Modeling of tidal current and residual currents patterns in Tomori Bay, North Morowali Regency, Central Sulawesi Province

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Abstract. Research has been carried out to model current patterns and residual current in Tomori Bay using Mohid Studio 2016. The model using a finite volume approach with a tidal model driven by the results of Geospatial Information Agency (BIG) predictions placed on the open boundary of the model. The modeling results are compared with the measurement results in Tomori Bay. The tidal current velocity in the high tide conditions increases the current velocity at the bay neck and weakens after passing Tokobae Island. The current velocity on the west side of Tokobae island is higher than that of the east of Tokobae. At the mouth of the bay, the current velocity on the north side is higher than at the south side of the bay mouth. The tidal current velocity is higher than the residual current with a maximum tidal current velocity of 25.3 cms$^{-1}$ and a maximum velocity of residual current 12.6 cms$^{-1}$. The residual current that describes the fate of pollutants while in the Tomori Bay waters. The residual flow pattern shows a vortex on the north side of the bay mouth and to the southeast of Tokobae Island.

1. Introduction

Tomori Bay, located on the east coast of Sulawesi Island, is a single sedimentary basin formed from Banggai-Sula microtectonics [1,2]. 210 885.89 mining land in North Morowali Regency [3] is mostly part of the river basin that empties into Tomori Bay. Tomori Bay is semi-closed water, so the circulation of seawater masses is greatly influenced by tides. Ocean currents in semi-closed bay waters are predominantly generated by tides [4,5,6].

The distribution of pollutants, nutrients, and water quality is influenced by ocean currents [7]. Dominant net transport in the bay waters is determined by tidal-induced circulation of residual currents [8]. The tidal propagation in the bay is influenced by bathymetry, river runoff which contributes to low salinity water masses and wind velocity [9].

Research on residual flows in bay waters has shown that residual flows are formed by lagrangian residual currents which form eddies that vary with the seasons [8, 10]. Increasing the tidal amplitude at the open boundary significantly causes the residual flow regime to become more complicated at the bay, the effect of bottom friction on the residual current is relatively weak compared to the tidal effect [11].

The purpose of this study was to determine the current and residual current patterns in the waters of Tomori Bay which affect the fate of nutrients and pollutants in the bay waters.
2. Methods
To develop a model using atmospheric data obtained from the European Center for Medium-Range Weather Forecasts (ECMWF), tides from the Geospatial Information Agency (GIA) prediction, and salinity temperature data from CTD measurements in Tomori Bay. Meanwhile, the model validation uses the results of tidal measurements for 3 days in Tomori Bay.

The hydrodynamic model of Tomori Bay (Figure 1) is divided into 105 x 65 grids with a horizontal grid size of 0.005° x 0.005° for each grid with a grid orientation according to Earth's north orientation. The hydrodynamic model in Palu Bay uses MOHID 3D, which is a hydrodynamic model based on the Navier-Stokes equation with Boussinesq and hydrostatic approaches [12]. MOHID 3D is formulated in a finite volume approach with generic vertical discretization that allows the simultaneous execution of various types of vertical coordinates.
3. Analysis

Analysis of the results of the model is carried out to obtain the residual current or transport average velocity by using the equation [13] 1980):

\[ V_{res} = \frac{\int_0^T V dt}{\int_0^T dt} \]  

(1)

Where \( V \) is the component of velocity (x or y), \( T \) is the tidal period, and \( t \) is time. The components of velocity (x or y) and elevation are obtained from the calculation of a hydrodynamic model that is integrated with depth.

The accuracy of the suitability of the model was tested using the Mean Absolute Percentage Error (MAPE) [14]. MAPE uses the results of the measurement model and the results of the tide model:

\[ MAPE = \frac{1}{n} \sum_{t=1}^{n} \left| \frac{\text{model} - \text{data}}{\text{data}} \right| \times 100 \]  

(2)

With MAPE value interpretation: MAPE<10 = highly accurate forecasting; 10<MAPE<20 = good forecasting; 20<MAPE<50 = reasonable forecasting; MAPE≥50 = inaccurate forecasting.

