Spatial Texture in AirSAR Images of the Greenland Ice Sheet

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0. ABSTRACT

This work presents studies of the spatial structure (texture) of SAR images of ice sheets and its role in their interpretation and classification. JPL polarimetric airSAR data of the southwestern part of the Greenland ice sheet is analysed using first order statistics, the Power Law Semivariogram (PSV), and the Grey Level Coocurrence Matrix (GLCM) techniques to determine the extent to which areas of wet snow and ice facies can be distinguished. First order statistics are not able to discriminate these classes. The PSV and GLCM techniques work at P band, especially in the case of the cross-polarized data.

KEYWORDS: Polarimetric AirSAR data, Texture analysis, Ice sheet surface interpretation and classification.

1. INTRODUCTION

The interpretation of SAR images from ice sheet surfaces has concentrated on how the scattering mechanism contributes to the image tone (i.e. backscatter values) (Bindschadler *et al.*, 1987; Bindschadler and Vornberger, 1993; Jezek *et al.*, 1993; Rott and Davis, 1993; Shi and Dozier, 1993). Little study has been performed on the textural aspect. Though image tone is informative in the interpretation, in many cases using the tone parameter alone may not be sufficient, for example in the separation of glacier ice and bare rock (Shi and Dozier, 1993). The mean backscatter values of these two objects are similar; to separate them, texture parameters have potential usefulness. In this work, texture information is quantified and used to support previous interpretations. Its potential for classification is also assessed.

2. DATA SET AND BACKGROUND INTERPRETATON

Data Set

JPL airborne SAR data (by courtesey of Dr M R Drinkwater, JPL/NASA, USA) with multiple frequencies (C 5.3GHz, L 1.2 GHz, P 0.4 GHz) and polarizations (HH, VV, VH) of the south-western part of the Greenland ice sheet is analysed (figure 1). This data set contains 9 scenes (three frequencies, and each frequency has three polarizations). It is four-look antenna-pattern corrected with an image size of 640 by 480 pixels (12km $*$ 16km). The resolution is 12m in azimuth and 7m in range whereas the pixel ground spacing is 24.2 m square. It was collected on 31st August 1989, near the end of the melt season. Though *in situ* ground truth data are not available, previous studies using SAR images of the same region provide valuable background (Bindschadler, 1987; Mader, 1991; Jezek and Gogineni, 1992; Bindschadler and Vornberger, 1993; Jezek *et al.*, 1993).

Background Interpretation of the Data Set

With the aid of an overlapping SEASAT image (Bindschadler and Vornberger, 1992; Jezek *et al.*, 1993), the location of this scene is believed to be just below the snow line. Within the scene (figure 1), large features like the 'arrow' and 'cross' shapes are topographical lows (Jezek *et al.*, 1993). The constituent inside these patterns is interpreted as the wet snow facies owing to its dark tone observed in the C band scenes and its bright tone observed in the L/P bands. The dark tone in the C band scenes is due to the strong absorption by water while in L/P bands, the bright tone is from the volume scattering from the ice glands and lenses (Jezek and Gogineni, 1992). For areas outside these topographical patterns, the situation is reversed. Bright tones are observed in the C band scenes whereas the tone in L/P band is dark. The constituent is believed to be the ice facies as the roughness of this newly formed ice may cause strong C band return. Since such roughness scale is not comparable to the longer wavelengths of L/P bands, a dark tone is obtained.

3. METHODOLOGY

The three texture techniques are introduced as follows. First order statistics provide basic statistical measures of the pixel DN distribution. The parameter used is NSTD (normalised standard deviation). The Power Law Semivariogram (PSV) technique is capable of revealing and linking the spatial information at different scales (Lin and Rees, 1992). FAD (fractal dimension) and SHIFT parameters are calculated. The GLCM technique has been widely used as a fundamental texture measure (Haralick *et al.*, 1973; Haralick, 1979). ASM (angular second moment) and DIS (dissimilarity) GLCM parameters are selected, the displacement vector is chosen to be 3 pixel in the x direction.

The dataset is examined in two aspects. Sample analysis calculates texture parameters of sample windows from wet snow and ice classes (figure 1). The window size is either 20 pixels square or 10 pixels square. Transformation analysis uses a moving window (size 20 pixel or 10 pixel square) to run through the image. Texture parameter images are produced which offer a synoptic view of the textural distribution.

