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THE URBAN EFFECT ON THE DAILY MIN AIR-TEMPERATURE IN THESSALONIKI

WPŁYW MIASTA NA DOBOWE MINIMA TEMPERATURY POWIETRZA W SALONIKACH

The absolute minimum daily temperatures of three meteorological stations in the region of Thessaloniki are used, that is the meteorological station at the Aristotle's University of Thessaloniki (1950–1995), the meteorological station of the airport Mikra (1960–1995) and the meteorological station of the old military airport of Sedes (1950–1970). The mean monthly, seasonal and annual minimum temperatures have been calculated for all three stations; also the daily differences between temperature data from the stations of the University and the airport Mikra have been calculated, for their common period (1960–1995). Finally, an interpretation of the results has been attempted.

INTRODUCTION

Thessaloniki (40°37′N, 22°57′E) is one of the most ancient Greek cities. It was founded the 315 BC by the King of Macedonia, Kassandros, who named it by the Sister of Alexander the Great. Into its long and adventurous history, many things have changed in it; e.g., its urban planning, its population, the composition of its inhabitants, etc. Temperature records in the Thessaloniki area date from 1892, although the meteorological stations have many times changed place over the years.

As it is known, air temperature exhibits temporal variations related to changes in weather and climate, as well as, spatial variations related to geographical changes, to topography and surface characteristics. Especially, in urban areas the air temperature or better the climatological elements have certain peculiarities as a result of the changes in the surface radiation properties due to the substitution of building materials for soil and plants, the air flow modification caused by the buildings and the release of heat and moisture from fuel combustion (Oke 1987). This affects the energy

exchange and as a result, cities are usually warmer than the surrounding countryside. This effect is generally referred to as urban heat island (Landsberg 1981) until now the greater number of the relative studies are mainly referred to large cities of the world Moreno-Garcia (1994), Spellman (1995), Tayanc (1997) and they have concluded that exists an increase of the urban air temperature about 0.1°C per decade in some of them (Kukla et al. 1986), while other researches showed that the urban effect magnitude is less than the recent global warming. Many papers are also dedicated to connections existing between the air pollution, the low-level ozone and the health of the human beings.

Thessaloniki is a modern city, very densely built without great parks or public gardens. Around it at its north limits there is a pine forest of restricted expanse (a great part of which was burned during the last summer). Very close to the city, towards west, is established the industrial zone with refineries, chemical products, etc., which undoubtedly charge the air with pollutants. We note here that unfortunately until now a systematic investigation of the released heat into the atmosphere of Thessaloniki has not be realised, like the one concerning Łódź (Kłysik 1996).

With this present paper we would like to illustrate the result of all the above mentioned factors on the change of the minimum temperatures – occurrence of the urban heat island – without separating each one of them according to its participation on the final formation of the air temperature. We refer also that the topography of the area serves to create a peculiar circulation over the city, because of which the sea-breeze (especially during spring and summer) cannot spread deep into the urbanised area. At least for cooling purposes the streets should be parallel to the direction of the regional winds.

METHOD – DATA

In order to ascertain the existence of the urban heat island phenomenon in Thessaloniki, we used the classic, called, approach method. According to this, the study is based on the records and the comparisons of the air temperature values of three meteorological stations. Among them, one is situated within the city centre and the other two outside the city at the airports. The previous mentioned stations are: the meteorological station of the Aristotle University of Thessaloniki (AUTH), situated in the centre of the city (urban station) and two non urban stations towards east, one at the old military airport (Sedes) and another at the civil airport "Macedonia" (Mikra). The data used are the daily minimum temperatures and the covered periods are: for the station of AUTH the period 1950–1995 (46 years), for Sedes 1950–1970 (21 years) and for Mikra 1960–1995 (36 years). From the

daily min temperatures are calculated the mean monthly, mean seasonal and mean annual temperatures for the three under consideration stations. Apart from these, the differences of the corresponding daily min values are also calculated for the common period 1960–1990 for the stations of AUTH-Mikra for the determination of the influence of the various weather types on the formation of the different thermal situations in Thessaloniki. The temperature course is separately studied for the three general groups: the stable circulation types, the unstable and the mixed. Into the last referred group are also included the weather types that result over the city the local wind "Vardaris".

