ΣΥΝΕΔΡΙΑ ΤΗΣ 11ΗΣ ΜΑΪΟΥ 1978

ΠΡΟΕΔΡΙΑ ΜΙΧΑΗΛ ΣΤΑΣΙΝΟΠΟΥΛΟΥ

ΑΣΤΡΟΝΟΜΙΑ.— **A new index of Solar activity**, *by J. Xanthakis and C. Poulakos**. Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Ἰ. Ξανθάκη.

ABSTRACT

A new index of solar activity is introduced i.e. the index $I_\alpha(R)$ defined with the help of the relation $I_\alpha(R) = 56 - 3(18 - \sqrt{R}) \cos^2 \frac{\pi}{36} \sqrt{R}$.

A comparison of the variation of the new areas index $I_\alpha(R)$ with the variation of the areas index I_α (Xanthakis, 1969) and some other indices of solar activity is shown. A prediction of solar activity for the present sunspot cycle is also given.

INDRODUCTION

In 1849 Wolf of Zurich introduced the first index of solar activity, being defined by the relation $R = K(10g + f)$ which is well known as the relative sunspot numbers, R. In the last decades of the 19th century some other indices of solar activity were introduced such as the areas of sunspots, the areas of faculae, the prominences and others. During the last decade of the present century the amount of the indices of solar activity that were introduced was astonishing. The fast growing importance of finding an index which could express the variation of solar activity within each 11-year solar cycle and from cycle to cycle in a very satisfactory way has led Xanthakis (1969) to introduce a new

* Ι. ΞΑΝΘΑΚΗ - Κ. ΠΟΥΛΑΚΟΥ, Ἕνας νέος δείκτης τῆς Ἡλιακῆς δραστηριότητος.

index of solar activity which could express better one principal characteristic of an active region and which could be considered, in some way, as an index characterising the size of the activity centers. This new index was defined by the relation,

$$I_\alpha = 1/2\,[\sqrt{A} + \sqrt{f}] \qquad (1)$$

where A and f are respectively the areas of sunspots and faculae given by the relevant publications of the Royal Greenwich Observatory (RGO).

Xanthakis' previous work (Xanthakis, 1971, 1973, 1975) proved that the use of the areas index I_α instead of the Wolf numbers R, provides better correlations with the various solar and terrestrial phenomena while the advantages of the index I_α over the different other indices of solar activity are described in the work of Poulakos and Tritakis (1973).

The time interval for which the values of the areas index I_α can be considered is limited from 1874 to 1966; this is due to the fact that the necessary observational data i. e. the areas of A and f, are given by the relevant publications of the RGO with a delay of 10 years about and therefore the study of solar activity by means of the index I_α becomes restricted according to the difinition of the index I_α (see relation 1).

In view of these facts we considered that we should introduce a new index of solar activity which a) should not depend on the observavional data given by the RGO b) could substitude the areas index I_α with a very satisfactory approximation and c) could be expressed analytically as a function of the relative sunspot numbers i.e. on observational data which are immediately available.

In what follows, an attempt has been made to find the analytical expression of the areas index I_α as a function of the wolf numbers, R, by means of a statistical study of these two indices of solar activity. As a result of this investigation we introduced a new index of solar activity which can be expressed as function of only one parameter i.e. the $\sqrt{R}$.

A comparative study of the new index with some other indices as well as a prediction of solar activity for the present sunspot cycle are also given.

1. The Areas Index $I_\alpha(R)$ and the Wolf Numbers R.

The existence of a relation between the mean annual values of the areas index I_α and the corresponding mean annual values of the quantity, $\sqrt{R}$, has been shown by Poulakos and Tritakis (1973).

In the present report, as a first step in our computations, we tried to find out which function of $\sqrt{R}$, being combined with I_α, provides the highest degree of correlation.

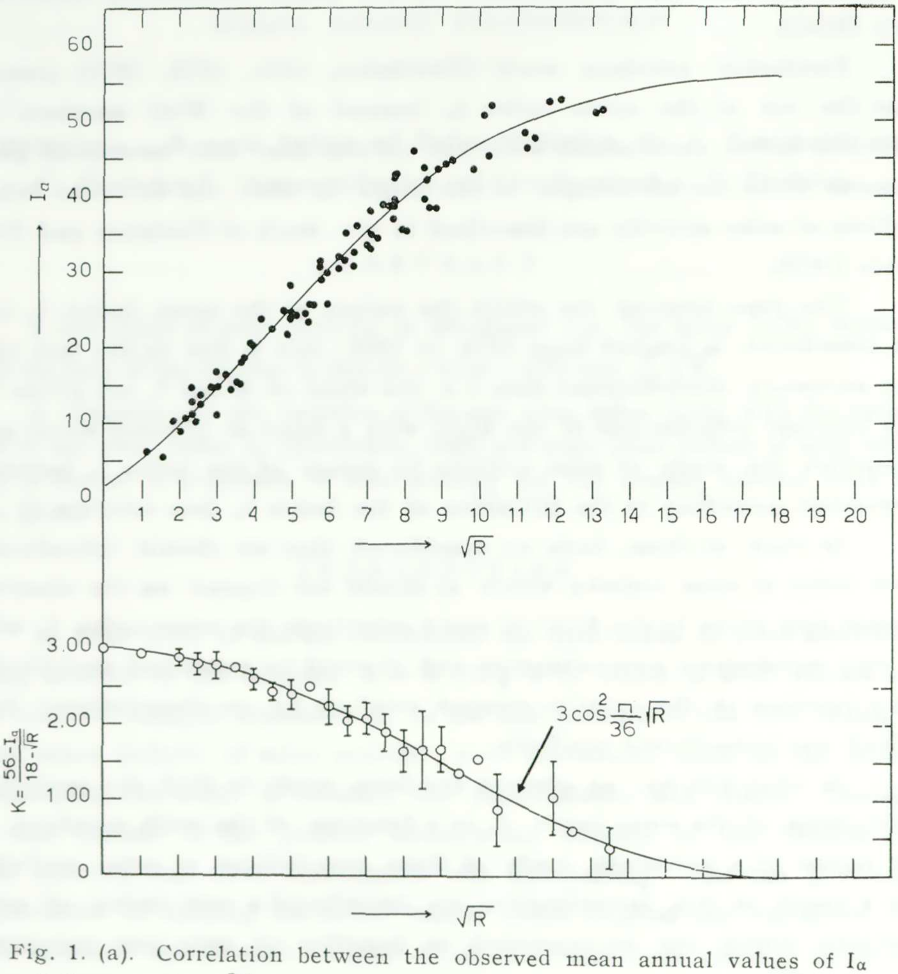

Fig. 1. (a). Correlation between the observed mean annual values of I_α and the quantity $\sqrt{R}$ for the sunspot cycles $N = 12$ to 19. (b). Abscissae represent the mean annual values of the quantity $\sqrt{R}$ and ordinates represent the corresponding values of the quantity $K = \frac{56 - I_\alpha}{18 - \sqrt{R}}$.

Segments give the dispersion.

To this purpose we calculated the correlation between the observed mean annual values of I_α and the corresponding values of $\sqrt{R}$ for the sunspot cycles $N = 12$ to 19.

