Meddelelser fra
NORSK INSTITUTT FOR SKOGFORSKNING
Communications of the Norwegian Forest Research Institute
40.2

Soil temperature variations at the field station Nordmoen

Variasjoner i jordtemperatur ved Nordmoen feltstasjon

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Ås 1987

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Abstract

BJOR, KRISTIAN & HUSE, MAGNE 1987. Soil temperature variations at the field station Nordmoen. (Variasjoner i jordtemperatur ved Nordmoen feltstasjon.) Medd. Nor. inst. skogforsk. 40(2): 1-12.

Soil temperature investigations in 10 profiles, with thermocouples at 10 levels down to 6 m depth, have been conducted for background information for research activities at field station Nordmoen over 20 years.

Results from the periods 1965-67 and 1984-85 show summer and winter examples of isotherms in a 6 m deep and 634 m long terrain profile which passes through forests of different ages. The isotherm pattern is mostly affected during the summer by forest stand variation.

Annual soil temperature variations in clearcut and forest stands show that the time for maximum and minimum temperatures are delayed with depth. Thus, the minimum temperature at 6 m depth occurs in mid summer and the maximum in mid winter.

A temperature profile down to 18 m depth showed an almost constant annual temperature of close to 5 °C from the 10 m depth. This value corresponds to the mean annual soil temperature, which is expected to be the same at all soil depths.

Key words: Soil temperature, annual variation, forest stand, clearcut.

Utdrag

BJOR, KRISTIAN & HUSE, MAGNE 1987. Soil temperature variations at the field station Nordmoen. (Variasjoner i jordtemperatur ved Nordmomen feltstasjon.) Medd. Nor. inst. skogforsk. 40(2): 1-12.

Jordtemperaturen er undersøkt i 10 profiler, med 10 termoelementer i hvert, ned til 6 m dyp. Målingene er utført som bakgrunnsmateriale for de mange forsøk som er utført ved Nordmoen feltstasjon gjennom 20 år.

Resultater fra periodene 1965-67 og 1984-85 gir eksempler fra sommer og vinter på isotermer i et 6 m dypt og 634 m langt terrengprofil som går gjennom skog av ulik alder. Mønsteret av isotermer er mest påvirket av skogen i sommerperioden.

Årlig variasjon i jordtemperatur i skog og på hogstflate viser at tiden for maksimum og minimum forsinkes nedover i jorden. Således inntreffer minimum temperatur i 6 m dyp midtsommers og maksimum midtvinters.

Et temperaturprofil ned til 18 m dyp viste nesten konstant årlig temperatur, nær 5 °C, fra 10 m dyp. Denne verdi korresponderer med jordens årlige middeltemperatur som regnes å være den samme for alle jorddyp.

Nøkkelord: Jordtemperatur, årlig variasjon, skogbestand, flate.

Preface

This soil temperature investigation serves as background information for the various experiments conducted at the field station Nordmoen during the last 20 years.

Forest technician Magne Huse has been responsible for the instrumentation and the measurements.

We wish to thank Mrs. Harriet Ask Kihle for drawing the figures, and Mrs. Jacqueline Esser for correcting the English text.

Ås, August 1986

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I. Introduction

The investigation concerns the annual soil temperature variations down to 6 m depth, in regeneration areas and in forest stands at the field station Nordmoen. The study area is located close to Gardermoen in the county of Akershus, 200 m elevation (lat. 60°16′N; long. 11°6′E). Description of soil and vegetation are published in ABRAHAMSEN et al. (1976) and STUANES & SVEISTRUP (1979).

In summary, the vegetation type is a *Eu-Piceetum Myrtillus* subassociation with small patches of *Vaccinio Pinetum*. The conifer forest is a mixture of Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*). The pine regeneration has in recent decades been destroyed by heavy moose browsing, resulting in a higher percentage of young spruce forest than earlier in this century.

The soil, a Typic Udipsamment (SOIL SURVEY STAFF 1975), is developed in parent material of glacifluvial sediments with some ridges. The deposits, about 60 m deep, overlie Precambrian and Permian crystalline bedrock.

