MODIS STANDARD (OC3) CHLOROPHYLL-A ALGORITHM EVALUATION IN INDONESIAN SEAS

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Abstract. The MODIS-estimated chlorophyll-a information was widely used in some operational application in Indonesia. However, there is no information about the performance of MODIS chlorophyll-a in Indonesian seas and there is no data used in development of algorithm was taken in Indonesian seas. Even the algorithm was validated in other area, it is important to know the performance of the algorithm work in Indonesian seas. Performance of MODIS Standard (OC3) algorithm at Indonesian seas was analyzed in this paper. The in-situ chlorophyll-a concentration data was collected during MOMSEI (*Monsoon Offset Monitoring and Its Social and Ecosystem Impact)* 2012 Cruise 25th April – 12th May 2012 and also from archived data of the Research and Development Center for Marine Coastal Resources, Agency of Marine and Fisheries Research and Development, Indonesian Ministry of Marine Affairs and Fisheries. The in-situ data used in this research is located in Indian Ocean the west of Sumatera part and Pacific Ocean the north of Papua Province part. Satellite data which is used is Ocean Color MODIS Level-2 Product that downloaded from NASA and MODIS L-0 from LAPAN Ground Station. MODIS Level 0 from LAPAN then processed to Level-2 using latest SeaDAS Software. The match-up resulted the MNB(%) is -4.8% that means satellite-estimated was underestimate in 4.8 % and RMSE is 0.058. When the data was separated following to the data source, the correlation and trend line equation became better. From MOMSEI Cruise data, the MNB(%) was -18.8% and RMSE 0.05. From Pacific Ocean Data, MNB (%) was -27 % and RMSE 0.049. From SONNE Cruise 2005, MNB (%) was -27 % and RMSE 0.049. MODIS standard algorithm is work well in Indonesia case-1 seawaters, which contain chlorophyll-a only, and derived that influence to the electromagnetic wave.

Keywords: *MODIS, Chlorophyll-a, OC3 Algorithm, Indonesian seas*

1 INTRODUCTION

MODIS sensor board on Aqua EOS Satellite was starting to be operational since 2002.Aqua MODIS are viewing the entire earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths. Bringing many spectral bands onboard, MODIS have wide application uses in range of information about the earth's water cycle, including evaporation from the oceans, water vapor in the atmosphere, clouds, precipitation, soil moisture, sea ice, land ice, and snow cover on the land and ice. Additional variables also being measured by Aqua include radiative energy fluxes, aerosols, vegetation cover on the land, phytoplankton and dissolved organic matter in the oceans, and air, land, and water temperatures. The most important in MODIS sensor is a group of wavelengths that provide ocean color information through specific wavelengths for ocean application as successor of CZCS (Coastal Zone Color Scanner) sensor board on Nimbus-7.

Data from the CZCS provided the first demonstration of the ability to observe the abundance and distribution of phytoplankton chlorophyll in the world's ocean from space (Gordon, et al.,1980). The data have been used extensively to gain better understanding of marine food webs and the role of the ocean in important biogeochemical cycles, including carbon and nitrogen. The near synoptic and global data provided by polar orbiting satellites fill a fundamental need for ocean scientists, since conventional platforms cannot adequately cover the vast, rapidly varying ocean at the appropriate time and space scales (Esaias, 1980). Remote sensing by aircraft or satellite provides even broader spatial coverage of phytoplankton abundance. This technique is based on the fact that the radiance reflected from the sea surface in the visible spectrum (400-700 nm) is related to the concentration of chlorophyll. Because chlorophyll is green, water color changes from blue to green as chlorophyll concentration increases and the relative color difference can be used as a measure of chlorophyll concentration (Lalli and Parsons, 1997).

