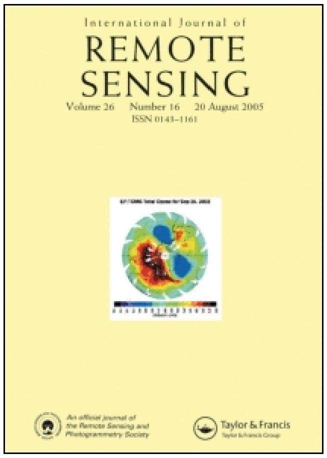

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X. F. Gu [a]; G. Guyot [a]; M. Verbrugghe [a]
[a] INRA Bioclimatologie, 84143 Montfavet Cédex, France

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Evaluation of measurement errors in ground surface reflectance for satellite calibration

X. F. GU, G. GUYOT and M. VERBRUGGHE
INRA Bioclimatologie, BP 91, 84143 Montfavet Cédex, France

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Abstract. One of the more efficient methods used for in-flight calibration of Earth resource satellites is based on measurements performed at ground level on a test site. An experimental study has been conducted in La Crau Sèche (south-east France), where a calibration site for SPOT satellites is intended. The accuracy of the calibration depends, critically, on the accuracy of ground bidirectional reflectance factor (BDRF) measurements.

All of the different sources of error are analysed. These are due to two series of factors depending on the characteristics of the radiometer (electronic characteristics, absolute calibration, angular setting of the radiometer) and of the ground surface (the spectral, spatial, angular and temporal variability of the BDRF). The relative weight of these different causes of error is determined from experimental data. This analysis shows that, besides the well-known disturbing factors such as the calibration of the radiometer and the spatial variability of the BDRF, two other factors can introduce large measurement errors: the spectral and angular variability of reflectance of the site.

This detailed analysis of the different causes of error is not only valid for the calibration of a satellite, but it can also be used to draw up guidelines for performing accurate BDRF measurements in natural conditions for any application.

1. Introduction

The comparison and the combination of multitemporal and multisystem satellite images requires knowledge of the absolute calibration coefficients of the satellites. One of the more efficient methods used for the determination of these coefficients in the visible and near-infrared domains is based on measurements performed at ground level on a test site (Slater *et al.* 1987). The radiance at the satellite level is estimated from atmospheric parameters and the measured bidirectional reflectance factor (BDRF) of the ground surface. The absolute calibration coefficient is then determined by comparing the radiance estimate to the mean digital count, corresponding to the calibration site, on the satellite image.

In the method based on test-site measurements the accuracy of the satellite calibration depends, critically, on the accuracy of ground BDRF measurements. The other sources of errors are related to the determination of atmospheric spectral optical depth and gaseous transmittance, the atmospheric radiative transfer code used and the digital count uncertainties of the test site (Slater *et al.* 1987). Comparison of these different sources of errors shows that the error in ground BDRF plays an important role (Slater *et al.* 1987, Vermote 1990). So, before initiating any calibration procedure, it is necessary to determine the accuracy of the test-site BDRF measurements.

The accuracy of ground BDRF measurements depends on several factors: the characteristics of the radiometer (Guyot *et al.* 1984, Jackson and Robinson 1985), its absolute calibration (Jackson *et al.* 1987, Biggar *et al.* 1988), the method used for irradiance measurements (Milton 1981, Kimes and Kirchner 1982, Lord *et al.* 1985) and the spatial variation of the BDRF (Curran and Williamson 1985, 1986, Curran and Hay 1986). Field measurements performed in order to prepare a French calibration site for the SPOT satellite have been used to analyse the errors due to these different factors.

2. Materials and methods

2.1. *Calibration site*

The calibration site is a $400 \times 400\,m^2$ area, used for the absolute calibration of SPOT. It is located in the centre of La Crau Sèche, a $60\,km^2$ pebbly flat area in the south-east of France, on the eastern bank of the River Rhone and at about 50 km north-west of Marseille (Gu *et al.* 1990). This area has a dry and sunny Mediterranean climate. The soil is mainly composed of pebbles and is sparsely covered by a low vegetation, so its optical properties vary little during the year.

2.2. *Data acquisition*

The BDRF measurements were performed with SPOT simulation radiometers, which simultaneously measure the radiance and the irradiance in the SPOT channels (Guyot *et al.* 1984). In order to analyse the accuracy of BDRF measurements, the non-Lambertian response of the irradiance head and reference panel and the optical characteristics of the site (spectral, spatial, angular and diurnal variations of the BDRF) have been determined.

2.2.1. *Determination of the angular response of the irradiance head and reference panel*

The angular response of the irradiance head of the radiometer does not follow the cosine law because the diffusers used are not perfect (Guyot *et al.* 1984). Therefore, it is neccessary to determine the correction factor that must be applied as a function of the solar zenith angle. This was determined from measurements performed during the summer of 1989. The irradiance head was fixed on a telescope stand, in order to vary the incidence of the Sun's beam for a given solar position. For each incidence angle, the response of the radiometer to global and diffuse irradiance was determined (the radiometer was shadowed with a small panel masking the Sun) in order to determine its response for direct irradiance.

