper the seasonal , 1-, 2-, 11- and 22- year cosmic rays variations jointly with interplanetary magnetic field (IMF) variations –***B***, y-component IMF – *By*, y-component by modul of IMF - $|By|$ and indexes of the solar activity for the period from 1970 up to 1993 years were calculated. At the calculations of the cosmic rays variations the stratospheric data of the cosmic rays registered at the different altitudes of the Earth atmosphere from the Earth surface up to 35 km by means of radiosound flights in Mirny (Antarctica), on the Kola peninsula near Moscow and Almaty from 1970 up to 1993 years were used. Both the global general ionized and vertical component of the cosmic radiation is registered. Also the data of the cosmic radiation neutron component received by world network of the neutron monitors were used. At calculations of the solar activity variations the data of the coronal intensity with wave length λ=5303Å (green coronal line), which permits with high power of accuracy to calculate the solar activity variations taking, into account dependence on heliolatitude are used.

We suppose that interesting result is definition of the contribution of the general magnetic field factors existing inside solar convective zone in the observed variations. In this zone currents run causing the rise of the global variable magnetic fields which have 22 year periodicity, but the magnetic field module has 11- year cycle. In the active solar years the magnetic field in the convective zone has a toroidal structure (azimuthal direction) (Voloshin et al., 1986). About the magnetic intensity of this field it can try by the field values $H \approx (2\text{-}4) \cdot 10^3$ gauss in the solar spots (Gibbson, 1973), which present itself the regions of the magnetic lines of force field exit (entrance) “coming to the surface”. Therefore the supposition about the existence of the magnetic field by magnetic intensity equal to several kilogauss in the years of the solar activity maximum in the convective zone is presented most probably. From the surface to the bottom of the convective zone the field ***B*** can somewhat increases. In the years of the quiet Sun (in the minimum of the 11- year cycle) the field in the convective zone decreases by at least one order of magnitude. As the Sun general magnetic field is mainly azimuthal and at the both sides of the helioequator directs oppositely then at the stretching itself by solar wind the region is formed where the magnetic lines of the force with the opposite directions are closely met and the magnetic field intensity becomes equal to zero in this region. In conjunction with that in the plane of the helioequator the wavy current layer is formed. The Earth crosses the magnetic windows twice a year where the modulational processes of the charged particles differ from the modulation in the usual cosmic space. Therefore the investigation of the semi-annual (seasonal) interplanetary magnetic field variations on the basis of the experimental data, obtained by cosmic ships presents a great interest.

The seasonal variations in the periods of the positive (1972-1979 years), negative (1982-1990 years), half periods of the magnetic cycle and in the periods of the magnetic field polarity inversions (1970-1972 years, 1980-1982 years and 1992-1993 years) were calulated. The data of the interplanetary magnetic field for a period 1970-1999 years (King J.H) were subjected to the following mathematical processing. The sliding with a different number of points was conducted (Afanaseva, 1953; Dorman, 1957). Then average of data was conducted by the method of epoch laying (Chree-method). The months when the Earth passes cross the helioequator plane: June, December were given for 0-days. This data of the interplanetary magnetic field, data of the neutron's component of the cosmic radiation registered at the Earth's surface and data of the total ionized component registered at the different altitudes of the Earth's atmosphere and also data of the solar activity where the index characterizing the solar activity is the green coronal line with λ=5303Å (data of heliolatitudes 0^0-30^0) N and (0^0-30^0) S) were processed. In the fig.1 the changes of the interplanetary magnetic field after the processing by Chree-method for the period 1972-1979 years are presented.

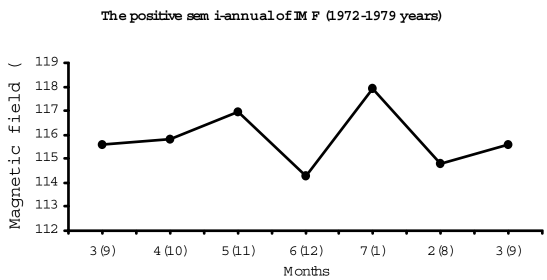
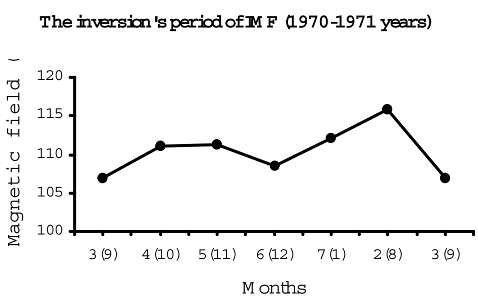


Fig. 1. Seasonal variation of IMF

The data of the interplanetary magnetic field, data of the cosmic radiation and data of the solar activity were normalized to 1976 year. On axis of abscissa the numbers of month are laid and on axis of ordinate the data of the interplanetary magnetic field ***B***, *By* and $|By|$ in percents relativity to 1976 year are laid. From figure 1 two minimums are seen: first is on June and second is on December of months. That is the seasonal variations with the high level of the confidence are observed.

