Stratification on the Vertical Structure of the Tidal Ellipse and Power Density Estimation in the Larantuka Strait, East Flores Based on ADCP Measurement Data

H Siagian1,3,*, A Ismanto1,2, T W L Putra1,3 and Pranata3

1Faculty of Fisheries and Marine Science, Department of Oceanography, Diponegoro University
Jl. Prof. H. Sudarto, SH, Tembalang Telp/Fax (024)7474698 Semarang – 50276
2Center for Coastal Rehabilitation and Disaster Mitigation Studies (CoREM), Diponegoro University, Center of Excellence Science and Technology (PUI), Indonesia
3Pranata Hidro-oceanografi Group, Semarang, Indonesia
E-mail: henryropinus@gmail.com

Abstract. An understanding of tidal current stratification with a tidal ellipse in coastal oceanography is needed, especially in the development of power density for renewable energy. The movement of the water mass can be converted into power density, by optimizing potential energy (sea level) and kinetic energy (tidal currents). Interaction between tidal current and stratification layer has been of importance to optimize the energy conversion (also turbine selection) at each depth layer. The stratification on the vertical structure can be described by variability of the tidal ellipse, in terms of the semi-major axis, the semi-minor axis, the direction of rotation, ellipticity, inclination angle and phase. ADCP measurement is implemented at Larantuka Strait to examine the tidal behavior on a vertical layer of depth. $M_2$ tidal constituent presents the highest amplitudes among the tidal constituents, predominantly straight line, being the most energetic in Larantuka Strait. $M_2$ constituent the highest major-axis at the near-surface layer when compared with $S_2$ with 243.7 cm/s, 128.9cm/s respectively. Most ellipses rotate clockwise 74° as inclination characterizes the current ellipse orientation. Estimation power density conversion is shown >20.000 kW/m², with power density average 5014.9 Watt/m² in spring tide condition. Power density degenerates at the near-surface layer following changes in the depth layer, major-minor axis, inclination angle, and tidal phase of the tidal ellipse.

1. Introduction
The development of renewable energy from ocean currents is more detailed by knowing the movement patterns of the sea. Ocean currents are the movement of the water mass due to changes in water level in an area, hereinafter referred to as tidal currents. The movement of tidal currents can be predicted because the patterns of change are spatially influenced by tides. This is very beneficial for the sector's efficiency and effectiveness in utilizing tidal current as a renewable energy source.

Larantuka Strait, East Flores, one of the waters in the East Nusa Tenggara island group, has a narrow channel/strait waters morphology. This strait stretches from north to south separating the islands of Flores and Adonara, with the narrowest area of strait around 800m. The northern and southern parts of the strait are 6000m, 5000m long, respectively. Previous research studies in these waters, Yuningsih [1] and Siagian [2] tidal current velocity reaches 2.83 - 2.98 m/s, tides have a peak level about 3 meters.
Siagian [3] astronomical tidal constituent semi-diurnal $M_2$ and $S_2$ affects the occurrence of strong currents in the Larantuka Strait. Orhan[3], [4] cross profile about depths of 20 - 35m at nearest middle strait. Sprintall [5] waters crossed by Indonesi through-flow (Arlindo) with a velocity of 3sv. There are quite a lot of previous research results to motivate this water area to become a renewable energy utilization area.

An understanding of this energy source in oceanography needs to be developed. Tidal energy channeled through ocean currents caused by variations in astronomical tidal constituent [6]. Each layer of depth has variations in current velocity due to tidal changes[7], friction between layers [8], bottom friction [9], and wind [10]. Understanding tidal current stratification with the tidal ellipse approach in oceanographic studies is needed, especially as a study of optimizing power density for renewable energy. The stratification on the vertical structure of the current profile can be explained by using the variability of the tidal ellipse. This approach will be able to explain the current pattern behavior in terms of the semi-major axis, semi-minor axis, direction rotation, ellipticity, inclination, and phase concerning each depth. The main factors that cause differences in the tidal ellipse pattern at each depth include Earth – Moon Interaction, morphology, stratification, and friction [9]. This will have an impact on the mixed layer in the water column.

