

Comparison of Chlorophyll-a Measurement Using Multi Spatial Imagery and Numerical Model in Bali Strait

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Abstract. One of abundance of nutrient in coastal area is chlorophyll-a, where chlorophyll-a is a driving factor to derive fishing ground location. There's several method has been used to derive chlorophyll-a concentration from insitu data, remote sensing satellite data, and ocean dynamics models, but we are not decide those data for certain area in coastal area and open ocean. In this paper, we will use Aqua-Terra MODIS, Landsat -8 and INDESO Satellite observation dataset to detect chlorophyll-a and also using dynamic modelling produced by INDESO and MyOcean/Marine Copernicus. Using a lot variation of data to understand the differences of spatial resolution and accuracy with observed insitu data. After calculating data comparison with insitu data in bali strait on 2014, we can conclude that Landsat-8 data has the highest r value $r=0.41$. For model data, comparison between insitu data and MyOcean data has $r=0.3$. in the other hand, insitu data and INDESO data model has $r=0.26$. In coastal areas (case 2 water), Landsat-8 data performed to give detail information of chlorophyll-a. Furthermore for open ocean areas (case 1 water), we can use numerical model from MyOcean/Marine Copernicus because it has lower resolution and able to forecast. For those data, it can help non artisanal fisheries to predict chlorophyll-a area in their fishing ground areas

1. Introduction

Chlorophyll is one of oceanographic parameters that able to define a fishing ground location [19]. In the other hand, Bahrenfield (2006) mention that chlorophyll-a is supporting factor of phytoplankton number and productivity which is correspond with fisheries. Kunarso, et al [13] observe oceanographic parameters in southern bali to understand the highly connection between fish abundance and chlorophyll-a. Peak season of thunnus catchment when there's higher chlorophyll-a concentration. Therefore, we need precise and accurate method to determine the distribution of chlorophyll-a concentration in the ocean either on the coastal area or in the open ocean area.

We would like to understand how the best method are suitable for coastal and open ocean between satellite and numerical model data, so it could reduce cost of insitu measurement data retrieval. According to [16], from few past decade, an earth observation programme using satellite technology has been prioritized in research activities to investigate the quality of remote sensing data. Remote sensing technology has been used to detect chlorophyll-a, [2] using MODIS Satellite, [15] using MODIS, SEAWIFS and MERIS to explain reflectance uncertainty of chlorophyll-a value, [11] with ADEOS/OCTS satellite and [6] using Landsat-8 LDCM Satellite. Those satellite dataset has various spatial resolution. MODIS satellite with 1 km spatial resolution and Landsat-8 data with 30 m spatial



resolution. Based on these studies, algorithm and Landsat-8 satellite effectively identify chlorophyll-a distribution for coastal areas.

The weakness of remote sensing satellite to monitor chlorophyll-a daily is cloud [8]. Aqua-Terra MODIS Satellite and LANDSAT-8 are remote sensing satellite with passive sensor. Passive sensor needs energy source from the sun to observe object on earth. The sensor can not capture earth object with cloud.

Numerical models approach, which is combining satellite data and insitu data, is one of new approach to create oceanographic parameters data spatially without cloud. One of modelling data provider of chlorophyll-a in global areas has been launched by MyOcean/Marine Copernicus (<http://marine.copernicus.eu/>). Indonesia also has National Oceanographic Data Center located in Institute for Marine Research and Observation in INDESO Project (www.indeso.web.id). NODC INDESO Project produce oceanographic models of physical and biogeochemical which consist of chlorophyll-a models. Both models created by INDESO and MyOcean has 9 km grid resolution with 1 day temporal resolution forecasted for 10 days ahead. Using large scale modelling approach and forecasted, the model is expected to explain variation of chlorophyll-a in case-1 water and able to predict to help fisherman catch the fish. In the other hand, for case-2 water, the spatial resolution of models is not enough to describe dynamics of physical and biogeochemical parameters in case-2 water.

Both method to observe chlorophyll-a use several approach to get the data. In Kahru et al. [9] has been evaluate 5 satellite data to retrieve chlorophyll-a using standard algorithm from both satellite. In the other hand, the difference between multi spatial and multi sensor has been explained by [1] using airborne sensor hyperpectral CASI with 1 meter spatial resolution, Worldview-2 with 1,8 meter, Sentinel-2 with 20 meter, Landsat-8 with 30 meter and MODIS with 250 meter spatial resolution [17]. has been created simulation to understand the difference between temporal and spatial resolution from MODIS and 3 dimensional physical and biogeochemical oceanographic parameters developed by Hamburg University called ECOHAM 3 Model.

We would like to compare remote sensing satellite data and numerical model of chlorophyll-a parameter in case 2 water / coastal and case - 1 water / open ocean. Bali strait choosed as our research location because there's abundance of fisheries potential. Using this research to observe chlorophyll-a for fisheries, it has higher implication to artisanal fisheries and non artisanal fisheries in bali strait. Furthermore, it could be the direction for fishing ground location in coastal and open ocean.

