The ice winter of 2009/10 on the German North and Baltic Sea coasts

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Long-term comparison of the ice winter of 2009/10

In terms of ice volume and duration of the ice cover in the German coastal waters, the severity of the ice winter of 2009/10 ranges **between moderate and severe**. It was the first winter in 13 years (since 1995/96) during which ice formed also in the offshore waters of the western Baltic Sea. The severity of ice winters is determined on the basis of observation data from 13 climatological stations on the Baltic Sea coast and 13 climatological stations on the North Sea coast. It is expressed by the *reduced ice sum and the accumulated areal ice volume* ($V_{A\Sigma}$). An explanation of these terms is provided at http://www.bsh.de/en/Marine_data/Observations/Ice/StatisticsCoasts.jsp.

Ice winters on the German coast are subdivided into 5 categories:

	$V_{A\Sigma}$ (Baltic), m	$V_{A\Sigma}$ (North Sea), m
Weak	< 0.50	< 0.35
Moderate	0.50 - 4.00	0.35 - 3.50
Severe	4.01 - 9.00	3.51 - 6.00
Very severe	9.01 - 20.00	6.01 - 13.00
Extremely severe	> 20.00	> 13.00.

The computed figures for the ice winter of 2009/10 are shown in Table 1.

Table 1. Reduced ice sums and accumulated areal ice volumes on the German coasts in the winter of 2009/10

Area	Reduced ice sum	Accumulated areal ice volume
North Sea coast	**31.2**	**3.11** m
Baltic Sea coast	**45.8**	**4.22** m
Mecklenburg/Vorpommern Baltic coast	51.1	5.33 m
Schleswig-Holstein Baltic coast	39.5	2.93 m

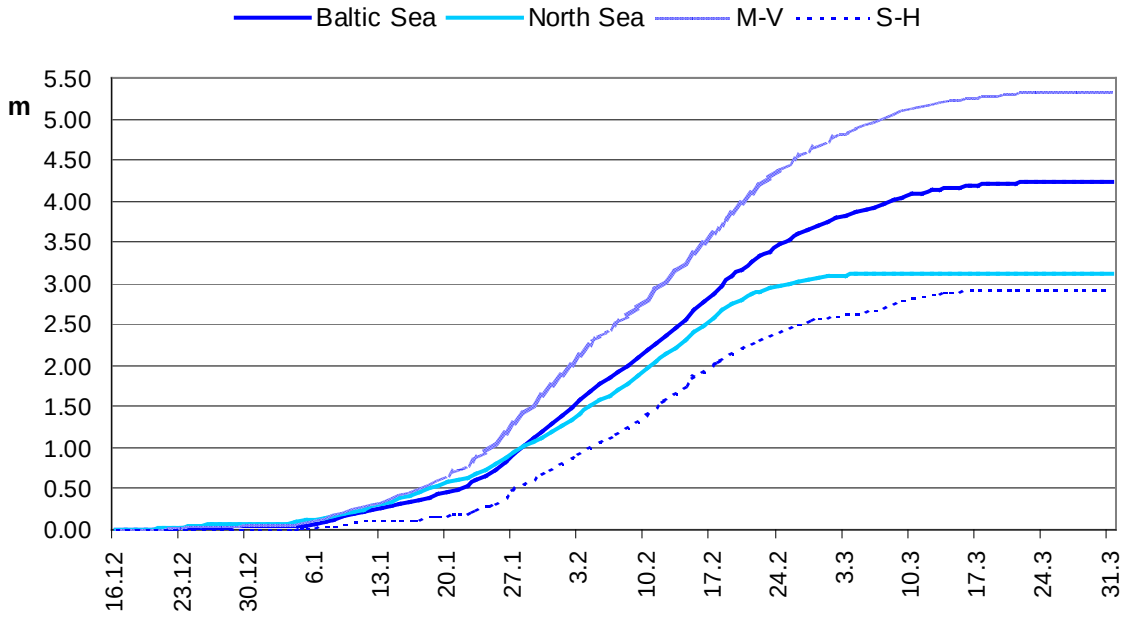

Figure 1. Accumulated areal ice volume on the German coasts in the winter of 2009/10

Ice production in the eastern part of the German Baltic Sea coast again was stronger than in the western part, as every winter, due to the stronger continental climate impact in the eastern coastal sections. The winter of 2009/10 was a moderate ice winter on the Baltic coast of Schleswig-Holstein, but has been classified as a strong ice winter on the coast of Mecklenburg-Vorpommern, cf. Figure 1. The ice winter of 2009/10 on the North Sea coast has been classified as a moderate ice winter.

The severity of this ice winter, expressed by $V_{A\Sigma}$, and its meteorological character, expressed by the modified 'Winterzahl' (W^*_z) (Koslowski, 1989; Schmelzer, 2004) are in good agreement, as shown in Figures 2 to 4.

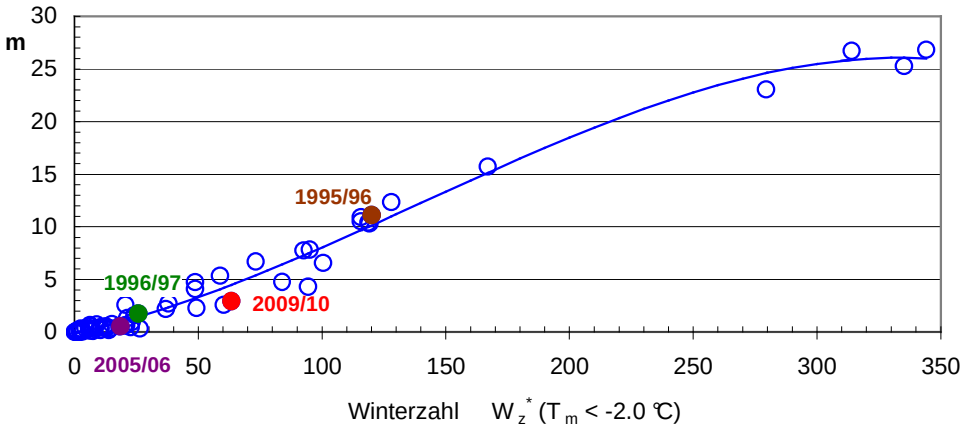

Figure 2. Regression curve for the accumulated areal ice volume and 'Winterzahl' (T m < -2.0 ℃) of Schleswig: $V_{A\Sigma} = - 0{,}1017 + 0{,}0506\ W_z^* + 0{,}4033 * 10^{-3}\ W_z^{*2} - 0{,}9588 * 10^{-6}\ W_z^{*3}$