The rotational behavior pattern of the current direction of motion at each depth in the water column will become a new perspective in the development of ocean currents as a renewable energy source. We also calculated the power density estimates for each layer of depth on the semi-diurnal component of the measurement results. As a means of supporting the objective of this study, the Acoustic Doppler Current Profiler (ADCP) was chosen as the measurement tool in the Larantuka Strait, to obtain a current profile picture as needed.

The primary objective of the study is to analysis stratification on the vertical structure of the tidal ellipse approached, from the interaction of semidiurnal and diurnal astronomical constituent ($M_2$, $S_2$, $K_1$, $O_1$) in Larantuka Strait, East Flores. Depth layer as represented power density estimation result from the semi-diurnal constituent.

2. Methods

2.1. Study Area and Measurements

The study region located on the East Flores, as specific on Larantuka Strait UTM projection 51S, between 9074000mS and 9086000mS and 496000mE to 506000mE. This region presents an irregular coastline with narrow channel between the Flores sea at the north and the Flores strait at the south. This strait has general orientation North–South direction. The area interest is region known as Larantuka Strait, illustrated in Figure 1. In the previous study about this site, the dominant astronomical tidal constituent are the principal lunar semidiurnal $M_2$ and principal solar semidiurnal $S_2$ [3], [4], [11], [12].

From October 30 to November 13, 2017, an acoustic module of SonTek Argonaut-XR broadband ADCP was placed and deployed (seabed mounting) in the center of Larantuka Strait, locations on UTM projections are 51 L 502571mE 9080955mS are shown Figure 1 with bathymetry color ramp interval abot 10m.

The ADCP measurement used in this study has been obtained from an instrument seabed mounted at Larantuka Strait, East Flores Waters. The acoustic instrument has been running at 75KHz ADCP between October 30 - November 13 2017 during the neap-spring cycle. The ADCP locations on UTM projections are 51 L 502571mE 9080955mS are shown Figure 1 with bathymetry color ramp interval abot 10m.

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SonTek Argonaut -XR ADCP was set to measure the current using 75 KHz, interval sample applied 300s, and averaged interval of 600s. ADCP has a 0.8m blank distance with 0.7 heights of the bottom frame, ADCP faces upward water column are separated into 2meters bins at 10 layers. ADCP was located on the bottom mounting at 24.5 meters below LAT.

We also collecting water elevation data on the north and south sites at Larantuka Strait. Measurement using data logging instrument RBR Virtuoso, located at UTM 51L of north tide 502139.347mE,
9082656.3564mS, and south tide location 499244.018mE, 9078272.6584mS. RBR Virtuoso as a water level instrument with 300s interval sample, on this study water level as support data to analyze stratification on the vertical of the tidal ellipse and to improve how tidal works on sea currents.

Figure 1. Study area, indicating of East Flores on inset maps, the bathymetry of the color ramp focused on Larantuka Strait with a 20-m resolution of the grid, and pinpoint measurement location of current and water level (October 30 – November 13, 2017).

2.2. Tidal Current Harmonic Analysis

We analyze the sea level time series at each site, Larantuka Strait, with tidal harmonic based on a least-square fit and the result are presented in time series comparing with the current velocity at 25hr neap – spring condition. This helps to improve understanding of how water elevation works on current velocities in depth-averaged. Least squares have similarities of analysis to Fourier number with linear regression, other side is preferable because tidal frequencies are not integer multiple of fundamental frequencies.

\[
ht_i = S_0 + \sum_{n=1}^{n} H_n \cos(\omega_n t_1 + g_n)
\]

Where \( A_n = H_n \cos(g_n) \) and \( B_n = H_n \sin(g_n) \) at a set of meter point; \( ht_i \) is elevation of current velocity \( i \); \( H_n \) are amplitude component; \( \omega \) is the frequency of a given constituent; \( t_1 \) is period component, \( g_n \) is a phase of the component; and \( S_0 \) is still water level at set meter point.
The interaction between stratification on the vertical structure and astronomical tidal constituent, we use tidal ellipse analysis. Our study focused on the vertical variability of astronomical constituent, focused on semi-diurnal and diurnal component tidal ellipse, following [6], [8], [11], [13], [14]. We start analyzing each tidal ellipse parameter in each layer of the ADCP measurement depth. Create a tidal ellipse illustration and compare it to the measured depth point. Visually observe the stratification that occurs in the vertical layer. The data that is executed in the calculation are all measurement data, from neap to spring tides. The equations that represent the tidal ellipse are:

\[
\begin{align*}
    u(t_i) &= [L_k \cos \cos (\sigma t - g_k)] \cos \theta - [L_k \sin \sin (\sigma t - g_k)] \sin \theta \\
    v(t_i) &= [L_k \cos \cos (\sigma t - g_k)] \sin \theta - [L_k \sin \sin (\sigma t - g_k)] \cos \theta
\end{align*}
\]

Their orientation of rotation indicates that tidal currents are dominantly aligned with strait channel and depth layer, presenting backward and forward movement without significance lateral displacement. The major and minor axes represent maximum and minimum current velocities of the given tidal harmonics, the inclination is the counterclockwise angle between the east direction and the major axis [11]. The major axis (M), minor axis (m), ellipticity (\(\varepsilon\)), inclination angle (\(\psi\)) and phase (\(\varphi\)) are then calculated to show the temporal and spatial variability (z-coordinate) of the tidal ellipse: [8]

\[
\begin{align*}
    M &= U_{ac} + U_c \\
    m &= U_{ac} - U_c \\
    \varepsilon &= \frac{m}{M} \\
    \psi &= \frac{g_{ac} + g_c}{2} \\
    \varphi &= -\frac{(g_{ac} - g_c)}{2}
\end{align*}
\]
Figure 2. A conceptual measurement of the vertical profile structure of the water column for with ADCP SonTek Argonaut XR installed bottom mounting, total current profile area 20m of depth.

2.3. Power Density Analysis

The instantaneous power density of a flowing fluid incident on a tidal current turbine is given by equations following as [6]:

\[ P = \frac{1}{2} \rho A V^3 \]

Where \( P \) is the kinetic power energy of the tidal stream. \( A \) is the efficiency and the area in the direction of the stream of the turbine, respectively, and \( \rho \) is the density of salt-water (1025 kg/m\(^3\)). \( V \) is the current velocity (m/s), by convention. Kinetic power density is expressed in units of kW/m\(^2\), mean kinetic power density and ebb/flood asymmetry are calculated similarly to currents.

We have also presented the results of the spatial stratification of the vertical power density structures that have been interpolated at each depth and time. It aims to see the color contrast as a power density value for each predetermined condition, namely neap, daily neap-spring, and spring tidal.

3. Result

3.1. Correlation between water level and velocity component at Larantuka Strait, East Flores

3.2. The measurement of ocean currents has produced a component of current velocity, has worked on the north-south and east-west axes. As mentioned earlier, the Larantuka Strait stretches from north-south with the open boundary conditions of the Flores Sea (northern side) and the Flores Strait (southern side). [11] mention v-velocity the dominant of harmonic features about 81.67%, and non-harmonic component emerge around 18.3%. u-velocity the dominant of harmonic features emerge about 86.2%, and non-harmonic component emerge around 13.8% from total current measurement. The measurement results have shown that the dominant current velocity component is north-south (v-velocity), previous research shows the dominance of v-velocity is more than 3 m/s or 300cm/s compared to u-velocity 0.8 m/s. [11].

Figure 3 shows how tides work with v-velocity. Tidal phase changes affect changes in the speed and direction of ocean currents in the Larantuka Strait. Changes in the direction of the current are indicated by the main y-axis at positive and negative values, while the value on the y-axis shows the value of the velocity that occurs.

![Figure 3](image-url) Comparison between water level (red line) and v-velocity component of the near-surface layer (layer 10 read on ADCP), show elevation changes work on current speed and direction.

Results shown an excerpt on spring tidal conditions (Figure 4), it constituted to obtain significant patterns due to changes in tidal, [4], [15]. 81.67% v-velocity is dominated by astronomical components [11]. Figure 3 current speed 300 cm/s on the positive axis shown at 11.00, the position of the water level is at a value near 0m. Meanwhile, when the current speed is above 300cm/s at 17.00, the position of the water is near 0m. Tidal currents are mainly semi-diurnal and M\(_2\) is the largest tidal component and has a role affected on it (Table 1). Changes in current speed and direction are influenced by tidal
patterns. Approaching water elevation 0m (MSL) shows the current speed reaches the maximum condition, whereas during the current maximum elevation approaching 0cm / s [16][17], [18].

