VICARIOUS CALIBRATION CAMPAIGN IN ARGENTINA FOR RADIOMETRIC CALIBRATION OF A MULTISPECTRAL IMAGER ON-BOARD SUMBANDILA SATELLITE

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ABSTRACT

Continuous assessment of the radiometric response of Earth Observation (EO) satellite imagers is necessary for the quality assurance of derived data products. With the launch of South Africa's SumbandilaSat in September 2009, a number of vicarious calibration campaigns have been planned and executed to meet this requirement for the high-resolution multispectral imager payload. This paper describes a vicarious calibration campaign executed in Argentina in October 2010. A number of salt pans in Argentina were visited and characterised during this campaign. SumbandilaSat images of two of the sites were captured simultaneously with in situ measurements.

Index Terms— Vicarious calibration, SumbandilaSat, surface reflectance, atmospheric characterisation, Getis statistics

1. INTRODUCTION

In South Africa, the demand for remote sensing data is rapidly increasing. Such data is key input to understanding the Earth System, particularly with regard to its weather, climate, oceans, land, geology, natural resources, ecosystems and natural and human-induced hazards. This has lead to the commissioning of Sumbandila Satellite (hereafter called SumbandilaSat in the text) by the Department of Science and Technology (DST) [1]. SumbandilaSat is a Low Earth Orbiting (LEO) microsatellite and its main payload is a multispectral imaging system with 6.25 m spatial resolution.

SumbandilaSat was launched on the 17th of September 2009 by the Russian space agency Roscosmos from the Baikonur cosmodrome. During launch and when on-orbit , the imaging system is exposed to extreme conditions making it susceptible to systematic and asystematic effects such as the degradation of the optical system and changes in the offset, linearity, stability, cross talk, sensitivity and spectral response of the detectors. To correct for these effects and to obtain reliable and accurate data products, continuous radiometric calibration and validation (CalVal) of this imaging system is critical. The primary objective of radiometric calibration is to determine an accurate relationship between the incident spectral radiance and the instrument output [2]. This relationship can be obtained using different radiometric calibration methods, (1) laboratory calibration (pre-flight); (2) on board calibration; (3) inter-sensor radiometric calibration, and (4) ground-based vicarious calibrations [ref.3]. For SumbandilaSat`s multi-spectral imager, the vicarious calibration approach is preferred (there is no on board calibration system). The vicarious calibration approach is based on measurements performed over selected test sites on the earth's surface during a satellite overpass. Measured insitu parameters include the surface reflectance or the surface-leaving radiance and the atmospheric characteristics such as aerosol optical thickness, and perceptible water vapour. These parameters are used as inputs into a Radiative Transfer Code (RTC) to compute the Top of Atmosphere (TOA) spectral radiance over the selected test site.

A ground-based vicarious calibration campaign was held in Argentina to support the radiometric calibration of SumbandilaSat`s multi-spectral imager. The campaign was carried out from the 18th to the 26th of October 2010 by researchers and students from the Council for Scientific and Industrial Research (CSIR), Comisión Nacional de

Actividades Espaciales (CONAE), Centro de Investigaciones Ópticas (CIOP), from Consejo Nacional deInvestigaciones Científicas y Técnicas (CONICET) and Comisión de Investigaciones Científicas de la Provincia de Buenos Aires (CIC) Facultad de Ciencias Agrarias y Forestales, Universidad Nacional de La Plata (FCAyF, UNLP). In this paper, the data captured during this campaign is reported. Captured data include surface spectral reflectance, ozone, atmospheric pressure, aerosol optical thickness, water vapour content and SumbandilSat images over the sites. This data will be used as inputs into a RTC to compute the TOA spectral radiance. The average Digital Numbers (DNs) of each calibration site will be computed from the images acquired during satellite overpass. The TOA spectral radiance will then be used together with average DNs to estimate radiometric calibration coefficients.

