LAND SURFACE EMISSIVITY ESTIMATION FROM VNIR/SWIR REFLECTANCE

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ABSTRACT:

For the Land surface estimation from the satellite on the basis of the split-window method, the land surface emissivity have to be the known value. To estimate these value from the VNIR/SWIR land surface reflectance, the attempts are made that the emissivity category are defined from the definition of the average emissivity and the spectral dependency of the emissivity, the number of pixels of each category are counted and the statistical analysis between the emissivity of 10.8 and 12.0 micrometer and VNIR/SWIR reflectance are made. Using 10 years of MODIS global mapped reflectance product (MOD09CFG) and Land surface temperature and emissivity product (MOD11C1), these analysis are made and verified.

1 INTRODUCTION

The operational satellite based land surface temperature (LST) estimation started around 2000 which are made by MODIS, ASTER and AATSR. For the LST estimation, the split window algorithm are mainly used for AATSR (Prata, 2002) and MODIS (Wan, 1999), which the land surface emissivity must be the known value. The upcoming JAXA's sensor SGLI (Second generation GLobal Imager) (Honda, 2006) on board GCOM–C1 will have the similar spectral channel as AVHRR, MODIS and AATSR (10.8 and 12.0 [μm]) and the split windows algorithm are planned to use for the LST estimation (Moriyama, 2009). For the land surface emissivity definition, so far the land cover classification based method are used (Wan, 1999, Prata, 2002), which provide the emissivity set for the conventional land cover categories such as forest, bare soil area and so on. This concept has assumptions that the emissivity of each category are always the same and the each pixel can be classified into the single land cover category. Actually, these assumptions can be easily violated by the category mixture and water content fluctuation. This paper proposes the reflectance based land surface emissivity estimation method which are on the basis of the statistical analysis between the emissivity from MODIS Day/Night land surface temperature product and the index derived from the MODIS land surface reflectance product.

2 SPATIAL AND TEMPORAL DISTRIBUTION OF THE LAND SURFACE EMISSIVITY

2.1 Dataset

Terra/MODIS continues to observe the earth for 10 years and many kinds of the product are generated. Among the products, this research uses the daily global mapped Day/Night land surface temperature product (MOD11C1) is used for the spatial and temporal emissivity distribution analysis. This product is based on the Day/Night land surface temperature estimation algorithm which the simultaneous radiative transfer equation of the day and night observation radiance of 6 emission spectral channel data at the same location are used for the day and night land surface temperature estimation and the classification based land surface emissivity validation (Wan, 1999). Since this algorithm can verify the classification based land surface emissivity by the radiometric consistency analysis, the emissivity represents the actual condition of the surface. Also as the surface reflectance, the daily global mapped surface reflectance product (MOD09CMG) is used. This product is generate from the atmospheric correction process using the satellite detected radiance and the MODIS derived atmospheric data. Both of the dataset has the same spatial resolution, 0.05[deg.]. These 2 data set from 5 Mar. 2000 to 31 Dec. 2009 are used for the analysis. From the LST product, the pixel of the daytime LST Quality flag is used for the mask data for the both product. As the example of the data, 1 Jan. 2001 mask data, ch. 31 emissivity and ch. 32 emissivity are shown in Figure 1–3.

