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Astronomy and Meteorology Department, Faculty of Science, Cairo University, Egypt

Fluctuations of surface air temperature in the Eastern Mediterranean

H. M. Hasanean

With 3 Figures

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Summary

Changes in surface air temperature during the last century are widely discussed among researchers in the field of climatic change. Using various techniques, we investigate trends and periodicity of surface air temperature series from eight meteorological stations in the Eastern Mediterranean. For the analysis, we use the Mann-Kendall rank test, low-pass filtering, autocorrelation spectral analysis and maximum entropy spectral analysis. The latter two tests are compared. The study is based on series over one hundred years in length for four stations, and over fifty years in length for the other four. Increasing and decreasing surface temperature trends were found. These trends, however, are only significant for Malta, Jerusalem, and Tripoli at the 99% confidence level (positive trend) and for Amman at the 95% confidence level (negative trend). We also found inter-decadal variations in surface air temperature, including a fairly regular quasi 20-year oscillation, although its amplitude varied between different cycles. A period of warming began around 1910 at all stations. During the 1970s, the annual mean temperature series exhibit warming, but this warming was not uniform, continuous or of the same order at all the stations.

The results of the Autocorrelation Spectral Analysis and the Maximum Entropy Spectral Analysis are similar, pointing to the reliability of the results. The quasi-biennial oscillation (QBO) exists at all stations during both increasing and decreasing trends. Similarly, a broad maximum from 3–8 years (related to El Niño) is found at Malta, Athens, Jerusalem, Beirut, and Latakia. An inverse relationship between El Niño and the North Atlantic Oscillation with surface air temperature over the Eastern Mediterranean is found at a highly significant confidence level.

1. Introduction

Regional variations of annual temperature for different regions have been studied extensively, see e.g. Escourrou (1978), Wigley and Farmer (1982), Colacino and Roselle (1983), Jones and Kelly (1983), Repaips (1984), Balzano and Tobago (1985), Maheras (1989) and Arseni and Maheras (1991). Analyses have developed with the advent of high resolution signal processing and spectral analysis, for instance, Chiders (1978); Haykin (1979); Robinson and Treitel (1980). The use of high resolution techniques is due to Burg (1975) and is termed MESA (the maximum entropy spectral analysis). Spectral variance analysis of long European and North American air temperature records was done using conventional autocorrelation and maximum entropy techniques by Malcher and Schönwiese (1987). The MESA technique is used for analysis of annual mean terrestrial and marine surface temperature series in the northern and southern hemisphere. It is found that there exist long-term linear warming trends of 0.12 to 0.56 °C/century with superposed significant periods in the ranges of 5–6 yr, 10–11 yr, 15 yr, 20 yr, 28–32 yr and 55–80 yr. (Lane and Teixeira, 1990). The studies showed that there might be two fundamental time-scales in the interannual variability of the monsoon-ocean-atmosphere system. The first is a quasi-two-year cycle associated with the tropical biennial oscillation (TBO) and the second is a 4–6 year cycle associated with the El-Niño Southern Oscillation (ENSO). Mankin Mak (1995) found that 5.3 and 2.6 year cycles in the marine surface temperature clearly delineate El-Niño and La-Niña events.

In this paper, an attempt is made to examine the mean annual variation of surface air temperature for eight Meteorological stations over the eastern Mediterranean. Before analysis, the homogeneity of the records is tested. The methods of Woodruff and Hu (1997) and Mann-Kendall rank statistic are then used to quantify the direction and magnitude of any trend. To investigate periodicity, autocorrelation spectral analyses (ASA) and maximum entropy spectral analysis (MESA) are used for the temperature time series. Also, to investigate the relationships between large-scale phenomena or processes such as ENSO and the North Atlantic Oscillation (NAO) a simple correlation method is used (Mood et al. 1974).

2. Data

Annual mean surface air temperature observations at eight stations situated in the eastern Mediterranean were used: Malta (35.9° N, 14.5° E) from 1853 to 1991, Athens (38.0° N, 23.7° E) from 1858 to 1991, Tripoli (32.9° N, 13.2° E) from 1944 to 1991, Alexandria (31.2° N, 29.8° E) from 1942 to 1991, Amman (32.0° N, 35.9° E) from 1923 to 1991, Beirut (33.9° N, 35.5° E) from 1875 to 1991, Jerusalem (31.8° N, 35.2° E) from 1882 to 1991, and Latakia (35.6° N, 35.8° E) from 1952 to 1991. The sources of data are: Archives of Egyptian Meteorological Authority; Archives of Libyan Meteorological Authority and Carbon Dioxide Information Analysis Center (CDIAC). Monthly data of NAO, and global sea surface temperature (SST) anomalies (El-Niño) were obtained from the Climate Prediction Center, National Oceanic Atmospheric Administration (NOAA).

Lack of homogeneity in data series creates a big problem for studying time series. Climatic elements could be affected by changes in instrumental exposure, station location, and method of estimating daily and monthly averages. We used the short-cut Barlet test (Mitchell et al., 1966) to examine the homogeneity of the surface air temperature series at designated stations.

Table 1. Bartlet Test (short-cut) Result for eight Mediterranean Stations (n is the number of Terms in each Sub-period k, and k is the Number of the Sub-period)

Station	95% Significant point	$S^2_{\max}/S^2_{\min}$
Malta, $n = 23, k = 6$	2.46	1.83
Athens, $n = 22, k = 6$	2.67	2.60
Tripoli, $n = 16, k = 3$	3.54	2.10
Alexandria, $n = 16, k = 3$	3.54	1.39
Amman, $n = 23, k = 3$	2.38	2.30
Beirut, $n = 25, k = 5$	3.16	2.72
Jerusalem, $n = 22, k = 5$	3.53	1.81
Latakia, $n = 15, k = 3$	3.54	1.57

The short-cut Bartlet test of homogeneity of variance for annual surface air temperature is applied by dividing the series into k equal sub-periods, where $k \geq 2$. In each of these sub-periods the sample variance is calculated, i.e.;

$$S_k = \frac{1}{n}\left\{\sum x_i - \frac{1}{n}\left(\sum x_i\right)^2\right\}, \tag{1}$$

Where the summations range over the n values of the series in the sub-period k. Let $S^2_{\max}$ and $S^2_{\min}$ denotes the maximum and the minimum of the values of S^2_k, respectively. The 95% significance points ratio $S^2_{\max}/S^2_{\min}$ can be obtained by comparing this ratio with the values given in Biometrika table 31 (Pearson and Hartley, 1958). All time series used, are found to be homogeneous, Table 1.

3. Method of analysis

The identification of trend can be made by using the sequential version of the Mann-Kendall rank statistic method, Mitchel et al. (1966), Sneyers (1975), and Chu et al. (1994). This test seems to be the most appropriate method for analyzing climatic changes Goossnes and Berger (1986). The statistic τ is computed from:

$$\tau = \frac{4\sum n_i}{N(N-1)} - 1, \tag{2}$$

Where n_i is the number of values larger than the i value in the series subsequent to its position in the time series. The test statistic $(\tau)_t$ is:

$$(\tau)_t = \pm t_g \sqrt{\frac{4N+10}{9N(N-1)}}, \tag{3}$$

Here t_g is the value of t at the probability point in the Gaussian distribution appropriate to the two-tailed test.

