Pre-analysis assessment of Sea Surface Temperature (SST) products in the region of Malaysian coastal water

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Abstract. This paper presents the pre-analysis of validation between the acquisition satellite data and in situ data. To carry out this assessment, Sea Surface Temperature (SST) data are acquired to be regressed with SST In situ. With the launch of the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite with a sensor on the Terra spacecraft, data sets of the global distribution of sea surface temperature are retrieved, and need to be validated and analyzed. Radar Altimeter Database System (RADS) also has an archived data of Optimal Interpolation SST (OISST) that can be retrieved based on satellite track of altimeter. The aim of this paper is to present inter-comparison study between pixel based (MODIS SST) and point based (RADS SST). The value of root mean square error (rmse) is computed to see the performance of the data product. It is an assessment and evaluation to see the performance for both data. The objective of this paper is to evaluate Malaysian coastal area through validation with in situ data. To achieve the objective, we perform pre-analysis study of the MODIS products and RADS SST to see the performance of both data in terms of spatial value during seasonal changes. However, the scope of this analysis covers only on the spatial MODIS pixel value and the OISST point value during the southwest monsoon daytime. From the result, RADS SST/RADS show higher root mean square error (rmse) at 0.731/0.677 (before calibration) and 0.6951/0.476 (after calibration). From the rmse result, we could deduce that the RADS SST has random error arising from the fact that the interpolated points are based on the track.

1. Introduction

The Southern South China Seas (SSCS) is connected with the Sulu Sea in the east of Mindoro and Balabac straits with average depth of 60 metre. The SSCS has complex geographical setting that influences the sea surface current circulation. The sea surface current circulation at the SSCS is controlled by monsoon. Weaker southwesterly summer monsoon winds prevail from April to August causing great circulation coastal jet off the Vietnam[6]. However, there is still lack of understanding of water characteristics during seasonal changes. There are previous studies on the water characteristic in the Malaysia coastal area through intensive hydrography observation but it is limited...
to certain area and time [8]. The understanding about the physical characteristics such as current circulation, temperature/salinity profile is limited to the observation carried out. Furthermore previous study by [12], provide some understanding of the SSCS in small area which does not include Malaysian coastal area.

With the availability of satellite derived sea surface temperature (SST), we have improve our understanding the characteristics of surface water. The satellite data covered large area and high resolution depending on the product of SST. For Moderate Resolution Imaging Spectroradiometer(MODIS)SST product, the data have been established since 2000 until present with improvement of the payloads sensor on the platform. MODIS is freely available at the web based oceancolor. SST studies using MODIS in Malaysia has been done by [8] with interest on the surface circulation monitoring. MODIS have sensor on board of TERRA and AQUA, the data is available in pixel based sensor. However, the Malaysian coastal area is less covered by the MODDIS daily resolution data, having SST spatial characteristics information about Malaysian coast limited only to the availability of the imageries data.

With various improvement such as data impairment techniques, SST is available on a weekly basis with a large scale area. Data undergoes interpolation process to fill gap and such interpolation technique requires error control. Interestingly, NOAA provides data interpolation known as Optimal interpolated Sea Surface Temperature (OISST) using AVHRR sensor with controlled error. This data has passed through the process of interpolation to obtain weekly resolution [11] and also has its resolution stretcher modified as discussed in version 2 [14]. The data is also known as the Reynolds SST, named after Richard W. Reynolds that produce these products for National Centre Environmental Prediction(NCEP). OISST can be used to study climate change such as El Nino; the El Nino anomalies values can be calculated by subtracting weekly OISST to monthly OISST. The spatial resolution of the data is 1° (111km) but has been resampled at 0.25° for OISST version 2. In Comparing the OISST product to MODIS, MODIS product data can also be found on a weekly basis but do not cover the whole region of Malaysia. However, MODIS has better spatial resolution of 9km. The degree of resolution is able to interpret the sea in more detail which can be used for monitoring current [8].

