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FLEX-TOPO: Proof of concept in a central European landscape

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Landscape classification into meaningful hydrological units has important implications for hydrological modeling. Conceptual hydrological models, such as HBV-type models, are most commonly designed to represent catchments in a lumped or semi-distributed way at best, i.e. treating them as single entities or sometimes accounting for topographical and land cover variability by introducing some level of stratification. Moreover, such models often combine different dominant runoff mechanisms (such as Hortonian overland flow, saturation overland flow and rapid subsurface flow) into one mechanism, so as to avoid large numbers of parameters. These oversimplifications can frequently lead to substantial misrepresentations of flow generating processes in the catchments in question, as feedback processes between topography, land cover and hydrology in different landscape units can arguably lead to distinct hydrological patterns.

By making use of readily available topographical information, hydrological units can be identified based on the concept of "Height above Nearest Drainage" (HAND; Rennó et al., 2008; Nobre et al., 2011). These hydrological units are characterized by different hydrological behavior with different dominant runoff generating mechanisms and can thus be assigned different model structures (Savenije, 2010). In this study we classified the Wark Catchment in Grand Duchy of Luxembourg into three distinct landscape units: plateau, wetland and hillslope, on the basis of a 5×5 m2 DEM. A revised and extended version of HAND gave preliminary estimates of uncertainty in the landscape unit identification as they were implemented in a stochastic framework. As the transition thresholds between the landscape units are a priori unknown, they were calibrated against landscape units observed in the field using a single probability based objective function. As a result, each grid cell of the DEM was characterized by a certain probability of being a certain landscape unit, producing maps of dominant landscape and therefore hydrological units.

The maps of the landscape classification using HAND and slope in a probabilistic framework were then used to determine the proportions of the three individual hydrological response units in the catchment. The classified landscapes were used to assign different model structures to the individual hydrological response units. As an example deep percolation was defined as dominant process for plateaus, rapid subsurface flow as dominant process for hillslope, and saturation overland flow as dominant process for wetlands. The modeled runoffs from each hydrological unit were combined in a parallel set-up to proportionally contribute to the total catchment runoff. The hydrological units are, in addition, linked by a common groundwater reservoir. The parallel hydrological units, although increasing the number of parameters, have the benefit of separate calibration. By stepwise calibration different mechanisms can be calibrated at periods when these mechanisms are active in isolation. For instance, the groundwater module is calibrated during dry season recession and the wetland module during isolated summer storms when the hillslopes are below the activating threshold. Moreover, one can constrain the parameters by realistic conditions. As an example, one may consider the lag time of wetland to be shorter than the lag time of water traveling to the outlet from a plateau. Moreover, due to the dominance of forest on hillslopes in this catchment, the interception threshold should be higher on the hillslopes than on the plateaus, which are mainly used for agriculture. Furthermore fluxes and processes can be compared. For example, actual evaporation from wetland can potentially be higher than from other entities within a catchment as wetlands are water logged and evaporation thus less supply limited than on plateaus. To include all the comparisons and criteria in calibration, an evolutionary algorithm was used. The algorithm was adapted and applied in a way that in subsequent steps more and more comparative criteria are forced to be satisfied.

Including landscape classification into hydrological models appears to be a powerful tool to achieve higher realism. Not only does it allow to consider and to make use of crucial feedback processes between the hydrological system and the eco-system, it also leads to more detailed information on how a catchment may work than would be the case in a lumped model.