

Simulation of current using a two-dimensional numerical model in the Aceh Barat Daya waters, Indonesia

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Abstract. The waters of Aceh Barat Daya are located in the southwest of the province of Aceh, Indonesia. These waters is influenced by the monsoon because these waters are part of the Indian Ocean. The motivation of this research is to simulate the current with 2 D numerical model. Current simulations are performed during the Monsoon (April) transition period from 2014-2016 by using wind data obtained from ECMWF. The wind direction comes from the west. According to this simulation, the pattern of ocean currents is directed to southeast direction. This corresponds to Ekman's theory.

1. Introduction

Aceh Barat Daya (Abdya) is located along the southwest coast of Aceh (30.34 '24 " - 40 05' 37" N and 960 34 '57 " - 970 09' 19" E), bordering 3 Aceh districts, namely South Aceh, Gayo Lues, and Nagan Raya. Abdya waters have several potentials, namely fisheries [1], mineral resources (iron and gold), transportation, and marine tourism which so far have not been managed and utilized.

Abdya waters get the influence of the monsoon system every year. Northeast Monsoons are valid from December to February while the southwest monsoon is valid from June to September [2]. The monsoon transition (April-May) is a transition between the northeast monsoon and the southwest monsoon. According to [3] in April southwest winds began to form along the coasts of Myanmar and Thailand. At that time, the wind might reach the waters of Aceh. Wind is a major marine current generator, in certain waters such as in the Korean Strait, the wind is the main factor of Ekman transport [4]. In the Malacca Strait, the wind can encourage eddy formation and distort tidal [5].

So far, several studies have been conducted in Aceh waters, such as [6] and [7] regarding tidal flows, concerning sediment distribution [8], concerning current circulation during monsoon in Andaman and Malacca Strait [2], concerning fish catching areas in Aceh waters [1] and [9], regarding flows in the northern waters of Aceh [10], and regarding waves in Aceh waters [11]. There are still a few studies related to oceanography in Abdya waters. This study aims to determine the dynamics of ocean currents in the Abdya waters with the generating force in the form of surface wind speed.



2. Materials and Methods

The study locations were Abdya waters, Aceh Province, Indonesia (96.2–97°E and 3.5–4.1°N) see Figure 1. Bathymetry data is obtained from SRTM30 data [12]. This data is quite good because the resolution is quite high and in accordance with bathymetry data obtained from Hydrography and Oceanography Center, Indonesian Navy. This data has been also used for numerical simulations of ocean currents in the northern waters of Aceh [10].

The generating force in the form of wind circulation is obtained from ECMWF interim. ECMWF interim provides a number of global data related to atmospheric/weather prediction for medium to long term. The wind data used is the wind component (Uwind, Vwind) at an altitude of 10 meters. Before inputting in numeric models this data is interpolated and extracted with the Grid Analysis Display System (GrADS) software.

For the two-dimensional numeric model, the model discretization is prepared to $\Delta x = \Delta y = 0.5$ minutes or 925 meters and time interval (Δt) = 30 seconds (according to CFL criteria). Numerical simulations are run for two months, from March to April (2014-2016). To ensure the stability of the output data analyzed is data in April. So that for each year the simulation duration is two months.

The numerical model used is based on complete Navier-Stokes equations for two dimensions [13]. This model has been successfully applied for simulating ocean currents in the Malacca Strait waters [14], the Gulf of Thailand [15], the waters of northern Aceh [10]. The equation used for a two-dimensional numerical model can be seen as follows:

$$\frac{\partial u}{\partial t} + Adv_h(u) - fv = -g \frac{\partial \eta}{\partial x} + \frac{\tau_x^{wind} - \tau_x^{bot}}{\rho_0} + Diff(u) \quad (1)$$

$$\frac{\partial v}{\partial t} + Adv_h(v) + fu = -g \frac{\partial \eta}{\partial y} + \frac{\tau_y^{wind} - \tau_y^{bot}}{\rho_0} + Diff(v) \quad (2)$$

