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ΠΡΟΕΔΡΙΑ ΜΙΧΑΗΛ ΣΤΑΣΙΝΟΠΟΥΛΟΥ

ΜΕΤΕΩΡΟΛΟΓΙΑ.— **On the Reality of a Possible Sun-weather Correlation,** *by C. S. Zerefos and B. P. Tritakis**. Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Ἠλία Γ. Μαριολοπούλου.

In recent years a considerable debate on sun-weather relations appeared as a consequence of the increasing international interest on climatic change and its causes (S. F. Shapley, 1975). However, most of these studies were questioned by people which were either sceptical from the begining or those who became sceptical by the growing and in many cases conflicting evidence of the so-called solar-weather relations. Very few empirical solar-weather studies are by now enough promissing to stand the before mentioned scientific critisism.

In a series of papers, Xanthakis (1973, 1975, 1978) reported a striking correlation between solar activity and zonal mean rainfall departures from minimum on a global scale. This resulted in a high negative correlation in the latitude belt 60-70° N while other belts showed either a change in time from negative to positive correlation or no correlation at all. Roberts (1974) and Gerety et al. (1978) decided that these correlations needed a totally independent confirmation by using a much more extensive number of data points (2548 globally distributed stations for the period 1850-1973).

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In the following, we shall re-investigate the similarities and disparities that appear between the rainfall records of Xanthakis' and the corresponding records of Gerety et al. (in the following cited as G.O.R.). We shall confine our discussion to the latitude belts 50° - 60° N and 60° - 70° N were data are available to us from both analyses (see also Xanthakis, 1978 and Gerety, 1978, reply).

Both analyses make use of the same statistic (X_k) for the zonal rainfall departures from minimum, namely:

$$X_k = \frac{1}{N} \sum_{1}^{N} (R_{kj} - R_{jm}) \qquad (1)$$

where N is the number of stations with data in a given year, j the number of the station, k the year, R_{kj} the annual total precipitation at station j for year k and R_{jm} the long-term minimum annual precipitation taken from the entire record for the j^{th} station.

Gerety et al. (G. O. R., 1978) compared the time series of the statistic X_k, as given by equation (1), with corresponding series of that statistic from Xanthakis' analysis which, however, was based on a more limited data base. This comparison showed a general similarity between the two records but according to G. O. R. (1978), substantial disparities appeared as well. If these disparities were to be statistically proven, it would mean that the solar activity signal as reported by Xanthakis on the X_k statistic is either very weak or even absent, because Xanthakis' correlations with the solar index would become insignificant as the data points increase. G. O. R. and Gerety (1978) referred to «some similarity» between these records and it is that matter that we come here to discuss.

Figure 1 shows the X_k time series as computed by these authors, the yearly number of stations used in the calculations for the belt 50° - 60° N and the solar activity index. Figure 2 displays similar things but for the latitude belt 60° - 70° N. From these figures it appears that in the last decade (1951 - 1960) the number of stations used in the G.O.R. analysis almost doubled and resulted to an abrupt discontinuity in the gradual trend evident in the number of stations before the 1950's. In the following we shall first compare the X_k time series of Xanthakis' with the corresponding G. O. R. series.

In the latitude belt 50° - 60° N (fig. 1) the correlation coefficient between the two X_k time series for the entire available record (1890 -

