

Campaign report

September 2017

TIFAX 2017 Campaign

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



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TIFAX 2017 campaign

Date: 10. August – 02 September 2017
Stations: Station Nord, Alert
Aircraft: Polar 6
Expedition permit: C-17-21
Crew: Manuel Sellmann (engineer), Jan Rohde (engineer), William Dyer (chief pilot), Benjamin Leduc-Hebert (second pilot), Kevin Riehl (mechanic), Thomas Krumpfen (lead scientist)

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1.0 Background

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, Meier et al., 2014) and its mean thickness has decreased by 0.58 m +/- 0.07 m per decade over the period 2000 - 2012 (Lindsay et al., 2015). The thinning of sea ice is accompanied by an increase of ice drift velocity (Spren et al., 2011), deformation (Rampal et al., 2009) 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 (Vravus et al., 2012). 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 2016 during several aircraft (PAMARCMIP, TIFAX) and Polarstern campaigns. The first aim of the TIFAX 2017 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 number 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 extend 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 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. In addition to measurements over sea ice, laser scanner flights over glaciers were made within the framework of MABANG.

1.1 Weather and ice information

Weather and sea ice information are obtained via FTP from the German Weather Service (DWD). The DWD offers meteograms for different locations, cloud cover forecasts (78 h) from different models and temperature, humidity and pressure charts. Prior flight, weather information is used to locate sites suitable for low level flight operations.

1.2 Flight operations

Flights were made towards one or more pre-defined points of return. The point of return and profile length were chosen according to

1. fuel capacity
2. weather condition
3. ice condition

1.3 Flight hours

Date	Route	Type	Air Time	T/O Time	Ldg Time
Aug-03-2017	EDDW- EDDW	Test flight	1,70	13:53	15:35
Aug 10-2017	EDDW-ENTC	Ferry flight	5,30	07:13	12:29
Aug 11-2017	ENTC-ENSB	Ferry flight	2,70	08:27	11:10
Aug 12-2017	ENSB-BGNO	Ferry flight	2,30	17:46	20:06
Aug 13 2017	BGNO-BGNO	Survey flight	2,70	14:25	17:16
Aug 19 2017	BGNO-BGNO	Survey flight	7,30	11:21	18:36
Aug 20 2017	BGNO-BGNO	Survey flight	6,20	12:00	18:12
Aug 21 2017	BGNO-BGNO	Survey flight	3,10	10:07	13:10
Aug 22 2017	BGNO-BGNO	Survey flight	6,80	10:11	16:58
Aug 22 2017	BGNO-BGNO	Survey flight	0,60	20:01	20:45
Aug 24 2017	BGNO-ENSB	Ferry flight	2,20	10:30	12:46
Aug 25 2017	ENSB-CYLT	Ferry flight	3,90	12:59	16:53
Aug 28 2017	CYLT-CYLT	Survey flight	0,90	13:54	14:46
Aug 29 2017	CYLT-BGNO	Ferry flight	2,00	19:24	21:23
Aug 30 2017	BGNO-BGNO	Survey flight	6,90	14:24	21:20
Aug 31 2017	BGNO-BGNO	Survey flight	0,30	14:25	14:44
Sep 01 2017	BGNO-ENSB	Ferry flight	2,10	10:40	12:44
Sep 02 2017	ENSB-ENTC	Ferry flight	5,00	06:54	11:54
Sep 02 2017	ENTC-EDDW	Ferry flight	3,30	12:42	16:06

Survey hours 36,5 h

Ferry hours 28,9 h

Fuel consumption Alert 2.250 liters

Fuel consumption Station Nord 21.751 liters

2.0 Daily report



Fig: Crew of Polar 6 and Station Nord before departue on Sep. 01, 2017

2.1 Aug 10-11, 2017

After integration of the EM-Bird system in EDDW (Bremen), the ferry flight to ENSB (Longyearbyen) was made with an overnight stay in ENTC (Tromsoe). After arrival on August 11 system checks were made and EM-Bird was mounted.

2.2 Aug 12, 2017

Further system checks and were made in the morning. In the early afternoon, ferry flight to BGNO (Station Nord) was performed.

2.3 Aug 13, 2017

Flight North of Greenland with EM-Bird and Laserscanner. Low visibility and ceiling limited survey activities to areas below 84°N.

Date	Route	Type	Air time	T/O Time	Ldg Time
Aug 13 2017	BGNO-BGNO	Survey flight	2,70	14:25	17:16

Instrumentation: Basic meteorology, INS/GPS, EM-Bird, Canon Camera, Laser Scanner

Comments: None

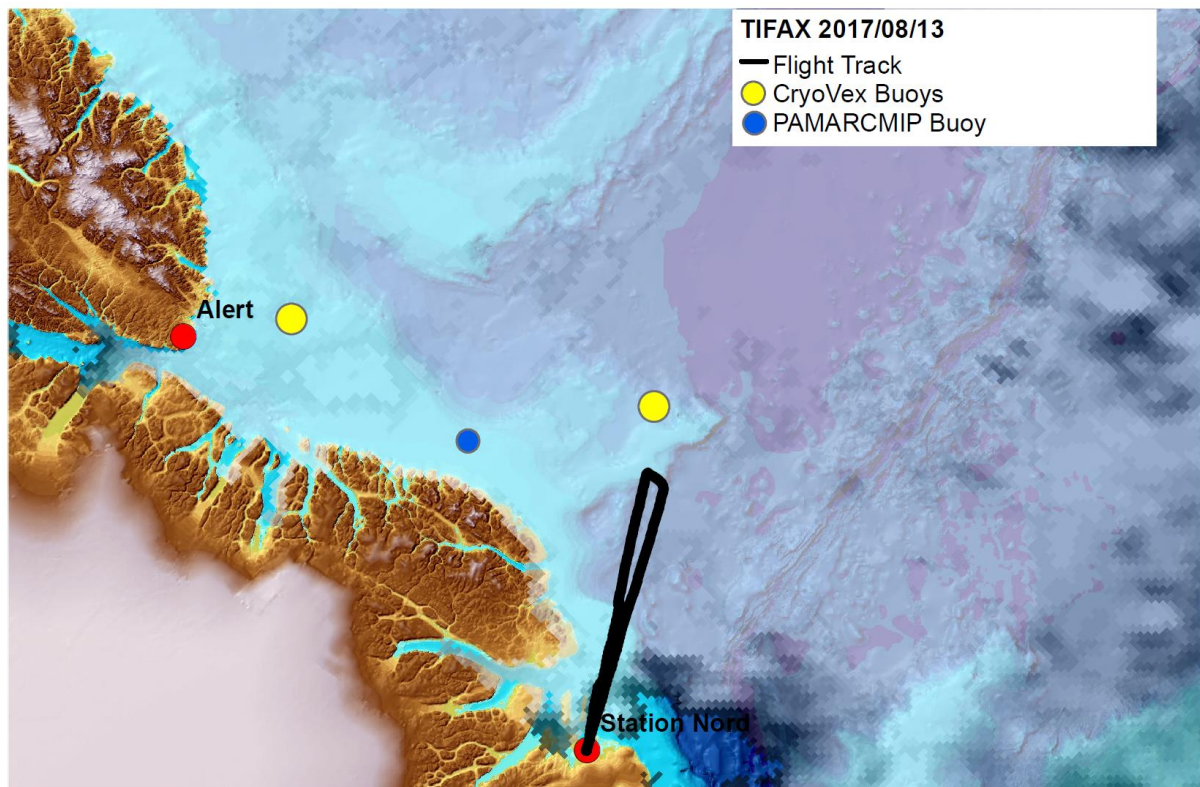


Fig: Flight track and location of buoys deployed in spring 2017 during PAMARCMIP and CryoVex

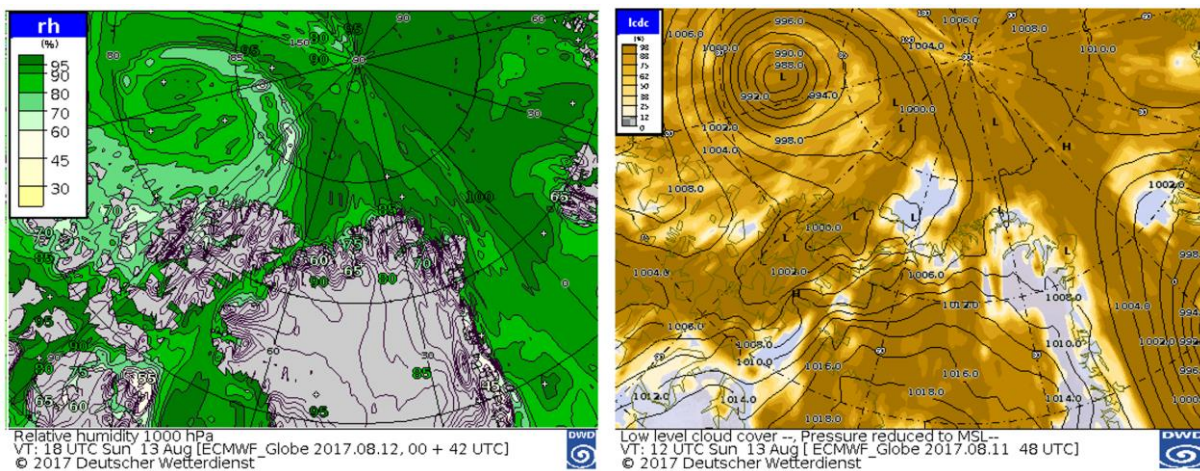


Fig: Weather forecast (August 13, 2017, relative humidity and cloud coverage at low level, Source: DWD/ECMWF)

