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VERTICAL GROUND TEMPERATURE DISTRIBUTION IN SOME CHOSEN ECOTOPES ON KAFFIÖYRA (NW SPITSBERGEN) IN THE SUMMER OF 1989

INTRODUCTION

The measurements for the present study were taken during the 8th polar expedition to Spitsbergen organized in the summer of 1989 by the Institute of Geography of the Mikołaj Kopernik University in Toruń. Similarly to the previous expeditions the studies on the ground temperature were conducted in three chosen ecotopes (beach, moraine, tundra) that are characteristic for the north part of the coastal plain Kaffiöyra. The localization of this place can be expressed by the following coordinates: $\varphi = 78°41'$N, $\lambda = 11°51'$E.

All the measurements were taken by means of elbow thermometers at the depths of 1, 5, 10, 20, and 50 cm each day during the period from July 18th to Sept. 7 th, 1989 (i.e. on 52 days) at 01, 07, 13, and 19 LMT. At the same time meteorological observations were conducted.

Meteorological conditions in the summer of 1989 were described elsewhere (Wójcik, Marciniak, Przybylak, Kejna, 1990; Marciniak, Przybylak, Kejna, 1991). While comparing mean values of meteorological elements of the same period (i.e. 21.07-31.08) during the eight so-far conducted Toruń expeditions the following conclusions concerning the summer of 1989 may be drawn: 1) its solar, thermal, and moisture conditions were similar to the many-year mean values, 2) the speed of wind was higher, 3) total rainfall amount was below the average, 4) there was an early appearance of snowfalls and snow cover (since Aug. 27th).

The ecotopes in which the studies on the thermal regimes of the ground were conducted differed in the type of cover and physical properties (capacity, absorption abilities, and heat conductivity). A detailed description of the vertical soil profiles at the measuring sites can be find elsewhere (among others in: Wójcik, Marciniak, 1987; Wójcik, Marciniak, Przybylak, Kejna, 1990).

THE AIM AND THE METHOD

The aim of the present study is to show ground thermal variation in time (during the 24-hour period and from day to day) and in space (among ecotopes) during the polar summer. The study takes account of the surface part of the active layer (up to 50) in which 24-hour ground temperature variations take place. The mean 24-hour ground temperature distribution was elaborated as a background for the analysis of the frequency of gradients and types as well as subtypes of veritical distributions of ground temperature. The latter problem has been discussed on the basis of the typology comprising three types (normal, isothermic, and inversive) that were divided into 4 subtypes each (Fig. 1). In the case of the I type, inversive subtype (c) was further divided according to the depth of inversion (5, 10, and 20 cm).

The basis for the division into types was the vertical distribution of ground temperatures in the layer of 20-50 cm that has a considerable thermal stability not only in the 24-hour period but also from day to day during the polar summer; whereas subtypes were distinguished on the basis of the temperature distribution in the layer of 1-20 cm that is characterized by the greatest variability during the 24-hour period and in relation to the weather conditions. The situations in which the temperature difference between the measuring levels did not exceed 0.1°C were classified as isothermal types and subtypes.

The vertical gradients of ground temperature were calculated for 5 layers, i.e. 1-5, 5-10, 10-20, 20-50, 1-50 cm. In order to preserve comparability of gradients in individual layers they were calculated for the depth of 10 cm in each of the instances.

It should be noticed that the number and depth of the measuring levels as well as the number of measurements during the 24-hour period influences the results of the ground temperature studies to some extent; e.g.an additional measurement in the layer 20-50 cm would be very useful in determining the range of deeper inversions.

THE MEAN VERTICAL DISTRIBUTION OF GROUND TEMPERATURE

The problem has been illustrated in Tab. 1 and Fig. 2 that present the values for the whole study period (18.07-7.09), as well as the mean decade values. In the case of the 24-hour period (m) all the ecotopes show a normal (temperature decrease with the increasing depth) vertical distribution of ground temperature. The ecotopes differ in the absolute temperature values (the relations between them change in relation to depth) and in the degree of the vertical differentiation in the layer 1-50 cm. Beach (B) is the warmest environment in the ground surface layer (up to about 10 cm); moraine (M) and tundra (T) covered with scarce vegetation come next. It results from the appearance of dried surface layer (up to 5 cm deep) that is a sandy and gravel formation on the beach. Deeper, in the layer below 10 cm moraine is the warmest environment. Tundra is the coolest ecotope in the layer of 1-30 cm; and in the deeper layer it takes the medial position between the beach and the moraine.

The highest temperature differences between ecotopes (in the layer of 1-50 cm) appear at the depth of 50 cm (on the average 2.2°C difference between the warmest moraine and the coolest beach). The differences slowly disappear to reach the minimum at the depth of 10 cm (the difference of 0.5° between the moraine and the tundra) and decrease a little up to 0.6°C on the surface (0-1 cm).

The thermal differentiation presented above (horizontal and vertical) changes slightly in the course of 24-hours and from day to day. It is especially prominent in the layer of 1-20 cm. Similarly to the mean 24-hour values, a normal type of the vertical ground temperature distribution in the whole layer 1-50 cm appears at 1:00 a.m., but the spatial differentiation at that hour is the highest of all 4 terms of measurement taking during the 24-hour period. The temperature distribution at 7:00 p.m. (except the thin inversive layer of 1-5 cm in the beach and moraine) was the closest to the mean 24-hour distribution as far as the type and absolute values are concerned. At 1:00 a.m. temperature inversion appears at all the measuring sites at the depth of 1-20 cm.

