The 47th International Liège Colloquium
Marine Environmental Monitoring, Modelling and Prediction
May 4-8, 2015 - Liège, Belgium

Unstructured-mesh simulation of flow and sediment fluxes in the Mahakam land-sea continuum, Indonesia

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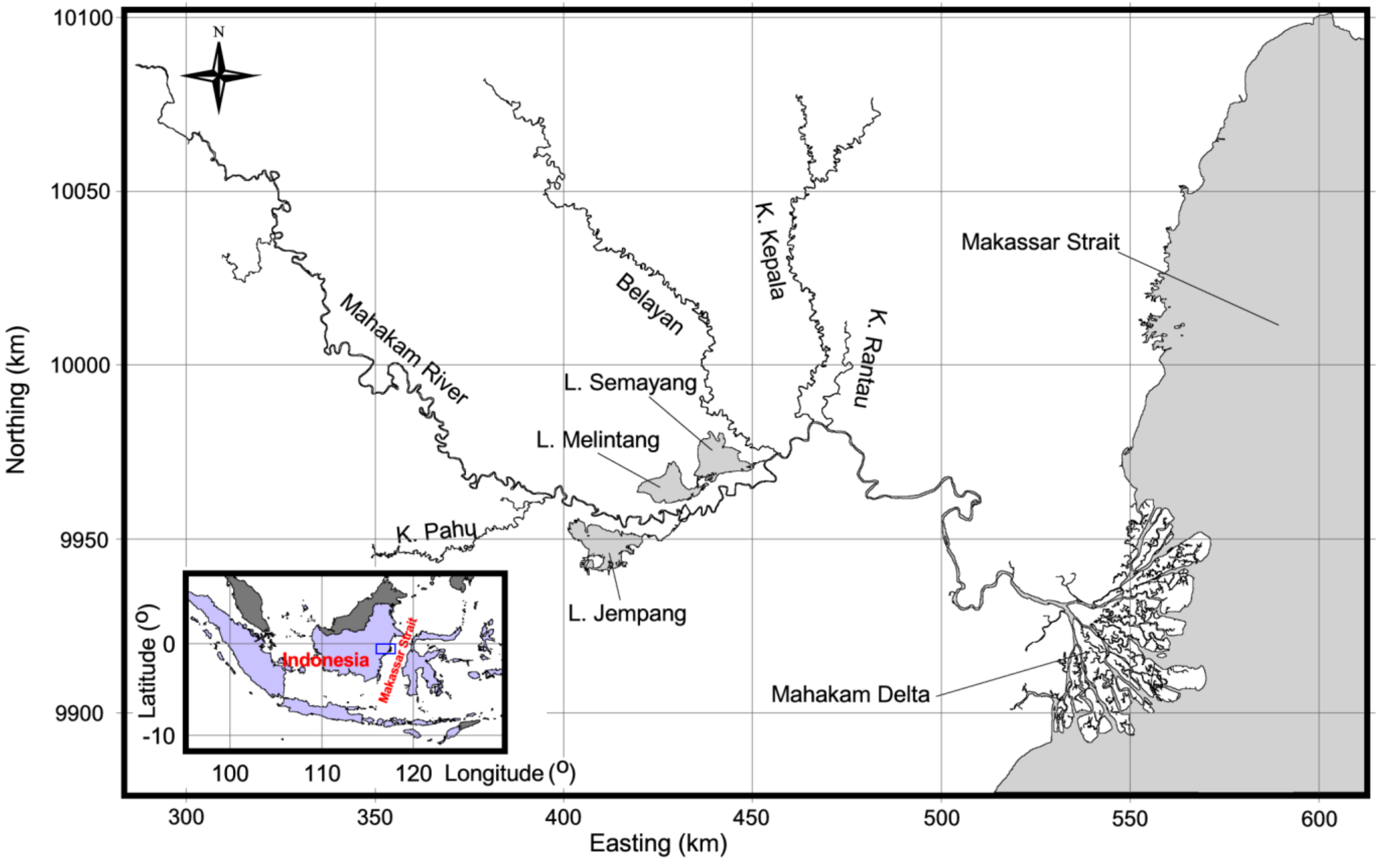
With many thanks to all those who contibuted to the development of SLIM (www.climate.be/slim)

Domain of interest: the Mahakam land-sea continuum (I)



Various types of water bodies: deep sea, (shallow) coastal region, delta, rivers, lakes. A **multi-scale/physics problem** is to be dealt with.

