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Season-long sensitivity studies on the role of soil moisture for convective precipitation

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Soil moisture strongly influences the partitioning of surface energy fluxes into sensible and latent heat. As a day evolves, enhanced evapotranspiration keeps near-surface air cooler and moister over moist soils and delays the vertical growth of the convective boundary layer compared to that over dry soils.
It is a priori unclear how this different behavior influences the atmosphere's potential for deep moist convection, whose rainfall accounts for the greater half of precipitation totals in the summer season in continental Europe. We investigate the impact of soil-moisture on subsequent deep moist convection by conducting season-long simulations with the convection-resolving numerical weather prediction model AROME. Soil moisture is modelled with the ISBA multilayer diffusion scheme with 14 vertical layers. The soil hydrology uses the mixed form of the Richards equation to describe the water mass transfer within the soil via Darcy‘s law. The tendency is solved in terms of volumetric water, and the hydraulic gradient is solved in terms of water pressure head.

The study is set in the Eastern Alpine region in two summers of opposed character: 2014 (unusually wet with abundant convective precipitation) and 2015 (extremely dry and hot with largely suppressed convective activity). For both summers, AROME is initialized with three different conditions of soil moisture on 1 May: once the operational values of that respective day are maintained ("reference experiment"), once it is reduced to the vegetation's wilting point ("dry experiment"), and once it is increased to the soil's field capacity ("wet experiment"). The simulations are run until 31 August and are evaluated with special emphasis on the patterns of precipitation accumulations and convection parameters.
The results confirm the hypothesis that "recycling" of evaporating moisture plays a crucial role to feed future convective precipitation on local to regional scales. Four-month rainfall totals are on the order of 20-30% higher in the wet experiments than in the dry experiments. An increase of the median and 90th percentile of CAPE reveals that boundary layer moistening overcompensates slower daytime heating in wet situations and thus results in a net enhancement of the convection potential. The differences remain visible throughout the summer, confirming the presence of "feed-forward" mechanisms which reinforce and sustain wet or dry summer periods unless no dramatic shift in the general weather pattern occurs. Finally, characteristic differences between primary convection (over the mountains) and secondary convection (over their forelands) are highlighted and placed into a conceptual context.