The ice winter of 2018/19 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

Ice coverage in the southern Bay of Bothnia, near Kokkola, at the morning of the 29th March 2019.

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

Weather conditions at the German coastal areas

The winter 2018/19 was mild at the German coast. The averaged monthly mean temperatures of November to March were from 0.2°C to 3.9°C higher than those of the 1981-2010 reference period (Tab. 1). In the months December and February, deviations were the strongest.

Table 1: Monthly mean air temperatures (°C) and their deviations from the reference period (1981 – 2010) in °C for the winter 2018/19. (Data source: Deutscher Wetterdienst, www.dwd.de).

Station	November		December		January		February		March	
	T_{air}	ΔT_{air}	T_{air}	ΔT_{air}	T_{air}	ΔT_{air}	T_{air}	ΔT_{air}	T_{air}	ΔT_{air}
Greifswald	5.3	0.6	4.5	3.0	1.6	0.9	5.0	3.9	5.3	2.9
Rostock-Warnemünde	6.4	0.9	5.2	2.9	2.3	0.9	5.2	3.5	6.6	3.2
Schleswig	6.2	1.2	5.0	3.0	2.0	0.7	4.9	3.5	6.2	2.3
Norderney	6.8	0.2	5.8	2.3	3.6	1.0	5.7	3.1	7.3	2.4

The weather conditions were comparatively unstable over the entire winter. Inflows from cold polar air masses were frequently interrupted by west- and south-wind conditions so that air temperatures at the German coasts increased rapidly after short-lasting drops. Only in late January, cold polar air masses dominated the weather conditions at the coast for some days. However, in the beginning of February, the wind turned again and the westerly wind conditions brought mild and humid air from the Atlantic to the north German regions.

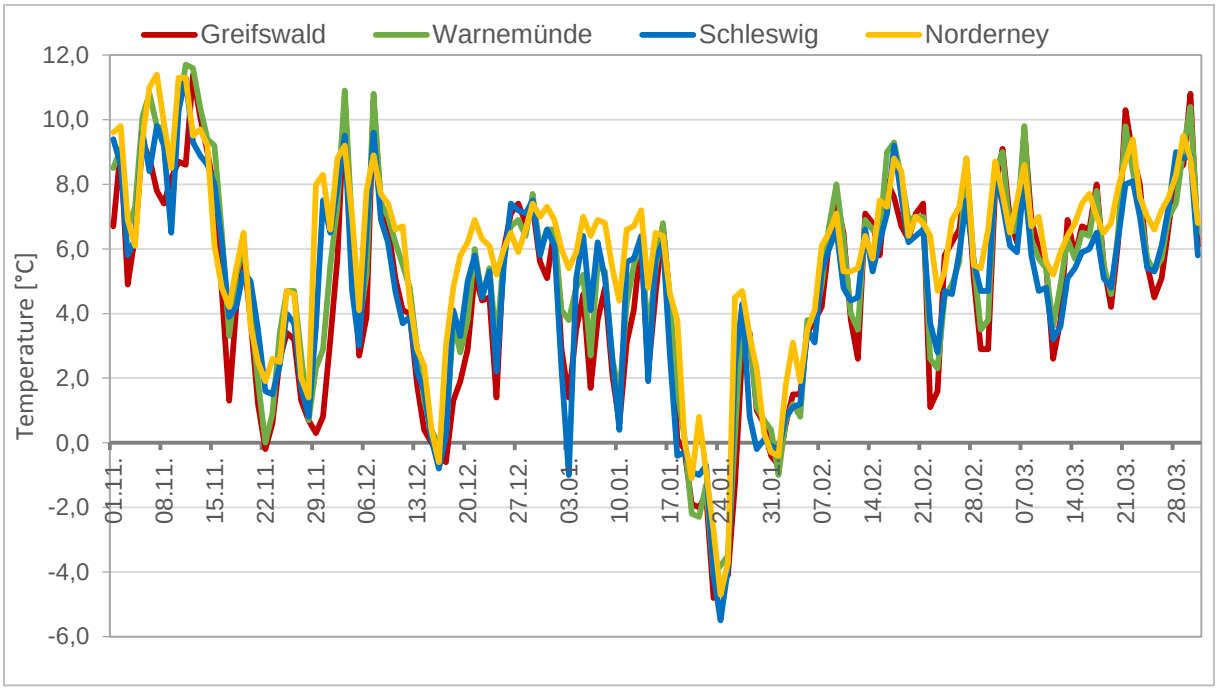

Figure 1: Daily averaged air temperatures in the winter 2018/19 (Data source: Deutscher Wetterdienst, www.dwd.de/) exemplarily for Greifswald, Rostock-Warnemünde, Schleswig und Norderney.

Figure 1 shows the development of winter temperatures in 2018/19, exemplarily for the stations Greifswald, Warnemünde, Schleswig and Norderney. In the beginning of November, temperatures varied between 4°C and 12°C, but towards mid-November, they started to decrease. Until mid-January, however, temperatures only sporadically felt slightly below the freezing point. Between 17th to 26th January, minimum daily mean temperatures decreased down to -6°C within this short-lasting cold period. Afterwards, there were only one to two

days end of January when daily averaged temperatures went below 0°C at the coast. In the following days, temperatures rose and stayed permanently above the freezing point.

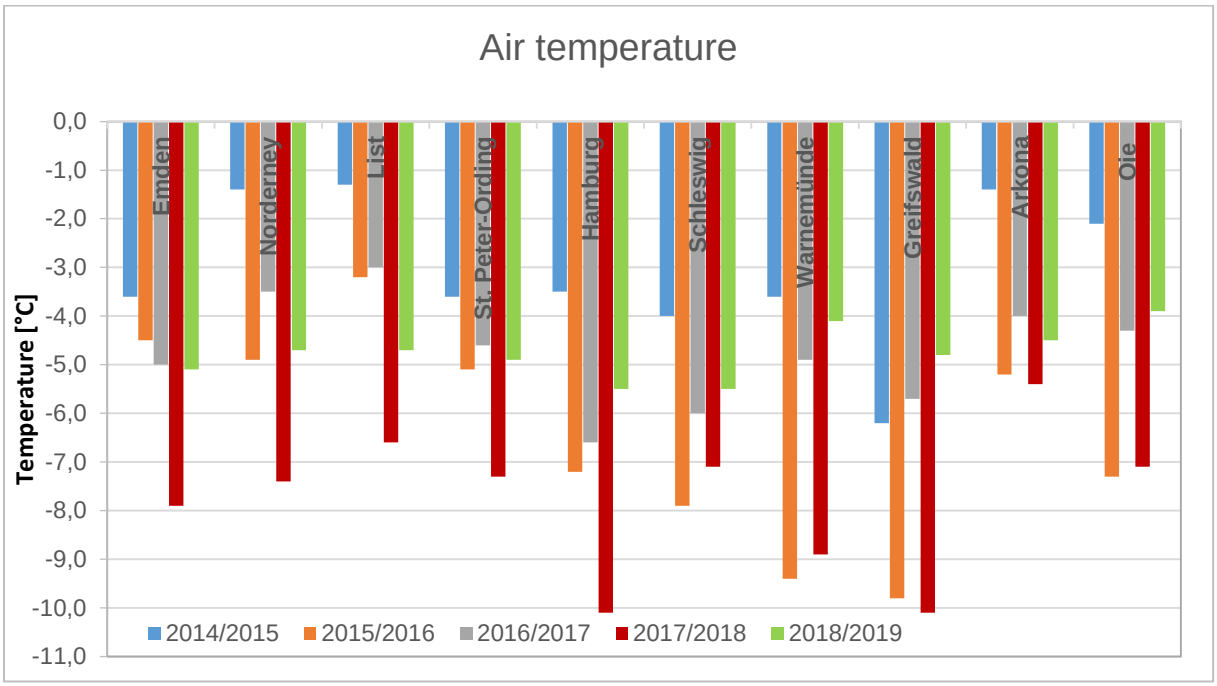

Figure 2: Minimum daily averaged air temperatures for chosen stations from west to east along the German coast for the winters 2014/2015, 2015/2016, 2016/2017, 2017/2018 and 2018/2019.