The highest ground temperatures during the whole measuring period appeared in the end of July (28-31.07) on sunny days. They were the highest thermal point of the summer of 1989. That is why the data gathered concern mainly the second, regressive part of the polar summer during which a general decreasing trend in temperatures could be observed. It is clearly noticeable in the light of mean decade values (Tab. 1).

The lowest ground temperatures appeared during the period of cooling down in the third decade of August (beginnig on Aug. 25th) during which air temperature dropped below 0°C (minimum -3.8°C at the hight of 2 m). Snowfalls that took place at that time produced a snow cover of 13 cm. The course of temperature in the 3 ecotopes during that cool period is shown in Fig. 3. First, the surface ground layers underwent intensive cooling, then the whole layer 0-50 cm was cooled down and that may be seen from the vertical course of the thermoisopleths. Futher cooling was stopped by the snow cover (Aug. 28th-31st) that isolated the ground from the influence of external atmospheric conditions.

VERTICAL GRADIENTS OF GROUND TEMPERATURE

On the average, among the studied ecotopes the highest vertical temperature gradient (Tab. 2) in the whole layer 1-50 cm appeared on the beach that, as it has already been said, from being the warmest environment on the surface becomes the coldest in the layer below 30 cm. This pattern results, on the one hand, from the warming up of the dry surface layer of sand with low heat conductivity, and, on the other hand, from the relatively shallow position of the permafrost roof (maximum 103 cm in the summer of 1989). Moraine has on the average the smallest vertical gradient. It results from the high heat conductivity in this environment and deep position of the permafrost roof (below 2.5 m). The lowered mean vertical gradient in tundra in relation to beach is caused mainly by the insulating vegetation cover that reduces surface warming of the ground layers during the day and protects from heat escape during the night.

The mean thermal relations discussed above appeared in the layer 1-50 cm on all 4 measuring dates (Tab. 2), whereas absolute gradient values change. On the average they are the highest around noon at 1:00 p.m., and the lowest at night at 1:00 a.m. When individual ground layers are analyzed differentiation of the values and signs in time and space appears to be much greater than in the case of the whole layer 1-50 cm. At night (1:00 a.m.) a negative (temperature increase with the increase of depth) vertical ground temperature gradient that is the deepest at the moraine can be observed in all the studied ecotopes in the surface layer. A negative gradient appears already at 7:00 p.m. on the beach and moraine (in the layer 1-5 cm) and on the moraine in the layer 10-20 cm at 7:00 a.m. Further information on the changes in the gradient values in the indvidual decades can be read in Tab. 2.

A detailed review of the structure of the vertical ground temperature values during the cours of 24 hours (for 4 study dates) in the three ecotopes is given in Tab. 3 that contains the frequency of gradients in the 0.5°C intervals (except border values). The analysis of data in Tab. 3 allows for the following conclusions:

1) gradients in the range from -0.5°C to 1.0°C/10 cm are predominant;

2) the value of gradients gradually decreases with the increasing depth;

3) the greatest gradient span appears on the beach, and much smaller on the moraine and tundra;

4) both positive and negative gradients appear with different frequencies in all the ecotopes, on all the dates and individual depths (this information cannot be seen from the mean vertical distributions of temperature;

The review of everyday gradients showed that in the layer 1-5 cm their maximum values on the beach reached 10.25°C/10 cm (July 27th, 1:00 p.m.). As a rule, they appeared around noon on the days with small cloud cover.

THE FREQUENCY OF TYPES AND SUBTYPES OF THE VERTICAL TEMPERATURE DISTRIBUTION

Any analysis of the vertical ground temperature distribution on the basis of the mean values for the whole measuring period, or decades and pentads (which is the prevailing method in the literature on this subject) obscures the dynamics of these distributions appearing from date to date and from day to day. That is why the present study classified vertical ground temperature distributions from all the measuring terms (208 terms in 3 ecotopes in all) into certain types and subtypes according to the assumed typology (Fig. 1) and the frequency of their appearance was calculated (Tab. 4).

As may be seen from the data in Tab. 4 type I of the vertical ground temperature distribution clearly dominates in all the studied ecotopes, i.e. temperature decrease at the depth of 20 cm. On the beach it constitutes 80% of all the measurements, on the tundra - 77.5%, and on the moraine - 63.4%. It means that type I is characteristic of the polar summer. The analysis of the type I frequency structure shows that on the beach and tundra subtype Ia is the most frequent (normal), and then inversive subtype (Ic). Whereas on the moraine on which thermal regime is significantly different from the beach and the tundra, the inversive subtype dominates (up to as many as 36.5% of all the cases). In the 24-hour course the normal subtype Ia is the most frequent at 1:00 p.m. (though on the beach it appears with almost the same frequency at 7:00 a.m. and on the tundra at 7:00 p.m. and 7:00 a.m.) and only exceptionally at night (at 1:00 a.m.). On the other hand, the frequency of the inversive subtype is clearly the highest at 1:00 a.m.; and quite frequent at 7:00 p.m. For that reason the total frequency of type I does not differ during the 24-hour period.

The isothermal type II was the least frequent during the study period, i.e. from 2.5% (tundra) to 5.8% (moraine).

The inversive type (III) is the most frequent on the moraine (30.9%), then on the tundra (20.2%) and beach (17.3%). In the 24-hour course it dominates at 7:00 a.m. This type of vertical distribution was predominant at the end of the measuring period after snow cover had been formed.

