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The Bintan MOS development: contribution of ideas to realize Nusantara marine observation network

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ABSTRACT

Several marine research have attempted to design a data observation system using Internet of Things (IoT). In the future, this system is predicted to become a necessity for marine researchers as a strategic technology to continuously access data. Therefore, this study provides information on the development and application of observation and data collection systems using IoT. The coastal weather and tidal data were obtained via the automatic coastal weather station and acoustic gauge respectively. Meanwhile, the various research activities commenced in July, 2018. In the first year, an operational observation system was developed, while comprehensive baseline data such as air temperature, humidity, wind speed, and sea surface level were also collected. This collection system is reliable, provides real-time data, and easily accessible with internet connection. Furthermore, the Bintan Marine Observation System (The Bintan MOS) is also suitable for other uses such as; monitoring water quality and marine mammals, as well as disaster mitigation. The adoption of this system by other sectors potentially conditions marine researchers for data exchange, to fully understand the fluctuations in coastal weather of Western and Eastern Indonesia as well as the tropical and sub-tropical marine weather. This study successfully developed the Bintan MOS, capable of providing reliable information both off-line and real-time.

Introduction

Marine and weather dynamics usually affect the various human activities in coastal areas (Halpern *et al*., 2008). This potentially increase the risk of coastal communities to climate change (Mafi-Gholami *et al*., 2020). To predict the impact of this changes, one of the important steps is to monitor weather and sea water dynamics. Previous studies recommended that continuous observations need to be carried out over a long period before the information is considered reliable. Such technique has to be carried out in real-time before being considered as a tool in decision making at local, regional, and global scales (Dexter and Summerhayes, 2010).

Data collection on the field, especially in marine waters, has its own challenges as the samples obtained are usually few, expensive, require a lot of time and high level of difficulty (Glenn *et al*., 2000). Therefore, an extended real-time monitoring is the best solution to fully understand the dynamics of these changes and the resultant impacts on coastal and marine resources (Moersdorf and Meindl, 2003; Ruberg *et al*., 2007; Lynch *et al*., 2014).

Networks of marine observation stations have been developed in several developed countries (Isemer, 1995; Glenn *et al*., 2000; Van-Den-Broeke *et al*., 2004; Conlee and Moersdorf, 2005; Novellino *et al*., 2014). However, for Indonesia, this system has not been fully Incorporated with the Internet of Things (IoT) hence, data collection is still short-term and temporal.

When these monitoring and observations are carried out in a continuous and real-time manner, it promotes the complete understanding of the global

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climate dynamics and impacts on human life. Meanwhile, this is only achievable through long-term time analysis of the key parameters obtained at permanent observation station.

Therefore, the development of a Marine Observation System (MOS) located in Bintan aims to provide data and information in relation to coastal weather conditions and sea-level dynamics as a pioneering form of national maritime technology independence.

Materials and Methods

Location and times

The marine stations were located on Bintan Island, Riau Islands Province, Indonesia (Figure 1). Meanwhile, the MOS were installed in 2 places namely, Berakit Station (on the beach) and Bakau Bay Station (at the sea). The detailed position of MOS on Bintan Island is presented in Table 1 meanwhile, the initiation for the Bintan MOS development commenced from May 2018 to January 2020.

Figure 1. Location of Bintan MOS.

Table 1. MOS Position in Bintan Island

MOS Location	Position
Station of Bakau Bay (Sea)	08°54’34.81.” LS and 116°17’51.35” BT
Station of Berakit (Beach)	08°54’35.34” LS and 116°17’52.53” BT

Tools and materials

This study was performed using Automatic Weather Station (AWS) and Mobile Tide and Water Level Instrument (MOTIWALI) based on acoustic sensor.

Automatic weather station design

AWS is automatically designed to measure weather data such as wind speed and direction, temperature, as well as humidity. The current AWS was developed by (Kusumah *et al*., 2016; Syafi'i, 2018). This study was conducted using AWS with an automatic transmission system utilizing GSM (Global System for Mobile) as a medium for delivering information. This instrument is useful for obtaining data quickly, economically, and practically.

