ΜΕΤΕΩΡΟΛΟΓΙΑ.-- **Tests of Randomness Against Other Alternatives in the Mean Monthly and Mean Yearly Air temperatures in Athens, Greece,** *by Christos S. Zerefos**. Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Ι. Ξανθάκη.

ABSTRACT

Tests of randomness against trend, persistence, cyclic phenomena, aperiodic changes or slippages of the mean, were applied to the mean yearly and the mean monthly air temperatures at the National Observatory of Athens, Greece. The information collected from these tests can be summarized as follows : Complete lack of trend in both the mean yearly and in the mean monthly temperature values in Athens. Also, both time-series (mean monthly and mean yearly) can be approximately expressed by a first-order autoregressive model although, mean monthly temperature values display the well-known quasi-biennial pulse and short periodic oscillations with periods ranging from 2 to 3.5 months. A secular change is insignificantly evident in the mean yearly values, which, however, became significant when mean monthly temperature values were examined. When larger maximum time lags were used to compute the spectrum of mean yearly values the secular change was very ′lear.

1. INTRODUCTION

A climatological time series may consist either of completely randomn or non-randomn variations, or of a mixture of both randomn and non-randomn components. From experience, we know that some major fraction of the total variance of climatological time series behaves as a randomn variable. The question is then, can any appreciable fraction of the total variance be ascribed to non-randomn changes, and, if so, what can we surmise about the nature of non-randomness. That is, if non-randomness is present, does it take the form of persistence, trend, periodic or aperiodic fluctuations or perhaps some combination of these?

* ΧΡΗΣΤΟΥ Σ. ΖΕΡΕΦΟΥ, Ἔλεγχοι τοῦ τυχαίου ἐν σχέσει πρὸς ἑτέρας ἐναλλακτικὰς ὑποθέσεις εἰς τὰς Μέσας Μηνιαίας καὶ τὰς Μέσας Ἐτησίας τιμὰς τῆς θερμοκρασίας τοῦ ἀέρος ἐν Ἀθήναις.

In the following we shall try to give approximate answers to the above mentioned questions, in examining the mean monthly and annual values of air temperature in Athens. Curves with original mean yearly temperature values at the National Observatory of Athens were first given for the period 1858 - 1929 by Mariolopoulos (1938) and completed up to 1972 by Arseni - Papadimitriou (1973). These data were used to examine the time series of mean annual and mean monthly air temperature in Athens during the rather long record 1858 - 1972. Although before the year 1890 the station was located on various sites inside the city of Athens, the material used it will be shown to be free from discontinuities or slippages of the mean, in agreement with P. Karapiperis' (1954) belief. Since 1890 the station's location is at the National Observatory of Athens (Lat. 37°58′ N and Long. 23°40′ E) on the well known hill «Lophos Nymphon».

As it will be shown latter in this study, differences between means obtained at different sub-periods of the entire record, suggest the existence of non-randomness in the time series under investigation, the more likely form of which is persistence. Also, it was found that trends reported earlier to exist in this record (Karapiperis, 1954, Arseni - Papadimitriou, 1973 and Metaxas, 1974) were insignificant in the light of widely accepted climatological tests. It is obvious that the expanding city of Athens has a small effect on air temperature since our analysis has shown that no significant trends appear in this record or parts of it (see below), as suggested by the above mentioned authors. On the contrary, what has been observed are only «fluctuations in temperature sometimes in one direction and other times in the opposite» as pointed out recently by Mariolopoulos (1971), the non-randomn form being that of weak Markov-type persistence. Mariolopoulos (1971) discussed also the minor importance of the exhaust gases in the climatic fluctuations. The absence of significant trends does not substantiate the expanding city hypothesis of Karapiperis (1954) and Arseni (1972).

2. RESULTS

Part I: Mean Annual Temperatures.

To start with, a comparison between the overall mean of the entire record (1858 - 1972) and the means of certain parts of the record, gives an idea of the stability of this record. Cramer's test (1946) was applied to check whether the differences of the means are no larger than would be compatible with a «null» hypothesis of randomness. The whole record was devided into three parts (each of 38-year length) the means being compared with the mean of the entire record. Table I shows Student's -t of this test for each part of the record.

