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IMPACTS OF GLOBAL CLIMATE CHANGE ON INDONESIA OCEAN ENVIRONMENT

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KEYWORDS: climate change; sea level, significant wave height, temperature.

ABSTRACT
The problems in coastal and ocean area related with climate change have continued to receive a high level of attention. Elevate average of sea level, variation in significant wave height and increased ocean temperature are linked to global climate in many ways. Thus, climate variability and future climate change should become a major interest for engineer, stakeholders, and decision makers, especially for developing strategies for mitigation and adaptation for future coastal development. The objective of this paper is to analyze the impacts of global climate change to Indonesian ocean environments due to global warming. This paper focus on the impacts of climate change to sea level, wave climate and sea water temperature. Increasing trend of sea level rise, warmer ocean temperature and increased of significant wave height are among a few example of what climate change may bring to Indonesia ocean environments. These problems should received serious attention from government to develop adaptation and mitigation plans for future developments.

INTRODUCTION
Climate change could affect coastal and ocean environments in different of ways. Coasts are sensitive to sea level rise, changes in the frequency and intensity of wind speed, increases in significant wave height, and increases in ocean temperature. Moreover, rising concentrations of carbon dioxide (CO2) are causing the oceans to absorb more of the gas and become more acidic. This rising acidity could have significant impacts on coastal environments and marine ecosystems. The impacts of climate change are likely to worsen many problems that ocean and coastal areas already face. Coastal erosion, coastal flooding, and water pollution are common problems that affect man-made infrastructure and ecosystems in coastal areas.

As the world's largest archipelagic state, Indonesia have more than 17,500 islands with over 81,000 kilometers of coastline. The coastline of Indonesia is highly populated because around 220 million Indonesians reside within 100 km of the coast, and of these over 150 million people rely on marine resources for their livelihoods (WRI, 2001). All activities in the coastal and ocean, such as marine transportation, offshore industry, naval industry, resource extraction, fish cultivation and tourism become an important part of Indonesian economy grow. Therefore, information about the effect of climate change on ocean and coastal areas is the major knowledge for engineer, stakeholders, or decision makers to develop strategies for mitigation and adaptation for future development.

SEA LEVEL
Global warming as a result of the effects of greenhouse gases, have an impact on rise in sea levels. IPCC (2007) reported that the sea level has risen by an average of 2.5 millimeters annually. As an archipelago country with over 80.000 kilometers of coastlines, Indonesia is very vulnerable to sea level rise. Recently, there are several remote sensing technologies that can monitor the condition of the oceans continuously. Satellite altimeter technology is one of technique to monitor sea level change. During the past two decades, observations from satellite altimeters have demonstrated dramatic descriptions of sea level variability with higher spatial resolution than the traditional tide gauges (Ami et al, 2012).

This section described the projected increase in sea level based on the data of satellite altimeter. In this study, we use GDR (Geophysical Data Record) data that obtained from Jason-2 satellite for period 2009-2012 which passed Indonesian waters. Cycle data which is used in this paper after selection is ranging from 018-165 cycles. This data

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were obtained from NOAA server (http://data.nodc.noaa.gov/jason2/gdr/gdr site). These data will be used to calculate Sea Level Anomaly (SLA) for the analysis of sea level rise. There are 4 observation points deployed along the trajectory following the Jason-2 orbits that pass through the territory of Indonesia as seen in Figure 1 (which are Medan, Pemangkat, Ambon, and Manokwari). The process and analysis of sea level data were carried out using Basic Radar Altimetry Toolbox 3.1.0 (BRAT). The results indicated that the highest sea level rise is in Manokwari 14.1 mm / year, and the lowest is in Ambon at 1,175 mm / year. Table 1 shows the statistics of sea level anomaly for Jason-2 after correcting for sea level height.

Figure 1. Observation points in Indonesia area

Table 1. Sea level trend based on altimeter data.

