Numerical Weather Prediction

SeaWinds Revisited

Forecasting Research Technical Report No. 472

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Approvals.

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Contents.

Executive summary.

Data are presented in this report that demonstrate that measurements from the QuikSCAT scatterometer instrument have a bias of approximately 0.6m/s compared to wind speeds recorded on fixed platforms in the ocean. Comparison with model background field values also reinforces this result. It is also shown that applying a bias correction to the QuikSCAT wind speed data produces a higher bias in the 0-5m/s regime and a lower bias in the 5-15m/s regime than for the uncorrected QuikSCAT wind speed data. The present bias correction is also shown to produce larger negative biases at higher wind speeds. The QuikSCAT data are also compared with ERS2 radar altimeter wind speed data and a bias of ~1m/s is found, although this study was limited by the low number of match-ups arising from the ERS RA coverage problem. A new set of bias correction coefficients are proposed based on a study of 3 months of QuikSCAT data. These new coefficients have been incorporated into a forecast trial on the SX6 via a change to the scatterometer namelist. The results of the trial are presented in section 5 of this report along with a recommendation that these new coefficients should be included in the next SA upgrade package.

The annexes to this report describe other proposed changes to the OPS (QuikSCAT swath use changes, MLE, rain flag settings and U and V component errors), which were found to be unadvisable following various studies and are therefore kept separate from the main body of the report.

1. Introduction.

The aim of this report is to describe proposed changes to the way that the OPS processes QuikSCAT data in order to produce a positive benefit for NWP. Many of these changes follow signs from Stoffelen 1998 and Portabella 2002, which demonstrate that improvements in the use of QuikSCAT are possible. These changes were originally proposed to be:

- QuikSCAT bias correction
- Usage of QuikSCAT swath
- MLE threshold setting and normalisation scheme
- Rain flag setting
- U and V component error investigation

However, the major success of the above investigations turned out to be the benefit to NWP that was shown to result from revisiting the QuikSCAT bias correction. For this reason the swath, MLE, rain flag and U and V component error investigations are reported as annexes to this document so as not to detract attention from the main result.

A bias correction is currently applied to QuikSCAT wind speeds prior to assimilation in the Met Office model because a bias was observed in the data when they were first being studied (Candy and Offiler 2002). It was thought to be time to revisit this situation to see if this bias correction is still necessary in the light of any improvements that may have been made at NESDIS to the QuikSCAT product and any improvements that may have been made to the Met Office model.

One of the important justifications for this work was the observation made by NMC (National Meteorological Centre) that model winds appear to be too low compared to QuikSCAT near to the centre of deep depressions. This gives the impression that the modelled depression is weaker than it actually is. It is therefore important to try to adjust QuikSCAT data to better represent the true situation at higher wind speeds. This is not easy because high winds are not common so there will be limited data for tuning a bias correction scheme at high winds.

To check the magnitude of the QuikSCAT wind speed data, the data are compared in section 2 of this report with data from model background field and fixed ocean platforms. Fixed platforms here are taken to be moored buoys, oil/gas platforms and light vessels that report data to the Met Office. The period of interest was 22/5/2004 – 16/6/2004. Over 4,800 match up points were obtained. In addition, bias corrected and uncorrected QuikSCAT data are compared with analysis and background wind speed values. This resulted in over 8 million data points for the period 22/5/2004 – 16/6/2004, which is 26 days.

To confirm the results of the comparison with fixed platforms, the QuikSCAT wind speed data are compared with wind speed data from the ERS radar altimeter. These results are shown in section 3 of this report. In section 4 a new set of bias correction coefficients are computed using three months of QuikSCAT data and model data merged back into MetDB. These coefficients were included in an N144 3D Var forecast trial and the results are presented in section 5.

2. Comparison of QuikSCAT with fixed platform data.

In order to look for a bias in the QuikSCAT wind speed data it is useful to collocate them with data from fixed ocean platforms. The period used for this analysis was 22nd May 2004 – 16th June 2004. This gave a total of 26 days of data. This period was used as analysis mergeback data was available in the MetDB. The figure below (figure 2.1) shows the geographical distribution of the match ups.

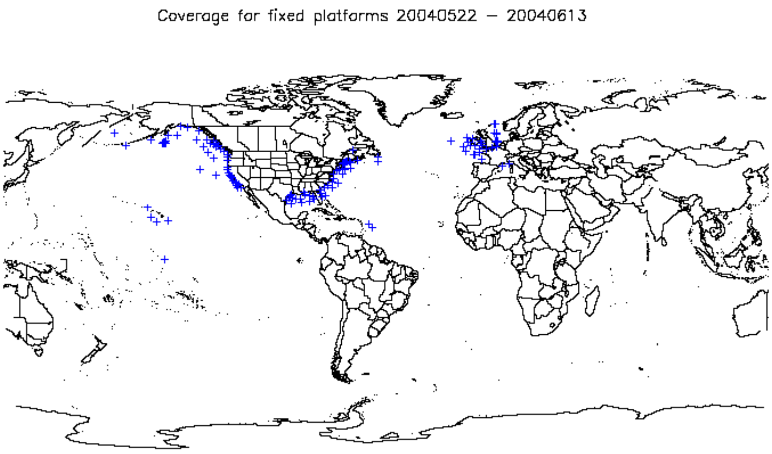


Figure 2.1 Blue crosses show the location of fixed platforms used in this analysis. Most are located off the coast of the USA and Canada or UK with a few existing in the Pacific and equatorial Atlantic.

The match up process used the following criteria. To be considered to be coincident the measurements must be within 50km of the QuikSCAT measurement cell centre and performed within 59 minutes of the overpass. In the event that several QuikSCAT points fulfilled this criteria for a single fixed platform measurement the match up was taken to be the QuikSCAT data point that was spatially closest. This resulted with a mean distance of ~7.5km between the fixed platform and QuikSCAT measurements with a standard deviation of ~4.3km.

An extra analysis was performed as a check. This involved using QuikSCAT data only and the associated analysis and background field data. This analysis is presented in the section 2.6 of the report.

2.1 Results of comparing QuikSCAT with fixed platforms.

The resulting data from the match up process described in the method had to be filtered to eliminate data that contained erroneous Fixed Platform data (e.g. there was one record where QuikSCAT was recording ~10m/s wind speed while a buoy was reporting 90m/s!). This filtering was achieved by ignoring any match up which did not satisfy the wind speed criteria that ABS(QuikSCAT-FixedPlatform) =< 8m/s. This only meant eliminating approximately 0.3% of the match up data.

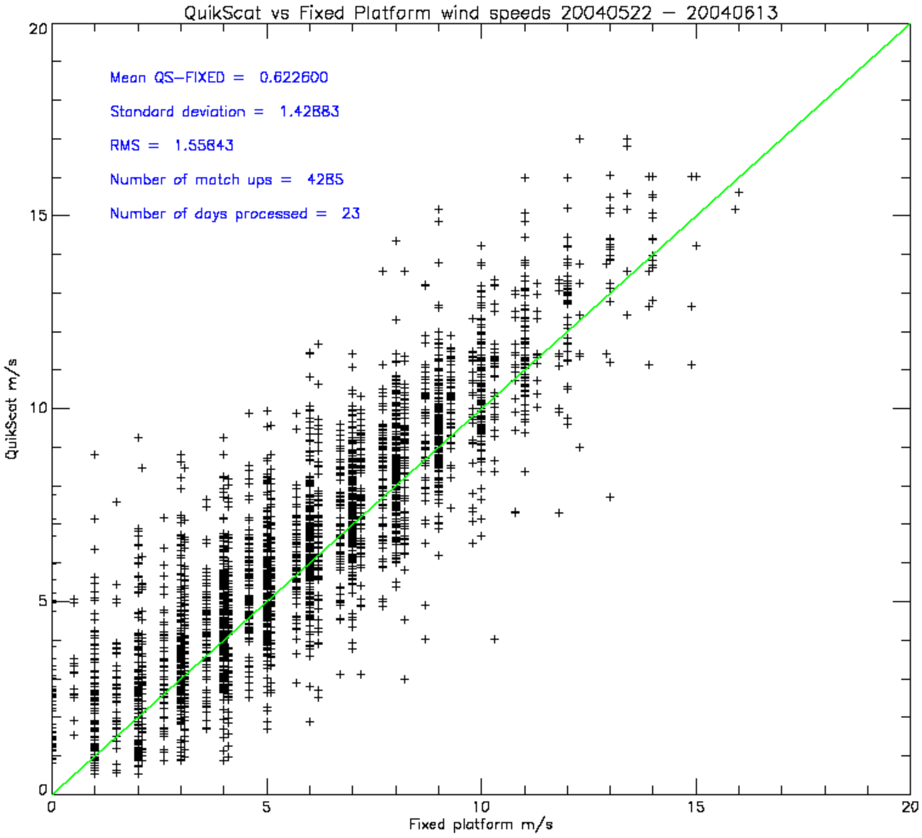


Figure 2.1.1 Fixed Platform wind speeds versus those measured by QuikSCAT.

The data show that there is a bias of approximately 0.62m/s between the QuikSCAT and Fixed Platform wind speeds (see figure 2.1.1) with a standard deviation of ~1.43m/s.

2.2 Comparison of QuikSCAT with Model Background.

The same process was followed as in 2.1 to produce figure 2.2.1 below. It can be seen that there is also a positive bias of approximately 0.48m/s between the QuikSCAT and Background Field wind speed data with a standard deviation of ~1.46m/s.

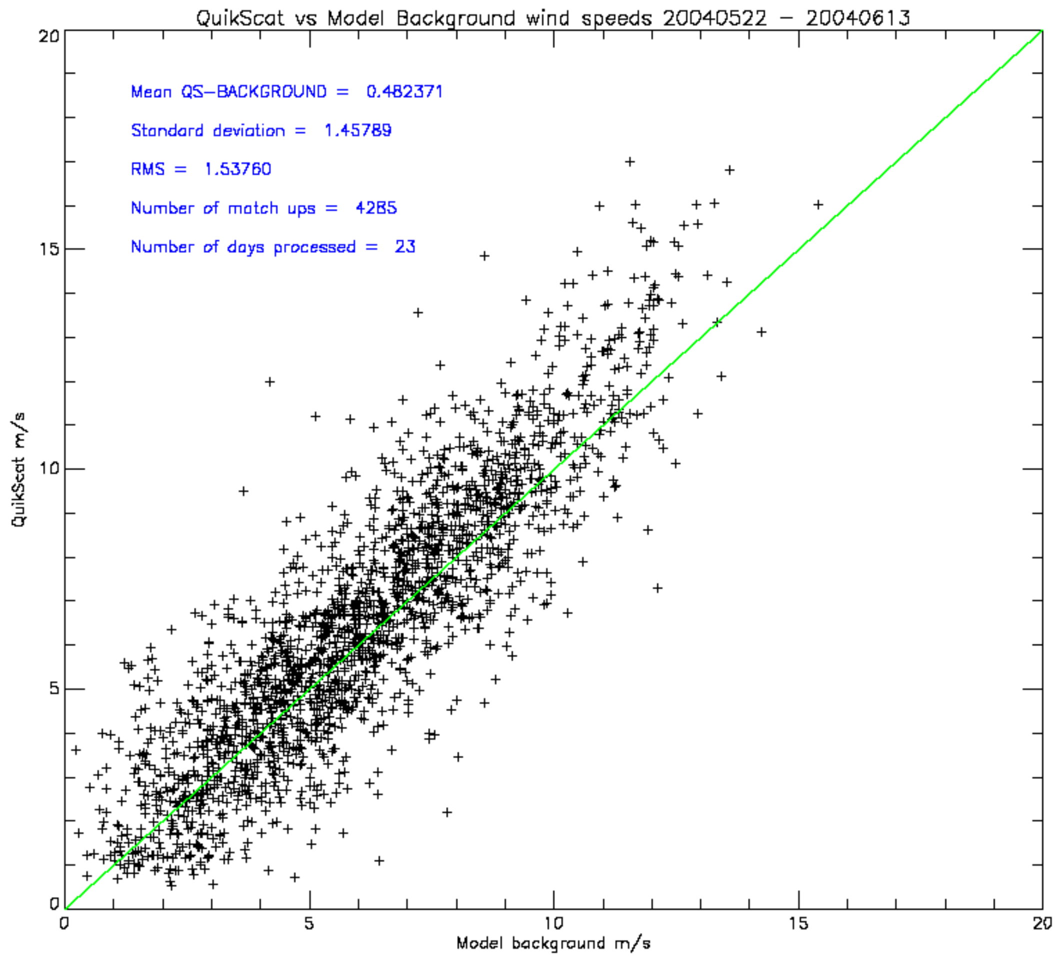


Figure 2.2.1 QuikSCAT wind speeds versus those from the Model Background Field.

2.3 Comparison of Model Background with Fixed Platforms.

The same process as described above was used to generate the comparison between the Model Background Field and the Fixed Platform wind speed data. It is shown in the figure that there is a negative bias of -0.15m/s between the Model Background and the Fixed Platform wind speeds with a standard deviation of ~1.6m/s in the differences. The results are shown in figure 2.3.1 below.

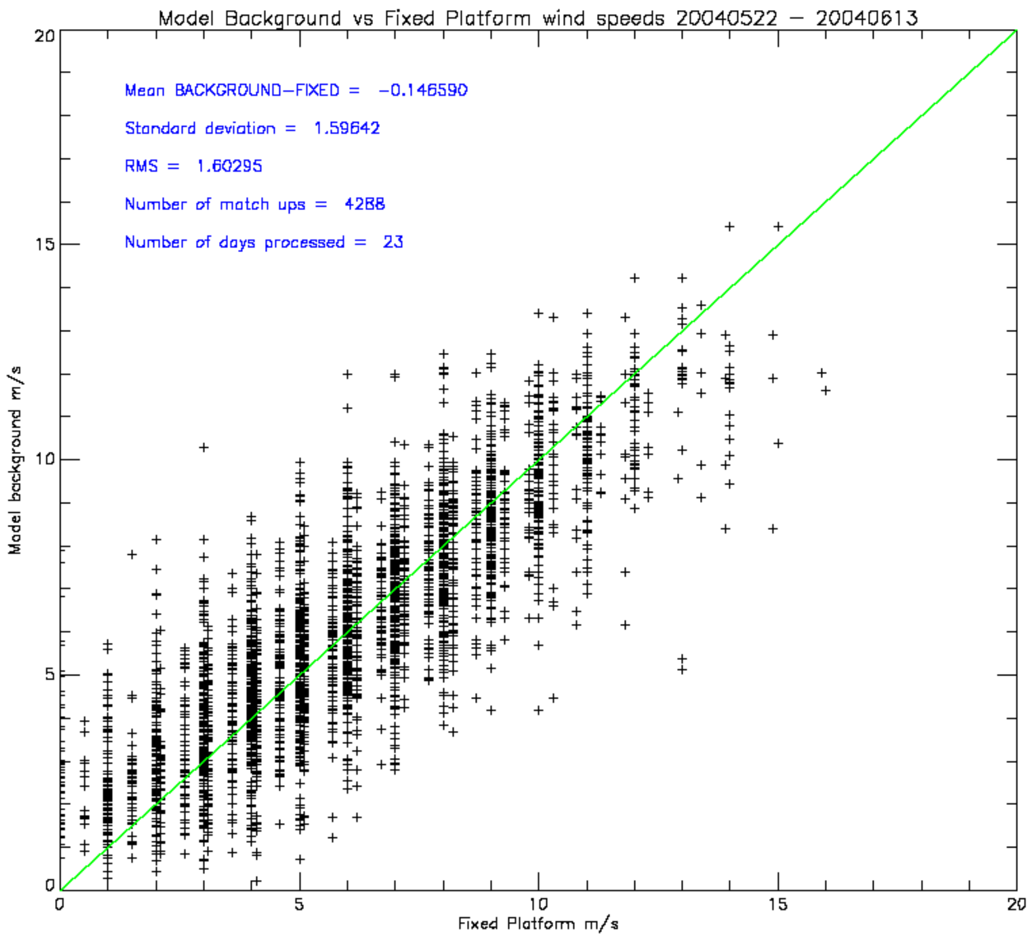


Figure 2.3.1 Model Background Field wind speeds versus those recorded by Fixed Platforms.

2.4 Comparison of bias corrected wind speeds with fixed platforms.

Data from the SEAWINDS scatterometer are bias corrected in the observations processing system. This bias correction (Equation 1) is applied to all SEAWINDS data prior to quality control procedures and assimilation. The coefficient values are defined in the operational namelist "WindRetrieval.nl" and are valid for winds up to 40m/s, though only bias corrected winds less than 25m/s and greater than 2m/s are subsequently used in the 4D Var assimilation process.

$$BC\_wind\_speed = BC1 + BC2*ws + BC3*ws^2 + BC4*ws^3$$ *Equation 1.*

Where;

BC_wind_speed = bias corrected wind speed
ws = uncorrected wind speed from QuikSCAT in m/s
BC1 = 1.0277 m/s
BC2 = 0.7629
BC3 = 0.007126 s/m
BC4 = -0.0002554 s^2/m^2

It is important to note though that this is the old bias correction, developed in 2002, which has different coefficients from that derived later in section 4. Below we examine the validity of this old bias correction and underline the need for it to be revised.

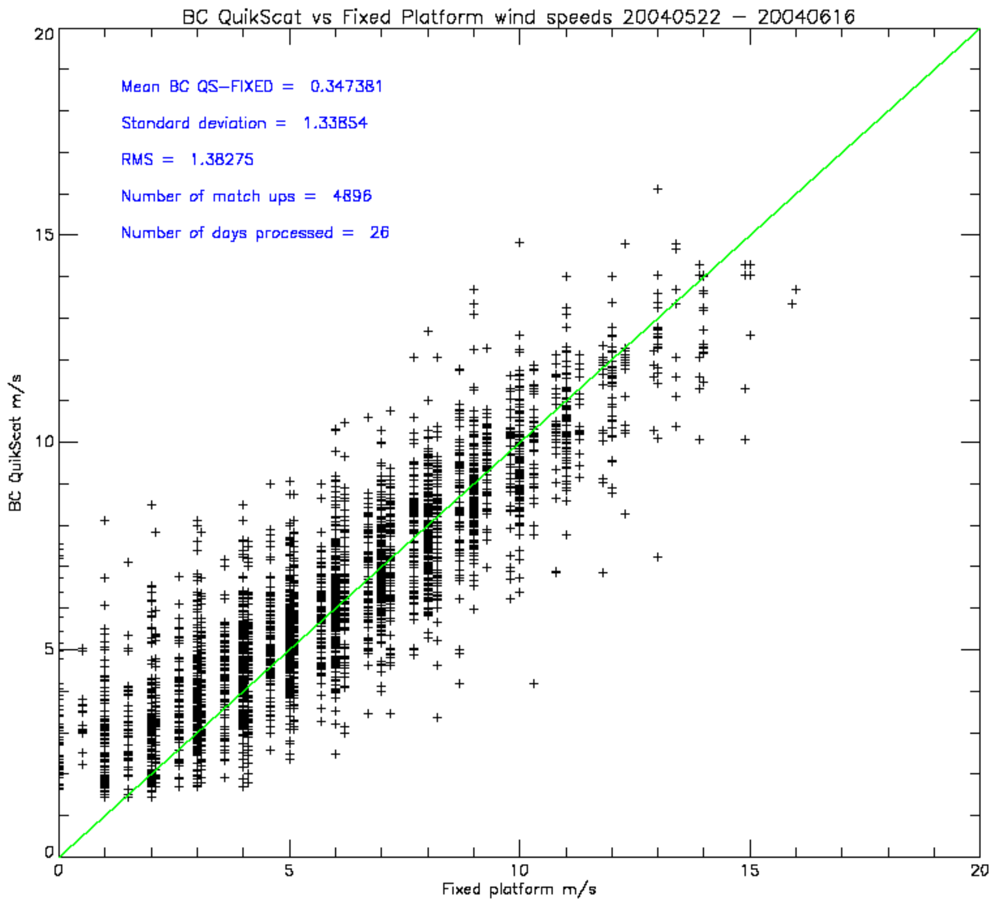


Figure 2.4.1 Bias corrected QuikSCAT wind speed versus fixed platform wind speed.

