Chapter 7

COMPARISON OF METEOROLOGICAL CONDITIONS IN THE AREA OF FORLANDSUNDET IN THE SUMMER SEASONS OF 2010-2011 WITH METEOROLOGICAL CONDITIONS IN THE YEARS OF 1975–2011

7.1. Introduction

In the years of 1975–2011 meteorological observations and measurements in the area of Kaffiøyra were conducted during the 19 TPEs. As far as polar areas are concerned, a data acquisition period like this is long enough to justify climatological summaries, and so, a number of synthetic works of this kind have recently been published (for example, Przybylak and Szczeblewska 2002; Przybylak et al. 2004, 2009, 2010, 2011; Przybylak and Araźny 2006). For the area of Hornsund, a similar study has been developed by Araźny et al. (2010).

In this Chapter we described the meteorological conditions occurring during the two summer seasons of 2010 and 2011, when the observations were carried out as part of the AWAKE project, and compared them with long-term conditions existing in the area. The analysis concerned two diametrically opposite natural environments in the area of Kaffiøyra: non-glaciated in the case of the Base Station (KH), and glaciated, as represented by sites located on the Waldemar Glacier (LW2) and immediately at its front (LW1).

7.2. Kaffiøyra

The Base Station on the Kaffiøyra Plain has always been our most important site for meteorological observations in the area of Forlandsundet, and the one for which the amount of collected data is the most complete. The available long-term series of temperature and precipitation records have made it possible to supplement some missing data for the years when observations were not carried out. For that purpose, the data collected at the Norwegian station in Ny-Ålesund, just 30 km north of our station, were used (Przybylak et al. 2011).

An integrated overview of the weather conditions occurring during the 19th TPE in the common period has been shown in Table 7.1. It shows that the last two years, compared with the others, were characterised by notably greater values of wind speed, slightly lesser cloudiness, longer sunshine duration and considerable dryness of the air, also evident in the very small precipitation amounts. The year 2010 was particularly extreme with its highest average wind speed (5.8 ms^{-1}), and the smallest precipitation (only 8.5 mm), compared with the other 18 periods of observation. It was also the second coldest summer season (sharing the record with 1980). The summer of 2011 was apparently warmer than the previous one (by 1.6°C on average) and the long-term standard (Tab. 7.1). However, the other meteorological elements displayed similar characteristics as in the summer of 2010, although they lacked such extreme values. The reason for the dissimilarities was the substantially different atmospheric circulation types in the two seasons, and the exceptionally high frequency of influxes of air masses from the northern sector in 2010 against its typical frequency structure in 2011 (for more details of the atmospheric circulation and its relationship with the climate, see Chapters 2 and 6). In the case of averaged data from both seasons the conditions are close to the long-term standard. Therefore, an assumption can be made that the combined data are representative of the average conditions in the area of Kaffiøyra, and thus a similar conclusion can be offered for the wider area of Forlandsundet, as studied during the last two years.

As regards the ground temperatures, measured on the Kaffiøyra Plain in all summer seasons at 5 depths, the two summers of interest to us here differed substantially from long-term average temperatures, yet did not display any particularly extreme values. In the summer of 2010 the ground temperature was below standard, and in 2011 it was above (Tab. 7.2). Unquestionably, the warmest conditions in the ground occurred in the summer of 2007, whereas the lowest ground temperatures were recorded in the summer of 1997 (except for at a depth of 0.5 m, where it was the coldest in 1982).

Detailed relationships between the weather conditions and ground temperature in day-to-day courses in the summers of 2010 and 2011, compared with the long-term standard of 1975-2011, have been shown in Figure 7.1 and Figure 7.2, respectively. The last eleven days of July in both summer seasons barely missed the long-term average of air temperature (being slightly colder), and water vapour content (Fig. 7.1). The wind speed and relative humidity were mostly higher and the diurnal precipitation totals were lower, but the cloudiness and sunshine both greatly departed from the standard, in plus and in minus. At that time, the ground temperature was distinctly lower in 2010, but in 2011 it was either near the standard or higher, depending on the depth of measurement (Fig. 7.2).

Sunshine duration and the cloud amount in August of those two years also displayed considerable day-to-day variability. On many days, the diurnal sums of sunshine duration and average cloud amount were close to standard or their respective maximum or minimum values recorded in the years of 1975-2011 (overlapping or running close to the dashed line). The values of diurnal sums of zero sunshine duration (or the lack of sunshine) and of the average overcast for weather are typical for the climate conditions on Spitsbergen, therefore they are not identified as being extreme. For this reason they were excluded from the long-term data in Figure 7.1A. The first half of August was very windy in both summer seasons, however in 2010 particularly high values were recorded and lasted a little longer, until 17 August. A period of exceptionally strong winds fell on 15–17 August, with the maximum average diurnal value (14 ms^{-1}) recorded on 16 August. This was the highest ever average diurnal wind speed calculated

Table 7.1. Mean (or sums) of selected meteorological elements on the Kaffiøyra in the summer seasons (21 July – 31 August) of 1975-2011

