Annual report on the 2005/06 ice season

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With milder than normal weather on the German coasts in November and December (Lefebvre, 2006), ice development in the German coastal waters began later than usual this winter season. Although the first cold spell at the end of November (Fig. 1) led to sporadic ice formation in the eastern Bodden waters (e.g. Neuendorf, cf. Annex1), this first ice melted away quickly, and the ice season really began in early January. A major cold spell occurred in the 4th calendar week (CW), in the course of which the largest ice coverage of the German coastal waters was reached (Fig. 3). In the following weeks, daily mean temperatures fluctuated around freezing point and caused some new ice formation in sheltered areas, but on the whole the ice cover decreased. Another cold spell in the 10th/11th sheltered areas, but on the whole the ice cover decreased. Another cold spell in the 10th/11th CW led to wide-spread development of new ice over night, but prolonged insolation by day led to an overall decrease of ice.

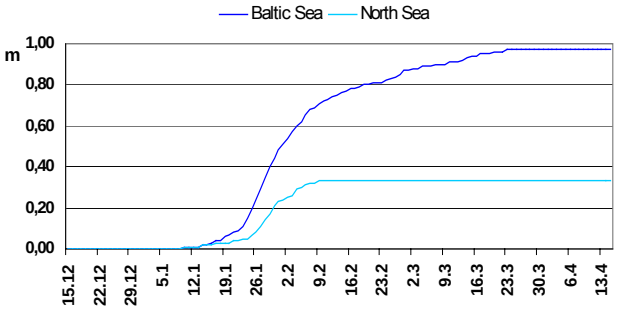


Figure 2: Accumulated areal ice volume on the North Sea and Baltic Sea coasts, ice season 2005/06

The accumulated areal ice volume ($V_{A\Sigma}$, an indicator of the severity of ice winters; Koslowski, 1989) was 0.97 m on the Baltic Sea coast, and 0.33 m on the North Sea coast (Fig. 2). Therefore, the winter of 2005/06 has been classified as a moderate ice winter. In the past 110 years, 48 winters on the Baltic coast were stronger, and 61 weaker than the last winter season; on the North Sea coast, 64 winters were stronger and 45 weaker than the last winter season. The reduced ice sum (average number of days with ice; Büdel, 1947; Nusser, 1948) was 16.2 days for the Baltic Sea, and 5.9 days for the North Sea.

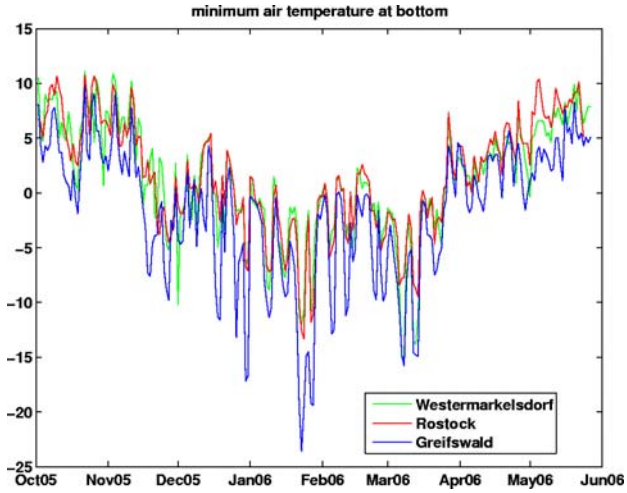


Figure 1:Daily minimum air temperatures on the ground, measured at the Greifswald, Rostock, and Westermarkelsdorf stations (data from German Weather Service, cf. http://www.dwd.de).

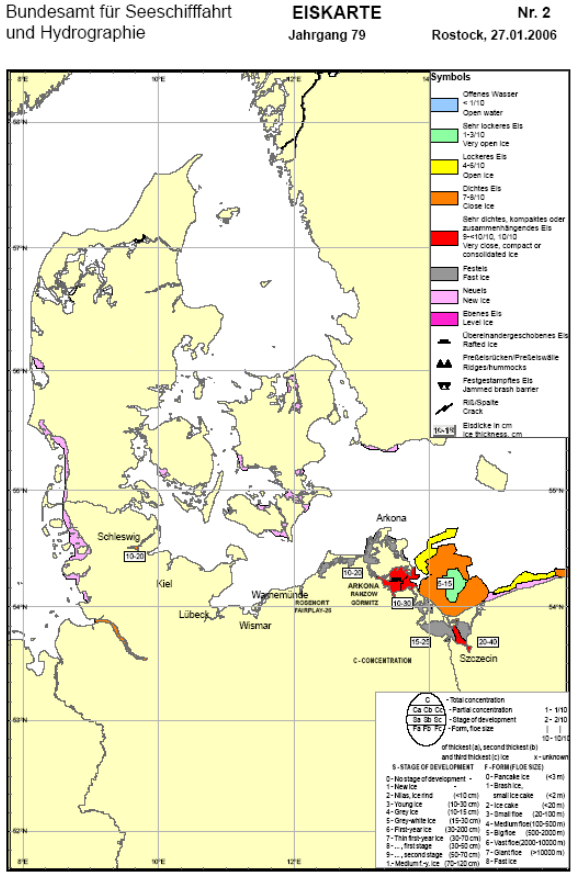


Figure 3: Ice conditions in the southern and western Baltic Sea and on the German North Sea coast at the time of the maximum ice coverage (27 January in the 2005/06 season.

