RELATIONSHIPS BETWEEN AIR AND GROUND TEMPERATURES IN SPRUCE AND FIR FORESTS

by

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ABSTRACT

The seasonal changes in air and ground temperatures in a spruce stand in New Brunswick are presented in this report. This information provides some guidelines (on the basis of 16-year means) concerning average temperature conditions in this area. The influence of snow cover on ground temperature is examined. For comparison, air and ground temperatures during a single year are reported for a young balsam fir stand in Cape Breton in both its natural condition and after operational spacing.

Manipulations of the relationships between air and ground temperatures for both New Brunswick and Cape Breton stands were carried out. The calendar year was arbitrarily divided into "seasons" based on directional shifts in ground temperature. Air temperatures were regressed against ground temperatures for these "seasons". When the resulting regression lines were superimposed on each other a geometric area was described which may be related to the heat available to drive root growth and decomposer activities in individual stands.

RESUME

Ce travail présente les changements saisonniers des températures de l'air et du sol dans un peuplement d'Epinette au Nouveau-Brunswick. Cette information fournit quelques lignes directrices (fondées sur des moyennes de 16 ans) touchant les conditions de température moyenne dans la région précitée. Pour fins de comparaison, les températures de l'air et du sol furent notées au cours d'une année donnée dans un jeune peuplement de Sapin baumier au Cap Breton tant dans son état naturel qu'après des travaux d'espacement.

On a arrangé des rapports entre les températures de l'air et du sol à la fois dans des peuplements du Nouveau-Brunswick et du Cap Breton: l'année du calendrier fut divisée arbitrairement en "saisons" en se fondant sur les changements de la température au sol. Les auteurs utilisèrent l'analyse de régression des températures de l'air par rapport à celles au sol pendant ces "saisons". Par superposition des lignes de régression les unes sur les autres on décrivit un secteur géométrique qui peut révéler la chaleur disponible pour activer la croissance des racines et les activités décomposantes dans des peuplements distincts.

INTRODUCTION

In the mid 1930's, efforts were made to determine the influence of air and ground temperatures on the survival of some insect pests. The data collected on air and ground temperatures in a spruce stand in 1936 were in conjunction with biological studies of the spruce sawfly which spends part of its life cycle just below the surface of the organic layer of forest soil. The data on the spruce site collected by C.C. Smith from 1936 to 1956 have been referred to extensively at the Maritimes Forest Research Centre as unpublished material, and formal documentation will facilitate their use by a wider spectrum of research workers in the Atlantic region. The data on the balsam fir forest were collected by H. Piene in 1974-75, over a 1 year period, and result from studies of effects of operational spacing on biomass accumulation and nutrient cycling.

There exist in the literature many studies of seasonal variations in soil temperature, and Geiger (1959) deals most thoroughly with current concepts and findings in this field. This report deals with two specific forest situations in Atlantic Canada and it is hoped that the data will serve as reference points for soil conditions which can be expected in these situations. The intent is to present the data with minimal comment, although some manipulations of the data require an explanation.

METHODS

The data on the forest floor under spruce were taken from a stand on the campus of the University of New Brunswick at Fredericton. The slope is 5-10% northeast draining to the Saint John River. The stand was 90% white spruce (*Picea glauca*) and included scattered balsam fir (*Abies balsamea*), white pine (*Pinus strobus*), and tamarack (*Larix laricina*). It was approximately 70 years of age in 1956 and had an average dbh of 21.5 cm. In the immediate area of the meteorological instruments, there were about 320 m^3/ha of total volume. The ground surface was typically of mound and pit relief with an amplitude of about 45 cm. The soil was characterized as an orthic humo-ferric podzol (System of Soil Classification for Canada). From 1936 to 1940, spring and summer maximum soil temperatures were taken 2.5 cm below the surface. After May 1940, a Taylor recording thermometer was used making year-round data available. Snow depth was measured weekly when the recorder charts were changed. Air temperature records were taken with standard maximum-minimum thermometers in a Stevenson Screen at the 1.3 m level in an open field about 200 m from the edge of the stand where ground temperatures were taken.

The data from the forest floor on Cape Breton Highlands, Nova Scotia were taken from two areas of the same stand. One area was under pure, dense, young balsam fir, the other under the same forest, which had been spaced to approximately 2.4 x 2.4 m. These data were taken for a full year during 1974 and 1975, using a "Sumner" long-term temperature recorder (Timmer and Weetman 1969) at approximately 2.5 cm below the surface of the organic layer. The stand was about 22 years old. The soil surface has a mound and pit relief with a smaller amplitude than that in the spruce stand in New Brunswick. The soil under this fir forest is a humo-ferric podzol. Air temperature records were taken from the Atmospheric Environment Service records for Northeast Margaree which is approximately 10 km from the fir stand and about 200 m lower in elevation. These air temperatures are not necessarily entirely representative of the situation in the Highlands but were used solely for reference purposes as they indicate general large air mass changes over Cape Breton.

