In-lab radiometric instruments calibration and uncertainties assessment

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Abstract

Extracting quantitative information from both airborne and orbital sensors data requires information about their absolute calibration. The most common in-flight absolute calibration method is based on radiometric data collected from a reference surface located on the Earth. The first step of that method is the surface characterization, which involves radiometric measurements to determine the average Reflectance Factor of the surface. Frequently these reference surfaces are relatively large and the radiometric measurements have been performed by instruments, which must be calibrated. Thus, analyzing the instruments conditions and their respective contributions to the final uncertainty of the measurements experiments have to be performed in laboratory. The objective of this paper is to describe some in-lab instruments calibration procedures including the uncertainties assessment.

Keywords: calibration, uncertainty estimation, instruments characterization

1. Introduction

The application of remote sensing techniques to quantitative information extraction from data collected by optical sensors (airborne and orbital sensors) includes knowledge of their absolute calibration. The most common in-flight absolute calibration method is based on radiometric data collected from a reference surface located on the Earth. The first step of that method is the surface characterization that involves radiometric measurements to determine the average or representative Reflectance Factor (RF) of the surface. Frequently these reference surfaces are relatively large and the radiometric measurements have been performed by portable spectroradiometers and reference panels, which must be calibrated to ensure reliability to the measurements results.

A field campaign dedicated to spectrally characterize a specific reference surface located at Correntina town (Bahia state, Brazil) was performed in April, 2010.

Before and after this campaign, radiometers and reference panels were cross-calibrated at the Laboratório de Radiometria e Caracterização de Sensores Eletro-ópticos (LaRaC) of the Instituto de Estudos Avançados (IEAv). These in-lab experiments were performed to analyze the instruments conditions and their respective contributions to the final measurements uncertainty. The objective of this paper is to describe some in-lab instruments calibration procedures including the uncertainties assessment.

2. Radiometric Measurements Laboratory

The LaRaC was built to provide an environment propitious to perform radiometric measurements. The laboratory has no windows, the walls and ceiling are painted with black paint, to avoid reflections. During the measurements temperature and humidity information was collected by a digital thermo-hygrometer from Oregon Scientific. In general, measurements were made with the temperature ranging from 18 to 21°C and relative humidity between 50 and 70%. Addition, to avoid a possible influence on the measurements, laboratory lamps were turned off during the experiments.

In the experiment conducted in LaRaC three spectralon reference panels (LABSPHERE, 2009) and two spectroradiometers FieldSpec (ASD, 1999) that were used in the Correntina fieldwork were evaluated in relation to similar equipment belonging to LaRaC, recently calibrated from the manufacturers and considered as standards.

2.1. Spectroradiometers Calibration Methodology

For the calibration of the two FieldSpec instruments used in the fieldwork (FieldSpec 6479 and 6246) a third FieldSpec (FieldSpec 6426), belonging to LaRaC, was used as standard. The methodology explored to cross-calibrate the spectroradiometers can be visualized in Figure 1.

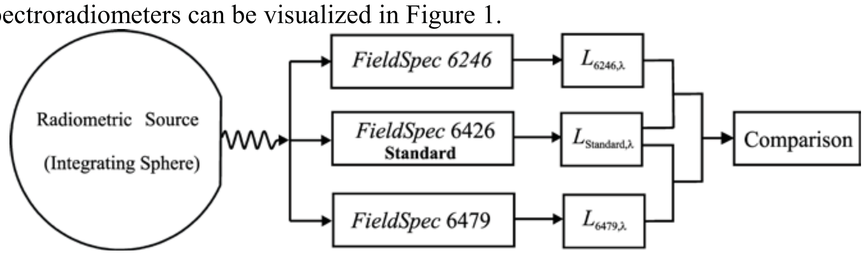

Figure 1: Flowchart of the methodology to calibrate the two spectroradiometers used in the fieldwork.

The three spectroradiometers were exposed to the same electromagnetic radiation intensity and the radiance values of the FieldSpec 6246 and 6479 were compared to the radiance generated by the standard FieldSpec 6426 and finally we determined their absolute differences and relationships.

Performing the FieldSpec instruments evaluation we used an experimental setup involving an integrating sphere (IS), model USS2000, as a radiometric source. The IS has an internal diameter of 50cm and a circular opening with a diameter of approximately 20 cm and it allows using four tungsten halogen lamps: two of 45 W, one of 100 W and another of 150 W.

The three spectroradiometers (two used in the fieldwork and one belonging to LaRaC) were positioned on the sphere aperture at a vertical geometry, and the distance between the aperture and the FieldSpec optical cable was fixed on 10 cm. The experimental setup can be seen in Figure 2.

