Investigating Labrador Fens and Bogs using Multi-Temporal ERS-2 and RADARSAT Data

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Abstract

Bog and fen 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. The level of moisture saturation, chemistry, topography and climate influences the development of wetland systems. Consequently, slight changes in these environmental factors can significantly alter vegetation species and health. As persistent cloud cover often limits the utility of optical data in Atlantic Canada, the value of using the all-weather capabilities of radar data is evident. Temporal sequences of Radarsat images (C-HH) were acquired in May, June and August 1999, during which four Radarsat scenes, with incidence angles spanning 20-49° (Standard 1, 4, 7 and Fine 1) were acquired for each time period. Throughout the study period, 6 ERS-2 images (C-VV) were also acquired. This paper describes changes in radar backscatter as a function of incidence angle, vegetation structure and polarization.

Introduction

Wetlands are an important component in the hydrological cycle and are involved in patterns of evaporation, transpiration, water distribution and flow. Wetlands can help control changes in water quality and quantity by lowering flood crests, reducing erosion, supporting ground water recharge and filtering toxins and sediments. 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 can often be in conflict with one another. Wetland classification and monitoring are the first steps to protecting these valuable resources, if they have not been studied and identified, they are mostly likely not protected.

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 small and stunted. Fens are also peatlands, characterised by a high water table, and often have areas of open water with emergent vegetation. In the fen environment, vegetation takes advantage of the mineral-rich water, resulting in the growth of different plant species than found in the bog environment. Bog wetlands are characterised by evergreen trees, shrubs, and sphagnum moss, and contain vegetation species such as Black Spruce, Tamarack, Leatherleaf, Labrador Tea, Sundews and Pitcher Plants. Fen environments contain more soft-stemmed herbaceous, aquatic vegetation, such as water lilies, bog bean, and aquatic grasses.

There are many advantages to using remote sensing techniques to monitor wetland environments, including the most significant benefit of large, continuous spatial coverage. Ground-based observations are labour intensive, expensive, and often cover a small area, whereas remote sensing systems can offer regional coverage within a few days. Remote sensing images utilise the full range of the electromagnetic spectrum, allowing different information to be collected from the image and are available in digital form, which can be directly manipulated by the user. With the large number of airborne and satellite sensor's available for environmental monitoring, wetland studies can take advantage of the variety of different resolutions, image geometry, spatial coverage and various spectral ranges. However, the success of various wetland research using remote sensing is varied. All sensors have different image parameters and therefore have different imaging strengths and weaknesses for specific wetland characteristics.

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, polarization and wetland structure, over a seasonal period.

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, which are representative of the wetlands in the Goose Bay/ Happy Valley region, during a field campaign in July 1999. Wetland sites were defined by the boundaries of homogenous vegetation type, on the image and ground observations. The locations of wetland study sites are shown in Fig. 1.

The first wetland site, near the Mealy Mountains, is a wetland complex with numerous streams and irregularly shaped ponds. The hummocks and ridges of the plateau bog (Bog-W1) are along the forest edge, while the fen ponds are centred in the middle of the wetland area (Fen-W1). The second wetland is an elongated slope fen (Fen-W2) 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 (Bog-W3) 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 complex, located north of Lake Melville, contains a slope bog (Bog-W4) and a ribbed fen (Fen-W4). 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 complex contains both a plateau bog (Bog-W5) and string bog/ribbed fen (Fen-W5). 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.

