PORTABLE INFRARED CAMERA AS A TOOL IN TOPOCLIMATIC RESEARCH*

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Abstract
The paper presents some possibilities of application of a portable infrared camera for topoclimatic researches, especially for establishing the differences in temperatures of the so-called active surface layer. Demonstrated is the dependence of surface temperature on surface characteristics, such as land use, morphological features and the time of the day. The results can be useful for establishing topoclimatic units with similar temperature regimes.

Key words: infrared (thermal) camera, thermal monitoring, surface temperature, topoclimate

PRENOSNA INFRARDEČA KAMERA KOT PRIPOMOČEK PRI TOPOKLIMATSKEM RAZISKOVANJU

Izvleček
V prispevku so predstavljene možnosti uporabe prenosne infrardeče kamere pri topoklimatskem raziskovanju, še posebej pri ugotavljanju razlik v temperaturi t.i. aktivnega sloja površja. Na primerih posnetkov iz okolice Kopra in Olomouca je prikazana odvisnost temperature površja od njegovih značilnosti, npr. rabe in morfoloških potez ter dnevnega časa. Rezultati analiz so lahko v pomoč pri opredeljevanju značilnosti topoklimatskih enot.

Ključne besede: infrardeča (termalna) kamera, termalni monitoring, temperatura površja, topoklima

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1. INTRODUCTION

It is of crucial importance in the study of topoclimate to understand the temperature regime of the surface atmosphere layer, since it significantly depends on the oscillation of surface layer temperatures of individual types of active surface. If we want to furnish topoclimatic research with reliable results in terms of quality and quantity, it is necessary to obtain the data on surface layer temperatures. It is possible to describe the typical temperature-regime features of individual topoclimatic areas merely on the basis of insolation values without performing field measurements, since the insolation depends on the inclination, aspect and the type of active surface layer (Vysoudil 1993). Observations, performed in the network of operative stations, act as a possible step towards better understanding of the temperature regime. However, to meet the needs of contemporary requirements, the most accurate data for topoclimatic information must be provided.

The characteristics of the thermodynamic processes play the main role in the structure of topoclimate. These processes can be identified, investigated and explicated by using detailed data on spatial distribution of surface temperatures. The data on surface temperatures are generally accessible from the satellite or aerial thermal images. In comparison with satellite or aerial monitoring, surface monitoring with the portable thermal camera represents a more efficient mode of obtaining detailed data on temperature. For their experimental monitoring, the authors applied the portable thermal camera 'Fluke Ti55 IR fusion technology', which makes possible a combination of visible light images and infrared images to create a single image with much enhanced details. It is very useful for low contrast views when the infrared image appears all in one colour. Technical specifications of the thermal camera, adjusted for topoclimate research, are mainly as follow:

Spectral band: 8–14 µm
Thermal sensitivity: ≤ 0,050 ºC on 30 ºC
Accuracy: ±2 ºC or 2 %
Detector frame: 60 Hz
Sequency: 9–9999 sec.
Field of view: 20 mm/0.8–23º horizontal x 17º vertical
Spatial resolution (IFOV): 1.30 mrad IFOV
Optics: 20/54 mm
Image size, detector resolution: 320 x 240 pixels

A trustworthy assessment of the background temperature of the prevailing type of active surface layer is the basic criterion for thermal scanning data to be taken as the representative. The accuracy of surface temperatures of the neighboring areas and objects depends on the obtained string of surface background temperatures. Initial experiences showed that the measurements 'in situ' – if feasible – served as the best point of reference. Secondly, the state of monitored active surface emissivity serves as the determining parameter of the final result. However, this is a complicated task, mainly due to a considerable diversity of the active surface layer. Thus, to make a catalogue of emissivity of active surface based of CORINE database, for example, is an important but separate task.

1.1. The dependence of area size on target distance

Topoclimatic research is usually presented on the map in the scale of 1:25.000 or 1:50.000, with the usual minimum size of an individual topoclimatic field of 250 x 250 m or 500 x 500 m, respectively. The spatial resolution of the camera, e.g. to register the surface temperature of elementary areas, appears to be fit for topoclimatic mapping in the scale 1:25.000 or 1:50.000 as well (Table 1).