Domain of interest: the Mahakam land-sea continuum (II)

♦ The **river**:

- length $\approx 10^3$ km
- catchment area $\approx 8 \times 10^4$ km^2
- discharge $\approx 5 \times 10^3$ m^3 s^{-1}
- depth ≈ 10 m

♦ The **delta**:

- influenced by tides and river dicharge
- stable morphology
- rather constant discharge
- oil and gas fields

♦ The **lakes**: buffer floods/droughts and capture sediments.

♦ The **human** impacts: coal mining and palm tree plantations, leading to stronger erosion and increased (fine) sediment input.

(Bart Vermeulen, personal communication, 2009)

Goal of the study:

Set up a **multi-scale** numerical model capable of reproducing the **water** and (fine) **sediment** fluxes in the domain of interest, with a particular focus on the **delta**

The Second-generation Louvain-la-Neuve Ice-ocean Model (SLIM, www.climate.be/slim)

♦ SLIM is a **multi-scale/physics** numerical model of some of the components of the **land-sea continuum**.

♦ Key ingredients/steps:

- Collaboration of mechanical engineers and GEFD specialists;
- Programming in C++;
- Adopting the finite element (FE) method, then switching to Discontinuous Galerkin FE (DG FE ≈ hybrid of FE and FV);
- Inserting SLIM in the FE software built around the source code of Gmsh (www.geuz.org/gmsh).

What SLIM can and cannot do

♦ SLIM solves **partial differential equations** in 1, 2 or 3 space dimensions for unknowns of the form $\psi(t,\mathbf{x})$. The generic form of (most of) these equations is:

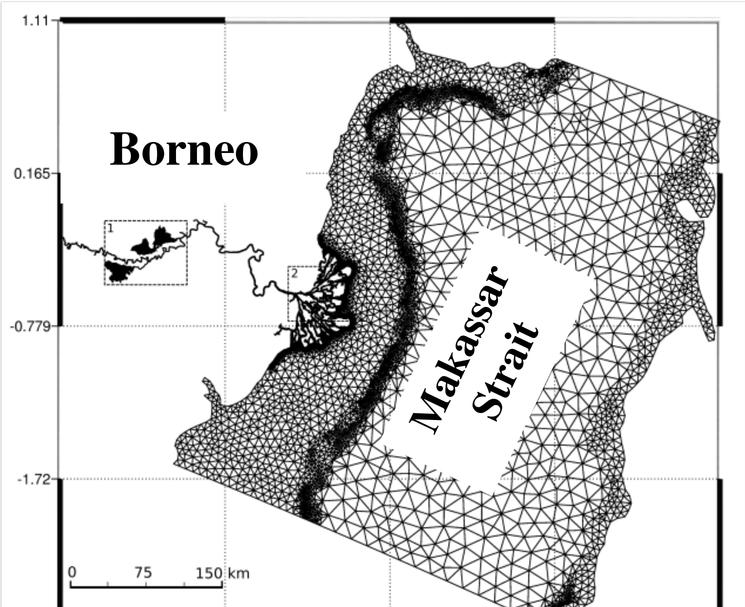
$$\underbrace{\frac{\partial \psi}{\partial t} + \nabla \bullet (\overbrace{\mathbf{v}\psi - \mathbf{K} \bullet \nabla \psi}^{\text{advect.+diff. flux}})} = \underbrace{\overbrace{P - D}^{\text{"reactions"}}}$$

