The ice winter of 2015/16 on the German North and Baltic Sea coasts with a brief description of ice conditions in the entire Baltic Sea region

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Content

Southern Beach of Thiessow in the Bay of Greifswald on 09.01.2016 Courtesy of Frank Sakuth

Progression of the ice winter on the German North and Baltic Sea coasts

Weather conditions on the German coastal areas

The seasonal cooling of the air and water proceeded very slowly in November and December 2015. With monthly mean air temperatures between 6°C and 10°C on the German coasts, November and December values lay well above those of the reference period from 1961 to 1990 (Ch. Lefebvre, 2013). In January, in contrast, air temperatures were lower than the long-term average on the east German coast, on the western part, however, it was also slightly too warm for that time of the year. Nevertheless, the January was the coolest months in the winter 2015/2016. The weather situation was dominated by continental air masses from the south-east. As a consequence, air temperatures were below the freezing point in the beginning of January. Around the 9th January, it became warmer for few days due to a short-term west wind situation, but at the 17th January, a new frost period started.

Table 1: Monthly mean air temperatures (°C) in the winter of 2015/16 and their deviations from the 1961 – 1990 (K) climatology (Data source: Deutscher Wetterdienst, www.dwd.de).

Station	November		December		January		February		March	
	°C	K	°C	K	°C	K	°C	K	°C	K
Greifswald	7.3	2.7	6.75	5.65	-0.85	-0.25	3.45	3.45	4.3	1.6
Rostock-Warnemünde	8.1	2.8	7.7	5.8	0.1	-0.1	3.7	3	4.55	1.45
Schleswig	7.7	2.8	7.4	5.7	0.7	0.4	3.1	2.5	4.3	1.5
Norderney	9.6	3.3	8.7	5.5	2.4	0.8	4.6	2.8	5	1.0

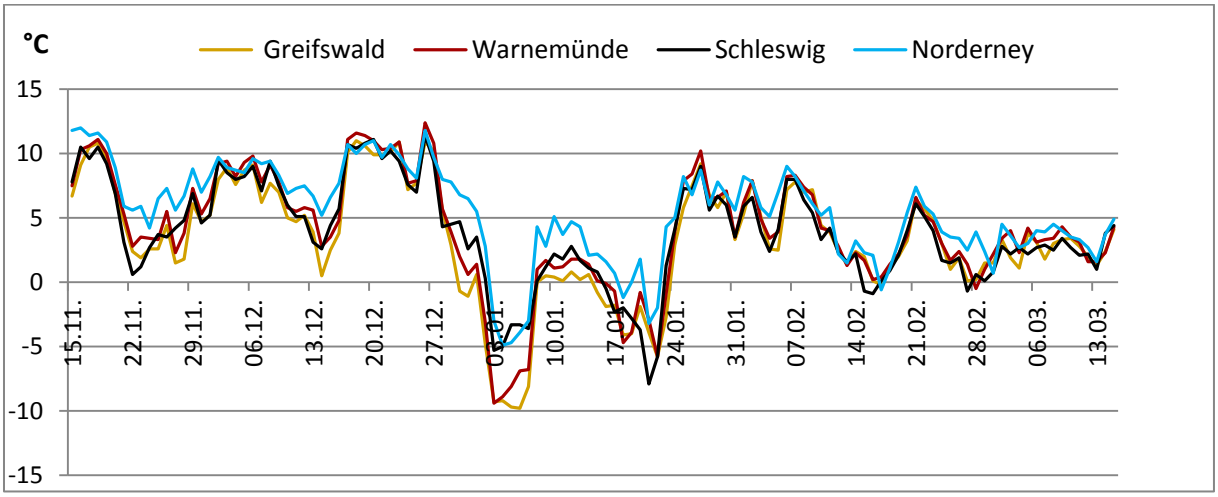


Figure 1: Daily averages of air temperatures in the winter 2015/16 (Data source: Deutscher Wetterdienst, www.dwd.de/)

Hence, in the winter 2015/2016, two closely subsequent cold periods occurred in the time from beginning of January through the end of January 2016. The lowest air temperatures measured in this period lay between -3 and -10°C, in which air temperatures were generally lower in the east than in the west. Figure 2 illustrates this gradient from the west (German North Sea coast) to the east (German Baltic Sea coast). End of January, around the 23rd/24th, a west wind situation established again and air temperatures rose nearly consistently above the freezing point on the German coasts. Afterwards, air temperatures below 0°C were measured only occasionally, with the consequence that short-time new ice formation occurred again locally.

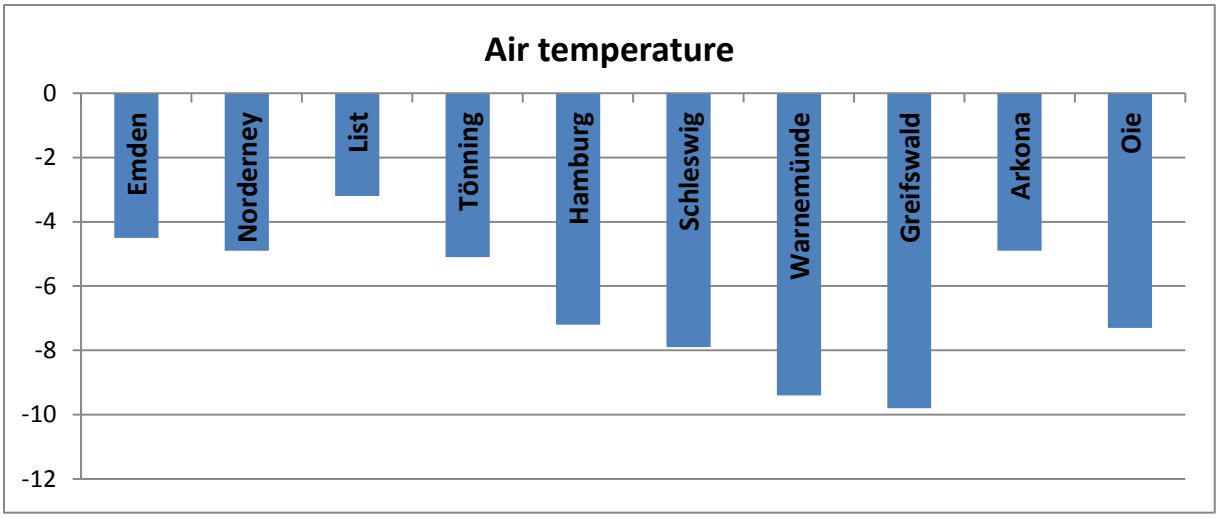
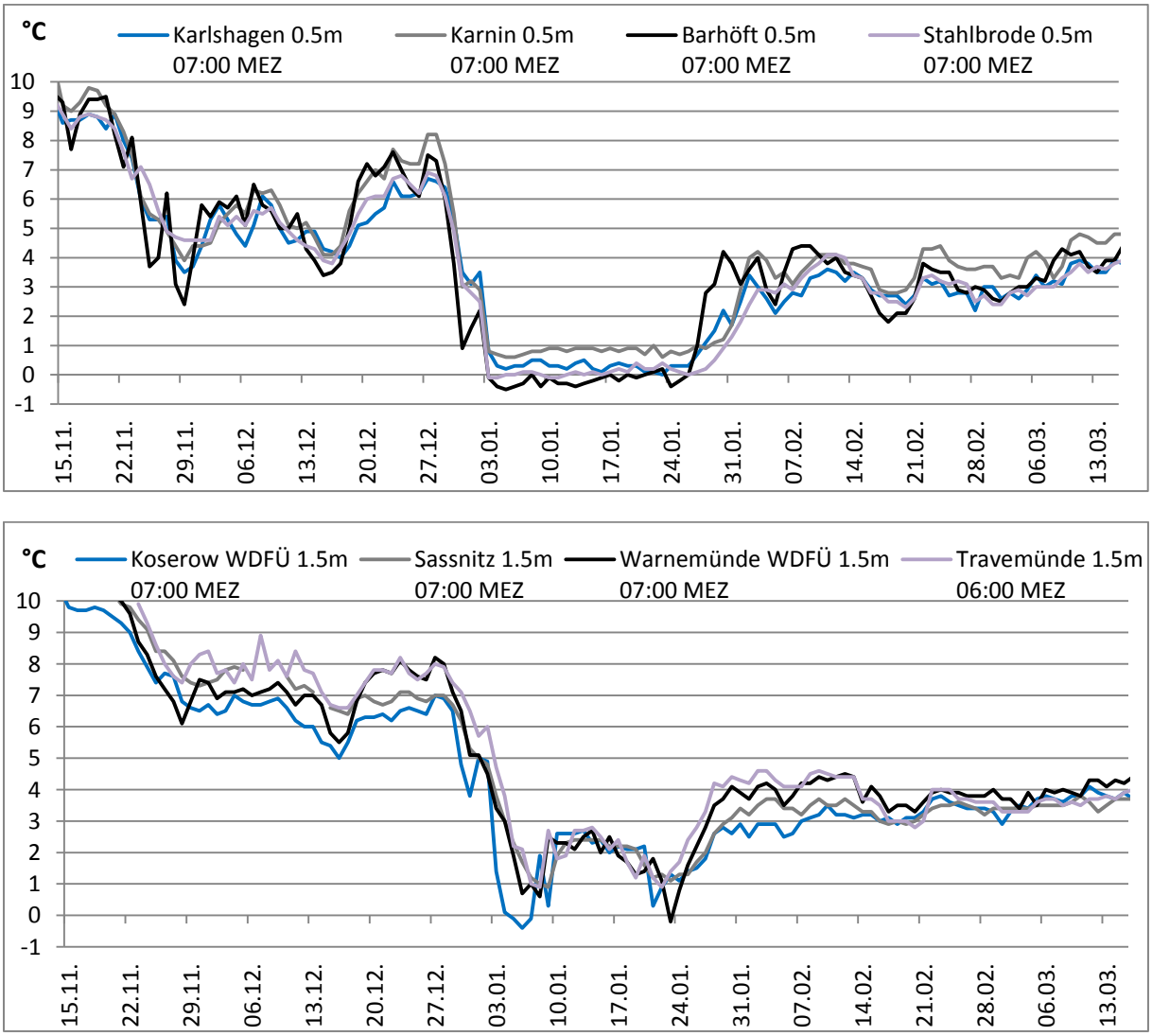