Several ocean-color algorithms have been developed for both global and regional scales. In terms of complexity, they can be classified as empirical and semi-analytical functional forms (e.g., Clark, 1997; O'Reilly *et al.*, 2000; Maritorena *et al.*, 2002; Carder *et al.*, 2003). Some algorithms for MODIS data application were validated included algorithm for estimated the chlorophyll-a concentration both in Case-1 and Case-2 waters (Darecki and Stramski, 2004, De Pasquale, *et. al.*, 2005, Campbell and Feng, 2005, Pan *et al.*, 2010, Siswanto *et al.,* 2011). Ocean waters classified into Case-1 and Case-2, Case-1 is that of concentration of phytoplankton high compared to other particle, inorganic particle are dominant in case-1 (Morel and Prieur, 1997 in Mobley *et al.,* 2004).

Previous studies mentioned that NASA standard Chl-a algorithm used in the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and Moderate Resolution Imaging Spectro-radiometer (MODIS) data such as SeaWiFS OC4 and MODIS OC3M respectively can retrieve Chl-a well in the case-1 water (i.e., open ocean) but not in the case-2 water (such as that in the coastal region) (Ab.Lah, *et. al.*, 2013). The latest version of Standard MODIS Chlorophyll-a was validated using NOMAD version 2 dataset, resulted good correlation R^2 = 0.855, RMS = 0,255 and bias = -0.000 (OBPG, 2010). However, the standard algorithm was failed in case-2 water of Baltic Sea (Darecki and Stramski, 2004). While, Campbell and Feng, (2005) shown a good validation result with R^2 = 0.84, RMSE = 0.277 and bias = -0.0077. Before use for operational activity, need to know the performance of MODIS chlorophyll-a algorithm at the seawaters where the algorithm will be used.

Almost of validation research was done I out of Indonesian seas. The nearest validation place is done by Ab.Lah *et al.*, (2013). The MODIS-estimated chlorophyll-a information was widely used in some operational application in Indonesia. However, there is no information about the performance of MODIS chlorophyll-a in Indonesian seas and there is no data used in development of algorithm was taken in Indonesian seas. Even the algorithm was validated in other area, it is important to know the performance of the algorithm work in Indonesian seas. This paper explained the result of the match-up analysis between satellite-based estimated chlorophyll-a and in-situ measurement at Indonesian seas.

2 MATERIAL AND METHOD

2.1 Satellite Data

MODIS data is main data in this study. MODIS is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) Satellites. The ocean color bands on MODIS are very similar to SeaWiFS bands, with the advantage that they are narrower than SeaWiFS, a result of the large aperture and throughput of MODIS (Esaias *et al.*, 1998). The narrower bands will enhance atmospheric correction. For example, the ocean band at 748 nm is about a half width of the equivalent SeaWiFS band and, therefore, avoids the nearby atmospheric oxygen absorption feature altogether. Bands 8 and 9 have 15-nm width to achieve needed SNR (signal to noise ratio). MODIS band 11 at 531-nm exhibits the largest band difference from SeaWiFS positions. The analogous

SeaWiFS band position is at 510 nm, due to the location of the SeaWiFS dichroic beam splitter (Barnes *et al.*, 1998). A center wavelength of 531 nm was selected for MODIS to improve the response to accessory pigments, rather than to maintain continuity with precursor sensors. Also, there is less spectral structure in this region, and therefore, slight on orbit will not significantly affect radiometric calibration.

Satellite data which is used is Ocean Color MODIS Level-2 Product that downloaded from NASA and MODIS L-0 from LAPAN Ground Station. MODIS Level 0 from LAPAN then processed to Level-2 using latest SeaDAS Software Vesion 6.2.

2.2 Atmospheric Correction

At the ocean, about 10% of the total light detected by a satellite is water-leaving radiance, while the other 90% of the light is due to atmospheric effects. Corrections to the data must be necessary to remove this atmospheric radiance. Once the radiance signal has been corrected for atmospheric light scattering, the signal is then corrected for the solar zenith angle. This gives us the normalized water leaving radiance, which is the radiance that would be measured when the surface of the ocean is flat, the sun at zenith is directly overhead and the atmosphere is absent. The normalized water leaving radiances are then used in algorithms to produce geophysical values, such as chlorophyll-a concentration.

