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A layer-based morphodynamic model for unsteady outburst geomorphic floods: application in real world events

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1. Introduction

Outburst floods generally comprise advancing intense water waves which can induce considerable geomorphic change rapidly. Therefore, the exploration and investigation of such floods cannot be limited to water flow itself, but must also consider flow-induced sediment transport. However, many numerical models do consider the flow as clear water, neglecting sediment transport processes. Although this treatment simplifies the numerical model, it must be open to question in terms of understanding real flood behaviours. In recent years, investigations on sediment transport in transient outburst floods are increasingly carried out; however, the understanding of how sediment load transports and interacts with water in flood propagation is still ambiguous and scarce. The aim of this project is to develop a layer-based morphodynamic model, and then to understand more of fluvial hydraulics and sediment-flow interactions in large scale outburst floods.

2. Layer-based model framework

For bedload dominant sheet flow, sediment generally accumulates and transports at the bottom, while flood water propagates as an agent of sediment in the upper layer. Therefore, based on that consideration, a layer-based concept model is adopted here (see Fig.1). Accordingly, the model system is governed by: mass and momentum conservation of the whole mixture flow, as well as mass conservation of sediment at bottom layer. The proposed model system is primarily composed of a combination of the following modules:

- *Hydrodynamic module*: governed by 2D shallow water equation with consideration of sediment effects.
- *Sediment transport module*: controlling the sediment mass conservation.
- *Morphological evolution module*: for updating the bed elevation after erosion and deposition.

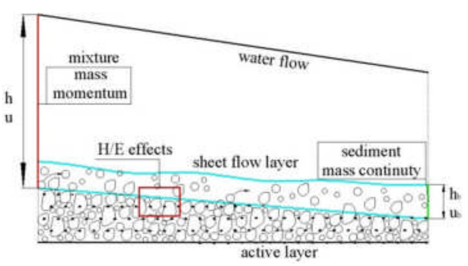

Figure 1: schematic drawing of the layer-based conceptual model

3. Results and discussions

3.1 Model validation

The proposed model was validated by a series of experimental works, involving: (1) dam break flow over movable bed of sand and PVC particles; (2) sediment aggradation in the transcritical flow (3) dam breach due to flow overtopping; (4) dam break flow over movable bed channel with a sudden enlargement; etc. These cases are well reproduced by the layer-based numerical model.

3.2 Application to volcano-induced GLOF

The layer-based model is applied to simulate a large scale volcano-induced glacial outburst flood occurred at Sólheimajökull, Iceland in 1999. Fig.2 shows the water depth at 2 hours with and without sediment and the distribution of sediment erosion and deposition after 6 hours. Therein, the erosion and deposition primarily occur in the main channel with eroded volume of $7.3\times10^5 m^3$ and deposit volume of around $4.6\times10^5 m^3$. Further, through the comparisons and analysis between the simulations of flood with and without incorporation of sediment, it is found that sediment accelerates the flood propagation but decreases the water level at most cross sections. As for the effects of sediment size, the sensitivity is analysed by inputting three different sediment sizes as: mixed diameter, d_{50}=40mm and d_{50}=80mm. It was found that (1) sediment grain size does not have significant influence on hydrodynamic process; but (2) it directly decides the features and extent of geomorphic change caused by the flood.

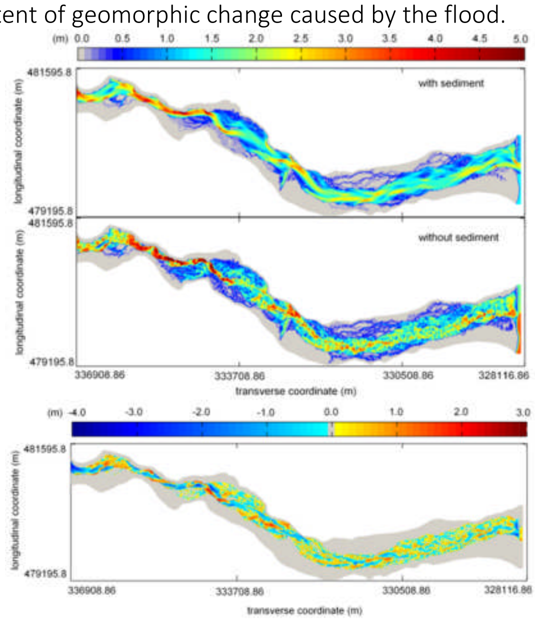

Figure 2: water depth with and without sediment at 2 hours and the distribution of erosion and deposition

4. Conclusions

A novel layer-based morphodynamic model is proposed for rapid geomorphic floods. The model fully considers the hydraulic and sedimentary factors and it is validated by a series of experiments with good performances. In large scale flooding, sediment transport has significant effects on hydraulic features and rapid geomorphic change. Therefore, understanding the effects clearly and predicting the flood accurately are very important for flood risk management and flood hazard mitigation.

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