Table 1: Dependence of pixel and area sizes on the distance to the target in view of the optics
Preglednica 1: Odvisnost velikosti piksla in območja od oddaljenosti objekta in optike kamere

Distance to target (m)	Pixel size (m)	Area size (m)
	Optics 20 mm / 54 mm	Optics 20 mm / 54 mm
500	0,635 x 0,635 / 0,235 x 0,235	203,00 x 152,00 / 75 x 54
1000	1,270 x 1,270 / 0,47 x 0,47	406,00 x 305,00 / 150 x 112
1500	1,905 x 1,905 / 0,70 x 0,70	609,00 x 457,00 / 225 x 169
2000	2,540 x 2,540 / 0,94 x 0,94	812,00 x 609,00 / 301 x 225
3000	3,810 x 3,810 / 1,41 x 1,41	1219,00 x 914,00 / 451 x 338

1.2. Types of thermal images

As mentioned before, the used thermal camera with IR ‘fusion’ technology enables the combination of visible light with thermal images. Thus, a single image can comprise greatly enhanced details, which means that it is easier to follow the processing and analyzing of the image by the image matching method. Otherwise, only fully visible or complete thermal images are available for such investigation.

1.3. Software support

The system includes the SmartView™ software which allows the basic manipulation and interpretation of thermal images. The main functions of the software are as follow:

- precise matching of complementary visible and thermal images;
- additional correction of emissivity and background temperature values;
- recalculation of temperature values for each pixel (cell) as to the changed values of surface emissivity and background temperature;
- image editing can cover, for example, the selection of appropriate colour palette, the marking of the hottest and/or the coldest point, illustration of temperature value of a randomly selected spot;
- ‘on screen’ digitizing. The function allows to specify directly an actual topoclimatic field on the image; the area can be irregular; basic temperature characteristics (T_{max}, T_{min}, T_{avg}) can be defined;
- temperature alarm function. It allows the marking of the landscape areas having the surface temperature above/below the set limit; or, the temperatures range within the specified

temperature span;
- possibility of exporting images in the desired graphic format (*.bmp, *.jpg, *.tif, *.gif, *.png) or text (*.txt, *.csv) files; possibility of importing GIS files, such as ArcGis or ERDAS, when a detailed climatological analysis is required.

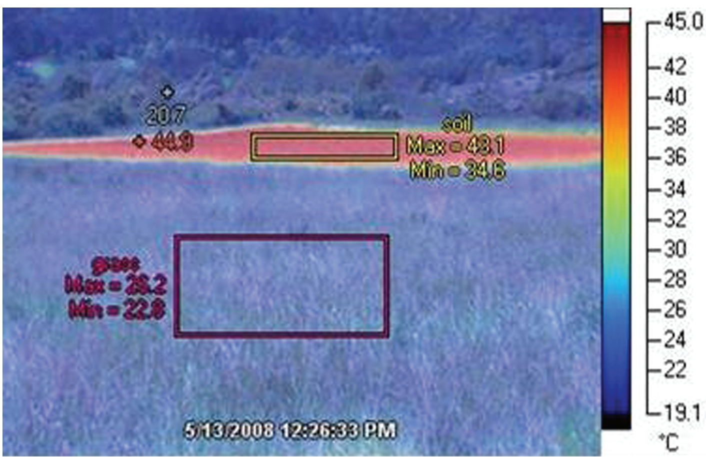
2. APPLICATION IN TOPOCLIMATIC RESEARCHES – A CASE STUDY

The main goal of these experimental measurements was to test the possibilities of portable thermal camera and its application in topoclimatic investigations. The field measurements were carried out at two different locations: the Istrian peninsula, in the surroundings of Koper (Slovenia), and the Central Moravia, in the surroundings of Olomouc (Czech Republic). All measurements were performed in suitable weather conditions, meaning the radiation-type weather. The monitored (study) areas differed one from another by the active surface features, morphological features of the surface and also the shots were taken at different times of the day.

2.1. Surface temperatures of grassy vegetation and bare soil

The examples show distinct differences in extreme surface temperatures between grassy vegetation and bare soil. On grassland, T_{max} read 26.2 ºC and T_{min} 22.8 ºC; on bare soil, T_{max} read 43.1 ºC, and T_{min} 34.6 ºC. The differences between the maximum and minimum temperatures amount to 16.9 ºC, and 11.8 ºC respectively, in both cases to the plus of bare soil.

