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Monitoring soil moisture patterns in alpine meadows using ground sensor networks and remote sensing techniques

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Soil moisture content (SMC) 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 SMC in mountain catchments is an essential step towards improving quantitative predictions of catchment hydrological processes and related ecosystem services.

The interacting influences of precipitation, soil properties, vegetation, and topography on SMC and the influence of SMC patterns on runoff generation processes have been extensively investigated (Vereecken et al., 2014). However, in mountain areas, obtaining reliable SMC estimations is still challenging, because of the high variability in topography, soil and vegetation properties. In the last few years, there has been an increasing interest in the estimation of surface SMC at local scales. On the one hand, low cost wireless sensor networks provide high-resolution SMC time series. On the other hand, active remote sensing microwave techniques, such as Synthetic Aperture Radars (SARs), show promising results (Bertoldi et al. 2014). As these data provide continuous coverage of large spatial extents with high spatial resolution (10–20 m), they are particularly in demand for mountain areas. However, there are still limitations related to the fact that the SAR signal can penetrate only a few centimeters in the soil. Moreover, the signal is strongly influenced by vegetation, surface roughness and topography.

In this contribution, we analyse the spatial and temporal dynamics of surface and root-zone SMC (2.5 - 5 - 25 cm depth) of alpine meadows and pastures in the Long Term Ecological Research (LTER) Area Mazia Valley (South Tyrol – Italy) with different techniques: (I) a network of 18 stations; (II) field campaigns with mobile ground sensors; (III) 20-m resolution RADARSAT2 SAR images; (IV) numerical simulations using the GEOtop hydrological model (Rigon et al., 2006; Endrizzi et al., 2014).

The objective of this work is to understand the physical controls of the observed SCM patterns. In particular, we want to investigate:

• How the SMC signal propagates with depth, to understand the capability of SAR surface SMC observations to predict root-zone SMC.

• The role of land management and vegetation properties with respect to soil and bedrock properties in determining SMC spatial variability and temporal patterns.

In this context, we use the GEOtop model to understand if a relationship exists between the observed SMC patterns and the underlying runoff generation processes.

Results show that meadows and pastures have different behaviours. Meadows are in general wetter because of irrigation and the presence of soils with higher organic content and higher water holding capacity. Moreover, surface and root depth SCM dynamics are correlated. In contrast, pastures are drier, with lower vegetation density and more compact soils due animal trampling. Because of shallow soils and impermeable bedrock, root zone SMC shows a different behaviour with respect to the surface, with occurrence of sub-surface saturation excess, as verified from numerical experiments performed with the hydrological model.

Results suggest how SAR retrieved surface SMC can be used to extrapolate root zone SMC, when soil properties are homogenous and differences in vegetation density are properly accounted with a robust retrieval processes (Pasolli et al., in press 2015). However, in situations characterized by shallow subsurface saturation excess flow, a more sophisticated modelling approach is required to estimate root zone SMC using remote sensing observations.

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