Title: Frequency of Ice Days at Selected Meteorological Stations in Svalbard

Author: Ewa Łupikasza, Tadeusz Niedźwiedź

Citation style: Łupikasza Ewa, Niedźwiedź Tadeusz. (2013). Frequency of Ice Days at Selected Meteorological Stations in Svalbard. "Bulletin of Geography. Physical Geography Series" (2013, vol. 6, iss. 1, p. 81-97), doi 10.2478/bgeo-2013-0005

Bulletin of Geography – **Physical Geography Series**
No 6/2013: 81–97 http://dx.doi.org/10.2478/bgeo-2013-0005

EWA ŁUPIKASZA, TADEUSZ NIEDŹWIEDŹ

Department of Climatology, Faculty of Earth Science,
University of Silesia in Katowice,
Będzińska 60, 41-200 Sosnowiec, Poland
ewa.lupikasza@us.edu.pl

FREQUENCY OF ICE DAYS AT SELECTED METEOROLOGICAL STATIONS IN SVALBARD

Abstract: The paper aims to present research into both the long-term variability in the ice days in Svalbard representing the Atlantic sector of the Arctic, and their relations to atmospheric circulation. Ice days are defined as days with a daily maximum temperature below 0°C (Tmax<0°C). They are considered to be amongst the most important indices of current climate change. All the available data on daily maximum air temperature from three Norwegian stations (Svalbard Airport (Svalbard Lufthavn), Bjørnøya and Hopen) and from the Polish Polar Station in Hornsund (SW Spitsbergen) have been employed. The relevance of atmospheric circulation to the frequency of the occurrence of ice days was evaluated by calculating the Spearman correlation coefficients between the frequency of ice days and three regional circulation indices: zonal westerly circulation index (W), meridional southerly circulation index (S) and index of cyclonicity (C). At all the stations the number of ice days exhibited significant decreasing trends in the period of 1979-2012.

Key words: maximum air temperature, ice days, circulation indices, Svalbard, Arctic

Introduction

The Arctic, and thus Spitsbergen, differs from most parts of the world with respect to the climate conditions. This is due to its location at high latitudes, which determines the length of the day, and consequently, the amount of solar radiation. As a result, the influences of climate factors vary throughout the year. In the warmer part of the year (from the second decade of May to the second decade of September, Marsz 2013), the atmospheric conditions are created under the influence of atmospheric circulation and solar radiation. Atmospheric circulation, which is responsible for the majority of current climate changes in the Arctic (Serreze et al. 1993; Serreze and Francis 2006), determines the weather conditions in the Arctic during the whole year. The strength of climate factors, varying throughout the year, determines the annual course of air temperature in the Arctic and thus the frequency of ice days, which are considered to be an important indicator of current climate change. The analysis of recent air temperature changes in the Arctic revealed dramatic warming of approximately 1°C in the period 1995–2005, which was the most pronounced in autumn and winter (Przybylak 2007). Other studies have also revealed significant growing trends within the said area (Steffensen 1982; Ustrnul 1987; Nordli 1990; Nordli et al. 1996; Førland et al. 1997; Tuomenvirta et al. 2000; Førland and Hanssen-Bauer 2003; Nordli 2005; Przybylak 2007; Bednorz 2011; Marsz and Styszyńska 2013). In Svalbard, trends in the average annual temperature calculated for the period 1976–2001 varied from +0.49°C per decade in Bjørnøya to +0.84°C per decade in Hopen (Førland and Hanssen-Bauer 2003). In Central Spitsbergen, the winter temperature trend of +1.65°C per decade (1975–2008) led to less frequent negative anomalies of extreme temperature with a decrease of 5 days per decade (Bednorz 2011). Homogenized on the basis of all the available information, the longest (1911–2004) series of air temperature for Svalbard Airport representing Central Spitsbergen (Nordli et al. 1996, Nordli 2005) showed a positive mean annual temperature trend of +0.16°C per decade. The series also indicated the largest air-temperature change in spring, with the trend of +0.42°C per decade. In Hornsund, these trends were accompanied by a significant decrease in the number of ice days in May, July and December in the period 1979-2011 (Niedźwiedź et al. 2012).

This paper aims to assess the variability in the frequency of the occurrence of ice days in the Arctic and relationships between their occurrence and atmospheric circulation at four synoptic stations located above the latitude 70°N within the Atlantic sector of the Arctic: Svalbard Airport (Lufthavn, WMO No 01008, latitude 78°15’N, longitude 15°28’E, altitude 2 m), the Polish Polar Station in Hornsund (01003, 77°00’N, 15°33’E, 11 m), Hopen (01062, 76°30’N, 25°04’E, 6 m) and Bjørnøya (01028, 74°31’N, 19°01’E, 16 m). Ice days (Glickman 2000) are defined as days with a daily maximum temperature below 0°C (Tmax<0°C). They are amongst the most important indices of current climate change.