2. RADIOMETRIC CALIBRATION SITES

The radiometric calibration sites measured during the campaign are Barreal Blanco playa, Salar de Arizaro, Salina La Antigua and Salinas Grandes. Barreal Blanco is a dry lake bed, Salar de Arizaro is a dry salt lake with a surface that is extremely rough, locally uniform and bright and Salinas Grandes is covered homogeneously by salt. Barreal Blanco and Salar de Arizaro have been used previously for radiometric calibration of EO-1 Advanced Land Imager (ALI) and Hyperion [4] as well as Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER on the Terra satellite) by CONAE and United States Geological Survey (USGS) [5, 6].

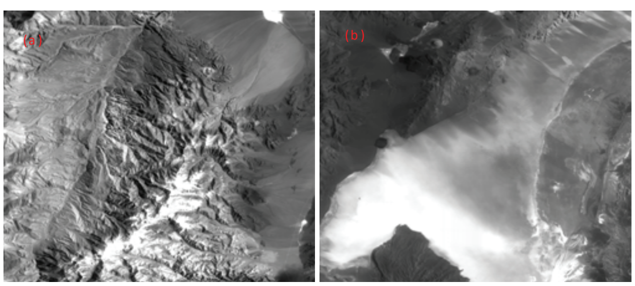

Figure 1: Sample of images acquired by SumbandilaSat of (a) Barreal Blanco and (b) Salar de Arizaro.

On the 19th and 24th of October 2010, SumbandilaSat was scheduled to acquire the images of Barreal Blanco and Salar de Arizaro, respectively (see Figure 1 (a) and (b)). SumbandilaSat images comprise the red band (630-685nm), red-edge band (690-730nm) and a near infrared (NIR, 845-890nm) band. The images acquired were used to assess the homogeneity of the sites using the Getis statistics.

3. SITE HOMOGENEITY ANALYSIS

The Getis statistics is the most widely used method of assessing the spatial homogeneity of a calibration site [7, 8]. The notion behind the Getis statistics is that a cluster of pixels with similar digital numbers have a positive autocorrelation while clusters of pixels with varying values will have a negative autocorrelation. The formula for the Getis statistics is shown in Equation 1 [7].

$$G_i^*(d) = \frac{\sum_{j=1} w_{ij}(d) x_j - W_i^* \mu}{\sigma \sqrt{\frac{W_i^*(n - W_i^*)}{(n-1)}}} \qquad (1)$$

Where μ and σ are the mean and standard deviation of all pixel values within the image respectively, i is the location of the target pixel, x_j is the DN value of the pixel located at j, n is the total number of pixels in the image, d is the distance from the target pixel x_j and w_{ij} is matrix of spatial weightings where $w_{ij}=1$ if j is within d and $w_{ij} = 0$ otherwise. W^* is the number of pixels within the distance d, with the pixel x_i included.

The Getis statistics was performed on SumbandilaSat images of Barreal Blanco and Salar de Arizaro. The computation was performed using a 3×3 pixel window (d=2). The results of this computation are shown in Figure 2 and Figure 3.

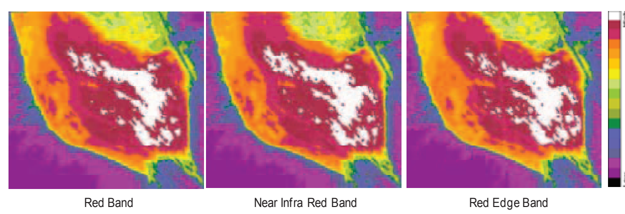

Figure 2: Getis Statistics Results for Barreal.

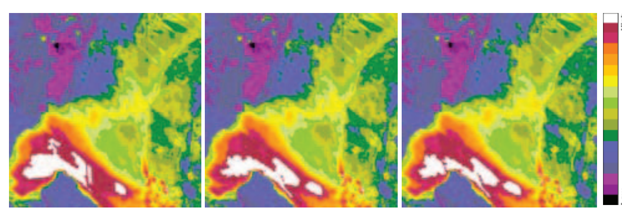

Figure 3: Getis statistics results for Salar de Arizaro.

The results show that the spatial patterns are nearly identical in all bands for both calibration sites. This may suggest that, these two sites are spectrally flat, but this can only be validated using spectral reflectance data. The results also show that there are regions within both calibration sites that are locally uniform and homogenous. Results of the Barreal Blanco reveal that the reflectance is high at the centre of the site as compared to the sides of the pan. Results of Salar de Arizora reveal that the reflectance is high at the southern part of the site.