Assuming that the ice reports (Amtsblatt) published reflect the length of the Baltic Sea ice season, the ice season began on 7 December 2005, about one week later than the long-term mean, and ended on 24 May 2006, which corresponds approximately to the long-term mean. Because of the late beginning of the ice season, only 116 reports were issued, which is 5 issues less than the long-term mean. Based on the ice report (Deutsche Ostseeküste), the ice season on the German coast began on 18 January 2006 and ended on 29 March 2006. However, as the first ice report is not published immediately as soon as first ice occurs and the last one is issued before the last remnants of ice have disappeared, the ice season defined in this way of course is somewhat shorter than the real one.

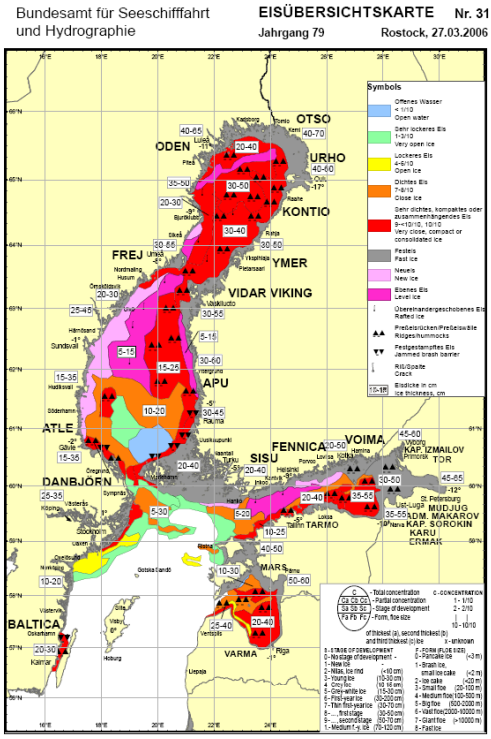


Figure 4: Ice chart showing maximum ice coverage of the Baltic Sea in the winter of 2005/06.

From the end of November, continuous frost prevailed in the northernmost part of the Baltic and led to new ice formation in the inner archipelagos of the northern Bay of Bothnia and in the eastern part of the Gulf of Finland in early December. In the course of December, the ice cover increased, and new ice began to form in the Gulf of Riga just after mid-December, and in the inner coastal waters of Germany in late December. However, due to inflows of milder air in the first half of January, the development of ice during this period was very slow in the southern Baltic. Then, at the end of January, moderate to very strong continuous frost set in on the German Baltic Sea coast, causing a marked growth of ice in the inner fairways, some of which had to be closed to navigation. East of Rügen, the ice spread to the adjacent sea areas, and thin ice also formed in sheltered sections of the North Sea coast. Ice coverage on the German coasts peaked on 27 January (Fig. 3). At the same time, the weather was relatively mild in the northern Baltic area, and the ice cover even decreased slightly due to the prevailing winds. In the course of February, ice coverage in the northern Baltic increased again, including the formation of leads and ridges in response to the wind, while the situation along the German coast relaxed. Under the influence of polar air, new ice formed again in sheltered sections of the German coast in early March, and ice coverage in the northern and central parts of the Baltic Sea continued to increase. In the second half of March, the maximum ice coverage of the Baltic Sea was reached (Fig. 4). The Gulfs of Bothnia, Finland, and Riga as well as the northern part of the northern Baltic Sea were covered completely with ice. In late March/early April, several low pressure systems tracked across the Baltic and brought relatively mild air to the area, and by the second week of April, the southern Baltic Sea waters were almost free of ice. Due to the rapid retreat of the ice, in connection with wind drift, large areas in the southern parts of the Gulfs of Riga and Finland were almost free of ice. The steady retreat of ice continued in the following weeks. At the beginning of May, ice was observed only in the Saimaa Lake and north of 63°N, and on 26 May 2006 only a few drifting ice floes and floe bits were observed in the Bay of Bothnia.