2. Method

We are using 3 differences satellite remote sensing, Landsat-8, Aqua-Terra MODIS and INDESO Satellite Observation / INDESO Satobs. INDESO Satobs is re-analysis data from NPP Suomi Satellite VIIRS Sensor. Table 1 explain spatial, temporal and radiometrik from each satellite. And also we're using 2 different models came from INDESO Models using optimum interpolation and using open boundary condition, and also Marine Copernicus Models using optimum interpolation - regional kriging method.

Table 1. Satellite Remote Sensing Characteristic Comparison

	Landsat 8	Aqua-Terra MODIS	INDESO Satobs / NPP-Suomi VIIRS
Spatial	Multi : 30 m Pan : 15 m	Multi : 250 m, 500 m, 1000 m	Imagery band : 375 m Moderate band : 750 m
Temporal	16 day	1 day	1 day
Radiometric	16 bit	12 bit	12 it

2.1 Landsat 8

Landsat 8 data used in this paper is path row 117/066 downloaded from <http://earthexplorer.usgs.gov> using Bulk Download Application. Date of acquisition and imagery scene used in this paper mention in table 2.

Table 2. date and scene ID of Landsat 8

Path Row	Nama File	Tanggal	Waktu Perekaman
Path 117 Row 066	LC81170662014157LGN00	06.06.2014	10.29.38 WITA
	LC81170662014173LGN00	22.06.2014	10.29.41 WITA
	LC81170662014237LGN00	25.08.2014	10.30.03 WITA
	LC81170662014253LGN00	10.09.2014	10.30.07 WITA
	LC81170662014269LGN00	26.09.2014	10.30.04 WITA
	LC81170662014285LGN00	12.10.2014	10.30.11 WITA
	LC81170662014301LGN00	28.10.2014	10.30.09 WITA

7 scene imagery of Landsat -8 used to observe chlorophyll-a in bali strait has identic date of acquisition around 10.30 WITA and water sample acquisition around 07.00 - 11.00 WITA. The true colour of Landsat - 8 imagery shown in figure 1 below. Bali strait lies from 2,3 km to 53 km.



Figure 1. True Colour Composite of Landsat -8 path row 117/066 date acquisition september 26th 2014

Extraction of chlorophyll-a from Landsat-8 using Motoaki (1998) algorithm. This algorithm comes from ADEOS-OCTS satellite and modified in Hanintyo (2015) which has same wavelength with Landsat-8. Motoaki algorithm that has been modified shows below

$$chl = 0.2818 \left(\frac{L_3}{L_2} \right)^{3.497}$$

Where :

L2 = Reflectance value of Band 2 Landsat 8

L3 = Reflectance value of Band 3 Landsat 8

2.2 Aqua-Terra MODIS

The Aqua-Terra MODIS used in this paper came from Level 2 data of MODIS with Chlorophyll-a parameters. Those Level 2 data refers to ATDB MOD 22 of MODIS. The data downloaded from www.oceancolor.gsfc.nasa.gov with same acquisition date of Landsat-8 data. In figure 2 shows us the level 2 data of Aqua-Terra MODIS for Chlorophyll-a. The left image is an image before reprojection and the right image is an image after reprojection

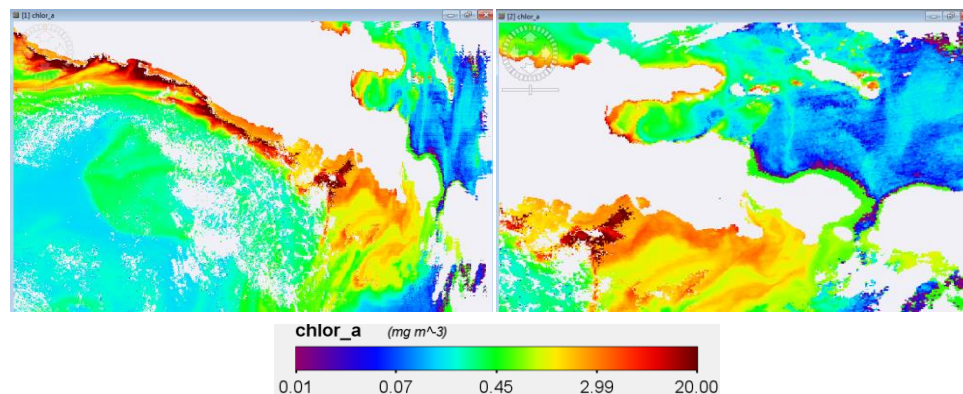


Figure 2. MODIS Level 2 chlorophyll september 26th 2014 before reprojection (left) and after reprojection (right)

2.3 INDESO Satellite Observation

The dataset of INDESO Satellite Observation / Satobs came from multiple satellite imagery to Chlorophyll-a parameters derive from VIIRS sensor on Suomi NPP Satellite [7]. There's 3 process has been done to derive INDESO Satobs data, which is level - 2 processing, level 2 editing and level 3 processing. This dataset has 0.02^0 spatial resolution or equal to 2,2 km. The dataset downloaded from INDESO webportal in <http://www.indeso.web.id>. In Figure 3 show us INDESO Satobs dataset for the whole data. The coverage of INDESO Satobs lies on Indonesia area and cover some part of south east asia, australia and papua new guinea. Some part of ocean areas, there is a blank area without data that indicate that areas are cloud. This is happening because this data was a reanalysis of satellite remote sensing imagery.

