

# Super-resolution of MTSAT Land Surface Temperature by Blending MODIS and AVNIR2

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## Abstract

In this study, we developed a method for the improvements of emissivity mapping toward a MTSAT based land surface temperature retrieval by blending MODIS and AVNIR2. Firstly, a spectral mixture analysis including vegetation, soil and water was carried out using the daily-synchronized pairs of AVNIR2 and MODIS images in Ulanbaatar, Tokyo, Bangkok and Jakarta over the range of different climate zone, seasonality and satellite zenith angle. Secondly those endmembers of vegetation, soil and water were evaluated over the entire MTSAT global disk coverage and time-series of emissivity map of IR1 and IR2 were estimated in 250m spatial resolution. Thirdly land surface temperature (LST) was estimated using generalized split window algorithm. Those MTSAT derived LST were evaluated using MODIS derived LST (MOD11) product. The root means square errors ranged from 2.8 to 3.8 in Kelvin with biases from 0.3 to 2.2 in Kelvin. It was found that MTSAT LST retrieval has a drastic improvement aided by AVNIR2 and MODIS derived 250m emissivity map. Further study should be investigated in a water vapor measurement method for the better improvements of the LST retrieval. A continuous accurate and timely determination of the satellite orbit and attitude are also indispensable in order to perform geometric correction of Earth images acquired by geostationary meteorological satellites.

**Key words:** Emissivity, spectral mixture analysis and data fusion.

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## 1 Introduction

### 1.1 Needs for better information

Multi-purpose Transmission SATellite (MTSAT) is Japanese weather satellite for geosynchronous orbit. MTSAT is a three-axis stabilized spacecraft and carries both a meteorological mission and an aeronautical communications mission. The Japan Meteorological Agency (JMA) contracted for MTSAT as a successor to GMS-5, in cooperation with the Civil Aviation Bureau (CAB), of the Ministry of Transport

of Japan (JMA, 2003). Land surface temperature (LST) retrieval from MTSAT is one of the most important parameters and it is expected to give great contributions to urban heat island monitoring (Oyoshi, 2009), burned area mapping (Boschetti, 2003) and hot spot detection of wild fires (Takeuchi, 2008). In order to improve the accuracy of LST retrieval from satellite remote sensing data, the information of atmospheric water vapor content and emissivity refinement are absolutely imperative (Akatsuka, 2008).

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There have been several studies to produce emissivity maps of thermal infrared measurements by using remote sensing data with high spatial resolutions such as ALOS AVNIR2 or Landsat ETM. High spatial resolution data are effective in monitoring thermal environment at the local or regional scale, however, it may not cover a large area because of its narrow swath width. Extending the area would require use of wide coverage data such as MODIS or MTSAT. On the other hand, MTSAT data may not detect fine spatial structures in mixtures of vegetation, soil and water because of its coarse spatial resolution. In this sense, it is necessary to devise a method for the fusion of the data with different spatial resolutions (Takeuchi, 2003).

### 1.2 Objective of this research

In this paper, we develop a method for mapping of MTSAT emissivity improvements by blending MODIS and AVNIR2 measurements using the daily-synchronized pairs of AVNIR2 and MODIS scenes.

## 2 Methodology

Figure 1 shows a framework of land surface temperature mapping by blending MODIS and AVNIR2. Four pairs of AVNIR2 VNIR and MODIS VNIR images are collected to cover Bangkok, Tokyo, Ulanbaatar and Jakarta. A spectral mixture analysis was carried out to estimate the endmembers of vegetation, soil and water collectively called as VSW map (Bateson, 2000). Secondly, a series of emissivity for vegetation, soil and water of MTSAT IR1 and IR2 were computed by integrating spectral response functions with ASTER spectral library (Salisbury, 1992). MTSAT data are downloaded from University of Tokyo MTSAT data processing system (<http://webgms.iis.u-tokyo.ac.jp/>). Thirdly, a generalized split window algorithm was applied to MTSAT IR1, IR2 and those of emissivities (Sobrino, 2004) as shown in equation (1). IR1 and IR2 are brightness temperatures,  $\epsilon$  represents an average of emissivity of IR1 and IR2,  $\Delta\epsilon$  represents a subtraction of those and aiare coefficients. Those Coefficients were calibrated based on the

results of simulated MTSAT thermal measurements with LOWTRAN simulation code (Oyoshi, 2009). Finally those MTSAT derived LST were evaluated using MODIS derived LST (MOD11) product.

$$LST = IR1 + a1(IR1 - IR2) + a2(IR1 - IR2)^2 + a3(1-\epsilon) + a4W(1-\epsilon) + a5\Delta\epsilon + a6W\Delta\epsilon + a0 \quad (1)$$

