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SOME FEATURES OF URBAN INFLUENCE ON TEMPERATURE EXTREMITIES

by

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A város hatása a hőmérsékleti szélsőségekre

A dolgozat a különböző beépítettségű területek hatását elemzi a nyári, téli és fagyos napok számának területi eloszlására, valamint az első és utolsó fagyos nap bekövetkezésének dátumára és a fagymentes időszak hosszára. A vizsgálat a Szegeden működött városi állomáshálózat adatsorain alapul. Az eredmények szerint a területi eloszlások nagymértékben függenek a beépített területek sűrűségétől és építési anyagaitól, továbbá a nagyobb vízfelületek hatása is meglehetősen jelentős.

This paper examines the influence of different built-up areas on the spatial distribution of numbers of summer, winter and frost days, as well as of dates of the last and first frost days and the lengths of the frost-free period. The investigation is based on the data series of an urban station network set up in Szeged, Hungary. The results revealed that the distribution patterns largely depend on the density and the building materials of the built-up areas, furthermore that the influence of large water bodies is rather significant.

Key-words: Urban station network, temperature extremities, spatial distribution, Szeged, Hungary

INTRODUCTION

The investigation of effects modifying climate in human settlements is a very important topic of climatology. During the recent decades the urban areas and the ratio of urban population have grown continuously so the analysis of the modifying effects and their physical explanation are required. There have been several papers, some valuable overviews and books about the results (e.g. *Probáld*, 1974; *Oke*, 1974, 1979; *Landsberg*, 1981) and there are a lot of ways of examination procedures. One way, for example, is the investigation of the date of the last frost day in different parts of the city (*Woollum*, 1964) or of the frequency of days which are interesting in some kind of meteorological aspect. This paper aims to reveal the areal distribution of such climatological indicators.

STUDY AREA AND URBAN STATION NETWORK

Szeged is situated in the south-east of Hungary at 79 m above sea level (46°15'N, 20°09'E). The town and its surroundings are free from orographical effects (altitude differences inside the town are only a few metres) and it is a long way from large water bodies except the River Tisza intersecting the town (*Fig. 1*). So its geographical situation is favourable to have relatively undisturbed urban climate. Szeged had 175 000 inhabitants in the investigated years (1978–1980) and its built-up area was approximately 46 km^2. The study area has continental climate with a long warm season by Trewartha's classification (*Péczely*, 1979). 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).

In 1977 a network was established in the town where meteorological observations had been taken between July 1977 and May 1981. 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. 1*).

