HALO-(AC)^3 – 2022/04/08 – HALO research flight #15

Objectives:

- Divergence and vorticity estimates of Polar Low west of Svalbard
- Crossing Polar Low several times to sample characteristics with remote sensing package
- Short scale airmass evolution when cycled around Polar Low (east: ocean, west: sea ice)

Mission PI HALO:

Andreas Walbröl

HALO Crew	
Mission PI	Andreas Walbröl
HAMP	Henning Dorff
WALES	Georgios Dekoutsidis
SMART/VELOX	Michael Schäfer
specMACS	Anna Weber
Dropsondes	Geet George
Optional	Roel Neggers
Pilots	Roland Welser and Thomas Kalfas
Engineer	Alexander Wolf

Flight times:

HALO	
Take off	**04:25 UTC**
Touch down	**11:43 UTC**

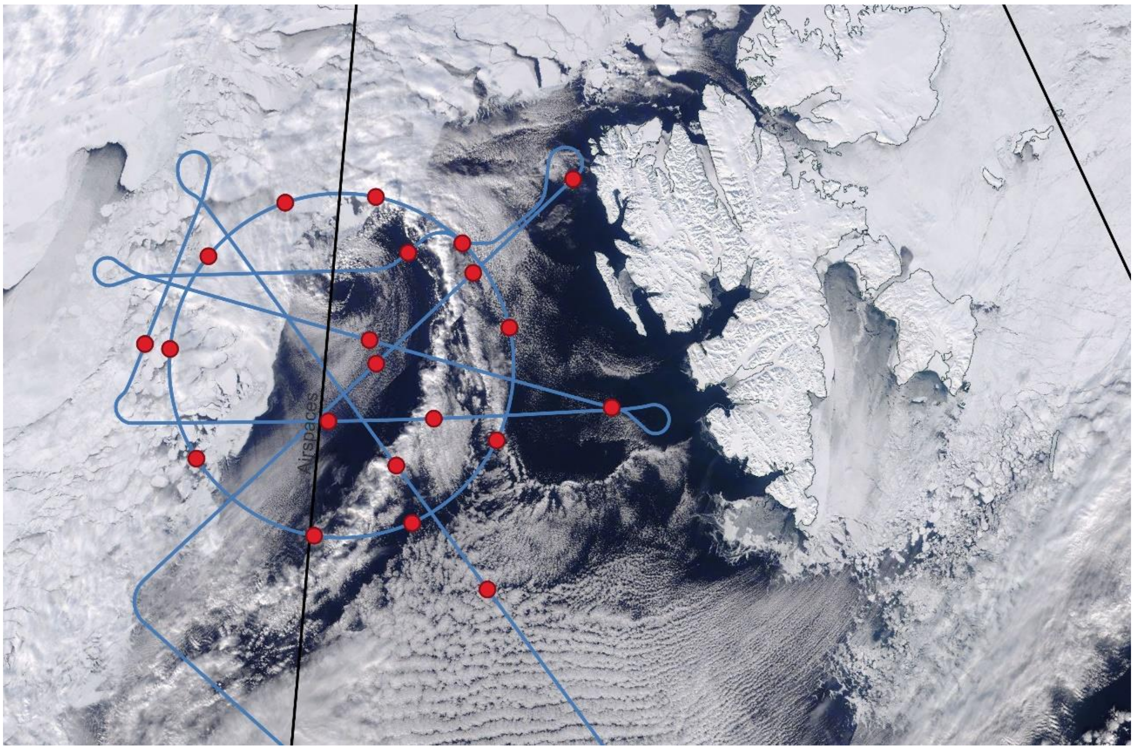

Fig. 1: MODIS Terra reflectance image from 8th April 2022. The flight track (blue line), dropsondes (red circles) and airspace boundaries (black lines) are also included.

Weather situation as observed during the flight (compare to forecast):

A high pressure system over the central Arctic and a low pressure complex over Scandinavia drive northerly and north-easterly winds in the Fram Strait and over Svalbard, respectively (see **Fig. 2**). The lower tropospheric flow is disrupted by the island, forming several convergence lines in the eastern Fram Strait. Together with temperature gradients between the cold air over the sea ice and the warmer ocean, small vortices formed at the convergence lines (see **Fig. 3b**). With the arrival of a trough on the 7th April 2022, as seen in the 500 hPa geopotential, the vortices were supported by positive vorticity advection, developing into a Polar Low. The trough is still visible in the 500 hPa Geopotential and temperature chart from ECMWF (see **Fig. 3a**). The forecast of the position and intensity of the Polar Low changed frequently during the flight planning phase. Especially its position remained uncertain until the morning of the research flight. In the end, the predicted position matched very well with the observations and we could observe an almost cloudfree eye, surrounded by a wall of convective clouds reaching up to 4 km altitude with heavy precipitation (especially from the south-eastern to the northern part of the low). The predicted cloud cover and precipitation are shown in **Fig. 4**.

