What does a spectroradiometer see?

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Introduction

The field of view (FOV) and it's uniformity are poorly considered in field spectroscopy and manufacturer's specifications generally lack detail. For users, determining the scene within the FOV is largely an exercise in guess work. If the FOV and its uniformity are unknown, the surfaces contributing to the reflectance recorded will be ill defined. Especially for heterogeneous earth surfaces these details matter. We report here initial findings into accurate measurement of the FOV and its uniformity for GER 3700 and ASD FieldSpec Pro field spectroradiometers.

Methods

Field of view is used to define the solid angle through which light incident on the input or fore optics will enter the detector system. It is a vague parameter and gives no indication as to the responsivity of the system to light from different angles within the FOV. An alternative approach is to generate a *directional response function* (DRF), which details the response of the system to the angle of incident light.

To determine the DRF of a spectroradiometer, linear stages with micrometers were used to move a point source vertically and horizontally with respect to the optical axis of the spectroradiometer (figure 1). This method allowed great precision over the small angles of movement required.

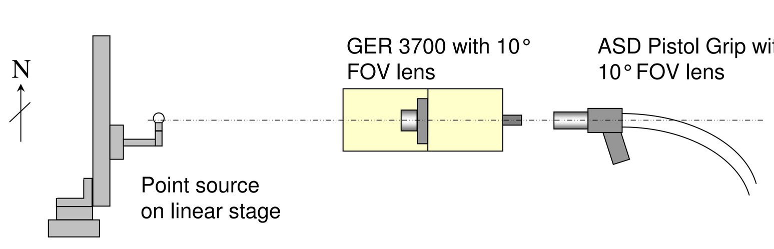


Figure 1 Setup of spectroradiometer fore optics

Instruments

The FOVs of an ASD FieldSpec Pro FR and a SVC GER 3700 spectroradiometer were measured. Both these instruments cover the spectral range 350 to 2500nm but the two systems use different technologies. The ASD records the full spectral range using three separate spectrometers with light from the fore optic being transmitted to the individual spectrometers via a randomised optical fibre bundle (figure 2).

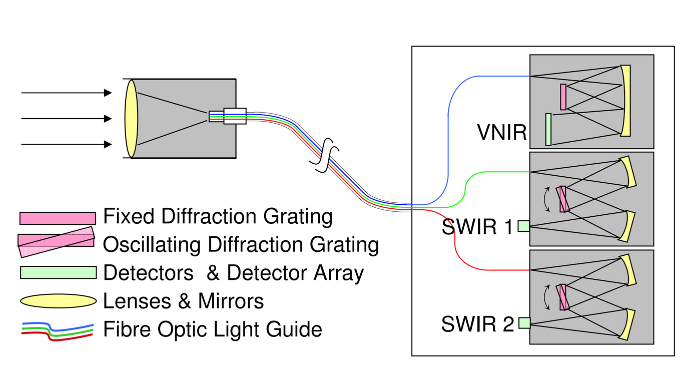


Figure 2. Optical layout of ASD FieldSpec Pro FR

The optical path through the GER 3700 is split into three spectrometers using a combination of lenses, apertures, mirrors and beam splitters (figure 3). This complex arrangement requires careful design and alignment to minimise differences in the directional response. Both systems were fitted with their manufacturer's 10º FOV lens for measurements in this research.

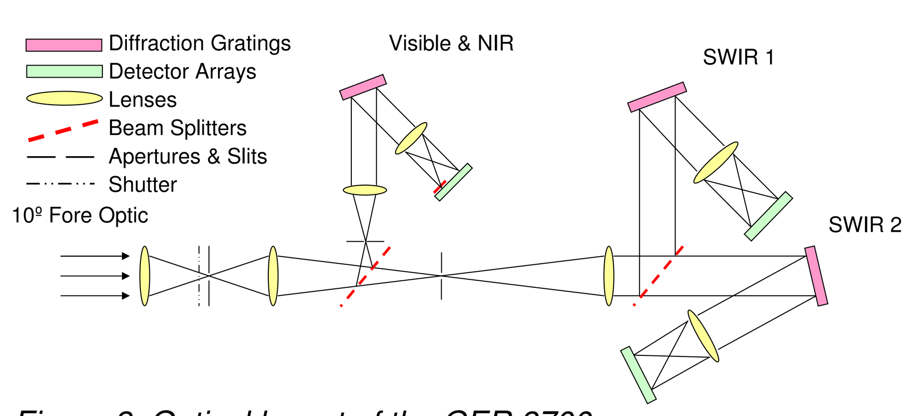


Figure 3. Optical layout of the GER 3700

Results - ASD FieldSpec Pro FR

The geostatistically interpolated data presented in Figure 4 represents the DRF for the upper two quadrants of the FOV for wavelengths typifying the response of each of the three spectral channels, VNIR, SWIR 1 and SWIR 2.