## 3 Results and Discussions

### 3.1 Endmember selection and emissivity estimation

Figure 2 shows a scatter plot between MODIS Channel 1 and 2 space. A triangle in the image shows endmembers of vegetation, soil and water respectively. All those scatter plots shows a triangle-shaped spatial distribution and the vertex are located outside the triangles. This implies that MODIS 250m resolution is not enough to estimate pure pixels of vegetation, soil and water (endmembers), and enhance the importance of spectral mixture analysis aided by AVNIR2 with 10m resolution. Scene-by-scene defined endmembers have variations in four pairs of scenes characterized by land cover types. Figure 2-(a) shows dense plots at rich vegetation cover in Bangkok city, (b) shows lower reflectances both in channel 1 and channel 2 characterized by less vegetation in Tokyo, (c) gives higher values near a soil line from vertex S to W and (d) have some plots outside the triangle. Those facts yield big variations in endmembers of vegetation and soil, especially. We have employed the endmember pair based on the policy to include as much as pixels in the four types of triangles as shown in Table 1. Underlined values are selected endmember pairs in the further study.

A series of emissivity for vegetation, soil and water of MTSAT IR1 and IR2 were computed by integrating spectral response functions as shown in Table 2.

### 3.2 Land surface temperature estimation

The selected endmembers were used to map emissivities of

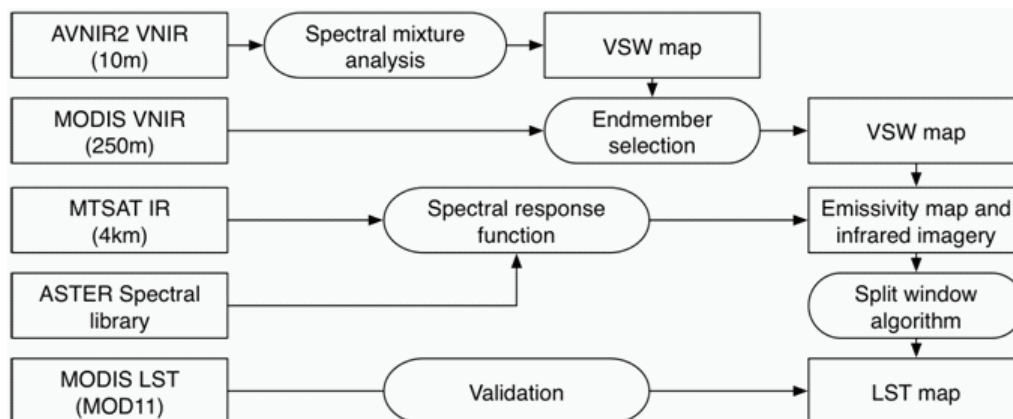


Figure 1. A flowchart of land surface temperature mapping by blending MODIS and AVNIR-2.

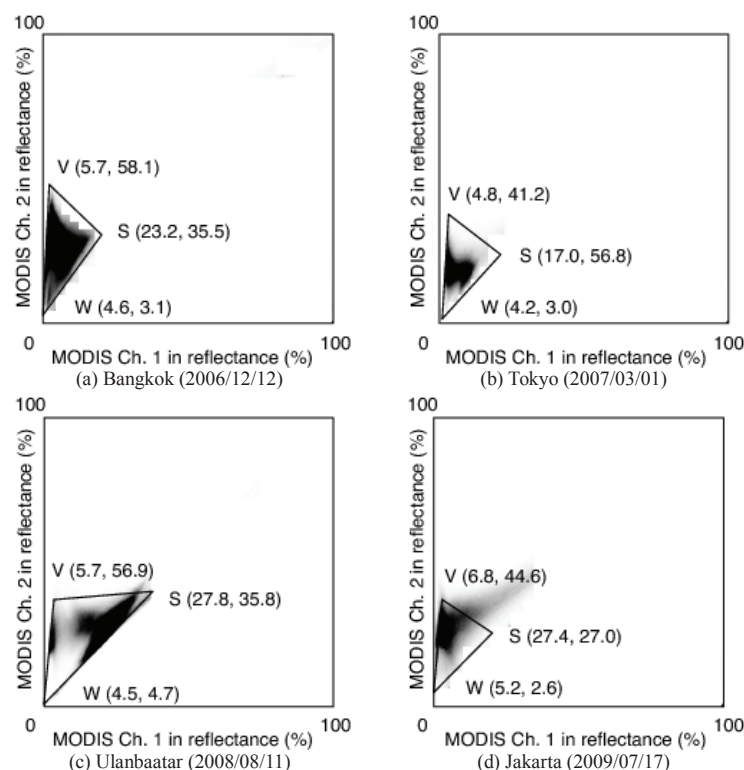


Figure 2. Scatter plot between MODIS Channel 1 and 2 space. A triangle in the image shows endmembers of vegetation, soil and water respectively.