TABLE I

Period	No of Years	Mean	Stand. Dev.	Cramer's - t
1858 - 1895	38	17.713	0.501	0.724
1896 - 1933	38	17.465	0.517	− 2.918
1934 - 1971	38	17.818	0.487	+ 2.278

The results of table I suggest that non-randomness is present in this record.

Our next task was to do a comparison between the mean values of the series corresponding to two different periods of the record. A suitable test in that case is the familiar t-test for the difference between two means. Couples of records which were compared are shown below:

(1858 - 1895) with (1896 - 1933) $|t| = 2.095$
(1896 - 1933) with (1934 - 1971) $|t| = 3.018$
(1858 - 1895) with (1934 - 1971) $|t| = 0.914$

These results show that inconstancy of the mean is evident in the first two couples of periods, while there is no reason to believe that the means of the periods (1858 - 1895) and (1934 - 1971) do differ by a statistically significant amount.

The above findings suggest the presence of non-randomness in the series under investigation and so effort should be donne in order to test the form of non-randomnes i. e. trend, slippage of the mean, persistence e.t.c. It is well known that in urban stations a likely alternative to randomness is some kind of trend. Since we have no reason to suppose that trends in question are linear ones, we decided to use Mann - Kendall's rank test, which is of nearly uniform power for alternatives of non-linear trends. Mann - Kendall's τ is defined by:

$$\tau = 4P/N(N-1) - 1$$

where $P = \sum_{1}^{N-1} n_i$, n_i being the number of latter terms whose values exceed the consecutive values of the time series, N the record length and for $N \geqslant 10$, τ is nearly Gaussian with zero expectation value and variance equal to $(4N+10)/9N(N-1)$, so, it can be tested for its statistical significance.

Three periods were chosen to be tested for trend (1858 - 1895), (1934 - 1971) and (1910 - 1950). Mann - Kendall's τ and its $t_{0.95}$ value are shown in table below. Also shown in this table is the result of the trend test for the entire record (1858 - 1972).

TABLE II

Period	τ	$t_{0.95}$
1858 - 1895	−0.1578	−0.2217
1934 - 1971	−0.1749	−0.2217
1911 - 1950	+0.1128	+0.2156
1858 - 1972	−0.0001	−0.1237

From the results shown in table II we conclude that we cannot attribute the non-randomness to trend since none of the ranks exceeds its 95% confidence value.

Since from our analysis no form of trend can be considered as a real alternative to randomness, we decided to check the available record for 1) persistence and 2) for a likelihood of non-stationary slippages of the mean.

The first task was thus to compute the lag-one autocorrelation r_1 for the entire record. This autocorrelation was found to be statistically significant at the 0.05 confidence level ($r_1 = 0.2327$ and its 5% C. L. = 0.1441). However, we are quite unlikely to attribute the difference between means to a «stationary» process as for example is persistence, which, although a form of non-randomness, does not involve non-stationary slippage of the mean. Consequently, since persistence is evident in our data, to which Student's t-test between means was applied, we wish to allow for the effect of this persistence in the test so that this test will show the likelihood only of non-stationary slippages of the mean. The two periods used at that stage where 1858 - 1890 ($\mu_1 = 17.75^{\circ}$ C, $\sigma_1 = 0.496$ and $r_1 = 0.102$) and 1891 - 1931 ($\mu_2 = 17.47^{\circ}$ C, $\sigma_2 = 0.508^{\circ}$ C and $r_2 = 0.447$). In order to allow for persistence, let us first consider the t-test of the differences between means :

$$t = \frac{\mu_1 - \mu_2}{\left[\frac{N_1 s_1^2 + N_2 s_2^2}{N_1 + N_2 - 2}\,(1/N_1 + 1/N_2)\right]^{\frac{1}{2}}}$$

where $N_1 = 33$ years and $N_2 = 41$ years and S_1, S_2 the sample variances in the two periods of the record. This t-statistic can be modified, to allow for persistence, by using the «effective lengths» N_1' and N_2', instead of N_1 and N_2, which are defined by:

$$N_1' = N_1 \frac{1 - r_1}{1 + r_1}, \qquad N_2' = N_2 \frac{1 - r_2}{1 + r_2}.$$

