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Evaluation of Spectral Indices for Differentiating Melt Pond from Sea Ice

[1]Chang-Uk Hyun, [2]Hong Lyun Park, [3]Sang-Hwan Lee and [4]Hyun-Cheol Kim

[1]Korea Polar Research Institute, Incheon 406-840, Republic of Korea; cuhyun@kopri.re.kr
[2]Korea Polar Research Institute, Incheon 406-840, Republic of Korea; parkhonglyun@kopri.re.kr
[3]Korea Institute of Science and Technology Information, Daejeon 305-806, Republic of Korea; san-glee@kisti.re.kr
[4]Korea Polar Research Institute, Incheon 406-840, Republic of Korea; kimhc@kopri.re.kr

Abstract

Spectral indices using two reflectance bands were evaluated to implement fast differencing the melt pond from sea ice. The spectral indices comprise simple band-ratio calculations and these ratio-based methods can compensate light variations within individual images. The spectral indices developed for emphasizing ice, snow and water were evaluated with fine snow, melting snow having a shallow puddle of water on top and sea water reflectance spectra selected from existing spectral libraries. Pairs of two bands of green and SWIR (shortwave infrared), red and SWIR, green and NIR (near infrared), and green and red wavelength regions were used as input bands for the spectral indices. The differences of the spectral indices between fine snow and water and be-tween melting snow and sea water for every pairs were calculated to compare performance of the spectral indices. The indices using green and SWIR band pairs and red and SWIR band pairs showed larger differences between fine snow and sea water and between melting snow and sea water than the indices using green and NIR band pairs and green and red band pairs. The highest separability inferred from averaged index differences between fine snow and water and between melting snow and water was obtained from the pairs of red and SWIR bands. The results can be applied to planning of a spectral imager specialized for polar region or to choose reasonable bands from existing remote sensing sensors.

Introduction

Melt pond covering sea ice over Arctic sea has shown quick development and transition during spring and summer season, and has also been known to significantly affect regional and global climate system as it changes sea ice albedo. Multiple or multi-temporal high-spatial-resolution optical images, e.g., aerial or UAV images, are desirable dataset to differentiate the fast-changing melt pond from sea ice.

In this study, spectral indices using two reflectance bands were evaluated as a preliminary study for implementation of effective and fast differencing the melt pond from sea ice with large volume of images. The spectral indices comprise simple band-ratio calculations and these ratio based methods can compensate light variations within individual images, possibly exaggerated in high Arctic region.

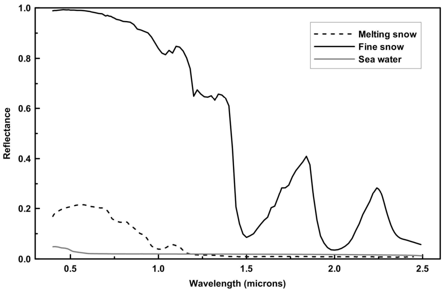
Methods

1. Spectral reflectances of snow, melting snow and water

Surface of sea ice consists of few materials, i.e., snow, ice and water, showing more simple composition of constituents than ordinary land covers. Three representative materials, fine snow, melting snow having a shallow puddle of water on top and sea water reflectance spectra, were selected from existing USGS Digital Spectral Library and NASA ASTER Spectral Library. The selected endmembers show distinct differences in their reflectance amplitudes.

Spectral reflectance curves of water, snow and ice selected from existing spectral libraries.

Spectrum	Specification	Source
Fine snow	Effective particle size is 24 micrometers.	NASA ASTER Spectral Library [1]
Melting snow 1-16.26925	This sample had a puddle of approximately 3 cm of water on top of the snow.	USGS Digital Spectral Library [2]
Sea water	The water was sampled from Atlantic ocean.	USGS Digital Spectral Library [2]



Spectral reflectance curves selected for calculation of spectral indices.

2. Spectral indices for water, snow and ice identification

The spectral indices comprise simple band-ratio calculations and these ratio based methods can compensate light variations within individual images, possibly exaggerated in high Arctic region. The spectral indices developed for emphasizing ice, snow and water were evaluated with the selected spectra. Pairs of two bands of green and SWIR, red and SWIR, green and NIR, and green and red wavelength regions were used as in-put bands for the spectral indices.

Spectral indices devised to emphasize or identify ice, snow or water endmember from other land covers.

