Potential of HyspIRI/TIR Emissivity Spectra for Snow/Ice Monitoring (2)

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ABSTRACT

In snow/ice remote sensing, thermal infrared (TIR) bands are used for observing surface temperature, but not used for analyzing spectral features in emissivity. It is, however, known that snow/ice emissivity spectra in this spectral region are affected by grain size and degree of cementation (Salisbury et al., 1994), which indicates that TIR emissivity spectra can be used for monitoring of snow/ice conditions. We therefore have proposed snow/ice emissivity indices for ASTER/TIR and MODIS/TIR, and applied them to Antarctic glaciers and Japanese frozen lakes (Tonooka et al., 2005). The sensitivity of TIR Snow/ice Index (TSI) to snow/ice conditions depends on the spectral distance of two bands used for TSI. Compared to ASTER and MODIS, HyspIRI has more suitable band-pair for TSI analysis. In the present study, it is reviewed and also some results of TSI analyses for Antarctic and Greenland glaciers are demonstrated.

Keywords: snow and ice, thermal infrared, spectral emissivity ratio, ASTER, MODIS, grain size, packing fraction

Introduction

In remote sensing of snow and ice fields, the solar reflective and/or the microwave spectral regions are frequently used. In comparison with these regions, the thermal-infrared (TIR) spectral region may be less frequently used in general, while this region provides surface temperature which is a key parameter in climate process studies. Furthermore, spectral emissivity of snow/ice surfaces in this region has been researched or discussed by several investigators [1][2][3], but these studies are basically focused on improvement of accuracy in surface temperature determination or radiation budget evaluation: that is, spectral emissivity is not a signal or information, but a noise or uncertain factor.

On the other hand, laboratory measurements of terrestrial materials' emissivity indicate that snow/ice emissivity changes spectrally with snow/ice conditions such as grain size and packing fraction [4]. Thus, we have proposed the TIR Snow/ice Index (TSI) based on spectral emissivity ratio for ASTER/TIR and MODIS/TIR.

In the last HyspIRI workshop, we showed the potential of HyspIRI for snow/ice monitoring with TSI, and introduced some preliminary results of TSI analyses for frozen lakes and Antarctica.

In the present study, we review the potential of HyspIRI for TSI analysis and show some results obtained from Antarctica and Greenland glaciers.

Snow/Ice emissivity and TSI

Fig. 1 displays the directional hemispherical emissivity spectra of ice, fine snow (ϕ = 24 μm), medium snow (ϕ = 82 μm), coarse snow (ϕ = 178 μm), and frost (ϕ = 10 μm) which were derived from the directional hemispherical reflectance spectra measured in laboratory [4][5]. As shown, these spectra are dependent on conditions such as grain size and degree of cementation—particularly, spectral emissivity in 10.5 to 13 μm changes more largely. Based on this fact, TIR Snow/ice Index (TSI) can be defined by the ratio of two band emissivities located in this spectral region such as B13/B14 for ASTER, B31/B32 for MODIS, and B6/B8 for HyspIRI.

TSI is more sensitive to snow/ice condition changes as the two bands are more distant in a spectral region of 10.5 to 13 μm. Fig. 2 shows TSI changes with samples for ASTER, MODIS, and HyspIRI, indicating that HyspIRI is the most sensitive to snow/ice condition changes.

