# Impact of the structure function definition on ASCAT variational ambiguity removal

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## 1. Introduction

The two-dimensional variational ambiguity removal scheme (2DVAR) provides a spatial analysis of the sampled ocean vector winds to resolve the local Advanced Scatterometers (ASCATs) dual wind vector ambiguity. 2DVAR is in general effective, but it may select the wrong ambiguity under certain conditions, e.g., when the background mislocates frontal (convergence) areas or low-pressure centers, or when it misses convective systems. The background in 2DVAR consists of forecasts from the European Centre for Medium-range Weather Forecasts (ECMWF). The relative influence of the background and the ASCAT wind fields in the resulting 2DVAR analysis field can be controlled by adjusting the background error spatial correlation structure, and the background and/or observation error variances. In this study, an adaptive 2DVAR approach is proposed to improve ASCAT ambiguity removal:

- using background error spatial correlations estimated from the autocorrelation of observed scatterometer wind components minus ECMWF forecasts (i.e., numerical structure function, NSF);
- using background and observation errors estimated from triple collocation (TC) analysis on collocated buoy, ASCAT, and ECMWF data.

## 2. Methodologies

The ASCAT inversion residual or Maximum Likelihood Estimator (MLE) contains valuable information on the sub- wind vector cell (WVC) variability, which is generally associated to wind convergence (fronts) and divergence (e.g., downdrafts) conditions [1]. Moreover, *Lin et al.* show that an image processing technique called singularity analysis (SA) can be used to detect subtle disturbances in the ASCAT-derived wind field ambiguities which may be associated with wind fronts. A thorough characterization of the MLE and SA-based (i.e., the singularity exponents or SE) parameters derived from ASCAT product is carried out.

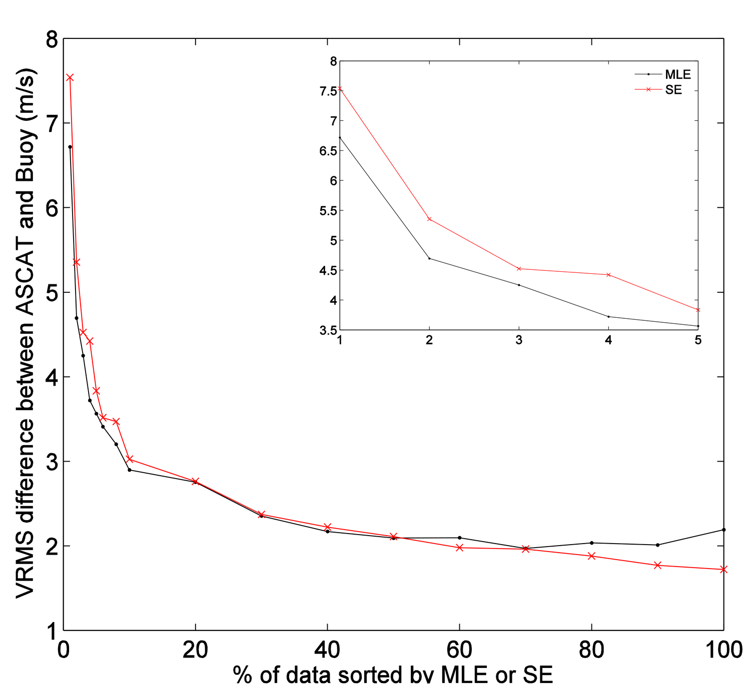



Fig. 1 The Vector Root-Mean-Square (VRMS) difference between ASCAT (25-km product) and buoy winds as a function of the percent of data sorted by MLE (in descending order) and SE (in ascending order). A zoom of the first 5% of data is shown on the right-upper corner.

