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Mapping Snow Cover Using AVHRR/NDVI 10-day Composite Data

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Abstract

A method for mapping snow cover using Advanced Very High Resolution Radiometer (AVHRR)/ Normalized Difference Vegetation Index (NDVI) 10-day composite data was developed at the continental scale. The 10-day AVHRR/NDVI composite data and snow depth data of AmeDas (Automated Meteorological Data Acquisition System) in 1999 were compared to extract the snow cover land surface by determining NDVI threshold values. Initially, one threshold value was applied to all over Japan. However, the results showed inaccuracies in snow map for the different land cover effects the NDVI values greatly. To improve the estimation accuracy, classifying the land cover into 5 categories was conducted. The snow maps derived from different threshold values for different land cover categories instead of one threshold value for all over Japan showed better accuracy. The areas where the accuracy of mapping got better are in the forest area such as alpine vegetation and urban area especially around Kanto.

Key words: AmeDas data, AVHRR/NDVI data, Land classification, Snow cover mapping, Threshold

1. Introduction

Snow cover is an important factor in the Earth's climate system due to its special properties different from other land-covers such as the high surface reflectance and low thermal conductivity. These special properties of snow are believed to have an impact on biological, chemical, geological process and many aspects of human life. Accurate information on spatial distribution of snow cover is required for numerical weather forecasting and hydrological and climate modelling.

Satellites are well suited to the measurement of snow cover because the high albedo of snow presents a good contrast with almost other natural surfaces except clouds. Hall (1995) developed a method that made an index of Normalize Difference Snow Index (NDSI) with band 2 and band 5 of the Landsat TM to map snow coverage. Although Landsat sensor has a high spatial resolution, it is difficult to provide expansive spatial coverage of measurements in regional or global research. At the same time, Landsat sensor has a long period of 16 days that it is not enough to measure the meteorological condition like snow.

Recently it has reported that Moderate Resolution Imaging Spectraradiometer (MODIS) provides imagery of the Earth's surface and clouds in 36 discrete spectral bands all over the world (Hall *et al.*, 2002). MODIS bands 1-7 are likely to be useful for snow-cover and snow-albedo mapping (Winther and Hall, 1999). But the satellite embarking of this sensor has just been sent up for a few years and it is impossible for us to investigate snow cover of past decades using MODIS data.

NOAA-AVHRR data not only has high temporal resolution and covers wide land area but also has long history so that it is considered as an ideal tool for long-time snow cover studying. But it has no channel corresponding exactly to band2 and band5 of Landsat TM to calculate NDSI. In this study a new snow-cover mapping method using NDVI (Normalized Difference Vegetation Index) 10-day composite data of AVHRR sensor was proposed. Although NDVI is widely used as an index for vegetation, previous studies have pointed out that the high spectral albedo of snow will cause the NDVI of a snow-cover landscape to be lower than the value for snow-free conditions (Dye and Tucker, 2003). Therefore, the declining snow-cover may be responsible for the higher NDVI value. We developed threshold value of NDVI to estimate snow cover by examining the correspondence between the NDVI value and the snow cover. Both only one NDVI threshold value applied to all of Japan and different NDVI threshold values applied to different land categories were conducted to map snow cover in 1999.

2. Materials and Methods

10-day composite AVHRR/NDVI data of 1999 ("20G4MAVHRR NDVI dataset of Chiba University") was used in this study. To remove the effect of the cloud, a composing criterion was used in which only the maximum of NDVI observed in each given pixel location within each consecutive 10-day period was retained for analysis (Cihlar, 1996 ; Dye and Tucker, 2003). During composing, the values of pixels have been changed to 0-255 from the ranges –1 to 1 by linear analysis. The images were also resampled to 8km×8km

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pixel size to make it convenient for large geographic coverage and long time series coverage investigation. The snow depth data (Ground Truth Data) used in this study was obtained from Automated Meteorological Data Acquisition System (AmeDas). The 10-day average snow depth was used to compromise the temporal resolution of the satellite data.

Figure 1 shows the relationship between NDVI value and snow depth. In the points which snow cover deeper than 50cm, the NDVI values are hardly beyond 150. But in the points where snow cover is small, the NDVI values become higher and higher. It is feasible for us to discriminate the snow cover by NDVI value threshold. Considering the NDVI will not be so sensible to the shallow snow cover, a station location is defined as snow covered when the recorded snow depth is greater than or equal to 5cm.

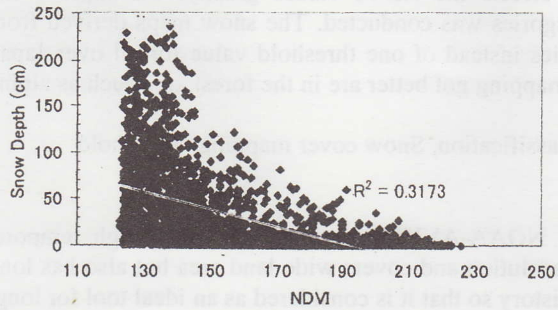


Fig. 1. Relationship between NDVI values and snow depth.

