Mapping Soil Moisture with Cosmic Ray Probes over Grassland

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Study Objective

To estimate the accuracy of cosmic ray probes (CRP) over grassland and their potential to (i) acquire large-scale high-resolution soil moisture maps, including airborne applications in areas inaccessible to vehicles, and (ii) be used as a calibration/validation sensor for satellite missions such as the upcoming NASA's Soil Moisture Active Passive (SMAP).

Data Set

The data set was collected during the Soil Moisture Active Passive Experiment (SMAPEx-3) conducted in Sept. 2011 at the Murrumbidgee River catchment in Australia (see Fig. 1). It consists of:

- Aerial and ground-based CRP measurements acquired with the COSMOS Rover (from University of Arizona) every 1min over a 3km×3km grassland area (YC) and along regional surveys (see sampling area in Fig. 1, and the airborne setup in Fig. 2);
- CPR measurements at the CosmOz network tower in Yanco, Australia (see Fig. 2 bottom);
- airborne 1km and 150m resolution brightness temperature (TB) observations acquired with PLMR (Polarimetric L-band Multibeam Radiometer); and
- top 5-cm soil moisture collected in focus sampling areas and at monitoring stations from the OzNet network (http://www.oznet.org.au).

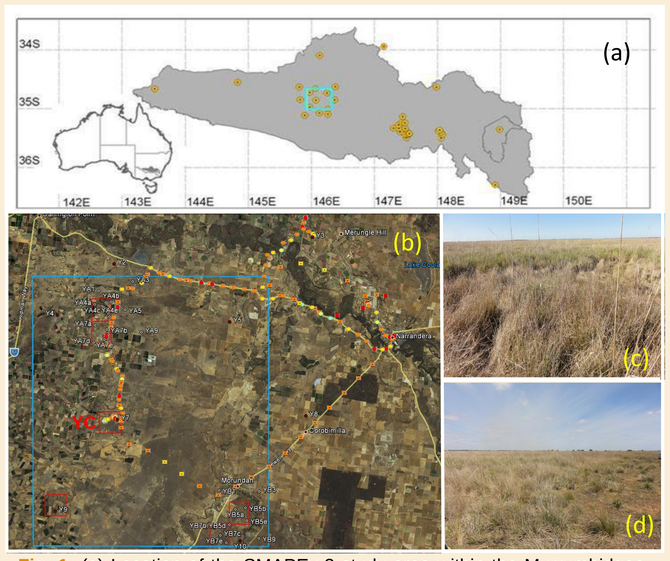

Fig. 1: (a) Location of the SMAPEx-3 study area within the Murrumbidgee River catchment, NSW, Australia. (b) Google Earth image of the SMAP pixel-size site (blue square), focus sampling areas (red squares) and location of the permanent and semi-permanent monitoring stations. Focus areas YC /YB7and COSMOS Rover transects are highlighted. (c)-(d) Grassland in YC and YB7, respectively.

Fig. 2: (top) COSMOS Rover installed in the aircraft used for the surveys;; **(bottom)** CosmOz tower in Yanco, Australia.

Results (A)

Top 0-5 cm soil moisture sampled in a 250m grid at the focus area YB7 (HDAS, mean and std over the 3km×3km) and from OzNet stations (YB7a,c,d,e), and 1h area-averaged soil moisture from the CosmOz cosmic ray probe are represented in Fig. 3. Higher soil moisture estimates from CRP with respect from point measurements at the monitoring stations are believed to be due to the area averaging (note the large std in the HDAS measurements within the 3km×3km) and to deeper soil layers (with moisture content in the range of 0.2 to 0.35m^3/m^3).

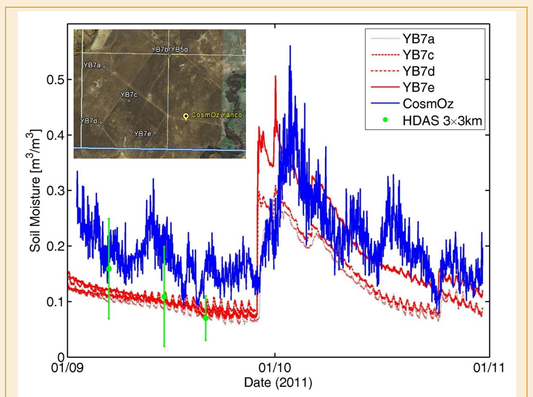

Fig. 3: Soil moisture measured by the CosmOz probe (blue), OzNet monitoring stations (red), and intensive soil sampling at YB7 (green; mean/std over the 3km×3km)