RESULTS

Mean maximum and minimum ground and air temperatures at Fredericton are presented in Fig. 1 (one point for each 7-day period). Insolation values for Fredericton were not available. The insolation values for Caribou, Maine (Mateer 1955) have been incorporated into Fig. 1. The values for Fredericton, which is 70 miles south and 70 miles east of Caribou, are estimated to be within 10 g cal cm^{-2} (Langleys) of those at Caribou, so no corrections have been made. The absolute maximum air temperature for the 21-year period was 36.1°C recorded June 29, 1944 and the absolute minimum air temperature was -34.4°C recorded February 5, 1948. The absolute maximum and minimum ground temperatures were 22.2°C and -13.9°C. The average ranges between mean minimum and mean maximum temperatures for both ground and air and the average difference between ground and air temperatures for the 7-day periods (as read from the smoothed curves) are shown in Fig. 2.

The winters of 1942-43 and 1943-44 showed the greatest differences in ground temperatures and snow cover during the period 1940-1956. The effect of heavy snow cover is shown in Fig. 3 and that of light snow and later ice cover is shown in Fig. 4. Deviations of daily extreme air and ground temperatures from normal air and ground temperatures (16-year means) for the two, 4-month periods are displayed. The minimum ground temperature (-13.9°C) for the entire measurement period occurred during the winter of 1943-44 under a cover of ice (Fig. 4). The nearly linear relationship between air and ground temperatures (data not shown) disappears when snow cover exceeds 20 cm.

Mean air and ground temperatures and snow depths for weekly periods are shown in Fig. 5. Based on the pattern in Fig. 5, three "seasons" of the year were arbitrarily chosen from directional changes in the ground temperature curve. These were summer heating, late summer and fall cooling, and stable conditions during winter under snow cover. Linear regressions were run using daily mean air and ground temperatures for the 16-21 year period for each of these "seasons" and when the three resulting regression lines were put together a triangular shape was described (Fig. 6). It is our feeling that the area bounded by the temperature relationships in Fig. 6 may represent heat characteristics of the soil on this site as it is influenced by the canopy. We feel that comparisons of similar graphical presentations of data from other sites might aid in comparisons of the amount of heat which is available on individual sites to drive such processes as decomposition and root growth which are to a large extent controlled by soil temperature.

The data from Cape Breton in Fig. 7 are daily mean ground temperatures for one year from two parts of the same fir stand separated by a distance of only a few meters. One part of this extremely dense young forest was operationally spaced and the other part was left in its original condition. The air temperatures were not available from the immediate vicinity of the Cape Breton Highlands balsam fir stand so we chose to use for comparison purposes the daily mean air temperatures from Northeast Margaree. Again, directional shifts in ground temperature were arbitrarily chosen from the data in Fig. 7 and linear regressions were run between daily mean air and ground temperatures for each of the control and spaced conditions. The areas bounded by the temperature relationships for each of the "seasons" for the spaced and control conditions are shown in Fig. 8. The relative sizes of the areas in Fig. 8 for the spaced and control situations suggest that these areas may be related to the actual heat available to drive root growth and decomposition processes in the soil. Data on hand (not presented here) show that since the operational spacing was carried out, decomposition has exceeded litterfall in the spaced condition while in the control area litterfall has exceeded decomposition. This has led to an increase in the humus layer in the control condition and a decrease in the humus layer in the spaced condition in the five years since operational spacing.