With similar subject concerning certain Greek cities have been occupied some Greek researchers, like Katsoulis (1987) for Athens and Balafoutis (1985) for Thessaloniki.

THE ANNUAL COURSE OF THE MEAN MIN TEMPERATURE

From Fig. 1, where the mean min air temperatures are represented for all the months of the year and only for the common period of the three stations 1960–1971 has been proved that:

a) the centre of the city (AUTH) is warmer than the surroundings,
b) the mean min temperatures are always positive and even greater than 1.0°C,
c) the differences between AUTH and Mikra values lie from 1.0°C (January, February) to 2.7°C (May), while between AUTH and Sedes from 0.8°C (January, February) to 1.9°C (May).

This means that during the cold period the min temperatures in the three stations are closer than during the warm.

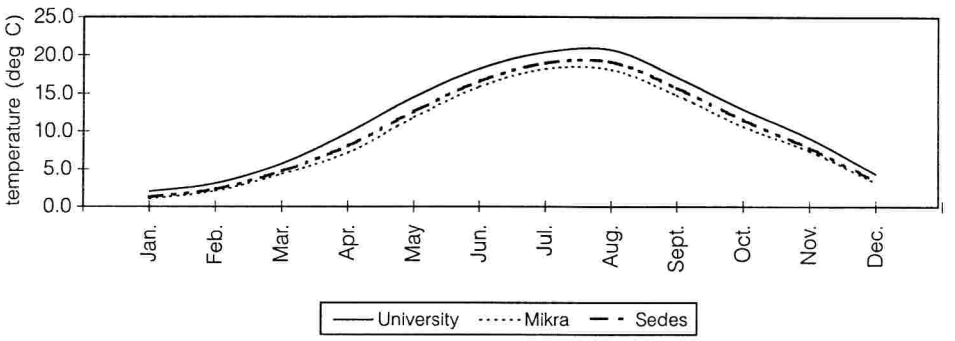

Fig. 1. Annual variation of mean min temperature in Thessaloniki 1960–1971

Rys. 1. Roczny przebieg średniej minimalnej temperatury w Salonikach 1960–1971

Temporal variations of the mean min temperatures

In Fig. 2, where the mean min annual temperatures are represented for the period 1950–1995, we can observe the different thermal behaviour of these stations: Sedes is colder than AUTH and its series represents a continuous decreasing. The two mentioned stations are in phase. The AUTH values show a restricted increase at the beginning of the period and after that the temperatures fluctuate around their mean value (11.4°C). Certain peaks that are localised at the years 1966, 1985 and 1994 do not exceed the 12.0°C.

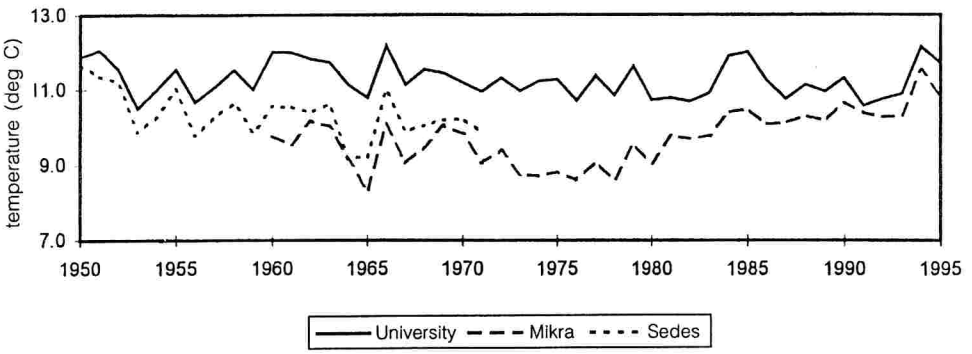

Fig. 2. Long-term course of mean min annual temperature at major area of Thessaloniki

