CHLOROPHYLL-A CONCENTRATIONS ESTIMATION FROM AQUA-MODIS AND VIIRS-NPP SATELLITE SENSORS IN SOUTH JAVA SEA WATERS

Rayhan Nuris[1], Jonson Lumban Gaol[1]*, Teguh Prayogo[2]
[1]Department of Marine Science and Technology, Faculty of Fisheries and Marine Science, Bogor Agricultural University
[2]Remote Sensing Applications Center, National Institute of Aeronautics and Space (LAPAN)
*Corresponding author e-mail: jonson_lumbangaol@yahoo.com
Received: 6 March 2015; Revised: 3 May 2015; Approved: 29 May 2015

Abstract. This study aimed to estimate the concentration of chlorophyll-a from satellite imagery of National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) in the south Java Sea waters and compare it to the concentrations of chlorophyll-a estimation result from the MODIS-Aqua satellite. NPP satellite had Visible/Infrared Imager Radiometer Suite (VIIRS) sensors which performance was same as Moderate Resolution Imaging Spectroradiometer (MODIS) sensor with a better spatial resolution. This study used daily satellite imagery of VIIRS-NPP for the period of September 2012 to August 2013. The algorithm that was used to estimate the concentration of chlorophyll-a was Ocean Color 3-band ratio (OC-3). The results showed that the spatial distribution pattern of chlorophyll-a concentration between VIIRS - NPP sensor and MODIS had the same pattern, but the estimation of chlorophyll-a concentration from the MODIS sensor was higher than VIIRS -NPP sensor. The concentration of chlorophyll-a showed that there were spatial and temporal variation in the south Java Sea waters. Generally, concentrations of chlorophyll-a was higher in East monsoon than West monsoon.

Keywords: *Aqua-MODIS, chlorophyll-a, VIIRS-NPP, remote sensing, south Java Sea waters*

1 INTRODUCTION

Indonesian sea waters had special characteristics that existed between two continents and two oceans. Season conditions that were affected by Asia and Australia continents caused the oceanographic conditions of Indonesian sea waters very dynamic. Monitoring of oceanographic dynamics was needed to acquire an understanding of environmental processes that affected marine resources and fisheries. Basic oceanographic parameters that were often observed i.e. sea surface temperature, salinity, nutrient content including chlorophyll-a concentration, and etc. The concentration of chlorophyll-a was one of the important oceanographic parameters as indicators of fertility and productivity of fisheries. It was necessary for monitoring the concentration of chlorophyll-a periodically to determine the fertility of sea waters condition.

One of the marine remote sensing application was the observation of chlorophyll-a concentration of the sea waters from satellite sensor. over the last three decades the observation of chlorophyll-a had been conducted by using remote sensing satellite sensors that observed the sea color, such as *Coastal Zone Color Scanner*(CZCS) on the Nimbus satellite, *Sea Wide Field-of view Sensor* (SeaWiFS) on the OrbView satellite, and *Moderate Resolution Imaging Spectroradio-meter* (MODIS)sensor on the Terra satellite/ Aqua-MODIS. CZCS sensor was a first sensor made for the development of knowledge about the condition of sea waters (Short, 2013). SeaWiFS sensor

served to record the quantitative data of bio-optical properties of the global sea waters, such as ocean waters changing that was indicating various types and number of marine phytoplankton (Piwowar, 2010).

Currently NASA continued the *ocean color satellite* mission by launching Suomi satellite NPOESS *Preparatory Project* (NPP). This satellite was designed to do the three-environment satellite mission that existed today, the *Polar-Orbiting Operational Environmental Satellite* (POEs), *Defense Meteorological Satellite Program* (DMSP) and the *Earth Observing System* (EOS), which would be integrated satellite.