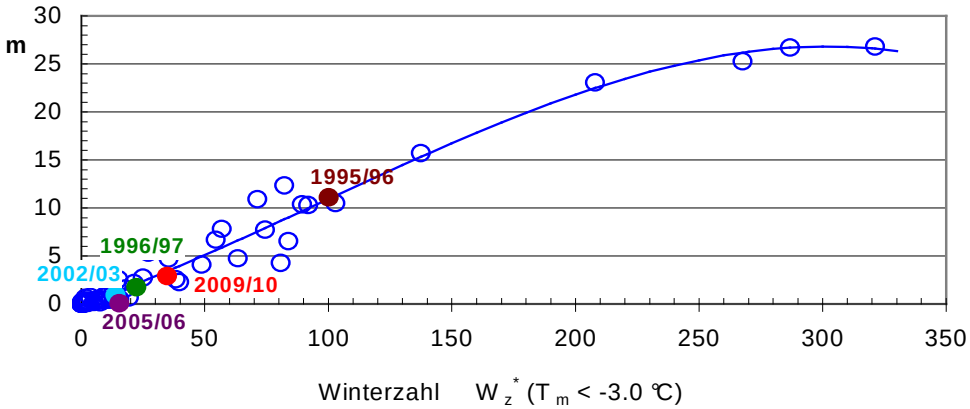

Figure 3.Regression curve for the accumulated areal ice volume and 'Winterzahl' (T m < -3.0 ℃ of Schleswig): $V_{A\Sigma} = - 0{,}068 + 0{,}092\ W_z^* + 0{,}276 * 10^{-3}\ W_z^{*2} - 0{,}946 * 10^{-6}\ W_z^{*3}$

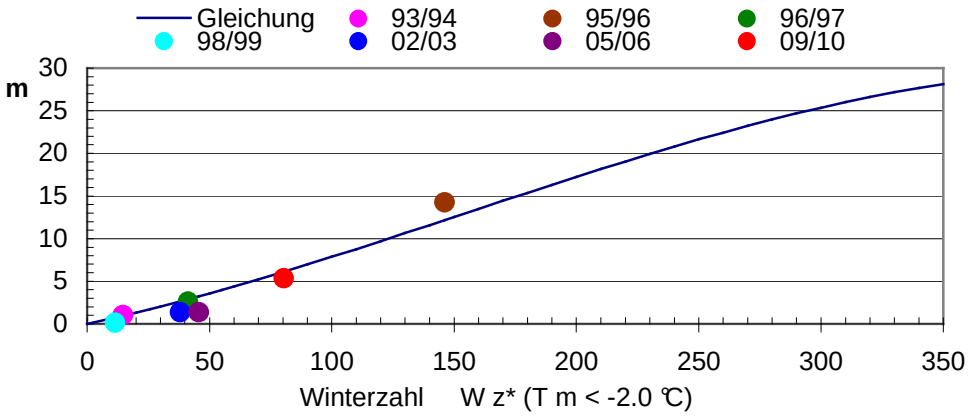

Figure 4. Regression curve of the accumulated areal ice volume and 'Winterzahl' (T m < -2.0 ℃) of Putbus (Greifswald):
$V_{A\Sigma} = - 0{,}00071 + 0{,}062\ W_z^* + 0{,}213 * 10^{-3}\ W_z^{*2} - 0{,}458 * 10^{-6}\ W_z^{*3}$

The severity of the ice winter of 2009/10 in comparison with the winters of the long-term series is shown in Figures 5 and 6.
In the observation series since 1896/97, only 20 ice winters stronger than 2009/10 have been recorded on the German Baltic coast, and 27 on the North Sea coast.

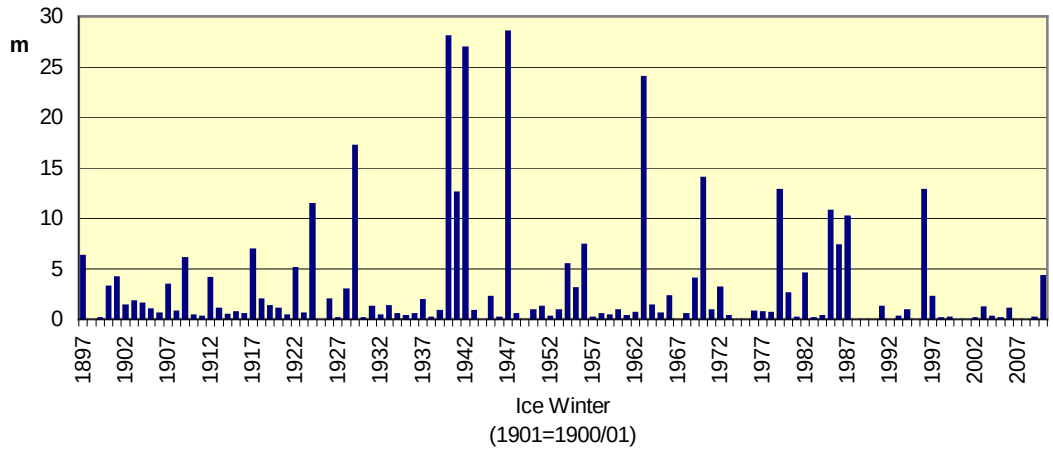

Figure 5. Distribution of accumulated areal ice volume on the German Baltic Sea coast

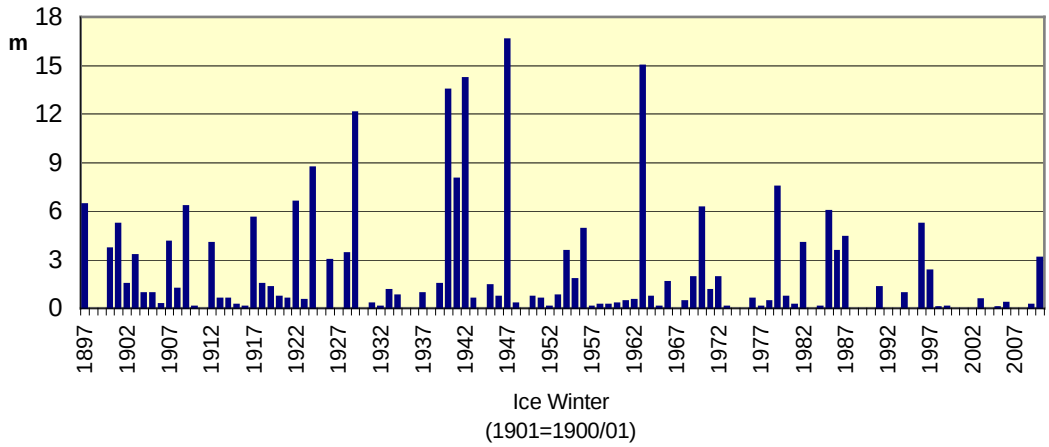

Figure 6. Distribution of accumulated areal ice volume on the German North Sea coast

The ice winter of 2009/10 on the German North and Baltic Sea coasts

Weather development

The winter of 2009/10 was very cold, with considerable snowfall, especially in the northeastern part of Germany. Coastal weather was determined mainly by cyclonic systems. In all months of this winter, air temperatures were below the long-term means in all parts of the German coast; cf. Table 2. Precipitation in the northeast fell mostly as snow reaching depths of up to 40-60 cm and lasting for weeks.