Comparison of different ice coverages

The BSH's operational model is also used to compute the ice coverage, inter alia. Another method of determining the ice cover is based on satellite data. As the quality of measurements in the visual and infrared ranges is impaired considerably by the presence of clouds, continuous temporal coverage can only be achieved by using the microwave range. Measurements using active methods (e.g. Radarsat) generally are very expensive and do not provide complete coverage on a daily basis. Therefore, only passive measurements have been taken into account. We compare two products: ice coverage computed from SSMI data and that based on AMSR data. The SSMI ice coverage was computed

using the NASA Team method; the data were obtained from NSIDC, at http://nsidc.org/). Ice coverage based on the AMSR data was computed by means of the „Artistic Sea ice“ method with data from Bremen University (http://seaice.de). The decisive difference between the two methods is their spatial resolution, which is about 15km*13km (at 85.5 GHz; at 36.5 GHz: 37km*28km) with the SSMI sensor (frequencies 19.3, 22.3, 36.5, 85.5 GHz), and about 6km*4km (at 89.0 GHz; at 36.5 Ghz: 14km*8 km) using AMSR (frequencies 6.9, 10.7, 18.7, 23.8, 36.5, and 89.0 GHz). Both methods have difficulties detecting ice close to the coast, i.e. they may also detect ice in coastal waters although there is none. For example, in summer, both methods detected ice in the Baltic Sea east of 15°E, SSMI indicating about four times the quantity detected by AMSR. The factor four corresponds more or less to the difference in the footprint size. Besides, very open ice or new ice sometimes fails to be detected at all.

Because of the considerable influence of the coasts, satellite data in this form is unsuitable for use in the area of the southwestern Baltic Sea (Fig. 5). Although the highest peak in the AMSR data temporally matches the modelled maximum of ice coverage, this match may be mere coincidence because it does not differ significantly from other peaks within the noise. However, considering only the area east of 15°E (Fig. 6), the ratio between coastal zone and open sea is smaller and the ice cover of the open water larger, so that the satellite data are well suitable in this area. With larger ice coverage, there is a good match between SSMI data and AMSR data, although SSMI produces slightly higher values, probably due to the greater influence of the coast. Once the ice coverage is large enough to be easily detected in the AMSR data, the modelled ice cover is always larger than that derived from the AMSR data. This may be attributable to the fact that open ice cannot be detected and these areas are missing, in contrast to the model. But the model, too, has its deficiencies.

While SSMI data may be less suitable for the determination of ice coverage of the Baltic Sea than AMSR data, they have the advantage of covering a longer period of time than the AMSR data, with data available from 1987 as compared to 2003. It is apparent from this longer time series (Fig. 7) that only three winter seasons (1993/94, 1995/96, and 2003/04) since 1987 had a larger ice coverage than the ice winter of 2005/06. In the southwestern Baltic (no Fig.), the only clear signal among the noise is the winter of 1995/96.

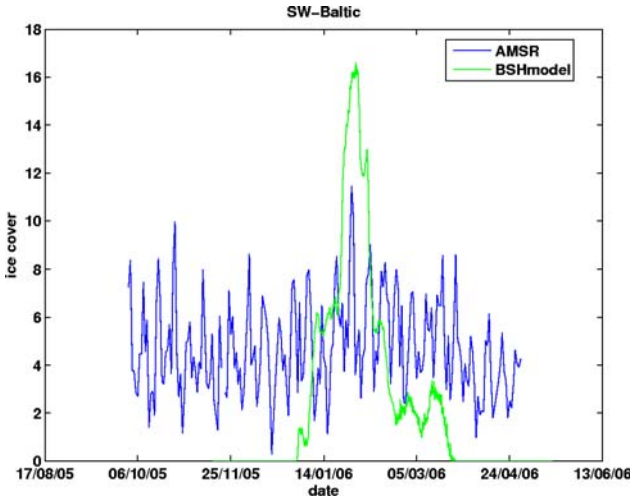


Figure 5: Ice coverage from AMSR-E data (blue) and from BSH model data (green) for the southwestern Baltic Sea.

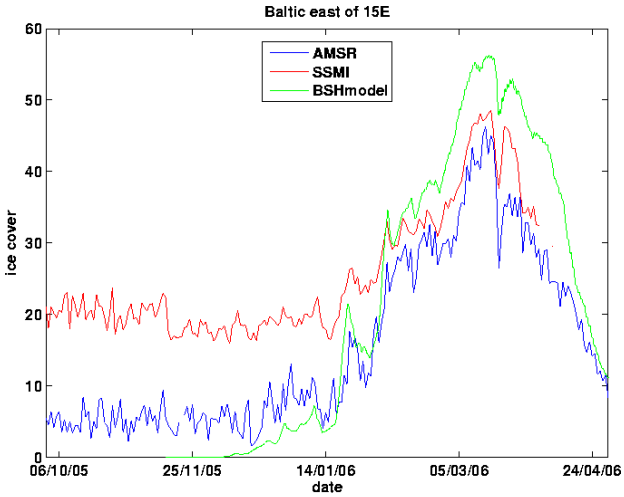


Figure 6: Ice coverage of the Baltic Sea east of 15°E computed from AMSR (blue), SSMI (red), and from BSH model data (green).

