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THE MAIN RESULTS OF THE NEARLY 30-YEAR-OLD URBAN CLIMATOLOGICAL RESEARCH IN SZEGED, HUNGARY

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Összefoglalás - A dolgozat egy közepes méretű magyar városban, Szegeden folyó városklímakutatás legfontosabb eredményeit tekinti át, amely közel 30 éves múltra vezethető vissza. Az áttekintés az 1967 és 1995 közötti korszakot elemzi és ismertet minden olyan fellelhető munkát (cikket, disszertációt és kéziratot), amely Szeged városklímájával foglalkozik. A sokéves dokumentáció azért is értékes, mert általa a vidéki városaink közül itt nyerhetjük a legrészletesebb, legátfogóbb képet egy nagyobb város klímamódosító hatásairól.

Summary - This paper describes the most important results of urban climatological investigations, which goes back to the 1960s, in a medium-sized Hungarian town, Szeged. The overview analyses the period between 1967 and 1995 and it contains every retraceable work (papers, theses and manuscripts) which dealt with the urban climate of Szeged. So many years of documentation is also valuable as it gives the most detailed and most extensive picture among the Hungarian country towns of the climate modification effects of a bigger town.

Key words: urban climate, Szeged, Hungary, chronological overview

INTRODUCTION

The establishment of towns strongly alters the original natural surface. It modifies the materials, the structure and the energy-balance. There are other anthropogenic modifying factors such as the artificial heat release and the air polluted by different gases and aerosols. The joint effects of these factors determine a peculiar local climate in towns. It is the so called *urban climate*.

The main feature of an urban climate is that almost every meteorological element in the town shows some alteration compared to the ones in the surroundings free of anthropogenic effects. The magnitudes of the modifying effect of a town on the different elements depend on the mezo-climate of the wider area, on the geographical and orographical circumstances, on the features of industry, on the structure and surface of the built-up area, as well as on the population of the town.

The climate modifying effect of the town is disadvantageous from the aspects of human bioclimatology and sometimes it is very loading although its health damage depends mainly on air pollution. The disadvantageous effects can be decreased by appropriate planning methods and for this reason we have to know the local climate of the town.

The big towns in Hungary can be put in three orographical region types: juncture of mountains and plain, valley, and plain.

In the case of the first two types the artficial modifying effects are disturbed by the varied orographical conditions thus their recognition is difficult. To demonstrate the undisturbed urban climate, a town situated on a plain is the most suitable. The detailed climatological measurements of this town can give us a basis for drawing general urban climatological conclusions. Besides laying the foundation of future plans of urbanization scientifically this fact has also given reason to investigate the urban climate of the town, Szeged.

STUDY AREA

Szeged is situated in the south-east of Hungary at 79 m above sea level on a plain (46°15'N, 20°09'E) and altitude differences inside the town are only a few metres. In 1980, Szeged had 175 000 inhabitants and its built-up area was approximately 46 km^2. The town is a long way from large water bodies except the River Tisza intersecting the town. The area has a continental climate with a long warm season. The main average meteorological parameters of Szeged region are as follows:

- mean annual temperature is 11.2°C,
- mean January and July temperatures are -1.2°C and 22.4°C respectively,
- mean annual precipitation is 573 mm,
- mean annual sunshine duration is 2102 hours (*Péczely*, 1979).

The ground of the town structure is a boulevard-avenue street system rested on the River Tisza (*Fig. 1*). Its advantage is that the town structure is easy to survey, but its disadvantage is that the traffic concentrates towards the town centre which increases air pollution. The industrial area is located mainly in the north-western part of the town. Thus the prevailing westerly and northerly winds transport the pollution originating from this area towards the central parts of the town which is also helped by the supposed inhaling effect of the Tisza valley channel.

During the last decades the structure of the built-up areas has been significantly modified by the construction of huge housing estates with pre-fabricated concrete slabs oin the