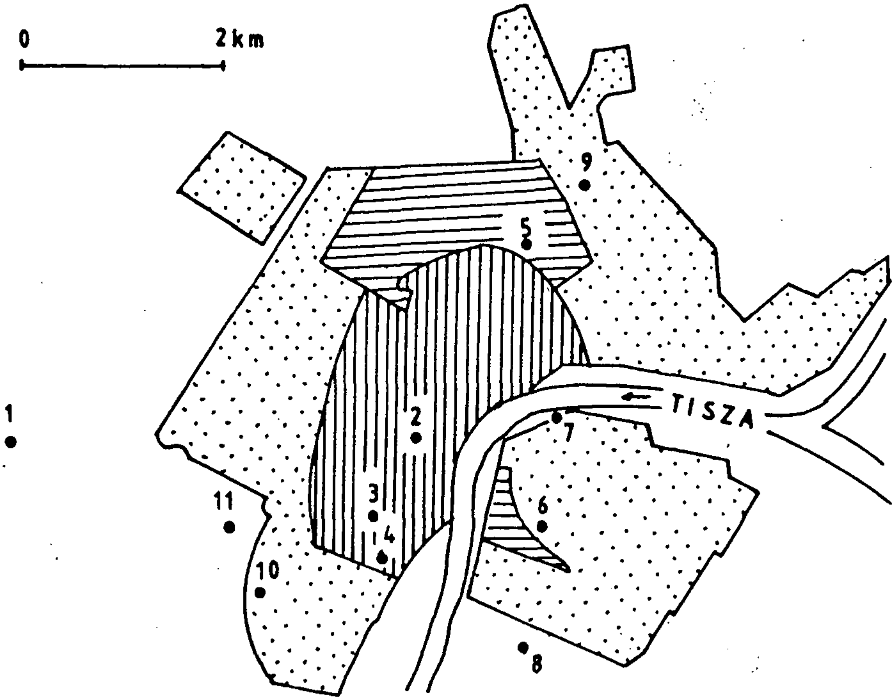

Fig. 1 The urban climatological station network and the main types of built-up areas in Szeged

- Downtown (2–4 storey old buildings)
- Housing estates with pre-fabricated concrete slabs (5–10 storey buildings)
- Suburbs (detached houses with gardens)

The 11 different observation sites and their features are as follows:
– The station, which is free from urban climate modifying 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.

- Station 2 was located in the town centre in a paved square bounded by multi-storey buildings.
- Station 3 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 4 was between the town centre and the suburb with detached houses and gardens.
- Station 5 was set up at a new housing estate with 5–10 storey buildings built from pre-fabricated concrete slabs.
- Station 6 was located at the grovy garden of the Children's Hospital bounded by busy streets.
- Station 7 on the river bank represented the modification effects of Tisza.
- Station 8 was set up at the southern edge of the town in the University Botanical Garden.
- Station 9 was at the suburb to the north-east of the town centre.
- Station 10 was at the suburb to the south-west of the town centre.
- Station 11 was situated in a site with small lakes and natural vegetation.

PROCEDURES AND DATA SELECTION

The results of some earlier investigations using daily and monthly temperature means verify the existence of the urban heat island in Szeged (e.g. *Károssy and Gyarmati*, 1980; *Unger*, 1992a, 1992b; *Unger and Csáki*, 1994). The aim of this study is to investigate the influence of different built-up areas on temperature using extreme days. The meteorologically extreme days are created with the help of daily minimum and maximum temperatures.

The extreme days and their criteria are as follows:

summer day – daily maximum temperature > 25 °C,
winter day – daily maximum temperature < 0 °C,
frost day – daily minimum temperature < 0 °C.

Data are avaliable for three entire years, from 1978 to 1980. It means 1096 days altogether for each station. *Table 1* shows the absolute numbers of the different extreme days experienced at each stations in this period.

For further examination the average date of the last and the first frost and the average length of the period without frost were determined for each stations and as a consequence for the different parts of the town (*Table 2*).

In *Table 1* the counted values of Station 4 and 9 are missing since big gaps were found in data series. The absence of data also caused a further lack (Station 3) among the stations in *Table 2*. So the data series which can be used for a fair examination are the ones of the remaining stations.

Table 1

The absolute numbers of the extreme days by stations over a 3-year period (1978–1980)

Station	Summer day	Winter day	Frost day
1.	208	63	265
2.	243	37	222
3.	258	–	–
5.	231	61	187
6.	216	48	251
7.	184	54	184
8.	214	62	290
10.	211	68	237
11.	198	61	193

Table 2

The average dates of the latest and the first frost and the average lengths of the frost-free period by stations (1978 - 1980)

Station	Last frost	First frost	Length of the frost-free period in a year (day)
1.	24 April	26 October	185
2.	21 March	28 October	221
5.	21 March	31 October	224
6.	5 April	28 October	206
7.	21 March	28 October	221
8.	23 April	19 October	179
10.	6 April	26 October	205
11.	5 April	26 October	204

In order to exhibit the areal distribution of the different parameters in the town isolines can be drawn using the values of *Table 1* and *2*. In the next part of the paper the different areal features of these parameters and their behaviours will be analysed and explanation is going to be made.

We must add, however, that the threshold values of the extreme days are a bit arbitraries. For example an area within the town with maximum temperature −1 °C and an another one with −10 °C on the same day have also winter days, but as we can imagine they mean rather different situations from human bioclimatological aspects (clothing, demand of fuel consumption, etc.). But the simplicity of this method to approach the question of urban climate modifying effects supports this way of the examination as one of the possible ways which can show these effects expressively.

