IMPROVEMENTS IN THE USE OF SCATTEROMETER WINDS IN THE OPERATIONAL NWP SYSTEM AT METEO-FRANCE

Christophe Payan

CNRM-GAME, Météo-France and CNRS, 42 avenue Gaspard Coriolis, Toulouse, France

Abstract

Significant improvements have been made in the last 2 years in the use of scatterometer winds in the operational NWP system at Météo-France. First, 4 wind solutions, different in direction, are now taken into account in the assimilation process of QuikScat instead of the 2 closest to the GMF initially. This change reduces the departure with respect to the model in areas of high departure, without loss of information where this departure is lower. Last, as wind data are now considered as neutral, the stability effect in the boundary layer can be ignored, whereas it was treated implicitly only in GMF. The main impact is a reduction of the speed bias with respect to the model, mainly for QuikScat data, and a better agreement between the model and its analysis in the extra-tropical hemispheres.

1. INTRODUCTION

Scatterometers provide 10m-wind data over sea, trough an heuristic relation, called Geophysical Model Function (GMF). These data have been assimilated operationally in the Numerical Weather Prediction (NWP) models of Meteo-France, now for almost 6 years:

- first, since October 2004, from the Seawinds scatterometer on-board the satellite QuikScat, with an in-house inversion using QSCAT-1. At first, only the 2 most likely solutions on up to 4 were considered in the assimilation;
- then we have assimilated winds from the AMI instrument on-board the satellite ERS-2 since September 2007, also with an in-house inversion using first CMOD5.4;
- finally Ascat on-board the satellite Metop-A have been assimilated since February 2008. These data come from the Koninklijk Nederlands Meteorologisch Instituut (KNMI) in the frame of the Eumetsat Ocean-Sea Ice Satellite Application Facility and the inversion began with CMOD5.

For these 2 latter data sets (from ERS-2 and Metop), the number of likely solutions is restricted to 2.

For all instruments, the de-aliasing (or the removal of the ambiguity between the solutions) is to choose the solution closest to the model in the assimilation process.

The impact of these new data was studied each time in the frame of our Global Model Arpège, then their operational use extended to our LAM models (Aladin for our regional needs over Europe, and Arome for our local needs over France). The monitoring against the model background shows that these data have a better quality than similar data as ships and buoys, with a global oceanic coverage. The studies showed a neutral or weak positive impact on the forecast scores, with, for QuikScat data, a strict selection of the observations, with a high rate of rejection due to rain contamination and in the case of a lack of diversity in the wind directions (between the 2 solutions chosen a-priori).

Dramatic improvements have been made in the last 2 years in the use of these data in the operational NWP system of Météo-France trough:

- the use of 4 instead of 2 most likely solutions for the QuikScat winds, and before the failure of the satellite, in last November;
- the replacement of the real-wind operator by a neutral-wind operator in the data assimilation process.

This paper describes theses changes and their impact.

2. USE OF 4 SOLUTIONS FOR THE QUIKSCAT WINDS

The commissioning of Metop-A in 2007 and the use of Ascat wind measurements in our assimilation system since February 2008 allowed to compare this data set with this from QuikScat. The figure 1 shows on a globe map, by squares of 10 degrees, the norm of the mean vector difference observation minus model background for the solutions effectively used in the assimilation, the Ascat winds on left, the QuikScat winds on right, for the second quarter of 2008. For QuikScat, only the 2 most likely wind solutions on up to 4 are used in the de-aliasing. Blue squares indicate a low mean vector difference whereas differences are becoming higher respectively in the green and yellow squares.