In the periods of inversion (1970-1971 and 1990-1991 years) the seasonal variations are also observed but already with the lesser level of the confidence (fig. 2).



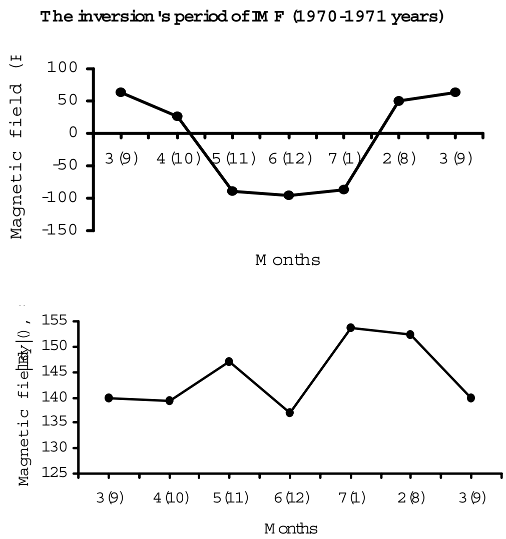


Fig. 2. Seasonal variation of IMF

In the others periods the seasonal variations are not vivid expressed. The maximum values of the seasonal variations must be observed when the Earth is maximum removed from helioequator – on March, September. Taking into account aforesaid two maximums of the interplanetary magnetic field intensity are also observed. With decreasing of the solar activity the seasonal variations must grow weak and possibly completely disappear in the years of the quiet Sun.

For studying of the dynamic picture of the variations the data of the interplanetary magnetic field were processing by the mathematical filter. One year and 2- year interplanetary magnetic field variations were calculated and analyzed. The level of the confidence of the one year interplanetary magnetic field variations is low and the amplitude is within errors. By data of the general magnetic field of the Sun the considerable increase of the one year variation amplitude observed in 1982 year. This increase is explained by harshly increase of the magnetic momentum Sun dipole component (Hockema et al., 1986; Wilcox, 1991). It is also necessary to note that after such a considerable increase the following reduction of the present value passes very slowly and it returns to its average to increase of the magnetic fields intensity in the heliosphere (Slavin et al., 1986), but this in its turn increases the level of the values observed for the period 1977-1981 years, only in 1988 year. As it is known that increase of the magnetic momentum leads fluctuations of the interplanetary magnetic field (Perko et al., 1987), which is responsible for the modulation of the Galactic cosmic rays but the observed effects in 1982 year can be tied with the increasing of the solar magnetic momentum. Variations of the interplanetary magnetic field have the expressed 2- year cycle and the amplitude of the wave is several percents.

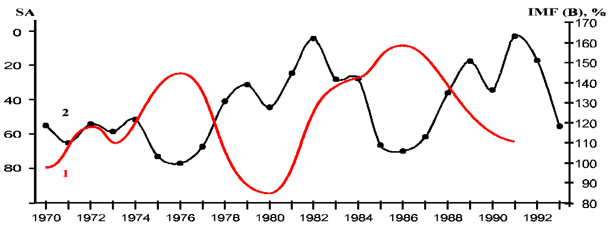


Fig.3. 11-year variation of the solar activity(1) and IMF (2)

In fig. 3 the 11- year variation of the interplanetary magnetic field ***B*** is presented. 11- year variation of the module magnetic field component $|By|$ has the analogous shape. From figure 3 it is seen, that 11- year variation of the interplanetary magnetic field ***B*** is in antiphase with the solar activity.

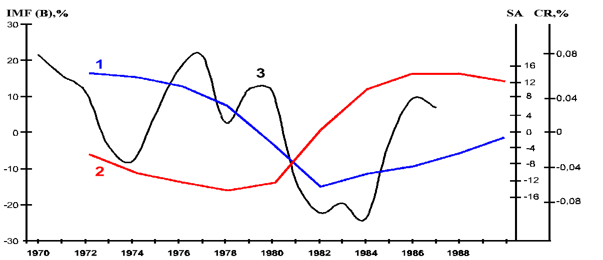


Fig.5. 22- year variations of the solar activity (curve 1), cosmic rays (curve 2) and IMF (curve 3)

In the fig. 4 22- year variation of the interplanetary magnetic field is presented. 22- year variation of the interplanetary magnetic field can be observed in the case of 2 near by not equal the 11- year solar cycles or in the case of the solar general magnetic field inversion. In figure 5 22- year variations of the cosmic radiation , solar activity and interplanetary magnetic field are presented accordingly. As it is seen from figure 5 the clear wave of the cosmic radiation takes place which is in antiphase with the solar activity and interplanetary magnetic field. The one year variations of the cosmic radiation solar activity and interplanetary magnetic field were calculated and analyzed. The clear expressed variations take place. The one year wave of the cosmic radiation is caused by the corresponding wave of the solar activity and IMF but also taking into account not coincidence of the helioequator plane with the ecliptic plane the corresponding contribution carried in the dependence of the solar activity on heliolatitude and the change of the magnetic field direction by half-years. It is noted that amplitude of one year cosmic radiation variations with increasing of the particles energy in the main decreases that is if the energetic spectrum of the one year intensity cosmic radiation changes is approximated by power function but exponent of a power is negative and between the limits 0.6÷1.2. But sometimes the intervals of time are observed when the one year variation has the rigid spectrum. The amplitude of the one year variation considerably increased in 1982 year. In fig.6 the seasonal variations of the cosmic radiation and solar activity are presented.

