

SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year 2025/07/01 - 2026/06/30.....

Project Title: Arctic Weather Satellite All-sky Radiance DA Implementation (AWARI)
.....

Computer Project Account: **spnogued**.....

Principal Investigator(s): Stephanie Guedj (stephanieg@met.no), Máté Mile (matem@met.no), Per Dahlgren (perd@met.no), Roohollah Azad (razad@met.no), Harald Schyberg (haralds@met.no) and Roger Randriamampianina (rogerr@met.no).....

Affiliation: Norwegian Meteorological Institute.....

Name of ECMWF scientist(s) collaborating to the project
(if applicable) ...

Start date of the project: May 1, 2025

Expected end date: April 30, 2028

Computer resources allocated/used for the current year and the previous one
(if applicable)

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)			30,000,000	6,583,213
Data storage capacity	(Gbytes)			150,000	147,422 ECFS+scratch

Summary of project objectives (10 lines max)

The Arctic Weather Satellite (AWS) is carrying a 19-channel cross-track microwave radiometer. A rotating mirror collects temperature and humidity data from the atmosphere as well as information on surface properties, even in thick clouds, storms, and rain. AWS was launched in August 2024 and was declared operational last week, 4th of June.

There are 3 objectives for this project: 1) Follow-up on the initial developments of the Nordic ESA project to extend the operational assimilation of the AWS in the regional AROME-Arctic NWP system. 2) Explore innovative approaches for microwave “all-sky” & toward “all-surface” data assimilation, especially using the new set of channels available on AWS (i.e. around 325 GHz). 3) Contribute to the preparation for the assimilation of the potential EUMETSAT Polar System (EPS) Sterna constellation satellite.

Summary of problems encountered (10 lines max)

Major difficulties have been encountered regarding the HARMONIE-AROME codebase (cycle release cy49) we are using. That explains why all allocated sbu were not used. The following problems and implementation challenges were tackled or identified:

- The all-sky route and implementation in cy49 is rather incomplete and we had to make changes to activate model-equivalent GOM arrays for hydrometeors, also to make changes in the linear model of HARMONIE-AROME 4D-Var (thanks to a cooperation with FMI and KNMI colleagues), and to implement observation thinning and superobbing specifically for all-sky.
- Issues related to cycle validation and other observation types (e.g., memory issue with radiosonde observation preprocessing: <https://github.com/Hirlam/HarmonieCSC/issues/241>; aircraft observation flight phase calculation: <https://github.com/Hirlam/HarmonieCSC/issues/244>). These issues are not related to all-sky implementation, therefore, temporarily fixed for the time being.
- In order to obtain the same/similar data counts in satellite radiance for AWS in cy49 (compared to current operational cy46), the VARBC initialization had to be changed as well.

Now that most technical issues have been solved, in this second year we will be able to run longer experiment and use the total amount of sbu allocation.

Summary of plans for the continuation of the project (10 lines max)

This project started one year ago and the work is organized in 3 steps: 1) Operational implementation of AWS in clear-sky while investigating toward the assimilation of AWS in all-sky conditions and over all-surfaces with a special attention given to sea-ice regions – **Done & soon published**. 2) In a second step, we are implementing the new findings and testing them into our NWP AROME-Arctic forecast system. The model will be run over two periods (winter and summer) in several test configurations – **Ongoing**. 3) Finally, we will evaluate the benefits of assimilating AWS data into the AROME-Arctic forecast system. The reference will be compared to an experiment with AWS 1) in clear-sky, 2) all-sky, 3) all-sky and all-surfaces. The overall forecast scores against independent observations will be computed for each test configuration, together with a Polar Low case study – **To be done**.

List of publications/reports from the project with complete references

Guedj, S., Mile, M., Schönach, D., Lindskog, M., Hagelin, S. and Dybbroe, A. (2026) ‘Dynamical Emissivity for Microwave Radiance Assimilation in Regional NWP: Preparing for the Arctic Weather Satellite and EPS-Sterna’, *Tellus*, 78(1), p. 22–46. Available at: <https://doi.org/10.16993/tellus.4117>.

Guedj S., Mile M., Dahlgren P., Azad R., Schyberg H., Randriamampianina R. (2026): Initial state of the Arctic Weather Satellite data assimilation, monitoring and working plan, The AWARI Project, Deliverable 1 Technical report. **Enclosed**

Guedj, S., P. Dahlgren, and M. Mile (2026). “Evaluation and assimilation of the Arctic Weather Satellite data in the AROME-Arctic forecast system”. Quarterly Journal of the Royal Meteorological Society, under review.