Location	Sea level anomaly (mm/year)
Medan	12.9
Pemangkat	3.53
Ambon	1.18
Manokwari	14.1

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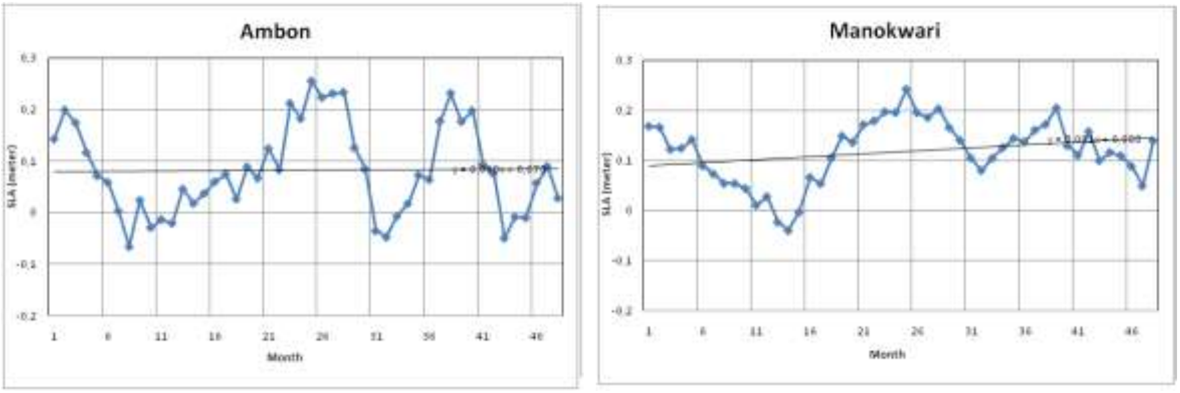


Figure 2. Trend of sea level rise in Indonesia regions

SIGNIFICANT WAVE HEIGHT

The global ocean wave climate has long been of interest to the ocean engineering community because of the need for accurate operational wave data for applications such as vessel design, design of offshore and coastal structures, naval operations or energy assessment (Zikra et al., 2016). Recently, there has been a major interest in wave climate changes as a result of global warming. Therefore, studies on predicting the effect of global warming on ocean wave climate are required. The objectives of this section are to analyze the variability of significant wave height for the 35 year period 1980-2014.

In Indonesia, long-term wave records based on in situ measurements are still limited. Due to that reason, in this study, temporal variation in wind speed and significant wave height are studied using hindcasting model from ERA-Interim reanalysis data from ECMWF (European Centre for Medium-Range Weather Forecasts) for 35 years period from 1980-2014. The ERA-Interim reanalysis data provides wind speed and significant wave height (SWH) data with 1 x 1 degree resolution. For this study, 10 observation locations were chosen on the nearest of Indonesia sea. Those observation points are shown in the Figure 1 and names of each location is presented in Table 1.

Zikra et. al. (2015) concluded that from 1980-2014, the trend of annual mean significant wave height was depend on observation location and time (season). Also, the results showed that the mean of significant wave height in the South of Java Sea (point I) have an increasing trend for all months as shown in Table 3.

