Université catholique de Louvain
Institute of Mechanics, Materials and Civil Engineering

New applications of SLIM: the Mahakam, Mekong and Yangtze river-sea continua

Presented by:
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26 February 2018

Contents

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2 Mekong

3 Yangtze

1 Mahakam

2 Mekong

3 Yangtze

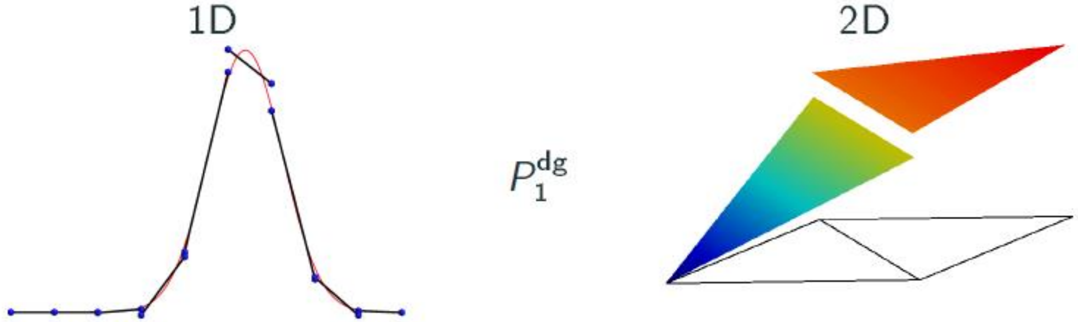
SLIM

•1D river model :linear river segments.

•2D model :triangular elements.

•3D model : triangular prismatic elements.

•Discontinuous Galerkin-FEM approach.

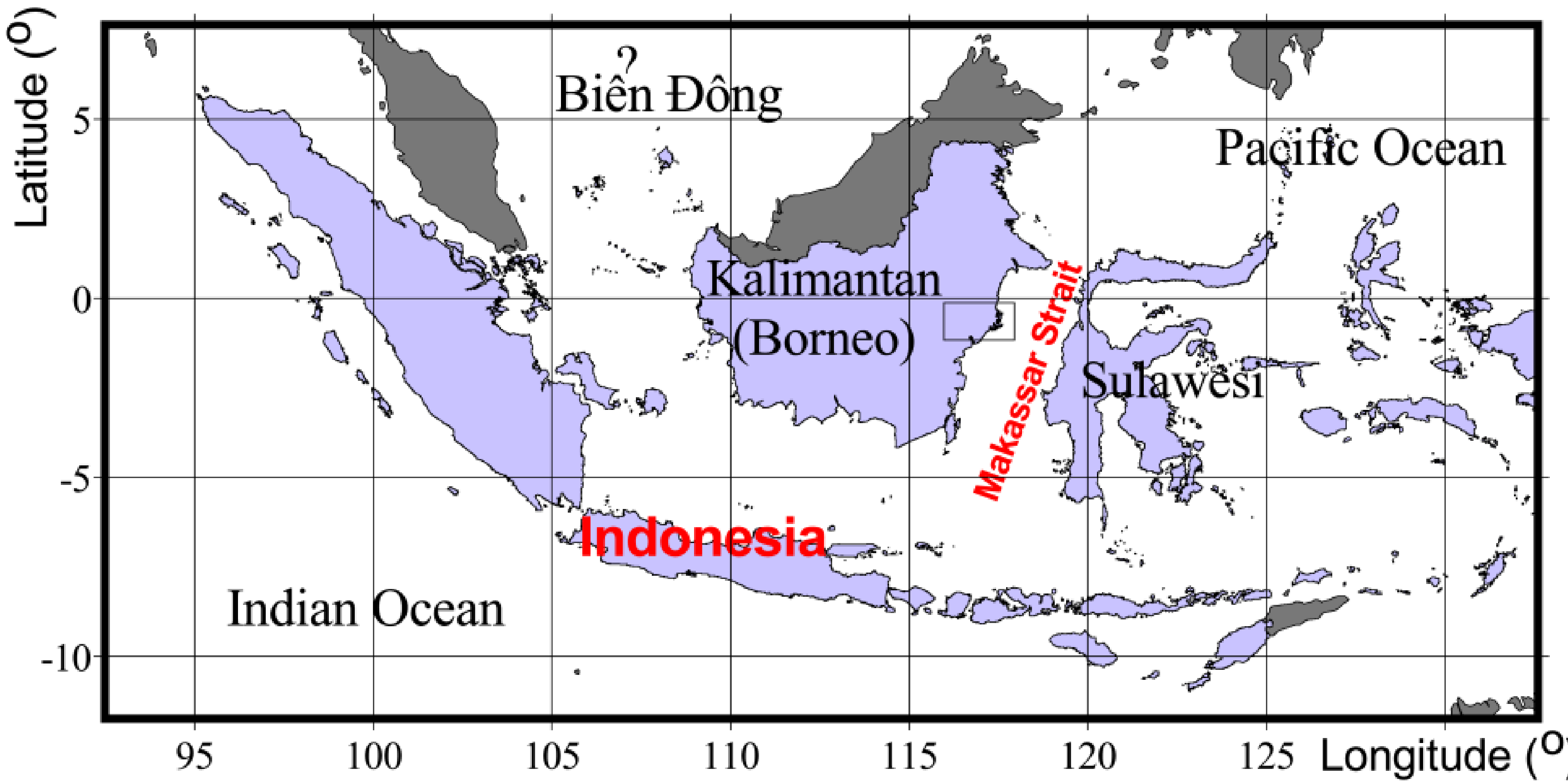


•Time stepping: explicit and semi-explicit Runge-Kutta

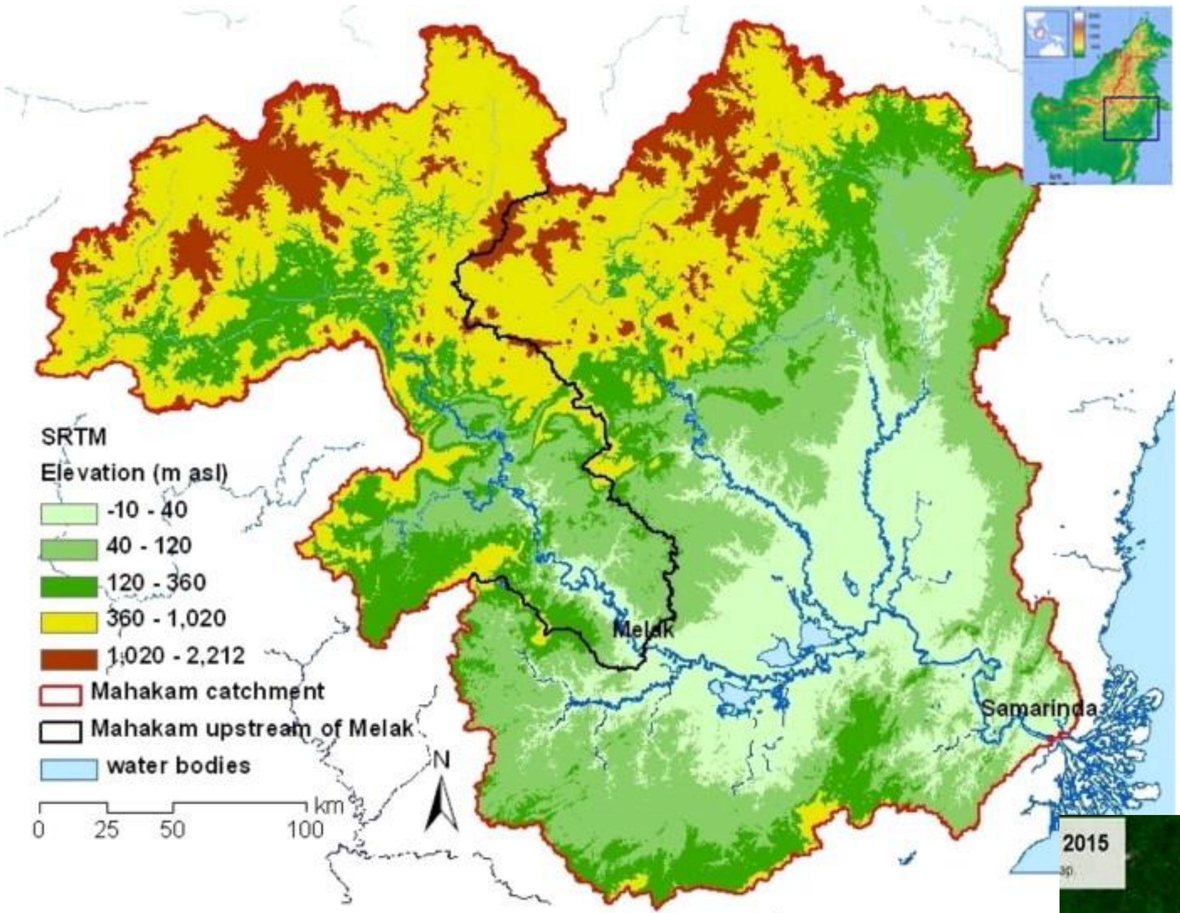
schemes & diagonally implicit Runge-Kutta.

Modeling and diagnosing transport processes in a tropical
river-lake-delta-sea continuum
Application to the Mahakam River (Borneo Island, Indonisia)

The domain of study



- Width: 200 and 300 km
- length : 600 km.
- Mean daily tidal range : 1.2m



The river:

- length : 900 km
- catchment area :75,000 km^2
- water discharge:3000 m^3/s

The delta:

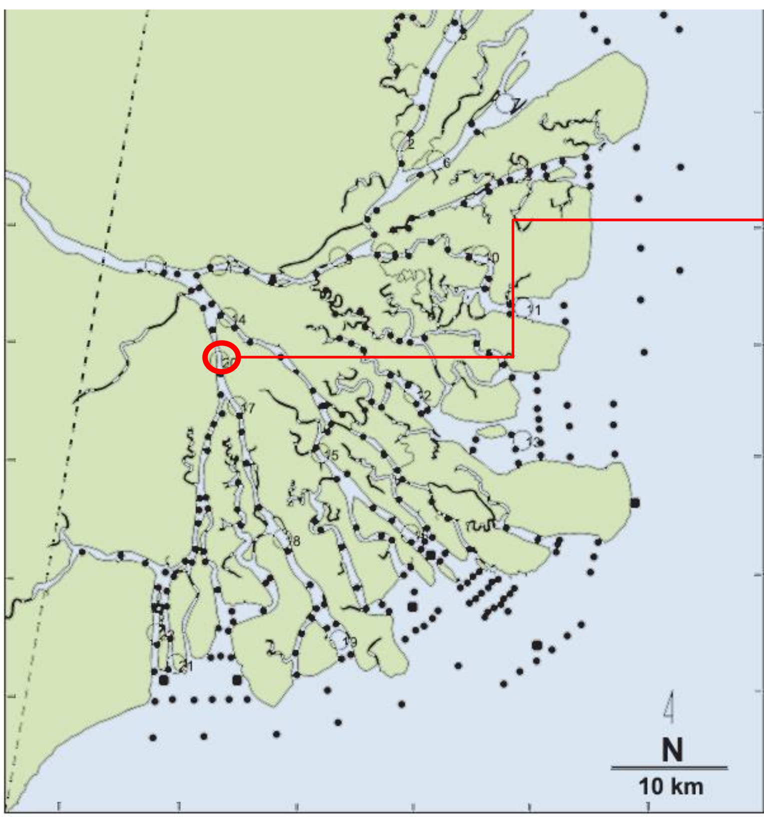
- Radius: 50 km
- Delta plain of 2800 km^2

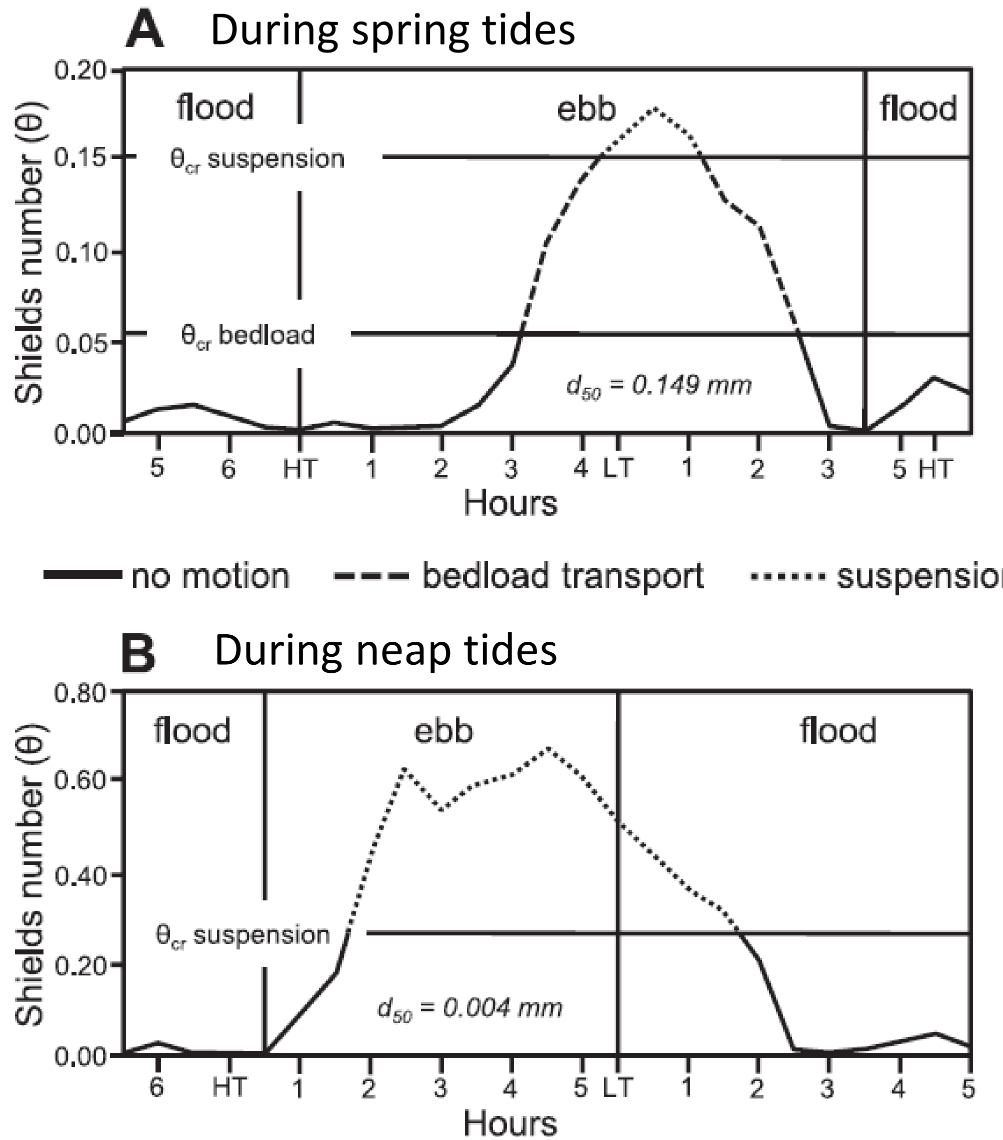
Do we need to study the hole domain River-lakes-delta-sea?

