An initial evaluation of the Arctic Weather Satellite data using NWP fields from two centres

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1. Introduction

The Arctic Weather Satellite (AWS) is an ESA mission which was launched in August 2024. This small satellite concept is a precursor to a proposed EUMETSAT *EPS Sterna* constellation of up to six satellites in three orbits, with several studies (e.g. Lean et al., 2025) showing the assimilation of data from such a constellation will yield large forecast impacts, even in the presence of measurements in the existing conventional satellite orbits.

In addition to the standard temperature sounding (50-60 GHz) and water vapour sounding channels (183 GHz) the AWS radiometer also contains new channels operating in the submm at 325 GHz. In this evaluation we will compare the observations from each channel with first guess NWP fields from two global NWP centres – Met Office and DWD. The comparisons are made in measurement space using the RTTOV radiative transfer model within the observation operator.

High quality, stable observations are essential for use in NWP data assimilation schemes e.g. observation errors for tropospheric temperature channels are required to be in range 0.1-0.2 K and 1-2 K for water vapour channels (Kaluri, 2021). We also show similar statistics of the observation; model differences for the ATMS sounder which is a key operational instrument that has similar channels to the AWS radiometer in bands 1 to 3 and meets these observation error requirements.

2. Method

Preprocessing of the observations: The feedhorns of the radiometer are not co-aligned. This requires remapping of the data onto a common grid. We have chosen to remap the data onto the 183 GHz sample positions using the AWS processing module in AAPP (AAPP-AWS). The observation locations also highly oversampled and so we have also applied a spatial averaging to the data. This is 3x3 averaging for Met Office processing and 5x5 at DWD. An example of the remapped averaged data can be seen in Figure 1. Notice the strong scattering due to ice from the new submm channels (channel 19 is shown in Figure 1)

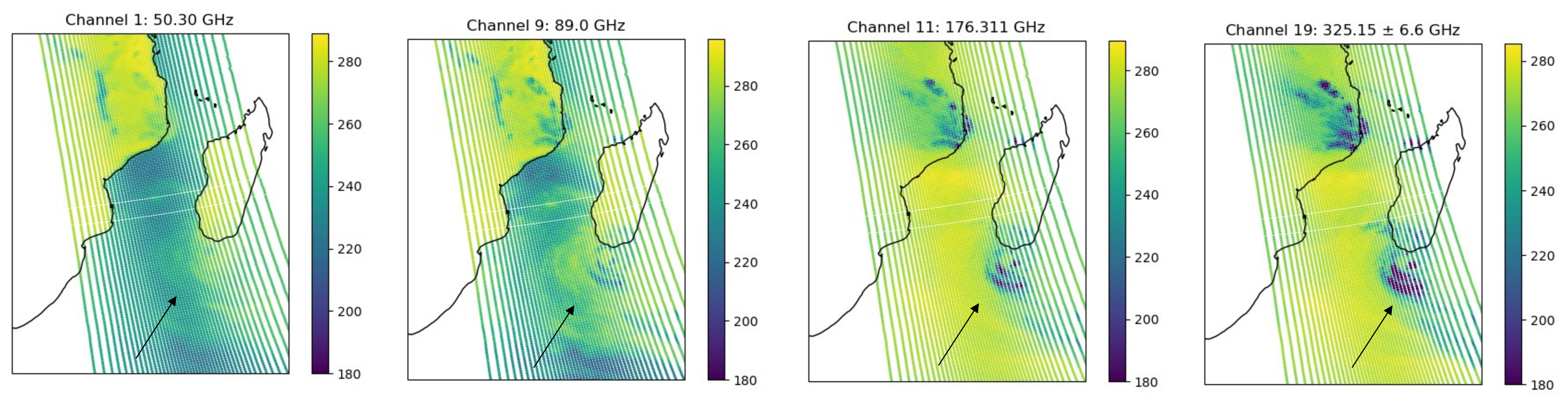


Figure 1. AWS data mapped (and averaged) onto a common grid (here the 183 GHz FOVs) via AAPP-AWS. This is an overpass containing Tropical cyclone Honde. One channel from each feedhorn is shown and the tropical cyclone is denoted by an arrow.