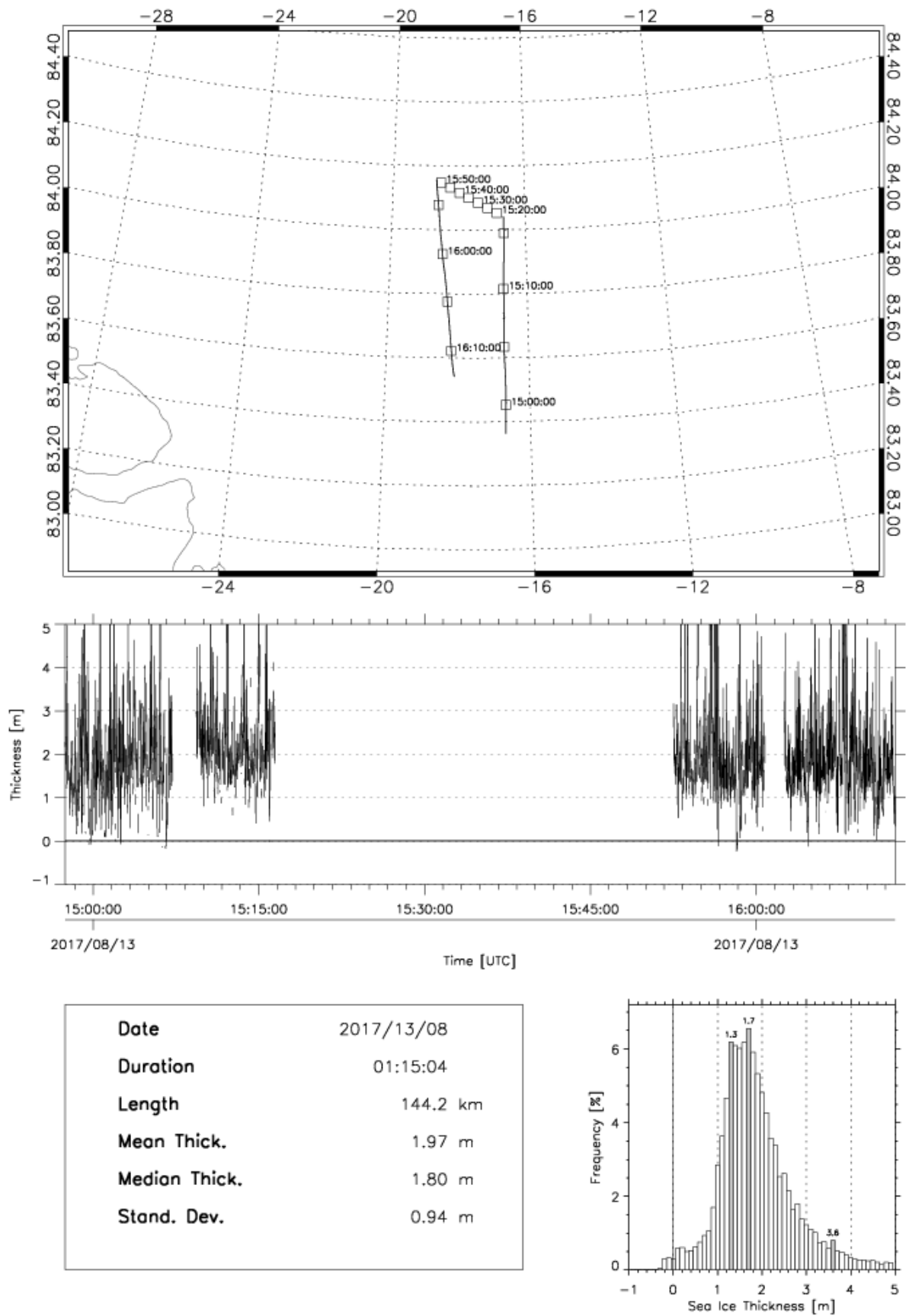


Fig: EM sea ice thickness measurements obtained during flight (top: geographical location of measurements, center: thickness profile, bottom: sea ice thickness histogram).

2.4 Aug 14, 2017

Snow fall, runway closed

2.5 Aug 15, 2017

Snow fall, runway closed.

2.6 Aug 16, 2017

Snow fall, runway closed

2.7 Aug 17, 2017

Soft ground. Runway closed.

2.8 Aug 18, 2017

Soft ground. Runway closed

2.9 Aug 19, 2017

Flight along former CryoVex surveying sites (April 2017, grey circles in Fig.) with EM-Bird and laserscanner. Drift of CryoVex sites were marked with 2 buoys deployed during field work in spring (yellow circles in Fig.). The most western CryoVex Buoy was successfully backup with a CALIB buoy (blue circle). Another CALIB was deployed at the northern edge of the poleward directed second part of the flight track (87.5°N).

Date	Route	Type	Air time	T/O Time	Ldg Time
Aug 19 2017	BGNO-BGNO	Survey flight	7,30	11:21	18:36

Instrumentation: Basic meteorology, INS/GPS, EM-Bird, Canon Camera, Laser Scanner

Other activities: 2 CALIB buoy deployments (IMEI: *9680 [Link: Deployment Report](#), [Link: Life Map](#), and *8630 [Link: Deployment Report](#), [Link: Life Map](#))

Comments: Temporary laser scanner failures

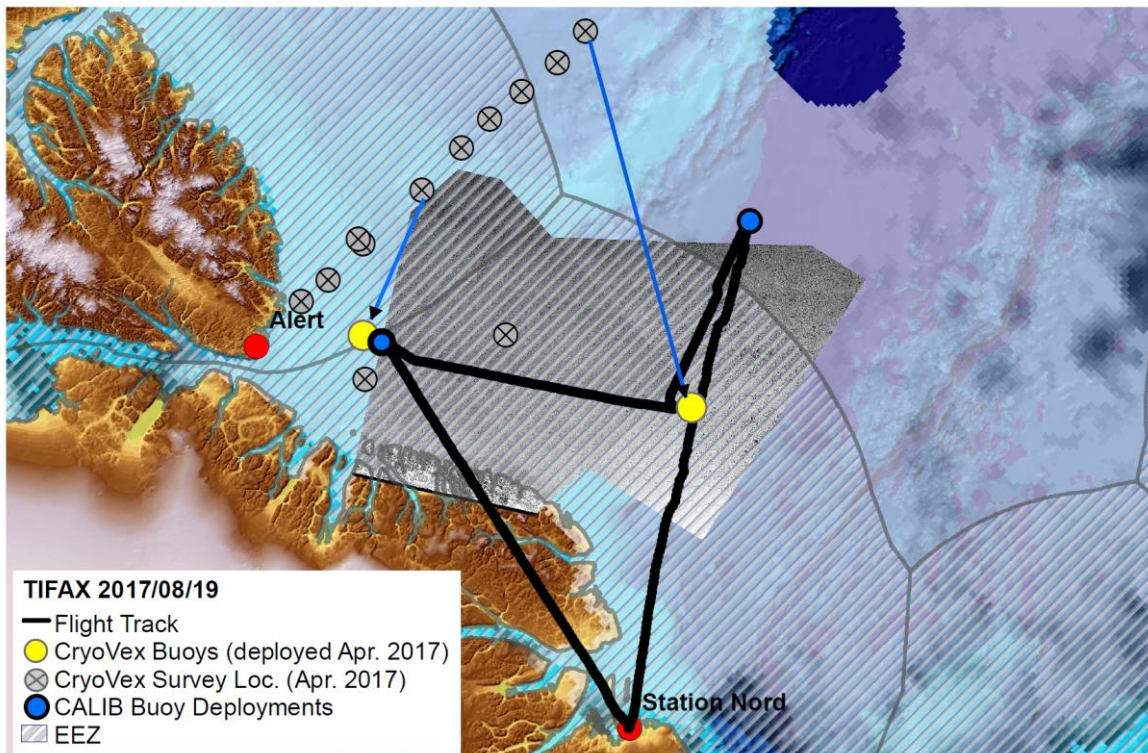


Fig: Flight track and location of buoys deployed in spring 2017 during PAMARCMIP and CryoVex and CALIB replacements made during TIFAX 2017

