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THE INFLUENCE OF CLOUDINESS AND SYNOPTIC SITUATIONS ON THE SOLAR RADIATION BALANCE IN THE AREA OF KAFFIØYRA (NW SPITSBERGEN) IN THE SUMMER SEASONS 2010 AND 2011

Abstract: This article describes the influence of cloudiness and synoptic situations on individual components of the radiation balance such as: global solar radiation; surface-reflected radiation; longwave terrestrial and atmospheric radiation, and the long- and shortwave balance of two types of ground cover typical to Spitsbergen (the Kaffiøyra region), i.e. morainal and glacial. The research was carried out in the summer seasons of 2010 and 2011, using a Kipp & Zonen CNR4 net radiometer. A substantial influence of the presence of clouds on the individual components of the radiation balance was observed. The type of air masses related to specific synoptic situations was also found to affect the incoming and outgoing solar radiation, as well as its losses.

Key words: radiation balance, cloudiness, synoptic situations, Kaffiøyra, Spitsbergen

Introduction

The solar radiation balance of the Earth's surface (Q*) determines the gains and losses of energy in the form of long- and shortwave radiation. It consists of a net shortwave radiation (K*) and a net longwave radiation (L*), and is described by the following equations in the whole spectrum range (Oke 1996):

$$Q^* = K^* + L^*;$$
$$K^* = K\downarrow - K\uparrow; \qquad L^* = L\downarrow - L\uparrow$$
$$Q^* = (K\downarrow - K\uparrow) + (L\downarrow - L\uparrow)$$

where:

Q^* − net radiation balance,
K^* − net shortwave solar radiation,
L^* − net longwave solar radiation,
$K\downarrow$ − incoming shortwave solar radiation (direct and diffuse),
$K\uparrow$ − outgoing shortwave solar radiation, reflected by the active surface,
$L\downarrow$ − incoming longwave radiation,
$L\uparrow$ − outgoing longwave radiation, emitted by the active surface.

The amount of incoming solar radiation depends on the angle at which the sun rays reach the ground surface, and this changes with latitude, season, time of the day and properties of the atmosphere. Atmospheric extinction is determined by the distance which the sun's rays have to cover in the atmosphere (or the elevation of the sun) and by the presence and amount of clouds, water vapour and aerosols.

Specific insolation conditions occur in polar regions, particularly at the time of the polar day or night (Curry et al. 1996; Pinto et al. 1997; Walsh and Chapman 1998; Láska et al. 2010). The development of the solar radiation balance is significantly influenced by clouds, which have a high albedo and absorb a large amount both of solar radiation and of the longwave radiation emitted by the surface. In the Arctic summer there is a considerable amount of cloud (Beesley and Moritz 1998; Przybylak 2003), which affects the radiation balance (Walsh and Chapman 1998). In the area of Svalbard, the prevailing clouds are low layer sheet clouds, which curb the influx of radiation and its losses the most (Nardino and Georgiadis 2003). On the other hand, the aerosol content in the area of Svalbard is low. Most of it comes from natural sources and occurs in the form of sea salt or ice crystals, dust driven off the land or volcanic dust (Dörnbrack et al. 2010). However, instances of anthropogenic air pollution coming from lower latitudes have become increasingly frequent, causing Arctic haze (Quinn et al. 2007).

On Spitsbergen (the largest island of the Svalbard archipelago) measurements of solar radiation and radiation balance components have been carried out in just a few areas. Near the Polish Polar Station at Hornsund, for example, observations were started by Kosiba (1960) and continued by such others as: Baranowski 1977; Pereyma 1983; Głowicki 1985; Brázdil et al. 1988; Niedźwiedź 1993; Styszyńska 1997; Marsz and Styszyńska 2007; Budzik et al. 2009. Since 1981 actinometric stations have been in operation at Ny Ålesund (NW Spitsbergen) and results of the observations can be found in the works of: Hisdal et. al. 1992; Ørbaek et al. 1999; Kupfer et al. 2003; Budzik 2004. In the area of Kaffiøyra, actinometric measurements have been performed by Wójcik (1989); Wójcik and Marciniak (1993, 2002); Kejna (2000); Caputa et al. (2002); Budzik (2003); Kejna et al. (2011, 2012) and others.

Topoclimatic and actinometric studies conducted on Spitsbergen (Arnold and Rees 2009; Budzik et al. 2009; Kryza et. al 2010; Witoszová and Láska 2010; Kejna et al. 2011 and 2012) and in other polar regions, such as Greenland or the Antarctic (Duynkerke and van den Broeke 1994; Bintanja 1995; Bintanja and van den Broeke 1996a,b), have demonstrated considerable diversity in the radiation balance, depending on the type of ground. In this article, an attempt is made to identify the influence of cloudiness and synoptic situations on the radiation balance of morainal and glacial surfaces, which prevail on Spitsbergen, on the basis of observations carried out in the Kaffiøyra region (NW Spitsbergen) in the summers of 2010 and 2011.

