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Chlorophyll-a, and Sea Surface Temperature (SST) as proxies for Climate Changes: Case Study in Batu Ampar waters, Riau Islands

S Antoni[1*], R A Bantan[1], T A Al-Dubai[1], M Z Lubis[2], W Anurogo[2], R D Silaban[2]

[1]Marine Geology Department, Faculty of Marine Sciences, King Abdulaziz University, Jeddah 21589, Saudi Arabia

[2] Geomatics Engineering, Politeknik Negeri Batam, Batam 29461, Indonesia

*Email: suddin@stu.kau.edu.sa

Abstract. The condition of Indonesian oceanography is largely determined by the development of the Monsoon Wind and the Indonesian Cross Flow (ARLINDO). The development of marine remote sensing technology that is so fast, able to make it easier to map the condition of waters in Indonesia in an actual way easily and cheaply. This can make it easier to obtain information about climate change approaches to the physical oceanography conditions in Indonesian waters. The purpose of this research is to study the changes of the physical oceanography parameters resulting from climate changes. Based on the results of the research that for the highest Sea Surface Temperature (SST) exist in 2013 (above 30,75^{o} C). It has increased from the previous year i.e. in 2012 with an increase of SST value of 30 ^{o} C. In 2013 SST is spread high on the Batu Ampar Permit - Harbor Bay ferry port. Analyzing the value of chlorophyll-a, sea surface temperature, and sea level to see global climate change in the waters of Batu Ampar. The analysis shows the highest sea level with an elevation of 3.1 meters, with sea surface temperature in the range of 29,5^{o} C - 29,75 ^{o} C, at the time of recording 00:05-02:55 (August 1, 2017 - September 1, 2017). The results of the analysis obtained from the oceanographic conditions in the waters of Batu Ampar did not experience a fluctuating change in global climate change in the waters. The annual SST interval spacing interval of 0.5-0.75 ^{o}C and the changing phase relationship could have an impact on subsequent climate change and sea level rise to be concrete evidence. Reduced levels of chlorophyll-a each year will have an impact on the heat of the sea level, thus rising sea levels and indicating a climate with hot temperatures (ice at the poles melt).

Keywords: Climate Change, Chlorophyll-a, Sea Surface Temperature (SST), Batu Ampar waters

1. Introduction
One of the impacts of global warming is climate change affecting the condition of the marine ecosystem [1], and also the pattern of wind movement in Indonesia in general with the movement of seasons [2]. Each season has a different direction of wind movement. In marine ecosystems, oceanographic parameters such as Sea Surface Temperature (SST), chlorophyll-a, tidal seawater can be used to determine the relationship of oceanographic conditions to climate change. Chlorophyll-a is a pigment commonly called an important factor contained in phytoplankton in the process of photosynthesis [3-5]. While the photosynthesis process influenced by the temperature either directly or indirectly. Franz et al. (2005) stated that global chlorophyll content has undergone changes in recent years due to the influence of SST. On the other hand, sea surface temperature plays a pivotal role in variations of the tidal conditions [7-9]. However, the water mass movements affect the variability of surface oceanic variables such as SST and chlorophyll-a [10]. Thus, the oceanographic conditions are associated indirectly with the climate changes in the area. Sea surface temperature and chlorophyll-a are important parameters oceanographic sciences that function in the process of improving the aspects of marine and fishery resources. Sea surface temperature can be used as an indicator of the predicted location of upwelling, downwelling, fronts associated with the potential area of tuna [11]. While the values of chlorophyll-a located at sea level is an indicator of fertility and productivity for aquatic [12].

Mapping in Indonesian`s areas especially Batam island is very scarce until recently, however, some maps have already been completed, particularly with regard to sea surface temperature [13]. Therefore, this research aims to study the variations of the oceanographic conditions resulted from climate changes in Batu Ampar waters area, Riau Islands using Sea Surface Temperature (SST) and Chlorophyll-a data obtained from Terra Modis satellite using level 3 data.

2. Materials and Methods

2.1 *Location and research flow diagram*

This research was conducted in August 2017 at Punggur Sea, Batam, Kepulauan Riau-Indonesia, located between latitudes 1 ° 03.2448 and 1 ° 03.3977 N and longitudes 104 ° 08,7102 and 104 ° 08.8133 E (Figure 1), and the research flow diagram can be seen in Figure 2.

