Campaign report

August 2018

IceBird 2018 Summer Campaign

Sea ice thickness measurements with Polar 6 from Station Nord and Alert

Authors

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This work was funded by the
Federal Ministry of Education and Research

IceBird 2018 summer campaign

Basecamp: Station Nord/Alert
Aircraft: Polar 6
Expedition permit: C-18-28
Number of flight hours granted: 75 h (excluding ferry)

Crew: Manuel Sellmann (engineer), Helge Goessling (scientist), William Houghton (chief pilot), Ben Guinan (second pilot), Kevin Riehl (mechanic), Esther Horvath (communication and media), Thomas Krumpen (lead scientist)

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1.0 Aims and objectives of ICEBIRD 2018:

Arctic sea ice extent and thickness have undergone dramatic changes in the past decades: Summer sea ice extent has declined at an annual rate of approximately 12.7 % per decade over the satellite record (1978 – present, [5]) and its mean thickness has decreased by 0.58 m +/- 0.07 m per decade over the period 2000 - 2012 [3]. The thinning of sea ice is accompanied by an increase of ice drift velocity [8], deformation [7] and a decrease of net ice growth rates. Climate model simulations indicate that ice extent and thickness will further decline through the 21st century in response to atmospheric greenhouse gas increases. However, the mass balance of Arctic sea ice is not only determined by changes in the energy balance of the coupled ice-ocean-atmosphere system but also by the increasing influence of dynamic effects. One aspect of the mass balance of Arctic sea ice are changes of ice volume export rates through Fram Strait and the decline of thick and old multi-year ice North of Ellesmere Island. Thickness surveys carried out north of Greenland and Fram Strait give insight into composition and properties of Arctic sea ice in general and how it changes over time. An extensive data set of ground-based and airborne electromagnetic ice thickness measurements were collected between 2001 and 2017 during several aircraft (PAMARCMIP, TIFAX) and Polarstern campaigns. The first aim of the ICEBIRD 2018 campaign is to complement earlier measurements made north of Svalbard, Greenland and in Fram Strait. Sea ice thickness information will be used to examine the connection between thickness variability, ice age and source area. Together with satellite based information on sea ice motion, data will be used to quantify sea ice outflow through Fram Strait in summer. These estimates shall improve the understanding of interannual variability in summer sea ice outflow and complement existing winter volume flux calculations. A second objective is to extent sea ice thickness measurements to the Lincoln Sea where we will study thinning of sea ice due to reduction of old multi-year ice in this area. Like the measurements planned over the Fram Strait area, the surveys are a continuation of earlier aircraft campaigns made north of Alert and shall improve understanding of ice mass balance changes in the Arctic.

Fig 1: Pictures taken by Esther Horvath/AWI.

ICEBIRD photo and video documentary

K&M participated the ICEBIRD 2018 campaign with the main goal to highlight the scientific work of AWI, continue to collect long term video and photo material about the sea ice thickness measurements and raise public awareness about the changes of sea ice in the Arctic. Focus of the documentary was on operation with Polar 6, science activities in the airplane and at Station Nord. The photo documentary is planned to be featured in The New York Times, National Geographic, Stern Magazine, Everyday Climate Change international photo exhibition and presented in Wildscreen Film festival in UK.

Flight hours

Airport Codes			
CYQA	Muskoka, Canada	ENSB	Longyearbyen, Svalbard
CYYR	Goose Bay, Canada	BGNO	Station Nord, Greenland
BIKF	Keflavik, Greenland	CYLT	Alert, Canada

Date	Route	Type	Air Time	Flight time	Instruments
Jul 24-2018	CYQA-CYQA	Test flight	1	1.3	EM-Bird, laserscanner, camera
Jul 25-2018	CYQA-CYYR	Ferry flight	4.3	4.7	None
Jul 26-2018	CYYR-BIKF	Ferry flight	7	7.4	None
Jul 27-2018	BIKF-ENSB	Ferry flight	5.3	5.8	None
Jul 30-2018	ENSB-BGNO	Ferry flight	2.4	3	None
Jul 30-2018	BGNO-CYLT	Ferry flight	2.4	2.8	None
Jul 31-2018	CYLT-CYLT	Survey flight	3.2	3.7	EM-Bird, laserscanner, camera
Aug 01-2018	CYLT-CYLT	Survey flight	7	7.5	EM-Bird, laserscanner, camera, drop sond
Aug 02-2018	CYLT-CYLT	Survey flight	2.2	2.7	None
Aug 03-2018	CYLT-BGNO	Ferry flight	2.5	2.9	None
Aug 04-2018	BGNO-BGNO	Survey flight	4.6	5.1	EM-Bird, laserscanner
Aug 06-2018	BGNO-BGNO	Survey flight	3.2	3.7	None
Aug 07-2018	BGNO-BGNO	Survey flight	2.5	2.9	EM-Bird, laserscanner, camera
Aug 11-2018	BGNO-BGNO	Survey flight	6.2	6.7	EM-Bird, laserscanner, camera
Aug 12-2018	BGNO-BGNO	Survey flight	5.9	6.4	EM-Bird, laserscanner, camera
Aug 13-2018	BGNO-BGNO	Survey flight	6	6.5	EM-Bird, laserscanner, camera, drop sond
Aug 13-2018	BGNO-BGNO	Test flight	0.8	1	EM-Bird test
Aug 15-2018	BGNO-ENSB	Ferry flight	2.4	2.8	None
Total flight hours			68.9	77.1	
Total flight hours excluding ferry			42.6	47.5	

2.0 Preliminary results

Available weather information

Weather information were obtained via FTP from the German Weather Service (DWD). The DWD provided a tailored collection of meteograms and EPS-grams (120h ahead; initialized 00UTC and 12UTC, available with 9h delay) for different key locations as well as forecast maps of the relevant region for cloud cover (low, medium, high), near-surface temperature, humidity, pressure and winds (available with 7.5h delay). All of these parameters were provided from the ECMWF forecast system, most also from the ICON system, and some in addition from the GFS system.
In addition, short-term (48h) forecast maps for near-surface visibility were obtained from the Danish Meteorological Institute (DMI, in collaboration with the Icelandic Meteorological Office, IMO) from their high-resolution (3km) Greenland/Iceland forecast domain.