We can write the total reflectance, measured at the top of the atmosphere in the each band as

$$\rho_t = \rho_r + (\rho_a + \rho_{ra}) + t\rho_{wc} + t\rho_g + t\rho_w \qquad (2\text{-}1)$$

where ρ_r is the reflectance resulting from multiple scattering by air molecules (Rayleigh scattering) in the absence of aerosols, ρ_a the reflectance resulting from multiple scattering by aerosols in the absence of air, ρ_{ra} the interaction term between molecular and aerosol scattering, ρ_g the direct solar beam reflectance, ρ_{wc} one of reflected from the (rough) ocean surface, ρ_w the water leaving reflectance and t denotes the diffuse transmittance of the atmosphere.

The term ρ_{ra} accounts for the interaction between Rayleigh and aerosol scattering, e.g., photons first scattered by the air then scattered by aerosols, or photons first scattered by aerosols then by the air. This term is set to zero in the single-scattering case, in which photons are assumed be scattered only once (Gordon and Wang 1994).

The process of radiometric correction can be seen in Figure 2-1. From this process we got ρ_w and removed other reflectance, but this value is still affected by solar zenith angle and atmosphere from just above seawater to sensor. To remove this effect, is normalized ρ_w by the equation:

$$n\rho_w = \rho_w / t(\theta_0, \lambda),$$
$$t(\theta_0, \lambda) = \exp\left[- \{(\tau r(\lambda)/2) + \tau Oz(\lambda)\} (1/\cos\theta_0) \right], \qquad (2\text{-}2)$$

where τr and τOz are Rayleigh and ozone optical thickness and θ_0 denotes solar zenith angle. Then we converted back to radiance by the following equation:

$$nLw = n\rho w \,.F_0 \,/\, \pi, \qquad (2\text{-}3)$$

where F_0 is the solar irradiance. Finally, we got the normalized water leaving radiance *nLw*. The normalized water leaving radiances are the radiance that would be measured when the surface of the ocean is flat and the sun at zenith (directly overhead) and the atmosphere absent. The normalized water-leaving radiances are then used in algorithms to produce geophysical values, such as chlorophyll concentration. The radiometric correction has been processed using SeaDAS Software.

2.3 Chlorophyll-a Calculation

Chlorophyll-a concentration algorithm was developed based on semi-analytical, bio-optical of remote sensing reflectance (Rrs). The Rrs is calculated by the equation bellow:

$Rrs(\lambda) = nLw(\lambda) \ / \ F_0 \ (\lambda)$, (2-4)

where $F_0(\lambda)$ is mean solar irradiance. The "best" value of $F_0(\lambda)$ should be computed as a full band wavelength of $nLw(\lambda)$, but nominal value of $F_0(\lambda)$ is computed from a 10-nm square distribution, centered at the sensor nominal wavelength. For standard processing, the $nLw(\lambda)$ is reported as a nominal band value. From $Rrs(\lambda)$ we calculated the chlorophyll-a concentration (*Ca)* by the standard algorithm explained in MODIS Ocean Color Discipline website (O'Reilly *et al.*, 2000), then modified by OBPG (2010):

$$Ca = 10^{CR} \quad \text{mg/m}^3 \qquad (2\text{-}5)$$

$$CR = 0.2424 - 2.7423R + 1.8017R^2 + 0.0015R^3 - 1.2280R^4 \qquad (2\text{-}6)$$

where R = $\log_{10}$ ((Rrs443> Rrs489)/ Rrs547) and (Rrs443> Rrs489) is a shorthand representation meaning that the argument of the logarithm is the maximum of two values.

2.4 In-situ Data

The in-situ chlorophyll-a concentration data was collected during MOMSEI (*Monsoon Offset Monitoring and Its Social and Ecosystem Impact)* 2012 Cruise 25th April – 12th May 2012.

