IceBird CAN24

Polar 5 sea ice and snow survey campaign with focus on Canada
in the winter of 2024

Inuvik, Resolute Bay, Eureka, and Station Nord

April 11 – May 7, 2024

Final Report

Christian Haas, PI, AWI

Contents

1. Executive summary

IceBird is a series of scientific, long-term airborne campaigns carried out by AWI to observe the variability and change of Arctic sea ice on seasonal, interannual, and decadal scales. The IceBird campaigns include a unique electromagnetic, laser, and radar instrument suite to obtain coincident measurements of sea ice and snow thickness and freeboard. IceBird CAN24 had a special focus on sea ice and terrestrial snow in the Canadian Arctic, and for the first time operated an additional imaging radar dedicated to the observation of snow on land and sea ice, the CryoSAR of the University of Waterloo. Between April 11 and May 6 thirteen survey flights were carried out between Inuvik, NWT, and Station Nord, Greenland (see map in Figure 1). These covered a range of different sea ice regimes and terrestrial snow sites including over Devon Ice Cap. Flights included surveys of sites with extensive in-situ measurements by numerous collaborators for validation of our airborne sea ice and snow retrievals.

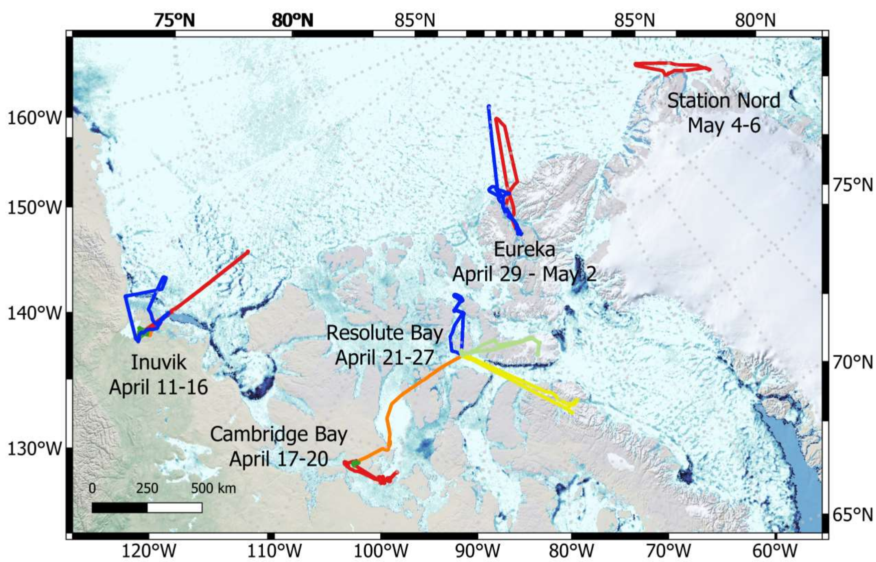

Figure 1: Overview of all sea ice and snow surveys carried out during IceBird CAN24.

2. Acknowledgements

We are grateful for the support of the AWI logistics and aircraft hangar teams, in particular Daniel Steinhage and Thomas Krumpen. Funding was obtained from many sources, but in particular from AWI and AWIs BMBF grant Enhanced Cryosphere Airborne Sensor System (ECASS), NFRF/DFG SmartIce/Sikutiaq, ESA St3TART, University of Waterloo, CFI, and NSERC Discovery. In addition we acknowledge welcoming support for accommodations and lodging by the Aurora Research Institute (Inuvik), Canadian High Arctic Research Station (CHARS, Cambridge Bay), Polar Continental Shelf Program (PCSP, Resolute Bay), Environment and Climate Chance Canada (Eureka), and the Arctic Command (Station Nord). Finally we wish to thank our many collaborators and supporters who contributed to in-situ validation measurements and data processing (see Chapter 7).

3. About the IceBird Arctic sea ice campaigns

IceBird is a long-term airborne observation campaign to observe changes of **sea ice thickness, roughness, snow cover**, and melt ponds in the Arctic. Its main instrument is the EM Bird, a towed sensor that measures sea ice thickness by means of electromagnetic induction (EM) and a laser altimeter (Haas et al., 2009 & 2010).

The IceBird program systematically observes sea ice variability and change in the Arctic Ocean north of Canada and Greenland with a summer and winter campaign with AWI's Polar 5 and 6 aircraft (Haas et al., 2010; Krumpen et al., 2016; Belter et al., 2021, von Albedyll et al., 2021, Jutila et al., 2022).

IceBird CAN 24 is a collaboration between AWI's Sea Ice Geophysics and Remote Sensing group and the Theoretical & Applied Earth Observation Science (TAEOS) Lab of the University of Waterloo in Ontario, Canada.