The angular response of the reference panel, used for the calibration of the radiometer, is also different from that of a perfect Lambertian diffuser (Jackson *et al.* 1987, Biggar *et al.* 1988). Its directional response was determined in the laboratory using a goniometer and the direct illumination of a lamp (Verbrugghe and Lecomte 1990).

2.2.2. *Reflectance spectra of the ground surface*

In order to determine the effect of the non-concidence of the spectral bands of the radiometer and of the satellite, it was necessary to determine the mean reflectance spectrum of the site. This was determined in the range of 450–1000 nm

(2 nm step) with a spectro-radiometer Barringer REFSPEC II A†. Sixteen spectra were determined (on 17 May 1989) on sample surfaces of 0·25 m^2 scattered within a circle of 50 m in diameter.

2.2.3. *Spatial variation of the reflectance of the site*

Two series of airborne measurements were performed, on 22 March and 21 July 1988. The spatial variation of the BDRF of the site was analysed from digitized multispectral aerial photographs with square pixels of 0·60 m (Gu *et al.* 1990). From these pixels, different ground resolutions were simulated (1·2, 2·4, 4·8, 9·6 and 19·2 m) and the variation coefficient of the BDRF of the pixels was determined. This analysis combined with ground-level BDRF measurements allowed the best sampling design for characterizing the BDRF of the site with ground-level measurements to be defined.

2.2.4. *Angular variation of the reflectance of the site*

The angular variation of the BDRF of the site was determined with a SPOT simulation radiometer fixed at the extremity of an inclinable boom mounted on wheels, in order to be easily moved from one place to another (figure 1) (Guyot *et al.* 1989). With this equipment the ground BDRF was measured in vertical planes from −70 to +70° (5 or 10° steps). The measurements were performed for different solar zenith angles on 18 February, 9 March, 14 April and 27 July 1988 in azimuthal planes, with respect to the Sun position, of 0, 45, 90 and 135°. The data obtained were used to draw up polar diagrams representing the angular variation of the ground BDRF.

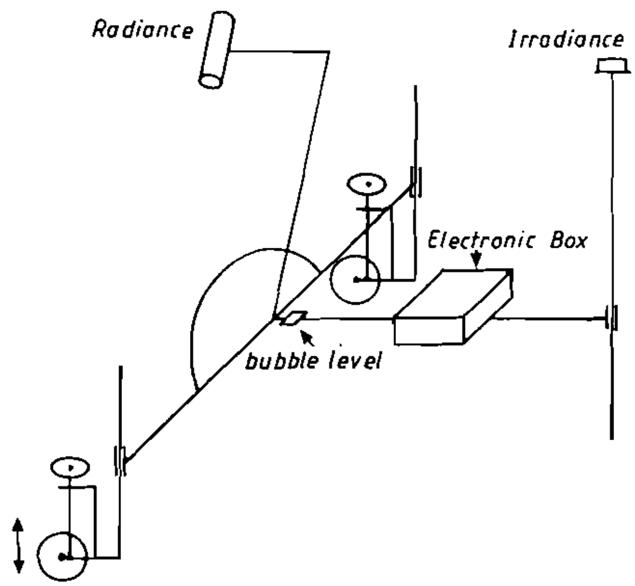

Figure 1. Schematic representation of the mobile boom used for determining the angular variation of the ground reflectance.

†Trade names and company names are included for the convenience of the reader and imply no endorsement by the Station de Bioclimatologie de l'INRA at Avignon Montfavet (France).

2.2.5. *Diurnal variation of the ground reflectance*

The diurnal course of the ground reflectance was measured on 19 and 20 September 1988. The radiance head of the radiometer viewed vertically the same surface throughout the day. The irradiance was simultaneously measured. Data were corrected according to the variation in response of the irradiance head, as a function of the solar zenith angle, before calculating the ground BDRF.

3. Evaluation of measurement errors in the ground reflectance

The measurement errors are due to two series of factors related to the radiometer and to the characteristics of the viewed area.

3.1. *Measurement errors due to the radiometer*

The measurement errors due to the radiometer depend on the characteristics of its electronics, on its calibration and on its angular setting.

3.1.1. *Measurement errors due to the electronics of the radiometer*

Four factors can affect the response of the radiometer: the linearity of the detector and electronics, the background noise, the thermal drift and the long-term stability.

The detector used in the radiometer is a silicon photodiode which has a good thermal stability (Jackson and Robinson 1985, Slater 1985). The electronics have been designed and the detector has been selected (Guyot *et al.* 1984) in order to minimize the different sources of error. So the errors due to the electronics of the radiometer are the following (data supplied by the manufacturer of the components of the radiometer):

- linearity of the detector $\pm 0{\cdot}25$ per cent
- linearity of the electronics $\pm 0{\cdot}10$ per cent
- background noise, thermal drift, long-term stability $\pm 0{\cdot}25$ per cent

Thus, the total error due to the electronics of the radiometer is $\pm 0{\cdot}37$ per cent (expressed as the quadratic sum).