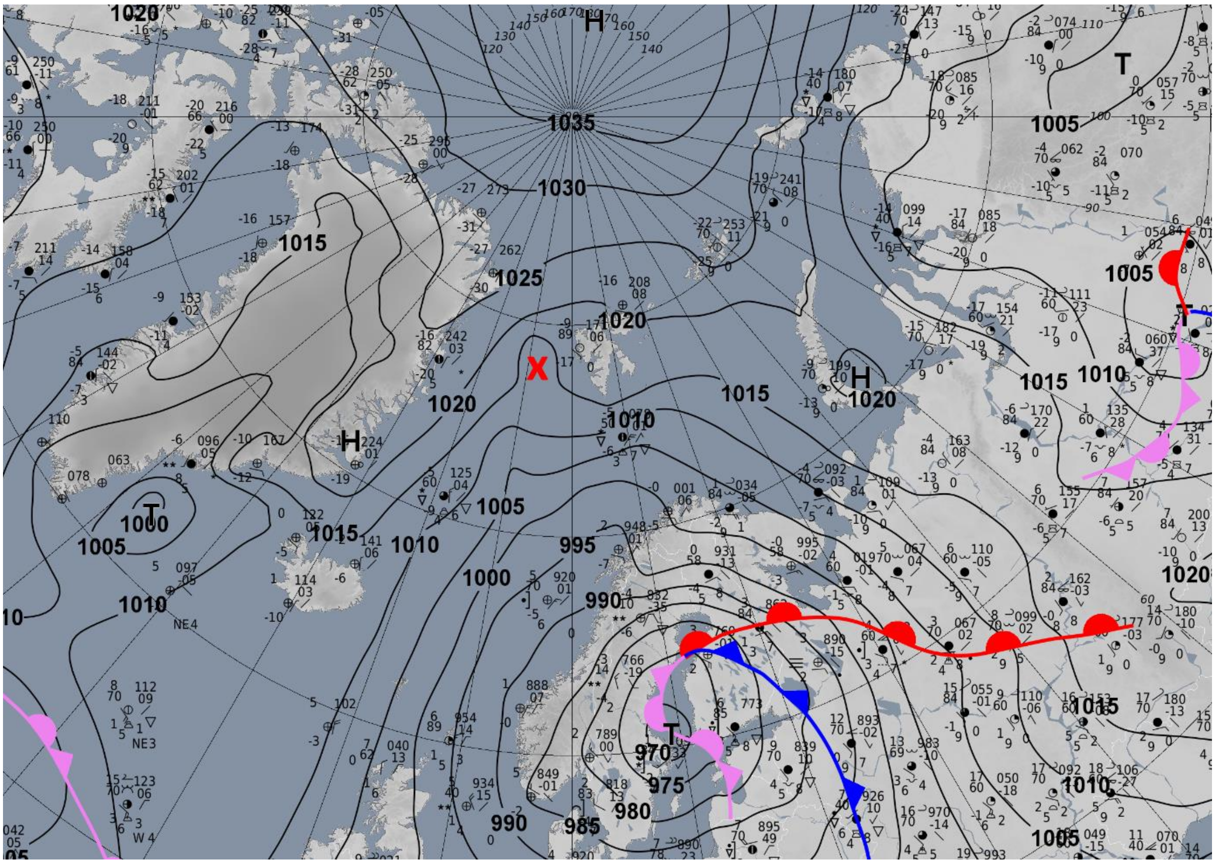

Fig. 2: DWD surface analysis of Friday, 8th April 2022, 12 UTC. The red cross marks the Polar Low in the Fram Strait.

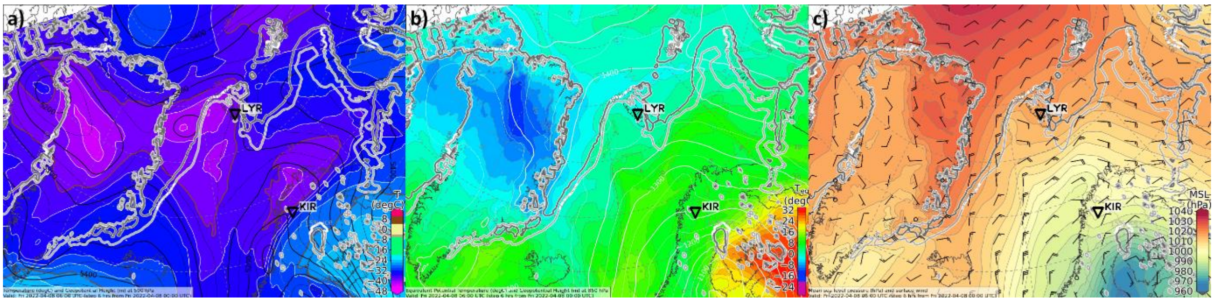

Fig. 3: 8th April 2022, 06 UTC charts of the ECMWF operational run (init: 2022-04-08 00Z). a): 500 hPa geopotential (black contour lines) and temperature (colours), b): 850 hPa equivalent potential temperature (°C) and geopotential (white contour lines), c): Mean sea level pressure (colours) and surface winds (barbs).