Data and methods

Maximum daily air temperature from the four meteorological stations mentioned above was used for extracting ice days. The large part of the data for Svalbard Airport (Svalbard Lufthavn), Hopen and Bjørnøya was derived from the Norwegian Meteorological Institute eKlima database (eklima.met.no). Some of the data were also taken from the European Climate Assessment & Dataset (ECA&D) (Klein Tank et al. 2002). The data for Hornsund come from the published Bulletins of IMGW (Miętus 2000–2001) and Bulletins of the Institute of Geophysics of the Polish Academy of Sciences including electronic ones (Institute of Geophysics 2001, 2003, Instytut Geofizyki PAN, 2009-2012). The most recent part of the data (October 1999–March 2013) was checked and updated by using the synoptic messages (SYNOP) available in the OGIMET database (Valor 2013).

Chronological series of maximum daily air temperature span various periods depending on the station. The longest series of over 67 yrs were gathered for Hopen (from November 1946 to March 2013) and Bjørnøya (from January 1946 to March 2013). The lengths of the other series amount to over 38 yrs in the case of Svalbard Airport (Lufthavn) (from January 1975 to March 2013) and to over 34 yrs in the case of Hornsund (from July 1978 to March 2013). The characteristics of the occurrence of ice days in Hornsund were published earlier (Niedźwiedź et al. 2012).

Three questions were brought up in the paper, namely the annual course of ice days, long-term variability of ice days and relations between the variability of the occurrence of ice days and circulation indices. The annual course of the frequency of ice days, including seasonal values, was analysed by calculating various descriptive statistics for the period of the data lapping (1979–2012). This allowed the spatial differentiation of the analysed index to be assessed. The second question concerns trends in the monthly and seasonal frequencies of the occurrence of ice days. These trends were calculated for all the available data (various periods depending on station), for a common period of 1979–2012 and for the period of dramatic warming in the Arctic detected by Przybylak (2007), which started in 1995 (1995–

2013). Statistical significance of the trends was assessed with the Mann-Kendall test (with correction for ties where necessary), whereas the magnitude and direction of the trends were estimated with the method of least-square linear trend. The relevance of atmospheric circulation to the frequency of ice days was evaluated by calculating the Spearman correlation coefficients between the frequency of the ice days and the frequency of three regional circulation indices by Niedźwiedź (2013 a, b). These circulation indices are W Index, S Index, which describe the strength of western and southern flow, respectively, and C Index (cyclonicity index), which informs about the frequency of cyclones. The indices were calculated on the basis of the frequency of particular circulation types while adapting the considerably modified method of Murray and Lewis (1966).

The western circulation index was calculated by the summation of scores (points) for days with different directions of air flow as follows: +2 for W, +1 for NW and SW types, −2 for E and −1 for types NE and SE. Positive values of this index occur when there is a distinct predominance of air advection from the west, whilst negative ones point to a strong easterly air flow.

The index of southerly circulation was calculated by the summation of scores allocated as follows: +2 for type S, +1 for types SW and SE, −2 for type N and −1 for types NW and NE. Hence, high positive values of index S point to an intensive meridional advection of air masses from the south, whilst negative ones point rather to advection from the north.

The third index, the cyclonicity index, was calculated by the summation of scores (points) for days with particular forms of circulation as follows: +2 for the centre of a cyclone Cc or a trough Bc, +1 for other cyclonic situations (Nc, NEc, Ec, SEc, Sc, SWc, Wc and NWc), −1 for advective anti-cyclonic types Na, NEa, Ea, SEa, Sa, SWa,Wa and NWa, −2 for the centre of an anticyclone Ca or a wedge Ka. Thus, positive values of C mean a measure of the domination of cyclonic types of circulation over anticyclonic ones.

The monthly total of the obtained scores (points) was divided by double the number of days in a particular month. Thus the values of the indices were expressed in relative numbers varying from -100 to 100%. The value of 100% of any index indicates that in a particular month the only types that occurred were those with the scores of +2, whereas the value of -100% means that types with the scores -2 only appeared in a particular month.

Annual course of ice days

The average annual number of ice days varied from 133 days (36% of days) at Bjørnøya station located at the lowest latitude to 195 days (53% of days) at Svalbard Airport, which is the station which juts out the furthest towards the north. The frequency of ice days for the period from July to June is almost the same as the annual one. The range of the annual number of ice days is the greatest at Bjørnøya – with 100 days – whereas at the other stations it reaches slightly over 90 days. In the July-June period the maximum range of the frequency of ice days characterizes Svalbard Airport (Table 1). Both annual and July-June average values of the frequency of ice days at Hopen are slightly lower than those of Svalbard Airport located further to the north and much higher than those of Hornsund located at nearly the same latitude as Hopen. The spatial distribution of the frequency of ice days depends on the season. In winter the highest number of ice days occurs in Svalbard Airport and Hopen, whereas the lowest number has been noted in Bjørnøya. The frequency of days with Tmax< 0°C amounts to over 80% of winter days except for Bjørnøya with ice days constituting 68% of winter days. In spring the maximum frequency of the occurrence of ice days was recorded in Hopen (77 days, 85% of spring days) and next Svalbard Airport (68 days, 74% of spring days). At all the stations ice days in spring were more frequent than in autumn (Table 1). Ice days occurred even in summer; however their frequency was very low then (Table 1).

