Smart flood forecasting infrastructure with uncertainties

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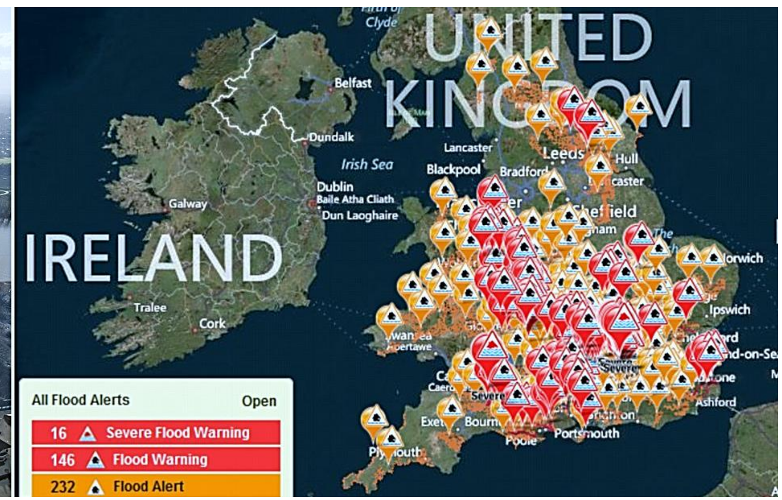
University of Sheffield



Acknowledgements

EPSRC
Engineering and Physical Sciences Research Council

UEA
University of East Anglia

UNIVERSITY OF LEEDS

University of BRISTOL

BMT WBM

DHI

Environment Agency

ch2m

XP solutions

Innovyze®

1. Strategic Importance

Need for improved flood forecasting tools

Policy-makers

'Increased budgets won't be enough'

'Reliable warning maps for the public'

Water industry

'Increased versatility and intelligence'

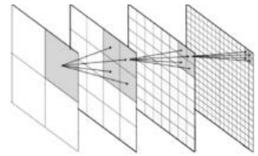
'Efficient handling of uncertainties'

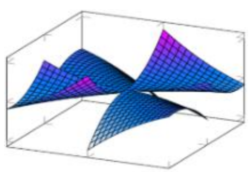
Academic calls

'Adapt itself to the optimum scale'

'More accurate and multi-purpose'

2. Present Challenges





- Error control
- Data transfer
- Fitness for purpose

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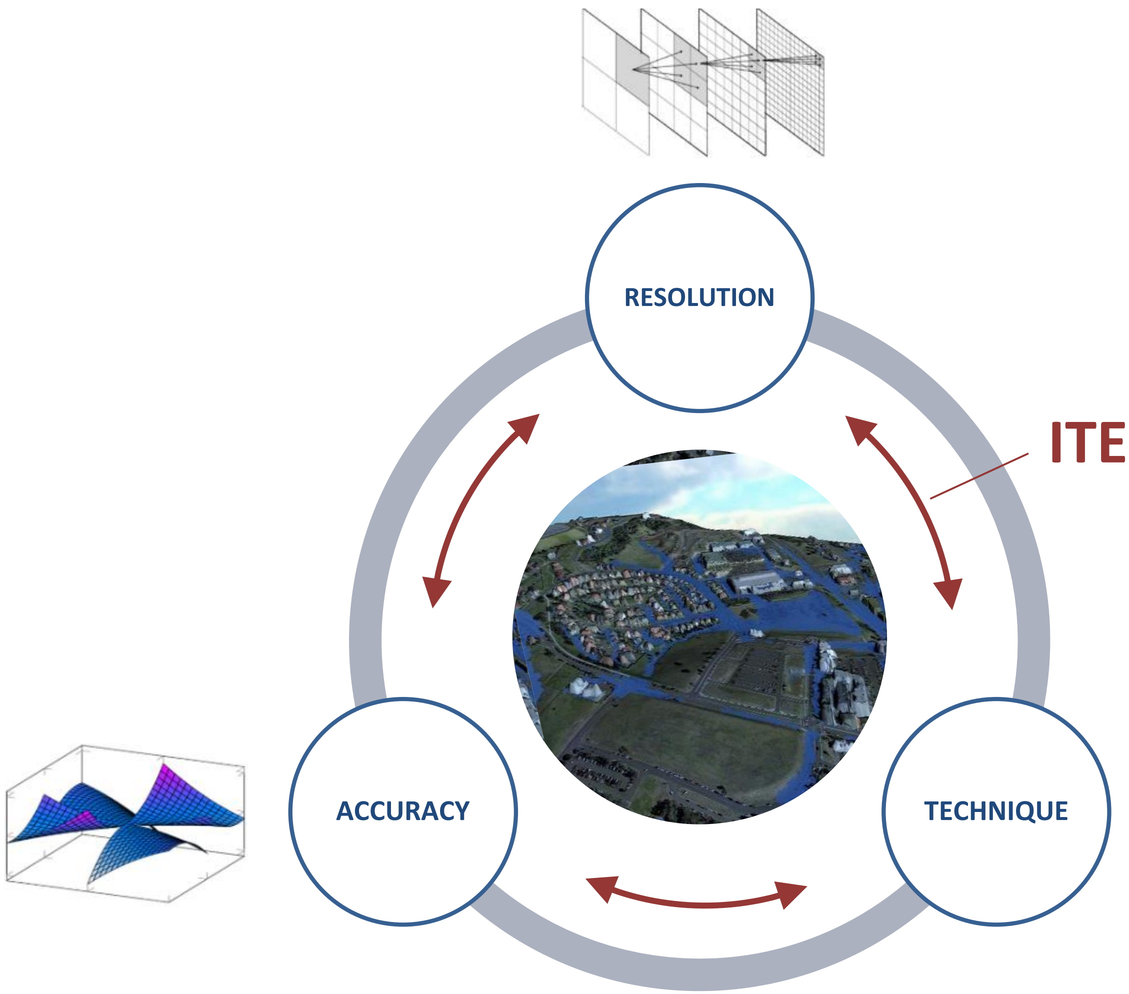

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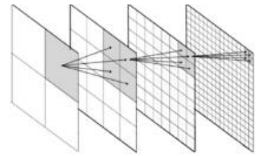
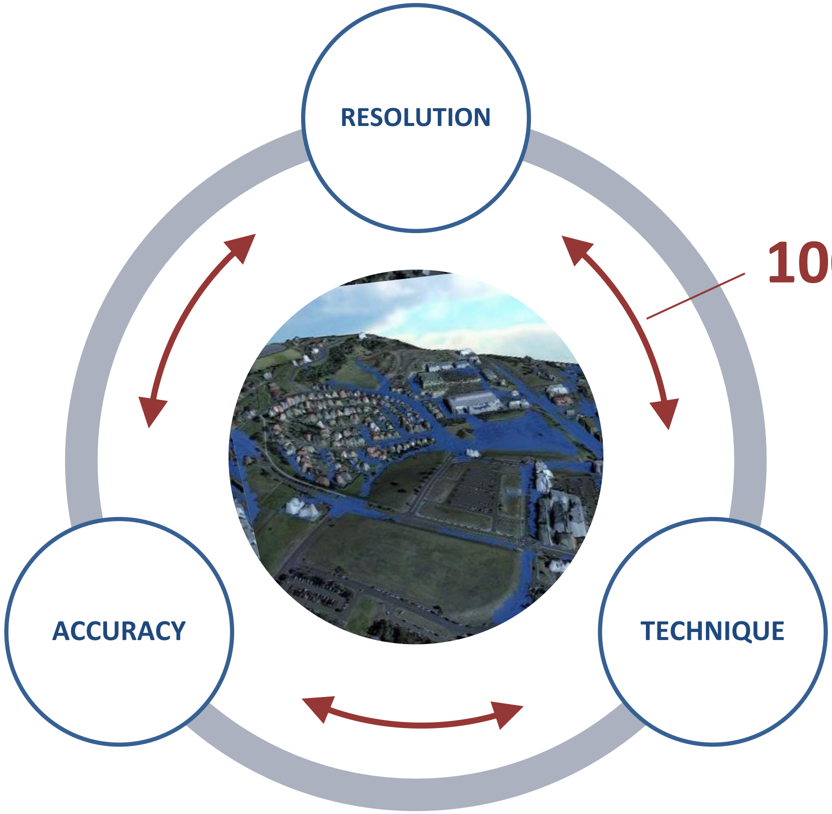
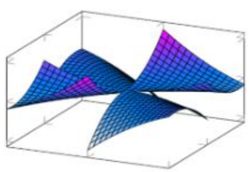