Table 2. Monthly mean air temperatures *(℃) in the winter of 2009/10, and deviations from the 1961 – 1990 climate means (K) (data from Deutscher Wetterdienst,* www.dwd.de*)*

Station	November		December		January		February		March	
	℃	K	℃	K	℃	K	℃	K	℃	K
Greifswald	7.2	2.6	-0.0	-2.1	-4.5	-3.9	-0.8	-0.8	3.8	1.1
Rostock-Warnemünde	7.7	2.4	0.9	-1.0	-3.5	-3.7	-0.5	-1.2	4.1	1.0
Schleswig	7.8	2.9	0.7	-1.0	-3.3	-3.6	-1.1	-1.7	4.0	1.2
Helgoland	9.7	2.1	3.8	-0.6	-0.7	-3.2	-0.0	-2.1	3.6	0.2

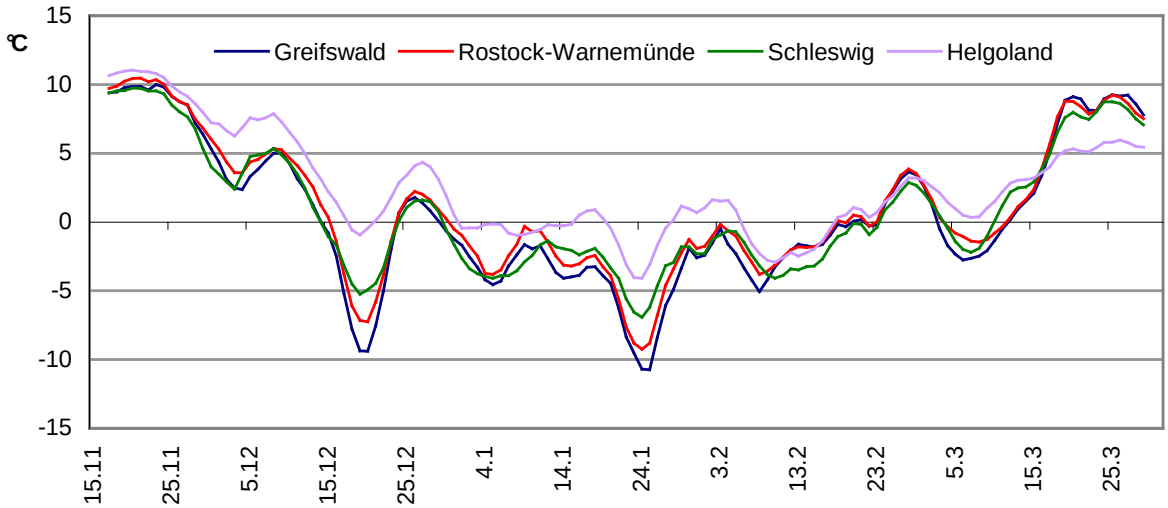

Figure 7. Daily mean air temperatures in the winter of *2009/10 (data from Deutscher Wetterdienst, www.dwd.de/)*

This winter was marked by a cold spell lasting from mid-December to the end of February, briefly interrupted by a warmer spell around the end of the year. The lowest values of the daily mean temperatures, recorded around 20 December and 25 January, ranged from –13 to –8 ℃ (even lower in the north-east).

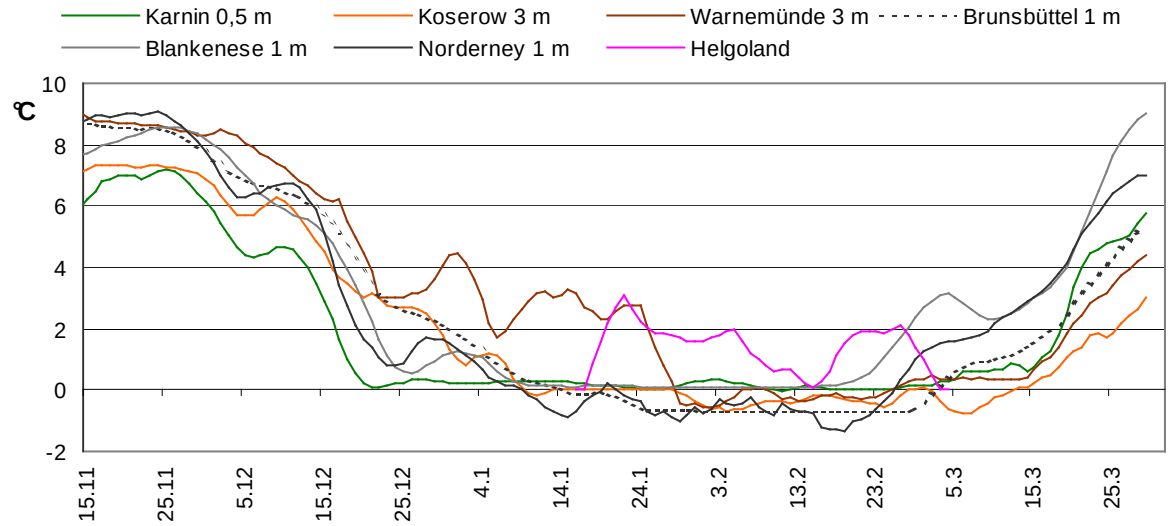

Figure 8. Water temperatures (7 h CET; Helgoland 14 h CET) in the German coastal waters

Sources of the water temperature data:

Karnin	Waterways and Shipping Board (WSA), Stralsund
Koserow	State Agency of Environment and Nature (StAUN), Ueckermünde
Warnemünde	State Agency of Environment and Nature (StAUN), Rostock
Brunsbüttel	Waterways and Shipping Board (WSA), Brunsbüttel
Norderney	German Sea Rescue
Blankenese	Institut für Hygiene und Umwelt, Hamburg

The inner coastal waters of the Baltic coast reached freezing temperatures in mid-December, waters in the Pomeranian Bight and on the North and East Frisian coasts in the second decade of January, and the waters off Warnemünde in late January; cf. Figure 8.

In the southern part of Kiel Bight and in the sea area north of the Darss peninsula, water temperatures dropped below 0℃ in early February, and temperatur es in the Arkona Basin were just above 0℃ in February and March. Conditions allowing ice to form in the German Bight offshore waters never existed at any time in the winter of 2009/10; cf. Figure 9.

