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Modelling of flood risks to people and property in a flood diversion zone

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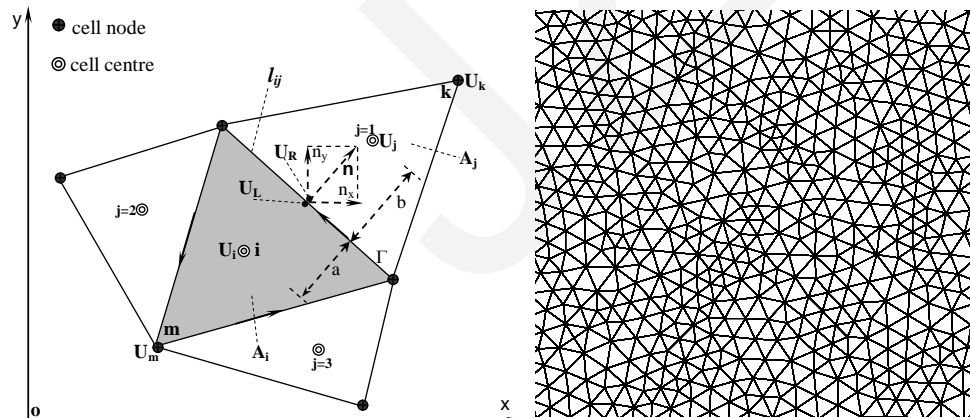
1. Numerical model for flood risk assessment

(I) Module for 2D hydrodynamics

The depth-averaged **2D shallow water equations** (Xia et al. 2011ICE-WM;2011EMS) used in the current model can be written in a general conservative form as:

$$\frac{\partial \mathbf{U}}{\partial t} + \frac{\partial \mathbf{E}}{\partial x} + \frac{\partial \mathbf{G}}{\partial y} = \frac{\partial \tilde{\mathbf{E}}}{\partial x} + \frac{\partial \tilde{\mathbf{G}}}{\partial y} + \mathbf{S}$$

$$\mathbf{U} = \begin{bmatrix} h \\ hu \\ hv \end{bmatrix} \quad \mathbf{E} = \begin{bmatrix} hu \\ hu^2 + \frac{1}{2} gh^2 \\ huv \end{bmatrix} \quad \mathbf{G} = \begin{bmatrix} hv \\ huv \\ hv^2 + \frac{1}{2} gh^2 \end{bmatrix} \quad \tilde{\mathbf{E}} = \begin{bmatrix} 0 \\ \tau_{xx} \\ \tau_{yx} \end{bmatrix} \quad \tilde{\mathbf{G}} = \begin{bmatrix} 0 \\ \tau_{xy} \\ \tau_{yy} \end{bmatrix} \quad \mathbf{S} = \begin{bmatrix} 0 \\ gh(S_{bx} - S_{fx}) \\ gh(S_{by} - S_{fy}) \end{bmatrix}$$



Finite volume method (FVM);
 Unstructured triangular mesh;
 Roe-MUSCL(TVD) ;
 Predictor-corrector;
 wetting and drying fronts;
 Validated by existing analytical solutions and measurements (Xia et al. 2011ICE-WM;2011EMS);

1. Numerical model for flood risk assessment

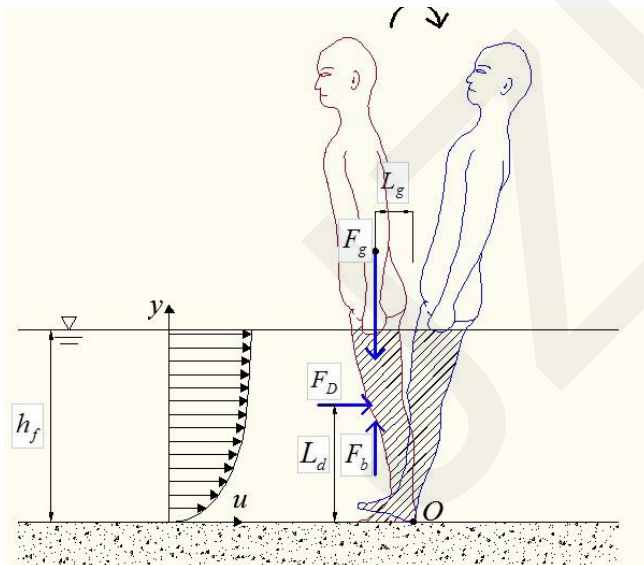
(II) Module of estimating flood risks to people and property

The adopted method for estimating the flood risk to **people in floodwaters** was derived based on the **mechanics-based equilibrium conditions** (Xia et al., 2014,52(1), JHR).

