SURFACE EMISSIVITY IN DETERMINING LAND SURFACE TEMPERATURE

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ABSTRACT

Land surface temperatures are important in global change studies, in estimating radiation budgets in heat balance studies and as a control for climate models. Land surface temperature (LST) is strongly influenced by the ability of the surface to emit radiation (i.e. surface emissivity). Therefore, knowledge of the surface emissivity is crucial for estimating the radiation balance at the earth surface. In this paper, we will evaluate the use of Landsat data for determining LST in Ho Chi Minh City based on association surface emissivity value with land cover information.

Keywords: Land surface temperature; Surface emissivity; Classification-based emissivity

1. INTRODUCTION

Land surface temperature is maintained by the incoming solar and longwave irradiation, the outgoing terrestrial infrared radiation, the sensible and latent heat flux, and the ground heart flux. Therefore, LST is a good indicator of the energy balance at the Earth's surface. LST is also strongly influenced by the ability of the surface to emit radiation (i.e. surface emissivity). Surface emissivity (ε) is the ratio of energy emitted from a natural material to that from an ideal blackbody at the same temperature. The recovery of land surface temperature and emissivity from thermal infrared remote sensing data is important for the study of urban planning, water and energy balances, climate models, lithological mapping and resource exploration, among others.

However, effects of LST and emissivity on thermal radiance are so closely coupled that their separation from thermal radiance measurements alone is quite difficult. This is because a single multispectral thermal measurement with N bands presents equations in $N + 1$ unknowns (spectral emissivities and LST). Without any prior information, it is impossible for us to recover both LST and emissivity exactly. Most LST-emissivity separation studies used one additional empirical equation so that measurements plus this additional equation can be solved for *1* unknowns. Therefore, retrieval of LST from multispectral thermal data requires an accurate measurement of emissivity values of the surface. Many methods have been developed to extract emissivity such as the reference channel method (REF), which indicates that the value of the emissivity for one of the image channels is constant and known *a priori*, reducing the number of unknowns to the number of equations; The normalization emissivity method (NOR), which indicates that the value of the emissivity for all image channels is constant for a given pixel, calculating LST and deriving emissivity values for other channels is then achieved as the REF method. Recently, a more detailed ‘emissivity classification’ was conducted by Snyder *et al*. (1998) based on the conventional land cover classification. Therefore, each pixel in the thermal image can be classified as one of fourteen ‘emissivity classes’ according to the conventional land cover classification results. The objective of this study is to retrieve the LST in Ho Chi Minh City from Landsat-7 ETM+ thermal infrared data using surface emissivity which was based on the conventional land cover classification.

2. METHOD

2.1 Study area and data

The study area is located at the North of Ho Chi Minh City, which is a mega city with more than 6 millions people, the biggest industrial and commercial center in Vietnam. The study area composes of major part of Hochiminh City and parts of surrounding Long An, Tay Ninh, Binh Duong, Ba Ria and Dong Nai provinces, which are reported to have rapid built-up expansion since the last decade.

Ho Chi Minh City can be classified into three regions based on urbanization: Urban inner core region - this region is finished with urbanization, now needs to reurbanize and regenerate in the direction to multi-center; Urban fringe region - this region is quickly going on urbanization; Suburban region - this region has mainly agriculture land.

One scene of Landsat ETM+ image acquired on February 13, 2002 (path 125/row 52) was applied in this study (Figure 1).

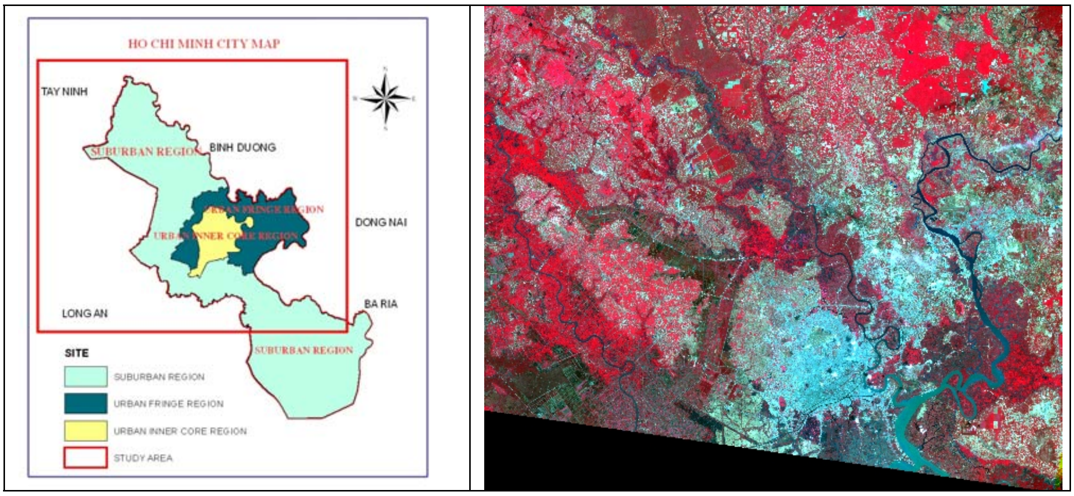


Figure 1. Study area

Surface emissivities were retrieved from conventional land cover classification of the Landsat ETM+ multispectral image.

