Flight Report
HALO-AC3_HALO_20220410_RF16
Siberian Moisture Advection

Objectives:

- Measuring 3D structure of the **moist and warm intrusion from Siberia** south of Svalbard (with moisture budget closure) including over sea ice southeast of Svalbard
- Cross-section along **precipitation and rainfall-to-snowfall transition** along the cold outflow from Greenland
- Remote sensing of **clouds** west of Svalbard together with Polar 5&6 along the golden leg across sea ice edge (clouds forming in the upper-air outflow from Siberian moist intrusion)

Figure 1: Photo of clouds over sea ice southeast of Svalbard within the Siberian moisture intrusion

Mission PI HALO:

HALO Crew	
Mission PI	Irina Gorodetskaya
HAMP	Clémantyne Aubry
WALES	Silke Gross
SMART/VELOX	Michael Schäfer
specMACS	Lea Volkmar
Dropsondes	Henning Dorff
Camera	Andreas Walbröl
Pilots	Stefan Grillenbeck Thomas Kalfas
Engineer	Thomas Leder

Flight times:

HALO	
Take off (UTC)	10 April 09:45 UTC
Touch down (UTC)	10 April 16:30 UTC

Weather situation the day before:

The Scandinavian Low (persisting already for several days) was centered over the Bothnic Bay on Saturday, 9 April. It was blocked on its eastern flank by a high-pressure ridge over western Siberia directing warm and moist flow from Siberia, passing over Novaya Zemlya and south of Svalbard. On 9 April this warm and moist intrusion showed the highest horizontal integrated vapour transport (IVT) values.

Weather situation during the flight day:

On April 10 the eye of the Scandinavian Low shifted to northern Sweden (very close to Kiruna) continuing snowfall that lasted three consecutive days already in Kiruna itself. Warm and moist advection from Siberia south of Svalbard continued, however now with weaker IVT compared to the previous day. When the flow was turning south along approximately 0º meridian it was converging with the cold air outflowing from Greenland ice sheet. This convergence led to snowfall formation in the north transitioning to a rainfall zone in the south. A strong flow shear developed south of Greenland with low-level flow going southwest, and at the upper levels (above 700hPa) flowing northwest towards west Greenland. The northerly upper-level flow was bringing cirrus and mid-level clouds west of Svalbard and north of Greenland, while the forecast changing rapidly and these clouds were observed later, on Monday 11 April (see RF17 report).

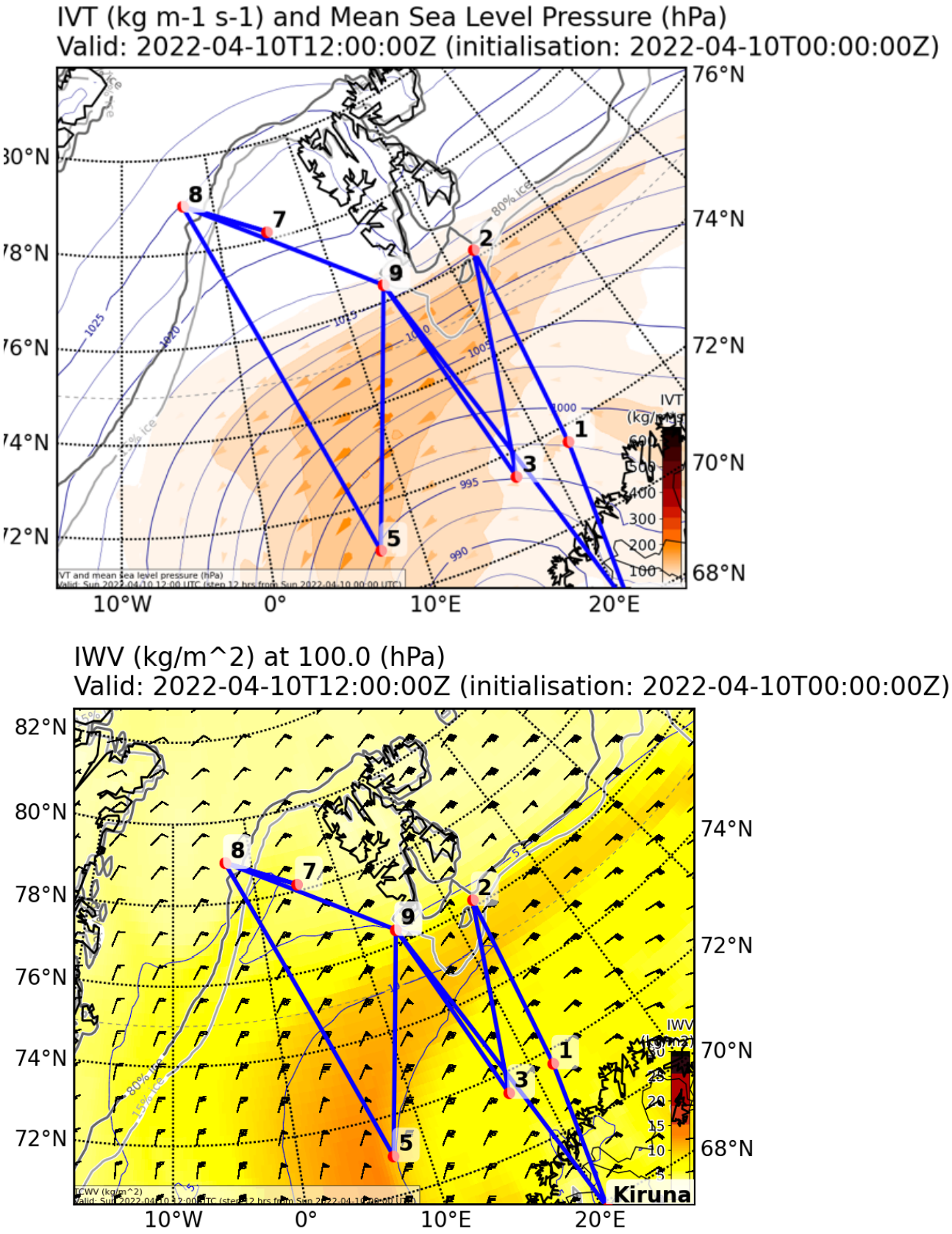

Figure 2: ECMWF forecast initialized on 2022-04-10 00UTC, valid for 12UTC: (upper) integrated vapour transport (IVT) and mean sea level pressure and (bottom) integrated water vapor (IWV) with near surface wind field.

