ΠΡΑΚΤΙΚΑ ΤΗΣ ΑΚΑΔΗΜΙΑΣ ΑΘΗΝΩΝ

ΣΥΝΕΔΡΙΑ ΤΗΣ 5ΗΣ ΜΑΪΟΥ 1988

ΠΡΟΕΔΡΙΑ ΓΕΩΡΓΙΟΥ ΜΕΡΙΚΑ

ΑΣΤΡΟΝΟΜΙΑ.— **An analytical expression of cosmic-ray intensity as a function of the time,** by *J. Xanthakis, H. Mavromichalaki, B. Petropoulos**, διὰ τοῦ Ἀκαδημαϊκοῦ κ. *Ἰωάννη Ξανθάκη*.

ABSTRACT

Application of analyzing time-series into trigonometric series allow the investigation of cosmic-ray intensity variations in a wide periodicity range from a few months to 10 or even more years. By this technique the amplitude and the phase of all observed fluctuations can be given. For this purpose cosmic-ray data of five ground-based Neutron Monitor Stations for the time interval 1964-1985 have been used.

The possible origin of each observed variation as due to a contribution either of cosmic-ray interaction in the upper atmosphere or to the solar dynamics, is discussed.

1. INTRODUCTION

As it is known the intensity of galactic cosmic - rays is assumed to be essentially constant outside the heliosphere. But the main characteristic of cosmic-rays observed inside the solar cavity is the time variability on a wide range of time scales. The temporal changes observed must be due to the interaction of cosmic-ray particles with the interplanetary magnetic field (IMF) which is carried by the solar wind. So the problem is to find out the pattern of the interplanetary magnetic field and its flow, to determine the time and spatial evolution of their configurations and to relate them to

* Ι. ΞΑΝΘΑΚΗ, Ε. ΜΑΥΡΟΜΙΧΑΛΑΚΗ, Β. ΠΕΤΡΟΠΟΥΛΟΥ, **Ἀναλυτικὴ ἔκφραση τῆς ἔντασης τῆς Κοσμικῆς Ἀκτινοβολίας συναρτήσει τοῦ χρόνου.**

cosmic-ray variations. Unfortunately the direct measurements of the IMF and of the solar-wind plasma are insufficient because they are limited to a region close to the ecliptic plane. On the other hand cosmic-ray particles provide an indirect measurement of the global structure of IMF since the sample a large volume of the solar cavity in their travel from its boundary to the Earth.

Continuous registrations of cosmic-ray intensity detecting by IGY detectors and later by Neutron - Monitor Stations extend back to 1937 and cover now almost 4 solar cycles. There is then the possibility for a statistical study of long-term variations and periodicities to say, greater than one year. Most cosmic-ray variational studies include eleven-year solar cycle variation, Forbush decreases, 27-day variation and the various harmonics of the daily variation.

Recently Dorman and Putskin (1981) have proposed that the possible natural large scale pulsations of the heliosphere is probably the origin of a new type of cosmic ray variations with characteristic periods varying from 1-2 years to tens of years.

Attolini et al (1987) applied their statistical technique of cyclograms to the Climax neutron monitoring station data studied the cosmic-ray intensity variations in the periodicity range of 1 to 10 years. The two year variation in cosmic-rays was observed clearly and not correlated with the sunspot cyclic variations. They had no significant evidence for the existence of longer period variation.

Okhlopkov et al (1986) have studied the cosmic-ray variations at different isobaric levels and revealed a new kind of galactic cosmic-ray modulation-zonal modulation. The frequency structure of the cosmic-ray variations has presented significant peaks with periods $T \backsim 2$, 1.5, 1, 0. 75 and 0.5 year.

In this paper we investigate the possibility of detecting cosmic-ray variations at periods greater than 2 yrs as well as other recurrences smaller than 2yrs by analyzing the time-evolution of the cosmic ray fluctuations into a network of trigonometric series.

2. DATA ANALYSIS

Monthly mean values of five Ground-based Cosmic-Ray Stations data have been used for investigating the possible periodicities and its harmonics. These data cover the time interval 1964-1985, since the Super Neutron Monitor Stations were in operation. The altitude, the geographic coordinates and the geomagnetic cut-off rigidity of each station are listed in Table I. The cosmic-ray data (corrected for pressure) for each station were normalized during each solar cycle, such as the intensities at solar minimum are taken equal to 1.00 and at solar maximum are taken equal to zero.

Analyzing these time series of cosmic-ray data into trigonometric series we have obtained the expressions given in Tables IIa, IIb, IIc, IId, IIe for the five stations respectively. From these tables we can summarized that we have a set of long-term periodicities greater than two years and another one of short-term periodicities (given by the symbol W) smaller than two years. The amplitude and the phase of these periodical terms are given also in the above mentioned Tables. A graphic presentation of this analysis is given in the Figures Ia, Ib, Ic, Id, Ie for the five Neutron Monitoring Stations respectively. We ought to note from these figures that the observed values of cosmic-rays are in a very good agreement with the calculated ones by the above given expressions. This last point is also confirmed from the standard deviation between observed and calculated values of cosmic-ray intensity indicated in each of the tables IIa, IIb, IIc, IId, IIe. An anomalous behaviour of the cosmic-ray data is appeared in the Goose-Bay Station during the year 1978. It is due perhaps to an error of measurements.

A summation of all periods found in this work is listed in Table III. As we can see the long-term periodicities appear a small variability from station to station. We can grouped them into three categories. The first one includes the peaks centred at 10.41 yrs, the second one at 8.41 yrs and the third one at 5.50 yrs. On the other hand the short-term periodicities (Table III) are similar in all examined in this work stations and are independent of the geomagnetic coordinates. This point is confirmed by a power spectral analysis of cosmic-ray data according to the Blackman and Tuckey known method (Blackman and Tuckey, 1959). A typical example of the power spectrum for the Inuvik station is given in Figure II. The peaks of 22, 14,6 and 3 months are appeared at a significance level of 95%, but peaks of 22 and 14 months are really significant (99%).

TABLE I

Station (Super MM-64)	Altitude (m)	Geogr. Latitude	Coordinates Longitude	Cut-off Rigidity (GV)
Alert	57	82.50N	62.33 W	0.00
Inuvik	21	68.25N	133.7 W	0.18
Goose Bay	46	53.27N	60.40 W	0.52
Deep River	145	46.56N	77.50 W	1.02
Kiel	54	54.30N	10.10 E	2.29

Characteristics of the Neutron-Monitor stations whose data has been utilized in this paper.

