Tidal Current Circulation in Western Bali Sea Using a 2-D Hydrodynamic Model

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Abstract. The circulation of tidal currents in the northern part of the Bali Sea was created using two main steps, namely a large model simulation and a small model simulation. The first step, a large model simulation detailing the circulation of tidal currents in the Bali Strait, uses a 2D barotropic hydrodynamic model that utilizes tidal-generating forces and Gebo bathymetry data with a 30-second resolution. In this large model simulation, tidal heights are procured which are then used as data for the small model. The second step, a small model circulation which focuses on the northern part of the Bali Sea, uses a 2D barotropic hydrodynamic model and utilizes tidal-generating forces from the large model and BIG (Geospatial Information Agency) bathymetry data with a 50-meter resolution. This smaller resolution is used to observe the effects of the cape in the northern Bali Sea. The tidal simulation is done for 29 days (May 2016) with inputted data in the form of bathymetry and tidal data at four points with open boundary conditions. The results of the tidal simulation indicate that tidal currents follow the phase of the tides. During high tides, the tidal currents move North and during low tides, the currents move South. Meanwhile, for the area around the Gondol Cape in Northern Bali, an eastward-westward current is observed.

Keywords: Tidal Currents, 2-D Hydrodynamic Model, Western Bali Sea.

1. Introduction

Ocean currents are an important hydrodynamic parameter to observe when defining the characteristics of a body of water. Ocean currents are the movement of seawater mass, also called mass movements, in either the vertical or horizontal direction [1]. This movement of seawater is caused by various generative forces. Ocean currents are the movement of seawater mass from one place to another, which means a change in position. Ocean current movements happen throughout the world and the movements influence each other, either vertically or horizontally [2]. Everything connected to maritime processes and events is not exempt from the role of ocean currents, including marine resource exploration in the industries of fishing, minerals, hydrography and ocean mapping, meteorology and climate, and the connection between the ocean and coastal building construction [3].
The island of Bali is known as a good tourist location in Indonesia. Besides that, the western area of the Bali Sea is also used for aquacultures such as the cultivation of pearls and tuna. There is also dolphin conservation areas. The western part of the Bali Sea is a mixture of waters from the Java Sea, Flores Sea, and Makassar Strait. The western part of the Bali Sea is very productive but its characteristics are still unknown, including the characteristics of its tidal currents. Tidal currents have a very close relationship with the tides in these waters [4]. The tides in the Badung Strait in Bali have the dominant harmonic components of M2 (Lunar Semidiurnal) and S2 (Principal Solar Semidiurnal) [5]. The pattern of the tidal currents is vital to figuring out the characteristics of the western part of the Bali Sea. Because of that, the writer of this paper observed the patterns of the tidal currents in the western part of the Bali Sea using a 2D hydrodynamic model.

2. Methodology

The tidal current simulation was done for May 2016. The generative force used is tidal forcing obtained from Tide Model Driver (TMD). The two-dimensional hydrodynamic model used is the Princeton Ocean Modelling (POM). This simulation uses a barotropic model, that does not account for the difference in pressure for the vertical components. The observation area does not only encompass the Bali Strait, but also the western part of the Bali Sea which has never been specifically simulated for its tidal currents. Previous studies have been done, but only in the Bali Strait and not including the western part of the Bali Sea.

Two different bathymetry data are used. The bathymetry for the large-scale model is obtained from Gebco with a resolution of 30 seconds or around 930 meters. This bathymetry was taken from 114.3295 ° E – 115.1942 ° E and 7.7561 ° S – 8.6936° S. It was then converted into a grid with dimensions of 930 meters x 930 meters. The number of grids for this bathymetry is 104 x 113 grids. The maximum depth is 1108 meters. The bathymetry in the western part of the Bali Sea indicates that the area near the shore and near the Bali Strait has a depth of around 100 – 200 meters. These waters are rather shallow. Meanwhile, the eastern side of this large-scale model has a reasonably deep depth. The bathymetry for the small model was obtained from the Geospatial Information Agency which was then resampled. This bathymetry was taken from 114.35 ° E – 114.55 ° E and 8.10 ° S – 8.40º S. It was then converted into a grid with dimensions of 50 meters x 50 meters. The number of grids for this bathymetry is 26 x 31 grids. The maximum depth of this bathymetry is 55 meters at a basin near the Gondol Cape.

3. Results and Discussion

The large-scale model is a simulation with a large observed area that covers the Bali Strait. In this model, open boundaries are used at the north, south, and west sides. The results of the large model show that the maximum elevation is 1.2 meters and the lowest is 0.9 meters. These values are taken from the spring high tide and spring low tide.

The tidal elevation for the large-scale model was taken from TMD for May 1st 2016 to May 31st 2016. In May of 2016, field data for oceanographic parameters were taken at Gondol, Bali. The field data used to verify the simulation in this study are current data and tidal data. The tidal data were obtained from field observations for 15 days, from May 21st 2016 to June 4th 2016 at the Grand Center for Aquaculture Research and Development (BBPPBL), Gondol, West Bali Sea. Stationary current data was obtained from an ADCP at coordinates 8° 9’ 10.05” S and 114° 43’ 7.11” E. Current data were taken at depths of 1.6 meters, 2.6 meters, and 3.6 meters from the sea surface. Aside from stationary current data, scattered current data was also taken at coordinates 114.71° E – 114.73° E dan 8.14° S – 8.16º S.

