Chapter 4

THERMAL CONDITIONS

4.1. Ground temperature

4.1.1. Introduction

Ground temperature is just one of the climate controls determining the climate of a given region. It exhibits spatial diversity depending on the state and character of the surface and its thermal properties, such as the ability to absorb and conduct heat, and on the thermal capacity of the ground, which includes both its permanent components and the air and water content. In polar areas, solar radiation reaching the ground has to penetrate the barrier of frozen surfaces. Overcoming the boundary temperature of 0°C requires large amounts of heat, which is used to melt the ice, therefore the surface (layer), which has the transition temperature, at which water changes its state to solid (ice) or vice versa, is often referred to as the 'zero-curtain effect'. In the heat balance of the ground sensible heat is just as significant as latent heat, generated or consumed in phase transition processes. Infiltration of water brings heat into the ground and substantially increases its heat conductivity. Therefore, heat permeates deeper in wet ground, but this kind of ground warms up less and gives up less heat than dry ground (Kejna et al. 1993).

The literature dealing with ground temperature studies on the Kaffiøyra Plain is plentiful and can be found as references in articles describing general weather conditions during specific expeditions, for example: Leszkiewicz 1977; Wójcik 1982; Marciniak and Przybylak 1983, 1991; Wójcik and Marciniak 1983; Kejna and Dzieniszewski 1993; Wójcik et al. 1997 and Araźny 1999, 2002. Detailed studies of the ground temperature have also been published by, for example: Wójcik and Marciniak 1987; Wójcik et al. 1988, 1990; Kejna 1990, 1991; Kejna et al. 1993; Marciniak et al. 1991; Araźny 2001, and Przybylak et al. 2010.

In the summer seasons of 2010 and 2011, studies of the spatial diversity of ground temperature were continued on the basis of sites located in three ecotopes on the Kaffiøyra Plain, all characteristic of the polar zone (terminology after Wójcik and Marciniak 1987): on a sandy beach, on the flat top of the terminal-lateral moraine of the Aavatsmark Glacier and in the tundra:

- The beach site (P) is located on a coastal accumulation plain out of reach of the strongest tidal motions of the Greenland Sea (Photos 1.5 and 1.6 in Section 1.2). The beach consists of sand and gravel, which is characterised by low thermal conductivity and thermal capacity, and high albedo. The high degree of porosity of sand and gravel contributes to substantial drying-up of the surface layer of the ground.
- The tundra site (T) is located on an outwash fan, 70% covered with tundra plants, which protrudes from the morainal arc of the Aavatsmark Glacier.

The ground at this site is moist (Photos 1.5 and 1.8 in Section 1.2).

– The moraine site (M) is located on the terminal-lateral moraine of the Aavatsmark Glacier, which consists of sandy clay, gravelly clay and loamy clay. The surface of the moraine is dark and thus has a low albedo. It is covered with vegetation to approximately 20% (Photos 1.5 and 1.7 in Section 1.2).

4.1.2. The course of ground temperature

In the summer seasons of 2010 and 2011 the values of ground temperature in all studied ecotopes were associated with the courses of the prevailing meteorological conditions. The thermal conditions of the ground depended on the heat balance of its surface, in which the most important factor is the radiation balance. Moreover, ground temperature is affected by air temperature, sunshine duration, cloudiness and precipitation. All these meteorological variables have been described in detail elsewhere in this work (Chapters 2-5).

Other significant factors include the albedo of the surface, the vegetation cover, thermal characteristics and humidity of the ground, and the thickness of the permafrost. Results of measurements conducted for many years have demonstrated that the active layer of the permafrost at the end of the summer season is the thickest on the moraine (> 2 m), and the thinnest on the beach (a little more than 1 m) (Araźny and Grześ 2000). Observations carried out in the most recent seasons have verified these findings. At the end of summer in 2010 and 2011, the maximum thaw depth was measured on the beach (131 and 130 cm, respectively), in the tundra (140 and 157 cm) and on the moraine (213 and 198 cm).

It is the surface layer of the ground that undergoes temperature fluctuations the most, both throughout the day and on a daily basis (see Appendixes 5 and 6, and Figs. 4.1 and 4.2). These fluctuations are caused by a quicker exchange of heat between the ground and the near-ground layer of air. Comparing the ground temperature in the analysed ecotopes it was observed that the average temperature at a depth of 1 cm (i.e. in the active layer) in the comparable period (21 July – 31 August), was the highest on the beach and on the moraine. In the summers, the temperature was 5.8 and 5.9°C at the respective sites in 2010, and 7.3 and 7.2°C in 2011. The lowest temperature of the two analysed seasons at 1 cm below ground level was in the tundra (5.5 and 6.7°C). This diversity was due to the poor heat conductivity and limited capacity of the sand and gravel deposits on the beach and the morainal forms on the moraine, which enabled warming up of the surface ground layers, whereas in the tundra the vegetation prevents the ground from such warming. In both summer seasons, the temperatures recorded at all sites at a depth of 1 cm (Tab. 4.1, Figs. 4.1 and 4.2) show that the first and second ten-day periods of July were the warmest. In 2010, in the second ten-day period of August the ground was subject to substantial cooling as a result of an advection of cold air from the north. On 16 August 2010, the mean diurnal temperature reached only 0.8°C in the tundra, 1.0°C on the moraine and 1.1°C on the beach. Later, in the period from 19 to 24 August, the area of the Forlandsundet came under the influence of

Table 4.1. Mean ten-day temperatures (°C) of the ground in selected ecotopes on the Kaffiøyra at 4 times of observation (01:00, 07:00, 13:00, and 19:00 LMT) and diurnal means (m) in the period from 7 July to 02 September 2010

Beach	**1 cm**					**5 cm**					**10 cm**					**20 cm**					**50 cm**					**100 cm**				
Period	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**
11–20 Jul	6.7	7.2	9.1	8.3	7.8	6.4	6.7	8.3	8.0	7.4	6.4	6.3	7.6	7.6	7.0	5.9	5.3	5.9	6.0	5.8	2.9	2.8	2.8	2.8	2.8	0.1	0.2	0.2	0.2	0.2
21–31 Jul	5.4	6.0	8.7	7.9	7.0	5.4	5.7	7.8	7.5	6.6	5.5	5.4	7.1	7.2	6.3	5.3	4.6	5.3	6.0	5.3	2.8	2.8	2.8	2.8	2.8	0.3	0.3	0.3	0.3	0.3
1–10 Aug	5.3	6.3	9.0	6.9	6.8	5.2	5.8	7.8	6.7	6.4	5.4	5.4	6.9	6.6	6.1	5.2	4.6	5.2	5.7	5.2	3.0	3.0	2.9	2.9	3.0	0.6	0.5	0.5	0.6	0.5
11–20 Aug	1.5	3.9	6.3	4.8	4.1	1.7	2.7	5.1	4.5	3.5	2.2	2.6	4.4	4.4	3.4	2.2	2.0	2.8	3.5	2.6	1.7	1.6	1.6	1.6	1.6	0.4	0.4	0.4	0.4	0.4
21–31 Aug	2.9	4.7	7.7	5.5	5.2	3.2	3.6	6.0	5.4	4.6	3.6	3.4	5.1	5.2	4.3	3.7	3.1	3.5	4.1	3.6	2.4	2.4	2.3	2.3	2.4	0.6	0.6	0.6	0.7	0.6
21 Jul–31 Aug	3.8	5.2	7.9	6.3	5.8	3.9	4.4	6.7	6.1	5.3	4.2	4.2	5.9	5.9	5.0	4.1	3.6	4.2	4.8	4.2	2.5	2.5	2.4	2.4	2.4	0.5	0.5	0.5	0.5	0.5
7 Jul–2 Sep	4.5	5.9	8.5	6.9	6.5	4.6	5.1	7.3	6.7	5.9	4.8	4.8	6.4	6.4	5.6	4.6	4.1	4.7	5.2	4.6	2.6	2.6	2.5	2.5	2.5	0.4	0.4	0.4	0.4	0.4
Tundra	**1 cm**					**5 cm**					**10 cm**					**20 cm**					**50 cm**					**100 cm**				
Period	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**
11–20 Jul	6.5	7.1	8.5	7.9	7.5	6.6	6.4	7.3	7.7	7.0	6.5	6.1	7.0	7.4	6.7	5.8	5.4	5.7	6.2	5.8	3.9	3.8	3.8	3.8	3.8	1.6	1.6	1.6	1.7	1.6
21–31 Jul	5.6	6.1	7.8	7.8	6.8	5.8	5.5	6.9	7.2	6.4	5.8	5.4	6.6	7.1	6.2	5.3	4.8	5.4	5.9	5.3	3.6	3.5	3.5	3.6	3.6	1.7	1.8	1.8	1.9	1.8
1–10 Aug	5.2	6.1	8.1	6.7	6.5	5.5	5.4	6.8	6.6	6.1	5.6	5.3	6.5	6.5	6.0	5.2	4.7	5.3	5.7	5.2	3.8	3.7	3.6	3.7	3.7	2.0	2.0	2.0	2.0	2.0
11–20 Aug	1.8	3.3	5.2	4.4	3.7	2.6	2.6	4.2	4.5	3.5	2.7	2.4	3.9	4.3	3.3	2.6	2.1	3.0	3.5	2.8	2.2	2.1	2.0	2.1	2.1	1.3	1.3	1.2	1.2	1.2
21–31 Aug	3.1	4.0	6.5	5.2	4.7	4.0	3.7	5.3	5.4	4.6	4.0	3.6	4.9	5.3	4.4	4.0	3.3	4.0	4.6	4.0	3.1	3.0	3.0	3.0	3.0	1.7	1.7	1.7	1.7	1.7
21 Jul–31 Aug	4.0	4.9	6.9	6.0	5.5	4.5	4.3	5.8	5.9	5.1	4.5	4.2	5.5	5.8	5.0	4.3	3.7	4.4	5.0	4.4	3.2	3.1	3.0	3.1	3.1	1.7	1.7	1.7	1.7	1.7
7 Jul–2 Sep	4.6	5.4	7.4	6.5	6.0	5.0	4.8	6.2	6.4	5.6	5.0	4.7	5.9	6.2	5.4	4.7	4.1	4.8	5.3	4.7	3.3	3.2	3.2	3.3	3.2	1.6	1.6	1.6	1.6	1.6
Moraine	**1 cm**					**5 cm**					**10 cm**					**20 cm**					**50 cm**					**100 cm**				
Period	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**
11–20 Jul	6.8	7.3	8.8	8.3	7.8	7.5	7.3	8.4	8.4	7.9	7.7	7.3	8.0	8.3	7.8	7.9	7.4	7.7	8.1	7.8	7.4	7.2	7.1	7.1	7.2	6.0	6.0	6.0	5.9	6.0
21–31 Jul	5.5	6.2	8.8	7.7	7.0	6.0	6.1	8.1	7.7	7.0	6.5	6.1	7.4	7.6	6.9	6.7	6.1	6.8	7.4	6.8	6.1	6.1	5.9	6.0	6.0	5.0	4.9	5.0	5.0	5.0
1–10 Aug	5.2	6.3	8.9	6.5	6.7	5.6	6.0	8.1	6.8	6.6	6.1	5.9	7.3	7.1	6.6	6.4	5.9	6.8	7.0	6.5	6.0	5.9	5.8	5.9	5.9	4.8	4.8	4.8	4.8	4.8
11–20 Aug	2.0	3.8	6.5	4.8	4.3	2.5	3.1	5.5	4.9	4.0	3.4	3.2	4.9	4.9	4.1	3.5	3.1	4.0	4.6	3.8	3.7	3.6	3.4	3.6	3.6	3.2	3.2	3.2	3.1	3.2
21–31 Aug	3.5	4.4	8.0	5.6	5.4	4.2	4.2	7.0	6.1	5.4	4.9	4.4	6.1	6.2	5.4	5.2	4.5	5.2	6.0	5.2	4.9	4.7	4.6	4.6	4.7	3.8	3.8	3.8	3.8	3.8
21 Jul–31 Aug	4.0	5.2	8.0	6.2	5.9	4.6	4.9	7.2	6.4	5.8	5.3	4.9	6.4	6.5	5.8	5.5	4.9	5.7	6.3	5.6	5.2	5.1	4.9	5.0	5.1	4.2	4.2	4.2	4.2	4.2
7 Jul–2 Sep	4.7	5.8	8.4	6.8	6.4	5.3	5.5	7.7	7.0	6.4	5.9	5.6	6.9	7.0	6.4	6.1	5.6	6.3	6.8	6.2	5.7	5.6	5.5	5.6	5.6	4.6	4.6	4.6	4.6	4.6

Table 4.2. Mean ten-day temperatures (°C) of the ground in selected ecotopes on the Kaffiøyra at 4 times of observation (01:00, 07:00, 13:00, and 19:00 LMT) and diurnal means (m) in the period from 11 July to 31 August 2011