LITERATURE CITED

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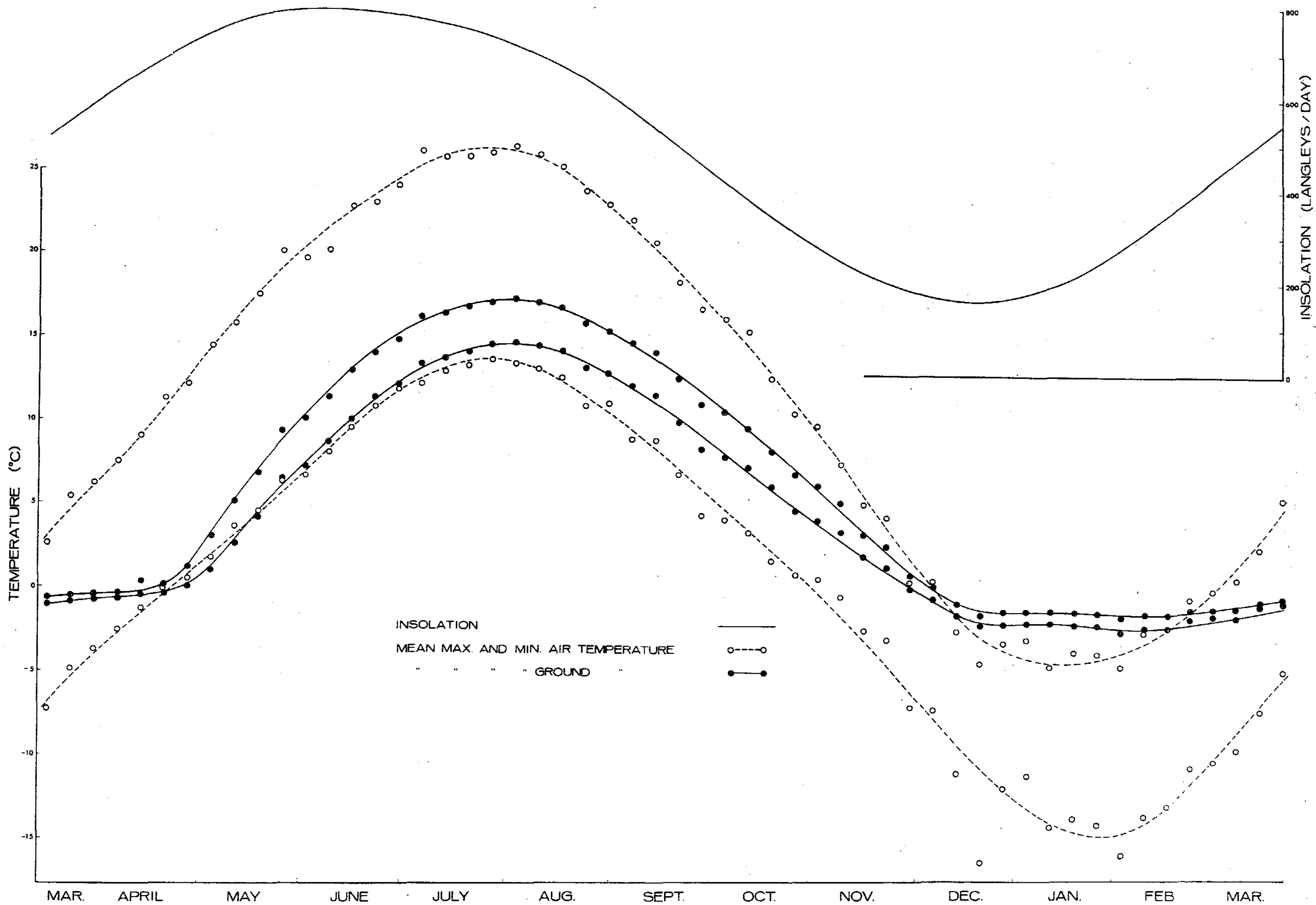

Fig. 1. Mean maximum and mean minimum temperatures for air and ground at Fredericton and observed insolation at Caribou, Maine. (Weekly means for 16-21 years observations.)