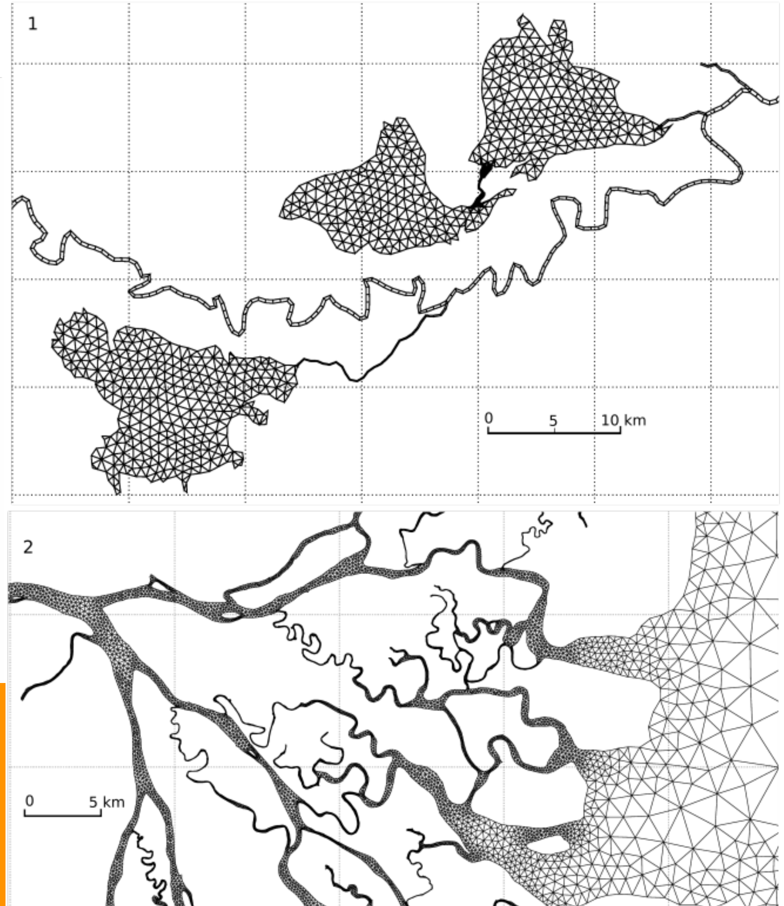
Dealt with by SLIM on an unstructured mesh by means of the discontinuous Galerkin finite element method in a C++ code

Dealt with by SLIM or by external modules interfaced with SLIM

We are not (always) reinventing the wheel...

Unstructured mesh model setup





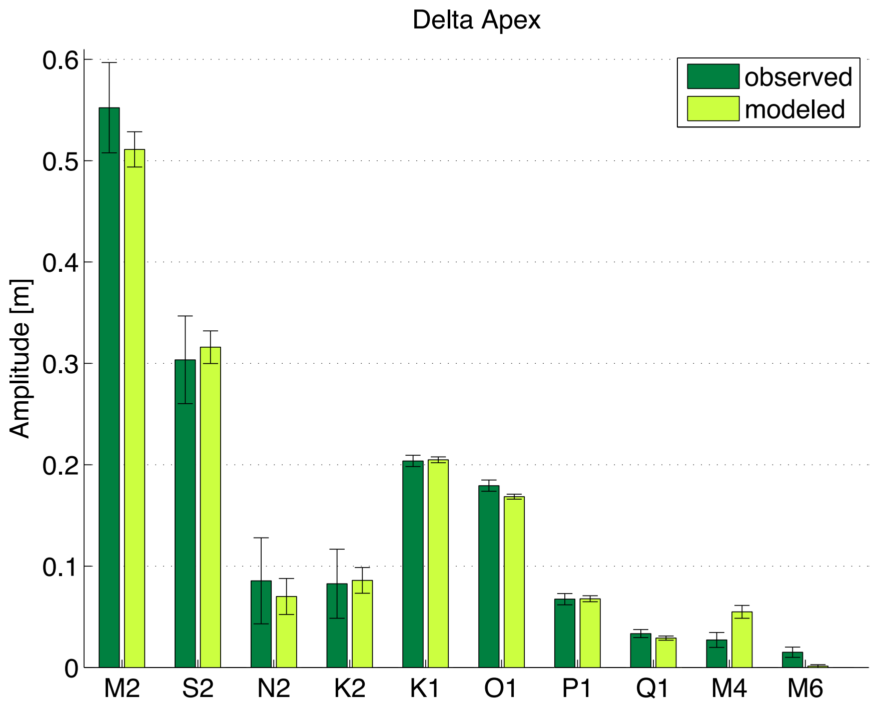
de Brye et al. (*Ocean Dynamics*, 2011)
Sassi et al. (*Ocean Dynamics*, 2011)
Sassi et al. (*JGR - Earth Surface*, 2012)
Pham Van et al. (*JHeR*., submitted)

