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Climate Variability and Urbanization in Athens

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With 5 Figures

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Summary

The effects of urbanization on the Athens National Observatory (NOA) long records are investigated, in the present study, examining the mean monthly maximum and minimum air temperature for the period 1925–1996, for NOA and the corresponding time series for Aliartos (ALI), a rural station located 70 km NW of Athens. The existing small urbanization effect in NOA before the second world war period increased after the war and up to about 1990, when the effect became stationary. The urbanization effect in NOA referred mainly to maximum temperature and to the warmer seasons of the year. It is attributed to the extensive building of Athens after the war around NOA site and up to the sea which increases the temperature of the sea breeze. The effect is also attributed to the rapid increase of the population and the number of motor vehicles mainly after 1970. Moreover the decreasing trend of precipitation during the period 1970–1990 may have contributed to the increase of maximum air temperature. The urbanization effect on maximum temperatures of NOA amounts about 2 °C in spring, summer and less in fall, while no urbanization effect is clear in winter.

1. Introduction

A large number of studies for climate variability or climate change appeared during the last decades investigating mainly the air temperature records. In a hemispherical basis, the surface air temperature has been raised by 0.5–0.7 °C since the beginning of the Century (WMO, 1996). From its lowest level, in about the beginning of the Century (in fact from the end of the little ice age period), the annual temperature raised abruptly up to about 1940. Then, a slow and irregular fall follows till about 1970s succeeded by an abrupt raise till 1995, which was the warmest year in earth since 1860 (WMO, 1996).

The temperature in the Mediterranean basin follows the same general march as the global one. In fact, the first and main minimum appeared a little later, in about 1910, and the first and main maximum a little earlier than 1940. A secondary minimum appeared in the Mediterranean in about 1955 and a secondary maximum in about 1965. The last minimum appeared then in mid 1970s in the W Mediterranean, and on late 1970s in the east, due to persistence of low pressures in the extreme E Mediterranean and the intensification of the northerly winds in the eastern Mediterranean during this period (see e.g., Metaxas et al., 1991; Bartzokas and Metaxas, 1991).

The study of the variability of precipitation and other climatic parameters is more complex. Nevertheless, a *detailed* description of the march of temperature is difficult too, because it also depends on the considered atmospheric level, on the filter used to remove the high frequencies and on the extent of the area of the earth considered. Serious errors for a climate change study are inserted when urbanization is also involved and this is the case for a large percentage of stations with long records. The urban influence on air temperature, in most mid-latitude cities, appears

as warming. However, there are marked differences in seasonal and diurnal warming caused by a complex combination of factors. For example, in London the urban warming is strongest on summer nights when heat which has been absorbed by buildings during daytime is released. Even with a decline of population during the last decades, the night time minimum has been increased (Lee, 1992). In Kuwait City, a desert city but near the coast, the urban influence on maximum and minimum air temperature is almost negligible probably because of the similarities in the urban-rural landscape and the close proximity of the sea (Nasrallah et al., 1990). Finally, if maximum and minimum temperatures are used, the precipitation variability is also important. It will be seen that the recent serious decrease of precipitation possibly affected the increasing trend of the maximum temperature in the E Mediterranean (see e.g., Bartzokas and Metaxas, 1995).

In Greece there were more than ten stations in function before 1900, but almost all of them either have been moved or discontinued during the two world wars or later. National Observatory of Athens (NOA) operates in the same position since 1890, though it was established 40 years earlier but operated in various positions. Temperature trends for NOA have been studied by several climatologists (see e.g., Carapiperis and Catsoulis, 1977; Ginis and Zambakas, 1976). Unfortunately, there are indications that NOA has been recently affected by urbanization (see e.g., Repapis and Philandras, 1988; Metaxas et al., 1991). In that case, the effect must be estimated and removed from the air temperature time series in order to study climatic changes.

The urban *heat island* in Athens city has been identified in many studies (see e.g., Katsoulis and Theoharatos, 1985; Repapis and Metaxas, 1986; Chronopoulou-Sereli, 1993). In the present study we try to assess the time and the amount of temperature change at NOA due to urbanization, as NOA is a station with a special interest because of its long record.