Element	V [ms^{-1}]	C [0-10]	SS [h]	SS [%]	Tmax abs [°C]	Tmax [°C]	Ti [°C]	Tmin [°C]	Tmin abs [°C]	DTR [°C]	e [hPa]	f [%]	Δe [hPa]	P [mm]
1975	4.3	8.7	112.9	11.5	11.5	6.7	4.9	3.3	1.4	3.4	7.8	90	0.9	66.5
1977*	3.2	8.7	146.6	15.9	13.5	7.0	5.0	3.5	0.6	3.5	7.8	89	1.0	44.4
1978	4.6	8.8	119.9	12.1	10.0	6.3	4.7	3.1	0.7	3.2	7.7	89	0.9	44.2
1979	5.0	7.3	281.9	29.0	18.9	6.6	4.5	2.5	-0.5	4.1	7.6	89	0.9	17.7
1980	5.5	9.1	90.9	9.1	12.5	5.6	4.1	2.6	-0.8	3.0	7.3	88	0.9	108.0
1982	4.2	8.8	91.3	9.2	10.4	4.8	3.3	1.8	-4.2	3.0	6.8	88	1.0	54.5
1985	3.2	7.2	309.5	32.2	16.0	6.9	5.4	4.0	0.9	2.9	8.1	89	1.0	13.9
1989	5.0	8.3	203.0	20.5	11.5	5.5	4.0	2.7	-3.6	2.8	7.4	90	0.8	27.0
1997**	5.4	8.4	165.0	16.8	10.8	5.4	4.2	2.7	-0.2	2.7	7.5	90	0.8	122.5
1998	4.0	9.1	93.5	9.5	14.0	7.6	6.3	5.0	1.8	2.6	8.7	91	0.9	16.0
1999	3.8	8.9	150.1	15.2	10.3	6.4	4.9	3.5	0.0	2.9	7.3	85	1.3	58.4
2000	4.6	7.2	213.3	21.6	8.8	5.9	3.9	2.2	-3.6	3.7	7.2	88	1.0	29.1
2005	3.8	9.1	149.4	15.1	12.1	7.5	5.8	4.1	1.4	3.4	8.1	87	1.2	49.9
2006	4.9	8.3	158.8	16.0	11.9	7.0	5.2	3.9	1.0	3.1	8.1	91	0.8	25.0
2007	3.7	8.7	132.0	13.3	14.9	7.4	5.5	4.0	-1.3	3.6	7.8	85	1.4	12.3
2008	5.4	8.9	131.7	13.3	12.4	6.1	4.5	2.9	-0.8	3.2	7.5	88	1.0	22.2
2009	3.1	8.0	220.0	22.2	13.0	7.6	6.1	4.1	0.9	3.5	7.9	87	1.0	12.5
2010	5.8	8.2	219.9	22.2	10.8	6.1	4.1	2.7	-0.6	3.4	7.2	87	1.1	8.5
2011	5.0	8.1	200.0	20.2	16.8	7.4	5.7	3.6	1.0	3.8	7.9	89	1.2	28.1
1975-2011	**4.4**	**8.4**	**167.9**	**17.1**	**18.9**	**6.5**	**4.8**	**3.3**	**-4.2**	**3.3**	**7.7**	**88**	**1.0**	**40.0**

Explanations: * - 21.07-28.08; ** - 28.07-31.08 (V, Tmax $_{abs,}$ Tmax, Tmin, Tmin $_{abs}$); V – wind velocity; C– cloudiness; SS– sunshine duration; T — air temperature; DTR- diurnal range of air temperature, e – water vapour pressure; f – relative air humidity; Δe – saturation deficit; P –atmospheric precipitation on the Kaffiøyra. Besides the two days of August 2010, in the rest of the second half of August the wind conditions were usually below standard in both analysed seasons (Fig. 7.1A).

Table 7.2. Mean values of ground temperature (°C) at the beach site on the Kaffiøyra in the period from 21 July to 31 August (1975-2011)

Depth	1 cm	5 cm	10 cm	20 cm	50 cm
1975	6.3	5.7	5.4	4.2	2.6
1977	6.7	6.1	5.8	4.9	2.7
1978	5.8	5.2	4.4	4.1	1.8
1979	6.3	5.8	5.4	4.5	2.2
1980	5.7	5.1	4.8	4,0	2.2
1982	5.2	4.7	4.2	3.6	1.7
1985	7.2	6.8	6.6	5.8	3.4
1989	6,0	5.6	5.2	4.4	2.2
1997	*4.6*	4.2	4.1	3.4	1.9
1998	8.1	7.5	6.6	5.4	2.4
1999	6.7	6.4	5.9	5.2	3.4
2000	5.6	5.5	5,0	4.4	2.1
2005	8.0	7.4	6.9	5.9	3.5
2006	7.1	6.7	6.8	5.9	4.2
2007	8.3	7.8	7.4	6.4	4.4
2008	6.0	5.7	5.4	4.7	2.8
2009	7.9	7.1	6.6	5.9	3.5
2010	5.8	5.3	5.0	4.2	2.4
2011	7.3	6.8	6.5	6.0	3.9
1975–2011	**6.6**	**6.1**	**5.7**	**4.9**	**2.8**

