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Detection of changes in urban environment based on infrared satellite data

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Abstract. Changes in the microclimate of the urban environment often occur as a result of changes in urban development, artificial changes in the relief, and the cutting down of forest plantations. Due to changes in the urban environment there is a change in the microclimate of the city, which entails a direct change in the land surface temperature. Changes in the urban environment can be detected using space images of different spatial resolution in the visible and far infrared range. Landsat data is currently the most accessible, complete, and open for studying these changes. Thermal imaging is widely used for monitoring urban sites. To increase the spatial resolution, synthesis of Landsat-8 images with higher spatial resolution images of Planet Scope is used, which allows increasing the spatial resolution of surface temperature maps produced from Landsat-8 images from 30 meters to 3 meters. The paper presents the results of an assessment of the land surface temperature in the city of Krasnoyarsk for a two-year period from September 2016 to September 2018 based on the analysis of Landsat-8 and Planet Scope satellite images.

1. Introduction

The microclimate of the territory, in the conditions of a natural landscape, is formed under the influence of local natural factors, such as relief, proximity to water bodies, the nature of the underlying surface. In the conditions of artificial landscape, anthropogenic factors such as urban development, asphalt coating of vegetation and natural soils, artificial heat flows and air pollution have a great influence [1].

An important feature of the change of microclimate in the city, and as a result of changes in surface temperature, is that it affects the ecological situation in the city. With a stable stratification of the atmosphere, especially with temperature inversions, smoke can accumulate in the surface layer of the atmosphere in such an amount that it has a harmful physiological effect. Road transport also contributes to urban air pollution as a frequent cause of smog [2].

As a result of changes in the urban environment, a change in microclimate of the city takes place, which entails a direct change in the land surface temperature; these changes can be assessed using field measurements as well as remote sensing methods. As remote methods of studying the temperature, data from space imaging of the Earth in the far infrared range are used. Such images contain information about temperature, which is practically impossible to obtain in any other way such as using images in

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the visible and near-infrared range [3, 4]. Thermal imaging is widely used for research and monitoring of man-made objects such as pipelines, urban facilities, industrial facilities and pollution [5, 6].

The paper presents examples of changes in the temperature of the land surface in the city of Krasnoyarsk for the two-year period from September 2016 to September 2018 based on the analysis of satellite images Landsat-8 and Planet Scope. The choice of this time period is associated with the active development of the city. It should be noted that not only Landsat data are used to estimate surface temperature [7, 8], but these data have the highest spatial resolution. The use of high-resolution Planet Scope data can improve the resolution of heat maps obtained on the basis of thermal images Landsat-8 [9, 10]. The technique for detection of temperature changes within one territory for a certain time interval is presented and its applicability for determination of anthropogenic changes of a landscape is shown.

2. Increasing the spatial resolution of the image

In February 2013 the launch of the modern Landsat-8 satellite, which receives data using two different sensors - Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), took place. Its data is presented on the online service (https://www.earthexplorer.usgs.gov). The TIRS thermal range scanner surveys two bands of 10.6–11.2 μm (band 10) and 11.5–12.5 μm (band11) with a spatial resolution of 100 meters [11].

The spatial resolution of the temperature map obtained from Landsat 8 multispectral channels is 30 meters. To study the urban area there is a need to improve spatial resolution. Therefore, it was decided to use Planet Scope constellation data (high-resolution images) to create an image classification. These data are presented in the appropriate online service (https://www.planet.com/products/explorer/). The Planet Scope constellation consists of 120 satellites, evenly spaced in orbit, and is designed for regular space monitoring of any territory in high spatial resolution. Four spectral channels with a resolution of 3.7 meters – blue (0.450-0.515 microns), green (0.515 – 0.595 microns), red (0.605 – 0.695 microns), near infrared (0.740 – 0.900 microns).

At the next stage, the Landsat-8 and Planet Scope space images are synthesized. Traditionally, an approach based on improving the spatial resolution of one image with help of another is used. So, Landsat-8 allows to obtain digital images of the land surface with a spatial resolution of 30 m in the visible range and 100 m in the far infrared range, while the Planet Scope receives images with a spatial resolution of 3 m in the visible range. The synthesis of these images allows to increase spatial resolution of Landsat-8 to 3 meters and calculate the land surface temperature using Landsat-8's 10th thermal band and classification of the land surface based on Planet Scope image (figure 1).

