Variability of Field Spectroradiometric Measurements Using Nearly Lambertian Surfaces

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Abstract. Field spectroscopy is a technique of fundamental importance in remote sensing, since it deals with interactions between electromagnetic energy and objects in the natural environment. The most widely used methodology in field spectroscopy concerns measurement of the reflectance of composite surfaces in situ. Several authors have published practical suggestions for improving the consistency and accuracy of field data collected using radiometers and spectroradiometers. According to literature, for single beams spectroradiometers, in order to avoid any errors due to significant changes in the prevailing atmospheric conditions, the measurements over the calibrated panel and the target should be taken in a short time. In this case, it is assumed that irradiance is not changing significantly, which is true for non hazy days. However several factors should be taken into consideration such as the viewing geometry, sky conditions, the height of the instrument etc. This paper aims to highlight some practical considerations for field spectroradiometric measurements which should be taken into consideration. Indeed the variability of such measurements using homogenous and nearly Lambertian targets is assessed in this study. Two identical single beam ground spectroradiometers, Spectra Vista GER 1500 (350 nm – 1050 nm) are used simultaneously: the first one is used in order to measure reflectance from a calibrated panel (99.98% Lambertian surface) while the second one is used in order to measure reflectance from the targets. Several targets (e.g. grey homogenous asphalt) are continually measured between 11:30-12:30 local time (1-2 minutes interval time). The analysis of the results show that for clear, non hazy days only small variations can be observed for the same target (less than 1%). This error is far more less than satellite observations (≈ 5%), according to the literature.

Keywords. Spectroradiometer, accuracy assessment, nearly Lambertian surfaces.

1. Introduction

Remote sensing is focused at the interpretation of electromagnetic radiation as recorded from several sensors. These specially designed sensors are able to record a part of the incoming electromagnetic radiation including visible and near infrared spectrum.

Such kinds of sensors are widely used to record this radiation from satellites while handheld sensors can be used for field measurements. As Milton [1] argues, ground spectroscopy involves the study of the spectral characteristics of objects according to their physical properties. In contrast to the satellite or aerial sensors, ground measurements are considered as “truth data” due to the relatively short distance from the object. Therefore any noise is minimized [2]. However the term “truth data” is not correct since even these ground measurements are subject to errors, which researchers should take into account [3].

The main assumption made during spectroradiometric campaigns is that the sun illumination is constant. However this is not true for hazy days. Moreover in the interval of these measurements, the atmospheric conditions are assumed to be the same (unchanged). To overcome such limitations, ground spectroradiometers are often used along with a calibrated Lambertian target, called "spectralon". Therefore, the measurements over the calibrated panel and the target should be taken in a short time; in order to avoid any errors due to significant changes in the prevailing atmospheric conditions [4]. In this case it is assumed that irradiance is not changing significantly. In this case, Milton et al. [5] emphasizes that a critical factor for good and reliable results is the calibration of this Lambertian target.

In general, for single beams spectroradiometers (the same instrument is used for the calibration and for the in-situ measurement) the methodology applied is as follows: a reference spectralon panel is used to measure the incoming solar radiation and then the same spectroradiometer is used for recording the radiation over the area of interest. The Lambertian spectralon panel (≈100% reflectance) measurement is used as reference target while the measurement over the area of interest as a target. Therefore reflectance for each measurement can be calculated using the following equation (1):

$$\text{Reflectance} = (\text{Target Radiance} / \text{Panel Radiance}) \times \text{Calibration of the panel} \quad (1)$$

This paper aims to evaluate the above considerations (time interval between spectralon and target measurement) taken when using field spectroradiometric measurements. Several measurements using homogenous and nearly Lambertian targets have been assessed in this study. Two identical single beam ground spectroradiometers, Spectra Vista GER 1500 have been used simultaneously: the first one was used in order to measure reflectance from a calibrated panel (99.98% Lambertian surface) while the second one to measure reflectance from the targets.

