TOWARD AN IMPROVED AMBIGUITY REMOVAL FOR ASCAT-DERIVED WINDS

Wenming Lin[1], Marcos Portabella[1], Ad Stoffelen[2], Jur Vogelzang[2], Anton Verhoef[2], Antonio Turiel[1], Verónica González[1]

[1] Institut de Ciències del Mar (ICM-CSIC), Barcelona, Spain
[2] Royal Netherlands Meteorological Institute (KNMI), De Bilt, The Netherlands

ABSTRACT

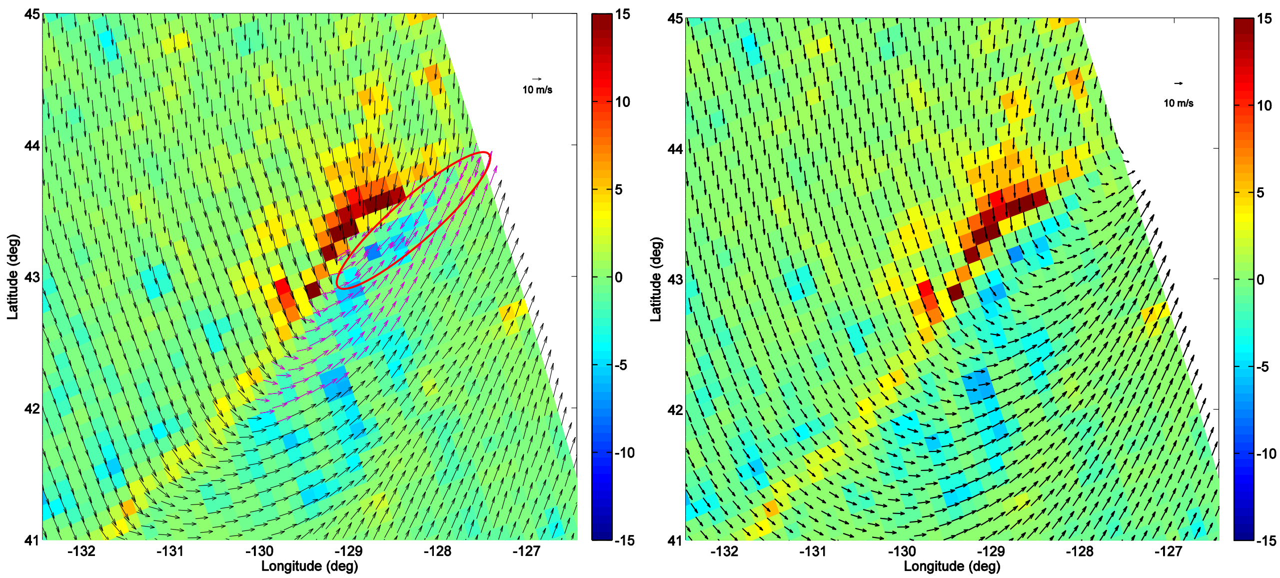
The current ASCAT Wind Data Processor (AWDP) uses the 2D variational ambiguity removal (2DVAR) scheme to select a unique wind field from a set of retrieved ambiguities. This has led to spatially consistent and accurate ASCAT Level 2 wind products. Nevertheless, recent research shows that 2DVAR picks up the wrong wind direction ambiguities in regions where the background field shows mislocation of fronts (convergence) or misses convective systems. In this paper, the exploitation of complementary information derived from the inversion and from an image processing technique is proposed to improve the current 2DVAR for ASCAT in mesoscale conditions.

Index Terms— ASCAT, ambiguity removal, MLE, singularity analysis, rain effects

1. INTRODUCTION

The Advanced Scatterometers (ASCATs) onboard the Metop satellite series are designed to determine the near surface winds over the ocean. ASCAT operates at C-band microwave frequency (5.255 GHz), with three vertically polarized fan beams tracing a swath at each side of the sub-satellite track. Three backscatter measurements, named a triplet, are thus accumulated over each across-track wind vector cell (WVC) as the satellite passes. In the 3-D measurement space visualization, ASCAT triplets are distributed around a well-defined "conical" surface. The latter surface is described by the geophysical model function (GMF), which has been empirically derived as the best fit of measured backscatter to 10-m equivalent neutral wind vectors. In general, triplets lie close to the cone surface, leading to two wind ambiguities with similar wind speed values and opposite wind directions. In case the backscatter measurements are affected by geophysical conditions other than those modelled by the GMF, such as increased local wind variability, rain, land or ice contamination and confused sea state, the measured triplets generally lie close to the GMF cone center. This situation often leads to more than 2 wind solutions and lower quality wind retrieval. The wind solutions are obtained by minimizing the distance between the triplets and the GMF cone surface, i.e., the wind inversion residual or maximum likelihood estimator (MLE). The latter is defined with a positive (negative) sign when the triplets are located inside (outside) the cone. Triplets in areas of increased sub-WVC wind variability or unstable flow conditions generally appear inside the cone and result in positive MLE values. On the other hand, triplets in stable flow conditions, i.e., in areas of low sub-WVC wind variability, generally appear outside the cone surface and therefore result in negative MLE values [1].