The **main objectives** of the IceBird CAN24 campaign are:

- Continue long-term IceBird observations of snow and ice thickness in the Arctic Ocean north of Canada and Greenland, and in the Northwest Passage
- Obtain snow thickness, SWE, and backscatter over land, sea ice, and glacier ice surfaces with **CryoSAR, a new imaging synthetic-aperture radar (SAR) of the University of Waterloo**
- Study Ku and L-band backscattering properties of rough ice and slush in preparation of retrieval algorithms for NISAR & ROSE-L
- Closely collaborate with **SmartICE and Sikuttiaq projects**, with our own **Canadian/German NFRF/DFG funding**
- Validate CryoSat-2, ICESat-2, and Sentinel-3 ice thickness retrievals within our **ESA-funded St3TART Follow On project**.

Our main instruments are

- EM Bird for sea ice thickness
- CryoSAR dual-frequency (Ku- and L-band) polarized SAR for snow water equivalent (SWE) retrieval and ice type classification; integration funded by Enhanced Cryosphere Airborne Sensor System (ECASS; AWI BMBF grant)
- Ultra-wide band, FMCW Snow Radar for snow thickness retrievals
- Airborne Laser Scanner (ALS) for sea ice surface roughness
- MACS RGB, NIR and TIR cameras for melt pond and melt process observations and general documentation of ice conditions.

Please visit the **CryoSAR blog** of Richard Kelly from the University of Waterloo for near-real time stories and photos: https://cryosar.blogspot.com

4. Short summary of activities during the campaign

4.1 Instrument integration and test flight in Muskoka, March 22 to April 8

Polar 5 arrived in Muskoka, Ontario, on March 22, and installation of all instruments at the premises of Lake Central Air Services was started immediately by Cristina Sans Col, Clemens Gollin, and Henner Eickhoff from the AWI hangar and supported by Arttu Jutila, snow radar expert from the Finnish Meteorological Institute (FMI). Martin Gehrmann and Christian Haas joined the team on April 2.

A ground test of the IceBird CAN24 configuration was required for certification of the new CryoSAR, and was carried out on April 5 by Jim Watson.

On April 6 we carried out a test flight over Georgian Bay, revealing numerous issues that could subsequently be solved.

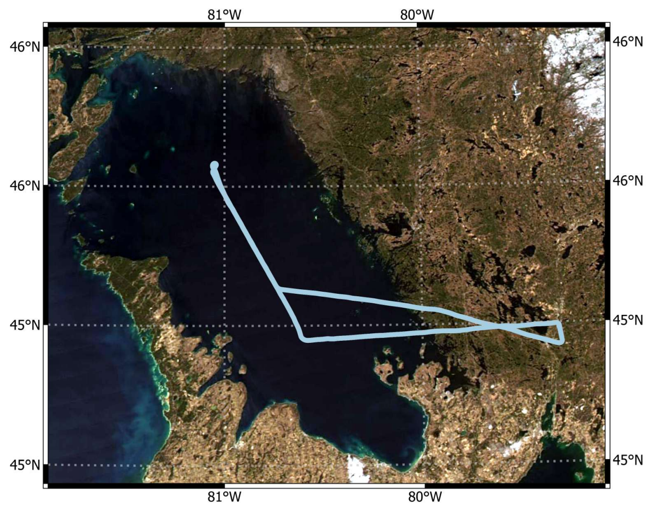

Figure 2: Map of flight track of test flight over Georgian Bay on April 6.

On April 9 and 10 Polar 5 transited to Inuvik with three crew and all equipment and cargo, while the science team flew commercially. All united in Inuvik in the afternoon of April 10.

4.2 Surveys from Inuvik, April 11 to 16

On April 11 we carried out a successful survey of the Trail Valley Creek (TVC) watershed with CryoSAR (Fig. 3). TVC is a long-term research site led by Phil Marsh of Wilfrid Laurier University in Waterloo, Ontario, where also scientist from AWI Potsdam carry out research; see https://www.trailvalleycreek.ca . Unfortunately there were major issues with our airborne laser scanner and we could not obtain any laser scanner data. Further debugging and grounds tests after landing did not resolve the issue, and we already discussed plans for a replacement with another laser scanner from Bremen.

On April 12 we took advantage of a short window of good weather over the Beaufort Sea to survey the sea ice between 71 N to 74 N, including young and old first-year ice and the multiyear ice to the north (Fig 4). Unfortunately we had to abort the survey at 74 N due to thick low clouds. CryoSAR was operated on the return flight with images covering the EM Bird flight track. During the flight, we could finally resolve the laser issues which appeared to be due to wrong software configuration of the system. Eventually the correct settings were chosen and plausible laser scanner data were obtained.

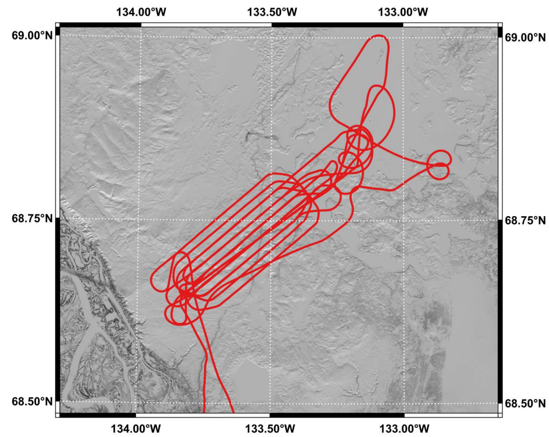

Figure 3: Map of the region of Trail Valley Creek with the flight track of the CryoSAR survey on April 11. Background is Sentinel-2 image from April 11.