2. Methodology

The spectroradiometric instruments used to register the spectral signature were 2 GER 1500. These instruments may record electromagnetic radiation from a range of 350 nm up to 1050 nm. They include more than 500 different channels and each channel covers a range of about 1.5 nm. The field of view (FOV) of the instruments was set to 4^o ($\approx 0,02\ m^2$).

Figure 1: The GER 1500 spectroradiometer used in this study (left) and the calibrated spectralon panel (right).

The first GER 1500 was used in order to record the electromagnetic radiation over the calibrated spectralon surface while the second identical instrument was used to record the radiation over the area of interest. Both measurements were taken simultaneously. This pair of measurements was taken every 1 minute from 11:30 until 12:30 local time. Two main targets were used: (a) the same calibrated surface (Case A) and (b) a gray asphalt (Case B) (Figure 2).

Figure 2: Photos during the field campaign.

The narrow band reflectance values were converted to Landsat broadband reflectance values. The authors have selected to simulate these data to Landsat TM /ETM+ satellite imagery based on Relative Spectral Response (RSR) filters. RSR filters describe the instrument relative sensitivity to radiance at various part of the electromagnetic spectrum [6]. These spectral responses have a value of 0 to 1 and have no units since they are relative to the peak response (Figure 3). Band-pass filters are used in the same way in spectroradiometers in order to transmit a certain wavelength band, and block others. The reflectance from the spectroradiometer was calculated based on the wavelength of each sensor and the RSR filter as follows:

$$Rband = \Sigma (Ri * RSRi) / \Sigma RSRi \quad (2)$$

where:

Rband = reflectance at a range of wavelength (e.g. Band 1)
Ri = reflectance at a specific wavelength (e.g R 450 nm)
RSRi = Relative Response value at the specific wavelength

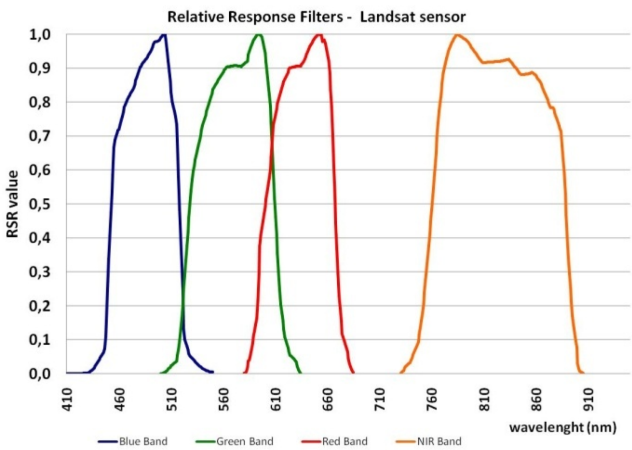


Figure 3: RSR filters of the Landsat sensor [5].

Finally, the reflectance values were plotted for each band and each target along time.

3. Results

3.1. Reflectance values

Reflectance values for both cases A and B are shown in Figures 4 and 5 respectively. Reflectance fluctuations for both targets are plotted against the time of measurement. The results show that in case A, the variation of reflectance was less than 0.35% , while in case B the variation n was less than 1%. This was expected since grey asphalt was not homogenous.

