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Major Sources of Uncertainities in Flood Modelling - A Review

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ABSTRACT

Flood is among one of three major natural disasters-Flood, Earthquake and Droughts and it takes toll of millions of lives as well as huge economic loss through out the world. With increase of climate change as well as human encroachments, its effect has got magnified in the recent years.

The devastating effects of flood could be mitigated through the use of development of flood warning systems based on flood modelling techniques. Over the years, there have been many developments in increasing the sophistication of the flood modelling techniques such as process based 2D as well as 3D models in order to overcome the stochastic as well as epistemic uncertainities. However, the implementations of those developments was constrained due to higher computational cost as well as cost of collection of field data related to topography as well as stage and discharge time series. Moreover, their application was limited to the gauged catchments alone and in case of ungauged catchments the application of such warning system was largely stunted.

INTRODUCTION

Floods are one of the major natural extreme events which cause huge economic loss as well as loss of infrastructure and human lives. They have increased in recent times due to increase of global warming as well as human encroachments (Sene, 2008). The devastating effects of floods can be mitigated if not eliminated by reducing uncertainties associated with the flood modeling. The uncertainty in the modeling arise due to errors in model forcings conditions such as upstream discharge, accuracy of DEM and topography data, representation of bed friction as well as sophistication of the model structure to represent the various physical processes.

Flood modeling

There can be various approaches to minimize the error associated with the hydrodynamic flood model such as improving the accuracy in model forcings, removing biases in DEMs, increasing the sophistication in the model structure however data assimilation is one such approach which is widely used to optimize the hydrodynamic model without directly altering the other conditions in the model. This study aims at developing flood models with data assimilation through altimetry satellites in order to improvise the accuracy of flood modelling.

The modeling of flood flows can be carried out through three distinct approaches- Empirical, Numerical as well as Conceptual (Teng et al 2017). However, among all three approaches the numerical hydrodynamic models have the best capacity to represent the detailed flow characteristics since they explicitly take the various physical processes into account. The hydrodynamic models are classified into 1D, 2D and 3D models and their application is dependent on the nature of flood problem in terms of the spatial resolution, availability of computational resources as well as the extent of field measurements available. Among all three approaches of hydrodynamic model, the 1D model is widely used for modeling of flood flows in the river due to its simplicity as well as ability to give accurate results for most of the flood related problems. The typical domain of a 1D and 2D model is shown in the Figure 1