In the binary classification system, snow will be mapped in a pixel when its NDVI lower than a threshold value. Some thresholds were assumed to determine the snow condition in one pixel. By comparing the snow depth record with the snow cover estimation by every assumed threshold, the discrimination ratios in all Amedas points (D1), in snow cover points (D2) and in snow-free points (D3) can be obtained.

Table1 illustrates the concept of discrimination ratio. 'True' represents the situation where the snow condition observed by AmeDas and the condition we estimated by NDVI value coincide to each other, and the 'False' represents the situation when they are contradictory. The 'a' is the number of cases in which snow cover was observed by AmeDas data and also estimated from NDVI value; 'b' is the number of the situations in which snow cover was observed by AmeDas data but snow-free as estimated from NDVI value; 'c' is number of cases in which snow cover was not observed from AmeDas data but with snow cover estimated from NDVI value; and, 'd' is number of situations in which snow cover was neither observed from AmeDas data nor NDVI value.

The final threshold value will be decided in the NDVI value where the average of the discrimination ratios in snow points (D2) and snow-free points (D3) is the highest.

Table 1. Discrimination ratio of snow or no snow.

Snow condition estimated from NDVI / Snow condition observed by AmeDas	Snow	No snow
Snow	a: True	b: False
No snow	c: False	d: True

Discrimination ratio of snow or no snow (D1): (a+d)/(a+b+c+d);

Discrimination ratio of snow cover period (D2): a/(a+b);

Discrimination ratio of snow-free period (D3): d/(c+d).

