DEVELOPMENT OF NDVI WMS GEOSERVICE FROM REFLECTANCE DMC IMAGERY AT ICC

L. Martínez [a] *, F. Pérez [a], R. Arbiol [b], A. Magariños [c]

[a] Suporting Centre for the Catalan Earth Observation Program. Direction Area. Institut Cartogràfic de Catalunya.
Parc de Montjuïc s/n 08038 Barcelona, Spain. (Lucas.Martinez, Fernando.Perez)@icc.cat
[b] Management Area. Institut Cartogràfic de Catalunya.
Parc de Montjuïc s/n 08038 Barcelona, Spain. Roman.Arbiol@icc.cat
[c] Geoprocessing Area. Institut Cartogràfic de Catalunya.
Parc de Montjuïc s/n 08038 Barcelona, Spain. Antonio.Magarinos@icc.cat

Commission VI, WG VI/4

KEY WORDS: NDVI, DMC, Radiometric calibration, WMS service

ABSTRACT:

This work is a review of the Digital Metric Camera (DMC) calibration carried out by the Institut Cartogràfic de Catalunya (ICC) during these last months and an overview of the NDVI layer of Catalonia (Spain) area. From the very beginning of the DMC operation, ICC has been concerned about colorimetric calibration, physical interpretation of the digital numbers (DN) provided by the camera, atmospheric correction of the imagery, and similar issues. In this sense, several field experiments were performed, in order to overcome the difficulties associated to the DMC radiometric calibration. The next step was the development and integration of a new information layer seamlessly integrated in the ICC ortophoto and photogrammetric workflows. It consists of a Normalized Difference Vegetation Index (NDVI) derived from reflectance DMC imagery of Catalonia (32,000 km^2) at 25 cm GSD, involving a 8 bit-per-pixel raster "on the fly" orto-rectification of aerial photos without stitching. The selected DMC imagery is LR4 (without pan-sharpening) with absolute radiometric calibration (either using camera manufacturer coefficients measured at laboratory or an ICC procedure by means of simultaneous acquisition of DMC and CASI (Compact Airborne Spectral Imager sensor) imagery. At the moment, no atmospheric correction is performed to the data. The layer is provided as a web map service (WMS) Geoservice freely disseminated according to ICC data policy. This service is available for most SIG environments: ArcMap, Miramon, gvSig, etc. Besides, there is a public interface to ICC WMS services that allows accessing the NDVI layer information at http://www.ortoXpres.cat. OrtoXpres provides a toponymy layer and coordinate searching capability. It allows fast online publication just a few weeks after the flight has been carried out. Agriculture Department of the Generalitat de Catalunya (Catalonia regional government) is already using the NDVI layer it to verify agriculture policy (ie. vineyards, cereal, etc.).

1. INTRODUCTION

In 2004 the Institut Cartogràfic de Catalunya (ICC) decided to make a commitment to a totally digital mapping workflow. The selection phase for a digital camera was completed with the delivering of two Zeiss/Intergraph Digital Mapping Camera (Z/I DMC) systems the ICC. The Z/I DMC camera includes a four-band multispectral frame sensor (http://www.intergraph.com).

ICC has a long experience deriving information from satellite and airborne multispectral remote sensing imagery. The expertise areas include land cover maps, change detection, cartography of burnt forest, precision farming, crop water shortage management, crop water stress characterization, etc.

In this context, we wondered if it was possible to derive thematic information from DMC camera imagery. ICC regularly produces an ortophotomap layer of Catalonia (Spain) area. That means 32,000 km^2 at 25 cm ground sample distance (GSD) regularly updated information that could feed thematic processors and yield valuable information for territorial management. There would be then a chance to transform DMC imagery into functional and realistic new products suitable for research and development of fresh high quality Earth observation products.

The main difficulty in the move towards that aim was the lack of a camera absolute radiometric calibration (Ryan and Pagnutti, 2009; Honkavaara et al., 2009). This sort of calibration is a foremost prerequisite to find a correct pixel reflectance. In this sense, several field experiments were performed, in order to overcome the difficulties associated to the DMC radiometric calibration (Martínez et al., 2008; Martínez et al., 2010a). Nowadays, we also have a laboratory-measured absolute radiometric calibration for DMC provided by the manufacturer. Once we are able to perform a physical interpretation of the digital numbers (DN) captured by the camera, atmospheric correction of the imagery, colorimetric calibration and similar issues are real options for DMC imagery (Martínez et al., 2007).