Figure 1. Map of research location

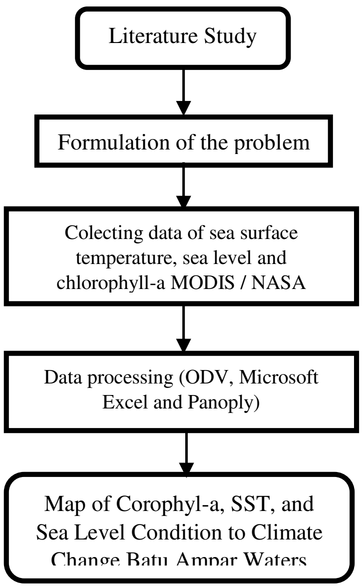

Figure 2. Research flow diagram

2.2 *Chlorophyll –a*

The studied areas at the Batu Ampar waters and Riau Islands (Figure 1), obtained chlorophyll-a data using Terra-MODIS 3 level satellite images with temporal resolution (9 km) from 2012 to August 2016 (during 5 years). The data was obtained from Ocean Color Web website from NASA - USA [14]. Terra-MODIS imagery processed in consideration of 7 cloud-free images collected annually until August 2016. Chlorophyll-a has a concentration using the following equation:

$$C = a^{(a_0+a_1R+a_2R^2+a_3R^3+a_4R^4)}$$

$$a = 0.2830, -2.753, 1.457, 0.659, -1.403$$

Where,
$R = \log_{10}\left(\frac{R_{rs}443 > R_{rs}488}{R_{rs}551}\right)$
R_{rs} is a reflectant sensor

2.3 *Sea Surface Temperature (SST)*

Sea Surface Temperature (SST) data were obtained using Terra-MODIS / NASA 3 level temporal resolution (9 km) images from 2010 to August 2017 (during 7 years). Terra-MODIS imagery processed with the consideration of 8 cloud-free images collected every August each year. Analysis of SST data have done by using a thermal infrared channel consisting of band 10 - band 14, so utilizing each band can be calculated each radian value and brightness temperature. To get the radians value used the equation, that is:

$$rad = (DN-1) * UCC_{band}$$

Where:
rad = Radian value (*Watts*/ m^2sr m)
DN = Digital number on each band
UCC_{band} = Unit conversion coefficients, (watts/ $meter^2$/ steradian/ micrometer)/ DN
Then convert the radian value to the temperature value, the following equation is used:

$$BT = \frac{C_2}{\lambda c Ln(\frac{C1}{\lambda c^5 rad}+1)}$$

Where:
BT = Brightness temperature (^{0}K)
Λc = Central Wavelength (m)
c1 = Constants (3,741775 x 10^{-22} W-m^3-μ^{-1})
c2 = Constants (0,0143877 m-^{0}K)
rad = Radian Spectral Value (watts/ m^2sr m)

The data obtained is converted into units of celcius where:

T ºCelsius = T ºKelvin - 273º
SST = a + b10*T10 + b11*T11 + b12*T12 + b13*T13 + b14*T1

Where:
T10, T11, T12, T13, T14 = *Brightness temperature* of *band*

3. Results and discussion

3.1 *Chlorophyll –a*

Based on the results of data processing obtained, it is showed that the distribution of chlorophyll-a concentration (above 1 mg/m^3) occurred in 2011, while it was (above 2 mg/m^3) in the previous year, ranging from 2 and 2.3 mg/m^3. Whereas the distribution of chlorophyll-a concentration during 2014 ranged between 1.1 - 1.3 mg/mg^3, while in 2013 in the varied from 2.1 and 2.3 mg/mg^3. This result can be expressed as a high-level chlorophyll group [15-16]. Also, it reveals the significant changes in chlorophyll-a levels caused by climate change. Therefore, the occurrence of these changes in chlorophyll-a concentrations can be considered as an indicator of climate change.