In summary, the winter 2018/19 consisted of one short-lasting cold period. Most stations at the German coast observed the lowest temperatures between the 21st and 25th January. Over these days, daily mean temperatures varied between -3.9°C at the Greifswalder Oie and -5.5°C in Hamburg and Schleswig. The temperatures in the winter 2018/19 were similarly mild as those in the years 2014/15 and 2015/16 (see Fig. 2).

According to the mild air temperatures, water temperatures went only in very few regions below 0°C. In the inner waters of the eastern Baltic Sea coast, e.g., water temperatures slightly below 0°C occurred between 23rd January and 3rd February. Before, there were only in Karnin two days with water temperatures at the freezing point end of November/early December. However, shortly after, temperatures went above 4°C again. Further west and in the outer coastal waters, water temperatures did not reach the freezing point within the entire winter season, nor did they do in most parts of the inner waters of the North Sea.

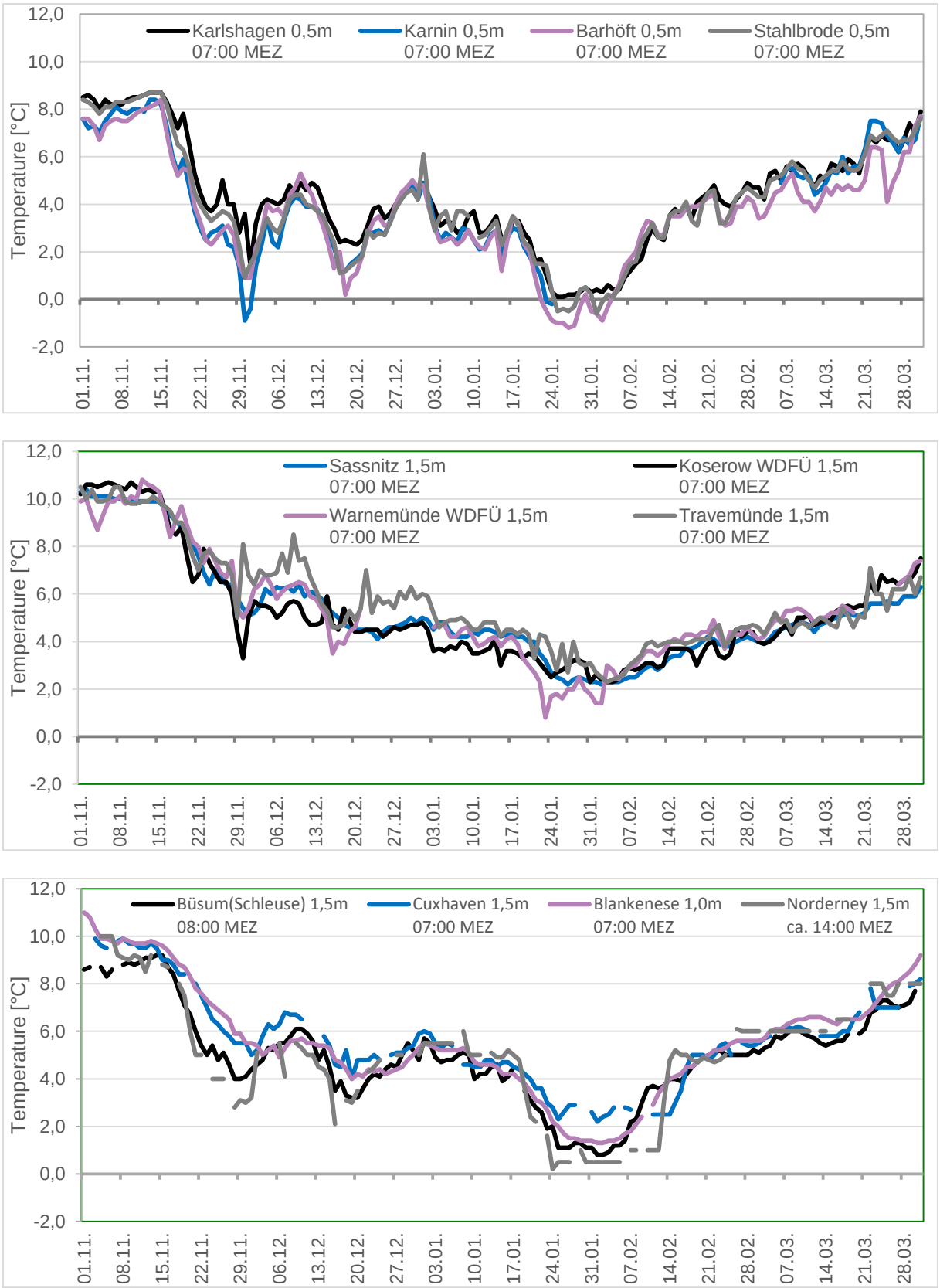

Figure 3: Water temperatures of the German coastal waters in the winter 2018/19. Data sources: Karlshagen, Karnin, Barhöft, Stahlbrode, Koserow, Sassnitz and Warnemünde – WSA Stralsund; Travemünde – WSA Lübeck; Büsum – Schleuse Büsum; Brunsbüttel – WSA Brunsbüttel; Norderney – Deutsche Gesellschaft zur Rettung Schiffbrüchiger (DGZRS); Blankenese – Institut für Hygiene und Umwelt.

Ice conditions at the German North and Baltic Sea coasts

The ice season 2018/19 consisted of one single, short-lasting period of ice formation from end of January to early February. At the North Sea, the first sea ice formed in Emden on the 20th January 2019, and the last ice was seen on the 26th January in Sylt and in the sea area of the Eiderdamm. In total, sea ice occurrence was reported for 4 stations only: In the new inner harbour of Emden, sea ice was present for 6 days and reached thicknesses of up to 10 cm. On the river Ems and in the outer harbour of Emden, there were sea ice pieces for 2 days. Also in the harbour of List on Sylt and in the sea area of the Eiderdamm ice was observed on 2 days only, which was covering only a small area and grew up to 5 cm thickness. At the Baltic Sea, sea ice was observed between the 20th January and the 6th February, mainly in very sheltered regions like the harbour of Thiessow (Fig. 4). The sea areas predominantly stayed ice free.

Figure 4: The harbour of Thiessow (left) was covered by thin ice for a few days, as were some other sheltered regions in the winter 2018/19. At sea (right), no ice formed. Courtesy of Frank Sakuth.

The first ice at the German coast of the Baltic Sea had formed on the 20th January on the river Schlei and in the Bay of Eckernförde. In the following days, some ice formed further east in sheltered regions, too, mainly in the Bodden waters. Maximum ice thicknesses were 10-15 cm in the Dänische Wiek and in the harbour of Neuendorf. Elsewhere, mostly new ice and 5-10 cm were observed.

The longest period with ice coverage amounted to 18 days and occurred on the river Schlei in this winter (see Tab. A1 and A2). In the Dänische Wiek, in Warthe, in the harbours of Hiddensee und in the harbours of the Darß-Zingster Bodden chain, sea ice was observed on 10 to 14 days. Elsewhere, sea ice coverage lasted only for a few days. At the North Sea coast, sea ice stayed longest in Emden (new inner harbour) with 6 days of occurrence.

The development of the ice winter is shown in Figure A1 in the appendix. In Tables A1 and A2 of the appendix, the most important ice parameters for the season are summarized.