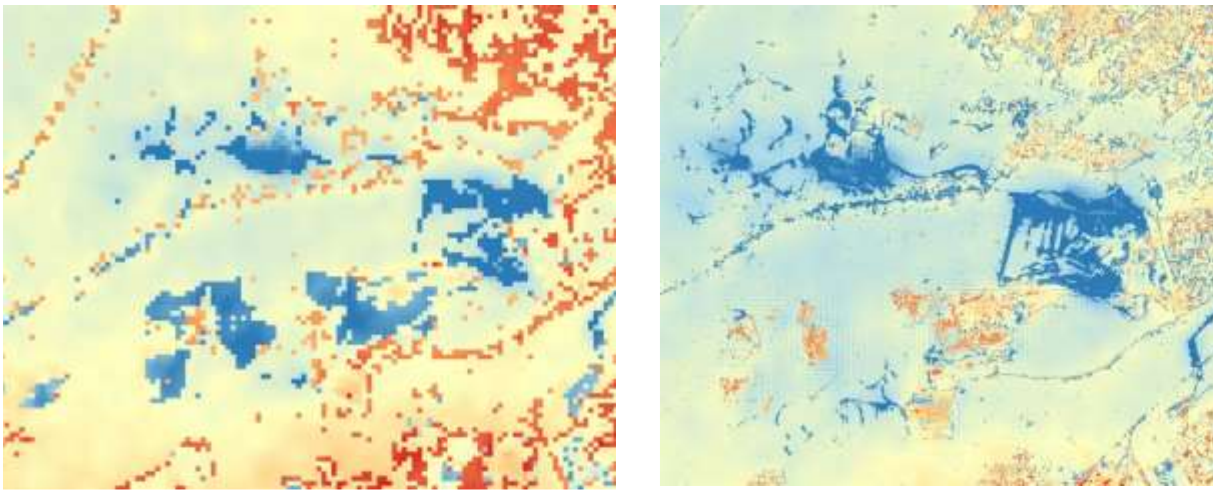

Figure 1. Classification by Landsat-8 image only (left) and by Landsat-8/PlanetScope couple (right).

For each study date, you must create your own map of the earth's surface temperature. The method of calculating the temperature of the land surface is described in detail in previous works of the authors [12, 13].

3. Methods for detection of changes in the urban environment by land surface temperature

The influence of a large modern city on the formation of its microclimate is considerable, this is especially evident in some city blocks, where urban development changes or significant changes are made in the natural landscape. One of the signs of a change in the urban climate is a change in temperature relative to the environment, also noticeable are pollution of the atmosphere, a change in its optical characteristics, an increase in turbidity, a decrease in the influx of solar radiation [14].

The method for detection of changes in the urban environment is based on the use of temperature maps obtained from satellite data from the 10th thermal band Landsat-8 and visible range satellite data from the Planet Scope [15].

A mandatory step is the pre-processing of satellite data, which includes atmospheric correction, classification of the image of the planet by the type of underlying surface, delineation of the overlay along the boundaries of the object under study, in our case, the boundaries of the city of Krasnoyarsk with small neighborhoods. The classification of satellite images with training on the basis of test areas is used in the work.

An important step is the normalization of data to allow comparison of the obtained temperature maps with each other. Using the statistical characteristics of each image, namely, the average temperature value of the map, an increment value is calculated for the normalization operation. After this, the mathematical operation of maps algebra is carried out, allowing one map to be subtracted from another. The result is a new image containing the difference between the temperature values in each pixel.

To correctly detect changes between two satellite images, it is necessary to use cloudless, same-season satellite images with the most equivalent meteorological conditions. To test the method for detection of changes in the urban environment, the authors selected satellite images of the territory of the city of Krasnoyarsk with identical weather conditions dated from September 2016 and September 2018. The set of satellite images consists of images on the dates of 20/09/2018 and 05/09/2016 from the Landsat-8 satellite and high-resolution images from Planet Scope on 20/09/2018 and 20/09/2016. The table shows the air temperature at the study dates and the land surface temperature, which is obtained from satellite images. The land surface temperature in the picture corresponds to the shooting time of Landsat-8 at 12 PM.