Research methodology

Actinometric measurements in the area of Kaffiøyra were taken by means of a CNR4 net radiometer (Kipp&Zonen, The Netherlands) set composed of two pyranometers and two pyrgeometers directed upwards and downwards. The equipment measures components of the solar radiation balance between incoming shortwave and longwave radiation, and reflected shortwave radiation and outgoing longwave radiation from the ground. Each of the instruments was individually calibrated, but they were not vented. The radiation balance measurements were performed in four locations KH, KT, LW1 and LW2 (Fig. 1) with different surface conditions and elevations. Their results were presented in previous articles of the authors (Kejna et al. 2011, 2012).

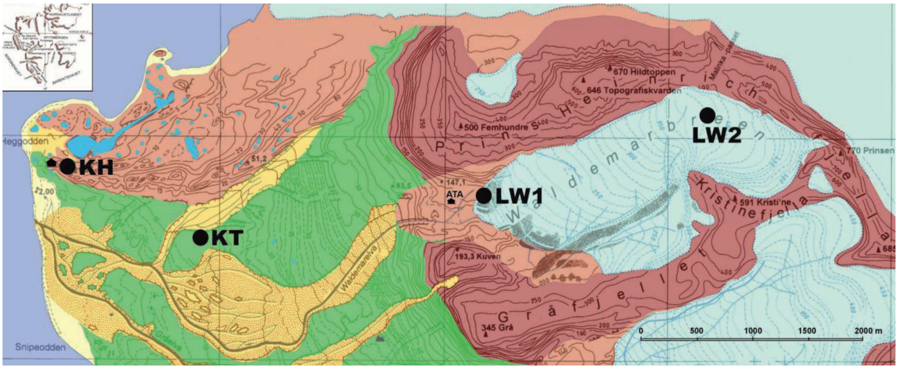

Fig. 1. Location of measurement points in the Kaffiøyra region (NW Spitsbergen)

In this article, the presented data was sourced from two sites: Kaffiøyra-Heggodden (KH), located on the terminal-lateral moraine of the Aavatsmark Glacier at 11.5 m a.s.l., and on the firn field of the Waldemar Glacier (LW2) at 375 m a.s.l., where melting snow and glacial ice occurred. The distance between the two sites was 6 km. CNR4 sensors were installed at a height of 2 m above the ground. The measurements were taken in summer seasons: from 16 July until 31 August 2010, and from 21 July until 31 August 2011, at 1- minute intervals. The collected data was complete at the KH site, but at the LW2 site there was a break from 2 August until 9 August 2011, with the missing data extrapolated thanks to a significant linear correlation between both sites.

The cloud cover (indicated on a scale from 0 to 10) and cloud types were observed at KH only, four times per day at 01:00, 07:00, 13:00, and 19:00 hours local time. For the purpose of this article a calendar of synoptic situations for Spitsbergen was used (Niedźwiedź 2011) and the types were associated in the manner proposed by Przybylak (1992).

RESULTS

Radiation balance on the moraine and glacier

In the comparable period (21 July – 31 August), the mean diurnal sum of incoming radiation (K↓) on the moraine (KH) amounted to 11.12 MJ m^{-2} in 2010, and 11.07 MJ m^{-2} in 2011 (Table 1). As the height of the Sun over the horizon decreased and the polar day ended (24 August), the intensity of solar radiation grew smaller and smaller (Figs 2 and 3). For example, in 2011 the value of K↓ dropped from 15.44 MJ m^{-2} to 4.65 MJ m^{-2} in the last ten days of August. Days with limited cloud cover and a high intensity of solar radiation were evident (e.g. on 1/08/2010, the sum of K↓ was 22.9 MJ m^{-2}, and on 26/07/2011 it reached 25.51 MJ m^{-2}). On cloudy days, the diurnal sums of K↓ did not exceed 5 MJ m^{-2} and amounted to, e.g. 2.20 MJ m^{-2} on 20/08/2011.

Table 1. Radiation balance components (MJ m^{-2}) at the Kaffiøyra-Heggodden in the summer seasons 2010 and 2011

Period	K↓	K↑	A%	K*	L↓	L↑	L*	Q*
21–31.07.10	13.43	1.85	14.2	11.58	27.82	30.87	−3.05	8.53
1–10.08.10	10.66	1.46	14.5	9.20	28.28	30.70	−2.42	6.78
11–20.08.10	10.87	1.57	15.7	9.30	25.83	29.55	−3.72	5.58
21–31.08.10	9.47	1.38	15.3	8.09	26.13	29.84	−3.71	4.38
21.07–31.08 2010	**11.12**	**1.57**	**14.9**	**9.56**	**27.26**	**30.25**	**−3.23**	**6.32**
21–31.07.11	15.44	2.56	16.3	12.88	27.83	31.09	−3.27	9.62
1–10.08.11	12.45	2.37	19.5	10.08	28.28	30.70	−2.42	7.67
11–20.08.11	11.94	2.33	19.4	9.61	25.83	29.55	−3.72	5.89
21–31.08.11	4.65	0.79	17.4	3.86	26.13	29.84	−3.71	0.14
21.07–31.08 2011	**11.07**	**2.00**	**18.1**	**9.07**	**27.01**	**30.30**	**−3.29**	**5.78**