The tidal current circulation can be measured from the phase of the spring and neap tides. During the spring high tide, the elevation in the western part of the Bali Sea ranges from 0.8 to 1.2 meters, while the tidal current reaches its maximum during the spring high tide with a speed of 2.6 meters/second. The current circulation shows that the dominant direction for the current is southward in the Bali Strait and westward in the western part of the Bali Sea. During the transition from the spring high
tide to the spring low tide, the elevation in the western part of the Bali Sea ranges from -0.8 to 0.1 meters while the current has a maximum speed of 1.3 meters/second. The current circulation shows that the dominant direction is westward in the Bali Strait and westward in the western part of the Bali Sea as well. During the spring low tide, the elevation in the western part of the Bali Sea ranges from -0.9 to -0.7 meters, while the maximum current speed is 2.1 meters/second. The current circulation shows that the dominant direction in the Bali Strait is northward. During the transition from the spring low tide to the spring high tide, the elevation in the western part of the Bali Strait ranges from -0.1 to 0.3 meters, while the tidal current has a maximum speed of 2.0 meters/second. The current circulation shows that the dominant direction in the Bali Strait is northward. During the transition from the neap high tide to the neap low tide, the elevation in the western part of the Bali Sea ranges from -0.4 to -0.1 meters, while the maximum current speed is 1.0 meters/second. The current circulation shows that the dominant direction is westward in the Bali Strait and westward in the western part of the Bali Sea as well. During the neap low tide, the elevation in the western part of the Bali Sea ranges from 0.1 to 0.3 meters while the current has a maximum speed of 2.2 meters/second. The current circulation shows that the dominant direction is westward in the Bali Strait and westward in the western part of the Bali Sea as well. During the transition from the low tide to the neap high tide, the elevation in the western part of the Bali Strait ranges from -0.7 to -0.1 meters, while the tidal current has a maximum speed of 1.0 meters/second.

The current circulation shows that the dominant direction in the Bali Strait is northward. The small-scale model is a simulation with a specific observed area to get a more detailed area of the western part of the Bali Sea near Gondol. The tidal elevation data is obtained from the large-scale model. The model uses open boundaries at the north, east, and west sides. The results of the small model show that the maximum elevation is 0.302 meters and the lowest elevation is -0.855 meters. These values are taken from the spring high tide and spring low tide. The tidal current circulation can be measured from the phase of the spring and neap tides.

![Figure 1. Current circulation in Bali Sea during (a) high tide and (b) low tide.](image)

The current circulation shows that the dominant direction in the Bali Strait is northward. The small-scale model is a simulation with a specific observed area to get a more detailed area of the western part of the Bali Sea near Gondol. The tidal elevation data is obtained from the large-scale model. The model uses open boundaries at the north, east, and west sides. The results of the small model show that the maximum elevation is 0.302 meters and the lowest elevation is -0.855 meters. These values are taken from the spring high tide and spring low tide. The tidal current circulation can be measured from the phase of the spring and neap tides.
During the spring high tide, the elevation in the western part of the Bali Sea is 0.166 meters, while the tidal current reaches its maximum during the spring high tide with a speed of 0.03 meters/second. The current circulation shows that the dominant direction for the current is eastward in the western part of the Bali Sea. During the transition from the spring high tide to the spring low tide, the elevation in the western part of the Bali Sea is 0.044 meters while the current has a maximum speed of 0.02 meters/second. The current circulation shows that the dominant direction is westward in the western part of the Bali Sea as well.

![Tidal current during high tide](image1)
![Tidal current during low tide](image2)

Figure 2. Current circulation in the western part of Bali during (a) high tide and (b) low tide refer to current circulation in Bali Sea until Bali Strait.

During the spring low tide, the elevation in the western part of the Bali Sea is -0.855 meters, while the maximum current speed is 0.02 meters/second. The current circulation shows that the dominant direction in the western part of the Bali Sea is northward. During the transition from the spring low tide to the spring high tide, the elevation in the western part of the Bali Strait is -0.038 meters, while the tidal current has a maximum speed of 0.02 meters/second. The current circulation shows that the dominant direction in the western part of the Bali Strait is westward on the right of the cape and eastward on the left of the cape. During the neap high tide, the elevation in the western part of the Bali Sea is -0.301 meters, while the maximum current speed is 0.02 meters. During the transition from the neap high tide to the neap low tide, the elevation in the western part of the Bali Sea is around 0.124 meters while the current has a maximum speed of 0.02 meters/second. During the neap low tide, the elevation in the western part of the Bali Sea is around -0.303 meters, while the maximum current speed is 0.02 meters/second. During the transition from the low tide to the neap high tide, the elevation in the western part of the Bali Strait is around -0.088 meters, while the tidal current has a maximum speed of 0.02 meters/second.
4. Conclusion
To conclude, the type of tide in the western part of the Bali Sea is a mixed predominantly semidiurnal type with a Formzahl number of 1.108 from the K1, O1, M2, and S2 components. Verification of the elevation shows a root mean square error for the large model and small model of 0.16 and 0.10, respectively (in meters). Verification of the tidal currents for the small model in the east-west direction and in the north-south direction shows a root mean square error of 0.026 and 0.022, respectively (in meters/second). The maximum current speed occurs during the spring high tide with a speed of 0.03 meters/second and the minimum current speed occurs during the neap low tide with a speed of 0.02 meters/second. The current in the western part of the Bali Sea is predominantly eastward during the high tide and westward during the low tide.

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