An Approach Using Contextual Analysis to Monitor River Ice from RADARSAT Data

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ABSTRACT

An approach using contextual analysis to monitor river ice from RADARSAT data is presented. It is based on the assumption that the radar backscattering is influenced by the structure and composition of the ice cover and that the use of contextual information can help optimize the characterization of river ice from radar data. The context of the river channel and environment is established through a GIS and homogeneous reaches are determined. The spectral context is established through texture analysis. It is shown that a single texture parameter could improve unsupervised classification and that four texture parameters can help discriminate between different ice conditions.

I. INTRODUCTION

The potential of SAR data for river ice monitoring has often been discussed in the past (Leconte and Pultz, 1991; Leconte and Klassen, 1991; Petryk *et al.*, 1993) and recent studies had confirmed RADARSAT's capability to detect several river ice characteristics (Gauthier *et al.*, 2001; Murphy *et al.*, 2001; Weber *et al.*, 2001). However, these studies have also shown that there are some limitations when trying to characterize river ice from the radar signal only. First, because the radar scattering mechanisms from river ice are not always fully understood. Secondly, because of the complex nature of river ice. More than just a mixture of ice and air, a river ice cover can contain water, wet snow and dirt, it can be composed of multiple ice layers and the roughness at the visible air-ice interface can be totally different from the roughness at the invisible ice-water or ice-channel bottom interface. The formation and composition of the river ice cover is usually a result of the thermal regime (meteorological conditions) and of the water regime (channel morphology), showing that a good knowledge of the river characteristics and environment is essential to understand the information content of a radar image Therefore, the goal of this ongoing study is to optimize river ice characterization from SAR data using contextual analysis. This paper presents the approach and some first results with texture analysis.

II. ESTABLISHING THE CONTEXT

To establish the physical context, we first need to characterize the river and its environment. This is done through the use of a Geographical Information System (GIS) from which we can determine the channel morphology and the channel environment (Figure 1). From various sources of data, the river channel is characterized according to width, depth, sinuosity and slope of the

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surface. As they play a role in the formation and deformation of river ice, the presence of islands, tributaries and man made structures are also taken into account. Finally, hydrometric data, weather data and historical data give a portrait of present and past conditions on the river. With this information, we should be able to determine the probable water regime and therefore, the probable ice type and processes occurring there.

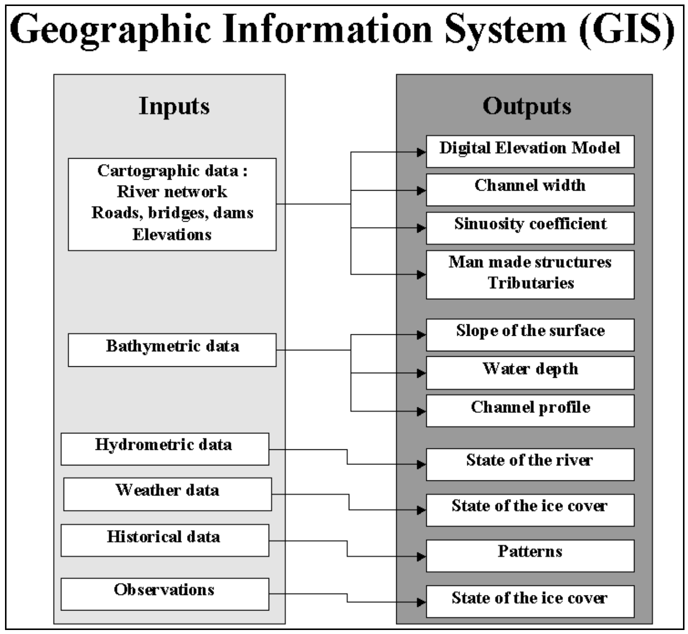

Figure 1: Data used in the Geographic Information System to establish the physical context.

Based on this GIS, we can also segment the river into sections having homogeneous characteristics and an homogeneous context. These reaches will thereafter be the basic unit for the analysis of the radar signal.

Having established the context of the river, we shall then characterize the radar signal and its environment. We start by transforming the raw signal into backscattering coefficients, which is where most people usually stop. We then proceed to a texture analysis, which looks at the pixel in relationship to its neighbors. We use contrast measures, measures of orderliness and descriptive statistics based on the Grey Level Co-occurrence Matrix (GLCM).