Survey site selection based on forecast data

In the evenings and mornings before each flight, weather information from ECMWF, ICON or GFS were used to locate sites suitable for low-level flight operations, and to assess the risk of unsuitable conditions for landing at Station Nord, Alert, and/or Longyearbyen. If doubts remained, the chief pilot called the Greenlandic aviation weather authorities to ask for guidance. The information obtained were largely consistent with the conclusions we had drawn based on the DWD and DMI products.
The primary parameter used for the planning of the low-level survey flights (aircraft at 200ft = 70m) was the near-surface relative humidity, with values below 90% indicating reduced risk of near-surface clouds. This parameter was preferred over the low-level cloud maps because the latter include clouds higher up in the boundary layer / lower troposphere which could still allow surveying.

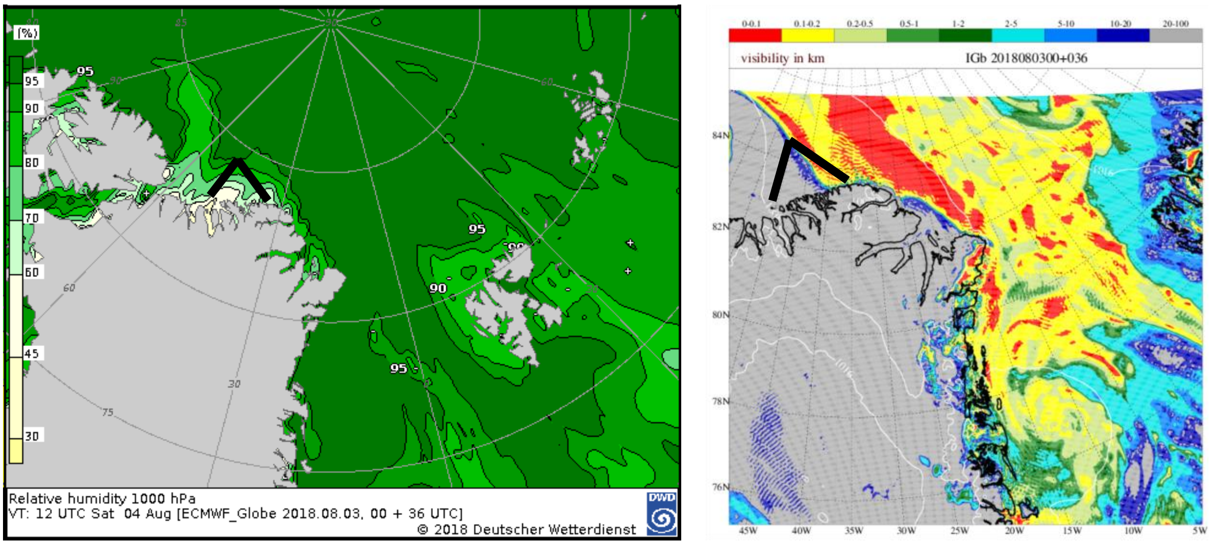

Fig 2: 36h forecasts for August 4, 12:00 UTC, for near-surface relative humidity (ECMWF; left) and near-surface visibility (DMI; right). Black lines denote the approximate track surveyed around that time. The forecasts proved to be quite accurate.

An example where the ECMWF near-surface humidity and DMI near-surface visibility proved to be very accurate and useful to plan the survey route is shown in Fig. 2. The forecasts from the previous day, August 3, 00:00 UTC, for 12:00 UTC on August 4 (36h forecast lead time) indicated clear conditions along 50W northward up to 84-84.5N, which is precisely what we encountered. We then turned towards Station Nord (east-southeastward) and had the fog bank remaining in sight to the left of our track, as forecast.

Overall, fog prevailed over most parts of the potential survey area during most of the campaign, with the near-surface relative humidity forecast beyond 95%. In the second half of the campaign, we therefore had little guidance to find suitable places to survey, but searched and found suitable conditions in fog gaps during some days, as can be seen from the survey tracks. In these high-humidity conditions, the DMI visibility appeared not to be very accurate, with low correlation between areas forecast to have higher visibility and those where we actually met suitable conditions.

For future campaigns, we recommend to add cloud base height (i.e. ceiling), both at key locations and as maps, to the collection of available products. This would be useful not only for finding suitable locations for low-level surveys, but also for the landings because a sufficiently high cloud base height (e.g., 400ft = 130m in Longyearbyen) is required to see the runway.