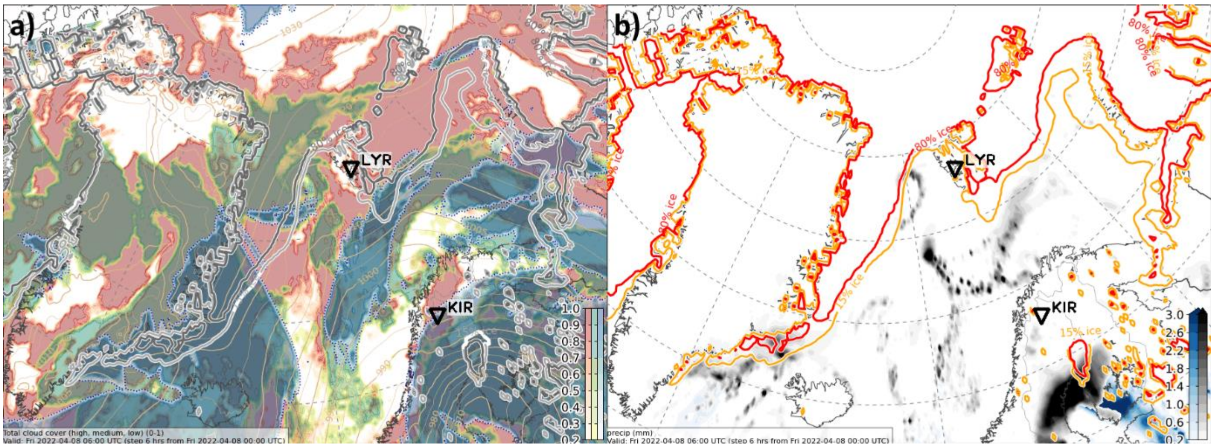

Fig. 4: 8th April 2022, 06 UTC charts of the ECMWF operational run (init: 2022-04-08 00Z). a): Total cloud cover, b): 2-hourly precipitation from 04 till 06 UTC.

Overview:

Although the first signs of the Polar Low sampled during the flight was already visible in the ECMWF forecast on Sunday, 3rd April 2022, there were still large uncertainties regarding its development. Over the course of the week, ICON and ECMWF saw their own development, being projected either further to the north east (ICON) or in the central Fram Strait (ECMWF). Therefore, two flight plans were created, each having the circle and cross section pattern set to the respective position of the Polar Low. In the morning of Friday, 8th April 2022, both models converged to the ECMWF version of the position of the Polar Low so that we decided to take that flight pattern (see **Fig. 5**).

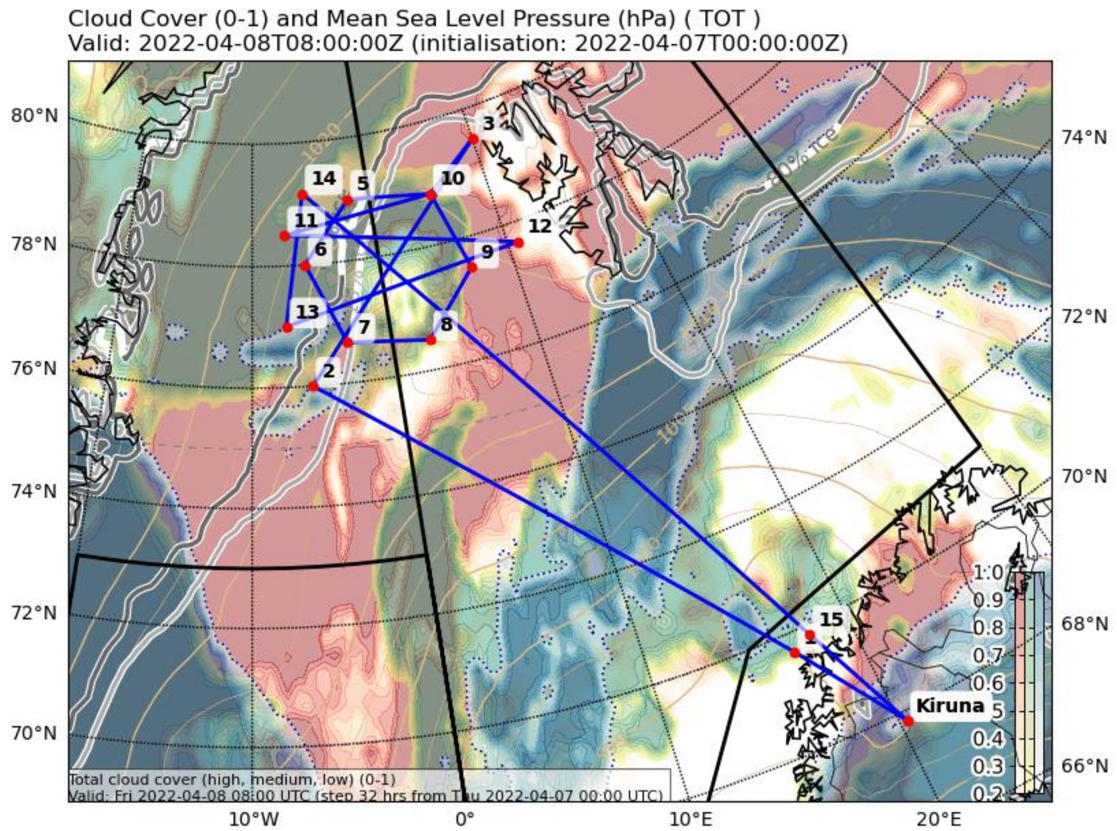

Fig. 5: 8th April 2022, 08 UTC total cloud cover of the ECMWF operational run (init: 2022-04-07 00Z) and planned flight track.

During the transfer from Kiruna to waypoint (WP) 2, new satellite images sent by the ground team confirmed the latest model runs that the centre of the circle should be shifted slightly to the north. We arranged a shift by 0.3° to the north so that the updated centre of the circle was at 78.04°N, 0.66°E. Arriving at WP2, the pattern to sample the Polar Low began:

- WP2-3, 3 dropsondes: First cross section that extended the boundaries of the predicted Polar Low to make sure that we could find it. Besides the provided satellite image, we relied on visual contact of the Polar Low, assisted by dropsondes that should indicate the low-tropospheric winds. As we approached the expected centre of the Polar Low, we could identify curvy cirrus to the left of the aircraft, a pronouned band of convection ahead and to the right and a relatively cloudfree region in between. We found it!
- WP4-10, 10 dropsondes: The full circle around the Polar Low was accompanied by 10 dropsondes to compute divergence and vorticity. One sonde did not record relative humidity and temperature and was therefore later replaced (WP13-14).
- WP10-11, 1 dropsonde: Cross section through the northern precipitation field of the Polar Low.
- WP11-12, 2 dropsondes: Cross section through the eye and eastern convection (also precipitating). We dropped a sonde close to the eye of the Polar Low.
- WP12-13, 2 dropsondes: Cross section through the southern part of the Polar Low.
- WP13-14: 1 dropsonde: Going around the Polar Low for a final cross section and we replaced dropsonde 07 that did not record temperature and relative humidity.
- WP14-Kiruna, 2 dropsondes: Final cross section from northwest to southeast of the Polar Low, flying through the eye and southeastern convection.

