Exploring the use of machine-learning techniques to integrate ground- and remote sensing-based observations for efficient near-surface soil moisture mapping

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Mapping near-surface soil moisture (θ) is of tremendous relevance for a broad range of environment-related disciplines and meteorological, ecological, hydrological and agricultural applications. Globally available products offer the opportunity to address θ in large-scale modelling with coarse spatial resolution such as at the landscape level. However, θ estimation at higher spatial resolution is of vital importance for many small-scale applications. Therefore, we focus our study on a small-scale catchment (MFC2) belonging to the “Alento” hydrological observatory, located in southern Italy (Campania Region). The goal of this study is to develop new machine-learning approaches to estimate high grid-resolution (about 17 m cell size) θ maps from mainly backscatter measurements retrieved from C-band Synthetic Aperture Radar (SAR) based on Sentinel-1 (S1) images and from gridded terrain attributes. Thus, a workflow comprising a total of 48 SAR-based θ patterns estimated for 24 satellite overpass dates (revisit time of 6 days) each with ascendant and descendent orbits will be presented. To enable for the mapping, SAR-based θ data was calibrated with in-situ measurements carried out with a portable device during eight measurement campaigns at time of satellite overpasses (four overpass days in total with each ascendant and descendent satellite overpasses per day in November 2018). After the calibration procedure, data validation was executed from November 10, 2018 till March 28, 2019 by using two stationary sensors monitoring θ at high-temporal (1-min recording time). The specific sensor locations reflected two contrasting field conditions, one bare soil plot (frequently kept clear, without disturbance of vegetation cover) and one non-bare soil plot (real-world condition). Point-scale ground observations of θ were compared to pixel-scale (17 m × 17 m), SAR-based θ estimated for those pixels corresponding to the specific positions of the stationary sensors. Mapping performance was estimated through the root mean squared error (RMSE). For a short-term time series of θ (Nov 2018) integrating 136 in situ, sensor-based θ (θ_in situ) and 74 gravimetric-based θ (θ_gravimetric) measurements during a total of eight S1 overpasses, mapping performance already proved to be satisfactory with RMSE=0.039 m³m⁻³ and R²=0.92, respectively with RMSE=0.041 m³m⁻³ and R²=0.91. First results further reveal that estimated satellite-based θ
patterns respond to the evolution of rainfall. With our workflow developed and results, we intend to contribute to improved environmental risk assessment by assimilating the results into hydrological models (e.g., HydroGeoSphere), and to support future studies on combined ground-based and SAR-based $\theta$ retrieval for forested land (future missions operating at larger wavelengths e.g. NISARL-band, Biomass P-band sensors).