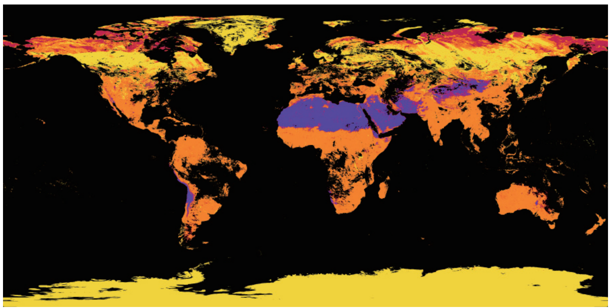

Figure 1: MODIS ch. 31 emissivity on 1 Jan. 2001

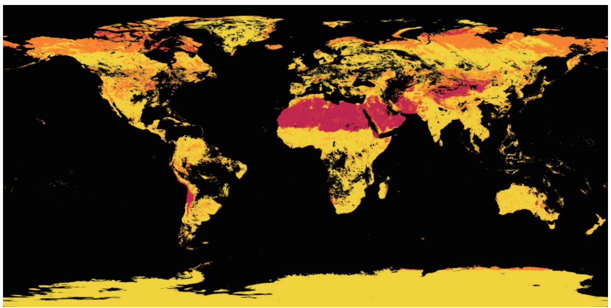

Figure 2: MODIS ch. 32 emissivity on 1 Jan. 2001

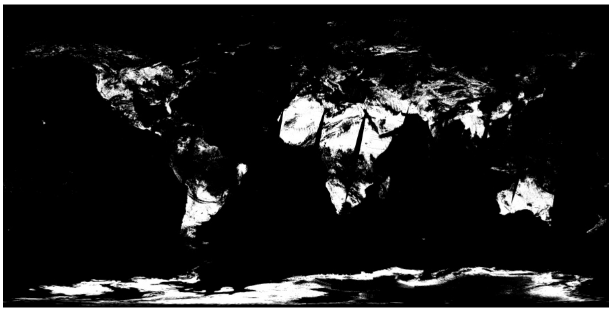

Figure 3: The mask image on 1 Jan. 2001

2.2 Emissivity category

The land surface emissivity widely varies with the land cover and the wavelength. For the rough estimation of the emissivity variation, the emissivity category is defined. To separate the spectral dependency and the magnitude of the emissivity, the following two parameters, the average emissivity $\bar{\varepsilon}$ and the spectral dependency parameter a are defined as Eq. (1 – 3),

$$\bar{\varepsilon} = \frac{\varepsilon_1 + \varepsilon_2}{2} \tag{1}$$

$$\Delta\varepsilon = \frac{\varepsilon_1 - \varepsilon_2}{2} \tag{2}$$

$$a = \frac{\Delta\varepsilon}{1 - \bar{\varepsilon}} \tag{3}$$

where ε_1 and ε_2 are emissivity at MODIS ch. 31 (11[μm]) and ch. 32 (12[μm]) respectively. To make the 0.02 interval grid on $\varepsilon_1 - \varepsilon_2$ plane, $\bar{\varepsilon}$ and a are divided and the emissivity category is defined as Figure 4.

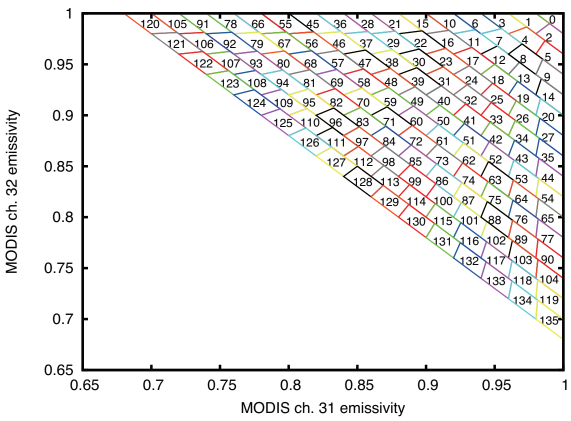

Figure 4: The emissivity category

2.3 Temporal and spatial distribution of the emissivity category

From 10 years daily dataset, the total numbers of pixel of each emissivity category are counted. The result of all category is shown in Figure 5 and the result of 0 – 20th. category is shown in Figure 6. The green dashed line in the both figure show the relative cumulative frequency, up to 7th. emissivity category, almost all land cover are included.

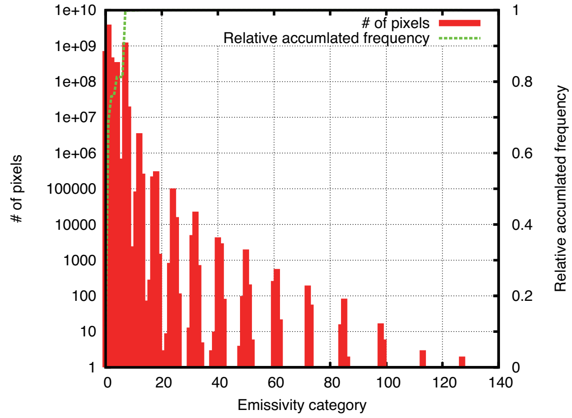

Figure 5: Total pixel of the emissivity category (All category)