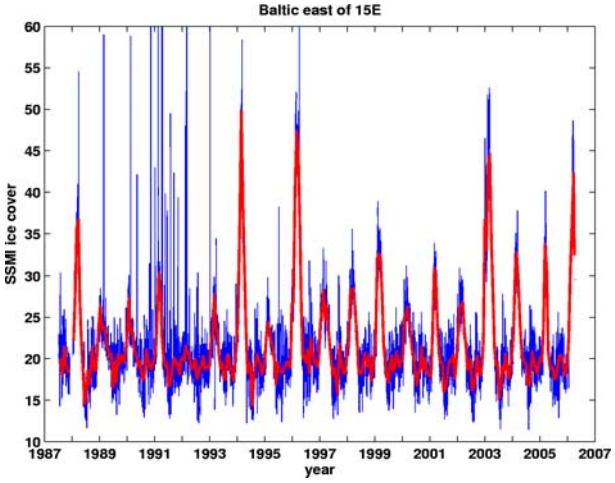


Figure 7: Ice coverage of the Baltic Sea east of 15°E computed from SSMI data (daily values blue, smoothed values red).

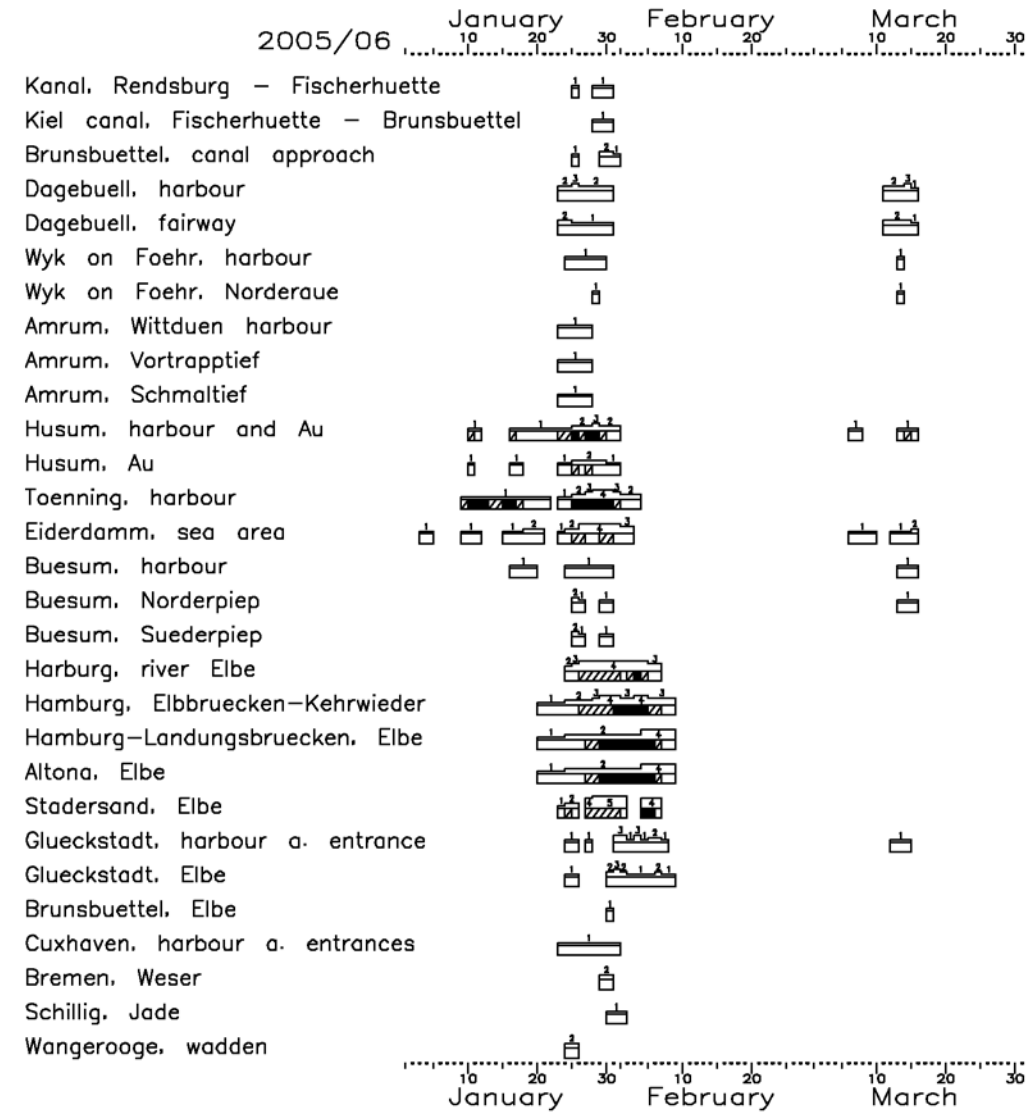
Literatur*:*

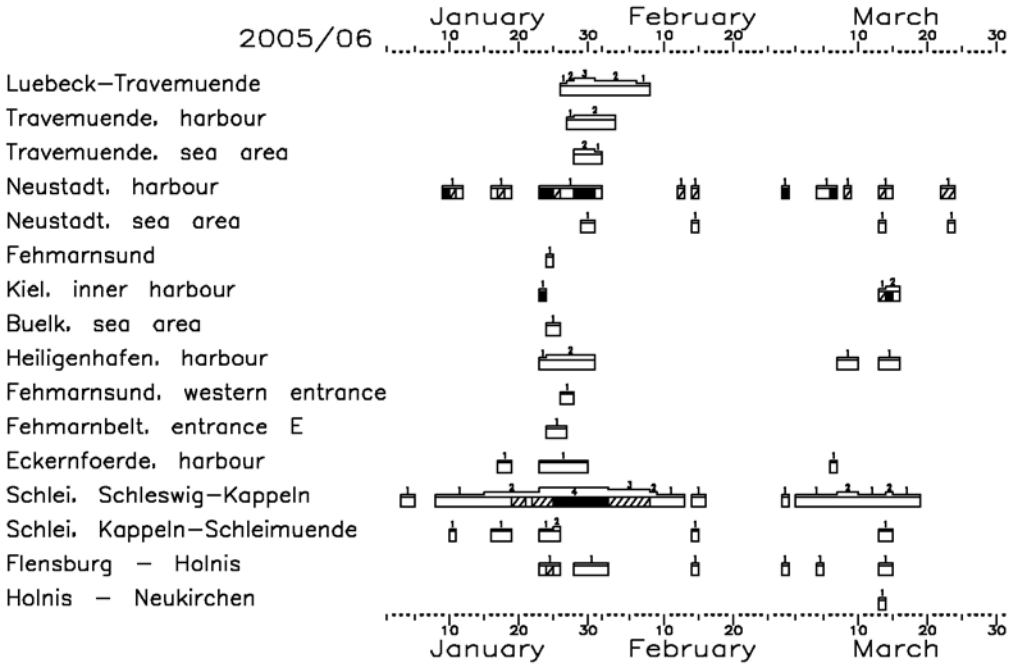
Büdel, J., 1947: Der Eiswinter 1945/46 an den deutschen Küsten (Brit. Zone) im Vergleich zu den Eiswintern 