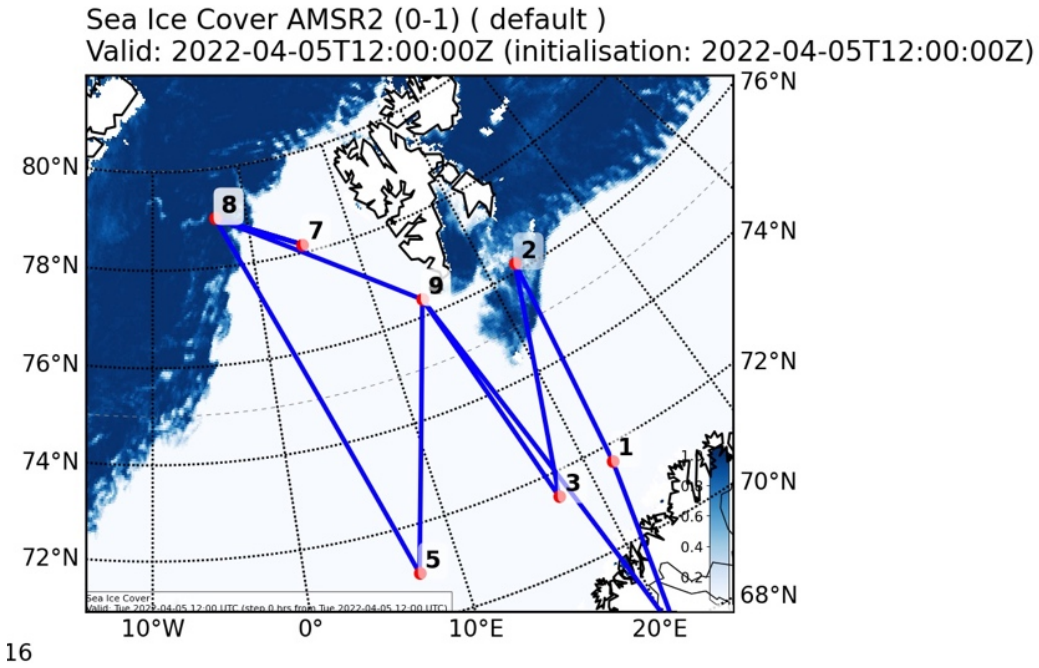

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Figure 3: Sea ice cover from AMSR2.

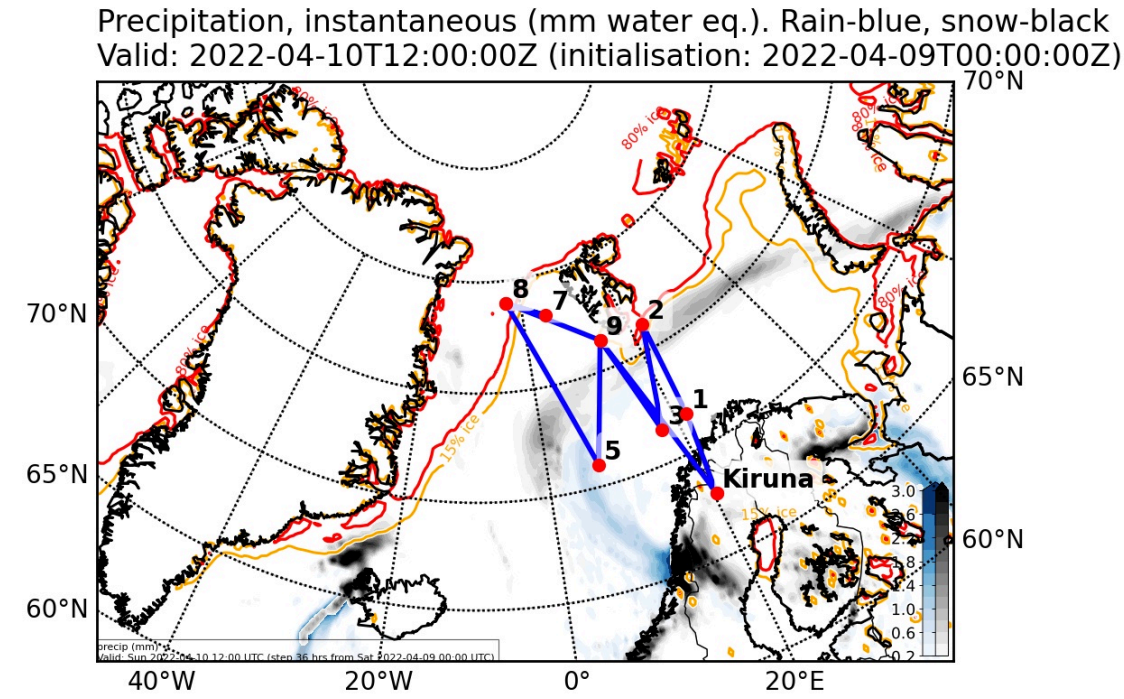


Figure 4: Precipitation (rain – blue, snow – black/grey) and contours for sea ice extent (red: 80% SIC, yellow: 15% SIC) from ECWMF forecast.