4. INSTRUMENTATION AND METHODOLOGY

Surface spectral reflectance measurements in Barreal Blanco and Salar de Arizora were performed in a 15 × 15 m area (an area that contains one pixel) about the same time of the day as SumbandilSat overpass these test sites. Since there was no SumbandilaSat overpass at Salina La Antigua and Salinas Grandes, data measured from these sites will only be used to characterize these sites for suitability as radiometric calibration sites.

A surface region that is locally uniform was selected at the each site for ground base measurements. Several parameters must be measured using a spectroradiometer in order to obtain the surface reflectance (ρ_λ). The surface reflectance factor (ρ_λ) was measured with reference to a calibrated Spectralon® white reference panel using an LI-1800 Portable Spectroradiometer.

The LI-1800 Portable Spectroradiometer is an excellent instrument for the determination of the spectral distribution. The Spectroradiometer has scanning limits of 300–1100 nm, with selectable scan intervals of 1, 2, 5, or 10 nm. The radiant flux reflected from the surface of the Spectralon panel is collected by a telescope with a 15° Field-of-View (FOV) and transferred to the Spectroradiometer which measures the spectral power distributions. A Teflon-dome optical receiver with a hemispherical (2π steradian) FOV was used to monitor the global horizontal and the diffuse horizontal irradiances. The measurements at Barreal Blanco and Salar de Arizaro were performed in the wavelength range of 600 - 920 nm (to coincide with the bands of the multi-spectral imager), with a scan interval of 1 nm. Surface spectral reflectance is computed by dividing the surface measurements by the Spectralon measurements.

The atmosphere was characterized using a handheld sunphotometer (Solar Light MicroTOPS II). Using built in processing capabilities, the sunphotometer computes various atmospheric parameters such as Aerosol Optical Thickness (AOT), atmospheric pressure and perceptible water vapour. The instrument provides AOT and at 440, 500, 675, 870 and 936 nm. To minimize the errors associated with the atmosphere when calibrating a multi-spectral imager, the total column ozone amount data was retrieved from the Ozone Monitoring Instrument (OMI) on the Aura spacecraft [9].

5. RESULTS AND DISCUSSION

Figure 4 shows the computed surface spectral reflectance obtained at each calibration site, being the average of all data points collected over the entire site. Note that the number of points of measurement was variable at each site. In Barreal Blanco and Salar de Arizaro, measurements were made in the wavelength range of 600 - 920 nm. This covers the SumbandilaSat red, red-edge and NIR bands. The surfaces spectral reflectance obtained at the various sites are notably different. The spectral reflectance difference at these sites is due to the differences in the composition and structure of the surfaces. The surface reflectance obtained at Salar La Antigua shows that the surface is spectrally flat in the visible and NIR wavelengths with lowest surface reflectance as shown in Figure 4.

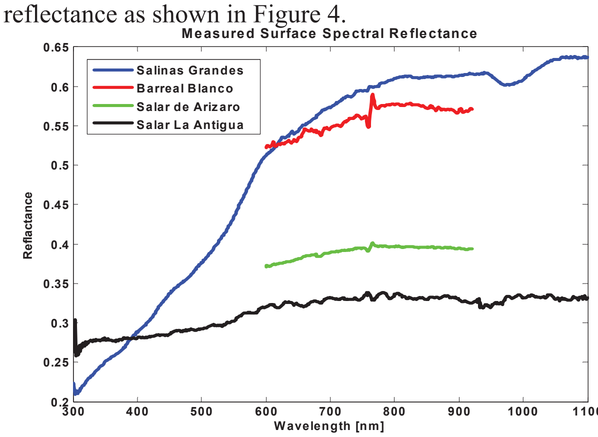

Figure 4: Spectral Reflectance at the different calibration sites over SumbandilaSat bands.