The instrument material was designed to be waterproof in order to preserve the sensor performance. Besides, the cup counting on the wind speed gauge is half of a plastic ball (Figure 2).

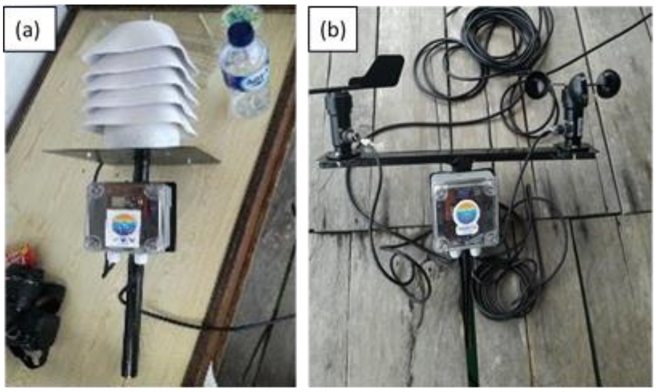

Figure 2. Instrument design; (a) humidity sensor, (b) wind sensor.

The electronic box was made with glass and plastic, to prevent contact with rain, dust, and direct sunlight. Furthermore, the electronic system was divided into several circuits including main, sensor, transceiver, and data logger. The main circuit used Arduino as the brain hence, it gives instructions to other components. The Arduino Promini and Uno receiver were connected to the sensor together with the data sending module and ethernet shield respectively. In addition, the Arduino Promini was also connected to RTC (Real Time Clock), micro SD (Secure Digital) and indicator led while three sensors were connected to the transmitter. Opto rotary was connected to pin D2 (Digital Pin), Magnetor HMC5883L series to pins A4 and A5 (I2C), and the DHT-11 series temperature and humidity sensor to pin D3 (Digital Pin).

The transceiver circuit was made with the KYL200 series modules and functions for sending and receiving signal. It is connected to the MAX3232 series IC converter. The logger series was used to store data (sensors & time). In addition, the RTC DS1307 series was connected to pins A4 and A5 (I2C), while the micro SD Adapter was connected to pins D11 (miso), D13 (Serial Clock), D12 (mosi), and D10 (cs) Serial Peripheral Interface (SPI) led indicators, connected to pin D9.

The main energy source for the transmitter circuit was a 12 Volt battery, connected to a solar panel whereas, a 5V 1A adapter was used for the receiver circuit to convert the ac to dc, needed for energy in the data logger circuit.

The AWS software was designed to perform functions such as: reading, sending, receiving, writing (sensors and timing), and data storage. The flow of the software is shown in Figures 3 and 4.

