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INFLUENCE OF UPWELLING IN THE SOUTHERN WATERS OF JAVA ON CO_2 CONCENTRATION IN KOTOTABANG, AGAM DISTRICT WEST

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ABSTRACT

Absorption of atmospheric CO_2 by the sea through two processes, namely solubility pumps and biological pumps. This study aims to determine the effect of upwelling in the southern waters of Java on atmospheric CO_2 concentrations in Kototabang. The data used are in situ CO_2 concentration, sea surface temperature and chlorophyll-a concentration from 2004-2016. The method used was descriptive analysis. The results showed that upwelling that occurred during JJA-SON caused a decrease in sea surface temperature to 26.8 °C and 27.1 °C respectively, as well as an increase chlorophyll-a concentration to 2.03 mg/m^3 and 2.19 mg/m^3. In both seasons CO_2 concentration in Kototabang dropped to 385.8 ppm and 385.4 ppm. Meanwhile, when there was no upwelling during DJF-MAM, sea surface temperatures rose to 28.8 °C and 29.0 °C, and chlorophyll-a concentration dropped to 0.32 mg/m^3 and 0.54 mg/m^3. CO_2 concentration in DJF and MAM increased to 386.3 ppm and 386.5 ppm. Based on these results it is known that when upwelling occurs, CO_2 concentration decrease and vice versa.

Keywords: *upwelling, CO_2, sea surface temperature, chlorophyll-a irradiation*

INTRODUCTION

CO_2 is one of the greenhouse gases that received much attention. The sea and biosphere are the main absorbents of CO_2 in the atmosphere. The global ocean is estimated to have absorbed about 30% of the concentration of CO_2 in the atmosphere over the past few decades [1]. Absorption of atmospheric CO_2 by the sea through two processes called solubility pumps and biological pumps [2]. In a solubility pumps, atmospheric CO_2 enters the ocean through the process of gases exchange between air and sea which is affected by sea temperature and wind speed.

Biological pumps has an important role in the transfer of CO_2 from the atmosphere to the interior of the ocean and sediments [3]. The transfer process of CO_2 is determined by the amount of primary productivity [4]. Primary productivity takes CO_2 through photosynthesis. The content of primary productivity is indicated by the concentration of chlorophyll-a [5]. And meanwhile, solubility pumps is affected by sea temperature. If the sea temperature gets colder, the more CO_2 is absorbed by the sea.

The concentration of chlorophyll-a in the marine waters is influenced by upwelling. Upwelling location has a high chlorophyll-a concentration [6, 7]. Upwelling is a rise of water mass from below to the surface layer. This mass of water has cold temperature, high salinity and nutrients. Therefore, the presence of chlorophyll-a concentration determines the biological pumps. Chlorophyll-a has an important role in the biogeochemical cycle in the ocean [8] and affect the temperature and circulation of surface currents [9].

Upwelling in the southern waters of Java is known very intensive [10,11]. This upwelling location reaches the west coast of Sumatra. Research about upwelling in the south of Java has been carried out, among others by [12,13,14,15]. The intensity of upwelling gets stronger when occur El Niño, on the contrary it gets weaker when occur La Nina [16,17,18].

There has not been much research on the effect of upwelling on atmospheric CO_2 concentration. So far, the focus of research has only been on the impact of upwelling on the marine environment such as changes in sea surface temperature, chlorophyll-a concentration, salinity and its relation to fish catch production. Whereas upwelling has a big impact on weather and climate variability [19,20]. Therefore, research on the effect of upwelling on CO_2 concentrations needs to be done in order to understand the carbon cycle between the atmosphere and the ocean. The purpose of this study was to determine the effect of upwelling in the southern waters of Java on concentration of CO_2 in Kototabang.