3.1.2. *Measurement errors due to irradiance determination*

The BDRF measured by the radiometer (Robinson and Biehl 1979) corresponds to the quotient of directional radiance (measured by the radiance head) to hemispherical irradiance, which can be determined in two different ways. A reference panel can be viewed between two measurements of the target with the same radiometer (Slater *et al.* 1986, 1987) or two heads can simultaneously measure radiance and irradiance (Duggin 1980, Duggin and Cunia 1983, Guyot *et al.* 1984). Three factors can introduce measurement errors: the variation of solar irradiance, the horizontality of the reference panel or irradiance head and the angular response of the panel or irradiance head.

The solar irradiance varies as a function of the Sun zenith angle and the atmospheric conditions. The Sun zenith angle introduces low-frequency variations of irradiance and they can be minimized if the measurements are performed around solar noon. At the other extreme, atmospheric conditions can introduce high-frequency variations (up to 100 per cent within 5-min periods) (Lord *et al.* 1985). In order to reduce the latter effects, radiance and irradiance can be measured simultaneously. If such measurements are not possible, it is neccessary to select clear days and small enough time intervals to minimize the effects of irradiance variations.

The irradiance head must be set horizontally. With an inclination of $\pm 1°$, the error in irradiance measurement will be ± 1 per cent for a Sun zenith angle of 30° and ± 3 per cent for a Sun zenith angle of 60°. In the present case, the horizontality of the irradiance head was determined with an accuracy of $\pm 0{\cdot}4°$ by using a precision bubble level. The error in direct irradiance was lower than $\pm 0{\cdot}5$ per cent. But for a clear day, the direct irradiance represents about 80 per cent of the global irradiance, so the error, due to the inclination of the irradiance, is about $\pm 0{\cdot}4$ per cent for clear days.

The angular response of an irradiance head of a reference panel does not exactly follow Lambert's law (Kimes and Kirchner 1982, Guyot *et al.* 1984, Jackson *et al.* 1987, Biggar *et al.* 1988). The two components of irradiance (direct and diffuse) must be separated and corrected independently. The direct component must be multiplied by a coefficient determined from the angular variation of the response of the panel (or of the irradiance head). The diffuse component must be multiplied by a coefficient deduced from the average directional response of the panel (or of the irradiance head). If such corrections are not applied the error introduced can reach ± 5 per cent, depending on the Sun zenith angle and atmospheric conditions (figure 2).

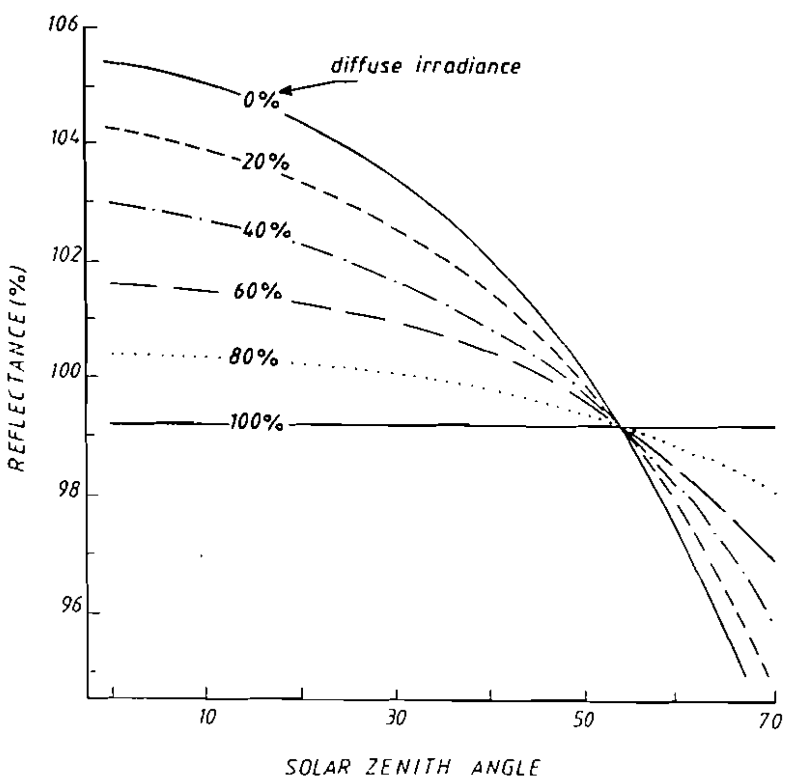

Figure 2. Variation of the reflectance of a spectralon reference panel as function of Sun zenith angle and for different proportions of diffuse and direct irradiance (SPOT XS1 channel).