Explanations: statistically approximated value is shown using italic font

Thermally, August was considerably different in both summer seasons. In 2010, except for a few days around 20 August, the month was colder than usual, particularly in the middle. August 2011 was the opposite, being distinctly warmer than the long-term standard suggests, except for a few days at the beginning of its second ten-day part. A substantial warming was noted immediately after the above-mentioned cooler period, i.e. in mid-August. The positive anomaly, *Ti*, exceeded 6°C, and *Tmax* even 8°C (Fig. 7.1B). At the end of August the temperature in both summer seasons approached the long-term standard values. It is also noteworthy that on certain days in those two years, mainly in the second half of the month, the highest values of the three temperature parameters recorded were the record values for all 19 summer seasons (solid lines overlapping dashed lines).

The average diurnal values of air humidity in August 2010 and 2011 were marked by their dissimilarity with the long-term values, depending on the parameter in question, i.e. the water vapour pressure or the relative humidity (Fig. 7.1C). The content of water vapour in the air is a more stable parameter, therefore it was similar to the reference value on the first days of August and in July of both years. However, at the end of the first ten-day part of August it evidently dropped, remaining below the long-term value on nearly all subsequent days of August 2010. Between 14 and 17 August it reached the bottom range of all low values recorded for that period during all TPEs. At the same time they were some of the lowest diurnal values recorded in the whole summer season (Fig. 7.1C). In 2011, on the other hand, the water vapour pressure drop ceased after 14 August, and the amount of water vapour considerably exceeded (usually by more than 2 hPa) the long-term standard, remaining high until the end of the month. On 19 and 21 August, its record values were observed, reaching 8.7 hPa and 9.3 hPa, respectively.

Day-to-day changes in the air humidity are more complex in an analysis of relative humidity. In 2010, in the first ten-day period of August the air was, on average, generally more saturated than usual, but on subsequent days of August it became less saturated (Fig. 7.1C). In 2011, on the other hand, it underwent dramatic changes, reaching both the highest and the lowest diurnal values recorded during all the TPEs. For that time, we were able to distinguish three periods of substantially increased and three periods of greatly decreased vapour content in the air, as compared with long-term values.

The diurnal precipitation totals in August, similarly to the last eleven days of July, were usually below the long-term standard in both seasons. On only one day in 2010, 5 August, on five days in 2011 did the diurnal totals exceed the average long-term values (Fig. 7.1C). No precipitation was observed on as many as 24 and 18 days, respectively.

Throughout most of August 2010 the ground temperature at the 'beach' site was below the standard (which was particularly evident at the beginning of the second half of the month) or close to it (Fig. 7.2). Noticeably warmer weather was observed only on a few days after 20 August. In 2011 the situation was completely different, with the ground being much warmer than the standard value on most days. A particular warming occurred in the second part of August. From 17 August until the end of the month the mean temperature at a depth of 50 cm was mainly at least 1.5°C higher than the long-term average, with the maximum difference of 2.6°C falling on 20 August. It is interesting to point out that on all days between 18 and 28 August the average diurnal ground temperatures at that depth were the highest of all such values ever calculated for the same periods in 1975-2011.

