[3]CAT-3/MOTS, AN EXPERIMENTAL NANOSATELLITE FOR MULTISPECTRAL AND GNSS-R EARTH OBSERVATION: AIRBORNE OPTICAL AND GNSS-R CAMPAIGN

J. Castellvi-Esturi [1, 2], A. Camps[1], J. Corbera[2], R. Onrubia[1], R. Alamús[2], D. Pascual[1], J. Querol[1], and H. Park[1].*

[1]Universitat Politècnica de Catalunya – BarcelonaTech and IEEC/UPC, CommSensLab, Departament de Teoria del Senyal i Comunicacions, Campus Nord, Edifici D4, 08034 Barcelona, Spain. Tel. +34 93 4017362.
[2]Institut Cartogràfic i Geològic de Catalunya, Parc de Montjuïc, s/n, 08038 Barcelona, Spain. Tel. +34 93 5671500.
(*) E-mail: jordi.castellvi@tsc.upc.edu, DIUPC.jordi.castellvi@icgc.cat

ABSTRACT

The [3]Cat-3/MOTS mission is a joint initiative between the Institut Cartogràfic i Geològic de Catalunya (ICGC) and the Universitat Politècnica de Catalunya-BarcelonaTech (UPC) to foster new and innovative technologies on Earth Observation (EO) based on the data fusion of Global Navigation Satellite Systems Reflectometry (GNSS-R) and optical payloads on a 6U CubeSat platform. The final objective of the mission is to provide soil moisture mapping through the GNSS-R payload and improve its resolution by data fusion with the multi-spectral optical data acquired. This technique has been successfully applied to SMOS, but never performed from a 6U CubeSat carrying both payloads. An airborne optical and GNSS-R field experiment has been carried out to test/develop the algorithm and to analyze the results both separately (GNSS-R + optical data) and as a soil moisture product, once performed the data fusion.

1. INTRODUCTION

Soil moisture is a key indicator for the management of a resource as precious/scarce as water. Sectors such as agriculture, environmental monitoring, and territory management, need to know the soil hydrological stress to take the appropriate actions.
This work describes the first airborne optical and GNSS-R campaign conducted in the framework of the HUMIT project to test the readiness of the data fusion technique [1]. The flight was carried out the 30th of November 2017 and lasted approximately 4 hours, taking off from Barcelona airport and heading to the North-West part of Catalunya. Flying altitude was set to 1200 m for legislation reasons in urban areas. Two separated regions of interest were defined: the surroundings of Balaguer city (41.79°, 0.80°), and the Tremp area (42.16°, 0.89°). The first Target Area (TA1) is rural, mainly dedicated to agriculture, with a very flat topography and a mixture of irrigated and rainfed land. The second Target Area (TA2) is much closer to the Pyrenees, and therefore, the profile of the terrain is rougher. Fields in TA2 are much smaller than in TA1 and mainly rainfed.

2. EXPERIMENT DESCRIPTION

The plane (CESSNA Caravan [2]) carried 4 different instruments: a hyperspectral camera (AisaEAGLE-II [3]), AISA from now on, a thermal camera (TASI [4]), a reflectometer (CORTO [5]), and a radiometer (ARIEL [6]). It was also tested the Scatterometric Techniques in Airborne Reflectometry (STAR) instrument, a dual band GNSS reflectometer (L1 and L2) as part of the validation tests for the Microwave Interferometric Reflectometer (MIR) instrument [7]. There were used the up-looking GPS antennas of the plane used for navigation, one over each photogrametric window, as well as a L1/L2 down looking GPS antenna for the reflected signal. Also, the APPLANIX Inertial Navigation System (INS) on-board, consisting of a GNSS receiver and a IMU (Inertial Measurement Unit), was later on used to perform the geometric correction of the images.
The main scope of the experiment was to acquire optical data with the AISA and the TASI instruments to perform a data fusion with the soil moisture data retrieved from the CORTO. The L-band radiometer will be used, later on, to perform an instrumental performance inter-comparison once all data has been processed. The campaign date was set as to coincide with a Sentinel 2A pass over the studied area so as to use the images acquired by the MSI (MultiSpectral Imager [8]) instrument as validation and backup, but due to weather conditions, the take off was delayed a few days and there was no Sentinel pass on November the 30th.