The blue dashed semi-circle represents the theoretical FOV of the 10º fore optic at a distance of 1750mm.

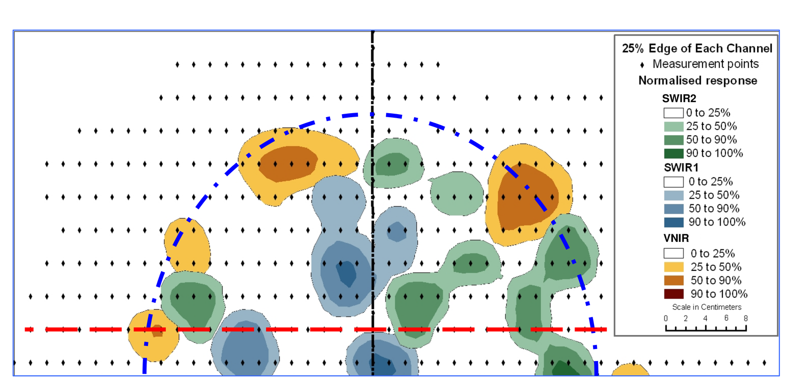


Figure 4 25, 50 and 90% directional response contours for ASD FieldSpec Pro FR at 600, 1600 and 2100nm.

A cross-section (red dashed line, figure 4) of the ASD's system's responsivity from the three channels is shown in figure 5. This also highlights the strong spectral and spatial dependencies across the spectroradiometer's field of view.

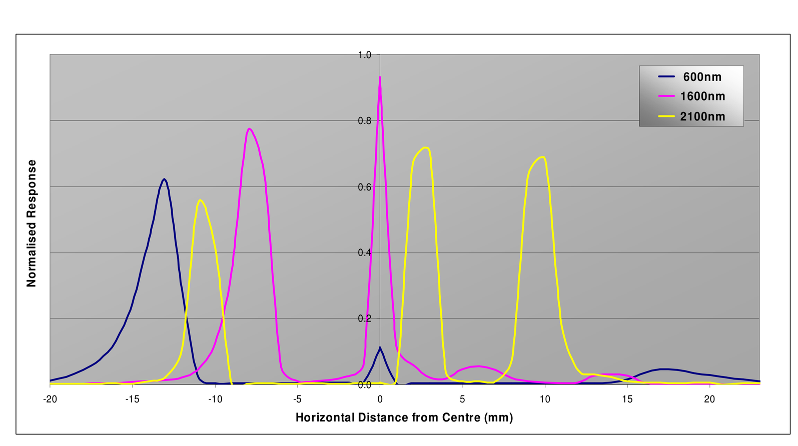


Figure 5 Normalised response across the field of view of the ASD FieldSpec Pro FR

The combined FOV (5% response level) for the three channels demonstrates that areas outside the theoretical FOV influence the reflectance recorded (figure 6).

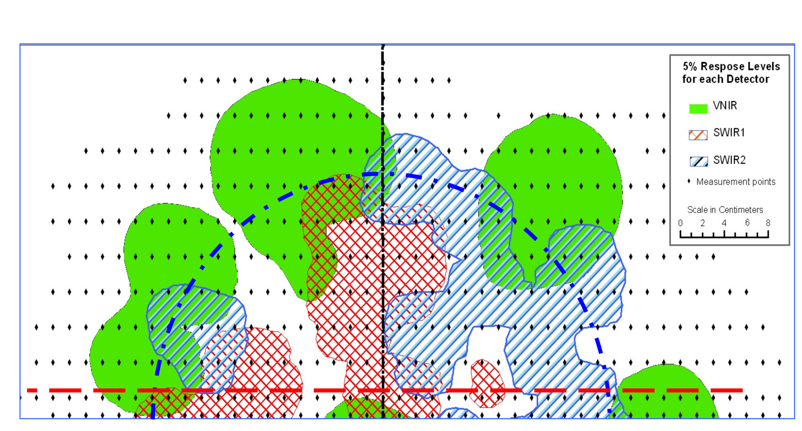
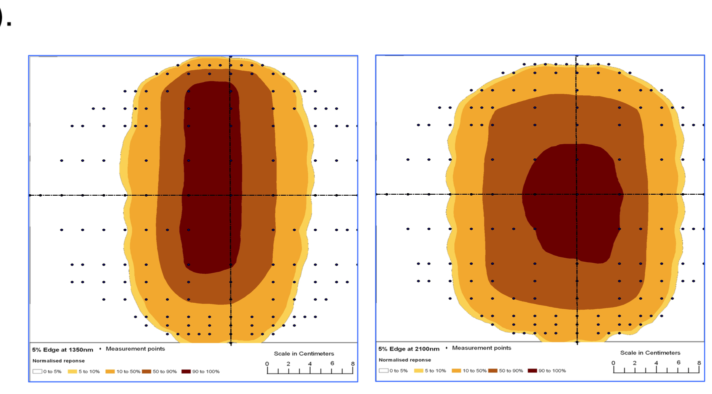


