Supplementary Material

Spring Campaign Meteorology and Flight Summary

Week 1 (May 28-May 31, 2024)

The spring deployment began with a focus on capturing the initial sea ice conditions. On 28 May, the passage of an Arctic cyclone across the Lincoln Sea on 27 May resulted in a thinning of the cloud layer, relatively low predicted AODs (< 0.1) from the NASA Goddard Earth Observing System forward processing (GEOS-FP, see Section 7d) model, and decreasing relative humidity at mid-levels (500-700 hPa) over the buoy region, which was covered with fresh snow. Strong northerly winds persisted over the Canadian Archipelago and contributed to the cold air advection toward Ellesmere Island and across the Lincoln Sea. The northerly wind combined with a developing cyclone over northern Baffin Bay, and together with a strong northeasterly flow at the surface through the Nares Strait, effectively transported the surface air mass from the Lincoln Sea into Baffin Bay. These factors produced cloud-free conditions over the Lincoln Sea, supporting the SIMB survey flight (RF1, P-3B only, Table S1). After a high-altitude transit from Pituffik, the SIMB survey consisted of a mix of high-altitude and low-altitude legs and a square spiral over Buoy O on 28 May. The aircraft returned at low altitude (< 250m) via the Nares Strait, where high winds at flight level (15 to 25 m s^{-1}), blowing snow over sea ice, and sea spray over the polynya, were observed, as well as a gradient in aerosol size distribution and hygroscopicity. On this and many subsequent flights, the aircraft also passed near the long-term ground aerosol sampling station at Alert, Canada (82.50°N, 62.35°W) (Sturges and Barrie, 1989; Sharma et al., 2019), as it transited between Pituffik and the Lincoln Sea, enabling comparisons of ARCSIX data to the long-term aerosol record. In the spring, at least one of the ARCSIX aircraft transited near Alert on all flight days.

A weak Arctic cyclone was centered over the buoy region in the Lincoln Sea on 30 May. Behind the westward moving cyclone was an area of single-layered, low-level clouds (i.e., no mid or high clouds) that was sampled using two cloud walls (RF2). This cloud system developed in part due to the northward transport of dry continental air across the northern Greenland coast into the Lincoln Sea at mid-levels that merged with the strong northward advection of a warm air mass through the Fram Strait. GEOS-FP and the FLEXPART (FLEXible PARTicle) Lagrangian particle dispersion model (see Section 7e) predicted aged, elevated smoke over the buoys, that FLEXPART footprint emission sensitivities suggest originated from fires in boreal North America. The NASA High-Altitude Lidar Observatory (HALO; Section 4b) also indicated elevated smoke, some of which was in contact with the sampled clouds. Near-surface easterlies (westerlies) were found on the northern (southern) end of the two cloud walls. The P-3B aircraft also overflew the Thule High Arctic Atmospheric Observatory (THAAO) station (see Section 6b) during this flight.

31 May marked the first occurrence of severe clear-sky conditions in the domain, prompting a BRDF module focused on Buoy Q, north of Ellesmere Island (RF3). The weak Arctic cyclone over the Lincoln Sea moved westward and was replaced by a developing high-pressure system providing relatively quiescent conditions. Cloud-free skies and light, variable surface winds were observed north of Ellesmere Island. Although the strong warm air advection through the Fram Strait no longer extended to the North Pole, forward trajectories of Fram Strait parcels suggested that the low-level air mass sampled near Buoy Q may have originated from the Fram Strait approximately two days prior. The GEOS-FP and FLEXPART models did not predict appreciable dust, anthropogenic, or biomass burning aerosols near the surface in this region.

Week 2 (June 3-June 7, 2024)

Week two of the spring deployment focused on cloud lifecycle and aerosol objectives. Four flights were flown with three cloud-focused flights that included multi-day quasi-Lagrangian sampling and one BRDF flight. The week began with a broad high-pressure system developing over Greenland, extending northward, and generating light

westerly winds over the Lincoln Sea. Although the flow was quiescent north of Greenland, a moist air mass consisting of multi-layered clouds had dominated the northern flight domain over the previous few days and was gradually advecting westward. This air mass was replaced by another moist air mass from the east, containing a complex cloud scene sampled on 3 June with two cloud walls off the north coast of Greenland. The eruption of Iceland's Fagradalsfjall volcano on 29-30 May also provided a target-of-opportunity for the flights on 3, 5, and 6 June, as possible remnants of the air mass from this event were advected over the ARCSIX study area in the Lincoln Sea. Given the comprehensive aircraft payloads for characterizing aerosols, this represented a unique opportunity to assess the possible sulfate and ash evolution in an aged volcanic plume. Having coordinated flights of the P-3B and G-III on those days was particularly advantageous for capturing subtle aspects of the aged particles' physical and chemical properties.

Cloud-free conditions prevailed over the Lincoln Sea and the buoy array on 5 June as the broad high-pressure system over Greenland expanded northward. These conditions provided the second opportunity (RF5) to sample pre-melt onset/dry snow BRDF and sea ice properties in a neighboring region to RF3. Across the Lincoln Sea, surface winds were calm, increasing slightly with altitude, and from the east at 700 hPa. Southerly flow on the western side of the Greenland anticyclone, supported by a weak developing cyclone over northern Baffin Bay, advected mid and high clouds across the northern Greenland coast into the Lincoln Sea, southeast of the ARCSIX flight track. Forecasted conditions over the next two days were favorable for a quasi-Lagrangian flight series. In preparation, the G-III left the standard BRDF raster pattern to release several dropsondes to the east and pre-sample the air mass that was expected to move into the region. The CVI was turned on during fog observed at one end of the BRDF pattern (RF5) to capture aerosol residuals in the droplets.

Other aerosol types may have influenced the region as well. On both 5 and 6 June, the Aerosol Robotic Network (AERONET) station (Holben et al. 1998; Giles et al. 2019) at Alert, Canada had a brief spike in aerosol optical depth at 340-675 nm (AOD; up to >1 on 6 June) and a dip in the Angstrom exponent, indicating coarse aerosols, possibly dust or transported volcanic ash, in the column. Also on both days, GEOS-FP predicted dilute aged smoke slightly to the north of the region up to ~700 hPa that FLEXPART did not predict. On 5 June, the aircraft observed an aerosol layer at ~4 km with hygroscopic particles during transit, and another hygroscopic aerosol layer at ~2 km during the BRDF raster pattern. FLEXPART predicted the respective sources of these two layers to be predominantly from aged Eurasian sources and more recent Scandinavian sources. Maritime particles were also forecast over Baffin Bay during this time.

The forecast for 6 and 7 June generally captured the observed large-scale flow conditions permitting successful back-to-back quasi-Lagrangian flights (RF6 and RF7). On 6 June, the high-pressure system to the northwest of the ARCSIX flight region strengthened rapidly and expanded towards the North Pole. As a result, the Lincoln Sea experienced warming due to large-scale subsidence. At the same time, northerly winds transported zonal bands of moist air into the Lincoln Sea, resulting in low-level clouds near the surface along the ARCSIX flight track. The 6 June flight track started with a single, coordinated cloud wall off the northeast Greenland coast followed by both the P-3B and the G-III sampling the forecasted axis of the transport into the Lincoln Sea. During this survey flight line, the P-3B sequentially performed a standard cloud wall including long porpoising segments. There was limited below-cloud sampling during the porpoise. Preliminary hygroscopicity data indicated potential differences between aerosol properties near the two walls and FLEXPART indicated that at the ~1 km aerosol sampling leg for the first cloud wall may have had an Icelandic influence, whereas for the second wall may have been more influenced by smoke from boreal North America below 4 km. The G-III overflew the P-3B twice by adding delay maneuvers that also sampled the spatial gradients perpendicular to the survey line.

Light easterly winds persisted near the surface along the northern Greenland coast on 7 June allowing for the sampling of an air mass downwind of the Fram Strait. The broad high-pressure system continued to dominate the area north of Greenland on 7 June producing large-scale subsidence over the Lincoln Sea. Mid-level conditions were similar to 6 June but with increased northeasterly wind flow across the Lincoln Sea. The Lincoln Sea was blanketed

with low clouds that remained quasi-stationary and advected slowly westward during the day. A single cloud wall was flown on the eastern edge of Lincoln Sea containing three separate G-III overflights on the wall (one along the wall and two cross-sections). The HALO instrument observed a layer of what appeared to be predominantly combustion aerosols from the surface up to ~2km. GEOS-FP and FLEXPART predicted this layer would include some aged Canadian biomass burning aerosol, possibly some Eurasian anthropogenic sources, and that the air masses closer to the surface may have had some Icelandic (thus possibly volcanic) influence as well. Above and below the cloud wall specifically, FLEXPART predicted aerosols to have diverse sources, mainly from the central Arctic, but with more of a boreal North American influence to the north of the cloud leg, and more of North Atlantic source to the south of the cloud leg. Over the buoy area, a high-altitude smoke layer at ~9 km that FLEXPART predicted included some aged Eurasian carbonaceous aerosol (anthropogenic plus smoke aerosol) mixed in with aged smoke from Northern Canada. GEOS-FP also predicted the arrival and composition mixture of this aerosol layer, but it predicted it to arrive a day later. The P-3B ended RF7 with a low-level sampling run toward the mouth of the Nares Strait along the large-scale flow before returning to base.