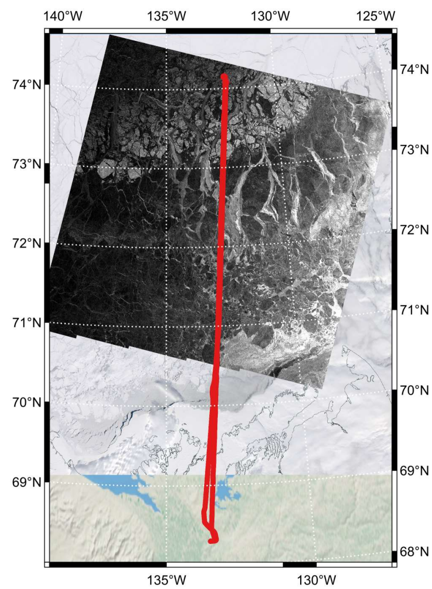

Figure 4: Map of the sea ice survey over the Beaufort Sea on April 12.

After the first two successful flights out of Inuvik poor weather prevented further surveys over the weekend. However, the weather forecast promised fantastic conditions in the new week, allowing us to plan a succession of further snow and sea ice flights.

Therefore, on April 15 we decided to go back to Trail Valley Creek to complete the laser scanner and snow radar survey that remained unfinished due to problems with the laser scanner in the previous week. We flew a total of 28 survey lines at 1500 ft above ground, repeating a similar survey carried out by IceBird Winter 2023 in the previous year (Fig 5). With this we obtained a unique data set of snow surface elevation, thickness, and backscattering properties that will be used to observe snow amount, dynamics, and interannual variability by groups in Canada and at AWI Potsdam.

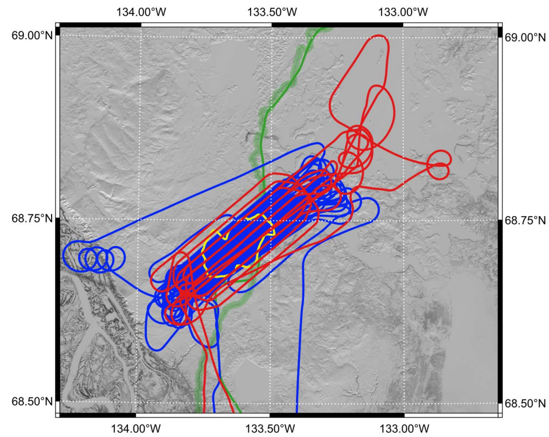

Figure 5: Map of the region of Trail Valley Creek (watershed outlined in yellow) with all flight tracks (Blue: ALS and snow radar; red: CryoSAR; green: Inuvik Tuktoyaktuk Highway ITH). Background is Sentinel-2 image from April 11.

On April 16 we carried out a second survey of the sea ice in the Beaufort Sea (Fig. 6), this time focusing on different ice types formed in the coastal polynya, the fast ice and shallow and brackish water of the Mackenzie Delta, and validation of Sentinel-3 measurements along two of its ground tracks for our St3TART project. Finally we surveyed an intensive study region selected by SmartICE with complete coverage of EM Bird, laser scanner, snow radar, and CryoSAR flown at three different surveying altitudes (200 ft, 1500 ft, and 3300 ft). On the return to Inuvik we attempted to obtain ALS data along the Inuvik Tuktoyaktuk Highway (ITH) but unfortunately the flight track was mostly offset too far to the East.

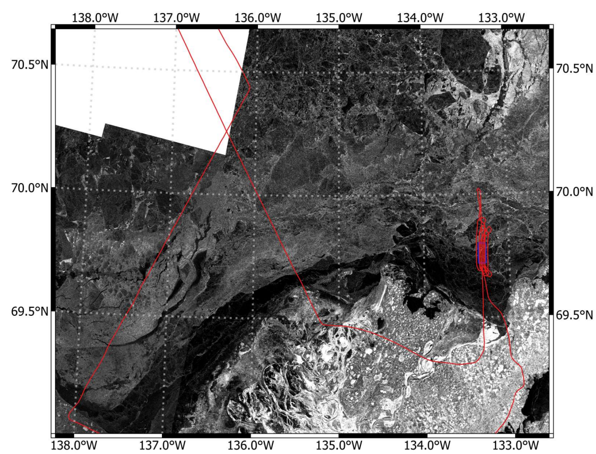

Figure 6: Map of the sea ice survey over the Beaufort Sea on April 16, including S3 underpasses, the SmartIce box near Tuk, and an ALS survey of the ITH highway.

With 4 out of 6 successful days in Inuvik and all objectives met we left our nice accommodations at the Aurora College Row Houses and transited to Cambridge Bay on April 17. Our colleague Arttu Jutila left our team as he had successfully completed the installation of the snow radar and training of operators. In Cambridge Bay we received ground support by Adlair and at their hangar, and were met and hosted by staff of the Canadian High Arctic Research Station CHARS.