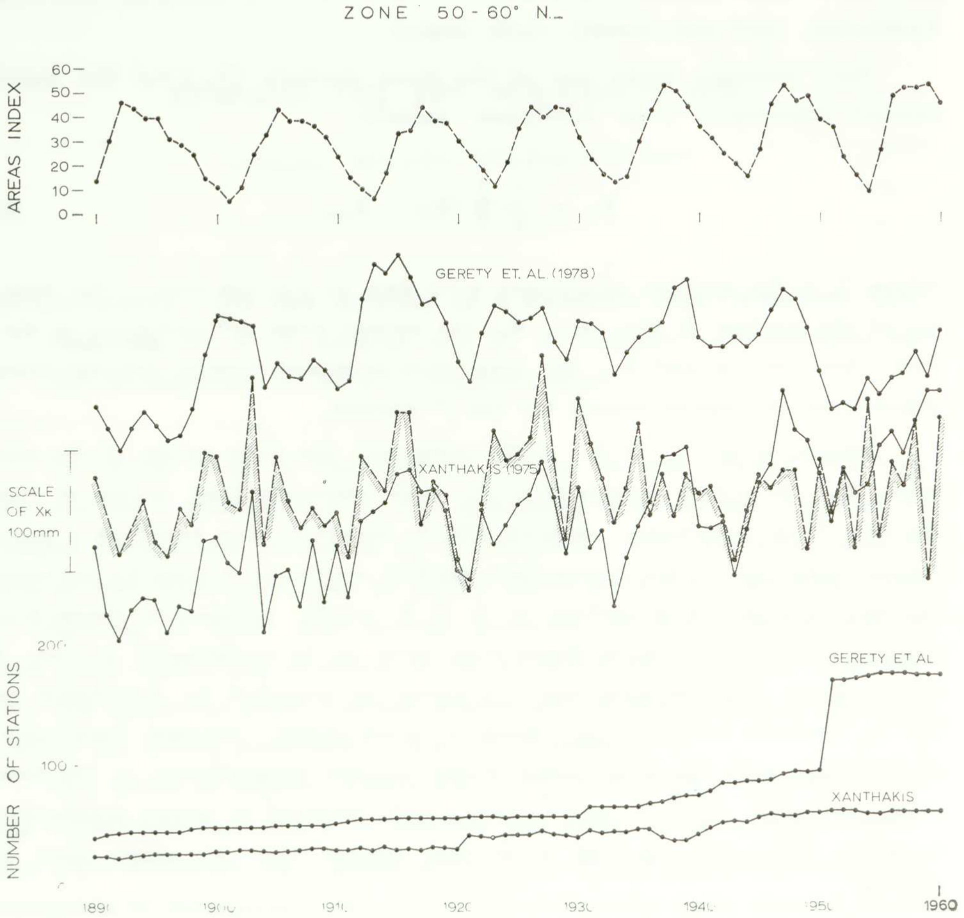

Fig. 1.

1960) is not higher than .534. This correlation coefficient, however, becomes as high as .791, if the last decade (1951 - 1960) is not included in the computation. This result implies that Xanthakis' and G. O. R. series are highly correlated before the 1950's, inspite the fact that G. O. R. analysis included twice as many stations as those used by Xanthakis (see fig. 1). In other words, by excluding the last decade, more than 60% of the total variance of G.O.R.'s X_k series is explained by the total variance of Xanthakis' series.

We now come to discuss the folowing question: in calculating regional (zonal) mean rainfall departures, what is the effect of a signi-