National Polar-Orbiting Operational Environmental Satellite System (NPOESS). This satellite had *ocean color sensor*, *Visible/Infrared Imager Radiometer Suite* (VIIRS). VIIRS sensor had a better spatial resolution than the previous *ocean color sensors* (Terra/Aqua-MODIS), which was 375 meters and 750 meters (NASA 2011). Since the launch of Suomi NPP satellite in mid-2012, the earth data receiving station of environment and weather satellite, LAPAN located in Pare-Pare, South Sulawesi, had received the Suomi NPP satellite data. The Availability of data would be very useful for monitoring environmental conditions, particularly the oceanographic conditions in Indonesian sea waters. In order using the satellite data, so the research of chlorophyll-a estimation from the satellite Suomi NPP was needed.

The research that would be conducted was aiming to estimate the chlorophyll-a concentration derived from the Suomi NPP satellite imagery and compare it with the chlorophyll-a concentration derived from Aqua-MODIS satellite. Selecting south Java Sea waters as the study area was because of this region had a very dynamic seasonal dynamics of chlorophyll-a abundance associated with upwelling phenomenon that occurred every year. The objections for this study were (1) Predicting the concentration of chlorophyll-a in the south Java Sea waters by using NPP satellite imagery and (2) Comparing the results of chlorophyll-a concentration derived from NPP satellite imagery with Aqua-MODIS satellite imagery.

2 MATERIALS AND METHODOLOGY

2.1 Time and Location of Research

This research was conducted in May to September 2013. The data processing was held in the Coastal and Marine Resources sector, Remote Sensing Applications Center-LAPAN, Pekayon, East Jakarta, and the Laboratory of Remote Sensing and Marine GIS, Marine Sciences and Technology Department, Bogor Agricultural University. The study area of this research was south Java Sea waters, which was located at 5^0-12'S and 105^0-115'E. Map of the study area could be seen in Figure 2-1. The dots in Figure 1 shows the location of the data retrieval of chlorophyll-a from the satellite imagery ofAqua-MODIS and VIIRS-NPP to compare the results of chlorophyll-a concentrations the estimation from both sensors.

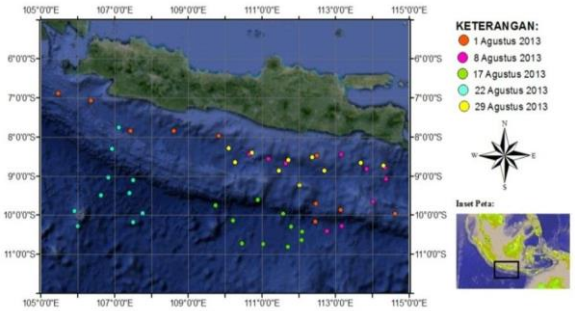

Figure 2-1: Map of the study area and the sample point of the chlorophyll-a value from satellite imagery of VIIRS -NPP and Aqua-MODIS

The materials that was used in this study were the daily image from NPP satellite Level-2 from September 2012 to August 2013 and the daily image from Aqua-MODIS satellite Level-2 in August 2013. The coverage area of the image that

was processed and analyzed was south Java Sea waters and its surroundings with the geographical coordinates limit on 5º-12'S and 105º-115'E.

The tools that were used in this study was a set of computers equipped by the image processing software, namely Seadas 7.0 (Windows), Global Mapper 8, ERMapper 6.4 and Microsoft Excel. For the Visualization of chlorophyll-a distribution, the tools was Ocean Data View software (ODV) 4.0.

2.2 Imagery Data Acquisition

The images of VIIRS Level-2 and Aqua-MODIS NPP were downloaded from the NASA-Ocean Color (http://oceancolor.gsfc.nasa.gov) and the images that were free from cloud cover was selected as the data. Aqua-MODIS image data form was Hierarchical Data Format (*.HDF) file, while the NPP images form was HDF-5 (*.h5). The Level 2 images had been corrected geometrically and contained some information such as the content of chlorophyll-a (OC3 Algorithm), latitude, longitude, and etc. The information was the correction result of level-1 images to Level-2.

