Thermal dispersion model of cooling water discharges from industrial activities of steam power plants (PLTU) on the north coast of Paiton, East Java

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Abstract. Necessity electricity in the society especially in industrial activities every year there is an increase in demand. The technology that used in production electricity is one of the Steam Power Plant (PLTU), where Paiton Power Plant is one of the largest power plant in Indonesia and can distribute electricity to Java and Bali. The purpose of this research is to know the process of hot water waste distribution from PLTU Paiton either horizontally or vertically with observation method and numerical model. Tidal model validation with observation data has a high correlation value ($r = +0.908$). Validation model of hot water waste distribution on surface with observation result has RMSE value equal to ($e = 0.96$). The observation results show the temperature of the hot water waste in front of the outlet is recorded between 30 °C to 40 °C. Vertically, the distribution of hot water waste near the outlet reaches a depth of 5 m and horizontally the thickness becomes thinner at a distance of about 500 m from the outlet mouth. The model result shows that the distribution of hot water waste distribution occurs more broadly when the low tide.

1. Introduction

The steam power plant in Paiton is one of the largest power plants in Indonesia with 9 units and has a capacity of 4972 MW. The Paiton power plant can distribute electricity to Java and Bali. Sea water that comes out of the drain or outlet can be called hot water waste. The amount of sea water discharged from the outlet is 200,000 m$^3$/hour [1].

According to the Regulation of the Minister of Environment [2] that the maximum temperature limit of hot water waste that comes out of the outlet is 40 °C. If the condition of the water temperature exceeds the limit, it is suspected to have a negative impact on the quality of sea water, aquatic ecosystems and other activities in the vicinity. Waste hot water that comes out of the outlet will spread and mix with the surrounding sea water which is affected by the hydrodynamic process. In general in estuary or coastal waters tidal parameters are more influential on the hydrodynamic process. In addition to the effects of tides, bottom waters friction, interactions between the atmosphere and sea level, as well as variations in topography in a waters have a role in the movement of sea water on the coast. Hydrodynamic processes in estuaries or coasts are classified as having complex and non-linear hydrodynamic processes [3].

Current speed determines the intensity of friction and the hot water waste mixture that comes out of the outlet. The process of hot water waste distribution is influenced by wind, tides, water column stratification, and bathymetry [4]. Advection and diffusion are included in the hydraulics process. Advection is a process of mass transfer of water and concentration that is influenced by physical processes, one example of an advection process is the transfer of water with high-temperature waters without changing its value and concentration. Diffusion is the process of decaying the concentration of
water mass of the water mass molecule, one example of the diffusion process is the decay of the temperature of the water resulting from pressure differences [5].

Study of the distribution of hot water waste Paiton PLTU is conducted to study and understand the process of the distribution of hot water waste that comes out of the outlet. The distribution of hot water waste can be seen from the results of the model scenario both at high tide and at low tide. In addition to the presence of PLTU in Paiton, in the waters of Paiton there are coral reef ecosystems and several cages. It is necessary to do modeling to determine the distribution of hot water waste related to the area of coral reefs and cages concerning or not about the area.

2. Method
To predict the distribution of hot water waste from Paiton power plant, numerical modeling and observation are carried out. The results of the simulation model will be validated to determine the accuracy of the model results with observation. The validated model simulation parameters are tides, currents and temperatures. In addition, the results of the model and operation are also spatially presented to determine the distribution pattern of hot water waste that comes out of the Paiton power plant outlet.

2.1. Time and location of observation
Field data collection was conducted on February 28, 2017 to March 3, 2017 in the Madura Strait, Situbondo Regency, East Java Province. Data processing and model configuration are performed at the Data Processing Laboratory and Physics Oceanography Laboratory, Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University. The following is the location of research and data collection presented in Figure 1. Seen in the picture there are transects or station points in field data collection, while the domain or shown in the image is the second nesting domain. Yellow land polygons are areas or large areas of the Paiton power plant and there are outlets or hot water effluent outlets in accordance with the outlet written on the picture. Lines that almost form squares or parallels that are purple are transects of the measurement of surface water temperature data by means of towing. Build a small black triangle in Figure is a vertical temperature measurement point (drifting) and a small black rectangular shape is a measurement point for currents and tides by mooring.