Table 1. Weather data for satellite images.

Date	Air temperature, °C		Average land surface temperature on image, °C
20/09/2018	Day +15	Night +4	15.9
05/09/2016	Day +19	Night +14	19.7

Let us provide more detail on the application of normalization in detection of temperature changes between two years. All calculations are carried out within the boundaries of the city of Krasnoyarsk. Comparing the average land surface temperature on 20/09/2016 (LST2016) and 05/09/2018 (LST2018), shown in the table, we find that the value in 2016 is greater than in 2018. Therefore, we subtract the average temperature of 2018 from the average of 2016 and get the difference which we add to the LST 2018 card, as a result we get LST2018plus. After normalization, the average values of the LST2016 and LST2018plus become equal. Next is the mathematical operation of map algebra, subtraction of LST2016 from the LST2018plus.

As a result of the subtraction, a new image is obtained, containing the difference between the temperature values in each pixel for the studied dates, 2016 values are subtracted from 2018 values. For clarity, the values obtained are divided into 3 groups: an increase in temperature, minor changes / no change and a decrease in temperature.

4. Results and discussion

Temperature changes observed are both increases and decreases. The temperature difference greater than zero indicates an increase in temperature in 2018, relative to temperature in 2016, and vice versa, if the temperature difference is less than zero, then there was a decrease in temperature in 2018 relative to 2016.

Figure 2 shows the change in surface temperature as a result of the construction of a sports facility; in 2016, construction of the facility was just beginning. The red color shows areas with an increase in the land surface temperature, which coincide with the contour of the object constructed in 2018.

Figure 2. The change of the land surface temperature around the new ice arena.

Figure 3 shows the territory of the former Krasnoyarsk Combine-Harvester Plant, where the demolition of industrial buildings for the construction of residential buildings began in 2017. Image fro 2016 is before the start of the preparation of construction site. In figure 2018, the demolition of buildings in the city center has been completed and the construction site is being prepared. On the third fragment is the map of changes in the land surface temperature over two years, an increase of the land surface temperature resulting from the demolition of industrial buildings is shown in red.

Figure 3. The changes in the territory of the Combine-Harvester Plant from 2016 to 2018.

Due to holding of XXIX Winter Universiade 2019 in Krasnoyarsk, active construction of ski slopes was carried out in forest areas within the city limits, large areas of tree plantations were cut down. Figure 4 shows the change in the land surface temperature in the Universiade construction site on Sopka and Akademgorodok in the city of Krasnoyarsk, in 2016, the forest is before the construction, and the next stage shows the final construction phase in 2018. In the figure, blue indicates the temperature change towards lower level, which corresponds to the contours of the ski slopes, built for competitions in the forests of the city during the Universiade.

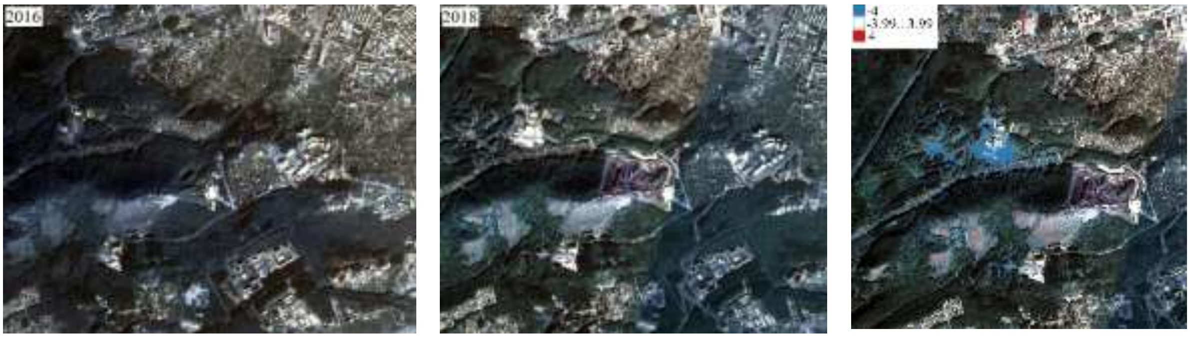

Figure 4. The change the land surface temperature in the forest in the area of construction of Krasnoyarsk Winter Universiade facilities from 2016 to 2018.