The results are shown in figure 1 (up. p.). From this figure we see that a strong correlation there exists between I_α and $\sqrt{R}$ ($r_{I_\alpha, \sqrt{R}} = 0.97$). Besides, it is obvious that a trigonometric component should be also applied to the values of $\sqrt{R}$, in order to get a higher correlation between I_α and $\sqrt{R}$. This is clearly seen in figure 1 (lower part) where abscissae represent the mean annual values of, $\sqrt{R}$, and ordinates the corresponding values of the quantity $K = \frac{56 - I_\alpha}{18 - \sqrt{R}}$.

The curve represents the trigonometric component $3 \cos^2 \frac{\pi}{36} \sqrt{R}$. Segments give the dispersion.

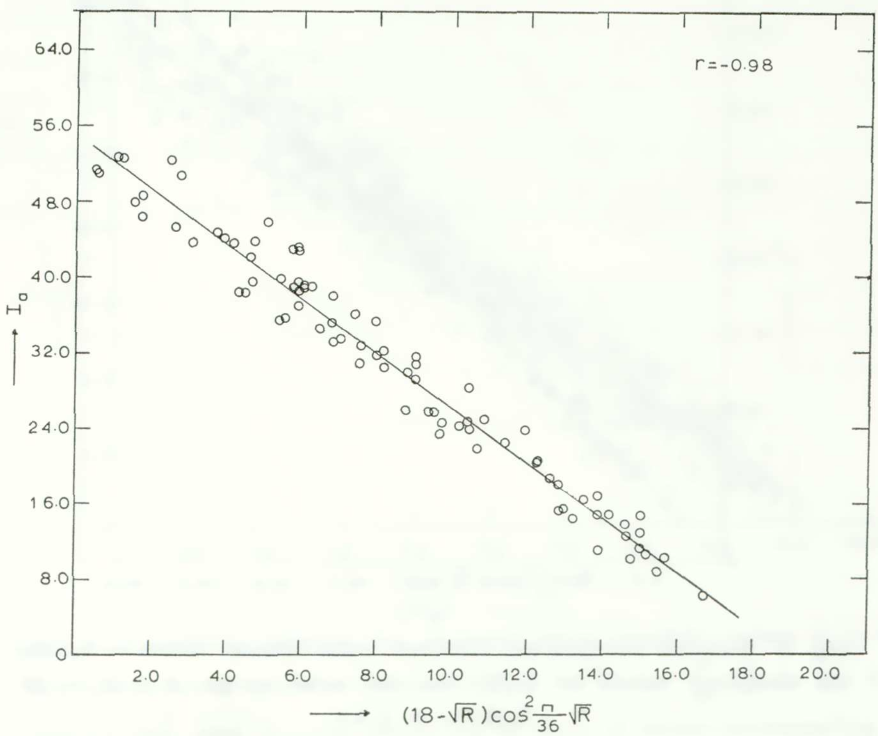

Fig. 2. Correlation between the observed mean annual values of I_α and the quantity $(18 - \sqrt{R}) \cos^2 \frac{\pi}{36} \sqrt{R}$. The correlation coefficient for the period 1880 - 1964 is noted in the upper part.

Based upon these results our next step was to calculate the correlation between the observed mean annual values of I_α and the corresponding values of the term $(18-\sqrt{R})\cos^2\frac{\pi}{36}\sqrt{R}$. The numerical results are shown in figure 2.

If we consequently, apply now the least square method for I_α and the term $(18-\sqrt{R})\cos^2\frac{\pi}{36}\sqrt{R}$ for the time interval 1880 - 1964 we get the relation:

$$I_\alpha(R) = 55.21 - 2.92\,(18-\sqrt{R})\cos^2\frac{\pi}{36}\sqrt{R}. \qquad (2)$$

Equation 2 represents the mean annual values of the areas index

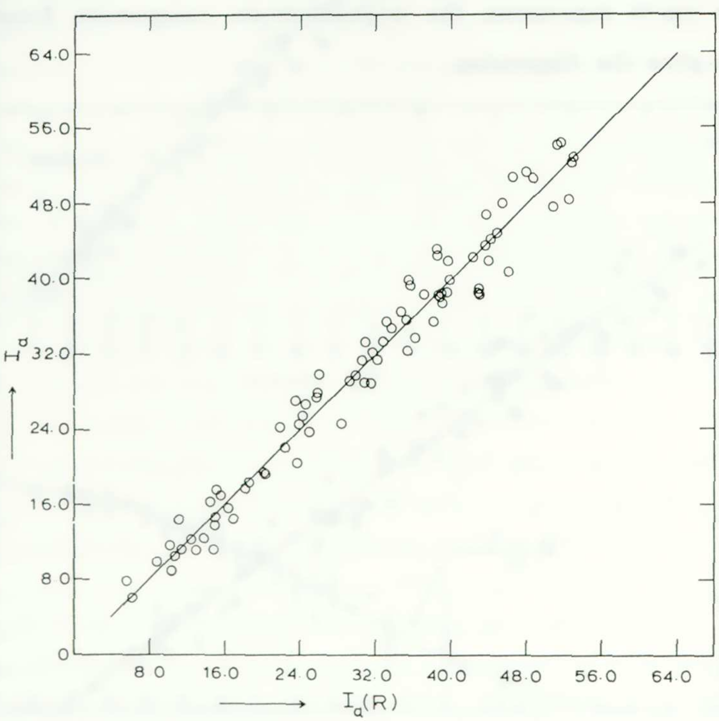

Fig. 3. Relation between the observed mean annual velues of I_α and the computed values of $I_\alpha(R)$ for the solar cycles $N = 12$ to 19. $I_\alpha(R) = I_\alpha \pm 2.3$.

I_α, observed during the sunspot cycles $N = 12$ to 19, with an accuracy equal to 92.3%. The above results are better shown in figure 3. This figure shows the relation between the observed mean annual values of the areas index I_α (ordinates) and the computed values of the new index $I_\alpha(R)$. The dispersion was found equal to $\sigma = \pm 2.33$ i. e. between I_α and $I_\alpha(R)$ there exists a relation of the form

$$I_\alpha = I_\alpha(R) \pm 2.33 . \qquad (3)$$

2. The New Index $I_\alpha(R)$ and the Mean Monthly Values of the Relative Sunspot Numbers.

The simplest approach to test whether relation 2 is also valid for the individual years of a given solar cycle was then to repeat the whole work by using the mean monthly values of the areas index I_α and of