Beach	1 cm					5 cm					10 cm					20 cm					50 cm					100 cm
Period	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**13**
11–20 Jul	7.5	9.3	11.5	11.0	9.8	7.7	7.8	9.5	10.0	8.7	7.7	7.3	8.8	9.5	8.3	7.3	6.7	7.8	8.5	7.6	4.3	4.4	4.2	4.3	4.4	0.5
21–31 Jul	7.1	8.4	10.5	8.9	8.7	7.4	7.3	8.6	8.7	8.0	7.8	7.2	8.1	8.5	7.9	7.6	6.9	7.4	7.8	7.4	4.8	4.8	4.6	4.7	4.6	1.1
1–10 Aug	5.8	7.1	9.3	7.7	7.5	6.0	6.0	7.6	7.3	6.7	6.0	5.7	6.6	7.0	6.3	5.8	5.3	5.8	6.3	5.8	3.5	3.7	3.5	3.6	3.6	1.3
11–20 Aug	4.8	6.5	9.1	8.2	7.2	5.2	5.6	8.1	8.0	6.7	5.6	5.3	7.0	7.3	6.3	5.5	5.0	5.8	6.6	5.7	3.4	3.6	3.5	3.5	3.6	1.4
21–31 Aug	4.6	5.3	7.3	6.3	5.9	5.0	5.0	6.4	6.1	5.6	5.3	5.0	5.8	6.0	5.5	5.3	4.8	5.1	5.6	5.2	3.8	3.7	3.7	3.7	3.7	1.6
21 Jul–31 Aug	5.6	6.8	9.0	7.8	7.3	5.9	6.0	7.7	7.5	6.8	6.2	5.8	6.9	7.2	6.5	6.1	5.5	6.1	6.6	6.0	3.9	3.9	3.8	3.9	3.9	1.4
11 Jul–31 Aug	6.0	7.3	9.5	8.4	7.8	6.3	6.3	8.0	8.0	7.2	6.5	6.1	7.3	7.6	6.9	6.3	5.7	6.4	6.9	6.3	4.0	4.0	3.9	4.0	4.0	1.2
Tundra	**1 cm**					**5 cm**					**10 cm**					**20 cm**					**50 cm**					**100 cm**
Period	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**13**
11–20 Jul	6.8	8.6	10.2	10.3	9.0	7.0	7.3	8.6	9.3	8.1	7.1	6.7	8.0	8.9	7.7	6.8	6.0	7.1	7.7	6.9	4.8	4.8	5.0	4.9	5.0	2.6
21–31 Jul	7.0	7.3	9.0	8.5	7.9	7.4	7.0	7.8	8.3	7.6	7.3	6.8	7.5	8.0	7.4	7.1	6.3	6.9	7.3	6.9	5.5	5.3	5.2	5.3	5.3	3.1
1–10 Aug	5.5	6.1	7.6	6.8	6.5	5.6	5.2	6.3	6.5	5.9	5.6	5.1	6.1	6.5	5.8	5.5	4.9	5.4	6.0	5.5	4.3	4.1	4.1	4.2	4.3	2.5
11–20 Aug	5.1	5.6	8.0	7.7	6.6	5.3	5.1	6.7	7.3	6.1	5.3	4.9	6.3	7.0	5.9	5.4	4.7	5.6	6.2	5.5	4.1	4.2	4.1	4.2	4.3	2.5
21–31 Aug	5.1	5.2	6.6	6.2	5.8	5.2	5.0	5.9	6.0	5.5	5.2	4.9	5.6	5.8	5.4	5.2	4.8	5.1	5.5	5.2	4.4	4.3	4.1	4.3	4.2	2.9
21 Jul–31 Aug	5.7	6.1	7.8	7.3	6.7	5.9	5.6	6.7	7.0	6.3	5.9	5.5	6.4	6.8	6.1	5.8	5.2	5.8	6.3	5.8	4.6	4.5	4.4	4.5	4.5	2.8
11 Jul–31 Aug	5.9	6.5	8.3	7.9	7.1	6.1	5.9	7.1	7.5	6.6	6.1	5.7	6.7	7.2	6.4	6.0	5.4	6.0	6.5	6.0	4.6	4.6	4.5	4.6	4.6	2.7
Moraine	**1 cm**					**5 cm**					**10 cm**					**20 cm**					**50 cm**					**100 cm**
Period	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**1**	**7**	**13**	**19**	**m**	**13**
11–20 Jul	7.5	9.0	11.8	10.9	9.8	7.6	8.0	10.7	10.7	9.3	7.9	7.7	10.0	10.3	9.0	7.8	7.3	7.7	9.0	7.9	7.1	6.9	6.9	7.0	7.1	5.6
21–31 Jul	7.1	7.7	10.2	8.7	8.4	7.4	7.7	9.9	9.0	8.5	7.9	7.6	9.5	9.3	8.6	8.5	7.7	8.2	8.6	8.3	8.0	8.0	7.8	7.9	7.7	6.8
1–10 Aug	5.6	6.4	8.5	7.1	6.9	5.8	5.9	7.7	7.0	6.6	6.1	5.9	7.3	7.1	6.6	6.0	5.6	6.1	6.5	6.0	5.6	5.6	5.6	5.6	5.6	5.0
11–20 Aug	5.4	6.5	9.7	8.3	7.4	5.5	5.8	8.4	8.2	7.0	5.8	5.7	7.7	8.2	6.9	5.9	5.2	6.2	7.0	6.1	5.2	5.3	5.3	5.3	5.3	4.7
21–31 Aug	5.2	5.5	7.1	6.5	6.1	5.4	5.3	6.6	6.4	5.9	5.7	5.5	6.4	6.6	6.0	5.7	5.4	5.7	6.0	5.7	5.7	5.7	5.6	5.7	5.6	5.4
21 Jul–31 Aug	5.8	6.5	8.9	7.6	7.2	6.0	6.2	8.2	7.6	7.0	6.4	6.2	7.7	7.8	7.0	6.6	6.0	6.6	7.0	6.5	6.2	6.2	6.1	6.1	6.1	5.5
11 Jul–31 Aug	6.1	7.0	9.4	8.3	7.7	6.3	6.5	8.6	8.2	7.4	6.7	6.5	8.2	8.3	7.4	6.8	6.3	6.8	7.4	6.8	6.4	6.3	6.3	6.3	6.3	5.5

anticyclonic circulation systems with extensive sunshine duration (*cf*. Section 3.2 of this work), which was reflected in a rise of temperature in the subsurface layer of the ground layer. From that moment onwards, the temperature gradually fell until the last days of August (Fig. 4.1). In August 2011, the observed pattern in the course of the temperature of the active layer was similar. The minimum temperatures at 1 cm b.g.l. were recorded on 11 August, when the diurnal mean was 2.6°C on the moraine, 3.0°C on the beach and 3.2°C in the tundra. In the following days, from 16 to 20 August, the ground became considerably warmer due to an advection of warm air (Fig. 4.2).

In a diurnal course, the lowest temperature at a depth of 1 cm (in the period of 21 July – 31 August) was recorded at 01:00, the coldest place being the beach: 3.8°C (2010) and 5.6°C (2011), and the highest at 13:00, when the warmest places were the beach (7.9 and 9.0°C, resp.) and the moraine (8.0 and 8.9°C). The mean diurnal range of ground temperature, based on four fixed-time observations, reached the highest value in the summers of 2010 and 2011 on the beach (4.1 and 3.5°C, resp.), and the lowest in both seasons in the tundra (3.0 and 2.1°C). The thermal diversity in the ground surface in individual ecotopes rose on sunny days and fell substantially in cloudy and overcast weather. In the analysed times of observation, the ground reached its maximum temperature (19.5°C) at 13:00 on 20 July 2011, and the minimum (0.0°C) at 01:00 on 16 August 2010. Both these values were measured on the beach.

The ground temperature at greater depths (5, 10, 20, 50 and 100 cm) is correlated with the temperature measured at 1 cm b.g.l., however the heat/cold propagation rate decreases with depth (Figs. 4.1 and 4.2). As a consequence, at greater depths the range of temperature fluctuations weakened in the whole period of observations, reaching, for example, the following values at the beach (in 2010): 13.9°C (at 5 cm), 12.2°C (at 10 cm) and 9.1°C (at 20 cm); similar correlations can be seen at the other sites in both summer seasons.

The times at which the highest and the lowest temperatures occur (recorded during four fixed-time observations) shift with depth, as the heat/cold takes time to reach deeper ground layers. Of all the depths, the highest diurnal temperatures were recorded at 5 cm b.g.l. on the moraine (7.9°C) and beach (7.7°C) at 13:00 (2011), and the maximum temperature (7.0°C) occurred in the coldest tundra in the evening measuring time. The highest diurnal temperatures at 10 cm b.g.l. occurred at 19:00: 7.8°C at the (warmest) moraine site and 6.8°C at the (coldest) tundra site; at the same time at 20 cm b.g.l., the temperatures were 7.0°C at the (warmest) moraine site and 6.3°C at the (coldest) tundra site. In the analysed summer season of 2011, the lowest mean diurnal temperatures at 5 cm b.g.l. on the beach (5.9°C) and on the moraine (6.0°C) occurred at 01:00 LMT, however in the moist tundra ground the diurnal minimum (5.6°C) shifted to the morning time. At depths of 10 and 20 cm the lowest observed ground temperature at all sites occurred at 07:00 LMT, when the warmest of the three ecotopes was the moraine, and the coldest the tundra.

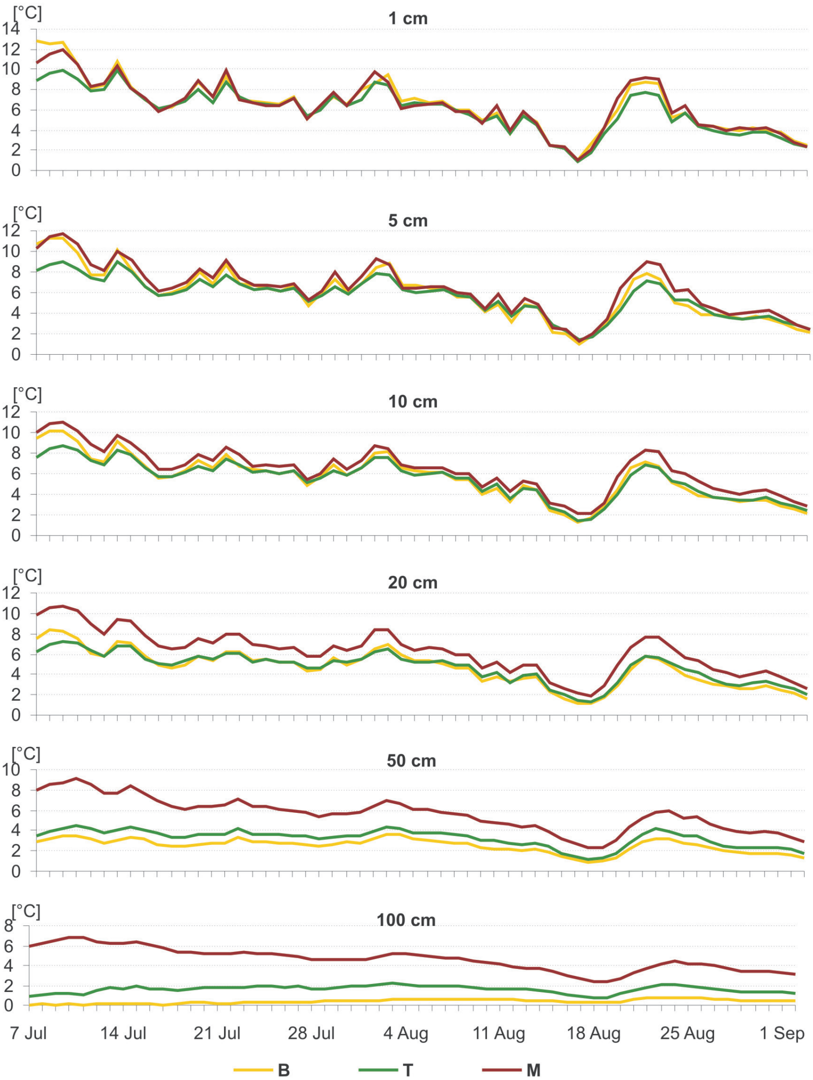

Figure 4.1. Courses of ground temperature at the depths of 1, 5, 10, 20, 50 and 100 cm measured on the beach site (B), in the tundra (T) and on the moraine (M) of the Kaffiøyra in the period from 7 July to 2 September 2010

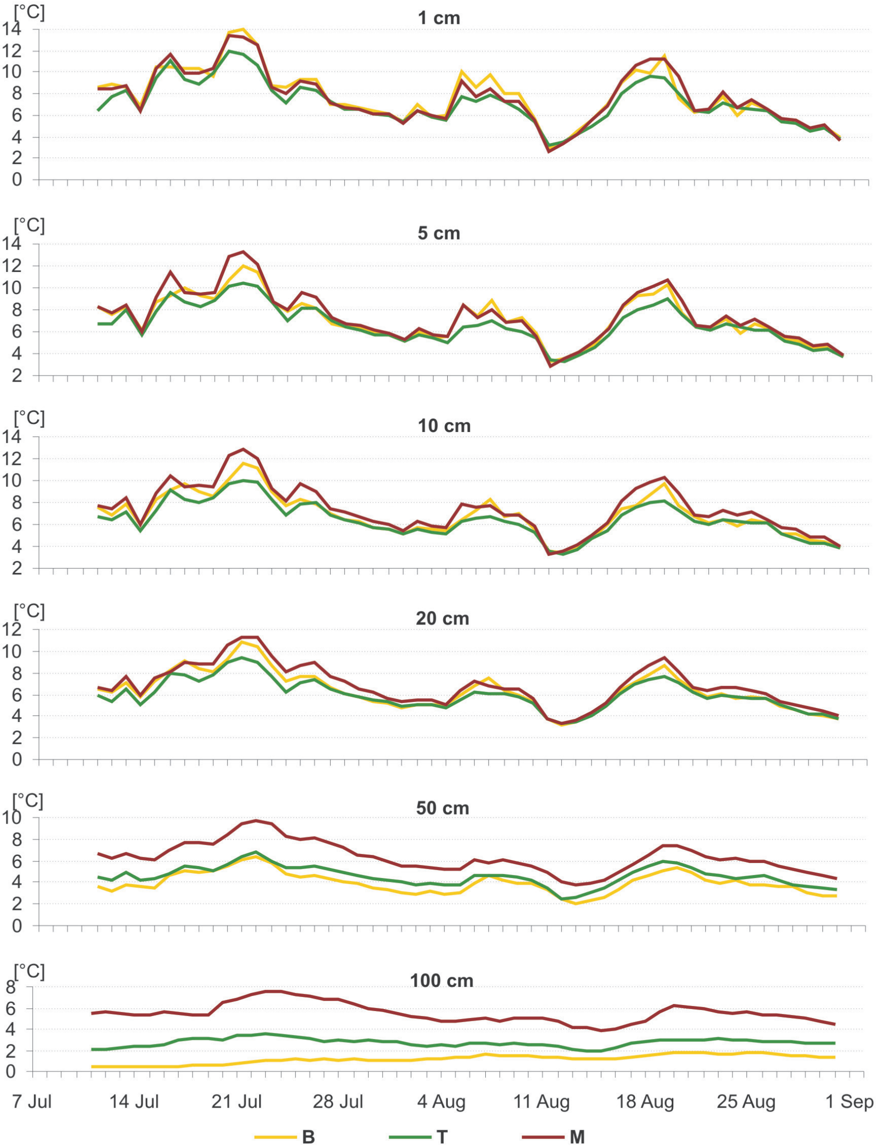

Figure 4.2. Courses of ground temperature at the depths of 1, 5, 10, 20, 50 and 100 cm measured on the beach site (B), in the tundra (T) and on the moraine (M) of the Kaffiøyra in the period from 11 July to 31 August 2011

The thermal conditions of the ground at depths of 50 and 100 cm, depend mainly on the heat conductivity and capacity and the thickness of permafrost (Kejna et al. 1993). At 50 cm b.g.l., the terrain most susceptible to changes in weather is the moraine, which was the warmest site at this depth, both in 2010 (5.1°C) and in 2011 (6.1°C), because good conditions for heat penetration determine the greatest depth at which permafrost occurs. The temperatures of the beach and tundra at 50 cm b.g.l. are similar. As the permafrost lies near the surface, its cooling effect is strong and the layer exhibits little susceptibility to external weather stimuli, and therefore its seasonal temperature range is minor. The mean temperature for the whole period of observations and all times is comparable, and the highest value occurred at 01:00 LMT. This means that the diurnal course of temperature is reversed at that depth.

At 100 cm b.g.l., the most evident influence on the ground temperature is that of permafrost. At this depth the warmest site was at the moraine (approx. 4-5°C), whereas the sites on the beach and in the tundra recorded approx. 0.5 to 2.8°C, depending on the measurement point and the season. In 2010 the thermal conditions of the ground were measured at four main times of observation. The mean temperature for the whole period of the observations and all times was the same at all three sites, thus it lacks a diurnal course. Therefore, in 2011 measurements at 100 cm b.g.l. were taken only at 13:00 LMT, which is a common practice at synoptic stations in Poland.

