Image Cover Sheet

CLASSIFICATION	SYSTEM NUMBER 515351
UNCLASSIFIED	

TITLE

Multi-temporal backscatter and target-to-clutter estimates for several micro-environments

System Number:

Patron Number:

Requester:

Notes:

DSIS Use only:

Deliver to:

This page is left blank

This page is left blank

Multi-Temporal Backscatter and Target-to-Clutter Estimates for Several Micro-Environments

M. L. Yeremy and F. L. Laforce[1]

DREO, 3701 Carling Avenue, Ottawa, Ontario, Canada, K1A 0Z4.
PHONE: 613-993-8381, FAX: 613-990-8906, E-mail: maureen.yeremy@dreo.dnd.ca, laff01@gel.usherb.ca

ABSTRACT

A multi-temporal study of backscatter variability from environmental changes, is presented here for Radarsat images centered on an Atlantic-Canadian region. This study region has distinct seasonal climate variation and several types of environmental features. Both environmental features and man-made targets are studied.

This paper presents backscatter results in relation to the environment. Overlapping the image collection time period, a hydrographic experiment was conducted in the same area. The measurements from this hydrographic study were recorded daily (e.g.; soil moisture and meteorological data) and are compared with the multi-temporal backscatter statistics in this paper.

Most of the backscatter results here indicate a decreasing trend in backscatter from the spring to autumn seasons, and a sharp backscatter increase at the onset of spring.

INTRODUCTION

A collection of Radarsat 1 Synthetic Aperture Radar (SAR) images, centered over the Canadian Forces Base (CFB) Gagetown, New Brunswick, Canada has been gathered so that seasonal and environmental characteristics are captured. The base's extent is about 40 by 35 km. In this paper, we present backscatter statistics for these imagery and evaluate the backscatter variability in reference to environmental data.

These imagery also captured a wide variety of targets on the military base. For this study, Target-to-Clutter Ratio (TCR) estimates of stationary fire fighting planes at a nearby airport are presented. A selection of urban backscatter estimates are also studied here.

The study region experiences all four seasons with snow and ice conditions in winter and lush deciduous growth in the summer season. Typical environmental features includes the following; several types of boreal forest, marshland, farmland, deforested areas and grubbed areas. Grubbed regions are areas which have been deforested, and then prepared so that minimal vegetative growth occurs. In particular, the residual woody material are buried with the underlying mineral soil from below. After this process the grubbed areas are typically barren, rough surfaced regions for about 5 years. Thereafter only modest vegetative growth occurs. In contrast, at clear-cut sites, woody slash and stumps remain.

DATA

Eleven Radarsat 1 images from May, 1996 until March, 1998 were obtained for this multi-temporal study. The C-band, HH image products studied here are either the fine beam, Single Look Complex (SLC) product or the SAR Geo-referenced Fine (SGF) product and are described further in [1]. Information regarding these images and ground-truthing of the environment can be found in [2].

This paper concentrates on the time period between December, 1996 and late summer, 1997 since meteorological and hydrographic data are available for these dates. This period emphasizes the transition from no foliage in winter to spring growth followed by peak foliage in summer and then the more dehydrated, aging vegetation after this peak. Snow was not present when any of these images were captured, thereby reducing the interpretation complexity with one less parameter (snow) to consider. The air temperatures for the December image were slightly above the freezing mark, and for the other image times, they were above 5°C. There was no precipitation for at least 2 days prior to any of the image collection times presented here.

Many smaller regions were selected for each category and combined for the ensemble average presented here. These smaller sample areas were selected so that other parameters need not be considered. For instance, small forest stands were selected so that they were not near streams, in order to avoid the introduction of additional backscatter effects from the stream. The variability of each of these regions, and more detailed statistical analysis is forthcoming in a future Defence Research Establishment Ottawa (DREO) report.

The specific locations selected for this study are based on either ground-truthed information [2] or information provided by environmental personnel on the base. Only flatter regions are selected here so that radiometric corrections from topographical relief are not required.

[1] F. L. Laforce worked at DREO in a student program and is now at Universite' de Sherbrooke, Sherbrooke, Que'bec, Canada

Reprinted from IEEE 1999 International Geoscience and Remote Sensing Symposium, IGARSS'99
p 1099-101 vol 2

The image dates presented here are as follows; December 11/96, May 28/97, June 4/97, July 15/97 and August 8/97. The categories of micro-environments studied include; grassland, marshland, grubbed and clear cut regions, spruce, pine and mixed forests. The maximum number of regions (and total pixel number) included for each of the above categories' backscatter estimates are respectively; 11 (28,691), 6 (2326), 7 (10,657), 5 (30,525), 4 (3924), 3 (7615), 10 (15,470). Some of these regions are not available in all the images. Urban areas of modest sizes are also studied and are separated into commercial and residential categories which are comprised respectively from a maximum number of regions (and total pixel number); 2 (2977), 3 (9698). Commercial areas refer to sites like offices, factories and shopping centres.