4. Results and discussion

![Figure 2. Plot of model and measurement results from tide height in Tomori Bay](image)

4.1 Model validation

Model validation was carried out by comparing the tides measured for 3 days with the tides that were modeled on the corresponding date (Figure 2). The results of the comparison using MAPE show a value of 5.5 or are in the highly accurate forecasting category. The validation results show that the model has good compatibility with the measurement results so that the results of the hydrodynamic model in Tomori Bay can represent environmental conditions at that location.

4.2 Tidal Current

Tomori Bay bathymetry forms a basin in the southeast of Tokobae Island which is the central part of Tomori Bay. This condition affects the current velocity, both total and residual current by tidal propagation in Tomori Bay. The current pattern at high tide shows that the current enters Tomori Bay from the mouth of the bay at a relatively higher velocity compared to other locations (Figure 3). The current pattern that enters Tomori Bay is divided into two, first the current passing through the northern part of Tokobae Island and the second current passing through the southern part of Tokobae Island. In the southeastern part of Tokobae Island, the current velocity has decreased by increasing depth. Current
velocity increased again on the northern side of Tokobae Island by silting waters; this pattern is consistent with the results of research in the Bay of South San Francisco [15]. The current that passes through the southern part of Tokobae Island is divided into two, some moving south and some moving north. The current moving south is weakened because it meets the Kolonodale coastline. The current that moves north to meet the current passing through the northern part of Tokobae Island is also experiencing a slowdown in velocity by silting until it reaches the head of the bay. The decrease in current velocity due to silting is consistent with the results of research in Kangjin Bay [16]. The current pattern in the conditions towards high tide generally shows the current pattern entering the bay following the tidal propagation.

Figure 3. Current pattern in Tomori Bay at low tide to high tide

The tidal type of Tomori Bay is a mixed tide prevailing semidiurnal which is part of the Banda Sea. The current pattern in high tide to low tide conditions shows that the current velocity is moving out of Tomori Bay (Figure 4). The current pattern with low velocity along the coast of the head of the bay both in the north and in the south. The current propagates following tidal waves out of the bay has increased after entering a narrow gap in the north and south of Tokobae Island. velocity increase occurs by the tidal propagation process, which enters a narrow area [17,18]. The velocity of tidal currents passing through the northern part of Tokobae Island has decreased after turning south into deeper waters before increasing after moving out of Tomori Bay, leaving the model area.
4.3 Residual Current
The sea level height by tides in one period if averaged will be zero. So with this assumption, if the current that is formed due to the pressure difference due to the high difference caused by the tide will also be zero. In the case of the bay, the inflow during high tide will come out at low tide, but after averaging it, there is still a value known as the residual current value. Residual currents are formed by the interaction of tidal currents with the bottom topography of the waters, due to the Coriolis effect, friction, and advection [19].

The tidal current velocity is greater than the residual current at all locations in Tomori Bay. The residual current pattern shows a different pattern from the tidal current velocity pattern. Due to friction with bathymetry and the islands in Tomori Bay, two large eddies are formed in the north and south of Tokobae Island. This vortex plays a role in holding pollutants that remain in the water column in the waters of Tomori Bay. The velocity of tidal currents also increases in the area close to the islands in Tomori Bay. This pattern corresponds to tidal residual flows generated by flows interacting with islands [19, 20].

Figure 4. Current pattern in Tomori Bay at high tide to low tide
5. Conclusion

The current pattern in Tomori Bay at tide conditions shows the current pattern that moves into the bay with a large variation of velocity influenced by flow width and flow depth with a maximum current speed of 25.3 cms\(^{-1}\). The current pattern in tide to ebb conditions moves out of Tomori Bay with a maximum speed of 19.7 cms\(^{-1}\). Although the residual flow is small (maximum 12.6 cms\(^{-1}\)), it forms several eddies that have the potential to trap nutrients in the water column in Tomori Bay, this can have a negative impact on the waters of Tomori Bay if exposed to pollutants because it will settle in the bay environment.

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