Bias corrected wind speeds were compared with fixed platform wind speeds and the results are shown in figure 2.4.1. The mean difference was 0.35m/s with a standard deviation of 1.33m/s. This demonstrates that, relative to the fixed platform observations, the bias correction has had a positive effect when the data in figure 2.1.1 are considered.

2.5 Comparison of bias corrected wind speeds with model background fields.

The bias corrected wind speeds were compared with model background field data and the results are shown in figure 2.5.1 below. The mean difference was 0.21m/s and the standard deviation was 1.28m/s. This again is a improvement over the results displayed in figure 2.2.1. The standard deviation is reduced significantly by ~25%. The reduction in bias by the bias correction is of the order of 50%, which is useful but could be better. It is for this reason that the bias correction was reworked as is described later in section 4.

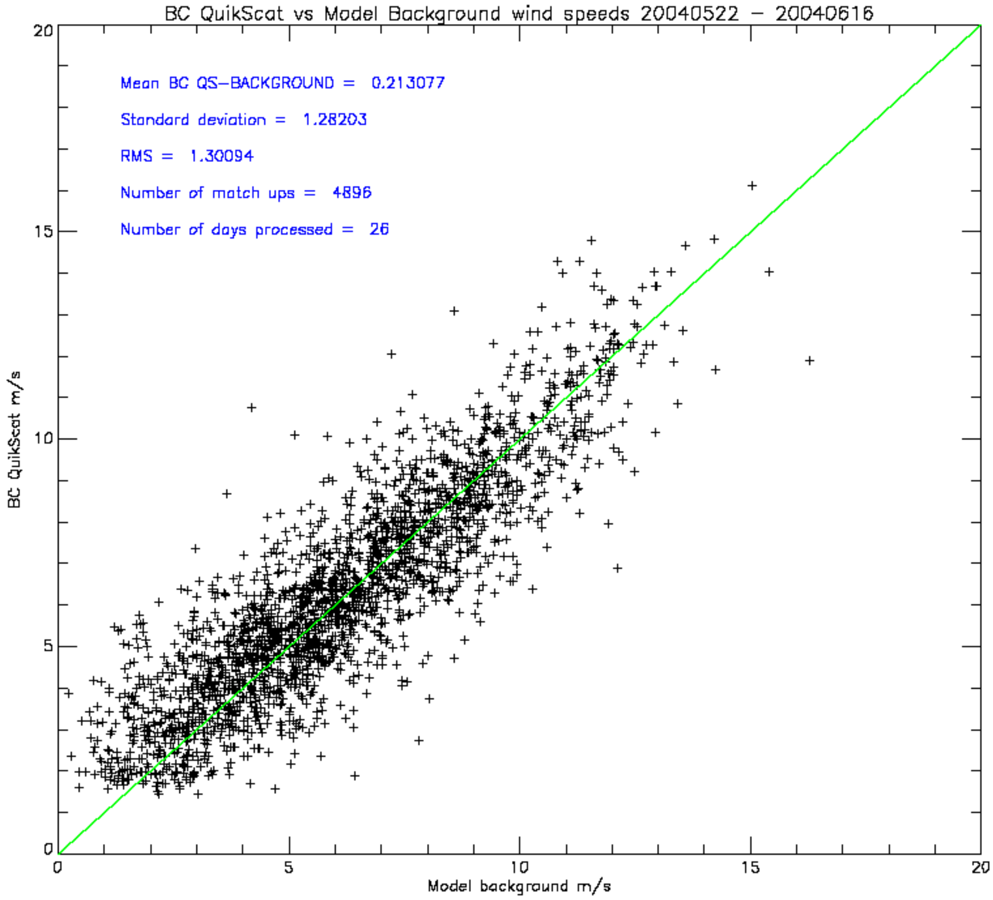


Figure 2.5.1 Bias corrected wind speeds compared with model background fields.

2.6 Discussion of results for QuikSCAT comparison with fixed platforms.

The statistics from the above comparisons are summarised in table 2.6.1. It is clear that if the Fixed Platform data are to be regarded as ‘truth’ then there does appear to be a bias of around 0.6m/s in the QuikSCAT wind speeds as they are reported.

Table 2.6.1 Comparison statistics.

Comparison	Mean difference m/s	Standard deviation m/s	RMS m/s
QuikSCAT - Fixed	+0.62	1.43	1.56
BC QuikSCAT – Fixed	+0.35	1.33	1.38
QuikSCAT - Background	+0.48	1.46	1.54
BC QuikSCAT - Background	+0.21	1.28	1.30
Background-Fixed	-0.15	1.60	1.60

The comparison with QuikSCAT and the background field yielded similar results although this may be because the background field is heavy weighted towards the buoy observations as these measurements tend to be made in otherwise data sparse regions.

The bias correction of the data that is performed in the OPS has had a significant effect on the average bias, which is reduced from 0.62 to 0.35 when compared to fixed platform data. The corresponding standard deviations in the different biases was also significantly reduced from 1.43 to 1.33.

Further work was required to ascertain whether or not the bias is constant with wind speed or whether there is instead a dependency on wind speed.

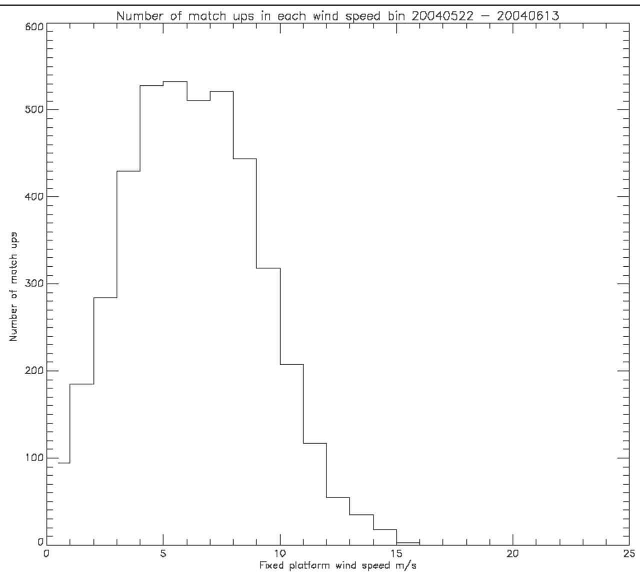


Figure 2.6.1 Number of match ups in each 1m/s bin.

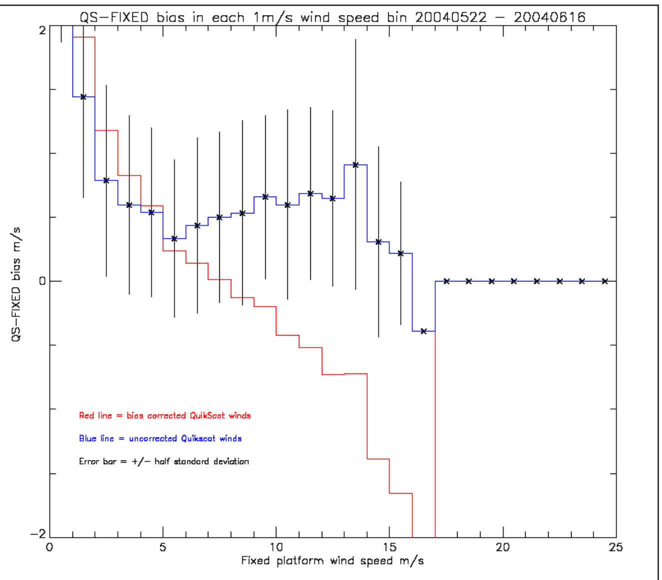


Figure 2.6.2 Bias between QuikSCAT (corrected and uncorrected) and Fixed Platform wind speeds for wind speeds 0-25m/s. Note that above 15m/s there are very few match ups.

The figures (2.6.1 and 2.6.2) demonstrate that most of the match ups occur at wind speeds between 1-15m/s. This means that the biases in figure 2.6.2 are only really valid in this range. Error bars are plotted in figure 2.6.2 to represent the standard deviations in the biases. Where the bias is made up of only a single match up the error bar is set to zero.

Figures 2.6.3 and 2.6.4 were produced similarly to figures 2.6.1 and 2.6.2 but using model background values instead of those from fixed platforms.

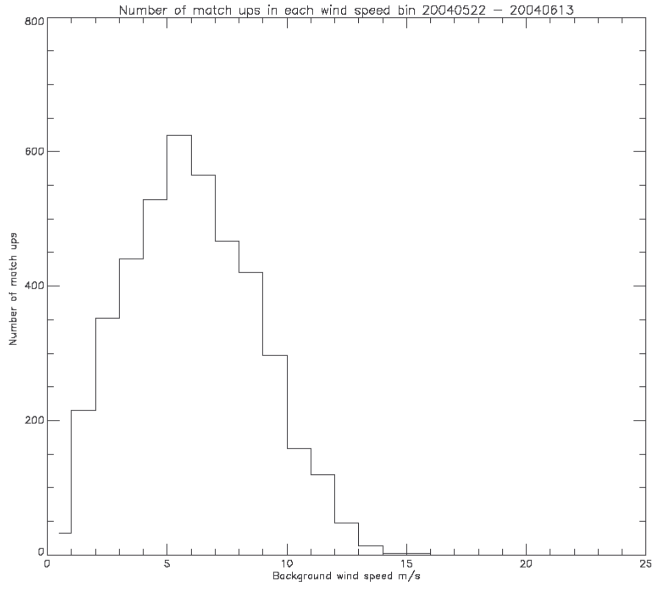


Figure 2.6.3 Plot showing the number of match ups in each 1m/s wind speed bin.

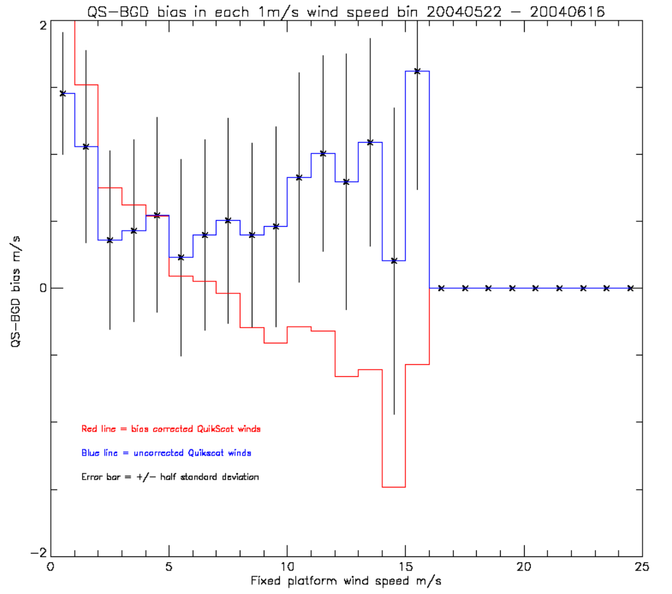


Figure 2.6.4 plot showing the mean bias between QuikSCAT wind speeds (corrected and uncorrected) and those from the model background fields.

Again the number of match ups is concentrated between 1-15m/s as is evident in figure 2.6.3. Figures 2.6.2 and 2.6.4 are broadly similar in that they both show a decreasing bias in the range 0-15m/s.

There are two interesting points to note from figures 2.6.2 and 2.6.4, which are:

- Both the uncorrected and corrected wind speeds from QuikSCAT appear to overestimate the true wind speed (assuming the fixed platform or background field values to be true) by as much as 2m/s at very low wind speed, which is a large percentage error.
- In the 0-15m/s regime the bias corrected QuikSCAT wind speed biases continually decrease with wind speed. If we can extrapolate this trend then it could be the case the large negative biases are evident at very high wind speeds, although there was no fixed platform data available to evaluate this hypothesis.

To look at the case of higher wind speeds the bias corrected and uncorrected QuikSCAT data were binned by both analysis and background wind speeds and are plotted below as histograms in figures 2.6.5 and 2.6.6. These figures demonstrate that the bias correction has a very low mean (e.g. for O-A = 0.047m/s) but there is a decreasing trend in the bias, which becomes increasingly negative at the higher wind speeds making the bias correction invalid. It is believed that this is because

- The original bias correction polynomial was tuned against data from 2002 and that in the intervening years since then the Met Office model and/or QuikSCAT wind product has improved, thereby making the original bias correction inaccurate for this period.
- The original polynomial was a basic regression against model background, which produces data consistent when binned one way but not the other (e.g. when binned by observations but not when binned by model background values.

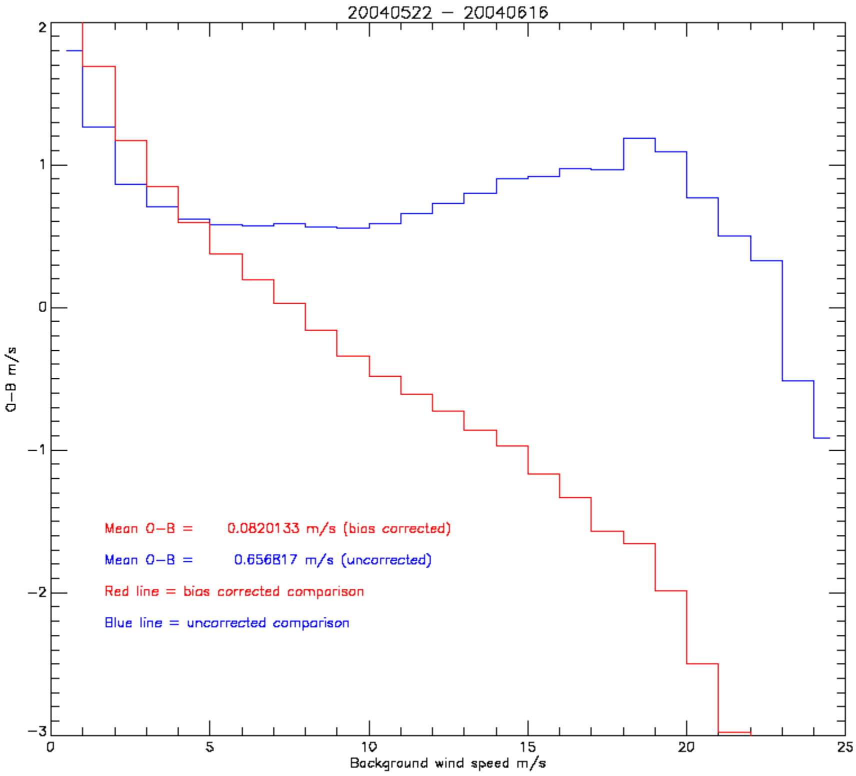


Figure 2.6.5 O-B plotted versus background wind speeds for all QuikSCAT data in the period.

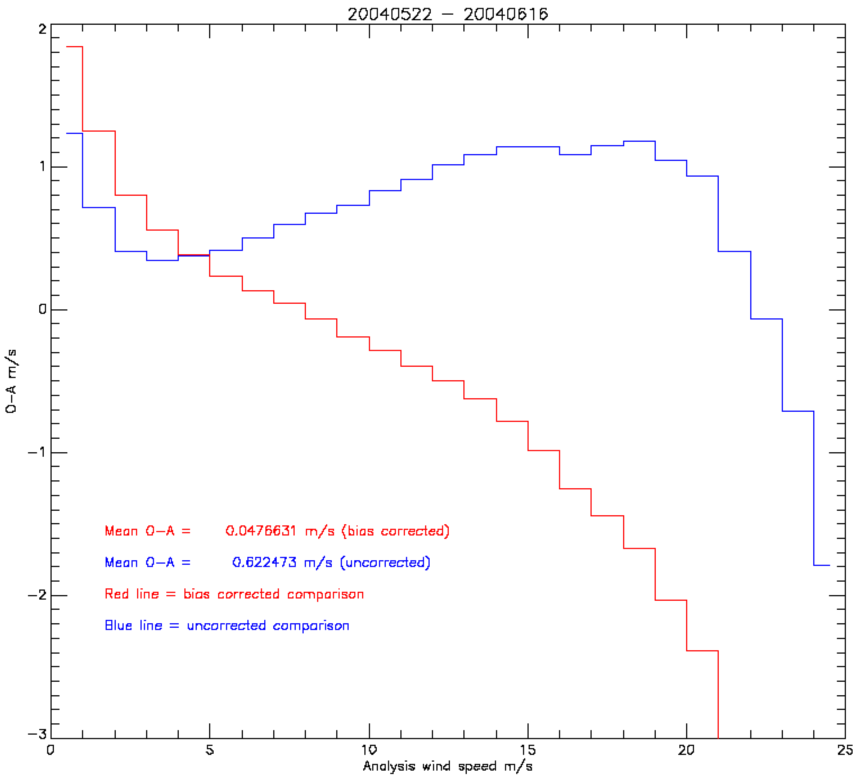


Figure 2.6.6 O-A plotted versus analysis wind speeds for all QuikSCAT data in the period.

In order to further examine the effects of the bias correction the above plots were reproduced but this time with the x axis being the observed rather than modelled wind speed. These results are described in figures 2.6.7 and 2.6.8 below. These actually show that the old bias correction is still beneficial but only when binned by observation, which may give a misleading impression that it is still doing a good job. The previous figures (2.6.5 and 2.6.6) however demonstrate that this is not the case and that we ought to do better.