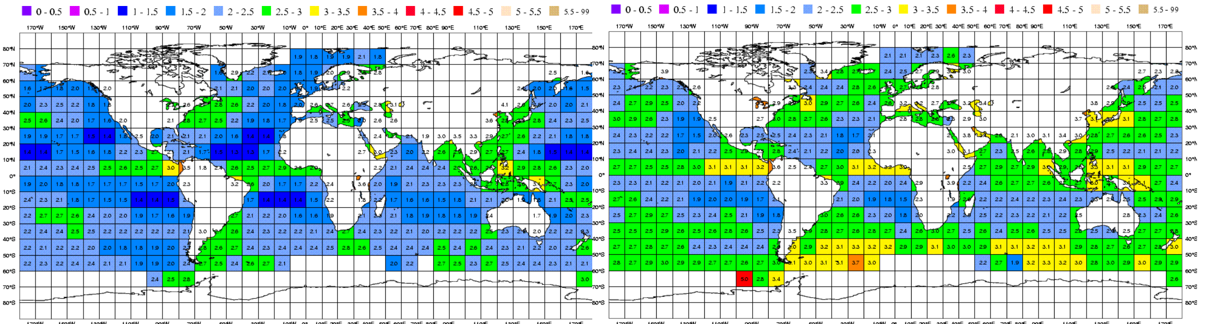


Figure 1: **Mean Vector Difference (Observation – Background) by square of 10 degrees of assimilated data, operational monitoring, 2nd quarter 2008, Ascat winds on left, 2 most likely QuikScat winds on right, plotted values in m.s^{-1}.**

We can see that with the use of 2 solutions only, differences for QuikScat winds are locally higher than for Ascat winds, and mainly in the Inter Tropic Convergence Zone (ITCZ) and in the winter mid-latitudes, where the atmosphere is more rainy and the winds are stronger. This translates ultimately by a global QuikScat departure with respect to the background higher than for Ascat, respectively 2.7 m.s^{-1} and 2.3 m.s^{-1}.

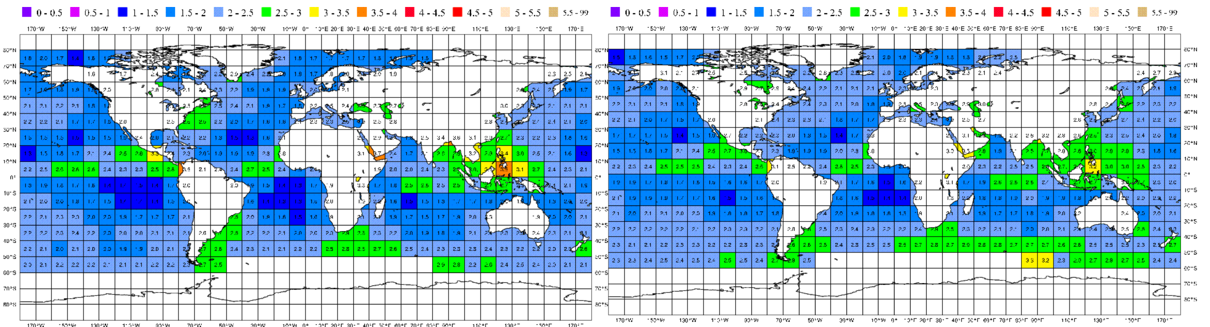


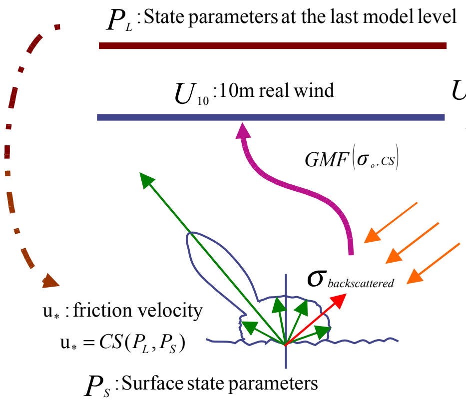
Figure 2: **As figure 1, but for the 3rd quarter 2008, Ascat winds on left, 4 solutions QuikScat winds on right, plotted values in m.s^{-1}.**

