GLORI Airborne Campaign: Results for agricultural and Forest Areas

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Background

Global Navigation Satellite System Reflectometry (GNSS-R) is a technique using signals of opportunity emitted by satellite navigation constellations, reflected by the Earth surface (ocean or land) and received by ground based, airborne or low Earth orbit receivers to perform bistatic radar measurements of geophysical parameters.

In the past decade, several studies [1,2] have demonstrated that this technology could be used for the determination of land parameters such as soil moisture, vegetation water content and forest biomass, with advantages such as a low cost of the observation systems and long term availability of the transmission signals.

Motivation

GLORIE (Global navigation satellite system Reflectometry Experiment) [3] is an airborne campaign that took place in 2015 in the south west of France. The idea is to gather a measurement database that could be used to assess / confirm the sensitivity of airborne GNSS-R to land parameters, with the goal of validating bistatic radar vegetation models and of developing robust inversion methods. The long term objective is to design operational systems for large scale monitoring of soil moisture and biomass, complementing actual systems limited by their spatial or temporal resolution.

The GLORI airborne measurements

The GLORI receiver [3] is based on one up-looking and one down-looking dual polarization hemispherical antennas feeding a low-cost 4-channel direct down-conversion receiver tuned to the GPS L1 frequency. The raw measurements are sampled at 10MSPS and stored as 2-bit, IQ binary 36s files.

The aircraft inertial Measurement Unit records attitude information and an additional commercial GPS receiver records ancillary information such as visible satellites azimuth and elevation, estimated Doppler and code phase as well as receiver location.

The June-July 2015 Campaign

Six flights were performed between June 19th and July 6th in the south-west of France, representing more than 15 hours of polarimetric raw data and ancillary data [3]. The ATR-42 flew at an altitude of approx. 600m AGL, a speed of about 100 m/s and the track was designed to cover 4 areas of interest (crops and forests).

Data Processing

The GLORI processing chain is composed of 4 main blocks using raw data, GPS ephemeris, flight ancillary data and a digital elevation model (DEM) as inputs [3]:

1 - GNSS processing of raw dataset
   Acquisition and tracking of modulated signal to compute correlation waveforms (integration time 1, 3 and 20ms).

2 - Time tagging and extraction of waveform maxima
   Processing of the navigation message to get transmission time and extraction of the peak correlation power.

3 - Instrument corrections and Incoherent averaging
   Correction for antenna gain and instrumental noise, incoherent averaging and computation of the Interferometric Complex Field ICF and reflectivity [1].

4 - Geolocalisation and merging of individual files
   Computation of the footprint location and shape on the surface, merging of individual measurements in a consolidated file.

   Eventually, collocation with in situ measurements is performed against shapefiles of fields/plots.

Conclusions and outlook

• A campaign dedicated to the analysis of airborne GNSS-R sensitivity to land parameters was conducted, with more than 15 hours of raw data recorded.

• A large amount of ground truth was collected, mostly related to soil moisture and forest biomass parameters.

• Analysis of the Data over agricultural areas show a good correlation with vegetation height, related to biomass for these crops, and a moderate correlation with soil moisture.

• Preliminary analysis with forest data shows little correlation with biomass, probably linked to the presence of a thick vegetation cover on the ground.

• Electromagnetic modeling of the scattering and attenuation mechanisms is needed to better understand the observations and move towards an efficient inversion algorithm.

References


Agricultural areas

As NDVI and VWC data is not available for all fields, Figure (a) tells us that the NDVI is strongly correlated with LAI and VWC with height (can be used as a proxy).

Taking all angles (30-90deg), Figure (b) shows a moderate correlation between UHCP reflectivity and LAI and soil moisture, and a better correlation with vegetation height.

However, Figure (c) shows the angular dependence of the fit, with increasing correlation for LAI and Height with decreasing elevation angle, and opposite behavior for soil moisture, except for very high elevation angle, probably due to the limited amount of data.

Figure (d) shows that fitting both height and soil moisture to the reflectivity gives a very decent correlation (r2 = 0.7).

Forest areas

Preliminary comparison between reflectivity and forest biomass and tree high show very little correlation, with a very fast saturation of the signal. This is probably due to vegetation cover.

Figure (e) shows the data distribution with a box plot for each data set.