Table 1. Descriptive statistics of the frequency of ice days at selected stations within the Atlantic sector of the Arctic in the period 1979–2012

Period	Station	Frq [%]	Avg (±SE) [no of days]	Confidence intervals -95%	Confidence intervals +95%	Min	Max	SD
Year	Svalbard Airport	53	195(±3)	188	202	139	230	20
	Hornsund	50	182(±4)	174	189	136	227	21
	Hopen	52	191 (±4)	184	198	143	234	21
	Bjørnøya	36	133(±5)	123	142	81	181	27

Table 1. contd.

Period	Station	Frq [%]	Avg (±SE) [no of days]	Confidence intervals -95%	Confidence intervals +95%	Min	Max	SD
Jul – Jun	Svalbard Airport	53	195(±4)	188	202	133	238	21
	Hornsund	50	182(±4)	175	190	132	228	21
	Hopen	53	192(±4)	185	199	145	239	21
	Bjørnøya	37	134(±4)	125	142	79	176	25
Winter	Svalbard Airport	85	77(±4	74	80	48	89	9
	Hornsund	83	74(±4)	71	78	46	88	10
	Hopen	85	77(±4)	73	80	52	86	9
	Bjørnøya	68	61(±4)	57	66	31	82	13
Spring	Svalbard Airport	74	68(±4)	65	71	39	90	9
	Hornsund	71	66(±4)	63	68	46	90	8
	Hopen	77	71(±4)	68	74	53	88	8
	Bjørnøya	58	48(±4)	44	52	18	71	12
Summer	Svalbard Airport	1	1(±4)	0	2	0	8	2
	Hornsund	1	1(±4)	0	1	0	6	2
	Hopen	5	5(±4)	4	6	0	12	3
	Bjørnøya	1	1(±4)	0	2	0	8	2
Autumn	Svalbard Airport	54	49(±4)	46	52	27	73	9
	Hornsund	45	41(±4)	37	45	21	68	11
	Hopen	43	39(±4)	35	43	14	65	12
	Bjørnøya	25	23(±4)	19	27	2	44	11

Frq – frequency in % of days in a particular period (year, July – June, season), Avg – average number of ice days, SE – standard error, Min – minimum, Max – maximum, SD – standard deviation.

Located at the lowest latitude Bjørnøya is the warmest of the stations during the whole year. Except for summer, the seasonal number of ice days varied from 23 days (25% of autumn days) to 61 days (68% of winter days). The average difference between the number of days with Tmax< 0°C at Bjørnøya station and the other stations amounts to 20 days in spring and autumn and to 15 days in winter.

During the year the frequency of ice days reached its maximum in January or in March depending on the station (Fig. 1). Both in January and March ice days constituted on average from 21 days in Bjørnøya to 27 days in Hopen and Svalbard Airport. The ranges of the monthly numbers of ice days from