A spatial filter, the so-called ambiguity removal (AR) scheme, is applied over the ASCAT swath such that a unique wind field is selected from the available wind solutions or ambiguities at each WVC. Various AR schemes have been proposed, as summarized in [2]. For ASCAT, a more sophisticated scheme, the so-called 2-D variational ambiguity removal (2DVAR), is used. It consists of two steps: 1) an analyzed wind field is derived from a prior background field (i.e., the European Centre for Medium-Range Weather Forecasting or ECMWF winds) and a set of ASCAT ambiguous winds, properly accounting for background and observation errors as well as background error correlation; 2) the ASCAT wind ambiguity closest to the analysis wind is selected at each WVC. In general, 2DVAR proves to be effective in removing the ASCAT wind ambiguities. However, the wrong wind direction ambiguity can also be selected when the background field is off by 180 degrees, e.g., in case of mislocation of frontal (convergence) areas or missing convective systems. Due to the dual ambiguity nature of the ASCAT wind inversion, two solutions 180 degrees apart are equally likely. Therefore, if the background wind is 180 degrees off, the ASCAT wind ambiguities do not add complementary information in the analysis step to correct for the erroneous background. As a result, the frontal areas in the ASCAT selected field likely coincide with those in the background field. The influence of the background is therefore distorting and undesirable in such cases. Figures 1(*a*) and 1(*b*) illustrate an ASCAT wind field and the collocated ECMWF background wind field, respectively, with the ASCAT inversion residuals (MLE) superimposed. At the frontal region, enhanced sub-WVC wind variability leads to large (positive) inversion residual values (MLE). The offset of the selected wind front (spurious wind front, denoted by red ellipse) with respect to the MLE front therefore indicates poor AR over these areas.



(*a*) (*b*)

Fig. 1. (*a*) ASCAT selected wind field observed at 05:06, January 2nd 2009, superimposed with the inversion residuals (MLE, see the color bar and main text). The magenta arrows indicate WVCs in which the variational quality control (VQC) flag is set, thus indicating a large difference between the selected ambiguity and the analysis wind. (*b*) The background ECMWF wind field used in 2DVAR, which shows the frontal zone further south as compared with the MLE front, impacts the location of the selected wind convergence area (in the red ellipse) in Fig. 1(*a*).

Additional ASCAT information on the location of such wind disturbances is in principle available to help the 2DVAR process. In section 2, the MLE information and an image processing technique are firstly exploited to identify the potential misplacement of the selected wind field in frontal and convergence areas. Then, we discuss the potential ways to improve 2DVAR for such cases. Section 3 presents the preliminary results of the improved 2DVAR process. Finally, conclusions can be found in section 4.

2. METHODOLOGY

The study consists of two steps: in the first step, the decorrelation of an ASCAT WVC wind with respect to its nearest neighbors is examined using an image processing method known as singularity analysis [3] [4] [5]. The apparent ASCAT wind front corresponds to low negative singularity exponents, which are derived from the minimum exponents of the singularity maps associated to the U and V wind components (see Fig. 2). The frontal areas with low negative singularity exponents (SE<-0.5) and low absolute MLE values (|MLE| <5) are most likely to be spurious wind fronts (as indicated by the red ellipses in Fig. 2 and Fig. 1(*a*)), and as such selected for further testing.

The influence of the background in the AR process can be tuned by the 2DVAR parameters. It is decreased by either increasing the background error variance, decreasing the observation error variance, increasing the background error correlation length or decreasing the observation gross error probabilities [6]. Therefore, in the second step, the background error variance or the correlation length is increased in order to limit the influence of the background wind on 2DVAR processing over the selected areas. Smaller AR errors over frontal areas have been achieved in [6] by well specifying the static background error correlations. Furthermore, the impact of adaptive observation and background error variances on 2DVAR needs to be explored, especially for rainy areas, where errors are more variable.