Sampling location shown in Figure 2-2(a) that are following MOMSEI station. Sampling preparation was done using standard procedure, seawater is taken from surface then 2 liters water was filtered and the filter stored in refrigerator. Chlorophyll-a concentration was measured after the cruise at the IPB (Bogor Agriculture Institute) Laboratory using APHA edition 21 2005 standard method Spectrophoto-meter based measurements. However, the spectrometer based measurement is not common use in ocean color field. Satellite-based ocean color corresponds to fluorometric measurement. In some cases, necessary to convert spectrometer-based measurement to fluorometric based using value correction by multiple with 0.64 (Darecki and Stramski , 2004). From this cruise was resulted 25 in-situ chlorophyll-a measurement. Continues measurement during the cruise was done using 10-AU fluorometer, but the result could not be used because continue measurement was failed in calibration.

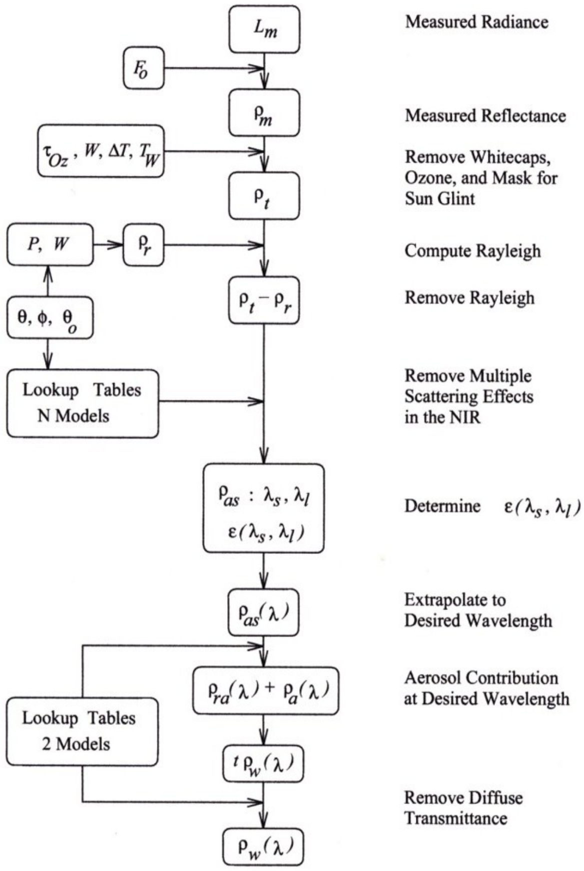


Figure 2-1: Flow diagram to derive the normalized water-leaving radiance algorithm processes (Gordon and Voss 1999)

The other source of in-situ data is also from archived data of the Research and Development Center for Marine Coastal Resources (P3SDLP), Agency of Marine and Fisheries Research and Development (Balitbang KP), Indonesian Ministry of Marine Affairs and Fisheries (KKP). Archived in-situ data belong to this Agency includes some ocean parameters and seems a complete data for all Indonesian seawaters. After filtered only data which contains chlorophyll-a measurement, the spreading of data was reduces a lot of only remain some station located in Pacific Ocean northward of Papua Island (See

Figure 2-2(b)). The method and instrument be used is unknown, what is spectrometric or fluorometric.

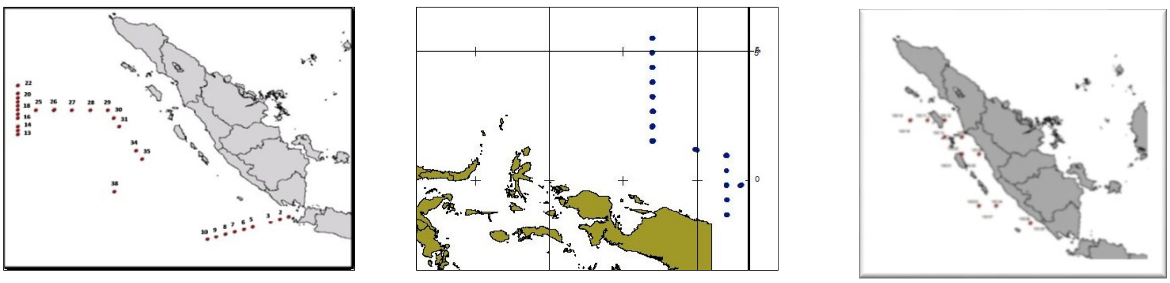
One more in-situ dataset is also got from the Research and Development Agency of Marine and Fisheries Affairs Ministry collected from SONNE 2005 Cruise (Baumgart *et. al.*, 2005). The chlorophyll-a measurement from water is collected from CTD and not from the surface water. There are a lot of data, then filtered into only upper layer data only (shallowest deep of water sampling). That's means the chlorophyll-a is not surface water and should be noted in discussion.

