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A modified slope-dependent formulation for groundwater runoff in a regional climate model

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Soil moisture influences the state of the overlying atmosphere considerably and thus plays a major role in the climate system. Its spatial distribution is strongly modulated by the underlying orography. Yet, the vertical transport of soil water and especially the drainage at the bottom of the soil column is currently treated in a very crude way in most atmospheric models. This potentially leads to large biases in near-surface temperatures during summertime as the soil dries out and induces elevation-dependent biases in climate simulations. We present a modified formulation for the groundwater runoff formation in the regional climate model COSMO-CLM (multi-layer soil model TERRA_ML). It is based on Darcy's law, allows for saturated aquifers and includes a slope-dependent discharge. Employing flux limiters ensures a physically consistent treatment. An implementation of this formulation into TERRA_ML is tested and validated both in idealized and real-case simulations for cloud-resolving as well as hydrostatic scales. Idealized simulations display a physically meaningful recharge and discharge of the saturated zone and exhibit a closed water budget. Decade-long climate simulations over Europe exhibit a more realistic representation of the groundwater distribution in mountainous areas, an improved annual cycle of surface latent heat fluxes and as a consequence reductions of the long-standing bias in near-surface temperatures in semi-arid regions.