RESULTS AND DISCUSSION

In the case of summer days the spatial distribution shows the highest numbers (above 240 days) at Station 2 and 3 (*Fig. 2*). This was expected because they are situated in the town centre where the effect of increasing temperature is the strongest. At the warmest site of the town the annual average number of days, when the temperature exceeds 25 °C is 86, this means almost 3 months. The housing estate called „Tarján" (Station 5) appears as the second warmest area of the town. This area is a housing estate with 5–10 storey buildings, which were built from concrete slabs and its bulding-density is relatively high.

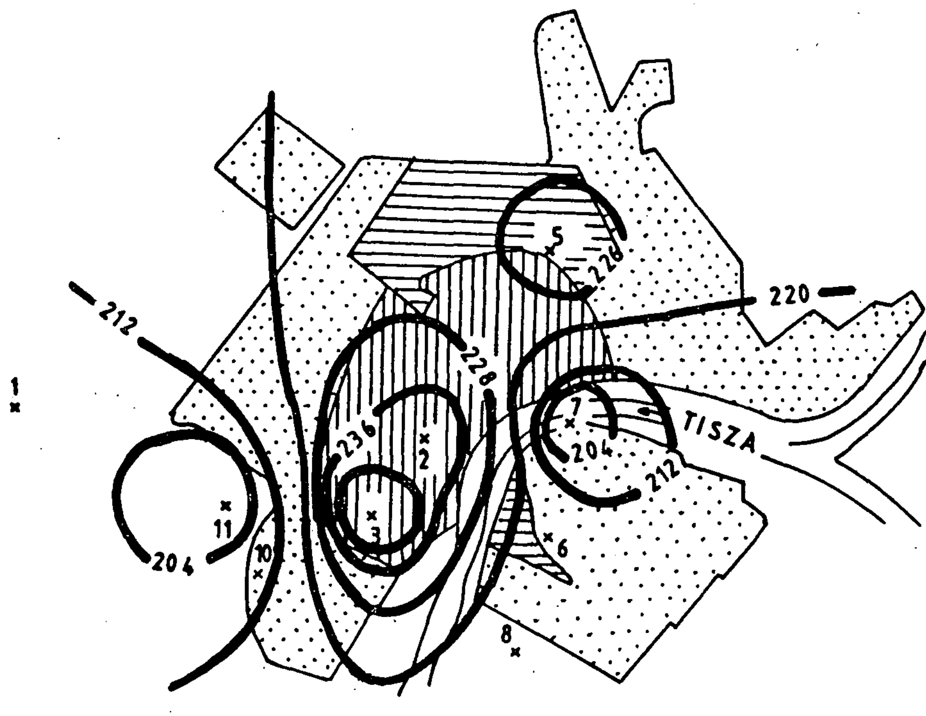

Fig. 2 Spatial distribution of the absolute number of summer days over a 3-year period (1978–1980)

The isoline of 220 separates the warm and the cool parts of the town. The cooler parts consist of the suburbs with detached houses and gardens as well as the open spaces, for instance areas around Station 1, 8 and 11. There are two places where the number of summer days is under 200 (Station 7 and 11). The large mass of water moderates the temperature extremities, thus in summer it decreases the temperature. Both observation sites were set up near water bodies, viz. near the River Tisza and near small lakes and the numbers are only 184 and 198 respectively. In the former case the mass of water is larger and it streams so the moderate effect of the river is stronger than the one of shallow lakes. At the coolest site of the town the annual average number of summer days is only 61, this means 2 months, thus in the town centre the period of summer days lasts almost 1 month longer than at the river bank (it is important to mention that the periods are not necessarily continuous).