In natural conditions the BDRF of the reference panel can be deduced from its hemispherical reflectance and its directional response (Jackson *et al.* 1987). The directional response corresponds to the direct solar irradiance, and the hemispherical reflectance is applied to the diffuse component. The relative weight of these two components depends on atmospheric conditions. A $0{\cdot}5 \times 0{\cdot}5\text{-m}^2$ panel covered with spectralon (Labsphere Inc., Ref SRT 99 180), whose mean hemispherical reflectance was 99·2 per cent between 300 and 1600 nm (table 1), has been used in these measurements. The panel was calibrated by the manufacturer using a double beam ratio recording integrating sphere reflectometer and a ceramic tile as a reference; the tile was calibrated by the National Institute of Standards and Technology. The measurement repeatability, applicable to absolute BDRF values provided by Labsphere Inc., is given to have a standard deviation less than 0·005. Thus, the calibration error of the panel is less than $\pm 1{\cdot}0$ per cent (two times the standard deviation).

But this panel is not perfectly Lambertian (Verbrugghe and Lecomte 1990), and figure 2 shows the variation of its BDRF when it is viewed vertically for different Sun zenith angles and different atmospheric conditions. The error, which can reach ± 5 per cent without any correction, can be reduced to ± 1 per cent if it is assumed that the global irradiance corresponds only to direct Sun radiation. If the relative weight of diffuse and direct components is introduced, the error can be reduced to $\pm 0{\cdot}15$ per cent. In this case, the diffuse radiation is assumed to be isotropic.

3.1.3. *Measurement errors due to the radiometer calibration*

The BDRF of a surface is determined from the ratio of the signals corresponding to radiance and irradiance measurements, multiplied by a calibration coefficient. This calibration coefficient is determined by viewing a calibrated reference panel.

For calibration of the SPOT simulation radiometer, the calibrated reference panel was viewed vertically in natural conditions. The angular variation of the panel BDRF was corrected using the data on figure 2. Without these corrections, the

Table 1. Hemispherical reflectance factors for the reference panel (Labsphere Target No. SRT-99-180-3617-A) (original data measured with 50-nm steps).

Wavelength (nm)	Hemispherical reflectance factor
300	0·987
400	0·989
500	0·991
600	0·993
700	0·992
800	0·992
900	0·993
1000	0·993
1100	0·993
1200	0·992
1300	0·991
1400	0·990
1500	0·992
1600	0·992

Table 2. Measurement errors in radiometer calibration.

Source of errors	Error (%)
Electronics of the radiometer	±0·4
Hemispherical reflectance of reference panel (calibration by the manufacturer)	±1·0
Horizontality of the reference panel	±0·4
Horizontality of irradiance head	±0·4
Residual error due to the correction of non-Lambertian response of the reference panel	±1·0
Non-isotropy of diffuse irradiance	±0·2
Total error (quadratic sum)	±1·59

calibration coefficient would only be valid for the conditions in which it had been determined.

From this analysis, the measurement errors due to the radiometer calibration are as summarized (table 2).

3.2. *Measurement errors due to the characteristics of the target*

3.2.1. *Measurement errors due to the non-coincidence of the spectral bands of the radiometer with those of the satellite*

The spectral bands of the radiometer are defined by interference filters that have optical characteristics different from those of the optical system used aboard the satellite for defining different channels. Moreover, as seen in figure 3, the two HRV instruments of SPOT-1 are different (Begni 1985). If the target BDRF varies as a function of wavelength, the different instruments will not give the same data.

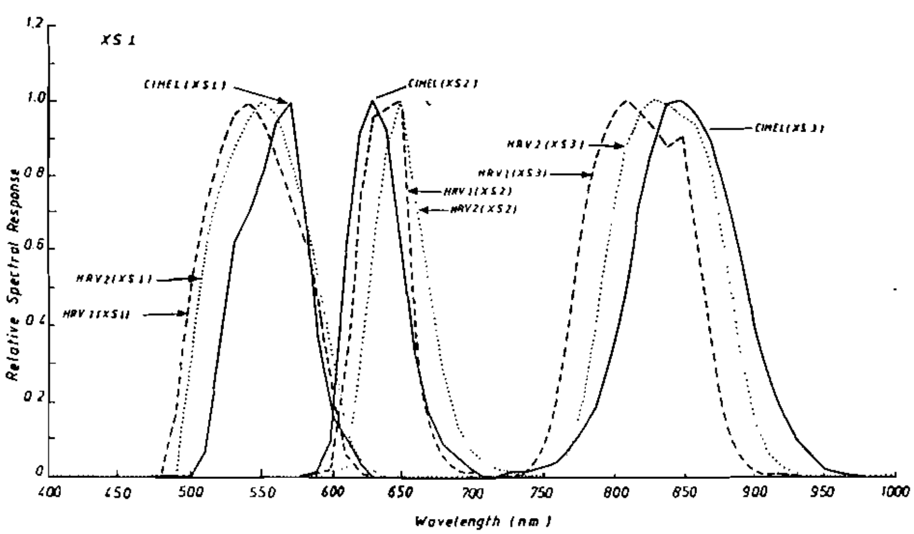

Figure 3. Spectral responses of the SPOT simulation radiometer and of the two HRV instruments of the SPOT-1 satellite.

Table 3. Mean reflectances of La Crau for the three SPOT channels as a function of the instrument considered.