The communication of flight plan adaptations, i.e. shifting the circle and WP13 a bit to the north or announcing when to leave the circle to correctly place the final dropsonde (13), was great and without problems. Flight level 360 was our altitude of choice for the whole flight.

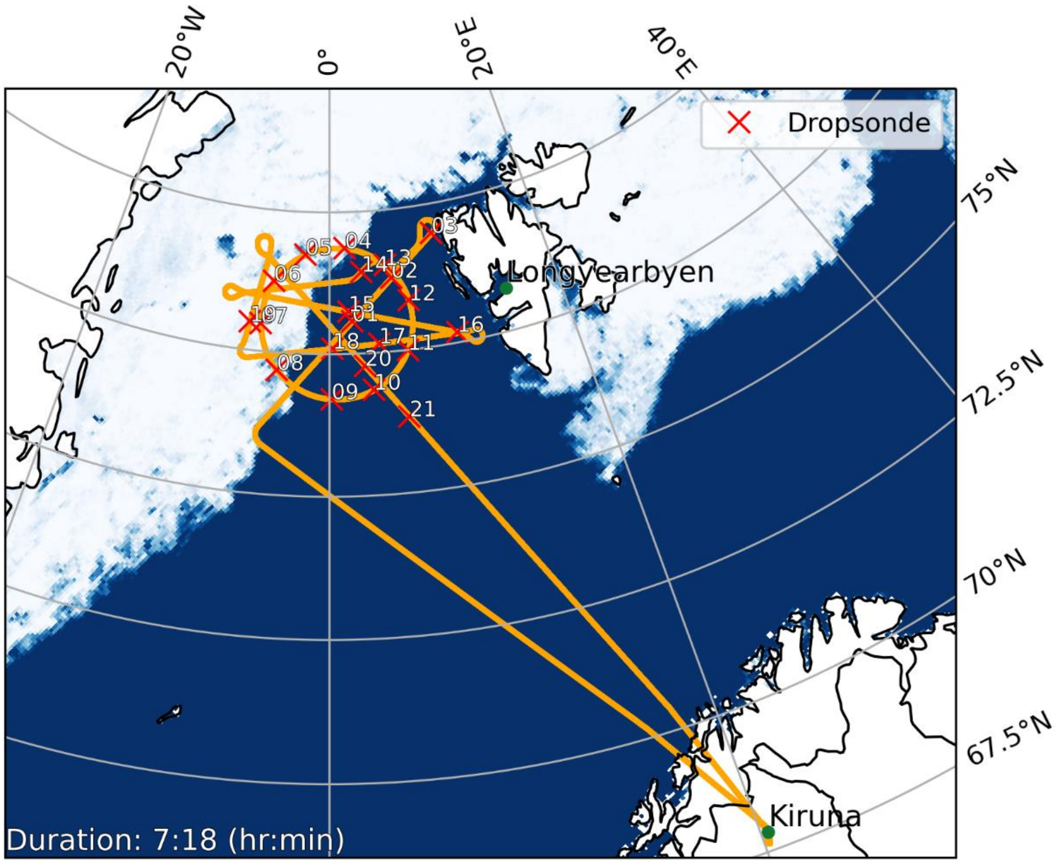

Fig. 6: Sea ice concentration and performed flight track, including the positions of the dropsondes (red crosses).

Instrument Status:

HALO	
BAHAMAS	
BACARDI	
HAMP Radar	
HAMP Radiometer	
WALES	
SMART	
VELOX	
specMACS	
Dropsondes	one replacement

Table 1: Instrument status as reported after the flight for all instruments on HALO.

Dropsonde 07 did not record temperature and relative humidity and was therefore replaced by dropsonde 19 on a later leg (WP13-14). specMACS had all the shutters open!

Detailed Flight Logs (time in UTC):

0420: Start taxi
0425: Take off
0427: Break through low level clouds (few higher clouds above to the NW)
0430: climb to FL360, closed SC deck over Swedish mountains
0431: Norwegian mountains stick out of SC deck
0435: radar measurements initiated

Fig. 7: 0438: Lee part of Norwegian mountains in clear sky
0447: FL360 reached
0457: Convective showers below
0501: Arranging new center coords of circle: 78.04N, 0.66E (based on satellite image and forecast)
0502: Flying over deep clouds, sometimes precip, otherwise no low level clouds, cloud base 2km above MSL
0509: Cloud deck opens to some convective cumuli with some mid-level stratiform hovering above
0525: eventually we pass a second meso-cyclone south of our target, visible contact portside
0528: finished new plan for dropsondes: 21 are planned
0530: below aircraft: just SC with some slight showers; rarely also covered by mid-level clouds on top
0535: back on track to WP2 (diverted probably due to military ops off the coast of Norway)
0545: clear sky underneath, some convective cells around (starboard)
0557: WP2 is reached, turning to the leg of WP2->3
0601: preparation of first dropsonde
0608: low cloud cover region around the aircraft; convective clouds on starboard side; no precip around aircraft; some clouds with base of 1.5 km (radar)
0612: waiting for clearance for dropsonde launches (estimated: 0615)