Week 3 (June 10-June 14, 2024)

The final week of the spring deployment focused on capturing a last glance of the Lincoln Sea ice conditions. Cloudy conditions prevailed during most of the week leading to cloud-focused flights on 10 and 13 June and a sea ice survey flight on 11 June.

The 10 June flight (RF8) included the only cloud wall flight over the Baffin Bay. A low-pressure system was centered over the eastern Baffin Bay (south of Pituffik) creating cyclonic flow on 10 June. Deep, precipitating clouds moved towards Pituffik as the cyclone progressed northward, although northern Baffin Bay remained relatively cloud-free throughout the flight. This flight was planned to be shorter because of worsening conditions at Pituffik airfield. As was common, surface winds transported an air mass from the Lincoln Sea into the northern Baffin Bay through the Nares Strait. The northerly flow connected air passing over the ice-free North Water Polynya with a single-layer cloud system over sea ice in the northern Baffin Bay. The P-3B approached the cloud system starting from the ice-free region to the north at ~150 m and subsequently sampled the cloud with the wall pattern. This marked the only cloud wall of the spring deployment without P-3B/G-III coordination. The P-3B sampled sea spray aerosol, which forecasts and observations indicated was the dominant aerosol type sampled during this low-level flight. The G-III overflew THAAO and launched a single dropsonde in the northern Baffin Bay. Over this region, high sea spray concentrations in the Nares Strait were noted near the surface and many sea birds in the open water and on floating ice, which prior studies indicate could impact locally sampled aerosol properties (Croft et al. 2016). The G-III then performed a large-scale survey from west of the Canadian Archipelago to the Lincoln Sea, releasing sondes along its path. This flight plan characterized the regions that we expected to sample on the subsequent two flights. During this portion of the flight, the HALO and the NASA Micro-Pulse Lidar Network (MPLNET) lidar (Welton et al. 2000, 2001) from the Zero Altitude PEARL Auxiliary Laboratory (ØPAL) at the Eureka Weather station on Ellesmere Island captured a likely high latitude dust emission event over Ellesmere Island that had not been predicted by the models, and strong biomass burning aerosol layers at 2 to 4 and 6 to 9 km that the models suggest may have been sourced from boreal North America and Europe, respectively.

The high-pressure system that had lingered over the Arctic seas north of Greenland for the prior several days moved west of the ARCSIX flight domain on 11 June. The warm air mass over the buoys due to the large-scale subsidence was gradually being replaced by colder air advected from the North Pole, resulting in low predicted fine-mode AOD (~ < 0.1) in the International Cooperative for Aerosol Prediction (ICAP) multi-model ensemble over the Lincoln Sea. The northerly winds also transported a moist air mass at mid- to upper-levels bringing mid- and high-level clouds into the northern flight domain. This resulted in intermittently cloudy conditions over the Lincoln Sea. Forecasts indicated that 11 June was the last opportunity to sample sea ice conditions before the end of the spring

deployment. The presence of mid-level clouds required the P-3B to fly near ~3 km over the Lincoln Sea for much of RF9, reducing the LVIS swath width from ~1.2 to ~ 0.6 km, relative to the nominal 6 km flight altitude. At or above flight level (3-5 km), an aerosol layer was detected by HALO. Forecasts indicate that this aerosol layer may have had combustion sources mainly from boreal North America and Eurasia. Aerosols sampled at this altitude did not appear to be very hygroscopic. Subsequent analysis indicated that 11 and 12 June marked melt onset for much of the sea ice in the Lincoln Sea. The P-3B flight path resembled the survey flight on RF1 with high- and low-altitude runs over the same flight lines and crossing the buoy array to sample the sea ice thickness gradient indicated by satellite data. The G-III overflew the P-3B several times during the survey; however, the mid-level clouds made it difficult to observe the surface. Due to this and given the likelihood of a cloud-focused flight on 12 or 13 June, the G-III was directed in-flight to add an excursion to the east to release dropsondes and pre-sample the air mass that was forecasted to move into the Lincoln Sea. The P-3B completed Nares Strait sampling, including observations of some low-level clouds and sea spray before returning to base.

The flight on 13 June marked the final flight of the spring deployment and consisted of a single cloud wall with a long leg along the axis of the large-scale flow (RF10). Converging winds from the north and south over the crown of Greenland were subject to sheared flow and primarily advected to the southeast towards Villum. This resulted from a stationary, strong cyclone being located to the northeast and a weaker cyclone to the southwest over the Canadian Archipelago. The flow through the Nares Strait had reversed the typical direction and was transporting air from the Baffin Bay into the Lincoln Sea. The flight began with high-altitude transit over Greenland by the P-3B and G-III. Both aircraft overflew the Villum Research Station and the P-3B performed a square spiral in clear-sky offshore through a sulfur-enhanced layer at 0.3-1 km and a strong inversion at 200 m that included the top of a cloud/fog layer. The P-3B then conducted a transit porpoising leg through a thin, low-lying cloud, a coordinated cloud wall with the G-III over the crown of Greenland, and then more porpoising on the return. The P-3B concluded its flight with a low-altitude run down the Nares Strait sampling sea spray and a comparatively deep cloud with the CVI. The G-III overflew several SIMBs buoys on its return and followed a similar track as the P-3.

Table S1: Summary of the Spring deployment research flights, including flight date, time, and special notes. Flights labelled with a "T" indicate transit flights. Standard ICAO airport codes are used below [KWAL (NASA Wallops Flight Facility), KLFI (NASA Langley Research Center), KBTV (Burlington, VT), KBGR (Bangor, ME), BGTL (Pituffik Space Force Base)]. Column 3 describes the flight coordination strategy, where "single" corresponds to one aircraft research flight, "coordinated" represents a two or three aircraft research flight executing planned temporal and spatial collocation, and "joint" represents a two or three aircraft research flight without collocation.

RF	**Date (MM-DD)**	**Single/ Joint/ Coordinated**	**Flight type/ Region**	**P-3**		**G-III**			**Special Notes**
				Takeoff (UTC)	Landing (UTC)	Takeoff (UTC)	Landing (UTC)	Sondes	
T-1	05-24	Single	Transit	10:02:48	17:45:41	--	--	--	Flight originated from KWAL to BGTL.
T-2	05-28	Single	Transit	--	--	Leg 1: 11:48:47 Leg 2: 13:57:47	Leg 1: 13:11:30 Leg 2: 18:26:41	0	Flight originated from KLFI to KBTV, then onto BGTL.
1	05-28	Single	Sea ice survey/Lincoln Sea	11:57:19	18:35:40	--	--	--	Square spiral at Buoy O, in clear-sky, no discernible cirrus above aircraft, low-level Nares leg
2	05-30	Coordinated	Cloud walls/Lincoln Sea	10:58:01	18:17:29	12:46:07	17:29:52	9	
3	05-31	Coordinated	BRDF Bowling Alley/North of	12:30:58	18:30:00	12:58:25	17:50:54	4	Multiple aerosol layers observed. Profiled stratospherically influenced air based ozone and methane observations.

			Ellesmere Island						
4	06-03	Coordinated	Cloud wall/North Greenland Coast	10:59:25	18:01:51	11:55:02	16:51:344	7	Research power system several instruments. Some inlet icing. Clouds during both walls appeared multilayered and generally complex, dissipated towards end of West wall.
5	06-05	Coordinated	BRDF Bowling Alley	11:02:45	18:51:11	12:08:58	17:39:21	12	Nares Strait run at 500 ft, Bowling alley center line flew at 3 altitudes (300, 1500, and 7200 ft). G-III broke off the raster pattern earlier than planned to survey the atmosphere to the east, dropping sondes upwind of the expected region of LaGrangian cloud sampling operations in the following days.
6	06-06	Coordinated	Cloud wall (quasi-LaGrangian)	11:01:40	18:42:55	12:26:46	17:50:01	11	Good coincidence with G-III during porpoising leg of cloud wall. Cloud bases below aircraft flight level (300ft). Poor aerosol sampling below cloud base. Good aerosol sampling above cloud top on porpoise leg.
7	06-07	Coordinated	Cloud wall (LaGrangian)	13:19:04	18:46:10	13:54:50	18:52:41	16	Extended wall leg durations (up to ~24 minutes). Initial observations of low cloud tops, clouds with large-scale 'roll' structure in wall region. Wind speed during minimum altitude leg provided good aerosol sampling at 300 ft.
8	06-10	Joint	Cloud wall	11:08:17	15:57:35	10:57:09	15:44:54	3	Baffin Bay flight focused on aerosol-cloud interaction objectives. Surface aerosol reports were mostly hygroscopic sea spray aerosol. G-III spotted breaks in the ice near Buoy Q. Limited spatial collocation between the P-3 and G-III.
9	06-11	Coordinated	Sea ice survey	11:03:04	18:50:42	11:26:25	16:51:59	7	On climb-out observed a layer of new particle formation. Sampled elevated concentration of aerosol on the Buoy-Q to Buoy-N leg at 10 kft; nitrate/organic/sulfate composition.
10	06-13	Coordinated	Cloud wall	10:59:58	18:24:41	12:08:30	17:08:00	9	Square spiral down just off the coast near Villum station. Clouds initially low and optically thin, tops generally below 500 ft. When able to sample below cloud CCN < 30 per cc.
T-3	06-14	Single	Transit	--	--	Leg 1: 11:28:46 Leg 2: 17:41:56	Leg 1: 16:14:17 Leg 2: 19:27:21	0	G-III Transit flight originated at BGTL to KBGR, then onto KLFI
T-4	06-17	Single	Transit	Leg 1: 11:00:06 Leg 2: 17:47:47	Leg 1: 17:05:40 Leg 2: 19:30:38				P-3 Transit flight originated from BGTL to KBTV, then onto KWAL

