

Rajmund Przybylak, Andrzej Arażny, Marek Kejna

Nicolaus Copernicus University, Institute of Geography
Department of Climatology, Toruń, Poland
e-mail: rp11@umk.pl

Introduction, data and methods

The ground thermal conditions in Spitsbergen are shaped by a variety of factors, including the inflow of solar energy, the advection of air masses, atmospheric precipitation, the albedo, the extent of surface vegetation, snow cover, and the earth's inclination in relation to solar exposure. Furthermore they are also dependant on the thermal properties and moisture level of the ground itself, as well as the depth of the permafrost.

Research into ground temperatures on the Kaffiøyra Plain (NW Spitsbergen, fig. 1, photos 1-3) was conducted over 17 summer seasons (with "summer" here being taken as July 21st to August 31st in the years 1975, 1977-80, 1982, 1985, 1989, 1997, 1998, 2000, 2005-09. The study was conducted as part of the Toruń Polar Expeditions organized by the Institute of Geography at the Nicolaus Copernicus University in Toruń. Among the studies investigating ground temperature in Kaffiøyra are Wójcik & Marciniak (1987); Wójcik, Marciniak & Przybylak (1988); Wójcik *et al.* (1990); Kejna *et al.* (1993) and Arażny (2001). During all the research periods measurements were always taken in the same locations and the same measurement techniques were used. Ground temperatures were measured using mercury thermometers placed at depths of 5, 10, 20 and 50 cm. An additional measurement of ground temperature was taken at a depth of 1 cm using a regular thermometer. Thermometer readings were taken 1⁰⁰, 7⁰⁰, 13⁰⁰ and 19⁰⁰ local mean time (LMT) (UTC + 1 hour). Measurement sites were selected with reference to three ecotopes: a sandy beach, the flat frontal-lateral summit moraine of the Aavatsmark Glacier, and the tundra (figs 1-2, photos 1-3).

the beach site (B) is located on the flat shoreline away from the range of influence of the Greenland Sea. The ground here is mostly sand and gravel and the surface layer is dry and free of vegetation.

the moraine site (M) is situated on the flat frontal-lateral summit moraine of the Aavatsmark Glacier composed of sandy clay, gravel, mud, and sand. About 20% of the moraine has vegetation cover.

the tundra site (T) is situated on the cone of the glacial outwash (sandur) emerging from the moraine of the Aavatsmark