4.3 Surveys from Cambridge Bay, April 18 to 20, and transit to Resolute Bay

On April 18 weather forecasts looked good for all our survey targets over the sea ice and land. However, as we took off for our ice thickness survey of Victoria Strait we encountered ground fog en-route which cast doubts of the feasibility of the survey. Luckily the fog did not cover the southern parts of Victoria Strait, allowing surveying some of the most deformed and rough ice regions there that we had identified by analysis of time series of satellite SAR imagery (Fig. 7). However, fog prevailed in the north preventing us from underflying another Sentinel-3 track over very deformed ice, and from completing a full cross-section of Victoria Strait upon our return. However, we were able to survey part of our AEM, laser scanner, and snow radar profiles with the CryoSAR when we returned.

With the Victoria Strait surveys partially completed we surveyed a SmartICE region between the Finlayson Islands with all sensors (Fig. 7). Afterwards we moved on to the MOACC site just north of Cambridge Bay (Multidisciplinary Observatory for Arctic Climate Change and Extreme Events Monitoring), an intensive observation site of terrestrial snow studied by colleagues from the University of Sherbrooke, Environment Canada, and others. Once the CryoSAR lines were completed we descended to 1500 ft agl for the ALS lines by which time fog was rolling in, leading to the abortion of the survey and rapid return to Cambridge Bay.

The fog was the messenger of a blizzard on April 19, keeping us grounded all day.

In the morning of April 20 we completed the missing ALS lines over the MOACC site and added more CryoSAR lines (Fig. 7). Then we loaded the aircraft to head to Resolute Bay. Along the way we attempted to obtain ice thickness data over M'Clintock Channel, in support of SAR image acquisitions by our Canadian collaborators, and validation of Sentinel-3 (Fig. 8). Unfortunately there were problems with the data transmission from the EM Bird that prevented useful data acquisition. The cause of the problems remains unknown, however they could be related to moist air or ice crystals as the weather forecast indicated a high probability of fog although the air was actually clear. However, we obtained ALS and snow radar data along the flight track instead. In Resolute Bay we were welcomed by the Polar Continental Shelf Project where we will stay for the coming week.

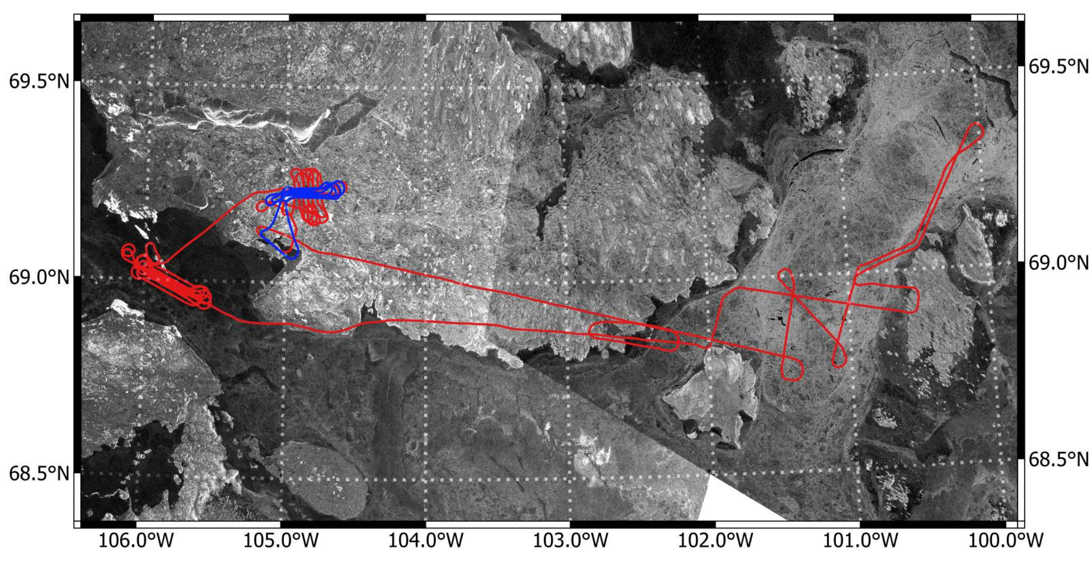

Figure 7: Map of Victoria Strait survey on April 18, including a SmartIce box between the Finlayson Islands and a snow survey of the MOACC site (red). Blue track shows repeat of snow survey over MOACC site on April 20.

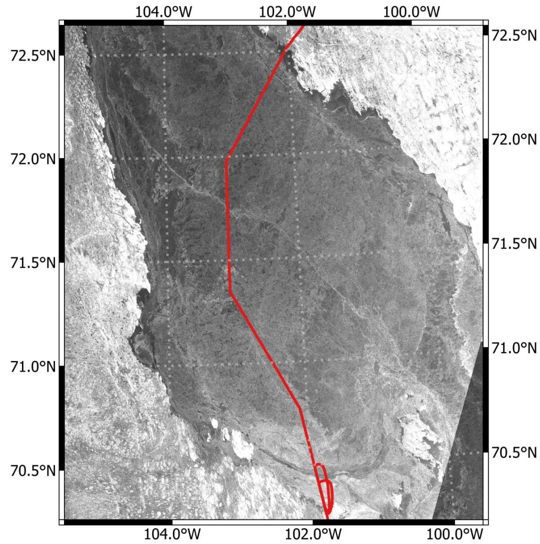

Figure 8: Map of M'Clintock Channel with the ALS and snow radar survey on April 20, including coverage of ALOS PALSAR imagery and two S3 ground tracks. Note that the EM Bird did not work on this day.