Data screening and observation operator: As we wish to evaluate the quality of the new measurements a screening process is applied to the observations to remove scenes that are complex to model by the observation operator. This screening removes scenes that are over land and sea-ice (surface emissivity uncertain) and also scenes over sea containing scattering due to significant amounts of cloud, or high liquid water path in case of DWD setup.

For the data passing screening RTTOV simulations are performed using the NWP first guess profiles at each observation location. The NWP and RTTOV settings for each centre are shown below:

		DWD	Met Office
NWP model	Horizontal resolution	13 km	15 km
	Vertical levels	120	80
DA Method		EnVar	Hybrid 4D-Var
Cycling		3 hour	6 hours
RTTOV		13.2	12.3
AWS preprocessing	Mapping	To band 3 locations	To band 3 locations
	Averaging	5x5 averaging	3x3 averaging
	thinning	60 km	1 in 3

Monitoring period: The period of monitoring for the results shown here are from 20th March to 16th April 2025. The observations include an update made on 13th March 2025 to the antenna corrections. In the following sections the observation minus model differences are denoted in the following way: O-B without bias correction, C-B with bias correction.

3 a) Results: Observation – Model differences by scan position

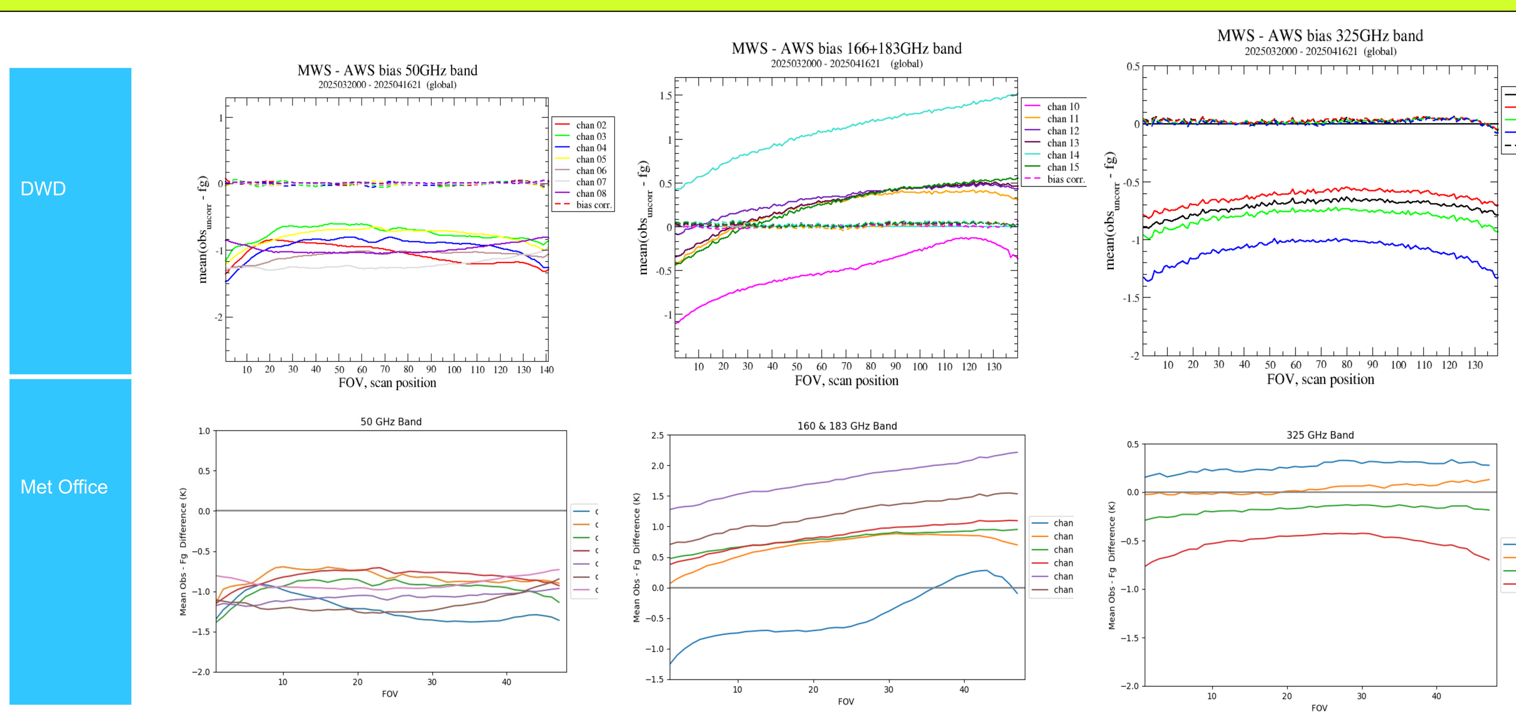


Figure 2. Cross scan O-B difference for each of the main bands in the AWS radiometer. The *top row* are from DWD monitoring, the *bottom row* from Met Office monitoring

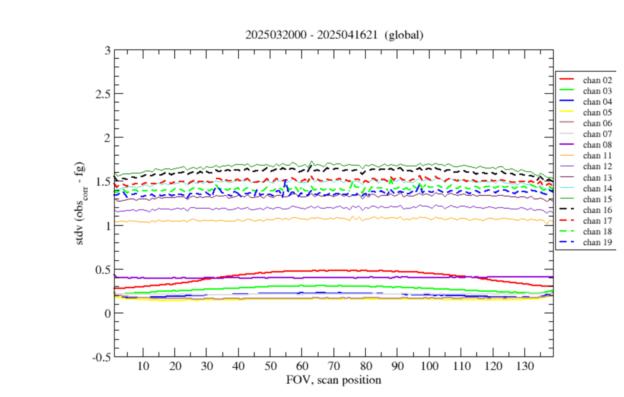
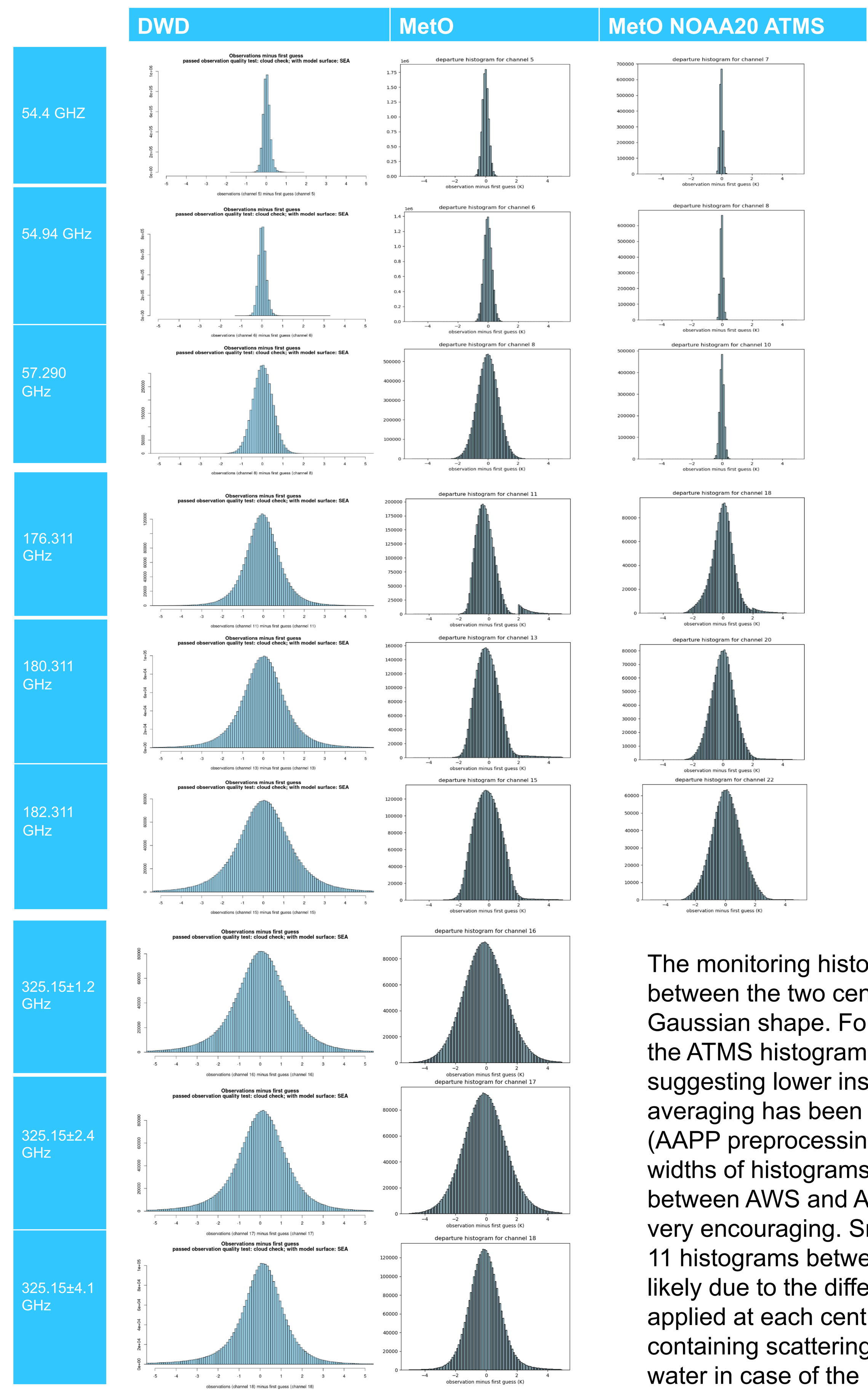