To understand the nature of trend, the series were subjected to a low-pass filter in order to suppress the high frequency oscillations. This removes variations with periods shorter than 10 years in the time series and retains variations of inter-decadal time scales. To give extra weight to the surface air temperature in the central position (year) of an 11-year running window, Hu et al. (1998) assigned different weights to each of the 11-years in the running mean. These weights, from the first through the 11th year in the running window are 1/24, 1/24, 1/12, 1/8, 1/8, 1/6, 1/8, 1/8, 1/12, 1/24, and 1/24, respectively. The symmetry of the weight distribution guarantees no phase shift of the variations in the time series after the filter is applied. The response function of the low-pass filter has a response function which equals to unity at infinite wavelength and it tails off asymptotically to zero with decreasing wavelengths.

The power spectrum of the surface temperature time series was computed using the autocorrelation spectral analysis (ASA), Blackman and Tukey (1959) and Mitchell et al. (1966), and maximum entropy spectral analysis (MESA), Burg (1975), and Olberg and Radoczi (1985).

The ASA is smoother and more accurate than fast fourier transformation (FFT) but the amplitude relationship is poorly reflected (Padmanabhan, 1991). Our discussion will focus on practical aspects of the functional form for the ASA power spectrum B_i,

$$B_i = \frac{r_o}{m} + \frac{2}{m}\sum_{L=1}^{m-1} r_L \cos\left(\frac{360}{2m} iL\right) + \frac{r_m}{m}(-1)^i, \tag{4}$$

where r_L is the autocorrelation coefficient of lag L. In the case of B_o and B_m the coefficients resulting from the formula have to be divided by two. The above formula, however, does not give the best estimate of the smoothed spectrum function. Final spectral estimates S_i are then computed by smoothing the raw estimates with a 3-term weighted average. In the "Hamming" method, Mitchell et al. (1966), the smoothing formulae are

$$S_i = 0.25B_{i-1} + 0.5B_i + 0.25B_{i+1}. \tag{5}$$

The MESA method identifies the frequencies accurately (Padmanabhan, 1991). Moreover, the order of the filter to be used in this method is somewhat subjective. Also, this method is more accurate than both FFT and ASA methods. This is because the MESA method increases the spectral resolution in the low frequency domain and gives a more realistic power estimate. The procedure is a formulation of the method of the MESA power spectrum $P(f)$ at frequency f, $P(f)$ is estimated by the following formula:

$$P(f) = \frac{P(m)\Delta t}{\left|1 - \sum_{n=1}^{m} a_{mn} e^{-2\pi i f n \Delta t}\right|^2}, \tag{6}$$

Where $P(m), a_{mn}$ and n are the output power long prediction error filter, the number of coefficients, and the number of a data set, equally spaced (i.e. $\Delta t = 1$), respectively.

4. Results and discussion

4.1 Fluctuations in temperature

Mann-Kendall statistics, which make no assumption about probability distribution for the original data, are tested for significance using a standard normal distribution. Table 2 shows the Mann-Kendall statistics for the eight sites in the Eastern Mediterranean. Four stations have positive values (a positive value indicates a positive trend in the standardized annual surface temperature), Malta, Jerusalem, Tripoli, and Beirut, and the others have negative values. It is also indicated in Table 2 that, for values of the Mann-Kendall statistic which are significantly different from zero at the 5% and/or 1% level, we find that only four stations are highly significant. Three of the four, Malta, Jerusalem, and Tripoli, have positive significance while the fourth, Amman, has a negative τ-value.

Time series of surface air temperature at the eight stations are presented in Fig. 1. They show both the annual surface temperature and its running mean, which retains only variations over periods longer than 10 years. The main feature of Fig. 1 is the presence of outstanding inter-decadal variations in the annual surface temperature. Among these variations, there appears a fairly regular variation of a quasi 20-year period, although its amplitude varies between different cycles. Another noteworthy feature is an important warming around 1910 which began at all

Table 2. Mann-Kendall rank statistic, τ at 8 stations over Eastern Mediterranean

Station	Annual
Malta	0.211**
Athens	−0.005
Jerusalem	0.342**
Alexandria	−0.100
Tripoli	0.246**
Amman	−0.165*
Beirut	0.007
Latakia	−0.133