METHODS

1. Research location

The study location included the southern waters of Java from the coastline to 9 ° S and Kototabang, Agam Regency, West Sumatra located at coordinates 0 ° 12'07 '' LS and 100 ° 19 '05 '' BT as shown in Figure 1. Kototabang was chosen because there is a Global Atmospheric Monitoring station (GAW). GAW Kototabang is one of the monitoring stations coordinated by the World Meteorological Organization (WMO) to monitor the atmosphere and global air quality along with 16 other GAW scattered in various countries. One of the data produced by GAW Kototabang is CO_2 concentration data.

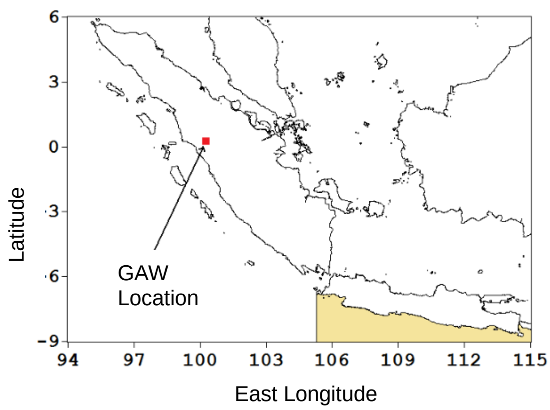

Figure 1. Research Location (in the brown block is the upwelling location south of Java)

2. Data

The data used consists of chlorophyll-a concentration, sea surface temperature, and CO_2 concentration from 2004-2016, as well as the NIÑO3.4 index and Dipole Mode Index. Chlorophyll-a concentration data was obtained from Oceanwatch NOAA, CO_2 concentration data was obtained from Laboratory Research System NOAA, sea surface temperature was obtained from Physical Oceanographic Distributed Active Archive Center NASA. The NIÑO3.4 index was obtained from the Climate Prediction Center NOAA, while the Dipole Mode Index was obtained from Jamstec.

3. Analysis

The method used is descriptive analysis, with compare the conditions of chlorophyll-a concentration and sea surface temperature in the southern waters of Java when upwelling with CO_2 concentration in Kototabang. Upwelling in the southern waters of Java occur from the east season (JJA) to the second transitional season (SON). Comparisons were conducted in normal conditions, El Niño 2015 and Indian Ocean Dipole 2016. The NIÑO3.4 index as an indicator of El Niño 2015 in the Pacific Ocean and the Dipole Mode Index (DMI) as an indicator of Indian Ocean Dipole (IOD) in the Indian Ocean were shown in Figure 2. Anomalies of NIÑO3.4 more than 1 °C show that El Niño in 2015 is very strong. Meanwhile, a negative DMI with a value greater than -0.75 °C indicated that the negative IOD in 2016 was quite strong.

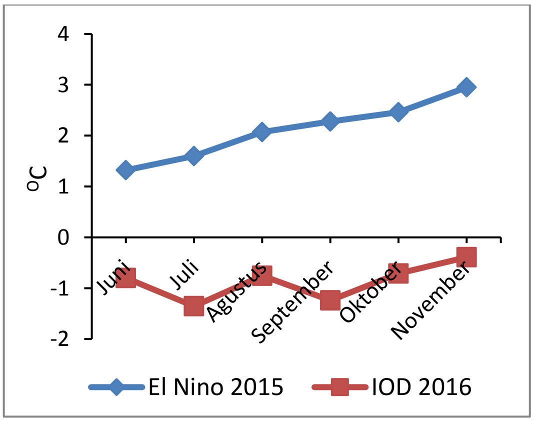

Figure 2. NIÑO3.4 dan IOD index

RESULTS AND DISCUSSION

Seasonal pattern of sea surface temperature in the southern waters of Java are shown in Figure 3. During upwelling, sea surface temperature drops to 26.8 °C in the east season (JJA) and 27 °C in the second transition season (SON). Sea surface temperature increased to 28.8 °C during the west season (DJF) and reached a maximum of up to 29 °C during the first transition season (MAM).