2.5 Match-Up Analysis

Match-up process between field chlorophyll-a and satellite-estimated chlorophyll-a done by WIM Match that is one of module in WIM Software. According to Kahru (2007) *Wam_match* is a complex utility that is based on WAM functions but also uses routines from other libraries (e.g. graphics and data grid). The purpose of *wam_match* is to generate match-up datasets between satellite and *in situ* data. The idea behind this utility is that you have a set of *in situ* data (a set of points) collected from a set of locations in space and time, i.e. specified by longitude, latitude and time. You then use a list of satellite images and try to find matching points between the points and the images by applying several constraints, e.g. that the time interval between the point value and the satellite pass is no larger than *dT* hours and the ground point is inside the satellite image and has valid values (i.e. is not cloud-covered or otherwise invalid). When making time comparisons between point and satellite data we therefore assume that the point data have a fixed sampling time (*Tpoint*) but the satellite data have a range from start (*Tstart*) to end (*Tend*). We set a maximum time difference *dTmax* and assume that we have a match-up in time between a point and a satellite image. Tpoint >= (Tstart – dTmax) and dPoint <= (Tend + dTmax).

The following figure illustrates this condition. Point time *Tpoint* can be between *Tstart* and *Tend* but does not have to. It needs to be between *Tstart – dTmax* and *Tend + dTmax*. Typical maximum time difference *dTmax* is 3 or 4 hours when using a single satellite pass but can be relaxed to cover more than 1 day.

The restriction on space is typically that the point sample is within a certain rectangular window centered at the nearest matching pixel. Typical windows are 3 x 3 or 5 x 5 pixels in size. It is possible to use the value from the single nearest satellite pixel but more often the mean or the median of the valid pixels within the 3 x 3 window are used. This is because the nearest pixel may not be the best match-up with a point sample considering advection by ocean currents during the time interval between the point sample and satellite image. Due to the limitation of in-situ data and to reach more pair of matchup data, the 28 hour different between in situ measurement and satellite data and 7x7 windows size were used in this analysis.



(a) (b) (c)

Figure 2-2: In-situ observation station location. (a) MOMSEI CRUISE 2012 (b) Archive Data In Situ P3SDLP-Balitbang KP (c) SONNE Cruise 2005

3 RESULT AND DISCUSSION

3.1 Accuracy Assessment

The need to understand the relationships between satellite data and ground measurements is fundamental in any application of satellite measurements. The problem is that satellites never measure exactly the same variables as ground measurements. Of course, ground measurements can also use different methods that need to be inter-calibrated and inter-validated (Kahru, 2007). To understand the performance standard algorithm work on Indonesian seawaters, the macth up analysis was done, using several of source of field data arround Indonesian seas. Unfortunately, only data from case 1 water was gotten and only from outer Indonesian seawaters. There were no data from case-2 water that issue of algorithm performance is interesting.

Using 3 different sources of field data, resulted 69 data that could be compared. The match-up resulted the MNB (%) is -4.8% that means satellite-estimated was underestimate in 4.8 % and RMSE was 0.058. This result seems fairly good, although this result was affected the low chlorophyll-a concentration that measured in deep ocean area. However, between field and satellite-estimated did not show good correlation and trend line equation (See Figure 3-1a). This result seems due to the different source of field data that might use different method to measured the field chlorophyll-a. Data from P3SDLP Balitbang KP was not known well what the method was used. Data from SONNE 2005 cruise were taken not from surface but from some meters of depth. To support this argument, the analysis was separated into the source of the data.

