Water Mass Characteristic in The Eastern Inflow Region of The Indonesian Throughflow During Leg-3 of Nusa Manggala Expedition (December 2018)

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Abstract. The Nusa Manggala (ENM) leg-3 expedition in 2018 was held on December 6-16 2018. The survey achieved eighteen Conductivity Temperature Depth measurement points and centered at North of West Papua and Halmahera Sea as the inflow area of eastern part of Indonesian Throughflow (ITF). The results of this study prove that Pacific Surface Water is present on the surface up to 70 m with a temperature of 26 °C - 30°C and salinity of 24 psu – 24.5 psu. Then, South Pacific Subtropical Water and South Pacific Intermediate Water are simultaneously 70 m - 250 m and 250 m - 1000 m at the northern of Halmahera Sea. They not exceed till the southern part of Halmahera Sea.

Keywords: Water mass, eastern part of ITF, Nusa Manggala Expedition 2018

1. Introduction

Indonesian Throughflow (ITF) is the flow of water from the Pacific Ocean to the Indian Ocean through Indonesian waters. The ITF have two pathways, they are western and eastern pathways. The main pathway is in the western part with the inflow area at Makassar Strait. The inflow of eastern pathway is in the Halmahera Sea [1]. Halmahera sea bringing water masses from Western North Pacific Ocean (WNPO) waters [2][3][4]. Strength of ITF transport is influenced by monsoon winds, which reach a maximum during southeast monsoon and a minimum during northwest monsoon [3][5].

The circulation around Halmahera sea was mainly influenced by New Guinea Coastal current (NGCC) and New Guinea Coastal under current (NGCUC) [1].The annual cycle of ITF trough Halmahera shows
that the current velocity became much stronger during the Southeast Monsoon (Jul-Aug-Sept) than that of Northwest Monsoon (Nov-Dec-Jan) period [5]. Thus, the transported water mass carried out by the current will be increased or decreased. Based on [6] The Western North Pacific Ocean (WNPO) influenced the water mass of Weda Bay. It flows through the Halmahera Sea and driven by ITF. The water mass is indicated by low salinity below 34 psu in surface. Then the Southern Subtropical Lower Water (SSLW) presence in the thermocline layer.

The Nusa Manggala Expedition (ENM) leg-3 was from 06 to 16 December 2018 at Halmahera sea to the front of southern part of Weda Bay. In this study the influence of The Western North Pacific Ocean (WNPO) is examined to occur until the front of Weda Bay.

2. Method
2.1 Field Survey

The observation and measurement conducted in 18 stations (fig. 1). The water depth was around 50 m to 6000 m [7]. The bathymetry of Halmahera and Northern of West Papua formed a deep and steep basin with the depth of 50 m to 4000 m (fig. 1). This condition could lead the water masses in Weda Bay has uniform physical conditions in horizontal distribution. Furthermore, the depth was decreasing toward the Southern and Eastern Halmahera coasts while the depth was increasing toward Halmahera Sea.

Figure 1. Map of ENM 2019 leg-3 Survey Area
(source: GEBCO, 2016)

The Conductivity-Temperature-Depth (CTD) Sea Bird Electronics SBE-911 (CTD-911) was vertically lower down in 18 stations to measure temperature, depth pressure, and conductivity. The maximum depth of CTD measurement was down to 6000 m. The accuracy and resolution of temperature sensor was 0.001 °C and ±0.0002 °C. The accuracy and resolution of conductivity sensor was 0.0003 Siemens/meter (S/m)
and ±0.00004 S/m. The accuracy and resolution of pressure sensor was 0.015% of full scale and 0.001% of full scale [6]. The data collected from measurements were processed by SBE Data Processing 5.37e before getting analyze.

2.2 Data Analysis

The vertical and horizontal pattern of temperature (T) and salinity (S) for all stations were drawn to identify general characteristics of water mass. Then, the T-S diagrams were made to analyze the relation between salinity and temperature in the same time along the water column to identify the water mass characteristics [6][8]. The analysis was made to identify the origin of water masses refer to water mass characteristics of their properties, by following the rule from [9][10].

3 Results and discussion

3.1 Water mass property

Subsurface temperature and salinity are showed on fig. 2 (a) and (b). The transect for vertical section showed on fig. 3 (c). In general, the temperature has a uniform value from surface to 100 m with a range of 25 °C - 30.5 °C. Then temperature between 100 m – 300 m is dominated by 19 °C. In some places even to a depth of 400 m, such as in the north west of Papua to the northern part of Halmahera Sea. Furthermore, the uniform temperature values along the transect from 400 m down to the bottom is around 5 °C.
Figure 2. Sea sub-surface temperature (a), salinity (b), transect (c) in ENM 2018 leg-3 area

Subsurface salinity

Subsurface salinity by following transects as in Fig. 2 (c) is shown by Fig. 2 (b). In general, the maximum salinity value exists at 75 m - 300 m depth with value range 35 psu - 35.5 psu. In northern Halmahera Sea the maximum value exceeds to 400 m. Meanwhile, the maximum salinity around Weda Bay is only 35.25 psu.

