HYDROSOIL, SOIL MOISTURE AND VEGETATION PARAMETERS RETRIEVAL WITH A C-BAND GB-SAR: CAMPAIGN IMPLEMENTATION AND FIRST RESULTS

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ABSTRACT

HydroSoil is a measurement campaign, funded by the European Space Agency (ESA), where the temporal evolutions of two crops, barley and corn, have been continuously monitored during the whole crop period by means of a C-band Fully Polarimetric C-band Ground-Based Synthetic Aperture Radar (GB-SAR). SAR data has been collected together with ancillary data, and both are being processed to demonstrate the retrieval of soil moisture and vegetation parameters in an agricultural field under controlled conditions, to simulate the frequent acquisitions of GeoSAR missions.

Index Terms— GeoSAR, GB-SAR, Water cicle, Soil moisture, Vegetation mapping, Vegetation parameters

1. INTRODUCTION

Understanding changes in the Earth system and the impact that humankind is one of the reasons that justify the study and development of new satellite missions for Earth Observation (EO). Future satellite missions will offer a stream of innovative measurement techniques to explore and understand different aspects of the Earth system as weather forecasting, hydrology, cryosphere, etc. Among them, there is a special focus on observing and understanding rapid processes of the water cycle over land, in which soil and vegetation interact at a very fast rate. A major improvement in the time-scale of observations is the development of geosynchronous SAR missions (GEOSAR) which, for the first time, would allow for continuous monitoring. This concept is currently under study in Europe (Hydroterra, formerly named G-CLASS, an ESA Earth Explorer candidate [1]) and China [2]. For these reasons UPC has proposed and started the HydroSoil campaign, supported by European Space Agency. The main objective of the campaign is to demonstrate the retrieval of soil moisture and vegetation parameters in an agricultural field under controlled conditions using a ground based fully-polarimetric SAR instrument (GB-PolSAR) to simulate the frequent acquisitions of GeoSAR missions.

From March 2020, two radar backscattering data-sets on Barley and Corn fields have been acquired, producing a large amount of continuous monitoring data taken every 10 minutes. The main sensor is a Fully Polarimetric C-band (GB-SAR) with metric resolution in both range and cross-range axes after SAR processing. The radar measurements required an intensive acquisition of ground truth data encompassing continuous acquisition of relevant meteorological parameters, soil moisture and crop parameters such as plant water content, leaf area index and height. Soil moisture has been continuous monitored with a set of sensors deployed in the field. Frequent vegetation sampling and processing have also been performed.

The HydroSoil data set, with more than 40.000 polarimetric radar acquisitions at the end of November 2020, is now being processed to obtain high resolution images to allow further processing.

2. EXPERIMENT DESCRIPTION

Because of the strict lockdown imposed in Spain since the beginning of the first campaign, the main RADAR instrument and sensors for ancillary data gathering were hardly deployed for the barley campaign, and the whole number of them were not installed until the beginning of the corn campaign.

2.1. Test Site

The test site is the experimental agricultural field of the Barcelona School of Agricultural Engineering EEABB, UPC. The field is in front of the North North-West façade of the EEABB building. The cultivated area is 22 m by 60 m (depth and width), 25 m far from the façade. The GB-SAR is mounted on the roof of the building (figure 1), centered with respect to the crop area. The incidence angles of the radar in the test field are from 50˚at near range to 65˚ at far range, similar to those of geosynchronous satellite observations over Europe. In comparison to usual tower-based measurements, affected by wind induced motion, the EEABB building provides an excellent observation stability, which is ideal to assess phase changes induced by crop, soil moisture and atmospheric dynamics.

Parameter	Value
Central Freq (Bandwidth)	5.6 GHz (200 MHz)
Modulation	Saw-Tooth FM-CW
Chirp PRF	338.5 Hz
Receiver Noise Figure	2 dB
3dB Antenna Beamwidth	60˚ (Az.), 40˚ (El.)
Aperture length (rail speed)	1.5m (1m/s)
Radar acquisition interval	10 min

Table 1. Radar main parameters

Figure 1. (Top) The Metallic structure that holds the rail is attached to the building. (Bottom) The location of the radar can be seen on the roof of EEABB building

2.2. Main Instrument

The main instrument is a C-band Ground Based Full-Polarimetric Synthetic Aperture Radar (GB-PolSAR) [3]. A set of pyramidal horn antennas, two in transmission and two in reception, are used as radiation elements. The main parameters of the radar system are listed in table 1.

Signal bandwidth and aperture length bring a number of looks for the following three angular sectors, 55.2° - 59.1°, 59.1° - 63° and 63° - 66.9°, in the order of 140, 335 and 485 respectively.