2. Data

The NOA station is situated on a hill close to Acropolis, 70 m above the valley floor of Athens, almost 5 km from the coast and close to the town

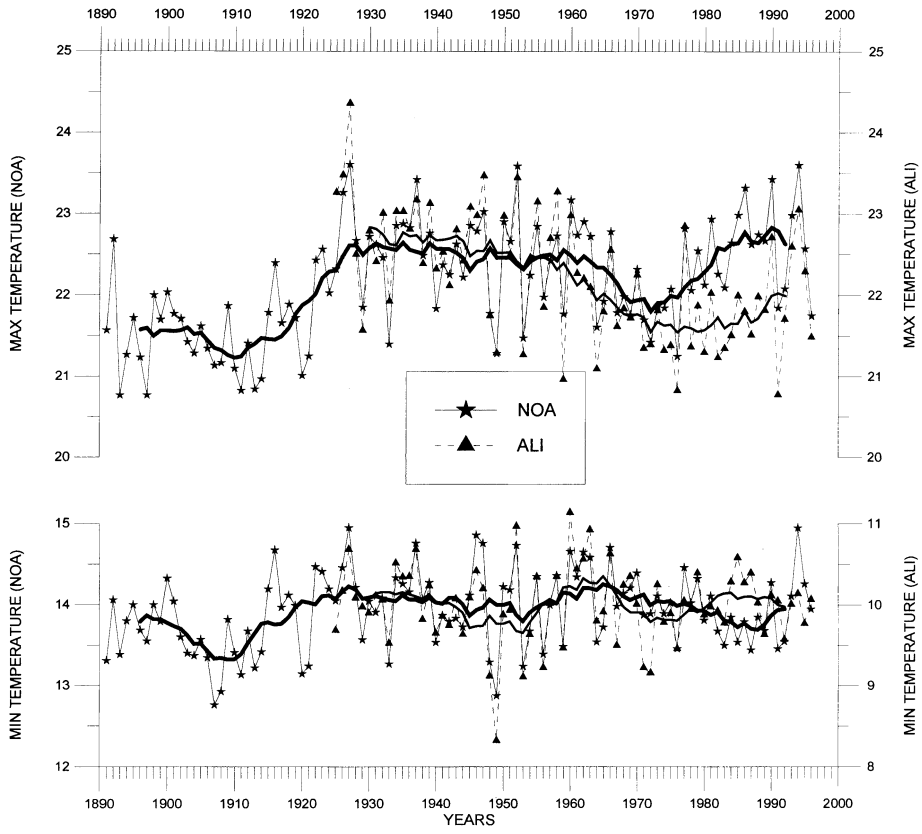

Fig. 1. Annual march of maximum and minimum air temperature for NOA and ALI, along with a ten year moving average filter

center nowadays, where most of the urban activities are taking place. The close environment of this station is wide open and has not been appreciably changed during the 20th Century. In the beginning of the century, Athens had a population of less than 500.000, i.e. less than the sixth of today's. Also recently, the number of automobiles has been rapidly increased to more than 1.5 millions. After the end of the second world war and up to about 1985, the town has been spread and densely populated in the valley and the area between the town center and the coast. This latter, has certainly affected the characteristics of the sea breeze, which is a strong and very important for temperature conditions factor in these latitudes during the warm period of the year. It has been shown (Metaxas et al., 1991) that the maximum temperature in NOA during summer has been significantly increasing from 1970 to 1990 although the minimum temperature has been almost decreasing during that period, indicating the important urbanization influence on maximum temperature.