The study area is located within the more than 100 km^2 Romerike groundwater reservoir (ØSTMO 1976).

II. Methods

Ten temperature profiles down to 6 m depth were established with soldered copper-constantan thermocouples (0.5 mm wire) at the following depths:

Top of humus layer, top of mineral soil, 0.25 m, 0.50 m, 1 m, 2 m, 3 m, 4 m, 5 m, 6 m.

One of the profiles was measured down to 18 m depth. The soldered thermocouple was put into a polyethylene tube and sealed. Almost all elements are intact after 20 years in the soil.

The temperature elements were installed in this way: A 15 mm iron pipe was pushed by hand into the sandy soil to the desired depth in the profile. Pipes of 4 m length were screwed together. The pipe was then drawn up again. The thermocouple wires were taped together with the sealed elements at the wanted internal distance. This string of wires was drawn into the iron pipe. At the bottom element a small anchor of wood ended the wire and served as end plug in the pipe. The iron pipe with the elements at the proper internal distances was pushed back into the soil. The wooden end plug fastened in the soil, and the pipe could be drawn up, leaving the elements in the right positions. In this sandy soil, this technique worked well down to 18 m depth.

Temperature readings were taken monthly during the periods 1965-67 and 1984-85. The thermocouples and mV meter were critically controlled during the experiment.

III. Results

Figs. 1, 2, 3 and 4 show the isotherms in a 6 m deep and 634 m long terrain profile. The silhouette of the forest illustrates a variation in stand height from clearcut areas to old forest. The line from A to J is located in an approximately west-east position.

The 0°C isotherm in Fig. 1, from January 1966, indicates frozen soil down to about 0.5 m depth. That winter had been rather cold, but a snowcover, about 0.5 m deep when the measurement was taken, resulted in relatively moderate soil surface temperatures. At 6 m depth the temperature varied between 4.9 and 5.9°C. The soil winter temperatures are not much affected by the variation in forest stands. At point H there is a combined effect from the old stand and high groundwater level giving a cooler soil profile.

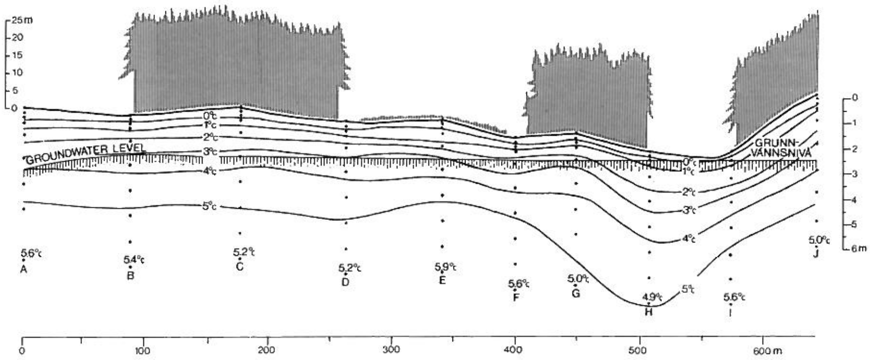

Fig. 1. Isotherms in the terrain profile, January 11, 1966.
Isotermer i terrengprofilet 11. januar 1966.

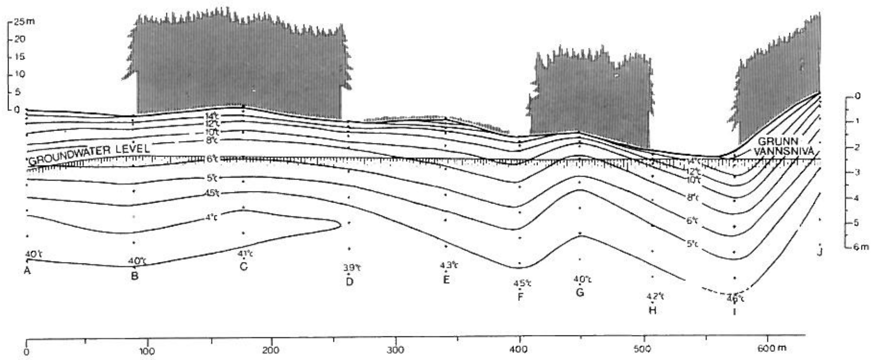

Fig. 2. Isotherms in the terrain profile, July 26, 1966.
Isotermer i terrengprofilet 26. juli 1966.

