ICC experiences on DMC radiometric calibration

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Abstract

Solar-spectrum, passive remote sensing sensors measure mainly the radiance reflected by the atmosphere-ground system. Those images content radiometric distortions that should be corrected to obtain accurate physical measurements, multitemporal series or more realistic colours. After a proper radiometric calibration atmospheric radiative processes remain disturbing the measurement. Orthophotomap series are intended to depict the territory as realistically as possible and the colours of the multi-spectral images do not match the real colours. This is due to the different sensitivity of the sensor versus the Human Visual System (HVS). The Institut Cartografic de Catalunya (ICC) adopts several solutions to overcome it. Multispectral satellite images are atmospherically corrected with a two-step system that links together a semi-empirical method based on a physical model, followed by an empirical method based on normalizing over the time the radiometry of pseudo-invariant areas. Hyperspectral airborne images are corrected by means of the semi-empirical method adapted to the characteristics of the Compact Airborne Spectrographic Imager (CASI) airborne sensor. By 2005, the acquisition of hyperspectral CASI data and the Z/I Digital Mapping Camera (DMC) with field handheld radiometer measurements on Banyoles (Spain) was made. The aim is to validate and improve the algorithms and to enhance the radiometric likely of the DMC and geometric characteristics of the CASI data. Two methodologies are proposed for parameter estimation. Compatible atmospheric parameters are obtained in the inversion process using both of them. The DMC radiometric calibration is performed by a linear regression of the DMC-like (from CASI data) vs. DMC (without pan-sharpen processing) scatter plot for each band and f-number available, also taking into account the exposition time of each set of bands. The results indicate that DMC camera is suitable to be used as a calibrated sensor. Finally, our approximation of the colorimetric calibration involves finding a polynomial expression that allows the change from a given colour space to another one. This expression is calculated from the GretagMacbeth ColorChecker chart spectrums. The results indicate that DMC is able to produce imagery with realistic colours.

1. Introduction

Solar-spectrum, passive remote sensing sensors measure mainly the radiance reflected by the atmosphere-ground system. Those images content several kinds of geometric and radiometric distortions. Radiometric distortions should be corrected in order to obtain accurate physical measurements, develop studies based on multitemporal series of images, compare images acquired with different sensors or obtain more realistic colours.

Radiance measured by a sensor depends on illumination geometry and on reflectance characteristics of the observed surface. After a proper radiometric calibration in order to get a physical value of the energy measured by the sensor, the foremost remaining radiometric distortion is produced by the atmosphere. Two atmospheric radiative processes disturb this measurement: gas absorption and both Rayleigh and Mie scattering. Finally, orthophotomap series are intended to depict the territory as realistically as possible. Unfortunately, the colours of the multi-spectral images do not match the real colours due to the different sensitivity of the sensor versus the Human Visual System (HVS) (Toth C., 2005).

In the following sections a description of the solutions adopted by Institut Cartogràfic de Catalunya (ICC) is made. Then, a short description of the actual projects at ICC regarding radiometric calibration, atmospheric correction and colorimetric calibration is performed.

2. Activities with multispectral satellite images

Atmospheric-effect corrected remote sensing series from multispectral satellite sensors are routinely obtained at ICC with a self-developed Solar Spectrum Atmospheric Correction System (Martínez et al., 2003). It consists of a two-step system that links together a method based on a physical model and radiative transfer simulation with the Second simulation of the satellite signal in the solar spectrum (Vermote et al., 1997), followed by an empirical method based on normalizing over the time the radiometry of pseudo-invariant areas. The first step allows the incorporation of synchronous ancillary atmospheric data (standard atmospheric and aerosol profiles) during the radiative transfer simulation process in order to individually obtain absolute radiance measurements on every image. Later, the empirical step refines the multitemporal series of remote sensed data. These methodologies have been applied to LANDSAT ETM+ and SPOT 5 images in the frame of a Change Detection project (Martínez et al., 2005, 2007i).

3. Activities with hyperspectral airborne images

The framework of the atmospheric correction was extended to the hyperspectral domain with a self-developed Compact Airborne Spectrographic Imager (CASI) atmospheric correction system. It basically consists of the previous physical model with 6S method radiative transfer simulations adapted to the characteristics of the CASI airborne sensor. The system was first used in the frame of a Precision Farming project (Kurz et al., 2005). Then, the CASI atmospheric correction system was improved by means of field measurements in order to derive the atmospheric state from the hyperspectral images. This way water vapour content and aerosols profile and aerosols total load are actually derived from the CASI images.