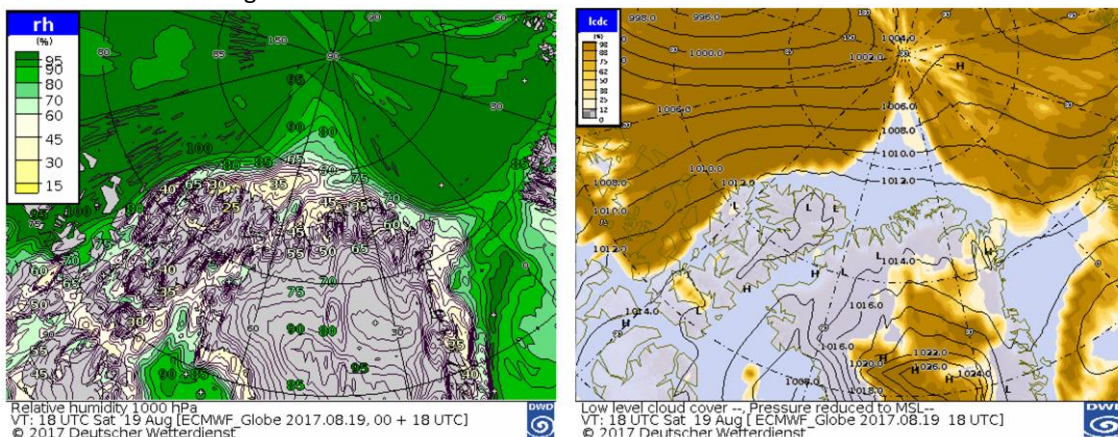


Fig: Weather forecast (August 19, 2017, relative humidity and cloud coverage at low level, source: DWD/ECMWF)

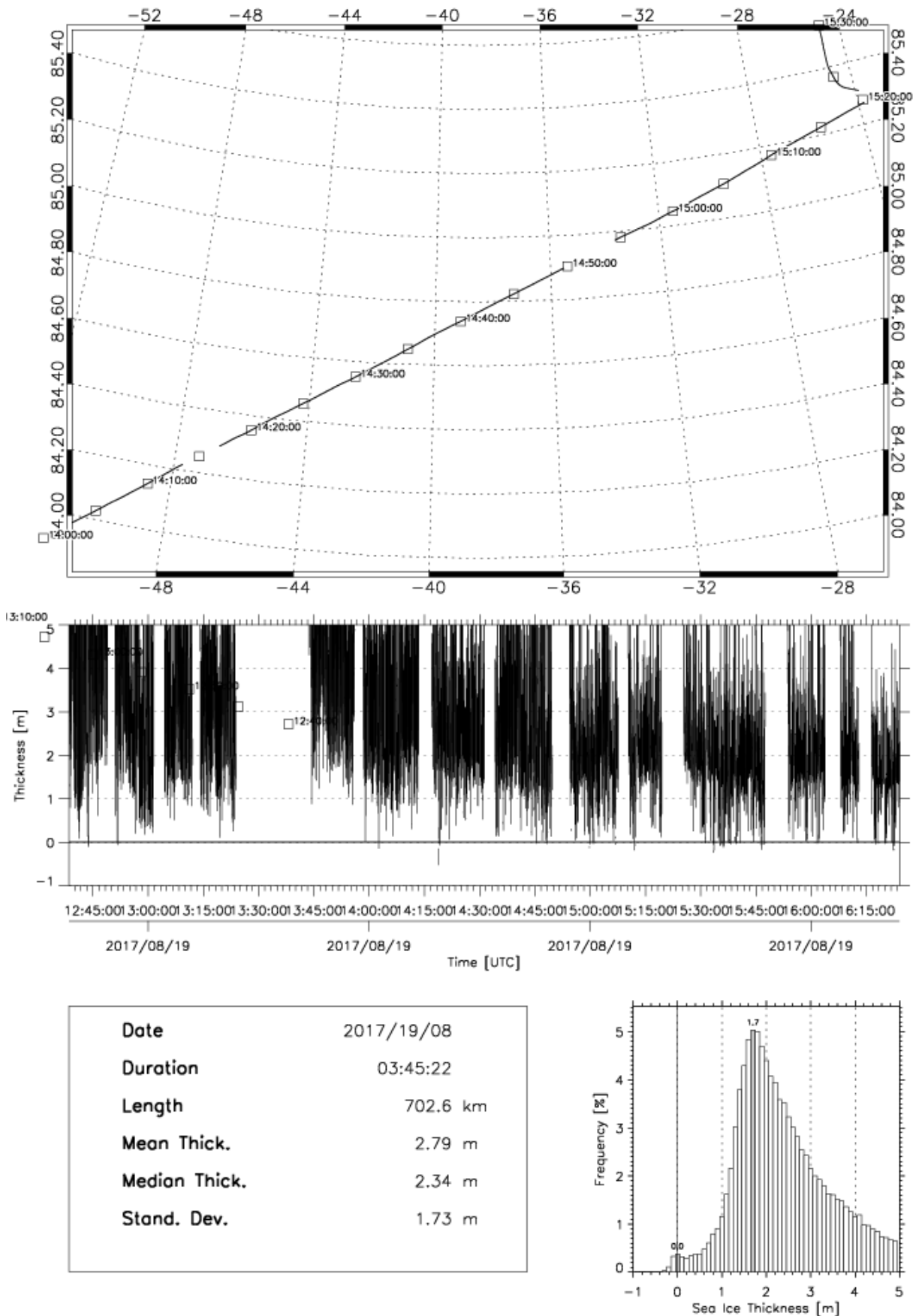


Fig: EM sea ice thickness measurements obtained during flight (top: geographical location of measurements, center: thickness profile, bottom: sea ice thickness histogram).

2.10 Aug 20, 2017

EM-Bird and laserscanner survey flight across and along Fram Strait. Low visibility and ceiling limited flight operations to an area south of 82.5° N.

Date	Route	Type	Air time	T/O Time	Ldg Time
Aug 20 2017	BGNO-BGNO	Survey flight	6,20	12:00	18:12

Instrumentation: Basic meteorology, INS/GPS, EM-Bird, Canon Camera, Laser Scanner
 Comments: None

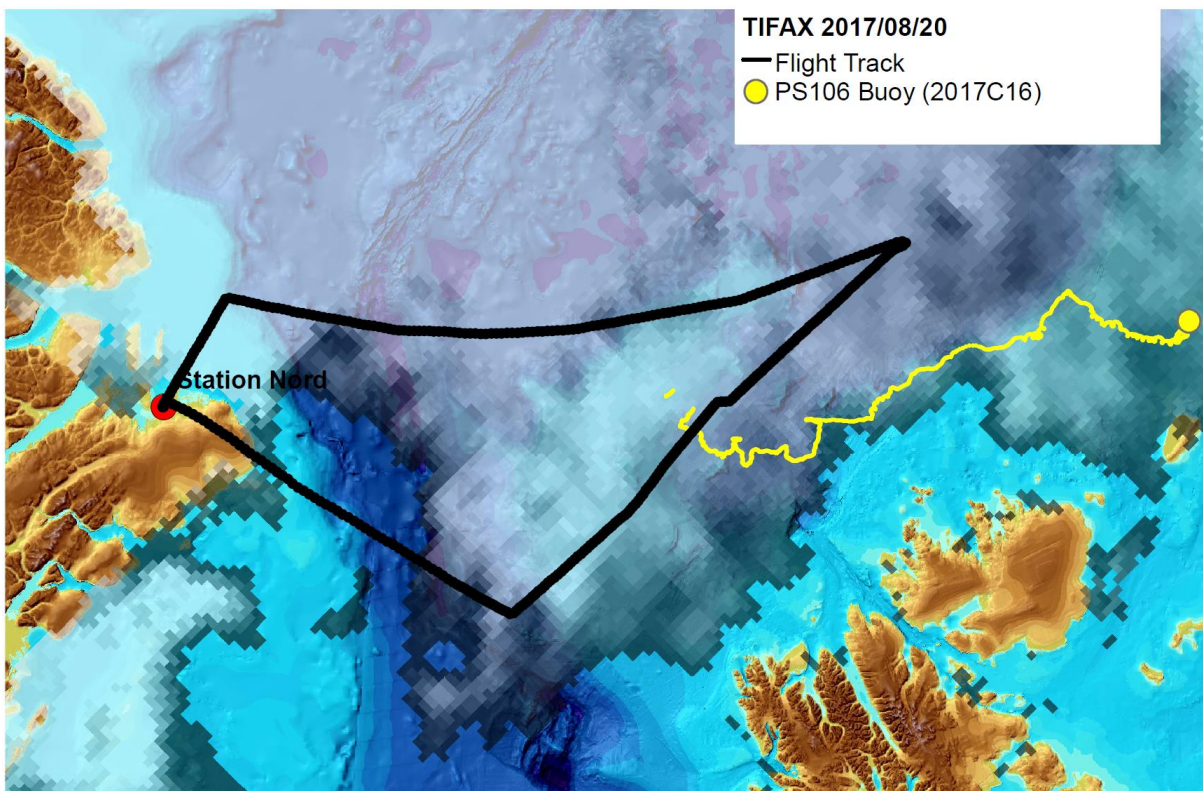


Fig: Flight track across and along Fram Strait

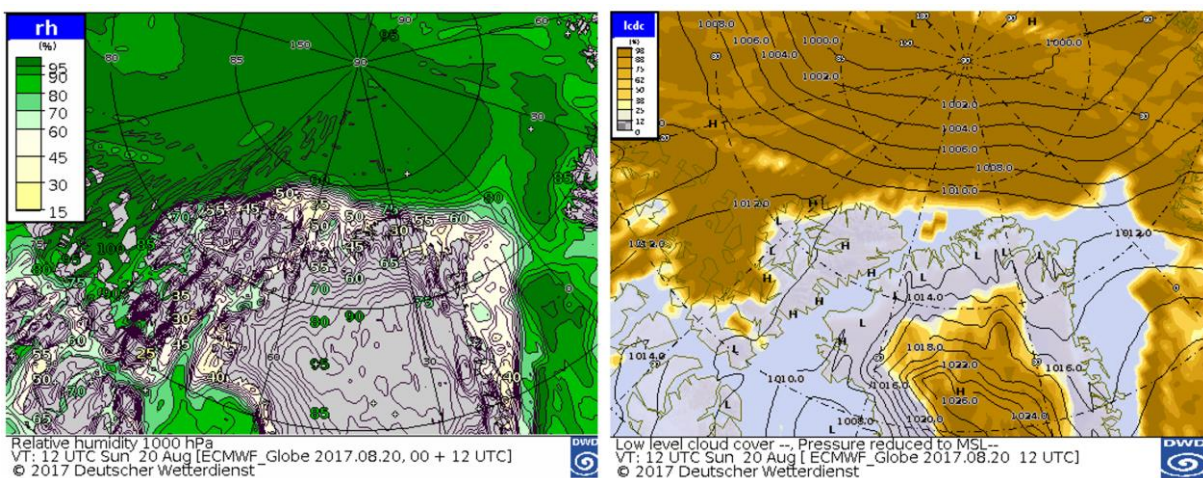


Fig: Weather forecast (August 20, 2017, relative humidity and cloud coverage at low level)

