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MODEL OF SPATIAL DIFFERENTATION OF TEMPERATURE IN KOLOZSVÁR (ROMANIA)

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Összefoglalás - A cikk Kolozsvár területének hőháztartás-modelljét mutatja be. A szerzők a különböző városi felszínek (beton, aszfalt, víz- és zöldterület) eltérő termikus tulajdonságait alapul véve, a nap négy jellegzetes időpillanatának ábrázolására vállalkoztak. A modell megszerkesztésére a végesdifferencia módszerét használták. Mindez ideális meteorológiai körülményeket, egy hidegfront elvonulása utáni nyári napot feltételez. Ilyen ideális körülmények voltak 1997. június 6-án, amikorra a tanulmány vonatkozik. A modell szerint napközben a város leghidegebb felszíneit a vízfolyás és a zöldterületek képezik. Ezzel szemben a legmagasabb hőmérsékletű térségeket a beton- és az aszfaltfelszínek jelentik. A legnagyobb hőmérsékletű eltérések este és éjszaka mérhetők.

Summary - The structure of urban area may give some different effects on the surface radiation the heat budget and also the heat island phenomenon. The aim of the paper is to study how the urban climate is influenced by different surfaces which characterise the city area. In order to receive a more comprehensive understanding of the thermal patterns in and around urban areas in a themperate climate, the present study was carried out in a different urban areas (e.g. green and water surfaces, streets). Important objectures are:
- to study if the diversified size of the multivarious urban influences the magnitude of the temperature difference between the different style of built-up area;
- to study in what way the density and the structure of the built-up area respectively influences temperature pattern;
- to study the alternation of upwarming and cooling rate in the green and built-up area and its dependence on changes in cloud cover.

The city of Kolozsvár (Cluj, Romania) has been chosen as study area. The study is caried out with the help of physical model using computer simulations.

Key words: heat island, thermical model, thermical conductance, urban area.

INTRODUCTION AND THE INVESTIGATED AREA

The investigation of effects modifying climate in human settlements is a very important topic of urban ecology. During the recent decades the urban areas and the ratio of urban population have grown continuously so the analysis of modifying effects and their physical explanation are required. On the other hand the city should be considered as a whole system, which includes not only buildings and streets but also infrastructure greenery and energy webs. This system functions on basic processes of energy flow. Our investigation is based on the modelling of the thermical characteristics of different built-up surfaces.

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?

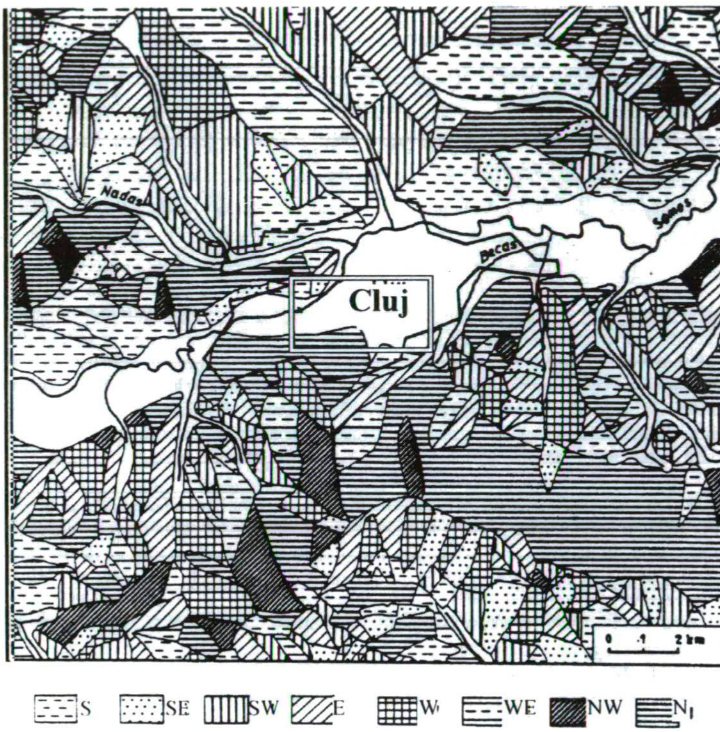

Fig. 1. Exposure of slopes in Cluj and its surroundings

Cluj (Kolozsvár) is situated in the middle north-west part of Romania, at 340 m above the sea level. The territory of the city is extended on ten geomorphological surfaces (e.g. tide land, eight terraces and neighbouring hills). So except the city centre, its geographical situation is not favourable to have relatively undisturbed urban climate (*Fig. 1*).