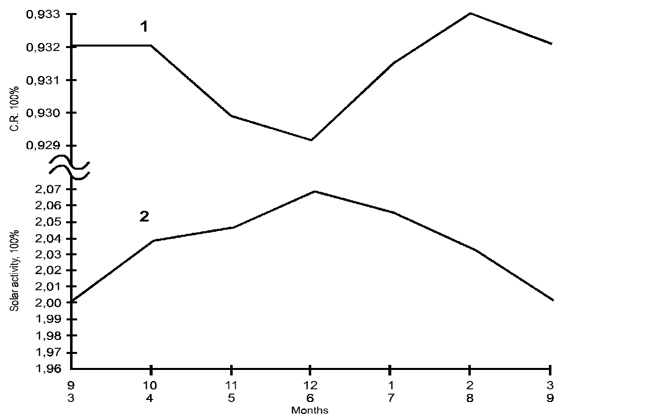


Fig.6. Seasonal variation of the cosmic rays (curve 1) and the solar activity (curve 2) (average)

The amplitude of the two year variations in the region of the energies more than 10-50 GeV in some intervals of time increases with increasing of the energy and reach several per cents. The coefficients of the correlation between IMF and solar activity were calculated. The correlation was conducted between smoothed data of the IMF and intensity of the green coronal line λ=5303Å (index of solar activity). Coefficient of the correlation is high for heliolatitude ±30°. For other hiliolatitudes the correlation coefficients between data of the continuous registration of the neutron component at the Earth's surface and general ionized component of the galactic cosmic radiation registered by radiosounds at the different levels of the Earth atmosphere (50, 100, 140, 200, 300)g/cm^2 were also calculated. The coefficients of the correlation are positive and between the limits 0,9 and 0,97. At the calculations the mean monthly data of the cosmic radiation are used excluding Forbush-effects and flares on the Sun. The accuracy of the mean monthly data of the cosmic radiation is 0,1%.

3. Conclusions

From above-mentioned it can conclude that 1-, 2-, 11- and 22- year variations of the interplanetary magnetic field, cosmic radiation and solar activity take place. We suppose that the level of the coincidence of the received results don't give a doubt in that the variations take place. The magnetic field intensity in the convective zone of the Sun can depend on time which is tied with the solar activity. In this case it can observe the 1 year wave as the plane of the equator don't coincides with the plane of the helioecliptic.

11- year variation of the interplanetary magnetic field is caused 11- year regular changes of the solar activity so far as the number of the highly speedy fluxes in the interplanetary space and hence the change of the level of the interplanetary magnetic field disturbance changes with the change of the solar activity. The value $|By|$ is maximum in the maximum of the 11- year cycle of the solar activity. The main point of the 22- year variation of the interplanetary magnetic field consists in the inversion of the solar general magnetic field that is the change of the magnetic fields sign in the heliosphere happens – the transition from periods with $\vec{M} \downarrow\uparrow \vec{\Omega}$ to periods with $\vec{M} \uparrow\uparrow \vec{\Omega}$ where $\vec{M}$ and $\vec{\Omega}$ – are the magnetic moment and direction of the axis of the Sun rotation.

References

1. Voloshin M.B., Vysostkii M.I., Okun L.B.*JETP*, *1986, v. 91,vyp. 3(9),* p.761- 766.
2. Gibbson E.G. *The quiet Sun*. NASA, Washington, 1973.
3. King J.H. *Interplanetary medium data for 1965-1999*. NSSDC/WDC-A-R.
4. Afanaseva V.I. *Reference books on variable magnetic fields of USSR*, Gigrometizdat, 1953.
5. Dorman L.I. *Variations of cosmic ray*. M., 1957.
6. Hocksema I.T., Scherrer P.H. *An atlas of photospheric magnetic fields: 1976-1985*. Report VAG694, World Data Center for solar-terresterial physics, 1986.
7. Wilcox J.M. *The solar magnetic field 1985 through 1990. An atlas of photospheric magnetic field observation and computed coronal magnetic fields from J.M.Wilcox*. Solar observatory at Stanford, 1985-1990, *vol.21*. Hocksema Center for space science and astrophysics Report CSSA-ASTRO-91-01/.
8. Slavin I.A., Jungmen G., Smith E.J. The interplanetary magnetic field during solar cycle 21: ISEE-3/ICE observations/-*Geophys. Res. Let.*, *1986, vol. 13, №6*, p. 513-516.
9. Rerko J.S., Burlaga L.F. *Proc. 20-th ICRC*, *Moscow, 1987, vol.3.,* p.389-392.