1903/04 bis 1942/43. Unveröff. Wiss. Arb. Dt. Hydrogr. Inst. Nr. 34.

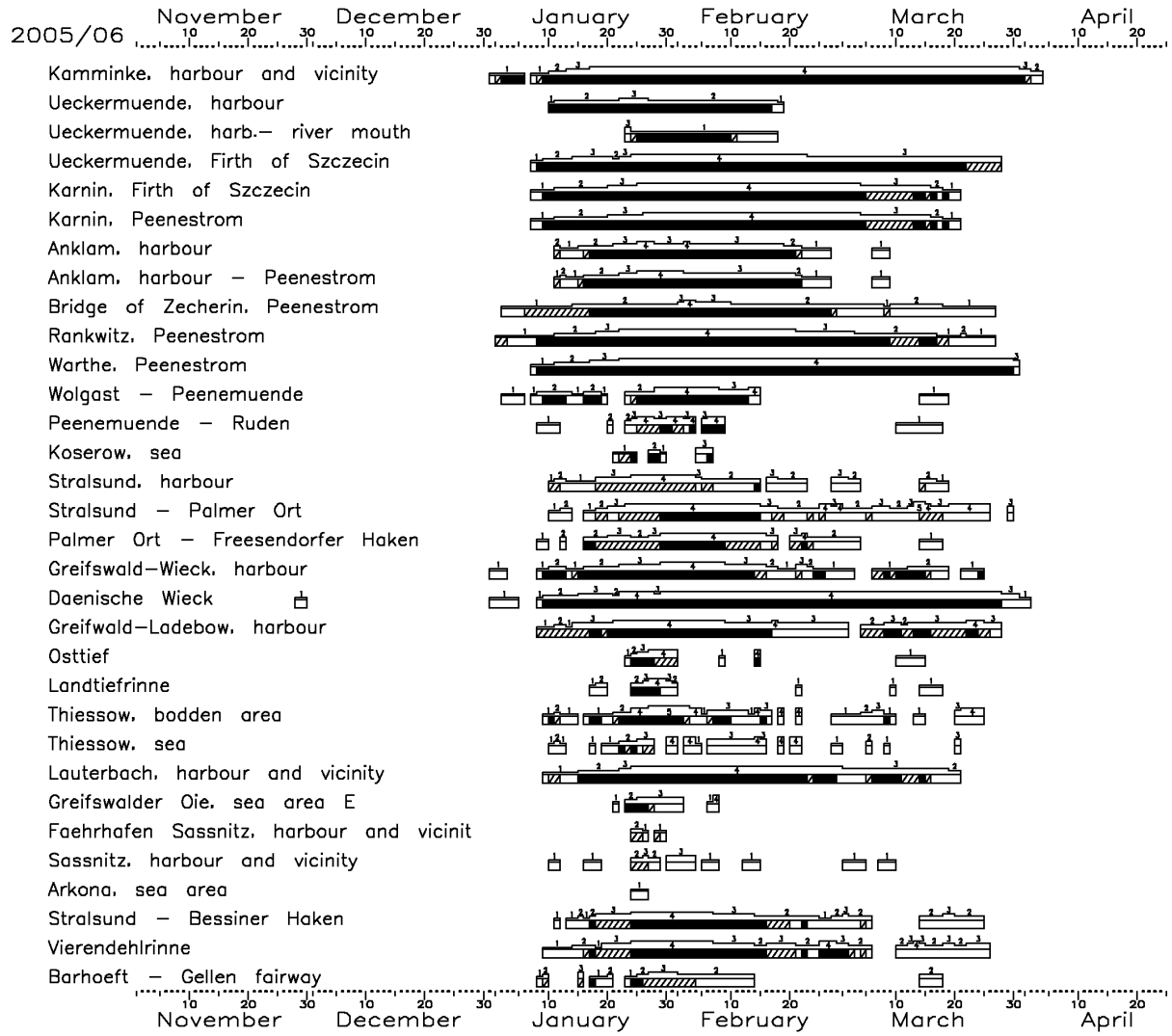
Koslowski, G., Die flächenbezogene Eisvolumensumme, eine neue Maßzahl für die Bewertung des Eiswinters an der Ostseeküste Schleswig-Holsteins und ihr Zusammenhang mit dem Charakter des meteorologischen Winters, Dt. Hydrogr. Z. **42**, 61-80, 1989