Vertical temperature profiles at individual times of observation for the three ecotopes have been shown in Table 4.3 and Figure 4.3. The upper layer of the ground, readily responding to the changing angle of solar rays and to daily solar radiation, exhibits a diurnal course to a depth of 20 cm. The vertical temperature profile depends on the amount of heat from the surface, and the differences at individual sites result from the structural diversity and the moisture content of the analysed ecotopes. The upper layer, from 1 to 20 cm b.g.l. also responds to atmospheric influences and undergoes the greatest variability, both in a diurnal course and day by day. Deeper, at 20–100 cm b.g.l., climate controls have a smaller influence on the ground layers, and the temperature variability is either insignificant or non-existent (Fig. 4.3). The smallest differences between the ecotopes occur at night, whereas the greatest are observed in the afternoon.

At 01:00 LMT, at all sites an inversion occurs, which reaches a depth of 20 cm on the moraine, and 10 cm on the beach and in the tundra (Tab. 4.3, Fig. 4.3). The inversion pattern recedes at 07:00 LMT and a regular pattern begins to form, most evidently at around midday. At 13:00 LMT, at all sites the highest vertical gradients are observed, which reach, for example, in the 1–10 cm b.g.l layer on the beach: γ = -2.2 ÷ -2.4°C/10 cm (in 2010 and 2011, resp.), on the moraine: γ = -1.3 ÷ -1.8°C/10 cm and in the tundra: γ = -1.6°C/10 cm. In the evening, at 19:00 LMT, the regular pattern evolves into isothermy and inclines towards inversion. In the deeper layer of the ground (20-100 cm b.g.l.) the regular pattern continues throughout the day and night (Tab. 4.3, Fig. 4.3).

Table 4.3. Vertical gradients of ground temperature (°C/10 cm) at the following sites: the beach (B), the tundra (T) and the moraine (M), on the Kaffiøyra Plain, in the main times of observation (01:00, 07:00, 13:00 and 19:00 LMT) and the seasonal means (m) in the period from 21 July to 31 August 2010 and 2011

Year/sites	2010														
	Beach					Tundra					Moraine				
Hours	1	7	13	19	m	1	7	13	19	m	1	7	13	19	m
1–5 cm	-0.2	1.9	3.1	0.6	1.3	-1.3	1.4	2.7	0.3	0.8	-1.4	0.8	2.1	-0.6	0.2
1–10 cm	-0.5	1.2	2.2	0.5	0.9	-0.6	0.8	1.6	0.3	0.5	-1.3	0.3	1.8	-0.3	0.1
10–20 cm	0.1	0.6	1.7	1.0	0.8	0.2	0.5	1.0	0.9	0.6	-0.2	0.0	0.7	0.2	0.2
20–50 cm	0.5	0.4	0.6	0.8	0.6	0.4	0.2	0.5	0.6	0.4	0.1	-0.1	0.3	0.4	0.2
1–50 cm	0.3	0.6	1.1	0.8	0.7	0.2	0.4	0.8	0.6	0.5	-0.2	0.0	0.6	0.2	0.2
50–100 cm	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.2	0.2
1–100 cm	0.3	0.5	0.8	0.6	0.5	0.2	0.3	0.5	0.4	0.4	0.0	0.1	0.4	0.2	0.2
Year/sites	2011														
	Beach					Tundra					Moraine				
Hours	1	7	13	19	m	1	7	13	19	m	1	7	13	19	m
1–5 cm	-0.9	2.2	3.4	0.6	1.3	-0.6	1.2	2.7	0.7	1.0	-0.5	0.9	1.8	0.0	0.5
1–10 cm	-0.7	1.1	2.4	0.6	0.9	-0.2	0.7	1.6	0.5	0.6	-0.7	0.4	1.3	-0.2	0.2
10–20 cm	0.1	0.3	0.8	0.6	0.5	0.1	0.3	0.6	0.5	0.4	-0.1	0.2	1.2	0.8	0.5
20–50 cm	0.7	0.5	0.7	0.9	0.7	0.4	0.2	0.4	0.6	0.4	0.1	0.0	0.2	0.3	0.2
1–50 cm	0.3	0.6	1.1	0.8	0.7	0.2	0.3	0.7	0.6	0.4	-0.1	0.1	0.6	0.3	0.2
50–100 cm			0.5					0.3					0.1		
1–100 cm			0.8					0.5					0.3		

An analysis of thermo-isopleths makes it possible to see the whole picture of the distribution of ground temperature, not only at the specified levels, but also in the whole profile (1-100 cm b.g.l.) in the period of observations. The ground at individual sites demonstrates warm and cold thermal periods, caused by changes in the cloud cover and the directions of advection of air masses. There is a clear-cut delay in the transfer of heat from the surface into the deeper ground layers.

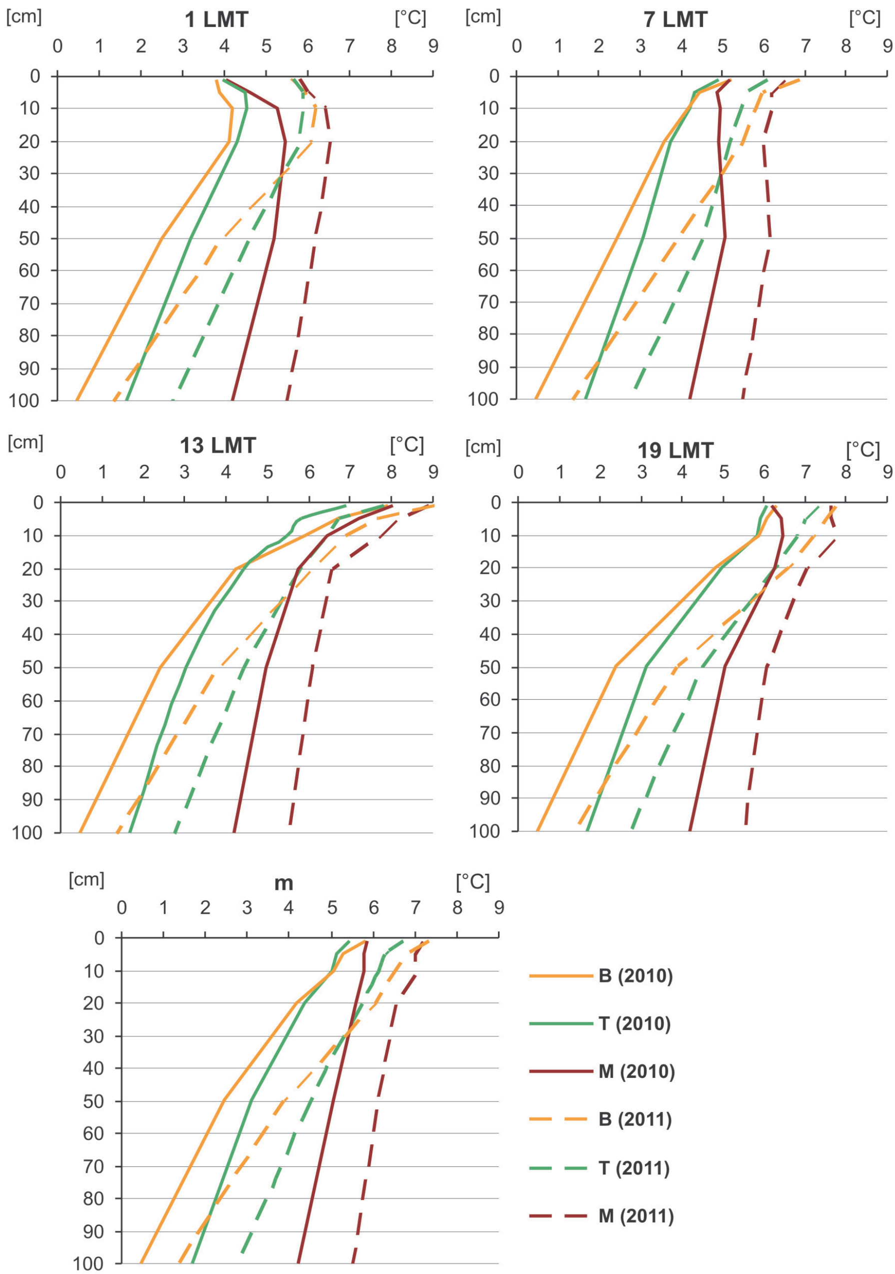

Figure 4.3. Vertical profiles of mean seasonal ground temperature at the following sites: the beach (B), the tundra (T) and the moraine (M), on the Kaffiøyra Plain, in the main times of observation (01:00, 07:00, 13:00 and 19:00 LMT) and the daily means (m) in the period from od 21 July to 31 August 2010 and 2011

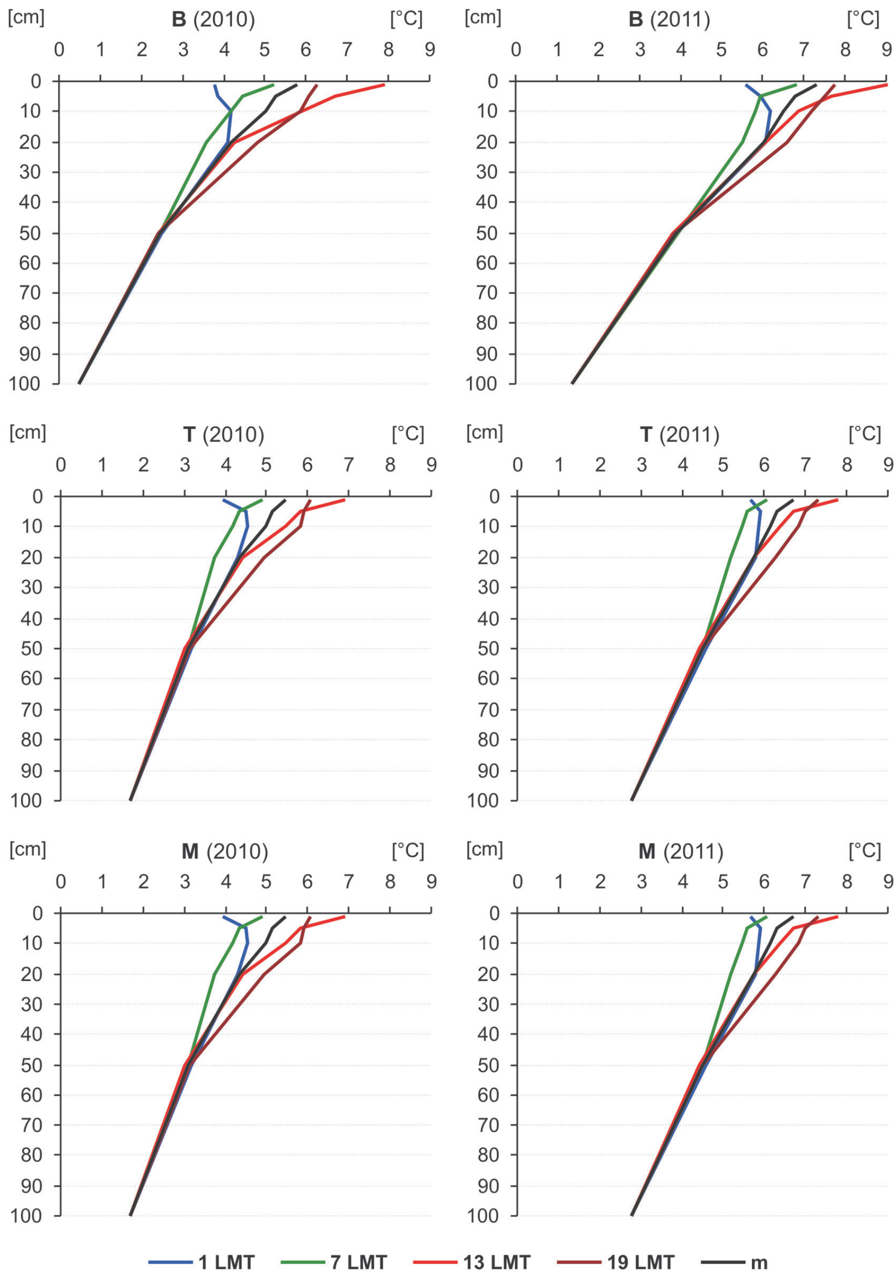

Figure 4.3. cont.

The isopleths of the ground temperature at the beach site for the summers of 2010 and 2011 have been shown in Figures 4.4 and 4.5. The arrangement of the thermo-isopleths reflects the type of weather and prevalent meteorological conditions at the time. In the season of 2010, there are four, and a year later, three periods of intense heat penetration into the ground (determined using the course of the 6.0°C isotherm). These periods were caused by a sudden increase in solar radiation, as compared to the previous periods (*cf.* Section 3.3 of this work). The warmer periods are separated by advective cooling of the ground. Particularly conspicuous are the periods from 14 to 17 August 2010, from 21 to 23 July 2011, and from 10 to 14 August 2011, when the ground gave up great amounts of heat within just few days. For example, in 2010 the diurnal ground temperature on the beach reached 5.7°C at 1 cm b.g.l. on 10 August, and fell to 1.1°C only 6 days later, whereas at 20 cm b.g.l. it dropped from 3.8°C to 1.2°C in the same period. A similar situation was observed on 21–23 July 2011, when the mean diurnal ground temperature on the beach reached 14.0°C at 1 cm b.g.l. on 21 July, only to drop to 8.8°C on 23 July, whereas at 20 cm b.g.l., the respective values were 10.9°C and 8.7°C. The other sites experienced a similar situation. The greatest heat loss in the period occurred in the subsurface layers of the ground (to 20 cm b.g.l.), after which cooling penetrates from the surface and affects the whole layer, as confirmed by the arrangement of the isopleths (Figs. 4.4 and 4.5).

