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USING THE DOS METHOD FOR CALCULATING THE SPECTRAL BRIGHTNES COEFFICIENT OF THE SURFACE OF MARS

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In the present work, it is proposed to use the DOS (Dark Object Subtraction) method to calculate the spatial distribution of the spectral brightness coefficient (SBC) on the surface of Mars using satellite images. This method is used to account for the effect of atmospheric haze on the surface of the planet SBC.

1. INTRODUCTION

Since the end of the 20th century, interplanetary stations have greatly expanded our knowledge about the planet of Mars. Currently, the study of Mars is an important part of space research programs [1].

The purpose of this research is to collect scientific data on the current conditions of Mars. Studies of the red planet are necessary for a better understanding of the past and possible future of the Earth [1, 2].

In the last decade a number of artificial satellites conducted multispectral shooting the surface of Mars [1, 3]. They were repeatedly measured passive reflected solar radiation from the surface of Mars.

An important informative parameter for remote sensing (RS) of the planet's surface is its SBK [2, 4]. Currently, the DOS method is being successfully used to estimate the SBK of the earth's surface from satellites. Dark object substraction is a radiometric correction technique for satellite imagery. The dark object subtraction model (DOS) developed by Chavez 1998 [5] is applied for the earth's atmospheric correction of the satellite data.

The objectives of this work were to examine the applicability of the DOS method to estimate the distribution of SBC surface of Mars using satellite im-

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ages. This method is one of the most common radio metric correction techniques used for remotely sensed data of earth's surface. In accordance with this method, it is assumed that some of the atmospheric effects such as reflection can be removed by finding the darkest pixels in an image and subtracting their values from all other pixels.

2. DETERMINATION OF SBC BY DOS METHOD

The relationship between the at-satellite radiance and the surface reflectance for lambertian surface reflectance approximation, can be described as [4, 6]:

$$L_{sat} = L_{haze} + F^{\downarrow} T \rho_0 / \pi \tag{1}$$

where $_{sat}$ is the at-satellite radiance (in W$\cdot$ $m^{-2} \cdot sr^{-1} \cdot mkm^{(}-1)$, is the path radiance (in W$\cdot$ $m^{-2} \cdot sr^{-1} \cdot mkm^{-1}$), is the irradiance received at the surface (in W$\cdot$ $m^{-2} \cdot mkm^{-1}$), T is the atmospheric transmittance from the target toward the sensor of satellite and ρ_0 is the surface reflectance.

The incoming irradiance at the Earth surface

$$F^{\downarrow} = E + E_{down} \tag{2}$$

where E_{down} is the downwelling diffuse irradiance and E is the beam irradiance, $E = E_0 \mu_0 T_\theta$, where T_θ the atmospheric transmittance in the illumination direction, $\mu_0 = cos(\theta_0)$and θ_0 is the solar zenith angle, $E_0 = \mu_0 \cdot E_{san}/\pi \cdot r^2$ is the exoatmospheric solar constant; E_{san} is the mean solar exoatmospheric irradiances, r is the mean distance of Mars from the Sun in astronomical units.

From Eq. (1), we get for SBC

$$\rho = \pi(L_{sat} - L_{haze})/T(E_0 \mu_0 T_\theta + E_{down}) \tag{3}$$

Due to the atmospheric scattering effects, the dark object is not absolutely dark. Assuming 1% surface reflectance for the dark objects. In accordance with DOS, the L_{haze} radiation in (1) can be written as [5]:

$$L_{haze} = L_{min} - L1\% \tag{4}$$

where L_{min} is the radiance value of the identified darkest within-scene object (spectral radiation for a 1% dark object), L1% is a reflection of a dark object, it is assumed that it has a reflection coefficient of 0.01.

Conversion of luminance values Estimates of L_{sat} in (1) and, accordingly, the estimates of ρin (3) are determined by the conversion of the original (raw DN) pixel brightness values into radiation values in absolute units [5, 6].

$$L_{sat} = \frac{L_{max} - L_{min}}{Q_{cal\,max} - Q_{cal\,min}}(DN_{cal} - Q_{cal\,min}) + L_{min} \tag{5}$$

where: L_{sat} - spectral radiation, which came on the satellite sensor;DN_{cal} - pixel brightness values of raw geoimage; $Q_{cal\,min}$ - the minimum possible pixel value of image; $Q_{cal\,max}$- the maximum possible pixel value geoimage; L_{min}- the minimum value of the spectral radiation for a particular satellite sensor for a particular image; L_{max} - the maximum value of the spectral radiation for a particular satellite sensor for a particular image.

3. RESULTS AND DISCUSSION

Currently, various modifications of the DOS method are used for remotely Earth remote investigation. For the application of this method in the exploration of Mars, we use DOS2(COST) technique.