These backscatter results are compared to meteorological and soil moisture data that are available from a hydrographic study conducted on the base [3,4], which involves the collection of meteorological data sampled daily or hourly at eight stations on the base. At each station, two soil moisture probes, at a depth of 10 cm, record the soil water potential daily. Each probe is placed in a distinctive hydrographic region near the meteorological station [3,4], so that different drainage areas are monitored. Only data from two stations are available.

Only one target is analyzed here for the TCR estimates. This target is a group of fire fighting planes, which were parked in a row at the Fredericton Airport. These planes are nearly identical and their length and wing span are about the same dimensions as the pixels analyzed here.

ANALYSIS

In this report, the average backscattering coefficients are calculated for each environmental category. Here, the backscattering coefficient,

$$\sigma^0 = P/K \qquad (1)$$

is defined as the Radar Cross Section (RCS) per unit area and it is a measure of the received power P, relative to the Radarsat system constant K, which includes incidence angle, antenna gain and other system parameters [5].

These backscatter estimates are calculated and topographic corrections [6], as well as Radarsat baseline error corrections are made in order to determine the geographic locations [7,8] as accurately as possible. Radarsat baseline error corrections are inferred from several tie points. The topographic corrections are based on information from a 1:50000 vector map of CFB Gagetown. Additionally, tie points from maps and aerial photographs are used to ensure that the same geographic location is consistently found from image to image.

It is impossible to analyze the same area from image to image because of base line and elevation map errors. For this study, a concerted effort was made to ensure that the same geographic areas were studied from image to image. The geographic coordinates were located within a maximum error of about 30 m. Any candidate micro-environment which was not consistently located was not included in these results. The geographic error allowed for this study depended on the category studied. Larger geographic errors were tolerated for environmental features where the surrounding area was the same. In contrast, only targets which are identified to the pixel are used here.

The TCR estimate used here is the ratio between the target and clutter backscattering coefficient. For these results, only the maximum TCR estimates are presented.

RESULTS

Fig. 1 shows the average backscatter coefficients for the two urban categories, commercial and residential. (The lines in Fig. 1 and 2 do not represent interpolation in time, but are there solely to distinguish between categories). The backscatter from the residential areas are almost constant. In contrast, the backscatter from commercial areas is larger by about 3 dB and varies throughout the seasons. In particular, the backscatter decreases (1 dB) in the spring and is followed by an increase of 1.5 dB in the summer. It is impossible to comment on these temporal changes because of transient traffic in these areas.

Fig. 2 shows the average backscatter coefficients for all the environmental categories. One attribute, common to all the categories, is the distinct increase (1 to 3 dB) in backscatter between the winter and spring seasons. The images from the previous year demonstrated a similar increase which occurred between the beginning and middle of May, 1996.

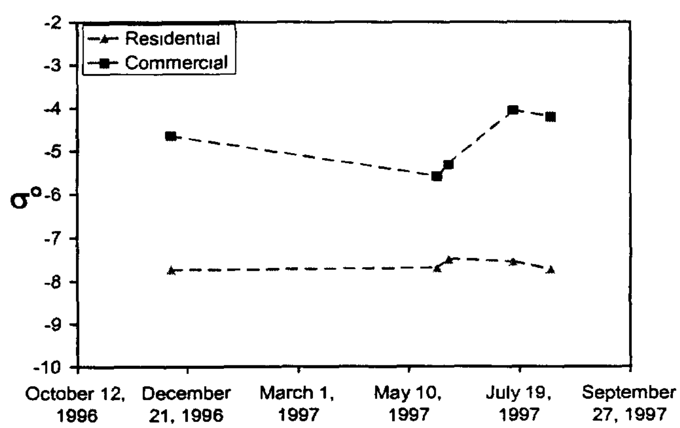

Figure 1. Average backscatter coefficients for commercial and residential urban areas as a function of time.

One possible explanation for the backscattering increase in spring is from new deciduous growth. However, for the barren grubbed areas the backscatter increase (1 dB) is probably due to soil moisture instead, since these areas often have high clay content and therefore greater water retention capability for retaining more water near the surface. The 2 dB backscatter increase for the spruce and pine forests in spring are difficult to explain since structurally these forests change marginally from season to season. It is speculated that the high water content in the soil, or higher water content in the needles and trunk are responsible.