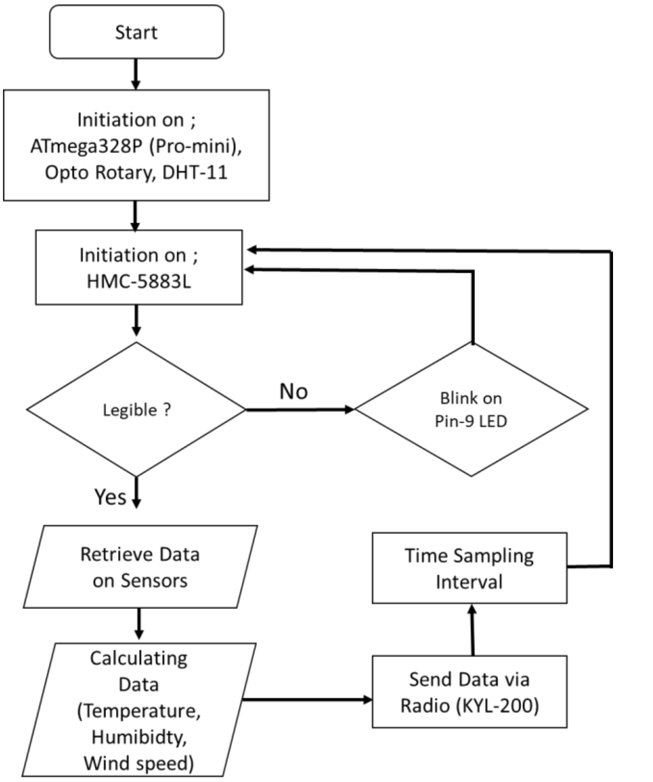

Figure 3. Transmitter software workflow.

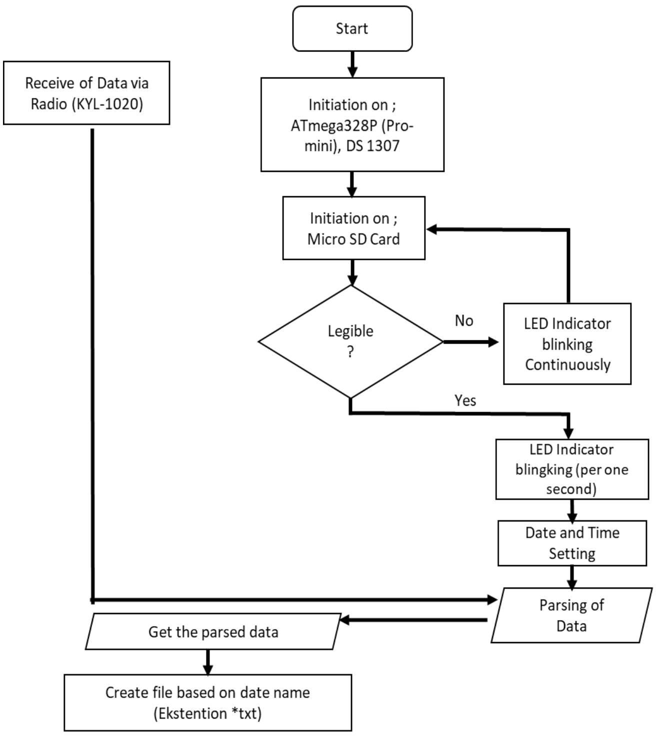

Figure 4. Receiver software workflow.

Acoustic tide gauge/MOTIWALI

Sea-level dynamics were measured using tide gauges with MOTIWALI (Mobile Tide and Water Level Instrument). The principle of this instrument is based on acoustics (ultrasonic sound waves). It works by simply calculating the time taken for one acoustic pulse to hit the sea level and then return to the sensor, the travel time is then converted to distance. Furthermore, MOTIWALI (Figure 5) was developed by the Laboratory of Marine Instrumentation and Robotics IPB University, Bogor (Patent registration number SID201811234/2018 under the name Prof. Indra Jaya. The performance accuracy of the instrument was published by Bemba *et al.* (2019).

Figure 5. Acoustic Tide Gauge (MOTIWALI).

Marine observation system

Sensor and data acquisition system

A sensor is a device which convert physical quantities into electrical hence, conditioning it to be processed electronically. The quantities measured in this system include temperature, humidity, wave direction, speed and sea level.

The sensor output is characterized with few changes and tends to be unstable, therefore, it requires a buffer circuit that stabilize the output changes while amplifying the sensor signals. This output was then relayed to the ADC (Analog to Digital Converter) system to convert the analog sensor into digital signals which were further processed by the microcontroller. The ADC used in the Bintan MOS system has a built-in feature of the microcontroller (Figure 6). This feature included, 10-bit precision (1024 possible outputs), working voltage 0-5 volts, frequency of 12,500 kHz, and successive approximation type.