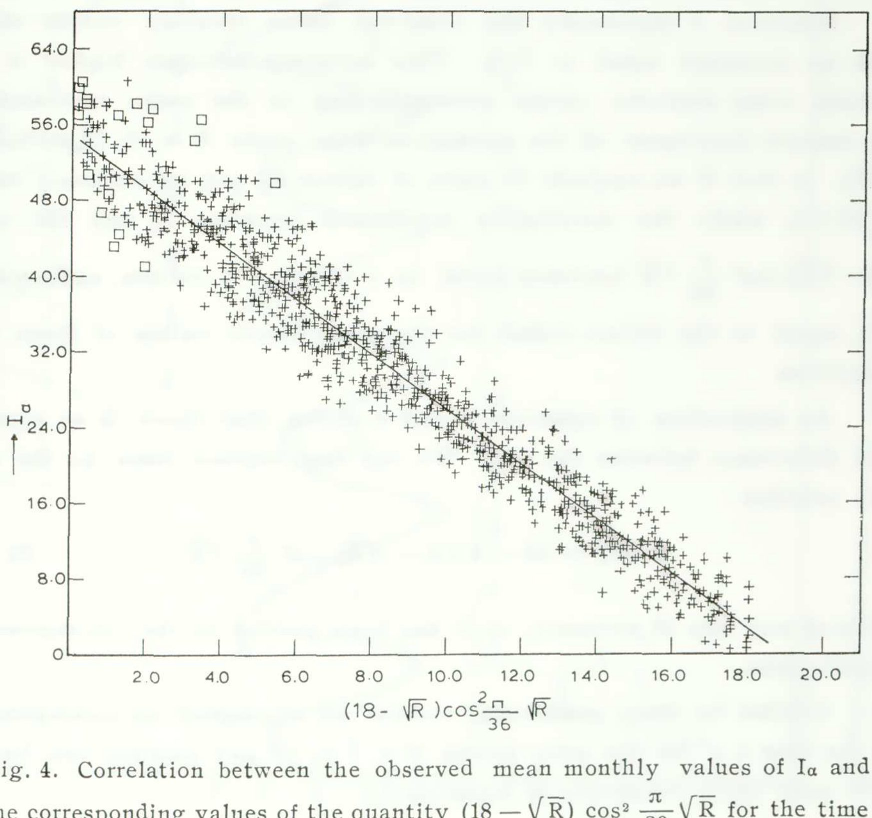

Fig. 4. Correlation between the observed mean monthly values of I_α and the corresponding values of the quantity $(18 - \sqrt{R}) \cos^2 \frac{\pi}{30} \sqrt{R}$ for the time interval 1880 - 1964. Squares denote the 18 pairs of values corresponding to the years surrounding the year of sunspot maximum of the anomalous solar cycle N = 19. The mean square error between the observed and computed values of I_α and $I_\alpha(R)$ was found equal to $\sigma = \pm 2.6$.

the quantity $(18-\sqrt{R})\cos^2\frac{\pi}{36}\sqrt{R}$ for the time interval 1880 - 1964. Figure 4 shows the correlation between the mean monthly values of I_α and the corresponding values of the term $(18-\sqrt{R})\cos^2\frac{\pi}{36}\sqrt{R}$ for the solar cycles N = 12 to 19.

Thus we find that the index I_α can be expressed analytically as a function of $\sqrt{R}$ with the help of the relation:

$$I_\alpha(R) = 55.05 - 2.92\,(18-\sqrt{R})\cos^2\frac{\pi}{36}\sqrt{R}. \qquad (4)$$

The correlation coefficient was found equal to r = 0.97.

Equation 4 represents the observed mean monthly values of I_α with an accuracy equal to 91%. This accuracy becomes higher if we exclude some extreme values corresponding to the years surrounding the sunspot maximum of the anomalous solar cycle N = 19 (Xanthakis, 1966). In fact if we exclude 18 pairs of values we get an accuracy equal to 92.1% while the correlation coefficient between I_α and the term $(18-\sqrt{R})\cos^2\frac{\pi}{36}\sqrt{R}$ becomes equal to r = 0.98 i. e. values, approximately, equal to the values found for the mean yearly values of these two quantities.

An inspection of equation 2 and 4 shows that there is no significant difference between the two. We can thus replace them by the unique relation:

$$I_\alpha(R) = 56 - 3\,(18-\sqrt{R})\cos^2\frac{\pi}{36}\sqrt{R} \qquad (5)$$

without any loss of accuracy, as it has been proved by the corresponding calculations.

Guided by these promissing results we attempted an extrapolation to the past i. e. for the solar cycles N = 7 to 11 and another one for the 20th solar cycle by means of equation 5.

The numerical results are represented by figures 5(a) and 5(c) respectively. Figure 5(b) shows the variation of the observed mean annual values of the areas index I_α (continuous line) and of the new index $I_\alpha(R)$ (dashed line) computed with the help of equation 5.