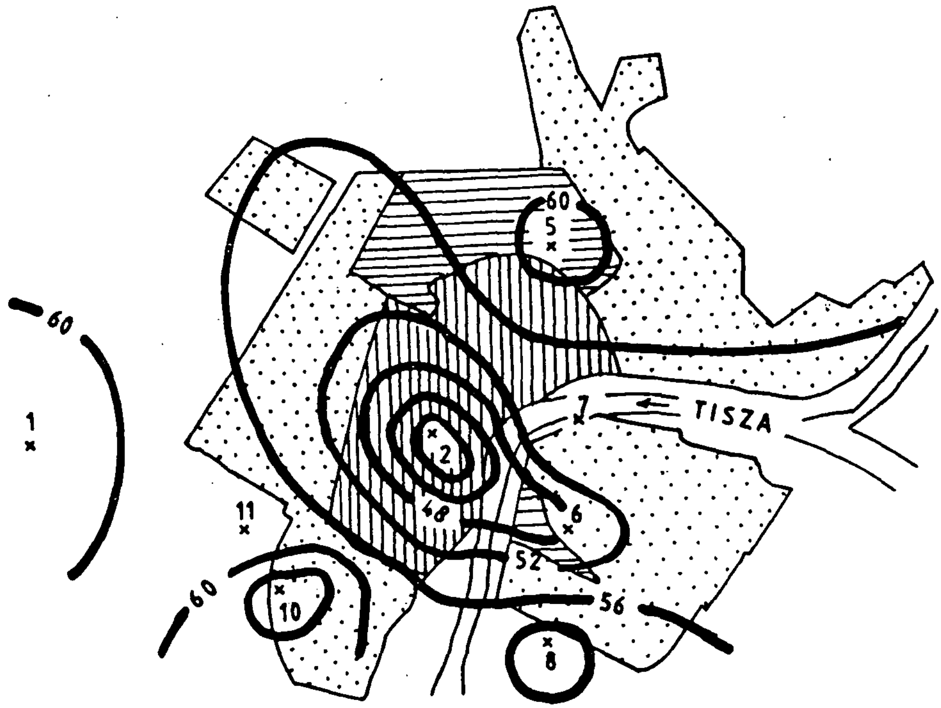

Fig. 3 Spatial distribution of the absolute number of winter days over a 3-year period (1978–1980)

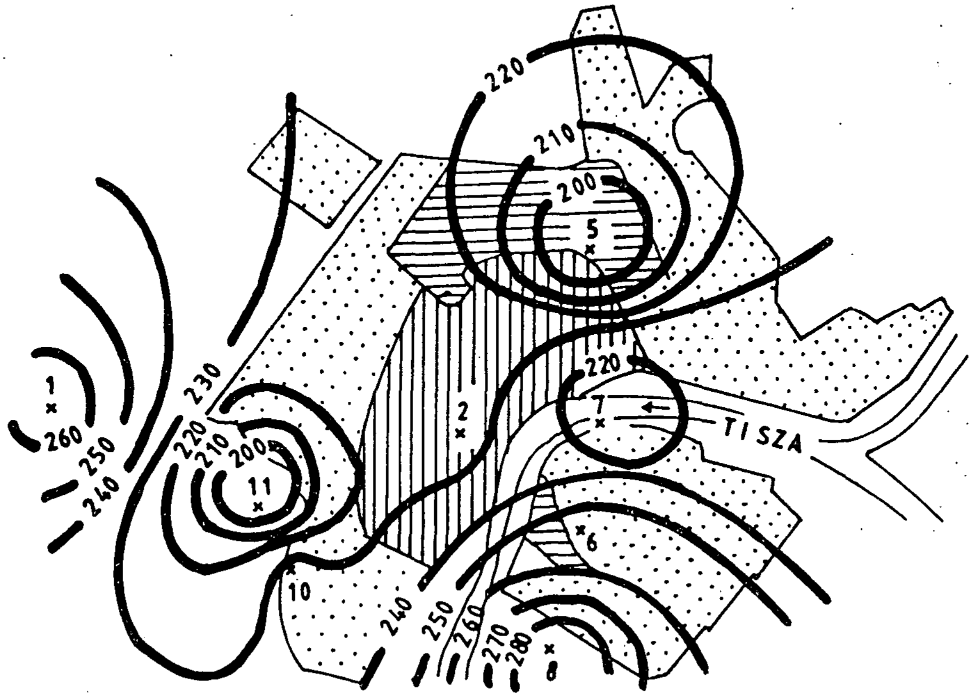

Fig. 4 Spatial distribution of the absolute number of frost days over a 3-year period (1978–1980)