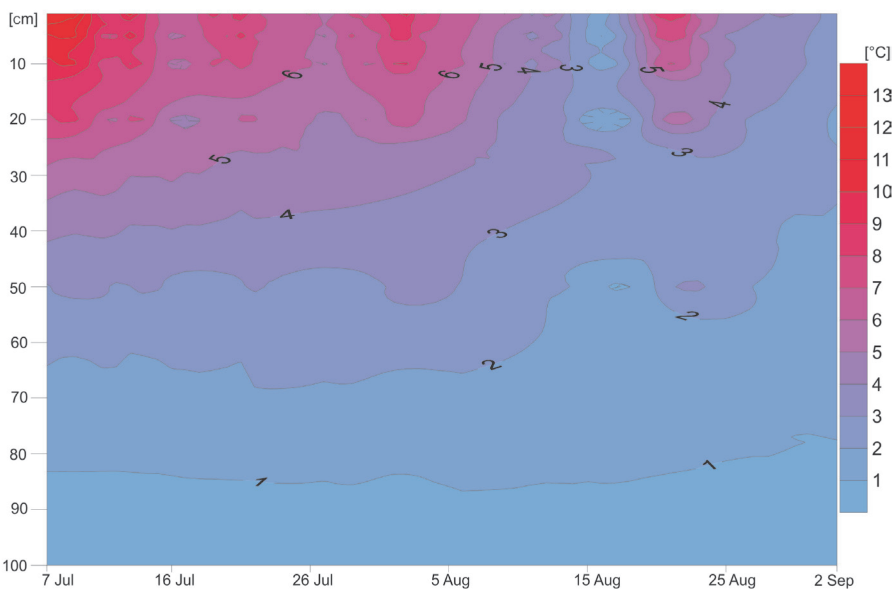

Figure 4.4. Isopleths of the ground temperature on the beach (B) site of the Kaffiøyra in the period from 7 July to 2 September 2010

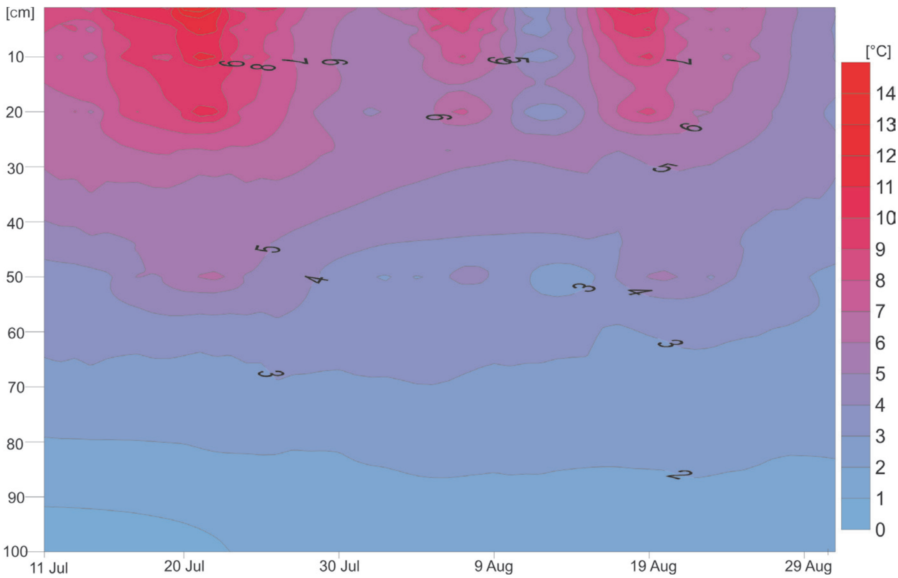

Figure 4.5. Isopleths of the ground temperature on the beach (B) site of the Kaffiøyra in the period from 11 July to 31 August 2011

4.2. Air temperature

4.2.1. Introduction

The spatial diversity of the air temperature (and a number of other meteorological elements) on a local scale was first looked into by Polish scientists during the national expedition to Hornsund, within the framework of the International Geophysical Year (IGY), in 1957. On that occasion, besides the measurements taken at a meteorological site situated near the established station, observations were conducted at a glaciological station set up in the upper part of the Werenskiöld Glacier (Kosiba 1960). At both sites, observations continued every year until 1960, however year-long measurements and observations were performed only at the time of the IGY, and were later limited to the summer season (Marsz and Styszyńska 2007).

The first topoclimatic research on Spitsbergen took place as early as between July 1899 and August 1900, during a Swedish-Russian scientific expedition to the north-eastern part of the island. Although its primary goal was to participate in the measurement of the curvature of the Prime Meridian, meteorological observations were carried out regularly at two sites: on the coast of the Treurenberg Bay, at the station building (21.9 m a.s.l.) and on the west slope of the Olimp Massif (408 m a.s.l.) (Przybylak and Dzierżawski 2004).

In the area of Hornsund, topoclimatic observations, were much more extended in space, as compared with the period of 1957-1960, and were resumed in 1970-1974 during a series of so-called 'Wrocław expeditions' (e.g. Baranowski and Głowicki 1975; Baranowski 1977; Pereyma 1983; Pereyma and Piasecki 1984). Observations there have been carried out by scientists and researchers of the University of Wrocław (either during individual projects or general expeditions, re-launched in 1978) until the present, however their time frames and range have changed from time to time. The observations have not been regular, either (e.g. Pereyma and Piasecki 1988; Pereyma and Nasiółkowski 2007; Migała et al. 2008).

The other Polish academic centre which pioneered the studies of spatial diversity of air temperature on Spitsbergen (the area of Kaffiøyra), is the Nicolaus Copernicus University in Toruń (NCU). Topoclimatic studies started in the summer of 1975, as part of the first TPE. The history of the investigations has been presented in detail in the Introduction to this monograph (Section 1.1).

In the decades that followed, topoclimatic studies which included measurements of air temperature were taken up by other academic centres, organising polar expeditions to Spitsbergen: the Maria Curie-Skłodowska University in Lublin (MCSU) in 1987 (e.g. Gluza and Piasecki 1989; Brázdil et al. 1991; Gluza et al. 2004) and the Adam Mickiewicz University in Poznań (AMU) in 2001 (e.g. Rachlewicz 2009; Bednorz and Kolendowicz 2010).

4.2.2. The complete period of observations (July 2010–August 2011)

A complete year-long cycle of measurements of topoclimatic conditions to the extent accomplished within the AWAKE project for the Forlandsundet had never been performed in Svalbard before. In the area of the Kaffiøyra, such long-term observations, although at 4 sites only (KH, ATA, LW1 and LW2), have been carried out even longer, since the summer of 2005, but have not been worked out and published yet. Therefore, this Subsection contains the first results of topoclimatic diversity in the area of the Forlandsundet, covering all the months and seasons of the year. The seasons were distinguished as proposed in the work of Putnins et al. (1959) and Gavrilova and Sokolov (1969), who defined the winter season as the period from November to March, the spring as April – May, the summer as June – August and the autumn as September and October.

The basic monthly and seasonal statistical data concerning the air temperature at 14 measuring points (sites) were collected in Tables 4.4-4.5 and Figures 4.6-4.7. At 4 of the sites the data could not be obtained due to sensor faults or damage.

The annual course of air temperature in the Forlandsundet between August 2010 and August 2011 shows three evident minimums in November, January and March. Definitely, the lowest values of monthly means at all of the sites were obtained for January (Tab. 4.4, Fig. 4.6). They ranged from -12.4°C at the PK1 site, with the highest temperatures in January, to -13.9°C at PH1. From November until March the air temperature changes were moderate. Significant temperature drops/rises are visible in the transitory seasons, autumn and spring. The temperature becomes stabilised again in the summer. The highest average monthly temperatures at most of the sites were recorded in August 2011, with the highest mean at KT (6.5°C), and the lowest on the Waldemar Glacier (LW2, 4.5°C) and in the mountains (PH1, 4.7°C).

Table 4.4. Mean monthly air temperatures (°C) in the Forlandsundet area in the period from 1 August 2010 to 31 August 2011

Sites	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
	2010					2011							
KH	3.8	1.9	-2.2	-9.4	-9.2	-13.6	-10.5	-10.5	-4.2	-1.4	4.0	5.9	5.5
SAT	3.9	2.3	-1.5	-8.6	-8.8	-13.7	-11.3	-9.8	-3.8	-1.1	4.1	6.0	5.5
SAO	3.9	1.8	-2.8	-10.6	-10.2	-13.6	-10.1	-11.1	-4.8	-1.6	3.9	6.3	6.0
KT	3.9	2.0	-2.3	-9.9	-9.3	-12.5	-8.4	-10.0	-3.7	-1.2	4.3	6.4	6.5
ATA	3.7	1.6	-2.9	-10.8	-9.9	-13.2	-8.9	-10.5	-4.2	-1.2	4.2	6.2	6.1
KU	3.3	1.4	-3.0	-10.4	-9.8	-12.6	-8.6	-10.7	-4.5	-2.3	3.3	5.4	5.8
GF	2.1	0.8	-3.9	-11.1	-10.6	-13.0	-9.4	-12.0	-5.7	-3.7	2.0	4.3	5.2
LW1	3.5	1.6	-2.9	-10.4	-9.7	-12.7	-8.7	-10.5	-4.1	-1.1	3.7	5.4	6.0
LW2	1.4	0.8	-4.1	-11.6	-10.9	-13.3	-9.3	-11.8	-5.1	-2.2	3.3	4.2	4.5
PH1	2.2	0.3	-5.3	-12.5	-12.1	-13.9	-10.5	-13.1	-5.9	-2.6	3.8	4.5	4.7
PK1	4.3	2.4	-2.0	-9.5	-9.2	-12.4	-9.0	-10.4	-4.2	-1.4	3.9	6.4	6.5
PK4	4.2	2.3	-1.8	-9.2	-8.9	-12.9	-9.5	-10.1	-4.2	-1.4	3.7	6.4	6.3
SJ1	4.2	2.5	-2.2	-9.7	-10.2	-12.7	-9.2	–	–	–	–	–	5.5
SJ3	3.3	2.2	-2.4	-10.4	-10.3	-13.3	-9.5	-11.3	-4.4	-1.4	3.5	5.6	5.7

Explanation: „ – „ - denotes lack of data

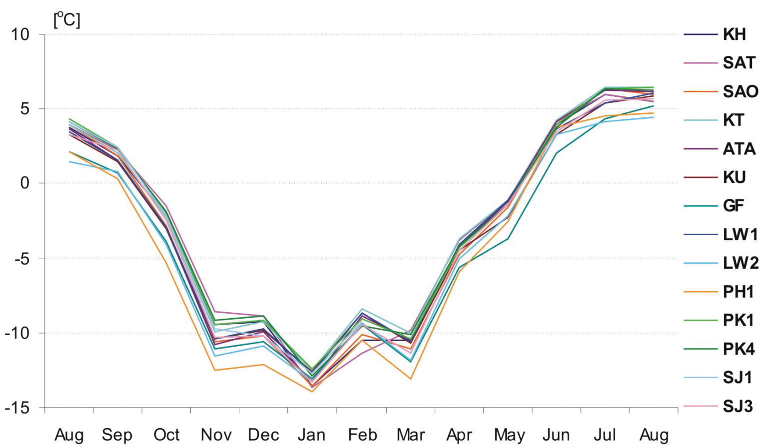

Figure 4.6. Annual course of air temperature in the Forlandsundet area in the period from August 2010 to August 2011

This is an anomaly, as the warmest month on Spitsbergen is usually July (*cf*. Przybylak 1992a). Discussing the annual pattern of air temperature, it is interesting to note the anomaly observed in February at such sites as KH, SAO, and – particularly – SAT, where the lowest monthly mean of all analysed sites was recorded (Tab. 4.4, Fig. 4.6). The extremely low temperatures in February at those sites were likely caused by the ice condition of the Forlandsundet and the frequent advective inversion connected with foehnic winds, whose occurrence should have been very common due to the considerably high positive anomaly of the frequency of influx of SE air masses (see Chapter 2).

In the other months, the coldest places were the Prins Heinrichfjella massif (September – April, without the February), Mt. Gråfjellet (May and June), and the firn area of the Waldemar Glacier (at the height of summer, in July and August). Naturally, the absolute height determined the occurrence of the lowest temperature at PH1, whereas at GF a significant factor contributing to the temperature decrease with height was the regular occurrence of low-level clouds, such as *St* and *Sc*, wreathing the mountain top. In the case of the Waldemar Glacier, the melting snow and ice surface added to the effect (a high inherent albedo and substantial energy expenditure due to the melting).

Table 4.5. Mean seasonal air temperature in the autumn (Sep-Oct), winter (Nov-Mar), spring (Apr-May), and summer (Jun-Aug), and in the period from September 2010 to August 2011

Sites	Autumn	Winter	Spring	Summer	Sep-Aug
KH	-0.1	-10.6	-2.8	5.1	-3.6
SAT	0.4	-10.4	-2.4	5.2	-3.4
SAO	-0.5	-11.1	-3.2	5.4	-3.9
KT	-0.1	-10.0	-2.4	5.7	-3.2
ATA	-0.7	-10.7	-2.7	5.5	-3.6
KU	-0.8	-10.4	-3.4	4.9	-3.8
GF	-1.6	-11.2	-4.7	3.9	-4.8
LW1	-0.7	-10.4	-2.6	5.0	-3.6
LW2	-1.7	-11.4	-3.6	4.0	-4.6
PH1	-2.5	-12.4	-4.2	4.3	-5.2
PK1	0.2	-10.1	-2.8	5.6	-3.2
PK4	0.2	-10.1	-2.8	5.5	-3.3
SJ1	0.1	-10.5*	–	–	–
SJ3	-0.1	-10.9	-2.9	4.9	-3.8

Explanations: * - Nov 2010 - Feb 2011; „ – „ - denotes lack of data

An analysis of the mean monthly values shows that in the cold half of the year (in autumn and winter) the coldest site was PH1, and – in the warm half – the GF site (Tab. 4.5). The average lowest temperature in the year was recorded at PH1 (-5.4°C). The areas with the highest temperatures, maintained over a few months, were: SAT (Oct-Dec, March and April), KT (February, April and Jun-Aug) and PK1 (January, Jul-Aug). Considering seasonal means, the markedly warmest was the site located on a coastal terrace, approx. 2 km from the shore (KT), except for autumn, in which the warmest site was the one on the Sarstangen Peninsula (SAT).

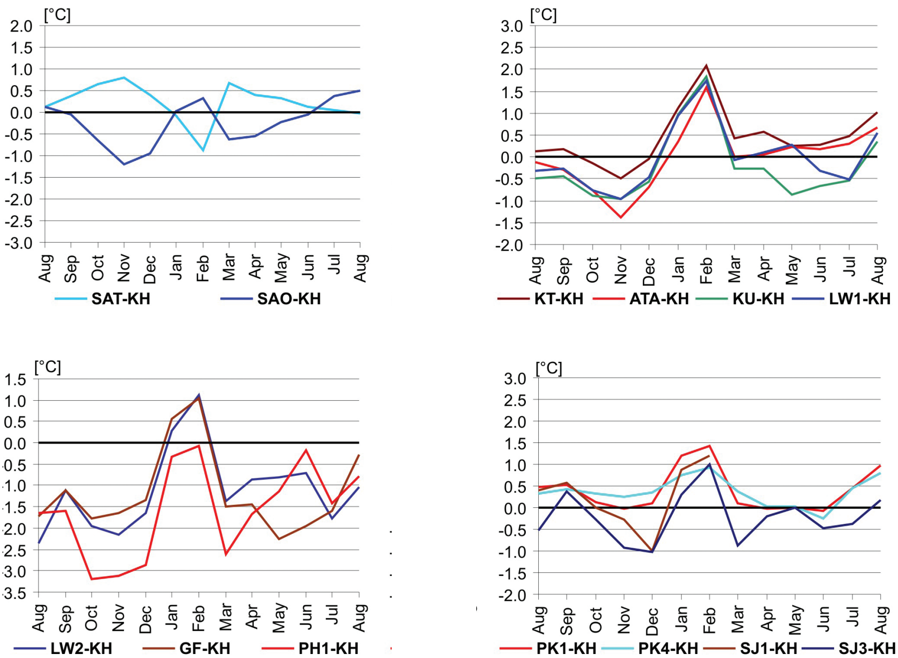

Figure 4.7. Annual course of the differences of air temperature (°C) between the sites situated in the area of the Forlandsundet and the Base Station (KH) in the period of August 2010–August 2011

In the spring, the mean value there was identical with the one recorded at KT (Tab. 4.5). The place with the highest average temperatures in the year was Prins Karls Forland island and the area around the KT site. The correlation between the temperature in the Forlandsundet area and the reference station at the Kaffiøyra is shown in Figure 4.7. The differences, both positive and negative, are generally limited to 2°C. In January and February, the spatial distribution of temperature clearly deviated from the standard, as the measurement points around the glacier (except for PH1) recorded higher temperatures than those situated on the coast, including the KH site. It is interesting to compare the thermal conditions at the sites located in close proximity (KH and SAT) with the one situated near the Forlandsundet (SAO). The SAT site, due to its position on the cape of a narrow peninsula which juts far into the Forlandsundet, is generally warmer than the Kaffiøyra site, whereas SAO, despite being sited slightly lower, is colder, which is possibly caused by the coastal cliffs hindering the influx of maritime air masses from the Sound. This effect is particularly visible in the cold half of the year, disappearing in the summer when more impact comes from the tundra vegetation, which intensely absorbs solar radiation. For that reason, and because of the flat ground surface, in the summer the site is warmer than KH (Fig. 4.7), with a convex base in the form of the terminal-lateral moraine of the Aavatsmark Glacier.