Rys. 2. Wieloletni przebieg średniej rocznej minimalnej temperatury w rejonie Salonik

The Mikra's temperature series represents the most intense variations. More analytically from the beginning of the period and until the mid 70's exhibits a small decrease, which is followed by an enhance of the temperatures of about 3.0°C. After mid 70's it shows a good correspondence with the variation of the AUTH series. The increase of Mikra can be attributed on the changes of the environment around the airport "Macedonia". Initially, the installations of the airport "Macedonia" were consisted only by very few and low buildings, while after some years the necessities of it imposed new installations with new and taller buildings; we should also mention the addition of new asphalt runways at the region of the airport for the aeroplanes' needs.

Another reason which justifies the increase of the min temperature at Mikra is the extension of the city towards east, although this new part of Thessaloniki consists by individual houses, not so tall with gardens and by a small number of light manufactures which cause undoubtedly changes in the use of the surrounding land.

Believing that we will be led to useful conclusions, we intend to examine the temperature variations separately for every season.

Winter mean min temperatures

For Fig. 3a is observed that the three stations represent until 1968 intense changes from year to year. After the mid 60's the winter temperatures of the city (station AUTH) fluctuate around a new mean value that is practically higher (about 0.4°C) than the mean value of the first period. If we examine the enhance of the Thessaloniki's population (Tab. 1) as it is registered after the 6 recent census, we would result that the population increase started with high rhythm after 1951, but it has reached to its maximum point (46.5%) after 1961. This fact is in good relation to the change of the thermal behaviour of Thessaloniki after the mid 60's (after 1968).

Table 1

The enhance of the Thessaloniki's population

Wzrost liczby ludności w Salonikach

Year	Population	Difference
1941	278.399	
		24.236 (8.7%)
1951	302.635	
		78.013 (25.8%)
1961	380.648	
		176.712 (46.5%)
1971	557.360	
		148.820 (26.7%)
1981	706.180	
		42.865 (6.1%)
1991	749.045	

It is worth mentioned that at the beginning of 50's there is a coincidence of the Sedes and AUTH curves, while they are differentiated after the end of the same decade where the city appears to be warmer than the non-urban area of Sedes.

Concerning the temperatures of Mikra, they represent an increasing trend after 1975, which is not observed in AUTH. This can be explained by the fact that the reconstruction of the city centre was completed very soon, before 1975. This rebuilding gave a new character to the city, as it is consisted by tall buildings in continuous blocks, by asphalt streets,