- Influence of lake on the discharge downstream
- Boundary condition

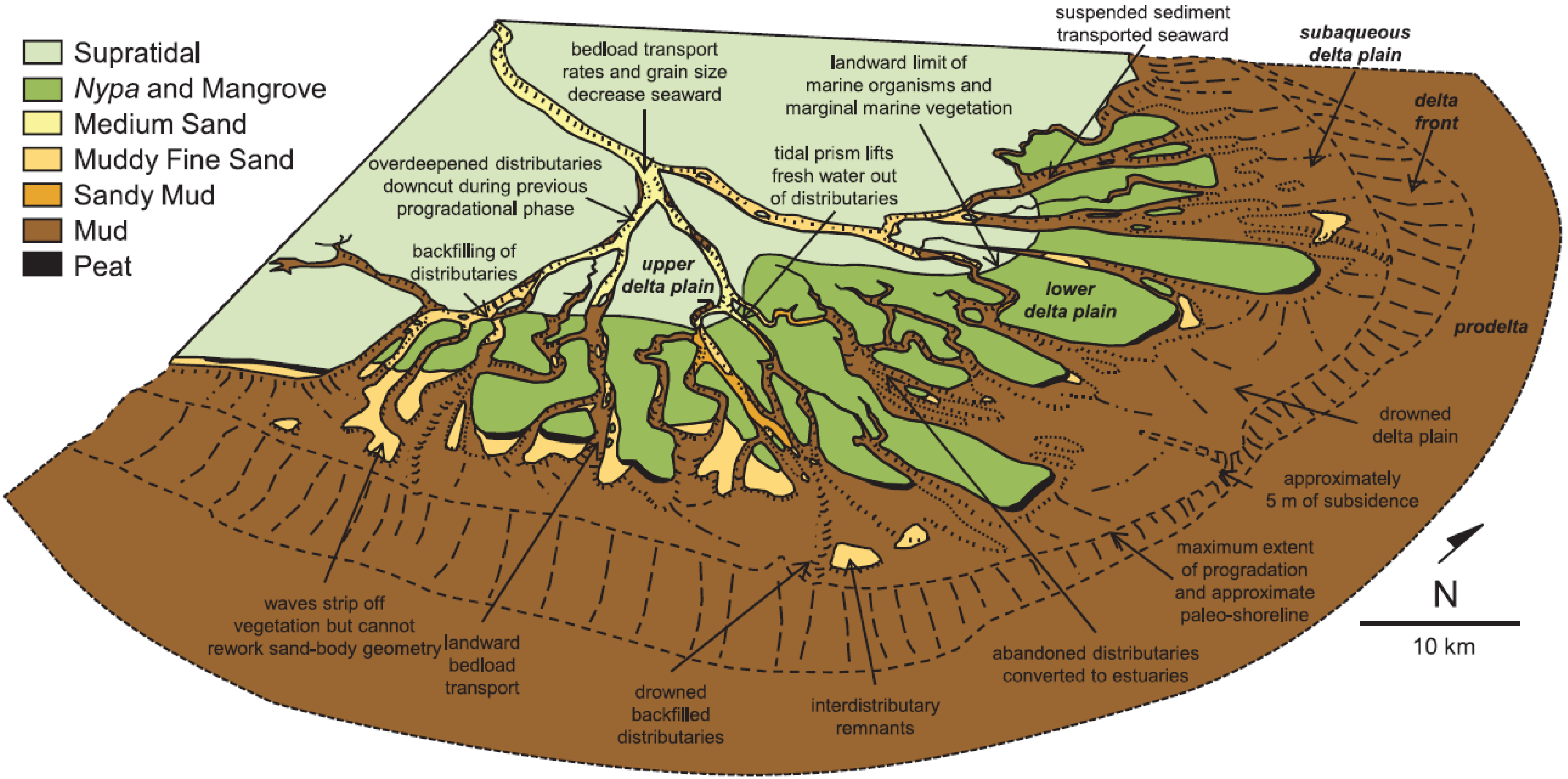
A total rate of 6.35 10^5m3 /yr of sediment can not be neglected!

- 96% of mud
- The transport is influenced by :
  - the tidal cycle
  - the position



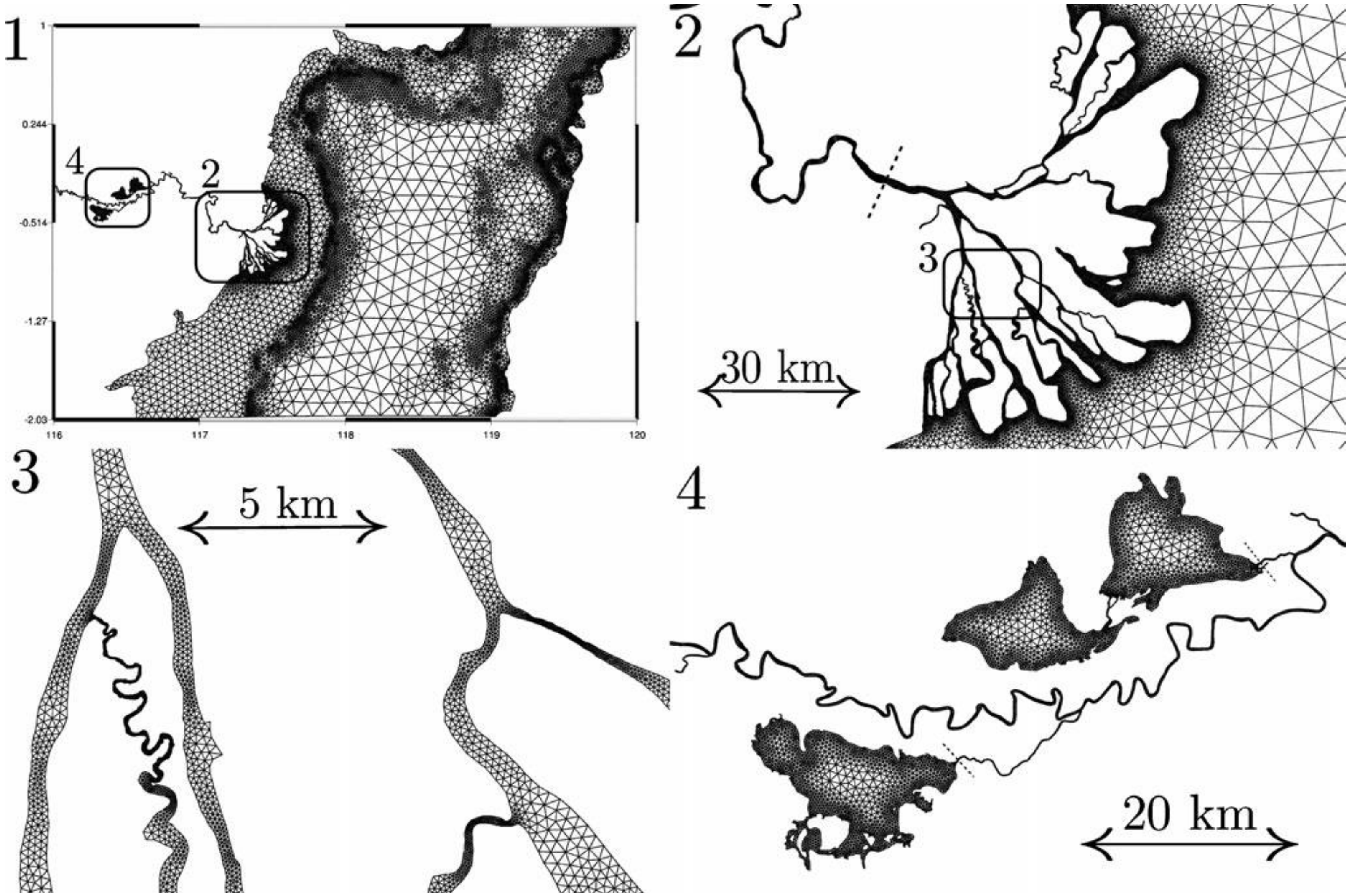


The delta is in progradation!

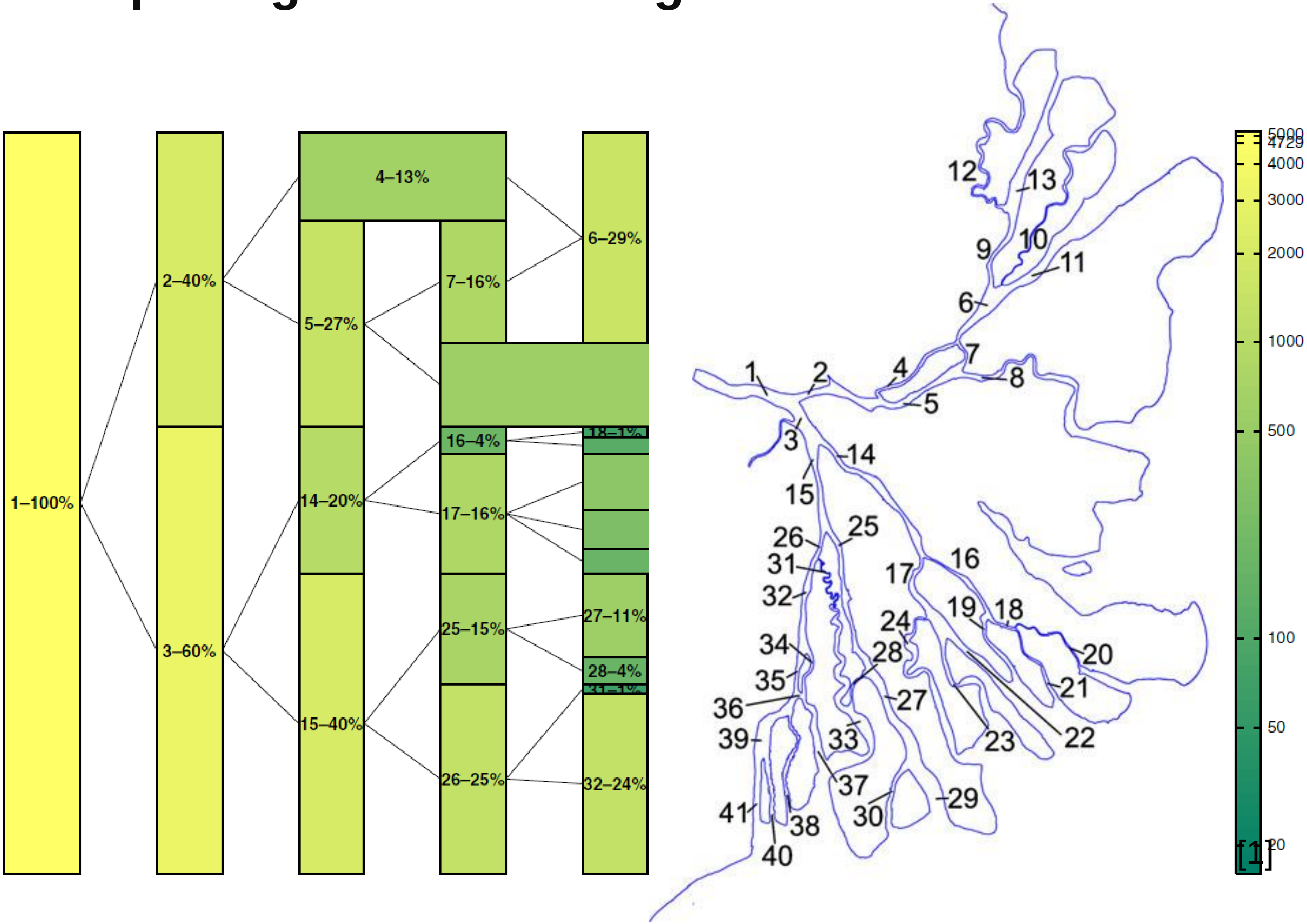


What has been done: First results using SLIM

Benjamin de Brye (2011): “Finite-Element Modelling of River-Sea continua”[1]