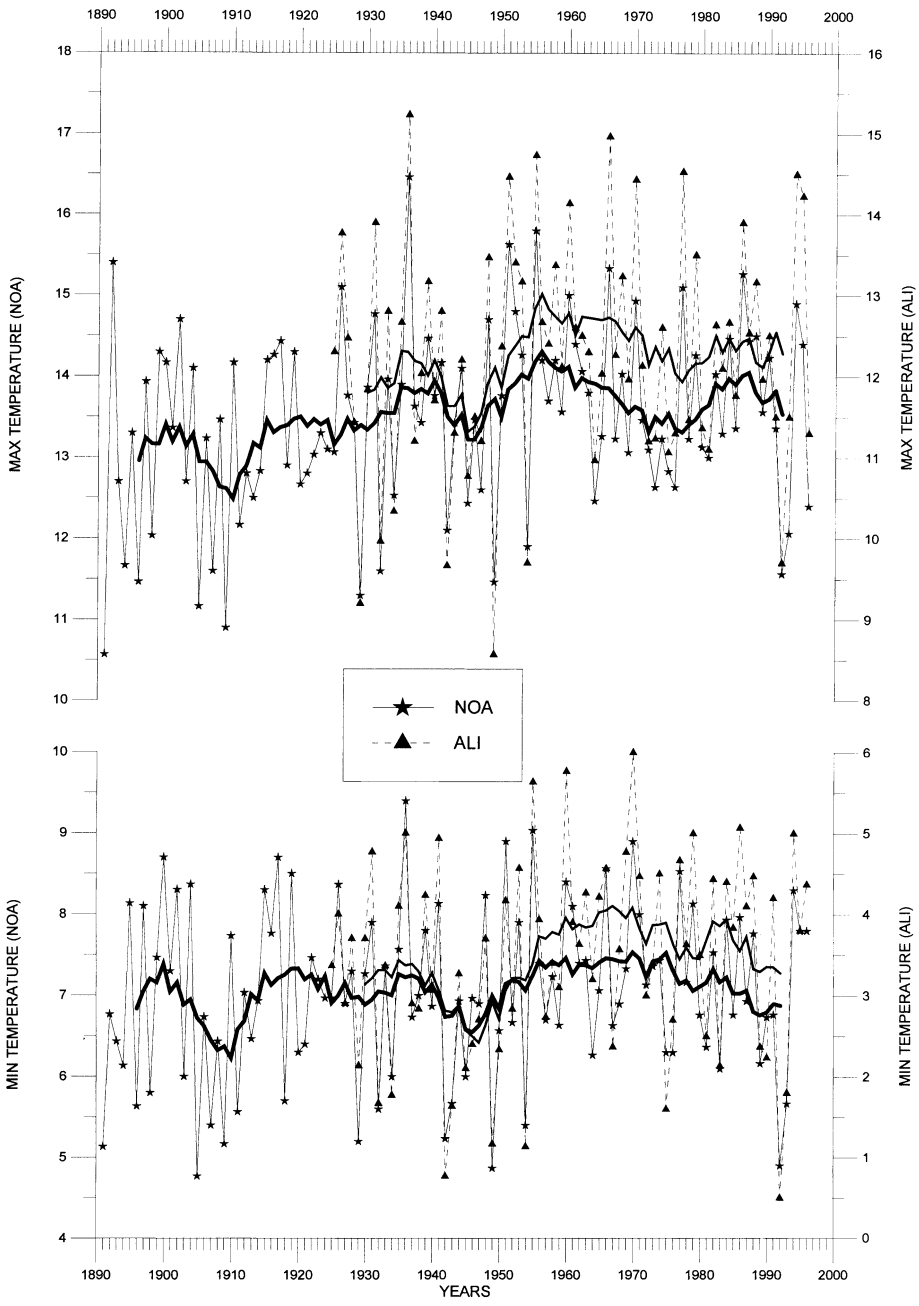

Fig. 2. Winter march of maximum and minimum air temperature for NOA and ALI, along with a ten year moving average

The main purpose of this work is to estimate when and how much urbanization has affected temperature in NOA. For this work the agricultural station of Aliartos (ALI) has been examined. The station is located in about 70 km NW of Athens and 30 km from the sea to NE, and its close environment has not been changed except probably during the last few years. We used the rather homogeneous period 1925 to 1996 for ALI although the data during the 1940s are less reliable because of the world war II and the political confusion during the followed few years. Some missing data of ALI were estimated using Tanagra airport station, about 35 km NNW of Athens and about 25 km from the coast to NE. The available data for ALI consist originally of monthly mean maximum and minimum air temperatures.