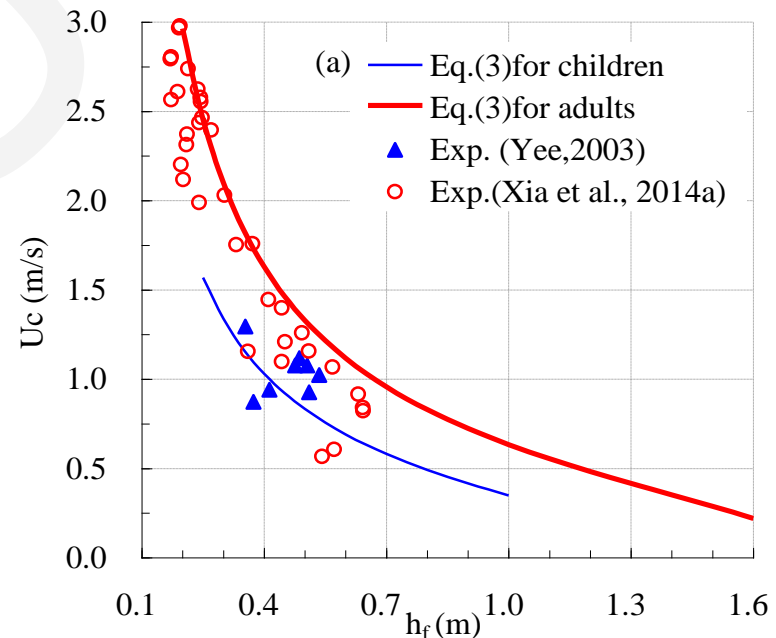
$$U_c = \alpha \left(\frac{h_f}{h_p} \right)^\beta \sqrt{\frac{m_p}{\rho_f h_f^2} - \left(\frac{a_1}{h_p^2} + \frac{b_1}{h_f h_p} \right) (a_2 m_p + b_2)}$$

h_p , m_p = height and mass of a human body

with $\alpha = 3.472 \text{ m}^{0.5}/\text{s}$ and $\beta = 0.188$ being calibrated using total 46 tests in a flume.



