# Monitoring wetland hydrology in Atlantic Canada using multi-temporal and multi-beam RADARSAT data

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**Abstract** Wetland complexes comprise a large percentage of ground cover in central Labrador, and contain some of the largest peatlands in North America. The region experiences long cold winters and short cool summers, resulting in a limited growth period. Fens and bogs are the dominant wetland types. The level of moisture saturation, chemistry, topography and climate influence the development of wetland systems. Slight changes in these environmental factors can significantly alter vegetation species and health. As persistent cloud cover often limits the utility of optical remotely sensed data in Atlantic Canada, the value of using the all-weather capabilities of radar data become evident. Temporal sequences of Radarsat images were acquired in May, June and August 1999. During each time period, four Radarsat scenes with incidence angles spanning 20-49° (Standard 1, 4, 7 and Fine 1)

were acquired. This paper describes changes in radar backscatter as a function of incidence angle, vegetation structure and moisture conditions.

## INTRODUCTION

Wetlands are an important component in the hydrological cycle and are involved in patterns of evaporation-precipitation, water distribution and flow. They assist in lowering flood crests, reducing erosion, supporting ground water recharge and improving water quality (Niering,1998). They are also invaluable from a biological point of view, supporting unique plants and animals, acting as carbon sinks, and producing organic matter, such as peat. The most commonly known benefits of wetlands are the recreational, educational, aesthetic and commercial aspects, which are often in conflict with one another. Each wetland type has its own unique attributes that warrant classification standards.

The Canadian wetland classification system, developed by the National Wetlands Working Group (1988), divides wetlands into five broad classes: bog, fen, swamp, marsh, and shallow open water. Bogs and fens, peat-producing wetlands, are the predominant wetland types found in Labrador. Bogs are peat-covered wetlands which support vegetation well adapted to acidic, nutrient-poor, wet environments. Trees and shrubs may be absent; however, if present, they are low level and stunted. Fens are also peatlands, characterised by a high water table. In these environments, vegetation takes advantage of the mineral-rich water flowing through the fen, resulting in different plant species found in the bog wetlands.

Both optical and radar remote sensing techniques have been used in wetland research, however radar remote sensing has been used more frequently in the last few years in coastal and wetland environments (Augusteijn and Warrender, 1998; Brisco and Pultz, 1998; Mougin et al., 1999). The ability of radar sensors to penetrate through cloud cover, and the relatively frequent repeat cycle gives these satellites a great advantage over optical sensors, especially in the coastal regions of Atlantic Canada where there is frequent cloud cover.

This paper investigates the differences in radar backscatter values of various wetland sites, with respect to incidence angle and wetland structure. Changes in backscatter are analyzed according to wetland type and from a temporal perspective.

## GOOSE BAY WETLAND STUDY SITES

The town of Goose Bay / Happy Valley is located in eastern Labrador at the western end of Lake Melville, with a latitude and longitude of 53.19N, 60.33W. Black spruce, lichen forests, and wetland environments (bogs and fens) dominate the landscape. Ground data were collected from five wetland sites in the Goose Bay/ Happy Valley region in July 1999. The sites chosen are representative of the wetlands in the region. They were defined by the boundaries of homogenous vegetation type, which often results in wetland complexes of various sizes. The locations of wetland study sites are shown in Fig. 1.

The first wetland site, near the Mealy Mountains, is a plateau bog with numerous streams and irregularly shaped ponds that support fen species. The hummocks and ridges of the bog are along the forest edge, while the fen ponds are centred in the middle of the wetland area. The second wetland is an elongated slope fen on the southern shore of Goose Bay. Slightly raised ridges of vegetation separate the narrow pools of water, although both are equally dominant throughout the fen. The third wetland site is a raised bog that is relatively open with only a few stunted trees and shrubs. The bog is raised approximately 1 meter from the surrounding black spruce forest and the water surface is 10 cm below the vegetation. The fourth wetland site, located north of Lake Melville, contains a slope bog and a ribbed fen. In the slope bog wetland, the water level is just below the surface of the vegetation, inhibiting the development of large hummock formations. The ribbed fen contained many parallel string pools and the water level is at the vegetation surface. The fifth wetland site contains both a plateau bog and string bog/ribbed fen. The northern section of this elongated wetland show more elements of a bog environment, while the southern section of the wetland contains equal amounts of bog and fen elements.

## DATA DESCRITPION AND METHODOLGY

The 1999 wetland field campaign took place between July 3rd and July 7th, 1999. At each visit, wetlands were classified, ground photos acquired, vegetation structure/species were recorded, and environmental conditions noted (water level, weather conditions). Environment Canada collected meteorological data at Goose Bay Airport. An important aspect of the field visit was to map the vegetation composition of each wetland, and note structural differences between wetland sites.