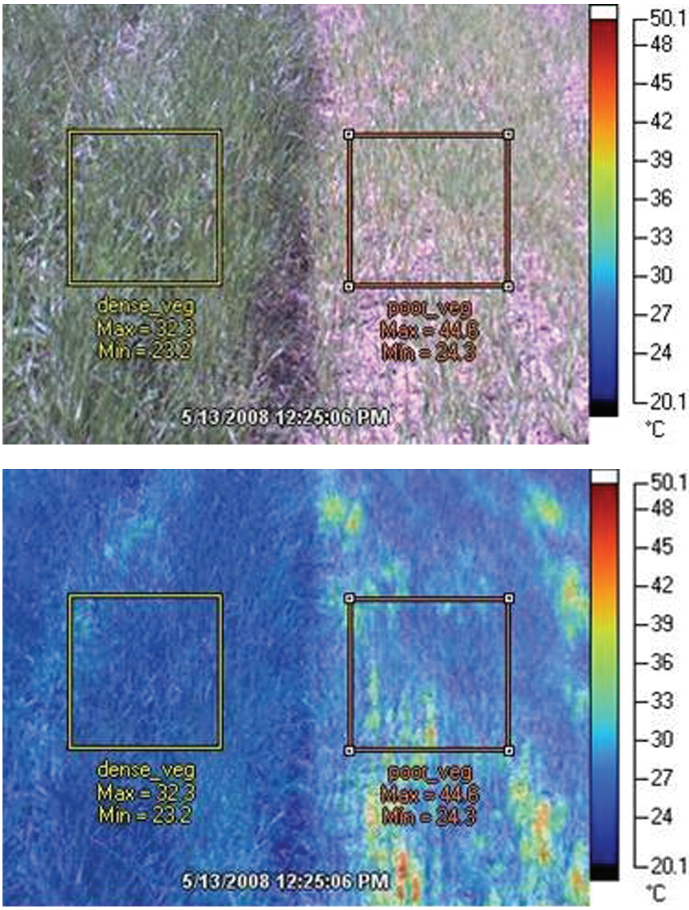
Figure 1: Extreme surface temperatures of grassy vegetation and bare soil (Movraž environs, Slovenia, 13 May 2008)
Slika 1: Ekstremne temperature na travnati površini in golih tleh (okolica Movraža, 13. 5. 2008)



2.2. Surface temperature of dense and sparse vegetation

The differences in surface temperatures of dense and sparse vegetation were less explicit. The maximum/minimum surface temperature of dense vegetation read 32.3 ºC/23.2 ºC and of sparse vegetation, 44.6 ºC /24.3 ºC. The maximum temperature of sparse vegetation was higher by 12.3 ºC and the minimum temperature by 1.1 ºC. Evidently, more expressive difference occurred in maximum temperatures only.

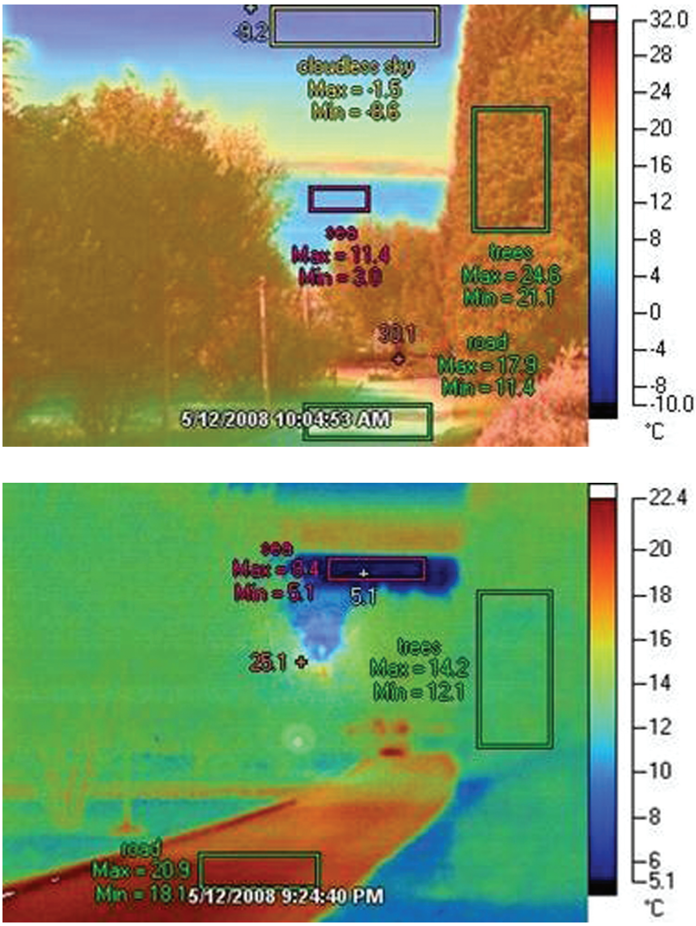
Figure 2: Extreme surface temperatures of dense and sparse vegetation (Movraž environs, Slovenia, 13 May 2008)
Slika 2: Ekstremne temperature na površini aktivnega sloja poršja z gostim in redkim rastlinjem (okolica Movraža, 13. 5. 2008)