Figure 1. Research location and field data measurement.
2.2 Tools and data
Tools used in measurement include GPS sounder 585, CTD (Conductivity, Temperature, and Depth), Montiwali (tidal gauges), Electromagnetic Current Meters (ECM), and desktop PCs (Intel Core i7 Processor and 32 GB RAM). The Operating System used to process data is Windows 8.1. While the software used in data processing, namely Microsoft Excel 2013, Microsoft Word 2013, Ocean Data View 4 (ODV_4) 2012, ArcGIS 10.3 2014, MatLab 2013b and Modulo Hidrodinamico [6] are software used to simulate models and visualize model results. Table 1 is some primary and secondary data sets that are used to simulate the model and visualize the observation data.

Table 1. Data used in the study.

| No. | Parameter                | Period/Interval | Tools / Method            | Remarks                           |
|-----|--------------------------|-----------------|---------------------------|-----------------------------------|
| 1.  | Depth/Bathymetry         | 1 second        | Sounder / Tracking        | Field measurement (data input model) |
| 2.  | Depth/Bathymetry         | 30 seconds      | Reanalysis                | GEBCO (data input model)         |
| 3.  | Tide                     | 5 minutes       | Montiwali / Mooring       | Field measurement (validation data) |
| 4.  | Tide                     | 1/8° x 1/8°     | Reanalysis                | FES 2004                          |
| 5.  | Current                  | 30 seconds      | ECM / Mooring             | Field measurement (validation data) |
| 6.  | Sea water temperature    | 1 second        | CTD / Towing & Drifting   | Field Measurement                 |
| 7.  | Wind                     | 9 km            | Observation               | CMEMS                             |
| 8.  | Atmosphere               | 9 km            | Reanalysis                | INDESO                            |

2.3. Observation
Data processing procedures are divided into two stages, the first stage of data processing to display the results of observations and the second stage of data processing prepared as input data validation between the results of the model and observation. Data processing is carried out related to tidal parameters, currents, bathymetry, and water temperature. According to the result of observation data, it came out with two functions such as forcing and initial conditions in numerical model.

2.4. Model
2.4.1. Equation of motion. The model conducted in the study of the distribution of hot water waste in the Paiton power plant is based on 3-dimensional primitive equations. Primitive equations are equations that have incompressible properties or characteristics of water that cannot be compressed. The equilibrium momentum obtained from the derivative results can be implemented to calculate the velocity values horizontally and vertically in the coordinates of the cartons [6].

2.4.2. Boundary Condition and Initial Value. Boundary conditions in the model are needed because as a derivative of space on a surface free of water, a solid boundary or land boundary, an open boundary or ocean boundary, and a displacement boundary. Flow or friction diffusion of momentum can be explained explicitly that there is wind friction on the surface, \( \tau_w \) [6]:

3
Wind friction can be calculated according to the law of quadratic friction:

\[ v \frac{\partial \bar{V}_H}{\partial x} \mid _{surface} = \bar{t}_w \]  

(1)

where \( \bar{t}_w \) is the friction coefficient depending on the wind speed which has a variation in values between 0.001 and 0.002, \( \rho_a \) as the density of the air and \( \bar{W} \) is the resultant wind speed (10 m above sea level) used to estimate the value of the coefficient of friction.

The bottom boundary condition is a mass that advances forward and the value of the transverse momentum is zero and the flow or friction is diffusion in momentum. The process of diffusion at the bottom of the waters can be written [6]:

\[ v \frac{\partial \bar{V}_H}{\partial z} \mid _{bottom} = \frac{\bar{t}_b}{\rho} = C_f \bar{V}_H | \bar{V}_n | \]  

(2)

where \( C_f \) as the coefficient of basic friction can be calculated based on the speed \( \bar{V}_H \) used to calculate bottom friction.

