IceBird CAN25

Polar 6 sea ice and snow survey campaign with focus on Canada in the winter of 2025

Whitehorse, Inuvik, Resolute Bay, Pond Inlet, Eureka, Station Nord, and Longyearbyen

March 13 – April 21, 2025

Final Report

Christian Haas (PI, AWI), Richard Kelly (UWaterloo), Luisa Wagner (AWI), Maximilian Stöhr (AWI)

Contents

1. Executive summary

Between March 13 and April 21, 2025, the IceBird CAN25 airborne campaign of AWI's Polar 6 research airplane took place in Canada, Greenland, and Svalbard to survey characteristic sites of snow on land and sea ice, to observe long-term sea ice variability and change, and to develop new snow remote sensing techniques. During 21 survey flights snow and sea ice in the vicinity of Whitehorse (YT), Inuvik (NWT), Cambridge Bay, Resolute Bay, Pond Inlet (all NU), Station Nord (Greenland), and Longyearbyen (Svalbard) took place. These included overflights of seven sites in Trial Valley Creek, Tuktoyaktuk, Cambridge Bay, Pond Inlet, Resolute Bay and Longyearbyen where collaborators from the SmartIce/Sikunnguak, MOACC, Str3TART, and IceView projects had collected extensive in-situ validation data.

2. 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; Krumpen et al., 2025).

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 & 2025; Belter et al., 2021, von Albedyll et al., 2021, Jutila et al., 2022).

IceBird CAN25 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, with many other partners carrying out in situ measurements. It is a continuation and extension of the IceBird CAN24 campaign in April/May 2024, in order to study interannual variability, more ice and snow targets with colder snow conditions earlier in the year, and with more extensive in situ data.

The **main objectives** of the IceBird CAN25 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 that was first used during IceBird CAN24.**
- 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.

Most instruments require different flying altitudes. Therefore we mostly implemented three different mission scenarios: 1. Ice thickness surveys with the EM Bird at an aircraft altitude of about 240 ft agl, with snow radar and laser scanner operated in low altitude mode; 2. Surface roughness and snow thickness grid mapping over extended regions with in situ measurements, with flying altitudes between 1100 and 1600 ft agl; and 3. CryoSAR surveys at an altitude of 4600 ft agl. As the CryoSAR is right looking, CryoSAR flight tracks were offset from the flight tracks to facilitate observing the same ice. For the long sea ice transects that meant backtracking the EM Bird flight track at an altitude of 4600 ft agl.

3. Overview map of all survey flights carried out between March 18 and April 21, 2025

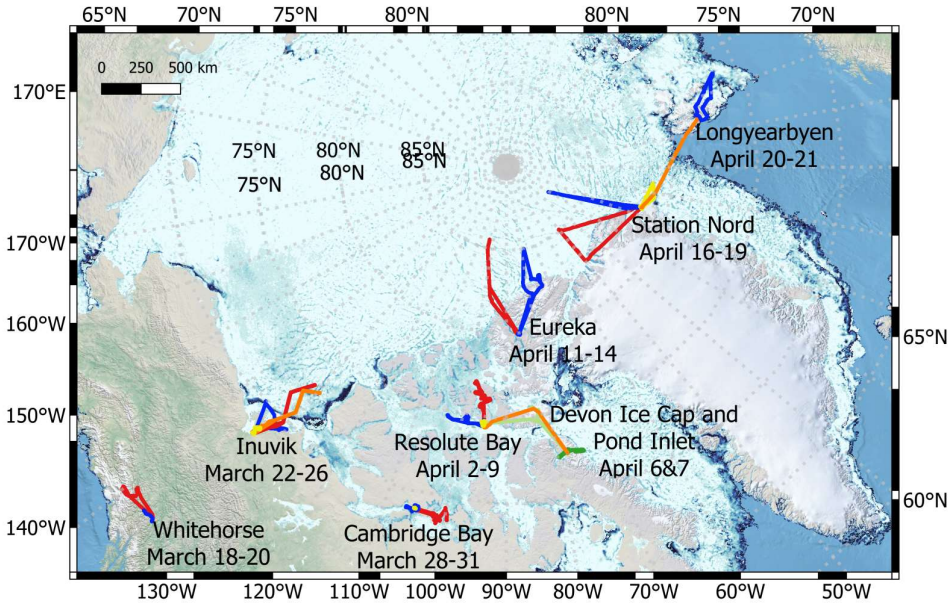

Figure 1: Overview of all IceBird CAN25 snow and sea ice surveys. See Table 1 and subsequent summaries for more information. Map shows ice conditions on April 14, 2025 (courtesy L. Kaleschke).

4. Short summary of survey flights

4.1 Installation and testing in Muskoka, March 2 to 14: MacDonald Lakes

Cristina Sans Coll and Clemens Gollin from the AWI hangar and Luisa Wagner (AWI PhD student) and Arttu Jutila (former AWI PhD student and Postdoc, now with the Finnish Meteorological Institute, FMI) travelled to the premises of Lake Central Air Services (LCAS) in Muskoka, Ontario, to begin with the installation and testing of the scientific instrumentation on the Polar 6 which came from Antarctica via Calgary AB. On March 9 they were followed by Christian Haas and Maximilian Stöhr, another engineer from the AWI hangar. We carried out a test flight over Georgian Bay and MacDonald Lake near Haliburton on March 13 (Figures 2 and 3). Installation and test flight were supported by Kenn Borek staff Luke Cirtwill (AME), Almina Kovcic (FO), and Dean Emberly (Captain). On March 14 Arttu Jutila left after successful testing and training with the snow radar, and Kevin Riehl replaced Luke Cirtwill. The Polar 6 left Muskoka on March 16 to fly to Whitehorse with an overnight stay in Hay River. Christian Haas, Luisa Wagner, and Max Stöhr followed on March 17 with Air Canada via Vancouver.

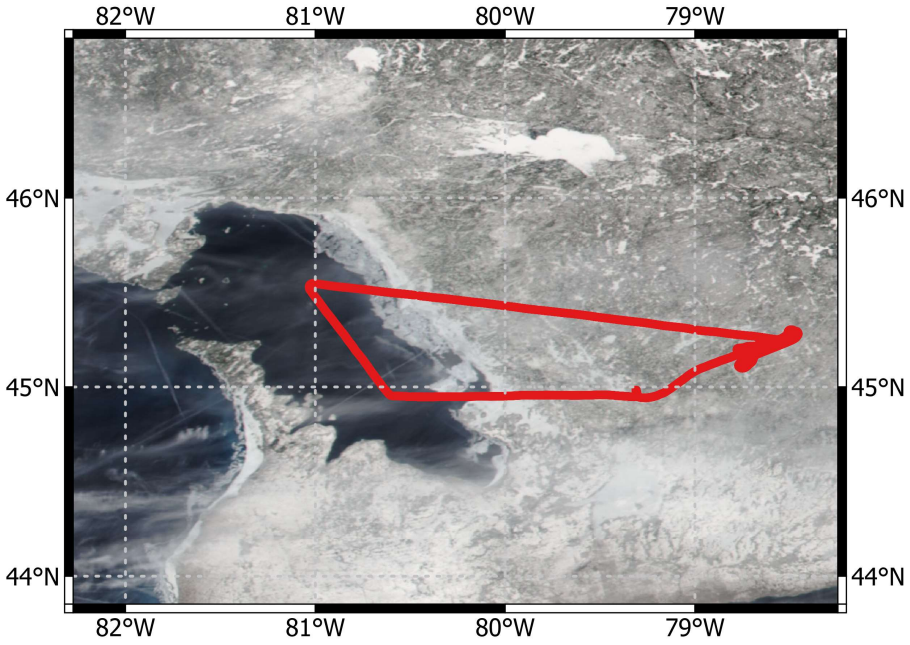

Figure 2: Map of the flight track of the test flight over Georgian Bay and MacDonald Lake near Haliburton on March 13. Note ice cover on lakes visible in MODIS image of same day.