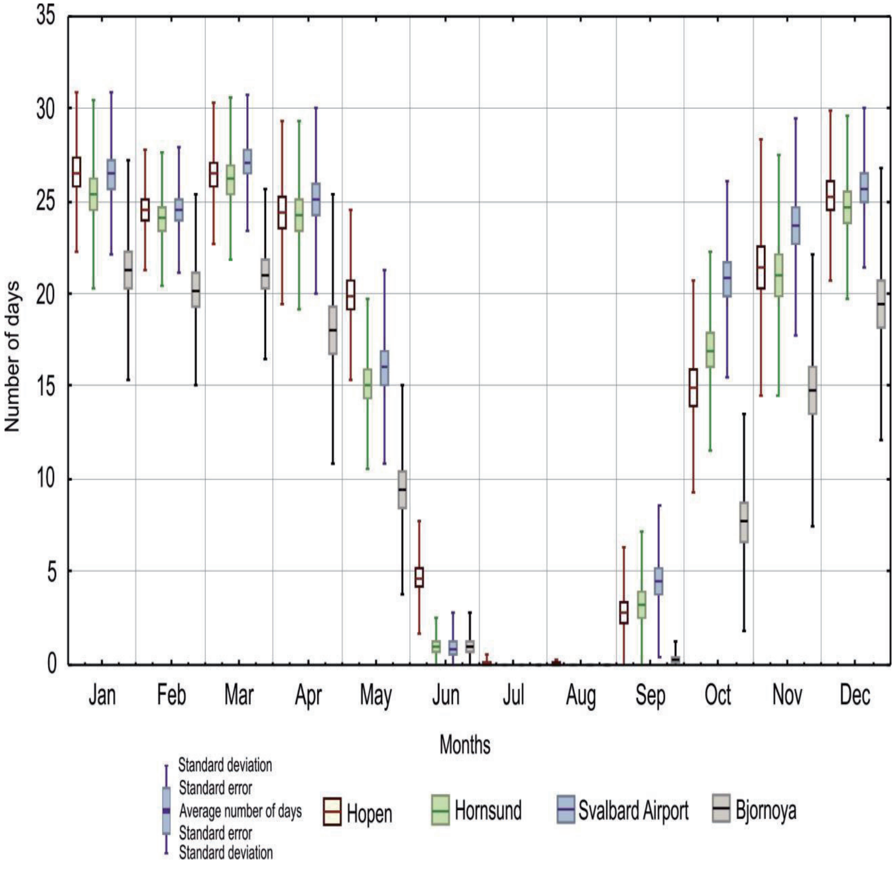

Fig. 1. Statistics of the annual course of the occurrence of ice days at selected stations within the Atlantic sector of the Arctic in the period 1979–2012

December to April were small (6 days in Hopen to 11 days in Svalbard Airport and Hornsund) when compared with the remaining part of the year. The number of ice days was dramatically falling from April to June and was increasing from September toDecember. In Hopen and Svalbard Airport ice days also occurred in the warmest months of the year (July, August). There were 3 ice days and 1 ice day noted in all Julies and Augusts respectively at Hopen station, and 30 ice days noted in all Julies at Svalbard Airport station in the period 1979–2012. The frequency of ice days in these months is greater when considering all the available data: 18 days in Julies and 9 days in Augusts in Hopen, 59 days in all Julies in Svalbard Airport and 2 days in Julies in Bjørnøya.

Long-term variability of ice days

Decrease in the frequency of ice days dominated within the research area. Each of the significant trends was negative. Both the magnitude and significance of the trends varied depending on the analysed period (all the available data, 1979–2012 and 1995–2012). The majority of monthly and seasonal trends in the frequency of ice days in the period of 1995–2012, which is considered as a period of dramatic warming in the Arctic, were insignificant except for May; however, the rate of the changes was the largest when compared with the other periods (all the available data and the period 1979–2012).

Taking into consideration monthly values, the most distinct changes in the frequency of ice days characterized May and June. At Hopen and Bjørnøya stations, significant decreases were recognized in all the investigated periods. The magnitude of negative trends at Bjørnøya station reached -3.2 days/10 yrs in the period of 1979–2012 and -8.1 days/10yrs in the period of 1995–2012. The rate of ice day decrease at Hopen was smaller (Table 2). Significant changes in the occurrence of ice days in May were also recognized in Svalbard Airport in the periods of 1979–2012 and 1995–2012 and in Hornsund in the period of 1995–2012. Negative trends of the frequency of ice days occurred in December. These trends were significant in the period of 1979–2012 at each of the analysed stations as well as in the periods of the available data at Hornsund and in the period of 1995–2012 at Bjørnøya.

Table 2. Statistical significance and magnitude of trends in the monthly number of ice days at selected stations within the Atlantic sector of the Arctic

Month	Period	Svalbard Airport		Hornsund		Hopen		Bjørnøya	
		P	t/10yrs.	p	t/10yrs.	p	t/10yrs.	p	t/10yrs.
Jan	a			0.072	-2.0	0.321	-0.3	**0.033**	**-0.7**
	b	**0.041**	**-1.7**	0.128	-1.9	0.102	-1.7	**0.017**	**-2.6**
	c	0.100	-3.6	0.127	-4.5	0.156	-3.2	0.342	-2.5
Feb	a			0.852	-0.3	0.859	0.0	0.782	-0.1
	b	0.811	-0.5	0.940	-0.3	0.730	0.0	0.613	0.2
	c	0.100	-3.0	0.154	-3.4	0.140	-3.0	0.159	-4.0
Mar	a			0.407	0.2	0.639	0.1	0.899	0.0
	b	0.288	0.5	0.483	0.1	0.893	0.1	0.917	-0.4
	c	0.758	0.3	1.000	-0.8	0.400	-1.1	0.703	-2.2
Apr	a			0.244	-1.4	0.824	-0.2	0.523	-0.5
	b	0.379	-1.1	0.244	-1.4	0.644	-0.6	0.555	-1.2
	c	0.702	-1.3	0.729	-1.0	0.491	-1.1	0.157	-6.1
May	a			0.089	-2.0	**0.017**	**-0.7**	**0.000**	**-1.2**
	b	**0.025**	**-2.4**	0.089	-2.0	**0.020**	**-1.8**	**0.000**	**-3.2**
	c	0.036	-5.8	0.022	-5.0	0.040	-4.2	0.001	-8.1
Jun	a			**0.007**	**-0.7**	**0.002**	**-0.8**	**0.008**	**-0.3**
	b	**0.011**	**-0.9**	**0.007**	**-0.7**	**0.037**	**-1.3**	**0.024**	**-0.8**
	c	0.112	-0.8	0.248	-0.5	0.818	-0.6	1.000	-0.1
Sep	a			0.209	-1.1	**0.010**	**-0.5**	0.143	-0.1
	b	0.178	-1.1	0.373	-0.9	**0.017**	**-1.3**	0.201	-0.2
	c	0.375	-1.4	0.534	-0.7	0.119	-1.3	1.000	0.0
Oct	a			0.176	-1.4	0.649	-0.2	0.536	-0.2
	b	0.396	-0.9	0.222	-1.4	0.144	-1.7	**0.045**	**-2.0**
	c	0.540	-0.4	0.192	-2.3	0.073	-3.1	0.195	-3.3