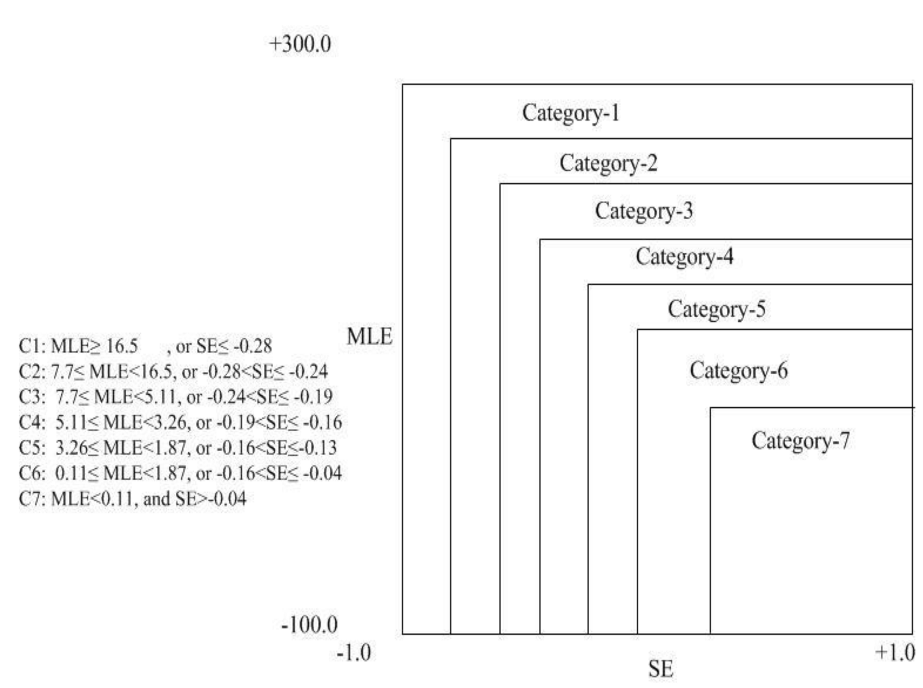



Fig. 2 Schematic representation of the seven categories in which triple collocation data set is separated in order to develop situation-dependent Observation (O) and Background (B) errors. The percentiles from the most variable category (C1) to the most stable category (C7) are 1.1%, 1.6%, 2.5%, 3.1%, 5.6%,31.6%, and 54.5% respectively.

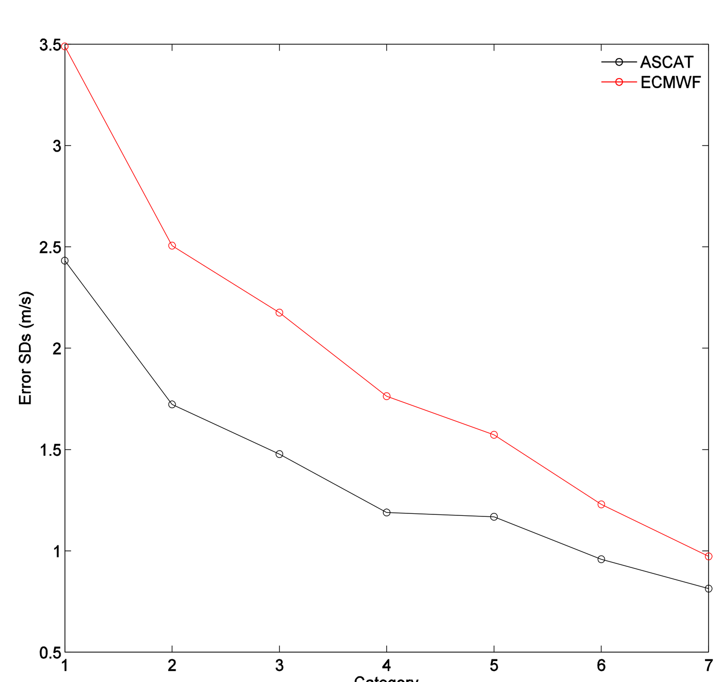



Fig. 3 Root-Mean-Square (RMS) error (the average of the random errors associated with wind $u$ and $v$ components, i.e. $\sqrt{\frac{SD_u^2+SD_v^2}{2}}$ ) on the ECMWF scale for ASCAT and ECMWF winds.