4.4 Surveys from Resolute Bay, April 21 to 27

Difficult weather conditions on April 21 prevented SmartIce surveys in Pond Inlet and a flight to the multiyear ice and ice island in Byam Martin Channel. However, conditions were sufficient for sea ice observations in Penny Strait (Fig. 9), related to observations of hidden polynyas due to increased heat flux from the water below.

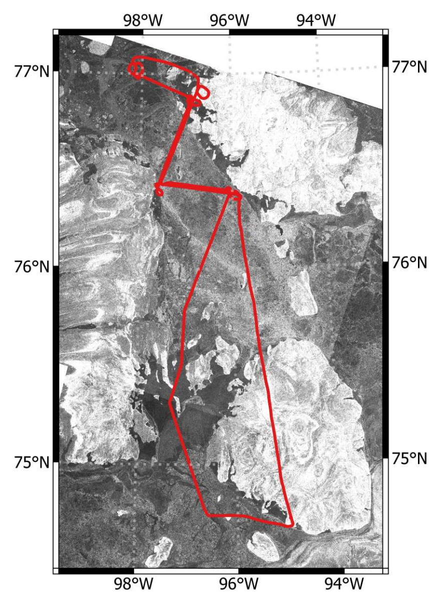

Figure 9: Map of the Penny Strait sea ice survey on April 21.

After the successful sea ice survey in Penny Strait on April 21 the weather did not allow surveys for the next four days. Flight planning was very challenging because the weather had to be good both in Resolute Bay for take off and landing, and in the respective study regions. On April 24 Nils Hutter, our new team member from AWI arrived to take over the snow radar measurements for the upcoming surveys on Ellesmere Island and Greenland.

However, on April 26 weather conditions were just right for a survey of the sea ice at Pond Inlet (Fig. 10), although deteriorating conditions there did not allow to land and to pick up and return additional sea ice observers from the SmartICE project there. After a successful survey over the SmartIce study region we relocated to Emmerson Island where slush has been reported by local SmartICE observers. However, there clouds had already entered the survey area and the survey was marginal, overall confirming our expectations of weather conditions and our strategy for successful observations.

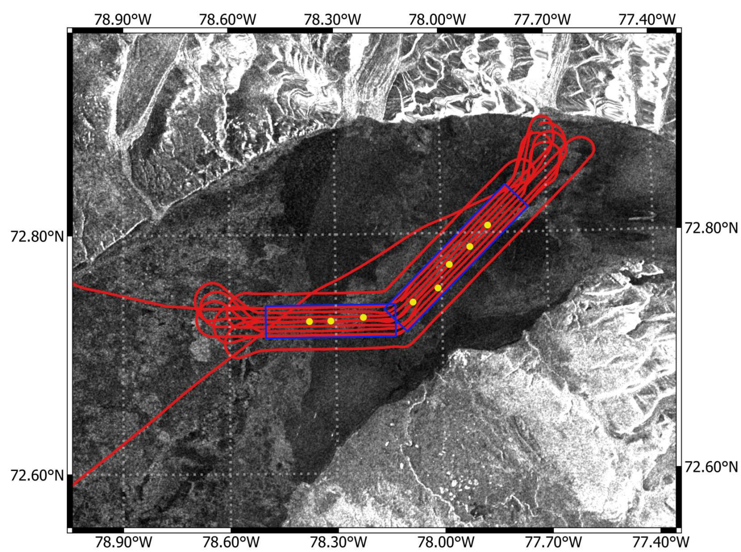

Figure 10: Map of the CryoSAR, snow radar, and ALS survey of the SmartICE study region in Eclipse Sound close to Pond Inlet on April 26. Flight track shown in red, SmartICE regions of interest in blue, and intensive snow study sites by yellow dots.

Despite another generally poor weather forecast for Resolute Bay and Devon Island on April 27, the cloud maps on Windy.com promised clear conditions in just our small survey area on the west side of the Devon Ice Cap. Therefore we set out for a survey of the western margin and CryoSAT lines across the ice cap where observations were already carried out by Uwe Nixdorf and Veit Helm in 2004, and where good in-situ measurements are available by our collaborators Dave Burgess and Brad Danielson from the Canadian Glaciological Survey who were on the ice during those days. During two overpasses we obtained a complete set of CryoSAR, Snow Radar, and ALS data which will help observe different glacier facies (Fig. 11). The permanently changing terrain was a challenge for the pilots who had to keep the aircraft within a fixed altitude above the ground with little tolerances. On the way back from Devon Island we also flew by the Houghton Crater, an old impact crater that is used by scientists as an analogue for Mars (Fig. 12). There are numerous permanent buildings and installations there, and an overflight with CryoSAR was of interest for your collaborator Mike Daly at York University who studies radar backscatter from different soils on Mars and in the Houghton Crater. Before landing, we overflew the YRB runway twice and crossed it once for ALS geometry calibration (Fig. 13).