TABLE IIa

ALERT

(6=+0.033, Freedom of Degree=149)

$$I_{cal}=0.558+0.400\sin\frac{2\pi}{114}(T\text{-}1962III)+0.350\sin\frac{2\pi}{72}(T\text{-}1971\ IX)+0.400\sin\frac{1\pi}{120}(T\text{-}1975\ I)+W$$

1962III-71 IX   1971IX-74VII   1975I-85XII

$$W=a_1\sin\frac{2\pi}{24}T+a_2\sin\frac{2\pi}{12}T+a_3\sin\frac{2\pi}{8}T+a_4\sin\frac{2\pi}{6}T$$

a_1	T
+.100	1967IX-68IX
—.150	1970III-71III, 1972VII-73VII
+.150	1974XI-75XI 1976III-77III
—.200	1978XII-79XII

a_2	T
+.150	1965IX-66III, 1981V-81XI
+.100	1966I-66VII, 1973XII-74VI, 1979 XII-80VI
—.100	1970III-70IX, 1971I-71VIII, 1973I —.73VII
—.200	1973III-73IX
—.050	1976VII-77I
—.070	1977IV-77X
—.250	1978II-78VIII
+.300	1981X-82IV
—.150	1982VI-82XII
+.200	1983VIII-84II

a_3	T
+.100	1968XII-69IV
—.150	1969IV-69VIII
+.200	1975XII-76IV, 1983I-83V
—.100	1980IX-81I
+.300	1982II-82VI
+.150	1983V-83IX, 1983XII-84IV
+.070	1978IXII-79V

a_4	T
—.100	1966VIII-66XII, 1972VII-72X
+.100	1967II-67V, 1984V-84VIII
+.070	1967VI-67IX, 1972II-72VIII, 1978II-78V, 1978
—.150	1968X-69I
+.150	1971X-72I
+.050	1977X-78I, 1980XII-81VI

TABLE IIb

INUVIK

(6=+0.028, Freedom of Degree=134)

$$I_{cal} = 0.565 + 0.400\sin\frac{2\pi}{96}(T\text{-}1963I) + 0.250\sin\frac{2\pi}{80}(T\text{-}1971I) + 0.400\sin\frac{2\pi}{128}(T\text{-}1974V)$$

1963I-71I 1971I-74V 1974V-1985II

+W

$$W = a_1\sin\frac{2\pi}{24}T + a_2\sin\frac{2\pi}{12}T + a_3\sin\frac{2\pi}{8}T + a_4\sin\frac{2\pi}{6}T$$

a_1	T
+1.50	1967VI-68VI
—1.50	1969II-70XII
—1.00	1972V-73V
+2.00	1974X-75X-75X, 1981V-82V, 1983IV-84IV

a_2	T
—1.00	1964III-64IX
—0.50	1966II-66VIII
+0.80	1969VI-69XII
—2.00	1972XI-73V
+0.50	1975VII-76II, 1976V-76XI
+3.50	1982II-82VIII
—1.50	1979V-80V

a_3	T
—0.80	1966III-65XI, 1979III-79VII
+0.80	1973IX-74V, 1975VII-75XI
—0.5C	1977V-77IX
+0.50	1977IX-78IX, 1978X-79II, 1978 XI-79III
—1.50	1978IV-78VII

a_4	T
—0.80	1966IX-66XII, 1969II-69V, 1970XI-71II, 1982X-83I
—0.50	1967I-67IV
+1.00	1968IV-68X
—1.50	1970II-70V, 1981IX-81XII

a_5	T
—1.00	1972II-72V, 1984IV-84VII
+0.50	1973II-73V
+0.80	1980VI-81I
—2.50	1982V-82VIII
+1.50	1983II-83V

TABLE IIc

GOOSE BAY

(6=+0.030, Freedom of Degree=111)

$$I_{cal}=0.420+0.400\sin\frac{2\pi}{96}(T\text{-}1963V)+0.250\sin\frac{2\pi}{80}(T\text{-}1971V)+300\sin\frac{2\pi}{130}$$

1963V-71V 1971V-74VII

$$(T\text{-}1974III)+0.600\sin\frac{2\pi}{130}(T\text{-}1984XII)+W$$

1974III-84III

$$W=a_1\sin\frac{2\pi}{24}T+a_2\sin\frac{2\pi}{12}T+a_3\sin\frac{2\pi}{8}T+a_4\sin\frac{2\pi}{6}T$$

a_1	T
+.150	1967XI-68XI, 1978XII-79XII
—.150	1972IX-74IX
—.100	1975VII-76VII, 1984II-85II

a_2	T
+.100	1965I-65VII, 1965IX-66III, 1981XI-82V
+.080	1967VI-67XII, 1978VII-79I
+.150	1968XII-69VI
—.100	1969II-70II, 1974II-74VII, 1977V -77XI, 1984II-84VIII
—.150	1970VIII-71II, 1974IV-74X, 1982VI-82XII
—.080	1970XII-71XII

a_3	T
—.200	1970V-70IX
—.100	1980IX-81I
+.080	1981VI-81X, 1981II-82VI
—.800	1985X86I

a_4	T
—.050	1965XII-66VI, 1971XII-72III, 1975X-76IV, 1979IV-79X, 1983-84I, 1986VII-86X
—.150	1966XII-67II, 1972VII-72X, 1973III-73VI
—.080	1968II-68V, 1968V-68VIII, 1968 X-69I, 1985VI-85IX, 1986X-87I
+.080	1969XII-70VI
—.100	1972V-72VIII, 1981III-81VI, 1982XI-83II, 1986I-86IV
—.050	1982IV-82VII

TABLE IId

DEEP RIVER

(6=+0.033, Freedom of Degree=154)

$$I^{cal}=0.606+0.400\sin\frac{2\pi}{104}(T\text{-}1962IX)+0{,}350\sin\frac{2\pi}{72}(T\text{-}1971V)+0.400\sin\frac{2\pi}{125}(T\text{-}1974X)+W$$

