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Design, construction, and stability test of aerial wireless coastal buoy

L O Wahidin[1], I Jaya[2*], A S Atmadipoera[2]

[1] Marine Technology Department, Bogor Agricultural University (IPB), Bogor, Indonesia;
[2] Department of Marine Science and Technology, IPB Bogor, Indonesia;
*e-mail : indrajaya.ipb@gmail.com; indrajaya@ipb.ac.id

Abstract. Due to its highly dynamic nature, coastal waters are necessary to be continuously monitor. Aerial wireless coastal buoy (AWCB) is one of the ocean instrument commonly deployed for observing oceanographic phenomena in coastal waters and around small islands. In this paper we describe the design, construction and the stability test result of new AWCB. The new AWCB is using water temperature sensors to collect data and transferring them through specific aerial wavelengths at real time and low cost in coastal areas. The AWCB is completed three steps. First, the buoy was designed using CAD software to determine its size, form and color. Next, the buoy was constructed using material from fiberglass. Last buoy was tested for its buoyancy and stability at the Acoustic and Instrument Laboratory, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University. At sea-trial was also carried out around Pramuka Island, and during the trial it shows that the buoy is stable condition within waves swaying and surface water current. It is floating well on seawater surface and stable for six days installing duration.

1. Introduction

Coastal water only covers 8% of entire sea surface around the world, however it plays an important role dominantly for many process mainly relating with interchanging land and sea areas [1]. Coastal areas (shorelines and waters) function as a bridge system both ecological and social aspects to connecting many components. Its ecosystems are crucial for human being which provide huge complexity relationships especially in biological aspects differently in every area where human activities taking place. Coastal area and sea are facing some environmentally challenging pressures, such as increasing population and coastal developing pressures, followed by sea level raise and 21 century climate challenges [2]. Coastal water monitoring is a potentially effort to answer those challenges above. It provides further opportunities to understand developing geological hazards along the times. The monitoring also potential to seek solutions in increasing models and predicting the hazard's behaviors. However, coastal areas characteristics always exhibit obstacles for achieving those goals [3].

Coastal zones and sea monitoring are being necessary needs in serving data and information which are highly relating with coastal and ocean dynamics. These data availability are able to reveal hidden curtain phenomena. Providing these data and information *in situ* format especially for physical oceanography are prominently to observe quick temporal changes of coastal water. Therefore, it is needed an instrument that can be operated through times in order to watch the coastal phenomena in real time. [4] Coastal monitoring system using buoy can construct innovative solutions that intends to measure, such other activities, coastal water condition. Comparing other monitoring technologies, surface buoy supplies simple installing and autonomous. It is being a proper outlet to measure and to control coastal and sea environments.

Aerial wireless coastal buoy, a verily needed marine instrument for observing oceanographic phenomena in coastal areas which is completed with sensors to collect and transmit data through certain sound wavelengths. Developing this buoy, dimension of the buoy is an important indicator key to be bearing in mind. [5] Conducting research in aerial coastal monitoring expresses that a small instrument, low cost, and wear-resistant are being ideal solutions for a mooring buoy system which has resolution advantage, both spatial and temporal. Thereof, it is required a further study about the buoy design that can be proper deploying for coastal waters. The size of buoy is portable and does not need a heavy vehicle in installation are considered. Filling those objective above makes the research about it notably to be conducted. This paper focusses on exploring mechanical process of a set design and construction of Aerial Coastal Buoy. Explicitly, this paper aimed to develop design and construct aerial coastal buoy and to test its stability in laboratory scale and field testing.