Figure 6 ASD FieldSpec Pr FR 5% directional response contours for VNIR, SWIR1 and SWIR2 channels,

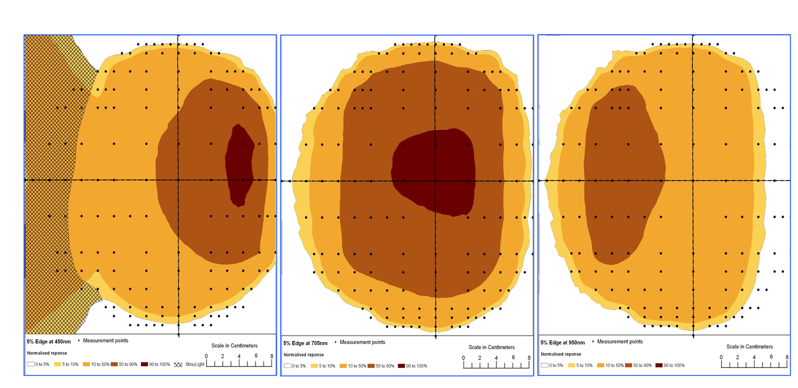
Results - GER 3700

The normalised response plots for the SWIR-1 and SWIR-2 channels of the GER 3700 demonstrate the influence of the rectangular aperture slit (figures 7a & b).



Figures 7a & 6b SWIR 1 (1350 nm) & SWIR 2 (2100 nm) directional response contours of the GER 3700 with 10º fore optic.

The DSF of the VNIR channel at 450, 705 and 950nm respectively are shown in figure 8. The peak response contours show a marked shift from left to right of the FOV as the wavelength is scanned from the blue to the near infrared. Thus, the left hand side of the DRF has a greater bias to blue light compared to the right hand side where the NIR has its maximum response.



Figures 8a, 8b & 8c Directional response contours for 450, 705 & 950 nm wavebands of the GER 3700 with 10º fore optic

The shaded area on the left side of figure 8a, where the signal at 450nm would be expected to drop to zero, remains high due to NIR stray light being detected at the blue end of the detector array.

The FOV data is summarised in Table 1 which lists the horizontal and vertical view angles at the 90, 50, 10 and 5% responsivity contours.

Table1. View angles and offsets for the GER3700 instrument

Waveband (nm)	90% contour				50% contour			
	Horizontal (E-W)		Vertical (N-S)		Horizontal (E-W)		Vertical (N-S)	
	View angle	Offset	View angle	Offset	View angle	Offset	View angle	Offset
450	1.3 °	2.6 °	2.9	0.5 °	4.6 °	1.3 °	6.5 °	0.3 °
705	3.1 °	-0.2 °	3.3 °	0.3 °	6.5 °	-0.7 °	8.5 °	0.0 °
950	N/A	N/A	N/A	N/A	4.2 °	-2.1 °	6.4 °	0.2 °
1350	1.8 °	0.7 °	7.2 °	0.7 °	3.3 °	-0.3 °	8.5 °	0.3 °
2100	3.1 °	-0.2 °	0.4 °	-0.3 °	5.1 °	-0.4 °	8.0 °	-0.4 °
Waveband (nm)	10% contour				5% contour			
	Horizontal (E-W)		Vertical (N-S)		Horizontal (E-W)		Vertical (N-S)	
	View angle	Offset	View angle	Offset	View angle	Offset	View angle	Offset
450	7.8 °	0.0 °	9.6 °	0.2 °	8.5 °	0.0 °	10.0 °	0.2 °
705	8.5 °	-0.8 °	10.0 °	-0.2 °	9.7 °	-1.0 °	10.4 °	-0.2 °
950	7.6 °	-1.5 °	9.7 °	-0.2 °	8.8 °	-1.5 °	10.2 °	-0.2 °
1350	5.4 °	-0.3 °	10.7 °	0.0 °	5.9 °	-0.3 °	11.0 °	0.0 °
2100	7.0 °	-0.4 °	10.0 °	0.3 °	7.2 °	-0.3 °	10.4 °	0.3 °

Conclusions

The general use of the term 'field of view' by manufacturers has been shown to be inadequate in the two instruments tested. If the responsivity is uneven across the measurement field and the area measured is different from that assumed, the components considered to be within a scene may not be represented in the gross reflectance recorded. This may lead to erroneous characterisation and poor quantification of (bio)physical and (bio)chemical variables.

Field campaigns on heterogeneous targets should include procedures to verify the performance and repeatability of the optical equipment used. New designs should also be sought for fore optic accessories or systems which offer improved uniformity without totally sacrificing spectroradiometer sensitivity.

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