CASI CHARACTERIZATION AND ATMOSPHERIC CORRECTION FOR EUROSDR BANYOLES08 DATASET

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ABSTRACT:

Hyperspectral remote sensing data are widely used for applications such as agriculture, forestry, water quality, environment, sensor intercalibration, etc. Both satellite and airborne sensors are able to provide remote sensing information based on high resolution hyperspectral data. However, airborne sensors have some advantages such as the possibility of accurate laboratory re-calibrations, a greater ground resolution and spectral configuration capability, superior flight versatility and simultaneous acquisition with other sensors from the same airborne platform. In the optical spectral window, surface reflectance is usually the starting point for the retrieval of parameters from remote measurements. Therefore, reliable radiometric and spectral calibration and accurate atmospheric correction are crucial in the interpretation of the surface reflectance. The Institut Cartogràfic de Catalunya (ICC) operates an airborne Compact Airborne Spectral Imager (CASI) sensor that produces high spectral (a few nm) and spatial (up to 1 m) resolution imagery. The sensor measures the upwelling reflected solar radiation that depends on the reflective characteristics of the observed surface and also on the acquisition geometry and atmosphere behaviour. In this work, an atmospheric correction algorithm for airborne hyperspectral imagery data developed at ICC is used to correct multiple overlapping images over the same area taken from different heights. First, the spectral calibration is assessed by the characterization of the "smiling" effect and real bandwith. Next, the atmospherically corrected hyperspectral imagery is obtained. The utility of the algorithm is discussed in the frame of EuroSDR Banyoles08 dataset as a tool to compute the Digital Metric Camera (DMC) radiometric calibration. This calibration is a previous requisite to improve the quality of the DMC image products and to generate new ones such as atmospherically corrected DMC images.

1. INTRODUCTION

In 2008 the European Spatial Data Research (EuroSDR) organisation started a collaborative applied research project focused on Radiometric Performance of Digital Cameras. As a EuroSDR activity the Institut Cartogràfic de Catalunya led Banyoles 2008 campaign as a part of the empirical study, in collaboration with other cartographic institutions (Finnish Geodetic Institute, FGI), universities and research centres (Centre de Recerca Ecològica i Aplicacions Forestals, CREAF; Instituto de Desarrollo Regional, IDR-UCLM; Universitat Politècnica de Catalunya, UPC; Universitat de Barcelona, UB and Servei Meteorològic de Catalunya, SMC).

The first EuroSDR Banyoles 2008 goals were:

i) Radiometric calibration of a Z/I Digital Mapping Camera (DMC) with the simultaneous acquisition of Compact Airborne Spectrographic Imager (CASI) imagery.

ii) Spectral characterization of CASI images regarding bandwidth and smiling effect.

iii) Atmospheric correction of CASI imagery with aerosol distribution and load, and water vapour derivation by an inversion method.

After these three steps it would be possible to deal with these additional goals:

iv) Atmospheric correction of DMC images by using CASI derived atmosphere parameters.

v) Colorimetric calibration of DMC sensor towards CIE standard colour space.

Most of the Banyoles08 goals are closely related to the EuroSDR "Radiometric Perfomance of Digital Cameras" project objectives. The rest of Banyoles08 goals are a previous requisite or a way to understand how to succeed with the EuroSDR objectives.

Radiance measured by passive remote sensing sensors depends on geometry and on reflectance characteristics of the observed surface. After a proper radiometric lab calibration to get a physical value out of the signal measured by the sensor, the primary radiometric distortion is produced by the atmosphere These Radiometric distortions should be corrected in order to obtain accurate physical measurements and also to derive valuable products from the imagery.

In this communication the EuroSDR Banyoles 2008 multisensor dataset is described. Then, an overview of the CASI atmospheric correction is introduced with especial emphasis on CASI imagery pre-process regarding bandwidth and smiling effect. Next, the improvements on metric camera imagery obtained thanks to CASI data are discussed. Finally some main conclusions are commented.