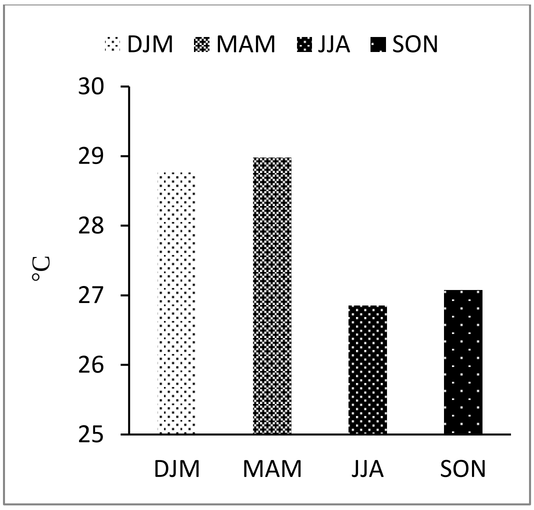

Figure 3. Seasonal pattern of sea surface temperature

The seasonal pattern of chlorophyll-a concentration in the southern waters of Java is shown in Figure 4. Figure 4 shows that the seasonal pattern of chlorophyll-a is inversely proportional to sea surface temperature. The concentration of chlorophyll-a in the west season ranges from 0.32 mg/m^3 and the first transition season to 0.54 mg/m^3. During the east season and the second transition season when occur upwelling, the concentration of chlorophyll-a reaches 2.03 mg/m3 and 2.19 mg/m3.

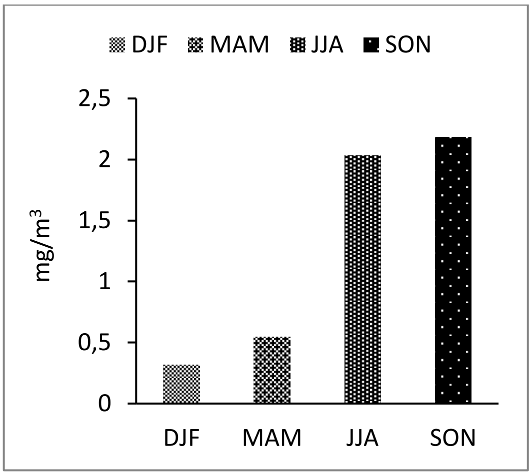

Figure 4. Seasonal pattern of chlorophyll-a

Figure 5 shows the seasonal variation of CO_2 concentrations in Kototabang. During upwelling, CO_2 concentrations decreased to 385.84 ppm in the east season and in the second transition season to reach 385.37 ppm. During the western season, CO_2 concentrations increase to 386.27 ppm and reach a maximum of 386.52 ppm in the first transition season.

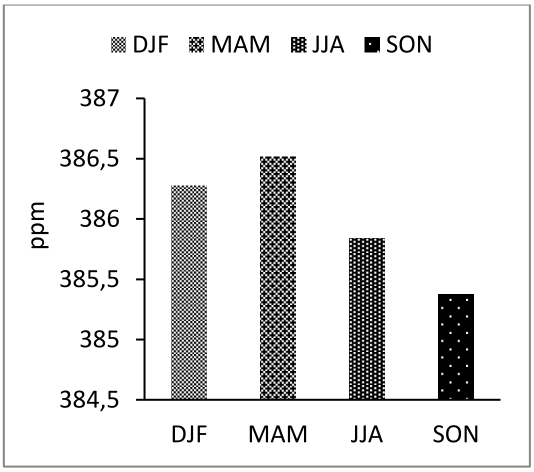

Figure 5. Seasonal pattern of CO_2 concentration

The concentration of CO_2 when the El Niño 2015 and the IOD 2016 are shown in Figure 6. Seasonal variation of CO_2 concentration in 2015 and 2016 differ from annual variation. The CO_2 concentration in the El Niño 2015 was around 394.82 ppm in the east season, and then experienced a significant increase to 400.71 ppm in the second transition season. In 2016, CO_2 concentration rose from 397.43 ppm in the east season to 397.57 ppm in the second transition season.