Fig. 8: 0614: curved cirrus with convective cells on portside (northern flank of Polar Low)
0616: we can spot also higher convective clouds on 11‘o’clock
0620: Dropsonde DS1: success

Fig. 9: 0624: main precip band was portside, some high reaching convection
0627: DS2: success; SC field starboard
0630: Svalbard ahead and starboard
0632: Sea Ice visible on portside
0633: Svalbard lee effect still visible; low cloud cover close to Svalbard
0635: DS3: success

Fig. 10: 0636: turn after WP3 to return to circle
0639: report from dropsondes: DS1 low pressure, quite dry, DS2: quite humid
0644: entering circle; ahead we can see again the convective precip band of the Polar Low
0648: SC with quite large precip field; occasionally a second layer in mid-level
0649: main precip of northern Polar Low flank: portside
0652: DS4: success
0654: sea ice starboard and underneath the aircraft
0655: portside, curvy clouds around Polar Low
0657: DS5: success
0703: DS6: success
0709: DS7: no T and hum
0714: western flank of Polar Low, we‘re over the sea ice (marginally)
0715: entering some cloud streets off the sea ice; northerly flow on western flank of Polar Low
0716: DS8: success
0722: 10’o’clock heading: higher convective cells visible again (associated with southeastern part of Polar Low)
0724: DS9: success

Fig. 11: 0726: nice visuals of the southern cloud band on port side
0727: and also the curl of low cloud fraction and some scattered SC is visible
0731: DS10: success
0738: DS11: success; and we‘re now on the southeastern flank; pretty high humidity
0744: Svalbard at the starboard side
0745: DS12: success
0748: higher convection again
0751: DS13: success

Fig. 12: 0754: DS14: in precip region; pretty heavy precip below; about 3 km deep

0756: exited circle to get back on track to WP11
0758: visual contact of the eye (portside)
0804: apparently, some ghost called for a break because everyone in the cabin stood up approx. at the same time
0807: over marginal sea ice in almost clear sky

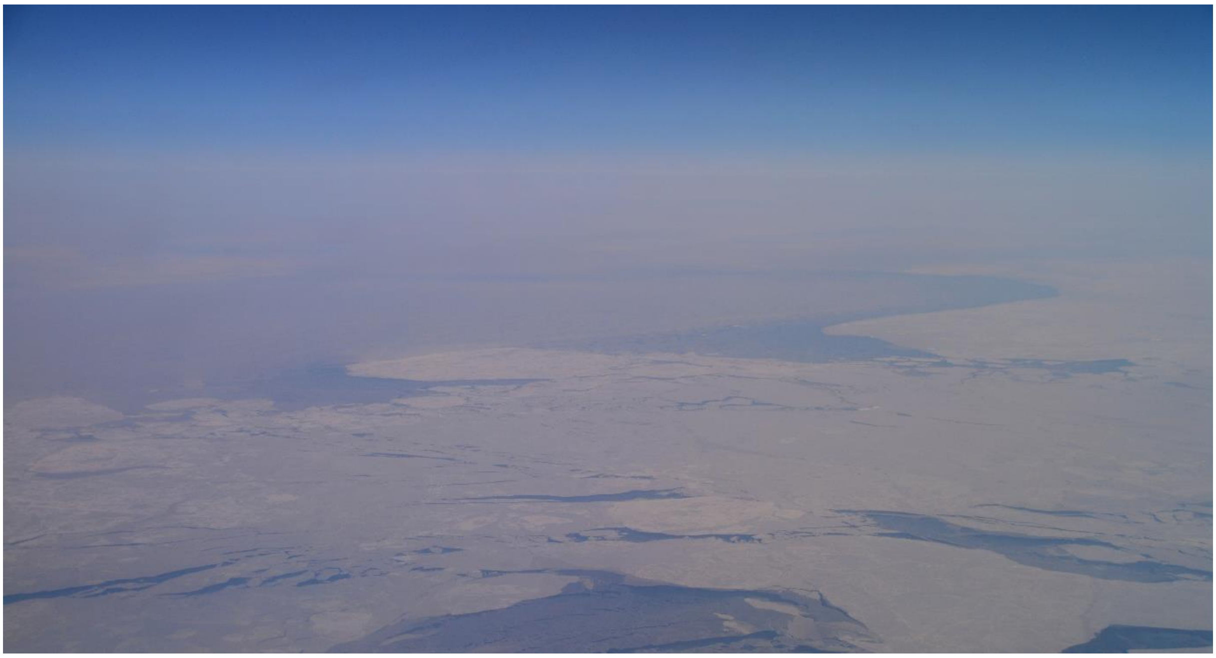

Fig. 13: 0810: DS14 apparently hit the precip band well with high moisture up to 600 hPa; huge leads starbord
0811: procedure turn at WP11
0823: after procedure turn: return to Polar Low; curvy cirrus visible portside; discussion that dropsonde shall be thrown in main precip field. Requires checking the windows and radar
0825: also higher convective clouds at heading 11’o’clock

Fig. 14: 0831: DS15: launch close to the eye, which was visually approved in the cockpit... right before hitting the wall of precip, which was also well visible from the cockpit and starboard windows

0837: visual contact with Svalbard again, close to the circle track
0839: Lee effect of Svalbard causes low cloud fraction and then some scattered SC with some showers a bit further off
0846: DS16: success; almost clear sky
0846: procedure turn at WP12
0847: directly west of LYR
0855: changed heading of WP12->13 leg to fly according to the updated Polar Low position
0857: some higher SC – Cu portside
0901: entering the circle again

