Flight Report

HALO-$(AC)^3$ – 2022/03/30

HALO research flight RF11

Weak Cold Air Outbreak over the Fram Strait

Objectives:

- To track and sample a southbound air mass in the Fram Strait that was already visited in the north over the sea ice by RF10 on the day before, at 84N, 19E. Lagranto back- and forward-trajectories were used for estimating the exact position of the air mass.
- To fly three mesoscale circles in the air mass for estimating mesoscale gradients and mass divergence. The first circle is situated over the sea ice at the entrance of the Fram Strait, the second over open water at the exact forward trajectory from Tuesday's circle during RF10, and the third at a downstream location to the south at about the same distance.
- To launch 10 dropsondes in each circle, 8 on the perimeter and two within, as equally spaced as possible to achieve a homogeneous area density.
- To supplement these sonde data in the circles with data from all of HALO's other remote sensing instruments, as well as data from P5 and P6 aircraft which sampled the circles immediately afterwards.
- To include two straight flight legs in the flight, the one longitudinal one oriented across the flow, the other in meridional direction parallel to the flow
- To colocate with the FAAM and ATR
- To use the combined data i) to increase our understanding of long-range air mass transformations in the Arctic, ii) to estimate mesoscale divergence along its path, iii) to drive high-resolution Lagrangian LES simulations exclusively with observations, and iv) to evaluate these experiments against independent datasets.

Ground-Mission-PI HALO:

Benjamin Kirbus

HALO Crew	
Mission PI	Roel Neggers
HAMP	Florian Ewald
WALES	Silke Groß
SMART/VELOX	Johannes Röttenbacher
specMACS	Anna Weber
Dropsondes	Fiona Paulus
Optional	Geet George
Pilots	Roland Welser, Thomas Kalfas
Engineer	Alexander Wolf

Flight times:

HALO	
Take off	**07:56 UTC**
Touch down	**16:20 UTC**

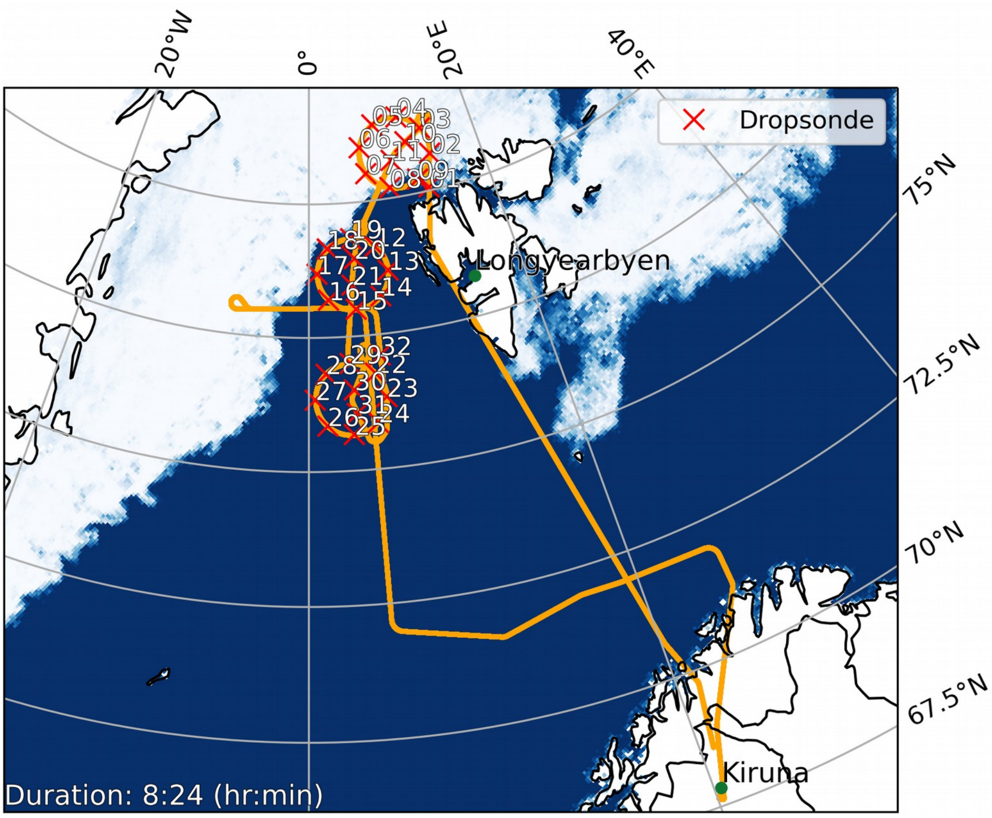
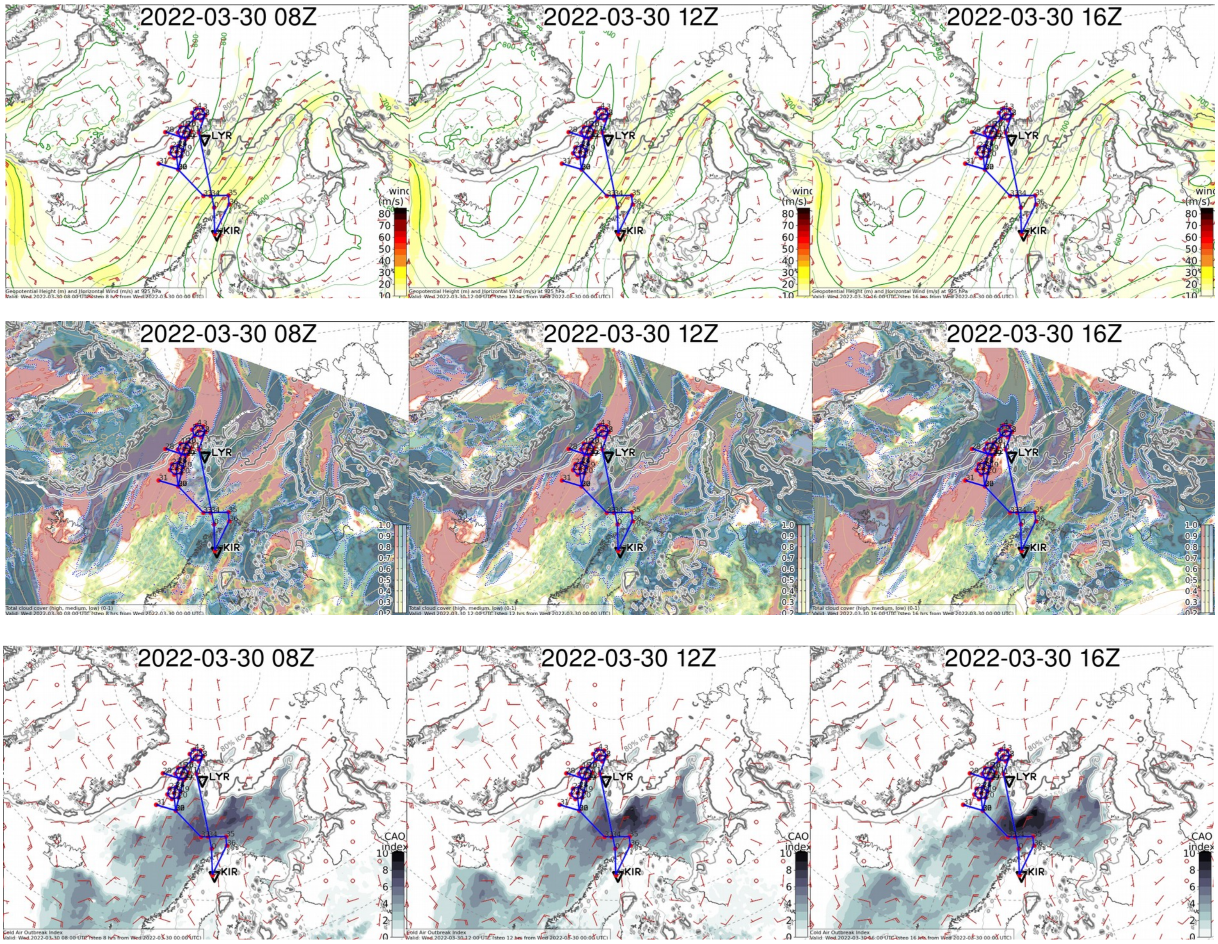
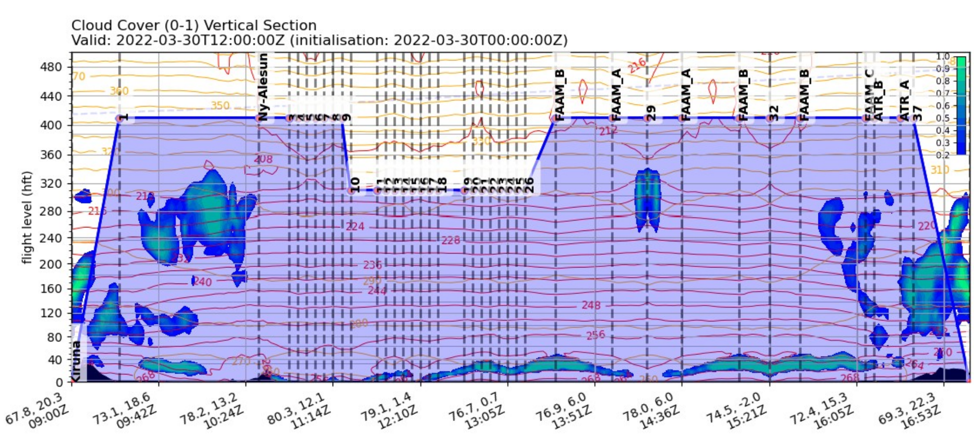


Fig. 1: Map of SMART coordinates (orange line) and dropsonde launches (red cross) during HALO RF11. Sea ice fraction as observed by the Advanced Microwave Scanning Radiometer (AMSR2) by the University of Bremen (Spreen et al., 2008).

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

The weak northerly flow off the sea ice entering the Fram Strait was exactly as presistently forecast for days in advance. Thoughout the day the low level flow was stationary. The area north of the Norwegian coast was dominated by mixed phase convective clouds. Some cirrus was detected on the way to the target area, as forecast. The lee area around Svalbard was very pronounced. Low level clouds over the sea ice seemed absent, although thin ice clouds might have been remained undetected. In the target area marine shallow convective clouds were present, as predicted. The cloud field featured well defined streets, which formed directly over leads at the sea ice edge. The street pattern broke up further downstream, approximately in the area of the 3d circle. In that area the cloud cover increased significantly, and precipitation was detected that reached the surface.