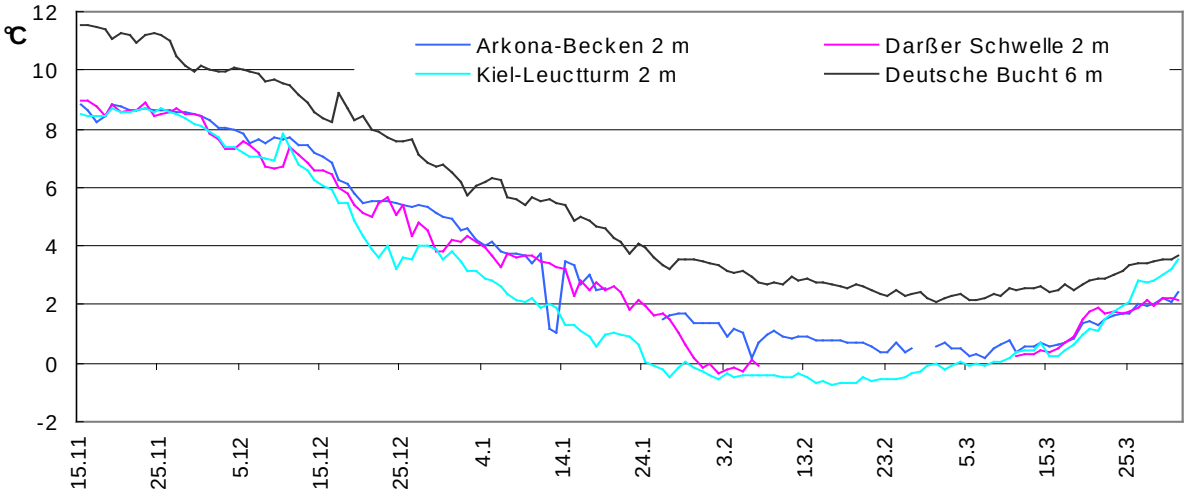

Figure 9. Water temperatures (about 7 h CET) in the offshore waters of the western Baltic Sea and in the German Bight.

Data from MARNET monitoring network, Bundesamt für Seeschifffahrt und Hydrographie (BSH), Leibniz-Institut für Ostseeforschung Warnemünde (IOW)

Ice conditions

The development of the ice winter of 2009/10 on the German North and Baltic Sea coasts is shown in Figures A1 – A5 in the Annex. The essential ice parameters have been compiled in Tables A1 and A2 in the Annex.

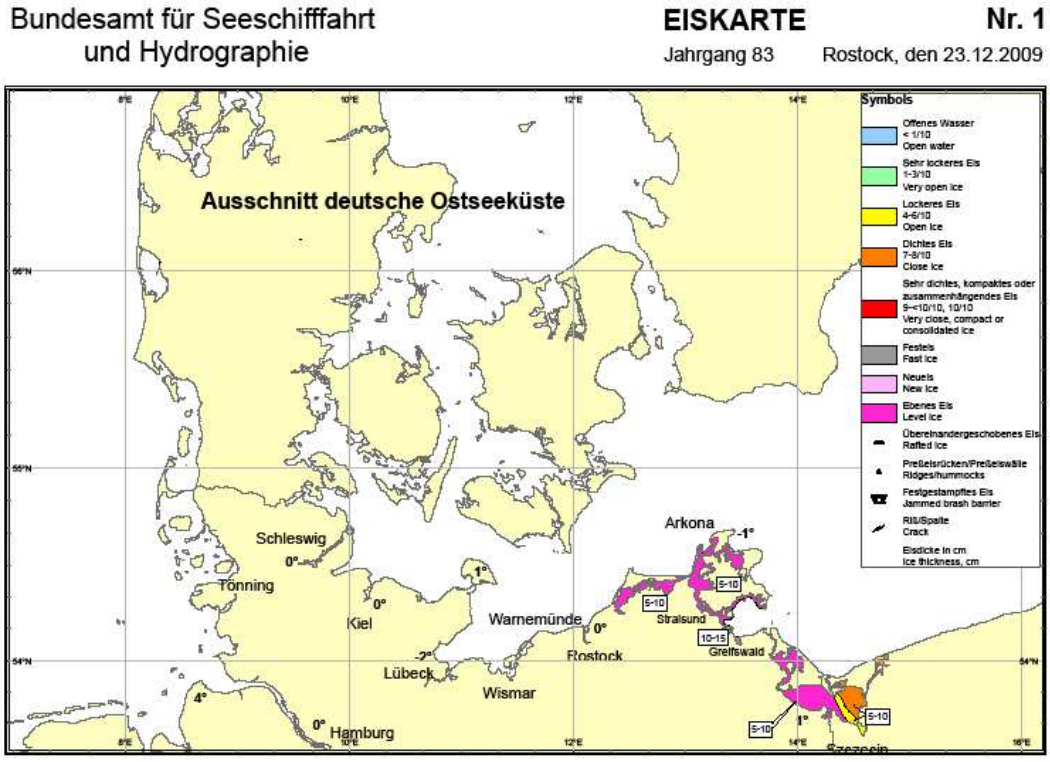

Figure 10. Beginning of ice formation on the German Baltic coast

First ice formed in the eastern bodden waters on 16 December 2009, in the inner navigation channels of the western Baltic Sea around 20 December, and on the North Frisian coast and Lower Elbe

between 16 and 23 December. Because of thawing temperatures over Christmas, ice development in the Baltic Sea stagnated, and the thin ice cover that had formed in the North Sea coastal waters disappeared completely. Ice formation resumed in the eastern waters in early January and spread quickly westward on the sheltered inner coastal waters (cf. Figure 11). Ice formation continued until mid-February. By the end of January, new ice had also formed on the outer coasts, and the Pomeranian Bight was completely covered with ice. Strong snowfall in early February led to the formation of large areas of grease ice and slush in the offshore waters of the Kiel and Mecklenburg Bights, parts of which froze and formed aggregates during the cold nights. However, the formation of a closed ice cover was prevented by wind and water motion.

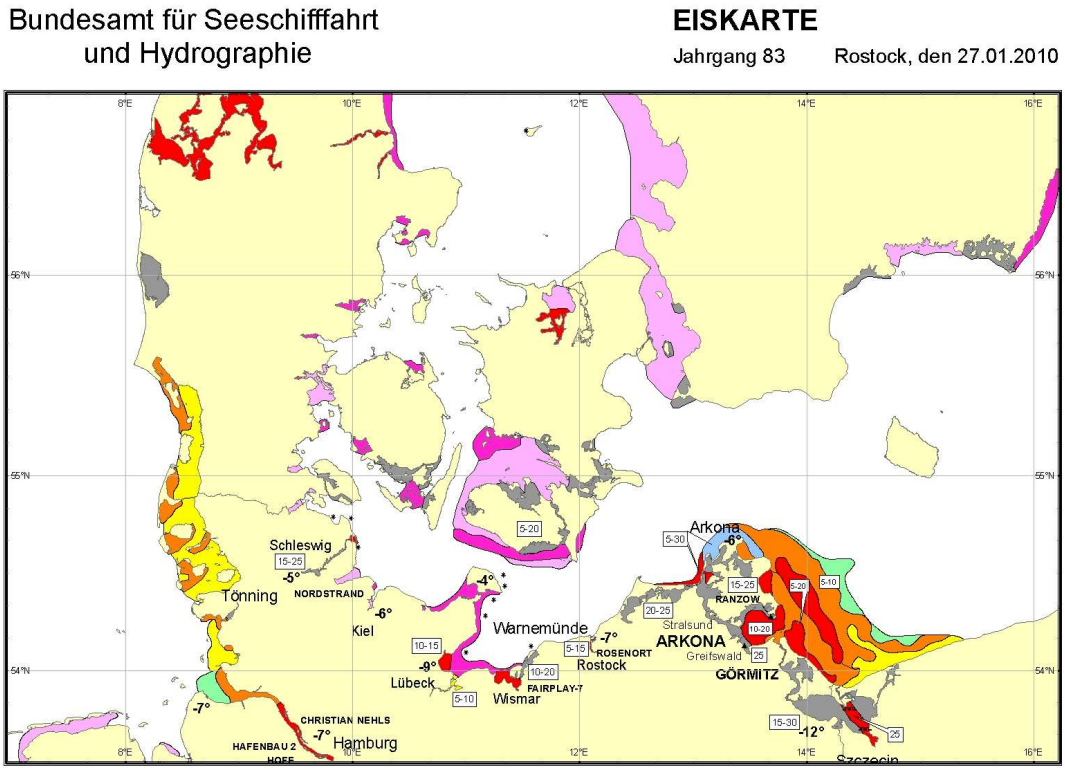

Figure 11. Ice extent on the German North and Baltic Sea coasts at the end of January 2010