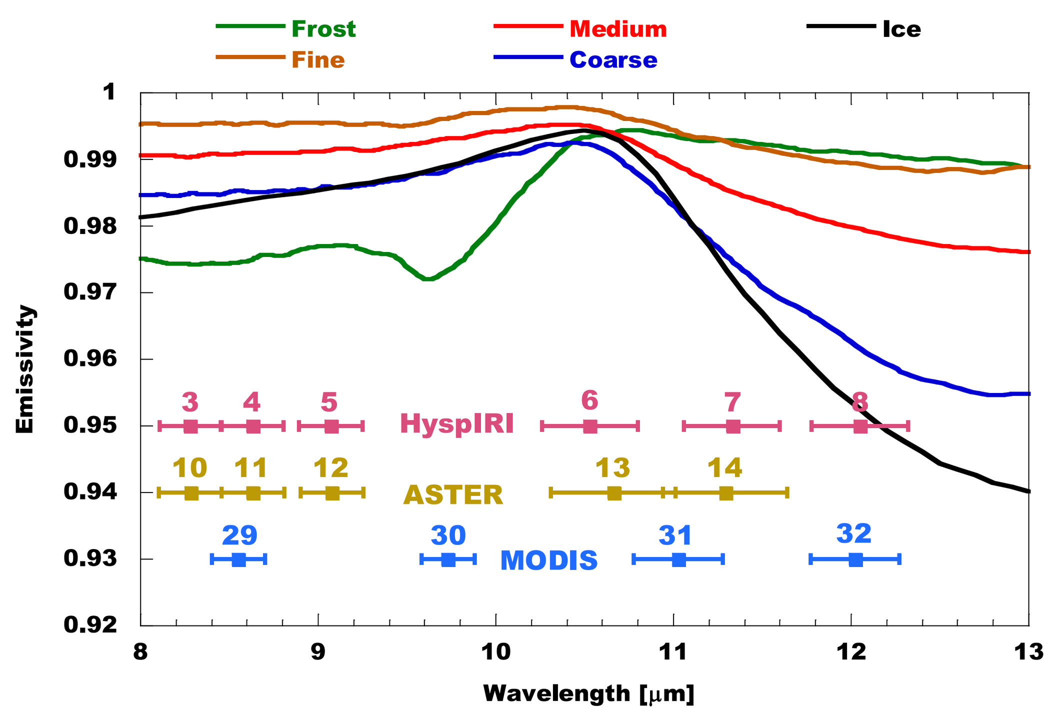

Fig. 1: Emissivity spectra of frost, fine snow, medium snow, coarse snow, and ice. TIR band positions of HyspIRI, ASTER, and MODIS are also shown.

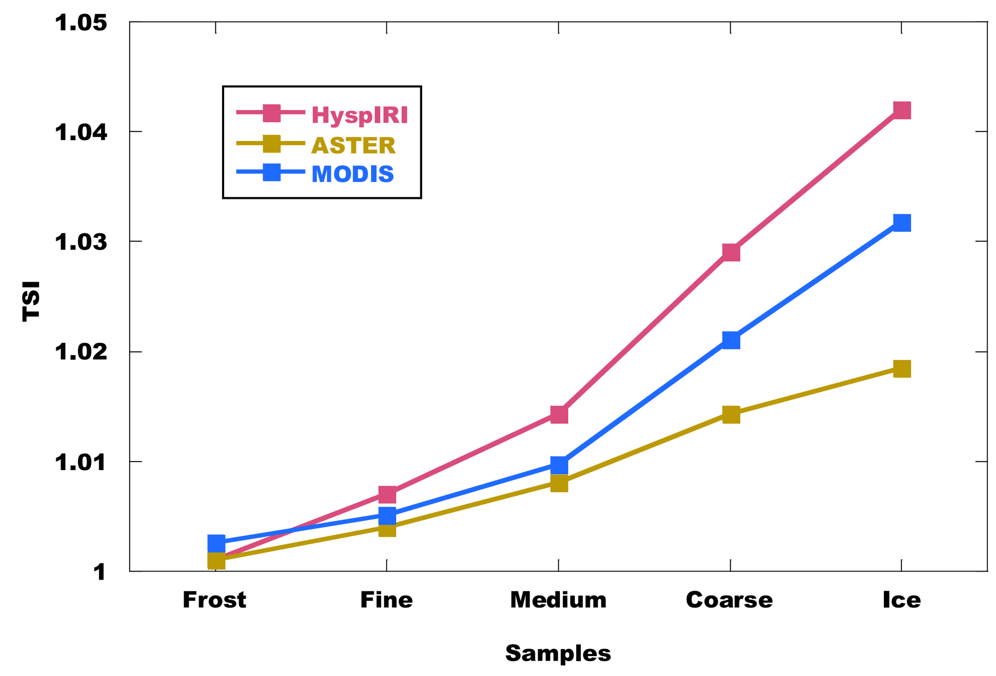

Fig. 2: TSI changes with samples for HyspIRI, ASTER, and MODIS.