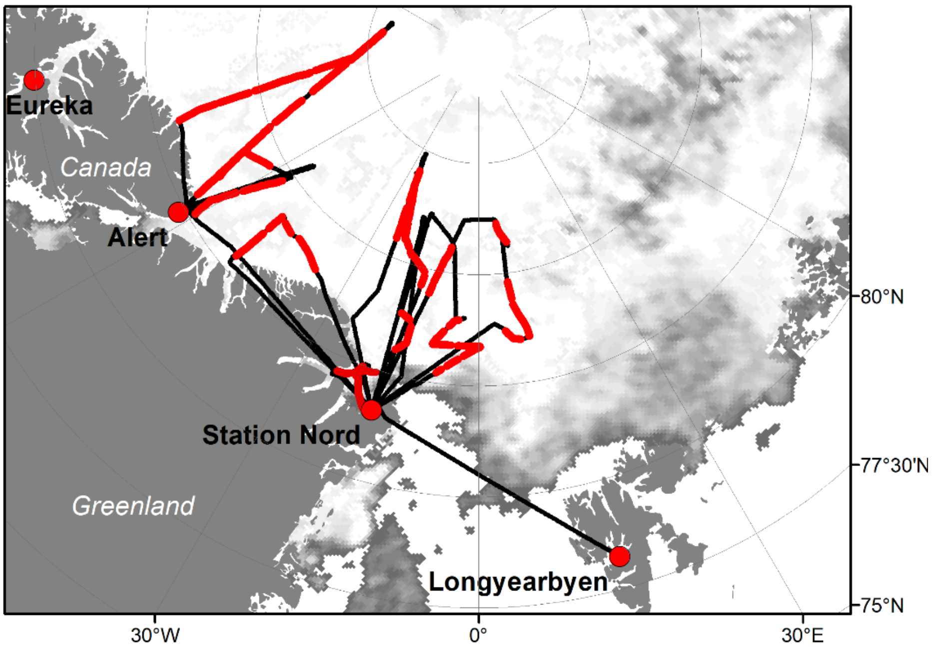

Fig 3: Flight tracks (black) for the period between July 31st and August 14th, 2018. Red lines indicate subsections of flight tracks carried out at low level (EM-Bird surveys). Sea ice concentration on July 26th, 2018 is shown in the background (source AMSR2/JAXA provided by DriftNoise.com)

Electromagnetic (EM) sea ice thickness measurements

An overview of all EM sea ice thickness measurements made during ICEBIRD 2018 is given in Figure 3. EM ice thickness measurements utilize the contrast of electrical conductivity between sea water and sea ice to determine the distance of the instrument to the ice-water interface [1]. Surveys were conducted with the research aircraft *Polar-6* operating from the Danish Station Nord in Nord-East Greenland and Alert in Canada. The accuracy of the EM measurements is in the order of ± 0.1 m over level sea ice [6]. The AEM thickness data enables us to determine the general thermodynamic and dynamic boundary conditions of ice formation [9, 4]. The most frequently occurring ice thickness, the mode of the distribution, represents level ice thickness and is the result of winter accretion and summer ablation. We assume the bias that arises from the unknown snow thickness to be negligible, since temperatures above freezing had certainly led to a significantly reduced snow cover or no snow cover at all [10]. For details about data processing and handling we refer to [1, 2].

Fram Strait and Transpolar Drift sea ice thickness (2001 – 2018)

Between 2001 and 2017, several sea ice thickness surveys were carried out in Fram Strait area and southern part of the Transpolar Drift to investigate interannual and seasonal changes in the sea ice cover at the major exit gate of the Arctic Ocean [2]. Fig. 4 summarizes EM thickness data from different years obtained between 79° and 87° N and 30°W and 20°E. Owing to the rather limited number of campaigns and the snapshot character of the surveys a trend analysis of the time series may be of limited value. Nevertheless, given the overlapping study regions and seasons and the large lengths of surveys, the EM data provide evidence of a changing sea ice cover that stands out of the interannual variability and bias that may arise from year to year varying snow cover. According to Fig. 4 the modal ice thickness has decreased by 30 % over the past 17 years, with a distinct reduction in ice thickness after 2004, when the mode dropped from 2.2m (2004) to 1.2m (2016). Modal thickness in 2018 was around 1.5 m. The decrease in modal thickness is accompanied by a decrease in mean thickness and ridged ice (fraction of ice thicker than 3 m, not shown).