At the time of maximum ice development, on 17 February 2010 (Figure 12), all inner waters of the German North and Baltic Sea coasts were covered with ice. In the outer coastal waters, ice occurred in the Bay of Lübeck, Fehmarnsund, and in the Wadden Sea areas of the North Sea. Maximum thermal ice growth on the Baltic Sea coast was 15 – 35 cm in the eastern bodden waters, between 10 and 20 cm in the inner coastal waters on the western Baltic coast, and between 5 and 15 cm in the Kiel Canal and offshore waters. The term „thermal ice growth“ is not suitable for the Wadden Sea areas of the North Sea including its tributaries because tidal influence in these areas causes ice rafting and ridging, which may result in the formation of thicker ice floes at freezing temperatures. In the winter of 2009/2010, level ice reached thicknesses of 15 – 50 cm on the North Frisian coast, 5 – 30 cm in the river Elbe, and 5 – 15 cm in most parts of the East Frisian coast. Rafting and ridging were also observed, as were sporadic ice blocks of 60 cm to 2 m height. In the inner navigation channels and inshore waters of the Baltic Sea, ice ridging and rafting up to 2 m height occurred on coasts affected by frequent strong onshore winds, at the fast-ice edge, and on shoals, e.g. along the coasts of the Darss/Zingst peninsula and in Greifswalder Bodden; see photos below.

In the third decade of February, southwesterly winds brought warmer air into the coastal region, causing the ice to retreat gradually. The North Sea coast, its tributaries, and Kiel Canal were completely free of ice by 7 March, the Baltic waters of Schleswig-Holstein by 20 March, and the bodden waters along the coast of Mecklenburg-Vorpommern by 25 March. The numbers of days with ice varied considerably in the different areas: in the river Weser near Brake, ice occurred only on one day, compared to 96 days in the harbour of Neuendorf on the island of Hiddensee. Only a few stations, most of them located in the German Bight, remained free of ice throughout the winter of 2009/10.

Photo Ingrid Lange

Ice rafting on the shore, Zingst observation station, sea area (January 2010)

Photo Frank Sakuth

Ridged ice in the Greifswalder Bodden, view from Thiessow toward Ruden, 18.01.2010

Bundesamt für Seeschifffahrt und Hydrographie

EISKARTE

Jahrgang 83

Nr. 21

Rostock, 17.02.2010

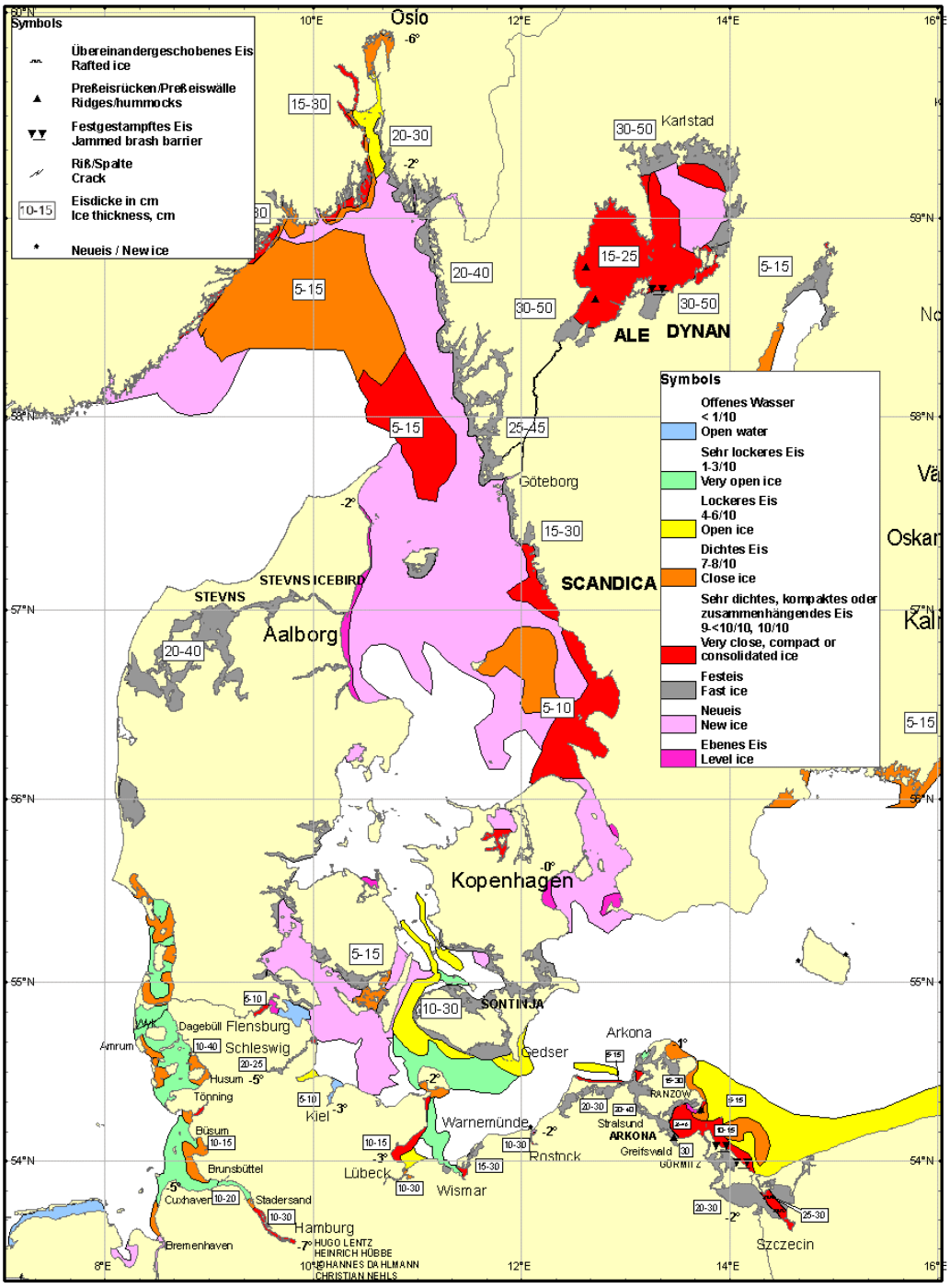

Figure 12. Ice extent on the German North and Baltic Sea coasts, and in the Kattegat and Skagerrak at the time of maximum ice development in the winter of 2009/10

Navigation conditions

On the German North Sea coast, commercial coastal navigation in the North Sea was hardly obstructed by ice during the past ice winter. Obstructions occurred particularly in the North Frisian tidal flats and in the Lower Elbe. In the port of Hamburg, the ice was continually broken, and assistance was provided to ships as required. The harbour of Tönning was closed from 9 January to 2 March.