1962IX-1971V 1971V-1974V 1974X-1985I

$$W=a_1\sin\frac{2\pi}{24}T+a_2\sin\frac{2\pi}{12}T+a_3\sin\frac{2\pi}{8}T+a4\sin\frac{2\pi}{6}T$$

a_1	T
—. 300	1970III-71III
—. 150	1972V-73V
+.200	1973VIII-74VIII
+.150	1974XI-75XI
—. 200	1977XI-78XI
—. 250	1978XII-79XII
+.050	1985VIII-86VIII
+.250	1983VI-84VI
+.100	1984XI-85XI

a_2	T
—. 100	1965V-66V, 1971XI-72V, 1972 IV-72X, 1977V-77X
+.100	1981VI-81XII, 1986VII-87I
+.150	1967XII-68VI
—. 250	1973III-73IX
—. 300	1980VII-81I
+.200	1983I-83VII

a_3	T
+.090	1968XI-69IV, 1982V-82VIII
—. 200	1969IV-79VIII
+.150	1970VI-70XI
+.050	1970X-71II
—. 100	1974IV-74VIII
—. 050	1978IX-79I
+.200	1981XI-82III

a_4	T
+.050	1967V-67IX, 1978I -78IV
—. 150	1968X-69I, 1979VII-79X, 1984 II-84V
—. 100	1973III-73VI, 1978IV-78X, 1980V-80VIII, 1980VII-81I, 1981III-81VI
—. 500	1981II-81IV
—. 300	1982V-82VIII
+. 100	1983VI-83IX
—. 100	1986I-86VII

TABLE IIe

KIEL

($\sigma=+0.024$ Freedom of Degree=115)

$$I_{cal}=0.582+0.400\sin\frac{2\pi}{26}(T\text{-}1963III)+0.2500\sin\frac{2\pi}{86}(T\text{-}1971III)+0.400\sin\frac{2\pi}{120}(T\text{-}1974XI)+W$$

1963III-71V 1971III-74III 1974XI-85XII

$$W=a_1\sin\frac{2\pi}{24}T+a_2\sin\frac{2\pi}{12}T+a_3\sin\frac{2\pi}{8}T+a_4\sin\frac{2\pi}{6}T$$

a_1	T
+.050	1985I-86I
—.150	1970IV-73V
—.100	1972V-73V
+.150	1975XII-76XII
+.200	1983VII-84VII

a_2	T
—.100	1965V-65XI, 1972XII-73V
—.080	1966V-66XI
+.100	1967VIII-68II, 1967XII-68VI, 1973XI-74XI
—.050	1970XII-71IV, 1974V-74XI
—.200	1978II-78VIII
—.150	1979V-80V
+.150	1981V-81XI, 1983I-83VII
+.250	1981X-82IV

a_3	T
—.050	1964XII-65IV
—.080	1966II-66VI, 1966XII-67IV
+.100	1968VI-68X, 1968XII-67IV
—.150	1969IV-69VIII
—.200	1970IV-70VII
+.080	1975XII-76IV
—.100	1979II-79X

a_4	T
—.150	1966VIII-66XI
+.100	1968III-68VI
—.100	1968X-69I, 1970IV-70IX
+.050	1971VI-71VIII, 1976VIII-76XI, 1980VII-81I, 1982VI-82IX, 1985X-86I
—.080	1971III-71VI, 1977VII-77X, 1979XII-78III
+.080	1975V-75XI, 1975VII-75XI, 1982IX-82XII
+.150	1976X-77I
—.050	1984X-85I

Tables IIa, IIb, IIc, IId, IIe. Analytical expressions of cosmic-ray intensity for the a) Alert, b) Inuvik, c) Goose Bay, d) Deep River and e) Kiel stations respectively.

TABLE III

A synoptic table of the periodicities observed in Neutron Monitor data.

Station	Long-term periods (Months)			Short-term periods (Months)			
Alert	120	72	114	24	12	8	6
Inuvik	128	80	96	24	12	8	6
Goose Bay	130	80	96	24	12	8	6
Deep River	125	72	104	24	12	8	6
Kiel	120	86	96	24	12	8	6

3. DISCUSSION OF RESULTS

From the above analysis it is resulted that there are appeared two kinds of periodicities in the cosmic-ray data. The first one are occurrences at periods greater than 2 years which are a little differing in amplitude from station to station but similar in phase and the second one are periodicities smaller than 2 years which are similar in all stations but are appeared in variable time intervals. This is pointed out in figure III where we have presented all the periodicities (long-term and short-term) for all stations for the time interval 1964-1985. We ought to note that there is a reversal of phase during the year of the solar minimum (1975) which is due to the secondary maximum of cosmic-ray intensity (1972) characterized the 20th solar cycle as an odd cycle and it is not appeared in the 21st solar cycle which is an even cycle (Otaola et al, 1985; Mavromichalaki et al, 1988).

a. Long-Term Periodicities

The long-term periodic behaviour of cosmic-ray intensity consist of three groups centered on 10.41, 8.41 and 5.50 years.

The first group of periods is the well known variation of 11-years mentioned several times in the data and on the evidence available from the sunspot numbers. This variation seems to be significant in any description of the solar cycle. In our analysis this period seems to be variable from 118 to 130 months for the examined here Neutron Monitoring stations.

Cole (1973) suggested that the free-running length of the solar cycle is 11.8 years but that it is triggered every 10.45 years. The amplitude is modulated by a seasonal periodicity of 11.9 years. Recently Attolini et al (1987) using the Cosmic-Ray data of Huancayo (1937-1953) and Climax (1953-

