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THE DIFFERENCE BETWEEN LABORATORY AND IN-SITU PIXEL-AVERAGED EMISSIVITY: THE EFFECTS ON TEMPERATURE-EMISSIVITY SEPARATION

Tsuneo Matsunaga

Geophysics Department, Geological Survey of Japan
1-1-3, Higashi, Tsukuba, Ibaraki, 305, Japan

1. INTRODUCTION

Advanced Spaceborne Thermal Emission and Reflection Radiometer(ASTER) is a Japanese future imaging sensor which has five channels in thermal infrared(TIR) region. To extract spectral emissivity information from ASTER and/or TIMS data, various temperature-emissivity(T-E) separation methods have been developed to date. Most of them require assumptions on surface emissivity, in which emissivity measured in a laboratory is often used instead of in-situ pixel-averaged emissivity. But if these two *emissivities* are different, accuracies of separated emissivity and surface temperature are reduced.

In this study, the difference between laboratory and in-situ pixel-averaged emissivity and its effect on T-E separation are discussed. TIMS data of an area containing both rocks and vegetation were also processed to retrieve emissivity spectra using two T-E separation methods.

2. THE DIFFERENCE BETWEEN LABORATORY AND IN-SITU PIXEL-AVERAGED EMISSIVITY OF LAND SURFACE

The difference between laboratory and in-situ pixel-averaged emissivity has several causes. A pixel generally contains different materials of different temperatures. Since a pure isothermal sample is usually measured in a laboratory, laboratory emissivity may differ from pixel-averaged emissivity(heterogeneity effect).

Due to less-than-unity emissivity of land surface, incident thermal radiation to the surface is partially reflected and observed by a sensor. Incident radiation consists of downwelling radiance from the atmosphere including clouds and thermal radiation from the surrounding. In addition to reflection, the surface roughness causes scattering of thermal emission from the surface itself. Thus, apparent emissivity is expected to be higher than laboratory emissivity because of these scattering/reflection effect.

3. TEMPERATURE-EMISSIVITY SEPARATION METHODS

In this study, Emissivity Spectrum Normalization(ESN: *Realmuto*, 1990) and Mean-Maximum Difference(MMD: *Matsunaga*, 1993a, b) methods were considered. The MMD method is based on a relationship between the mean and the spectral variation of emissivity of terrestrial materials in TIR region. Similar methods have been developed by *Kealy and Gabell* [1990], *Stoll* [1991] and *Hook* [personal communication]. In the MMD method, the relationship between the mean(M) and the difference between the maximum and the minimum(Maximum Difference: MD) of emissivity for TIMS six channels is assumed to be linear. MD corresponds to spectral contrast or variation. Surface temperature and spectral emissivity can be separated based on this assumption. Fig. 1 shows M-MD relationship for various earth's surface materials. Volcanic rocks have high contrast and low mean of spectral emissivity. On the contrary, spectra of water surface and vegetation are very flat and close to unity. This relationship can be approximated to linear, though the distribution is somewhat scattered.

4. EVALUATION OF EFFECTS OF SURFACE HETEROGENEITY AND SCATTERING/REFLECTION BY SIMPLE SIMULATIONS

4.1. Surface Heterogeneity

Pixel-averaged emissivity of an isothermal pixel comprised of two materials

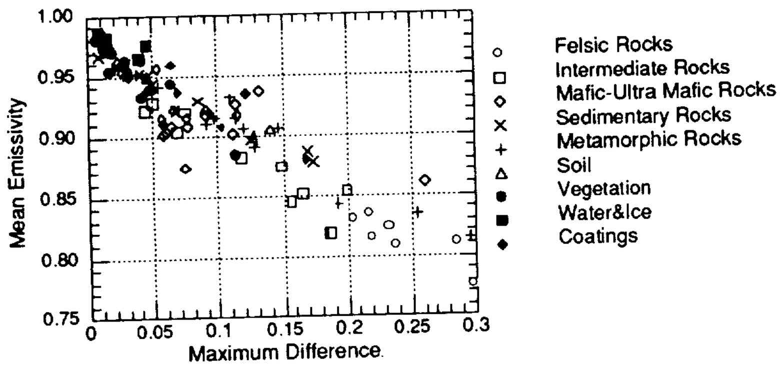

Fig. 1 Mean-maximum difference relationship for various terrestrial materials.