Table 2. contd.

Month	Period	Svalbard Airport		Hornsund		Hopen		Bjørnøya	
		P	t/10yrs.	p	t/10yrs.	p	t/10yrs.	p	t/10yrs.
	a			0.171	-1.6	0.848	0.0	0.398	-0.6
Nov	b	0.165	-1.3	0.166	-1.7	0.063	-2.5	**0.022**	**-3.3**
	c	1.00	-1.0	0.970	-1.4	1.000	-0.2	0.491	-3.9
	a			**0.001**	**-2.1**	0.211	-0.1	0.173	-0.5
Dec	b	**0.004**	**-1.6**	**0.001**	**-2.2**	**0.000**	**-2.2**	**0.000**	**-4.1**
	c	0.437	-1.7	0.061	-3.5	0.304	-2.0	**0.029**	**-5.4**

Periods of trends analysis: a – all available data at particular stations, b – 1979–2012, c – 1995–2012, p – level of statistical significance calculated with Mann-Kendall test, t – trend magnitude calculated with the method of least squares, bold values are significant at $\alpha \leq 0.05$.

The number of ice days was significantly declining in January (periods of the available data and 1979-2012) at Svalbard Airport and Bjørnøya stations located furthest to the north and south, in February (period of all the available data) at Svalbard Airport station, in September (period of 1979–2012) at Hopen station and in October and November at Bjørnøya stations (1979–2012) (Table 2).

An insignificant but uniform direction of the trends (downward) in the majority of monthly frequencies of ice days resulted in the statistically significant negative trends of annual and July-June numbers of ice days during each of the analysed periods. The most significant changes appeared in the period of 1979–2012, particularly for annual values. The magnitudes of these trends were the greatest in the period of 1995–2012. The changes in the frequency of ice days are in line with the general air temperature increase in the Arctic for annual values as well as for the season of the occurrence of ice days (July–June). The statistical significance of seasonal trends revealed important changes in the frequency of ice days in summer (period of the available data, and 1979–2012), winter and autumn (various periods depending on the station). Important changes in the index occurred in the period of 1979–2012. In Hopen, a significant decrease was also detected in 1995–2012. In autumn the trends were significant only in the period of 1979–2012. At the majority of the stations, the trends in the frequency of spring ice days were not significant except for Bjørnøya (Table 3).

Table 3. Statistical significance and magnitude of trends in the annual and seasonal numbers of ice days at selected stations within the Atlantic sector of the Arctic

Season	Period	Svalbard Airport		Hornsund		Hopen		Bjørnøya	
		p	t/10yrs.	p	t/10yrs.	p	t/10yrs.	p	t/10yrs.
Year	a			**<0.0001**	**-12.3**	**0.028**	**-2.8**	**0.007**	**-4.4**
	b	**0.000**	**-11.0**	**<0.0001**	**-12.3**	**<0.0001**	**-13.1**	**<0.0001**	**-18.0**
	c	**0.007**	**-18.6**	**0.008**	**-22.9**	**0.007**	**-20.0**	**0.000**	**-35.1**
July-June	a			**0.001**	**-12.1**	**0.022**	**-2.7**	**0.013**	**-4.4**
	b	**0.001**	**-11.2**	**0.001**	**-12.1**	**0.000**	**-13.6**	**<0.0001**	**-17.9**
	c	**0.019**	-21.3	0.003	-24.0	0.005	-22.4	0.000	-40.3
Winter DJF	a			**0.011**	**-4.5**	0.461	-0.4	0.119	-1.3
	b	**0.012**	**-3.8**	**0.026**	**-4.1**	**0.006**	**-4.0**	**0.003**	**-6.5**
	c	**0.034**	**-8.0**	0.062	-9.4	**0.049**	**-7.6**	0.067	-11.9
Spring MAM	a			0.099	-3.2	0.106	-0.8	**0.010**	**-2.0**
	b	0.162	-3.0	0.099	-3.2	0.141	-2.3	**0.009**	**-5.6**
	c	0.119	-6.7	0.073	-6.7	0.119	-6.4	**0.001**	**-18.6**
Summer JJA	a			**0.007**	**-0.7**	**0.001**	**-0.9**	**0.007**	**-0.3**
	b	**0.011**	**-0.9**	**0.007**	**-0.7**	**0.034**	**-1.3**	**0.024**	**-0.8**
	c	0.112	-0.8	0.248	-0.5	0.618	-0.9	1.000	-0.1
Autumn SON	a			**0.008**	**-4.1**	0.253	-0.7	0.211	-0.9
	b	**0.048**	**-3.4**	**0.017**	**-4.0**	**0.005**	**-5.5**	**0.005**	**-5.6**
	c	0.323	-2.8	0.170	-4.4	0.362	-4.6	0.161	-7.2