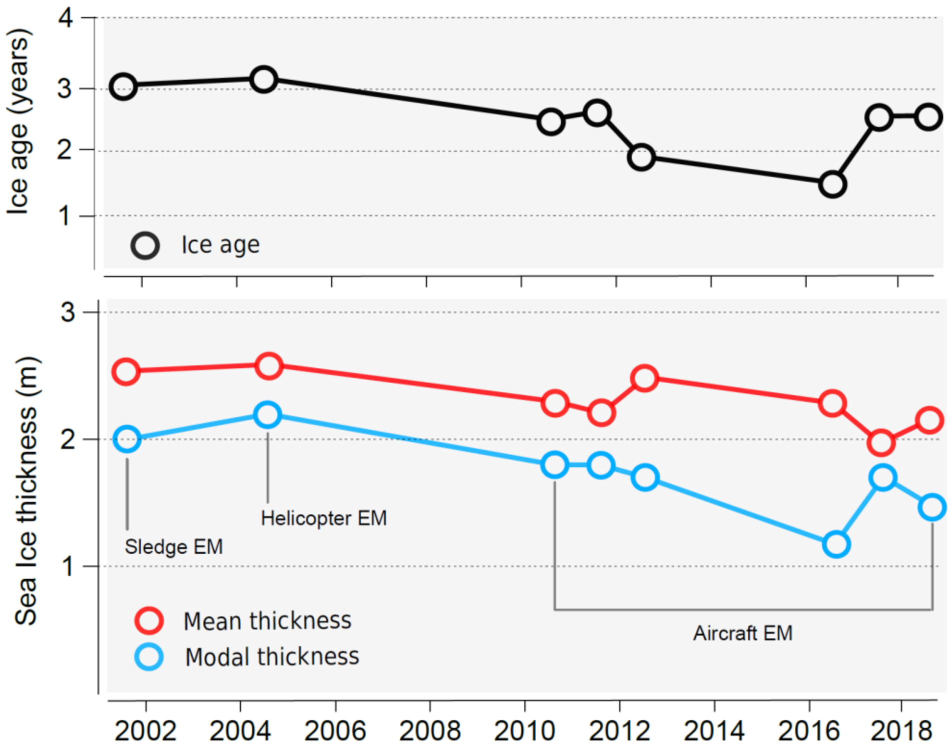

Fig 4: Upper panel: Time series of sea ice age sampled in Fram Strait and Transpolar Drift obtained from backtracking of sea ice (Fig. 5) between 2001 and 2018. Lower panel: Time series all EM ice thickness measurements obtained in the Fram Strait region during two cruises with the German ice-breaker RV *Polarstern* (August 2001 and 2004) and six surveys with the research aircrafts *Polar 5* and *Polar 6*. Mean and modal EM ice thickness (ice plus snow thickness) are marked with red and blue circles. The survey sections used for analysis are given in Fig. 5.

Pathways and source area of sea ice in Fram Strait and Transpolar Drift

To determine source areas and pathways of surveyed sea ice we apply a Lagrangian approach (ICETrack) that traces sea ice backward in time using a combination of satellite-derived low resolution drift products. The tracking approach works as follows: An ice parcel is traced backward in time on a daily basis. Tracking is stopped if a) ice hits the coastline or fast ice edge, or b) ice concentration at a specific location drops below 25 % and we assume the ice to be formed. Fig. 5 shows the backward trajectories of ice surveyed in the area of interest between 2001 and 2018. The analysis shows that the largest fraction of surveyed sea ice in 2018 originated in the Laptev Sea. It took approximately 2–3 years of drift with the Transpolar Drift until ice reached Fram Strait. In contrast, the ice surveyed in 2010 and 2017 west of the 0° meridian mostly originated from the Beaufort Gyre.

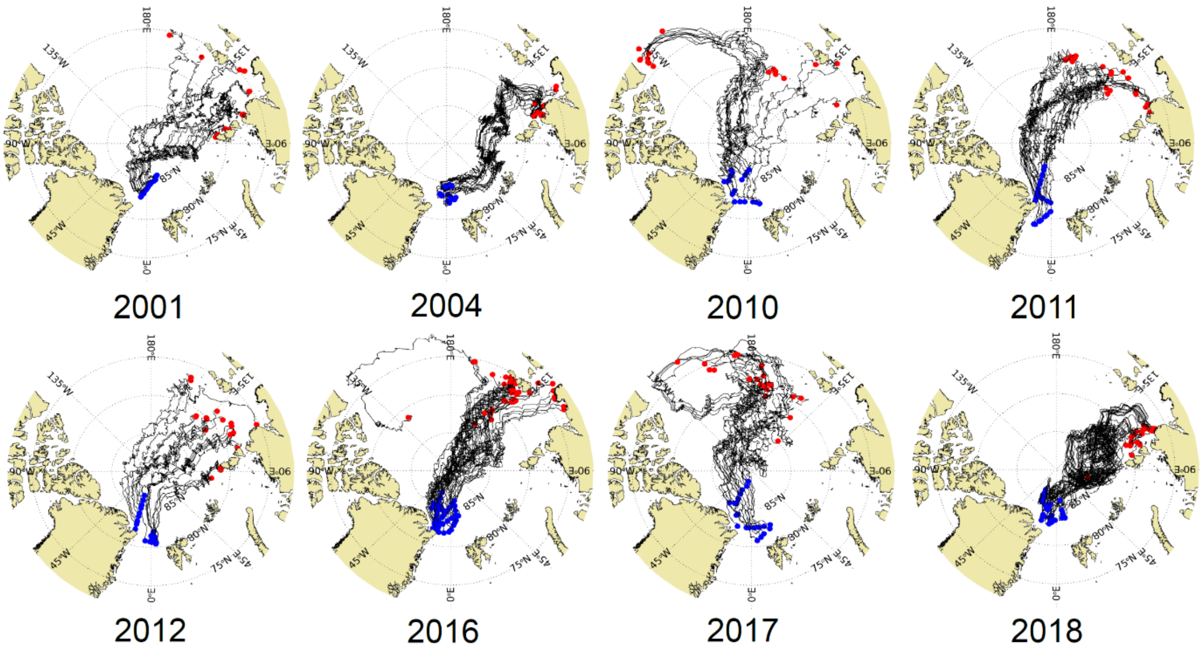

Fig 5: Backtracking of sampled sea ice in Fram Strait and southern Transpolar Drift using a combination of ice drift and concentration information. The start points (blue dots) of the backward trajectories (gray lines) are equivalent to the positions where EM measurements were obtained during the individual years. The red dots indicate where the ice was formed. The largest fraction of surveyed sea ice in 2018 (Fram Strait and southern Transpolar Drift) originates from the Laptev Sea and was on average 2.6 years old.

3.0 Daily reports

July 26-29, 2018

System integration in Muskoka including test flight. On 26th July, ferry to ENSB with arrival on July 28th. After arrival, system checks were made on 29th July at ENSB.

Date	Route	Type	Air Time	Flight time	Instruments
Jul 24-2018	CYQA-CYQA	Test flight	1	1.3	EM-Bird, laserscanner, camera
Jul 25-2018	CYQA-CYYR	Ferry flight	4.3	4.7	None
Jul 26-2018	CYYR-BIKF	Ferry flight	7	7.4	None
Jul 27-2018	BIKF-ENSB	Ferry flight	5.3	5.8	None

July 30, 2018

Ferry flight from ENSB to BGNO in the morning. At BGNO part of equipment was unloaded and ferry flight to CYLT was continued in the afternoon. Participants without clearance for CYLT were left behind at BGNO (Helge Goessling, Esther Horvath).

