STUDIES OF SNOWCOVER - PERMAFROST RELATIONSHIPS AT SCHEFFERVILLE

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ABSTRACT

The snow cover has long been recognized as one of the main factors controlling permafrost distribution in the Schefferville area. The details of this relationship are, however, not well known. A research program is now underway to examine the relationship between snow cover and permafrost distribution in greater detail. The program involves digital modeling of permafrost - terrain relationships and detailed spatial/temporal monitoring of surface energy balance factors and indices such as snow stratigraphy, snow temperature profiles, snow/ground interface temperatures, spectral attenuation of solar radiation by the snow cover and net radiation in different terrain situations. The paper describes the background to the program, outlines the part studies currently in progress and gives a brief description of equipment that has been developed or otherwise been made available to the project.

INTRODUCTION

The strong relationship between the spatial distribution patterns of snow and discontinuous permafrost has stimulated much research on the spatial and temporal distribution of the seasonal snow cover in the Schefferville area. Early research focussed on mapping of the spatial snow distribution at the time of the deepest snow cover (usually March - April). Roy (1963), Barnett (1964) and Annersten (1964) produced snow maps in the upland areas near Ferriman Ridge and Denault Lake by probing snow depths along traverses crisscrossing the terrain. Sequence aerial photography was introduced in 1969 as a means of rapidly mapping the approximate depth variations (Granberg and Thom, 1970; Granberg, 1972; 1973) and later was applied on a large scale for several melt seasons, mapping the spatial variations of snowcover distribution in the ridge areas west of Schefferville (Nicholson, 1975).

Fixed snowcourses where snow depths were repeatedly measured were introduced in the upland areas by Annersten (1961; 1964). Later Thom (1969), Granberg (1972) and Nicholson (1975) operated several extensive snowcourses in the Timmins - Barney area NW of Schefferville. Adams and Barr (1979) with the aid of Trent University students made an intensive snow depth, waterequivalent and density survey of the Elisabeth Lake Basin some seven kilometres southwest of Schefferville in late February 1979, using a surveyed grid.

In the lowlands near the townsite a variety of snow surveys were also made (Adams and Findlay, 1966; Granberg, 1973; 1980) and snow courses were established and operated for varying lengths of time. Harrison (1963) established the "Schefferville Vale Snowcourse" in 1961-62. This "McGill Snowcourse" provided a daily record of snow depths at 11 or (after 1968) 10 snow stakes over several years and provided the official Schefferville snow depth data until 1971 when McGill ceased to operate the Schefferville weather station. After 1971 the weather station was moved and operated by Department of Transport personnel at the airport. The official snow course was then also moved so as to be more easily accessible by car. Unfortunately, this move was detrimental to the quality of the snow depth information now reported by the Schefferville weather station. After 1971 the McGill snow course has been operated on a weekly basis and it is still in operation. A time-profile site (Bader et al, 1939) has been maintained in most winters since 1963 providing a wealth of data on the evolution of snow stratigraphy over time (Adams and Findlay, 1966; Adams et al., 1966; Rogerson, 1967; McGill data files).

The Timmins 4 snowcourse was established in 1968. It was intensively surveyed through the 1968-69 winter and thereafter intermittently until 1974 (Granberg, 1972). The data set was collected for the purpose of developing a hindcasting technique for mapping snowcovers that previously existed over mine pits where permafrost was encountered. A relatively successful method based on stepwise multiple regression and digital terrain modeling techniques was developed by Granberg (1972; 1973). This method for spatial prediction of snow depths has recently been further developed for use in a snow information system developed for Defence Research Establishment Suffield (Granberg, 1986). For this later development, a large digital terrain model (DTM) was established in the Timmins-Barney area, some 20 km NW of Schefferville. The DTM covers an area approximately 5.6 by 7.4 km in size. The DTM and its associated computer routines form a digital geographic information system which can generate different kinds of information and produce thematic maps on a variety of topics. A series of microclimate routines are part of the geographic information system including a direct and diffuse solar radiation model, thermal radiation and airflow models. The system also has considerable capabilities to map snow cover variables such as depth and density both spatially and temporally.

Recently, through funding from the Earth Physics Branch of Energy, Mines and Resources and through the cooperation of the Iron Ore Company of Canada it was possible to collect all permafrost-related information that has accumulated during some 25 years of permafrost research at Schefferville. The materials were collected into two reports totalling 42 volumes and one magnetic tape (Granberg et al, 1983; 1984). The tape contains data from 214 thermocables and some 20 000 test pits. It forms a valuable resource for verification of predictions of the spatial extent of discontinuous permafrost. This unique setting of background snow and permafrost data forms a strong base for a program of intensive modelling and detailed field studies of permafrost - terrain relationships. Such a program was recently initiated through funding from EMR, NSERC and DIAND with some additional funds from AES.

FIELD RESEARCH IN PROGRESS

This paper briefly describes some of the field research currently in progress within the aforementioned context. Other outputs from this program are given by Desrochers and Granberg (this volume), Kulkarni and Granberg (this volume), Nadeau and Granberg (this volume) and Granberg and Wener (this volume). The field efforts currently include five main projects. First, snow stratigraphic studies are underway to assess grainsize and density variations through the winter. This study and the one detailed below are backed by a parallel development of an "Index Snowcover Model" which, driven by weather observations, predicts the stratigraphic development of the snow cover through the winter (Granberg, 1986).

Secondly, a detailed study of snow/ground interface temperatures is underway. This study aims first to document temporal and spatial variations in these temperatures but also to improve our understanding of the factors influencing heat and mass transfers through the snow cover and through the near-surface layers of the ground.

