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UNIVERSITY OF SZCZECIN
IMCS
INSTITUTE OF MARINE AND COASTAL SCIENCES

SMUS

8TH WORKSHOP ON BALTIC SEA ICE CLIMATE

23RD-26TH SEPTEMBER 2014 POLAND

Funded by

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Practical Information

The Eight Workshop on the Baltic Sea Ice Climate will be held on 23-26 of September 2014 in Szczecin and Miedzyzdroje, Poland. The workshop will be organized by the University of Szczecin, Faculty of geosciences, Institute of Marine and Coastal Sciences. Marine Station in Miedzyzdroje.

Miedzyzdroje is a seaside resort in northwestern Poland on the island of Wolin on the Baltic coast. It is situated between wide sandy beaches with high cliffs and the forests of the Woliński National Park

The workshop will start at Szczecin, the first session will be followed at Faculty of Geosciences University of Szczecin, then all participants will be transferred to Międzyzdroje, where participants will be accommodated at holiday resort “Stilo”.

Program:

Tuesday, September 23, Szczecin, Faculty of Geosciences University od Szczecin

10:00 - 14:00 **Registration**

11:00 -11:30 **Opening**

11:30 - 14:30 **Session I: Baltic Ice**

Chairman: Stanisław Musielak

Ants Erm, Fred Buschmann:

Optical Properties of Organic Matter in Ice and Ice Melt-Water

Natalija Schmelzer, Jürgen Holfort:

Short presentation of Climatological Ice Atlas for the western and southern Baltic Sea' and of 'Climatological Ice Atlas for the German Bight'

Jürgen Holfort:

Ideas to represent climatological ice data in S411, the new standard for ice information in ECDIS

Tomasz Kolerski:

Mathematical modelling of ice jam formation in river outlets

14:45 - 15:45 **Lunch**

16:00 - 18:30 **transfer from Szczecin to Międzyzdroje**

18:30 **Arriving to Międzyzdroje**

19:00 - 21:00 **Dinner (IBP)**

Wednesday, September 24, Międzyzdroje, Morning

9:00 - 10:00 **Breakfast**

10:00 - 13:00 **Session II: Climate of Baltic Sea ice**

Chairman: Jürgen Holfort

Natalija Schmelzer, Jürgen Holfort:

Maximum Annual Ice Volume in the Baltic Sea in the Period 1973 - 2014

Jouni Vainio Anni Montonen:

Comparison of 30-years ice statistics, Finnish data, years 1961-1990 and 1981-2010

Marzena Sztobryn:

Sea-ice index

Iina Ronkainen:

Long- term sea ice changes in the Baltic Sea

Wednesday, September 24, Międzyzdroje, Afternoon

13:00 - 14:00 **Lunch**

15:00 - 18:00 **Session III: Sea ice modelling**

Chairman: Marzena Sztobryn

Toni Düskau, Natalija Schmelzer, Jürgen Holfort:

Ice thickness estimates from atmospheric and oceanic variables

Tomasz Kolerski:

Freezing degree day method for river ice thickness forecasting

Fred Buschmann:

Spectral characteristics of ice cover of some Estonian water bodies

19:00 **Dinner**

Thursday, September 25, Międzyzdroje

9:00 - 10:00 **Breakfast**

10:00 - 13:00 **Session IV: Sea Ice Observation and Presentation**

Chairman: Natalija Schmelzer

Natalija Schmelzer:

Short presentation of new layout of the German ice charts

Ove Pärn:

Drifting GPS Buoys comparison with NEMO/ BALTIX model in winter 2011

Tomasz Olechwir:

Morphology of Szczecin Lagoon Ice.

13:00 - 14:00 Closing discussion

14:00 - 15:00 Lunch

16:00 - 19:00 Excursion

19:00 - 20:00 Dinner

Friday, September 26, Międzyzdroje

8:00 - 9:00 Breakfast

10:00 Free programme (meetings, discussions, excursions, departure).