Solar radiation is partially reflected by the active surface. In the comparable period of 21/07 – 31/08, the mean diurnal sum of outgoing shortwave radiation K↑ at KH amounted to 1.66 MJ m^{-2} in 2010 and 2.56 MJ m^{-2} in 2011. Therefore, the morainal surface has a low albedo. At the KH site albedo was 14.9% in 2010, and 18.1% in 2011. The net shortwave radiation (K*) at KH amounted to +9.56 MJ m^{-2} in 2010, and 9.07 MJ m^{-2} in 2011.

Warmed up ground surface becomes a source of longwave radiation (L↑) emitted to the atmosphere, and its intensity depends on the temperature of the surface. On the moraine, the average ground temperature at a depth of 1 cm, in the comparable period, reached 5.9°C in 2010, and 7.2°C in 2011 (Araźny 2012). At KH, the mean diurnal sum of L↑ reached 30.25 MJ m^{-2} in 2010, and 30.30 MJ m^{-2} in 2011. A substantial portion of the radiation emitted from the ground surface is absorbed by the atmosphere, which becomes a secondary source of longwave radiation. The downward atmospheric radiation (L↓) at KH amounted to 27.26 MJ m^{-2} in 2010, and 27.01 MJ m^{-2} in 2011. Mean values of the net longwave radiation (L*) at KH were negative and amounted to –3.05 MJ m^{2} in 2010, and –3.29 MJ m^{2} in 2011. Very low values of L* occurred principally on bright days, when a large portion of L↑ is emitted through the atmosphere and into space. The net radiation balance (Q*) of the morainal surface on Spitsbergen in the summer season is positive. At KH, it reached +6.45 MJ m^{2} in 2010, and 5.78 MJ m^{2} in 2011. On sunny days, the values of Q* exceeded 10 MJ m^{2} for morainal surface, e.g. on 28 July 2010 Q* reached 13.6 MJ m^{2} at the KH site.

On the firn field of the Waldemar Glacier (LW2), the mean diurnal sums of K↓, in the comparable period (21/07 – 31/08), amounted to 10.59 MJ m^{-2} in 2010, and 10.36 MJ m^{-2} in 2011 (Table 2). A large portion of the radiation was reflected by the snowy glacial surface of LW2 – the values of K↑ averaged at 7.25 MJ m^{-2} in 2010, and 6.05 MJ m^{-2} in 2011. The albedo at LW2 reached 60.9% in 2010, and 46.7% in the following year. The albedo varied due to the degree of ablation, which caused the winter snow to melt sooner in 2011, and the uncovered blue ice, which was built up by dark rock material from the surrounding hills, thus largely reducing the albedo of the surface. In 2010, on the other hand, the snow cover lasted longer, and summer snowfalls were more frequent, which significantly increased the albedo (up to 80 – 90%). As a result, the net shortwave radiation at LW2 was definitely less favourable, amounting to +4.31 MJ m^{-2} in 2010, and +5.40 MJ m^{-2} in 2011.