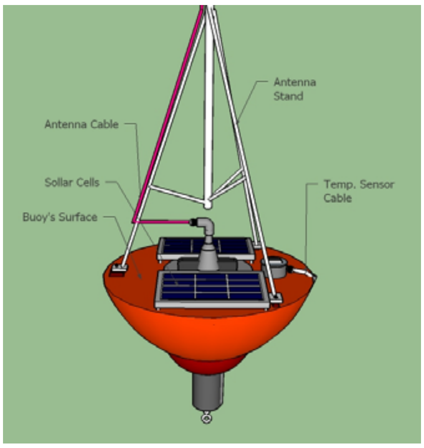
2. Material and method

2.1. Description of the study

This research was conducted on July 2016 to November 2017 in Marine Instrumental Laboratory, Fisheries and Marine Science Faculty, Bogor Agricultural University (IPB) for mechanical process, field testing was conducted on May 2017 in around Pramuka Island, Kepulauan Seribu, DKI Jakarta Province. The research phase was divided into four research steps. First, designing the body parts of buoy using compatible three dimensions (3D) software that aimed to reflect the expected buoy. Second, detailing and transforming the 3D designed buoy into flatted 2D parts that were beneficial to construct the buoy according to the available materials, tools and equipment in the laboratory. The two last steps were to test the constructed buoy in freshwater media (fresh water body) to seeking buoyancy and stability of the buoy, and field testing such as coastal waters to find out its rill condition where it was swayed by sea surface currents and waves.

2.2. Designing buoy

Initializing step to contrive a design was to crystallize an idea about the expected buoy, including form and size (dimension). Designing started from rough sketch in a paper, then followed with sketching in a 3D software. In this research, the Sketchup 16.1.1449 trial version was using and it was downloaded from http://www.sketchup.com/. This software is a powerful in the design process. Form and size were considered in this design step. The buoy was expected to be cycle on the upper surface (discuss) and cambering arrowed down. The upper surface was hoped to give more buoyancy and the lower part to be attached weight. The buoy dimension was determined as no more than one meter in length and width, and no more than 30 kg in weight in order to be portable use. Figure 1 below is a new aerial coastal buoy (AWCB) design with two displays, top and side views.



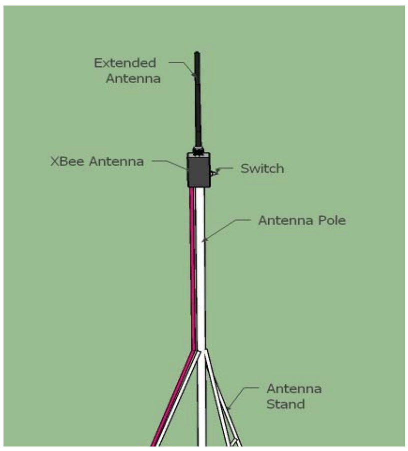


Figure 1. A new Aerial Wareless Coastal Buoy Design, side view (left) and top (right).

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2.3. Construction

The buoy construction was a further step. The resulted 3D design was transformed into 2D forms (flatted forms). Tools and equipment availability was a crucial aspect in this step. Mechanical works conducted using woodworking equipment and materials which were available in the marine instrumental laboratory of IPB and some materials were ordered in close store building and online shopping. Materials and equipment were involved in all the buoy designing, construction and testing process are listed in the table 1 below.

Table 1. Materials and equipment of all Aerial Wireless Coastal Buoy (AWCB) making process in Marine Instrument Workshop of IPB.

Material/Tool	Type	Total/Function
A. Material		
Plywood 3 mm	3 mm thick	2 leaves
Matt		25 meters
Resin	157 BQTN	60 kg
Catalytic	Mepoxe	0.5 kg
Stainless steel 8 mm		3 meters
Nail 3 cm		½ kg
Plastic Pipe 4 inch	PVC	3 meters
Plastic Pipe ¾ inch	PVC	4 meters
Plastic Pipe ½ inch	PVC	4 meters
Set Dop 8 inch	PCV	4 units
B. Tool		
Laptop	ASUS S46C	Designing the buoy and data processing;
Software	Sketchup 16.1.1449 *trial version*	Software 3D;
Hand grinder machine	Krisbow	Cutting and cleaning up some parts of the buoy;
Hand drill	Krisbow KW07-1000	Perforating some parts of the master and mold of buoy;
Meter	Sumoku Eco	Measuring length of working process;
Screwdriver	Plus (+) and Minus (-)	Tightening screws to connect parts of the buoy;
Hummer		Helping to construct the buoy making process;
Paintbrush	Eterna 2’’ dan 4 ‘‘	Helping attaches resin and matts;
Stopwatch		Determining times for stability testing;
Camera		Documenting research process.