Oral Session Abstracts

Session I: Baltic Ice

Optical Properties of Organic Matter in Ice and Ice Melt-Water

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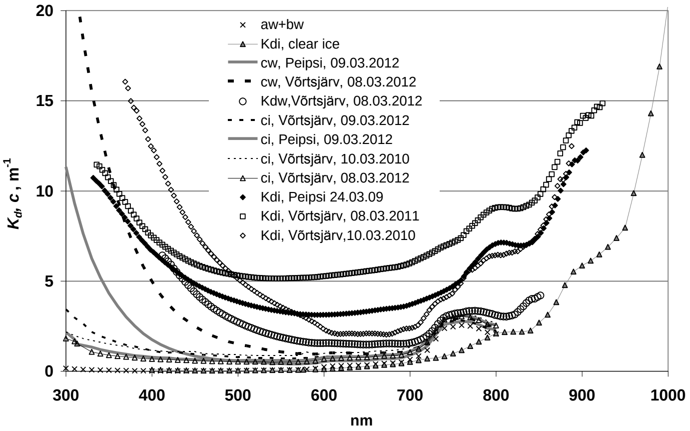
The optical studies in the Estonian lakes began in the frame of Finnish-Estonian co-operation project in year 2000. One goal of the studies was to find an algorithm to explain optical properties of the ice cover through concentration and optical characteristics of the ice melt-water. However, correlations between ice and its melt-water parameters were unsatisfactory low using PAR sensors. It was shown, that some irreversible phase transition processes will take place by melting-freezing cycles.

Ramses spectral radiometer (Trios Corp.) mounted on the frame constructed by Finnish colleagues and improved by authors (2009) was used to measure the spectral characteristics of ice in this study. A database from years 2000-2010 of field and laboratory investigations of ice cover, ice samples and ice melt-water samples of two Estonian great lakes - Lake Peipsi (3555 km^2) and Lake Võrtsjärv (270 km^2) - is analysed and discussed in this work. Maximum thickness of ice in ivestigated lakes normally was between 40-70 centimeters. Radiation spectra in the range 300-900 nm were measured above as well as under the ice cover, also the restriction coefficient $r(\lambda)$ of ice and snow were registered for every series of measurements. From the measured field data attenuation coefficients were calculated separately for the snow, ice and under ice water. These coefficients varied in great ranges (10-20 m^{-1} for the snow, 1-6 m^{-1} for the ice and water) depending on the ice and snow structure and existing of optically active substances (OAS) in these. Doe to the both, high restriction and attenuation coefficients the transparency of the ice cover depended more on the snow cover than on the optical density of ice.

Beam attenuation spectra and suspended matter (SPM) concentrations melt-water of ice layers (of the snow- and congelation ice in the most cases) were measured in the laboratory. Collected data showed that the congelation ice was much more pure than the overlying sheets of the snow ice and snow (attenuation rates about ~1 m^{-1}, ~5 m^{-1} and 5-10 m^{-1} accordingly).

As values of $K_{d,ice}(\lambda)$ as well of $c\ (\lambda)$of ice melt-water differed obviously from the values of pure water and clear ice only in UV-range (300-400 nm, Fig. 1), some specific OAS must dominate in ice that absorbs meanly UV-radiation. There could be some traces of coloured dissolved organic matter (CDOM) inside the ice. Also the only experimentally determined optical characteristic that showed a significant dependence on the concentration of SPM in ice melt-water was the beam attenuation coefficient of the ice melt-water in the UV region ($c_S(380)$, Fig.

2).



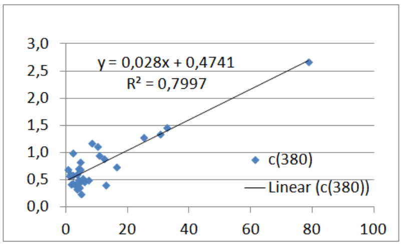


Figure 2. Beam attenuation coefficients at 380 nm (c_S*(380,* m^{-1}) of the ice melt-water depending on SPM (C_s, g) in the melt-water samples of the lakes Peipsi and Võrtsjärv.

