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Retrieval of Land Surface Temperature from MTSAT-1R

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Abstract : The land surface temperature (LST) can be defined as a weighted average temperature of components which constitute a pixel. The coefficients of split-window algorithm for MTSAT-1R were obtained by means of a statistical regression analysis from radiative transfer simulations using MODTRAN 4.0 for a wide range of atmospheric, satellite viewing angle (SVA) and lapse rate conditions. 6 types of atmospheric profile data imbedded in the MODTRAN 4 are used for the radiative transfer simulations. The RMSE is clearly larger on warm and humid profiles than cold and dry profiles, especially when the satellite viewing angle and lapse rate are large. The derivation of LST equations according to the atmospheric profiles clearly decreased the RMSE without regard to the SVA and lapse rate. The bias and RMSE are decreased as the more controls factors included. This preliminary result indicates that the characteristics of atmosphere, SVA and lapse rate should be included in the LST equation.

Key Words : Land surface temperature, MODTRAN4, MTSAT-1R, Split-window.

1. Introduction

The land surface temperature (LST) can be defined as a weighted average temperature of components which constitute a pixel. It is one of the biophysical parameters of land surface which control the processes of energy and water between land and atmosphere. So, the LST is a useful product for a wide range of applications, agriculture, numerical and climate modeling community. Whereas, operational observation of LST is far from the needs of application community both in spatial and temporal scale. Retrieval of LST from satellite data is regarded as a surrogate for the conventional observation of LST as in the sea surface temperature (SST). The split-window methods for deriving SST in a clear sky have proven to be very efficient and are currently being used operationally.

Theoretical possibility for the retrieval of LST using split-window methods have been shown by Becker and Li (1990), and many others. Various algorithms for the retrieval of LST from meteorological satellite data have been developed and tested in many countries (e.g., Kerr *et al.*, 1992; Ulivieri *et al.*, 1994; Wan and Dozier, 1996). However, operational retrieval of LST from satellite

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data is very limited due to the poor accuracy of retrieved LST. The lower quality of retrieved LST is mainly caused by the combined effects of spectrally and temporally varying emissivity and atmosphere. Recently, the various background data (e.g., land cover, vegetation index) and methods (vegetation coverage method: valor and Caselles, 1996) for the estimation of spectral emissivity are developed. And the quality of satellite data is clearly improved in radiometric, navigation and signal to noise ratio. As the results, the quality of retrieved LST is being improved steadily.

The aim of this study is to develop the LST retrieval algorithm from MTSAT-1R data over East Asian region. The coefficients are obtained by means of regression analysis from various atmospheric radiative transfer simulations using MODTRAN 4.

2. Simulation of MTSAT-1R Measurements

To retrieve the LST using split-window methods, ground match-up data are needed for the coefficients of regression equation. However, available match-up data are severely limited in LST. So, we performed radiative transfer simulations using MODTRAN 4 with various atmospheric and satellite viewing conditions. The factors affect the retrieved LST using split-window method using two adjacent IR channels are atmospheric profiles, spectral emissivity, satellite viewing angle and intensity of inversion. The atmospheric radiative transfer simulations are designed to include all the impacting factors mentioned above.

- Atmospheric profiles : 6 profiles imbedded in the MODTRAN 4, and 40 sets of atmospheric profiles extracted from TIGR atmospheric profile data. (Tropic (TRO: T_a=299.7K CWV=3.3cm), Mid-latitude summer (MLS: T_a=294.2K CWV=2.3cm), Mid-latitude winter (MLW: T_a=272.2K CWV=0.7cm), Sub-arctic summer (SAS: T_a=287.2K CWV=1.7cm), Sub-arctic winter (SAW: T_a= 257.2K CWV=0.3cm), U.S. standard atmosphere (US: T_a=288.2K CWV=1.1cm).
- Satellite zenith angle : 12 viewing angles are selected to cover the MTSAT-1R viewing angles range from nadir to 55° in steps of 5°.
- Inversion intensity : the LST are prescribed as T_a - 6K to T_a + 15K in steps of 2K. This wide range of LST represents the night time (T_a - 6K to T_a + 2K) and day time (T_a - 2K to T_a + 15K) conditions.
- Band emissivity : the emissivities of IR_{11} and IR_{12} are range from 0.94 to 1.0 in step of 0.02 and the differences between two bands are from -0.0135 to 0.0227 in steps of 0.004525.

