Sea Surface Temperature Mapping at Medium Scale Using Landsat 8 -TIRS Satellite Image

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Kata Kunci— Mono Window Algorithm, Split Window Algorithm, Algoritma Planck, Syariz, Peta SPL Skala Menengah

***Abstract*— The Sea Surface Temperature (SST) retrieval from satellites data has been available since 1980's both temporally and spatially. Some researchers have established SST inversion models depending on the correlation between the TM/ETM+ TIR radiance and the in-situ data. The objective of this research is to evaluate the performance of Landsat 8-estimated SST from 4 existing algorithms: Planck, Mono-Window Algorithm (MWA), Syariz and Split Window Algorithm (SWA) algorithms on 4 different tested areas: Eastern Bali, Bangkalan, Bombana and Poteran waters. Algorithm of Syariz dan SWA produced acceptable accuracy on all tested area with the NMAE ranged at 0.2-19.6% and 3.4-9.9% for Syariz and SWA, respectively. However, MWA and Planck produced NMAE larger than 30% on Bali and Poteran waters. Following the successful of SWA algorithm, the same algorithm was developed using insitu data collected on Poteran waters. The estimated SST by the developed algorithm produced acceptable accuracies on all tested water areas with the NMAE ranged from 0.401% to 16.630%. It was indicated that Syariz, SWA and the developed algorithms were applicable for SST retrieval on all tested waters**

Keywords—Mono Window Algorithm, Split Window Algorithm, Planck Algorithm, Syariz Algorithm, Medium Scale SST Map

I. INTRODUCTION

Indonesia is an archipelagic country, which has about 17,500 islands with sea area of 2,981,211 km^2 [1], [2]. Because of this vast territory, we need a method that can present sea conditions and its changes spatially and temporally.

Sea Surface Temperature (SST) is one of water quality parameters that need to be measured for monitoring sea condition[3]–[5]. SST is used for meteorological study, fish feeding speed and distribution as well as growth metabolism and abundance of fish.

For monitoring SST that change spatially and temporally, a method utilized remote sensing technique by considering atmospheric effect is recommended [6]. Fortunately, remote sensing can offer repetitive, consistent, efficient and comprehensive spatial and temporal views[7]–[9].

The development of remote sensing technology is very fast, many satellites are equipped with thermal infrared sensors to estimate SST, both oceanographic satellites and Earth resource satellites. Several studies have been conducted using NOAA-AVHRR, MODS, Fengsyun and Nimbus satellite imagery. The satellites work well on a very wide area but have low spatial resolution.

In this research, the study area was in shallow water and near coastal areas that require more high-resolution images to avoid a pixel mixing between water and land that occurred in low spatial resolution image. However, for SST study, a thermal infrared (TIR) band is required and not equipped in high resolution image. For this case, a medium spatial resolution image such as Landsat 8 (with two TIR bands) and Sentinel 2 data could be used.

Many factors influence the accuracy of water parameters retrieval (e.g. SST), especially the effect of the atmosphere. Difficulty in atmospheric correction limits the use of TIRs band in coastal and inland waters [10]–[14]. Several studies have developed SST algorithms based on a correlations between TIR radian data and in situ temperature data [15]. It this research we evaluated the applicability of some existing algorithms such as Plank algorithm, Mono-Window Algorithm (MWA), Syariz algorithm, and Split Window Algorithm on Indonesia waters especially in Bombana, Bangkalan, East Bali and Poteran island waters

II. METHOD

A. *Tools and Data*

To test the performance of each existing algorithm, the in-situ SST data has been collected from 4 different regions as well as its corresponding Landsat-8 data (with the same acquisition time as the in-situ data). The distribution of area study was presented in Figure 1. Following Satellite data collected on:

(1) Bombana Coastal Area: LC81130632015324LGN00 (November 20, 2015)
(2) Bangkalan Coastal Area: LC81180652015295LGN00 (October 22, 2015)
(3) Eastern Bali: LC81160662016076LGN00 (March 16, 2016)
(4) Poteran Island: LC811706520151t12LGN00 (April 22, 2015)

All processing steps were performed in QGIS and SNAP software.