Navigational conditions at the German Baltic Sea coast

As there was only little ice formation over the entire winter, ship traffic was not affected significantly in the ice season 2018/19.

Figure 5: At low ice coverage, ship traffic was not hampered by the ice seriously. Courtesy of Frank Sakuth.

Ice winter intensity

The winter 2018/19 was a very weak ice season. Nearly all of the 13 climatological stations at the North Sea coast stayed ice free. Only in Emden, new ice had formed and lasted for two days in late January, but it covered less than 10% of the area. At the Baltic Sea coast, sea ice formed at two of the 13 climatological stations and stayed for a few days. The accumulated areal ice volume for the German Baltic coast is 0.048 m. This corresponds to a tenth of the amount from the winter 2017/18. The indices for the ice winter strength are calculated out of observational data from the 13 climatological stations at the Baltic Sea coast and the 13 climatological stations at the North Sea coast. They are expressed in terms of the reduced ice sum and as the accumulated areal ice volume ($V_{A\Sigma}$), respectively. The calculated values for the ice winter 2018/19 are shown in Table 2. For the Baltic Sea, the ice winter strength was also calculated for the coasts of Mecklenburg-West Pomerania and Schleswig-Holstein separately. This winter, sea ice formed only in very sheltered areas at the Mecklenburg-West Pomeranian coast. Therefore, at none of the climatological stations ice occurred and accordingly the areal ice volume sum amounts to 0.0 m for this part of the Baltic Sea coast, although there had been little ice at some non-climatological stations. At the coast of Schleswig-Holstein, instead, ice formed nearly exclusively at climatological stations. Hence, the areal ice volume sum for the entire German Baltic Sea coast results from the ice occurrence at the coast of Schleswig-Holstein.

Table 2: Reduced ice sum and accumulated areal ice volume at the German coasts in the winter 2018/19.

Area	Reduced ice sum	Accumulated areal ice volume
North Sea coast	0.2	**0.002**
Baltic Sea coast	2.1	**0.048**
Coast of Mecklenburg-West Pomerania	0.0	0.000
Coast of Schleswig-Holstein	3.9	0.089

Figure 6 shows the development of the ice formation at the climatological stations considering the daily areal accumulated ice volume for both coasts.

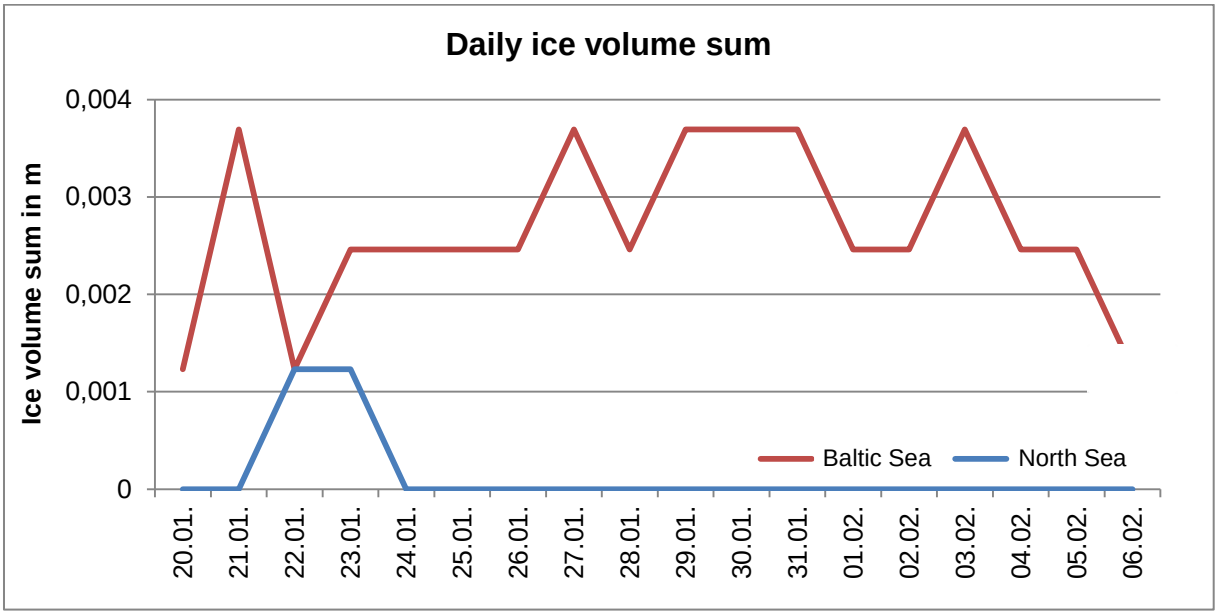

Figure 6: Areal ice volume at the German coasts in the winter 2018/19.

At the Baltic Sea, there was a short period between the 20th January and the 6th February, when ice formation occurred at the climate stations. During this period, ice production or ice occurrence was quite steady. At no time, ice formation showed a distinct behaviour.
Basically, a thin sea ice layer existed consistently within those 14 days, which quickly melted away early in February. From the 4 ice covered stations at the North Sea, only the station Emden - Ems and outer harbour counts to the climate stations. There, little sea ice was observed on two days only, which was already melted away again on the 24th January.

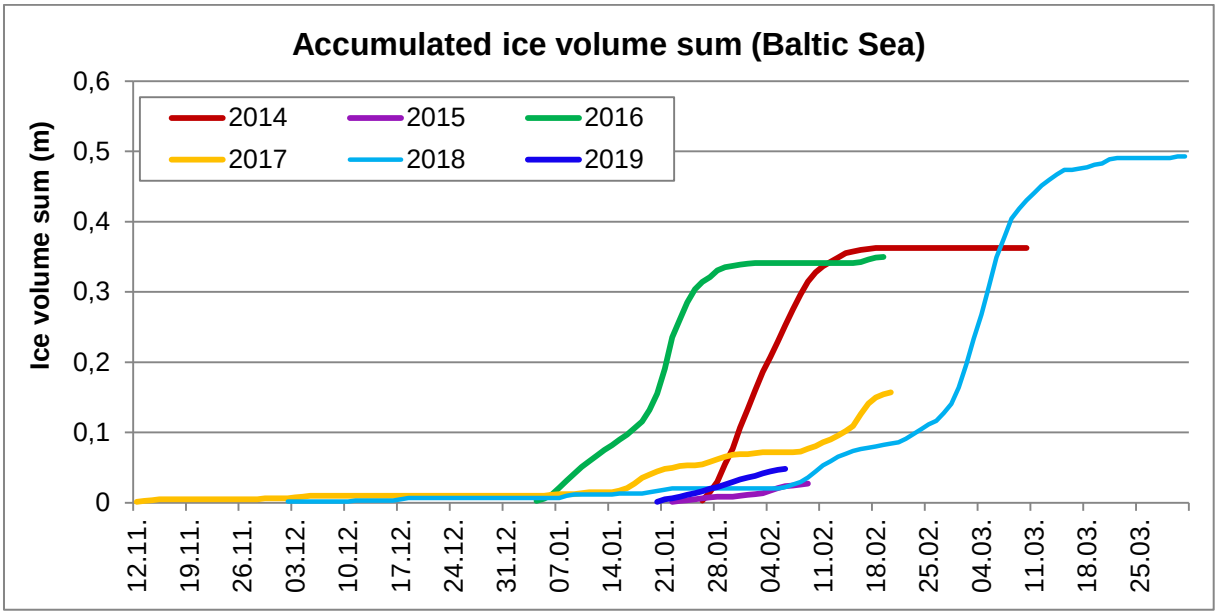

Figure 7: Accumulated areal ice volume sums at the German Baltic Sea coast for the winters 2013/14 to 2018/19.