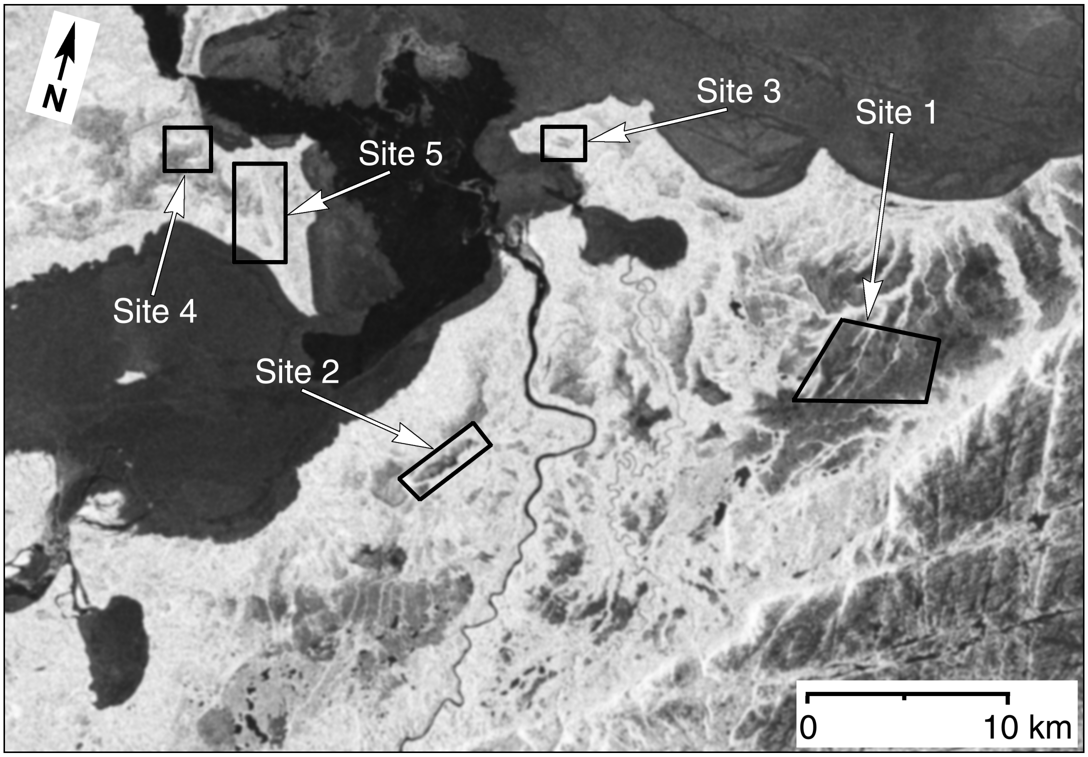

Figure 1: Location of Wetland Study Sites in the Goose Bay Region on May 9, 1999

Data Description

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 vegetation structural differences between wetland sites.

A total of 12 Radarsat images of the Goose Bay region were acquired from May 9th to August 23rd, 1999 (refer to Table 1 for the dates and scene parameters). All images are ascending passes 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 wetland sites were in excess of 1,000 pixels, thereby reducing random speckle influences to obtain a representative sample of the radar brightness.

Six ERS-2 images were acquired during the study period, between May 14th and August 27th, 1999 (Table 2). Some were coincident with ground data collection, while others were obtained within 24 hours of Radarsat data acquisitions, acquired on both ascending and descending passes. ERS-2 data were processed by CCRS to the standard MLD product at the Gatineau Satellite Station using Earth View Advanced Precision Processor created by Atlantis Scientific Inc. ERS-2 MLD products have comparable ground resolution and swath widths to Radarsat Standard Beam SGX products, and incidence angles similar to Standard 1 beam modes. All wetland sites were contained within the ERS-2 images, and as it is stated that this processor is calibrated (Meadows et al., 1999), digital numbers obtained in the product were scaled to give radar backscatter in Beta-Nought (β°). The same procedures as were employed for the Radarsat images were used to locate and extract average backscatter values for the wetland sites from the ERS-2 images.

Results

Backscatter values in dB (β°), for all Radarsat image dates and slope equations for all wetland sites, are plotted in Figure 2. This graph plots the β° backscatter values against incidence angle, with fens marked with white symbols and bogs marked with dark symbols. Variations in backscatter are observed between image dates, incidence angles and wetland types. Four aspects of analysis was conducted in this study, the results will be discussed in this format. Changes in radar backscatter are analysed as a function of time (May to August), wetland type (vegetation composition and structure), polarization (C-VV and C-HH) and incidence angles (20 – 50°).

As seen in Figure 3, little change in backscatter occurs temporally in these wetland targets, indicating the environments are not very dynamic from the May to August time period. ERS-2 values are only slightly more variable then Radarsat values, but could result from the mix of ascending and descending orbits, taken at different times during the day. For each Radarsat beam mode, values for the wetland sites remain relatively unchanged over the temporal sequence. This may be due to the cool, short growing season in the Goose Bay region and the lack of nutrients in these wetlands (peat wetlands). Northern wetlands exhibit different characteristics than those in the southern Canada. One of the major differences is the vegetation; plants do not loose leaves over the year and vegetation growth is extremely slow, therefore reducing the backscatter differences over the summer season. For example, a tamarack tree in one of the bog sites studied in the 1999 field campaign was estimated at 100 years old, but only stood 2 feet tall.