Summer Deployment Meteorology and Flight Summary

Week 1 (July 22-July 25, 2024)

With summer came additional challenges from local weather conditions, Lincoln Sea sky conditions, and G-III availability. The G-III experienced maintenance issues and diverted during the transit flight returning to Langley. The G-III was unavailable for science flights during the first two weeks of the deployment. An effort was made to use the P-3B to replace some aspects of the data that the G-III was providing by adding a higher altitude above-cloud leg to gather additional remote sensing data, when possible. At the beginning of the summer deployment, the radiation and surface characterization objectives were prioritized as they were less impacted by G-III's absence (Table S2).

As with the spring deployment, a top priority for the beginning of the summer deployment was to capture the Lincoln Sea surface conditions. The first summer flight on 25 July (RF11) contained a buoy survey as the primary objective. The flight domain was characterized by a strong southerly surge of moisture through the Fram Strait towards the North Pole and a relatively quiescent (but partly cloudy) region over the Lincoln Sea. Multiple thin cloud layers were observed in the Lincoln Sea below a deck of mid-level clouds at ~3 km. Although several model forecasts suggested a thinning of these clouds throughout the day, the clouds persisted throughout the flight with limited clearing (e.g., only a small pocket of clear sky along the north coast of Ellesmere Island). The P-3B began by sampling the buoy region; however, the presence of mid-level clouds required the aircraft to descend to 3 km to view the surface. The attempt to survey the surface had mixed success. During the second part of the flight, the P-3B sampled the low-level (< 1 km) clouds using the cloud wall flight pattern. For the first time during the campaign, the Learjet joined the P-3B, sampling the same cloud system. The Learjet performed a porpoising leg through the targeted cloud layer. AOD was predicted to be low (< 0.1) over the buoys based on the ICAP models, although a haze layer was observed in photos near Pituffik, and FLEXPART predicted a dilute, elevated smoke layer, which the aircraft appeared to capture during high-altitude transit.

Week 2 (July 29-August 2, 2024)

The next four summer flights, 29-30 July and 1-2 August focused on surface characterization, sea ice conditions, and surface radiation budget. These flights did not repeatedly survey the same locations because (1) the Lincoln Sea was often cloudy during the summer deployment and (2) anomalous sea ice conditions appeared off the Greenland northeast coast associated with warm air flowing northward through the Fram Strait both melting and pushing sea ice northward.

The primary objectives of the P-3B on 29 and 30 July (RF12, RF13) were to collect data needed to characterize the BRDF. By this point, the surface had been melting for more than a month and RF12 was the first opportunity to characterize the sea ice BRDF with melt ponds. On 29 July, a low-pressure system moved westward from the Lincoln Sea towards the northern coast of Ellesmere Island. This cyclone transported a moist, warm air mass northward through the Fram Strait towards the Lincoln Sea with abundant, multi-layered clouds. Behind the cyclone was a clearing over the crown of Greenland that expanded to the northwest through the day and became the target area for RF12. FLEXPART indicated the surface airmasses from that area and over the buoys had recent influence from the surface of north and northeastern Greenland.

The overall weather conditions persisted into 30 July as the Arctic cyclone centered off the northern coast of Ellesmere Island produced strong southerlies across the northern Greenland coast, the Lincoln Sea, and the Fram Strait over a deep atmospheric layer below ~200 hPa. This advection of dry continental air from over Greenland contributed to the expansive cloud-free area sampled on 30 July and low (< 0.1) predicted AODs from GEOS-FP. New particle formation was observed at a variety of altitudes in this flight, including at the surface. These flights marked the first implementations of the adjusted BRDF flight plan both sampling the eastern Lincoln Sea. RF12 also overflew the Japanese SIGMA-B sampling station north of Pituffik (Nishimura et al., 2023). The Learjet flew on these days, and,

because of its cloud-focused payload, the sorties were not coordinated with the P-3B and collected cloud microphysical data in the region north of Queen Elizabeth Islands.

The 30 July flight marked the first characterization of the northeast Greenland coast sea ice anomaly in the Wandel Sea. The P-3B sampled the region with high-altitude legs across the gradients in the sea ice concentration. The high altitude-legs captured sea ice topography and freeboard (thickness of sea ice above the ocean surface) in a region undergoing melt and a rapid reduction in sea ice concentration. With the emergence of the sea ice anomaly, the northeastern coast of Greenland became a focal point for the rest of the summer deployment.

A series of Arctic cyclones characterized the weather conditions over the ARCSIX domain for the first week of August: one large cyclone near the North Pole, another strong cyclone to the southeast of Greenland, and a smaller and weaker cyclone over the Canadian Archipelago. West-southwesterly winds over the Lincoln Sea were driven by the cyclone to the north, while the relatively moist air mass over the northern flight domain was advected by the strong southwesterlies across the Canadian Archipelago and northern Baffin Bay towards the Lincoln Sea. Clouds were present over much of the Lincoln Sea, except off the northeast Greenland coast (including Villum) behind the passing low-pressure system and the westward expansion of a broad high-pressure system east of Svalbard. As a result, the 1 August flight (RF14) returned to the northeastern coast of Greenland.

RF14 began with a Villum overflight, in coordination with the CleanCloud CLAVIER field campaign (see section 7g). The P-3B aircraft performed a square spiral off the coast that passed through an elevated aerosol layer, followed by several low-altitude legs over the low sea ice concentration region to characterize surface aerosol conditions. No distinct coarse mode aerosol was observed during the flight. On transit from the base of the spiral to the bowtie location (Fig. 2), the aircraft overflew a large chunk of previously land-fast sea ice that had broken off two days prior, with melt ponds and dark material covering the ice, likely from sediment, but possibly also including some aerosol deposition (Fig. S1). From around Villum to the bowtie location, the Polar5 aircraft, as part of the Norwegian IceBird campaign, flew along the same ARCSIX P-3B track to sample complementary ice characteristics (e.g., melt ponds), at which point that aircraft diverged to overfly the Norwegian Research Vessel Kronprins Haakon icebreaker with additional ice data ~ 280 km to the northeast. This flight marked the first implementation of the bowtie flight maneuver for BRDF measurements and was reused throughout the summer including after the G-III was operational.

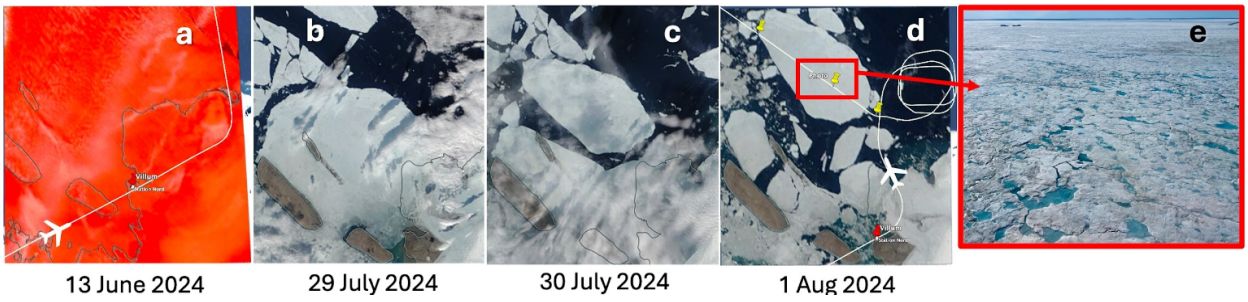

Figure S1: Land-fast sea ice prior to and after breaking off the coast of northern Greenland near the Villum Research Station (red pin in d). (a) shows the 13 June G-III overflight track (white line) and extensive early season sea ice from NASA WorldView Corrected Reflectance Terra/MODIS, Bands 3-6-7. The yellow pins indicate where darkened sea ice was observed (d) during the P-3B flight on 1 August 2024 (white line), which may be related to sediment and/or aerosol-deposition. Satellite images from NASA WorldView. Photo credit Matteo Ottaviani.

