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SEA SURFACE TEMPERATURE RETRIEVAL USING TRMM MICROWAVE IMAGER DATA IN SOUTH CHINA SEA

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ABSTRACT: The passive microwave TRMM Microwave Imager (TMI) sensor which is payload of the Tropical Rainfall Measurement Mission (TRMM) satellite was launched in 1997 by the National Aeronautics and Space Administration (NASA) and National Space Development Agency of Japan (NASDA). The TMI provides daily maps, 3 day average, weekly and monthly binary data via internet that can be used to retrieve geophysical parameters such as sea surface temperature (SST), surface wind speed, atmospheric water vapor, liquid cloud water and precipitation rates. This paper reports on a study that was carried out to map the sea surface temperature over South China Sea using TMI data from 10.7 GHz channel. The advantage of using this data is that the SST can be measured through clouds which are nearly transparent on this channel. This is distinct advantage over the traditional infrared SST observations that require a cloud-free field of view. In this study multitemporal TMI binary data were processed using FORTRAN Programming Language to evaluate the SST variations with time over the study area. Comparisons between SST from TMI data and in-situ SST differ by about $\pm 0.2^{o}$C.

1. INTRODUCTION

Sea Surface Temperature (SST) is one of the geophysical parameters which is required by researchers for various applications. Conventional techniques can be used to retrieve SST values using ship, coastal stations and also drifting bouys (Emery and Yu,1997) within limited area coverage. Remote sensing from satellites has the advantage of obtaining global coverage more frequently. The major limitation of using the optical sensor is cloud cover problem especially in tropical areas (Chelton *et al*. 2000). In these areas, microwave sensor system has the additional advantage to provide its own illumination and capabilities to penetrate through cloud and operates in any climate conditions.

This paper reports on the studies using TRMM Microwave Imager (TMI) which is one of the payload of TRMM satellite to retrieve SST in South China Sea. Binary data from 10.7 GHz channel provide values of SST which can be extracted using FORTRAN Language Programming. TMI data are suitable in tropical areas for obtaining SST values.

2. STUDY AREA

The study was conducted in South China Sea located between 2^o N to 7^o N and 100^o E to 107^o E which includes Malaysia, Indonesia, Thailand, Taiwan and Philippines (Figure 1). This area undergoes climate changes during the monsoon and inter-monsoon periods. The SST values also vary during these periods.

Figure 1: Study area

3. SATELLITE DATA

3.1 TRMM Microwave Imager Characteristics

TRMM is a joint mission between the National Aeronautics and Space Administration (NASA) of the United States and the National Space Development Agency (NASDA) of Japan (NASA Facts,1997). TMI is a nine-channel 10.7 GHz passive microwave radiometer with horizontal and vertical polarizations. TMI is 65 kg in weight and requires 50 W of main power to obtain data in 8.5 kbps (Kummerow and Barnes,1998). The characteristics of TMI are summarized in Table 1.

Table 1: TMI characteristics of 9 channels.

Channel Number	1	2	3	4	5	6	7	8	9
Center Frequency (GHz)	10.65	10.65	19.35	19.35	21.3	37.0	37.0	85.5	85.5
Polarization	V	H	V	H	V	V	H	V	H
Beam Width (degree)	3.68	3.75	1.90	1.88	1.70	1.00	1.00	0.42	0.43
IFOV-DT (km)	59.0	60.1	30.5	30.1	27.2	16.0	16.0	6.7	6.9
IFOV-CT (km)	35.7	36.4	18.4	18.2	16.5	9.7	9.7	4.1	4.2
Integrated time (ms)/sample	6.60	6.60	6.60	6.60	6.60	6.60	6.60	3.30	3.30
EFOV-CT (km)	9.1	9.1	9.1	9.1	9.1	9.1	9.1	4.6	4.6
EFOV-DT (km)	63.2	63.2	30.4	30.4	22.6	16.0	16.0	7.2	7.2
Number of EFOVs per scan	104	104	104	104	104	104	104	208	208
Number of Samples (N)/beam width	4	4	2	2	2	1	1	1	1
Beam EFOV (km x km)	63x37	63x37	30x18	30x18	23x18	16x9	16x9	7x5	7x5
Number of Beam EFOVs per scan	26	26	52	52	52	104	104	208	208

The instantaneous field of view (IFOV) is the footprint resulting from the intersection of antenna beamwidth and the Earth's surface. Due to the shape of antenna and incident angle, the footprint can be described by an ellipse. The ellipse's major diameter is in the down-track direction called IFOV-DT and minor diameter in cross-track direction called IFOV-CT. The EFOV is the position of the antenna beam at the midpoint of the integration period. Figure 2 shows the IFOV and EFOV of TMI footprint characteristics.