Channel	HRV1	HRV2	Field radiometer
XS1	0·160	0·165	0·169
XS2	0·215	0·219	0·215
XS3	0·318	0·326	0·331

Therefore, it is necessary to correct for these effects. The spectral response of the sensors (figure 3) must be combined with the ground reflectance spectrum in order to give the correction coefficient to be applied (Duggin 1983). Table 3 displays, as an example, the different BDRFs that can be measured on La Crau with the field radiometer and the two HRV instruments. It shows that this error cannot be neglected.

In the present case the correction coefficients were determined from reflectance spectra obtained with a high-resolution spectro-radiometer (Barringer REFSPEC II A). The average ground reflectance spectrum used corresponds to 16 measurements performed at different places. As can be seen in figure 4, the average ground reflectance spectrum does not present any strong absorption features. Such a spectrum is typical of a bare soil, and influence of the scarce natural vegetation being limited. In this case, it is not necessary to consider the whole reflectance spectrum; it would be sufficient just to use the centre of each band and to perform a linear interpolation. If this linear interpolation is used, the residual error determined by comparison with our spectral measurements is less than $\pm 0{\cdot}5$ per cent.

3.2.2. *Measurement errors due to the spatial variation of the reflectance*

A natural surface is never a perfectly homogeneous reflector. Its BDRF has a random spatial variation around the mean value. This variability of the BDRF

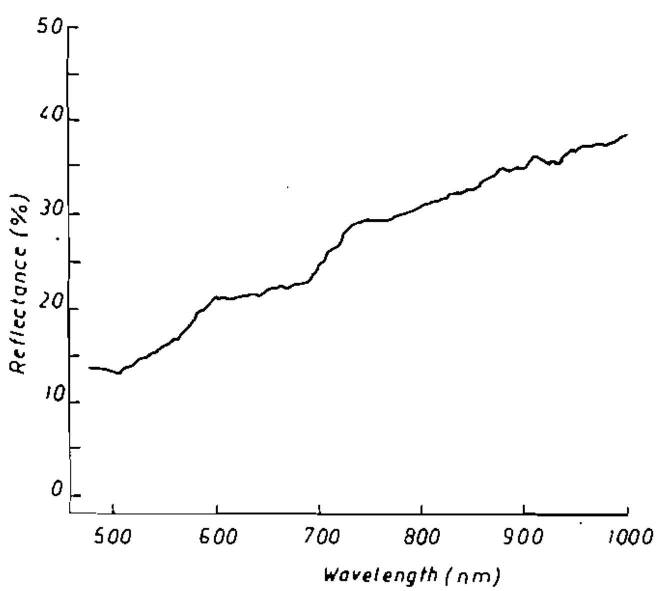

Figure 4. Average reflectance spectrum of La Crau between 400 and 1000 nm.

induces measurement errors that depend on the spatial distribution of the samples, their number and their size (Curran and Williamson 1985, 1986, Curran and Hay 1986).

The effect of the size of the samples was studied on digitized multispectral aerial photographs corresponding to the central part of the calibration site ($154 \times 154\,m^2$) (Guyot *et al.* 1989, Gu *et al.* 1990). This area was divided into 256×256 pixels of $0{\cdot}6\,m^2$ square. These pixels were then combined to form larger pixels (1·2, 2·4, 4·8, 9·6 and 19·2 m). The coefficient of variation of the different pixels is shown in figure 5. It shows that this coefficient of variation decreases when the pixel size increases; but this decrease is relatively small, because the ground heterogeneities are regularly distributed at the different scales considered. It can also be noted that the coefficient of variation is smaller in near-infrared (XS3) than in the visible (XS1 and XS2). This phenomenon is due to the particular characteristics of the calibration site where the dry vegetation has a BDRF quite comparable to that of the pebbles in near-infrared, while these two components of the ground surface have different optical properties in the visible domain.

For practical estimation on the average BDRF of a given surface, a limited number of samples was considered. In this study, the $154 \times 154\text{-}m^2$ surface with 0·6-m elementary pixels was used. The average BDRF of this surface was calculated with increasing numbers of pixels regularly distributed. The surface was then divided into N elementary square areas, each elementary square containing Q pixels. For calculating the average BDRF of the surface, one pixel was taken in each elementary square (Q average BDRFs calculated on N pixels). We then calculated the coefficient

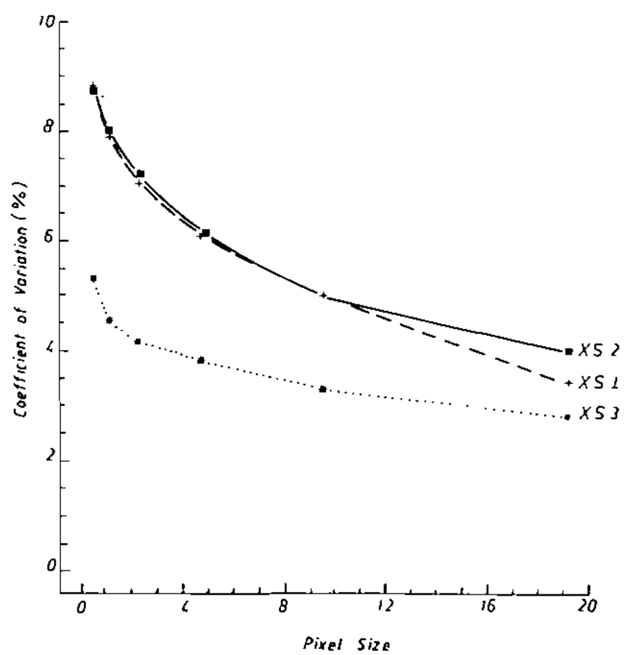

Figure 5. Effect of the pixel size on the coefficient of variation of the BDRF. Analysis performed from digitalized multispectral photographs.