After the data was separated following to the data source, the correlation and trend line equation became better (See Figure 3-1b). From MOMSEI Cruise data, correlation equation was Y= 0.621X – 0.018, R^2 0.61, MNB(%) -48 % and RMSE 0.06. The correlation equation was better than previous correlation using all data, although R^2 increase to value 0.6 and MNB (%) decrease to -48%. This match-up result is better when the fluorometric correction following Darecki and Stramski (2004) was done. That the best result was gotten in this analysis (see Table 3-1) is correlation equation Y= 0.971X – 0.018, R^2 0.6, MNB(%) -18.8% and RMSE 0.05.

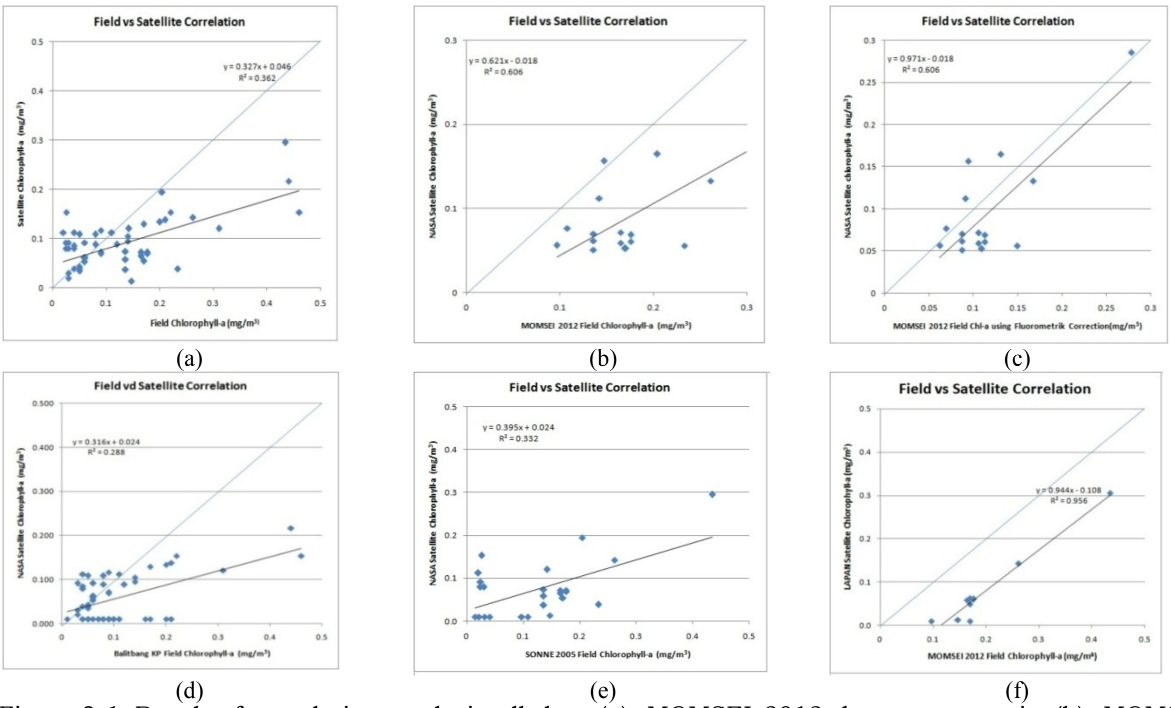


Figure 3-1: Result of correlation analysis all data (a), MOMSEI 2012 data no correction(b), MOMSEI 2012 data fluorometric correction(c), P3SDLP-Balitbang KP Data(d), Sonne 2005 data (e) and LAPAN satellite data with MOMSEI 2012 Data (f) respectively

Table 3-1: Match up result of in-situ data with satellite-estimated chlorophyll-a using standard algorithm at in-situ data sources different

No	Citra	In-Situ	Slope	Intercept	R^2	NMB (%)	RMSE	n (Data)
1	NASA Level-2	All	0.327	0.046	0.36	-4.8	0.06	69
2	NASA Level-2	MOMSEI 2012	0.621	-0.018	0.61	-48	0.06	17
3	NASA Level-2	MOMSEI 2012 Correction	0.991	0.018	0.60	-18.8	0.05	17
4	NASA Level-2	P3SDLP-Balitbang KP	0.316	0.024	0.29	-27	0.049	59
5	NASA Level-2	Sonne, 2005	0.395	0.024	0.33	14.7	0.059	26
6	LAPAN oc3	MOMSEI 2012	0.944	-0.108	0.96	-68.3	0.089	9