4. Multisensor activities

By 2005 ICC was already operating Digital Metric Camera (DMC), manufactured by Z/Imaging. It supports the simultaneous capture of panchromatic, RGB colour and near-infrared images with a very high spatial resolution. Then, it was decided to survey the potential of simultaneous acquisition of the hyperspectral CASI sensor, the high spatial resolution DMC and field handheld radiometer measurements. The foremost aim of ICC multisensor activities is to test the atmospheric correction of CASI images, to develop and test the algorithms that enhance the radiometric likely of the DMC and geometric characteristics of the CASI data. Finally, DMC radiometrically calibrated images are suitable to apply colorimetric calibrations towards common colour spaces or atmospheric corrections in order to obtain bottom of the atmosphere reflectances.

4.1 Banyoles radiometric test campaign

On June 29th, 2005 a multisensor acquisition on Banyoles (Spain) area was made. Airborne CASI and DMC images were simultaneously acquired with a Cessna Caravan B20, between 10-11 am on 2 test sites on Banyoles area. The acquisition included a total of 9 flight lines and 3 different altitudes (1120, 2240 and 4480 m). CASI images were acquired on Enhanced Spectral Mode and 32, 74 or 144 spectral bands between 410 and 960nm and a nominal pixel size of 1.5, 3 or 6m. The DMC acquired 124 images that had RGB, Nir and Pan bands, and several exposition time and f-number, and a nominal pixel size of 0.1, 0.2 or 0.3m. Almost simultaneously, a field campaign was developed to install 4 man-made covers and to perform the field 400-1000nm reflectance measurements using an ASD FieldSpec Pro radiometer. Besides, different natural or artificial covers were measured: grass, concrete, bare soil and on a lake.

4.2 CASI atmospheric correction

The objective is to retrieve the atmospheric optical parameters (Aerosol Optical Thickness (AOT) and water vapour content) for the whole area where the atmospheric correction is performed. For those estimations, the atmospheric state is considered invariant within the area covered by the image. This assumption is quite realistic for the area imaged during the test flight.

Two methodologies are proposed for parameter estimation. First, the inversion procedure is performed by minimizing a cost function δ_{mes}^2 that measures the difference between atmospherically corrected reflectances and field measurements. In a second approach, a new inversion procedure is performed by minimizing a more complex cost function δ_{hom}^2 that consists of the difference between atmospherically corrected reflectances calculated on homologous areas observed on different images plus one field measurement (Martínez et al., 2006).

Compatible atmospheric parameters are obtained in the inversion process using both methodologies. After validation step, similar standard deviations are also obtained in both cases. We can then conclude that an inversion procedure using homologous areas plus a single field measurement yield accurate atmospheric parameters with less ground information and without specific atmospheric data (Martínez et al., 2006). Figure 4.2.1 and 4.2.2 show an example of the atmospheric correction for vegetation and bare soil with the atmospheric data obtained.