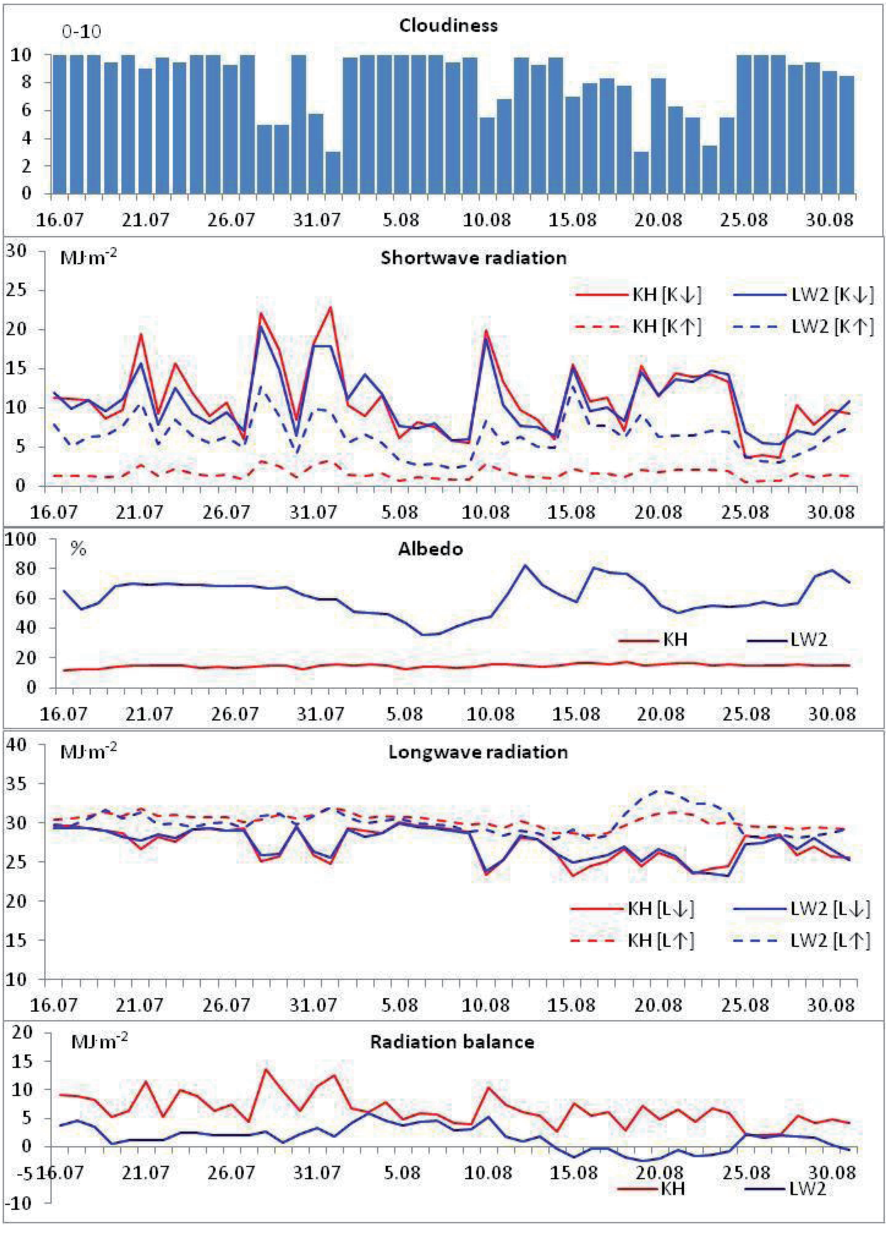

Fig. 2. The course of cloudiness and solar radiation fluxes at KH and LW2 stations in the summer season 2010