3. INSTRUMENTAL CHARACTERISTICS

The AISA instrument is a pushbroom hyperspectral sensor in the VNIR (Visible and Near InfraRed), from the 406 nm to the 993 nm. It has a maximum of 254 bands with a bandwidth of 2.4 nm. For the HUMIT campaign the sensor was configured with 126 bands, coupling together every two bands with a mean bandwidth of ~4.8 nm.

The TASI (Thermal Airborne Spectrographic Imager) instrument is a hyperspectral sensor in the TIR (Thermal InfraRed). It has 32 bands between the 8050 nm and the 11450 nm, with a bmean bandwidth of 109.5 nm. The HUMIT campaign used al 32 bands.

The CORTO (COmpact Reflectometer for Terrain Observations), performs the correlations between the direct and the reflected GNSS signals and processes the data to obtain soil moisture from reflectivity.

4. OPTICAL DATA AND PRE-PROCESSING

At the time of writing this abstract, the optical data from the AISA and the TASI have started to be processed. Due to the flight altitude and the intrinsic characteristics of the instruments, the resulting images have a spatial resolution of approximately 2 m. The image processing chain has been divided in 3 steps: Radiometric correction (already performed), Geometric correction (already performed), and atmospheric correction (in process).

The Radiometric correction for the AISA converts the information of each pixel expressed in digital levels (DNs) into units of spectral radiance L_λ (measured in SRUs, Standard Radiance Units):

$$1 \text{ SRU} = 1\mu\text{W}\cdot\text{cm}^{-2}\cdot\text{sr}^{-1}\cdot\text{nm}^{-1} \quad (1)$$

The radiometric correction for the TASI consisted of three main steps: a noise correction (dark current), which is strongly depended on the sensor temperature, a calibration using the manufacturers data, and a spectral correction, also dependent on the temperature.

After the radiometric correction, the geometric correction is performed using the GNSS receiver and the IMU data. GNSS observations provide a temporal reference frame (GPS time for HUMIT campaign), and associated positioning information. The INS provides observations of angular velocity and linear accelerations for 3 independent axes of rotation during the flight. The 2 meter resolution DEM (Digital Elevation Model) provided by the same ICGC is also used to obtain the altitude of each observed pixel.

The following images show an orthophoto of one of the measurement points, and the images AISA and TASI pre and post geometric correction.

The Sentinel-2A radiometric correction would not have been necessary to obtain radiance images because at their current pre-processing level (L1C), ESA-S2 images are already TOA (Top Of Atmosphere) reflectivity images. The geometric correction is also provided by ESA. For atmospheric and topographic correction, ESA-S2 images are also available at processed level L2A.

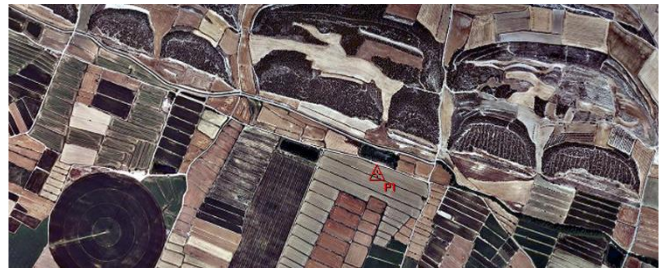

Fig. 1: Orthophoto of MP8 (measurement point 8) of the HUMIT campaign (41.78 N, 0.88 E).

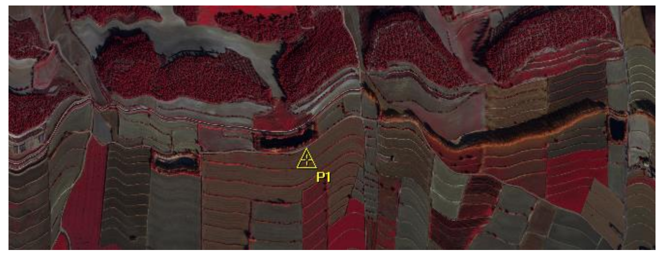

Fig. 2: Radiometrically corrected, but not geometrically corrected, AISA image of MP8.

