NEW RADIOMETRIC CALIBRATION SITE LOCATED AT GOBABEB, NAMIB DESERT

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ABSTRACT

A new permanently instrumented radiometric calibration site for high/medium resolution imaging satellite sensors is currently under development, focussing on the visible and near infra-red parts of the spectrum. The site will become a European contribution to the Committee on Earth Observation Satellites (CEOS) initiative RadCalNet (Radiometric Calibration Network). This paper describes the site characterisation that was carried out, both to define the exact location of permanent monitoring instrumentation, and to provide an initial detailed assessment of the site's properties. The characterisation involved a range of tests, using an ASD FieldSpec spectroradiometer, and the Gonio Radiometric Spectrometer System, a hyperspectral, multi-angle HDRF instrument. Teams from NPL and CNES each performed parts of this characterisation, working together to acquire the data and generate the final outcome

Index Terms— RadCalNet, site characterisation, HDRF, vicarious calibration

1. INTRODUCTION

Vicarious calibration and validation using ground reference sites is a key technique in Earth Observation, both for the cross comparison of sensors (including calibration of lower accuracy sensors against sensors with better radiometric calibration) and for monitoring long-term drift (effectively by comparison against themselves using a stable ground reference). It is common to use accessible desert sites for -field-campaign measurements that are made to coincide with a satellite overpass.

CEOS, the space arm of GEO (Group on Earth Observations), is in the process of establishing RadCalNet, a network of instrumented test sites, where field-measurement campaigns are supplemented by permanent instrumentation which takes measurements of the ground throughout the day. In the prototype phase RadCalNet is being established with four reference sites: University of Arizona/NASA's site at Railroad Playa, Arizona, USA; AoE's site at Baotou, China; the CNES site at La Crau, France; and the new ESA/CNES site in Gobabeb, Namibia. It is hoped that once RadCalNet is fully established (during 2016), additional sites will be added.

In addition to the requirements of RadCalNet, which will initially be limited to nadir, the Gobabeb site will provide off-nadir measurements to increase the number of matching overpasses. The site is being established as part of a collaborative project between ESA and CNES, in conjunction with NPL and Magellium.

To achieve SI traceability for the new ESA/CNES RadCalNet site, NPL has performed a detailed characterisation and calibration of the instruments and artefacts to be used on the site.

This paper describes the establishment of the Gobabeb site, including how the site area and specific site locations were chosen, together with the results of measurements of a field campaign in November 2015.

2. PREPARATION

2.1. Area Selection

The location of the new ESA/CNES vicarious calibration site was selected following a comprehensive global study by Magellium for suitable RadCalNet sites. Scores were given to areas on Earth based on the following criteria: spatial homogeneity at 1 km^2 resolution; spatial homogeneity at 10 km^2 resolution; flatness; atmospheric aerosol content and percentage of cloud free days. These scores were used to establish regions of interest, which were then studied in greater detail including accessibility, GSM coverage and proximity to inhabited areas. In total 86 sites across the world were flagged as potential sites by the study. From this list the new ESA/CNES site was chosen to be based near the Gobabeb Research and Training Centre in Namibia.

Further surface homogeneity studies focusing on individual Gobabeb areas were performed by CNES using Sentinel 2 and PLEIADES data. The most important criterion for the test site is its homogeneity over different spatial scales, i.e. the representativeness of small scale areas (~10 m^2) compared with much larger ones (100 m^2), to enable calibration of several satellite sensors with different image resolutions.

2.2. Instrument Characterisation

To reduce the uncertainty in the field site characterisation, NPL performed a range of tests on the instruments that were be used on the site to provide traceability to SI. This was done for the instruments intended for the initial characterisation of the site, for the in-situ calibration standards and for the permanent monitoring instrumentation. The site characterisation instrumentation included two ASD FieldSpec spectroradiometers for measuring nadir surface reflectance and GRASS (Gonio RAdiometric Spectrometer System), a system for measuring reflectance at different viewing angles. The in-situ SI traceable standards included Spectralon™ panels and tarpaulins. The instrument intended for permanent autonomous operation is a CIMEL sun photometer. The results of these laboratory tests are presented in [1].