In July of the same year (Fig. 2) there are higher soil temperatures in the regeneration areas than under old stands. The curvature of the isotherms suggests limited horizontal ground water movement. In this case, the ground water level was about the same in January and in July. Normally there is a difference of about one meter between the level before and after snowmelt.

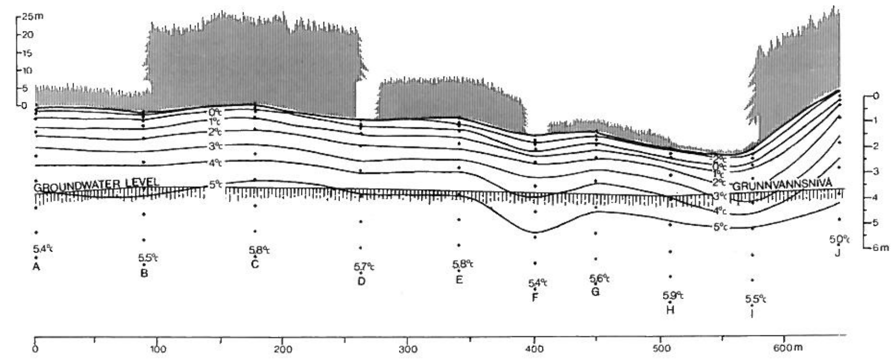

Fig. 3. Isotherms in the terrain profile, January 14, 1985.
Isotermer i terrengprofilet 14. januar 1985.

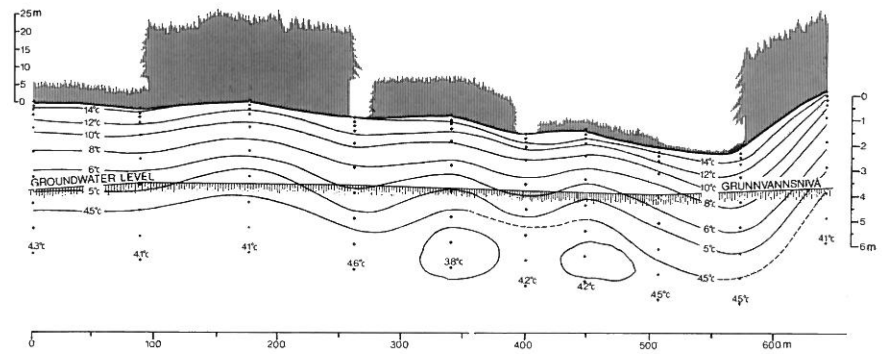

Fig. 4. Isotherms in the terrain profile, July 20, 1984.
Isotermer i terrengprofilet 20. juli 1984.

Nineteen years later (Figs. 3 and 4), the silhouette of the forest has changed. The old stand between 400 and 500 m was cut and planted in 1972. The winter soil temperature (Fig. 3) had a similar pattern as in 1966. Low temperatures combined with a scanty snowcover resulted in lower surface temperatures in January 1985.

The summer soil temperatures in 1984 (Fig. 4) differed little from those in 1966 in the deeper layers. The surface layer was warmest in 1966. During the 1970's the groundwater table sank and was located about 1.5 m deeper in 1985 than in 1966.

Annual temperature variations down to 6 m depth are shown for clear-felled areas (Profile A) and forest stands (Profile C) in figs. 5 and 6, respectively. The dates for maximum and minimum temperature are delayed with depth in the soil. Thus, the minimum temperature at 6 m depth occurs in mid summer and the maximum in mid winter.

