

In this chapter, an overview of pressure constellations, air masses, wind regimes and precipitation fields will be given in the area that will be covered during the HALO-(AC)3 campaign. This includes the Norwegian, Greenland and Barents Sea, Svalbard and the northern part of Scandinavia. Furthermore, the take-off and landing conditions at Longyearbyen (LYR, Svalbard) and sometimes also at Kiruna (Sweden) will be assessed. Table 1 is supposed to serve as a visual assistance of the following weather report and refers to conditions in the area reachable by all three aircrafts. Time references will always be with respect to the Universal Coordinated Time (UTC; i.e., night: 00 UTC).

At the beginning of the observation period (8th March 2021) - which was exactly one year before the actual HALO-(AC)3 campaign starts - there is an extended high pressure system over the North Pole. A secondary low visits the Fram Strait, heading towards the north-eastern tip of Greenland later that day. During the day, this low is north-west of Svalbard causing weak westerly winds to the west and south-easterly or easterly winds to the north of Svalbard. With a lack of clear meridional winds, neither cold nor warm air advection plays a major role on this day. The low is accompanied by a trough in the 500 hPa geopotential height and it is therefore not surprising to see clouds in all layers and some precipitation around it. Take-off and landing conditions at both airports look good.

On the next day (9th March 2021), the high over the North Pole has faded but a strong dynamic cyclone has formed in the Laptev Sea north of Siberia. It transports a significant amount of moisture (Integrated Water Vapour (IWV) up to 8 mm) into the central Arctic but remains unreachable for the Polar aircrafts. HALO might have the opportunity to fly through the warm and moist air advection of this cyclone. However, for a thorough investigation (flying through it multiple times) its distance to Kiruna is simply too great. In reachable destinations around Svalbard, the weather is rather calm but cloudy with the remnants of the cyclone from the day before. In the Fram Strait, the wind mainly flows from south to north, slowly increasing the 850 hPa equivalent potential temperature (EPT) but is too weak to be called a warm air intrusion. Precipitation and cloud cover are similar to the day before and flight conditions are tricky due to poor visibility at LYR.

On the 10th March 2021, a secondary low, that has formed north of the central low over Iceland when it got access to extremely cold air over the sea ice and Greenland, reaches the south-western coast of Svalbard and transports high amounts of moisture from lower latitudes of the North Atlantic on its eastern side. IWV increases up to 8 mm and the 850 hPa EPT is 10-15 K higher than 24 h before. In the Fram Strait, northerly winds of cold and dry air converge with the warm and moist flow. If one was looking for precipitation on that day, this would be the place where one could certainly find it. More precipitation (also in liquid form) can be found along the entire eastern flank of this secondary cyclone. Only because this warm air intrusion has pulled the emergency break when it reached the south-western coast of Svalbard, it is not rated a pronounced WAI (see Table 1). The warm air was blocked from going further northwards because it was not supported by the mid- and upper tropospheric airstream any longer. Flight conditions in LYR are difficult due to bad visibility (especially in the afternoon). It is likely that no flights would have been performed from LYR.

In the night from 10th to 11th March 2021, the secondary low moves straight over Svalbard and continues eastwards, influenced by the upper level geopotential height trough from the still remarkably strong dynamic cyclone north of Siberia. A slight high pressure influence (a remainder of the strong anticyclone on the 8th March) can be noted on the north-eastern flank of Greenland and the western border of the Fram Strait. In combination with the secondary low to the east of Svalbard, this results in north or north-easterly winds in the Fram strait, causing a pronounced cold air outbreak (CAO, see Table 1). The 850 hPa EPT decreases by more than 15 K in some parts of the Fram Strait. The high pressure influence, which started to be supported by a shallow ridge (and closed anticyclonic flow) in the 500 hPa geopotential height, dissolves high level clouds. This first occurred over the Fram Strait

and later affected Svalbard (around noon). The missing high clouds and undisturbed northerly flow cause nicely structured cloud streets to the west of Svalbard with some precipitation leaking out of them. The take-off at LYR probably would not be permitted before noon but only afterwards when the sky clears up.

