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Detecting polar lows with SAR

Gunnar Noer, Jakob Grahn
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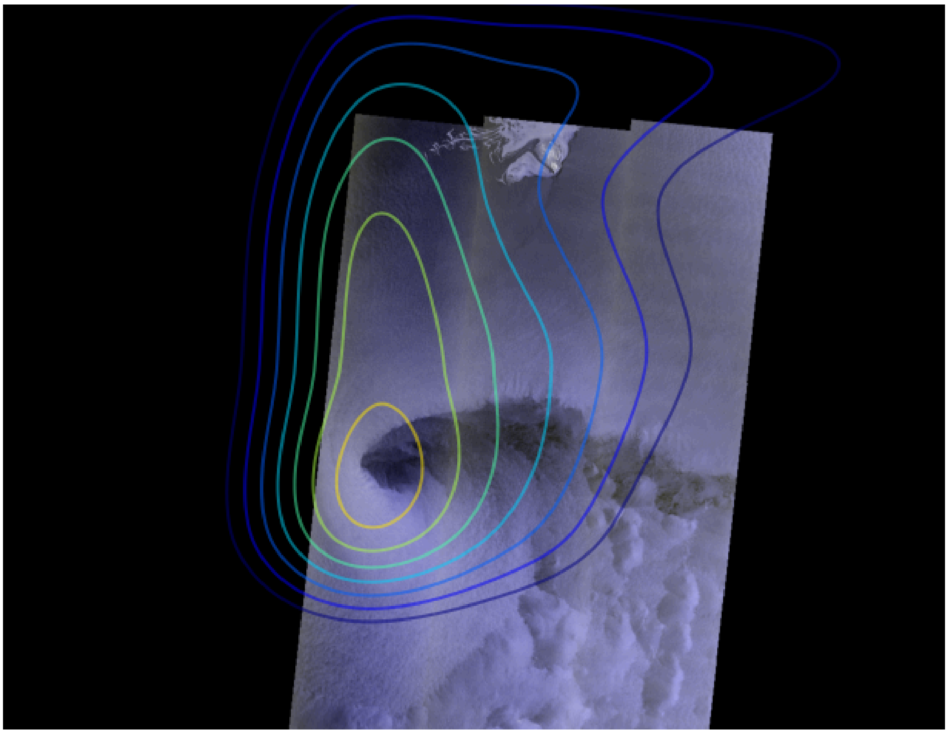

Title Detecting polar lows with synthetic aperture radar (SAR)	**Date** January 2025
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Abstract

Polar lows are small but relatively intense cyclones that form north of the polar front in maritime regions. They are particularly common in the Norwegian Sea and the Barents Sea during the winter season and frequently impact coastal communities in northern Norway. Polar lows bring strong winds and heavy snowfall, posing significant hazards to these areas by causing frequent traffic disruptions and increasing the local risk of snow avalanches.

Currently, polar lows are forecasted using numerical weather prediction (NWP) models, supplemented by manual analysis of remotely sensed data, primarily from Advanced very-high-resolution radiometer (AVHRR) imagery. Although Synthetic Aperture Radar (SAR) data offers high resolution and is unaffected by cloud cover, its use in this context has been limited. This is due to challenges in interpretation as well as constraints in the data's coverage and regularity.

Scientists at the Norwegian Research Center (NORCE) in Tromsø have developed machine learning methods to detect polar lows using SAR data (Grahn and Bianchi, 2022). With the anticipated increase in SAR-imagery coverage in the coming years, the utility of SAR for operational weather forecasting is expected to improve significantly. This report however shows that the algorithm is not yet ready for the task of identifying polar lows systematically, primarily due to a too high false alarm rate. This could probably be improved by: i) adding detection criteria from NWPs, ii) extending or modifying the training data, and iii) improving model training by reinforcement learning from human inputs. However, with the current availability of SAR images to draw from, it does not have the coverage required for operational forecasting.

Keywords

Synthetic Aperture Radar. Polar Lows. Arctic meteorology. Artificial Intelligence.

Gunnar Noer, Jacob Grahn

Disciplinary signature

Jørn Kristiansen

Responsible signature

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

www.met.no

Abstract

Polar lows are small, but relatively intense cyclones that form northwards of the polar front in maritime areas. They are relatively common in the Norwegian Sea and the Barents Sea during the winter season, and regularly affect the coastal communities along the coast of northern Norway. Polar lows give strong wind and heavy snowfall and pose a severe hazard to coastal communities in the form of frequent traffic disruptions and also locally severely increased risk of snow avalanches.

Today, polar lows are forecasted with numerical weather prediction (NWP) models as well as manual inspection of remotely sensed data, of which AVHRR imagery is the main source. Despite the fact that SAR data have a very high resolution and is independent of cloud cover, it has so far had limited use in this context. This is because there are challenges in the interpretation, as well as limitations in the extent and regularity of the data.

Identifying and classifying polar lows from the rest of the plethora of different and more or less similar weather types in this area is difficult, even for a trained forecaster. Thus there is a need for better tools. Even though this may seem like a tall order for an automatic routine, the promise of machine learning means that it is worth trying. Polar lows with its very distinct visual appearance should pose as an achievable type of weather to investigate further with an AI approach.

Scientists at the NORCE in Tromsø have shown that machine learning algorithms can indeed detect polar lows from SAR data (Grahn and Bianchi 2022). As the coverage of SAR-imagery is expected to increase in the future, one can expect the usefulness of SAR to the operational weather forecasting to improve. This report gives a brief survey on the result of an experimental algorithm for detection of polar lows with SAR-data, focusing on events during the month of January 2024.

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Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

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1 Introduction

1.1 The focus for this study:

We are focusing on January 2024 with the aim to address the usefulness of an AI based detection algorithm (DA) to detect polar lows from SAR images (Grahn and Bianchi, 2022), and to assess whether this can be included as part of the operational suite of tools at MET Norway. In January 2024 there were 35 cases where the DA indicated a polar low in the data in the area between Greenland and Novaya Zemlya. Only three observed polar lows were recorded at the MET Norway forecast center in Tromsø within our area of responsibility, - from the Greenland east coast to 30 deg E, plus the fishing areas of Nordbanken and Kildinbanken.

The following two aspects are considered:

1. The ability of the DA to detect the polar low and to identify polar lows as a unique weather phenomena apart from other similar phenomena in the area.
2. The timeliness: Do the classified SAR data arrive soon enough to give added value, considering other available data; AVHRR and NWP. To this end, we use the timestamp of the original SAR image, as we expect the DA postprocessing to give only a small time delay.

1.2 AI based detection algorithm

The detection algorithm (DA) developed for identifying polar lows in SAR data is described in detail in (Grahn and Bianchi, 2022). It utilizes a deep learning approach, specifically a customized convolutional neural network (CNN) architecture inspired by Xception. This algorithm was trained on a dataset constructed from Sentinel-1 imagery and the ERA5 reanalysis dataset. The dataset includes over 2,000 images, classified

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

www.met.no

as containing mesocyclones or not, with features manually validated for distinct cyclonic patterns. High-resolution SAR imagery (500 m) was used to retain critical atmospheric details such as wind shear, sharp fronts, and cyclonic eyes, which are vital for detecting polar lows. Advanced data augmentation techniques were employed during training to enhance model robustness, while interpretability methods such as Gradient-Weighted Class Activation Mapping (Grad-CAM) provided insights into the features driving classification. The DA achieved a high F1 score of 0.94 in terms of binary classification.

In this report, the Grad-CAM interpretability technique is employed to highlight and indicate the potential location of polar lows within the SAR imagery. Grad-CAM generates heatmaps that overlay the original SAR images, visually emphasizing the regions most influential in the detection decision made by the algorithm. An example is shown in figure 1, where a SAR image is shown to the left, and the Grad-CAM is overlaid on the right. This technique identifies key features such as cyclonic eyes, sharp atmospheric fronts, and wind shear, which are characteristic of polar lows. By incorporating Grad-CAM visualizations, the analysis presented in this report aims to enhance understanding of the detection algorithm's outputs and its capability to identify polar lows accurately within the challenging conditions of Arctic environments.

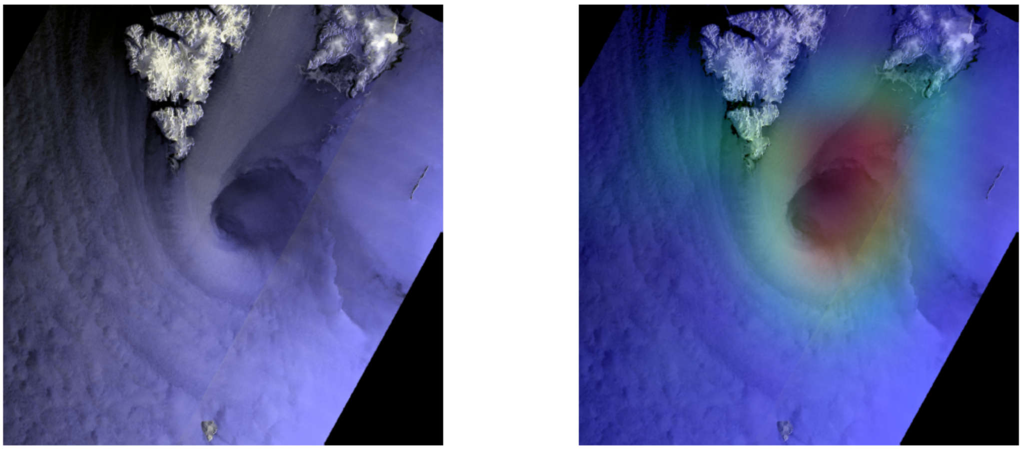

Figure 1. A 400×400 km input tile (left) is classified as a polar low, and the Grad-CAM is computed and overlaid (right).

In figure 1, the Grad-CAM was computed on a single 400x400km input image, by the processing steps shown in Figure 2. This is the image size the model is trained on. Larger images, covering the whole AOI considered in this report, can be considered by patching the AOI into 400×400 km overlapping tiles, computing heatmaps on each tile, and merging all tiles through averaging.

Figure 2. A 400×400 km input tile is inputted to the workflow. Intersecting products are downloaded and geocoded onto the tile grid. Features are extracted and represented as a RGB colour composite. The RGB image is inputted to the deep learning model. If the model predicts a polar low, the model prediction is interpreted in terms of gradient-weighted class activation mapping (Grad-CAM) in order to highlight the relevant features in the image. This results in a heatmap.

1.3 SAR data coverage

The ESA Sentinel-1 satellites carry side-looking SAR sensors, and the imaging swath (the width of the SAR image) varies depending on the operational mode, from approximately 250 km in Interferometric Wide (IW) mode to about 400 km in Extra Wide (EW) mode. The IW mode is narrower but with higher spatial resolution, and is generally acquired over land. The EW mode is wider but with a lower spatial resolution, typically operated over sea.

The Sentinel-1 satellites fly in a sun-synchronous polar orbit that repeats its ground track every 12 days, enabling global coverage at these swath widths. Because the orbit is polar, the ground tracks are naturally most sparsely spaced at the equator. In order to secure full coverage at the equator (and consequently globally), successive ground tracks are spaced by about one swath width. This spacing ultimately determines the revisit frequency, which for Sentinel-1 is 12 days. But the convergence of the tracks towards the poles significantly boosts revisit frequency in high latitudes. This is the case in the northern seas off the coast of Norway, where the revisit frequency can be daily at some regions, depending on imaging mode and specific acquisition pattern.

In order to illustrate the revisit frequency over the AROME-Arctic model domain (the selected AOI for this study), the average number of SAR acquisitions per day is displayed on a map in figure 3. This is for a single Sentinel-1 satellite. In the normal Sentinel-1 constellation, two satellites are operational, doubling the revisit frequency. However, during the test period of this project, only Sentinel-1 A was operational.

For the AROME-Arctic model domain, the satellite passes occur either in the morning, roughly between 4 and 8 o’clock, or afternoon, typically between 15 and 17 o’clock, depending on location. The revisit frequency for the morning passes are shown in figure 4, and the evening passes in figure 5. It can be seen that morning passes are more frequent, thus are more likely to observe polar lows.

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

www.met.no

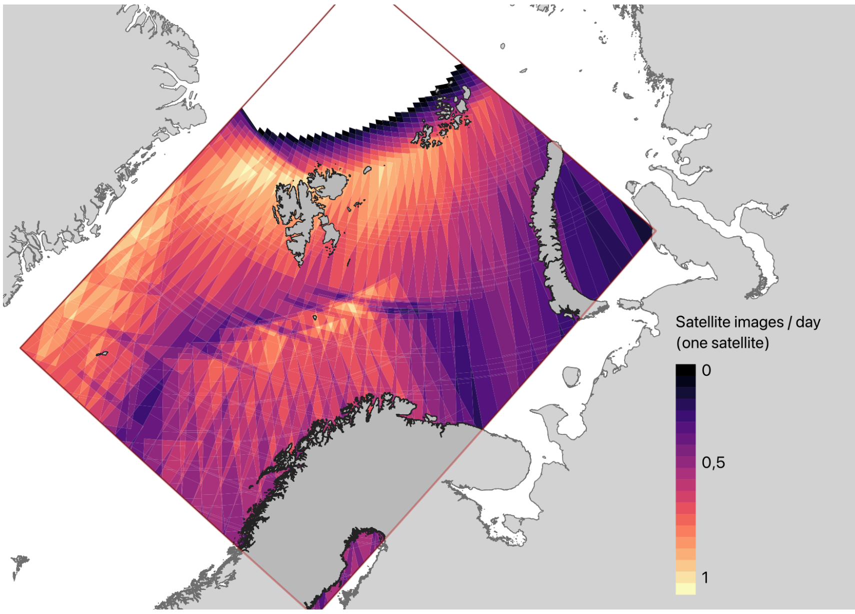

Figure 3. *The number of satellite passes per day for Sentinel-1 A (a single satellite), over the AROME-Arctic model domain. Close to the North pole, no data is acquired due to the SAR viewing geometry and orbital configuration of the satellite. The majority of the domain gets one image every second day. In the normal satellite configuration, there are two satellites, resulting in one image per day on average for the AOI.*

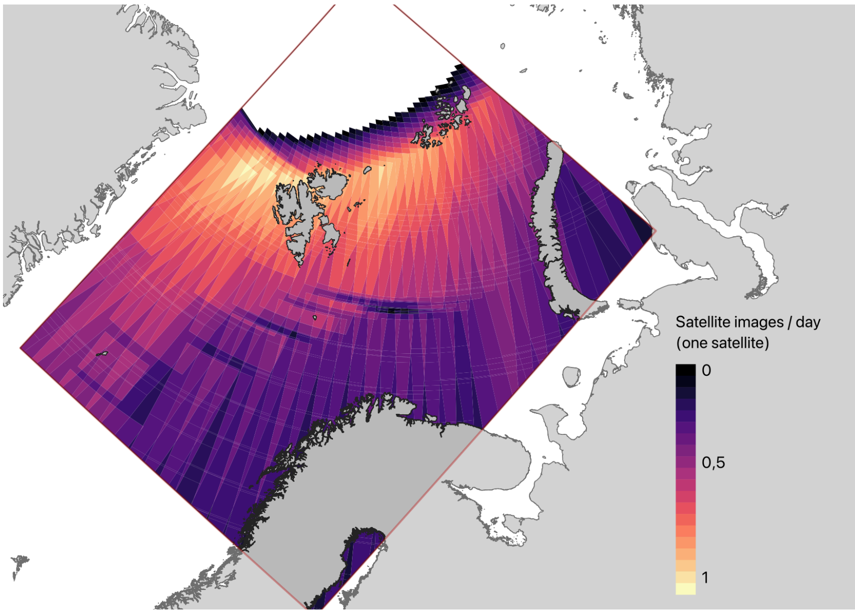

Figure 4. The number of ***morning*** passes per day for Sentinel-1 A (a single satellite), over the AROME-Arctic model domain.