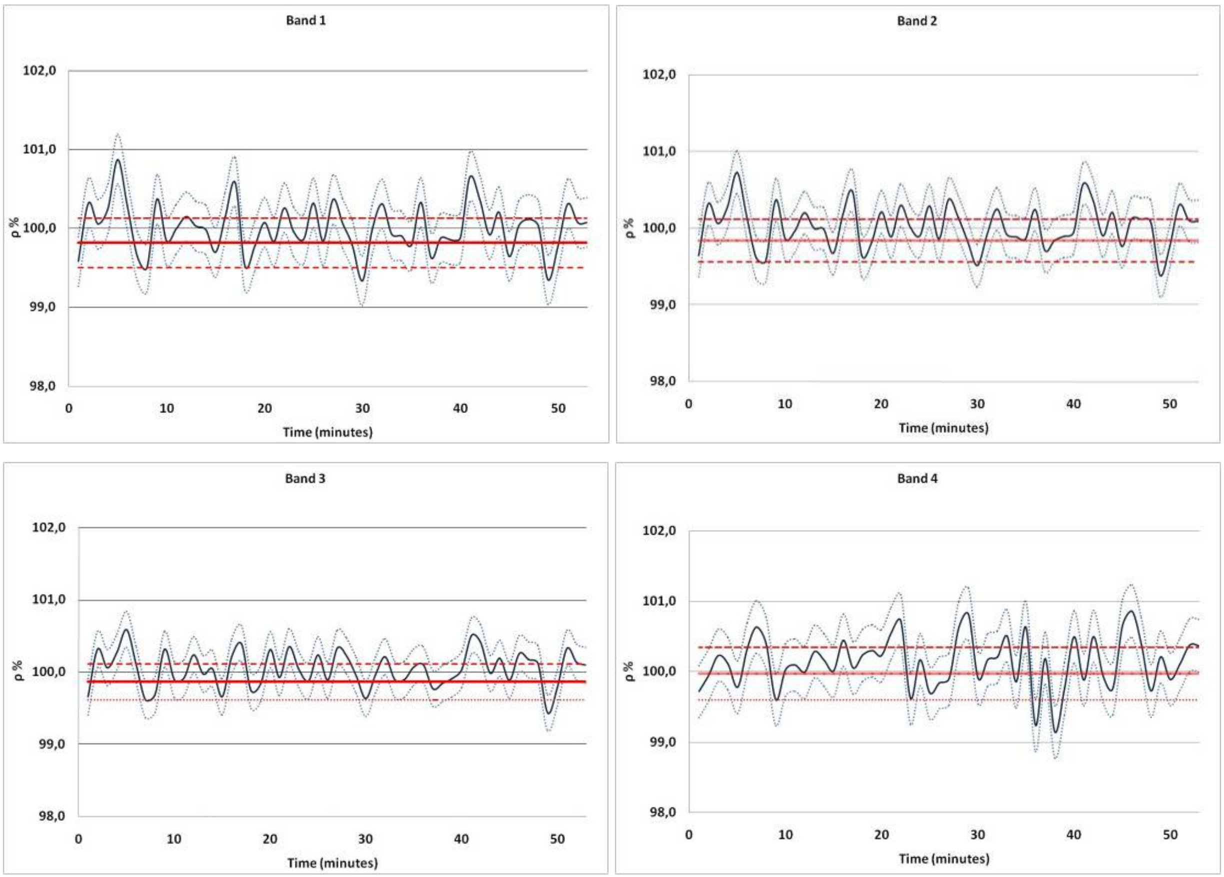
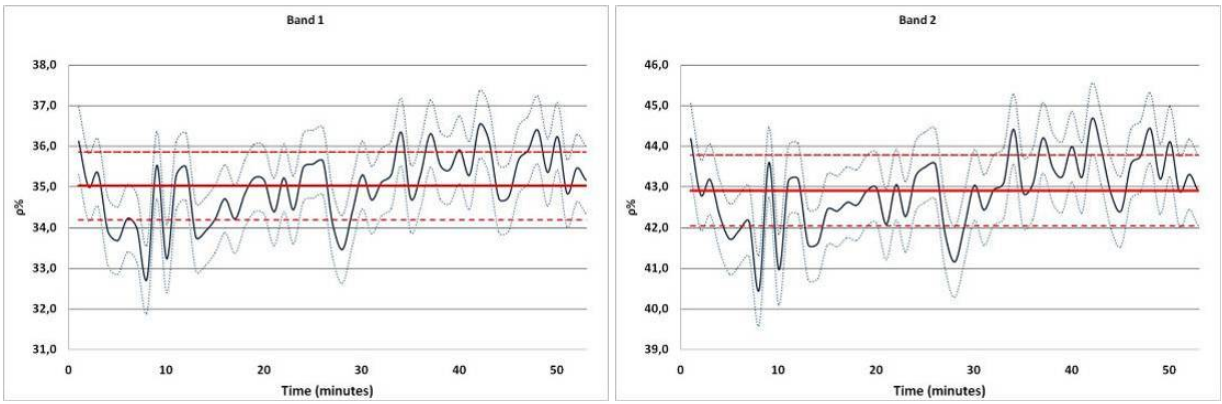


Figure 4: Reflectance values for case A. Red line indicates the mean values while the dashed line the standard deviation of the measurements.