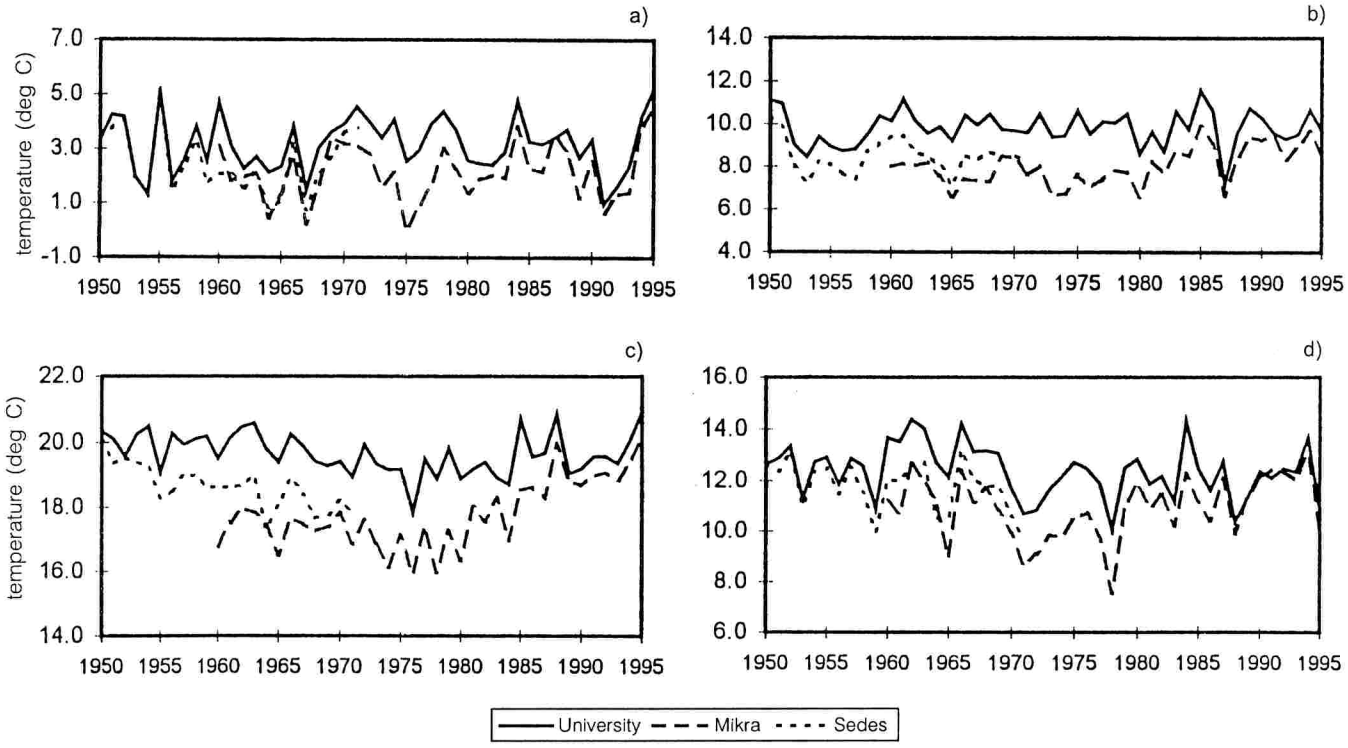

Fig. 3. Long-term course of mean min seasonal temperature at major area of Thessaloniki
a – winter, b – spring, c – summer, d – autumn

Rys. 3. Wieloletni przebieg średniej minimalnej temperatury w poszczególnych sezonach w rejonie Salonik
a – zima, b – wiosna, c – lato, d – jesień

reduction of green areas, etc. Someone should add to all previous mentioned the establishment of the industrial zone to the west that has the consequence of heat and pollutants release in the atmosphere of the city. The rebuilding of Thessaloniki continued also after 1975, but far from the centre creating new suburbs with low building and houses. After 1985 the curves of AUTH and Mikra have been almost coincided, as the development of Mikra has already started and in a few years it will be a suburb of Thessaloniki. We note also that only during the winter of 1987 city appears to be cooler than Mikra. In fact the winter of 1987 was a long cold and cloudy, which means that the urban effect was not so frequent.

Spring mean min temperatures

The spring mean min temperatures at AUTH, as we can see in Fig. 3b have a clear superiority regarding the other two non-urban stations. The differences become greater between AUTH and Mikra. After 1985 the above-mentioned differences are lower than during the former period. Thessaloniki's spring min temperatures do not demonstrate very sharp changes from 1960 to 1985.

Summer mean min temperatures

As we can observe in Fig. 3c Sedes' summer temperatures are in continuous decrease during all its operation period. Concerning the stations of AUTH and Mikra is perceived again the increasing trend that was observed after 1975 in the other two seasons. The increasing rate in Mikra is more intense, so after 1987 the differences between the two stations are diminished. The above--mentioned differences reached, at the beginning of Mikra's period, yet the 3.0°C. Certain differences on the thermal behaviour after 1987 (higher values, greater dispersion, curves approach, etc.) coincide with the occurrence of the heat-waves and the drought period that started after 1987 at the Greek area.