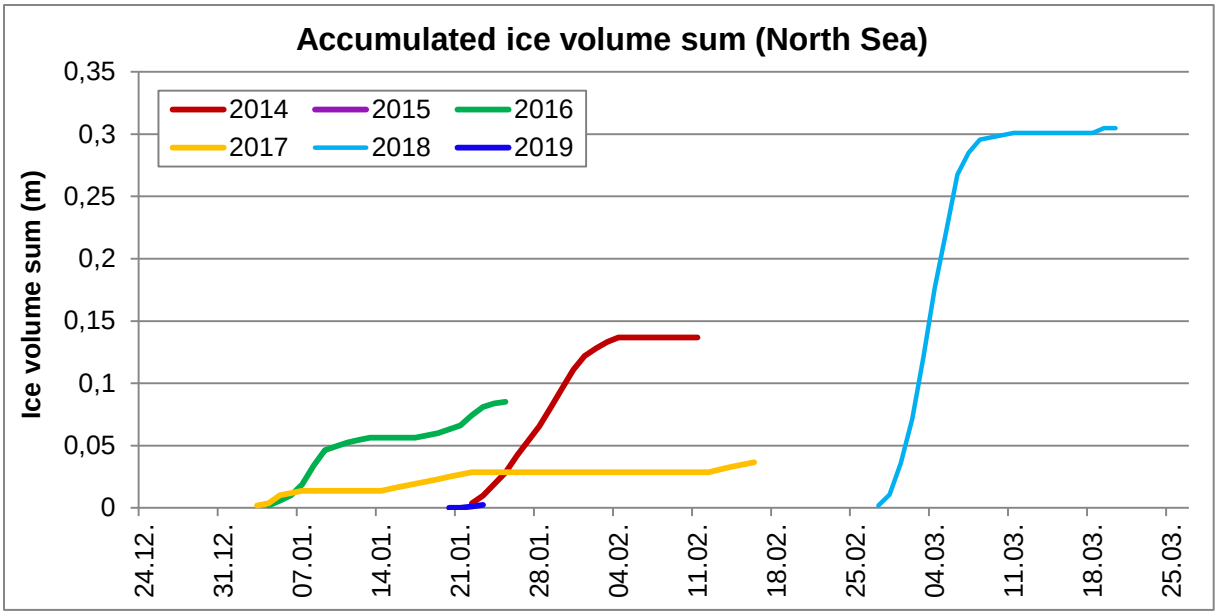

Figure 8: Accumulated areal sea ice volume sum at the German North Sea coasts for the winters 2013/14 to 2018/19.

In Figure 7 and 8, the seasonal accumulated sea ice volume sums from the climatological stations are shown for the winter 2018/19 in comparison with the 5 previous winters for the Baltic Sea and for the North Sea, respectively. For the Baltic Sea (Fig. 7), the ice winter strength and development of the season 2018/19 (dark blue) are similar to those of the winter 2014/15 (purple). As the winter temperature conditions were very similar in both years (in fact, temperatures in 2014/15 were slightly milder than in 2018/19, accordingly, the areal accumulated sea ice volume was slightly lower in 2014/15), this similarity could be expected. The other winters were considerably stronger. For all winters, the date of maximum ice extent varies between end of January and mid-March.
For the North Sea, the ice season 2018/19 was one of the weakest, although there was at least little ice. In the winter season 2014/15, for comparison, no ice had formed due the mild temperatures. As for the Baltic Sea, the date of maximum ice extent varies in the North Sea between end of January and mid-March.

The BSH reported on ice conditions and expected ice development in the entire Baltic Sea region and German coastal waters in the ice winter **2018/19** by the following reports and ice charts:

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

The current ice reports and charts of the BSH are available online and free of charge under https://www.bsh.de/DE/DATEN/Eisberichte-und-Eiskarten/Eisberichte-und-Eiskarten_node.html. The archive with all ice charts issued so far is available at ftp://ftp.bsh.de/outgoing/Eisbericht/.

The strength of the ice winter 2018/19 is shown in Figure 9 and 10, compared to former winters. Since 1896/97 (123 years) 16 winters at the German North Sea coast and 18 winters at the German Baltic Sea coast, respectively, have been weaker than the ice season in 2018/19. In total, the winter 2018/19 is the 7th consecutive weak winter.

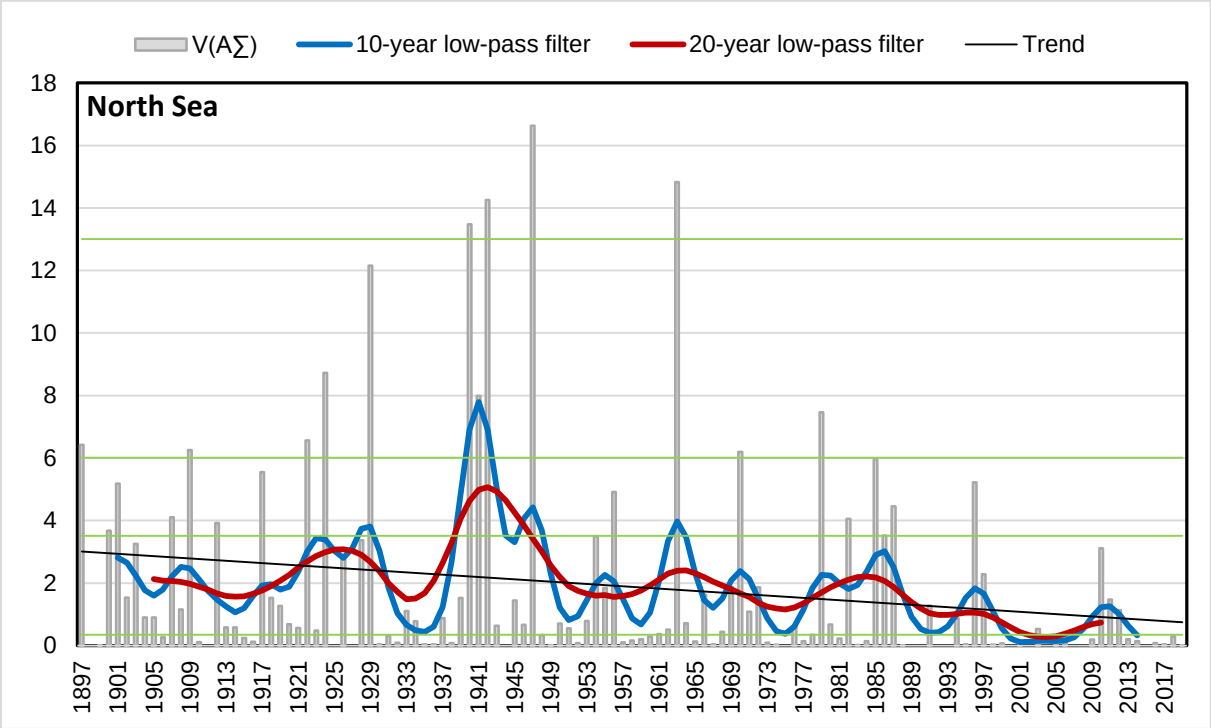

Figure 9: Distribution of the areal ice volume sum for the German North Sea coast with 10-year (blue) and 20-year (red) low-pass filter as well as the long-term trend (black).