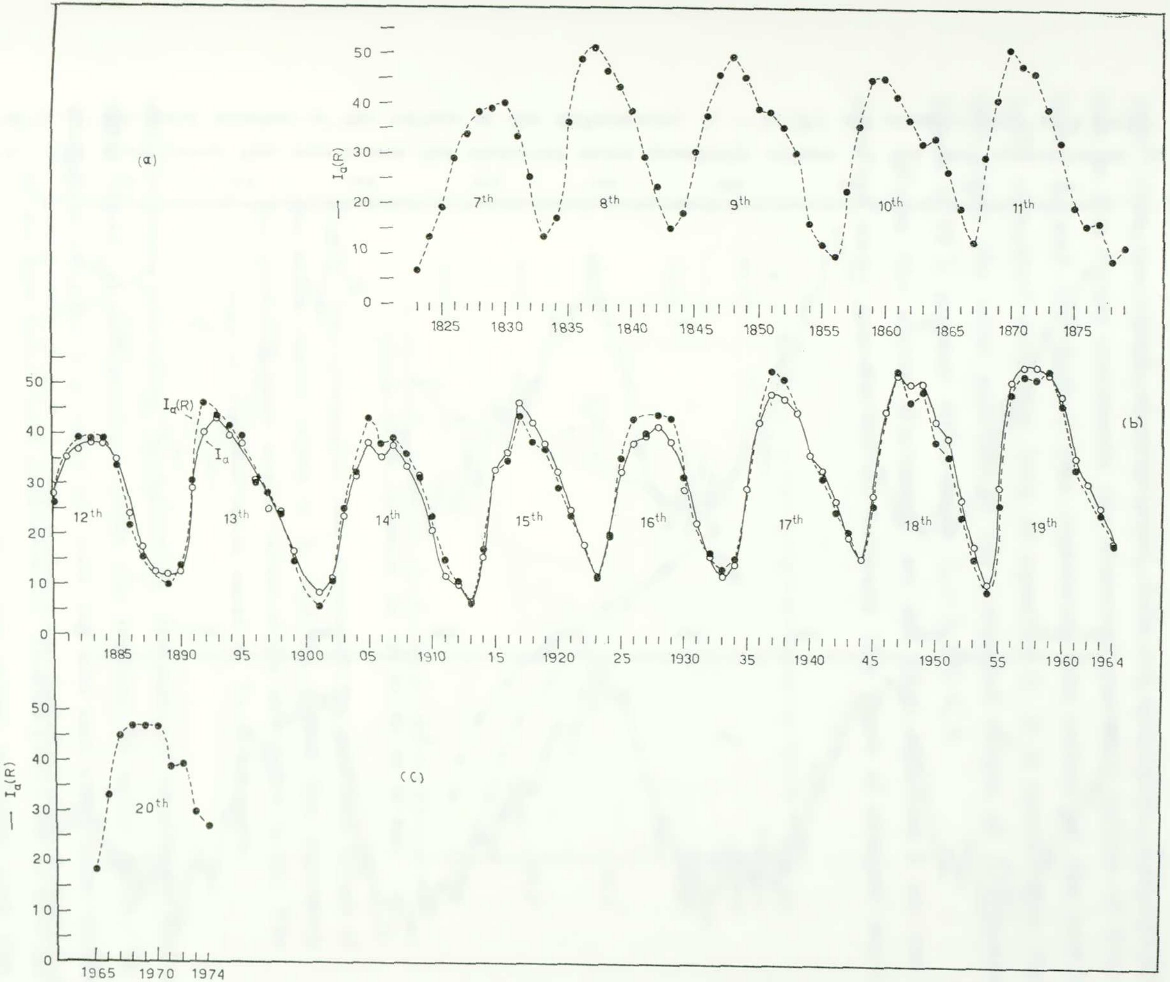

Fig. 5. (a). Extrapolated mean annual values of the new index $I\alpha(R)$ computed from equation 5 for the solar cycles $N = 7$ to 11. (b). Comparison of the mean annual variation of the areas index $I\alpha$ (continuous line) with the corresponding values of the new index $I\alpha(R)$ computed from equation 5 (dashed line) for the period 1880 - 1964 ($N = 12$ to 19). (c) Extrapolated mean annual values of $I\alpha(R)$ computed from equation 5 for the solar cycle $N = 20$.

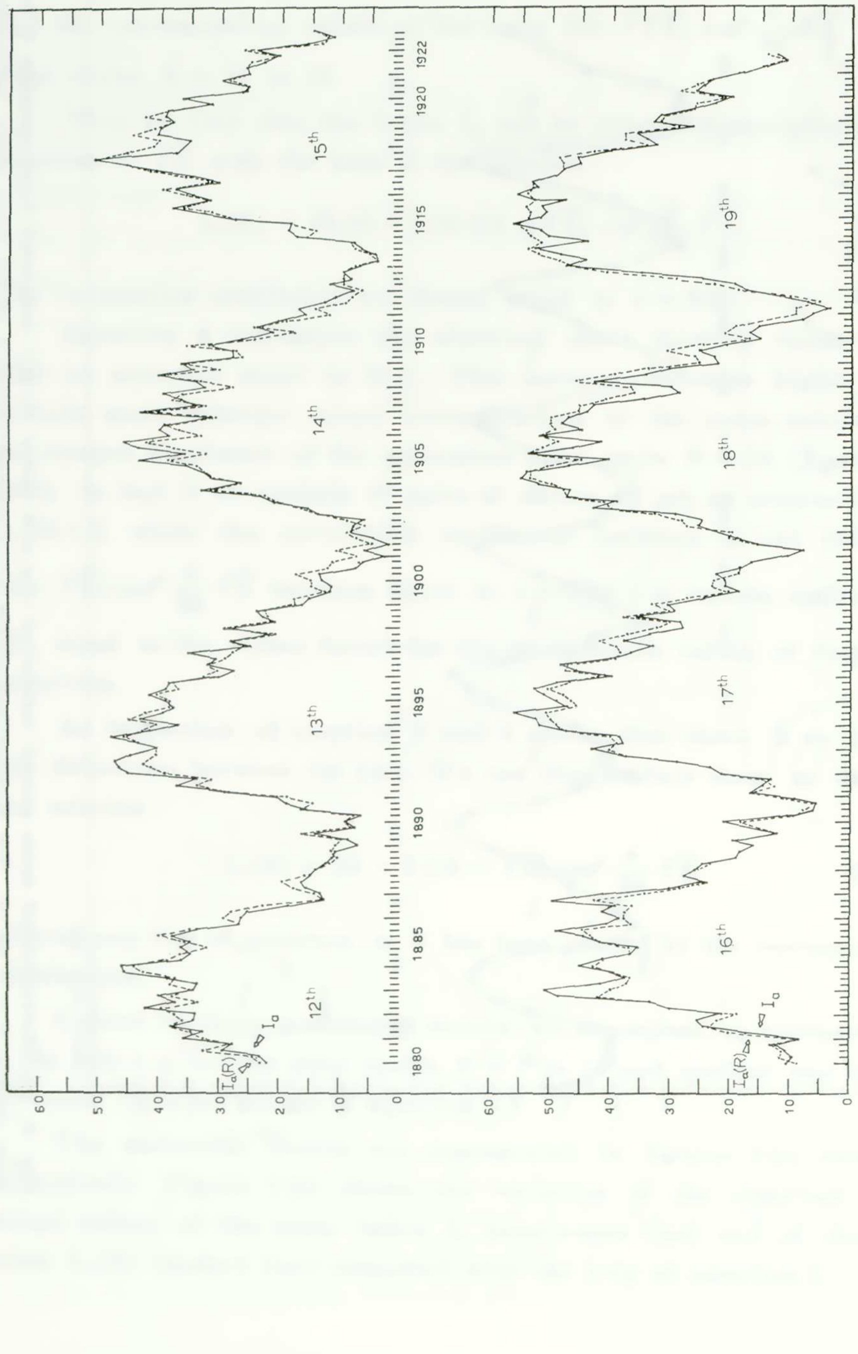

Fig. 6. The ncontinous line represents the observed mean quarterly values of the new areas index Iα (R). 92 % of the total number of the values of the defferences Iα — Iα (R) are smaller than of 5 units.

Appendix A gives the mean monthly as well as the mean yearly values of the new index $I_\alpha(R)$ computed with the help of equation 5.

Figure 6 shows the variation of I_α and $I_\alpha(R)$ for the time interval 1880 - 1964 for which observational data are available. The continuous line in this figure represents the observed quarterly values of the areas index I_α and the dashed line represents the values of the new index $I_\alpha(R)$ computed with the help of equation 5. It is remarkable the fact that from the total number of the computed values of $I_\alpha(R)$, used in figure 6, 92 % present differences $I_\alpha - I_\alpha(R) \leqslant 5$.

From the above discussion we see that equation 5 on one hand does not make any distinction between the years of sunspot maximum

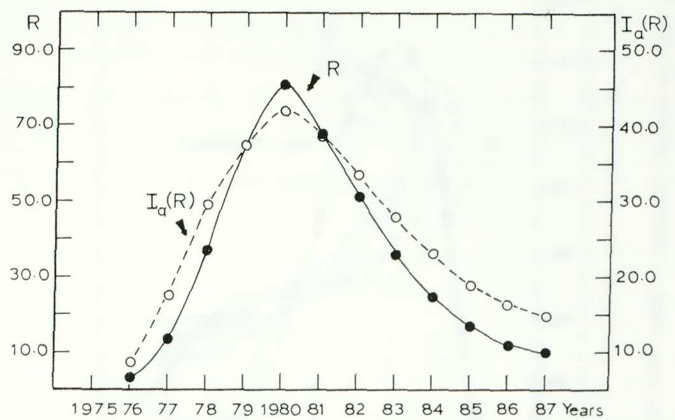

Fig. 7. The continuous line represents the predicted values of the mean annual values of R, and the dashed line represents the predicted mean annual values of the new index $I_\alpha(R)$. The time of rise was taken equal to $T_R = 4.6$ years.

and the years preceding or following the sunspot maximum and on the other hand is independent from the number of solar cycle; in other words the relation 5 is valid for both the odd and even solar cycles.