FINAL REMARKS

The typology of vertical ground temperature distribution worked out by the present authors can be used for the analysis of the frequencies of these distributions in the yearly temperature course. Mean values of the ground temperatures in Hornsund (SW Spitsbergen) presented by Baranowski (1968) show that type I of the vertical temperature distribution characteristic of the summer season appears already in April and lasts till September or even October. In the remaining part of the year the inversive type III is predominant. Type II (isothermic) with the lowest frequency appears mainly during transitional periods between domination of type I and III. The problem of the frequency of the types of vertical ground temperature distribution in the yearly course can only be analysed on the basis of data for each of the measuring dates.

Translated by Ewa Gnyp

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STRESZCZENIE

Opracowanie zostało wykonane na podstawie materiałów zebranych w sezonie letnim 1989 r. podczas VIII Toruńskiej Wyprawy Polarnej na Spitsbergen. Badania obejmowały 3 ekotopy (plaża-B, morena-M, tundra-T) położone w pobliżu Stacji Naukowej Uniwersytetu Mikołaja Kopernika w północnej części Równiny Kaffiöyra . Ekotopy te różniły się między sobą pokryciem i właściwościami fizycznymi gruntu.

Pomiary temperatury gruntu w tych środowiskach prowadzono codziennie w okresie 18.07-7.09 1989 r. (tj. 52 dni) o godz. 01, 07, 13, 19 LMT na głębokościach 1, 5, 10, 20 i 50 cm.

W badaniach reżimu termicznego gruntu uwzględniono powierzchniową część warstwy aktywnej (do głębokości 50 cm), w której zachodzą wahania dobowe temperatury. Zagadnienie pionowego rozkładu temperatury gruntu opracowano porównawczo dla 3 ekotopów w świetle: 1) wielkości i częstości gradientów pionowych, 2) częstości typów i podtypów pionowych rozkładów temperatury gruntu wg przyjętej typologii (rys. 1). Tłem do tych rozważań szczegółowych jest przedstawienie średniego rozkładu temperatury w przebiegu dobowym (tab. 1, rys. 2).

Gradienty pionowe temperatury obliczono dla 5 warstw: 1-5, 5-10, 10-20, 20-50 i 1-50 cm. Średnie gradienty dekadowe i dla całego okresu pomiarów w 4 terminach przedstawia tab. 2, a ich częstości w przedziałach co 0.5°C/10 cm tab. 3.

Dynamikę rozkładów pionowych temperatury gruntu przedstawiono poprzez zaklasyfikowanie każdego terminu pomiarowego (łącznie 208 terminów w 3 ekotopach) do określonego typu i podtypu wg przyjętej typologii, obejmującej 3 typy (normalny, izotermiczny i inwersyjny) z których każdy został podzielony na 4 podtypy. Podstawą wydzielenia typów był rozkład pionowy temperatury gruntu w warstwie 20-50 cm, odznaczającej się w okresie lata polarnego znaczną stabilnością w ciągu doby i z dnia na dzień. Natomiast podtypy wydzielono na podstawie rozkładu temperatury w warstwie 1-20 cm o największej dynamice w przebiegu dobowym i w zależności od warunków pogodowych. Do typów i podtypów izotermicznych zaliczono sytuacje przy których różnice temperatury między poziomami pomiarowymi nie przekraczały 0.1°C.

Z obliczonych częstości typów i podtypów (tab. 4) wynika, że w okresie lata polarnego najczęściej występuje typ I (normalny), rzadko zdarza się typ II (izotermiczny), a typ III (inwersyjny) pojawia się przy schyłku lata i po utworzeniu pokrywy śnieżnej (rys. 3).

Zaproponowana przez autorów niniejszego opracowania typologia może być zastosowana do rozpatrzenia zagadnienia częstości pionowych rozkładów temperatury gruntu w przebiegu całego roku oraz do studiów porównawczych reżimu termicznego gruntu w różnych środowiskach polarnych.

Table 1. Mean decade ground temperatures (°C) in the chosen ecotopes (Beach-B, Moraine-M, Tundra-T) in the Kaffiöyra Plain for 4 observational terms (01, 07, 13, 19 LMT) in the period since 18th July to 7th September 1989.