METHODS

The investigation supposes a common summer day with optimal meteorological conditions. That means calm period which occurs after a cold front and cloudless sky. Such conditions occured on 6th June 1997, when the data of this study were registered.

The work supposes the following steps:

1. Preparing the map.
2. Defining the cities built up environment index. Usually two categories of urban areas are distinguished: open and built-up ones. According to these categories, a land-use classification of each 200 m square was adopted and scored:
   - 2.5 for very densely built up territory
     (concrete, asphalt, bitumen, brick and roof tile surfaces)
   - 2.0 for districts without gardens
   - 1.5 for neighbourhoods with green patches
   - 1.0 for suburbs with gardens
   - 0.0 water surfaces.
3. Solving the differential equation for thermical system:

$$[cT(r,t)]+[T(r,t)] = f(r,t)$$

where t representes time, c is heat capacity, is the density of materials. is the thermical conductance, f is the source density (sunshine, irradiation, etc.) and r is the relative coordinate (x,y). The result is T temperature given in °C.
4. Plotting the results.

Modelling the thermal characteristics of an urban area is a very difficult problem. There are many parameters and large scales. Handling this large amount of data requires special techniques in numerical methods and in programming. Solving the differential equations which control heat flow in environment needs very large memory to store data and long calculating time to reach proper accuracy and resolution enough in space. In this case like description of urban area in two dimension with initial and boundary conditions some different methods exist from which we selected the so called finite difference method. This technique is the most applicable in our case, because we can disregard some not so important things. We shall approach the real problem with very similar but much simplest model which is able to produce effect in which we are interested. Supposing that the examined territory is flat with some different pattern styles like green patches, buildings from concrete slabs, gardens, parks and water surfaces. We have to make some steps to reach to the calculations. First of all preparation of map from investigated urban area it is necessary to make an scanned picture from paper map and to clear the not necessary details like names of streets an other marks from bitmap picture. After that some different but well defined colours is converted in the different areas, which corresponds different heat capacity and irradiation coefficients.

The next step is to solve the differential equations for this system by taking in account that every pixel corresponds with a different heat emitter which is defined by altitude of sun. The differential equation that we have is the common equation for the heat diffusion processes. In this modelling for initial values we set the totally equal values for over the city. The boundary conditions at the edge were fixed temperatures which are defined by average over city temperature in each time step. This pixel is building up the plane using Descartes coordinate system with variables x and y or in vector for written using r symbol. Supposing that is the clear, not cloudy day without any wind motion. This one is mostly after weather change in summer. In this way we can write set of equations and can solve it with iteration methods to receive testable result. In the next step changing the radiation which influences heat source and doing again the calculations with new conditions you get the time evolution of temperature map of investigated area. Reaching the typical daytime we saving the information to bitmap picture in which every pixel describes the temperature in every position. We are interested only in the special daytime temperature. However, we must carry out the calculations through time step by step. If we are interested in the time evolution of selected point we must use a different plotting view. For example, if we knew how the temperature evolves at given coordinate in time, we should get a two dimension plot showing temperature versus time. Thus we have the final result but to make a better quality we have to rescale the temperature map in this way we can show better the temperature differences between different areas and at different time as well.

RESULTS AND DISCUSSION

At 2 p.m. the spatial distribution shows the highest temperature, heat islands in the town centre and the territory which are built-up from concrete (factories, sports grounds) situated in the north-west. The housing estates appear the second warmest area of town (*Fig. 2*). This area - in the south and south-west part of the map - is a housing estate with 4-10 storey buildings, which are built from concrete slabs and rubble, and its building-density is relatively high. Along the river the large mass of water moderates temperature extremities thus in the afternoon it decreases temperature. Cold areas appear at mainly vegetated open spaces like parks, cemetery, citadel (the former citadel does not exist, its place is occupied by family houses with large gardens and open parks area) and the esplanade. Between the two extremitiesmoderately warm up territories are situated like the suburbs, the neighbourhoods with green patches, open spaces with grass and the built-up areas with detached houses, especially those with vegetation (mainly situated in middle and in the south-east part of the city). The difference between the very upwarmed and relatively warm areas are more of 9°C (*Fig. 3*).

The map at midnight shows a relatively balanced situation (*Fig. 4*). The warmest areas are the riverbank and around the esplanade where the temperature is higher than 20°C. On the other hand the concrete and bricks surfaces where the vegetation is completely absent are turned cold. The highest difference of the temperature in the city is around 7°C. The temperature decreases step by step until 5 a.m., when almost all thermical differences are coming to an end: they reached just 4°C (*Fig. 5*).