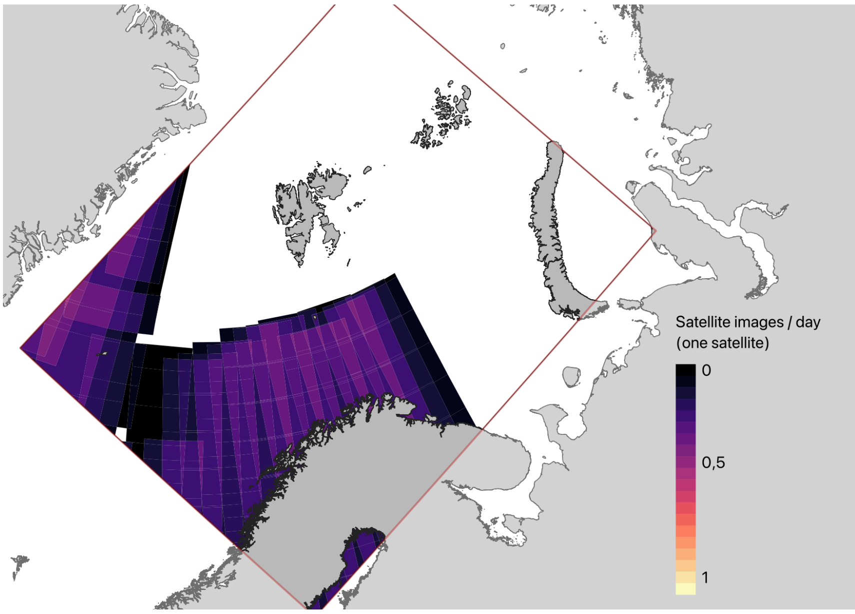

*Figure 5. The number of **evening** passes per day for Sentinel-1 A (a single satellite), over the AROME-Arctic model domain.*

1.4 The use of remotely sensed data in operational forecasting

SAR can be included and visualized together with other observational data, such as synoptic observations or Advanced Scatterometer (ASCAT) data. It can have an impact on the forecasting of warnings for turbulence in steep coastal terrain, on forecasts for general wind along the coast or offshore associated with mesoscale phenomena such as fronts, troughs or polar lows. With the present performance, the visual output from the algorithm needs to be assessed and checked manually.

Current forecasting techniques are based on NWP models, both deterministic and with ensemble prediction systems (EPS), giving reasonably good indications of development of the main synoptic lows and highs and frontal systems with up to 66 hours lead time, which is the maximum for the 2,5km resolution models. Smaller mesoscale systems like polar lows, troughs or meso circulations are usually well forecasted on 24 hours lead time, but often with some uncertainty in the exact location, - it is quite common with a misplacement of 50 to 100km at 18 hours lead time. In addition, there is good coverage of AVHRR satellite pictures 24 hours of the day, except a small lapse around midnight. There are some synoptic observations providing hourly observations scattered on the islands in the Arctic oceans and on the Svalbard area. Also there is good cover from the ASCAT instrument during daytime, in the morning covering only the easternmost area of the Barents sea, then gradually further westwards, and eventually covering the Greenland coast in the afternoon.

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

www.met.no

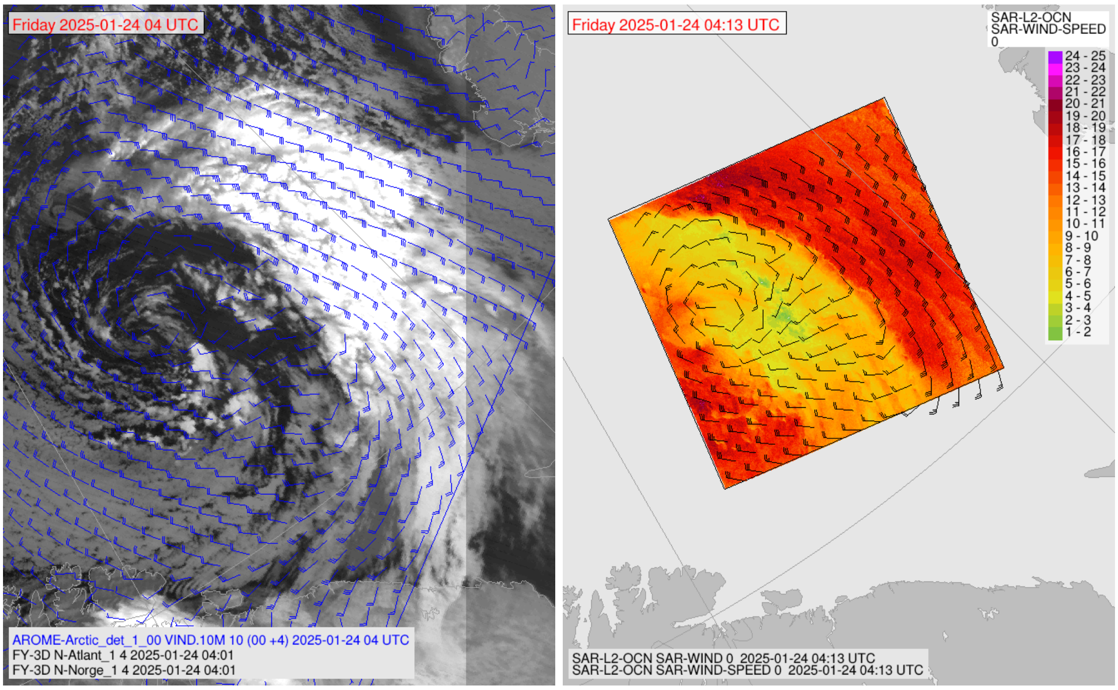

Figure 6. An AVHRR satellite image (left) with wind barbs from AROME-Arctic, and a corresponding SAR-image with quantified wind speed, as is currently available to the forecasters at MET Norway

Almost all the 35 cases where the DA have indicated a possible polar low are from the morning SAR passes, between 05 to 07 UTC, since this is the time when Sentinel-1 has the most frequent coverage. (See the Sentinel-1 data coverage in figures 4 and 5). In the following, a sample of the cases are presented in chapter 2, then some examples of missed cases are shown in chapter 3. The discussion comes in chapter 4 and conclusion and recommendations are in chapter 5. Future outlooks are given in chapter 6. Finally the cases not mentioned in chapter 2 are presented in the appendix at the end of the report.

2 Some cases from January 2024, indicated by the SAR detection algorithm:

In the following we have compared images from SAR with signals from the DA to AVHRR images, in order to investigate what kind of features trigger the detection algorithm. Some cases are supported by plots of mean sea level pressure (MSLP) or 10m wind speed from AROME-Arctic. We have also checked the corresponding tracking data from AROME-Arctic, since this is based on criteria for static instability, vorticity and diameter of the polar low, and the inclusion of such criteria would be an obvious next step in the effort to detect polar lows with a DA. We have identified five typical wind patterns, and an example of each are presented here, in addition to the two clear polar low cases. The rest of the cases are presented in an appendix at the end of the report.

2.1 1 January

A large synoptic low due west of Spitsbergen developed into a convective low with the appearance and characteristics of a polar low on the early morning to the 1st January. The DA indicated two areas; one correctly placed along a shear zone associated with the northern center. The other at a local minimum in wind fields associated with terrain on the Greenland east coast.

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

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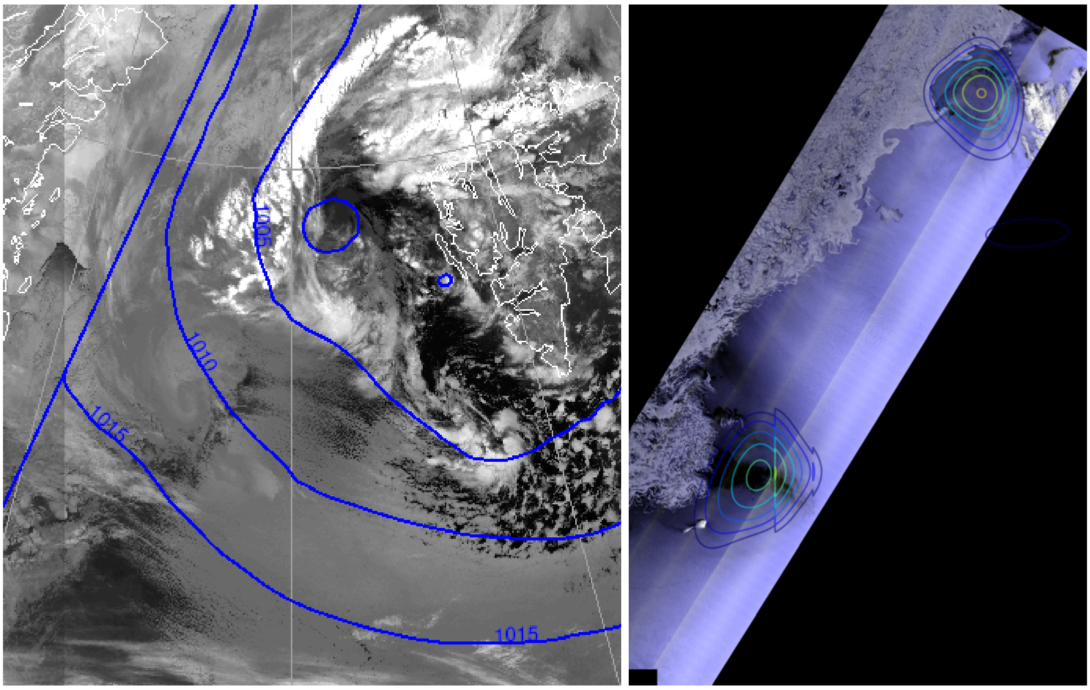

Figure 7. AVHRR with MSLP from AROME-Arctic showing a large synoptic low on the 1st of January (left), with a small low developing within the main center due west of Spitsbergen. The SAR image (right) with detection from the DA. The northwest tip of Spitsbergen is seen at the top of the swath.

The low was well seen in AVHRR images at 00 on the 1st, and also in the model as early as from the 0-run from the 30th of December 2023, with 55 hours lead time.

2.2 4 January

Here the DA gives a signal on an area of stratiform clouds and calm winds, but otherwise, there is no indication of development of a polar low or other vortex-like feature. This is an example where the DA reacts to a local minimum in the surface wind.

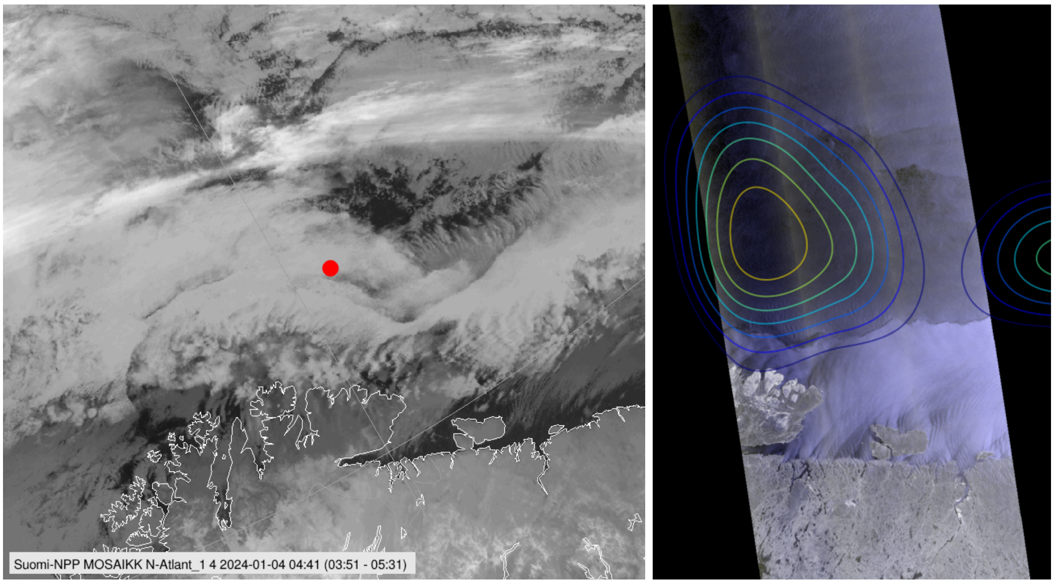

Figure 8. *AVHRR (left). The corresponding sar image (right) indicates a development at the position marked by the red spot in the satellite image.*

2.3 5 January

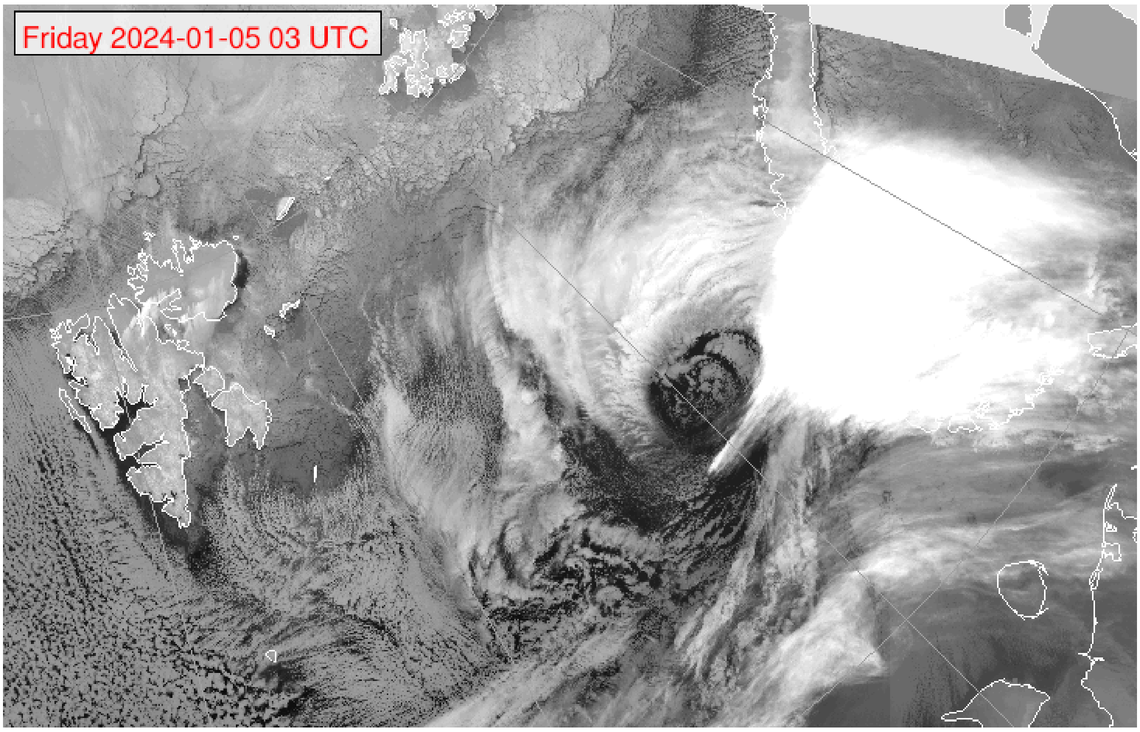

Figure 9. *The 5th of January low as seen in the AVHRR*

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

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A polar low or small synoptic low developed east of Bear Island (74°30'N, 31°30'N) at 18utc on Thursday the 4th, then moved eastwards and deepened and gradually took on the shape of a synoptic scale low. At 03utc on the 5th it was located west of Novaya Zemlya at 74°30'N 44°45'N. At this point it was seen by the SAR, and the DA gave a positive signal on the shear zone and wind minimum in the vicinity of the low center.