* significant at 95% confidence level
** significant at 99% confidence level

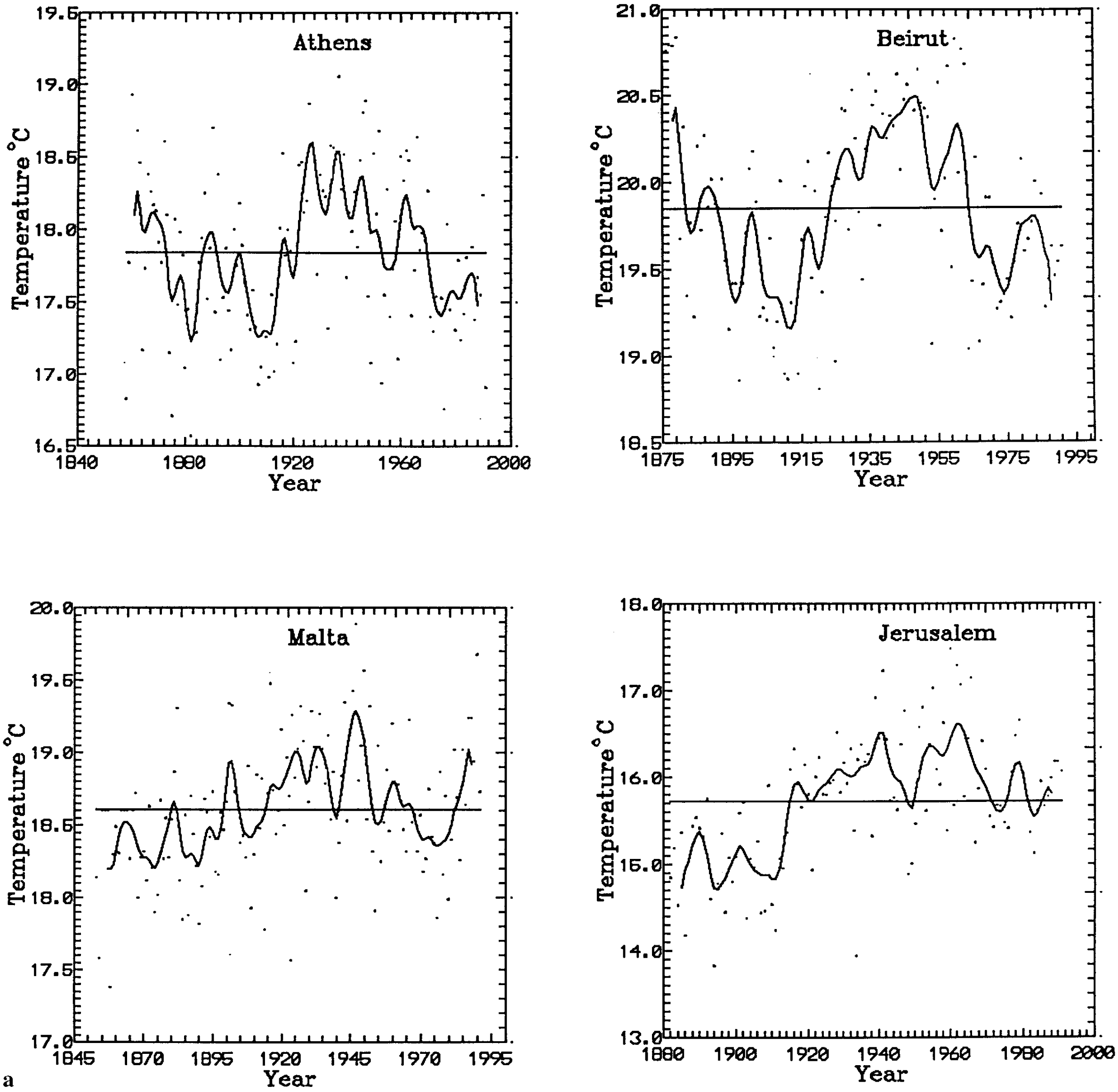

Fig. 1a. The fluctuations of surface air temperature over the stations Athens, Malta, Beirut, and Jerusalem

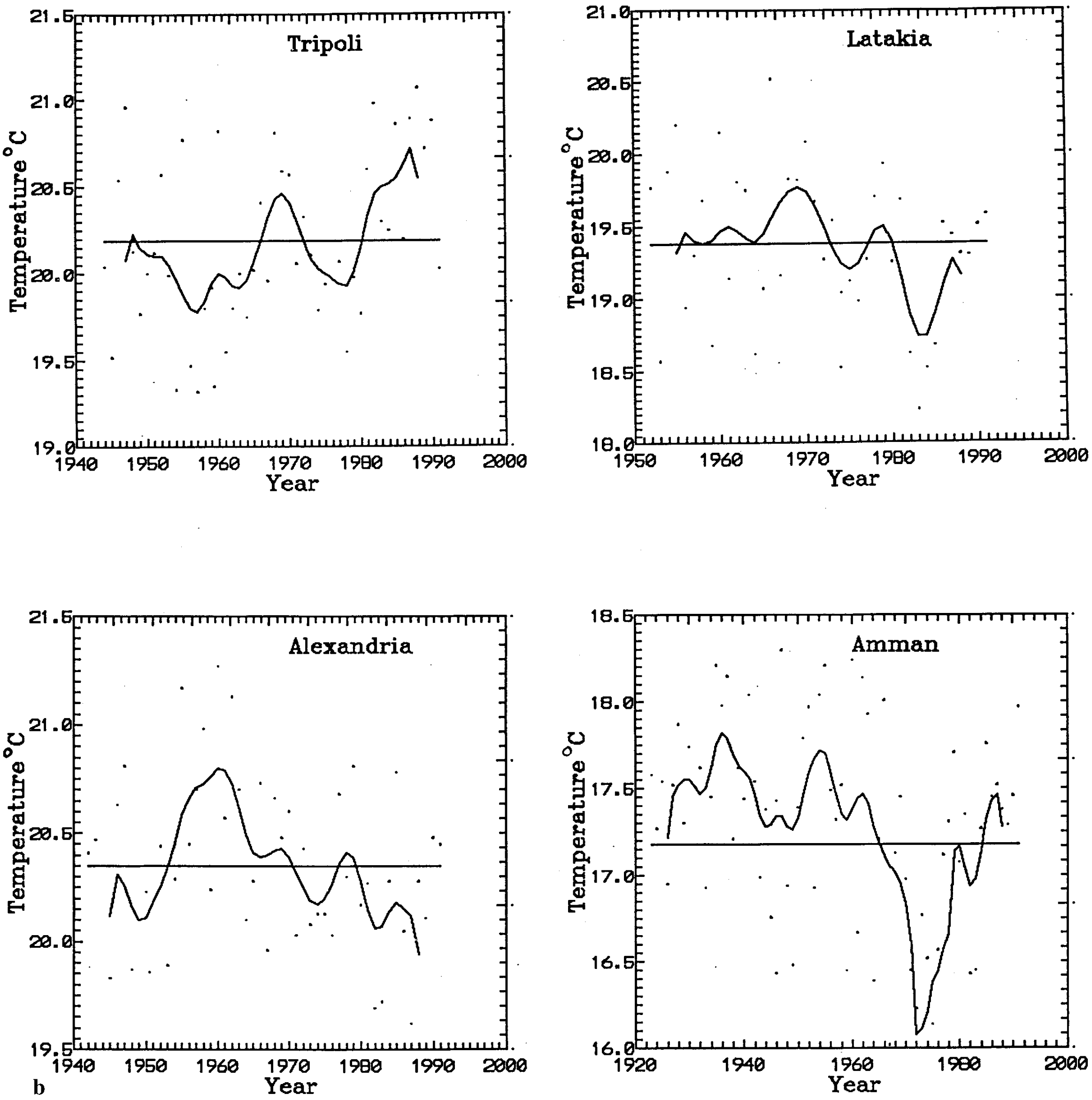

Fig. 1b. The fluctuations of surface air temperature over the stations Tripoli, Alexandria, Amman and Latakia

stations. Also, in agreement with Folland et al. (1990) and Arseni and Maheras (1991), it is found that during the seventies the time series exhibit warming. The warming, however, not of the same order at all stations under investigation and was neither uniform nor continuous.

Figure 1a shows that for Malta there is a gradual warming during the period 1853–1951 and cooling occurred for the two following decades (1951–1971). In the last period (1971–1991), a sharp warming occurred. At Athens there is a rise (warming) of temperature during the period (1875–1940), then temperatures fell (cooling) until the final year (1991). Jerusalem exhibits a gradual warming over the whole record. At Beirut there is a fluctuation of warming and cooling up to 1960, then a little change toward warming is occurs up to 1991. Similar to Beirut, Amman shows a fluctuation between periods of warming and cooling. A warming during the 1950s, as is shown in Fig. 1b, is found at Alexandria, and there is a fluctuation around the mean value until 1991. The mean annual temperature at Tripoli exhibits gradual warming up to 1991. At Latakia a gradual warming occurs from the first period up to the late 1960s, followed by cooling up to the mid 1980s, followed by warming to the end of the period (Fig. 1b).