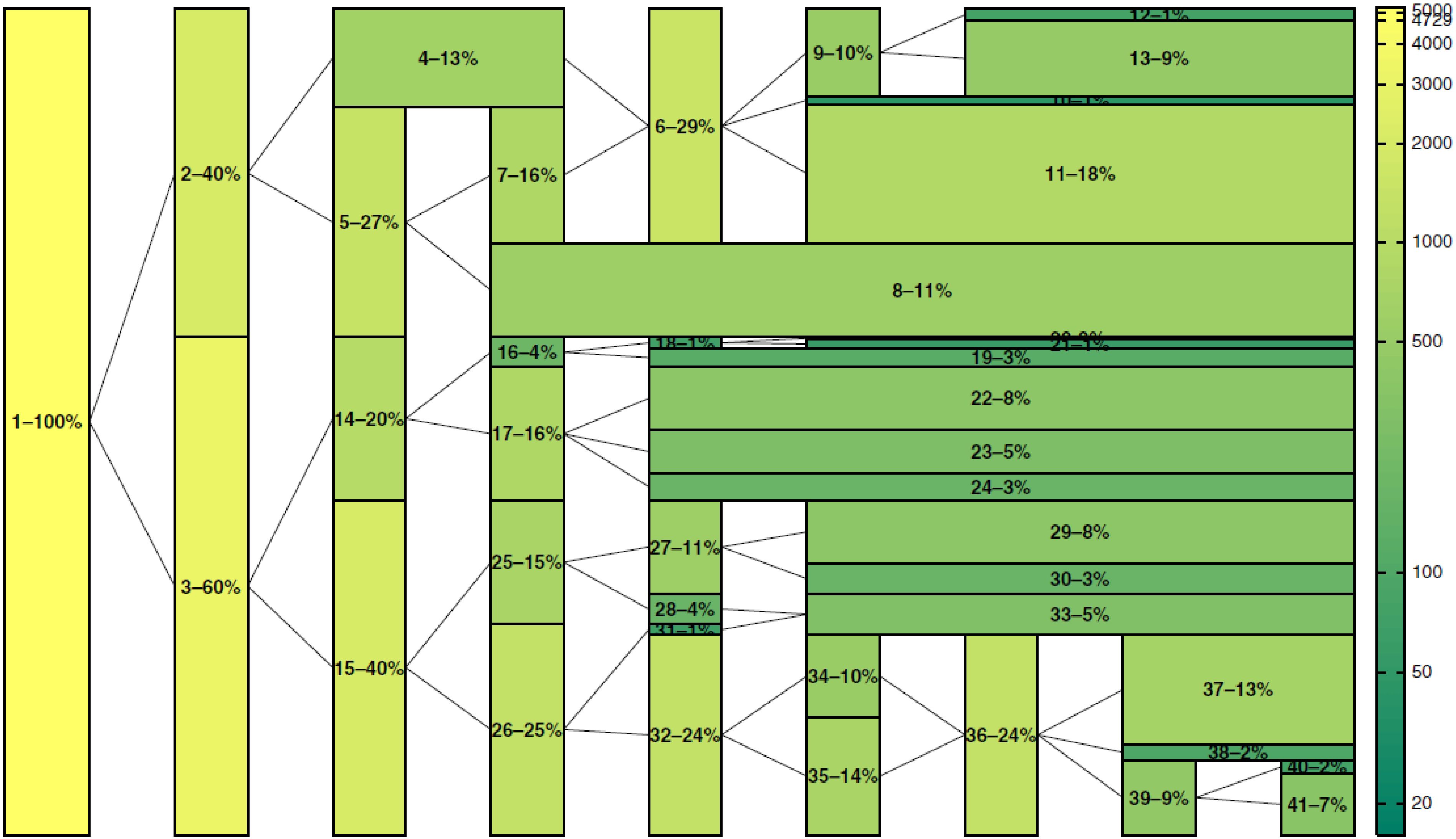


The splitting of the discharge

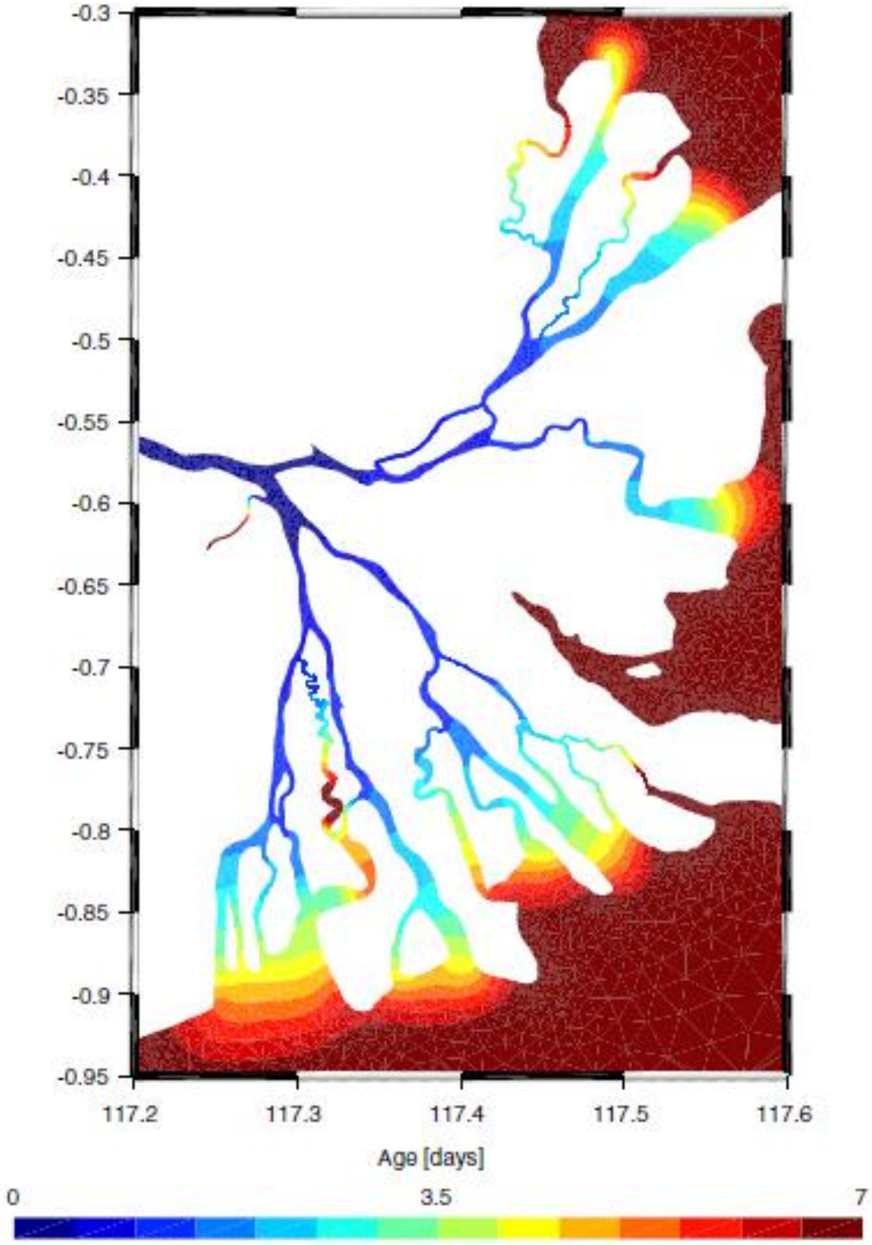


[1]

The splitting of the discharge

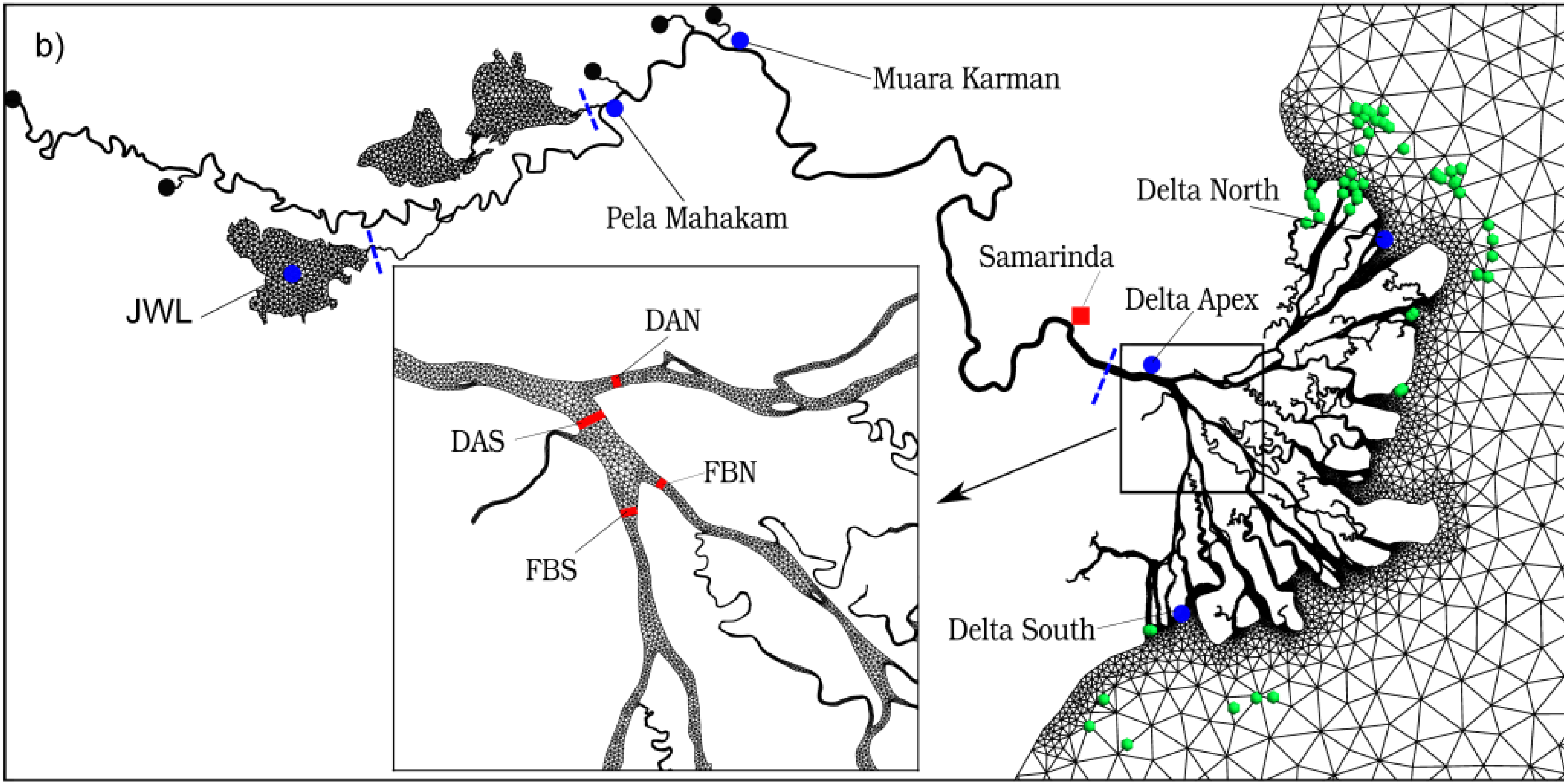


The age of water parcel:

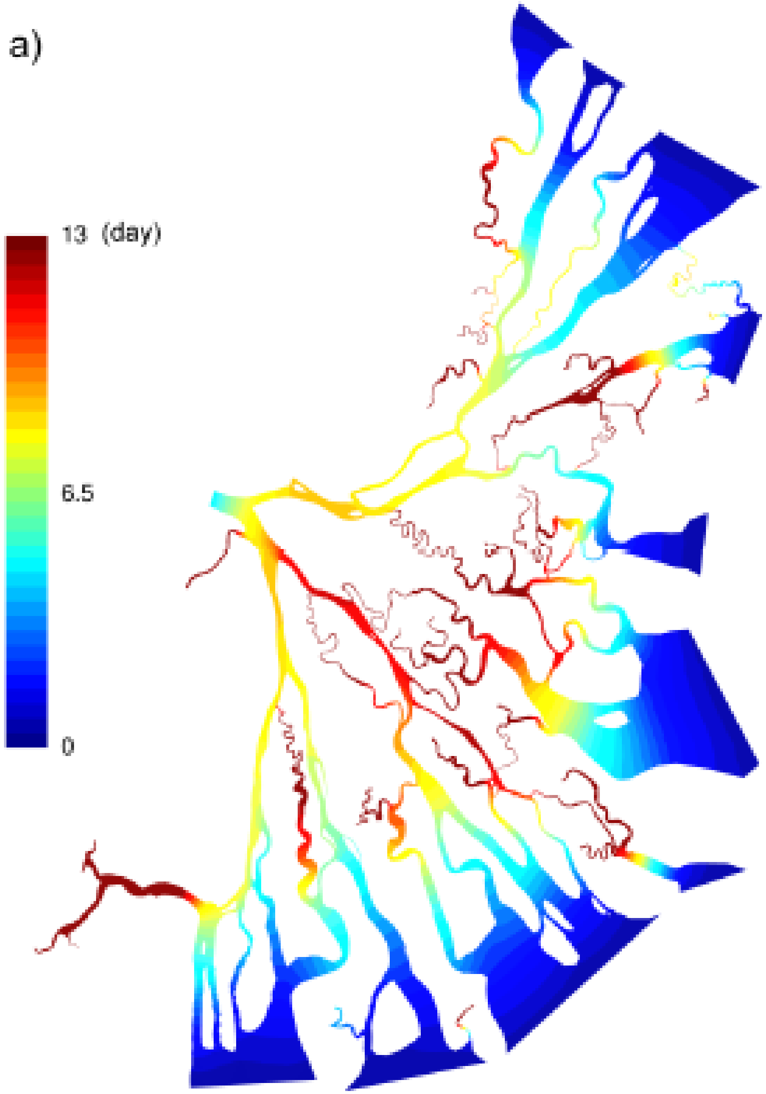


[1]

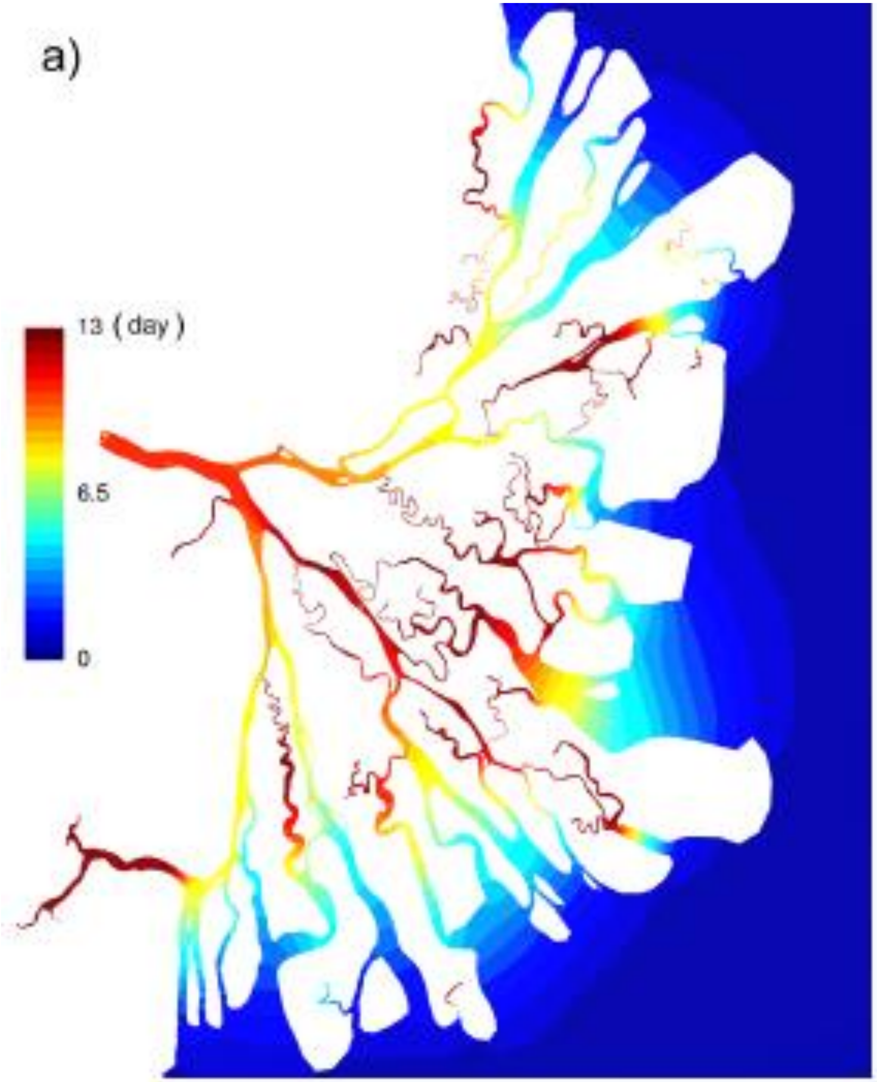
Chien Pham Van(2014) :"Development of a finite element model simulating flow and sediment dynamics: Application to the Mahakam land-sea continuum (Indonesia)"[2]



Residence time

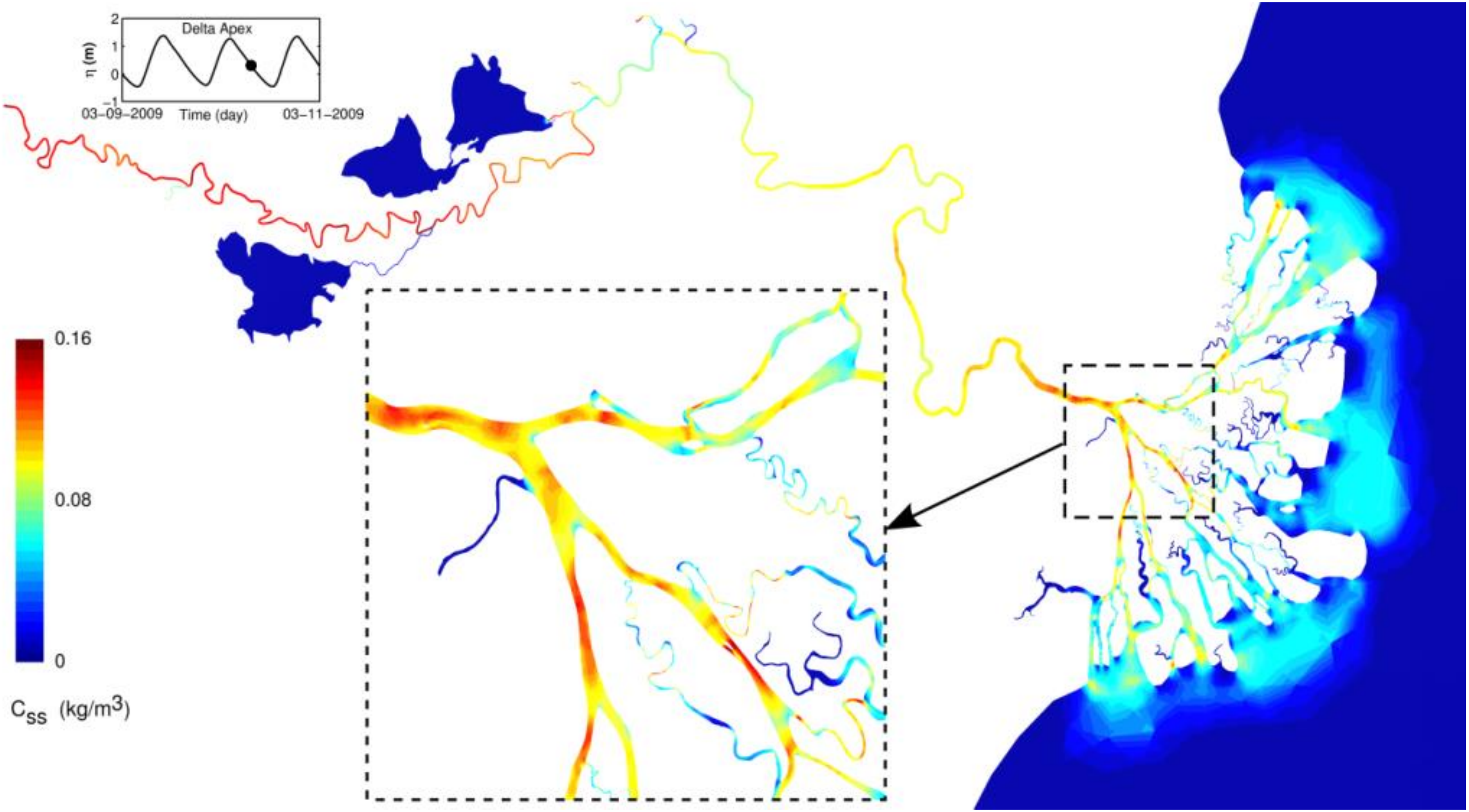


Exposure time



[2]