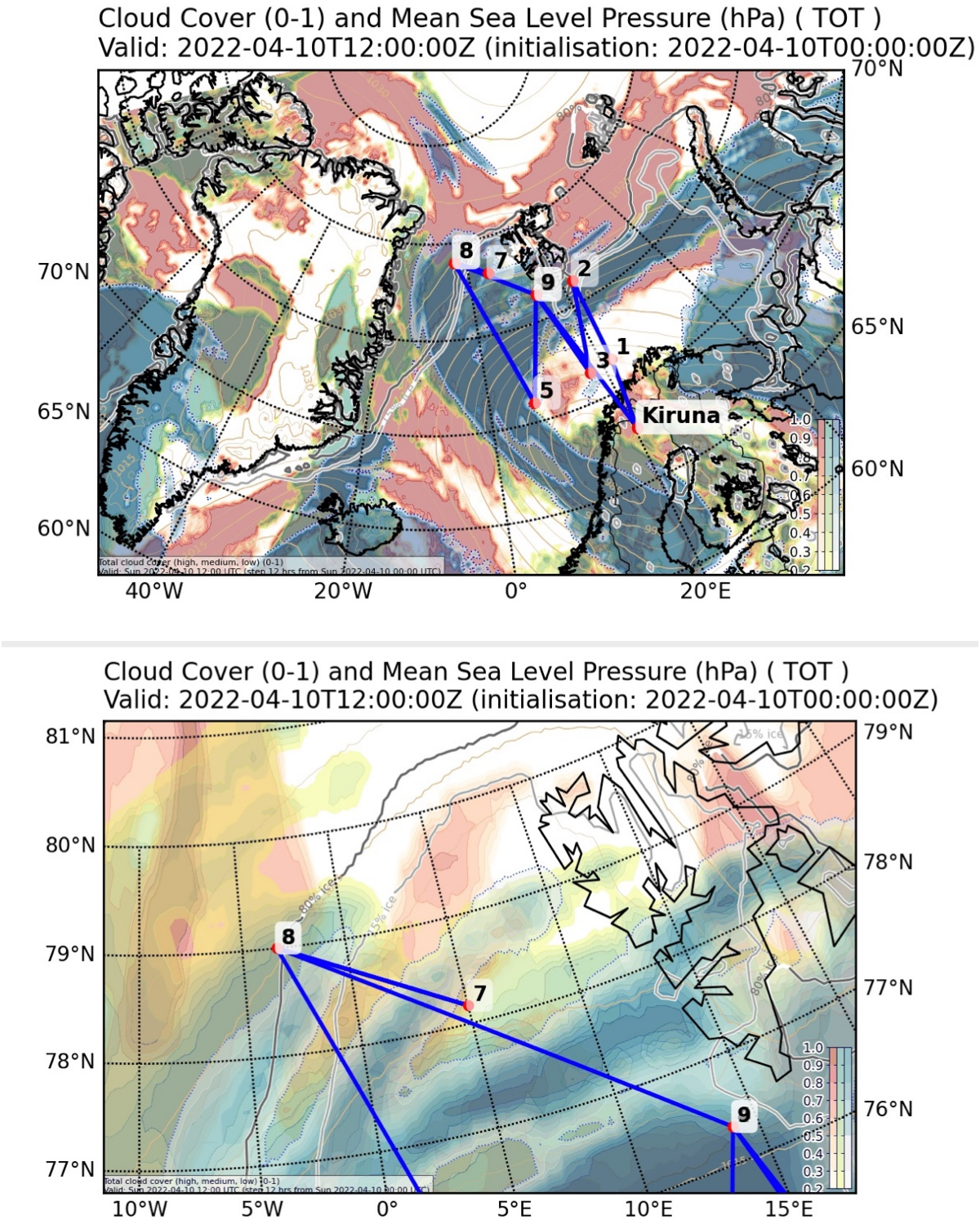


Figure 5: Cloud cover (0-1, colors, high/medium/low) from ECMWF

Overview of the flight

The RF16 flight pattern was designed to sample the moist and warm intrusion from Siberia into the Arctic and its impacts on clouds, precipitation and radiative budget. The first target of the flight was the moisture flux, from its eastern extent and intrusion over the sea ice southeast of Svalbard to the western edge where the moisture flux was turning south (Figs 2 and 3). The tracks were planned to follow a sawtooth flight pattern for the moisture budget closure (see EGU presentation by Henning Dorf et al (2022):

Dorff, H., Konow, H., Schemann, V., and Ament, F.: Moisture Budget Closure of Arctic Atmospheric Rivers from Saw-Tooth Flight Pattern – A Feasibility Study in High-Resolution Model Data, EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022, EGU22-13313, https://doi.org/10.5194/egusphere-egu22-13313, 2022.

Five dropsondes (DS) were released along each internal leg across the moisture intrusion to capture the transition over the warm sector, the core and the cold sector. One additional DS was released on the transitional legs (Figs. 2 and 3). Three internal legs: WP1-WP2 from Scandinavia to the southeast of Svalbard (over sea ice), WP3-WP4 from north of Scandinavia to southwest of Svalbard (open ocean), and WP5-WP6 in the western extent of the moisture intrusion (turning south) to northeast of Greenland over sea ice. It was interesting to see how the Siberian moist band has pretty much sharp cloud boundaries with vertically extended ice clouds within its core. The WP5-WP6 leg was planned to capture the precipitation transition from rainfall to snowfall, where the moist/warm flux from Siberia was converging with the cold outflow from Greenland. Because of the delayed departure we did not capture this precipitation pattern entirely, but we captured shallow precipitation further north (at 13:38UTC, DS16) and a sharp temperature inversion above the clouds.

The final target of this flight was to measure clouds in the Fram strait and their transition over the sea ice edge (Fig. 5). The forecast of the cloud amounts and heights changed significantly, and we observed more low level clouds compared to the forecast and less cirrus clouds. Because of the delayed departure and shortened overall flight time, we could not continue further north to sample cirrus clouds related to the northward excursion of the Siberian moisture intrusion in the upper troposphere. (they were measured in the following day during RF17 flight). The clouds over the Fram strait were measured by the collocated P5&P6 flights, and HALO arrived to the same leg later launching two extra DS along the “Golden leg”. The position of the Golden Leg was slightly more to the south compared to the previous flights as was requested by P5&P6 in order to capture the cloud field (it was their last synchronous flight). The extension of the cirrus clouds further north was measured the following day on RF17 flight. The last two sondes of the flight (DS21&DS22) were released when we entered back into the Siberian moisture band just southwest of Svalbard measuring the changing cloud field (low level liquid-containing clouds and vertically extended ice clouds, which appeared now less optically thick).

