Current Structure and Preliminary Indication of Mentawaian-Jet in the Southeastern Mentawai Waters, Indonesia

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Abstract. The baseline observations of water current in the southeastern Mentawai waters using Shipboard Acoustic Doppler Current Profiler (SADCP) of the RV Baruna Jaya VIII in April 2013 were presented study. This study aims to reveal the current subsurface system in the internal western Sumatra waters, the southeastern Mentawai Islands waters. We found unique hydrodynamics in this region where the southeastward flows were observed in the upper 50 m yet persistent northwestward flow below. We suggest that the southeastward flows in the upper layer were the remaining Southeast Monsoon-driven circulations. The northwestward flows below were likely acting as counter-current due to continuity processes in this semi-enclosed sea. This counter-current exceeds 1 m s⁻¹ at a depth of>125 m, a localized jet-like current. We propose to name this high magnitude current as Mentawaian Jet as it feeds the western Sumatra internal waters.

1. Introduction
The Indonesian region is exposed to the monsoonal winds system, the Northwest Monsoon (NWM) winds, and the Southeast Monsoon (SEM) winds during boreal winter and austral winter. Yet, the Indonesian region has four different seasons, i.e., the main monsoon period of the NWM from December to March, the first transition monsoon from April to May, the main southeast monsoon period from June to August, and the second transition monsoon from October to November [1]. During the transition monsoon periods, decreasing wind orientation and magnitude occur. Most previous studies on circulations in the eastern equatorial Indian Ocean were estimated using the indirect method, employing temperature-salinity profiles and sea-level observations from tide gauge [2] and satellite altimeter [3]; hence can only produce climatological interpretation with fewer direct observations on subsurface circulations.

The circulation in the eastern Indian Ocean, including the current magnitude and direction, is affected by a year-round monsoonal winds system. Located in the vicinity of the Indian Ocean, the western offshore of Sumatra Island has been exposed to the eastward Indian Equatorial Counter Current (IECC). In December, the IECC is located around the equator and can extend to 6° S with a
decreasing magnitude. In January and February, when NWM winds get stronger, the IECC is pushed southward by the Indian North Equatorial Current (INEC), which extends up to 3-5° N. From March to April, the IECC is stronger and can extend from 3° N – 5° S with a typical magnitude of 0.5 – 0.8 m s⁻¹ [1], [4]. During the transition periods an eastward equatorial jet appears in the tropical Indian Ocean, namely the Wyrtki Jet [5]. This jet appears twice a year, i.e., during the transition monsoons period at a depth of 80-100 m [6], [7], and is characterized by warm water; hence is the potential to deepen the mixed layer around the western Sumatra waters. From the beginning of April to June, the jet speed can reach up to 0.7 m s⁻¹ [4]. During the second transition period with a typical rate of 1.0-1.3 m s⁻¹.

Strong South Java Coastal Current also features the western Sumatra waters and along the southern Java waters (SJCC), intensified during NWM, and weakened during SEM [7], [8]. This SJCC has seasonal variations along the southern coast of Java, yet little is observed in the western internal Sumatra waters. Exposed to the monsoonal winds system, the eastern tropical Indian Ocean, especially the southern part of west Sumatra waters, also has unique characteristics. This region has been exposed to persistent seasonal upwelling during the SEM period, from July to October, since hundreds of thousand years ago. It has correlated to primary productivity [9] and fishing ground [10]. The SJCC may drive eddies related to the yellowfin tuna catches [11]. The current systems in this region also control debris distribution, such as plastic [12].

Here, we present the analysis of direct current measurements using SADCP (Shipboard Acoustic Doppler Current Profiler) in 2013, at one of the essential regions in the eastern Indian Ocean boundary system. This study is intended to reveal the hydrodynamics in one of the less observed areas in the Indonesian territorial waters, the semi-enclosed sea, the southeastern Mentawai waters. Understanding the circulations setting is a crucial stage to assess and map oceanic natural resources’ potency in this region.

2. Materials and Method

A dataset of SADCP 75 kHz *RD Instruments* mounted in RV Baruna Jaya VIII Research Center for Oceanography-Indonesian Institute of Sciences (RCO-LIPI), measured using transect method (see Figure 1a) on 13-20 April 2013, the first transition monsoon, in the southeastern Mentawai Islands waters, was processed. The SADCP has blank after transmitting zone ~10 m and 5 m vertical bin; hence the first depth of the measurements was 15 m. Unfortunately, due to system failure, our SADCP can only cover the upper 150 m depth measurements. There are nine SADCP transects processed in this study. Each transect is separated by around 10 km distance to be able to capture a vast region of observation with limited time of observations. Figure 1 shows the location of the observations.

The measured currents were processed using the WINADCP data processing module to extract the zonal and meridional components. We processed the datasets using spatio-temporal averaging [13]. Since the vessel was moving with a relatively constant speed of ~6 knots, we use spatial Bartlett averaging 1 km. This method is aimed to reduce spatio-temporal variations for current transect measurements. To inspect the circulations spatial variability, we produce 25 m vertically-averaged currents, i.e., >25 depth, 25-50 m, 50-75 m, 75-100 m, 100-125 m, and 125-150 m.

We also found that the waters are characterized by mixed tide prevailing semiidiurnal and have a very low zonal and meridional component amplitude, with a speed less than 3 cm s⁻¹; hence supposedly can be omitted out from the measured components using the above method. Predicted tidal height, zonal and meridional current components gained from Oregon State University tidal inversion software (OTIS) [14], including the observation time in the Lombok Strait and field observation design is shown in Figure 1c-d.
3. Results and discussion

In general, the upper 50 m current pattern was dominated by southeastward flow, parallel to the western coast of Sumatra Island (Figure 2a). Below 50 m depth layers up to 150 m, the southeastward flow intensity decreases as the northwestward flows increase (Figure 2b-f). Unfortunately, we were not able to inspect the deeper layer due to SADCP failure.