Overview:

The goal of RF11 was to revisit and sample a southbound air mass in the Fram Strait that was probed on the previous day during RF10, when it was situated over the sea ice near (84N, 19E). A special goal was to fly three 150km radius circles featuring dense dropsonde launches, providing information about the mesoscale environment in which the polar clouds are embedded. A prime goal is to thus measure the mesoscale vertical velocity in the air mass, which plays a big role in how the air mass transforms as it moves out of the Arctic. Measuring vertical velocity and divergence is a classical problem in the atmospheric sciences, which has eluded scientists for decades. The recent NARVAL and EUREC^{4}A field campaigns have for the first time shown that the dropsonde circle method can effectively be used to this purpose. During RF10 and RF11 of HALO-(AC)^3 this method was applied in the Arctic for the first time ever. The circle data will be used later to i) gain insight into polar dynamics and ii) to drive high resolution simulations of Arctic air masses in transformation. Colocated flight legs with the FAAM and ATR aircraft took place during the second part of the flight.

Summary of key events and outcomes:

- Three circles were flown successfully, all sonde launches were also successful (32 out of 32)
- No significant problems occurred during the flight. The onboard coffee tasted excellent.
- The flight plan shown in Figs. 1 and 2 was executed as planned, except for i) a small deviation right after takeoff and ii) a western shift and extension of the southbound leg at 5E.
- Colocation with the FAAM and ATR took place as planned. P5 and P6 sampled circles1 and 2.
- A significant aerosol layer was detected by WALES in Circle 1 at a few km height. The sonde profiles all show a strong humidity inversion at about 1.5km. These two features suggest this was a recycled air mass from continental origins, that has already spent some time in the Arctic.

Instrument Status:

HALO	
BAHAMAS	
BACARDI	
HAMP Radar	
HAMP Radiometer	
WALES	
SMART	
VELOX	
specMACS	
Dropsondes	32/32

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

Detailed Flight Log (times are approximate):

7:57Z T/O from Kiruna

8:10Z Thick cloud over Norwegian mountains. Extra waypoint was inserted between KIR and WP1, but original flight path followed after WP1

8:32Z Many convective cores off the Norwegian coast, featuring overshoots and icy outflow clouds. Very thin cirrus patches spotted.

8:43Z The cirrus thickens, while the low level cloud deck becomes more homogeneous.

8:50Z Visual contact with FAAM below (contrails). Low level cloud deck still quite homogeneous

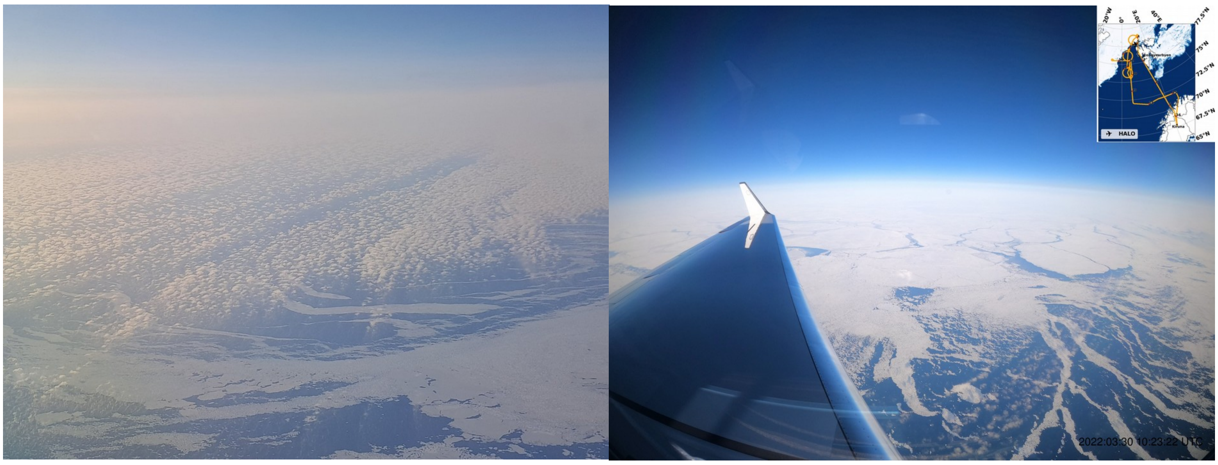
8:57Z Passing Bear Island east of us.

9:10Z Entering Svalbard's southern lee area, low clouds completely gone. Streaks of white sea ice below, surrounded by black (new?) ice.

9:27Z Approaching WP2 at Nye Aalesund. Thicker cirrus here.

9:37Z Banking over Nye Aalesund, while descending towards circle cruising height. Beautiful view of Svalbard and its glaciers.

9:47Z Test sonde DS01 launched successfully. Shallow cloud streets visible over the water near the sea ice edge. Lead triggered?



Circle #1 (left: 10:17 UTC, right: 10:23 UTC)

9:54Z Entered Circle #1 orbit (counterclockwise). Sondes are launched at every 45 degrees heading change, to space them evenly. The sea ice in this area, in particular the northern part of the circle, is pretty homogeneous. Some leads exist, some open and some looking recently overfrozen. Air conditions are a bit hazy. No detectable low level clouds present in the nothern part of the circle. On the southern side, cloud streets seem to initiate at the bigger leads or cracks.

10:00Z Thick aerosol layer above 6km is detected by WALES.

10:30Z Circle #1 orbit completed. 8 sondes were launched successfully on the rim, 2 within. Exit through standard procedure turn.

10:45Z HALO now aligns with the flow direction, heading south. Shallow cloud streets become more established away from the ice edge, with the individual clouds nicely detected by the instruments.