Figure 2: Lowest air temperatures along the German coasts, from the west to the east.

Water temperatures dropped below the freezing point at the 3rd January in the inner waters of the German Baltic Sea coast and at the 4th January on the outer coastal parts, and in the second cold period at the 23rd January. On the German North Sea coast, water temperatures reached the freezing point only in sheltered areas and only for a short time, see Figure 3.



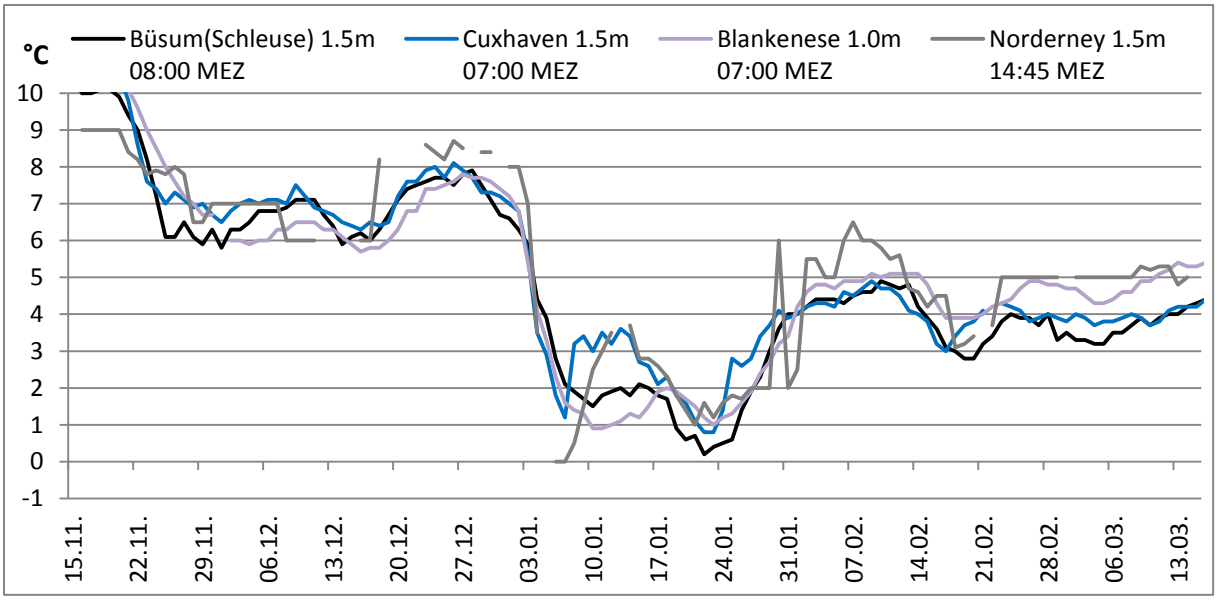


Figure 3: Water temperatures of the German coastal waters. Data sources: Karlshagen, Karnin, Barhöft, Stahlbrode, Koserow, Sassnitz and Warnemünde – WSA Stralsund; Travemünde – WSA Lübeck; Büsum – Schleuse Büsum; Cuxhaven and Norderney – Deutscher Wetterdienst; Brunsbüttel – WSA Brunsbüttel.

Ice conditions on the German North and Baltic Sea coasts

Since the two cold periods were close to each other in January, the ice winter 2015/2016 consisted of only one single ice period on the German coast which persisted from 3rd January through 2nd February. The development of the ice winter is illustrated in Figure A1 in the Appendix. In Table A1 and A2 in the Appendix, the most important ice parameters have been summarised.

Figure 4: Ice conditions in Thiessow at the time of maximum ice extent on the German Baltic Sea coast.
Courtesy of Frank Sakuth.

The first ice formation started on both coastal areas relatively simultaneously in smaller harbours and sheltered waters around the 4th January. On the North Sea, there was ice through the 21st January; on the Baltic Sea, ice persisted until the beginning of February in places. By the time of the maximum ice extent, which was observed on the 22nd/23rd January 2016 (Figure 5), sea ice occurred only next to Tönning on the North-Frisian coast. On the river Elbe, there was very little ice, open water was observed in places. Off the German North Sea coast, no ice formation took place. Ice thicknesses reached values of 5 to 15 cm. On the side of the Baltic Sea, the Schlei was covered by very close, 5-15 cm thick ice and the Wismar Bay was partly covered by new ice in sheltered areas. Further to the east, the Zingst-Darß Bodden chain and the Bodden waters around the island Rügen up to the Szczecin Lagoon were covered partly by very close ice and fast ice. On the river Warnow, a new ice cover formed. Ice thicknesses varied between less than 5 cm in regions with new ice coverage and up to 30 cm in the sheltered areas where ice formation had already started in the beginning of January.