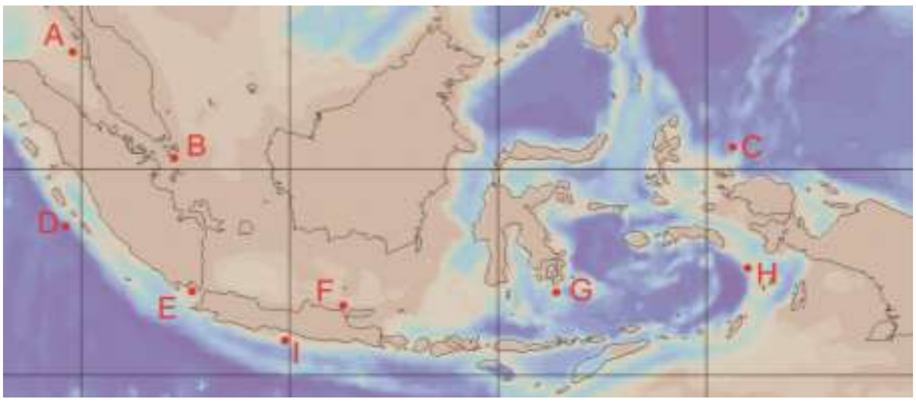


Figure: 3 Observations points in Indonesia seas

Table 2: Observation points

Point	Coordinate	Location
A	3.75^0 N and 99.75^0 E	Malacca Strait
B	0.75^0 N and 105^0 E	Natuna sea, Riau Island
C	0.75^0 N and 130.50^0 E	Pacific Ocean

D	3.75^0 S and 99.75^0 E	Indian Ocean, Mentawai Island
E	6.00^0 S and 105.75^0 E	Sunda Strait
F	6.75^0 S and 112.50^0 E	Java Sea
G	6.75^0 S and 121.50^0 E	Flores Sea
H	2.25^0 S and 131.25^0 E	Banda Sea
I	110.5^0 S and 2.25 E	South of Java Sea

Table 3: Trend of monthly mean significant wave height (SWH) during 1980- 2014

Month	**Monthly Mean SWH Trend (cm/years)**								
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
January	0.20	0.04	0.76	-0.52	0.55	-1.87	-0.50	0.76	5.05
February	0.20	0.20	0.34	0.56	0.34	0.84	-0.47	0.34	2.09
March	0.20	0.55	0.38	0.37	0.61	1.82	0.02	0.38	2.70
April	-0.18	0.18	0.61	0.05	0.20	1.23	0.57	0.61	2.80
May	-0.19	0.22	0.51	-0.17	-0.11	-0.08	0.87	0.51	2.63
June	-0.37	0.09	0.56	-0.35	-0.19	-1.48	0.81	0.56	2.47
July	-0.29	0.03	0.60	0.03	-0.02	-2.47	1.11	0.60	2.73
August	-0.27	-0.03	0.10	0.16	0.04	-2.62	0.50	0.10	2.54
September	-0.20	0.17	0.19	0.14	0.52	-1.50	-0.02	0.19	0.17
October	-0.84	-0.40	0.51	0.17	0.59	-0.73	-0.30	0.51	2.29
November	0.07	-0.02	0.51	-0.07	0.29	-2.34	-0.04	0.51	5.05
December	-0.45	-0.20	0.14	0.01	0.30	-4.08	-0.20	0.14	1.85

Table 4. Monthly averaged significant wave height in Indonesian Sea

Month	1		2		3		4		5		6		7		8		9	
	H_{avg}	T	Havg	T	Havg	T	Havg	T	Havg	T	Havg	T	Havg	T	Havg	T	Havg	T
1	1,27	5,01	0,86	4,98	0,82	4,99	1,26	8,06	0,67	7,52	1,32	4,49	0,44	4,19	1,24	4,96	2,40	8,52
2	1,25	4,84	0,65	4,67	0,67	4,67	1,24	8,03	0,68	7,60	1,29	4,33	0,44	4,25	1,21	4,91	2,24	8,48
3	1,22	4,67	0,51	4,49	0,62	4,49	1,21	8,54	0,53	7,82	1,18	4,26	0,40	4,27	1,17	4,82	1,91	8,95
4	1,21	4,53	0,40	4,23	0,35	4,23	1,20	8,62	0,51	8,06	1,03	4,32	0,45	4,44	1,19	4,86	1,96	9,04
5	1,35	4,46	0,39	4,00	0,34	4,00	1,34	8,76	0,72	8,24	0,86	4,47	0,57	4,74	1,38	5,11	2,03	9,00
6	1,57	4,54	0,45	3,96	0,41	3,97	1,57	8,88	0,92	8,37	0,80	4,57	0,65	4,81	1,53	5,18	2,14	9,11
7	1,62	4,60	0,51	4,05	0,48	4,06	1,62	8,81	0,97	8,31	0,82	4,58	0,64	4,72	1,64	5,08	2,17	9,13
8	1,69	4,70	0,54	4,18	0,51	4,19	1,68	8,66	0,89	8,24	0,84	4,49	0,60	4,60	1,70	4,91	2,21	9,19
9	1,61	4,63	0,47	4,15	0,45	4,16	1,61	8,56	0,69	8,08	0,80	4,33	0,46	4,42	1,61	4,79	2,17	9,28
10	1,44	4,98	0,54	4,64	0,51	4,65	1,44	8,43	0,51	7,81	0,94	4,32	0,38	4,27	1,41	4,88	2,28	8,95
11	1,29	5,13	0,58	5,00	0,56	5,00	1,29	8,24	0,39	7,58	1,06	4,42	0,33	4,24	1,20	5,01	2,32	8,62
12	1,24	5,25	0,84	5,19	0,81	5,20	1,23	8,10	0,51	7,57	1,28	4,57	0,39	4,22	1,18	5,06	2,35	8,58