The significant global warming which occurred at 1910 has been mentioned by other researchers, Kelly et al. (1982); Wigley and Farmer (1982), Colacino and Rovelli (1983), Jones and Kelly (1983), Repapis (1984), Balzano et Todaro (1985), Maheras (1989), and Arseni and Maheras (1991) over large areas of the world. It seems that this warm period also occurred in the Mediterranean, and also in the northern hemisphere, or in certain other areas and stations, with some exceptions, Arseni and Maheras (1991).

4.2 Periodicity in temperature series

Variance spectra of all the time series have been estimated using two different techniques, the Autocorrelation Spectral Analysis (ASA) and the Maximum Entropy Spectral Analysis (MESA). The statistical confidence of the power spectra is tested for the two techniques using the Markov red noise theory and χ^2-tests (Mitchell et al., 1966) or, respectively, Monte Carlo methods (Junk 1983). Although these two algorithms are fundamentally different, the spectra coincide as is shown in Fig. 2b and Fig. 3b. For instance, peaks

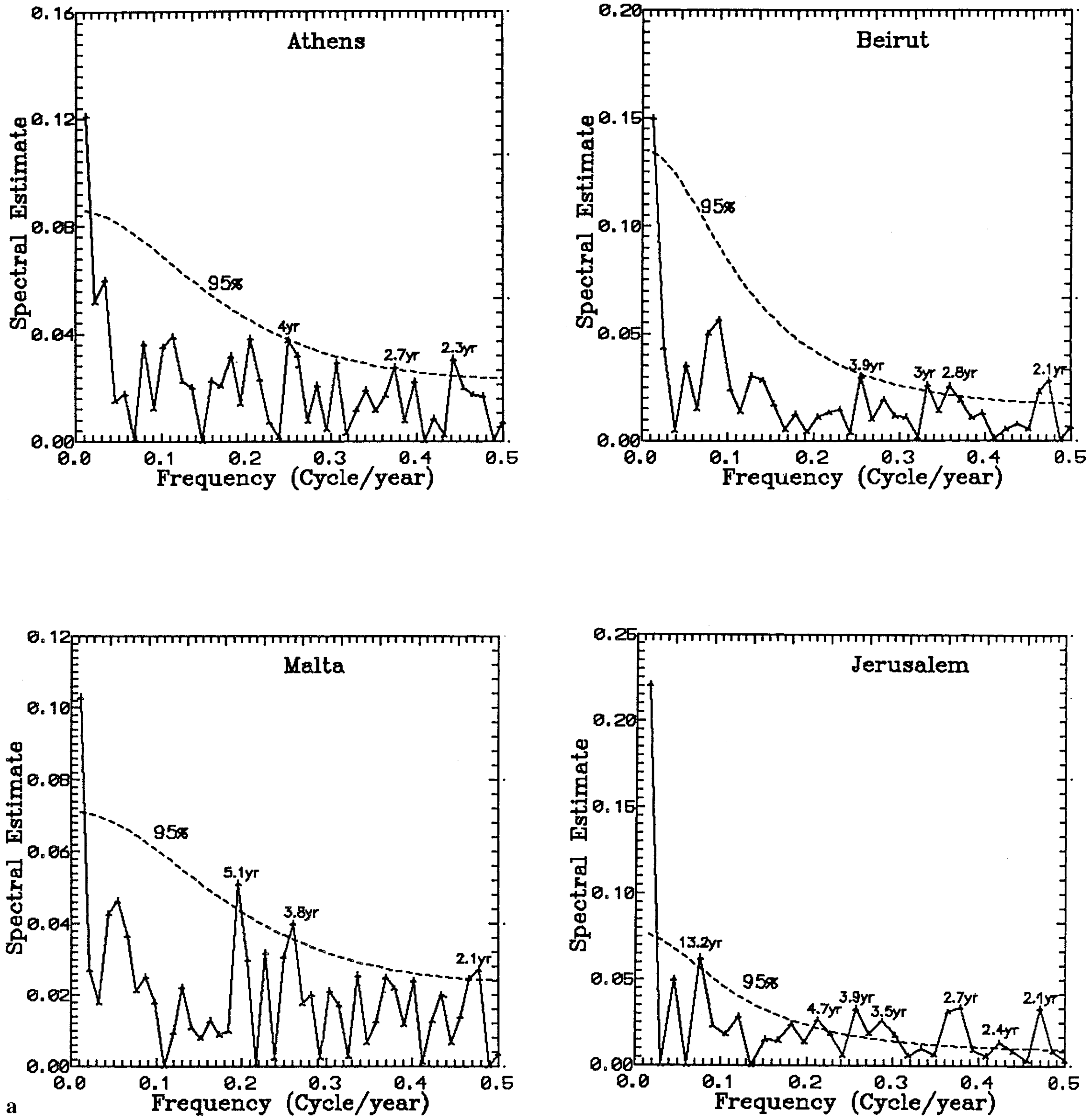

Fig. 2a. Autocorrelation spectral analysis ASA of mean annual surface temperature at stations Athens, Malta, Beirut, and Jerusalem (Solid curve), and 95% confidence level (dashed curve)