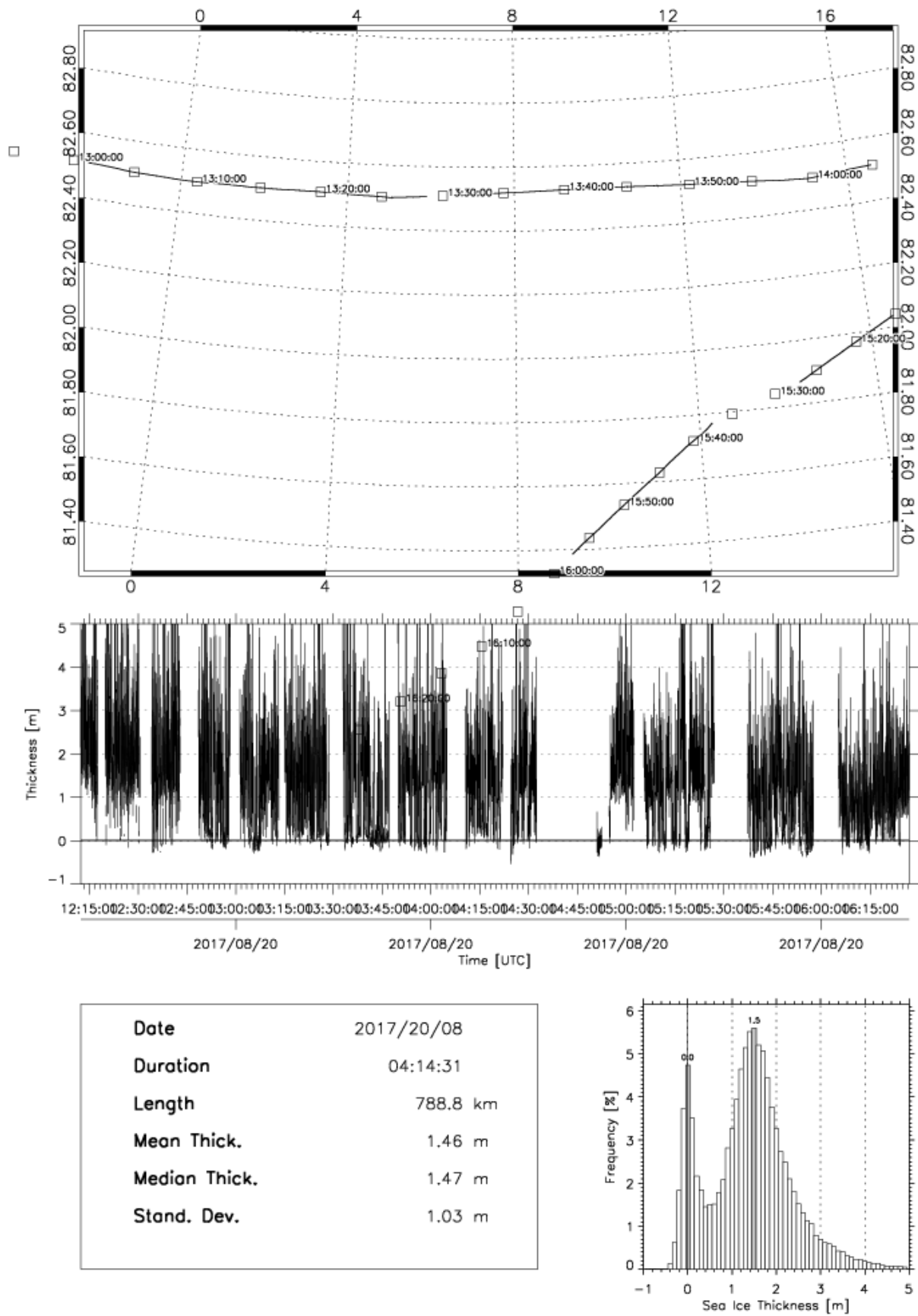


Fig: EM sea ice thickness measurements obtained during flight (top: geographical location of measurements, center: thickness profile, bottom: sea ice thickness histogram).

2.11 Aug 21, 2017

MABANG laser scanner survey over glacier near 79°N. Low contrast and ceiling limited survey flights in eastern MABANG area.

Date	Route	Type	Air time	T/O Time	Ldg Time
Aug 21 2017	BGNO-BGNO	Survey flight	3,10	10:07	13:10

Instrumentation: Basic meteorology, INS/GPS, Canon Camera, Laser Scanner

Comments: None

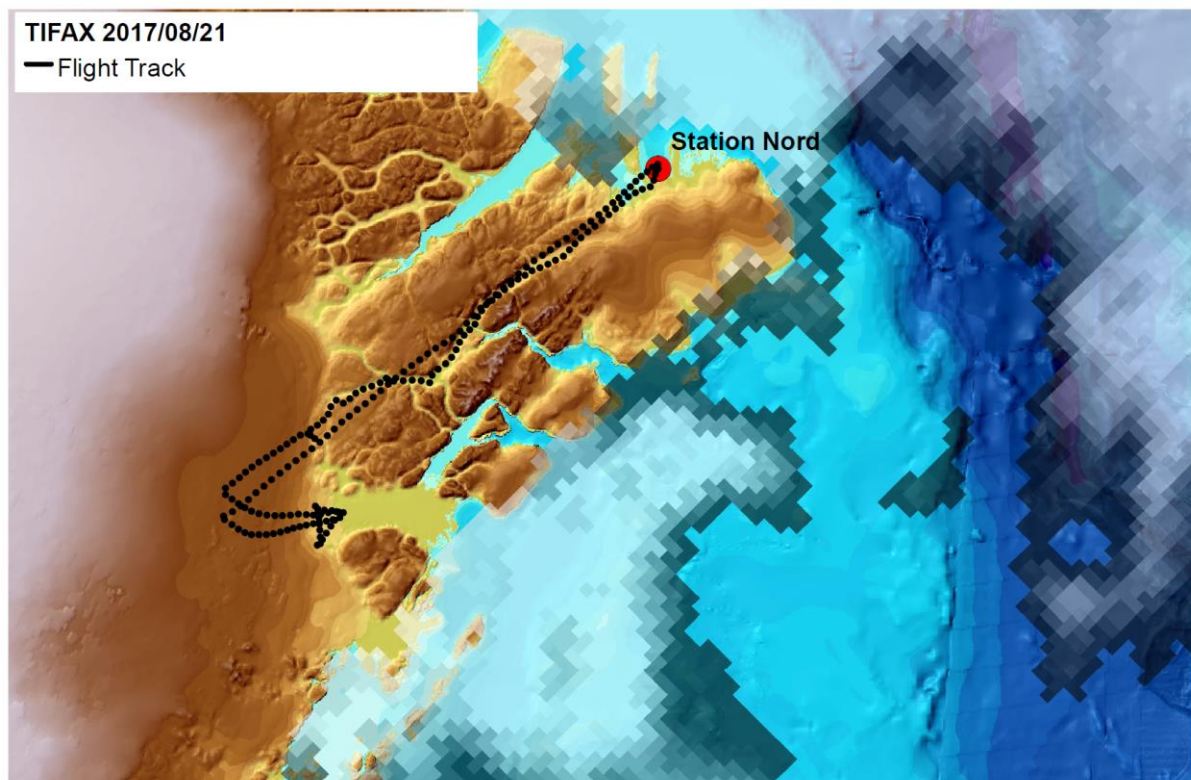


Fig: Flight track across and along Fram Strait

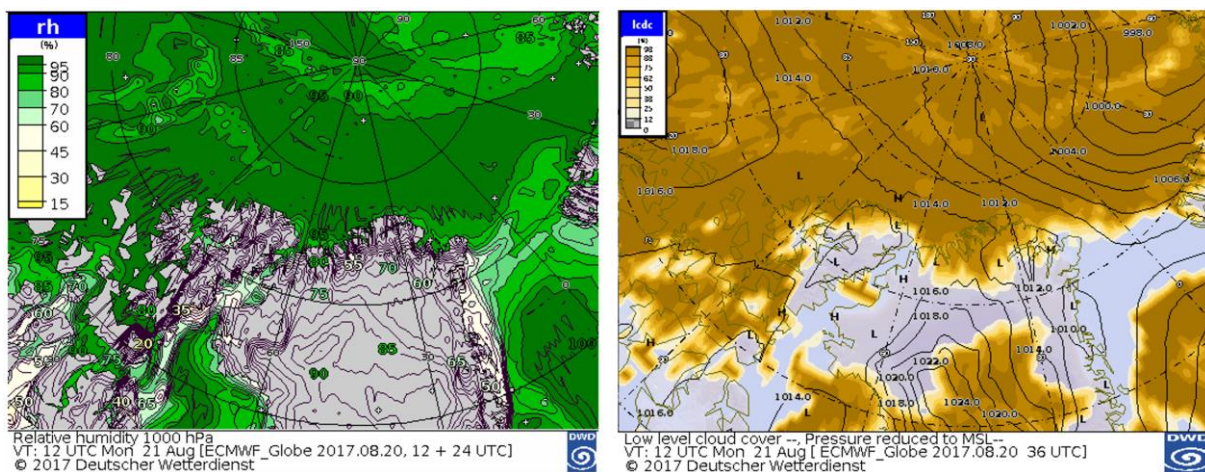


Fig: Weather forecast (August 21, 2017, relative humidity and cloud coverage at low level)