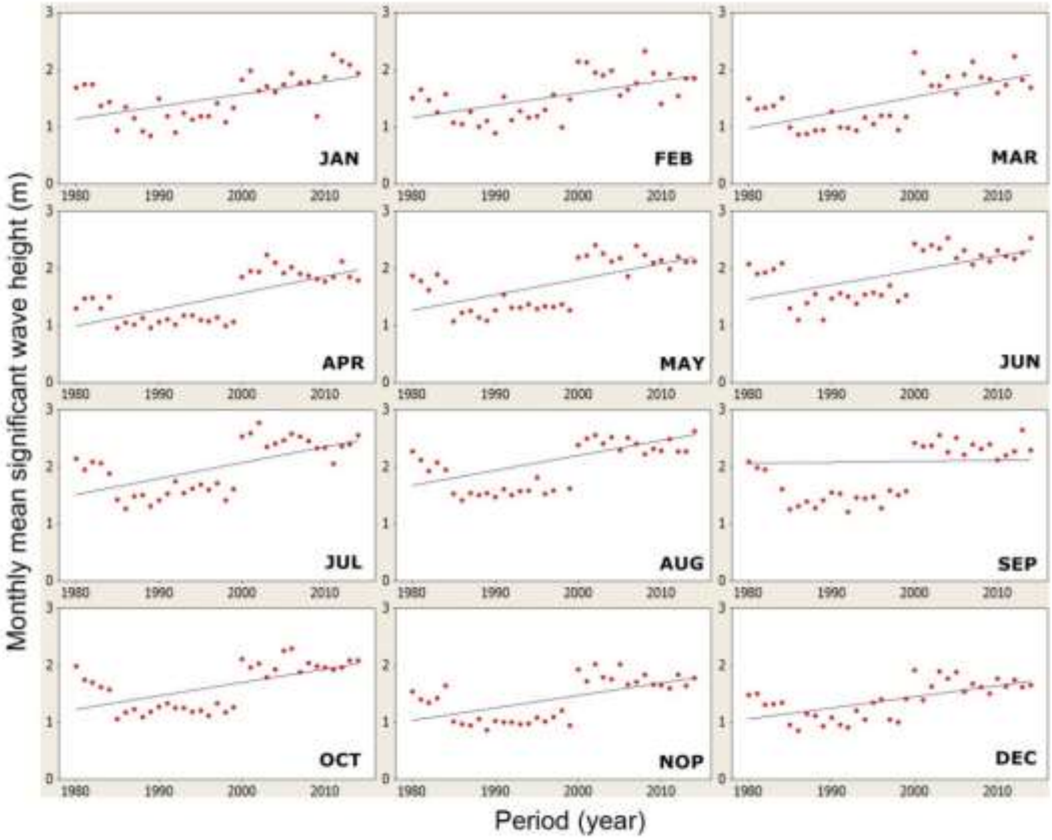


Figure 4. Variations of monthly mean significant wave height (SWH) in Indian Ocean near south of Java (Point I)