On the 12th March 2021, Svalbard gets under the influence of a shallow high, sitting between the dynamic lows close to Iceland and Siberia. In the Fram Strait, weak winds from different directions in the lower and mainly zonal winds in the higher atmosphere jointly act to remove the clear CAO structure from the previous day. In fact, the 850 hPa EPT slightly increases in this region and remains roughly constant over Svalbard. Low clouds persist from the previous day but they show no interest to precipitate. The Polar aircrafts could be used to sample turbulence in the Fram Strait where the wind is calm. The cold air advection has instead moved to regions to the east of Svalbard. There, north-easterly winds form cloud streets when blowing from the sea ice to the open ocean. Good flight conditions in LYR persist throughout the entire day.

On the 13th March 2021, the high over Svalbard loses its closed circular structure but strengthens nonetheless. Cyclonic flow in high altitudes brings some high clouds to the Fram Strait and Svalbard. At the surface, northerly winds push cold and dry air from the central Arctic to the open ocean in the Fram Strait, forming again a pronounced CAO with cloud streets. According to ECMWF's operational run, these clouds are a bit less motivated to precipitate than those from 11th March. Despite some high clouds, the conditions at LYR are okay for take-off and landing. For the 14th March 2021, the whole constellation is similar but with weaker winds and higher pressure. Nevertheless, the cloud street structure of the cold air outbreak remains, as do the high clouds.

On the 15th March 2021, the constellation was still surprisingly similar to the previous 2 days but with even higher pressure all around Svalbard. The cyclonic flow in the upper troposphere with its related trough of 500 hPa geopotential height suggests that the high surface pressure forms due to cooling (cold air high). Some shallow cyclones form in the Fram Strait along weak convergence lines and along fading cyclones. Precipitation is only worth mentioning close to those cyclones. Flight conditions might be impaired by fog on this day.

On the 16th March, the pressure over, to the north and west of Svalbard increases further and the northerly flow gets disrupted. The wind calms down except for regions around two of the cyclones that had formed the day before. Therefore, the cold air advection weakens to the west of Svalbard and the cloud streets lose their structure. One shallow cyclone is located in the Fram Strait, but a pronounced ridge in the 500 hPa geopotential height suppresses its development. The other cyclone (see chapter: Polar Low), which is located to the south-east of Svalbard around noon, is supported by the upper atmosphere and can therefore deepen. It circles cooled moist subpolar air from the Norwegian and Barents Sea with even colder and drier air from the sea ice east of Svalbard. This causes cold air advection to the north of Norway which is hard to reach for the Polar aircrafts. Precipitation and high clouds are only significant in proximity to the cyclones. Hence, a flight from LYR would not be hampered.

On the 17th March 2021, the high pressure was nearly centered over Svalbard, supported by an upper tropospheric ridge. This causes a southerly flow to the west and calm winds to the east of Svalbard. The southern flow increases the 850 hPa EPT by 5 K and a band of IWV up to 7 mm reaches the Fram Strait. Along a weak convergence line in the Fram Strait, some precipitation and deeper clouds form. To the south-east of Svalbard, the cyclone (Polar Low) starts dissolving and is about to hit the Nordkapp. Missing temperature gradients, its location in the centre of the trough and scratching the Norwegian Coast do not favour further deepening. At LYR, the flight conditions are perfectly calm and sunny.

On the 18th March 2021, the high pressure and its associated ridge have moved eastwards so that the surface near southerly flow to the west of Svalbard remains. Warm and moist air is advected along the eastern flank of a cyclone located over Greenland into the Fram Strait. There, the 850 hPa EPT has increased by 15 K and I WV reaches more than 8 mm in some regions. Missing support of the meridional flow in the upper troposphere results in yet another WAI that stops right at the latitude of LYR. Unsurprisingly, the WAI is accompanied by high clouds and precipitation. At the south-western coast of Svalbard, orographically induced clouds are likely to boost precipitation later in the day. Flight conditions at LYR are only okay in the morning. This low develops into a Shapiro Keyser Cyclone, where the cold front gets fractured and does not occlude with the warm front like in a frequently observed Norwegian Cyclone. Instead, the warm air gets circled around the centre and meets the cold air to the north-west of the centre.

