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APPLICATION OF VISIBLE AND NIR REMOTE SENSING DATA FOR DERIVING OF EARTH'S SURFACE THERMAL FIELDS OF HIGH SPATIAL RESOLUTION

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Застосування супутникових даних видимого та ближнього інфрачервоного діапазону для картування теплових полів земної поверхні із високою просторовою розрізненностю

Недостатня просторова розрізненність даних космічного знімання у діапазоні 8-14 мкм не дозволяє достатньо детально досліджувати теплові поля територій із високою неоднорідністю поверхонь, наприклад, міського середовища. Дані видимого та ближнього інфрачервоного діапазону, які зазвичай мають значно більшу просторову розрізненність, дозволяють отримати розподіл коефіцієнта теплового випромінювання, що не лише дозволяє розрахувати фізичну температуру земної поверхні засобами дистанційного зондування, а і значно підвищити інформативність отриманого зображення теплового поля.

Sensors that are provide 3-14 μm data have been widely used in the field of Earth remote sensing and allow the creation of products based on the detection of cells of intense thermal radiation (detection of forest fires, study of volcanic activity) or the formation of maps of the thermal field of low spatial resolution for the solution of meteorological problems. However, the possibility of creating of detailed thermal field maps is complicated by constraints associated with significantly lower energy of quantum radiation compared with the visible and near infrared radiance. Therefore, most existing sensor systems have a spatial resolution of 3-14 microns ≈1 km and are unsuitable for studying many of types landscapes like urban areas.

The TIRS sensor installed on the Landsat-8 satellite is used for this purpose [1]. The sensor provides data in two bands (10.3-11.3 μm and 11.5-12.5 μm), has a spatial resolution of 100 m, interpolated to 30 m, which corresponds to the spatial resolution of the second sensor of the visible and infrared data provided by OLI sensor. Landsat-8 continues a series of Landsat satellites, and its data can be combined with Landsat-4, 5, and 7 images, thus, it is possible to create time series from 1982.

The end-product of the long-wavelength infrared radiance data processing is the Earth's surface physical temperature. It takes into account the thermal emissivity of the presented surfaces. The emissivity can be estimated on the basis of the visible and near infrared data processing, which allows obtaining sufficiently detailed data on the thermal characteristics of the presented landscapes and significantly improving the informativity of the resulting surface temperature distribution.

Determination of the Earth's surfaces emissivity distribution using remote sensing data is performed by processing images of the visible and near-infrared range, in particular by establishing of the relationship between emissivity the NDVI index distribution. The source of the visible and near-infrared data can be any satellite sensor that able to provide it. The emissivity is a rather inert surface feature, and for its determination it is possible to involve data obtained with some time interval in comparison with the data of the long-wavelength range. The determination emissivity and the NDVI index relationship for the surfaces covered with vegetation and bare soil is established separately from other types of surfaces, including artificial ones.

For soils and vegetative cover, this dependence is established on the basis of the projective vegetation cover density for each individual pixel based on the image of the NDVI distribution, which is defined as follows [2]:

$$F = \left(\frac{NDVI - NDVI_0}{NDVI_\infty - NDVI_0} \right)^2 \quad (1)$$

where $NDVI$ – the value of the normalized vegetation index in the current pixel; $NDVI_0$ – - maximum value of normalized vegetation index of bare soil; $NDVI_\infty$ – minimum value of the normalized vegetation index of the surface, completely covered with vegetation.

The calculation of the total emissivity is carried out as follows:

$$\varepsilon_\lambda = \varepsilon_{v\lambda} \cdot F + \varepsilon_{s\lambda}(1-F) + \Delta\varepsilon_\lambda, \quad (2)$$

where ε_λ – surface emissivity in current pixel; $\varepsilon_{v\lambda}$, $\varepsilon_{s\lambda}$ – emissivities for a surface completely covered with vegetation and bare soil or another surface, where there is no vegetation relatively; $\Delta\varepsilon_\lambda$ – an amendment that takes into account the irregularity of radiation due to rough surface (the standard value for a rough surface is 0,005).

This relationship for other types of covers is estimated on the basis of the regressive dependence between artificial surfaces spectra taken from ASTER Spectral Library and NDVI index outside its range which corresponds to the vegetation cover and open soil. On the basis of the obtained spectra a point cloud of dependence of the averaged emissivity of each of the typical spectra from NDVI index is expressed through zonal sensor signals in the red and near infrared bands. The resulting cloud of points is averaged over both axes and the quasi-optimal spline-approximation of the dependence is performed through the obtained averaged point (Fig. 1).