Thirdly, a study of the detailed spectral attenuation of solar radiation within the seasonal snow cover is in progress. The role of radiant absorption by the snow cover is currently not well understood. It probably plays an important role in controlling the wintertime energy balance at the snow/ground interface. The primary aim at this stage is to develop methods for measuring the spectral attenuation of solar radiation by snow and to acquire some field data to aid in model development.

Fourthly, we have developed a new net radiometer that allows us to monitor net radiation at multiple points and thus study its spatial variations. Intermittently through this past winter an array of 44 such net radiometers has been operated at a forest edge near Schefferville. A detailed digital model of solar radiation in subarctic woodlands has been developed (Granberg, 1986) and will be adapted to this forest edge site.

Fifthly, through the auspices of the Atmospheric Environment Service (AES), a permanent station for long-term monitoring of ground temperatures, snow depth and weather factors has been installed at Ferriman Ridge at one of the thermocables that were installed in 1960. This station monitors ground temperatures with an accuracy of 0.1 degrees C or better at hourly intervals and will provide a long-term record intended for use in modeling of permafrost - atmosphere interactions.

The modeling aspects of the research program currently focus on the further development of the Index Snowcover Model and on the development and field verification of spatial microclimate routines within the Geographic Information System. Funds have recently been obtained from EMR to expand the digital terrain model to include all thermocable sites. This will enable detailed analysis of snowcover and terrain influences on permafrost using the full thermocable data set.

EQUIPMENT

Our equipment includes two HP9816 computers with an HP9133 15 Mb hard disc drive. An HP9845C Color Graphics computer with a 16 Mb disc, a Zeiss Stereocord G2 Digitizing Stereoscope, an HP9874 digitizer, a two-pen and a four-pen plotter are also available to the project.

For field data acquisition, three Campbell Scientific 21X Microloggers with AM32 64-channel multiplexers are currently in use. One is permanently installed at the AES site on Ferriman Ridge. The other two are used for detailed monitoring of snow/ground interface temperatures at one forested and one alpine tundra site. At each site, interface temperatures are monitored by thermistor arrays containing 50 to 100 thermistors in a grid or line arrangement. Measurements by the fixed arrays are complemented by spatial surveys using specially designed snow temperature probes of low heat capacity. Snow and soil temperature gradients are also continuously monitored at each site. A Campbell Scientific CR7 56 channel datalogger is used for the net radiation study. All of the dataloggers employ cassette tape recorders for data storage. We have developed geothermally heated shelters which enable us to operate the tape decks reliably although air temperatures may dip to the vicinity of -40 degrees C.

A new net radiometer has been designed (Granberg and Nadeau, in prep.). Forty-four of these new radiometers have been deployed in a grid sampling network at a forest edge near Schefferville. The new net radiometers do not require nitrogen purging and condensation problems have been eliminated. They are therefore suited for relatively unattended operation with field visits only once or twice per day to check the sensor levelling and to change data tapes. Data written to the tapes are dumped via a Campbell Scientific C20 interface to disc. The C20 interface can also be used to provide tape backup for the disc drive.

For the study of spectral attenuation of solar radiation in the snow cover, a Li-Cor Li-1800 Spectroradiometer is used. A special probe has been developed which enables measurements to be obtained inside the snow cover (Granberg, in prep.). A portable setup, consisting of a TRS-80 Model 100 computer with a 3.5 inch disc drive is employed in the field to store the large quantity of data generated by the spectroradiometer (Granberg and Kulkarni, in prep.). The minimum step change in wavelength sensitivity of this setup is one nanometer and the throughput is approximately one measurement per minute, disregarding setup time. Each such measurement includes some 700 data values. The Model 100 computer is interfaced with the spectroradiometer for transfer of data to disc in the field. In the laboratory the Model 100 is employed to transfer the data to one of the HP 9816 computers which are used for analysis and graphics.

The snow stratigraphy studies employ a Swedish snow density sampler (Granberg, 1984a) and specially deviced samplers for detailed density stratification work (Granberg and Crocker, 1984a; b), an automated sieve shaker with a stack of standard sieves (4,2,1,.5,.25 and .125 mm), a Mettler electronic balance and a camera equipped for microphotography.

An automated weather and permafrost monitoring station was installed at Ferriman Ridge in early April, 1985. The station which is owned by AES monitors ground temperatures at hourly and daily intervals at one of the first installed thermocables in the Schefferville area. Soil moisture, air temperature and relative humidity, wind speed and direction and snow depth are also monitored automatically at hourly or daily intervals. The uncorrected accuracy of the ground temperatures is approximately 0.1 degrees C but cablehead temperatures and datalogger temperatures are monitored for the purpose of further improving the measurement accuracy by correcting for stray electromotive forces generated by temperature gradients and cable imperfections. The instrument shelter is geothermally heated for trouble-free, unattended operation of the datalogger and tape recorder. The station is designed for 6-month unattended operation, i.e. only two visits per annum are needed for data retrieval and battery change. A detailed description of the station is given elsewhere (Granberg, 1985a).

With the available equipment we are now able to maintain not only a high accuracy but also a high spatial and temporal resolution of our measurements. Some effort has been expended towards developing efficient ways of displaying the large quantities of data with a minimum loss of resolution in order to enable rapid review of the contents of the data sets. The available computer graphics facilities enable a very large amount of data to be summarized in one graph. Figure 3 in Nadeau and Granberg (this volume), for example, is a plot of 65360 data points representing net radiation at 44 points measured at one-minute intervals throughout one day. Figures 4 and 5 of the same paper show diurnal variations in net radiation along a transect from open terrain into an open spruce forest at two different times of winter. Such graphs are efficient tools for communicating the contents of a large data set to the researcher and enable a high spatial and temporal resolution to be maintained in the measurement programs. Although the dataloggers have the capability to perform spatial or temporal averaging, computer graphics make such averaging, with its unavoidable loss of resolution, unnecessary.

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