Index	Equations
NDSI (normalized difference snow index) [3]	NDSI = (TM 2 (green) - TM 5 (SWIR))/(TM 2 - TM 5)
NDSI [4]	NDSI = (AVHRR 1 (green) - AVHRR 3 (SWIR))/(AVHRR 1 - AVHRR 3)
NDSI [5]	NDSI = (MODIS 4 (green) - MODIS 6 (SWIR))/(MODIS 4 - MODIS 6)
NDSI [6]	NDSI = (ASTER 1 (green) - ASTER 4 (SWIR))/(ASTER 1 - ASTER 4)
NDSII (normalized difference snow/ice index) [7]	NDSI = (TM 3 (red) - TM 5 (SWIR))/(TM 3 - TM 5)
NDGI (normalized difference glacier index) [6]	NDSI = (ASTER 2 (red) - ASTER 3 (NIR))/ (ASTER 2 - ASTER 3)
NDWI (normalized difference water index) [8]	NDWI = (MSS 2 (green) - MSS 4 (NIR))/(MSS 2 - MSS 4)

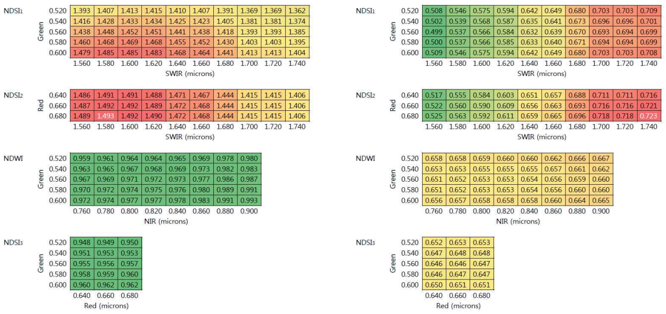
[1]TM: Landsat Thematic Mapper, [2]AVHRR: Advanced Very High Resolution Radiometer, [3]MODIS: Moderate Resolution Imaging Spectroradiometer, [4]ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer, [5]MSS: Landsat Multispectral Scanner

Spectral indices designated for the selected spectral ranges. The spectra resampled to the spectral resolution of 20 nm were used as input bands of the spectral indices.

Index	Equations	Specifications of bands
$NDSI_1$	$(R_{green} – R_{SWIR})/(R_{green} – R_{SWIR})$	Green: 0.52 – 0.60 μm, SWIR: 1.56 – 1.74 μm
$NDSI_2$	$(R_{red} – R_{SWIR})/(R_{red} – R_{SWIR})$	Red: 0.64 – 0.68 μm, SWIR: 1.56 – 1.74 μm
$NDSI_3$	$(R_{green} – R_{red})/(R_{green} – R_{red})$	Green: 0.52 – 0.60 μm, Red: 1.56 – 1.74 μm
NDWI	$(R_{green} – R_{NIR})/(R_{green} – R_{NIR})$	Green: 0.52 – 0.60 μm, NIR: 0.80 – 1.10 μm

Results

The differences of the spectral indices between fine snow and sea water and between melting snow and sea water for every pairs were calculated to compare performance of the spectral indices. The larger difference indicates more sensitive spectral pairs to differentiate melt ponds from sea ice. The indices using green and SWIR band pairs and red and SWIR band pairs showed larger differences between fine snow and sea water and between melting snow and sea water than the indices using green and NIR band pairs and green and red band pairs. The highest separability inferred from averaged index differences between fine snow and sea water and between melting snow and sea water was obtained from the pairs of red and SWIR bands. Spectral indices of spectral mixture using the index and bands which showed high sepaeability in this study were able to be calculated.



(a)

NDSI1

Green	1.560	1.580	1.600	1.620	1.640	1.660	1.680	1.700	1.720	1.740
0.520	1.393	1.407	1.413	1.415	1.410	1.407	1.391	1.369	1.369	1.362
0.540	1.416	1.428	1.433	1.434	1.425	1.423	1.405	1.381	1.381	1.374
0.560	1.438	1.448	1.452	1.451	1.441	1.438	1.418	1.393	1.393	1.385
0.580	1.460	1.468	1.469	1.468	1.455	1.452	1.430	1.403	1.403	1.395
0.600	1.479	1.485	1.485	1.483	1.468	1.464	1.441	1.413	1.413	1.404

SWIR (microns)

NDSI2

Red	1.560	1.580	1.600	1.620	1.640	1.660	1.680	1.700	1.720	1.740
0.640	1.486	1.491	1.491	1.488	1.471	1.467	1.444	1.415	1.415	1.406
0.660	1.487	1.492	1.492	1.489	1.472	1.468	1.444	1.415	1.415	1.406
0.680	1.489	1.493	1.492	1.490	1.472	1.468	1.444	1.415	1.415	1.406

SWIR (microns)

NDWI

Green	0.760	0.780	0.800	0.820	0.840	0.860	0.880	0.900
0.520	0.959	0.961	0.964	0.964	0.965	0.969	0.978	0.980
0.540	0.963	0.965	0.967	0.968	0.969	0.973	0.982	0.983
0.560	0.967	0.969	0.971	0.972	0.973	0.977	0.986	0.987
0.580	0.970	0.972	0.974	0.975	0.976	0.980	0.989	0.991
0.600	0.972	0.974	0.977	0.977	0.978	0.983	0.991	0.993