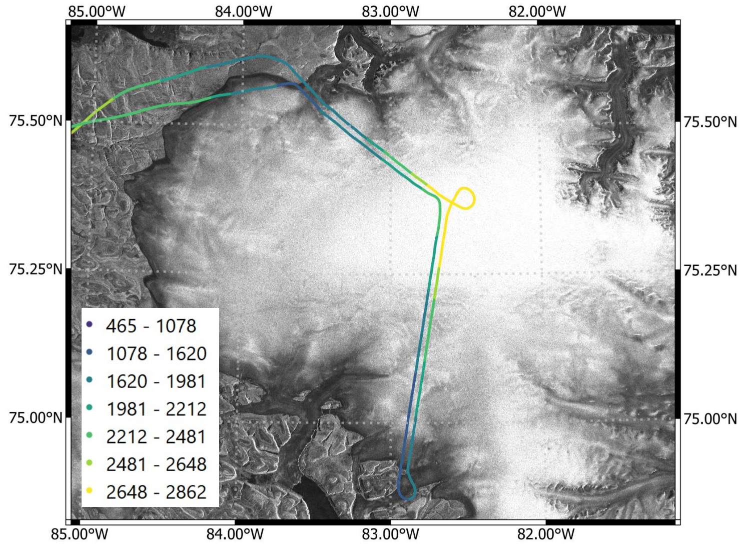

Figure 11: SAR image of the Devon Ice Cap showing our flight path on April 27. Colors show survey altitude in meters (see legend inset). Note offset between tracks due to side looking CryoSAR observing the same snow and ice as nadir looking Snow Radar and ALS.

Figure 12: Arial photograph of part of the Houghton Crater, with some research station installations visible in the foreground.

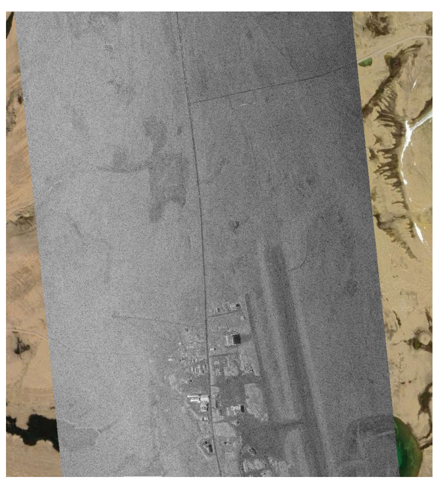

Figure 13: CryoSAR image (Ku-VV) of part of the Resolute airport. The runway and airport were overflown repeatedly on April 27 for calibration of ALS, MACS, and CryoSAR.

On Sunday April 28 we deinstalled the CryoSAR as planned in order to continue our snow and ice thickness surveys and long-term monitoring north of Ellesmere Island and Greenland. However, the weather forecast did not look good in Resolute Bay for the coming days with a risk of getting stuck there. Therefore we decided in the afternoon to leave for Eureka already on the same day. The KBA crew and MG, NH, and CH left Resolute at about 4 pm and arrived in Eureka just before 7 pm, where we were warmly welcome by the station staff. Richard Kelly and Jeff Welch stayed back in Resolute as planned to take a flight back to Waterloo on the next day.

We have achieved 3 out of our four objectives in Resolute Bay. Due to weather conditions and our early departure we were not able to survey the multiyear ice and ice island in McClure Strait. The operation of CryoSAR jointly with the snow radar and laser scanner over sites with extensive in-situ data proved to provide exciting new opportunities for better snow and sea ice mapping.

4.5 Surveys from Eureka, April 29 to May 2

On April 29 the weather looked good to the north, however, there where thick and low clouds over the mountains requiring us to try different routes before reaching the pack ice (Fig. 14). There we flew to 84.5 N, over a CryoSat-2 ground track with the satellite passing over at approximately 15:25 LT. We chose an adjacent IceSat-2 track for the return at high altitude, passing us at 14:44 LT; however there were mostly high clouds which probably inhibited coincident IceSat-2 measurements.

After two days of poor weather either at Eureka or over the Arctic Ocean conditions were again good on May 2, when we set out for a highly successful IceSat-2 underflight to the north (Fig. 14). We delayed our departure in order to meet IceSat-2 near the northern end of our profile. Conditions were good up to 85 N, with IceSat-2 passing over our head at 15:03 LT when we chose a specific zig-zag course along the satellite track to assure that we will hit it regularly at some points. We flew back high along the same track in order to obtain better MACS imagery for exact identification of coincident ice surveyed by us and by IceSat-2. Once back at the coast, we flew to the mouth of Nansen Sound to survey some multiyear fast ice identified on SAR images and then surveyed over specific sampling sites of Lisa Matthes' DFO Last Ice project, all the way into Eureka Sound.