3. Preliminary Results: Sensitivity Analysis

To evaluate the sensitivity of LST regression equations to the impacting factors, following equations are derived and tested.

$$LST = a + b\,T_{11} + c\,\Delta T + d\,\Delta T^2 \quad (1)$$

$$LST = a + b\,T_{11} + c\,\Delta T + d\,\Delta T^2 + e\,(\sec\theta - 1) \quad (2)$$

$$LST(Pf) = a(Pf) + b(Pf)\,T_{11} + c(Pf)\,\Delta T + d(Pf)\,\Delta T^2 + e(Pf)\,(\sec\theta - 1) \quad (3)$$

$$LST(\theta) = a(\theta) + b(\theta)\,T11 + c(\theta)\,\chi T + d(\theta)\,\Delta T2 \quad (4)$$

$$LST(LR) = a(LR) + b(LR)\,T_{11} + c(LR)\,\theta T + d(LR)\,\Delta T^2 + e(LR)\,(\sec\theta - 1) \quad (5)$$

$$LST(\varepsilon) = a + b\,T_{11} + c\,\Delta T + d\,\Delta T^2 + e\,(\sec\theta - 1) + f(\varepsilon) + g(\Delta\varepsilon) \quad (6)$$

Where θ = satellite veiwing angle

ε = emissivity

Pf = atmospheric profiles

LR = lapse rate between surface and Ta

a, b, ~ f, g = coefficients calculated from regression method using the simulated T_{11} and T_{12}

Fig. 1 shows the RMSE of Eq. (1) as a function of satellite viewing angle and lapse rate at the surface. The RMSE is clearly larger on warm and humid profiles (e.g., TRO, MLS) than cold and dry profiles (e.g., SAW, MLW), especially when the satellite viewing angle and lapse rate are large. It indicates that the different thermal characteristics of atmosphere according to the seasons and geographic locations should be included in the regression

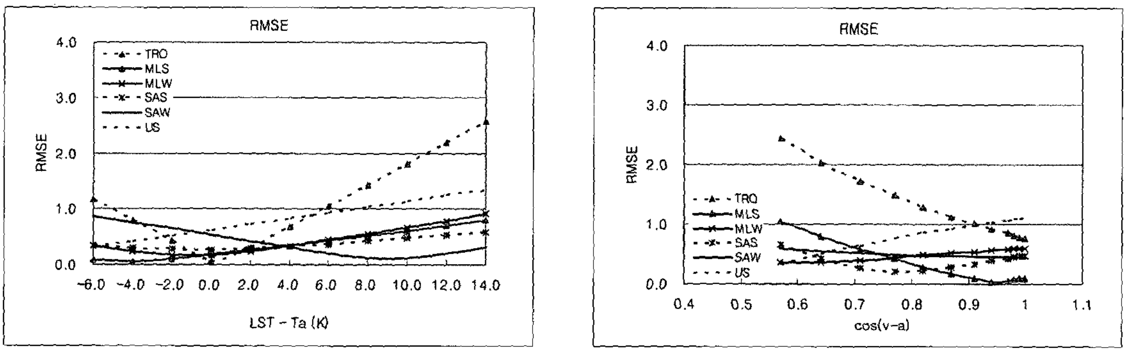

Figure 1. The RMSE of Eq. (1) as a function of satellite viewing angle and lapse rate at the surface for the six atmospheric profiles included in MODTRAN 4.