Period	Depth	1 cm					5 cm					10 cm					20 cm					50 cm				
	Term	01	07	13	19	m	01	07	13	19	m	01	07	13	19	m	01	07	13	19	m	01	07	13	19	m
	B	5.2	7.6	12.1	8.7	8.4	5.6	6.1	9.8	8.6	7.5	5.6	5.5	8.6	8.1	7.0	5.5	4.9	5.9	6.6	5.7	2.4	2.5	2.4	2.5	2.4
21-31.07	M	4.6	6.6	9.1	7.3	6.9	5.3	6.1	8.9	7.6	6.9	5.4	5.5	7.8	7.4	6.5	6.0	5.4	6.4	6.8	6.1	5.3	5.0	5.2	5.4	5.2
	T	4.9	6.1	8.1	7.2	6.6	5.2	5.4	7.1	7.0	6.2	5.3	4.9	6.3	6.5	5.8	5.0	4.5	5.1	5.6	5.0	3.3	3.3	3.2	3.4	3.3
	B	5.7	6.8	9.8	7.3	7.4	5.9	6.2	8.2	7.4	6.9	5.8	5.7	7.3	7.2	6.5	5.6	5.1	5.5	6.1	5.6	2.8	2.8	2.7	2.7	2.7
01-10.08	M	5.7	6.4	8.3	6.9	6.8	5.9	6.2	7.9	7.2	6.8	6.1	6.0	7.2	7.2	6.6	6.3	5.9	6.3	6.8	6.3	5.7	5.6	5.5	5.5	5.6
	T	5.7	6.1	7.8	7.0	6.7	5.6	5.6	6.7	6.7	6.2	5.6	5.3	6.0	6.3	5.8	5.3	5.2	5.1	5.4	5.2	3.6	3.6	3.6	3.6	3.6
	B	3.6	5.7	8.7	6.0	6.0	4.1	4.9	7.5	6.2	5.7	4.3	4.2	6.4	6.0	5.2	4.5	3.8	4.5	5.1	4.5	2.5	2.4	2.4	2.4	2.4
11-20.08	M	3.9	5.2	7.4	5.7	5.6	4.3	4.9	7.0	5.9	5.6	4.6	4.6	6.2	6.0	5.4	5.1	4.6	5.2	5.7	5.2	4.9	4.8	4.6	4.8	4.8
	T	4.3	4.9	6.9	6.1	5.5	4.5	4.3	5.8	5.7	5.1	4.6	4.2	5.2	5.5	4.8	4.4	4.1	4.4	4.8	4.4	3.2	3.1	3.1	3.1	3.1
	B	1.6	2.2	3.8	2.0	2.4	2.0	2.1	3.3	2.3	2.4	2.0	1.8	2.8	2.3	2.2	2.2	1.9	2.1	2.2	2.1	1.5	1.4	1.3	1.3	1.4
21-31.08	M	1.8	2.0	3.1	2.0	2.2	2.1	2.1	3.2	2.3	2.4	2.3	2.1	2.8	2.4	2.4	2.8	2.4	2.6	2.7	2.6	3.0	2.8	2.7	2.7	2.8
	T	2.1	2.1	3.1	2.3	2.4	2.2	1.9	2.6	2.3	2.2	2.3	2.0	2.3	2.3	2.2	2.5	2.2	2.2	2.3	2.3	2.0	1.8	1.8	1.7	1.8
	B	-1.1	-1.1	1.2	0.3	-0.2	-0.3	-0.7	0.5	0.4	0.0	-0.3	-0.5	0.2	0.3	-0.1	0.0	-0.1	0.0	0.2	0.0	0.0	0.1	0.1	0.1	0.1
01-07.09	M	-0.4	-0.1	1.7	0.8	0.5	0.3	0.1	1.4	1.1	0.7	0.3	0.1	0.8	0.9	0.5	0.6	0.4	0.6	0.9	0.6	0.6	0.6	0.6	0.6	0.6
	T	0.0	0.0	0.1	0.1	0.0	-0.1	-0.1	-0.1	0.0	-0.1	-0.2	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	B	3.4	4.7	7.5	5.3	5.2	3.8	4.1	6.3	5.3	4.9	3.9	3.7	5.4	5.1	4.5	3.9	3.4	3.9	4.4	3.9	2.0	2.0	1.9	1.9	1.9
18.07- -07.09	M	3.5	4.4	6.3	4.8	4.8	3.9	4.3	6.0	5.2	4.6	4.1	4.0	5.3	5.1	4.6	4.5	4.1	4.6	4.9	4.5	4.2	4.1	4.0	4.1	4.1
	T	3.7	4.2	5.6	4.9	4.6	3.8	3.8	4.8	4.7	4.3	3.9	3.6	4.3	4.5	4.1	3.8	3.5	3.7	3.9	3.7	2.6	2.6	2.6	2.6	2.6

m - daily mean

Table 2. Mean decade of vertical gradients of ground temperature (°C/10 cm) in the chosen ecotopes (Beach-B, Moraine-M, Tundra-T) in the Kaffiöyra Plain for 4 observational terms (01, 07, 13, 19 LMT) in the period since 18th July to 7th September, 1989,