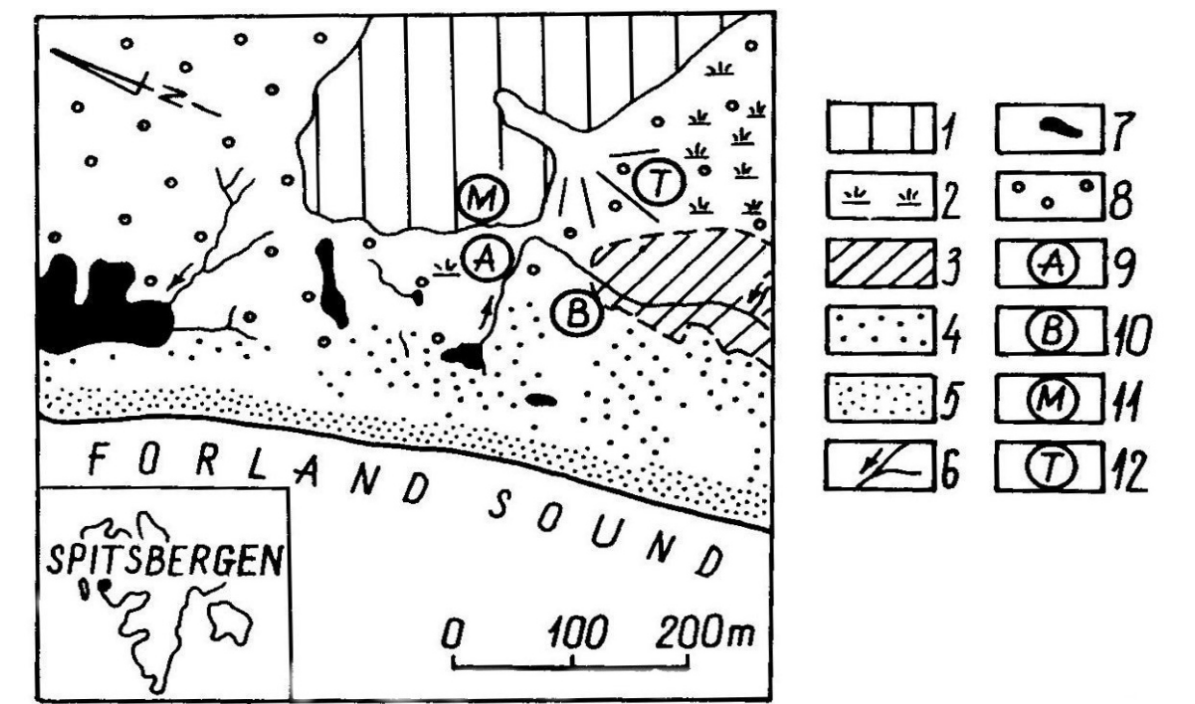


Fig. 1.
A morphological sketch of the area of the Nicolaus Copernicus University Research Station and the location of the measurement sites.

Key: 1- moraine, 2- tundra, 3- area subject to occasional flooding during high tides, 4- storm ridges, 5- beach area subject to occasional flooding during high tides, 6- currents, 7- lake, 8- glacial outwash (sandur), 9- research station, 10, 11, 12- ground temperature measurement sites: Beach (B), Moraine (M), Tundra (T).



Photos 1-3
Ground thermometers on the Kaffiøyra: the beach site (B), the moraine site (M) and the tundra site (T).

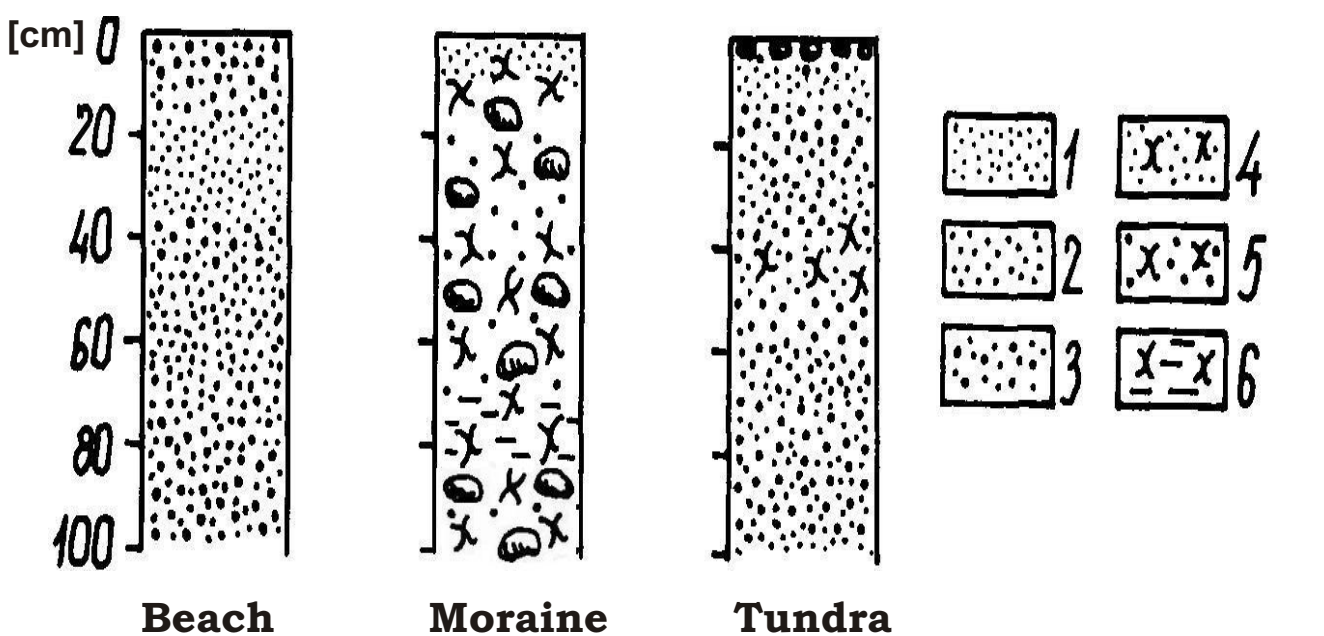


Fig. 2.
Ground structure of the ecotopes in which ground temperature was measured.