Spatial distribution of SSC



My PhD: The future work

- Applying a morphodynamical model to the delta
- Introduction Partial age to the model
- Generating a 3D model

1. Mahakam
2. Mekong
3. Yangtze

Introduction

Presenter:	**Le Hoang Anh**
	(at UCL since Sept. 2016)
Supervisors:	**Prof. Sandra Soares-Frazão** (UCL)
	Dr. Nicolas Gratiot (CARE, Vietnam)
Commitee members:	**Prof. Eric Deleersnijder** (UCL)
	Dr. Jonathan Lambrecht (UCL)
	Ass. Prof. Nguyen Thong (CARE, Vietnam)
Fundings:	Université catholique de Louvain (UCL)
Collaborations:	Centre Asiatique de Recherche sur L'Eau (CARE)

Simulating hydrodynamics and sediment transport in the Lower Mekong River

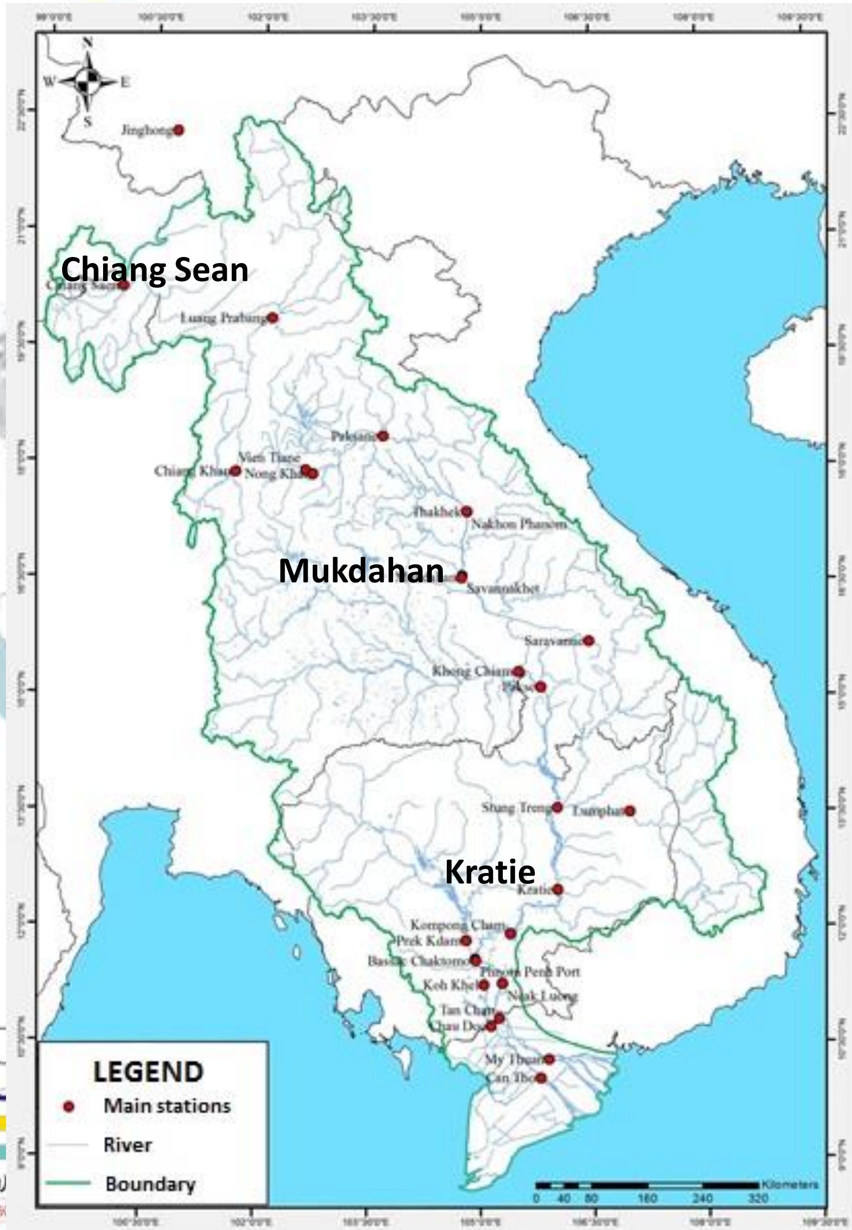
Challenges

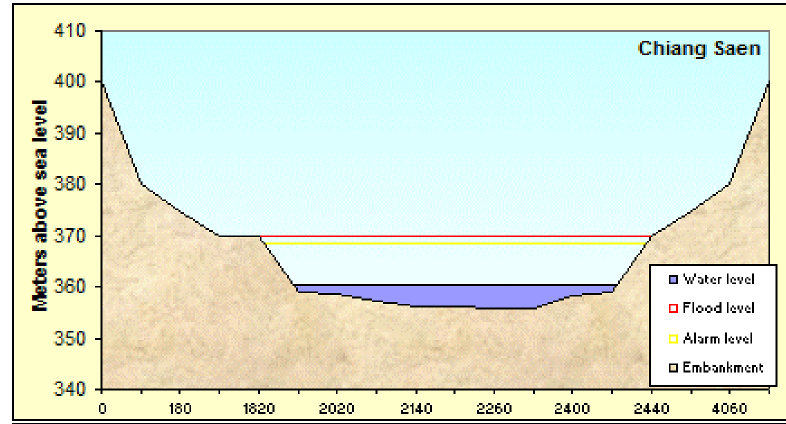
- Changes in hydrological flow;
- Erosion and siltation;
- Saltwater intrusion and water pollution.

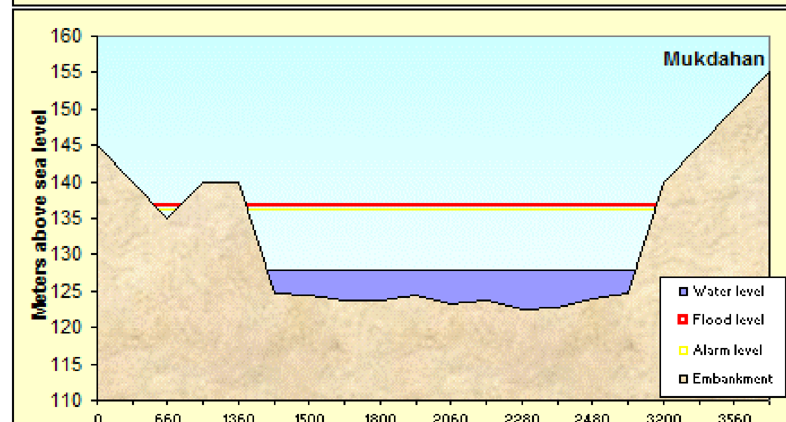
Objectives

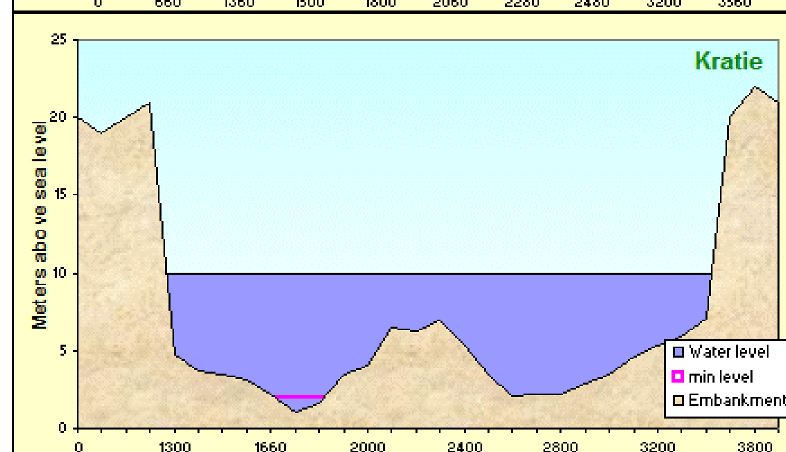
- Modelling the distribution and fluctuation of the flow;
- Simulating suspended sediment dynamics;
- Assessing salt intrusion / water quality.

Mekong River Basin

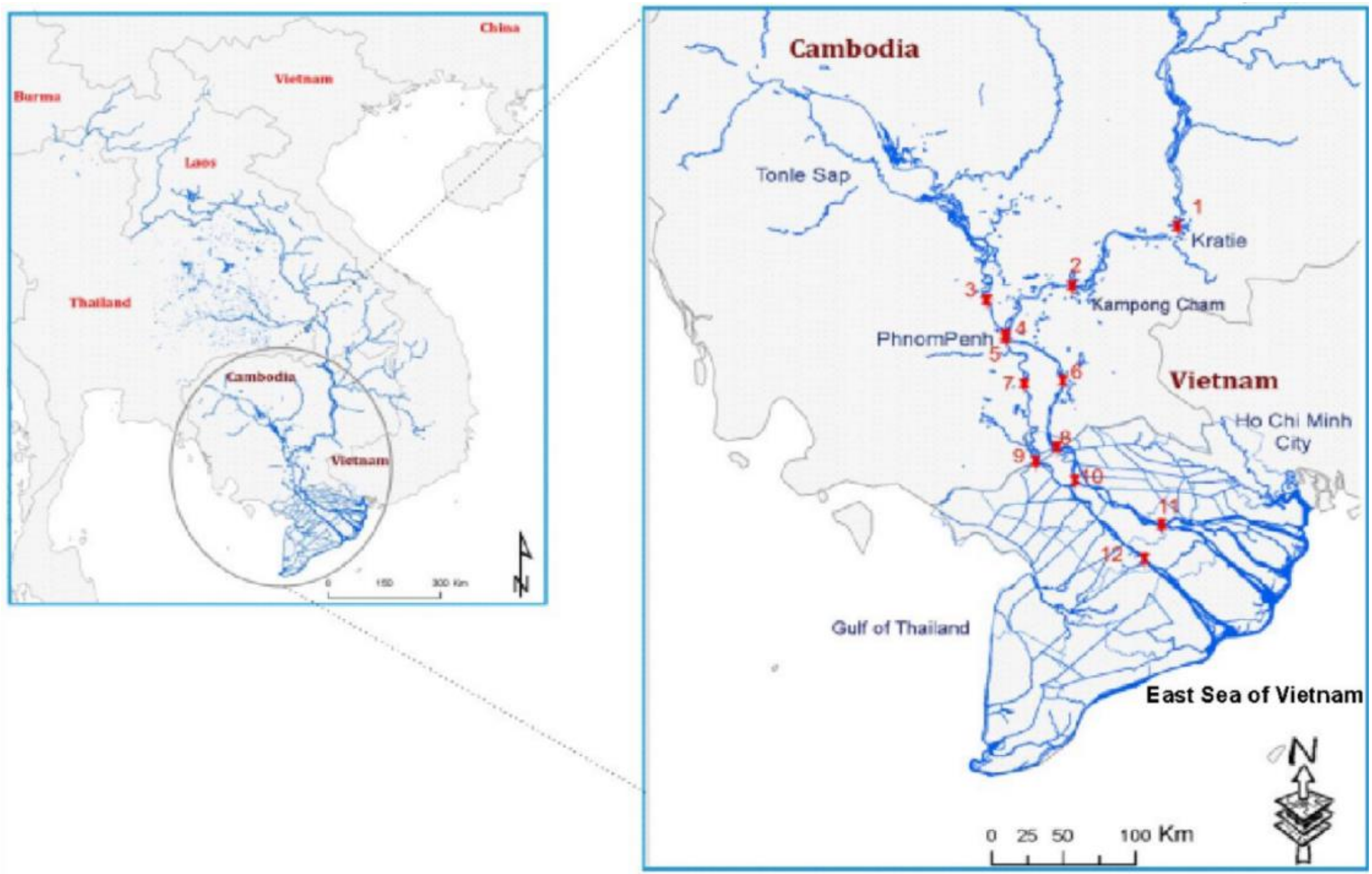






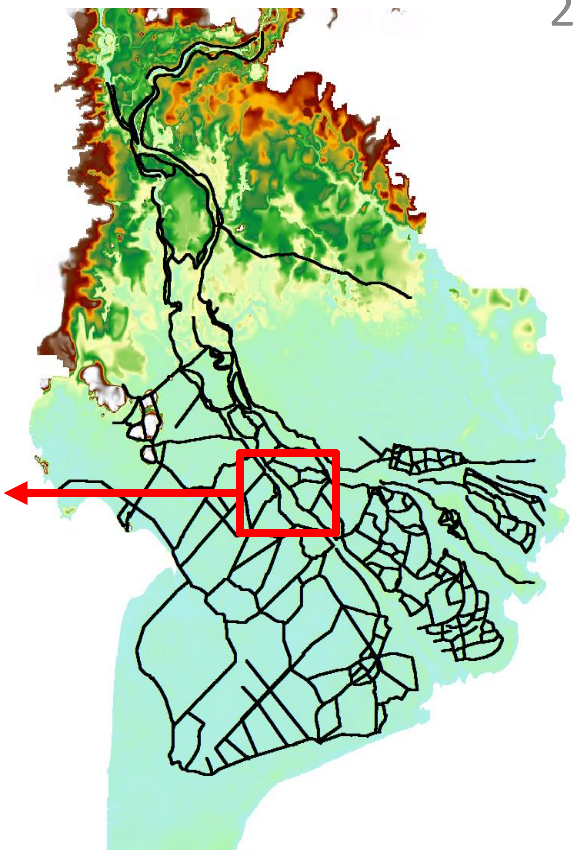


2D domain

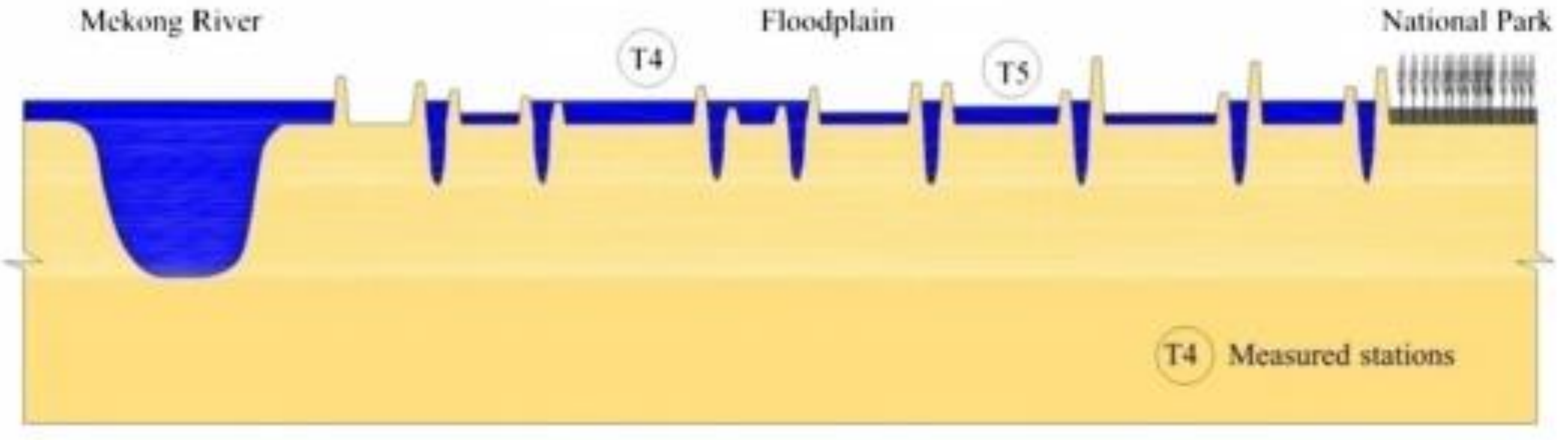

China
Vietnam
Burma
Laos
Thailand
Cambodia
Vietnam
0 150 300 Km
Cambodia
Tonle Sap
1
Kratie
2
3
Kampong Cham
PhnomPenh
4
5
6
7
Vietnam
Ho Chi Minh City
8
9
10
11
12
Gulf of Thailand
East Sea of Vietnam
N
0 25 50 100 Km