We managed to return to Kiruna airport at 16:30UTC (18:30 local - before its closure at 19h). Many thanks to the pilots and DLR team for their collaboration and very efficient communication during this flight with many challenges: the flight took place on Sunday with shorter opening hours and limited stuff at the airport, after a day off for HALO on Saturday (thus the final plan had to be submitted on Friday noon); collocation with P5&P6 (which made very successful last synchronous flights); significant changes in the forecast with

shorter lead times before the flight, intense snowfall and bad weather in Kiruna preceding days (uncertainty if the flight would be cancelled), the departure delayed by 3 hours.

Dropsonde locations:

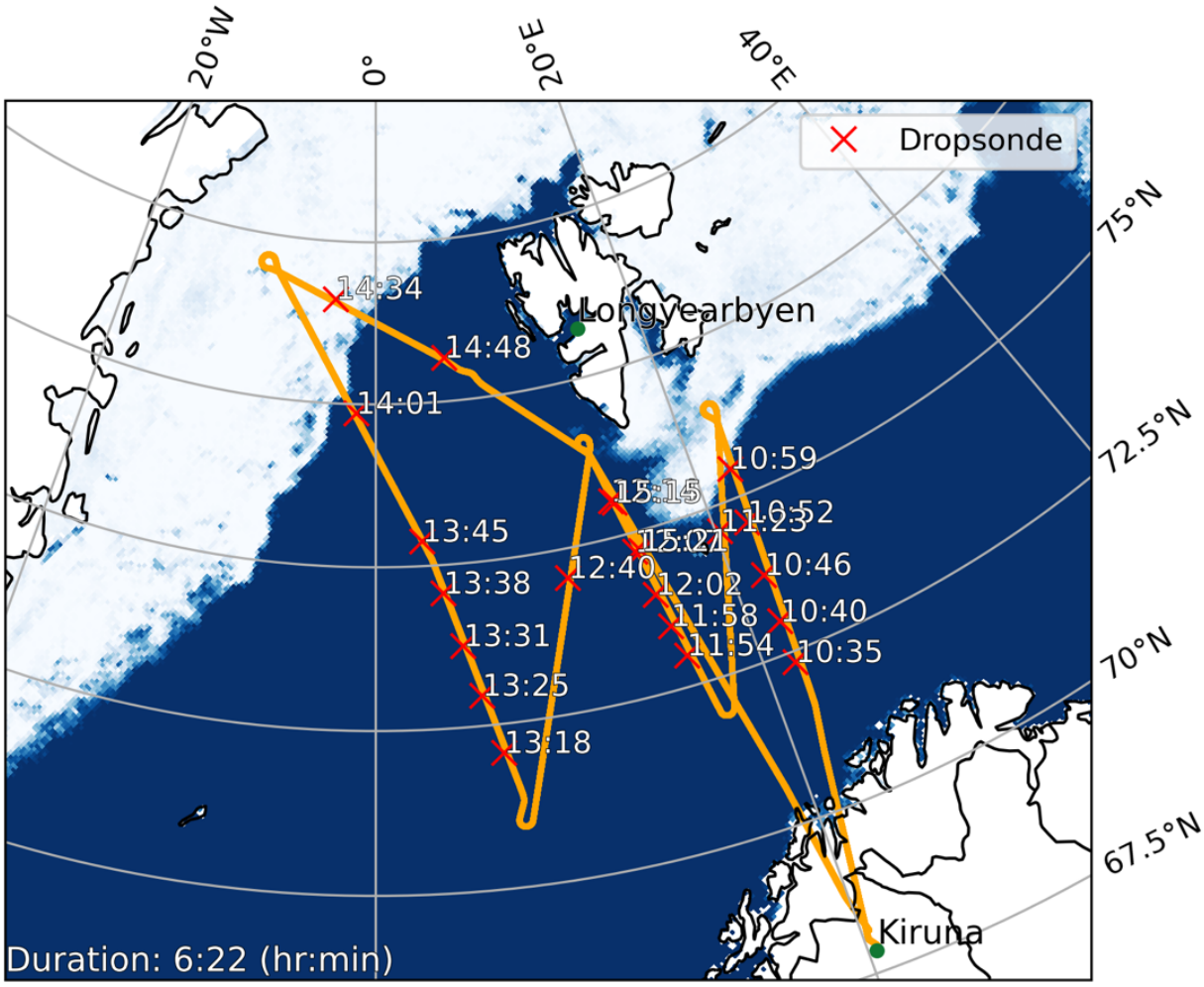


Figure 6: Sea ice extent and dropsonde time in UTC

Instrument Status:

Table 1: Instrument status as reported after the flight by the instrument PIs on HALO.

HALO	
BAHAMAS	
BACARDI	
HAMP Radar	14:50UTC: radar calibration procedure
HAMP Radiometer	
WALES	
SMART	
VELOX	
specMACS	
Dropsondes	22/22

Flight Logs (all times in UTC)

Planned departure: 6:45UTC. Delayed 3 hours. The airport had to clean the runway from snow and the Arctic Arena zone was the last one. Lots of snowfall in Kiruna from the same moisture intrusion from the east that we are going to measure. Morning of 10 April snowfall stopped at 9UTC, partly cloudy.

08:52: doors closed. Roll out

09:40: ready for departure

09:48: DEPARTURE

09:58 Climb check completed

10:00: above a thick deck of stratocumulus, overcast

10:07: Turned Laser on for WALES (Silke)

10:08 announcement about launching met sondes. First DS in 10-15min. Communication with P5&P6


20200410_10:08z (portside-west)

10:09: started clearing on the west and an overcast on the east side (from where the moisture intrusion is coming).

