QUALITY OF HIGH RESOLUTION ASCAT WIND FIELDS

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Abstract

The Advanced Scatterometer (ASCAT) delivers high resolution measurements of the ocean surface vector winds since 2006. Level 2 processing is done with the ASCAT Wind Data Processor (AWDP). AWDP builds upon the experience gained with the European scatterometers on board ERS-1 and ERS-2 as well as the American SeaWinds scatterometer carried by QuikSCAT. It has several advanced features, in particular the Multiple Solution Scheme (MSS) and Two Dimensional Variational Ambiguity Removal (2DVAR). The effect of these features on the quality of the 25 km and 12.5 km ASCAT wind products is studied in this paper.

1. INTRODUCTION

ASCAT carried by MetOp-A is a C-band scatterometer operated by the EUropean METeorological SATellite organisation (EUMETSAT). Level 2 processing is done with AWDP. It builds upon the experience gained with the European scatterometers on board ERS-1 and ERS-2 as well as the American SeaWinds scatterometer carried by QuikSCAT. AWDP has several advanced features, in particular the Multiple Solution Scheme (MSS) and Two Dimensional Variational Ambiguity Removal (2DVAR). These features are introduced in Vogelzang et al. (2008a) and the reader is referred to that contribution since AWDP uses the same basic routines for inversion, quality control and ambiguity removal as the SeaWinds Data Processor (SDP).

AWDP is developed in the framework of the Satellite Application Facility for Numerical Weather Prediction (NWP SAF), see (Portabella et al. 2008) for more details. AWDP is being beta-tested now and expected to become operational near the end of 2008. The software will be obtainable free of charge from the NWP SAF web site at www.metoffice.gov.uk/research/interproj/nwpsaf/scatterometer. The 25 km wind products are available as demonstration product from the Ocean and Sea Ice (OSI) SAF web site at www.knmi.nl/ scatterometer. Figure 1 shows an example of ASCAT’s coverage over the globe in 24 hours. Moreover, the OSI SAF web site also contains statistics of buoy comparisons for validation purposes and comparisons to the ECMWF model winds for monitoring.

A 12.5 km product is running experimentally at KNMI. An example of this product is shown by Portabella et al. (2008). In 2009 this product will become operational, while a high resolution coastal product is foreseen for 2011 (Portabella et al., 2008).

It should be noted here that the 25 km ASCAT product has a wind vector cell (WVC) or gridding size of 25 km, but its spatial resolution is 50 km. Similarly, the 12.5 km product has 12.5 km WVC size, but its spatial resolution is 25 km. The difference between WVC size and spatial resolution is due to spatial averaging using a Hamming window when calculating the level 1 radar cross sections. In the remainder of this paper we will distinguish the ASCAT products to their WVC size.

In this paper the quality of the 25 km and 12.5 km ASCAT products will be assessed using some statistical tools that already have been applied to SeaWinds. In particular, the covariance of the AWDP wind field is studied to detect if white noise is present. The ASCAT winds are compared statistically with ECMWF background winds. The effect of the a-priori probability on 2DVAR with or without MSS is studied, and the frequency of quality flag setting is investigated.
2. QUALITY OF THE ASCAT WIND FIELDS

2.1 Observation noise

The first question addressed here is whether or not the ASCAT data contain observational white noise. This is known to be the case for SeaWinds, especially at nadir and in the outer swath. It is caused by its measurement geometry; see Vogelzang et al. (2008a) for a more detailed explanation. Since the observation geometry of ASCAT is much more favourable, observational noise is expected to be negligible. A simple and robust method for estimating the noise level is to study the autocorrelation or covariance of the scatterometer winds along the satellite orbit: a white noise contribution gives a delta-function like signal at zero distance and therefore reveals itself as a discontinuity (Vogelzang et al. 2007, 2008b).