Closed lateral boundary conditions are boundaries that are limited by land. The closed lateral boundary conditions in the model do not have velocity directions perpendicular to the land.

\[ \frac{\partial \bar{V}_H}{\partial \eta} = 0 \]  

(4)

\[ \bar{v}, \bar{n} = 0 \]  

(5)

The initial value in the model is the condition of the model before it is simulated. This explains that interactions have not yet occurred in the waters, so that the water is in a constant or stationary position. Some parameters as initial values are zero, including:

\[ \eta = 0 \]  

(6)

\[ u, v, w = 0 \]  

(7)

\[ \bar{W} = 0 \]  

(8)

where \( \eta \) is the tides, then \( u, v, \) and \( w \) are velocity components on the \( x, y, z \), and \( \bar{W} \) axes result are the resultant values of the wind. In the model the water temperature value is constantly being defined. The temperature value is defined as the initial value of the temperature in a waters or environmental temperature value. The value of the ambient temperature is as follows:

\[ T = 28 \, ^\circ C \]

2.4.3. Thermal dispersion equation. The water properties defined in the model related to the Paiton power plant waste water distribution study are temperature and salinity. According to [6] in defining water properties in the model can be written in the differential equation in the value of each parameter per unit volume (\( P \)):

\[ \frac{\partial p}{\partial t} = - \frac{\partial}{\partial x_1} \left( u_1 P - v \frac{\partial p}{\partial x_1} \right) + (S_o - S_l) \]  

(9)

where \( P \) is the volume of the level of accumulation of a parameter in these waters carried by the process of advection and diffusion with \( S_o \) as a source of pollutants (temperature with a high value) and \( S_l \) is a parameter in the aquatic environment (ambience temperature).

2.4.4. Model domain. The area of study or AOI when conducting field measurements can be seen in Figure 2C, while the domain used in conducting model simulations can be seen in Figure 2A.
2B, and Figure 2C by implementing the nesting procedure. The nesting procedure requirement in Mohid is that the grid width is not more than 1/5 of the width of the large domain grid or the reference domain.

2.4.5. Model area discretization. The model length was simulated for 7 days and simulated on February 26, 2017 to March 4, 2017. The scenarios created in the model are seen from the tide and ebb conditions, then sampled according to the time of observation. The results of simulated models that are sampled according to the time of observation can be validated spatially or statistically. The configuration of the Paiton power plant waste water distribution model is shown in Table 2.

![Figure 2. A) Domain of simulation model 1, B) domain 2, and (C) model domain 3](image)

The results of simulated models that are sampled according to the time of observation can be validated spatially or statistically. The configuration of the Paiton power plant waste water distribution model is shown in Table 2.

| Parameter | Value | Unit | Remarks |
|-----------|-------|------|---------|
| Number of X (I) Cells (Domain 1) | 90 | - | |
| Number of Y (J) Cells (Domain 1) | 156 | - | |
| Vertical Grid Coordinate (Domain 1) | 4 | Layer | Sigma |
| X Grid Size (Domain 1) | 1000 | m | |
| Y Grid Size (Domain 1) | 1000 | m | |
| Domain Length 1 | 156000 | m | |
| Domain wide 1 | 90000 | m | |
| Forcing [Tidal Comp.: M2, N2, S2, K2, 2N2, O1, Q1, K1, P1, Mf, Mm, Mtm, dan MSqm (Domain 1)] | 1/8 | (°) | FES 2004 |
| Time step of Model (Domain 1) | 30 | s | |
2.4.6. Model validation. The calculation of the Root Mean Square Error (RMSE) is a general statistical calculation to calculate the error rate from model results in meteorology, air quality and climatology or in the field of earth. RMSE values can be calculated as in this equation;

\[ RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} e_i^2} \]  

(10)

where \( n \) as the number of input data calculated, \( e_i^2 \) is the difference between the model results and observations which are then squared.

