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FIELD SPECTROSCOPY MEASUREMENTS OF ROCKS IN EARTH OBSERVATIONS

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ABSTRACT. Remote sensing applications in Earth observation begin with the design and development of equipment for carrying out research of the monitored objects remotely and without disturbing their integrity. Ground-truth data in Earth observation of the environment and in the remote sensing investigations are very important. The main goal in the geological remote sensing is the determination of the chemical and/or mineral composition and the structure of the rocks. For this purpose the field spectroscopy measurements of the samples of the main rock types are performed. These measurements are made to collect, compile and complete guide with spectral characteristics of different rocks for their reliable identification and for the determination of their mineral and chemical composition. The experiments are based on major physical principles such as light scattering, absorption of light, and reflection of light in the electromagnetic spectrum. In the field-based studies the Thematically Oriented Multi-channel Spectrometer designed and constructed in Remote Sensing Systems Department at SRTI-BAS is used. The spectrometer with increased spectral resolution works in (400-900) nm range of the spectrum. The obtained spectral data are compared with similar data from different instruments for Earth observation included in the spectral libraries. They correspond to the shape of the spectral signature in the same spectral range obtained with other spectrometers. These promising results encourage us to plan the next campaigns for the field spectroscopy measurements in different regions of Bulgaria.

ТЕРЕННИ СПЕКТРОМЕТРИЧНИ ИЗМЕРВАНИЯ НА СКАЛИ В КОМПЛЕКСНИТЕ НАБЛЮДЕНИЯ НА ЗЕМЯТА

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РЕЗЮМЕ. Приложението на спътниковите изображения при комплексните наблюдения на Земята започва с проектирането и конструирането на апаратура за извършване на наблюдения на изучаваните обекти от разстояние и без да се нарушава тяхната цялост. Наземните данни са много важни в мониторинга на околната среда и в дистанционни изследвания на Земята. Една основна цел в дистанционните изследвания за нуждите на геологията е определянето на химичния и/или минерален състав и на структурата на скалите. За тази цел са извършени полеви (теренни) спектрометрични измервания на образци от основните видове скали. Тези измервания са направени, за да се събере, състави и периодично да се попълва ръководство със спектрални характеристики на различните скали с цел тяхното надеждно идентифициране и за определяне на минералния и химичния им състав. Експериментите са базирани на основни физични принципи като разсейване, абсорбция и отражение на светлината в електромагнитния спектър /ЕМС/. В теренните проучвания е използван тематично ориентиран многоканален спектрометър, проектиран и изработен в секция Системи за дистанционни изследвания /СДИ/ в ИКИТ-БАН. Спектрометърът с повишена спектрална разделителна способност работи в диапазона на ЕМС (400-900) nm. Получените спектрални данни са сравнени с подобни данни от различни инструменти за наблюдение на Земята, включени в спектрални библиотеки. Получените зависимости съответстват на формата на спектралните сигнатури в същия обхват на спектъра, получени с други спектрометри. Тези обещаващи резултати ни насърчават да планираме следващи кампании за теренни спектрометрични измервания в различни региони на България.

Introduction

Remote sensing using geophysical principles begins with the development and design of equipment for performing research of objects remotely and without disturbing their integrity. In geological remote sensing studies the determination of the chemical/mineral composition and the structure of the objects within the field of view of the instrument either obtained in the lab, with a field spectrometer, or with a remote sensor is a main goal. Or in other words: "What kind of rock am I looking at?" For this purpose field spectrometric studies of rocks were made to collect spectral signatures of different rock types for the reliable detection and identification of their mineral and chemical composition. The aim of this study is to present and test the procedure of preprocessing of the field spectrometric data. The experiments are based on major physical principles such as light scattering, absorption of light, and reflection of light in the electromagnetic spectrum (EMS). Field spectral measurements were made with Thematically Oriented Multi-channel Spectrometer designed and constructed in Remote Sensing Systems Department at SRTI-BAS. The spectrometer with increased spectral resolution works in (400-900) nm range of EMS. The results are compared with similar data from spectral libraries. They correspond to the shape of reflectance spectra in the same range of EMS obtained with other spectrometers.

Theory and Methods

Physical principles. Main physical principles that are based for performed experimental measurements are: scattering, absorption and reflection of the solar radiation in the visible range of electromagnetic spectrum (ems). Two major definitions which refer to the measurements carried out:

• Rocks are natural mineral aggregates and thus considered in the experiments;

• Hapke's equation to model the reflectance (r_λ) from an exposed rock (Hapke, 1981). The point of all of this is that with knowledge of known optical constants of various minerals and the angle of incident and emitted light, we can model the reflectance of a rock with mixed minerals and grain sizes.