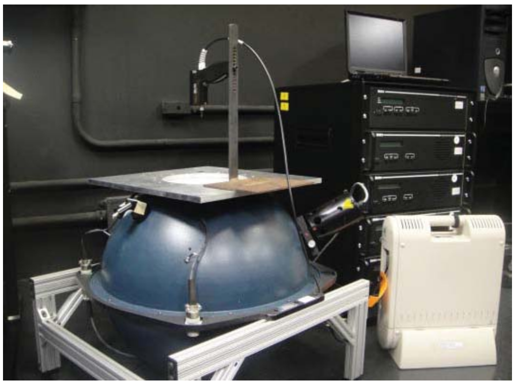

Figure 2: Overview of the experimental setup, using an integrating sphere for the FieldSpecs evaluation.

It was used six arrangements: (a) FieldSpec 6426 with FOV of 8º and 25°; (b) FieldSpec 6479 with FOV of 8º and 25°; and (c) FieldSpec 6246 with FOV of 8º and 25°. For each one of these arrangements it was evaluated four levels of radiation with EI: (i) with lamps of 150, 100 and 45W turned on (level 1); (ii) with the lamps of 150W and 45W turned on (level 2); (iii) with only lamp of 45W turned on (level 3); and (iv) with all lamps turned off (level 4).

Initially, it was taken measurements of the sphere with FieldSpec 6426 (standard spectroradiometer), which was connected along the lamps of 150, 100 and 45 W (level 1). To ensure that the system was stabilized (heated lamps and equipment), it was expected half an hour before the start of the measurements, as recommended by the manufacturers. After, successive radiance measurements of the sphere were performed every minute for 10 minutes (accounting 10 measurements).

Upon completion of this measurement sequence it was turned off the lamp of 100 W, creating the second combination of lamps (150 and 45 W, level 2), and the same procedure was repeated. Then, the lamp of 150 W was turned off, carrying out the third configuration with only lamp of 45 W (level 3). Finally, the lamp of 45 W was turned off, having no lamp access, and the same procedure was again performed (level 4). Posteriorly, both FieldSpec 6246 and 6479 underwent the same sequence of measurements in replace the standard spectroradiometer.

2.2. Reference Panels Calibration Methodology

The RF values were obtained indirectly by the spectral radiance of the interest material (target) and an ideal Lambertian surface ratio under the same conditions of illumination and observation.

The radiometric measurements performed during the field campaigns relied on the use of three reference panels. Thus, it was necessary to cross-calibrate them. So, we determined the Reflectance Factor of the panels (RF_{Panel}). A Spectralon panel, model SRT- 99-120 (LABSPHERE, 2004) was used as a standard panel.

We have developed an experimental setup (Figure 3) for determine the RF_{Panel}. Each reference panel was placed perpendicular to the FieldSpec optical cable at a distance of 10 cm. The panels were illuminated by a tungsten halogen lamp of 50 W, at a 25° angle from the normal. The illumination source was fixed on a tripod positioned at 25 cm from the reference panel.

The spectroradiometer was positioned at the nadir in relation to the geometric center of the panels and the measurements were carried out using field of view (FOV) of 8° and 25°. Measurements were taken using the three spectroradiometers FieldSpec (two used in the fieldwork and one laboratory standard), obtaining all combinations with spectroradiometers and panels.

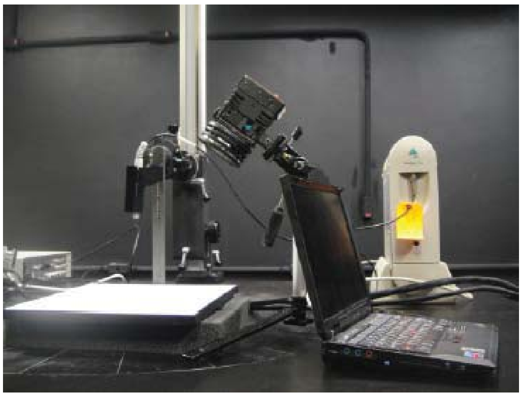

Figure 3: Overview of the experimental setup to obtain the reflectance factor of the reference panels.

Again, the same six arrangements performed to calibrate the FieldSpec were adopted: (a) FieldSpec 6426 with FOV of 8° and 25°; (b) FieldSpec 6479 with FOV of 8° and 25°; and (c) FieldSpec 6246 with FOV of 8° and 25°. For each arrangement it was taken measurements with the three reference panels.

Regarding the experimental procedure, initially we turned on the tungsten halogen lamp and FieldSpec 6426, and we expected thirty minutes before the start of the measurements, so that the system was stabilized. After, we made successive reflectance measurements of the standard laboratory panel were performed at every 10 seconds during 1 minute and 40 seconds (10 measurements). Then the same procedure was repeated with the other three reference panels used in the fieldwork. Finally, it was again taken reflectance measurements of the standard laboratory panel in order to verify if the values of the panel reflectance changed during the experiment. Subsequently, the other two FieldSpec (6246 and 6479) were subjected to the same measurement process to replace the standard spectroradiometer.

3. Results and Discussion

3.1. Spectroradiometers Calibration

Figure 4 shows the mean of ten radiance measurements and its relative uncertainty obtained in the experiment before the fieldwork for the total power of 295 W of IS, with the three spectroradiometers using the 25° FOV.