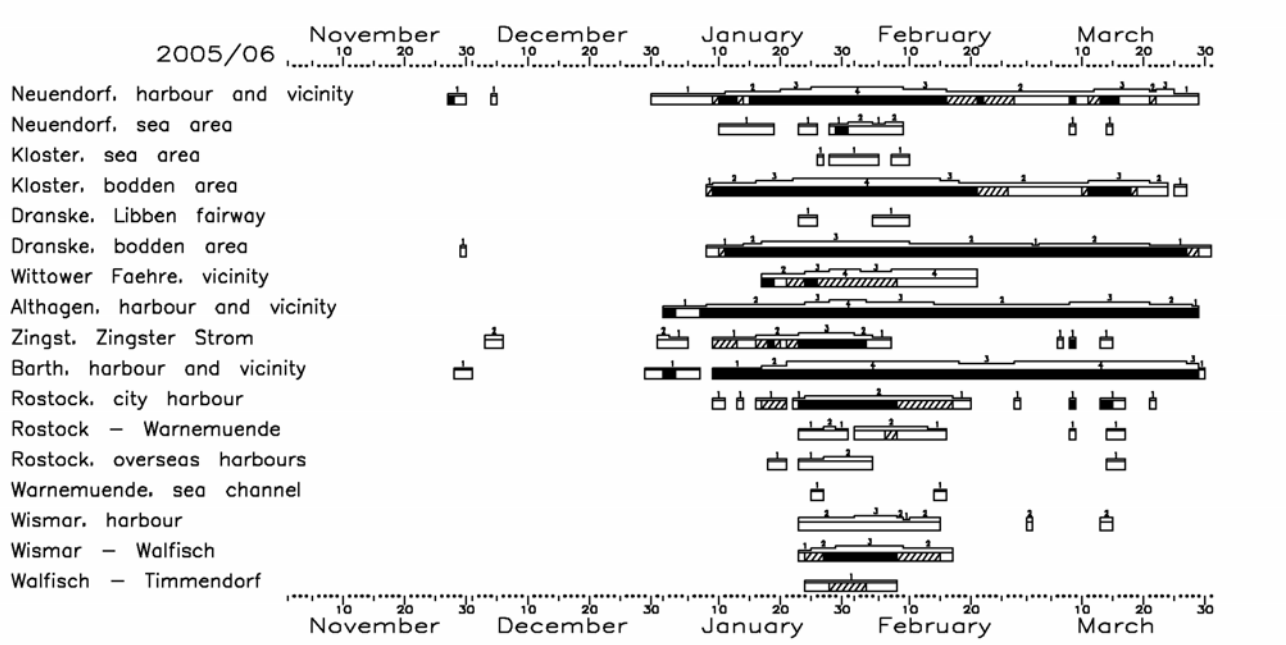
Lefebvre, C.; Die Witterung in den deutschen Küstengebieten im November und Dezember 2005. Der Wetterlotse, 57, Nr.707/708, S.219-225

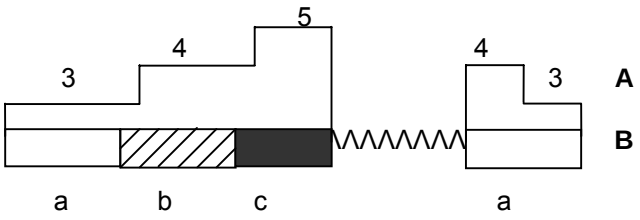
Annex 1: Concentration and thickness of ice in the waters of the German North Sea and Baltic Sea coasts in the winter of 2005/06