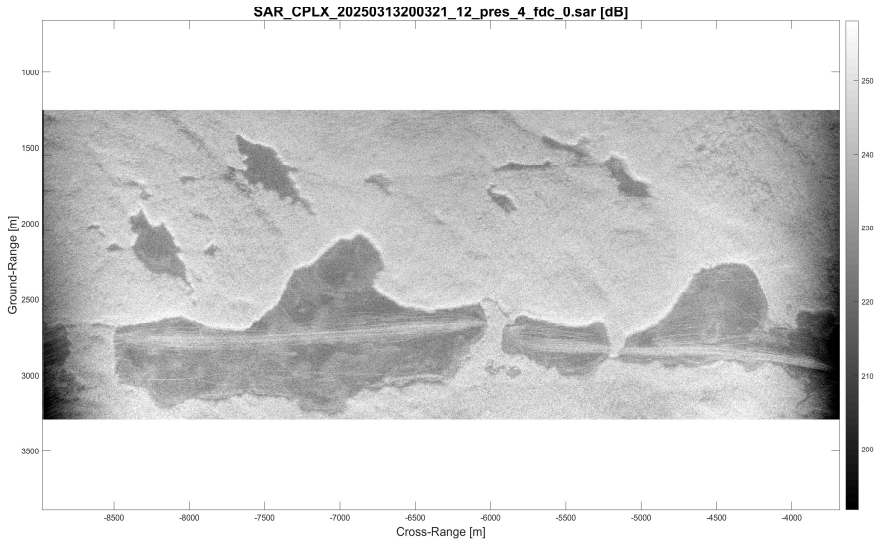

Figure 3: CryoSAR L-Band co-pol image quickview over the MacDonald Lake complex, showing Clean (left) and Eyre Lakes (right). Note snowmobile tracks on lake.

4.2 Whitehorse, March 18 to 20: Eclipse Ice Field and Kluane Lake

For the first time we planned to include some snow surveys over the Wolf Creek watershed observatory maintained by McMaster and Yukon Universities, for which we collaborated with Stephanie Saal from Yukon University. In addition, we planned to map the extent of a perennial firn aquifer (PFA) over the Eclipse Ice Field in the Kluane Mountains on the upper reaches of Kaskawulsh Glacier, in collaboration with Luke Copland (UOttawa) and Brittany Main

(UWaterloo and YukonU). The ice on Kluane Lake served as a backup plan. Due to challenging weather conditions with sever mechanical turbulence we had to abort a flight on March 18 early on. March 19 saw poor weather conditions as well. Finally, on March 20 weather was good enough for a CryoSAR flight at 14600 feet altitude over the Eclipse Ice Field with spectactular views of Mount Logan. However, when descending Kaskawulsh Glacier at 1500 ft above ground with the snow radar, strong turbulence at lower elevations required us to abort any further surveying with the snow radar. Instead, we diverted to a small region over Kluane Lake where in situ measurements were carried out a few days earlier by Grant Gunn from the University of Waterloo, in conjunction with some SWOT overpasses.

Unfortunately we were unable to carry out a survey over Wolf Creek due to persistent cloud cover there. In Whitehorse, we were supported by Alkan Air who provided perfect conditions for the Polar 6 and our team.

Figure 4: The Polar 6 at the Aklan Air hangar in Whitehorse. Photo by Kevin Riehl.

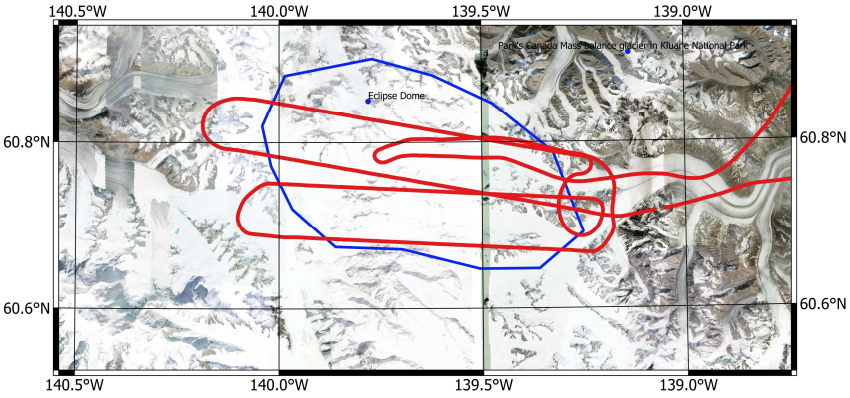

Figure 5: Map of CryoSAR and short snow radar flight track over the Eclipse Ice Field, Yukon, on March 20. Blue outline shows suspected extent of perennial firn aquifer (L. Copland, pers. comm).

Figure 6: Polar 6 turning over the Eclipse Ice Field.

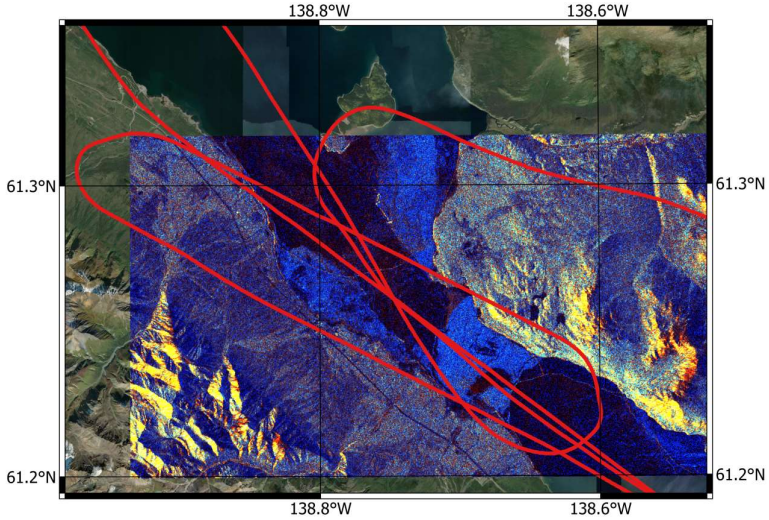

Figure 7: Map of CryoSAR and snow radar flight track over Kluane Lake, on March 20. Colored inset shows false-color, polarimetric radar backscatter from Sentinel 1, showing different lake ice zones.

Figure 8: The survey region on Kluane Lake seen from the south (narrow region with little snow).

4.3 Inuvik, March 21 to 26: Beaufort Sea, Liverpool Bay, and TVC

On March 21 we all transited with the Polar 6 to Inuvik, where we welcomed Richard Kelly who had other commitments earlier on. While the air crew stayed in the Capital Suites, the scientists moved into the Arctic Research Institutes Row Houses, where we shared a house with the group of Julia Boike from AWI Potsdam who carried out in situ measurements in Trail Valley Creek (TVC). On March 22 we were able to carry out much of the TVC laser scanner, CryoSAR, and snow radar survey, but could not complete it fully due to the long time required. On March 23 we set out for a Beaufort Sea ice survey and Sentinel 3 underflight, but were stopped by an unexpected bank of cloud of unknown extent. Due to our early morning departure and early solar time there were no suitable satellite images available yet that would have shown the clouds. Instead we returned south to Liverpool Bay where the Tuktoyaktuk SmartIce team had carried out in situ measurements the days before, and then back to TVC to complete the laser scanner and snow radar survey. Based on the experiences with the weather satellite data we decided to plan flights only later in the day, since good images were available from 11 am an later. These showed good conditions over the Beaufort on March 25 and 26 despite questionable ECMWF cloud forecasts. We were able to carry out two good sea ice surveys over the Mackenzie polynya and multiyear ice farther north on March 25 and 26, including shorter sections of Sentinel 3 (orbits 36020 and 36025 on March 25, and orbit 36034 on March 26) and RCM underflights. On our return on March 26 we surveyed over the Inuvik Tuk Highway (ITH). The flights were joined by Todd Gruben, a wildlife observer from the Inuvik HTC.

Great operating conditions at the Aklak Air Hangar and Inuvik terminal building.