UNCERTAINTY QUANTIFICATION

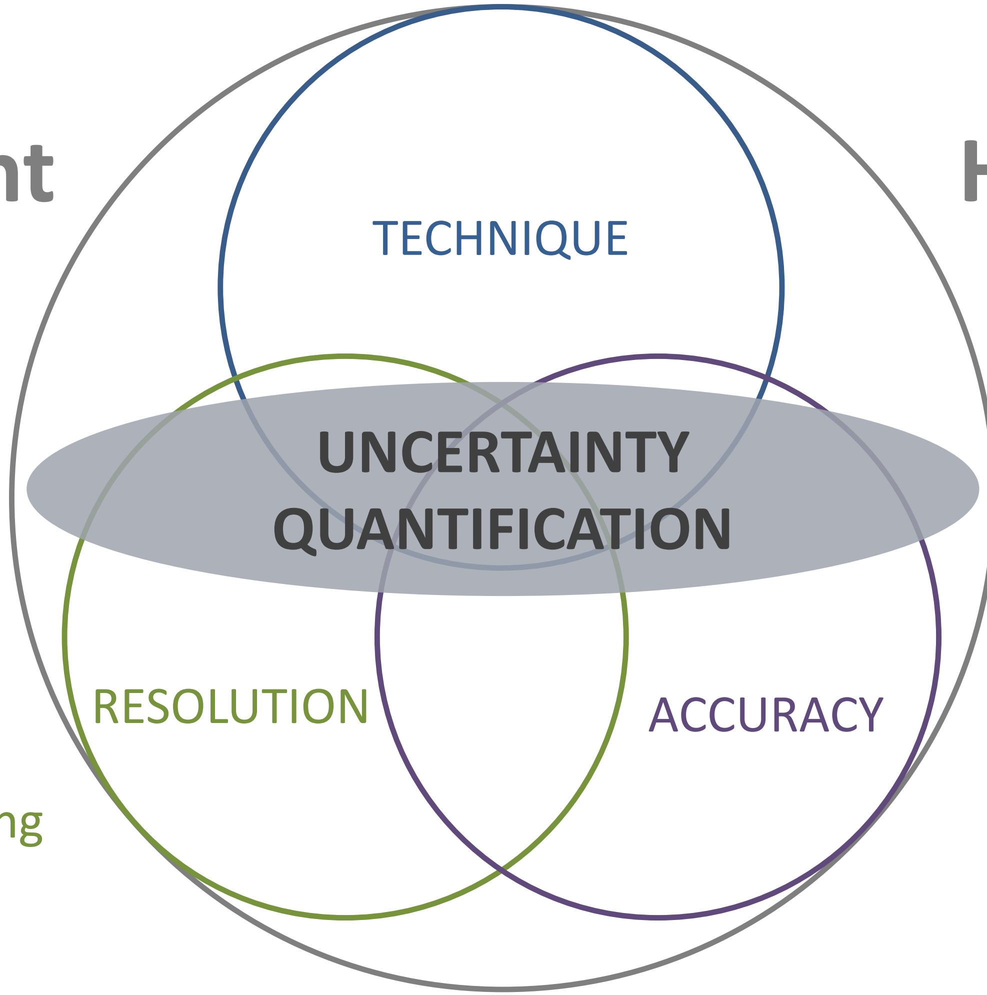
1000+ ITERATIONS

- Error control
- Data transfer
- Fitness for purpose

3. Vision

Intelligent

Holistic



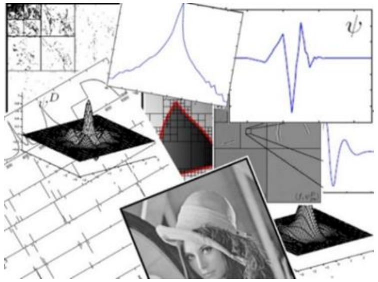
Automated decision-making

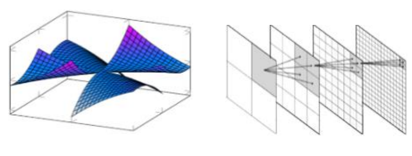
Various scales of grid and domain sizes

~~ITERATIONS~~

4. Technique

MULTI-WAVELETS





POLYNOMIAL ACCURACY

UNCERTAINTY STATISTICS

RESOLUTION DECISION

Single model structure

5. Concept

$$\underbrace{\sum_{j=0}^{2^n-1} u_j^{(n)}\,\varphi_j^{(n)}(x)}_{\text{single-scale}} \approx u(x) \approx \underbrace{\underbrace{u_j^{(0)}\,\varphi(x)}_{\text{coarsest datum}} + \underbrace{\sum_{lev=0}^{(n-1)}\left(\sum_{j=0}^{2^{lev}-1} d_j^{(lev)}\,\psi_j^{(lev)}(x)\right)}_{\text{details}}}_{\text{multi-scale}}$$

5. Concept

- Retain the significant details by **truncation** according to a threshold $\boldsymbol{\varepsilon}$:

$$\check{d}_j^{(lev)} = \begin{cases} d_j^{(lev)} & if \ \left| d_j^{(lev)} \right| > \ \boldsymbol{\varepsilon} \, 2^{lev-L} \\ 0 & otherwise \end{cases}$$

- **Encode** the details to decide an adaptive mesh and then carry out the calculation.

- Only one parameter is needed, which is the $\boldsymbol{\varepsilon}$:

$$\mathbf{0} < \boldsymbol{\varepsilon} < \mathbf{1}$$

6. Feasible basis for Finite Volume models

- $L = 9$ (max. level of resolution allowing $2^9 = 512$ cells)
- $N = 1$ (coarsest datum represented by 1 cell)
- $0.1 \leq \varepsilon \leq 0.001$

