Identification of Tidal Current Vertical Structure in Ombai Strait and Timor Passage

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Abstract. Indonesian seas are strongly affected by strong semidiurnal tidal signals from the Indian Ocean and diurnal signals from the Pacific Ocean. Therefore, within the internal seas, there is possibility of mixed tides (semidiurnal and diurnal signals). This research is focused on determining tidal current based on the velocity data measured during the INSTANT (International Nusantara Stratification and Transport) program. The velocity data from Ombai Strait and Timor Passage from January 18, 2004 to December 31, 2004 are analyzed. Characteristics of tidal current data at certain fixed depths (50, 100, 350 and 750 meters) are processed and calculated using MATLAB software and present the magnitude and variability of total currents, residual currents, and tidal currents as well as vertical variability at these straits. In Ombai Strait and Timor Passage currents tend to move zonally (east – west). The dominant tidal currents are observed at 350 and 750 meters, while subtidal (nontidal) current dominant occurs with 50 to 150 meters.

1. Introduction
Ocean current is horizontal movement of sea water masses due to driving forces such as tides, waves, wind stress, or due to pressure gradient in the ocean. Currents in Indonesia give more effects to currents circulation both in regional and global was known as Indonesian Throughflow (ITF). This currents have big effect on global circulation component including heat, freshwater, and nutrient production in Pasifik Ocean and Indian Ocean. This research will more discuss about ocean currents that separated into tidal currents and residual currents in Ombai Strait and Timor Passage which is located in Indonesian Easterns’s Seas.
2. Data and Methods

The study area for this research is located in Ombai Strait and Timor Passage. Velocity data measured during the INSTANT (International Nusantara Stratification and Transport) program from January 18, 2004 to December 31, 2004 to analyze total currents, residual currents, and tidal currents at these straits. Coordinate points at these straits is shown in the following table.

| Location      | Latitude     | Longitude    |
|---------------|--------------|--------------|
| Timor Passage | 11,3682°LS   | 112,9598°BT  |
| Ombai Strait  | 8,5300°LS    | 125,0064°BT  |

Data for this research is based on velocity data measured during the INSTANT (International Nusantara Stratification and Transport) program from 2004 to 2006. The data obtained from scientists at many countries like Indonesia, Australia, Netherlands, France, and United States. This program held installation 11 moorings to measure currents, temperature, and salinity in Makassar Strait, Limafatola Strait, Lombok Strait, Timor Passage, and Ombai Strait. Data components for this research is shown in the following table.

| Location      | Length of Data | Current Velocity |
|---------------|----------------|------------------|
| Timor Passage | January 18, 2004 to Desember 31, 2004 | u and v at 50, 100, 350 and 750 meters |
| Ombai Strait  |                | 350 and 750 meters |

The velocities data are analyzed visually by using signal analysis method carried out by a high pass filter processed. This process is carried out by passing signals with a frequency higher than the cut-off frequency. A cut-off period of 25 hours was used to see magnitude and direction of the currents during a certain time interval. The total current is separated into tidal currents and non-tidal currents (residual currents) with the high pass filter processed.

3. Results and Discussion

3.1 Tidal Currents and Residual Currents in Timor Passage

The influenced of residual currents magnitude in zonal direction is greater than the influenced of tidal currents magnitude at 50, 150, and 350 meters in Timor Passage at 11,3682°S 112,9598°E. The influenced of tidal currents magnitude is greater than the influenced of residual currents magnitude both in zonal and meridional direction at 750 meters. The average velocity range of the residual current is 0,061 – 0,286 m/s in zonal direction and 0,028 – 0,146 m/s in meridional direction and the large average velocity of residual currents both in zonal and meridional direction is at 50 meters. The average velocity range of the tidal currents is 0,066 – 0,090 m/s in zonal direction and 0,033 – 0,046 m/s in meridional direction and the large average velocity of the tidal currents both in zonal and meridional direction is at 750 meters.
Figure 1. Magnitude of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 50 meters in Timor Passage