2.12 Aug 22, 2017

Stabile weather conditions forecasted for BGNO with heigh ceiling and westerly winds, with a small band of relatively low humidity and high ceiling predicted for the area between North Pole and 87.5°N. Hence, a flight towards North Pole was made extending the northward directed profile obtained on Aug. 19th. In the evening, a short survey flight was performed with station crew members in the surrounding of the station.

Date	Route	Type	Air time	T/O Time	Ldg Time
Aug 22 2017	BGNO-BGNO	Survey flight	6,80	10:11	16:58
Aug 22 2017	BGNO-BGNO	Survey flight	0,60	20:01	20:45

Instrumentation: EM-Bird, Basic meteorology, INS/GPS, Canon Camera, Laser Scanner

Comments: Ferry out to 87°N at high altitude. EM-Bird measurements were made only between 87°N and 89°N. At North Pole, CALIB buoy (IMEI *6690, [Link: Deployment Report](#), [Link: Life Map](#)) was deployed and laser scanner measurements were conducted.

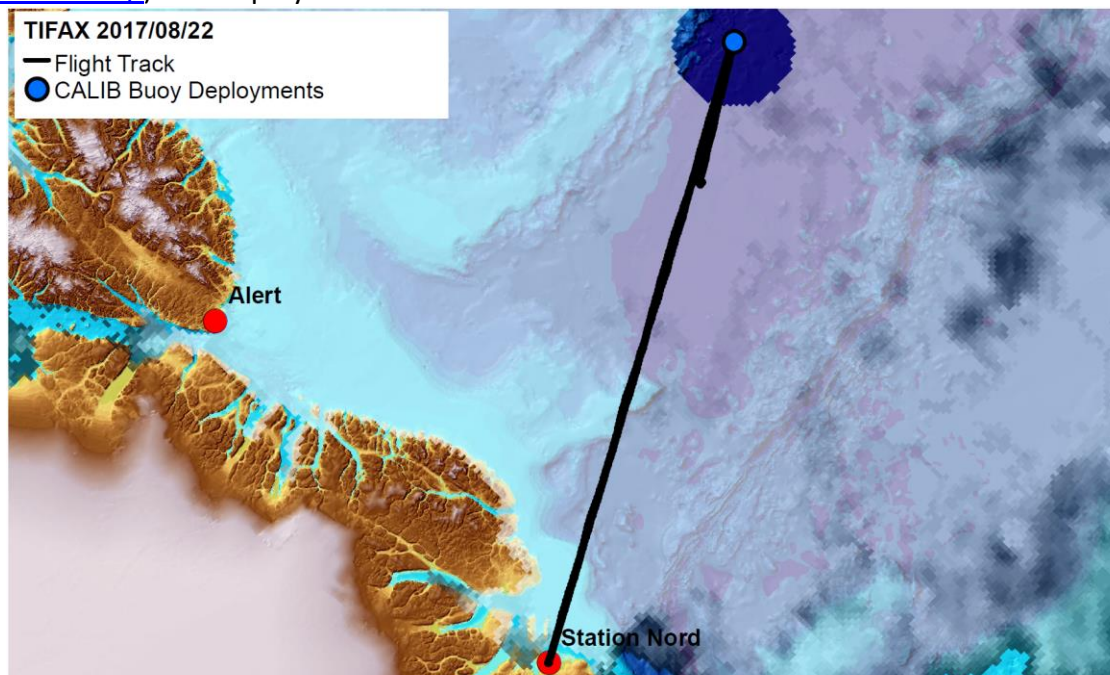


Fig: Flight track

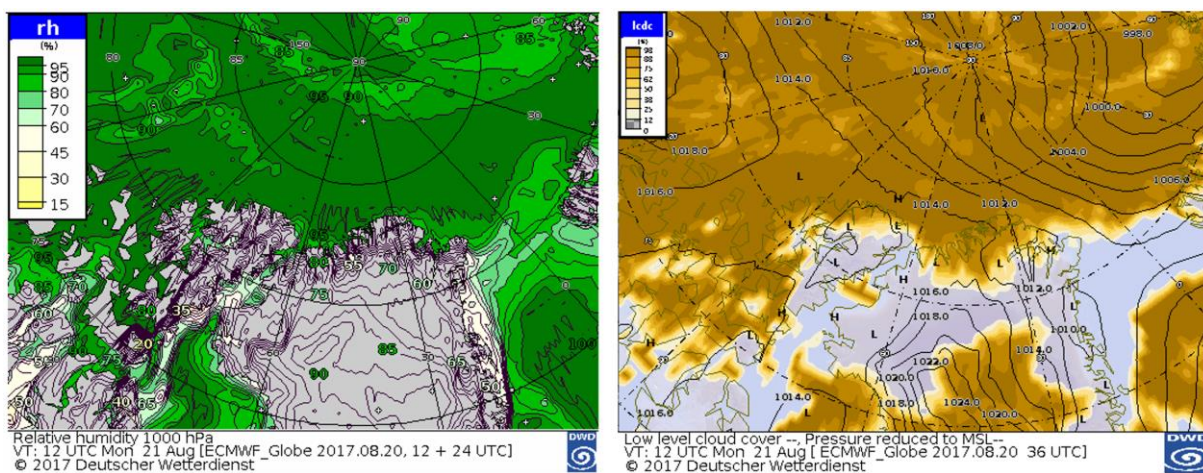


Fig: Weather forecast (August 22, 2017, relative humidity and cloud coverage at low level)