2.3. Surface temperatures of different active surfaces in the time of positive/negative energy balance

The efficient detection of differences in surface temperatures during the day/night time plays an important role in topoclimatic research, e.g. in the identification and description of local circulation. Figure 3 shows differences in temperatures on different types of surface by day and at night.

Figure 3: Surface temperatures of different active surfaces: a) 10:04 AM, b) 09:24 PM (Debeli rtič, Slovenia, 13 May 2008)
Slika 3: Temperature na različnih aktivnih slojih površja ob: a) 10:04; b) 21:24 (Debeli rtič, 13. 5. 2008)



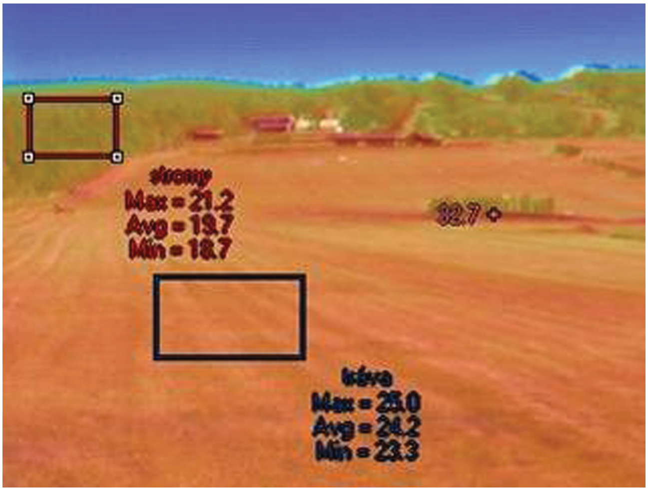
2.4. Temperatures of the selected types of active surface by day

To know the surface temperature of differently facing slopes, it is necessary to assess the intensity of temperature and its range for the level surface layer. On the southwestern slope, where the temperatures were recorded at 09:00 AM and 11:00 AM, with all monitored temperature characteristics, marked differences were manifested (Table 2, Fig. 4). The increase in the average temperature between 09:00 AM and 11:00 AM was 3.6 ºC (grassland) and 1.6 ºC (forest).

Table 2: Surface temperatures and their differences, measured at 09:00 AM and 11:00 AM on the grassland and in the forest on the southwestern slope (Véska village environs, Czech Republic, 18 June 2008)
Tabela 2: Temperature površja in razlike med njimi, izmerjene ob 9:00 in 11:00 na travnatih površinah in v gozdu na jugozahodnem pobočju (okolica vasi Véska, Češka, 18. 6. 2008)

Surface	T_{max} ºC			T_{min} ºC			T_{avg} ºC		
	09:00	11:00	= 2 h	09:00	11:00	= 2 h	09:00	11:00	= 2 h
Grass	21.5	25.0	3.5	20.1	23.3	3.2	20.7	24.3	3.6
Forest	20.2	21.2	1.0	17.0	19.7	2.7	18.1	19.7	1.6