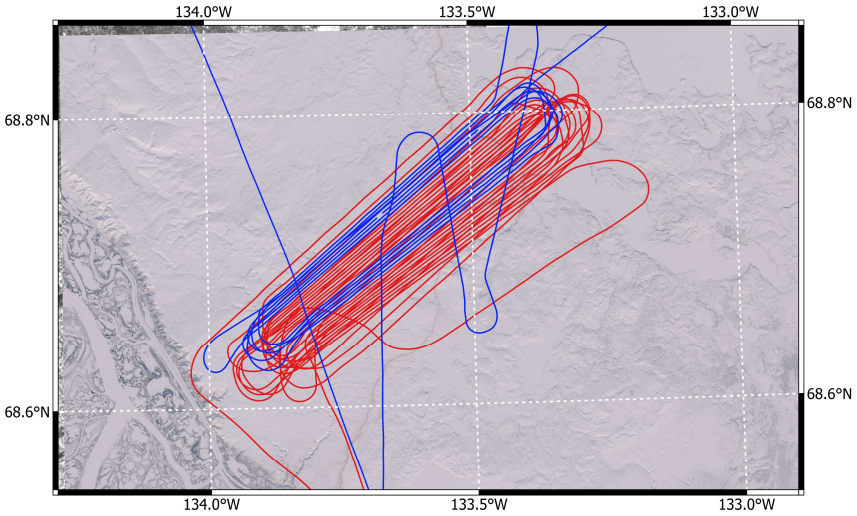

Figure 9: Sentinel-2 image of March 30, showing the flight tracks over Trail Valley Creek on March 22 and 23. Note Inuvik Tuk Highway crossing through the center of the image from bottom to top.

Figure 10: The Trail Valley Creek field camp operated by Wilfrid Laurier University.

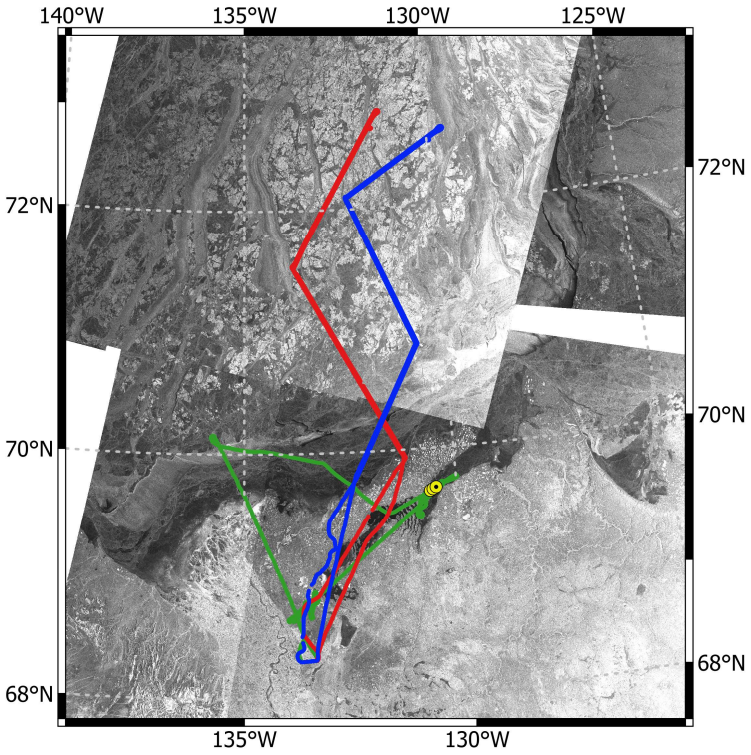

Figure 11: Map of the sea ice surveys over the Beaufort Sea on March 23 (green), 25 (red), and 26 (blue). Yellow circles show SmartIce in situ sampling sites in Liverpool Bay. Wiggly blue line over land follows Inuvik Tuk Highway.

Figure 12: A pingo on Campbell Island in Liverpool Bay, NWT.

Figure 13: Fresh ridges and leads in multiyear ice floes, Beaufort Sea March 26.

Figure 14: New lead covered with various types of new ice, Beaufort Sea March 26

4.4 Cambridge Bay, March 27 to 31: Victoria Strait, Finlayson Islands, and MOACC

With all objectives achieved in Inuvik we transited to Cambridge Bay on March 27 with all seven team members and all equipment and cargo. We parked at and received ground support by Adlair, and stayed at the Canadian High Arctic Research Station (CHARS), with strong support by Daniel Kramer, snow researcher at Sherbrooke University. Immediately after our arrival we contributed to a community science event at CHARS where we presented the IceBird project to about 20 attendees from all over Cambridge Bay. The next morning we reported live to two school events in the Waterloo region. As there was mechanical turbulence forecasted, March 28 was spent with visits to the HTC and NIRB to inquire about sea ice interest of local hunters and about our Nunavut research license. On March 29 we carried out a sea ice survey over the mobile and heavily deformed ice in Victoria Strait, including an underflight of Sentinel 3, orbit 36104 acquired on March 31. On March 30 we took off for a survey of the Multidisciplinary Observatory for Arctic Climate Change and Extreme Events Monitoring (MOACC) terrestrial snow site and SmartIce sea ice transect, but moments afterwards low clouds had moved in and we decided to abort the mission. It was attempted again on March 31, and successfully completed with high quality airborne and in situ data. The March 31 survey was flown by Bill Houghton who replaced Dean Emberly as the Polar 6 Captain from there on.

Figure 15: Icebird science event at CHARS on April 27, organized by Daniel Kramer (left) and stimulating intensive discussions with participants (right).

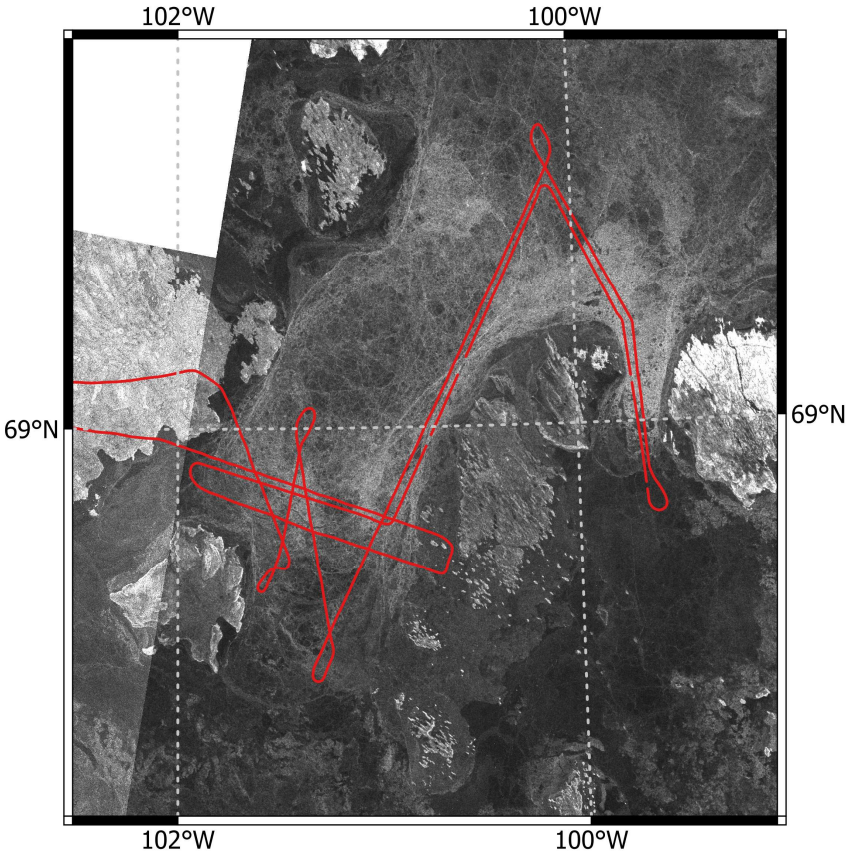

Figure 16: Flight track over Victoria Strait on March 29. Long northward section coincides with Sentinel 3 orbit 36104.

Figure 17: Open lead and heavily deformed ice in Victoria Strait, March 29.

Figure 18: Cambridge Bay on March 31.

Figure 19: Northern large passage between Finlayson Islands on March 31. Center shows small island in track of EM Bird flight.

4.5 Resolute Bay, April 1 to 10: Penny Strait, ice islands in Viscount Melville Sound, and KuKa sites

After the successful completion of all planned missions in Cambridge Bay we transited to Resolute Bay on April 1 where we received ideal operating and lodging support by the Polar Continental Shelf Project (PCSP) and the Kenn Borek hangar team. We took a slight detour over Victoria Strait in order to repeat a short section of the previous sea ice profile that was missed by the CryoSAR due to issues with the Ku band system.