B. *Research Method*

The first process was conversion the value of Digital Numbers (DN) to radians. The equation used was as follows:

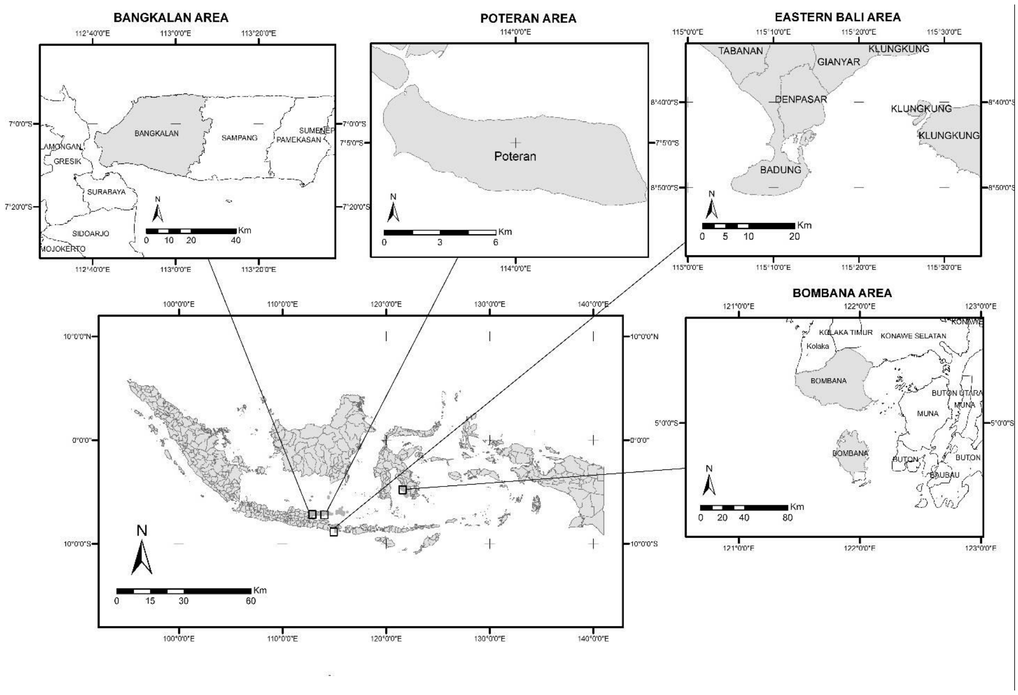

Figure 1. Study Area

$$L_\lambda = M_L Q_{cal} + A_L \quad (1)$$

L_λ is top of atmospheric radiance, M_L is multiplicative rescalling factor for each band, A_L is additive rescaling factor, Q_{cal} is digital number (DN) from the image, and A_L is *offsets* for TIR bands [16].

This radiance value than converted into Brightness Temperatur using an equation as follow*:*

$$T = \frac{K2}{ln(\frac{K1}{L_\lambda}+1)} \quad (2)$$

T is Brightness Temperature in Kelvin. K_1 and K_2 is thermal conversion factor [17].

Plank and Mono-Window Algorithm (MWA) algorithms need object emissivity value that related to the thermal infrared energy emitted by the object. These two algorithms generally implemented over land surface area, that required the value of Normalized Difference Vegetation Index (NDVI). The equation used to calculate the object's NDVI value was explained in the equation (3):

$$NDVI = \frac{NIR-R}{NIR+R} \quad (3)$$

NIR and *R* are remote sensing reflectance at near infrared and red band, respectively.

Based on Ndossi [16] Zhang's algorithm, has the best performance in Landsat-8 surface temperature retrieval. Zhang's algorithm determined the surface temperature based on classified pixel values by each pixel class.

The SST value using Plank function and MWA algorithm can be performed after the surface temperature was determined. The Plank algorithm was described in equation (4) below:

$$T_S = \frac{BT}{\left\{1+\left(\frac{\lambda.BT}{\rho}\right).ln\varepsilon\right\}} \quad (4)$$

T_s is SST in Kelvin (K); *BT* is Brightness Temperature at sensor (K), λ is wavelength ; ρ is $(h*c/\sigma)$ = $1.438.10^{-2}$ *mK;* and ε is spectral emissivity [16].