Figure 2 shows the covariance in the ASCAT 25 km wind product (solid curves) and in the ECMWF background (dashed curves) for the zonal and meridional wind components \( u \) (blue curves) and \( v \) (red curves). The curves were obtained using all available data from January 2008. The scatterometer winds were processed with standard AWDP settings without MSS. The right hand panel of figure 2 is an enlargement at small distances.

Figure 2 shows no sign of any discontinuity at short distances, indicating that the level of observation noise in ASCAT is very low. Note the different behaviour of the wind components at short distances: the \( u \) component of the ECMWF wind field contains more variance than the ASCAT winds while the \( v \) component contains less. Moreover, looking at the slope of the covariances, it is clear that the scatterometer contains more variability on the smallest scales, in particular for the meridional wind.
Figure 2: Covariance of the zonal and meridional wind components $u$ (blue curves) and $v$ (red curves) against distance for the ASCAT 25 km winds (solid curves) and the ECMWF background (dashed curves). The right hand panel is an enlargement at short distances.

Figure 3: As figure 2, but for the 12.5 km product. Note the difference in scale for the left hand panel.

Figure 3 is similar to figure 2, showing the covariance of the 12.5 km product for all data in the period August 15, 2008, 13:45 h to August 24, 2008, 24:00 h (almost 9 ½ days). Figure 3 is very similar to figure 2, except that the covariance in $u$ is lower in the 12.5 km product than in the 25 km product.

2.2 Comparison with model wind

Figure 4 shows the standard deviation of the differences in wind components $u$ (solid curves) and $v$ (dashed curves) between the ASCAT winds and the ECMWF background as a function of WVC number. The ASCAT winds were obtained with MSS (red curves) and without (blue curves) for the 25 km product (left) and the 12.5 km product (right). Figure 4 shows that application of MSS decreases
the standard deviation, notably for the meridional wind component $v$. The decrease is according to expectation, because without MSS 2DVAR can choose from two ambiguities, while with MSS there are 144 ambiguities. It is therefore likely that 2DVAR with MSS chooses a solution with reasonable a-priori probability that lies closer to the background.

Figure 4: Standard deviation of the difference between the ASCAT wind components and the ECMWF background. Results are shown with and without MSS and for the 25 km (left) and 12.5 km (right) products.

Without MSS the standard deviation in the 12.5 km product is somewhat higher than in the 25 km product. This is also as expected, because the ASCAT winds at fine resolution contain details that are not present in the ECMWF background. If this view is correct, then the ASCAT 12.5 km winds should compare better to buoy measurements than the 25 km winds, similar to SeaWinds (Vogelzang et al., 2008a, b). However, the buoy comparison for the 12.5 km product is not yet available.

Note that application of MSS has only a small effect that is independent of WVC number. The results with MSS give almost the same values for the standard deviations in $u$ and $v$. Comparison with buoy measurements may help to find out if this behaviour is realistic and if MSS has added value for ASCAT processing. The higher noise level in the results for the 12.5 km product is due to the limited data used (9 ½ days instead of one month for the 25 km product).

2.3 Selection probabilities

2DVAR produces wind fields that are not only spatially but also statistically consistent, because the a-priori probability that an ambiguity is the correct solution is properly taken into account in 2DVAR. Statistical consistency can be checked by plotting the conditional probability $p(\text{Sel} | P)$ that an ambiguity is selected by 2DVAR given it’s a-priori probability $P$. Figure 5 shows the results for the ASCAT 25 km product with MSS (right hand side panel) and without (left hand side panel) using three ambiguity removal methods: 2DVAR (solid curves), first rank (dot-dashed curves) and closest-to-background (dotted curves). The dashed curve labelled “Perfect” shows perfect statistical consistency, $p(\text{Sel} | P) = 2P$.

First rank and closest-to-background are very simple ambiguity removal methods. First rank chooses the ambiguity with highest a-priori probability while closest-to-background chooses the ambiguity closest to the background wind.
Figure 5: Selection probability for various ambiguity removal methods in the ASCAT 25 km wind product without MSS (left) and with MSS (right). The curve labelled “Perfect” denotes perfect statistical consistency.