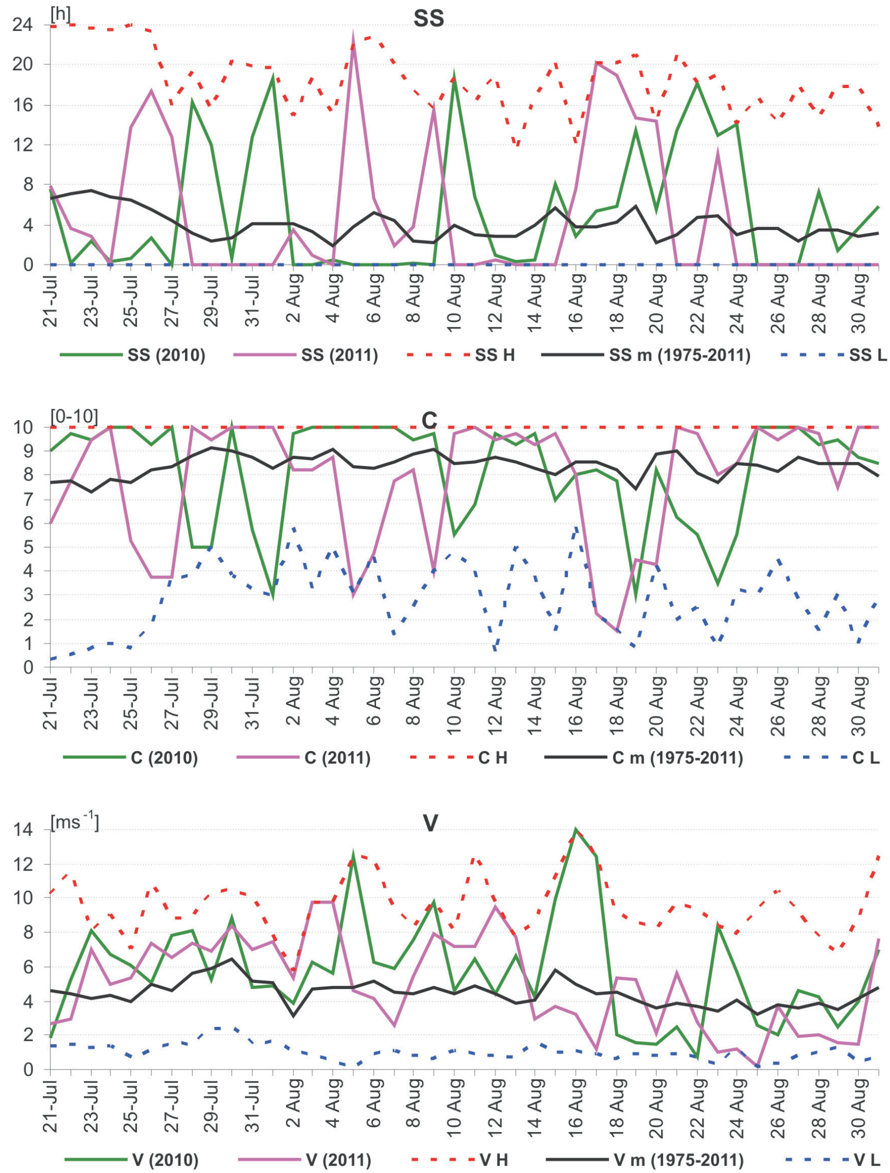

Figure 7.1A. Course of diurnal sums of sunshine (SS) and mean diurnal values of cloudiness (C) and wind speed at 2 m a.s.l. (V) in the summer season (21 July–31 August) of 2010 and 2011, and in 1975–2011

Explanations: m – mean diurnal values (or sums), H – highest diurnal values (or sums), L – lowest diurnal values (or sums)

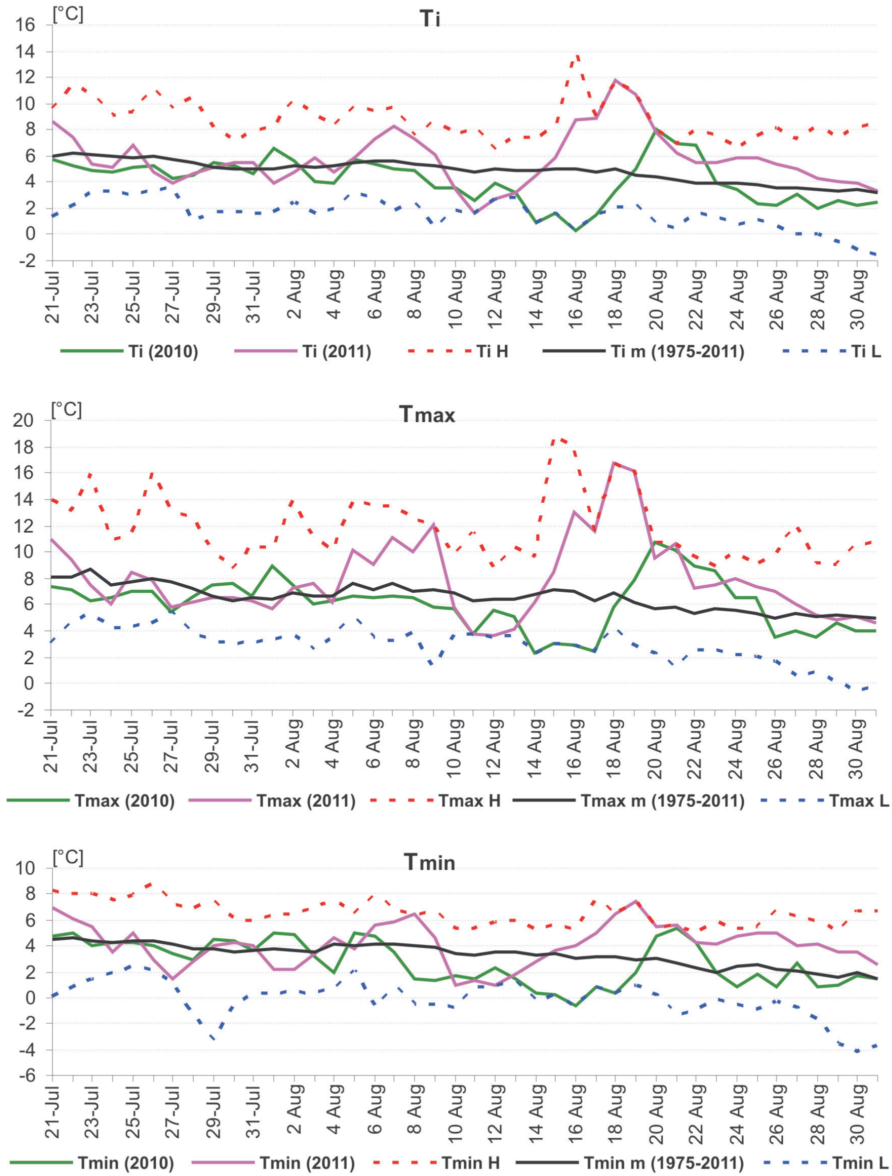

Figure 7.1B. Diurnal courses of mean temperature (Ti), maximum temperature (Tmax) and minimum temperature (Tmin) in the summer seasons (21 July–31 August) of 2010 and 2011, and in 1975–2011

