XXVIII INTERNATIONAL SYMPOSIUM ON
MODERN TECHNOLOGIES, EDUCATION AND PROFESSIONAL PRACTICE
IN GEODESY AND RELATED FIELDS

Sofia, 08 - 09 November 2018

REMOTE SENSING SYSTEMS FOR THEMATIC SPECTRAL DATA COLLECTION

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Abstract.

Remote sensing technique is a general tool to study the different surfaces of the Earth and to investigate the planets in the Solar System. The development of the implementation capabilities of the optoelectronic devices which are long-term-tested in the laboratory, in the field and are mounted on-board of the remote sensing platforms further improves the capability of instruments to acquire information about the Earth and its resources in different scales. Remote sensing application in the Earth and planet observations begins with the design and the assembling of equipment for performing research of the observed objects remotely and without disturbing their integrity. Remote sensing methods for studying of rocks are closely related to current programs for the mineral and chemical composition study of the Earth, Mars and Phobos surfaces. Ground-truth data in the Earth observations of the environment and in the remote sensing investigations are very important. The experience and the knowledge from previous experiments in space missions encourage us to continue our efforts to acquire spectral data using different remote sensing systems, to compare the obtained results, and to use the acquired data for filling the thematic spectral data collection. For this purpose the laboratory and the terrain spectrometric measurements are completed. These measurements are made for filling data collection with spectral reflectance data of rocks for their reliable identification and for the determination of their mineral and chemical composition. In the present study ex-situ and in-situ spectrometric measurements of the granites together with their rock-forming minerals from the territory of Bulgaria in visible and near infrared range of the electromagnetic spectrum are performed using following remote sensing systems: SRM, (400-820) nm; SPS-1, (550-1100) nm; Thematically Oriented Multi-channel Spectrometer /TOMS/, (400-900) nm; all of them designed and constructed in Remote Sensing Systems Department at Space Research and Technology Institute-Bulgarian Academy of Sciences /RSS-SRTI-BAS/. All the systems are calibrated before and through the performed measurements. The obtained spectral data are compared with similar data from different instruments for Earth observation included in the reference spectral data collections, also known as spectral libraries. Our results correspond to the shape of the spectral signatures in the same spectral range obtained with other spectrometers. The achieved results proved that this methodology could be applied for comparing the spectral data acquired by different remote sensing systems. These results give us confidence to plan the next campaigns for the terrain spectrometric measurements in different regions of Bulgaria.

Introduction

In Earth observations for supporting mineral exploration and mapping geology, and for recognizing minerals and rocks by their spectral signatures, and for the future planning of satellite missions, the in-situ reference spectral data are very important. Remote sensing measurements made in laboratory and in terrain (in-situ) provide helpful information for research studies and for analyzing data from remote sensing systems located on airborne and satellite platforms. Remote sensing methods for studying of rocks are closely related to current international programs for the mineral and chemical composition studies of the Earth, Moon, Mars and Phobos surfaces.

The authors of this study aimed to present the application of the remote sensing systems for thematic spectral data collection as well as in own previous experiments [1,2] and as in the new ones for a thematic spectral data collection, in this case, filled with spectral reflectance data for rock types. For the purpose of the present paper ex-situ and in-situ spectrometric measurements of the granites together with their rock-forming minerals from the territory of Bulgaria in the visible and near infrared /VNIR/ range of the electromagnetic spectrum /EMS/ are performed using following optical remote sensing spectrometric systems in selected ranges: SRM, (400-820) nm; SPS-1, (550-1100) nm; Thematically Oriented Multi-channel Spectrometer /TOMS/, (400-900) nm. All the systems have been developed in RSS at SRTI-BAS. The obtained spectral data are compared with similar data from different instruments for Earth observation included in the reference spectral data collections, also known as spectral libraries. The U.S. Geological Survey - USGS spectral library is a biggest one and is related as to Earth observations as well as spacecraft mission planning [3]. In the USGS spectral library are described forms of a knowledge base for the characterization and mapping of materials and provides important compositional standards. The USGS spectral library contains information about spectral features and characteristics mainly of minerals and rocks but also for soil and vegetation.

Our results correspond to the shape of the spectral signatures in the same spectral range obtained with other spectrometers. The achieved results proved that this methodology could be applied for comparing the spectral data acquired from different remote sensing systems. These promising results encourage us to plan the next campaigns for the terrain spectrometric measurements in different regions of Bulgaria.