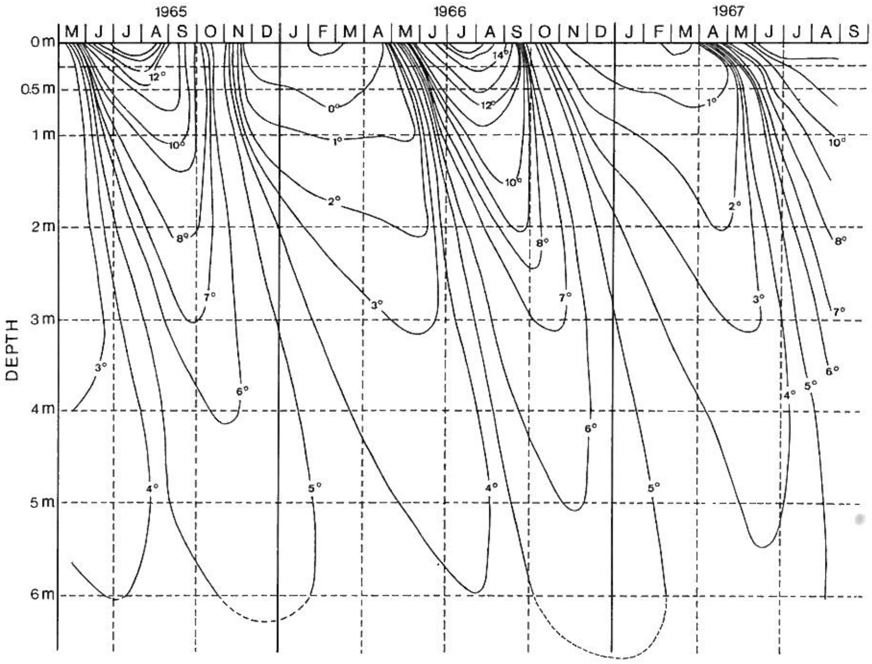

Fig. 5. Annual soil temperature variations on a clear-felled area (Profile A).
Årlige variasjoner i jordtemperatur på hogstflate (Profil A).

Annual maximum and minimum temperatures in soil profiles on clearcut (A) and in forest stand (C), in Fig. 7 reveal that minimum temperatures are almost the same in clear felling and forest stand profiles. In 1966, the maximum temperature in the mineral soil top layer was about 3 °C warmer in the clear felling than in the forest stand. At 6 m depth the difference is only 0.6 °C. The annual temperature amplitude at 6 m depth is 0.8 °C in forest and 1.3 °C on clear felling. From 10 m and deeper, the temperature profile I, which is 18 m deep, showed an almost constant temperature throughout the year close to 5 °C.