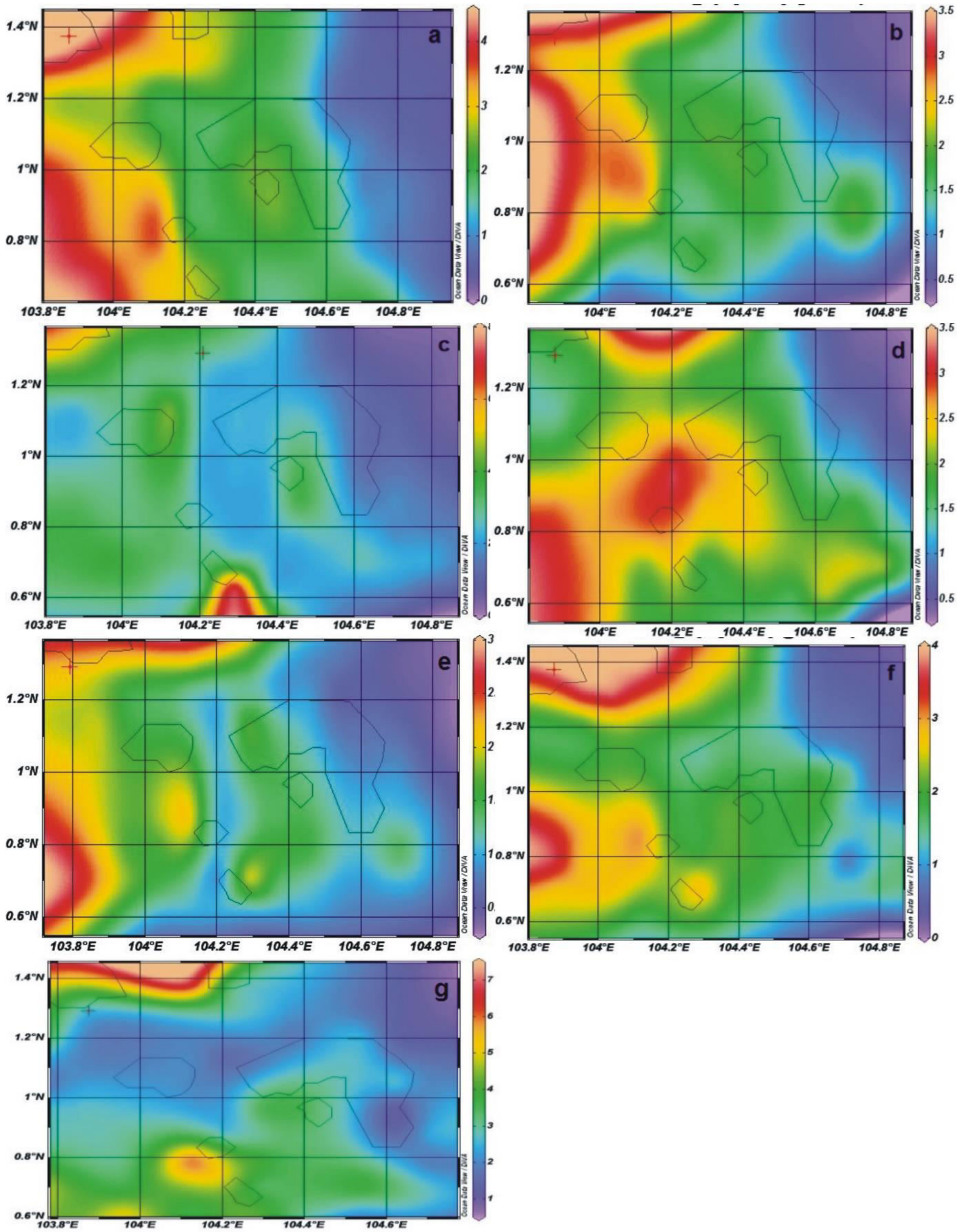

Figure 3. Chlorophyll a (a = 2010, b = 2011, c = Year 2012, d = Year 2013, e = Year 2014, f = Year 2015, g = Year 2016)

In 2015 the Batu Ampar waters (around the harbour bay ferry) show the distribution of chlorophyll-a in the range 1.9-2.1 mg / mg^3, which indicates the chlorophyll-a content of that year is at a moderate level. In 2016, there was no significant change in chlorophyll-a from the previous year, as evidenced by the chlorophyll-a levels in the range of 1.9 mg / mg^3 , but only a different distribution than the previous year in which chlorophyll-a spread western region of Batam city that is in Sekupang waters area.

3.2 *Sea Surface Temperature (SST)*

Based on the results of the research, the highest SST value occurred in 2013 (above 30,75°C). Where increased with an average 3°C from the previous year i.e. in 2012. In 2013, SST was spread highly on the Batu Ampar Permit - Harbor Bay ferry port. The indication of this SST increase occurs unevenly with sea surface temperature (SST) condition with the value of 30.5°C in the northern area of Batam city that is the waters of steel-sekupang.