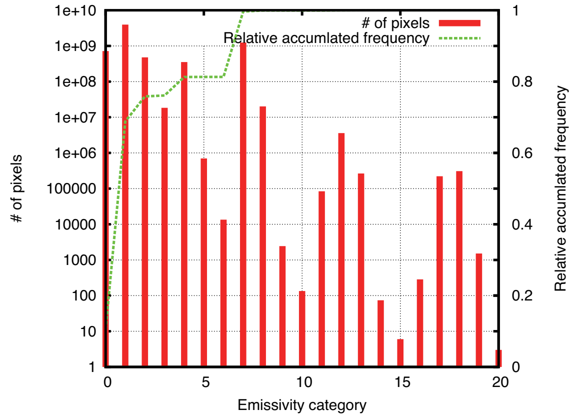

Figure 6: Total pixel of the emissivity category (0–20th. category)

The variation of the pixel number of each category are shown in Figure 7 and 8. It is clarified that the 0th. and 1st. category varied in the inverse phase, the 2nd. and 4th. category varied in the similar phase and the 7th. category kept constant. Also it is clarified that this 5 emissivity categories are significant.

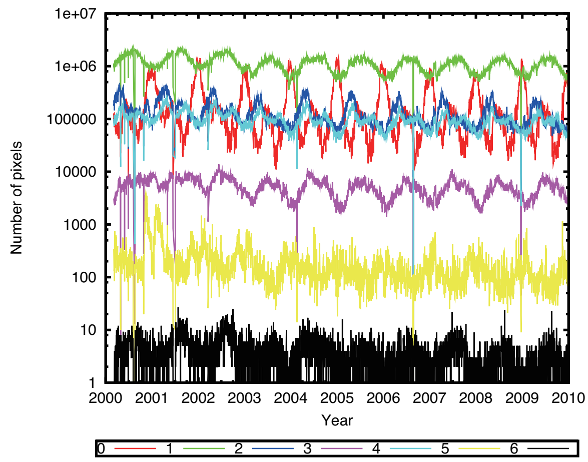

Figure 7: Daily variation of the pixel number of the emissivity category (0–6th. category)

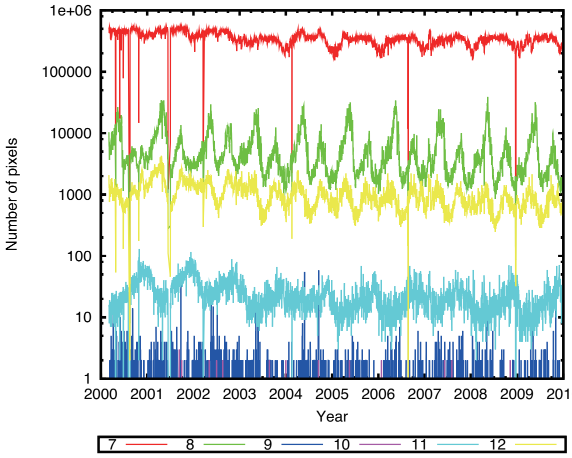

Figure 8: Daily variation of the pixel number of the emissivity category (7–12th. category)

To identify the emissivity categories, the average and standard deviation of LST of each emissivity category are computed, The results are shown in Figure 9 and 10. Al so the 0 - 2nd. categories and 3rd, 4th. and 7th. categories of 1 Jan. 2001 and 1 July 2001 are shown in Figure 11 and 12.

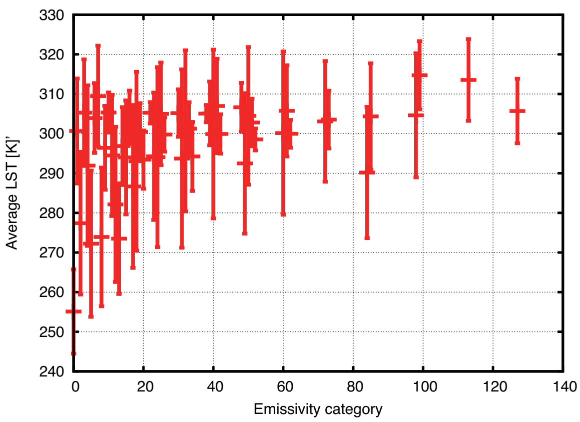

Figure 9: The average and standard deviation of LST at each category (All category)