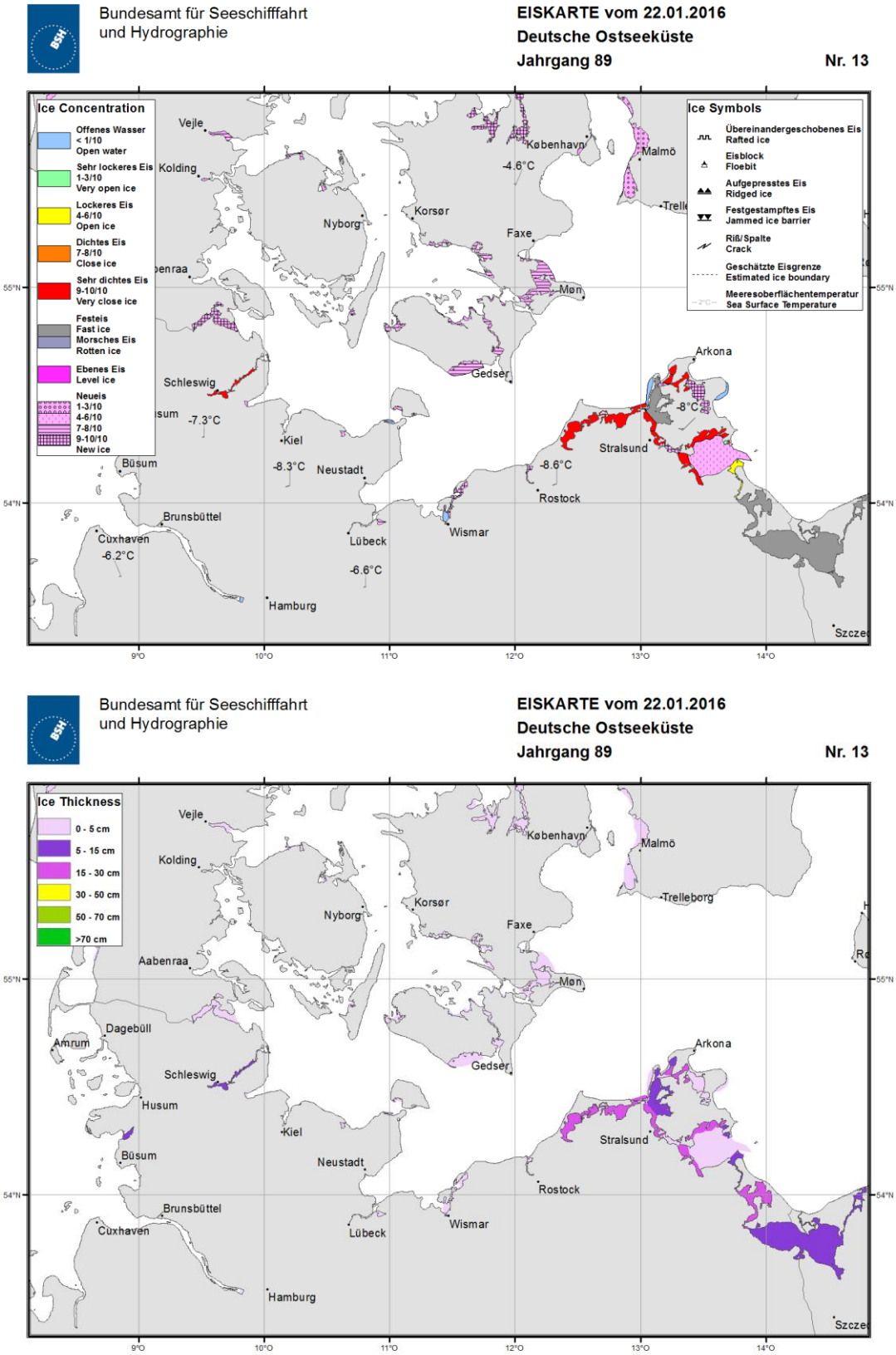


Figure 5: Sea ice extent and sea ice thickness in the German waters off the North and Baltic Sea coasts at the time of maximum ice formation in the ice winter 2015/16.

End of January, westerly and south-westerly winds transported warm air masses into the coastal regions and initiated the ice retreat for that winter. The number of days with ice varied in the ice winter 2015/2016 significantly (see Tab. A1 and A2): In the sheltered areas of the Greifswalder Bodden and the Szczecin Lagoon ice was present on up to 32 days and also the Zingst-Darßer Bodden chain was

covered by ice on up to 26 days. On the outer coasts of the Island Rügen and Usedom, there was ice on only 2 days, except for Thiessow, where ice occurred on 12 days in the sea area. In the Wismar Bay, ice was observed on 11-20 days, the Schlei was covered by ice on 25 days in places. On the river Elbe, there was ice on 4 days, on the river Ems, ice occurred on 14 days. The sea area off the German coast stayed ice free during the winter 2015/2016.

Navigational conditions on the German Baltic Sea coast

On the German North Sea coast and in the western inner fairways of the German Baltic Sea there were barely any appreciable restrictions for the navigation. Only from 20th January until 8th February 2016, the locking of ships in the Eider barrier and the Watergates Nordfeld and Lexfähr was not possible for few days (WSA Tönning, 2016). Due to the ice occurrence in the coastal waters of Western Pomerania, navigation during night was prohibited for the northern ship route to Stralsund (including the Bodden waters west) as well as the eastern ship route to Stralsund from Palmer-Ort-Rinne, for the driveway Ladebow and for the northern and southern Peenestrom and the Szczecin Lagoon from the 14th January 2016 on (WSA Stralsund, 2016). This prohibition was persistent through the 23rd February 2016.

Figure 6: In sheltered harbours, a closed new ice cover formed temporarily. This picture shows the harbour of Thiessow with such a new ice cover at the 16. January 2016. *Foto: Frank Sakuth*

Ice winter intensity

The ice winter 2015/16 was a weak one for both the North Sea and the Baltic Sea. Hence, this winter was the 4th weak winter in succession. The indices for the ice winter strength are calculated from observation data from the 13 climatological stations at the Baltic Sea coast and the 13 climatological stations at the North Sea coast and are expressed in terms of the reduced ice sum, or as the accumulated areal ice volume ($V_{A\Sigma}$), respectively. An explanation of the terminology is available on http://www.bsh.de/de/Meeresdaten/Beobachtungen/Eis/Kuesten.jsp.
The calculated indices for the ice winter 2015/16 are summarized in Table 1. Although the ice production at the coast of Mecklenburg-Western Pomerania was stronger than on the coast of Schleswig-Holstein, which can be explained by the stronger impact of the continental climate in Mecklenburg-Western-Pomerania, the winter 2015/2016 has been classified as weak winter for both coastal areas, see Table 2.

Table 2: Reduced ice sum and accumulated areal ice volume at the German coasts in the winter of 2015/16.

Area	Reduced ice sum	Accumulated areal ice volume
North Sea coast	**2.0**	**0.09** m
Baltic Sea coast	**9.1**	**0.35** m
Coast of Mecklenburg-West Pomerania	10.0	0.45 m
Coast of Schleswig-Holsteins	8.0	0.23 m

Figure 7 shows the evolution of the ice formation by means of the daily areal sea ice volume for both German coastal areas. From beginning of January up to the 7th/8th January, the ice volume increased. Between 8th and 17th January it stagnated. During this time, mean daily air temperatures were slightly above 0°C so that no new ice formation took place and the existing ice melted slowly. Afterwards, a second cold period occurred, in the North Sea only shortly, in the Baltic Sea it persisted for some days, and the sea ice volume increased for a short time before it increased again after the end of the cooling period. Figure 8 shows the respective daily accumulated areal ice volume over the climate stations, which reached its maximum by definition at the end of the ice winter period (total mass of ice in a winter).

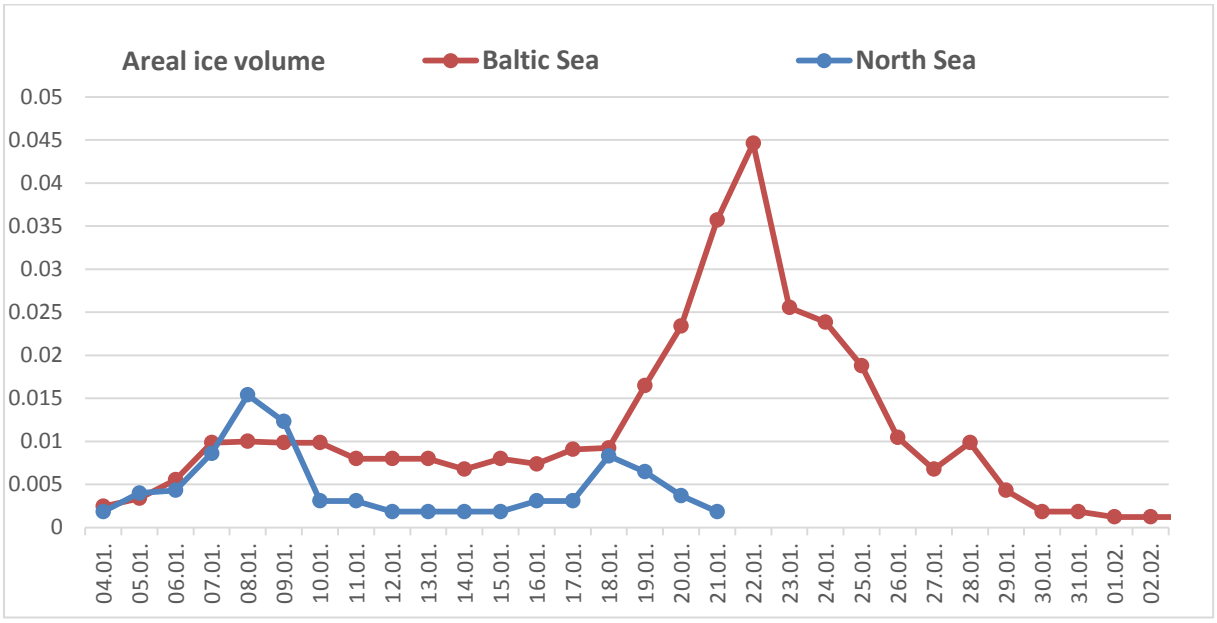


Figure 7: Areal ice volume at the German coasts in the winter of 2015/16.

