ASCAT SCATTEROMETER CALIBRATION OVER THE OCEAN: ANALYSIS OF THE 3-DIMENSIONAL MEASUREMENT SPACE

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ABSTRACT

A new scatterometer, the so-called Advanced scatterometer (ASCAT), onboard MetOp-A satellite was successfully launched on October 19 2006. During the commissioning phase one of the main goals is to accurately calibrate the instrument. The radar backscatter has been calibrated using three ground-based transponders only in February 2008. However, stable and good quality ASCAT winds are produced routinely at KNMI since March 2007, as the first MetOp-A geophysical product. This Ocean and Sea Ice Satellite Application Facility (OSISAF) wind product was established by exploiting the wind manifold in the 3-dimensional measurement space. Further verification of the ASCAT calibration over the ocean is done by comparing the backscatter measurements with backscatter values derived from collocated NWP winds.
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1 INTRODUCTION

The absolute calibration of the scatterometer backscatter signal is essential for the retrieval of optimum quality geophysical products. It is not simple to obtain an accurate absolute calibration. For the calibration of the ASCAT scatterometer, EUMETSAT performs the absolute calibration by a controlled radar return to the scatterometer from transponders when these are illuminated by one of the six scatterometer radar beams. In addition, an inter-beam comparison is performed over sea ice and rain forest where the radar cross section is known to be very stable and rather time independent. Furthermore, the incidence angle response is known to be smooth over sea ice and rain forest. In addition, calibration procedures over the ocean have the advantage that they may be applied over a large portion of the globe and consequently may provide accurate results over a relatively short period.

2 MEASUREMENT SPACE AND GMF

An important tool for ASCAT inter-beam calibration is the visualization of triplets of radar backscatter in the 3-dimensional measurement space [1]. Every Wind Vector Cell (WVC) is illuminated by three antenna beams at different azimuth angles, For a given WVC number, i.e., position across the swath, it is shown that the ASCAT measured triplets are distributed around a well-defined "conical" surface. Such cone (see Figure 1) is the visualization of, for example, the C-band Geophysical Model Function (GMF) CMOD5.n in measurement space, and can in turn be used for ASCAT calibration. The same GMF can be used for ASCAT and its predecessor, the European Remote-sensing Satellite (ERS), since both ERS scatterometer and ASCAT are C-band vertically-polarized fan-beam antenna systems. That is, for coincident ERS/ASCAT incidence angle ranges the ASCAT triplets are expected to be distributed around the cone in the same way as for the ERS scatterometer.

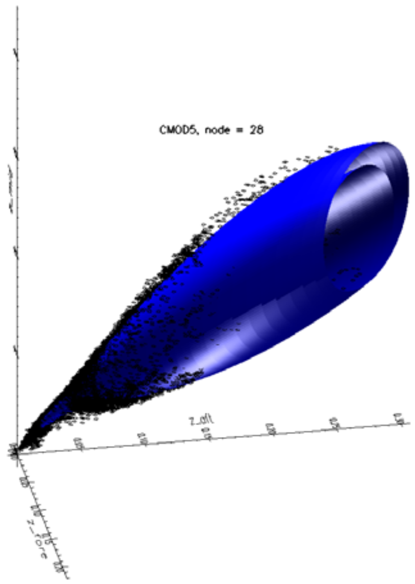


Figure 1. Visualization of the CMOD5.n GMF (blue surface) and the ASCAT triplets (black dots) in 3D measurement space, for WVC number 28. The axes represent the fore-, aft- and mid beam backscatter in z-space, i.e., (z_{fore}, z_{aft}, z_{mid}) where $z=(\sigma^o)^{0.625}$ [1].

3 CORRECTION FACTORS

Systematic displacements of the cloud of triplets in any direction of the 3D space are mainly due to absolute beam biases, which can be adequately removed by applying corrections.

A visual correction is done in order to match the cloud of ASCAT backscatter σ° triplets to the CMOD5.n geophysical model function (GMF) in the 3-D measurement space [2]. The visual correction balances the fore and aft beam for cone symmetry and brings the mid beam measurements in line with the CMOD5.n values on the cone [3].

Figure 2a shows a cut of the wind cone at zfore = zaft and the projection of the triplets in the vicinity of such plane, for WVC 42, i.e., the outermost WVC of the right swath. The measurement triplets correspond to the EUMETSAT first release of the ASCAT level 1b data. Green and purple points belong to the inner (downwind) and outer (upwind) sheets of the cone surface, respectively (see Figure 1). A correction (scaling) factor for the mid beam (vertical axis) is determined such that the triplets fit the CMOD5.n cone for each WVC. Figure 2b shows the distribution of triplets after correction.