3. Urbanization and Climate Change in Max and Min Temperatures

It is known (see e.g., Metaxas et al., 1991) that the lowest temperatures of air and sea in the

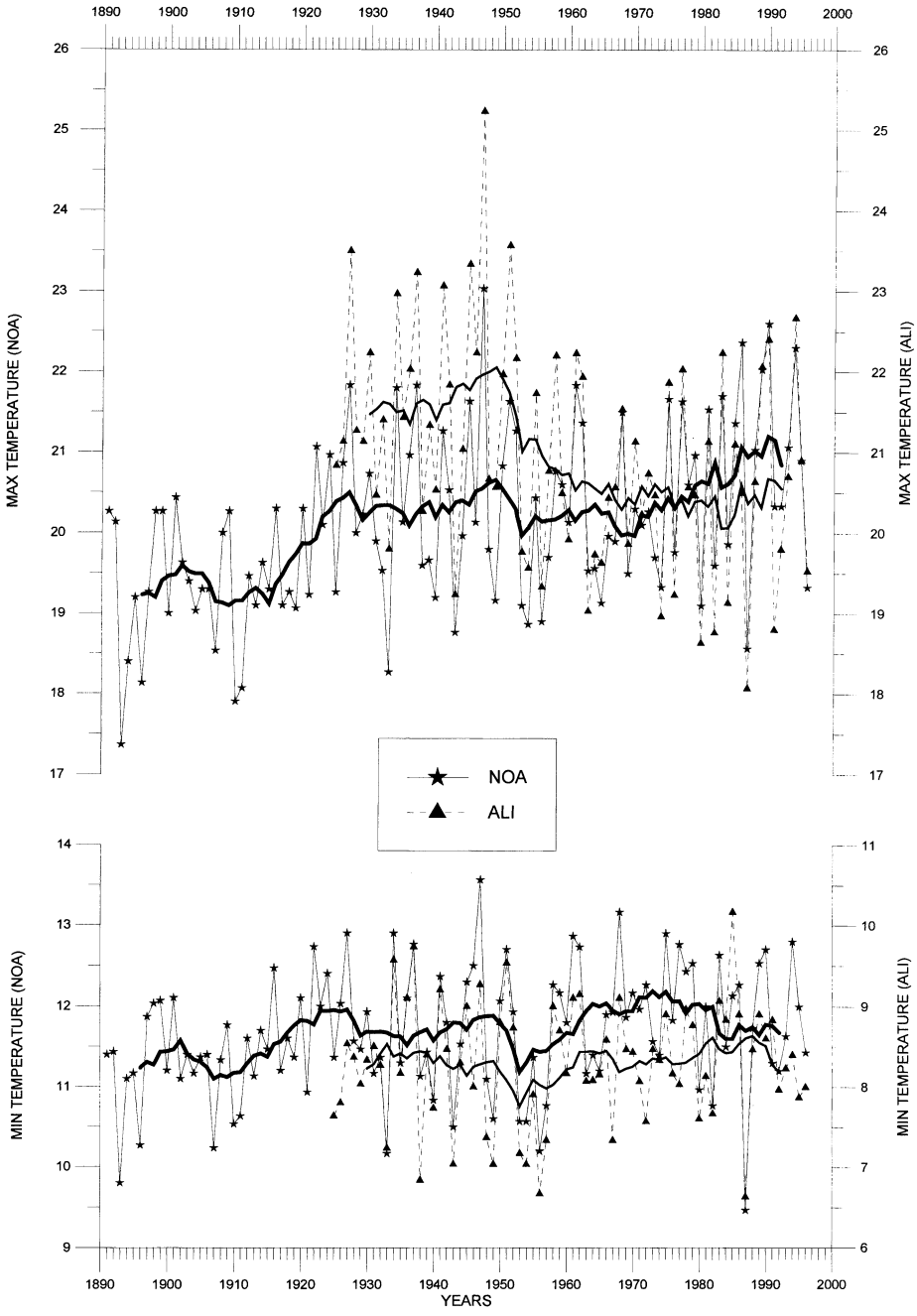

Fig. 3. Spring march of maximum and minimum air temperature for NOA and ALI, along with a ten year moving average filter

Mediterranean area are observed in about 1910. The reliable record for ALI begins in 1925, about the first temperature maximum in the Mediterranean region.

