MULTI-PLATFORM RADIOMETER SYSTEMS FOR SURFACE SOIL MOISTURE RETRIEVAL

Xiaoling Wu[1]*, Nan Ye*[1]*, Jeffrey Walker*[1]*, James Hills*[2]*, Francois Jonard*[3]*, Valentijn.Pauwels*[1]

[1]Department of Civil Engineering, Monash University, Clayton Campus, VIC 3800, Australia
[2]Tasmanian Institute of Agriculture, University of Tasmania, Hobart, TAS 7001, Australia
[3]Forschungszentrum Jülich GmbH, Institute of Bio- and Geosciences – Agrosphere, Jülich 52425, Germany

ABSTRACT

Readily available soil moisture data will help farmers to better optimize their irrigation scheduling and minimize water consumption. Consequently, there is a large and accelerating interest in using sensing technologies in precision agriculture worldwide. Among them, passive microwave sensing technology has been considered as the most accurate in retrieving soil moisture. This study compares the performance of an L-band radiometer system at two different platforms: airborne and near-surface (buggy). Field experiments have been conducted across an agricultural site in Tasmania, Australia for three consecutive days for. Ground sampling was also conducted in order to evaluate the accuracy of both L-band radiometer systems. Brightness temperature data from the buggy showed a larger temporal variation on individual days than the aircraft data, likely due to the irrigation activity during the longer period required for data collection by the buggy than for the aircraft. In terms of the relationship between brightness temperature and soil moisture, both platforms showed similar results while the buggy-based data showed a slightly better correlation with soil moisture.

Index Terms— brightness temperature, soil moisture, L-band, field experiment, precision agriculture.

1. INTRODUCTION

Water is a scarce resource that limits the amount of land which can be irrigated, so even a minor water saving through optimized application rates will allow more land to be irrigated. Access to real-time data on the soil moisture content will allow growers to control their water application rates. Over the past three decades there have been numerous ground-, air- and space-based near-surface (top 5 cm) soil moisture remote sensing studies using visible, thermal-infrared (surface temperature) and microwave (passive and active) electromagnetic radiation [1, 2]. Of these, microwave has proven to be the most promising approach due to its all-weather capability and direct relationship with soil moisture through the soil dielectric constant. Whilst active (radar) microwave sensing at L-band showed some positive results for soil moisture retrieval [3], passive (radiometer) microwave measurements at L-band are less impacted by land surface roughness and vegetation cover [4]. Thus, satellite mission such as the Soil Moisture and Ocean Salinity (SMOS) satellite [5], launched by European Space Agency (ESA) with L-band radiometer onboard, has the capability of retrieving

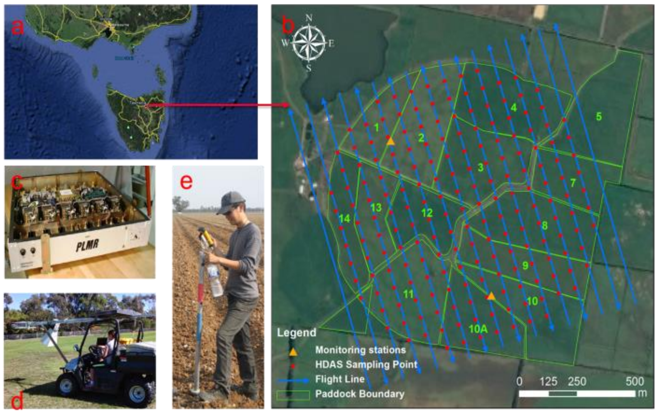

Figure 1. (a) Location of the study area in Tasmania Australia; (b) Flight lines and sampling points; (c) the Polarmetric L-band Multibeam Radiometer (PLMR) system; (d) the ESA L-band radiometer (ELBARA III); and (e) the Hydraprobe Data Acquisition System (HDAS) used for ground truthing.

soil moisture accurately at global scale but with poor resolution (~40km), which has limited its application at regional scales especially in the agricultural area. Compared with satellite, the airborne sensing technology is more cost-effective and can provide higher resolution for the agricultural application. Nowadays the precision agriculture is experiencing substantial growth thanks to the availability of improved and cost-effective instrument for data collection, such as the ground-based proximal sensing technology, which is able to compete with satellite and aircraft, due to low operational costs, high operational flexibility and high spatial resolution although it has limited covering area.

In order to optimize the use of these sensing technologies from different platform for precision agriculture, their technical, scientific and economic performances need to be assessed. For this purpose, this study was designed to compare the performance of an L-band radiometer from a buggy- and an aircraft-based platforms, and then evaluated against the ground truth obtained by a soil moisture measurement probe (Fig.1).

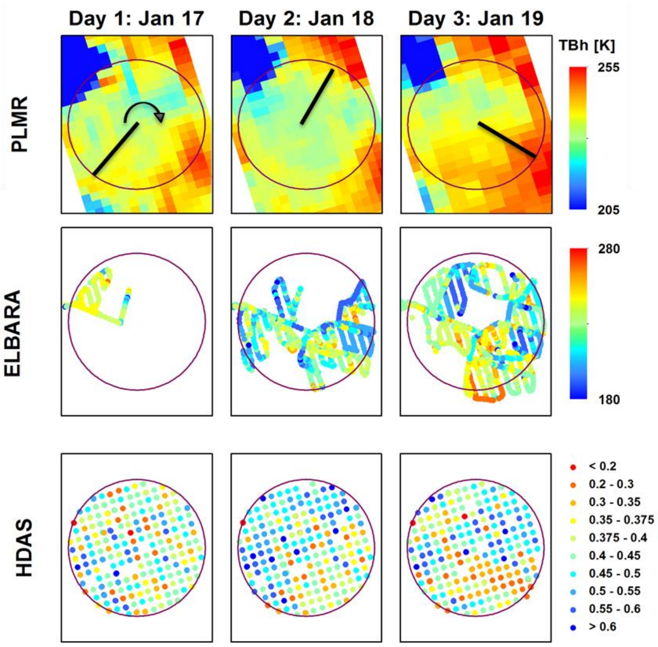

Figure 2. Data collected on 17th, 18th and 19th January 2017: PLMR brightness temperature at h-pol (in Kelvin); ELBARA brightness temperature at h-pol (in Kelvin); and HDAS soil moisture data (in cm^3/cm^3). Also shown here is the location of irrigation boom (black bars) on each day which moved anti-clockwise.