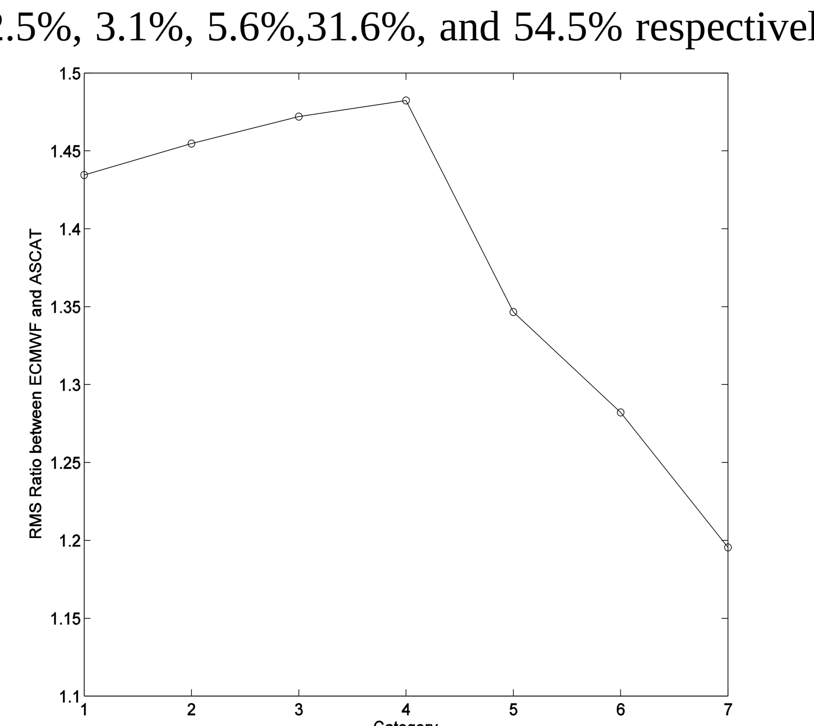
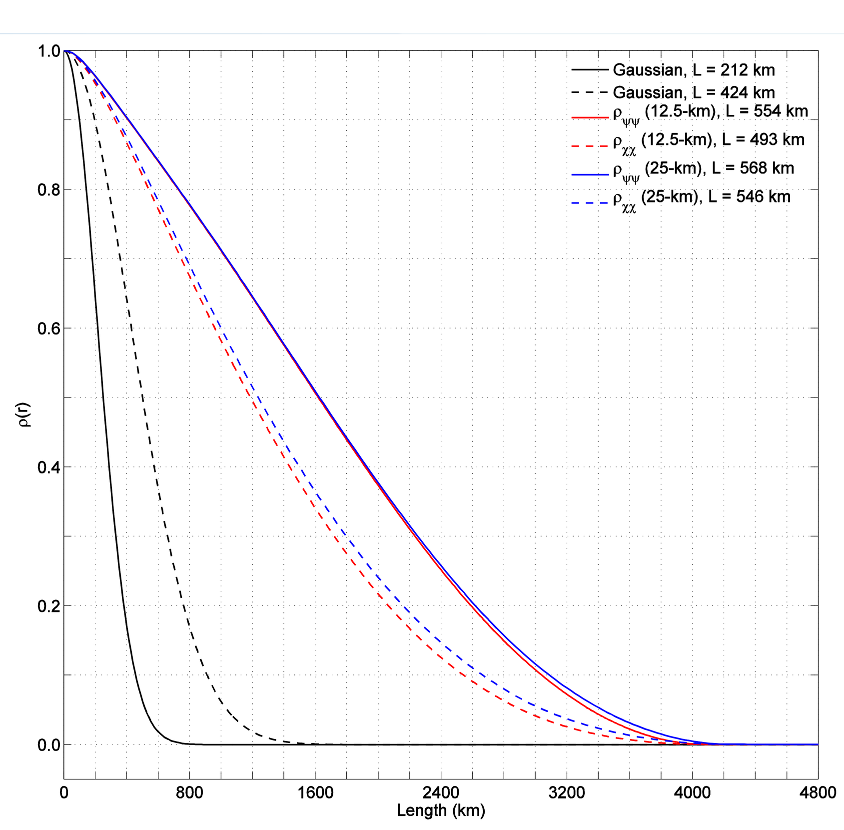



Fig. 4 RMS error ratio between ECMWF and ASCAT winds on the ECMWF scale.

Fig. 5 The structure functions (Stream function, dashed curve; Velocity potential, solid curve) estimated from ASCAT 12.5-km (red) and 25-km (blue) wind data [3] . The default Gaussian structure functions (GSFs), currently used in the operational 2DVAR scheme with different length scales for the Tropics (black dashed curve) and Extratropics (black solid curve), are also presented as a reference. The numerical structure functions (NSFs) are much broader than the Gaussian structure functions. Since the spatial structure functions act as spatial filtering functions in meteorological analysis, one may expect that smoother analyses result from broader background error structure functions. Moreover, in case of dense observation coverage at high weight, such as from ASCAT, broad structure functions may cause overfitting.