Explanations: m – mean diurnal values, H – highest diurnal values, L – lowest diurnal values

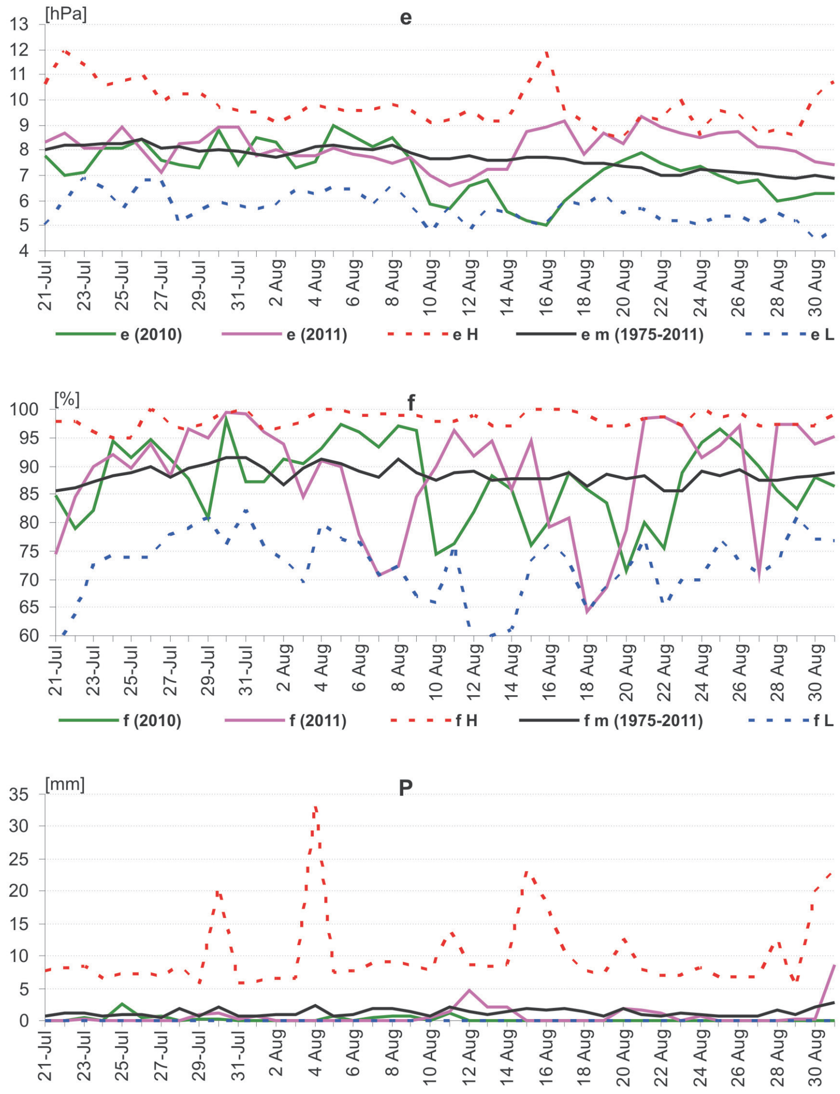

Figure 7.1C. Course of water vapour pressure (e) and relative humidity (f), and diurnal values of precipitation totals (P) in the summer seasons (21 July–31 August) of 2010 and 2011, and in 1975–2011

Explanations: m – mean diurnal values (or sums), H – highest diurnal values (or sums), L – lowest diurnal values (or sums)