If we now take into account that Xanthakis (1967 a) has given a relation with which we can predict the mean monthly and the mean yearly values of the relative sunspot numbers R, with an accuracy equal to 84.7 % we can, therefore, extrapolate the values of the new index $I_\alpha(R)$ to the past as well as to the future without any loss of accuracy

(82 %) and without losing its principal advantages over the other indices of solar activity such as the Wolf numbers, the areas of sunspots the areas of faculae the prominences etc.

Figure 7 shows our prediction for the 21th solar cycle. For the predicted values of R, the relation given by Xanthakis (1967 a) was used. The time of rise was taken equal to $T_R = 4.6$ years (Xanthakis, 1967 b).

It should be noted that although the predictions for the 20th cycle given by Xanthakis (1966), which was derived with the help of analy-

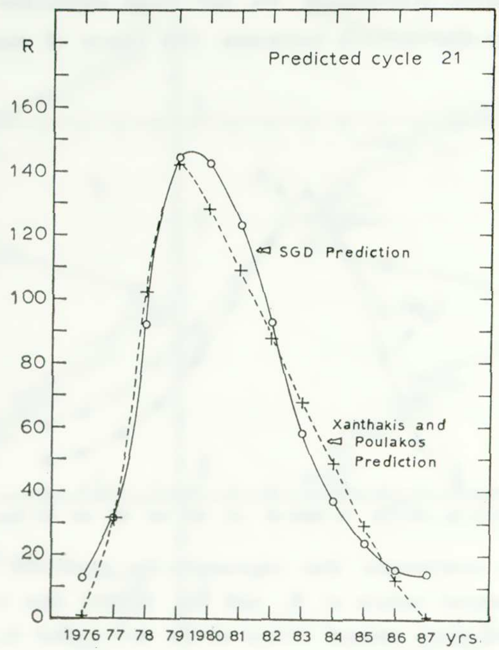

Fig. 8. Predicted mean annual values of the Wolf numbers, R, corresponding to $T_R = 3.2$. The small circles represent the prediction given by SGD and the crosses represent Xanthakis and Poulakos prediction.

tical relations and that published in Solar Geophysical Data (Coffey, 1969), (SGD), which was derived from a regression analysis of the cycles $N = 8$ to $N = 19$, were very similar and with an accuracy of about 82 %, their predictions for the current cycle $N = 21$ differ significantly (Coffey,

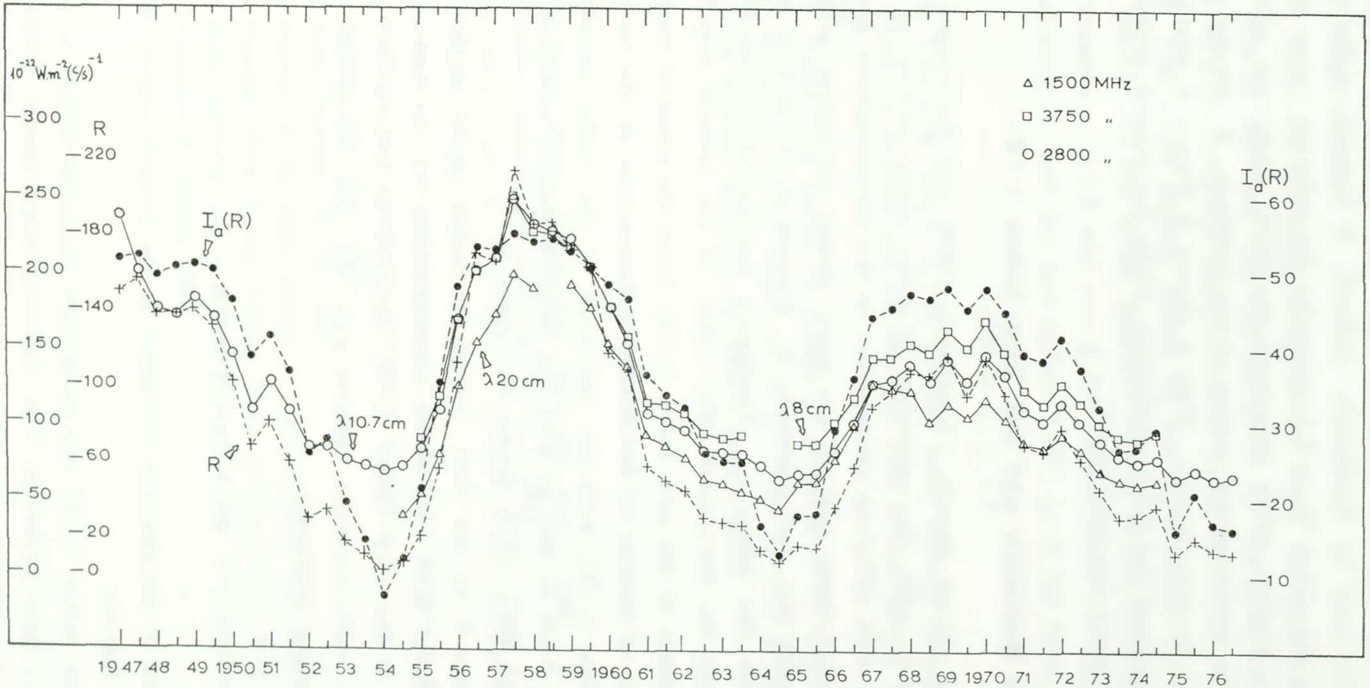

Fig 9. A comparison of the variation of the semi — annual values of the new index Iα (R) computed from equation 5 with the corresponting values of some radio emission indices in the frequences 1500 MHz (ΔΔΔ), 2800 MHz (OOO) and 3750 MHz (000) for the time interval 1947 - 1976.

1978). This discrepancy is due to the different values of the time of rise, T_R, used by SGD and by Xanthakis. Indeed, if instead of the value $T_R = 4.6$ we use the value $T_R = 3\ 2$, given by the relevant curve of the SGD's prediction (Coffey, 1978) then both the SGD prediction and our prediction for the mean annual values of the numbers, R, for the cycle $N = 21$ appear to be very similar. This is shown if Figure 8 where the small circles represent the SGD prediction while the crosses connected with dashes represent our prediction.

3. **Solar Radio Emission and the New Index I_α (R).**

It has been shown already (Xanthakis, 1969) that the variation of the areas index I_α with the variation of some other indices of solar activity related with different phenomena in the chromosphere and the corona shows that these indices are more closely correlated with the index I_α than with the wolf numbers, R. Because of the lack of observational data for the index I_α, Xanthakis was forced to restrict his investigation only for the period 1955 - 1962. In the present report due to the independence of the new index I_α (R) from the areas of sunspots, A, and the areas of faculae, f, we attempt a comparison of the variation of the new index I_α (R) with the variation of the radio emission at 20 cm, 10,7 cm, 8 cm as well as with the relative sunspot numbers R for the time interval 1947 - 1976, shown in Figure 9.

From figure 9 we see that for all the solar cycles of the time interval considered here, the curve corresponding to the mean semi-annual values of the new index I_α (R) appears to have a very close march with the radio-emission indices with the sole exception of the years of the sunspot minimum.

CONCLUSIONS

The results of the analysis discussed in the present report, may be summarized as follows.

