The Soil Moisture Active Passive Experiments: Towards Active Passive Retrieval and Downscaling

J. P. Walker [1], A. Monerris [1], Y. Gao [1], X. Wu [1], R. Panciera [2], M. Tanase [2], D. Ryu [2], D. Gray [3], H. Yardley [3], A. Goh [3], T. Jackson [4]

[1]Department of Civil Engineering, Monash University, Australia (E-mail: jeff.walker@monash.edu)
[2]Department of Infrastructure Engineering, The University of Melbourne, Australia
[3]Department of Electrical and Electronic Engineering, The University of Adelaide, Australia
[4]United States Department of Agriculture, United States

Study Objective

The soil moisture dedicated mission of NASA's SMAP (Soil Moisture Active Passive) is scheduled for launch in 2014, with the aim of providing an accurate soil moisture product at 9km resolution, by combining high resolution (3km) but noisy radar observations with the more accurate yet lower resolution (36km) radiometer observations. To achieve these objectives, algorithms need to be developed and tested with simulated data that SMAP will provide, and therefore the Soil Moisture Active Passive Experiment (SMAPEx) field campaigns have been carried out to facilitate the development and validation of algorithms, by:

- collecting test data of an entire SMAP radiometer pixel from airborne simulator flights and ground sampling activities;
- processing radar and radiometer observations from airborne flights to simulate the SMAP prototype data, by dealing with the issues of incidence angle normalisation, spatial scaling and azimuth variations; and
- producing 1km resolution passive only soil moisture maps for validation of active-passive retrieval and downscaling studies.