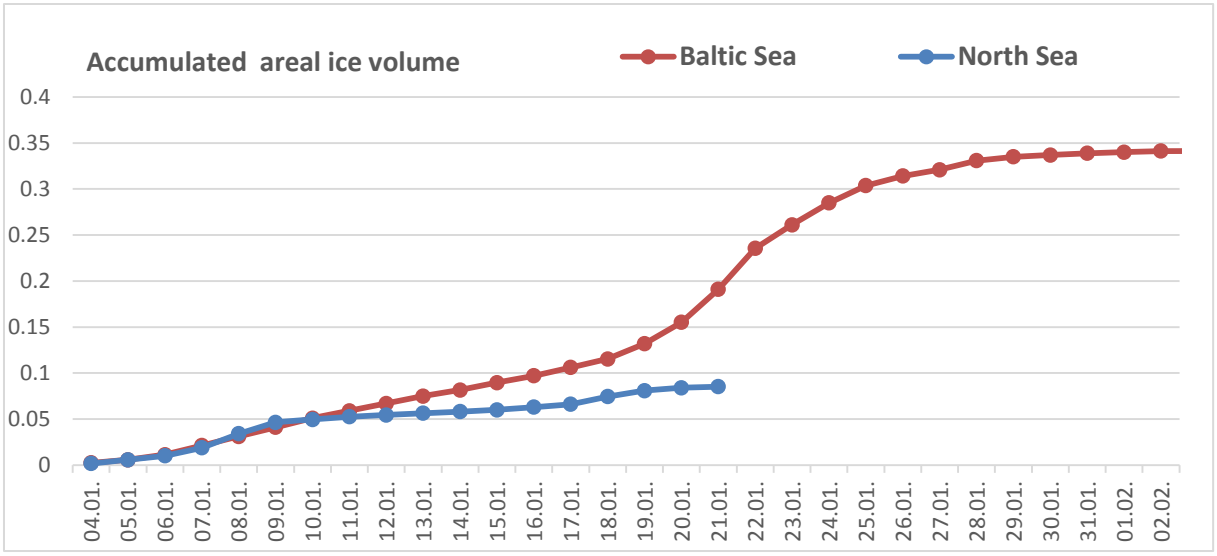


Figure 8: Accumulated areal ice volume at the German coasts in the winter of 2015/16.

The BSH reported on ice conditions and expected ice development in the entire Baltic Sea region and German coastal waters in the ice winter **2015/16** by:

103 ice reports (official reports issued Mondays to Fridays),
19 German Ice Reports (international exchange, issued when ice forms in German fairways),
about 20 NAVTEX - reports (in German and English for the German North and Baltic Sea coasts),
22 ice reports “German Baltic Sea coast” (detailed description of ice situation for German users),
9 ice reports “German North Sea coast” (detailed description of ice situation for German users),
22 weekly reports (information for the BMVBW and the public),
20 general ice charts (once per week as reference for the entire Baltic Sea),
21 special ice charts (German Baltic Sea coast).

The current ice reports and ice charts of the BSH are available online and free of charge under http://www.bsh.de/en/Marine_data/Observations/Ice/index.jsp. The archive with all ice charts issued so far is available at ftp://ftp.bsh.de/outgoing/Eisbericht/.

The strength of the ice winter 2015/2016, compared to former years, is shown in Figure 9 and Figure 10. Since 1896/97 (120 years), 32 winters have been less strong than the winter 2015/16 on the German North Sea coast and on the German Baltic Sea coast 40 ice winters have been less strong. In total, the winter 2015/2016 is the 4th weak winter in succession. Figure 9 and 10 also illustrate that there have always been periods with weak winters followed by single years or periods with moderate to strong winters again, also in former years.

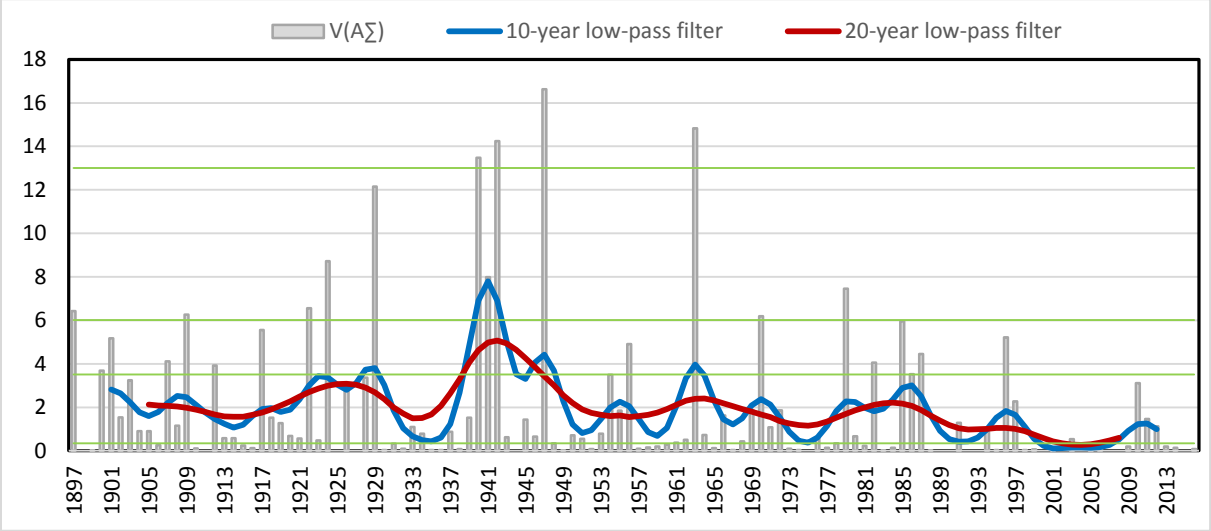


Figure 9: Distribution of the areal ice volume sum for the German North Sea coast with 10-year (blue) and 20-year (red) low-pass filter.

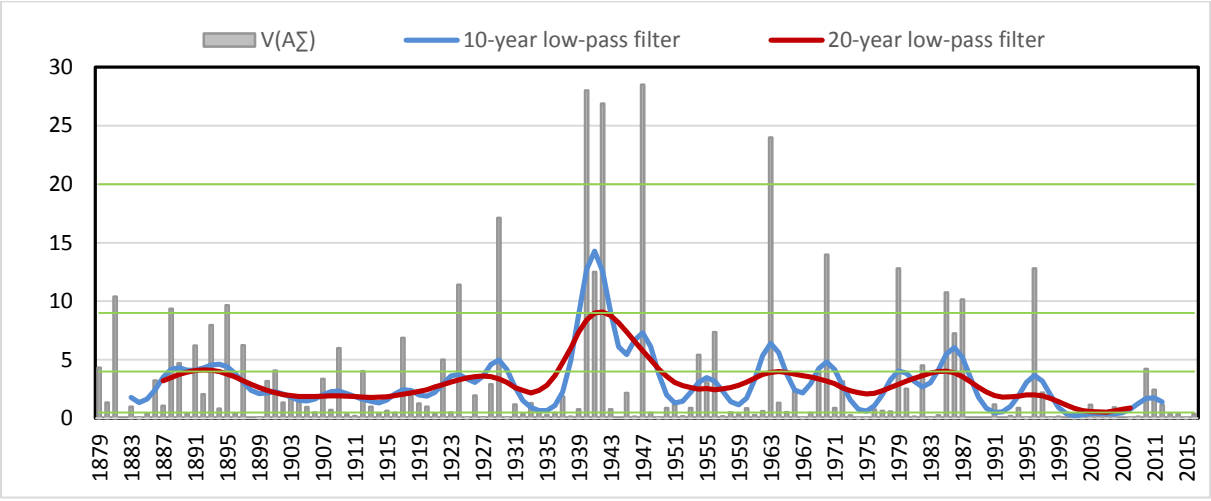


Figure 10: Distribution of the areal ice volume sum for the German Baltic Sea coast with 10-year (blue) and 20-year (red) low-pass filter.

Ice conditions in the western and southern Baltic Sea

In the Danish waters of the western Baltic Sea, new ice formed for some days in smaller harbours and shallow and sheltered coastal sections between 18th January and 2nd February. However, the major shipping was not affected.