Water components

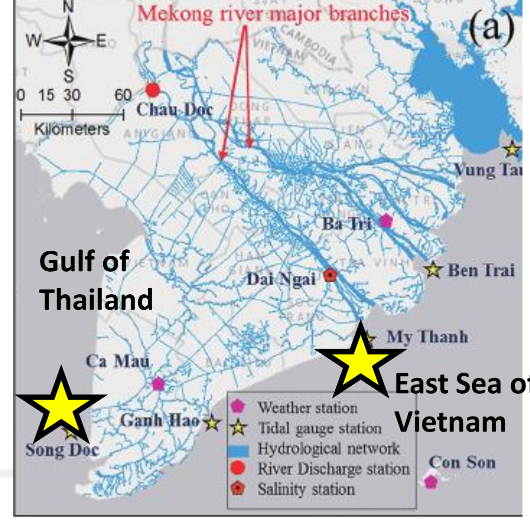
- The interconnection between various water elements (river, lake, delta, floodplains);
- Different construction works (main roads, dikes, sluide and roads).



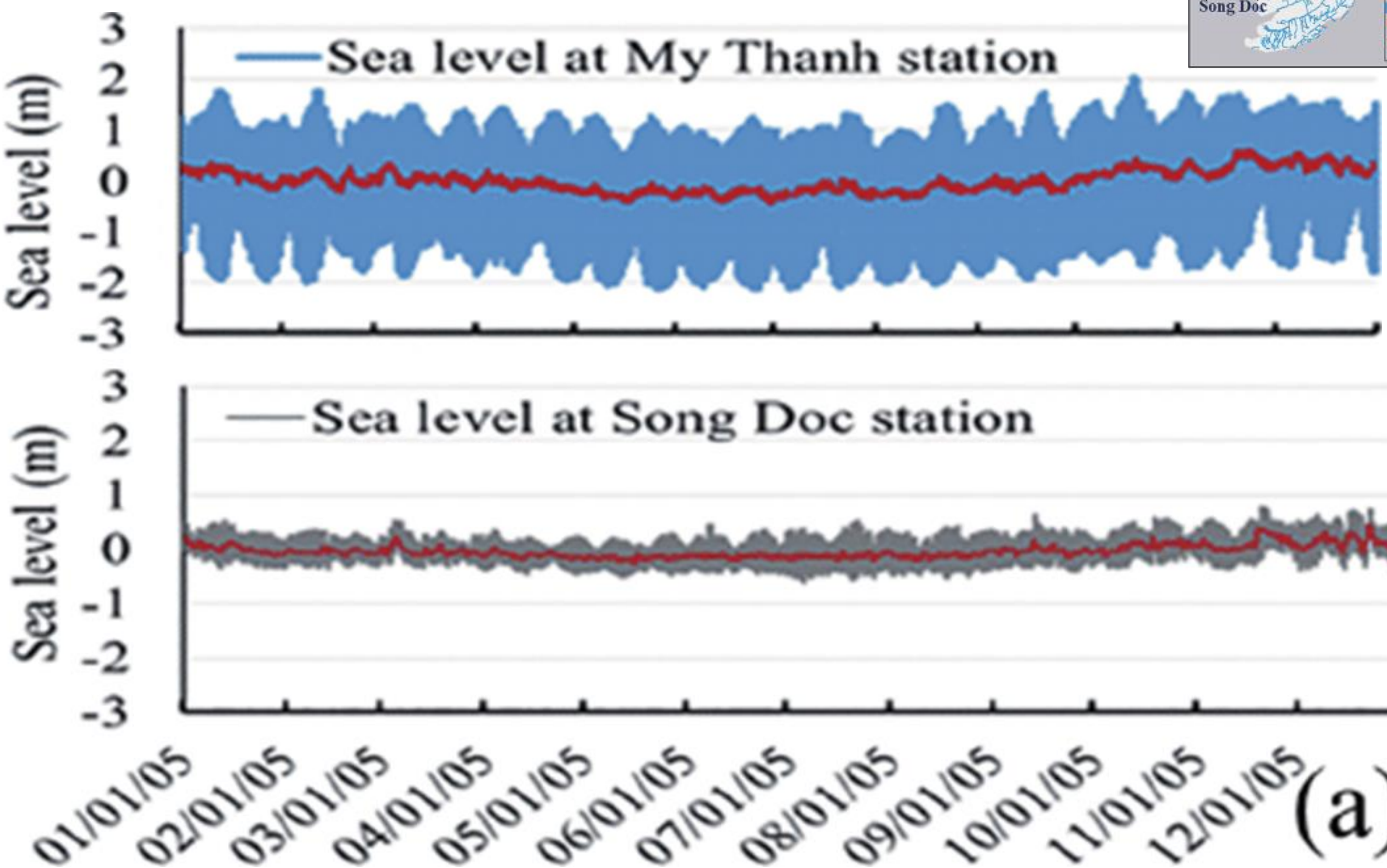
(Hung et al., 2012)



Tidal regimes



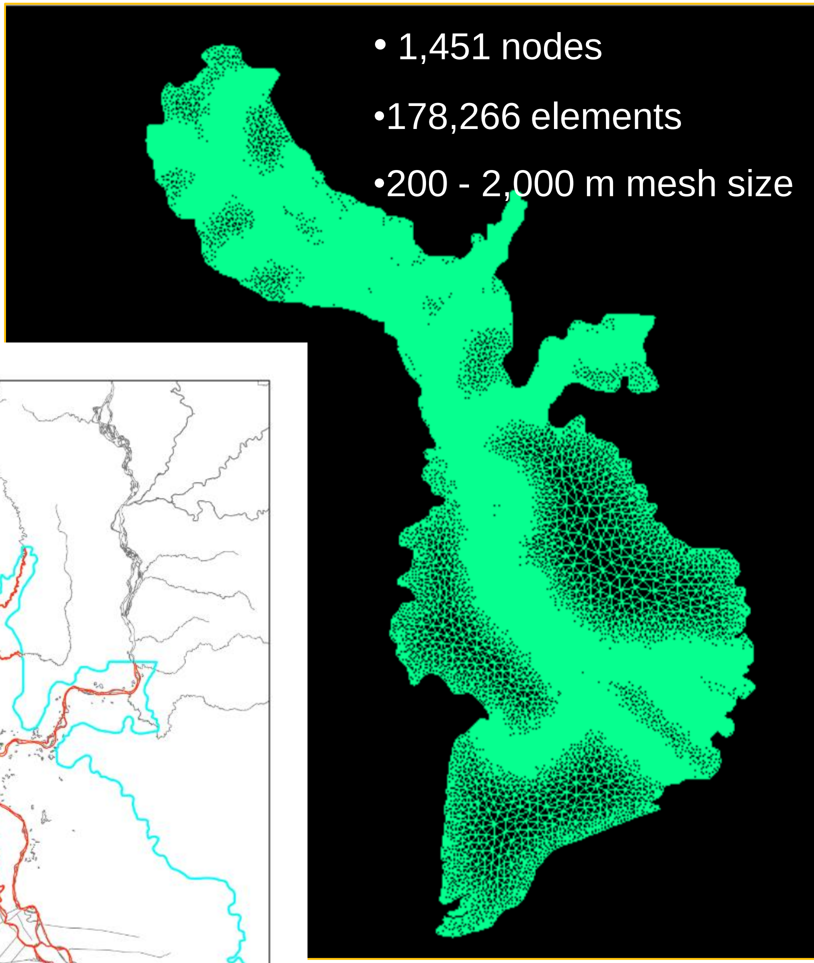
(Danet Hak, 2006)

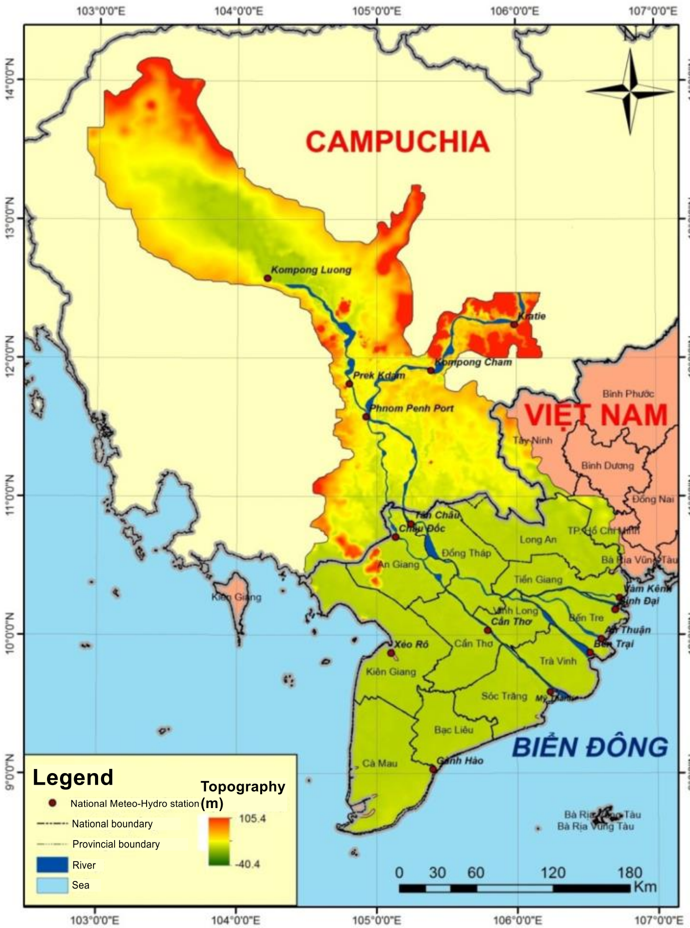


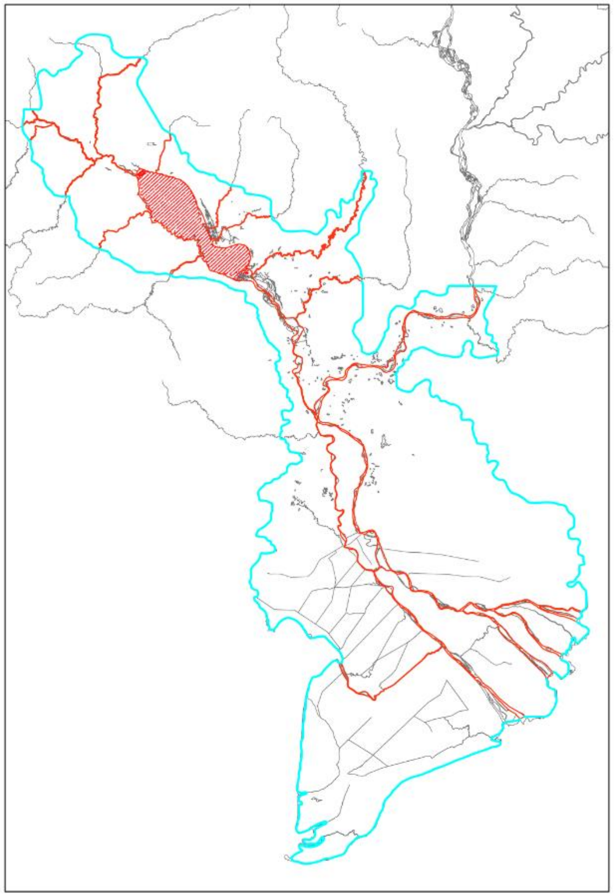
(Danet Hak, 2006)

Data and mesh generation

- Topography;
- Bed elevation: River sections and DEM (50m x 50m);
- Construction works: roads, dikes, colmatages, etc.;







New Wetting – Drying algorithm

Conservation form of the shallow-water equation:

$$\frac{\partial H\mathrm{u}}{\partial t} + \nabla . \frac{H\mathrm{u}H\mathrm{u}}{H} + g\nabla \frac{|H|H}{2} + \frac{c}{H^{7/3}} |H\mathrm{u}|\, Hu = -gH\nabla \mathrm{b}$$

- Drag: $ng \frac{|u|}{H^{4/3}} = ng \frac{|Hu|}{H^{7/3}}$ H is solved by max (H, Ɛ)
- Advection: $Huu = \frac{HuHu}{H}$ H is solved by max (H, 20Ɛ)
- Viscosity: $-\nabla .\mathrm{H}\nabla \mathrm{u}$

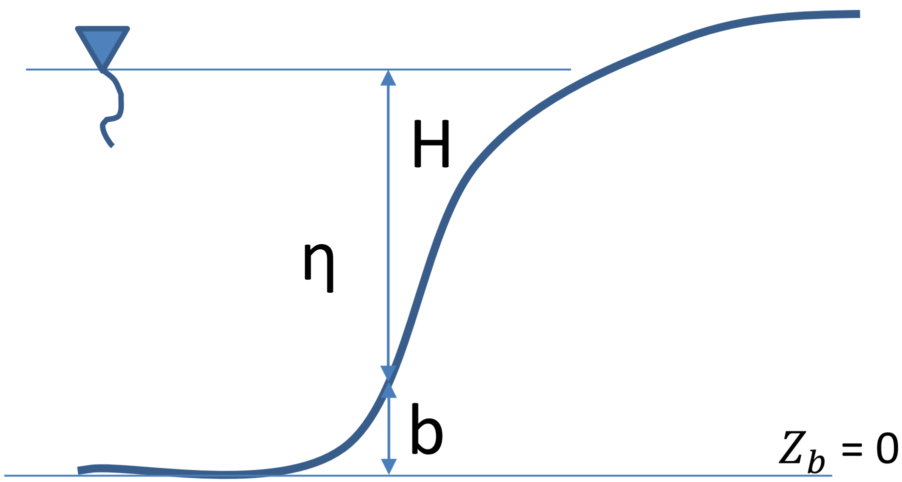
$\mathrm{H}\nabla \mathrm{u} = \mathrm{H}\nabla \frac{Hu}{H} = \nabla \mathrm{Hu} - \frac{Hu}{H} \nabla \mathrm{H}$ H is solved by max (H, Ɛ)

(Vater et al. 2015)