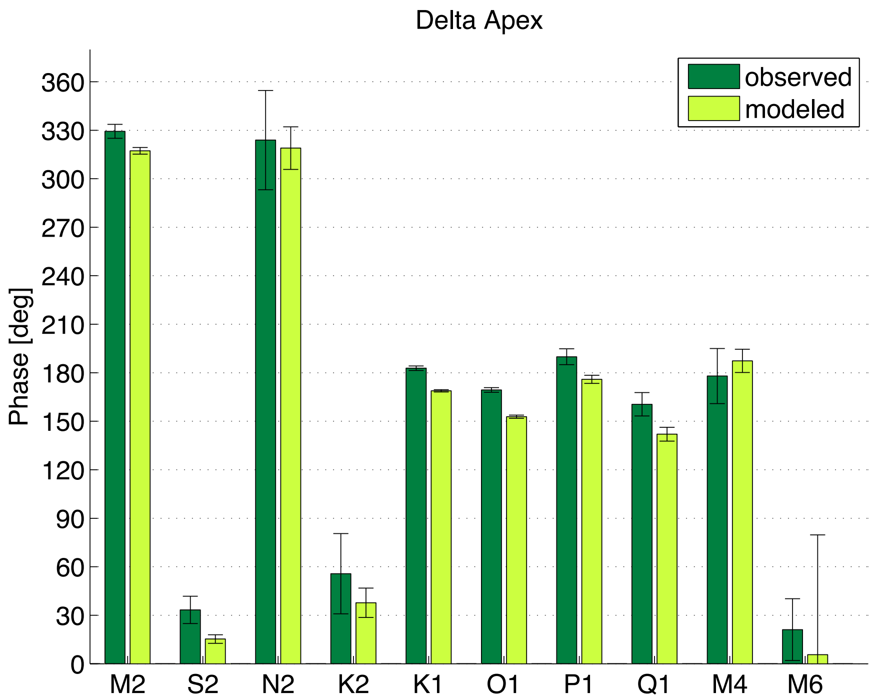
Water and sediment transport in 1D (rivers) + 2D (lakes, delta, sea).

Sediment: parameterization of erosion and deposition after modernized versions of Partheniades (1965) and Einstein and Krone (1962), respectively.

Forcings: wind stress, tides at the open sea boundaries, (time-dependent) river discharge and equilibrium suspended sediment concentration at the upstream (riverine) boundaries