All sites located at 100 m a.s.l. or higher, which are mostly colder than the reference site throughout the year (Fig. 4.8A), become notably warmer when the influence of absolute height is removed using a gradient of 0.6°C/100 m (Fig. 4.8B). Therefore, having reduced the temperature to sea level the sites that were actually colder than the Kaffiøyra site are only SAO (except for summer) and SJ3 (except for autumn). In the autumn, the highest values of such reduced temperature were observed on the firn field of the Waldemar Glacier, and in the winter (besides LW2), also on Mt. Gråfjellet. In the spring, and the summer in particular, the warmest was the PH1 site. Differences in the mean seasonal values of air temperature between the sites, either actual or reduced to sea level, reached 2-3°C; considering their geographic proximity, they are therefore very significant.

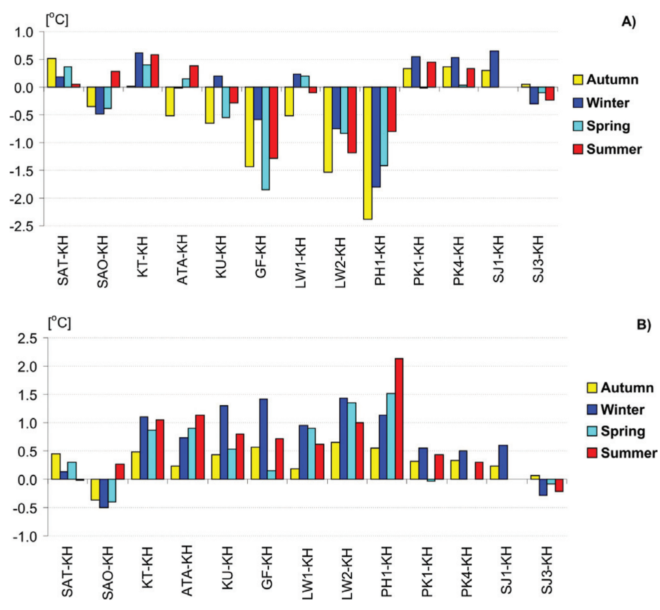

Figure 4.8. Differences in mean seasonal values of air temperature (°C) between the sites situated in the area of the Forlandsundet and the Base Station (KH) in the autumn (Sep-Oct) of 2010, winter (Nov-Mar) of 2010/2011, spring (Apr-May) of 2011, and summer (Jun-Aug) of 2011 A) – actual temperature recorded, B) – temperature reduced to sea level

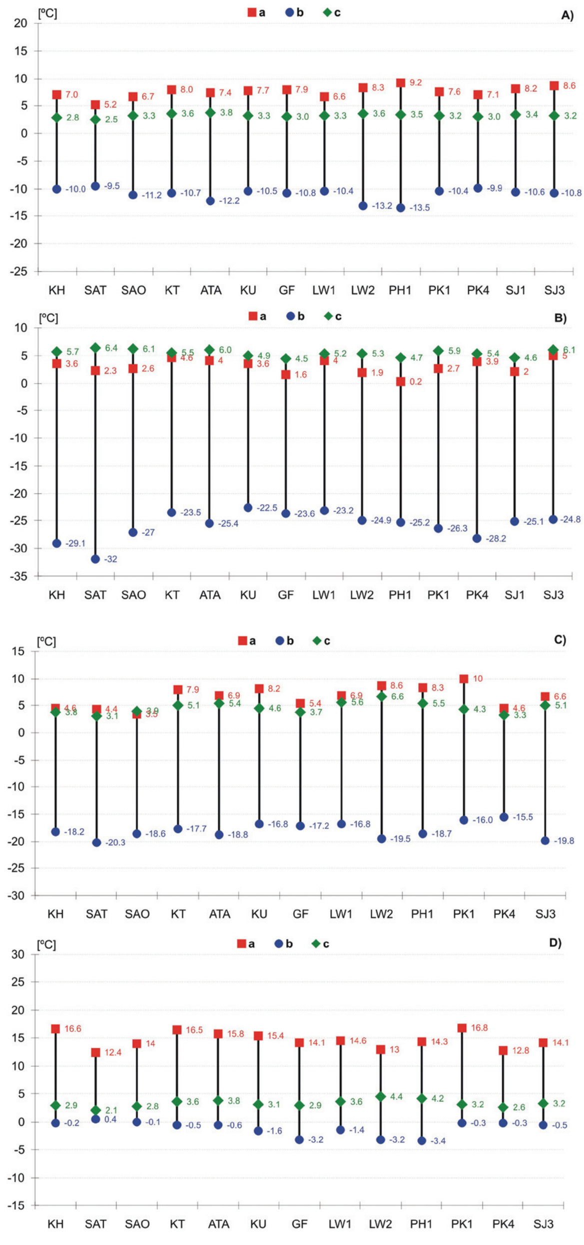

Figure 4.9. Values of absolute maximum (a), absolute minimum (b) and mean diurnal range (c) of air temperature in the area of the Forlandsundet in the autumn (Sep–Oct) of 2010 (A), winter (Nov–Dec) of 2010/2011 (B), spring (Apr–May) of 2011 (C) and summer (Jun–Aug) of 2011 (D)

The range of changes in the absolute values of air temperature (maximum and minimum) recorded at the measuring points in all four seasons of the year has been shown in Figure 4.9.

The highest values of maximum temperature in the summer at all sites considerably exceeded 10°C, ranging from 12.4°C at the SAT site (characterised by the most oceanic climate), to 16.8°C (on 17 August 2011) on the west coast of Prins Karls Forland (PK1). In the winter, the absolute maximum temperature changed in a similar pattern, ranging from 0.2°C at PH1 to 5.0°C at SJ3. In the spring, the diversity of the temperatures was the greatest, reaching 6.5°C and ranging from 3.5°C (SAO) to 10.0°C (PK1). In the autumn, the highest values of air temperature did not exceed 10°C, and their distribution was comparable to the summer pattern. Extreme values were recorded in the summer at SAT (5.2°C) and PH1 (9.2°C). Both the lowest and the highest seasonal absolute minimum temperatures were recorded at the SAT site: -32.0°C in the winter (31 January and 1 February 2011) and 0.4°C in the summer. At the same site, the lowest minimum temperature was also recorded in the spring (-20.3°C), and the highest in the autumn (-9.5°C). As a consequence, SAT can be considered as characterised by the most extreme temperature conditions. The other site distinguished by such conditions is the Prins Heinrichfjella, where the lowest air temperatures were recorded in the autumn (-13.4°C) and summer (-3.4°C). The minimum temperature decreased the least in the winter at KU (to -22.5°C only), and in the spring at PK4 (-15.5°C) (Fig. 4.9). In the winter the range of changes is more than twice as great as in the other seasons of the year.

The diurnal course of air temperature in the area of the Forlandsundet is considerably diversified, as shown in Figure 4.10. In the autumn, mean courses (Fig. 4.10A) at most of the sites display clear rises in value in the afternoon, as well as drops in the 'night' hours from 21:00 to 06:00. A lack of diversity in the diurnal course of temperature is noticeable at the SAT site (with the greatest oceanicity of the climate) and at GF (where the measuring point is located at the height of low-level clouds). In the winter, the diurnal courses are balanced and the occurrence of any highest or lowest hourly values of air temperature is random (Fig. 4.10B). However, the diurnal ranges of the air temperature are the greatest in the winter, typically exceeding 5°C, except for LW1, LW2 and PH1, where the greatest ranges were observed in the spring (Fig. 4.9). The spring ranges at the remaining sites are greater than those observed in the summer or autumn. In the spring, the highest seasonal mean range of 6.6°C was recorded at the LW2 site. Mean diurnal courses of air temperature were the most evident in that season (Fig. 4.10C), even at the sites located at Mt. Gråfjellet and on the Sarstangen. In the summer, diurnal courses of air temperature were still well-developed, with the exception of the SAT and PH1 sites, where the range was exceptionally uniform. The mean highest temperatures, as well as the lowest, occurred at the same times of the day as in the autumn, described above. Although the mean diurnal courses in the summer are much more clear-cut than in the autumn (Fig. 4.10D), their mean diurnal ranges are similar, however the summer is characterised by a greater spatial diversity (Fig. 4.9).

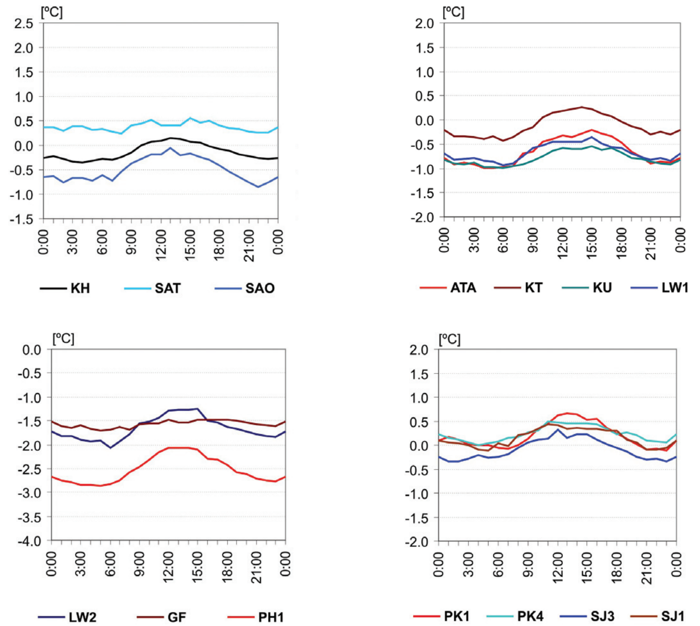

Figure 4.10A. Mean diurnal course of air temperature in the autumn (Sep–Oct) of 2010 in the area of the Forlandsundet

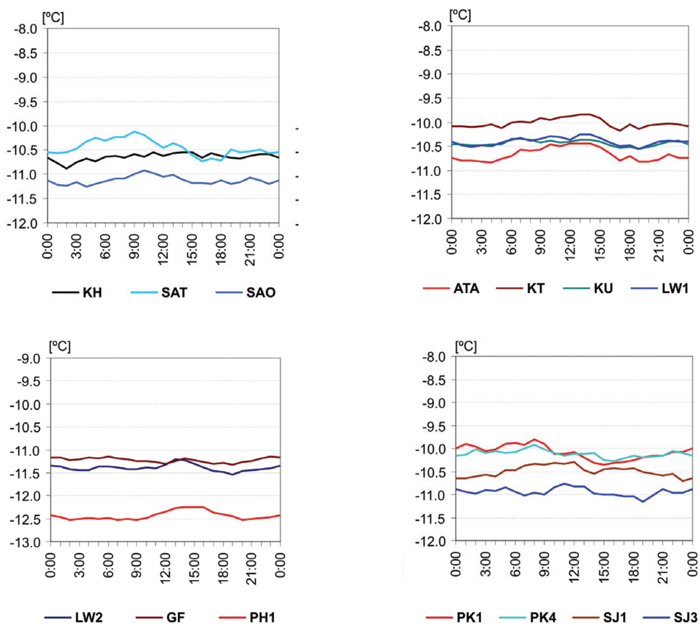

Figure 4.10B. Mean diurnal course of air temperature in the winter (Nov–Mar) of 2010/2011 in the area of the Forlandsundet

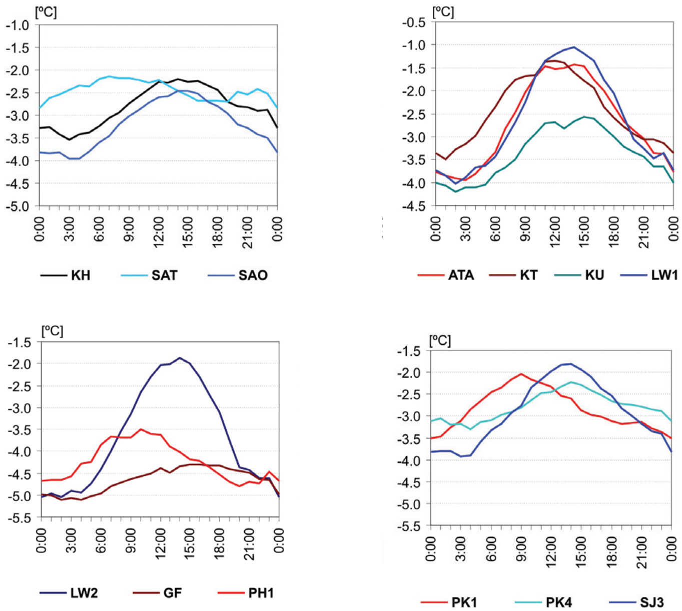

Figure 4.10C. Mean diurnal course of air temperature in the spring (Apr–May) of 2011 in the area of the Forlandsundet

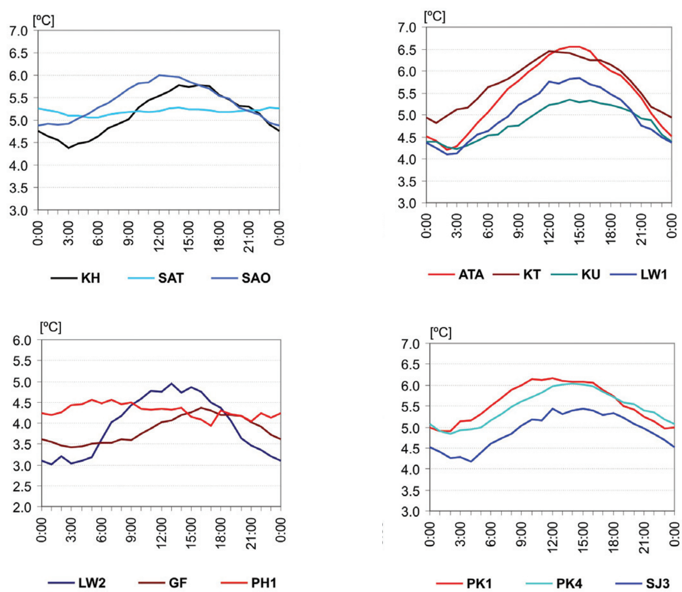

Figure 4.10D. Mean diurnal course of air temperature in the summer (Jun–Aug) of 2011 in the area of the Forlandsundet

In order to better understand the topoclimatic characteristics of the area of Forlandsundet the frequency of occurrence of the so-called ‘characteristic days’ was also determined, according to the proposition presented for the Canadian Arctic by Przybylak and Vizi (2005). In the winter, frost days (*T*max < 0°C) occurred with a frequency of 27.9% of all days at SJ1 to 41.7% at PH1 and slight frost days (*T*max > 0°C and *T*min ≤ 0°C) between 18% at SAT and 42.6% at LW2. These two types were the most frequent (Fig. 4.11A).