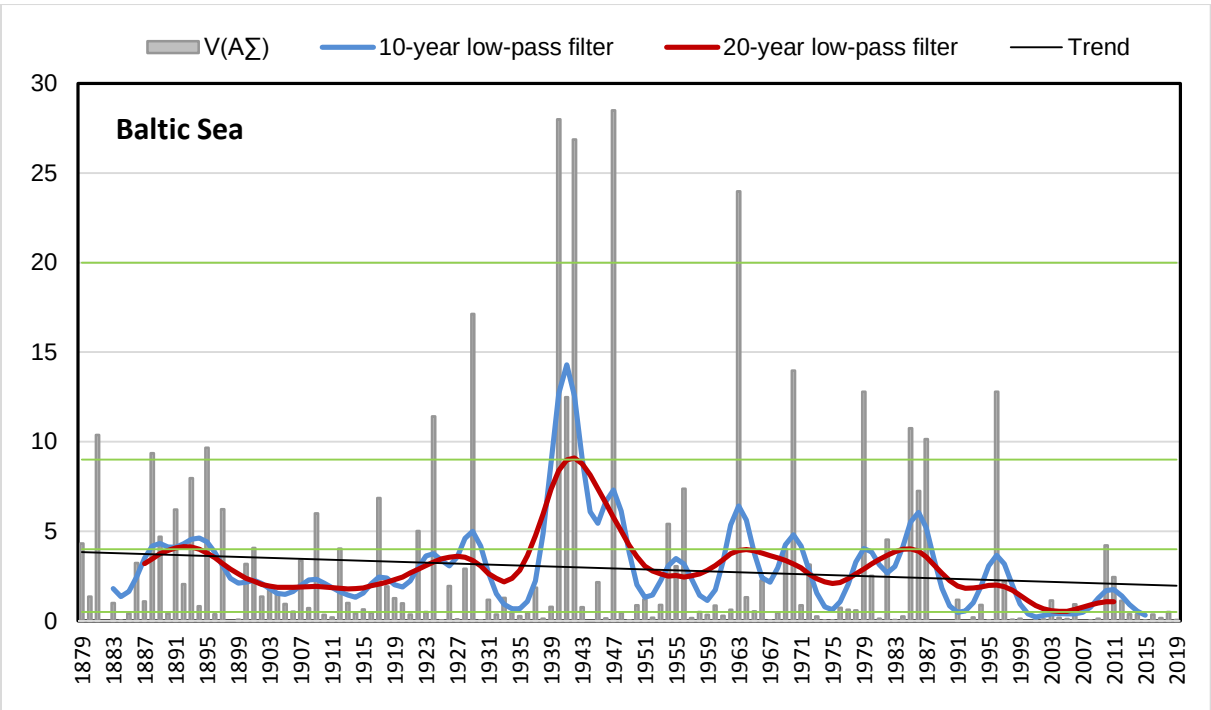

Figure 10: Distribution of the areal ice volume sum for the German Baltic Sea coast with 10-year (blue) and 20-year (red) low-pass filter as well as the long-term trend (black).

Ice conditions in the western and southern Baltic Sea

In the Danish waters, no considerable ice formation occurred in the winter 2018/19.

In the southern Baltic Sea, the first pack ice was observed in the Curonian Lagoon early in December. Mid-January, some ice formed in the Vistula Lagoon and in late January/early February ice formation started in the Bay of Puck and in the Szczecin Lagoon. Ice thicknesses varied between 5 cm in the Szczecin Lagoon and in the Bay of Puck, where the sea ice stayed only for few days, and 10-15 cm in the Curonian Lagoon, which became ice free in mid-March.

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

In the winter 2018/19, the first sea ice had already formed in early November in the northern archipelagos of the Bay of Bothnia. Noticeable new ice formation, however, started around the 19th November, only. By that time, new ice grew rapidly along the coast of the Bay of Bothnia, Norra Kvarken and in the northern Sea of Bothnia. Afterwards, there was a standstill in new ice formation until mid-December, which was replaced by slow sea ice growth until 27th January 2019, when the maximum sea ice extent was reached. By that time, the Bay of Bothnia was nearly completely covered by sea ice, except for a small region in the central south. In the Sea of Bothnia, there was some thin sea ice only along the coast. In the Gulf of Finland, fast ice occurred along the northern coast. In its eastern part, very close thin ice could be found off the fast ice up to the Narva Bay in the south and up to Helsinki in the north. In the Gulf of Riga, mostly level ice occurred in Väinameri and further south, thin level ice and new ice were present. From early April on, sea ice started to decrease rapidly south of the Bay of Bothnia. In the Bay of Bothnia, the last ice remained until mid-May 2019.

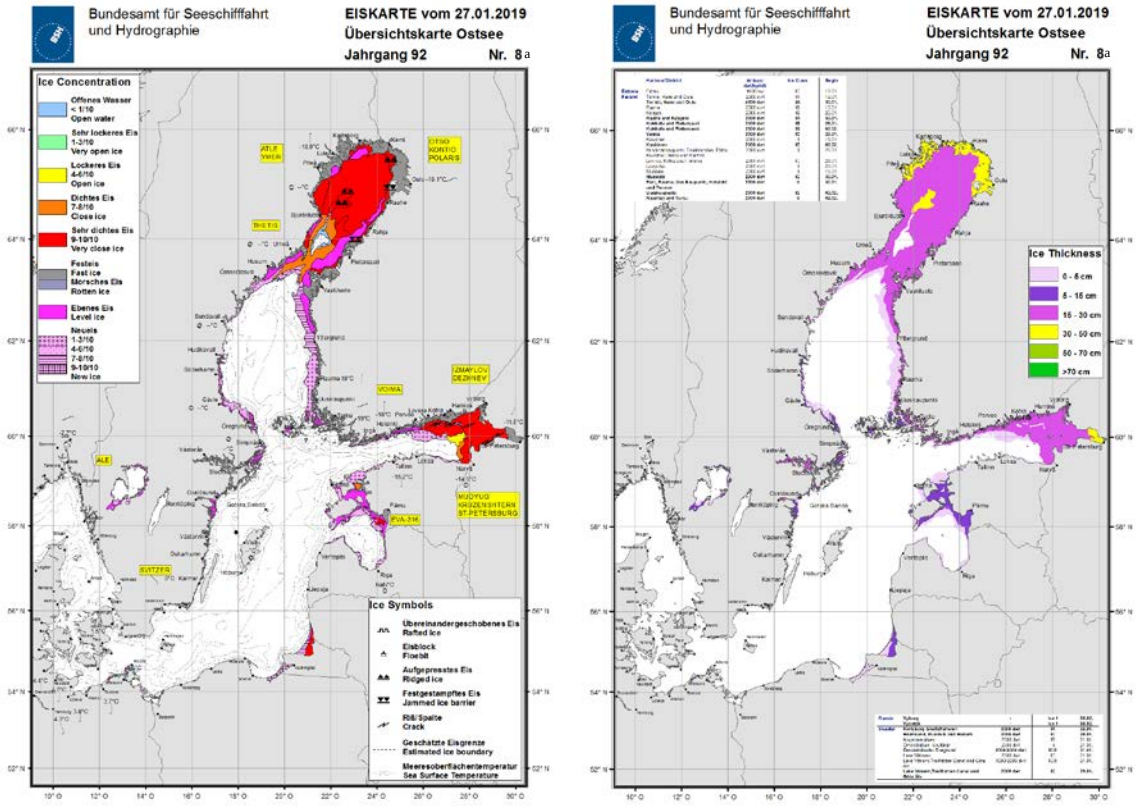

Figure 11: Ice chart for the entire Baltic Sea at the day of maximum sea ice extent in this winter (27th January 2019). Left: Ice coverage (coloured), form of the ice (symbol), temperature and wind at individual stations, water temperature and icebreaker operation for shipping assistance. Right: Ice thickness distribution and shipping restrictions.

The fast ice in the Bay of Bothnia reached maximum thicknesses of 40-80 cm, the pack ice grew up to 30-50 cm. In the Gulf of Finland, ice thicknesses varied between 45 cm for the fast ice and 10-35 cm for the pack ice. In the Gulf of Riga, sea ice reached thicknesses of 10-40 cm.

