ASSESSMENT OF EPISTEMIC UNCERTAINTY IN FLOOD INUNDATION MODELING

ABSTRACT

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Flooding is one of the most devastating natural disasters in the world and it exacerbated during the past decades. In order to reduce the loss of lives and properties from repeating flooding events, reliable flood predictions are required. Currently, there exist a series of hydrodynamic models that have different model structures which solve different forms of governing equations in one- (1D), two- (2D) or three- (3D) dimensions, thus providing various possible predictions for decision makers to choose from. Even for the same model, depending on how the model is implemented for a specific parameter set, input data and channel geometry representation, the prediction is different. Therefore, investigating the reducible uncertainty (epistemic uncertainty) in flood inundation modeling and finding a proper way to generate robust predictions are very crucial for future modelers. In this dissertation, epistemic uncertainty sources from model structure, model parameter and model input are investigated and evaluated by using stream reaches ranging from reach scale to watershed scale in different geographical settings. The three objectives of this dissertation are to: (1) evaluate the impact of hydrodynamic model structure uncertainty on predicted water stages and inundation extents under different geophysical settings, and explore the influence of channel and floodplain roughness on model performance respectively, (2) investigate and apply a multi-model combing approach, Bayesian model averaging (BMA), to produce reliable predictions by considering four uncertainty sources including channel width, channel

cross-sectional shape, channel roughness and flow forcing and (3) separate and prioritize different uncertainty sources, including DEM resolution, channel width, channel cross-sectional shape, channel roughness and flow forcing, based on their relative influences using hierarchical Bayesian model averaging (HBMA).

In the first objective, the performance of four hydraulic models including HEC-RAS 1D, HEC-RAS 2D, LISFLOOD-FP diffusive and LISFLOOD-FP subgrid are evaluated at four rivers that have different geophysical settings in the United States. The results show that HEC-RAS 2D does not perform well at low channel roughness condition. However, at high channel roughness condition, the performance of HEC-RAS 2D and HEC-RAS 1D are comparable. The performance of the subgrid version of LISFLOOD-FP (LS) is more stable under different channel roughness conditions, and in general it performs better than the diffusive version (LD) in simulating floodplain inundation. Moreover, applying distributed floodplain roughness does not necessarily improve model performances.

In the second objective, LISFLOOD-FP subgrid model is applied for a relatively large catchment-Black River watershed in Missouri and Arkansas considering four uncertainty sources using BMA approach. The results indicate that although BMA deterministic prediction may not always outperform all the model members in the ensemble, this approach is able to provide a relatively robust water stage prediction. Typically, BMA deterministic prediction behaves better than most of the member predictions in the ensemble and ensemble mean prediction. BMA has better performance than ensemble mean prediction for high-chance flood regions at Black River watershed. On the other hand, there is no significant difference between two types of probabilistic flood maps for low-chance flood regions.

In the third objective, LISFLOOD-FP subgrid model is also set up in the Black River watershed to find out the relative influence of five different uncertainty sources. The results demonstrate that channel width and topographical data resolution have largest impact on the hydrodynamic model predictions. These two sources are followed by flow forcing, which has relatively greater influence than channel cross-sectional shape and model parameter. However, when model weights are taken into account, input (topography and input forcing) and model parameter (roughness) have larger impact on prediction variance than model structure (channel shape and width).