The marches of the annual values of maximum and minimum temperatures, for NOA and ALI are shown in (Fig. 1). It can be seen at first that NOA_{max} and NOA_{min} show an abrupt rising between 1910 and late 1920s by 2° and 1 °C respectively, which corresponds to the worldwide climate change (see e.g., WMO, 1996). From early 1930s up to 1960 the maximum temperatures of ALI display a negligible decreasing trend which is no apparent on NOA_{max} time series. From early 1960s the maximum temperatures for both stations show decreasing trends up to 1970s. After that, NOA_{max} increased rapidly while ALI_{max} increased only the last decade. The decreasing trend from early 1960s is apparent also on the minimum temperature time series for both stations though again the slope is steeper for the case of ALI. The differences between the trend slopes of the maximum and minimum time series after 1960s for NOA and the corresponding ones for ALI should be attributed to urbanization effect on NOA time series. The effect being small in the 1960s reached 1 °C on the maximum temperature during the 1980s.

In winter, air temperature time series show much larger interannual fluctuations (Fig. 2). The marches of the two stations time series are similar after 1950s. This similarity indicates that no urbanization effect can be observed in NOA during winter, considering that, there is no any reason ALI station to be affected by urbanization and on the other hand the ALI data during the

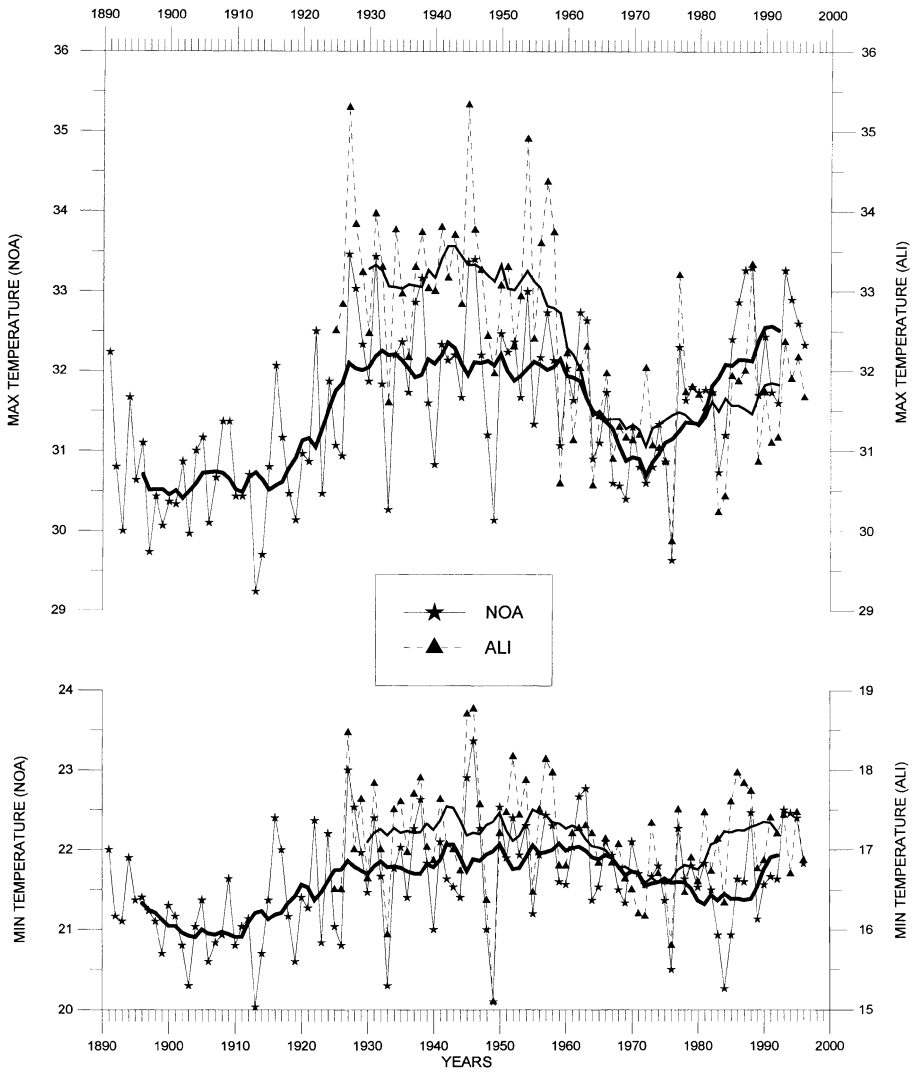

Fig. 4. Summer march of maximum and minimum air temperature for NOA and ALI, along with a ten year moving average filter

1940s, when the two curves coincide, are less reliable.

In spring, ALI_{max} displays a decreasing trend of almost 1.5 °C from 1950 to late 1980s while NOA_{max} displays an abrupt drop of 0.5 °C on early 1950s and then levels on for two decades followed by an increase trend of 1.0 °C from 1970 up to the end of the period (Fig. 3). The decrease of ALI_{max} by 1.5 °C from 1950 onwards constitutes a climate change in the region of eastern Mediterranean, as reductions in maximum air temperature during spring and summer over that period have also been reported for Greece and Israel (Jaffe, 1991; Cohen and Stanhill, 1996; Proedrou et al., 1997). The decrease of NOA_{max} temperature by only 0.5 °C in the beginning of that period and the followed increase of 1.0 °C should be attributed to urbanization effect in NOA_{max} by almost 2.0 °C. The minimum temperature time series of the two stations display almost parallel marches.

In summer, from late 1950s to early 1970s the maximum temperatures have been decreased in both stations (Fig. 4). In fact, while ALI_{max} during that period has been steadily decreasing by about 2 °C, NOA_{max} decreased only by about 1 °C, and this total difference should be attributed to urban warming of almost 1 °C. From early