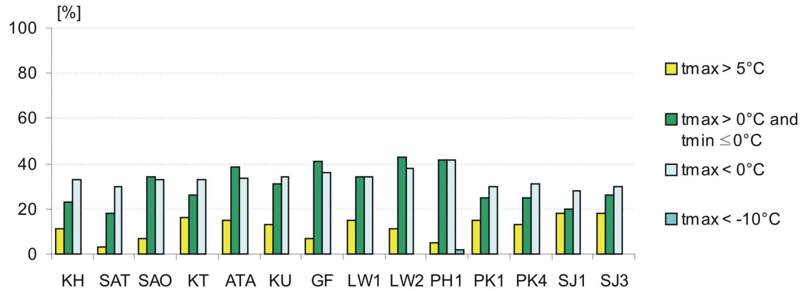

Figure 4.11A. Relative frequency of occurrence (%) of characteristic days in the area of the Forlandsundet in the autumn (Sep–Oct) of 2010

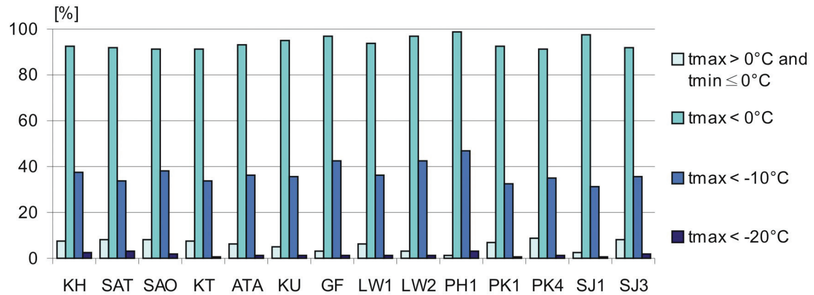

Figure 4.11B. Relative frequency of occurrence (%) of characteristic days in the area of the Forlandsundet in the winter (Nov–Mar) of 2010/2011

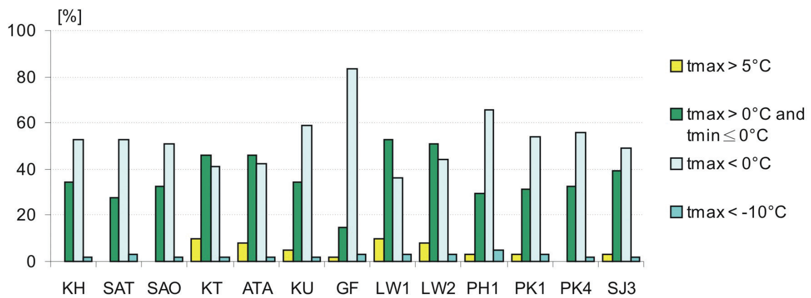

Figure 4.11C. Relative frequency of occurrence (%) of characteristic days in the area of the Forlandsundet in the spring (Apr–May) of 2011

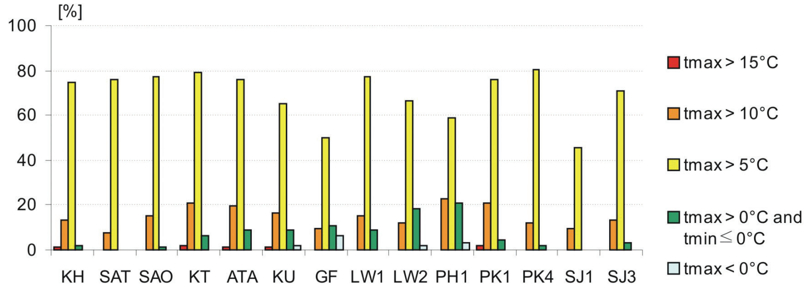

Figure 4.11D. Relative frequency of occurrence (%) of characteristic days in the area of the Forlandsundet in the summer (Jun–Aug) of 2011

The number of days on which the maximum temperature exceeded 5°C (from 3.3% at SAT to 18% at SJ1 and SJ3) were quite frequent. Cold days (*T*max < -10°C) occurred only at the highest elevated site, PH1, yet even there only with a very low frequency (1.7%). In the winter, at all sites frost days prevailed (>90%) and there were a lot of cold days, as well (Fig. 4.11B). As expected, cold days were noted the most often at the PH1 site (47%), and the least often at SJ1 (31.1%). Very cold days (*T*max < -20°C) occurred at all of the sites, however with a low frequency. Also, there were very few days with slight frost (< 10%). In the spring, like in the autumn, at most of the sites frost days prevailed, with the maximum frequency observed at Mt. Gråfjellet (83.6%), and the minimum at LW1 (36.1%) (Fig. 4.11C). Slight frost days were a little less frequent, ranging from 52.5% at LW1 to 14.8% at Mt. Gråfjellet. Positive temperature values of 5°C or more occurred with the frequency of <10%, and at a few of the sites (KH, SAT, SAO and PK4), which were subject to the greatest oceanicity of the climate, did not occur at all. Cold days were occasionally noted. In the summer, the most common of the characteristic days were warm days (*T*max > 5°C), whose frequency ranged from 45.7% at SJ1 to 80.4% at PK4 (Fig. 4.11D). Very warm days were also common – from 7.6% at SAT to as much as 22.8% at the highest situated measuring point, PH1. At 5 sites (KH, KT, ATA, KU and PK1) exceptionally warm days (*T*max > 15°C) were observed. At most of the sites slight frost days were noted, and their highest frequency was recorded at PH1. Frost days occurred at 4 sites only (KU, GF, LW2 and PH1).

4.2.3. The summer period (21 July–31 August)

The description of the spatial diversity of air temperature in the area of the Forlandsundet mainly utilises the data concerning individual ten-day periods and the whole common period of observations for all sites. The information in Table 4.6 clearly shows that the summer of 2011 was much warmer (by approx. 1.5 – 2.5°C) at all analysed sites in comparison with the summer of 2010 (see also Appendixes 1 and 2). The main reason for that was the influence of atmospheric circulation, which in 2011 was generally close to its long-term standard, but in 2010 exhibited a major positive anomaly in the occurrence of air masses from the north (Section 2.1). The biggest difference was observed at the GF site (2.7°C), and the smallest at SAT and SJ (1.2°C). The noted significant seasonal diversity between individual sites can be explained by:

i) Different radiation balance trends in both seasons at the KH site (decrease), representing well-ventilated coastal areas, and at the LW2 site (increase), representing the interior of the island with restricted access of air masses, inflowing as part of the general atmospheric circulation (Chapter 3, Tab. 3.13), and

ii) The considerable influence of local conditions on radiation and circulation relations shaping the weather in the area of the Forlandsundet.

Most of the sites located below 100 m a.s.l. were warmer in the summer of 2010 than the reference site at the Base Station (KH), with the exception of PK2 (middle of Prins Karls Forland) and SJ3 (cooling influence of the nearby glaciers) (Tab. 4.6). The highest mean values of air temperature were recorded on the west coast of Prins Karls Forland (PK1, 4.6°C) in 2010, but on the east coast in 2011 (PK3, 6.5°C). It was also notably warmer, compared to the area of the Kaffiøyra, at St. Jonsfjorden. All the sites located above 100 m a.s.l. had mean temperatures lower than 4.0°C (in 2010) and 5.0°C in 2011 (Tab. 4.6). However, the coldest place in both years was not the highest elevated mountain ridge (i.e. PH1 and PH2), but the firn field of the Waldemar Glacier (LW2 – 1.6°C and 4.1°C in the summers of 2010 and 2011, respectively). This means that on Spitsbergen the cooling power of the ice cover is more significant in the summer than the cooling effect of the absolute height. It is also noteworthy that the air temperature at Mt. Gråfjellet (GF), situated at a height of 345 m a.s.l., was relatively low (2.2°C) in 2010. In that year, it was the same as at the PH1 site (500 m a.s.l.) and only slightly lower (by 0.2°C) than at the PH2 site (590 m a.s.l.). The low temperature at the mountain site was likely caused by frequent covering of the ridge with *St* or *Sc* clouds of modest thickness, which might not always reach the higher parts of the Prins Heinrichfjella, where the PH1 and PH2 sites are situated.

It is interesting to look into the spatial diversity of air temperature when the influence of absolute height is removed using a gradient of 0.6°C/100 m. Except for two sites (SJ3 and LW2) in 2010 and one (SAT) in 2011, all the others were warmer than on the Kaffiøyra Plain (Tab. 4.7, Fig. 4.12). In the case of ten-day values of the differences in air temperature, there were a little more situations where the reference station was warmer than some other sites. Such cases were markedly more common in the summer of 2010 than in the following summer (Fig. 4.12). The highest-located sites, i.e. those situated on the ridge of the Prins Henrichfjella (PH1 and PH2), turned out to be notably warmer. In comparison with the Kaffiøyra, the air temperature there was higher, on average, by 1.0-1.3°C in the analysed period of 2010, and by as much as 1.9-2.3°C in 2011. Furthermore, in some of the ten-day periods, it reached nearly 3°C in both summer seasons (Fig. 4.12).

Table 4.6. Mean values of air temperature (°C) in the area of the Forlandsundet in the summer seasons of 2010 and 2011

Sites	21–31 Jul		01–10 Aug		11–20 Aug		21–31 Aug		21 Jul–31 Aug	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
KH	5.1	5.4	4.9	5.4	3.1	6.4	3.5	4.8	4.1	5.5
SAT	5.3	5.6	5.0	5.4	3.4	6.0	3.6	5.0	4.3	5.5
SAO	5.2	5.8	4.9	6.1	3.3	6.9	3.6	5.1	4.3	5.9
KT	4.9	6.1	4.7	6.6	3.4	7.7	3.8	5.4	4.2	6.4
ATA	4.6	5.5	4.5	6.6	3.1	7.2	3.5	4.8	3.9	6.0
KU	4.0	5.0	3.9	5.9	2.8	7.1	3.2	4.6	3.5	5.6
GF	2.6	3.9	2.5	5.2	1.5	6.5	2.2	4.1	2.2	4.9
LW1	4.4	5.2	4.2	6.5	3.0	6.9	3.3	4.8	3.7	5.8
LW2	1.9	3.2	1.8	4.7	0.9	5.7	1.6	3.0	1.6	4.1
PH1	2.2	3.7	2.3	4.9	1.4	5.7	2.8	3.6	2.2	4.4
PH2	1.8	3.8	2.4	4.7	1.0	5.3	2.8	3.5	2.0	4.3
PK1	5.3	5.4	4.8	6.9	3.9	7.1	4.2	5.4	4.6	6.2
PK2	4.6	5.0	4.3	6.2	3.3	6.6	3.6	4.7	4.0	5.6
PK3	5.3	6.3	5.1	7.3	3.8	7.1	4.0	5.5	4.5	6.5
PK4	5.3	6.0	4.7	6.6	4.1	6.9	3.4	5.5	4.4	6.2
SJ1	5.4	6.3	5.4	6.4	3.6	6.2	3.6	4.1	4.5	5.7
SJ2	5.1	6.7	5.1	7.0	3.4	7.0	3.3	4.8	4.3	6.4
SJ3	4.5	5.3	4.2	6.3	3.0	6.9	2.8	3.9	3.6	5.6

Table 4.7. Mean values of air temperature reduced to sea level (°C) at the Base Station (KH) and their differences in relation to the other analysed sites in the area of the Forlandsundet in the summer seasons of 2010 and 2011

Sites	21–31 Jul		01–10 Aug		11–20 Aug		21–31 Aug		21 Jul–31 Aug	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
KH	5.1	5.5	4.9	5.5	3.2	6.4	3.6	4.8	4.2	5.5
SAT-KH	0.1	0.1	0.1	-0.1	0.3	-0.5	0.0	0.2	0.1	0.0
SAO-KH	0.2	0.4	0.1	0.7	0.2	0.5	0.0	0.3	0.1	0.5
KT-KH	0.3	1.2	0.3	1.6	0.8	1.8	0.7	1.1	0.5	1.4
ATA-KH	0.3	0.8	0.4	1.9	0.7	1.6	0.7	0.8	0.5	1.3
KU-KH	0.1	0.7	0.2	1.6	0.8	1.8	0.8	1.0	0.5	1.2
GF-KH	-0.4	0.5	-0.3	1.8	0.4	2.1	0.7	1.3	0.1	1.4
LW1-KH	0.0	0.5	0.0	1.9	0.6	1.2	0.5	0.7	0.3	1.0
LW2-KH	-1.0	0.0	-0.8	1.5	0.0	1.5	0.2	0.5	-0.4	0.8
PH1-KH	0.0	1.2	0.4	2.4	1.2	2.2	2.2	1.8	1.0	1.9
PH2-KH	0.2	1.9	1.0	2.7	1.4	2.4	2.7	2.2	1.3	2.3
PK1-KH	0.2	0.0	0.0	1.5	0.8	0.7	0.7	0.6	0.4	0.7
PK2-KH	-0.1	-0.1	-0.2	1.1	0.6	0.6	0.4	0.3	0.2	0.5
PK3-KH	0.2	0.8	0.2	1.9	0.6	0.7	0.4	0.8	0.4	1.0
PK4-KH	0.2	0.5	-0.2	1.2	1.0	0.5	-0.2	0.7	0.2	0.7
SJ1-KH	0.3	0.9	0.4	0.9	0.4	-0.2	0.1	-0.7	0.3	0.2
SJ2-KH	0.0	1.3	0.2	1.6	0.3	0.6	-0.2	0.0	0.1	0.8
SJ3-KH	-0.5	-0.1	-0.6	1.0	-0.1	0.6	-0.8	-0.8	-0.5	0.1

The fact that the differences in the air temperature in the mountains and on the glaciers (or in areas subject to glacial influences) were much greater, as compared with the reference site values (KH), in 2011 than in 2010 is probably connected with the specific radiation balance which – in 2011 – was much more favourable in the inner part of the island (LW2) than on the coast (KH) (see Chapter 3, Tab. 3.13 of this work). Comparable or lower values of air temperature than on the Kaffiøyra Plain, recorded at the sites referred to earlier, resulted from a similar influence of maritime air masses and/or cool weather associated with the glacial surfaces (direct at LW2, or indirect at SJ3, through katabatic wind).