Period	Term	01					07					13					19				
	Layer	1-5	5-10	10-20	20-50	1-50	1-5	5-10	10-20	20-50	1-50	1-5	5-10	10-20	20-50	1-50	1-5	5-10	10-20	20-50	1-50
21-31.07	B	-1.48	-0.15	0.06	1.01	0.49	3.75	1.27	0.63	0.76	1.03	5.59	2.45	2.72	1.16	1.97	0.34	0.84	1.55	1.32	1.24
	M	-1.55	-0.36	-0.51	0.20	-0.14	1.34	1.24	0.05	0.08	0.29	0.55	2.20	1.37	0.38	0.78	-0.70	0.56	0.65	0.35	0.35
	T	-1.00	-0.11	0.33	0.58	0.33	1.91	0.95	0.34	0.40	0.56	3.16	1.55	1.16	0.61	1.03	0.70	0.85	0.96	0.72	0.78
01-10.08	B	-0.60	0.16	0.26	0.93	0.59	1.55	1.00	0.64	0.76	0.82	4.03	1.82	1.74	0.95	1.45	-0.28	0.46	1.02	1.04	0.87
	M	-0.68	-0.26	-0.23	0.19	-0.01	0.33	0.52	0.06	0.10	0.16	1.10	1.36	0.84	0.27	0.57	-0.80	0.06	0.36	0.44	0.28
	T	0.15	0.02	0.33	0.56	0.42	1.15	0.70	0.31	0.46	0.51	2.65	1.42	0.95	0.47	0.84	0.88	0.68	0.91	0.62	0.70
11-20.08	B	-1.35	-0.30	-0.19	0.66	0.22	1.93	1.32	0.39	0.46	0.66	2.98	2.38	1.85	0.71	1.30	-0.45	0.38	0.88	0.91	0.74
	M	-1.03	-0.58	-0.50	0.07	-0.20	0.68	0.70	-0.05	-0.04	0.07	1.03	1.58	1.04	0.21	0.58	-0.68	-0.04	0.23	0.32	0.18
	T	-0.48	-0.20	0.12	0.40	0.21	1.58	0.24	0.10	0.31	0.36	2.70	1.28	0.78	0.44	0.78	0.85	0.54	0.70	0.54	0.60
21-31.08	B	-1.11	0.11	-0.28	0.25	0.01	0.32	0.45	-0.05	0.14	0.14	1.05	1.11	0.72	0.25	0.50	-0.86	0.04	0.09	0.32	0.14
	M	-0.84	-0.31	-0.49	-0.09	-0.25	-0.48	0.07	-0.34	-0.14	-0.19	-0.25	0.85	0.15	-0.03	0.08	-0.93	-0.13	-0.26	-0.02	-0.15
	T	-0.14	-0.27	-0.15	0.14	0.01	0.32	-0.13	-0.17	0.11	0.05	1.34	0.44	0.13	0.15	0.27	0.02	0.04	0.01	0.19	0.12
01-07.09	B	-1.84	-0.07	-0.22	0.11	-0.13	-0.34	-0.22	-0.28	0.06	-0.07	2.07	0.93	0.53	0.12	0.44	-0.27	0.30	0.27	0.20	0.19
	M	-1.61	-0.09	-0.24	-0.01	-0.20	-0.57	0.00	-0.26	-0.06	-0.13	0.75	1.26	0.21	0.00	0.23	-0.71	0.31	0.01	0.11	0.04
	T	0.29	0.06	-0.17	0.01	0.00	0.18	0.09	-0.17	0.00	-0.01	0.50	0.14	-0.17	0.00	0.02	0.21	0.09	-0.14	0.02	0.01
18.07- -07.09	B	-1.21	-0.04	-0.06	0.64	0.28	1.43	0.79	0.31	0.47	0.55	3.05	1.73	1.53	0.67	1.15	-0.22	0.39	0.78	0.78	0.66
	M	-1.08	-0.31	-0.39	0.07	-0.16	0.32	0.52	-0.10	0.00	0.06	0.61	1.42	0.74	0.18	0.45	-0.76	0.15	0.19	0.24	0.14
	T	-0.32	-0.10	0.12	0.37	0.22	1.01	0.39	0.11	0.28	0.32	2.06	1.04	0.63	0.37	0.63	0.50	0.47	0.53	0.45	0.47