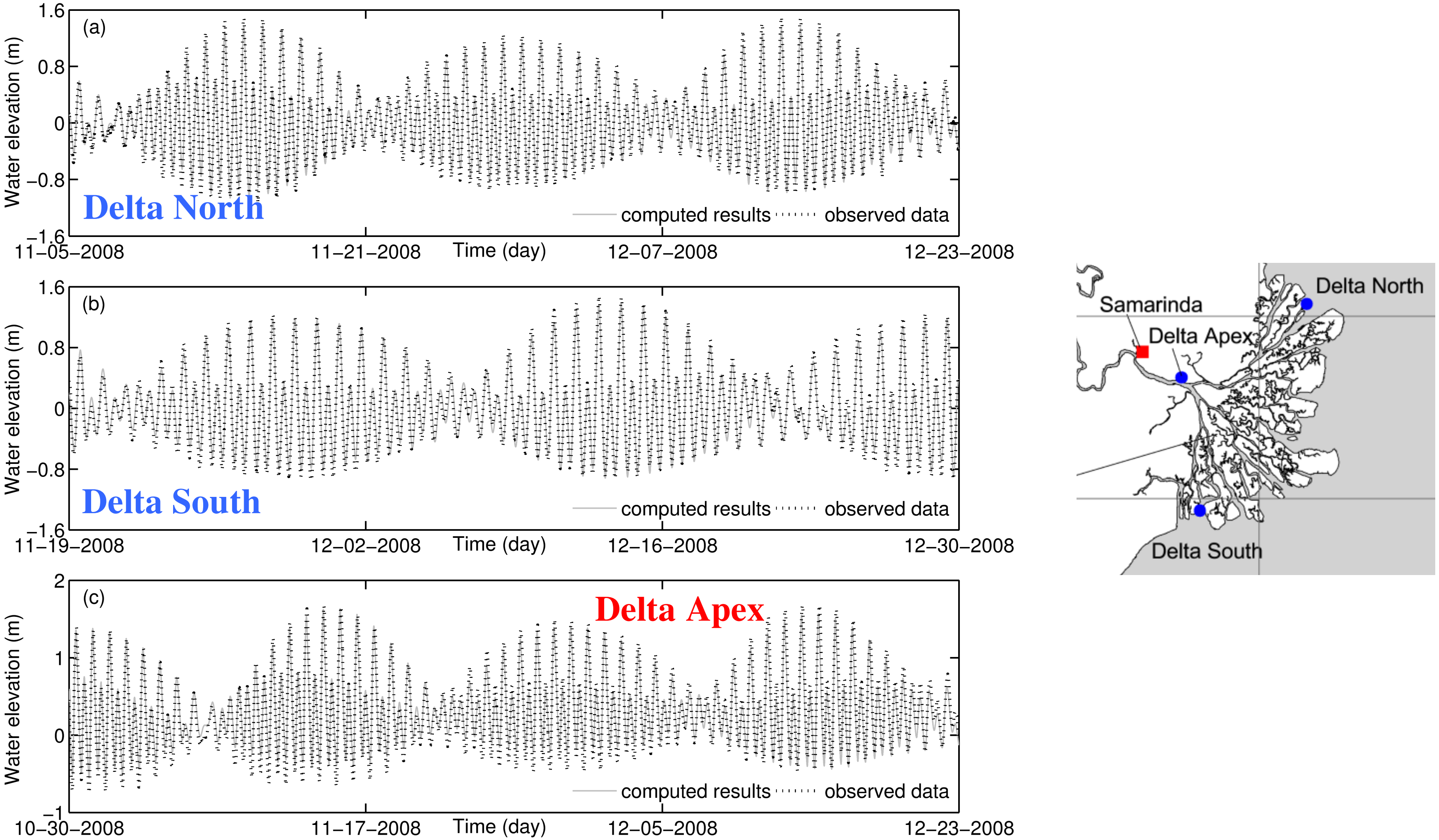
Model results: tidal constituents



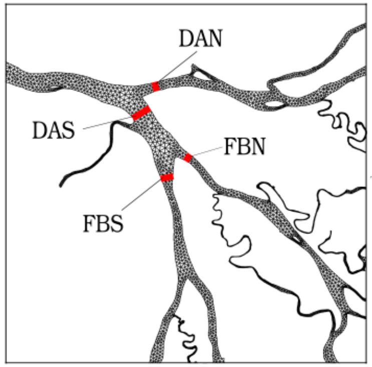