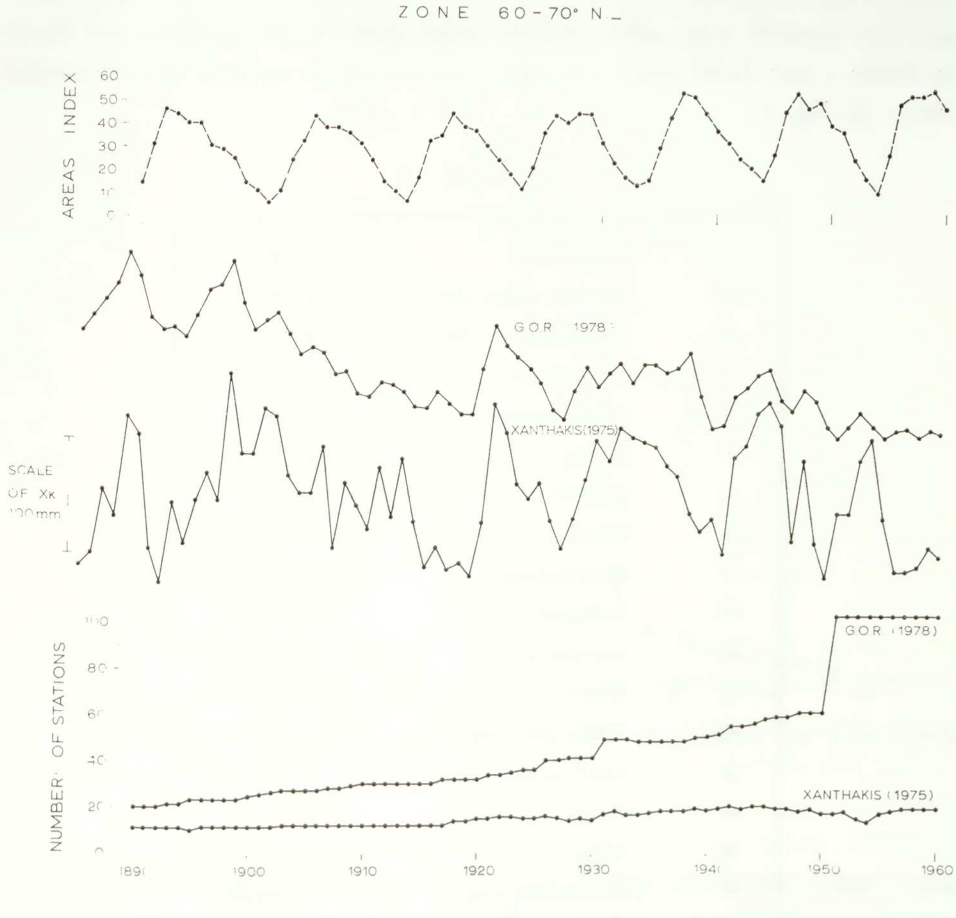

Fig. 2.

ficant increase in the number stations (data points) used in the calculation of the regional average? It is well established (see for example Mitchell, 1966) that great care should be given each time a station is to be included in an averaging process and that a check for homogeneity should be applied each time new data points are added. To answer more quantitatively to the problem at hand we took from

«World Weather Records» stations with uninterrupted records since the year 1890. These data were used to construct a new time series of X_k's using the same number of stations for the entire period 1890-1960. Before including a station in the averaging process, the station's record was first examined for homogeneity according to the objective criteria described by Mitchell (1966). The names of the stations pocessing homogeneous records since 1890 which were used in our analysis are listed in Table I and their zonal average time series is seen as dotted-shaded curve in fig. 1.

TABLE I

1	Greenwich	51° 28′ N
2	Utrecht - De - Bilt	52° 06′ N
3	Frankfurt am Main	50° 07′ N
4	Christiania	59° 55′ N
5	Copenhagen	55° 41′ N
6	Berlin	52° 33′ N
7	Uppsala	59° 51′ N
8	Breslau	51° 07′ N
9	Konigsberg	54° 43′ N
10	Valencia	51° 56′ N
11	Aberdeen	57° 10′ N
12	Warsaw	52° 13′ N
13	Vilna (Wilno)	54° 41′ N
14	Leningrad	59° 56′ N
15	Kiev	50° 27′ N
16	Moscow	55° 50′ N
17	Nikolaewskoe	51° 27′ N
18	Kasan	55° 47′ N
19	Barkerville	53° 20′ N
20	Kamloops	50° 41′ N
21	Calgary	51° 02′ N
22	Edmonton	53° 33′ N
23	Prince Albert	53° 10′ N

It is clear that at the begining of the record (say during the first decade) most of the stations used by Xanthakis are included in our sample. It follows then, that any appreciable change in the magnitude of the correlation coefficient between later parts of the homogeneous record and corresponding parts of Xanthakis record would show the effect the abrupt increase of the number of station has on the homogeneous record. To investigate that matter, the total record has been

