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A new wetting – drying algorithm integrated in SLIM, with an application to the Tonle Sap lake, Mekong

Hoang Anh Le (1,2), Vu Xuan Huyen Dang (2), Jonathan Lambrechts (3), Sigrun Ortleb (4), Valentin Vallaeys (3), David Vincent (3), Nicolas Gratiot (2), Sandra Soares-Frazao (1), Eric Deleersnijder (5,6)

(1) Civil and Environmental Engineering, Institute of Mechanics, Materials and Civil Engineering (IMMC), Université catholique de Louvain, Place du Levant 1, B-1348 Louvain – la – Neuve, Belgium, (2) Asian Research Center on Water (CARE-Rescif), Ho Chi Minh City University of Technology, Block B7, 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam, (3) Université catholique de Louvain, Institute of Mechanics, Materials and Civil Engineering (IMMC), 4 avenue Georges Lemaître, B-1348 Louvain – la – Neuve, Belgium, (4) Universität Kassel, FB 10, Institut für Mathematik, Heinrich-Plett-Straße 40, D-34132 Kassel, Germany, (5) Université catholique de Louvain, Institute of Mechanics, Materials and Civil Engineering (IMMC) & Earth and Life Institute (ELI), 4 avenue Georges Lemaître, B-1348 Louvain – la – Neuve, Belgium, (6) Delft University of Technology, Delft Institute of Applied Mathematics (DIAM), Mekelweg 4, 2628CD Delft, The Netherlands

Numerical simulation of inundation processes and subsequent drying of floodplains is a challenging issue for hydrodynamic models. In particular, classical approaches are designed for explicit schemes, hence they are time-consuming and prevent fully implicit time integration. In this work, a new wetting – drying algorithm with implicit time-stepping is developed based on piecewise linear Runge - Kutta discontinuous Galerkin approximations for the shallow water equations. The principle of this algorithm is to set a limitation for the fluid depth and a blending parameter in order to ensure local mass conservation and rapid transition of a wet - dry interface. This scheme is integrated into the Second-generation Louvain-la-Neuve Ice-ocean Model (SLIM). The method is first validated by means of the analytical Thacker test case, showing its well-balancing property. Then, it is applied to the Tonle Sap Lake in the Cambodia floodplain, an integral component of the Mekong River Basin. This lake plays an important role in livelihoods of the Southeast Asian riparian residents and has a unique flow feature: it constitutes a storage area for flows coming from the Mekong River during the flooding seasons and then, during the dry seasons, it provides water to the Mekong delta. As a consequence, the Tonle Sap Lake experiences significant water level fluctuations during a year, with large variations of the total flooded area. The simulation results are investigated for two distinct flow seasons, pointing to the well-foundedness of the new wetting-drying scheme.

KEY WORDS: Mekong, Tonle Sap, wetting – drying algorithm, discontinuous Galerkin, finite element method, SLIM.

A new wetting – drying algorithm integrated in SLIM, with an application to the Tonle Sap lake, Mekong

H.A. Le [1,2], V.X.H. Dang [2], J. Lambrechts [1], S. Ortleb [3], V. Vallaeys [1], D. Vincent [1], N. Gratiot [2], S. Soares-Frazao [1], E. Deleersnijder [1,4]

(1) Université catholique de Louvain (UCL), Belgium,
(2) Asian Research Center on Water (CARE-Rescif), Vietnam,
(3) Universität Kassel, Germany,
(4) Delft University of Technology, (TUD) The Netherlands

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Introduction

- Numerical simulation of inundation and drying processes of floodplains is a challenge for hydrodynamic models,
- Classical approaches for Wetting and Drying designed for explicit schemes are time-consuming,
- New Wetting-Drying (W-D) algorithm with implicit time-stepping is presented,
- Local mass conservation and efficiency at rapid transitions are verified,
- Validation using analytical and field test cases.

The Second generation Louvain-la-Neuve Ice-ocean Model (SLIM) [1]

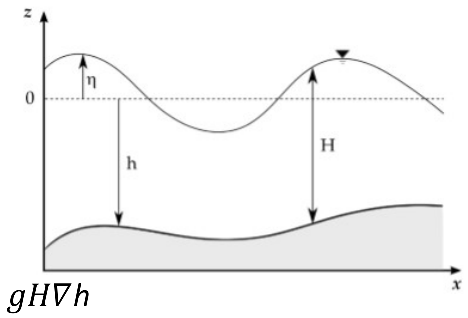
It solves the 2D depth averaged shallow water equations with the following features:

- unstructured mesh,
- discontinuous Galerkin Finite Element Method,
- implicit Runge-Kutta temporal scheme.