Where r_1 and r_2 are the lag-one autocorrelations obtained for the two sub-periods (see for example Mitschell, 1963). In our example $N_1' = 26.898$ years and $N_2' = 15.668$ years resulting to a t-value equal to 1.728, insignificant at the 0.05 level. Thus, non-stationary slippages of the mean are not a likely alternative to randomness. We can thus accept that a form of persistence is a real alternative to randomness in the mean yearly temperatures in Athens. Calculated serial correlation coefficients for the entire record, at lags one, two and three showed that $\varrho_1^k \approx \varrho_k$, k being the time lag ($k = 1, 2, 3$), which, together with the above mentioned statistical significance of r_1 at the 0.05 level, suggest that simple Markov «red noise» is present in this record. The simple Markov process states that each realization of the process is composed by a part caused by the last realization and by a noise term, which is, independently, normally distributed. Thus, each yearly temperature will depend only on its immediate predecessor value, but it should be pointed out that all the above mentioned tests yield only approximate answers to the questions which they intend to answer.

The last alternative to randomness to be discussed here is the form of possible periodicities present in this time series. Power spectrum analysis is presently the most suitable method to study the periodical alternative to randomness. Blackman and Tukey's (1958) procedures were used in this study, briefly summarized as follows: Given a series of N equally spaced values, all serial covariances are computed for lags of 0 to m time units ($m < N$). Next, $m + 1$ raw spectral estimates are derived by computing the cosine transform of these $m + 1$ lagged correlations. These «raw spectral estimates» are then «Hammed», that is, smoothed by a 3-term weighted moving average with weights equal to 1/4, 1/2 and 1/4 respectively.

The procedure for evaluating the power spectrum starts by fitting a «null» continuum, the shape of which depends on the significance of the lag-one serial correlation. As mentioned above the appropriate continuum in our record is that of Markov «red noise». Finally, the level of statistical significance for each spectral estimate is derived by comparing the ratio of any sample spectral estimate S_k to its local value of the continuum, with the critical percentage point levels of a x^2/v distribution for each v (v being the degrees of freedom of each spectral estimate).

In the following, maximum time lags used where 38 years and 57 years. The 38-year max. lag is approximately the one third of the length of the record, that is a reasonable fraction of it to get enough resolution. The second maximum lag of 57 years is, however, very large (half of the total record length) but it was used to emphasize the possibility of the existence of a long periodic oscillation, which could not be revealed when 38-year lag was used. We will return at this point latter.

Figure 1 shows the power spectrum of the series of mean yearly temperatures at the National Observatory of Athens, Greece. The maximum lag used was 38 years. Red noise continuum and associated 95% confidence limits are also shown in that figure. The comparison of the spectrum in that figure with the «null» continuum and its confidence limits, yield that none of the spectral estimates exceeds the 95% confidence limit. Peaks at about 4.75 and 2.6 years, although possibly related to the well known quasi-biennial atmospheric pulse, are insignificant at the 95% confidence level. The peak at lag-one is possibly related to the insignificant trend discussed previously.