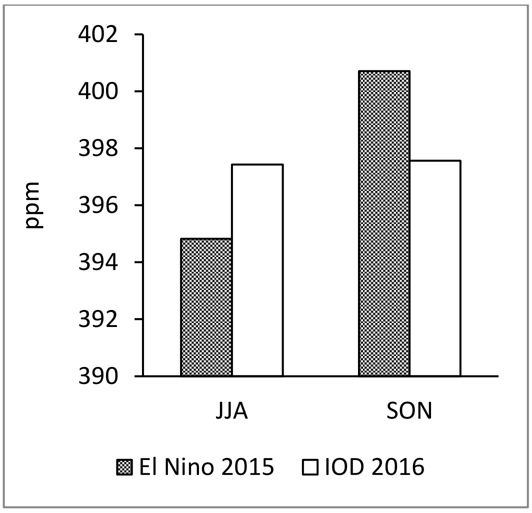

Figure 6. CO_2 consentration when *El Niño* 2015 and *IOD* 2016

The anomaly of chlorophyll-a concentration during the east season and the second transition season when the El Niño 2015 and IOD 2016 was shown in Figure 7. When El Niño 2015, chlorophyll-a concentration increased which was indicated by a positive anomaly value. Anomaly in the east season 0.45 mg/m3 with an increase of about 22% and anomaly in the second transition season 2.05 mg/m3 with an increase of 94%. Conversely, during the IOD 2016 the concentration of chlorophyll-a decreased quite high. The anomaly of chlorophyll-a concentration during the east season -1.55 mg/m3 decreased by 76% and during the second transition season it dropped 84% with an anomaly of -1.84 mg/m3.

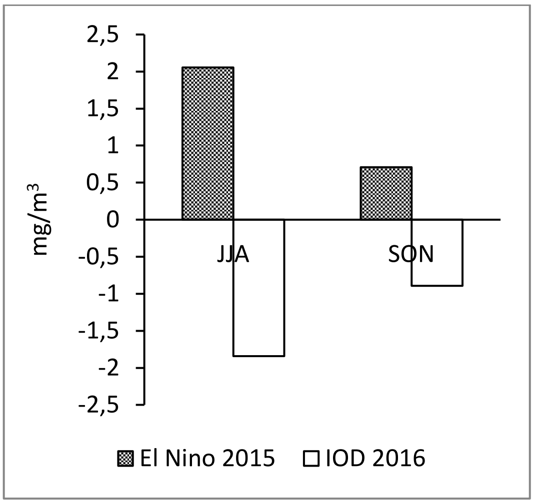

Figure 7. Anomaly of chlorophyll-a concentration when *El Niño* 2016 and *IOD* 2016

The anomaly of Sea surface temperature during the El Niño 2015 and IOD 2016 was shown in Figure 8. During El Niño 2015, sea surface temperature dropped with anomaly values of -0.3 ^{O}C in the east season and -0.2 ^{O}C in the second transition season. Conversely, sea surface temperature rise during the IOD 2016 with anomalies of 1.9 ^{O}C in the east season and 1.2 ^{O}C during the second transition season.

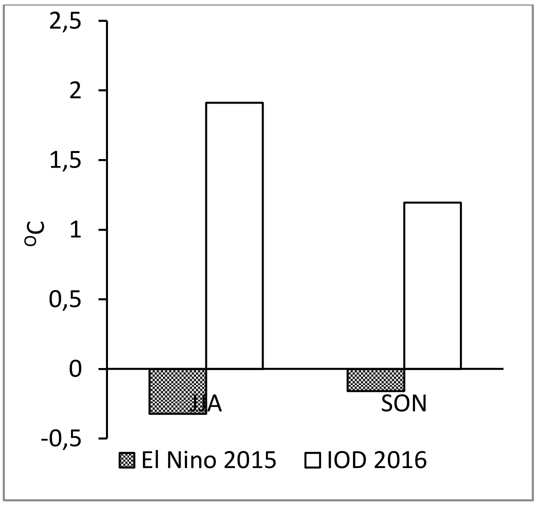

Figure 8. Anomaly of sea surface temperature when El Niño 2015 and IOD 2016

Based on the results it is known that seasonal variation of CO_2 concentration in Kototabang is inversely proportional to sea surface temperature, directly proportional to chlorophyll-a concentration in the southern waters of Java. In Indonesia, forests and oceans are the main absorbents of CO_2 [21,22]. Therefore, the wider the area of forest and land fires, the lower the ability of forests to absorb CO_2. Forest and land fires in 2015 were one of the sources of CO_2 emissions that contributed greatly to increasing CO_2 concentrations in Indonesia [23].

