# Gonioreflectometric properties of the sand from RadCalNet Gobabeb test site

Dmitri Lanevski[1], Agnieszka Bialek[1], Emma Woolliams[2], Farshid Manoocheri[1], Nigel Fox[2] and Erkki Ikonen[1,3]

*[1]Metrology Research Institute, Aalto University, Espoo, Finland; [2]NPL, Teddington, UK; [3]VTT MIKES, Espoo, Finland*
*Corresponding e-mail address: Dmitri.lanevski@aalto.fi*

**Gobabeb test site is one of the instrumented semi-invariant locations on Earth that is used for vicarious post-launch calibration of satellite optical sensors. Recent studies suggest that a more site specific model of ground BRDF might decrease the uncertainty of such calibrations. For this reason a sample of sand from Gobabeb test site was collected and measured in a laboratory using a 3D goniometer. Data are compared to on-site measurements and suggested as an empirical base for a new site-specific BRDF model.**

## INTRODUCTION

In order to provide accurate data regarding our planet, optical sensors of Earth observation satellites require precise calibration. While large satellites often have on-board calibration devices, such devices age in orbit and vicarious calibration methods provide a valuable check of stability and inter-sensor biases. The move towards smaller and cheaper satellites also demand vicarious solutions. For this reason ground based reference test sites were developed. They are represented by optically semi-invariant locations on Earth that can be simultaneously observed by the satellites and by the automated ground stations [1]. Data from these sites coupled with site-specific Top-Of-Atmosphere (TOA) models provide satellite operators with SI-traceable spectrally-resolved reflectances to aid in the post-launch radiometric calibration and validation of optical imaging sensors.

The Gobabeb test site is a part of the Radiometric Calibration Network (RadCalNet) and is located on the edge of the Namib desert [2]. Its TOA model is based on radiative transfer code MODTRAN [3] that requires information about the atmospheric conditions and surface reflectance as an input. The latter is derived from in situ measurements and application of Roujean BRDF model that was developed firstly for la Crau site [4]. Studies showed that this approach provides quite consistent calibration results with an uncertainty of 1%-4%. Further developments of the test-site, however, suggest that application of more site-specific BRDF model will reduce the uncertainty associated with non-nadir observations.

Development of a new BRDF model for a site requires a set of SI-traceable empirical data. This is challenging on-site due to the changing solar illumination and relatively long data acquisition times, field conditions vary significantly during in situ measurements and increase uncertainty levels up to 2%. For this reason, laboratory measurements of test site ground samples are required. This article describes the Gobabeb test site sample, equipment, and procedures required for such measurements as well as results compared to the in situ measurements.

## GOBABEB TEST SITE GROUND SAMPLE

**Figure 1.** Photograph of the ground from Gobabeb test site. 5cm long screw (marked with red ellipse) is placed on the ground for scale.

Figure 1 shows that the Gobabeb ground consists mostly of sand and relatively small-sized gravel. Only a small fraction of dried out vegetation and animal remnants are present. A sample of this ground was collected into 3-litre container and transported to the laboratories at NPL and Aalto for further characterization and gonioreflectometric BRDF measurements. The sample consisted mostly of fine sand with the grain size less than 200 µm and gravel with diameter ranging from 1.5 mm to 15 mm with the average diameter of 6.2 mm. Fractions of intermediate size were rare.

## MEASUREMENT EQUIPMENT AND PROCEDURES

Since the main fraction of the sample of interest is sand that is highly loose and volatile material, the only way to reliably measure its gonioreflectometric properties is to place the sample horizontally and minimize its movement during measurements. For this reason, a specific 3D goniometer developed at Aalto was used (figure 2).