4. RESULTS AND DISCUSSION FOR THE SAMPLE ANALYSIS

Wet Snow Samples

The NSTD parameter of the wet snow samples increases with the increase of the wavelength. The lowest value (0.09) is obtained in the C band scenes while the highest value, 0.12, is found in P band.

The PSV texture is illustrated by the log-log semi-variograms (Lin and Rees, 1992). In general, wet snow samples have near horizontal distribution of the semivariances from lag 1 to lag 14 (24.2m to 338.8m) in all 9 scenes (figure 2.a). Therefore, not much difference is found by the FAD parameter. However, similar to the NSTD result, higher SHIFT values are measured in the P band and the cross polarization data. These higher values obtained in P band are probably attributable to volume scattering effects. The higher values observed in the cross-polarised cases have not yet been fully explained.

The GLCM DIS parameter represents the contrast within a pixel pair, so that similar results are obtained as from the first order and PSV analyses.

The ASM parameter (indicating homogeneity) increases with the increase of the wavelength. In addition, a higher value is measured in the cross polarization data.

Ice Samples

For ice samples, a higer NSTD value is again measured in the P band and the cross-polarization scenes. The occurrence of such high texture in P band is of interest as backscatter observed visually from these areas is uniform and low. The texture signature reveals the incompleteness of the current understanding and the possibility of the existence of other processes which are non-correlated or even negatively related to the tone.

The log-log semivariograms of ice samples are shown in figure 2.b. These show log semivariances independent of lag to at least 14 pixels. Similar to the NSTD measure, the highest SHIFT value is acquired from the P band signal, especially in PVH. Ground truth data with detailed modelling of the polarimetric data will be essential to explain this result.

In the GLCM analysis, similar to the wet snow result, P band has higher ASM than L than C bands while not much difference is found in DIS.

Classification of Wet Snow and Ice

It is not possible to classify wet snow and ice in C and L band scenes using both first order statistics and PSV techniques (figure 3). However, in the P band scenes, because most of the ice samples have higher texture values than the wet snow, a better distinction is obtained though a complete separation is not yet achieved. Using GLCM parameters, clear classification is acquired in CVH (figure 3.b), PHH, PVV and PVH scenes. In the CVH case, ice samples have lower ASM (lower uniformity) values than the wet snow samples thus the two classes are distinguished. In P band, the situation is reversed. Owing to the high ASM obtained in the ice facies, the classification is achieved.

5. RESULTS AND DISCUSSION FOR TRANSFORMATION ANALYSIS

The most representative cases (CHH, CVH, and PVH scenes) of the transformation analysis are discussed.

CHH Scene

Observing the original image, features are characterised by different tones inside and outside the topographic lows (corresponding to wet snow and ice). Other features such as the stream systems and lakes are also visible. The NSTD image reveals clearly the topographical boundaries, though no other features are found. As the boundaries are areas where major tonal changes occur, large deviation from the mean value is expected, thus a high NSTD is correspondent. Both FAD and SHIFT parameters are capable of detecting edges and most of the visually rough areas related to the stream systems. The PSV parameters of these visually rough areas are between the two extremes, i.e. between those of the edges and the visually smooth areas. The lowest FAD is acquired at the boundaries because the rapid change of DN with the increase of scales causes a steep increase in the log-log semivariogram. Visually smooth areas show semivariances independent of scale, which corresponds to a high FAD.

CVH Scene

CVH and CHH scenes show similar results in first order statistics and PSV analysis (figure 4.a). In addition, a distinct separation between wet snow and ice is found in the ASM parameter image (figure 4.b) where wet snow areas have a much higher value (homogeneity) than the ice areas. This result also shows the importance in quantifying the texture as such classification could not be achieved otherwise.

PVH Scene

A generally low tone is observed in the PVH scene. Again, the NSTD parameter image shows only edges. The PSV analysis shows unexpectedly high values of the SHIFT parameter at visually smooth areas for which no satisfactory explanation has yet been produced.