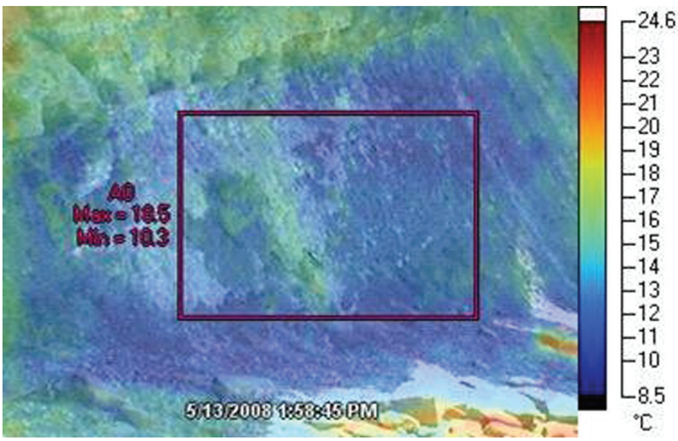
Figure 4: Surface temperatures and their differences, measured at 09:00 AM and 11:00 AM on the grassland and in the forest on the southwestern slope (Véska village environs, Czech Republic, 18 June 2008)
Slika 4: Temperature površja in razlike med njimi, izmerjene ob 9:00 in 11:00 na travnatih površinah in v gozdu na jugozahodnem pobočju (okolica vasi Véska, Češka, 18. 6. 2008)

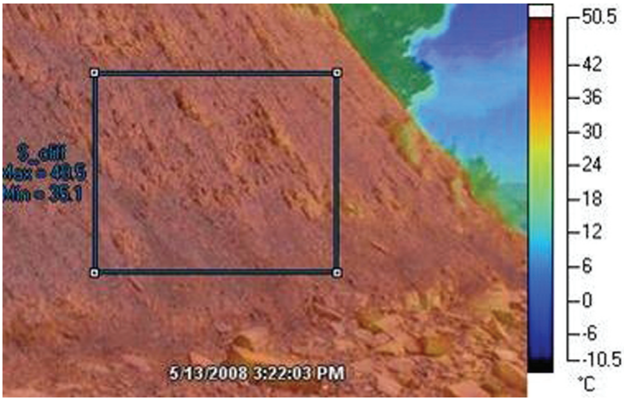


2.5. Extreme temperatures of differently facing slopes

Fig. 5 shows the variations of extreme temperatures on markedly sloping surfaces, e.g. on cliffs. The maximum temperature on the south-facing cliff is as much as 30.0 ºC higher than that on the north-facing cliff. The difference in minimum temperatures amounts to 24.8 ºC. The amplitude on the southern cliff is 13.4 ºC, and 8.2 ºC on the northern one. The temperature regime with greater temperature extremes can be noticed on southern slopes.

Figure 5: Surface temperatures of markedly sloping areas: a) north-facing cliff, b) south-facing cliff (Debeli rtič, Slovenia, 13 May 2008)
Slika 5: Temperature aktivnega sloja poršja na izrazito nagnjenem pobočju: a) severni klif, b) južni klif (Debeli rtič, 13. 5. 2008)

