The use of satellite images to estimate snow depth and distribution on the forested winter range of the Beverly caribou herd.

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Abstract: Satellite imagery of passive microwave emissions from the earth accurately determined both snow depth and distribution on the Beverly caribou herd's forested winter range.

Keywords: caribou, snow depth, satellites, microwaves, pastures

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Introduction

Snow cover has a profound influence on caribou energetics. Snow depth and distribution affects both food availability and the amount of energy required for locomotion and cratering (Pruitt 1959, Skogland 1978, Fancy 1986). Snow also affects caribou distribution. Between 1982 and 1989 Thomas and Kiliaan (1989) monitored snow depth in relation to the winter distribution of the Beverly caribou herd. They concluded that by late winter snow was usually deeper on the eastern portion of the range and that caribou had adapted to that snow distribution pattern by using the eastern portion of their range early in the winter, moving westward to occupy areas where the snow was shallower in late winter.

The use of satellite imagery to determine snow depth would help to clarify the effects of snow on caribou ecology because snow conditions could be monitored, not just sampled, more frequently and over larger areas than has been practical with direct field measurements. For over 20 years it has been possible to determine the extent of snow cover using visible sensors on NOAA satellites (Chang *et al.* 1990) but only when there is no cloud cover (see Lent 1980, Fleck and Gunn 1982, Eastland *et al.* 1989). Recently, algorithms have been developed to estimate snow depth and distribution from satellite imagery of passive microwave emissions from the earth which have been collected and archived since 1978 (Chang *et al.* 1990, Goodison *et al.* 1990). Microwave emissions are unaffected by clouds but they are influenced by snow moisture content, topography and tree cover.

Our objective was to examine the ability of satellite imagery to determine snow depth and distribution on the forested winter range of the Beverly caribou herd by comparing archived satellite data to Thomas and Killiaan's (1989) direct snow depth measurements.

Methods

Satellite images of passive microwave emissions in the 37Ghz range were obtained from Scanning Multichannel Microwave Radiometer data aboard the Nimbus-7 satellite. Ph.D. Associates Inc. (Calgary, Alberta) did the data processing, based on algorithms developed by Dr. B. E. Goodison (Canadian Climate Centre, Atmospheric Environment Service, Downsview, Ontario), and produced snow depth maps for March 1982 (Fig 1), 1983, and 1984, and January 1983, 1984, and 1985. Algorithms did not account for regional habitat differences within the study area which included boreal forest from 59.5° to 62° N latitude by 104° to 111° W longitude. Snow density was assumed to be constant at 0.2 gm/cm^3.

Snow depth data from the satellite and from ground stations measured by Thomas and Kiliaan (1989) were entered into a geographic information system (Tydac SPANS). The satellite snow depths were contoured with SPANS to provide estimates of