Unfortunately the weather forecast suggested that we could not carry out a survey of any of the ice shelfs along Ellesmere Island's north coast. Therefore we decided to move on to Station Nord, one day earlier than planned. We departed Eureka at ca. 14:00 on May 3, and arrived at Nord at around 23:00 LT, due to the 5 hour time shift.

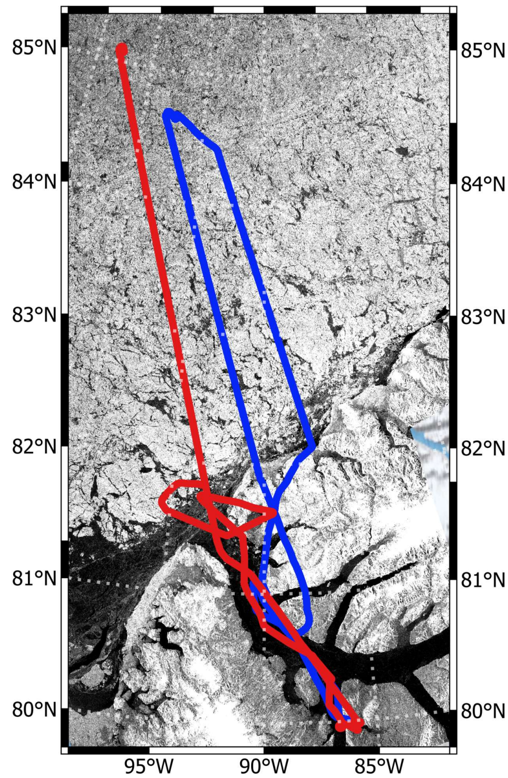

Figure 14: Overview of the two surveys out of Eureka, carried out on April 29 (blue; CryoSat-2 and IceSat-2 underflight) and May 2 (red; IceSat-2 underflight and survey of Nansen Sound). Background shows RCM SAR images obtained on the same days.

4.6 Surveys from Station Nord, May 4 to May 6

Despite ideal weather conditions at Station Nord and over the sea ice to the north we were not able to carry out any surveys on May 4 and 5, because we had failed to obtain the Greenlandic Expedition Permit in time, and because the expedition office was closed on these two weekend days. The military helped us strongly to secure the permit on Monday morning, once the expedition office in Nuuk had commenced work, whose time zone is two hours after the one at Station Nord. Therefore we were able to carry out a short survey after lunch on May 6 (Fig. 15), while there remained a small open cloud window up to 84.5N, 30W (Fig. 16), much farther west then we would have liked to go. Still some good ice could be surveyed, including over the impressive shear zones between the pack ice and the fast ice near the coast.

4.7 Return of science team and Polar 5

With poor weather forecasted for Station Nord on and after May 7, we decided to fly to Longyearbyen on May 7, one day earlier than planned. Take off at Nord and landing at Longyearbyen saw some difficult conditions with light snowfall and poor visibility at Nord and a layer of low stratus with icing conditions at Longyearbyen. Due to those conditions it was not possible to carry out a laser scanner survey of Vallakrabreen on Svalbard, a glacier that we surveyed last summer and that is the subject of a MSc thesis at UNIS. Instead we deinstalled the EM Bird and prepared Polar 5 for the return to Muskoka where the actual deinstallation of all instruments was planned. MG and NH were able to reserve seats on a flight to Germany on May 8. Polar 5 left Longyearbyen on May 9 to fly to Keflavik on Iceland. From there they could only continue to Goose Bay on May 11, and arrived in Muskoka on May 12. CH left Longyearbyen on May 10 to arrive in Germany on the same day. This ended a very successful IceBird CAN24 campaign.

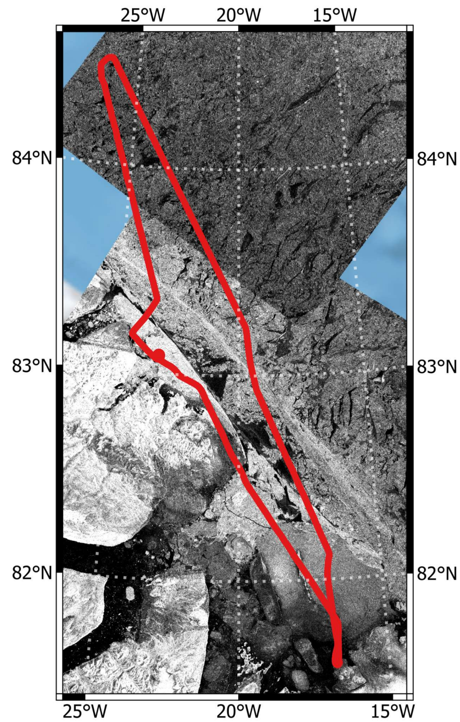

Figure 15: Map of the survey out of Station Nord on May 6, with RCM SAR images acquired on May 5. Note bright signatures of shear zones at the fast ice edge.

