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Characteristic soil moisture range transitioning between energy and water limitation of the biosphere

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Evapotranspiration (ET) is a key variable through which land surface conditions can impact near-surface weather. ET can be limited by energy (temperature) and water (soil moisture). In water limitation, soil moisture anomalies directly affect and therefore correlate well with ET anomalies (land influencing near-surface weather). By contrast, in energy limitation, temperature anomalies correlate well with ET anomalies (atmosphere influencing near-surface weather). In this study, we determine and explore the controls on the critical soil moisture (range; CSMR) which marks the transition between energy and water limitation.

We employ surface soil moisture (ESA CCI) data, which is found to be a reasonable proxy for root-zone soil moisture dynamics. Further, we use temperature data (E-OBS) alongside satellite-based Sun-Induced Chlorophyll Fluorescence (SIF; GOME-2) which we tentatively consider as a proxy for ET. A main finding from our study is that a general CSMR exists. We further find that soil texture, vegetation type and climate characteristics exert a similar influence on the CSMR. Comparable CSMRs are found when using different energy (vapor pressure deficit) and vegetation (normalized difference vegetation index) variables. This highlights the robustness of our results with respect to different variables and datasets. Modeled soil moisture datasets, alongside the above-used temperature and SIF data, however, fail to reproduce the satellite-based CSMR. Further research will identify and address the models' shortcomings.

Determining the CSMR and its controls allows for a better understanding of hydrology-biosphere-climate interactions. In particular, it is key to infer the direction of causality in these interactions, i.e. from soil moisture to near-surface weather or vice versa. Further, the determined CSMR may serve as a benchmark for model testing and development.