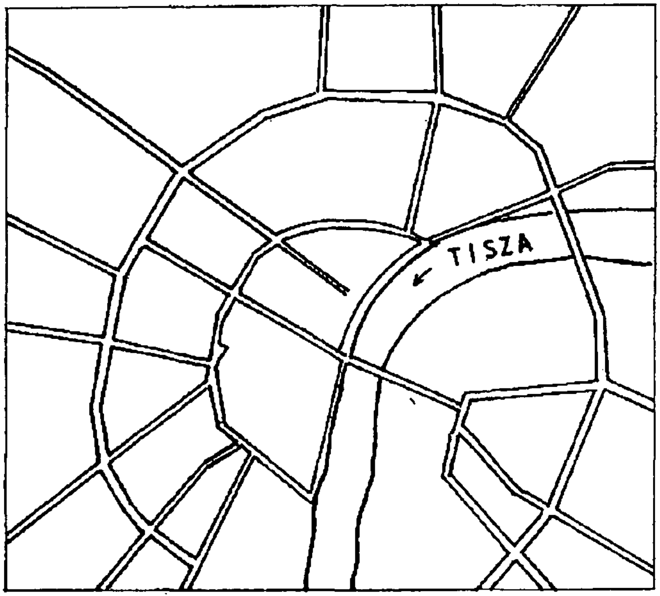

Fig. 1 Urban structure scheme of Szeged

northern and eastern outskirts. They mean particular structure proportions because there is a belt with detached houses with lots of gardens and green areas between the town centre with densely packed 2-4-storey buildings and the tall, concrete, not too densely built 5-10-storey buildings of the new housing estates. This area with tall buildings used to be a gradual transition built-up area between the town centre and the open spaces.

In the next part of the paper the main results of the investigations related to the urban climatology of Szeged will be exhibited in chronological order. The results and establishments can be found in published papers, in manuscripts of theses and doctoral theses as well as in other manuscripts.

CHRONOLOGICAL OVERVIEW OF THE URBAN CLIMATE INVESTIGATIONS IN SZEGED

The first work was a doctoral thesis (*Jantos*, 1967) which investigated the temperature differences between two stations situated in the town centre and near the town respectively using 15-year data series (1951-65). The urban station was above the Department of Climatology on the top of the University Building and the rural station was to west of the town at the airfield. The mean urban-rural differences were highest at 07h in July (1.5°C), at 14h in September (0.9°C) and at 21h in August (2.3°C). In other months the greatest differences also appeared at 21h and the smallest ones - sometimes negative values - at 14h. At the monthly mean temperatures the highest differences were in the summer months (>1°C). At the extreme temperatures the monthly mean minimum temperature difference exceeded 2°C in July and the

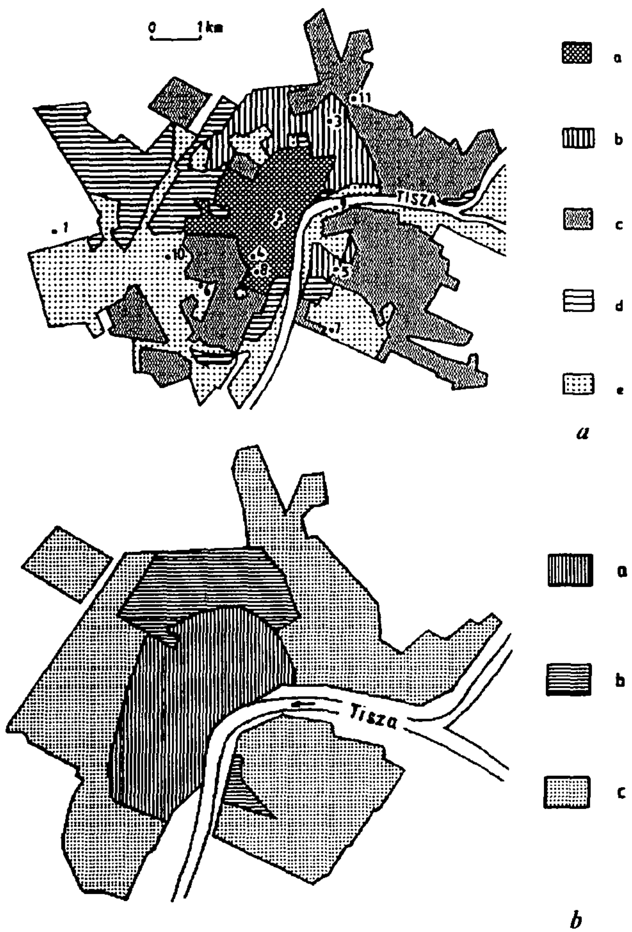

Fig. 2 *a*. Urban climatological station network of Szeged and its main built-up types. *b*. The simpler built-up structure draw of the town used earlier /a - town centre (2-4-storey buildings), b - housing estates with pre-fabricated concrete blocks (5-10-storey buildings), c - detached houses with gardens, d - industrial areas, e - green areas/

difference of monthly absolute minimum was even greater. The urban-rural temperature differential is reflected in differences in the number of meteorologically rigorous (very cold) days (urban 9; and 11.5) and in the number of heat days (very hot) (urban 26; and 22).