To estimate the background error variance under different rain conditions, ECMWF winds are collocated with the tropical moored buoy winds and the Tropical Rainfall Measuring Mission's (TRMM) Microwave Imager (TMI) rain data. The background winds are acquired by interpolating three 3-hourly forecast winds on a 62.5-km grid both spatially and temporally to the TMI data acquisition location and time, respectively. The collocation criteria between TMI and buoy data are less than 30 minutes distance in time and 0.25° distance in space. The total amount of collocations over 2007 to 2009 is about 164 thousand, in which 14 thousand collocations are with TMI rain rate (RR) >0 mm/h. Figure 3 shows the difference between ECMWF and buoy winds as a function of TMI RR. The standard deviation (SD) values clearly increase with rain rate, indicating local variability near rain, i.e., increased error variances and shorter background error correlation scales.

3. RESULTS

In [6], it is shown that 2DVAR with numerical structure functions (brick-wall cut off) produces an analysis with less noise at scales of 40 km and below, which indicates more

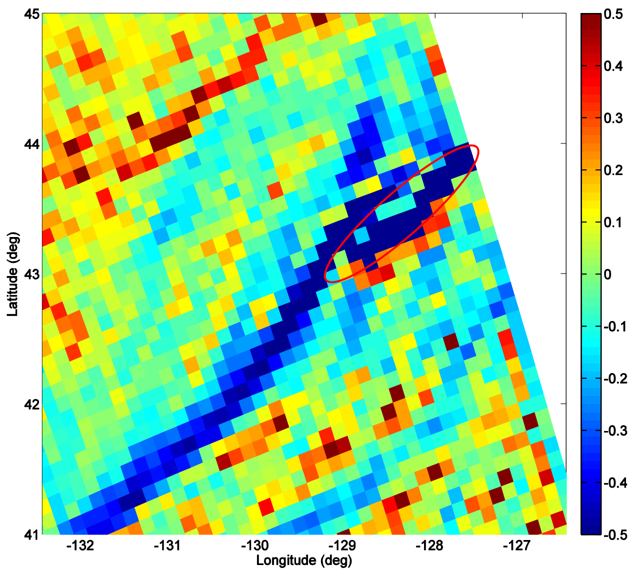


Fig. 2 Singularity map of the ASCAT-retrieved wind field shown in Fig. 1(*a*). The map is constructed as the minimum exponents of the singularity maps associated with the U and V wind components.

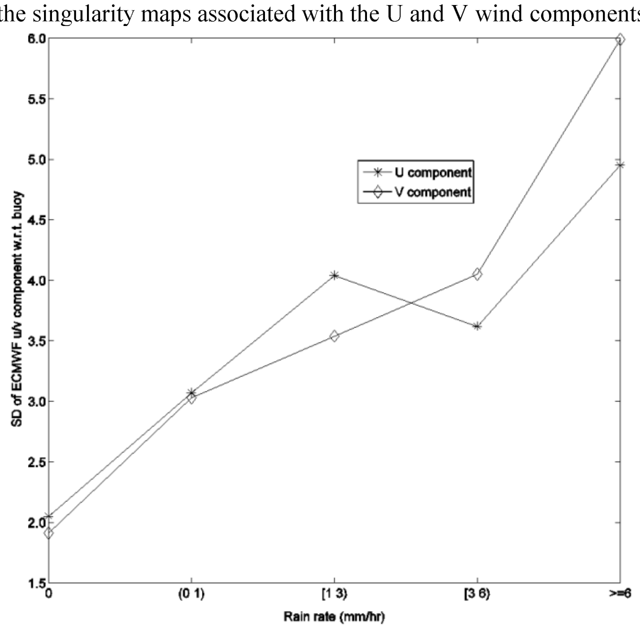


Fig. 3 Standard deviation (SD) of ECMWF wind components with respect to buoy winds as a function of TMI RR.

