ANALYSIS OF THE ASCAT 3-DIMENSIONAL MEASUREMENT SPACE

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ABSTRACT

The ASCAT instrument onboard MetOp is a real aperture vertically polarized C-band radar with high radiometric stability. It has two sets of three fixed fan beam antennas, each set pointing at either side of the sub-satellite track. Because of the similarities of both the ERS (scatterometer) and ASCAT measurement systems, we have the opportunity to use the ERS geophysical model function (GMF) as a calibration tool for ASCAT. A method, based on the visualization of the 3-dimensional measurement space, will be used to determine and remove beam-to-beam biases and verify the GMF. This work is expected to contribute to the ASCAT calibration activities during the commissioning phase. As such, a calibration report will be delivered by the end of such phase. After calibration and in order to improve the interpretation of the ASCAT data, the effect of a variety of geophysical parameters, such as wind variability or wave age, will be investigated. For such purpose, the maximum likelihood estimator (MLE) magnitude and sign and the ASCAT-derived winds will be compared against numerical model output. A final report, which will also include the calibration results, will be delivered at the end of the project.

1 INTRODUCTION

The work proposal presented in this paper complements the ASCAT plans from EUMETSAT and the Ocean & Sea Ice (OSI) Satellite Application Facilities (SAF) Calibration/Validation team.

The ASCAT instrument is a real aperture vertically polarised C-band radar with high radiometric stability. It has two sets of three fixed fan beam antennas, each set pointing at either side of the sub-satellite track [1] (see Fig. 1). Over the ocean, the backscatter measurement from any antenna beam can be expressed as a function of the surface wind speed, the wind direction relative to the beam azimuth angle, the beam incidence angle, polarization, and frequency, i.e. the geophysical model function (GMF).

The relative geometry, polarization, and frequency of each ASCAT set of antennas is identical to the ERS one-sided set [2]. As such, the ERS empirically derived C-band geophysical model function (GMF), e.g., CMOD5 [3], is also applicable to ASCAT (note that for the outermost ASCAT nodes the GMF will still have to be derived since the ASCAT range of incidence angles is slightly enlarged and shifted towards higher values as compared to ERS).

As shown in Fig. 1, any given area across the swath (i.e., wind vector cell or WVC) is illuminated by the three beams, i.e. fore, mid, and aft, at three different azimuth angles. For a given triplet of backscatter measurements, the GMF may be inverted to retrieve the mean wind vector over the WVC [4], [5].

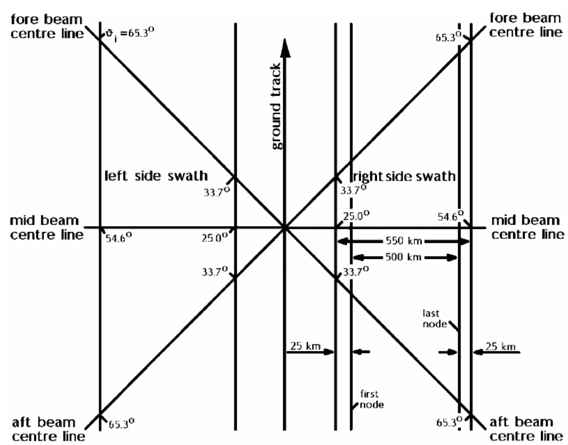

Fig. 1. ASCAT swath geometry (Fig. II.4 of [1]).

An important tool in the interpretation of the data is the visualization of triplets of radar backscatter in the 3-dimensional measurement space. For a given node or WVC number, i.e., position across the swath (see Fig. 1), [6] shows that the ERS measured triplets are distributed around a well-defined “conical” surface and hence that the signal largely depends on just two geophysical parameters, i.e., wind speed and direction (see Fig. 2). Such cone (visualization of, for example, CMOD5 GMF in the measurement space) can in turn be used for ASCAT inter-beam calibration. That is, for coincident ERS/ASCAT incidence angle ranges, the ASCAT triplets are also expected to be distributed around the cone (see Fig. 3). Systematic displacements of the cloud of triplets in Fig. 3 in any direction are mainly due to beam biases, which should be adequately removed (calibration).