In the southern Baltic Sea, the first pack ice occurred in the Curonian Lagoon on the 4th January. Two days later, ice had formed on the Szczecin Lagoon. At the same time, the first ice occurred in the Bay of Puck. The Vistula Lagoon was already covered by 8 cm thick fast ice by that time. The sea ice grew to a thickness of up to 10-15 cm in the Szczecin Lagoon by the 26th January and up to 23 cm in the Bay of Puck and Vistula Lagoon. In the harbour of Gdansk, drift ice with a thickness of up to 10 cm occurred between 18th and 22nd January. Afterwards, the melting period started. On 6th February, the Szczecin Lagoon was almost ice free, in the Curonian and Vistula Lagoons ice remained up to the 22nd and 12th February, respectively.

Ice conditions in the northern Baltic Sea (north of 56°N)

The first ice of the winter season 2015/2016 formed in the archipelagos of the northern Bay of Bothnia during the first December days. Until mid-December, ice formation started also in the Gulf of Finland. In the beginning, the ice grew slowly. End of December, ice appeared in the Sea of Bothnia, and in the beginning of January, ice formation had started in the entire Baltic Sea in sheltered areas. The ice coverage increased quickly in January, as a consequence of moderate to strong frost, and reached its winter maximum sea ice extent on the 22nd/23rd January. By this time, most parts of the Bay of Bothnia were covered by sea ice with thicknesses between 15 and 50 cm. At some places, also new ice occurred with thicknesses of up to 5 cm. The ice coverage along the coasts of the Sea of Bothnia reached southward up to the Archipelago Sea and measured a thickness of 5-30 cm. Also the Gulf of Finland was covered mostly by very close, up to 5-15 cm thick sea ice. Close to the coasts, sea ice also reached thicknesses of up to 50 cm. At the coast of the Gulf of Riga, sea ice was up to 30 cm thick.

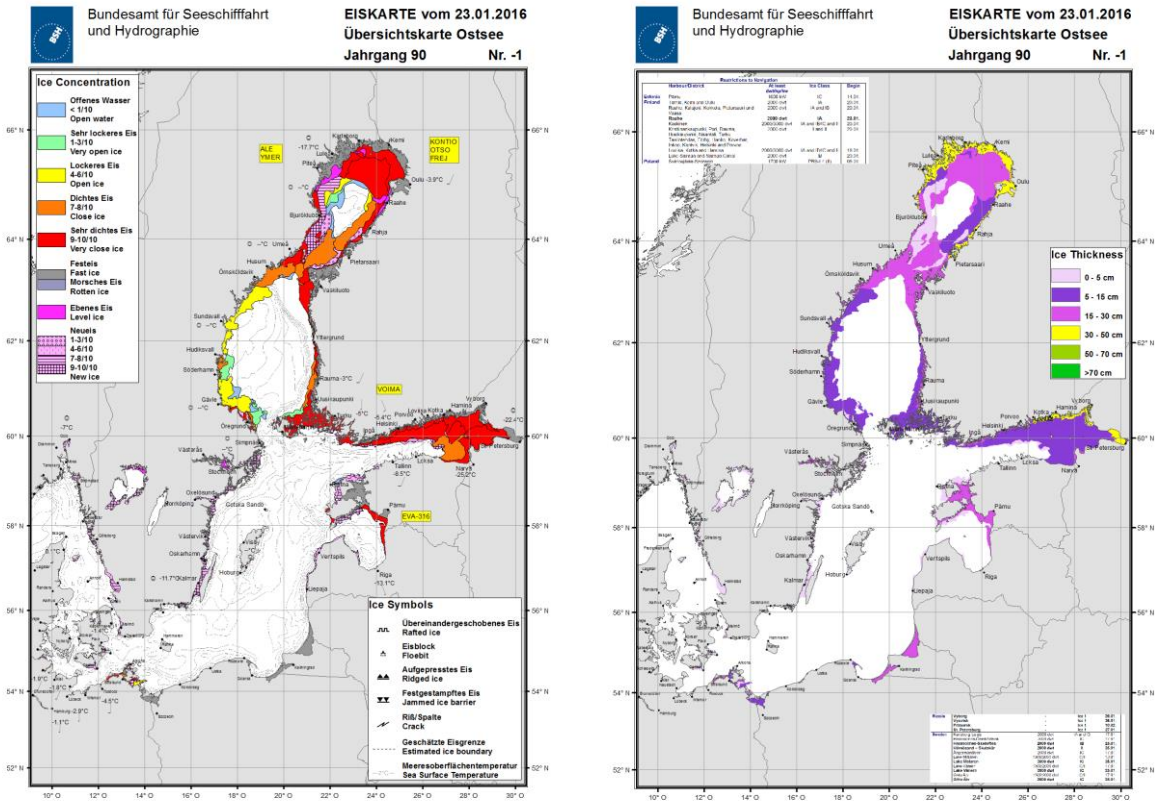


Figure 11: Ice chart for the entire Baltic Sea at the day of maximum sea ice extent in this winter (22./23. January 2016). Left: Ice coverage (coloured), form of the ice (symbol), temperature and wind at individual stations, water temperature and icebreaker operation for shipping assistance. Right: Ice thickness distribution and shipping restrictions.

After the maximum ice extent end of January, ice started to decrease until mid of February since air temperatures rose above 0°C in many places. In the second half of February, a new frost period started, which resulted again in an increase of the ice extent. The respective second sea ice extent maximum was then reached in the second half of March. By this time, the Bay of Bothnia was nearly completely covered by sea ice. Over the proceeding winter, the ice had reached thicknesses of up to 75 cm close to the coasts. In the Sea of Bothnia on the other hand, barely any ice was present at the same time and also in the Gulf of Finland, sea ice extent was much smaller compared to the January maximum ice coverage. In the course of April, the sea ice coverage decreased slowly until it disappeared completely mid of May.

The maximum ice extent of the entire Baltic Sea reached on the 22nd/23rd January amounted to 110000 km^2 according to the Finnish, 111000 km^2 according to the Swedish and 114500 km^2 according to the German ice service. The deviation of 4% from the total extent between the ice services can be explained by different factors: On the one hand, there are slight differences in the land masks used from the services; on the other hand, the boundaries of the Baltic Sea are not clearly defined. Taking the Skagerrak-Kattegat region not into account, e.g., the maximum ice extent would decrease by 3700 km^2. The deviation of the individual amounts of maximum ice extent does generally not result in a difference of the ice winter classification: all three calculated maximum sea ice extents lead to the result that the ice winter 2015/2016 was a weak one, according to the respective Finnish classification (Seinä und Palosuo, 1996).

The maximum ice volume was measured around the 23rd March and amounts to 14.1 km^3. Hence, regarding the ice volume the winter 2015/2016 is classified as an extreme weak winter. Figure 12 shows the sea ice extent by the time of the maximum sea ice volume and the respective ice thickness distribution. While the sea ice extent was significantly smaller compared to end of January, ice thicknesses had increased further, which is the reason for the higher sea ice volume end of March compared to end of January.