Materials and methods

Remote sensing systems

In this study for measuring the reflectance spectra of the granite samples and their rock-forming minerals three remote sensing systems described below are used.

Remote sensing system SRM [4,5] for laboratory and terrain measurements accomplished from the components:

1) monochromator Joben-Yvon, sampler H-10;
2) digital radiometer Tektronix, sampler J-16.

The system has the following main specifications:

- spectral range of the monochromator - 300-820 nm;
- operating spectral range - 400-820nm;
- number of channels - 43;
- channels width band - 8 nm;
- focused diffraction grating with 1800 lines per mm;
- radiometer spectral range - 374-1100 nm;
- digital indication.

Remote sensing system SPS-1 [6,7] for laboratory measurements (Figure 1) is the second one. The main parameters of the system are:

1) monochromator SPM-1 Karl-Zeiss;
2) photosensor RL512S - Reticon;
3) archive of the spectral information 5.25” Mini-Disk;
4) interface RS-323.

Figure 1. Remote sensing system SPS-1

Technical specification of the spectrometric system:
- operating spectral range - 360-1100 nm;
- spectral resolution - 0.24 nm, 0.384 nm, 5.4 nm;
- photosensor dynamic range - > 10^4;
- exposure time - 50 ms;
- dynamic RAM - 44 кB.

Remote sensing system TOMS [8,9] for thematic laboratory and terrain measurements is described below (Figure 2):

Figure 2. Remote sensing system TOMS

Components of the system:

- VIS-NIR multichannel spectrometer
- optical unit – lenses and fiber
- module for pre-processing of spectrometric data
- communication system for data transmission

Technical specification of the spectrometric system:
Spectral VIS- NIR range: (450 ÷ 900) nm
Number of spectral channels: 128 - 64
Channel location: even
Spectral resolution: (3 ÷ 10) nm
Spatial resolution: (1 ÷ 25) m^2
CCD line elements: 2048
Dynamic range:
- of the system - 4 x 10^4
- per scan - 2000 : 1
Exposure time: (3 ÷ 60) ms
Measurement duration: (10 ÷ 30) min

Petrographic description

The objects of this experimental study are samples of granite as representative of the petrographic group of granite-rhyolite. Group is considered as a major because granites are the most common intrusive igneous rocks. Most of the granite samples are bright and contain an average of about 10% ferrous minerals [10]. The granite samples are massive and from coarse-to-medium-to-fine-grained. The main minerals are K-feldspar, quartz and plagioclase, secondary - biotite and accessory - zircon and magnetite [11]. Also objects of the research are the single solid samples of potassium feldspar, orthoclase, quartz and muscovite. The reflectance spectra of the all rock-forming minerals present as inclusions in the studied rock samples are also measured. The samples of the granites are from the regions from Bulgaria.

Mineral content of the studied objects is of particular importance. It determines the distribution of the reflected from the surface radiation. The amount of the reflected light depends on the mineral content. The studied samples of granites are with different proportion of mafic (biotite /Bio/, amphibole /Amph/) and salic (quartz /Q/, potassic feldspar /KFsp/, plagioclase /Pl/, muscovite /Mu/) rock-forming minerals.

Preprocessing of spectral data

The preprocessing is an important part for the obtained spectral data and is relevant to a quantitative estimation of the data. It includes the 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 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 [12-15].

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.

Spectral data are pre-corrected under laboratory conditions.

The preprocessing algorithms of the received data are performed by the software of the spectrometers and include: the correction for electrical dark, the noise correction, the radiometric correction, the statistical correction and calibration. The atmospheric correction is not needed in these experiments because of the low distance between the studied object and the fore optics of the spectrometer. As a part of the preprocessing data the additional information has to take in account: the integration time for each acquisition (t_i = 5 ms), the number of statistically averaged spectra (λ_n = 100) and the distance between the object and the device fore optics (H_{oo} = 10 cm).

For the reflectance calibration of the spectrometric measurements we used a reference standard. The 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 [16]. The used reference standard is made from barium sulphate and its surface exhibits lambertian behavior.

The obtained spectral data are converted into the value of the spectral reflectance in percent or as a part of the unit by applying the following equation $r_\lambda = L_\lambda / L_{calib}$. It represents a measure of the ability of a surface to reflect the radiation which criterion is equal to the ratio of the reflected radiation by the object for each wavelength L_λ [W/(m^2.sr)] to the reflected radiation by the calibrated reference surface the same wavelength L_{calib} [W/(m^2.sr)] in the same conditions of the measurements. Resultant graph plotted as a functional dependence r_λ vs. λ is called the spectrum or spectral curve, or spectral reflectance characteristics, or spectral signature, or reflectance spectra.