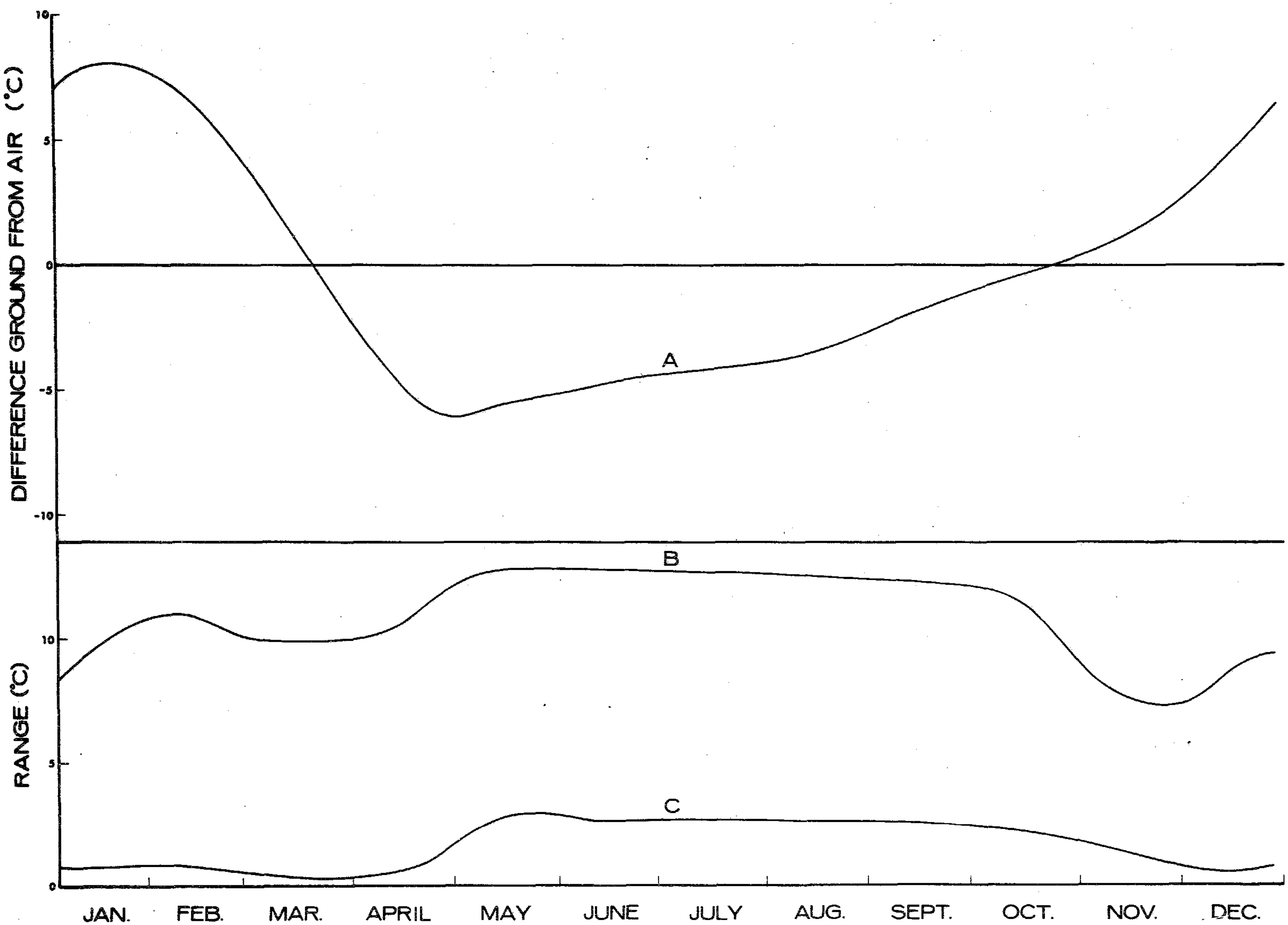

Fig. 2. Deviation of ground from air temperatures (A) and daily ranges air (B) and ground (C) temperature at Fredericton. (Weekly means for 16-21 years observations.)

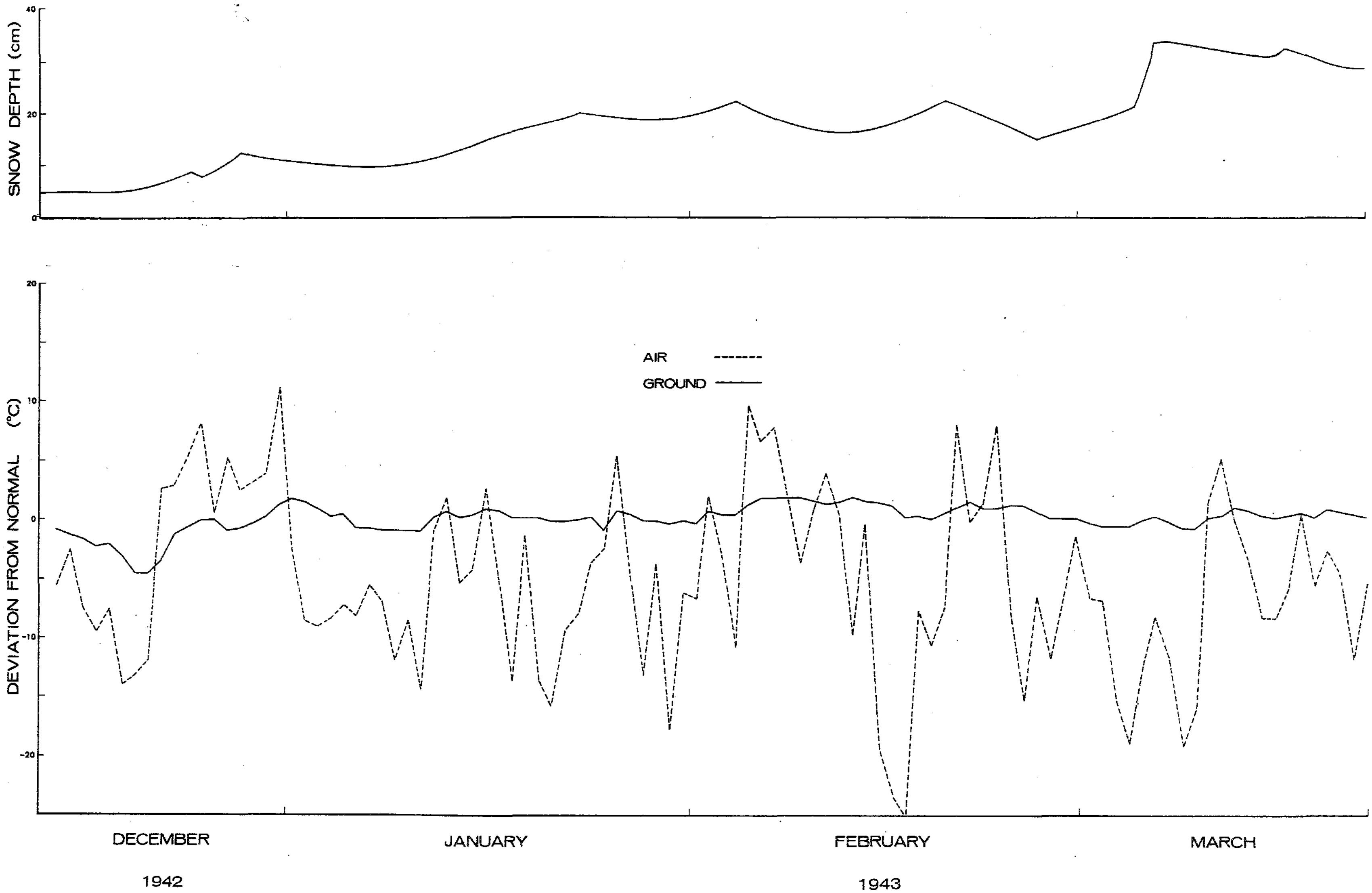

Fig. 3. Snow cover and deviations from normal (16 year means) of daily extreme air and ground temperature during a winter of heavy snow at Fredericton.