2.4. The buoy testing

Stability testing was carried out when all construction process over. This step aimed to seek the buoy ability on the water surface and how it could be stabilized its self from outside effects. The test assumed that when an object merged into the water column having some forces such as the object’s weight itself (F_G) with it vertically downward direction and upward water pressure vertically. Weight force is centered in axis weight of the object. The upward force of merged object is called buoyancy (F_G). This force works on all surface areas of the object. All forces work on the object is weight force (F_G) and hydrostatic forces that happen to all the object’ merged surface areas. Bear in mind that assuming the object is in static position (silent), therefore static force horizontal direction will be equal to be excluded. In this condition, the hydrostatic working force on surfaces of the object is a buoyancy. All forces working of the object is shown in figure 2 as below.

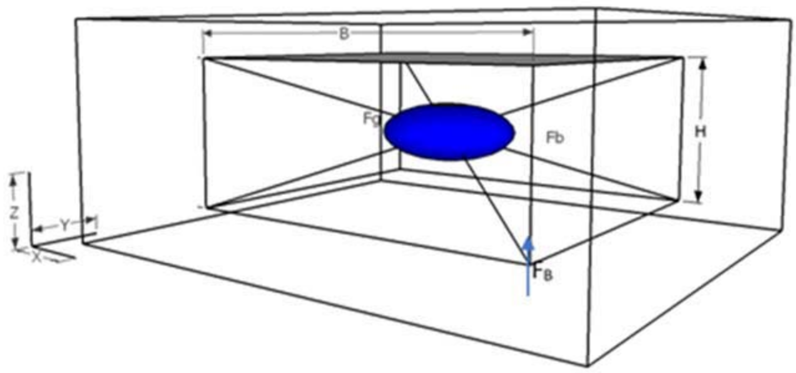

Figure 2. Working forces on a floating object.

In systematically, all those forces above working on a floating object are counted in wide unit measurement according to the formula [7] as follows:

$$F_G = \gamma bBH \quad (1)$$

$$F_b = \rho_o \,.\, B, \text{where } \rho_o = \rho_w \,.\, \mathrm{H} \quad (2)$$

where: F_G = Object weight force; F_b= Buoyancy; ρ_o= Object's density; B = Diameter of floating object; H = Depth; ρ_w = Water density; γb = Object mass.

In quit position, a resultant force either vertical or horizontal are equal to be zero, then by using formula [7]:

$$\sum F_x = 0 \quad (3)$$

$$\sum F_z = 0 \quad (4)$$

$$\rightarrow \quad F_B = F_G$$

$$\rho_o \,.\, B = F_G$$

$$F_G = \rho_w \,.\, h.B$$

$$F_G = \rho_w \,.\, A$$

where: F_{xy} = Weight force of object; F_z = Force on Z axis; F_B = Buoyancy; F_g = Weight force of object; ρ_o= Object's density; B = Diameter of floating object; H = Depth of merged object; ρ_w= Water density; A = Merged surface areas.

Stability of floating object is not affected by small disturbance (force) that tries to be un-stable. A floating object in stable position is happened when it's central weight point (*Bo*) is under the buoyancy point (*Ao*) and reversely, the unstable condition will be happened. When central weight point (*Bo*) is so close to the buoyancy point (*Ao*) causes the object will be in different position as seen in figure 3 below.