of variation of the Q average BDRFs (Guyot *et al.* 1989, Gu *et al.* 1990). The results of these calculations are present in figure 6. It shows that the coefficient of variation of the average BRDF decreases when the size of the pixels and their number increase.

The comparison of figures 5 and 6 shows that the coefficient of variation of the average BDRF determined from N pixels practically equals the coefficient of variation of the pixels on the whole surface divided by $\sqrt{N}$ (Gaussian distribution).

Figure 6 also shows that the coefficient of variation of the average BDRF decreases asymptotically towards a limit independent of the pixel size. From a practical point of view, therefore, it is better to increase the number of measurements, performed with a field radiometer, than to increase the pixel size.

The number ($N > 30$) of measurements that are neccessary to estimate the average BDRF (R) of a given area with precision p is given, for a 95 per cent confidence interval, by the following equation (Dagnelie 1970):

$$N = 2(1{\cdot}96\sigma/pR)^2$$

in which σ is the standard deviation of the statistical distribution. Table 4 displays the results of calculations performed on ground radiometric measurements on La Crau (Gu *et al.* 1990).

If, for example, 200 measurements are performed on the SPOT calibration area, the precision of the average BDRF will be around 2 per cent in the visible and around 1 per cent in the near-infrared.

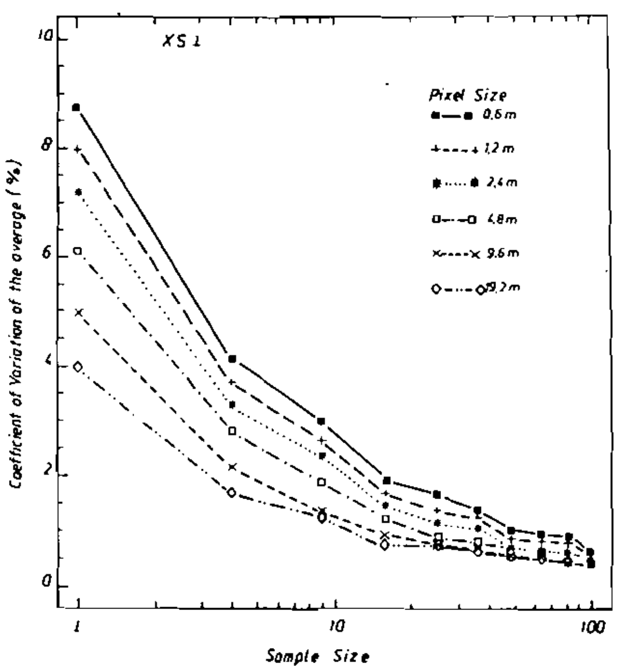

Figure 6. Coefficient of variation of average BDRFs of the test site as a function of sample size for six spatial resolutions (SPOT XS1 channel, simulated from multispectral aerial photographs).

Table 4. Number of measurements necessary for the estimation for the average BDRF of the SPOT calibration site with a given precision.

	SPOT Channels		
	XS1	XS2	XS3
Coefficient of variation	10·7	10·0	5·1
Precision 1 %	880	764	200
Precision 1·5 %	390	341	88
Precision 2 %	218	192	50
Precision 2·5 %	141	122	32

3.2.3. *Measurement errors due to the non-Lambertian characteristics of the surface*

The BDRF of a natural surface varies according to the Sun position and according to zenith and azimuth view angles (Guyot 1989). Figure 7 displays the results of measurements performed on La Crau (Guyot *et al.* 1989).

The azimuth, with respect to the Sun, is indicated on the external circle. The concentric circles correspond to different inclinations of the view axis. The cone coresponding to the range of variation of the inclination of the SPOT view axis corresponds to the central circle (30°).

The angular variation of the BDRF is quite similar for the two visible channels (XS1 and XS2) (Guyot *et al.* 1989); for this reason, just the figure corresponding to XS2 has been represented. In near-infrared (XS3) some difference from the visible domain can be observed, because the hot spot is less marked due to the presence of low vegetation.

When SPOT passes over a given area, the azimuth of a scanning line, with respect to the Sun, depends on the time of the year and the off-nadir view angle, as indicated in table 5.

The combination of these data with figure 7 shows that the ground BDRF of La Crau, viewed by SPOT, can have variations larger than ± 10 per cent if both nadir and $\pm 30°$ off-nadir view angles are considered. Therefore, it is necessary to correct for this effect.