The Arduino Nano type microcontroller was used and performed three main functions which include (1) as an ADC which is a built-in feature of the instrument, (2) signal processor that has been read by the ADC, and arrange data into a format and regulates the timing and synchronization of data transmission to the sending system (transmitter), (3) transmit and receives responses from/to the sending system via the RS232 line (a circuit that converts parallel paths to serial).

Transmiter system

The data transmission system used the GSM frequency (900 MHz or 1800 MHz). Data transmission was carried out in the form of SMS (Short Message Service). Meanwhile, the GSM module used was Wavecom which receive data and commands from the microcontroller and then send data using the SMS service on GSM.

Power supply

The power supply used for operating the tools or sensors include solar power, battery / 12 Volt Accu batteries.

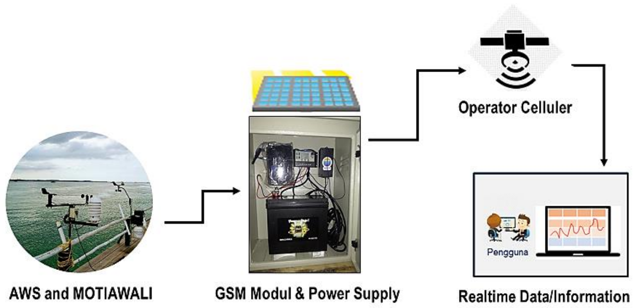

Figure 6. Bintan MOS prototype.

Results

Instrument installation and data collection were carried out from July 2018 to May 2020. The data from each sensor ranged from 15,132 to 212. 722. Moreover, several temperature and humidity data were later sent in December 2019, as the sensors were scheduled for repair (maintenance). The results of Bintan MOS development at Berakit and Bakau Bay Stations are presented in Figure 7, and detailed data characteristics are presented in Table 2.

Wind speed

The wind speed data were collected per 5 minutes for ± 20.25 months. During this period, there were data gaps at certain times (Figure 8) due to several disturbances in communication and transmissions, sensors, repair of equipment, and also from power supply system (batteries and solar panels) due to rainy season conditions. Wind speed ranged from 0.1 - 16.61 m / sec, with an average of 3.73 (± 0.02) m /sec.

Air temperature and humidity

Temperature and humidity data were recorded every 5 minutes for ± 17.75 months with a total of 107,387 and 15,132 data units at the Bakau Bay and Berakit station respectively. In addition, the temperature ranged from 23 to 34^{0}C, with an average of 29 (± 1.2) ^{0}C on Bintan Island while the air humidity ranged from 40 - 92%, with an average of 78 (±2.0) %. Detailed information on temperature and humidity data are presented in Figure 9.

Table 2. Types and characteristics of data on Bintan MOS.

Station	Type of Data	Acquisition Time		Amount
		Start	End	(Data Unit)
Bakau Bay	Wind speed	July 2018	Jan 2020	105.725
Berakit		July 2018	Aug 2019	29.875
Bakau Bay	Temperature	July 2018	Dec 2019	107.387
Berakit		Juli 2018	Nov 2019	15.132
Bakau Bay	Humidity	Juli 2018	Des 2019	107.387
Berakit		Juli 2018	Nov 2019	15.132
Bakau Bay	Tides	Juli 2018	Jan2020	212.722
Berakit		Juli 2018	Mei 2020	104.918

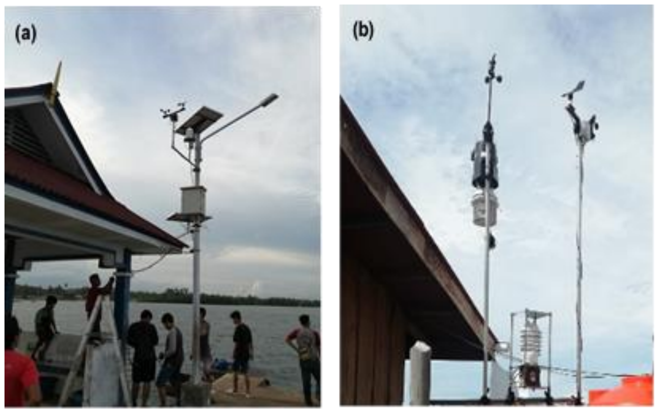

Figure 7. Installation of Bintan MOS; (a) Berakit Station, utilizing a lighting pole belonging to the Bintan Regency Transportation Agency, (b) Bakau Bay Station, using a galvanized iron pole.