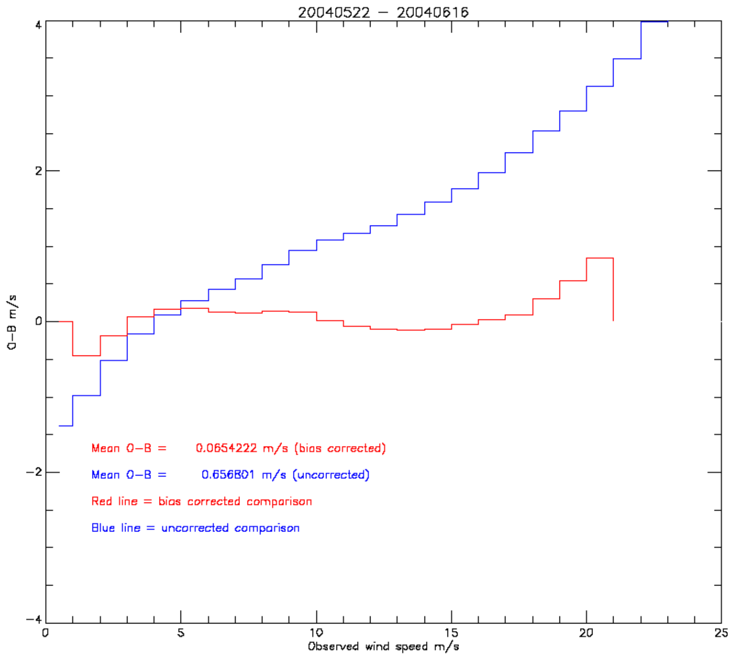


Figure 2.6.7 O-B plotted versus uncorrected wind speed from QuikSCAT.

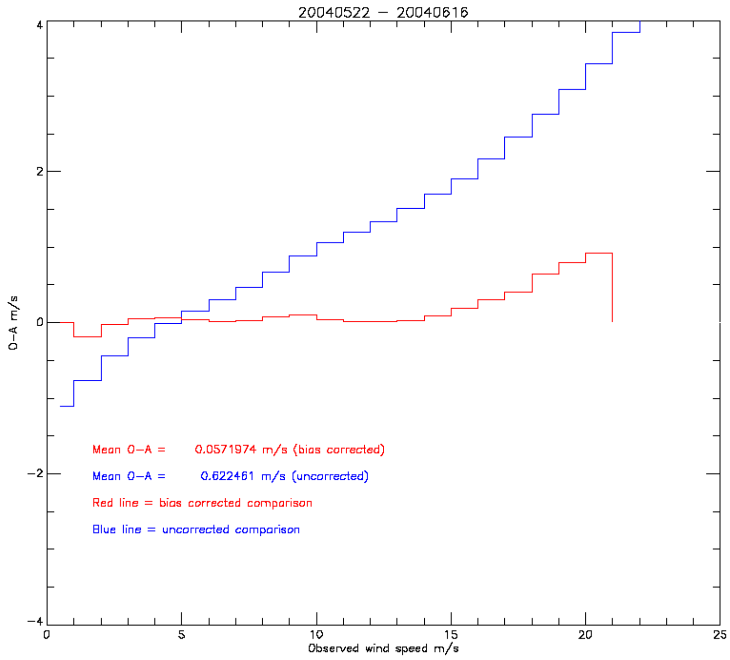


Figure 2.6.8 O-A plotted versus uncorrected wind speed from QuikSCAT.

Compare the results in figure 2.6.8 with those in figure 2.6.9 taken from ref. (i).

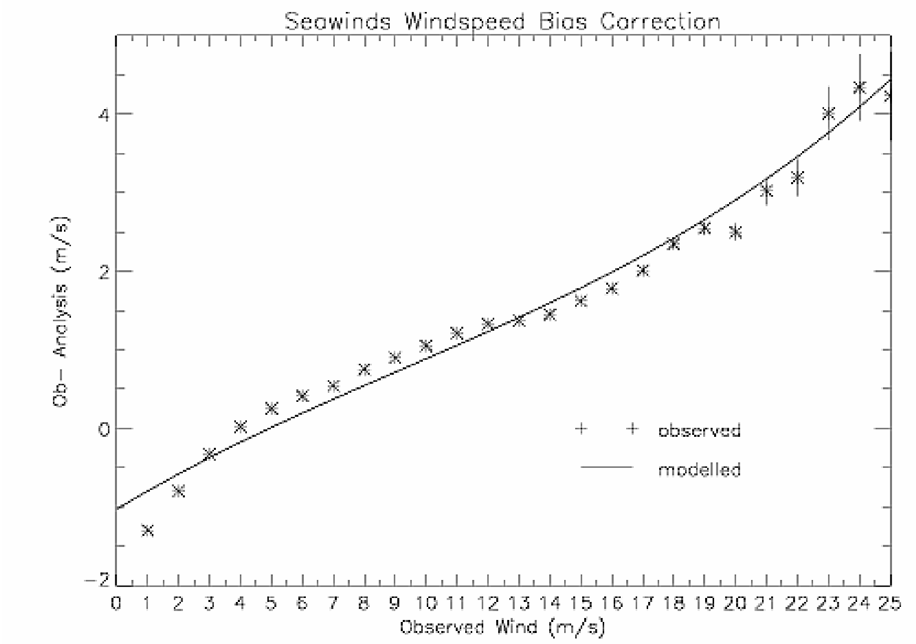


Figure 2.6.9 O-A versus uncorrected QuikSCAT wind speed.

It is clear that there are large biases at high reported wind speeds from figures 2.6.7 and 2.6.8 if B and A values are considered to be close to the truth.

When a bias correction is applied (red lines in figures 2.6.7 and 2.6.8) then the average bias corrected O-B and O-A values are small in each observed (uncorrected) wind speed bin.

3. Comparison of QuikSCAT with ERS Radar Altimeter.

A study has been performed in section 2 to investigate the performance of QuikSCAT relative to 'fixed' ocean platform observations of wind speed. The study demonstrated that QuikSCAT had a positive bias with respect to the in situ ocean observations, which supports the NMC comments reported in the introduction of this document. It was recommended that QuikSCAT be compared with radar altimeter wind speed observations so that this positive bias could be verified as radar altimeter winds are not assimilated. The ultimate aim of comparing QuikSCAT data with several independent data sources is to check that the QuikSCAT bias correction (described in ref. (i)) that is currently applied to QuikSCAT is performing well and to recommend changes to the bias correction if this is found not to be the case.

A QuikSCAT observation was considered to be a match for an altimeter observation if it fulfilled two criteria;

- The observation was within +/- half an hour of the altimeter observation

and

- The observation was within a 10km radius of the altimeter observation

This yielded 961 match ups for the 18 day period from 1st -18th July 2004.

3.1 Match up coverage.

The ERSURA data in MetDB are limited to areas of the northern hemisphere due to problems with the ERS platform. This resulted in this analysis only containing match ups from the far northern hemisphere. The coverage of the match ups is demonstrated in figure 3.1 below.

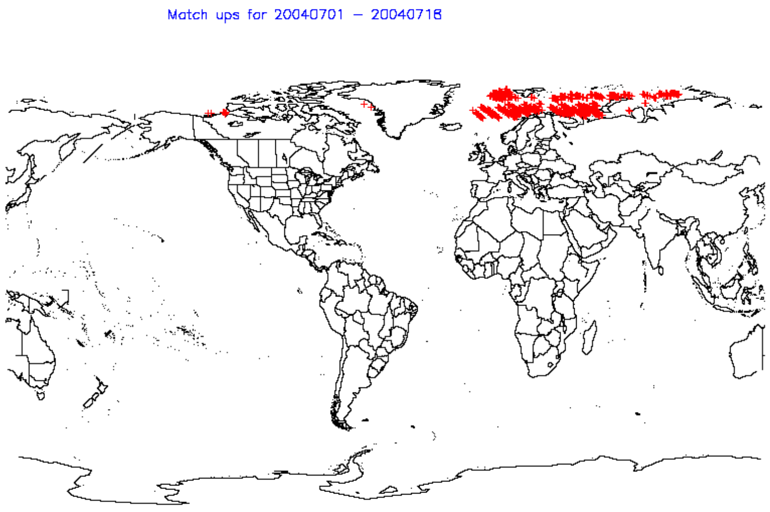


Figure 3.1.1 Coverage of Match up points.

3.2 Wind speed distribution for period.

The wind speed distribution in figure 3.2.1 is produced from ERS radar altimeter measurements.

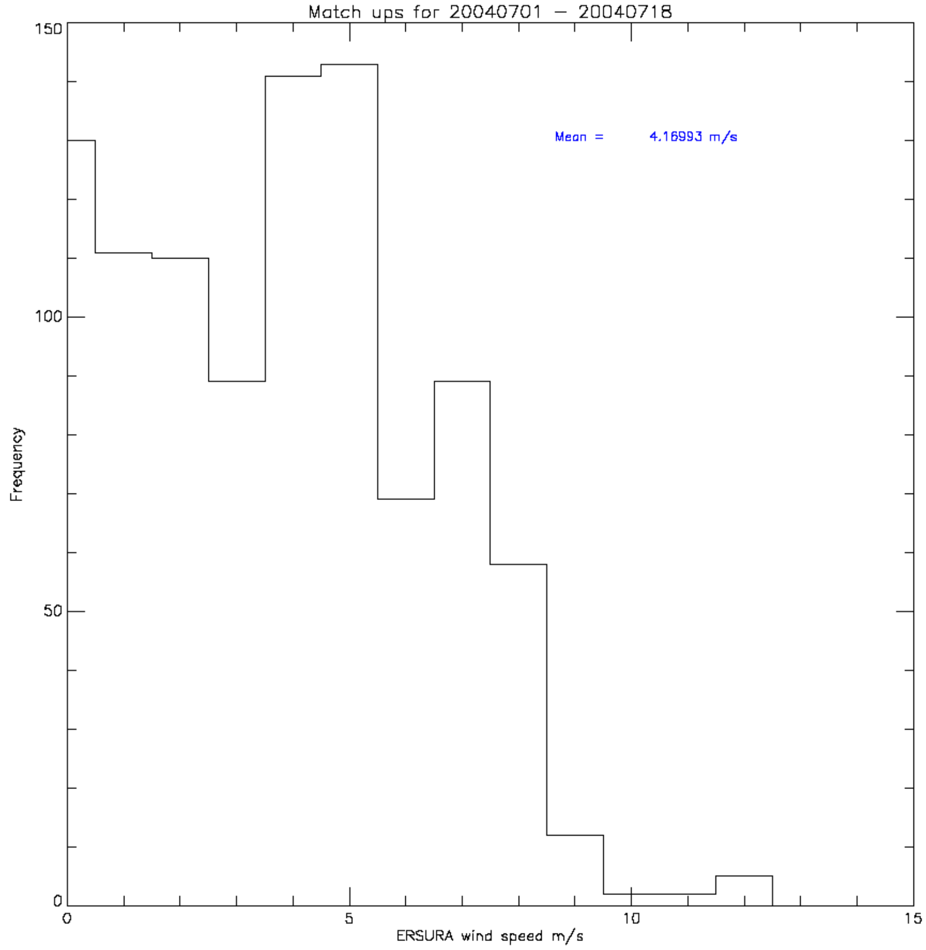


Figure 3.2.1 Wind speed distribution from ERS radar altimeter.

3.3 Wind speed statistics for match ups between QuikSCAT and the ERS radar altimeter.

QuikSCAT and ERSURA wind speeds are plotted in figure 3.3.1 It can be seen that there is a positive bias of 1.01m/s between the QuikSCAT and ERSURA wind speed observations with a standard deviation of 0.96m/s and an RMS difference of 1.39m/s. These figures are for 961 match ups derived over 18 days.

As the mean wind speed is so low (only ~4m/s) the statistics were generated again using only the match ups where the ERSURA wind speed was greater than 2m/s (and a mean wind speed of ~5.6m/s). The mean bias fell to ~0.80m/s from 1.00m/s and the standard deviation also fell to 0.72m/s from 0.96m/s.

Worryingly, the mean QuikSCAT O-A and O-B values were negative for these 961 match ups, which gives the impression that the QuikSCAT observations were low compared to the model and high compared to the radar altimeter. Daily monitoring of QuikSCAT has found that O-A biases of +0.6m/s are more usual. This discrepancy is likely to be due to the small number of match ups obtained here (961) compared to the millions of QuikSCAT observations used to estimate the mean O-A and O-B biases. This means that statistically there are unlikely to be enough samples here to draw any conclusions.

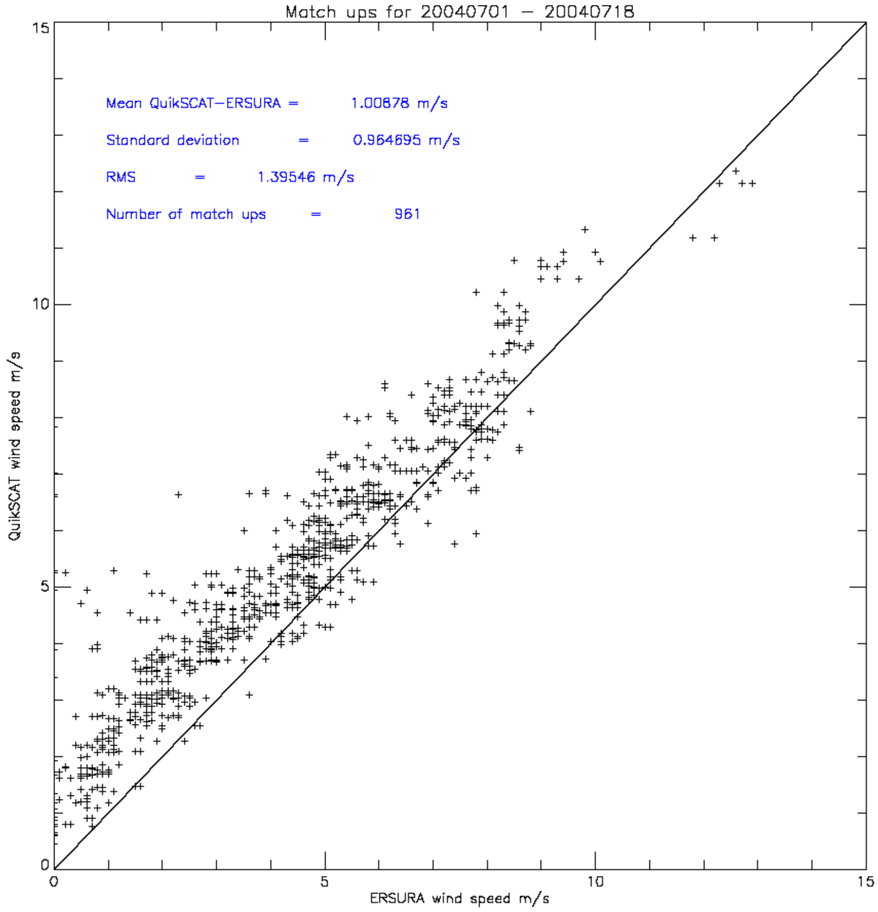


Figure 3.3.1 Radar altimeter wind speed observations versus QuikSCAT wind speed observations. Note that the solid line Y=X is plotted for clarity.

3.4 Discussion on comparison of QuikSCAT with ERS Radar Altimeter.

It appears that there is also a positive bias between QuikSCAT and ERSURA wind speed data in the range 0-15m/s although there are very few match ups above 10m/s to be confident that this bias will still be the case at higher wind speeds. The results of this study do however back up the findings in section 2, which demonstrated that QuikSCAT had a positive bias of approximately 0.6m/s relative to observations obtained from fixed ocean platforms. However, the mean wind speed in this match up data set was only ~4m/s, which (compared to a global mean of ~7m/s) has biased this study somewhat towards the lower wind speed regime. A much larger match up data set is really required for this study to be more statistically significant but unfortunately the coverage of ERSURA data is very limited at this time.

4. New bias correction.

It was decided to review the bias correction polynomial used by the OPS to see if a better polynomial could be fitted to the data. Three months of QuikSCAT and Met Office model analysis data (August-October 2004) were used to produce a new wind speed bias correction for QuikSCAT. Each day of data was binned first by observed wind speed and then by analysis wind speed. With hindsight, it could be argued that the new bias correction coefficients could be better produced by comparing observations with background values rather than analysis values. However, as the analysis is likely to be far more dominated by other observation types (e.g. SSMI) it is unlikely that any significant differences would result in either case. It should be noted that the bias correction has been developed for the operational swath only. Conditions were set to mirror the operational configuration as far as possible e.g. upper wind speed limit set to 25m/s.

4.1 Comparison of old bias correction with uncorrected case.

Figure 4.1.1 demonstrates that the old bias correction (in red) produced a positive benefit compared to how the data would have looked if it were not corrected (in black). In the ideal case the two curves (corresponding to data binned firstly by analysis and then observation) would be close to and symmetrical about the line Y=X. The red data points for the bias corrected case are clearly more in agreement with the ideal case than the black uncorrected data points.

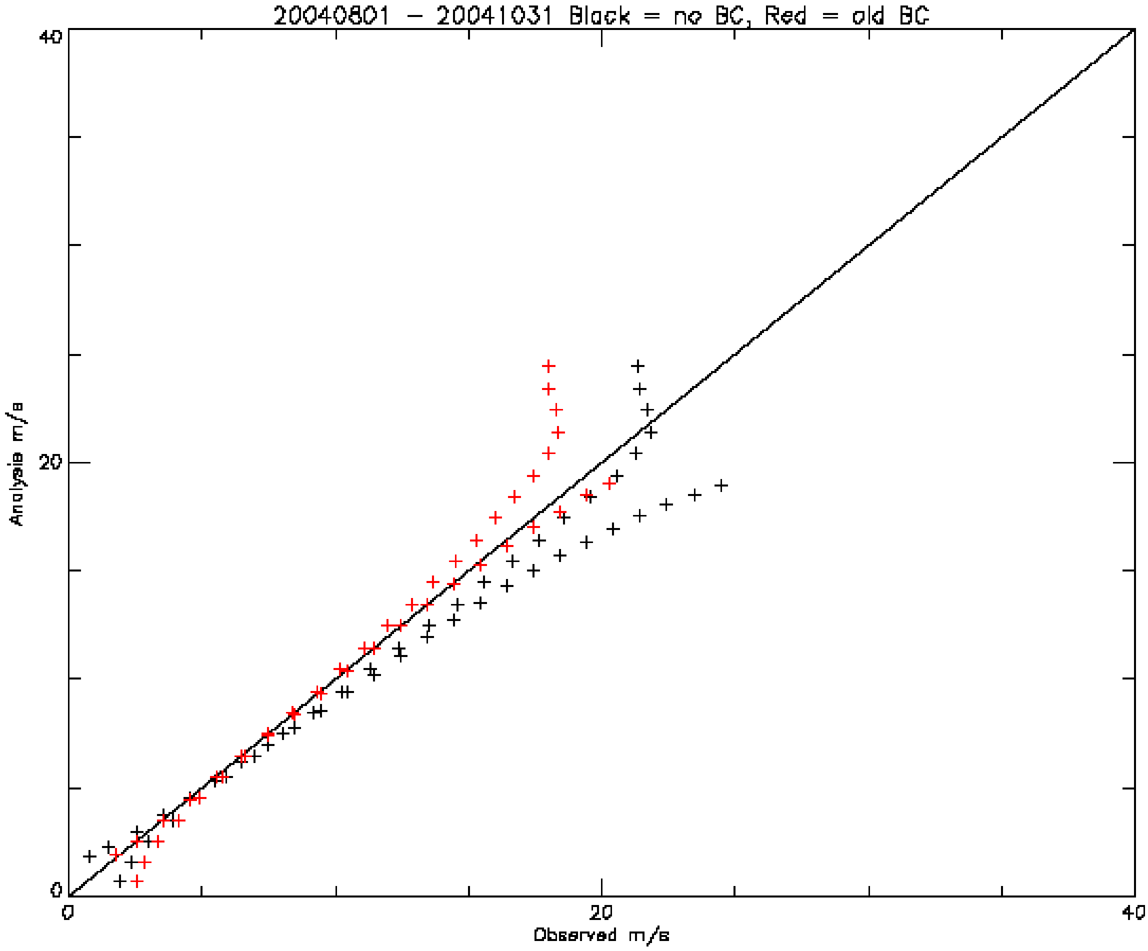


Figure 4.1.1 Uncorrected (black) and old bias corrected (red) for binned by observation and analysis.