Autumn mean min temperatures

The autumn temperature course as it is represented in Fig. 3d is a little different than the other seasons. At the beginning of the series (decade 50's) the city seems to be warmer than the non-urban area of Sedes and Mikra. The differences between the two sites (urban and non-urban) reach

their higher point at the beginning of 60's, while after 1985 the curves of AUTH and Mikra are converged. It is worth noting that after 1970 the AUTH temperatures fluctuate around a value lower than at the period before. After 1970 is observed an increasing trend at the Mikra's values, i.e., a little earlier than to the other examined seasons.

This observation is in agreement with the views of Hughes et al. (1996), who in his paper concerned certain cities of South Africa found that the autumn min temperatures decrease, while the spring values increase. This fact can be attributed to atmospheric situations that are different from season to season.

CIRCULATION TYPES AND MIN TEMPERATURES

As it is known the principal role on the formation of the thermal regime over an urbanised complex is played by the city itself, as its presence effects on the environment change. The building materials in comparison, with a non urban area retain and release the solar radiation in different manner. We must add also the vehicles, whose number augment according to its population and their economical situation. Except all the above, the temperatures are affected on the atmospheric conditions over it, which is the result of the general atmospheric circulation. The atmospheric conditions form the different circulation types. In our paper we will use the classification of circulation types made by Maheras (1982), but regrouped in three great categories: the stable (48%), the unstable (44%) and the mixed circulation types (8%). At the following we will examine their influence on the formation of the min temperatures for every season and only for the period 1960–1990. Our study will be based on the differences of the daily min temperatures between the stations AUTH and Mikra, as it is accepted that the urban effect is more obvious on the minimum temperatures.

Analysis of the relations between the circulation types and the min temperatures

From Fig. 4, where the mean annual differences are represented for all the circulation types, is considered that low negative differences are detected only by the occurrence of the mixed types, that means that in this case the city centre is colder that the surrounding area. In this category are also included the synoptic conditions which are responsible for the appearance of the local wind "Vardaris" over Thessaloniki. This wind is a cold and

dry Katabatic wind that strikes on Thessaloniki and can destroy the "urban heat island" that probably existed before, Maheras et al. (1982), Arseni et al. (1985).

In the same figure it is shown that greater temperature differences are noted with the stable circulation types, besides these are characterised in majority by cloudless sky and consequently by intense heat emission during the night, and low min temperatures. This phenomenon is stronger in a non-urban area, as into a city the buildings and the streets release the heat restored in them all day, so the city appears warmer than the rural area.

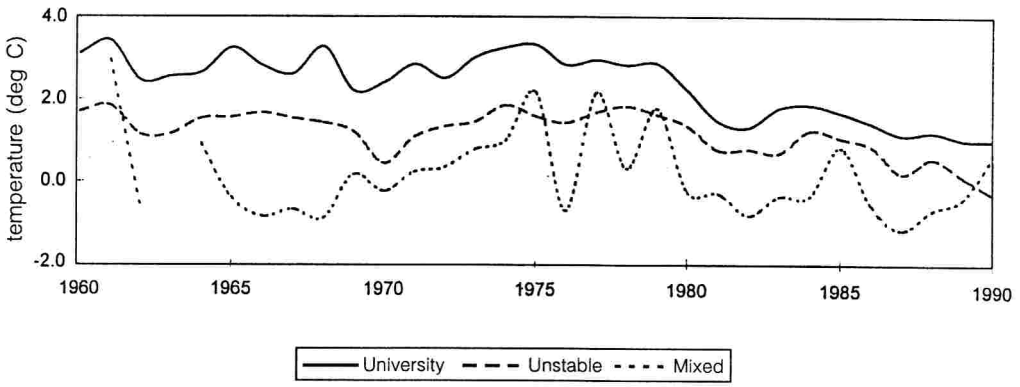

Fig. 4. Long-term course of mean min temperatures' differences between AUTH and Mikra, according to the circulation types for the year

Rys. 4. Wieloletni przebieg różnic średniej minimalnej temperatury między stacjami AUTH i Mikra w zależności od typów cyrkulacji atmosferycznej dla roku

After 1978 is clearly observed a perceptible decline of the curve that corresponds to the stable circulation types. This effect must be attributed to the beginning of urban effect over Mikra and not to the weakening of it over city.