10:19: planning DS01 in about 100nm

10:23: stratocumulus are thinner now on the west and started clearing on the east


20200410_10:30z (starbrd-east)

10:35: DS01 launched. Signal OK

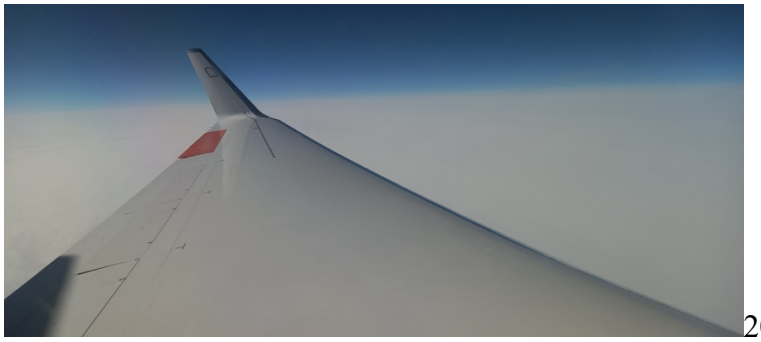

20220410_10:35z (portside-west)

10:40: 2km cloud top for the low-level cumuli

10:40: DS02 launched. Signal OK

10:46: DS03 released. Signal OK


20220410_10:44 (portside-west)


20220410_10:51z (portside-west)


20220410_10:51 (starboard-east)

5,5min till the next dropsonde (about 1min per 10 nm)

10:47: pilots ask about procedure turns. PI confirmed all turns are important to capture the edge of the moisture band

10:51 entering thick ice clouds on both sides

10:53: DS04 launched. Signal good

10:56: 5min ago entered a continuous deck of altocumuli. HAMP shows 7km top height

From Henning: first sondes didn't show high WS. RH is high at low levels. WS<5ms

10:59: according to ECMWF forecast we have now entered the core of the easterly moisture advection (or its remnants)

10:59: DS05 launched. Signal good

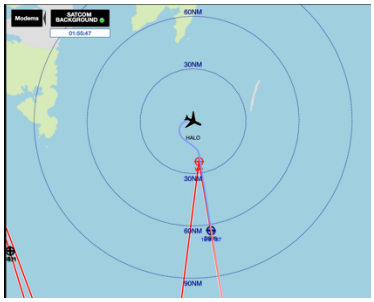
First cross-section with 5 sondes is over. All sondes successful. All WMO reports sent.

DS03 just reached the ground. Moist level 100hPa. No high wind speeds

11:01 still in the vertically extended ice clouds. Arriving to WP2 (south-east of Svalbard over sea ice)

Silke: WALES lidar captured well low-level clouds (not visible in HAMP radar) and the extent of the thick ice clouds showing also patches of liquid lenses

20220410_11:05z (portside)
Clouds over sea ice southeast of Svalbard (WP2)

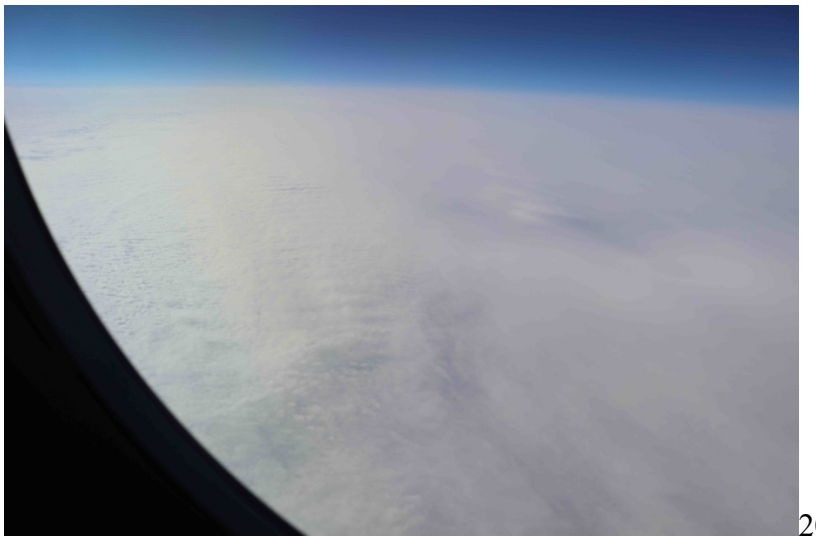


11:09 Doing the procedure turn at WP2
Position: 76.4936°N; 22.5572°E; Altitude: FL400; 11790m

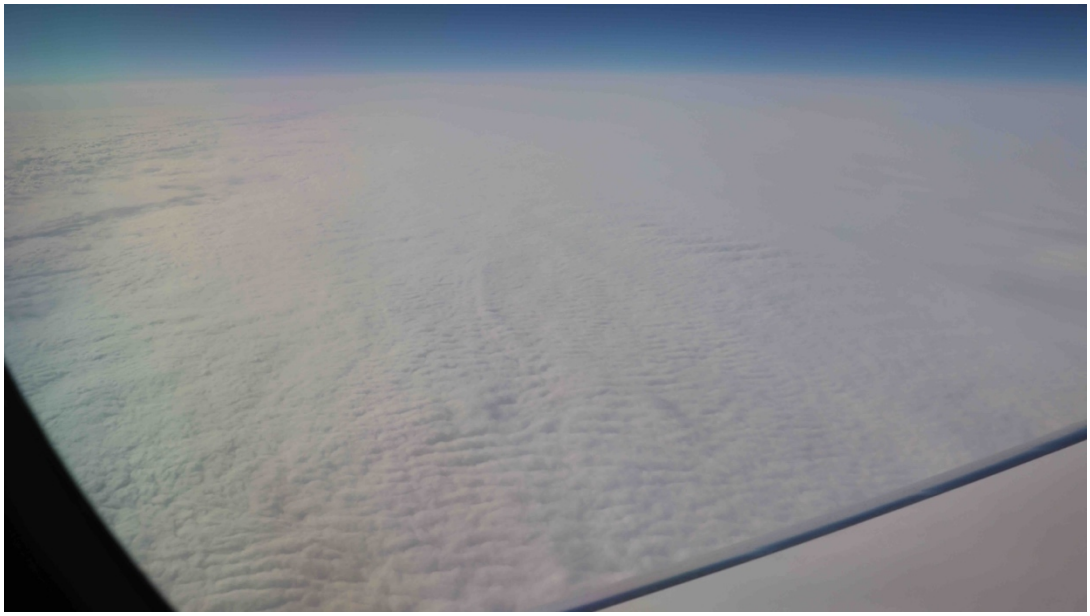
11:10 Heading south from WP2 to WP3. One DS to launch on this leg