4.2 Construction of the new polynomial fit.

The new polynomial fit will also be of the same form as the polynomial fit for the old bias correction as detailed in ref (i). This is **$Y = a + bX + cX^2 + dX^3$** , where Y=bias corrected wind speed and X=observed wind speed. This resulted in the following new coefficients [a,b,c,d], which now replace the old bias correction coefficients.

New coefficients = [1.11220,0.488799,0.0418553,-0.00115649]
Old coefficients = [1.0277,0.7629,0.007126,-0.0002554]

Figure 4.2.1 shows the form of the new polynomial (green) which fits between the two sets of black data points, which are the uncorrected data binned firstly by observed wind speed and then by analysis wind speed.

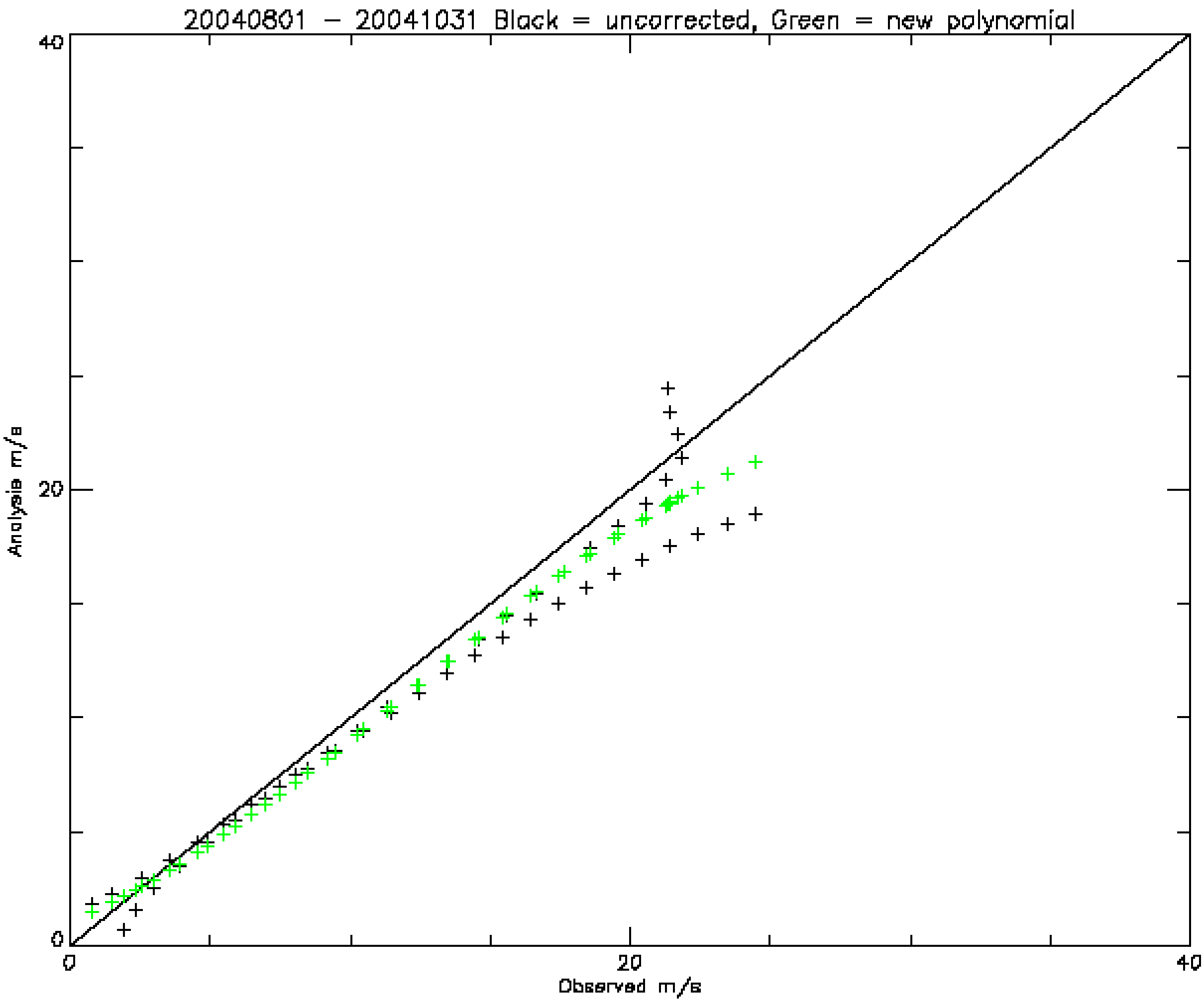
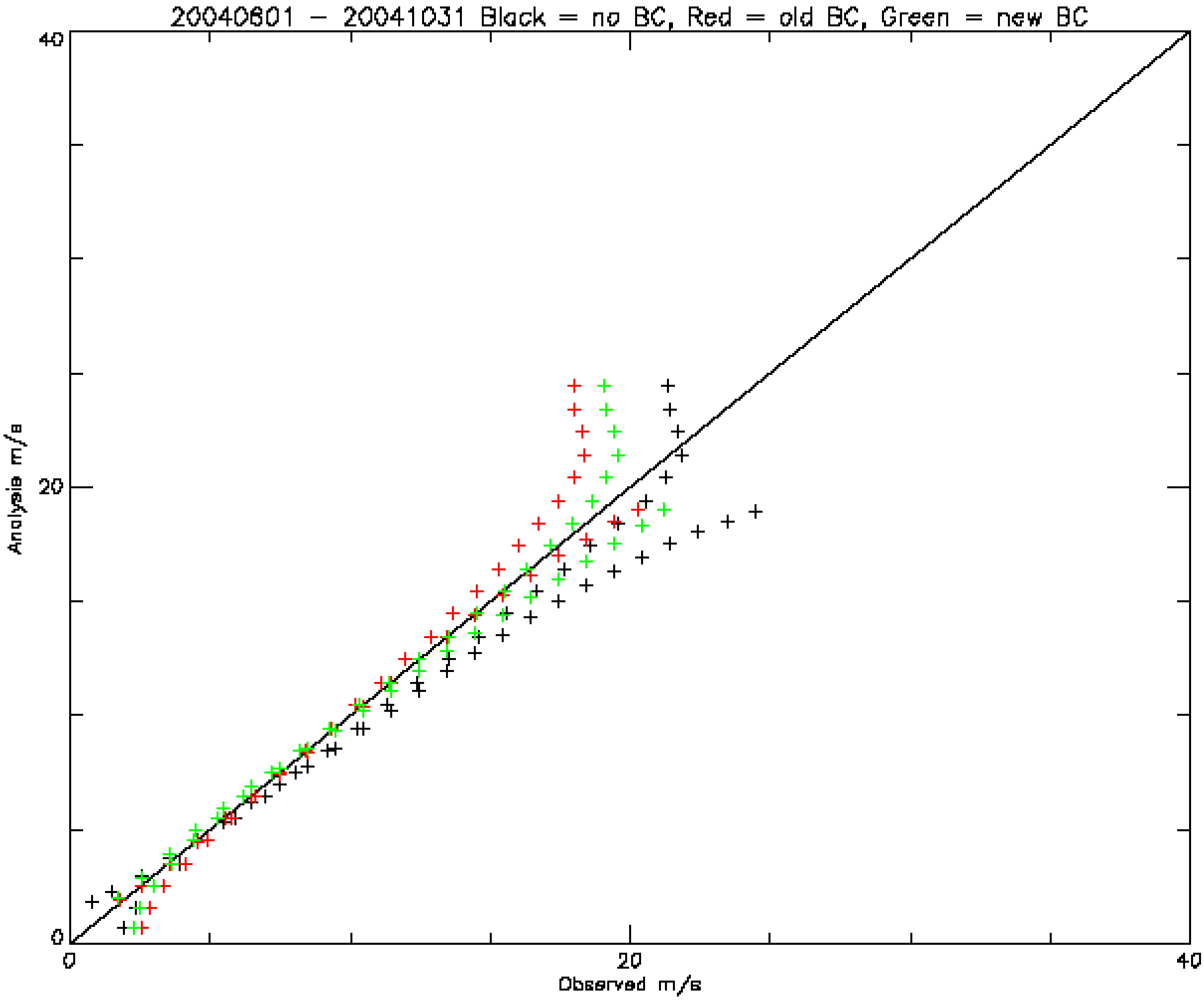


Figure 4.2.1 Construction of new polynomial fit to data.

4.3 Comparison of new and old polynomial fits.

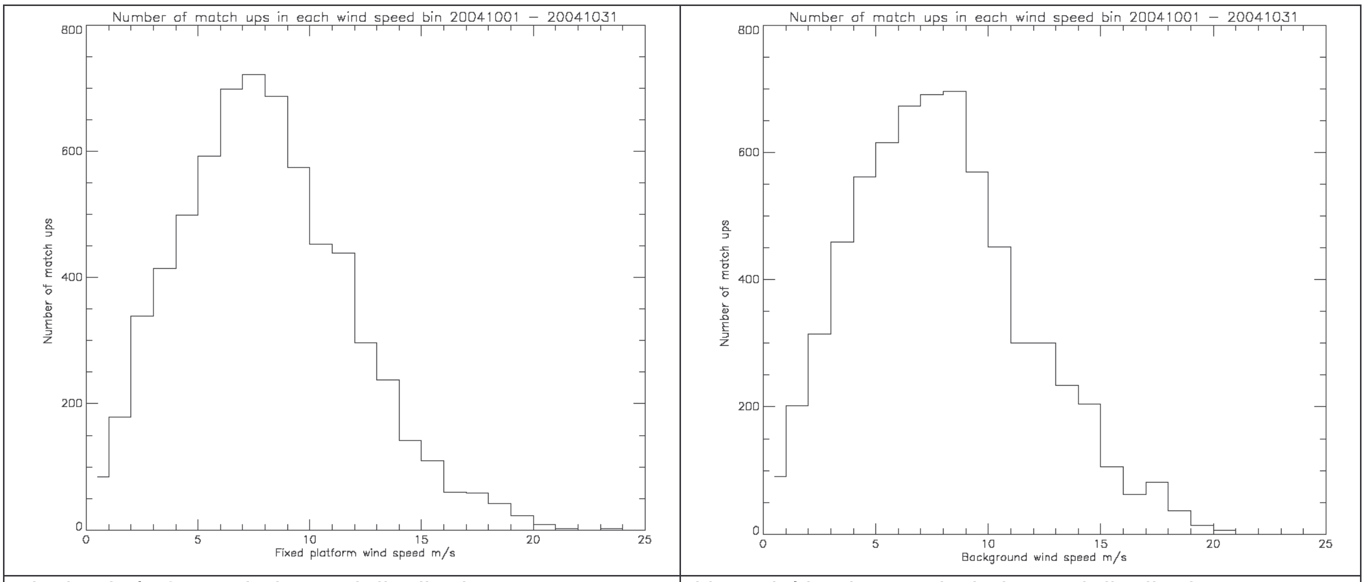
Figure 4.3.1 demonstrates that the new polynomial fit (green) is much closer to the ideal case of both sets of points (binned by analysis then observation) lying close to the line Y=X and being symmetrical about it. There seems to be a curious tail in the data as though QuikSCAT is saturating above 20m/s. This was first thought to be a representivity problem as the model has a 60km resolution, which is low compared to the QuikSCAT resolution of 25km. However, this would produce the opposite result of QS>Analysis i.e. model saturation. The cause of this scatterometer saturation (or “scaturation”) remains unknown and may be a statistical artefact.



4.3.1 Comparison of old and new bias corrections with the uncorrected case.

4.4 Comparison of the new polynomial fit using fixed platform data.

Data from 1st – 31st October 2004 were used to evaluate the performance of the polynomial against in situ data from fixed platforms as well as model background values. Over 6600 QuikSCAT match ups were found. Figure 4.4.1 shows the wind speed distribution for the period. It can be seen that there are more higher wind speeds (>15m/s) in the period than was the case with the earlier study in this document.



a) Fixed platform wind speed distribution | b) Model background wind speed distribution

Figure 4.4.1 Wind speed distributions for QuikSCAT match ups.

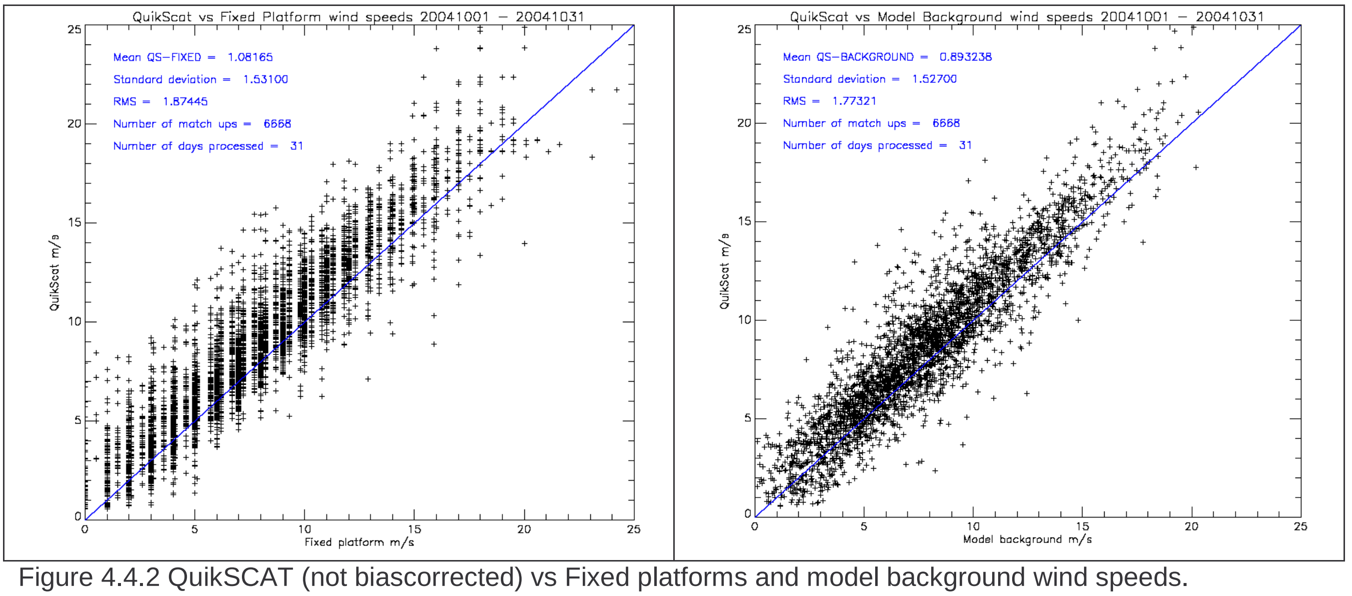


Figure 4.4.2 QuikSCAT (not biascorrected) vs Fixed platforms and model background wind speeds.

The performance of QuikSCAT against fixed platforms and model background field data is shown for cases of QuikSCAT wind speeds that have; no bias correction (fig. 4.4.2), old bias correction (fig. 4.4.3) and new bias correction (fig. 4.4.4). The associated statistics show that the old and new bias corrections perform better overall than having no bias correction at all and that the new bias correction is better than the old bias correction. The statistics are summarised below in tables 4.4.1 and 4.4.2. It should be noted that the data in these tables were not computed by binning the data. Rather, all data were used in a bulk approach to calculated the overall statistics.

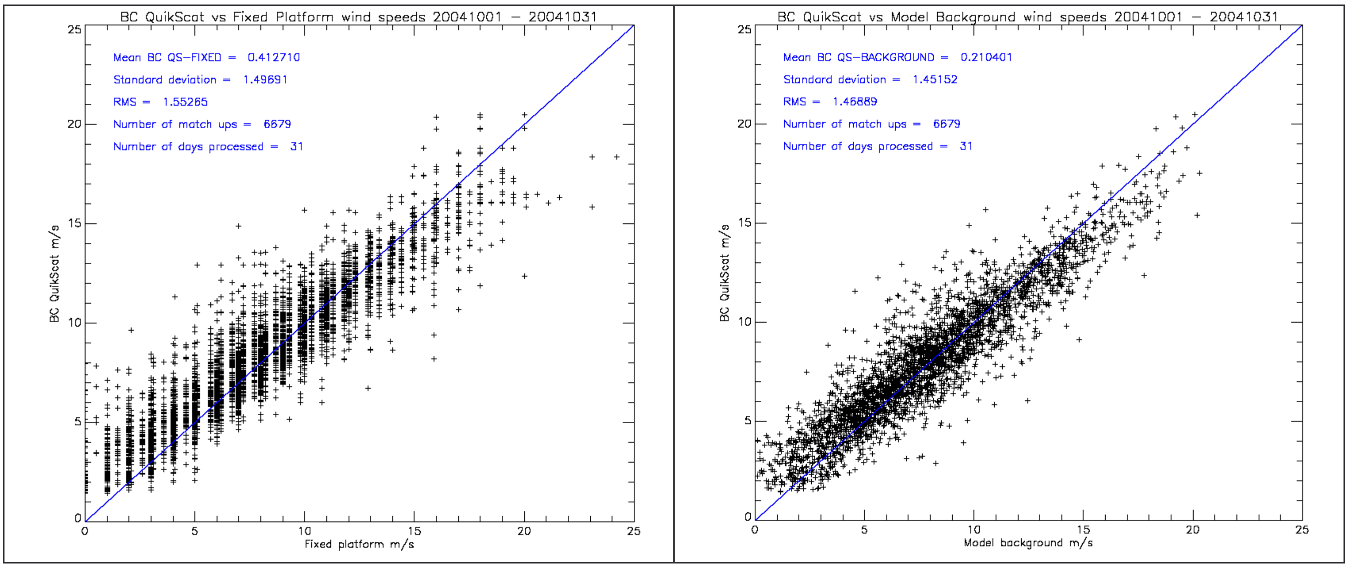


Figure 4.4.3 <u>Old</u> bias corrected QuikSCAT vs Fixed platforms and model background wind speeds.

