Mapping snow cover extent from polarimetric imaging radar

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1. Introduction

Microwave remote sensing can provide timely information about snow parameters and their temporal and spatial variability regardless of weather, time, and solar illumination. In addition, microwaves can penetrate the snowpack, allowing us to obtain the bulk properties of a snowpack as well as variations in other surface and subsurface features. Particularly, Synthetic Aperture Radar (SAR) remote sensing allows snow observation with high spatial resolution. Most of previous studies on mapping snow covered area have been carried out on the basis of the use of C-band or higher frequencies due to their higher sensitivity to snow properties (e.g., [1],[2]).

Since snow is a highly dynamic media in conjunction with energy fluxes, wind, moisture, water vapor, and pressure, integrated observation of snow-covered areas from multi-frequency SAR data can play an important role in mapping and monitoring snow properties and dynamics. This study aims at elucidating the capability of L-band space-borne SAR for detection of seasonal snow-covered areas. The seasonal change of backscattering from a snow-covered mountainous ecosystem was studied using the Phased array L-band Synthetic Aperture Radar (PALSAR) onboard the Advanced Land Observing Satellite (ALOS). This study places the focus on utilization of the fully polarimetric scattering observation, maximizing information on the seasonal changes of snow-cover.

The selected study site is Uonuma area in Southern Niigata Prefecture. This area is on the northern edge of the Japanese Alps and has some of the heaviest snowfall in the country due to a winter monsoon blowing from Siberia to the islands of Japan. For the study site in Niigata Prefecture, four polarimetric PALSAR images in ascending mode have been acquired.

2. Methodology

One special characteristic of SAR polarimetry is that it allows interpretation of different scattering mechanisms without additional in-situ information. In this study, we recall two approaches: the eigenvector-based [3] and the model-based [4] target decomposition methods.

An eigenvalue-eigenvector decomposition of the coherency matrix provides information about the polarimetric scattering mechanisms with matrix-characterizing parameters such as the polarimetric entropy (H), anisotropy (A), and average scattering angle ($\overline{\alpha}$). The polarimetric entropy and anisotropy indicate the randomness of the scatterer and the relationship between the secondary scattering processes, respectively. The angle $\overline{\alpha}$ indicates the mean scattering mechanism.

According to the model-based decomposition method, measured target matrix can be decomposed into a combination of physical scattering mechanisms, which correspond to the surface (P_s), double-bounce (P_d), volume (P_v), and helix scattering (P_c) mechanisms. This type of decomposition method is based on simple scattering models that lead to an easy-to-interpret scatter type discrimination.

This study examines the seasonal sensitivity of three types of polarimetric parameters: 1) backscattering coefficients at different polarization channels; 2) entropy, anisotropy, and $\overline{\alpha}$ of the eigenvalue-eigenvector decomposition; and 3) P_s, P_d, and P_v of the model-based decomposition. Results indicate that, at low incidence angle, the major change in snow-related scattering property includes decreases of the volume and double-bounce scattering powers, and, consequently, the surface scattering contribution becomes a single dominant scattering mechanism. At high incidence angle, the surface scattering power also decreases with the presence of snowpack, and, consequently, average eigenvalue parameters become less efficient to detect snow-covered area.

3. Results

According to the characteristics of snow-induced changes of scattering properties between the snow image and the reference (snow-free) image, different polarimetric parameters provide different information on mapping seasonal snow-covered area. Among them, changes of the polarimetric entropy, ΔH, and the cross-pol backscatter, ΔHV, have been selected in this study because they give complementary information on the snow-covered area in different topographic and thematic conditions. Since those parameters contain different information with different domains, it is important to express them with the same mathematical tool in the frame of the information fusion. The fuzzy set theory has been implemented in this study for alliance of polarimetric information.

The proposed information fusion approach has been applied to ALOS PALSAR data (Figure 1(b)) and evaluated by comparing with a conventional single-polarization based method such as the intensity ratio of VV-polarized backscattering coefficient between the snow image and the snow-free image (Figure 1(a)). The use of single co-polarization intensity cannot provide appropriate information on snow extent. On the other hand, the combined membership degree of polarimetric indices is closely related to the snow-covered area in optical images. Snow extent can be identified successfully by combining polarimetric indices with an overall accuracy of 74.4% as compared with in-situ measurements and 77.0% as compared with optical images.

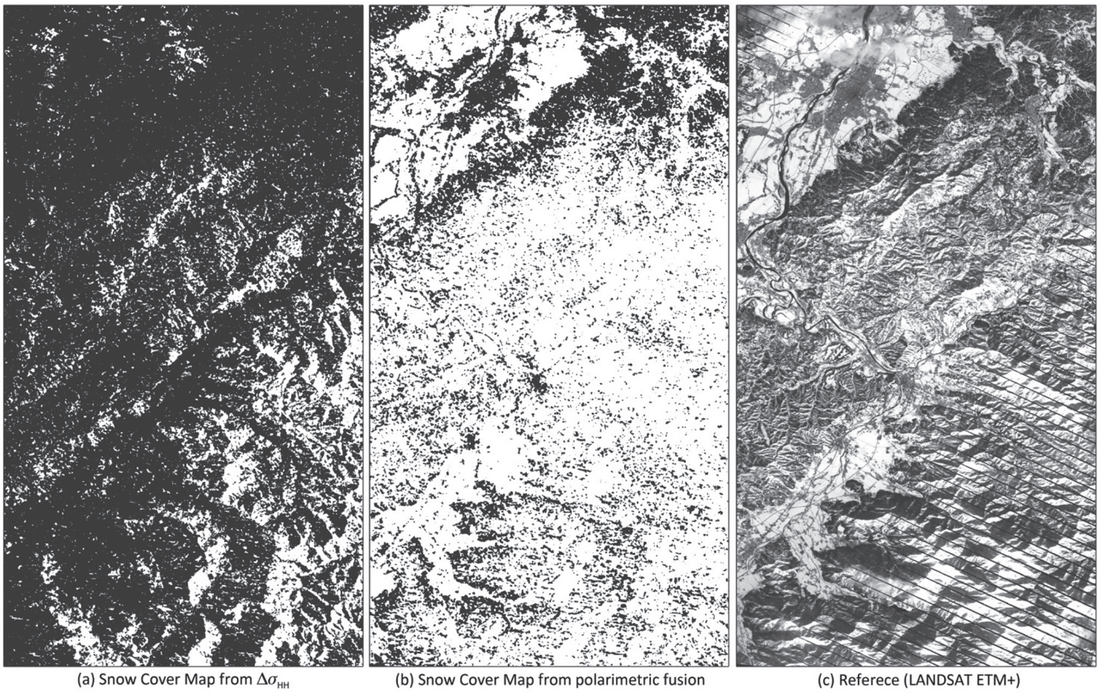

Figure 1. ALOS-PALSAR derived snow cover map on February 6, 2008. (a) Calculated from the conventional approach: single polarization indicator (VV-polarized backscatter changes); and (b) from the new approach: fully polarimetric information fusion approach. (c) Reference snow cover image: Landsat 7 ETM+ optical image (white color: snow).

参考文献

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