Periods of trends analysis: a – all available data at particular stations, b – 1979–2012, c – 1995–2012, p – level of statistical significance calculated with Mann-Kendall test, t – trend magnitude calculated with the method of least squares, bold values are significant at $\alpha \leq 0.05$.

Relations between the variability of the occurrence of ice days and circulation indices

Atmospheric circulation has a significant impact on the occurrence of ice days in the Atlantic sector of the Arctic. The correlations between the frequency of ice days and W index are statistically significant in the majority of months. The relations are significant from November to April and are the strongest in February and March for all of the stations. Significant correlation coefficients are negative, which means that the stronger inflow is from the west, the smaller the number of ice days is. The nature of the relationships between the occurrence of ice days and other circulation indices is similar. Correlations between ice days and S Index are significant from September (Hornsund, Hopen, Bjørnøya) or October (Svalbard Airport) to May (Svalbard Airport, Hopen, Bjørnøya) or April (Hornsund). The strongest ones persist in November and December (Fig. 2). The sign of the correlation coefficients indicates that an inflow from the northern sector causes an increase in the frequency of ice days.

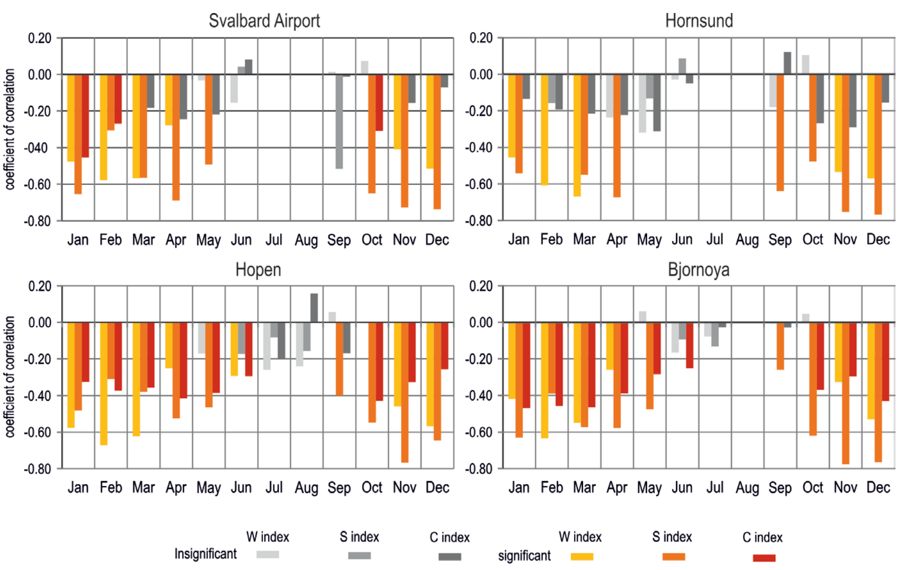

Fig. 2. Correlation coefficients between the monthly number of ice days and circulation indices at selected stations within the Atlantic sector of the Arctic (various periods depending on station – Svalbard Airport: 1979–2013, Hornsund: 1978–2012, Hopen and Bjørnøya: 1950–2013), significance level α=0.05.

In Svalbard Airport and Hornsund, the relation between S index and the frequency of ice days is significant during a shorter part of the year (fewer months) than in Hopen and Bjørnøya. This applies also to the W index. The C type has no influence on the monthly frequency of ice days in Hornsund. In Svalbard Airport the frequency of days with Tmax<0°C depends upon the frequency of cyclones only in January, February and October. In Hopen and Bjørnøya correlations between the occurrence of ice days and C Index were significant from October to June, and revealed that the existence of cyclones was not favourable for ice days.

The calculated correlation between the seasonal values indicated that the frequency of the occurrence of ice days was triggered mostly by S weather types. For the majority of the stations the strongest correlations were found in winter, except for Svalbard Airport, where the highest correlation fell in autumn. In winter and spring the frequency of ice days is also related to the strength of inflow from the west (W index), which caused a decrease in the number of such days. Relations between the seasonal number of ice days and C index varied depending on the stations. These were statistically significant in spring at Svalbard Airport and Hornsund stations, in winter at Hopen station and in both winter and spring at Bjørnøya station (Fig. 3). However, it must be remembered that the result of the correlation analysis has been influenced by the fact that the obtained data refer to different periods available at the particular stations.

