AIRBORNE FOREST MONITORING DURING SMAPEX-3 CAMPAIGN

C.Vittucci(1), L.Guerriero(1), P.Ferrazzoli(1), R. Rahmoune(1), M.Tanase(2), R.Panciera (2), A.Monerris(3), C. Rüdiger(3), J.P.Walker(3)

(1) DICII, Tor Vergata University, Roma, Italy, Email: vittucci@disp.uniroma2.it
(2) CRC-SI, University of Melbourne, Melbourne, Australia
(3) Department of Civil Engineering, Monash University, Clayton, Australia

ABSTRACT

This study investigates the potentialities offered by active and passive simultaneous acquisitions at L band for monitoring of soil moisture in forested areas. Airborne data, acquired over the moderately dense Gillenbah forest in the framework of SMAPEx-3 project, have been analyzed to derive the sensitivity of emissivity and backscattering coefficient to soil moisture variations during the campaign, considering a full set of ground measurements characterizing the forest environment.

Index Terms— SMAPEx, soil moisture, forests.

1. INTRODUCTION

To address the requirement for higher resolution soil moisture data, the National Aeronautics and Space Administration (NASA) has proposed the Soil Moisture Active Passive (SMAP) mission, with an expected launch date in 2014. This mission will provide global maps of soil moisture at ~9 km spatial resolution with a 2-3 days repeat through the combined use of radiometer data at 36 km and radar data at 3 km spatial resolution [1]. The Soil Moisture Active and Passive Experiment (SMAPEx) consisted of three airborne campaigns held in the Murrumbidgee Catchment (New South Wales, Australia) between 2010 and 2011, in order to encompass seasonal variations of soil moisture and vegetation [2]. The SMAPEx airborne facility consists of the Polarimetric L-band Multibeam Radiometer (PLMR; 1.41 GHz) and the Polarimetric L-band Imaging Synthetic aperture radar (PLIS; 1.26 GHz) which, when used together on the same aircraft at a flight altitude of 3 km, allows acquiring SMAP-like data with passive microwave footprints at 1km and active microwave footprints at better than 10m resolution [3, 4]. The present study focuses on the analysis of passive data collected over the Gillenbah and Boona State Forests during the third SMAPEx campaign (SMAPEx-3), which took place during the austral spring in September 2011. A sensitivity analysis to soil moisture content and tree biophysical parameters, provided by the ground sampling in the growing season, has been performed. The SMAPEx-3 data have been interpreted using the theoretical model developed at Tor Vergata University, and will be used to test and verify earlier theoretical findings [5]. The model is based on a discrete approach and is able to simulate both active and passive microwave signature of forests [6, 7].

2. DATASET

A total of eight PLIS/PLMR flights were conducted over Gillenbah (7 km x 8 km) and Boona State Forests during the austral spring (5^{th} to 23^{rd} September 2011) in the Yanco Region (NSW, Australia), together with a detailed forest inventory accounting for vegetation structure (Fig.1). This area presents semiarid characteristics and has been monitored since 2001 for remote sensing purposes [8]. The main trees species in the forests are Murray Pine (Calitris Glucophylla) and mixed Murray Pine and Grey Box (Eucalyptus microcarpa).

Ground sampling and inventory was performed at 20 locations. In the Gillenbah Forest, 12 different sites consisting of 5 plots each, were sampled to characterize an area of about 1ha around the site center. Inside each plot, all trees with diameter at breast height (DBH) > 5 cm were recorded and the total and crown height [m] were measured. The smaller trees (DBH < 5 cm) were counted and their average height visually estimated. The total biomass for each tree was calculated using allometric equations [9, 10] and aggregated at plot level [t ha^{-1}]. For representative trees, the crown (CWC [m^3/m^3]) and trunk water content (TWC [m^3/m^3]) were measured for each tree species. Soil moisture (SM [m^3/m^3]) and soil surface temperature (Ts [K]) were measured using Hydraprobe instruments.

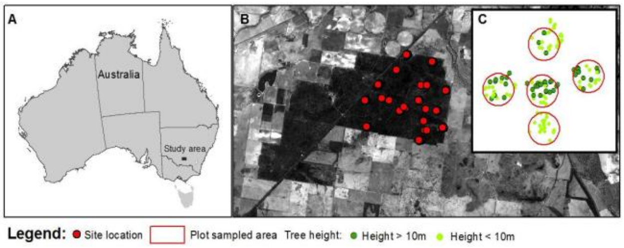

Figure 1. Location of the study area (black square in panel A) and field data sampling locations in Gillenbah forest (red dots in panel B). The inset (C) shows the layout of sampled plots at each site and an example of the tree spatial distribution measured at one sampling location. Panel B has as background a Landsat ETM+ panchromatic image.

