Mapping Soil Moisture Variability: Inter-comparison Between L-band Radiometry and Cosmic Ray Neutron Emissions

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Study Objective

To estimate the accuracy of the Cosmic-ray Soil Moisture Observing System (COSMOS) Rover measurements and its 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) mission by:

- comparing local spatial patterns measured by the COSMOS Rover and the Polarimetric L-band Multi-beam Radiometer (PLMR);
- comparing the soil moisture estimated from area-averaged COSMOS Rover and PLMR observations and validating them against the high-resolution ground observations; and
- analysing the differences between aerial and ground-based cosmic-ray surveys of the same region.

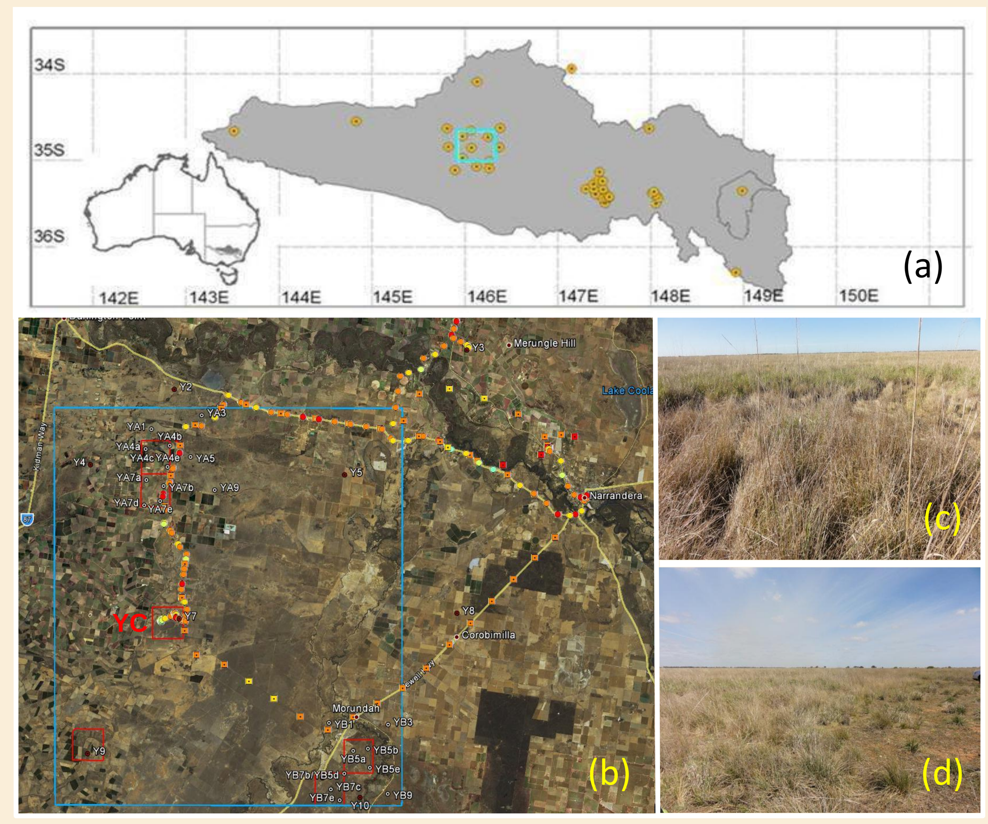

Fig. 1: (a) Location of the SMAPEx-3 study area within the Murrumbidgee River catchment, NSW, Australia. (b) Google Earth image of the SMAP pixel-size site (blue square), focus sampling areas (red squares) and location of the permanent and semi-permanent monitoring stations. Focus area YC and COSMOS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

Data Set

Fig. 2: (top) Installation of the COSMOS Rover in the aircraft used for the surveys; (bottom) detail of the COSMOS Rover.

Aerial and ground-based cosmic-ray fast neutrons intensity every 1min over a 3km × 3km grassland area and along regional transects (see sampling area in Fig. 1, and the airborne setup in Fig. 2), airborne 1km and 150m resolution brightness temperature (TB) observations, and top 5-cm soil moisture collected in focus sampling areas and at monitoring stations were used in this study. 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).

Methodology

- Soil moisture is inferred from COSMOS measurements by using a set of parameters calibrated with independent field soil moisture data;
- Top 5-cm soil moisture from monitoring stations and 250m-spaced grids (in YC) is compared against COSMOS soil moisture maps.
- In a next step, soil moisture will be retrieved from PLMR TB using the τ-ω model, and then compared to area averaged ground soil moisture and COSMOS estimates.

Results (A)

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 cosmic-ray measurements in Fig. 3. 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 0.06 v/v for car transects and 0.03 v/v for airborne transects in YC.