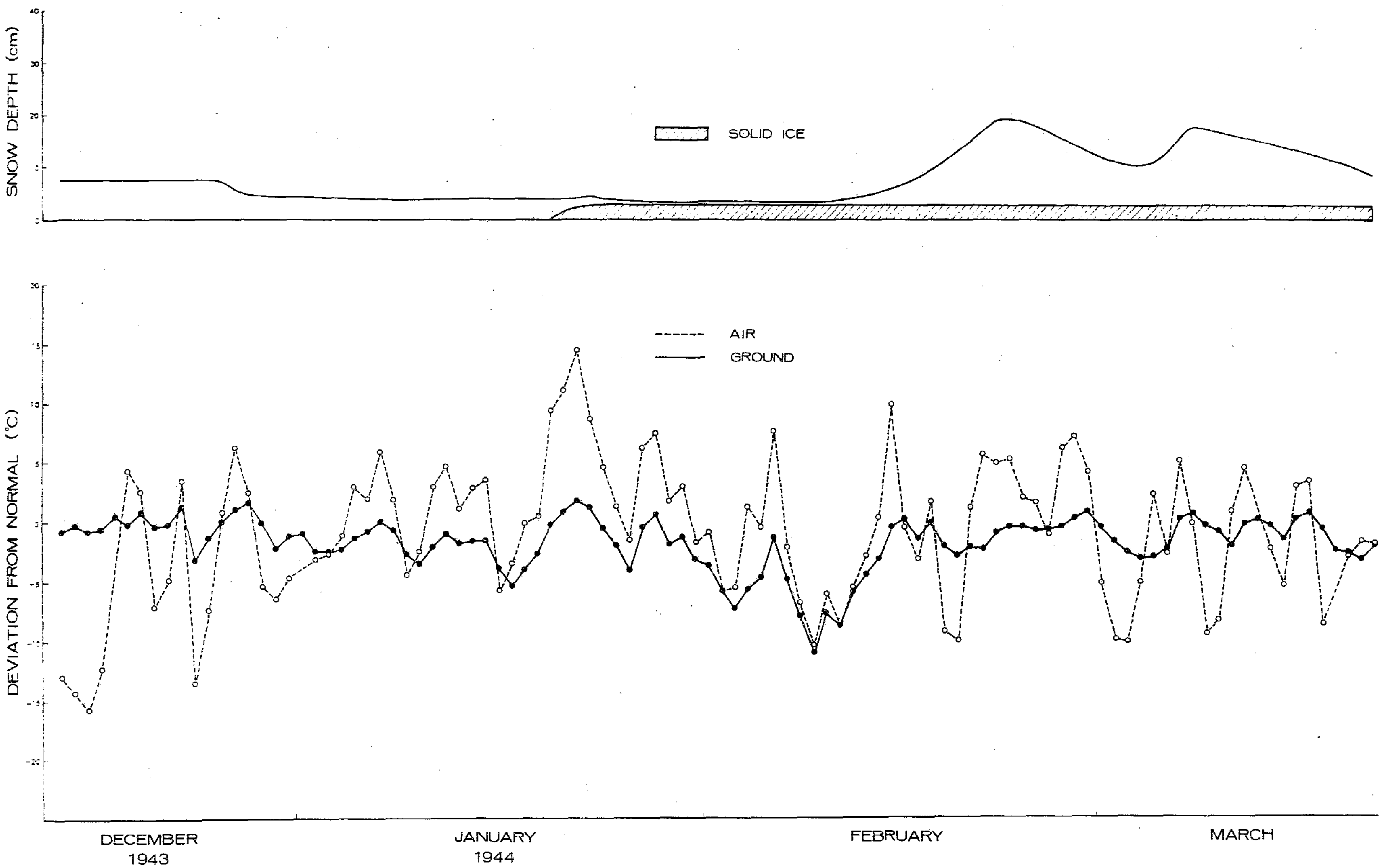

Fig. 4. Snow cover and deviations from normal (16 year means) of daily extreme air and ground temperature during a winter of light snow cover at Fredericton.