Figure 3. standard deviation of the C-B difference against scan position (DWD monitoring).

Large variation in mean bias across scan – seen in all three bands and by both centres. In particular, bands 1 and 3 appear quite asymmetric. However, the variation appears stable with time and so a correction by scan position can remove the bias as seen in the DWD plots (dashed lines). Figure 3 (left) shows the variation across the scan of the standard deviation of the C-B difference after bias correction. Notice the higher values in the middle of the scan for channels 2 & 3. This reflects the larger contribution from the surface at smaller scan angles (shorter path length), where especially the FG for data over land, which are included here, has a larger uncertainty.

3 b) Results: Histograms of corrected Observation – Model Differences

Figure 4 (below). AWS histograms of the C-B for key channels in each of the major bands. Column 1 shows DWD monitoring results, column 2 shows Met Office results. As a comparison, column 3 shows ATMS monitoring results.



AWS Instrument Specifications		
Channel	Band	Centre Frequency (GHz)
1	1	50.30
2		52.80
3		53.246
4		53.596
5		54.40
6		54.94
7		55.50
8		57.290344
9	2	89.0
10	3	165.5
11		176.311
12		178.811
13		180.311
14		181.511
15		182.311
16	4	325.15 ± 1.2
17		325.15 ± 2.4
18		325.15 ± 4.1
19		325.15 ± 6.6

The monitoring histograms are very similar between the two centres and generally show a Gaussian shape. For the 50 GHz band generally the ATMS histograms are smaller in width suggesting lower instrument noise. A 3x3 averaging has been applied to the ATMS data (AAPP preprocessing). There are comparable widths of histograms for the 183 GHz band between AWS and ATMS instruments which is very encouraging. Small differences in channel 11 histograms between DWD and Met Office are likely due to the differing cloud tests being applied at each centre to remove scenes containing scattering or too much cloud liquid water in case of the DWD setup.