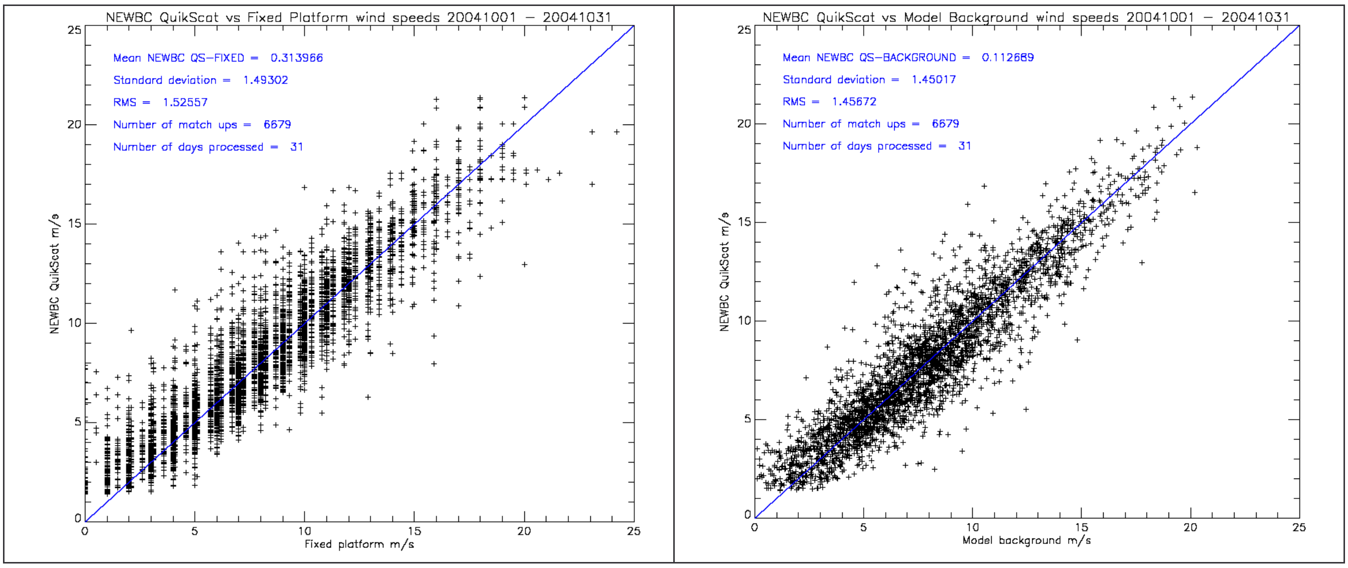


Figure 4.4.4 <u>New</u> bias correction for QuikSCAT vs Fixed Platforms and model background wind speeds.

The original bias of ~1m/s for the uncorrected QuikSCAT vs fixed platforms is reduced to 0.41m/s with the old bias correction and further to 0.31m/s with the new bias correction. These results agree well with the collocated comparison against model background field wind speeds, where the uncorrected bias is reduced from +0.89m/s to +0.21m/s by the old bias correction and then further to +0.11m/s by the new bias correction. These results are, however, biased towards the northern hemisphere wind climatology for the period.

Table 4.4.1 QuikSCAT performance against fixed platforms.

Wind speed type	Mean difference m/s	Standard deviation m/s	RMS m/s
Uncorrected - fixed	1.08	1.53	1.87
Bias corrected - fixed	0.41	1.49	1.55
New Bias Corrected - fixed	0.31	1.49	1.55

Table 4.4.2 QuikSCAT performance against model background.

Wind speed type	Mean difference m/s	Standard deviation m/s	RMS m/s
Uncorrected - model background	0.89	1.52	1.77
Bias corrected - model background	0.21	1.45	1.47
New Bias Corrected - model background	0.11	1.45	1.46

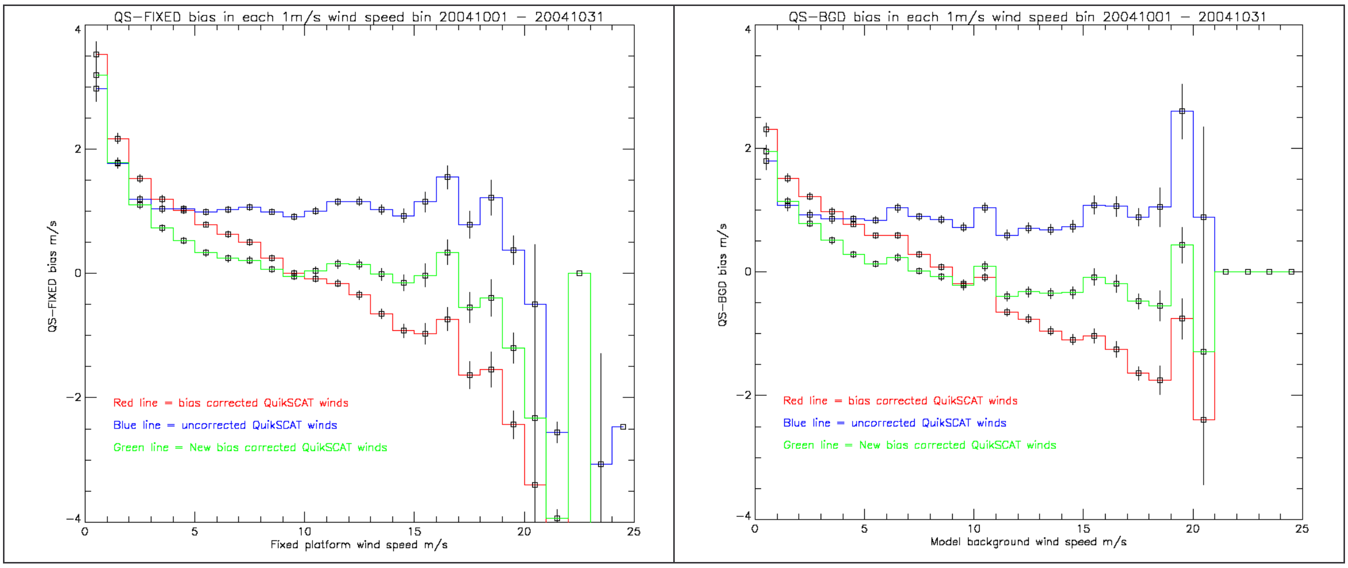


Figure 4.4.5 Performance of QuikSCAT bias corrections with wind speed. Error bars signify the standard deviation divided by the square root of the number of matches in each bin minus one.

It must be stressed that the bias correction applied to these data depends critically on the method used to bin the data (Stoffelen, 1998). One finds a different bias correction to be hinted at if data are binned by observation or model value. The approach used here is to bin the data both ways and then average the two resulting bias curves are used to compute a bias correction.

5. Forecast trial on SX6 of new bias correction coefficients.

In order to test the true performance of the new bias correction coefficients it was necessary to incorporate them into the scatterometer namelist file (WindRetrieval.nl) and run a single season N144 3D VAR trial on the SX6. The season used was 24th January 2004 – 17th February 2004. The experimental job was named SCAT012. This experimental job differed only from the control forecast job in two respects; a) it contained the bias correction detailed in this document and b) it contained the swath extension detailed in reference (ii). The control job (against which the experimental job was compared) was called SCAT006 and it differed from the original forecast job in only one respect in that it contained the swath extension only. Therefore any difference in the output between the two jobs (SCAT012 – SCAT006) should be due to the change in bias correction only as the change to the swath is common to both jobs.

The trial is verified both against SCAT006 (as described above) and JanCtlN (the original forecast job). This document is only concerned with the comparison between SCAT012 and SCAT006. The following results are a brief summary of those presented on the web page.

5.1 The NWP index.

The aim of the change of bias correction coefficients is ultimately to improve the NWP index, thereby ensuring that Met Office customers receive better forecast products. The difference between the NWP index from the experiment and control jobs gives an indication of the impact of the change. If Test – Control is negative then this means that a worse forecast has resulted from the change. If Test – Control is positive then this means that a better forecast has resulted from the change. Test – Control index values of between -0.5 and +0.5 are modest and fairly neutral. It is unlikely that any change resulting in a Test – Control value of less than -0.5 would be considered further as a candidate for inclusion in the next operational change.

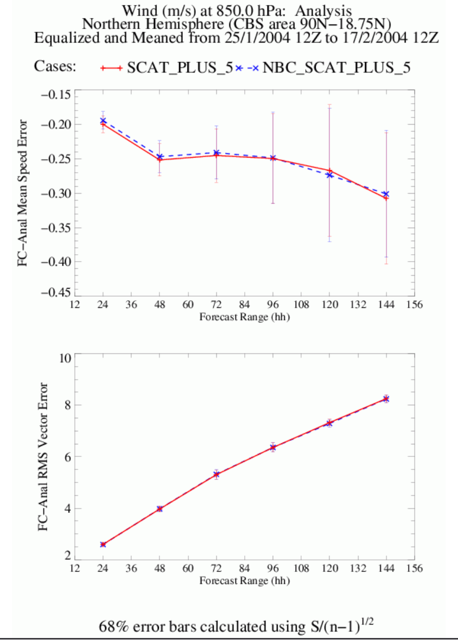
Table 5.1.1 *NWP Index Summary.*

SCAT012-SCAT006 verified against observations	SCAT012-SCAT006 verified against analysis
Total Weighted Mean Skill (total weight = 100) Control Case = 81.516 Test Case = 81.519 Test - Control = 0.004 Estimated Obs Based Global Index (36 Month, normalised to March 2000) Control Case = 119.358 Test Case = 119.370 Test - Control = 0.012 (0.010 %)	Total Weighted Mean Skill (total weight = 100) Control Case = 88.133 Test Case = 88.189 Test - Control = 0.057 Estimated Analysis Based Global Index (36 Month, normalised to March 2000) Control Case = 123.914 Test Case = 124.212 Test - Control = 0.298 (0.240 %)

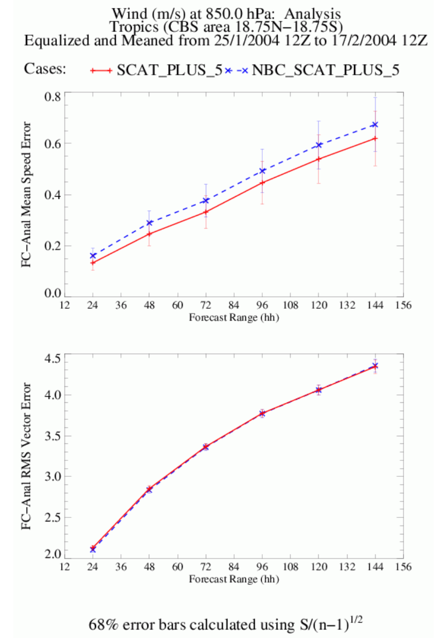
These results in table 5.1.1 demonstrate that overall there is a small positive benefit to including the new bias correction coefficients. This is true whether the results are verified against observations or model analysis.

5.2 Performance change with forecast range.

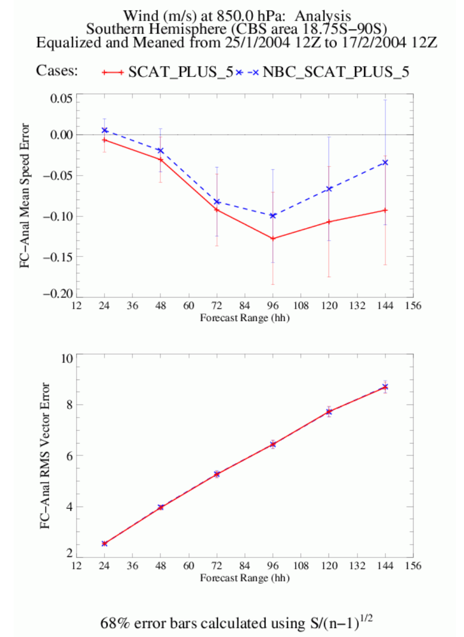
In most cases there was very little change in Forecast – Analysis values with forecast range but there are a few notable exceptions and these are demonstrated below.



Northern Hemisphere - neutral speed benefit.

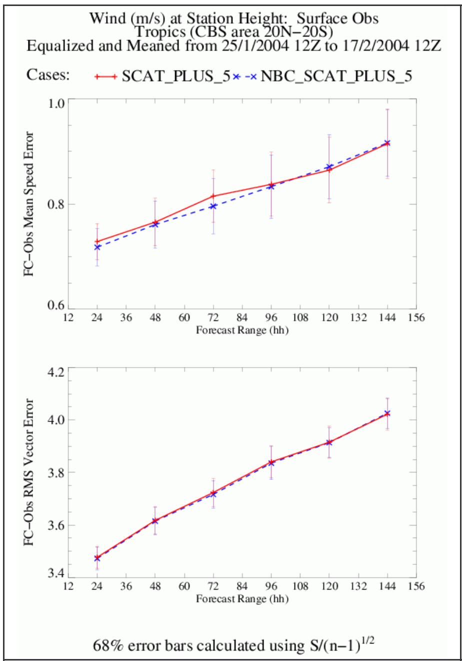


Tropics – consistent slight speed worsening but tropical analysis thought not to be very accurate (Candy, personal communication)

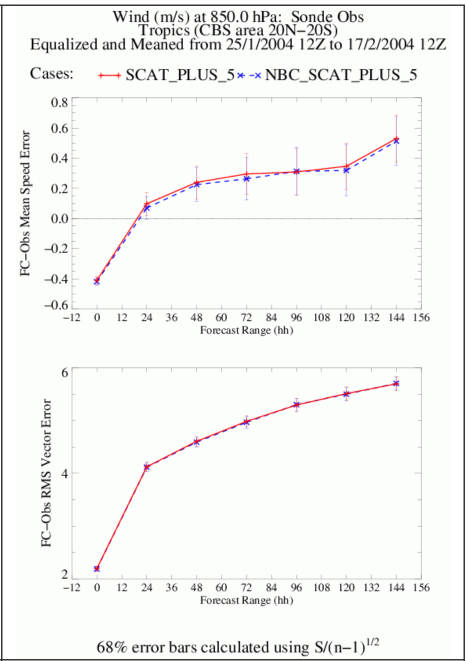


Southern Hemisphere – shows consistently better performance even at long forecast ranges

Figure 5.2.1 Performance against analysis with forecast range for 850hpa wind speed. Blue dashed line represents performance of new bias correction (NBC), red line is control.



Speed difference in the tropics lower at short forecast range for new bias correction



Small benefit to 850hpa wind speeds verified against sondes.

Figure 5.2.2 Performance against observations (surface and sonde) with forecast range for surface and 850hpa wind speed. Blue dashed line represents performance of new bias correction (NBC), red line is control.

5.3 Performance throughout the trail.

Most results were again quite similar for both experiment and control. However, in the tropics there did seem to be an improvement to the RMS forecast vector error at T+24 and T+48 (fig. 5.3.1), which is consistent on a daily basis. There was also a benefit to Forecast-Observation Vector Error (fig. 5.3.2) in the Tropics.

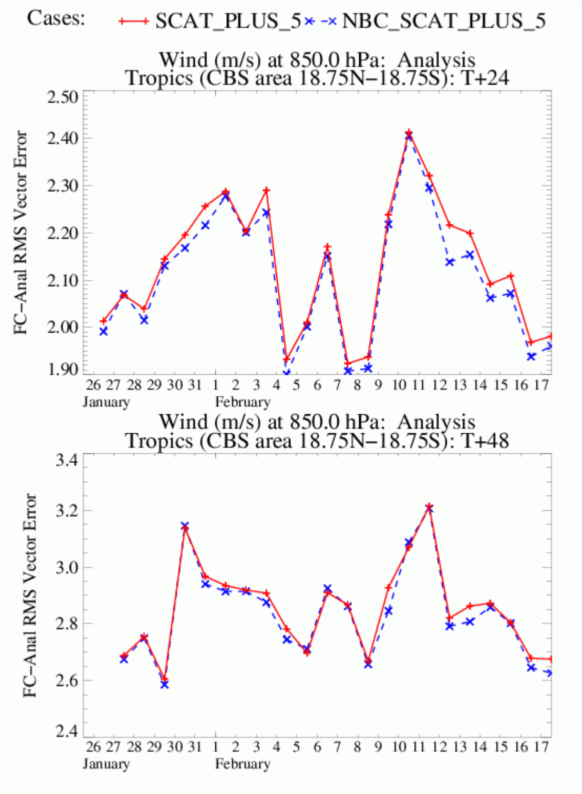


Figure 5.3.1 Performance against analysis of RMS Forecast Vector Error throughout the trial for 850hpa wind vectors in the tropics for both T+24 and T+48 forecasts.