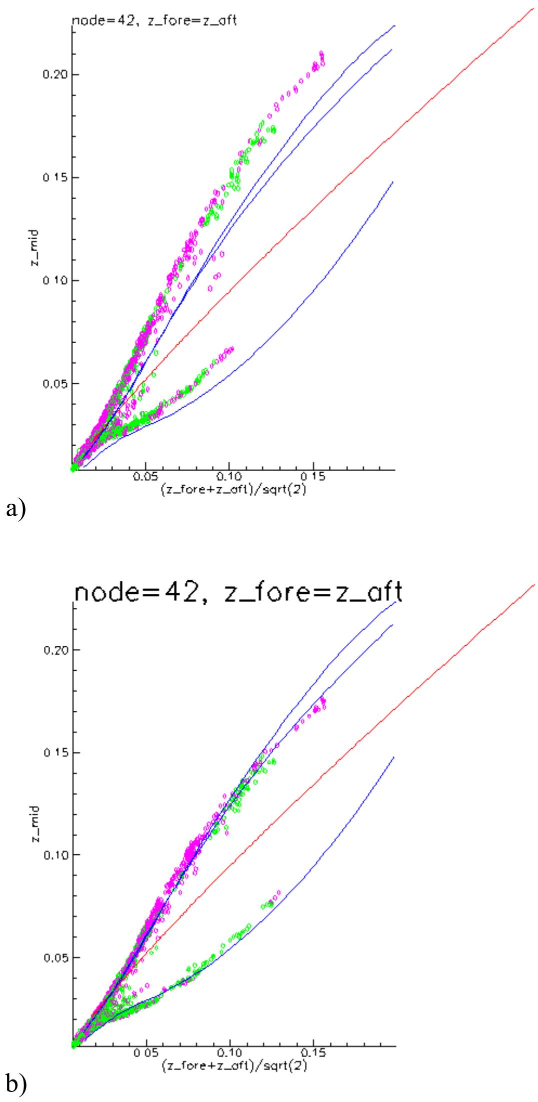


Figure 2: Cut of the CMOD5.5 cone (blue curves) at the vertical plane zfore = zaft for WVC number 42, and projection of the triplets (coloured dots) in the vicinity of such plane before (a) and after (b) visual correction.

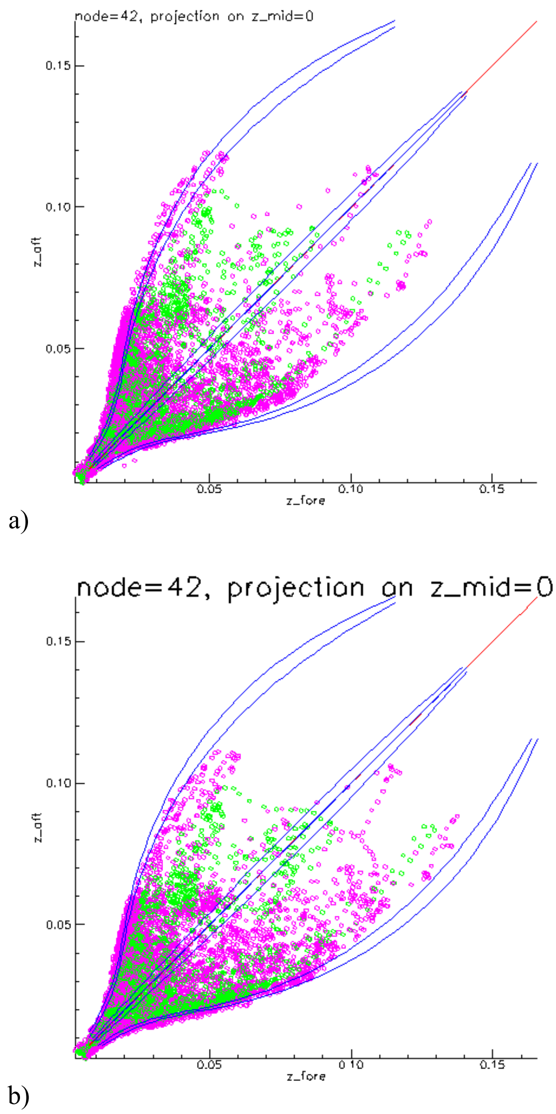


Figure 3: Projection of the CMOD5.n cone (blue curves) and the triplets (coloured dots) on the plane zmid = 0 for WVC number 42 before (a) and after (b) visual correction.