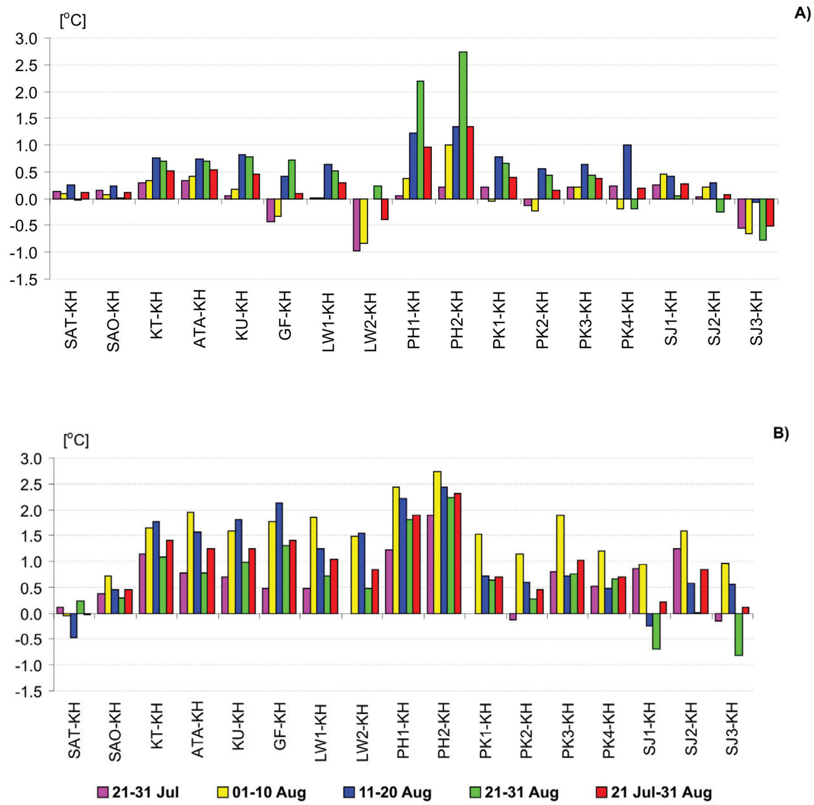

Figure 4.12. Differences in mean ten-day values of air temperature (°C) reduced to sea level between the observation sites in the area of the Forlandsundet and the Base Station (KH) in the summer seasons of 2010 (A) and 2011 (B)

The highest and the lowest recorded values of air temperature, as well as the mean temperature ranges in the reference period are shown in Tables 4.8-4.10 and Figure 4.13.

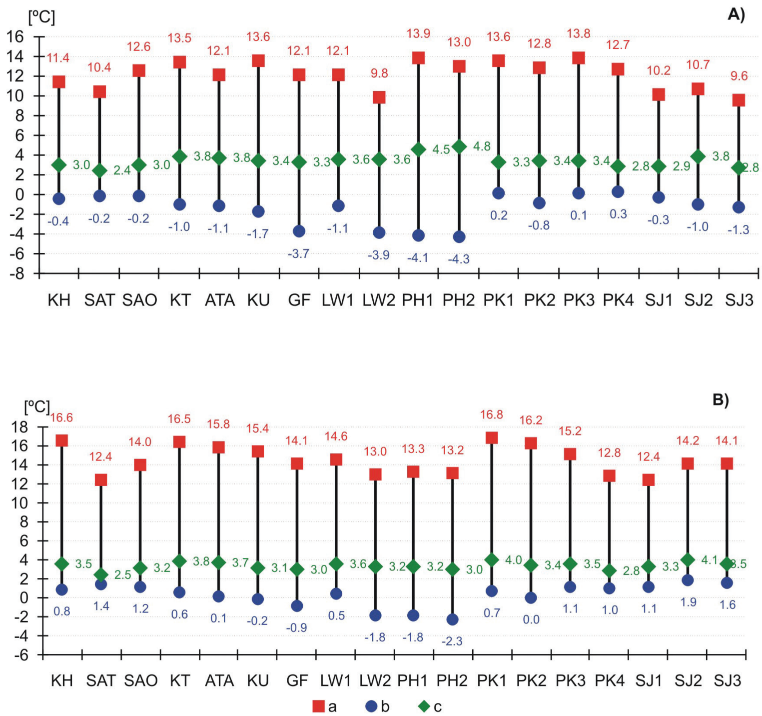

Figure 4.13. Air temperature values: absolute maximum (a), absolute minimum (b) and diurnal mean range (c) in the area of the Forlandsundet in the periods of 21Jul–31 Aug in 2010 (A) and 2011 (B)

Prominently higher absolute maximum values of air temperature occurred at the mountain sites (particularly in 2010) and those located far from the sea, and the lowest temperatures were observed at glaciated sites and/or those lying near glaciers or the open sea (except for the KH site in 2011, where an exceptionally high maximum temperature was recorded, prompted by a strong foehnic wind). The highest maximum temperature of 13.9°C in the summer of 2010 was noted at PH1 on 20 August. In the following year, the highest temperature was 16.8°C and occurred at PK1 on 17 August. The lowest maximum temperatures (9.6°C in 2010 and 12.4°C in 2011) were recorded at SJ3 on 20 August 2010, and at SAT (17 August 2011) and SJ1 (18 August 2011). As expected, the lowest values of the minimum temperature in both years were noted at PH2: in the summer of 2010 it was -4.3°C (16 August), and in the following summer, -2.3°C (11 August). The highest values of minimum temperature exceeded 0°C, reaching 0.3°C in the summer of 2010 (at PK4 on 16 August), and 1.9°C in the summer of 2011 (at SJ2 on 11 August). The range of diversity of absolute temperatures at individual sites exceeds 4°C and is greater than in the case of mean values (Tables 4.8-4.9, Fig. 4.13).

An analysis of mean diurnal ranges of air temperature yields some interesting observations. The highest values of the temperature ranges in the summer of 2010 were evidently recorded at the highest-elevated sites (PH1 and PH2), where they reached 4.5 and 4.8°C, respectively (Tab. 4.10, Fig. 4.13A). Most probably, the reason for this was intense warming of the mountain ridges situated relatively often above the reach of low clouds, which prevents the lower-lying areas from such warming. In the summer of 2011, on the other hand, the diurnal range was not as high there (Fig. 4.13B). Increased values of air temperature ranges occurred in the forefield of the Waldemar Glacier and in the central part of the St. Jonsfjorden (SJ2, southern exposure). As anticipated, the lowest diurnal ranges were noted at the sites under the strongest maritime influences, i.e. at SAT (2.4-2.5°C), PK3 (2.8°C) and SJ3 (2.8°C, only in 2010). The SAT site, located at the end of a narrow peninsula jutted far into the Forlandsundet (Fig. 1.1, Section 1.2), has a notably lower range (by approx. 0.6-1.0°C on average) than the nearby two coastal sites of SAO and KH.

Table 4.8. Maximum values of air temperature (°C) in the area of the Forlandsundet in the summer seasons of 2010 and 2011

Sites	21–31 Jul		01–10 Aug		11–20 Aug		21–31 Aug		21 Jul–31 Aug	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
KH	7.2	10.4	8.4	11.6	11.4	16.6	10.2	8.4	11.4	16.6
SAT	7.8	10.6	8.1	10.6	10.4	12.4	9.1	7.6	10.4	12.4
SAO	7.6	10.1	8.0	11.4	12.6	14.0	10.5	7.9	12.6	14.0
KT	8.2	11.4	9.6	12.2	13.5	16.5	12.8	10.5	13.5	16.5
ATA	7.7	10.9	9.4	11.8	12.1	15.8	11.8	9.8	12.1	15.8
KU	6.8	9.5	8.4	11.1	13.6	15.4	11.8	10.0	13.6	15.4
GF	5.8	8.9	7.3	10.2	12.1	14.1	10.6	9.8	12.1	14.1
LW1	8.2	10.6	8.7	11.6	12.1	14.6	10.6	9.5	12.1	14.6
LW2	7.1	7.3	6.3	8.8	9.8	13.0	9.2	8.6	9.8	13.0
PH1	8.4	10.6	8.0	11.8	13.9	13.3	12.2	10.8	13.9	13.3
PH2	8.3	9.3	8.0	10.8	13.0	13.2	12.7	10.2	13.0	13.2
PK1	7.9	11.0	8.9	11.8	13.6	16.8	12.3	9.2	13.6	16.8
PK2	7.6	9.4	8.4	10.6	12.8	16.2	10.9	8.8	12.8	16.2
PK3	7.6	11.4	9.9	11.2	13.8	15.2	11.4	9.6	13.8	15.2
PK4	8.3	11.0	7.1	10.9	12.7	12.8	7.9	8.2	12.7	12.8
SJ1	7.7	10.0	9.5	11.6	10.2	12.4	9.3	7.1	10.2	12.4
SJ2	8.3	10.6	9.5	13.2	10.7	14.2	9.6	8.9	10.7	14.2
SJ3	7.0	9.1	6.8	12.2	9.6	14.1	9.0	7.9	9.6	14.1

Table 4.9. Minimum values of air temperature (°C) in the area of the Forlandsundet in the summer seasons of 2010 and 2011

Sites	21–31 Jul		01–10 Aug		11–20 Aug		21–31 Aug		21 Jul–31 Aug	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
KH	2.8	1.3	1.4	1.9	-0.4	0.8	0.6	2.4	-0.4	0.8
SAT	2.8	2.0	1.6	2.6	-0.2	1.4	1.3	3.4	-0.2	1.4
SAO	3.0	1.9	1.5	1.8	-0.2	1.2	0.4	2.8	-0.2	1.2
KT	2.3	1.5	0.9	1.6	-1.0	0.6	0.0	2.1	-1.0	0.6
ATA	2.3	1.4	0.8	1.1	-1.1	0.1	-0.3	1.7	-1.1	0.1
KU	1.4	1.1	0.2	0.6	-1.7	-0.2	-0.6	1.3	-1.7	-0.2
GF	0.1	-0.2	-1.4	-0.5	-3.7	-0.9	-1.8	0.4	-3.7	-0.9
LW1	2.3	1.2	0.7	1.3	-1.1	0.5	-0.4	1.7	-1.1	0.5
LW2	-0.2	-0.7	-1.6	-1.1	-3.9	-1.8	-2.9	-0.3	-3.9	-1.8
PH1	-0.6	-0.3	-1.5	-1.2	-4.1	-1.8	-2.5	-0.5	-4.1	-1.8
PH2	-0.8	0.6	-2.0	-1.5	-4.3	-2.3	-3.0	-0.5	-4.3	-2.3
PK1	3.4	0.7	1.4	2.0	0.2	0.8	0.8	2.5	0.2	0.7
PK2	2.4	0.4	0.9	1.4	-0.8	0.0	0.1	1.5	-0.8	0.0
PK3	3.2	1.4	1.4	2.9	0.1	1.1	0.6	2.6	0.1	1.1
PK4	3.2	2.1	1.4	2.8	0.3	1.0	0.7	2.7	0.3	1.0
SJ1	3.8	3.7	2.5	2.5	0.3	1.1	-0.3	1.7	-0.3	1.1
SJ2	3.3	2.7	1.9	3.6	0.2	1.9	-1.0	2.3	-1.0	1.9
SJ3	3.1	2.0	1.6	2.4	0.2	1.6	-1.3	1.6	-1.3	1.6

Table 4.10. Mean diurnal ranges of air temperature (°C) in the area of the Forlandsundet in the summer seasons of 2010 and 2011

Sites	21–31 Jul		01–10 Aug		11–20 Aug		21–31 Aug		21 Jul–31 Aug	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
KH	2.4	2.9	3.0	4.3	3.3	4.8	3.2	2.3	3.0	3.5
SAT	2.0	2.4	2.6	3.1	2.6	3.0	2.6	1.4	2.4	2.5
SAO	2.3	2.9	3.0	4.1	3.5	3.8	3.1	2.0	3.0	3.2
KT	3.1	3.3	3.8	5.0	4.5	4.5	4.1	2.6	3.8	3.8
ATA	3.1	3.2	3.8	4.9	4.0	4.4	4.2	2.7	3.8	3.7
KU	2.9	2.8	3.5	4.5	3.7	3.1	3.7	2.3	3.4	3.1
GF	3.2	2.5	3.3	4.0	3.8	3.2	3.0	2.3	3.3	3.0
LW1	3.3	3.4	3.6	5.0	3.7	3.4	4.0	2.8	3.6	3.6
LW2	3.1	3.1	3.6	4.4	3.8	3.1	3.8	2.4	3.6	3.2
PH1	4.0	3.5	4.1	4.2	5.1	2.9	5.0	2.4	4.5	3.2
PH2	3.8	3.2	4.6	3.6	5.3	3.1	5.5	2.2	4.8	3.0
PK1	2.5	3.4	2.7	5.2	4.1	5.3	3.9	2.5	3.3	4.0
PK2	2.9	3.0	3.2	4.2	4.0	4.6	3.7	2.2	3.4	3.4
PK3	2.8	3.2	3.4	4.4	3.8	4.3	3.7	2.4	3.4	3.5
PK4	2.6	3.0	2.9	3.5	3.1	3.1	2.7	1.7	2.8	2.8
SJ1	2.3	3.2	3.2	4.3	3.0	3.4	3.0	2.4	2.9	3.3
SJ2	2.8	3.6	3.9	5.0	4.6	4.6	4.1	3.2	3.8	4.1
SJ3	2.4	3.0	2.5	5.0	3.3	3.9	2.8	2.3	2.8	3.5

In individual ten-day periods, and particularly on individual days, the general outline of spatial diversity presented so far may be substantially different (Tables 4.6-4.9, Figs. 4.12-4.16), as the differences between the coldest and the warmest areas on any given day range from 3 to 4°C (Fig. 4.14).