In the inner navigation channels of the western German Baltic coast, ships needed assistance only on a few days, for example in the approach to Wismar. Ice caused some problems in the coastal waters of Vorpommern. Ships bound for the harbours of Stralsund, Greifswald, Greifswald-Ladebow and Wolgast, as well as ferry traffic to the island of Hiddensee used channels broken by the multi-purpose vessel ARKONA, the service vessel GÖRMITZ, and the buoy tender RANZOW. In the time from 4 – 25 March, warnings were issued recommending that only vessels with a propulsion power of at least 1,000 kW should navigate the channels leading to harbours in the Greifswalder Bodden and to Stralsund. The northern approach to Stralsund, the southern part of Peenestrom, the river Peene, and Kleines Haff were closed to shipping in the time from early January to the end of March. This is quite normal for this area even in moderate ice winters.

Ice conditions in the North Sea, Skagerrak, and Kattegat

On the Dutch North Sea coast, loose thin ice occurred only on a few days in January and February. In the Limfjord
in Denmark, ice formed at the end of December in some sheltered areas. In the course of January, this ice developed to a solid fast ice cover the last remnants of which melted as late as the third decade of March. Ice thicknesses ranged from 20 to 40 cm.

In the *Skagerrak,* the last winter with major ice formation and obstructions to shipping was 1995/96. In the winter of 2009/10, some small fjords on the Norwegian coast were completely covered with ice from early January to late March, and a few of them were closed to shipping. Left undisturbed, the ice cover in places reached thicknesses over 50 cm. Major quantities of ice occurred temporarily in the navigation channel to Kristiansand and in the Oslofjord. In February, ice belts which only high-powered ice-class vessels were able to navigate floated off the coasts.
In smaller harbours and fjords on the Danish coast in *Kattegat*, the ice reached 10 – 30 cm thickness. In mid-February, 20 – 45 cm fast ice was observed in the skerries and sheltered bays of the Swedish coast north of Gothenburg, and 10 – 25 cm south of it. Areas with thin ice or new ice occurred in the offshore waters, and in the *Belts* and *Sound*.

Lake *Vänern* was completely covered with ice from mid-February to late March: the maximum thickness of fast ice in the skerries ranged from 30 to 50 cm, and very close 15 – 25 thick ice occurred in offshore waters.

Ice conditions in the western and southern Baltic Sea

Maximum ice coverage was reached in mid-February. At this time, 10 – 30 cm thick fast ice occurred in the *western* Baltic Sea in some small harbours and shallow, sheltered waters on the Danish coast, and thin open ice or new ice was encountered temporarily in the offshore waters. Navigation of large vessels was not obstructed. In the *southern* Baltic Sea, 20 – 30 cm fast ice formed in the Szczecin Lagoon on the coast of Poland, and close to very open ice up to 15 cm thick or new ice occurred in the coastal harbours. In the Pomeranian Bight and on the outer Baltic coast, a belt of 10 – 15 cm thick ice extended eastward beyond Kołobrzeg. In the Gulf of Gdansk, open 15 – 30 cm thick ice occurred farther offshore.

Vistula Lagoon and Courland Lagoon were covered with 20-60 cm thick fast ice.

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

First ice formed in the northernmost inner skerries of the Bay of Bothnia at the end of November. Ice formation on the coastal waters in the northern Gulf of Bothnia continued until mid-December, but the ice cover was limited to the northern skerries and sheltered inner areas of small bays farther south. In the eastern part of the Gulf of Finland, ice began to form in the second decade of December. Although the beginning of ice formation was 2 – 3 weeks later than normal, the ice increase from mid-January was normal in all areas. Ice cover and ice thicknesses increased continuously until mid-March, showing the development typical of a moderate ice winter at any time in the course of ice growth. The maximum ice extent in the northern Baltic Sea area was reached around 8 March: the Gulfs of Bothnia, Finland and Riga were covered completely with ice; the southern ice limit was located

approximately at latitude 58°30' N, and a 40 nm wid e belt of thin ice extended along the Swedish and Latvian (Baltic) coasts; cf. ice map in Figure 13. At this time, fast ice in the skerries in the Bay of Bothnia was 40 – 80 cm thick, 20 – 50 cm in the Sea of Bothnia, 40 – 60 cm in the eastern Gulf of Finland, 20 – 45 cm in the western Gulf of Finland and in the Archipelago Sea, 20 – 50 cm in the Gulf of Riga, and 20 – 40 cm in the skerries in the central Baltic Sea. In the open sea, level ice reached thicknesses of 30 - 60 cm in the Bay of Bothnia, 10 – 40 cm in the Sea of Bothnia, 10 – 25 cm, in the Åland Sea, 15 - 45 cm in the Gulf of Finland, and 15 – 35 cm in the Gulf of Riga.