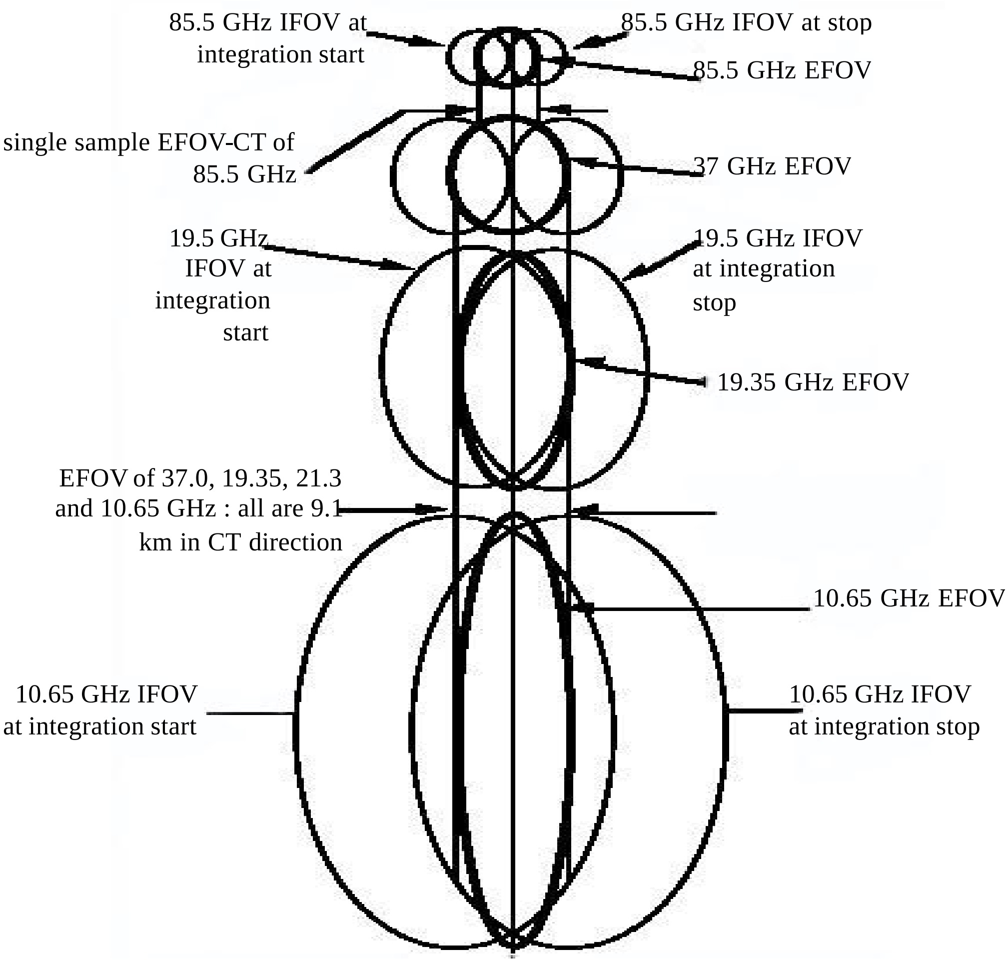


Figure 2: TRMM Microwave Imager footprint characteristics.
(Source: Kummerow and Barnes, 1998)

3.2 TMI data characteristics

Each daily binary data file available in ftp.site, consists of fourteen 0.25 x 0.25 degree grid of 1440 x 320 byte maps. Seven ascending maps include SST and six other geophysical parameters. The center of the first cell of the 1440 column and 320 row map is located at 0.125 E and –39.875 N latitude while the center of the second cell is at 0.375 E longitude, -39.875 N latitude. All the data values fall between 0 and 255. Specific values have been reserved as follows:

255	=	land mass
254	=	no. of TMI observations
253	=	TMI observations exist, but are bad
252	=	'data set not used'
251	=	missing wind speed due to rain, or missing vapor due to heavy rain
0 to 250	=	valid geophysical data.