The Department of Climatology initiated a plan to measure the local climate features of two new housing estates with tall concrete blocks ('Tarján' and 'Odessza') during a month, from May to June, 1973 (*Péczely et al.*, 1975). These data were compared to the ones of the station at the airfield. The information material was incomplete so all that can be established is that the greatest temperature excess appeared at night. During the day the temperature of the housing estate with a lot of trees ('Odessza') was lower with 1.5°C on average than that of the other one. The advantageous effect of the urban afforestation was verified because it decreased the heat load of the human body even in the warmest time of the day.

Five years later a doctoral thesis (*Sindely,* 1978) used 5-year temperature and humidity data sets (1967-1971) and revealed that the annual average minimum temperature at the urban station was 1.6°C higher than the annual average at the rural site. The differences of maximum temperatures were smaller and they equalized during the year. The greatest differences of temperature excess appeared at 01h in summer and at 07h in winter with the means of 1.4°C and 1°C, respectively. The relative humidity differences showed that the town was drier than its surroundings in winter, in early spring and at the end of summer. Finally, the author found only insignificant vapour pressure differences.

In 1977 a network of meteorological observation stations was established in the town and data were collected between July 1977 and May 1981. Thus, there are three years whose data sets were complete. Air temperature, humidity (3 or 4 times a day), maximum and minimum temperature and precipitation were measured. The stations more or less represented the different built-up areas of the town (*Fig. 2*). The 11 different observation sites and their features were as follows:

- The station, which is free from urban climate modification effects (Station 1 = Aerological Observatory of Hungarian Meteorological Service), is situated at a distance of 4.4 km to the west of the town centre. The surrounding area is a cultivated land and it is considered to be a good example of the rural area. The station has been working till now.
- Station 2 was located in the town centre in a paved square bounded by multi-storey buildings.
- Station 3 was set up in a new housing estate with 5-10 storey buildings built from pre-fabricated concrete slabs.
- Station 4 was beside the 3-storey University building and in this way it represented the climate of streets with more-storey buildings built from traditional materials.
- Station 5 was located in the grovy garden of the Children's Hospital bounded by busy streets.
- Station 6 was in the suburb to the south-west of the town centre.
- Station 7 was set up at the south edge of the town in the University Botanical Garden.
- Station 8 was between the town centre and the suburb with detached houses and gardens.
- Station 9 on the river bank represented the modification effects of Tisza.
- Station 10 was situated in a site with small lakes and natural vegetation.
- Station 11 was in the suburb to the north-east of the town centre.

The following thesis (*Vámos*, 1979) investigated 10-year temperature and humidity series of the station at the airfield and the station on the top of the University Building (1962-1971). The urban heating effect was the most significant in summer and in autumn. The monthly mean temperature excess were highest in August (0.86°C) and in October (0.89°C). The monthly mean minimum temperature excess was the greatest also in August (1.58°C). Such characteristic picture did not take form in the case of maximum temperatures. The relative humidity differences were the greatest in September (-6.4 %) and in October (-7.0 %), which were in negative accordance with the differences in the heat excess. The vapour pressure differences were negligible. The further part of the thesis used the monthly mean minimum and maximum temperatures of eight stations of the station network in 1978 were used because the network had already serviced data at that time. Station 1 was the rural station (and this application will be used in each of the works mentioned later). The spatial distribution of the monthly mean minimum temperatures showed that the pattern of excess

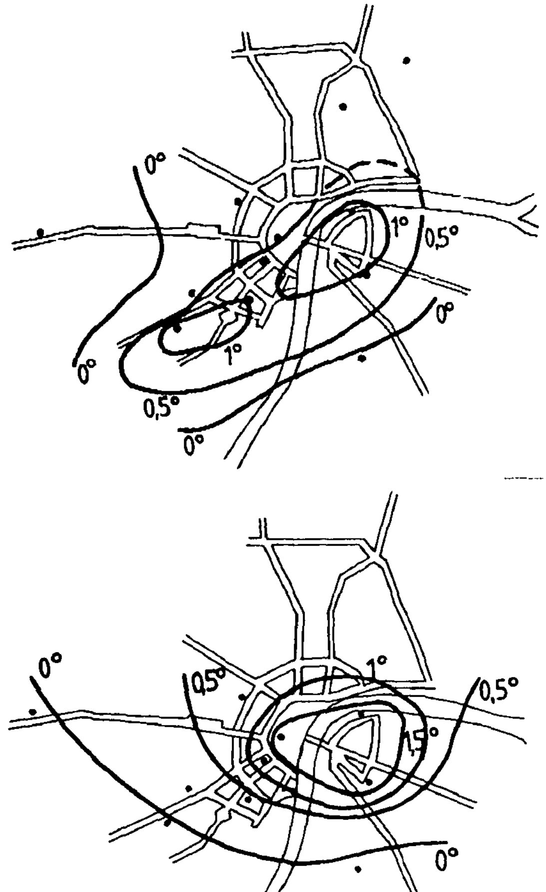

Fig. 3 Isotherms of mean minimum temperature differences in winter (Januar, Februar and December, 1978) and in summer (June-August, 1978) (after *Vámos*, 1978)

expressed itself more strongly in summer, the isolines became denser towards the centre. In winter the isolines showed smaller differences (*Fig. 3*).