3. SITE CHARACTERISATION

Several tests were conducted during a two week measurement campaign in Autumn 2015. This involved a visual assessment of the candidate test sites' surfaces, GSM coverage tests (to ensure the permanently installed instrument can use the GSM network as a means of data transmission), and a detailed characterisation study of the spectral reflectance and homogeneity of the chosen test site, as described in more detail in the following sections.

3.1. Nadir measurement

The nadir ground reflectance measurements were performed using ASD FieldSpec portable spectral radiometers. The ASD instrument has good sensitivity over a wavelength range of 400 nm to 2400 nm. It can be used with a bare fibre (with approximately 25° FOV) or with a lens, which has either an 8° FOV (NPL) or 5° FOV (CNES). Measurements taken with the ASD are in radiance units. For traceable reflectance values, measurements of a reference diffuser (Spectralon) are necessary, taken with the same measurement geometry and under the same illumination conditions as the ground measurements.

Figure 1: Measurements with the ASD spectrometer

3.1.1. Area Characterisation

Area characterisation was performed over a set of small squares. NPL took repeated measurements over the same small set of points to obtain an understanding of repeatability and stability, while CNES took measurements over a much wider area to understand surface homogeneity on different scales (from a few cm to a km).

Measurement of a single point consisted of a short sequence that approximately took 5 minutes: a Spectralon measurement, four ground measurements (eight for CNES) at slightly different positions, then a final Spectralon measurement. For NPL's method, each of these included 5 readings from the ASD at each position, which were then averaged. For CNES' method, each position included 20 scans - which were averaged by ASD's software.

3.1.2. Static test

In order to understand the ground BRF (Bidirectional Reflectance Factor) effects and to check that the solar zenith angle changes could be correctly accounted for in the area characterisation data, an investigation was carried out to study the variation in reflectance at a single ground point. Spectralon measurements were taken in quick sets of five, every half an hour, and between those times, a single reading from the ground was taken every two minutes, to provide a near continuous record of the ground reflectance. The Spectralon readings were interpolated, using BRF values every 10 degrees from laboratory calibration prior to the field campaign, on a smooth curve to give estimated BRF values for all times of ground measurements.

3.1.3. Tarpaulins

A set of three large, uniform reference tarpaulins was brought to the site. These were manufactured to have Lambertian reflectance properties and three different grey scale levels. They were previously calibrated for total diffuse reflectance and 0°:45° radiance factor at NPL. In the field they were used to provide a large uniform area over which we could perform comparisons of different measurement procedures, and investigate how much effect changing the ASD operator has on the results.

Figure 2: Measurements with tarpaulins

3.1.4. Downwelling Irradiance

In order to measure the downwelling irradiance (from the Sun and sky) at the site, the ASD was used with an alternative input optic. A diffuser replaced the lens at the end of the input fibre and the instrument was set up vertically upwards. The ASD and tripod were set up a short distance away from the

GRASS structure (far enough to ensure that it did not affect the GRASS measurements, but close enough to be comparable), and left monitoring for the entire morning. These data were intended to be used partly as validation of the downwelling measurements made using GRASS, and also to provide a representative idea of the variation in solar irradiance over a day.

Figure 3: Close-up of diffuser input

3.2. Multi-angular measurements

Ground-based measurements of the hemispherical directional reflectance factor (HDRF) of the site were carried out with the GRASS [2]. GRASS is designed to record quasi-simultaneous, multi-angle, hyperspectral measurements of the Earth's surface reflectance. Signal collectors mounted on a hemispherical frame and aiming at the same target area are connected with fibre optic cables to a V-SWIR spectroradiometer, operating over a wavelength range from 400 nm to 1700 nm. A full description of the system can be found in [3] and [4].

Figure 4: GRASS instrument in situ

3.2.1. GRASS measurements

During the campaign, measurements were made using GRASS with clear sky conditions over viewing zenith angles from 0º to 50º with a 10º interval and azimuth angles from 0º to 360º with a 30º interval. Changes in illumination were monitored with an integrating sphere mounted on the instrument and a reference measurement was recorded at nadir over a Spectralon panel. Random sampling points were chosen over an area of 300 m × 300 m that was selected in the first stage of the project based on criteria given in Section 2.1. Repeated measurements at different sampling points allowed HDRF datasets to be obtained over a range of solar zenith angles. Furthermore, measurements were timed to correspond to key satellite overpasses (Sentinel 2A MSI and Landsat 8 OLI).