From the 18th to the 19th March 2021, the cyclone from Greenland has followed the southwesterly flow of the middle and upper troposphere. Around noon on the 19th March it is centered over Svalbard, resulting in northerly flow to the west and southerly flow to the east of the island. Therefore, there is both cold air advection and warm air intrusion around Svalbard. Since the warm air has already significantly cooled down, this event is not marked in Table 1. The cold air outbreak is strong but overlapped with warm air circling around the cyclone centre. Further west in the Fram Strait, the 850 hPa EPT has decreased by more than 15 K compared to the previous day. Bad visibility through deep clouds and precipitation prevent take-off and landing at LYR. On the southern end of the cyclone, heavy (partly orographically induced) precipitation hits the Norwegian Coast. The lee effect of the mountains lead to relatively calm weather over Kiruna so that flights are still possible from here.

On the 20th March 2021, the centre of the Shapiro Keyser Cyclone is just off the east coast of Svalbard so that northerly flow persisted in the Fram Strait. Hence, the air mass continues to cool down and the eastward propagation of the cyclone leads to a cooling of the eastern border of the Fram Strait as well. With the warm sector of the cyclone being to the east of Svalbard, a temperature gradient of 18 K at the 850 hPa pressure level between the two regions has been established. Precipitation can be found all around the island and the Fram Strait once more features cloud streets from cold air being advected over the ice free ocean. The greater the distance to Svalbard to the west, the less high clouds can be found. On the southern end of the cold air whirled around by the Shapiro Keyser Cyclone, a secondary low forms at the baroclinic convergence line of the cold and warm air. It continues to produce heavy precipitation at the Norwegian Coast, still supported by orographic lifting. Flight conditions in Kiruna are still acceptable and at LYR the visibility is sufficient for take-off and landing.

From the 20th to the 21st March 2021, the Shapiro Keyser Cyclone over Svalbard has not moved much. Its centre is still located just off the east coast of Svalbard but the core pressure has slightly increased. The northerly flow in the Fram Strait has weakened marginally. The temperatures have not dropped further to the west but the warm sector to the east of Svalbard has lost heat to the cold surroundings. The cloud streets accompanied by the CAO remain, but clouds over LYR prevent safe take-off and landing conditions. Precipitation can mostly be found at the northern tip of Svalbard where the northerly flow is forced to ascend when hitting the coastal mountains and among the cloud streets in the Greenland and Norwegian Sea. The secondary low that hit the Norwegian Coast the day before has passed Kiruna and moved to the border of Finland and Russia. Moist air from the North Atlantic keeps hitting the Norwegian mountains, driving orographically induced precipitation. Due to lee effects and being located on the back side of the secondary cyclone, none of this impairs flight conditions in Kiruna.

On the 22nd March 2021, the former Shapiro Keyser Cyclone dissolves further and is centered to the north-east of Svalbard, not far off the coast. From south-west, a new cyclone

with two spinning centres approaches Svalbard, supported by an upper level trough on whose front side it is located. Like the cyclones before, it has utilized the baroclinicity of the moist air of the North Atlantic and much colder air from over the sea ice to develop. Over the west coast of Svalbard, the winds are calm and coming from different directions (north-easterlies to north-westerlies) because this lies in between the fading Shapiro Keyser Cyclone and the approaching one. Typical for the Shapiro Keyser Cyclone, although fading, the aged warm sector is more active regarding wind and precipitation than the cold sector. The latter actually features no high clouds, negligible precipitation and good low level visibility. This makes for good flight conditions at LYR. With the warm conveyor belt of the approaching cyclone, plenty of precipitation is on its way to Svalbard but will not arrive at the island before the night.

On the 23rd March 2021, the approaching cyclone has merged with the fading Shapiro Keyser cyclone and deepened to core pressure of 955 hPa, centered to the south of Svalbard in an upper level trough. Despite the strong north-easterly winds that have been established in the Fram Strait, the EPT stays the same or has even increased with respect to 24 h before because air from the warm conveyor belt has already reached the centre of the cyclone. On the southern end of the cyclone, cloud streets could be observed nonetheless as a result of the cold sector air blowing from the sea ice to the open ocean. Precipitation and clouds are severe over Svalbard and surroundings so that take-off conditions are poor. Kiruna profits from lee effects yet again so that only a negligible amount of precipitation reaches it.