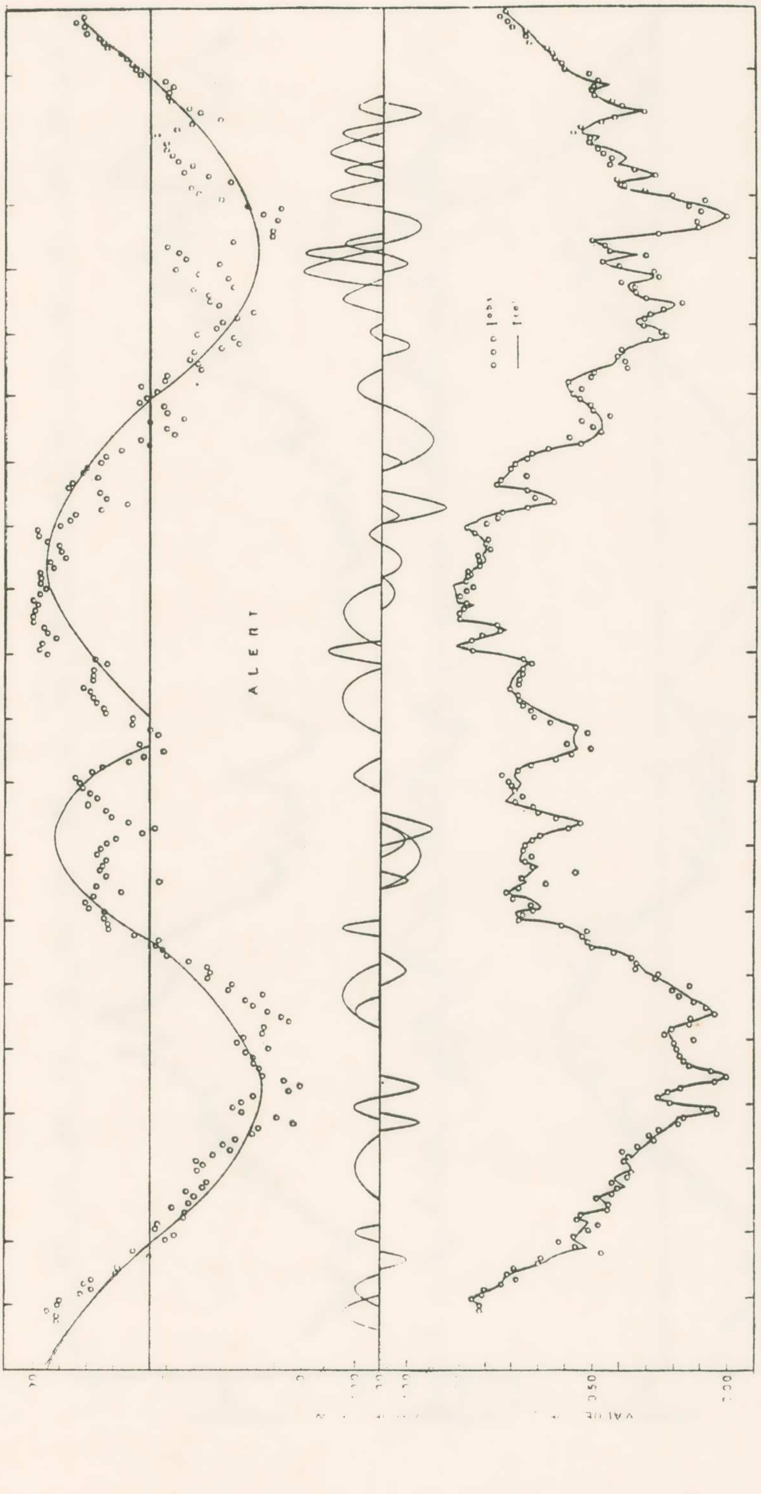

Fig. Ia.

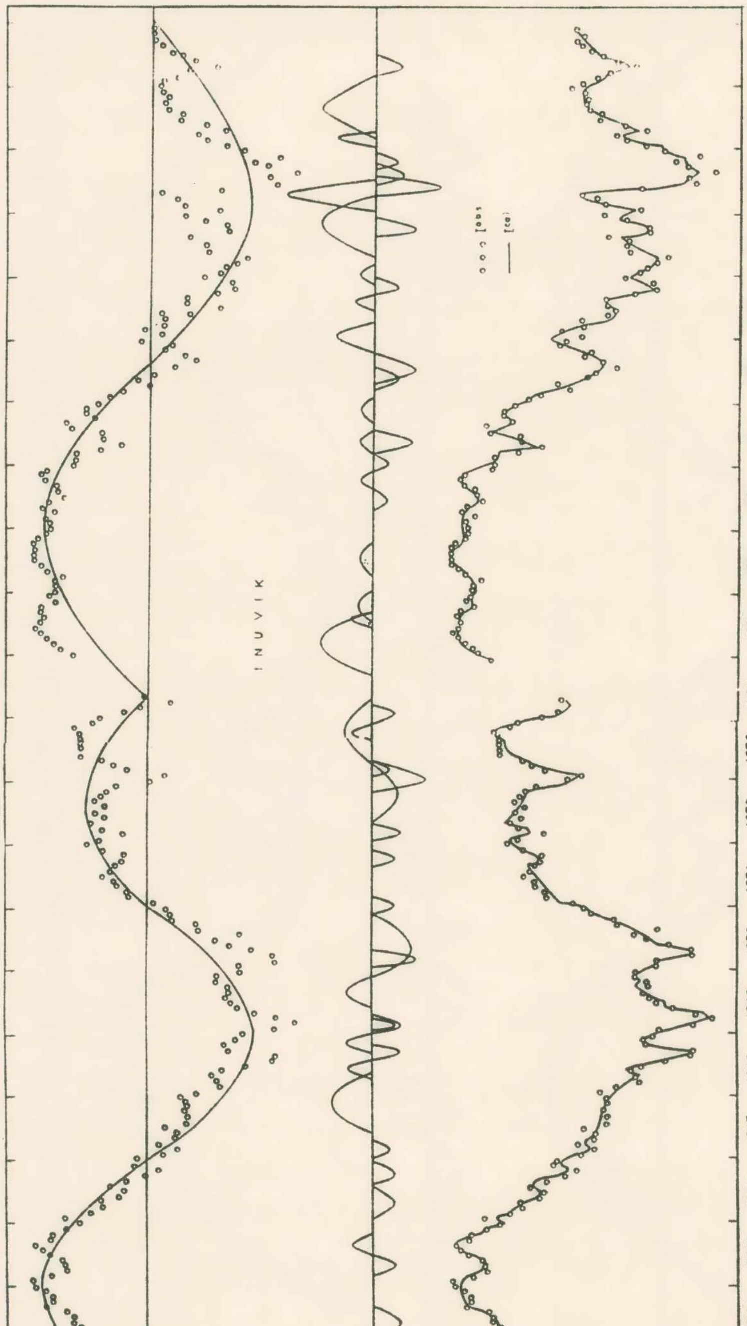
INUVIK
YEARS
VALUES OF I
VALUES OF W
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1.00
0.50
0.00

Fig. Ib.