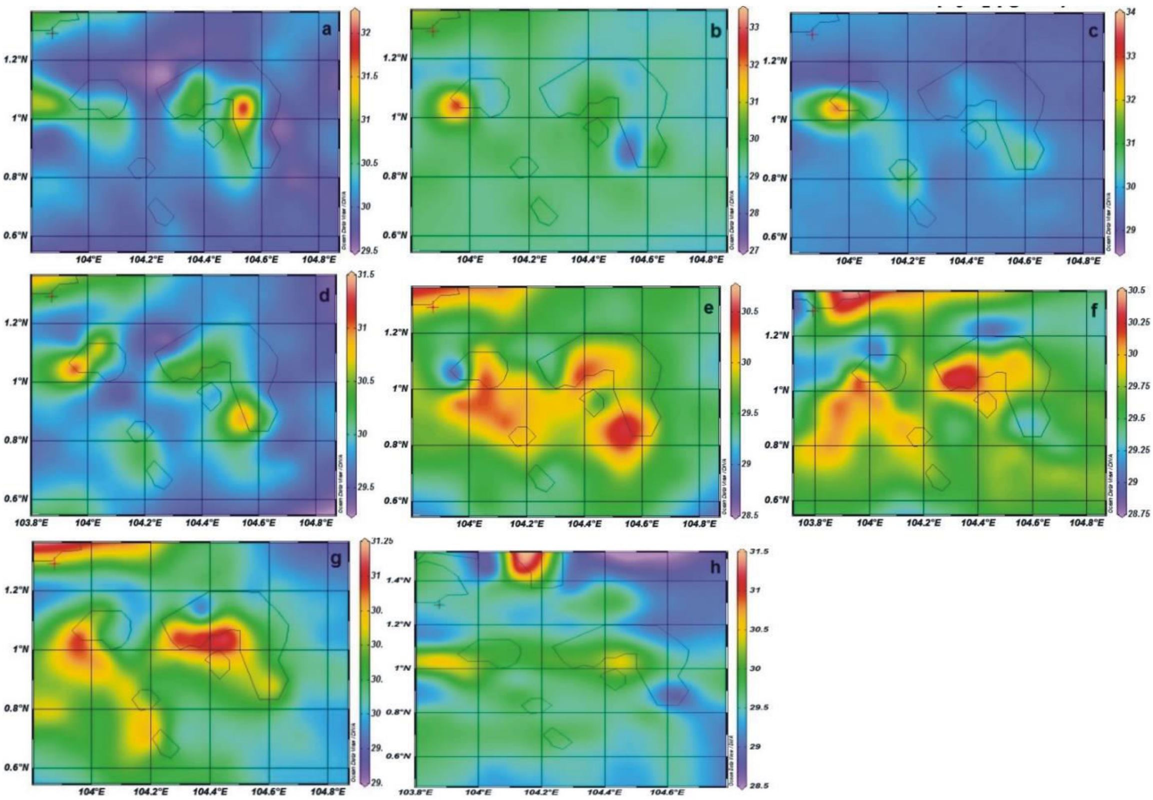

Figure 4. SST (a = 2010, b = 2011, c = Year 2012, d = Year 2013, e = Year 2014, f = Year 2015, g = Year 2016, h = August 2017)

Oceanographic conditions occurred in 2014 where there was an impairment of SST to 30.15°C (previous year was 30,75°C). Hence, this analysis showed the effect of the climatic changes on the variations of SST in the area. This year the SST value dominates in the northern part of Batam (Batu Bay-Harbor Bay Ferry), whereas in the north-western region of Batam (Sekupang) occurs in the range of 29.5°C. For the lowest SST occurred in 2011 (29°C), where there was evenly distributed for the Batu Ampar-Nongsa-Sekupang Waters region (blue tasks). This indication is decreased from the previous year SST value of 29,75°C (purple). This will affect the condition of marine ecosystems located in Sekupang area [17].

In the year 2015, there was an uneven spread of SST scores. For Sekupang and Batam city area, the SST temperature was in the range of 29.2-29.5°C. As for the territorial waters of Batu Ampar and Nongsa was in the range 29.05-29.0°C. The increase of SST occurred in the next year 2016 which happened unevenly for all parts of North of Batam city. For Sekupang-Lubuk steel SST area was 30.6°C. Then at Batu Ampar-Bengkong Waters area, the SST level was 30.4°C. While the Nongsa area, the SST value was 30°C. The increase of SST from 2015-2016, probably can be considered an indicator of changing climate conditions in Batam City every year.

Besides using the data, in this study also used SST Terra Modis / NASA data with resolution 4 km in 2000, 2004, 2007 and 2017 as other comparisons (Figure 5).

