Comparison of Linear and Nonlinear Methods to Interpolate Sparse Soil Moisture Observations

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Abstract. Soil moisture acts as a key state variable in the interaction between the atmosphere and land surface, strongly influencing radiation and precipitation partitioning and thus many components of the hydrologic cycle. However, measuring soil moisture patterns with adequate spatial resolutions over useful spatial extents remains a significant challenge due to both physical and economic constraints. For this reason, ancillary data such as topographic attributes have been employed as process proxies and predictor variables for soil moisture. Most methods that have been used to estimate soil moisture from ancillary variables assume that soil moisture is linearly related to these variables. However, unsaturated zone water transport is typically modeled as a nonlinear function of the soil moisture state. While that fact does not necessarily imply nonlinear relationships with the ancillary variables, there is some evidence suggesting nonlinear methods may be more efficient than linear methods for interpolating sparse soil moisture observations based on ancillary data. This research investigates the value of nonlinear estimation techniques, namely density mixture modeling and spatial artificial neural networks, for interpolating soil moisture patterns from sparse measurements and ancillary data. Both of the nonlinear methods interpolate soil moisture by conditioning the estimated joint distribution between soil moisture and the ancillary predictor variables. The set of candidate predictor variables in this work includes terrain attributes calculated from digital elevation models that have been widely interpreted as process proxies and related to soil moisture. The methods are applied in both sequential and multivariate implementations, where the sequential implementation allows consideration of predictor variables with different spatial resolutions. In the sequential implementation, mutual information is employed to quantify relationships between the candidate predictor variables and soil moisture and to select an efficient set of ancillary data as predictor variables. The sensitivity of the methods to input data resolution and number of predictor variables is explored, and the methods are compared to each other as well as to linear regression. The results demonstrate that no method clearly outperforms the others under all circumstances. However, under certain conditions nonlinear methods may outperform multiple linear regression.