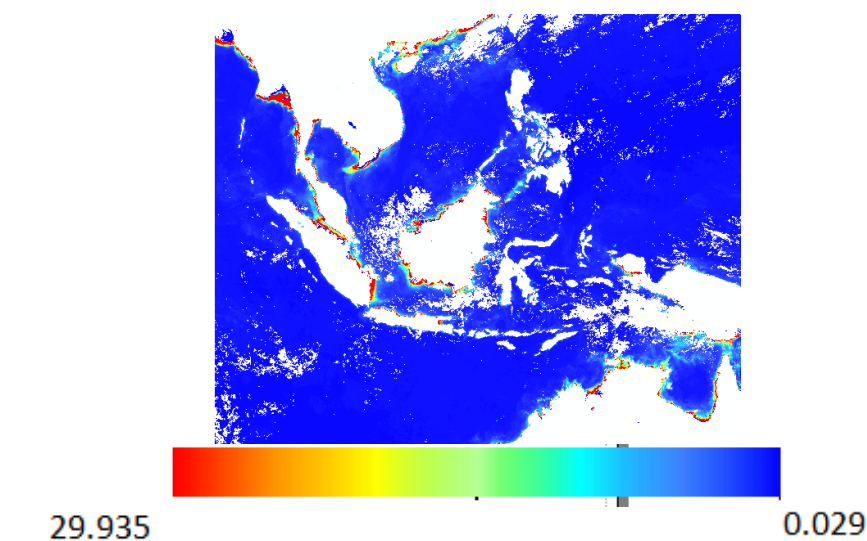


Figure 3. INDESO Satobs dataset for chlorophyll-a on februari 1st 2015

2.4 INDESO Optimum Interpolation Models

INDESO has been started operational since september 2014. Every thursday at 00.00 Central Indonesia Time (WITA), INDESO start creating numerical model for physical and biogeochemical oceanographic parameter and forecasted for 10 days ahead. SST_CHLA_NPP_cloudless will be used in this paper as INDESO Models data of Chlorophyll-a. This dataset will be renewed every thursday for 10 days ahead.

In the framework of INDESO Project, coupled model of physical and biogeochemical oceanographic parameter developed from 90-144 E and 20 S - 25 N which cover all Indonesia Areas [5]. Physical model (SST Parameter) based on OPA Model (NEMO2.3) will be called as INDO12 Model [18] In the other hand, Biogeochemical model simulated by PISCES Model version 3.2 [5]. Models simulated by Open Boundary Condition (OBC) to understand the condition of models. For biogeochemical models, OBC derived from a lot of climatology database such as nitrate, phosphate, dissolved silicate, oxygen, dissolved inorganic carbon and alkalinity [5]. For Physical oceanographic parameters, derived from the daily output of global ocean forecasting system on 1/4° produce by Mercator Ocean [18]. INDESO Model for chlorophyll-a show in figure 5. The data range lies from 0.04 ,g/m3 until 7.05 mg/m3. For this research, we will match up the dataset with the same date as Landsat-8 dataset passing.

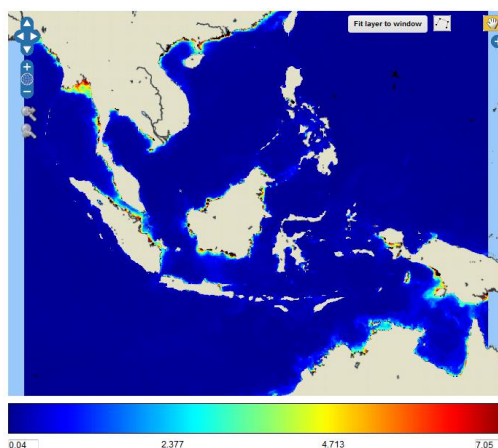


Figure 4. INDESO Chlorophyll-a models from INDESO (date : februari 1st 2015)

2.5 Marine Copernicus models

Marine Copernicus is one of project under European Commission which observe oceanographic parameters using remote sensing technology or using numerical model. In this research, we will use optimum interpolation - numerical model from Marine Copernicus downloaded from <http://www.Marine.copernicus.eu> with dataset called Global_ocean_color_chlorophyll_Optimal_Interpolation. We are using same timeframe as Landsat-8 passing date. To download Marine Copernicus Model, we are using Motu Python Script because there will be a large dataset and the possibility to subset the global dataset using Motu Python Script. Figure 5 shows the models of Marine Copernicus - chlorophyll-a parameters. This dataset has been cropped from global model with 25 N - 20 S and 90-160 E.