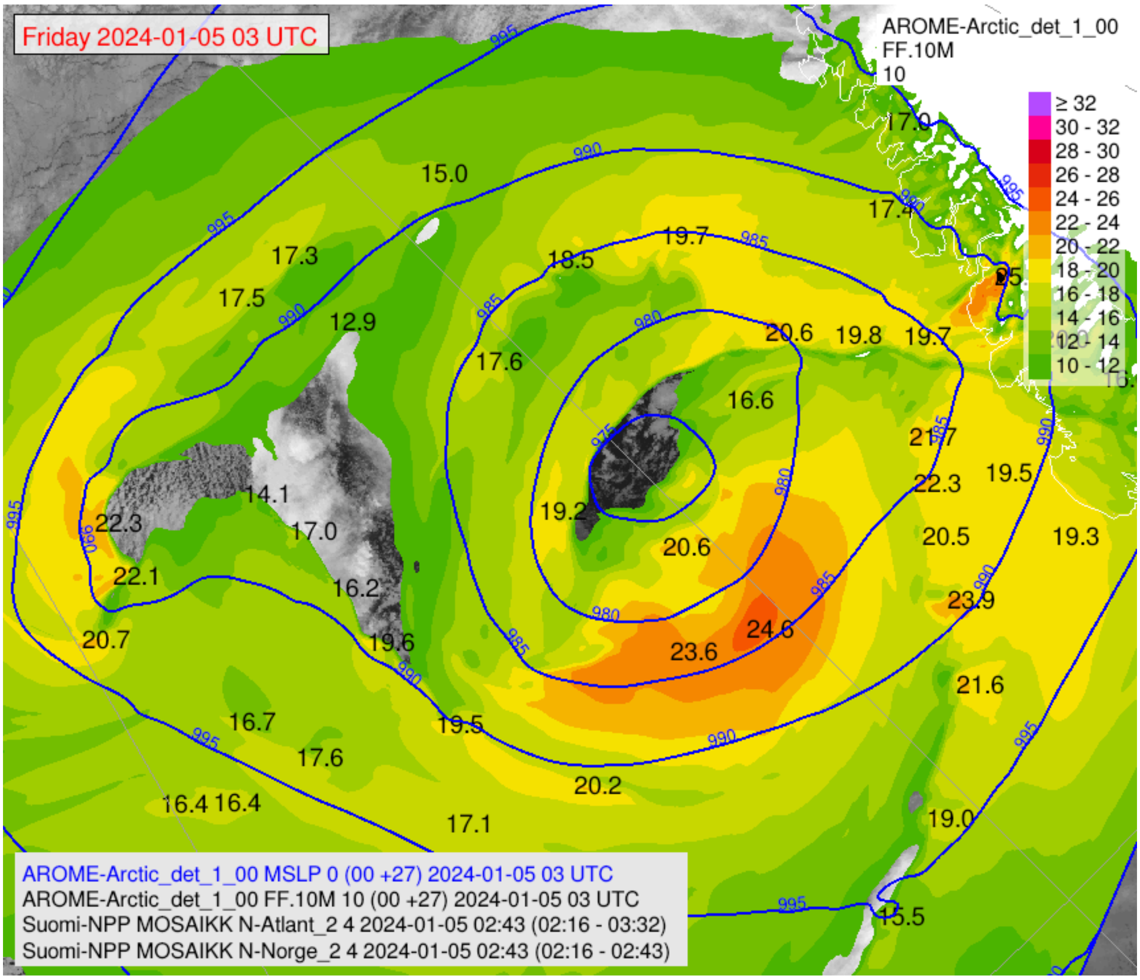

Figure 10. The forecasted surface wind from the 0-run from the 4th of January from AROME-Arctic. The northern sharp gradient in wind speed was well taken in the model.

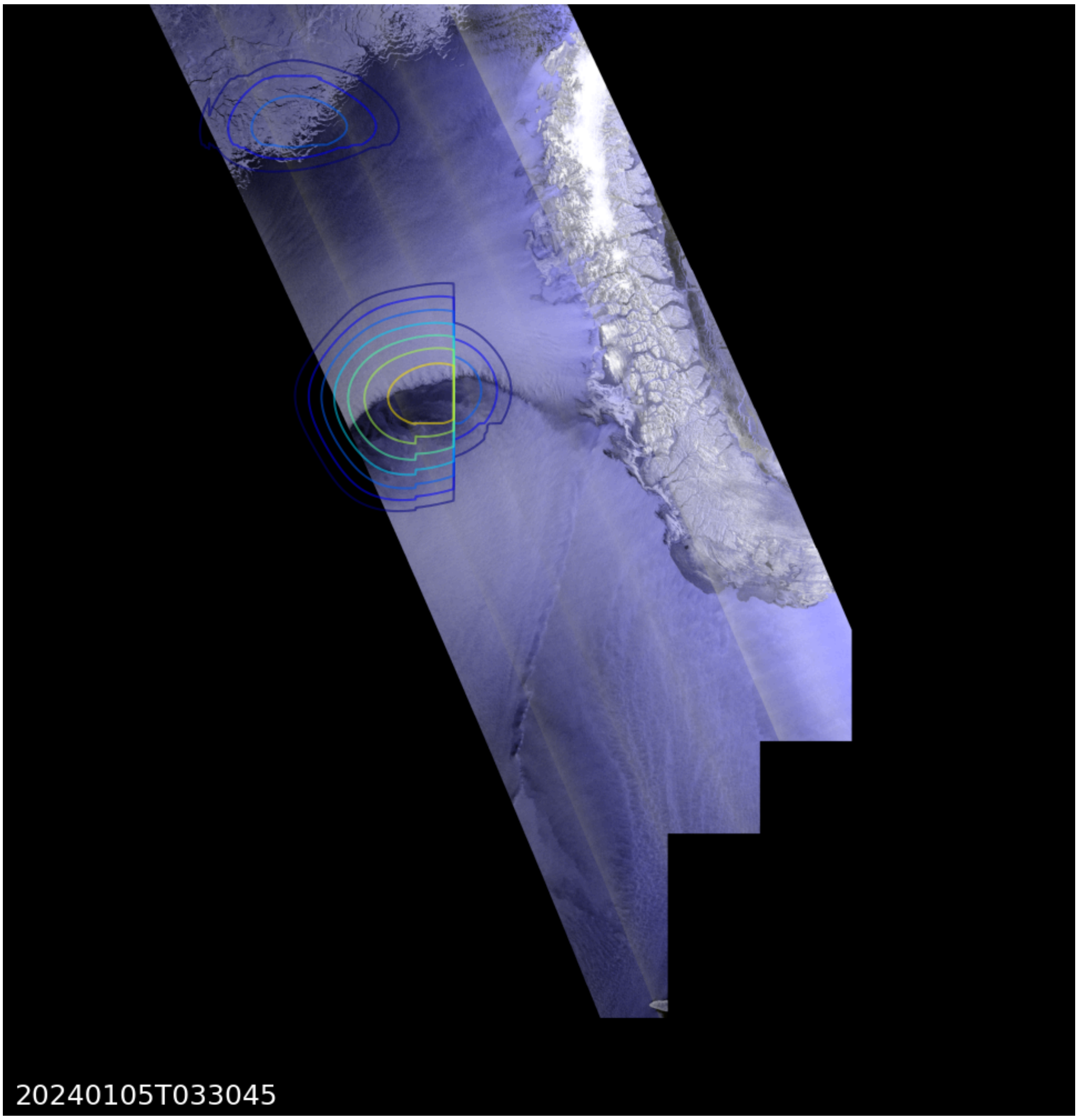

Figure 11. A rare SAR image of an actual polar low west of Novaya Zemlja on the 5 January at 03:30utc. The DA indicates a development along the shear zone in the low.

The low was well taken by the model, already in the 0-run from the 3rd it was well forecasted with 51 hours lead time, and was spot on from the 03-run from the 4th. Although there were no ASCAT winds at the time, the 04th-00 run gave realistic 10m winds at 25 m/s to the south of the low center and a realistic shear zone at the northern eyewall of the low. The SAR image captured this low at 03:30utc on the 5th when the low was at a mature stage. In the AVHRR imagery the low was seen at its incipient stage at 18utc on the 4th. Thus the SAR became available too late in the lifespan of the

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

www.met.no

low to have a significant impact for the forecast, but it can be used in a case-study to assess the details of the low and the models ability to forecast the associated winds.

2.4 10 January

On the 10 January a shallow low (meso circulation) with stratiform clouds with cloud top temperatures of -22 to -30°C formed west of Spitsbergen, close to the East-Greenland ice. The DA indicates two positions for polar lows. The northernmost is associated with a wind minima in the lee off the north coast of Spitsbergen. The southern spot seems to be randomly placed, and curiously not associated with the actual low center and shear zone approximately 200 km further north. There are few observations of wind at the time of the SAR image (07utc), but later observations from the ASCAT indicated 12 to 15 m/s surface winds around the center at 10utc.

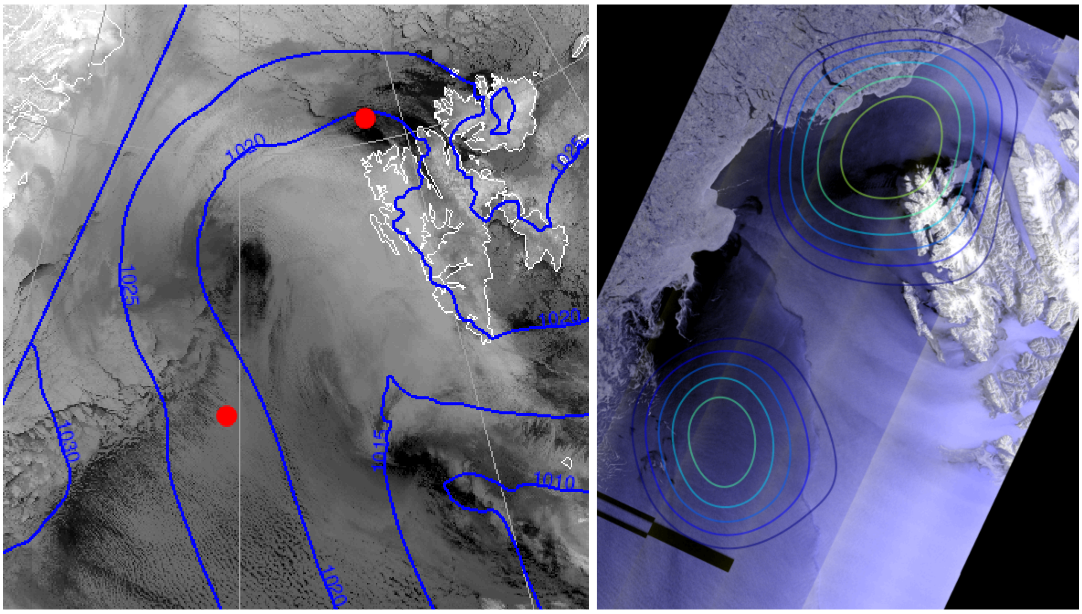

Figure 12. AVHRR satellite image and MSLP field from the AROME-Arctic (blue lines) from 10 January at 07utc (left) . The DA indicated polar lows at positions indicated by red spots. The center of the meso circulation is seen as a dark spot aproximately at 78N and 0E. SAR image (right) and the indicated possible locations for polar lows from the DA from the 10 January.

The meso circulation was seen developing in the AVHRR images at 03utc in the morning of the 10th, that is four hours prior to the SAR capture, and it . The low was well seen in the AROME-Arctic at max lead time, 66hours prior to the development, with correctly indicated 10m winds of 13 m/s west of the center. This is typical for the kind of forecasting setting for these types of weather. Typically developments are well seen in the NWP models more than 24 hours prior to development, and seen in the AVHRR images quite soon after initial development and then monitored via both sources on an hourly basis through its lifetime.

2.5 16 January

This is a rare case where organized flow at the surface is seen earlier in the SAR than what would be anticipated from the satellite image. The satellite image shows one mature polar low west of Novaya Zemlya, with the typical appearance of a vortex around a warm and clear eye. To the southwest of this there is a cluster of disorganized Cumulonimbus (Cb) clouds, with only a very weak hint of cyclonic circulation emerging (indicated in satellite image with a red spot). This is where the SAR shows quite smooth flow at the surface and a shear zone that the DA is able to detect.
One can debate whether an early indication like this would have been useful in an operational setting. Similar signatures of surface winds are common and could be associated with a plethora of weather types, so a signal such as this would probably not be enough to decisively identify an emerging polar low as a unique phenomenon.

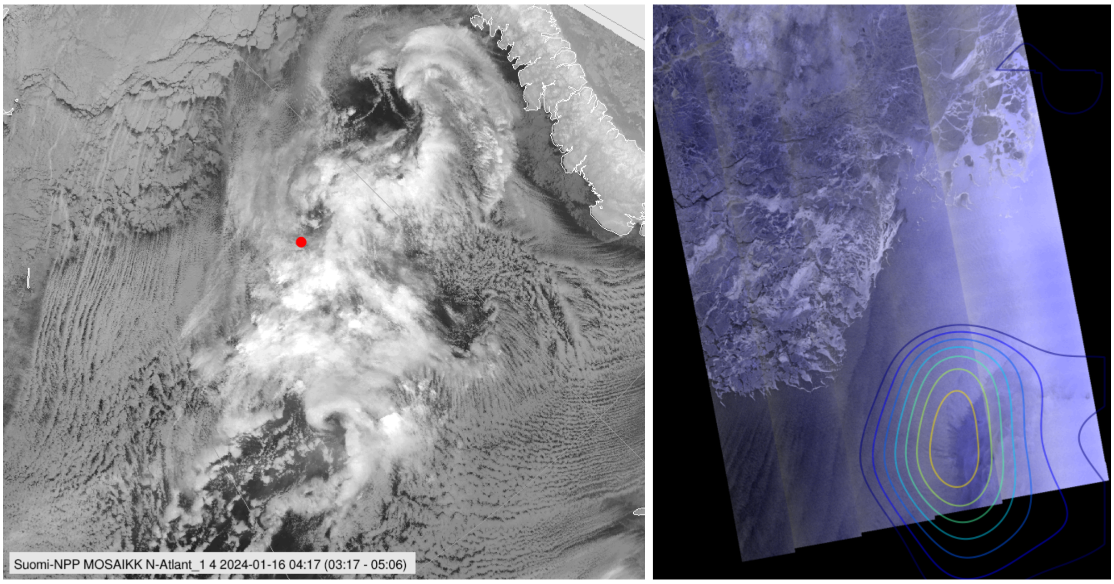

Figure 13. The situation on the 16th January. The red dot in the satellite image on the left indicated the position of the DA signal as seen in the right image.

2.6 18 January 15:22z

In the afternoon of the 18th a mesoscale circulation formed east of Bear Island. A mesoscale circulation is a shallow low with similar size as a polar low, but with lesser static instability and wind speed at the surface. The cloud tops are at a lower level than in a polar low, as can be seen from the gray coloration in the satellite images. This low

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

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later developed into a polar low further west of Bjørnøya, and was then detected by the MET tracking routine.

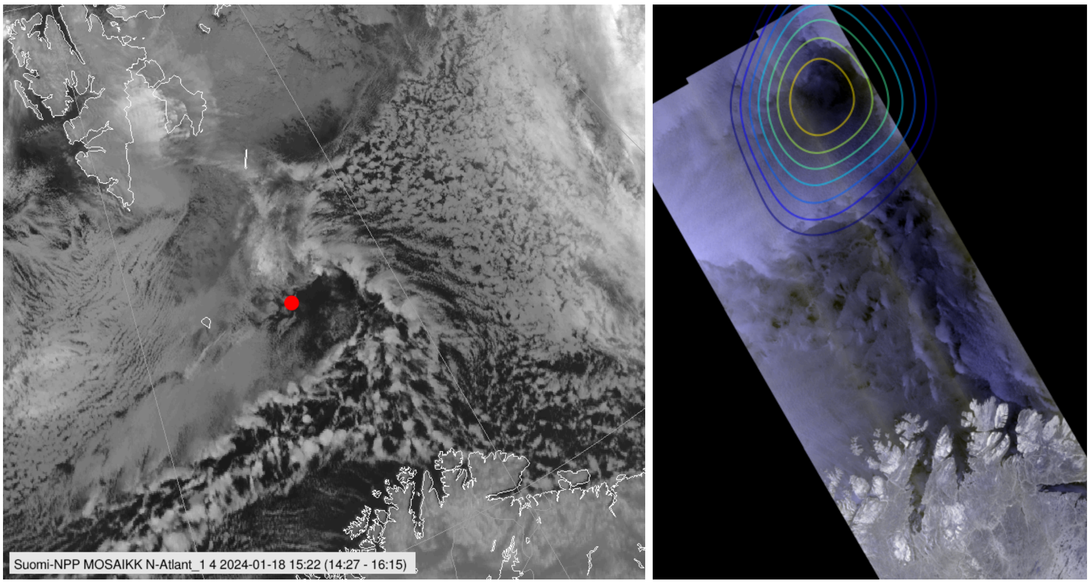

Figure 14. The case from the afternoon of 18 January. The wind was at most measured to 10m/s at Bjørnøya during this event.

The mesocirculation on the 18th was intersected by the SAR and detected by the DA, reacting to shear and a local wind minimum, even though the signal in the SAR was generally weaker than in e.g. the case of the 5th. The circulation was not detected by the tracking routine despite having sufficient instability, and with SST - T_{500} being 45℃. Probably either the wind speed, the diameter or the vorticity was below criteria to trigger the tracking routine in this case.