Examples of the results of calculations of the SBC distributions from images of the surface of Mars in Fig.1 and 2 and the shooting parameters in the table are shown in fig.3 and 4. In the calculations used matlab software package [8]. In

Table 1. Parameters of shooting images in fig. 1 and 2, [3, 7].

Parameters						
$L_{\lambda min}, W \cdot m^{-2} \cdot sr^{-1} \cdot mkm^{-1}$	$L_{\lambda\,max}, W \cdot m^{-2} \cdot sr{-}1 \cdot mkm^{-1}$	$Q_{cal\,min}$	$Q_{cal\,max}$	$E_{\lambda san}$ $W \cdot m^{-2}$ mkm-1	μ_0	r, a.u. (at the minimum approximation distance)
-5.0	95.4	256	1	1969.000	0	1.38

fig.1 and fig.3 the images from NASA's Mars Odyssey shows part of Arena Colles (fig.1) and polar ise of Mars (fig.3).

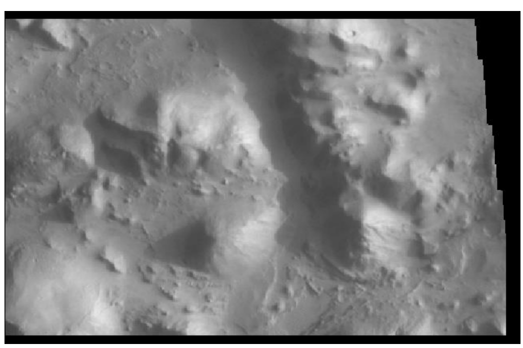

Fig. 1. 1.Image of mars. Mission: from NASA's Mars Odyssey (2001), Addition Date for 2019-07-15, Instrument: THEMIS.

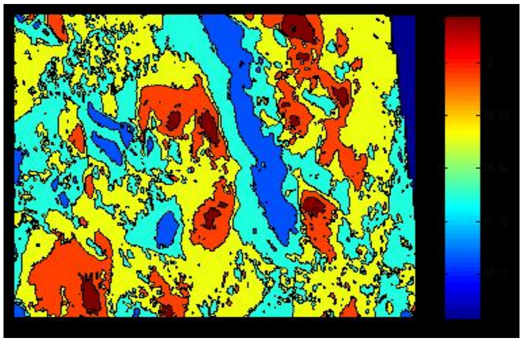

Fig. 2. The distribution of the SBC of the underlying surface, calculated from the satellite image from fig. 1.

Figure 1 clearly seen sharp outlines of light and shadows on the surface of Mars. Accordingly, as can be seen from Fig. 2, this leads to a strong difference in the distribution of SBC in the gorges, lowlands, shadow and illuminated parts of the surface of Mars.

The value of SBC is the smallest in the gorges and the greatest in the lighted part of the mountain peaks. This distinction occurs more than 5 times.

In fig. 3 lighter areas result in high SBC distributions (fig. 4). And here we see a strong contrast of SBC distributions.

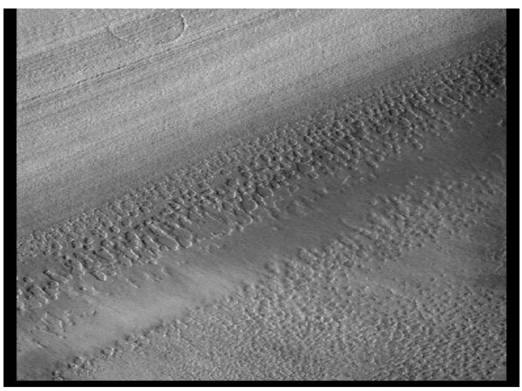

Fig. 3. Image of mars. Mission: from NASA's Mars Odyssey (2001), Addition Date for 9-03-15,Instrument: THEMIS.

This can be caused by the polluting action of strong dust storms occurring on the surface of Mars. On the example of Figures 2 and 4, it can be seen that the SBC calculations using the DOS method make it possible to clearly distinguish the difference in the reflecting properties of the Mars surface.

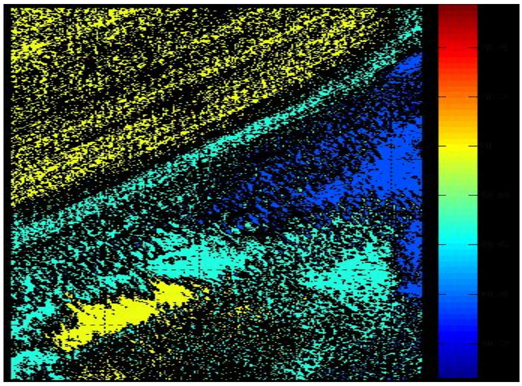

Fig. 4. The distribution of the SBC of the underlying surface, calculated from the satellite image from fig. 4.

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