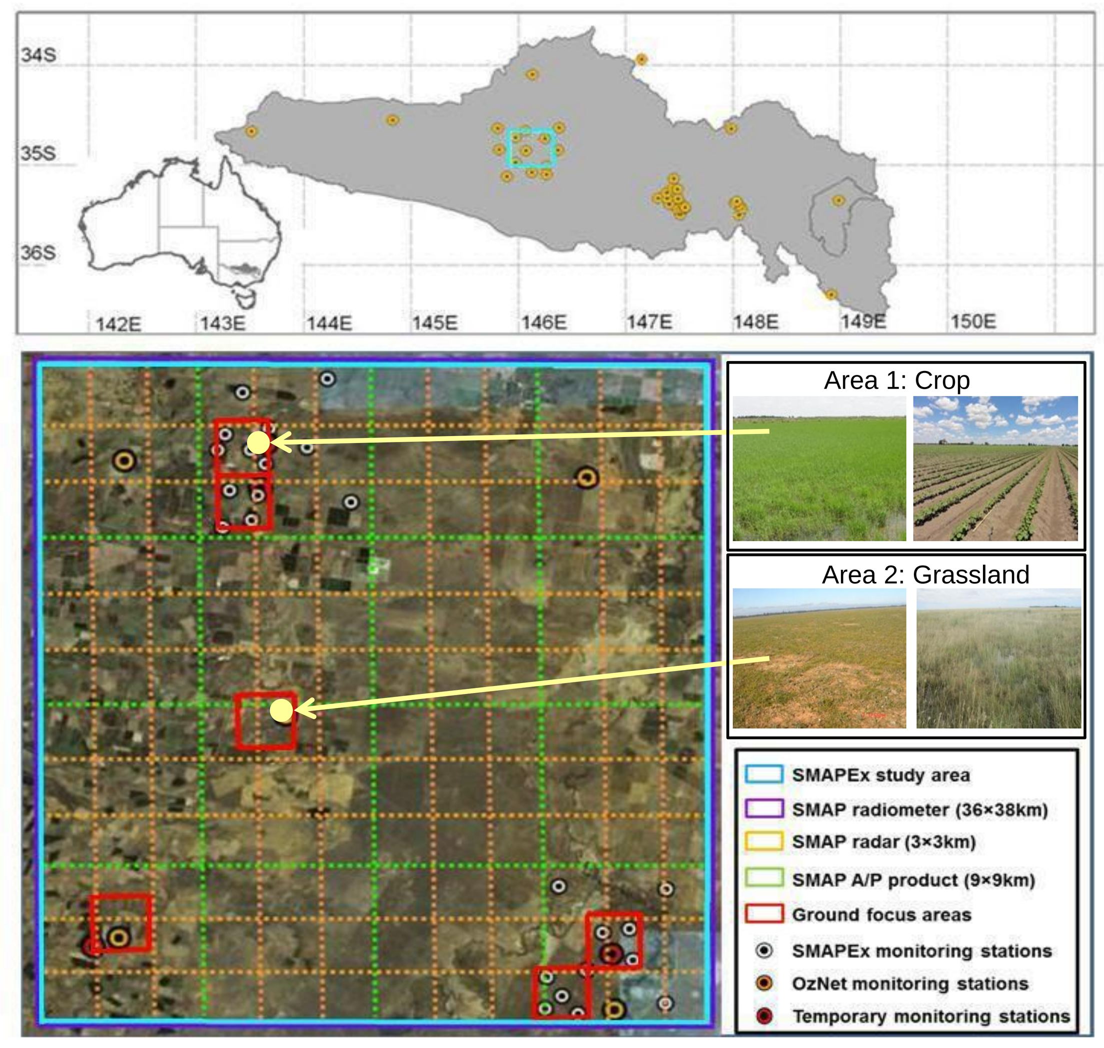

Fig. 1: Overview of the SMAP test-bed showing the SMAP pixel simulated by airborne data with a ~36km resolution radiometer pixel, 3km radar pixels, and 9km radar-radiometer downscaled pixels. Ground validation sites and focus areas are also shown.

SMAPEx Data Set

SMAPEx comprises three campaigns across an approximately one year timeframe: SMAPEx-1 from 5th to 10th July 2010, SMAPEx-2 from 4th to 8th December 2010, and SMAPEx-3 from 5th to 23rd September 2011. The objective of these campaigns was to collect airborne prototype SMAP data together with ground observations of soil moisture and ancillary data during different seasons. The test-bed chosen for this study was the Yanco area of the Murrumbidgee Catchment located in south-eastern Australia (Fig. 1), being characterized by flat topography with grassland and a mix of irrigated and non-irrigated crops. During each campaign, the flights simulating the SMAP mission were conducted at 3000m flying height (1km radiometer, 10-30m radar resolution) across the entire 36km SMAP pixel with a 2-3 day temporal repeat. Additional target flights were also conducted to deal with the issues of incidence angle normalization, spatial scaling and azimuth variations. Moreover, extensive ground data on soil moisture and vegetation were collected concurrently with the flights for validation of soil moisture retrieval studies. Access to the SMAPEx data set is through the website: http://www.smapex.monash.edu.au/.

