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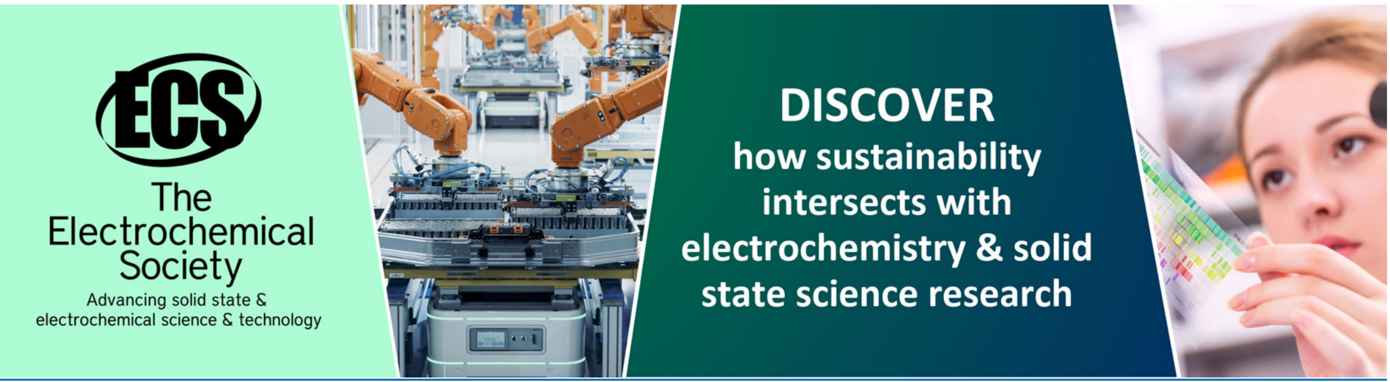

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Simulation of two-dimensional currents to the depth and suspended sediment concentration in Aceh Besar Waters

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Abstract. Aceh Besar Waters are geographically located at 5.3º - 5.7ºN and 95.1º - 95.6ºE which border Indian Ocean, Andaman Sea, and Malacca Strait in the West, North, and East, respectively. The purpose of this study was to simulate the circulation of current and suspended sediment transport driven by southwest and northeast monsoon. Model discretization cover 0.5 x 0.5 arcminutes (925 x 925 m) of spatial resolution with time interval of 9 seconds. The parameters of the model are wind friction Cd = 1.285×10^{-3}, bottom friction r = 0.0025, lateral eddy viscosity = 2500 m^2/s. The primary data of estuary suspended sediment concentrations were collected in the coastal waters of Lhok Nga, Ulee Lheue, Lampulo, Alue Naga and Krueng Raya as input for the suspended sediment distribution model. The results of the study show that during southwest monsoon, the current in the western part of Aceh Besar Waters move northward and during northeast monsoon in the western and eastern part of the region, the current move toward south and west. Thus, the distribution of suspended sediments follows the direction of the current, where sediment concentrations are reduced when they are away from the coast.

1. Introduction

The Aceh Besar Waters is part of Aceh Waters that is geographically located in the northern tip of Sumatera Island at 5.3º - 5.7ºN and 95.1º - 95.6ºE. It is adjacent to Indian Ocean, Andaman Sea, and Malacca Strait. Study on current circulation have been carried out including circulation in the Indian Ocean [1, 2]; the Malacca Strait [3, 4]; the northern waters of Aceh [5]; and in the Andaman Sea [6].

The study of sediment dynamics has been carried out [7] regarding suspended sediment transport 3D modeling in tidal estuary waters; Sravanthi et al. [8] conducted a numerical application of drifting sediment transport in Central Kerala, West-coast of India. Thus, it is very important to examine the circulation and sediment transport in the coastal waters of Aceh Besar (figure 1). The purpose of this study is to obtain a current-driven southwest and northeast monsoon and suspended sediment transport driven by current circulation which results in a distribution of suspended sediment concentrations.