3. Results and discussion

3.1. Comparison of model and observation data

The pattern of the tidal graph shows patterns that resemble the results of the model and field measurements as shown in Figure 3. The difference in the highest tidal values between the model results and the simulation results is 0.4 meters and the tidal values of the model simulation results tend to be higher than on the field measurement results. The tidal graph shown in Figure 3 shows the tidal tides from the simulation model of 1.6 meters and the tidal tides from the observation results of 1.5 meters.

| Parameter | Value | Unit | Remarks |
|-----------|-------|------|---------|
| Max. Number of time step (Domain 1) | 20160 |      |         |
| Number of X (I) Cells (Domain 2) | 110 | - |         |
| Number of Y (J) Cells (Domain 2) | 160 | - |         |
| Vertical Grid Coordinate (Domain 2) | 4 | Layer | Sigma |
| X Grid Size (Domain 2) | 100 | m |         |
| Y Grid Size (Domain 2) | 100 | m |         |
| Domain Length 2 | 16000 | m |         |
| Domain Wide 2 | 11000 | m |         |
| Forcing [Wind Velocity U-Comp and V-Comp] | 9 (3) | km (hours) | CMEMS (Spatial temporal) |
| Time step of Model (Domain 2) | 10 | s |         |
| Max. Number of time step (Domain 2) | 60480 | |         |
| Number of X (I) Cells (Domain 3) | 155 | - |         |
| Number of Y (J) Cells (Domain 3) | 155 | - |         |
| Vertical Grid Coordinate (Domain 3) | 4 | Layer | Sigma |
| X Grid Size (Domain 3) | 20 | m |         |
| Y Grid Size (Domain 3) | 20 | m |         |
| Domain Length 3 | 3100 | m |         |
| Domain Wide 3 | 3100 | m |         |
| Forcing [Wind Velocity U-Comp and V-Comp] | 3 | hours | INDESO (temporal) |
| ATMOSPHERE [Solar radiation, Air Temperature, dan Relative Humidity] | 3 | hours | INDESO (temporal) |
| Debit Discharge | 120 | m³/s | Constant |
| Tracer Discharge [Temperature] | 40 | °C | Constant |
| Time step of Model (Domain 3) | 2 | s |         |
| Max. Number of time step (Domain 3) | 302400 | |         |
The RMSE value or error value from the results of the field measurements and the results of the model simulation are \( e = 0.028 \). This shows that the difference in sea level elevation from field measurements and simulation models is 0.028 m. The value of the RMSE displayed shows that there is a slight error or difference in the value of the results from the field measurements and the model simulation results [7].

**Figure 3.** Validation of tides from observations and models.

Field current measurements are measured at a depth of 1.5 m conducted on March 1, 2017 to March 2, 2017. Flow results from the simulation model are sampled according to the time of field measurements. There are different patterns and values of the measurement results and model simulation results, but the current direction of the simulation and observation results show the same distribution direction as shown in Figure 4. Conditions when the scatter pairs are scattered on the axis (-x) and at axis (-y), whereas at low tide the scatter graph distribution is on the axis (+ x) and on the axis (+ y). RMSE values of the two components and from the results of field measurements and model simulations are \( e_u = 0.113 \) and \( e_v = 0.027 \). This shows that the error value or the difference in the value of the zonal current component is 0.113 m/sec, while the error value or the difference in the meridional current component is 0.027 m/sec. The RMSE value shows that the two data have a small difference in value, so that the accuracy of the results of field measurements with the results of simulation models is quite accurate [7].
Figure 4. Validation of flows from observations and models.

The results between field measurements and model simulation results are quite significant differences in temperature values presented in Figure 5. The difference in the highest temperature is 1030 m from the outlet mouth at 1.355°C, while the lowest temperature difference is at a distance of 00 from the outlet mouth amounted to 0,106°C. The results of the temperature validation graph show a pattern on the same temperature graph, which is a temperature graph of water that has a decreased gradient from the mouth of the outlet to the surrounding waters. RMSE calculation value on the validation of the results of the distribution of hot water waste has a value of 0.96.