3. METHODOLOGY

The purpose of this work is to investigate the sensitivity of L-band radiometry to ground measured variables at the three standard PLMR incidence angles (±7°, ±21.5°, ±38.5°). Maps of brightness temperature (TB) have been processed for each flight and polarization, showing V polarization values slightly higher than the corresponding H polarization. The images highlighted the day–to-day differences, showing an increasing overall trend in TB as expected, given the spring local temperature conditions during the campaign.

In order for data to be independent of the soil surface temperature Ts, the emissivity e=TB/Ts was calculated using the surface temperature measured at the closest temporary monitoring station. At V polarization, the latter showed an increasing trend with angle while the opposite trend is observed at H polarization.

Since the flights were not conducted during the same days as forest sampling, the radiometric data were associated to the ground data collected on the nearest date. For each flight, only the PLMR-TB pixels that fell into a circular area around each site center (see previous section) were taken into consideration. These circles have a diameter of about 1.1 km.

4. PRELIMINARY RESULTS

An example of the results obtained at 21.5° incidence angles is provided in Figure 2. The plot highlights the relationship between the computed emissivity (reported in terms of average and standard deviation values inside a site) and the soil moisture. The data show higher values of emissivity at V polarization, while the dynamic range is similar for both polarizations. The soil moisture content decreases with time (because of the rainfall registered during the first days of the experiment and the subsequent dry out) and a corresponding increase of emissivity is observed. This result confirms the possibility to correlate SM with the emissivity at 1.41 GHz over moderately dense forests, such as the Gillenbah one with an average biomass of about 65t/ha.

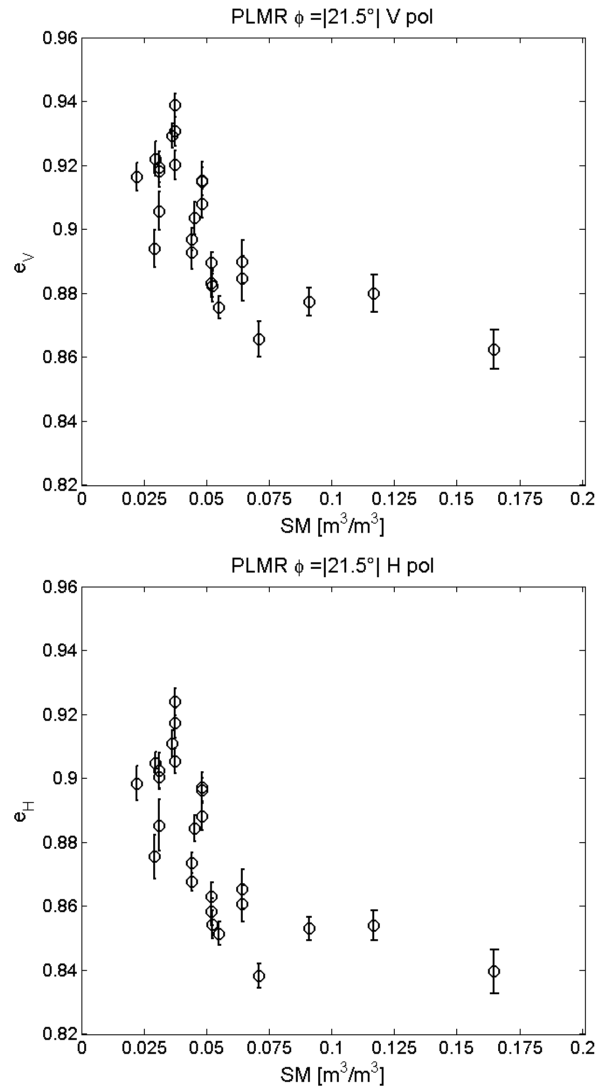

Figure 2. Emissivity vs. measured soil moisture. Top: V polarization. Bottom: H polarization.

An analogous study is underway with active data at 10 m spatial resolution. The acquisitions of PLMR and PLIS have allowed the extraction of averaged backscattering coefficient during each flight day simultaneous to the measured emissivity at each site. Both active and passive measurements will be studied and interpreted with the support of the TorVergata forward model [6, 7]. In particular we have verified that these results are in agreement with the theoretical results obtained by the Tor Vergata model in [11]. The daily variation of SM sampled by Hydraprobe data as well as by a temporary station located near the Gillenbah forest allowed to evaluate the sensitivity of radiometer and SAR data by means of maps computed for the emissivity and the backscattering coefficient respectively.