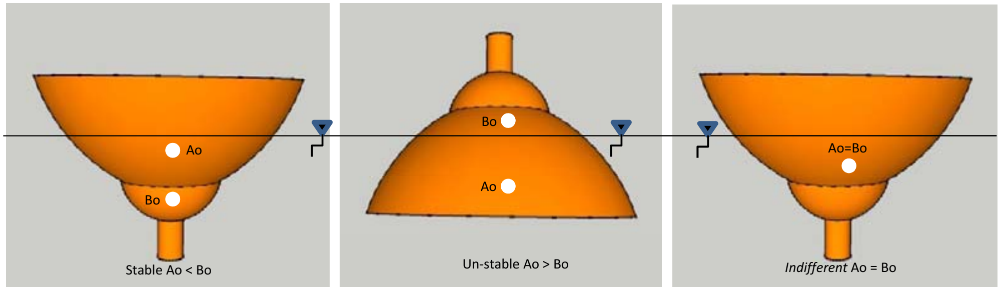

Figure 3. Floating stability of the buoy, stable (left), un-stable (center), and indifferent (right).

Metacentric high of all three body of buoys above is determined by [7] formula as below.

$$m = \frac{I_o}{V} - A_o B_o \quad (5)$$

This formula is consisted of *Io* is a moment inertia of cut object by surface of the liquid, *V* is a volume of transferred liquid of object, and *AoBo* is a distance between buoyancy point and an object point. According to the high value of metacentric (*m*) indicates that if *m*>0 showing the object is table position; *m* = 0 of the object reveals the neutral stability (indifferent), and if *m* < 0 is indicating that the object is not stable position.

3. Results and discussion

A new aerial wireless coastal buoy (AWCB) designing is a long process that has been passed among aspects of idea, mechanical process, data transmitting frameworks and field testing of it. Results of this paper are focusing on some of those process such as design, mechanicals process of construction and stability test of designed buoy and plotting transmitted temperature sensors data.

3.1. Buoy designing process

The three dimension (3D) designing of buoy was carried out using CAD software namely Sketchup 16.1.1449 *trial version*. This software is suitable for designing 3D which has many understandable features. The designed phase consists of outer body, electronic compartment holders and transmitting system (antenna). The body is expected to be a discuss form with 70 cm in diameter and it wanes toward down with an indention in 35 cm diameters that function as weight component from cements and moistened sands. The lower is made to be extending for 15 cm length and 10 cm in diameters, respectively. The last lower part is constructed by PVC pipe containing cement that functions as additional weight and stability of the buoy as seen in the following figure.

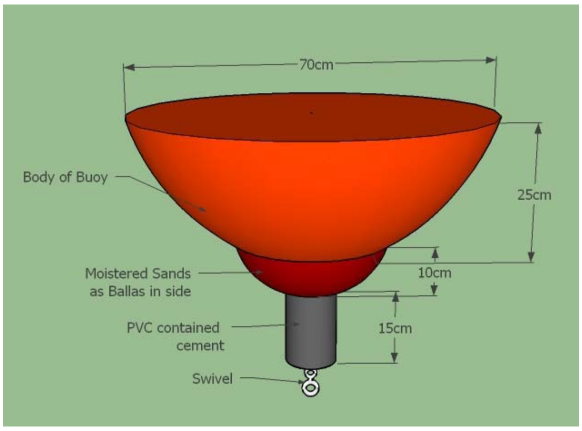

Figure 4. Body of aerial wireless coastal buoy and its size (side view).

Electronical compartment holder is made to be a tube which is a PVC DOP that has been completed with drat lock. The dop is set in center of the buoy with diameter and high are 20 cm and 22 cm, respectively. In addition, it is functioned as the foundation of antenna pole that is installed perpendicularly on body of the buoy. Solar panels were set in opposite on flattened cycle surface of the buoy. The set panel is looked for well operating the electronic components of the buoy that is about 10 watts power in each. Furthermore, they are posted slightly sidewise about 10^0 that is assuming the received sunshine in the solar panels is well distributed and no-obstacles. Parts of the design well shown in the following figure.