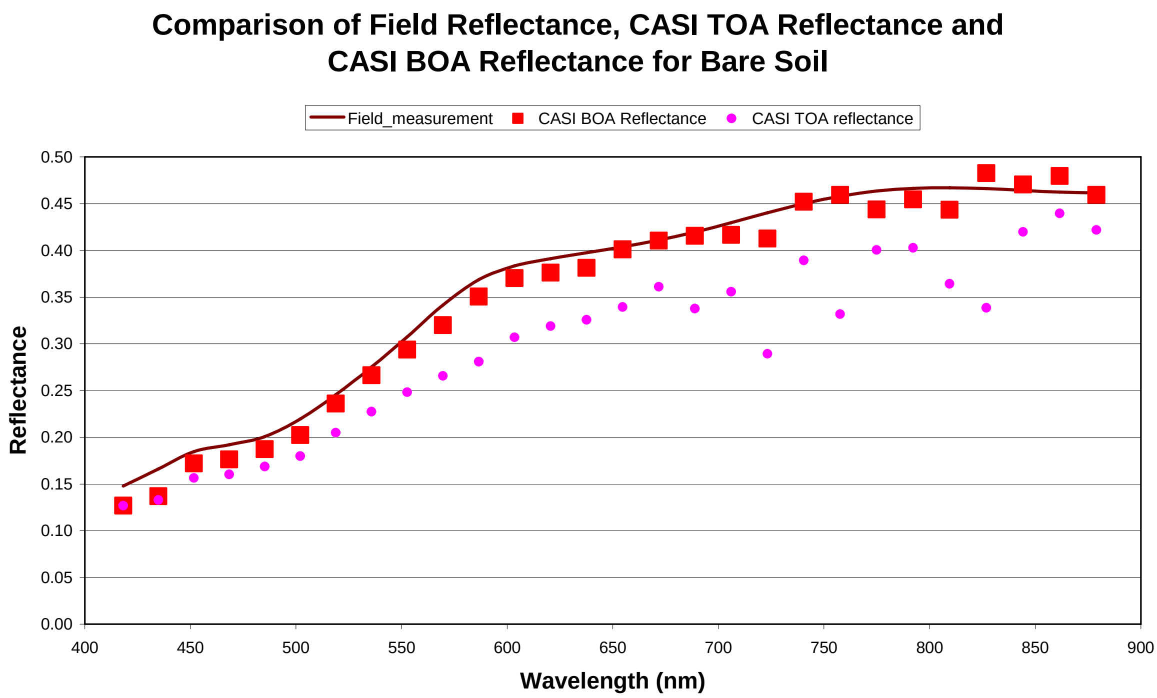

Figure 4.2.1 Comparison of field reflectance, CASI TOA reflectance and CASI BOA Reflectance for bare soil on Banyoles area.

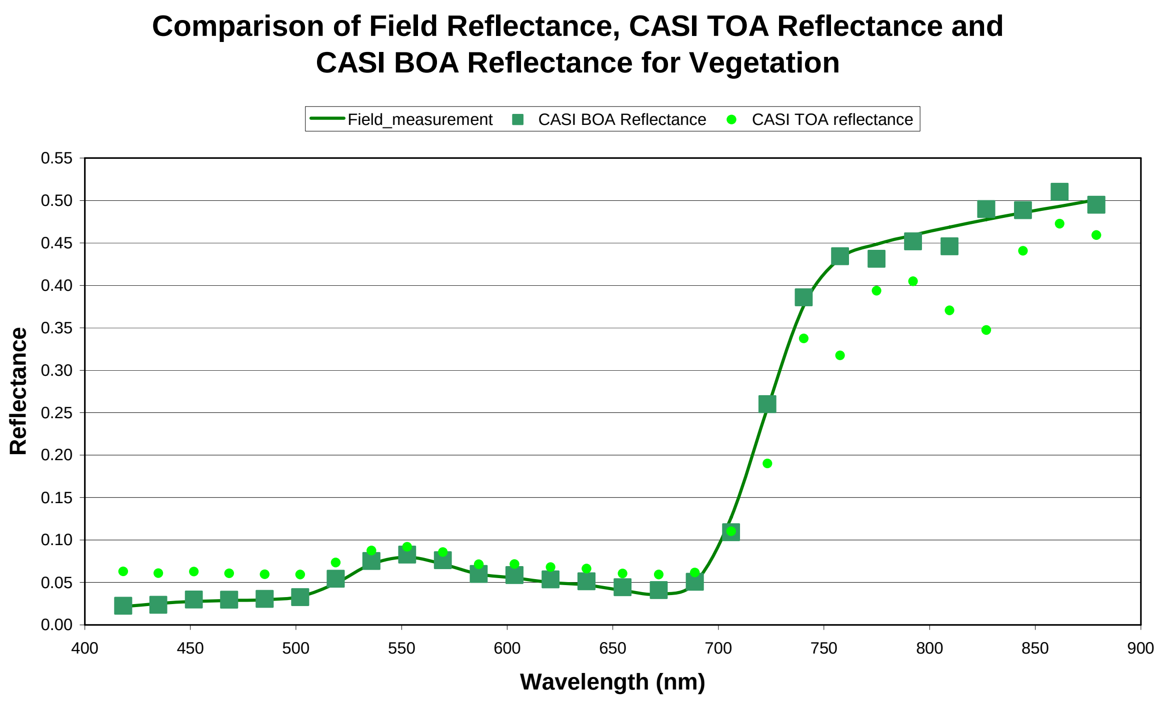

Figure 4.2.4 Comparison of field reflectance, CASI TOA reflectance and CASI BOA Reflectance for vegetation on Banyoles area.