Figure 5: Validation of vertical surface temperatures from observations and models.

3.2. Field measurement
The pattern of current distribution around the waters of the Madura Sea is predominantly influenced by tides. This can be seen in Figure 6 which shows the direction of motion of the current flowplot which follows the tidal graph pattern. The location of the current measurements in Figure 9 is carried out in front of the Paiton PLTU pier using an electronic current meter that is tethered to the mooring in front
of the pier. The data shown in Figure 6 is the hourly averaging result data. This was done to make it more visible the direction of the current plot stick at any time.

The direction of the current stick plot shown in Figure 6 shows the direction of the opposite current which follows the tidal pattern. However, there are deficiencies in determining the position of placing the measuring instrument which is located right next to the pier which has a pier wall, so that the direction of movement of the tool is limited. This can be seen at low tide, the direction of motion of the current at low tide rarely reverses the direction of motion at high tide. The value of the current speed at Paiton PLTU jetty ranges from 0 - 2.5 cm/sec.

The current velocity value in front of the outlet can be said to be higher than the current velocity value around the Madura Sea waters, this is caused by the discharge from hot water effluent that continuously exits through the outlet with a maximum current velocity value of around 70 cm / sec as presented in Figure 7. The direction of the dominant current stick plot towards the Northeast, it is influenced by the velocity of the flow out of the outlet is greater than the speed of the current around the waters of the Madura Sea and is also influenced by the position of the mouth of the outlet facing the Northeast. It can be seen in Figure 14 that the direction and speed of the flow naturally around the mouth of the outlet, both at high tide and at low tide.

Figure 6. Stick plot of current at Paiton PLTU jetty.

Figure 7. Stick plots of current at the Paiton power plant outlet.

3.3. Thermal dispersion from Paiton Power Plant from Observation

Observation results shown in Figure 8 show that there are differences in the distribution pattern of hot-produced water spatially horizontally from each observation time. The color in Figure 8 is the thermal dispersion distribution shows the high and low values of the water temperature that is affected by warm water. The red color represents the highest temperature distribution, which is 40 ° C. Gradation from
red to blue indicates a decrease in the temperature distribution of waters with blue indicates the lowest temperature distribution, which is 28 ºC.

The distribution of hot-produced water that comes out around the mouth of the outlet in November 2016 and February 2017 appears to be spatially more dominating color is the gradation of green to red, it shows the value of the temperature distribution that comes out of the outlet ranges from 34 º C to 37ºC. This shows that the temperature distribution in the representative month of the West Season is higher than the temperature distribution in the representative month of the East Season.

In the West Season the long duration of the sun shines on the southern part of the earth for longer, thus affecting the value of sea surface temperature in the southern part of the earth according to [8]. Paiton sea waters are in the southern part of the earth and are in accordance with the results of observations of the distribution of produced hot water values higher during the West Season. The distribution of produced hot water around the outlet mouth in May 2017 and August 2017 has large temperature values ranging from 33 º C to 36 º C with spatial color distribution starting from the gradation of blue to gradation of red.

Figure 8. Spatial distribution of produced hot water from observations in 4 periods within a year (November 2016, February 2017, May 2017, and August 2017).