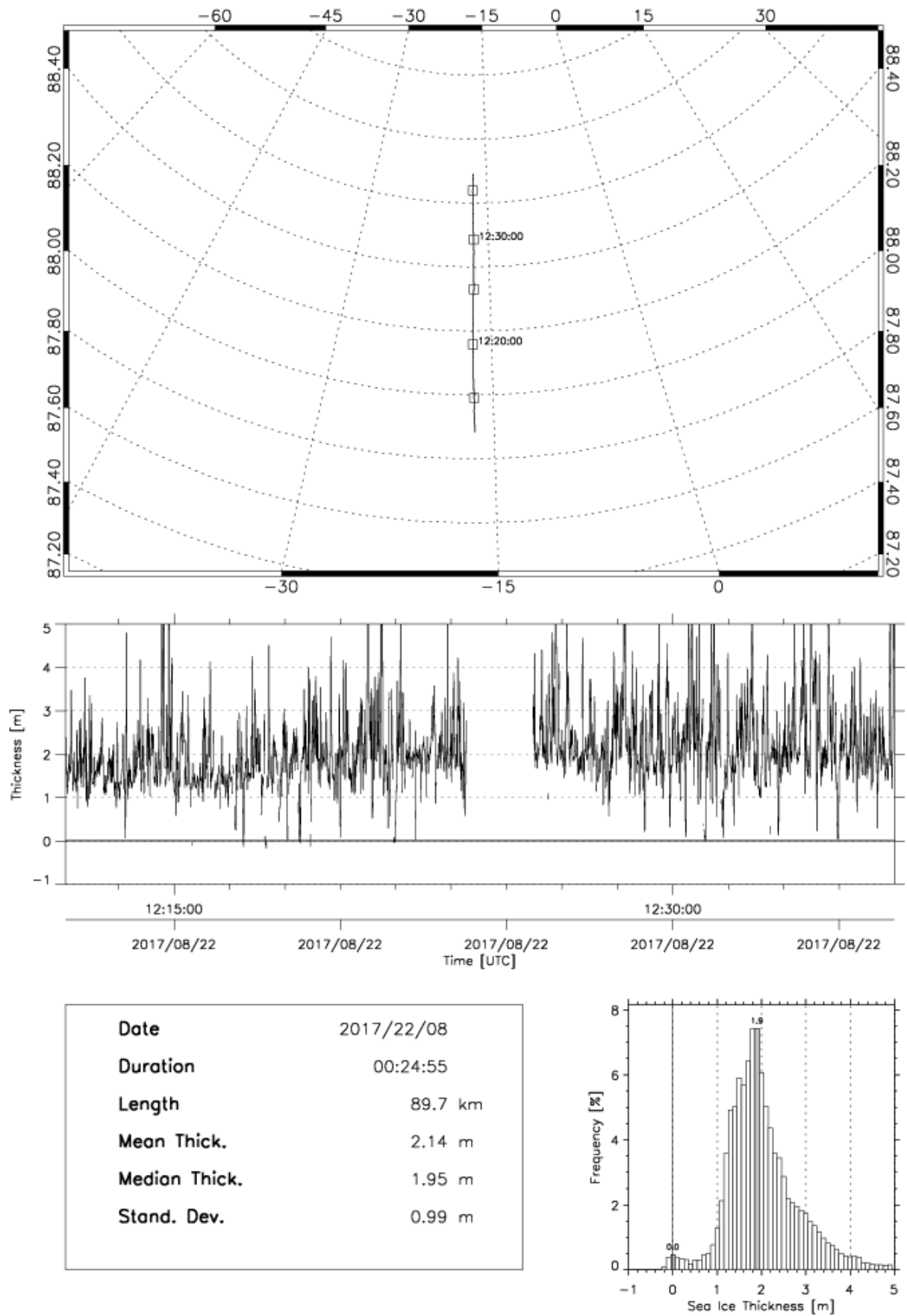


Fig: EM sea ice thickness measurements obtained during flight (top: geographical location of measurements, center: thickness profile, bottom: sea ice thickness histogram).

2.13 Aug 23, 2017

Low visibility and cloud cover forecasted for the surrounding of the station and over sea ice. Hence, no surveying activities.

2.14 Aug 24, 2017

Snowfall and low ceiling forecasted. To avoid closure of runway, early take off from BGNO to ENSB at 1003 UTC. Direct ferry to CYLT was not possible, since tower in CYLT only opens at 1200 UTC.

Date	Route	Type	Air time	T/O Time	Ldg Time
Aug 23 2017	BGNO-ENSB	Ferry flight	2,20	10:03	12:46

2.15 Aug 25, 2017

Ferry from ENSB to CYLT at 1259 UTC.

2.16 Aug 26, 2017

CYLT: Airport closed during weekend

2.17 Aug 27, 2017

CYLT: Airport closed during weekend

2.18 Aug 28, 2017

Survey flight north of Alert that was interrupted after 20 minutes due to fog and icing.

Date	Route	Type	Air time	T/O Time	Ldg Time
Aug 28 2017	CYLT-CYLT	Survey flight	0,90	13:54	14:46

Instrumentation: EM-Bird, Basic meteorology, INS/GPS, Canon Camera, Laser Scanner

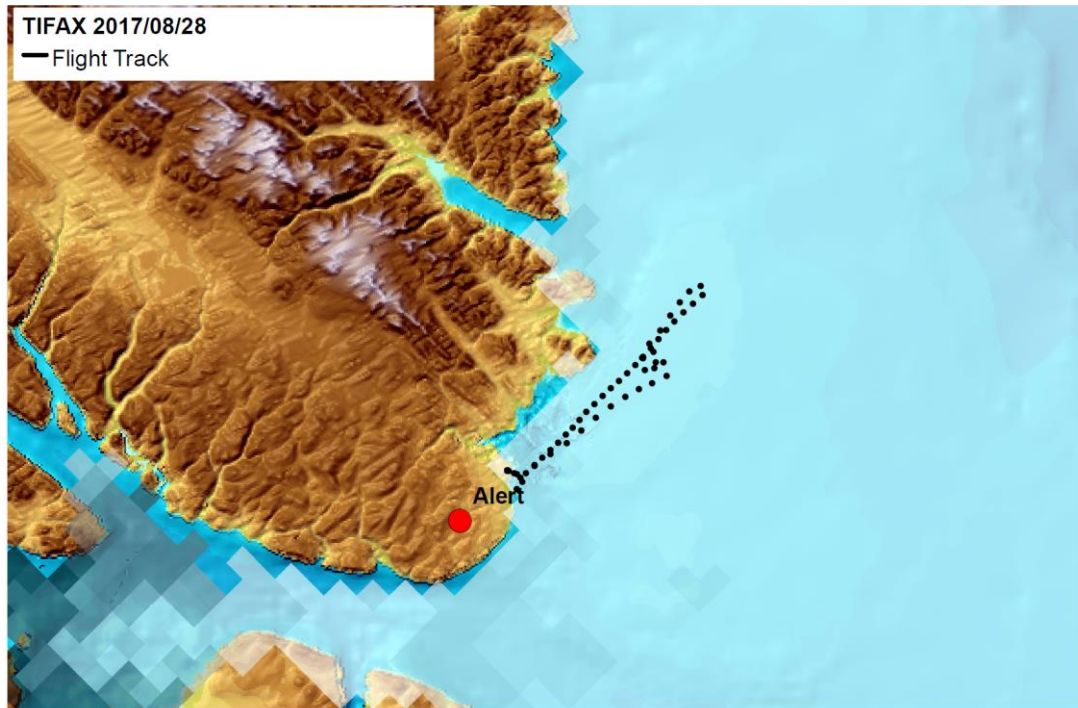


Fig: Flight track

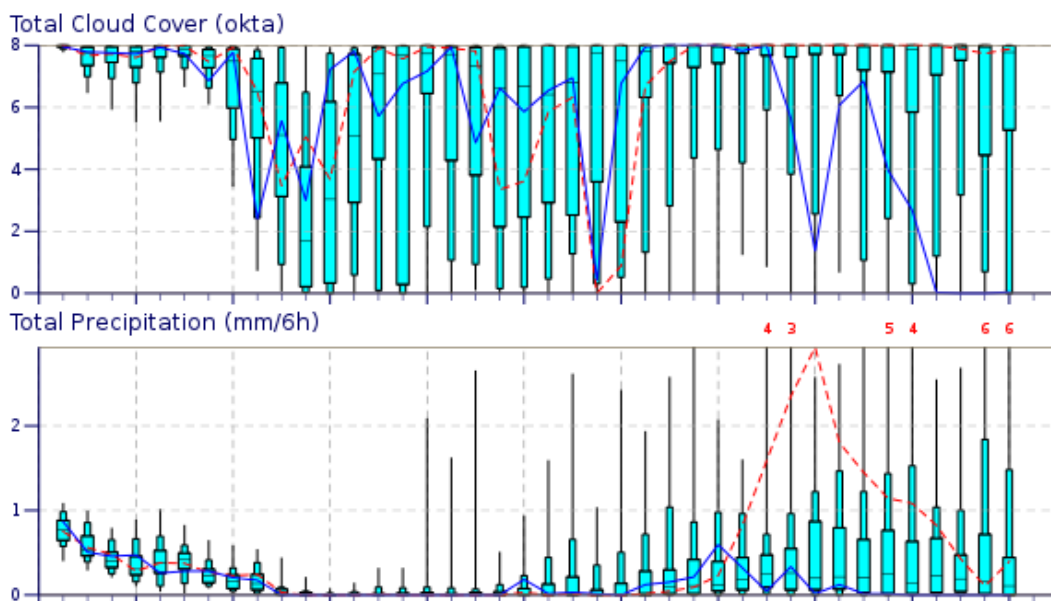
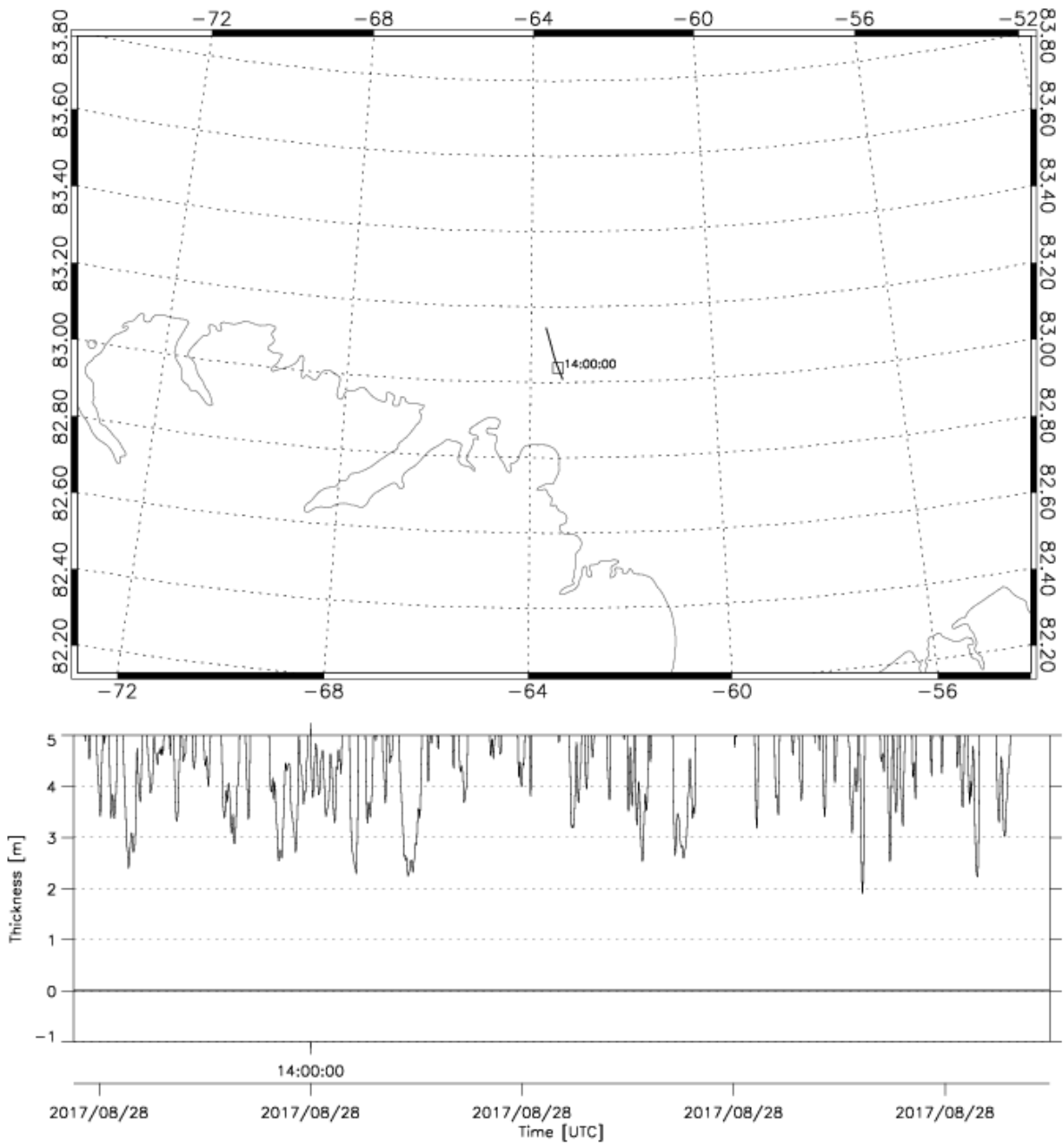
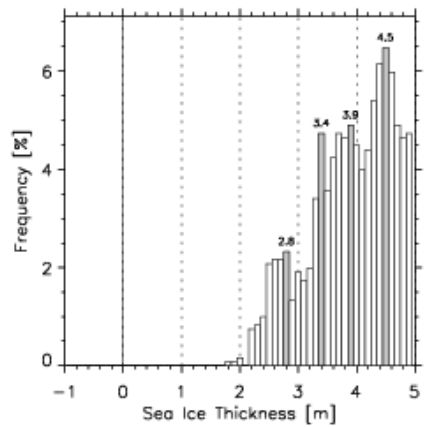