Subsurface temperature and subsurface salinity in the northern region of West Papua to the north of the Halmahera Sea have similar characteristics. This is different from the central Halmahera Sea and the mouth of the Weda Bay. That is caused by differences in the influence of water mass characteristics. The water mass at the northern Halmahera Sea and northern West Papua is supposed to originate from the Western North Ocean Pacific (WNOP) identified by Wyrtki [9]. The influence of WNOP was seen to be strong in the north of West Papua and weakened at the Halmahera Sea. WNOP water masses are not found around the mouth of the Weda Bay and the southern Halmahera Sea. Thus, the mass of water from the Pacific was only detected in the northern Halmahera Sea at a depth of 75 m-400 m. The water mass cannot
enter the Halmahera Sea or the mouth of the Weda Bay probably because of the western monsoon which causes the southward current to weaken [5]. This is clearly seen from Fig. 2 (b) in the southern Halmahera Sea region high salinity values are not seen at surface to bottom.

### 3.2 Influenced area by Pacific water mass

For water mass analysis, we conducted the T-S diagram from 18 CTD stations (Fig. 3). From Fig. 3 and Fig. 1 we conclude that in general, the water mass of 2018 ENM region leg-3 is divided into three parts. First in the north of West Papua (Stations OS23, OS24, OS25, BUDD01, BUDD02, BUDD03, and BUDD04 – then we called it Area I) which are characterized by a maximum salinity value of 35.5 psu. Then the other water masses located in the north of Halmahera Sea (Stations OS26, OS27, OS28, OS29, OS30, and OS31 – then we called it Area II) are characterized by salinity values of 35.25 psu - 35.35 psu. Third, the water mass in front of the mouth of Weda Bay (Stations OS32, OS33 and OS34 – then we called it Area III) which have salinity characteristics below 35.25 psu.

![Figure 3](image)

**Figure 3.** (a) Station of Water sampler (b) T-S Diagram at ENM 2018 leg-3 area

Based on the analysis of the T-S diagram, we identified numbers of water mass in the study area. Based on the description of the known water mass [8] [11] [12] [13] [14] [15], the identified water mass (as in figure 3) are:

(i) The local water mass of the Banda Sea and Seram with density range $\sigma$ 21 - 22, temperature 29.24 – 28.56 °C, and salinity 33.068 – 33.942 psu;

(ii) Type of mixed water mass between Halmahera Strait and Misol waters with density range $\sigma$ 21 – 23, temperature 29.26 – 27.00 °C, and salinity 33.901 - 34.213 psu;
(iii) South Pacific Subtropical Water (SPSW) with density range $\sigma_{25.5} - 26.3$, temperature 14 – 16.03 °C, and salinity 34.63 - 34.98 psu;

(iv) North Pacific Equatorial Water (NPEW) with density range $\sigma_{26.26} - 26.76$, temperature 9 – 10.2°C, and salinity 34.2 - 34.52 psu

(v) South Pacific Intermediate Water (SPIW) with density range $\sigma_{27} - 27.5$, temperature 5.3 - 8.3 °C, and salinity 34.5 - 34.7 psu; and

(vi) Antarctic Intermediate Water (AAIW) with density range $\sigma_{27.5} - 28$, temperature 1.6 - 3.2 °C, and salinity 34.5 - 34.61 psu

In general, water masses from the Pacific Ocean are detected at stations of Area I at 100 m - 400 m. Then in the same depth the effect is reduced at Area II. Furthermore, it is not seen at all in Area III. This inconsistency is due to the sill in the southeast of Halmahera Island. The sill’s height from bottom is around 700 m [6]. The currents that carry Pacific water masses are hampered by the sill. Even in the NorthWest monsoon when the transport is southward the Pacific water masses is not clearly seen in Weda bay.

4 Conclusion

The results of this study is that we can identify the existence of Pacific Surface Water in the In The Eastern Inflow Region Of The Indonesian Throughflow down to 70 m with temperature ranges of 26 °C - 30°C and salinity of 24 psu – 24.5 psu. Then, we also identify South Pacific Subtropical Water and South Pacific Intermediate Water at 70 m - 250 m and 250 m - 1000 m at the northern of Halmahera Sea. Those water masses are not really clear appear in the southern part of Halmahera Sea because the sill in the southeast of Halmahera Island hampering their mixing process.

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