Date	Route	Type	Air Time	Flight time	Instruments
Jul 30-2018	ENSB-BGNO	Ferry flight	2.4	3	None
Jul 30-2018	BGNO-CYLT	Ferry flight	2.4	2.8	None

Jul 31, 2018

Test and survey flight north of CYLT over multiyear ice. All systems (except camera) worked well. Due to low visibility north of 84°N survey activities were limited to the vicinity of CYLT.

Date	Route	Type	Air Time	Flight time	Instruments
Jul 31-2018	CYLT-CYLT	Survey flight	3.2	3.7	EM-Bird, Laser scanner

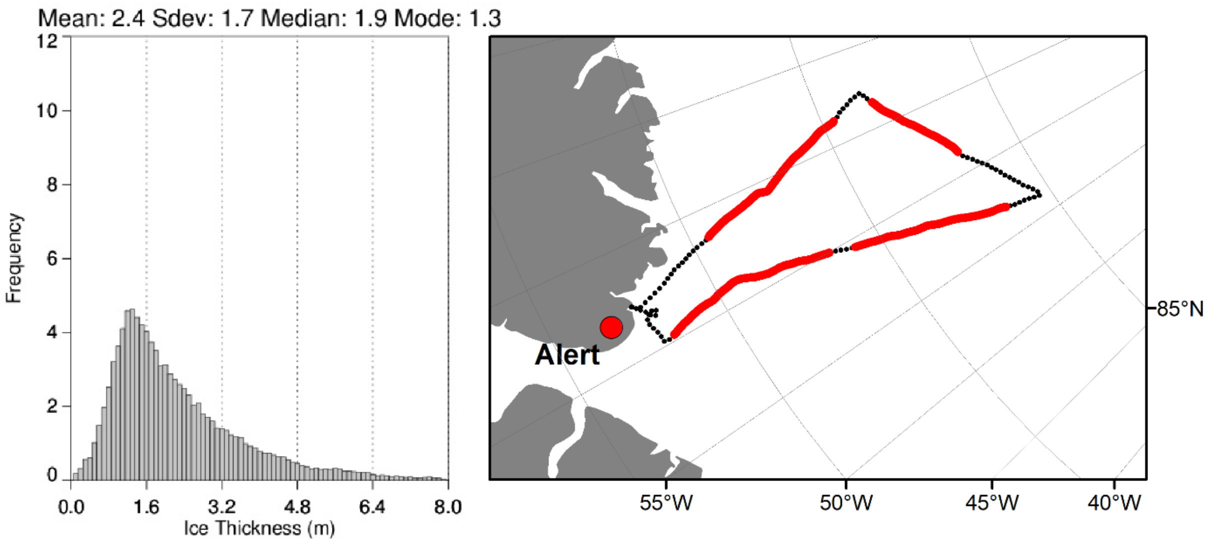

Fig: Sea ice thickness histogram (left) and survey area (right) for flight date.

August 01, 2018

Weather cleared up in the late afternoon of Jul 31st. Hence a survey flight was carried out in the night starting at 0200 AM local time. Aim of the survey was to repeat an EM survey line obtained earlier by C. Haas on May 3rd (see Fig.). Along survey line a number of buoys were dropped (P51, P53, P56/57, see Meereisportal.de) to keep track of sampled sea ice after surveying activities. The most recent position updates provided by buoys were used to plan the survey on Aug. 01.
The EM survey was carried out successfully. To complement earlier buoy deployments, an additional CALIB buoy was dropped at the northern most point of the survey line. However, the parachute did not open and the deployment failed (IMEI number 300234065867170).

Date	Route	Type	Air Time	Flight time	Instruments
Aug 01-2018	CYLT-CYLT	Survey flight	7	7.5	EM-Bird, laserscanner, camera, CALIB buoy