1. The new index I_α(R) can substitude the areas index I_α with a very satisfactory approximation. The observed mean annual values of I_α and the observed mean monthly values of I_α can be represented by means

of equation 5 with a very high accuracy of the order of 92.3% and 92.1% respectively.

2. Equation 5, being independent from the data published by the RGO, can be used for the extrapolation to the past as well as to the future with an accuracy approximately equal to 91%.

3. The mean square errors of the defferences $I_\alpha - I_\alpha(R)$ for the mean yearly and the mean monthly values of the indices I_α and $I_\alpha(R)$ were found $\sigma = \pm 2.3$ and $\sigma = \pm 2.6$ rerpectively i. e. the existing relation between I_α and the new index $I_\alpha(R)$ is of the form:

$$I_\alpha(R) = I_\alpha \pm 2.5 .$$

4. The new index $I_\alpha(R)$ is also very closely correlated with the radio emission indices the correlation coefficient being of the order of $r = 0.97$.

5. Prediction made, by means of equation 5 for the 20th solar cycle had an accuracy of the order of 91%. This is very promissing for the prediction of solar activity on future solar cycles.

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APPENDIX A.

Mean Monthly and mean yearly Values of the New Index of Solar Activity $I_\alpha(R)$.

$$I_\alpha(R) = 56 - 3\,(18 - \sqrt{R})\cos^2\frac{\pi}{36}\sqrt{R}.$$

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly
1880	23.46	25.08	20.87	21.03	23.20	28.20	22.34	33.57	38.91	31.75	26.70	26.19	27.40
1881	29.15	35.21	34.70	34.70	31.94	37.43	41.60	36.81	35.21	38.48	35.72	33.29	35.58
1882	32.48	39.84	39.13	45.38	38.44	32.52	32.62	30.78	36.63	37.03	43.22	31.31	37.21
1883	37.43	33.15	31.65	42.73	27.05	41.44	42.42	32.81	35.03	43.07	43.22	41.36	38.31
1884	44.61	43.71	43.82	41.40	39.04	34.61	35.21	36.04	37.83	33.43	29.25	33.24	38.26
1885	31.65	40.38	34.14	35.81	40.67	43.07	39.04	34.05	30.43	30.09	26.80	22.24	34.89
1886	26.34	24.42	36.49	31.39	26.70	25.03	26.50	19.46	22.09	13.68	3.77	16.97	24.17
1887	15.02	17.07	9.67	12.28	21.28	18.71	23.10	22.09	12.69	12.00	12.28	21.68	17.02
1888	16.73	12.42	13.02	10.59	12.37	12.42	8.42	8.04	13.87	7.14	15.31	12.09	12.18
1889	4.98	13.63	12.09	9.75	7.55	11.82	14.35	21.63	11.91	7.14	3.43	12.09	11.72
1890	10.77	4.54	10.59	6.38	10.28	5.92	15.99	13.63	19.67	15.70	14.49	13.02	12.42
1891	17.27	22.49	15.07	21.58	31.02	33.62	36.94	27.70	35.40	34.70	31.31	27.50	28.85
1892	39.72	41.28	34.14	39.84	42.19	41.44	41.52	46.31	38.05	40.09	38.78	41.99	40.67
1893	41.16	40.67	38.87	43.96	43.26	44.29	44.04	50.05	41.84	42.27	41.20	45.03	43.34

Appendix A (continued)

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly
1894	42.96	43.26	34.93	42.62	46.28	45.88	47.05	40.01	38.91	41.28	36.26	37.30	41.84
1895	38.22	39.25	37.56	41.60	39.34	40.34	33.43	39.68	36.63	39.42	33.24	40.14	38.40
1896	25.94	36.54	34.84	32.04	25.28	33.86	32.48	25.08	37.65	25.79	29.79	31.61	31 31
1897	30.83	26.09	25.94	26.85	21.28	15.75	25.23	22.29	33.57	17.82	13.54	27.85	24.57
1898	26.50	29.15	29.94	17.97	24.37	22.55	14.01	27.00	28.50	28.35	26.80	16.68	24.83
1899	21.03	14.16	20.17	17.77	12.93	21.58	17.27	8.17	13.54	16.97	13.02	15.17	16.34
1900	14.35	17.37	13.68	18.91	18.41	16.34	13.45	9.75	13.45	16 88	9.97	3.77	14.40
1901	3.43	7.55	9.97	2.00	14.93	11.27	4.80	5.39	4.54	9.10	9.23	2.00	7.92
1902	11.00	2.00	16.53	2.00	8.04	6.07	5.20	7.42	12.88	19.11	15.02	5.58	10.50
1903	13.45	19.92	17.27	24.52	18.01	19.11	25.38	25.84	15.60	30.19	32.28	32.67	23.66
1904	27.10	23.71	29.50	31.75	30.38	31.31	34.37	36.76	26.45	35.53	29.79	35.67	31.36
1905	35.72	43.48	36.26	30.34	33.53	33.86	40.67	36.94	35.81	41.99	47.20	35.95	38.26
1906	32.67	26.95	38 53	35.90	36.63	38.18	46.67	33.43	36.13	20.02	30.19	38.57	35.40
1907	41.48	47.36	37.47	35.03	31.70	30.78	34.09	35.58	43.34	38.57	37.70	33.29	37.83
1908	30.29	28.10	25.79	36.58	30.92	33.57	30.38	44.40	43.71	27.40	32.67	30.38	33.67
1909	36.31	33.05	39.00	27.40	29.00	22.70	28.90	23.00	30.14	36.81	36.04	35.53	32.09
1910	24.68	27.05	22.09	13.54	22.49	16.48	17.67	15.90	24.57	29.94	10.37	11.27	20.47

Appendix A (continued)

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly
1911	8.76	14.01	13.02	19.21	14.01	7.26	8.89	9.45	9.45	7.79	9.67	7.26	11.18
1912	3.77	2.00	10.37	9.97	9.88	9.53	8.29	3.77	14.40	10.06	5.58	11.82	9.02
1913	7.42	8.17	4.33	5.20	2.00	2.00	6.54	3.43	5.77	8.42	4.80	9.23	6.07
1914	8.04	7.79	8.42	19.72	10.68	15.85	10.86	12.93	16.73	13.35	19.16	22.55	14.49
1915	22.95	31.46	30.14	31.12	27.70	39.63	40.34	39.84	34.05	35.30	31.56	28.35	33.29
1916	32.57	35.90	39.21	40.38	41.04	39.38	35.30	28.68	32.52	34.42	38.83	35.17	36.45
1917	41.08	40.43	45.21	41.08	48.19	48.31	48.96	52.35	50.08	40.51	45.48	50.05	46.70
1918	45.41	38.74	40.51	42.38	41.56	37.12	47.27	46.35	42.27	43.34	43.00	37.03	42.42
1919	33.57	42.19	39.04	34.79	43.96	47.81	38.57	39.72	35.72	35.12	31.36	28.55	38.26
1920	34.56	35.44	40.01	18.16	27.85	30.09	25.18	20.82	29.10	34.05	25.08	26.34	29.64
1921	27.05	25.59	24.83	27.45	22.49	28.05	31.31	22.80	20.02	20.27	20.02	21.48	24.52
1922	16.14	24.68	35.72	15.55	13.21	11.27	15.46	11.91	10.19	11.63	12.69	19.82	17.77
1923	9.97	6.23	8.67	11.54	8.55	14.11	8.89	4.33	17.07	15.99	14.78	8.04	11.27
1924	4.33	10.59	6.70	15.75	21.73	23.46	25.49	20.87	24.02	24.27	22.65	19.21	19.36
1925	11.00	23.05	20.12	27.15	31.65	33.34	29.99	29.79	37.34	39.76	36.90	45.85	32.23
1926	40.38	39.93	38.00	29.99	38.48	40.79	34.93	37.74	37.52	40.34	37.43	42.15	38.35
1927	42.62	44.86	39.84	44.96	42.07	37.03	35.76	35.40	39.55	38.13	39.25	32.52	39.72