Sketch of governing forces acting on a flooded human body at toppling

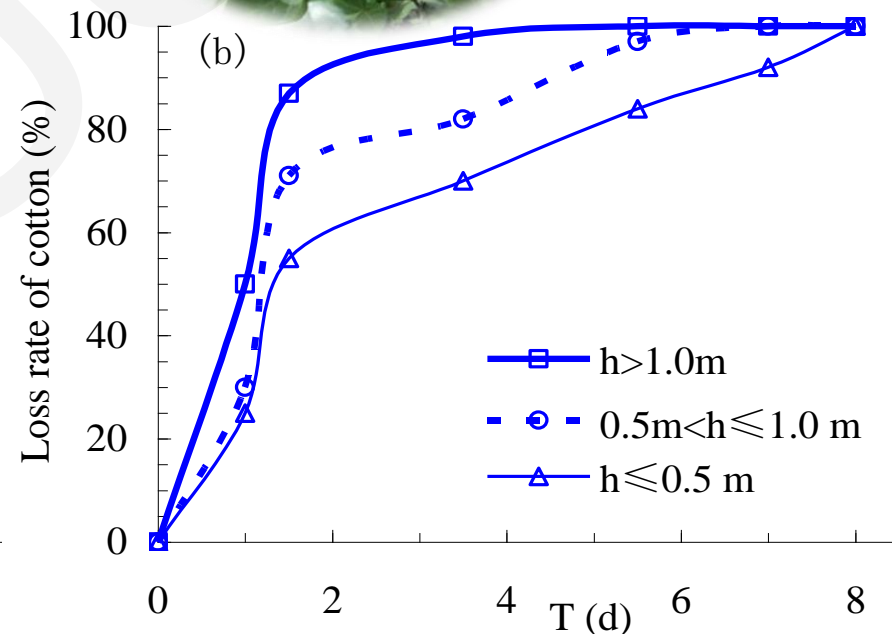
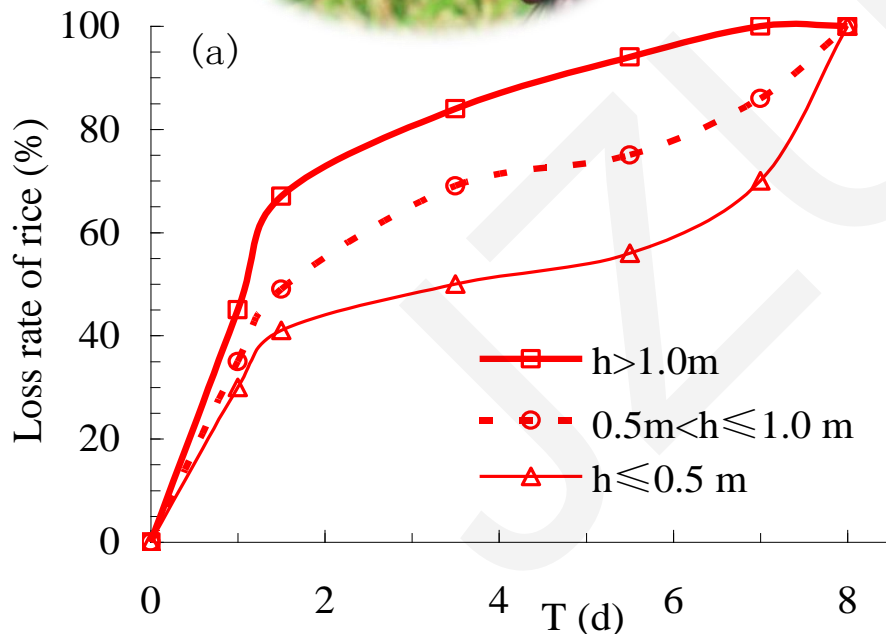


Suggested stability thresholds for children and adults

1. Numerical model for flood risk assessment

(II) Module of estimating flood risks to people and property

Flood loss rates for **rice** and **cotton** presented by Liu et al. (1999) were adopted in this study.



Flood loss rates under different submergence durations for (a) rice; and (b) cotton.

1. Numerical model for flood risk assessment

(II) Module of estimating flood risks to people and property

The method used for the risk to **buildings** (Defra and EA, 2006) is an indicative assessment taken from an **average of damage scale** for each building type proposed by Kelman(2002).

$$HD = 0.7U^{0.14} \Delta h^{0.34}$$

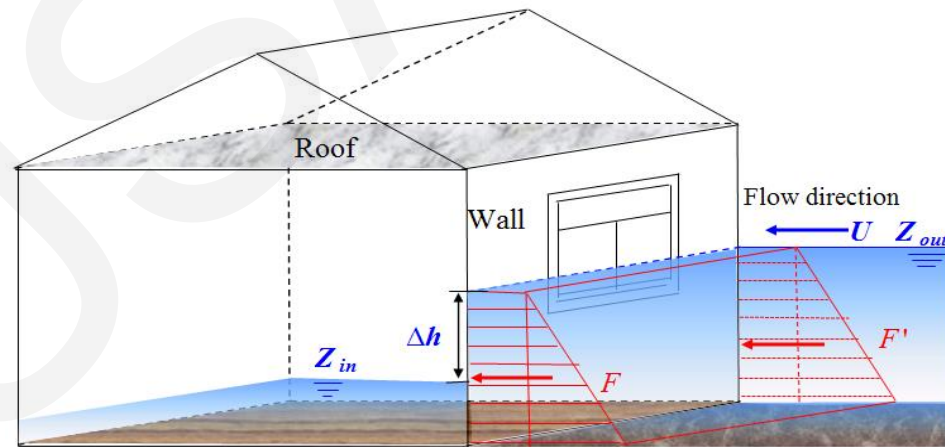
U =velocity near the building (m/s)