Key: 1 - fine sand, 2 - medium grained sand, 3 - sand gravel, 4 - sand till, 5 - gravel till, 6 - silt till

Results

The ground temperature on the Kaffiøyra Plain, similar to most meteorological elements, is subject to considerable variability from year to year (tab. 1-2). The ground temperature is significantly correlated with the air tempertaure.

Long-term analysis of the ground temperature data confirms that the coolest site at all depths (1-50 cm) is the measurement point on the sandy beach; the tundra is warmer, and the warmest is the moraine site (tab. 2). The biggest thermic differences between the ecotopes are at the depth of 50 cm (on the average 2.5°C between the warmest moraine and coolest beach).

The smallest temperature differences between the readings for the different ecotypes are those recorded at 1⁰⁰ LMT, while the greatest are observed in the afternoon (fig. 3). In the surface ground layer (1-20 cm) at 1⁰⁰ LMT at all sites there appears an inverse pattern between measurements, which diminishes away from the surface. At 7⁰⁰ LMT the pattern begins to appear more normal, and becomes most clearly defined at 13⁰⁰ LMT. At 19⁰⁰ LMT a normal course develops in the isotherms, moving towards inversion. At the deeper ground layer (20-50 cm) there is a normal course throughout the day.

The highest mean ground temperatures during the whole measuring period occurred in the end of July (figs 4-5). The lowest mean ground temperatures were noted in the third decade of August (e.g.: the air temperature dropped below 0°C, sometimes occurred snowfalls).

In the period analysed a rising ground temperature trend was noted during the summer seasons, e.g. at the beach site (5 and 50 cm) where an increase was recorded (fig. 6).