Term	Interval / Layer		>5.0	4.5- 5.0	4.0- 4.5	3.5- 4.0	3.0- 3.5	2.5- 3.0	2.0- 2.5	1.5- 2.0	1.0- 1.5	0.5- 1.0	0.0- 0.5	-0.5- 0.0	-1.0- -0.5	-1.5- -1.0	-2.0- -1.5	-2.5- -2.0	-3.0- -2.5	<-3.0
01	1-5	B	.	.	.	.	.	.	.	.	0.5	0.5	3.4	5.8	4.8	3.4	1.4	1.4	1.0	2.9
		M	.	.	.	.	.	.	.	.	.	.	2.4	6.2	5.8	6.2	2.4	0.5	.	1.4
		T	.	.	.	.	.	.	.	.	0.5	1.0	10.6	4.3	4.3	2.4	1.4	0.5	.	.
	5-10	B	.	.	.	.	.	.	.	.	1.0	1.4	11.5	8.7	1.9	.	0.5	.	.	.
		M	.	.	.	.	.	.	.	.	.	1.0	5.8	11.5	5.3	1.4	.	.	.	.
		T	.	.	.	.	.	.	.	.	.	.	16.8	5.3	2.4	0.5	.	.	.	.
	10-20	B	.	.	.	.	.	.	.	.	.	1.9	10.6	10.6	1.4	0.5	.	.	.	.
		M	.	.	.	.	.	.	.	.	.	.	3.8	14.4	5.3	1.4	.	.	.	.
		T	.	.	.	.	.	.	.	.	.	2.9	13.9	7.7	0.5	.	.	.	.	.
	20-50	B	.	.	.	.	.	.	.	0.5	4.8	11.1	3.8	4.8	.	.	.	.	.	.
		M	.	.	.	.	.	.	.	.	.	1.4	14.4	8.7	0.5	.	.	.	.	.
		T	.	.	.	.	.	.	.	.	.	7.7	15.9	1.4	.	.	.	.	.	.
	1-50	B	.	.	.	.	.	.	.	.	0.5	8.7	9.1	6.2	0.5	.	.	.	.	.
		M	.	.	.	.	.	.	.	.	.	.	7.2	16.8	1.0	.	.	.	.	.
		T	.	.	.	.	.	.	.	.	.	3.4	18.8	2.9	.	.	.	.	.	.
07	1-5	B	1.4	.	1.0	1.9	.	0.5	4.3	1.0	1.4	3.8	3.4	4.3	0.5	0.5	0.5	.	0.5	.
		M	.	.	0.5	.	.	.	.	1.4	2.4	5.8	6.2	4.3	1.9	1.9	0.5	.	.	.
		T	0.5	0.5	.	.	0.5	1.0	1.9	2.4	3.4	1.4	7.2	2.4	0.5	0.5	.	0.5	.	.
	5-10	B	.	.	.	0.5	.	.	.	3.8	3.8	9.1	5.3	1.4	.	.	.	1.0	.	.
		M	.	.	.	.	0.5	0.5	.	1.0	2.9	5.3	10.1	3.8	1.0	.	.	.	.	.
		T	.	.	.	.	.	0.5	.	1.0	1.0	4.3	14.4	3.4	0.5	.	.	.	.	.
	10-20	B	.	.	.	.	.	.	.	.	1.0	10.1	7.7	4.8	1.0	.	0.5	.	.	.
		M	.	.	.	.	.	.	.	.	.	0.5	12.5	8.7	3.4	.	.	.	.	.
		T	.	.	.	.	.	.	.	.	.	1.4	15.4	8.2	.	.	.	.	.	.
	20-50	B	.	.	.	.	.	.	.	0.5	0.5	12.5	6.2	5.3	.	.	.	.	.	.
		M	.	.	.	.	.	.	.	.	.	.	13.5	11.5	.	.	.	.	.	.
		T	.	.	.	.	.	.	.	.	.	1.9	21.2	1.9	.	.	.	.	.	.
	1-50	B	.	.	.	.	.	.	.	0.5	2.9	13.0	2.9	4.8	1.0	.	.	.	.	.
		M	.	.	.	.	.	.	.	.	0.5	.	15.9	8.2	0.5	.	.	.	.	.
		T	.	.	.	.	.	.	.	.	.	7.7	12.0	5.3	.	.	.	.	.	.
13	1-5	B	5.8	.	0.5	1.4	.	1.4	3.4	1.4	1.0	3.8	5.3	0.5	.	.	.	.	.	.
		M	.	.	.	.	0.5	1.0	1.0	1.0	3.4	4.3	8.7	3.4	1.0	0.5	0.5	.	.	.
		T	1.4	0.5	2.4	1.9	1.0	1.4	1.9	2.9	1.9	1.9	6.2	0.5	1.0	.	.	.	.	.
	5-10	B	.	.	0.5	1.9	2.4	2.4	2.4	1.9	3.8	5.8	3.4	2.4	0.5	.	.	.	.	.
		M	.	.	.	1.9	1.0	1.9	2.4	1.4	3.8	6.7	5.8	4.8	.	.	.	.	.	.
		T	.	.	.	.	.	1.0	1.4	5.3	3.4	6.7	5.8	5.3	.	.	.	.	.	.
	10-20	B	.	.	0.5	1.4	2.4	1.4	1.9	2.9	5.3	3.8	2.4	2.4	0.5	.	.	.	.	.
		M	.	.	.	.	0.5	0.5	1.0	2.9	2.9	5.3	7.2	4.8	.	.	.	.	.	.
		T	.	.	.	.	.	0.5	.	1.4	5.3	6.7	5.8	5.3	.	.	.	.	.	.
	20-50	B	.	.	.	.	.	.	.	0.5	5.3	12.0	1.9	5.3	.	.	.	.	.	.
		M	.	.	.	.	.	.	.	.	.	1.9	17.2	5.8	.	.	.	.	.	.
		T	.	.	.	.	.	.	.	.	.	8.7	14.4	1.9	.	.	.	.	.	.
	1-50	B	.	.	.	.	.	1.4	3.4	2.4	6.7	5.3	2.9	2.9	.	.	.	.	.	.
		M	.	.	.	.	.	.	.	.	4.3	5.8	10.6	4.3	.	.	.	.	.	.
		T	.	.	.	.	.	.	.	.	5.3	11.1	6.2	2.4	.	.	.	.	.	.
19	1-5	B	.	0.5	.	.	0.5	.	0.5	.	1.4	0.5	7.7	5.8	2.9	2.4	1.9	0.5	.	0.5
		M	.	.	.	.	.	.	.	.	.	.	2.4	11.1	5.3	3.8	1.9	0.5	.	.
		T	.	.	.	.	.	.	.	0.5	3.8	6.7	11.1	1.4	.	1.4	.	.	.	.
	5-10	B	.	.	.	.	.	.	.	1.0	1.4	6.2	13.5	1.9	.	0.5	0.5	.	.	.
		M	.	.	.	.	.	0.5	.	1.0	.	1.9	13.5	6.7	1.0	0.5	.	.	.	.
		T	.	.	.	.	.	.	.	.	2.9	10.1	9.1	2.9	.	.	.	.	.	.
	10-20	B	.	.	.	.	.	.	1.0	2.4	5.8	4.8	7.2	3.8	.	.	.	.	.	.
		M	.	.	.	.	.	.	.	0.5	2.9	5.8	11.1	6.2	1.4	.	.	.	.	.
		T	.	.	.	.	.	0.5	.	0.5	.	8.2	7.2	5.8	.	.	.	.	.	.
	20-50	B	.	.	.	.	.	.	.	2.9	6.2	8.2	2.9	4.8	.	.	.	.	.	.
		M	.	.	.	.	.	.	.	.	.	5.3	14.4	4.8	0.5	.	.	.	.	.
		T	.	.	.	.	.	.	.	.	0.5	12.0	10.6	1.9	.	.	.	.	.	.
	1-50	B	.	.	.	.	.	.	0.5	1.4	3.4	10.6	4.3	4.8	.	.	.	.	.	.
		M	.	.	.	.	.	.	.	.	.	2.9	14.9	7.2	.	.	.	.	.	.
		T	.	.	.	.	.	.	.	.	1.4	11.1	9.1	3.4	.	.	.	.	.	.

Table 3. A relative frequency (%) of vertical gradients of ground temperature (°C/10cm) in the chosen ecotopes (Beach-B, Moraine-M, Tundra-T) in the Kaffiöyra Plain for 4 observational terms (01, 07, 13, 19 LMT) in the period since 18th July to 7th September, 1989,

Table 4. Absolute (n) and relative (%) frequency of types and subtypes of vertical distributions of ground temperature in the chosen ecotopes (Beach-B, Moraine-M, Tundra-T) in the Kaffiöyra Plain for 4 observational terms (01, 07, 13, 19 LMT) in the period since 18th July to 7th September, 1989.