Finally, we use an object oriented classification (Definiens Imaging, 2001) to make use of the contextual information and to characterize the river ice cover from the SAR images. This classification method takes into account the object itself, inter-objects relationships and context. It first uses intrinsic features, which are the physical characteristics extracted from the radar images (backscattering coefficients and texture). It also uses topological features, which are the geometric relationships between the objects or the whole scene. A simple example of this type of feature could be to say that border ice is always adjacent to the channel bank. Finally it uses context features, which are the semantic relationships between objects. An example would be to say that static ice is always formed under laminar flow conditions and never under turbulent conditions.

III. STUDY AREA AND AVAILABLE DATA

This contextual approach is developed on a 50-km stretch of the Saint-François river (Quebec, Canada), located between the towns of Windsor and Drummondville. It flows north-west and discharges into the Saint-Lawrence river, about 100 km east of Montreal. This test site has been chosen for its accessibility, its good RADARSAT coverage, its changing river channel characteristics, the presence of dams, and the frequent occurrence of ice jams.

Through different programs of the Canadian Space Agency and from the CRYSYS program at Environment Canada, a total of 19 RADARSAT Fine mode images (9 m spatial resolution) have been acquired over the area during the 2000-2001, 2001-2002 and 2002-2003 winter seasons. Table 1 gives a summary of the image acquisition parameters and prevailing ice conditions.

Table 1. Image acquisition parameters and prevailing ice conditions.

Date	Mode	Beam	Ice conditions
11-24-2000	Descending	F5	Mainly open water
11-26-2000	Ascending	F5	Mainly open water
12-18-2000	Descending	F5	Fall break-up
01-11-2001	Descending	F5	Complete ice cover
02-28-2001	Descending	F5	Complete ice cover
03-16-2001	Ascending	F1	Complete ice cover
03-17-2001	Descending	F3	Complete ice cover
03-24-2001	Descending	F5	Wet snow over ice
03-26-2001	Ascending	F5	Wet snow over ice
04-09-2001	Ascending	F1	Partial ice cover
04-10-2001	Descending	F3	Partial ice cover
04-17-2001	Descending	F5	Open water
04-19-2001	Ascending	F5	Open water
12-15-2001	Descending	F5	Open water
01-06-2002	Descending	F5	Partial ice cover
01-30-2002	Descending	F5	Partial ice cover
03-04-2002	Ascending	F3N	Partial ice cover
03-19-2002	Descending	F5	Open water
02-11-2003	Descending	F3	Complete ice cover

Concurrent field observations, meteorological data and some level and discharge measurements are available for image interpretation. Ice thickness measurements were also made on two occasions, as well as an helicopter survey.

IV. TEXTURE ANALYSIS

Based on the GIS, two homogeneous reaches were chosen to start the texture analysis (Figure 2). The first one, site #6, is located a few kilometers upstream from a dam and it is therefore a section with one of the largest (250–300m) and deepest (2–4.5m) channel. Consequently, it also has a low sinuosity (1.02) and an almost non-existing slope, which result in low water velocity. This reach contains about 5000 pixels.

The second selected reach, site #12, is narrower (200–250m) presents shallow waters (0.5–2.5m), a stronger surface slope (0.18) and is nested between two islands. It contains about 4500 pixels.