2.7 20 January

This is a correct placement of an actual polar low that developed on the 19th due west of Bjørnøya and was captured by the SAR and subsequently in the DA at 06:36utc in the morning on the 20th. The low was relatively small in size even for a polar low, and had a diameter of about 150 km. The visual appearance from the AVHRR indicated that it had started on its dissipating stage, with isolated convection emerging within the cloud band, which normally indicates a less organized flow at the surface. The SAR however shows that there was still a very smooth flow around the center. Other typical features can also be seen: The sharp gradient in wind is typical for a polar low. Further south there is deep open cell convection in northwesterly flow, with downdrafts giving strong outflow forwards of the cell and weak winds to the rear, and the typical footprint of convection in the SAR image. The DA correctly identifies the area of calm wind in the center of the low. This is an example where the SAR adds valuable information on the details in the wind pattern around the area affected by the polar low.

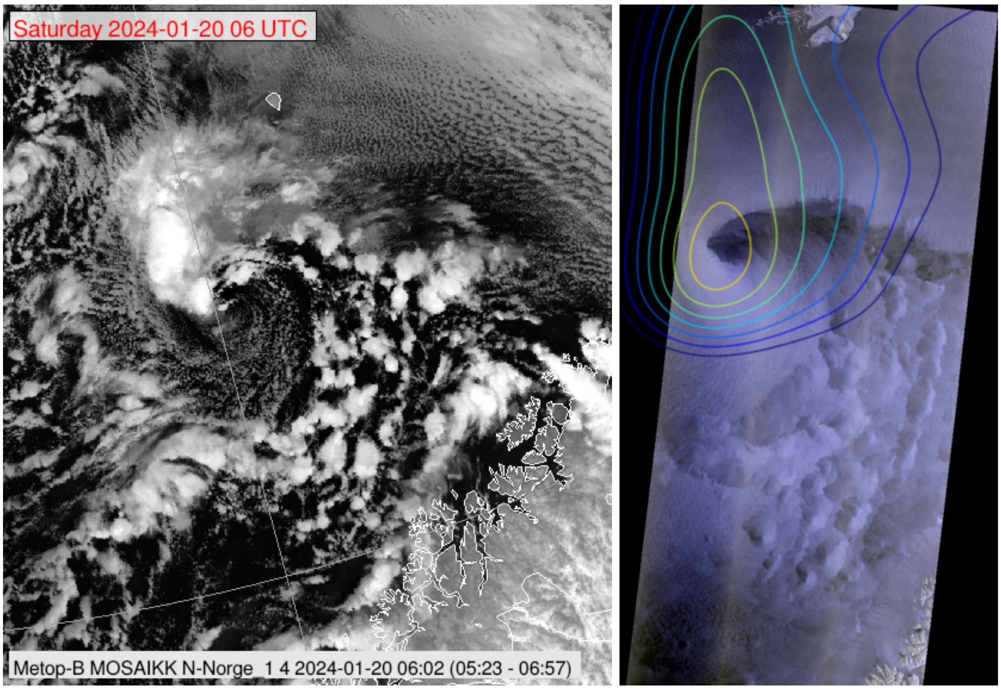

Figure 15. The polar low from the 20 January 2024 from the AVHRR (left) and SAR and DA (right)

This low was seen in the AROME-Arctic in the 0-run from the 18th, at 54 hours lead time with a spatial error at 05 utc on the 20th of about 80 km, and it was well forecast by the tracking routine. Also in the AVHRR the low was well captured throughout its lifetime. For practical purposes, the DA may not have had much impact on the forecasts, since it became available as the low was in its later stages.

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

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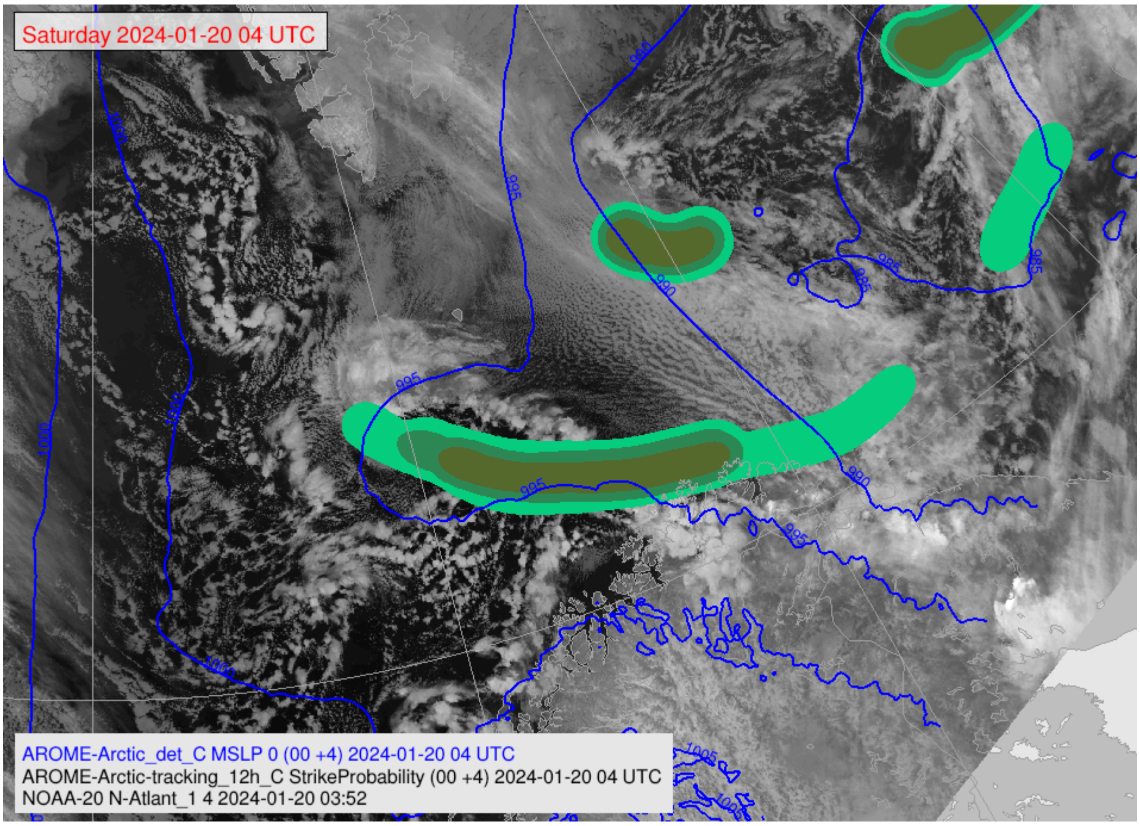

Figure 16. The low from the 20 January as forecasted by the AROME-Arctic tracking routine.

2.8 22 January

Here, the DA reacted to wind shear on a frontal zone that stretched from approximately 78°N 10°W, i.e. the central Norwegian Sea, and across Finnmark. The front was associated with a synoptic low over Iceland and strong southeasterly winds across the coast of Troms and Finnmark. The rather dramatic distribution of wind in the fjords of Finnmark can clearly be seen from the SAR. This is perhaps the best lesson to be learned from the SAR images, the very local variations in wind in coastal areas with complex terrain. In the area of the indicated position from the DA, there is a shear zone and some features that might resemble a vortex, but this is quite common in the context of a frontal zone. Otherwise, there is no vortex or polar low like feature in the area, so again, here is a false positive from the SAR DA.

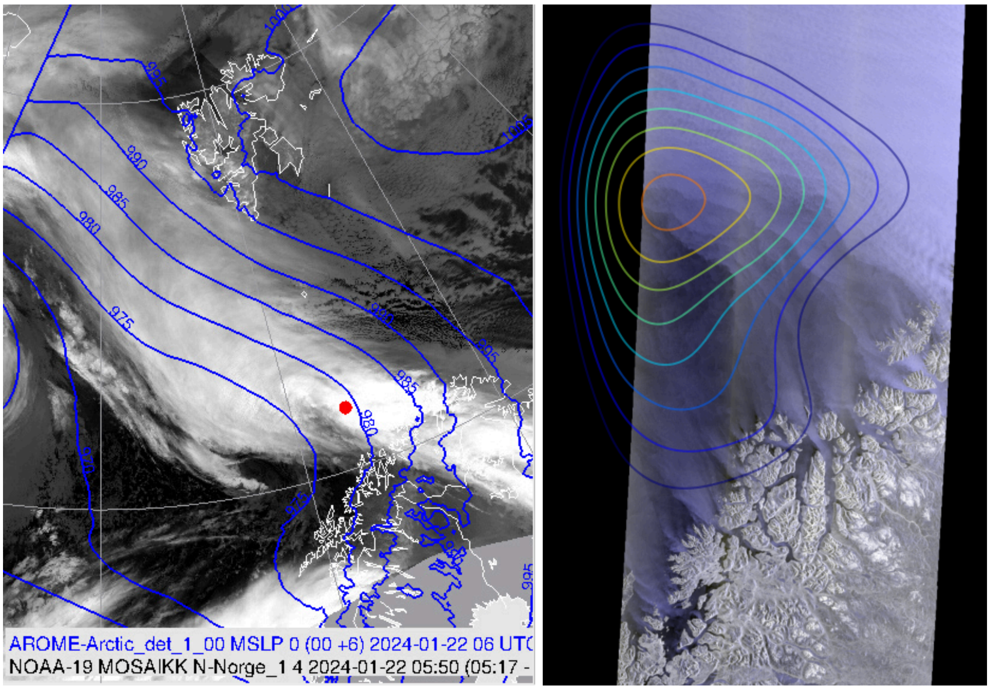

Figure 17. AVHRR image with MSLP from AROME-Arctic with the DA location (left) and the corresponding SAR image and DA location (right). Note the brighter areas indicating strong southeasterly winds out the fjords of Troms and Finnmark.

2.9 29 January

The DA gives a signal on a wide area of smooth but strong wind associated with a frontal zone in the area. This indication on a wind maximum was found in only two cases, the other was in an area of generally weaker winds. This kind of wind distribution would typically be found outside of the eyewall of the low on the windy side, but is of course also seen in any smooth wind field associated with e.g. a synoptic scale low.

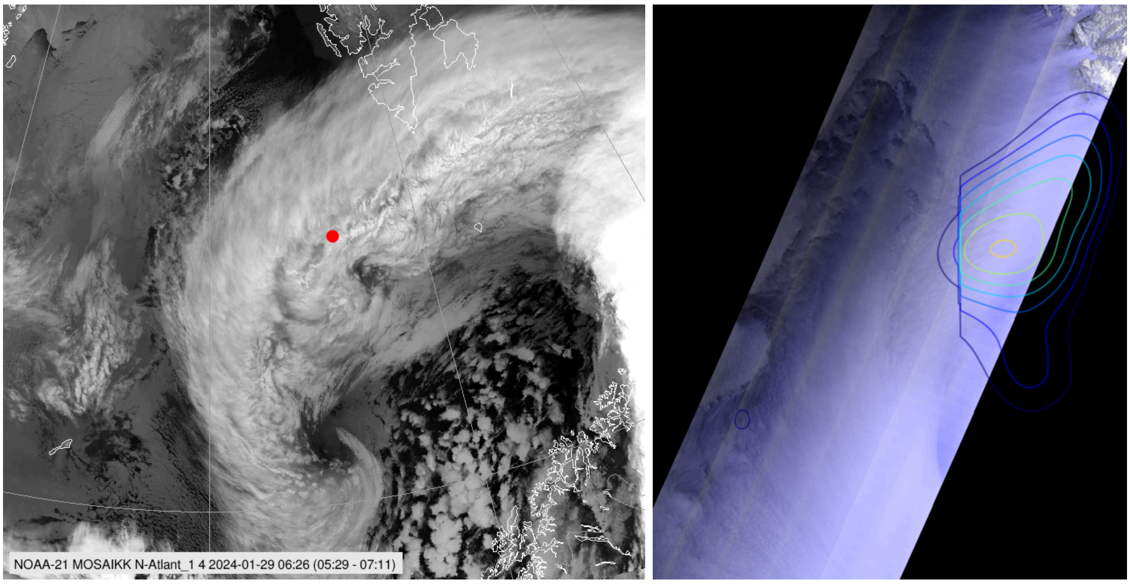

Figure 18. Satellite image and SAR with DA signal from the 29 January.

2.10 30 January

This was a synoptic scale storm on 30 January, locally called 'Little Ingunn' because it preceded the 'Ingunn' extreme weather event later that same week. The storm had hurricane force winds locally along the Finnmark coast. This was an interesting case where the DA was able to correctly recognize the center of the low, indicating on a local minimum.

For detecting polar lows however, this is another false positive in the effort of identifying polar low. Synoptic storms such as this one have quite different properties than polar lows, and they are treated differently in weather forecasting. The low was seen several days prior to development in the NWP data. It was well developed already at 12 UTC on the 29th, and was followed throughout its life span in the AVHRR as well as coastal radar and ASCAT observations. The DA could not have contributed noticeably to the useful collection of observational data to have an impact on the forecasting of this event.

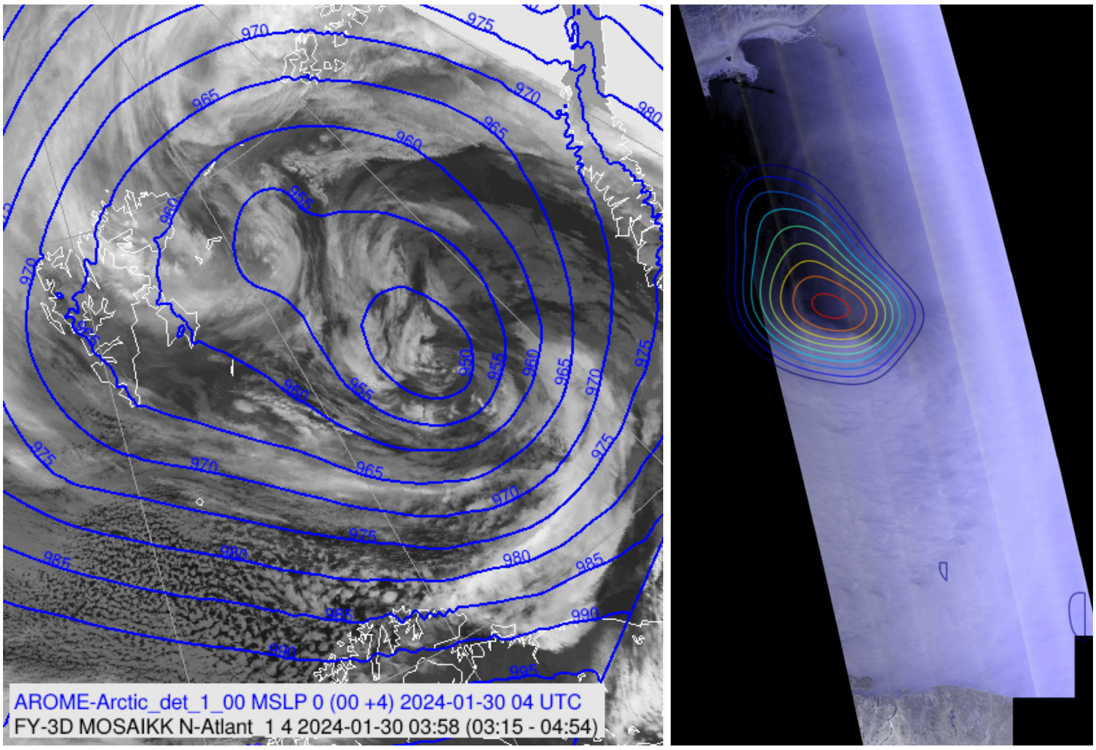

Figure 19. AVHRR image with MSLP field from AROME-Arctic (left) and the corresponding SAR image and DA location (right). The center of the low can be seen as a dark spot surrounded by a brighter smooth area. The north coast of the Kola peninsula can be seen in the lower part of the SAR image.

3 Some missed cases

There were several events with polar lows this month, but due to the limited coverage of Sentinel-1, many of them were missed by the SAR. This shows that one Sentinel-1 satellite is not enough for reliable polar low detection. Thankfully, things should improve next year (2025) with the launch of Sentinel-1C and NASA's NISAR. Plus, more SAR missions like ROSE-L are planned soon, which will help increase coverage.