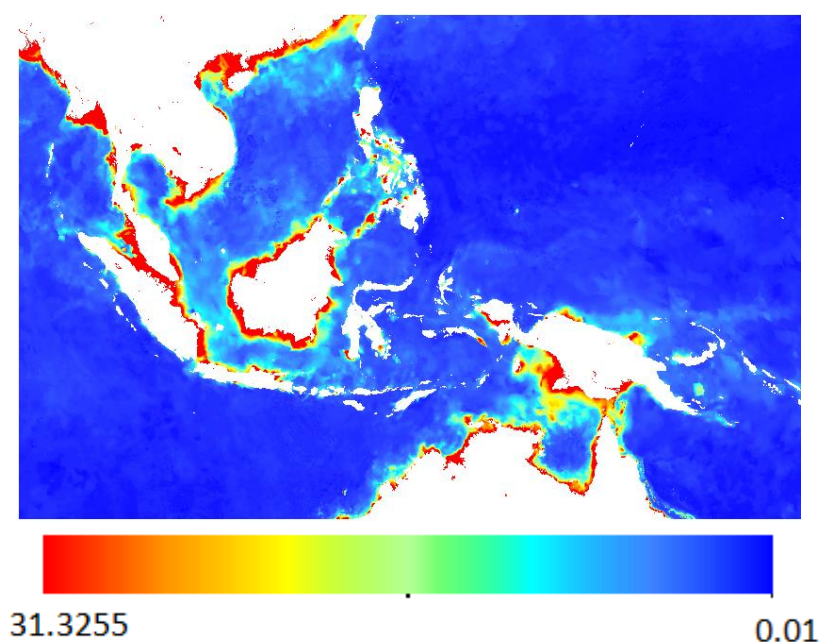


Figure 5. Marine Copernicus Models of Chlorophyll-a parameters

2.7 Field Observation Data

We have been held a field survey in Bali Strait started from June 1st 2014 until November 3rd 2014 to collect physical and biological oceanographic parameters. One of biological parameters is chlorophyll-a. For each day of survey, we have been collected 2 different locations. For this paper, we're using 7 days or 14 field datasets. For each field dataset, we will match up the coordinate with remote sensing imagery and models to read each chlorophyll-a value in the pixels.

The water sample that has been collected each day will be analyzed in a water quality laboratory in IMRO (LKP BPOL). LKP BPOL has been accredited by KAN no. LP-454-DN for ISO.IEV 17025-2005. Chlorophyll-a filtering using GFF filter paper and using UV-VIS Spectrometer Scotech SPUV-24. Figure 6 shows us the location of field survey for the whole date. Spatial location of field survey based on sardinella lemuru fisherman in Bali Strait. When fishermen catch sardinella lemuru fish, we are collecting the water sample for each site 5 liters. The sample will be delivered to LKP-BPOL to be analyzed using Standard Method.

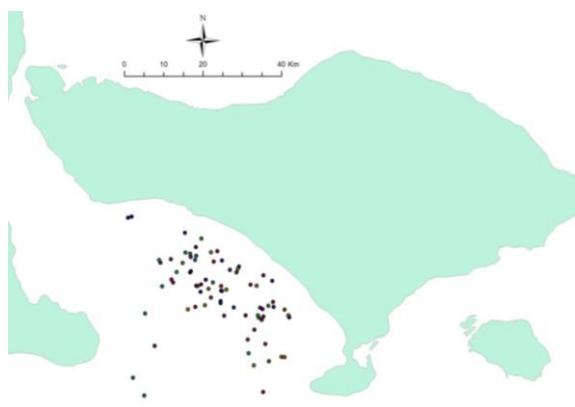


Figure 6. Location of field survey in Bali Strait from June until November 2014

3. Result

3.1 Landsat-8

The algorithm that has been used to detect chlorophyll-a on Landsat-8 satellite data, adopted from chlorophyll-a algorithm from Motoaki Kishino [11]. Those algorithm used for ADEOS-OCTS and has been modified as mention on Rizki, 2015. On Rizki [6] explained that there's a huge differences between ADEOS-OCTS and Landsat-8 data on green wavelength. ADEOS-OCTS has 2 band of green wavelength, in the other hand Landsat-8 just has 1 band of green wavelength. if we take a look deeper on the wavelength, ADEOS-OCTS lies between 0.511-0.575 μm , therefore on Landsat-8 lies between 0.525-0.6 μm .

Figure 7 is the result of chlorophyll-a algorithm of Landsat-8 on september 26th 2014 using modified algorithm from Rizki [6]. The chlorophyll-a has range from 0.0152 $\mu\text{g L}^{-1}$ until 0.2818 $\mu\text{g L}^{-1}$ with mean value 0.09622 $\mu\text{g L}^{-1}$.