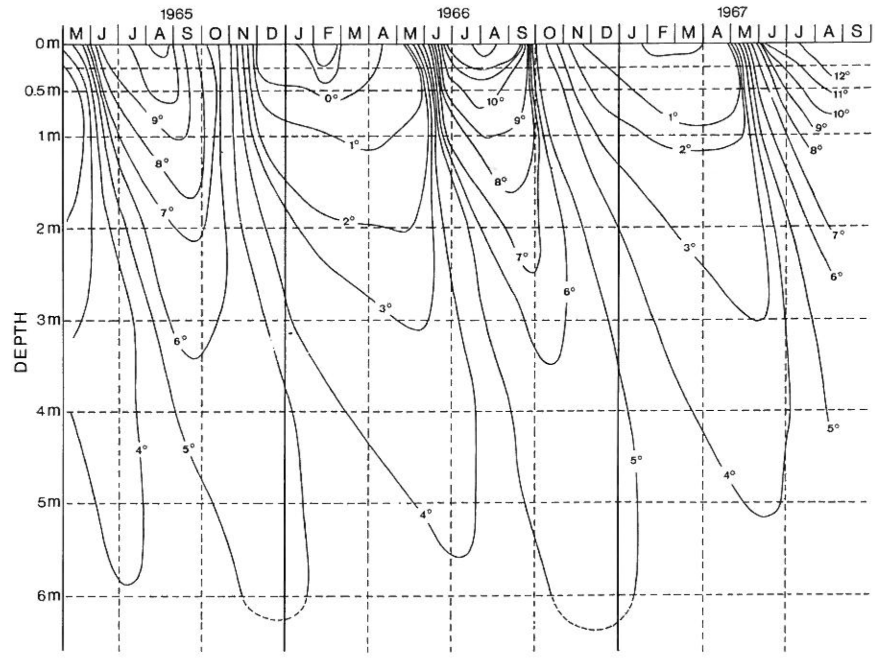

Fig. 6. Annual soil temperature variations in an old, mixed spruce-pine stand (Profile C).
Årlige variasjoner i jordtemperatur i et gammelt blandingsbestand av gran og furu (Profil C).

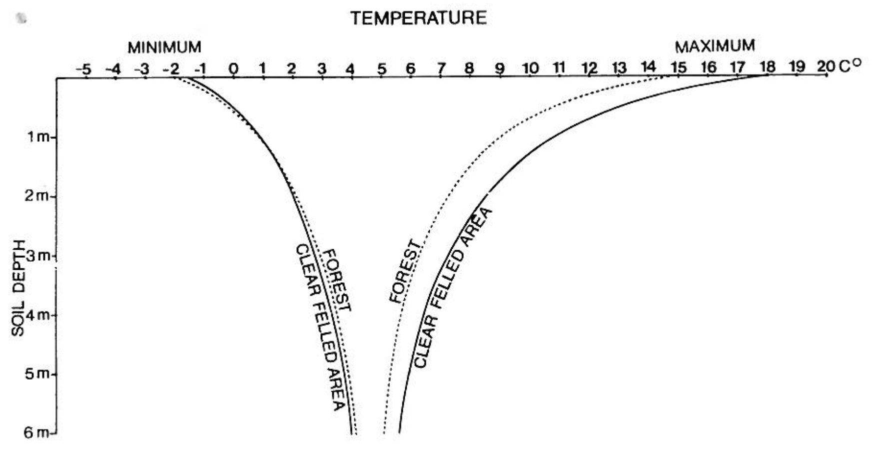

Fig. 7. Annual maximum and minimum temperatures in soil profiles on clear-felled area (Profile A) and in forest stand (Profile C).
Årlig maximum og minimum temperatur i jordprofil på snauflate (Profil A) og i bestand (Profil C).

IV. Discussion

The temperature of a soil is one of its important properties. Within limits, temperature controls the possibilities for plant growth and for soil formation. Below the freezing point there is practically no biotic activity and water no longer moves as a liquid. Between 0 and 5 °C, root growth of most plants ceases. A horizon as cold as 5 °C is a thermal pan to roots of most plants (SOIL SURVEY STAFF 1975).

Excavation of root system of a spruce and a pine tree near Profile J revealed roots down to 2.75 and 3.5 m depth for the spruce and pine, respectively (Fig. 8). That means a yearly temperature amplitude between 3 and 6 °C for the deepest growing roots. Even if these deep-growing roots are important for a stable water supply for trees on soils with a deep lying ground water level, the main fine-root system is located near the soil surface.

