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ABOUT REGIONAL COSMIC MONITORING OF SNOW COVER IN THE SOUTH-EASTERN REGION OF THE GREATER CAUCASUS

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A methodological approach to space monitoring of snow cover in the south-eastern region of the Greater Caucasus is considered. Based on the Landsat 9 image data, an index image was constructed for the winter season and a classification of snow cover was carried out.

Keywords: space monitoring – south-eastern region of the Greater Caucasus –snow cover

1. INTRODUCTION

The current stage of development of space research is characterized by the regular use of satellite data to obtain prompt and accurate information about the state of the environment both at the local and global levels. These studies are based on Earth remote sensing (ERS) methods. These methods are based on spectrophotometric measurements of the energy characteristics of the reflection of sunlight from the "atmosphere – earth's surface" system [1, 6]. Remote sensing data are indispensable sources when studying natural phenomena in remote mountainous areas. Current problems of remote sensing include issues of cartographic modeling of snow cover using geoinformation systems technologies. Modeling the snow cover of mountain peaks is one of the stages of modeling the hydrological cycle as a whole [2,6]. In this work, a comprehensive study of snow cover is carried out using data from the Landsat 9 satellite for the South-Eastern region of the Greater Caucasus. This region is famous for its Shollar water (spring water pro-

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duced in the village of Shollar, Khachmaz region of the Republic of Azerbaijan) [7].

2. METHOD OF CALCULATION

Data obtained from satellites is initially considered an unprocessed or “raw” product [6]. Processing of spatial images is divided into several stages. (fig. 1) [1–3]: - obtaining unprocessed (raw) images;

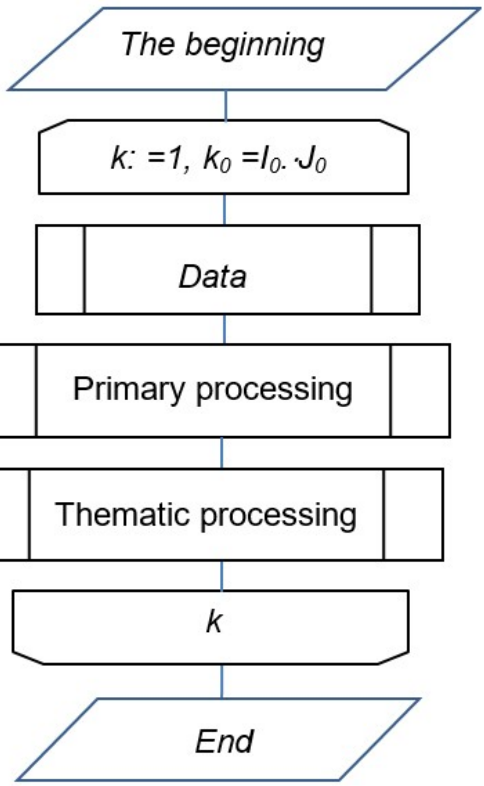

Fig. 1. Block diagram of spatial image processing.

- pre-processing (level 0): image restoration of fuzzy areas, sorting data in chronological order with full resolution and saving all auxiliary data;

– pre-processing (level 1): geometric, radiometric and atmospheric correction;

– secondary processing (level 2): determination of spectral characteristics, spatial structure and temporal changes of observed objects (for example, classification and decoding of an object or area);

– detailed integrated processing (level 3): data generation, thematic processing of aerospace data.

As can be seen from fig. 1, processing of remote sensing data is reduced to thematic processing of images of the earth's surface. This procedure includes image indexing and classification of the earth's surface. The main purpose of this procedure is to map the soil cover.

Indexing of images is based on the calculation of special indices - indicators calculated as a result of arithmetic operations (addition, subtraction, division, multiplication) over different spectral ranges (channels) of remote sensing data, characterizing the reflective and absorption features of the soil cover in a given pixel of the image [2–4] or indexing images are derived mainly empirically [1].