Where $\partial u/\partial t$ and $\partial v/\partial t$ are x-direction and y-direction acceleration, respectively; while $Adv_h(u,v)$ are x-direction and y-direction advection, respectively; fv and fu are Coriolis force; g is acceleration due to gravitation; $\eta(x,y,t)$ is sea level elevation, $\tau_{x,y}^{wind}$ is wind stress; $\tau_{x,y}^{bot}$ is stress due to bottom friction; ρ is sea density; h is water depth; $Diff(u,v)$ are x-direction and y-direction advection, respectively. The bottom friction coefficient is 0.001, while the constant of wind stress is 0.0012 N/m and wind density is 1.1184 kg/m.

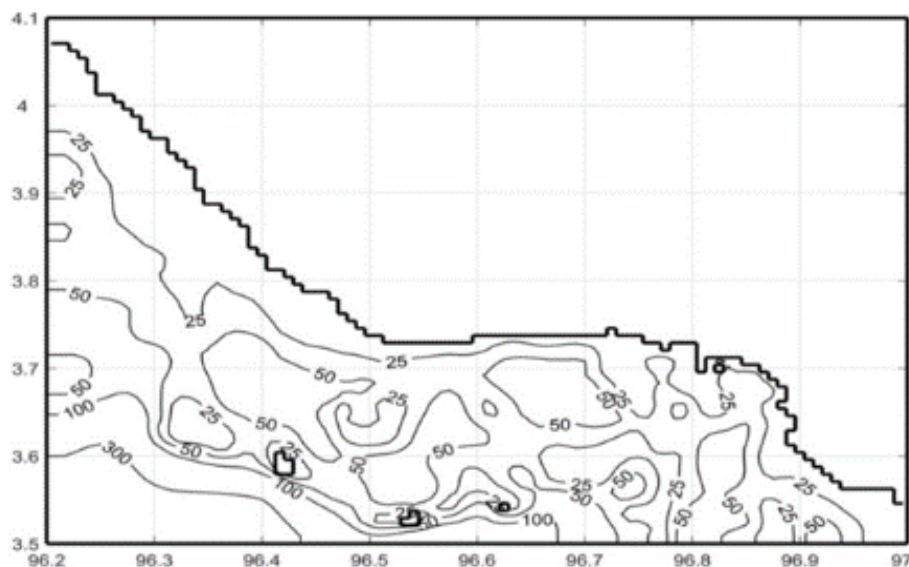


Figure 1. The bathymetry of the Aceh Waters (in meters). It is obtained from the Shuttle Radar Topography Mission (SRTM).

3. Results and Discussion

The average wind circulation in April 2014 in Abdya waters is shown in Figure 2. Winds are dominated by western winds which are slightly deflected to the southeast when approaching the coastline. Wind speed is 1.5 m/s. Circulation of ocean currents in April 2014 is shown in Figure 3. Currents flow in Abdya waters move from north and northwest to southeast with maximum speed in the north (headland) and minimum current velocity in the south (bay). Currents along the coastline tend to be parallel to the coast except in the southeastern part of the domain. In this section, the inflow goes to the coastline.

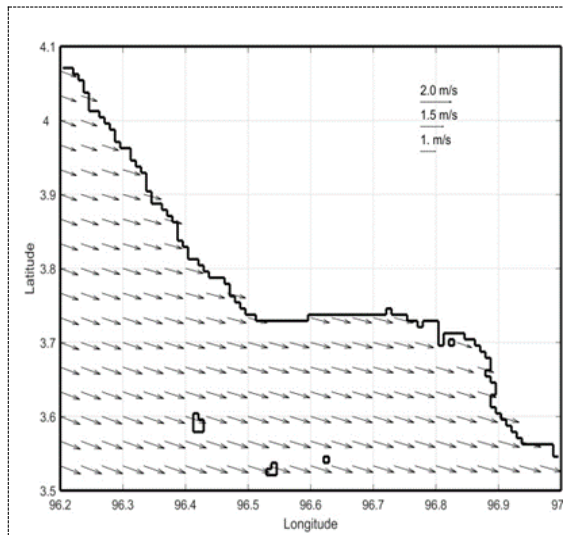


Figure 2. Wind speed and direction in April 2014 (m/s)