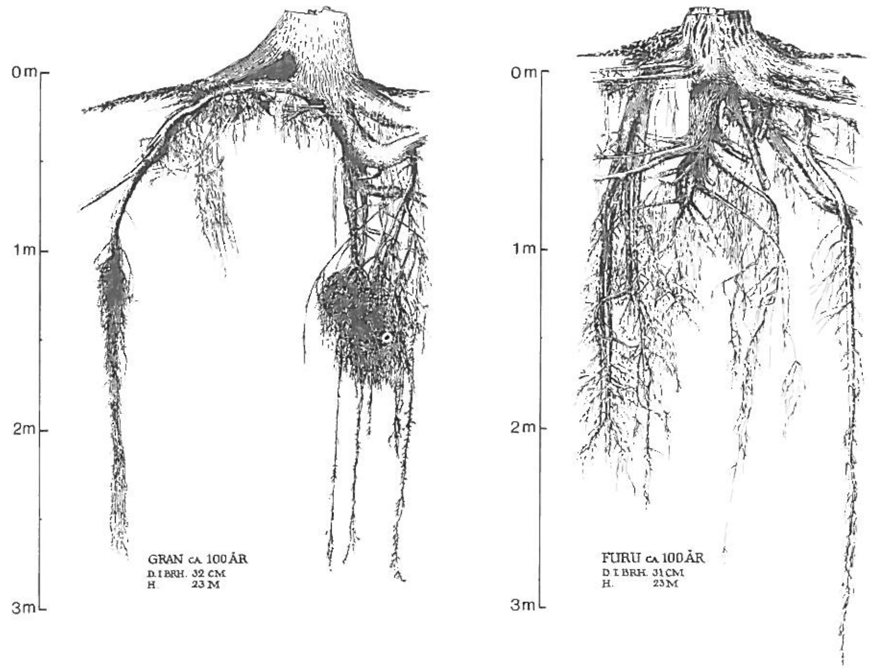

Fig. 8. Root systems of Norway spruce and Scots pine on sandy soil with deep-lying ground water level.
Rotsystemer av gran og furu i sandjord med dyptliggende grunnvannsnivå.

The daily temperature amplitudes on selected clear summer days (BJOR 1972) near Profile A ranged from frost by night to more than 50 °C by day in the moss vegetation. The daily tempmerature rhythms have almost ceased at 0.5 m depth, although the yearly amplitude here is about 13°C (fig. 5). BERGAN (1974) found similar temperature extremes in the moss vegetation and almost the same magnitude of the yearly temperature amplitude at 0,5 m depth on sandy soils as far north as in Troms (lat. 69°02′N; long. 19°22′).

The soil depth where a constant soil temperature is found varies. Shallow ground water reduces the depth due to the high specific heat of water (SMITH et al. 1964). According to CHANG (1958), the seasonal fluctuations of soil temperature, in absence of ground water, penetrate to 20 m in Alaska, 15 m in midlatitudes and 10 m in the Tropics.

The mean annual soil temperature is expected to be the same at all soil depths. Calculated from the monthly values, the mean annual soil temperature is close to 5°C in our investigation. The «normal» mean annual air temperature is 4.3°C. The mean annual soil temperature is expected to be closely related to the mean annual air temperature, but the relationship is also affected by other conditions (SMITH et al. 1964).

Variasjoner i jordtemperatur ved Nordmoen feltstasjon

Feltstasjonen Nordmoen ligger like nord for Gardermoen flyplass i Akershus, 200 m o.h. Skogen er en blanding av furu og gran. Sandjorden i området er breelvavsetninger med enkelte flyvesandrygger og dødisgroper. Avsetningene er ca. 60 m dype. Stasjonen ligger innen det mer enn 100 km² store grunnvannsområde på Romerike.

Ti temperaturprofiler ned til 6 m dyp ble montert med kobber-konstantan termoelementer i følgende jorddyp: Humusoverflate, mineraljordoverflate, 0,25 m, 0,5 m, 1 m, 2 m, 3·m, 4 m, 5 m, 6 m. Ett profil ble målt ned til 18 m dyp. Nesten alle elementene er intakt etter 20 år i jorden.

Figurene 1, 2 3 og 4 viser isotermer i et 6 m dypt og 634 m langt terrengprofil. Silhuetten av skog viser variasjonen i høyde fra snauhogst til gamle bestand. Målelinjen fra A til J går i tilnærmet vest-østlig retning.

Isotermen for 0°C i fig. 1 fra januar 1966, indikerer tele ned til ca. 0,5 m dyp. Vinteren hadde vært kald, men det 0,5 m dype snødekket på måletidspunktet gav relativt moderate temperaturer i de øvre jordlag. Jordtemperaturen om vinteren er lite påvirket av skogens bestandsvariasjoner. Ved målepunkt H gir en kombinert effekt av gammelt skogbestand og liten avstand til grunnvannsspeilet et noe kjøligere jordprofil.