Δh =depth difference between water levels outside and inside a building (m)

Some damage ($HD \leq 0.5$)

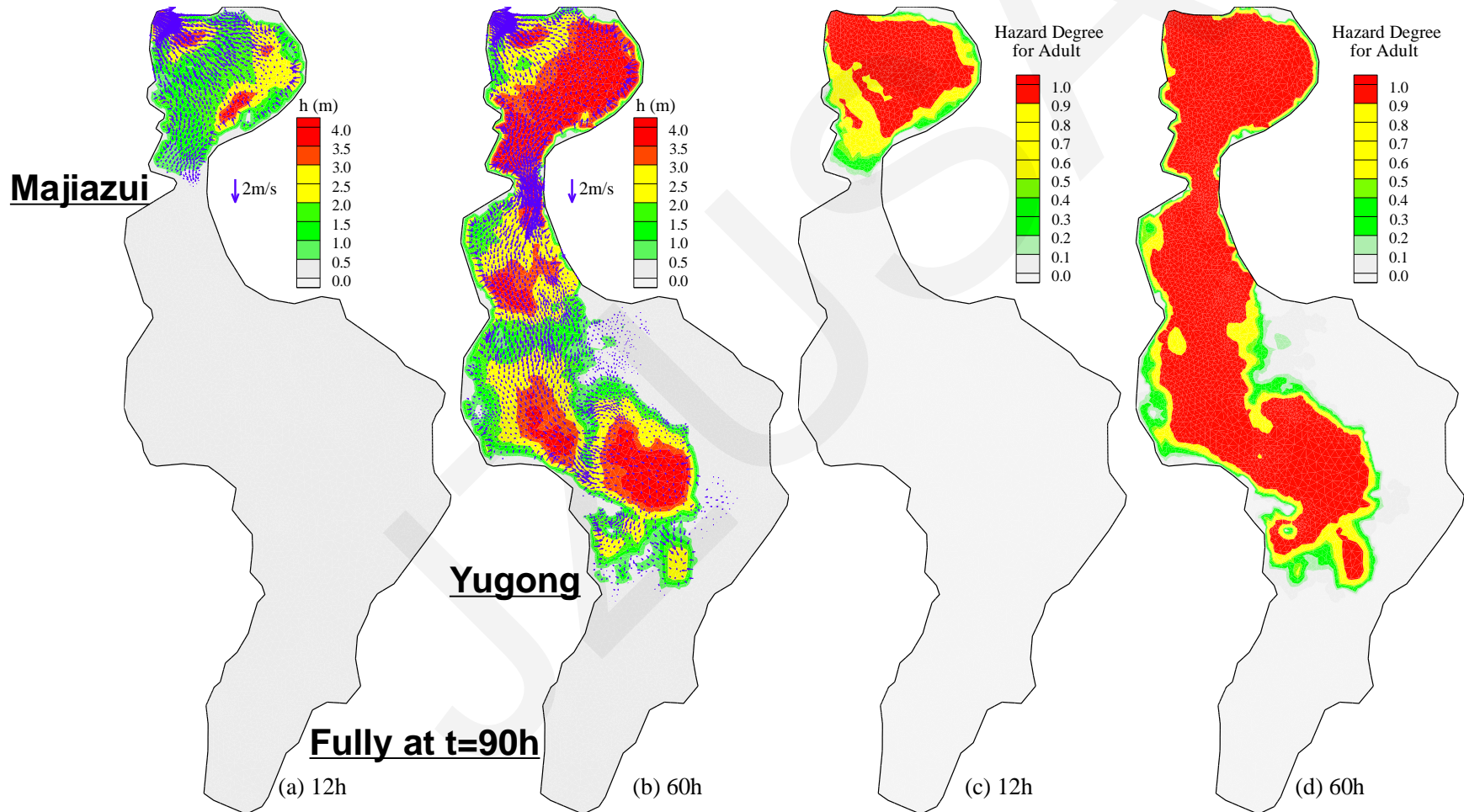
Severe damage ($0.5 < HD < 0.98$)