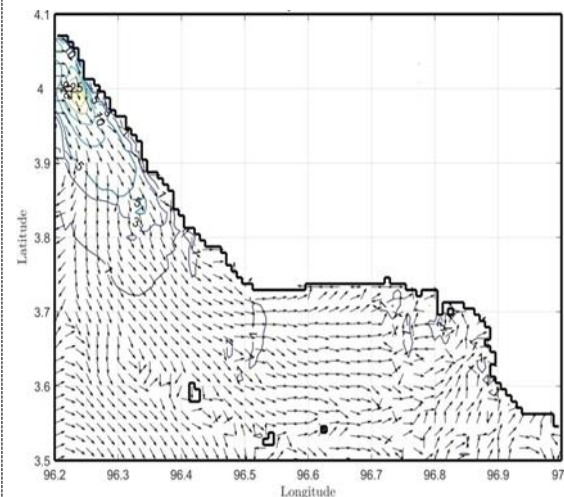


Figure 3. Current speed and direction in April 2014 (cm/s)

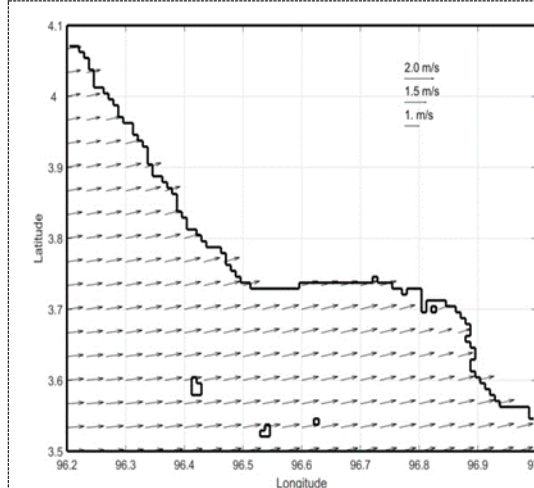


Figure 4. Wind speed and direction in April 2015 (m/s)

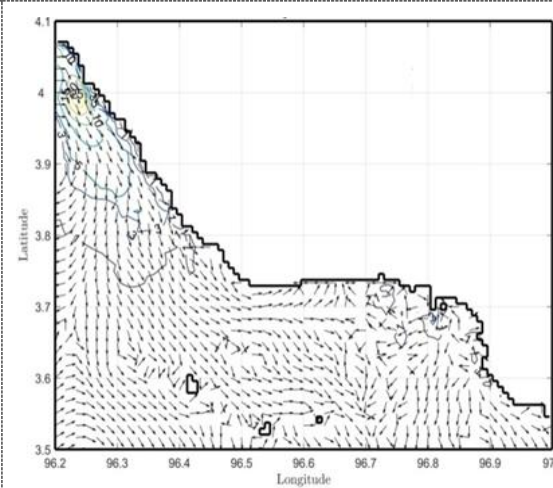


Figure 5. Current speed and direction in April 2015 (cm/s)

Wind circulation in April 2015 is shown in Figure 4. The wind is dominated by western winds at a speed of 1.5 m/s. Figure 5 shows the current circulation in April 2015. Ocean currents move from north to southeast with maximum speed in the north (headland). Currents along the headland are parallel to the coast. The current becomes unstable when approaching the bay. At the bay, the outflow flows to the shoreline.