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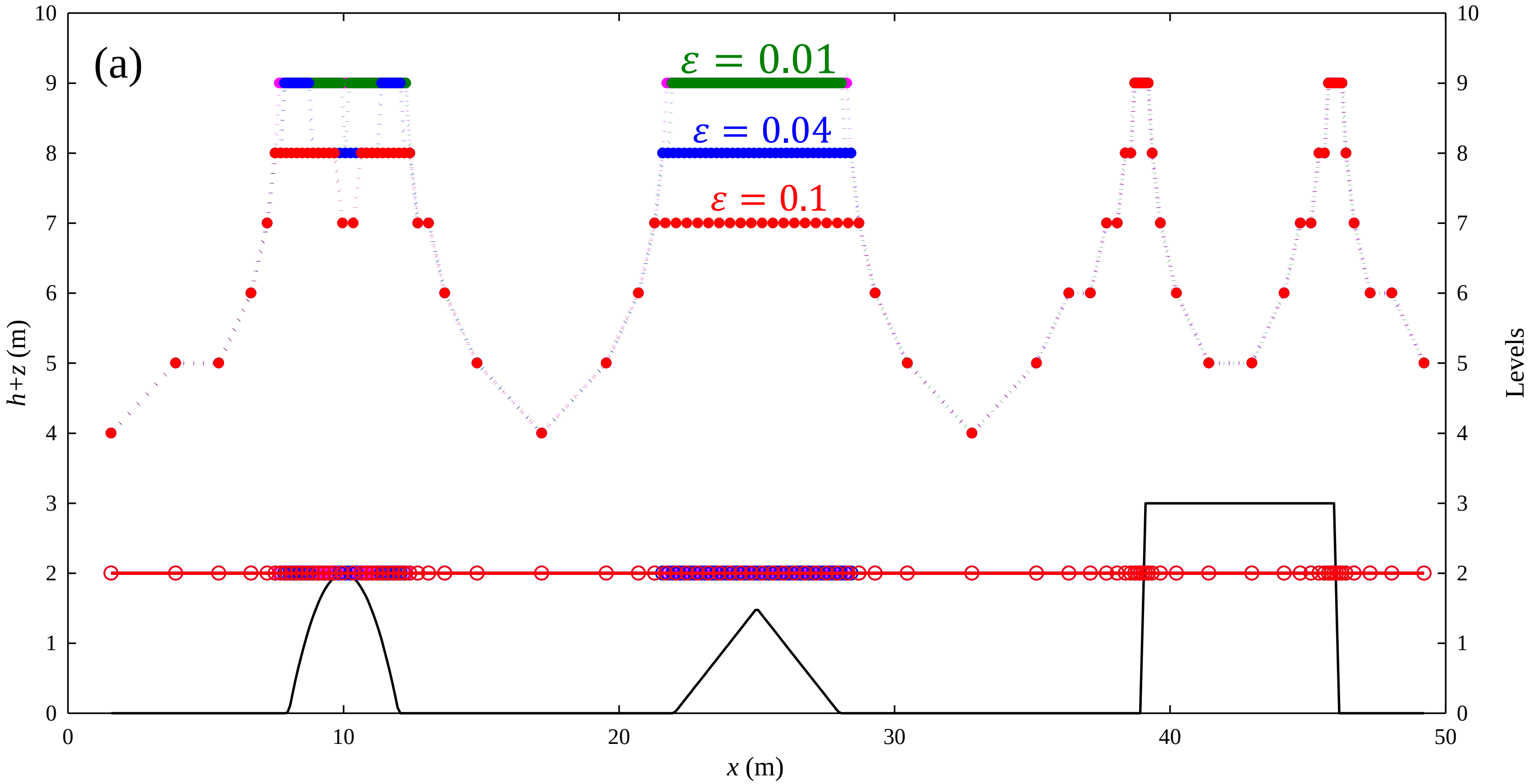

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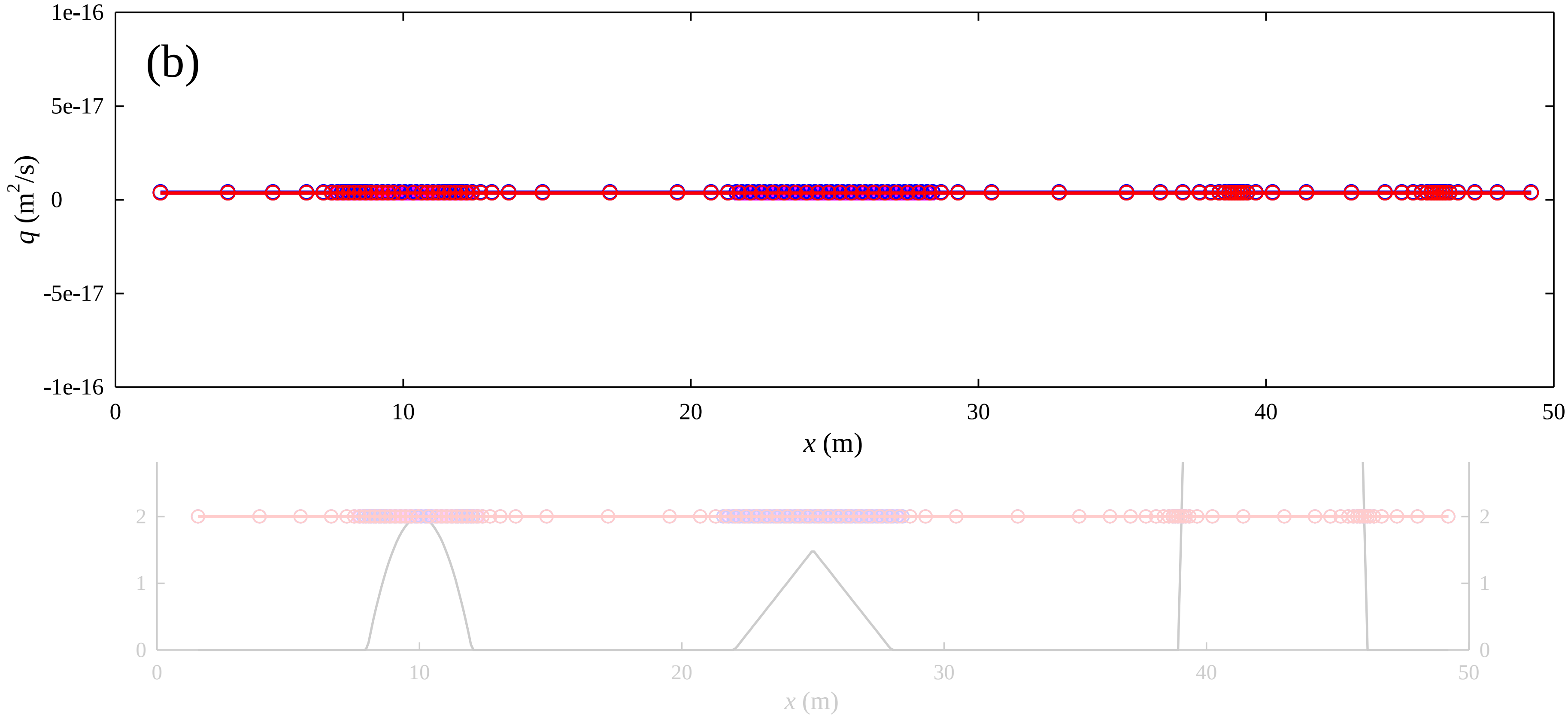