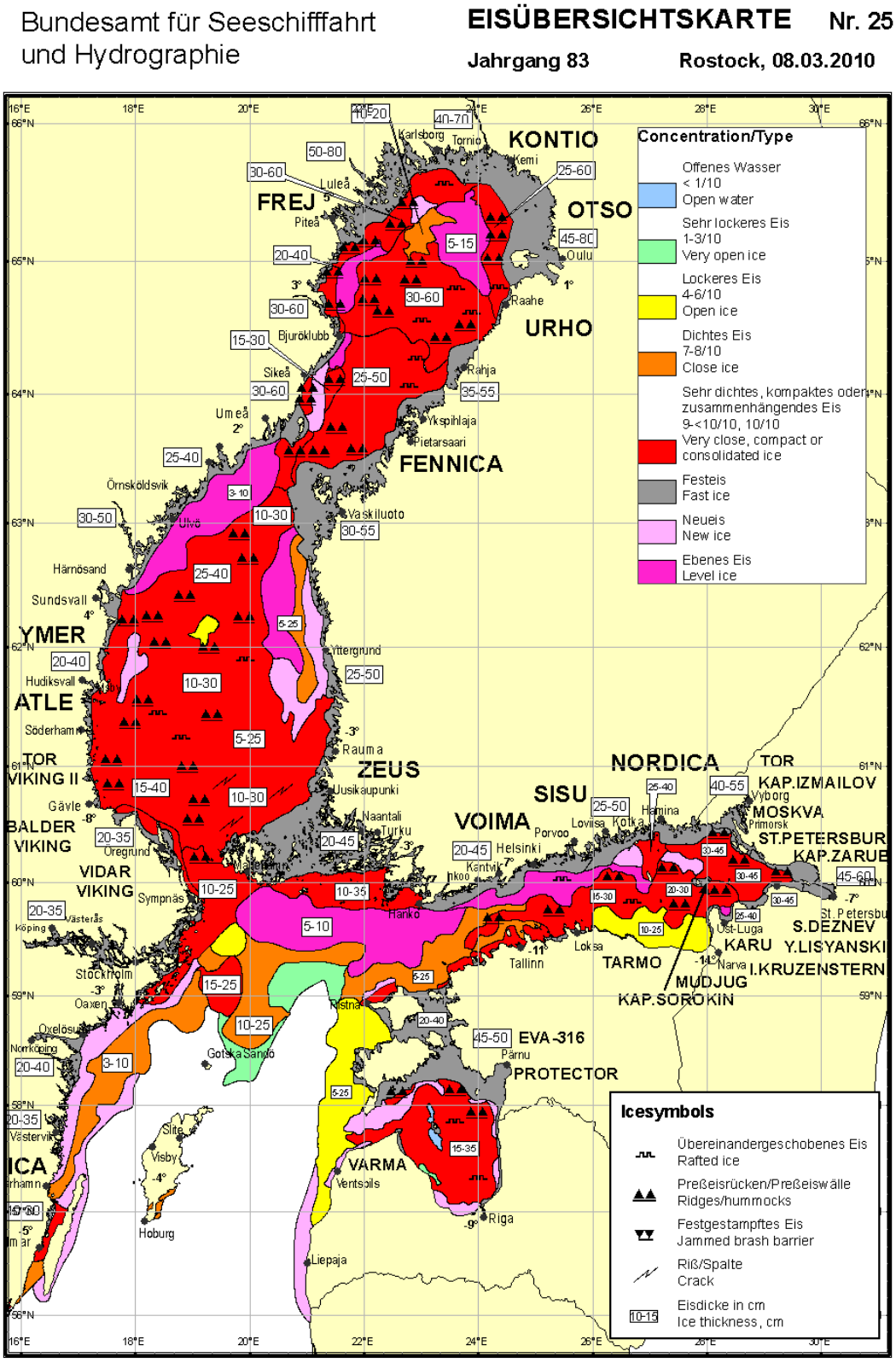

Figure 13. General ice map of 8 March 2010 with maximum ice extent

Around this time, 30 icebreakers were operating in the Baltic Sea. Navigation in all sea areas was obstructed by ice hummocks, ridging, and rafting on windward coasts and at the ice edges. Obstructions were particularly widespread in the northern part of the Bay of Bothnia, and on Finland's coast on the Gulf of Bothnia. In early March 2010, about 50 ships which were ice-locked in the Åland Sea, among them big passenger vessels, received wide publicity. The cause was ice pressure, of which all Ice Services had warned in time.
At the end of March, the seasonal ice retreat began in the south and continued slowly and unspectacularly. The last drift ice in the central part of the Bay of Bothnia melted in late May, which is the average time for the ice melt. Taking into account the maximum ice extent (about 240,000 km^2) and the Finnish classification of ice winters (Seina and Palosuo, 1996), the 2009/10 ice season in the northern part of the Baltic Sea has been classified as a moderate ice winter.

Summary

On the whole, the ice winter of 2009/10 meets the criteria for a moderate ice winter. Although this was the first winter in 13 years (since 1995/96) in which ice also formed in the offshore waters of the western Baltic Sea, the ice volume produced and the duration of offshore ice occurrence did not meet the criteria for classification as a severe or very severe ice winter, see Table 3. For comparison, Figs. 14 and 15 show the ice conditions at the time of maximum ice development in the winters of 1995/96 and 1986/87 (very severe ice winters), respectively.

Table 3. Characteristic features of ice winter types in the German Baltic Sea region (Occurrence and percentage of winter types are given for the period 1961 - 2000)

Type of ice winter Occurrence (%)	**Area**	**Duration of ice**	**Ice thickness** predominantly	**Ice concentration** predominantly
Very weak to weak 18 (45 %)	Inner coastal waters Outer Baltic coast	1 – 4 weeks up to 3 days	5 – 10 cm up to 5 cm	6/10 – 8/10 1/10 – 3/10
Moderate 14 (35 %)	Inner coastal waters, Outer Baltic coast	3 – 10 weeks up to 3 weeks	10 – 30 cm up to 10 cm	10/10 6/10 – 8/10
Severe 2 (5 %)	Inner coastal waters Outer Baltic coast, open sea	6 – 12 weeks 2 – 10 weeks	20 – 30 cm 15 – 25 cm	10/10 6/10 – 10/10
Very severe 5 (12 %)	Inner coastal waters Open sea	2 – 3.5 months 1.5 – 3 months	30 – 50 cm 30 – 40 cm	10/10 9/10 – 10/10
Extremely severe 1 (2 %)	Inner coastal waters Open sea	3 – 5 months 2 – 3.5 months	50 – 70 cm 50 – 70 cm	10/10 9/10 – 10/10

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Seina, A., Palosuo, E., 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*

Schmelzer, N., 2004: Die Eiswinter 1999/2000 bos 2003/04 an der deutschen Nord- und Ostseeküste, Berichte des BSH, Nr. 37