The correlation equation in better although is still in value 0.6 but MNB(%) and RMSE increase. This result is the best among other correlation in this research and the trend line was laid almost near and straight to prefect one by one line. The correlation from Balitbang KP and SONNE cruises was not so good (See Figure 3-1d and e) although fluorometric correction was done. The measurement method from 2 sources of field data is unknown and the SONNE cruise data was taken from some meters depth of water.

Compared with other region validation, this correlation result was still better. The best result validation was resulted by Campbell and Feng (2005) using NOMAD data with R^2 = 0,84 and RMSE = 0.277. Pan et al (2010) performed the correlation analysis in South China Sea using MODIS OC3M standard algorithm, the best result is in1x1 windows size and 48 hours different resulted correlation equation Y=0.966X+0.055 R^2= 0.557 and RMSE = 0.269. South China Sea was categorized case-1 waters or oligotrophic condition. The OC3M also work well at Eastern Arabian Sea that resulted no significant difference between insitu Chlorophyll-a and OC3M with R^2 = 0.73 and RSME = 0.309 and OC3M was supperior compared with GSM (Garver-Siegel-Maritorena) and GIOP (Generalized Inherent Optical Property) algorithm (Tilstone, *et al.*, 2013). The eastern Arabian Sea coastal shelf is influenced by river run-off, winter convection and monsoon upwelling (Tilstone, *et al.,* 2013), but this area faced derectly to Indian Ocean and seemed to be Case-1 waters.

Performance of MODIS standard algorithm was bad in case-2 water as Darecki and Stramski (2004) result. The nearest place of validation was in Malaka Strait (Ab.Lah *et al.*, 2013), resulted not so good correlation with R^2 = 0.031 and RMSE = 0.547 because that place seemed to be case-2 water in some part.

3.2 Chlorophyll-a Distribution

Information of chlorophyll-a concentration is important because marine productivity including fish and sea mammals depends entirely by the productivity of photosynthetic organism. Primary production is linked to fishery yield through bottom-up processes. Total primary production resulting from the photosynthetic process can be defined as the amount of organic matter produced in a given period of time. It is proportional to the chlorophyll-a values in the surface layer of the ocean (Zagaglia *et al.*, 2004). One of method that attempts to estimate phytoplankton biomass is to determine the quantity of chlorophyll-a in seawater. This method is often used because chlorophyll-a is universally present in all species of phytoplankton, can be easily measured, and its relative abundance enables to estimate the productive capacity of the phytoplankton community (Lalli and Parson, 1997).

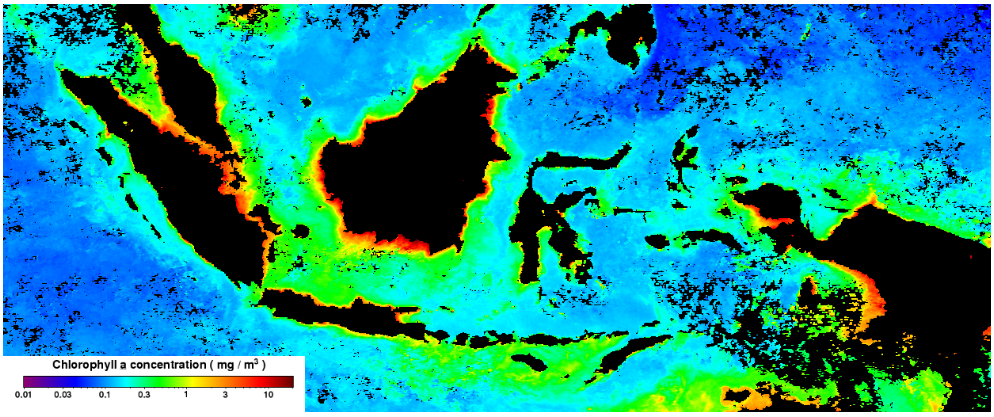


Figure 3-2: The Distribution of Monthly Average of Chlorophyll-a Concentration at Indonesian Seas estimated from MODIS Data (April, 2012)