Fig: Surveying area (top) and meteogram for Alert: Light snow fall and high cloud cover predicted for upcoming days



Date	2017/28/08
Duration	00:04:36
Length	15.9 km
Mean Thick.	5.69 m
Medion Thick.	5.28 m
Stand. Dev.	2.19 m



2.19 Aug 29, 2017

Early departure from Alert back to Station Nord due strong cyclone activity north of Greenland/Canada with snow fall and icing over pack ice areas. Hence, no surveying possible for 29th and 30th August from Alert.

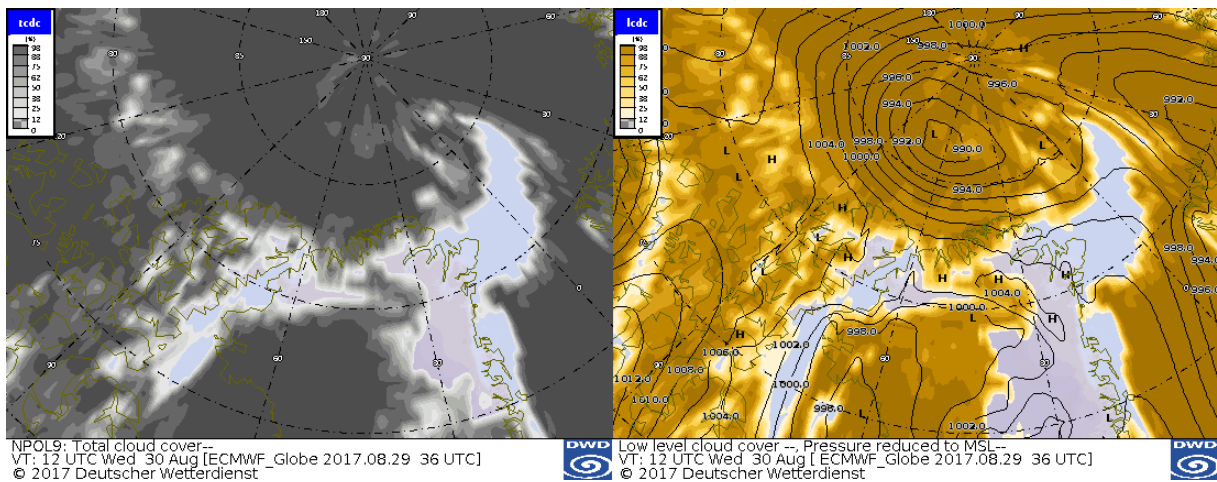


Fig: Cloud cover forecasted for 30th of August. Total cloud cover (left) and low level cloud cover (top) with isobaths.

Date	Route	Type	Air time	T/O Time	Ldg Time
Aug 29 2017	CYLT-BGNO	Ferry flight	2,00	19:24	21:23

2.20 Aug 30, 2017

MABANG laser scanner survey over glaciers.

Date	Route	Type	Air time	T/O Time	Ldg Time
Aug 30 2017	BGNO-BGNO	Survey flight	6,90	14:24	21:20

Instrumentation: Basic meteorology, INS/GPS, Canon Camera, Laser Scanner
Comments: None

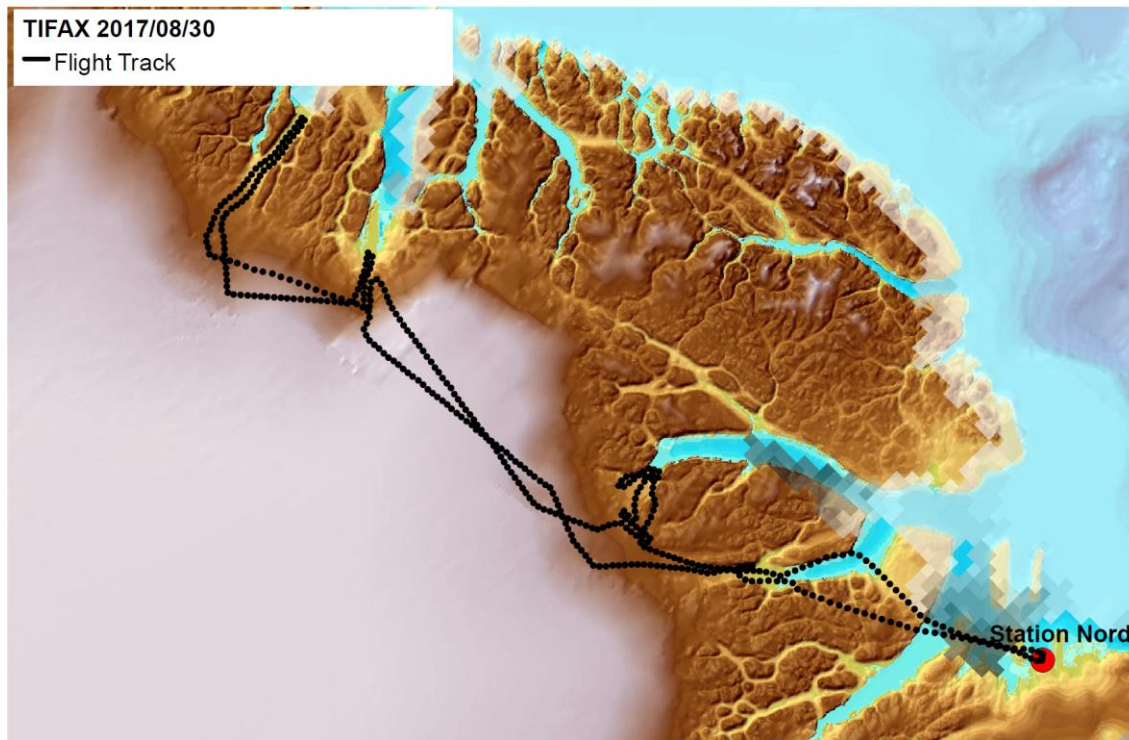


Fig: Flight track

2.20 Aug 31, 2017

Laser calibration flight over runway at Station Nord.

