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Revealing process dynamics of soil moisture patterns using spatio-temporal geostatistics

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Environmental systems monitoring aims at its core at the detection of spatio-temporal patterns of processes and system states, which is a prerequisite for understanding and explaining their confusing heterogeneity. Most observation networks rely on spatially distributed point sampling of states and fluxes of interest. Sampling design approaches range from regular grids, random selection, over functional units to somewhat derived clusters and sampling along or across soil catenas or flow paths. Spatial covariance patterns derived using geostatistical methods always produce a static snapshot of the target variable's spatial dependencies. But if the covariance structure is time-variant, classic geostatistical tools are likely to either unravel incomplete pictures or ignore fundamental dynamics.

We suggest to analyze the spatial variability of processes, for instance changes in soil moisture values, than to investigate the spatial variability of soil moisture states themselves. Transforming state variables like soil moisture to a rank-based representation of wetness within the catchment can enable us to produce more robust variograms, which reflect rather the spatial covariance of the drainage process i.e. the change in the soil moisture state than of the absolute soil moisture state itself. We demonstrate this approach by presenting analyses using data from the distributed soil moisture observation network of the CAOS research unit in the Attert catchment in Luxemburg during a long recession period in summer. More specifically we estimated daily variograms of the soil moisture ranks as a function of time using a moving window approach and repeated the analysis for soil moisture observations in different soil depths. The evolution of the variograms over time was found to be particularly useful to detect rapid changes in the underlying patterns, which are likely caused by changes in the dominant processes.