VARIATIONS IN NET RADIATION OVER SNOW AT A BOREAL FOREST EDGE

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1. INTRODUCTION

The boreal forest has a discontinuous canopy and a large part of its total surface is open, treeless ground. Depending on solar elevation, a variable portion of the forest floor is exposed to direct solar radiation. When the ground is snow covered this implies a large diurnal variation in the albedo of the forest as a whole, as the snow surface may have an albedo around 0.8 while the albedo of spruce trees ranges between 0.05 and 0.07 (Berglund and Mace, 1972). The diffuse and thermal radiation components exhibit a great spatial variation within the boreal forest as the proportion of the sky exposed to the forest floor depends strongly on the particular vantage point. The boreal forest is therefore an environment of large spatial variations in the individual component fluxes of the radiation balance. Consequently, neither the individual fluxes, nor the net radiation of a snow covered boreal forest floor are easily measured.

The spatial variability in the different fluxes pose one problem. In addition, however, there are problems posed by the view factors of the radiation sensors. These make the measurements sensitive to the elevation of the sensor. They also cause problems when a slanted direct solar beam hits the upward facing sensor while the surface below the sensor remains shaded. Conversely, the sensor surface may be shaded while the surface below it remains in the sun. Not much attention has been paid to these problems in the literature.

The high cost of net radiometers and the great difficulties encountered in maintaining them in good operating order in the field has prevented the use of more than a few sensors in most of the studies reported in the literature. Furthermore, shortage of recording equipment has often forced the investigators to series-connect sensors, thereby effectively eliminating the opportunity for error analysis and reduction of errors in the data set prior to analysis. Series connection also eliminates any opportunity to analyze the detailed spatial variations in net radiation within the woodland. Consequently, our knowledge of the spatial and temporal variability in net radiation in the boreal forest is very limited.

In 1984 the authors developed a new net radiometer (Granberg and Nadeau, in prep.). It measures net radiation in the range of 0.3 to 60 micrometers using a 16 junction thermopile. Laboratory tests indicate that the instrument gives less than 3 percent discrepancy between the calibrations for short- and longwave radiation. The radiometer is not susceptible to condensation problems and therefore gives reliable data without intensive field supervision or nitrogen purging. These features make the radiometer suited for use in spatial surveys.

This paper represents a preliminary analysis of parts of a multitemporal data set that was obtained at a a forest edge near Schefferville, Quebec. A more detailed analysis is in progress and will be presented elsewhere (C.A. Nadeau, M.Sc. thesis in preparation).

2. FIELD SETUP

The study plot straddles a forest edge in the vicinity of Schefferville, Quebec (54°48'N, 66°49'W). The forest may be characterized as open boreal woodland as described by Hare and Ritchie (1972).

Net radiation was measured on a 30 X 18 m. grid extending from within the forest to an open unforested area, using a total of 44 net radiometers. The radiometers were in four columns and 11 rows, spaced equidistantly three metres apart along both sides of two signal cables (Fig. 1). The net radiometers were maintained at a fixed height of 45 cm above the snow surface. All radiometers were scanned every minute using a CR7 Campbell Scientific data logger enclosed in a temperature-controlled, water-proof instrument shelter. The time interval between scanning of the first and last net radiometer on the scan was 2.16 seconds so, for the purpose of this paper, the readings have been regarded as simultaneous. The data was stored on cassette tapes by the datalogger for later retrieval using a Campbell Scientific C20 interface with a Hewlett-Packard 16 computer, which was used in the analysis.

Three field surveys were made in 1985-86. One took place in early winter (December). The second covered the mid-winter period (February) and the third survey the late winter - snowmelt period (April-May). All instruments were removed after each field survey and were reassembled in the same positions prior to the following survey. With the positioning of the radiometers only 45 cm above the snow surface, the unavoidable disturbance of the snow surface during installation and daily levelling was sufficiently removed from the field of view of the radiometers to be of small influence. To further minimize this effect, data logging did not commence until after subsequent snowfall (Fig. 2).