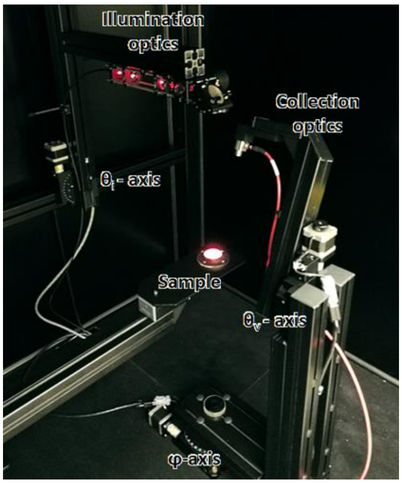


**Figure 2.** Photograph of the gonioreflectometer used to perform BRDF measurements.

The gonioreflectometer consists of a horizontal sample holder and multiple arms that move illumination and detector around the sample. The device allowed in- and out-of-plane 3D BRDF measurements with a 4° blind spot around the illumination. An NKT photonics supercontinuum laser coupled with laser line tuneable filters (LLTF) was used as the illumination source that allowed the illumination wavelength to vary from 400 nm to 2200 nm with spectral bandwidth of 2.5 nm to 5 nm. The optics allowed to change the beam size from 5 mm to 20 mm. The light reflected by the sample was collected by a parabolic mirror into optical fibre that guided collected light to the detection system, which allowed 3 different detectors to be chosen: silicon photodiode for visible wavelength range, InGaAs detector for NIR spectral region (900 nm to 1700 nm) and extended InGaAs allowing to expand sensing span up to 2070 nm. The repeatability of the instrument was better than 0.5%.

SI-traceability of the 3D goniometer was achieved by measuring a spectralon PTFE sample, the BRDF of which had been characterised by an absolute reference goniometer with an uncertainty of 0.2%. Correction factors were derived from the ratio between absolute and relative spectralon BRDF measurements, giving an estimate of the BRDF of Gobabeb test site ground samples with an uncertainty of less than 1 %.

## PRELIMINARY RESULTS

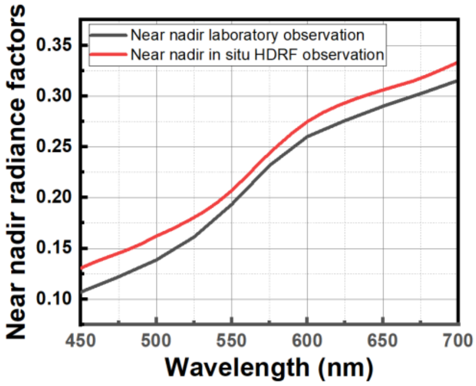


**Figure 3.** Radiance factors of near nadir observations of Ghobabeb sand in visible spectral range in laboratory and in situ (RadCalNet data measured on 01.11.2019 at 09:00).

Several measurements of the BRDF of Gobabeb sand were performed in the visible range with the illumination angle of 0°. Results depicted in figure 3 show that near-nadir BRDF values measured in laboratory are similar in shape, yet lower in value compared to in situ values. This is likely due to the significantly smaller illumination area which doesn't include bigger gravel pebbles in the measurement sample and because of the 4° blind spot around illumination that didn't collect the full reflectance data at nadir. This problem, however, should have less effect on off-nadir BRDF measurements, which are currently in progress.


## ACKNOWLEDGEMENTS

This work was funded by the project MetEOC-3 (16ENV03) of the European Metrology Programme for Innovation and Research (EMPIR). The EMPIR is jointly funded by the EMPIR participating countries within EURAMET and the European Union's Horizon 2020 program.


## REFERENCES


1. Bouvet, M. et al, RadCalNet: A radiometric calibration network for Earth observing imagers operating in the visible to shortwave infrared spectral range. Remote Sens., 11(20), 2401. 2019
2. A Bialek, Greenwell et al., New radiometric calibration site located at Gobabeb Namib desert, Proc. IGARSS, 6094-6097, 2016.
3. Meygret, A.; Santer, R.; Berthelot, B. ROSAS: A robotic station for atmosphere and surface characterization dedicated to on-orbit calibration. In Proceedings of the Earth Observing Systems XVI, San Diego, CA, USA, 13 September 2011.
4. J. Roujean, M. Leroy et al., A bidirectional reflectance model of the Earth surface for the correction of remote sensing data, J. Geophys. Res., 97(D18), 20455– 20468, 1992.