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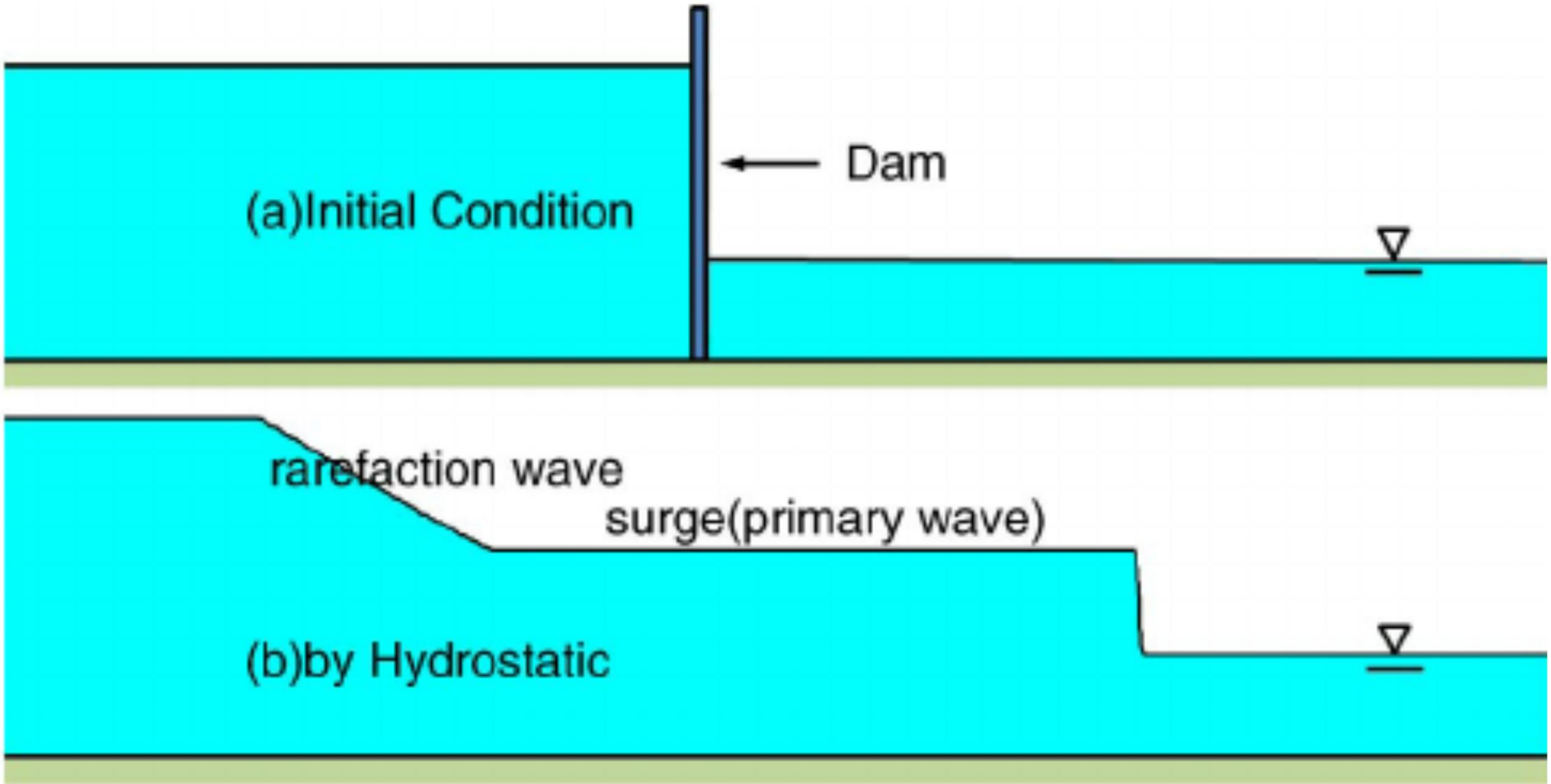

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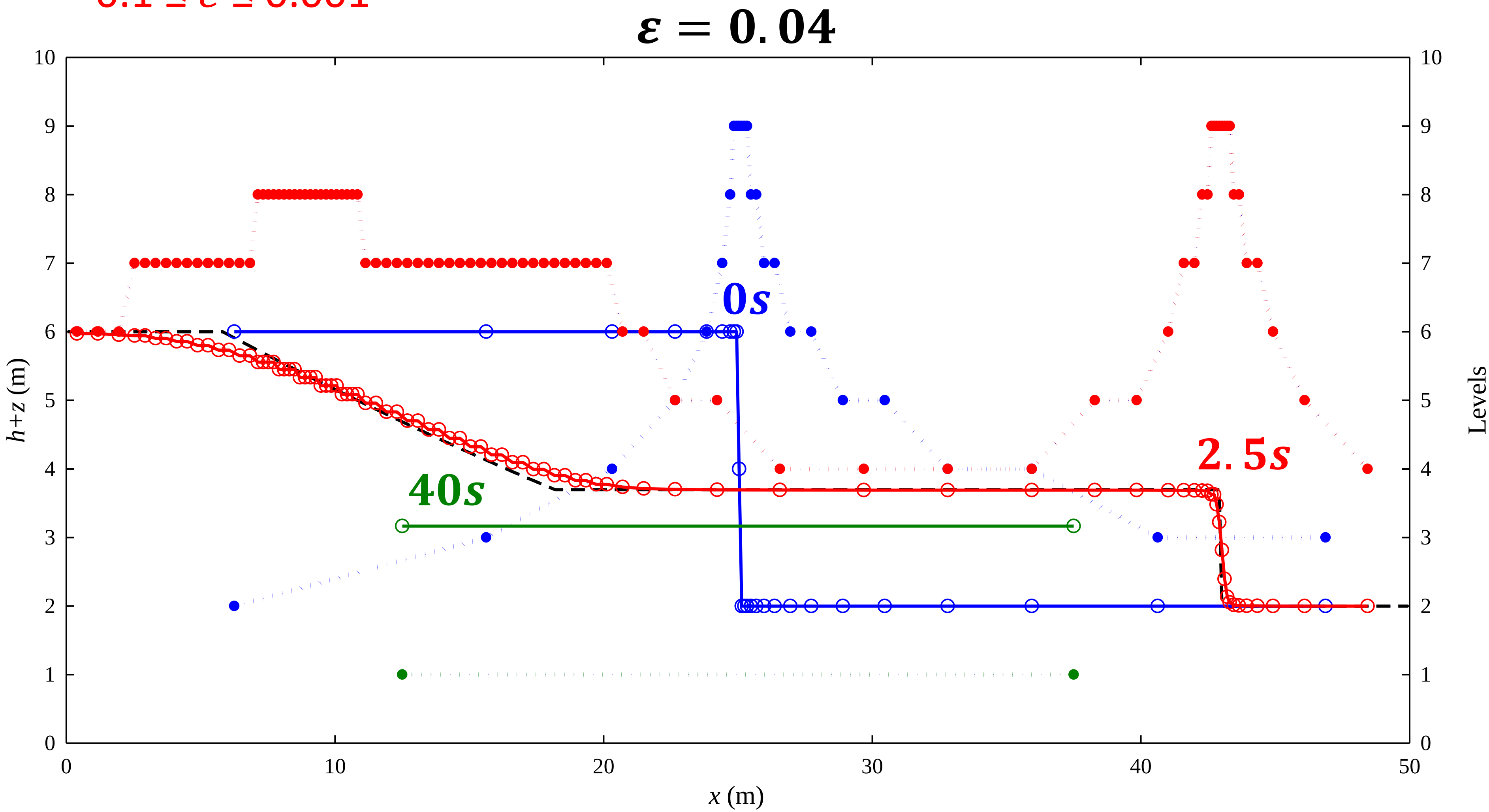