Without MSS there are only two ambiguities to choose from, so statistical consistency is rather easy to achieve. Indeed both 2DVAR and closest-to-background are close to perfect statistical consistency. The first rank method is not, because the ambiguity with a-priori probability larger than 0.5 will be automatically chosen, resulting in a step-function like behaviour.

With MSS there are 144 ambiguities to choose from. Now the 2DVAR result lies in between the first rank and closest-to-background results, indicating that 2DVAR takes the a-priori probabilities properly into account. Note that the results become noisy for $P > 0.5$ and stop completely for $P > 0.7$, because large a-priori probabilities are rare when using MSS. Therefore none of the ambiguity removal methods is close to perfect statistical consistency. If, however, $P$ is restricted to values smaller than about 0.7, the line for perfect statistical consistency would become steeper because the area under this line should remain 1. In that case 2DVAR would give the best result for its curve is closest to a straight line.

2.4 Flag setting frequency

Two flags give more information on the quality of the ASACT wind products: the quality control or MLE flag and the variational quality control or VarQC flag. The MLE flag is set after inversion depending on the value of the MLE, i.e., the distance (in observation space) between the ambiguities on the geophysical model function and the observation. Large values for the MLE may indicate that the observation is contaminated by rain or confused sea state, effects often found near fronts. The VarQC flag is set when the observation cost function in 2DVAR exceeds a certain threshold value. It may indicate sea ice or large differences between the scatterometer wind and the background.

Figure 6 shows the frequency of the MLE and VarQC flag settings, solid and dashed curves, respectively, as a function of WVC number for the 25 km (left hand panel) and 12.5 km products (right hand panel). The frequency of VarQC flag setting is low. It is fairly constant over the swath, showing only a slight increase in the middle of the swath at low incidence angles, and depends little on the WVC size. The frequency of the MLE flag setting is low, but it depends strongly on WVC number and WVC size. The flag setting frequency increases at the edges of the swath, towards high incidence angle, and is higher in the 12.5 km product. As before, the noise in the results for the 12.5 km product is due to the rather limited data set.
The setting of the MLE flag depends on a number of effects. Confused sea state and wind variability cause similar anomalies at all WVC's. Rain absorption changes with slant range through the rain cloud, and therefore with WVC number, but its effect is expected to be minor. Rain impact on the sea surface has a larger effect as a function of WVC due to the changing of the Bragg resonance wavelength.

Moreover, the geophysical model function for ASCAT has the shape of a folded cone with two sheets. The MLE distribution is cut at a certain threshold, but the shape of the geophysical model function makes that observations within the cone are less likely rejected in the inner swath. These effects together determine the observed MLE flag setting frequency. It should be stressed that the MLE flag setting frequency is very low: less than 1% in the 25 km product and less than 2% in the 12.5 km product.

3 CONCLUSIONS

The ASCAT Wind Data Processor (AWDP) processes the level 1 ASCAT data into a level 2 wind product. Before the end of 2008 version 1.0 of AWDP and its 25 km wind product become operational. AWDP uses 2DVAR for ambiguity removal. The value added by MSS when processing the ASCAT data is yet unclear, in contrast with SeaWinds data. This is due to ASCAT's favourable measurement geometry and radiometric accuracy which limit the observation noise. Comparison with buoy measurements and detailed case studies will be needed to clarify this point.

The 12.5 km wind product compares well to the 25 km product, but more elaborate testing is needed before this product can be made operational.

The ASCAT quality flag (MLE flag) rejects little data, but the rejection rate depends on WVC number. This can be understood by the dependence of rain induced Bragg scattering with incidence angle and details of the inversion process. Spatially inconsistent winds and large discrepancies between scatterometer winds and background, as flagged by the VarQC procedure, are a minor percentage as well.
REFERENCES