Results and discussion

The granites reflectance spectra obtained using the described remote sensing systems are presented on Figure 3. The results show one and the same tendency in the spectral data for studied granites. The values of reflectance are depending on the structural and chemical composition of the granite samples.

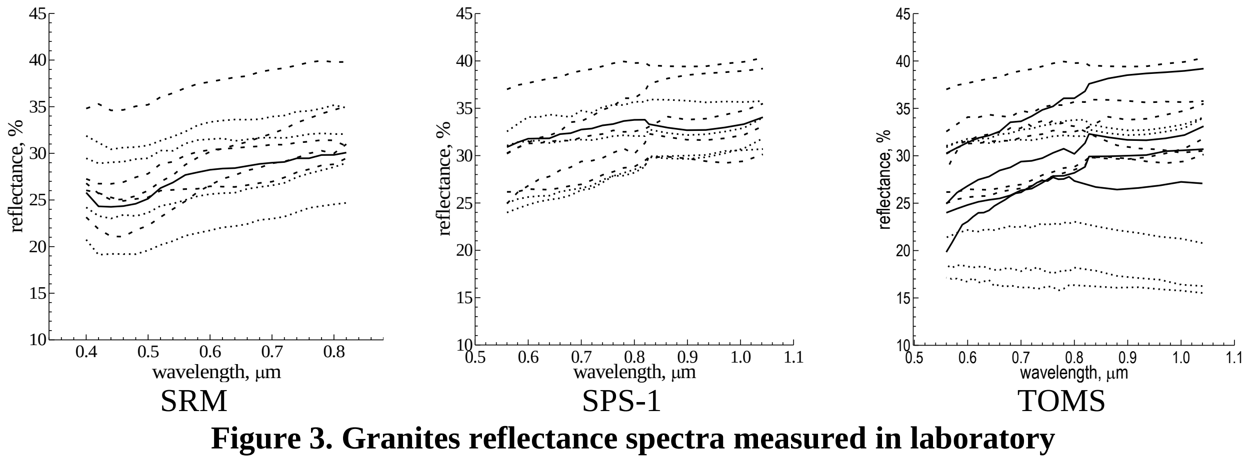
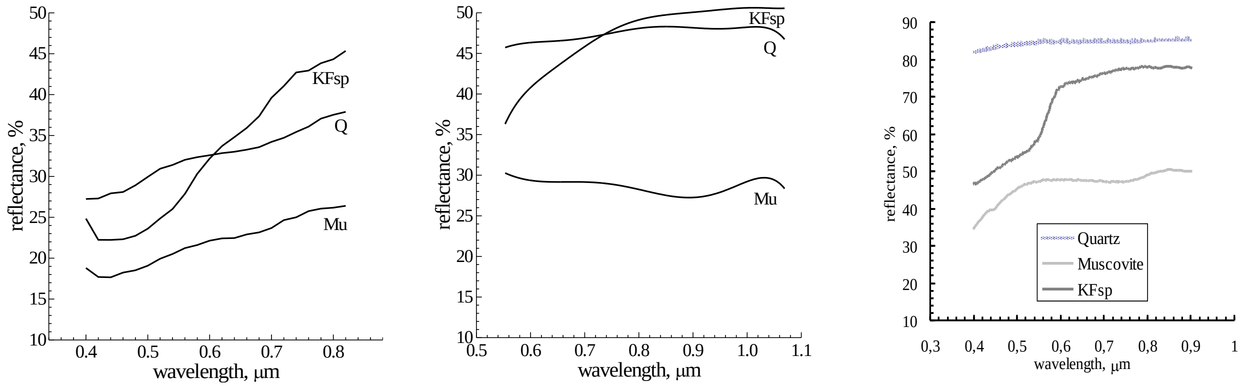


Figure 3. Granites reflectance spectra measured in laboratory

Figure 4 shows the reflectance spectra of the rock-forming minerals of the granites as mineral samples measured by the three remote sensing systems. The results for the minerals demonstrate the correlation between the spectral data. The three studied minerals (quartz, muscovite and K-feldspar) have different reflectance values but express similar behavior and position in the diagrams.