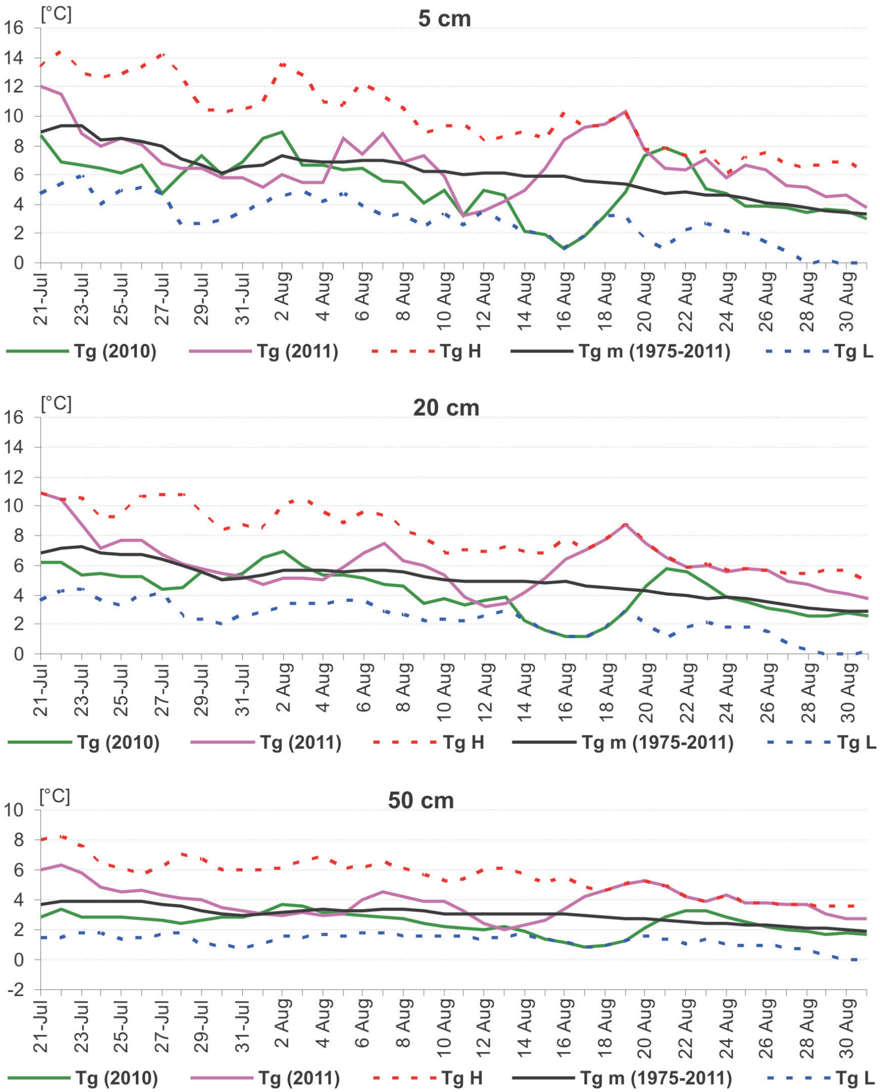

Figure 7.2. Diurnal courses of ground temperature: mean (Tg m), highest (Tg H) and lowest (Tg L) at the beach site in the summer seasons (21 July–31 August) of 2010 and 2011, and in 1975–2011

Explanations: m – mean diurnal values, H – highest diurnal values, L – lowest diurnal values

7.3. Waldemar Glacier

The possibility to provide a full comparison of the weather conditions on the Waldemar Glacier in the summer seasons of 2010 and 2011 with the conditions observed during all TPEs is limited. Therefore, only two the most significant meteorological elements have been addressed below, namely the air temperature and precipitation, for which there are enough data from most of the summer seasons, during which meteorological observations were conducted.

From the point of view of temperature, the summer seasons of 2010 and 2011 were substantially different. The summer of 2010 on the glacier was much colder than average. Thermal anomalies at two observation sites, LW1 and LW2, reached -0.7 and -1.3°C, respectively (Tab. 7.3, Fig. 7.3A). On the other hand, the air on the Waldemar Glacier was much warmer in 2011 than the average. Positive thermal anomalies at the above-mentioned sites were 1.4 and 1.2°C, respectively. At the site located immediately at the glacier front, the mean temperature of the air in that season (and the 2009 season, as well) was the highest of all analysed TPE seasons (Tab. 7.3, Fig. 7.3A). Nevertheless, on the firn field the mean temperature was only 0.1°C lower than in the warmest summer at that site (in 2009). Figure 7.3A clearly shows that the Waldemar Glacier has become considerably warmer in the last few dozen years.

Table 7. 3. Mean values of air temperature (Ti) and its lapse rates (LR) on the Kaffiøyra (KH) and at the Waldemar Glacier (LW1 and LW2) in the period from 21 July to 31 August, during the TPEs

Year	Ti (°C)			LR (°C/100m)		
	KH	LW1	LW2	KH-LW2	KH-LW1	LW1-LW2
1978#	4.4	3.5	2.1	0.63	0.76	0.57
1979	4.5	3.7	2.6	0.52	0.68	0.45
1980	4.1	3.0	1.9	0.61	0.93	0.45
1982	3.3	2.6	1.3	0.55	0.59	0.53
1985	5.4	4.6	3.3	0.58	0.68	0.53
1989	4.0	3.4	1.9	0.58	0.51	0.61
1997*	4.0	3.3	1.6	0.66	0.59	0.69
1998	6.3	5.5	4.1	0.61	0.68	0.57
1999	4.9	3.9	2.5	0.66	0.84	0.57
2005	5.8	4.6	3.0	0.77	1.01	0.65
2006	5.2	4.4	2.4	0.77	0.68	0.82
2007	5.5	4.3	2.7	0.77	1.01	0.65
2008	4.5	3.6	2.3	0.60	0.75	0.53
2009	6.1	5.8	4.2	0.52	0.25	0.65
2010	4.1	3.7	1.6	0.69	0.34	0.86
2011	5.7	5.8	4.1	0.45	-0.06	0.69
1978-2011	**4.9**	**4.4**	**2.9**	**0.62**	**0.64**	**0.61**