The amount of chlorophyll-a concentration in the seas relates with the number of phytoplankton, the growing of phytoplankton increase the chlorophyll-a concentration. Collectively, phytoplankton grow abundantly in oceans around the world and are the foundation of the marine food chain (Herring, 2006). The growing of phytoplankton is influenced by available of sunlight and nutrient (Haney and Jackson, 1996). In tropical area sunlight be abundant enough that difference with sub-tropical and polar region. So the phytoplankton growing is driven only by the amount of available nutrient. Sunlight increases the sea surface temperature and generates strong water stratification that leads the lack of nutrient at the surface water. The source of nutrient is from deeper water and from river discharge.

Spatial distribution of chlorophyll-a concentration is showed on Figure 3-2. High chlorophyll-a concentration could be found at coastal area and at the open ocean the chlorophyll-a concentration is low. In-situ measurement of chlorophyll-a concentration resulted concentration around 0.2 – 0.5 mg/m^3, because the measurement was done at open ocean. High concentration also found at the area which oceanographic phenomenon pump up the deep water into to surface such as upwelling and water mixing due to strong wind that generate water mixing. Generally, Indonesian seas are affected by Asian monsoon that generate variation of wind speed and wind direction. In additional also affected by El Nino Southern Oscillation (ENSO) and Indian Dipole Mode. Siswanto and Suratno (2008) found the upwelling phenomenon at South of Java-Bali coast that is driven by monsoon wind. Relative high chlorophyll-a area was found at that area although that area was ocean.

Upwelling was also occurred at Arafuru Sea Waters during east monsoon (Aisyah, 2002 in Winarso and Kurniawan, 2014). The upwelling at Java-Sumatera Indian Ocean coast that related with ENSO was confirmed by Susanto *et al.*, (2001).

The other high area of chlorophyll-a concentration is Malacca Street which the main nutrient sources are river discharge and could be found along Kalimantan Island Coast, Northern Java coast and Southern Papua Coast. In Malacca Strait the high chlorophyll-a not only due to river discharge but also due to upwelling phenomenon and over estimation of chlorophyll-a algorithm caused by turbid water (Tan *et al.*, 2006). Over estimation could be happened also at almost coastal due to turbid water during river discharge. Wind driven mixing might possible to increase chlorophyll concentration as reported by Winarso (2012) that in Eastern Lampung Coast the chlorophyll-a enhancement occurred during northwest monsoon wind between Dec – Feb. This phenomenon clarified by fisherman that at that time the fish catch was increased.

The chlorophyll-a concentration was used for fisheries study. Sartimbul *et al.*, (2010) studied the variation of chlorohpyll-a concentration during 2003-2007 in Bali Strait Indonesia using MODIS satellite and their relationships with catch per unit effort of *Sardinella lemuru*. MODIS-derived sea surface temperature and chlorophyll-a consentration operationally used for producing fishing-ground information for whole Indonesias Seas (Pusfatja-LAPAN, 2013).

4 CONCLUSION

MODIS standard algorithm is work well in Indonesia case-1 seawaters both in-water algorithm and atmospheric correction model. The accuracy of estimated chlorophyll-a between 60-85 % using MNB (%) method analysis depend on the quality of field measurement data. The best result was came from MOMSEI dataset (n=17) after fluorometric correction with R^2 = 0.991 and RMSE 0.05. The MODIS standard algorithm is recommended to be used as standard algorithm for operational in case-1 Indonesia seas.

Due to the relatively small number of available in situ data and the fact that our in situ data set only represents the oligotrophic ocean (case-1) conditions, the algorithms evaluation have to be considered to be very preliminary and deep research into the reasons of global algorithm misfit are still needed. A larger data set of bio-optical in situ measurements is useful and obviously necessary to know the performance of the algorithm for a large region like Indonesian Seawaters.

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