RC1: 'Comment on amt-2023-112', Anonymous Referee #1

This manuscript proposes a higher-order calibration method for the WindRAD, with the objective of mitigating the non-linear characteristics of the radar measured sigma0, and in turn deriving high-quality winds. The methodology is well described, and the results are quite promising. I think the manuscript may draw common interests from the ocean surface wind community. However, a few minor questions need to be addressed before publication.

We would like to thank the reviewer for his/her valuable remarks which are helpful to improve the manuscript. All reviewer points are provided below in the black text, with our response directly beneath in blue.

1. Do you use all of the sea surface data in the analysis of Figures 4 and 8? I would like to know how you deal with the quality control and the negative sigma0s.

Only the data with latitude between -55◦ to 65◦ are used, to exclude the sea ice. KNMI quality control has been applied, which excludes rain contamination and failed inversion, since the simulated NRCS in the calibration procedure assume a pure wind GMF. Negative sigma0s are not shown in the figures. Because of the noise, especially for Ku band (noisier than C band), there are negative sigma0s in the data. However, we cannot just throw out the negative sigma0s because they represent the low winds, and the climatological distribution of the wind might be distorted by throwing them out. Negative sigma0s are used in the inversion by adding a penalizing logarithmic term in the cost function, derived from a Bayesian theorem assigning zero probability to negative winds. The resulting logarithmic term contributes strongly to the MLE, when the wind speed approaches zero and thus penalizes the cost function, in line with a low probability for low winds. It has been implemented in PenWP (Pencil-beam Wind Processor, Verhoef, 2018) and CWDP (CFOSAT Wind Data Processor, Li et al., 2021).

The text below is added in the manuscript at line 108:

'The σ◦ distributions shown in section 3.1 Fig. 4 and section 3.2 Fig. 8 are with a restriction on the latitude to be between 55◦S to 65◦N to exclude sea ice, and KNMI quality control has been applied, which excludes rain contamination and failed inversions. Negative σ◦s are not shown in the figures, while these are used.'

Verhoef, A. (2018). PenWP SoftwareEUMETSAT NWP SAF,Version 2.2. Retrieved from: https://nwp-saf.eumetsat.int/site/software/scatterometer/penwp/

Li, Z., Stoffelen, A., Verhoef, A., & Verspeek, J. (2021). Numerical weather prediction Ocean Calibration for the Chinese-French Oceanography Satellite wind scatterometer and wind retrieval evaluation. Earth and Space Science, 8, e2020EA001606. https://doi.org/10.1029/2020EA001606.

2. The schematic illustration of HOC in Fig. 3 is fine. However, how do you calibrate each particular sigma0 value according the bias derived from Fig. 3? Is it done in linear space or in dB? Again, how do you deal with the negative sigma0s?

At the beginning of section 3 "HOC calculates σ◦ dependent calibration in intervals of 0.1 dB", which means for a particular sigma0 value, the bin for this sigma0 is determined first, then the HOC calibration for this sigma0 bin is applied to the particular sigma0. The text is edited and moved to line 86 to make the explanation clearer:

'In practice, HOC calculates the σ◦ dependent calibration in intervals of 0.1 dB, using a lookup-table. First, the corresponding bin for a measured σ◦ is determined, and then the HOC calibration for this bin is applied to the measured σ◦.'

As explained in section 2.2, paragraph 2: "We take the CDF of the simulated σ◦ data as a reference and the CDF of the measured σ◦ data is calibrated in dB unit space with respect to the reference." The calibration is done in dB, and negative sigma0s are not included in HOC because the percentage of negative sigma0s is very low at about 0.4%, which implies that the CDF matching has very little shifting at the low sigma0s, and they are corresponding generally to the wind speed lower than 1m/s, therefore the impact would be minor. The way to utilize negative sigma0s is explained in the answer to the first comment.

Texts are added in the manuscript at line 88:

'Negative σ◦s are not included in HOC calculation because the percentage of negative σ◦s is very low at about 0.4%, which implies that the CDF matching has negligible shift at the low σ◦s, and they are generally corresponding to wind speeds lower than 1 m/s. Therefore the impact on the CDF matching is minor.'

3. The azimuth-dependent bias in Figures 13 and 18 is quite suspicious. Does it exist in both versions of data? What could be the reason for the azimuth-dependent bias? Moreover, are the HOC and NOCant results the same for both versions of data?

Yes, it exists in both versions of data, the difference in the amplitude of the azimuth-dependent (wave pattern) is less for v2oper compared to v1oper.

There are two possible reasons: 1. The rotation might cause the antenna gain to decay and recover, thus leading to the azimuth-dependent variation; 2. The way level-0 data is derived. We do not know the exact method of how the level-0 data is derived by CMA (data provider); however, it relates to this wave pattern, because after the level-0 data update, the v2oper version has a reduced wave pattern. An azimuth-dependent calibration was analyzed for other rotating fan-beam scatterometers as well, such as CFOSAT (Li et al., 2021) and ISRO's ScatSat. The difference of the dependence between WindRAD and CFOSAT is that CFOSAT NOCant does not have such strong wave pattern, while ScatSat needed also an azimuth-dependent calibration correction.

The HOC and NOCant work on both versions of data, and HOC&NOCant gives the optimal calibration for both versions as well, which is explained in section 4.3.

Li, Z., Stoffelen, A., Verhoef, A., & Verspeek, J. (2021). Numerical weather prediction Ocean Calibration for the Chinese-French Oceanography Satellite wind scatterometer and wind retrieval evaluation. Earth and Space Science, 8, e2020EA001606. https://doi.org/10.1029/2020EA001606.

4. It would be nice to see an illustration or a table on the HOC and the NOCant results.

The bin size of the HOC is 0.1dB, which means that there are 600 bins in total (dB range [-50, 10]). It is not very practical to show the HOC in a table, however, we show the HOC result in Figures 5 – 7 and Figures 9 – 11 for illustration purposes. Same reason for not showing NOCant in a table, but it is shown in Figures 13 and 18.

The wind retrieval results with HOC and NOCant are compared and shown in Figures 14, 15 and Figures 19, 20.

5. Page 3, line 68: “correcting for air mass density” should be “correcting for the effect of air mass density”

It has been corrected.