2005/06
November
December
January
February
March
April
Kamminke, harbour and vicinity
Ueckermuende, harbour
Ueckermuende, harb.– river mouth
Ueckermuende, Firth of Szczecin
Karnin, Firth of Szczecin
Karnin, Peenestrom
Anklam, harbour
Anklam, harbour – Peenestrom
Bridge of Zecherin, Peenestrom
Rankwitz, Peenestrom
Warthe, Peenestrom
Wolgast – Peenemuende
Peenemuende – Ruden
Koserow, sea
Stralsund, harbour
Stralsund – Palmer Ort
Palmer Ort – Freesendorfer Haken
Greifswald–Wieck, harbour
Daenische Wieck
Greifwald–Ladebow, harbour
Osttief
Landtiefrinne
Thiessow, bodden area
Thiessow, sea
Lauterbach, harbour and vicinity
Greifswalder Oie, sea area E
Faehrhafen Sassnitz, harbour and vicinit
Sassnitz, harbour and vicinity
Arkona, sea area
Stralsund – Bessiner Haken
Vierendehlrinne
Barhoeft – Gellen fairway


2005/06
November
December
January
February
March
Neuendorf, harbour and vicinity
Neuendorf, sea area
Kloster, sea area
Kloster, bodden area
Dranske, Libben fairway
Dranske, bodden area
Wittower Faehre, vicinity
Althagen, harbour and vicinity
Zingst, Zingster Strom
Barth, harbour and vicinity
Rostock, city harbour
Rostock – Warnemuende
Rostock, overseas harbours
Warnemuende, sea channel
Wismar, harbour
Wismar – Walfisch
Walfisch – Timmendorf



A – Eisdicke / Ice thickness
1: < 5 cm 2: 5-10 cm
3: 11-15 cm 4: 16-30 cm
5: 31-50 cm

B – Bedeckungsgrad / Ice Concentration
a: < 7/10 b: 7/10-8/10
c: 9/10-10/10

ΛΛΛΛΛ - aufgepresstes Eis / ridged ice

Annex 2: Ice conditions in the waters of the German North Sea and Baltic Sea coasts in the winter of 2005/06

Observation stations	Beginning if ice occurrence	End of ice occurrence	Number of days with ice	Max. thickness of level ice, cm
Kanal, Rendsburg - Fischerhütte	25.1	30.1	4	< 5
Kanal, Fischerhütte - Brunsbüttel	28.1	30.1	3	< 5
Brunsbüttel, Kanalzufahrt	25.1	31.1	4	5
Dagebüll, Hafen	23.1	15.3	13	10-15
Dagebüller Fahrwasser	23.1	15.3	13	5-10
Wyk auf Föhr, Hafen	24.1	13.3	7	3
Wyk auf Föhr, Norderaue	28.1	13.3	2	2
Amrum, Hafen Wittdün	23.1	27.1	5	5
Amrum, Vortrapptief	23.1	27.1	5	< 5
Amrum, Schmaltief	23.1	27.1	5	< 5
Husum, Hafen	10.1	15.3	23	10
Husum, Au	10.1	31.1	12	10
Tönning, Hafen	9.1	3.2	25	10-15
Eiderdamm, Seegebiet	3.1	15.3	30	8-25
Büsum, Hafen	16.1	15.3	14	3
Büsum, Norderpiep	25.1	15.3	7	5
Büsum, Süderpiep	25.1	30.1	4	5
Harburg, Elbe	24.1	6.2	14	15-20
Hamburg, Elbbrücken-Kehrwieder	20.1	8.2	20	20
Hamburg-Landungsbrücken, Elbe	20.1	8.2	20	10-25
Altona, Elbe	20.1	8.2	20	10-25
Stadersand, Elbe	23.1	6.2	12	15-30
Glückstadt, Hafen und Einfahrt	24.1	14.3	14	10-15
Glückstadt, Elbe	24.1	8.2	12	10-15
Brunsbüttel, Elbe	30.1	30.1	1	< 5
Cuxhaven, Hafen und Einfahrten	23.1	31.1	9	2
Bremen, Weser	29.1	30.1	2	5-10
Schilling, Jadegebiet	30.1	1.2	3	< 5
Wangerooge, Watten	24.1	25.1	2	5-10