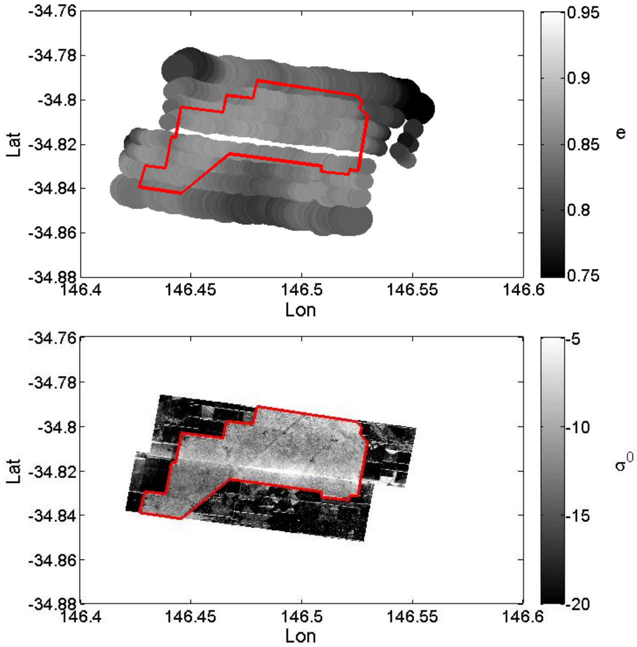

Figure 3. Maps of the Gillenbah forest area from PLMR and PLIS data acquired on the 7th September 2011, the forest boundaries are highlighted by the red shape. Top: emissivity computed at H polarization. Bottom: backscattering coefficient at HH polarization expressed in dB.

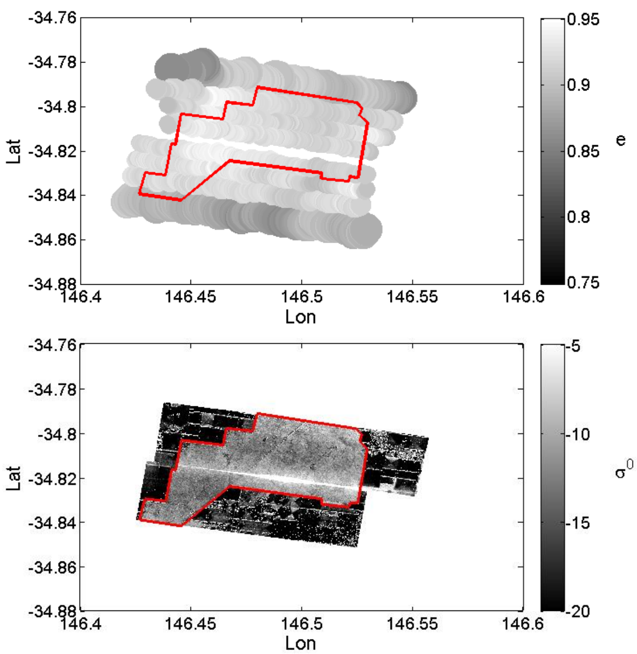

Figure 4. Maps of the Gillenbah forest area from PLMR and PLIS data acquired on the 21st September 2011, the forest boundaries are highlighted by the red shape. Top: emissivity computed at H polarization. Bottom: backscattering coefficient at HH polarization expressed in dB.

Figure 3 shows the forest area as imaged by the two sensors on the 7th September 2011, while the same maps are shown in figure 4 for the 21st September 2011.

The dates of the maps of figure 3 and figure 4 represent the wetter and the dryer days of the forest sampling campaign, respectively.

Comparing the dynamics of the maps, the better sensitivity of passive measurements to SM variations over forested areas is confirmed. Indeed. the emissivity increases of about 0.05 units from the 7th to 21st September because of a soil moisture decrease from about 15% to 2%. The backscattering coefficient seems more influenced by tree characteristics that tend to hide the Soil Moisture effects on the maps. On the other hand the backscattering coefficient enhances discrimination between forest and agriculture crops better than emissivity

5. CONCLUSION

A complete set of in situ data, collected during the SMAPEx-3 campaign, was exploited to study the effectiveness of active and passive L band contemporary acquisitions to monitor soil moisture changes of forest regions. Daily multi-angular PLMR data and ground measurements were analyzed to study the sensitivity of emissivity to SM variations over Gillenbah forest site, divided in distributed plots. A similar analysis was conducted using PLIS SAR data. Maps of emissivity and backscattering coefficient confirm the higher sensitivity to changes of soil moisture content of passive data. A preliminary investigation showed that the results are in agreement with the theoretical outcomes obtained by the Tor Vergata model.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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