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THE URBAN INFLUENCE ON THE DIURNAL AND ANNUAL PATTERNS OF ABSOLUTE HUMIDITY IN SZEGED, HUNGARY

by

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A város hatása az abszolút nedvesség napi és évi menetére Szegeden.
3 éven keresztül napi négyszeri vízgőznyomás mérések értékeinek felhasználásával vizsgáltuk a város és környéke közötti abszolút nedvesség-különbségek napi és éves járását Szegeden. A város egész évben nedvesebbnek bizonyult környezeténél. A nedvesség városi többlete a város és környéke eltérő energiamérlegével és a rendelkezésre álló nedvesség eltérő forrásaival magyarázható. Szoros kapcsolat létezik egyrészt a város és környéke abszolút nedvesség-különbsége, másrészt az éjszakai hősziget intenzitása, az ariditási index járása, valamint a Tisza vízhőmérsékletének járása között.

Measurements of vapour pressure taken four times daily over a 3-year period were used to investigate diurnal and annual patterns of urban-rural absolute humidity differences in Szeged. The city was found to be more humid than its surroundings during the whole year. Variation of urban humidity surplus can be explained by reference to urban and rural energy balances and sources of moisture. Good relationships exist between urban-rural absolute humidity differences and partly nocturnal heat island intensity, partly the variation of aridity index, partly the variation of the water temperature of the River Tisza.

INTRODUCTION

The urban area is an important place where atmosphere should be studied and understood in greater detail. This atmosphere is modifided by the artificial surface of the city, the anthropogenic heat emission and the air pollution in gaseous and aerosol phases. This process of urbanization has been investigated at an ever increasing rate throughout the world. Although in recent years the observational studies of various climatic elements are still of great importance, greater attention has been paid to investigation of the urban boundary and canopy layers.

The urban heat island is now well documented from many cities, but there are very few studies about the urban influence on atmospheric humidity.

Only a very small fraction of the water existing on the earth is in the air. However, humidity plays several important roles among the meteorological processes which are taking place within the atmosphere. It is an agent for transferring energy from one place to the other on the earth's surface and humidity, together with clouds, affects the transmission of radiation both to and from the surface. Humidity is also an important input for determining the state of human physiological comfort.

Very few studies have made effective comparison of urban-rural vapour pressure values. Efforts have concentrated on relative humidity characteristics. Relative humidity values may be useful in human comfort studies, but they are not of great value in climate process work, especially since they are highly controlled by temperature values. However, for certain purposes such as studies of radiative fluxes and of the role of water vapour in air pollutant reactions, absolute humidities and their differences are needed.

In this light, this paper concerns itself with the characteristics of some aspects of atmospheric vapour content in the city.

In Leicester (England) and in Chapel Hill (N.C., United States) surface traverse measurements have been made (*Chandler,* 1967; *Kopec,* 1973). The cities have been found to be moist at night and dry by day relative to the surroundings. In Edmonton (Canada) and in London (England) the urban absolute humidities were lower by day but higher at night than those in the country in the warm season. In winter the absolute humidity was higher in the city at all hours (*Hage,* 1975; *Lee,* 1991). In a tropical city, in Ibadan (Nigeria), the absolute humidity was higher in the city during the wet season and lower during the dry season (*Adebayo,* 1991).

THE INVESTIGATED AREA, DATA AND METHODS

Szeged is situated in the south-east and flat (69 m above sea level) territory of Hungary, free from orographical effects. The number of inhabitants of the city was up to 175 000 in the investigated term, in 1978.

Most regions of Hungary are in climatic region *Cf* by Köppen (temperate warm climate with comparatively equal precipitation distribution) or in climatic region *D.1* by Trewartha (continental climate with a long warm season). A better climatic partitioning can be made by using the mean temperature of vegetation season (t_v) and the $H=E/LC$ aridity index (where E is the net radiation, L is the evaporation heat and C is the amount of precipitation). So Szeged is in the warm-dry climatic region which is characterized with $t_v > 17.5$ °C and $H > 1.15$ (*Péczely*, 1979).

In Szeged a 10-meteorological-station network was established where observations were taken between 1978 and 1980. With possibilities taken into consideration, the stations represented several types of built-up areas of the city *(Fig. 1.)*.

