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Evaluating the impacts of surface and subsurface lateral water flows on summer precipitation in a complex terrain region: A WRF-Hydro ensemble case study

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Traditional land surface models parameterize terrestrial water flows as a one-dimensional, vertical process. Recent model improvements relaxed this constraint, e.g. by including descriptions of lateral terrestrial water flows to allow for a more comprehensive representation of processes on the land surface and their interactions on the land-atmosphere interface. In this study the Advanced Research version of the Weather Research and Forecasting (WRF-ARW) model core and its hydrologically improved variant WRF-Hydro are applied to a region covering Southern Germany and the Central Alps with a convection-permitting model resolution of 3 km. A small ensemble with five members for each model configuration is used to investigate the impacts of the hydrological enhancements offered by the WRF-Hydro model. The model results are compared with gridded and station observations of precipitation, temperature and river discharge for six catchments with different properties in terms of topography, climate, pedology, human impact or land use and sizes ranging from 60 to 12,000 square kilometers. Differences between WRF and WRF-Hydro ensembles are further examined with the help of an atmospheric-terrestrial water budget analysis to assess the impacts of perturbed atmospheric initial conditions and the improved description of hydrological processes on the land surface, whereby the latter leads to prominent changes in the partitioning of (near-) surface runoff and percolation. With regard to precipitation, both ensembles are able to reproduce the observed daily precipitation reasonably well (mean error: 0.12 - 1.15 mm, root-mean-square error: 5.2 - 7.2 mm, correlation coefficient: 0.70 - 0.82), noting that the WRF-Hydro ensemble exhibits a slightly larger ensemble spread. Likewise, a comparison between observed and simulated hourly discharge values showed that WRF-Hydro can reach Nash-Sutcliffe model efficiency coefficients up to 0.62 in small headwater catchments.