4. SATELLITE DATA PROCESSING

The 3-day, weekly and monthly binary files are similar to the daily TMI binary files. All data consists of six maps with grid size of 0.25^o by 0.25^o and each file can be read as a 1440, 320, 6 array. For the data processing, the data values between 0 and 250 need to be scaled to obtain meaningful geophysical data. To scale the SST from the binary data, multiply by scale factors as expressed below ; i.e

(SST * 0.15) – 3.0 to obtain SST between –3^{o}C and 34.5^{o}C.

FORTRAN Programming Language is used to evaluate the SST values in each of the binary data on 19-22 June 2000 on subimage at 5.625 N latitude, 105.25 E to 107.25 E longitude.

5. RESULTS

The SST values derived from FORTRAN Programming Language are tabulated in Table 2.

Table 2: SST values derived from TMI data.

Location (degrees)		SST Values of 4 Multitemporal Data (^oC)			
Longitude	Latitude	19/06/2000	20/06/2000	21/06/2000	22/06/2000
105.25	5.625	29.70	29.55	30.30	31.35
105.50	5.625	29.40	29.55	30.15	30.15
105.75	5.625	29.25	30.00	30.00	29.85
106.00	5.625	29.85	30.00	29.85	29.70
106.25	5.625	29.25	29.85	29.85	29.55
106.50	5.625	29.70	31.05	29.85	30.00
106.75	5.625	29.40	31.05	29.55	29.70
107.00	5.625	29.25	29.25	29.55	29.70
107.25	5.625	29.40	29.55	29.70	29.55

The TMI scanning system causes striping that contains 0 or invalid data. Samples were taken at locations where data are available (no striping). Regression analysis was carried out using the SST from TMI data and in-situ data obtained from the Meteorological Department of Malaysia. Table 3 shows the SST values for 9 points extracted from TMI and in-situ data.

Table 3: Comparison of SST values from TMI data and in-situ data.

Date of data	Location (degrees)		SST (^oC)	
	Longitude	Latitude	TMI	In-situ
19/06/2000	100.90	2.80	29.8	29.7
	102.97	5.56	30.5	31.0
20/06/2000	106.90	5.20	29.8	29.7
	100.90	2.80	29.5	29.3
	102.90	5.60	31.0	30.7
21/06/2000	100.90	2.80	29.8	29.7
	102.82	5.88	30.7	30.5
22/06/2000	100.90	2.80	29.8	29.7
	104.40	3.70	31.5	31.3

The two dimensional scatterplot between TMI data and in-situ data gives a correlation of 0.89 (Figure 3). The SST distribution is shown in figure 4.