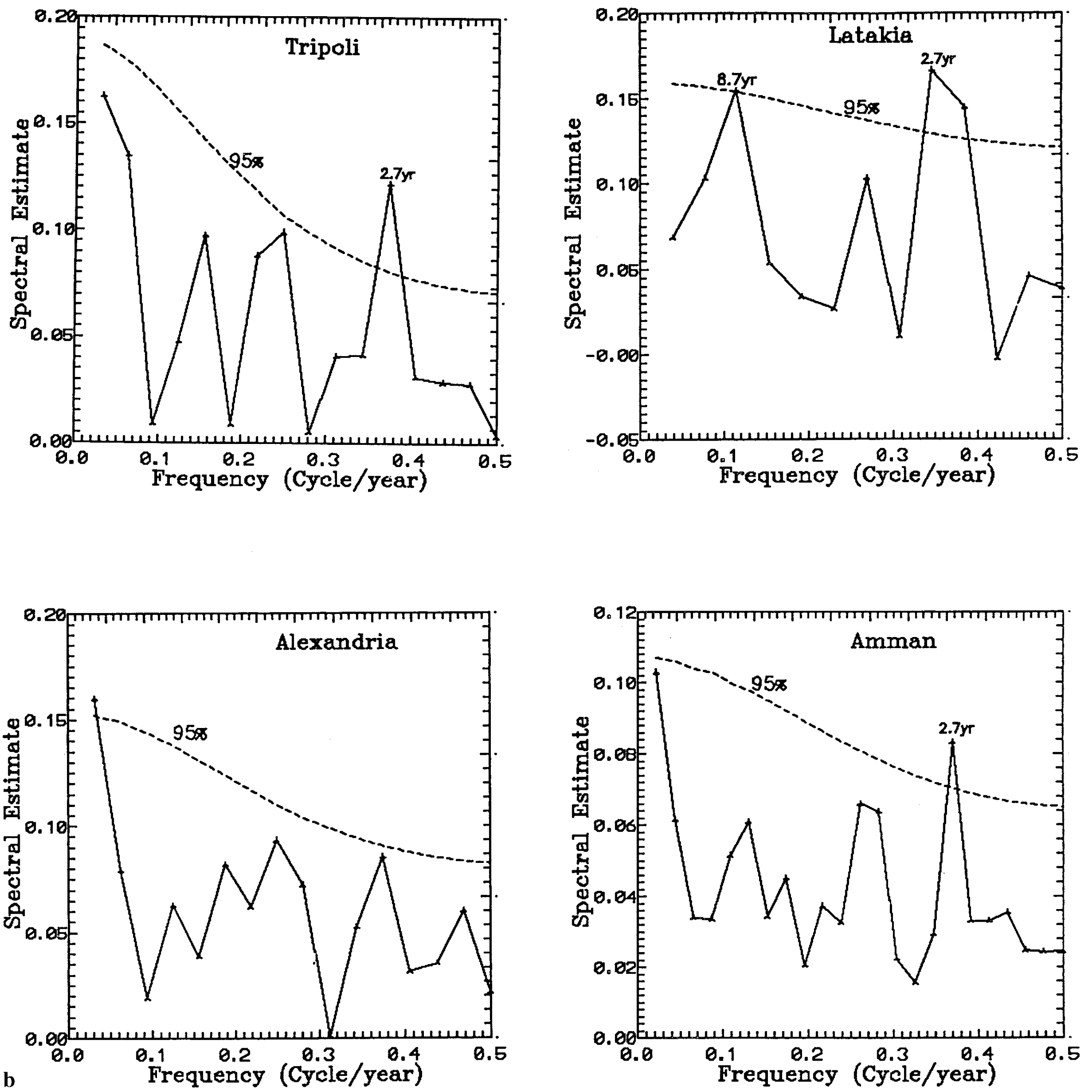

Fig. 2b. Autocorrelation spectral analysis of mean annual surface temperature at stations Tripoli, Alexandria, Amman and Latakia. (Solid curve), and 95% confidence level (dashed curve)

at Tripoli and Amman are identical at periods of 2.7 yr with respect to the 95% significance level.

The spectral analysis of all temperature records (including also inhomogeneous time series since inhomogeneities affect only the long term component of the spectrum, Schonwiese (1971)), shows that they are quite similar for certain stations, and different for other stations. Figures 2 and 3 show that the eight stations have similar spectral behavior. A significance at the 95% confidence level, e.g. at periods of about 5.1 yr, 3.8–3.2 yr, and 2.7–2.1 yr for Malta (139 years) is shown. The spectral analysis of the 134 year series for Athens gives dominant peaks at about 4.0–3 yr, and 2.7–2.3 yr. For Jerusalem (110 years), 13.2 yr and 12.3 yr middle wave, and 5.5–3.5 yr, 2.6–2.1 yr short wave are identified at the 95% significant confidence level. While the results for Beirut station (117 years) produce dominant waves at about 3.9 yr, 3.0 yr, 2.8 yr, and 2.1 yrs.

The results from applying the ASA and MESA techniques to Amman (69 years) and Tripoli (48 years) reveal peaks around 2.7 yrs. Spectral analysis of Alexandria (50 years) gives 4.0 yr and 2.7 yr significance at the 95% confidence level. Spectral analysis of Latakia (40 years)

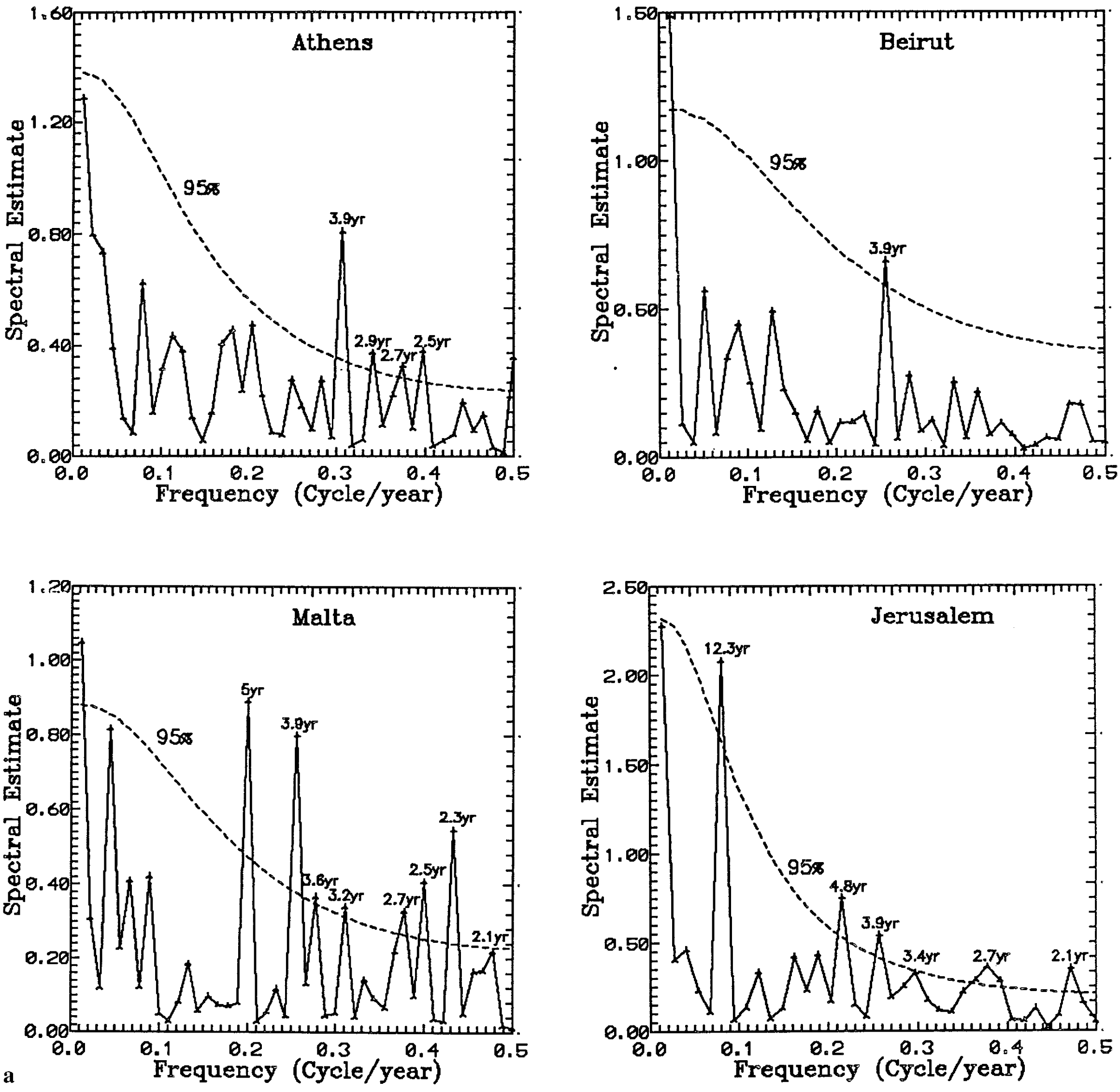

Fig. 3a. As Fig. 2a but for maximum entropy spectral analysis

reveals 8.7 yr, 3.7 yr and 2.9 yr significance at the 95% confidence level.