2.2 Retrieval of LST from Landsat ETM+ imagery

The LST were derived from the Landsat ETM+ thermal infrared band (10.44–12.42 μm), which has a spatial resolution of 60 m. The following equation was used to convert the digital number (DN) of Landsat ETM+ thermal infrared band into spectral radiance (Landsat Project Science Office, 2002):

$$L_\lambda = 0.0370588xDN + 3.2$$

The next step is to convert the spectral radiance to at-satellite brightness temperature (i.e., blackbody temperature, T_B) under the assumption of uniform emissivity (Landsat Project Science Office, 2002). The conversion formula is:

$$T_B = \frac{K_2}{\ln(\frac{K_1}{L_\lambda} + 1)}$$

Where T_B is effective at-satellite temperature in K, L_λ is spectral radiance in W/(m^2 ster μm); and K_2 and K_1 are pre-launch calibration constants. For Landsat-7 ETM+, K_2 = 1282.71 K, and K_1 = 666.09 mW cm^{-2} sr^{-1} μm^{-1}.

The temperature values obtained above are referenced to a black body. Therefore, corrections for spectral emissivity (ε) became necessary according to the nature of land cover. The job for retrieving spectral emissivity is mentioned in the section "surface emissivity". The emissivity corrected land surface temperatures (S_t) were computed as follows (Artis & Carnahan, 1982):

$$S_t = \frac{T_B}{1 + (\lambda x T_B / \rho)\ln\varepsilon}$$

Where: λ = wavelength of emitted radiance, ρ = hxc/σ (1.438x10^{-2} m K), σ = Boltzmann constant (1.38x10^{-23} J/K), h = Planck's constant (6.626x10^{-34} J s), c = velocity of light (2.998x10^8 m/s).

2.3 Surface Emissivity

Surface emissivity is known to be one important factor in radiance balance and transfer. However, the Earth's surface is comprised of complicated land-use and land-cover types and the surface emissivity is difficult to measure accurately.

The effect of surface emissivity on satellite measurements can be generalized into three categories (Prata,1993):

+ Emissivity causes a reduction of surface-emitted radiance.
+ Nonblack surfaces reflect radiance.
+ The anisotropy of reflectivity and emissivity may reduce or increase the total radiance from the surface.

Therefore, retrieval of LST from multispectral data requires an accurate measurement of emissivity values of the surface. The emissivity of a surface is controlled by such factors as water content, chemical composition, structure, and roughness (Snyder et al., 1998). For vegetated surfaces, emissivity can vary significantly with plant species, areal density, and growth stage (Snyder et al., 1998). In the mean time, emissivity is a function of wavelength, commonly referred to as spectral emissivity (Dash et al., 2002). Estimation of emissivities for ground objects from passive sensor data has been measured using different techniques. Among these techniques are the reference channel method (REF) (Kahle, 1980), the normalized emissivity method (NOR) (Gillespie, 1985), Temperature-Indpendent Spectral Indices method (TISI) (Becker & Li, 1990), ALPHA emissivity method (ALPHA) [Kealy and Gabell, 1990] and emissivity RE-normalization method (RE) [Stoll, 1993]. These techniques are applicable to separate temperatures from emissivities, so that the effect of emissivity on estimated LST can be determined.

The REF method assumes that the emissivity in channel r is constant for all pixels. An approximate surface temperature is then derived from atmospherically corrected radiances and used to retrieve the emissivity values for the remaining channels. While, the NOR method assumes a constant emissivity in all N channels for a given pixel, which enables N temperatures to be calculated, the maximum of which is considered to be the Land Surface emperature. Deriving emissivity values for the otherchannels is then achieved as for the REF method. Among these above methods, many papers have shown that the NOR method provides the best results (Sobrino et al., 2002).

Snyder et al. (1998) proposed a new approach in order to recover surface emissivity value. They use kernel methods applied to three bidirectional reflectance distribution function (BRDF) models (a geometric model for sparse vegetation, a volumetric model for dense vegetation, and a specular model for water and ice), so that each pixel can be categorized into 1 of the 14 emissivity classes based on conventional land cover classification and dynamic and seasonal factors.

