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Modelling and observing soil moisture patterns in alpine meadows using multi-source ground and remote-sensing observations

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Soil moisture is a key factor for numerous processes, including runoff generation, groundwater recharge, evapotranspiration, soil respiration, and biological productivity. Understanding the controls on the spatial and temporal variability of soil moisture in mountain catchments is an essential step towards improving quantitative predictions of catchment processes and ecosystem services.

The interacting influences of precipitation, soil properties, vegetation, and topography on soil moisture have been extensively investigated. However, due to the extreme variability in topography, soil and vegetation properties of mountain areas, obtaining reliable predictions of soil moisture of spatial and temporal patterns is still challenging. Physically-based hydrological models often face the problem of over-parameterization and equifinality. At the same time, field campaigns are intensive and limited to too small areas, whereas soil moisture retrieval from remote sensing in alpine context is promising. However, surface heterogeneity and overpassing frequency issues still limit its effectiveness. For this reason, an integration of hydrological models, ground surveys, and new remote-sensing products is essential to improve soil moisture estimation.

In this contribution, we analyze the spatial dynamics of surface soil moisture (0 - 5 cm depth) of alpine meadows and pastures in the Mazia Valley (South Tyrol – Italy), at different spatial scales and with different techniques: (I) a network of fixed stations; (II) field campaigns with mobile ground sensors; (III) soil moisture retrieval from 20-m resolution polarimetric RADARSAT2 SAR images; (IV) numerical simulations using the GEOtop hydrological model. The strength and the weaknesses and the consistency of the different estimation techniques are evaluated and, in particular, the GEOtop model is used to understand the physical controls of the observed patterns in RADARSAT2 products.

Results show that the model, once calibrated for the different vegetation and soil properties, accurately predicts the observed dynamics in stations location. However, RADARSAT2 soil moisture estimation corresponds well to the spatial ground surveys, but shows different patterns with respect to the model, especially for irrigated meadows. While RADARSAT2 patterns strongly reflect observed vegetation patterns, model output is more correlated with topography, especially in moister conditions. Differences are likely due to the strong sensitivity of the SAR signal to surface roughness and vegetation density and to the difficulties to know the irrigation amount for model input. Therefore, results suggest that all the considered techniques have limited ability to fully detect soil moisture patterns, and that the integration of model results with observations at different spatial scales is the only effective approach to improve surface soil moisture estimation in alpine catchments.