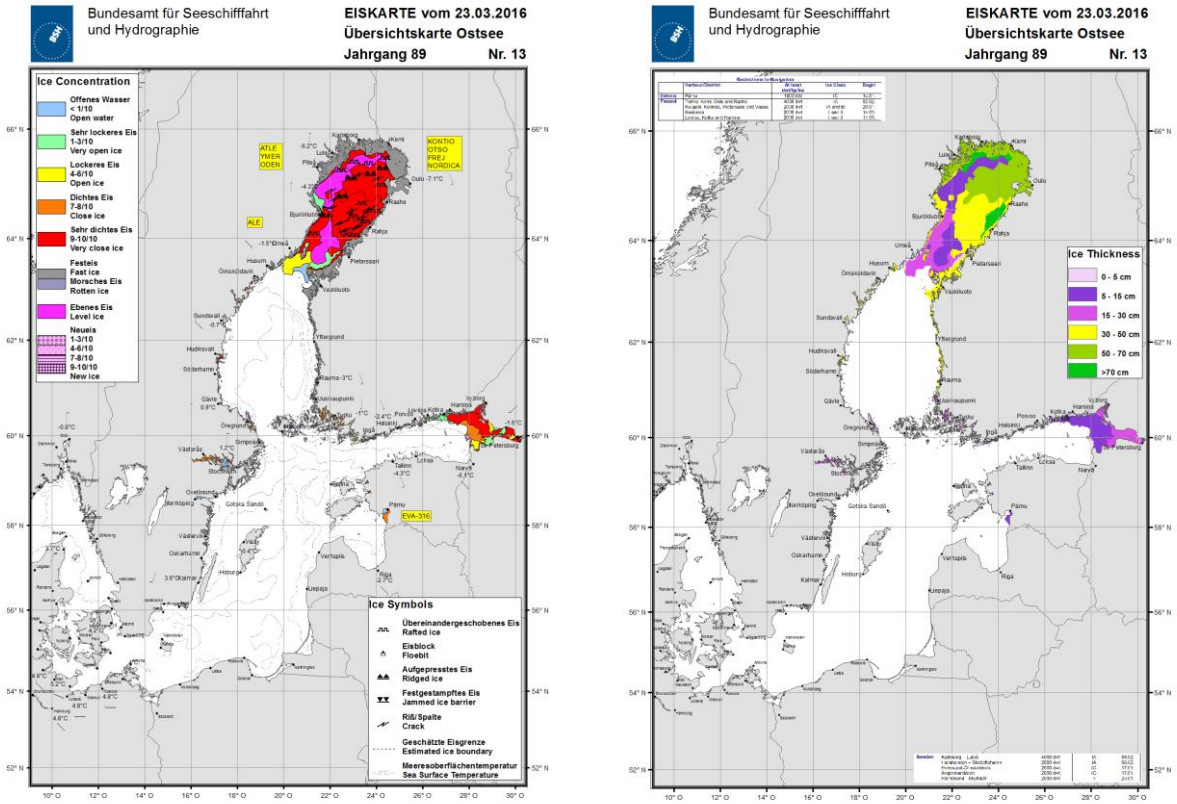


Figure 12: Ice chart for the entire Baltic Sea at the day of maximum ice volume in this winter (23. March 2016). Left: Ice coverage (coloured), form of the ice (symbol), temperature and wind at individual stations, water temperature and icebreaker operation for shipping assistance. Right: Ice thickness distribution and shipping restrictions.

Although the winter 2015/2016 can be classified as a weak to very weak winter the ship traffic was restricted by the formation of pressure ridges, ice compression and rafted ice in the ice covered sea areas. In the Gulfs of Bothnia, Finland and Riga restrictions for navigation regarding ice class, ship size and deadweight were announced and several icebreakers were deployed for shipping assistance. The Lake Saimaa and Saimaa Canal were closed for ship traffic from January 25th to April 9th 2016.

Maximum sea ice extent and maximum sea ice volume in the Baltic Sea

The Finnish ice service uses for the classification of the ice winter strength the reconstructed or the calculated data of the yearly maximum sea ice extent of the Baltic Sea (Seinä und Palosuo, 1996). The German ice service calculates the maximum yearly sea ice extent and the sea ice volume for the entire Baltic Sea based on the ice charts, which instead are based on information from satellite data as well as on ice observations. The sea ice concentration and the sea ice thickness are thereby projected on a 0.5°x0.5° grid (Feistel et al, 2008).

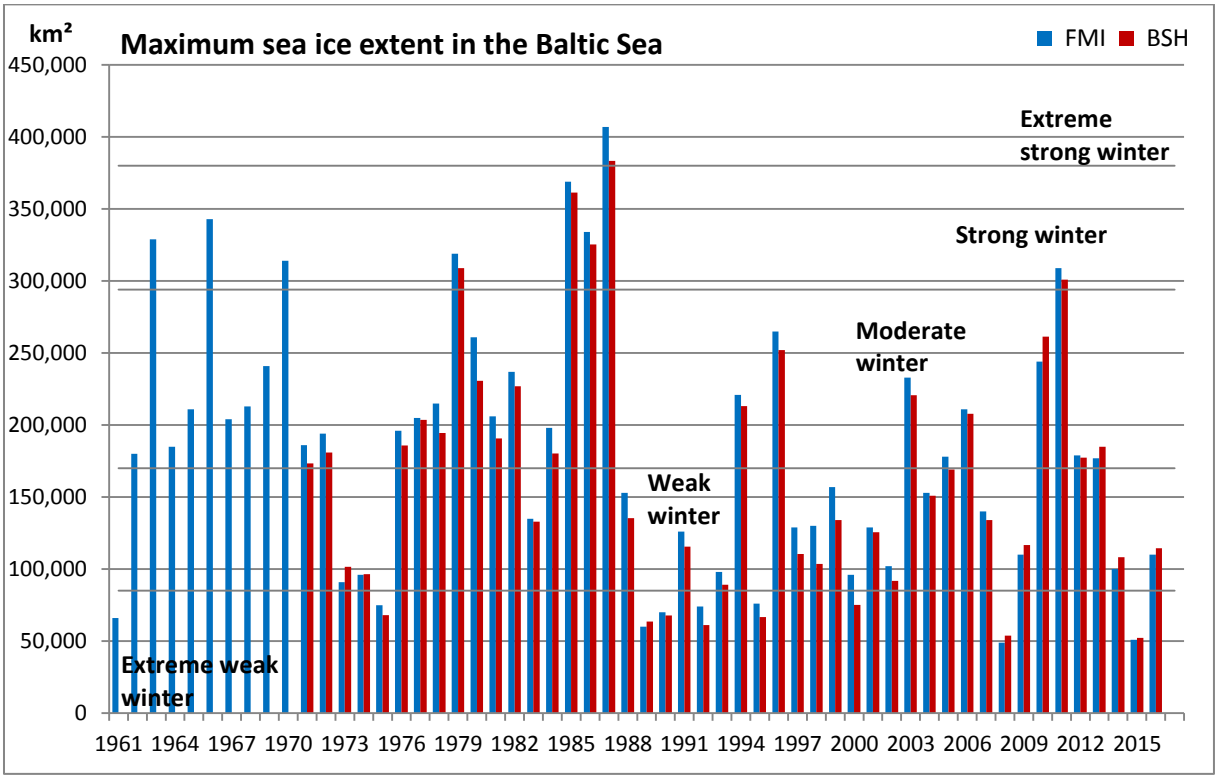


Figure 13: Yearly maximum sea ice extent in the Baltic Sea for the period 1961 – 2016 (Data Source: FMI and BSH).

Figure 13 shows the maximum sea ice extent of each winter calculated from the Finnish and German ice service, respectively, compared to each other. In addition the class boundaries of the five ice winter types are marked. In each year, there are slight deviations between the Finnish and the German data, reasons for that were given above. The differences, however, do generally not result in different ice winter classifications. As described before, the winter 2015/2016 is classified as a weak winter; the 17th weak winter since 1961. This winter type is the second most frequent one, at least during the past 55 years, slightly more often moderate winters have occurred since today. Extreme weak and extreme strong winters are balanced in there frequency and occurred only half as often as weak or moderate ones. However, the frequency of strong and very strong winters has decreased since the 1980s, whereas the frequency of extreme weak winters has decreased.

Table 3: Class boundaries for different ice winter types.

Max. Area 1000*km^2	Min. Area 1000*km^2		Max. Volume km^3	Min. Volume km^3
405 (1987)	> 380	Extreme strong ice winter	**99.4** (1987)	> 89
380	295	Strong ice winter	89	65
294	171	Moderate ice winter	64	30
170	85	Weak ice winter	29	17
< 85	**49** (2008)	Extreme weak ice winter	< 17	**7.6** (1992)

Figure 14 shows the maximum sea ice volume from the BSH data set since 1971. As the maximum yearly sea ice volume comprises the ice extent as well as the sea ice thickness, it is a much better measure for the description of the ice winter strength. Although a lot of winters have a lower sea ice extent compared to that in 2015/2016, this winter's maximum sea ice volume is the 4th lowest since the beginning of the 1970s. That indicates that ice thicknesses were comparably low during the winter 2015/2016.

