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Using lagged dependence to identify vertical soil moisture (de)coupling

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Recent advances in radar remote sensing have popularized surface soil moisture mapping at different spatial scales. Surface soil moisture measurements are used in hydrologic models to determine subsurface soil moisture values. However, due to variability of soil moisture across the soil column decoupling between surface and subsurface can occur. Decoupling can affect estimates of depth-integrated soil moisture values which are sought in many hydrological modeling studies. Decoupling was first investigated by Capehart and Carlson (1997) to refer to the divergence in drying rates of the soil at different depths; implying that surface values no longer constitute an integrated measure of the soil column. In this study, we employed new methods to investigate the occurrence of (de)coupling between surface and subsurface soil moisture. Lagged dependence was incorporated in assessing (de)coupling with the idea that coupling occurs when conditions at the surface are reflected at the subsurface after a certain delay. This new approach was tested using four daily time series from the Twente soil moisture and temperature monitoring network covering the years 2012 to 2014. Surface values were measured at 5 cm depth while subsurface values were at a depth of 40 cm. A distributed lag non-linear model (DLNM) was used as the main approach to simultaneously represent both functional relation and lag structure in the time series dataset. As an exploratory step, we analyzed the residuals from a fitted loess function was performed as a posteriori information to determine (de)coupled values. Both methods allow for a range of (de)coupled soil moisture values to be quantified, but more attention is given to decoupled values because it implies greater vertical soil moisture variability. Three of the four sites (SM05,SM09,SM20) show decoupled values towards drier soil moisture range while one site showed decoupling at wet conditions (SM13). These results provide new insights that decoupling is not limited to dry conditions. Knowledge of the conditions when decoupling occur is useful in identifying important physical controls for vertical soil moisture variability to improve model estimates. The methods applied are deemed robust as there were no assumptions made on the type of relation between surface and subsurface. This can also be extended to other soil depths. A possible limitation of using these methods is that lagged dependence sought might be affected by dominant lateral subsurface flow or influence of groundwater, which was the case in one of the stations (SM20) under consideration.

References:

Capehart, W. J., & Carlson, T. N. (1997). Decoupling of surface and near-surface soil water content: A remote sensing perspective. Water Resources Research, 33(6), 1383-1395.