Results (B)

PLMR brightness temperatures at 1km resolution and both h- and v-polarisations are plotted and compared to soil moisture inferred from airborne and ground cosmic-ray measurements in Fig. 4. Soil moisture recorded at the top 5-cm during the experiment period by the monitoring stations close to the transects is shown in Fig. 5. Less than 0.02m^3/m^3 change in moisture is observed at each of the stations during the surveys which allows the inter-comparison of CRP results for different dates. Soil moisture within the area varied from 0.04 to 0.2m^3/m^3 which follows the trend of the area-averaged value provided by the COSMOS Rover and PLMR TB spatial patterns.

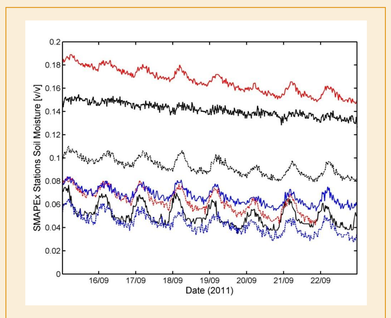

Fig. 5: Soil moisture values at 5-cm acquired by the OzNet stations from Sept. 15 to 23, 2011. The stations are distributed across the SMAPEx experiment site.

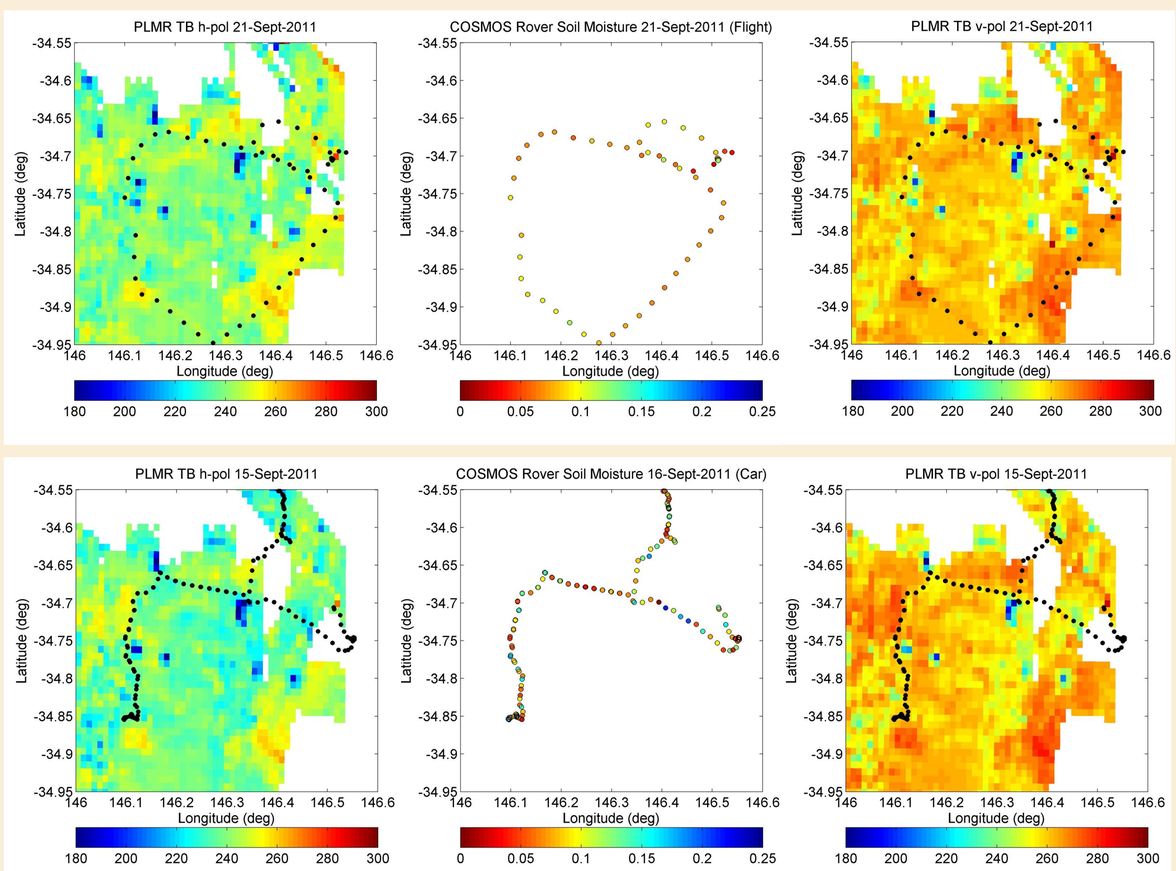

Fig. 4: Images of the dual-polarized brightness temperature maps (TB_h and TB_v) of the SMAPEx site on Sept. 15 and 21 and COSMOS Rover transects on Sept. 16 (ground transect) and 21 (airborne transect), 2011.