Fig. 15: 0904: DS17: success (target of the sonde marked with red arrow)
0905: crossing the wall of precip clouds (2-3 km deep) into the eye again
0910: DS18: success; close to border of Denmark airspace
0911: P6 appeared on PLANET; overcast SC on portside, getting less the closer to sea ice we get; DS17 detected lots of moisture

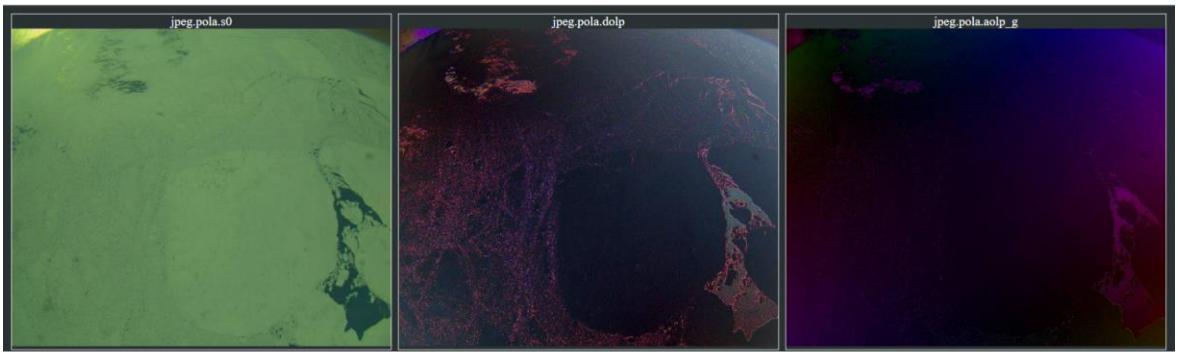

Fig. 16: 0915: specMACS: clear sky over sea ice; sea ice quite broken (marginal sea ice zone)
0917: broken sea ice with some low level clouds
0921: turn for WP13->14, where the one sonde was going to be replaced
0926: DS19: success

0928: broken sea ice to the left with some low level clouds at about 2 km altitude, not precipitating
0934: round sea ice edge to the left
0936: passing WP14
0937: freshly frozen leads on portside
0938: beginning of procedure turn around WP14
0943: decision not to fly a radar calib pattern because the clear sky region close to Norway is too slim and winds close to Svalbard are too high (sea foam)

Fig. 17: 0951: nice visuals of northern flank convective clouds (maybe 4 km deep)
0955: inside the cloudfree centre again
0959: close to the border of the cloudfree (extended eye) region; dropsonde 20 planned to be in the precip band outside the cloudfree area
1002: DS20: success
1005: P6 entered the Fram Strait, we leave our flown circle towards Kiruna
1007: entering SC field outside the Polar Low (south east of the centre)
1011: DS21: success, launch outside the circle to get the environmental conditions of the Polar Low
1032: higher clouds with some SC showers below
1038: Mid level clouds (altostratus), no SC below, no precip
1042: Cu field over the ocean; first divergence and convergence computations onboard by Geet and Roel: 0-2 km: convergence, above: divergence

Fig. 18: 1052: curly clouds with convection (of the other meso-cyclone)
1110: begin of descent
1113: Norway mountains and fjords below, radar measurements terminated
1117: luv side of Norwegian mountains still in clouds
1143: touch down

Quicklooks:

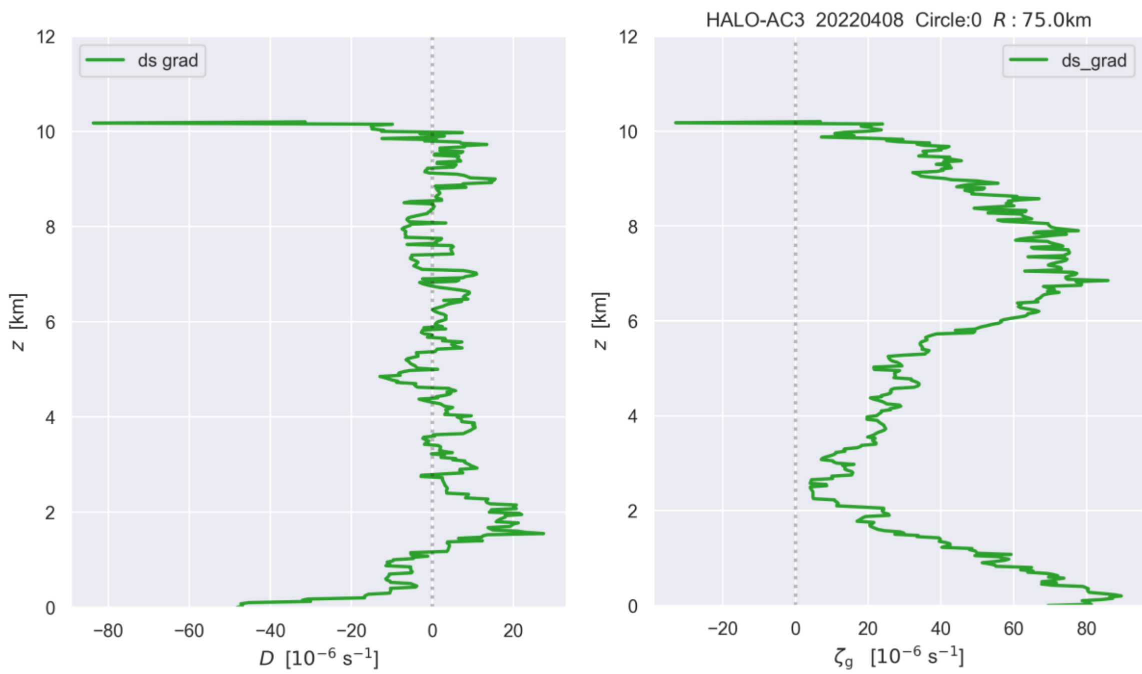

Fig 19: Divergence (left) and vorticity (right) computed from dropsonde measurements.

