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Assimilating soil moisture into an Earth System Model

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Several modelling studies reported potential impacts of soil moisture anomalies on regional climate. In particular for short prediction periods, perturbations of the soil moisture state may result in significant alteration of surface temperature in the following season. However, it is not clear yet whether or not soil moisture anomalies affect climate also on larger temporal and spatial scales.

In an earlier study, we showed that soil moisture anomalies can persist for several seasons in the deeper soil layers of a land surface model. Additionally, those anomalies can influence root zone moisture, in particular during explicitly dry or wet periods. Thus, one prerequisite for predictability, namely the existence of long term memory, is evident for simulated soil moisture and might be exploited to improve climate predictions. The second prerequisite is the sensitivity of the climate system to soil moisture. In order to investigate this sensitivity for decadal simulations, we implemented a soil moisture assimilation scheme into the Max-Planck Institute for Meteorology's Earth System Model (MPI-ESM). The assimilation scheme is based on a simple nudging algorithm and updates the surface soil moisture state once per day.

In our experiments, the MPI-ESM is used which includes model components for the interactive simulation of atmosphere, land and ocean. Artificial assimilation data is created from a control simulation to nudge the MPI-ESM towards predominantly dry and wet states. First analyses are focused on the impact of the assimilation on land surface variables and reveal distinct differences in the long-term mean values between wet and dry state simulations. Precipitation, evapotranspiration and runoff are larger in the wet state compared to the dry state, resulting in an increased moisture transport from the land to atmosphere and ocean. Consequently, surface temperatures are lower in the wet state simulations by more than one Kelvin. In terms of spatial pattern, the largest differences between both simulations are seen for continental areas, while regions with a maritime climate are least sensitive to soil moisture assimilation.