3. RESULTS

The data sets are large samples (44 per min.) and therefore enable analysis of the dispersion of net radiation values around the mean throughout the day for different and often rapidly changing sky conditions.

A plot of all net radiation data recorded on a clear day is shown in Figure 3 which represents 63 360 measurements obtained from the 44 net radiometers on April 29, 1986. A broad range in instantaneous net radiation values of approximately 200 Watts per square metre is obtained during daylight hours. In addition, there is a wide scatter of values which may exceed the mean in excess of 100 per cent or which are negative during sunlight hours. It is assumed that this scatter is related to situations where the particular radiometer may be shaded while the ground beneath it is sunlit or conversely where the radiometer is sunlit while the ground beneath it is shaded. Such values do not represent the net radiation balance at the snow surface but result from the height differential existing between the radiometer and the snow surface. Conditions when tree shadows are cast on a considerable portion of the snow surface within view of the downfacing sensor and not on the sensor surface result in overestimates of incoming radiation. Similarly, conditions in which the sensor is in shadow and most of the underlying snow surface remains fully irradiated results in the measurement of a false negative flux.

With complete cloud cover the scatter is reduced and negative daytime readings disappear. Sky conditions recorded for April 24, 1986 varied from partial cloud cover in the morning to complete overcast later in the day. The net radiation plot for that day (Fig. 4) shows a marked decrease in erroneous readings as well as a sharply decreased spatial variability in net radiation with increasing cloud cover.

A time profile of data (10-minute averages) from one of the radiometer transects on April 29, 1986 (Fig. 5), demonstrates the effect of non uniforn shade conditions in the forest environment on a clear day. To correct for discrepancies induced in the time average estimates by shade effects, minimum and maximum values from eight radiometers in the open were used as acceptable limits during daylight hours. Values obtained exceeding the limits for any scan are eliminated from the time averages.

While the open area exhibits the characteristic diurnal pattern of net radiation, the net radiation measured in the forest is highly variable. Within the forest the greatest variability in net radiation is present during the midday period with individual sensor maxima distributed about, but not

