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Integrated simulations of mass and energy fluxes in the terrestrial system: concepts and applications

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Remote sensing (airborne and satellite) in combination with in-situ measurements provide unprecedented observations across multiple space and time scales of the terrestrial hydrologic, energy, and also biogeochemical cycles. These observations are useful in the quantification of mass fluxes within and between the major compartments of the terrestrial system that are the subsurface, the land surface and the atmosphere. As a matter of fact, one may argue that our analyses and simulation capabilities are lacking behind our current and future observation capabilities, since multi-physics modeling platforms are missing, which are able to simulate the terrestrial system at the required spatial and temporal resolutions over continents and the climate time scale. This is especially disconcerting, because, ultimately, the amalgamation of observations and simulations at the respective scales is the only viable option of arriving at useful predictions and uncertainty estimates of states and fluxes, which are urgently needed in the context of global change.

In order to close this gap, a simulation approach is presented, which is based on coupling of physics-based modeling platforms from the deeper subsurface into the atmosphere closing the hydrologic and energy cycles in terrestrial system models. The resulting integrated Terrestrials Systems Modeling Platform, TerrSysMP, is applied over regional watersheds and the European continent (Euro-CORDEX domain) in order to compare to a suite of in-situ measurements and remotely sensed observations, and understand the challenges and possibilities of the proposed simulation approach. We find that the memory effects of deeper groundwater dynamics pose a challenge in arriving at physically consistent initial conditions, which is also well-known in ocean modeling. The great potential lies in the ability to characterize all components of the hydrologic and energy cycle, which is not possible with more traditional simulation approaches, and, thus, synthesize and assimilate all available observations consistently.