2.3 Data Processing of Chlorophyll-a Concentration

Pre-treatment that was performed was merging multiple images to produce a picture that covered the entire area of research on 5º-12'S and 105º-115'E coordinates. The steps were merging image used *Mosaic* module to combine the scene image, set the image *georeference*, cut the combined results, and choose the information that contained in the scene to be present at the combined result image (longitude, latitude and the value of chlorophyll-a) on the Seadas 7.0 (Windows) software.

Research study areas included south Java Sea waters, thus cutting the composite image was required to get the value of chlorophyll-a concentration south Java Sea waters. Cutting the composite image was done by using ERMapper 6.4 software. Monthly and seasonal composite image that had been cut and only coveredthe south Java Sea waters was then exported into *.txt form. Furthermore, the data processing of chlorophyll-a concentration was done to get the average, maximum and minimum values.

The estimation of chlorophyll-a concentration value in NPP satellite and the Aqua-MODIS that was acquired by using the *Ocean Color 3-band ratio* (OC-3) algorithm. OC-3 algorithm for MODIS (OC3M) was using the maximum band ratio from channels reflectance 443 nm and 490 nm to 550 nm (O'Reilly et al. 2000). OC3 algorithm for VIIRS (OC3V) in equation 1 was an algorithm approach taken by Carder et al. And modified for VIIRS purposes (NASA, 2011). The variable X was obtained from the comparison of the value of RRS (445)/ RRS (555) with RRS (488)/RRS (555), the larger value was multiplied by log10 and the result was included in the following equation,

$$\log(C) = \alpha_0 + \alpha_1 x + \alpha_2 x^2 + \alpha_3 x^3 + \alpha_4 x^4$$

$$x = \log\left[\frac{\max(R_{rs}(445), R_{rs}(488))}{R_{rs}(555)}\right] \qquad (2\text{-}1)$$

Which,
α_0 =0.283,
α_1 =-2.753,
α_2 =1.457,
α_3 =0.659,
α_4 =-1.403 Else,
C =chlorophyll-a concentrations,
Rrs =reflectance of *remote sensing,*
a =coefficient ofabsorption, and
x =empirical coefficient.

2.4 Data Analysis Procedures

The analysis was done spatially and temporally by looking the chlorophyll-a

distribution from the image of the NPP in the West season (December 2012-February 2013), Season Transition I (March-May 2013), East season (June-August 2013), and Season Transition II (September-November 2012). The Information of chlorophyll-a concentrations abundance (mg/m3) in the south Java Sea waters in every season was represented by the satellite images on a period of one year from September 2012 to August 2013. Comparative analysis of chlorophyll-a value that was generated from NPP and Aqua- MODIS satellite was done by comparing the chlorophyll-a value in August 2013.

3 RESULTS AND DISCUSSION

3.1 Chlorophyll-a from VIIRS -NPP and MODIS

Spatial distribution of chlorophyll-a concentrations based on Aqua-MODIS and VIIRS-NPP data from1, 8, 17, 22 and August 29, 2013 shown in Figure 3-1. Spatially seen that the distribution of chlorophyll-a concentration which was generated from both MODIS and VIIRS -NPP image had the same pattern. During the month of August 2013 showed that chlorophyll-a concentration was very high around the east coast of south Java up to the Bali straits. However, the estimated value of the chlorophyll-a concentration from VIIRS -NPP sensor was lower than Aqua-MODIS on each station (Figure 3-2). Spatially the concentrations in the south waters of East Java up to Bali straits was high enough in accordance with the results of previous studies (Lumban-Gaol *et al.* 2004).

From 50 stations observed by MODIS sensor, there were 44 stations found to have higher chlorophyll-a concentrations value. The mean difference between the two was 0.451 mg/m3.