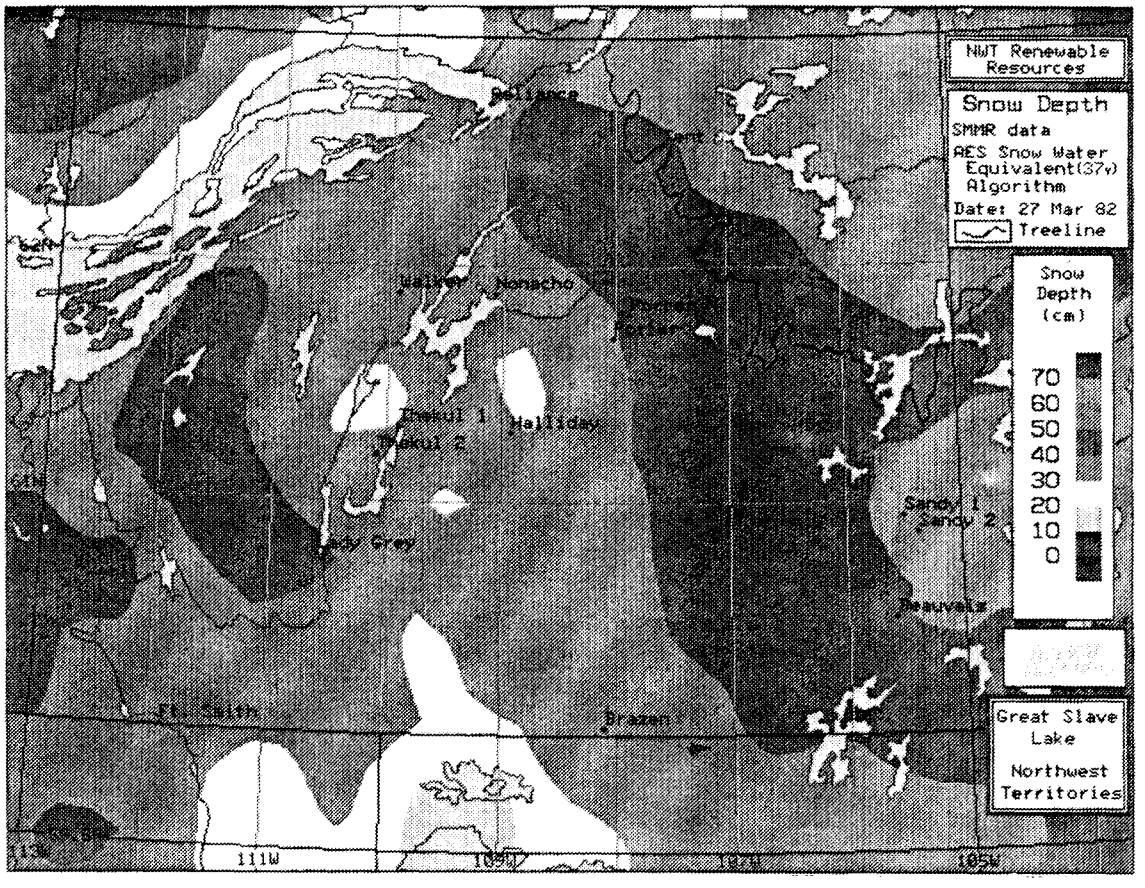

Figure 1. Depth and distribution of snow on the Beverly caribou herd's winter range 27 March 1982 based on a satellite image of microwave emissions from the earth.

snow depth to compare with the ground stations measured by Thomas and Kiliaan (1989) in March 1982.

Results and discussion

Satellite snow depth (SSD) estimates were correlated but significantly lower than measured snow depths ($n=20$, $r=.504$, $P=0.023$, $t=9.49$ $P=0.0001$) but can be modified on the basis of the March 1982 data so that the regression of corrected snow depth (CSD) estimates on measured snow depths passes through the origin with a slope of one (CSD = 1.715 SSD -11.85, Fig 2).

Satellite and measured snow depths showed the same trend with longitude for all 6 sampling periods

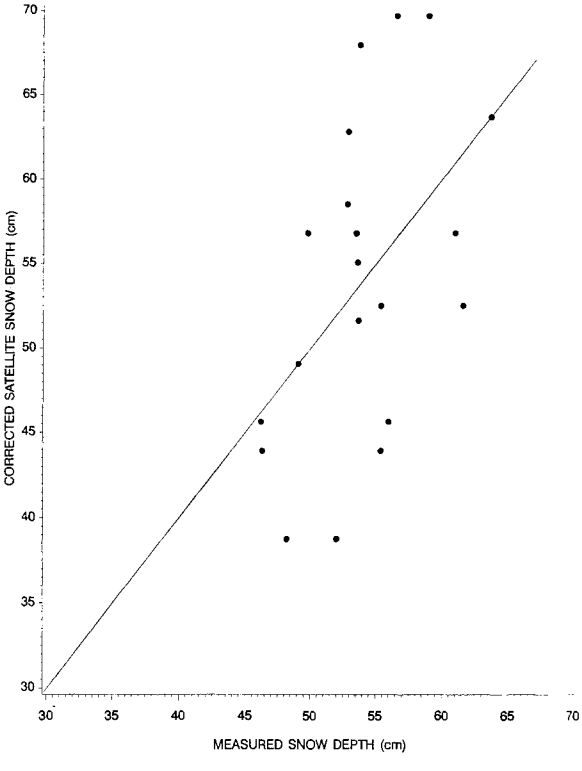

Figure 2. Relationship between the corrected satellite estimates of snow depth and snow depths measured by Thomas and Kiliaan (1989) at 20 sites on the forested winter range of the Beverly caribou herd in March 1982.

examined. Both the measured and satellite estimated snow depths for March 1982, 1983, 1984, and January 1984 declined with increasing longitude (probability that the slope being zero, $P < 0.05$ except for measured snow depths in March 1983 when $P = 0.067$). In January 1983 and 1985 neither the measured or the satellite estimated snow depths were related to longitude ($P > 0.10$).

Because microwaves are affected by trees, and water (both snow moisture content and lakes), the accuracy of snow depth estimates may be improved by taking into account regional differences in forest cover density, time of year (as an index of snow density and snow moisture content), large lakes, and lake density.

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