Figure 1. More characteristic spectral optical parameters of investigated lakes: a_w+b_w – attenuation (absorbtion + backscattering) of the clearest ocean water (by Bricaud *et al.* 1995), K_{dw} – diffuse attenuation coefficient of the under ice water, c_w – beam attenuation coefficient of the under ice water, $K_{di,clear\ ice}$ – diffuse attenuation of the clearest ice (by Grenfell & Perovich 1981), c_i – beam attenuation coefficient of the ice melt-water, K_{di} – diffuse attenuation coefficient of the ice sheet.

It let us estimate from the slope of a plot c_f*(380) vs. Cs* (Fig. 2) a spectral optical cross-section value of CDOM in the ice melt-water being ~0.03 m^{2}g^{-1}. This value is much lower than calculated for the DOM earlier in literature – 0.25-0.565 m^{2}g^{-1}. As by the same amount of OAS the optical cross-section is reversibly proportional to the particles' diameter, some larger organic conglomerates must dominate in the ice melt-water rather than the common CDOM. To prove these hypothesis detailed laboratory structural and chemical investigations of ice and ice melt-water samples must be carried out.

Climatological Ice Atlas for the western and southern Baltic Sea

Climatological Ice Atlas for the German Bight

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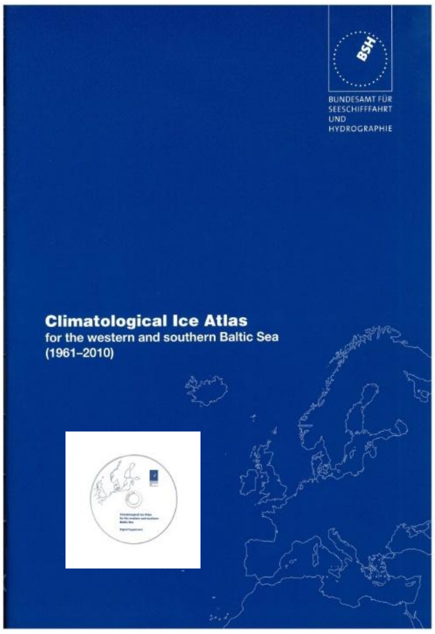
Short presentation of the ‘Climatological Ice Atlas for the western and southern Baltic Sea’ (published 2012), and status of the work on ‘Climatological Ice Atlas for the German Bight’ (will be published late 2015)

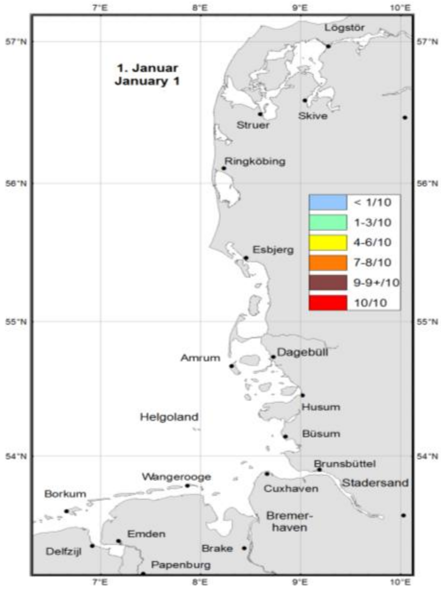


The Ice Atlas presents a compilation of the results of a statistical evaluation of ice data from the Baltic Sea region south of 56° N covering the period 1961 – 2010 (50 years). Data from the offshore waters and from fourteen selected ice observation stations located along the southern Baltic Sea coastline have been included in the analysis. Additionally, the ice parameters from three 30-year periods (1961 – 1990, 1970 – 2000, 1981 – 2010) have been analysed and compared with each other. Here, too, data are available from offshore waters and from the fourteen ice observation stations referred to above. The results in the form of charts and tables are available on the enclosed CD.

The Atlas is available in A3 format at a price of 29 € (ISBN 978-3-86987-278-0. BSH no. 2338). The Atlas can also be downloaded free of charge from the BSH’s homepage in English (91 MB) and in German (47 MB) http://www.bsh.de/en/Marine_data/Observations/Ice/index.jsp.