VIIRS - NPP Sensor had 16 moderate channels, 5 imagery channels, and 1 Day-Night Band (DNB) channel, while the MODIS sensor had 36 channels. The difference estimation value of the chlorophyll-a concentration could be caused by spectral resolution differences on ocean color channels of VIIRS –NPP and Aqua-MODIS sensor. Ocean color channel width at Aqua-MODIS sensor, smaller than the channel width at VIIRS -NPP sensor.

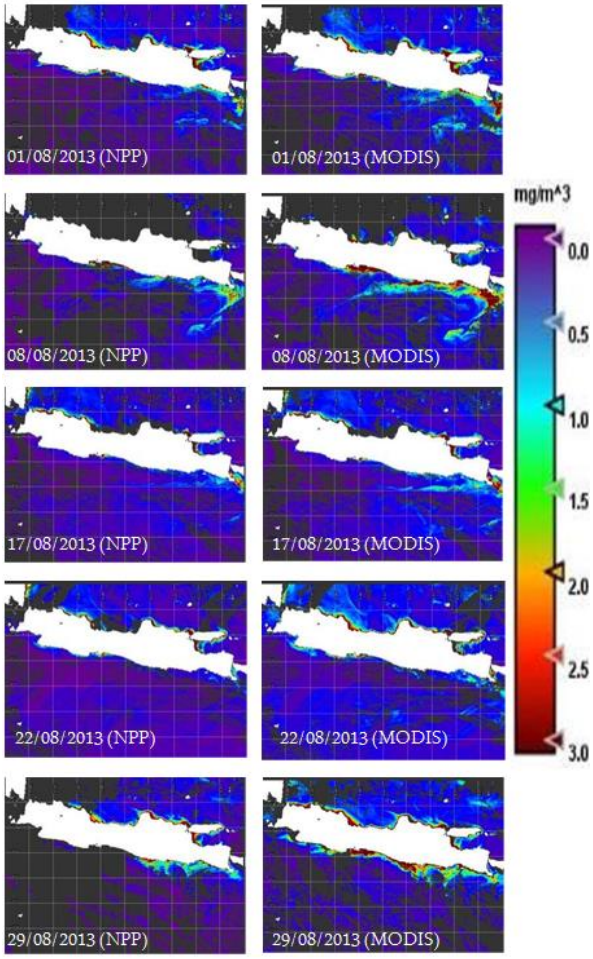

Figure 3-1: Daily distribution of chlorophyll-a from VIIRS -NPP (left) and Aqua-MODIS (right) in the South Java Sea waters

Spectral resolution was a factor that determines the quality of a sensor to generate remote sensing image (Suwargana, 2013). Generally, the narrower channel width of the sensor, the higher sensitivity of the sensor to distinguish the spectrum of energy emitted by the object. Research that was conducted by Pahlevan *et al.*

(2013) concluded that the green/blue channel on VIIRS-NPP had a low response.

Atmospheric correction also became the cause of the low value of chlorophyll-a produced by VIIRS-NPP satellite. Based on the study results of Hlaing *et al.*, (2013), for VIIRS-NPP and MODIS data was processed with the same processing procedures, but the bias on the MODIS sensor was much smaller than the resulting bias on VIIRS -NPP. This might occur due to the limitations of the aerosol model that was used to the atmospheric correction. According to Davis *et al.*, (2013), VIIRS-NPP would be able to replace the Terra/Aqua-MODIS when the calibrating was done.

VIIRS quality assessment based on data from ocean color EDR had been done by Turpie et al. (2013). Each of NASA and NOAA team performed evaluations using NASA standard algorithms, but the team of NOAA enhanced calibration. The result showed that the chlorophyll-a concentration based on the evaluation of NOAA team was higher than the standard evaluation of NASA.