The correction that must be applied can be deduced from figure 7 if the off-nadir view angle and the orientation of the scanning lines are known. The error on BDRF will depend on the accuracy of the diagram. In the present case, it is estimated to be about ± 1 per cent.

For calibration of the satellite, this error can be avoided by performing ground BDRF measurements with the same viewing geometry as the satellite. For this purpose we have designed a support for the radiance head of the radiometer has been designed that allows the easy adjustment of the zenith and azimuth view angles (figure 8). It is fixed at the extremity of an horizontal arm oriented towards the Sun.

3.2.4. *Measurement errors due to the temporal variation of the reflectance*

For characterizing a surface, it is neceassary to make measurements over a certain number of points with respect to the accuracy needed (table 4). The Sun zenith and azimuth angles vary during these measurements. Therefore, it is necessary to introduce corrections for the non-Lambertian characteristics of the surface and

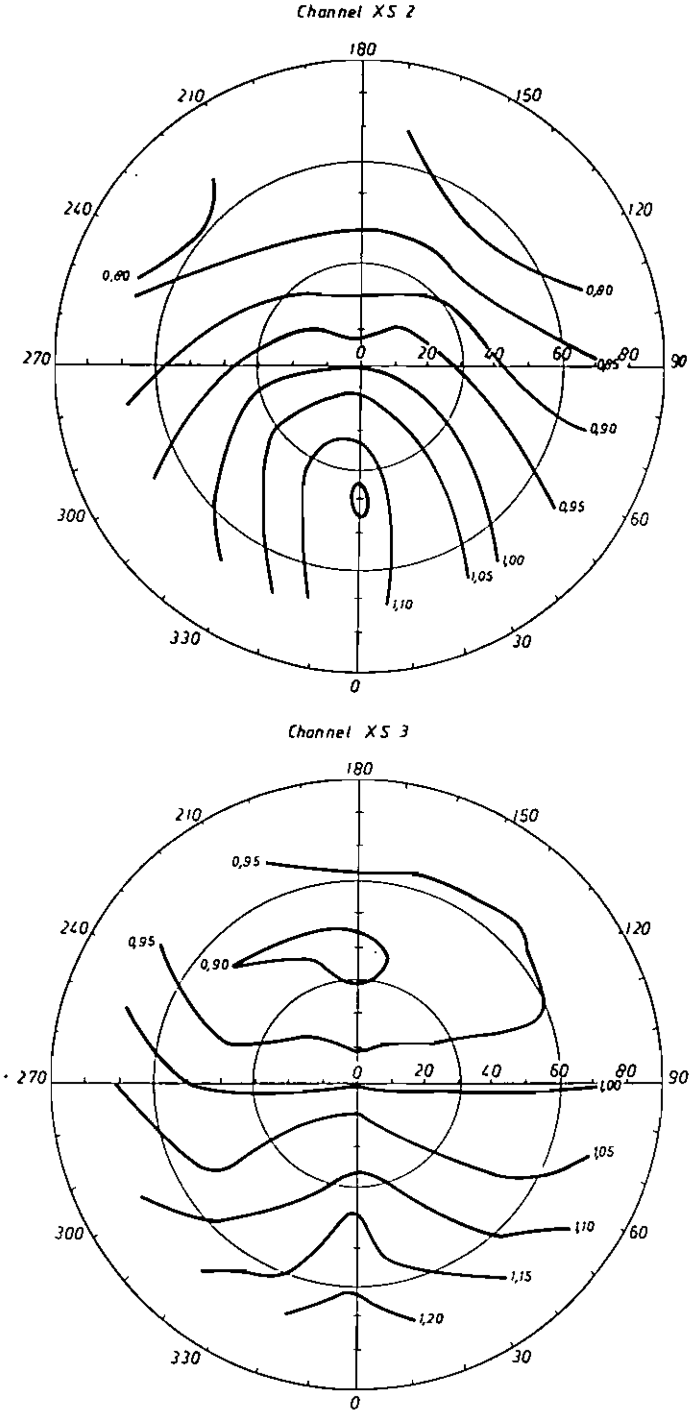

Figure 7. Relative variation of the BDRF of La Crau. The nadir measurement is taken as a reference. The concentric circles correspond to zenith view angles and the graduations, on the external circle, correspond to the azimuth with respect to the Sun. The measurements were performed in SPOT channels XS2 and XS3 on 27 July 1988 at 11h 52 a.m.

Table 5. Azimuth of SPOT scanning lines, over La Crau (43·34° N 4·52° E), for different dates and different off-nadir view angles. The orientation towards East is counted positively.

	SPOT off-nadir view angles (degrees)						
Dates	−30	−20	−10	0	+10	+20	+30
21 June	44·5	44·0	43·0	41·0	140·0	141·5	142·5
21 March 23 September	59·5	59·0	58·0	56·0	125·0	126·5	127·5
21 December	66·5	66·0	65·0	63·0	118·0	119·5	120·5

eventually for the effect of crop row orientation. As the Sun zenith angle does not vary strongly around solar noon, this time of day is best for performing BDRF measurements.