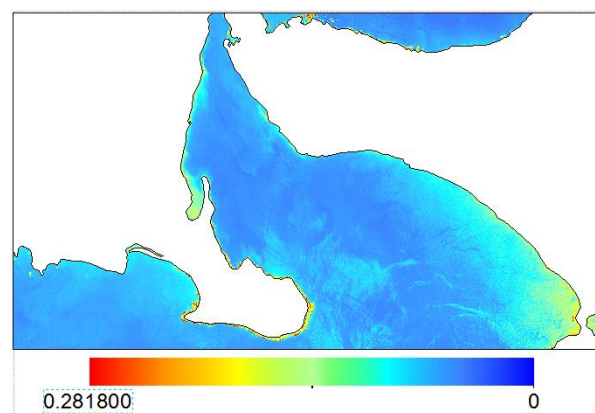


Figure 7. Chlorophyll - a data from Landsat 8 acquisition date September 26th 2014

In figure 8, we're able to see the negative correlation trends between satellite data from Landsat 8 and insitu data with $r = 0.41$. If we take look deeper on spatial distribution between insitu data position, we're able to see that on one pixels of Landsat data represent from one insitu data location.

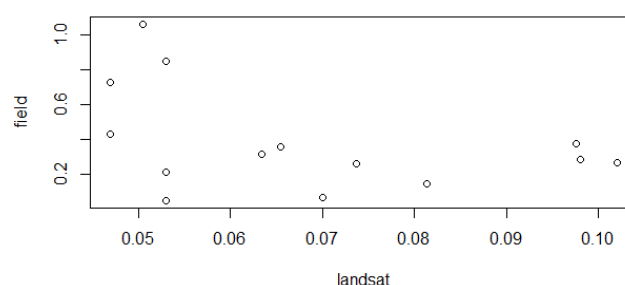


Figure 8. scatter plot of Landsat 8 data and insitu data

3.2 Aqua-Terra MODIS

The Aqua Terra MODIS satellite has a narrow wavelength (15 nm) to observe ocean color properties. Compared to Landsat 8 data, it has a wide wavelength (100nm) to derive chlorophyll-a. Chlorophyll-a algorithm for Aqua-Terra MODIS has been documented on Algorithm Theoretical Base Document / ATDB 19 [10]. Aqua Terra MODIS on figure 9 has lower spatial resolution (1km) compared with Landsat 8 data (30m). The coastline of bali unable to defined very well because of coarse spatial resolution. Un-mixing pixels will be occurred on some coastal object and the result of chlorophyll-a

parameter will be vary. On some location, we are able to see some cloud formation with white colour. On those area, we can not identify chlorophyll-a and other parameters.

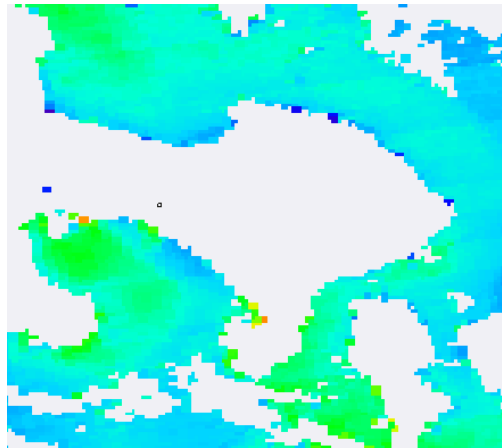


Figure 9. Level 2 chlorophyll-a imagery of Aqua Terra MODIS (acq date September 26th 2014)

Scatter plot on figure 10 shows us separability of modis and field data. There is 2 outlier with chlorophyll-a $2 \mu\text{g L}^{-1}$ concentration. Aqua Terra MODIS has low correlation with $r = -0.02$

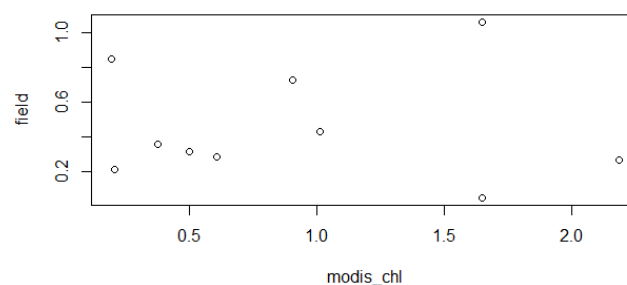


Figure 10. scatter plot of Aqua Terra MODIS

3.3 INDESO Satobs

The INDESO satobs data has 2 product on it, Sea Surface Temperature data and Chlorophyll-a data. The sea surface temperature data collected from 4 satellite data, which is

- Aqua MODIS Satellite
- Terra MODIS Satellite
- AVHRR Sensor on METOP-A Satellite
- AVHRR Sensor on METOP-B Satellite

In the other hand, for Chlorophyll-a data collected from VIIRS Sensor on NPP-Suomi satellite. The VIIRS data of INDESO collected from OceanColor Website on near real time with 5 hours delay from acquisition. The VIIRS sensor has 750m spatial resolution (Vandemuelen, 2015). There is 3 step to finalize level 1 VIIRS data to be INDESO Satobs data, which is :

- Level 2 processing, is a deriving phytoplankton data using Polymer Algorithm (Steinmetz, et al, 2011). The benefit of using that algorithm is able to compute phytoplankton on a thin cloud, dust and some area with sunglint. The level 2 processing of VIIRS on figure 11.