Type Subtype		Beach					Moraine					Tundra				
		01	07	13	19	Σ	01	07	13	19	Σ	01	07	13	19	Σ
Ia	n	1	33	38	11	83	2	14	31	1	48	9	29	36	34	108
	%	0.5	15.7	18.3	5.3	39.8	1.0	6.7	14.9	0.5	23.1	4.3	13.9	17.3	16.3	51.8
Ib	n	6	2	1	9	18	1	1	3	3	8	4	1	1	2	8
	%	2.9	1.0	0.5	4.3	8.7	0.5	0.5	1.4	1.4	3.8	1.9	0.5	0.5	1.0	3.9
Ic5	n	11	2	2	16	31	4	1	2	18	25	11	3	2	2	18
	%	5.3	1.0	1.0	7.7	15.0	1.9	0.5	1.0	8.7	12.0	5.3	1.4	1.0	1.0	8.7
Ic10	n	6	.	.	4	10	2	.	.	13	15	10	.	.	2	12
	%	2.9	.	.	1.9	4.8	1.0	.	.	6.2	7.2	4.8	.	.	1.0	5.8
Ic20	n	19	2	.	3	24	25	1	4	6	36	6	3	.	2	[illegible]
	%	9.1	1.0	.	1.4	11.5	12.0	0.5	1.9	2.9	17.3	2.9	1.4	.	1.0	5.3
Id	n	.	.	.	.	.	.	.	.	.	.	1	1	.	2	4
	%	.	.	.	.	.	.	.	.	.	.	0.5	0.5	.	1.0	2.0
Σ	n	43	39	41	43	166	34	17	40	41	132	41	37	39	45	[illegible]
	%	20.7	18.7	19.7	20.7	79.8	16.3	8.2	19.2	19.7	63.4	19.7	17.7	18.8	21.3	[illegible]
IIa	n	.	.	.	.	.	.	.	.	.	.	1	.	1	.	[illegible]
	%	.	.	.	.	.	.	.	.	.	.	0.5	.	0.5	.	[illegible]
IIb	n	.	.	2	1	3	.	1	1	.	2	1	1	.	.	[illegible]
	%	.	.	1.0	0.5	1.5	.	0.5	0.5	.	1.0	0.5	0.5	.	.	[illegible]
IIc	n	.	1	2	.	3	.	8	1	.	9	.	.	1	.	[illegible]
	%	.	0.5	1.0	.	1.5	.	3.8	0.5	.	4.3	.	.	0.5	.	[illegible]
IId	n	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.
	%	.	.	.	.	.	.	0.5	.	.	0.5	.	.	.	.	.
Σ	n	.	1	4	1	6	.	10	2	.	12	2	1	2	.	[illegible]
	%	.	0.5	2.0	0.5	3.0	.	4.8	1.0	.	5.8	1.0	0.5	1.0	.	[illegible]
IIIa	n	5	6	.	2	13	16	14	1	9	40	2	5	.	.	[illegible]
	%	2.4	2.9	.	1.0	6.3	7.7	6.7	0.5	4.3	19.2	1.0	2.4	.	.	[illegible]
IIIb	n	.	2	2	.	4	1	1	1	.	3	2	3	1	3	[illegible]
	%	.	1.0	1.0	.	1.9	0.5	0.5	0.5	.	1.5	1.0	1.4	0.5	1.4	[illegible]
IIIc	n	4	1	5	5	15	1	8	6	1	16	5	5	10	5	[illegible]
	%	1.9	0.5	2.4	2.4	7.2	0.5	3.8	2.9	0.5	7.7	2.4	2.4	4.8	2.4	[illegible]
IIId	n	.	3	.	1	4	.	2	2	1	5	.	1	.	.	.
	%	.	1.4	.	0.5	1.9	.	1.0	1.0	0.5	2.5	.	0.5	.	.	[illegible]
Σ	n	9	12	7	8	36	18	25	10	11	64	9	14	11	8	[illegible]
	%	4.3	5.7	3.4	3.9	17.3	8.7	12.0	4.9	5.3	30.9	4.3	6.7	5.3	3.8	[illegible]

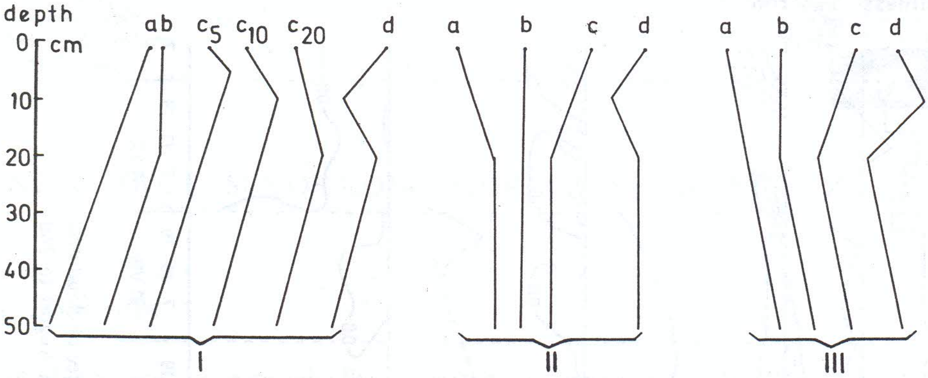

Fig. 1. A typology of vertical distributions of ground temperature in the layer of 1-50 cm:
— Types (layer 20-50 cm): I-normal, II-isothermic, III-inversive
— Subtypes (layer 1-20 cm): a-normal, b-isothermic, c-inversive till the depth of 5, 10 and 20 cm, d-mixed.

