Operational radiometric calibration of broadscale satellite sensors using hyperspectral airborne remote sensing of prairie rangeland: first trials

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Abstract. A new approach is being investigated to facilitate operational monitoring of post-launch satellite sensor performance. Airborne hyperspectral data are used to provide spatially extended ground-reference data applicable to the spectral bands of many sensors. Two rangeland sites in Alberta, Canada, were used for the first data acquisitions to test the method. This paper focuses on the data-acquisition program and the resulting data sets.

1. Introduction

An initiative is under way to provide semicontinuous monitoring of quality assurance and stability reference (QUASAR) test sites as an important step towards a calibration/validation infrastructure beneficial to mainstream users [1, 2]. The approach is a hybrid of the reflectance-based and radiance-based methods used for vicarious calibration of satellite sensors [3]. The QUASAR concept utilizes low-altitude hyperspectral data sets acquired routinely over spatially extensive monitoring sites to produce benchmark data sets in the spectral bands of commonly used sensors and make them widely available on a rapid and frequent basis. The intent is that such QUASAR data sets should provide an operational, repetitive capability for the interim performance monitoring of many satellite sensors, including those with large footprint sizes, between high-accuracy sensor calibration updates.

Initial tests of the QUASAR approach involve two different kinds of site. Prairie rangeland in Alberta provides slowly varying phenology and relatively uniform vegetative cover over large tracts of land, in spite of slightly rolling topography and directional reflectance effects. A common target such as this is relatively easy to access for airborne sorties initiated in Canada and tests the feasibility of using less-unique sites for interim performance monitoring of satellite sensors. For cross-calibration with international sensors and standards, special sites such as the bright playas often used for vicarious calibration purposes in the United States and elsewhere will also be imaged periodically as part of the QUASAR approach.

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Trial data-acquisition campaigns took place in Nevada in June 1997 and in Alberta in July 1997. This paper describes the data sets obtained at two rangeland sites in Alberta, including ground-based measurements, satellite imagery, and hyperspectral data acquired using the Canadian Compact Airborne Spectrographic Imager, *casi*.

2. Alberta rangeland QUASAR sites

Potentially uniform sites in the Canadian prairies include croplands and rangeland. While croplands are usually very flat and uniform, any given crop type is limited to 1.6 km by 1.6 km or less in size and at times such land-cover exhibits high rates of phenological change. Native rangeland provides potentially uniform vegetation with more slowly varying phenology. The utilization of flatter and more productive rangeland for grazing, and the incursion of petroleum exploration into unspoiled rangeland, diminishes the chance of finding extended regions of undisturbed and flat native rangeland. Nevertheless, based on visual examination of NOAA Advanced Very High Resolution Radiometer (AVHRR) imagery, aerial photographs, topographic maps, and field reconnaissance, two rangeland sites in south-eastern Alberta were selected for initial QUASAR studies:

The Newell County Site is located north-west of Medecine Hat, Alberta, and the Cutbank Creek Site is located near the Alberta-Saskatchewan-USA border south-east of Medecine Hat. In order to minimize acquisition costs of the preliminary airborne data, both sites are 10 km (east-west) by 5 km (north-south) in size, which is smaller than the otherwise preferable 10 km by 10 km size. Additional site descriptors are given in Table 1.

Table 1. Characteristics of the Newell County and Cutbank Creek sites.

Feature	Newell County site	Cutbank Creek site
Lat.-long. location (north-west corner)	Lat. 50° 20′ 0.7″ Long. 111° 36′ 11.8″	Lat. 49° 06′ 9.7″ Long. 110° 05′ 37.8″
UTM location (north-west corner)	5575889 m northing 457065 m easting (Zone 12)	5439267 m northing 566143 m easting (Zone 12)
Site dimensions	10 km (E-W) by 5 km (N-S)	10 km (E-W) by 5 km (N-S)
Mean terrain elevation	750 m ASL (above sea level)	879 m ASL
Terrain elevation standard deviation	4.5 m ASL	10.3 m ASL
Average slope	0.1°	0.3°
Maximum slope	0.9°	1.2°
Terrain character	flat to sloping or long rolling	sloping to moderate rolling
Wetland inclusions	< 1 %, < 100 m in size	< 2 %, < 200 m in size
Remarks	significant petroleum development	no petroleum development

3. 1977 data acquisition in Alberta

Tables 2 and 3 summarize data sets collected for the two Alberta test sites. Surface data collection at each site included: (i) spectral radiance measurements with a GER3700 spectrometer, which were combined with near-simultaneous measurements of a calibrated, white reflectance panel (™Spectralon) to yield surface reflectance; and (ii) GPS recording of the reflectance measurement location as well as others used for geometric control in the airborne data. The GER data were acquired at 50 points in a 25 m by 25 m area included in the airborne *casi* coverage. The surface area sampled by the GER data corresponded to approximately 1 % of the 25 m by 25 m area.