2. EUROSDR BANYOLES 2008 MULTISENSOR DATASET

The campaign was held on July 15th 2008 in Banyoles (Spain) area. A CASI, a DMC and an Incident Light System (ILS) acquired data from a plane over ICC test field from ICC Cessna Caravan B208 (Figure 2.1). Simultaneously, an exhaustive field campaign was undertaken by CREAF and IDR-UCLM to obtain reflectance measurements on the test field targets and the rest of the area, including still water from a lake. Atmospheric ancillary data were obtained from the test field by means of an atmospheric LIDAR operated by UPC and sun photometer measurements performed by UB. In addition, meteorological data and information was provided by SMC.

(a)

(b)

(c)

Figure 2.1.Sensors on board Cessna Caravan B208. (a) DMC camera (b) CASI sensor head (c) ILS sensor.

Airborne data were acquired from flight lines designed to minimize the bidirectional reflectance effect. CASI sensor acquired hyperspectral data from three different altitudes (besides, DMC acquired multispectral data from an additional altitude) with multiple overlapping flight lines from each altitude. GSD for CASI ranged from 1.5 to 6 m. GSD for DMC panchromatic data ranged from 10 to 40 cm and multispectral data ranged from 0.4 to 1.6m. ILS data for each flight line were collected and calibrated to a single irradiance value for each CASI acquisition. As the capture of a single strip takes a short time, this approximation is accurate enough and noiseless.

The UCLM and CREAF groups performed simultaneous radiance and reflectance measurements along the day. The total measuring time was reduced to five hours around the flight-time (from 9.00 AM to 14.00 PM). The target sites consisted of invariant surfaces, i.e. no changing characteristics of the surface for the acquisition time. Besides, five colour canvases (man-made covers) provided by ICC (red, blue, green, black and white) were measured by both groups (Figure 2.2).

Figure2.2. ICC test field with canvas covers deployed (15 July 2008).

The UB sun photometer (Figure 2.3) measures sun and sky radiances to derive total column water vapour, ozone and aerosols properties using a combination of spectral filters and azimuth/zenith viewing conditions. The aerosol optical depth show low values indicating a very low turbidity during the campaign and small aerosol size. The atmospheric conditions and the in-situ observations made during the campaign suggest that the measurements did remain constant throughout that morning.

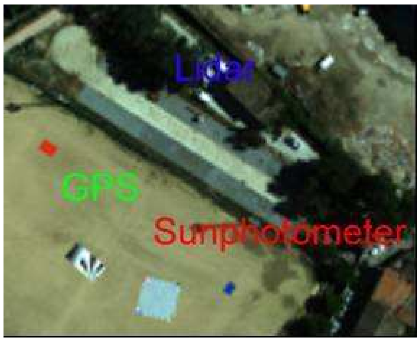

Figure2.3. Atmosphere measurements location during Banyoles08 acquisition day.

The UPC LIDAR (Figure 2.3) was set to simultaneously measure the 1064-nm and the 532-nm elastic backscattered radiation. LIDAR inversion with data acquired at 7:57 UTC yield that the resulting LIDAR AOT were 0.082 and 0.027. The inversion results show a temporal evolution of the boundary layer that rose with time and a second layer on top of the boundary layer that appeared after 8:27 UTC.

The SMC provided weather forecast and some ancillary meteorological data from the Banyoles automatic weather station data. As a real radiosounding was not available for the area, a MM5 metrological model vertical profile estimated at 12:00 UTC of the acquisition day was provided.

3. CASI ATMOSPHERIC CORRECTION

As a previous step to the atmospheric correction, smiling effect and real sensitivity of the bands should be calculated. The smiling effect is a spectral shift caused by the optical system when diffracting the incident radiation onto the CCD. It modifies the nominal relationship between bands and wavelengths in the across track direction. Some absorption features from atmosphere gas species such us O2 are used to compute this miscalibration of the imaging system.

Figure 3.1 shows the spectral shift computed for the CASI sensor. Note that the amount of shift is larger than the nominal sampling distance of the CASI imager. This result supports the hypothesis that spectral shift must be taken into account for an accurate radiometric characterisation of the CASI.