Analysis for Byrd and Darwin glaciers in Antarctica

Scambos et al. have proposed a method for estimating snow grain size using MODIS VNIR bands [6] [7]. Basically their approach is based on correlation between the snow grain size and the band ratio of band 1 (0.62 to 0.67 μm) and band 2 (0.84 to 0.87 μm) under consideration of the solar zenith angle.

In the present study, we generated a snow grain size image by their method for Byrd and Darwin glaciers in Antarctica, and compared it to a TSI image generated using MODIS bands 31 and 32.

In Byrd glacier (site A), large values are indicated on the snow grain size image (Fig. 6) but small values are indicated on the TSI image (Fig. 7), probably because seracs (see Figs. 4 and 5) reduced spectral contrast in emissivity. In Darwin glacier (site B), large values are indicated on both the snow grain size image and the TSI image, indicating the existence of smooth surfaces.

Like these facts, TSI will give different information from other snow/ice indices. Thus, combining different type of indices will be useful for more detailed analysis of snow and ices.

As an example, we combined the Scambos's snow grain size, TSI, and NDSI (normalized difference snow index) (Fig. 8) [8], and input to the ISODATA classifier. The obtained classification map (Fig. 9) distinguishes different types of snow and ice by different colors.

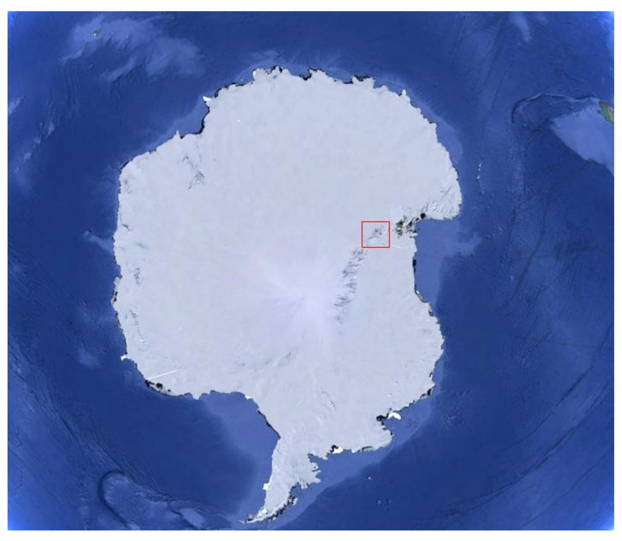

Fig 3: Antarctica

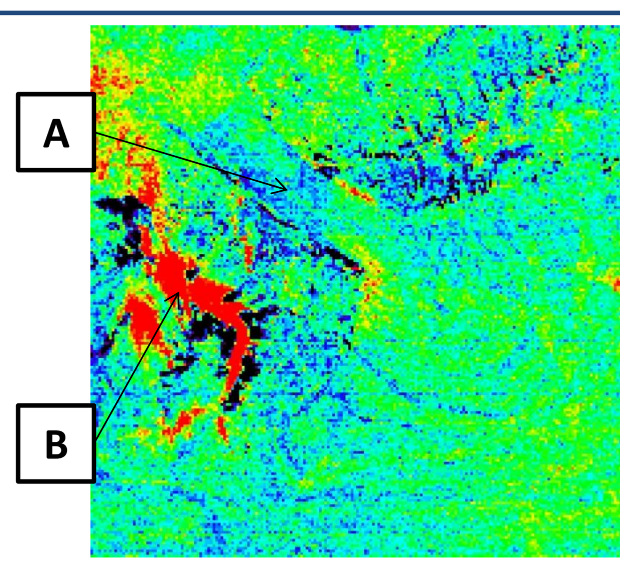

Fig 6 : TSI image

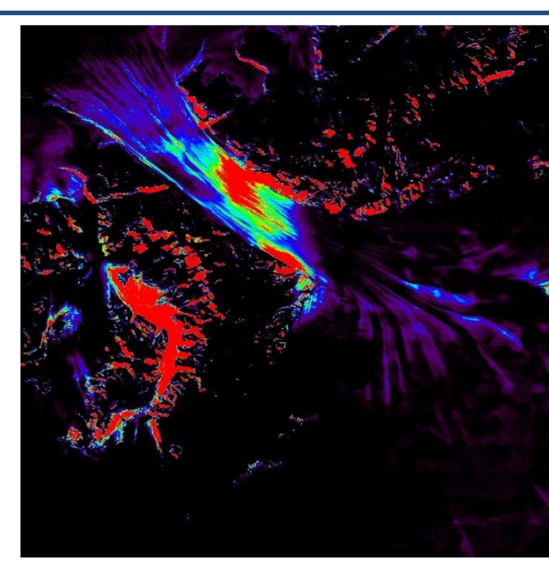

Fig 7 : Snow grain size image

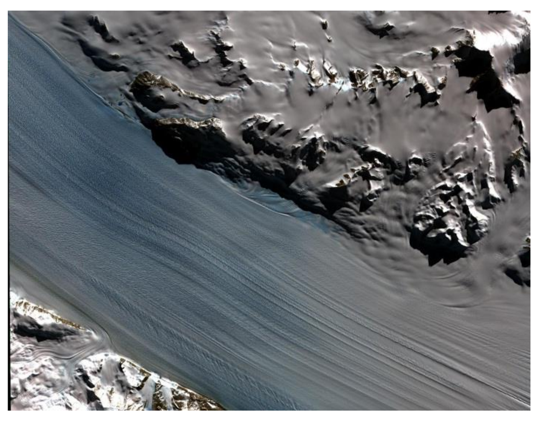

Fig 4 : ASTER/VNIR image around Byrd glacier in Antarctica.

Fig. 5: Seracs seen around Byrd glacier.

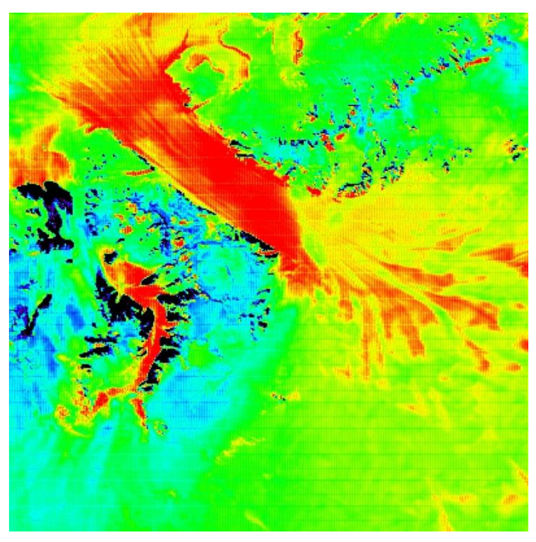

Fig. 8 :NDSI image

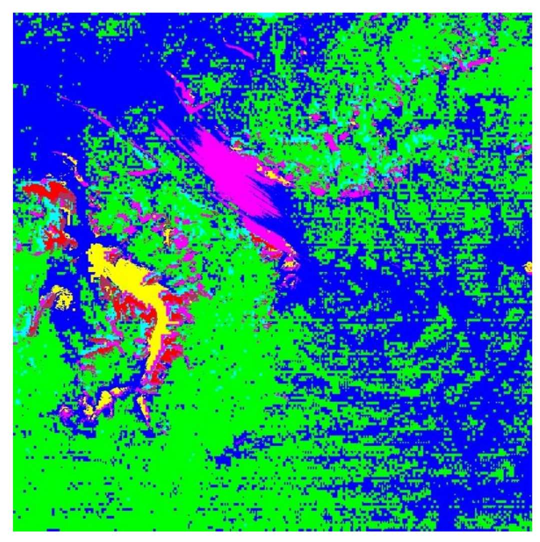

Fig. 9 : ISODATA classification result

Time-series analysis of MODIS snow grain size and TSI for Jakobshavn glacier in Greenland

