Indonesia sea surface temperature from TRMM Microwave Imaging (TMI) sensor

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Abstract. We analysis the Tropical Rainfall Measuring Mission's (TRMM) Microwave Imager (TMI) data to monitor the sea surface temperature (SST) of Indonesia waters for a decade of 2005-2014. The TMI SST data shows the seasonal and interannual SST in Indonesian waters. In general, the SST average was highest in March-May period with SST average was 29.4°C, and the lowest was in June – August period with the SST average was 28.5°C. The monthly SST average fluctuation of Indonesian waters for 10 years tends to increase. The lowest SST average of Indonesia occurred in August 2006 with the SST average was 27.6°C, while the maximum occurred in May 2014 with the monthly SST average temperature was 29.9 °C.

1. Introduction
Sea surface temperature is one of the parameters that determine the waters quality, and directly affect the life of marine organisms as well. Temperature changes will affect the metabolism, reproduction, and distribution of fish in the sea [1]. Sea surface temperature (SST) variations experienced from time to time in accordance with the natural conditions that affect the waters. These changes occur on a daily, seasonal, interannual and long-term (decadal). Monitoring long-term changes in the ocean temperature and circulation is important for understanding both the causes and results of climate change, since the oceans provide a net sink for both anthropogenic CO2 emissions and the additional heat trapped by changes in the atmospheric composition, as well as providing an important SST-dependent feedback mechanism via evaporation [2].

Currently SST measurements have been simplified with the presence of remote sensing technology that can reach synoptic sea-level areas to detect dynamic sea-level physical changes when compared to in situ field observations. the National Oceanic and Atmospheric Administration's geostationary satellite (NOAA) was the first satellite to measure sea surface parameters using infrared sensors in the 1970s [3]. Infrared sensors provide measurements with relatively high spatial resolution, but unable penetrate clouds and aerosols, this is the limitation of using IR sensor measurements of all weather conditions.

This is different when using a microwave sensor because thermal radiation at microwave frequencies is less to be affected by cloud cover and water vapor contamination as well [4-5]. Those advantages make the microwave SST data widely used for ocean research and SSTs play an important role in Earth science research [6-11]. Satellite microwave radiometry able to measure of SST in all-weather condition except area of active rain, sun-glitter and close to the shoreline due to side-lobe contamination. Side-lobe contamination caused ± 50 km from shore have no SST value [12].

[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12]
TRMM Microwave Imager (TMI) is one of five instruments carried by Tropical Rain Measuring Mission (TRMM) satellite. TRMM is one passive microwave satellite which was launched in 1997 by NASA (National Aeronautics and Space Administration) and NASDA (National Space Development Agency of Japan), but on April 8th, 2015 the satellite was shut down, however we still can access the TMI data from Remote Sensing System website. Remote Sensing System (RSS) is established by Frank J. Wentz in 1974. It is a scientific research company with specializing in satellite microwave remote sensing on earth. RSS started to process the TRMM data on December 7th, 1997 until April 8th, 2015.

Microwaves penetrate clouds with little attenuation, giving an uninterrupted view of the ocean surface. The comparisons TMI SST with ocean buoys show a root mean square difference of about 0.6°C, which is partly due to the satellite-buoy spatial-temporal sampling mismatch and the difference between the ocean skin temperature and bulk temperature [4]. Gross [13] compared 4 years of TMI SSTs by the Tropical Atmosphere Ocean/Triangle Trans-Ocean Buoy Network (TAO/TRITON), and Pilot Research Moored Array in Tropical Atlantic (PIRATA) moored buoy in situ SSTs, and the result shown that TMI SSTs have a mean bias of -0.07°C and a standard deviation of 0.57°C. A study of daily SST availability from an IR polar orbiter, IR geostationary, and TMI gave SST coverage of 48%, 56%, and 78%, respectively [14], and in this study, we will demonstrate the ability of TMI STT data that can provide free cloud cover SST information to describe the sea surface temperature in Indonesia waters for a decade of 2005-2014.

2. Method

The research was done in the Indonesian water with boundary coordinate 10°N – 16°S and 92° – 143°E. Data used in this study were monthly TMI SSTs data from 2005 – 2014. TMI data was downloaded from Remote Sensing Systems (RSS) Website (http://data.remss.com/tmi/).

The RSS is provided TMI SST data as daily, 3-day, weekly, and monthly data. Daily data consists two data coverage data which are ascending orbit segment (daytime) and descending orbit segments (night time). 3-day data is the average of 3 days ending on and including file date. For example, 3-day data dated April 3, 2014, then the data is the average of data dated April 1, 2, and April 3, 2014. Weekly data is an average of 7 days, starting from Sunday through Saturday. For example, the date of weekly SPL data is April 12, 2014, then the data is the average of the daily data of April 6, 2014 (Sunday) to April 12, 2014 (Saturday), while the monthly data is the average of all data within the calendar month.

Any binary data is available at http://data.remss.com/tmi, consists of fourteen grid for daily data and six grids for average data (3-day, weekly and monthly data) sized 0.25 X 0.25 degrees from (1440,720) byte maps.