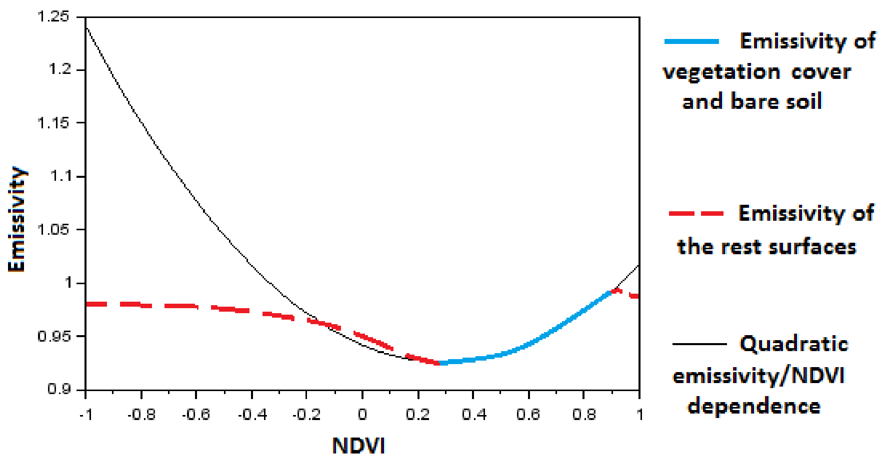
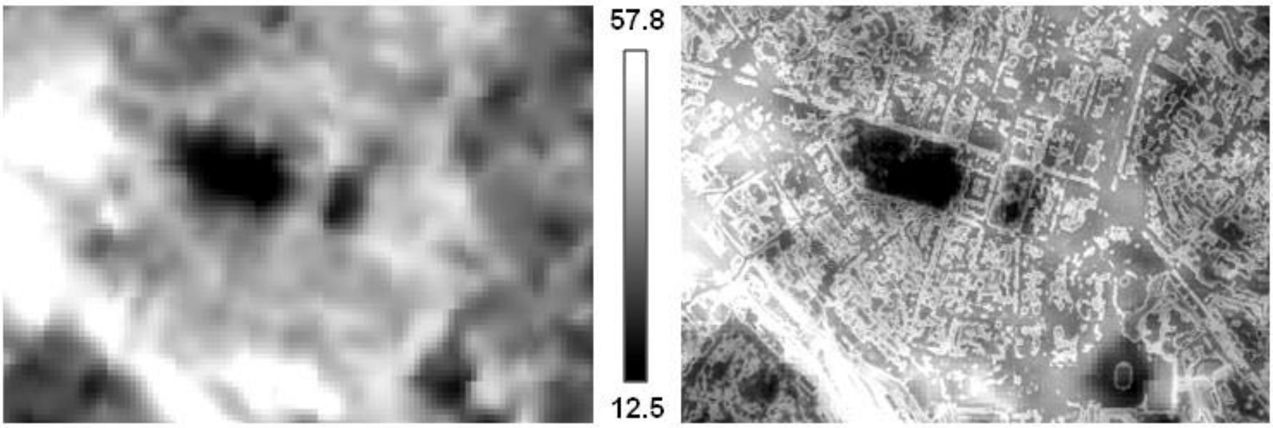


Fig. 1. Distribution of the relationship between Earth's surfaces emissivity and NDVI vegetation index

This method of the Earth's surface temperature distribution obtaining is most effective with the visible and near-infrared data obtained by Sentinel series satellites of the in combination with the long-wavelength infrared data provided by the Landsat satellites. Although additional image adjustments are required, the Sentinel data has a spatial resolution of 10 m in the visible and near infrared, compared to 30 m for Landsat. Fig. 2 shows a comparison of temperature distribution images based on input data of the TIRS sensor and with use of emissivity distribution based on Sentinel-2 data.



a *b*

Fig.3. The urban landscape temperature destribution: *a*) with generic TIRS sensor data, *b*) with emissivity derived using Sentinel-2 visible and NIR data

It is also possible to achieve further spatial resolution increase using specialized subpixel processing of pairs of emissivity distribution images [3]. Obtaining an image of enhanced spatial resolution from a pair of images of low spatial resolution is achieved by performing a sequence of actions:

- Generation of a noise distribution image common for both input images;
- Merge low-resolution input images into a common resampled image by interlaced scan to a grid of high resolution, replacing two pixels diagonally with pixels of input images, taking into account the subpixel offset and noise matrix;
- Estimation of the inverse operator matrix, due to rest of the pixels restoration;
- Restoration of the image of high spatial resolution;
- Iterative image reconstruction to eliminate irregularities and suppress noise.

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