The figure 2 shows the same statistics but on the third quarter of 2008, always Metop winds on left, QuikScat winds on right. For Quikscat winds, the 4 solutions are now considered in the assimilation (the closest to the model in the assimilation process is chosen). We can see that differences between the 2 charts have disappeared. Where the vector difference was higher for QuikScat winds, it has been now reduced at the same level as for Ascat data and without losing information where the 2 datasets have already been in agreement (and with lower differences to the background). The risk, by increasing the number of possible solutions for QuikScat winds, was effectively to loose information by a too good agreement with the model, which is used for the choice of the solution.
With the use of 4 solutions for QuikScat winds, we have now the same level of quality between the 2 data sets (Ascat and QuikScat), with a vector difference to the background around 2.2 m/s. The use of 4 solutions for QuikScat has been operational since this 3rd quarter of 2008, but without visible impact

on the forecast scores. But before the failure of the instrument, a relaxation in the QC was planned, in the aim to assimilate more data.

3. REPLACEMENT OF THE REAL WIND OPERATOR BY A NEUTRAL WIND OPERATOR

The Geophysical Model Function used for inverting raw data to winds treats implicitly the conditions of stability in the boundary layer, between the sea surface, where the measurement is made and the 10m-level where the wind is computed by the inversion. It is valid on average but it is a source of error for a singular observation. In theory, 10meters wind depends of backscatter signals and of the conditions of stability between, as shown in figure 3.



$$U_{10} = U_L\left[LN(z_0, z=10\text{m}) - COR(CS)\right] / BD(U_L, u_*)$$

with U_L *model wind at the last level*, ~17m

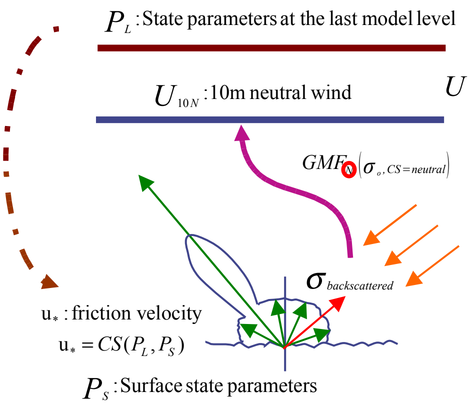
z_0 *roughness length*

LN Logarithmic function of z_0 *and* z

COR correction of stability conditions

BD drag coefficient function of U_L *and* u_*

Figure 3: **Conceptual design of the GMF dependence of the backscatter signals (noted σ_o) measured at the sea level and of the conditions of stability in the atmospheric boundary layer (noted *CS*) and real wind operator used in the assimilation system, based on Geleyn, 1987.**



$$U_{10N} = U_L\left[\ln(z_0, z=10\text{m}) - COR(CS)\right] / BD(U_L, u_*)$$

Figure 4: **Conceptual design of a neutral GMF (the conditions of stability in the atmospheric boundary layer are supposed now neutral) and modification to apply in the wind observation operator for retrieving a neutral equivalent model wind at the observation location at 10 meters.**

In practice, we cannot access to this information. A solution is to consider a virtual neutral wind, which will be computed by a neutral GMF, noted *GMFN*, with it we will suppose that the conditions of stability will be neutral. That implies also to modify the observation operator based in the NWP system on Geleyn, 1987, which interpolates the model equivalent to the observation location for computing the adjustment to apply in the assimilation process, by considering now not a real wind but a “neutral” wind. That consists to neglect in this observation operator the stability correction term noted *COR(CS)*, as it is described in figure 4. We are seeing now how a small cause can have a great effect.

