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Directional emissivity and reflectance: dependence on emergence angle

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Dependence of laboratory measured emissivity spectra from the emergence angle is a subject that still needs a lot of investigations to be fully understood. Most of the previous work is based on reflectance measurements in the VIS-NIR spectral region and on emissivity measurements of flat, solid surfaces (mainly metals), which are not directly applicable to the analysis of remote sensing data. Small bodies in particular (c.f. asteroids Itokawa and 1999JU3, the respective targets of JAXA Hayabusa and Hayabusa 2 missions) have a very irregular surface; hence the spectra from those rough surfaces are difficult to compare with laboratory spectra, where the observing geometry is always close to "nadir".
At the Planetary Emissivity Laboratory (PEL) of the German Aerospace Center (DLR) we have set-up a series of spectral measurements to investigate this problem in the 1 – 16 μm spectral region. We measured the emissivity for two asteroid analog materials (meteorite Millbillillie and a synthetic enstatite) in vacuum and under purged air, at surface temperature of 100°C, for emergence angles of 0°, 5°, 10°, 20°, 30°, 40°, 50°, and 60°. Emissivity of a serpentinite slab, already used as calibration target for the MARA instrument on Hayabusa 2 MASCOT lander, and for the Thermal Infrared Imager (TIR) spectrometer on Hayabusa 2 orbiter was measured under the same conditions. Additionally a second basalt slab was measured. Both slabs were not measured at 5° inclination. Complementary reflectance measurements of the four samples were taken. For all the samples measured, we found that for calibrated emissivity, significant variations from values obtained at nadir (0° emergence angle) appear only for emergence angles $\geq$ 40°. Reflectance measurements confirmed this finding, showing the same trend of variations.