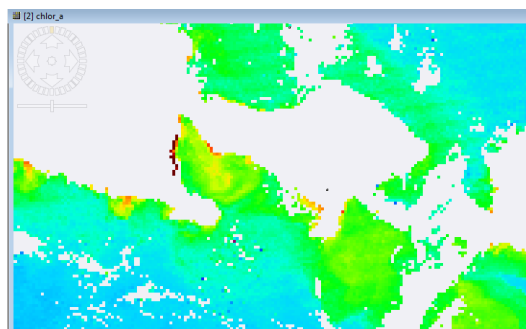


Figure 11. VIIRS level 2 processing over Bali Strait Area

- Level 2 editing, is a process to correct low quality pixel, de-stripping process using gaussian filtering and change grid size output with 0.01^0 spatial resolution.
- Level 3 processing, is a final data processing. Using imagery from 0.01^0 resolution and converted to 0.02^0 resolution / 2,2 km to get the INDESO Satobs data. Figure 12 is a result of INDESO Satobs data, which is a re-analysis data from 750m to 2,2 km. If we compare between figure 12 and figure 11, spatial resolution converting process reduce some details on coastal object.

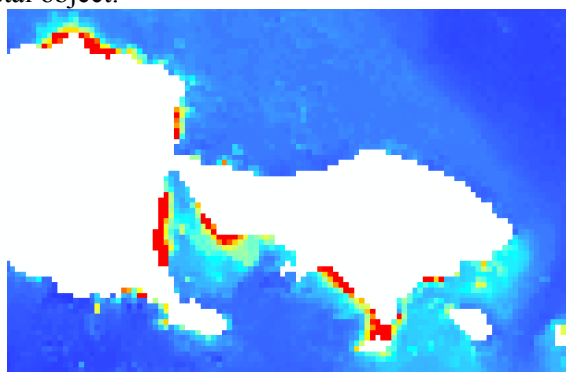


Figure 12. Result of Level 3 Processing of INDESO Satobs data.

3 dimensional scatter plot on figure 13 shows data of INDESO Satobs, Landsat data and field data. The effect of spatial resolution occur between INDESO Satobs data with Landsat data, which is INDESO Satobs data seems overvalue compared with Landsat and field data. Using up scaling of VIIRS data on INDESO Satobs data, the pixel value that has been filtered using gaussian filter. The gaussian filter is a low pass filter that will make a pixel smoother [3]. On 2 dimensional scatter plot (figure 13), there is a negative correlation between INDESO Satobs data and field data with r value $r = -0.25$.

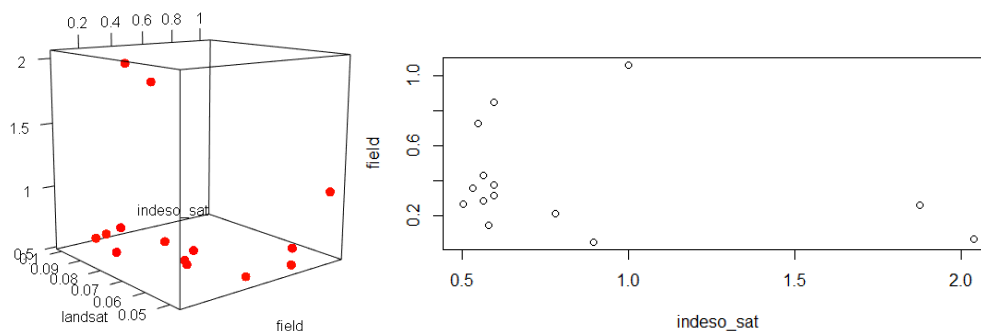


Figure 13. 3 dimension chart and scatter plot of INDESO Satobs data

3.4 INDESO Optimum Interpolation

INDESO Optimum Interpolation / INDESO OI downloaded directly from INDESO web portal on www.indeso.web.id. the downloaded data is a gridded data with a netCDF format. "Multidimension Tools" on ArcGIS has been used to extract this data. Extraction of INDESO OI data on specific location of field data using "extract multi value to point" tools on ArcGIS.

On figure 14, we can not see a cloud formation on INDESO OI data. That is a benefit using numerical model method. Therefore, using numerical model will resulted a coarse spatial resolution and a lower information of coastal object. For example, we can not extract information near Benoa port of Bali, because the spatial resolution is coarse.

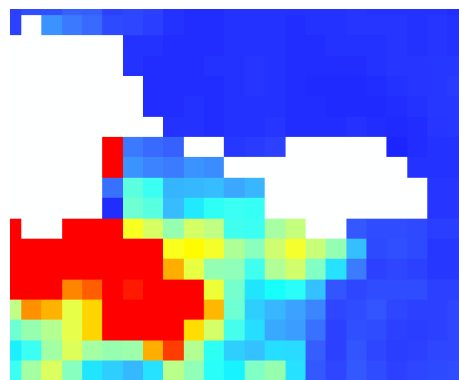


Figure 14, Raster view of INDESO OI data over Bali Strait on September 26th 2014.

