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SOME BIOCLIMATIC INDICATORS OF KOLOZSVÁR (CLUJ-NAPOCA), ROMANIA

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Összefoglalás - Cikkünkben a Kolozsvár (Cluj-Napoca) hivatalos állomásáról és másik három jellemző pontjáról rendelkezésre álló egy évszázados, illetve rövidebb kolozsvári éghajlati adatsorokat felhasználva, különböző bioklimatikus mérőszámok - a pulmonáris, a termális komfort és a termohigrometrikus indexek - értékelésére vállalkozunk.

Summary - This paper investigates some bioclimatical indicators (pulmonary, thermal comfort and thermohygrometrical indices) given by a hundred-year and shorter climatological data series which are measured at the official station and another three characteristic parts of Kolozsvár (Cluj-Napoca).

Keywords: bioclimatical indicators, urban climate, spatial differences, annual and diurnal courses

INTRODUCTION

Our environment is a very dynamical system, its components are in close relation. These components can be classified in three groups as natural, social and artificial ones. The base is built up by the natural environment whereupon the other two components are lying. Considering this problem the urban climate is the most relevant example. The urban areas are characterized by a transformed climate, which is being formed under the influence of built-up territories, effect of specific upwarming and emission of pollutants.

The question is how this arificial modification of the natural environment influences the bioclimatological comfort sensation of human individuals. What are the advantageous and the disadvantageous effects of the modified climate on the population living in urban areas and how long do these effects take in the different parts of the built-up areas?

THE INVESTIGATED AREA AND DATA

Kolozsvár (Cluj-Napoca) is situated in the middle north-west part of Romania, in the valley of the Kis-Szamos River (Someşul Mic), between 300 and 700 m above the sea level (46°47'N, 23°35'E). From geographical point of view the city is situated at the junction of three topographically different areas: the mountains of Erdélyi-Szigethegység (Apuseni Mountains), the hillocks of Erdélyi-Mezőség (Câmpia Transilvaniei) and the hills of Szamos Plain (Podişul Someşan). The city's territory reaches 4068 ha and its population is 340000 in 1996. The surface of the city extends on three height levels, which are as follows:

- the tide land of Kis-Szamos River (Someşul Mic) and its affluent Nádas Rivulet,
- the neighbouring hills (Felek, Lomb and Hoja),
- the river terraces (*Fig. 1*).