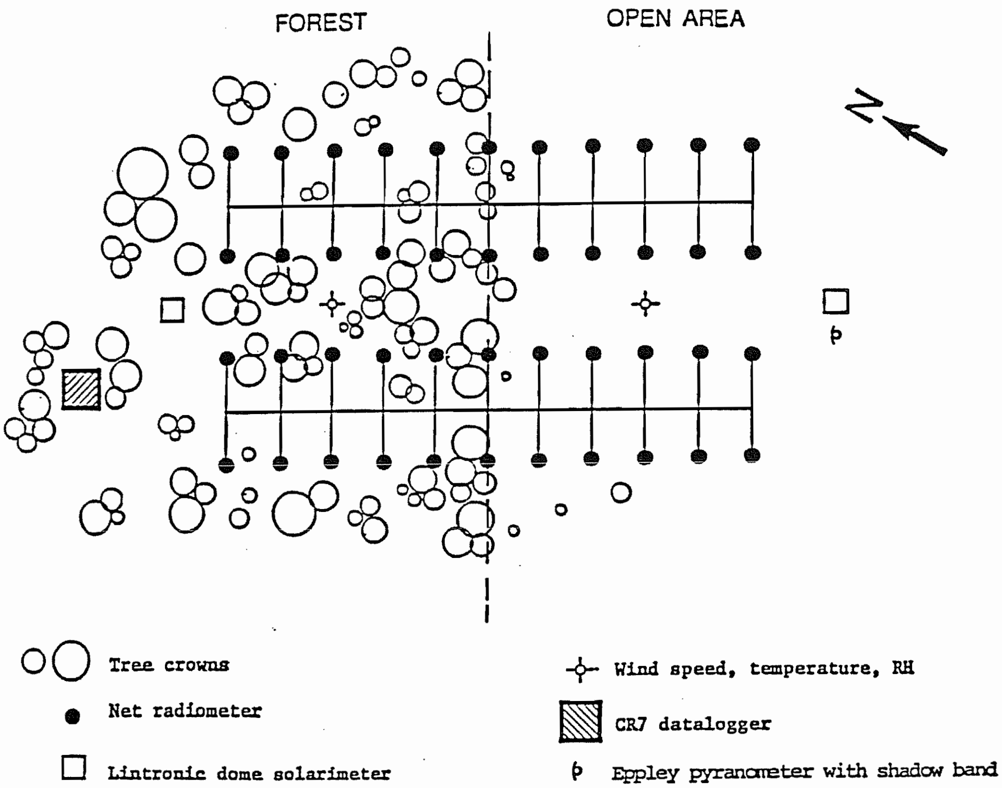

Figure 1. Schematic diagram indicating site configuration and instrumentation.

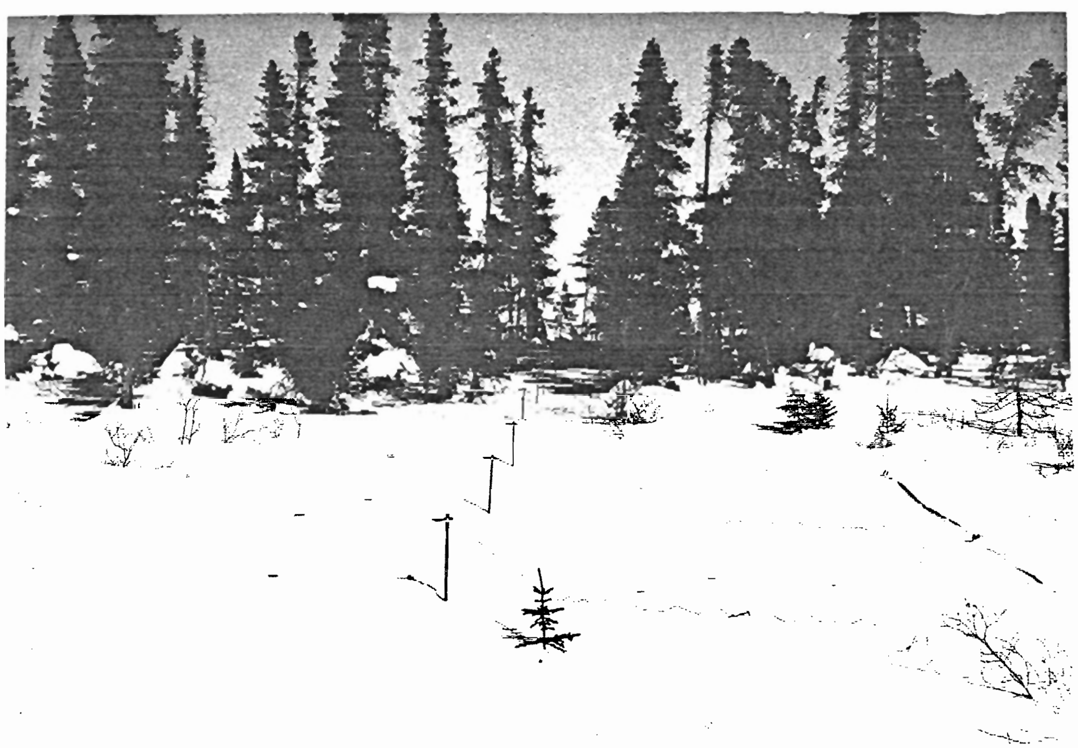

Figure 2. A radiometer transect extending into the forest canopy.