MWA algorithm was explained as follow:

$$Ts = \frac{a_i(1-C_i-D_i)+[b_i(1-C_i-D_i)+C_i+D_i]T_i-D_iT_a}{C_i} \quad (5)$$

T_S is SST in Kelvin, T_i is Brightness Temperature*,* T_a is average atmospheric temperatur, a_i = -67.355351, b_i = 0.458606. The value of C_i and D_i can be calculated using following equations:

$$C_i = \varepsilon_i \tau_i \quad (6)$$

$$D_i = (1-\tau_i)[1+(1+\varepsilon_i)\tau_i] \quad (7)$$

ε_i is surface emissivity and τ_i is atmospheric transmittance [16].

Syariz [3] developed an algorithm to obtain SST value at Poteran Island waters area by using a regression model of in-situ measured temperature and corresponding Landsat 8 brightness temperature. For band 10, Syariz provided three different regression model for linier and polynomial equations as follow:

$$y=-0.0835x+31.192 \quad (8)$$

$$y = -0.0273x^2 + 0.7474x + 43.461 \quad (9)$$

$$y = -0.0054x^3 + 0.2166x^2 - 2.9425x + 43.461 \quad (10)$$

x is Brightness Temperature in celcius (^oC), and y is estimated SST (^oC).

For band 11, Syariz also provided three different regression model for linier and polynomial equations as follow:

$$y = -0.0996x + 30.899 \quad (11)$$

$$y = -0.0273x^2 + 0.7474x + 43.461 \quad (12)$$

$$y = -0.0054x^3 + 0.2166x^2 - 2.9425x + 43.461 \quad (13)$$

In this study, the equation (13) was used.

Split Window Algorithm (SWA) was developed for surface temperature. In this study we follow the modified MWA developed by Agung [4], as explained in equation (14)

$$T_s = BT_{10} + \left(2.946 \times (BT_{10} - BT_{11})\right) - 0.038 \quad (14)$$

T_s is SST in Celcius (^oC), BT_{10} and BT_{11} are Brightness Temperature at band 10 and 11 [4].

C. Accuracy assessment

The accuracy of estimated temperature was assessed using determination coefficient (R^2) and *Normalized Mean Absolute Error* (NMAE) as follow:

$$r = \frac{N\sum_{i=1}^{N}(x_i y_i) - (\sum_{i=1}^{N} x_i)(\sum_{i=1}^{N} y_i)}{\sqrt{(N(\sum_{i=1}^{N} x_i^2) - (\sum_{i=1}^{N} x_i)^2)(N(\sum_{i=1}^{N} y_i^2) - (\sum_{i=1}^{N} y_i)^2)}} \quad (15)$$

$$NMAE = \left(\frac{1}{N}\sum \frac{x_i - y_i}{y_i}\right) \times 100\% \quad (16)$$

x and y are estimated and in-situ measured SST, N is the number of sample.

III. RESULTS AND DISCUSSION

A. Existing Algorithms

As presented in Table 1, the performance of all existing algorithms slightly different on different tested area. On Eastern Bali waters, the most accurate algorithm produced by Syariz (NMAE of 2.4%), following by SWA, Planck and MWA with NMAE of 9.9%, 31.3%, and 31.5% respectively. In this region, only Syariz and SWA algorithms met the minimum accuracy requirements (NMAE ≤ 30%).

Table 1. Estimated Sea Surface Temperature

Area	Alg's	Ave. SST (^OC)	MaxSST (^OC)	Min. SST (^OC)	NMAE (%)	N
Bali	Syariz	27.592	28.243	27.353	2.408	17
	Plank	18.521	19.073	16.923	31.262	
	MWA	21.878	22.415	20.323	31.506	
	SWA	29.603	30.232	27.840	9.865	
Bang-kalan	Syariz	23.467	24.840	21.153	19.556	12
	Plank	25.685	28.750	23.695	12.051	
	MWA	25.616	28.679	23.627	12.288	
	SWA	30.474	36.618	25.796	4.204	
Bom-bana	Syariz	28.574	28.611	28.549	19.284	5
	Plank	23.387	23.644	23.011	33.960	
	MWA	23.375	23.632	22.999	33.992	
	SWA	33.205	33.641	32.848	6.225	
Poteran	Syariz	31.315	31.997	28.880	0.218	48
	Plank	8.429	10.934	-0.500	71.827	
	MWA	8.366	10.871	-0.604	72.03	
	SWA	31.016	34.081	22.175	3.452	

On Bangkalan waters, the most accurate algorithm produced by SWA (NMAE of 4.2%), following by Planck, MWA and Syariz with NMAE of 12.1%, 12.3%, and 19.6% respectively. In this region, all algorithms met the minimum accuracy requirements.