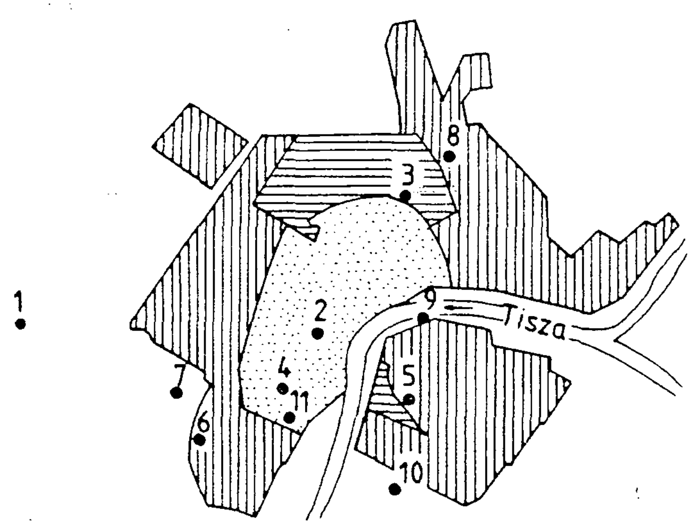

Fig. 1. The morphological types of Szeged and the urban meteorological station network (St.1 — Aerological Observatory, St.2 — Restaurant of Napsugár)

The present research used the data of two stations, Station 1 and 2, whose data were useful the investigation to urban influence on humadity differences. Station 1 and 2 represent the rural place and the inner city, respectively. Station 2 was set up at the city centre influenced freshly by climate modification effects of the town, at a paved square bounded by multi-storey buildings.

The vapour pressure measurements were taken four times a day (at 01, 07, 13 and 19 hours, Central European Time) from 1978 to 1980. Both stations had a thermometer shelter with an Assman-type psychrometer.

The monthly mean vapour pressure values were determined for both stations at different observation times and the differences of means were counted. On the basis of these differences the annual variation of the absolute humidity surplus can be drawn at the given observation times and their connection with the maximum urban heat island intensity (*Unger*, 1992), with the monthly values of the aridity index (*Dobosi*, 1973; *Péczely*, 1984) and with the monthly mean water temperature values of the river Tisza can be examined.

RESULTS AND CONCLUSIONS

Let's consider the monthly means of absolute humidity differences in the different times between Station 1 and 2 (**Table I**):

Table I

The monthly mean vapour pressure surplus of the town
(Station 2 — Station 1) (1978—1980)

(mb)	J	F	M	A	M	J	J	A	S	O	N	D
01h	1.0	0.7	1.4	2.0	2.3	2.6	3.0	3.4	2.9	2.4	0.8	1.4
07h	0.9	0.7	1.5	1.6	1.7	2.9	3.0	3.6	2.0	2.2	0.8	1.0
13h	1.2	0.8	2.3	2.2	2.5	3.9	4.2	4.8	3.1	2.3	2.2	1.1
19h	1.0	0.9	1.9	2.1	3.5	4.6	5.0	5.6	3.0	2.8	0.8	0.7

By means of these data, the diagram of the absolute humidity surplus can be drawn at all observation times *(Fig. 2.)*.

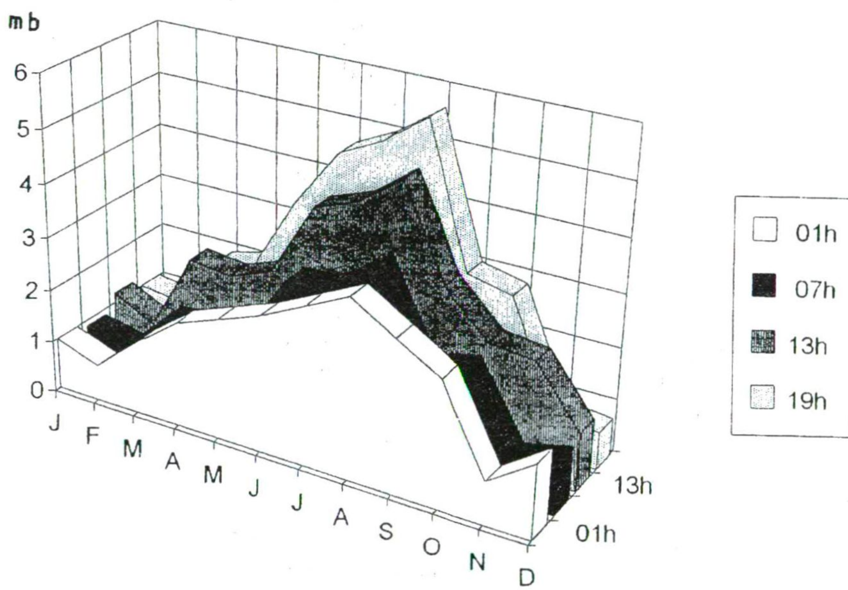

Fig. 2. The annual variation of absolute humidity surplus of the town (1978—1980)

The *Fig.* 2. shows clearly that the town has an absolute humidity surplus during the whole year and this surplus is increasing continuously from January-February to August and then it is decreasing till November-December at each observational time.

The maximum of August is increasing from 01 to 19 hours (from 3.4 to 5.6 mb). The minimum values are in February and December (0.7 and 0.8 mb). Thus the annual variation of urban absolute humidity surplus in Szeged is only partly similar to the results of the other cities mentioned above, so this phenomenon has to be explained. To this explaination further climatological values have to be taken into consideration.