10:55Z Circle #2 orbit entered, clockwise this time. The Svalbard lee is to the east, shallow cumulus cloud streets in the middle of the ice-free channel. Almost no sea ice!

11:15Z Cloud streets seem to break up near the southern end of Circle #2. In this region cloud cover increases, with stratocumulus-type patches separated by areas of clear air. **11:35Z** Circle #2 orbit completed, again 8 sondes were successfully launched. Two more sondes launched in the middle. Circle #2 (left: 11:23 UTC, right: 11:30 UTC)

11:57Z Entering Circle #3, clock-wise. Clouds are much thicker here, in the shape of a solid stratocumulus cloud deck with small openings.

12:15Z Thick stratocumulus, with some open and elongated narrow gaps. Snowfall was detected by the instruments for the first time near the southern end of circle, reaching the surface. This was also predicted by the models.

12:54Z Circle #3 orbit completed, again 8 sondes were successfully launched. Two additional sondes were launched in the middle. Afterwards, a shortcut was inserted by bypassing the upcoming waypoint, to gain some time for the colocation with the FAAM.

13:00Z HALO flies north near the cloud edge, with the Svalbard lee to the east. The CMET balloon is relatively close.

13:06Z Extra dropsonde launched at the same latitude as the CMET balloon, upon request.

13:46Z HALO is now on its longitudinal leg just south of Circle #2. At the western end, clouds over open leads spottted. Air looks hazy, which might be caused by the aerosol or vapor. The cloud edge pretty much coincides with the sea ice edge.

13:50Z The subsequent meridional leg (southbound) was moved to the west a bit, to align with the FAAM aircraft. It was also extended much further south, in order to accommodate water vapor measurements along the flow.

Circle #3 (left: 11:59 UTC, right: 12:36 UTC)

14:04Z The low level clouds to the east look like broken unorganized stratocumulus. To the right the stratocumulus is much more homogeneous. Gaps that suspiciously look like Pockets of Open Cells (POCs) are spotted.

14:10Z The instruments detect some rain in the clouds below.

15:27Z At the end of the soutbound leg, and on the subsequent eastbound leg, the clouds look much more convective. This includes cumuliform convective cores with icy outflow streaks.

15:45Z HALO is now in the area where the ATR is also flying.

16:20Z T/D Kiruna

Quicklooks:

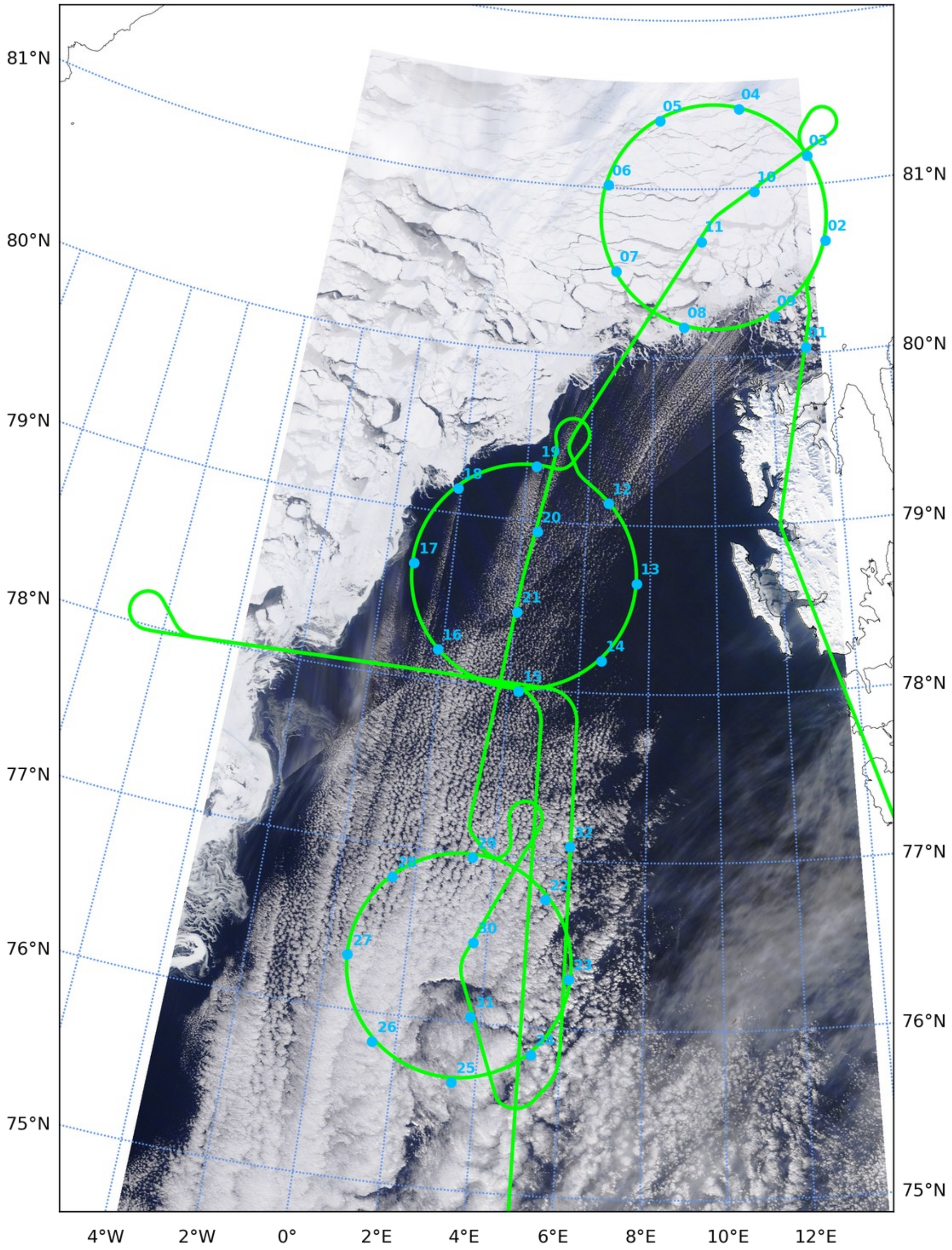


Fig. 2: MODIS Terra true color satellite image of clouds and sea ice in the Fram Strait on 30 March 2022. The HALO flight path is show in green. Dropsonde launch locations are indicated in blue. The low level air mass transitioned from stable over the sea ice via shallow well-mixed at cloud onset to stratocumulus topped mixed layers in the south.

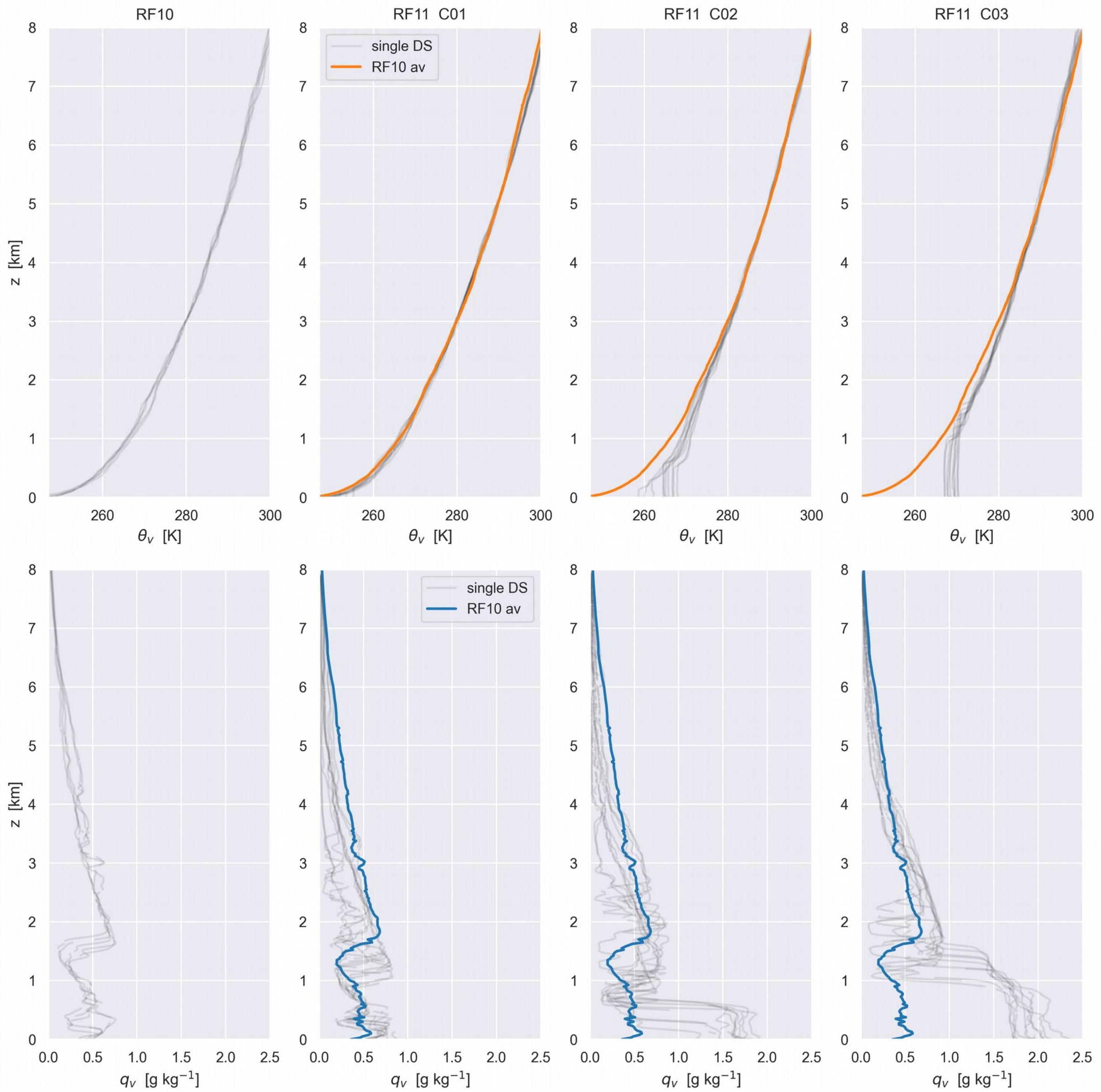


Fig. 3: Dropsonde profiles of virtual potential temperature (top) and water vapor specific humidity (bottom) for alll three circles. The RF10 circle is also included, for reference (left panels). Grey lines represent single sonde profiles. The colored line represents the average over all sondes in the RF10 circle. The deviations in the sonde profiles in the three RF11 circles from the RF10 profile are an expression of air mass transformations.