Using 142 MODIS scenes acquired over Jakobshavn Glacier, Greenland, from April 2006 to March 2007, Scambos's snow grain size and TSI were compared. The test site used is an area of 3 by 3 km2 on the glacier (Fig. 10). In the period from November to March, only TSI values were derived from 25 TIR scenes because this period is in polar night around Greenland.

Fig. 11 and 12 show time-series plots for TSI and the snow grain size, respectively. In summer (July to September), the snow grain size shows high values, but TSI shows low values, probably due to melting effects. In October, the latter showed remarkably high values (see Fig. 13) probably because flat ice surfaces were observed under large sensor zenith angles (see Fig. 14).

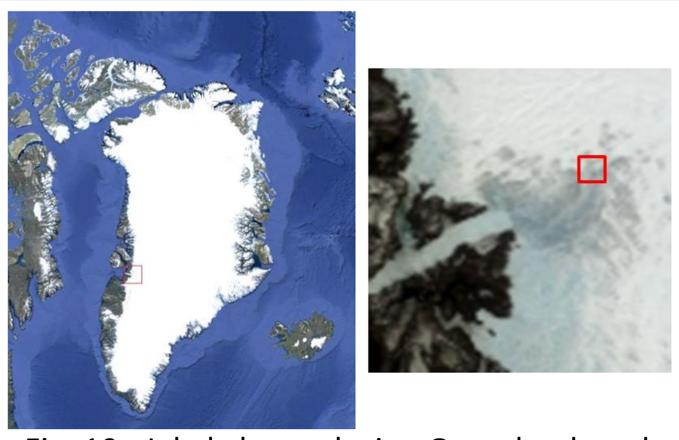

Fig. 10 : Jakobshavn glacier, Greenland, and the test site (red box)