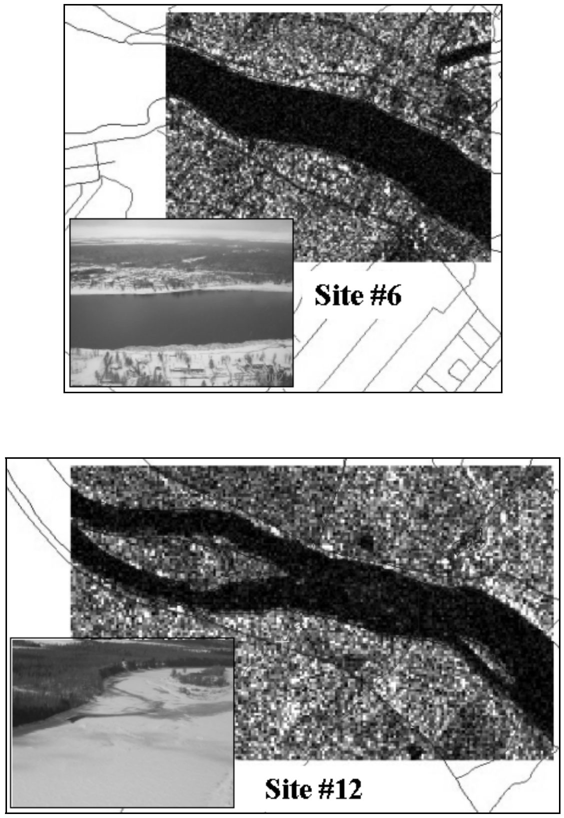

Figure 2: Homogeneous reaches selected for the texture analysis.

The mean backscattering coefficient was first calculated for site #6, under seven ice conditions. On November 24, 2000, this section is covered by a recently formed smooth ice cover and a thin dry snow cover. On December 18, 2000, strong winds and heavy rains had caused a fall breakup and broken ice is moving downstream. On February 28, 2001, the cover had consolidated again and is estimated at 60 cm. On March 24, above 0ºC temperatures resulted in wet snow covering the ice. On April 17, all ice had left. On January 6, 2002, the ice cover is complete but thinner than normal for that time of year. Some puddles of water are visible. On March 4, 2002, the ice cover is complete, measured at 36 cm, snow-free, but already under thermal transformation. The ice was broken by an ice breaker on a longitudinal path.

At the reach level, there is a 12dB difference between the backscattering of open water (April 17, 2001) and the backscattering of a complete and rough ice cover (February 28, 2001) (Figure 3). This indicates a wide range of possible backscattering signatures. The lower backscatterings (around –25dB) correspond to open water, wet snow and newly formed thin smooth ice. When the roughness and heterogeneity of the ice cover increase, the backscattering rises to –20 dB and even to –13 dB. However, you get similar backscattering coefficients for significantly different ice conditions. But looking at the standard deviation, expressed here in amplitudes, we can see that although brighter, the complete rough ice cover has a more homogeneous signature than the moving ice. The same observation applies to the complete smooth ice cover, which has a strong mean backscattering but a standard deviation similar to open water.

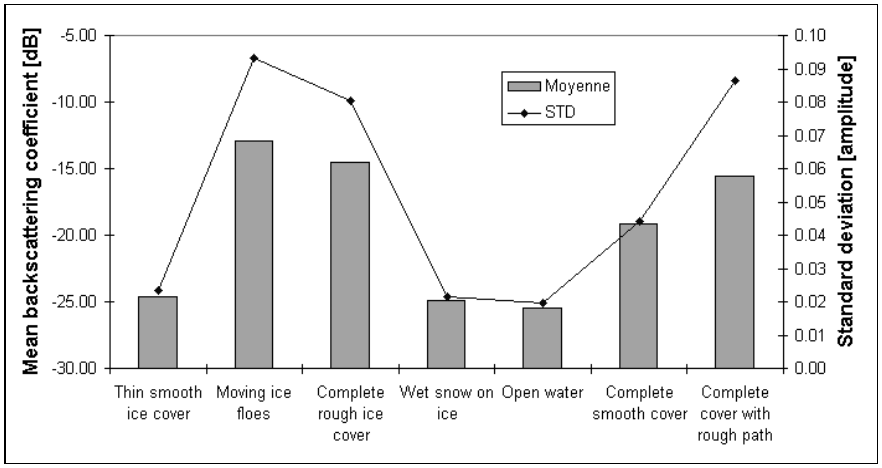

Figure 3: Mean backscattering for different ice conditions at the reach level - Site #6.

This behavior can be enhanced through the use of texture, which is a representation of the spatial relationship between pixels. As an example, we can first use it to simply enhance an image prior to an unsupervised classification. On site #6 (Figure 4), adding the "Mean" texture parameter, enables us to enhance a pattern specific to the mid-channel and to clearly show the ice bridge on the lower right of the reach. However, the average value of this texture parameter for reach #6 (Figure 5) still leaves much confusion between ice conditions.