4.3 DMC radiometric calibration

As an absolute radiometric calibration of the DMC is not available from the manufacturer, this relationship is obtained from simultaneous images incoming from both DMC and CASI sensors. The CASI system is periodically recalibrated at laboratory. That is possible due to the fact that the acquisition geometry, atmospheric effects and illumination geometry of the targets are the approximately equivalent for areas imaged simultaneously. Besides, the spectral resolution of CASI is high enough to reproduce DMC-like channels by adding calibrated CASI hyper-spectral bands. In order to verify the previous hypothesis and because of the different FoV of DMC and CASI, only the central area of the DMC scenes were used. In addition, DMC pixels were aggregated to fit the coarse CASI spatial resolution. Then a median floating window filter was applied to both CASI and DMC imagery to avoid misregistration and other sources of noise. Finally, a linear relationship between Digital Numbers (DN) from DMC and radiance values of a CASI image emulating DMC bands is derived (Martínez et al., 2007ii).

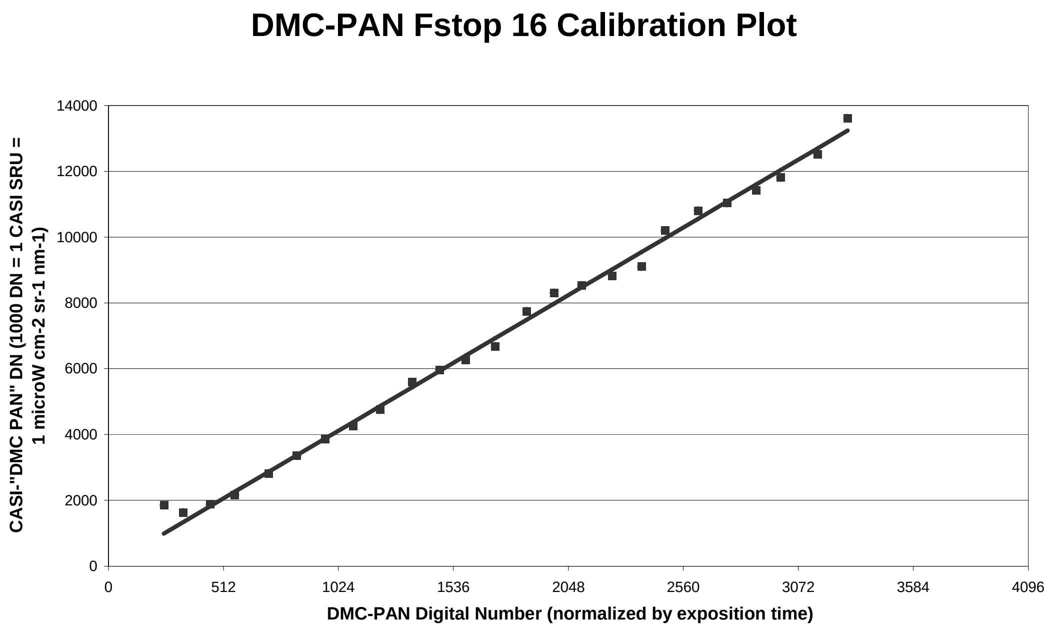

Figure 4.3.1 DMC-PAN Calibration Plot for Fstop 16 with DMC-PAN-like band from CASI images.

