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Downscaling satellite-derived soil moisture products based on soil thermal inertia: a comparison of three models over a semi-arid catchment in south-eastern Australia

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High spatial resolution soil moisture information is important for regional–scale hydrologic, climatic and agricultural applications. However, available point-scale in-situ measurements and coarse-scale (∼10s of km) satellite soil moisture retrievals are unable to capture hillslope to sub-catchment level spatial variability of soil moisture as required by many of these applications. Downscaling L-band satellite soil moisture retrievals appears to be a viable technique in estimating near surface (∼ top 5 cm) soil moisture at a high spatial resolution. Among different downscaling approaches, thermal data based methods exhibits a good potential over arid and semi-arid regions, i.e. in many parts of Australia.

This study investigates three downscaling approaches based on soil thermal inertia to estimate near surface soil moisture at high spatial resolution (1 km) over Krui and Merriwa River catchments in the Upper Hunter region of New South Wales, Australia. These methods are based upon the relationship between the diurnal soil temperature difference (ΔT) and daily mean soil moisture content (μSM). Regression tree models between ΔT and μSM were developed by using in-situ observations (in the first approach) and using land surface model (LSM) based estimates (in the second approach). The relationship between ΔT and μSM was modulated by the vegetation density and the Austral season. In the in-situ data based approach, soil texture was also employed as a modulating factor. These in-situ datasets were obtained from the Scaling and Assimilation of Soil Moisture and Streamflow (SASMAS) network and model-based estimates from the Global Land Data Assimilation System (GLDAS). Moderate Resolution Imaging Spectroradiometer (MODIS) derived Normalized Difference Vegetation Index (NDVI) products were used to define vegetation density. An ensemble machine-learning model was employed in the third approach using ΔT, NDVI and Austral season as predictors and μsm values as responses. Aggregated airborne soil moisture retrievals were used as the coarse resolution soil moisture products. These coarse resolution soil moisture simulations were downscaled to 1 km by employing the above three approaches using MODIS-derived ΔT and NDVI values.

The results from the three downscaling methods were compared against the 1 km soil moisture retrievals from the National Airborne Field Experiment 2005 (NAFE'05) over 3 days in November 2005. The results from both in-situ data and GLDAS-based regression tree models show RMSEs of 0.07 cm^3/cm^3 when compared against the high resolution NAFE'05 airborne soil moisture observations. The GLDAS-based model can be applied over a larger extent, whereas the in-situ data based model is catchment specific. These results were compared with the results from the machine-learnt model. A combination of these methods with additional forcing factors such as topography, meteorology, etc. can be utilized to develop an improved downscaling model. Such a model has a good potential in developing a time record of high resolution soil moisture products over south-eastern Australia from 2010 onwards by using the Soil Moisture and Ocean Salinity (SMOS) and Soil Moisture Active Passive (SMAP) satellite soil moisture products.