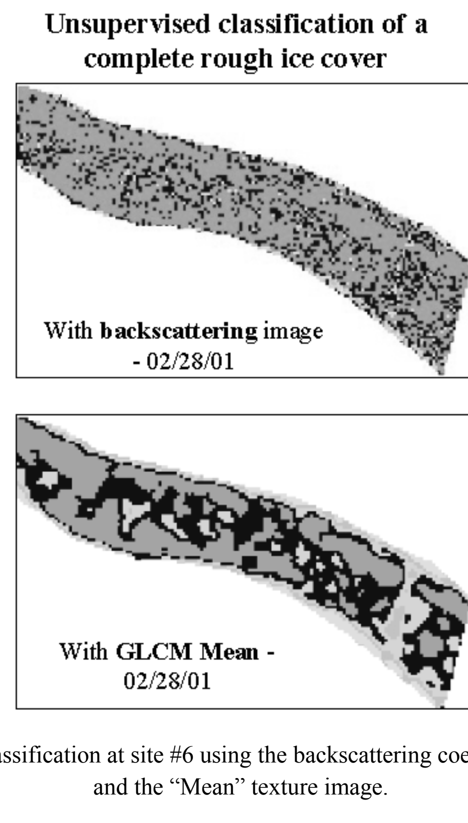

Figure 4: Unsupervised classification at site #6 using the backscattering coefficient image (02-28-2001) and the "Mean" texture image.

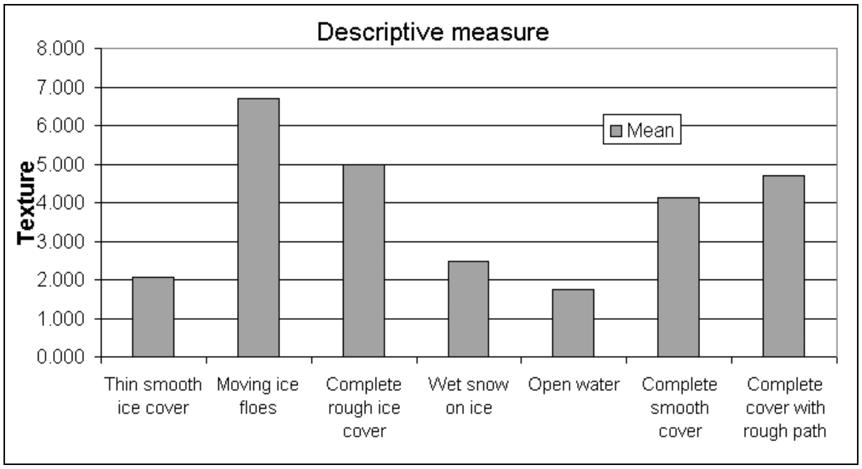

Figure 5: Average value of the "Mean" texture parameter for different ice conditions at the reach level—Site #6.

Therefore, we tested the use of more texture parameters. On Figure 6, we have plotted on the left graph, the value of a contrast measure against the value of an orderliness measure, averaged at the reach level (site #6). We clearly see the complete ice cover conditions on one side and we can also start to discriminate between open water and the other low backscattering conditions. On the right graph, two descriptive texture measures averaged for the same area can help to further discriminate between a complete smooth ice cover and some rougher conditions. These graphs could be used to determine thresholds, that could be transferred into a decision tree and used in a classification.

However, as expected, the results obtained for reach #6 are not directly applicable to reach #12 because of the different context. As shown on Figure 7, different channel characteristics result in different texture values. It is here harder to discriminate between open water and wet snow but you can however easily discriminate complete and partial ice covers.

V. CONCLUSION

We have presented here an approach using physical context as a way to better interpret the radar backscattering on an ice-affected river and spectral context as a way to help in characterizing the ice cover from RADARSAT images. The use of texture parameters has proven useful in discriminating between different ice conditions. This exercise will be repeated independently for all homogeneous reaches on the river prior to running the object-oriented classification. Other statistical tests will be added to the analysis. And although we have an interesting image database to work with, more ice events are also necessary to determine better texture thresholds. In 2003, an airborne polarimetric radar survey has also been done to investigate the potential of this technology for river ice.