3.2 Chlorophyll-a concentration variability from VIIRS-NPP

Monthly averages of the chlorophyll-a concentration from NPP VIIRS sensor from September 2013 to August 2013 were listed in Figure 3-3. During July, August, September and October, the concentration of chlorophyll-a was very high. This was due to the process of upwelling along the south coast of Java during the east monsoon (Wirtky, 1962. Lumban-Gaol *et al.*, 2002, Hendiarti et al. 2004). Chlorophyll-a concentration was around upwelling> 1.5 mg / m3.

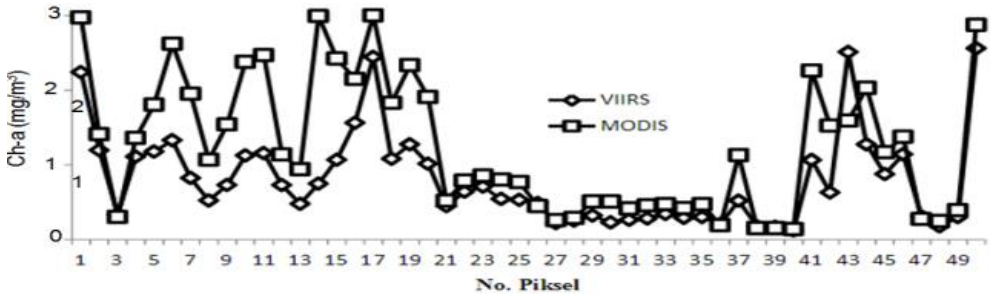

Figure 3-2: The difference of chlorophyll-a value from VIIRS-NPP satellite and the Aqua-MODIS on the same station

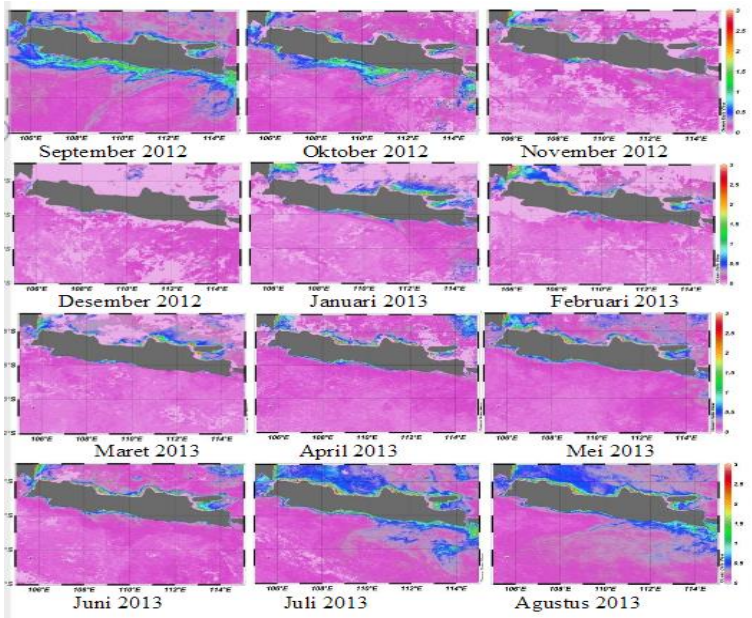

Figure 3-3. Spatial distribution of monthly averages of chlorophyll concentration from VIIRS -NPP image

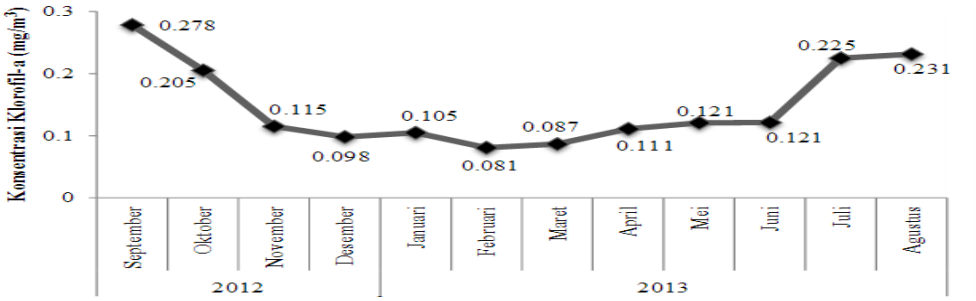

Figure 3-4: Monthly averages Fluctuations of chlorophyll-a concentration from VIIRS image-NPP in the south Java Sea waters