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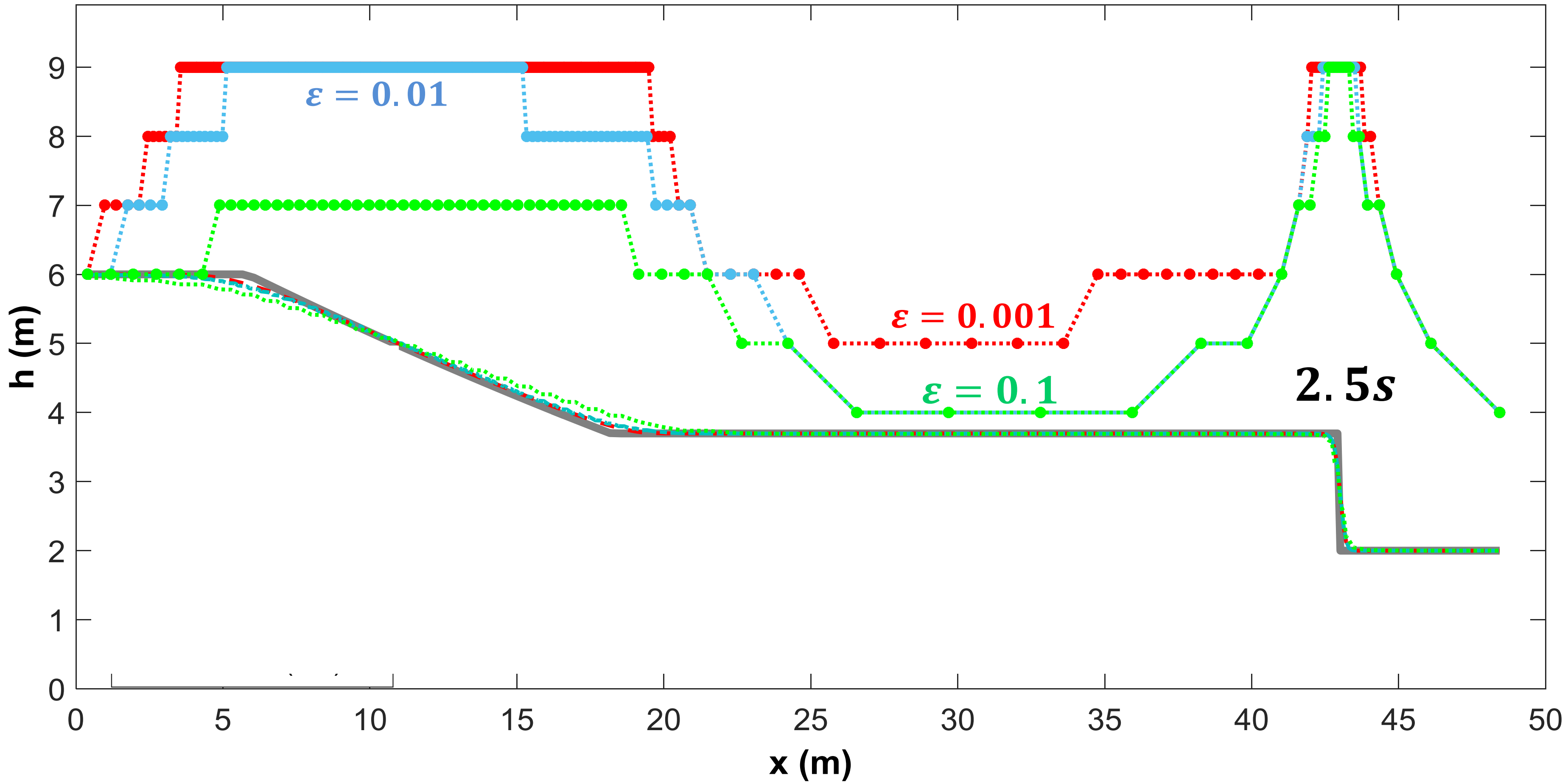

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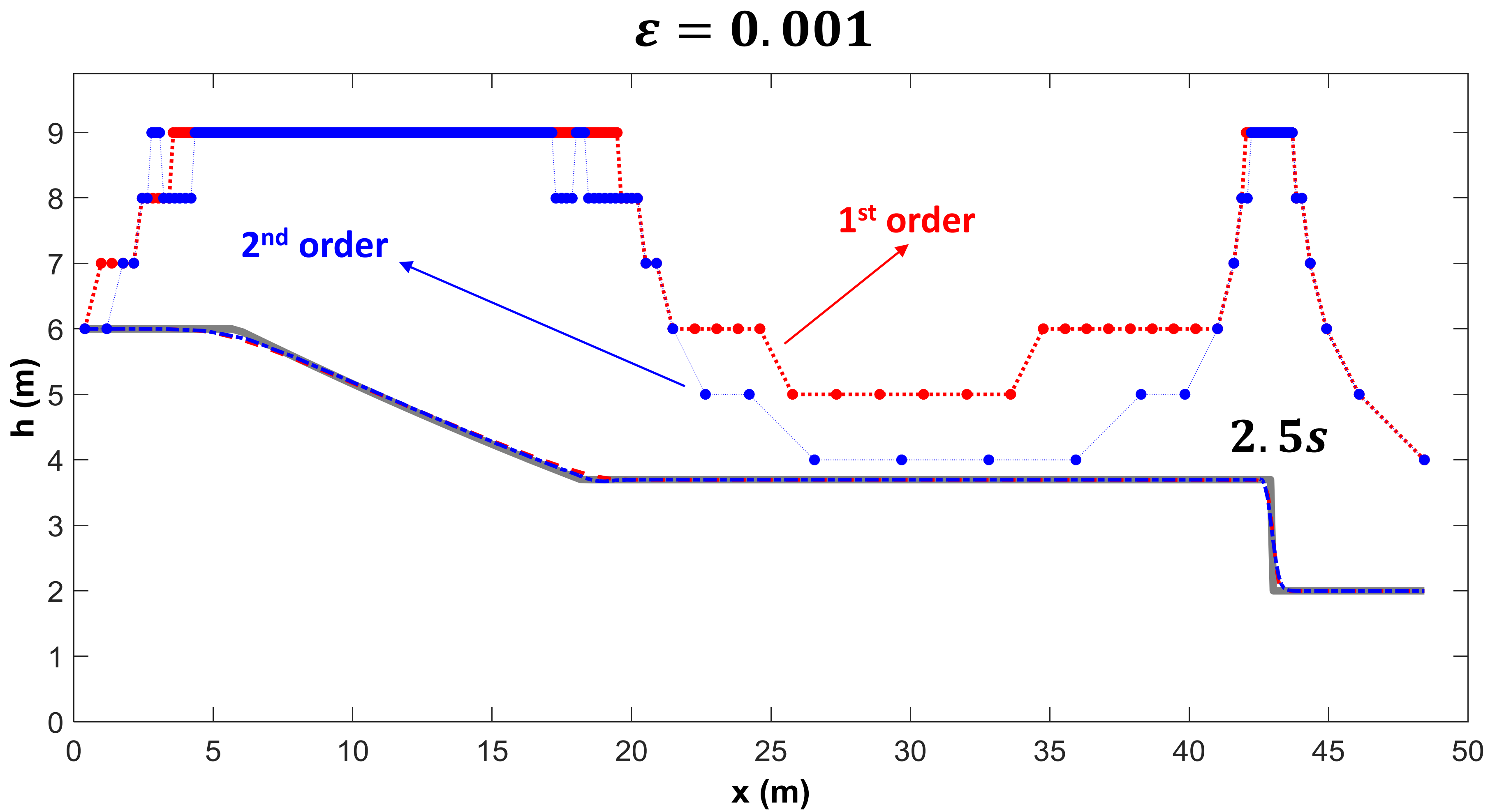
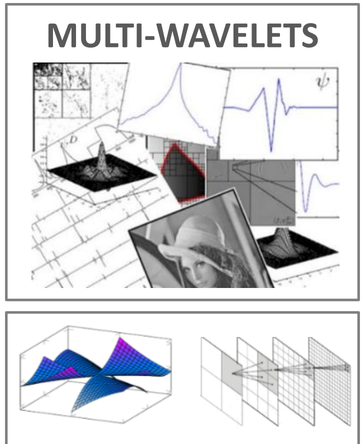


7. Current and future work



POLYNOMIAL ACCURACY | **UNCERTAINTY STATISTICS** | **RESOLUTION DECISION**

Single model structure

Polynomial accuracy in 2D for realistic applications (J. Ayog)

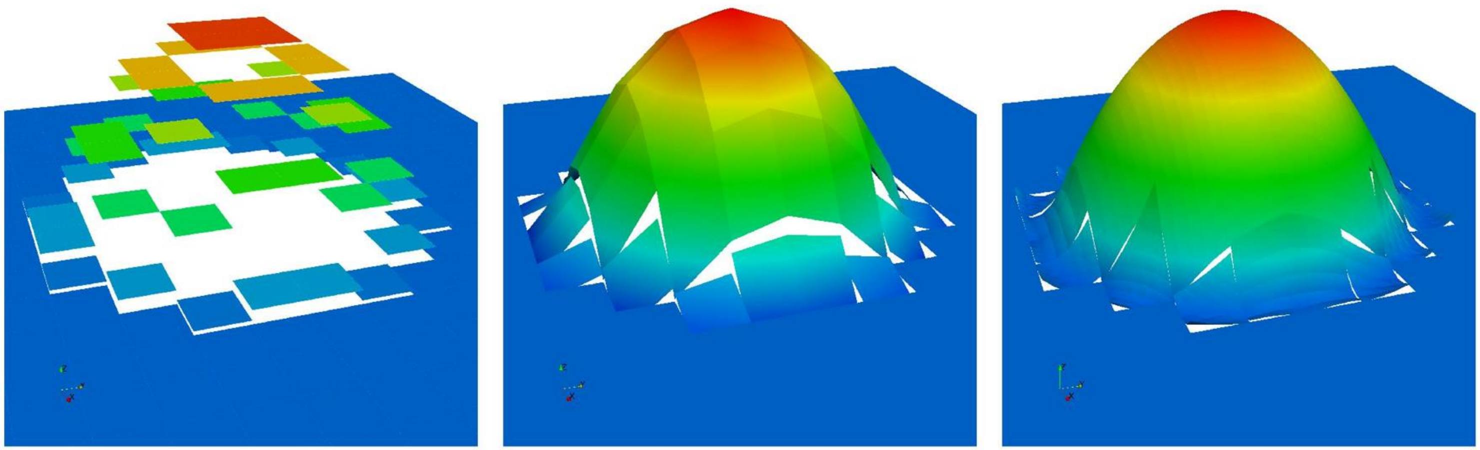
Agent-based version on GPUs (M. Shirvani)