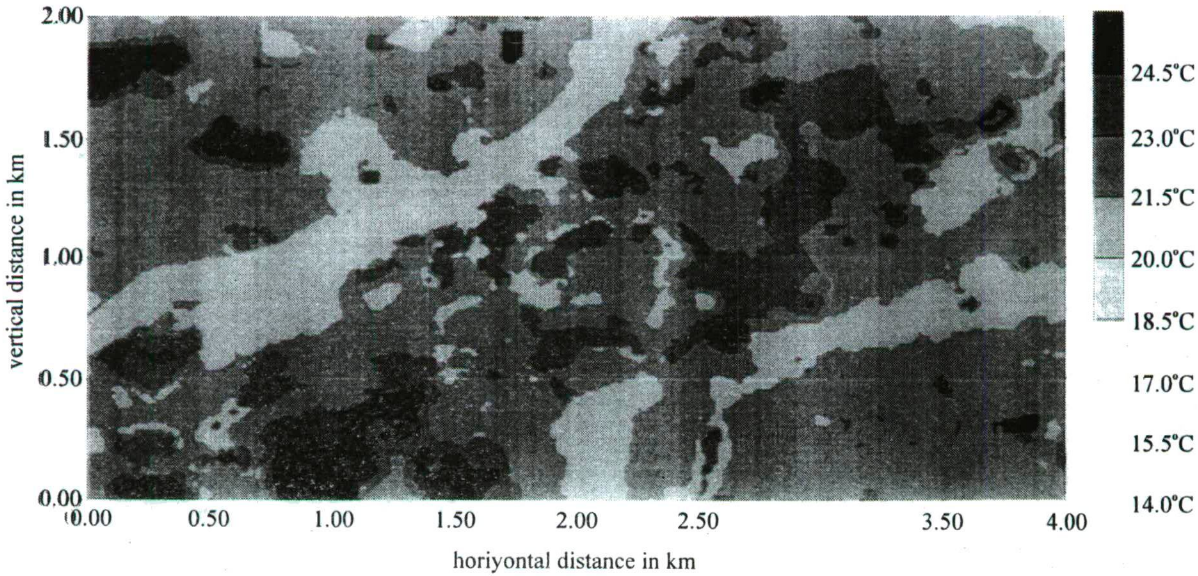

Fig. 2 Temperature map at 2 pm in °C

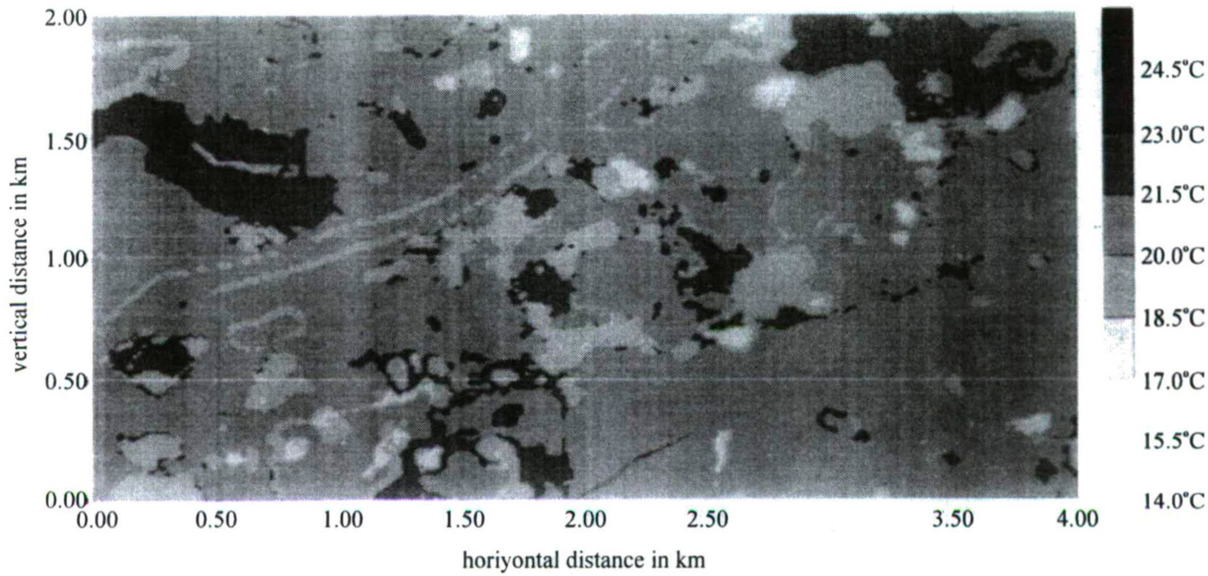

Fig. 3 Temperature map at 7 pm in °C

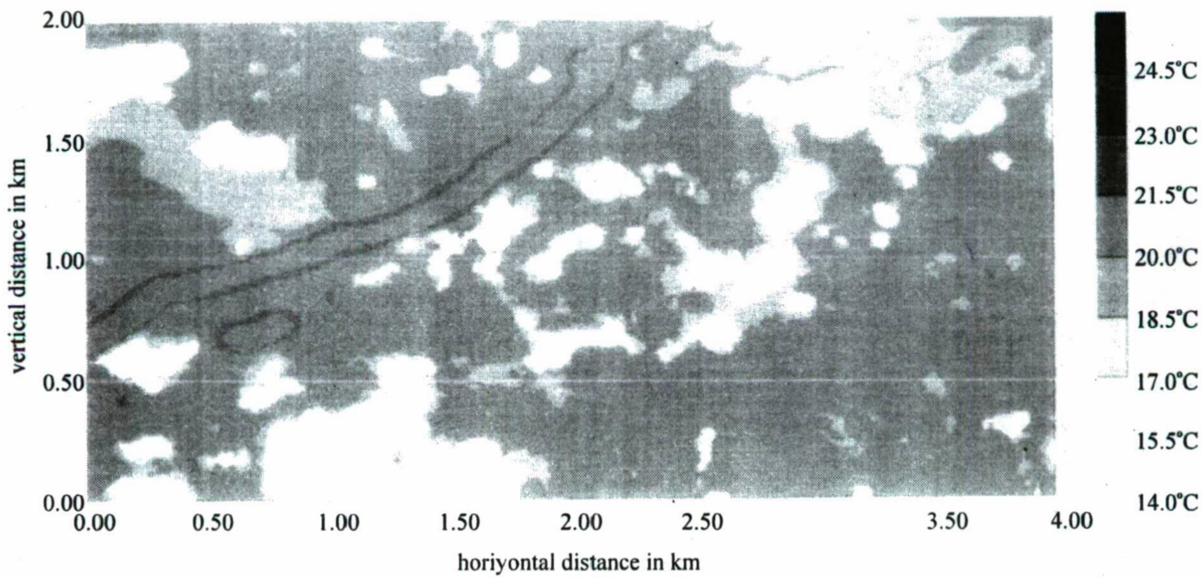