In the case of winter days the isoline of 56 can be emphasized as a border between the cold and the less cold parts of the town (*Fig. 3*). The less cold areas are around Station 2 in the town centre. At this site there are only 37 days (or 12 on annual average) when the temperature does not exceed 0 °C.

The isolines are not concentric around the centre but stretch along the river and towards the housing estate with concrete slabs called „Odessa" which is located at the opposite bank. The large mass of water and concrete building materials moderate the temperature extremities, thus in winter they increase the temperature. It is interesting to observe that the area of „Tarján" housing estate (Station 5) which has the same thermal behaviour as the centre in summer, in winter it is similar to the suburbs and open spaces. The explanation requires further investigations.

Cold areas appear around Station 1, 8 and 10, at the edges of the town, where there are mainly vegetated open spaces. The last observation site has the most winter days, this means 23 days on annual average. So there are half as many winter days in the centre as in the suburbs because of the temperature increasing effect of the town.

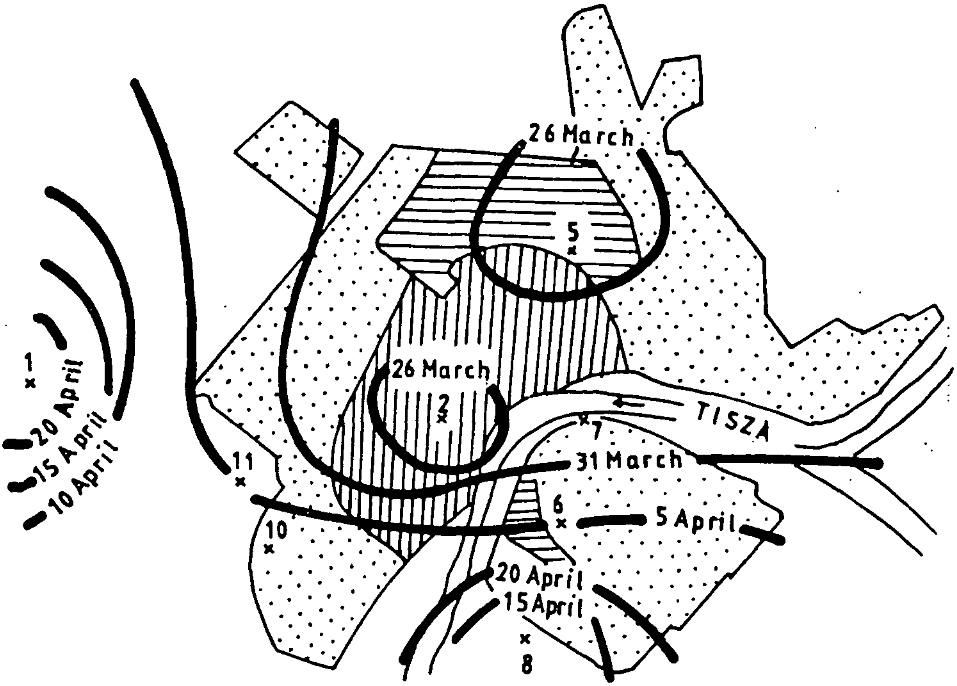

Fig. 5 Spatial distribution of the average date of the last frost (1978 – 1980)

This almost 2 week difference is very significant from the aspects of human bioclimate and of heating demand.