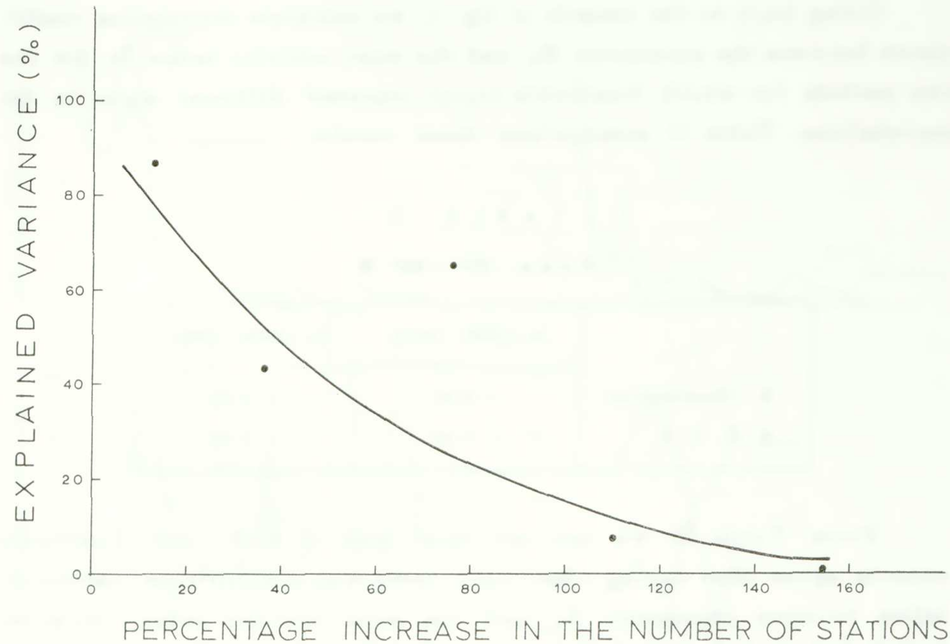

Fig. 3.

divided into different parts, each lasting for 15 years (1890-1904, 1905-1919, 1920-1934 etc). For every 15-year period we correlated Xanthakis' X_k's with the corresponding values of the homogeneous record. We must note that the homogeneous record was constructed by using the same number of stations (23) throughout the entire period under study. Figure 3 shows the percent of the total variance explained (square of the correlation coefficients) versus the average percentage by which the original 23 stations were increased for each 15-year period. It can be easily seen from fig. 3 that a doubling in the number of stations (100% increase) diminishes the percent of the total variance contributed by the Zonal average X_k for the original 24 stations. This result, however, does not imply that Xanthakis' or G. O. R. records have necessarily become non-homogeneous after, say, the gradual doubling of their data points. This can be judged only through statistical tests. It simply stresses the well known fact, on a more quantitative basis, that any abrupt and significant change in the number of stations must be treated with great caution.

Going back to the records of fig. 1, we calculate correlation coefficients between the parameter X_k and the solar activity index Ia, for the two periods for which Xanthakis (1975) reported different signs in the correlations. Table II summarizes these results.

TABLE II

Zone 50° - 60° N

	Ia (1890 - 1913)	Ia (1914 - 1960)
X (Xanthakis)	— 0.67	+ 0.80
X G. O. R.	— 0.63	+ 0.33

From Table II we can see that both G. O. R. and Xanthakis records agree that during 1890 - 1913 there was a significant anticorrelation between parameter X_k and the solar activity index. However during the period 1914 - 1960 only 10% of the total variance of X_k as calculated by G. O. R. is explained by the solar activity index, i. e. a different result from Xanthakis findings (64% of the total variance explained in Xanthakis' records). This discrepancy could be due to the objective criteria used by Xanthakis in selecting the data points (Xanthakis, 1975, 1978 and Gerety 1978). On the other hand, Gerety et al. (1978) reported that no significant power at 11 years was evident in the spectra of their X_k series. We should note here that G. O. R. (1978) have used a maximum lag of 31 years, so that the 11-year peridicity is to be found «somewhere» between the 5^{th} and the 6^{th} harmonic (corresponding to 12.4 years and 10.3 years respectively).