Ollivier M., Guedj S., Randriamampianina R. (2026): Impact of Lambertian vs specular surface reflection assumptions on microwave satellite data assimilation over snow and sea-ice in AROME-Arctic, Master report. **Enclosed**

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

This project aims at improving the assimilation of AWS in cloudy/rainy conditions but also paving the way toward microwave usage in all-surface conditions.

In this first year, we have validated a preliminary configuration for the on-the-fly monitoring of the AWS data that is presently being tested in the operational suite of AROME-Arctic. This configuration is using clear-sky data since it was the mandatory step before using AWS data more aggressively. The project annual report attached to this report describes in detail all the findings and the operationalization of AWS data assimilation in AROME-Arctic. Associated with this report, a scientific paper has been submitted and is at the stage of “accepted with minor reviews”. Here is the abstract:

The Arctic Weather Satellite (AWS) was launched on 16 August 2024 as a prototype and proof of concept for the future EUMETSAT Polar System (EPS)-Sterna constellation of small satellites. The AWS platform carries an innovative microwave sounder instrument providing information on temperature, humidity, and surface states. Many studies recently emphasized the critical value of assimilating microwave data in polar regions, demonstrating how improvements also extend to mid-latitudes. However, due the combined uncertainties in the model state and in the radiative transfer models, the use of microwave observations is still restrained to clear-sky conditions over

open ocean and snow-free land surfaces in our regional AROME-Arctic forecast system. In this paper, we present the new capabilities of AWS over polar regions for July and December 2025. The AWS instrument demonstrated similar performances than other operational MW instruments currently assimilated in the AROME-Arctic system. No visible asymmetric patterns in the residual bias of AWS First-Guess departures were found thanks to the multiple updates of the local on-ground processing chain. Observations errors and thinning distances have been tuned using FGd and other existing instruments as reference. The assimilation of AWS demonstrated an overall neutral to positive impact on the 3h-forecast fields through an improvement (up to 0.6%) of the fit to other satellite instruments (e.g., microwave and infrared data). In terms of forecast scores, the assimilation of AWS in clear-sky conditions has shown neutral to positive impacts on the forecast skills of the AROME-Arctic system with some significant improvements of the humidity at 700 hPa and close to the surface (about 1% to surface and 3 to 6% to radiosondes observations). The AROME-Arctic system is presently being set-up toward AWS all-sky assimilation.

In the continuation of this preliminary work, several DA experiments were run to extend the assimilation AWS in clear-sky to all-sky conditions. In close collaboration with FMI and KNMI, we managed to include AWS in the all-sky route and count around 15000 active AWS observations that might, later, contribute to generate a better atmospheric analysis for the AROME-Arctic forecast system (Fig. 1). These experiments have been run using the very innovative cycle 49 to benefit from some of the most recent developments included in IFS cycle 50. This work involved mostly technical implications and sanity checks.

ObsType 16 --- All-sky satellite radiances						
Codetype	215 --- metop	1	3 SENSOR=rhs			
Variable	DataCount		Jo_Costfunction	JO/n	ObsErr	BgErr
RAD	9010		12176.41200905	1.35	0.302E+01	0.000E+00
Codetype	215 --- metop	3	5 SENSOR=rhs			
Variable	DataCount		Jo_Costfunction	JO/n	ObsErr	BgErr
RAD	4140		5412.547880026	1.31	0.302E+01	0.000E+00
Codetype	215 --- aws	1	68 SENSOR=aws			
Variable	DataCount		Jo_Costfunction	JO/n	ObsErr	BgErr
RAD	15001		5857.258264355	0.39	0.872E+01	0.000E+00
ObsType 16 Total:	28231		23446.21815343	0.83		

Fig 1: logs from the first data assimilation that include AWS in all-sky (obstype=16)

In parallel, to improve the use of microwave observations over all surfaces, several experiments were run to explore the impact of using different surface hypotheses when retrieving the surface emissivity over snow and sea-ice. In fact, it was demonstrated that using a specular approximation, as set in the default operational configuration, may produce bias in the radiance simulation close to nadir positions (Guedj et al., 2010 and Bormann et al., 2022).

