Coastlab12, 2012, Ghent, Belgium. Book of Abstracts of the Fourth International Conference on the Application of Physical Modelling to Port and Coastal Protection. ISBN 978 90 382 2008 6

PRELIMINARY RESULTS OF A NUMERICAL MODEL OF SUSPENDED SEDIMENT IN THE MAHAKAM DELTA, INDONESIA

CHIEN PHAMVAN [1,*], BENJAMIN DE BRYE [2], SANDRA SOARES-FRAZAO [3] & ERIC DELEERSNIJDER [4]

[1] *Institute of Mechanics, Materials and Civil engineering, Université catholique de Louvain B-1348 Louvain-la-Neuve, Belgium*
* *Faculty of hydrology and water resource, Water Resources University. 175 Tayson Street, Dongda district, Hanoi, Vietnam*

[2] *Institute of Mechanics, Materials and Civil engineering & Georges Lemaître Centre for Earth and Climate Research, Université catholique de Louvain. B-1348 Louvain-la-Neuve, Belgium*

[3] *Institute of Mechanics, Materials and Civil engineering, Université catholique de Louvain B-1348 Louvain-la-Neuve, Belgium*

[4] *Institute of Mechanics, Materials and Civil engineering & Earth and Life Institute, Georges Lemaître Centre for Earth and Climate Research, Université catholique de Louvain. B-1348 Louvain-la-Neuve, Belgium*

1. Introduction

The Mahakam River is one of the longest rivers in the tropical monsoon areas of Indonesia. The river is located in the East Kalimantan province of Borneo and is over 900 km in length. The catchment area of the river is about 75,000 km^2. The middle part of the river is extremely flat. In this area, four large tributaries (River Kedang Pahu, River Belayan, Kelang Kepala, and Kedang Rantau) greatly contribute to the river flow and several shallow-water lakes (e.g. Lake Jempang, Lake Melingtang, Lake Semarang, etc) are connected to the river through a system of small channels. These lakes act as a buffer of the Mahakam River and regulate the discharge in the lower river part in flood situations through the damping of the flood surges (Storms *et al.*, 2005). Downstream of the river, the Mahakam Delta is characterized by a large number of active bifurcating distributaries and tidal branches. The delta is approximately 50 km in length, as measured from the Delta Apex to the delta front. The width of the branches and channels in this region ranges from 10 m to 3 km and all channels have variable depths in a range between 5 to 15 m. The Mahakam Delta discharges into the Makassar Strait, whose width varies between 200 and 300 km, with a length of about 600 km.

The Mahakam Delta plays an important role as a valuable natural resource for the human activities i.e. fishing industry, transportation, and recreation (Hadi *et al.*, 2006). The suspended sediment in the delta affects the morphology, and thus the navigation as well as flood mitigation infrastructure. In addition, it also influences the ecosystem in the delta by changing the habitat for benthic organism, transporting adsorbed toxic substances, and limiting light availability (Hadi *et al.*, 2006). Several environmental problems have arisen in the delta that is related to the degradation of water quality and increased coastal erosion (Chaineau *et al.*, 2010). To better understand the distribution of suspended sediment concentration (SSC) and thus to help in the management of living deltaic sources, the finite-element model SLIM (Second-generation Louvain-la-Neuve Ice-ocean Model, www.climate.be/slim) was used to reproduce the flow dynamics and sediment transport in the complete delta-river system that consists of the river, its large tributaries, the delta, and the adjacent coastal ocean.

2. Numerical method

In the domain of interest, SLIM solves the shallow-water equation and a sediment transport equation. The variation of water density due to the suspended sediment is taken into account in the shallow-water equations. A second-order diagonally implicit Runge-Kutta time stepping and the discontinuous Galerkin finite element method with linear shape functions are used to discretise the temporal and spatial operators, respectively. The wetting-drying algorithm designed by Kärnä *et al* (2011), which satisfies not only the continuity and momentum conservations but also the full mass conservation, was used in the model. More information about SLIM can be found in the Kärnä *et al* (2011) and related references therein.

A two-dimensional unstructured mesh exhibiting a highly variable resolution covers the Makassar Strait as well as the various branches of the Mahakam Delta. The Mahakam River itself and major tributaries are represented by one-dimensional elements. The measured bathymetry was used in the computational domain except for the continental shelf and Makassar Strait, where the GEBCO (www.gebco.net) database was utilized. The tides from the global ocean tidal model TPXO7.1 (http://volkov.oce.orst.edu/tides) are imposed at the entrance and at the exit of the Makassar Strait through elevation and velocity harmonics as downstream open sea conditions. A recent daily river flow time series (from December 2008 to May 2009) is used for the upstream condition. The total river flow varies in a range between 3400 to 7050 m^{3}s^{-1} in this period. Model parameters such as the Manning coefficient, the horizontal kinematic eddy viscosity, and diffusivity coefficient are given the same values as those of PhamVan *et al.* (2012). A value of SSC of 0.364 kg m^{-3} is imposed at the upstream boundary to investigate the distribution of suspended sediment in the delta and the effects of density variation on the flow. The initial SSC value is 0.005 kg m^{-3}.