We decided to repeart this power spectrum analysis by using maximum lag equal to 22 years, which in the event of an 11 year line spectrum, the corresponding line at 11 years would be centered exactly at the 4^{th} harmonic. Moreover, a cross-spectral analysis was applied between the X_k series and the solar activity index. The squared coherencies at different frequencies (periods) are shown in fig. 4 for the

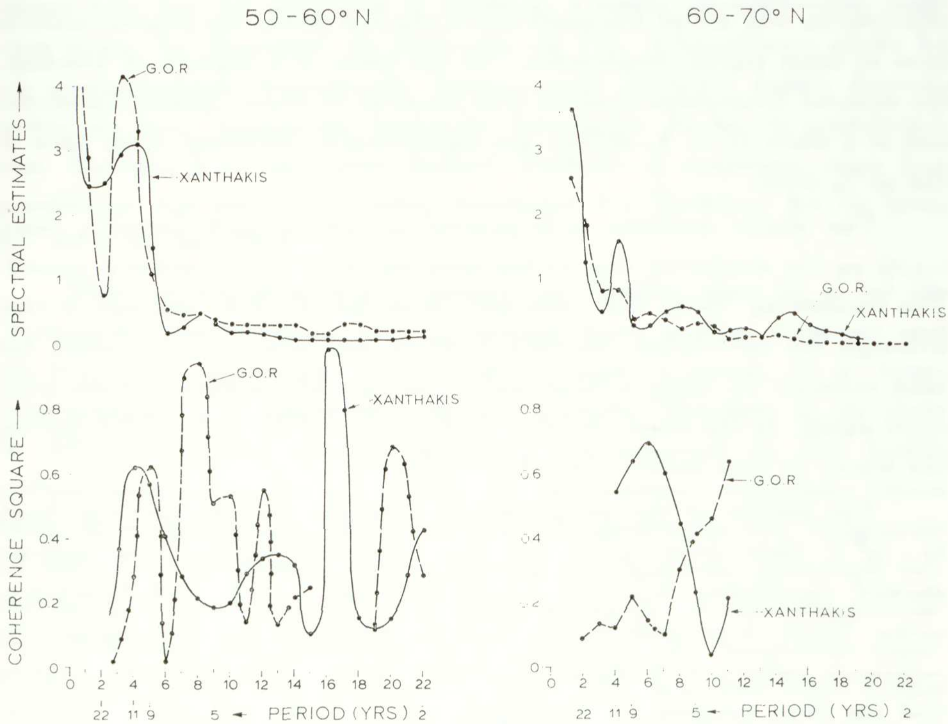

Fig. 4.

latitude band 50 - 60° N. In the same figure the corresponding power spectra are shown in the upper part of fig. 4. Whenever the squared coherency graph is broken it means that at these frequencies the squared coherence was not computable either due to zero or negative power spectral estimates or due to a sampling error (Jenkins, 1969).

From fig. 4 it appears that most of the power is found in both Xanthakis' and G. O. R. X_k series, between about 9 years and 15 years, both spectra peaking between 11 and 15 years. At periods less than 9 years ($\geqslant 5^{th}$ harmonic) all spectral estimates are in the noise level. The coherency spectrum of Xanthakis X_k - series has a peak (0.63) centered at 11 years, i.e. at the period of maximum power in the corresponding spectrum. Although the coherence square between the G. O. R. X_k series and the solar index is relatively low at 11-years (0.28) and it peaks at about 9 years (0.62). At all higher frequencies, any significant squared coherencies will not be discussed due to the low power the original spectra have at these higher frequencies. On the basis of 6 degrees of freedom, the squared coherences of about 0.60 found at 11-years (Xanthakis series) and at 9 years (G. O. R. series) are significantly different from zero at the 90 % level.

The above analysis is in general agreement with Gerety's reply (1978) on the similarity that exists between their and Xanthakis record. The interesting thing that emerged from the present analysis is that although the correlation between X series and solar activity index has been reduced by using a large and different data sample, a weak solar cycle signal in the zonal rainfall record (50 - 60° N) is till there during the whole 71 year period (i.e. 1890 - 1960).