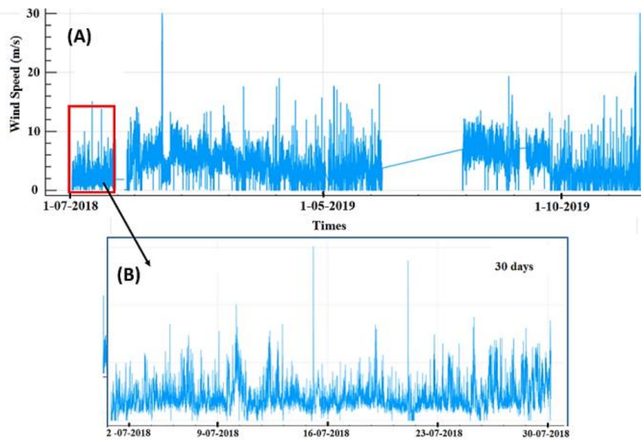

Figure 8. Wind Speed Data; (A) in a Time Range of 20.25 months, (B) plot the wind speed data for 30 days.

Tidal

The tidal data were collected every 3 minutes for ± 20.25 and 23.75 months at Bakau Bay and Berakit stations respectively. Data recording was carried in real-time via a cellular operator however, at the Berakit station, there are data gaps which lasted for approximately six months, as a result of disruption to the GSM-based sending system. The tidal height result in Bintan waters shows that there are high and low tide occurs two times in a day while the mixed tide tend to double daily. Moreover, the tide height ranged from 134 - 282 cm, with an average of 227 cm (Figure 10).

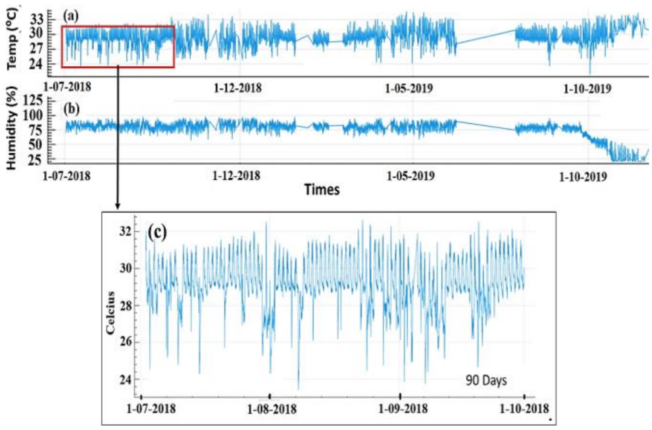

Figure 9. Results of data acquisition; (a) Temperature and (b) Humidity in a Time Range of 17.75 months, (c) plot wind speed data for 90 days.