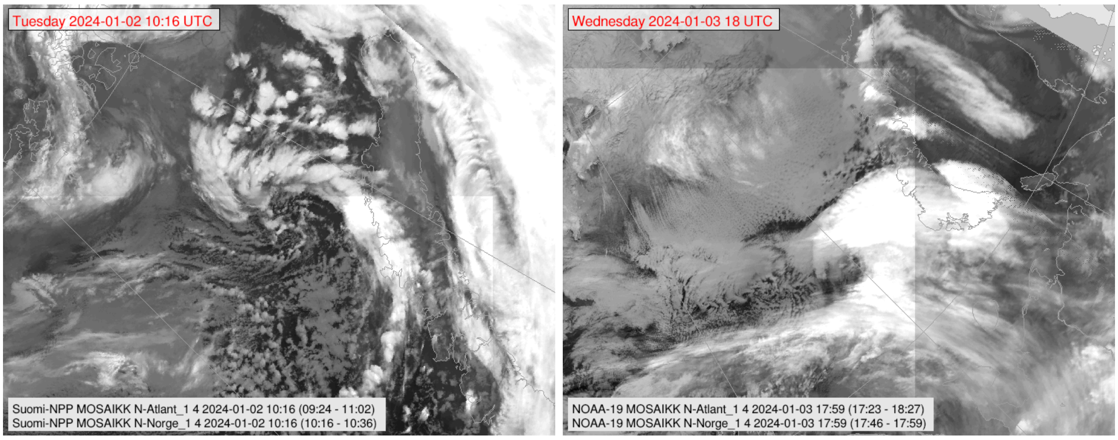

Figure 20. A polar low from 2nd January 2024 (left) in its dissipating stage with the typical pattern of individual Cb cells in the cloud bands, and a polar low on the 3rd January (right) in its mature stage, showing the smooth cirrus cloud formation around the center.

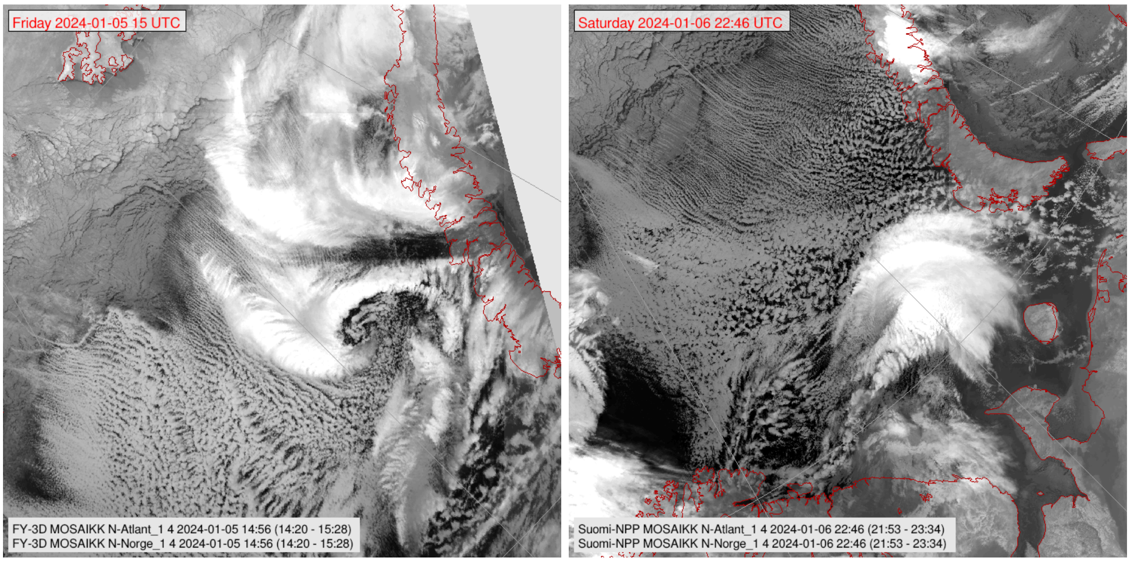

Figure 21. Polar lows from 5th January (left) and 6th January (right).

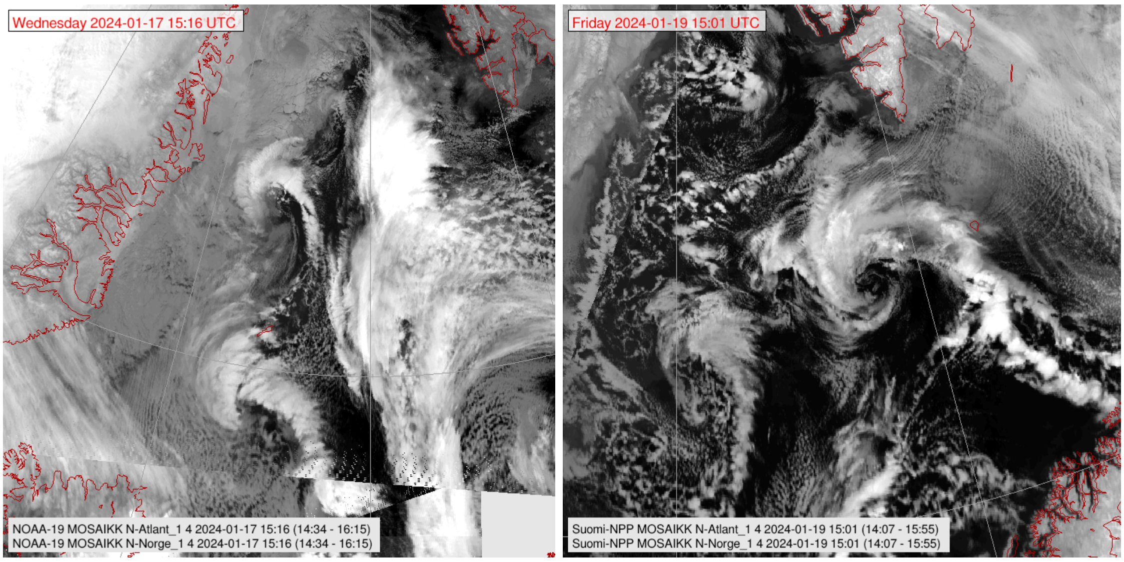

Figure 22. Polar lows from the 17th (left) and from the 19th (right) illustrate the plethora of forms and shapes of convective weather in the Arctic sea areas.

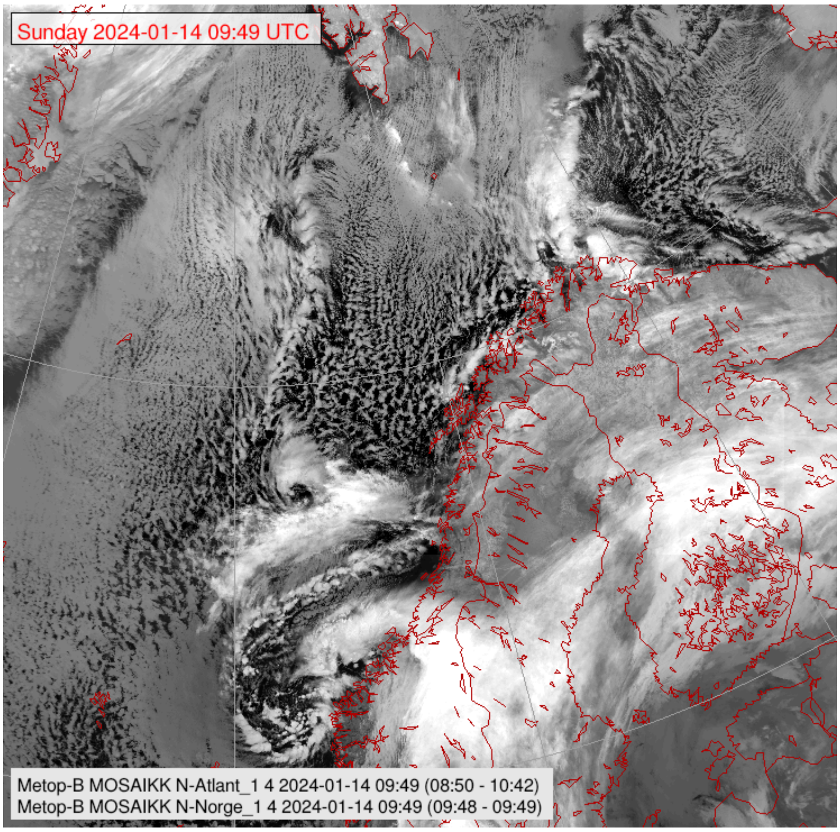

Figure 23. A mix of small polar lows, troughlines, convergence lines and Cb clusters from the 14th of January.

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

www.met.no

4 Discussion

Some key features in the cases in this report are listed in table 1:

Day of January 2024	**Classification / cloud type**	**Hit?**	**Trigger in SAR image**	**Tracked**
1	Synoptic low / polar low	Yes	Shear, local minimum	No
2	-	No	Ice edge, local minimum	No
3	Shallow low	No	Shear	No
4	Stratiform	No	Local minimum	No
5	Polar Low, dissipating stage	Yes	Shear, local min/max	Yes
8	Synoptic low/ frontal zone	No	Local minimum	No
9	Stratiform	No	Ice edge / local minimum	Off the domain
10	Stratiform	No	Shear, local minimum	No
12	Stratiform	No	Local minimum	No
13	Synoptic low/ frontal zone	No	Local minimum	No
16	Cb cluster	No	Shear	Partly
17	-	No	Shear, local minimum from terrain	No

17	Mixed convection	No	Local minimum	No
18	Frontal zone	No	Shear, local minimum	No
18	Mesoscale circulation	No	Shear, local minimum	No
20	Polar Low	Yes	Shear, local minimum	Yes
21	-	No	Local minimum	No
22	Frontal zone	No	Shear	No
23	Frontal zone,	No	Shear, ice edge	No
24	-	No	Local minimum	No
25	Frontal zone	No	Shear, local minimum	No
27	Frontal zone	No	Shear, local minimum	No
28	-	No	Shear, local maximum	No
29	Frontal zone	No	Maximum (?)	No
30	Synoptic low	No	Shear	No

Table 1. All the cases of January 2024 with a positive signal in the DA listed.

As can be seen from table 1, of the 25 cases considered, only three were correctly detected as polar lows, and the other 22 cases were false positives. There were at least 6 false negatives where polar lows were not detected at all, because there was no corresponding pass from the SAR intersecting the surface disturbance.

With a crude categorization, the algorithm is focusing on the following types of features:

1. Eight cases where the DA reacts to shear in the wind adjacent to a local wind minimum. The three cases of correctly placed polar lows fall into this category.
2. Seven cases where the DA reacts to local minima in the wind, without there being any other indication of a low center or wind shear.
3. Two cases of local wind maxima without shear in the vicinity.
4. Four cases where the DA reacts to wind shear, without an apparent wind minimum.
5. Four cases where the DA reacts to contrasts from the ice edge or in terrain induced wind flow.

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

www.met.no

Observing the different types of convective weather in the marine Arctic, from shallow closed cell convection, deeper open cell convection, convergence lines and troughs to the most convective polar lows, it is clear that a correct classification of polar lows is difficult, because there is a smooth transition from one state or type to the other. All these weather types have in common that they are associated with cold outbreaks. More stable weather types associated with warm air advection, e.g. frontal systems or large synoptic lows, have similar flow patterns. A common trait is that these weather types often give wind shear of various magnitudes at the surface, and as we have seen, currently the DA is not selective enough when such features are present.

Thus, for this detection algorithm to be successful, it must be supported by other indicators. The tracking algorithm currently in use at the MET Norway utilises the AROME-Arctic 2,5km NWP model, and uses vorticity, diameter of the low, 10m wind speed, and the temperature difference from sea surface to 500 hPa (a proxy for static instability) as criteria. Also there is a requirement that the event should last at least 6 hours. Since polar lows per definition forms well north of the polar front and the associated jet stream, the wind speed at 300 hPa has been suggested as an additional criteria (Stoll, 2022). As seen from the table above, the tracking routine gave a positive signal in only two of the 25 cases, and both of them were correctly associated with polar lows. The case on the 1st was not tracked due to the diameter exceeding the limit. If the DA had been mated to NWP using the same criteria, all the 24 cases of false positives would have been correctly eliminated, except for the case from 1st January. This was a large synoptic low that developed into a polar low at a later stage, and as such a difficult case to classify. In other words, with a coupling to other common criteria there would have been no more than two positive signals throughout all of January 2024 from the SAR-base DA.

5 Conclusion and recommendations

For a tool to be useful for the forecaster it needs to fulfil at least two important needs:

1. Ideally, it needs to detect most, if not all occurrences of a given weather phenomenon, and have an acceptably low number of false alarms.
2. It needs to be available, timely and relevant so that it is used on a regular basis. Infrequent use will render a tool irrelevant for the user.

Quite clearly the DA is not yet ready to take on the variety of different phenomena in the Arctic sea areas without being mated to other criteria, or given an improved training dataset or improved regularisation or reinforcement during the model training. The current count for polar low events including one or more fully developed polar lows from yr. 2000 till present is about 340 cases as recorded at MET Norway. It is an open question if this is enough to train the DA sufficiently for successful polar low detection. As of now, the DA only introduces more uncertainty since it gives far more false positives than actual hits, and hence does not meet the first criteria.

Timeliness and coverage is an issue. In almost all cases, the SAR image is acquired several hours later than the AVHRR images, which renders the DA output less useful for forecasting purposes. Also, the significant weather types; polar lows, troughs, squall lines and major frontal systems are seen in NWP well before both AVHRR images and SAR imagery are available. In this study, all the three polar lows detected were seen in the AROME-Arctic at more than 50 hours lead time. The current narrow coverage of the SAR images means that SAR data is generally not in use operationally at MET Norway. Rather, ASCAT or synoptic observations are the preferred source of in situ measurements of wind speed in the marine areas of the Arctic, and so, the SAR or DA does not meet the second requirement either. Therefore, considering the current state of the DA algorithm, it does not have a positive impact on the value chain in operational

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

www.met.no

forecasting, and so we do not recommend this routine to be implemented in the operational suite of tools at MET Norway for now.

On the other hand, SAR images are by virtue of the very high resolution a significant asset in case studies of surface wind in the marine Arctic. As such, they contribute significantly to the general knowledge on many weather types involving wind and complex flow patterns on a small scale.

In the period of January 2024 there were at least six events with polar lows, probably more, that were not intersected by the SAR. This highlights the fact that the coverage of SAR currently is too limited that it can be relied upon to catch all events. The use of AI in detecting polar lows will probably have a far greater potential for success if it is based on a multisensor approach, including AVHRR images, because of the greater coverage of these and higher timeliness and regularity of data.

If more SAR data were available, it could make a real difference in improving this tool. With a larger and more varied dataset, it would be possible to build a better training dataset, leading to a more reliable model that produces fewer false positives and can handle a wider range of cases. More data would also mean better coverage, allowing the model to catch more events and provide more useful results. Thankfully, things should improve next year (2025) with the launch of Sentinel-1C and NASA’s NISAR. Additionally, more SAR missions like ROSE-L are planned soon, which will help increase data availability and coverage. These developments are promising steps toward addressing the current limitations.

6 Future outlooks

Within the scope of the post-74 program - aimed to transition research into operational services - indeed, the technology remains underdeveloped, largely due to the limited spatial coverage of conventional SAR sensors, and limited number of satellites. Nonetheless, beyond the scope of post-74, and the resource requirements that an operational service needs to consider, further basic research and methodological development could be considered. Below are some venues highlighted.

As discussed, the limited number of polar low events captured by Sentinel-1 satellites constrains the development of a sufficiently large dataset for training deep learning models. However, approaches exist that could mitigate these challenges and enhance detection capabilities while reducing false alarms. Grahn and Bianchi (2022) expanded the training dataset to include a broader class of mesocyclones, increasing its size. However, this broad inclusion inadvertently caused the model to be overly sensitive, often misclassifying mesoscale wind phenomena as polar lows. Addressing this issue, *reinforcement learning from human feedback* could provide a promising solution. By iteratively validating model predictions with human input, the algorithm could adapt and improve its accuracy over time. This approach has already proven effective in advancing the capabilities of large language models, suggesting its viability for meteorological applications. In this context however, it would require the involvement of qualified personnel at MET Norway within the operational service. Given the above stated limitations in SAR coverage and the detection algorithm, this can not be expected to be prioritized at MET Norway.