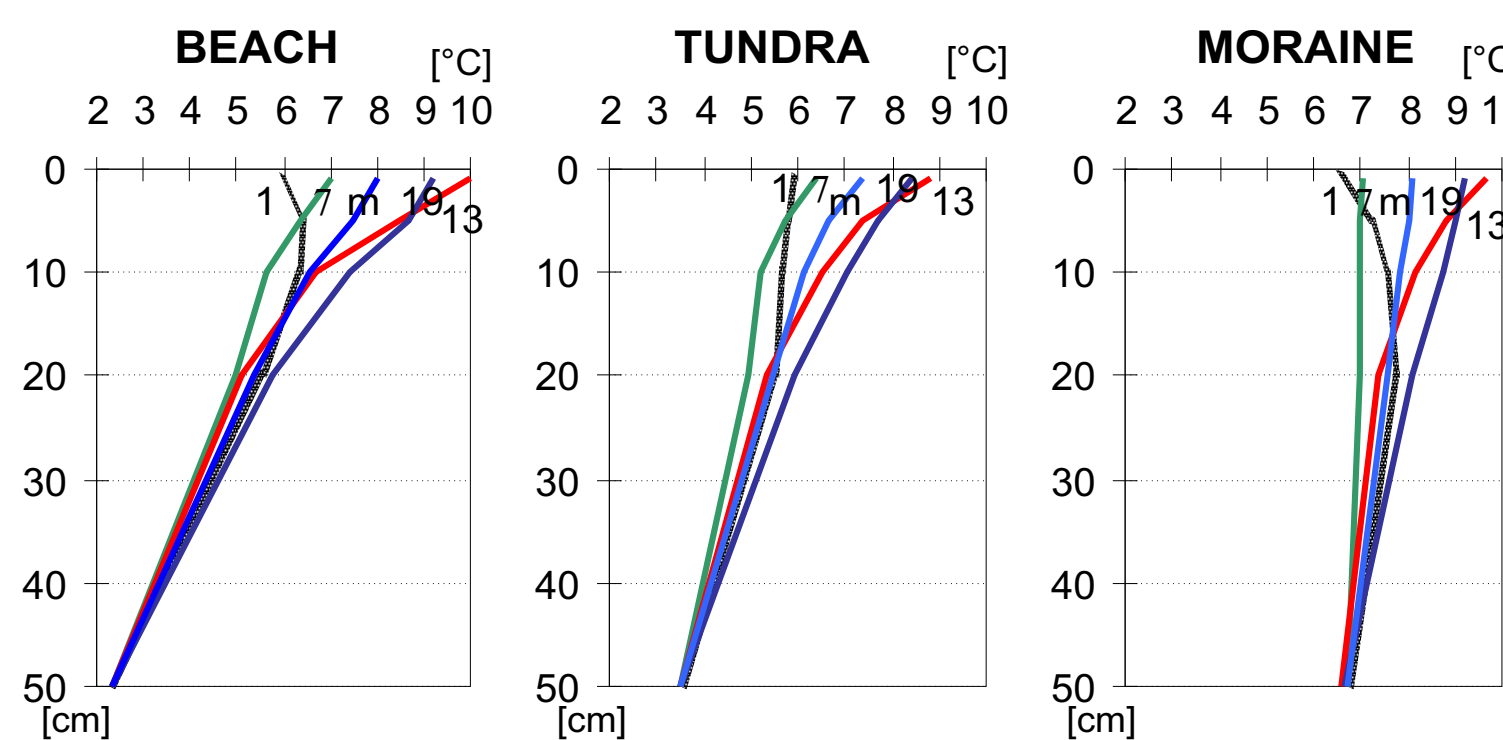


Fig. 3.
Vertical distribution of ground temperature on the stands: the beach, tundra and moraine in the summer season from 21st July to 31st August 1998.

