Measuring the spectral emissivity of rocks and the minerals that form them

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A new ground-based technique measures in their natural conditions, a prerequisite for satellite data processing.

Typically the Earth’s surface emits electromagnetic radiation in the thermal infrared (TIR) interval of 3-14 µm. This radiation contains much information about the land’s physical and chemical properties, but due to atmospheric absorption only the intervals 3-5 µm and 8-14 µm (known as atmospheric windows) are suitable for remote sensing purposes. The first of these is particularly useful for detecting hot targets, such as forest fires and geothermal activities, while the second is appropriate for investigating vegetation and rock and water surfaces. Our investigation is focused mainly on the spectral interval of 8-14 µm.

TIR remote sensing mainly investigates objects’ emissivity, the ability of a surface to radiate energy in the form of long-wave electromagnetic radiation. However, emissivity can change greatly with the surface condition of the material. It depends strongly on the surface roughness, the surface oxidized film, water content, and so on. For this reason, emissivity values in the literature usually lack information on data reliability and the measurement uncertainty is not clear for most measurement methods. With this in mind, we have developed a simple approach to measuring hemispherical spectral emissivity of rock and mineral samples that avoids the additional heating or grinding of the samples that accompany other techniques.2,3

Most emissivity measurements depend on several assumptions. These are, first, that the surface temperature does not change during the TIR measurement, or the correlation between the surface temperature and variations in the external radiation source is negligible. The second assumption is that the surface emissivity does not change during the TIR measurement, and the third is that the object has a diffuse surface or a specular reflecting surface.

Following these assumptions, a methodology was developed for measuring the hemispherical spectral emissivity of rock and mineral samples. The method relies on Kirchoff’s law, which states that for an opaque body, the relationship $\epsilon = 1 - \rho$ applies. This means that, after measuring the hemispherical reflectance $\rho$ of a surface, one can evaluate its emissivity $\epsilon$.

Experiment

The developed experimental set-up for measuring the hemispherical emissivity spectrum of samples is illustrated in Figures 1 and 2.

The emission of an infrared (IR) source is collimated by a ZnSe lens. Afterwards it irradiates the investigated sample, which is situated in the first focus of the elliptical gold-coated mirror. The

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IR radiation is reflected by the sample into a solid angle of $2\pi$ steradians, collected by the elliptical mirror, and focused into its second focus, where a lithium tantalite pyroelectric detector is located. The spectral resolution of the radiation reflected by the sample emission is provided by a set of 30 narrow-band transmission filters. A phase-sensitive detection technique is used to enhance the signal-to-noise ratio and the registered data were processed by a PC.

Determining emissivity spectra consists of two stages. The first is related to radiometric calibration of the measuring system. For this purpose the sample is replaced by a Lambertian ideal reflection standard, a gold-coated sandpaper. The second stage is the assessment of the reflectance spectrum of the investigated sample. The emissivity of the samples is then evaluated by the following ratio:

$$\varepsilon(\lambda) = 1 - \frac{U_S(\lambda)}{U_R(\lambda)}$$

where $\lambda$ is the wavelength, and $U_S(\lambda)$ and $U_R(\lambda)$ are the detector output voltages registered when measuring sample or standard, respectively.

**Results**

As an example, the emissivity spectrum of limestone is shown in Figure 3. We can distinguish some basic minerals and chemical compounds that have different spectral absorption. A well pronounced maximum around 8.6 $\mu$m and a minimum at 12.3 $\mu$m can be attributed to the quartz that appears in the limestone, while the deep minimum around 11.3 $\mu$m can be related to the carbonate content. The white limestone shown in Figure 4 is a sedimentary rock composed largely of the mineral calcite.

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The proposed set-up and methodology can be used to develop a simple portable device for measuring the emissivity of samples important for remote sensing performance.

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