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The Continental-Scale Soil-Moisture Precipitation Feedback at Convection-Resolving Resolution

David Leutwyler (1,2), Adel Imamovic (1), and Christoph Schär (1)

(1) Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland, (2) Max Planck Institute for Meteorology, Hamburg, Germany

In weather and climate simulations, the soil moisture-precipitation feedback is sensitive to the details of the convection parameterization. As observation-based and modeling studies have repeatedly shown, mesoscale circulations emerging along soil-moisture gradients frequently initiate deep convective systems on the dry side of the gradient. In convection-parameterizing simulations, these circulations are often captured only partly, and the representation of the feedback is thus associated with considerable uncertainty. For instance, in some previous studies, simulations yield a positive feedback if convection is parameterized, but a negative feedback if convection is represented explicitly. However, due to the substantial computational cost involved, simulations examining the processes at convection-resolving resolution were so far limited to sub-continental computational domains and season-long integration periods.

The capabilities of supercomputers equipped with GPU accelerators enable conducting decade-long simulations, at resolutions allowing explicit representation of the involved circulations and hence allow for a more credible representation of the processes involved in soil moisture-precipitation feedback. We exploit these capabilities to perform continental-scale soil-moisture perturbation experiments at convection-resolving (2.2 km) and convection-parametrizing resolution (12 km). The simulations are driven by the ERA-Interim reanalysis and cover ten summer seasons (JJA, 1999-2008) on a computational domain spanning continental Europe (1536x1536x60 grid points).

Results indicate an increasingly dominant role of moisture advection if soil moisture anomalies exceed a spatial scale of about 100 km. As a consequence, an overall positive feedback and considerable precipitation sensitivity along mountain ranges result for continental-scale perturbations. While convection-parameterizing and convection-resolving simulations obtain a similar spatial distribution of the soil-moisture induced precipitation change, substantial differences arise in the sensitivity of the feedback, and w.r.t. precipitation frequency and intensity distributions. Furthermore, in the parameterized framework the feedback appears to be stronger than with explicit simulations. To better understand these differences, ensembles of idealized convection-resolving simulations with simplified boundary conditions are additionally performed. Notably, the role of the horizontal advection, the spatial scale of the soil moisture anomaly and the domain size are assessed systematically.