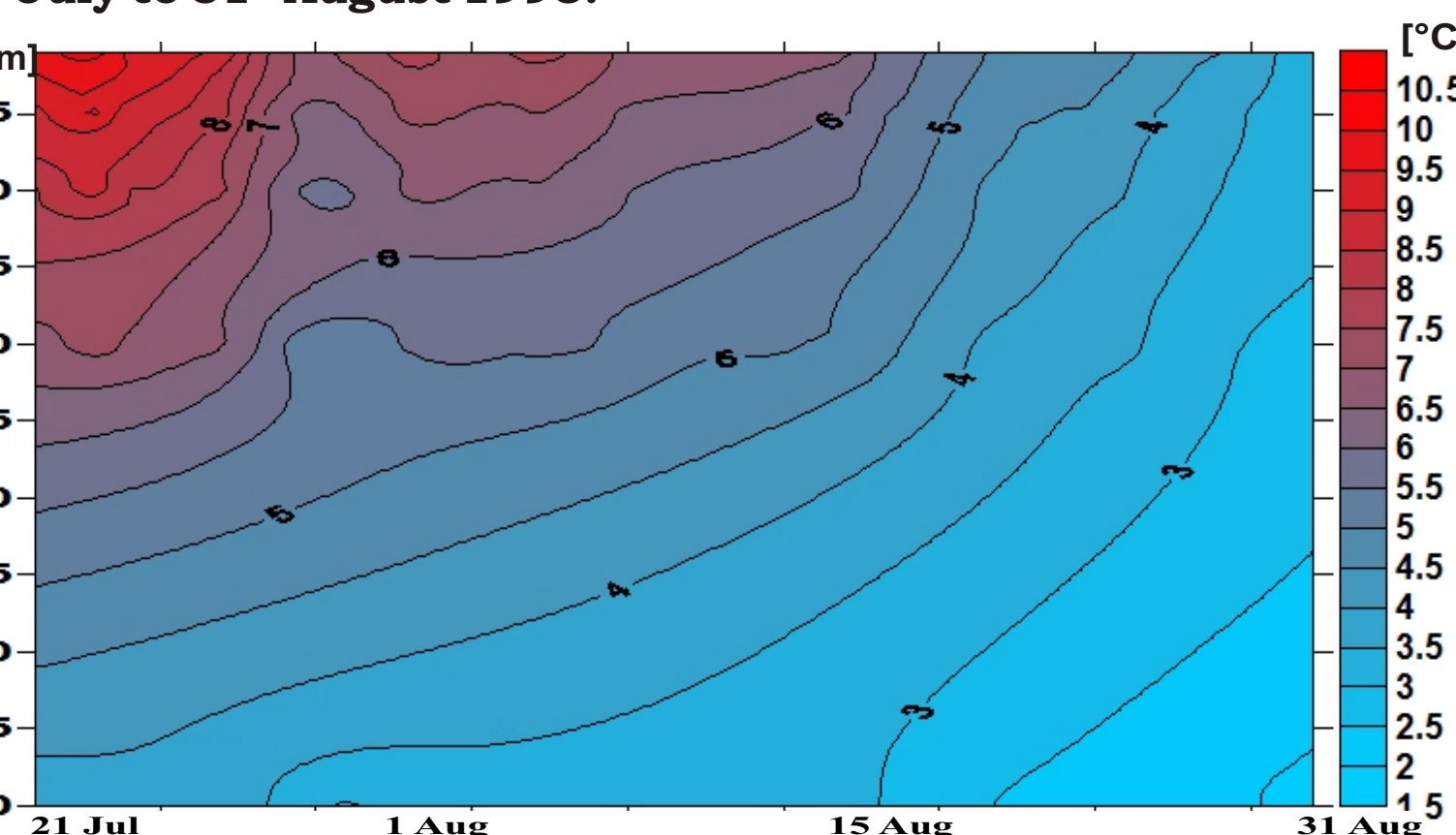


Fig. 5.
The courses of ground termoisoplethes on the beach in the summer season (21st July - 31st August), 1975-2009.