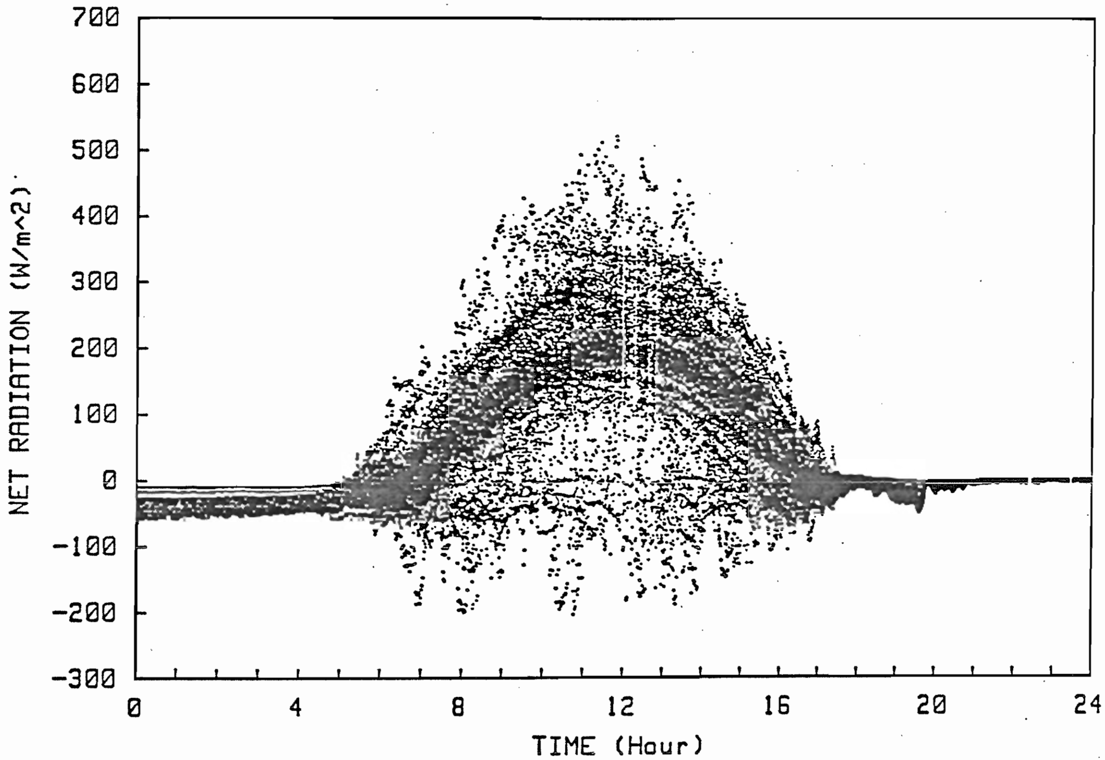

Figure 3. Range of net radiation values recorded with clear sky conditions at 44 sample locations on April 29, 1986.