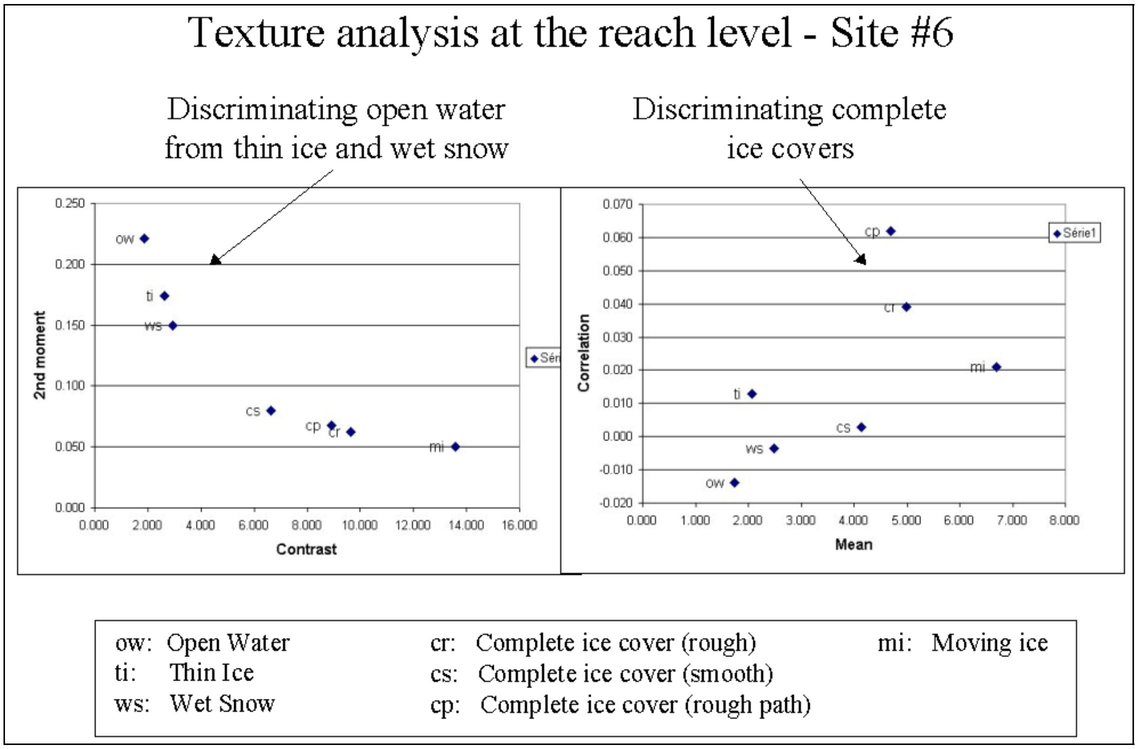

Figure 6: Average texture values at the reach level for different ice conditions at site #6.

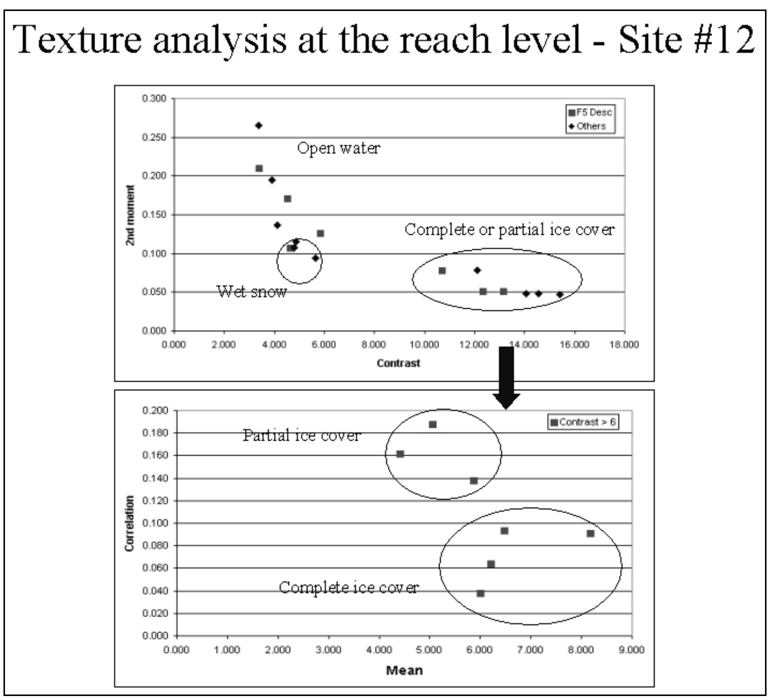

Figure 7: Average texture values at the reach level for different ice conditions at site #12.

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