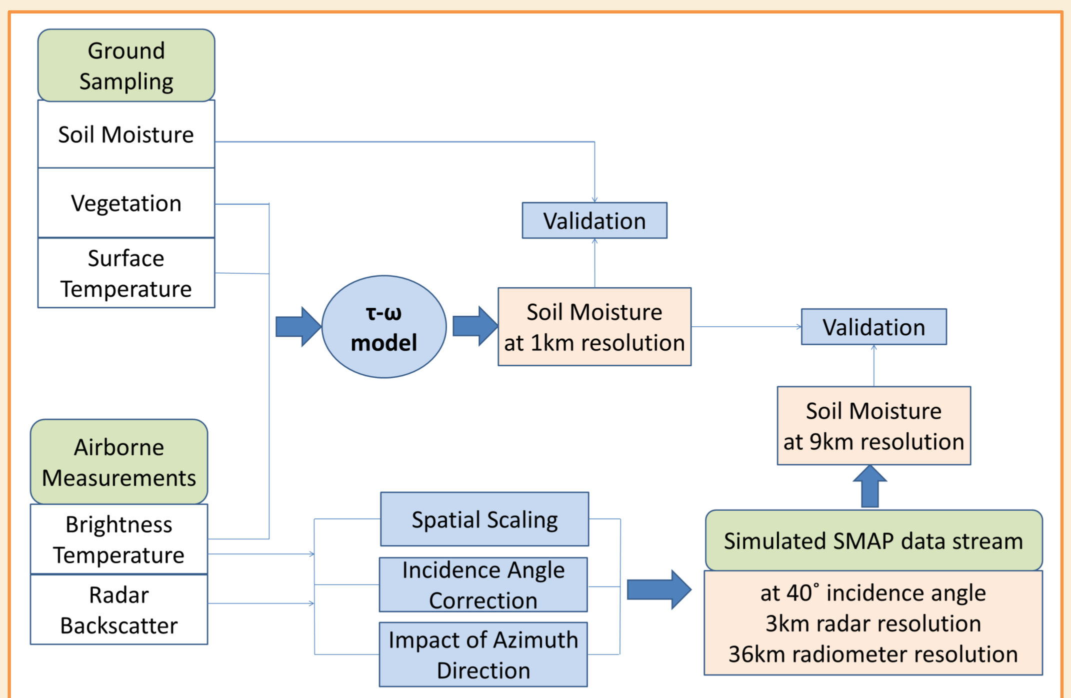

Fig. 2: Schematic of methodology.

Methodology

A. Incidence angle correction: due to limitations of the airborne simulator, data have been collected across a range of incidence angles, which do not match the viewing configuration (constant incidence angle of 40°) of the SMAP mission directly. Therefore, in order to simulate the SMAP data stream with consistent characteristics, incidence angles need to be normalized to that of SMAP. The Cumulative Distribution Function based (CDF-based) method is applied to normalize multi-angle observations to the reference angle by matching the CDF of observations for each non-reference angle to that for the reference angle.

B. Spatial scaling and azimuth variation: flights with different azimuth viewing angles over various testing areas have been conducted during SMAPEx-2. The relationship between azimuth view angle, backscatter and the variety of land cover types will be investigated. Radar data were also collected at 10m, 50m and 150m resolution, which will be used to evaluate the scaling accuracy, thus providing knowledge for better performance of radar observations and downscaling algorithm for the SMAP mission.

C. Development of 1km resolution soil moisture map: data sets applied include the 1km airborne brightness temperature, the ground surface and deep temperature (2.5cm and 40cm respectively) from monitoring stations, the 250m-spaced soil moisture sampling and the sampled vegetation water content of major vegetation types. Soil moisture product is retrieved at 1km resolution with the τ-ω model, and then compared to the ground soil moisture averaged within the 1km grids.

Results (A)

The airborne microwave backscatter observations acquired from the SMAPEx-3 dataset were used to validate the CDF-based normalization method. The normalization result in Fig. 3 shows that the CDF-based method can normalize backscatter observations with an accuracy of ~0.3 dB, drastically reducing stripe patterns. However a normalization error up to 2.5 dB arose over furrowed areas.