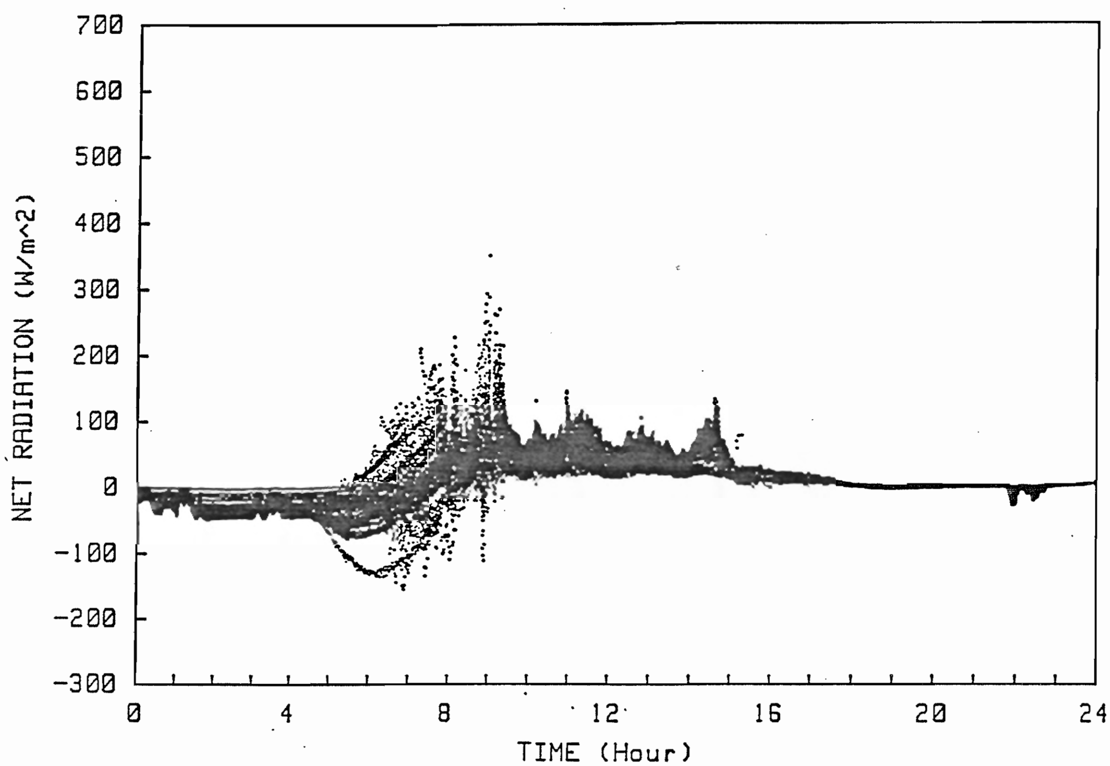

Figure 4. Range of net radiation values recorded with cloudy sky conditions at 44 sample locations on April 24, 1986.

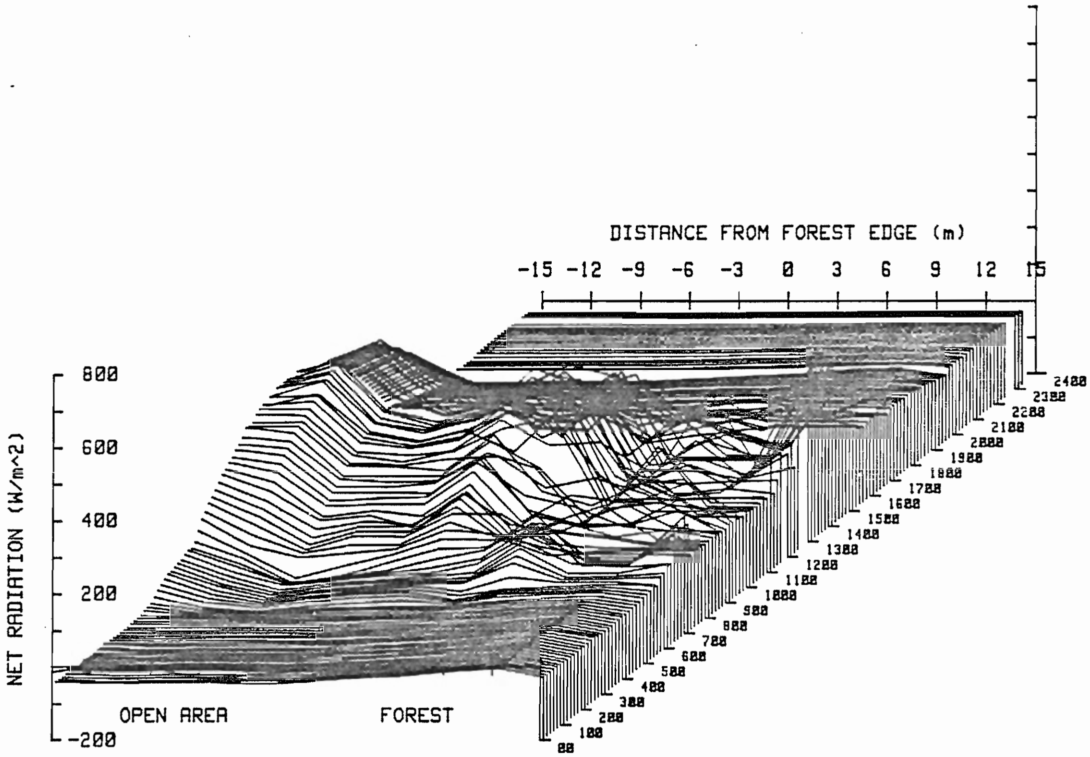

Figure 5. 24 hr. profile of net radiation data (10 min. averages of selected data) for Transect #4 on April 29,1986 with clear sky conditions.