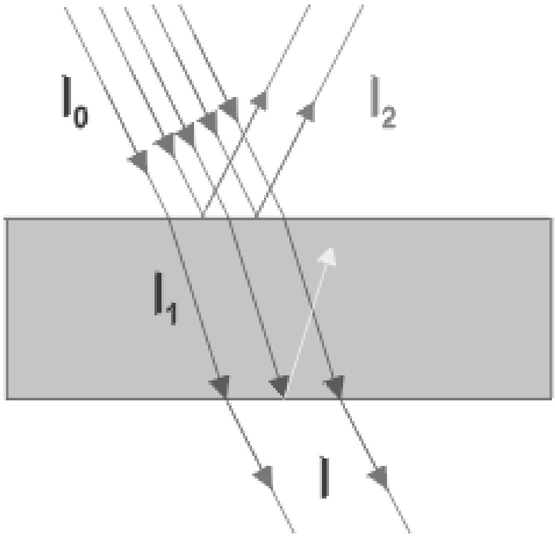

Fig. 1. Physical processes in solid transparent parallel plate

What does the solar radiation do when it hits a rock? When the radiation reaching the object (in this case - the rocks) it simultaneously scattered, reflected off of the grains either away from the surface or onto other grains, refracted through a grain onto other grains and absorbed by a grain. Thus the physical processes occur simultaneously (Figure 1) and following physical laws and relationships are applied:

• Beers Law (exponential law of absorption):

$$I = I_0 e^{-kx} \quad (1)$$

I – observed light intensity [W/sr], I_0 – original light intensity [W/sr], *k* – absorption coefficient ($k = 4K/\lambda$) [m^{-1}] and *x* is the distance traveled through the medium [m].

• Intensity of reflected solar radiation I_2 [W/sr]:

$$I_2 = I_0 \left(\frac{n-1}{n+1} \right)^2 \quad (2)$$

$$R = \left(\frac{n-1}{n+1} \right)^2 \quad (3)$$

R is the reflection coefficient, is defined for two types of media, and is not dependent on the direction of propagation and *n* is the relative refractive index of the reflecting medium.

• Spectral reflectance (measured in the field):

$$r_\lambda = L_\lambda / L_{calib} \quad (4)$$

represents a measure of the ability of a surface to reflect solar radiation which criterion is equal to the ratio of reflected solar radiation by the object for each wavelength L_λ [W/(m^2.sr)] to reflected solar radiation by the calibrated reference surface the same wavelength L_{calib} [W/(m^2.sr)] in the same conditions of these measurements. Resultant graph plotted as a functional dependence r_λ vs. λ is called the spectrum or the spectral reflectance characteristics, or the spectral signature.

Spectrometric measurements. The field spectrometric measurements in this research are performed using the thematically oriented multichannel spectrometer (TOMS) working in (400 - 900) nm range of the EMS (Petkov et al., 2005a,b). The main measuring device of the field spectrometer TOMS is USB2000 (Ocean Optics, 2013).

The preprocessing is an important part of analysis of imaging spectrometry data and is relevant to a quantitative estimation of the data. It includes realization of characterization and correction procedures eliminating at sensor effects and data correction algorithms accounting environmental conditions. The measured radiance is influenced by a number of factors such as instrument response characteristics, atmospheric conditions, changes in scene illumination and viewing geometry.

More spectrometer characteristics will be expected to remain constant through instrument life and can be characterized in laboratory condition, while others will be expected to change during the operating mode and these must be corrected at the field work The characterization methods and correspondence procedures are determined in detail on the basis of error analyses. The frequency of characterization processes and algorithm update will vary with rate of errors change.

The following preprocessing procedures are expected to be considered critical for data calibration:

- atmospheric correction;
- spectral data correction;
- radiometric data correction.

Atmospheric correction reduces the radiance at the sensor to a reflectance value at the object.

When detailed radiometric correction is not feasible, normalization is an alternative could be makes the corrected data independent of multiplicative noise such as topographic and solar spectrum effects. This can be performed using white calibrated target (reference standard), and the results are based on the relationship between radiance and reflectance.

A way for preprocessing of spectrometer data is indicated in the flow diagram (Figure 2).