No significant differences in backscatter values between bog and fen wetland classes are evident over the temporal sequence of images (Figure 4). The separability between these two wetland types, at all Radarsat values from various beam modes and ERS-2 values, is minimal. Although, a closer examination of the distribution of wetland sites, shows that the majority of lower values at each Radarsat beam mode and image date, appear to be fen sites. Average values for these fen sites are approximately 2 dB lower than bog sites, which may result from differences in vegetation distribution. Fen sites contain more areas of open water than the bog sites, therefore having lower backscatter values. Double bounce effects and volume scattering occurs in bog sites due to the vegetation above the water level, and subsequently increases backscatter values. This is however, a gross generalisation. Most fen sites in this area contain string like vegetation features, which support dryer, nutrient poor bog species, and bog sites often have bog pools with aquatic vegetation that form in depressions throughout the bog. This complexity with mixed vegetation species causes confusion from a remote sensing perspective and also results in uncertainty with classification on the ground. For this reason the majority of wetland sites (bogs and fens) exhibit similar backscatter values with only a couple of wetlands having notably higher or lowers values. One of these instances is the Fen wetland at site 1, which has notably lower values than other wetland sites. This fen is located in the coastal plateau along Lake Melville with the water table at the vegetation surface. This region is constantly saturated with water resulting in lower backscatter values during the entire summer season.

Backscatter values decrease as incidence angles increases. Variations in backscatter over incidence angles (Radarsat beam modes) are presented in Figure2. The decrease in average backscatter values from beam modes S1 to S7 (20-49°) corresponds to an average difference of 7 dB. Similar slope equations occur for all wetland sites, indicating little temporal changes over the acquisition time period which can also be seen in Figure 3. The intercept values range approximately 4 dB, and the data distribution between that range can be divided into 3 classes, representing high, medium and low backscatter slope equations (Figure 5). This division is based on visual analysis of the regression slope equations and the intercept values.

The low backscatter group contains only one wetland (Fen-W1), discussed in the above section. The middle range contains 5 out of 8 wetland sites (bogs and fens), and represents wetlands with mixed vegetation compositions. The high backscatter group includes 2 wetlands, a bog (Bog-W4) and fen (Fen-W5). The bog vegetation at site W4 is situated above the water level, and contains small trees and shrubs, thus increasing backscatter. It is uncertain why the fen is showing such high backscatter values, considering there is open water throughout the site. This particular fen is transitioning into a bog environment (refer to site description). The area is draining to the south east of the wetland which is why bog species were dominant in the north end of the wetland, however this will have to be investigated further. Analysis of variance tests (t-test) were completed for wetland slope equations and slope intercepts (Hubert, 1988). Bog and fen wetland slope equations were not significantly different at the 95% confidence level. Slope elevations for the 3 groups of wetlands (slope equations representing high, medium and low backscatter) were tested and considered significantly different at the 95% confidence level (not including the calibration error).

ERS-2 and Radarsat temporal backscatter values are presented in Figure 3. ERS-2 values are slightly more variable over the season than any single Radarsat beam mode, however this could be a result of using both ascending and descending passes. ERS-2 values are significantly lower, approximately 6 dB, than Radarsat Standard 1 beams with similar incidence angles. Pope et al. (1997) reported average SIR-C CVV values lower than CHH values for marsh wetlands during wet conditions. C-band VV at 23°, in areas of little leaf structure, may be interacting with the underlying ground structure more than the surface vegetation. These wetland targets have very little vertical structure, no tall or significant woody vegetation.

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. The harsh Labrador environment and short summer season limit the growth rate of many wetland species, resulting in no significant vegetation structure changes within a growing season. Both HH and VV radar backscatter values show little difference in the temporal sequence examined. The most significant differences in radar backscatter were a result of changes in incidence angles over various Radarsat beam modes. ERS-2 values exhibited lower backscatter values than Radarsat S1 images, with similar incidence angles. However, due to the lack of relative calibration estimates, caution must be taken when using these values.

Radar remote sensing techniques alone may not be adequate to classify these wetland regions, however radar data can provide information on the aerial extent 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. Differences in backscatter values are seen between C-band HH (Radarsat) and VV (ERS-2) for Labrador wetland sites. Radarsat-2, soon to be launched in 2001, will offer unique capabilities for monitoring wetland environments with fully polarimetric data. Further research will establish incidence angle corrections allowing multi-beam acquisitions for research studies and investigate the use of both C-band HH and VV for wetland studies.