Wind circulation in April 2016 is displayed in Figure 6. Winds are dominated by western winds at a speed of 1.5 m/s. The wind was slightly deflected to the southeast as it approached the coastline similar to the wind in April 2014 (Figure 2). Ocean flow circulation in April 2016 is shown in Figure 7. Ocean currents move from north to southeast. Ocean currents are still fast enough on the headland and weak at the bay. In the bay section the current moves towards the coastline.

In general, the circulation of ocean currents in the Abdya waters during April or the intermonsoon moves from north to southeast. This is driven by a relatively consistent west wind. This finding is in accordance with Ekman's theory, where the direction of the current shifts 45° to the right of the wind direction due to the Coriolis effect [16]. Although the location of the Abdya waters is close to the equator (3.5° N), but the Ekman current can still be seen.

The speed and direction of the current are also determined by the depth of the water. Relatively deep water in the southwest part causes the weak circulation in the southwest. While the current direction tends to be consistent towards the southeast. In the bay part, current is weak and unstable due to the influence of shallow bathymetry. In addition, this part is quite sensitive to the changes in the wind.

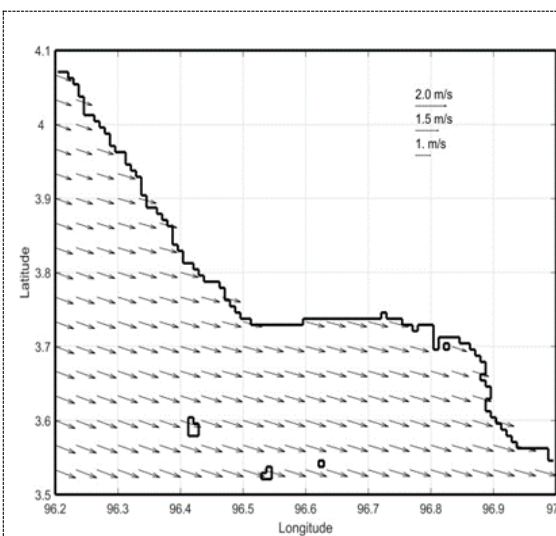


Figure 6. Wind speed and direction in April 2016 (m/s)

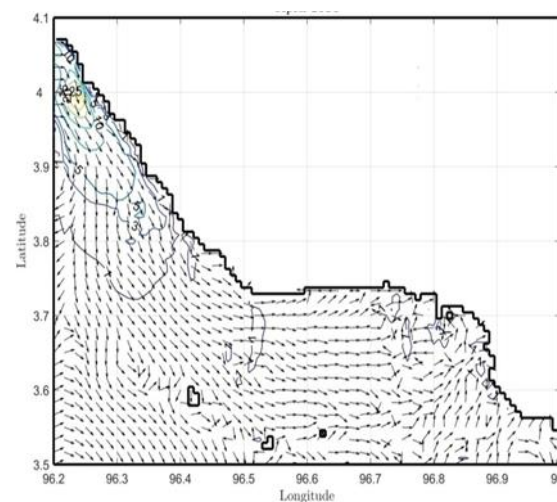


Figure 7. Current speed and direction in April 2016 (cm/s)

4. Conclusions

The dynamics of Abdya waters, Aceh, Indonesia have been studied with a two-dimensional numerical model developed by [13]. Simulation results show that the model is relatively consistent with surface wind speed and directions

In general, the speed and direction of the current in the Abdya waters are strongly influenced by the west wind and bathymetry contours. The circulation of the west wind causes the current to flow to the southeast, this is in accordance with the theory of Ekman. While bathymetric contours cause variations in the flow direction, especially in the headland and bay.

In April, the average wind speed in Abdya waters reached 1.5 m/s, while the average speed of the current is 25 cm/s. The current circulation is fast enough in the north of the Abdya (headland) waters. While the relatively weak current circulation is south of the Abdya waters (bay). Fast current speed is related to relatively shallow depth conditions. From the simulation results, it can also be concluded that the circulation patterns of flow and wind in Abdya waters in April (intermonsoon) are relatively the same.

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