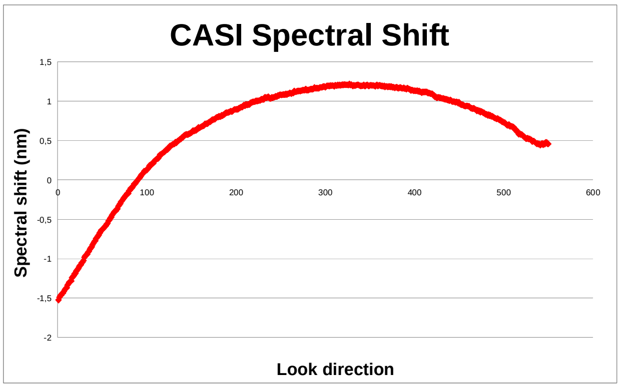

Figure 3.1. ICC CASI spectral shift computed by the displacement of O2 atmosphere absorption bands.

Regarding the spectral sensitivity and bandwidth, some results have been obtained. Figure 3.2 shows an example the spectral sensitivity of two bands belonging to a 32-band CASI configuration. A comparison of nominal and real bandwidths is depicted. In order to get a real estimation of the CASI bandwidth it is necessary to consider the real spectral sensitivity instead of the nominal one.

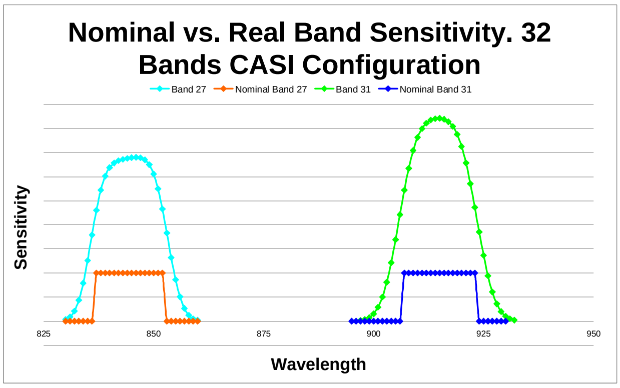

Figure 3.2. ICC CASI real and nominal spectral sensitivities comparison for a 32-band configuration.

The objective of the atmospheric correction algorithm 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 these 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. An inversion procedure is carried out by minimizing a cost function that consists of the difference between atmospherically corrected reflectances calculated on homologous areas observed on different images plus field measurements. A set of atmospheric parameters compatible with the field spectral measurements and simultaneous atmosphere measurements performed during the flight are obtained as a result of the inversion process.

4. IMPROVEMENTS ON METRIC CAMERA IMAGERY BY USING CASI DATA

As it was mentioned before, the study of hyperespectral data calibration and atmospheric correction gives a really good chance to prepare the methodologies for atmospheric correction of DMC imagery. But the spectral characterization of the CASI sensor is also mandatory to improve the cross calibration between DMC uncalibrated data and CASI laboratory absolute calibration. This is because the original DMC vs. CASI plots are very noisy and the compensation of this miscalibration on CASI imagery is expected to improve the results of DMC calibration.

Even if a laboratory absolute calibration is performed to a DMC sensor, it is necessary to verify the accuracy and drift of this calibration. This would be possible by acquiring DMC imagery together with CASI images in order to verify the stability of the camera calibration. Thus, the use of a CASI sensor as a calibration resource is a good strategy to assess the DMC radiometric characteristics.

5. CONCLUSIONS

The study of radiometric calibration and atmospheric correction of ICC CASI sensor gives an attractive chance to atmospherically correct DMC imagery. Real spectral sensitivity and spectral shift of CASI sensor are far from being negligible if a good radiometric accuracy is required.

These developments have been applied to EuroSRD Banyoles08 experiment with a good agreement between the results and the ancillary atmosphere and reflectance data acquired during the over flight.

Finally, the use of a CASI sensor together with a metric camera seems to be a good strategy even when an absolute calibration of the camera is available.

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