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Can parameterising models using physical understanding from research basins banish hydromythology and improve hydrological prediction?

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Hydrological prediction using physically based models requires model structures that can describe the hydrological cycle in at least the basin of interest. Model structure is defined here as the broad system concept of the model. Groups of parametrizations of hydrological processes are linked by the structure. The structures of most comprehensive physically based hydrological models are similar and can likely be generalized. What truly differs amongst models is the content: the parametrizations that compose the structure. For instance, all hydrological models need to consider structural elements such as precipitation, evaporation or runoff generation in their structure, but how they do this depends on the parametrization used. Many current model structures are based on what we term “hydromythologies”, older concepts that we now know to be incorrect, but which being well known still hamper the advance of scientific hydrology. Persistent popular hydromythologies include that evapotranspiration can be related to air temperature and humidity, that snowmelt can be simulated with a simple temperature index, that sublimation is negligible, that infiltration is dominated by matrix flow, that overland flow is prevalent, that snow stays on the ground where it falls, that all components of the land surface drain readily to a stream, and that frozen soils behave like wet unfrozen soils.

To reduce the prevalence of hydromythology in modelling, explore appropriate structural content, adopt model structure to specific process scales, and increase the physical basis of hydrological models, a modular hydrological model development platform and several research basins have been developed. The platform is the Cold Regions Hydrological Modelling Platform (CRHM) with which the user assembles a hydrological model from a selection of hydrological process modules (parametrizations). CRHM’s modularity provides the possibility to change process parametrizations from a selection of simpler, more conceptual parametrizations to strongly physically based ones. It is also possible to update parametrizations as advances in the understanding of processes occur, or as parametrizations become more appropriate, or to run models in parallel to compare the impact of differing parametrizations, parameter or driving data availability on model results. CRHM has been used to advise the development of parametrizations for operational hydrological models as well as to create basin models itself. The structure is indeed flexible, but our experience is that for adequate comprehensive hydrological modelling, the structure (types of modules) is essentially the same, only the structural content (modules) chosen changes.

Research basins were established in regions where persistent and spectacular model failures suggested an inadequate understanding or parametrization of hydrological principles. The Canadian Prairie region has presented formidable challenges for models due to its many internal drainages, large depressional storage, variable contributing area, high infiltration rates, wind redistribution of snow, solar radiation dominated snowmelt, frozen soils and low evapotranspiration rates. The western and northern mountains in Canada have also presented widespread problems to many models because of many of the aforementioned processes and sublimation of intercepted snow, the impact of slope and aspect on the snowmelt energy balance and sub-canopy radiation effects. The field research programme has therefore focussed on developing a better physical understanding of these processes at basins in Saskatchewan, Alberta and the Yukon using novel field experiments, and has resulted in improved parametrizations which are incorporated into CRHM as modules.

The impact of these parametrizations on the predictive performance of models created with CRHM is discussed using case studies from the research basins. For some basins these are the first successful hydrological process simulations ever conducted. These results may be instructive for other models for which the developers seek to fight hydromythology, explore how to add parametrizations to model structures, and improve physical realism in hydrology.