The reliability for the above time series has been discussed in detail by Jones et al. (1986a, 1986b, 1986c). Here we present some physical explanations of the periodicities mentioned above. The shorter waves (2.0–3.0 years) seem to be associated with the QBO. This connection has been mentioned by Angell et al. (1966), Schergag (1967), and Lamb (1972). Lamb (1972) noted that a QBO is related to the southern oscillation, which is the strength of subtropical high belt in both northern and southern hemispheres. Also, studies have shown that there may be two fundamental time-scales in the interannual variability of the monsoon-ocean-atmosphere system, i.e. a quasi-two-year cycle associated with tropical biennial oscillation (TBO) and a 4–6 year cycle associated with the El-Niño Southern Oscillation (ENSO). The ocean (El-Niño) may cause oscillations of between 3 and 8 years (WMO, 1985, Malcher and Schönwiese, 1987). Also minor peaks at periods in the range of 3–5 years appear to be associated with the southern oscillation, Folland et al. (1984). Other waves (11–13 years) seem to match the sunspot cycle and the period of 5–6.5 years, the second harmonic of sunspot cycles (Kane and Trivedi, 1985).

From the above results and discussion, the similarities in the results of ASA and MESA

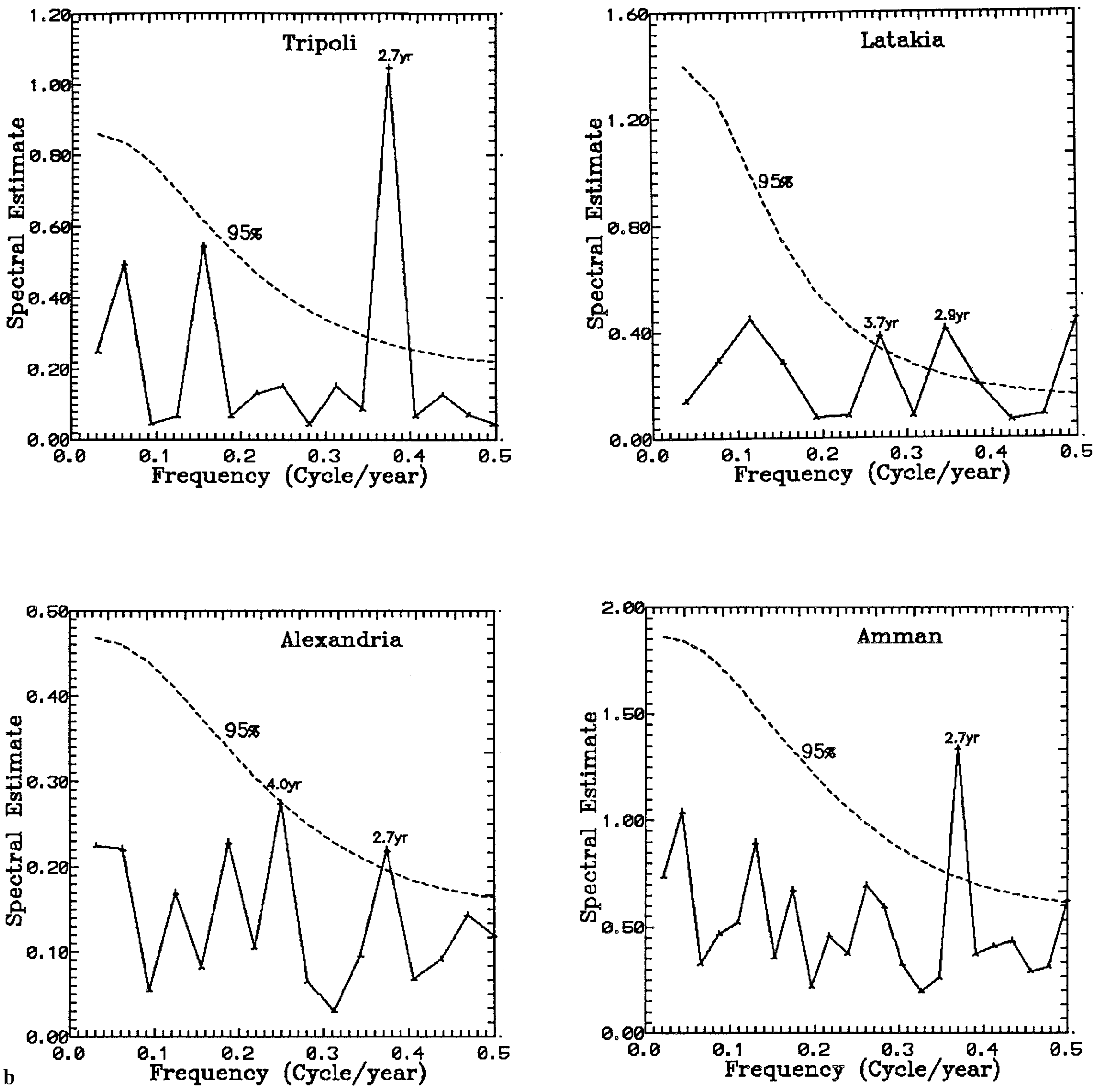

Fig. 3b. As Fig. 2b but for maximum entropy spectral analysis

methods suggest a high reliability of the spectral estimate. It could be verified that the ASA and MESA methods are accurate as shown by Schonwiese (1987), but the MESA method is more accurate. Also, one can conclude that all stations under study may be much affected by the QBO phenomenon, with a period from 2 to 3 years. The significant periodicity from 3 to 8 years appears at five stations (Malta, Athens, Jerusalem, Beirut, and Latakia), which may be affected by El-Niño. However, Jerusalem is the only site producing 13.2 and 12.3-year periodicities, which may be affected by the sunspot cycle.

4.3 Relationships between surface air temperature and large-scale phenomena

The correlation between larger scale phenomena and surface air temperature fluctuations over the Eastern Mediterranean are discussed below.