3 c) Results: Timeseries of corrected Observation – Model Differences

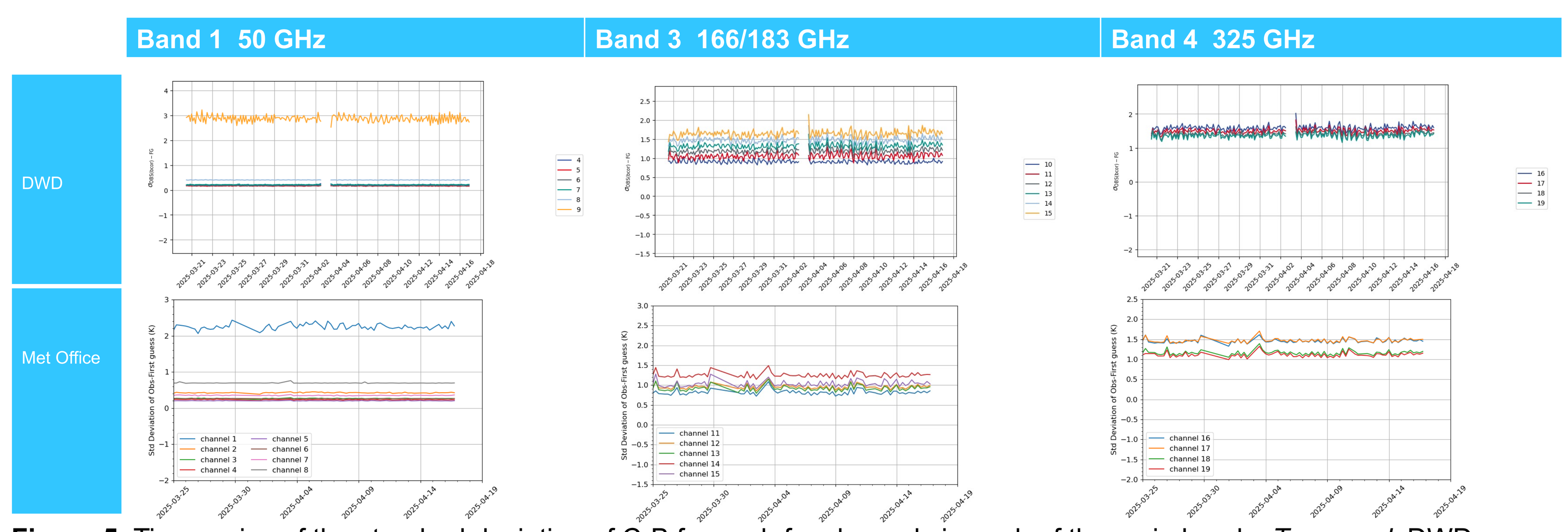


Figure 5. Time series of the standard deviation of C-B for each for channels in each of the main bands. *Top panel:* DWD monitoring (land and sea), *lower panel* Met Office monitoring (sea only).

Evidence of consistent values in these timeseries suggesting that the instrument quality is stable over time. Also, longer time series prior to the antenna correction update on 13th March showed a very stable behaviour. The order of channels differ in terms of relative size of standard deviation between the two centres and this is likely due to the differing cloud screening tests applied.

4) Summary

The monitoring activity performed at both DWD and Met Office on the AWS instrument has shown that in general there is a large bias variation with scan angle, but it appears to be stable so cross scan bias correction can remove it. After averaging the standard deviation of the fits to the NWP models are slightly higher than ATMS for the 50 GHz band and similar to ATMS for 166/183 GHz band. The time series of the C-B differences are very stable (in terms of bias and standard deviation) and this includes the new sub mm band. Channels in this new band based around the water vapour line at 325 GHZ show a similar performance to the well-known 183 GHz channels, after screening for scattering due to ice cloud. The availability of the 325 GHz channels on AWS also presents an excellent possibility to explore these frequencies in preparation for the ICI instrument that will fly on EPS-SG.

We find these results very encouraging and both DWD and Met Office satellite teams are planning to test the assimilation of AWS data in their respective global NWP models.

References and Further Information

For more information on AAPP-AWS see the *AAPP-AWS User Manual* at:
https://nwp-saf.eumetsat.int/site/software/aapp/documentation/

Kalluri, S (Ed.) (2021). Satellite Microwave Sounding Measurements in Weather Prediction: A Report of The Virtual NOAA Workshop on Microwave Sounders, : https://doi.org/10.25923/wkgd-pw75

Lean, K., Bormann, N., Healy, S. , English, S., Schuettemeyer, D., and Drusch, M. (2025). Assessing forecast benefits of future constellations of microwave sounders on small satellites using an ensemble of data assimilations. Quarterly Journal of the Royal Meteorological Society. 10.1002/qj.4939.

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