Conservation form of the shallow-water equations:

$$\frac{\partial H}{\partial t} + \nabla(H\boldsymbol{u}) = 0$$

$$\frac{\partial H\boldsymbol{u}}{\partial t} + \nabla.\frac{H\boldsymbol{u}H\boldsymbol{u}}{H} + g\nabla\frac{|H|H}{2} + \frac{ng}{H^{7/3}}|H\boldsymbol{u}|\,H\boldsymbol{u} + fe_z \times H\boldsymbol{u} - \nabla.(H\nu\nabla\boldsymbol{u}) = gH\nabla h$$



Wetting – Drying algorithm

The principles [2]

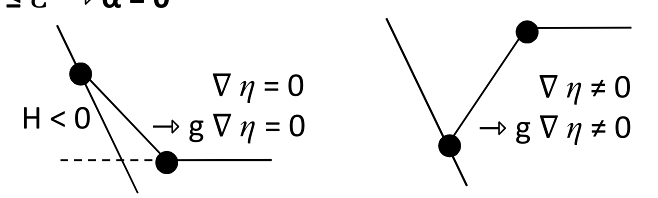
- **Drag**: $ng\frac{|\boldsymbol{u}|}{H^{4/3}} = ng\frac{|H\boldsymbol{u}|}{H^{7/3}}$ — H is solved by max (H, Ɛ)
- **Advection**: $H\boldsymbol{u}\boldsymbol{u} = \frac{H\boldsymbol{u}H\boldsymbol{u}}{H}$ — H is solved by max (H, 20Ɛ)
- **Viscosity**: $-\nabla.H\nu\nabla\boldsymbol{u}$

$H\nabla\boldsymbol{u} = H\nabla\frac{H\boldsymbol{u}}{H} = \nabla H\boldsymbol{u} - \frac{H\boldsymbol{u}}{H}\nabla H$ — H is solved by max (H, Ɛ)

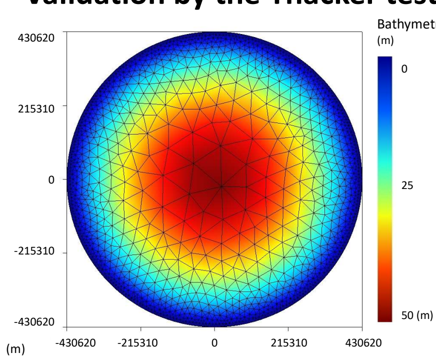
$H = \eta + h$ — $g\nabla\eta \rightarrow \alpha * g\nabla\eta$

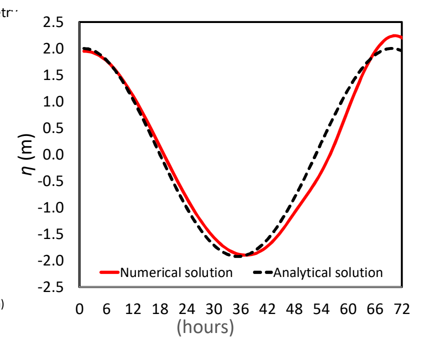
$f = \max(H) - \max(h)$ — $\alpha = \min(1, \max(0, \frac{f-\varepsilon}{4\varepsilon}))$

- **f ≤ Ɛ → α = 0**
- **f > Ɛ → α = 1**



Validation by the Thacker testcase [3]





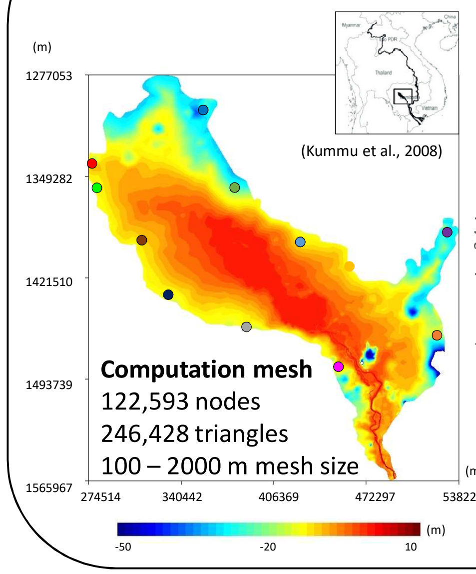
Computed mesh with 2412 triangles, size of 10 – 100 km, η_o = 2 m & h = 50 m