The change was tested always in the frame of the global model Arpège, on a period of one month and half at the end of 2008, exactly between the 22th of November and the 9th of January 2009. It was in an emergency context, after the switch to a neutral wind product for Ascat data from KNMI, at the end of November, by using a new neutral GMF CMOD5.N. The reference of the test was the pre-operational suite of the time, with, among the various changes, a new scheme of turbulence based on Cuxart et al, 2000, whereas the previous scheme, and yet operational, used to be based on Louis ,1979.For Ers-2 data, we also switched the home-made inversion to CMOD5.N, whereas for QuikScat winds, only a bias correction was revised, Qscat-1 being already a neutral GMF.

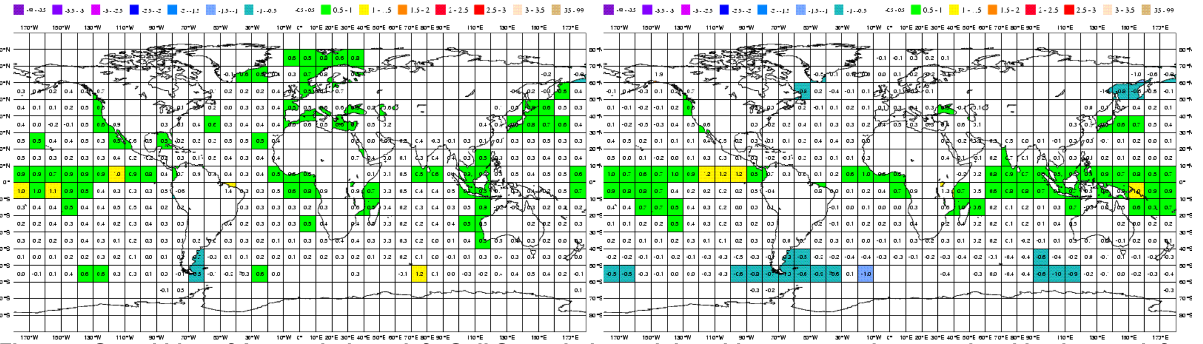


Figure 5: **Speed bias of Ascat winds on left, QuikScat winds on right, with respect to the operational background, from the 23/11/2008 to 08/01/2009. Overall speed bias of +0.3 m.s^{-1} (respectively +0.1 m.s^{-1}) for Ascat (respectively QuikScat). Plotted values by square of 10 degrees in m.s^{-1}.**

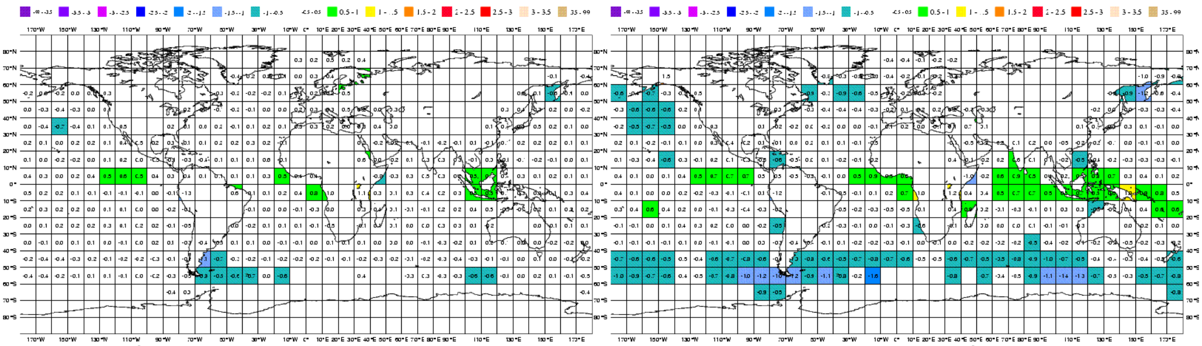


Figure 7: **As figure 6 but speed bias now with respect to the pre-operational background of the time, with a new turbulence scheme (see the main text for further details).**