Results (C)

Soil moisture sampled in a 250m grid at the focus area YC (see Fig. 1) is compared to soil moisture inferred from car transects and airborne CRP measurements in Fig. 6. Different icons stand for ground sampling (circles), car transects (squares) and flight transects (diamonds). Three car transects were conducted across YC with 1-week repeat time, and one flight at low altitude was conducted over the area for comparison. The root mean square error (rmse) between ground sampled and estimated soil moisture is 0.06m^3/m^3 for car transects and 0.03m^3/m^3 for airborne transects in YC.

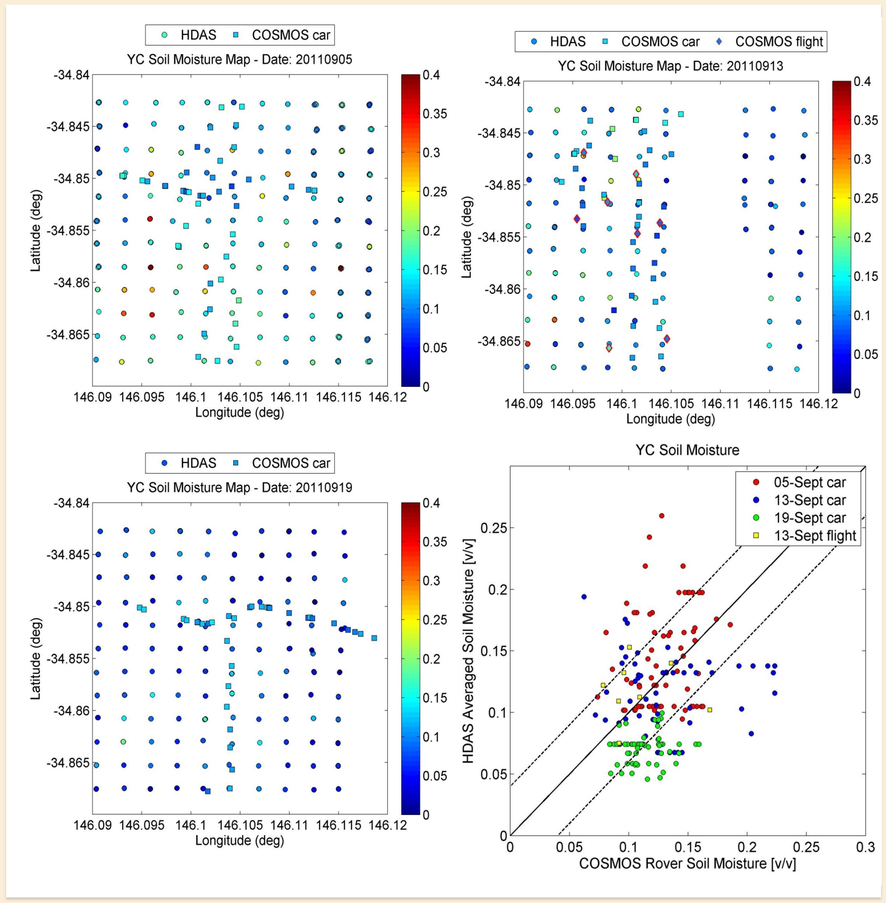

Fig. 6: Soil moisture mapping in YC by means of ground sampling and cosmic-ray measurements. A comparison between both values is presented for the three car transects (blue, red, green circles) and one flight (yellow circles).

Conclusions and further work

- Under Australian grassland conditions, the rmse between ground sampled and estimated soil moisture from CPR is ~0.06m^3/m^3
- COSMOS Rover surveys reproduce the same spatial patterns as the PLMR radiometer, which supports the potential for CRP use in large-scale soil moisture mapping.
- Next step: COSMOS Rover and CosmOz tower measurements will be compared to 1km resolution soil moisture maps derived from PLMR brightness temperatures.
- Links: **www.smapex.monash.edu.au**; **www.oznet.org.au**

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