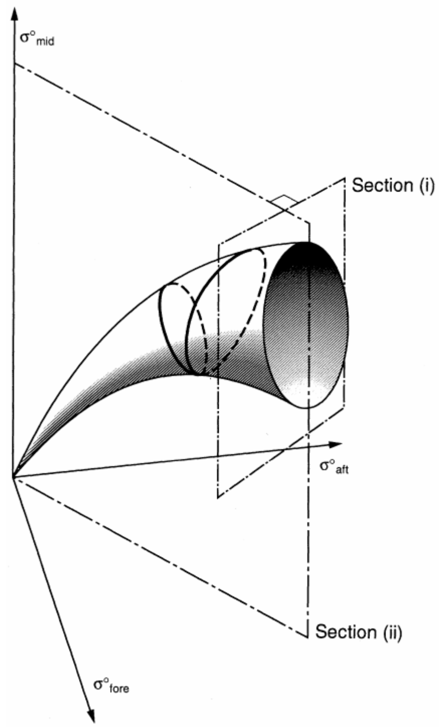

Fig. 2. Schematic representation of the GMF surface (cone) in the ASCAT 3D measurement space (Fig. II.1 of [4]). Triplets should lie close to this surface. The surface actually consists of two manifolds that can intersect (not shown). The cone cross section (i) roughly corresponds to a constant wind speed (the wind speed increases with the distance to the origin). The wind direction varies along the cone cross section.

The radar backscatter measurements may be a function of certain geophysical parameters other than wind, such as wave age, sea surface temperature or wind spatial and temporal variability (e.g., [7]). As such, it is important to assess the magnitude of the departures from a two-parameter function (i.e., the GMF). A way to investigate such departures is to look at the maximum likelihood estimator (MLE) parameter, which can be interpreted as a measure of the distance between the set of radar measurements (triplets) and the cone surface (see Fig. 3) in a slightly transformed measurement space where each axis of the measurement space is scaled by the measurement noise [6].

Reference [6] shows that, in general, the triplets lie close to the cone surface, further validating the two-parameter GMF. However, little work has been done in investigating the correlation between the mentioned geophysical parameters and the magnitude and the sign of the MLE. [Note: reference [8] shows that a sign can be assigned to the distance-to-cone, depending on whether the triplet is located inside or outside the cone surface (see Fig. 3)]. In this respect, an indication of some correlation between the MLE sign and atmospheric stability was shown by [9] (see Fig. 4). However, this has not been further investigated.

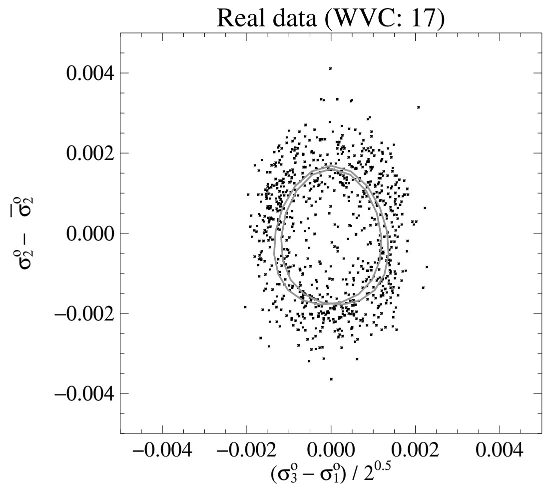

Fig. 3. CMOD-5 GMF (grey line) cross section (see section (i) of Fig. 2) for ERS WVC number 17 and a wind speed of about 4 m/s. ERS triplets are represented by dots.

The aim of this project is to contribute to the calibration of ASCAT and to improve the data interpretation for such scatterometer system.

2 WORK PLAN

The project will be conducted on the basis of 2 work packages (WP), which are described below. We anticipate that it will be conducted in collaboration with EUMETSAT and the OSI SAF in particular.

- WP-1: We plan to investigate the beam biases through visualization of the cone in the framework of the calibration activities (commissioning phase). The measurements-versus-cone consistency checks will be performed at a wide variety of cone cross sections, for every ASCAT node. Systematic displacements between the triplet distributions and the cone will be precisely determined and the appropriate beam bias corrections tested. For this WP, we need radar backscatter measurements "partially" calibrated, i.e., backscatter measurements after the initial geophysical calibration (transponder, ice, rain forest and ocean calibration) which is expected to be performed within the first 3 months of the commissioning phase. Such backscatter measurements can be found (for example) in the ASCAT level 2 product. A WP-1 report will be delivered by the end of the commissioning phase. The report will include some recommendations for the ASCAT processor on further backscatter calibration.