Snow typically has very high visible reflectivity (VIS) and very low short-wave infrared (SWIR) reflectivity. This feature is used for snow detection by distinguishing between snow and most types of clouds [2, 3]. We believe that the reflective properties of the earth's surface are most fully described by the spectral brightness coefficient (SBC) [1]:

$$\rho_\lambda(\mu_0,\mu) = L_\lambda(\mu_0,\mu)/S_{\lambda 0}\cdot\mu_0 \tag{1}$$

where $\rho_\lambda(\mu,\mu_0)$ is the SBC of the underlying surface of the Earth, $L_\lambda(\mu,\mu_0)\left[\mathrm{W}/\left(\mathrm{m}^2\cdot\mu\mathrm{m}\cdot\mathrm{sr}\right)\right]$ is the spectral brightness of direct solar radiation at the upper boundary of the atmosphere at radiation wavelength λ, S_{20} is the spectral solar constant, μ_0 and μ are direction cosines, respectively, the zenith angle of the Sun and the zenith angle of the observation direction.

To probe snow cover, the NDSI index (Normalized Differential Snow Index) is used [6]. Instead of the characteristic $L_2(\mu,\mu_0)$ we use SBC, then we can write:

$$NDSI = \frac{\rho_{\text{Green}} - \rho_{\text{STIR}}}{\rho_{\text{Green}} + \rho_{\text{SWIR}}} \tag{2}$$

where Green is the amount of green light with a wavelength of 0.525 - 6 mkm reflected from the area; SWIR is the amount of short-wave light with a wavelength of 1.56 - 1.66 mkm reflected from the same area. Classification (decoding) of the earth's surface as a method of environmental research is based on the relationship between the physical characteristics of natural objects and phenomena and the way they are reproduced in photographs [1, 2]. Classification of objects is carried out according to certain classes of objects to which they belong. To do this, the so-called decision function $i = f(x)$ is introduced, where i is the number of the class to which the feature vector x of the recognized object belongs. This function is constructed based on partitioning the feature space U into i_0 disjoint classes $U_i, i = 1, \ldots, i_0$:

$$\bigcup_{i}^{i_0} U_i = U, U_i \cap U_j = \varnothing \text{ at } i \neq j \tag{3}$$

The decision function $f(x)$ is used to determine the number i of the region U_i to which the argument x belongs. The criterion for choosing this function can be the minimum identification error. To carry out procedure (3) we use GIS programs.

We consider the use of a regional model of the optical atmosphere as an important condition for the use of formulas (2) and (3), since, as is known, the atmosphere is a significantly distorting factor in the deciphering characteristics of the earth's surface. We solve this problem by using a regional model of the atmosphere of the Caucasus-Caspian region given in [1, 5].

3. CALCULATION RESULTS

First of all, we will take into account the influence of the atmosphere on the rising solar radiation perceived by the sensor on board the satellite. Fig. 2 defines a two-dimensional space of spectral features of the territory of the south eastern region of the Greater Caucasus on the Green and SWIR axes. Due to the disproportionality of the readings in fig. 2, it follows that the effect of the atmosphere of the Green and SWIR channels is significant. Fig. 3 shows the vertical structure of the optical thickness of the atmosphere for the effective wavelength of solar radiation (green light) using an optical model of the atmosphere [1, 5]. The cases of reflection from the water surface and land are considered. The first case corresponds to the case of atmospheric correction of satellite images using the DOS (Dark Object Subtraction) method [6]. We use this case to reconstruct the vertical structure of the atmosphere over land.

In accordance with the scheme of fig. 1, further, indexing (fig. 4) and classification fig. 5 of the satellite image were carried out. Fig. 4 shows the calculated snow areas. The case we are considering corresponds to the case of heavy winter snow (01/31/2024).

Fig. 5 shows the classification of soil cover using a false-color image (table). As can be seen from this figure, the soil cover depends on the terrain. This dependence gives a complete picture of the regional climatic conditions characteristic of the area in question (shown by color characteristics). In accordance with the figure, snowfall on the date in question covers mountainous and foothill areas.

