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Ice at its southern limit in the Barents Sea: field investigation near Bear Island in April 2017-2018

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ABSTRACT

Knowledge of sea ice conditions near Bear Island (Norway) is interesting both from a practical point of view and for fundamental science. Sea ice information is requested by industry, as it reveals potential threats to extensive fishing and transport activities and possible oil and gas exploration. At the same time, ice at its most southern location in the Barents Sea (75˚N) is a remarkable natural phenomenon, persisting during ongoing global warming.

The University Centre in Svalbard (UNIS) Arctic Technology Department performed two expeditions on MS Polarsyssel in the region of the ice tongue which stretches to Bear Island. The expeditions took place in April 2017 and 2018, the time of maximal ice spreading in the frame of regular study cruises. In (Marchenko 2018), sea ice maps were compared with observed conditions. In 2018, we continued our investigation of sea ice properties (mechanical tests), laser scanning, and observation of ice floe composition and made a testing station in the place with very shallow water (20 m) where ice concentrated. The distinguishing feature of ice in this region is the existence of relatively small ice floes up to 5 m in thickness, containing consolidated ice ridges. In this article, we summarise two years of observations and data.

These field investigations provide a realistic characterisation of sea ice in the region and are a valuable addition to the long-term studies of sea ice performed by different institutions.

KEY WORDS: Sea Ice; Barents Sea; Bear Island; Field investigation; Laser scanning.

INTRODUCTION

The sea ice regime in the Barents Sea has been extensively investigated by various institutions (Vinje and Kvambekk 1991; Zubakin 2006; Årthun et al. 2012; Koenigk et al. 2009) because of its significant importance both for regional industry and for understanding global oceanic processes. As it is shown in (Lind, Ingvaldsen, and Furevik 2018), the Arctic has warmed dramatically in recent decades and the greatest temperature increases are observed in the Northern Barents Sea, where there is declining sea-ice import. Located along the main pathway of Atlantic Water entering the Arctic, the Barents Sea is the site of coupled feedback processes that are important for creating variability in the entire Arctic air-ice-ocean system. As warm Atlantic Water flows through the Barents Sea, it loses heat to the Arctic atmosphere. Warm periods, like the present, are associated with high northward heat transport, reduced Arctic sea ice cover, and high surface air temperatures (Smedsrud et al. 2013).

The investigation of fast ice thickness near Hopen island is particularly valuable. Over 40 years of monitoring by S. Gerland and co-authors (Gerland et al. 2008) demonstrates a trend in ice thickness anomalies of -0.11 m per decade, coinciding with decreasing seasonal maximum ice thickness, and an increase in local air and surface water temperatures.

Measurement of ice thickness with a helicopter-borne electromagnetic (HEM) system east of Svalbard (King et al. 2017) showed the range of possible ice thickness distributions. In cold years like 2003, the dominant ice class was more than two years old, and modal sea-ice thickness varied regionally from 0.6 to 1.4 m, with the thinner ice being either first-year ice or multiyear ice which had come into contact with warm Atlantic water. In 2014, the ice cover was predominantly locally-grown ice less than one month old (regional modes of 0.5–0.8 m).

Special attention of various researchers was devoted to the northwest Barents Sea and the region between Bear Island and Hopen, given interest in possible hydrocarbon production and fisheries, and because Atlantic and Arctic waters meet and interact at this location, forming the ice tongue phenomenon. Sea ice extends southward here as far as 75˚N in March and April, forming the peculiar ice tongue which is visible on satellite images and ice maps even during the present warm period. In the past, old ice near Bear Island at the end of the melting season was described by T. Vinje, who estimates old ice comprises 1% of the total number of ice observations during 1970-1981 (Vinje 1985). According to data from Russian ice reconnaissance conducted through air-borne observations and ice chart archives, the propagation of old ice along Spitsbergen to more southern areas (Bear Island) is a more frequent phenomenon (Buzin 2009).

In-situ observations of ice in the Bear Island region are scarce, which is why our expeditions have focused on sea ice properties in this area.

UNIS ARCTIC TECHNOLOGY CRUISES

The Arctic Technology Department of UNIS performs field investigations of sea ice in the western Barents Sea during research cruises, and with drifting buoys installed on the ice (Marchenko and Marchenko 2015). Cruises on vessels as part of the bachelor course AT-211 "Ice Mechanics, Loads on Structures and Instrumentation" at the end of April allow for the collection of interesting and valuable scientific data in an infrequently visited part of the Barents Sea (Marchenko and Marchenko 2017). Researchers from various institutions

(NTNU, C-Core, UCL, Cambridge University, Shirshov Institute of Oceanology) often take part in the cruises. During cruises, properties of sea ice are investigated and oceanographic measurements are performed.