4.3.1 Relationships between surface air temperature and ENSO

El-Niño refers to the occasional "anomalous" warming of the eastern tropical Pacific Ocean but it is commonly linked to a basin-scale warming

Table 3. Correlation coefficient between both ENSO and North Atlantic Oscillation and surface air temperature at eight stations over Eastern Mediterranean

Stations	ENSO	NAO
Malta	−0.13	−0.12
Athens	−0.29**	−0.20**
Amman	−0.21*	−0.27**
Jerusalem	−0.25**	−0.45**
Tripoli	−0.12	−0.32*
Alexandria	−0.31**	−0.28*
Beirut	−0.13	−0.33**
Latakia	−0.34**	−0.32*

* significant at 95% confidence level
** significant at 99% confidence level

extending from the coast of South America to the International dateline. La Niña refers to the opposite phase where SSTs are well below average. Both events are named only when the SST departures from average are reasonably large. A common working definition is that if the SSTs depart from the normal by more than 0.5 °C for more than 6 consecutive months over some region then an event is considered to have taken place (Trenberth and Hurrell, 1994). Both El-Niño and La-Niña events are a normal part of the behavior of SSTs in the tropical Pacific, where the main variations occur through atmosphere-ocean interactions on inter-annual time-scales (Philander, 1990). It is the basin-scale phenomenon, however, that is linked to global atmospheric circulation and associated weather anomalies.

The Nino3 index which covers the area between 5° N–5° S latitude and 150° W–90° W longitude is often used as an index of SST anomalies associated with the ENSO cycle, WMO (1996). Therefore Nino3 is used here to investigate the relationships between ENSO and surface air temperature over the Eastern Mediterranean. Table 3 shows the association between ENSO and surface temperature at all eight stations. Inverse relationships between ENSO and surface temperature is found at all stations. Most stations give a significance to the 99% confidence level.

4.3.2 Relationships between surface temperature and the NAO

The NAO, is a large-scale alternation of atmospheric mass with centers of action near the Icelandic low-pressure region (Stykkisholmur/Reykjavik) and the Azores high-pressure region (Ponta Delgada). It is a dominant mode of atmospheric behavior in the North Atlantic sectors. The NAO is most pronounced in winter but detectable as a characteristic pattern in all months. The winter NAO pattern contributes the largest fraction of the Northern Hemisphere temperature variability of any mid-latitude or tropical mode of fluctuation.

Table 3 exhibits the correlation between NAO and surface air temperature at the eight stations over Eastern Mediterranean. Negative relationships occur between the NAO and surface temperature over the Eastern Mediterranean with a high significance level.

4.3.3 Relationships between surface air temperature and the QBO

The QBO, is almost a biennial oscillation (average period: about 27 months) of the temperature and zonal wind in the tropical stratosphere (Reed et al., 1961). The maximum wind is located at an altitude of about 24 km; the wind system is alternatively coupled with the northern and southern hemispheric stratospheric wind regime, and the wind directions change between west and east. The bimodal circulation regime seems to be a large-scale internal oscillation of the global atmospheric system, Lindzen (1987), which appears to be related to the so-called “Berliner Phaenomen”, Scherhag (1952); Labitzake and van Loon (1988). The latter is a quite explosive warming of the stratosphere between 20 and 50 km, which occurs at different times in late winter, and leads to a rise of stratospheric temperature in the order of 50 to 70 K and causes a remarkable breakdown of the polar vortex.

The interaction between different influences on the stratosphere (ENSO, QBO, solar radiation, solar cycle, volcanoes, etc.) is very complex (Warnecke, 1991). The same statement is valid for the relationship between the QBO and extra-tropical temperatures, Wanner et al. (1997). Our results in section 4.2 indicate that there are relationships between surface air temperature over the Eastern Mediterranean and the QBO.

5. Conclusions

The Mann-Kendall statistic provides a test for positive or negative trends, which are not necessarily linear, in standardized surface air temperature series, but it does not readily give a value for the magnitude of the trend, which is found to be statistically significant. The Mann-Kendall statistic also does not provide evidence of other kinds of nonstationary properties in surface temperature series, as in the case where the variability of surface temperature in a particular year increases or decreases with time. Nevertheless it provides a robust test for trend, free from assumptions about mathematical form of the trend or the probability distribution of errors. Subject to these facts, the analysis of surface temperature at eight stations over the eastern Mediterranean using Mann-Kendall statistic leads to two conclusions. The first is that positive or negative τ values (corresponding to positive or negative trends in surface temperature, whether or not these are statistically significant) are equal. The second conclusion is that the number of statistically significant τ values is four, three positive (Malta, Jerusalem, and Tripoli) with 99% confidence level, and one negative (Amman) with 95% confidence level.

Trend studies lead to the following main conclusions:

i) A warm period began almost simultaneously at the stations with long records. The trend is similar at all stations. This warming extends from the beginning of the records to 1950 but it is not continuous.
ii) A warm period was found during the 1970s, but it was not uniform, continuous or of the same order.
iii) Outstanding inter-decadal variations in the annual temperature are found. Among these variations fairly regular variations of a quasi 20-year periodicity exist, although its amplitude varies between different cycles.
iv) During the period under study, a temperature decrease is observed. Recent warming has only occurred during the last two or three decades at most stations. This could possibly be attributed to human activities.

Annual temperature series were examined using Autocorrelation Spectral Analysis and Maximum Entropy Spectral Analysis techniques to extract the periodicities. It can be concluded that some periods seem to be significant in all temperature time series. These periodicities are from 2.1 yr to 3 yrs at all stations and from 3 to 8 yrs at Malta, Athens, Jerusalem, Beirut and Latakia. As a consequence, it can be shown that all the stations may be affected by the so-called "Quasi-biennial Oscillation" phenomenon. Also, five stations (Malta, Athens, Jerusalem, Beirut, and Latakia) may also be affected by El-Niño.

Negative relationships between ENSO and the NAO with surface air temperature are found at all eight stations. By studying past warm and cold episodes, scientists have discovered wide-ranging temperature and precipitation patterns over the subtropics and extratropics that are consistent from one episode to another, e.g., Ropelewski and Halpert (1987, 1989) and Halpert and Ropelewski (1992). Temperature and precipitation variations associated with the NAO also extend to the countries of the Mediterranean basin, WMO (1993).

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References

Angell JK, Kroshover J, Carpenter TH (1966) Note concerning the period of the quasi-biennial oscillation. Mon Wea Rev 94: 319–323

Arseni-Papadiomitriou A, Maheras P (1991) Some statistical characteristics of air temperature variations. Theor Appl Climatol 43: 105–112

Balzano R, Todaro C (1985) Mutamenti climatici a Milano'. Riv Met Aer 45: 41–48

Blackman RB, Tukey JW (1958) The measurement of power spectra. New York: Dover Publications, 190 pp

Burg JP (1975) Maximum entropy spectral analyses. PhD thesis Stanford University

Childers DG (1978) Modern spectrum analysis California, U.S.A: IEEE Press, 334 pp

Chu P-S, Yu Z-P, Hastenrath S (1994) Detecting climate change concurrent with deforestation in the Amazon Basin: Which way has it gone? Bull Amer Meteor Soc 75: 579–583

Colacino M, Rovelli A (1983) The early averaged air temperature in Rome from 1782 to 1975. Tellus 35A: 389–397

Escourrou G (1978) Climats et types de temps de Normandie. These d'Etat, Atel Reprod Theses, Univ Lille 3, 1081 pp

