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Spatially distributed soil water content in a small forested catchment and its relation to the catchment water budget on various timescales

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In the framework of the TERENO project, terrestrial observatories have been implemented in order to observe hydrological phenomena at several scales, from small highly instrumented headwater catchments to mesoscale watersheds. At the headwater catchment scale, field experiments are conducted in which the effects of land use change are monitored to provide empirical data describing hydrological processes and responses. The TERENO test site Wüstebach is a 38.5 ha small forested headwater catchment located in a low mountain range in Germany. For a period of 3 years prior to a partial deforestation in 2013, the catchment hydrology has been characterized by continuous measurements of runoff (R), actual evapotranspiration based on the eddy-covariance method (ET), and soil water content at 3 depths in 109 locations (θ). With nearby measurements of precipitation (P), as well as potential evapotranspiration (PET) for regression-based gap filling of ET, it was possible to analyse the water budget without relying on process-based models.
The long-term water budget P–ET–R was closed with a residual of less than 3% of annual precipitation. On the daily timescale, the increasing residual of the water budget was explained to a moderate extent by soil water content (R^2 = 0.40). Wavelet coherence analysis revealed timescales of about 4 days and less, which were presumably dominated by unaccounted fast-turnover storage terms such as interception, as a major source of uncertainty. At weekly resolution, soil water storage explained more than half (R^2 = 0.62) of the water budget residual. By means of a combined empirical orthogonal function and cluster analysis, differences in the spatial pattern of soil water content between wet and dry state (above and below 0.35 cm^3/cm^3 spatially averaged soil water content) of the catchment could be identified. Various analyses confirmed that ET was predominantly energy-limited, but gradually lost coherence with PET and thus energy supply during the dry state, especially during and after the dry spring 2011.