Conclusions

The occurrence of ice days in the Arctic for the stations of Svalbard Airport, Hornsund, Hopen and Bjørnøya varied from 36% to 53% of the days in the year. The number of ice days is influenced by atmospheric circulation and latitude. The highest frequency of ice days was the greatest in winter, and it was higher in spring than in autumn. Taking into consideration particular months, bimodal annual distribution of the frequency of ice days was found with the maximum in January and March. The relation between the occurrence of ice days and latitude was the strongest in winter, when ice days constituted the least number of ice days at the southernmost station Bjørnøya, and the greatest number of ice days at the northernmost station Svalbard Airport. The most rapid changes in the frequency of ice days occurred from April to June and from September to November.

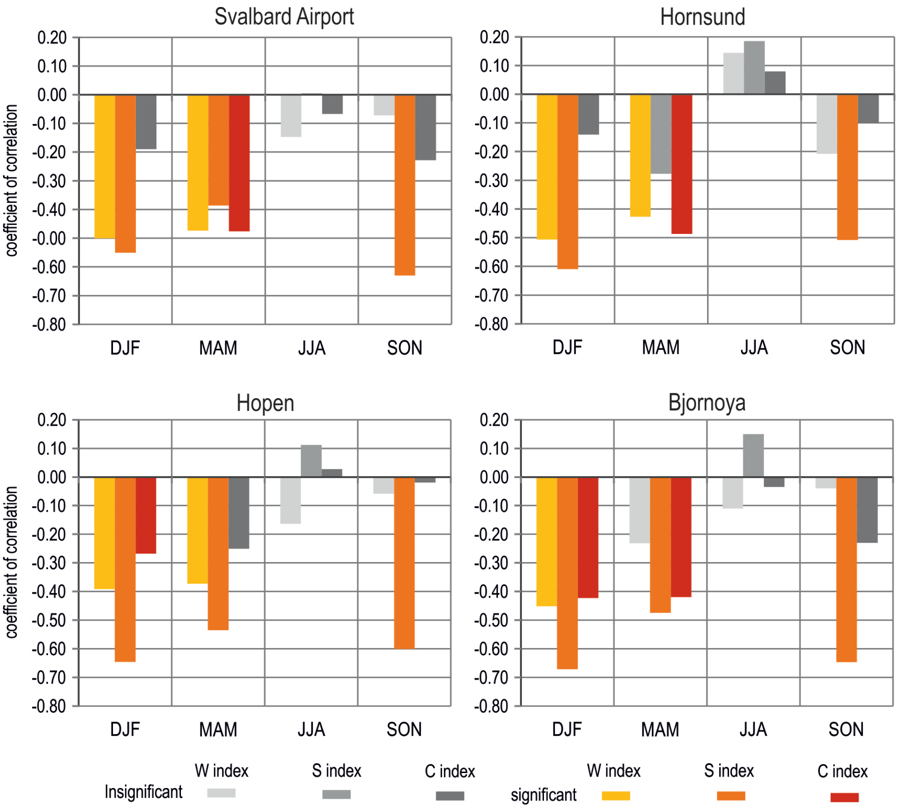

Fig. 3. Correlation coefficients between the seasonal number of ice days and circulation indices at selected stations within the Atlantic sector of the Arctic (various periods depending on station – Svalbard Airport: 1979–2013, Hornsund: 1978–2012, Hopen and Bjørnøya: 1950–2013), significance level α=0.05.

Both the annual and the July-June numbers of ice days were decreasing in the Atlantic sector of the Arctic. At all the stations seasonal values exhibited significant negative trends in the period of 1979-2012, which, however, were not detected while analysing all the available data (different periods depending on the station) and the period of 1995-2012. Monthly frequencies of ice days have significantly diminished in May, June and December. The trends in the frequency of ice days were insignificant, except for May, in the period of 1995-2012, which is considered as a period of dramatic warming in the Arctic; however the magnitude of the majority of the trends for this period was the greatest when compared with other analysed periods.

The frequency of the occurrence of ice days is the most related to atmospheric circulation at Bjørnøya and then at Hopen. The weakest relations were found for Hornsund. Of all the analysed circulation types, the S type had the strongest influence on the occurrence of ice days, whereas the C type had the least influence. At Bjørnøya, the importance of W index as a predictor of the occurrence of ice days was smaller than the C index.

References

BEDNORZ E., 2011, Occurrence of winter air temperature extremes in Central Spitsbergen, Theor. Appl. Climatol., 106(3–4), 547–556.

FØRLAND E.J., HANSSEN-BAUER I. and NORDLI P.Ø., 1997, Climate statistics and long term series of temperature and precipitation at Svalbard and Jan Mayen, DNMI—Rapport, 21/97. Norwegian Meteorological Institute, Oslo

FØRLAND E.J. and HANSSEN-BAUER I., 2003, Past and future climate variations in the Norwegian Arctic: overview and novel analyses, Polar Res., 22(2), 113–124.