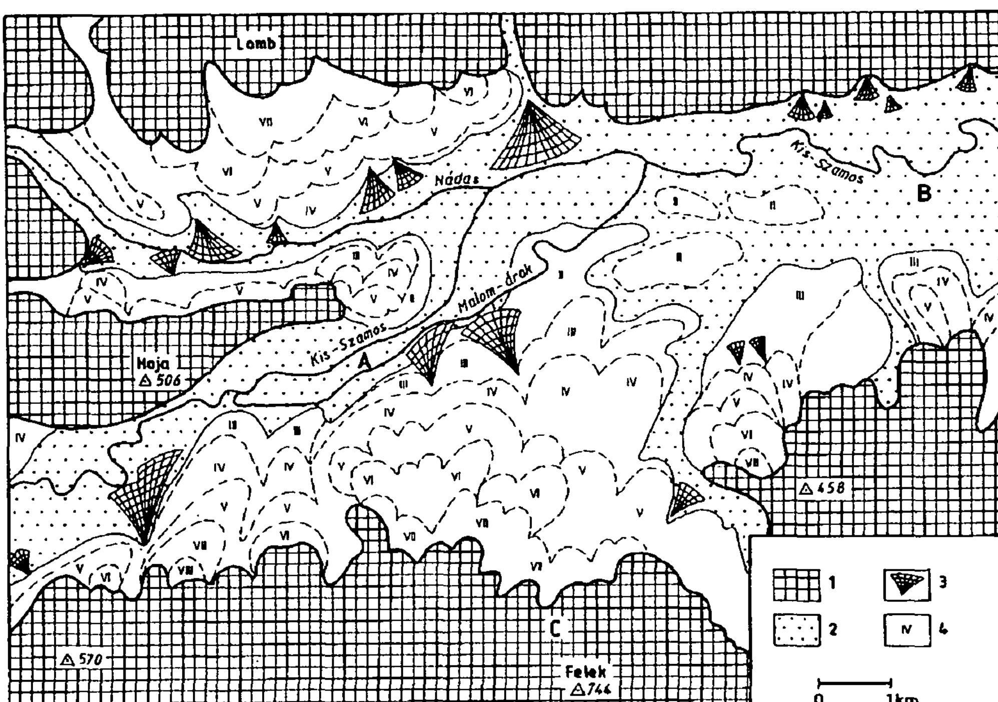

Fig. 1 Geomorphological map of Kolozsvár (Cluj-Napoca) and its surroundings: 1. hills, 2. tide land, 3. alluvial cones, 4. river terraces (I-VIII - number of terraces) as well as the meteorological station network: A. Centre, B. Airport, C. Felek Hill (*modified after Belozerov*, 1972)

The climatological parameters which determine the comfort sensation of the human body are temperature, humidity, air movement and radiation. In an investigated region the following measures could be accepted as simple bioclimatical indicators, for example:
- variations of average daily temperature,
- the numbers of summer, winter, heat days and the number of days with frost,
- the daily variation of relative humidity,
- the insolation.

However, the above enumerated indicators are not relevant enough, in the present study an attempt is made to analyse the joint effects of the climatological elements using complex bioclimatical indices like the pulmonary stress index, thermal comfort index and the thermohygrometrical index in the city centre and surroundings of Kolozsvár (Cluj-Napoca).

We are using averages of data series concerning the main climatological parameters being at disposal like vapour pressure, relative humidity and temperature. These parameters were measured at the official station of Kolozsvár (Kolozsvár Station), which changed its place during the time. Nowadays it has been on the Fellegvár (Cetăţuia) Hill near the city centre. Despite the moving of the observation site the series are homogeneous between 1880 and 1992. There is a gap between 1972 and 1982, thus the available data series are 102 years long. A part of our data was received from the microclimatological examinations made by *Belozerov* (1972) in the 1960's and 1970's. We have to emphasize that our results are preliminary ones because we did not take into consideration the urban development of the city during the last more than hundred years. This type of investigation will be the next aim of the following study.

Concerning the sites of the other three stations, which are lying in the represented areas of Kolozsvár as follows (*Fig. 1*):
- the first station (A) was placed on a square in the city centre, which is a very densely built-up area at 346 m a. s. l.;
- the second one (B) was situated 7 km to the east of the town centre at the airport at 334 m a. s. l.;
- the third station (C) was set up on the north part of Felek Hill, sheltered against the major air circulation, 7 km to the south from the centre at 702 m a. s. l. It is situated in an orchard area between the city and Felek village.

METHODS, RESULTS AND DISCUSSION

Among the important bioclimatical indicators there is the *pulmonary stress index*, which represents the real quantity of moisture getting in touch with the pulmonary mucous of the human body. Normal water vapour content of blood plasma is 31.3 hPa. In reality normal lung function produces evaporation to a vapour pressure of 19.7 to 23.8 hPa so that the true balance situation occurs at a vapour pressure of 7.5 to 11.6 hPa. For values above or below this it was deduced that the greater is the difference, the greater is the stress placed on the pulmonary interface. The pulmonary stress index values can be ranged in 7 class types between +2 (0 - 4 hPa) and -4 (26.6 - 31.2 hPa) (*Beçancenot*, 1974). The first value indicates the *dehydrating* state, the second one the *hydrating* state. The index gives the limit value for the normal function of the lung. Between the hydrating and dehydrating values, the *balanced* state (index 0) corresponds to the values of water vapour pressure from 7.5 hPa to 11.6 hPa. The value of 7.5 hPa represents the limit of tendency to dehydratation or blood condensation. Otherwise the value of 11.6 hPa represents the limit of tendency to hydratation or dilution of the plasma.