11:23 DS06 launched. Signal OK

11:24 overcast. Altocumulus with invading cirrostratus

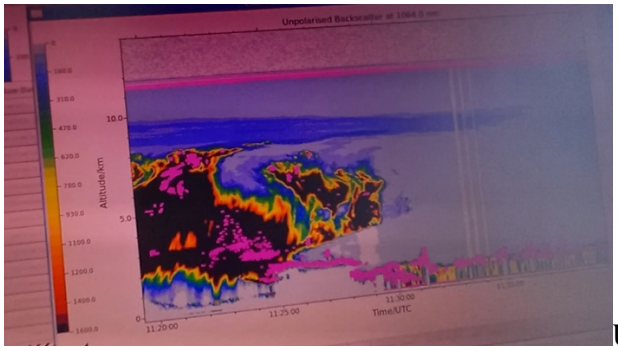

20220410_11:24z

11:26 Altocumulus. Cirrus sub-visible



11:29 starts clearing. Going out of the moist band core. WALES lidar shows a sharp transition in cloud height

20220410_11:30z



Unpolarised backscatter 1024nm

20220410_11:34z

11:34 stratocumulus, WALES: cloud top at 1-2km

20220410_11:40z

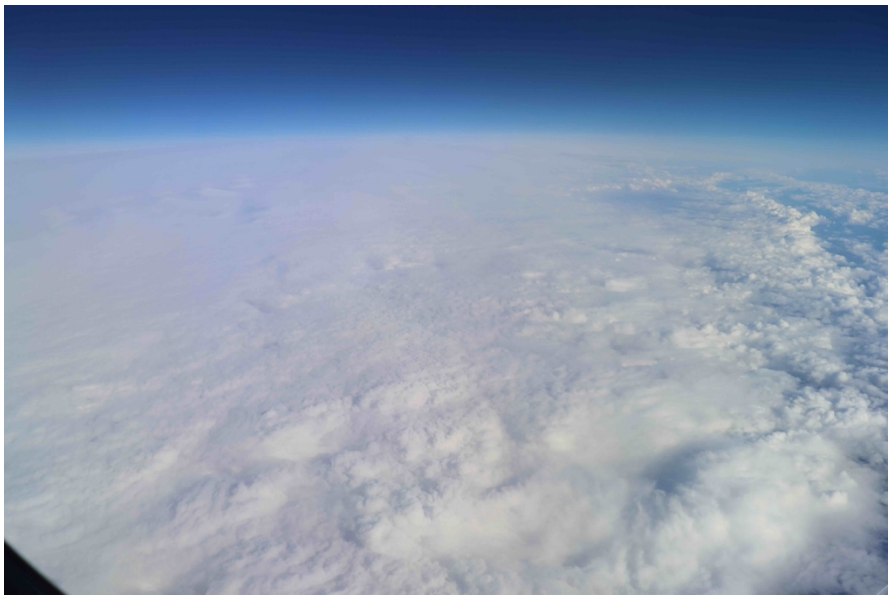
11:40: stratocumulus and cumulus

Turning at WP3…


20220410_11:47z

11:47 patchy stratocumulus and cumulus humilis

11:48 Heading north from WP3 to WP4 after doing a normal (not procedure) turn at WP3. Arrived to planned location of DS07 but not launching there:
Decided to shift the sondes along the leg WP3-WP4 more to the north to better capture the moist band: skip the position of DS07 and launch all 5 sondes starting at previous DS08 position (72.98N, 16.61E) until the previous DS11 (75.5N, 14.8E).


11:58z (photo): back to the altocumulus/altostratus and cirrostratus field of the moist band

11:54 DS07 launched. Signal OK
11:58 DS08 launched. Signal good
12:02 DS09 launched. Signal ok

12:02: back into the extended opaque ice clouds

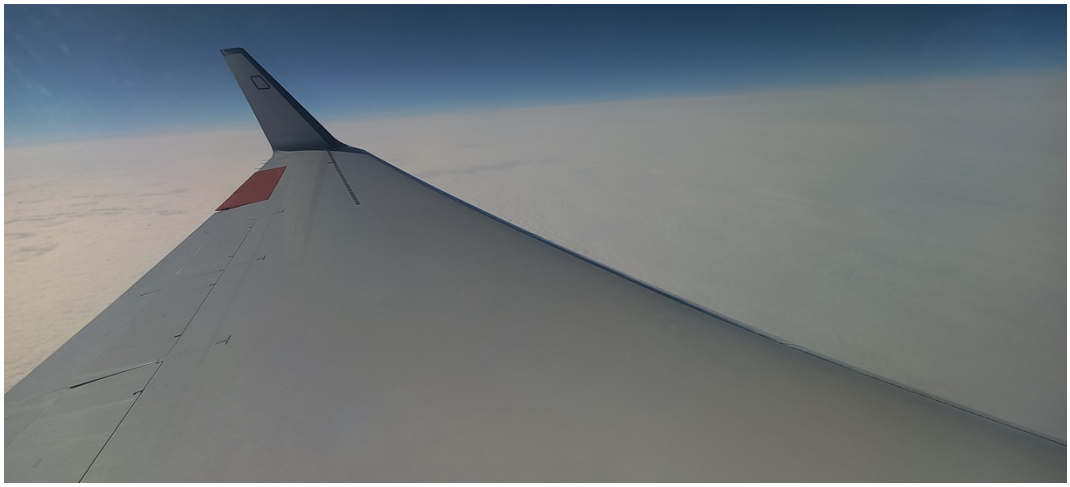
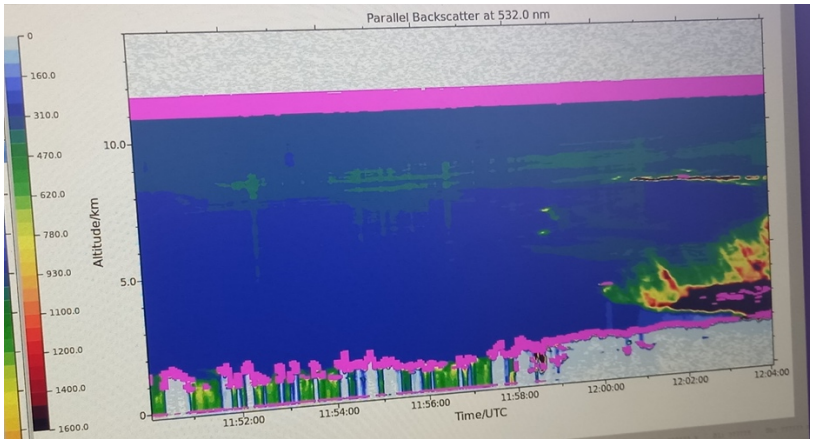


Photo: 12:02z (portside – west)



Polarised backscatter at 532nm

12:07 DS10 launched. Signal ok

Pilots: asked for extension to return 30min later to the airport. Waiting for confirmation

12:14: DS11 released.