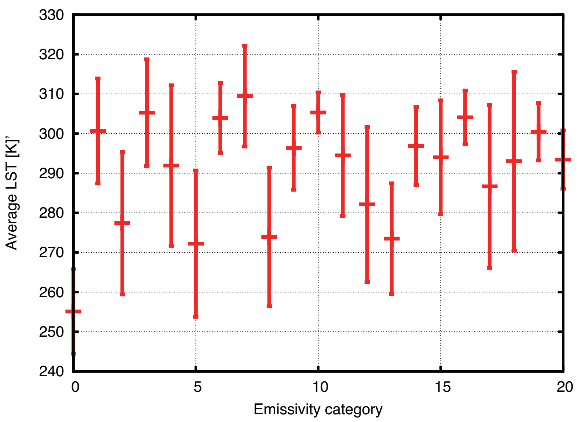

Figure 10: The average and standard deviation of LST at each category (0 – 20th. category)

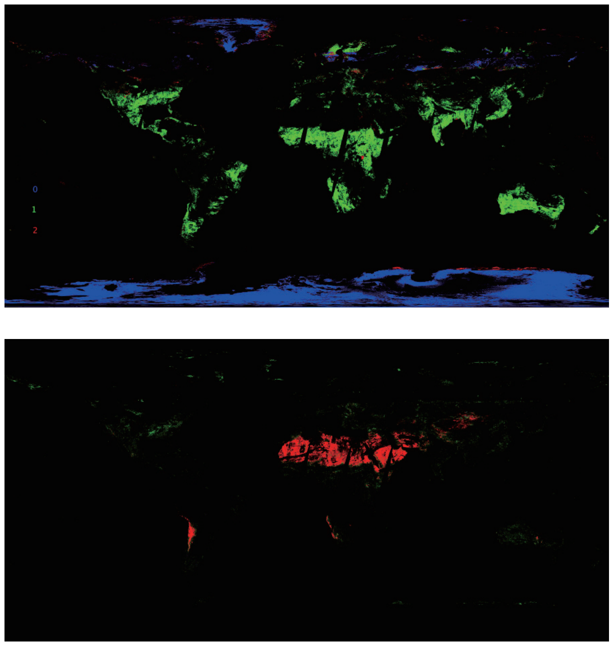

Figure 11: Emissivity category map of 1 Jan. 2001 (Upper: Red: 2, Green: 1, Blue: 0, Lower: Red: 7, Green: 4, Blue: 3)

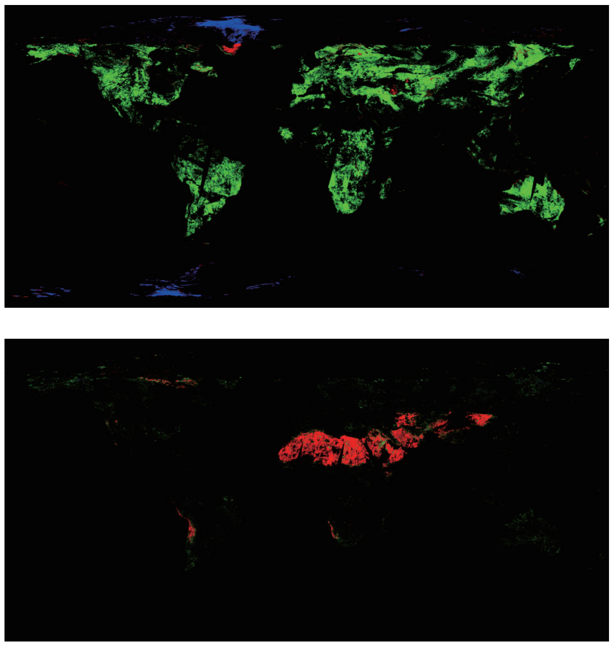

Figure 12: Emissivity category map of 1 July 2001 (Upper: Red: 2, Green: 1, Blue: 0, Lower: Red: 7, Green: 4, Blue: 3)

From the above analysis, it is clarified that the 0th. emissivity category corresponds to the snow/ice area and 1st. emissivity category corresponds to the vegetation. Also it is clarified the most significant emissivity change is the alternation of the 0th. and 1st emissivity category in the annual land cover change.

2.4 Land surface estimation from the VNIR/SWIR reflectance

The surface emissivity is affected by not only the land cover also the water content (J. W. Salisbery, 1992). To identify these condition, many kinds of indexes derived from the satellite data are proposed. Among these, this research use NDVI (Normalized Differential Vegetation Index) (de Griend and Owe, 1993) and

NDWI (Normalized Differential Water Index) (Gao, 1996) are used.