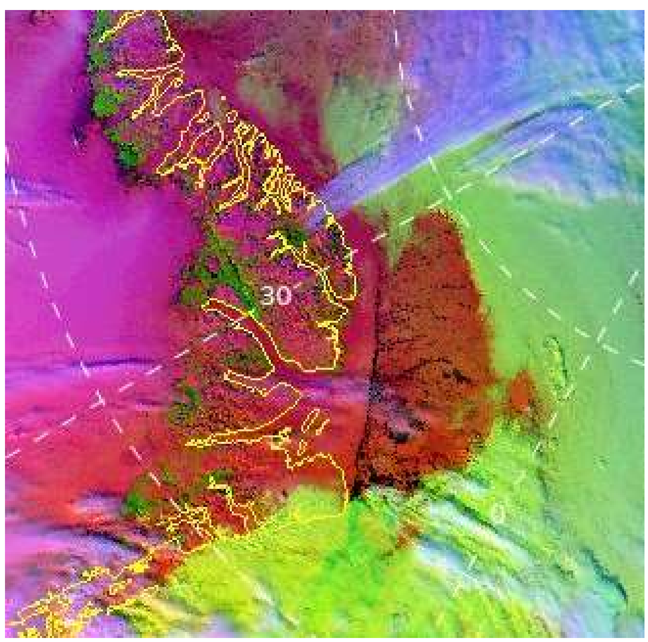

Figure 16: False color VIIRS image on May 6, 14:00 UTC, provided by DWD. Note small remaining window of cloud free conditions to the northwest of Station Nord in which the survey took place (Fig. 15).

5. Flight summary table

Table 1: Overview of all IceBird CAN 24 flights.

Date	Activity	Flight hours
April 6	Test flight over Georgian Bay	1.4
April 9&10	Ferry flight Muskoka-Inuvik	5.1+3.8 &3.6
April 11	CryoSAR survey of Trail Valley Creek (no ALS data)	3.5
April 12	Sea ice survey over Beaufort Sea between 71N and 74N, with all sensors (ALS data partially available)	5.0
April 15	Completion of ALS and snow radar survey over TVC	6.2
April 16	Sea ice survey over Beaufort Sea and fast ice	5.0
April 17	Transit to Cambridge Bay	3.1
April 18	Sea ice survey over Victoria Strait and Finlayson Islands, and part 1 of snow survey over MOACCA study site	5.6
April 20	Completion of MOACCA snow survey and transit to Resolute Bay including sea ice survey over M'Clintock Channel (no EM data)	0.8+3.8
April 21	Penny Strait sea ice survey	3.5
April 26	Extensive survey over intensive SmartIce study site near Pond Inlet, including slush near Emmerson Island	6.7
April 27	Survey across the Devon Ice Cap and the Houghton impact crater. ALS runway calibration in Resolute Bay	3.8
April 28	Transit to Eureka	2.0
April 29	Arctic Ocean sea ice survey, CryoSat-2 and IceSat-2 underflight	5.0
May 2	Arctic Ocean and Nansen Sound sea ice survey including IceSat-2 underflight	6.2
May 3	Transit to Station Nord	3.6
May 6	Sea ice survey to 84.5N, 26W	3.2
May 7	Transit to Longyearbyen	2.4
	Total air time surveys	61.9
	Total air time transit	21.4
	Total	**83.3**
Survey days	12	
Total days	26 (April 11 – May 7)	

6. The IceBird CAN24 team

Christian Haas (CH), PI, AWI, Germany
Richard Kelly (RK), Co-PI, University of Waterloo, Canada
Jeff Welch (JW), PhD student, University of Waterloo, Canada
Arttu Jutila (AJ, left after Inuvik), Scientist, Finnish Institute for Meteorology (FMI), Finland
Nils Hutter (NH, joined in Resolute Bay), Scientist, AWI, Germany
Martin Gehrmann (MG), Aircraft science engineer, AWI, Germany
Alan Gilbertson (AG), Captain, Kenn Borek Air, Calgary AB, Canada
Kyle Snethlage (replaced Shannon Kelly in Inuvik), FO, Kenn Borek Air, Calgary AB, Canada
Dwayne Bailey (DB), AME, Kenn Borek Air, Calgary AB, Canada

Figure 17: The IceBird CAN24 team in Resolute Bay, from left: Jeff, Dwayne, Alan, Kyle, Martin, Richard, Nils, Christian, and Arttu (left in Inuvik).

7. Main direct collaborators

Thomas Krumpen (Co-PI), Niklas Neckel, Veit Helm, Stefan Hendricks, AWI BHV, Germany
Julia Boike, AWI Potsdam, Germany
Arttu Jutila, Finnish Institute of Meteorology, Finland
Trevor Bell, SmartIce and Memorial University, Canada
Randy Scharien, University of Victoria, Canada
John Yackel, University of Calgary, Canada
Steve Howell and Mike Brady, ECCC, Canada
David Burgess, NRCan, Canada
Alex Langlois, University of Sherbrooke, Canada
Phil Marsh, Wilfrid Laurier University, Canada
Lisa Matthes, DFO Winnipeg, Canada

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