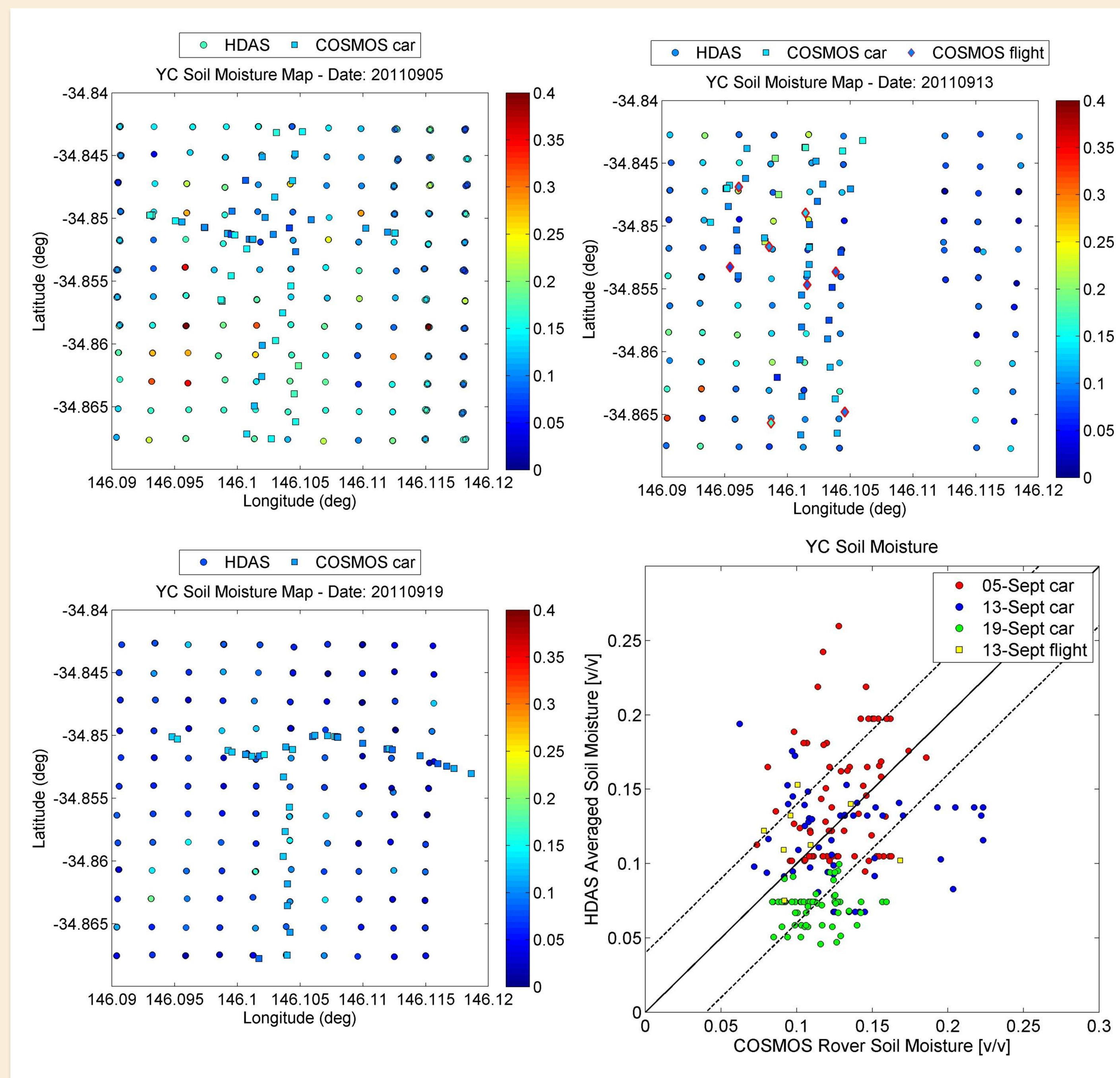

Fig. 3: Soil moisture mapping in YC by means of ground sampling and cosmic-ray measurements. A comparison between both values is presented for the three car transects (blue, red, green circles) and one flight (yellow circles).

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 0.02 v/v change in moisture is observed at each of the stations during the surveys which allows the inter-comparison of cosmic-ray results for different dates. Soil moisture within the area varied from 0.04 to 0.2 v/v which follows the trend of the area-averaged value provided by the COSMOS sensor and PLMR TBs spatial patterns.

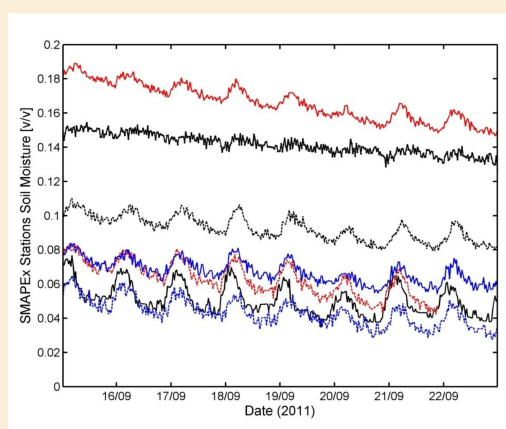

Fig. 5: Soil moisture values at 5-cm acquired by the monitoring stations from Sept. 15 to 23, 2011. The stations are distributed across the SMAPEx experiment site.