3. Results and discussions

Fig.1 shows the SSC in the whole computational domain at the tidal averaged condition in the neap tide around 17 April 2009. The SSC decreases significantly from the mouth of the Mahakam River (Delta Apex) to the delta front, especially in the tidal channels in the delta. Fig.2 depicts the depth-averaged SSC from December 2008 to May 2009 at several locations in the Mahakam River and in the delta. It is clearly observed that the variation of SSC at these locations is influenced by the tidal conditions. The SSC during a neap tide is higher than in a spring tide (e.g. at TC3 location). In addition, the SSC in the delta also changes during the neap-spring tidal cycle. For example, the SSC varies from 0.065 to 0.095 kg m^{-3} at the TC3 location while it changes around 0.09 kg m^{-3} at Samarinda and Delta Apex. These results are similar to the values that mentioned in Dutrieux (1991). The sediment concentration in the channels influenced by tides is low (0.02-0.03 kg m^{-3}) while it is high (0.08 kg m^{-3}) and can reach up to 0.16 kg m^{-3} in the channels influenced by the river.

The simulation results show that the water depth increases tiny (less than 5 mm) in the Mahakam River when the spatial variation of water density due to the SSC is taken into account in the shallow-water equations. The difference of water depth in the case with and without considering the water density variation is about 1 cm in the delta. These results suggest that the effects of water density variation can be neglected in the Mahakam Delta.

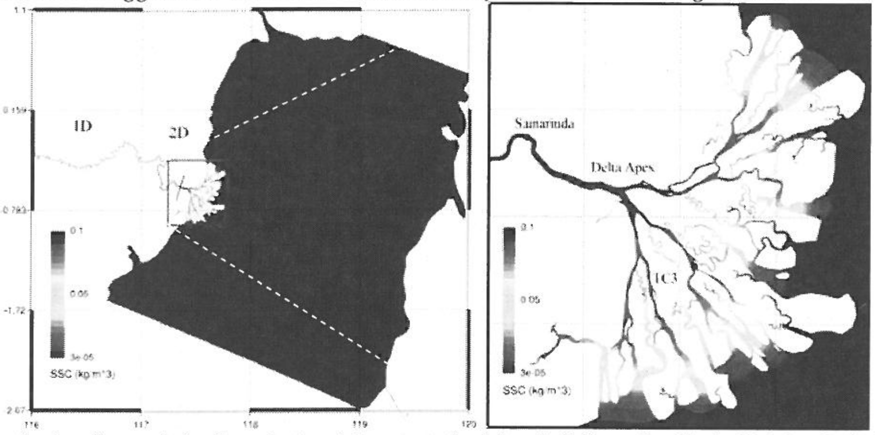

Figure 1. The distribution of suspended sediment in the whole computational domain (left panel) and in the Mahakam Delta (right panel) at tidal averaged condition for the neap tide around 17 April 2009

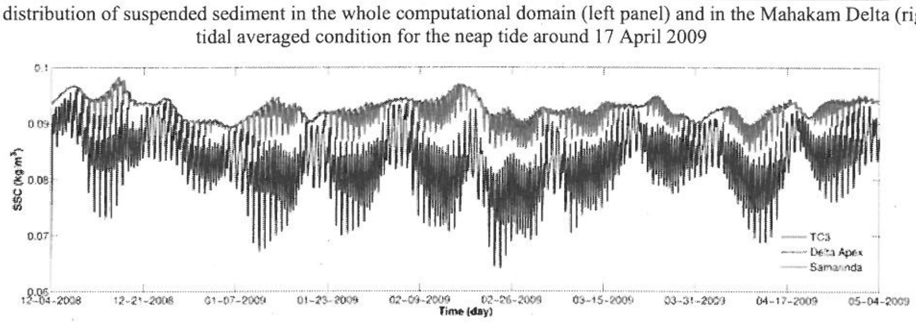

Figure 2. The depth-averaged SSC from December 2008 to May 2009 at several given locations in the River and the Delta

Acknowledgments

The present study was carried out in the framework of the project "Taking up the challenges of multi-scale marine modelling" which is funded by the Communauté Francaise de Belgique under contract ARC 10/15-028 (Actions de recherche concertées) with the aim of developing and using SLIM (www.climate.be/slim). Eric Deleersnijder and Sandra Soares-Frazão are honorary research associates with the Belgian National Fund for Scientific Research (F.R.S-FNRS).

References

Chaîneau CH, Miné J and Suripno (2010) The integration of biodiversity conservation with oil and gas exploration in sensitive tropical environments. *Biodiversity and Conservation* 19 (2), 587–600.

Dutrieux E (1991) Study of the ecological functioning of the Mahakam delta (east Kalimantan, Indonesia). *Estuarine, Coastal and Shelf Science, 32(4)*, 415-420.

Hadi S, Ningsih NS and Tarya A (2006) Study on seasonal variation of cohesive suspended sediment transport in estuary of Mahakam Delta by using numerical model. *Jurnal Teknik Sipil* 13 (1), 11–22.

PhamVan C, de Brye B, Spinewine B, Sassi M, Hidayat H, Deleersnijder E, Hoitink AJF and Soares-Frazao S Numerical model development of salinity intrusion in the Mahakam Delta, Indonesia (in preparation).

Kärnä T, de Brye B, Gourgue O, Lambrechts J, Comblen R, Legat V and Deleersnijder E (2011) A fully implicit wetting-drying method for DG-FEM shallow water models, with an application to the Scheldt Estuary. *Computer Methods in Applied Mechanics and Engineering, 200*, 509-524.

Storms JEA, Hoogendoorn RM, Dam RAC, Hoitink AJF and Koonenberg SB (2005) Late-Holocene evolution of the Mahakam delta, East Kalimantan, Indonesia. *Sedimentary Geology, 180*, 149-166.