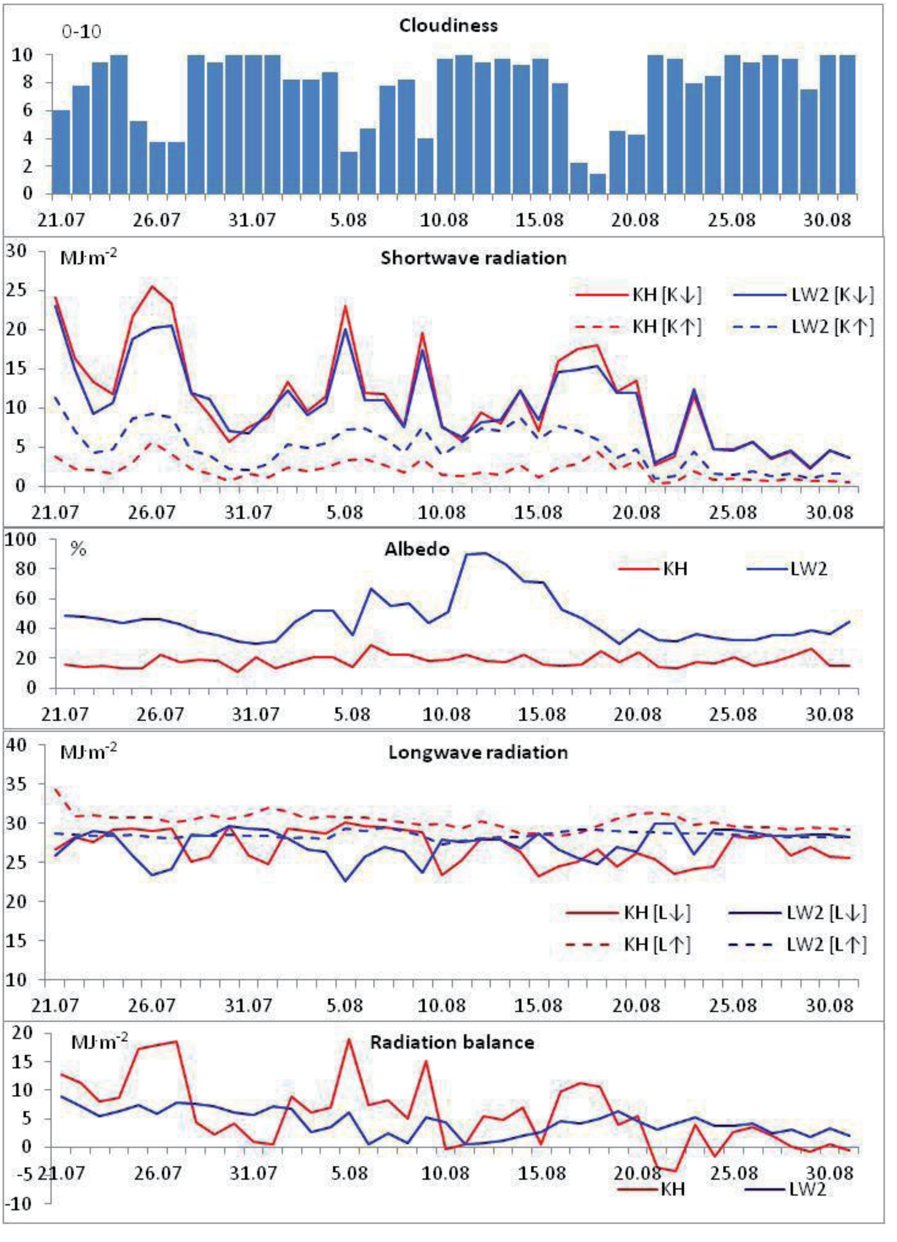

Fig. 3. The course of cloudiness and solar radiation fluxes at KH and LW2 stations in the summer season 2011

In the summer season, the melting point of snow/ice remains at 0°C on the glacier surface. However, ground frost occurs as well, especially at the end of August. At LW2, the mean values of longwave upward (terrestrial) radiation (L↑) amounted to 30.05 MJ m^{-2} in 2010, and 28.54 MJ m^{-2} in 2011, whereas values of the longwave downward (atmospheric) radiation (L↓) were 27.75 and 28.08 MJ m^{-2}, respectively. The net longwave radiation (L*) at LW2 was negative: 2.89 MJ m^2 in 2010, and –1.14 MJ m^2 in 2011. When sizeable cloudiness occurred, the values of L* were positive on some days, and L↓ exceeded the amount of lost surface energy. The net radiation balance (Q*) in the case of snowy and glacial surfaces is substantially less favourable. On the firn field of the Waldemar Glacier it reached only 1.58 MJ m^2 in 2010, and 4.36 MJ m^2 in 2011. Such a striking difference was due to the much lower albedo in 2011. On sunny days, the value of Q* for glacial surfaces was often lower than on cloudy days, e.g. on 28 July 2010 Q* amounted to 2.5 MJ m^2 at LW2. On the cloudy day of 3 August 2010 Q* reached 6.0 MJ m^2. At the end of August, the values of Q* were more and more often negative on the Waldemar Glacier.

Table 2. Radiation balance components (MJ m^{-2}) at the Waldemar Glacier (LW2) in the summer seasons 2010 and 2011

Period	K↓	K↑	A%	K*	L↓	L↑	L*	Q*
21–31.07.10	11.72	7.54	67.3	4.18	28.11	30.28	–2.18	2.00
1–10.08.10	10.86	4.93	46.1	5.93	28.24	30.14	–1.90	4.03
11–20.08.10	10.07	7.11	69.4	2.96	26.32	29.80	–3.48	–0.52
21–31.08.10	9.68	5.37	60.4	4.31	26.02	29.97	–3.95	0.37
21.07–31.08 2010	**10.59**	**6.25**	**60.9**	**4.34**	**27.17**	**30.05**	**–2.89**	**1.46**
21–31.07.11	14.00	6.05	41.5	7.94	27.37	28.47	–1.10	6.84
1–10.08.11	11.58	5.49	48.9	6.09	26.38	28.54	–2.15	3.93
11–20.08.11	11.22	6.38	61.4	4.84	26.98	28.64	–1.66	3.18
21–31.08.11	4.84	1.70	35.3	3.14	28.70	28.51	0.19	3.33
21.07–31.08 2011	**10.36**	**4.86**	**46.7**	**5.40**	**27.39**	**28.54**	**–1.14**	**4.36**

There are differences in individual components of Q* between the analysed sites. The values of K↓ are comparable, but the high albedo of the snowy and glacial surfaces at LW2 contributes to the less favourable shortwave radiation balance (K*) and, in consequence, affects the net radiation balance (Q*).

The influence of cloudiness on the radiation balance

An analysis of the cloudiness characteristics and the radiation balance components in the summer seasons of 2010 and 2011 revealed some significant relationships (Figs 2 and 3), which were presented as correlation diagrams in Figure 4. When cloudiness decreases the amount of incoming solar radiation (K↓) increases both on the moraine and on the glacier. Considering mean diurnal values, the determination coefficient (R^2) was 0.56 for the KH site (a change of 1.76 MJ m^{-2} per 1 degree of cloudiness) and 0.52 for the LW2 site (a change of 1.41 MJ m^{-2} per 1 degree of cloudiness). The reflected radiation also increases on bright days due to a greater intensity of K↓, which brings higher values of K↑ when the albedo is relatively constant.

The albedo did not demonstrate any susceptibility to cloudiness. At the KH site, it was practically unaltered, whereas significant changes at LW2 resulted from morainal material deposited by the melting of ice (decreased albedo) or from fresh snowfalls. Longwave terrestrial radiation increases in periods of clear weather, which is especially evident on morainal surfaces with a higher ground temperature. At the KH site, the change in L↑ reached 1.43 MJ m^{-2} per 1 degree of cloudiness ($R^2 = 0.53$). On cloudy days, the longwave downward radiation increases, which was visible on the glacier where L↓ rose by 0.65 MJ m^{-2} per 1 degree of cloudiness ($R^2 = 0.68$). At total cloudiness the fluxes of L↑ and L↓ compensate each other, and the reflected radiation becomes a major component of the net radiation balance (Bintanja and van den Broeke 1996).