Appendix A (continued)

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly
1928	43.03	40.79	43.41	42.42	41.60	44.58	45.75	43.07	44.25	37.70	34.28	36.99	41.80
1929	39.68	38.05	34.28	35.12	36.76	40.43	40.01	38.87	28.35	35.49	42.54	47.33	38.78
1930	38.74	34.14	28.60	29.89	29.35	25.84	22.34	23.91	27.35	28 35	28.85	24.37	28.85
1931	18.01	31.80	26.39	26.95	23.76	18.46	19.77	16.97	20.72	14.78	20.52	20.02	21.94
1932	16.34	15.26	15.70	15.70	20.07	22.49	14.49	12.18	9.45	13.92	13.35	15.55	15.60
1933	16.48	22.49	14.88	8.17	8.55	10.68	8.04	3.43	10.50	8.29	4.54	3.77	11.18
1934	8.76	13.02	9.75	15.75	21.13	12.09	14.25	13.45	9.45	11.18	13.78	18.51	13.78
1935	20.47	21.58	23.00	16.38	25.08	32.72	28.10	26.45	31.41	35.21	38.44	37.70	29.05
1936	38.05	41.00	41.64	41.12	35.67	39.97	34.93	43.74	41.40	44.11	48.37	49.39	42.23
1937	50.39	49.98	43.11	47.51	48.54	50.15	51.60	50.91	46.18	49.57	41.04	44.07	48.25
1938	45.82	48.87	43.63	46.25	49.85	45.65	53.10	48.42	44.25	45.92	49.23	44.82	47.57
1939	42.35	41.72	38.57	47.51	48.76	46.25	45.68	47.02	47.99	43.96	39.47	31.41	44.07
1940	34.37	37.12	43.00	37.47	35.63	43.11	39.34	46.95	39 04	35.81	36.81	39.51	39.38
1941	32.67	32.28	32.95	27.65	26.14	37.21	39.17	37.30	38.91	32.91	29.99	28.05	33.34
1942	28.85	35.12	35.53	37.47	23.97	15.85	19.97	21.38	19.67	20.82	26.70	22.65	26.65
1943	16.53	25.89	25.13	24.52	17.67	12.88	17.07	20.93	14.78	13.02	14.93	20.62	19.11
1944	9.10	4.33	15.55	3.77	7.67	10.50	10.50	19.36	17.82	19.46	15.41	25.64	14.49

Appendix A (continued)

Month / Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly
1945	20.42	16.73	22.14	27.30	26.65	29.10	31.61	24.42	28.55	39.63	32.81	25.13	27.80
1946	33.38	43.56	41.52	41.32	43.30	40.79	48.48	47.20	45.14	46.44	49.44	49.17	44.79
1947	48.42	50.49	50.10	51.99	54.78	53.00	52.61	54.31	53.35	52.99	49.90	48.51	52.13
1948	47.42	43.56	45.21	54.35	53.60	53.24	51.33	52.55	51.44	50.77	45.38	50.95	50.77
1949	48.84	54.02	52.57	51.75	47.08	49.17	49.67	49.44	51.60	50.30	51.46	48.65	50.63
1950	46.35	45.21	47.57	48.11	47.08	43.03	44.50	43.37	34.61	37.70	35.72	35.53	43.11
1951	37.25	37.25	36.08	44.86	47.42	46.18	37.70	37.56	42.96	34.70	34.98	32.76	39.80
1952	30.87	22.75	22.39	25.94	23.15	29.15	30.34	35.76	25.54	23.36	22.44	28.30	27.05
1953	24.73	9.32	14.78	25.33	16.63	22.29	13.68	23.20	20.87	13.35	6.38	7.67	17.57
1954	3.43	4.33	15.46	6.70	4.98	3.43	10.28	13.54	6.23	12.37	15.46	12.88	9.88
1955	23.00	21.73	10.37	15.75	25.89	27.15	24.83	30.87	31.61	36.85	44.15	41.60	29.79
1956	40.92	49.46	48.76	47.72	50.82	48.54	50.03	53.35	53.56	52.41	54.78	54.45	51.29
1957	53.08	50.15	52.57	53.67	53.05	54.76	54.24	52.61	55.59	55.80	55.07	55.64	54.37
1958	54.82	53.07	54.39	54.60	53.67	53.47	54.42	54.74	54.77	53.98	52.18	54.27	54.14
1959	55.23	51.42	54.18	52.97	53.49	53.31	51.97	54.73	51.60	47.81	49.46	49.57	52.68
1960	51.71	47.05	46.44	49.23	48.93	47.66	49.17	50.56	49.83	42.88	44.25	43.45	47.96
1961	36.67	32.86	35.17	37.70	34.51	41.72	40.01	36.08	38.26	29.69	27.55	30.58	35.44

Appendix A (continued)

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly
1962	30.09	34.28	32.67	32.95	31.99	31.36	22.29	22.29	34.61	30.38	24.93	23.05	29.60
1963	21.18	23.66	19.62	26.04	31.75	28.95	21.08	27.80	30.14	28.70	23.15	18.21	25.38
1964	18.46	19.97	19.21	13.68	14.40	14.11	8.42	14.25	10.19	11 54	12.69	18.36	18.16
1965	19.82	17.77	16.04	12.18	23.51	18.86	16.19	13.92	19.41	23.36	18.76	19.51	18.31
1966	25.54	23.66	24.12	33.76	32.57	33.43	36.31	34.61	34.28	36.45	36.45	40.05	32.85
1967	47.75	44.96	47.87	39.84	43.63	39.25	44.61	47.20	41.56	43.96	45.10	49.72	44.97
1968	49.20	47.90	44.72	42.54	49.83	47.66	45.41	47.51	48.62	47.30	43.52	47.60	47.02
1969	46.80	49.04	50.73	47.14	48.96	47.05	45.55	45.75	44.58	45.34	44.96	45.72	46.86
1970	47.84	49.88	46.54	47.54	49.85	47.14	47.99	44.86	45.98	43.67	45.27	43.03	46.73
1971	44.56	42.07	37.48	40.40	36.55	34.12	42.50	37.68	34.26	34.75	38.18	42.75	39.10
1972	37.71	44.01	42.31	38.18	42.39	43.93	41.51	41.57	38.40	37.65	31.22	32.57	39.58
1973	31.89	31.70	32.82	36.61	31.52	30.41	22.98	24.27	37.08	26.70	23.40	23.09	29.71
1974	25.25	24.47	22.01	30.72	30.41	29.00	36.04	27.99	30.68	33.21	23.97	21.57	28.33
1975	20.66	15.90	15.90	10.59	14.01	15.83	25.54	30.49	17.56	14.09	10.95	13.04	18.57
1976	13.29	9.77	22.34	20.60	16.54	16.40	6.85	19.16	17.29	21.63	10.68	18 47	16.64