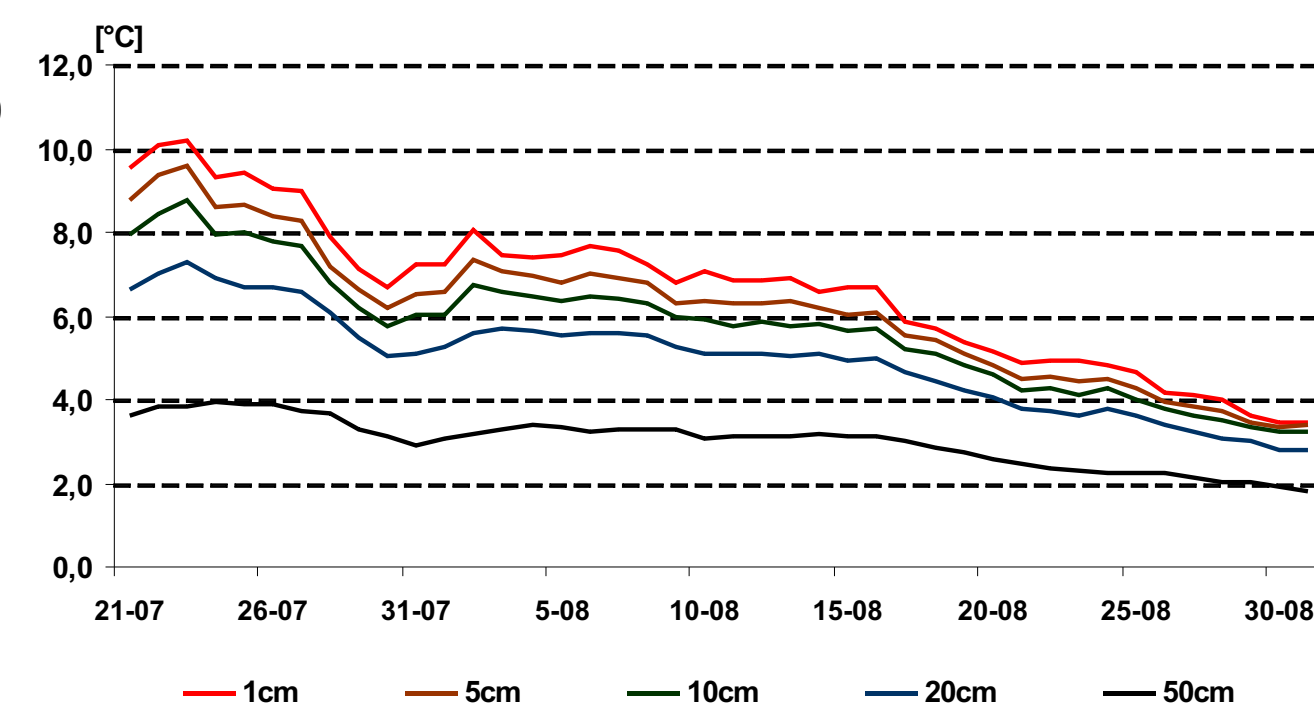


Fig. 4.
The mean courses of ground temperatures on the beach in the summer season (21st July - 31st August), 1975-2009.

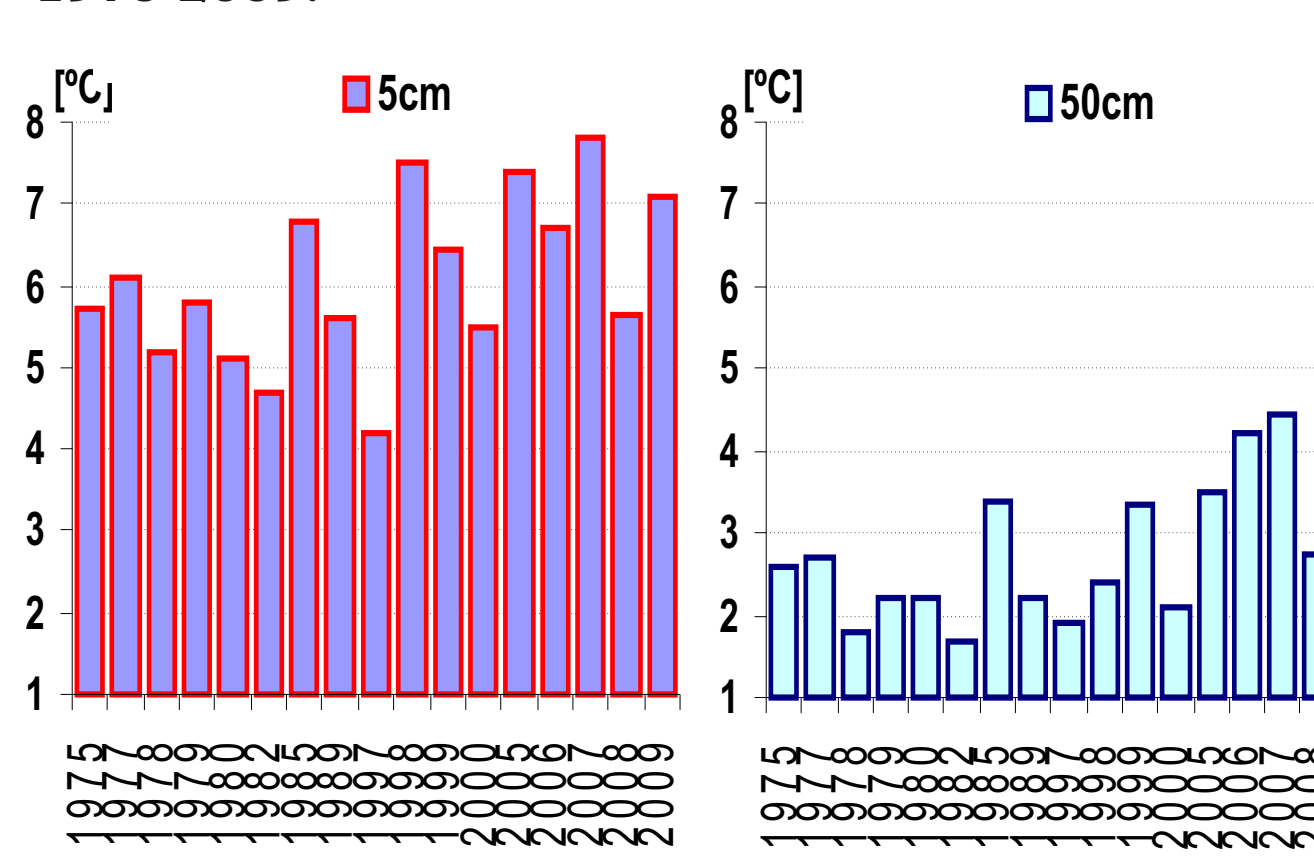


Fig. 6.
Variability of mean ground temperature on the beach at depth of 5 and 50 cm in the analysed period.