New Wetting – Drying algorithm

$\eta = H + b$

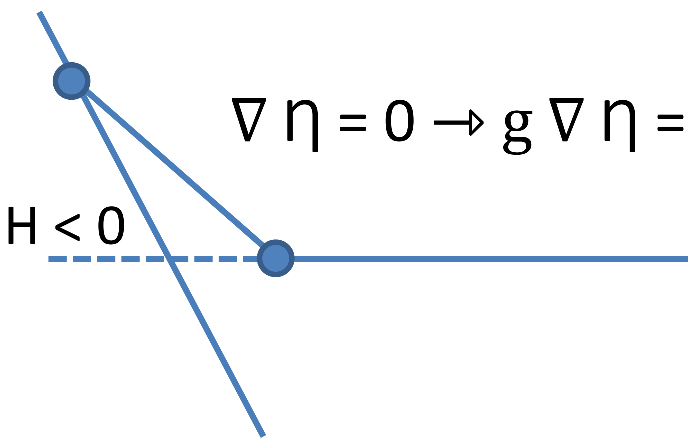
$f = \max(\eta) - \max(b)$



$g\nabla\eta \rightarrow \alpha^* g\nabla\eta$

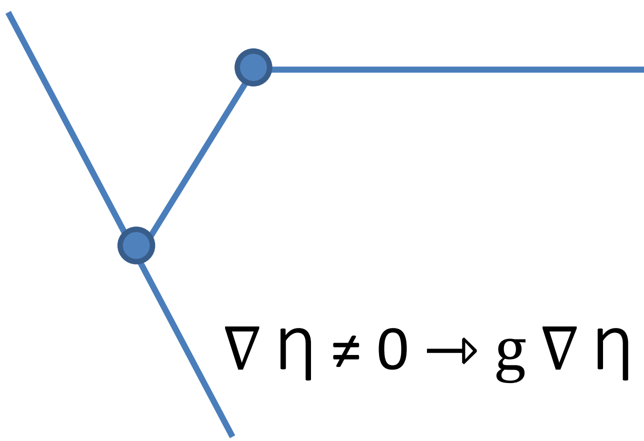
$\alpha = \min\left(1, \max\left(0, \frac{f - \varepsilon}{4\varepsilon}\right)\right)$

- **f ≤ Ɛ → α = 0**



$\nabla\eta = 0 \rightarrow g\nabla\eta = 0$

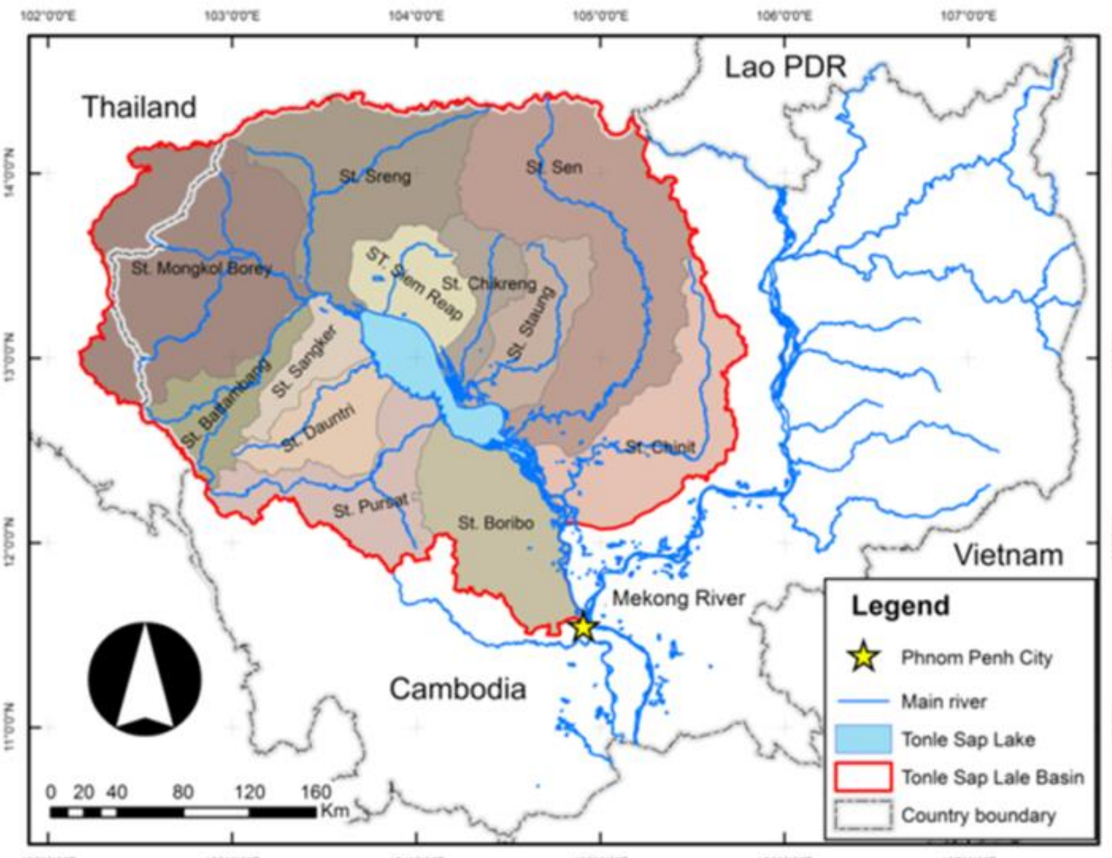
- **f ≥ 5Ɛ → α = 1**



$\nabla\eta \neq 0 \rightarrow g\nabla\eta \neq 0$

Tonle Sap

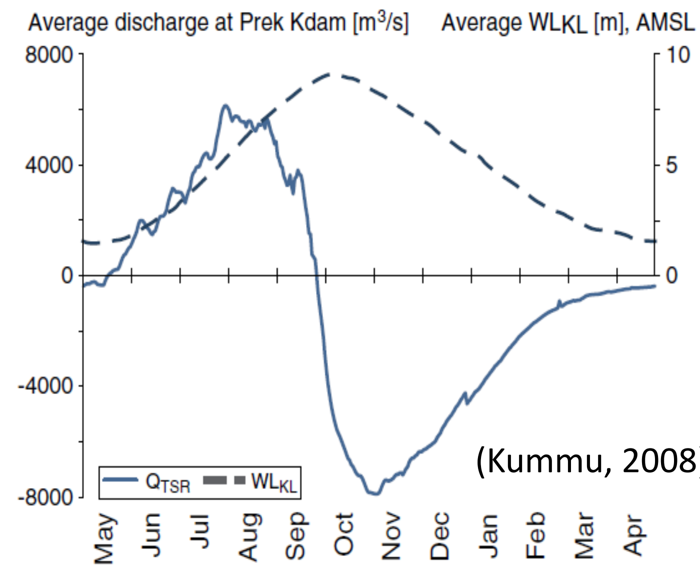
- In the Cambodia floodplain;
- The largest freshwater lake in SE Asian.



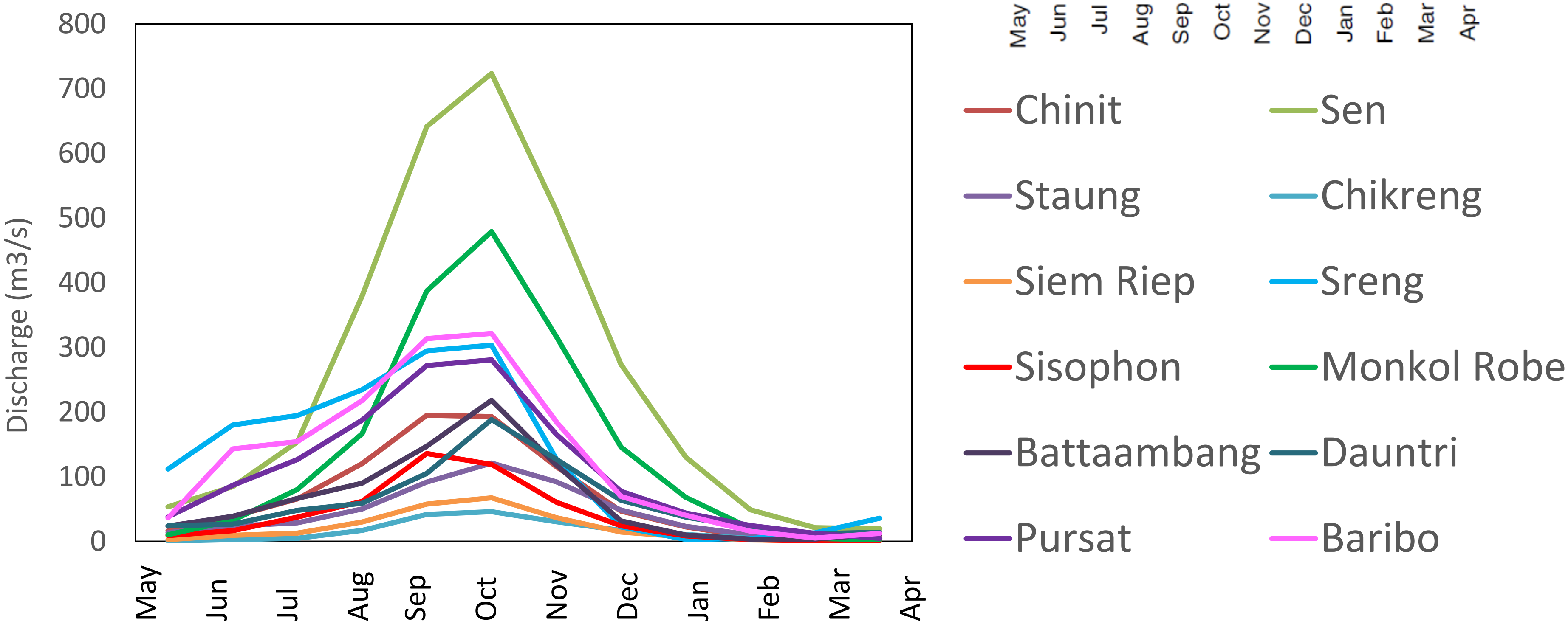
No	Subcatchment	Area (km²)
1	Chinit	8236
2	Sen	16359
3	Staung	4357
4	Chikreng	2714
5	Seam Reap	3619
6	Sreng	9986
7	Sisophon	4310
8	Mongkol Borey	10656
9	Sangker	6052
10	Dauntri	3695
11	Pursat	5965
12	Boribo	7153
	Total	83,102

Tonle Sap and its hydrology

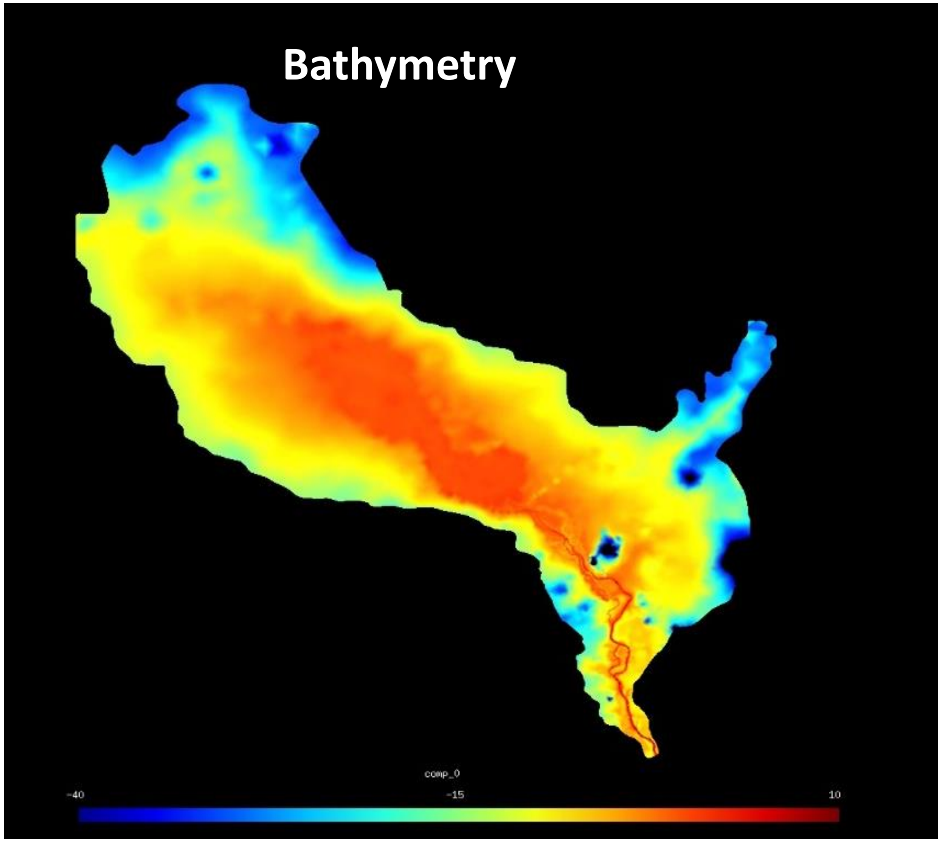
- In rain season, waterlevel is affected by:
  - Main Mekong river;
  - 12 tributaries;
  - Rainfall and Overland flow;
- In dry season, it plays as a regulation reservoir for the downstream Mekong.

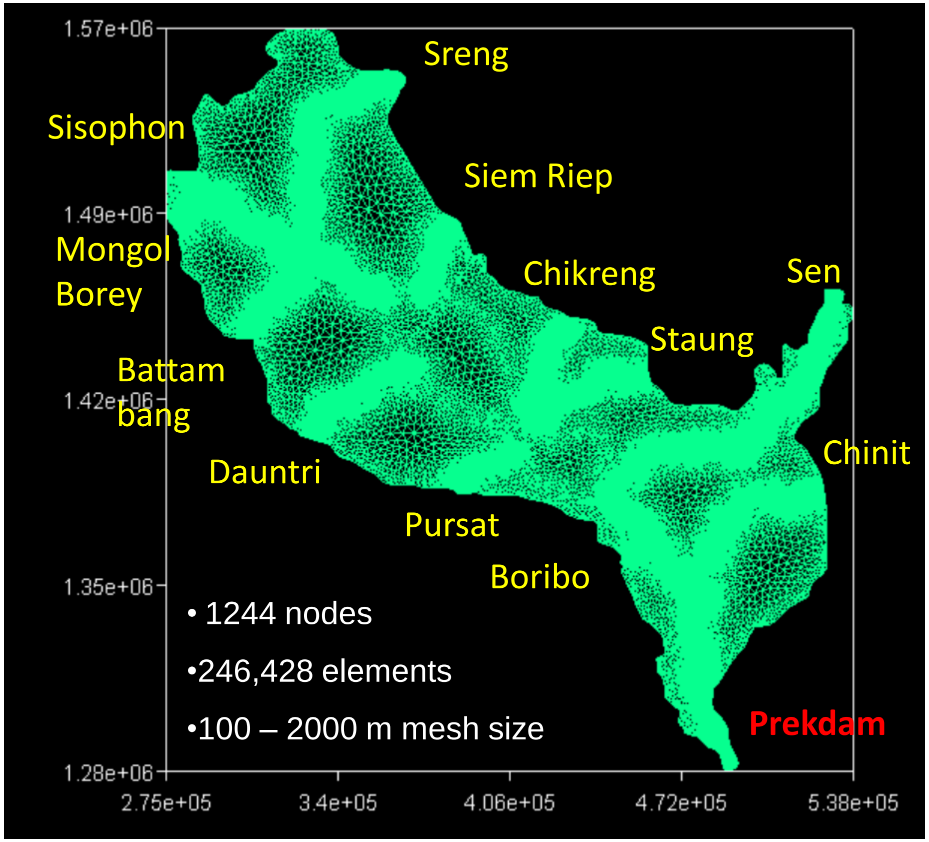


(Kummu, 2008)



Tonle Sap mesh generation





Boundary conditions:

- Upstream: 1-day discharges from 12 tributaries;
- Downstream: 1-day water level in Prekdam;

Initial conditions:

- Velocity = 0 m/s;
- Water level = constant;

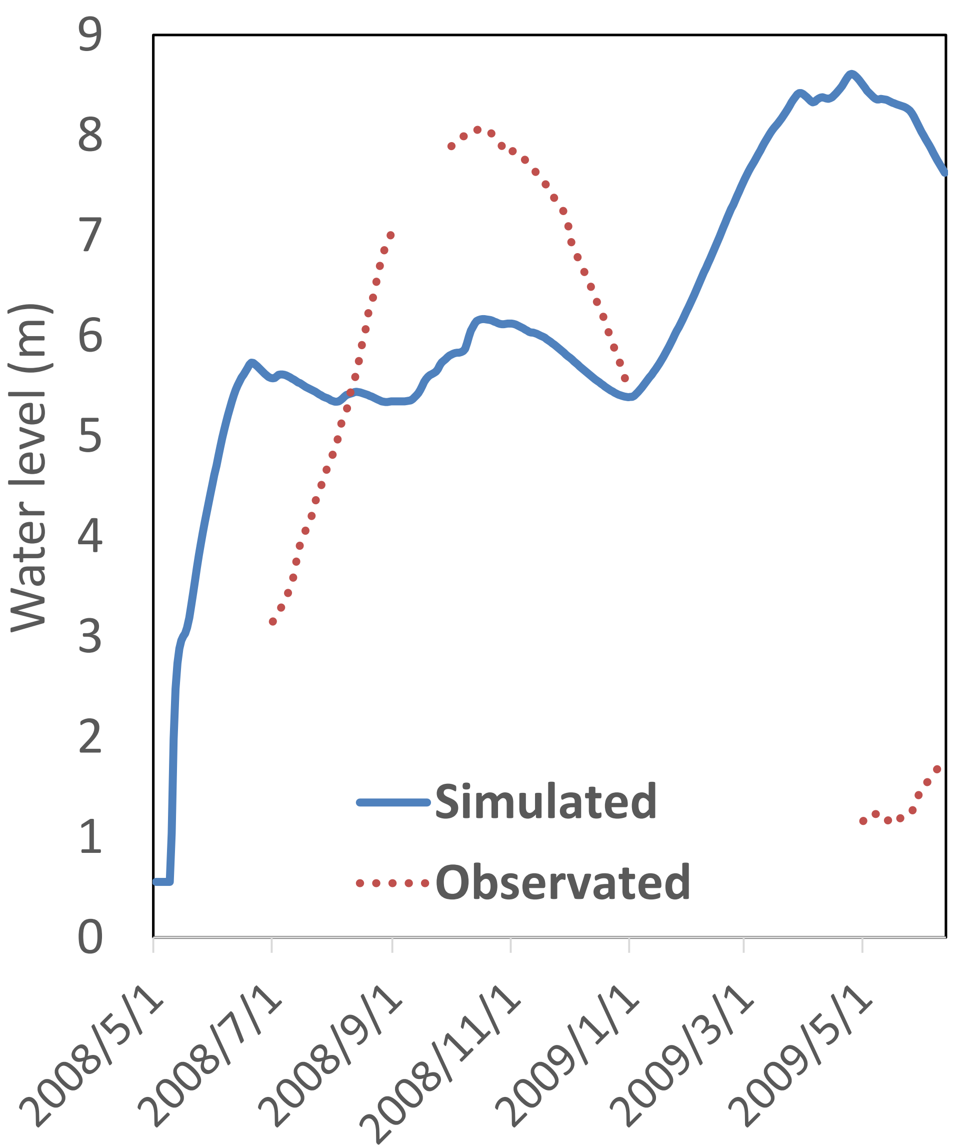
Simulation period:

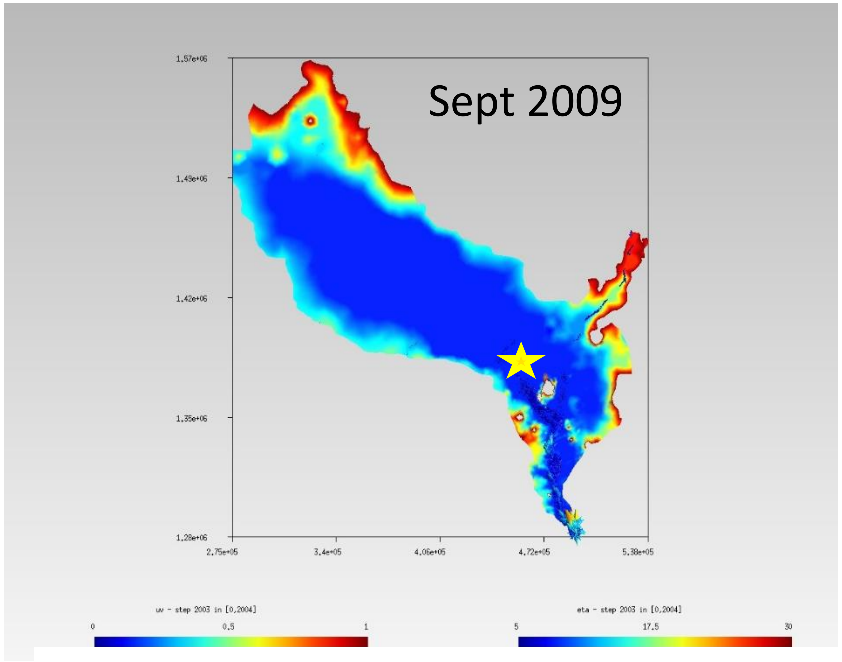
1st May 2008 – 30th April 2010;

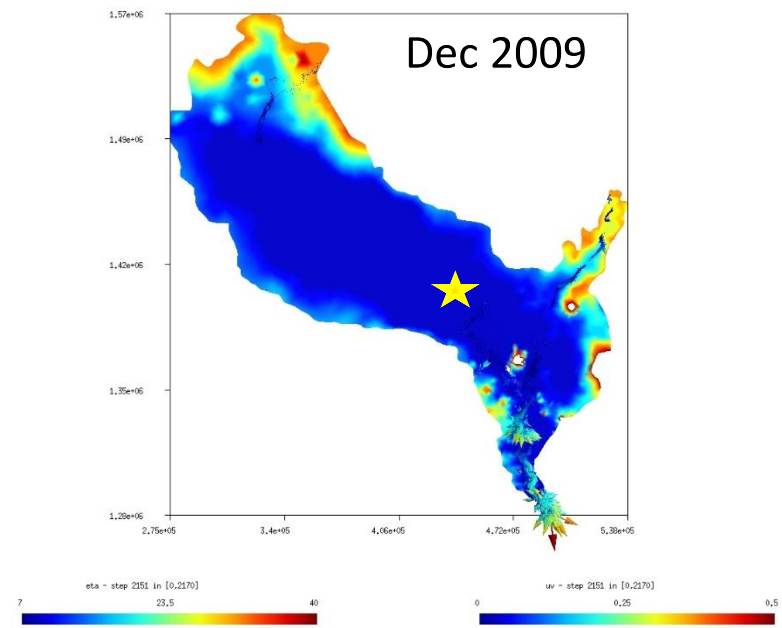
Modelling parameters:

- $\mathcal{E}$ = 0.9 m;
- n = 0.03 s. $m^{-1/3}$

Preliminary results







Difficulties and solutions

Difficulties

- No quality bathymetry;
- Unsufficient measured data;
- Very large and complicated domains.

Solutions

- Smooth bathymetry;
- Re-generate simulation mesh by detailing mesh sizes in the rivers or applying quad mesh.

Future works

1. Completing simulation for Tonle Sap;
2. Simulating for the Tonle Sap – Mekong delta by SLIM;
3. Comparing simulated results from SLIM and other models(2D-FEM, TELEMAC 2D, MIKE, etc.);
4. 1D model setup for the upper part.

1. Mahakam
2. Mekong
3. **Yangtze**

Modelling sediment transport process in the Yangtze River Estuary

Where is the Yangtze River ?

- 6,300 km length and 486 million tons sediment discharge
- Flooding problem

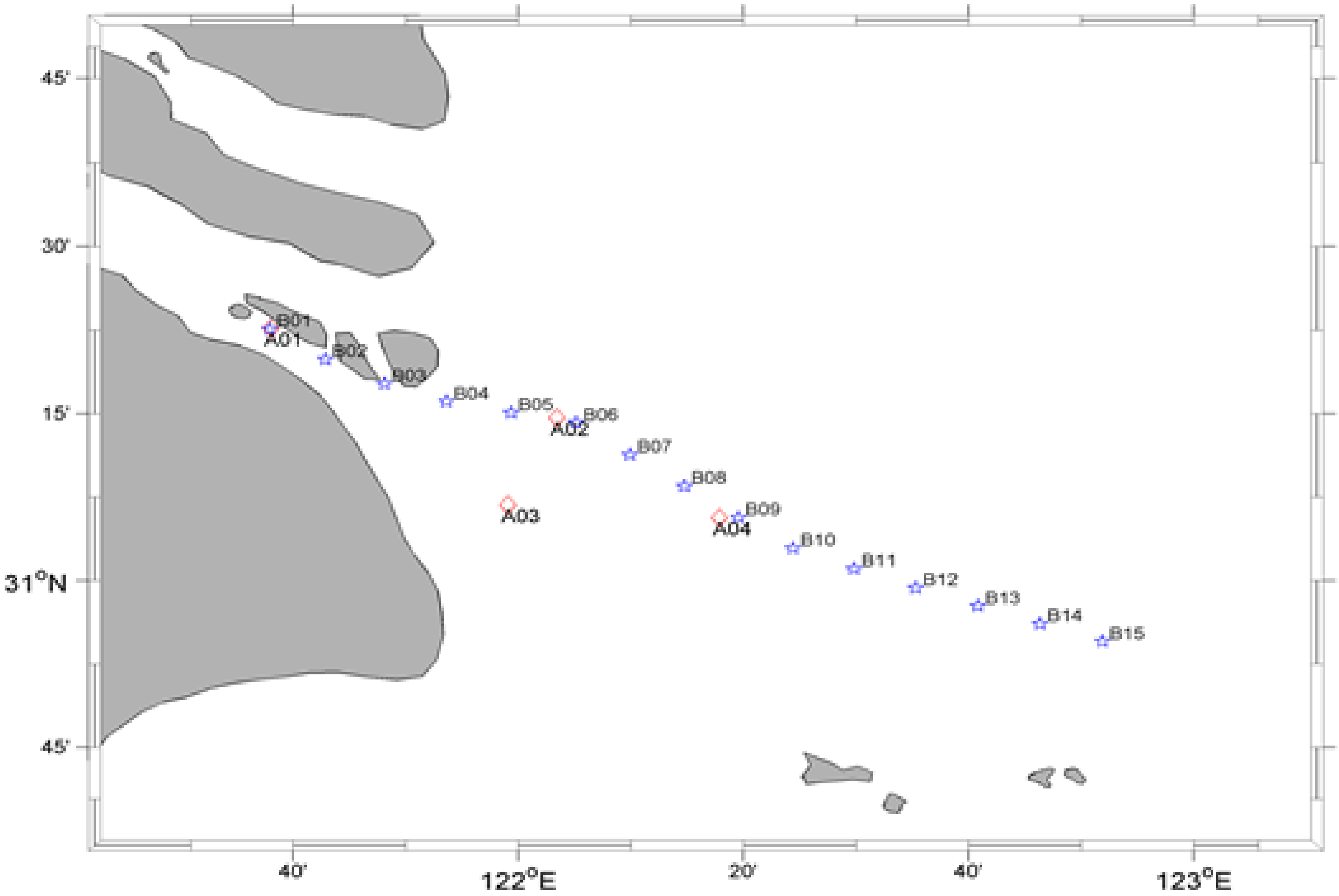
Impact of the Three Gorges Dam

- Trapping the sediment
- Riverbed in the downstream : from deposition to erosion

Research Purpose

- Sediment transport in the **Yangtze River Estuary**
- Numerical model : **SLIM 2D**
- Formation and seasonal variations of the **turbidity maximum**
- Effects of the Three Gorges Dam on the balance of sediment
- Future prediction