Figure 3a shows the projection of the wind cone and the triplets on the plane $z_{mid} = 0$. Correction factors for the fore and aft beams can be determined, such that the measurement points are distributed symmetrically with respect to the diagonal (see Figure 3b). The scaling correction factors (s^{cone}) are coupled in the following way:

$$s_{fore}^{cone} = 1 / s_{aft}^{cone} \qquad (1)$$

Another degree of freedom lies in the translation of the cone along its major axis. Its first order effect is a wind speed bias after CMOD5.n inversion. Therefore, a second correction is applied to correct for the remaining wind speed bias on top of the visual correction. The effect of this wind speed bias correction in measurement space is that the data cloud is stretched away from the origin (see Figure 4).

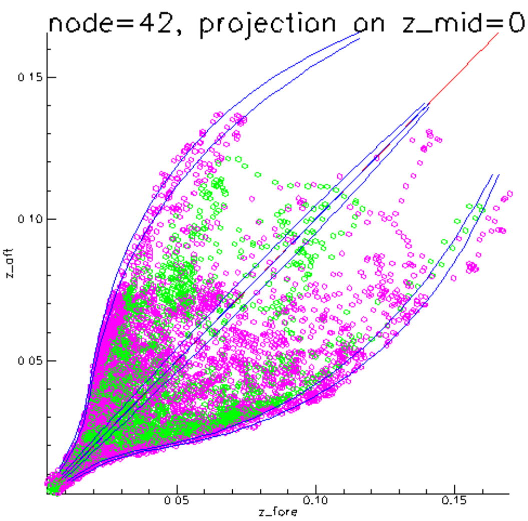


Figure 4: Same as Figure 3b but for visual + wind speed bias corrected triplets.

A third (normalisation) correction is applied for each new version of the L1b data stream. After proving that the differences with the previous L1b are small and thus linear, a correction based on the average difference per WVC and antenna between the new and previous version is carried out. The visual and wind speed bias correction remain unchanged.

4 OCEAN CALIBRATION

A 3-transponder calibration campaign has been carried out in February 2008 in order to calibrate the ASCAT antenna backscatter. The KNMI wind processing is using these 3-transponder calibrated backscatter data as input.

Within the framework of the OSISAF, KNMI has developed ocean calibration and visualization tools. The tools are complementary and, as such, consistency between both of them is checked to improve the accuracy of the calibration.

The ocean calibration tool can handle both real and simulated data. Simulations are useful to assess the accuracy of the method. The calibration method is based on Fourier analysis of the data [4]. The method consists of comparing the average measured backscatter from the antennae to the simulated backscatter from collocated Numerical Weather Prediction (NWP) vector winds, to assess the absolute values of the measurements and to show inter-beam biases. This ocean calibration needs only 6 hours of data to produce accurate results and is therefore also very suitable for monitoring purposes.

ECMWF winds are used as reference, but made uniform in wind direction for each wind speed class. More details on the implementation can be found in [5].

Figure 5 shows the difference between the real and the ECMWF simulated (using CMOD5.n GMF) measurements as a function of incidence angle, for the six ASCAT antenna beams. The calibration values for the uncorrected level 1b data (Figures 2a and 3a) and the KNMI calibrated (i.e., visual + wind speed bias corrected) data (Figure 4) are shown. It is clear that the latter shows smaller values than the former, which is an indication of improved calibration. There is little systematic behaviour in the σ^0 bias. Moreover, the range of differences is similar to the one obtained for the calibrated ERS data.

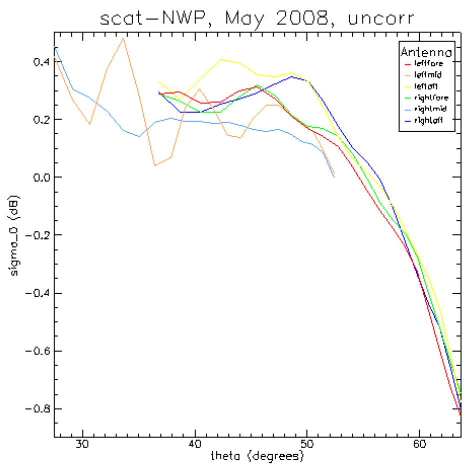
5 BUOY VALIDATION

On a monthly basis a comparison of scatterometer wind data with collocated buoy winds is made. The buoy winds are distributed through the GTS and have been retrieved from the ECMWF archive (blacklisted buoys, monthly reported by ECMWF, are not used). The data of approximately 140 moored buoys spread over the oceans (most of them in the tropical oceans and near Europe and North America) are used.