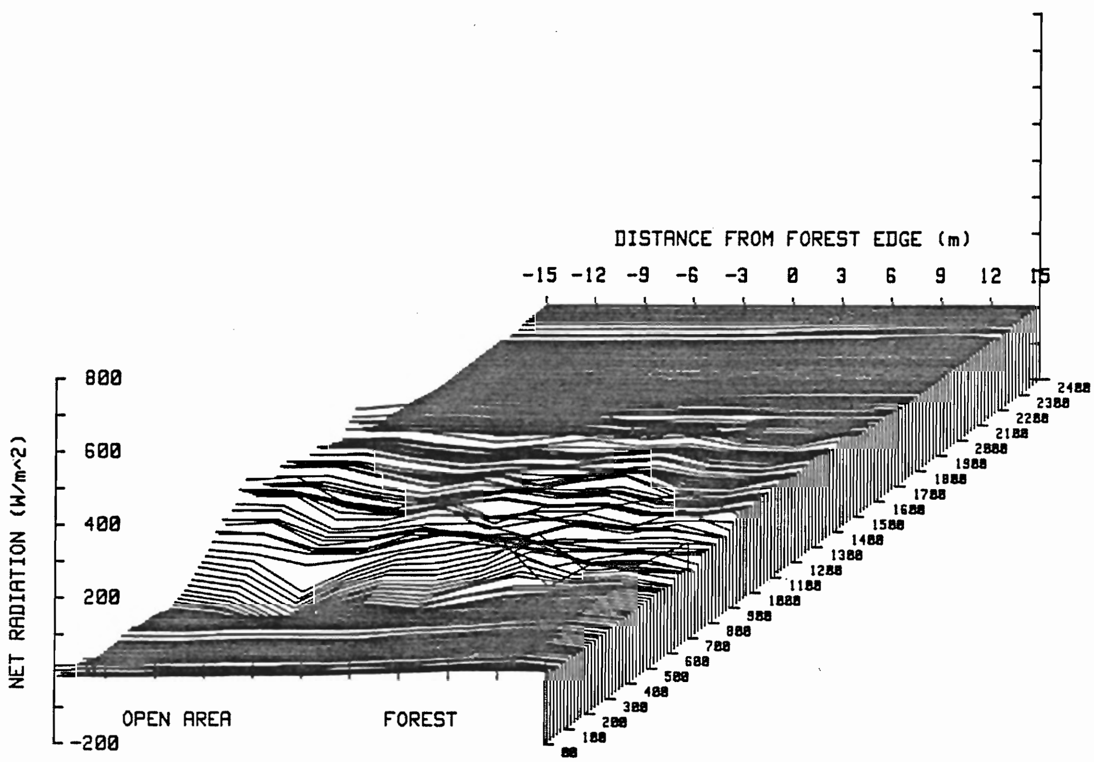

Figure 6. 24 hr. profile of net radiation data (10 min. averages of selected data) for Transect #4 on April 24, 1986 with cloudy sky conditions.

nessesarily corresponding to solar noon. During overcast conditions the variability in net radiation is greatly reduced since diffuse radiation dominates the input to the snow surface (Fig. 6).

Figures 5 and 6 show that in late April the net radiation at the snow surface in the forest is less than in the open during daytime, both in clear and overcast conditions. At night the net radiation is less negative in the forest than in the open during clear sky conditions. A sharp reduction in daytime net radiation is observed as the forest edge is approached from the open area.

4. CONCLUSIONS

A preliminary analysis of net radiation data from 44 net radiometers at a boreal forest edge shows a complex temporal and spatial variation in net radiation values. The variations are in part caused by differential shading of the radiometers with respect to the surface beneath them. Analysis and correction of these errors provides for a more accurate evaluation of the radiative exchange at the snow surface in boreal forests.

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