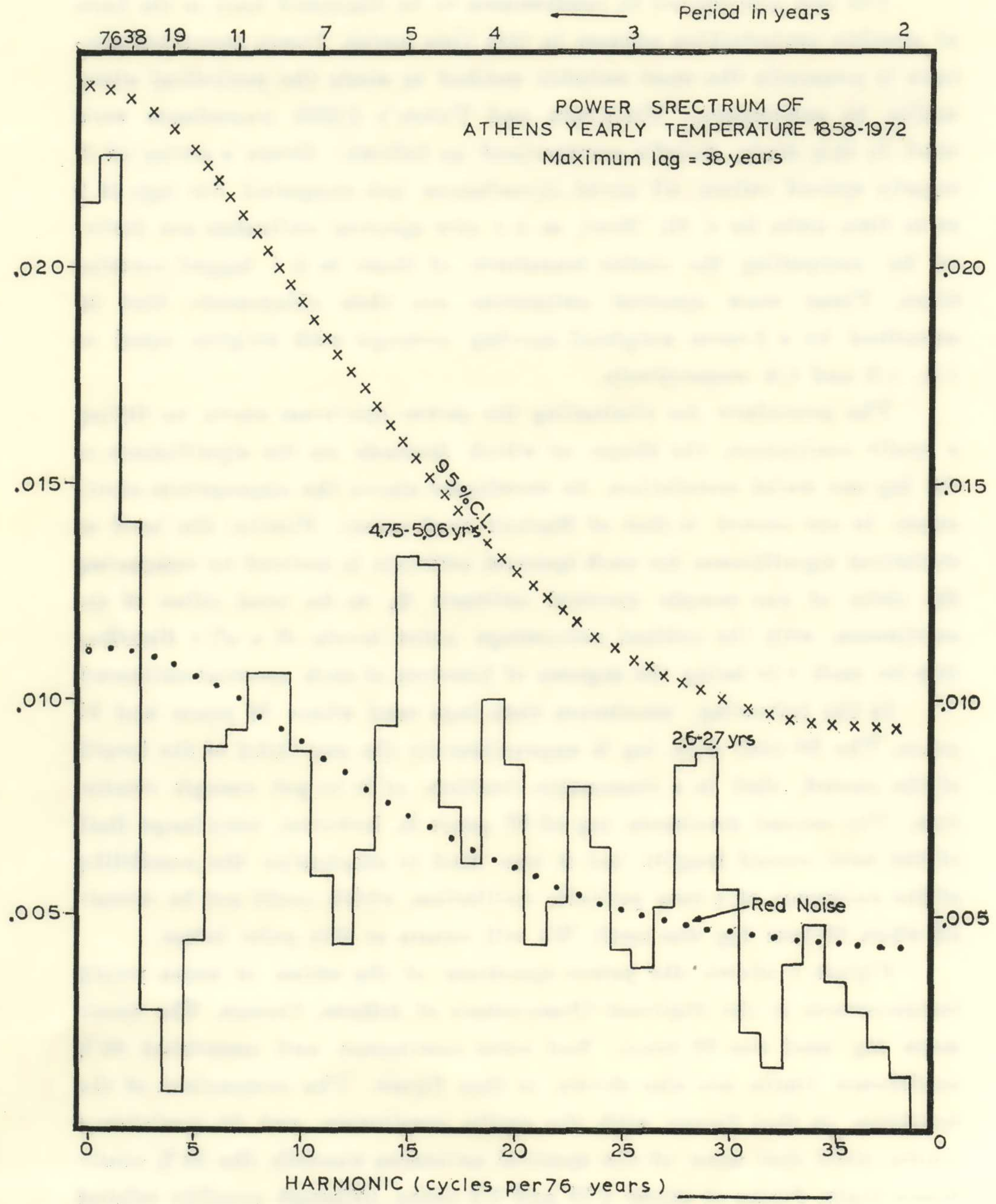

Fig. 1. Power spectrum of mean annual air temperatures at the National Observatory of Athens, Greece. Red-noise continuum and associated 95 °/₀ confidence limits are added.

Inspite of the absence of significant peaks in the spectrum of fig. 1, we decided, as mentioned before, to use a larger maximum lag, equal to half the record length. Although less resolution is obtained in this way, it seemed reasonable to use this relatively large m (= 57 years) for the following reasons:

1) The shape of the time series under study (see graph I in Arseni, 1973) made us to speculate a long wave-like oscillation with period greater than 50 years.

2) During the span 1858 - 1972 Metaxas (1974) pointed out that, statistically speaking, well above normal mean values were observed during the periods 1858 - 1890 and about 1930 - 1965 while below-normal mean yearly air temperatures were observed during the in-between period 1890 - 1925. Also, after about the 1960's a rather gradual lowering of temperatures is observed, which can be considered to be a characteristic feature of the Troposphere (Starr and Oort, 1973) and the lower Stratosphere over mid-low latitudes of the Northern hemisphere (Zerefos, 1974).

3) Finally, the t-test of the difference between means of this study, revealed that the means of the periods 1858 - 1895 and 1934 - 1971 were not statistically different, while, both, compared to the mean of the in-between period (1896 - 1933) were found to be statistically different (see also table II).