All 5 sondes from this leg (WP3-4) DS07-DS11 are successful

12:19: approaching WP4 on the northern edge of the moisture advection.

 photo: 12:19z

Andreas reported about the sondes: LLJ up to 25 m/s near the surface.

Moisture inversion is clear in the profile.

12:21: Procedure turn at WP4 (south of Svalbard). The pilots do a nice clockwise circle. **Going south**. One DS on this leg

We are back to the ice clouds aligned with the moisture band boundaries

12:40: DS12 released successfully


Photo: 12:54 50nm away from DS12 release point

Heading to WP5 (which is on the southern edge of the moisture advection) where we hope to capture precipitation field

13:06 Turning (without procedure turn) at WP5. **Going north to WP6**

14:02: P5&6 are back to LYR already. Extension to return later to Kiruna airport is not approved (staff shortage). Pilots say we have to shorten to return Kiruna by 19h local time. No time to fly shuttle between WP6 &WP7. Asked the pilots if instead it is possible to add a

point slightly more northwest of WP 6 (at 71.995N, 5.49E), extending the P5&6 leg and will go directly to WP9. Pilots are calculating if possible timewise.

Launching radiosondes within expected moisture/precipitation field:
13:18: DS13
13:25: DS14
13:31: DS15 Cloud between 800-900hpa. Surface air temp 0ºC.
13:38: DS16 Profile shows shallow precipitation (below 900hpa) and temperature inversion above it. Surface air temp 0ºC.
13:45: DS17 Cloud at 900hPa and mid-level. No precip. Interesting sharp T inversion just above the cloud at 900hPa. Surface air temperature -2ºC.

13:45 slight westerly shift of the HALO heading to the point slightly more northwest of WP 6 (at 71.995N, 5.49E) to extend the leg more over the sea ice

14:01: DS18 just before the sea ice edge. Shows cloud between 400-600hPa and dry layer below 600hpa. Surface air temperature -12ºC.

14:09: flying over sea ice.. covered by low level clouds with wavy structure

Photo: 14:08z (portside – west)