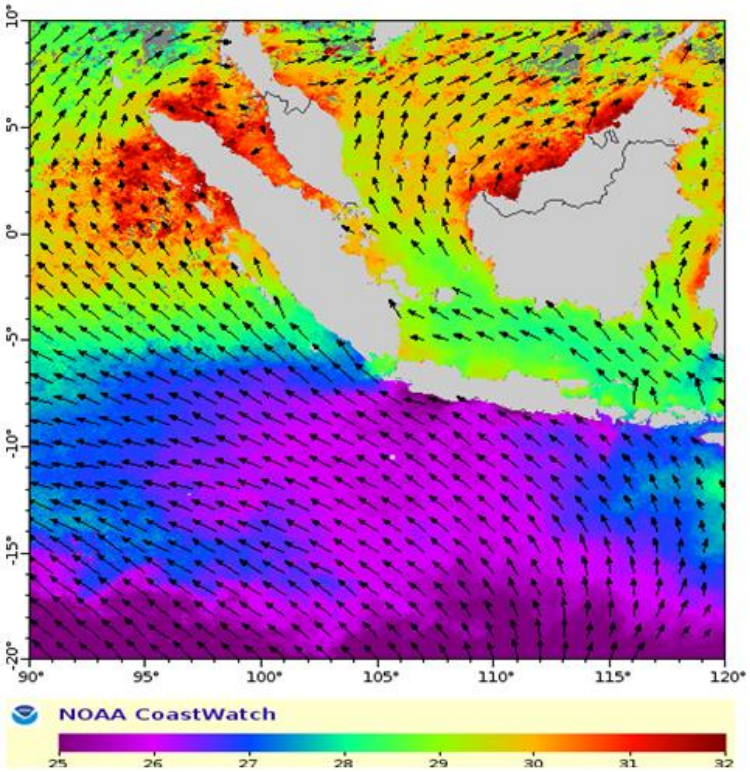

Figure 3-5: Wind conditions and sea surface temperature in the south Java at the east monsoon

The average fluctuations of chlorophyll-a concentration from VIIRS-NPP satellite imagery in the south Java Sea waters that was showed from September 2012 to August 2013 shown in Figure 3-4. The graph showed that the average value of chlorophyll-a was fluctuating throughout the year where the chlorophyll-a concentration began to increase in July and the peak was in September. The lowest value of chlorophyll-a concentration occurred in February 2013 and the highest was in September.

These results corresponded with the previous results of studies that used chlorophyll-a concentration data from both SeaWiFS and Aqua-MODIS sensor (Susan et al., 2001, Lumban-Gaol et al., 2002, Hendiarti et al., 2004, Kunarso et al. 2011) that stated that the chlorophyll-a concentration would be maximum during the peak of *upwelling* process was in August or September. In east monsoon wind blew from the southeast and fully pushedthe sea water masses along the south coast of Java, due to the coriolis forced the sea water masses would be diverted away from the south coast of

Java, causing sea water masses emptiness (Figure 3-5).

This emptiness would be filled by sea water masses from the inner layer (upwelling) During the process of *upwelling*, the sea water masses from inner layer that was colder and rich in nutrients rose to the surface layer, thus improving nutrient which further enhanced the growth of phytoplankton.

In east monsoon chlorophyll-a concentration in high seas of south waters of East Java up to Bali straits was quite high. The cause of the high value of chlorophyll-a concentration up to the high sea was eddy currents. According Wrytki (1961), eddy currents were commonly happening in south waters of East Java up to Bali. These currents were formed as a result of the current meeting of the Java coast and south equatorial currents. Eddy currents was a vortex of sea water masses containing chlorophyll-a fairly high as a result of removal of nutrients from inner layers to the surface (Vaillancourt et al., 2003, Oey, 2007, Lumban-Gaol *et al.*, 2010).