Following the above mentioned reasons we calculated spectral estimates using maximum lag 57 years. Only some figures are given here from that spectrum in order to save space. In this new spectrum it was found that only the first two harmonics exceeded their 95% confidence limits, S_2 being equal to 0.0191 and its 95% C. L. being equal to 0.0186, this peak corresponding to a probable periodicity of about 57 years. The first peak probably corresponding to a secular change can not be considered as trend since this hypothesis was rejected previously. However, no further conclusion can be drawn here untill the record will include another 30 years of data. We shall return to the periodical behaviour of air temperature in Athens in the next Part II, where the time series of mean monthly air temperatures is examined.

Part II: Mean Monthly Air Temperatures.

Mean monthly air temperature values at the National Observatory of Athens were next tested for randomness using the statistical tests described before. Since mean monthly air temperatures are dominated by the very strong annual variation, their spectrum can be significantly influenced not only by the annual march but at other wavelengths as well. This problem can be circumvented by «pre-whitening» (Blackman and Tukey, 1958) which process completely removes the annual march. The annual variation was removed by transforming the original mean monthly air temperature series T_i into a new series DT_i, where

$$DT_i = T_i - \bar{T}$$

$\bar{T}$ being the record-mean temperature for all values of the series pertaining to the same ith month.

The statistical tests used previously (Cramer's and Mann-Kendall's tests) applied to the, free from the annual march, mean monthly air temperature values, showed that non-randomness is present in this series, and that trend is a completely insignificant alternative to randomness. We recall that same results were obtained in the case of mean yearly air temperatures.

When power spectrum analysis was performed to the mean monthly air temperature (with the annual variation removed) some interesting features of this variable appeared to exist. To start with, figure 2 was constructed showing this particular spectrum, calculated by the use of maximum lag equal to 1/3 of the total length of this record (=460 months).

From that figure it appears that significant pulses do occur in mean monthly air temperatures in Athens. These oscillations range from a secular one (76.5 years), a quasi-biennial pulse (27 months) and shorter pulses from about 2 to approximately 3.5 months. All these significant peaks are indicated by small arrows in fig. 2.

3. CONCLUSIONS

The results of several tests of randomness against other alternatives applied to both the mean annual and the mean monthly air temperatures in Athens, can be summarized as follows:

1) The time series of mean monthly and mean yearly air temperatures in Athens are both non-randomn, as evidenced from Cramer's test