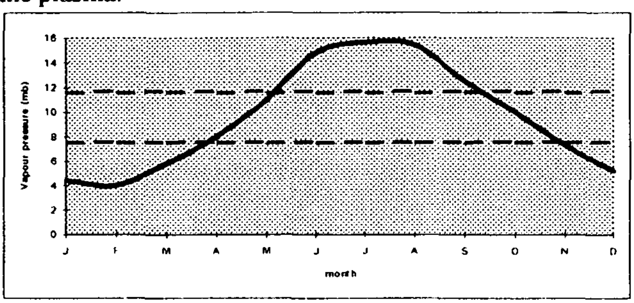

Fig. 2 The annual variation of the pulmonary stress index in Kolozsvár (Cluj-Napoca) (1880-1971) (dotted lines are the thresholds for normal function of lung)

Let us consider the monthly average index values of the Kolozsvár Station during the period 1880-1971 (*Fig. 2*). It can be given by computing the vapour pressure data at 1 o'clock AM and PM (*Besancenot*, 1974). The results show that the vapour pressure values are reduced in wintertime because dry masses of air occur in the investigated area at this time. Thus five months in winter half year are featured by *dehydrating* (+1) index values with a minimum of 4.0 hPa in January. Three months are *balanced* (April, May and October) and the rest of the year, the summer months belong to the *hydrating* (-1) stage with a maximum of 15.6 hPa in July. The monthly means increase steeply from the beginning of the year till July and then decrease till December. So only the three less extreme pulmonary stress index class type occur in this town (-1, 0 and +1). The annual average index is *balanced* with a value of 9.6 hPa.

The second complex bioclimatical indicator applied in this study is the so called *thermal comfort index*, which is based on an approach of the effective temperature according to the *Missenard* formula:

$$ET = t - 0.4(t - 10)\left(\frac{1 - f}{100}\right)$$

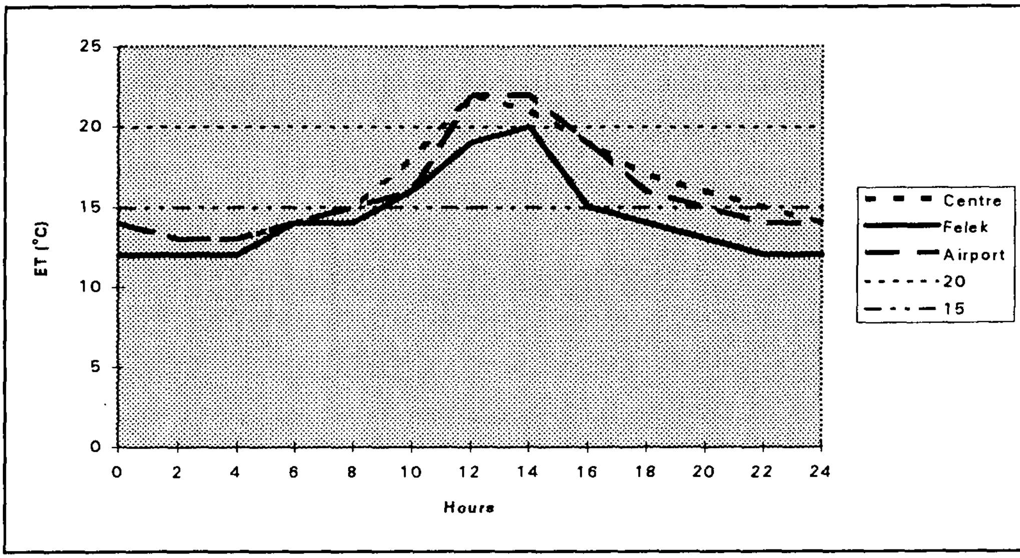

Fig. 3 Diurnal variation of thermal comfort index given by Missenard formula in the centre, at the airport and on the Felek Hill in Kolozsvár (Cluj-Napoca) (summer 1964) (the lines are the thresholds for the adequate thermal comfort)

This is a relation given by temperature in °C (t) and relative humidity in % (f), and *ET* represents the temperature effectively felt by the human body under different climatic conditions (*Missenard*, 1947). The adequate temperature for the human body varies between 15° and 20° *ET* for a sedentary standard man with light clothes. In this case the organism neither gains nor loses energy. If the temperature increases above the upper threshold or decreases under the lower one it would produce metabolic changes in order to maintain the body's internal temperature constant.