When viewed at a temperature interval of 36 ºC-40 ºC shows that in November 2016 showed a wider area of produced hot water compared to other periods. It can be seen on Figure 8 and Table 3 in February 2017 the extent of the distribution of produced hot water with a temperature interval of 36 ºC-40 ºC has an area of distribution of 1580.17 m². The distribution of produced hot water in February 2017 with the same temperature interval of 36 ºC-40 ºC shows that a smaller area compared to other periods.
Table 3. Extent distribution of produced water that exits through the outlet results from observation.

| Temp. (°C) | November 2016 | February 2017 | Mei 2017 | August 2017 |
|------------|---------------|---------------|----------|-------------|
| 36 – 40    | 12787.4       | 1580.17       | 5525.61  | 9014.94     |
| 34 – 36    | 207268        | 73634.8       | 114086   | 97360.1     |
| 32 – 34    | 310606        | 875208        | 907215   | 217683      |
| < 32       | 34373         | 591905        | 615800   | 1068820     |

The vertical distribution of produced water shown in Figure 9 shows the different distribution patterns of each season. The distribution of produced water coming out of the outlet has a distribution range of less than 500 meters from each month in the season representative. The range of the distribution below 500 meters can be seen from the temperature value above the ambient temperature of the marine waters (Figure 9). Produced water that comes out of the outlet mixed with sea water in the environment around Paiton causes a significant stratification of water temperature around the outlet. The temperature stratification occurred at a distance of about 0 - 200 m from the mouth of the outlet with a depth of no more than 8 m. Seawater temperature values appear to decrease at a distance of 0 - 200 m from 38 32 °C to 32 °C. The further away from the mouth of the outlet, the distribution of water temperatures decreases from each depth.

3.4. Tidal current

The velocity of current flow in the Madura Strait ranges from 0 m/sec and 1 m/sec. In Figure 10 (A) and (B) the flow velocity is seen to be faster in the narrow part of the Madura Strait compared to the flow velocity the eastern of Madura Strait where much wider, both at high tide and low tide. This occurs due to the flow of currents from the Java Sea that enter through narrow passages so that the flow velocity is faster [9]. Figure 10 (E) and (F) are domain as an area of research study. Can be seen in the picture that is marked in red box, there is water input from an outlet with a higher current value than the current at its around. This causes changes in the direction of current flow around the outlet, both at high tide and low tide. Flow patterns in Paiton coast waters derived from model results are dominantly influenced by tide.
Figure 9. Cross-shore section of seawater temperature at around outlet where produced water from Steam Power Plants activity flowed out (November 2016, February 2017, May 2017, and August 2017).

3.5. Model of thermal dispersion of water produced by cooling of gas and steam power plants

Figure 11 is a simulation result which is sampled from several sea level positions. Figure 11A shows the thermal dispersion resulting from the cooling of a steam engine when the position of the sea level goes to flood tide, Figure 11B at highest water level, Figure 11C goes to lowest tide, and Figure 11D at lowest low tide. When heading to high tide and highest high tide distribution of hot water waste spreads
to the west, while when heading to low tide and low tide the distribution of hot water waste spreads to the east.

The colors in Figure 11 show the high and low temperatures of the Paiton coastal waters affected by the thermal distribution of gas and steam power plant outlets. The deep red color scale shows an interval of 37 °C to 40 °C. Gradations of light green to orange depict temperature intervals of 31 °C to 37 °C, and gradations of blue to green represent temperature intervals of 28 °C to 31 °C.

The distribution of thermal will be restrained at high tide and vice versa occurs at low tide, so the extent of thermal spread is wider at low tide. In addition there are differences in area, there are also differences in the value of the temperature coming out of the outlet. During high tide there is an input of seawater entering the land, so that a decrease in the temperature of the water due to the mixing of water masses around the outlet. The condition is different at low tide which the direction of current flowing out of the outlet is in line with the direction of current flow at low tide, so that the water temperature is higher when compared to the high tide due to the least mixing of the mass of water around the outlet.

**Figure 10.** (A) Current distribution patterns in Domain 1 at high tide, (B) Domain 1 at low tide, (C) Domain 2 at high tide, (D) Domain 2 at low tide, (E) Domain 3 at high tide, and (F) Domain 3 at low tide.
Figure 11. (A) The distribution of thermal dispersion horizontally to the high tide, (B) at the highest tide, (C) to the ebb tide, and (D) at the lowest tide.