Fig. 4 Temperature map at midnight in °C

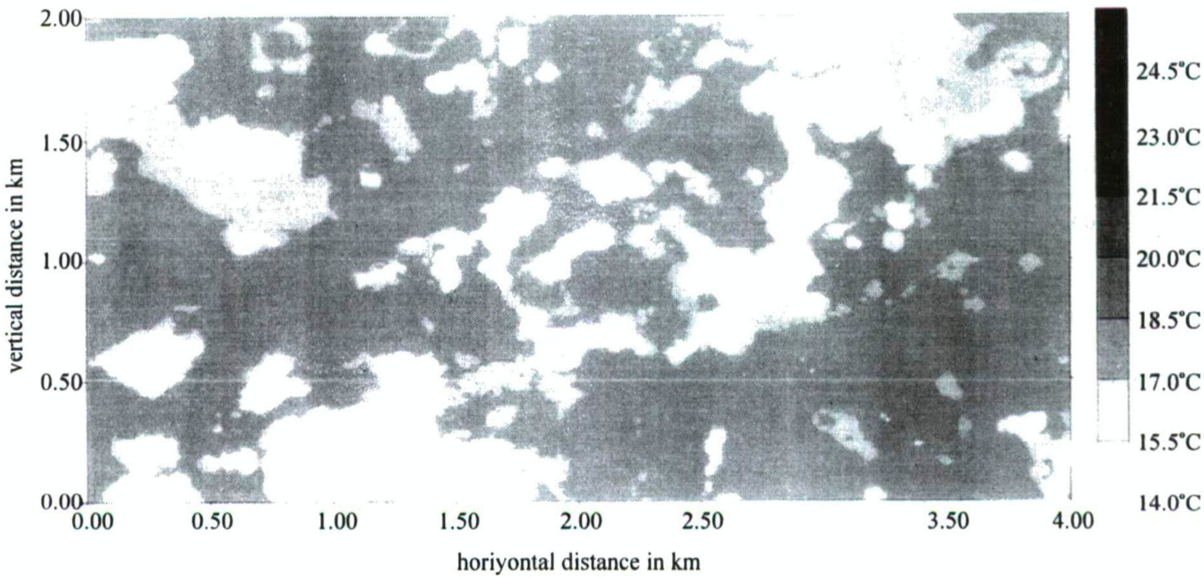

Fig. 5 Temperature map at 5 am in °C

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