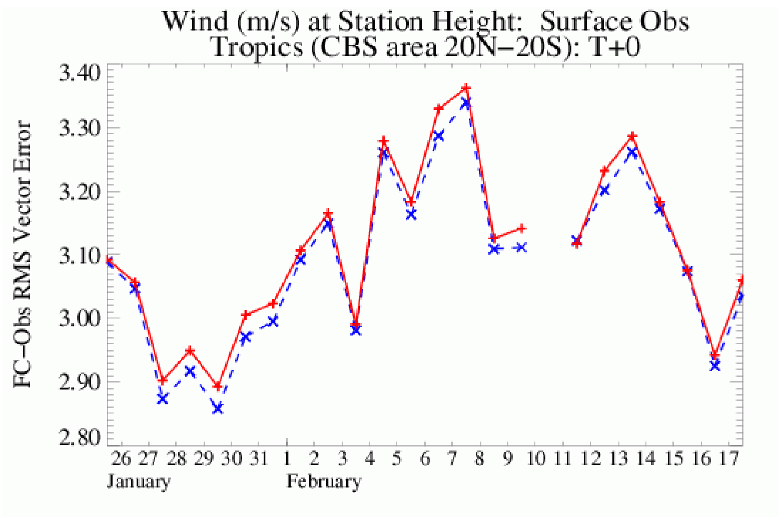
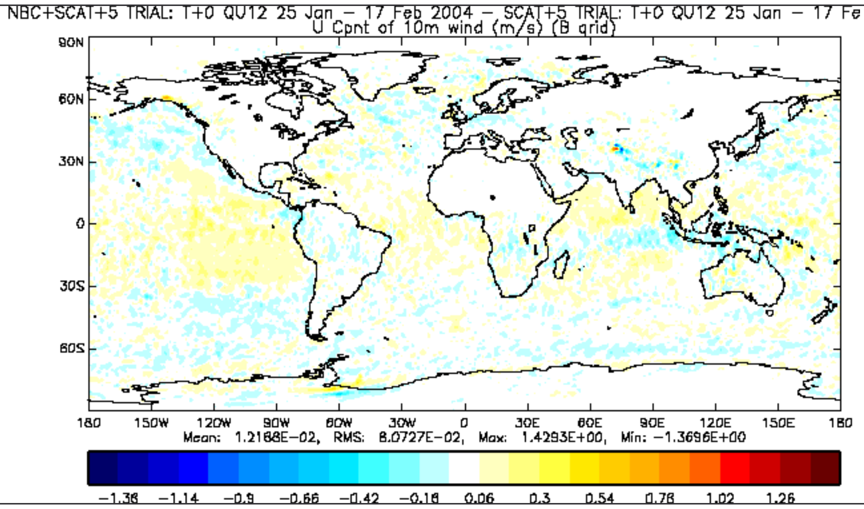
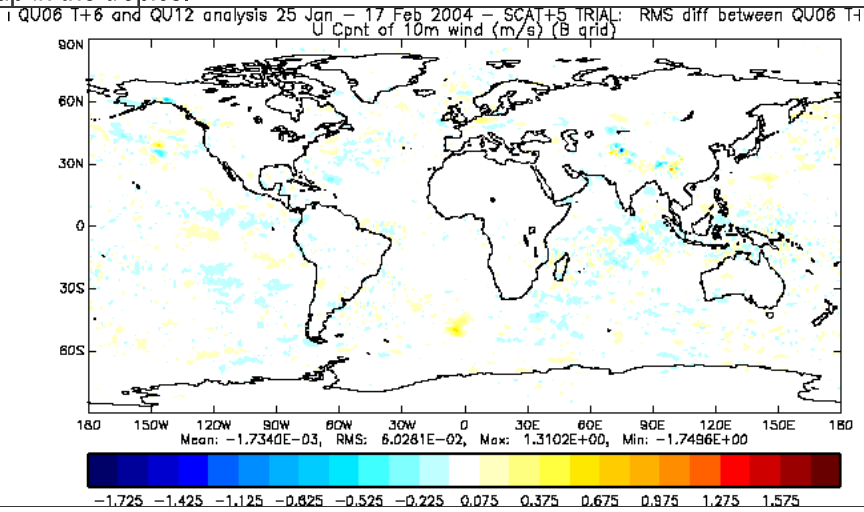


Figure 5.3.2 Small benefit to wind speeds in tropics against surface observations for the whole trial period.

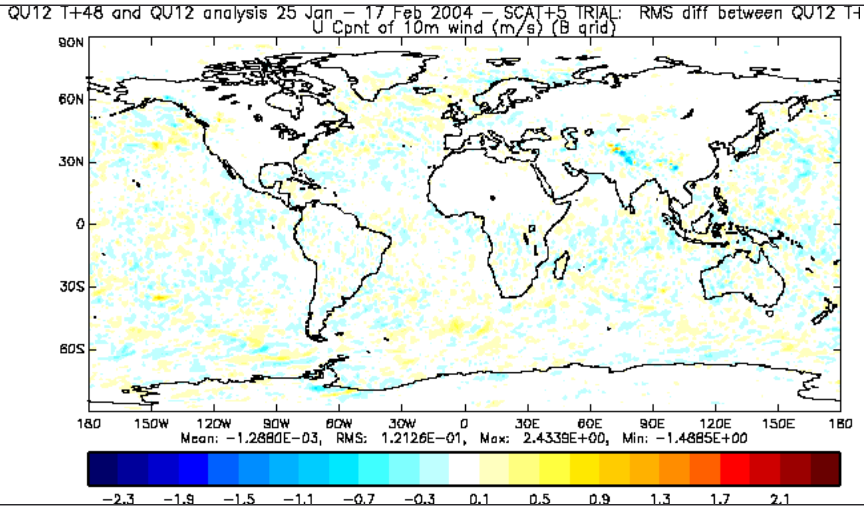
5.4 Global distribution of changes for U component 10 metre height wind speeds.



Analysis speeded up in the tropics.



Neutral effect for T+6.



Neutral effect for T+48.

Figure 5.4.1 Global performance for 10m U component wind speeds at T+0, T+6 and T+48.

In the above figure (5.4.1) it is evident that there is some small speed up of the U component of the 10m wind speed in the tropics at T+0. At forecast times of T+6 and T+48 we see a neutral global impact on the U component of the 10m wind speed. The results are very similar for the V component of the 10m wind speed (not shown here).

5.5 Forecast trial summary.

All the above results point to slight benefits to NWP of the change of bias correction coefficients. The biggest impacts are clearly in the southern hemisphere (fig. 5.2.1). This is because benefits in the northern hemisphere are swamped by the availability of so many other sources of observations.

It was perplexing that in fig 5.2.1 the change of bias coefficients appeared to have had a negative effect in the tropics on 850hpa wind speed when verified against analysis. This is especially odd when the speed error in the tropics at 850hpa verified against sondes (fig 5.2.2.) suggested a positive benefit. In addition, in fig. 5.2.2 the surface wind speed observations also suggested that the change of bias correction coefficients had had a benefit in the tropics to the surface wind speeds up to T+96. This is not inconsistent though with the view some hold that our analysis in the tropics may need some future improvement. This is thought to be mainly due to convection schemes not yet being mature enough to drive the atmospheric model dynamics in the tropics. This means that the background wind speed values used in the analysis will be subject to errors induced by inaccurate convection model physics.

The effect of the change of bias correction coefficients on the NWP index was slightly positive when verified against either observations or analysis. This is encouraging and should mean that a benefit to NWP should be apparent after the new bias correction coefficients are operationally implemented.

6. Conclusions and recommendations.

In conclusion there is still a positive bias between QuikSCAT wind speeds as delivered from NESDIS and those measured by fixed platforms and ERS radar altimeter. The magnitude of this bias is:

- +1.0 m/s compared to northern hemisphere fixed platforms (for October 2004) and ERS Radar Altimeter (for 1st – 18th July 2004) wind speeds
- +0.9 m/s compared to northern hemisphere Model Background wind speeds corresponding to the October 2004 fixed platform match ups
- +0.65 m/s compared to global Model Background wind speeds for the period 22nd May – 16th June 2004 and the NWP SAF monitoring web site shows this global average to be steady over time.

This does of course assume that the comparison sources are closer to truth than QuikSCAT, which may or may not be the case.

The first approach bias correction (Candy and Offiler, 2002) has been effective in reducing this bias, although at high wind speeds it is notable that this bias correction is likely to perform worse than no bias correction at all. The new bias correction coefficients described in section 4 has been shown to reduce the +1m/s bias against fixed platforms down to +0.3m/s and performs better the first approach, especially at high wind speeds. With hindsight, it could be argued that the new bias correction coefficients could be better produced by comparing observations with background values rather than analysis values. However, as the analysis is likely to be far more dominated by other observation types (e.g. SSMI) it is unlikely that any significant differences would result in either case.

A forecast trial on the SX6 has demonstrated a neutral to slightly positive benefit to the forecast of the new bias correction coefficients, which gives confidence that the new bias correction coefficients will not have a detrimental effect on forecast accuracy.

It was recommended that the new set of bias correction coefficients are included in the next operational change via the scatterometer namelist. These coefficients became operational on 14th June 2005.

7. References.

(i) Candy, B. and Offiler, D., ‘OSDP8: Scatterometer Processing Description’, Internal Report, July 2002.

(ii) Keogh, S.J. ‘Report on broadening the QuikSCAT swath’, Internal Report, September 2004.

(iii) Portabella, M. ‘Wind field retrieval from satellite radar systems’, PhD thesis, Astronomy and Meteorology Department, University of Barcelona, September 2002.

(iv) Stoffelen, A. ‘Scatterometry’, PhD thesis, University of Utrecht, 1998.

8. Acknowledgements.

Thanks go to Mary Forsythe and visiting scientist Howard Berger[1] for help with forecast trials. Thanks also go to Brett Candy for general advice on scatterometer data processing.

[1] Now at the University of Wisconsin.

Annex 1. Report on the broadening of the QuikSCAT swath for NWP.

Simon J. Keogh and Dave Offiler.

Final. 23rd September 2004.

Summary.

The aim of this report is to highlight the issues surrounding broadening of the 'used' part of the swath of the QuikSCAT scatterometer. A study is presented in which the author has used a month (30 days) of QuikSCAT data and compared them with background wind values from the MetDB. A recommendation was made to run a trial on the SX6 where the inner part of the scatterometer swath is extended by 5 nodes, giving 10 extra nodes of information for each swath. This forecast trial was then run but the effect of adding in the extra nodes was found to marginally decrease the NWP index. It is therefore recommended that no extra nodes be included in the next round of changes to the Met Office Observation Processing System.

1. Introduction.

The Seawinds swath can be seen the figure below. The swath is 76 cells (or nodes) wide but not all of the cells are used for N.W.P. purposes.

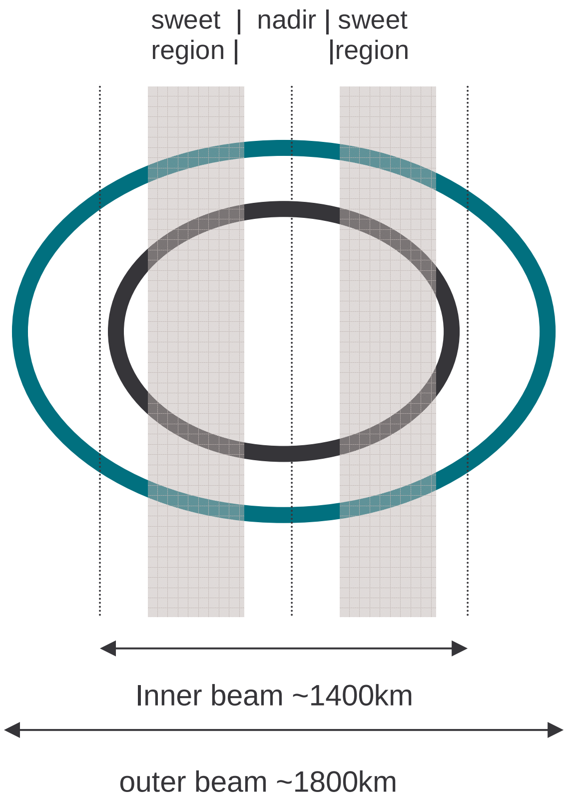


Figure 1. The Seawinds beam pattern.

Two conical scans allow each patch of the ocean in the inner part of the swath to be sampled by four beams. In the very centre of the beam the wind direction estimates will not be accurate because there is no information in the backscatter that relates to the component of the wind speed perpendicular to the sub-satellite track. Similarly at the extreme edge of the swath there will not be any information in the backscatter about the component of the wind speed parallel to the sub-satellite track. There is also the added problem that patches of ocean that are illuminated at the very edge of the swath are only sampled by one beam.

The shaded area in the figure represents the 'sweet region' that is used by Met Office for N.W.P. purposes. The purpose of this report is to look at the effect of adding extra cells onto this sweet region to see if extra observations can be provided for N.W.P. without adversely affecting the accuracy of the data. The shaded area is currently defined by nodes 11-28 and 49-65. They were chosen initially because there was a need to make the QuikSCAT data operational on a short timescale. A conservative approach was taken such that only the most reliable part of the swath was used. Now the issue is revisited with the aim of improving the quantity of good data available to N.W.P. for assimilation into forecast models.

2. Method.

Seawinds data are being archived daily on a local linux machine in order that daily monitoring statistics are produced for the external web site. Each morning a script extracts all of the previous days Seawinds data and background field values from the Metdb. Only data that is flagged as ‘sea only’ are retrieved. These data are saved in both a raw compressed format and as PV Wave ‘Save’ files. The latter can easily and quickly be restored into PV Wave for further processing. A PV Wave program restores data for one day at a time and accumulates information on the average O-B values of various parameters such as wind speed and wind direction. Another program then processes the output to produce the graphics shown in this report.

The model background values are used as ‘truth’ here in this report but it should be noted that the background field values are not in fact the truth but merely a convenient standard of comparison.

The Seawinds data used in this analysis had the following characteristics:

- Sea only coverage
- Rain probability < 0.1
- Normalised MLE < 1.80 and greater than zero
- Good associated merged background wind field data
- Data was from between 11th February – 11th March 2004, which is 30 days of data

This resulted in a baseline total of 9.4×10^6 Seawinds observations for the period when only those cells lying in the ‘sweet spot’ region are counted. This report describes later how this number can be increased by adding extra cells to either the inner or outer parts of the used swath.

Daily average O-B values were computed along with final 30 day averages, which are plotted in the results section of this report.

3. Results.

Various quantities are plotted here against node number. The node number varies from 1-76 and can be thought of as being the distance across the total QuikSCAT swath. Currently only nodes 12-28 and 49-65 are used by the Met Office model due to the poorer quality of the data from the inner most (29-48) and outer most (1-11 and 66-76) nodes.

All the data shown here are over sea only. Wind speeds and directions are those which are the first guess wind speed. These may differ from those actually selected by the model as up to four wind speeds/directions are presented to the model prior to assimilation.

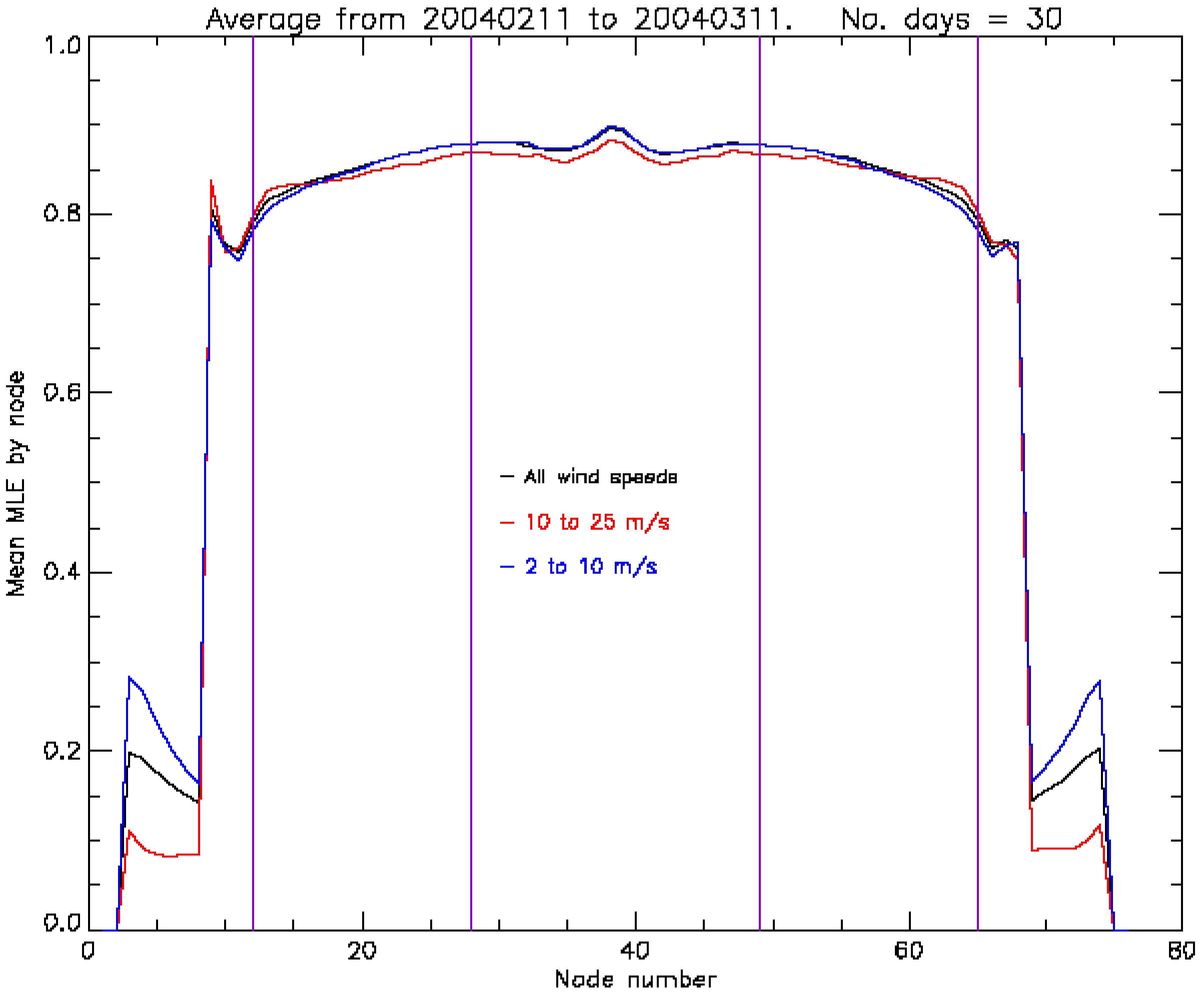


Figure 2. The 30 day averaged normalised MLE versus node number. Note that the sudden drop at nodes 8/9 and 67/68 indicates where the two beam retrieval technique is working with only 2 overpasses (single beam) rather than 3 or 4. See figure 1 for details.

This plot demonstrates the form of the Normalised distance to cone for various wind speeds. The red line represents the high wind speed regime and the blue line represents the lower wind speed regime. The black like represents the relationship between Normalised MLE and node number for all wind speeds. The vertical purple lines show the current limits of the swath as accepted by the Met Office model. The three curves are all composites of 30 days of QuikSCAT data.