The next step on the improvement of the use of DMC has been the development and integration of a new information layer seamlessly integrated in the ICC ortophoto and photogrammetric workflows. It consists of a Normalized Difference Vegetation Index (NDVI): an index which provides a measure of vegetation density and condition. It is influenced by the fractional cover of the ground by vegetation, the vegetation density and its greenness. It indicates the photosynthetic capacity of the land surface cover (Rouse et al., 1973). This layer is provided as a web map service (WMS) Geoservice freely disseminated according to ICC data policy.

This communication will start describing the absolute radiometric calibration of DMC imagery and its transformation into reflectance. Next we introduce the NDVI layer as a WMS OrtoXpres service. Finally we will present some open perspectives to be considered for future work.

2. ABSOLUTE RADIOMETRIC CALIBRATION OF DMC IMAGERY

The implemented procedure to produce radiance from DMC imagery is based on manufacturer's calibration of the camera. The suitable imagery for this process is the original DMC LR4 files (4 low resolution multispectral bands) extracted with the DMC post processing software and the absolute calibration of the camera. This means that pan-sharpening, gamma corrections, grey compensations or any other radiometric manipulations of the radiance are not allowed.

Under these premises, we calculate DMC radiance by using the Equation 1:

$$L = k \cdot DN \tag{1}$$

where:

L is the DMC radiance,
k is a calibration factor,
DN is the DMC 12 bbp digital number.

To estimate the calibration factor k we follow DMC manufacturer indications as in Equation 2:

$$k = c \frac{t_{calib}}{t_{actual}} \frac{f_{actual}^2}{f_{calib}^2} \tag{2}$$

where:

c is a calibration factor in the DMC tif file
t_{calib} is calibration exposition time,
t_{actual} is image exposition time,
f_{calib} is calibration diaphragm,
f_{actual} is image diaphragm.

At this point we have transformed multispectral DMC LR4 digital numbers into genuine physical radiance.

3. REFLECTANCE DMC IMAGERY

Once we can express DN from DMC in terms of physical radiance, it is possible to calculate reflectance for each DMC band. Reflectance (Equation 3) is a quotient between the incoming energy from the Sun and the reflected energy from the cover modulated by some geometric factors that depend on the location, data and time of the DMC acquisition.

$$\rho = \frac{\pi L}{\mu E_o} \tag{3}$$

where:

ρ is the apparent reflectance,
L is the previously calculated radiance,
μ is a geometric factor,
E_o is the extraterrestrial solar radiance.

To compute μ we use the Equation 4:

$$\mu = cos\, \theta_s \tag{4}$$

where θ_s is the solar zenithal angle.
Figure 1 and Figure 2 show a LR4 DMC image transformed into reflectance with two classical band configuration: RGB and Infrared False Color, respectively. These images will help us to analyze the result of the NDVI images we will obtain in the following sections.

Figure 1. DMC LR4 RGB image of apparent reflectance. (La Guineta d'Aneu 42º35'30''N 1º7'50''E WSG84)

4. NDVI DMC IMAGERY

Live green vegetation absorbs visible light (solar radiation) as part of the photosynthetic process. At the same time, plants scatter (reflect) solar energy in the near infrared. This difference in absorption is quite unique to live vegetation and provides a measure of the greenness of the vegetation. NDVI is calculated from the red and near-infrared reflectances ρ_{red} and ρ_{nir} as:

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}} \tag{5}$$

Figure 2. DMC LR4 IRC image of apparent reflectance. (La Guineta d'Aneu 42º35'30''N 1º7'50''E WSG84)

For many years, Equation 5 was used with DN instead of radiance or reflectance. That was justified by the hard work that supposed the proper calibration of remote sensing sensors. This approximation is far from being reasonable for monitoring vegetated cover because Equation 5 is based on reflectance spectrum of vegetation and bare soil. So if absolute calibration is available physical magnitudes are better than DN to compute NDVI index. Furthermore, the use of radiance instead of reflectance in DMC imagery leads to a bias in NDVI values in such a way that they become inoperative for quantitative studies (Figure 3). This is why equation 5 should always be used with reflectance values.