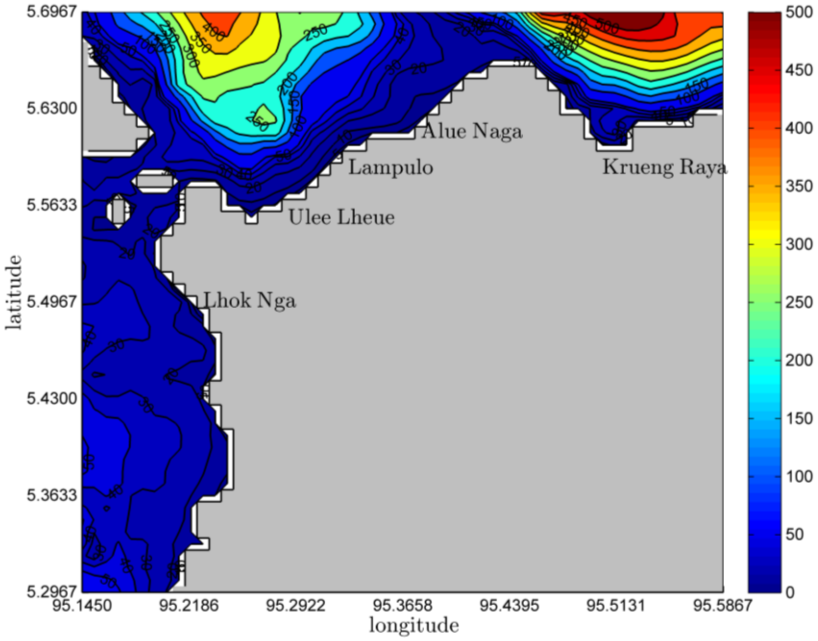

Figure 1. Bathymetric map (depth is in meters).

2. Material and methods

Hydrodynamics (equations 1-6) and advection-diffusion models (equation 7) are employed to simulate current circulation and suspended sediment transport driven by wind forcing [9, 10, 11] with a discretization of 0.5 x 0.5 arcminutes (925 x 925 m) with interval of 9 arcseconds, wind friction Cd = 1.285×10^{-3}, bottom friction r = 0.0025, lateral eddy viscosity = 2500 m^2/s. A couple of representative seasonal circulation include northeast and southwest monsoon. Wind data were retrieved from European Centre for Medium-Range Weather Forecasts (ECMWF) during February and August 2016 (figure 2 and figure 3). Data on estuary sediment concentrations were collected in the coastal waters of Lhok Nga, Ulee Lheue, Lampulo, Alue Naga and Krueng Raya as inputs for suspended sediment distribution models. The concentrations of Lhok Nga, Ulee Lheue, Lampulo, Alue Naga and Krueng Raya were 260 mg / l, 680 mg / l, 590 mg / l, 700 mg / l, and 740 mg / l, respectively.

$$\frac{\partial u}{\partial t} + Adv_h(u) - fv = -g\frac{\partial \eta}{\partial x} + \frac{\tau_x^{wind} - \tau_x^{bot}}{\rho_o} + Diff_h(u) \quad (1)$$

$$\frac{\partial v}{\partial t} + Adv_h(v) + fu = -g\frac{\partial \eta}{\partial y} + \frac{\tau_y^{wind} - \tau_y^{bot}}{\rho_o} + Diff_h(v) \quad (2)$$

$$\frac{\partial \eta}{\partial t} + \frac{\partial (uh)}{\partial x} + \frac{\partial (uh)}{\partial y} = 0 \quad (3)$$

$$dv(\psi) = u\frac{\partial \psi}{dx} + v\frac{\partial \psi}{dy} \quad (4)$$

$$Diff(\psi) = \frac{\partial}{\partial x}\left(A_h\frac{\partial \psi}{dx}\right) + \frac{\partial}{\partial x}\left(A_h\frac{\partial \psi}{dx}\right) \quad (5)$$