Data Collection



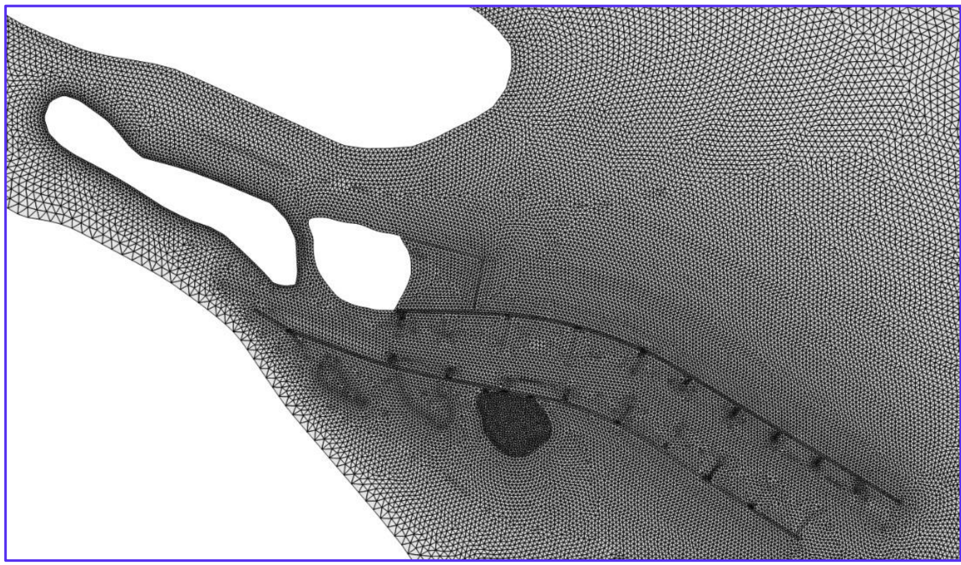
①Flood season : 20/08/2008-03/09/2008

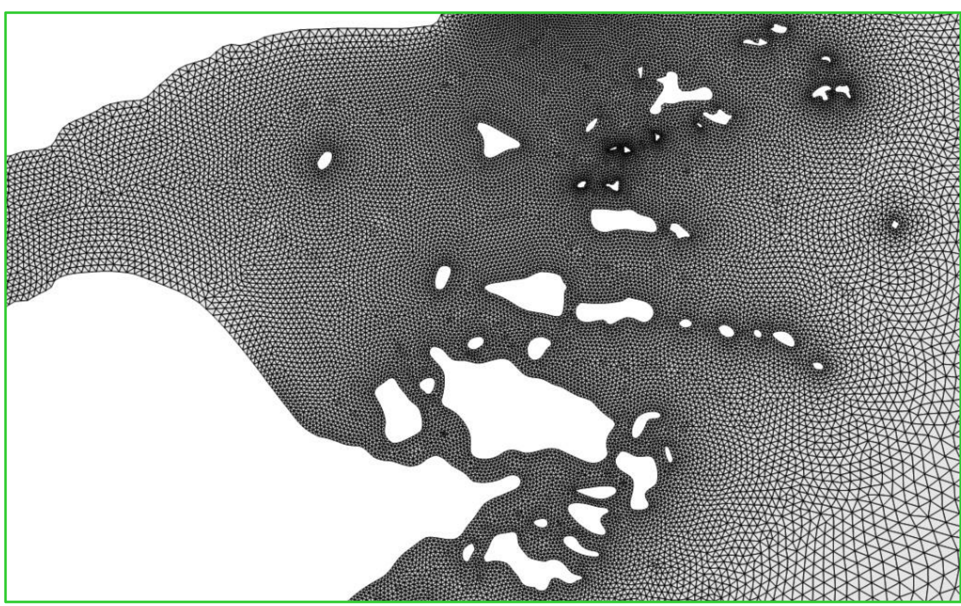
②Dry season : 25/03/2009-06/04/2009

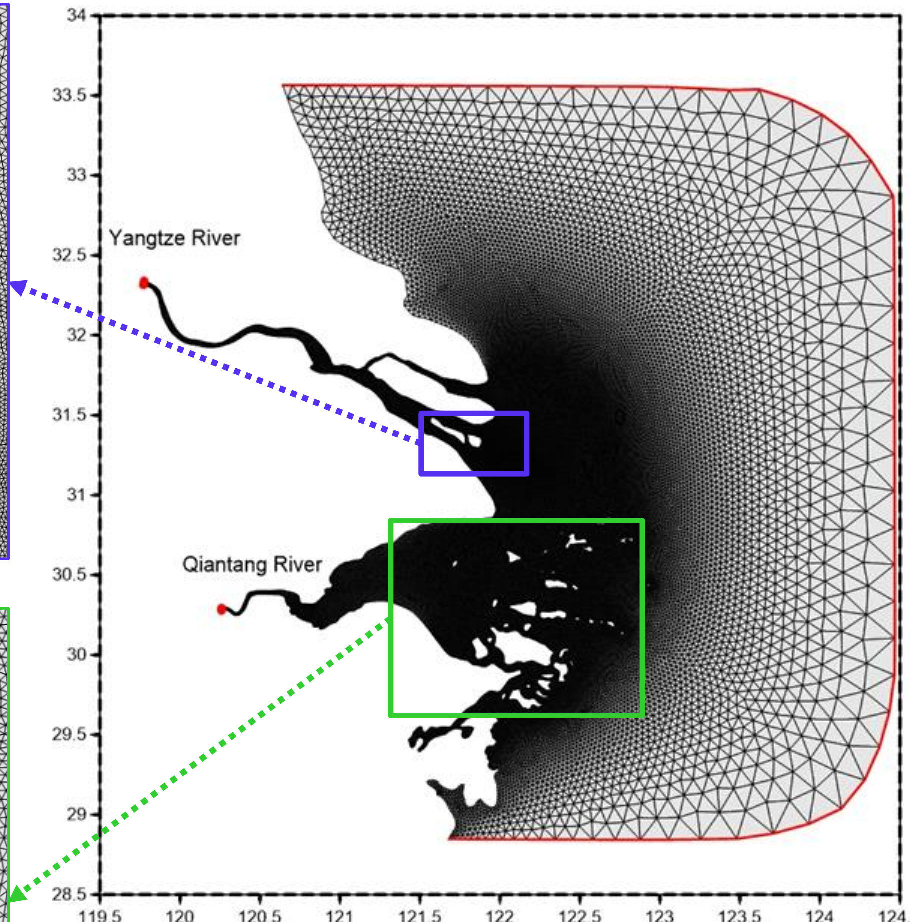
SLIM 2D

- Depth averaged model
- Finite element method
- Triangular unstructured grids
- Discrete Galerkin formulation
- Dissipation due to bottom friction: Chezy-Manning
- Turbulent viscosity: Smagorinsky

Research Domain







- 119.7°E — 124.5°, 28.8°N — 33.5°N
- Mesh size : from 100 m to 20,000 m
- 67,930 nodes and 132,397 elements

Boundary & Initial Conditions

- Open sea boundary : TPXO7.2
- Two inflow boundaries :

① Yangtze River : monthly averaged river discharge from 2001 to 2007

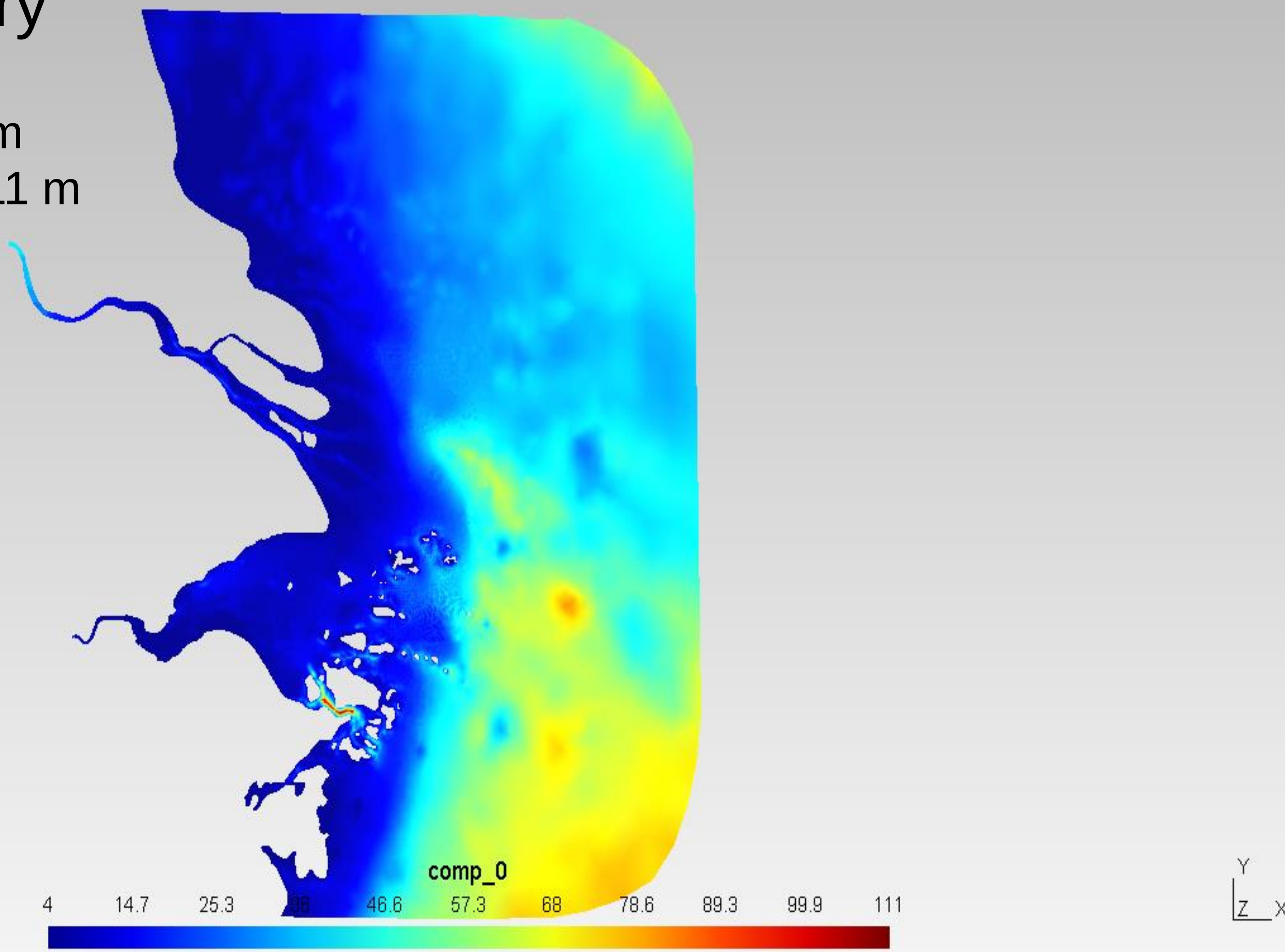
② Qiantang River : a constant river discharge

- Initial conditions : all zero
- Wind forcing : ERA Interim Daily
- Time step: 300 s
- Start & End : 31/07/2008 —14/09/2008 (UTC+8)

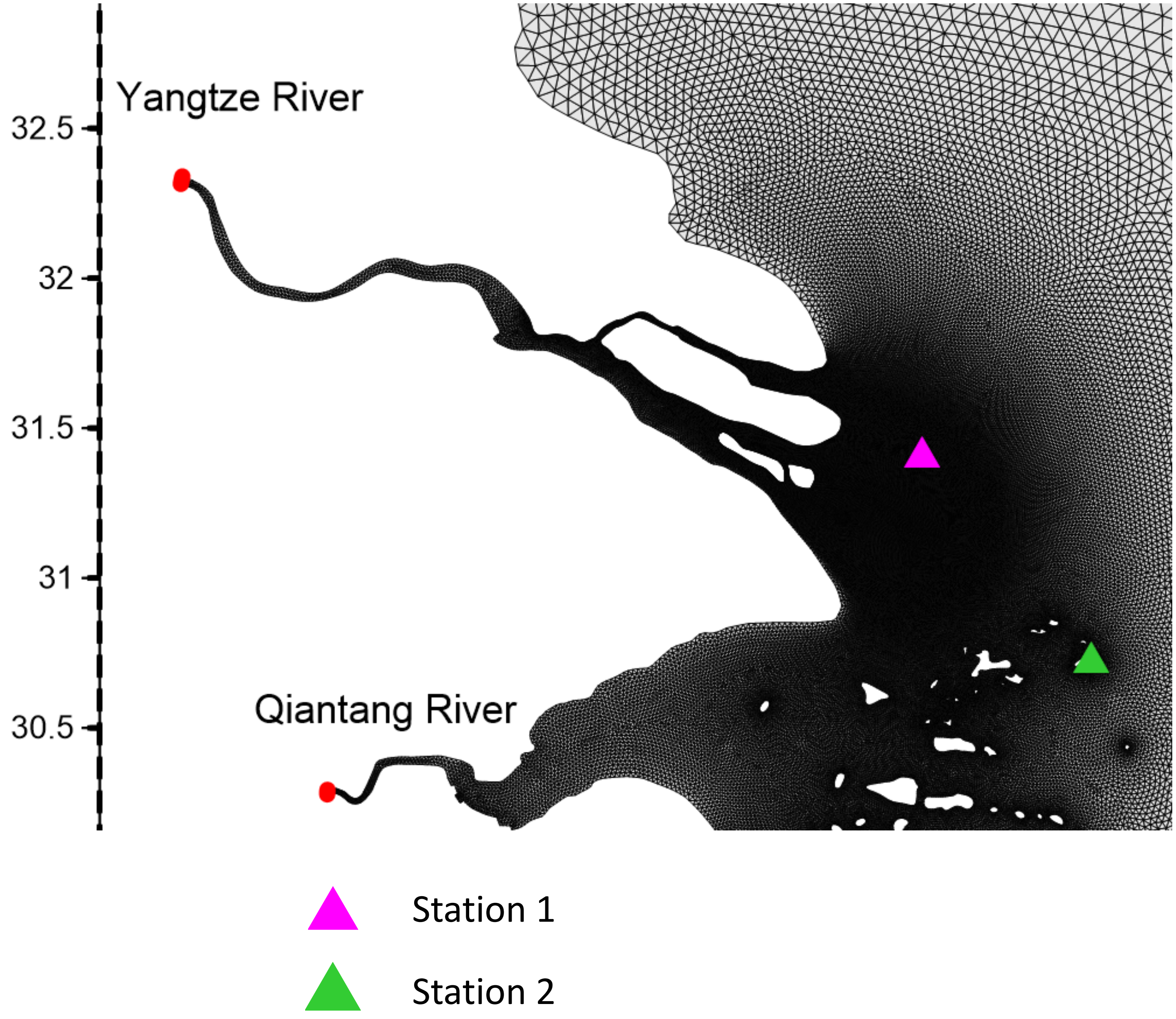
Preliminary Progress

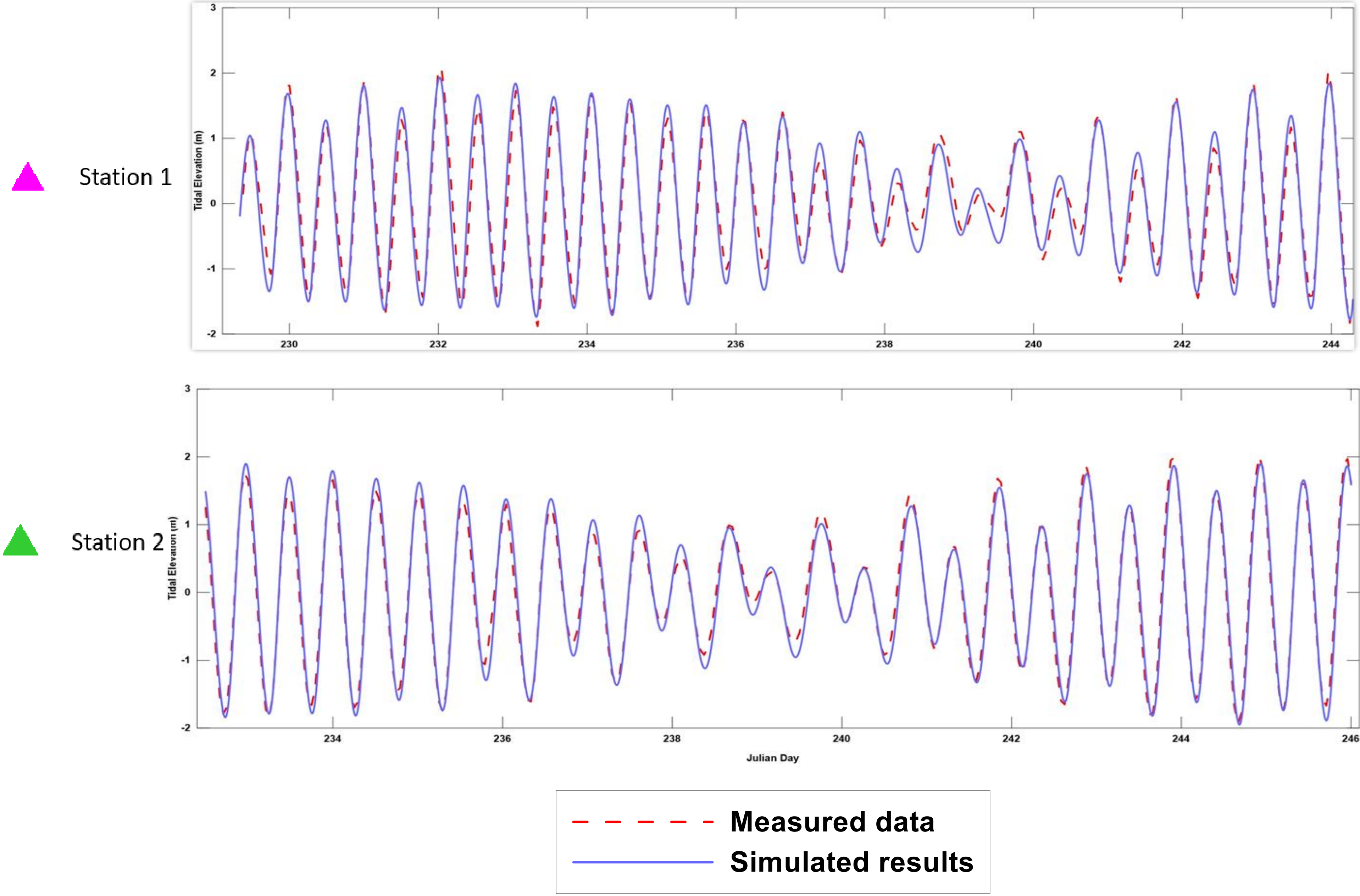
Bathymetry

Minimum : 4 m
Maximum : 111 m



Tidal elevation




Station 1
Station 2
Tidal Elevation (m)
Julian Day
Measured data
Simulated results

Future Work

- Further validations on flows and circulations in the YRE and its nearby zones
- Choosing appropriate parameters used in the sediment module
- Comparing simulated results with observed data and published papers, and performing analysis and discussion

Thank you for your attention!

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