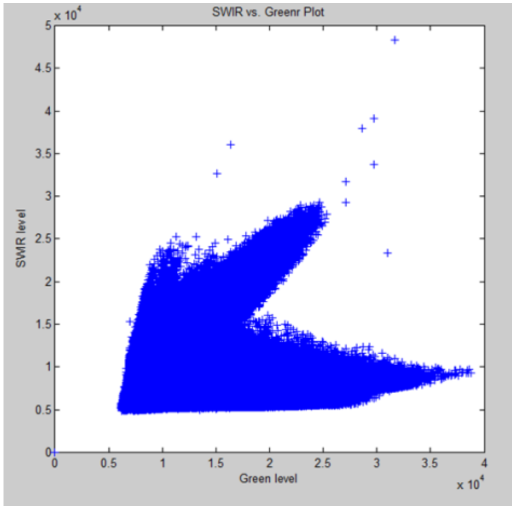

Fig. 2. Two-dimensional space of spectral features of images $LC09\_L1TP\_167032\_20240131\_20240131\_02\_T1\_B3$, and $LC09\_L1TP\_167032\_20240131\_20240131\_02\_T1\_B6$.

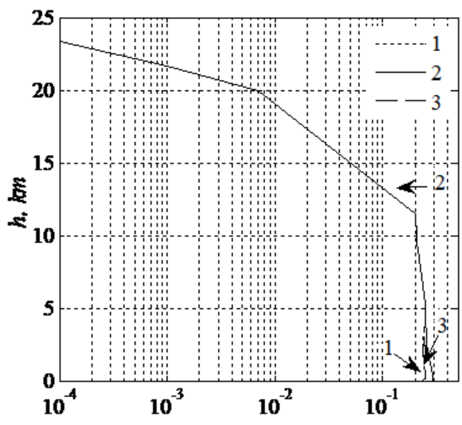

Fig. 3. Vertical profiles of the optical thickness of the atmosphere according to satellite imagery for: 1- the middle part of the Caucasus (the region of the Greater Caucasus), 2- Eastern part of the Caspian Sea, 3- southeastern part of the Caspian Sea ($LC09\_L1TP\_167032\_20240131\_20240131\_02\_T1\_refl$).

4. CONCLUSION

1. A step-by-step method for space monitoring of the southeastern slopes of the Greater Caucasus is given. in winter .

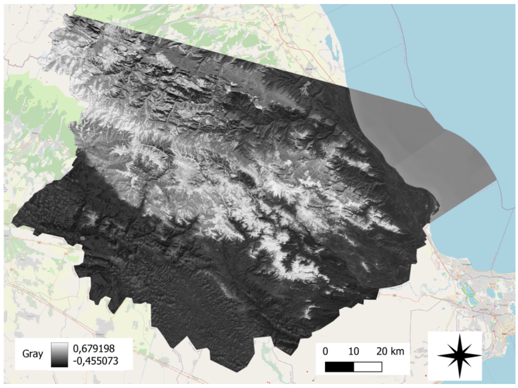

Fig. 4. NDSI for the southastern Greater Caucasus region $LC09\_L1TP\_167032\_20240131\_20240131\_02\_T1\_B3$,B6:Thick snow cover $-770km^2$,Thin snow cover -1533 km^2

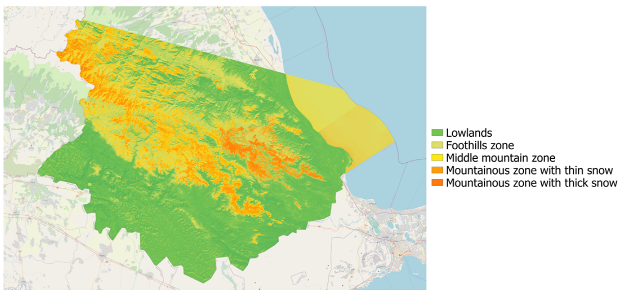

Fig. 5. The south-eastern region of the Greater Caucasus: Earth surface classification ($LC09\_L1TP\_167032\_20240131\_20240131\_02\_T1\_refl$).

Table 1. Image color conversion [1]

Image bands	Water color	Snow color	Soil color
Near IR, R, G	Black	Red	Gray blue

2. Indexing and classification of the Landsat 9 satellite image in the winter period (01/31/2024) was carried out.

3. Thematic maps were compiled and the areas of snow cover distribution were calculated.

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