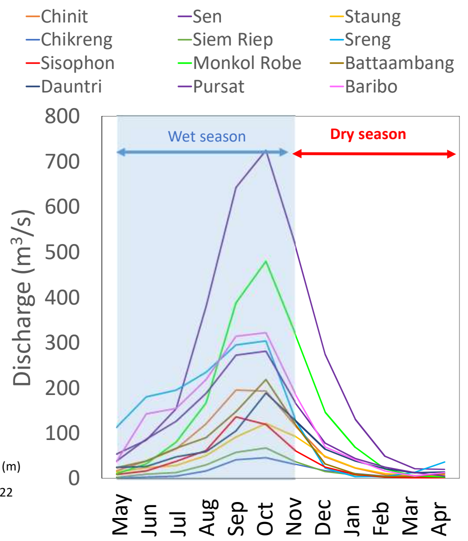
Evolution of the free surface in the domain center with Ɛ = 0.01 m

➢ The free surface evolution by the numerical model is very close to the analytical solution.

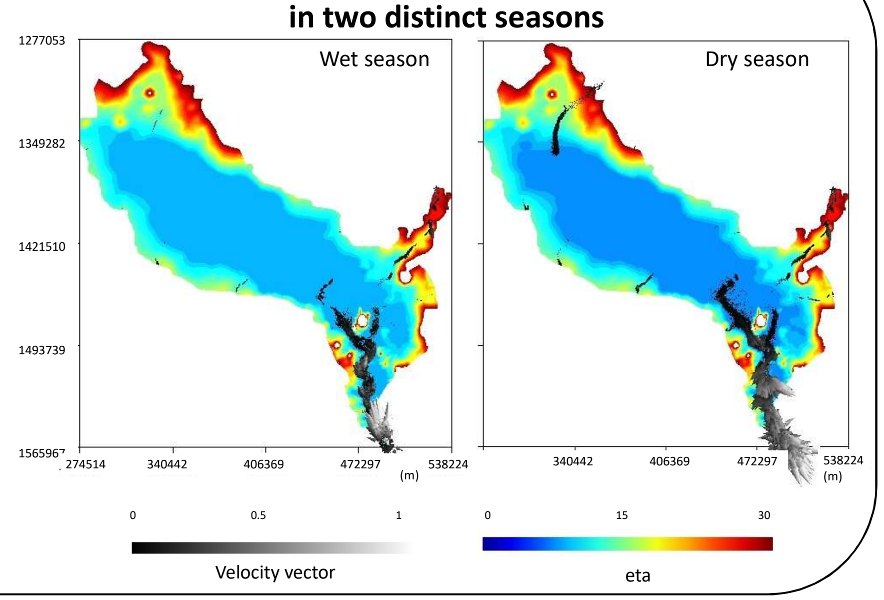
Tonle Sap

In the Cambodia floodplain, an integrated part of Mekong with large area of 83,102 km^2.





Water depth and flow direction of Tonle Sap lake in two distinct seasons



Conclusions

- The new W-D algorithm is well integrated in the SLIM model,
- By the Thacker testcase, it shows the well-balancing property and rapid transition of W-D interfaces in implicit scheme,
- During a year, the Tonle Sap experiences significant water level fluctuations and large variations of the flooded area,
- The simulation results are investigated for two flow seasons:
  - In wet season, water flows from Mekong river to Tonle Sap,
  - In dry season, water flow reverses.
- **Future work:**
  - Extension to higher order elements,
  - Applying to a larger domain of Cambodia floodplain and Mekong Delta.

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References

[1] www.climate.be/slim
[2] Vater, S., Beisiegel, N., & Behrens, J. (2015). A limiter-based well-balanced discontinuous Galerkin method for shallow-water flows with wetting and drying: One-dimensional case. *Advances in Water Resources*, *85*, 1-13.
[3] Thacker, W. C. (1981). Some exact solutions to the nonlinear shallow-water wave equations. *Journal of Fluid Mechanics*, *107*, 499-508.
[4] Kummu, M., & Sarkkula, J. (2008). Impact of the Mekong River flow alteration on the Tonle Sap flood pulse. *AMBIO: A Journal of the Human Environment*, *37*(3), 185-192.