The calculation of the extent of the thermal dispersion distribution in Table 4 is the thermal distribution at the time of tide, maximum tide, minimum tide and low tide. Calculation of the extent of thermal distribution is carried out using Arc Gis 10.3 2014 software by making water temperature categories or intervals. The extent of thermal distribution is influenced by the current impulse that carries the mass of water toward the sea. As a result of the attraction of the moon and the sun to the sea level on Earth, the mass of water from outlets that are aligned with the direction of movement due to the process of advection and dispersion, so that the mass flow of water is tighter at low tide which impacts the wider distribution of hot water waste.
Figure 12 shows the vertical distribution of temperature from the simulation results of the model. The results are extracted from each grid according to the drifting temperature measurement point. In the picture, a black dot is seen in the body of water, the point shows the simulated temperature value then extracted and visualized with ODV 4. The temperature value is in the range of 36°C to 40°C. The ambient temperature is 28°C and 40°C is the highest temperature flowing out of the outlet. The thermal distribution coming out of the outlet shows that there is a vertical temperature stratification in the water column, the stratification is caused by differences in pressure and density of the waters affected by the temperature.

The grid width in Figure 12 is 20 m and on the way to the high tide thermal distribution with temperature intervals ranging from 31°C to 40°C spread in the water column as far as 60 m from the outlet, while at the time of receding the distribution of thermal with temperature intervals ranging from 31°C up to 40°C spread in the water column as far as 540 m from the outlet. The temperature distribution at high tide looks like it is stuck near the outlet or the distribution is not too far away, it is suspected from the movement of currents that go ashore. The distribution of temperature at low tide shows the thermal distribution spreads away from the outlet, it is thought that the thermal that comes out of the outlet is torrentially the current recedes offshore.

The results of temperature measurements in food and simulation models are presented transversely (Figure 13). The picture is compared between the results of observation and the model. Figure 13A is the result of the simulation model, while Figure 13B is the result of observation. There is a difference in the results of both when seen from the stratification layer temperature at each depth. In the simulation results it can be seen that the temperature value at an interval of 36°C- 40°C is at a depth of 7 meters, then thinning the layer to the surface with a distance of 5 meters.
Figure 12. (A) Vertical distribution of thermal dispersion to the highest tide, (B) at low tide, (C) at maximum tide, and (D) at minimum ebb tide.

The process of depletion of the temperature layer in the water column is caused by an interaction between the atmosphere and the sea surface [5]. One of the processes in the interaction of atmosphere and sea level is the process of evaporation and convection. The evaporation process causes the temperature of waters with high temperature values will be more volatile, causing a decrease in the temperature value. Unlike the case with the convection process, where the process causes the mass of water with higher temperatures to be raised to the surface due to lower density. While the results of
observations of temperature at intervals of 36 °C-40 °C are at a depth of 3 meters, then thinning the layer to the surface with a spacing of 90-600 meters.

Figure 13. (A) Cross section of sea water temperature simulation results and (B) observation results.

4. Conclusion
Distribution of temperature values around outlets that are affected by thermal discharges from gas and steam power plants, based on the results of spatial temporal observations in November 2016 ranged from 32-39 °C, in February 2017 ranged from 32-36 °C, in May 2017 ranged from 32-37 °C, and in August 2017 ranged from 32-37 °C. Based on the calculation of the spatial extent of temperature distribution horizontally, wider temperature distribution occurs during the East Season than in other seasons. Likewise, the vertical distribution of temperatures in the East Season occurs stratification of deeper temperatures than in other seasons at intervals of 36-37 °C.

The results of the simulation model can show that the movement of hot water distribution follows the tidal motion pattern around the outlet. The model simulation results in temperature values coming out of the outlet ranging from 31-40 °C. This value is not too far different from the results of field measurements. At high tide the temperature distribution is compressed around the outlet. Whereas at low tide the temperature distribution spreads far from the mouth of the outlet, so it has a wider temperature distribution area due to the impetus from the environmental currents. This is influenced by the flow of currents to the sea.
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