Airborne *casi* data were acquired over each site and subsequently processed to spectral radiances in 96 contiguous spectral bands from 450 nm to 960 nm. The airborne data acquisition for each site took place from mid-morning to approximately solar noon, encompassing solar-zenith angles from 45° to 30°. Given the rectangular shape of the sites, east-west flight lines were used, with 30 % overlap between adjacent flight lines, and the resulting pixel size for the Alberta data sets is 3 m × 3 m. An additional flight line was flown down the middle of each site at 100 m above ground level in order to allow the estimation of atmospheric optical parameters for the correction of residual atmospheric effects in the airborne *casi* data and the retrieval of surface reflectances.

For both sites, optical satellite image data were obtained from the NOAA-14 AVHRR (aftermoon solar-zenith angles approximately 38°) on the same day as the field measurements and airborne data acquisitions (Tables 2 and 3). Unfortunately, Landsat Thematic Mapper (TM) or SPOT Haute Résolution Visible (HRV)

Table 2. Overview of data sets acquired (√) in July 1997 for the Newell County site in Alberta. The entries denoted × indicate unsuccessful image-acquisition opportunities for Landsat TM and SPOT HRV.

Data type	Source	Newell County site 1997				
		18 July	21 July	23 July	27 July	29 July
Sky conditions		n/a	clear	clear	n/a	cloudy
Surface data	GER3700		√			
Airborne data	*casi*		√			
Optical satellite data	Landsat-5 TM					×
	SPOT-2 HRV					×
	NOAA-14 AVHRR		√	√		
Microwave satellite data	Radarsat-1 SAR				√	
	ERS-2 SAR	√				

Table 3. Overview of data sets acquired (√) in July 1997 for the Cutbank Creek site in Alberta. The entries denoted × indicate unsuccessful image-acquisition opportunities for Landsat TM and NOAA AVHRR.

Data type	Source	Cutbank Creek site 1997			
		21 July	22 July	23 July	24 July
Sky conditions		cloudy	cloudy	clear	clear
Surface data	GER3700			√	
Airborne data	*casi*			√	
Optical satellite data	Landsat-5 TM		×		
	NOAA-14 AVHRR	×		√	√
Microwave satellite data	Radarsat-1 SAR	√			√

images were not available on or within a few days of the measurement sorties. C-band synthetic aperture radar (SAR) imagery from the Canadian Radarsat was also obtained for each site in order to assess moisture conditions and drainage patterns as suggested for optical remote-sensing test sites by Teillet et al. [4]. In the C-band, backscatter from most natural targets comes primarily from the surface layer (5 cm to 8 cm).

4. Concluding remarks

The QUASAR approach has considerable potential to facilitate operational monitoring of post-launch satellite sensor performance. It is applicable to many satellite sensors in the relevant spectral range and with small and large footprint sizes. The approach is being tested at special sites such as the bright playas in Nevada, as well as at more common sites such as prairie rangeland in Alberta. Analysis of 1997 Alberta *casi* and satellite image data has begun and will attempt to determine the suitability of rangeland sites for the QUASAR approach and to test the feasibility of the approach for stability monitoring of the NOAA-14 AVHRR channel 1 as an initial trial.

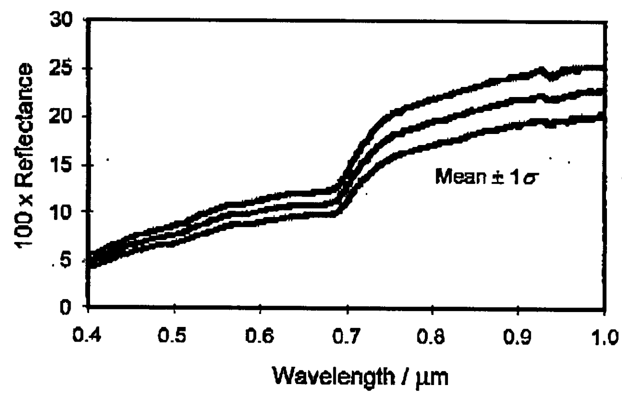

Figure 1. Mean and standard deviation results from surface reflectance spectra acquired using a GER3700 spectrometer at the Cutbank Creek site in Alberta on 1997-07-23.

Surface reflectance spectra acquired at Cutbank Creek (Figure 1) using the GER3700 spectrometer indicate that the rangeland is drier than many vegetated areas and that reflectance variations range from ± 1 % at shorter wavelengths to ± 3 % at longer wavelengths. SAR images reveal no significant drainage patterns or moisture variations across the rangeland sites.

An analysis of the uncertainty budget of the QUASAR method is under way in collaboration with the University of Sherbrooke. Among the various sources of uncertainty, the key factors are expected to be the calibration of the airborne sensor and the directional reflectance characteristics of the test sites. The QUASAR data-acquisition campaigns planned for 1998 include one mission to the Nevada test sites and an increased number of missions to at least one of the Alberta test sites.

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