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Seasonal and event scale dynamics of spatial soil moisture patterns at the small catchment scale

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A current challenge in hydrology is to observe, explain and model soil water content (SWC) patterns across multiple space-time scales. A promising technique for the assessment of SWC patterns at the catchment scale is the wireless sensor network. This technique has the potential to continuously monitor three-dimensional SWC fields with high spatial and temporal resolution, i.e. seasonal and event scale changes in SWC patterns. The objective of this study was to analyze the dynamics of SWC patterns in the TERENO forest hydrologic observatory Wüstebach (0.27 km^2) for various time scales (seasonal and event scale) and soil depths. We used the SoilNet wireless network system developed at Forschungszentrum Jülich. SWC measurements were taken every 15 minutes in three depths (5, 20, 50 cm) at 150 locations using EC-5 and 5TE sensors (Decagon Devices). This particular analysis is based on hourly aggregated SWC data measured from 1st of August 2009 to 31st of July 2010. Descriptive statistics and geostatistics were used to investigate the data set depending on soil depth and time scale. We analyzed the mean SWC, standard deviation and geostatististical parameters (nugget, sill and range) as a function of time and mean SWC. We found that the dynamics of SWC patterns depended on depth, mean soil moisture status, time scale and wetting versus drying period. The variability of the mean SWC, standard deviation and the range decreased with depth depending on soil moisture status. As already observed by others for temperate climate conditions, the standard deviation in the topsoil peaked at intermediate (critical) SWC, which means that during wetting the standard deviation increased for mean SWC below the critical SWC and decreased above the mean SWC (and vice versa for drying). In addition, high scattering in topsoil SWC variability in the intermediate SWC range was due to seasonality and distinct differences in wetting and drying periods. Higher SWC variability at the end of the growing season compared to lower variability in the beginning of the growing season was observed, leading to hysteresis effects. This was possibly due to hydrophobicity and preferential flow trough soil cracks after rainfall on dry topsoil. SWC variability was higher in wetting than drying periods in the intermediate SWC range possibly related to the spruce canopy that spatially redistributed precipitation. This led to more rapid increase of SWC variability than mean SWC, thus hysteresis on the event scale when the antecedent SWC was below a critical SWC. Furthermore, the topsoil spatial autocorrelation increased with decreasing SWC, except for autumn. In a spring event, a negative correlation was observed during drying (vice versa for wetting) related to groundwater effects, soil water redistribution and evapotranspiration. Multiple interacting factors like soil properties, topography, vegetation, groundwater, climate forcing and the antecedent SWC controlled complex processes and thus the dynamics of SWC patterns in the TERENO forest test site. The results of this study demonstrated that the SoilNet sensor network was able to detect seasonal and event scale changes in SWC patterns at the small catchment scale.