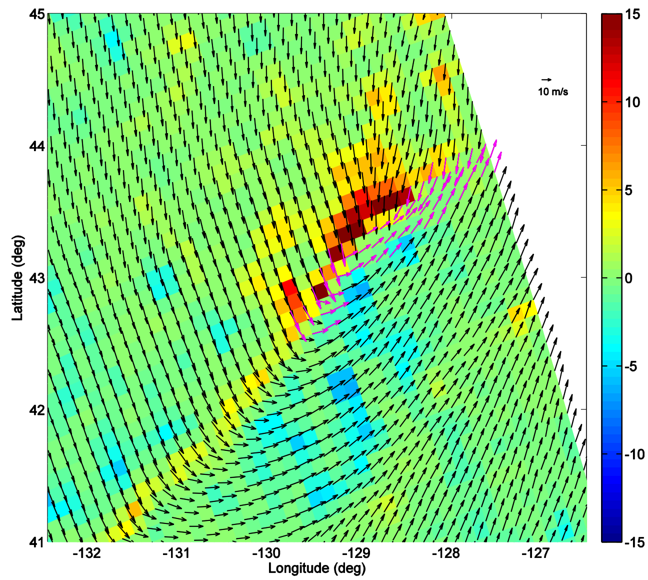


Fig. 4 Same 2DVAR as in Fig. 1(*a*), but with numerical structure functions with brick-wall cutoff. The magenta arrows indicate the VQC flagged WVCs.

detailed analyses for the case with rapidly varying wind direction over a fontal zone, resulting in fewer AR errors compared to the default fixed Gaussian structure functions (Fig. 1(*a*)). Figure 4 shows the same area but now using the numerical structure function with brick-wall cutoff. The AR errors become smaller, and VQC flags are restricted to a narrower zone. Meanwhile, the VQC flags are closer to the MLE front, in comparison with Fig. 1. Without additional wind information, it is difficult to conclude which is the most accurate wind field. Nevertheless, this test shows the potential of numerical structure functions for improving AR in very unstable conditions.

Furthermore, the impact of observation and background error variance on 2DVAR is explored. The default observation and background errors are 1.8 m/s and 2.0 m/s, respectively, for both along-track and along-swath components. By setting them to 2.8 m/s and 3.0 m/s, respectively, AR results do not change, except for the VQC flagging. That is because the VQC flag is set when the observation cost function value at a WVC exceeds a certain threshold. The observation cost function is proportional to the inverse of the squared observation error. So increasing the observation error reduces the observation cost, leading to less number of VQC flags for this case.

4. CONCLUSIONS

The current 2DVAR is generally effective for ASCAT, except for certain frontal and convective areas not well resolved (located) by the background field. Singularity analysis and MLE prove to be effective to detect spurious wind fronts. The current implementation of 2DVAR is rather standard in terms of the parameter settings, such as the background error correlation length, the error variance, and the grid dimension on which the analysis field is computed. It has already been shown that better specified background error correlation lengths can potentially improve the AR results. The impact of adaptive observation and background error variance and structure on 2DVAR will be further tested.

By exploiting the information content of MLE and singularity analysis, the mentioned 2DVAR parameters can being further adapted in order to improve AR effectiveness in frontal and convective areas.

REFERENCES

[1] M. Portabella, A. Stoffelen, A. Verhoef, and J. Verspeek, “A New Method for Improving Scatterometer Wind Quality Control,” *IEEE Trans. Geosci. Remote. Sens. Lett.*, vol. 9, no.4, pp. 579-583, 2012.

[2] J. Vogelzang, A. Stoffelen, A. de Verhoef, and H. Bonekamp, “Validation of Two-dimensional Variational Ambiguity Removal on SeaWinds Scatterometer Data,” *J. Atmos. Ocean. Technol.*, vol. 26, no. 7, pp. 1229–1245, Jul. 2010.

[3] A. Turiel, J. Sole, V. Nieves, J. Ballabrera-Poy, and E. Garcia-Ladona, “Tracking Oceanic Currents by Singularity Analysis of Micro-wave Sea Surface Temperature Images,” *Remote Sens. Environ.*, vol. 112, no. 5, pp. 2246–2260, May 2008.

[4] M. Portabella, A. Stoffelen, W. Lin, A. Turiel, A. Verhoef, J. Verspeek, and J. Ballabrera, “Rain Effects on ASCAT Wind Retrieval: Towards an Improved Quality Control”, *IEEE Trans. Geosci. Remote. Sens.*, vol. 50, no. 7, pp.2495-2506, 2012.

[5] W. Lin, M. Portabella, A. Stoffelen, A. Turiel, and A. Verhoef, “Rain Identification in ASCAT Winds using Singularity Analysis,” *IEEE Trans. Geosci. Remote. Sens. Lett.*, vol.11, no.9, pp.1519-1523, 2014.

[6] J. Vogelzang and A. Stoffelen, “NWP Model Error Structure Functions Obtained from Scatterometer Winds,” *IEEE Trans. Geosci. Remote Sens.*, vol. 50, no. 7, pp. 2525–2533, Jul. 2011.