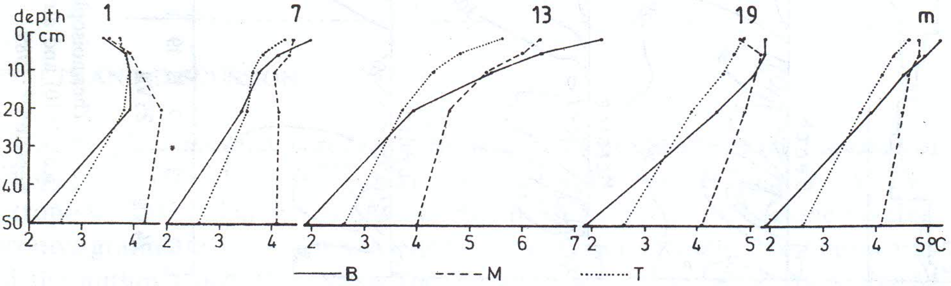

Fig. 2. Mean vertical distributions of ground temperature in the chosen ecotopes (Beach-B, Moraine-M, Tundra-T) in the Kaffiöyra Plain for 4 observational terms (01, 07, 13, 19 LMT) and daily means (m) in the period since 18 th July to 7 th September, 1989.

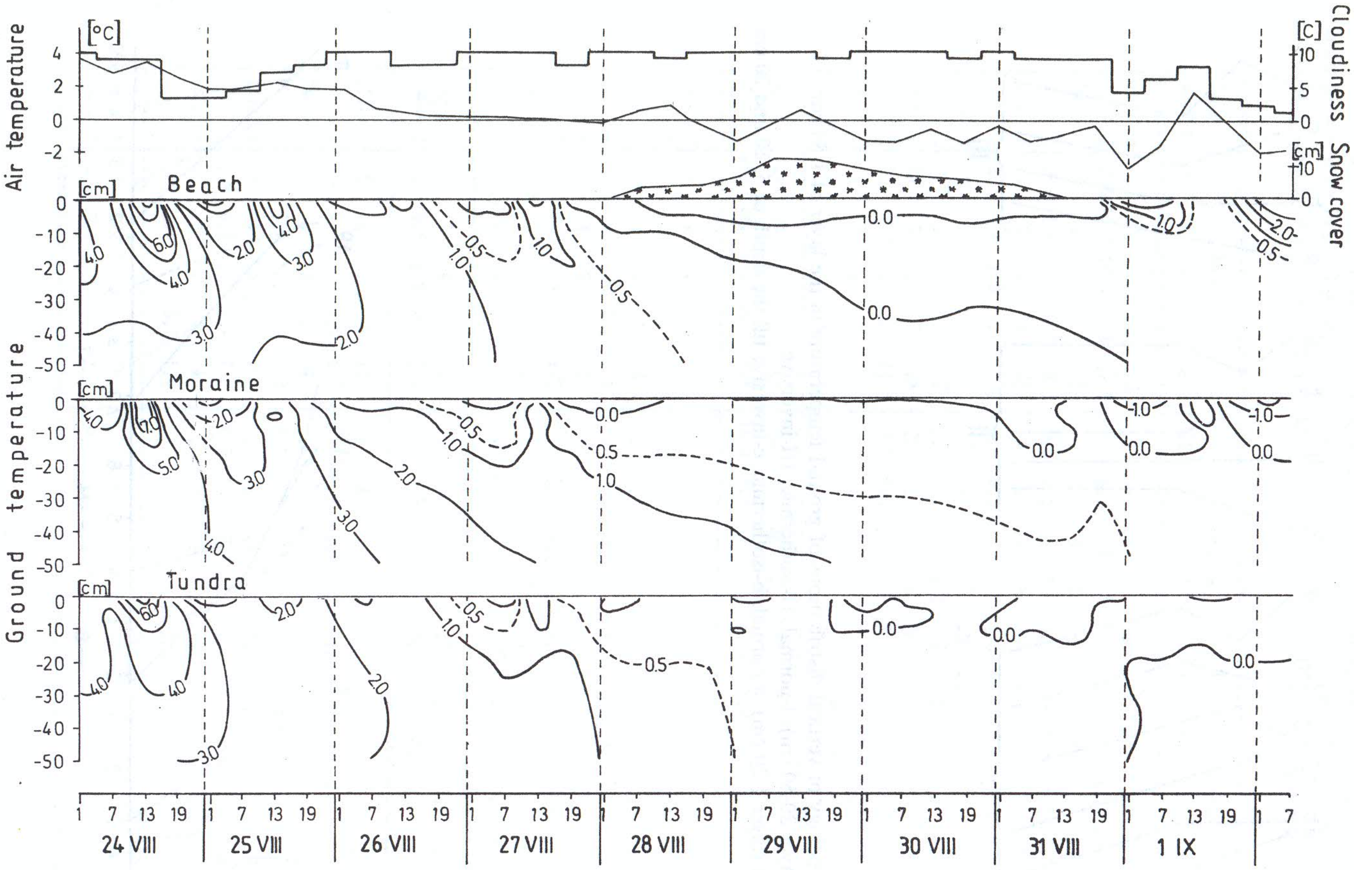

Fig. 3. Thermoisoplethes (in°C) of the ground in 3 ecotopes and the course of degree of cloudiness (scale 0-10) and air temperature at the heigth 2 m a.g.l. in the period since 24th August to 2nd September, 1989.