The maximum ice extent occurred on the 27th January 2019 and amounted to 88000 km^2 according to the Finnish ice service or 106016 km^2 according to the German ice service. Hence, the ice winter 2018/19 is classified as weak winter following the Finnish ice winter strength classification (Seinä und Palosuo, 1996). The sea ice volume had its maximum on the 8th February with 14.3 km^3. Hence, with respect to sea ice volume the winter 2018/19 was an extremely weak one.

Nevertheless, in the Gulfs of Bothnia, Finland and Riga restrictions 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 the 1st of January up to the 17th May 2019. The traffic separation scheme in the Quark was out of use between the 1st February and the 7th May. Furthermore, the transit traffic west of Holmöarna was forbidden between the 23rd January and the 21st March.

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

Figure 12 shows the maximum sea ice extent of each winter calculated from the Finnish and German ice services, respectively, compared to each other, as well as the class boundaries for the ice winter strength according to Nusser (1948) listed in Table 3.

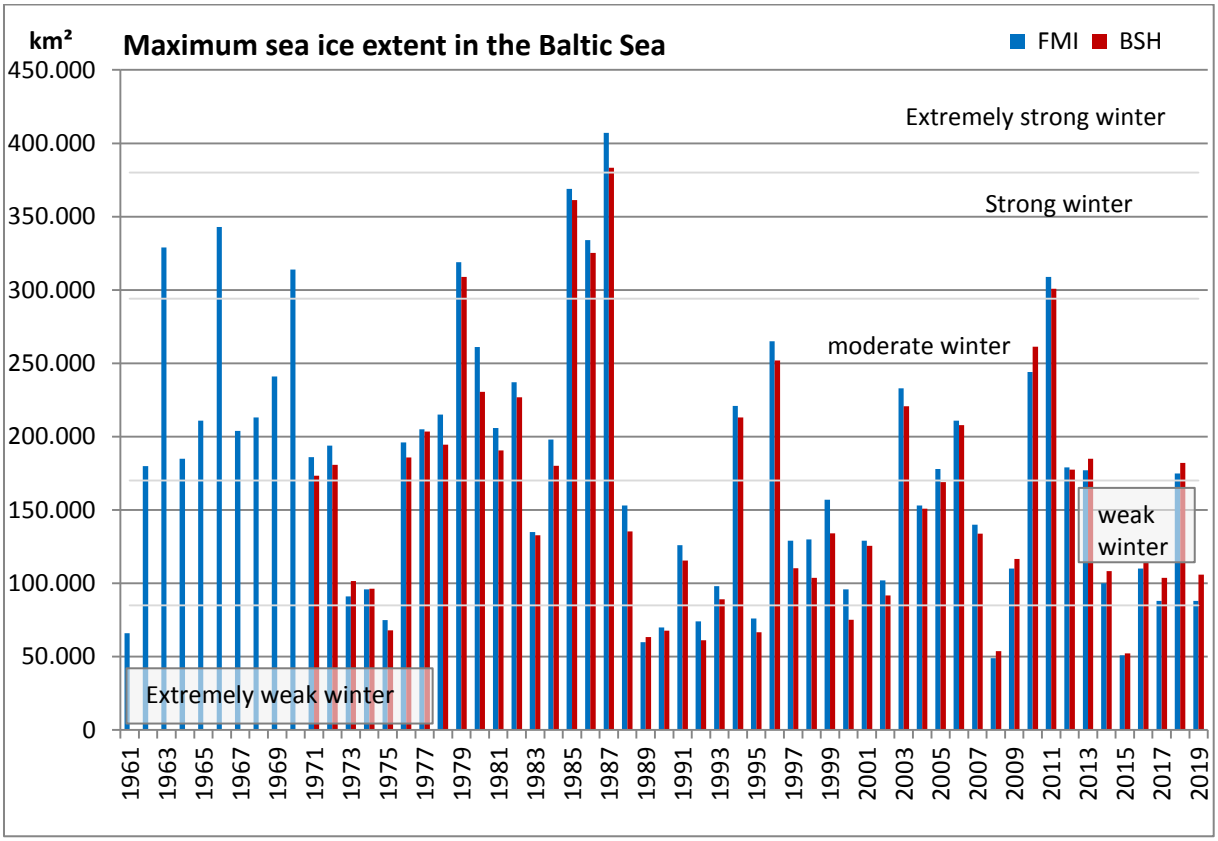

Figure 12: Yearly maximum sea ice extent in the Baltic Sea for the period 1961 – 2019 (Data source: FMI and BSH).

As in every year, there is a slight difference between the Finnish and the German maximum ice extent since the interpretation of satellite data may slightly differ and different land masks

are used in both services. However, the difference does generally not influence the classification of the ice winter strength. As mentioned before, the winter 2018/19 counts to the weak winters according to sea ice extent. This is the 19th weak winter since 1971 and 15 of them have been weaker or equally weak than the ice winter 2018/19.

Table 3: Class boundaries for different ice winter types.

Max. Area	Min. Area		Max. Volume	Min. Volume
1000*km^2	1000*km^2		km^3	km^3
405 (1987)	> 380	Extremely 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)	Extremely weak ice winter	< 17	**7.6** (1992)

Figure 13 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 sea ice thickness, it is a much better measure for the description of the ice winter strength. The maximum sea ice volume was 14.3 km^3 in this season and was already observed on the 8th February. This amount represents an extremely weak ice winter. In total, this sea ice volume maximum is the 8th lowest since 1971. Figure 13 shows also the trend for the sea ice volume over the period 1971 through 2019 as red line. Per decade, the maximum sea ice volume decreases by 4.4 km^3 on average. This trend is statistically significant.

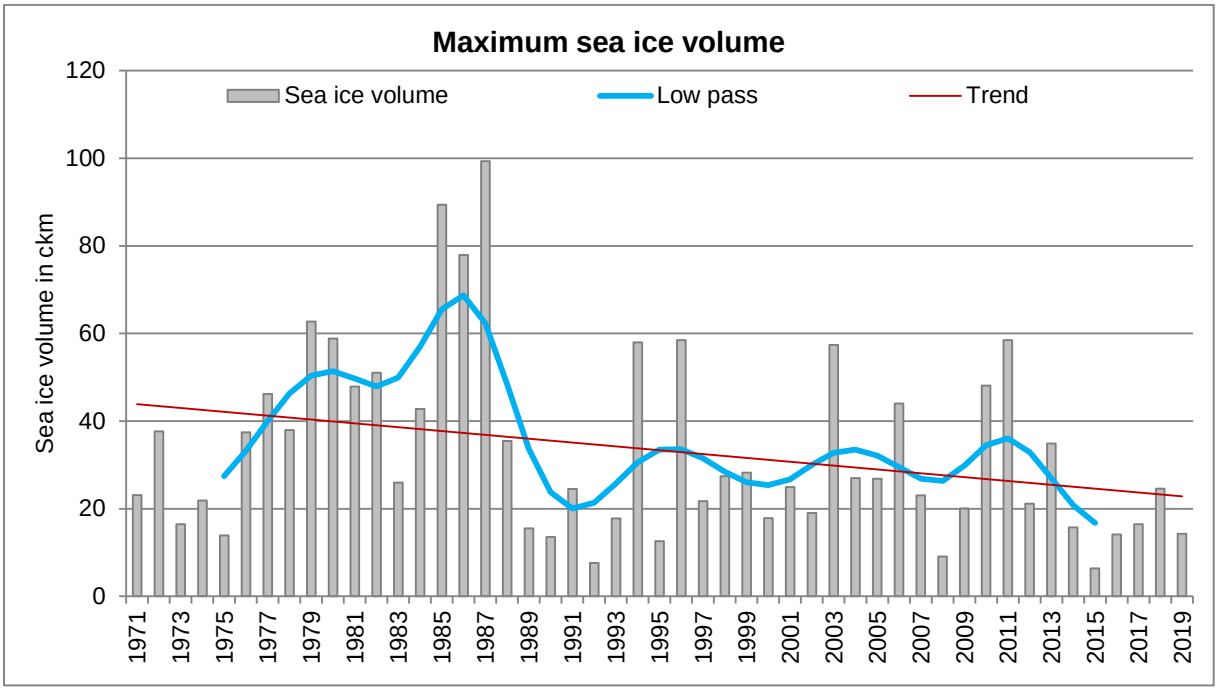

Figure 13: Yearly maximum sea ice volume of the Baltic Sea for the period 1971 – 2019.