On April 2 we carried out a successful survey of the sea ice and invisible polynyas in Queens Channel and Penny Strait north of Cornwallis Island. The ice in this region responds sensitively to variations in ocean currents and heat flux, and we observed both open and hidden polynyas. Poor weather conditions farther north inhibited continuation of the survey over the nearby multiyear ice in the Sverdrup Basin.

On April 3 we mapped a chain of grounded ice island fragments in Viscount Melville Sound and carried out a sea ice survey including some scattered multiyear ice. Poor weather farther west prevented us to reach the end point of the planned flight.

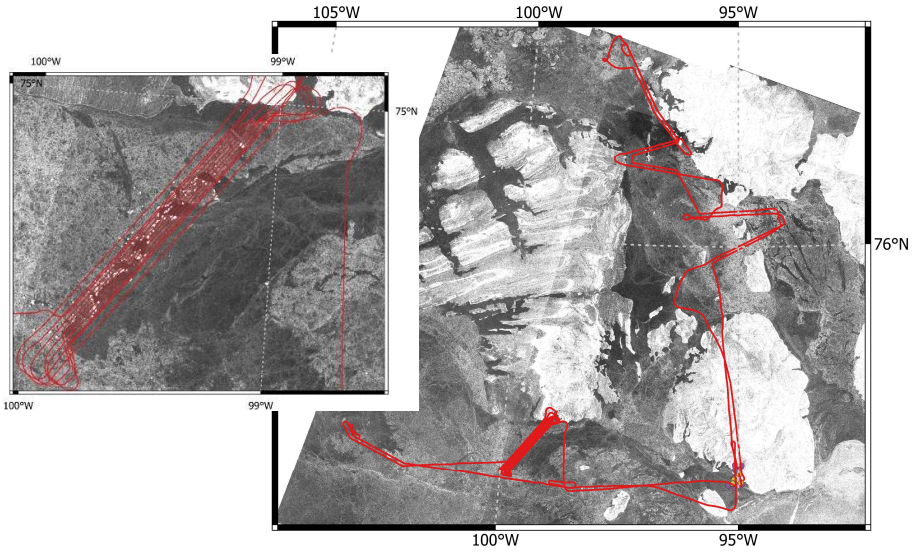

Figure 20: Map of flight tracks in Penny Strait and Queens Channel on April 2 as well as in Viscount Melville Sound and over the ice islands (see inset) on April 3.

Figure 21: Resolute Bay, airport and community.

Figure 22: Open water and heavily deformed ice in Pioneer Channel, north of Dundas Island, April 2.

Figure 23: The grounded ice island fragments in Viscount Melville Sound south of Bathurst Island

After a weather day on April 4, we carried out a short visit to Pond Inlet on April 5 and 6 to collect data over the Devon Ice Cap and in Eclipse Sound for our SmartIce project, see below. Once back, in deteriorating weather with strong winds and impeding precipitation in the morning of April 7, we were just able to overfly the sites of the KuKa radar measurements of our UK collaborators. One of these was on Tundra north of the runway, one on lake ice of Resolute Lake, and two on sea ice near the southwestern tip of Cornwallis Island. The surveys also included overflights of Small Lake where Dr. Laura Brown from the University of Toronto carries out continuous ice thickness measurements. We deinstalled the CryoSAR afterwards and had to wait until April 10 when the weather had improved enough to go to Eureka, without our team member Richard Kelly who flew back to Waterloo.

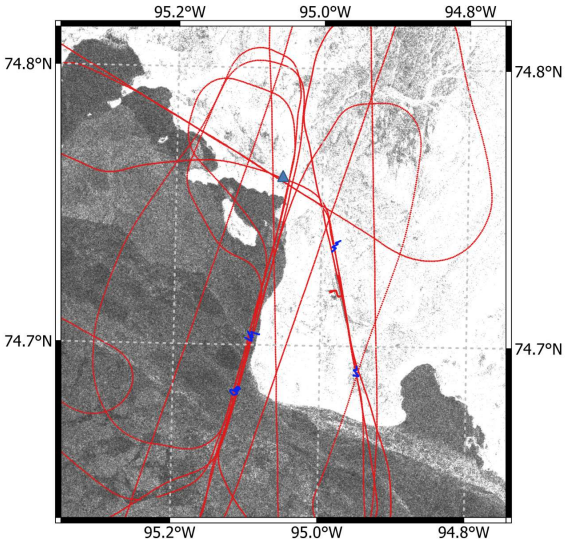

Figure 24: Flight tracks on April 7 close to Resolute Bay, showing the actual KuKa tracks on tundra (north of runway) and Resolute Lake (south of runway) as well as on sea ice as blue wiggly lines and Small Lake as blue triangle.

Figure 25: Arial photo of the region around Small Lake near the shore, at root of peninsula. Note Cristal City at bottom right and beginnings of Resolute airport infrastructure on bottom left.

4.6 Devon Ice Cap and Pond Inlet, April 5 and 6: SmartIce sites and floe edge

On April 5 and 6 good weather was forecasted for both Resolute Bay and Pond Inlet, and therefore we decided to plan a pre-arranged overnight stay in Pond Inlet to have more time for SmartIce surveys. The ferry flight to Pond Inlet was used, to survey snow accumulation and mass balance over Devon Island, in close collaboration with the Geological Survey of Canada. We followed their northwestern surface mass balance survey to the summit and from there a CryoSat ground track that was repeatedly surveyed even way back with the Polar 2 and the ASIRAS radar altimeter. As there were issue with the CryoSAR acquisitions at high altitude over the strongly inclined ice surface, the CryoSAR survey was repeated at lower altitude on the return flight to Resolute on April 6.

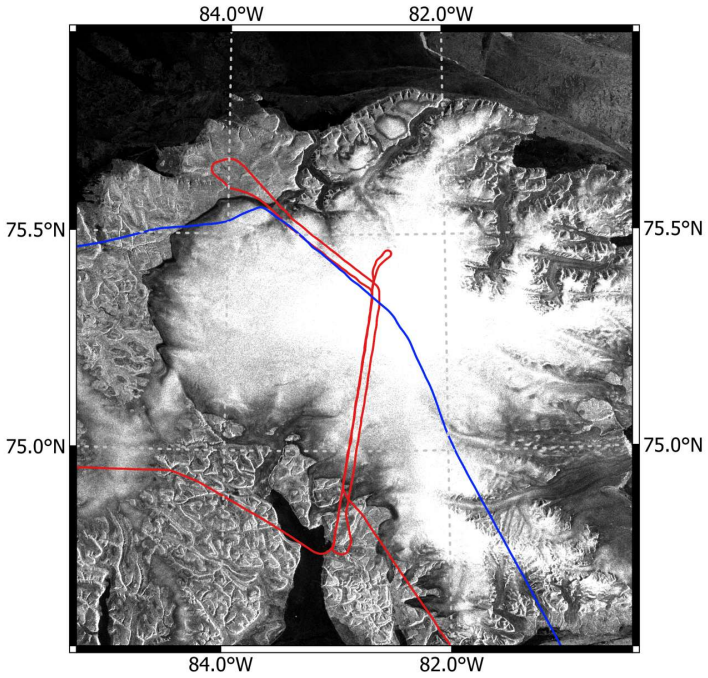

Figure 26: Flight tracks of Devon Ice Cap snow surveys on April 5 (red) and 6 (blue, CryoSAR only).

In Pond Inlet we found good facilities at the airport and reliable fuel support. The scientist overnighted with the SmartIce team in the ECCC lab near the beach, while the crew stayed in the hotel. On April 6 we were able to carry out a sea ice survey with all sensors over the SmartIce study sites and an EM survey of the sea ice around the floe edge and over the adjacent polynya. The flight was joined by two SmartIce sea ice observers.