ΠΕΡΙΛΗΨΙΣ

Ἡ κατὰ τὰ τελευταῖα ἔτη διαρκῶς αὐξανομένη ἀνάγκη νὰ εὑρεθῇ ἕνας δείκτης τῆς ἡλιακῆς δραστηριότητος ὅστις νὰ παριστᾶ τὸ φαινόμενον τοῦτο κατὰ τὸν πλέον ἱκανοποιητικὸν τρόπον, ὤθησε τὸν καθηγητὴν Ι. Ξανθάκην νὰ εἰσαγάγη τὸ 1969 ἕναν νέον δείκτην τῆς ἡλιακῆς δραστηριότητος παριστώμενον διὰ τοῦ συμβόλου $I_\alpha = \frac{1}{2}[\sqrt{A} + \sqrt{f}]$. Ἡ εἰσαγωγὴ τοῦ νέου τούτου δείκτου, γνωστοῦ πλέον ὡς δείκτου τῶν ἐμβαδῶν I_α, ἀπεκάλυψεν σημαντικὰς συσχετίσεις μεταξὺ αὐτοῦ καὶ τῶν διαφόρων φαινομένων τῆς ἡλιακῆς δραστηριότητος ὄχι μόνον εἰς τὴν φωτοσφαῖραν ἢ τὴν χρωμοσφαῖραν ἀλλὰ καὶ εἰς τὸ ἡλιακὸν στέμμα, καθὼς ἐπίσης καὶ μὲ διάφορα φαινόμενα τῆς γηΐνης ἀτμοσφαίρας.

Ὁ Σύνθετος ὅμως αὐτὸς δείκτης τῶν ἐμβαδῶν, ποὺ παρουσιάζει τὸ μέγα πλεονέκτημα ὅτι κέκτηται φυσικὴν σημασίαν, τὴν ὁποίαν δὲν ἔχουν οἱ ἀριθμοὶ Wolf, παρουσιάζει τὸ μειονέκτημα ὅτι στηρίζεται ἀποκλειστικῶς εἰς τὰς παρατηρήσεις τοῦ Ἀστεροσκοπείου τοῦ Greenwich, τὰ δεδομένα τῶν ὁποίων δημοσιεύονται, λόγῳ τῶν πολλῶν ὑπολογισμῶν οἱ ὁποῖοι ἀπαιτοῦνται, μὲ καθυστέρησιν 10 - 12 ἐτῶν. Εἶναι φανερὸν ὅτι οἱ διάφοροι ἐρευνηταί, ἀστρονόμοι, μετεωρολόγοι, γεωλόγοι, ποὺ χρησιμοποιοῦν τὸν δείκτην τῶν ἐμβαδῶν I_α δὲν δύνανται νὰ ἀναμένουν τόσον πολὺ διὰ νὰ χρησιμοποιήσουν τὸν δείκτην αὐτόν.

Εἰς τὴν παροῦσαν ἐργασίαν ἐπιζητεῖται ἡ ἀνεύρεσις ἑνὸς νέου δείκτου τῆς ἡλιακῆς δραστηριότητος, ποὺ νὰ παρουσιάζη ἀφ' ἑνὸς μὲν τὰ αὐτὰ μὲ τὸν δείκτην τῶν ἐμβαδῶν I_α πλεονεκτήματα, ἀφ' ἑτέρου δὲ νὰ δύναται νὰ ὑπολογισθῇ ταχέως.

Οὕτω τὰ ἀποτελέσματα τῆς ἐρεύνης δύνανται νὰ συνοψισθοῦν ὡς ἀκολούθως :

1) Εἰσάγεται ἕνας νέος δείκτης τῆς ἡλιακῆς δραστηριότητος, παριστώμενος διὰ τοῦ συμβόλου $I_\alpha(R)$, ὁ ὁποῖος εἶναι συνάρτησις τῆς τετραγωνικῆς ρίζης τῶν ἀριθμῶν Wolf, δίδεται δὲ ὑπὸ τῆς σχέσεως

$$I_\alpha(R) = 56 - 3\,(18 - \sqrt{R})\cos^2 \frac{\pi}{36}\sqrt{R}$$

2) Ὁ Νέος δείκτης $I_\alpha(R)$ παριστᾶ τὸν δείκτην τῶν ἐμβαδῶν I_α μὲ μίαν λίαν ὑψηλὴν προσέγγισιν, τῆς τάξεως τοῦ 92%.

3) Ὁ Νέος δείκτης $I_\alpha(R)$ εἶναι ἀνεξάρτητος τῶν ἐμβαδῶν τῶν κηλίδων καὶ τῶν πυρσῶν, ἤτοι δεδομένων δημοσιευομένων ὑπὸ τοῦ Ἀστεροσκοπείου τοῦ Greenwich μὲ καθυστέρησιν 10 - 12 ἐτῶν, δύναται νὰ ὑπολογισθῇ ταχέως καὶ

ἐπὶ πλέον νὰ προβλεφθοῦν αἱ τιμαί του διὰ τοὺς μελλοντικοὺς ἡλιακοὺς κύκλους μὲ μίαν ἀκρίβειαν τῆς τάξεως τοῦ 91%.

4) Μεταξὺ τοῦ νέου δείκτου $I_\alpha(R)$ καὶ τοῦ δείκτου τῶν ἐμβαδῶν, I_α ὑφίσταται μία ἁπλῆ ἀλγεβρικὴ σχέσις $I_\alpha(R) = I_\alpha \pm 2.5$.

5) Ἡ συσχέτισις τοῦ νέου δείκτου $I_\alpha(R)$ μετὰ τῶν ἄλλων δεικτῶν τῆς ἡλιακῆς δραστηριότητος εἶναι λίαν ὑψηλή.

6) Τέλος προβλέπεται ἡ πορεία τῆς ἡλιακῆς δραστηριότητος τοῦ 21ου κύκλου ἐκπεφρασμένη ὑπὸ τοῦ νέου δείκτου $I_\alpha(R)$.

Δεδομένου ὅτι ἡ πρέβλεψις Ξανθάκη τῆς ἡλιακῆς δραστηριότητος, ἐκπεφρασμένη εἰς ἀριθμοὺς Wolf, διὰ τὸν 20ὸν κύκλον ἔγινε μὲ ἀκρίβειαν 91%, τοῦτο μᾶς παρέχει σοβαρὰς ἐνδείξεις ὅτι ἡ πρόβλεψις τῆς ἡλιακῆς δραστηριότητος διὰ τοὺς μελλοντικοὺς κύκλους, συναρτήσει τοῦ νέου τούτου δείκτου ὅστις παρέχεται ὡς συνάρτησις τῶν ἀριθμῶν Wolf, θὰ εἶναι ἐξ ἴσου ἐπιτυχής.