The Ice Atlas for the German Bight is presently still at work. Similar to the Ice Atlas of the western and southern Baltic it will show statistical evaluation of ice data in the 50-year period 1961 – 2010 as well as in three 30-year periods (1961 – 1990, 1970 – 2000, 1981 – 2010). Additionally, the ice parameters in the moderate, strong, and very strong ice winters will be analysed.

However, the treatment of the ice data is here much more difficult. At first, there are a lot of missing data, especially for the Danish waters, so we have to use some models to fill the gaps. Secondly, we cannot define the ice thickness as a thickness of level ice due to tides and currents, which determine ice formation and ice development in the North Sea. We suggest some possible solutions to treat the ice thickness in these waters.



Session II: Climate of Baltic Sea ice

Maximum Annual Ice Volume in the Baltic Sea in the Period 1973 – 2014

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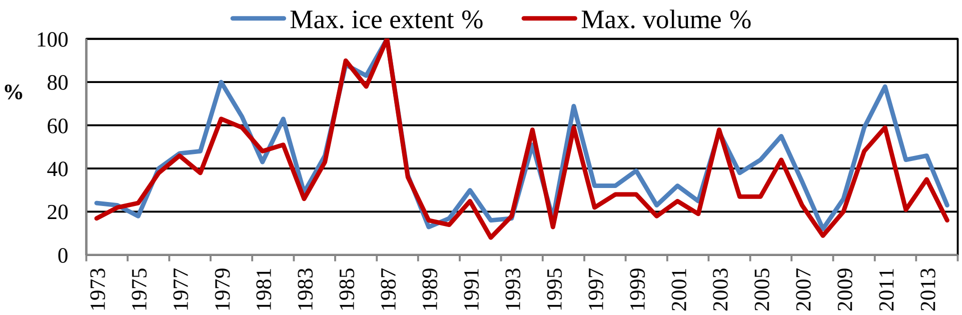
For classifying the intensity of an ice winter, the Finnish ice service uses the reconstructed or computed data of annual maximum ice extent in the Baltic Sea (Seinä and Palosuo, 1996). This data series comprises the period from 1720 to today. However, maximum annual ice volume is a more objective measure for describing the intensity of an ice winter since it takes into consideration not only ice extent, but also ice concentration and ice thickness. Therefore, maximum annual ice volume for the entire Baltic Sea was computed at the BSH ice service on the basis of ice concentration and ice thickness data on a 0.5°x0.5° grid (Feistel et al, 2008). Since reliable data on ice thickness is available only for the years as of 1973, the 42-year series (1973 – 2014) of extent and volume is analysed here. The presentation illustrate maximum ice extent and maximum ice volume for each winter from 1973 to today as well as the class boundaries of the 5 ice winter types as determined by the Nusser method (Nusser, 1948). These two values vary significantly from winter to winter: in the winter of 1986/87, the Baltic Sea was almost entirely covered by ice (405,000 km^2), compared to only 12% (49,000 km^2) in the winter of 2007/08. It is a very similar picture with regards to maximum ice volume; however, the lowest volume of ice formed in the winter 1991/92 and not in 2007/08. To compare these two measures, a percentage relative to maximum coverage and, respectively, to maximum volume was computed in the series 1973 – 2014 (cf. Fig. below).



Max. extent	Min. extent		Max. volume	Min. volume
%	%		%	%
	> 94	Extremely strong ice winters		> 90
94	73	Strong ice winters	90	65
72	42	Moderate ice winters	64	30
41	21	Mild ice winters	29	17
< 21		Extremely mild ice winters	< 17	

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Comparison of 30-years ice statistics, Finnish data, winters 1961 – 1990 and 1981 – 2010

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The Finnish Ice Service has 234 ice statistics points around the sea areas of Finland. Following five ice parameters are collected every year from these points: the first appearance of ice, start of the permanent ice cover, end of the permanent ice cover, the last day with ice and the number of days with ice. Furthermore, the severity of ice winter is classified using the maximum ice extent of the winter.