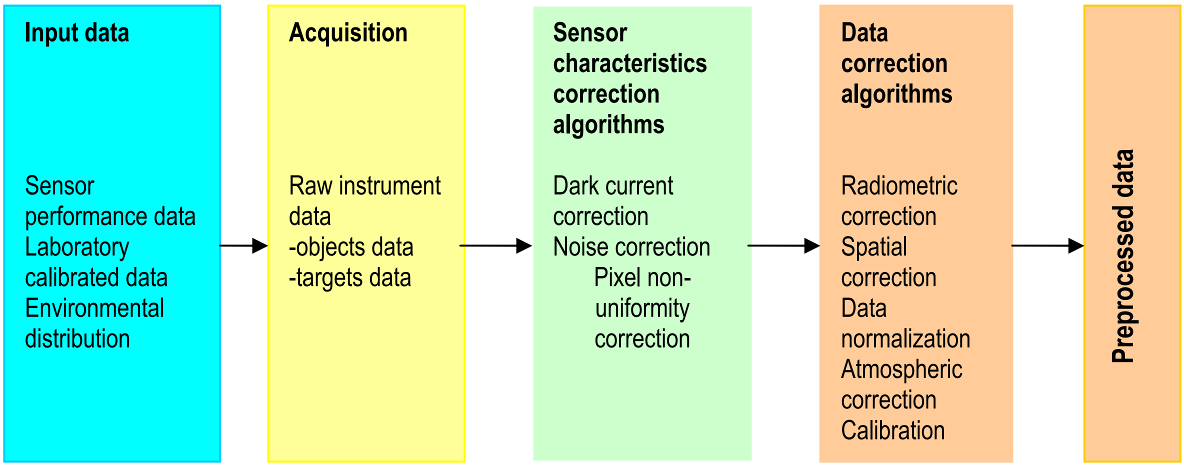

Fig. 2. Preprocessing data flow diagram

The preprocessing algorithms of the received data are performed by the software of the spectrometer and include: the correction for electrical dark, the noise correction, the radiometric correction, the statistical correction and calibration (Atanassov and Jelev, 2004; Atanassov et al., 2005). The atmospheric correction is not needed in these filed experiments because of the low distance between the studied object and the fore optics of the spectrometer (see Table 1).

In Table 1 as a part of the preprocessing data the additional information is presented. In addition we have to take in account GPS-coordinates of the field points of measurement (*GPS*), weather conditions of the measurements in the field experiments (*atm*), the integration time for each acquisition (t_i), the number of statistically averaged spectra (λ_n) and the distance between the object and the device fore optics (H_{oo}).

Table 1. *Additional information per experiment*

point	object	GPS coordinates	Mountain	atm	t_i, ms	λ_n	H_{oo}, cm
1	monzonite	N42°35'18" E23°17'34"	Vitosha	clear, shadow	5	100	10
2	granite	N42°09'14" E23°19'53"	Rila	clear, shadow	5	100	10
3	diorite	N43°07'39" E23°08'04"	Stara planina	clear, shadow	5	100	10
4	reference standard	at every point	at every point	clear, shadow	5	100	10

Short petrographic description. Plutonic rocks in the Vitosha mountain are gabbro, monzonites, leucosyenites and granosyenites (Димитров, 1942), which according to modern petrographic nomenclature are monzodiorites, quartz-monzodiorites, quartz-monzonites, syenites, and quartz-syenites (Дабовски и др., 2009). Field spectrometric studies in the area of Hotel Moreni are made for the monzonites. Monzonites are colorful, grey-greenish, and medium-to-coarse-grained, with a massive structure and monzonitic texture. The rock-forming minerals are plagioclase, K-feldspar, augite, amphibole, biotite, a little quartz, accessory magnetite, apatite and titanite. The rocks are relatively fresh, with the rarely overlaped secondary mineral association - sericite, clay minerals, carbonate, epidote and chlorite.

In Rila Mountain the area of the locality Kirilova polyana is consisted of high-grade metamorphic rocks, metamorphosed ultrabasic and basic igneous rocks; called South Bulgarian granitoids, aplite-pegmatoid granites and fine-grained biotite granites. Spectrometric studies were made of the fine-grained biotite granite. They expose near Kirilova polyana and in the West direction and form the Monastic Body. Fine-grained biotite granites are light gray with a massive structure and hypidiomorphic texture. The rock-forming minerals are magmatic K-feldspar, quartz, plagioclase, biotite and zircon and secondary - sericite, chlorite and clay minerals.