2.3. Data products

The data provided by the experiment are,

- Calibrated Quad-Pol Ground Based SAR data [4] with incidence angles between 55◦ and 67◦ with a temporal resolution of 10 minutes. Two Single Look Complex (SLC) products are generated, calibrated data (level 1b) and calibrated data with atmospheric refraction index changes correction (level 1c) [5]. A set of trihedral, 2 dihedrals with one of the with vertex tilted 45 degrees have been used for calibration
- Soil roughness: It has been characterised with a laser profiler after both crop sowing [6,7].
- Soil moisture. A set of electronic sensors have been placed on each side of the test field. Gravimetric samples were manually taken periodically by means of a T-Style Soil Sampler in different areas of the field, to supplement the automatic sensors.
- Vegetation sampling: plant density, planting row direction, size and orientation of main plant elements, biomass and crop phenology, water cycle, Leaf Area Index (LAI), crop height and vegetation water content along the crop period were periodically sampled [8].
- Meteorological parameters: A local weather station was deployed to gather different information as barometric pressure, rain precipitation, temperature, humidity and wind speed and direction.
- Detailed irrigation information when used.

3. PRELIMINARY RESULTS AND CONCLUSIONS

A complete growing season of barley and corn have been continuously monitored by the radar. Nowadays only the data from the barley campaign has been processed (figure 2). Shortly after the start of the barley campaign, COVID-19 outbreak resulted in a complete closure of UPC facilities. Since the radar was designed to operate autonomously with automatic acquisition routines and remote-control capabilities, this closure had not impacted the data takes nor the barley crop growth under monitoring.

For the barley campaign, the crop evolution is characterized in two phases: the first one with bare soil, rainy periods and a tendency to move to warmer days. In this phase the copular (HH and VV) backscattering shows a slight decay trend, interrupted shortly by rain showers until the beginning of May. The second phase, characterized by low humidity periods and few intense rains, is characterised by a backscattering increasing trend caused by the crop growth in its last phenological stages, when the height is boosting during the last month of the season and with water content significantly high.

From preliminary results, some conclusions and correlations can be extracted:

- Backscattering is highly dependent on precipitation. Clearly visible during March and May, but present during all the time series.

- Low frequency backscattering oscillation due to the daily cycle of humidity and temperature. Also appreciated, with a high degree of correlation, on the soil moisture measurements.
- Flooded areas in the field cause low reflectivity values around the last days of April. Strong rains produce pools of water in some areas of the field which cause specular reflection.
- Rapid growing of the crop increases the reflectivity in the last month of the season. The height and water content of the developed plants result in a dominant scattering mechanism of the field, taking into account the lower moisture and lighter rain events.

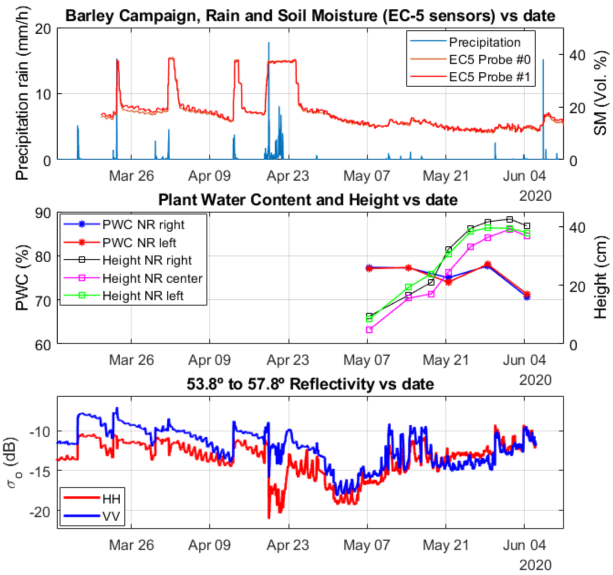

Figure 2. Time series of observations from the HydroSoil barley campaign. (Top) Precipitation and soil moisture (SSM) measurements. (Centre) In situ measurements of crop height and plant water content (PWC) in the near range (NR) region. (Bottom) Time series of calibrated backscattering coefficient (σ_0) at VV and HH channels (incidence angles from 55.2° to 59.1°)

In spite of the confinement restrictions due to the COVID-19 pandemic, the UPC team managed to successfully operate the radar remotely in 24x7 continuous operation every 10'. Only minor interruptions were experienced.

Different preliminary products, 1b and 1c Single Look Complex (SLC), will be shown together with the correlation between radar results and ancillary data.

4. ACKNOLEDGEMENTS

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