5. Conclusions

The method of visual analysis of visible range spectral bands makes it difficult to assess changes, especially in large areas. Detection of changes in visible range bands limits the quality of analysis to the human factor. Also, visual changes do not give an understanding of their hidden characteristics.

In this work, we tested the methodology for detection of changes in the urban environment by the land surface temperature based on satellite infrared data. As a result, a thematic temperature difference map for two years was created on 05/09/2016 and 20/09/2018. For further analysis of the territory of the city of Krasnoyarsk, areas with temperature changes are divided into 3 classes: temperature increase, minor changes / no change, and temperature decrease.

In the analysis of areas with maximum temperature changes, it is noted that change dynamic corresponds to urban development, namely the construction of new neighborhoods, shopping centers. Also, the change in surface temperature is associated with a change in forest landscapes, for example, in places where trees are cut down. Changes in the land surface temperature over a time period correspond to changes in urban development, forests, landscapes that influence climate formation. The described technique is suitable for solving problems of remote monitoring of changes in urban areas, is easy to organize and is suitable automated.

References

[1] Stone J and Rodgers M 2001 Urban form and thermal efficiency: how the design of cities influences the urban heat island effect *APA Journal* **67** 186-98

[2] Khromov S P and Petrosyants M A 2006 *Meteorology and climatology* (Moscow publishing house)

[3] Wang S, Ma Q, Ding H and Liang H 2018 Detection of urban expansion and land surface temperature change using multi-temporal landsat images *Resources, Conserv. & Recycling* **128** 526-34

[4] Effat H and Hassan O 2014 Change detection of urban heat islands and some related parameters using multi-temporal Landsat images; a case study for Cairo city, Egypt *Urban Climate* **10** 171-88

[5] Sharma R and Joshi P 2014 Identifying seasonal heat islands in urban settings of Delhi (India) using remotely sensed data – An anomaly based approach *Urban Climate* **9** 19-34

[6] Niclos R, Valiente J, Barbera M and Caselles V 2014 Land surface air temperature retrieval from EOS-MODIS images *IEEE Geosci. Rem. Sens. Let.* **11** 1380–4

[7] Merlin O, Duchemin B, Hagolle O, Jacob F, Coudert B, Chehbouni G, Dedieu G, Garatuza J and Kerr Y 2010 Disaggregation of MODIS surface temperature over an agricultural area using a time series of Formosat-2 images. *Rem. Sens. of Env.* **114** 2500–12

[8] Niclos R, Valiente J, Barbera M and Caselles V 2014 Land surface air temperature retrieval from EOS-MODIS images *IEEE Geosci. Rem. Sens. Let.* **11** 1380–4

[9] Windahl E and Beurs K 2016 An intercomparison of Landsat land surface temperature retrieval

methods under variable atmospheric conditions using in situ skin temperature *Int. J Appl. Earth Obs. Geoinf.* **51** 11-27

[10] Sheng L, Tang X, You H, Gu Q and Hu H 2017 Comparison of the urban heat island intensity quantified by using air temperature and Landsat land surface temperature in Hangzhou, China *Ecol. Indicators* **72** 738-46

[11] Fu P and Weng Q 2016 Consistent land surface temperature data generation from irregularly spaced Landsat imagery *Rem. Sens. of Env.* **184** 175-87

[12] Matuzko A K and Yakubailik O E 2018 Urban heat island effects over Krasnoyarsk obtained on the basis of Landsat 8 remote sensing data, *IOP Conf. Series: Earth and Environ. Sci.* **211** 012010

[13] Matuzko A, Yakubailik O 2018 Remote sensing methods for estimation of urban heat islands on the example of Krasnoyarsk city *18 Int. Multidiscip. Sci. GeoConf. SGEM 2018*. (SGEM2018 Conf. Proc., Issue 2.3) pp 167-74

[14] Hrebtov M and Hanjalić K 2017 Numerical study of winter diurnal convection over the city of Krasnoyarsk: effects of non-freezing river, undulating fog and steam devils *Bound. Layer Meteo.* **163** 469-95

[15] PlanetSope satellite imagery Available from: https://www.planet.com/products/explorer/