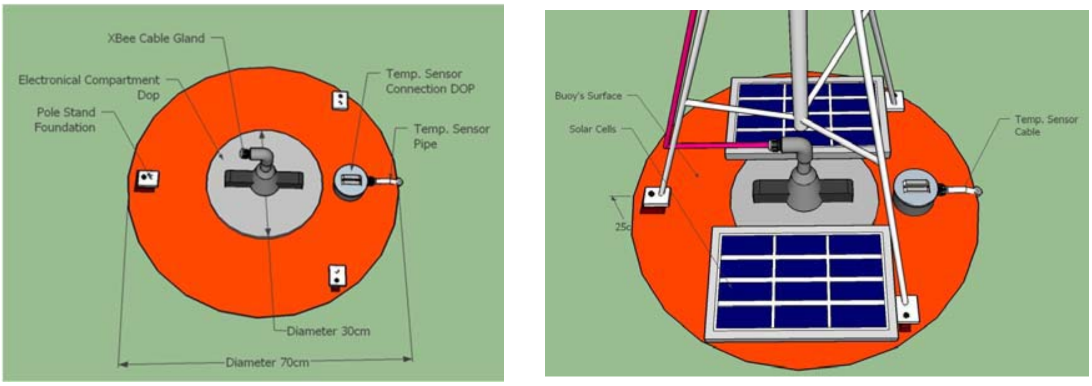

Figure 5. Surface part of the buoy, before setting solar cell panels (left) and after setting solar cell panels (right).

The last part of designing is antenna (transmission). Antenna high is referred on suggesting by [6] aimed that each instrument can transmit data as furthest. Hence, it will be consequence to the high of antenna. The designed antenna of this research is about 180 cm from the surface of buoy and about 200 cm from the seawater surface. This position is affected to data transmitting from nodes buoys in coastal water to the land-receiver in mainland. The antenna is slightly swinged by seawater waves and winds blowing. Therefore, it should be constructed from pipe iron. The top of antenna pole is set a very important transmitting component, an XBee, a transmission electronical shield and its extended antenna. This antenna and XBee are set together in order to be easy in controlling whenever any problems of transmitting. The antenna pole is also constructed to be portable and transportable. The whole body of design buoy is shown in the following figure.

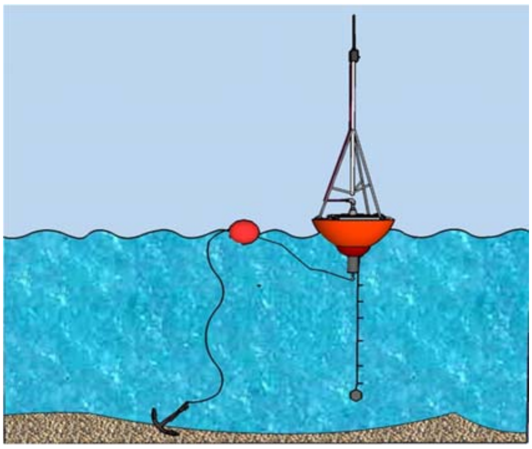

Figure 6. The whole view of designed buoy.

3.2. Construction

Constructing buoy is the second phase after the 3D designing over. The 3D design is transformed into 2D forms (flatted) as model to seek available way in constructing the buoy form at three dimensions in real condition. The construction process consists of three ways such as master making, moild making and constructing the desired buoy. The master is stringed up for being a half frame of buoy that are from plywood sheet which is cut to be pieces according to the printed 2D designed models. The half-framed model is covered with papers. Upper surface is smeared with mixed components which are resin, hardener, matt and talk. Those materials are compilers of fiberglass. The surface master is cleaned up using grinder machine and sandpapers until to be smoothly. Finally, the mirror glaze (wax) is stained on the master surface. Some process of master and mold making are shown below.