The past two years, cruises were performed on the vessel MS Polarsyssel in the marginal ice zone between Hopen and Bear Island (Fig. 1). MS Polarsyssel is a firefighting vessel built in 2014 with the following characteristics: IMO: 9690949, Gross Tonnage: 4324, Deadweight: 3700 t, and Length Overall x Breadth Extreme: 88.5m × 18.3m. The Svalbard governor's office uses Polarsyssel part of the year for rescue operations and daily needs. The vessel has ice class 1B, but due to the responsibility for preparedness for rescue missions, it does not typically operate in ice.

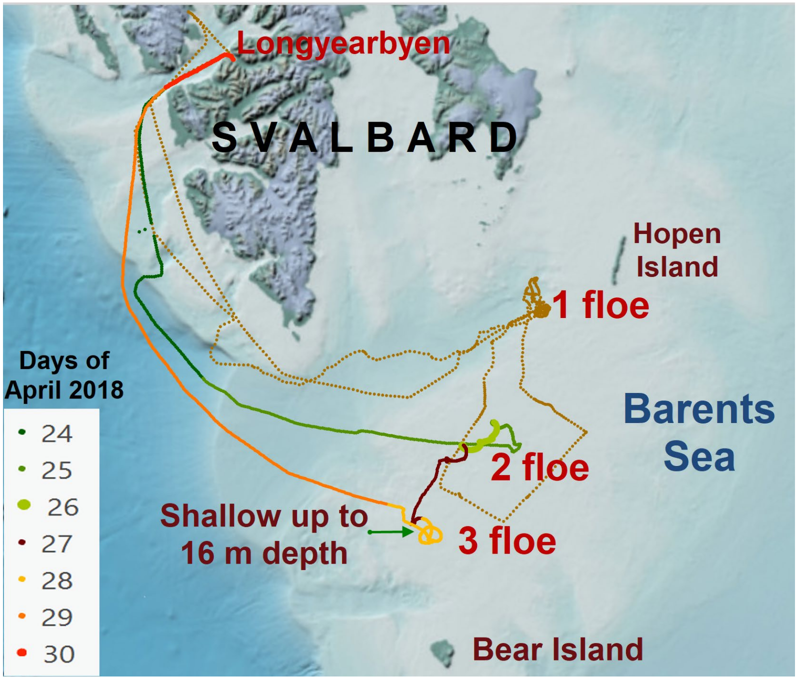


Figure 1. Polarsyssel tracks (brown line from 2017, and other coloured lines indicating dates in April 2018 as is shown in the legend) and locations of ice floe investigations.

Figure 2. 3D point cloud, layered with photographs, obtained from laser scanning of ice floe 2.

COMPARISON WITH SEA ICE MAPS

During the expedition at the end of April 2017, we crossed the ice tongue twice and made sea ice observations to compare in-situ conditions with the sea ice map from the Polarview portal (Norwegian Meteorological Institute 2018). We described sea ice appearance in the various ice map zones near the southern limit of ice extent. The ice maps from the Polarview portal are colour-coded with categories corresponding to ice concentration (Marchenko 2018). The observations in April 2018 confirmed the previous year's findings and are summarised below:

Red zone – Dense ice field consisting of small (4-5 m) angular ice floes, repeated larger floes (20-30 m) with hummocky formations (up to 2 m sail and 4 m draft) and smaller round pieces (less than 1 m) with debris in between;

Orange zone – in the northern part of the ice tongue, round floes (2-4 m) with frequent inclusions of ice floes (mainly 10-15 m, but up to 25 m) containing hummocks (up to 2 m sail); in the southern part of the ice tongue, dense and thick pancake ice with fairly uniform oval shape (25-30 cm wide and 35-45 cm long);

Yellow zone – in the northern part of the ice tongue, similar to the orange zone in composition, but with less ice coverage and fewer floes with hummocks; in the southern part of the ice tongue, thin pancake ice (20 cm in diameter) amidst dense slush;

Green zone – the peripheries of the ice tongue consist of ice strips tens to hundreds of meters wide with the same composition as the yellow zone, located within ice-free water.