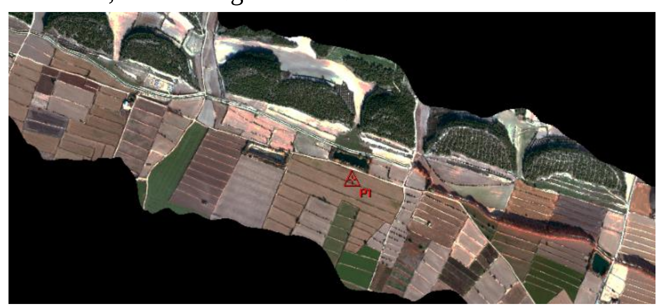

Fig. 3: AISA image of MP8 after radiometric and geometric corrections. To be compared to Fig. 1.

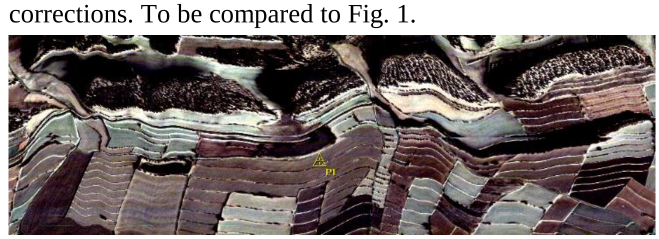

Fig. 4: TASI image of MP8 radiometrically corrected but before geometric correction.

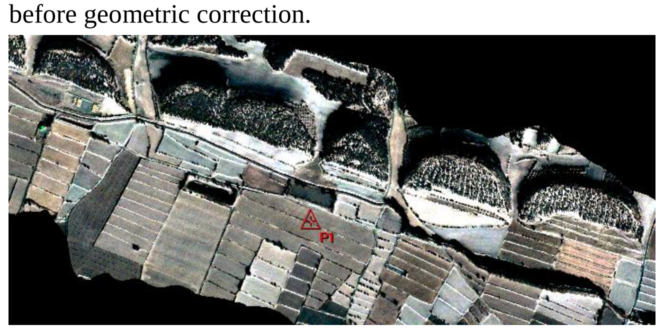

Fig. 5: TASI image of MP8 after radiometric and geometric corrections.

5. GNSS-R DATA AND RADIOMETRIC PRELIMINARY RESULTS

The GNSS-R data set is being processed, but is still in a preliminary phase. In a previous campaign performed by the UPC in the same plane, it was detected that the down looking antenna was collecting enough RHCP direct signal to force the down-looking receiver to lock at it. A LHCP (Left hand Circular Polarization) choke ring antenna has been purchased at to be used in a second airborne campaign (March 2018), hoping to better isolate the down looking antenna from the directed signal.
The following images show the first qualitative results obtained with the CORTO instrument and the radiometer:

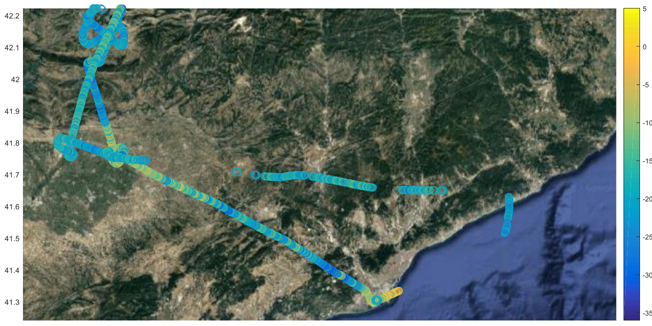

Fig. 6: CORTO reflectometer HUMIT airborne campaign preliminary image of reflectivity data.

Fig. 7: ARIEL radiometer HUMIT airborne campaign preliminary image.

6. CONCLUSIONS

The final objective of the HUMIT airborne campaign is to test the algorithms and performance of data fusion techniques for its use in a small satellite platform ([3]Cat-3/MOTS). The images acquired by the two hyperspectral sensors have been radiometrically and geometrically corrected and only the atmospheric correction is ongoing. Once all corrections are performed, the NDVI (Normalized Difference Vegetation Index) will be extracted from the AISA image, and the LST (Land Surface Temperature) will be obtained from the TASI image. With the soil moisture data from the CORTO it will be possible to perform a GNSS-R + optical data fusion and increase the spatial resolution of the GNSS-R measurements. The use of the Sentinel 2A data instead and the comparison with the radiometric data will open up alternative results. The validation of the results will be performed with the in-situ measurements that were done the same day of the airborne campaign, with the extraction of samples from all measured points and the resulting soil moisture and apparent density of the samples.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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