Next year a paper used longer data series of the station network than the previous one (*Károssy and Gyarmati*, 1980). The minimum and maximum temperature values of the cloudless and calm days between 1977 and 1979 were examined. There were 123 days in this period which were all connected with anticyclonic weather types. The authors grouped the temperature values by seasons and drew isolines of urban-rural differences. The patterns were better defined in winter in both cases. At that time the minimum differences exceeded 3°C and the maximum ones exceeded 2° C in the town centre (*Fig. 4*).

The next thesis (*Gyarmati*, 1981) partly contained the results of the previous paper and partly deducted further establishments from the data series of the station network (1979-1980). The examination of minimum and maximum temperature differences of days with advection grouped by seasons exhibited that the mean differences are smaller than 1°C every season. Thus the ventilation of the town in the days with advection was unambiguous. The relative humidity values observed at 13h at the rural and three urban stations showed that the mean urban values were higher than the rural ones in each season, with the exception of Station 3 which is located in the town centre.

Pelle (1983) discussed the establishments of *Károssy and Gyarmati* after a short overview of the urban climate of Szeged. Then the author examined the influence of a strong

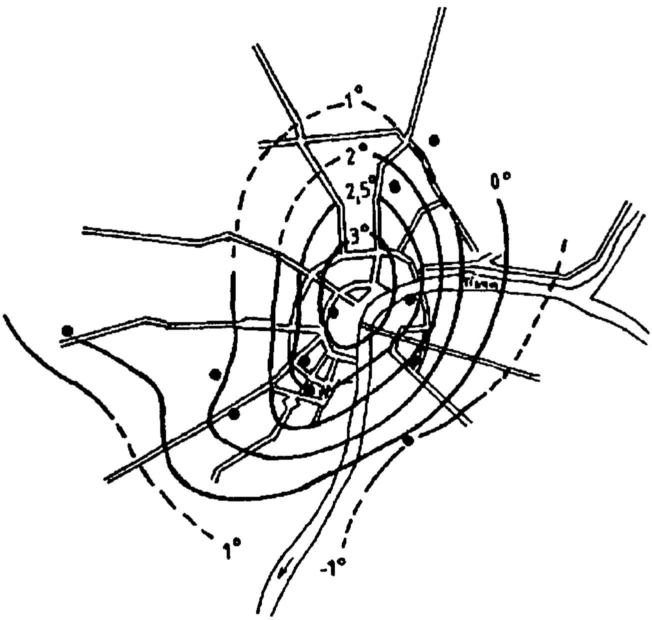

Fig. 4 Isotherms of daily mean minimum temperature difference in winter (after *Károssy and Gyarmati*, 1980)

cold front of 19 February, 1978 on the urban-rural difference of minimum temperature in the next 3 days. The isolines of the differences were drawn for each day (*Fig. 5*). On the 19th February the differences were normal, on the 20th it increased (in the centre the excess was 8.3°C!), then they gradually decreased on the 21st and 22nd. That is the town took over the energy from its surroundings with delay, which was advantageous from human bioclimatological aspect. So it can be stated that highly remarkable temperature differences can develop in certain macrosynoptical types between the town and its surroundings.

Another paper at that time (*Zsiga*, 1983) determined the built-up types in the town (*Fig. 6*). The area of big town type is the largest among the cities in the south-eastern part of the Great Hungarian Plain. It can be divided into parts: shopping, administrative, university and residential districts. It is difficult to separate the area of big and small town types because there are a lot of multi-storey houses in the latter area. This type also occupies a large territory. The surface of concrete housing estate type is similar to the previous one. Its location is not near but a long way from the town centre, it is in the former half-agricultural belt. The suburb type has the largest area. Its parts can be distinguished as a part of inside and as a part of outside the town circle dam. The author found good relationship between the built-up types and the distribution of differences of winter minimum and maximum temperatures (*Fig. 6*).