Table 1. Endmembers of MODIS channel 1 and 2 in reflectances at the land surface for vegetation, soil and water over Bangkok, Tokyo, Ulanbaatar and Jakarta. Underlined values are selected endmember pairs in the further study.

Scene location (date)	Ch. 1			Ch. 2		
	Vegetation	Soil	Water	Vegetation	Soil	Water
Bangkok (2006/12/12)	5.7	23.2	4.6	58.1	3.1	
Tokyo (2007/03/01)	4.8	17.0	4.2	41.2	56.8	3.0
Ulanbaatar (2008/08/11)	5.7	27.8	4.5	56.9	35.8	4.7
Jakarta (2009/07/17)	6.8	27.4	5.2	44.6	27.0	2.6

Table 2. Emissivities of vegetation, soil and water of MTSAT IR1 and IR2.

Channel (wavelength)	Vegetation	Soil	Water
IR1 (10.3-11.3 um)	0.9804	0.9689	0.9924
IR2 (11.5-12.5 um)	0.9787	0.9770	0.9880

IR1 and IR2 and a generalized split window algorithm were applied to MTSAT scenes by using equation (1). Figure 3 shows land surface temperature (LST) maps derived from MODIS LST product in 1km, MTSAT LST in 4km, MTSAT LST in 250m and MODIS VNIR color composite image in Bangkok, Tokyo, Ulanbaatar and Jakarta respectively. MODIS LST 1km and MODIS VNIR 250m shows that higher LST area are characterized by sparse vegetation cover and rich concrete or asphalt cover at urban cities. Overall MTSAT LST 4km have similar spatial patterns with MODIS LST 1km and MTSAT LST 250m captures much finer textual features than 4km product. A manual image shifting were required to overlay MTSAT scenes with MODIS scenes because of poor geometric accuracy of MTSAT. A continuous

accurate and timely de-termination of the satellite orbit and attitude are also indispensable in order to perform geometric correction of Earth images acquired by geostationary meteorological satellites (Takeuchi, 2007).

Figure 4 shows a scatter plot between MODIS LST and MTSAT LST. A linear line in the figure shows a regression line between them. Equation (2)-6 shows a result of linear regression between MODIS LST and MTSAT LST. x represents MODIS LST and y MTSAT LST respectively. It was found that the root means square errors (RMSEs) ranges from 2.8 to 3.8 in Kelvin with biases from 0.3 to 2.2 in Kelvin. The biggest error was found at MTSAT LST scene in Jakarta and it was caused by a relatively higher atmospheric