Explanations: # -2-31.08, * - 28.07-31.08

The relationships between the air temperature at the analysed glacier sites (LW1 and LW2) and the reference sites on the Kaffiøyra Plain (KH) are nonstandard in both summer seasons (Tab. 7.3, Fig. 7.3B). In 2010, the difference in the air temperature between the firn field of the glacier and the coast was close to the long-term average; the temperature lapse rate was 0.69°C/100 m with the long-term lapse rate showing 0.62°C/100 m. However, there was exceptionally small thermal diversity between the LW1 and the KH site. The temperature lapse rate for these sites was twice as small as the average calculated using long-term data. Then, in 2010, the temperature decrease along the longitudinal profile of the Waldemar Glacier was the greatest of all the summer seasons, during which the TPEs operated. The temperature lapse rate reached as much as 0.86°C/100 m, considering that the average was 0.61°C/100 m (Tab. 7.3, Fig. 7.3B). In the summer of 2011, the lapse rate on the glacier was close to the average, however the temperature differences between the glacier and the coast (the Base Station) evidently deviated from the long-term standard (Tab. 7.3, Fig. 7.3B). The lapse rates calculated for the LW2 and LW1 sites and for the KH site were markedly the lowest of all seasons studied during the TPEs. Negative anomalies of the lapse rates reached 0.17°C/100 m and 0.70°C/100 m, respectively. Table 7.3 indicates that, in that summer season, the higher-situated LW1 site was slightly warmer than KH. This had never happened during any of the TPEs before. The reason for such a big thermal anomaly was most probably the frequency of occurrence of foehnic winds, which significantly exceeded the average, as in this kind of wind conditions air temperature inversions are common in the analysed area.

Table 7.4. Precipitation totals (P) and their lapse rates (LR) on the Kaffiøyra (KH) and at the Waldemar Glacier (LW1 and LW2) in the period from 21 July to 31 August, during the TPEs

Year	P (mm)			LR (mm/100 m)		
	KH	LW1	LW2	LW2-KH	LW1-KH	LW2-LW1
1980*	92.8	172.3	256.5	45.0	67.1	34.4
1989	27.0	44.2	69.0	11.6	14.5	10.1
1997	122.5	129.8	195.5	20.1	6.2	26.8
1998	16.0	23.1	43.8	7.6	6.0	8.4
1999	58.4	85.3	108.9	13.9	22.7	9.6
2005	49.9	60.8	71.7	6.0	9.2	4.4
2006	25.0	39.8	56.2	8.6	12.5	6.7
2007	12.3	9.5	15.1	0.8	-2.4	2.3
2008	22.2	39.5	53.6	8.6	14.6	5.8
2009	12.5	15.9	25.4	3.5	2.9	3.9
2010	8.5	25.9	36.5	7.7	14.7	4.3
2011	28.1	44.7	81.2	14.6	14.0	14.9
1980–2011	**39.6**	**57.6**	**84.5**	**12.3**	**15.2**	**11.0**