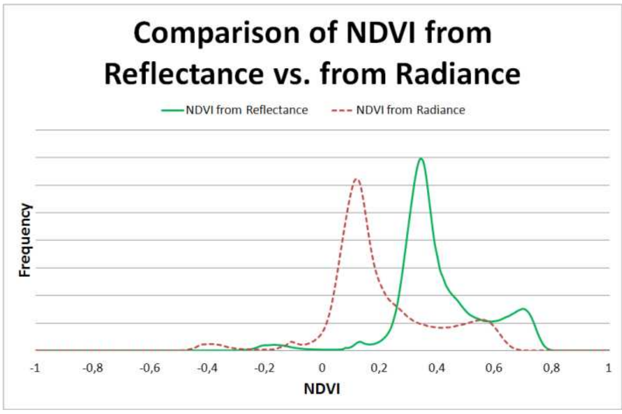

Figure 3. Comparison of DMC NDVI histograms of La Guineta d'Aneu calculated from radiance values vs. reflectance values.

On the other hand, thanks to the altitude of the flight the atmosphere only smoothly impacts the values of the NDVI so, at the moment, reflectance at the sensor is considered proper enough to perform an NDVI calculation (Martínez et al., 2010b).

By definition, NDVI values are always between -1 and +1. Bare soil NDVI ranges from 0.05 to 0.30 depending of soil brightness. On the other hand, pure vegetation NDVI is always high and up to 0.7 or 0.8. NDVI decreases for mixed pixels and also as leaves are subjected to water stress, become diseased or die. Snow NDVI values are close to zero, while water bodies have negative NDVI values.

Therefore, the valid range of NDVI values is [-1,1] and consequently if we want to use a 8 bbp image to represent this information, a linear transformation is required. The proposed transformation is to expand the [-1,1] range of real numbers to the [0,200] range of integers, and store the values in a 8 bpp image. See on Figure 4 NDVI data represented in a grey scale. However this product is not very appealing or easy to interpret for a general user. To overcome this difficulty we define a simple legend (Table 1) that helps when interpreting the NDVI image.

NDVI level colour	NDVI range
Red	NDVI < 0
Orange	0 < NDVI < 0.2
Yellow	0.2 < NDVI < 0.4
Green	0.4 < NDVI < 0.6
Dark Green	0.6 < NDVI

Table 1. Legend of NDVI images for visual interpretation.

Figure 5 shows the NDVI from La Guineta d'Aneu area with the proposed colours to support the general user with the data analysis.

Figure 4. DMC NDVI image from apparent reflectance. (La Guineta d'Aneu 42º35'30''N 1º7'50''E WSG84)

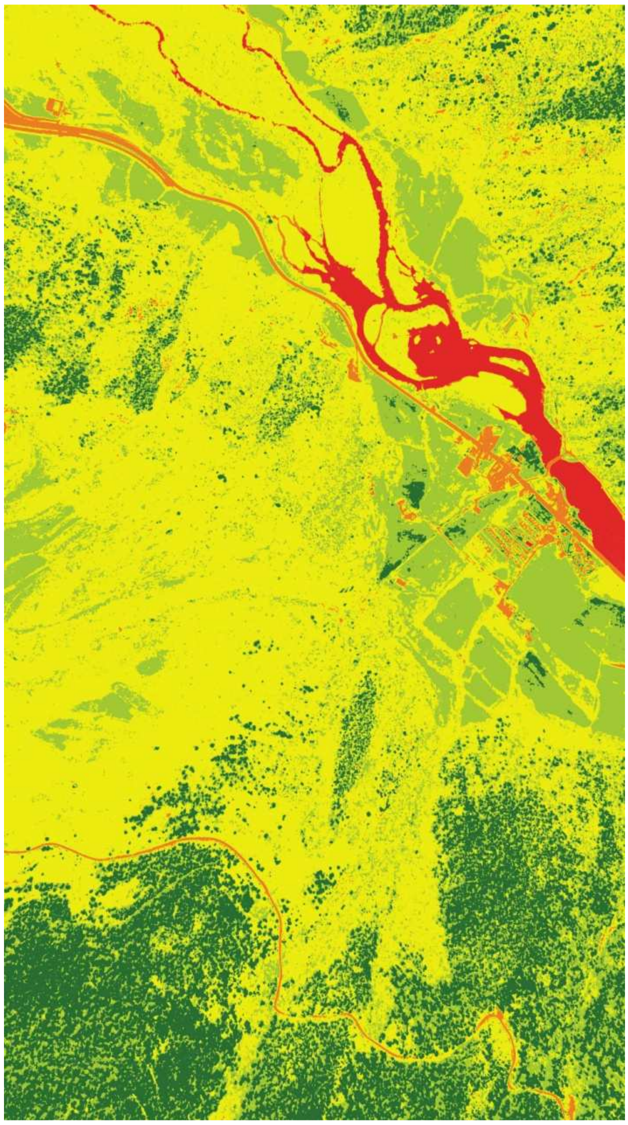

Figure 5. DMC NDVI image from apparent reflectance & Table 1 legend. (La Guineta d'Aneu 42º35'30''N 1º7'50''E WSG84)