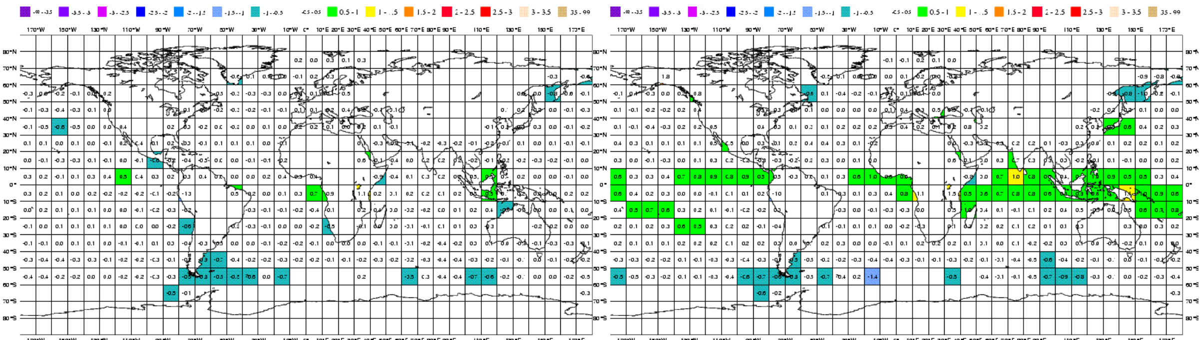


Figure 8: **As figure 7 but now with the neutral wind operator active for scatterometer winds.**

The figure 5 shows the speed bias against the Operational model background on the period of the experiment. Always on left for Ascat winds, on right for QuikScat winds. Positive bias (squares in green and yellow) are located mainly in the ITCZ, and also in the North Hemisphere for Ascat winds, whereas negative bias (in blue) are present in the South Hemisphere, mainly for QuikScat winds. Nevertheless, bias are globally positive, more positive for Ascat winds with +0.3 m/s.

The figure 7 shows the same statistics but against the new pre-operational background of the time. We can see that the positive bias is reduced in the ITCZ, it even disappears all in all for Ascat winds. This latter are almost unbiased, whereas the negative bias for QuikScat winds increases dramatically in the mid-latitudes. If we activate now the neutral-wind operator for the Scatterometer winds in this pre-operational suite, we see, with figure 8, no significant change for Ascat winds whereas the negative bias, seen previously for QuikScat winds, is again reduced, at the price of a very slight increase of the positive bias in the ITCZ. But globally, the bias is reduced.

In short, the neutral-wind operator has a neutral impact for the Ascat winds with respect to the pre-operational suite with its new turbulence scheme, whereas the speed bias is improved for the QuikScat winds with respect to the operational and the pre-operational suites, respectively in the ITCZ and in the mid-latitudes, and with overall a speed bias reduction.

Domain	SUD20									TROPIQ									NORD20								
Range	0	12	24	36	48	60	72	84	96	0	12	24	36	48	60	72	84	96	0	12	24	36	48	60	72	84	96
10								+																			
30	++		++		+																						
50	++		+																								
100																											
150	++	+																									
200	++	+																			+						
250	+	+																		-	++						
300	+	+																		-	+						
400	+																										
500	++	+	+																								
700	++	+	+																								
850	++	++	++																								
925	++	++	++																								
1000	++	++	++														.			-							

Figure 9: **Bootstrap statistic test on the geopotential forecast at different levels, between 1000 hPa on bottom and 10 hPa on top, for different ranges of forecast (in hours, until +96h) on different areas (SUD20: lat<20°S, TROPIQ: 20°S<lat<20°N, NORD20: lat>20°N from left to right). + (resp. ++) means that the test (with the neutral wind operator active) is better than the reference (the pre-operational suite) with 99% (resp. 99.9%) of confidence. - means that the test is worse than the reference with 99% of confidence.**

In term of impact on the forecast skill, the Bootstrap statistic test, with its own analysis as reference, indicates a positive impact of the use of the neutral-wind operator in the pre-operational suite, mainly in the first forecast ranges until 24 hours and in the South Hemisphere, as shown in figure 9 with the forecasts on the geopotential at different isobaric levels and forecast ranges until 4 days. The impact is slightly positive or at worse neutral with the other diagnoses as the Student test or as graphs of RMS differences.