Stochastic formulation (pending)

Polynomial accuracy in 2D for realistic applications (J. Ayog)

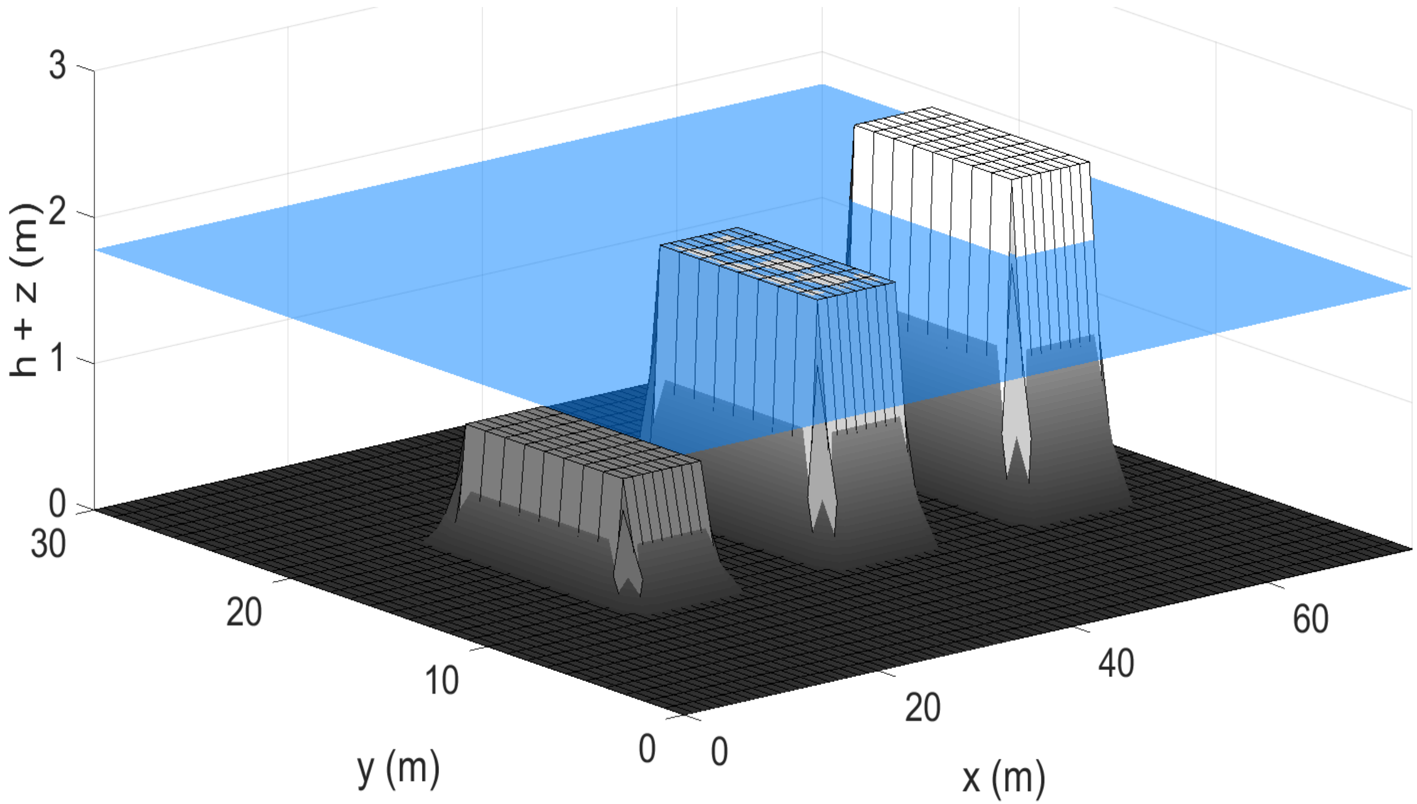
Fully well-balanced discontinuous Galerkin flood model