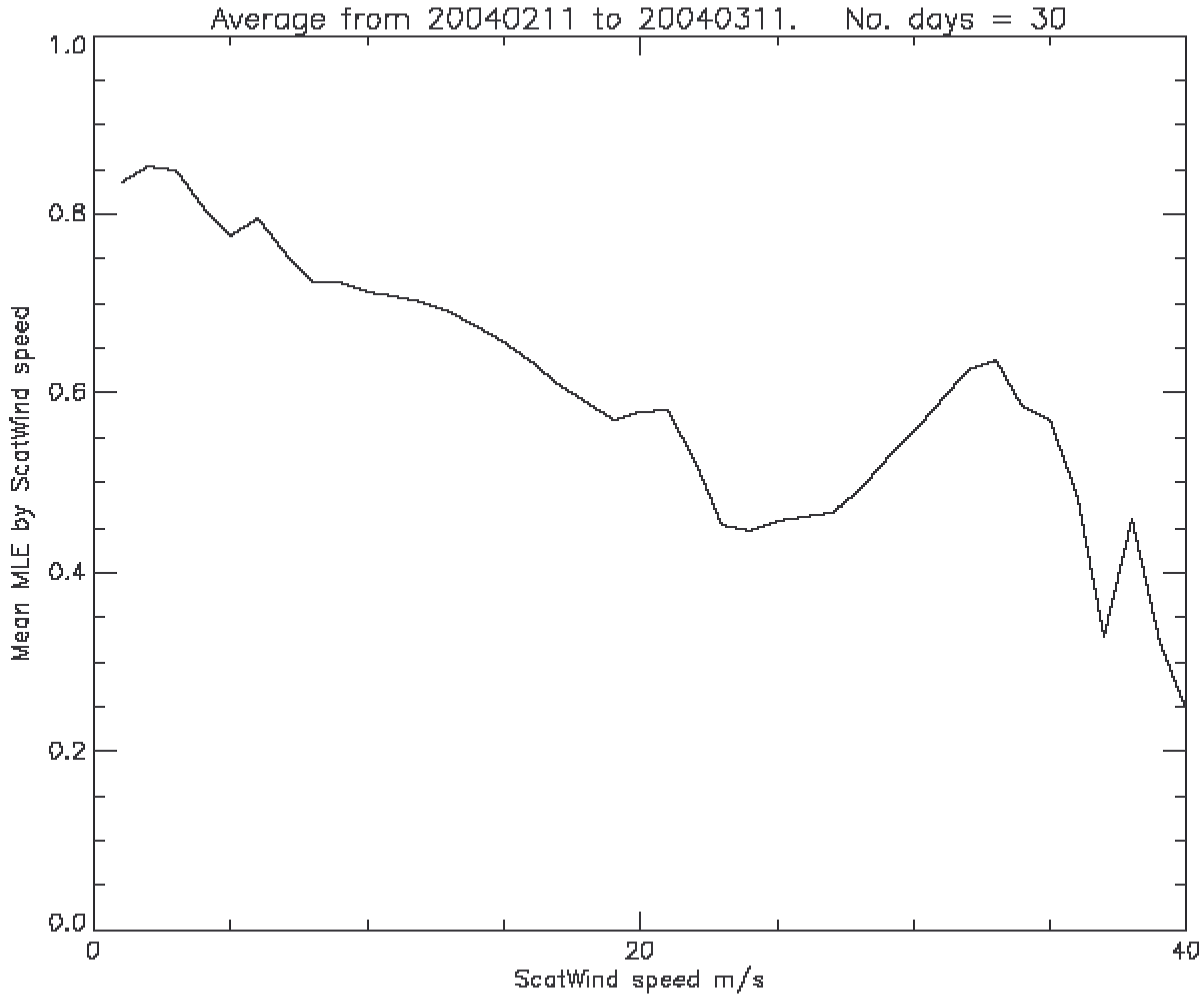


Figure 3. The 30 day averaged normalised MLE versus wind speed from QuikSCAT.

The above plot shows the relationship between the normalised MLE and wind speed over the period of observations. It is clear that the MLE decreases almost linearly between 0-25 m/s. Above 25m/s the relationship becomes more complicated, due in part to the smaller number of incidences of these very high wind speeds and the unclear relationship between wind speed and radar backscatter at very high sea states.

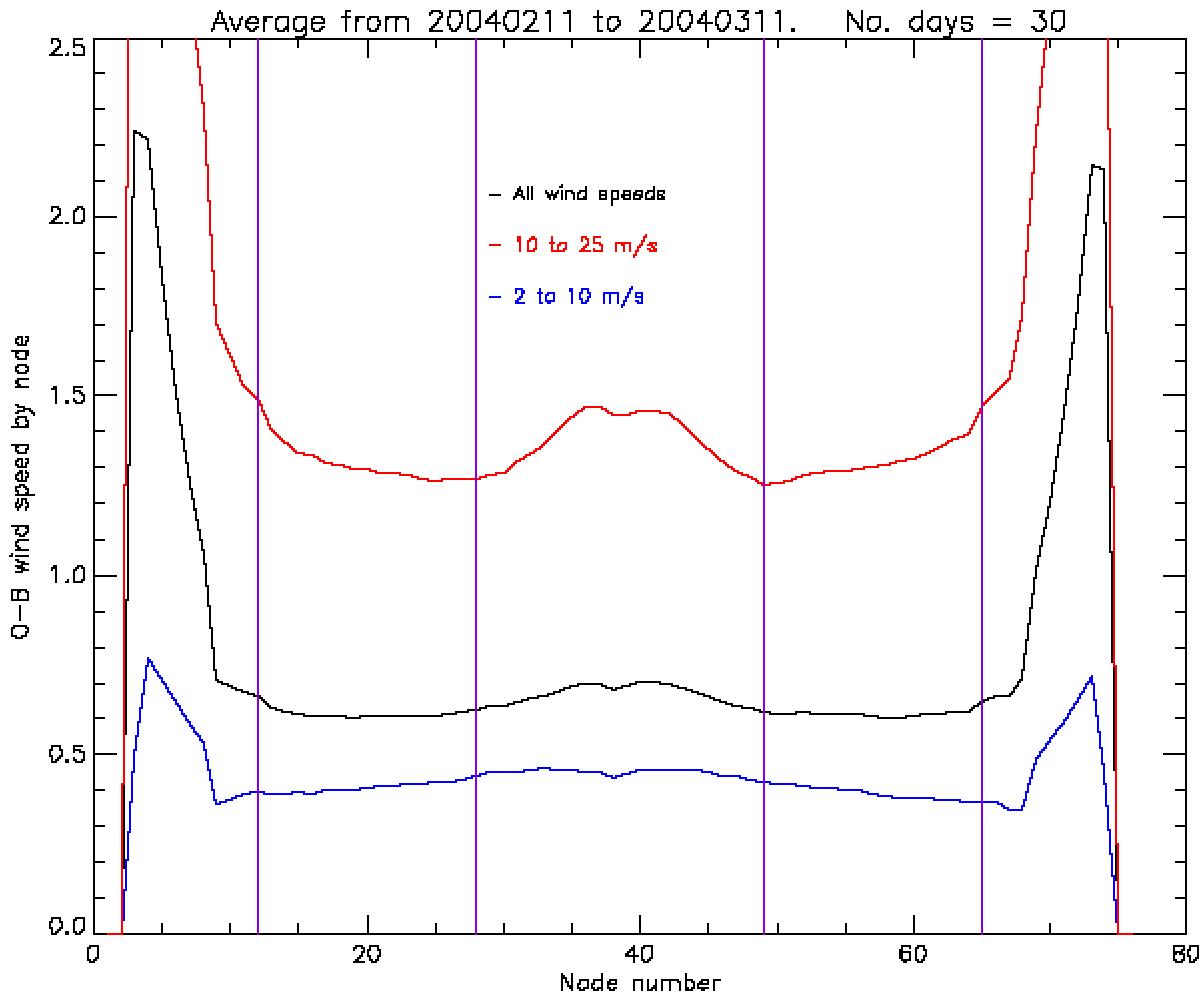


Figure 4. The 30 day averaged O-B wind speed versus node number for low/high/all wind speed regimes.

In this plot it is evident that the O-B wind speeds are much lower for the low wind regimes than for the higher wind regimes. The O-B wind speed for all wind cases (black line) is quite close to the low wind curve (blue line) because very high winds are infrequent at sea. Across all the 'used' nodes there is not much variation in the O-B wind speeds but in the outer most part of the swath the differences can be several m/s in the all wind speed case. In the inner most 'unused' part of the swath the O-B wind speeds are higher than for the 'used' part of the swath but only marginally so, approximately 0.1 m/s in the all winds case.

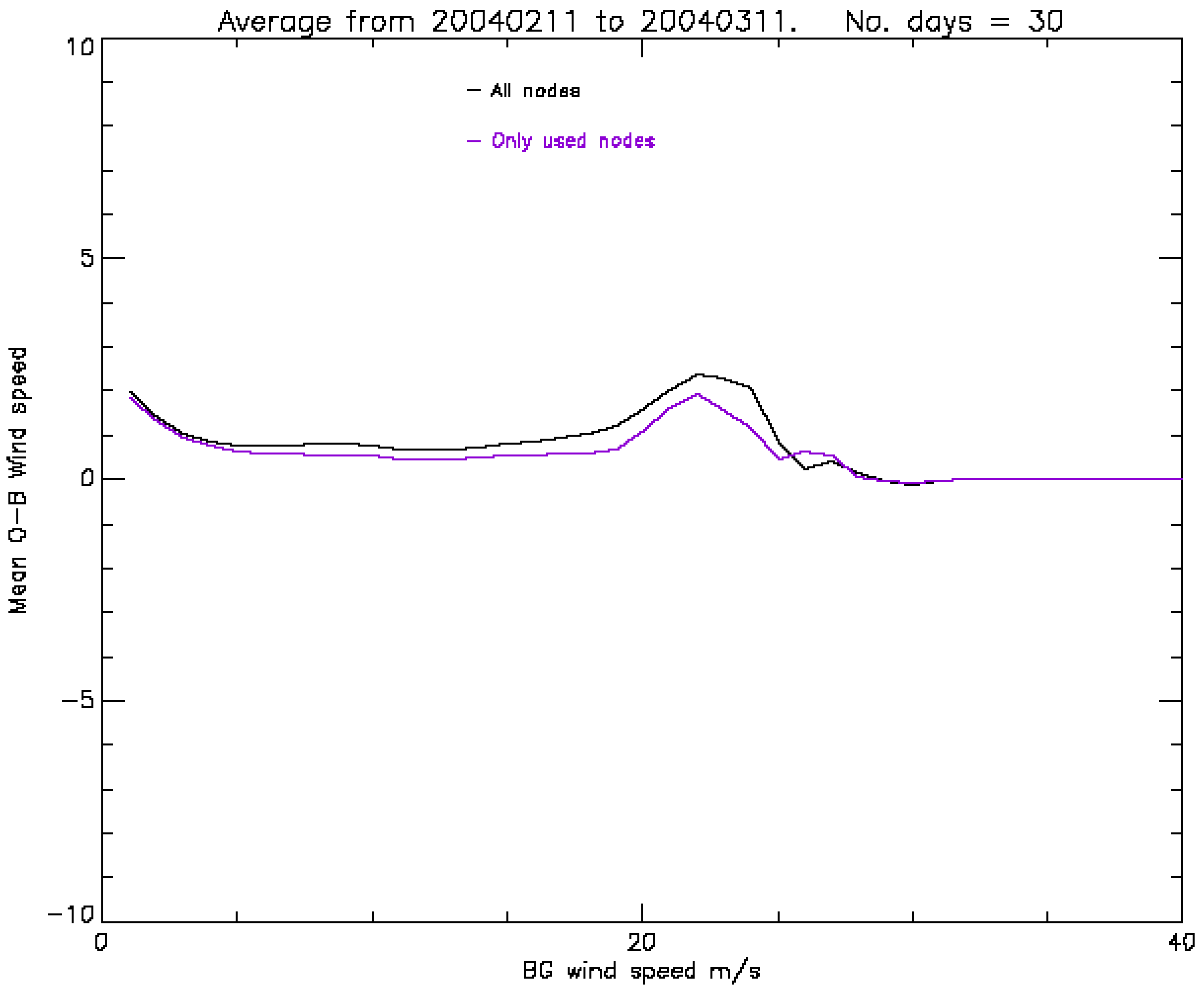


Figure 5. The 30 day mean O-B wind speed versus background values of wind speed for all/'used only' cells.

This plot demonstrates how the mean (O-B) wind speed varies with the background wind speed. It can be seen that for the 'used' nodes (purple line) there appears to be a bias of less than 1m/s across the range 5-20m/s, beyond which the bias seems to fluctuate, partly due to the inability of the QuikSCAT wind retrieval algorithms to cope with very high wind speeds and partly due to errors in the background field at higher wind speeds.

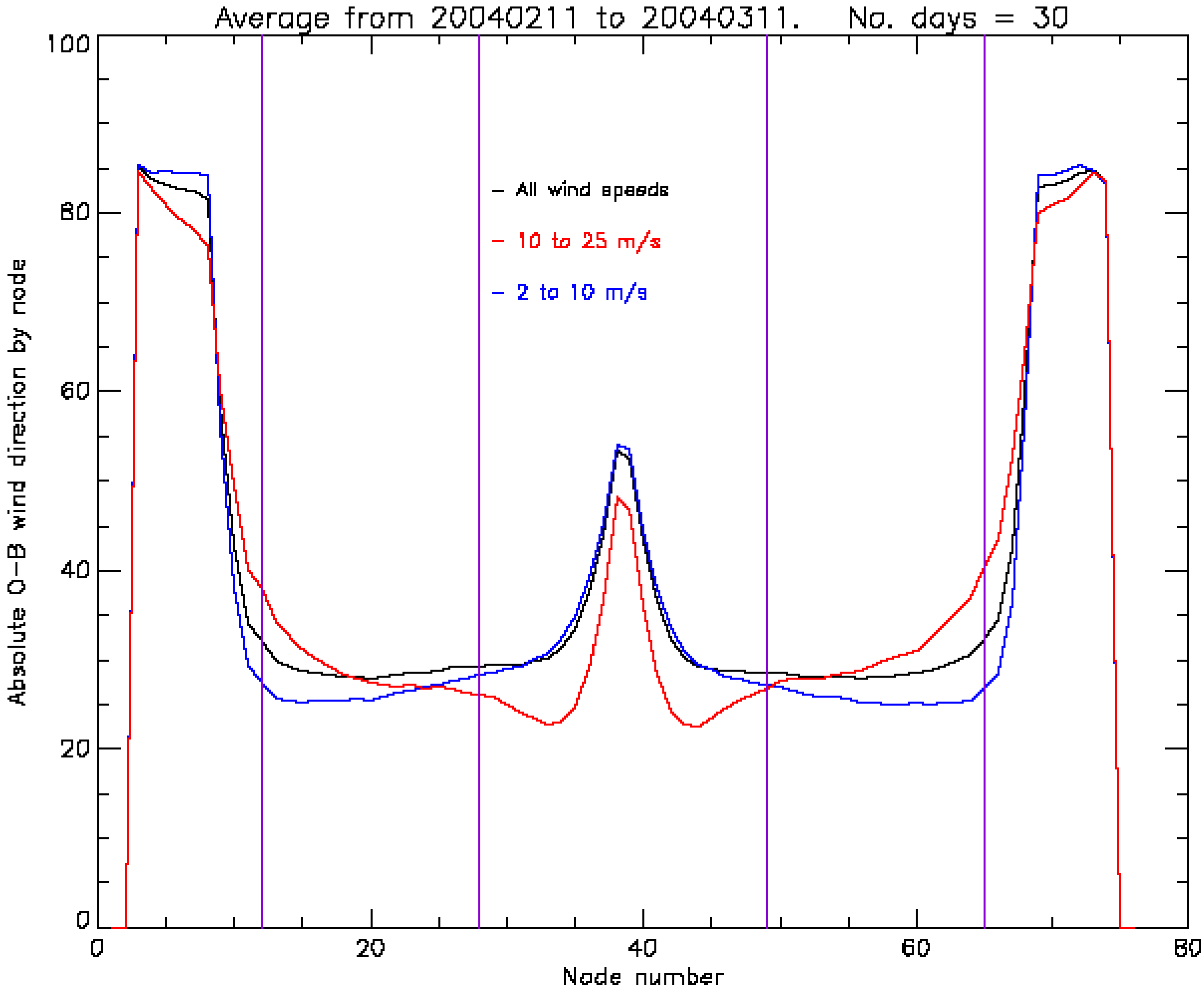


Figure 6. The 30 day averaged mean ABS(O-B) wind direction versus node number for low/high/all wind speed regimes.

This is an important plot. One of the most important features of scatterometer data is that it gives the user an indication of the wind direction. There are many satellite sensors in orbit that can give surface wind speeds but direction is a very scarce quantity. The plot demonstrate that the relationship between the average absolute O-B wind direction and the node number is very complicated. For the low wind speed case (blue line) it can be seen that the mean ABS(O-B) value decreases from the inside to the outside of the 'used' part of the swath, which is bounded by the vertical purple lines. However, in the high winds case (red line) the opposite is true with the mean ABS(O-B) value increasing from the inner to the outer 'used' part of the swath. However, it can be readily seen that in all cases the mean ABS(O-B) values increase rapidly as we move outwards from the centre into the outer 'unused' part of the swath between nodes 11-1 and 65-76. It can also be seen that the ABS(O-B) grows in the middle of the swath (nodes 35-42) where the two radar beams azimuth angles are tending either towards 0 or 180 degrees relative to the subsatellite track which results in a lack of azimuthal diversity, despite there being four overpasses – see figure 1 for more details. This means that directional measurements in the centre of the swath of not of sufficient quality for NWP.

3.1 Study of the effects of broadening the used part of the QuikSCAT swath – outer swath.

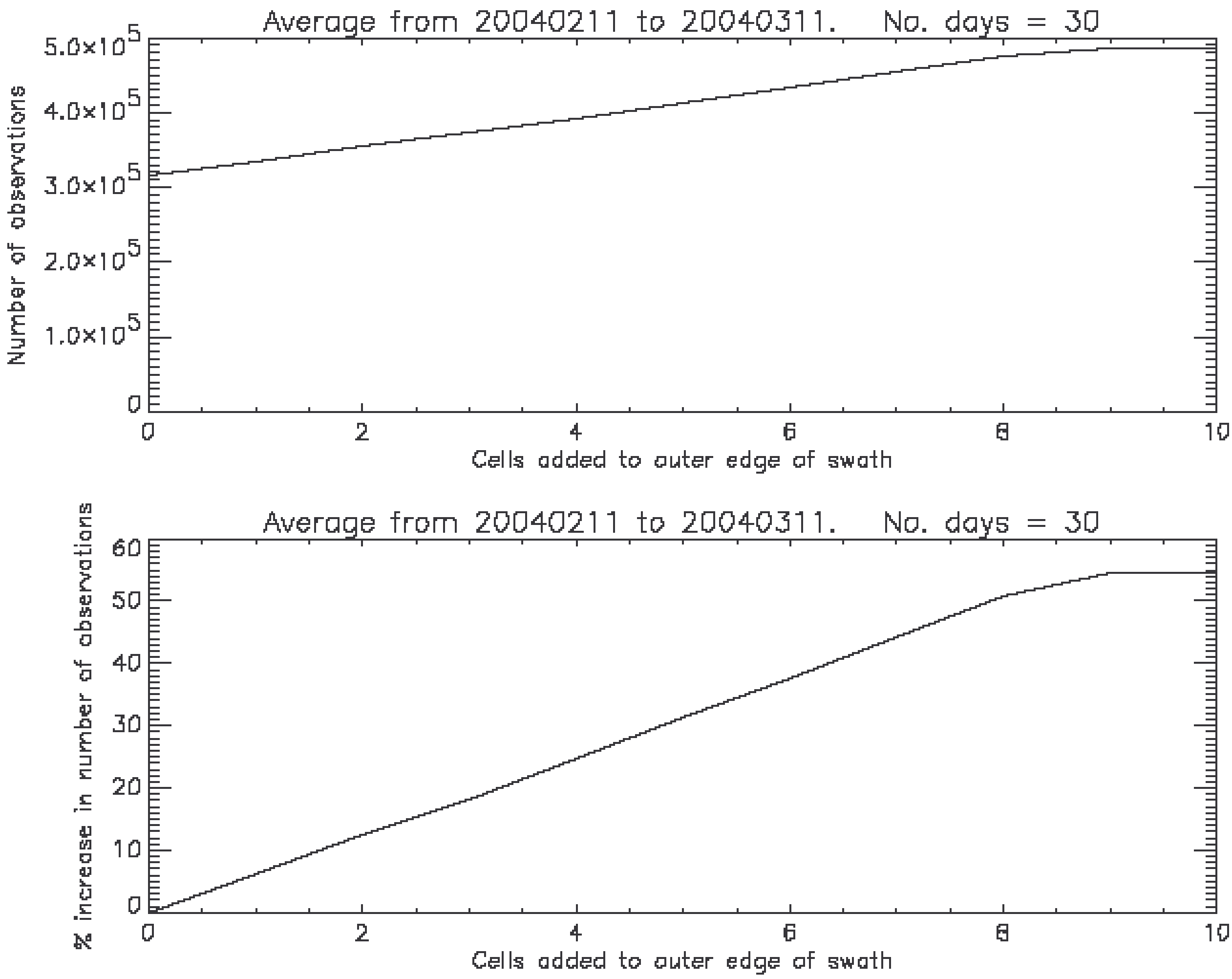


Figure 7. The benefits of adding extra cells to the outer part of the swath in terms of the number of extra observations recorded.