Folland CK, Parker DE, Kates FE (1984) Worldwide marine temperature fluctuations 1856–1981. Nature 310: 670–673

Folland CK, Karl TR, Vinnikov KYA (1990) Climatic change, The IPCC. Scientific Assessment WMO/UNEP, Intergovernmental panel on climatic change. Reported prepared for IPCC by working Group 1. Houghton JT, Jenkins GJJ, Ephraums JJ (eds) University Press Cambridge

Halpert MS, Ropelewski CF (1992) Surface temperature patterns associated with the southern oscillation. J Climate 5: 577–593

Haykin S (1979) Nonlinear methods of spectral analyses. (Topics in Applied Phys, 34), Vienna, Austria: Springer, 247 pp

Hu Q, Woodruff CM, Mudrick SE (1998) Interdecadal variations of annual precipitation in the Central United States. Bull Amer Meteor Soc 79(2): 221–229

Jones PD, Kelly PM (1983) The spatial and temporal characteristics of northern hemisphere surface air temperature variations. J Climatol 3: 243–252

Jones PD, Raper SCB, Bradley RS, Diaz HF, Kelly PM, Wigley TML (1986a) Northern hemisphere surface air temperature variations. 1851–1984. J Climate Appl Meteor 25: 161–179

Jones PD, Raper SCB, Wigley TML (1986b) Southern hemisphere surface air temperature variations: 1851–1984. J Climate Appl Meteor 25: 1213–1230

Jones PD, Wigley TML, Wright PB (1986c) Global temperature variations between 1861 and 1984. Nature 322: 430–434

Junk HP (1983) Dynamic MESA spectra of climatological time series. Proc II Int Meeting on Statistical Climatology, Inst Nac Meteorol Geof, Lisbon, 11.4.1–11.4.6

Kane RP, Teixeira NR (1990) Power spectrum analysis of the time series of annual mean surface air temperatures. Climatic Change 17: 121–130

Kelly P, Jones P, Sear C, Cherry B, Tavakol R (1982) Variations in surface air temperature. Part 2: Arctic regions: 1881–1980. Mon Wea Rev 110: 71–83

Kousky VE, Chu P-S (1978) Fluctuations in annual rainfall for Northeast Brazil. J Meteor Soc Japan 56: 457–465

Labitzke K, van Loon H (1988) Associations between the 11-year solar cycle, the QBO and the Atmosphere. Part I: The troposphere and stratosphere in the northern hemisphere winter. J Atmos Terr Phys 50: 197–206

Lamb HH (1972) Climate: Present, past and future fundamentals and climate now. Vol 1. London: Methuen, pp 240–250

Lindzen RS (1987) On the development of theory of the QBO. Bull Amer Meteor Soc 68: 329–337

Maheras P (1989) Principal component analysis of western Mediterranean air temperature variations 1866–1985. Theor Appl Climatol 39: 137–145

Malcher J, Schönwiese Ch-D (1987) Homogeneity, spatial correlation and spectral variance analyses of long European and North American air temperature records. Theor Appl Climatol 38: 157–166

Mankin Mak (1995) Orthogonal wavelet analyses: Interannual variability in the sea surface Temperature. Bull Amer Meteor Soc 76: 2179–2186

Metaxas DA, Bartzokas A, Vitsas A (1991) Temperature fluctuation in the Mediterranean area during the last 120 years. Int J Climatol 11: 897–908

Mitchell JM, et al (1966) Climatic change, WMO Tech Note 79. WMO No 195. TP-100 Geneva, 79 pp

Mood AM, Graybill FA, Boes DC (1974) Introduction to the theory of statistics. London: McGraw-Hill, 564 pp

Olberg M, Radoczi F (1984) Informationstheorie in Meteorologie und Geophysik. Berlin: Akademie-Verlag, 181 pp

Padmanabhan G (1991) Non-harmonic spectral analysis to investigate periodicity in hydrologic and climatologic time series. Theor Appl Climatol 13: 31–42

Reed RJ, Campell WJ, Rasmussen LA, Rogers DG (1961) Evidence of a down propagating, annual wind reversal in the equatorial stratosphere. J Geophys Res 66: 813–818

Repapis Ch (1984) Air temperature fluctuation in Athens and in the Northern hemisphere and their probable processes. Monography, Univ of Athens, 106 pp

Repapis CC, Philandras CM (1988) A note on the air temperature trends of the last 100 years as evidenced in the eastern Mediterranean time series. Theor Appl Climatol 39: 93–97

Robinson EA, Treitel S (1980) Geophysical signal processing. New Jersey, U.S.A: Prentice-Hall, 466 pp

Ropelewski CT, Halpert MS (1987) Global and regional scale precipitation patterns associated With the El Niño Southern Oscillation. Mon Wea Rev 115(8): 1606–1626

Ropelewski CT, Halpert MS (1989) Precipitation pattern associated with the high index phase of the southern oscillation. J Climate 2: 265–284

Rybak OO (1997) Statistical structure of air surface temperature time series. Atmosfera 10: 59–74

Scherhag R (1952) Wetteranalyse und Wetterprognose. Berlin: Springer, 424 pp

Scherhag R (1967) Bemerkungen zur Welt-Wetterlage im Meteorologischen Jahr 1966–67, Berliner Wetterkarte, Berlin, Free Univ (Inst of Met)

Schönwiese CD (1971) Temperatur-Varianzspektren der neuen homogenisierten Reihe von Muenchen. Meteor Rdsch 24: 122–125

Sneyers R (1975) Sur l'analyse statistique des series d'observations. OMM Publ No 415. Note technique 143, 192 pp

Ulrych TJ, Bishop TN (1975) Maximum entropy spectral analyses and autoregressive decomposition. Rev Geophys 13: 183–200

Wanner H, Rickli R, Salvisberg E, Schmutz C, Schuepp M (1997) Global climate change and variability and its influence on Alpine climate – Concepts and observation. Theor Appl Climatol 58: 221–243

Warnecke G (1991) Meteorologie und Umwelt. Berlin: Springer, 342 pp

Wigley TMI, Farmer G (1982) Climate of the Eastern Mediterranean and near East. In: Bintliff JL, VanZeist W (eds) Paleocl paleoenvir and human communication in Eastern Mediter Reg in later prehistory. Bar Intern Ser 133, 37 pp

Woodruff CM, Hu Q (1997) Precipitation features of climate at selected locations in Missouri. Research Bulletin 1072, University of Missouri, Columbia, 35 pp. [available from

Dept of Soil and Atmospheric Sciences, University of Missouri, Columbia, MO 65211]
WMO (1985) The global climate system: A critical review of the climate system during 1982–1984. World climate data programme, 52 pp
WMO (1993) The global climate system Review, WMO-No 819
WMO (1996) The global climate system Review, WMO-No 856

Author's address: Dr. H. M. Hasanean (e-mail: hasanean@sci-astro.cairo.eun.eg), Astronomy and Meteorology Department, Faculty of Science, Cairo University, Giza-Egypt.