3 dimensional scatter plot on figure 15 resulted a difference between field observation with INDESO OI data and Marine Copernicus / MyOcean Models. On 3d scatterplot, there are differences of maximum and minimum value from each data. INDESO OI data tend to be overestimated compared with field data, even MyOcean data is more overestimated. On 2d scatterplot, there is no linear regression and has negative correlation with $r = -0.26$.

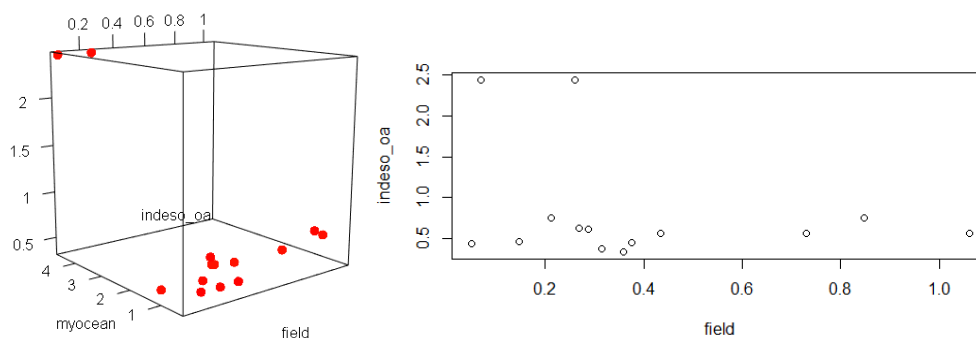


Figure 15. 3D and 2D scatter plots of INDESO OI data.

3.5 Marine Copernicus Model

Marine Copernicus / MyOcean Models developed using Optimum Interpolation Method. The models have 2 inputs from level 2 chlorophyll-a VIIRS sensor of NPP Suomi Satellite and Level 2 chlorophyll-a from MODIS. OI Models developed using "Regional Kriging Anisotropic Covariance Models". Compared to INDESO OI data, Marine Copernicus has a higher spatial resolution of input data. Using a higher spatial resolution input data, this model has a better spatial resolution (compared with INDESO OI) with 4.4 km. Figure 16 below is a result of the Marine Copernicus Model. Details of coastal objects have been better defined.

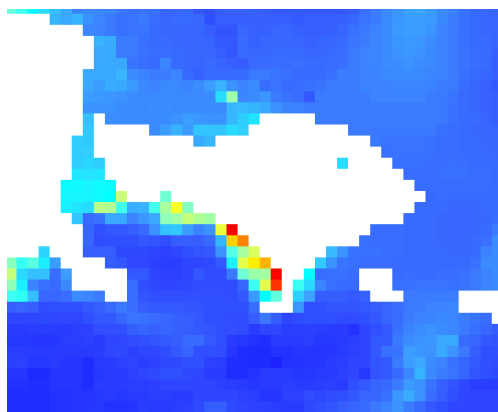


Figure 16. Raster view of Marine Copernicus model over Bali Strait on February 1st 2015.

On figure 17, scatter plot between Marine Copernicus data and field data show us that there's a huge different range between those data. As mentioned on INDESO OI, Marine Copernicus data tend to be overestimated where Marine Copernicus data has a data range from 1 - 4 $\mu\text{g L}^{-1}$. In the other hand, the field data range from 0 - 1 $\mu\text{g L}^{-1}$ and also has low r correlation with $r = -0.30$.

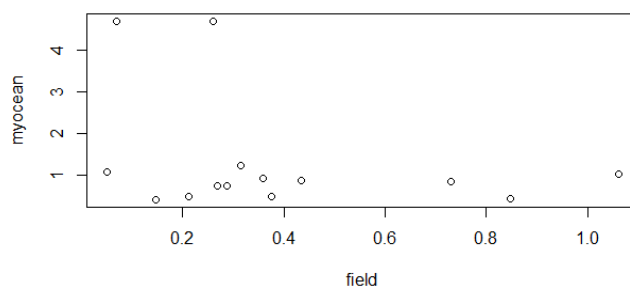


Figure 17. scatter plot between Marine Copernicus data and field data.

After extracting pixel value on field survey, these chart below on figure 18 show r value of each data on one chart. Figure 18 is a plot with r value for remote sensing and field data. We are using R script and a code from [20] to create this chart. Based on chart, Landsat data has a higher correlation with field data. Spatial resolution as a main factor of it. 30 meter spatial resolution able to describe chlorophyll-a value over coastal areas. The second factor is a depth of bit data where Landsat 8 has 16 bit data will has a pixel range from 0 - 65535. Pixel value of Landsat was so detail, so does chlorophyll - a value. Landsat 8 data able to help artisanal fisheries to understand where is the highest chlorophyll-a concentration.