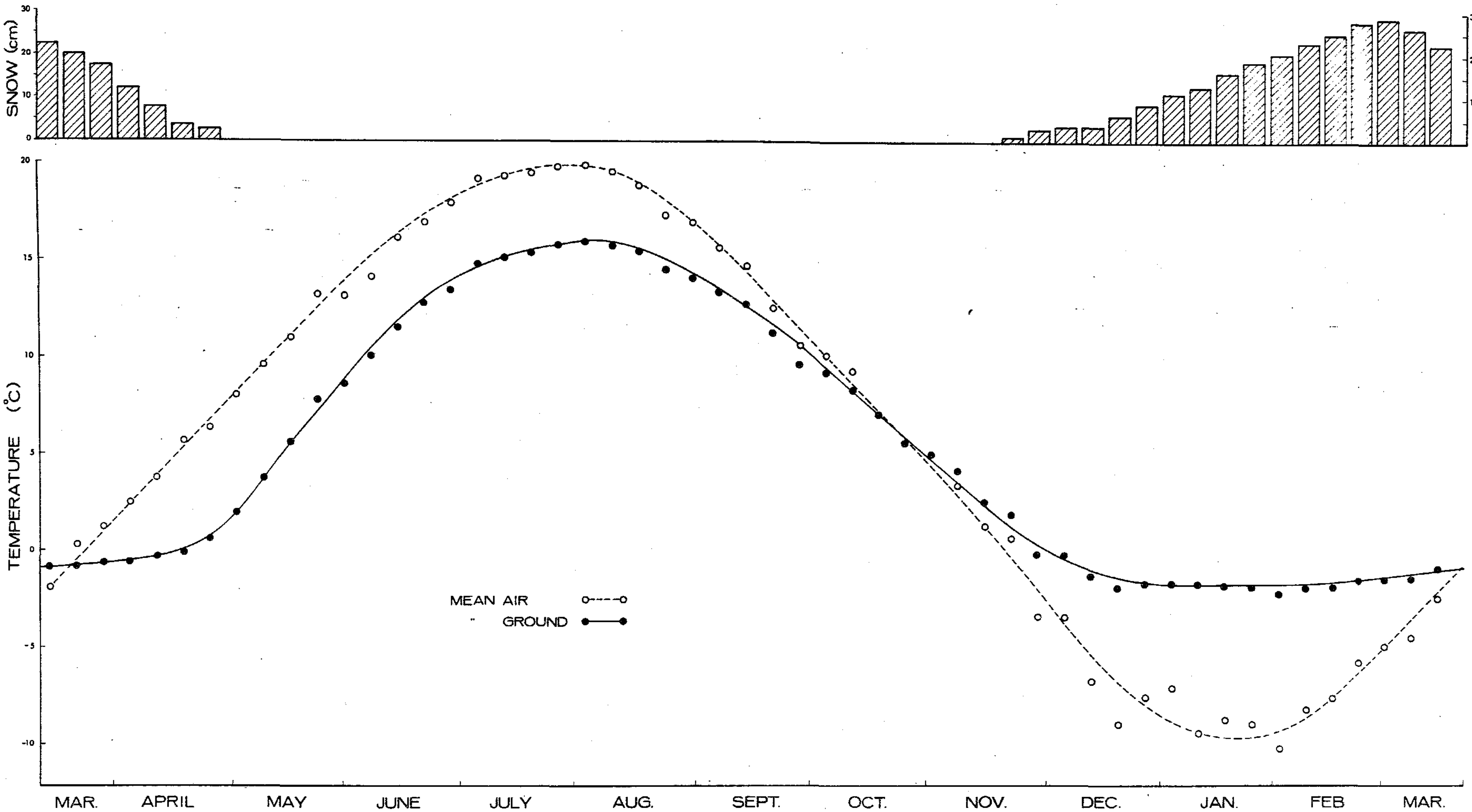

Fig. 5. Mean air and ground temperature and snow depth at Fredericton. (Weekly means for 16-21 years observations.)