The net radiation balance, a product of all the radiation fluxes, reveals different characteristics on morainal and glacial surfaces. At KH, a smaller amount of cloud resulted in an increase in Q* of 1.17 MJ m^{-2} per 1 degree of cloudiness ($R^2 = 0.36$), mainly due to a considerable increase in the net shortwave radiation (K*), which rose by 1.42 MJ m^{-2} per 1 degree of cloudiness ($R^2 = 0.53$) (Fig. 4). On the glacier (LW2) on the other hand, the Q* balance

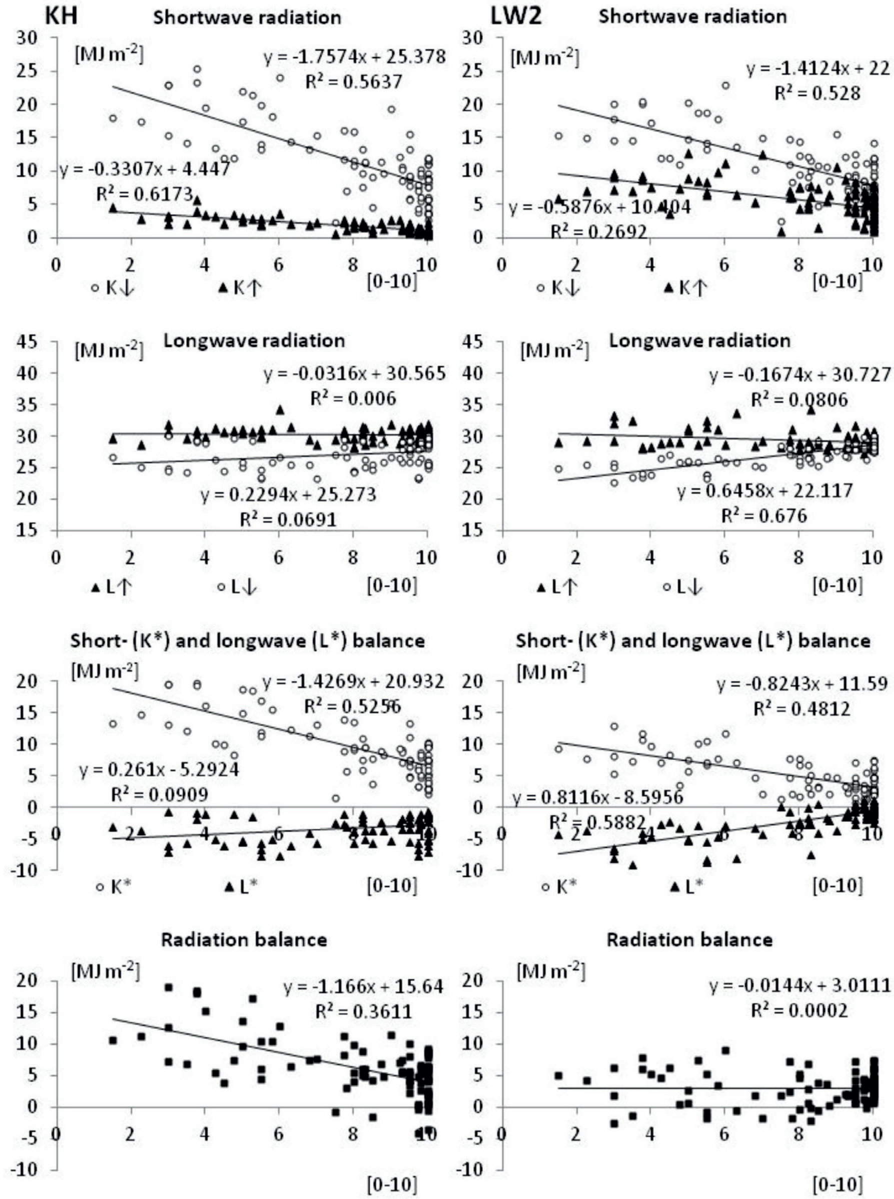

Fig. 4. The relation between daily values of cloudiness (0–10) and solar balance fluxes at KH and LW2 stations in summer seasons 2010 and 2011

measured on bright days had no correlation with the degree of cloudiness. This is an effect of a negative relationship between K* and cloudiness (a change by –0.82 MJ m^{-2} per 1 degree of cloudiness) and a positive one for L* (a change by 0.81 MJ m^{-2} per 1 degree of cloudiness). On sunny days at LW2, the absorption of energy by snow and ice is negligible because of their high albedo. However, on cloudy days the longwave downward radiation (L↓) increases, which results in a higher radiation balance for this type of surface.