Figure 2. Magnitude of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 150 meters in Timor Passage

Figure 3. Magnitude of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 350 meters in Timor Passage
**Figure 4.** Magnitude of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 750 meters in Timor Passage

**Table 3.** Tidal Currents and Residual Currents in Zonal Direction at Timor Passage

| Depth (m) | Tidal Currents | Residual Currents |
|-----------|----------------|-------------------|
|           | Average (m/s)  | Max velocity (m/s) | Direction of max velocity | Average (m/s)  | Max velocity (m/s) | Direction of max velocity |
| 50        | 0.090          | 0.868             | West                       | 0.286          | 0.636             | East                        |
| 150       | 0.070          | 0.513             | West                       | 0.180          | 0.505             | East                        |
| 350       | 0.066          | 0.314             | East                       | 0.074          | 0.314             | East                        |
| 750       | 0.071          | 0.290             | East                       | 0.061          | 0.200             | East                        |

**Table 4.** Tidal Currents and Residual Currents in Meridional Direction at Timor Passage

| Depth (m) | Tidal Currents | Residual Currents |
|-----------|----------------|-------------------|
|           | Average (m/s)  | Max velocity (m/s) | Direction of max velocity | Average (m/s)  | Max velocity (m/s) | Direction of max velocity |
| 50        | 0.046          | 0.304             | South                      | 0.146          | 0.560             | South                       |
| 150       | 0.040          | 0.220             | North                      | 0.094          | 0.410             | South                       |
| 350       | 0.043          | 0.225             | South                      | 0.065          | 0.348             | South                       |
| 750       | 0.033          | 0.160             | South                      | 0.028          | 0.116             | South                       |
Figure 5. Stick Plot of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 50 meters in Timor Passage

Figure 6. Stick Plot of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 150 meters in Timor Passage

Figure 7. Stick Plot of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 550 meters in Timor Passage
Figure 8. Stick Plot of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 550 meters in Timor Passage

The velocity data in Timor Passage at 11.3682°S 112.9598°E from January 18, 2004 to December 31, 2004 has random current movements in various directions over time. The figures show that total currents move based on the direction of residual currents at 50, 150, and 350 meters. Tidal currents influenced current movements and more dominant than residual currents at 750 meters. Overall, eastward residual currents and tidal currents were dominant in all depth. The influenced of tidal currents direction appear largely around the bottom. It caused the influenced of residual current (Indonesian Throughflow without tidal current) is greater in the surface to the depths around 150 – 200 meters while the influenced of residual current at the depths below 200 meters decreases. This caused the tidal currents more dominant and give more influenced to the dynamics ocean rather than residual current to the depths below 200 meters to the bottom.

3.2 Tidal Currents and Residual Currents in Ombai Strait

The influenced of residual currents magnitude in zonal direction is greater than the influenced of tidal currents magnitude at 50, 150, 350, and 750 meters in Ombai Strait at 8.5300°S 125.0064°E. The influenced of tidal currents magnitude is greater than the influenced of residual currents magnitude in meridional direction at 350 and 750 meters. The average velocity range of the residual currents is 0.123 – 0.529 m/s in zonal direction and 0.052 – 0.291 m/s in meridional direction and the large average velocity of residual currents both in zonal and meridional direction is at 50 meters. The average velocity range of the tidal currents is 0.105 – 0.280 m/s in zonal direction and 0.081 – 0.156 m/s in meridional direction and the large average velocity of tidal currents is 0.280 m/s at 50 meters in zonal direction and 0.156 m/s at 150 meters in meridional direction.