On 1 August, the Learjet sampled a single-layer cloud north of the Queen Elizabeth Islands over 1000 km west of the P-3B's bowtie. High concentrations of black carbon (BC) (at times > 700 ng m^{-3}) were predicted in the region by FLEXPART. During the transit from Pituffik at ~7-8 km, the crew could smell the smoke. This smoke was estimated

to have had a North American biomass burning source from a few days prior. However, BC concentrations in the cloud wall below 3 km were predicted to be unaffected by this elevated smoke layer.

A weakening low-pressure system over the Canadian archipelago was moving northward toward Ellesmere Island on 2 August inducing south-southwesterlies at mid-levels. The southwesterly winds along the Nares Strait from the previous few days had weakened, particularly near the surface, but persisted at mid- to upper-levels as the cyclone migrated northward. Skies were cloud free over the Lincoln Sea ahead of the approaching cyclone. Gradual warming occurred over the buoys due to the westward expansion of the high pressure over Svalbard and the strengthening high-pressure system over Greenland. This synoptic set-up created conditions for clear-sky BRDF sampling and an under flight of NASA's Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) on RF15. This coordinated under flight was only possible during the summer deployment, as ICESat-2 was in safehold mode during the spring deployment. In summer, most of the ICESat-2 overpasses within reach of the aircraft were either cloudy or unreachable within the airfield operational time window (11-19 UTC). The successful ICESat-2 underflight was a ~200 km line extending to the NW from a point to the west of Alert where ICESat-2 passed overhead while the P-3B was performing the transect. Wind data were not available to perform a drift correction. The remainder of this flight focused on collecting BRDF measurements between Buoys N and O, followed by porpoising through clear and cloudy skies on the return down the Nares Strait, and finally, a repeat of part of the Learjet sampling earlier in the day in the Baffin Bay. Because of the clear-sky focus of the P-3B flight, the Learjet sampled low-level clouds in the north Baffin Bay.

Aerosol predictions and measurements on August 2 showed smoke influence south of the Nares Strait and cleaner conditions in the buoy region. GEOS-FP predicted low AOD over the buoys, whereas FLEXPART indicated some smoke influence from boreal North America during the P-3B flight. Nearby Maritime Aerosol Network (MAN) data (Smirnov et al., 2009) from the RV Kronprins Haakon vessel showed AOD < 0.1 ~370 km northeast of Buoy O, with Alert data from ~120 km south or more similarly low.

Both FLEXPART and GEOS-FP models predicted high smoke concentrations in Baffin Bay (where the Lear sampled), with FLEXPART suggesting this extended primarily at higher altitudes through Nares Strait. P-3B photos and FLEXPART back trajectories confirmed an elevated biomass burning layer near the Nares Strait and offshore Ellesmere Island. A qualitative assessment of MPLNET ØPAL data suggests another aerosol layer up to ~1.5 km, approximately 275 km northwest of the Learjet flights, which FLEXPART also attributed to biomass burning.

Week 3 (August 5-9, 2024)

The G-III returned to full science operations beginning on 7 August. G-III transit flights between BGTL and CYYR (Goose Bay, Canada) occurred on 5 and 6 August, during which science data was collected, including sondes, underflying the Polar Radiant Energy in the Far InfraRed Experiment (PREFIRE; L'Ecuyer et al., 2021) satellite, and a survey of a potential phytoplankton bloom signature in the Baffin Bay. Elevated smoke layers were observed, as were near-surface sea spray aerosols. MODIS Terra/Aqua Combined AOD in the Baffin Bay was < 0.1.

A series of cloud-focused flights leveraging triple-aircraft coordination began on 7 August. Each of these flights included cloud walls in different regions, spanning northwest of Ellesmere Island (RF16), from the crown of Greenland into the Lincoln Sea (RF17), and the western Canadian Archipelago (RF18). These flights included coordination by all three aircraft on at least one of the cloud walls.

On 7 August, a persistent Arctic cyclone had centered itself near the North Pole and the cyclone's frontal (precipitating) band was draped over northeastern Ellesmere Island, with a tailing dry slot. As a result, relatively quiescent conditions and single-layered low-level clouds were observed over the northwestern coast of Ellesmere Island in the cold sector of the cyclone and sampled during RF16. One cloud wall was conducted with all three aircraft, and the other included P-3B and G-III coordination. The P-3B also overflew at ~16:23 UTC the Icebreaker Oden in

the Nares Strait during the North Greenland Earth-Ocean-Ecosystem Observatory (GEOEO) (GEOEO 2025) campaign. Aerosol conditions in the lower altitude cloud wall were predicted by GEOS-FP and FLEXPART to have relatively low levels of aerosols, but the HALO observed widespread aerosol above 4 km that FLEXPART suggested was influenced by an aged mix of North American and Russian smoke. New particle formation was observed during the spiral, and just before the spiral at a bit above 5 km, some large accumulation mode, non-hygroscopic particles were observed.

On 8 August 2024, the near-stationary Arctic cyclone centered over the North Pole pushed the air masses from northern Ellesmere Island northeastward and generated westerly winds across the buoys and the Lincoln Sea. As in RF16, the cloud walls over the Lincoln Sea sampled during RF17 were single-layer, low-level clouds within the outer bands of the cyclone. Again, only one of the two cloud walls involved the Learjet. There was also an Oden overflight by the P-3B (17:36 UTC). GEOS-FP predicted low AOD over the buoys. HALO observed some relatively dilute aerosol from 3-8 km that the P-3B likely sampled during transit; FLEXPART predicted this air mass included dilute aged North American biomass burning. The surface cloud wall was below this layer.

By the time of the third flight in this sequence on 9 August 2024, the Arctic cyclone had moved northward and was replaced by a strengthening high-pressure system from north of Queen Elizabeth Islands. Widespread low-level clouds were observed throughout the western Canadian Archipelago (RF18) sampling region with relatively weak northerly winds. Subsidence aloft formed a stable boundary layer capped by a sharp inversion near 925 hPa. Strong northwesterly winds at mid-levels continued to transport warm and moist air across the Canadian Archipelago. The P-3B flew several low-level (~90 m) passes along Axel Heiberg Island to characterize warm INP where very clean conditions were observed, perhaps due to recent precipitation, which was observed nearby during the flight (the ground also appeared wet). Total particle concentration reached as low as 20 cc^{-1} at low altitude. A cloud wall was then conducted with the G-III and the Learjet. The P-3B sampled a second cloud wall in the area before returning to base. New particle formation was observed in the above-cloud legs of the first cloud wall. The Learjet flew a second sortie on 9 August in the nearby Kane Basin porpoising through a mid-level (between 2-3 km) cloud layer straddling the coastline.

Week 4 (August 12-16, 2024)

The final research flight of the summer deployment occurred on 15 August (RF19), after previous attempts were thwarted by weather conditions. This flight provided a final opportunity to characterize the surface within the region of widespread sea ice loss to the northeast of Greenland, under clear-sky conditions. The northern flight domain was situated between an Arctic cyclone farther north and a deeper and broader cyclone over the Norwegian Sea (east of Greenland). As a result, relatively weak winds and widespread low clouds were observed over the Lincoln Sea. A sizable area of clear-sky occurred on the eastern edge of the cloud layer (i.e., to the east of Buoys N and L). In this clearing with a low sea ice concentration, the P-3B and G-III executed the only combined BRDF data collection (P-3B: bowtie; G-III: raster pattern) of the summer deployment, including a P-3B box spiral over the BRDF point. On the return to base, the P-3B sampled above and below a mid-level cloud including an overflight by the G-III. During the transit to the BRDF sampling region, the G-III and Learjet coordinated on a cloud leg. This coordination took place over the R/V Oden in the southern Lincoln Sea. There were some aged North American biomass burning aerosols predicted by GEOS-FP and FLEXPART and observed by the P-3B and G-III in the Lincoln Sea between 2 and 4 km during the flights. The P-3B also observed some new particle formation at the higher altitudes.

Science data were collected during the transit flight on 16 August. The P-3B and G-III began flying through the Baffin Bay. The P-3B sampled below 1 km in the Baffin Bay, at times sampling low clouds in what appears to be an interesting late-season contrast to RF8 on 10 June, under flying the G-III track. The G-III flew over a phytoplankton bloom and observed sea spray near the surface in the northern part of the Baffin Bay, and then elevated smoke throughout the return. The P-3B then diverged to under fly NASA's Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) satellite over

Canada on the return. The G-III separately underflew the European Space Agency's Earth Cloud Aerosol and Radiation Explorer (EarthCARE) satellite and was one of the first validation flights along the eastern seaboard of the U.S., sampling a thick biomass burning plume.

Table S2. As in Table S1 for the summer ARCSIX research flights. GRF refers to transit flights taken to accomplish maintenance needed where science data was taken.