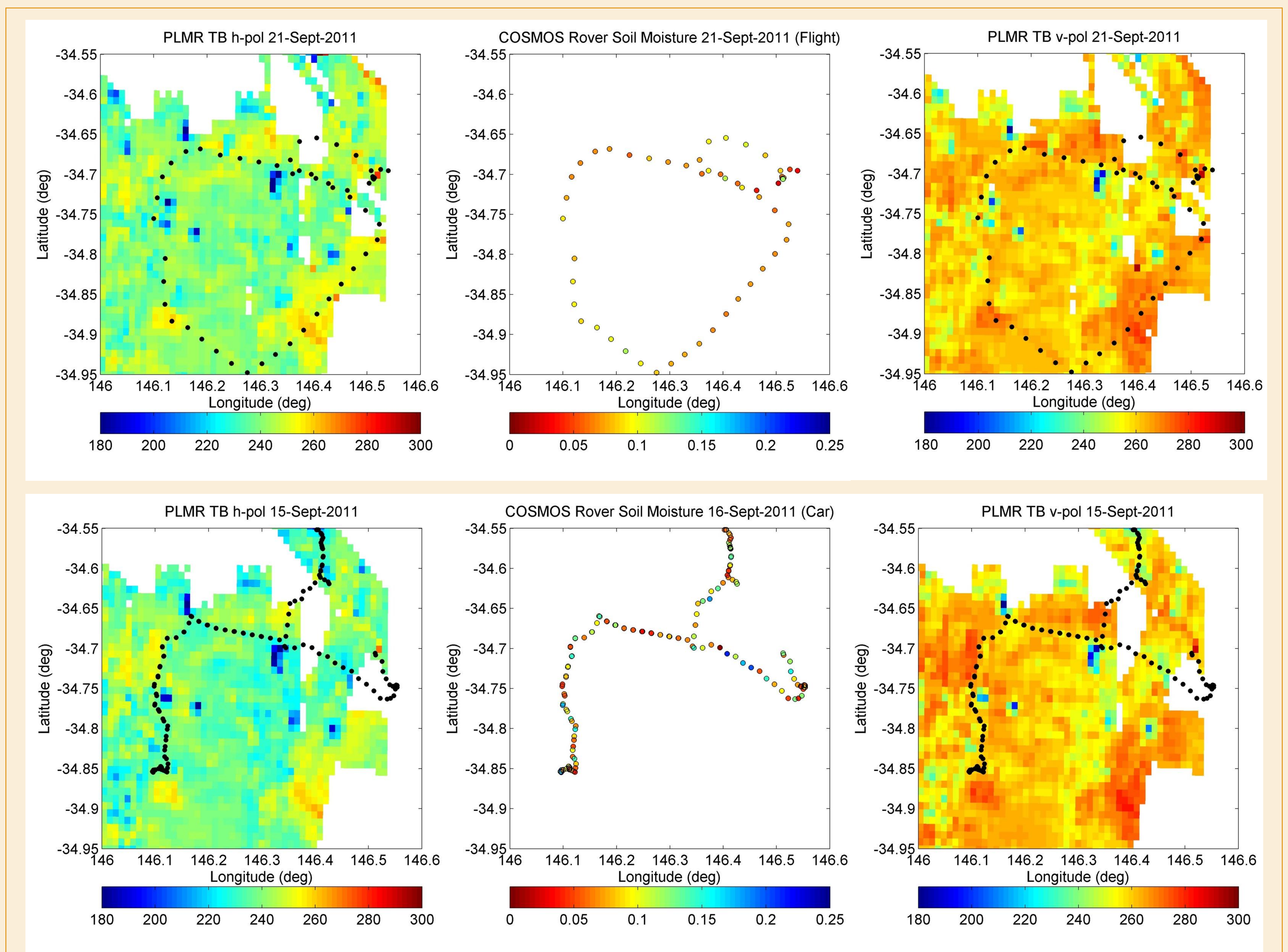

Fig. 4: Images of the dual-polarized brightness temperature maps (TB_h and TB_v) of the SMAPEx site on Sept. 15 and 21 and COSMOS Rover transects on Sept. 16 (ground transect) and 21 (airborne transect), 2011.

Conclusions

- In Australian grassland conditions, the rmse between ground sampled and estimated soil moisture from cosmic-rays is in the order of 0.06 v/v for ground transects and 0.03 v/v for airborne transects, both close to the 0.04 v/v target of SMAP.
- The roving COSMOS sensor reproduces the same spatial patterns as the PLMR radiometer, which supports the potential for its use in large-scale soil moisture mapping.
- Further calibration tunning will be attempted to improve the results. COSMOS measurements will also be compared to 1km resolution moisture maps derived from PLMR brightness temperatures.

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