Courant-Friedrich-Lewy (CFL) criterion for stability:

$$\Delta t \leq \frac{\min(\Delta x, \Delta y)}{\sqrt{2gh_{max}}} \quad (6)$$

$$\frac{\partial C}{\partial t} + Adv_h(C) = Diff_h(C) \quad (7)$$

Where t, $u(t, x, y)$, $v(t, x, y)$, ψ are time, magnitudes of ocean currents in the west-east and north-south directions, arbitrary parameters respectively. $Adv_h(u, v)$ is a horizontal component of advection, $Diff_h(u, v)$ is a component of horizontal diffusion. $-fv$ and $+fu$ are Coriolis forces. The gradient pressure force is $-g\ \partial\eta/\partial x$ and $-g\ \partial\eta/\partial y$. Whereas the sum of wind friction and bottom friction is $\frac{\tau_x^{wind} - \tau_x^{bottom}}{(\rho_0 h)}$ and $\frac{\tau_y^{wind} - \tau_y^{bottom}}{(\rho_0 h)}$. The depth of seawater is h and the maximum depth is h_{max}, while g is the gravitational force.

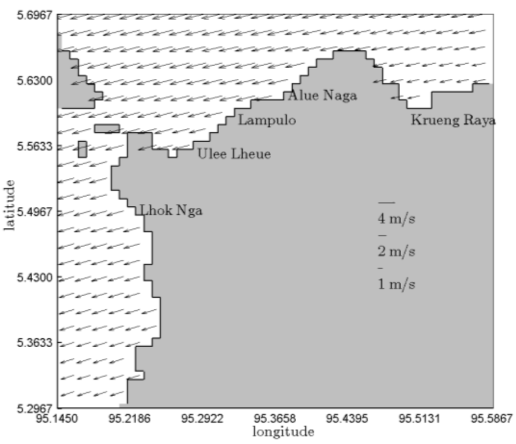

Figure 2. Wind vector during Northeast monsoon in the Aceh Besar waters (m/s).

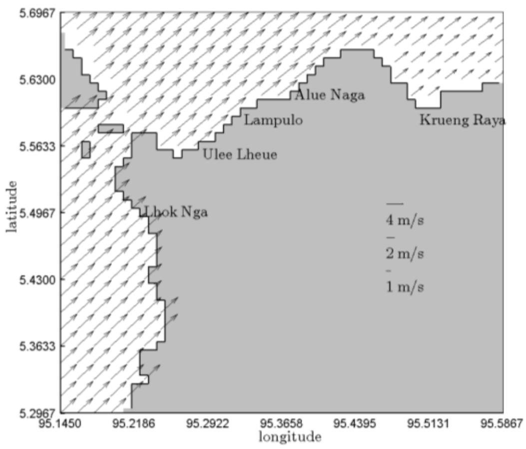

Figure 3. Wind vector during Southwest monsoon in the Aceh Besar waters (m/s).

3. Results and discussion

Current circulation and sediment transport simulations are shown in figure 4 and 5. The ocean current direction on February 2016 (figure 4) follows the effects of wind and Coriolis forces. In the western part of Aceh Besar, the current move northward following topographical condition. Current velocity is high at offshore and decreases when approaching the coastal area. The current velocity in the west coast reached 0.2 m/s while near coast was around 0.1 m/s.

On August 2016 (figure 5) the current in the western part of Aceh Besar moved southward with magnitudes of 0.2 m/s. Meanwhile, the distribution of suspended sediments followed the direction of the current, as the concentration of sediments moved away from the coast, the sediment concentration decreased (figure 4 and 5).

The model in this study was in accordance with the results obtained in previous studies [1, 2, 12]. The influence of the monsoonal circulation was well-described especially in the western part of the Aceh waters.