NIR (microns)

NDSI3

Green	0.640	0.660	0.680
0.520	0.948	0.949	0.950
0.540	0.951	0.953	0.953
0.560	0.955	0.956	0.957
0.580	0.958	0.959	0.960
0.600	0.960	0.962	0.962

Red (microns)

(b)

NDSI1

Green	1.560	1.580	1.600	1.620	1.640	1.660	1.680	1.700	1.720	1.740
0.520	0.508	0.546	0.575	0.594	0.642	0.649	0.680	0.703	0.703	0.709
0.540	0.502	0.539	0.568	0.587	0.635	0.641	0.673	0.696	0.696	0.701
0.560	0.499	0.537	0.566	0.584	0.632	0.639	0.670	0.693	0.694	0.699
0.580	0.500	0.537	0.566	0.585	0.633	0.640	0.671	0.694	0.694	0.699
0.600	0.509	0.546	0.575	0.594	0.642	0.649	0.680	0.703	0.703	0.708

SWIR (microns)

NDSI2

Red	1.560	1.580	1.600	1.620	1.640	1.660	1.680	1.700	1.720	1.740
0.640	0.517	0.555	0.584	0.603	0.651	0.657	0.688	0.711	0.711	0.716
0.660	0.522	0.560	0.590	0.609	0.656	0.663	0.693	0.716	0.716	0.721
0.680	0.525	0.563	0.592	0.611	0.659	0.665	0.696	0.718	0.718	0.723

SWIR (microns)

NDWI

Green	0.760	0.780	0.800	0.820	0.840	0.860	0.880	0.900
0.520	0.658	0.658	0.659	0.660	0.660	0.662	0.666	0.667
0.540	0.653	0.653	0.655	0.655	0.655	0.657	0.661	0.662
0.560	0.651	0.652	0.653	0.653	0.654	0.656	0.659	0.660
0.580	0.651	0.652	0.653	0.653	0.654	0.656	0.660	0.660
0.600	0.656	0.657	0.658	0.658	0.658	0.660	0.664	0.665

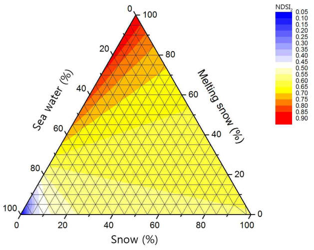
NIR (microns)

NDSI3

Green	0.640	0.660	0.680
0.520	0.652	0.653	0.653
0.540	0.647	0.648	0.648
0.560	0.646	0.646	0.647
0.580	0.646	0.647	0.647
0.600	0.650	0.651	0.651

Red (microns)

Spectral indices calculated using the selected spectra within designated spectral ranges: (a) the spectral index differences between fine snow and sea water and, (b) the spectral index differences between melting snow and sea water. Higher indices are filled with reddish colors.



Ternary diagram of spectral indices of spectral mixture using the $NDSI_2$ and 680 nm and 1,680 nm bands which showed high sepaeability in this study.

Conclusions

Relatively higher separability between fine snow and sea water and between melting snow and sea water was shown in the spectral index differences using the pairs of red and SWIR bands. The results from this study can be applied to planning of a spectral imager specialized for polar region or to choose reasonable bands from existing remote sensing sensors.

References

1. Baldridge A M, S J Hook, C I Grove & G Rivera, 2009. *The ASTER spectral library version 2.0.* Remote Sensing of Environment 113, 711-715.
2. Clark R N, G A Swayze, R Wise, E Livo, T Hoefen, R Kokaly & S J Sutley, 2007. *USGS digital spectral library splib06a*. U.S. Geological Survey, Digital Data Series 231.
3. Dozier J, 1989. *Spectral signature of alpine snow cover from the Landsat Thematic Mapper.* Remote Sensing of Environment 28, 9-22.
4. Wang J & W Li, 2003. *Comparison of methods of snow cover mapping by analyzing the solar spectrum of satellite remote sensing data in China.* International Journal of Remote Sensing 24, 4129-4136.
5. Hall D K, G A Riggs, V V Salomonson, N E DiGirolamo & K J Bayr, 2002. *MODIS snow-cover products.* Remote Sensing of Environment 83, 181-194.
6. Keshri A K, A Shukla & R P Gupta, 2009. *ASTER ratio indices for supraglacial terrain mapping.* International Journal of Remote Sensing 30, 519-524.
7. Xiao X, Z Shen & X Qin, 2001. *Assessing the potential of VEGETATION sensor data for mapping snow and ice cover: A normalized difference snow and ice index.* International Journal of Remote Sensing 22, 2479-2487.
8. McFeeters S K, 1996. *The use of Normalized Difference Water Index (NDWI) in the delineation of open water features.* International Journal of Remote Sensing 17, 1425-1432.

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