The unstable weather types favour the occurrence of urban effect but weaker than with the previous weather types. The characteristic decline after 1978 is also present, when someone studies the curve of the unstable types but the decreasing of the values is smoother than of the stable types.

By examining the seasonal curves (Fig. 5a, b, c, d) someone can reach to similar conclusions. Additionally it is marked that the higher differences (>4.0°C) are noted during spring, while the majority of them lies between 3.0°C and 4.0°C. The stable types show higher differences in all seasons of the year.

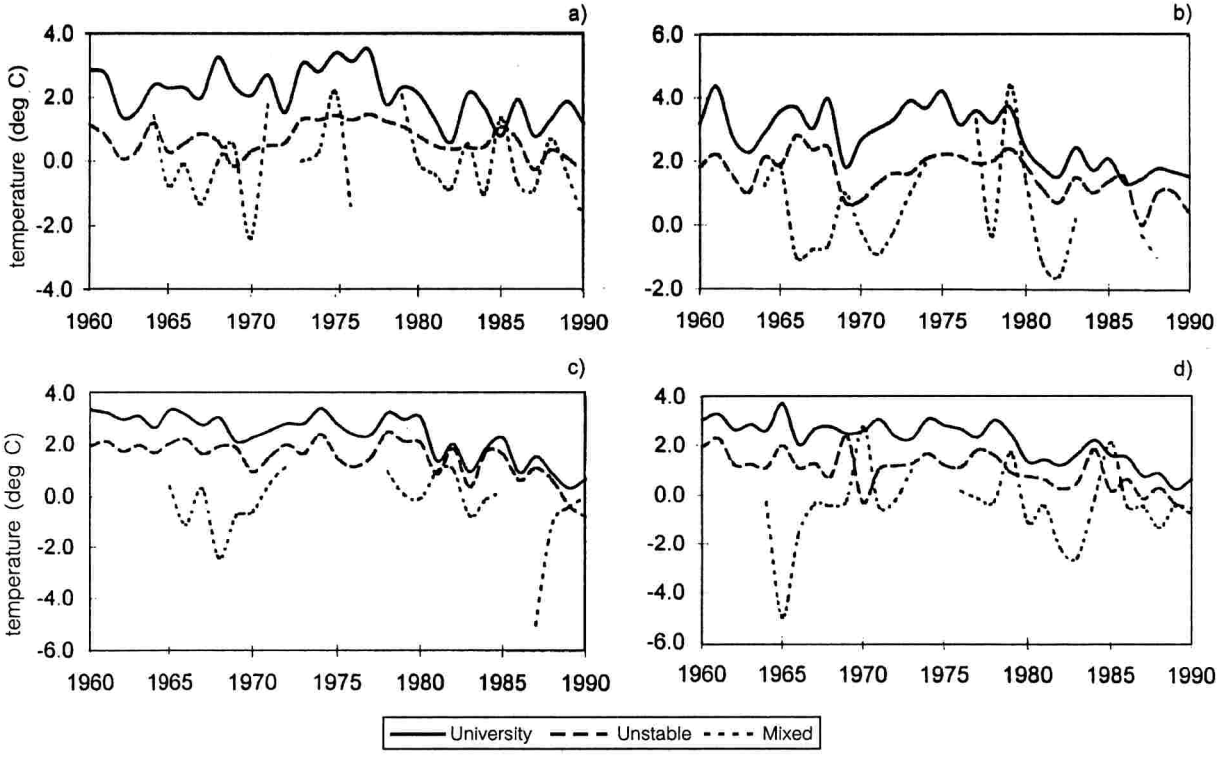

Fig. 5. Long-term course of mean min seasonal temperature differences between AUTH and Mikra, according to the circulation types for the seasons