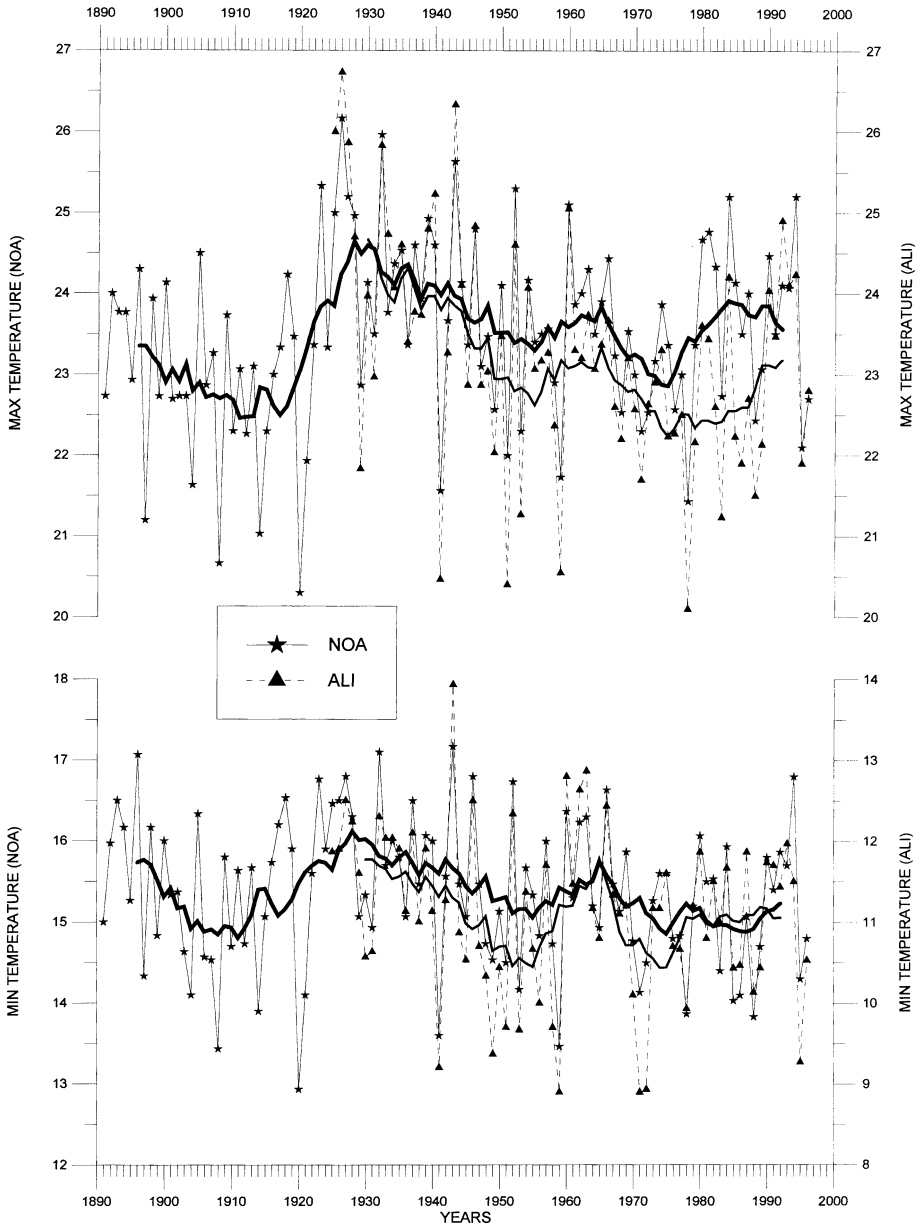

Fig. 5. Fall march of maximum and minimum air temperature for NOA and ALI, along with a ten year moving average filter

1970s up to 1990s, while ALI_{max} is only slightly rising, by less than 1 °C, NOA_{max} is rising more rapidly, almost by 2 °C, and this is a further influence of urbanization on NOA_{max}. Therefore, the total urbanization effect on NOA_{max} from 1950s to 1990s is assessed like in spring season to 2 °C.

The summer minimum temperature time series of the two stations display almost parallel marches again like in spring season.

In fall, the two maximum temperature time series display parallel decreasing trends up to mid 1970s (Fig. 5). From mid 1970s to mid 1980s NOA_{max} increased about 1 °C while during that period ALI_{max} remained constant. For the last decade an unexplained reverse tendency is shown.

4. Conclusions

From the above description it is apparent that there is an appreciable urban effect at the National Observatory of Athens, in spite of the fact that the close environment of NOA is open all around and its level is 70 meters higher than the valley floor and is only 5 km from the coast. The effect refers mainly to maximum temperature time series than in minimum temperature ones. In conclusion and in order to *restore* the NOA's series, the following should be taken into account:

At the beginning of the century there must have been some urbanization effect already in many locations in Athens, but at NOA, with its physical configuration described above, we think that no important urbanization effect existed (Repapis and Metaxas, 1986), while the significant increase of temperature observed after 1910 reflects the global *climate change* up to 1940s (see also Karapiperis P., 1961). Important influence of urbanization started at NOA after the World war II when large development began, with rapid increase of the number of motor vehicles on the one hand and the extensive building up all around and mainly in the formerly empty area between NOA and the coast. Therefore during the warmer half of the year, the cool sea breeze reaches NOA traversing a distance of about 5 km from the coast and is warmed up and/or reduced in strength and frequency. The modification of the sea breeze affects the maximum temperature, mainly during spring, summer and fall and hence urbanization increased the maximum temperatures by about 2 °C. The minimum air temperature time series do not display any significant trend. We also point out the opposite marches of maximum and minimum temperature between 1970 and 1990: the first is rising while the second is slightly falling. This phenomenon could be attributed possibly to the considerable reduction of precipitation during that period, which affected the maximum temperatures.

Finally, the annual values of maximum and minimum temperatures, after the first and main maximum of the 1930s, if examined linearly and taking into account the urban effect at NOA, did not show any increasing trend and therefore no definite sign of the *Green-House Effect* is apparent in this station. This is in agreement with Ceschia et al. (1994) who, analyzing the maximum and minimum time series for a large region in Italy, found that no significant trends are apparent for the last 40 years.

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