To inspect in detail the vertical variability of the northward and southward flows, we show in Figure 3 the meridional current components. Note that the zonal current component’s variability was less dominant compared to that of the meridional component. We found the southward flow in the upper 50 m layer (red plots in Figure 3) and intensified flow near the western coast of Sumatra Island. We observed a persistent northward flow below (blue plots in Figure 3). A powerful northward component was observed at transect 4, with the maximum speed exceeds 1.0 m s⁻¹.
Figure 2 Spatial stick plot currents variability in the southeastern Mentawai waters in April 2013 representing the Northwest Monsoon (NWM) period, averaged for some layers: (a) >25 m, (b) 25-50 m, (c) 50-75 m, (d) 75-100 m, (e) 100-125 m and (f) 125-150 m.
Figure 3 Meridional current components for nine transects in the southeastern Mentawai waters, measured on 13-20 April 2013 using Shipboard Acoustic Doppler Current Profiler (SADCP) RV Baruna Jaya VIII Research Center for Oceanography Indonesian Institute of Sciences (RCO-LIPI).

The eastern Mentawai Islands waters (~the Padang western waters) is a semi-enclosed sea, featured by deep waters yet surrounded by shallow waters with reef islands that separate the waters from the Indian Ocean. Such geographic settings made this region have unique circulation characteristics, i.e., two opposite flows to maintain continuity processes, as shown in Figure 2 and Figure 3: southeastward and northwestward flows in the upper and lower layers. This finding is the first-ever recorded spatial current structure in the western Sumatra internal waters and provides detailed subsurface circulations in this region. Hereinafter, we also introduce this region like the west of Sumatra internal waters as it is also within Indonesian territorial waters.

It appeared in large-scale circulations studies, the flow in this region (up to south Java waters) has a year-round southeastward direction due to strong Indian South Equatorial Current (ISEC) and South Java Coastal Current (SJCC) [1], [4], respectively. If we insist that the ISEC and SJC are dominant in this semi-enclosed sea during the observations period, yet the southeastward current we observed in this area was weaker and has a thinner layer compared to that observed by the previous study, where ISEC at 80.5°E, 0° and SJCC at 106.75°E, 8.5°S were still strong in April [8]. Therefore, in April (first transition monsoon period), the ISEC and its jet should appear at their maximum; yet we did not identify it from our observations.

The weakened intensity of the ISEC and SJCC in our observation area is possible due to this region’s geographical setting. This region is not exposed directly to the eastern Indian Ocean and has
complex topography (surrounded by reef Islands). The most interesting case we found is the persistent and strong northwestward flows below, which did not appear in the general circulation maps from previous studies. This jet-like flow has a maximum speed exceeding 1 m s\(^{-1}\) in the shallowing waters at latitude ~3.5° S (transect 4 in Figure 3), consistent spatially flowing northwestward, supplying the water mass into western Sumatra internal waters.

Despite our SADCP measurements was limited to 150 m only hence incapable of drawing the possible circulations in the deeper layer. Yet, we hypothesize that the circulation systems in the semi-enclosed waters of the western Sumatra differ from the circulation systems in the west of Mentawai Islands chain (generalized as western Sumatra waters in most papers). The influence of the Indian IECC and SJCC might be minor in these waters, as can be indicated from no observed Wyrtki Jet and the northwestward flows event’s timing in the lower layer (>50 m) was outside the period of the SJCC event. This strong northwestward flow might extend deeper and might be intensified during the NWM period and might be variably due to Kelvin wave activity.

Departing from a possible continuity flow in the semi-enclosed system, the southeastward flow in the upper layer should be balanced by the counter-flow below. Our observation was conducted during the early first transition monsoon period, from NWM to SEM; hence this flow might still be forced by the remaining NWM winds. The questions may arise from this continuity-based flow. What mechanisms are working to supply the water mass budget in the upper layer? We suggest that there can be water mass uplifting (upwelling?) in the northernmost waters, which supply the upper layer. The tidal influence from the open Indian Ocean on the Mentawai Islands’ western side may also contribute to feeding the upper layer water mass budget. This circulation system may also impact biological processes in this region. The uplifting of the lower layer water will supply the upper layer with nutrient rich-colder water which later will reduce the negative impact of warm surface water in the Mentawai waters fed by the Wyrtki Jet. This phenomenon may help this region to maintain reef habitat and other fisheries aspects. We realize that this observation was far from ideal, yet this study highlighted the importance of oceanographic exploration to reveal marine resources in this area.

4. Conclusions

Direct current measurements up to 150 m depth in the semi-enclosed sea, the southeastern Mentawai waters, exhibited a stratified flow pattern: the southeastward flow from the surface down to about 50 m northwestward flow below. We focused, with limited depth coverage of the current measurements, to map the spatial circulations. Separated from the Indian Ocean by islands chain, the semi-enclosed western Sumatra waters have a unique circulation pattern yet less explored. They have not been the focus for years by oceanographers. From these preliminary findings, we encourage to measure current profiles as well as seawater properties using a time-series method in the future to capture seasonal oceanographic variability in this area and to characterize the localized jet-like current, the Mentawaian Jet we indicated in this study.

Acknowledgment

Adi Purwandana contributed as the primary contributor/principal author while Edikusmanto, Mochamad Furqon Azis Ismail, Dewi Surinati, Ahmad Bayhaqi, Mochamad Riza Iskandar, Corry Corvianawatie, Muhadjirin, and Djamairo Irianto contributed as associate contributor to this paper. The authors thank the crew and Captain of the RV Baruna Jaya VIII for helping with the data acquisition during the observations.

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