All of the categories mentioned above can include icebergs. In 2017, we observed iceberg up to 10 m high in ice-free water (blue colour on the map) as far as 76˚N. In 2018, we saw and laser scanned an iceberg in the orange zone between 71,11˚ and 75,26˚N. During our observations, the ice field and ship drifted in oval-shaped tidal loops that were approximately 10 km long and 14 km wide (from west to east) (Fig.3). The iceberg had a complex topography with five peaks up to 4.2 m high, a pond in the middle, and a significant visible submerged part.

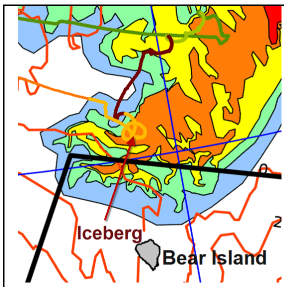
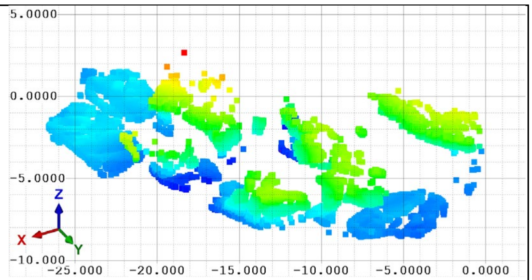
		
a. Sea Ice map. Iceberg location is shown by brown arrow	b. Photo from the bridge	c. 3D point cloud, coloured by altitude above the water surface. Difference between the highest and lowest part and height of the iceberg is 4.2 m

Figure 3. Iceberg observation on 28 April 2018. The most southern position was 75,12˚N and 19,13˚E

ICE FLOE MORPHOLOGY INVESTIGATION

In 2018, we made two stations to investigate representative ice floes for the region. The floes were moored to the ship when measurements were performed (Fig. 2).

We used laser scanning to survey the above-water ice floe surface and used drilling profiles to infer the submerged morphology. For the second floe in 2018, we used underwater video to supplement our other methods. After measuring a deep/long keel via drilling, we lowered a

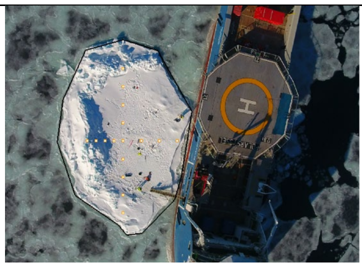
GoPro camera on a long pole into the drilled hole to view the underwater part of the ice floe (Fig.4).

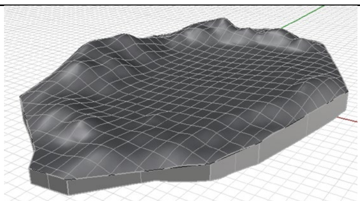
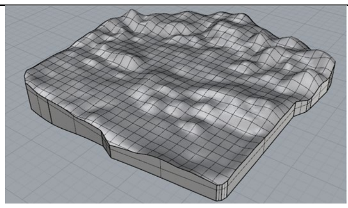
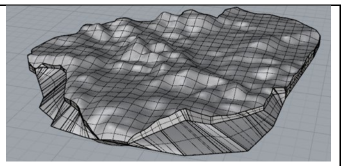
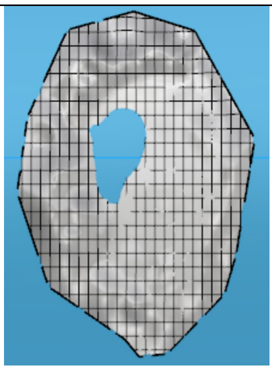
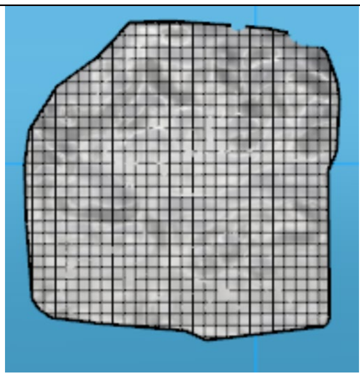
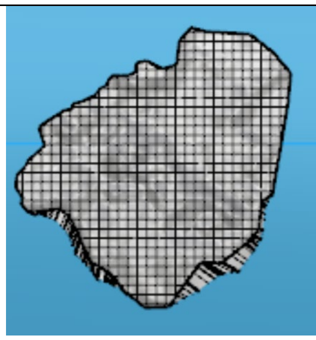
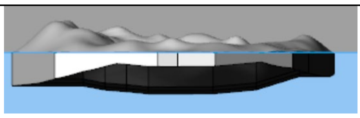
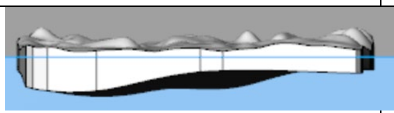
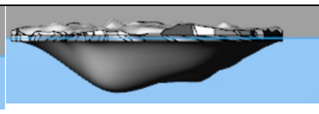
A laser scanner, using a light detection and ranging method, sends out pulsating light beams in an array towards its target. The reflected light is captured, and the distances between the laser scanner and points in the array are measured. The distances within the array are compiled to generate a point cloud that represents the 3D geometry of the target. An example point cloud image from a laser scan completed during the cruise is shown in Fig.1b. During the cruise, the laser scanner was placed both on the ship and on the centre of the ice floe to measure the ice floe's geometry. The point cloud was obtained and refined by removing unnecessary points, and then was imported into a 3D modelling software (Rhinoceros 3D) for analysis. In this software, above-surface and underwater measurements were used in conjunction with the point cloud to obtain final 3D ice flow models (lines 6-8 in Table 1). The main characteristics of the investigated ice floes (together with a floe measured in 2017) are presented in Table 1.