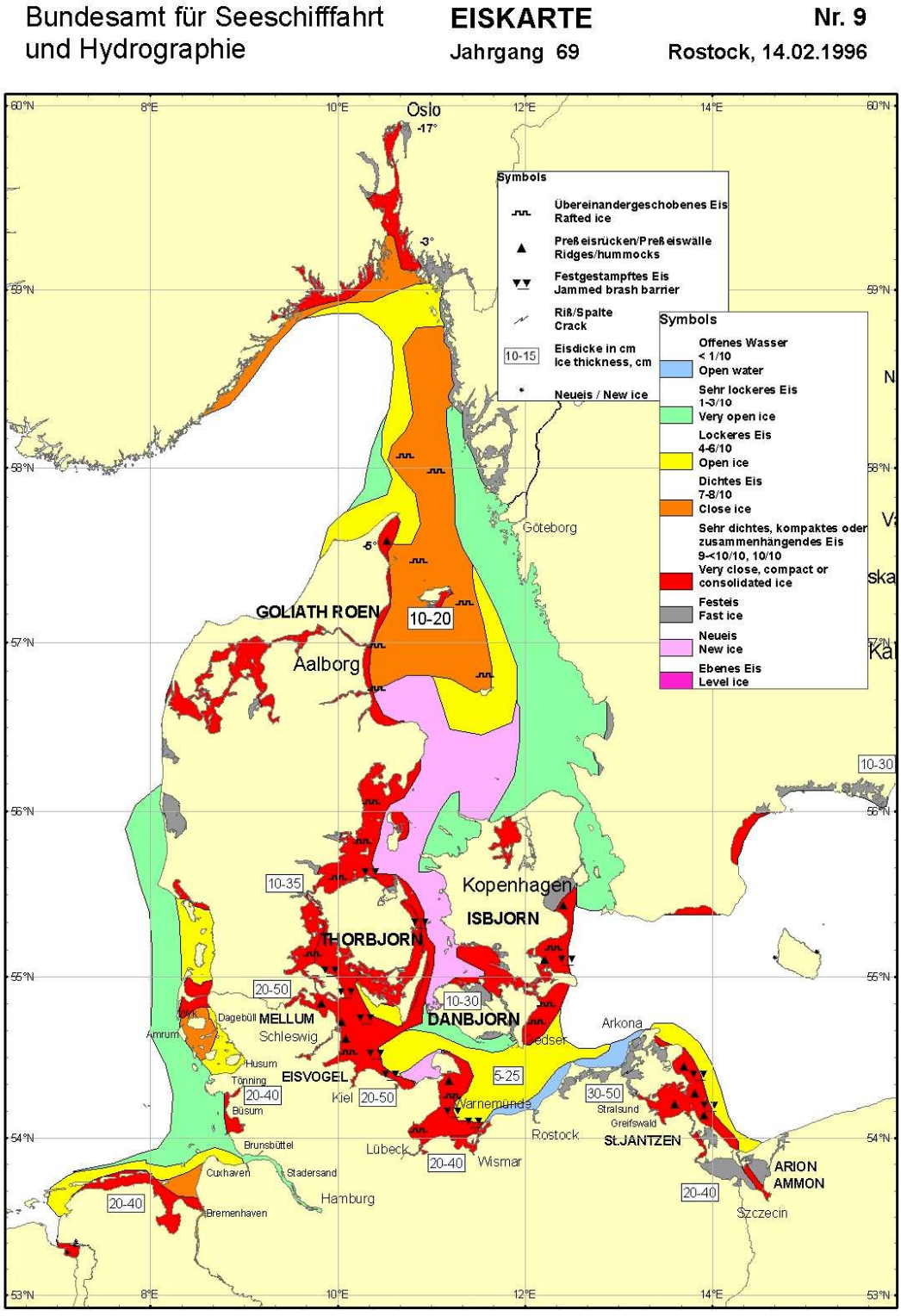

Figure 14. Ice conditions in the western Baltic Sea, Kattegat and Skagerrak in the very severe ice winter of 1995/96, on 14 February

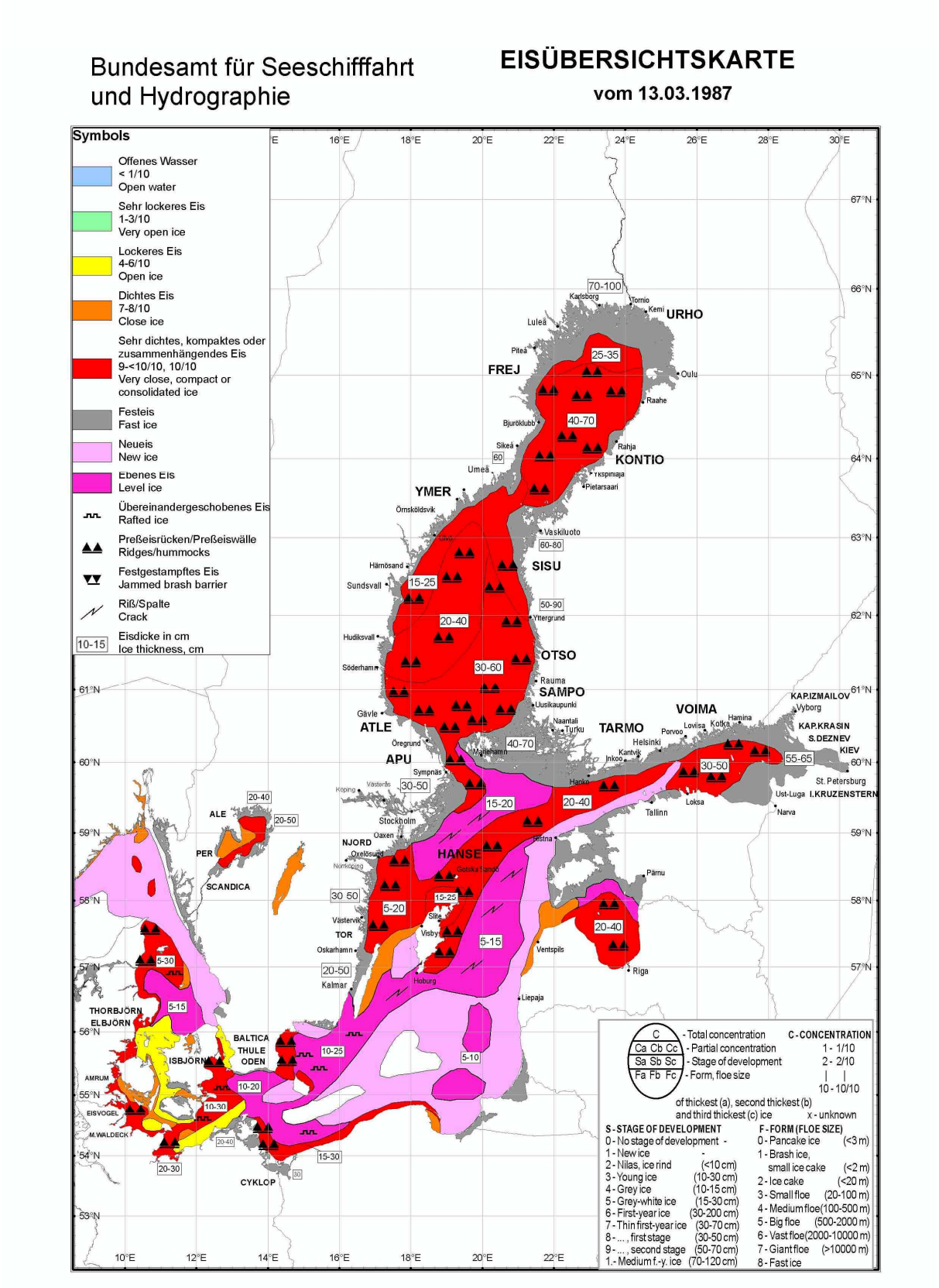

Figure 15. Ice conditions in the Baltic Sea in the very severe ice winter of 1986/87, on 13 March

In the ice winter of **2009/10**, the BSH issued the following publications showing the ice situation and expected ice development in the entire Baltic Sea and German coastal waters:

- 111 ice reports (official daily journal, available at a fee)
- 47 general ice charts (twice weekly, as an attachment to the ice reports)
- 90 German Ice Reports (international exchange, published when ice has formed on the German navigation channels)
- about 350 NAVTEX reports (in German and English for the German North and Baltic Sea coasts)
- 68 ice reports "German Baltic Sea coast" (detailed description of the ice situation for German users)
- 32 Ice Charts for the western Baltic Sea, Kattegat and Skagerrak
- 35 Ice Charts (Radiofax-Charts for the western Baltic Sea, Kattegat and Skagerrak)
- 21 special ice charts (sections of the German Baltic Sea coast)
- 24 weekly reports (information to Ministry of Transport, Building and Urban Affairs, and to MURSYS)
- information provided to individual users.