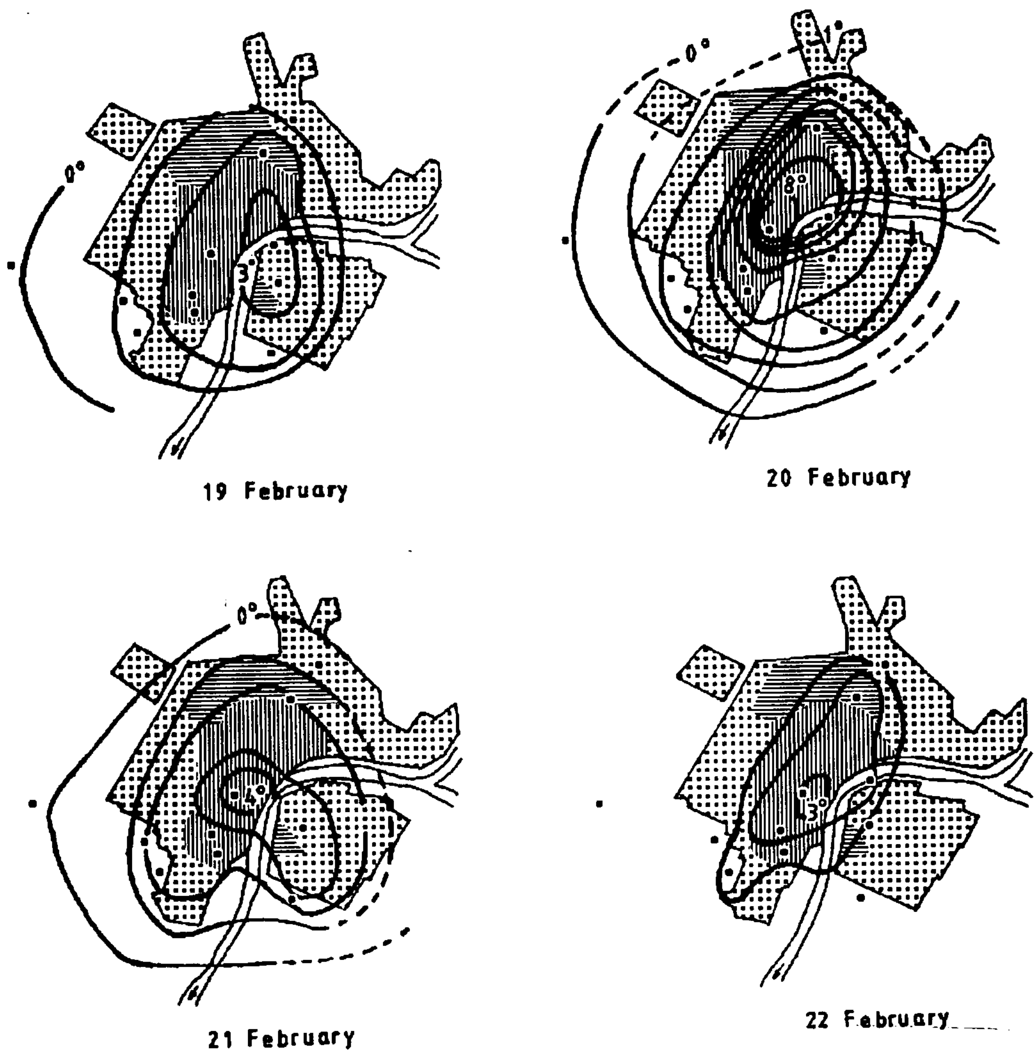

Fig. 5 Isotherms of daily minimum temperature difference in the days after a cold front 19-22 February, 1978) (after *Pelle*, 1983)

His paper five years later (*Zsiga*, 1988) dealt with the modifiying effect of the town on the wind-directions. The frequencies of wind-directions measured on the top of the University

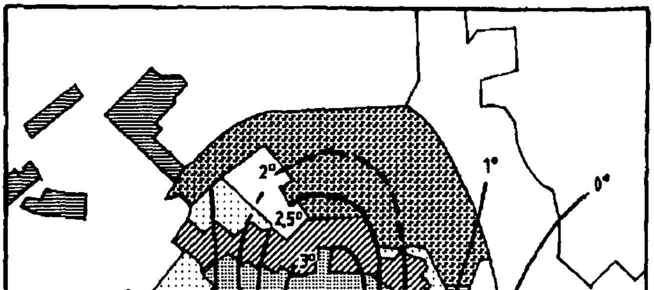

Fig. 6 The isotherms of daily mean minimum temperature difference in winter and morphological map of Szeged: 1 - big town type, 2 - concrete housing estate type, 3 - small town type, 4 - suburb type, 5 - village type (after *Zsiga*, 1983)

Building between 1931 and 1940 represented the urban conditions, while the frequencies measured at the airfield between 1971-1980 represented the rural conditions. The mean monthly, seasonal and yearly data showed that the wind-directions of north-west and south-east prevailed in the centre while northerly and southerly ones prevailed in the surroundings. That is the prevailing wind-directions in the town formed as a function of built-up conditions.