6. CONCLUSION

This work describes the analysis of the multi-frequency and polarization airSAR data in the textural aspects. The results show that textural information can provide independent support to the image interpretation. We also found the cross-polarization and P band singals contain much more texture than C/L bands and the linear like-polarization cases. Such information can be used to discriminate wet snow and ice facies. The texture signature of the ice areas also indicates the existence of other processes which were not revealed by the tone analysis. Further research incorporating field measurement in addition to detailed modelling of the interaction between the polarimetric signal with ice and snow will be necessary.

7. ACKNOWLEDGEMENTS

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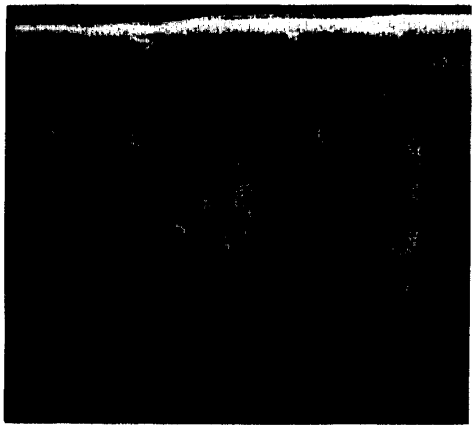

Figure 1.a: AirSAR CVH scene and sample locations. Wet snow samples are selected from the dark tone areas where ice samples are from the bright tone areas.

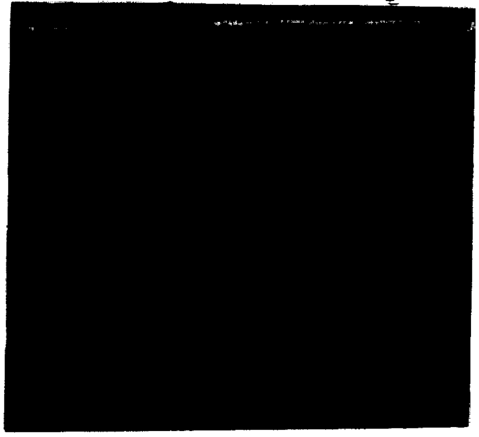

Figure 1.b: AirSAR PVH scene and sample locations. Samples at the same location as in the CVH scenes are chosen. Due to the contrast reversal phenomena, the wet snow samples are in the bright tone area of this scene while ice samples are from the area with dark tone.

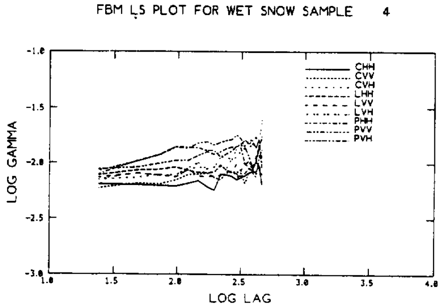

Figure 2.a: Log-log semi-variogram of a typical wet snow sample.

Figure 4.b: ASM textural transformation image for the CVH scene. →

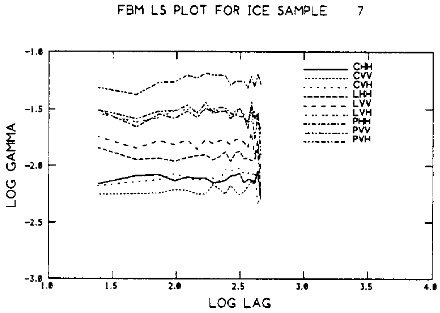

Figure 2.b: Log-log semi-variograms of a typical ice sample.

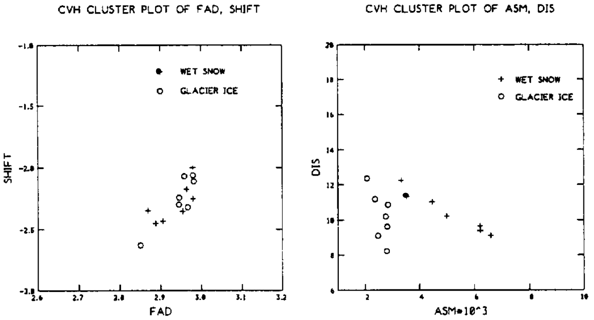

Figure 3: Cluster plot of the PSV and GLCM parameters of the CVH scene. ***Left*** **3.a: the PSV parameters, FAD against SHIFT.** ***Right*** **3.b: the GLCM parameters, ASM against DIS.**

Figure 4.a: FAD textural transformation image for the CVH scene.