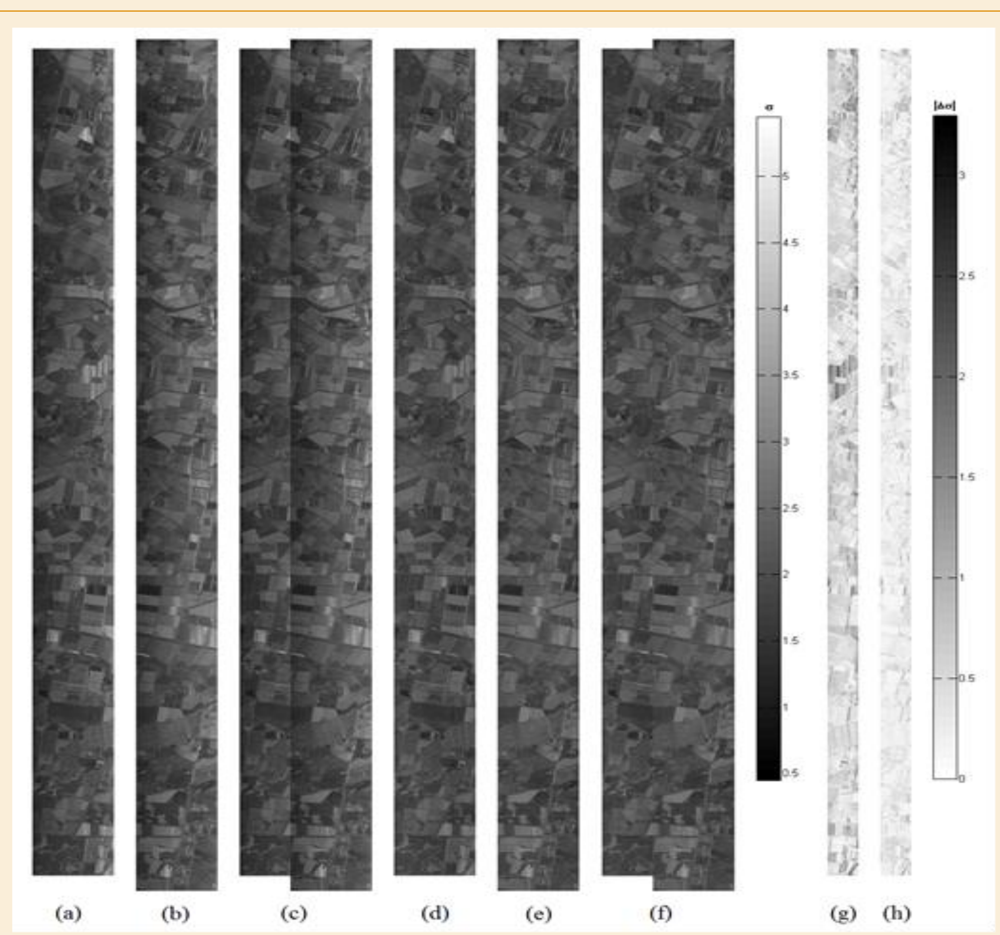

Fig. 3: Raw backscatter coefficient in the unit of dB over two adjacent swaths (a) and (b) in SMAPEx-3; (c) is the overlain geo-referenced image of (a) and (b) without normalization; (d) and (e) are normalized backscatter coefficient over those swaths using the 3D CDF-based normalization method; (f) is the overlain georeferenced image of (e) and (f); (g) and (h) are absolute scatter difference between those swaths within the overlapped area without and with normalization.

Results (B)

Airborne flights were designed to observe two focus areas from different azimuth view angles (0°-180° with 30° increments). The target areas included a heterogeneous site comprised of a mix of crop (Area 1) and one uniform grassland site (Area 2), shown in Fig. 1. This will allow the investigation of the effect of azimuth view angle on a variety of land cover types. Fig. 4a shows the approximately 500m radius overlapping coverage of these flights in Area 1 where observations were collected at multiple azimuth angles and spatial resolutions. The relationship between azimuth direction, radar observations and the variety of land cover types will be analysed. Radar backscatter has been scaled from 10m to 50m and 150m respectively (Fig. 4b), for comparison with observed data at these same lower resolutions.

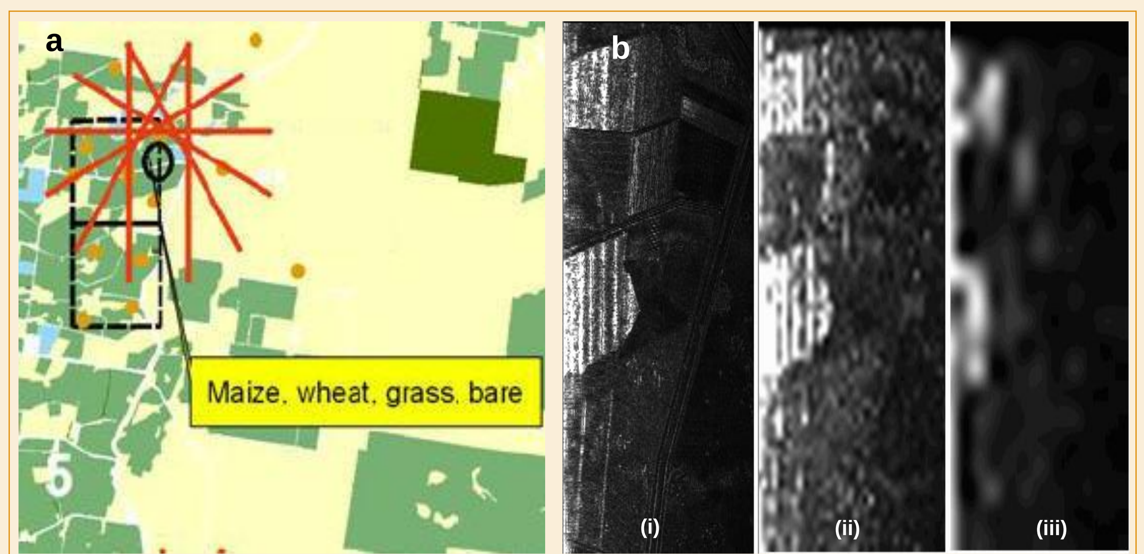

Fig. 4: **a**: Overview of multi-azimuth flight lines (in red) and coverage (black circle) in Area 1; **b**: Spatial scaling of radar backscatter: (i) original data observed at 10m resolution; (ii) data scaled to 50m resolution; and (iii) data scaled to 150m resolution.