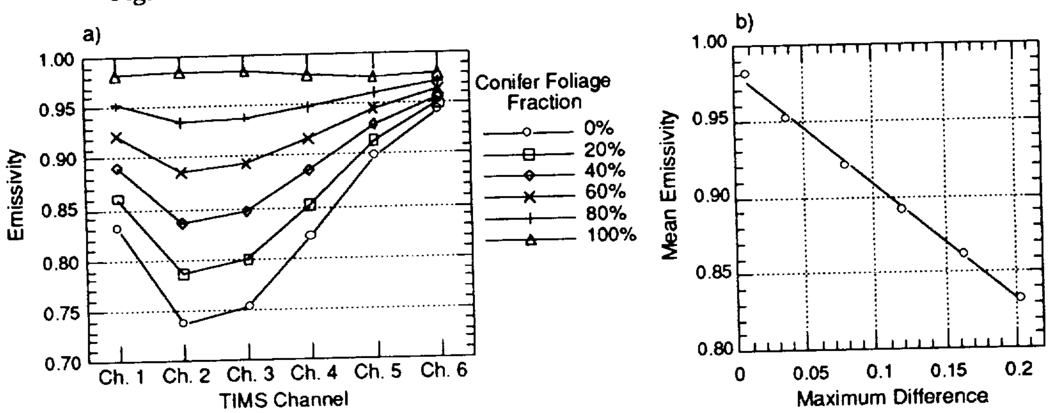

Fig. 2 Pixel-averaged emissivity spectra(a) and M-MD relationship(b) for varying areal fraction of conifer foliage.

having different spectral emissivity was calculated to evaluate the heterogeneity effect on spectral emissivity. Rhyolite and conifer foliage were chosen as the materials because volcanic rocks and vegetation generally have very different emissivity spectra. Simulated pixel-averaged emissivity spectra corresponding to varying conifer foliage area fraction are shown in Fig. 2a. Maximum emissivity increases according to the fraction. Therefore, assuming constant maximum emissivity in the ESN method causes errors if vegetation fraction in a pixel varies within a scene. Fig. 2b shows M-MD relationship for this case. Spectra of mixed pixels almost satisfy the linear relationship determined from pure rhyolite and conifer foliage spectra.

4.2. Surface Scattering/Reflection of Thermal Radiation

Because detailed calculation of scattering/reflection effects at land surface is difficult, single reflection effect was considered in case of the geometry shown in Fig. 3. The surface was illuminated by thermal emission from the surrounding wall. Both of them were assumed to be isothermal and isotropic reflectors/emitters with same emissivity as rhyolite and have same temperature. Long-wave sky radiation was ignored. Simulated emissivity spectra were shown in Fig. 4a for varying angle θ. As θ decreases, spectral contrast decreases and emissivity values increases. Thus, neglecting the scattering/reflection effect on surface emissivity results in overestimation of surface temperature. M-MD relationship was linear for varying θ(Fig. 4b).

These simulations show that the effects of surface heterogeneity and scattering/reflection can change in-situ pixel-averaged emissivity from the value measured in a laboratory. The robustness of the assumption used in the MMD method is also shown.

5. EXTRACTION OF EMISSIVITY SPECTRA FROM TIMS DATA

5.1. Acquisition and Atmospheric Correction of TIMS Data

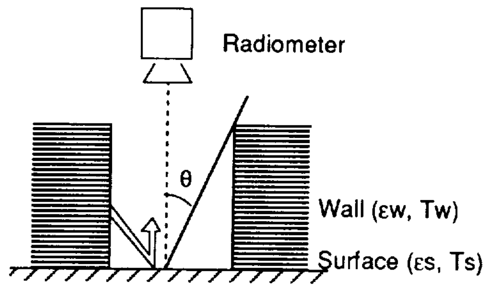

Fig. 3 A simple model for the simulation of scattering/reflection effect at the surface.

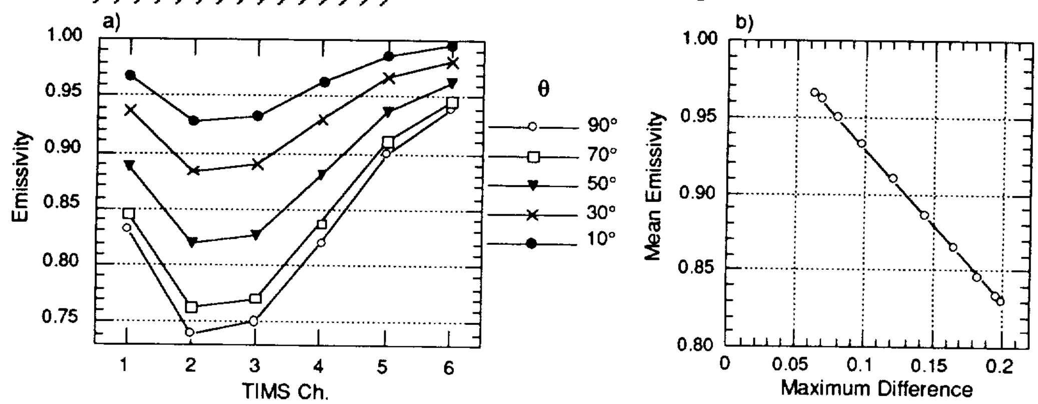

Fig. 4 Apparent emissivity spectra(a) and M-MD relationship(b) including single reflection effect. The surface and the wall were assumed to have rhyolite emissivity spectrum and same temperature.

