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Towards Fully Coupled Atmosphere-Hydrology Model Systems: Recent Developments and Performance Evaluation For Different Climate Regions

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Limitations in the adequate representation of terrestrial hydrologic processes controlling the land-atmosphere coupling are assumed to be a significant factor currently limiting prediction skills of regional atmospheric models. The necessity for more comprehensive process descriptions accounting for the interdependencies between water- and energy fluxes at the compartmental interfaces are driving recent developments in hydrometeorological modeling towards more sophisticated treatment of terrestrial hydrologic processes. It is particularly the lateral surface and subsurface water fluxes that are neglected in standard regional atmospheric models. Current developments in enhanced lateral hydrological process descriptions in the WRF model system will be presented. Based on WRF and WRF-Hydro, new modules and concepts for integrating the saturated zone by a 2-dim groundwater scheme and coupling approaches to the unsaturated zone will be presented.

The fully coupled model system allows to model the complete regional water cycle, from the top of the atmosphere, via the boundary layer, the land surface, the unsaturated zone and the saturated zone till the flow in the river beds. With this increasing complexity, that also allows to describe the complex interaction of the regional water cycle on different spatial and temporal scales, the reliability and predictability of model simulations can only be shown, if performance is tested for a variety of hydrological variables for different climatological environments. We will show results of fully coupled simulations for the regions of sempiternal humid Southern Bavaria/Germany (rivers Isar and Ammer) and semiarid to subhumid Westafrica (river Sissilli). In both regions, in addition to streamflow measurements, also the validation of heat fluxes is possible via Eddy-Covariance stations within hydrometeorological testbeds.

In the German Isar/Ammer region, e.g., we apply the extended WRF-Hydro modeling system in 3km atmospheric-grid resolution and 300m subsurface-grid resolution for the terrestrial hydrological processes. Our simulations comprise the period May 2004 till September 2005 with a special focus on the August 2005 century flooding event. For streamflow at selected gauges we achieve Nash-Sutcliff efficiencies of 0.86 in uncoupled mode (using observed meteorological driving) and of 0.49 in fully coupled mode of WRF-Hydro. In the West African Sissilli catchment our focus is on the year 2003. We apply WRF-Hydro in 2km atmospheric- and 500m subsurface horizontal resolutions and achieve Nash-Sutcliff efficiencies of 0.4.

Finally, a further validation of energy balance components obtained from EC-stations is shown and the sensitivity and differences of the fully coupled model system to corresponding uncoupled and one-way coupled mode results are discussed.