Geophysical Research Abstracts
Vol. 18, EGU2016-11197, 2016
EGU General Assembly 2016

A priori discretization quality metrics for distributed hydrologic modeling applications

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In distributed hydrologic modelling, a watershed is treated as a set of small homogeneous units that address the spatial heterogeneity of the watershed being simulated. The ability of models to reproduce observed spatial patterns firstly depends on the spatial discretization, which is the process of defining homogeneous units in the form of grid cells, subwatersheds, or hydrologic response units etc. It is common for hydrologic modelling studies to simply adopt a nominal or default discretization strategy without formally assessing alternative discretization levels. This approach lacks formal justifications and is thus problematic. More formalized discretization strategies are either a priori or a posteriori with respect to building and running a hydrologic simulation model. A posteriori approaches tend to be ad-hoc and compare model calibration and/or validation performance under various watershed discretizations. The construction and calibration of multiple versions of a distributed model can become a seriously limiting computational burden. Current a priori approaches are more formalized and compare overall heterogeneity statistics of dominant variables between candidate discretization schemes and input data or reference zones. While a priori approaches are efficient and do not require running a hydrologic model, they do not fully investigate the internal spatial pattern changes of variables of interest. Furthermore, the existing a priori approaches focus on landscape and soil data and do not assess impacts of discretization on stream channel definition even though its significance has been noted by numerous studies.

The primary goals of this study are to (1) introduce new a priori discretization quality metrics considering the spatial pattern changes of model input data; (2) introduce a two-step discretization decision-making approach to compress extreme errors and meet user-specified discretization expectations through non-uniform discretization threshold modification. The metrics for the first time provides quantification of the routing relevant information loss due to discretization according to the relationship between in-channel routing length and flow velocity. Moreover, it identifies and counts the spatial pattern changes of dominant hydrological variables by overlaying candidate discretization schemes upon input data and accumulating variable changes in area-weighted way. The metrics are straightforward and applicable to any semi-distributed or fully distributed hydrological model with grid scales are greater than input data resolutions.

The discretization metrics and decision-making approach are applied to the Grand River watershed located in southwestern Ontario, Canada where discretization decisions are required for a semi-distributed modelling application. Results show that discretization induced information loss monotonically increases as discretization gets rougher. With regards to routing information loss in subbasin discretization, multiple interesting points rather than just the watershed outlet should be considered. Moreover, subbasin and HRU discretization decisions should not be considered independently since subbasin input significantly influences the complexity of HRU discretization result. Finally, results show that the common and convenient approach of making uniform discretization decisions across the watershed domain performs worse compared to a metric informed non-uniform discretization approach as the later since is able to conserve more watershed heterogeneity under the same model complexity (number of computational units).