Another interesting feature in Fig. 2 is that for grubbed, marshland, grassland and clear-cut categories the backscatter decreases from spring until summer. Again, for the vegetated areas, this characteristic may be associated with the reduced water volume in the leaves and possibly in the soil. For the bare grubbed regions, only the reduced soil water volume is relevant. The soil moisture data supports this speculation since a drying trend is observed at most stations with the exception of boggy areas. The spruce, pine and mixed forest categories do not show the same backscatter decrease in the summer, perhaps, because C-band penetration through forest canopies is small. The backscattering from the mixed forest increases slightly (0.7dB) in July which coincides with the peak foliage development and decreases (0.4 dB) as the foliage ages in late summer. The pine forest's backscatter is almost constant during the summer months, while the spruce forest backscatter increases slightly (0.5dB) in the summer months.

Maximum TCR estimates for the fire fighting planes are 3, 13, 14, 16, 15, 8 and 11 dB respectively for the forests, clear-cut, grubbed, grassland, marshland, commercial urban and residential urban clutter categories. These maximum values indicate the best possible detection scenario for these type of targets in an environment like CFB Gagetown.

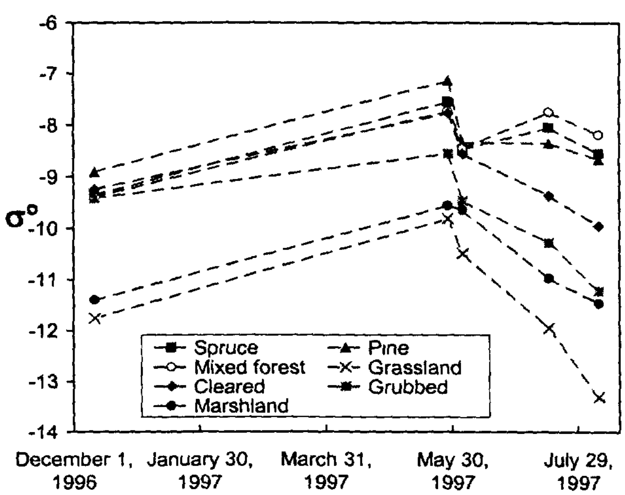

Figure 2. Average backscatter coefficients for environmental categories as a function of time.

CONCLUSION

In this paper, the backscatter from several different clutter types are calculated for a multi-temporal Radarsat image set of a region in Atlantic Canada. The purpose is to evaluate backscatter variability relative to seasonal and environmental changes. Categories studied include; spruce, pine and mixed forests, clear-cut, grubbed, grassland, marshland and urban regions (commercial and residential). Maximum TCR estimates for forest fire planes are also estimated.

All the natural categories' backscatter increased in the spring. The mixed, pine and spruce forests' backscatter did not vary much throughout the summer while the other natural categories' backscatter decreased as the summer progressed. The commercial urban backscatter is at least 3 dB larger than residential urban areas. Maximum TCR estimates for the various clutter types varied from 8 to 16 dB for urban and grassland clutter, respectively.

REFERENCES

[1] Radarsat, Canadian Data Processing Facility Data Products Manual, CDRL No. MN-2, 1995

[2} Yeremy, M, "Truthing and Preliminary Clutter Analysis for a Multi-Temporal SAR Data Set for CFB Gagetown, NB, Canada", in DREO review process.

[3] Keys, K., Isaac, C., Arp and P.A., "Soil and site conditions around eight meteorological stations at Gagetown, New Brunswick", Faculty of Forestry and Environment Management, University of New Brunswick, January, 1996, 22 pp.

[4] Keys, K., Isaac, C., Arp and P.A., "Physical and chemical properties of soils around eight meteorological stations at CFB Gagetown, New Brunswick", Faculty of Forestry and Environment Management, University of New Brunswick, January, 1996, 14 pp

[5] Ulaby, F.T. and Dobson, M.C.,Handbook of Radar Scattering Statistics for Terrain, Artech House, 1989.

[6] Lukowski, T.I. and Hawkins, R.I., "Quantitative Exploitation of RADARSAT CDPF Products for Land Applications: Geometric and Radiometric Corrections", IGARSS 98, pp. 2468-2470, 1998.

[7] Lukowski, T.I., "Determining Latitude and Longitude of RADARSAT CDPF Products in Ground Range Presentation", CCR S-TN-1998-003, 1998, 3pp.

[8] Explanatory Supplement to the Astronomical Almanac, Editor P.K. Seidelmann, Univ. Sc. Books, 1992.

#515351

CA010565