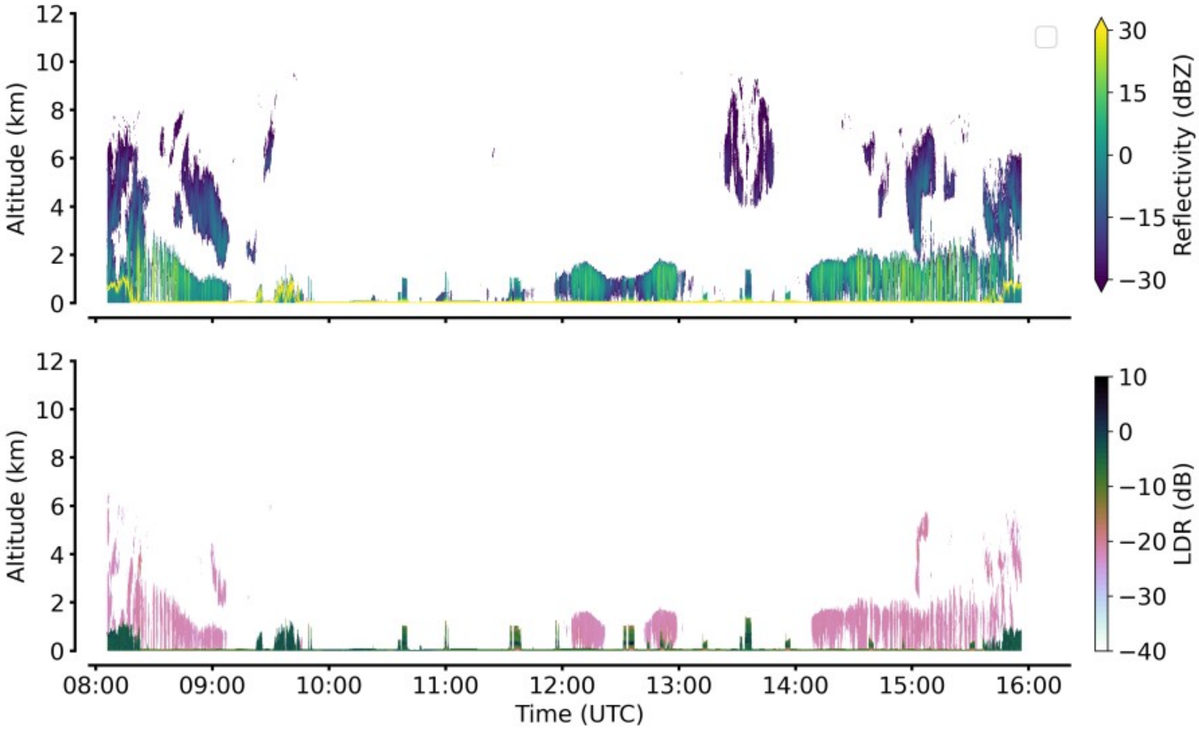


Fig. 4: Time-height plot of HAMP radar reflectivity (top) and LDR (bottom) during RF11. Circle times were 09:54-10:40 UTC, 11:00-11:35 UTC and 11:57-12:35 UTC for the first, second and third circle, respectively