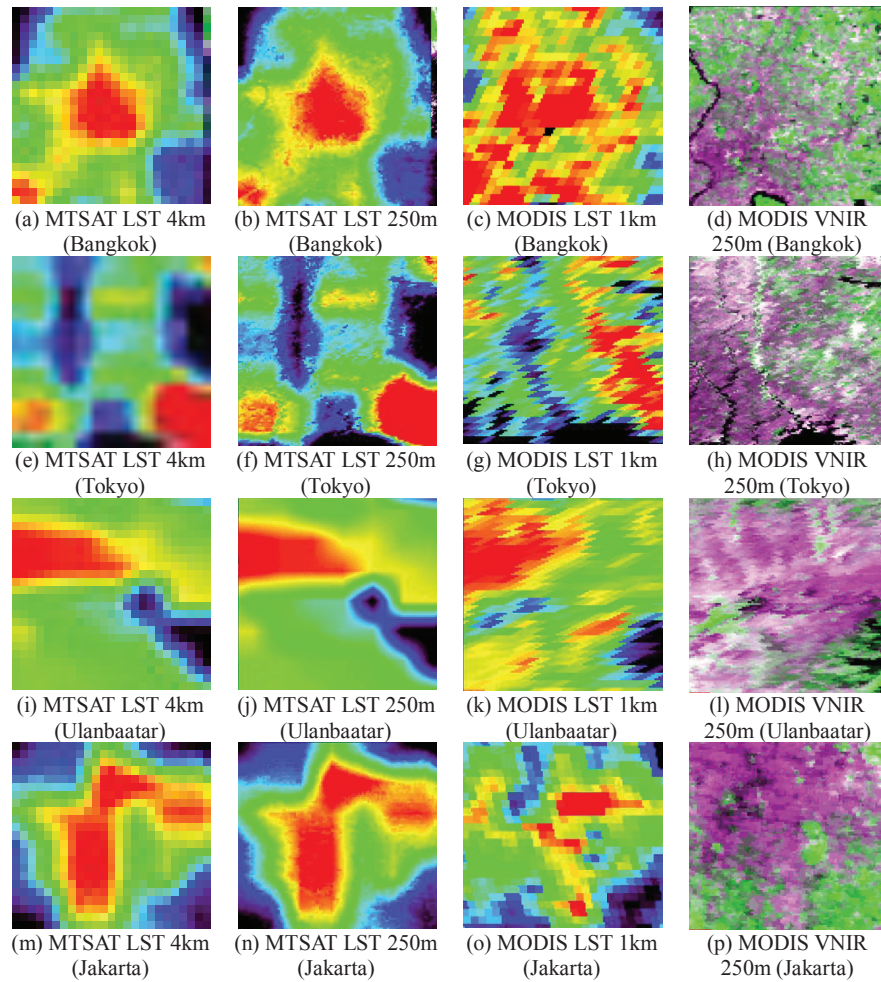


Figure 3. Land surface temperature (LST) map derived from MTSAT in 4km, MTSAT in 250m, MODIS product in 1km and MODIS VNIR color composite image in Bangkok, Tokyo, Ulanbaatar and Jakarta respectively.

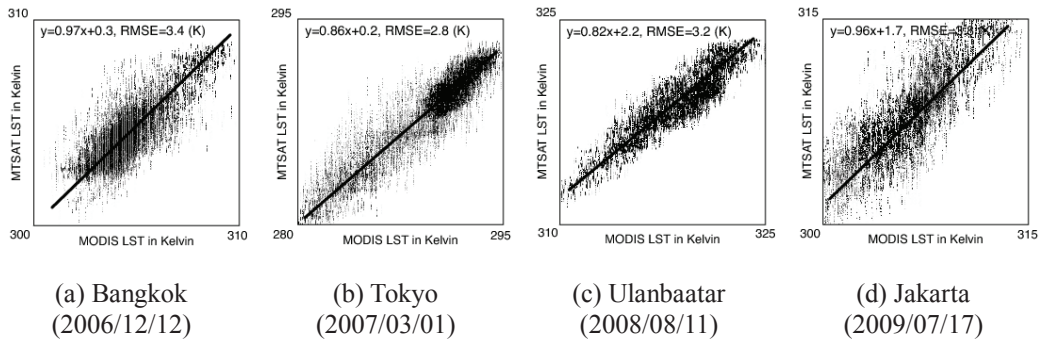


Figure 4. Scatter plot between MODIS LST and MTSAT LST. A linear line in the figure shows a regression line between them.

water vapor concentration. A further study is indispensable to estimate an accurate water vapor estimation model supplemented by a radiosonde (Akatsuka, 2008).

$$y = 0.97x + 0.3, \text{ RMSE}=3.4 \text{ (K)} \quad (2)$$

$$y = 0.86x + 0.2, \text{ RMSE}=2.8 \text{ (K)} \quad (3)$$

$$y = 0.82x + 2.2, \text{ RMSE}=3.2 \text{ (K)} \quad (4)$$

$$y = 0.96x + 1.7, \text{ RMSE}=3.8 \text{ (K)} \quad (5)$$

where  $x = \text{LST}_{\text{MODIS}}$ ,  $y = \text{LST}_{\text{MTSAT}}$  respectively.

#### 4 Concluding Remarks

This study demonstrated a method for mapping of emissivity improvements by blending MODIS and AVNIR2 measurements. A spectral mixture analysis including

vegetation, soil and water was carried out using the daily-synchronized pairs of AVNIR2 and MODIS images in Ulanbaatar, Tokyo, Bangkok and Jakarta over the range of different climate zone, seasonality and satellite zenith angle. Those endmembers of vegetation, soil and water were determined by considering convex hull of a triangle. Land surface temperature (LST) were estimated using generalized split window algorithm and were evaluated using MODIS derived LST (MOD11) product. The root square means errors ranges from 2.8 to 3.8 in Kelvin with biases from 0.3 to 2.2 in Kelvin. It was found that MTSAT LST retrieval has a drastic improvements aided by AVNIR2 and MODIS derived 250m emissivity map. Further study should be investigated in a water vapor measurement method for the better improvements of the LST retrieval. A continuous accurate and timely determination of the satellite orbit and attitude are also indispensable in order to perform geometric correction of Earth images acquired by geostationary meteorological satellites.

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