RF	**Date (MM-DD)**	**Single/ Joint/ Coordinated**	**Flight type**	**P-3**		**G-III**			**Learjet**		**Special Notes**
				Takeoff (UTC)	Landing (UTC)	Takeoff (UTC)	Landing (UTC)	Sondes	Takeoff (UTC)	Landing (UTC)	
T-5	07-22	Single	Transit	11:04:32	18:37:41	--	--	--	--	--	The flight originated from KWAL to BGTL.
11	07-25	Coordinated	Buoy Survey/ Cloud wall	11:24:46	18:43:42	--	--	--	14:19:24	17:58:18	Presence of multiple cloud layers required P-3 to descend to 3.0 km to be below the thickest cloud but still overflew a lower cloud. Clouds mostly liquid.
12	07-29	Joint	BRDF/surface characterization	11:19:47	18:51:10	--	--		11:53:20	15:49:28	The target region was cloudy. Pattern was moved east in-flight to the clear-sky region and became centered near Buoy O. Flight concluded with a 35-minute low-level Nares leg (150 m)
13	07-30	Joint	Sea ice survey/BRDF	11:06:26	18:16:26	--	--		11:27:44	15:41:27	Surface characterization across the sea ice anomaly northeast of Greenland, spiral descent to west ending with clear-sky surface BRDF characterization in the Lincoln Sea.
14	08-01	Joint	BRDF and sea ice characterization	11:13:45	18:39:49	--	--		11:29:03	15:28:28	Villum overflight with spiral descent offshore, low-level leg across sea ice gradient of the northeast coast of Greenland, BRDF 'bowtie' maneuver, Coastal sea ice survey towards buoy region. In coordination with the CleanCloud CLAVIER field campaign.
15	08-02	Joint	BRDF sea ice characterization	11:08:01	19:11:36	--	--		16:12:00	18:02:31	Clear-sky buoy survey and IceSat under flight, clear-sky BRDF characterization between buoy N to buoy O

GRF-10	08-05	Single						2			Transit from BGTL to CYYR
GRF-11	08-06	Single		--	--	10:19:42	15:25:31	9	--	--	Flight from CYYR to BGTL with a PREFIRE under flight, survey of north Baffin Bay aerosol; no phytoplankton bloom signature found.
16	08-07	Coordinated	Cloud walls	10:57:35	18:53:35	12:02:23	17:21:03	16	11:18:02	15:09:53	First 3-aircraft coordinated cloud wall sampling. Cloud sampling in cold sector of a Long-lived cyclone centered at 60W, 87N. Two cloud walls performed.
17	08-08	Coordinated	Cloud walls	11:00:36	18:29:38	11:58:38	17:10:57	16	11:50:11	15:02:13	Two cloud layers are both thin. Low-level Nares Strait leg. G-III extended figure "4" on cloud wall 2 gaining clear-sky views of the surface.
18	08-09	Coordinated	Cloud walls	11:05:03	18:41:25	12:13:27	17:48:07	14	Flight 1: 11:35:54 Flight 2: 16:40:28	Flight 1: 15:31:54 Flight 2: 18:36:48	Coordination with both the Learjet and G-III. P-3 flew a 2-hour low level segment at ~91m for INP measurements.
19	08-15	Coordinated	Clear-sky survey/surface characterization	11:00:51	18:31:45	11:36:36	16:36:15	15	13:08:03	17:22:54	Clear-sky survey in sea ice anomaly region oriented east-west from buoy N. BRDF maneuver underneath a G-III raster at the eastern end. Farthest east measurements of the campaign. A dominant smoke layer was observed to descend from 7-9 km down to 3.5-4.5 km over the raster pattern with the thickest smoke located over the northeast side. Aircraft were not collocated.
T-6	08-16	Single	Transit	Leg 1: 11:11:22 Leg 2: 19:02:06	Leg 1: 17:58:07 Leg 2: 20:39:02	--	--	--	--	--	P-3 Transit flight originated from BGTL to KBGR, then onto KWAL. BGTL to KBGR leg included low-level sampling in the Baffin Bay.
T-7	08-16	Single	Transit	--	--	Leg 1: 11:15:52 Leg 2: 17:52:24	Leg 1: 16:08:55 Leg 2: 20:25:06	15	--	--	G-III Transit flight from BGTL to KBGR, then onto KLFI. EarthCARE under flight off U.S. East Coast sampled smoke from Canadian wildfires.

Table S3: Summary of the 3-stage microanalysis particle sampler (MPS-3) filter samples.

Research Flight	Date	SampleNumber_Leg	Time Start (UTC)	Time Stop (UTC)	Sample Duration (hh:mm)
RF01	5/28/2024	RF01_1	12:23	15:12	2:49
		RF01_2	15:33	16:34	1:01
		RF01_3	16:43	17:59	1:16
RF02	5/30/2024	RF02_1	11:15	12:13	0:58
		RF02_2	12:24	13:21	0:57
		RF02_3	13:40	13:50	0:10
		RF02_4	14:00	14:15	0:15
		RF02_5	14:23	15:04	0:41
		RF02_6	15:18	15:36	0:18
		RF02_7	15:46	16:12	0:26
		RF02_8	16:43	17:27	0:44
RF03	5/31/2024	RF03_1	12:45	13:20	0:35
		RF03_2	13:40	15:03	1:23
		RF03_3	15:34	16:42	1:08
		RF03_4	16:54	18:06	1:12
RF04	6/3/2024	RF04_1	11:14	13:09	1:55

		RF04_2	13:37	13:43	0:06
		RF04_3	14:16	14:42	0:26
		RF04_4	15:24	16:03	0:39
		RF04_5	16:26	16:51	0:25
RF05	6/5/2024	RF05_1	11:10	11:53	0:43
		RF05_2	12:01	12:13	0:12
		RF05_3	12:24	13:47	1:23
		RF05_4	14:14	15:04	0:50
		RF05_5	17:09	18:21	1:12
RF06	6/6/2024	RF06_1	11:25	11:53	0:28
		RF06_2	12:01	13:04	1:03
		RF06_3	13:40	15:09	1:29
		RF06_4	15:58	16:45	0:47
		RF06_5	17:17	18:15	0:58

RF07	6/7/2024	RF07_1	15:22	15:44	0:22
			15:51	16:08	0:17
		RF07_2	16:19	17:30	1:11
RF08	6/10/2024	RF08_1	11:50	12:13	0:23
		RF08_2	13:51	14:11	0:20
		RF08_3	14:54	15:22	0:28
RF09	6/11/2024	RF09_1	11:27	12:28	1:01
		RF09_2	12:52	14:22	1:30
		RF09_3	14:57	16:13	1:16
		RF09_4	17:23	18:21	0:58
RF10	6/13/2024	RF10_1	11:56	12:56	1:00
		RF10_2	13:25	14:22	0:57
		RF10_3	14:33	14:49	0:16
		RF10_4	15:35	16:18	0:43
		RF10_5	16:33	17:27	0:54
		RF10_6	17:35	17:42	0:07
RF11	7/25/2024	RF11_1	11:51	12:25	0:34
		RF11_2	12:48	13:14	0:26
		RF11_3	15:27	15:40	0:13
		RF11_4	17:09	17:21	0:12
RF12	7/29/2024	RF12_1	11:46	13:16	1:30
		RF12_2	14:58	16:20	1:22
		RF12_3	17:27	17:54	0:27
RF13	7/30/2024	RF13_1	11:26	13:48	2:22
		RF13_2	14:14	14:55	0:41
		RF13_3	15:10	16:08	0:58
		RF13_4	16:19	17:20	1:01
RF14	8/1/2024	RF14_1	11:40	13:00	1:20
		RF14_2	13:47	15:41	1:54
		RF14_3	16:18	18:08	1:50
RF16	8/7/2024	RF16_1	11:29	12:34	1:05
		RF16_2	13:21	14:06	0:45
		RF16_3	14:15	15:27	1:12
		RF16_4	16:03	16:25	0:22
		RF16_5	16:32	16:54	0:22
		RF16_6	17:58	18:42	0:44
RF17	8/8/2024	RF17_1	11:40	12:40	1:00
		RF17_2	13:00	13:16	0:16
			13:30	13:39	0:09
		RF17_3	14:05	15:17	1:12
		RF17_4	16:00	16:23	0:23
		RF17_5	17:07	18:03	0:56

RF18	8/9/2024	RF18_1	11:30	12:48	1:18
		RF18_2	14:46	16:09	1:23
		RF18_3	17:24	17:54	0:30
RF19	8/15/2024	RF19_1	11:27	13:36	2:09
		RF19_2	14:36	14:58	0:22
		RF19_3	15:12	15:38	0:26
		RF19_4	17:15	18:05	0:50

Table S4: Summary of size and time-resolved aerosol collector (STAC) filter samples.