The results of the cross-spectral analysis for the latitude band 60 - 70° N (data from fig. 2) are also shown in fig. 4. This analysis showed completely different results between G. O. R. and Xanthakis' series. There is no peak in the G. O. R. spectrum, nor any appreciable coherence pattern with the solar activity index. This difference implies that the data samples of Xanthakis and G. O. R. are quite different (their correlation is only 0.45) Loocking back at fig. 2, we can see a dominant decreasing trend in the G. O. R. record, through the total record, opposite to the strong upward trend of the sunspots during the same period. Eddy (1976) has suggested that perhaps solar constant variations could, in the long-term, follow the envelope of the sunspot cycle curve. So as to conclude, are we observing in G. O. R. analysis a real anticorrelation between the zonal rainfall departures and the envelope of solar activity, or this anticorrelation ($r = -0.45$) is accidental?

ΠΕΡΙΛΗΨΙΣ

Εἰς τὴν παροῦσαν ἀνακοίνωσιν οἱ κ. κ. Ζερεφὸς καὶ Τριτάκης ἐπανεξετάζουν διὰ νέων μεθόδων διαφόρους συσχετίσεις μεταξὺ τῆς ἡλιακῆς δραστηριότητος καὶ τῆς μεταβολῆς τῆς μέσης βροχοπτώσεως εἰς δύο ζώνας τοῦ βορείου ἡμισφαιρίου (50 - 60° Β καὶ 60 - 70° Β).

Παρὰ τὸ γεγονὸς ὅτι παρόμοιοι συσχετίσεις ὑπελογίσθησαν τὸ πρῶτον πρὸ ὀλίγων ἐτῶν ὑπὸ τοῦ καθηγητοῦ κ. Ξανθάκη, ὁ ὁποῖος μεταγενεστέρως ἐπεξέτεινε ταύτας ἐφ' ὁλοκλήρου τῆς ἐπιφανείας τῆς Γῆς, ἡ ἐπανεξέτασις αὐτῶν διὰ τῆς χρησιμοποιήσεως διαφορετικῶν βροχομετρικῶν Σταθμῶν, ἐκρίθη ἀναγκαία καθότι μία ὁμὰς Ἀμερικανῶν ἐρευνητῶν ὑπεστήριξεν ὅτι διὰ τῆς χρησιμοποιήσεως διπλασίου ἢ καὶ τριπλασίου ἀριθμοῦ Σταθμῶν αἱ συσχετίσεις αὗται ἦσαν χαμηλότεραι ἀπὸ ἐκείνας τὰς ὁποίας ὑπελόγισεν ὁ κ. Ξανθάκης διὰ τὰς ζώνας 50 - 60° Β καὶ 60 - 70° Β.

Πλέον συγκεκριμένως οἱ κ. κ. Ζερεφὸς καὶ Τριτάκης εὗρον ὅτι αἱ ὑπὸ τῶν Ἀμερικανῶν ὑπολογισθεῖσαι μέσαι χρονοσειραὶ ἔχουν μεγάλην συσχέτισιν μετὰ τῶν ἀντιστοίχων χρονοσειρῶν τοῦ κ. Ξανθάκη, παρὰ τὸ γεγονὸς ὅτι οἱ Ἀμερικανοὶ χρησιμοποίησαν πολλαπλάσιον ἀριθμὸν Σταθμῶν. Ἰδιαιτέρως εἰς τὴν ζώνην 50 - 60° Β ἡ συσχέτισις τῶν δύο δειγμάτων ἦτο σημαντικὴ εἰς λίαν ὑψηλὴν στάθμην ἐμπιστοσύνης (ἕνα τοῖς χιλίοις). Εἰς τὴν παροῦσαν ἀνακοίνωσιν ἐγένετο ἐπίσης προσπάθεια ἐλέγχου τῆς ὁμοιογενείας τῶν χρονοσειρῶν τῶν Ἀμερικανῶν καὶ ἐκείνων τοῦ κ. Ξανθάκη, διὰ τῆς χρήσεως μιᾶς ὁμογενοῦς χρονοσειρᾶς ὑπολογισθείσης ἐξ ὁμογενῶν Σταθμῶν, ἐν συνεχῇ λειτουργίᾳ ἐπὶ μίαν ἑβδομηκονταετίαν. Ἡ ἀνάλυσις αὕτη ἀπεκάλυψεν ὅτι αἱ χρονοσειραὶ τῶν Ἀμερικανῶν παρουσίαζον ἀνομοιογένειαν κατὰ τὴν δεκαετίαν 1951 - 1960, διότι ἄνευ ἑτέρου ἐλέγχου οἱ ἐρευνηταὶ οὗτοι ἐδιπλασίασαν τοὺς Σταθμοὺς κατὰ τὴν δεκαετίαν ταύτην, μὲ ἀποτέλεσμα αἱ συσχετίσεις αὐτῶν μετὰ τῆς ἡλιακῆς δραστηριότητος νὰ εὑρεθοῦν ἠλαττωμέναι ἔναντι τῶν ἀντιστοίχων συσχετίσεων τοῦ κ. Ξανθάκη, ὁ ὁποῖος διετήρησε κατὰ μέγα ποσοστὸν τὴν ὁμοιογένειαν τοῦ δείγματος.