Observation stations	Beginning of ice occurrence	End of ice occurrence	Number of days with ice	Max. thickness of level ice, cm
Kamminke, Hafen und Umgebung	31.12.05	3.4.06	93	26
Ueckermünde, Hafen	10.1.06	18.2.06	40	5-10
Ueckermünde, Hafen- Ueckermündung	23.1.06	17.2.06	26	5-15
Ueckermünde, Stettiner Haff	7.1.06	27.3.06	80	20
Karnin, Stettiner Haff	7.1.06	20.3.06	73	20
Karnin, Peenestrom	7.1.06	20.3.06	73	20
Anklam, Hafen	11.1.06	8.3.06	50	15
Anklam, Hafen - Peenestrom	11.1.06	8.3.06	50	17
Brücke Zecherin, Peenestrom	2.1.06	26.3.06	84	15-20
Rankwitz, Peenestrom	1.1.06	26.3.06	85	25
Warthe, Peenestrom	7.1.06	30.3.06	83	24
Wolgast - Peenemünde	2.1.06	18.3.06	45	25
Peenemünde - Ruden	8.1.06	17.3.06	29	20-25
Koserow, Seegebiet	21.1.06	6.2.06	10	10-15
Stralsund, Hafen	10.1.06	18.3.06	53	25
Stralsund - Palmer Ort	10.1.06	29.3.06	74	30-40
Palmer Ort - Freesendorfer Haken	8.1.06	17.3.06	52	30
Greifswald-Wieck, Hafen	31.12.05	24.3.06	74	20
Dänische Wiek	28.11.06	1.4.06	91	27
Greifswald-Ladebow, Hafen	8.1.06	27.3.06	77	15-30
Osttief	23.1.06	14.3.06	16	15-20
Landtiefrinne	17.1.06	17.3.06	17	15-20
Thiessow, Boddengebiet	9.1.06	24.3.06	58	20
Thiessow, Seegebiet	10.1.06	20.3.06	36	10-20
Lauterbach, Hafen und Umgebung	9.1.06	20.3.06	71	20
Greifswalder Oie, östl. Seegebiet	21.1.06	7.2.06	13	10-15
Fährhafen Sassnitz und Umgebung	24.1.06	29.1.06	5	5-10
Fährhafen Sassnitz, Seegebiet				
Sassnitz, Hafen und Umgebung	10.1.06	9.3.06	28	10-15
Sassnitz, Seegebiet				
Arkona, Seegebiet	24.1.06	26.1.06	3	5
Stralsund - Bessiner Haken	11.1.06	24.3.06	64	20
Vierendehlrinne	9.1.06	25.3.06	72	25
Barhöft - Gellenfahrwasser	8.1.06	17.3.06	33	10-15
Neuendorf, Hafen und Umgebung	27.11.06	28.3.06	93	20
Neuendorf, Seegebiet	10.1.06	14.3.06	26	5-10
Kloster, Seegebiet	26.1.06	9.2.06	12	5
Kloster, Boddengebiet	8.1.06	26.3.06	77	20
Dranske, Libbenfahrwasser	23.1.06	9.2.06	9	5
Dranske, Boddengebiet	29.11.06	30.3.06	83	10-15
Wittower Fähre, Gewässer bei	17.1.06	20.2.06	35	10-20
Althagen, Hafen und Umgebung	1.1.06	28.3.06	87	16
Zingst, Zingster Strom	3.12.06	14.3.06	41	12
Zingst, Seegebiet				
Barth, Hafen und Umgebung	28.11.06	29.3.06	92	25
Rostock, Stadthafen	9.1.06	21.3.06	44	5-10
Rostock - Warnemünde	23.1.06	16.3.06	27	5-10
Rostock, Seehäfen	18.1.06	16.3.06	18	5-10
Warnemünde, Seekanal	25.1.06	15.2.06	4	5
Warnemünde, Seegebiet				
Ansteuerungstonne Rostock, See N				

Observation stations	Beginning of ice occurrence	End of ice occurrence	Number of days with ice	Max. thickness of level ice, cm
Wismar, Hafen	23.1.06	14.3.06	26	10
Wismar - Walfisch	23.1.06	16.2.06	25	10-15
Walfisch - Timmendorf	24.1.06	7.2.06	15	5
Timmendorf - Anst. Tonne Wismar				
Lübeck-Travemünde	26.1.06	7.2.06	13	10
Travemünde, Hafen	27.1.06	2.2.06	7	5-10
Travemünde, Seegebiet	28.1.06	31.1.06	4	5-10
Neustadt, Hafen	9.1.06	23.3.06	26	5
Neustadt, Seegebiet	29.1.06	23.3.06	5	5
Fehmarnsund	24.1.06	24.1.06	1	< 5
Kiel, Binnenhafen	23.1.06	15.3.06	4	5-10
Holtenau - Laboe				
Bülk, Seegebiet	24.1.06	25.1.06	2	< 5
Kiel-Leuchtturm, See im NE.				
Kiel-Leuchtturm, See im Osten				
Heiligenhafen, Hafen	23.1.06	15.3.06	14	5-10
Fehmarnsund, Westeingang	26.1.06	27.1.06	2	< 5
Westermarkelsdorf, Seegebiet				
Marienleuchte, Seegebiet				
Fehmarnbelt, Osteingang	24.1.06	26.1.06	3	< 5
Eckernförde, Hafen	17.1.06	6.3.06	10	< 5
Eckernförde, Bucht				
Schlei, Schleswig - Kappeln	3.1.06	18.3.06	59	15-30
Schlei, Kappeln - Schleimünde	10.1.06	14.3.06	10	5
Flensburg - Holnis	23.1.06	14.3.06	13	5
Holnis - Neukirchen	13.3.06	13.3.06	1	< 5
Neukirchen - Kalkgrund-Leuchtturm				