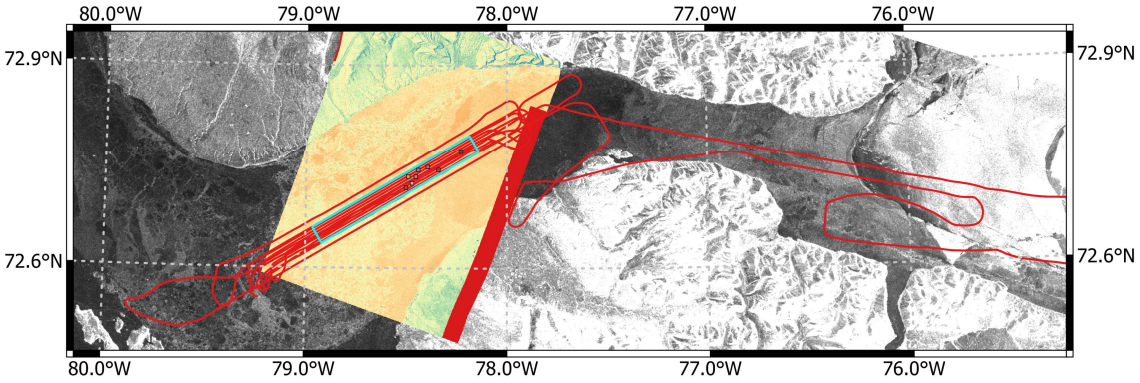

Figure 27: Map of the sea ice survey in Eclipse Sound on April 6. On the left the comprehensive mapping of the SmartIce study sites (within cyan rectangle) can be seen. Afterwards an EM survey of the ice at the floe edge and adjacent polynya was performed. Note triangular bright region of new ice surrounded by older fast ice at right bottom of SAR image. Colored inset is a pseudocolor TerraSAR-X Stripmap image from April 5 provided by DLR.

Figure 28: With the SmartIce team in the ECCC lab in Pond Inlet (left), and in surveying mode with SmartIce observer Peter Inootik in the bird operator seat (right).

Figure 29: Polar 6 at the pump in Pond Inlet.

Figure 30: The eastern floe edge of Eclipse Sound on April 6 (left). The triangular region of new ice also visible in the lower right of SAR image of April 6 map above. This region constitutes a significant travel hazard for hunters from Pond Inlet.

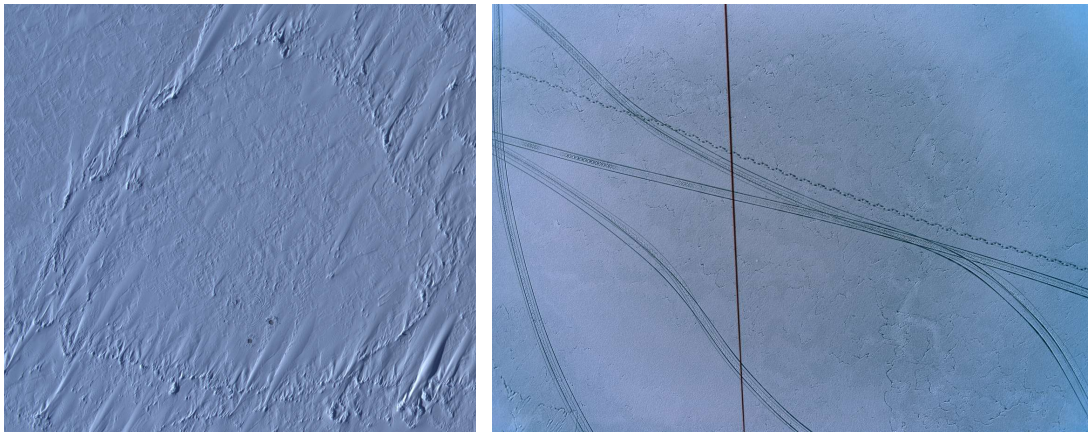

Figure 31: MACS images of a SmartIce sampling site with two large snow removal sites (left) and of the triangular region of new ice shown in the arial photo above showing polar bear track and snowmobile tracks (right).

4.7 Eureka, April 10 to 15: Last Ice Area, Lincoln Sea, and Ward Hunt &Milne Ice Shelves

With good weather forecast for landing in Eureka we left Resolute on April 10, without the CryoSAR and without Richard Kelly as planned. The objectives of the surveys in Eureka were to continue our long-term observations of the old ice in the Last Ice Area north of Ellesmere Island. Eureka is challenging because the only fuel available is from drums, and we only had fuel for two flights. In addition, there were challenging weather conditions with a jet of strong northeasterly gales along the north coast, and a wide band of clouds with sunny conditions further north. The satellite images received from the German Weather Service DWD were extremely helpful for flight planning, in particular time series of images that showed the moving direction and speed of cloud fields. However, on April 13 and 14 we were able to carry out two surveys reaching up to 85°N and farther. In order to facilitate this, we could only fly low on our way north, and returned at higher altitudes allowing for faster flying. The flight on April 13 covered the sea ice north of Nansen Sound, while the fast ice in Nansen Sound itself and the thin new ice in a large polynya farther north could not be surveyed. We were also able to air-drop two Calib GPS buoys that will track the sea ice in preparation of our surveys in the

summer. On April14 we were able to repeat surveys of the Ward Hunt Ice Shelf and multiyear ice to the north, while carrying out a snow radar and laser scanner survey of the Milne Ice Shelf and Glacier on return.

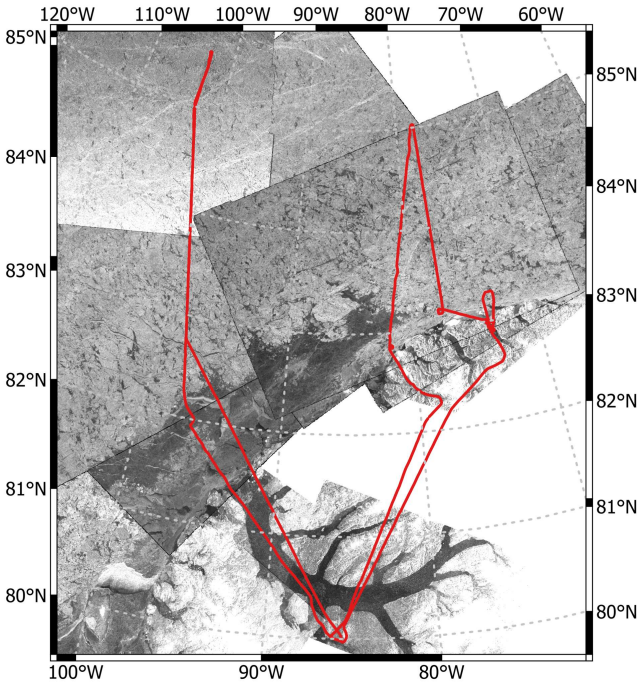

Figure 32: Map of the two flight tracks covered from Eureka, a Last Ice Area survey north of Nansen Sound on April 13 (western flight track), and a survey of the Ward Hunt and Milne Ice Shelves and the multiyear ice north of them on April 14.

Figure 33: The large coastal polynya and extensive cloud cover along the north coast of Ellesmere Island as seen on the return from the sea ice survey on April 13.

Figure 34: The eastern part of the remaining Ward Hunt Ice Shelf on April 14, with typical surface undulations and Ward Hunt Island in the back, separated by first-year fast ice in place of the former, more extensive ice shelf.

Figure 35: Heavily ridged multiyear ice and some refrozen leads in the Last Ice Area on April 14. Note absence of snow on new ridges.

Figure 36: Captain Bill and AME Kevin emptying a few drums at Eureka, with FO Almina invisible on the wing.

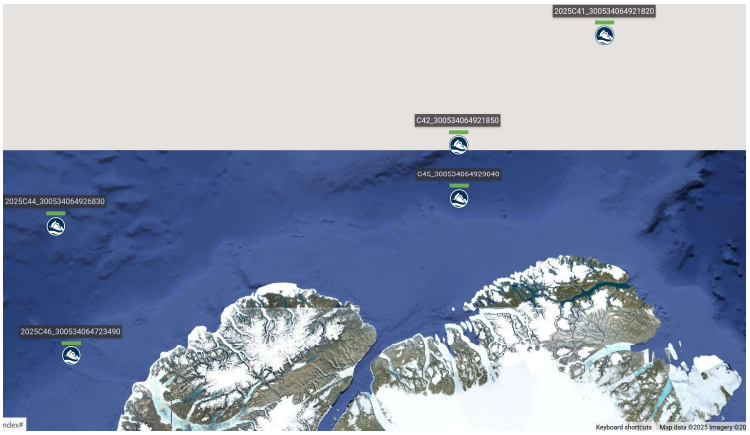

Figure 37: Map of the location of the five successful out of seven air deployments of Calib buoys in the Last Ice Area. The two eastern Calibs were deployed on the April 13 flight from Eureka, while the others were deployed on April 17 and 18 from Station Nord.