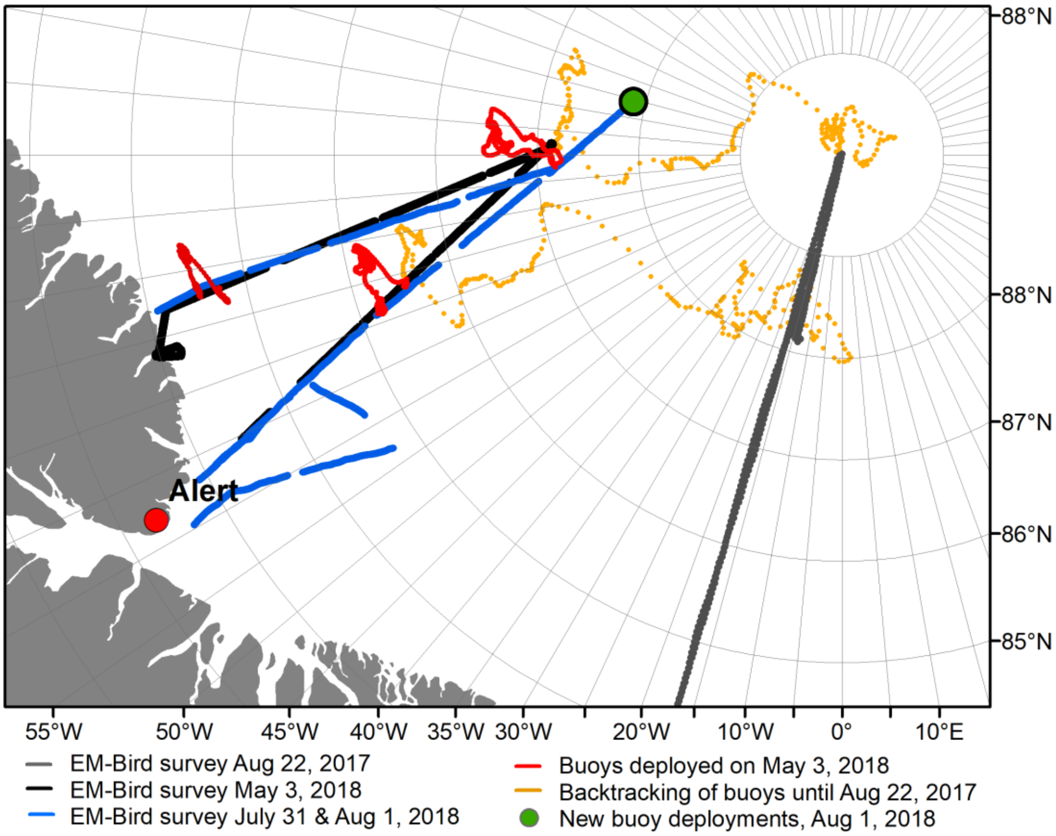

Fig: EM-Bird surveys carried out on July 31st and August 1st 2018. In addition, earlier measurements made in May 2018 and August 2017 are shown together with pathways of virtual and real buoys connecting earlier thickness observations with observations obtained during ICEBIRD.

August 02, 2018

Survey activity planned for an area northeast of CYLT. Here, relative humidity at surface level was predicted to be moderate compared to alternate destinations (ECWMF forecast). However, low ceiling and fog in the survey area did not allow EM-bird deployment and operation. Due to an abrupt weather change at CYLT, flight was interrupted after 1.5 hours and aircraft returned back home.

Date	Route	Type	Air Time	Flight time	Instruments
Aug 02-2018	CYLT-CYLT	Survey flight	2.2	2.7	None

August 03, 2018

Ferry flight from CYLT to BGNO in the morning. Unloading at BGNO.

Date	Route	Type	Air Time	Flight time	Instruments
Aug 03-2018	CYLT-BGNO	Ferry flight	2.5	2.9	None

August 04, 2018

Survey flight north of Greenland up to 84°N. North of 84°N fog and low ceiling limited survey activity.

Date	Route	Type	Air Time	Flight time	Instruments
Aug 04-2018	BGNO-BGNO	Survey flight	4.6	5.1	EM-Bird, laserscanner, camera

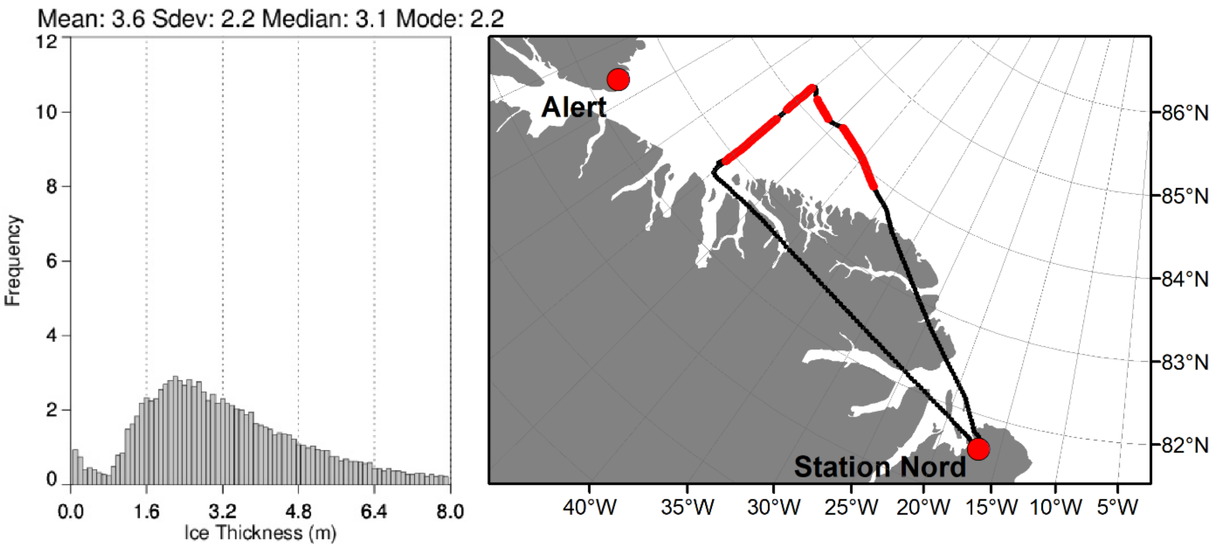

Fig: Sea ice thickness histogram (left) and survey area (right) for flight date.

August 05, 2018

No flight day due to unsatisfactory weather conditions.

Aug 06, 2018

Flight to the north of Station Nord. Fog at 1000 ft and low visibility made EM-Bird, camera and laserscanner operation impossible. Flight to 86° N and return to Station Nord.