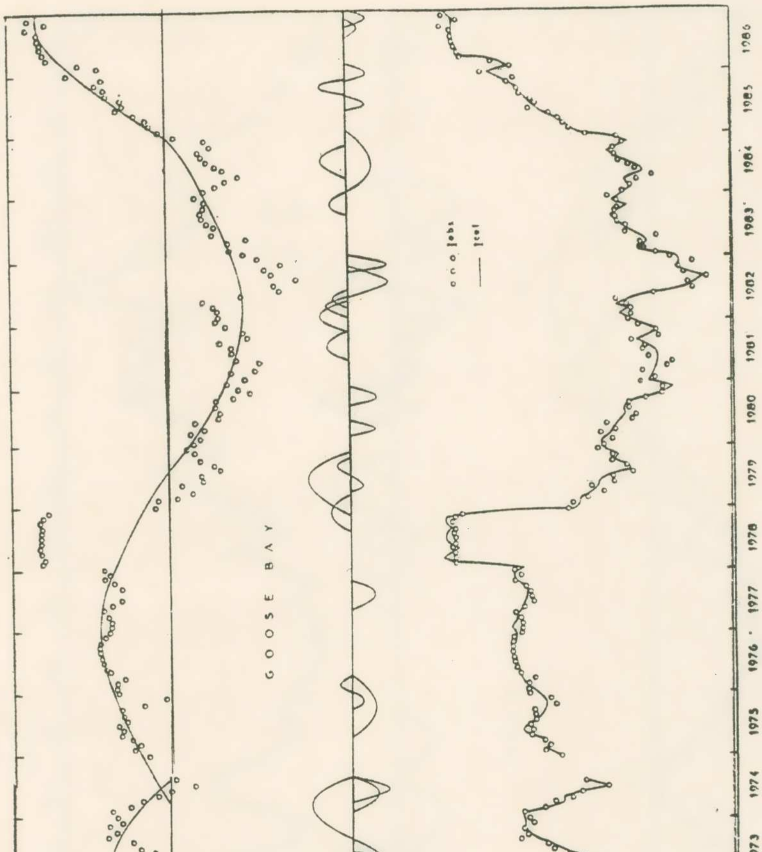
GOOSE BAY
YEARS
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986

Fig. Ic.

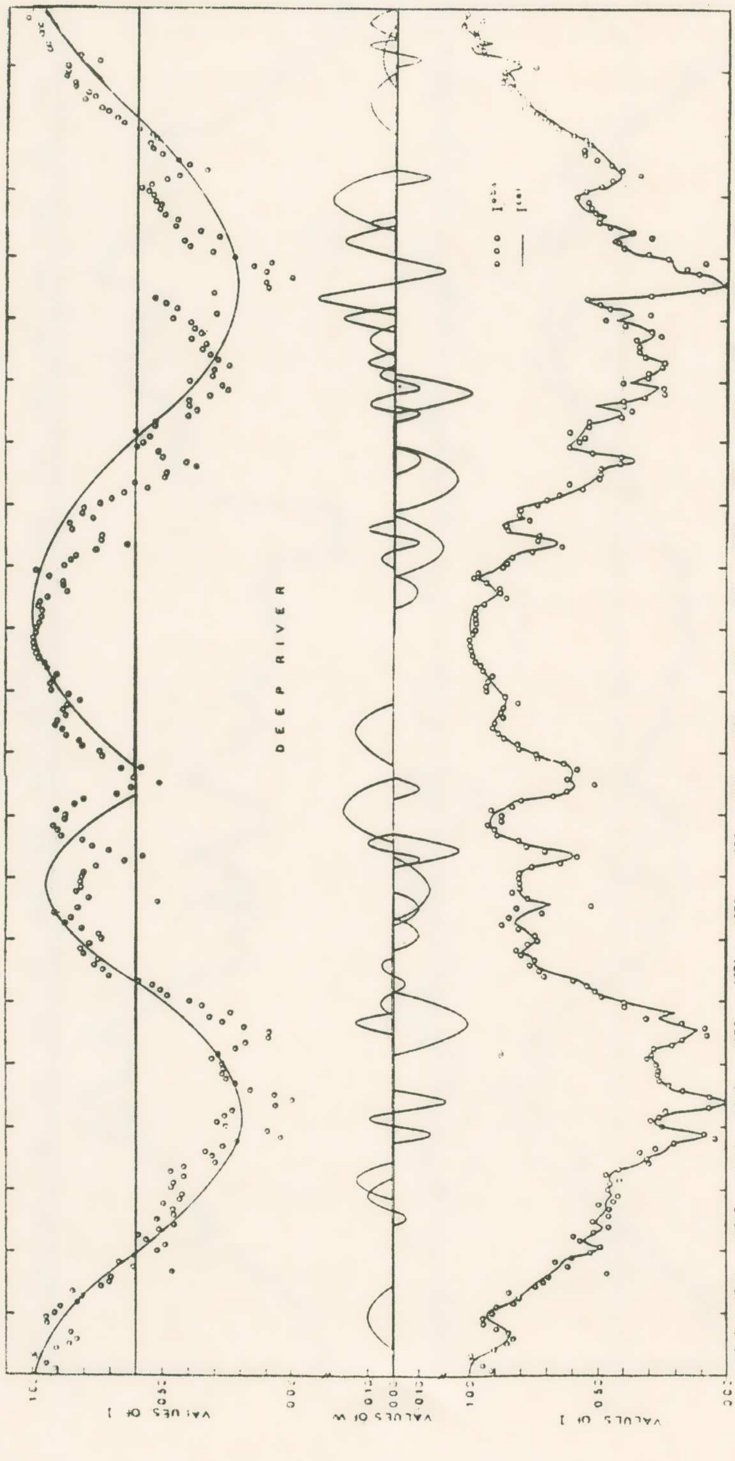

Fig. Id.

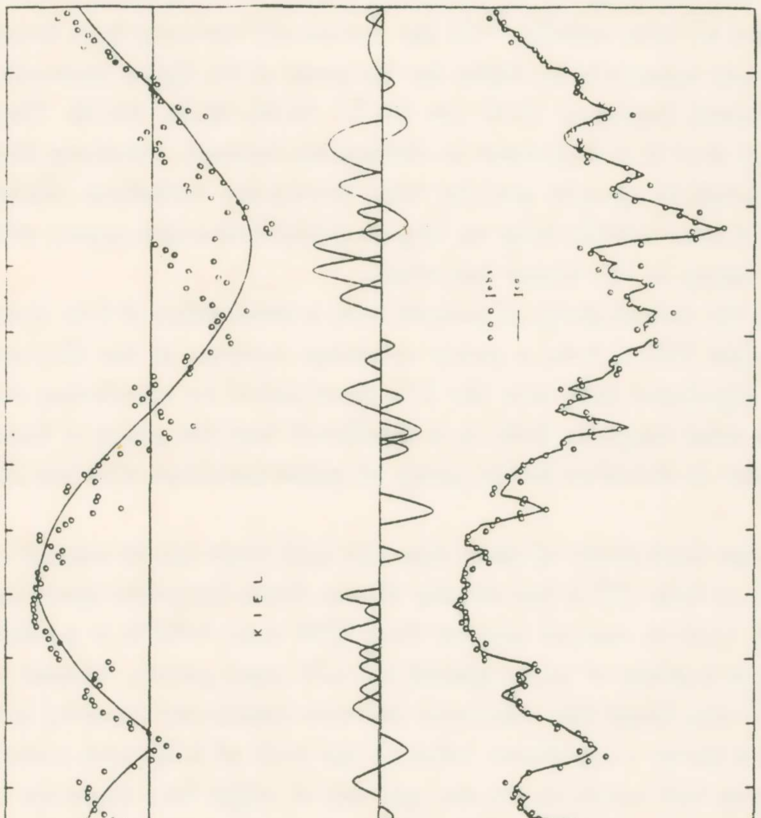

Fig. Ie.