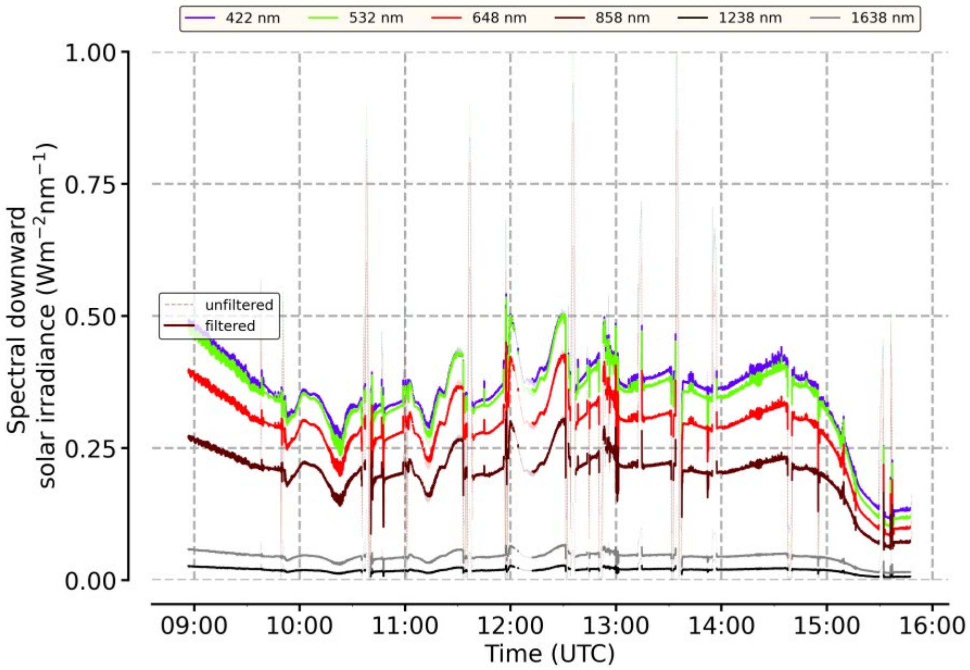
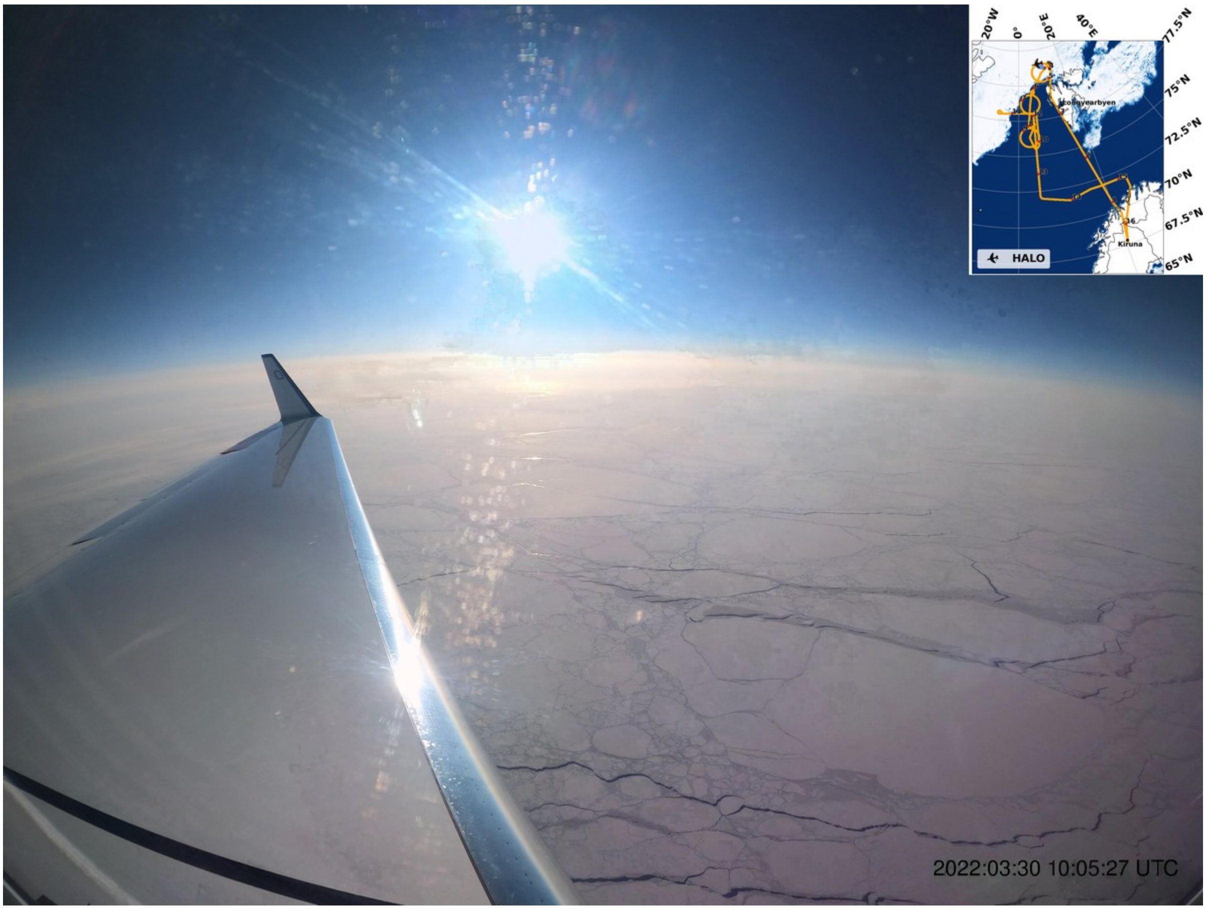
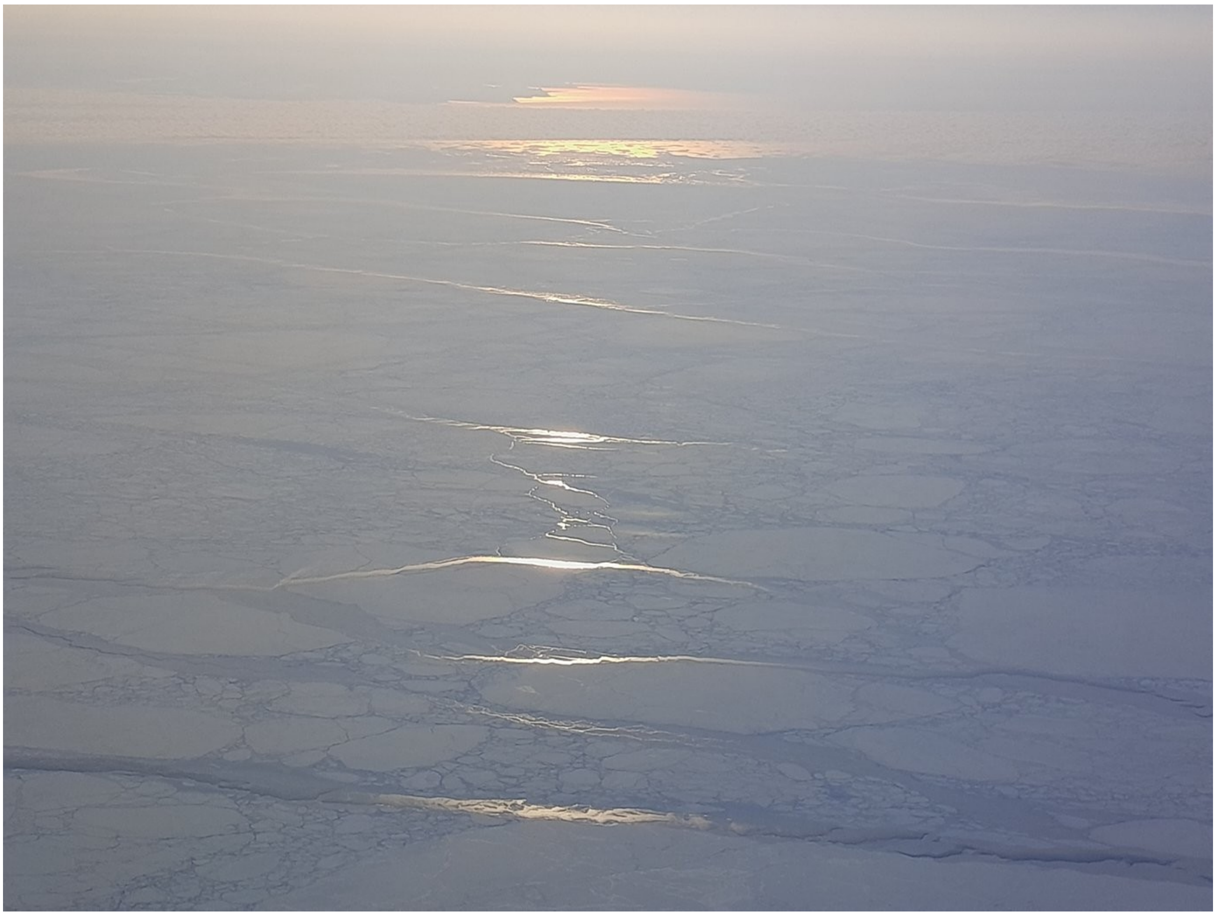