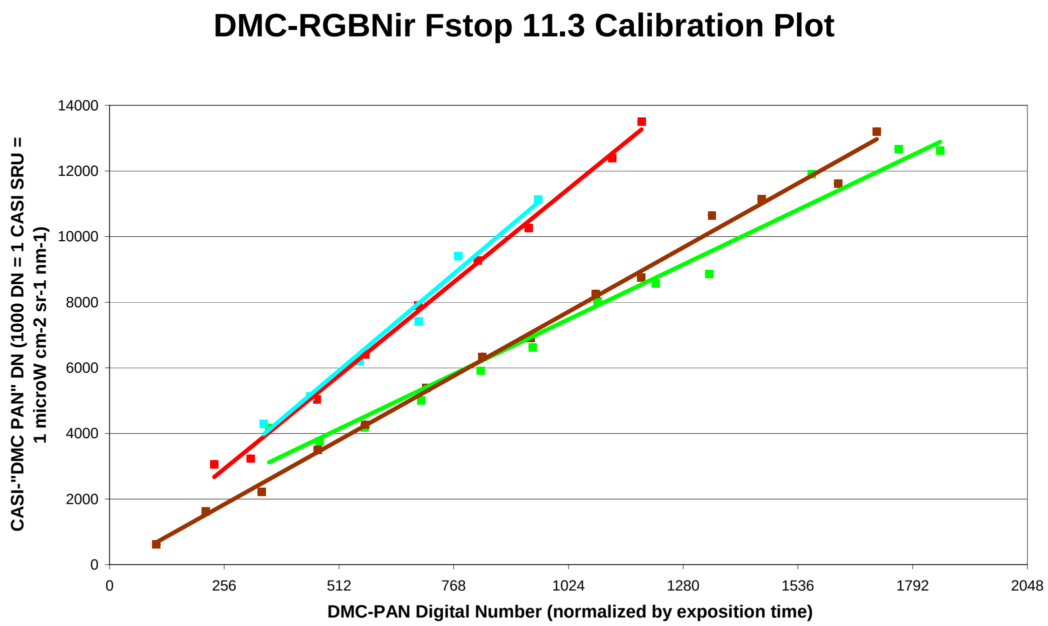

Figure 4.3.2 DMC-RGBNir Calibration Plot for Fstop 11.3 with DMC-RGBNir-like bands from CASI images.

The calibration is done by a linear regression of the DMC-like (from CASI data) vs. DMC (without pan-sharpen processing) scatter plot for each band and f-number available (Figure 4.3.1 and 4.3.1 give an example), also taking into account the exposition time of each set of bands. RGB and Pan data sets seem to fit better to a zero intercept line and Nir data sets presents a negative intercept. These results indicate that DMC cameras are suitable to be used as a calibrated sensor. Figure 4.3.3 show an example of the radiometric calibration of the DMC images.