The issue concerning data inter-comparison of SST product over the region of Malaysia is still less studied. Previous studies have focused more on areas of extreme variability or areas that has big changes of SST value[15]. Studies for areas of low variability such as SSCS is still lacking, especially in the region of Malaysian coastal water. The reason for the comparison is to show credibility before the product data is used for operations at sea. Inter-comparison of SST product by the Global High Resolution Sea Surface Temperature (GHRSSST ) to ensure that data can be used continuously by scientific community[3]. According to Global Data Assimilation Experiment(GODAE)[9], the data has to be check regularly to perform consistence analysis. It is an assessment and evaluation to see the effectiveness of technicality based on the performance analysis of the data based. The objective of this paper is to evaluate Malaysian coastal area through validation with insitu data. To achieve the objective, we perform pre- analysis study of the MODIS products and OISST to see the performance of both data in terms of spatial value during seasonal changes. However, the scope of this analysis covers only on the spatial MODIS pixel based value and the OISST point based value during the southwest monsoon daytime. The next session will be detailing on the selection of data analysis.
2. Material and method

2.1 In situ observation

The data sets from 1992-2008 has been selected as primary data for benchmarking. The data consists of temperature profile from the observation of GTSPP project. GTSPP is an abbreviation for Global Temperature Salinity Profile Project. This pilot project has been initiated by the NOAA agency. The observation is obtained from many platforms of fixed platform, drifting to several instrumentation such as Expandable Bathy Thermograph (XBT), Conductivity Temperature Depth (CTD) cast, moored bouy and Thermosalinographs. The data have passed through multiple steps of quality control programs through ‘QCed’ and ‘Mquest’[7]. In coastal Peninsular Malaysia, there are over 909 point/stations (figure 1) spanning from 1992-2006 and are well distributed. The data can be access through GTSSP website that provides in-situ primary data around the world [4]. However, only 14 selected stations have been utilised in this paper for southwest monsoon.

2.2 Satellite Data

2.2.1 Optimal Sea Surface Temperature

The SST used in this study is the Optimum Interpolation Sea Surface Temperature (OISST) which was retrieved from the RADS database; the data was optimized by the altimeter track. SST Database from RADS has never been tested, thus, there is the question of how the track of altimeter may affect the variability OISST data. The SST data is set to epoch of altimeter track. For the analysis, we use RADS SST to represent the OISST from RADS. The selection of data is matched with the time of in situ with latency of 6 hour max. The data selected is between March to April and September to October during the transition seasonal changes.

![Figure 1](image_url)  
Figure 1. Map of SST at region of Malaysia. Red line indicates of RADS SST and purple dots is the distribution of In situ SST.
2.2.2 Level 3 Binned MODIS Data

Level 3 MODIS Binned image in figure 2 shows the area of Malaysian coastal area, which is bounded by latitude 1° 15’ to 14° N and longitude 97° 30’ to 109° 15’ E. It is a SST image data and retrieved from the ocean color web based. The SST are available at a global scale, providing an image represent the water surface temperature at 9km resolution. MODIS data present an equal pixel based water surface and the data is an archived product from the NASA Goddard Space Flight Center Ocean Data Processing System.

![Figure 2. Level 3 data of SST data from MODIS satellite.](image)

| Name          | Temporal Resolution | Spatial Resolution (km) | Period            | Original data           |
|---------------|---------------------|-------------------------|-------------------|-------------------------|
| RADS SST(OISST v2) | Weekly              | 30                      | 1981-present      | AVHRR AVHRR+AMSR-E     |
| MODIS         | Daily (daytime/nightime) | 9                      | 2000-present      | TERRA/MODIS             |
2.3 Data processing

![Flowchart of data validation between RADS SST/MODIS SST and In situ SST.](image)

From the validation, the equation from the regression is used to calibrate the data. The regression equation is tested with root mean square error(rmse).

Validation of satellite data collected may have some problem with observation data in situ. This is because the epochs of the satellite passes may not correspond with the exact time of observation at the ocean. Thus, The temporal resolution of the satellite pass over the sampling site does not always match exactly with the observation data, for instance, in the mid-latitudes, the drifter experience a difference in time ranging from an hour to 10 hours. While the typical average time between fixes are around 2-3 h [6], the latency of satellite track position can cause water circulation at the upper ocean with strong inertia and strong tidal activity near the continental margins [4]. Usually, the uptake of data for match up study can be up 6 hour latency under consideration to resolve inertial motion[3]. For the validation part, the latency of epochs for the validation is limited to 6 hours.

In order to clarify the characteristic of each SST product, the RADS SST represent point based SST of OISST v2 data optimize by the track of satellite altimeter (figure 1), while MODIS is the pixel based SST data which represents the sensor of TERRA on board sensor. The advantage of the OISST is that the product has been used by several researchers and the data has been converted to 0.25 daily resolution using Reynolds optimum interpolation. Based on the objectives of this paper, the comparison of the SST products, through validation of SST with the in situ data was conducted in order to reveal the relative difference of spatial characteristic of both data at the same period. Considering the temporal differences, the data has been selected during the season of southwest monsoon. Thus, the only independent variable to be tested is the spatial characteristic. The spatial characteristics by all means are the pixel based data (MODIS data) and the point based data (RADS SST). However, the validation was performed only based on the relative differences between the two SST products. For the first assessment, we would like to evaluate the quantitative differences of the SST products. The next section is to test the model of SST product based on its linear equation.
3. Result and Discussion

The quantitative difference between the two SST products is depicted in figure 4. However, the accuracies of these SST products are still unknown; thus, the evaluation of the two SST products was performed by analysing the bias of each data products from the in-situ data. The histogram indicates the bias at each selected point.