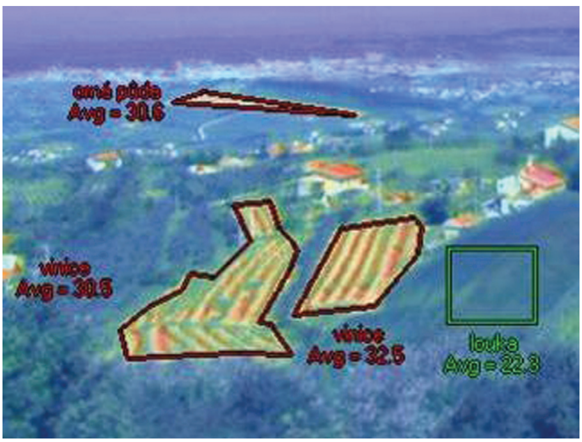


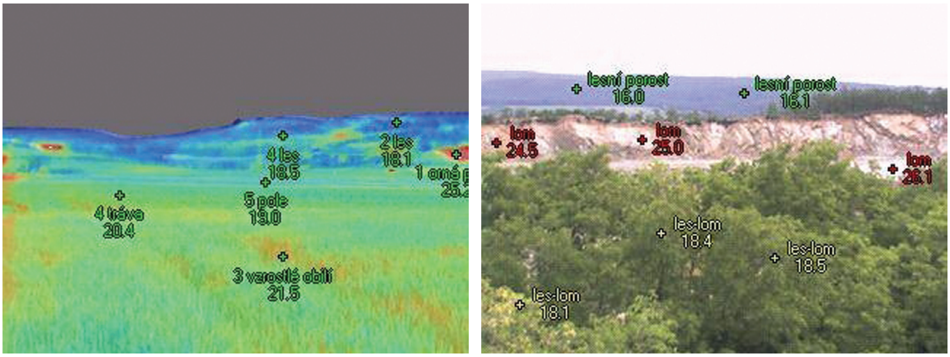


2.6. Spatial differences in surface temperatures of the selected active surfaces

The possibility to assess temperature characteristics of individual selected areas with different categories of topoclimate appears to be a step in the quality of the detailed topoclimatic mapping. Three types of surfaces (vineyard, bare soil, pasture) are marked on Figure 6a. The highest average temperature is linked with south- and southwest-facing vineyard (32.5 ºC), the lowest (22.3 ºC) with pasture in Marezige surroundings (Slovenia). It is possible to present similar spot differences of the most extended active surfaces in the cultural landscape (Figs. 6b and 6c).

Figure 6: Surface temperature of the selected land use types: a) Marezige surroundings (Slovenia, 14 May 2008), and b) and c) Olbramovice surroundings (Czech Republic, 18 June 2008)
Slika 6: Temperature površja na izbranih tipih rabe tal: a) v okolici Marezig (14. 5. 2008); b) in c) okolica Olbramovic (Češka, 18. 6. 2008)

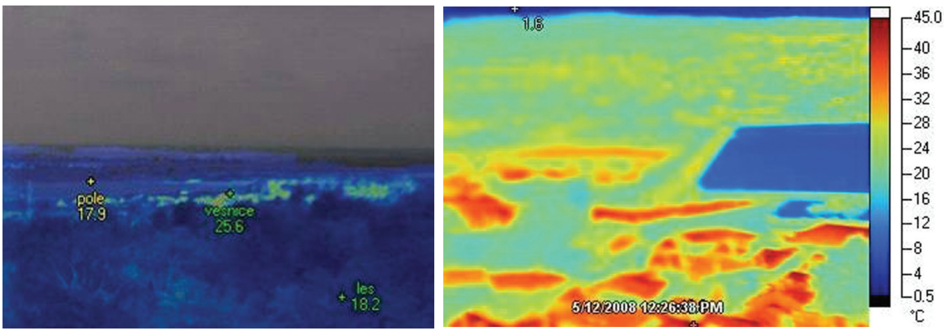




2.7. Temperatures of man-made areas

The portable camera can also be used for identification of man-made areas which usually represent the warmer islands in the landscape (Fig. 7a). It is possible to make a detailed explication of differences in surface temperatures which occur within the urban heat island.

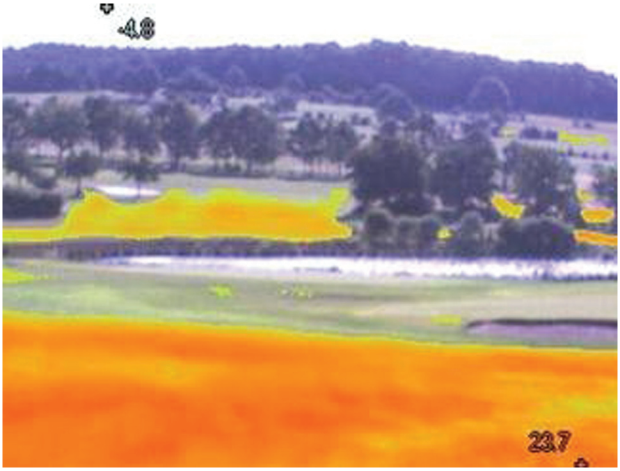
Figure 7: Village (centre) as a warmer island in the landscape: 7a Bohutice village (Czech Republic, 18 June 2008) and an urban heat island: 7b Koper (Slovenia, 12 May 2008)
Slika 7: Vas (v sredini) kot toplotni otok v pokrajini (7a vas Bohutice (Češka, 18. 6. 2008) in mestni toplotni otok (7b Koper (12. 5. 2008)



2.8. Selection of topoclimatic fields made by the 'temperature alarm' function

The use of the SmartView software 'temperature alarm' function renders possible a quick and easy locating of the area with selected surface temperature. The limit can be above, below or within the specific range of values. These areas can in fact represent the spatial distribution of individual topoclimatic fields (categories). Fig. 8 shows the sites warmer than 20 ºC.