Date	Route	Type	Air Time	Flight time	Instruments
Aug 06-2018	BGNO-BGNO	Survey flight	3.2	3.7	None

August 07, 2018

Survey flight over fast ice in the Independence Fjord and near Princess Dagmar Island. Survey over pack ice was limited due by weather conditions

Date	Route	Type	Air Time	Flight time	Instruments
Aug 07-2018	BGNO-BGNO	Survey flight	2.5	2.9	Laserscanner, EM-Bird, camera

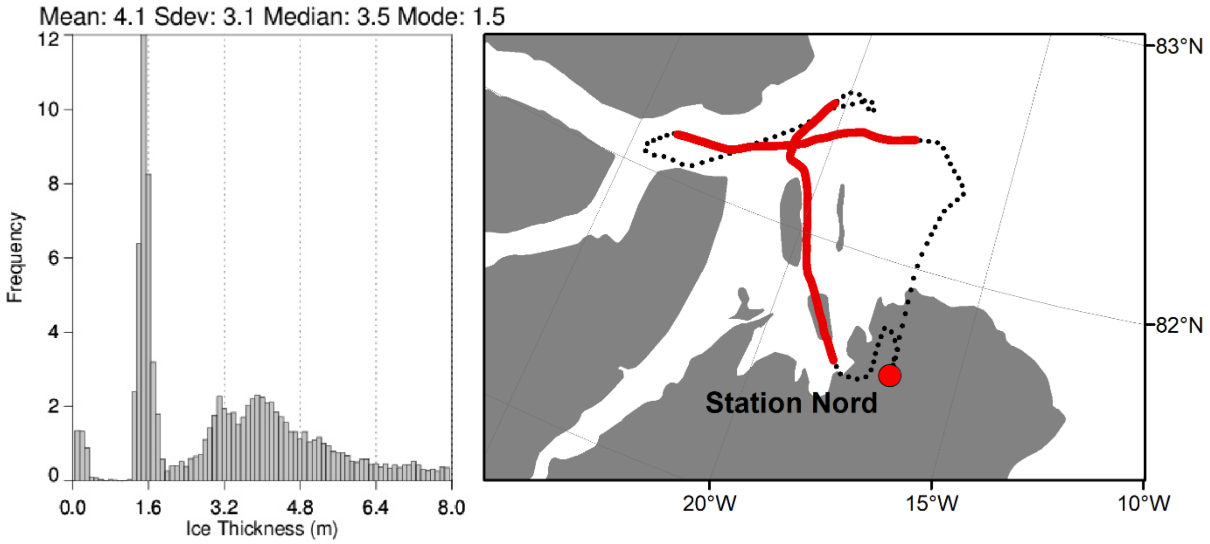

Fig: EM-Bird surveys carried out on August 07th in the Independence Fjord and near Princess Dagmar Islands. Survey activities are a continuation of thickness measurements obtained in the same area in 2016.

August 08-10, 2018

No survey activities due to low cloud level and fog banks near Alert and in survey area.

August 11, 2018

Low ceiling and fog limited survey activities in the North. Hence, EM-thickness measurements were made in the vicinity of Station Nord only.

Date	Route	Type	Air Time	Flight time	Instruments
Aug 11-2018	BGNO-BGNO	Survey flight	6.2	6.7	Laserscanner, EM-Bird, camera

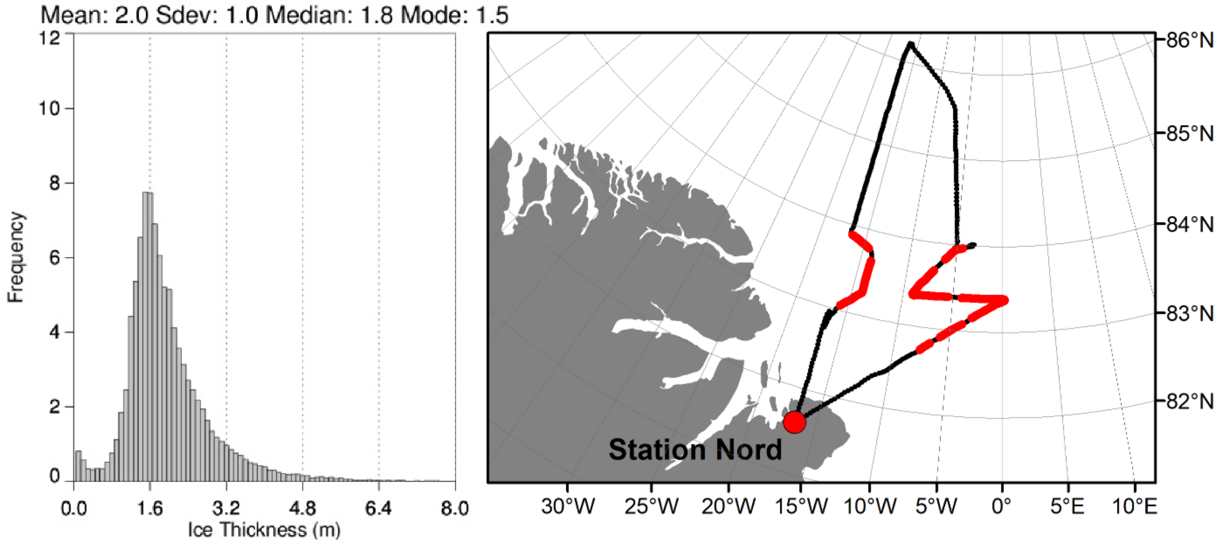

Fig: Sea ice thickness histogram (left) and survey area (right) for flight date.

August 12, 2018

Light winds and a change in wind direction led to a reduced relative humidity at surface north of 84°N. Hence, survey activities from the previous day were continued up to 87°N. Thickness measurements were interrupted several times due to low ceiling and fog along flight path.