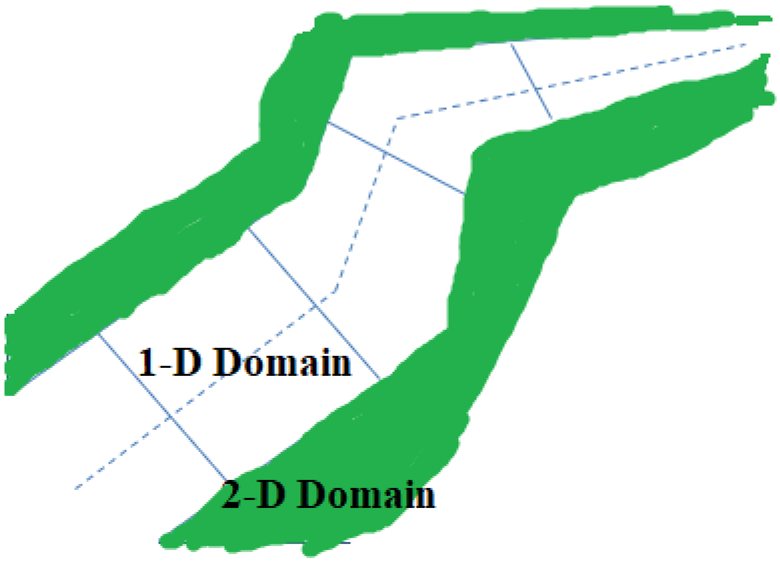

Figure 1. Model domain for 1D and 2D model

Hydrodynamic models are classified as 1D, 2D and 3D models. Models which are 1D are based on St-Venant's equations whereas 2D and 3D models are based on Navier's Stokes' equations (Geravand et al., 2020).1D models are frequently used in flood modelling even though they are subjected to various assumptions. These models assume uniform velocity across the section,one dimensionality of the flow and also they assume the water level is horizontal. However, such 1D model fail to give meaningful results for out of bank flows when the flood plain topography is complex with rural areas, urban areas, natural and man made obstacles, backwater area, diversion channels or ponding area. In these situations, topographic features affect the flow processes and the flow becomes two dimensional and velocity is no longer uniform. In such cases, it is more useful to go for 2D approaches where the topographic bathymetry of flood plain is also incorporated into model.(Tayefi et al 2007). Also, in the river flow whenever there is expansion and contraction of cross sectional area either naturally or around the structures, there is formation of turbulent eddies which leads to loss of momentum. But, in 1D flow this can't be calculated. However, these losses can be adjusted in the model through addition of some empirical terms in the 1D model equation. The situations where the effect of spiral flows and vertical flow structures becomes significant like flow around bridge piers, the use of fine resolution 3D models become necessary. Some of the most commonly used hydrodynamic flood models are MIKE Flood (DHI, 2017), HEC-RAS (US Army Corps of Engineer., 2016), TUFLOW (Wbm, B., 2019) SOBEK SUITE (Deltares, 2019) and LISFLOOD-FP (Bates et al, 2013).

Causes of Uncertainties in Flood Modeling

Warmink et al 2010 identified the major causes of uncertainties in the hydrodynamic models for the estimation of the modelled water levels.It was found that the bed friction equation as well as the upstream discharge were the main contributors of uncertainties. The upstream discharge in turn depends on the upstream rainfall as well as representation of catchment characteristics upstream. The other factors which were found to cause uncertainties in the flood inundation modelling are representation of flood plain topography, weir formulation, flood plain vegetation measurements, eddy viscosity and groyne formulation.

Rajulapti and Majumdar, 2019 stated that there are various factors which bring uncertainities in the modeling of floods such as uncertainity in model formulation as well as quality and quantity of input data. It was stated that it is important to quantify the amplitude of error associated with each factor as well as sources of error since the errors could also interact non-linearly with each other.

Glock et al 2019 stated that the treatment of flow resistance in river hydrodynamic models brings lot of uncertainties since the flow resistance involves multiple components like bank resistance, channel bed resistance, vegetation resistance, resistance due to natural and man made obstructions as well as resistance due to transported sediment. The current practise of addressing resistance in the numerical models is by use of various empirical equations such as Chezy's equation, Darcy-Weisbach and Manning's-strickler's equations. However, these empirical equations were developed for uniform sizes of channels and considered the resistance due to channel boundary alone.

Vozinaki et al 2017 stated that correct representation of topographic data of river cross section as well as flood plain is most important for modelling the flood inundation.

Grimaldi et al 2018 stated that the even though the topographic data as well as flow resistance is not properly represented in the numerical hydraulic models due to scarcity of available data, they are able to calibrate the simulated water levels with the observed water levels. The reason behind such occurrence is that the misrepresentation of topographic data as well as flow resistance compensate each to reach the solution with an approach known as equifinality. Although this problem could have lesser impact in modelling of large scale rivers but for medium and short scale, this could potentially create a problem.

CONCLUSION

The attempts to increase efficiency of flood modelling is necessary given the great devastation caused by floods. The study discussed the various types of flood modelling approaches and their relative strengths and limitations. Moreover, the various causes of uncertainties in the conventional approaches of flood modelling have been highlighted in the study. In order to overcome the uncertainties of flood modelling, the approach of data assimilation of satellite data in the flood modelling is proposed. The methodology of assimilating the satellite data into the flood modelling is presented. Various types of data assimilation have also been discussed in the study. Also, the study highlighted the different studies in the past which had utilized data assimilation in the flood models for rivers around the globe.

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