The data values fall between 0 and 255. Specific values have been reserved:

- 0 – 250 = valid geophysical data
- 251 = missing SST or wind speed due to rain, or missing water vapor due to heavy rain
- 252 =*not used in this data set*
- 253 = TMI observations exist, but are bad
- 254 = no TMI observations
- 255 = land mass

The data values between 0 and 250 need to be scaled to obtain meaningful geophysical data. To scale the data, multiply by the scale factors with the equation below:

\[ (\text{SST} \times 0.15) - 3 \]  

The valid data range is -3°C to 34.5°C.

The TMI binary data can be extracted using matlab, fortran, idl or phyton software. After the data are extracted, then the data are converted into a data format that can be read by image processing software such as ER Mapper, Envi, etc. for further analysis. The flowchart of TMI SSTs data processing presented on figure 1.
3. Result and Discussion

The extraction result of TMI SST binary data is shown in figure 2. The SST value is still in the range of 0-255, in order to produce the SST value in °C, the TMI SST binary data should be multiplied by the scale factor shown in equation 1, SST in °C is shown in figure 3. Figure 4 shows the monthly TMI SSTs data along 2005 and 2014.

Figure 1. The flowchart of TMI SSTs Data Processing

Figure 2. December 2014 monthly TMI SST distribution on scale 0 - 255

Figure 3. December 2014 monthly TMI SST distribution on celsius degree (°C)

![Flowchart of TMI SSTs Data Processing](image-url)
Figure 4. Monthly TMI SSTs 2005-2014
The annual average SST images displayed in figure 5. It was derived from calculating the monthly average SST data for a year. In general, the SST distribution in Indonesian waters is similar, northern parts of Indonesian waters have a higher SST distribution compared to the southern part.

**Figure 5.** Annual average of TMI SSTs 2005-2014
SST fluctuation from TMI data from 2005 to 2014 is presented as a graphic in figure 6. From the graphic we can see, generally, the SST fluctuations in Indonesian waters is sinusoidal form, where the highest peak usually occurs in May and lowest in August. This is in line with the previous research [15]. Eningtyas [15] performed an analysis of the rainfall and sea surface temperature correlation in Indonesia using NOAA data from 1986 to 2006. The results show SST was relatively higher compared to other months starting from January and reaching its peak in May. The low water temperatures in August due to the influence of upwelling zone south of Java and over the Arafura Shelf. The cool waters appear to be carried into the eastern Java Sea, then flow northwestward and enter the South China Sea through Karimata Strait [16].

Figure 6. Graph of temporal variability monthly SST average in Indonesian waters

Indonesian SST characteristics during 10 years based on TMI data ranged from 27.6° to 29.6°C, with the dominant temperature ranging from 28.0 – 29.0°C. Indonesia's sea surface temperature varies seasonally. Generally, the SST average was highest in March-May period with SST average was 29.4°C, and the lowest was in June – August with the SST average was 28.5°C. Another study showed the same result [17]. Habibie [17] studied the trend of SST changes in Indonesia by using the Integrated Global Ocean Services System (IGOSS) SST data from 1982 – 2009. The result showed that in March–May period generally was the warmest SST in Indonesia compared to other periods. March-May period is the transitional monsoon of the West monsoon to the East monsoon, it is said that during the transition monsoon the distribution of SPL in the territory of Indonesia is almost evenly distributed, there is no significant difference between the northern and southern hemispheres, in contrast to the conditions during the monsoon period in June - August which coincides with the period of the east monsoon or the Australian monsoon, the southern hemispheres much cooler than northern hemispheres.

Temporarily, the variation of sea surface temperature in the period 2005 - 2014 can be seen in figure 7. The monthly SST average fluctuation of Indonesian waters for 10 years tends to increase. The lowest SST average of Indonesia occurred in August 2006 with the SST average was 27.6° C, while the maximum occurred in May 2014 with the monthly SST average temperature was 29.9 ° C.
Figure 7. Graph of temporal variability monthly SST average in Indonesian waters during 2005-2014

The annual SST variation of Indonesian waters during 2005-2014 based on TMI data were ranging from 1.1°-1.7°C. The lowest annual SST variation occurred in 2009 and 2010 at 1.1°C while the highest occurred in 2012 and 2014 at 1.7°C. This corresponds to [18] statement, that the annual variation of Indonesian sea surface temperature is about 2° C. This condition also corresponds to the statement of [19] that the condition of the tropical sea surface layer is warm and the annual temperature variation is small and the daily temperature variation is not too high compared to sub-tropics and polar. The average annual temperature variation of tropical waters is less than 2 ° C in the equatorial area. The graphic annual variation and average of Indonesia’s SST during the 2005-2014 period can be seen in figure 8.

Figure 8. Annual variation and average TMI SSTs 2005 – 2014

4. Conclusion
This research showed that TMI data can describe the SST variability of Indonesian water monthly, seasonal, and interannual. Knowing the variability of the SST helps us to understand the anomaly of SST that occurred in Indonesian waters. Indonesian SST characteristics during 10 years based on TMI data ranged from 27.6° to 29.6°C, with the dominant temperature ranging from 28.0 – 29.0°C.

During the interval 2005-2014 the monthly SST average fluctuation of Indonesian waters for 10 years tends to increase, the lowest annual average of SST in Indonesian waters occurred in 2006 which is 28.6°C and the highest is in 2010 with the average temperature is 29.3°C. Generally, the SST average was highest in March-May period with SST average was 29.4°C, and the lowest was in June – August with the SST average was 28.5°C, with the annual SST variation of Indonesian waters during 2005-2014 based on TMI data were ranging from 1.1°-1.7°C.
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