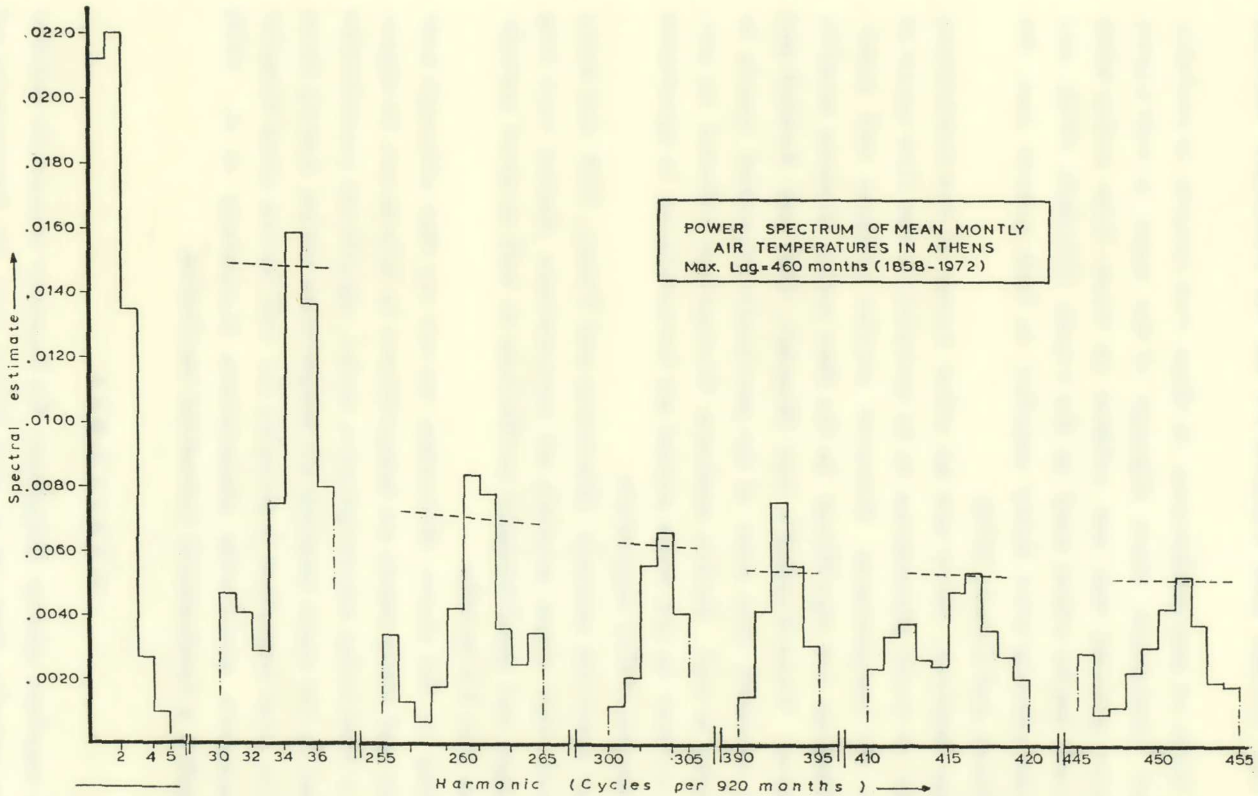

Fig. 2. Power spectrum of mean monthly air temperatures at the National Observatory of Athens, Greece. Since maximum lag of analysis was 460 months, only significant peaks are shown in order to save space. The 95 % confidence limits associated to the appropriate null continuum (red noise) are shown by the dashed lines. Abscissa shows the selected harmonics. Peak at harmonic 34 - 35 corresponds to the quasi-biennial pulse. Higher harmonics correspond to about 2 to 3.5 month periodicities.

on the stability of the records (Cramer, 1946), as well as from the difference between means obtained from intercomparison of some parts of each of the two records used (Student's-t for the difference between means).

2) The form of non-randomness in these two records is probably simple Markov persistence, since slippage of the mean (a well-known «non-stationary» process) was not evident in these time series when effective record lenths where used in the t-tests (Mitchell, 1963), and since, red noise criteria were fairly satisfied in both records (see, for example, Dehsara and Cehak, 1970).

3) At the moment, there are no other forms of non-randomness such as trends or cyclic phenomena to be accepted in the time series of mean annual air temperatures. However secular changes and quasi-biennial oscillations are significant in the time series of mean monthly air temperatures. Mann-Kendall's test (Kendall, 1948 and Kendall and Stuart, 1966) revealed that none of the previously suggested trends in these time series is real. Rather randomn fluctuations affected by persistence are evident in the mean annual air temperatures, in agreement with Mariolopoulos (1971) suggestion.

4) Power spectrum analysis (Blackman and Tukey, 1958 and many others) showed that mean monthly air temperatures display very long (secular) changes and quasi-biennial oscillations as well as short periodicities between 2 to 3.5 months.

According to the above discussion we can say that although both mean monthly and mean yearly air temperatures in Athens can be approximated by a first-order autorregressive model, significant periodicities are only found in the mean monthly air temperature series. Among these oscillations the most important is probably the well-known quasi-biennial pulse, an unknown world-wide phenomenon (Landsberg et al., 1963) which is possibly a fundamental terrestrial oscillation.

ΠΕΡΙΛΗΨΙΣ

Εἰς τὴν παροῦσαν μελέτην ἠλέγχθησαν διὰ διαφόρων στατιστικῶν μεθόδων τόσον αἱ μέσαι μηνιαῖαι, ὅσον καὶ αἱ μέσαι ἐτήσιαι τιμαὶ τῆς θερμοκρασίας τοῦ ἀέρος εἰς τὸ Ἐθνικὸν Ἀστεροσκοπεῖον τῶν Ἀθηνῶν κατὰ τὴν περίοδον 1858 -