I juli samme år (fig. 2) er jordtemperaturen noe høyere på foryngelsesarealene enn i de eldre bestand. Isotermkurvenes form tyder på liten horisontal vannbevegelse. I dette tilfelle er grunnvannsnivået tilfeldigvis nesten likt i januar og i juli. Normalt er forskjellen i grunnvannsnivå før og etter snøsmelting ca. 1 m.

Nitten år senere har skogprofilen endret seg. Det gamle bestand mellom 400 og 500 m ble hugget og arealet tilplantet i 1972. Jordtemperaturen om vinteren (fig. 3) hadde et lignende mønster som i 1966. En kald vinter, kombinert med lite snø, gav noe lavere temperatur i de øvre jordlag i januar 1985.

Jordtemperaturen sommeren 1984 (fig. 4) skilte seg lite fra temperaturen i juli 1966, i dypere jordlag. De øvre jordlag var varmest i 1966. Gjennom 1970-årene sank grunnvannsspeilet slik at det var ca. 1,5 m dypere i 1985 enn i 1966.

Årlige temperaturvariasjoner ned til 6 m dyp, for snauhogget flate (Profil A) og i skogbestand (Profil C) er vist i henholdsvis fig. 5 og 6. Tidspunktet for temperaturmaksimum og -minimum forsinkes ned gjennom profilet, slik at minimum i 6 m dyp inntreffer midt på sommeren og maksimum midt på vinteren.

Årlige maksimum- og minimumtemperaturer på snauhogst (Profil A) og i skogbestand (Profil C) i fig. 7 viser liten forskjell for minimum i skog og på flate. I 1966 var maksimum ca. 5°C varmere øverst i jordprofilet på snauhogst.

Det 18 m dype profilet viste tilnærmet konstant temperatur, nær 5°C, året rundt fra 10 m dyp.

Jordens temperatur er viktig både for plantenes vekstmuligheter og for jordsmonndannelsen. Under frysepunktet er det ingen biologisk virksomhet, og vannet beveger seg ikke i væskeform. Mellom 0 og 5°C opphører rotveksten for de fleste planter (SOIL SURVEY STAFF 1975).

Avdekkede rotsystemer for gran og furu nær Profil J viser granrøtter ned til 2,75 m og fururøtter ned til 3,5 m dyp (fig. 8). Det innebærer at temperaturen svinger mellom 3 og 6°C for de røtter som vokser dypest. Selv om disse dyptvoksende røtter kan være viktig for å sikre vanntilførselen der grunnvannsspeilet står dypt, befinner hovedmassen av finrøtter seg nær jordoverflaten.

Temperaturvariasjoner i utvalgte klare sommerdøgn (BJOR 1972) nær Profil A gikk fra frost om natten til over 50°C om dagen i mosedekket. Den døgnlige temperaturrytme er nesten utvisket i 0,5 m dyp, selv om den årlige amplityde der er ca. 13°C (fig. 5). BERGAN (1974) fant lignende temperaturekstremer i mosedekket og omtrent samme årlige amplityde i 0,5 m dyp i sandjord så langt nord som i Troms.

Jorddybden der det er konstant jordtemperatur varierer. Høytstående grunnvann reduserer dybden på grunn av vannets varmeegenskaper. SMITH et al. (1964) refererer at ifølge CHANG (1958) går de årlige temperaturvariasjoner i jord uten grunnvann ned til 20 m i Alaska, 15 m på midlere breddegrader og 10 m i tropene.

Den midlere årlige jordtemperatur er tilnærmet lik i alle jorddyp, og er en verdi nær den midlere årlige lufttemperatur (SMITH et al. 1964). Kalkulert fra de månedlige verdier, ligger den årlige middelverdi i våre undersøkte profiler nær 5°C. Den årlige «normale» middeltemperatur i luften er 4,3°C.

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