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Table 1 Radarsat Image Parameters

Date of Acquisition	Beam Mode	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

Table 2 ERS-2 Image Parameters

Date of Acquisition	Ascending/ Descending	Local Time (Goose Bay)
14-May-99	Desc.	12:28:08
26-Jun-99	Asc.	23:29:48
7-Jul-99	Desc.	12:28:53
15-Jul-99	Asc.	23:32:37
11-Aug-99	Desc.	12:28:54
27-Aug-99	Desc.	12:25:59

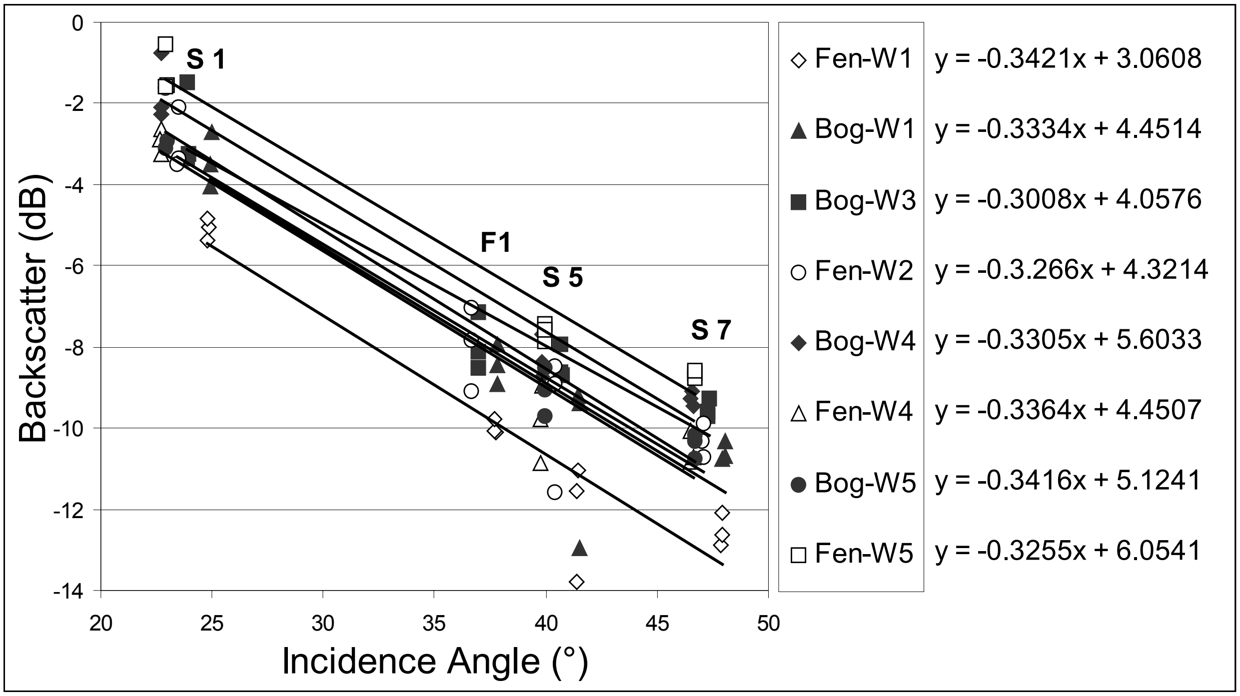
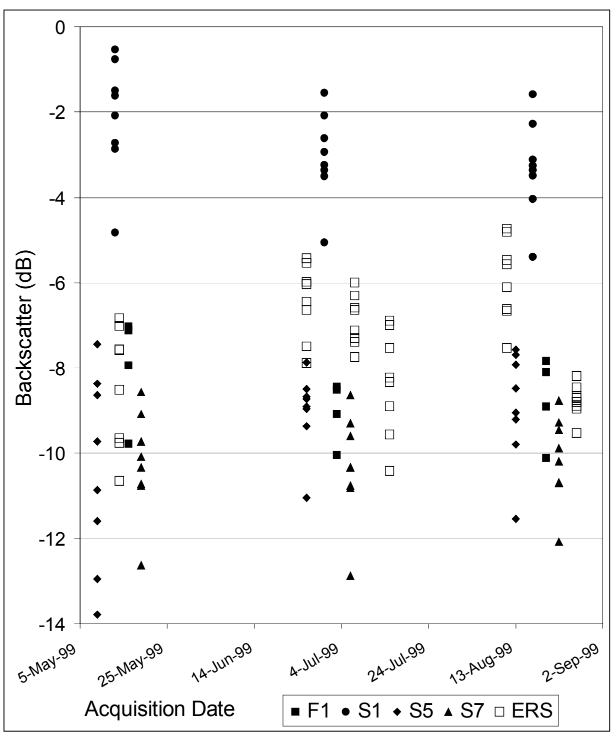