Result (C)

Soil moisture at 1km resolution was generated from the SMAPEx-1 datasets. Fig. 5a shows the comparison between model retrieved and ground observed soil moisture. The icons stand for mean soil moisture values and their shapes for different vegetation types. The whiskers indicate the standard deviation of the ground observed soil moisture values. It is seen that crop sites show better results than grassland and fallow sites when using default parameters. The tendency to overestimate soil moisture for grassland/fallow could be ascribed to the fact that land cover in grassland was highly heterogeneous and the pasture in Australia may have quite different biophysical features compared to those elsewhere.

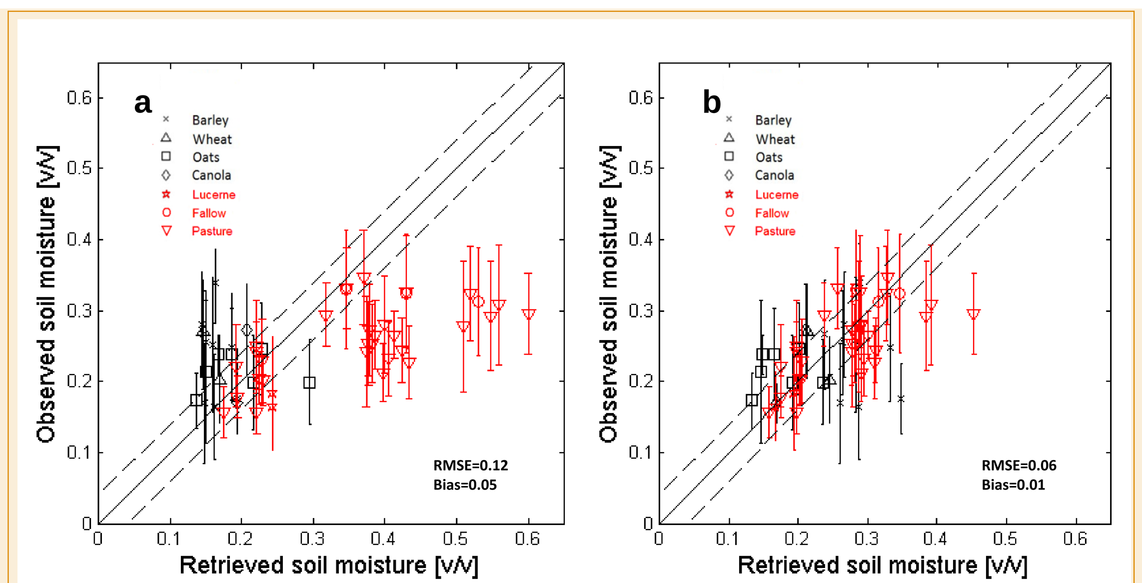

Fig. 5: **a.** Evaluation of soil moisture retrieval using default parameters; dashed lines indicate the SMAP target accuracy (0.04 m^3m^{-3}); fallow (or bare soil) and grass sites are shown in red, while crop sites are in black; **b.** Comparison between derived and observed soil moisture using optimised *b* parameter.

Fig. 5b shows the same comparison but after optimising for the *b* parameter. The RMSE was markedly reduced to 0.06 m^3m^{-3} after lowering the *b* value for grassland and fallow from 0.15 to 0.06, and raising it for barley and wheat from 0.08 to 0.85.

Summary

- SMAPEx field campaigns provide the experimental data sets for developing and validating the pre-launch algorithms of the SMAP mission.
- Data collected from airborne are being processed in terms of incidence angle normalization, azimuth variation and spatial scaling to closely repeat characteristics of the SMAP data stream.
- A soil moisture product at 1km resolution is being derived with an accuracy around 0.06 m^3m^{-3}, which will be utilized for validation of active-passive retrieval and downscaling related studies.

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