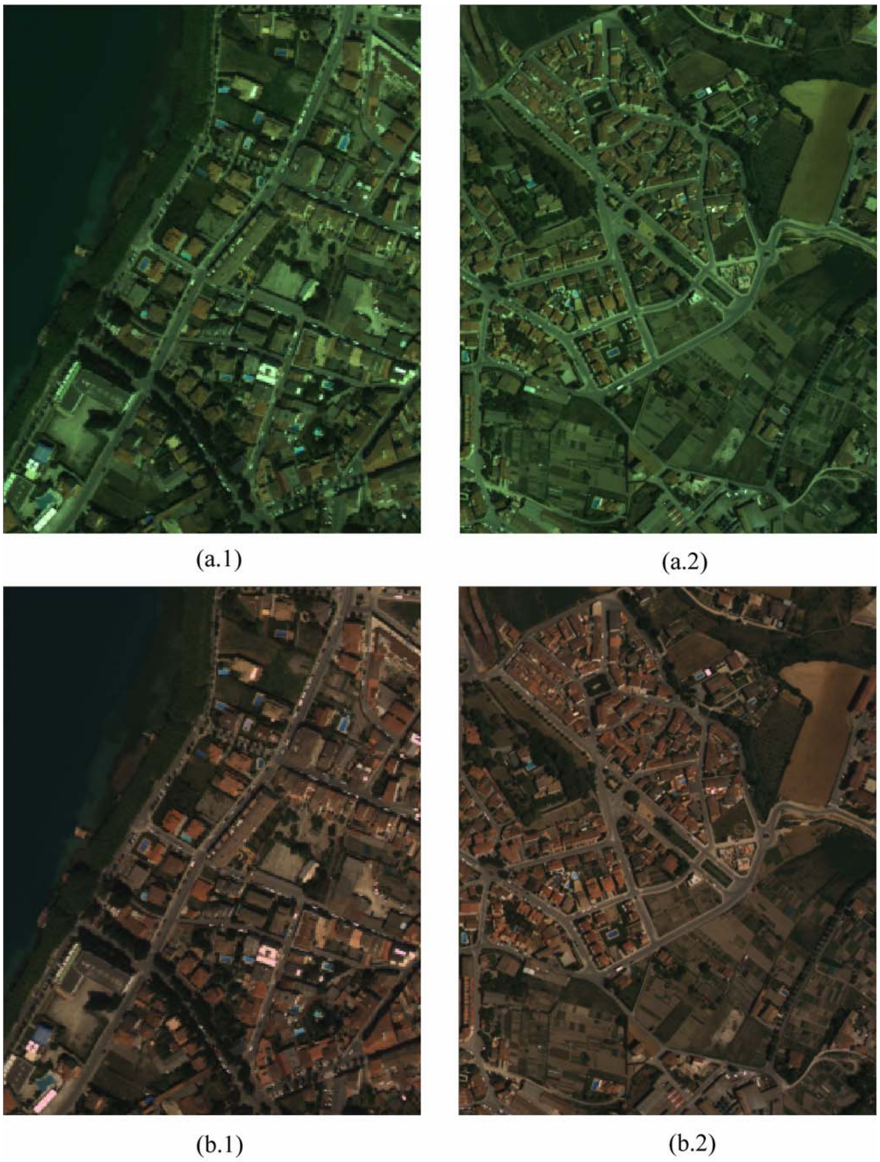

Figure 4.3.3 Example of radiometric calibration of DMC RGB bands. Subescene a.1 and a.2 are raw DMC lower flight images. Subescene b.1 and b.2 are the a.1 and a.2 DMC images radiometricaly calibarted.

4.4 DMC colorimetric calibration

The trichromatic theory of colour vision is based on the premise that there are three classes of cone receptors involved in colour vision and dates back to the 18th century. One important empirical aspect of this theory is that it is possible to match all of the colours in the visible spectrum by an appropriate mixing of three primary colours. In 1931 the Commission Internationale de L'Eclairage (CIE) proposed a basic space for the HVS known as CIE-XYZ with positive colour matching functions (CIE, 2004). From this space it is possible to reach all the other colour spaces such as RGB, Lab, etc. by means of some simple algebra.

DMC output constitutes a particular RGB space. In order to transfer its colour space to a camera independent space as XYZ there are methodologies fed by ancillary radiometric data. Our approximation of the colorimetric calibration involves finding a polynomial expression that allows the change from a given colour space to another one (Hong et al., 2001; Martínez-Verdú et al., 2003). This expression is calculated from the GretagMacbeth ColorChecker chart spectrums. The comparison of the training colours with the ones obtained after colorimetric calibration yields differences in 8bit DN that range from 4 to 36 DN with a mean value of 12 DN. These results indicate that DMC is able to produce imagery with realistic colours (Martínez et al., 2007). Figure 4.4.1 show an example of the colorimetric calibration of the DMC images.

Figure 4.4.1. Example of colorimetric calibration of DMC lower flight RGB bands. Subescene c.1 and c.2 are radiometricaly corrected DMC lower flight images. Subescene d.1 and d.2 are the c.1 and c.2 DMC images colorimetricaly calibarted. (Images normalized by the histograme values).

Future work

Future work is focused on the following issues. First, the validation of the atmospheric parameters derived during the inversion process. Next, the DMC radiometric calibration improvement and stability. Then, the application of DMC calibrated images for land use classification, change detection, agricultural o forestry studies, etc. Next, the study and application of DMC colour calibrations to produce Orthophotomap series with proper tones. Then, the application of atmospheric correction of DMC images with the atmospheric parameters derived from CASI images. Finally, the study of the link between the atmospheric effect and the absolute resolution of the DMC images.

Conclusions

In this work the methodologies adopted by ICC to solve radiometric calibration and distortions and the different sensitivity of the sensor versus the Human Visual System (HVS) are described. Multispectral and hyperspectral images are corrected by means of semi-empirical methods adapted to the characteristics of the sensors. DMC, CASI and handheld radiometer were used in simultaneous radiometric activities. Compatible atmospheric parameters are obtained in the atmospheric inversion process using two methodologies. We can then conclude that an inversion procedure using homologous areas plus a single field measurement yield accurate atmospheric parameters with less ground information. DMC calibration is performed by a linear regression of the DMC-like (from CASI data) vs. DMC (without pan-sharpen processing) scatter plot for each band and f-number available, also taking into account the exposition time of each set of bands. RGB and Pan data sets seem to fit better to a zero intercept line and Nir data sets presents a negative intercept. Our approximation of the colorimetric calibration involves finding a polynomial expression that allows the change from a given colour space to another one. This expression is calculated from the GretagMacbeth ColorChecker chart spectrums. The comparison of the training colours with the ones obtained after colorimetric calibration yields differences in 8bit DN that range from 4 to 36 DN with a mean value of 12 DN. These results indicate that DMC is able to produce imagery with realistic colours.

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