By the early years of the 1980s an enormous quantity of climatological data of the urban station network was accumulated. Only a small part of this data set was elaborated till the early years of the 1990s thus, it was necessary to make further analyses with more aspects. The work continued in 1992 with the investigation of the temperature means of days without advection between 1978 and 1980 (*Unger*, 1992a). 278 such days were found and the spatial distribution of the seasonal mean differences showed that the town centre was warmer than the rural areas from 1.5°C to 2°C every season, in autumn the difference even exceeded 2.5°C (*Fig. 7*).

That year *Unger* (1992b) examined the relationship between the urban morphological types and the urban heat excess from 1978 to 1980. The monthly mean temperature differences of 6 stations (1, 2, 3, 4, 5 and 6) representing different built-up areas (*Fig. 2*) reflected built-up

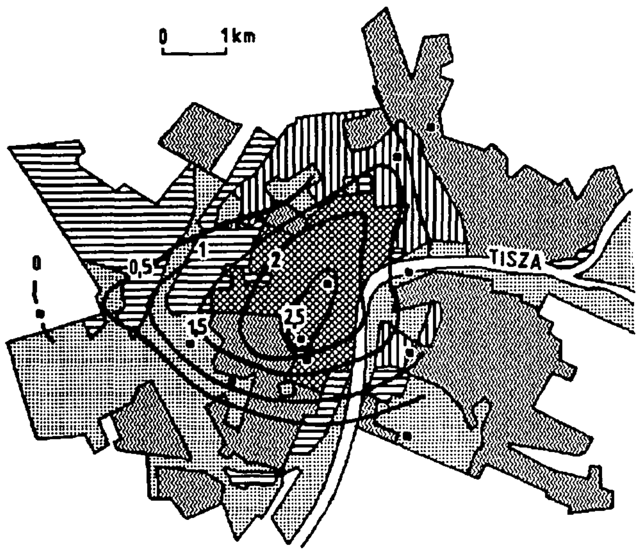

Fig. 7 Spatial distribution of the mean daily temperature difference in autumn (1978-80)

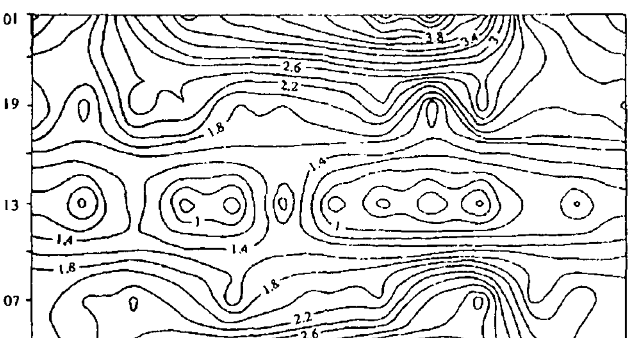

Fig. 8 Isopleths of the temperature excess of Station 2 (1978-80)

densities. Values differed by months and by observation times. The temperature increasing effect of the town was the most obvious in the town centre (Station 2). The largest difference was manifested at 1h in early autumn (*Fig. 8*). The ranking of built-up types as a funcion of decreasing heat excess were as follows: Station 3 (housing estate with tall concrete buildings), Station 4 (loosely built inner area), Station 5 (area between housing estate with tall concrete buildings and outskirts), and finally, Station 6 (outskirts).

A paper one year later (*Unger,* 1993) investigated the urban influence on vapour pressure. The daily and annual variation of urban-rural differences were exhibited using the vapour pressure values of urban (2) and rural (1) stations, which were observed four times a day between 1978 and 1980. The town was more humid than its surroundings during the whole year (*Fig. 9*). This urban humidity excess was explained by the different energy-balances, the different evaporative surfaces available and the influence of the urban traffic. Close relationships existed between the humidity difference and partly the nocturnal heat island intensity, partly the aridity index, partly the water temperature of the River Tisza.