Sample Name	Sampling Date	Flight number	Sampling Start Time (UTC)	Sampling Finish Time (UTC)	Sampling length (hh:mm)	Altitude (m; a.m.s.l)
NASA_Arcsix_20240528_Flight01_altitude5200m_IM01	5/28/2024	1	12:26	13:32	1:06	5,200
NASA_Arcsix_20240528_Flight01_altitude5200m_IM03	5/28/2024	1	13:35	14:55	1:20	5,200
NASA_Arcsix_20240528_Flight01_altitude170m_IM05	5/28/2024	1	15:33	16:31	0:58	170
NASA_Arcsix_20240528_Flight01_altitude170m_IM06	5/28/2024	1	16:50	17:25	0:35	170
NASA_Arcsix_20240528_Flight01_altitude170m_IM07	5/28/2024	1	17:25	17:59	0:34	170
NASA_Arcsix_20240530_Flight02_altitude3700m_IM08	5/30/2024	2	12:24	12:47	0:23	3,700
NASA_Arcsix_20240530_Flight02_altitude3300m_IM09	5/30/2024	2	13:07	13:11	0:04	3,300
			13:16	13:18	0:02	
			13:21	13:22	0:01	
			Total		0:07	
NASA_Arcsix_20240530_Flight02_altitude2800m_IM10	5/30/2024	2	14:12	14:17	0:05	2,800
			14:20	14:27	0:07	
			Total		0:12	
NASA_Arcsix_20240530_Flight02_altitude5200m_IM14	5/30/2024	2	16:23	17:27	1:04	5,200
NASA_Arcsix_20240531_Flight03_altitude5200m_IM15	5/31/2024	3	12:45	13:05	0:20	5,200
			13:38	14:38	1:00	
			14:49	15:10	0:21	
			16:54	18:06	1:12	
			Total		2:53	
NASA_Arcsix_20240531_Flight03_altitude4700m_IM17	5/31/2024	3	13:22	13:34	0:12	4,700
NASA_Arcsix_20240531_Flight03_altitude110m_IM18	5/31/2024	3	15:36	16:02	0:26	110
NASA_Arcsix_20240531_Flight03_altitude110m_IM19	5/31/2024	3	16:04	16:28	0:24	110
NASA_Arcsix_20240531_Flight03_altitude110m_IM20	5/31/2024	3	16:28	16:42	0:14	110
NASA_Arcsix_20240603_Flight04_altitude5700m_IM01	6/3/2024	4	11:16	11:56	0:40	5700
			12:07	12:08	0:01	
			12:40	13:07	0:27	

Sample Name	Sampling Date	Flight number	Sampling Start Time (UTC)	Sampling Finish Time (UTC)	Sampling length (hh:mm)	Altitude (m; a.m.s.l)
			Total		1:08	
NASA_Arcsix_20240603_Flight04_altitude6800m_IM02	6/3/2024	4	12:15	12:34	0:19	6800
NASA_Arcsix_20240603_Flight04_altitude5700m_IM03	6/3/2024	4	13:07	13:15	0:08	5700
NASA_Arcsix_20240603_Flight04_altitude300m_IM04	6/3/2024	4	13:41	13:46	0:05	300
			14:43	14:51	0:08	
			Total		0:21	
NASA_Arcsix_20240603_Flight04_altitude1900m_IM05	6/3/2024	4	13:51	13:56	0:05	1900
NASA_Arcsix_20240603_Flight04_altitude2300m_IM06	6/3/2024	4	15:00	15:19	0:19	2300
NASA_Arcsix_20240603_Flight04_altitude7400m_IM07	6/3/2024	4	16:46	17:26	0:40	7400 and 6700
NASA_Arcsix_20240605_Flight05_altitude3900m_IM08	6/5/2024	5	12:04	12:13	0:09	3900
NASA_Arcsix_20240605_Flight05_altitude5800m_IM09	6/5/2024	5	12:38	13:48	1:10	5800
NASA_Arcsix_20240605_Flight05_altitude100m_IM10	6/5/2024	5	14:16	15:03	0:47	100
NASA_Arcsix_20240605_Flight05_altitude440m_IM11	6/5/2024	5	15:29	15:56	0:27	440
NASA_Arcsix_20240605_Flight05_altitude2100m_IM13	6/5/2024	5	16:02	16:34	0:32	2100
NASA_Arcsix_20240605_Flight05_altitude440m_IM14	6/5/2024	5	17:13	17:29	0:16	440
			17:35	18:00	0:25	190
			Total		0:41	
NASA_Arcsix_20240605_Flight05_altitude190m_IM15	6/5/2024	5	18:00	18:21	0:21	190
NASA_Arcsix_20240606_Flight06_altitude190m_IM12	6/6/2024	6	11:21	11:52	0:31	5600
			12:01	12:08	0:07	5600
			12:09	13:17	1:08	5600
			Total		1:46	
NASA_Arcsix_20240606_Flight06_altitudewholecolumn_IM16	6/6/2024	6	13:19	13:28	0:09	5600-3100
			13:30	13:40	0:10	2600-300
			Total		0:19	
NASA_Arcsix_20240606_Flight06_altitude340_IM17	6/6/2024	6	13:58	14:11	0:13	340
NASA_Arcsix_20240606_Flight06_altitude1000_IM18	6/6/2024	6	14:14	14:27	0:13	1000

Sample Name	Sampling Date	Flight number	Sampling Start Time (UTC)	Sampling Finish Time (UTC)	Sampling length (hh:mm)	Altitude (m; a.m.s.l)
NASA_Arcsix_20240606_Flight06_altitude100-400m_IM19	6/6/2024	6	16:24	16:48	0:24	100-600
NASA_Arcsix_20240606_Flight06_altitude1100m_IM20	6/6/2024	6	16:52	16:57	0:05	1100
NASA_Arcsix_20240607_Flight07_altitude5700m_IM03	6/7/2024	7	13:42			5700
NASA_Arcsix_20240607_Flight07_altitude5700m_IM01	6/7/2024	7	14:39	14:47	0:08	5700
			14:49	14:55	0:06	
			Total		0:14	
NASA_Arcsix_20240607_Flight07_altitude110m_IM02	6/7/2024	7	15:18	15:45	0:27	110
NASA_Arcsix_20240607_Flight07_altitude740m_IM04	6/7/2024	7	15:51	16:15	0:24	740
NASA_Arcsix_20240607_Flight07_altitude5800m_IM05	6/7/2024	7	17:44	18:32	0:48	5800 and 4500
NASA_Arcsix_20240610_Flight08_altitude3800m_IM06	6/10/2024	8	11:16	11:30	0:14	3800
NASA_Arcsix_20240610_Flight08_altitude100m_IM07	6/10/2024	8	11:49	12:03	0:14	100
			12:10	12:12	0:02	
			12:25	12:45	0:20	
			Total		0:22	
NASA_Arcsix_20240610_Flight08_altitude100m_IM08	6/10/2024	8	12:45	12:53	0:08	100
			12:59	13:01	0:02	1200
			Total		0:10	
NASA_Arcsix_20240610_Flight08_altitude100m_IM09	6/10/2024	8	13:14	13:24	0:10	100
			14:15	14:21	0:06	250
			14:21	14:27	0:06	250
			Total		0:22	
NASA_Arcsix_20240610_Flight08_altitude700m_IM10	6/10/2024	8	13:28	13:39	0:11	700
NASA_Arcsix_20240610_Flight09_altitude5500m_IM03	6/11/2024	9	11:24	12:10	0:46	5500
			12:13	12:30	0:17	
			Total		1:03	
NASA_Arcsix_20240610_Flight09_altitude3000m_IM11	6/11/2024	9	12:42	14:02	1:20	3000
NASA_Arcsix_20240610_Flight09_altitude3000m_IM12	6/11/2024	9	14:02	14:22	0:20	3000

Sample Name	Sampling Date	Flight number	Sampling Start Time (UTC)	Sampling Finish Time (UTC)	Sampling length (hh:mm)	Altitude (m; a.m.s.l)
NASA_Arcsix_20240610_Flight09_altitude100m_IM13	6/11/2024	9	14:56	16:15	1:19	100
NASA_Arcsix_20240610_Flight09_altitude2400m_IM14	6/11/2024	9	16:37	16:49	0:12	2400
			16:51	17:14	0:23	
			Total		0:35	
NASA_Arcsix_20240610_Flight09_altitude100m_IM15	6/11/2024	9	17:30	17:36	0:06	100
			17:37	17:38	0:01	
			17:39	17:41	0:02	
			17:45	17:46	0:01	
			17:47	17:56	0:09	
			Total		0:19	
NASA_Arcsix_20240610_Flight10_altitude5600m_IM16	6/13/2024	10	11:25	12:57	1:32	5600
			12:58	13:03	0:05	
			Total		1:37	
NASA_Arcsix_20240610_Flight10_altitude100m_IM17	6/13/2024	10	14:49	15:02	0:13	100
NASA_Arcsix_20240610_Flight10_altitude1200m_IM18	6/13/2024	10	15:07	15:18	0:11	1200
NASA_Arcsix_20240610_Flight10_altitude100m_IM19	6/13/2024	10	16:34	17:31	0:57	100
NASA_Arcsix_20240610_Flight10_altitude100m_IM20	6/13/2024	10	17:31	17:42	0:11	100
			18:06	18:10	0:04	
			Total		0:15	
NASA_Arcsix_20240725_Flight11_altitude5500m_IM01	7/25/2024	11	11:49	12:25	0:36	5500
			12:39	13:09	0:30	5100
			Total		1:06	
NASA_Arcsix_20240725_Flight11_altitude2800m_IM02	7/25/2024	11	13:45	13:56	0:11	2800
			14:00	14:11	0:11	
			14:21	14:47	0:26	
			Total		0:48	
NASA_Arcsix_20240725_Flight11_altitude2800m_IM03	7/25/2024	11	14:59:00	15:11	0:12	In cloud