![Figure 4](image-url)  
**Figure 4.** Histogram plot of sea surface temperature biases between MODIS/RADS SST data in situ (GTSPP).

**Table 2.** Root Mean Square Error(RMSE) of MODIS SST and RADS SST(before calibration).

| SST product | RMSE  |
|-------------|-------|
| MODIS SST   | 0.677 |
| RADS SST    | 0.731 |

The red bars represent MODIS data which presents data with huge biases. Nevertheless, the root mean square error (rmse) gave a contrasting result (that is, the rmse of the MODIS is smaller than that of the RADS SST). This large rmse of the RADS SST data could be said to originate from the interpolation method of Reynolds Optimum method. The same inter-comparison of the Reynolds product has been conducted by [14]. Based on Iwasaki, the Reynolds OI SST which has 1 week resolution has spatial differences up to 1.2°C. Furthermore temporal resolution of the Reynolds OI SST is 1 week which may be one of the causes of the large RMSE. RADS SST data has weekly resolution data of optimum interpolation and also optimized by the altimeter track. The altimeter track gives the value of the SST as point based which may also contain error.
In this section, we try to validate the data of both products with the in-situ to see the relationship. For this assessment, is to evaluate the performance of the linear model of the both product. The reason of this model performance assessment is to evaluate the data performance after calibration. The calibration is based on the linear equation \( mx + c \). The data performance will indicates of reliability of the data. The root mean square been compute to see the error value after the calibration. The SST models were plotted based on its same condition. Both of the data has been selected during transitional of southwest monsoon seasons. There are some important differences that we consider of its spatial difference between the MODIS/RADS SST may not have the same difference distance. Figure 3 demonstrates the regression plots for validation of the two models in respect of MODIS SST and RADS SST; this is to examine the relationship between these two data.

| Table 3. Root Mean Square Error (RMSE) of MODIS SST and RADS SST (after calibration) |
|-----------------------------------------------|-----------|
| **Model**          | **RMSE** |
| MODIS SST          | 0.4762    |
| RADS SST           | 0.6951    |

The \( R^2 \) statistics for the model was computed to assess the goodness of fit of the regression curves. The OISST model shows consistency of data near the line with moderate \( R^2 \) of 0.5605, while MODIS showed inconsistency of data away from the line with poor \( R^2 \) of 0.2387. From the comparison of both models, the data plots of RADS SST shows better relations of \( R^2 \) with the in-situ. This suggests that the data has moderate relation in term of the identical value. However, after the data calibration, it was revealed that the RADS SST model contains larger error than MODIS SST (see Table 2).

As shown on table 2, the rmse of RADS SST is higher before the calibration; the continuous data contains higher errors after calibration. Both tables have indicated that RADS SST inhibits error from the interpolation data over the track of satellite altimeter.
4. Conclusion

This paper has described the spatial characteristics between RADS SST and MODIS SST. The aim of this study was to carry out a comparison of SST data between two global models in order to extract the correct information about the data reliability. The first assessment based on figure 4 was performed to determine the biases of each data selected. As demonstrated by numerous researchers, Calibration/Validation (Cal/Val) of satellite data is crucial to obtain accurate information of the models’ validity. This paper describes the spatial characteristics between RADS SST and MODIS SST. The aim of the study is to perform inter-comparison between pixel based (MODIS SST) and point based (RADS SST). From the above analysis, RADS SST shows higher root mean square error (rmse) of 0.731 (before calibration) and 0.6951 (after calibration). From the rmse result, we could deduce that the RADS SST has random error arising from the fact that the interpolated points are based on the track.

Acknowledgment

The authors would like to extend their sincerest appreciation toUniversiti Teknologi Malaysia for funding this research under Research University Grant (Vote No. 12H99) and the eScience fund (Vote No. 4S074) from the Ministry of Science, Technology and Innovation Malaysia. The authors wish to thank the Global Temperature and Salinity Profile Programme for providing the in-situ temperature profile data over the Malaysian region.

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