Irreparable damage ($HD \geq 0.98$)



2. Model application

Results: Predicted distributions of depth and velocity at different times



Distributions of depth, velocity and flood hazard degree for adults at different times

2. Model application

Results: Predicted flood risks to people and property

- The average flood loss rate would **increase gradually** with the flood propagation for each flooded object..

- Flood loss rates at $t = 140$ h :

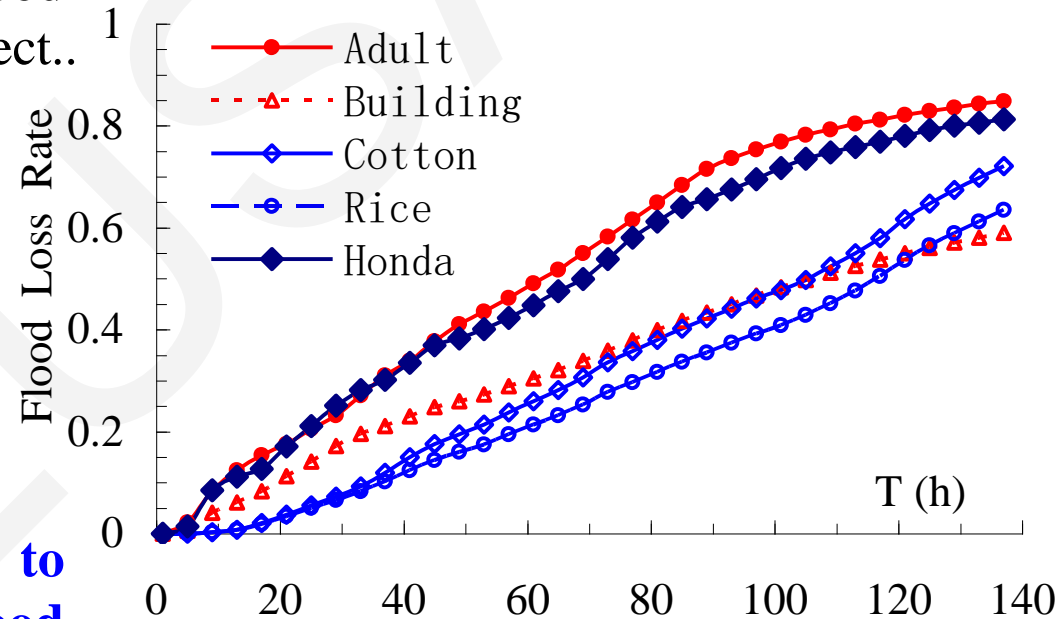
 - 84% for adults ;

 - 81% for vehicles;

 - 60% for buildings;

 - over 60% for rice or cotton.

- It should be cautious to consider the operation of a flood diversion zone, which usually results in a **huge loss of people and property** once operated.



Temporal variations in the average flood loss rates for adults, buildings and crops

3. Conclusions

- (i) **An integrated numerical model for estimating the flood risks to people and property in a flood diversion zone has been proposed herein**, including the module for predicting the two-dimensional hydrodynamic processes in a flood-prone zone with complex topography, and a special module for predicting the flood risks to people and property using the mechanics-based and empirical formulae.
- (ii) The flood inundation process and the variations in **people and property hazard degrees** were **predicted** for a hypothetical diversion process using the proposed model, and the predicted flood loss rates for adults, vehicles, buildings and crops would be relatively higher.
- (iii) **Effects on the model predictions of different roughness coefficients and people stability criteria were investigated**. The results show that it is necessary to set up variable Manning's roughness coefficients according to different underlying surface conditions in the hydrodynamic module, because they can influence the temporal and spatial variation in water depth and velocity; and a mechanics-based criterion of people stability in floodwaters should be adopted to assess the potential flood HDs.