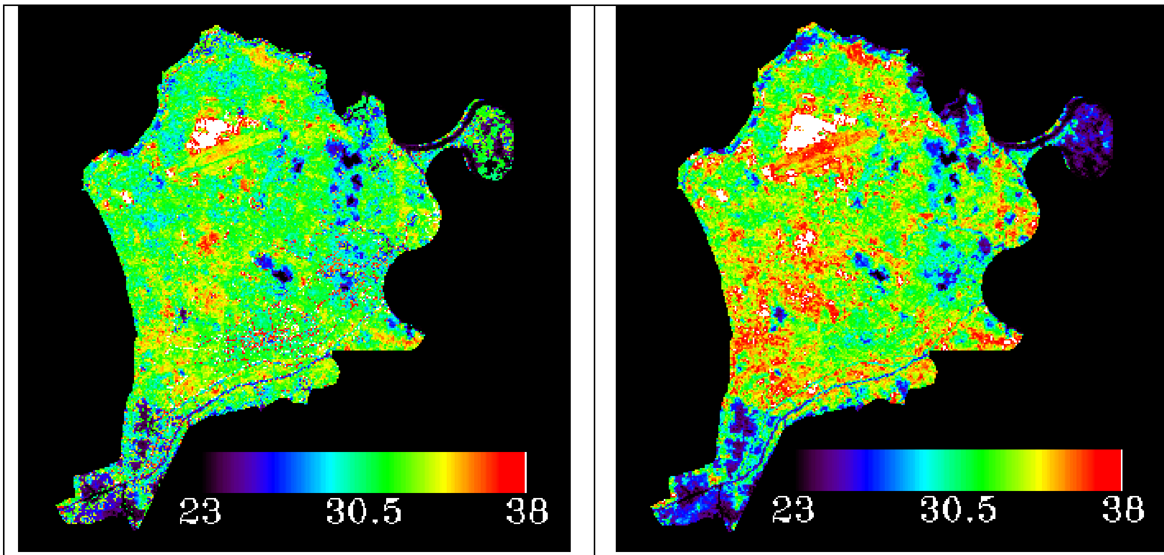
Both unsupervised and supervised classification methods were applied to classify the Landsat ETM+ multispectral image to land-cover map and to derive associated surface emissivity. In unsupervised classification, 15 clusters were applied to assist the selection of training sites. The land cover classification is then supervised classification using the *Maximum Likelihood* algorithm. After the classification, a post-classification recoding was applied to group the land cover types into six broad emissivity classes, *such as Broadleaf forest, Woody, Grass, Water, Organic bare soil, and Arid bare soil.* Each of the land cover categories was assigned an emissivity value by reference to the emissivity classification scheme by Snyder et al. (1998).

3. RESULTS

Digital numbers (DN) derived from ETM+ thermal data and converted brightness temperatures (ε), corrected emissivity to get land surface temperatures.

Surface emissivity derive from Classification-based emissivity method and the NOR method.

Urban inner core region in HCM City temperature map generate based on association surface emissivity value with classification-based method and the NOR method as figure 2.



Classification-based method | NOR method

Figure 2. Urban inner core region in HCM City temperature map

Analysis from imagery indicates that the industrial, residential areas are places with highest surface temperature relative to vegetation and water exhibiting lower temperature.

In order to test the LST obtained with the two methods, values measured in situ are needed. Unfortunately, these data are not available. So, in future, more ground truth temperatures will be collected for test. However, we test simply the results by evaluating the average temperature in each region. Comparison between the NOR method and Classification-based emissivity (CLASS) method is shown in Table 3.

Table 1. Difference of temperature between the two methods (NOR, CLASS)

REGION	METHOD	Temperature (^{o}C)			
		MIN	MAX	MEAN	STDEV
URBAN INNER CORE	NOR	23.36	37.69	32.58	2.16
	CLASS	23.05	38.25	32.34	2.28
URBAN FRINGE	NOR	23.75	38.52	30.52	2.59
	CLASS	23.46	39.42	30.46	2.81
SUBURBAN	NOR	25.05	37.74	30.13	2.34
	CLASS	24.08	38.69	30.03	2.30

The mean temperature value is distributed suitably to each region in HCM City, of which the highest is urban inner core region and the lowest is suburban area. This indicates that the LST data can be used to model urban planning by means of guiding the best land areas for effecttively using.

The result showed that the two methods were similar. The Landsat-7 ETM+ thermal infrared data can be retrieved the LST in Ho Chi Minh City from using surface emissivity based on utilization of targeted emissivity values.

4. CONCLUSION

Many factors affect the retrieval of LST from satellite thermal infrared data but some of them, such as transmittance, air moisture, downwelling and upwelling radiance, are usually difficult to obtain, especially from satellite observations. In this study, we chose a variables surface emissivity because it has been provided important in affecting the retrieval of LST from satellite thermal data. The Surface emissivity is derived from Classification-based emissivity method and the NOR method. The result showed that the two methods were similar. The Landsat-7 ETM+ thermal infrared data can be retrieved the LST in Ho Chi Minh City from using surface emissivity based on the conventional land cover classification. In future, more ground truth temperatures in different 'emissivity classes' will be collected and ancillary data will be applied to get the best result. We believe that with more ground truth temperature measured in different 'emissivity classes', the accuracy of the LST data will be further improved.

This study also indicated that LST data can provide a powerful way to model urban planning, monitor environment and human activities. Also, this will bring a perspective for the application of satellite thermal data in improving environment quality and the planning strategies for heat island reduction.

5. REFERENCES

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