Figure 4 is the result of the extraction of the water height meter placed on the north-tide station, Formzahl number analysis shown 0.73 means type of tidal is mixed with principally semi-diurnal [11]. A colored area is given to indicate the phase conditions used in this study in analyzing current conditions, tidal ellipse stratification, and potential power density. The phases include the neap phase, the neap-spring days, and the highest tidal range condition, spring [17]. The difference in tidal range will affect the moving water mass and also the total power density in the measurement station [7], [19]–[21].

Figure 4. The water level was recorded by tide gauges in the northern part of the Larantuka Strait. The blue area is the neap tide, the green is the daily neap to the tide, and the red is the spring tide.

3.3. Vertical stratification of $v$-velocity component at Larantuka Strait, East Flores

The method used in this study to extract tidal current from temporally and vertical spatially variable component current measurement allows for a determination of tides. We have shown (Figure 3) good agreement between current measurement from ADCP and tidal level changes correlates. Vertical stratification for $v$-velocity at each layer of depth, with a profile below the LAT value of 4.5m for 25 hours when the neap and spring conditions are shown in Figure 5. Each of the conditions shown in Figure 5 is a representation of the time series conditions referred to in Figure 4, neap tide condition (blue area) and spring condition (red area). For 25 hours in each condition, there is a change in velocity, which is getting higher when seen from the depth layer near the bottom to near the surface. The time condition is indicated by various color lines, showing that the current at each depth changes in velocity and direction influenced by tidal fluctuations that work with time.
Figure 5. Vertical observed variations by ADCP measurement with the depth of tidal currents (v-velocity component) at a different tidal hour, according to measurements of neap tide condition blue area in Figure 4 – left panel, and on spring tide condition red area in Figure 4 – right panel.

It is interesting here to learn, changes in current velocity do not occur simultaneously in all depths when elevation changes occur. Figure 5, spring tide conditions at t10, at 10.00, can be seen also in Figure 3. Conditions for changing the elevation from low tide to high tide, blue lines are seen along the y-axis, working on the negative and positive x-axis. This event shows changes in current velocity, which are influenced by tidal changes acting on the part near the bottom of the water body first (vertical stratification). As time moves, the upper current will follow the changes in its movement towards the positive axis.

The same pattern has been found in Figure 3, which is the v-velocity in the depth-averaged from the ADCP recording. The maximum current velocity, neap tide condition with a value of 130 cm / s to 90 cm/s in order from a depth of 4.5m - 22.5m below the LAT, works on the negative axis. Spring tide condition with a value of 320 cm/s to 260 cm/s from a depth of 4.5m - 22.5m below the surface, works towards the negative axis.
Figure 6. Time series measured velocity component profiles (near the bottom to near-surface layers) during 25 hours on neap condition 30 October 2017 (top panel), daily neap to spring condition 3 November 2017 (middle panel), and spring condition 7 November 2017 (bottom panel). Left panel u-velocity, and right panel v-velocity, at measurement station ADCP Larantuka Strait.

Presentation of the results of the vertical stratification of v-velocity components is displayed to see the temporal and spatial variations of the vertical structure of the tidal ellipse. Time series of the velocity component, about u, v velocity at ADCP measurement during 25 days at selected conditions (Figure 4) are shown in Figure 6. Neap condition is shown in the top panel, Figure 6, current velocity from near bottom to near-surface shows a difference of up to 30 - 40 cm/s for v-velocity (right panel). The daily neap-spring condition shown in Figure 6 (mid panel) shows the same pattern as the neap condition with a more contrasting color. The red color shows the velocity value on the positive axis, which means the current is moving north, while the blue shows the current moving on the negative axis, moving southward. The difference in current velocity from the layer near the bottom to near-surface has a difference of 90 cm/s. The current velocity near the bottom of the spring condition (Figure 6-bottom panel) is 270 cm / s for v-velocity, increasing when the stratification is close to the surface below the LAT which is 360 cm / s. The more contrast is seen during the tidal conditions during the full moon phase of the spring, with an R-B-R-B pattern.