From the 23rd to the 24th March 2021, the deep cyclone has propagated eastwards and its core pressure has been filled up to 973 hPa. At noon of the 24th March, it is located to the south-east of Svalbard. The air mass over Svalbard - mixed warm and cold sector of the aforementioned cyclone - converges with much colder air from the central Arctic ice sheet. Therefore, another shallow cyclone forms off the west coast of Svalbard, advecting cold air southwards through the Fram Strait. This results again in cloud streets to the west of this cyclone's centre. These are mainly confined to the west half of the Fram Strait because only there the wind has got a significant component perpendicular to the sea ice edge. Iceland has tossed another cyclone at Norway, which was able to develop on the front side of an upper level trough. Precipitation is only worth mentioning around this cyclone and the shallow one's centre off the west coast of Svalbard. Take-off conditions at LYR appear to be good since the cyclone off the west coast remains at a certain safe distance.

On the 25th March 2021, the shallow cyclone remains stationary to the west of Svalbard so that there are south to south-westerly winds over Svalbard and north to north-easterly winds in the western Fram Strait. However, cold air advection is marginal because mainly the aged air of the strong low from two days before is recycled. As one the previous day, cloud streets form in the west half of the Fram Strait but get pulled into the cyclone's centre. The former deep cyclone that was located to the south east of Svalbard 24 h before remains at its position but dissolved further. It drives easterly winds to the east of Svalbard. The cyclone that was about to hit Norway the day before has also dissolved and propagated along the Nordkapp to Russia. Over LYR and in the Fram Strait, precipitation and bad visibility cause poor flight conditions.

On the 26th March 2021, the cyclone to the west of Svalbard has merged with another one that approached Svalbard from Iceland. It drags humid and warm air northwards from the Norwegian to the Greenland sea with IWV peaking at 12 mm to the east of the Nordkapp. To the north-west of Svalbard, an anticyclone is located so that the Fram Strait is still under the influence of north-easterly winds. Here, the cloud streets become less structured because the wind flows parallel to the sea ice edge and some precipitation can be found in the remains of the cyclone that has merged with the one approaching from Iceland. To the east of Svalbard, the wind is calm as the cyclones in this region have continued to dissolve. Svalbard itself is mostly cloudfree so that take-off and landing is fairly possible at LYR.

With the arrival of the warm and moist air, dragged along by the cyclone that moved towards Svalbard and came from Iceland, deep layered clouds and precipitation cover the whole island on the 27th March 2021. Clear sky scenes can only be found behind the cold front, which is located to the south west of Svalbard on this day, and to the north of the cyclone with the high pressure influence. The cyclone is centered to the south-west of Svalbard, acting with an anticyclone to the north of Svalbard to form an easterly or north-easterly flow in the Fram Strait. The IWV over Svalbard reaches values up to 10 mm and the EPT has increased by more than 10 K in the past 24 h. As the fronts have already started to occlude the warm sector is much less pronounced than on the day before. Flights are not possible from LYR on this day, except the flight would be finished before 06 UTC.

On the 28th March 2021, a pronounced ridge in the 500 hPa geopotential height to the north of Svalbard with a part of its axis zonally oriented shows its effect on the propagation of the warm air once more. The WAI fails to make it past Longyearbyen and fades before it could reach the central Arctic. The cyclone associated with the warm air intrusion event dissolves and travels towards Greenland so that its centre is now in the west half of the Fram Strait. Furthermore, another circulation centre has formed out of the remainders of a cyclone to the south-east of Svalbard, corresponding with an upper level trough. This constellation results in weak south-easterly winds over Svalbard, southerly winds in the eastern Fram Strait and north-easterly winds at the coast of Greenland. The cold sector behind the occluded front has reached the western part of Svalbard, decreasing temperatures and reducing IWV. The overcast over LYR, which is located between the fading cyclone and the new circulation centre, from the previous day has been replaced by some broken low level clouds so that the flight conditions in the fjord of LYR look good.