On the road to the village Barziya in about 3 km after Petrohan pass are revealed magmatic rocks from Petrohan pluton. It is a complex magma body emplaced into rocks of Berkovska and Dalgidelska groups. It is made of several magmatic phases: the first is gabbro, widespread in northern part of the pluton near Berkovitsa; the second is represented by diorites, and the third - by granodiorites. The largest areas occupy diorites and granodiorites. Field spectrometric studies have been made of the diorites. They are gray, grey-greenish, medium-grained, and uniform-grained. Their structure is massive, and the texture – prismatic granular. The main rock-forming minerals are plagioclase (andesine) and amphibole, secondary – biotite and augite, and accessory - titanite and magnetite.

Results and Discussion

For the reflectance calibration of the spectrometric measurements in the field we used a reference standard. The field standards are reference materials that should exhibit a highly Lambertian reflectance over the whole spectral range of interest. In addition, the reflectance of the materials should be insensitive to the bidirectional reflectance distribution function effects and should reflect at least more than 80% of the incoming solar radiation.

Since contamination of the standards material is often a problem, the spectral and spatial characteristics should not degrade over time and – if used frequently in the field – should be able to be washed or rinsed to remove contamination or particles such as mud, sand or others (Schaepman, 1998). The used reference standard is made from barium sulphate and its surface exhibits lambertian behavior (Figure 3).

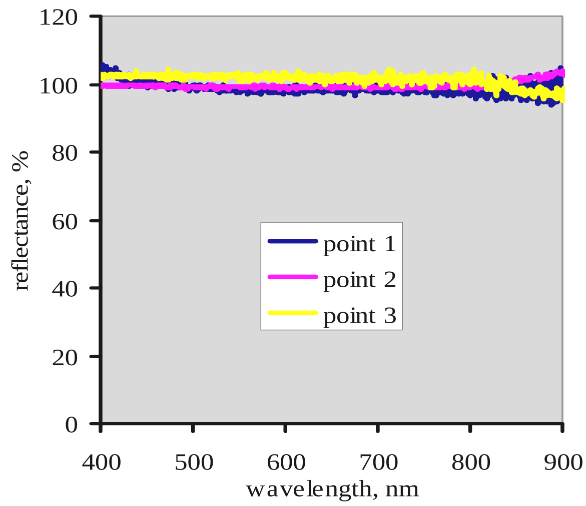

Fig. 3. Reflectance spectra of the used reference standard

In Figure 4 the presented reflectance spectra of three rock types are resulted as following the above described procedure. The obtained spectral data are pre-corrected under laboratory conditions.

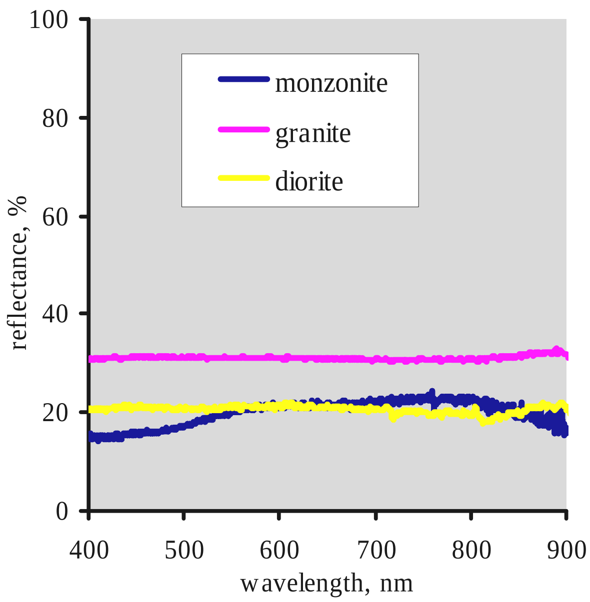

Fig. 4. Reflectance spectra of the studied rocks

The received, preprocessed and analyzed data are compared with similar data from the spectral libraries (USGS, 2013). The spectral libraries represent the collections of spectra of numerous minerals and rocks obtained using the spectrometers with high radiometric and spectral resolution. Collected spectra could be compared with other spectra in order to be more accurately identified objects of comparative research. It is particularly important to take into account that data from different spectrometers should be compared only when they are converted to the criterion of comparability - the reflectance coefficient. Such spectral libraries are the basis for comparative remote sensing studies of rocks.

Conclusions

The procedure of the preprocessing of the field spectrometric data is presented and tested. Obtained with the spectrometer TOMS the reflectance spectra of the studied rocks correspond as form and values of spectral reflectance in the same range of EMS to the similar signatures received using other spectrometers and presented in the spectral libraries.

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