Ἰδιαιτέρως εἰς τὴν ζώνην 50 - 60° Β εὑρέθη ὅτι ἀκόμη καὶ τὸ ἀνομοιογενὲς δεῖγμα τῶν Ἀμερικανῶν ἔχει ἱκανοποιητικὴν στατιστικὴν συνάφειαν (coherence) μετὰ τῆς ἡλιακῆς δραστηριότητος εἰς τὰς περιόδους μεταξὺ 9 καὶ 12 ἐτῶν περίπου. Τὸ γεγονὸς αὐτὸ διέφυγε τῆς προσοχῆς τῶν Ἀμερικανῶν διότι δὲν προέβησαν εἰς τοιαύτας ἀκριβεῖς ἐκτιμήσεις διὰ τοῦ ὑπολογισμοῦ τῆς στατιστικῆς συναφείας μεταξὺ τῶν φασμάτων ἰσχύος τῆς ἡλιακῆς δραστηριότητος καὶ τῆς ζωνικῆς βροχοπτώσεως.

Ἐκ τῶν ὑπαρχουσῶν βροχομετρικῶν παρατηρήσεων προκύπτει τὸ συμπέρασμα ὅτι περίπου τὸ 10 % τῆς ὁλικῆς μεταβλητότητος τῶν ἐτησίων τιμῶν τῆς βροχοπτώσεως εἰς τὴν ζώνην 50 - 60° B ἑρμηνεύεται ἀπὸ τὰς διακυμάνσεις τῆς ἡλιακῆς δραστηριότητος. Τὸ ἑνδεκαετὲς αὐτὸ σῆμα εἰς τὴν ζώνην 50 - 60° B εἶναι ἀρκούντως εὐκρινὲς τόσον εἰς τὸ δεῖγμα τῶν 180 Σταθμῶν ποὺ ἐχρησιμοποίησαν οἱ Ἀμερικανοὶ ἀκόμη δὲ πλέον εὐκρινὲς εἰς τὸ δεῖγμα τῶν 60 Σταθμῶν ποὺ ποὺ ἐχρησιμοποίησεν ὁ κ. Ξανθάκης.

Ἐν συμπεράσματι θὰ πρέπει νὰ ἀναφερθῇ ὅτι αἱ ἀνωτέρω συσχετίσεις μεταξὺ τῆς μέσης ζωνικῆς βροχοπτώσεως εἰς τὴν ζώνην 50 - 60° B καὶ τῆς ἡλιακῆς δραστηριότητος εἶναι ἀπὸ τὰς πολὺ ὀλίγας παρομοίας συσχετίσεις, αἱ ὁποῖαι παρέμειναν σημαντικαὶ μετὰ ἀπὸ διεξοδικοὺς στατιστικοὺς ἐλέγχους καὶ εἰς διαφορετικὰ δείγματα Σταθμῶν, τὸ γεγονὸς δὲ αὐτό, πιστεύομε ὅτι θὰ δώσῃ νέαν ὤθησιν εἰς τὰς σχέσεις ἡλίου - καιροῦ.

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