Figure 7. The buoy body's making process of Master (left), cleaning up the master (center) and set mold (right).

Next step is to make the buoy mold. The mold is made into two parts which is framed from fiberglass. Those parts then are gathered using small screws in both sides (Fig. 7 right above). Last step is the molding process. This process almost same with the process of mold making. However, the mixed fiberglass component is made thickly according to the expectation. The buoys are made three units according to the research scenario which consists of one end note units, two routers, and a land-receiver. All down parts of those buoys are combined with other components such as weights, electronic compartment DOPs, and antennas. Construction process of buoy making is displayed in the figure 8 below.

Figure 8. Process of buoy making. Uncovered buoy is floating in the freshwater (left), total molded buoy (center), coloring buoy (right).

3.3. Bouyancy and stability test

Buoyancy and stability tests are the last phase of aerial coastal buoy making process. Stability test is conducted to seek the buoy ability above the water surface in order to be deployed in the real condition, such as coastal waters and small islands. Hence, this test is a must to be conducted to all constructed buoys. Jordan and Beltran-Aguedo (2004) express that an important parameter of mooring buoy is stability, and the stability is expected to be returned on balancing condition. Measurement of some parameters which influences on constructed buoy are listed in the table 2 below.

Table 2. Test results of constructed coastal buoy.

Objects of Test	Results
FB (buoyancy)	9253.39 kg/m^3
FG (weight force)	264.6 kg/m^3
A (area)	0.850 m^2
P (object density)	561 kg/m^3
Psand (sand-weight density)	1400 kg/m^3
B (diameter of buoy)	0.70 m
H (merged buoy)	0.30 m
Ywater (water density)	1000 kg/m^3
Yb (buoy weight)	27 kg
M (Metasentrum)	27

Testing of buoyancy and stability of aerial coastal buoys as a resulted design is conducted on water surface in seeking its ability in real condition, before those buoys are deployed at the determined location, coastal areas and small islands. Displaying of test is shown as the following figure.

Figure 9. Stability and buoyancy test of the new AWCB in a pool at Fisheries and Marine Science Faculty, Bogor Agricultural University (IPB).

Deploying the aerial coastal buoy in a pool shows that the buoy is floating well on water surface through physical observation. An extreme action is done on the buoy by pressing one side of the buoy until its side reaches the water surface and releases it up. Time duration during the pressed side buoy and the buoy in stable position are recorded. The time shows that during the action is averaged about 28 seconds. Those testing shows that the buoy is stable on the water surface and suitable to face extreme situation at the pool scale. These tests are likely a physical simulation of the buoy for real situation. It is expected that the buoy can be deployed well in the real situation, even some seawater dynamic fluctuation. By those tests infer the buoy seems to be stable in deploying at the coastal areas.

3.4. Field testing

Field test of the new AWCB is the final step. This test is conducted in Pramuka Island sorrounding waters as long as six days of operation. Instalation of the buoy is carried out by mooring system. Three new AWCBs are installed in determining location and desired distance. Each buoy is moored to a small buoy using three meters long rope, and ten meters rope to an achor. Six temperature sensors are set as an array perpenducularly to the new AWCB. Distance of sensor is determined in a meter long. Physical observation shows that the buoy is swinged well on seawater waves, winds, and seawater surface current. Moreover, buoyancy of those buoys are good in seawater. The land-receiver functions as a receiving node in main land.

Figure 10. Field testing of aerial coastal buoys in surrounding waters of Pramuka Island, Node Buoy (left) and A Land-receiver (right).

3.5. Transmitting of seawater temperatures

Measuring water quality parameter such as seawater temperature in this research used Dallas 1820 temperature sensors. Those sensors were mounted in distance one meter each in every buoy node vertically as long as six meters seawater surface. Sea water temperatures were collected by those sensors then transmitted using Xbee Module to the land-receiver node in the mainland. Those sensors worked during a full day long. The results of seawater temperature recording by three buoy nodes on May 22, 2017 are displayed in the folowing figures.