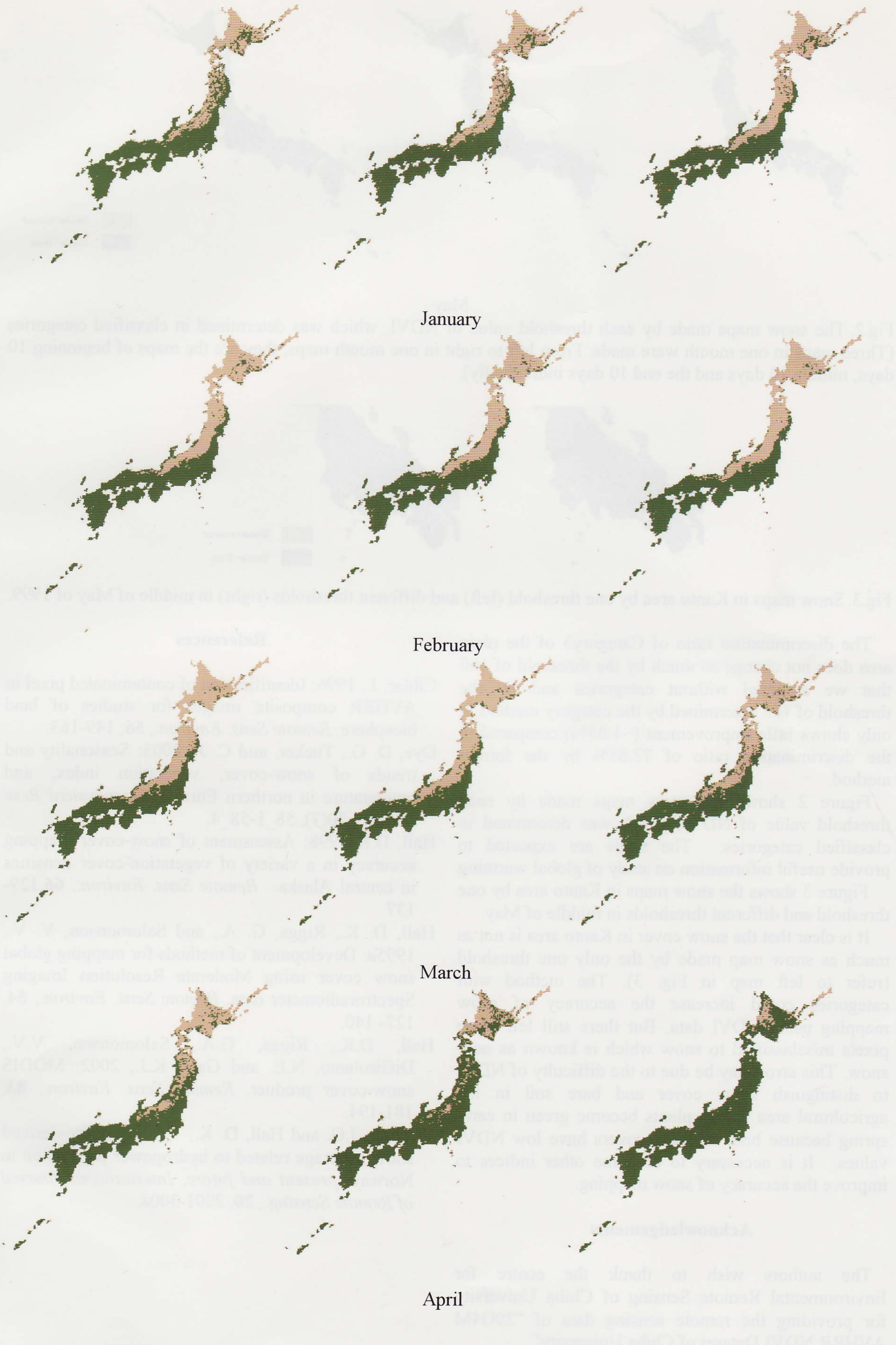
3. Results and Discussion

The NDVI threshold value for snow was increased incrementally from 125 to 215 in steps of 5. We compared the discrimination ratios in different assumed thresholds, and it is found when the NDVI is 160, the average discrimination ratio of D2 and D3 has the highest value of 70.1%. We mapped the snow cover by applying the threshold of 160 to all over Japan from January to June. However, since the whole Japan is not so homogeneous and the NDVI values are also influenced by different land covers, some errors occurred especially in Kanto area which has been mapped as snow covered even in May. Therefore, an additional test is necessary to recalculate the NDVI threshold on the base of categories of the land-cover to determine different threshold value for different categories to estimate the snow cover.

An ISODATA unsupervised classification was performed to get 5 land-cover categories. Since the snow cover points are very few in the two south categories areas which are considered as deciduous forest and evergreen forest areas, they were considered as snow-free areas. Different NDVI threshold value was estimated for the other three categories which are considered as snow cover areas.

In the category1 of urban area the threshold was estimated very low as 135 and the discrimination ratio in this value is 73.68%. The discrimination ratio of 160 used before in category 1 is only 57.36%. It means that more non-snow pixels had been mapped as snow by the previous threshold, adjusting the NDVI threshold downward helped decrease the error of identifying the non-snow pixels as snow. The discrimination ratio was improved by 16.32% in this category.

The discrimination ratio in category2 of Hokkaido, Tohoku and part of the Sea of Japan is around 86.62% by threshold of 145, but the discrimination ratio in threshold of 160 without categories is 79.91%. We have improved 6.71% in discriminating snow cover by the method of classifying land cover.


January
February
March
April

May

Fig.2. The snow maps made by each threshold value of NDVI, which was determined in classified categories (Three maps in one month were made. From left to right in one month maps, they are the maps of beginning 10 days, middle 10 days and the end 10 days individually).

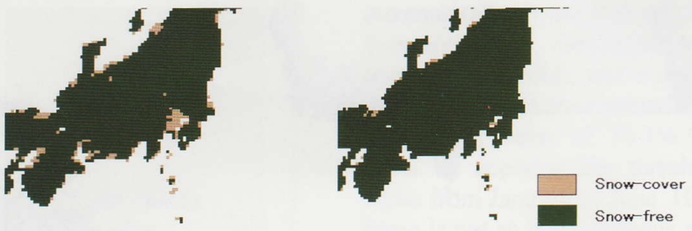


Fig.3. Snow maps in Kanto area by one threshold (left) and different thresholds (right) in middle of May of 1999.

The discrimination ratio of Category3 of the plain area does not change so much by the threshold of 160 that we assumed without categories and by the threshold of 165 determined by the category method. It only shows little improvement (~1.05%) compared to the discrimination ratio of 72.85% by the former method.

Figure 2 shows the snow maps made by each threshold value of NDVI, which was determined in classified categories. The maps are expected to provide useful information on study of global warming.

Figure 3 shows the snow maps in Kanto area by one threshold and different thresholds in middle of May.

It is clear that the snow cover in Kanto area is not as much as snow map made by the only one threshold (refer to left map in Fig. 3). The method with categories could increase the accuracy of snow mapping using NDVI data. But there still left some pixels misclassified to snow which is known as non-snow. This error may be due to the difficulty of NDVI to distinguish snow cover and bare soil in the agricultural area before plants become green in early spring because both the land covers have low NDVI values. It is necessary to combine other indices to improve the accuracy of snow mapping.

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References

Cihlar, J., 1996: Identification of contaminated pixel in AVHRR composite images for studies of land biosphere, *Remote Sens. Environ.*, **56**, 149-163.

Dye, D. G., Tucker, and C. J., 2003: Seasonality and trends of snow-cover, vegetation index, and temperature in northern Eurasia. *Geophysical Rese Letters.*, **30**(7), 58_1-58_4.

Hall, D.K 1998: Assessment of snow-cover mapping accuracy in a variety of vegetation-cover densities in central Alaska. *Remote Sens. Environ.*, **66**,129-137

Hall, D. K., Riggs, G. A., and Salomonson, V. V., 1995a: Development of methods for mapping global snow cover using Moderate Resolution Imaging Spectroradiometer data. *Remote Sens. Environ.*, **54**, 127- 140.

Hall, D.K., Riggs, G.A., Salomonson, V.V., DiGirolamo, N.E. and Gayr, K.J., 2002: MODIS snow-cover product. *Remote Sens. Environ.*, **83**, 181-194.

Winther, J.G. and Hall, D. K., 1999: Satellite-derived snow coverage related to hydropower production in Norway. *present and future, International Journal of Remote Sensing.*, **20**, 2991-3008.