Sample Name	Sampling Date	Flight number	Sampling Start Time (UTC)	Sampling Finish Time (UTC)	Sampling length (hh:mm)	Altitude (m; a.m.s.l)
			15:25	15:27	0:02	
			Total		0:14	
NASA_Arcsix_20240725_Flight11_altitude800m_IM04	7/25/2024	11	16:03	16:20	0:17	800
			16:24	16:36	0:12	
			Total		0:29	
NASA_Arcsix_20240725_Flight11_altitude600m_IM05	7/25/2024	11	16:33	16:52	0:19	600
NASA_Arcsix_20240725_Flight11_altitude6000m_IM06	7/25/2024	11	17:17	17:22	0:05	5500
NASA_Arcsix_20240729_Flight12_altitude6000m_IM07	7/29/2024	12	11:44	11:46	0:02	5500
			11:49	11:54	0:05	5500
			12:03	12:22	0:19	6000
			12:33	12:36	0:03	6000
			13:00	13:24	0:24	6000
			Total		0:53	
NASA_Arcsix_20240729_Flight12_altitude100m_IM08	7/29/2024	12	13:58	14:19	0:21	100
NASA_Arcsix_20240729_Flight12_altitude3700m_IM09	7/29/2024	12	14:27	14:46	0:19	3700
NASA_Arcsix_20240729_Flight12_altitude1400m_IM10	7/29/2024	12	14:56	15:15	0:19	1400
			15:33	16:17	0:44	
			Total		1:03	
NASA_Arcsix_20240729_Flight12_altitude1400m_IM11	7/29/2024	12	15:15	15:33	0:18	1400
			16:17	16:18	0:01	
			Total		0:19	
NASA_Arcsix_20240729_Flight12_altitude450m_IM12	7/29/2024	12	16:35	16:55	0:20	450
NASA_Arcsix_20240729_Flight12_altitude100m_IM13	7/29/2024	12	17:28	17:53	0:25	100
NASA_Arcsix_20240730_Flight13_altitude5500m_IM14	7/30/2024	13	11:26	13:49	2:23	5500
NASA_Arcsix_20240730_Flight13_altitude500m_IM15	7/30/2024	13	14:20	14:38	0:18	500
NASA_Arcsix_20240730_Flight13_altitude100m_IM16	7/30/2024	13	14:41	14:56	0:15	100
NASA_Arcsix_20240730_Flight13_altitude1500m_IM17	7/30/2024	13	15:03	15:13	0:10	1500

Sample Name	Sampling Date	Flight number	Sampling Start Time (UTC)	Sampling Finish Time (UTC)	Sampling length (hh:mm)	Altitude (m; a.m.s.l)
			15:34	15:59	0:25	
			Total		0:35	
NASA_Arcsix_20240730_Flight13_altitude1500m_IM18	7/30/2024	13	15:13	15:34	0:21	1500
			15:59	16:07	0:08	
			Total		0:29	
NASA_Arcsix_20240730_Flight13_altitudem_IM19	7/30/2024	13	16:07	16:19	0:12	Vertical profile
NASA_Arcsix_20240730_Flight13_altitude5500m_IM20	7/30/2024	13	16:19	17:20	1:01	5500
NASA_Arcsix_20240730_Flight14_altitude5600m_IM1	8/1/2024	14	11:35	11:51	0:16	5600
			11:59	12:01	0:02	
			12:06	12:19	0:13	
			12:20	12:23	0:03	
			12:25	13:18	0:53	
			16:01	16:24	0:23	
			16:51	16:55	0:04	
			17:01	17:21	0:20	
			17:25	18:07	0:42	
			Total		2:56	
NASA_Arcsix_20240730_Flight14_altitude100m_IM2	8/1/2024	14	13:46	14:19	0:33	100
			15:10	15:21	0:11	
			Total		0:44	
NASA_Arcsix_20240730_Flight14_altitude600m_IM3	8/1/2024	14	13:46	15:06	1:20	600
NASA_Arcsix_20240802_Flight15_altitude5800m_IM4	8/2/2024	15	11:44	11:45	0:01	5800
			11:50	13:50	2:00	
			Total		2:01	
NASA_Arcsix_20240802_Flight15_altitude100m_IM5	8/2/2024	15	14:32	14:43	0:11	100
NASA_Arcsix_20240802_Flight15_altitude100m_IM6	8/2/2024	15	14:43	15:04	0:21	100
NASA_Arcsix_20240802_Flight15_altitude1000m_IM7	8/2/2024	15	15:11	15:19	0:08	1000

Sample Name	Sampling Date	Flight number	Sampling Start Time (UTC)	Sampling Finish Time (UTC)	Sampling length (hh:mm)	Altitude (m; a.m.s.l)
			15:42	16:26	0:44	
			Total		0:52	
NASA_Arcsix_20240802_Flight15_altitude1000m_IM8	8/2/2024	15	15:19	15:42	0:23	1000
			16:26	16:37	0:11	
			Total		0:34	
NASA_Arcsix_20240802_Flight15_altitude1800m_IM9	8/2/2024	15	17:29	17:34	0:05	1800
			17:46	17:50	0:04	
			Total		0:09	
NASA_Arcsix_20240807_Flight16_altitude5700m_IM10	8/7/2024	16	11:18	13:08	1:50	5700
			17:21	18:01	0:40	
			Total		2:30	
NASA_Arcsix_20240807_Flight16_altitude100m_IM11	8/7/2024	16	13:19	13:44	0:25	100
NASA_Arcsix_20240807_Flight16_altitude1000m_IM12	8/7/2024	16	13:51	14:11	0:20	1000
NASA_Arcsix_20240807_Flight16_altitude100m_IM13	8/7/2024	16	15:34	15:54	0:20	100
NASA_Arcsix_20240807_Flight16_altitude1600m_IM14	8/7/2024	16	16:04	15:54	16:24	1600
NASA_Arcsix_20240808_Flight17_altitude160m_IM15	8/8/2024	17	13:02	13:14	0:12	160
NASA_Arcsix_20240808_Flight17_altitude1700m_IM16	8/8/2024	17	13:29	13:39	0:10	1700
NASA_Arcsix_20240808_Flight17_altitude100m_IM17	8/8/2024	17	15:19	15:30	0:11	100
NASA_Arcsix_20240808_Flight17_altitude2200m_IM18	8/8/2024	17	16:04	16:21	0:17	2200
			16:39	16:41	0:02	
			16:48	16:59	0:11	
			Total		0:30	
NASA_Arcsix_20240808_Flight17_altitude100m_IM19	8/8/2024	17	17:12	17:42	0:30	100
NASA_Arcsix_20240808_Flight17_altitude100m_IM20	8/8/2024	17	17:42	18:01	0:19	100
NASA_Arcsix_20240809_Flight18_altitude5600m_IM1	8/9/2024	18	11:29	12:56	1:27	5600
			16:56	17:54	0:58	
			Total		2:25	

Sample Name	Sampling Date	Flight number	Sampling Start Time (UTC)	Sampling Finish Time (UTC)	Sampling length (hh:mm)	Altitude (m; a.m.s.l)
NASA_Arcsix_20240809_Flight18_altitudexxxxm_IM2	8/9/2024	18	12:56	13:10	0:14	Vertical profile
			13:15	13:21	0:06	
			Total		0:20	
NASA_Arcsix_20240809_Flight18_altitude100m_IM3	8/9/2024	18	13:21	13:35	0:14	100
NASA_Arcsix_20240809_Flight18_altitude800m_IM4	8/9/2024	18	13:38	13:53	0:15	800
NASA_Arcsix_20240809_Flight18_altitude1800m_IM5	8/9/2024	18	14:00	14:12	0:12	1800
NASA_Arcsix_20240809_Flight18_altitude100m_IM6	8/9/2024	18	14:43	15:07	0:24	100
			15:28	15:48	0:20	
			Total		0:44	
NASA_Arcsix_20240809_Flight18_altitude100m_IM7	8/9/2024	18	15:48	16:12	0:24	100
NASA_Arcsix_20240815_Flight19_altitude5600m_IM8	8/15/2024	19	11:25	12:54	1:29	5600
			13:06	13:38	0:32	
			16:37	16:55	0:18	
			Total		2:19	
NASA_Arcsix_20240815_Flight19_altitude5200m_IM9	8/15/2024	19	12:54	13:06	0:12	5200
NASA_Arcsix_20240815_Flight19_altitude100m_IM10	8/15/2024	19	14:02	14:24	0:22	100
NASA_Arcsix_20240815_Flight19_altitude3600m_IM11	8/15/2024	19	14:31	14:51	0:20	3700
NASA_Arcsix_20240815_Flight19_altitude3600m_IM12	8/15/2024	19	14:51	14:58	0:07	3700
NASA_Arcsix_20240815_Flight19_altitude1800m_IM13	8/15/2024	19	15:05	15:37	0:32	1800
NASA_Arcsix_20240815_Flight19_altitude2700m_IM14	8/15/2024	19			0:02	2700
NASA_Arcsix_20240815_Flight19_altitude300m_IM15	8/15/2024	19	17:16	17:45	0:29	300
			18:05	18:06	0:01	
			Total		0:30	
NASA_Arcsix_20240815_transit0816_altitude100m_IM16	8/16/2024	transit0816	11:37	11:41	0:04	100
			11:51	12:05	0:14	366
			Total		0:18	
NASA_Arcsix_20240815_transit0816_altitude100m_IM17	8/16/2024	transit0816	12:10	12:31	0:21	560