As regards the areal distribution of frost days over the three year period, its behaviour is regulated in the same way as mentioned above in the former two cases (*Fig. 4*). The warm areas are near large water bodies (Station 7 and 11), in the „Tarján" housing estate (Station 5) and in the town centre (Station 2). The cold areas are at the edges of the town in a vegetated area and in an open space (Station 8 and 1). The difference between the coldest and warmest areas is 106 days, which means more than one month on annual average (35 days).

The spatial distribution of the average date of the last frost (*Fig. 5*) reveals that it occurs in the city core, in the housing estate and at the river bank the earliest (21 March). Towards the suburbs this time appears later and later. The Botanical Garden (Station 8) and the rural station have the latest times, namely 23 and 24 April. This is more than one month time difference and the features of the areal distribution of the time may provide a very important piece of information for the keeping of urban parks, tree lines and small gardens.

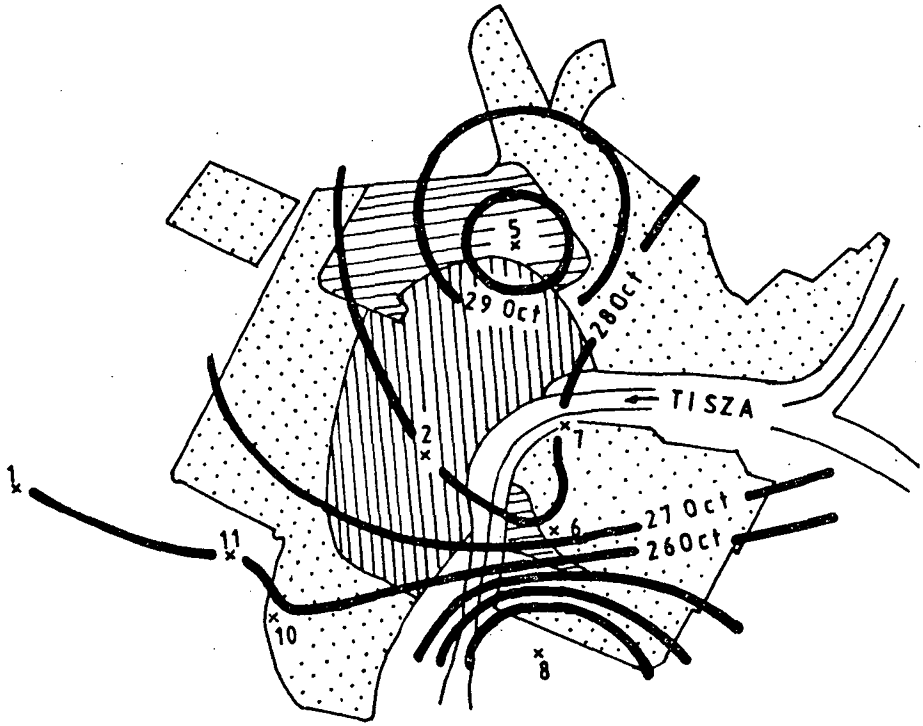

Fig. 6 Spatial distribution of the average date of the first frost (1978–1980)

In the case of the first frost the areal differences are smaller than at the last frost (*Fig. 6*). The first frost sets in 19 October in the southern suburbs (Station 8). Towards the centre and the housing estate in the north the first frost appears later and at around the Station 5 sets in 31 October. The difference is less than two weeks (12 days). It means that the thermal delaying effect of the town in autumn is less stronger than in spring.

The period between the last and the first frost is the frost-free period which has a great influence on the vegetation growth and the demand of fuel consumption (*Fig. 7*). Because this period depends on the dates of the last and the first frost, as we can expect, the length of the period is the longest in the inner part of the town (over 210 days) and the shortest at the southern and western outskirts (under 190 days). The warmest area (around Station 5) has a frost-free period of 224 days in a year (about 7.5 months) while the coldest area (around Station 8) has a period of 179 days (about 6 months). Thus the difference is rather significant, it is 1.5 months.