1972. Οἱ γενόμενοι στατιστικοὶ ἔλεγχοι τῶν δεδομένων τούτων ἀφεώρων εἰς τὴν εὕρεσιν κλιματικῶν τάσεων, ἐμμονῆς, περιοδικοτήτων κ. ἄ. Καὶ εἰς ὅ,τι ἀφορᾷ εἰς τὰς κατὰ τὸ παρελθὸν ἀναφερθείσας κλιματικὰς τάσεις, αἵτινες, ὡς εἶχεν ὑποστηριχθῆ παλαιότερον, ὠφείλοντο εἰς τὴν ἀνάπτυξιν τῆς πόλεως τῶν Ἀθηνῶν, εὑρέθη ὅτι αὗται δὲν ἀντιπροσωπεύουν ἐναλλακτικὴν τοῦ τυχαίου ὑπόθεσιν, καθότι εὑρέθησαν μὴ σημαντικαὶ εἰς τὴν στάθμην ἐμπιστοσύνης 95%. Ἡ ἔλλειψις κλιματικῆς τάσεως, τόσον εἰς τὰς μέσας μηνιαίας, ὅσον καὶ εἰς τὰς μέσας ἐτησίας τιμὰς τῆς θερμοκρασίας τοῦ ἀέρος ἐν Ἀθήναις, ἐπεβεβαιώθη διὰ τοῦ ἐλέγχου τῶν Mann - Kendall, τόσον διὰ τὰς ὑποπεριόδους (1858 - 1895), (1934 - 1971), (1911 - 1950), ὅσον καὶ διὰ ὁλόκληρον τὴν χρονοσειρὰν (1858 - 1972). Λόγῳ τῆς ἀνευρέσεως τοῦ μὴ τυχαίου εἰς τὰς ἀνωτέρω χρονοσειράς, διὰ τῆς ἐφαρμογῆς τῶν ἐλέγχων τοῦ Cramer καὶ τοῦ Student (τῆς διαφορᾶς τῶν μέσων διαφόρων ὑποπεριόδων), κατεβλήθη προσπάθεια ἀνευρέσεως τοῦ εἴδους καὶ τῆς μορφῆς αὐτοῦ εἰς τὰς χρονοσειρὰς ταύτας. Πράγματι, εὑρέθη ὅτι αἱ μέσαι ἐτήσιαι τιμαὶ ἐπιδεικνύουν ἐμμονὴν περίπου ἁπλοῦ Μαρκοβιανοῦ τύπου, ἄλλως καλουμένην καὶ ἐρυθρὸν θόρυβον. Ἡ κυριωτέρα ἰδιότης τῆς τοιαύτης ἐμμονῆς ἔγκειται εἰς τὸ ὅτι ἑκάστη τιμὴ τῆς χρονοσειρᾶς ἐξαρτᾶται μόνον ἐκ τῆς ἀμέσως προηγουμένης αὐτῆς τιμῆς. Κατὰ ταῦτα αἱ πιθανώτεραι πληροφορίαι διὰ τὸ προσεχὲς ἔτος, αἱ ἀφορῶσαι εἰς τὴν θερμοκρασίαν τοῦ ἀέρος ἐν Ἀθήναις, δέον ὅπως ληφθῶσι ἐκ τοῦ παρόντος ἔτους καὶ οὐχὶ ἐκ πληροφοριῶν ἐξαγομένων ἐκ παρελθόντων ἐτῶν. Ἡ ὕπαρξις τοῦ ἐρυθροῦ θορύβου εἰς τὰς μέσας ἐτησίας τιμὰς τῆς θερμοκρασίας τοῦ ἀέρος ἐν Ἀθήναις εὑρέθη εἰς τὴν στάθμην ἐμπιστοσύνης 95%. Ὀλισθήσεις τῶν μέσων τιμῶν δὲν ἀνευρέθησαν οὔτε εἰς τὰς μέσας ἐτησίας οὔτε εἰς τὰς μέσας μηνιαίας τιμάς. Ὡσαύτως αἱ ἐτήσιαι τιμαὶ δὲν ἐπιδεικνύουν σημαντικὰς περιοδικότητας, πλὴν πιθανῆς τινος αἰωνίας περιοδικῆς μεταβολῆς (μετὰ περιόδου μεγαλυτέρας τῶν 60 ἐτῶν), ἥτις ὅμως δὲν κατέστη δυνατὸν ὅπως ἀπομονωθῇ πλήρως κατὰ τὴν φασματικὴν ἀνάλυσιν τῆς χρονοσειρᾶς λόγῳ τοῦ σχετικῶς μικροῦ ἀριθμοῦ τῶν διατιθεμένων ἐτῶν. Ἀντιθέτως, καίτοι αἱ μέσαι μηνιαῖαι τιμαὶ τῆς θερμοκρασίας τοῦ ἀέρος ἐν Ἀθήναις δυνατὸν ὅπως παρασταθῶσι διὰ τοῦ προηγουμένως ἀναφερθέντος ἐρυθροῦ θορύβου, ἡ φασματικὴ ἀνάλυσις τούτων δεικνύει, εἰς τὴν 95% στάθμην ἐμπιστοσύνης, τὴν ὕπαρξιν μιᾶς σχεδὸν διετοῦς κυμάνσεως (27 μῆνες), ὡς ἐπίσης καί τινας ἄλλας περιοδικότητας μικροτέρας περιόδου μεταξὺ 2 καὶ 3.5 μηνῶν περίπου. Ἡ ἀνεύρεσις τῆς διετοῦς κυμάνσεως εἰς τὴν θερμοκρασίαν τοῦ ἀέρος εἰς τὰς Ἀθήνας ἐπιβεβαιοῖ τὴν παγκοσμίαν ἐμφάνισιν ταύτης εἰς τὰ καθέκαστα ἀτμοσφαιρικὰ φαινόμενα, αἱ δὲ εὑρεθεῖσαι περιοδικότητες δυνατὸν νὰ παράσχουν νέαν ὤθησιν εἰς τὰς προγνώσεις μέσης καὶ μακρᾶς διαρκείας διὰ τὴν περιοχὴν τῶν Ἀθηνῶν. Ἐν κατακλεῖδι συμπεραίνομεν ὅτι αἱ μέσαι τιμαὶ τῆς θερμοκρασίας τοῦ ἀέρος τῶν Ἀθηνῶν δύνανται νὰ παρασταθῶσι διά τινος αὐτοπαλινδρομουμένου προτύπου πρώτου βαθμοῦ καὶ δὴ εἰς στάθμην ἐμπιστοσύνης καλυτέραν τοῦ 95%.