## 3. Results

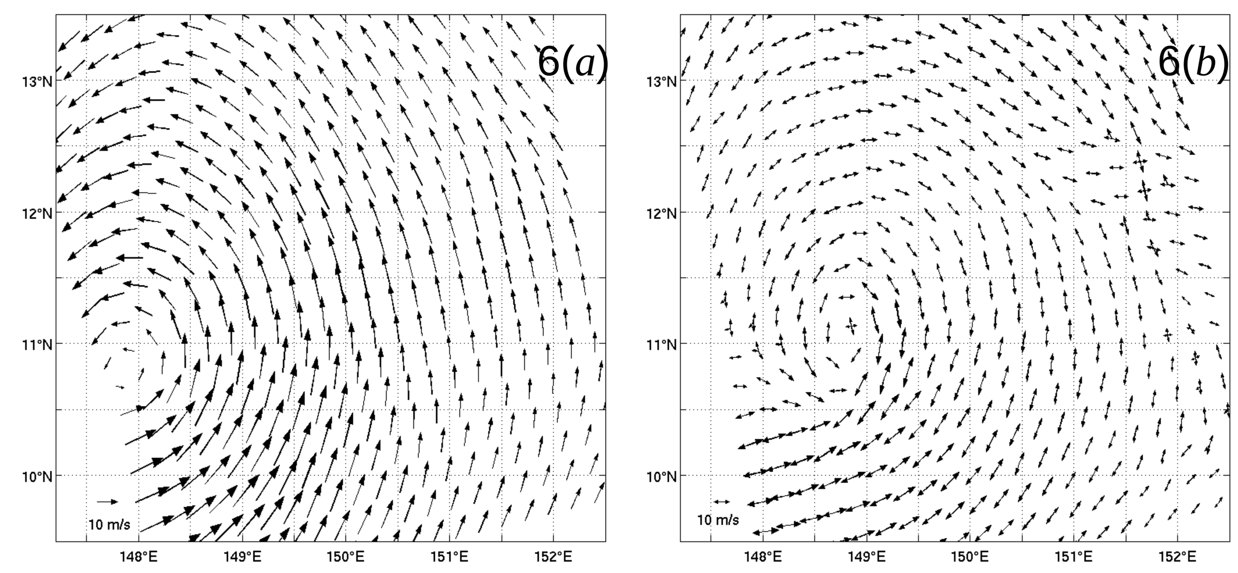



Fig. 6 (*a*) ECMWF forecast surface winds collocated with the ASCAT observation on July 3rd 2015, around 11:45 UTC; (*b*) ASCAT-derived wind ambiguities; the lower-left reference scale indicates two opposite ambiguities with the same speed of 10 m/s.