Figure 4. Underwater images of ice floe 2

Table 1. Ice floe characteristics (measurements and morphology)

Explanation of table line numbers: 1 – floe number and date of observation; 2 – coordinates; 3 – water depth; 4 – average air temperature/average ice salinity; 5 – photo; 6 – view of above water surface and side wall (3D model); 7 – aerial view (3D model); 8 – cross-section with waterline (3D model); 9 – horizontal size in m; 10 – max sail/draft in m; 11 – submerged volume/total ice volume in m^3

1	Floe 1 – 24 April 2017	Floe 2 – 26 April 2018	Floe 3 – 28 April 2018
2	76.394˚N and 22.865˚E	75.587˚N and 21.578˚E	75.182˚N and 19.205˚E
3	90 m	45 m	22 m
4	- 7˚C/ 7.7 ppt	- 8˚C/ 4.5 ppt	- 5˚C/ 4.5 ppt
5			

6			
7	 Grid 1 m x 2 m	 Grid 1 m x 1 m	 Grid 1 m x 1 m
8			
9	43 x 30 m	26.9 x 26.5 m	22.6 x 22.8 m
10	2.16/3.82 m	2.2 /2.94 m	1.6/4.56 m
11	2655/3270 m^3	942/1469 m^3	752/1000 m^3

PRACTICAL CONSIDERATION AFTER OBSERVATION.

Several time-lapse series were performed, using Polarsyssel bridge photo camera (see screenshot in Fig.5). On stations, laser scannings from the bridge were performed to determine the size of the ice floe and made camera/screen calibration.

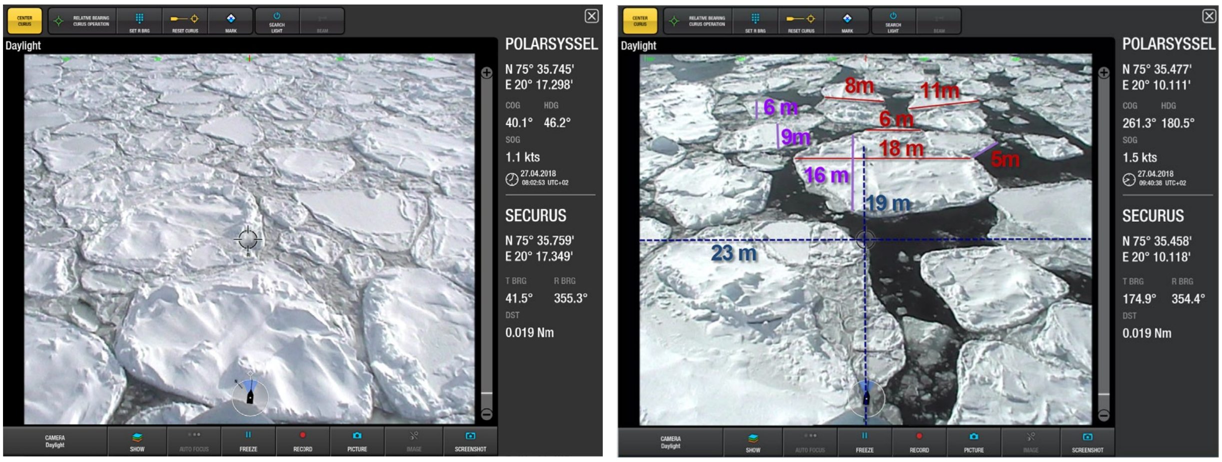


Figure 5. Ice floe composition observed near Bear Island in April 2018 (screenshots of Polarsyssel monitor with ice floe dimensions measured by laser scanner)