Table 1.
Mean values of the chosen meteorological elements on the Kaffiøyra Plain in the summer season (21st July - 31st August), 1975-2009.

Element	1975	1977	1978	1979	1980	1982	1985	1989	1997	1998	1999	2000	2005	2006	2007	2008	2009	1975-2009
V[m/s]	43	32	46	50	55	42	32	50	54	40	38	46	38	50	37	54	31	43
C[0-10]	87	87	88	73	91	88	72	83	84	91	89	72	91	83	87	89	79	84
SS[h]	1129	147.6	1199	281.9	909	913	309.5	2030	1650	935	1501	2133	1494	1580	1320	1317	2200	1629
SS[%]	112	159	121	290	91	92	322	205	168	95	152	216	151	236	221	236	220	182
Tmax _{air} [°C]	11.5	13.5	10.0	18.9	12.5	10.4	16.0	11.5	10.8	14.0	10.3	8.8	12.1	11.9	13.9	12.4	13.0	18.9
Tmax[°C]	6.7	7.0	6.3	6.6	5.6	4.8	6.9	5.5	5.4	7.6	6.4	5.9	7.5	7.0	7.4	6.1	7.6	6.5
Ti[°C]	4.9	5.0	4.7	4.5	4.1	3.3	5.4	4.0	4.2	6.3	4.9	3.9	5.8	5.2	5.5	4.5	6.1	4.8
Tmin[°C]	3.3	3.5	3.1	2.5	2.6	1.8	4.0	2.7	2.7	5.0	3.5	2.2	4.1	3.9	4.0	2.9	4.1	3.3
Tmin _{air} [°C]	1.4	0.6	0.7	-0.5	-0.8	-4.2	0.9	-3.6	-0.2	1.8	0.0	-3.6	1.4	1.0	-1.3	-0.8	0.9	-4.2
DTR[°C]	3.4	3.5	3.2	4.1	3.0	3.0	2.9	2.8	2.7	2.6	2.9	3.7	3.4	3.1	3.6	3.2	3.5	3.2
e[hPa]	7.8	7.8	7.7	7.6	7.3	6.8	8.1	7.4	7.5	8.7	7.3	7.2	8.1	8.1	7.8	7.5	8.2	7.7
f[%]	90	89	89	88	88	88	89	90	90	91	85	88	87	91	85	88	87	88
Δe[hPa]	0.9	1.0	0.9	0.9	0.9	1.0	1.0	0.8	0.8	0.9	1.3	1.0	1.2	0.8	1.4	1.0	1.3	1.0
P[mm]	66.5	44.4	44.2	17.7	108.0	54.5	13.9	27.0	122.5	16.0	58.4	29.1	49.9	25.1	12.3	22.2	13.0	42.6

Explanations: V- wind velocity; C - cloudiness; SS - sunshine duration; T - air temperature; DTR - diurnal temperature range, e - water vapour pressure; f - relative air humidity; Δe - saturation deficit; P - atmospheric precipitation

Table 2.
Mean values of ground temperature on the Kaffiøyra Plain in the summer season (21st July - 31st August), 1975-2009.