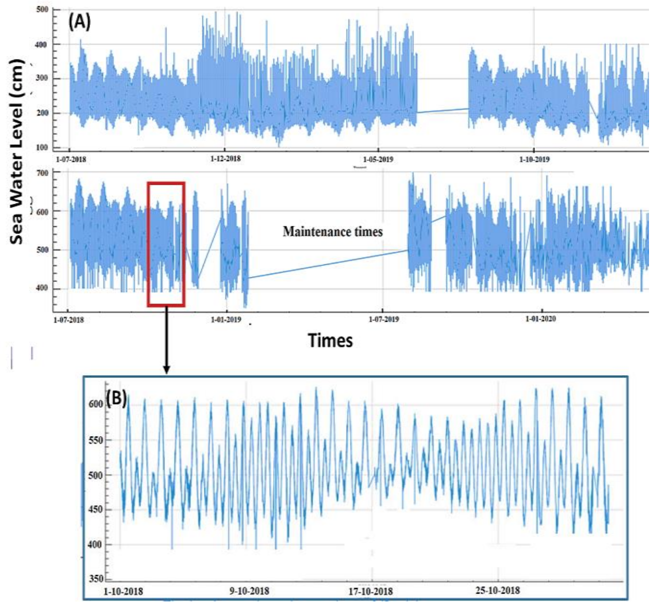

Figure 10. Result of acquisition of water level data; (A) tides over a period of 20.25 months for Bakau Bay and Berakit, (B) plot of tide data for 30 days.

Discussion

The result indicates that data obtained from Bintan MOS are reliable. Furthermore, the performance test and calibration of the Automatic Weather Station instrument for wind speed had a RMSE (Root Mean Squared Error) value of 0.51 m/s with an R2 of 0.87 ($p < 0.05$) (Kusumah *et al.*, 2018). Meanwhile, the MOTIWALI instrument produced distinctive result in measuring sea level distance using a transducer, as reported by Bemba *et al.* (2019) with an RMSE value of 1.86 cm amplitude (Khatimah *et al.*, 2016).

The tidal height measurement using Bintan MOS have also been compared with the results from BIG (Geospatial Information Agency) data, available on http://tides.big.go.id/pasut/index.html with a R^2 correlation coefficient of 0.83 ($p<0.05$). Comparisons were made between a 9-day tidal data sample from 26 December, 2019 to 3 January, 2020. It showed that the instrument's performance is scientifically justified. The linear regression graph for the water level of the Bintan MOS data with the tide height of BIG (Geospatial Information Agency) data are presented in Figure 11.

Several reasons for selecting GSM cellular telephone include, availability of the infrastructure network therefore, it provides convenience by not creating a new network that requires high costs. It also allows fast data transfer, hence, data are received in relatively large capacity. In addition, the operational costs are relatively cheap compared to the existing system where data access seldom require permission from the satellite owner but carried out directly.

The observation system developed consist of several parts including sensor and data acquisition system supported by the microcontroller as well as sending and receiving system (transceiver). Furthermore, the sensor system is supported by a microcontroller, power supply, and data sending system using the GSM frequency (900 MHz or 1800 MHz) with SMS (Short Message Service). Due to the affordability of this service, its development is important for campuses and environmental stakeholders which have limited funding.

There are still few limitations in the Bintan MOS development, such as the type and number of sensors providing real-time data which consist of five main sensors, including wind, temperature, humidity, and sea level. Besides, the Bintan MOS also provide information on other environmental parameters such as, current speed, waves, and aquatic biota monitoring (Underwater Television System), however, this information are not yet available online.

The urgency to incorporate marine observation station (MOS) to current conditions are as follows: (1) Practically, no maritime institution in Indonesia implements operational oceanography, involving (MOS) which routinely generate and transmit day to day, directly (real-time) data to be processed and further used for the benefit of marine development; (2) The temporal and spatial variations of Indonesian sea are very high and difficult to understand with one or two observation points. It takes many connected locations or observation networks to obtain a more complete description of the country's ocean dynamics. Therefore, it is necessary to develop a marine observation network in this archipelago (Nusantara); (3) Each marine institution has the ability and resources to establish a marine observation station in its respective location. The formation of MOS network with other marine organizations provides greater and wider benefits.