Figures Ia, Ib, Ic, Id, Ie. Graphic presentation of the cosmic-ray intensity for the a) Alert, b) Inuvik, c) Goose-Bay, d) Deep River and e) Kiel stations respectively. The upper panel gives the long-term periodicities and the middle one gives the short-term periodicities. The lower panel gives the observed (circle points) and calculated (continuous line) by the expressions of the Tables IIa, IIb, IIc, IId and IIe values of cosmic-ray intensity respectively.

1979) stations and searching for an overall correlation of the sunspot number (Rz) as an index of solar activity with the cosmic-ray intensity have found that the coherency appears to be higher for the peaks of the higher harmonics of the fundamental frequency 10.67 yrs (10.77, 10.58, 10.33, 10.18). They have also noted that it is important to distinguish between variations that are strictly related to sunspot activity from cosmic-ray variations related to other types of solar activity with an 11-year period that ought appear with a different spectrum in the higher harmonics.

As far as the second group of periods with a mean value of 8.41 years is concerned, Cole (1973) from a power spectrum analysis of the 22-years cycle found a significant peak near the 7.75 years period by considering the polarity of the solar magnetic field. It is significant that the group of these peaks are similar in structure to the group of peaks associated with the 22-year cycle.

Finally, the third group of peaks near the 5.50 years can be related to the 11-yr cycle as Cole (1973) has already shown. From his power spectrum analysis of the relative sunspot number from 1700 until 1969 it is pointed out that there is a group of peaks around the 5.75 years period. Attolini et al (1985b) have also found the coherence between cosmic-ray intensity and sunspot number shows a significant value εt the peak of 4.74 years period. As what concerns this vaariation, we can say that it might be a signature of a true effect, but it is not the second harmonic of the 11-year cycle as in tbe sunspot number since it does not appear in the coherency spectrum.

Dorman and Ptuskin (1981) have proposed that it is very much probable that so long period variations in the cosmic-ray intensity, as these of the 10.41, 8.40 and 5.50 years, are determined by the dynamics of the solar cavity. However, due to the scarce knowledge of the position and behaviour of the heliosphere boundary, the estimate of the proper pulsation periods of the cavity can range from 2-3 years to 10 or even more. On the other hand the length of the cosmic-ray data record (only two solar cycles) is insufficient to fully explore the resonance pulsation range.

b. Short-term periodicities

The short-term periodicities which have been found in the cosmic-ray data in this work are of the order of 24, 12, 8 and 6 months.

A significant variation with a period around 2 years has been revealed by the study of the cosmic-ray power spectrum by Attolini et al (1985a).

This cannot be explained as a high order harmonic of the 11-year solar cycle. They have proposed that the origin of this intensity change has to be found in a geomagnetic effect correlated to the solar activity. However, the connection is not completely clear and its origin as a resonance effect to heliosphere pulsation can not be ruled out, especially if we notice that the oscillations are dumped out with the 22-year cycle.

Sugiura and Poros (1977) have shown the existence of highly correlated quasi-biennual variations in the geomagnetic field and in the solar activity expressed by the sunspot number or by the Ottawa 10.7 solar flux. They have shown that there is the possibility that the 2-years variation in the cosmic-ray intensity is connected to the 2-years variation in solar activity via geomagnetic effect. This last point can be confirmed by the fact that the variation seems to change with the asymptotic longitude as found by Charakhchyan et al (1979a; b). The dependence on the polarity of the interplanetary medium with respect to the geomagnetic field can play an important role.

Examining the zonal modulation of the charged component of cosmic-rays in the lower atmoshpere in terms of sounding measurements have been also found the 2-year and 1-year variation which are different in amplitude from station to station.

The 2-years variation has been also identified in Neutron Monitor data by Kolomeets et al (1973) and atmospheric sounding data by Okhlopkov et al (1979) and Okhlopkov et al (1986). The 2-years periodicity has been also found in the number of high speed solar wind streams (Xanthakis et al, 1988), as also in the neutrino flux (Sakurai, 1981) measured by Davis (1978).

The one year periodicity have been also identified in Neutron Monitor data by Kolomeets et al (1973) and Attolini et al (1987). Okhlopkov et al (1986) found also the annual cosmic-ray variation in the lower atmosphere on the basis of cosmic-ray measurements on sounding balloons. They have also found periods of 9 and 6 months, which can be related to the 8, and 6-months periodicities of the cosmic-ray data found in the present work. We ought also to note that the number of high-speed solar wind streams present 8, 6 and 4 months variations (Xanthakis et al, 1988).