a – winter, b – spring, c – summer, d – autumn

Rys. 5. Wieloletni przebieg różnic średniej minimalnej temperatury między stacjami AUTH i Mikra w zależności od typów cyrkulacji atmosferycznej w poszczególnych sezonach

a – zima, b – wiosna, c – lato, d – jesień

Differences reaching the –5.0°C are localised on the mixed types' curve (autumn, 1965). In general, these curves show the more significant fluctuations over the years. The unstable types that do not result great values, demonstrate the known, after 1978, decreasing trend, which is in this case more regular.

CONCLUSIONS

The study of the min temperatures at three stations in the area of Thessaloniki – one urban and two non-urban, leads us to the following conclusions.

The urban effect is a reality for Thessaloniki and it affects on the increase of the min temperatures over it. This phenomenon appears on the mean annual values, as well as, on the mean seasonal ones.

The increasing course of the urban heat island is in very satisfied correlation with the augment of Thessaloniki's population for the decades of 50's, 60's and 70's, reaching in the record percentage of 50% at the 60's.

The station of Mikra shows an urban effect too, which is in initial stage, as the environment around the station has been recently changed. This can be explained, if someone takes into account the fact that the city started to extend towards east during the last years, while to the north it is limited by the existed forest, to the west by the industrial zone and to the south by the sea.

The great concentration of people in Thessaloniki whose number practically, surpass the 1.000.000, has as consequence the following: the establishment of some new light industries, the traffic increase, the greater heat release, etc. We note that the use of air-conditioning systems during summer is almost indispensable. The deterioration of the nearby sea, which receives all the urban and industrial sewage and its serious pollution is a great problem. All these will intensify the phenomenon of urban effect.

The occurrence of urban effect is more favoured by the stable circulation types. These types are more frequent during the warm period (from May to September). Less favourable for this phenomenon are the unstable types that result lower differences between the temperatures of AUTH and Mikra.

Concerning the mixed types their role on the formation of temperatures is more complicated. Sometimes their synoptic conditions destroy the urban effect over Thessaloniki, and make it to be cooler than the surrounding area. Thessaloniki after 1975 had not many possibilities of changing furthermore. Its change or its "disaster" according many people, was completed until 1975 so it was not attainable to change any more.

We believe that after the experience of Athens and Thessaloniki, where there are accumulated many and serious problems, the smaller Greek towns, as well as, the new suburbs of these two cities should pay attention on their future development. If Thessaloniki wants to stay for a long a viable city, should examine and localise some of its problems, as for instance to measure the amount of the heat release in its atmosphere, to determine its air circulation model and since its air is polluted to forbid the establishment of new industries close to the city.

Except all the above-mentioned, although it is not subject of our study, is necessary to cleanse the gulf of Thessaloniki, in such a way to be again the sea source of life like at the past. The problem of Thessaloniki's future is difficult enough but not unsolved.

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STRESZCZENIE

Do badań użyto absolutne minima dobowe temperatury powietrza z trzech stacji meteorologicznych w rejonie Salonik: stacji Uniwersytetu im. Arystotelesa (1950–1995), lotniska Mikra (1960–1995) oraz starego lotniska wojskowego Sedes (1950–1970). Obliczono średnie miesięczne, średnie w poszczególnych sezonach oraz średnie roczne minima temperatury. Obliczono także różnice temperatury pomiędzy stacją uniwersytecką a lotniskiem Mikra dla wspólnego okresu (1960–1995). Dokonano próby interpretacji otrzymanych wyników.