5. ICC ORTOXPRES WMS SERVICES

The NDVI layer is provided as a WMS Geoservice. WMS is a standard protocol for serving georeferenced map images over the Internet that is generated by a map server using data from a database. It consists of doc-view architecture on the web that serves the information demanded by the user from a database that stores all the imagery, ancillary data and image metadata.

Until now, the database contained the imagery, the orientation and a digital terrain model (DTM) and the produced layer had on-the-fly orthorectification of a single 8 bpp image without stitching (all zoom levels are not available). The waiting time between flight mission and data publishing for rough geometric accuracy (direct orientation) is 1-2 weeks, while it takes 1-2 months for best geometric accuracy (aerotriangulation). Now the database is fed with the proper data to perform the radiometric transformations described so a NDVI layer is automatically available from LR4 DMC imagery for both geometric accuracies. This WMS service is available for most SIG environments: ArcMap, Miramon, gvSig, etc.

ICC ortoXpres is a public and free service available on the internet devoted to publishing photogrammetric flights using WMS services (http://www.ortoXpres.cat). The doc-view architecture of the WMS service allows to serve cartography instead of create, store and distribute the cartography in a traditional way. This service reduces the customer waiting time for new data and adds the time line as an analysis element, also allowing data comparison. In addition, ortoXpres provides a toponymy layer and coordinate searching capability.

6. OPEN PERSPECTIVES

The incorporation of a radiometric calibrated product to the ICC ortophoto and photogrammetric workflows is a brand-new opportunity to derive thematic information from DMC camera imagery. The first NDVI cover of Catalonia at a 25 cm GSD is now a true reality. Agriculture Department of the Generalitat de Catalunya (Catalonia regional government) is already using the NDVI layer to assess its agriculture policy for several crops (vineyards, cereal, etc.) After this first step, new challenges are ahead for our group, such of the first 1:25,000 ortoNDVImap of Catalonia and other NDVI products derived from satellite imagery.

7. REFERENCES

Honkavaara, E., Arbiol, R., Markelin, L., Martínez , L., Cramer, M., Bovet, S., Chandelier, L., Ilves, R., Klonus, S., Marshal, P., Schläpfer, D., Tabor, M., Thom, C., and Veje, N., 2009. Digital airborne photogrammetry: a new tool for quantitative remote sensing?: a state-of-the-art review on radiometric aspects of digital photogrammetric images. *Remote Sensing*, 1(3):577-605.

Martínez, L., Caselles, V., Valor, E., Pérez, F., and García-Santos, V., 2010a. Vegetation Cover Method Emissivity Dependencies on Atmosphere and Multispectral Vegetation Index. 3rd International Symposium on Recent Advances in Quantitative Remote Sensing (RAQRS III). Torrent, Spain, Setember 27th – October 1st Oct.

Martínez, L., and Arbiol, R., 2008, ICC experiences on DMC radiometric calibration. *International Calibration and Orientation Workshop EuroCOW 2008*. Castelldefels, 30th genuary-1st February.

Martínez, L., Arbiol, R., and Pérez, F., 2010b. ICC experiences on DMC radiometric calibration. *International Calibration and Orientation Workshop EuroCOW 2010*. Castelldefels, 10th–12th February.

Martínez, L., Palà, V., Arbiol, R., and Pérez F., 2007. Digital Metric Camera radiometric and colorimetric calibration with simultaneous CASI imagery to a CIE Standard Observer based colour space. *IEEE International Geoscience and Remote Sensing Symposium*. Barcelona, 23rd-27th July.

Rouse, J. W., Haas, R. H., Schell, J. A., and Deering, D. W., 1973. Monitoring vegetation systems in the great plains with ERTS, *Third ERTS Symposium, NASA SP-351*, vol. 1, pp.309-317.

Ryan, R., and Pagnutti, M., (2009): “Enhanced Absolute and Radiometric Calibration for Digital Aerial Cameras”, *52 Photogrammetric Week.* Stuttgart.