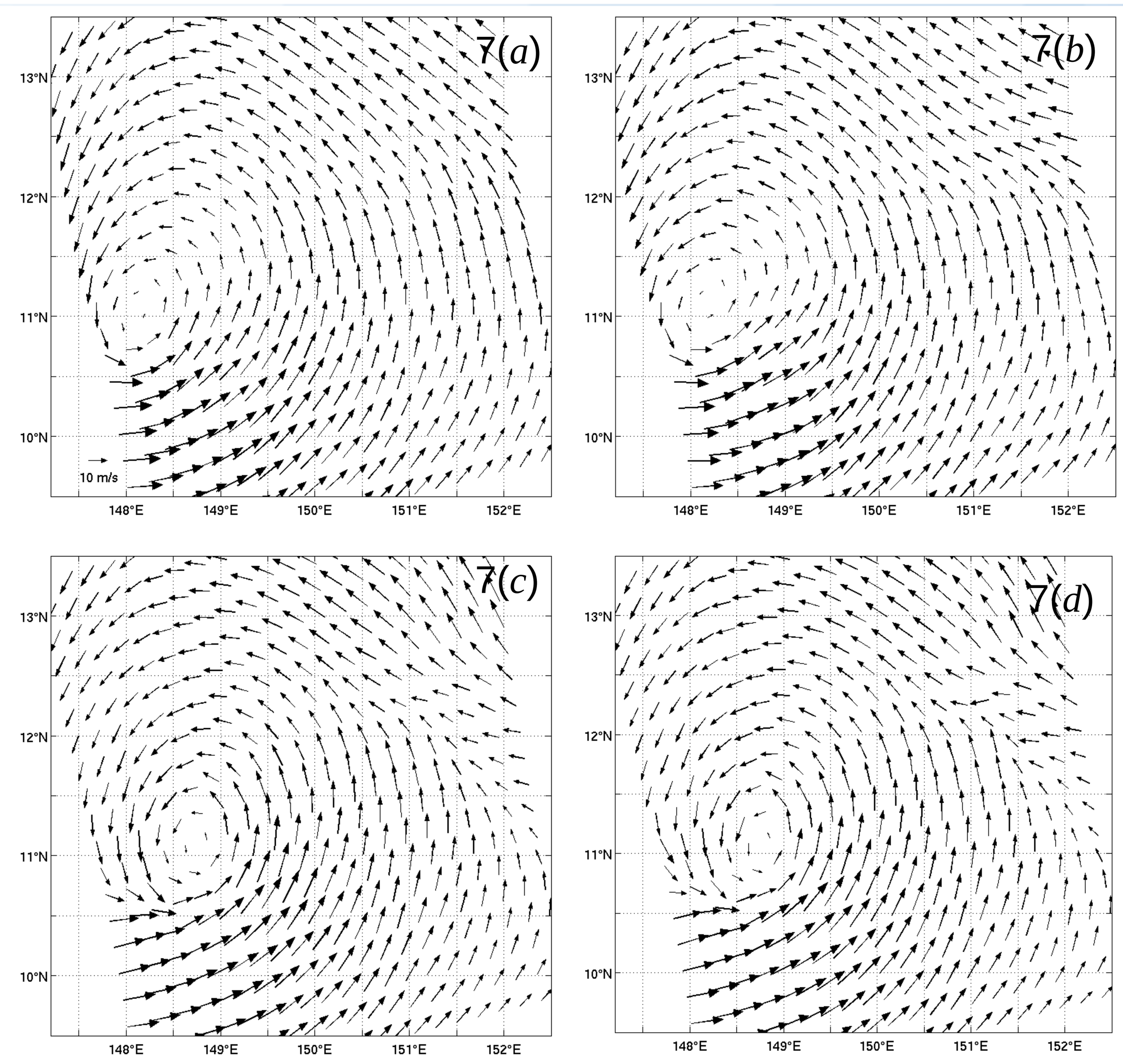



Fig. 7 2DVAR analysis wind field derived from: (*a*) Test 1, GSF + Fixed O/B errors, AWDP default setting; (*b*)Test 2, GSF and situation-dependent O/B errors; (*c*)Test 3, NSF and AWDP default O/B errors; (*d*)Test 4, NSF and situation-dependent O/B errors. The reference scale in the left-lower corner of (*a*) applies to all the panels.

- Given a certain background error structure function, the impact of the modified O/B errors on the analysis is generally neutral, but slightly positive in the vicinity of the cyclone center and wind front.
- The impact of NSF on 2DVAR analysis is remarkable. The low-pressure center is shifted from [148.2°E 11.0°N] in Fig. 7(*a*) and (*b*) to the position [148.7°E 11.1°N] in Fig. 7(*c*) and (*d*), getting closer to the real cyclone center depicted by the ambiguities flows of Fig. 6(*b*).

