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

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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]

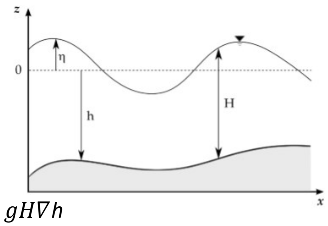
It solves the 2D depth averaged shallow water equations with the following features:

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

Conservation form of the shallow-water equations:

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

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



Wetting – Drying algorithm

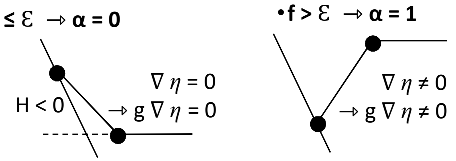
The principles [2]

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

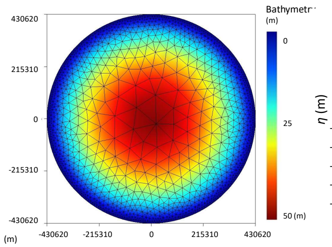
$H\nabla\mathbf{u} = H\nabla\frac{Hu}{H} = \nabla Hu - \frac{Hu}{H}\nabla H$ — H is solved by max (H, ε)

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

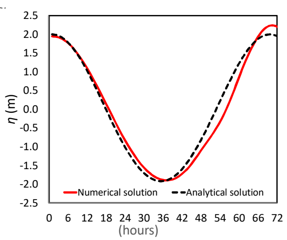
$f = \max(H) - \max(h)$ — $\alpha = \min(1, \max(0, \frac{f-\varepsilon}{4\varepsilon}))$



Validation by the Thacker testcase [3]



Computed mesh with 2412 triangles, size of 10 – 100 km, η_0 = 2 m & h = 50 m

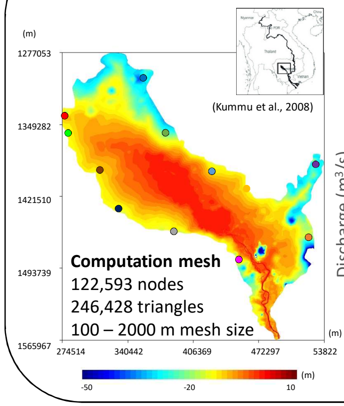


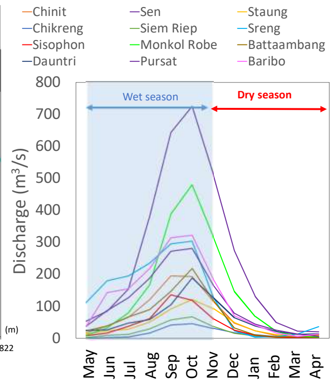
Evolution of the free surface in the domain center with ε = 0.01 m

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

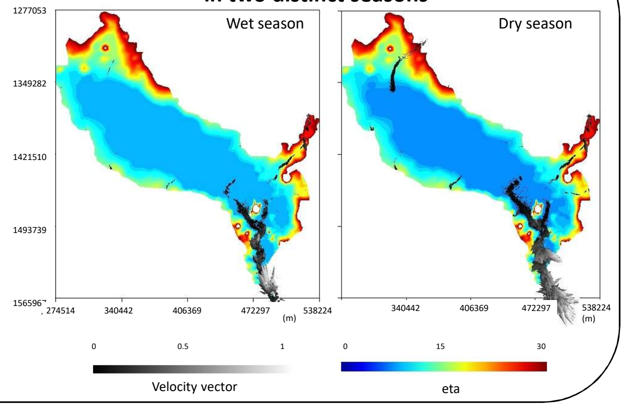
Tonle Sap

In the Cambodia floodplain, an integrated part of Mekong with large area of 83,102 km².





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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