BEACH																			
Depth	1975	1977	1978	1979	1980	1982	1985	1989	1997	1998	1999	2000	2005	2006	2007	2008	2009	1985-2009	
1cm	6.3	6.7	5.8	6.3	5.7	5.2	7.2	6.0	-	8.1	6.7	5.6	8.0	7.1	8.3	6.0	7.9	7.1	
5cm	5.7	6.1	5.2	5.8	5.1	4.7	6.8	5.6	4.2	7.5	6.4	5.5	7.4	6.7	7.8	5.7	7.1	6.4	
10cm	5.4	5.8	4.4	5.4	4.8	4.2	6.6	5.2	4.1	6.6	5.9	5.0	6.9	6.8	7.4	5.4	6.6	6.1	
20cm	4.2	4.9	4.1	4.5	4.0	3.6	5.8	4.4	3.4	5.4	5.2	4.4	5.9	5.9	6.4	4.7	5.9	5.2	
50cm	2.6	2.7	1.8	2.2	2.2	1.7	3.4	2.2	1.9	2.4	3.4	2.1	3.5	4.2	4.4	2.8	3.5	3.1	
MORaine																			
Depth	1975	1977	1978	1979	1980	1982	1985	1989	1997	1998	1999	2000	2005	2006	2007	2008	2009	1985-2009	
1cm	-	-	5.7	6.0	5.3	-	7.1	5.3	5.1	8.1	6.5	5.3	7.5	6.8	8.1	5.9	7.8	6.7	
5cm	-	-	5.7	5.8	5.1	-	6.9	5.4	4.8	8.0	6.5	5.1	7.3	6.6	7.8	5.6	7.6	6.5	
10cm	-	-	5.5	5.7	5.1	-	6.8	5.2	4.8	7.9	6.6	5.0	7.1	6.5	7.7	5.4	7.4	6.4	
20cm	-	-	5.3	5.4	4.9	-	6.7	5.0	4.6	7.6	6.2	5.0	6.9	6.3	7.6	5.4	7.3	6.2	
50cm	-	-	4.6	4.7	4.3	-	6.0	4.6	4.2	6.7	5.6	4.3	6.2	5.7	7.2	5.0	6.7	5.6	
TUNDRA																			
Depth	1975	1977	1978	1979	1980	1982	1985	1989	1997	1998	1999	2000	2005	2006	2007	2008	2009	1985-2009	
1cm	-	-	5.7	4.8	-	-	6.8	5.3	4.3	7.4	6.2	4.9	7.0	6.4	7.1	5.6	7.0	6.2	
5cm	-	-	5.5	4.5	-	-	6.7	4.9	4.1	6.7	6.0	4.9	6.4	6.1	6.9	5.2	6.5	5.9	
10cm	-	-	5.2	4.3	-	-	6.1	4.6	-	6.2	5.8	4.5	6.0	6.1	6.7	5.1	6.4	5.8	
20cm	-	-	4.7	3.8	-	-	5.5	4.2	3.4	5.5	4.5	3.9	5.4	5.6	6.1	4.8	5.6	5.0	
50cm	-	-	3.4	2.4	-	-	4.1	2.9	2.4	3.6	3.3	2.2	4.0	4.3	4.6	3.4	3.7	3.5	

References:

- Arażny A., 2001, Differentiation of soil temperature on the Kaffiøyra Plain (NW Spitsbergen) in summer 1997 and 1998 in comparison to the period 1975-98, Problemy Klimatologii Polarnej 11, Gdyni: 81-92 (in Polish).
- Wójcik G., Marciniak K., 1987, Ground temperature of main ecotopes of Kaffiøyra, Spitsbergen, summer 1978; Polish Polar Research, 8 (1): 25-46.
- Wójcik G., Marciniak K., Przybylak R., 1988, Time and spatial variation of temperature of active layer in summer on the Kaffiøyra Plain (NW Spitsbergen), V International Conference on Permafrost, Proceedings volume 1, Trondheim, Norway: 499-504.
- Wójcik G., Marciniak K., Przybylak R., Kejna M., 1990, Year-to-year changes of ground temperature in the period 1975-1989 on the Kaffiøyra Plain (NW Spitsbergen), [in:] Periglacial phenomena of Western Spitsbergen, Sesja Polarna, UMCS, Lublin: 233-243
- Kejna M., Marciniak K., Przybylak R., 1993, Ground temperature of main ecotopes of Kaffiøyra Plain (NW Spitsbergen) in the summer of 1989, Wyniki badań VIII Toruńskiej Wyprawy Polarnej Spitsbergen'89, UMK, Toruń: 47-64 (in Polish).