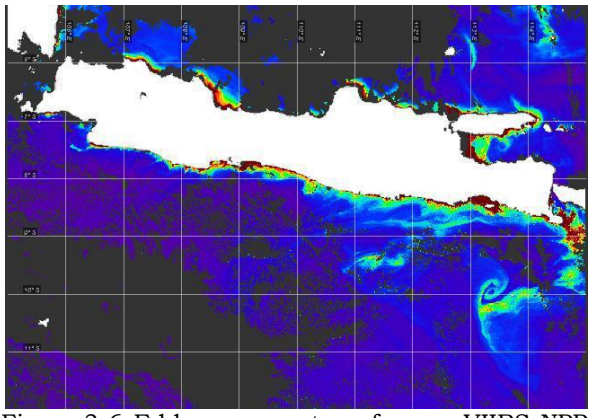

Figure 3-6: Eddy currents from VIIRS-NPP satellite imagery on July 30, 2013

At the time of the west monsoon, the pattern of wind movement along the south coast of Java that was reversed from west to east, causing a buildup of sea water masses in the length of the beach and sea surface temperature became higher than the east monsoon (Figure 3-7). The concentration of chlorophyll-a in the west monsoon gradually decreased from October to December with the average of 0.098 mg/m^3.

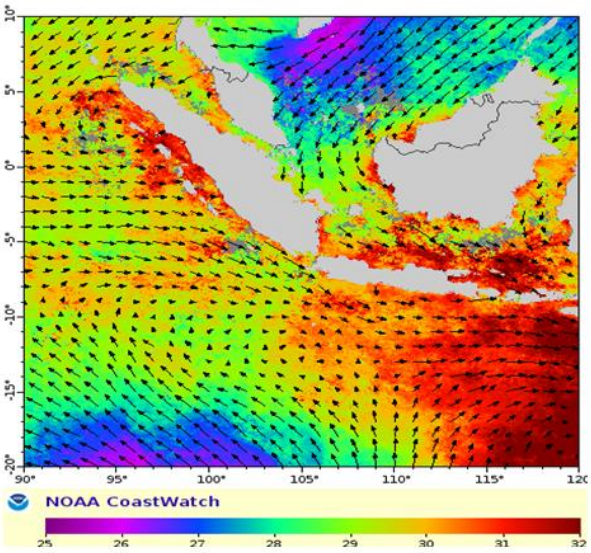

Figure 3-7: Wind conditions and sea surface temperature in the south Java at the time of west monsoon

4 CONCLUSION

VIIRS-NPP satellite imagery could potentially be used to estimate the chlorophyll-a concentration in the water as well as Aqua-MODIS imagery. Estimation of the chlorophyll-a concentration from VIIRS -NPP sensor was lower than the Aqua MODIS sensor.

The concentration value of chlorophyll-a varied temporally and spatially in the south Java Sea waters. Temporally chlorophyll-a concentration increased in East monsoon and declined in the west monsoon.

From the results of this study, further research was suggested by using the image of Environmental Data Record (Level-2) that were corrected atmospherically with the operational calibration. Satellite data validation could be done by in situ data.

ACKNOWLEDGEMENT

This research was facilitated by the Department of Marine Science and

Technology of Bogor Agricultural University and the Remote Sensing Applications Center of LAPAN.

REFERENCES

[NASA] National Aeronautics and Space Administration (US), (2011), VIIRS Ocean Color Chlorophyll Algorithm Theoretical Basis Document (ATBD). Goddard Space Flight Center Greenbelt. Maryland.

Davis CO, Tufillaro N., Nahorniak J., Jones B., Arnone R., (2013), Evaluating VIIRS Ocean Color Products for West Coast and Hawaiian Waters. US.