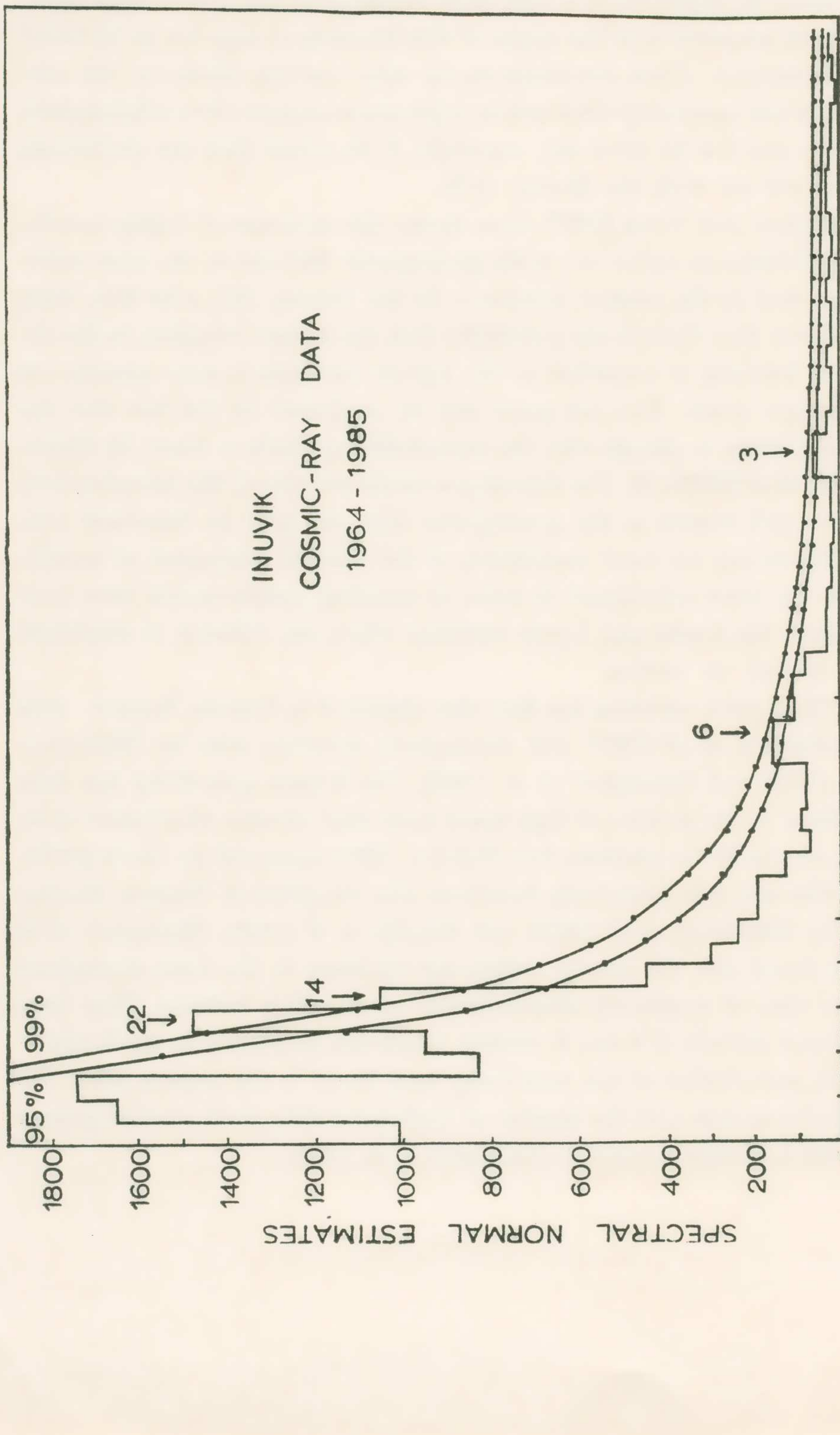

Figure 11. A typical example of the power spectrum analysis for the Inuvik station.

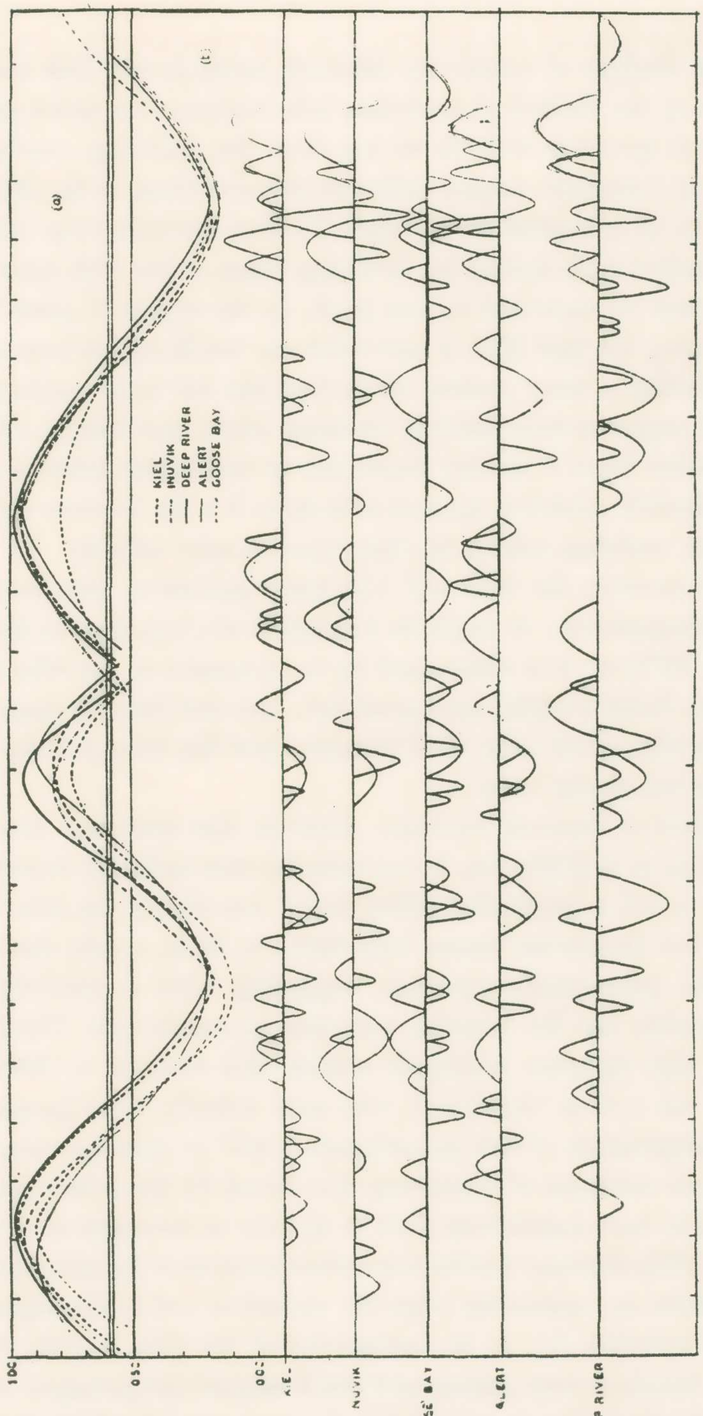

Figure III. Long-term and short-term periodicities for all examined here Neutron-Monitor stations

CONCLUSIONS

From the analysis of cosmic-ray intensity record in the 20th and 21st solar cycles using the method of analyzing into trigonometric series and the method of power spectrum analysis we can draw the following conclusions:

Cosmic-ray intensities exhibit different time-evolution in the 20th and 21st solar cycles. It is aparent from Figure III that the cosmic-ray intensity appears a secondary peak during the declining phase of the 20th cycle while the 21st cycle was characterized by one peak. So the change of phase which is appeared during the year 1975 is just what one would expect from a drift model incorpotating a wavy neutral sheet with the titl angle varying from small to larger angles as solar activity increases (Kota and Jokipii, 1983).

On the other hand it is very important to distinguish between variations that are strictly related to sunspot activity as it is the 11-years variation from cosmic-ray variation related to other types of solar activity.