Despite the current struggle with high false alarm rates, the deep learning model has shown its ability to leverage high-resolution surface wind features to infer weather phenomena in a new way. This raises an avenue for future exploration: integrating pixel-wise SAR wind retrieval with inter-pixel textural wind pattern analysis. While

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

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pixel-wise SAR wind retrieval offers detailed insights into wind speeds, it lacks directional information. On the other hand, the polar low detector explored in this report relies on wind pattern textures but does not utilize individual pixel-level data. A hybrid approach that combines these two methodologies could infer wind direction while maintaining high-resolution data accuracy. Notably, this remains an underexplored area as far as we know, presenting a potential research opportunity.

In conclusion, addressing the current algorithmic and data limitations requires both methodological refinement and broader SAR data coverage. Upcoming advancements, such as the launch of Sentinel-1C and other SAR missions like NASA's NISAR and ROSE-L, are expected to substantially enhance data availability and coverage. These developments, combined with innovative modeling techniques, could pave the way for more robust and reliable polar low detection systems. This would however be better suited in a research-oriented project rather than one aiming at direct operationalisation, under post-74 funding.

7 Appendix

In this section we present the cases where the SAR DA gave a signal, and that are not mentioned in chapter 2.

7.1 2 January

A large synoptic low was situated over the Frans Josefs land islands. Here the SAR DA gives a signal at the ice edge. The ice sheet appears bright in the image, reminiscent of an area with strong wind. There is a local minimum in the wind just south of the ice edge, and the difference in brightness is seen as a shear zone by the DA. From the satellite image there is no sign of development of a vortex in the area.

In the southwestern part of the SAR image there is another signal associated with a local minimum in the northerly wind west of the main low, but again this was not associated with any type of vortex.

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

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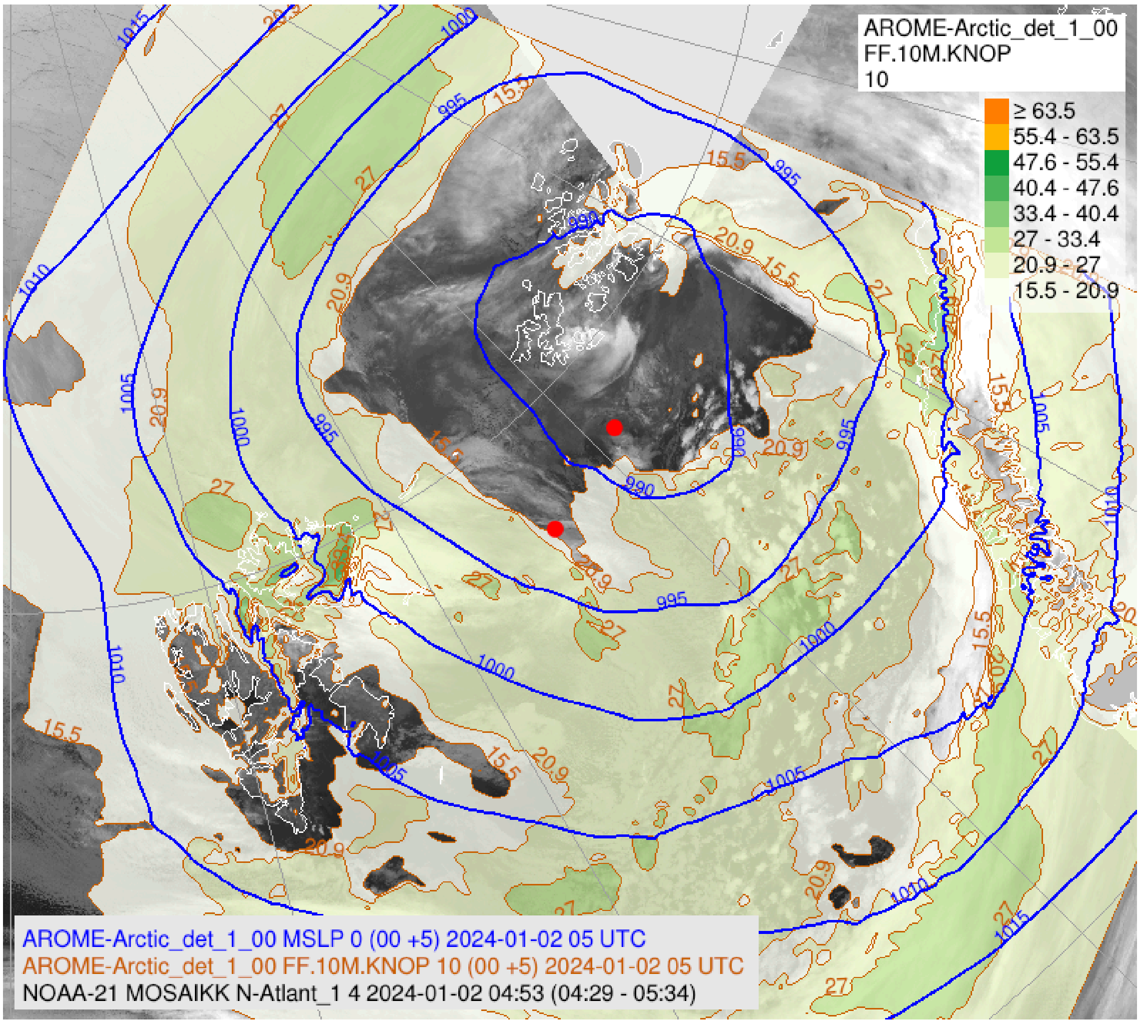

Figure 24. The situation on the 2nd January, as seen in the MSLP (blue lines) and wind (green shading). The position of the signals from the Da is marked as red spots.

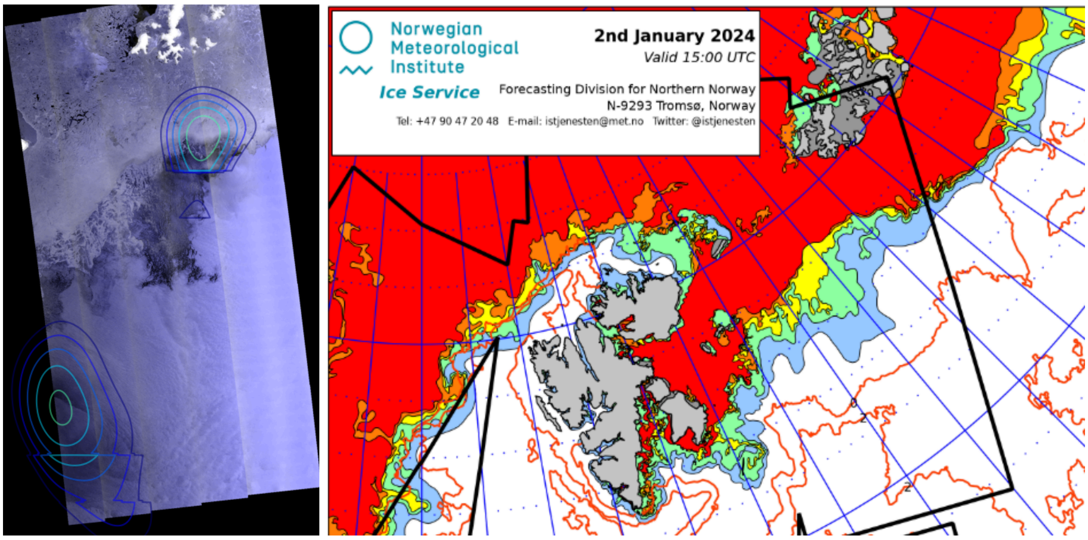

Figure 25. The SAR image with the DA signal (left) with the Ice-chart (right) from MET Norway from the 2nd January. The red shading corresponds to very close drift ice. Light blue shading is open water. Brown lines are SST.

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

www.met.no

7.2 3 January

This was an example that the DA so far is not discriminating enough when it comes to wind speed, and gives an indication despite the surface wind being only in the order of 10-12 m/s. Events with such wind speeds are not forecasted beyond general forecasts for the area at large. This low was not visible in the MSLP fields from the AROME-Arctic.

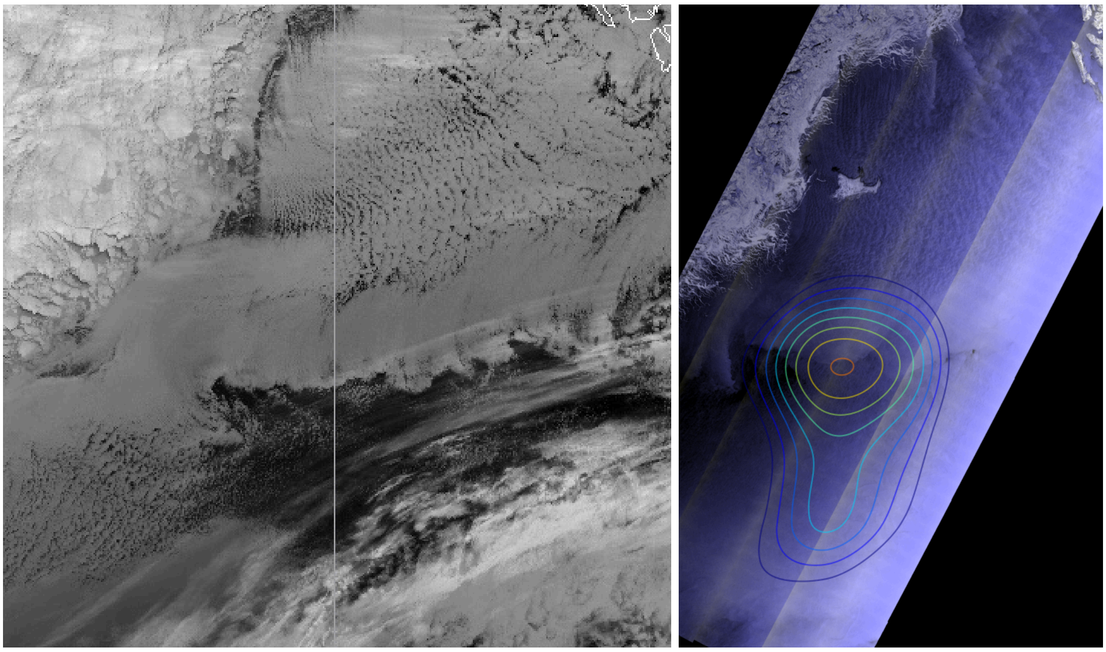

Figure 26. AVHRR image (left) showing a meso circulation close to the Greenland ice sheet with a shallow arctic front extending eastwards. The SAR image (right) with the DA gives a signal quite close to the vortex, but not in the actual center.

7.3 8 January

On the 8th there was a large but shallow low pressure system situated southwest of Spitsbergen with a front between the low center and Spitsbergen. The DA picks up a weak shear along this frontal zone, but there was no vortex or polar low in this area.

There was some convective activity in the cold air mass to the south of the center, but the depth or intensity of this can not be established from NWP data, and it is not associated with the indicated spot from the DA.

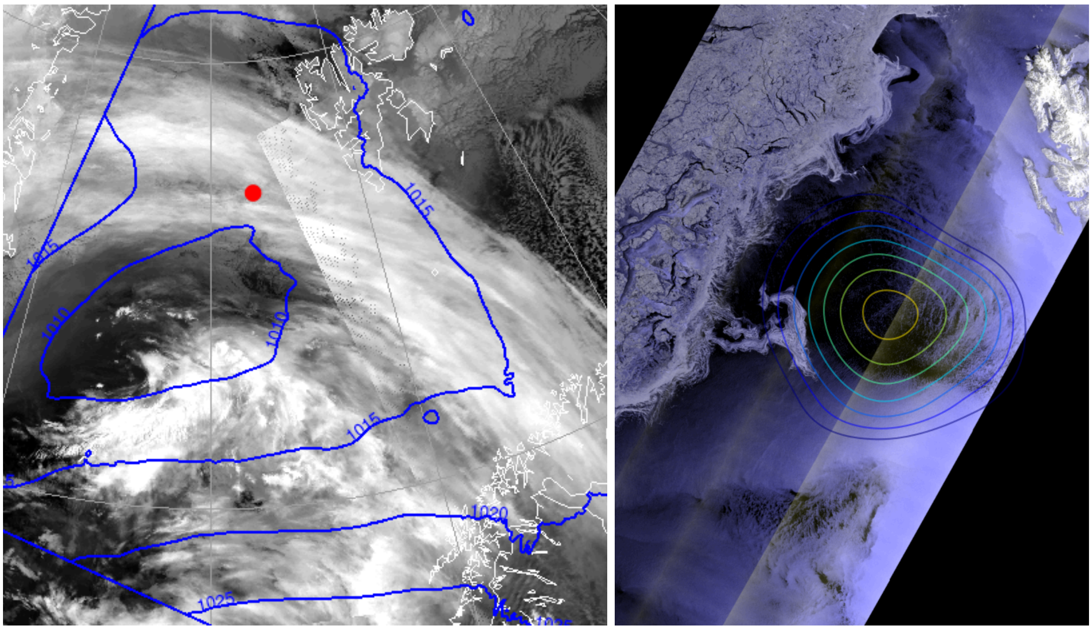

Figure 27. AVHRR satellite picture (left) of the low and associated front system southwest of Spitsbergen on 8 January 2024 at 07utc. The approximate position of the maximum from the DA is indicated with a red dot. MSLP is shown in blue lines. Right image shows the corresponding SAR image and signal from the DA.

7.4 9 January

A case similar to the one on the 2nd. The satellite image on the left in figure 28 suggested a polar low-like feature close to the Greenland coast. This was outside the frame for the SAR, and the DA instead gave a false positive signal on the ice edge and the bright-dark contrast here.

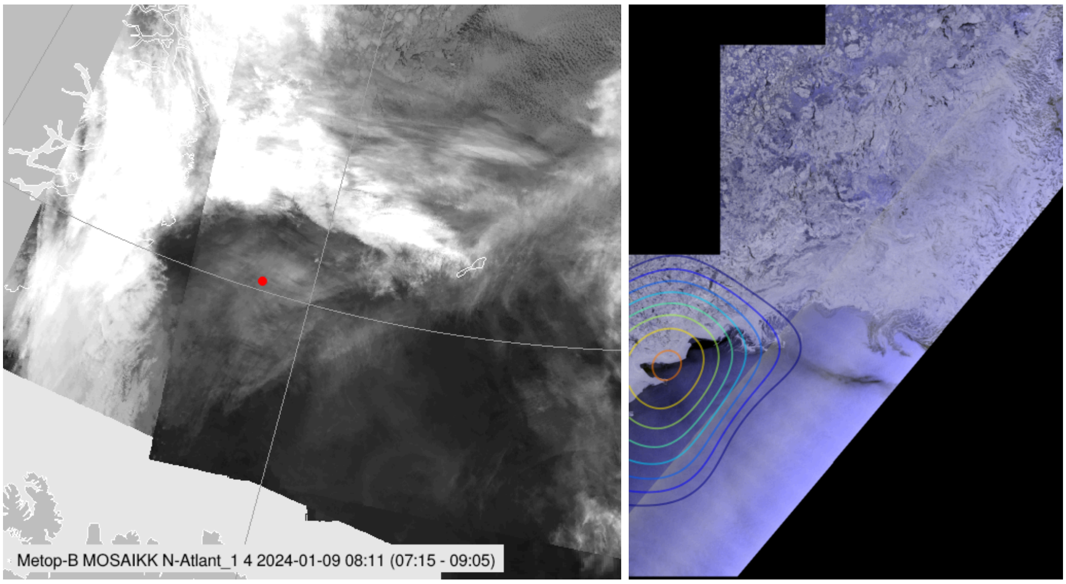

Figure 28. The situation on the 9th January. The AVHRR on the left with the red spot for the position of the SAR DA signal, as seen in the right image.

7.5 12 January

This day saw a synoptic low system east of Iceland, and a weaker system further north at approximately 73°N 15°W with a frontal zone extending southeast towards the coast of Nordland. To the north of this frontal zone were mixed stratiform clouds and weak southeasterly winds. The DA indicates a development just west of the southern part of Spitsbergen. This is probably associated with an area of calm and variable winds off the coast of Spitsbergen, and as such not associated with any actual point of deeper convection. This shows that the DA probably is acting on a too limited training set to be able to discern actual developments.