Date	Route	Type	Air Time	Flight time	Instruments
Aug 12-2018	BGNO-BGNO	Survey flight	5.9	6.4	Laserscanner, EM-Bird, camera

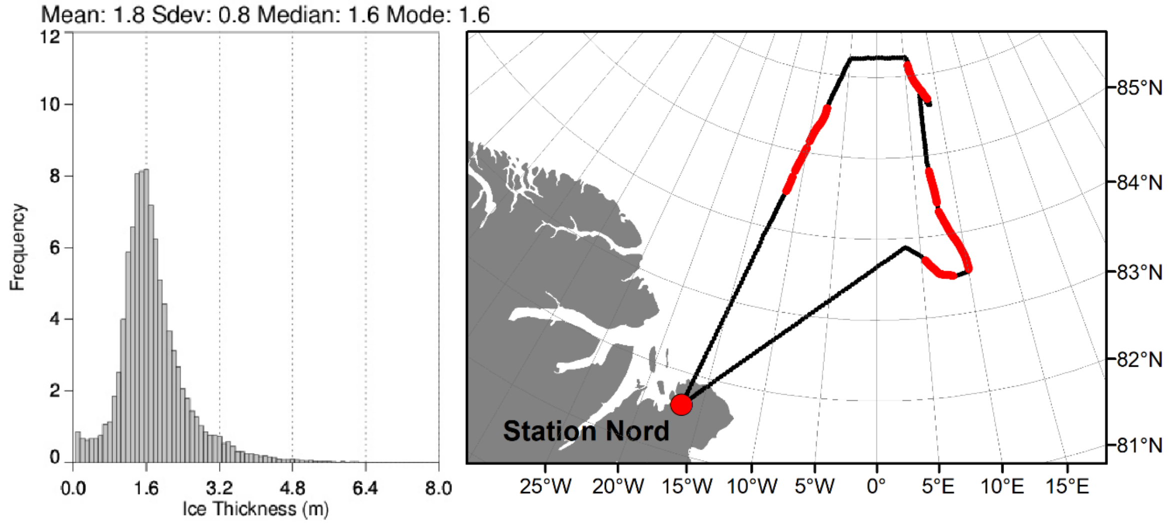

Fig: Sea ice thickness histogram (left) and survey area (right) for flight date.

August 13, 2018

Survey flight along 25°W towards 87°N. Low ceiling and fog limited survey activities north of 87°N. At 87°N/23W° a CALIB buoy was deployed (IMEI: 4130) at the end of the survey line. On the way back to station Nord, survey was continued until 85°N, 10°E. Back at Station Nord, a laser calibration was performed over the runway.
A second short flight in the afternoon was used for instrument tests and monitoring of sea ice conditions and infrastructure in the vicinity of the station with local authorities.

Date	Route	Type	Air Time	Flight time	Instruments
Aug 13-2018	BGNO-BGNO	Survey flight	6	6.5	Laserscanner, EM-Bird, camera, CALIB buoy
Aug 13-2018	BGNO-BGNO	Test flight	0.8	1	EM-Bird

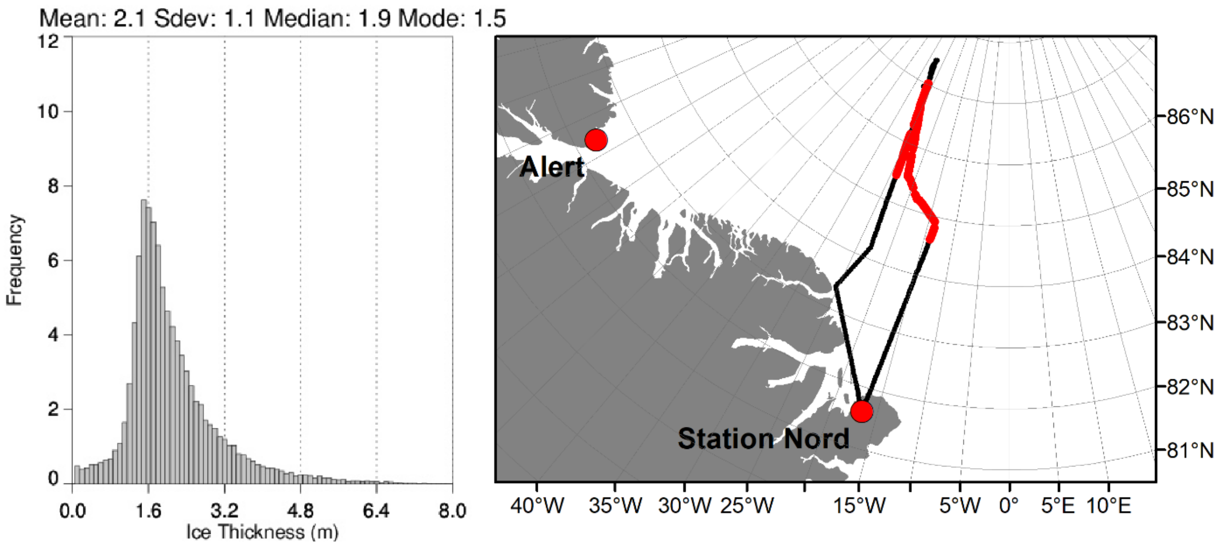

Fig: Sea ice thickness histogram (left) and survey area (right) for flight date.

August 14, 2018

End of surveying activity. Loading of the aircraft in the morning. Due to low ceiling at ENSB, departure from BGNO was postponed to next day.

August 15, 2018

Ferry flight to Longyearbyen. End of campaign and deintegration at ENSB on the following day. Campaign activities were followed by transport flights between ENSB and BGNO.

Date	Route	Type	Air Time	Flight time	Instruments
Aug 15-2018	BGNO-ENSB	Ferry flight	2.4	2.8	None

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[1] C. Haas, J. Lobach, S. Hendricks, L. Rabenstein, and A. Pfaffling. Helicopter-borne measurements of sea ice thickness, using a small and lightweight, digital EM system. *Journal of Applied Geophysics*, 67(3):234–241, 2009.

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