On Bombana waters, the most accurate algorithm produced by SWA (NMAE of 6.2 %), following by Syariz, Planck and MWA with NMAE of 19.3 %, 34.0%, and 34.0% respectively. In this region, only SWA and Syariz algorithms met the minimum accuracy requirements.

On Poteran waters, the most accurate algorithm produced by Syariz (NMAE of 0.2%), following by SWA, Planck and MWA with NMAE of 3.4%, 71.8%, and 72.0% respectively. In this region, only Syariz and SWA algorithm met the minimum accuracy requirements.

B. Developed Algorithm

The split window algorithm (SWA) developed by Cahyono [4] using insitu data collected on Sidoarjo's coast produced the most accurate result compared with other existing algorithm. Following his idea, the same algorithm was developed using insitu data collected on Poteran waters and validated on 4 different waters location.

Insitu data from Poteran waters and its corresponding satellite reflectance data collected on 24 stations (from 48 stations in total) were used to develop a new algorithm. This algorithm was based on a linear regression between insitu temperature (TSS) data and absolute difference between *Brigthness Temperature* at two thermal infrared bands as presented in Figure 2.

From above figure, a linier regression to calculate SST from two TIR bands as follow:

$$y = 0.146x + 29.147 \quad (17)$$

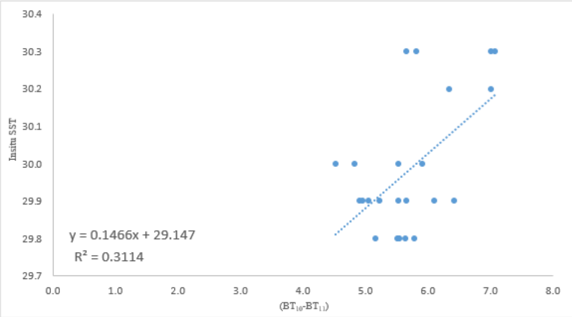

Figure 2. Relationship between insitu SST and absolute difference of two TIR bands