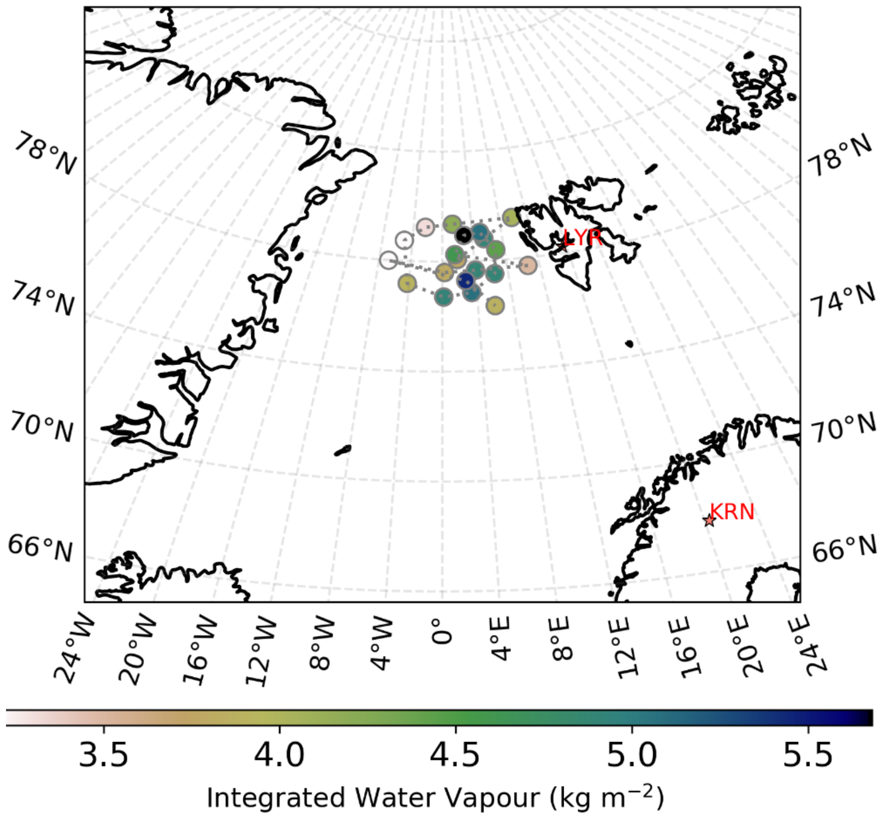

Fig. 20: Integrated water vapour for each dropsonde (except 07).

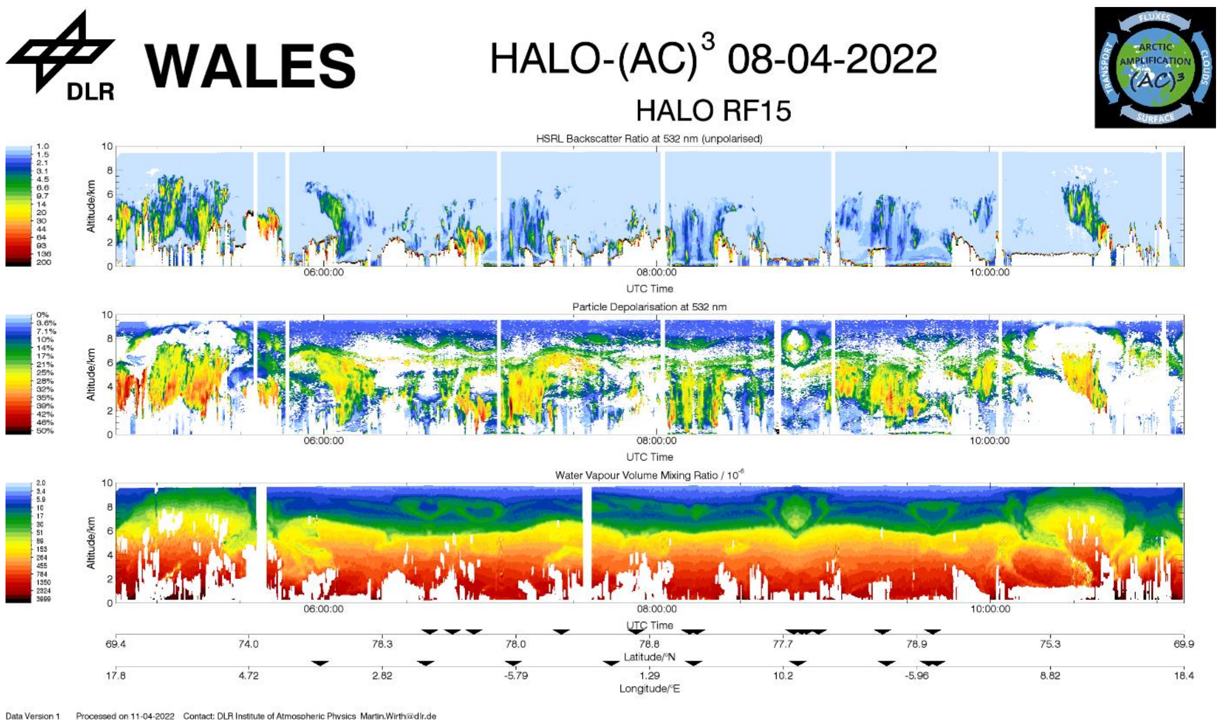

Fig. 21: WALES backscatter ratio, particle depolarization and water vapour mixing ratio.