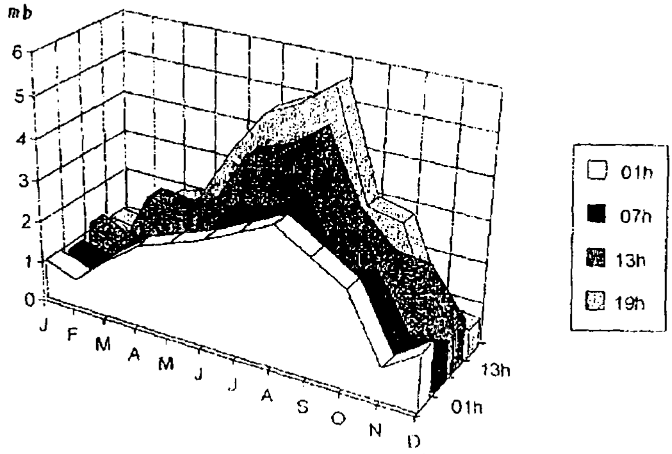

Fig. 9 The annual variation of water pressure excess at different observation times (1978-1980)

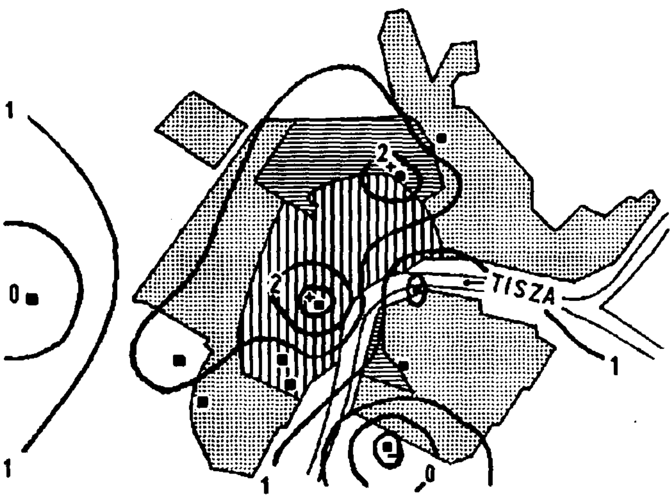

Fig. 10 Spatial structure of the urban heat island in September (1978-1980) (°C)

Unger and Csáki (1994) described the urban effect of Szeged on daily minimum temperature values in 1980. The characteristics of the heat island were examined by revealing relationships between the heat island intensity (temperature difference between rural and town centre sites) and cloudiness, wind speed at 01h and weather types. For strong development of heat island the anticyclonic weather types, little or no cloud and less than 2 m/s wind speed were favourable. The monthly mean urban-rural differences of minimum temperatures at the stations of the network between 1978 and 1980 clearly showed that the temperature excess increased towards the centre with a secondary warm pocket in the housing estate with tall concrete buildings, and was greatest in August, in September (see *Fig. 10*) and October.

The next paper (*Unger and Ondok*, 1995) examined the influence of different built-up areas on the spatial distribution of the number of summer, winter and frost days, as well as of the dates of the last and first frost and the length of the frost-free

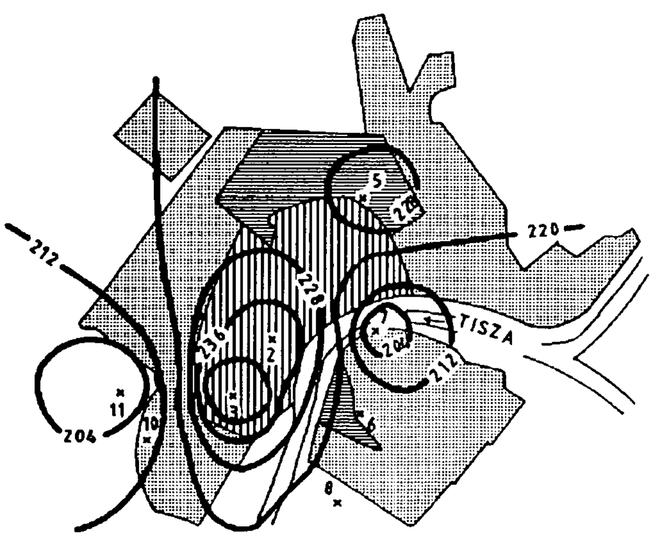

Fig. 11 Spatial distribution of the number of summer days (1978-1980)

period. The investigation was based on the data series of the urban station network during a three-year period mentioned above. The distribution patterns largely depended on the density and the building materials of the built-up areas, and the influence of large water bodies were rather significant because they tempered the extremes (*Fig. 11*).