TIMS data used in this study were acquired over Mono Lake/Mammoth Lakes area, California, on October 16, 1991. This area is located at the east flank of the Sierra Nevada. Flight altitude, spatial and temperature resolutions were about 7.5 km ASL, 13 m, and 0.25 - 0.30°C, respectively.

Atmospheric transmittance and upwelling radiance for each TIMS channel were preliminarily calculated using LOWTRAN7 with data from a radiosonde launched at the time of the overflight. Though lake surface brightness temperatures for TIMS Ch. 5 and 6 were same after LOWTRAN-based atmospheric correction, temperature for Ch. 1, 2, and 4 were higher than Ch. 5 and 6(Fig. 5) This discrepancy was also found at dark-grayish sand beach with a little grass. In this study, atmospheric transmittance and upwelling radiance calculated from TIMS data of the lake surface and the beach were used. For this calculation, it was assumed that these two sites were blackbody and brightness temperatures in Ch. 5 after LOWTRAN-based atmospheric correction were true surface temperatures.

5.2. Temperature-Emissivity Separation

The ESN and the MMD methods were applied to atmospherically corrected TIMS radiance data to retrieve surface emissivity spectra. Fig. 6 shows retrieved spectra for the transect from a coniferous forest to rhyolite-dominated field at the flank of Crater Mountain. Both methods could obtain emissivity troughs corresponding to SiO2 content for rhyolite, and flat spectra for forest. In addition, the MMD method could show higher emissivity values for the forest than for rhyolite and transitional spectra from forest to rhyolite(Point 57 and 58).

6. CONCLUSION

Simple simulations showed that in-situ pixel-averaged emissivity may differ from emissivity measured in a laboratory due to the effects of surface heterogeneity and scattering/reflection. It was also shown that T-E separation methods based on the relationship between the mean and the variation of spectral emissivity are relatively robust to these effects. It must be noted, however, that retrieved emissivity by these methods is apparent and still including scattering/reflection contribution.

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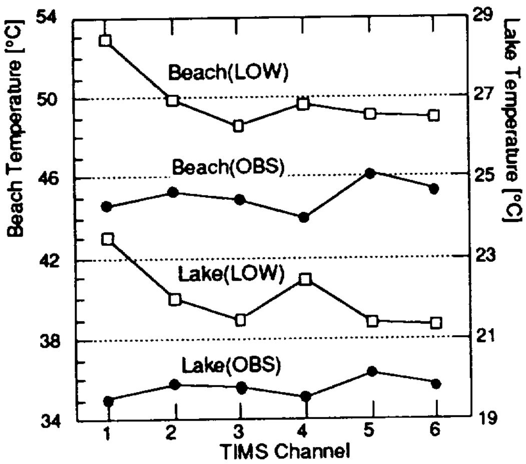

Fig. 5 TIMS brightness temperature of Mono Lake and the beach.
OBS: observed temperature
LOW: after LOWTRAN7-based atmospheric correction..

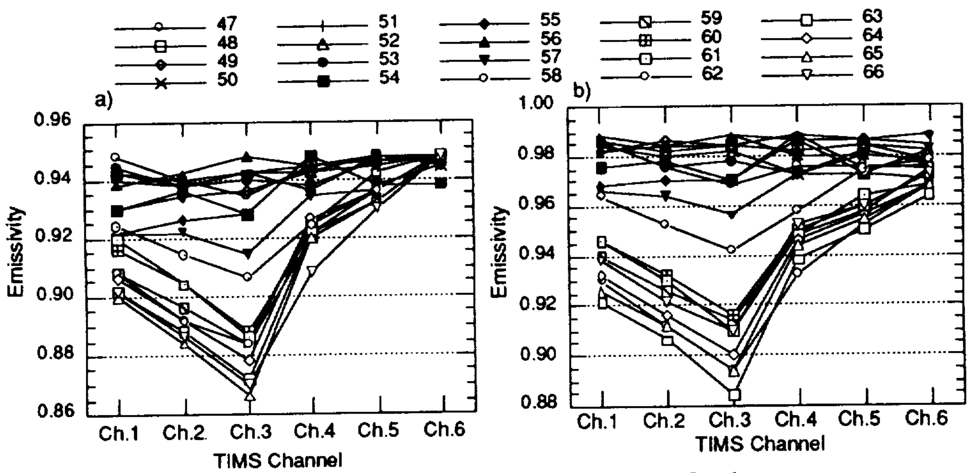

Fig. 6 Retrieved emissivity spectra from TIMS data for the transect from coniferous forest(47) to rhyolite field(66). a) ESN method, b) MMD method.

sity of Tokyo, Japan, for providing emissivity data of terrestrial materials integrated over TIMS response functions. Original emissivity spectra are described in *Salisbury et al.*[1988] and *Salisbury et al.*[1992]. The author is also grateful to personnels of JPL, DRI, University of Nevada System, and JAPEX Geoscience Institute who cooperated in the acquisition of TIMS data and field works.

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