Fig. 5: Time series of solar irradiances sampled by SMART at various wavelenths during RF11.



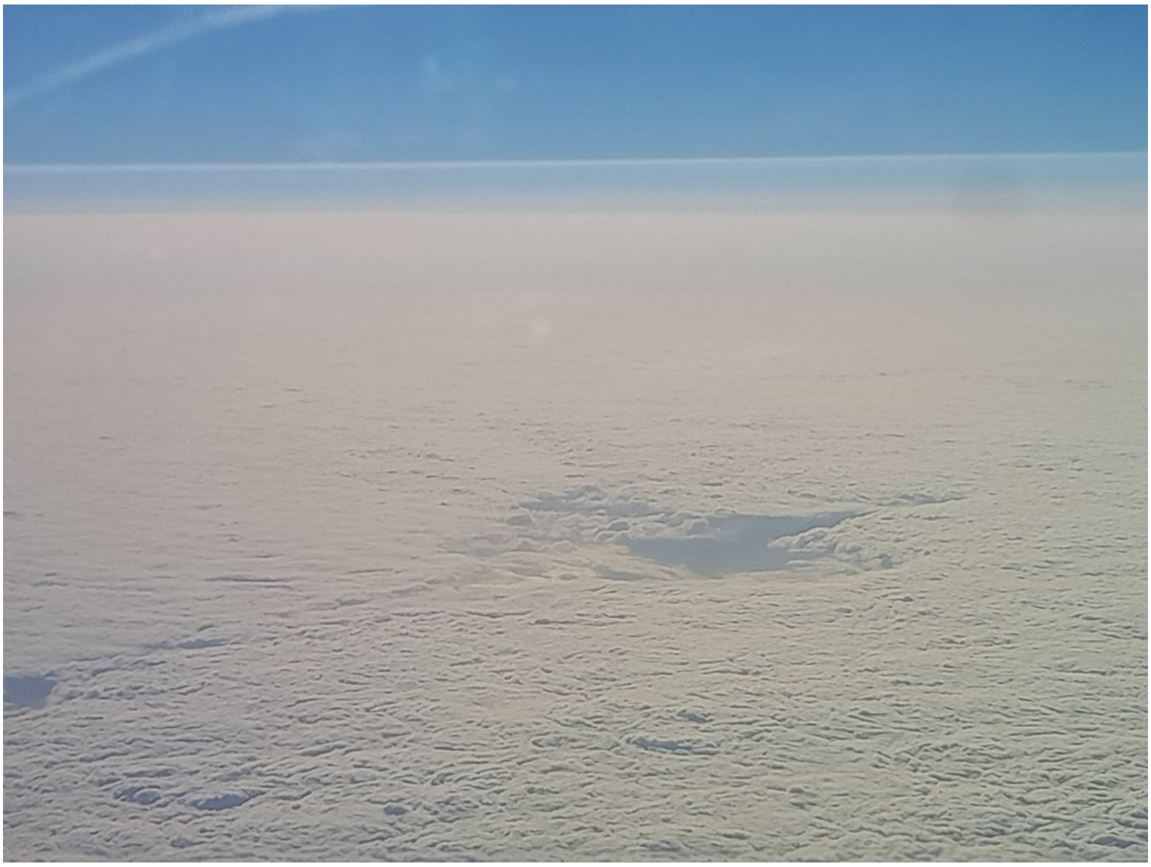


10:09 UTC, looking SE. Showing details of the sea ice structure in Circle #1

10:20 UTC, on Circle #1, looking SE. Svalbard westcoast in the background. Aerosol layer is visible.

10:55 UTC, on Circle #2, looking SE.

12:36 UTC, close up of Circle #3 convective clouds. Sea surface visible.



14:06 UTC, on the southbound meridional leg, looking SW. A gap in the stratocumulus cloud deck - is this a POC (Pocket of Open Cells)?