GLICKMAN T.S. (ed.), 2000, Glossary of Meteorology, Second Edition, American Meteorological Society, Boston Massachusetts, U.S.A., 855 pp.

INSTITUTE OF GEOPHYSICS POLISH ACADEMY OF SCIENCE, 2001, Meteorological conditions Hornsund, Spitsbergen 2000/2001, Publications of the Institute of Geophysics Polish Academy of Science, D-57(341).

INSTITUTE OF GEOPHYSICS POLISH ACADEMY OF SCIENCE, 2003. Meteorological conditions Hornsund, Spitsbergen 2001/2002, Publications of the Institute of Geophysics Polish Academy of Science, D-60(351).

INSTYTUT GEOFIZYKI PAN, 2009-2013, Biuletyn meteorologiczny – Spitsbergen – Hornsund (Meteorological Bulletin – Spitsbergen – Hornsund), 2009.10-2013.03 (available on line at: www.glacio-topoclim.org/index.php/reports).

KLEIN TANK A.M.G. and COAUTHORS, 2002, Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment, Int. J. Climatol., 22, 1441–1453. Data and metadata available at http://www.ecad.eu

MARSZ A.A., 2013, Air temperature, [in:] Marsz A.A., Styszyńska A. (eds), 2013, Climate and climate change at Hornsund, Svalbard, Maritime University, Gdynia, 145-187.

MARSZ A.A. and STYSZYŃSKA A. (eds), 2013, Climate and climate change at Hornsund, Svalbard, Maritime University, Gdynia, 402 pp.

MIĘTUS M. (ed.), 2000-2001, Roczniki Meteorologiczne Hornsund (Meteorological Yearbooks Hornsund) (1978/79–1980/81, 1982/83–1999/2000). Instytut Meteorologii i Gospodarki Wodnej Oddział Morski, Gdynia.

MURRAY R. and LEWIS R.P., 1966, Some aspects of the synoptic climatology of the British Isles as measured by simple indices, Meteorol. Magazine, 95, 193–203.

NIEDŹWIEDŹ T., ŁUPIKASZA E. and MAŁARZEWSKI Ł., 2012. Wpływ cyrkulacji atmosfery na występowanie dni mroźnych w Hornsundzie (Spitsbergen) (The influence of the atmospheric circulation on the occurrence of ice days in Hornsund (Spitsbergen), Probl. Klimatol. Pol., Gdynia, 22, 17–26 (in Polish, summary in English).

NIEDŹWIEDŹ T., 2013a, The atmospheric circulation, [in:] MARSZ A.A., STYSZYŃSKA A. (eds), 2013, Climate and climate change at Hornsund, Svalbard, Maritime University, Gdynia, 57–74.

NIEDŹWIEDŹ T., 2013b, Catalogue of circulation types above Spitsbergen (1951–2013), Department of Climatology, Faculty of Earth Sciences, University of Silesia, Sosnowiec, Poland. Computer file available on line at http://klimat.wnoz.us.edu.pl.

NORDLI P.Ø., 1990, Temperature and precipitation series at Norwegian Arctic meteorological stations, DNMI KLIMA. Rapport 40(90), 1–14.

NORDLI P.Ø., 2005, Long-term temperature trends and variability at Svalbard (1911–2004), Geophys., Res. Abstracts, 7(06939), SRef-ID: 1607-7962/gra/EGU05-A-06939.

NORDLI P.Ø., HANSSEN-BAUER I. and FØRLAND E.J., 1996, Homogeneity analyses of temperature and precipitation series from Svalbard and Jan Mayen, DNMI-klima. No. 16/96, 41 pp.

PRZYBYLAK R., 2007, Recent air-temperature changes in the Arctic, Annales Glaciol., 46, 316–324.

SERREZE M.C., BOX R.G., BARRY R.G. and WALSH J.E., 1993, Characteristics of Arctic synoptic activity, Mete. and Atmos. Phys., 51(3), 147–164.

SERREZE M.C. and FRANCIS J.A., 2006, The Arctic amplification debate, Clim. Change, 76, 241–264.

STEFFENSEN E.L., 1982, The climate at Norwegian Arctic stations, Det Norske Meteorologiske Institutt, Klima nr.5, Oslo.

TUOMENVIRTA H., ALEXANDERSSON H., DREBS A., FRICH P. and NORDLI P.Ø., 2000, Trends in Nordic and Arctic temperature extremes and ranges, J. Climate, 13(3), 977–990.

USTRNUL Z., 1987, Some characteristics of air thermal conditions in Hornsund, Spitsbergen, Polish Polar Res., 8 (3), 261–275.

VALOR G.B., 2013, OGIMET – Professional information about meteorological conditions in the world (SYNOP messages available on-line on the web site: http://www.ogimet.com). Last access 17 August 2013.