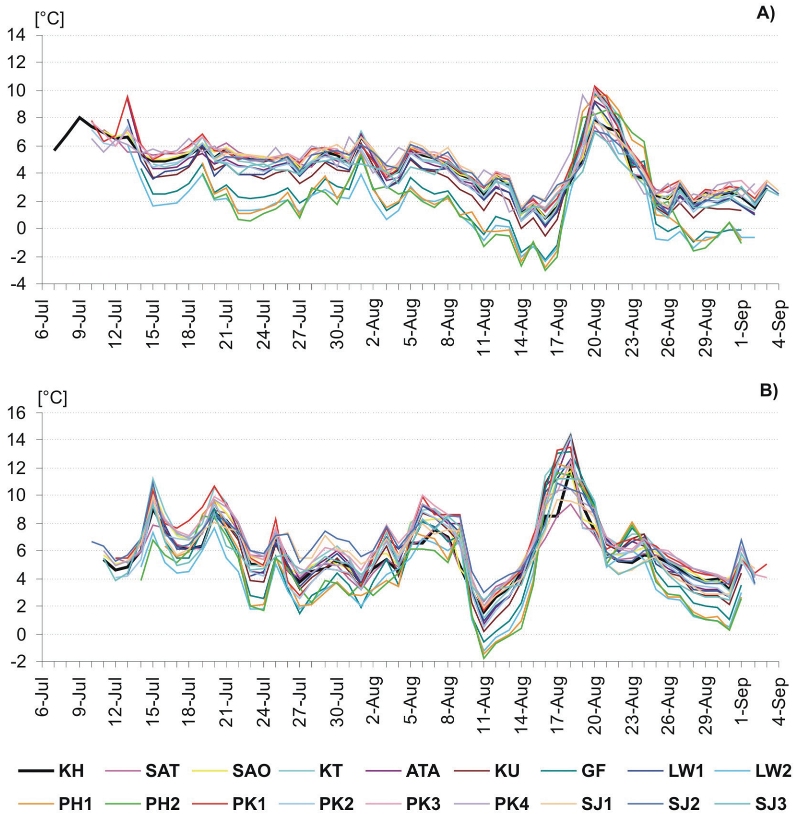

Figure 4.14. Course of mean diurnal air temperature in the area of the Forlandsundet in the summer seasons of 2010 (A) and 2011 (B)

In comparison to the reference point, the greatest differences, whether positive or negative, do not exceed 4°C (Figs. 4.15-4.16). In 2010, the differences are distinctly more stable than in the summer of 2011. In both summer seasons, they are the smallest, on average, at the SAT and SAO sites, and the greatest at the highest sites (LW2, GF, PH1 and PH2). In the former case, the differences usually range from -1 to +1°C, and from -3 to +3°C, in the latter. The pattern of spatial diversity of air temperature undergoes significant changes in the periods of sudden warming, which in both seasons occurred at a similar time, namely at the beginning of the second half of August (Figs. 4.14-4.16).

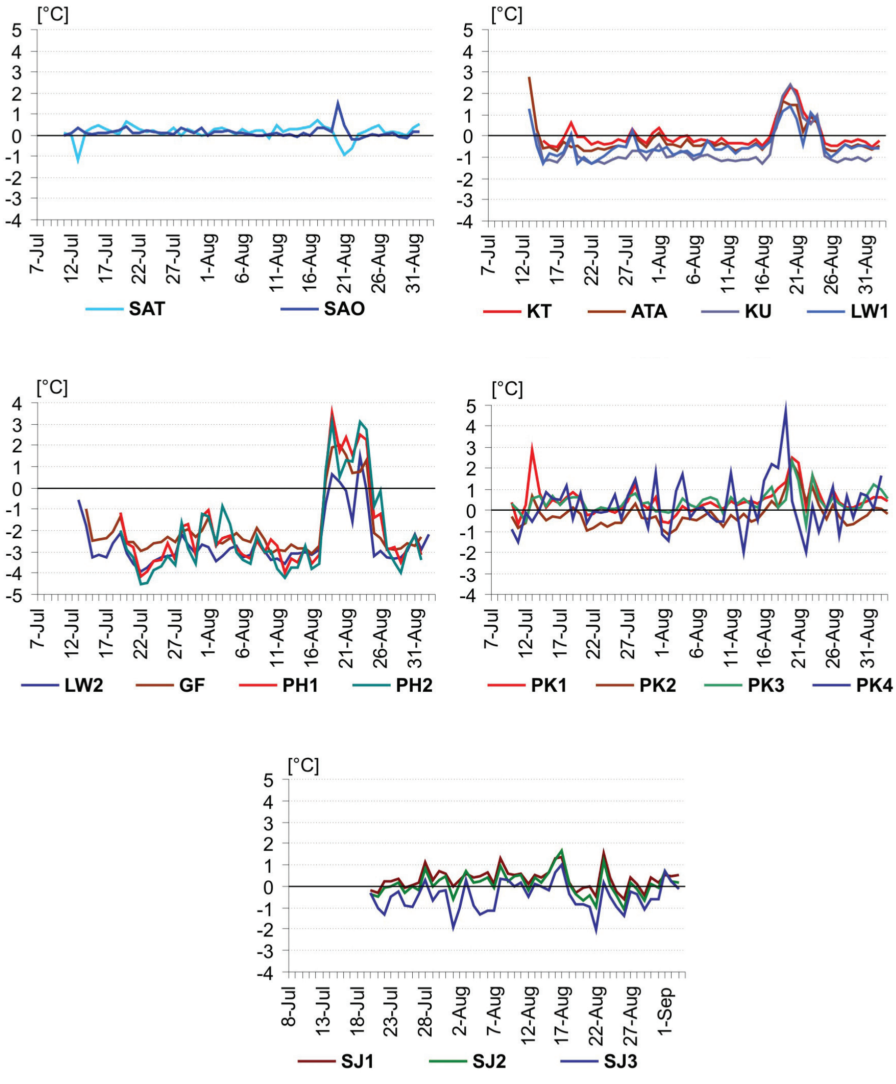

Figure 4.15. Differences in mean diurnal values of air temperature (°C) between the measuring points in the area of Forlandsundet and the Base Station (KH) in the summer season of 2010

In 2010 nearly the whole area covered by the observations, except for St. Jonsfjorden, was subject to warming, which requires a short account: the phenomenon was noted to have an enhanced intensity predominantly in the mountainous areas, which triggered strong inversions of air temperature. The rise in the mean air temperature between the second and the third ten-day period of August, ranged from 0.2 to 0.4°C at low situated sites, whereas at higher situated sites it reached 0.7°C (at GF and LW2), and 1.4 and 1.8°C at PH1 and PH2, respectively. The mean diurnal temperature at PH1 and PH2 increased by as much as about 6°C at that time (Fig. 4.15). Then, in the last week of August, the temperature values were approximately 2°C higher there than at KH (Fig. 4.15). Similar cases of strong inversions of air temperature in Hornsund were also noted by Migała et al. (2008).

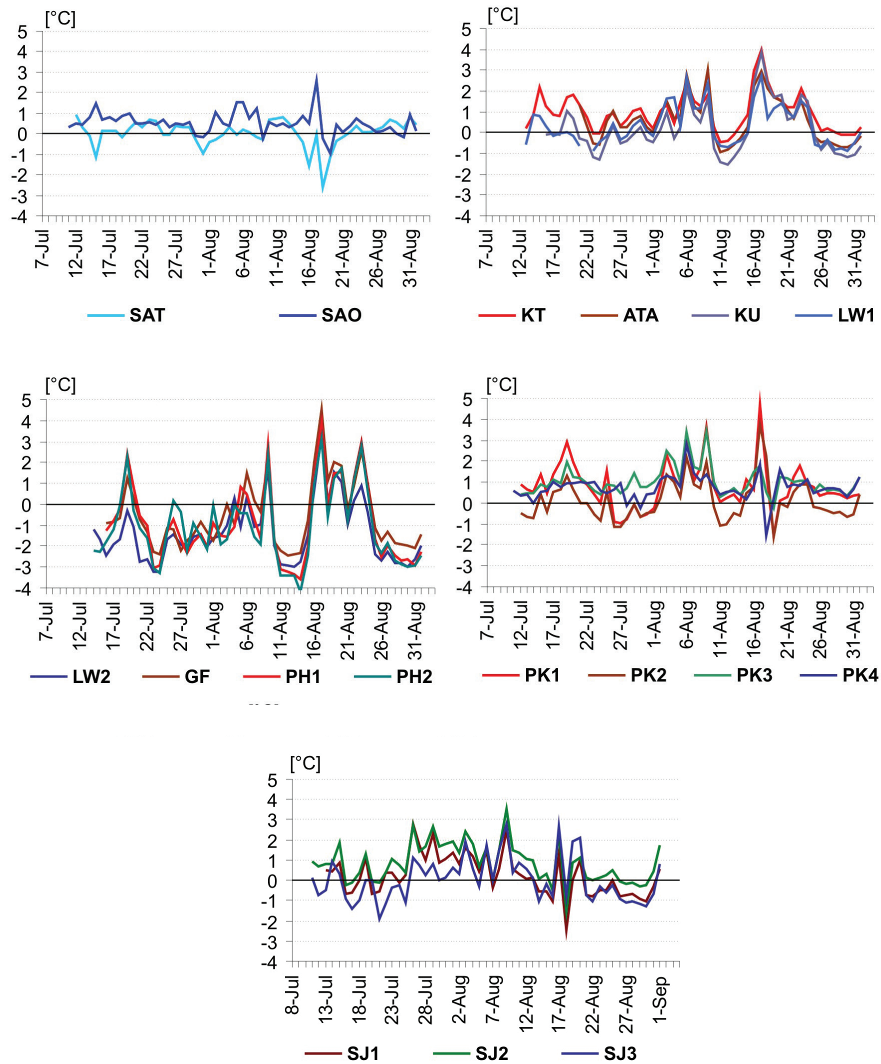

Figure 4.16. Differences in mean diurnal values of air temperature (°C) between the measuring points in the area of Forlandsundet and the Base Station (KH) in the summer season of 2011

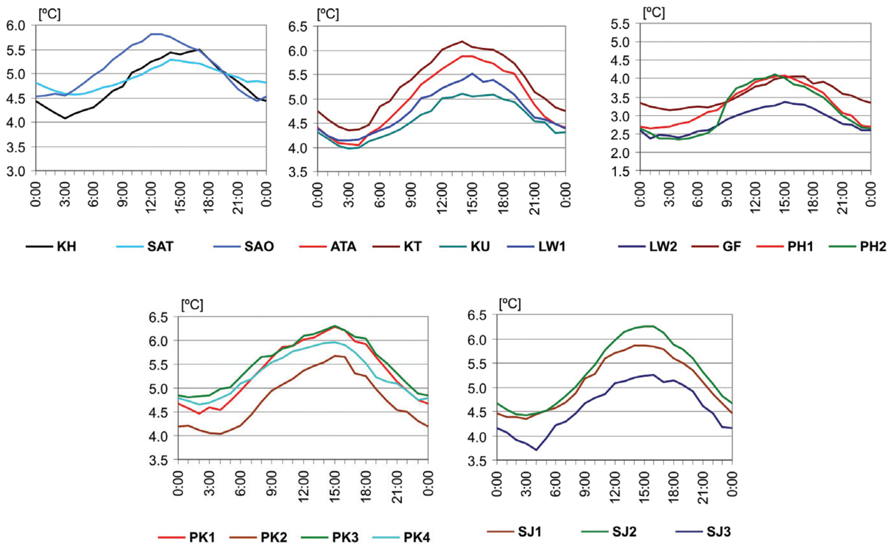

Figure 4.17. Mean diurnal course of air temperature in the area of the Forlandsundet in the summer seasons of 2010 and 2011

An analysis of mean diurnal courses of air temperature also provides some interesting results. It is evident that the proximity of glacial surfaces cools the air more at daytime than at the 'night' hours (Fig. 4.17). Essentially, the diversity of temperature among the sites is also greater at day than at night. Also, it is much greater and more complex on days with good weather than on cloudy days (due to a stronger influence of local conditions). At all of the sites the highest air temperature was observed, on average, in the afternoon (13:00 – 17:00), and the lowest during the corresponding 'night' hours (Fig. 4.17).

4.2.4. Comparison with Ny-Ålesund

Until recently the thermal conditions on the Kaffiøyra Plain have only been compared with the conditions in Ny-Ålesund for a part of the summer season (21 July – 31 August, Przybylak and Araźny 2006; Przybylak et al. 2011). Today though, it is possible to do this for the whole year. One of the goals of such a comparison is to verify the correctness of measurements taken in the area of the Forlandsundet, particularly in the parts of the year when unfavourable weather conditions prevailed and it was impossible to inspect the measuring points. Established correlations may be used to supplement or reconstruct the missing data. The synoptic station in Ny-Ålesund is situated merely 30 km north of our area of observations.

For the comparison, data from the Base Station (KH) was used. As shown in Fig. 4.18, the air temperature at Ny-Ålesund is lower by approximately 0.9°C on average.

The greatest differences were noted in the winter months, except for January and February, when the difference was 2°C. The mean winter temperature at Ny-Ålesund (-12.0°C) was 1.4°C lower than the temperature calculated for KH. In the spring and autumn, the difference was 0.9°C, and in the summer the mean temperature was identical at both stations (5.1°C). Diagrams showing the annual courses of temperature at the two stations are therefore very similar to each other. This similarity was confirmed by correlations of mean diurnal values of air temperature at the two stations, calculated for individual seasons of the year. The correlations proved to be very high, as was verified in an analysis of determination coefficients, whose highest values were obtained for the autumn ($r^2 = 0.991$), and the lowest for the summer ($r^2 = 0.890$) (Fig. 4.19).

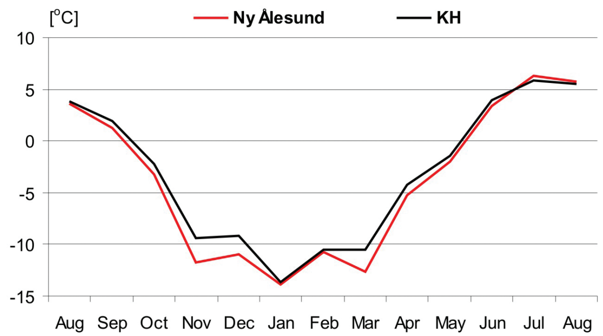

Figure 4.18. Annual course of air temperature at Ny-Ålesund and at the Base Station (KH) in the period from August 2010 to August 2011

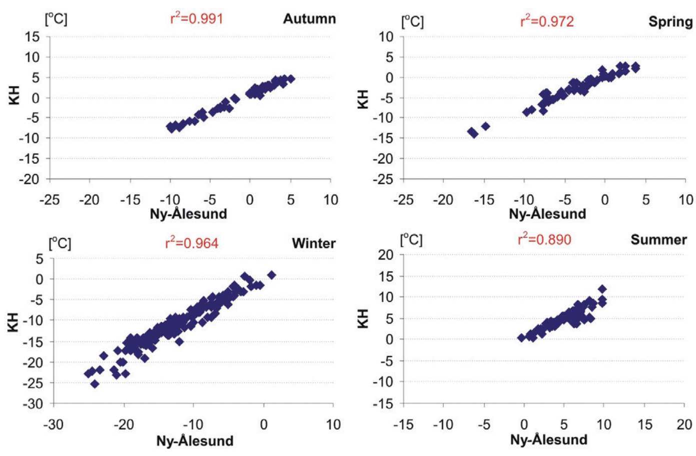

Figure 4.19. Correlation of mean diurnal values of air temperature at the Base Station (KH) with the data from the Ny–Ålesund station in the autumn (Sep–Oct) of 2010, winter (Nov–Mar) of 2010/2011, spring (Apr–May) of 2011, and summer (Jun–Aug) of 2011

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