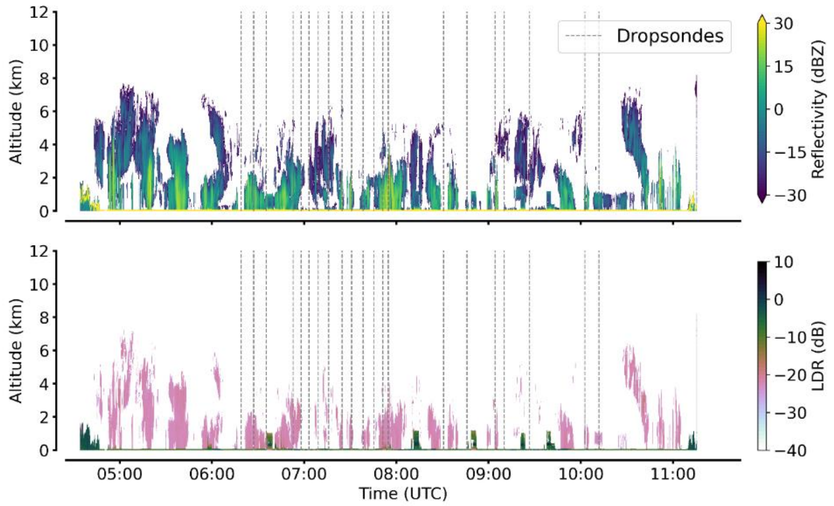

Fig. 22: HAMP radar reflectivity (top) and linear depolarization ratio (LDR, bottom).

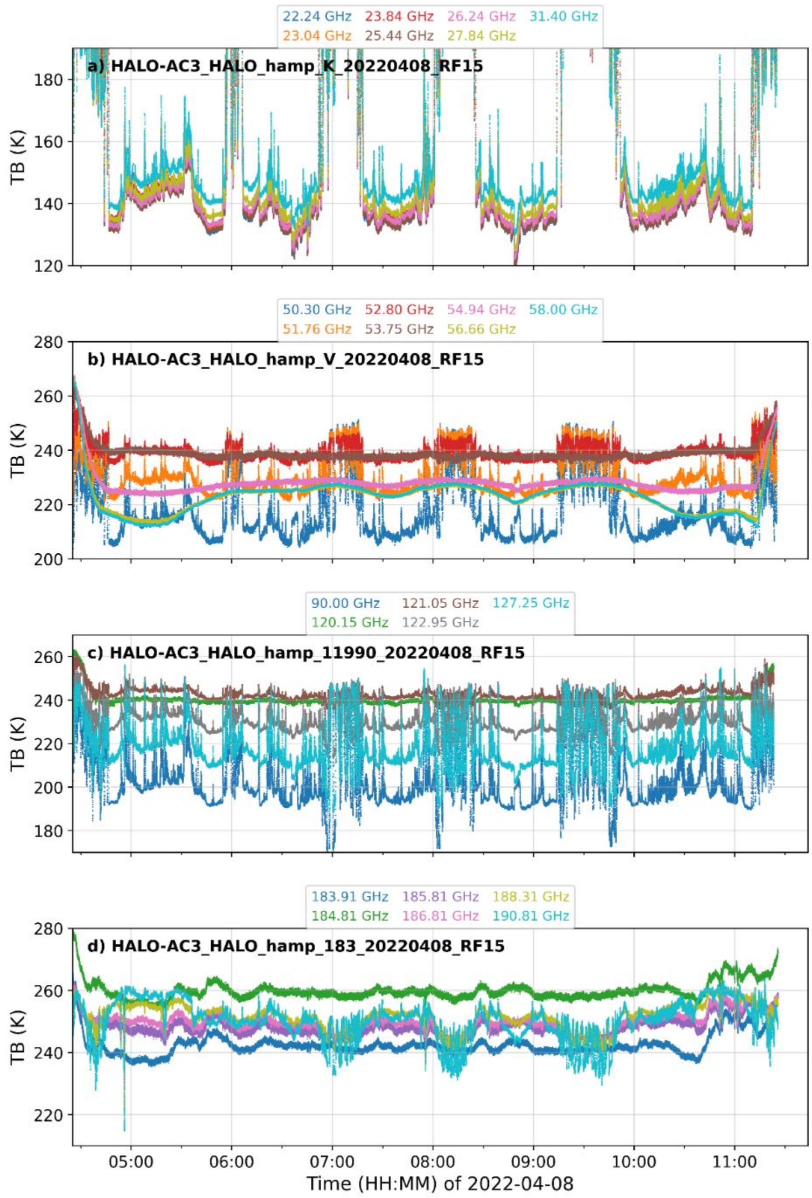

Fig. 23: HAMP microwave radiometers' brightness temperatures.

Many thanks to the crew of RF15!

Fig. 24: Crew of RF15 (left to rigt): Georgios Dekoutsidis, Anna Weber, Henning Dorff, Geet George, Roel Neggers, Andreas Walbröl, Michael Schäfer, HALO. Not in the picture: Alexander Wolf, Thomas Kalfas, Roland Welser