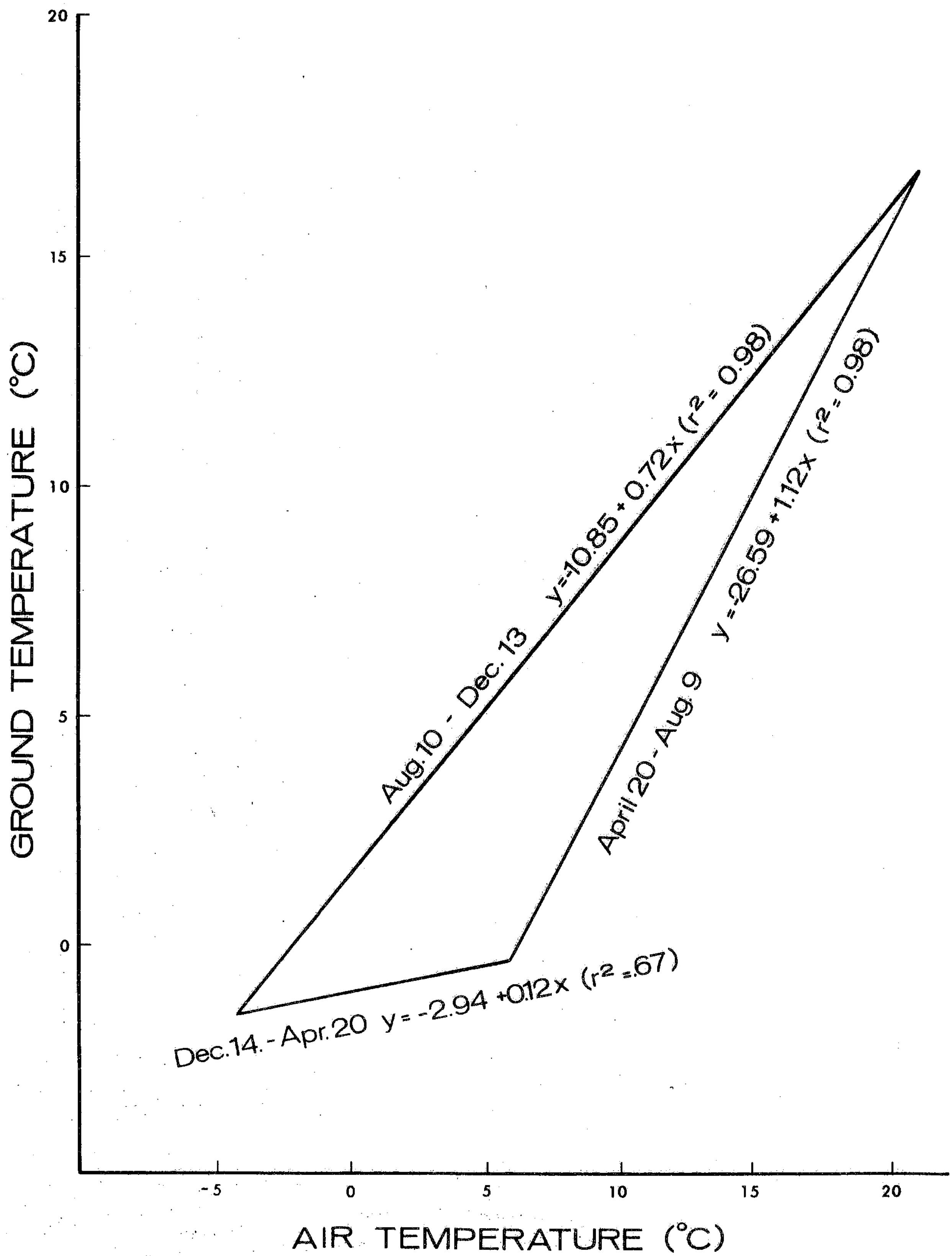

Fig. 6. Relationship of ground and air temperature for three "seasons" of the year for Fredericton. (Linear regression equations of daily means for 16-21 years observations.)