As what concerns the 8.40 and 5.50 years pulsations care should be taken in the interpretation. It might be a signature of a true effect in the solar activity (Cole, 1973) or it is determined by the dynamics of the solar cavity as Dorman and Putskin (1981) have predicted. The last point is much reliable because the high-speed solar wind streams show the same periodic behaviour with the cosmic-ray data.

The subject of biannual variation deserves also attention. According to Charakhchyan et al (1985) the 2-year variation seen earlier in stratosphere measurements is not a geophysical effect but it can clearly be observed in satellite data, too. Cosmic-ray fluxes were shown to be in a quite sharp antiphase with the geomagnetic Ap-index suggesting that a relatively local effect is responsible for the biennial variation of cosmic-rays. Though the magnitude of this variation undergoes considerable changes, a closer look seems to rule out a close connection with solar activity via a geomagnetic effect. The interpretation of this phenomenon is still an open question.

The annual variation of cosmic-ray flux found by the power spectrum analysis seems to have a shift from 12 to 14 months as have also observed by Attolini et al (1987). It means that there is a contamination of the influence of the solar coronal holes on cosmic-ray intensity variations and in the dependence of the annual variation due to the asymmetry of the solar activity itself.

Finally, the short term periods of 8 and 6 months and perhaps 3 months are appeared for first time in ground-based cosmic-ray intensities, but have also observed on sounding ballons. These periods have been also found in solar wind streams.

In this work we give for first time the amplitude and the phase of all observed periodicities in the cosmic-ray data which present one differing structure variation as a function of the time for every geographic latitude. It would be attributed to the anisotropies of the cosmic-ray intensity closely related to the local gradients, sidereal anisotropies and solar induced anisotropies (Kota, 1985). In the future the study of cosmic-ray periodicities with other Neutron Monitor stations during more than two solar cycles cosmic-ray records will lead us to have a better understanding of the origin of each observed variation, which is useful for the search of the interplanetary physical conditions.

Acknowledgements: Thanks are due to the Director of WDC-A for Solar-Terrestrial Physics and the colleagues for helpful correspondance in providing Cosmic-Ray Data. Also we are thankful to Miss A. Vassilaki and E. Marmatsouri for computing help and Mrs. E. Kountouriotou and P. Tatsi for technical help.

REFERENCES

Attolini M. R., Cecchini S., Castagnoli G. and Galli H., 1985a Proc. 19th ICRC (La Jolla) **5**, 71.

Attolini M. R., Cecchini S. and Galli M., 1985b Proc. 19th ICRC (La Jolla) **5**, 67.

Attolini M. R., Cecchini S. and Galli M., 1987 Astrophys. Space Sci. 134, 103

Blackman R. B. and Tuckey J. W., 1959 The Measurement of Power Spectra Dover, NY.

Charakhchyan T. N., Gorchakov E. V., Okhlopkov V. P., Okhlopkova L. S. and Tenovskaya M. V., 1985 Proc. 19th ICRC (La Jolla) **5**, 90.

Charakhchyan T. N., Okhlopkov V. P. and Okhlopkova L. S., 1979a, Proc. 16th ICRC (Kyoto) **3**, 297.

Charakhchyan T. N., Okhlopkov V. P. and Okhlopkova L. S., 1979b Proc. 16th ICRC (Kyoto) **3**, 308.

Cole T. W., 1973 Solar Phys. **30**, 103.

Davis R. Jr., Evans J. C. and Cleveland B. I., 1978 «The Solar Neutrino Problem» in E.C. Flower (ed) Neutrino Purdue Univ. Lafayette 78, 53.

Dorman L. I. and Putskin V. S., 1981 Astrophys. Space Sci. **79**, 397.

Kota J., 1985 Proc. 19th ICRC (La Jolla) **9**, 275.

Kota, J. and Jokipii J. P., 1983 Ap. Jour 265, 573.

Kolomeets E. V., Makhanov I. V. and Shvartsman Ya. E., 1973 Proc. 13th ICRC (Denver) **3**, 1207.

Mavromichalaki H., Marmatsouri E. and Vassilaki A., 1988 Earth, Moon and Planets **42**, 233.

Okhlopkov V. P., Okhlopkova L. S. and Charakhchyan T. N., 1979 Geomagnet and Aeronomy **19**, 287.

Okhlopkov V. P., Ohlopkova L. S. and Charakhchyan T. N., 1986 Geomagnet. and Aeronomy **26**, 19.

Otaola, J. A. Perez-Enriquez, R. and Valdes Galicia J. F., 1985 Proc. 19th ICRC (La Jolla) **4**, 93.

Sakurai Kunimito, 1981 Solar Phys. **74**, 38.

Sugiura M. and Poros D. J., 1977 J. Geophys. Res. 82, 5 621.

Xanthakis J., Poulakos C. and Petropoulos B, 1988 Astrophys. Space Sci. **141**, 233.

ΠΕΡΙΛΗΨΗ

Ἀναλυτικὴ ἔκφραση τῆς ἔντασης τῆς Κοσμικῆς Ἀκτινοβολίας συναρτήσει τοῦ χρόνου.

Ἐφαρμόζοντας τὴ μέθοδο τῆς ἀνάλυσης τῶν χρονοσειρῶν σὲ τριγωνομετρικὲς σειρὲς ἐρευνήσαμε τὶς μεταβολὲς τῆς ἔντασης τῆς Κοσμικῆς Ἀκτινοβολίας σὲ μία εὐρεία περιοχὴ περιοδικοτήτων ποὺ κυμαίνεται ἀπὸ μερικοὺς μῆνες μέχρι 10 καὶ πλέον χρόνια. Μὲ αὐτὴ τὴν τεχνικὴ μπορεῖ νὰ προσδιοριστεῖ τὸ πλάτος καὶ ἡ φάση τῶν παρατηρουμένων μεταβολῶν. Πρὸς τοῦτο χρησιμοποιήθηκαν δεδομένα τῆς Κοσμικῆς Ἀκτινοβολίας ἀπὸ πέντε ἐπίγειους σταθμοὺς Νετρονίων γιὰ τὸ χρονικὸ διάστημα 1964-1985. Ἐπίσης συζητήθηκε ἡ πιθανὴ φύση κάθε παρατηρούμενης μεταβολῆς ποὺ ὀφείλεται εἴτε στὶς ἀντιδράσεις τῆς Κοσμικῆς Ἀκτινοβολίας στὴν ἀνωτέρα ἀτμόσφαιρα εἴτε στὴ δυναμικὴ τοῦ ἥλιου.