Unger (1995a) analysed the influence of the medium-sized town on the bioclimatic comfort of individuals which is mainly determined by air temperature and humidity values. With the help of a suitable measure, the

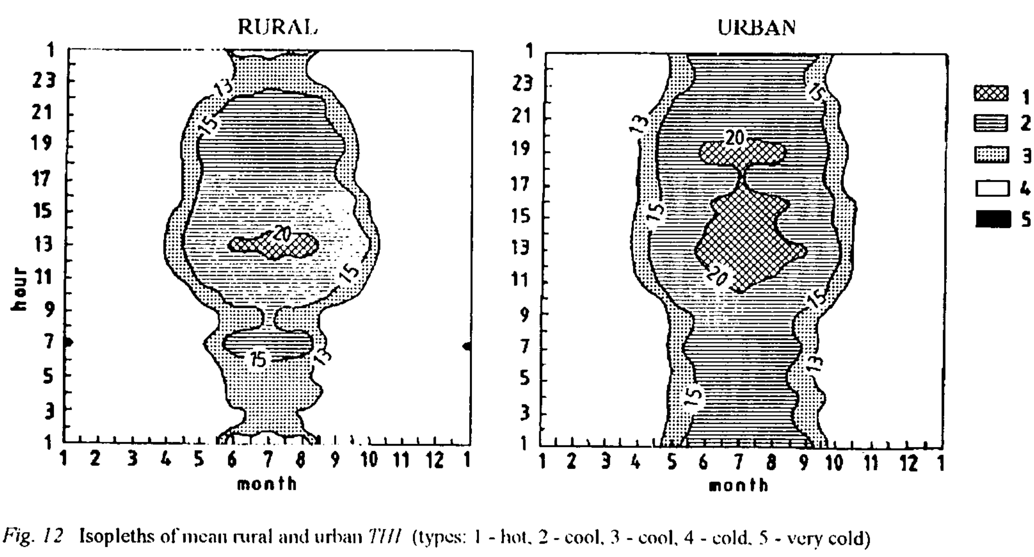

Fig. 12 Isopleths of mean rural and urban *THI* (types: 1 - hot, 2 - cool, 3 - cool, 4 - cold, 5 - very cold)

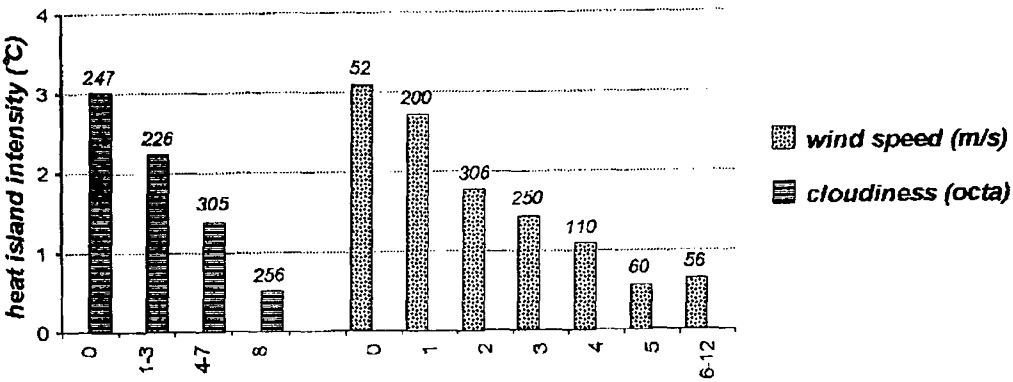

Fig. 13 Average heat island intensity as a function of cloud amount and of wind speed and the numbers of the days by categories (italics numbers) (1978-1980)

thermohygrometric index of Thom (*THI*) and its class types, the author demonstrated the differences of the annual and diurnal variation of human bioclimatic characteristics of the urban and rural environments (*Fig. 12*). The main features of the differences were as follows: considering a whole year as 100 %, in the urban and rural areas 6 and 1 % of the time were in the 'hot' *THI* type, 30 and 20 % were in the (most important) 'comfortable' type, 10 and 12 % were in the 'cool' type while 54 and 66 % were in the 'cold' type, respectively. Consequently, the town modified the main climatological elements inside the general climate of its region so that staying in the city was comfortable for longer than at rural places.

So far the last paper (*Unger*, 1995b) dealt with the effect of the town on minimum temperatures between 1978 and 1980. The characteristics of the urban heat island effect were examined by revealing of the relationships between heat island intensity and macrosynoptical types, cloudiness, wind speed as well as the combination of cloud amount and wind speed. As the results showed anticyclonic weather situations, little or no cloud coverage, and calm or slight wind were favourable for a strong development of the heat island effect (*Fig. 13*). In the case of extreme heat islands the domination of anticyclonic weather types was almost absolute.

This is the state of urban climate research in Szeged in January 1996. Work on further important aspects will be continued, partly in the direction of carrying out several new observations.

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