This study estimates the average emissivity $\bar{\varepsilon}$ (*cf.* Eq. (1)) and the spectral dependency parameter a (*cf.* Eq. (3)) using NDVI and NDWI derived from MOD09CMG product as follows,

$$NDVI = \frac{\rho_2 - \rho_1}{\rho_2 + \rho_1} \tag{4}$$

$$NDWI = \frac{\rho_2 - \rho_6}{\rho_2 + \rho_6} \tag{5}$$

where ρ means the surface reflectance and subscript shows the MODIS spectral channel.

At first the degree of variation of $\bar{\varepsilon}$ and a are computed from the 10 years dataset. The standard deviation of these variables are shown in Figure 13.

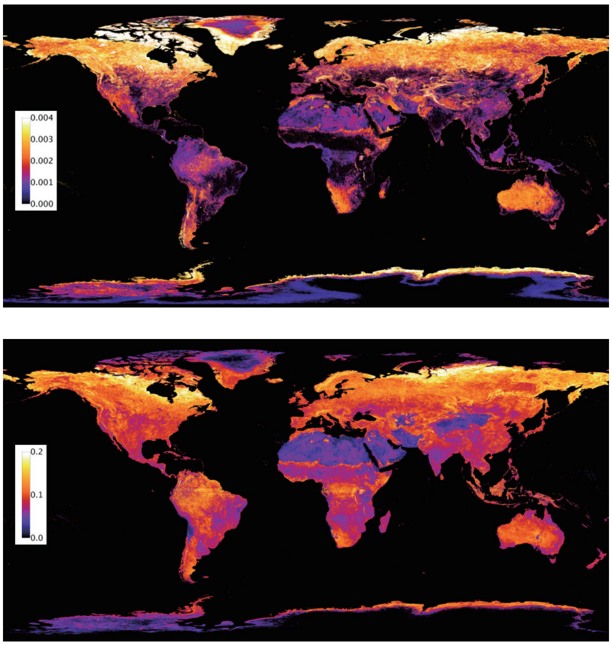

Figure 13: Standard deviation of $\bar{\varepsilon}$ (Upper) and a (Lower)

As the previous the emissivity category research, $\bar{\varepsilon}$ does not so much varied, but a varied especially in the high latitude area. This is because the category 0 (ice/snow) and 1 (vegetation) is the dominant category, the alternation of these 2 categories is the significant emissivity change and these 2 categories have similar emissivity. So that in this research, a is defined as the estimated variable.

To estimate a, the pixel–wise estimation is used, this means the a estimation formula is made at each pixel. For the definition of the independent variable of the estimation, the correlation coefficient between a and NDVI, NDWI are computed, the results are shown in Figure 14. The correlation between a and NDWI is high than that of NDVI, especially the high latitude area. This shows that the most significant emissivity change in the high latitude area can estimate the NDWI.

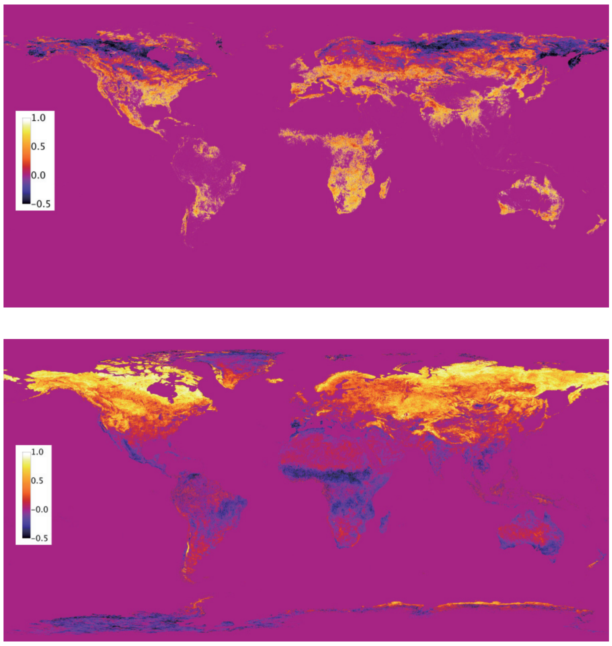

Figure 14: Correlation coefficient between a and NDVI (Upper), NDWI (Lower)

3 CONCLUSIONS

The previous discussions lead the following results. The land surface emissivity largely varies in the high latitude area because of the alternation of ice/snow and vegetation. To estimated the emissivity, NDWI is effective, especially the wavelength dependency of the emissivity estimation.

ACKNOWLEDGMENTS

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