In general, it is quite difficult to determine the thickness of the area with the highest velocity at the time of the neap phase, occurring both in u, v velocities. This can be seen in Figure 6, top panel, v-velocity at 15.00 - 23.00 orange color as the current is moving northward, the velocities area cannot be seen, such as the R-B-R-B pattern. This is because the current range at the time of the neap is relatively smaller, even though this condition in the Larantuka Strait still shows the optimal speed for conversion to a renewable energy source because it is still above the cut-in speed value.
3.4. **Stratification on the vertical structure of the tidal ellipse at Larantuka Strait, East Flores**

The vertical structure of tidal ellipses at ADCP station at ten depth layer below LAT at the different periods are shown in Figure 8. Detailed parameter about tidal ellipse each depth layer is shown in Table 1 and plot in depth graph at Figure 7, respectively over measurement periods. Semidiurnal variability occurs mainly in M$_2$ and S$_2$. Diurnal variability occurs mainly in K$_1$ and O$_1$ [11], [12], [14], other location shown similar condition [22]. Vertical spatial variabilities of the vertical structure of the tidal ellipse are analyzed in terms of the major axis, minor axis, the rotational direction, ellipticity, inclination angle and phase in this section. Figure 8 shows tidal current ellipse as representatives of typical of the tidal current structure [14].

As illustrated in Figure 10 at 4 astronomical components, the length of the major axis generally decreases from near-surface to near bottom of each tidal astronomical component during time measurements. The major axis of M$_2$ reach 243.7 cm/s at near-surface layer and 161.7 cm/s near-bottom layers. It’s a higher component as the dominant role of tide current Larantuka Strait. Other tidal components show the length of major axis ratio of near-surface to bottom are 1.49, 1.46, and 1.34 at tidal components S$_2$, K$_1$, and O$_1$ respectively, for a detail length major axis can show at Table 1. As shown in Figures 7 and 8, the major axis of tidal ellipses in the M$_2$ component have contrast than others, it happens at each layer of depth. The major axis of tidal ellipses as vertical structure stratification are 243.7, 243.3, 239.2, 234.3, 229.2, 223.6, 215.5, 205, 188, 161.7 cm/s at -4.5, -6.5, -8.5, -10.5, -12.5, -14.5, -16.5, -18.5, -20.5, -22.5 m below LAT respectively at ADCP station, you can show it at Figure 7 as compared with other astronomical components. It suggests a vertical maximum of major axis appear in the near-surface layer (-4.5m) during measurements, but sub-surface at -6.5m shows a great value, there is slightly different from the near-surface layer. Move to other astronomical components, S$_2$ has a second place as domain tidal current. As sample near-surface layer of the major axis has a ratio of 1.89 then M$_2$.

Diurnal astronomical components have a small value (shown in Figure 7 as a comparison of the graph in depth layer), occurs diurnal components are not the dominant role in the archipelago formation of waters. From K$_1$ and O$_1$, K$_1$ has a long value of major axis, then O$_1$, the major axis of tidal ellipses in K$_1$ component have 14.6, 14.5, 14.2, 14, 13.7, 13.5, 12.5, 11.7, and 10 at near-surface layer -4.5m to near bottom layer -22.5m with 2m interval of the layer of depth. O$_1$ generally has a small value and contribution of the tidal current at each depth layer. It has a maximum length of the major axis of the near-surface layer, these conditions as the same as with other astronomical components which higher at the near-surface layer and also exhibit a decrease to the bottom layer. The ratio of the near-surface to near bottom of O$_1$ major axis is 1.34, and the ratio O$_1$ with M$_2$ as main role of the tidal current at Larantuka Strait 22.0 (the result was a plot in Figure 7, at the first panel), this ratio shows how O$_1$ has small contribution but have an impact for tidal current appears at each depth layer at Larantuka Strait. Minor axis for each astronomical component are generally small, the longest minor axis occurs at the near-surface layer for each component. In another analyze we found that a small minor axis occurs at the middle layer the near-bottom, M$_2$, S$_2$, K$_1$, and O$_1$ found at 14.5, 18.5, 10.5, 12.5m below the surface respectively, there is the magnitude of baroclinic ellipses is varies with depth. Based on these results there is a relationship between the vertical structure of the tidal ellipse and depth varying eddy viscosity [8][14]. Especially, M$_2$ as the tidal current main role of semidiurnal, baroclinic M$_2$ ellipses found at 14.5m of depth. As shown in Figure 8 eddy viscosity affected leads to the significant near-surface to near bottom difference ellipticity, [8] mention small value at ellipticity, inclination angle, and phase of tidal ellipse indicated a constant vertical eddy viscosity.
The Tidal ellipse component at each vertical layer in the semi-diurnal and diurnal astronomical component calculated from ADCP measurement. semi-major and semi-minor axes are listed in cm/s, the inclination is listed in ° counter clockwise from east, phase lag listed in °.