Radiation balance and the types of synoptic situations

Atmospheric circulation is a crucial factor shaping the weather on Spitsbergen, predominantly through the types of incoming air masses, which have different physical features, stratification, cloudiness, and water vapour and aerosol content. This affects the optical characteristics of the atmosphere and modifies the components of the radiation balance.

In the analysed periods, different types of circulation occurred in the area of Spitsbergen. In 2010, cyclonic types prevailed (51.7%), whereas in 2011 anticyclonic types were more frequent (53.8%) (Przybylak and Maszewski 2012). Having combined the circulation types catalogued by Niedźwiedź (2011) as proposed by Przybylak (1992), the most frequent types in the two analysed summer seasons were found to have been Ca+Ka and NWc+Nc+NEc (both in 18.0% cases), and NWa+Na+NEa (16.9%). Other types occurred quite seldom: Ec+SEc (4.5%), Ea+SEa (5.6%) and X (4.5%) (Table 3).

At the KH site, the amount of incoming solar radiation K↓ was the greatest with such circulation types as Ea+SEa (14.1 MJ m^{-2}) and NWc+Nc+NEc (13.5 MJ m^{-2}), bringing air masses from the eastern and northern sectors (Table 3). On the other hand, during advection of cyclonic circulation the recorded amounts of radiation were 7.7 MJ m^{-2} for the eastern sector (Ec+SEc) and 8.6 MJ m^{-2} for the south and west (Sc+SWc+Wc). The reflected radiation (K↑) varied from 1.2 MJ m^{-2} with the Ec+SEc pattern to 2.6 MJ m^{-2} with Ea+SEa. The shortwave radiation balance (K*) at KH was the most favourable, with such circulation types as Ea+SEa (11.5 MJ m^{-2}) and NWc+Nc+NEc (11.4 MJ m^{-2}), and at LW2 with Ea+SEa (7.0 MJ m^{-2}) and NWa+Na+NEa (5.7 MJ m^{-2}).

Table. 3. Frequency of circulation types (days and %) and mean values of the radiation balance fluxes (in MJ m^{-2}) at KH and LW2 stations in summer seasons 2010 and 2011

Type	NWa+Na+ +NEa	Ea+SEa	Sa+SWa+ +Wa	Ca+Ka	NWc+Nc+ +NEc	Ec+SEc	Sc+SWc+ +Wc	Cc+Bc	X	Anticy-clonic	Cyclonic
Days	15	5	12	16	16	4	10	7	4	48	37
%	16.9	5.6	13.5	18.0	18.0	4.5	11.2	7.9	4.5	53.9	41.6
Kaffiøyra–Heggodden (KH)											
K↓	11.9	14.1	9.9	10.1	13.5	7.7	8.6	12.2	10.9	11.0	11.3
K↑	2.0	2.6	1.6	1.6	2.0	1.2	1.3	1.9	1.5	1.8	1.7
L↓	27.1	24.8	27.2	28.1	26.4	25.8	27.6	27.1	26.8	27.2	26.8
L↑	30.5	29.2	30.6	30.3	30.1	30.3	30.2	30.8	30.1	30.3	30.3
K*	9.9	11.5	8.2	8.5	11.4	6.5	7.3	10.4	9.4	9.2	9.6
L*	−3.4	−4.4	−3.4	−2.2	−3.7	−4.5	−2.6	−3.7	−3.3	−3.1	−3.5
Q*	6.6	7.2	4.9	6.3	7.7	2.0	4.7	6.6	6.1	6.1	6.1
Waldemar Glacier (LW2)											
K↓	11.9	13.0	9.5	9.7	12.3	8.0	7.2	11.5	9.9	10.7	10.3
K↑	6.2	6.0	4.8	4.2	7.4	3.4	4.6	6.2	6.9	5.2	6.0
L↓	25.9	26.6	28.5	27.9	26.4	28.5	28.6	27.8	27.2	27.3	27.5
L↑	30.5	29.0	29.1	29.0	29.3	29.1	28.7	28.9	29.5	29.5	29.1
K*	5.7	7.0	4.7	5.5	4.9	4.6	2.6	5.3	3.0	5.5	4.3
L*	−4.6	−2.4	−0.6	−1.1	−3.0	−0.7	−0.2	−1.1	−2.3	−2.2	−1.6
Q*	1.1	4.5	4.1	4.4	1.9	4.0	2.4	4.2	0.8	3.3	2.7

The longwave radiation emitted by the ground (L↑) reached its highest values with such patterns as Sa+SWa+Wa (30.6 MJ m^{-2}) and NWa+Na+NEa (30.5 MJ m^{-2}) at KH, whereas at the other site, LW2, with NWa+Na+NEa (30.5 MJ m^{-2}) and X (29.5 MJ m^{-2}). The downward atmospheric radiation (L↓) was the strongest with Ca+Ka (28.1 MJ m^{-2}) and Sc+SWc+Wc

(27.6 MJ m^{-2}) patterns at KH, whereas at LW2 it had its peaks with such circulation patterns as Sc+SWc+Wc (28.6 MJ m^{-2}), Sa+SWa+Wa and Ec+SEc (28.5 MJ m^{-2}). The net longwave radiation (L*) was negative and the greatest energy losses were observed at KH with Ec+SEc (–4.5 MJ m^{-2}) and Ea+SEa (–4.4 MJ m^{-2}) circulation types, and with NWa+Na+NEa (–4.6 MJ m^{-2}) on the glacier. At the glacier site (LW2) the value of L* was close to zero (–0.2 MJ m^{-2}) when the Sc+SWc+Wc pattern occurred.