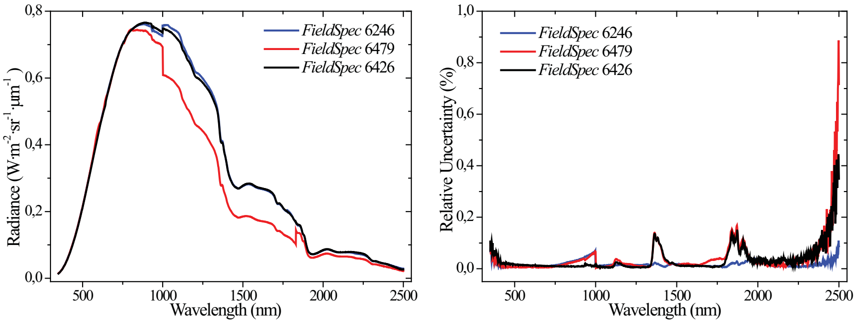

Figure 4: In (a) the radiance plot as a function of wavelength, with the three spectroradiometers with 25° FOV. Measurements were taken with the lamps 150, 100 and 45 W of IS turned on (total power of 295 W); in (b) graph of uncertainties as a function of wavelength, obtained with each of spectroradiometers.

The radiance behavior was similar for the three spectroradiometers. There were detected discontinuities in the radiance around 1000 and 1850 nm, corresponding to "exchange" of the radiometers FieldSpecs (Pinto, 2011). For FieldSpec 6479 it was possible noticing greater variation in the absolute value between 1000 to 1850 nm, corresponding to the second radiometer of FieldSepc, indicating a technical problem with this instrument. This problem may be related to the instrument calibration coefficients, or the detector sensitivity, or some optical cable disruption.

In Figure 4b shows the uncertainties across the spectral region from 350 to 2500 nm that were very small. FieldSpec 6426 (standard) data provided the smallest uncertainties (from 0.004 to 0.4%). From FieldSpec 6479 test we obtained the higher uncertainties, approximately 0.008 to 1.0%. And for FieldSpec 6246 the uncertainties ranged from 0.005 to 0.19%.

3.2. Reference Panels Calibration

Figure 5a shows the average of the RFs and their uncertainties of the three panels used in the fieldwork. The panels presented a similar spectral behavior. However the absolute values were different, probably due to their age and handling differences (MÖLLER et al., 2003). The uncertainties calculated to RF of the panels were less than 0.25% in the 350-450 nm spectral range, 0.035% in the 450-2400 nm spectral range, and 0.08% of the 2400 to 2500 nm spectral range (Figure 5b).

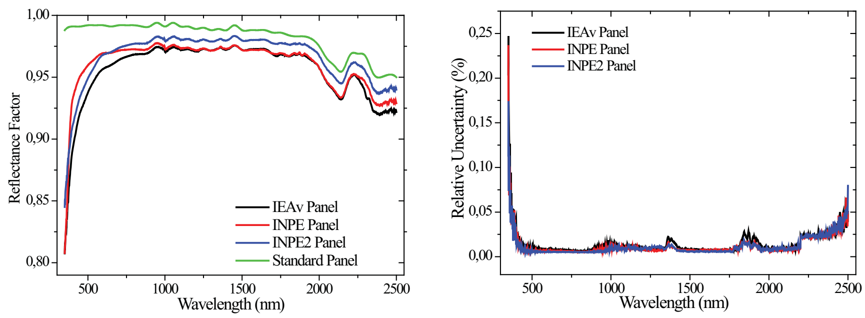

Figure 5: In (a) graph of RF as a function of wavelength, for the three panels used in the fieldwork, obtained in the post-field measurements with the FieldSpec 6246 with FOV of 25°. It is also plotted for reference purposes, the FR of the standard panel (provided by the manufacturer); and in (b) graph of uncertainties as a function of wavelength.

4. Conclusion

Concerning the spectroradiometers calibration the signal was noisy in three spectral regions: spectral range from 1850 to 2500 nm, the switch regions of the radiometer (around 1000 nm and 1850 nm) and in the regions of water absorption (about 1.4 and 1.9 mm). The instrumental uncertainties of spectroradiometers were small, less than 1%. It was possible to identify a problem with the FieldSpec 6479 in the spectral region between 1000 to 1850 nm.

In relation to the calibration panel, it was found that the panels did not have a reflectance equal to one, especially in the spectral regions of visible and UV. The uncertainties calculated to the reflectance of each panels were less than 0.25%.

Comparing measurements made before and after the fieldwork, the instruments remained the same "conditions", with the exception of the spectroradiometer FieldSpec 6479, which already had problems in the measurements performed before the fieldwork and after it was further compromised.

To ensure reliability in the measurements it is necessary to understand and study the instrument operation, especially in use conditions. Thus, it is must that users to worry about their measuring equipment and to undertake a systematic monitoring of each. This requires investment in standards, as well as training people to perform the experiments.

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