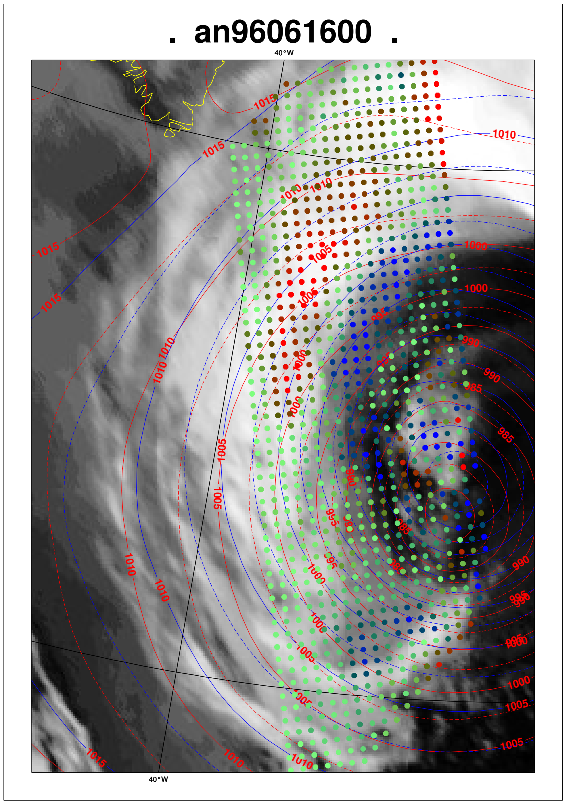

Fig. 4. ERS scatterometer pass (dots) over the North Atlantic region. In the background, a Meteosat IR image is shown together with red and blue contour maps representing the High Resolution Limited Area Model (HIRLAM) mean sea level pressure at two different forecasting steps (3 hour separation). Red and blue dots correspond to triplets significantly outside (negative MLE) and inside (positive MLE) the cone, respectively. They are most likely associated with unstable stratification and wind gustiness situations on the one hand (blue dots), and stable stratification and uniform flow situations on the other (red dots) [9]. [Note that green dots represent triplets very close to the cone].

- WP-2: We plan to conduct an exhaustive investigation on the relationship between the sign and magnitude of the MLE and several geophysical parameters, notably wind spatial and temporal variability, wave age, and sea-surface temperature. For such purpose we will collocate ASCAT–derived MLE values with model output, i.e., the European Centre for Medium-range Weather Forecast (ECMWF) Numerical Weather Prediction (NWP) model and the Wave Amplitude Model (WAM). In particular, we will use kinetic energy (wind turbulence), wave age, and sea-surface temperature data. We will also investigate the quality of the ASCAT-derived winds under the influence of the mentioned geophysical parameters. In order to well depict the areas of large spatial and temporal variability, in-situ measurements, e.g., buoys and/or oil platforms, as well as high-resolution model output, i.e., High Resolution Limited Area Model (HIRLAM), will be also used in the analysis. For such purpose, we will focus on the North Atlantic, a suitable area in terms of wind variability and data availability. The ASCAT level 2 product (processed at KNMI) will include information on both the MLE (sign and magnitude) and the derived sea-surface wind data. In order to perform WP-2, we need a calibrated and validated level 2 product. As such, WP-2 will start at the end of the commissioning phase (including WP-1). A final report, including WP-1 and WP-2), will be delivered at the end of the project.

3 SCHEDULE

The project will last 18 months and consists of two phases:

- Phase 1 will include work package (WP) 1 and start at approximately t0 (MetOp launch date) + 3 months, i.e., as soon as the geophysically calibrated backscatter product is available. Preparations will take 1 month and focus on developing an ASCAT level 2 reader and some analysis tools. The analysis will last another 2 months. As such, phase 1 is expected to last 3 months, thus ending at t0 + 6 months (end of commissioning phase).
- Phase 2 will include WP-2 and start at the end of the cal/val activities, i.e., t0 + 6 months. Preparations will take 5 months and focus on the development of a collocation software for ASCAT and model output data. The analysis will last for another 10 months. Therefore, phase 2 is expected to last 6 months, thus ending at (approximately) t0 + 21 months.

ACKNOWLEDGMENTS

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