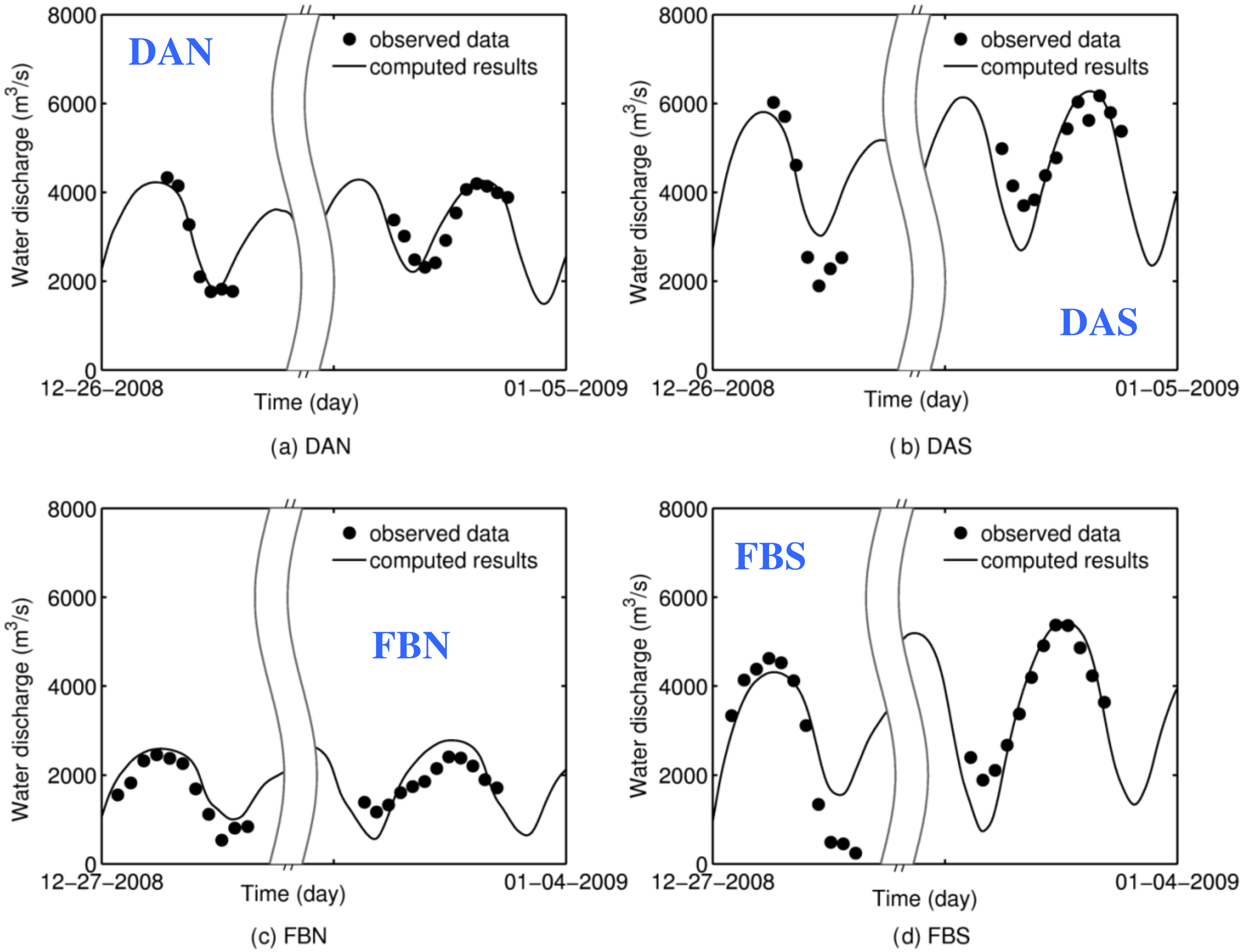
(model results and field data from the delta apex)