In Figure 14 is displayed, how often at which time of the year the maximum in sea ice extent and sea ice volume occurred considering the period from 1971 through 2019. The maximum sea ice extent (SIEmax, blue) occurs mostly in the second half of February, but also in March it appears relatively often. The sea ice volume of the Baltic Sea (SIVmax, red) reaches its seasonal maximum mostly in March. However, also the second half of February is probable. Up to mid-February and in April, a maximum in sea ice volume has only seldom occurred. This may be due to the fact that sea ice grows in the course of the season even if the sea ice extent has already stopped to do so. From the time when sea ice starts to melt continuously,

sea ice volume decreases while sea ice extent may also decrease when wind conditions support convergent ice drift and consolidates the ice field.

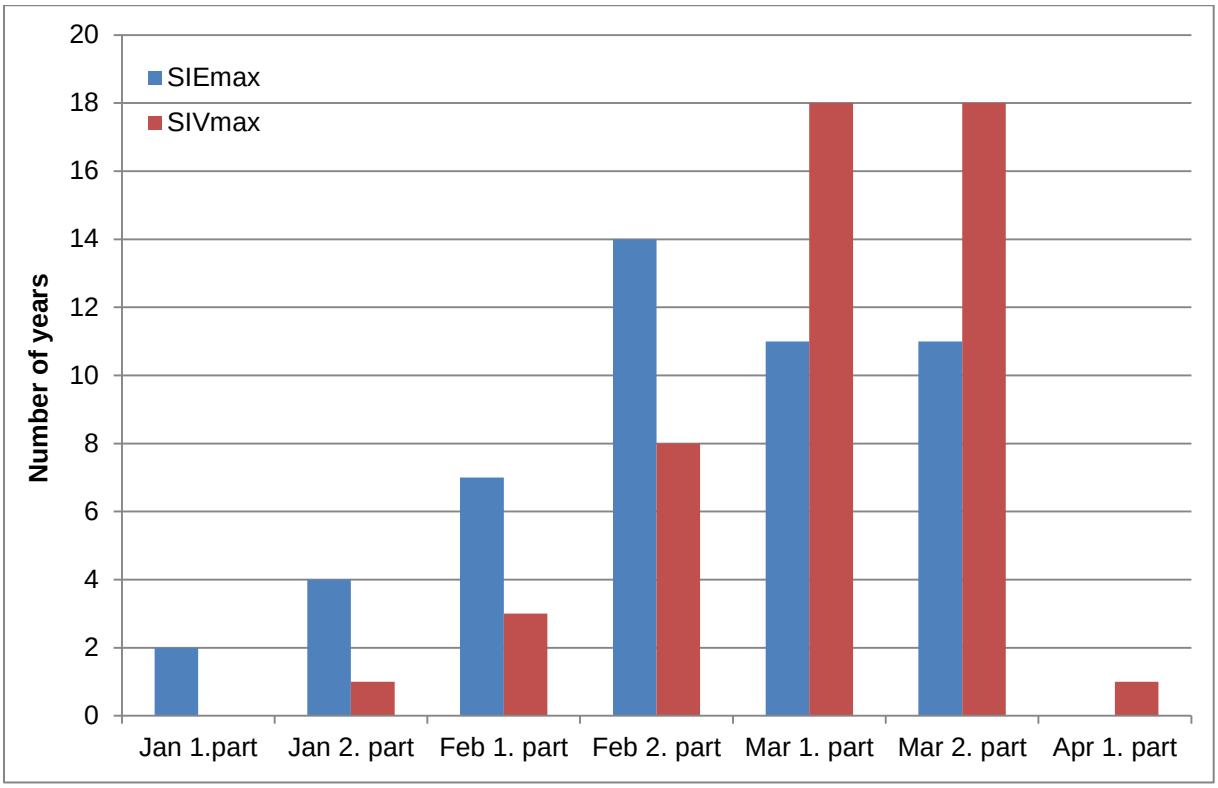

Figure 14: Frequency of dates when the maximum sea ice extent (SIEmax) and maximum sea ice volume (SIVmax) occur.

Figure 15 shows how the date of maximum ice extent and maximum ice volume has varied over the previous 48 years, using the day of year (doy) as a mean. Considering the doy of maximum sea ice extent (SIEmax), strong interannual variations appear. The earliest SIEmax was observed on 3rd January 2002 (doy 3). That year a weak winter occurred. The latest appearance of SIEmax was on 27th March 2008 (doy 87). That winter was an extremely weak one. Overall, there is no trend to earlier or later doy visible. Noticeable is nevertheless, that during the last 10 years, SIEmax occurred relatively early in the season. A relation to the ice winter strength is not obvious.

The doy on which sea ice volume reaches its maximum does not vary as strong as the doy of SIEmax and both do not necessarily correlate. There are years when SIEmax was early in the year and SIVmax occurred comparatively late in the same year. The earliest appearance of SIVmax was observed on 16th January 1989 (doy 16), which was a year with extremely weak ice coverage. The latest appearance occurred in 2013 on 2nd April (doy 92); a year with moderate ice winter. As for SIEmax, SIVmax does not show a significant trend over the past 48 years.