In Barreal Blanco, the surface reflectance at visible and NIR wavelengths is in the range 0.522 to 0.590 which is above the range 0.4 to 0.49 published in [4] in the same wavelength region. Similarly, in Salar de Arizaro the difference between the surface reflectance measured in this campaign is 0.391, with a value of 0.5 published in [5] and 0.55 published in [10]. This difference can probably be attributed for taking measurements at different regions within the playa. It can be observed in Figure 2 and Figure 3 that there exist regions that exhibit different surface reflectance within the same site. In Salar de Arizaro, the decrease in reflectance is also attributed to the heavy rain in the prior wet season that changed the surface properties as well as the homogeneity.

Table-1 shows the average AOT and perceptible water vapour together with their standard deviations for all the calibration sites.

In the table, the ozone obtained from OMI is also shown. The data shows that the aerosol loading of the atmosphere and water vapour at these sites is fairly low. Figure 5 (a) and Figure 5 (b) show the AOT measured at Barreal Blanco and Salar de Arizaro respectively. Measurements were carried out for 30 minutes, thus 15 minutes before and after satellite overpass. The AOT loading at both sites is very low and virtually invariant throughout the measurements.

Atmospheric Parameters	Barreal Blanco	Salina La Antigua	Salar de Arizaro	Salinas Grandes
AOT 440 nm	0.0256 ± 0.001	0.1804 ± 0.0001	0.0365± 0.0006	0.0473 ± 0.0001
AOT 500 nm	0.0473 ± 0.001	0.1895 ± 0.0015	0.0544± 0.0012	0.0781 ± 0.0013
AOT 675 nm	0.0405 ± 0.001	0.1284 ±0.0012	0.0501± 0.0009	0.0721 ± 0.0010
AOT 870 nm	0.0273 ± 0.001	0.0874 ± 0.0023	0.02607 ±0.0016	0.0404 ± 0.0017
AOT 936 nm	0.0248 ± 0.001	0.0795 ± 0.0022	0.0237 ±0.0012	0.0368 ± 0.0012
Water Vapour	0.172	1.428		0.0155
Ozone (DU)	264	No data	252	257

Table 1: Atmospheric parameters at each channel for the calibration site visited.

These sites have significantly different reflectance characteristics but the aerosol loading of the atmosphere and water vapor at three of these sites is generally low.

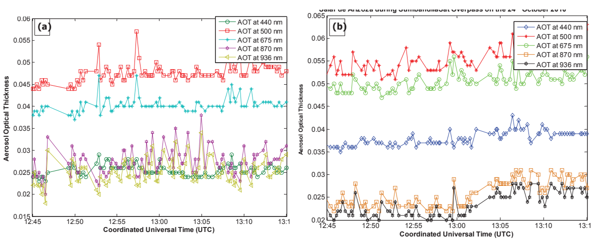

Figure 5: Aerosol optical thickness measured at (a) Barreal Blanco and (b) Salar de Arizaro, during SumbandilaSat overpass.

6. CONCLUSION

A vicarious calibration field campaign has been executed in Argentina to support monitoring of the radiometric response of the multispectral imager aboard SumbandilaSat. The spectral reflectance of a number of candidate sites was measured together with atmospheric parameters. The sites showed very diverse spectral reflectance, but aerosol loading and water vapour was generally low. At two of the sites, SumbandilaSat images were successfully captured simultaneously with in situ measurements. These images were used to compute Getis statistics in order to evaluate spatial homogeneity. The Getis statistics show that there are regions within these sites that are homogenous across all SumbandilaSat spectral bands.

7. ACKNOWLEDGEMENT

The author's thank Gladys Magagula of the SumbandilaSat team for helping with scheduling and image acquisition. They also acknowledge in particular Val Munsami and Kaizer Moroka from the Department of Science and Technology (DST) for their contributions on CalVal activities for SumbandilaSat. They thank also many people from the Comisión Nacional de Actividades Espaciales (CONAE), Centro de Investigaciones Ópticas (CIOP), from Consejo Nacional deInvestigaciones Científicas y Técnicas (CONICET) and Comisión de Investigaciones Científicas de la Provincia de Buenos Aires (CIC) Facultad de Ciencias Agrarias y Forestales, Universidad Nacional de La Plata (FCAyF, UNLP) in Argentina for help in our Argentina field campaign. The authors thank the CSIR, DST and CONAE for funding the campaign.

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