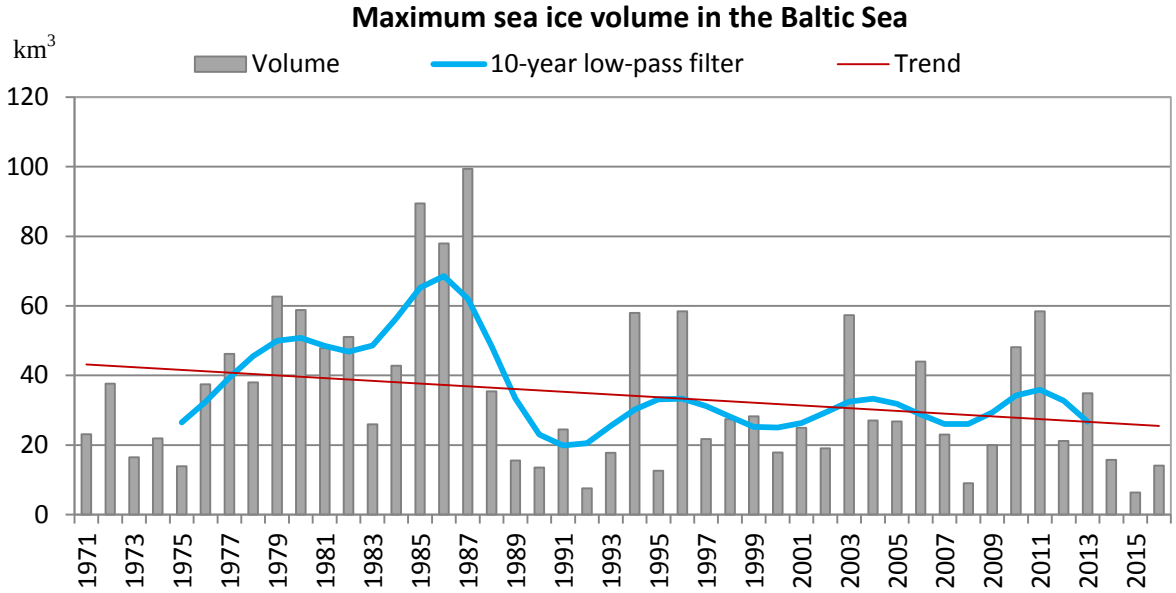


Figure 14: Yearly maximum sea ice volume of the Baltic Sea for the period 1971 – 2016.

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Appendix

Table A 1: Ice conditions at the German North Sea coast in the winter of 2015/16.

Observation station	Beginning of ice occurrence	End of ice occurrence	Days with ice	Maximum ice thickness
Ellenbogen (Sylt), Listertief	08.01.	24.01.	5	30 cm
Sylt, Harbour List	07.01.	07.01.	1	5 cm
Husum, Harbour	22.01.	24.01.	3	5 cm
Tönning, Harbour	05.01.	25.01.	15	20-30 cm
Eiderdamm, sea area	06.01.	25.01.	12	10 cm
Büsum, Harbour	22.01.	24.01.	3	5 cm
Harburg, Elbe	19.01.	22.01.	4	5 cm
Emden, New inner harbour	03.01.	24.01.	14	5 cm
Emden, Ems and outer harbour	04.01.	22.01.	8	5 cm

Table A 2: Ice conditions at the German Baltic Sea coast in the winter of 2015/16.

Observation station	Beginning of ice occurrence	End of ice occurrence	Days with ice	Maximum ice thickness
Kamminke, Harbour and vicinity	03.01.	03.02.	32	15 cm
Ueckermünde, Harbour		28.01.		10 cm
Ueckermünde, Harbour to Uecker mouth		28.01.		10 cm
Ueckermünde, Szczecin Lagoon		29.01.		10 cm
Anklam, Harbour	03.01.	31.01.	29	10-15 cm
Anklam, Harbour – Peenestrom	03.01.	31.01.	29	10-15 cm
Brücke Zecherin, Peenestrom	04.01.	28.01.	25	20-40 cm
Rankwitz, Peenestrom	03.01.	31.01.	29	20-30 cm
Warthe, Peenestrom	03.01.	31.01.	29	20-30 cm
Wolgast – Peenemünde	05.01.	29.01.	23	15 cm
Peenemünde – Ruden	07.01.	25.01.	4*	10 cm
Stralsund, Harbour	07.01.	27.01.	12*	30 cm
Stralsund – Palmer Ort	07.01.	27.01.	11*	15 cm
Palmer Ort – Freesendorfer Haken	07.01.	27.01.	8*	10 cm
Greifswald-Wieck, Harbour	04.01.	27.01.	24	15 cm
Dänische Wiek	04.01.	17.02.	27	25-30 cm
Greifswald-Ladebow, Harbour	03.01.	28.01	26	30 cm
Osttief	23.01.	25.01.	3*	10 cm
Landtiefrinne	09.01.	29.01.	20	5-10 cm
Thiessow, Bodden area	06.01.	02.02.	26	22 cm
Thiessow, Sea area	07.01.	31.01	12	22 cm
Lauterbach, Harbour and vicinity	04.01.	31.01.	26	20-30 cm
Greifswalder Oie, Eastern sea area	21.01.	22.01.	2	15 cm
Sassnitz, Harbour and vicinity	21.01.	24.01.	4	5 cm
Stralsund – Bessiner Haken	26.01.	22.01.	5*	30 cm
Vierendehlrinne	04.01.	02.02.	30	30 cm
Barhöft – Gellenfahrwasser	06.01.	07.01.	2	5 cm
Neuendorf, Harbour and vicinity	02.01.	30.01.	29	30 cm
Neuendorf, Sea area	22.01.	23.01.	2	5 cm
Schaprode – Hiddensee, Fairway	05.01.	29.01.	25	15 cm
Kloster, Bodden area	03.01.	29.01.	24	15 cm
Dranske, Bodden area	05.01.	30.01.	24	15 cm
Wittower ferry	03.01.	26.01.	24	15 cm
Zingst, Zingster Strom	02.01.	26.01.	25	15 cm
Barth, Harbour and vicinity	03.01.	28.01.	26	30 cm
Rostock, City harbour	05.01.	26.01.	22	10 cm
Rostock, Warnemünde	07.01.	26.01.	17	10 cm
Wismar, Harbour	06.01.	26.01.	20	5-10 cm
Wismar – Walfisch	06.01.	24.01.	11	5 cm
Walfisch – Timmendorf	07.01.	07.01.	1	5 cm
Lübeck – Travemünde	07.01.	10.01.	4	5-10 cm
Neustadt, Harbour	04.01.	25.01.	17	5-10 cm
Kiel, Inner harbour	07.01.	07.01.	1	5 cm
Heiligenhafen, Harbour	06.01.	24.01.	10	5 cm
Eckernförde, Harbour	21.01.	18.02.	6	5 cm
Schlei, Schleswig – Kappeln	04.01.	19.02.	28	15 cm
Schlei, Kappeln – Schleimünde	09.01.	22.01.	4	5 cm
Flensburg-Holnis	18.01.	17.02.	10	5 cm

*Exact number of days not known due to missing observations.