| Depth (m) | Semi-diurnal | m (cm/s) | $\psi$ (°) | $\phi$ (°) | Diurnal | M (cm/s) | m (cm/s) | $\psi$ (°) | $\phi$ (°) |
|-----------|--------------|----------|------------|------------|---------|----------|----------|------------|------------|
| -4.5      | 243.7        | -4.2     | 74         | 272.9      | 14.6    | 1.1      | 70.7     | 267.6      |
| -6.5      | 243.3        | -3.3     | 74.7       | 273.4      | 14.5    | 0.4      | 71.9     | 256.8      |
| -8.5      | 239.2        | -2.7     | 75.2       | 273.4      | 14.2    | 0        | 72.4     | 255.6      |
| -10.5     | 234.3        | -2.1     | 75.9       | 273.3      | 14      | -0.2     | 74.9     | 256.2      |
| -12.5     | M₂           | -1.8     | 76.7       | 273.1      | K₁      | 13.7     | -0.3     | 74.5       |
| -14.5     | 223.6        | -1.7     | 77.5       | 272.9      | 13.5    | -0.6     | 74.9     | 258.5      |
| -16.5     | 215.5        | -2.3     | 78.5       | 272.6      | 13      | -0.6     | 75.4     | 257.9      |
| -18.5     | 205          | -3.2     | 79.5       | 272.4      | 12.5    | -0.4     | 77       | 256.4      |
| -20.5     | 188          | -3.7     | 80.5       | 272.2      | 11.7    | -0.6     | 78.8     | 255.9      |
| -22.5     | 161.7        | -3.6     | 81.8       | 272.1      | 10      | -0.8     | 81.3     | 256        |

Table 1. The Tidal ellipse component at each vertical layer in the semi-diurnal and diurnal astronomical component calculated from ADCP measurement. semi-major and semi-minor axes are listed in cm/s, the inclination is listed in ° counter clockwise from east, phase lag listed in °. Ellipticities of the tidal ellipse is quite small at M₂, S₂, and K₁, while larger at the O₁ astronomical component. According to Figure 7, panel C near-surface to near bottom M₂, S₂, and K₁ are quite small they are 0.013, 0.016, and 0.018 respectively. At O₁ astronomical component shows a larger value of 0.05, indicating O₁ has a small impact for the tidal current on vertical structure tidal ellipse as a term. Due to the influence of strait morphology, tidal ellipses degenerate to rectilinear motion at each depth layer of the water column, as shown in Figure 8. Tidal ellipse rotates clockwise, shown in Figure 8 refer to blue color fill, at all depth layers from near-surface to the near bottom set to M₂ and S₂ astronomical component. The tidal ellipse rotates anti-clockwise found at K₁ and O₁ component at near-surface depth, and for O₁ applies to the near bottom layer, at Figure 8 you can show red labeled of an ellipse. The M₂ semi-diurnal astronomical component of the tidal ellipse inclination essentially directed parallel to strait morphology, or topography of close boundary from Larantuka Strait role on the inclination angle of tidal ellipse at each depth layer on the water column. Accordingly, the near-surface to the near bottom inclination angle difference ($\Delta \psi$) (6.6°) are generally small (<10°) [8] or angle getting bigger (74° to 81.8°) (Table 1, M₂ inclination row) Depth layer away from the near-surface getting bigger friction, as sample depth layer friction and bottom stress. This indicates that slight changes in the inclination angle tidal ellipse for other astronomical component S₂, K₁, and O₁, they are inclination angle difference ($\Delta \psi$) 8.3°, 10°, and 8.9° respectively. There is no rapid change of inclination angle appears at each depth layer on all semi-diurnal and diurnal astronomical component. It was shown that there were variations in the inclination angle differences for each tidal ellipse at each difference in depth until it was reached near the bottom. In the Larantuka Strait case, measurement divided 10 depth layers at 25m below surface.
Figure 7. Comparisons between four astronomical constituents $M_2$, $S_2$, $K_1$, and $O_1$, the five panels show tidal ellipse parameter versus depth as individually labeled (A) major axis (cm/s), (B) minor-axis (cm/s) (C) ellipticity (D) inclination angle and (E) phase at station ADCP during measurement (15-days) 30 October – 13 November 2017 Larantuka Strait. Note that the orange line ($M_2$), the green line ($S_2$), the blue line ($K_1$), and the red line refer to ($O_1$).