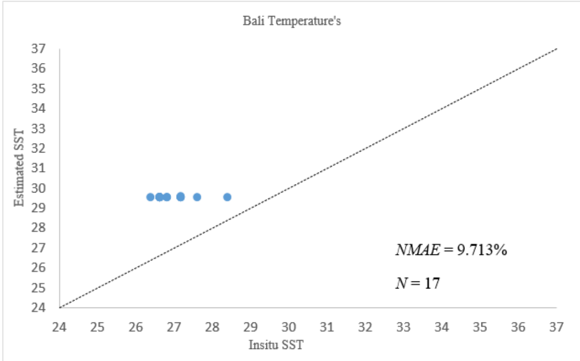

Figure 3. SST on Bali waters: estimated vs. insitu

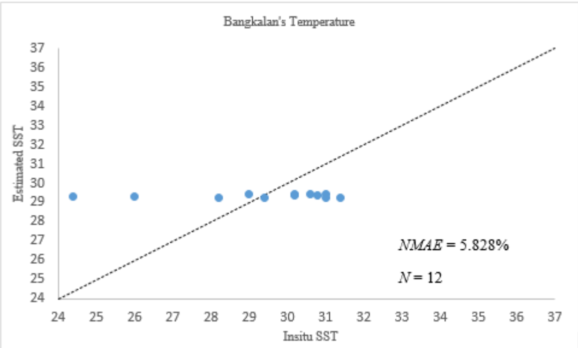

Figure 4. SST on Bangkalam waters: estimated vs. insitu

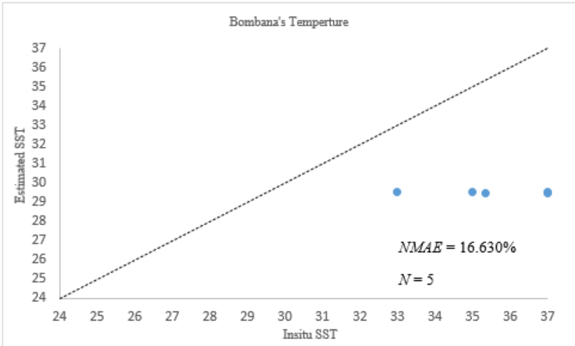

Figure 5. SST on Bombana waters: estimated vs. insitu

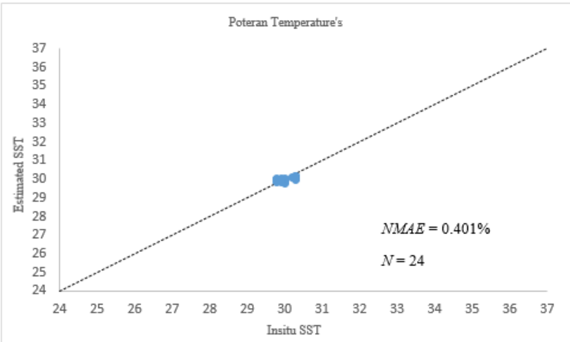

Figure 6. SST on Poteran waters: estimated vs. insitu

Table 2. Accuracy Assessment

Area	Average SST (^{o}C)	Max. SST (^{o}C)	Min, SST (^{o}C)	NMAE (%)	N
Bali	29.562	29.589	29.550	9.713	17
Bangkalan	29.331	29.451	29.231	5.828	12
Bombana	29.515	29.522	29.507	16.630	5
Poteran	29.983	30.184	29.804	0.401	48

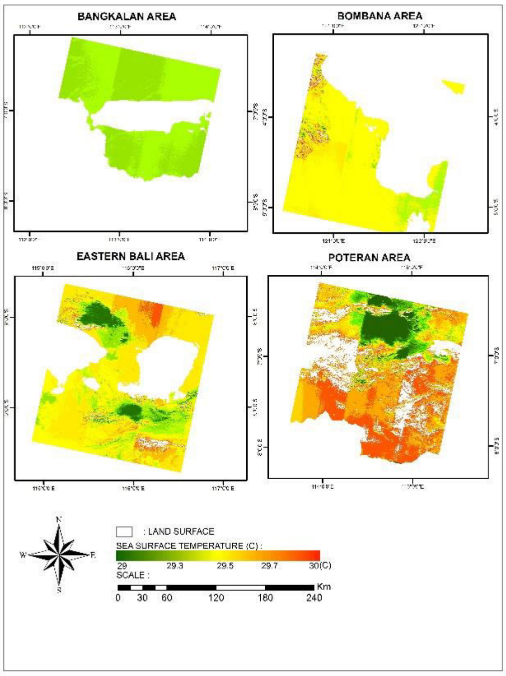

Figure 7. Distribution map of SST

x is the absolute difference of *Brightness Temperature* at band 10 and 11.

The validity of developed algorithm was tested on 4 different waters: Poteran (at different station location with the station used for algorithm development), East Bali, Bangkalan and Bombana waters. Accuracy assessment result was presented in Table 2. The estimated SST by the developed algorithm produced acceptable accuracies on all tested water areas with the NMAE value ranged from 0.401% to 16.630%.

Relationship between in situ SST and estimated SST by the developed algorithm were presented in Figure 3-6

C. Sea Surface Temperature Mapping

The developed algorithm was used to estimated SST for 4 full scene areas of study based on Landsat 8 data as presented in Figure 7. Generally, this algorithm produced SST in the range of 29°C to 30°C. In the scene of Eastern Bali and Poteran waters, many pixels at SST map were cover by cloud.

IV. CONCLUSION

We have processed remotely sensed data acquired by Landsat 8 for assessing the performance of 4 existing SST retrieval algorithms. Algorithm of Syariz dan SWA produced acceptable accuracy on all tested area with the NMAE ranged at 0.2-19.6% and 3.4-9.9% for Syariz and SWA, respectively. However, MWA and Planck produced NMAE larger than 30% on Bali and Poteran waters. Following the successful of SWA algorithm, the same algorithm was developed using insitu data collected on Poteran waters. The estimated SST by the developed algorithm produced acceptable accuracies on all tested water areas with the NMAE ranged from 0.401% to 16.630%. It was indicated that Syariz, SWA and the developed algorithms were applicable for SST retrieval on tested waters

V. ACKNOWLEDGEMENT

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