3.2.2. ASD - GRASS nadir view comparison

As an additional check on the consistency of the ground reflectance measurements, the ASD was used in conjunction with GRASS. Measurements were taken of the ground as observed by GRASS nadir view and with the ASD spectrometer as well. This was repeated with both the Spectralon Panel and then the tarpaulins placed in the view of GRASS and the ASD. These data provided an alternative route to compare nadir view results of the same ground patch from two instruments that have different footprint on the surface (the ASD footprint is around 9 cm diameter while GRASS is about 20 cm).

3.3. Site Impact

The impact of continuous foot traffic on the site is a concern. As visible in Figure 5 (from images with the high resolution sensor PLEIADES), the paths where area characterisation was done, and particularly the GRASS positions, show a marked change compared with other areas. Any future visits to the site will have to be planned carefully so that any damage to the site is minimised.

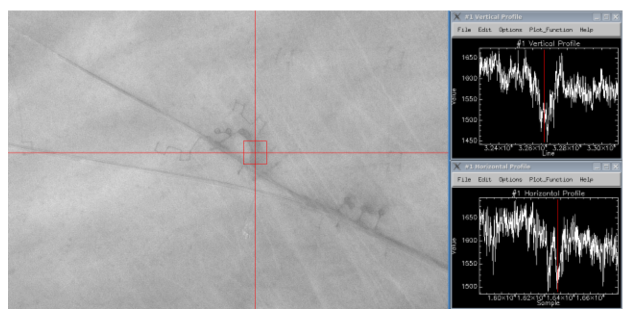

Figure 5: PLEIADES 70 cm-panchromatic image of the site, taken 18th December 2015, approximately two weeks after the field campaign darkened areas represent the surface damaged due to foot traffic and darkened circles GRASS positions (copyright CNES, Distribution Airbus Defence and Space)

4. EXPECTED OUTCOMES

4.1. Results from data

The data are currently being processed. They will provide information about surface homogeneity at the scale of a few square centimetres, which is equivalent to the footprint size of small zenith angles for the CIMEL Sun Photometer that will be used for the permanent instrumentation. The sparse measurements over larger areas of the test site will test the representativeness of the CIMEL sun photometer measurements over the overall area. In addition the ASD measurements will provide full hyperspectral information, which will be used to allow spectral interpolation of the 12 spectral bands provided by the CIMEL Sun Photometer.

The site characterisation included the necessary repetitions and additional testing required to establish a robust uncertainty budget for the reflectance values for the site. The characterisation and calibration of the instruments by NPL ensures rigorous traceability to SI.

GRASS measurements will produce HDRF information about the site, which can be compared with future CIMEL measurements.

4.2. Mast installation

The final stage of the site development will include the installation of the permanent instrumentation the mast and weather station. This will involve mounting the CIMEL instrument on top of a mast from which measurements of the atmosphere and surface will be taken. The original plan was to use the same type of mast at the new Gobabeb site as at the La Crau site [5]. This had to be modified as the Gobabeb site is located in the territory of the Namib-Naukluft National Park protected area, so the ground cannot be destroyed or permanently modified and only masts with guy ropes can be installed.

Taking into consideration surface damage during site characterisation (see fig 5), an additional set of mast installation practice runs will be performed in the UK to establish the least invasive method.

5. CONCLUSIONS AND SUMMARY

This paper presents a process for establishing a new radiometric calibration site for visible and NIR satellite sensor validation. The Gobabeb site is being developed as a European contribution to the RadCalNet network. This site was selected following an extensive study of the potential areas, based on a number of predefined criteria. The choice of the final position for the mast installation was supported by initial site characterisation campaign results. All instruments and artefacts used during the site characterisation were previously calibrated and/or characterised at NPL.

The in situ measurements on the site performed near the end of 2015 confirmed excellent environmental and surface homogeneity for this location. Due to surface dryness and moderate winds present, especially in the afternoon hours, the biggest challenge for the in situ measurements was to maintain a good state of the reference reflectance panels throughout the campaign duration. Several additional daily comparisons of standards were performed to monitor their stability. Site characterisation data processing is currently ongoing, and the results will be presented in the full version of this paper.

The installation of the permanent equipment is scheduled for Summer 2016. It is expected that the site will become operational soon after that.

6. ACKNOWLEDGEMENTS

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