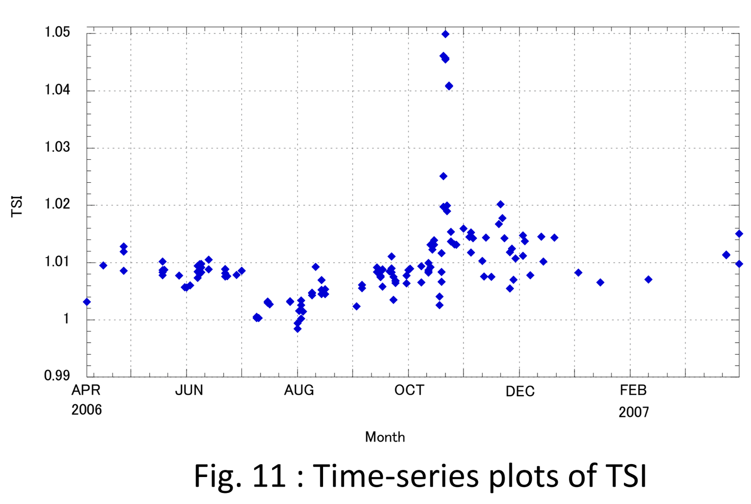

Fig. 11 : Time-series plots of TSI

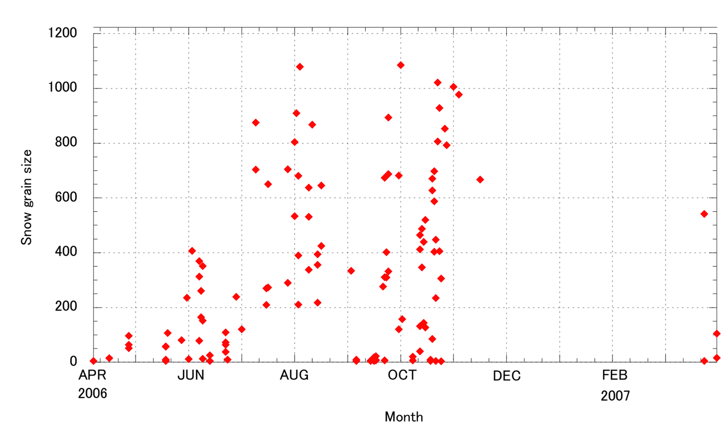

Fig. 12 : Time-series plots of the snow grain size

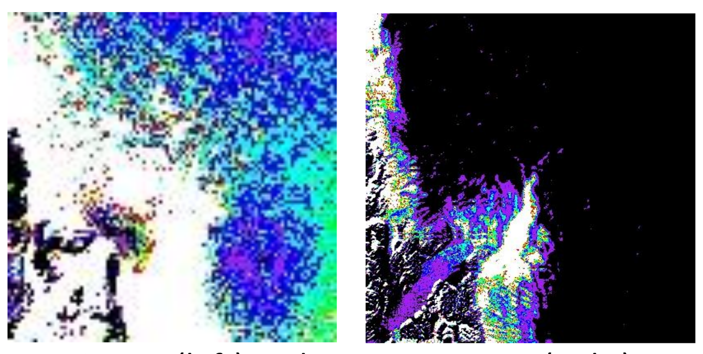

Fig. 13 : TSI (left) and snow grain size (right) on 17 October 2006.

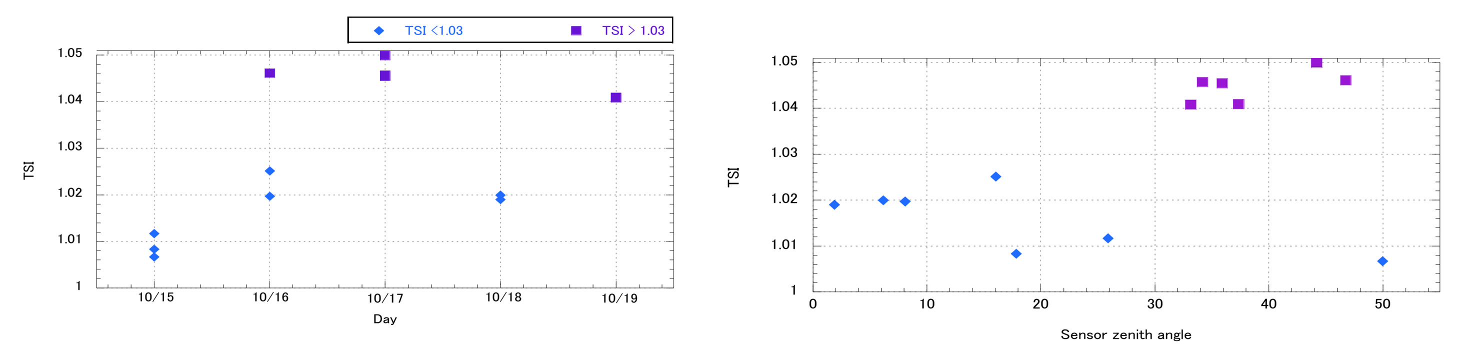

Fig. 14 : TSI values in the middle of October (left) and the relationship between the sensor zenith angle and TSI.

Conclusions

TIR Snow/ice Index (TSI) can provide additional information to traditional remote sensing for snow and ice. The index is more sensitive as two bands used are more distant in a spectral region of 10.5 to 13 μm. The sensitivity analysis using laboratory spectra shows that HyspIRI is 2.3 and 1.3 times sensitive than ASTER and MODIS, respectively, indicating that HyspIRI is more suitable for TSI-based analysis. TSI and other snow/ice indices like the MODIS snow grain size and NDSI will give different information, indicating that some combination of them will be useful.

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