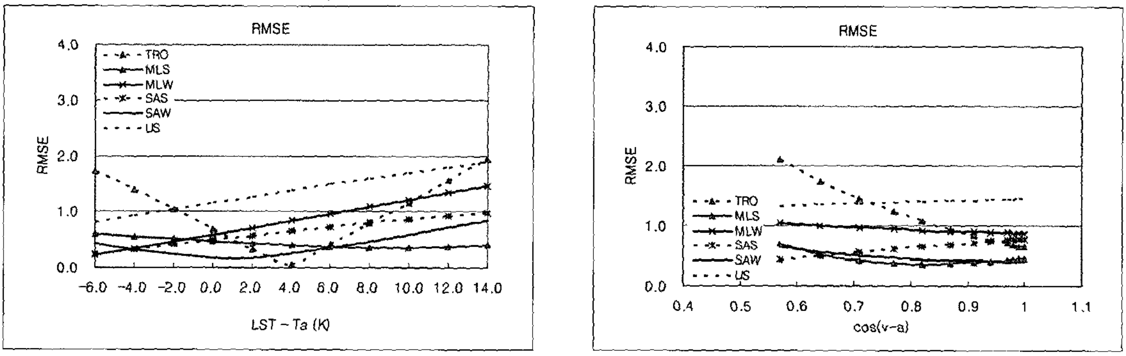

Figure 2. Same as in Figure 1 except for Eq. (2).

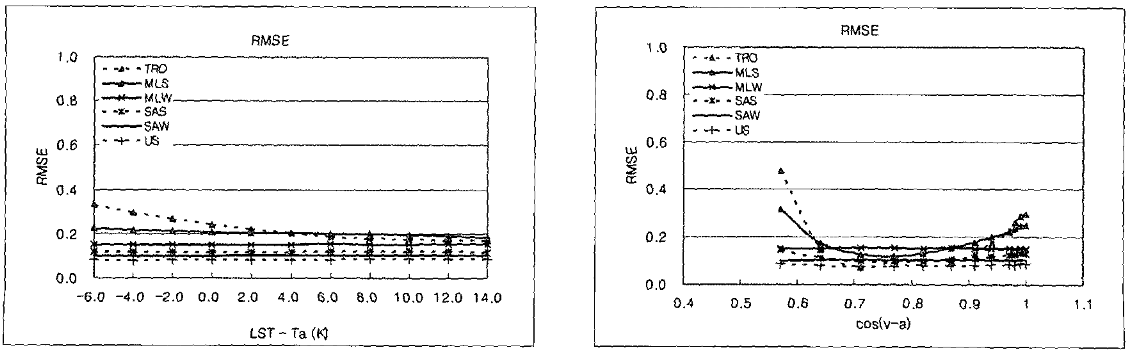

Figure 3. Same as in Figure 1 except for Eq. (3).

equation. And the satellite viewing angles and lapse rate are also included.

Fig. 2 shows the RMSE of Eq. (2) as a function of satellite viewing angle and lapse rate at the surface. In general, the inclusion of SVA at the regression decreased the RMSE, although the impacts are dependent on the atmospheric profiles and SVA. The derivation of LST equations according to the atmospheric profiles clearly decreased the RMSE without regard to the SVA and lapse rate (Fig. 3). It indicates that atmospheric profile (T, q) is one of the most important factors which control the retrieval level of LST. The derivation of LST equations according to the SVA decreased the RMSE without regard to the SVA and lapse rate. However, the impacts are generally weaker than those of Eq. (3).

4. Summary

In this study, we developed the LST retrieval algorithms from MTSAT-1R data through the radiative transfer simulations under various atmospheric, SVA and lapse rate conditions using MODTRAN.4 and performed sensitivity analysis to the atmospheric profiles, SVA and lapse rate. The RMSE is clearly larger on warm and humid profiles (e.g., TRO, MLS) than cold and dry profiles (e.g., SAW, MLW), especially when the satellite viewing angle and lapse rate are large. The derivation of LST equations according to the atmospheric profiles clearly decreased the RMSE without regard to the SVA and lapse rate. The bias and RMSE are decreased as the more controls factors included. This preliminary result indicates that the characteristics of atmosphere, SVA and lapse rate should be included in the LST equation.

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