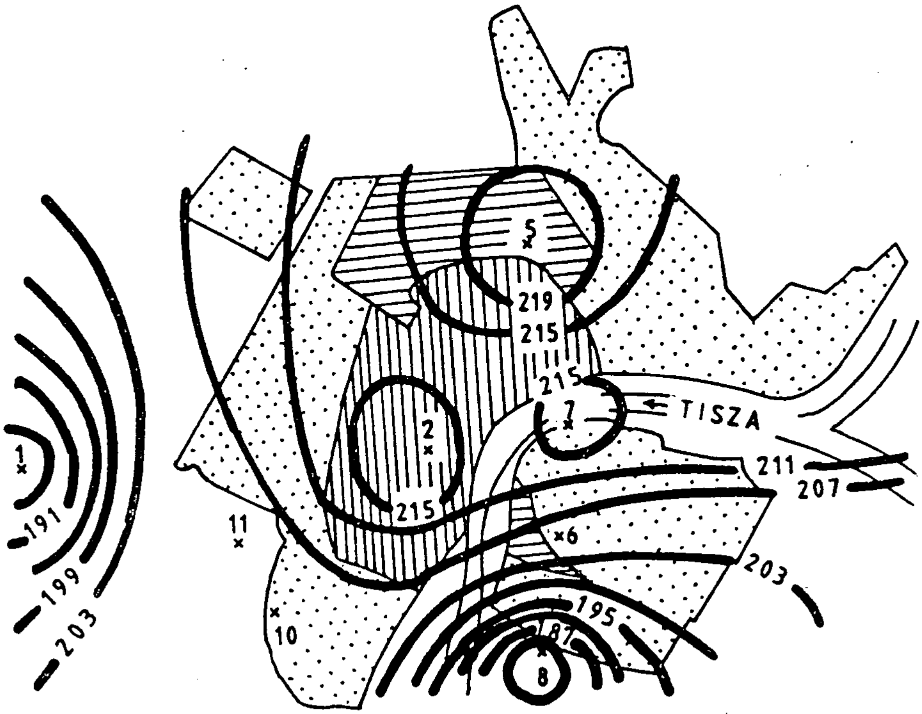

Fig. 7 Spatial distribution of the average length of the frost-free period (1978 – 1980)

CONCLUSIONS

The first part of the investigation revealed the spatial distributions of extreme days. The city core and the „Tarján" housing estate have the most summer days, the city core has the less winter days and the „Tarján" housing estate and the city core have the less frost days.

The above statements derive from the facts that these areas have large impermeable and small vegetated surfaces, the drainage system conducts the most part of the precipitation and their building materials have different physical properties from the elements of the natural surface, as well as the artificial heat release originated from industrial, traffic and household sources can be very significant. The urban morphological srtucture with streets, squares, tall and low buildings is also very different from the natural one, which also alters the energy balance. As the figures show already in a medium sized town like Szeged these alterations result in a rather noticeable heat exceed which is reflected in the frequency of the extreme days.

The modifying effect of large water bodies, mainly of the river, appears clearly. The large heat capacity of the water moderates the warm in summer and the cold in winter, thus near the river the frequencies of summer and frost days are the lowest, the frequency of winter days is rather low.

In aspect of human bioclimate the high number of summer days in the town centre is a bit disadvantageous because of its large heat stress effect. On the other hand the decreasing number of winter and frost days towards the centre from the suburbs is advantageous because of its decreasing cold stress effect.

In the next part the investigation revealed the spatial distribution of the dates of last and first frost days, as well as of the length of frost-free period. The areas where the last frost day occurs early and the first frost day late, viz. the frost-free period is rather long, are the same ones which are warm according to the results of the first part mentioned above.

The use of the maps with isolines can be a useful mean for keeping of urban parks, tree lines, other green areas and small gardens, as well as for the assessment of heating demand of buildings.

To sum it up, the temperature increasing effect of the town from the outskirts towards the centre is revealed by the study and it also verifies the existence of the heat island in Szeged.

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