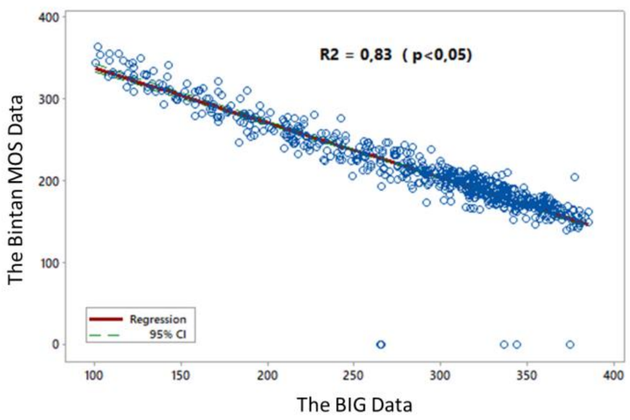

Figure 11. Correlation of tide measurement from Bintan MOS with BIG data.

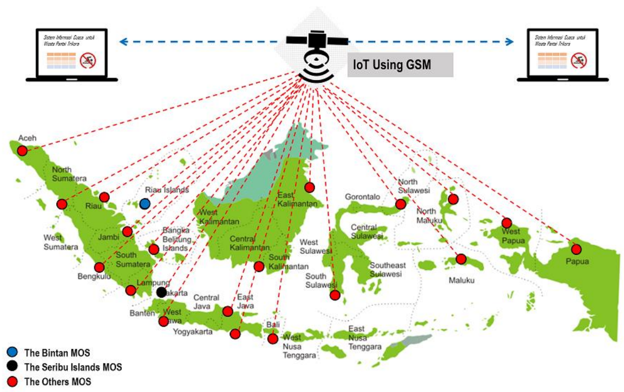

Figure 12. Prototype Network of Nusantara Marine Observation Stations.

Furthermore, the development of Bintan MOS implies that this system is also applicable in forecasting marine conditions and existing biological resources, monitoring water quality (Kusuma *et al.*, 2020; Xu *et al.*, 2019), marine mammals (Peng *et al.*, 2020), mitigation and management of ecosystems as well as coastal environmental resources (Durante *et al.*, 2020). Meanwhile, a major impact on the marine community is the availability of scientific research facilities. In addition, the adoption and development of this system elsewhere is useful for marine researchers as access to data exchange to fully understand or compare coastal weather fluctuations in western and eastern Indonesia or tropical and sub-tropical marine weather.

When every state and private university with fisheries and marine department in Indonesia develops and manages a customized MOS, data from a wide range of marine phenomena becomes comprehensively accessible (Figure 12). Hence, it is possible to establish a marine observation forum for state and private universities in Indonesia to openly share data. In addition, forum members are to be granted access to baseline data, for collaboration in scientific publication.

This network system is more effective and efficient, as each manager is only responsible for respective MOS, both in development and in maintenance. MOS sustainability requires simple strategy which include, developing the existing instruments and network activities, forming strategic partnerships, giving priority to the development of human resource capacity and web-based communication infrastructure. With consistent implementation, the MOS Nusantara is achieved as a form of self-sufficiency in marine technology in Indonesia.

Development opportunities

Due to past experience of receiving partially miss (blank data), it is necessary to optimize the power supply system (battery and solar panels) to ensure proper running of data reception and transmission. The five sensors in Bintan MOS are integrated with one central power supply system. This technique effectively reduces materials consumption and efficient in material shopping. However, the challenge is that when the power supply system is faulty, then all sensors are unable to receive or send the ordered data. Hence, optimizing the power supply system performance includes the capacity to provide energy when needed. Furthermore, lack of power potentially weakens the battery, while excess power deteriorates the battery's ability as a risk of using a directly connected solar panel.

To maximize the implementation of Bintan MOS, the output data are to be presented on android devise as coastal communities and fishermen are more familiar with this system hence, data become easily accessible. In addition, data presentation potentially becomes more effective, especially with the use of simple features such as water icons for tidal information, wind icons for wind speed, and others.

Conclusion

The Bintan MOS provides reliable data on tide and coastal and weather both in real-time and off-line. Moreover, the adoption and application of this system elsewhere, presents a broader scope of data collection to realize the Nusantara Marine Observation Station Network. Bintan MOS is accessible via www.lamun-bintan.net (Note: The observation system is currently under maintenance).

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