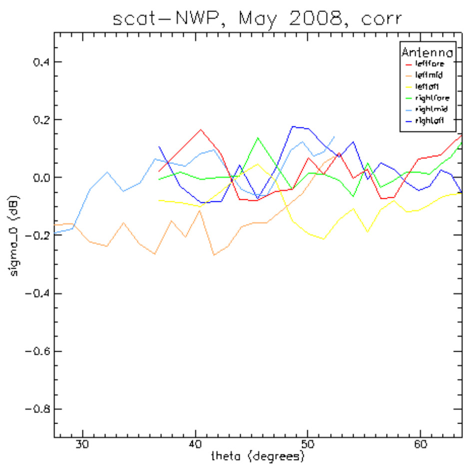
A scatterometer wind and a buoy wind measurement are considered to be collocated if the distance between the Wind Vector Cell (WVC) centre and the buoy location is less than 17.7 km compared to the ASCAT WVC spacing of 25 km, and the acquisition time difference is less than 30 minutes. These criteria give about 2500 collocations per month. The buoy winds are measured hourly by averaging the wind speed over 10 minutes. The real winds at a given anemometer height have been converted to 10-m neutral winds using the LKB model

[6] in order to make a good comparison with the 10-m scatterometer winds possible.

The results for the period of December 2007 to May 2008 are summarized in table 1. The values for bias and standard deviation lie within their expected range. The values averaged over the 6-month period result in a wind speed bias of -0.08 m/s for ASCAT 25 km wind versus buoy data and standard deviation (SD) for the zonal (u) and meridional (v) wind components of 1.76 m/s and 1.79 m/s respectively.



a)



b)

Figure 5. Difference between the ASCAT measurements and the ECMWF simulated measurements (using CMOD5.n GMF) as a function of incidence angle. The data from May 2008 are used without calibration correction (a) and with calibration correction (b).

	speed bias	dir SD	u SD	v SD
December 2007	-0.01	19.67	1.79	1.96
January 2008	-0.04	19.76	1.89	1.90
February 2008	-0.07	16.62	1.95	1.89
March 2008	-0.09	17.46	1.81	1.84
April 2008	-0.15	17.94	1.71	1.69
May 2008	-0.25	17.49	1.41	1.53
Average	-0.08	18.15	1.76	1.79

Table1. Wind speed bias, wind direction standard deviation (SD) and wind component SD for ASCAT 25 km wind versus buoy data.

6 CONCLUSIONS

Based on the OSI SAF cone visualisation tools at KNMI and the CMOD5.n wind sensitivity, improved calibration of the ASCAT scatterometer is attempted. CMOD5 was carefully derived for the ERS scatterometer and thus our calibration should result in the compatibility of the ERS and ASCAT scatterometer products. Indeed, the scatterometer wind product of ASCAT is shown to have similar characteristics to the ERS scatterometer wind product and meets the wind product requirements.

Since the commissioning phase started, KNMI has provided feedback to EUMETSAT on the backscatter calibration. EUMETSAT has released level 1b data based on a three-transponder calibration campaign in February 2008.

The ocean calibration proves to be a very effective procedure. The corrected ASCAT backscatter measurements produce good calibration results and winds of high quality. The ASCAT-derived winds are operationally disseminated by the EUMETSAT OSI SAF, where KNMI is responsible for the ASCAT level 2 (wind) processing.

When using the corrections, the level 2 wind product is of high quality. The aim is to get also a high quality product without using a correction table. Of course, this could be easily achieved by incorporating the correction table in the CMOD fit-parameters. This issue should be resolved by checking against other ancillary geophysical data like sea ice or rain forest. This will help in resolving any remaining errors and assessing the validity of the currently used CMOD version and L1b calibration, particularly for the high incidence angles.

A comparison with wind buoy data is performed routinely on a monthly basis. Results for wind bias and standard deviation are within expected range.

For more detailed information on the MetOp Research Announcement of Opportunity (RAO) ASCAT ocean calibration project #3031, see [3], [7], and [8]. For the latest developments on the OSI SAF scatterometer wind products (including the ASCAT coastal product), the software, NRT products, their visualisation and monitoring, visit www.knmi.nl/scatterometer/.

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