Sample Name	Sampling Date	Flight number	Sampling Start Time (UTC)	Sampling Finish Time (UTC)	Sampling length (hh:mm)	Altitude (m; a.m.s.l)
			12:33	12:36	0:03	640
			Total		0:24	
NASA_Arcsix_20240815_transit0816_altitude100m_IM18	8/16/2024	transit0816	12:44	12:49	0:05	100
NASA_Arcsix_20240815_transit0816_altitude6500m_IM19	8/16/2024	transit0816	13:50	14:27	0:37	6500
			14:35	14:37	0:02	
			Total		0:39	
NASA_Arcsix_20240815_transit0816_altitude6500m_IM20	8/16/2024	transit0816	14:27	14:31	0:04	6500
NASA_Arcsix_20240815_transit0816_altitude6500m_IM14	8/16/2024	transit0816	15:11	15:13	0:02	6500
			16:33	16:42	0:09	7500
			16:47	17:24	0:37	7500
			Total		0:48	

Table S5. Summary of complementary measurements available at THAAO during 2024.

Instrument [Company (Model)]	Measured / Retrieved Parameter	Altitude (km) [min – max]	Resolution [Time / Vert]	Reference [dataset]
Weather - Surface				
Disdrometer & rain gauge [Thies Clima (LPM) & MPS-System (TRwS 425)]	Precipitation Type, Particle Number, Size, Speed, and Cumulative Amount	sfc	1 min / —	N/A
Atmosphere - Vertical Profile / Column integrated				
Elastic Lidar [in-house developed]	Temperature profiles	25 – 75	2 h / 150 m	N/A
Elastic Lidar [in-house developed]	Aerosols profiles	0.5 – 30	30 s / 7.5 m	N/A
Micro Rain Radar [Metek (MRR-2@24 GHz)]	Reflectivity, Doppler velocity	0.1 – 3.1	1 min / 100 m	N/A
Microwave Radiometer [RPG (HATPRO G2)]	Temperature Profile	0 - 8	15 min / 50-400 m	N/A
Broadband and Spectral Radiation - Surface				
Zenith Spectrometer (320-950 nm) [Trios GmbH (MMS)]	Spectral Radiance (7° FOV))	sfc	10 s / —	N/A
Zenith Spectrometer (400-2400 nm) [Aerodyne Research Inc.]	Spectral Radiance (0.5° FOV), Cloud Optical Depth	sfc	3 s / —	N/A
Atmospheric Composition - Surface				
Air sampler [DadoLab (GIANO)]	Metals and PM10	sfc	48 h / —	N/A
Sky Imagers - Surface				
All-sky-imager [SIELTEC SL (SONA201D)]	RGB Radiance, Cloud Cover, AOD	sfc	1 min / —	N/A

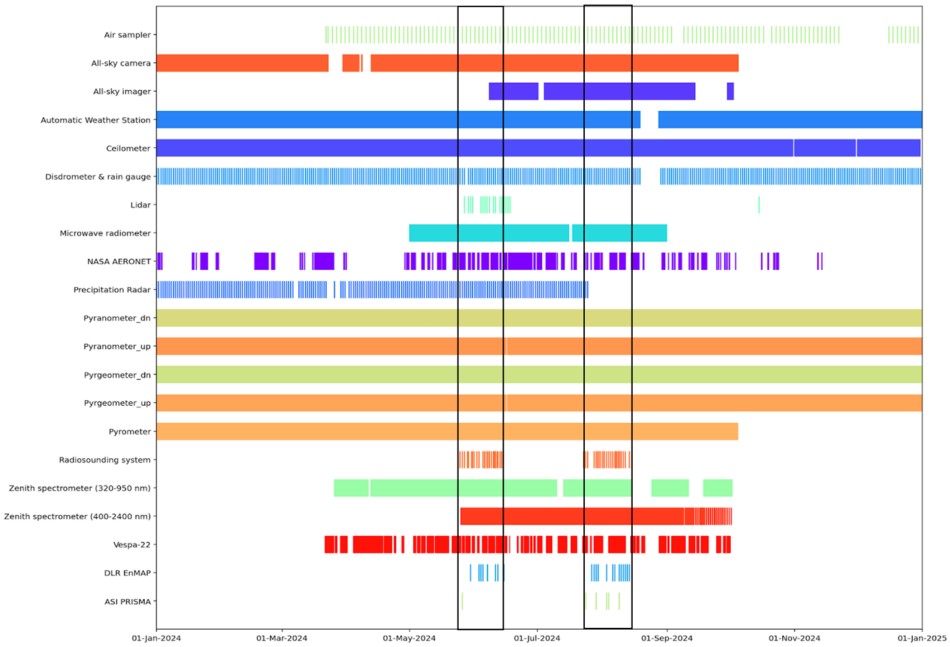

Figure S2: Summary of the instruments deployed at THAAO during the year 2024, with the periods of the NASA ARCSIX field campaign in the two vertical rectangles. DLR EnMAP and ASI PRISMA satellites overpasses are inserted. Colored bars represent the data availability for each instrument. Details for each instrument are available in Table S5.

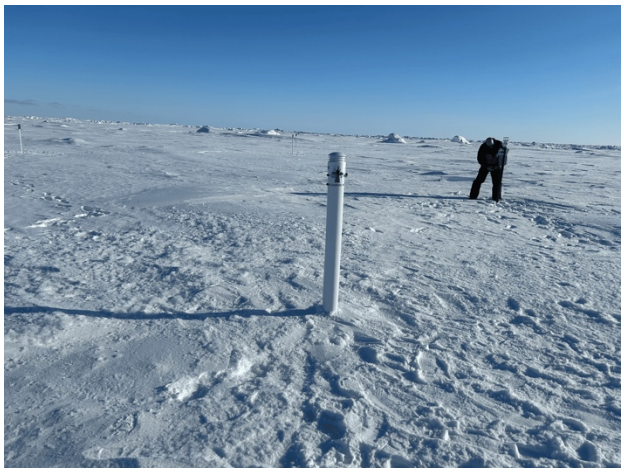

Figure S2: Picture of an SIMB3. Courtesy of Chris Polashenski.

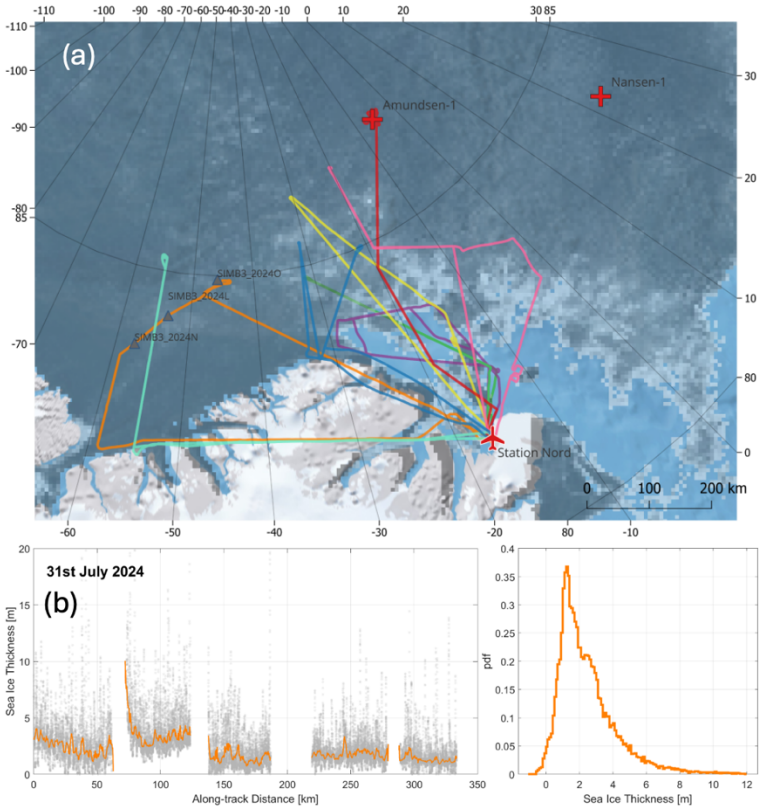

Figure S3: (a) Map of all sea ice surveys on top of the AMSR2 ice concentration on August 2nd and (b) EM-bird sea ice thickness profile and distribution for July 31st, covering the portion of the flight track from south to north between Nares Strait and 85N. An approx. 2-km running median has been applied to derive the colored

Figure S4: UiT MaxiMet GMX560 micro-met station deployed at the same ice floe as the SIMB3_2024K ice mass balance buoy.