Figure 8: Areas with the surface temperature above 20 ºC (southwestern slope in Véska village surroundings, Czech Republic, 18 June 2008)
Slika 8: Območja s temperaturo površja nad 20 ºC (jugozahodno pobočje v okolici vasi Véska, Češka, 18. 6. 2008)



3. CONCLUSIONS AND DISCUSSION

The field experiment, carried out in two geographically different areas, demonstrated the anticipated advantages of the handy thermal monitoring for topoclimate studies. Considered as the most important advantages should be the following:

- improved possibilities for specifying individual topoclimatic fields based on temperature characteristics of the active surface;
- possibility of a more thorough investigation of thermodynamic processes in the ground layer atmosphere, both in space and time dimensions, during the positive and negative energy balance, e.g. the process of cooling, local air circulation, etc.;
- efficiency of observations;
- possibility of exporting thermal images to the graphical and GIS software tools.

The data obtained from thermal images also enable the making of reference data bases for the emissivity and background temperatures of the most frequent types of active surface fields in the landscape, e.g. as to the aspect and inclination, time of the day and the year, and the weather type. In the subsequent stages these data can be very supportive both to topoclimatic and microclimatic researches, to urban climate investigation, as well as to the ecological, phytogeographical and geomorphological studies.

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Povzetek

Poznavanje temperaturnega režima prizemnega dela atmosfere je zelo pomembno pri topoklimatskih raziskavah. Ta režim je zelo odvisen od temperaturnih razmer Zemljinega površja, saj je temperatura ozračja v stabilnih vremenskih razmerah odvisna predvsem od temperature aktivnega sloja Zemljinega površja. Aktivni sloj Zemljinega površja pojmujemo kot tisti del površja, kjer poteka energijska izmenjava med površjem in atmosfero. Ker imamo pri topoklimatskih raziskavah običajno na razpolago le malo meritev temperaturnih parametrov, so ena od možnosti za pridobitev kvalitetnih informacij o temperaturi prizemnega dela ozračja termalni (infrardeči) posnetki površja. Ti nam omogočajo ugotavljanje enot Zemljinega površja, ki imajo podobne temperaturne značilnosti površja in posredno tudi sklepanje o temperaturnih razmerah v prizemnem sloju ozračja.

Sodobne termalne kamere omogočajo snemanje tako v infrardečem kot vidnem delu spektra in kombinacijo različnih spektrov, pripadajoča programska orodja pa številne možnosti obdelave slikovnega gradiva. V prispevku so na primeru termalnih posnetkov, ki so bili narejeni ob radiacijskem tipu vremena spomladi in poleti v okolici Kopra (Slovenija) in Olomouca (Češka), prikazane različne možnosti ugotavljanja razlik v temperaturi aktivnega dela površja, npr. golega in s travo poraslega, površja z redko in gosto travo, razlik zaradi različne rabe (vinogradi, travniki, urbane površine), razlik, ki so pogojene z reliefnimi danostmi (različno orientirana pobočja), in razlik, do katerih prihaja čez dan zaradi različnega Sončevega obseva oziroma med dnevom in nočjo. Termalni posnetki nudijo tudi možnost identifikacije območij, ki imajo izbrano temperaturo aktivnega dela površja, kar je lahko v veliko pomoč pri izločanju topoklimatskih enot in topoklimatskem kartiranju.

Kot najbolj koristni so se termalni posnetki pokazali pri spoznavanju temperaturnih značilnosti posameznih topoklimatskih enot, pri raziskovanju termodinamičnih procesov v prizemnem delu ozračja, tako v prostorski kot časovni skali in v času pozitivne oziroma negativne energijske bilance (npr. potek ohlajanja in potek lokalne zračne cirkulacije), in kot pripomoček pri opazovanju topoklimatskih pojavov. Dodatno uporabno vrednost daje termalnim posnetkom možnost izvoza in nadaljne obdelave v različnih grafičnih in GIS programskih orodjih. Podatki, pridobljeni s pomočjo termalnih posnetkov, omogočajo tudi

izdelavo referenčnih baz podatkov o emisivnosti in temperaturi ozadja najbolj pogostnih tipov aktivnega dela površja v pokrajini, npr. glede na ekspozicijo in nagnjenost, čas dneva/leta in tip vremena. Ti podatki so lahko v nadaljevanju v veliko pomoč pri topoklimatskih in mikroklimatskih raziskavah, pri raziskavah mestne klime, prav tako tudi pri ekoloških, fitogeografskih in geomorfoloških študijah.