4.8 Station Nord, April 15 to 20: Last Ice Area and Transpolar Drift

With all objectives achieved north of Eureka we headed to Station Nord on April 15. Weather conditions were again challenging, but thanks to the satellite images from DWD we were able to identify large enough cloud free regions that even warranted longer approach flights. For example, they showed on April 17 that there was a cloud free region from almost the coast up to 85°N at 50°W, a region that we have surveyed previously as well. We took the risk of going there and once heading north from the foggy coast were rewarded with a good flight over the Last Ice Area in the Lincoln Sea close to Alert, where we could also deploy two Calibs in preparation of the Contrast cruise of RV Polarstern in the summer. The ice was very compact with no open water along the complete flight track, and satellite images showed that it was part of an extensive region of immobile ice extending as far west as to the Ward Hunt Ice Shelf. It was also characterized by higher radar backscatter then regions farther north.

On April 18 weather conditions were favorable for a long sea ice survey just north from Station Nord, reaching the farthest north latitude of IceBird CAN25 of 87°05'N and deploying three more Calibs of which two failed.

On April 19 weather conditions were questionable throughout, but the remaining goal of a transect across Fram Strait and underflight of Sentinel-3 seemed just to be possible. Therefore we took off and headed east, but when crossing over the Flade Isblink ice cap we already encountered strong turbulence that continued over the ocean. While the coastal regions were almost cloud free, conditions farther east were marginal with low but patchy clouds, and eventually we decided to cancel the survey because flying very low with the EM bird would have been too difficult and dangerous. Instead, we had time to carry out a survey of the runway and buildings of Station Nord with overflights in two different directions which is required for accurate processing and projection of the laser scanner and MACS data.

The station personnel of Station Nord were very welcoming as always and interested in our work. Therefore we gave a short science presentation about the IceBird programme one night, and were also able to take each of them along on one of the survey flights in order to observe the lay of the land over which they watch and sea ice conditions farther north themselves for which they rarely get opportunities otherwise.

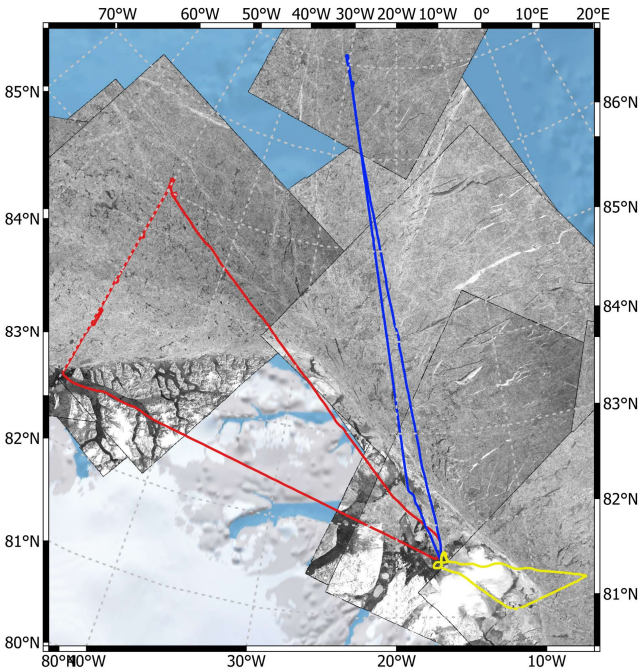

Figure 38: Map of all flight tracks out of Station Nord, on April 17 (red), 18 (blue), and 19 (yellow, aborted due to poor weather. On April 19 we were able to carry out a cross-over survey of Station Nord.

Figure 39: Heavy ridging with no open water whatsoever in the Last Ice Area of the Lincoln Sea at 50°W on April 17.

Figure 40: Extensive shear ridges along the northern Coast of northeast Greenland seen while returning from a sea ice survey on April 18.

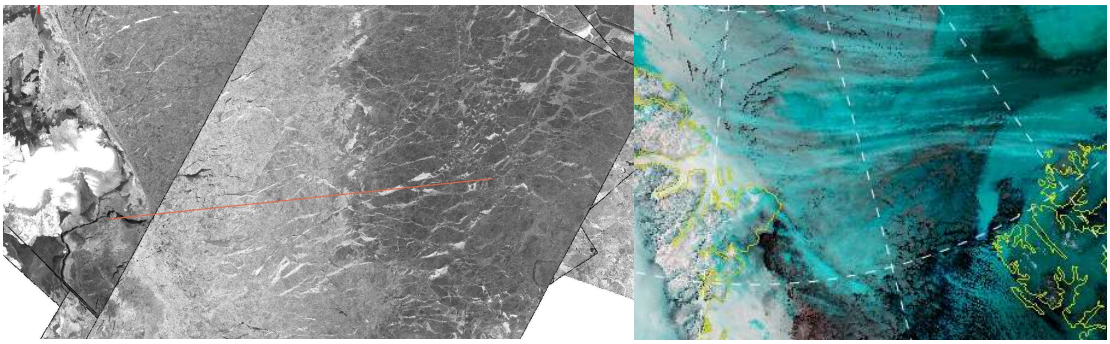

Figure 41: Planned survey on April 19 across Fram Strait following a Sentinel-3 ground track and crossing the prominent boundary between multiyear ice in the west and first-year ice in the east (left). However, DWD satellite images showed marginal conditions with broken clouds over Fram Strait, that turned out to be too dense to safely carry out a low level EM Bird flight.

Figure 42: Northern stretches of the Northeast Water Polynya in April 19, just south of the recurring fast ice region extending east from the northeastern corner of Greenland. Note shuga consisting of frazil ice crystals indicative of strong winds, and grounded icebergs that pin the fast ice.

Figure 43: MACS photo mosaic of Station Nord acquired on April 19.

Figure 44: Farewell from Station Nord, April 20

4.9 Longyearbyen, April 20 to 22: Van Mijenfjord, Storfjord, and St3TART transects & sites

On Easter Sunday, April 20, we transferred from Station Nord to Longyearbyen. As we were unsuccessful the previous day with a Sentinel-3 underflight, we decided to follow a Sentinel-3 track on this day as one happened to lay right along our planned route. Weather conditions were only slightly better than the day before, but did allow a survey with the snow radar and laser scanner at 1500 ft altitude for the most part, with denser fields of clouds and eventually icing conditions in between. In Longyearbyen we were able to access the hangar and a fork lift despite the Easter holiday when however commercial flights still schedule the airport. Therefore we unloaded the aircraft after our arrival to be ready for a survey the next day.

And indeed, weather conditions were questionable but eventually very favorable for a survey of the ice around Svalbard on April 19. We surveyed the fast ice in Van Mijenfjord in support of a joint ESA InSAR project led by the Norwegian Geosciences Institute (NGI), and where also some drill-hole data exist from a UNIS field course. Then, we crossed Spitzbergen to

Storfjord, where we surveyed the pack ice in the vicinity of Hopen and back to the mainland. This survey was a rare repeat of earlier surveys in Storfjorden (Hendricks et al., 2011, King et al., 2017), and also served our St3TART project by underflying a long Sentinel-3 reference track. At its northwestern end, in Agardhbukta, our survey also included measurements along the same lines that were surveyed by the NORCE snow radar drone by Robert Ricker a few days later. Similarly, we overflew terrestrial snow radar drone sites in Adventdalen before landing in Longyearbyen.

The Svalbard sea ice survey was joined by Esther Horvath, AWI's foremost photographer, and Torbjörn Kagel, master student and snow radar expert from the University of Utrecht and NORCE.

With several objectives achieved in Svalbard, we loaded the plane after the survey in preparation of our departure on April 22. Luisa, Max and Christian took a commercial flight to Hamburg that arrived on the same day, while the Polar 6 arrived in Bremen on April 23 after an overnight stay in Trondheim. This concluded a very successful IceBird CAN25 campaign, with the most work of data processing and interpretation only starting now.