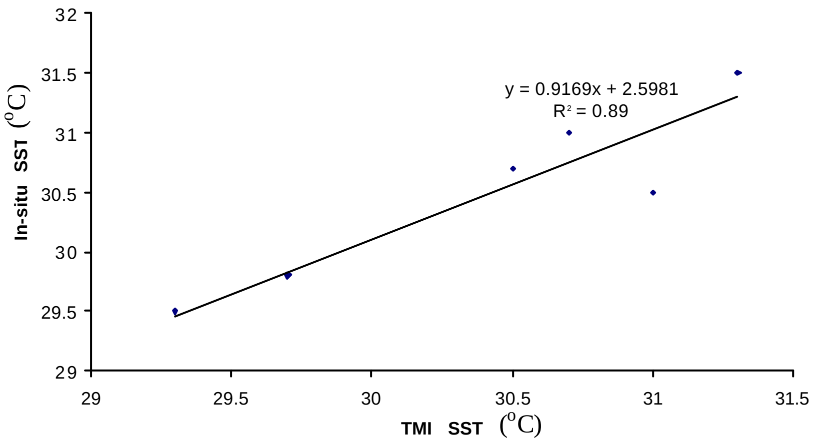
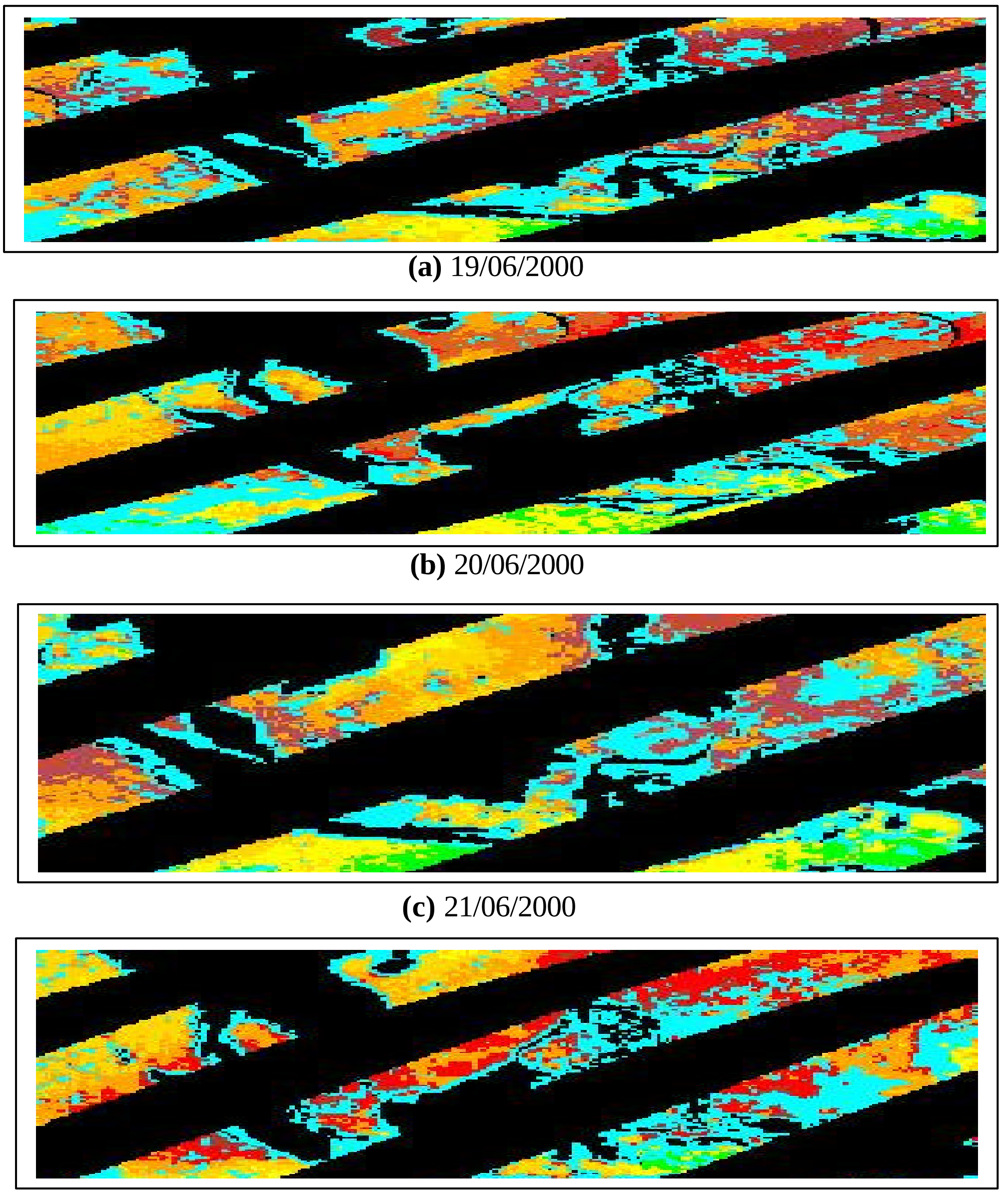


Figure 3: Graph of TMI SST versus in-situ SST.



(a) 19/06/2000

(b) 20/06/2000

(c) 21/06/2000

(d) 22/06/2000

Figure 4: Distribution of SST on (a) 19/06/2000, (b) 20/06/2000, (c) 21/06/2000 and (d) 22/06/2000 in South China Sea.

Table 4 shows the minimum and maximum temperatures during the 4 dates from TMI data. The SST ranges from 27°C to 35°C in the study area.

Table 4: SST during four different dates of TMI data.

Statistics	19/06/2000	20/06/2000	21/06/2000	22/06/2000
Minimum SST	27	28	27	29
Maximum SST	35	35	35	34

6. CONCLUSIONS

SST values can be derived accurately from TMI data. Comparisons with in-situ measurements indicate an accuracy of about ± 0.2°C. The correlation coefficient between in-situ and TMI SST is about 0.89. This shows that TMI data can be used to derive SST accurately over large areas of the sea.

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