Being involved in the projects devoted to Arctic Safety and Maritime preparedness, I recalled the accident with the cruise ship "Maksim Gorkiy" occurred in June 1989 in the Greenland Sea (Fig.6), 230 km west of Svalbard (290 km from Longyearbyen) in the marginal zone, ne ar the ice boundary (77.37˚N 4.10˚E). On the way from Iceland to Svalbard, "Maksim Gorkiy " encountered an ice field, hit an ice floe, got a hole and began taking on water with 953 people on board, of which 575 were passengers and 378 were crew. All passengers and one-third of the crew left the ship and spent several hours on the ice floes and in lifeboats, waiting for help. Fortunately, everyone was rescued by the Norwegian ship KV Senja and helicopters (Hovden 2014).

20.06.1989 04:50

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Fyllekalas om bord

Festen fortsatte i livbåtene

n stor del av mannskapet på Maxim Gorkij» holdt et re-elrett fyllekalas mens båten ned over 900 mennesker om ord var midt oppe i et drama å liv og død.

Det hevdes overfor Nordlys v flere nordmenn som deltok redningsaksjonen natt til tirsdag. Kritikken er drepende.

Evakueringen fra cruiseskipet var kaotisk og risikabel. Førerne av livbåtene hevet flaska og skålte mens de fraktet passasjerer mellom drivende isflak.

— Det store alkoholkonsumet blant en del av mannskapet var et sjokk for oss, sier overlege Mads Gilbert, som var med på redningsaksjonen.

SIDE 8-9

20.06.1989

20.06.1989 07:50

20.06.1989 10:50

Figure 6. Conditions during the Maksim Gorkiy accident in June 1989. Photos: Odd Mydland (Kleiven 2012)

There was no clear assessment of ice conditions at the time of the accident, but conditions can be inferred from reading reports and articles, and by examining available photos and video (Fig. 6). It was reported that the main reason for the accident was the captain Marat Galimov’s inexperience in polar water navigation, and his rush to bring tourists to Magdalena Fjord. When he saw the ice edge approximately 2-2.5 miles away on 19 June 1989 at 23:02, he was under the impression that the ice was young and thin and therefore not dangerous. The ship kept a high speed of 18.5 knots and started to manoeuvre, trying to follow ice-free leads (Smirnov et al. 1993). At 23:19 Maksim Gorkiy hit an ice floe on its port side. Ice conditions were described as “pieces of multiyear ice with compactness 6-7/10, the degree of destruction of 2-3 points interspersed with small icebergs ice thickness reached 5 m” ((Smirnov et al. 1993),page 306). At 23:50 the flow of water to the third deck cabins was reported and passengers began to gather on the lifeboat deck. A mayday signal was dispatched 20 June at 00:15, and KV Senja arrived at the scene at 04:00. The Commanding Officer on KV Senja, Sigurd Kleiven, reported “ice belt with approx. 1 m thick rotten ice floes, width about 1.5 nautical miles between Senja and "Maksim Gorkiy" (Kleiven 2012).

Photos from the event (Fig. 6) show that ice conditions changed rapidly during the rescue and within several hours Maksim Gorkiy was surrounded by ice-free water.

The Polar Code, adopted by the International Maritime Organization and enforced since 1 January 2017, dictates ship construction and equipment requirements and necessary crew skill/experience to ensure safe operations in polar waters. The boundary of polar waters runs directly through Bear Island (IMO 2014), making ice conditions in this region particularly important.

CONCLUSIONS

Expeditions on the vessel Polarsyssel in April 2017 and 2018 allowed us to collect data pertaining to ice conditions in the region between Bear and Hopen Islands, at the southern-most extension of ice in the Barents Sea. Sea ice at this location stretches as a tongue from the northeast to Bear island, and is indicated on the ice map as a combination of green (1-4/10ths), yellow (4-7/10ths) and orange (7-9/10ths)coloured categories, differentiated by ice compactness and presenting the combination of the various size ice floe. The essential characteristics for the green, yellow, and orange categories present in the ice tongue are ice floes 10-30 m across and up to 5 m thick, including consolidated ridges. Small icebergs are possible in these color categories. These ice floes and icebergs can be potentially dangerous for navigation and offshore construction, and thus should be taken into consideration and investigated further.

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