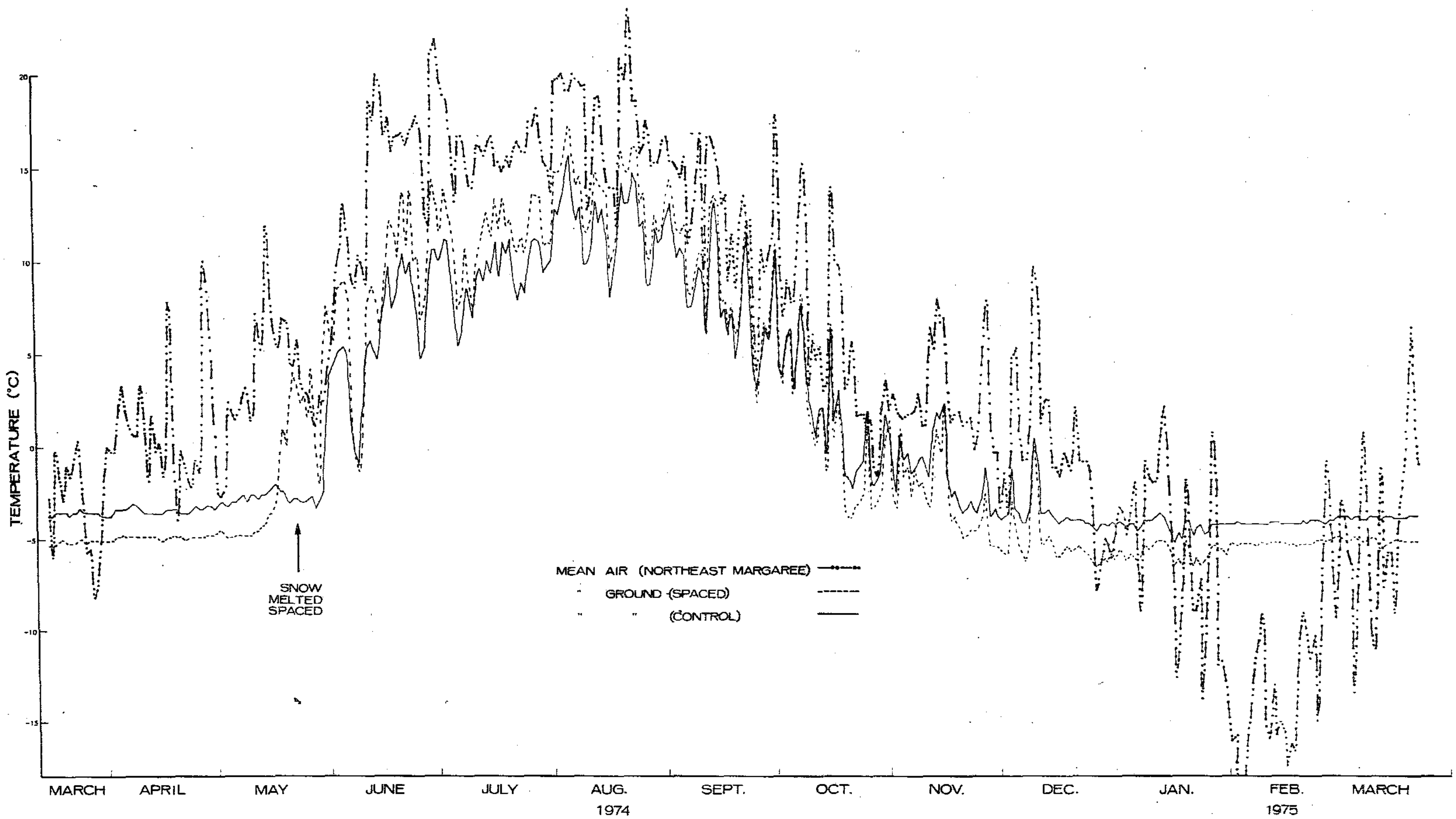

Fig. 7. Mean ground temperatures in control and spaced conditions in young balsam fir on the Cape Breton Highlands and mean air temperatures at Northeast Margaree. (Daily means for 1 year of observations.)

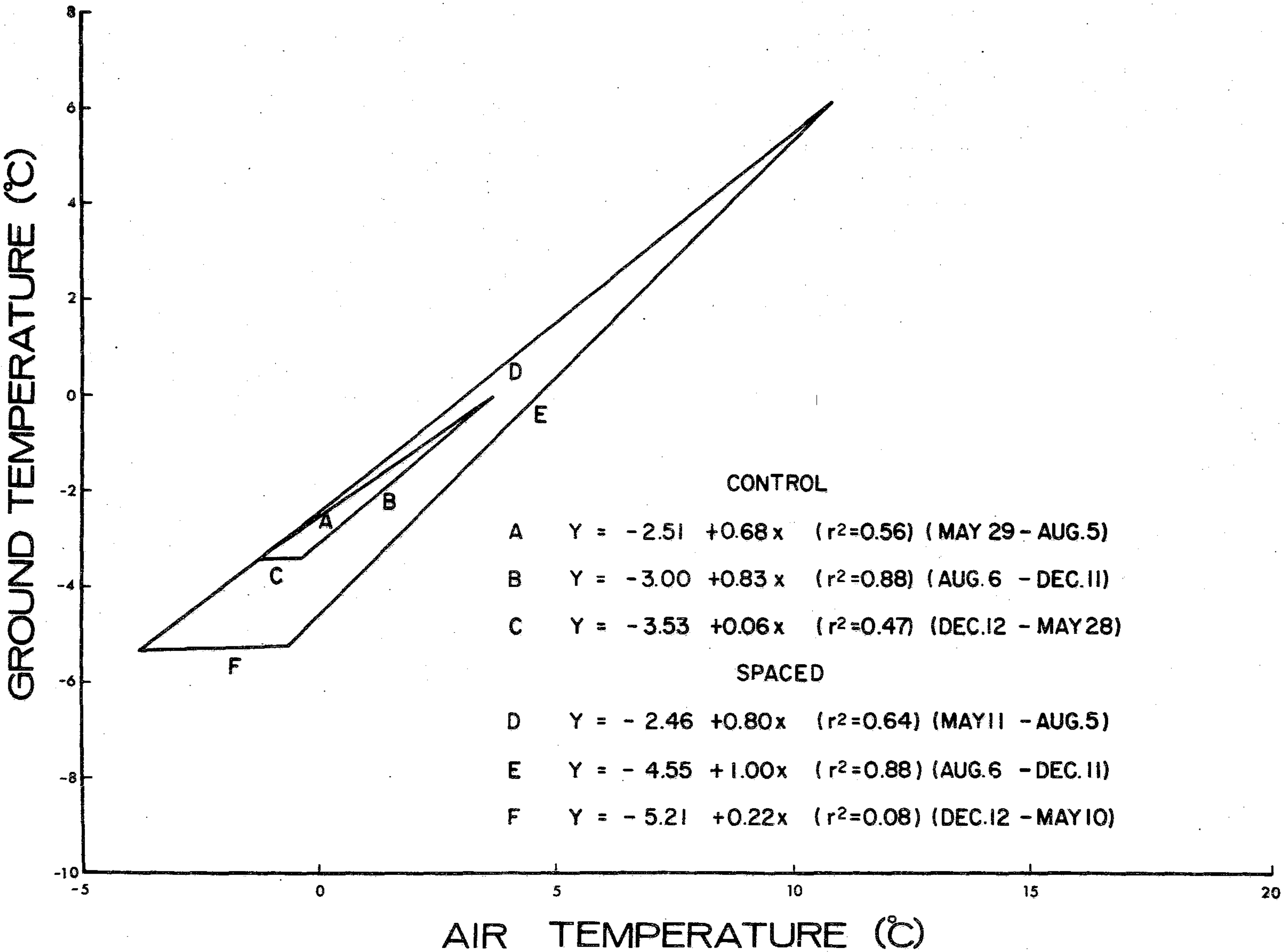

Fig. 8. Relationships of ground and air temperatures on Cape Breton Island for three "seasons". (Linear regression equations of daily means for 1 year of observations.)