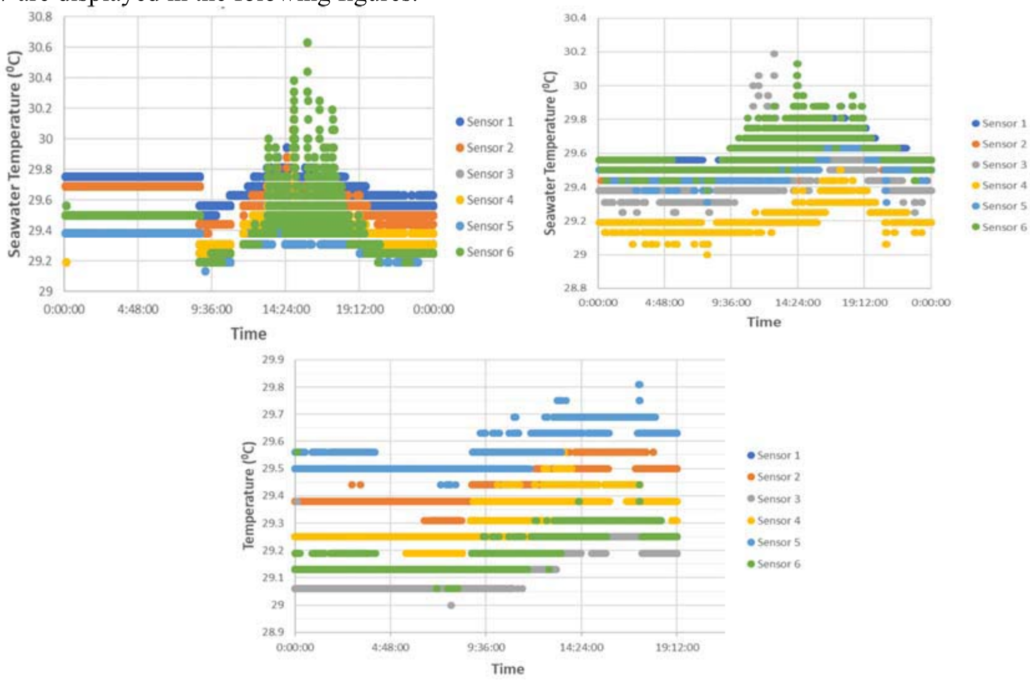

Figure 11. Seawater temperature fluctuation in three different node buoys such as buoy i (left), buoy ii (right), and buoy iii (center).

Those three figures above indicate that seawater tempeture in the serounding water are inranged of 29 to 30 ^{0}C. The water temperature are getting hot in midday at two o'clock as the peak of heat and then it getting down to the normal position. This trend is exhibited by almost all mounted sensors in the three nodes above. Seawater temperature fluctuation between day and night that is recorded in this research is small about 1 ^{0}C. It happens because of the buoy was deployed in shallow tropical coastal waters where variation of sea surface temperature is not so huge. More detail about seasurface temperature variation and its phenomena has been written by Kawai and Wada [7].

4. Conclusion

Steps of creating a new aerial wireless coastal buoy (New AWCB) in this research starts through some activities such design, construction, test of stability and buoyancy, and also field test. Detail works and availability of materials and tools are two crucial things along the working process. Understanding each work process and how to solve obstacles faced in construction of the buoy is a critical point. The accuracy between design process in computer and mechanical works is important to be beard in mind. Testing the buoy also important for making sure its stability and buoyancy. All process of buoy making and testing above infers that the buoy is already to be deployed in determined location. Field testing of those three new AWCB and its land-receiver points out those buoys are working well both recording and transmitting seawater temperature data.

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