Model results: instantaneous water height



Model results: instantaneous discharge

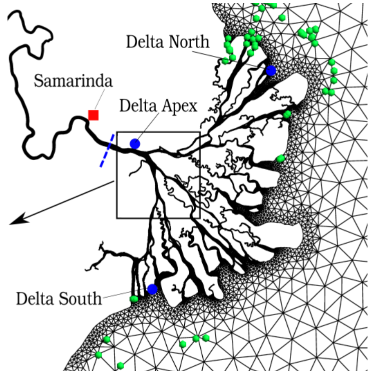




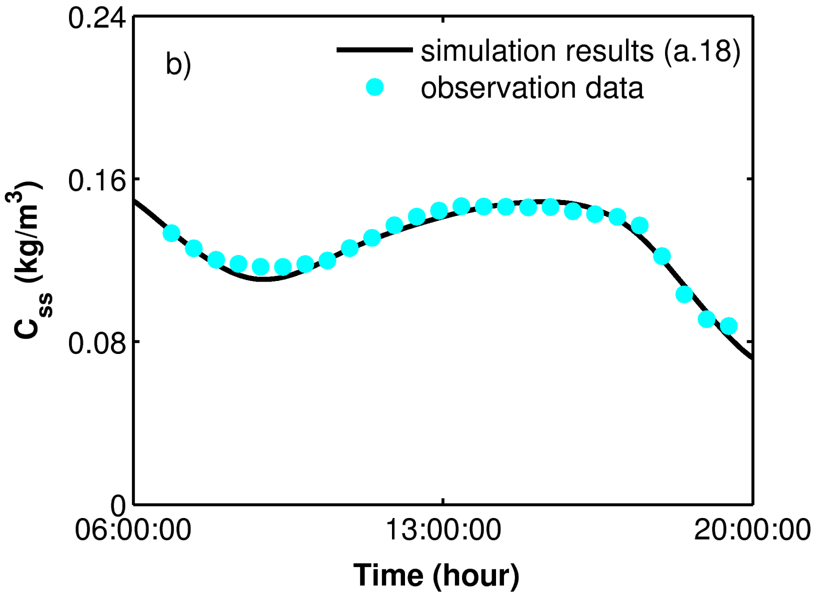
(a) DAN (b) DAS
(c) FBN (d) FBS

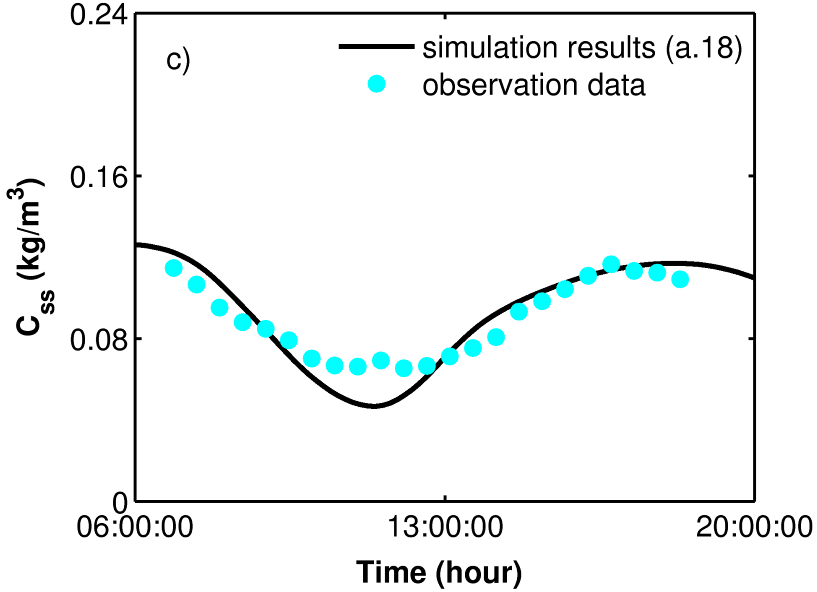
Water discharge in the delta

Model results: suspended sediment concentration (I)