Table II

The annual variation of the maximum heat island intensity (at 01), the water temperature of the river Tisza at Szeged (1978—1980), the aridity index, the monthly mean energy-balance, temperature and precipitation in Szeged (1900—1950)

	max T_{u-r} (°C)	*water* (°C)	*H*	E_s (MJm^{-2})	*T* (°C)	*P* (mm)
J	1.3	0.6	0.1	7.8	−1.2	32
F	1.6	1.8	0.2	14.0	0.6	34
M	2.9	5.1	0.9	88.1	6.3	38
A	3.5	10.4	1.5	178.1	11.4	49
M	3.6	15.2	1.8	278.6	16.8	61
J	3.7	21.4	1.9	322.9	20.0	68
J	4.0	20.9	2.3	292.8	22.3	51
A	4.5	22.1	2.0	242.3	21.4	48
S	4.8	18.4	1.2	142.9	17.5	47
O	3.8	13.8	0.5	68.7	11.9	52
N	1.9	7.0	−0.1	−11.3	5.9	52
D	1.6	3.1	−0.2	−16.8	1.4	41

By means of these data, diagrams can be drawn *(Fig. 3.)*.

The phenomenon mentioned above can be explained by comparison of *Fig.* 2. and *Fig. 3.*

The examination of annual variation of the aridity index in the Szeged region showed that the „humidity-hunger" of air is increasing till July continuously and it is also very great in August, since the precipitation is much less than the heat-energy being at the disposal of evaporation. This state is valid for Station 1 being free of urban influence which is far (5.0 km) from the evaporative surface of the River Tisza.

In the case of Station 2 the evaporative surface of the Tisza also gives the humidity (the distance between them is 0.6 km). The water of the river is the warmest and also the „humidity-hunger" of air is the greatest in summer months (June-August), so the water surface can give the most moisture to the air of its direct surroundings in this time. This time coincides with the maximum urban humidity surplus well.

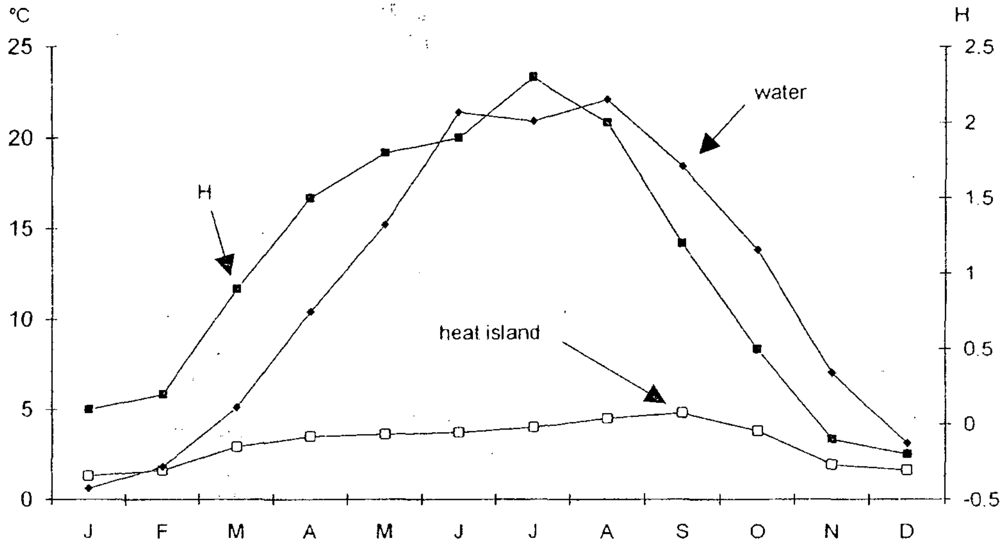

Fig. 3. The annual variation of the maximum heat island intensity, the water temperature of the river Tisza at Szeged (1978—1980) and the aridity index in Szeged (1900—1950)

Thus, the greater is the aridity index (it depends on the air temperature especially) and the higher is the water temperature of Tisza (with a bit of a lag because of the heat inertia) the greater is the urban-rural vapour pressure difference during the year.

The water vapour from traffic gas combustion also contributes to the existence of urban-rural humidity differences, because the urban station is situated on a very busy place of traffic. On the other hand the displacement of air is slow among the narrow streets of the inner city, so the vapour content of air is trapped there better than in the well aspirated surroundings.

At the end of summer the evapotranspiration of the rural natural surface is very weak because of the harvest and the almost complete desiccation of agricultural and natural vegetation. However in the city the parks and the gardens are irrigated mainly in the summer months. It guarantees the life of vegetation, so it gurantees the evapotranspiration. These facts also contribute to the summer maximum of urban-rural humidity difference.

In summary, this analyse study of 3 years of vapour pressure data from rural and urban climatological stations and other climatological data from Szeged area showed that the urban absolute humidity surplus with summer maximum can be explained by the climatological characteristics of the region of Szeged (aridity index), by the evaporative surfaces available (River Tisza, irrigated parks and gardens) and by the influence of the urban traffic.

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