Figure 9. Magnitude of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 50 meters in Ombai Strait
Figure 10. Magnitude of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 150 meters in Ombai Strait

Figure 11. Magnitude of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 350 meters in Ombai Strait

Figure 12. Magnitude of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 750 meters in Ombai Strait
Table 5. Tidal Currents and Residual Currents in Zonal Direction at Ombai Strait

| Depth (m) | Tidal Currents | Residual Currents |
|-----------|----------------|-------------------|
|           | Average        | Max velocity      | Direction of max velocity | Average | Max velocity | Direction of max velocity |
|           | (m/s)          | (m/s)             |                         | (m/s)   | (m/s)        |                         |
| 50        | 0.280          | 0.992             | West                    | 0.529   | 1.249        | East                    |
| 150       | 0.172          | 0.866             | West                    | 0.443   | 0.830        | East                    |
| 350       | 0.125          | 0.677             | East                    | 0.187   | 0.600        | East                    |
| 750       | 0.105          | 0.414             | West                    | 0.123   | 0.466        | East                    |

Table 6. Tidal Currents and Residual Currents in Meridional Direction at Ombai Strait

| Depth (m) | Tidal Currents | Residual Currents |
|-----------|----------------|-------------------|
|           | Average        | Max velocity      | Direction of max velocity | Average | Max velocity | Direction of max velocity |
|           | (m/s)          | (m/s)             |                         | (m/s)   | (m/s)        |                         |
| 50        | 0.117          | 0.721             | North                   | 0.291   | 0.730        | South                   |
| 150       | 0.156          | 0.720             | South                   | 0.265   | 0.544        | South                   |
| 350       | 0.132          | 0.572             | South                   | 0.116   | 0.326        | South                   |
| 750       | 0.081          | 0.312             | South                   | 0.052   | 0.172        | North                   |

Figure 13. Stick Plot of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 50 meters in Ombai Strait
Figure 14. Stick Plot of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 150 meters in Ombai Strait

Figure 15. Stick Plot of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 350 meters in Ombai Strait

Figure 16. Stick Plot of Total Currents (Top), Tidal Currents (Middle), and Residual Currents (Bottom) at 750 meters in Ombai Strait
The velocity data in Ombai Strait at 8,530°S 125,0064°E from January 18, 2004 to December 31, 2004 has random current movements in various directions over time. The figures show that total currents move based on the direction of residual currents at 50 and 150 meters. The influenced of residual currents appear smally and tidal currents appear largely at 350 and 750 meters. Eastward residual currents and tidal currents were dominant in these depths.

4. Conclusions

Currents in Ombai Strait and Timor Passage dominant movement zonally (east – west). Tidal currents relative dominant to residual currents about 53,90% in zonal direction and 54,31% in meridional direction meanwhile residual currents relative dominant to tidal currents about 46,10% in zonal direction and 45,69% in meridional direction at 750 meters in Timor Passage. Tidal currents relative dominant to residual currents about 53,16% meanwhile residual currents relative dominant to tidal currents about 46,84% in meridional direction at 350 meters in Ombai Strait. Tidal currents relative dominant to residual currents about 60,66% and residual currents relative dominant to tidal currents about 39,34% in Ombai Strait. From this research we also can conclude that residual current (Indonesian Throughflow without tidal current) dominant in the surface to the depths around 150 – 250 meters and decrease below 200 meters in these straits.

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References

[1] Hadi S and Ivonne M R 2009 Arus Laut (Bandung: Institut Teknologi Bandung)
[2] Bryden H L and Seturo I 2001 Ocean Transport of Heat In: Siedler G Church J Gould J eds. Ocean Circulation and Climate San Diego: Academic Press 455-475
[3] Hirst A C and John S G 1993 The Role of The Indonesian Throughflow in a Global Ocean GCM J Phys Oceanogr 23:1057-1086
[4] Potemra T Lukas R and Gary T M 1997 Large-Scale Estimation of Transport From The Pasific to The Indian Ocean J Geophys Res 102:27795-27812
[5] Schneider N 1988 The Indonesian Throughflow and The Global Climate System J Clim 11:676–689
[6] Dwi S and John M 2006 An Ocean Color Variability in The Indonesian Seas During The SeaWifs Era Geochem Geophys Geosys 7:1–16
[7] Erlin B 2019 Identifikasi Struktur Vertical Elips Arus Pasut di Perairan Indonesia Bagian Timur (Bandung: Institut Teknologi Bandung)