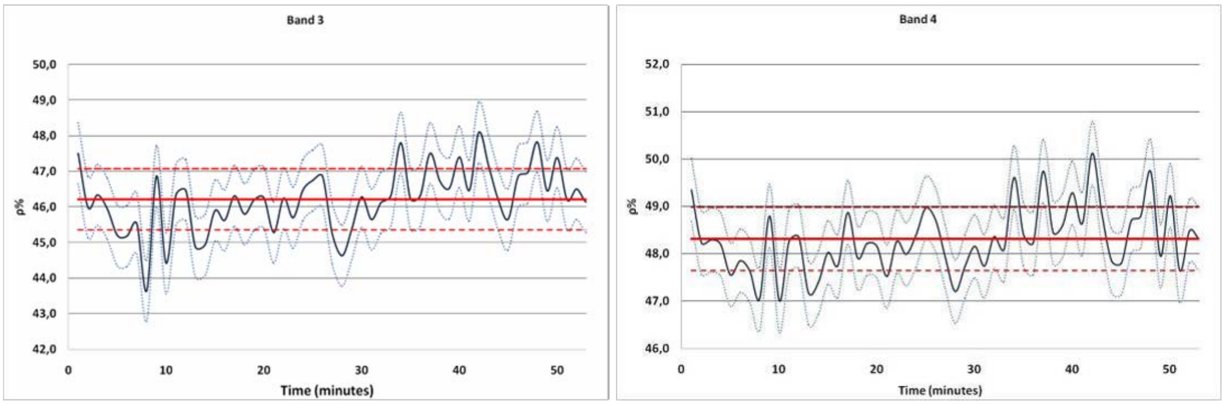


Figure 5: Reflectance values for case B. Red line indicates the mean values while the dashed line the standard deviation of the measurements.

In Figures 6 and 7 the effect of change in solar radiation for one hour (11:30 - 12:30) is shown. For this purpose, the reflectance values were calculated using the baseline measurement (time 11:30). Then equation 1 was used. This study was performed in order to examine how time lag influences the observation reflectance values target as changes in solar radiation. These observations, in case A (Figure 6) shows a gradual reduction of the visible radiation spectrum (Bands 1-3) up to 4%. In the near infrared, although the change is not constant and there is a variation of the radiation, it is estimated at ± 2% from the baseline. In case B, the measurements do not follow a particular pattern and show dispersion although the majority of these do not appear to exceed 1.5% for all channels.