The mean values for the 30-year periods of ice winters 1960/61 - 1989/90 and 1980/81 - 2009/10 are now compared. The comparison reveals that the first appearance of ice happened four days later and the last day with ice was a week earlier on the period 1981 - 2010 than on the period 1961 - 1990. Also the length of the permanent ice cover was 12 days shorter and the number of days with ice 13 days smaller during the latter 30-years period. Furthermore, the maximum ice extent was changed from the earlier periods 210 000 km^2 to 170 000 km^2 of the period 1981-2010.

Long-term sea ice changes in the Baltic Sea

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The Baltic Sea is situated on the edge of the northern sea ice zone, where changes in climate affect strongly ice conditions. The length of ice season in the Baltic Sea is 5-7 months. The amount of seasonal ice varies significantly from year to year. However, in the last 100 years there has been a decreasing trend in the ice occurrence, which has resulted mainly from climate warming.

Observations and model results were both analyzed in order to find out the long-term ice statistics, the changes in ice conditions and the reasons behind these changes. Three stations along the Finnish coast were chosen, Kemi in the Bay of Bothnia, Utö in the Archipelago Sea and Loviisa in the Gulf of Finland. The time series were 120 years long. They included the dates of freezing and break-up, the length of ice season and the maximum annual ice thickness. The model used was NEMO/LIM-3 and the modeled time was 1961-2007. The key questions for the study were the positive trend in ice thickness in Kemi station, the reasons for the 100 year long decreasing trends although the climate warming has not affected so long and the changes in drift ice thickness.

The study results show that the probability of ice occurrence has been decreasing in Utö and is now 81 %. In Kemi and Loviisa the probability is still 100 %. The freezing date has become 7-24 days later, while the break-up date has taken place 11-20 days earlier per century. Consequently, the observed length of ice season has become 18-46 days shorter per century. The trend of the maximum annual ice thickness is not so uniform. In Kemi station, there is an increasing trend, whereas in Loviisa the trend is decreasing. According to the model, the maximum annual ice thickness has a decreasing trend also in Kemi. The maximum annual ice volume has a decreasing trend in the entire Baltic Sea (Figure 1) and also in different basins (Bay of Bothnia, Bothnian Sea and Gulf of Finland). The modeled ice volume correlates well with the observed maximum annual ice extent even though the ice volume has higher inter-annual variations.

The possible other reasons besides rise in air temperature were detected. Sea ice thickness depends in addition to air temperature also greatly on snow accumulation and ice dynamics. The observation sites are not documented, so the places may have changed. The observation sites are usually near harbors and the increasing shipping might have affected ice conditions. The land uplift has been over one meter in Kemi during the 120 years, so that might also have an influence on the results. In Loviisa also the nuclear power plant might have affected the past few decades.

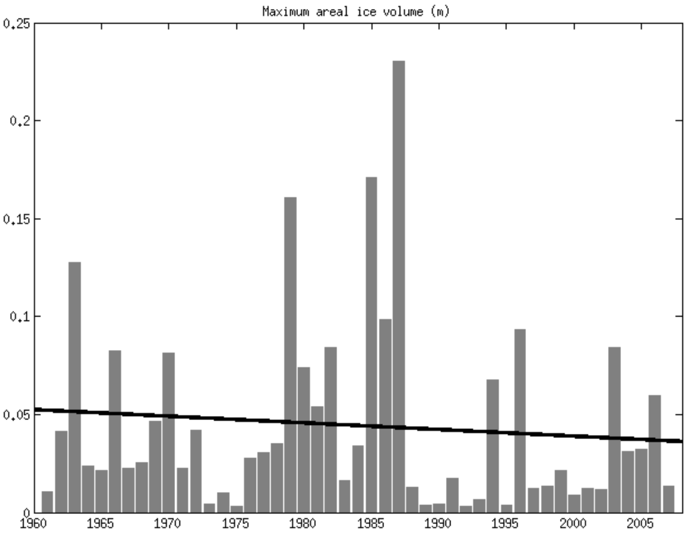

Figure 1. Maximum annual areal ice volume (m) in the Baltic Sea 1961–2007.