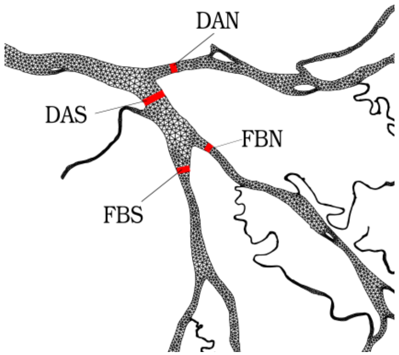


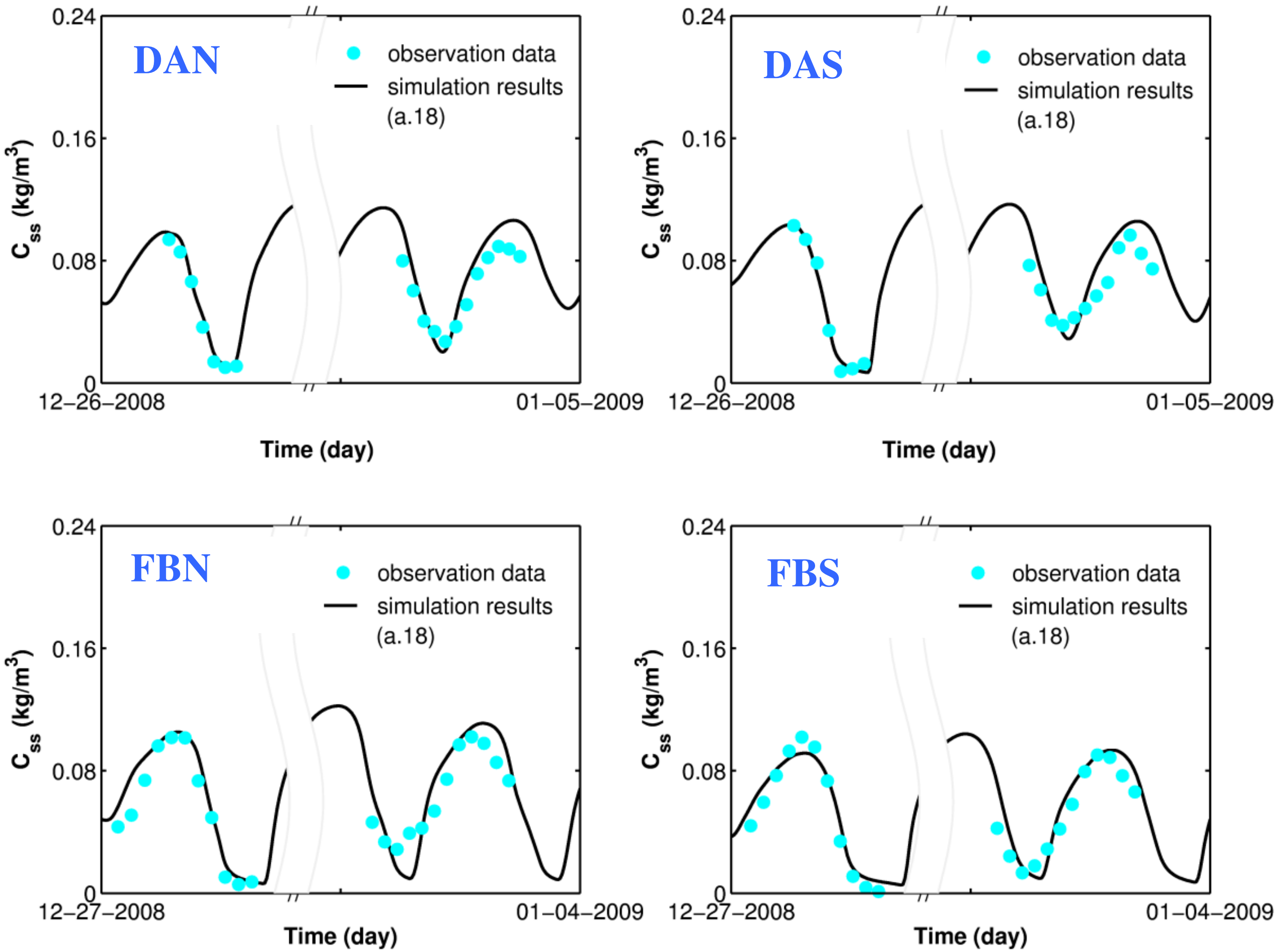
Suspended sediment concentration (SSC) at Samarinda (a little upstream of the delta apex)





Model results: suspended sediment concentration (II)





SSC in the delta

Conclusions and outlook

♦ SLIM already has some of the building blocks of a hydrospheric model, which are progressively coupled with eachother with a focus on the land-sea continuum.

♦ The results from the Mahakam are encouraging, as well as those from other land-sea continua, e.g. the Scheldt (Belgium, Netherlands), the Congo and the Great Barrier Reef (Australia).

♦ The 3D (baroclinic) version of SLIM is coming of age: successful applications to an idealised ROFI test case (Kärnä et al., OM, 2013) and a realistic one (Delandmeter et al., ECSS, submitted)

♦ Key numerical issues are still being addressed, in particular those related to CPU time consumption.

Thank you!