J. Ayog*, G. Kesserwani and D. Dau*

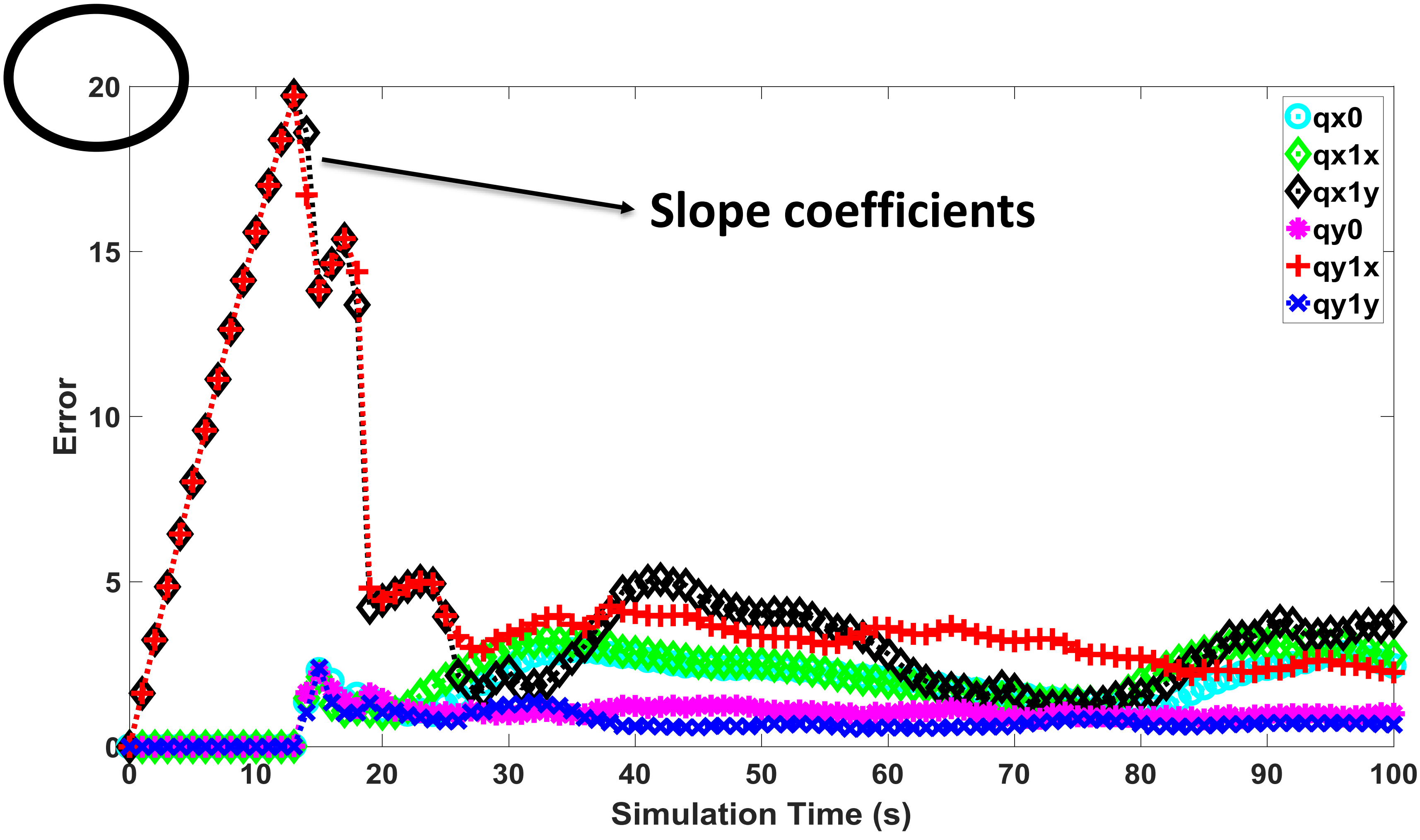


$P = 1$ $P = 2$ $P = 3$

Well-balanced: Discontinuous topography



Results: Not well-balanced for the slopes



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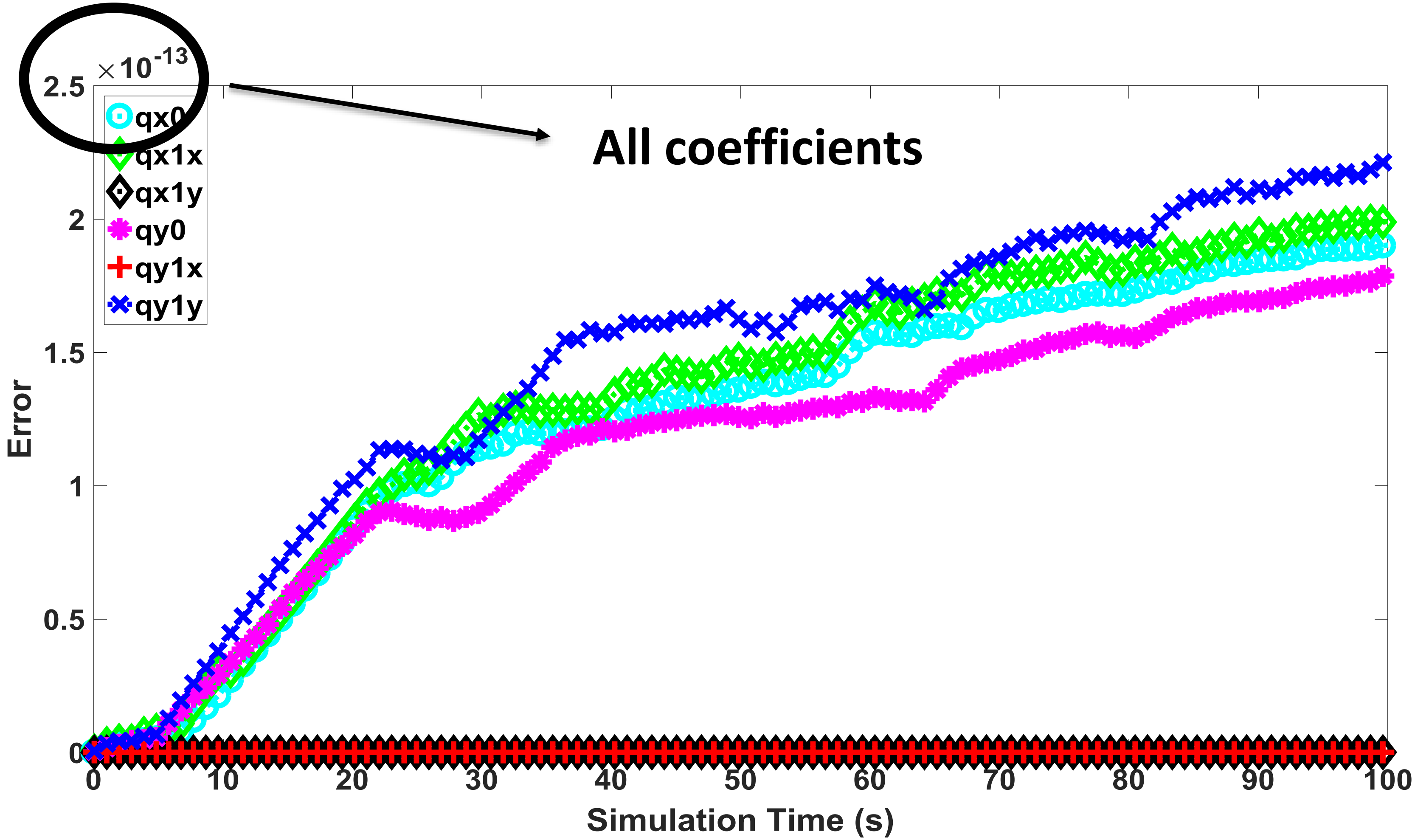
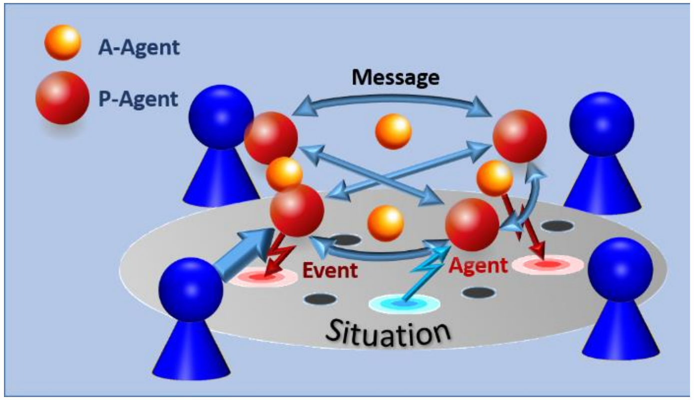


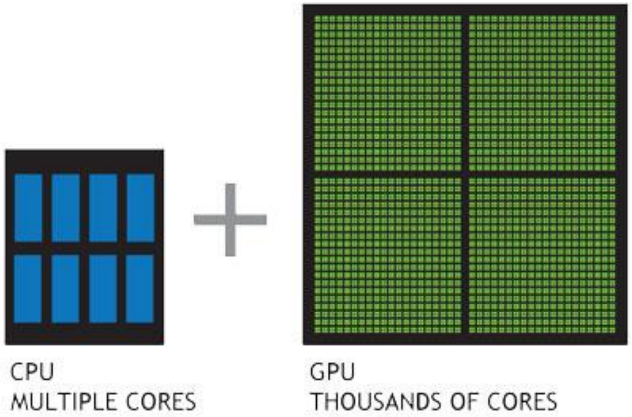
Agent-based version on GPUs (M. Shirvani)

A dynamic multi-agent based flood modelling on GPUs

M. Shirvani*, G. Kesserwani and P. Richmond*

FLAME GPU





Numerical flood model

$$\frac{\partial U}{\partial t} + \frac{\partial F(U)}{\partial x} + \frac{\partial G(U)}{\partial y} = S(U)$$

in which:

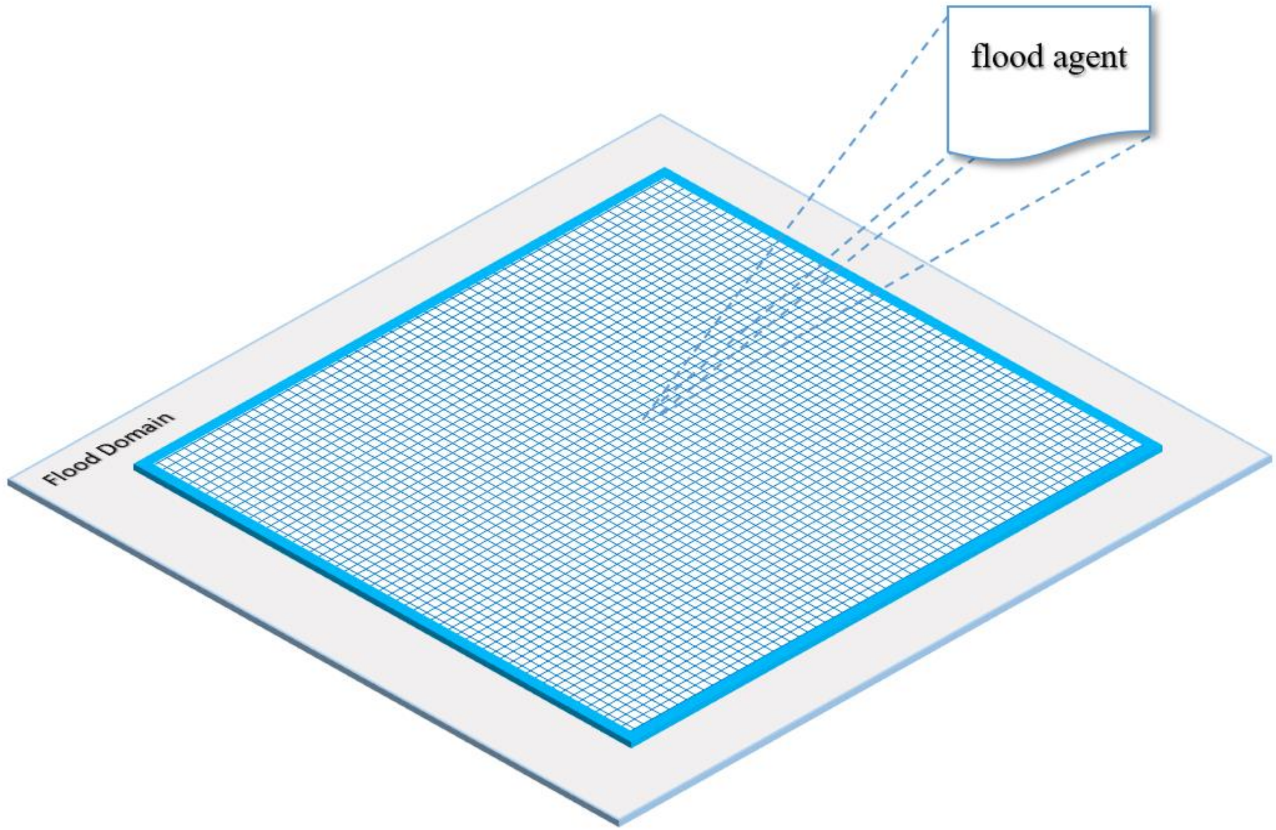
$$U = \begin{pmatrix} h \\ q_x \\ q_y \end{pmatrix} \qquad F(U) = \begin{pmatrix} q_x \\ \frac{{q_x}^2}{h} + \frac{1}{2} g h^2 \\ \frac{q_x\, q_y}{h} \end{pmatrix} \quad G(U) = \begin{pmatrix} q_y \\ \frac{q_x\, q_y}{h} \\ \frac{{q_y}^2}{h} + \frac{1}{2} g h^2 \end{pmatrix}$$

$$S(U) = \begin{pmatrix} 0 \\ gh(S_0^x - S_f^x) \\ gh(S_0^y - S_f^y) \end{pmatrix}$$

Finite Volume Method to solve shallow water equations

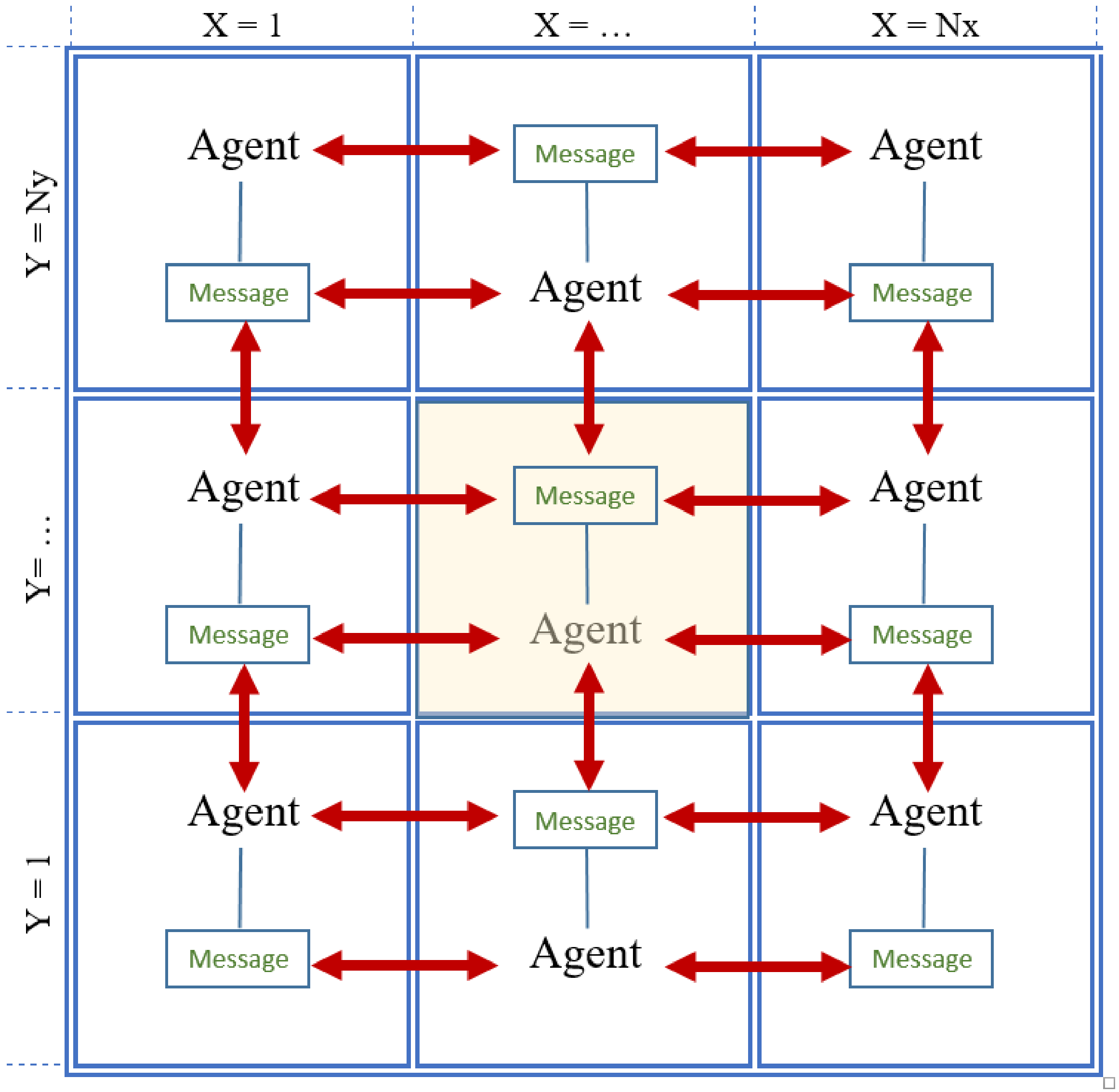
$$U_{i,j}^{n+1} = U_{i,j}^{n} - \frac{\Delta t}{\Delta x}\left(F_{i+\frac{1}{2},j}^{n} - F_{i-\frac{1}{2},j}^{n}\right) - \frac{\Delta t}{\Delta y}\left(G_{i,j+\frac{1}{2}}^{n} - G_{i,j-\frac{1}{2}}^{n}\right) + \Delta t\, S(U)$$

Main challenge



Cannot do sequential calculation

Main challenge



Thanks for listening.
Questions?

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