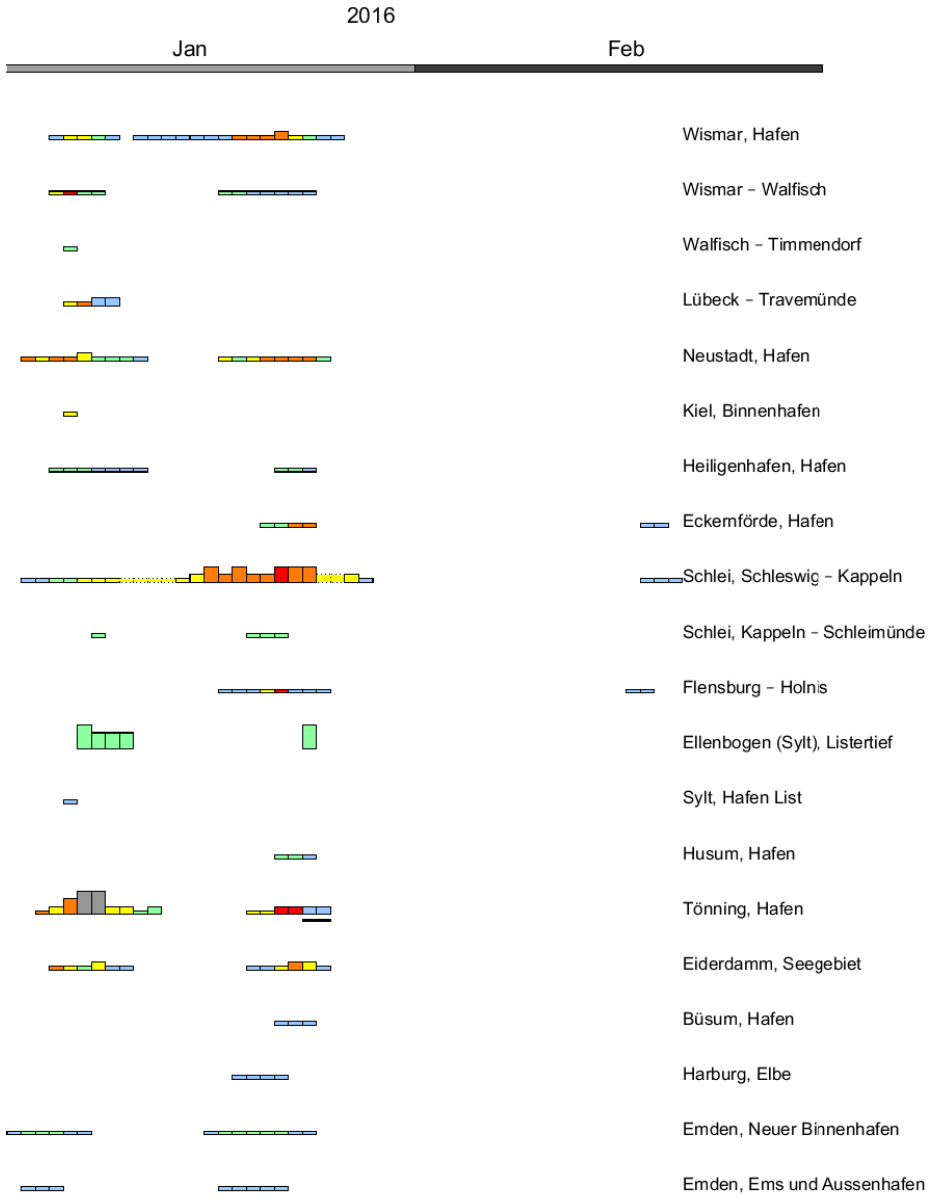


Figure A 1: Daily ice occurrence at the German North and Baltic Sea coast in the winter of 2015/16.

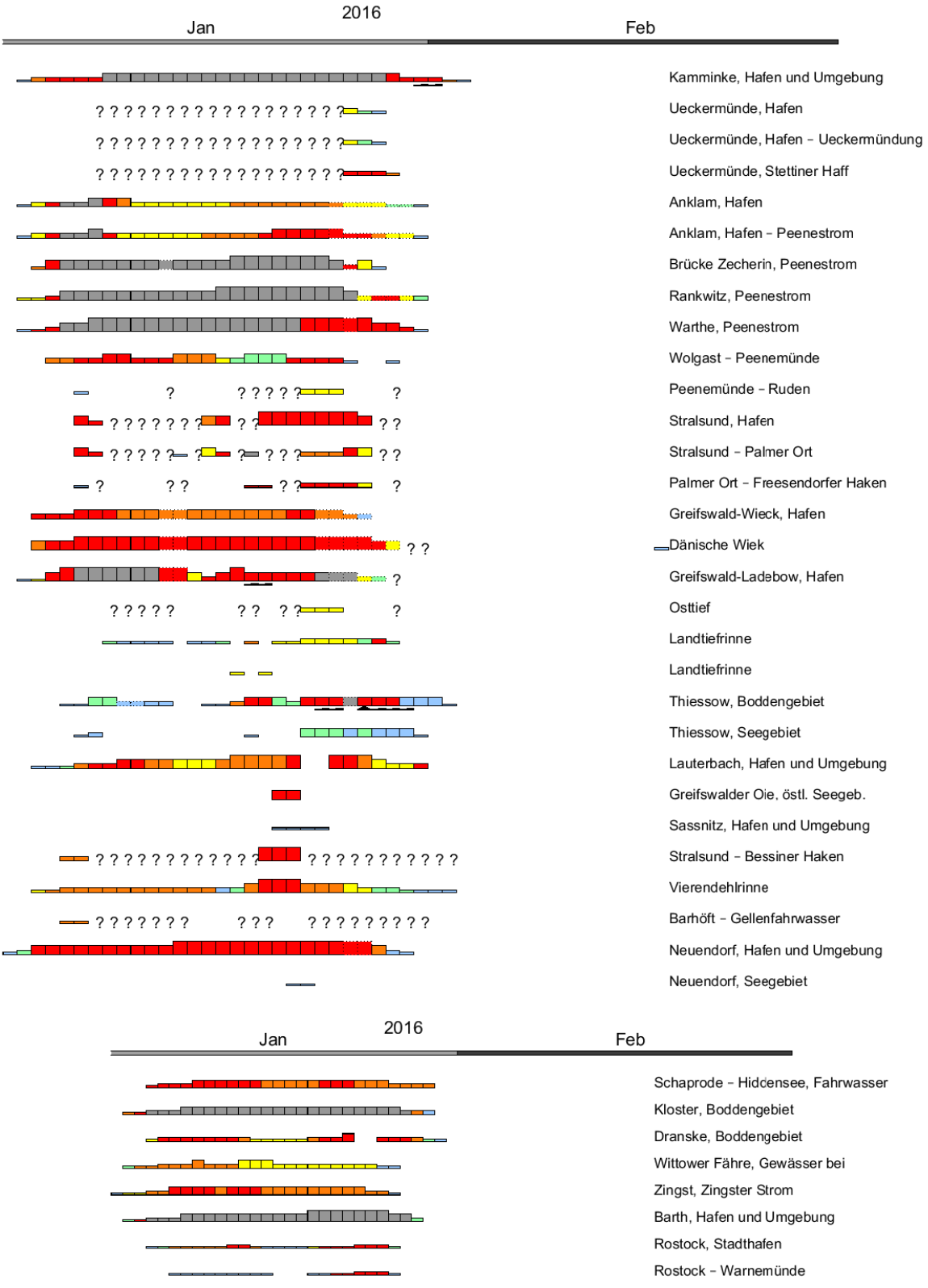
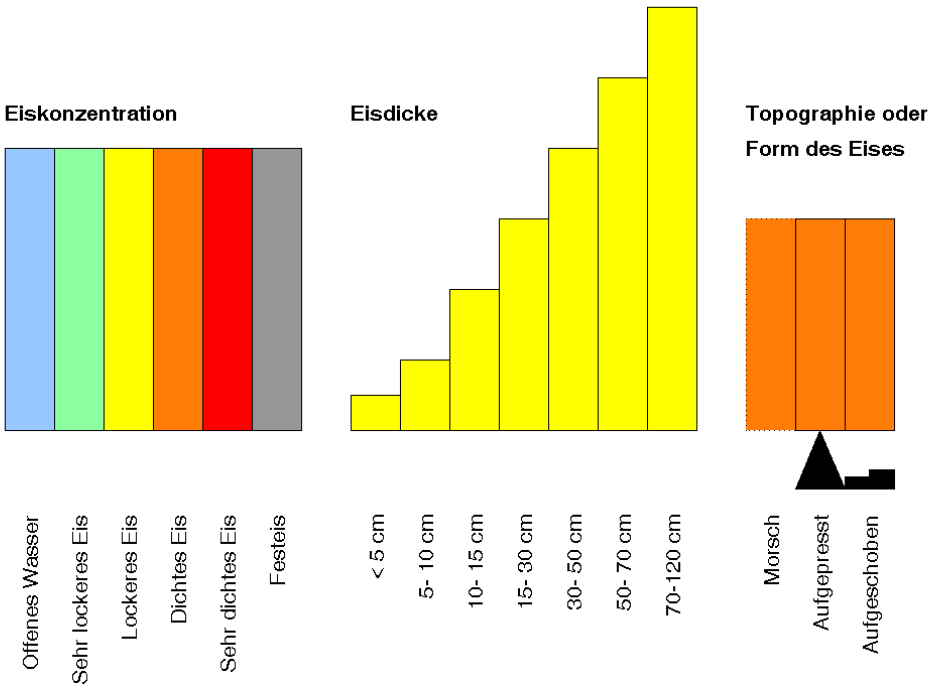


Figure A1: Continuation

Legende


Eiskonzentration
Offenes Wasser
Sehr lockeres Eis
Lockeres Eis
Dichtes Eis
Sehr dichtes Eis
Festeis
Eisdicke
< 5 cm
5- 10 cm
10- 15 cm
15- 30 cm
30- 50 cm
50- 70 cm
70-120 cm
Topographie oder
Form des Eises
Morsch
Aufgepresst
Aufgeschoben