A set of data assimilation has been run assuming the surface to reflect incident radiation from a specular to a Lambertian way as well as some intermediate approximations mixing both reflexion approximations. A detailed report attached to this report, produced by our master student that exploited the output of our experiment. The main finding of this study concerns AWS low-peaking humidity sounding channels (Ch. 11-13). The mean absolute error of first-guess departures (e.i. radiance observations minus simulations) reduced by more than 20% for channels 11 and 12 (more than 40% if only near-nadir observations are used) and by 18% for

channel 13 when the Lambertian approximation is used over sea-ice instead of the specular assumption (Fig. 2). Improving the first guess departures should drive an increase of the amount of active data passing through the quality control and hopefully translate into a positive impact on the forecast skill of AROME-Arctic.

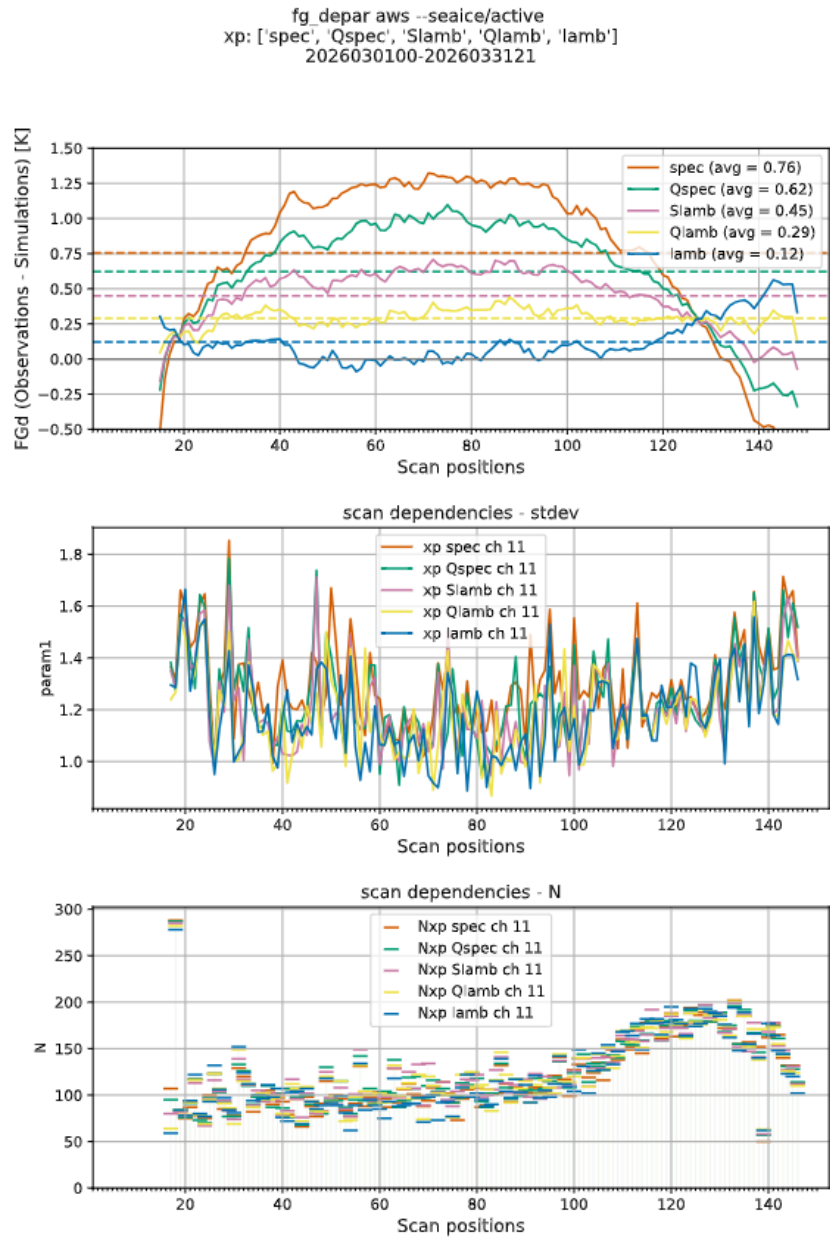


Fig 2: First-guess departures (in Kelvin) to AWS observations at channel 11 as a function of scan positions for different assumption of surface reflexion (Specular, quasi-specular, semi-Lambertian, quasi-Lambertian and Lambertian). Results are expressed in terms of bias (first line), standard deviation (second line) and amount of active data (third line).