Forest and land fires are common during the east and the second transition season which coincides with the dry season. This condition can be seen from the number of hotspots in Sumatra in 2016, in the west season there are no hotspots, in the first transition season 102, in the east season 1523 and in the second transition season 122 [24]. But at the same time the atmospheric CO_2 concentration dropped. This condition is indicated due to the effect of upwelling in the southern waters of Java which causes sea surface temperature in the south of Java to western Sumatera colder. This mechanism is closely related to the process of solubility and absorption of CO_2 by the sea. High latitude waters act as an absorber of atmospheric CO_2 [25]. This is due to low sea surface temperature so that the partial pressure of CO_2 at sea level is lower than in the atmosphere.

The solubility and absorption of CO_2 is determined by sea temperature condition and the amount of primary productivity. CO_2 solubility in the sea will be faster with a decrease in sea surface temperature, on the contrary ocean warming slows the solubility of CO_2 [26, 27]. Increasing of primary productivity will reduce pCO_2 of surface water and

CO_2 flux between the air-sea become negative, so that the sea acts as an absorber of CO_2 [28]. The higher primary productivity, the greater the ability of the ocean to absorb CO_2. The same condition was shown that in the Kodek Bay acts as an absorber of atmospheric CO_2 because it has a high chlorophyll-a concentration [29].

The decrease of CO_2 concentration during the east season and the second transition season is indicated to be very closely related to the decrease in sea surface temperature in the southern waters of Java which reached 2 ^{O}C and an increase in the concentration of chlorophyll-a which reached 489% due to upwelling. This is consistent with the results of several studies conducted by other researchers. CO_2 absorption in the Arctic sea and its surroundings is very high, due to cold water temperature and high amount of primary productivity [30].

The same condition was shown when El Niño 2015 and IOD 2016. This phenomenon affects the strength of upwelling in the southern waters of Java, which in turn will have an impact on CO_2 concentration in Kototabang. Forest and land fires in 2015 reached 2.61 million ha and fell 83% to 438.363 ha in 2016 [24]. Although, forest and land fires are large but the CO_2 concentration of during the eastern season of 2015 was only 394.8 ppm lower than the east season of 2016 which reached 397.4 ppm. This condition is indicated as a result of a decrease in sea surface temperature and a significant increase in chlorophyll-a concentration during 2015 El Niño.

On the contrary, during the IOD 2016 the sea surface temperature experienced a significant increase and the concentration of chlorophyll-a dropped, so that the CO_2 solubility process was slower and the absorption of CO_2 by the sea was less. With massive forest and land fires during the second transition season in 2015 and a very small increase in chlorophyll-a, the CO_2 concentration during the second transition season in 2015 is higher than in 2016.

CONCLUSION

Based on the analysis of the results it can be concluded that the concentration of CO_2 in Kototabang Bukittinggi was affected by upwelling in the southern waters of Java. Seasonal variation of CO_2 concentration is inversely proportional to sea surface temperature but directly proportional to chlorophyll-a concentration in the southern waters of Java. During the upwelling in the east season and the second transition season, sea surface temperature is cooler and concentration of chlorophyll-a has increased very significantly to reach 489%. An increase in chlorophyll-a and the decrease in sea surface temperature will cause the solubility and absorption of CO_2 to increase, so that the CO_2 concentration in Kototabang Bukittinggi decreases during the east season until the second transition season. Absorption of CO_2 by the sea due to El Nino 2015 is stronger than the impact of IOD 2016.

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