Figure 2 Radarsat Beta Nought (β°) Backscatter Values for Wetland Sites



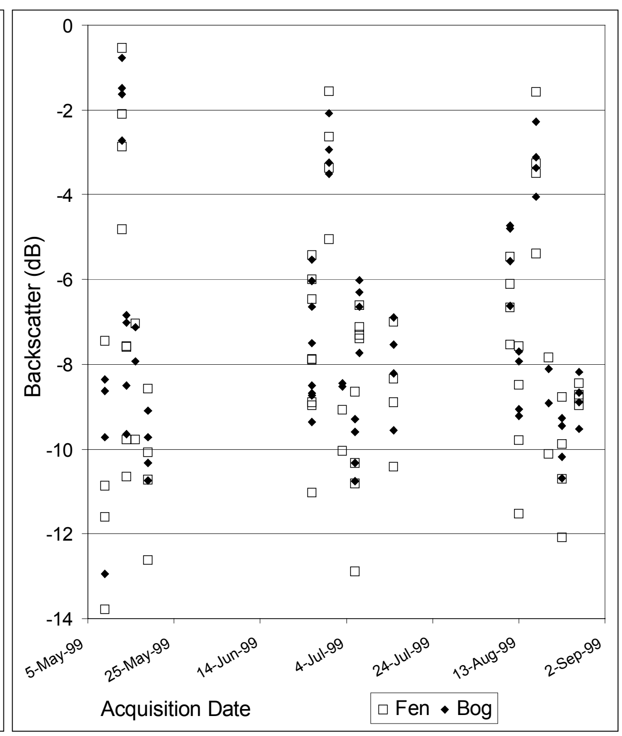


Figure 3 Temporal Sequence of β° by Beam mode *Figure 4 Temporal Sequence of β° by Wetland Type*

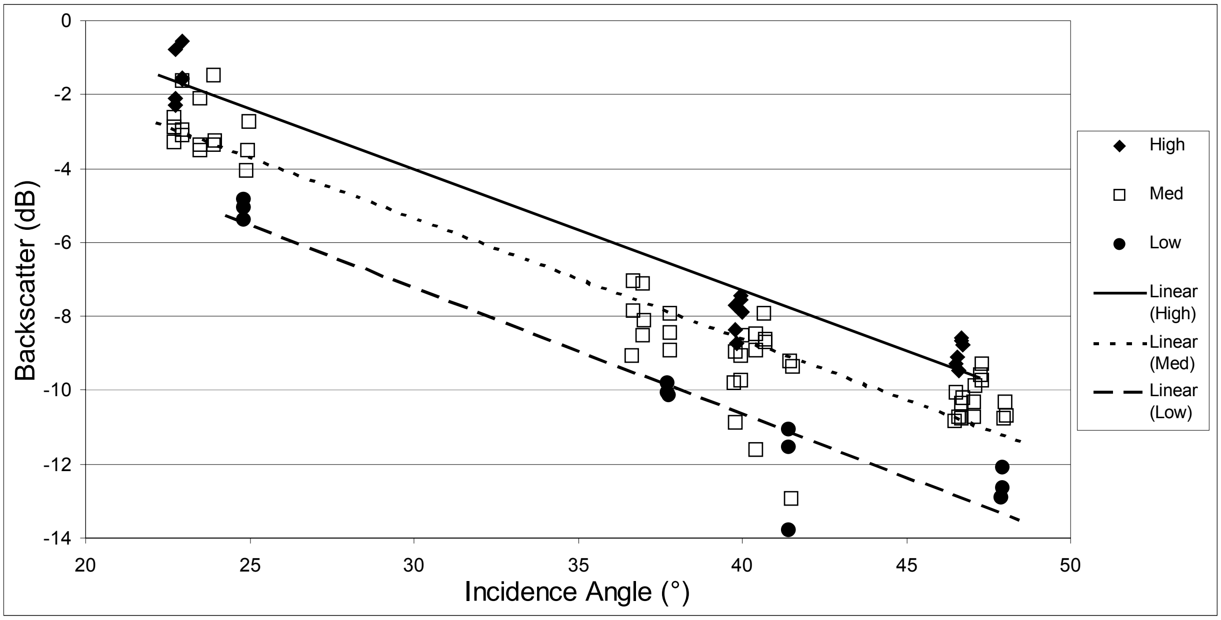


Figure 5 Slope Equations grouped into High, Medium, Low Backscatter Returns