Explanation: * 1-31.08

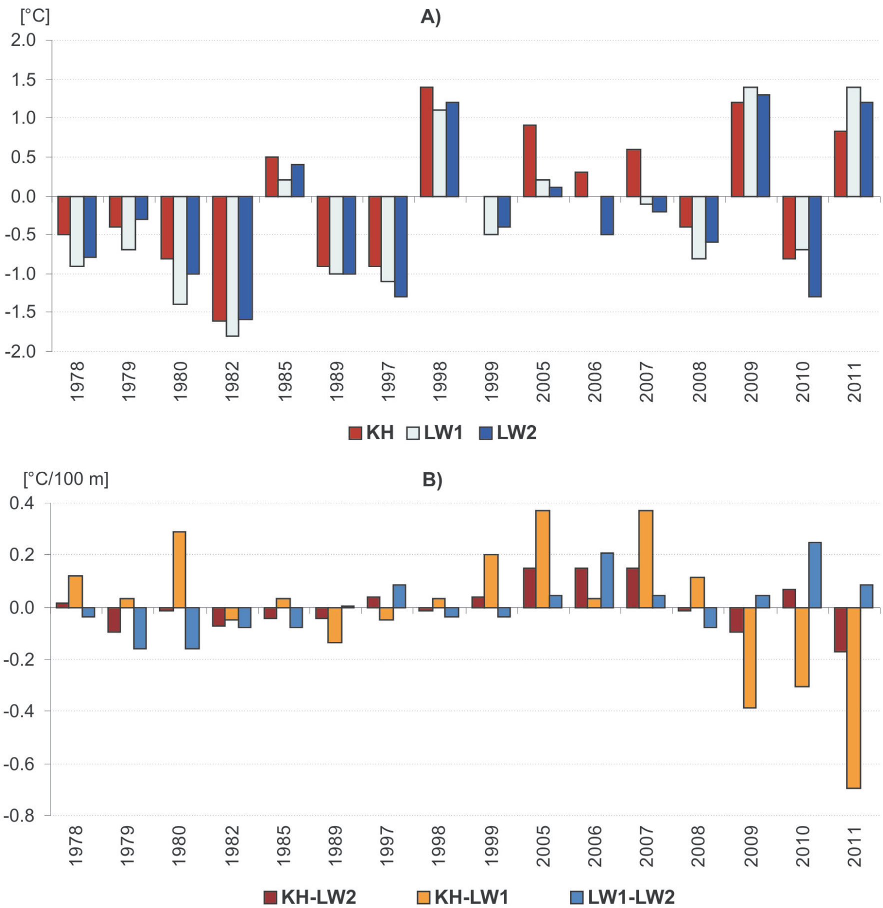

Figure 7.3. Anomalies in mean values of air temperature (A) and lapse rates (B) on the Kaffiøyra (KH) and at the Waldemar Glacier (LW1 and LW2) in the period from 21 July to 31 August, during the TPEs

Studies of the diversity of precipitation in the area of the Kaffiøyra were conducted during 12 TPEs (Tab. 7.4). In the summer season of 2010, at the Waldemar Glacier the precipitation was half the long-term total, however, unlike at KH, the recorded amounts were not the lowest in that area (Tab. 7.4, Fig. 7.4A).

The calculated precipitation lapse rates when comparing the KH site with the glacier sites are below average. However, the anomalies of the lapse rates are clearly negative for the site located in the firn field (4.6 mm/100 m) as compared to the one at the front of the Waldemar Glacier (0.5 mm/100 m). In the summer season of 2011, precipitation on the glacier remained below the long-term average, but its negative anomalies were not great, especially in the case of the LW2 site (Tab. 7.4, Fig. 7.4A). The precipitation lapse rates, however, were greater than the average, with the exception of the LW1 site (Tab. 7.4, Fig. 7.4B), and reached 14.9 mm/100 m between the two glacier sites, while the average long-term lapse rate was 11.0 mm/100 m. Evidently, the precipitation in the area of the Kaffiøyra was found to have been closer to the standard conditions in the summer of 2011.

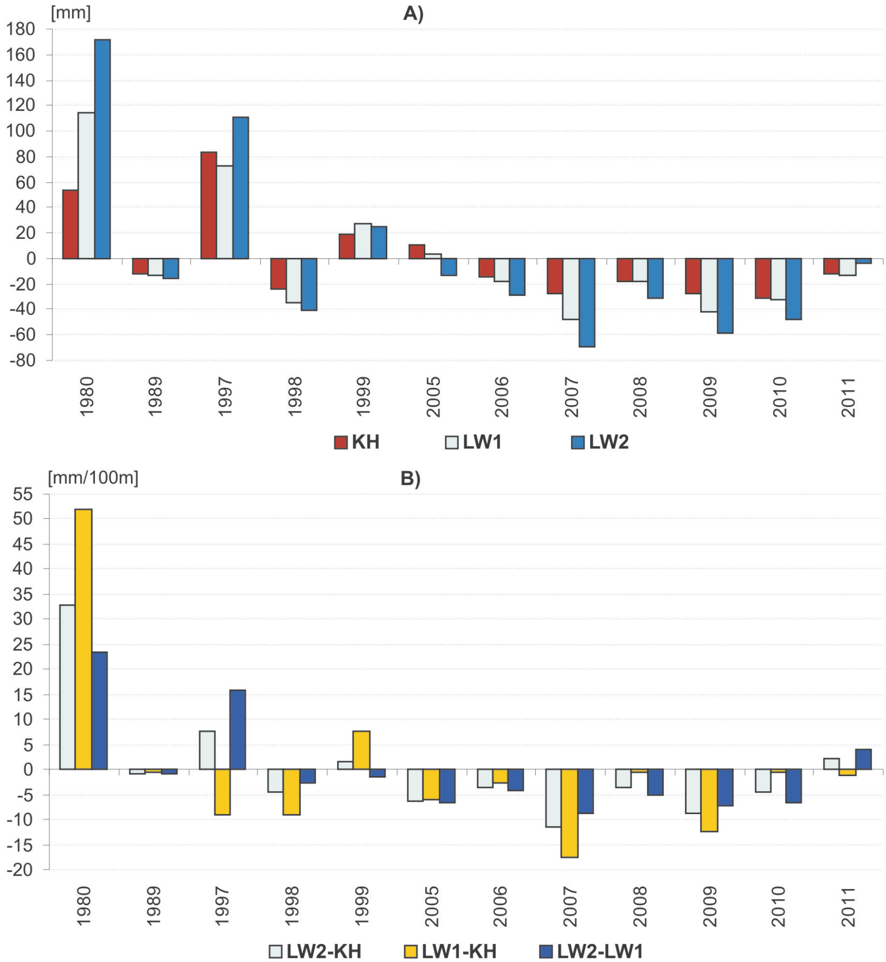

Figure 7.4. Anomalies in precipitation totals (A) and lapse rates (B) on the Kaffiøyra (KH) and at the Waldemar Glacier (LW1 and LW2) in the period from 21 July to 31 August, during the TPEs

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