Session III: Sea ice modelling

Ice thickness estimates from atmospheric and oceanic variables

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In climatological work, but also in the operational service, information about ice thickness is often missing or is incomplete. Also, depending on ice observer, weather conditions, etc. the uncertainty of the available ice thickness data can be large. To overcome this problems, empirical formula exist linking ice thickness to the cold sum. As most of these formulas are based on old data, we made the effort to use new station data from the German coast to determine the coefficients of such formulas based on the newer data and tried to include also further variables like ocean salinity, day of first ice appearance, snow cover, etc. to arrive to a more constraint formulation with lower error.

We will present the method and some comparisons with actual thickness data. Some of the work was already discussed shortly in the ice winter descriptions of the 2012/13 (Schmelzer et al. 2013) and 2013/14 (Schmelzer & Holfort 2014) available at the BSH website.

The formula was then used on and compared to gridded historical data of the western and southern Baltic (Schmelzer et at. 2012; the atlas is presented in another talk is available at the BSH website) and to gridded historical (0.5°x0.5°) of the whole Baltic (Feistel et al., data updated to 2012). At sea errors are generally to large, so that also the newer formula is not usable there. Near the coast and in regions of fast ice errors are lower, but usability depends to a large extent also on the meteorological forcing used.

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Spectral characteristics of ice cover on some Estonian water bodies

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Solar radiation that has reached the Earth’s ground is reflected and absorbed by the surface. In winter, spectral distribution of solar radiation penetrating lake ice depends on snow and ice thickness, their structure and light absorbing impurities like dust and sand. Therefore the most important spectral range for living organisms – photosynthetically active radiation (PAR) between wavelengths 400 to 700 nm, that is essential for photosynthesis, is somewhat diminished. In March 2013 optical measurements were performed on three Estonian water bodies – Lake Peipus (area 3555 km²), Lake Võrtsjärv (area 270 km²) and Lake Pühajärv (area 2,86 km²). In-situ activities included measurements of downwelling and upwelling irradiance below and above ice cover (using hyperspectral radiometer for the UV- VIS spectral range, 320 - 950 nm), also ice and snow sample collection and thickness measurements. Ice meltwater analyses were performed in the laboratory of Marine Systems Institute at Tallinn University of Technology where suspended matter concentrations and beam attenuation spectra were measured (using UV-VIS spectrophotometer, 300 – 900 nm). The meltwater was also used to determine the concentration of solid particles (light absorbing impurities) in different ice layers. Further work comprised comparing snow and ice optical parameters and finding relations between them.

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Session IV: Sea Ice Observation and Presentation

Morphology of Szczecin Lagoon Ice

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Szczecin Lagoon is a basin with a fairly significant differences physiographic. These differences results in morphology and topography of the ice cover. Previous studies on the morphology and topography of the ice cover a with the deformed ice forms on the Baltic Sea waters have been conducted mainly in the northern parts of the Baltic Sea (Palosuo 1975; Keinomen 1976, 1978; Leppäranta 1998).

Analysis of freezing the Szczecin Lagoon was based on the profiles of the ice during the winter 1995 / 96-1998 / 99. These profiles allow fairly well to present the construction of the ice cover, the average thickness along with all forms of deformed ice (Bruns 1962; Derjugin, Karelin 1954; Derjugin, Stepanjuk 1974).

On the littoral lagoons, which is the Szczecin Lagoon, the dominant form of solid ice is ice formed mainly as a result of the rise glass thickness of the ice.

This ice cover with high strength and relatively hard flat surface disintegrates. Resulting from the ice fields may build up over long distances, mainly in the foreland of ice piled.

The greatest thickness of ice ridges is observed mostly in the foreland of the hummock ice rarely been away from the hummock.

The biggest impact of the ice cap on the shore observed at the edges of the low mild slope. Is particularly evident on the peninsula

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