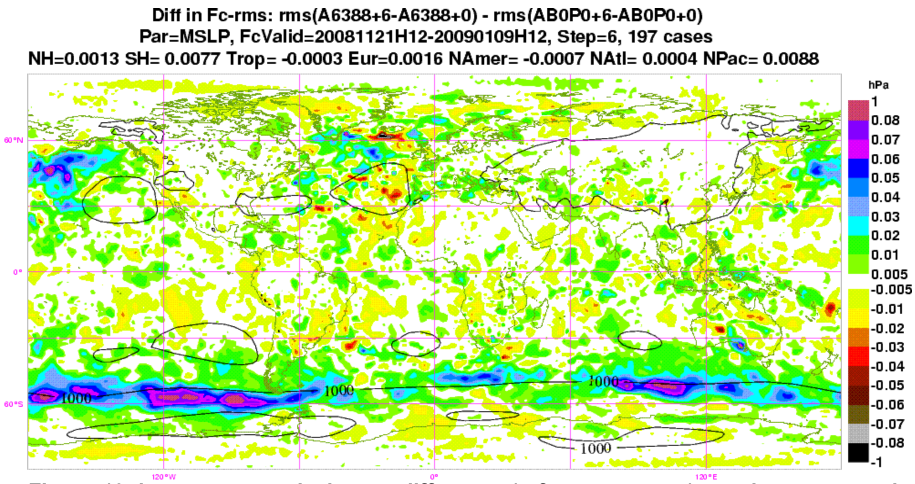


Figure 10: **increments analysis rms difference (reference – test), on the mean sea level pressure, since 21.11 r12 to 09.01 r12, 197 analyses by 6 hours step, scale color in hPa. Blue/purple color indicate an increments reduction for the test (with the neutral wind operator active), whereas red/brown colors indicate an increase, with respect to the reference (the pre-operational suite with a real wind operator)**

This impact is confirmed by the reduction of the analysis increments on the mean sea level pressure, as we can see in blue/purple on the figure 10. We also understand better why the impact is less important in the North hemisphere, because the fraction of land mass is higher. So the neutral-wind operator has became operational since February 2009.

3. CONCLUSION

We have shown that Ascat and QuikScat winds can have an equivalent quality under condition to have an appropriate use for QuikScat winds by using the 4 available solutions.
The introduction of the Neutral-wind operator allows to improve the QuikScat bias. It is without effect on Ascat winds after the turbulence scheme change made in the model and in the end it allows to improve the agreement between the Forecast Model with its Analysis.

Some adjustments remains to be lead in our assimilation process in term of Quality Control, mainly about the Ice contamination (the temperature threshold was initially fixed with the QuikScat 2 solutions algorithm and/or an analyzed sea-ice field could be used), and on a fine use of the Quality Control Flag supplied by the KNMI. There are also some tunings to look on the specification of the observation errors (dependence to the geometry of the instrument through the cell number, to the wind speed) and on the thinning (by reducing it from 100 kilometers to 50 kilometers for example), and at last, it remains some locally speed bias, mainly negative, with perhaps a seasonal dependence (not shown here) to investigate.

After the failure of the Ku-Band instrument on board QuikScat since last November, and the plan to stop ERS-2 this year, these investigations should be conduct in the hope to receive, in Near Real Time, data from the new Indian satellite OceanSat-2, with on board a scatterometer Iscat of same type of SeaWinds on board QuikScat. Later, wind data from Metop-B and the French-Chinese satellite CFOSAT should be also available. We have shown here that the possibility to have different sources of scatterometer winds could help, in addition to improve coverage, to have a better use of this type of data in our assimilation system, with a beneficial effect on the forecasts skill.

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