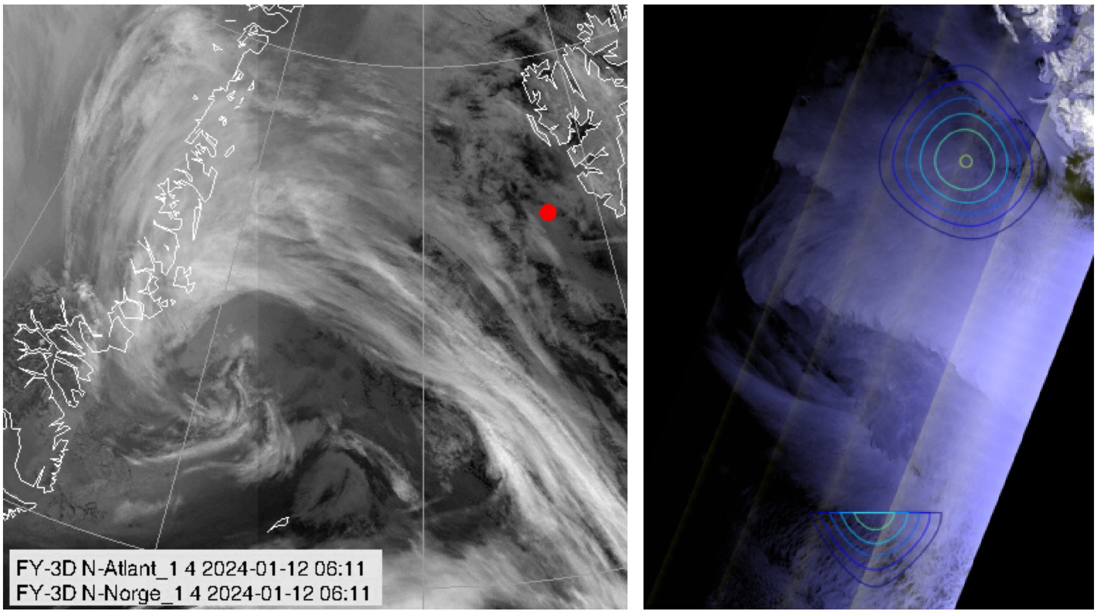

Figure 29. Satellite image (left) and SAR image with indications from the algorithm (right) from 12 January. The linear shear zone seen in the middle of the SAR image corresponds to the front seen in the middle of the satellite image.

7.6 13 January

A synoptic low formed northeast of Iceland on the 12th of January and moved eastwards towards the coast of Nordland on the 13th of January. It was detected by the SAR at 05utc on the 13th and indicated as a polar low by the algorithm based on a shear zone in the wind field north of the main center. By the forecaster on duty the low was classified as a large synoptic low based on its formation process, its size and general appearance with large frontal zones and embedded in the main polar front, and forecasted accordingly.

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

www.met.no

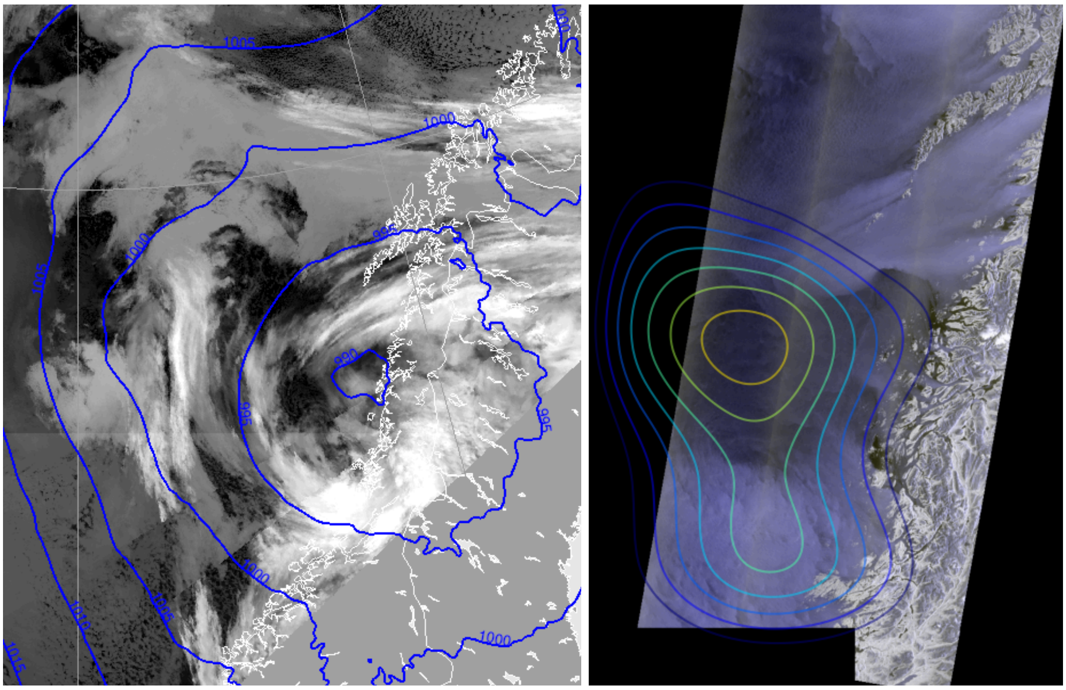

Figure 30. A large synoptic low as seen in the AVHRR (left) at 05utc on the 13th of January, with MSLP from the AROME-Arctic. The right image shows the corresponding SAR image with the DA location.

The low was seen several days ahead of the situation in the EC-HIRES forecasts, and seen throughout the 12th and the 13th in the AVHRR images.

7.7 17 January

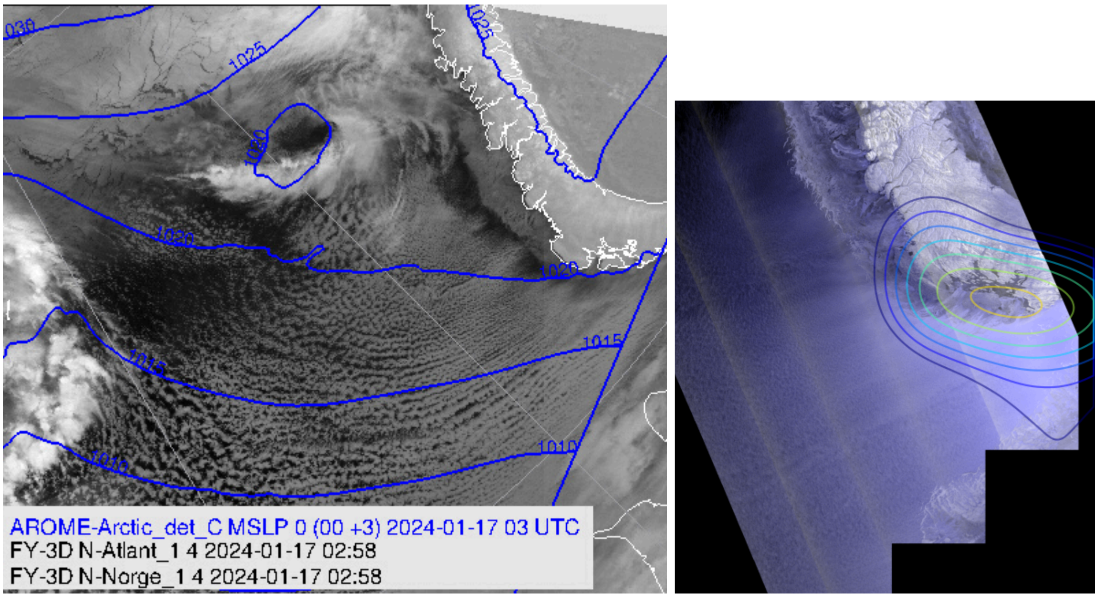

Figure 31. AVHRR satellite image with MSLP from the AROME-Arctic model (left) and SAR image with possible indication from the DA (rigth) from 17 January.

This is another example of false detection by the algorithm from a shear zone associated with terrain, and not from an actual vortex. In this case strong easterly flow off the south tip of Novaya Zemlya creates a lee wake and a shear between this and the undisturbed flow further south. Interestingly, there were several actual developments that day, for example one actual polar low seen in top center in the satellite image in figure 32 that was missed since it was outside the frame of the SAR.

7.8 17 January

Several developments took place on the 17th. To the southwest of Spitsbergen, at 73°30'N and 30°W, a small polar low was forming in the early morning hours. The SAR captured parts of this at 03utc, and the DA indicated two locations. The northernmost of these is associated with a minor vortex to the northeast of the polar low center in an area of wind minima, but with some vorticity. The DA also indicated on a spot further southwest along the cloudband south of the center. Curiously the routine did not capture the actual low or any of the more distinct features in the shear zone associated with it, which indicates that the algorithm is not trained sufficiently to focus on the right type of patterns that is indicative of a polar low.

This is however an example of the fine details that can be seen in the SAR images. Here some fine eddies can be seen along the shear zone radiating out from the center of the low in the southwestern part of the image. These kinds of details can not be observed with any other instrument than the SAR, and only sub-km models are so far able to reproduce these details realistically.

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

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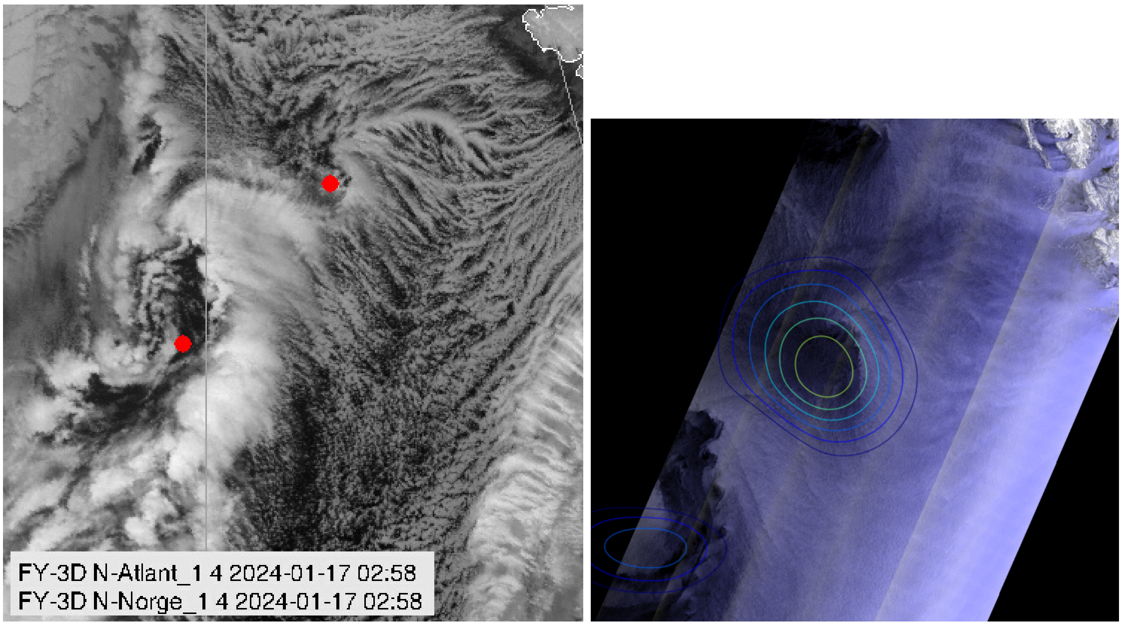

Figure 32. Satellite image (left) shows a cold air outbreak on the 17 January 03utc. A polar low is seen in the western half of the image with a dark, dry eye extending southwards from the center. The approximate locations indicated in the SAR image (right) are marked with red spots.

The emerging polar low was seen in the AVHRR already at 18utc on the 16 January, and the associated trough in the MSLP was seen in AROME-Arctic the 0-run from the 15 January, with 51 hours lead time. The actual low centras was indicated in the tracking routine from AROME-Arctic, so if the DA had been using similar criteria, this case would probably have passed those.

7.9 18 January

Here the SAR DA gives a signal on windshear in a frontal zone well east of the main low, which was outside the frame of the SAR. Although the pattern in the SAR looks like there might be a circulation there, neither the analysis or satellite imagery supports that there is any type of vortex here.

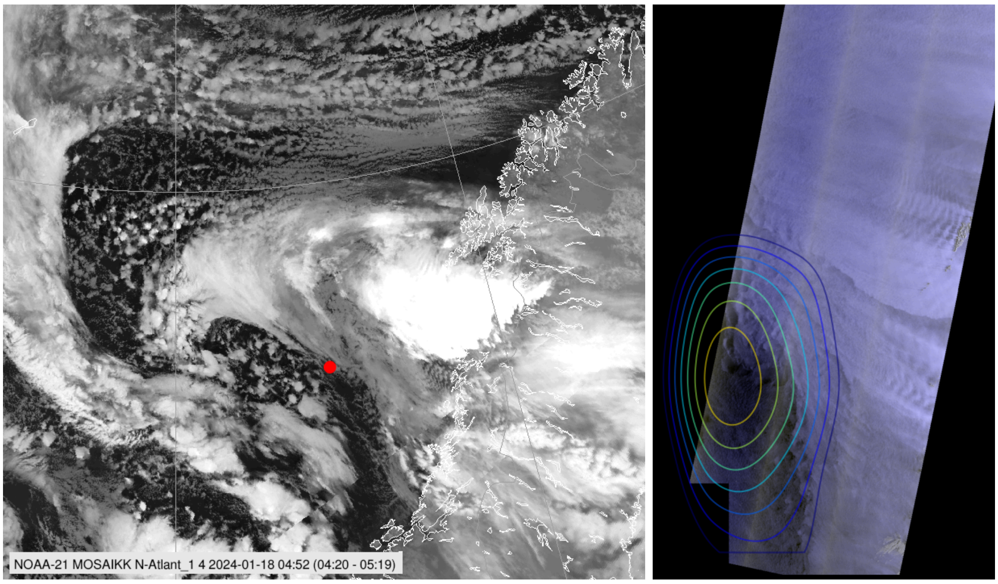

Figure 33. The situation at 04:52z on the 18th January. The position of the SAR DA is indicated with the red dot in the satellite image.

7.10 21 January

There were several small troughs and vortexes in the Barents Sea on this day. The SAR DA focuses on a minima between two small troughs, one north of Nordkinn, the other in the central Barents Sea, since this area gave the strongest signal within the frame of the SAR. The case highlights the limitation of the current coverage of the SAR.

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

www.met.no

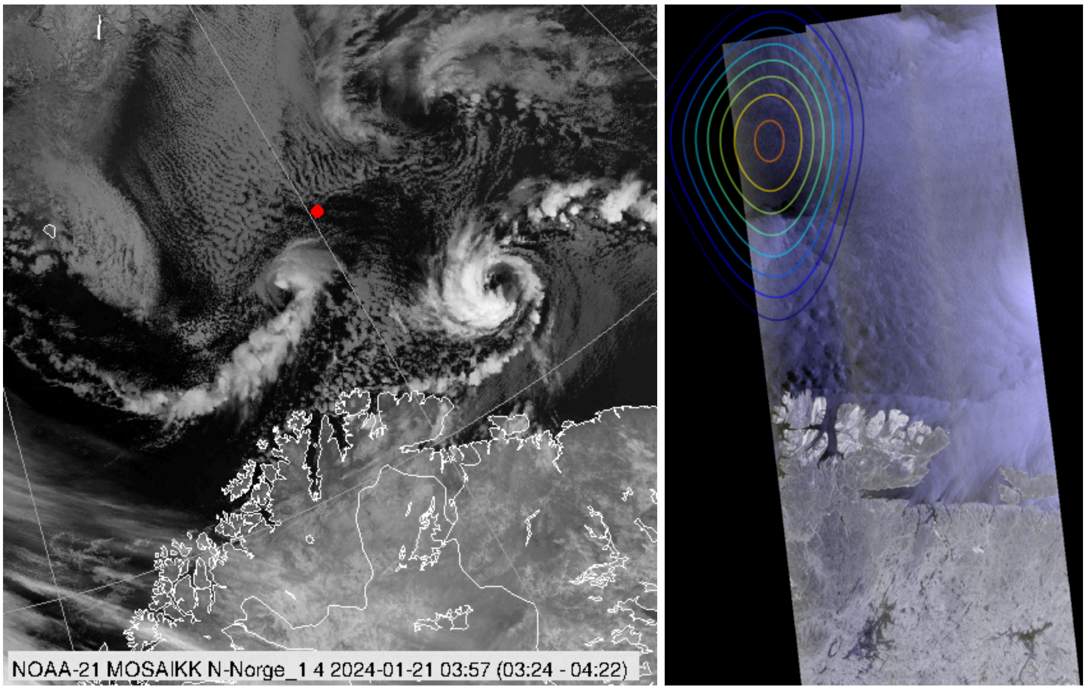

Figure 34. AVHRR image (left) and SAR image with DA position (right) from 21st January. The DA position is indicated in the AVHRR with the red dot. The center of the small polar low at 71 20'N and 34 50'E is just outside the SAR image, but the strong northerly winds can be seen in the right part of the image.