SEA WATER TEMPERATURE

Coastal waters have warmed during the last century, and are very likely to continue to warm by as much as 4 to 8°F in the 21st century (IPCC, 2007). This warming may lead to big changes in oceanic circulation patterns and salinity, affecting species that inhabit these areas. Along with the intensification of the process of global warming, the intensity of El Nino and La Nina is also increasing (Timmermann et al., 1999). The El Nino event in 1997/1998 caused a long dry season and caused coral bleaching in Indonesia. At the time of occurrence of La Nina in 1999, Indonesia experienced an increase in high rainfall, and high rise sea level of 20cm to 30cm, causing flooding in most Indonesian coastal territory areas (PEACE, 2007).

This section specifically analyze about the pattern of temperature and salinity changes upon the Pacific Ocean caused by El Nino and La Nina. This study used temperature and salinity data from TRITON buoy located at precisely 0°N 138°E south west side of the Pacific Ocean for 5 year period (2005-2010) as shown in Figure 6. This TRITON buoy was developed and deployed in the western equatorial Pacific and Indian Ocean since 1998 by Japan Agency for Marine-Earth Science and Technology. Basically, the purpose of this project is to observe ocean and atmosphere in the western tropical Pacific Ocean for better understanding of climate variability involving the El Nino and La Nina phenomena (JAMSTEC, 2010). The study concluded that the change in the sea surface temperature in the south west side of the Pacific Ocean towards the warm side, which explains the stronger and more frequent El Nino observed during 2005-2010 as shown in Figure 6.

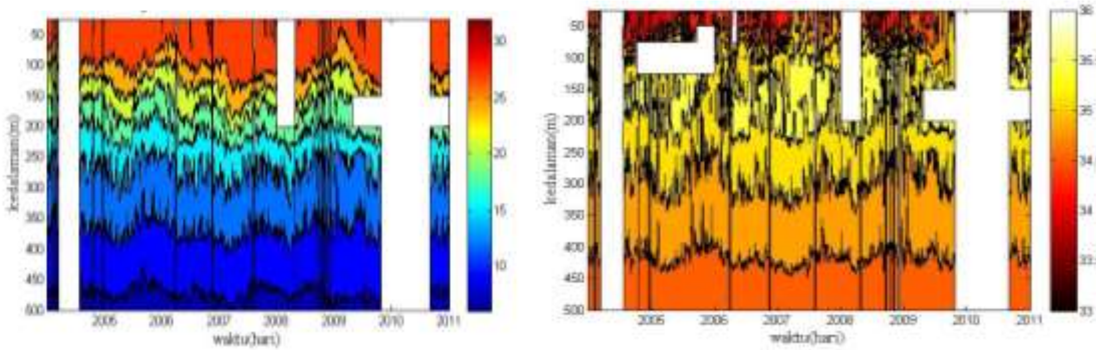
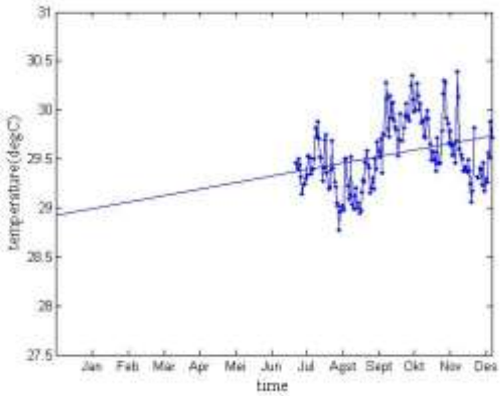
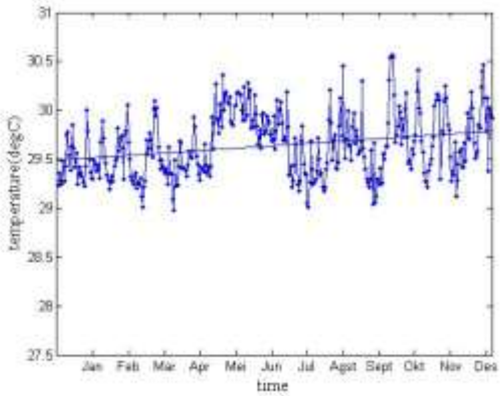