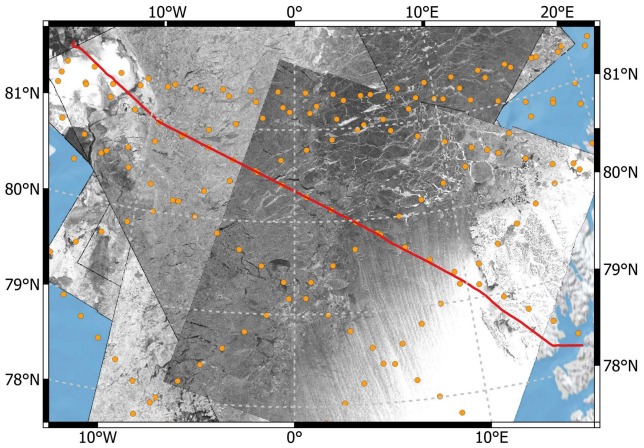

Figure 45: Map of the ferry flight from Station Nord to Longyearbyen across Fram Strait on April 20, where we were able to survey part of a Sentinel-3 ground track shown by orange circles(S3 orbit 36389). Note bright appearance of leads and streaks over the water south of the ice edge, indicative of strong northerly winds.

Figure 46: Arial view of the sea ice in Fram Strait on April 20 from an altitude of 1500 ft. Note variable cloud shadows and refreezing lead.

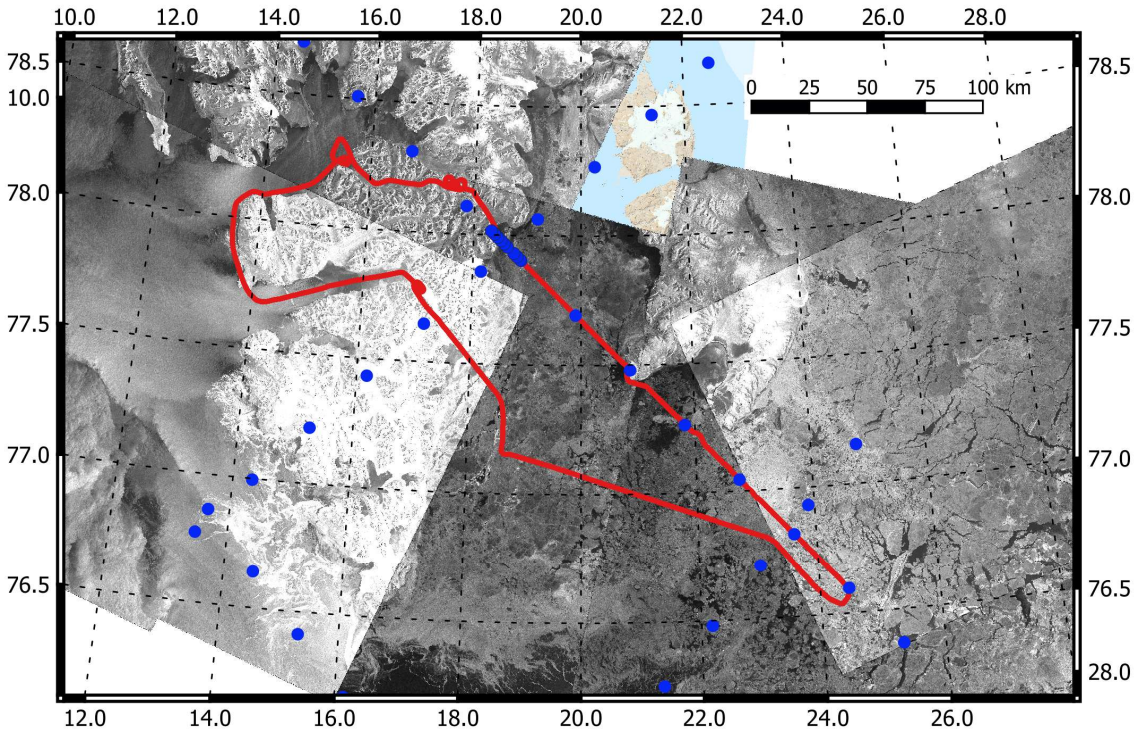

Figure 47: Map of the flight track over Van Mijenfjord and Storfjord, showing the island of Hopen in the bottom right. Blue dots indicate Sentinel-3 ground tracks, dense sequence of points shows NORCE snow radar survey in Agardhbukta.

Figure 48: Fast ice in Van Mijenfjord (in background, with remains of Sveagruva on the right) and Rindersbukta seen while climbing above Scheelebreen, a surging glacier surveyed by IceBird in August 2023.

Figure 49: Typical ice conditions in Storfjord on April 21, with widespread new ice interspersed with field of thick rubble.

5. Flying challenges

Most of our surveys require skilful flying by the pilots, as most measurements require an exact flight path with little altitude and attitude variations. The EM Bird requires altitude maintenance between 40 and 50 ft above the ice, and the CryoSAR and snow radar have narrow range acquisition windows. The figure below shows the CryoSAR GUI that shows the flight track and vertical and horizontal variations with much detail. It makes it easy for Richard to call out slight flight adjustments during the survey. There will be a prize for the pilot who is able to keep the Polar 5 the closest within the bull's eye shown on the right.

After more flying practise days both pilots have improved much and kept every instrument more steady. Below is an example of a bird flight that had very little height variations. Sophisticated statistical and Fourier analysis will be necessary to identify the winner of the contest.

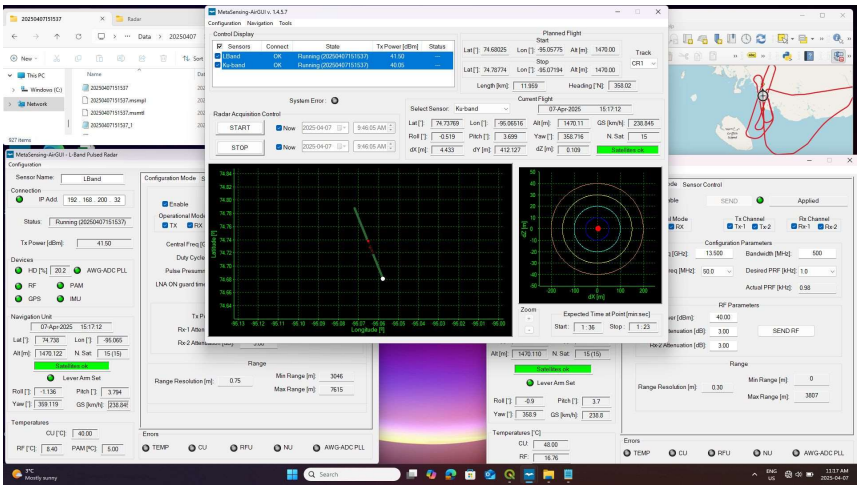

Figure 50: CryoSAR GUI showing relevant system and flight information. The red dot in the dark panel to the right shows that the Polar 6 is held right in the bull's eye, i.e. with perfect vertical and lateral alignment.

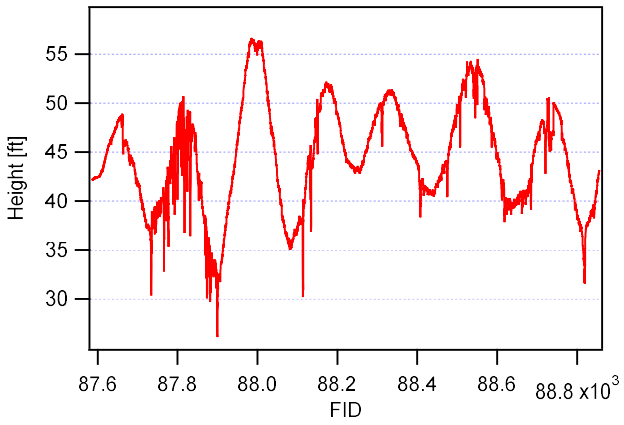

Figure 51: Short section of laser altimeter data (2 minutes, i.e. ca. 7.2 km) showing the usual, considerable altitude variations of the EM Bird.

6. Instrument status

All instruments worked very well. Few occasional issues with CryoSAR Ku channel; and low temperature issues with laser scanner, solved by external 230 VAC heater power over night. In addition, the winch computer on the Polar 6 did not boot properly and could not be used to operate the EM Bird. It has to be serviced before the next IceBird campaign with the Polar 6.

The mounting of the CryoSAR fairing became somewhat loose occasionally and the fairing began to vibrate during flight. Could be fixed by tightening bolts, but mounting design may have to be reviewed.

7. Flight Summary Table

Table 1: Overview of flights carried out during IceBird CAN 25.