7.11 23 January

A large synoptic low situated at the ice edge between Greenland east coast and Spitsbergen. A frontal zone extended southeast and southwards to Troms and Finnmark. The strongest wind was found north of the main occluded section of the front, between Ny Ålesund on Spitsbergen and the ice edge of Greenland.

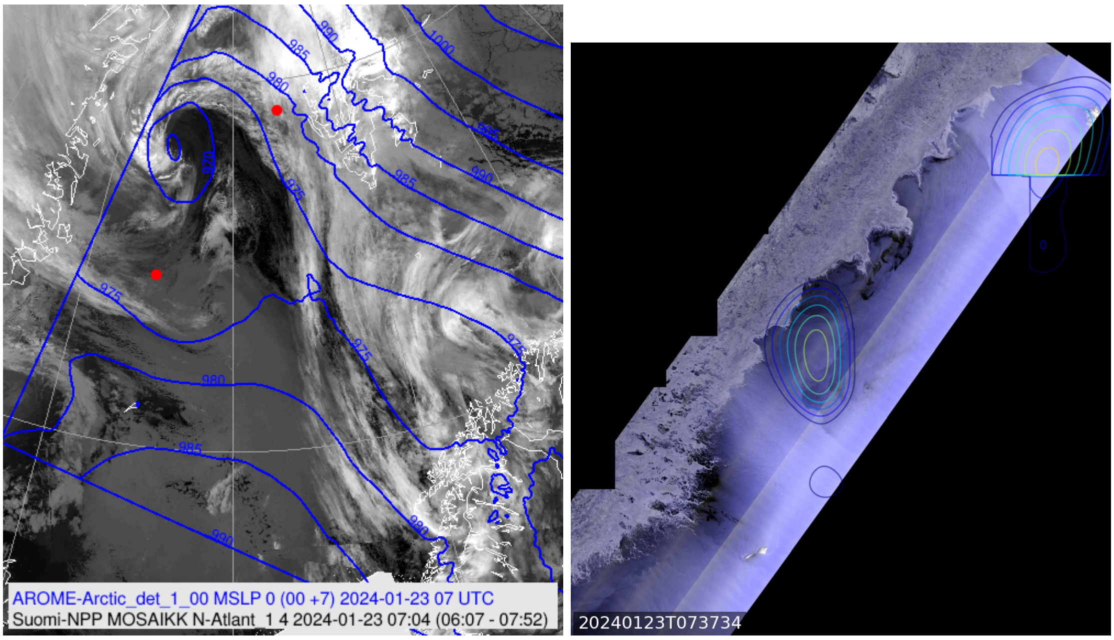

Figure 35. AVHRR image of the low from 23 January 2024 07utc (left), indicated by isolines for MSLP (blue lines). The approximate position of the indications from the DA is shown as red spots. The right image shows the SAR image and the indicated developments from the DA. The details in the left part of the image is sea-ice off the coast of Greenland. The Jan Mayen island can be seen in the lower part of the image.

In this case there was a false positive by the DA associated by wind shear in the frontal zones, but not related to any convective or polar low-like development.

7.12 24 January

On this day there was a large synoptic low north of Novaya Zemlya giving southeasterly winds 12 to 15 m/s over a large area northeast of Bjørnøya. There was a high pressure area over northern Scandinavia with northwesterly winds in the Norwegian Sea of 5 to 10 m/s. These two air masses were divided by a large frontal zone that stretched from Spitsbergen and into the southern Barents sea, with an area of calm winds, and shear both to the north and south of this. The SAR DA gives an indication in the area of the wind minimum, maybe because it appears similar to the center of a low. Again, this is a false positive as there were no polar low or other kinds of vortex in the area.

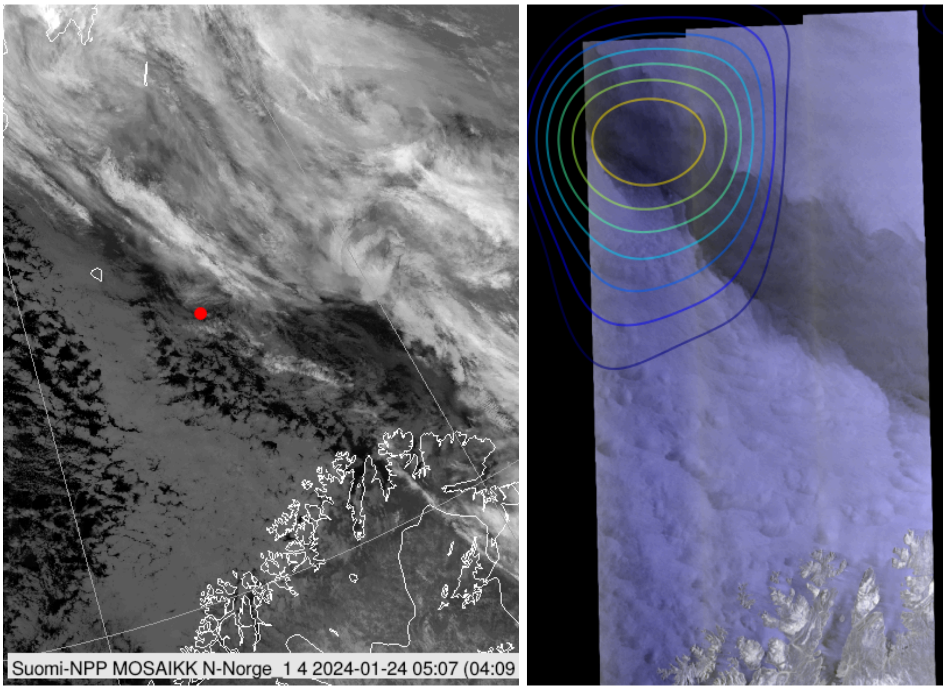

Figure 36. AVHRR (left) from the 24th January and the corresponding SAR with the DA location (right). The location of the SAR DA is indicated as a red dot in the AVHRR image.

7.13 25 January

Here is another example of the DA giving a signal from a weak wind shear and a local wind minimum associated with a frontal system, this time over the central Barent sea. As can be seen from the satellite image, there is only stratiform cloudiness in the area, and no polar low feature emerging, so a false positive in this case.

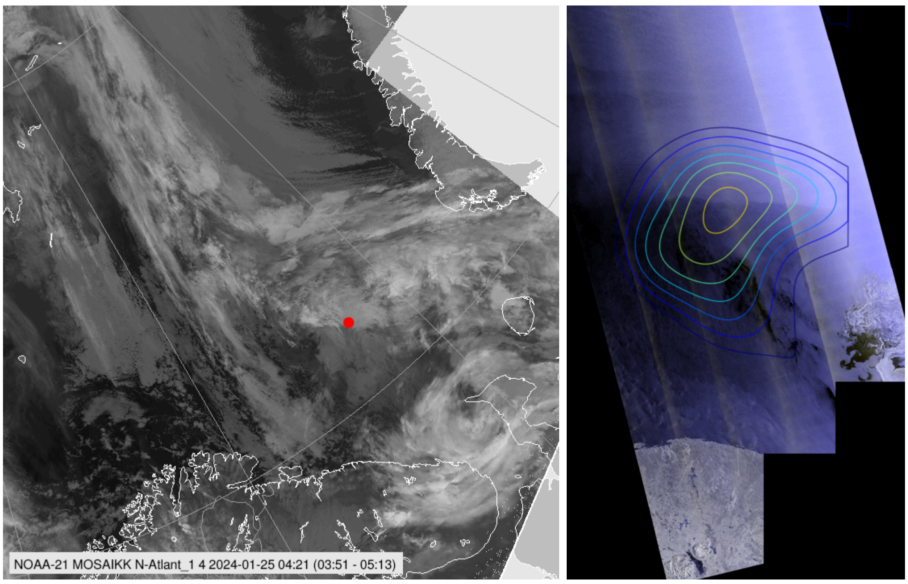

Figure 37. Satellite image and SAR with DA signal from 25 January.

7.14 27 January

This day there was a large synoptic low just west of Jan Mayen with a front system extending southeast towards West-Finnmark. A deep cold air outbreak was in progress to the south of the low, with a mix of convective phenomena, both clusters of Cumulonimus clouds (deep showers), troughs and polar lows. To the northeast of the low there were stratiform clouds in southerly flow, and the front separated these two air masses. The SAR has a too small extent in this case to see the convective action to the south, so the DA focuses on an area of weaker winds with shear on the northern side that is located within the frontal zone. The pattern in the SAR may be reminiscent of a low center but, but in this case is just one of many shear zones that can be found in frontal zones over sea.

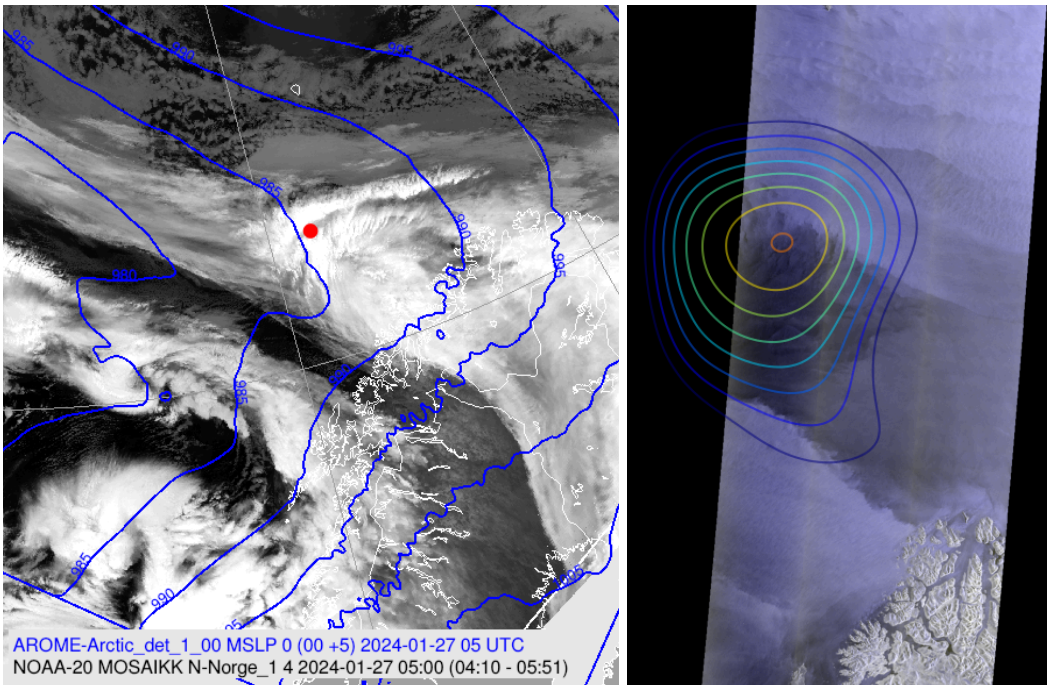

Figure 38. AVHRR from the 27th January with MSLP from the AROME-Arctic (left) and the corresponding SAR image with DA location (right). The location from the DA is indicated in the AVHRR as a red dot.

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

www.met.no

7.15 28 January

Three lows oriented from the Greenland east coast to the central Barents sea, along the 76°N latitude, with an area of stronger westerly winds on the south side of the low centras. The DA detected a possible center just west of the south tip of Spitsbergen, associated with a local shear in the easterly winds here.

This is another false positive associated with a local wind maxima. It is strange that the DA focuses on the relatively weak signal in this area, whereas the much stronger shear to the westerly winds in the southern parts do pass undetected. This is probably down to the training algorithms having been trained on a too low number of cases with insufficient diversity, and following an incomplete description of the appearance of polar lows.

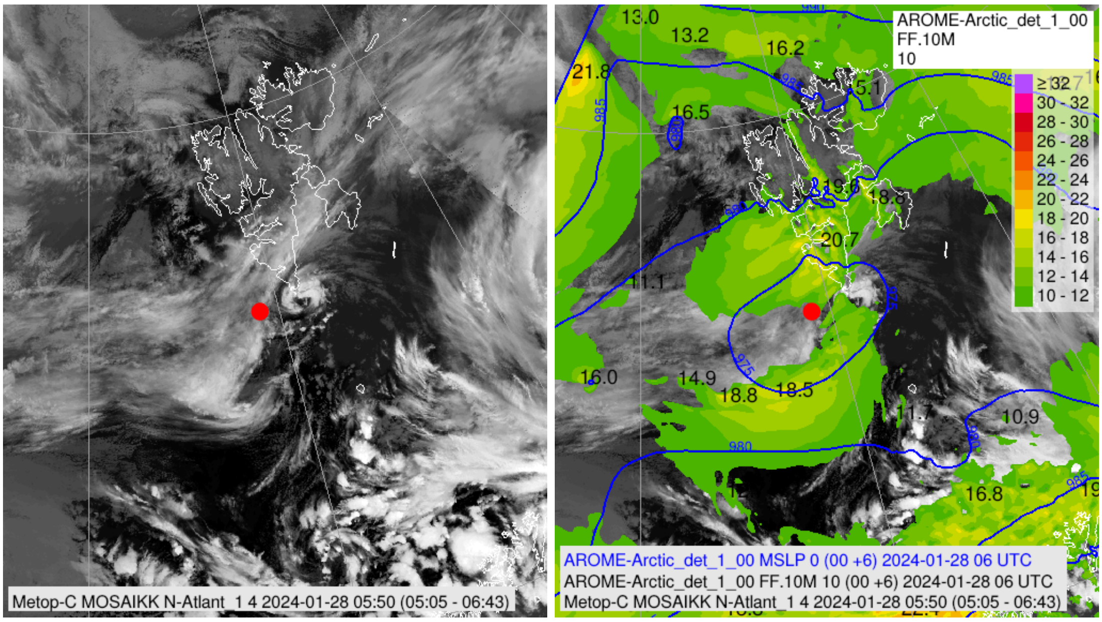

Figure 39. 28 January 2024 AVHRR image to the left and with AROME-Arctic MSLP (blue lines) and 10m wind speed (green shading) with the location from the DA at the red spot. The DA indicates at a local shear zone adjacent to a wind minimum.

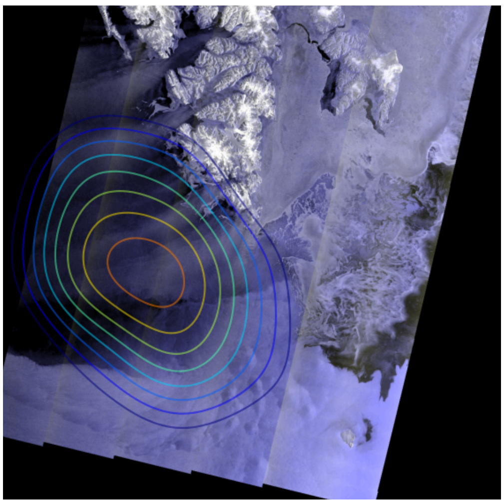

Figure 40. The SAR image from 06 UTC on 28 January 2024. The DA indicates a location at a weak wind maximum in easterly winds off the tip of Spitsbergen.

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Bibliography

Grahn, Jakob, and Filippo M. Bianchi. “Recognition of Polar Lows in Sentinel-1 SAR Images With Deep Learning.” IEEE Transactions on Geoscience and Remote Sensing, vol. 60, no. 1, 2022, pp. 1-12.

Stoll, P. J.: A global climatology of polar lows investigated for local differences and wind-shear environments, Weather Clim. Dynam., 3, 483–504, https://doi.org/10.5194/wcd-3-483-2022, 2022.

Meteorologisk institutt
Meteorological Institute
Org.no 971274042
post@met.no

Oslo
P.O. Box 43 Blindern
0313 Oslo, Norway
T. +47 22 96 30 00

Bergen
Allégaten 70
5007 Bergen, Norway
T. +47 55 23 66 00

Tromsø
P.O. Box 6314,
Langnes
9293 Tromsø, Norway
T. +47 77 62 13 00

www.met.no