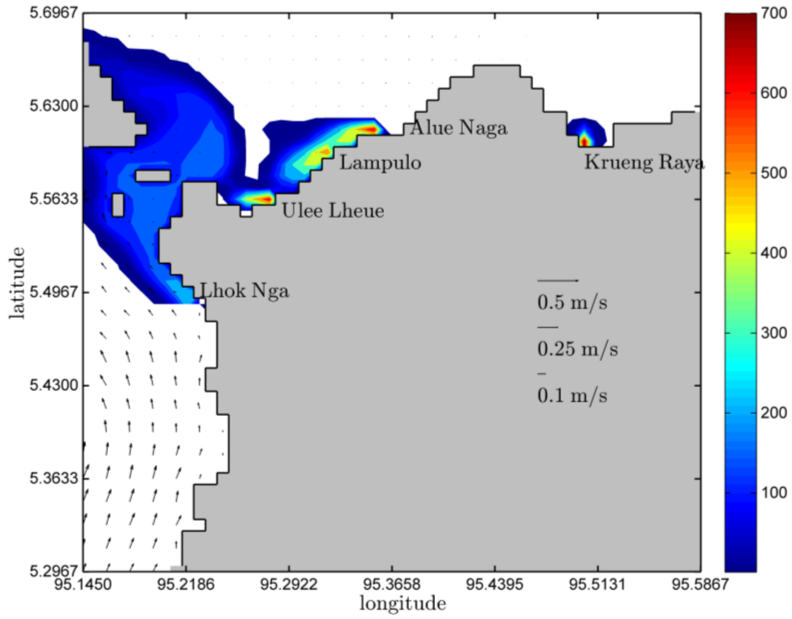

Figure 4. Average current in vector (m/s) and 1 month suspended sediment concentration in shaded contour (mg/l).

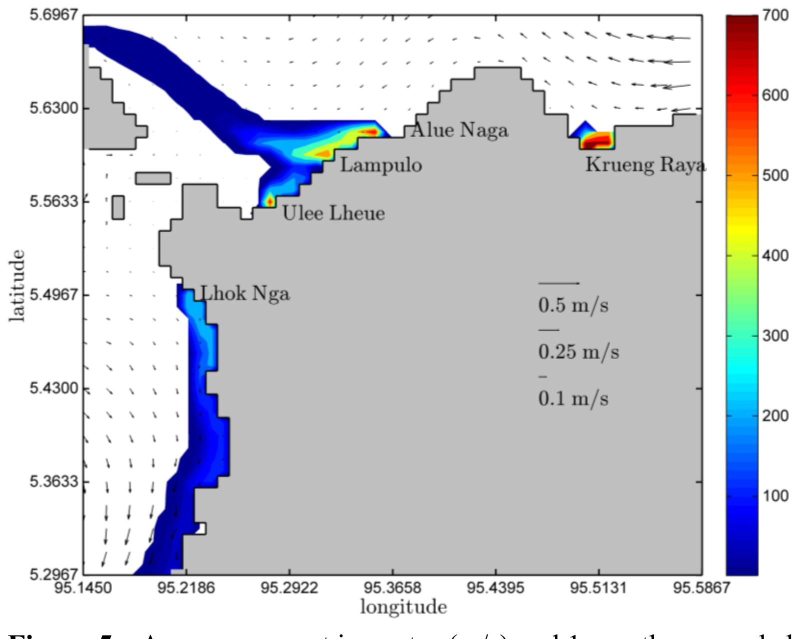

Figure 5. Average current in vector (m/s) and 1 month suspended sediment concentration in shaded contour (mg/l).

4. Conclusion

The simulation of two-dimensional currents to the depth and suspended sediment concentration has been carried out in Aceh Besar Waters. During the southwest monsoon, the current in the western part of Aceh Besar Waters move northward whereas during northeast monsoon in the western and eastern part of the region, the current move toward south and west. The distribution of suspended sediments follows the direction of the current, where sediment concentrations are reduced when they are away from the coast.

Acknowledgments
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