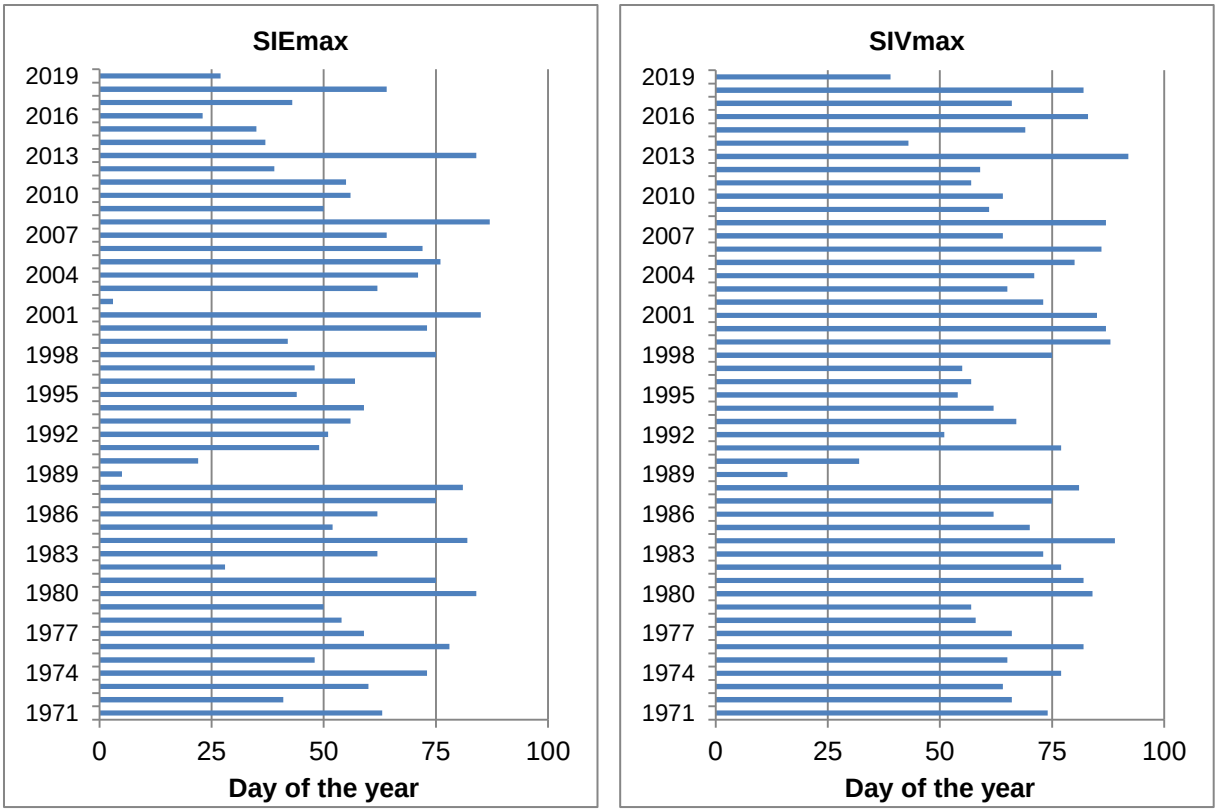

Figure 15: Day of the year when the maximum sea ice extent (left) and sea ice volume (right) occurred within the previous 48 years.

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Nusser, F., 1948: Die Eisverhältnisse des Winters 1947/48 an den deutschen Küsten. Dt. hydrogr. Z. 1, 149–156

Seinä, A., E. Palosuo, 1996: The classification of the maximum annual extent of ice cover in the Baltic Sea 1720-1995, Meri – Report Series of the Finnish Institute of Marine Research, No. 27, 79–91

Appendix

Table A 1: Ice conditions at the German North Sea coast in the winter 2018/19.

Observation station	Begin of ice occurrence	End of ice occurrence	Days with sea ice	Sea ice thickness
Sylt, Harbour List	25.01.	26.01.	2	5 cm
Eiderdamm, Sea area	25.01.	26.01.	2	5 cm
Emden, New inner harbour	20.01.	25.01.	6	10 cm
Emden, Ems and outer harbour	22.01.	23.01.	2	5 cm

Table A 2: Ice conditions at the German Baltic Sea coast in the winter 2018/19.

Observation area	Begin of ice occurrence	End of ice occurrence	Days with sea ice	Max. ice thickness
Kamminke, Harbour and vicinity	24.01.	28.01.	5	5 cm
Rankwitz, Peenestrom	25.01.	29.01.	5	5 cm
Warthe, Peenestrom	25.01.	05.02.	12	5 cm
Greifswald-Wieck, Harbour	24.01.	04.02.	9	10 cm
Dänische Wiek	24.01.	04.02.	10	15 cm
Greifswald-Ladebow, Harbour	26.01.	26.01.	1	5 cm
Thiessow, Bodden area	26.01.	26.01.	1	5 cm
Neuendorf, Harbour and vicinity	23.01.	06.02.	14	15 cm
Kloster, Bodden area	23.01.	05.02.	14	5 cm
Dranske, Libbenfahrwasser	25.01.	25.01.	1	5 cm
Dranske, Bodden area	25.01.	04.02.	6	5 cm
Wittower Ferry, Waters at	26.01.	29.01.	4	5 cm
Althagen, Harbour and vicinity	24.01.	05.02.	13	10 cm
Zingst, Zingster Strom	24.01.	28.01.	5	10 cm
Barth, Harbour and vicinity	24.01.	05.02.	13	5 cm
Rostock, City harbour	30.01.	04.02.	2	5 cm
Eckernförde, Harbour	20.01.	21.01.	2	5 cm
Schlei, Schleswig – Kappeln	20.01.	06.02.	18	10 cm
Flensburg-Holnis	21.01.	03.02.	9	5 cm

Figure A 1: Daily ice occurrence at the German North and Baltic Sea coast in the winter 2018/19.

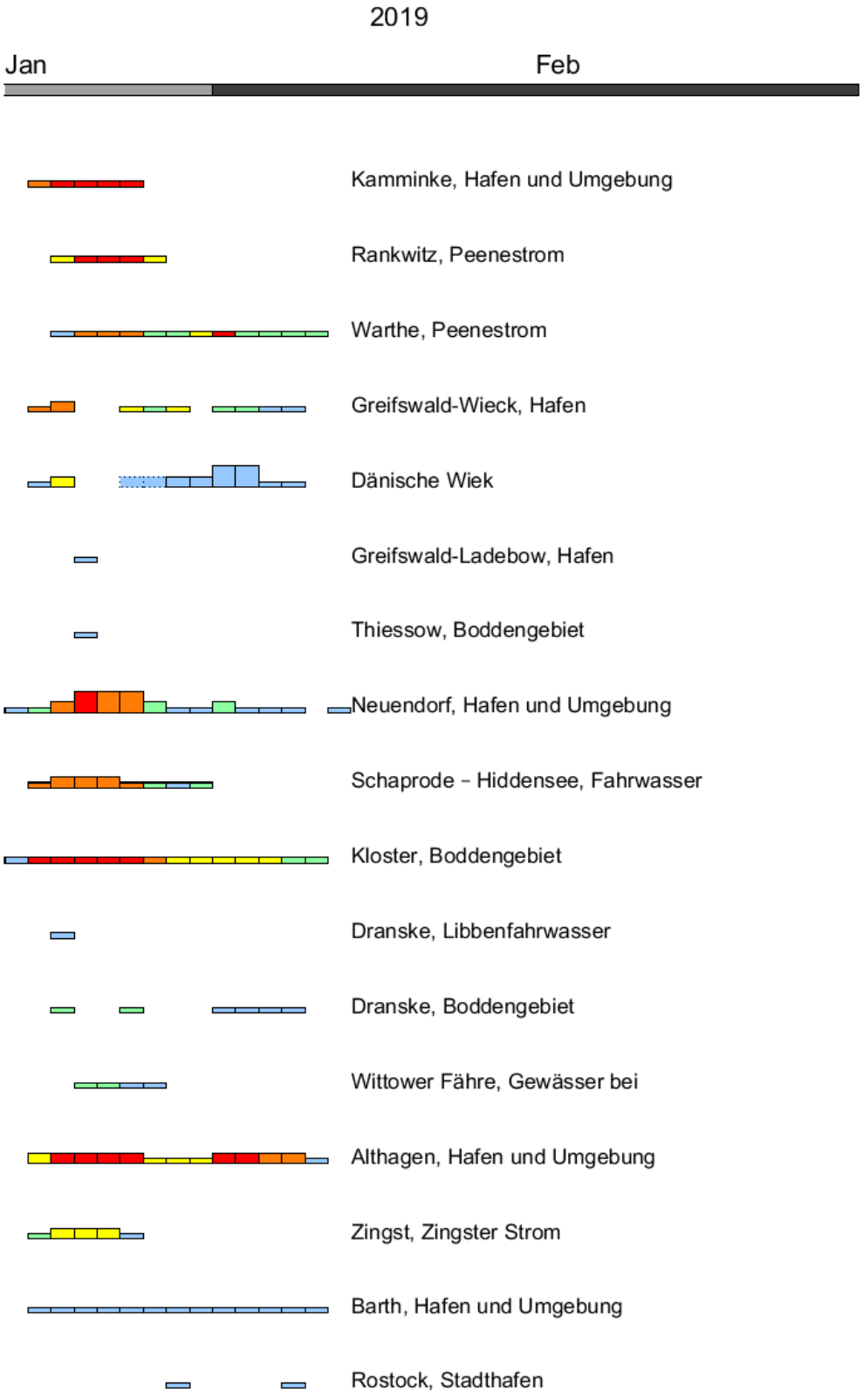

Figure A1: Continuation