Photo: 14:11z (starboard-east). Flying over sea ice

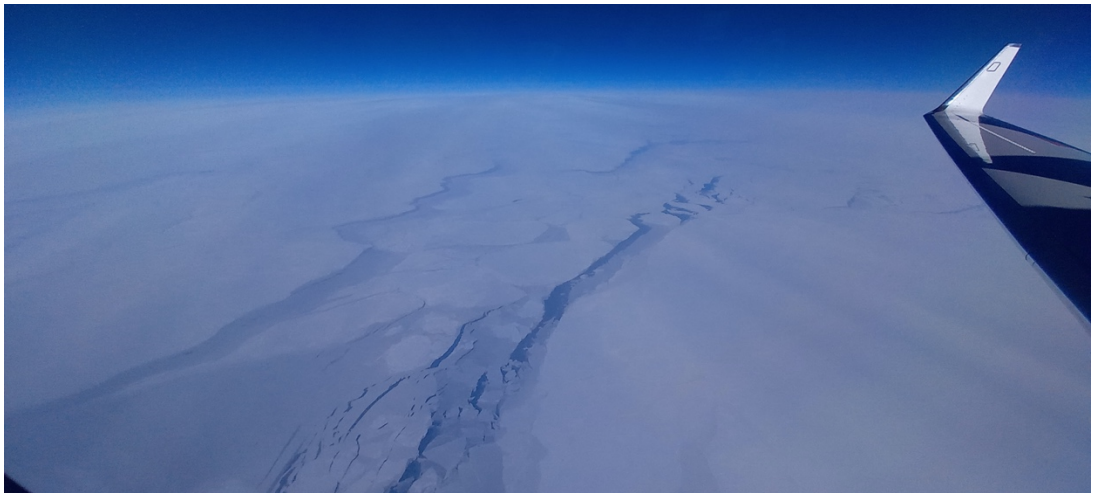


Photo: 14:16z. Cirrus streaks over sea ice. Leads with open water and refreezing

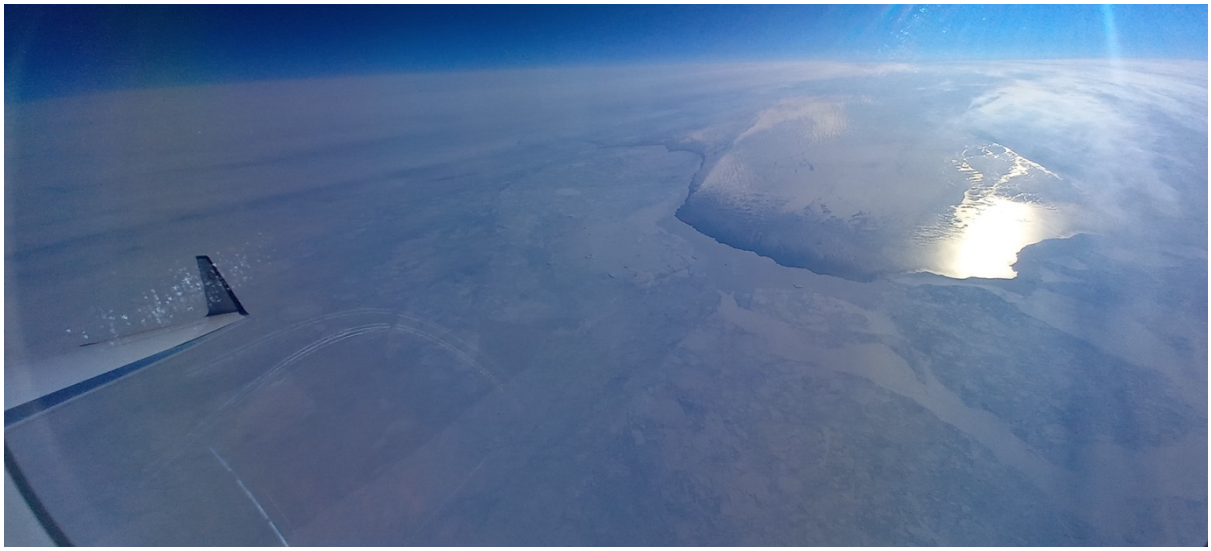


Photo: 14:22

14:25 Procedure turn to join WP6

14:35: DS19 released in cirrus region over sea ice

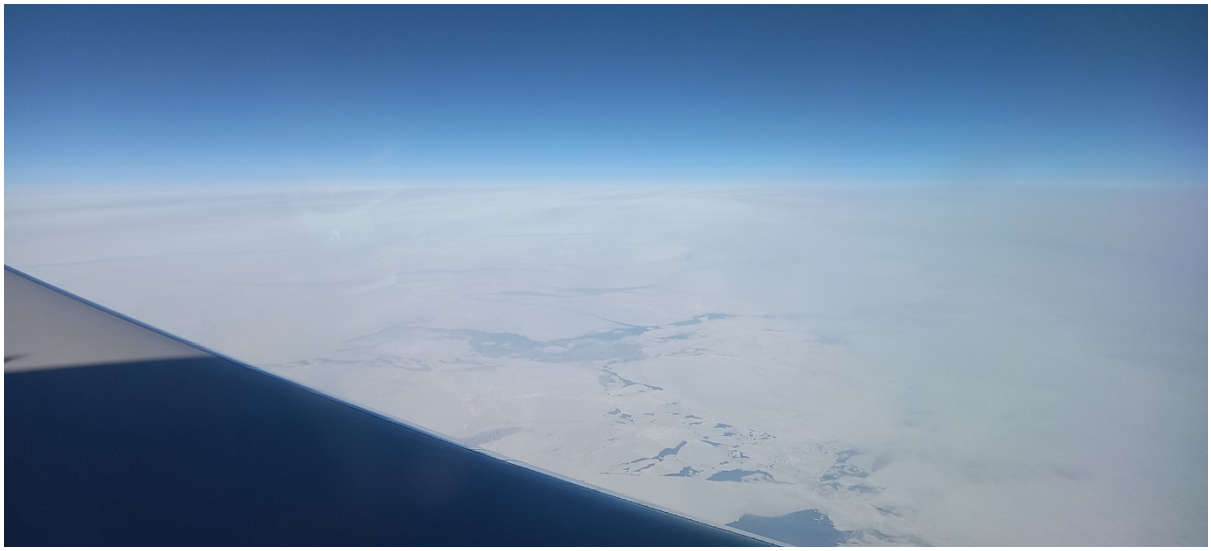


Photo: 14:35. Cirrus over sea ice where DS19 was launched

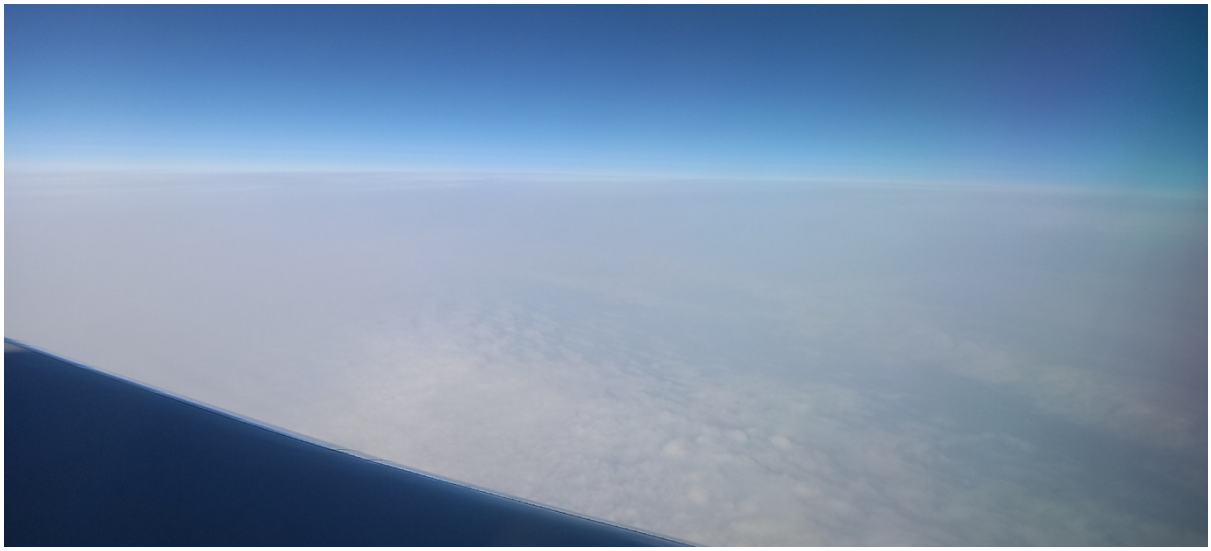


Photo: 14:40z. Just 5 min later low-level clouds over open water (near the sea ice edge)

14:48: DS20 released in low level cloud

14:50: radar calibration procedure (Clemantyne)

14:52 small patchy cumuli near the surface

15:06: we are entering back into the moist band and have ice clouds increase but now more optically thin

15:11: ice clouds vertical extent and optical thickness increase. Similar to the earlier profiles

15:22: DS22 released. Sc clouds. This was the last sonde for RF16 mission.

15:24: we are in stratocumulus deck

15:25 Also some slightly higher reaching stratocumuli (maybe you could call then cumuli humilis) ahead to the left (message from Andreas)

16:10: descending

16:30: Arrival to Kiruna airport. Just on time

In total 22 sondes launched. No failures