Substituting the two-hourly means of temperature and relative humidity and comparing the numbers of thermal comfort hours at the three stations in the summer months of 1964, we can find 12 hours at the centre, 8 hours on the Felek Hill and 10 hours at the airport which belong to the narrow interval of thermal comfort. The daily variation of this index is changing from one station to other (*Fig. 3*).

The average index values of the airport stations (B) in the representative months of the three warm seasons (April, July and October) in the periods 1964-1971 and 1983-1988 show that 6 thermal comfort hours can be found in the afternoon and 4 in the morning in the hottest month of the year, in July. Very pleasant afternoons can be exhibited in April with 6 comfort hours but this comfort period occurs four hours earlier than in July (*Fig. 4*). In

October there are only 4 hours which belong to the comfort type and they occur also in the afternoons. There are not comfortable hours mornings in the transition seasons.

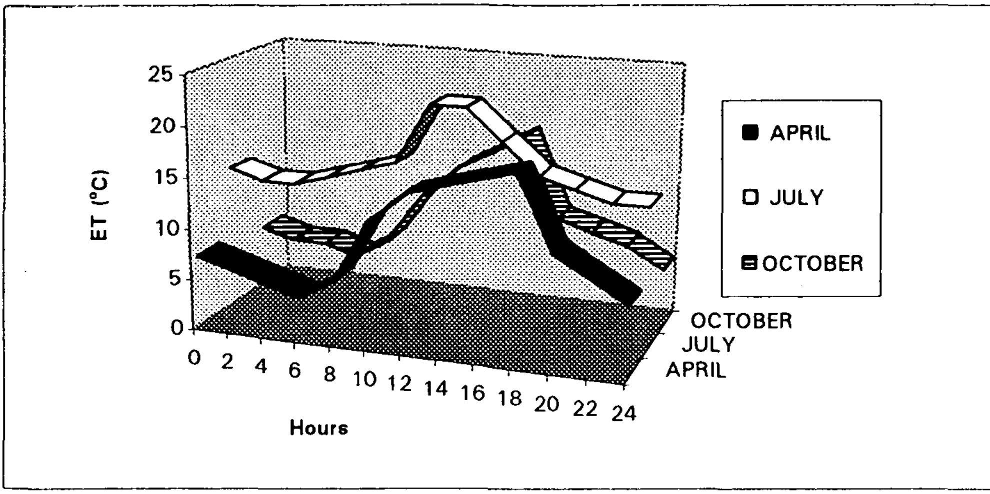

Fig. 4 Diurnal variation of the thermal comfort index in April, July and October at the airport station (B) in Kolozsvár (Cluj-Napoca) (1964-1971, 1983-1988)

Another bioclimatical indicator which was applied in our investigation, and also estimates the effective temperature is the *thermohygrometrical index*. It is writing according to the *Thom*'s empirical formula:

$$THI = t - (0.55 - 0.0055f)(t - 58).$$

where t is the air temperature in °C, f is the relative humidity in % and THI is given in °C (*Unger*, 1995). The optimal values of THI are between 15° and 20°. The THI was used originally to determine the discomfort due to heat stress, therefore *Beçancenot* (1978) evaluated it over a much wider range of conditions with 10 class types from *hyperglacial* (below -40°) to *torrid* (above +30°).

Using the monthly means of temperature and relative humidity of the Kolozsvár Station in the periods 1880-1971 and 1983-1988 the monthly average index values show that only the values in April and October belong to the narrow *comfort* type. The winter months belong to the *cold* interval between -1.7° and 12.9°, and the summer months to the *hot* class type (20° - 26.4°). Just in July the average THI value emerges into the *very hot* interval between 26.6° and 29.9°) (*Table 1*).