The net radiation balance (Q*) reached the highest mean values on the morainal surfaces (KH) with the NWc+Nc+NEc and Ea+SEa circulation patterns (7.7 and 7.2 MJ m^{-2}, respectively), and the lowest with Ec+SEc (2.0 MJ m^{-2}). On the glacial surfaces (LW2) the balance was the most favourable with Ea+SEa (4.5 MJ m^{-2}) and Ca+Ka (4.4 MJ m^{-2}), and the least favourable with the X type (0.8 MJ m^{-2}), or NWa+Na+NEa and NWc+Nc+NEc (1.1 and 1.9 MJ m^{-2}, respectively).

Discussion and conclusions

Individual components of the solar radiation balance measured at the study sites (KH and LW2), representing morainal and glacial surfaces, were found to differ depending on the degree of cloudiness and the prevailing synoptic situation.

The net radiation balance (Q*) was more favourable on the morainal surface than on the snowy and glacial surface, and in 2010 its diurnal value averaged 6.32 MJ m^2 at the KH site, whereas at LW2 it only reached 1.46 MJ m^2, and in 2011 the respective values were 5.78 MJ m^2 and 4.36 MJ m^2. This was due to a more favourable net shortwave radiation (K*) influenced by the low albedo of the morainal surface (KH), which did not exceed 15–18%, while the average albedo on the glacier was 61% in 2010, and 47% in 2011. The longwave radiation balance on the moraine (KH) was less favourable due to a greater upward longwave terrestrial radiation (L↑) emitted by the warmer active surface. A melting glacial surface (at 0°C) emits approx. 315 W m^{-2} (Bintanja and van den Broeke 1996a). The amount of downward longwave atmospheric radiation (L↓) at the study sites were similar.

In the patterns of the radiation balance components, periods of low and high degrees of cloudiness are evident. However, when estimating the influence of clouds their types must be considered, as the radiation effect of high-layer clouds is much smaller than that of thick low-layer clouds (Nardino and Georgiadis 2003).

The cloud amount limited the influx of solar radiation (K↓) to a similar extent at KH and LW2 (–1.76 and –1.41 MJ m^{-2} per 1 degree of cloudiness, respectively). Bintanja and van den Broeke (1996a) demonstrated that the correlation is curvilinear and the influence of clouds on incoming solar radiation is negligible. The value of albedo (A) depends on the characteristics of the active surface and no correlation with cloudiness was found in the study. A similar conclusion was drawn by Bintanja and van den Broeke (1996a) after their observations in Greenland and in the Antarctic. However, clouds reduce effective upward terrestrial radiation, and the amount of downward atmospheric radiation increases. On glacial surfaces of Greenland and the Antarctic, L* rises from 60 to 100 W m^{-2} when the degree of cloudiness grows from 0 to 10 (Bintanja and van den Broeke 1996a). At LW2, the correlation was found to reach 8.12 MJ m^{-2}. In consequence, the energy resources in the earth-atmosphere system increase, which is reflected in a higher air temperature despite the cloud cover. This is the so-called 'radiation paradox'.

Cloudless and sunny weather favours higher values of Q* on the morainal surfaces (KH) thanks to a more favourable net shortwave radiation (K*). When the degree of cloudiness increases from 0 to 10, the mean diurnal values of Q* at KH fall by 11.7 MJ m^{-2}. This results in cooling of the surface (Nardino and Georgiadis 2003). On the glacier, on the other hand, the net radiation balance (Q*) shows no susceptibility to the amount of cloud. This is due to the opposite correlation with K* (a drop of 8.2 MJ m^{-2} when the cloud amount rises from 0 to 10) and L* (a rise of 8.1 MJ m^{-2}). In both Greenland and Antarctic there are variable correlations between Q* and cloudiness. Bintanja and van den Broeke (1996a) found this to depend on local surface characteristics, particularly such as the albedo and cloud transmissivity.

The development of cloudiness and optical characteristics of the atmosphere depend on the characteristics of incoming air masses. It was found that individual components of the net radiation balance were more affected by the advection (direction and type of air masses) than by the kind of barometric centre (cyclonic or anticyclonic), shaping weather conditions on Spitsbergen. The largest amount of solar radiation reaches the ground surface when the air masses come from the north and the east, as the cloud amount and aerosol content in these types of advection are both low (Dörnbrack et al. 2010).

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