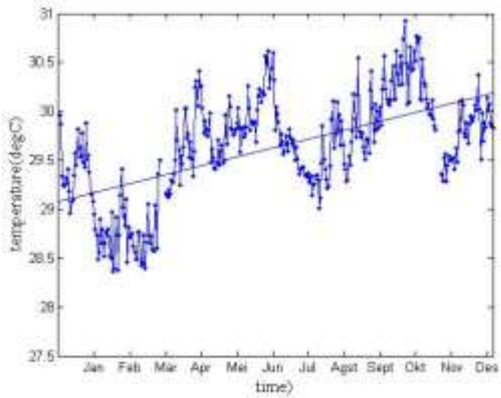
Figure 5. (left) temperature; (right) salinity.



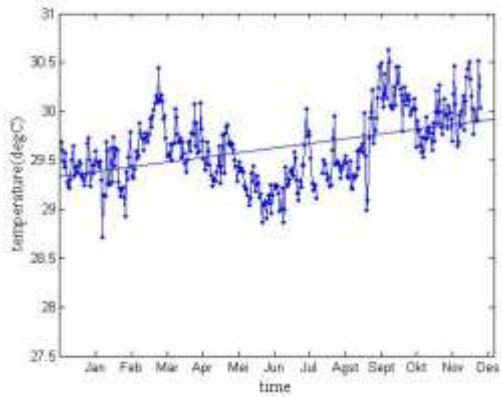
(a) 2005



(b) 2006



(c) 2007



(d) 2008

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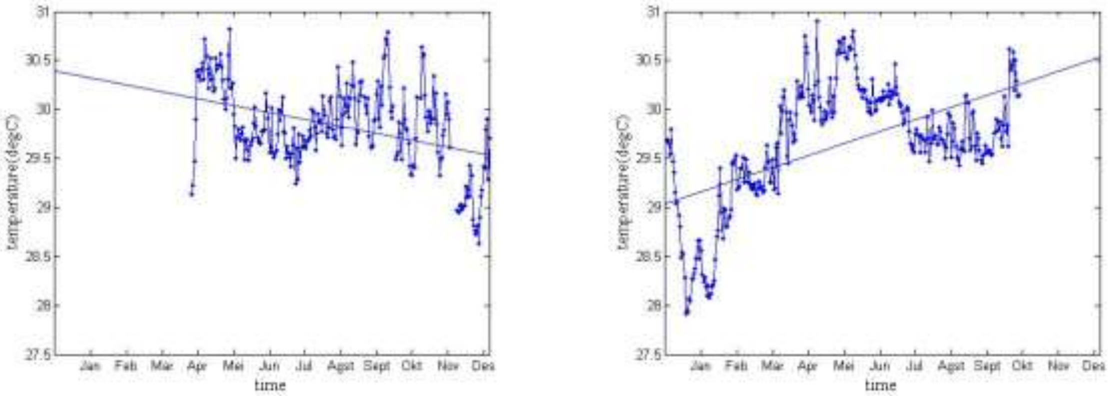

(e) 2009 *(f) 2010*

Figure 6. Trend of sea surface temperature from 2005-2010

CONCLUTION

The present study constitutes a preliminary step in analysing the impacts of global climate change to Indonesian ocean environments. This paper focus on the impacts of climate change to sea level, significant wave height and sea water temperature. As an archipelago with over 17.500 islands and over 81,000 kilometers of coastline, Indonesia coastal area is very vulnerable to climate change. Increasing trend of sea level rise, warmer ocean temperature and increased of significant wave height are among a few example of what climate change may bring to Indonesia ocean environmenst. These problems should received serious attention from government to develop adaptation and mitigation plans for future developments.

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