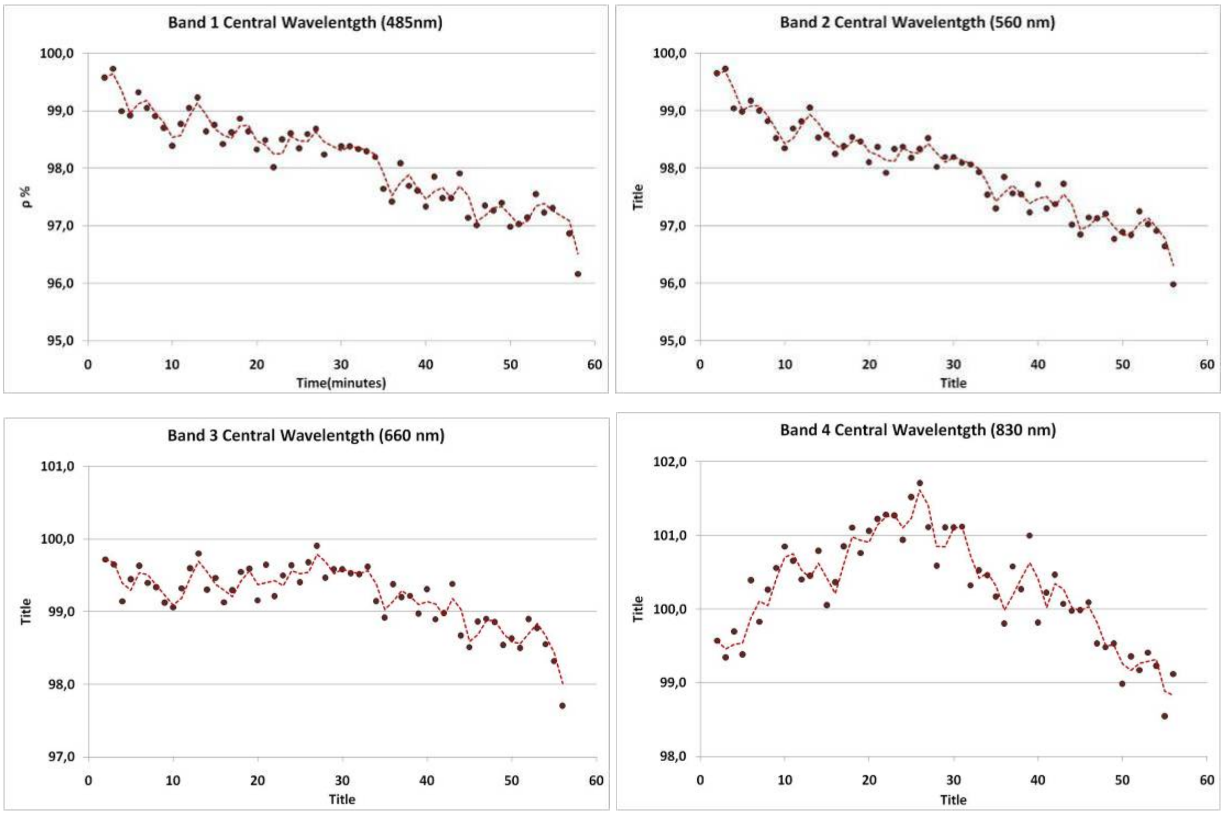


Figure 6: Reflectance fluctuations for case A, during 11:30 -12:30. The first measurement taken at 11:30 was considered as the reference value.