REFERENCES

1. A. Arseni - Papadimitriou, On the Annual Variation of Air Temperature in Athens, Meteorologika, 31, Thessaloniki, 1973.
2. R. B. Blackman and J. W. Tukey, Measurement of Power Spectra, Dover Publ., N. Y. 1958.
3. H. Cramer, Mathematical Methods in Statistics, Princeton University Press, Princ. N. J. 1946.
4. M. Dehsara and K. Cehak, A Global Survey on Periodicities in Annual Mean Temperatures and Precipitation Totals, Arch. Met. Geoph. Biokl., Ser. B, 18 (1970), 253 - 268.
5. P. P. Karapiperis, Trends in Athens Temperature, Geofis. Pura Appl., 29 (1954), 212 - 217.
6. M. G. Kendall, Rank Correlation Methods, Hafner, N. Y. 1948.
7. M. G. Kendall and A. Stuart, The Advanced Theory of Statistics, Hafner Publ. Co, V. 2, N. Y. 1966.
8. H. E. Landsberg, JR. Mitchell, J. M., H. L. Crutcher and F. T. Quinlan, Surface Signs of the Biennial Atmospheric Pulse, Mo. Weather Rev., Oct. - Dec. 1963, 549 - 556.
9. El. G. Mariolopoulos, The Climate of Greece, Athens 1938, p. 71.
10. ——, Is the Climate Changing?, Proc. Academy of Athens, 46 (1971), 38 - 53.
11. D. Metaxas, Climatic Fluctuation of Air Temperature in Athens, Tec. Report No 19, University of Ioannina 1974.
12. JR. Mitchell, J. M., Some Practical Considerations in the Analysis of Geophysical Time - Series (Available from Author) U. S. Weather Bureau, 30 p. Washington D. C. 1963.
13. V. P. Starr and A. H. Oort, Five-Year Climatic Trend for the Northern Hemisphere, Nature, 242 (1973), 310 - 313.
14. C. S. Zerefos, Trends and Quasi - Biennial Pulses in the Temperature Field of the Stratosphere During the Period 1957 - 1972, Proc. Academy of Athens, Nov. 49 (1974), 480 - 484.