Figure 8. The vertical structure of four astronomical constituents $M_2$, $S_2$, $K_1$, and $O_1$ tidal ellipses at station ADCP, Larantuka Strait, during 15-days measurement (30 October – 13 November 2017), the four panels shows ellipticity versus depth. Note that the blue ellipse represents the clockwise rotation of the ellipse, the red one’s ellipse represents an anti-clockwise rotation of the tidal ellipse, detail parameter feature of ellipse shown in Table 1.

3.5. Power Density

Time series of the density profiles at ADCP station during the selected time as shown in Figure 4 are shown in Figure 9 (top panel: neap condition, mid-panel: daily neap-spring condition, and bottom panel: spring condition). Power density means from near-surface to near bottom over a neap tide condition 118.176 Watt/m² (Figure 9, top panel), while 5914.9 Watt/m², with a maximum value around 20.000 Watt/m² in the spring tide condition (Figure 9, bottom panel). Daily neap to spring tide condition shown more contrast orange power density than neap tide condition, around 3342.69 Watt/m²(Figure 9, middle panel). The available power density capacity is closely related to the current speed [3], [20], [21], [23][24] refers to an equation of power density, so that it can be converted into a renewable energy source.

Development studies such as cut-in-speed and turbine efficiency can be calculated in the application of the turbine. utilization can be done with bottom deployment type power plants, to tidal bridges with vertical and horizontal axis turbines. Displaying stronger stratification in spring tidal
condition than neap tidal condition. Similar daily neap to spring variability of power density appears as a spring condition than neap tidal condition. It is interesting to note that a potential of power density at Larantuka Strait, appear when daily neap – spring and spring tide condition. When the slack time it is little time to no power density to produce from water because current speed shows below cut-in speed. The greatest condition for maximum power density appears in spring condition, the neap tidal condition also a good condition for conversion from current speed to power density. Comparing result refer from Figure 3 and 5, slack time condition has taken 30 – 40 minutes during one tidal cycle, there is no energy converted.

Figure 9. Time series of the power density per square profiles during 25 hours; neap condition (top panel), daily neap to spring condition (middle panel), and spring condition (bottom panel).
4. Conclusion

From result we conclude Larantuka Strait, East Flores, Semi-diurnal constituents are dominant, causing currents to occur at each layer of depth. The vertical structure of the Semidiurnal constituents, especially $M_2$ tidal ellipse is significantly higher and different during periods of stratification measurement, $M_2$ has 243.7 cm/s and $S_2$ has 128.9 cm/s. The relation between the bottom to surface ellipticity of the semi-major axis is linear, but the semi-minor of tidal ellipse shows very small at 14.5m. It suggests that the eddy viscosity can affect at depth varying of ellipticity of tidal ellipse. Allowing currents in the Larantuka Strait to be played out not only by astronomical influences, but also by the role of baroclinic, temperature gradients, salinity, and other water column profiles. At the station, the morphology condition is affected by the semi-major axis of the tidal ellipse, a near-surface layer has a longest semi-major axis than the bottom layer. The near-surface layer (layer 10) has a maximum power density of energy conversion with $>$20.000 w/m² and it decreases linearly with increasing depth stratification.

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