A total of 12 Radarsat images of the Goose Bay region were acquired from May 9th to August 23rd (refer to Table 1 for the dates and scene parameters). All images have an ascending orbit and were acquired at 19:20 local time. The area of coverage shifts east to west depending on the beam mode, however all five study sites are contained within the standard images, and sites 1, 2 and 4 are covered in the fine mode images. Statistical information for each study area was extracted in power values and converted to radar brightness ($\beta°$) dB values (Raney et al., 1994). The calibration accuracy, as defined by the Central Data Processing Facility (CDPF), between Radarsat scenes is approximately 1.5 dB (Srivastava et at., 1999). All sites were in excess of 1,000 pixels, thereby reducing random speckle influences to obtain a representative sample.

## RESULTS

Variations in backscatter are observed between image dates, incidence angles and wetland types. Backscatter values in dB, for all image dates and wetland sites, are plotted in Fig. 2. Slight differences in the temporal backscatter values for each wetland site are observed. However, no significant differences in backscatter values between bogs and fen wetlands are evident over the temporal sequence of images.

Variations in backscatter over incidence angles (beam modes) were also investigated. The total range of values for wetland sites differs between beam modes. The range of backscatter values for all wetland sites at S5 spans over 8 dB. This is significantly larger than all other beam modes, especially when compared to the smallest range of values at F1, spanning only 4.6 dB. However, no significant separation between bogs and fens appears at any beam mode, although the fen sites make up the majority of lower values (approximately 2 dB lower). Reduced backscatter results from larger open water areas and less emergent vegetation found in fen environments.

The most significant differences seen between beam modes relate to differences in incidence angles. As a rule, backscatter values decrease as incidence angles increase. Fig. 2 demonstrates the decrease in average backscatter values from S1 to S7, which corresponds to difference of 7 dB.

## DISCUSSION

Many of the bog and fen wetlands in the Goose Bay region are similar in vegetation composition and structure, and are therefore difficult to separate in radar imagery or to classify without extensive ground work (chemical and biological analysis). The harsh Labrador environment and short summer season limit the growth rate of many wetland species, and as a result, the vegetation structure does not change significantly within a growing season. From a radar remote sensing perspective, radar backscatter results show little difference in the temporal sequence examined. The most significant differences in radar backscatter were found to be due to changes in incidence angles over various beam modes.

Remote sensing techniques alone may not be adequate to classify these wetland regions, however radar can provide information on the quantity and distribution of water, which are important factors in classifying and monitoring wetlands. Before this application is possible, corrections for incidence angle effects must be considered. The variations in backscatter due to incidence angles must be corrected in order to quantify changes in environmental conditions. Further research will establish incidence angle corrections allowing multi-beam acquisitions for research studies.

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**Figure 1** Location of wetland study sites in the Goose Bay Region.

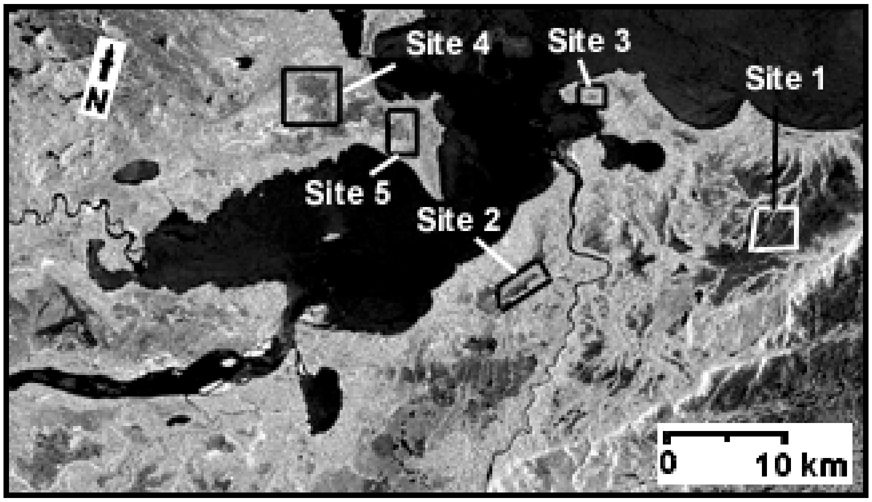


**Table 1** Radarsat Images and Scene Parameters

| Date of Acquisition | Beam | Incidence Angle(°) |
|---|---|---|
| 9-May-99 | S5 | 36-42 |
| 13-May-99 | S1 | 20-27 |
| 16-May-99 | F1 | 37-40 |
| 19-May-99 | S7 | 45-49 |
| 26-Jun-99 | S5 | 36-42 |
| 30-Jun-99 | S1 | 20-27 |
| 3-Jul-99 | F1 | 37-40 |
| 6-Jul-99 | S7 | 45-49 |
| 13-Aug-99 | S5 | 36-42 |
| 17-Aug-99 | S1 | 20-27 |
| 20-Aug-99 | F1 | 37-40 |
| 23-Aug-99 | S7 | 45-49 |

**Fig. 2** Beta Nought backscatter values for wetland sites