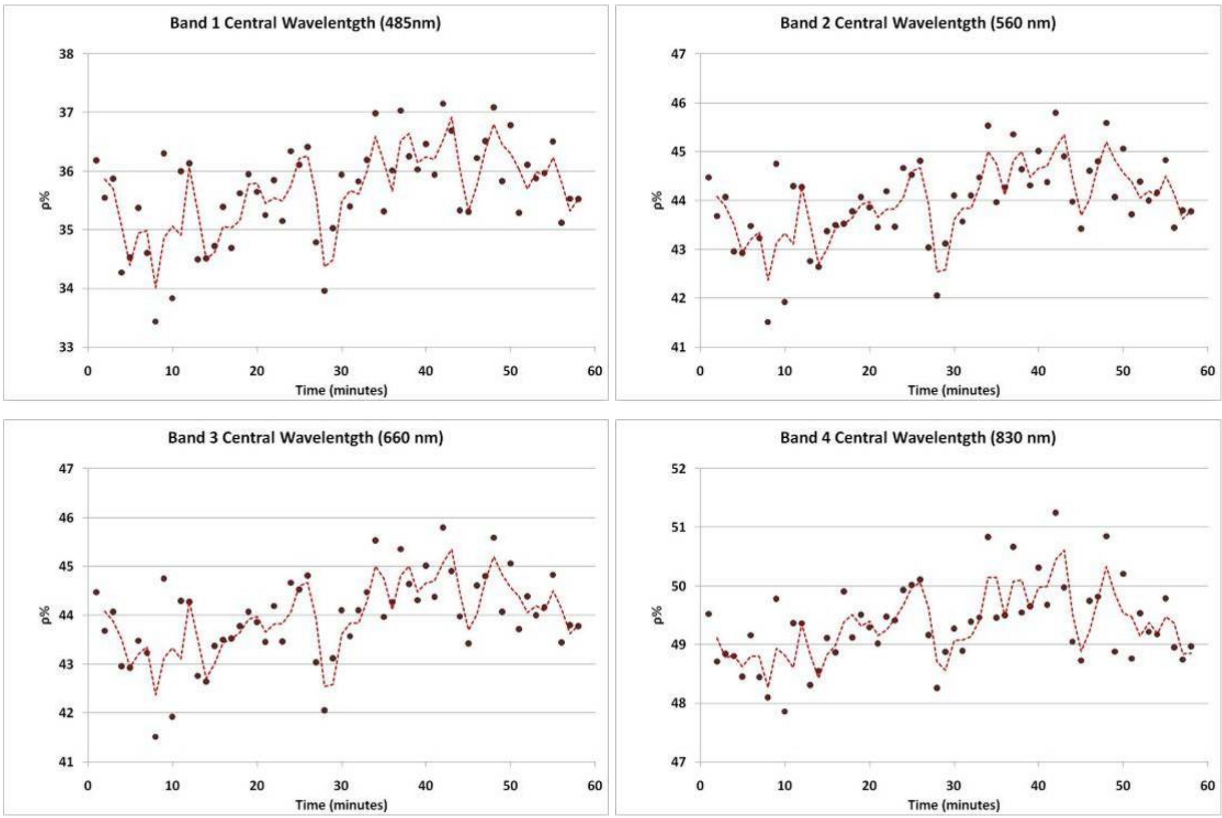


Figure 7: Reflectance fluctuations for case B, during 11:30 -12:30. The first measurement taken at 11:30 was considered as the reference value.

3.2. Impact on vegetation indices

To summarize, the result gives an indication that frequent measurements at the spectralon panel (less than 3 minutes) give sufficient accuracy for purposes of measuring the reflectivity of a target. Based on the previous results, Figure 8 shows the hypothetic impact of these fluctuations to the Normalized Difference Vegetation Index. In Figure 8, fluctuations of 1% and 2% changes at red and near infrared bands are highlighted. Such fluctuations have a very small impact (<0.5% of NDVI) in most of cases, while the largest difference is close to 2%. However, such fluctuations are almost negligible when the plant begins to grow. In this phenological cycle phase, the plant is characterized by high values in the near infrared reflectance and low values in the red spectrum.

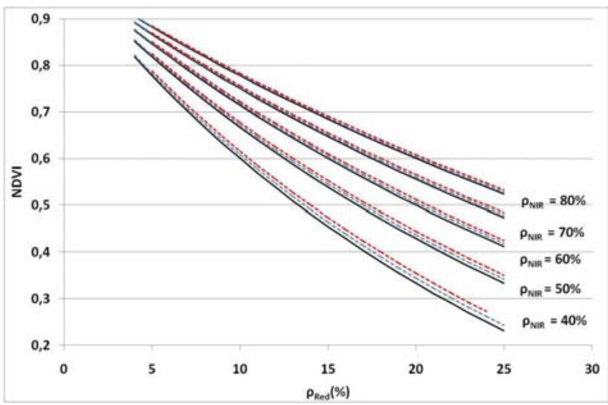


Figure 8: Impact of the spectroradiometer calibration for the NDVI index. In black is the NDVI as calculated without any impact, blue dash line with an impact of +1% and red dash line indicates the impact of the NDVI values with a +2% change.

4. Conclusions

This paper presents the impact of the time interval between the spectralon pane and the target measurements. For this purpose two identical spectroradiometers were used. Several targets have been continually measured between 11:30-12:30 local time (1-2 minutes interval time). The analysis of the results has shown that for clear, non hazy days only small variations can be observed for the same target (less than 1%). This error is far more less than satellite observations (≈ 5%), according to literature.

Moreover, these small variations are considered not significant when applied for vegetation indices. The mean values are less than 0.5% of the NDVI value. In addition, periods where the plant grows, the NDVI is minimized.

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