	J	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*
THI (°C)	0.6	3.7	11.6	18.5	22.7	24.6	26.7	25.4	21.4	15.3	8.5	2.2

Table 1 The annual variation of the thermohygrometrical index in Kolozsvár (Cluj-Napoca) (1880-1971, 1983-1988)

Considering the daily variations of the *THI* values of the three stations in a hot summer month, in July 1964, the following general features emerge (*Fig. 5*):

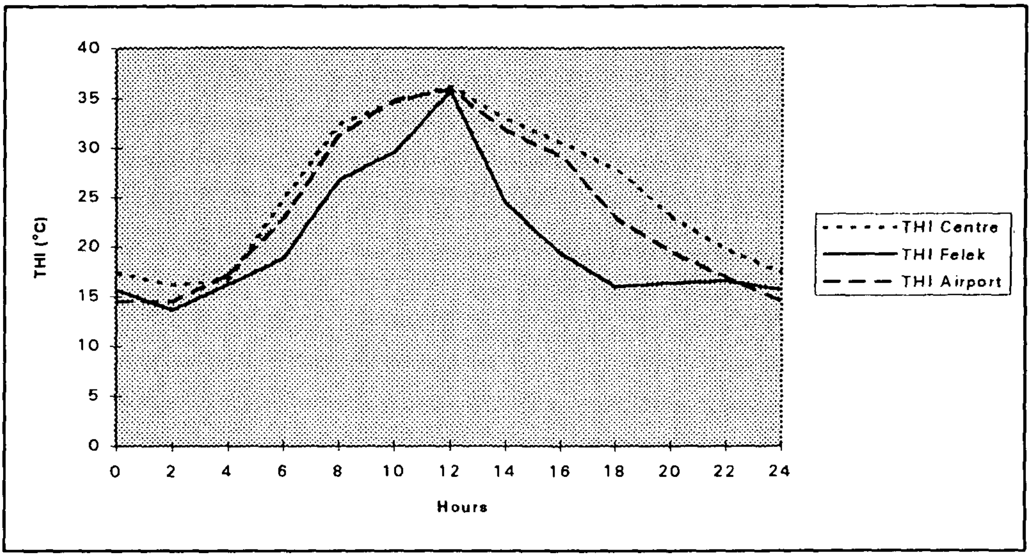

Fig. 5 The daily variation of the thermohygrometric index in the centre, at the airport and on the Felek Hill in Kolozsvár (Cluj-Napoca) in July 1964

- In the centre the most pleasant period occurs at night, between midnight and 6 AM (6 hours). During the day the *THI* values reach the *hot* and the *very hot* type and even the *torrid* one between 10 AM and 6 PM (max. 36.2°)
- Outside the centre on the Felek Hill the adequate period starts already at 6 PM and lasts till 8 AM. It takes 12 hours because the *THI* value sinks under 15° at 4 AM (13.6° - *cool* type). In the daytime there is a steep increase and a steep decrease and the highest value occurs at 2 PM (35.7° - *torrid* type).
- At the airport station the situation is similar to the one in the centre but the *comfortable* period is a little bit postponed (from 10 PM till 6 AM).

CONCLUSIONS

According the annual courses of the pulmonary stress index values, the vapour pressure conditions in Kolozsvár (Cluj-Napoca) do not cause a very loading situation, but the period which really advantageous lasts only three months and the rest of the year can be featured as slightly hydrating or slightly dehydrating ones. Only two months are comfortable by the annual courses of thermohygrometrical index, the rests are colder or warmer, which means a very disadvantageous effect during this long period.

The diurnal courses of bioclimatical indices shows spatial differences of the inside and outside urban climates. In the centre, an artificial innercity climate prevails in opposition with the one in the surrounding area. On the north part of Felek Hill the bioclimatic indices indicate a climate with north exposure slope characters. This is the most likely territory of the area which is featured by stimulating bioclimate: the temperature are quite moderate with the longest thermal comfort period during the summertime. The situations in the centre and at the airport are very similar. It can be explained with the huge amount of concrete at the airport, which thus has similar thermal properities as the densely built-up city centre.

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