SRM SPS-1 TOMS

Figure 4. Minerals reflectance spectra measured in laboratory

Figure 5a shows the reflectance spectra of granites measured in-situ using remote sensing system TOMS. The reflectance spectra of granites taken from reference spectral library [3] are shown on Figure 5b. The acquired experimental terrain spectral data for granites are compared with similar thematic spectral data from different instruments for Earth observation included in the reference spectral data collections. For this purpose granites with similar structural, mineral and chemical content are selected from [3]. These results correspond to the shape of the reference reflectance spectra in the same spectral range.

Conclusions

In the current study the used remote sensing systems and the received thematic spectral data are presented. All the systems are calibrated before and through measurements. The obtained thematic spectral data are compared with similar ones from different instruments for Earth observation applied in the reference spectral data collections and spectral libraries. Our results shows similarity corresponding to the shape of the spectral signatures in the same spectral range obtained from the reference spectral data collections. It is important to highlight once again that the spectral data acquired with different remote sensing systems should be compared using a common criterion of comparability.

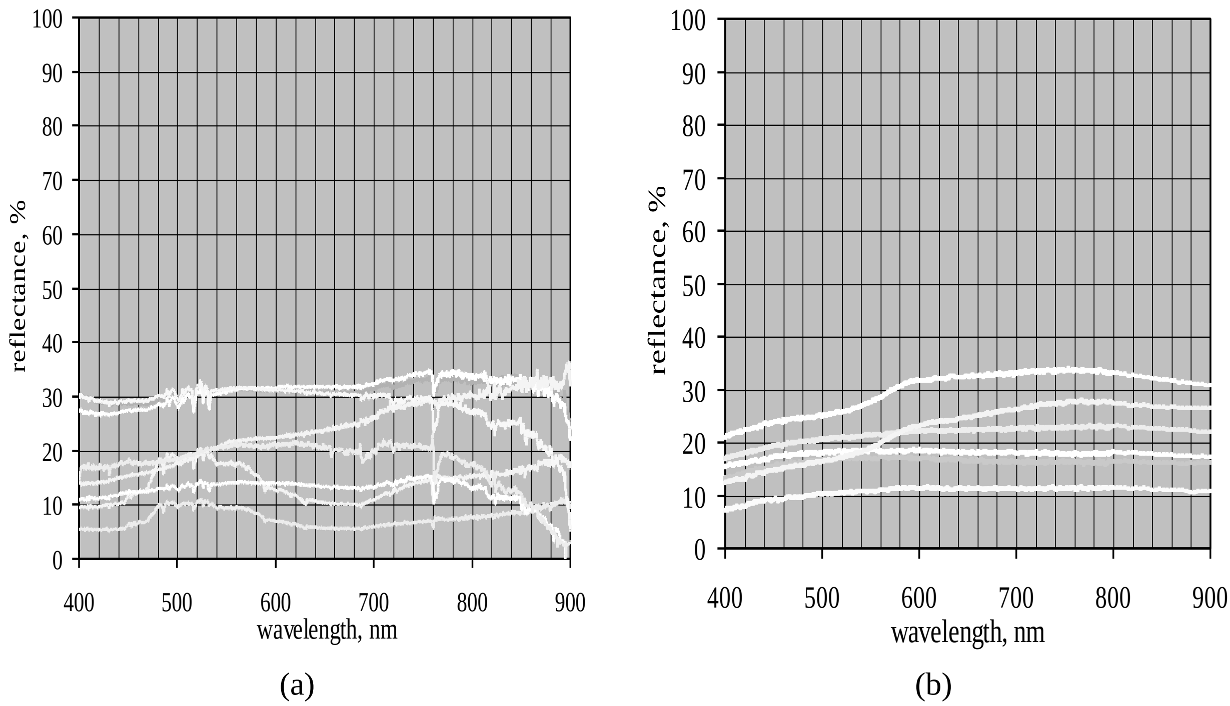


Figure 5. Granite reflectance spectra obtained from:
(a) in-situ measurements; (b) reference spectral library [3]

The achieved results proved that this methodology could be applied for comparing the spectral data acquired by different remote sensing systems. These types of spectral data collections and spectral libraries are the basis for comparative studies of remote sensing spectral data, including could be used in comparative planetology.

These results give us confidence to plan the next campaigns for the terrain spectrometric measurements in different regions of Bulgaria.

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