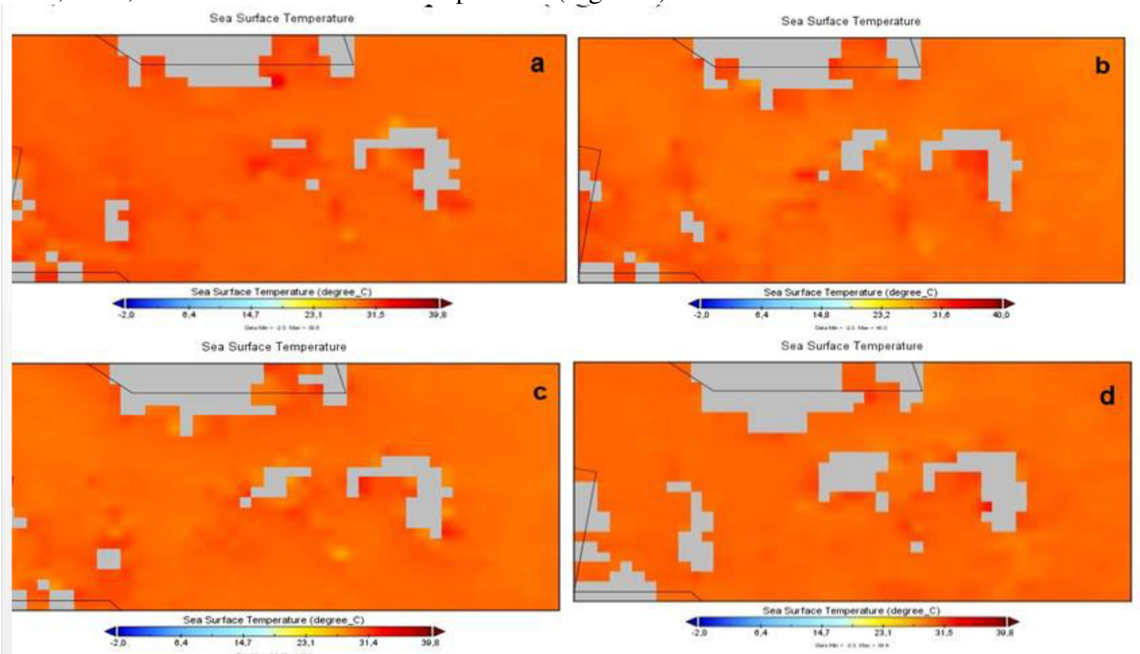

Figure 5. Panoply (a = Year 2000, b = Year 2004, c = Year 2007, d = Year 2017)

From the figure above shows that from 2000, 2004, 2007 and July 2017, the SST values of Batu Ampar water area ranging between 27 °C and 31°C (Figure 5). The results of the analysis using SST anomaly using anomaly data on data recording that is dated 1 August 2017 and 1 September 2017. In that month spread of SST value to Bintan, Region Singapore and Malacca Strait. In September, the SST Spread There was a decline. SST objects in anomaly move towards the southern Riau Islands and more dominantly located in the eastern part of Sumatra include Bangka-Belitung, to Palangkaraya. For the area, the SST Anomaly is in the range of -0.5-0.00^{0}C (Blue light blue) (Figure 6).

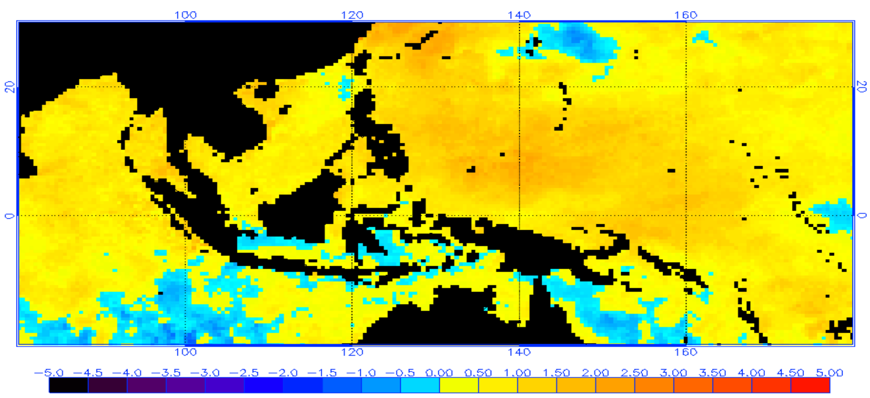

Figure 6. Sea surface temperature anomaly (SST) in August-September 2017.

4 Conclusion

From the results of research conducted using the data of 2000, 2004 and 2007 that the SST concentration decreased not very significant (low), while for the year 2010 -2017 produced that the SST concentration experienced a moderate categorized increase. This is evidenced by the widening of SST coverage in 2010-2017. As for chlorophyll-a in 2010-2016 had a low decrease. The annual SST interval spacing interval of 0.5-0.75 and the changing phase relationship will have an impact on subsequent climate change and sea level rise to be concrete evidence. Reduced levels of chlorophyll-a each year will have an impact on the heat of the sea level, thus rising sea levels and indicating a climate with hot temperatures (ice at the poles melt).

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