Date	Route	Type	Air time	T/O Time	Ldg Time
Aug 31 2017	BGNO-BGNO	Survey flight	0,30	14:25	14:44

Instrumentation: Basic meteorology, INS/GPS, Canon Camera, Laser Scanner
Comments: None

2.21 Sep 01, 2017

Ferry Flight to ENSB from BGNO. Overnight stay in ENSB

Date	Route	Type	Air time	T/O Time	Ldg Time
Sep 01 2017	BGNO-ENSB	Ferry flight	2,10	10:40	12:44

2.21 Sep 02, 2017

Ferry Flight from XXX to ENSB, end of campaign

Date	Route	Type	Air time	T/O Time	Ldg Time
Sep 02 2017	ENSB-ENTC	Ferry flight	5,00	06:54	11:54
Sep 02 2017	ENTC-EDDW	Ferry flight	3,30	12:42	16:06

3.0 Preliminary results

Summary of thickness measurements

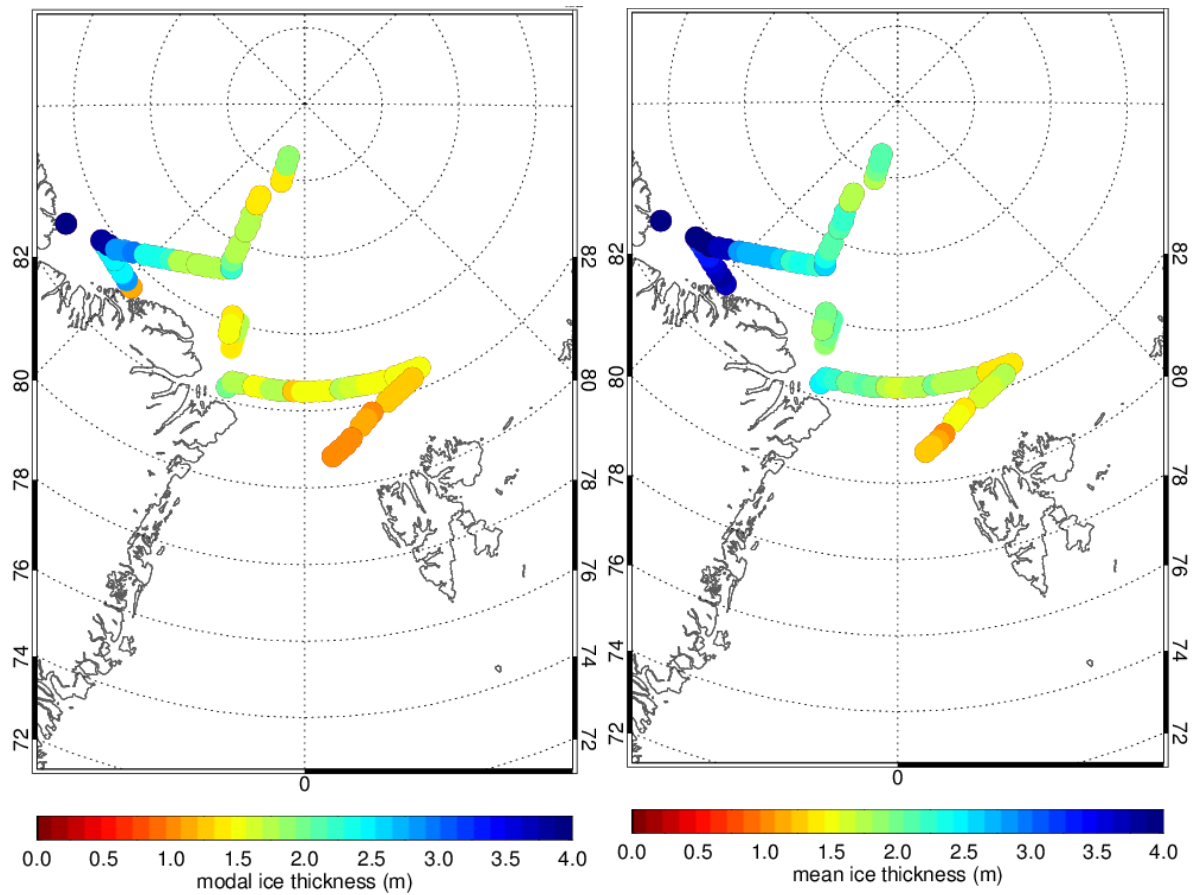
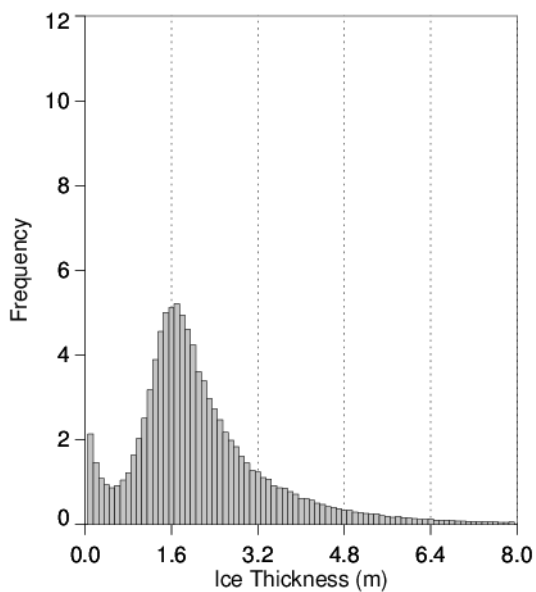


Fig: Modal (left) and mean (right) sea ice thickness of all surveying flights carried out between 13th August and 22nd September 2017.



Number of surveying flights:	5
Mean thickness:	2.3 m
Stddev:	1.5 m
Median:	1.9 m
Mode:	1.7 m

Total profile length:	3466 km
Open water fraction:	4.5 %
Fraction thicker than 3 m:	19.1 %
Fraction thicker than modal th:	61%

Fig: Sea ice thickness distribution of all measurements carried out between 13th August and 22nd September 2017 (left) plus statistics (right).

Comparison of thickness measurements with previous years

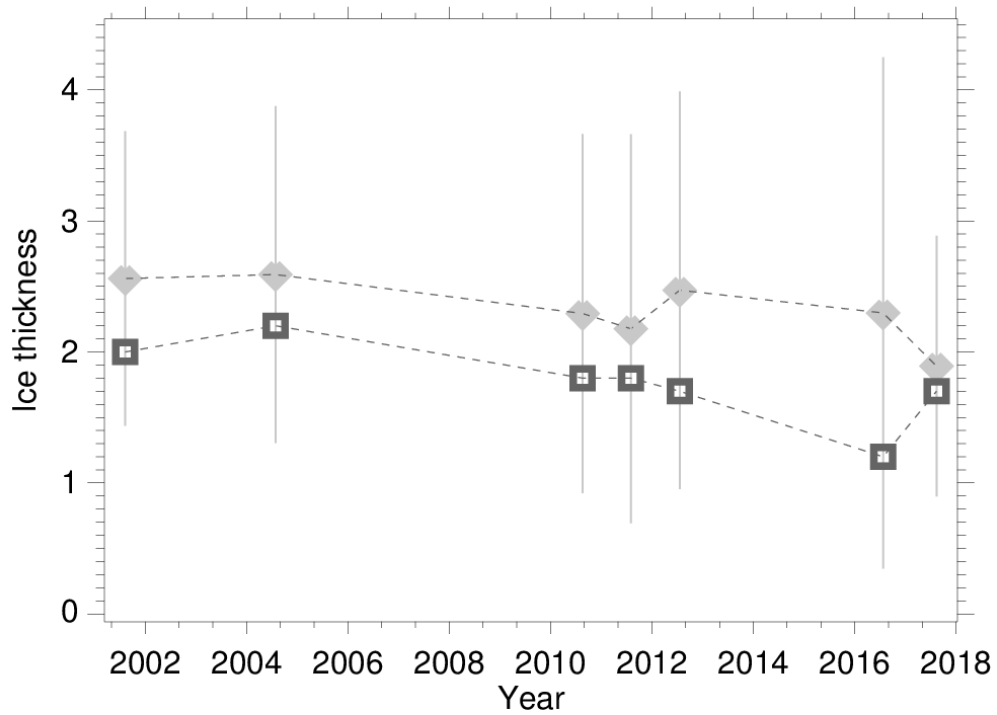
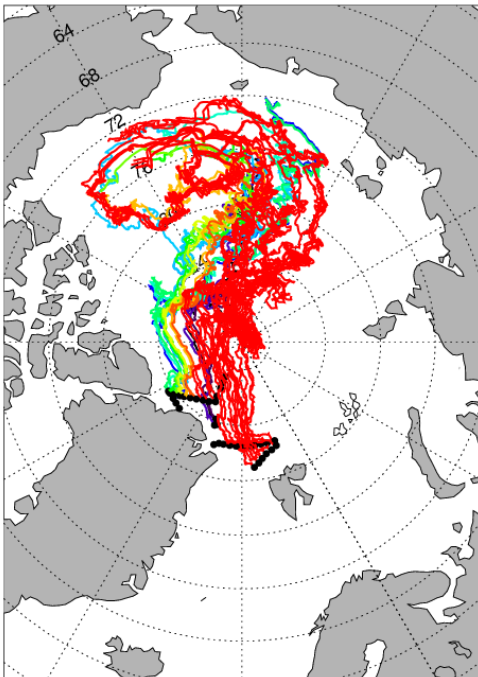


Fig: Changing sea ice in Fram Strait and Transpolar Drift: Modal (dark grey) and mean (light grey) sea ice thickness in July/August between 2001 and 2017.

Pathways and source area of sea ice



Number of surveying flights:	5
Mean ice age:	2.8 years
Stddev:	1.6 m
Median:	1.9 m
Mean distance travelled:	7414 km
Stddev	4241 km
Mean ice concentration along track:	89 %

Fig: Source area and pathways of sea ice sampled during TIFAX 2017. In contrast to earlier surveys (2001 – 2016), mean ice age is higher and pathways are significantly longer. Different to other years when most sea ice covered during TIFAX was formed in the Laptev Sea, in 2017 Fram Strait summer sea ice originated from the Beaufort Gyre.