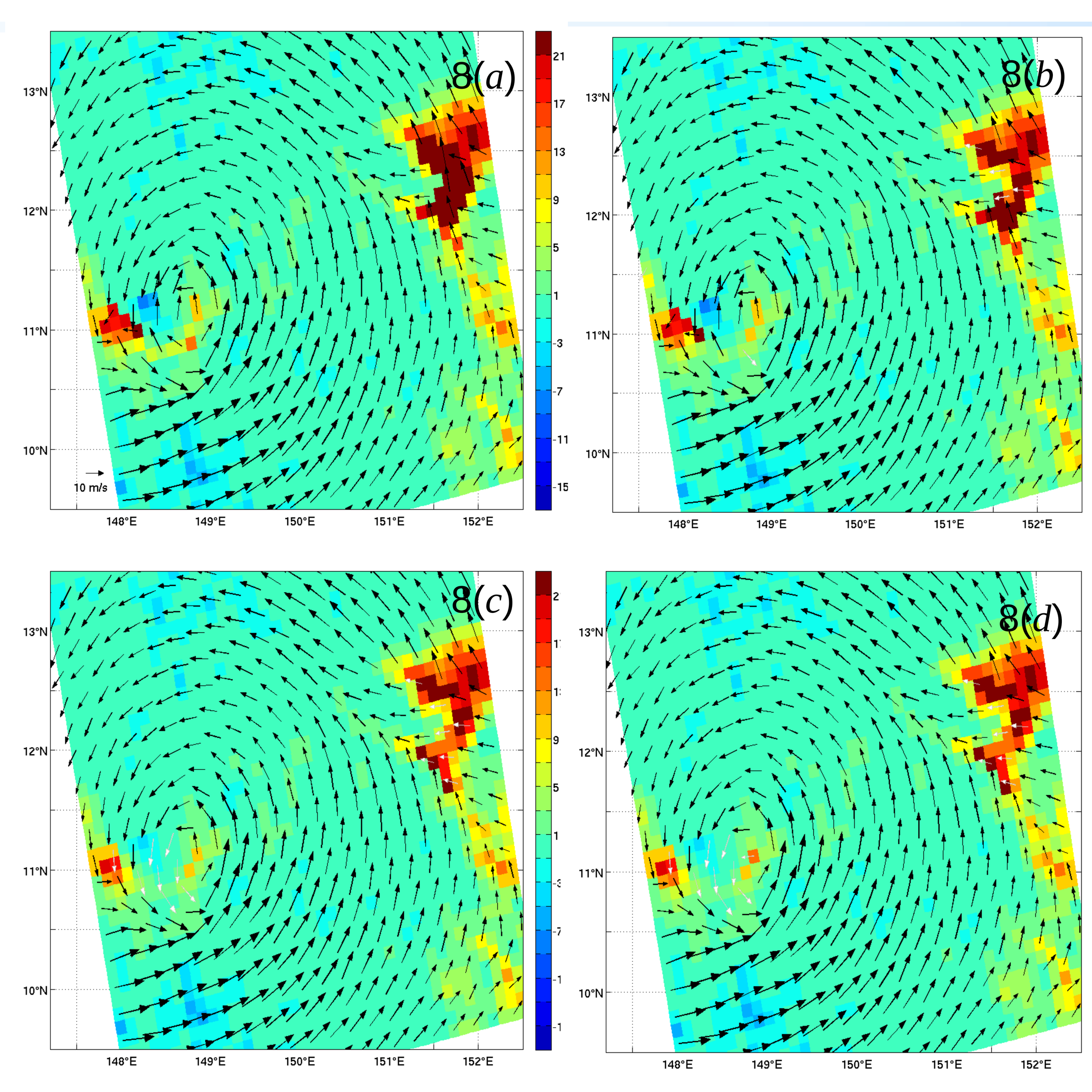



Fig. 8 ASCAT selected wind field superimposed with MLE values (see the color bars) for the four different tests in Fig. 7. The grey arrows in (*b*)-(*d*) indicate which selected wind vector ambiguities are different from those in (*a*).

- NSF reproduces the low-pressure center location in the analysis accurately and thus has significant positive impact on the ASCAT AR, leading to spatially consistent ASCAT cyclone winds in Fig. 8(*c*) and (*d*).
- Regarding the convergence region around [151.5°E 11.8°N], the use of flexible O/B errors (Test 2, Fig. 8*b*) and notably NSF (both with fixed, Fig. 8*c*, and with flexible O/B errors, Fig. 8*d*) leads to smaller AR errors, i.e., the selected ASCAT solutions are in better agreement with the 2DVAR analysis than for Test 1.

## Conclusions

1. Even though the combination of GSF and flexible O/B errors shows some improvement in the cyclone case, it generally does not produce better wind selection than the default setting. In fact, the ratio of observation and background error is, on the ECMWF scale, generally close to the default setting and not very weather dependent.
2. In contrast, by adopting NSF in 2DVAR, about 2% of the wind selections are modified w.r.t. the default 2DVAR scheme, since the much broader structure function effectively decreases the background weight.
3. Furthermore, the 2DVAR analysis becomes much closer to the selected ASCAT winds. The combination of NSF and flexible O/B errors slightly further improves the ASCAT wind quality, when compared against continuous buoy winds and mean buoy winds [4] .
4. Note that in 2DVAR the analysis' objective is to fit all scales present in the ambiguous scatterometer winds, while in Numerical Weather Prediction the degrees of freedom in the forecasting model should be initialized without creating small-scale noise. Although the NSF proves to be effective for ASCAT AR, its long tails will also impact NWP parameters outside the swath. Further studies are therefore required to verify whether NSF is also beneficial to the higher dimensional variational (e.g., 4D-var) data assimilation schemes.

## References

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