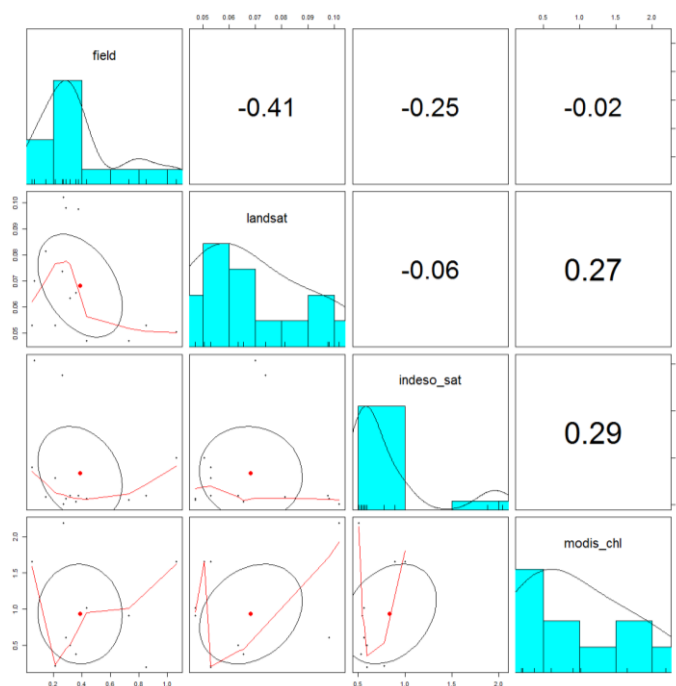


Figure 18. scatter plot and r value of remote sensing data.

For next figure, on figure 19, is chart for numerical model data. The chart show us that Marine Copernicus Model has higher correlation value than INDESO OI data. As stated above, spatial resolution is a main factor where Marine Copernicus has 4,4 km resolution and INDESO OI has 9 km resolution. Numerical model has a forecasting benefit and also a cloud free data. As marine copernicus has a good correlation value, it will be a benefit for bigger fisherman (more than 30 GT ships) to understand chlorophyll-a concentration on case - 1 water with a good prediction.

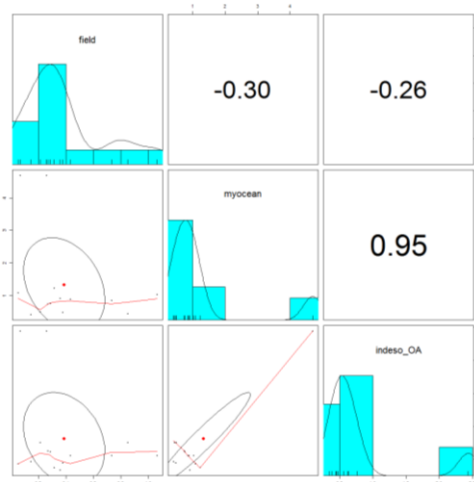


Figure 19. scatter plot and r value of numerical model data

4. Discussion

Based on measurement above, Landsat 8 data has the highest correlation value than the others. On Landsat data, one field data represent one pixels. But if we plot field data to model or remote sensing

imagery with lower spatial resolution, there will be one pixel on more than 2 field data, as we can see on figure 20.

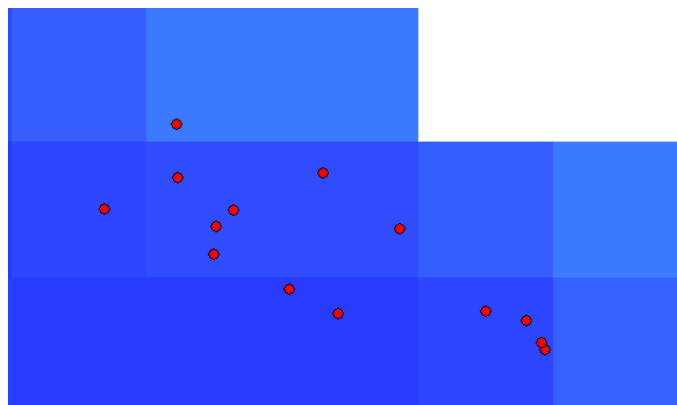


Figure 20. field data on INDES OI data models.

Differences of spatial resolution on remote sensing data is one of challenges to observe earth object. Landsat 8 data will be fitted to used by artisanal fisheries on case - 2 water because of higher spatial resolution but lack of temporal resolution (16 days). For prediction capability, Marine copernicus data will be a good data for fisheries on case - 1 water because it has a good spatial resolution then INDES OI data. We need a field observation data with a different range between field data to observe pixel per pixel. As mentioned on [18] and [5], insitu data for numerical model has a sparse distribution, so they can able to describe pixel per pixel observation.

5. Conclusion

Landsat 8 data has a tendency to approach with the result of field observation. Landsat 8 data good to be used for monitoring chlorophyll -a on coastal areas with a good spatial resolution (30 meter). In the other hand, Landsat 8 data has laxity of temporal resolution (16 days). Marine Copernicus data model good to be used for monitoring chlorophyll-a concentration on case -1 water because it has lower spatial resolution and prediction capability.

We need more analysis of numerical model data. The point sof representative field observation data of pixel values of numerical model is strongly recommended. It also necessary to develop algorithms for Landsat 8 Chlorophyll-a. The algorithm given that we used have a undervalue the estimated field data.

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