2. STUDY AREA AND INSTRUMENTATION

The field experiment was conducted over the Cressy farm site in Tasmania, Australia from the 17th through the 19th of January 2017 (Fig. 1). Three types of instruments were used during this experiment, including an airborne L-band radiometer, a buggy-based L-band radiometer, and the hand-held ground sampling instrument.

The Polarimetric L-band Multibeam Radiometer (PLMR) [6] mounted on a small low-cost aircraft provided L-band (1.413GHz) dual-polarized (horizontally and vertically) brightness temperature observations at 75 m resolution. Similarly, the ETH L-band radiometer (ELBARA III), mounted on a small all-terrain farm buggy, provided L-band (1.4GHz) dual-polarized (horizontally and vertically) brightness temperature observations at 25 m resolution. Moreover the Hydraprobe Data Acquisition System (HDAS, [7]) was used as a ground sampling tool for ground validation, providing soil moisture readings on a 75 m grid.

3. DATA SETS

Data from airborne and ground acquisitions were collected on 17th, 18th and 19th of January 2017, including the brightness temperature data at h- and v-pol from both PLMR and ELBARA, ancillary airborne data such as thermal infrared data, NDVI data and RGB images, and the ground HDAS soil moisture data. An example of collected data are shown in Fig. 2. The farm buggy with ELBARA III was navigated in the study area to primarily follow the flight lines. However, due to malfunctioning of the buggy at the beginning of the experiment and difficulties in entering some areas of the study site, the study area was only able to be partially covered by ELBARA.

4. RESULTS AND DISCUSSION

The brightness temperature (TB) from PLMR and ELBARA at each polarization were compared with ground truth on each day. As shown in Fig. 3, ELBARA has a bigger range of brightness temperature than PLMR, which was attributed to the irrigation that occurred during the time of ground data collection. Compared to PLMR data from the aircraft, ELBARA navigated much more slowly on the ground and thus captured more points that were closely aligned temporally with the instant change on soil moisture caused by irrigation activity. In terms of the correlation between soil moisture and brightness temperature, ELBARA had an average correlation coefficient of 0.23 while PLMR had a similar value of 0.22. Brightness temperature from v-pol had a slightly better performance, with correlation coefficient of 0.28 for ELBARA and 0.26 for PLMR.

It can be seen from this study that the brightness temperature from either aircraft or buggy-based L-band radiometer were generally not well correlated to the ground soil moisture. The main reason for this is the occurrence of irrigation during the period of experiment, meaning that sudden changes in soil moisture are not well reflected in the data due to a lack of coincidence in timing of ELBARA, aircraft and hand-held HDAS sampling. Better performance is expected when taking into account factors such as the variations on surface temperature both spatially and temporally, as well as the variation on Vegetation Water Content. Future studies will focus on sub-areas which have little influence from irrigation and timing issues to further evaluate the performance of both L-band radiometers. Meantime, an analysis on the effect from surface temperature and vegetation conditions will also be conducted. Furthermore, based on the collected brightness temperature data and other ancillary data such as surface temperature, NDVI, roughness and soil moisture data will be retrieved and then compared against the ground truth respectively.

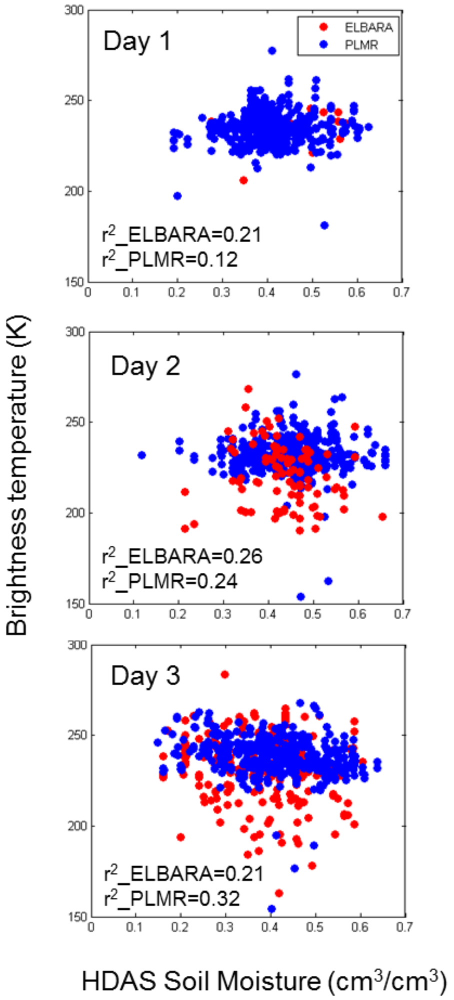

Figure 3. Relationship between brightness temperature (PLMR is in blue while ELBARA is in red) and ground sampled soil moisture on each day. Brightness temperature shown here is at h-pol.

5. ACKNOWLEDGEMENT

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