In the present test site, the BDRF of the pebbly soil covered with a sparse vegetation is relatively stable during the day, as can be seen on Figure 9. These data correspond to a series of measurements performed on one particular point whose reflectance was different from the mean value of the test site. If the measurements are performed around solar noon, the error is less than 0.2 per cent. A strong wind (the Mistral) can blow in this area, but, as the vegetation is very low, its shape is not affected by the wind and its effect has been neglected in this study.

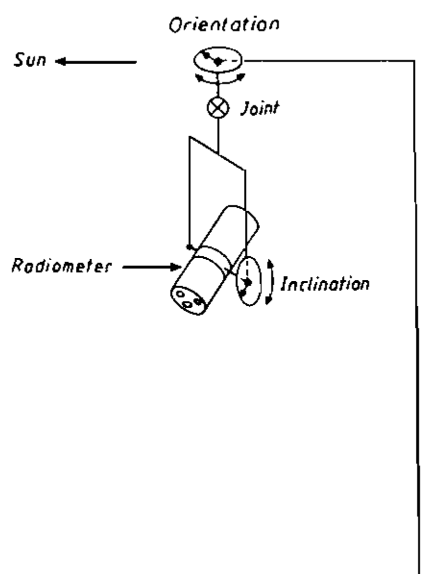

Figure 8. Schematic representation of the support developed for the measurement of ground radiance with SPOT viewing geometry.

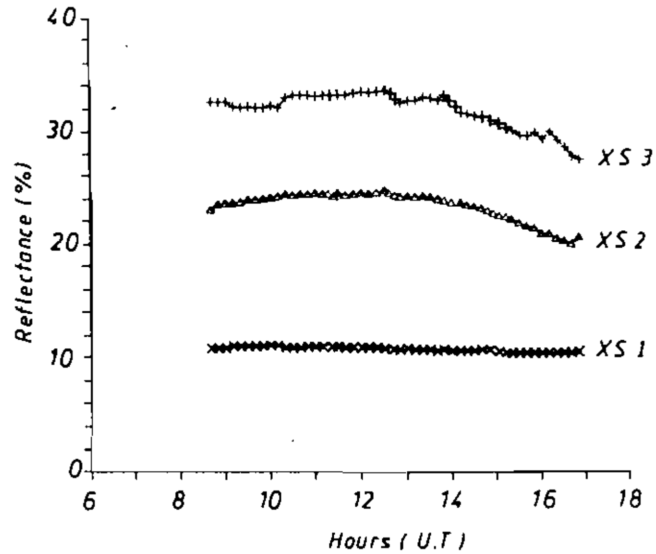

Figure 9. Diurnal variation of the BDRFs of La Crau measured on 20 September 1988.

3.3. *Determination of global error on the reflectance of La Crau*

The global measurement error in the BDRF of the SPOT calibration site can be determined from the preceding analysis. If the distribution of the different errors is assumed to be gaussian and they are assumed to be indpendent, the global error can be estimated as their quadratic sum (table 6).

Table 6 shows that two main sources of errors remain: the error due to the spatial variability of the site and the error due to the calibration of the radiometer. It is difficult to reduce them at the present time.

Table 6. Measurement error in the BDRF of SPOT calibration site.

Source of error	Error (%)
Radiometer	
Electronics	±0·4
Irradiance	
Horizontality of irradiance head	±0·4
Non-Lambertian response (after correction)	±0·5
Calibration	±1·6
Target	
Non-coincidence of spectral bands	±0·5
Spatial variation of reflectance (200 samples)	±2·0[a]
Non-Lambertian characteristics of the surface	±0·5
Temporal variation of the reflectance	±0·2
Total error	±2·76

[a]For XS1 and XS2 channels; the error for XS3 is ±1 %.

4. Conclusions

This study was primarily intended for determining the BDRF of the SPOT calibration site in La Crau. It has been necessary to investigate the different sources of measurement error. They are due to two series of factors, depending on the radiometer used and the target viewed. The effect, on the accuracy of the BDRF measurements, of the calibration of the radiometer and of the sampling design on the target, is well known. But this study has shown that two other factors, which are often neglected, can also introduce relatively large measurement errors.

The first factor is the non-Lambertian response of reference panels and the irradiance head of SPOT simulation radiometers. If these effects are not corrected, as a function of the solar zenith angle and of the atmospheric conditions (i.e. the relative proportion of direct and diffuse irradiance), the BDRF of a reference surface can have apparent seasonal variations reaching ± 20 per cent.

The second factor is the non-coincidence of the spectral bands of a field radiometer with those of a satellite. This effect is particularly important if the measurements by different instruments have to be compared in the same area. But while it is relatively easy to determine the corrections that must be applied for bare soils (which have a linear variation of the BDRF from visible to near-infrared), it is more difficult to determine those corresponding to a target, whose reflectance spectrum presents large variations within the spectral domain considered (such as vegetation). The correction must be based, in this case, on the detailed average reflectance spectrum of the target convoluted with the spectral response of the sensors.

The results of this study are not specific to satellite calibration. They have a wider domain of application and can be used in order to establish guidelines for performing any ground-level BDRF measurement.

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