Hendiarti N., Siegel H., Ohde T., (2004), Investigation of different coastal processes in Indonesian waters using SeaWiFS data. Deep-Sea Research II, 51:85-97.

Hlaing S., Gilerson A., Ahmed S., Wang M., Weidemann A., Arnone R., (2013), Validation of VIIRS Ocean Color, Primary Products In Coastal Regions. New York (US): City College of City University.

Kunarso SH, Ningsih NS, Baskoro MS, (2011), Variabilitas Suhu dan Klorofil-a di Daerah Upwelling pada Variasi Kejadian ENSO dan IOD di Perairan Selatan Jawa sampai Timor. Ilmu Kelautan 16(3): 171–180.

Lumban-Gaol J., Nababan B., (2010), Deteksi Mesoscale Eddies dari Satelit dan Hubungannya dengan Hasil Tangkapan Ikan Tuna Mata Besar (Thunnus obesus) di Perairan Selatan Jawa. Ilmu Kelautan Edisi Khusus 1:68-76.

Lumban-Gaol J., Pasaribu BP, Manurung D., Endriani R., (2004), Fluctuations of Cholorophyll-a Concentration Derived from Satellite Imagery and Catch of Oily Sardine (Sardinella lemuru) in Bali Strait. International Journal of Remote Sensing and Earth Sciences 1:1-7.

Lumban-Gaol J., Mahapatra K., Okada Y., (2002), Tuna Fish Catch and Variability of Satellite Derived Ocean Parameters in the South Java Sea During 1997-98 El Niño. Fisheries science 68 (sup1): 657-658.

O'Reilly JE, Maritorena S., Siegel DA, O'Brien MC, Toole D., Mitchell BG, and Hooker SB, (2000), Ocean color chlorophyll a algorithms for SeaWiFS, OC2, and OC4: Version 4. SeaWiFS postlaunch calibration and validation analyses, Part, 3: 9-23.

Oey LY, (2007), Loop Current and Deep Eddies. Princeton University, USA.

Pahlevan N., Lee Z., Arnone R., Lawson A., (2013), Investigating Consistency between VIIRS and MODIS Over the Oceans: The Sensor/Environmental Data Records. 93rd Annual AMS Meeting, Ninth Annual Symposium on Future Operational Environmental Satellite Systems. Boston. Piwowar JM. 2010. Orb-View 2. http:// uregina.ca/piwowarj/Satellites/OrbView.html (Accessed on May 26 2013).

Short NM, (2013), CZCS and SeaWiFS. www. fas.org/irp/imint/docs/rst/Sect14/ (Accessed on May 30 2013).

Susanto RD, Gordon AL, Zheng Q., (2001), Upwelling Along the Coasts of Java and Sumatera and its Relation to ENSO. Geophysical Research Letters 28(8): 1599-1602.

Suwargana N., (2013), Resolusi Spasial, Temporal dan Spektral pada Citra Satelit Landsat, Spot Dan Ikonos. WIDYA 1(2): 167-174.

Turpie KR, Balch B., Bowler B., Franz BA, Frouin R., Gregg W., McClain CR, Rousseaux C., Siegel D., Wang M., Eplee G., Robinson W., (2013), Quality Assesment of the Visible Infrared Imaging Radiometer Suite (VIIRS) Ocean Color Environment Data Records. US: NASA.

Vaillancourt RD, Marra J., Seki MP, Parsons ML, Bidigare RR, (2003), Impact of a Cyclonic Eddy on Phytoplankton Community Structure and Photosynthetic Competency in the Subtropical North Pacific Ocean. Deep Sea Research Part I: Oceanographic Research Papers 50(7): 829-847.

Wyrtki K., (1962), The Upwelling in the Region Between Java and Australia During the South-east Monsoon. Marine and Freshwater Research 13(3): 217-225.