Date	Activity	Flight hours
March 13	Test flight over Georgian Bay and MacDonald Lake	2.2
March 16&17	Ferry flight Muskoka-Whitehorse (scientists with Air Canada)	9.6+3.6
Mach 18	Kluane flight aborted due to severe turbulence	0.7
March 20	CryoSAR and short snow radar survey over Eclipse Ice Field; lake ice survey over Kluane Lake	3.5
March 21	Transit to Inuvik	2.6
March 22	CryoSAR survey over TVC, plus seventeen lines with ALS and snow radar	5.3
March 23	SmartIce survey in Liverpool Bay, and completion of TVC survey	5.5
March 25	Beaufort Sea survey, focusing on S3 underflight (orbits 36025 and 47385 (Mar 23))	5.3
March 26	Beaufort Sea MYI sea ice survey, including short RCM and S3 underflight (orbit 36034); surveying over Inuvik Tuk Highway (ITH) on return	5.4
March 27	Transit to Cambridge Bay	3.7
March 29	Victoria Strait sea ice survey, including S3 orbit 36104 (Mar 31)	4.3
March 30	Aborted mission due to sudden low clouds	0.2
March 31	Snow and sea ice surveys over MOACC area and SmartIce sites and Finlayson Islands	4.1
April 1	Transit to Resolute Bay, including short CryoSAR survey over Victoria Strait	3.1
April 2	Penny Strait and Queens Channel sea ice survey	4.4
April 3	Viscount Melville Sound sea ice and ice island survey	5.3
April 5	Devon Ice Cap snow survey and ferry to Pond Inlet	3.9
April 6	SmartIce field sites survey and floe edge flight, and ferry to Resolute with short Devon Ice Cap repeat survey	4.9+2.7
April 7	Snow surveys of KuKa sites near Resolute	2.3
April 10	Ferry to Eureka	2.1
April 13	Sea ice survey and buoy deployment to the northwest of Nansen Sound	5.6
April 14	Ice shelf and sea ice survey between Ward Hunt and Milne ice shelves	5.9
April 15	Ferry to Station Nord	3.6
April 17	Sea ice survey and buoy deployment northwest of Greenland, up to 85°N, 50°W	5.5
April 18	Sea ice survey and buoy deployment north of Nord, up to 87°N	5.4
April 19	Aborted survey across Fram Strait along S3 ground track due to poor weather. Cross-over survey of Station Nord	1.7
April 20	Ferry to Longyearbyen, with underflight of S3 orbit 36389 with snow radar and laser scanner for most part of the route over sea ice	2.6
April 21	Surveys in Van Mijenfjord, Storfjord, and Adventdalen in support for several joint St3TART activities and along S3 reference orbit 36446 (Apr 24)	3.8
	Total air time surveys	87.9
	Total air time transit	30.9
	Total	**118.8**
Survey days		21
Total days	(March 13 – Apr 21)	39

8. The IceBird CAN25 team

Christian Haas (CH), PI, AWI, Germany
Richard Kelly (RK), Co-PI, University of Waterloo, Canada
Luisa Wagner (LW), PhD student, AWI, Germany
Maximilian Stöhr (MS), Aircraft science engineer, AWI, Germany
Dean Emberly (DE), Captain, Kenn Borek Air, Calgary AB, Canada (until Mar 30)
William (Bill) Houghton (BH), Captain, Kenn Borek Air, Calgary AB, Canada (from Mar 31 on)
Almina Kovcic (AK), FO, Kenn Borek Air, Calgary AB, Canada
Kevin Riehl (KR), AME, Kenn Borek Air, Calgary AB, Canada

Figure 52: The IceBird CAN25 team in Resolute. From left: Kevin Riehl, Richard Kelly, Bill Houghton, Maximilan Stöhr, Luisa Wagner, Christian Haas, and Almina Kovcic (on her favorite wing).

8.1 Main direct collaborators:

Thomas Krumpen (Co-PI), Stefan Hendricks (Co-PI), Niklas Neckel, Veit Helm, AWI BHV, Germany
Wei Wang, University of Waterloo, Canada
Stephanie Saal, Yukon University, Canada
Luke Copland, University of Ottawa, Canada
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
Michel Tsamados & Tom Newman, UCL, UK
Steve Howell and Mike Brady, ECCC, Canada
David Burgess, NRCan, Canada
Alex Langlois and Dan Kramer, Sherbrooke University, Canada
Phil Marsh, Wilfrid Laurier University, Canada
Julienne Stroeve and Rosie Willat, AWI/UManitoba/UCL
Henriette Skourup, DTU, Denmark
Sara Fleury, LEGOS, France
Robert Ricker, NORCE, Norway
Dyre Damman and Ben Lange, NGI, Norway

9. Acknowledgements

We would like to thank the many people involved in the preparations and conduction of the IceBird CAN25 campaign, in particular Thomas Krumpen and Stefan Hendricks for planning and packing; Daniel Steinhage and Martin Gehrmann for applying for permits; Cristina Sans Col and Clements Gollin for leading the installation of all instruments in Muskoka; Silke Henkel and the Kenn Borek office for logistics during the campaign; Kelli Gillard and Mosha Cote for pushing the NIRB and NRI proposals over the finish line; and the countless people of the Aurora Research Institute, CHARS, PCSP, Eureka, and Station Nord that supported our stays and logistics support at their bases.

10. References

Belter, H. J., Krumpen, T., von Albedyll, L., Alekseeva, T. A., Birnbaum, G., Frolov, S. V., Hendricks, S., Herber, A., Polyakov, I., Raphael, I., Ricker, R., Serovetnikov, S. S., Webster, M., and Haas, C. (2021). Interannual variability in Transpolar Drift summer sea ice thickness and potential impact of Atlantification, The Cryosphere, 15, 2575–2591, https://doi.org/10.5194/tc-15-2575-2021.

Haas, C., Hendricks, S., Eicken, H., Herber, A. (2010). Synoptic airborne thickness surveys reveal state of Arctic sea ice cover, Geophysical Research Letters, 37, L09501, 5 p., doi:10.1029/2010GL042652.

Haas, C., Lobach, J., Hendricks, S., Rabenstein, L., Pfaffling, A. (2009). Helicopter-borne measurements of sea ice thickness, using a small and lightweight, digital EM system, Journal of Applied Geophysics, 67(3), 234-241., doi:10.1016/j.jappgeo.2008.05.005 .

Hendricks, S., Gerland, S., Smedsrud, L.H., Haas, C., Pfaffhuber, A.A., Nilsen, F. (2011). Sea Ice Thickness Variability in Storfjorden, Svalbard, Annals of Glaciology, 52(57), 61-68.

Jutila, A., Hendricks, S., Ricker, R., von Albedyll, L., Krumpen, T., and Haas, C. (2022): Retrieval and parameterisation of sea-ice bulk density from airborne multi-sensor measurements, The Cryosphere, 16, 259–275, https://doi.org/10.5194/tc-16-259-2022.

King, J., G. Spreen, S. Gerland, C. Haas, S. Hendricks, L. Kaleschke, and C. Wang (2017), Sea-ice thickness from field measurements in the northwestern Barents Sea, J. Geophys. Res. Oceans, 122, 1497–1512, doi:10.1002/2016JC012199.

Krumpen, T., R. Gerdes, C. Haas, S. Hendricks, A. Herber, V. Selyuzhenok, L. Smedsrud, and G. Spreen (2016), Recent summer sea ice thickness surveys in Fram Strait and associated ice volume fluxes , The Cryosphere, 10 , pp. 523-534 . doi: 10.5194/tc-10-523-2016

Krumpen, T., L. von Albedyll, H.J. Bünger, G. Castellani, J. Hartmann, V. Helm, S. Hendricks, N. Hutter, J.C. Landy, S. Lisovski, C. Lüpke, J. Rohde, M. Suhrhoff, and C. Haas (2025). Smoother sea ice with fewer pressure ridges in a more dynamic Arctic, Nat. Clim. Chang. (2025). https://doi.org/10.1038/s41558-024-02199-5

von Albedyll, L., Haas, C., and Dierking, W. (2021). Linking sea ice deformation to ice thickness redistribution using high-resolution satellite and airborne observations, The Cryosphere, 15, 2167–2186, https://doi.org/10.5194/tc-15-2167-2021.