The above plot demonstrates the increase in the number of observations that could be expected if the outer part of the swath were to be extended. Increasing the number of 'used' cells can increase the number of observations available by quite large amounts. If 8 cells could be added to the outer swath (actually 16 as we are extending both the port and starboard edges of the swath) then we could increase the number of observations by over 50%. However, there is a penalty associated with this as data in the outer part of the swath are generally of a poorer quality and so including them all may result in poor model performance.

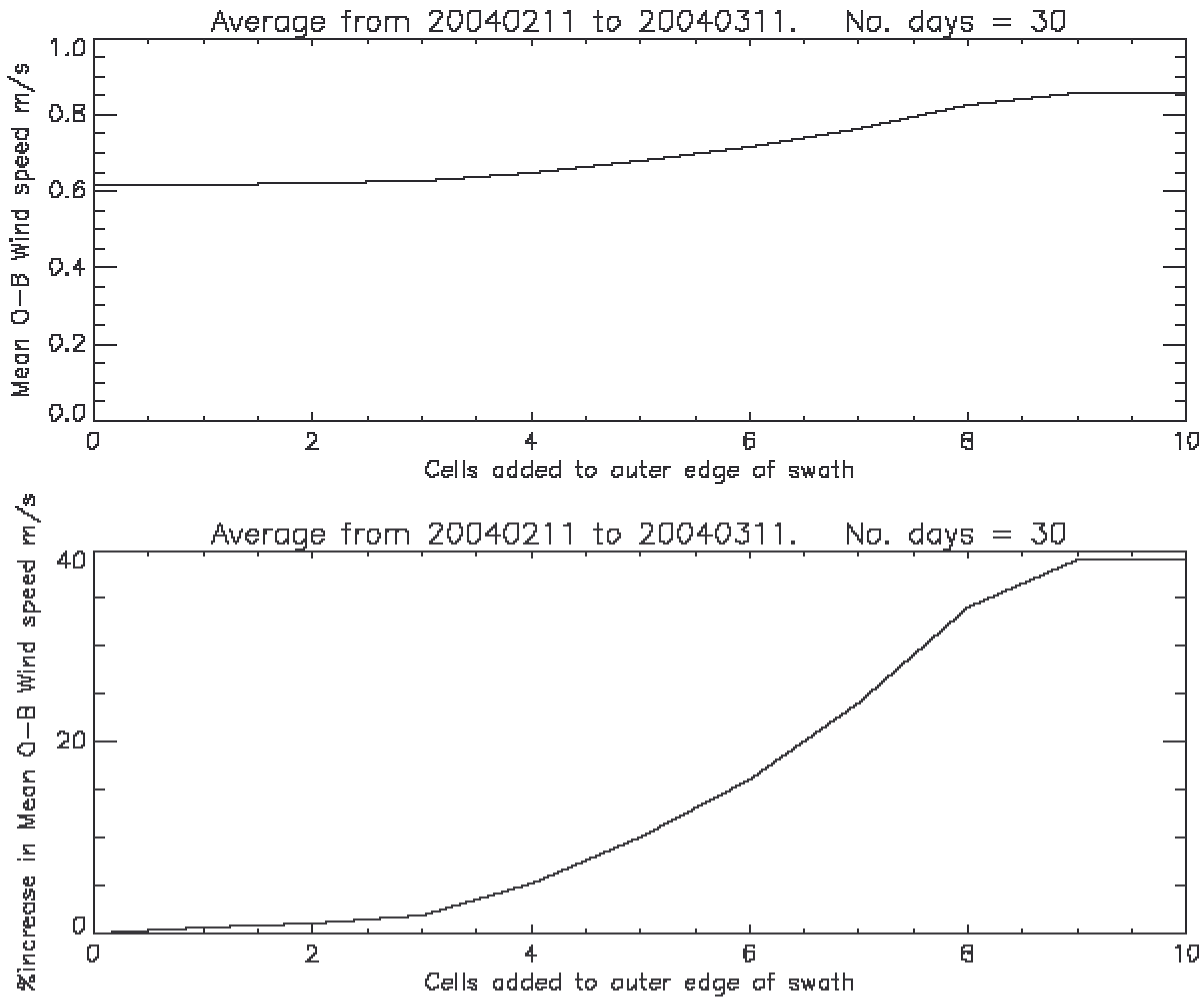


Figure 8. The effect of adding cells to the outer edge of the swath on the mean O-B wind speed.

This plot demonstrates that adding cells to the outer part of the swath results in an increase in the difference between the observed and background wind speed values. However, the lower plot shows that the % increase in the wind speed (O-B) values is modest for the first three cells added. Adding the fourth and subsequent cells results in a rapid increase in the O-B differences. This suggests that the outer swath could be extended by two or three cells if a modest increase in (O-B) wind speeds (say 3%) can be tolerated.

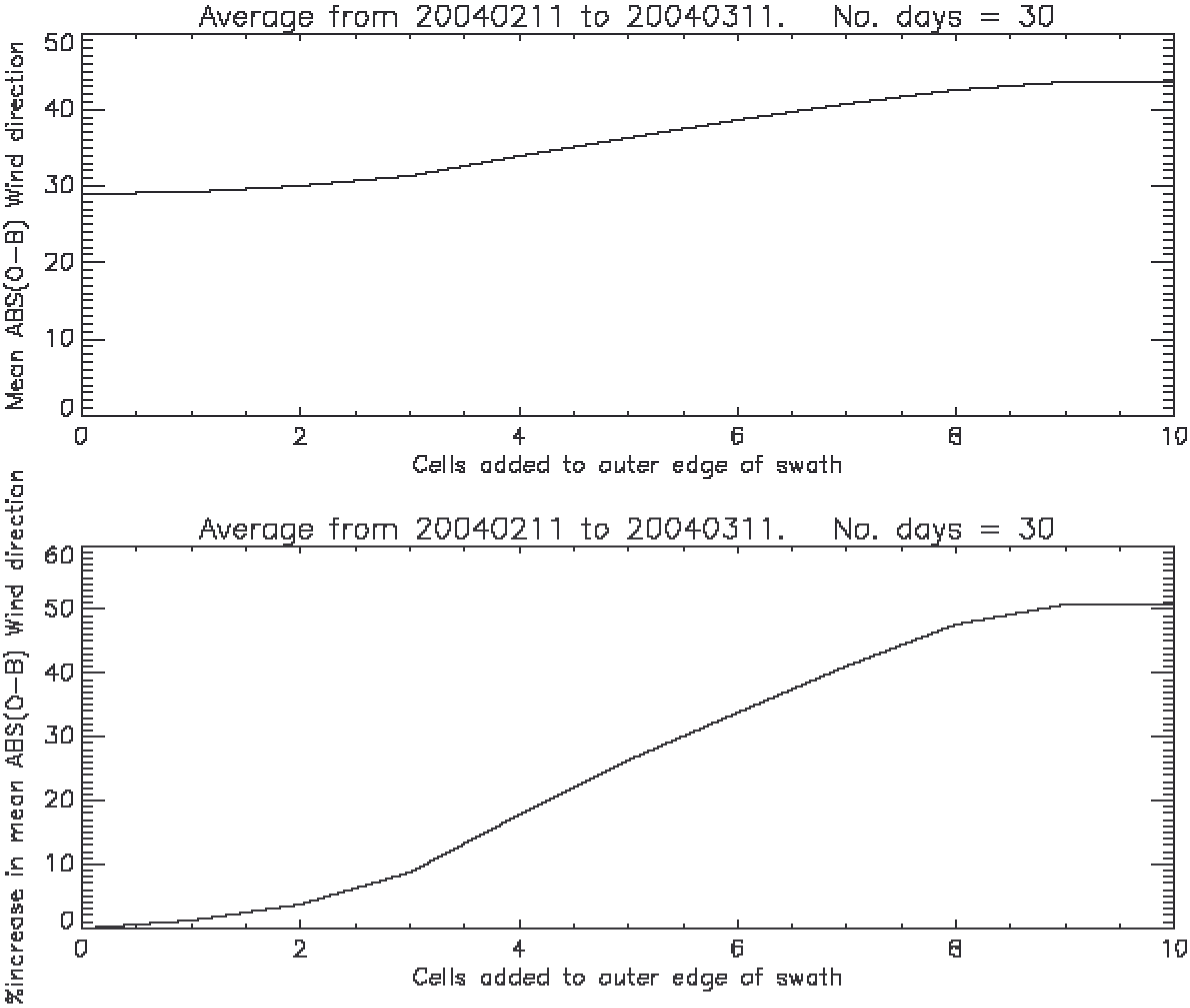


Figure 9. The effect of adding cells to the outer part of the swath on the mean ABS(O-B) wind direction.

This is an important plot. As the primary value of scatterometer data is its provision of accurate wind direction data the effect of broadening the outer part of the swath on the overall wind direction quality is critical. There would be no point in increasing the number of wind direction observations if the wind directions that were being added were erroneous. The lower plot demonstrates that adding cells to the outer part of the swath increases the mean ABS(O-B) wind direction by 50% if all the ‘unused’ outer cells are added. However, if only two cells are added then the mean ABS(O-B) value increases by only around 3%. After the third cell is added it can be seen that the mean ABS(O-B) values grow rapidly.

3.2 Study of the effects of broadening the used part of the QuikSCAT swath – inner swath.

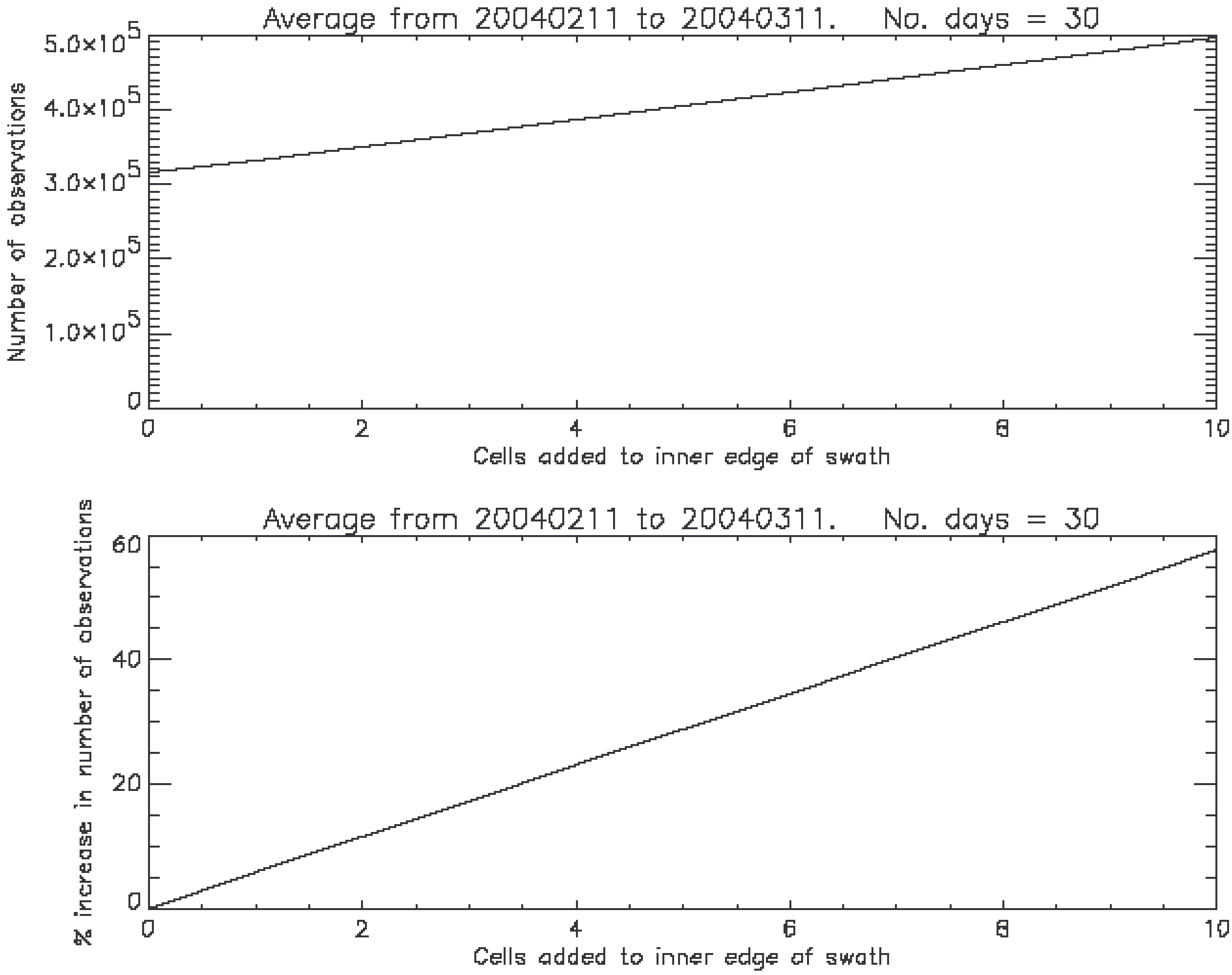


Figure 10. The benefits of adding extra cells to the inner part of the swath in terms of the extra number of observations gained.

The above plot demonstrates the benefit of extending the inner part of the swath in terms of the extra observations that would be available for N.W.P. purposes. If 9 or more cells were added to the inner swath (actually 18 or more as we are extending both the port and starboard inner edges of the swath) then we could increase the number of observations by over 50%.

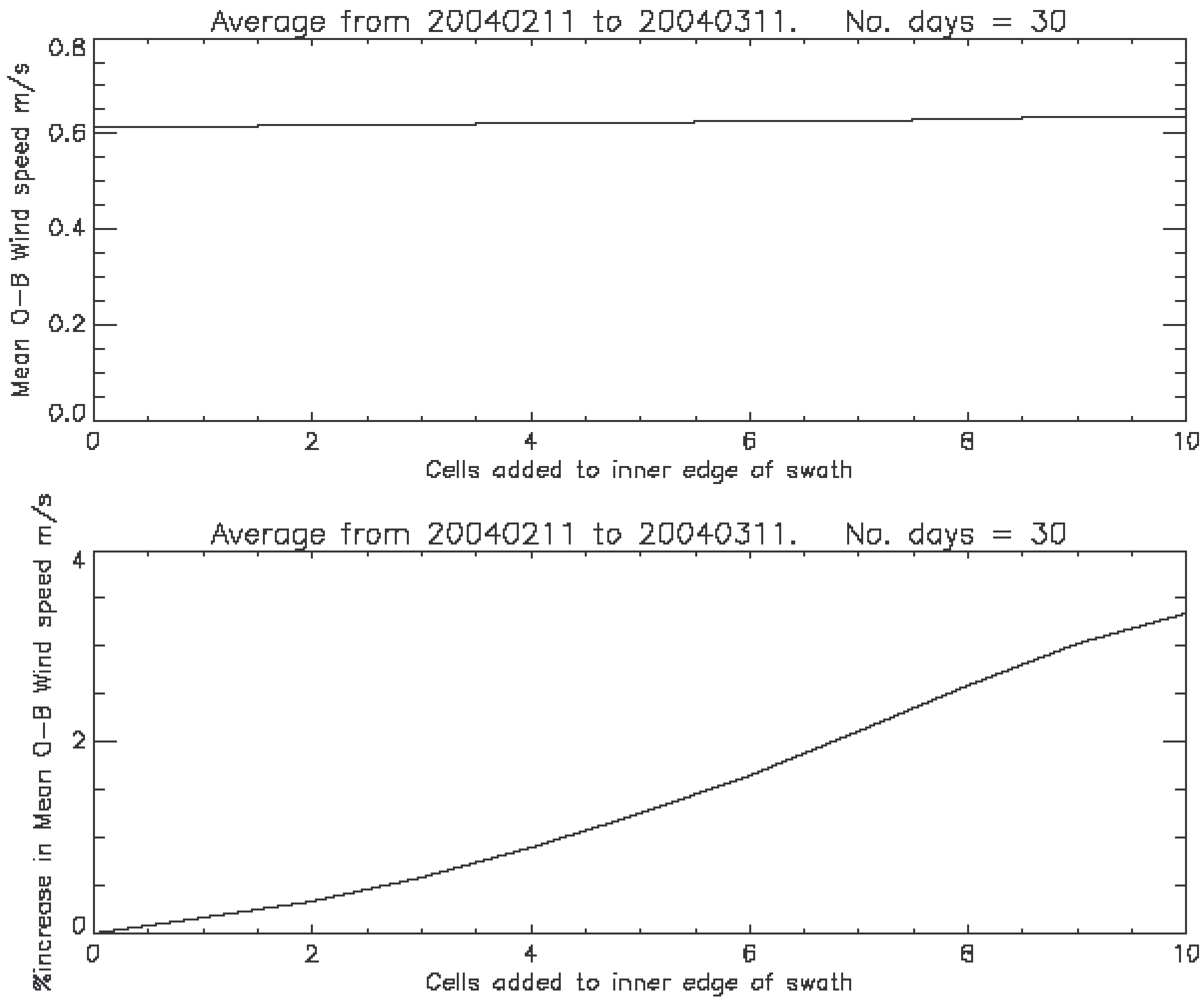


Figure 11. The effect of adding extra cells to the inner part of the swath on the mean O-B wind speed.

The plots above show that the effect of extending the inner part of the swath by a few cells on the mean O-B wind speed difference is relatively marginal compared with that of extending the outer part of the swath. It can be seen that adding 4 (actually 8 nodes as 4 port and 4 starboard nodes) to the inner edge of the swath increases the mean (O-B) wind speed by around 1%. Given that the mean (O-B) wind speed difference is only ~0.6m/s then 1% of this value is small. Adding four cells would also make more than 20% more observations available for N.W.P. purposes.

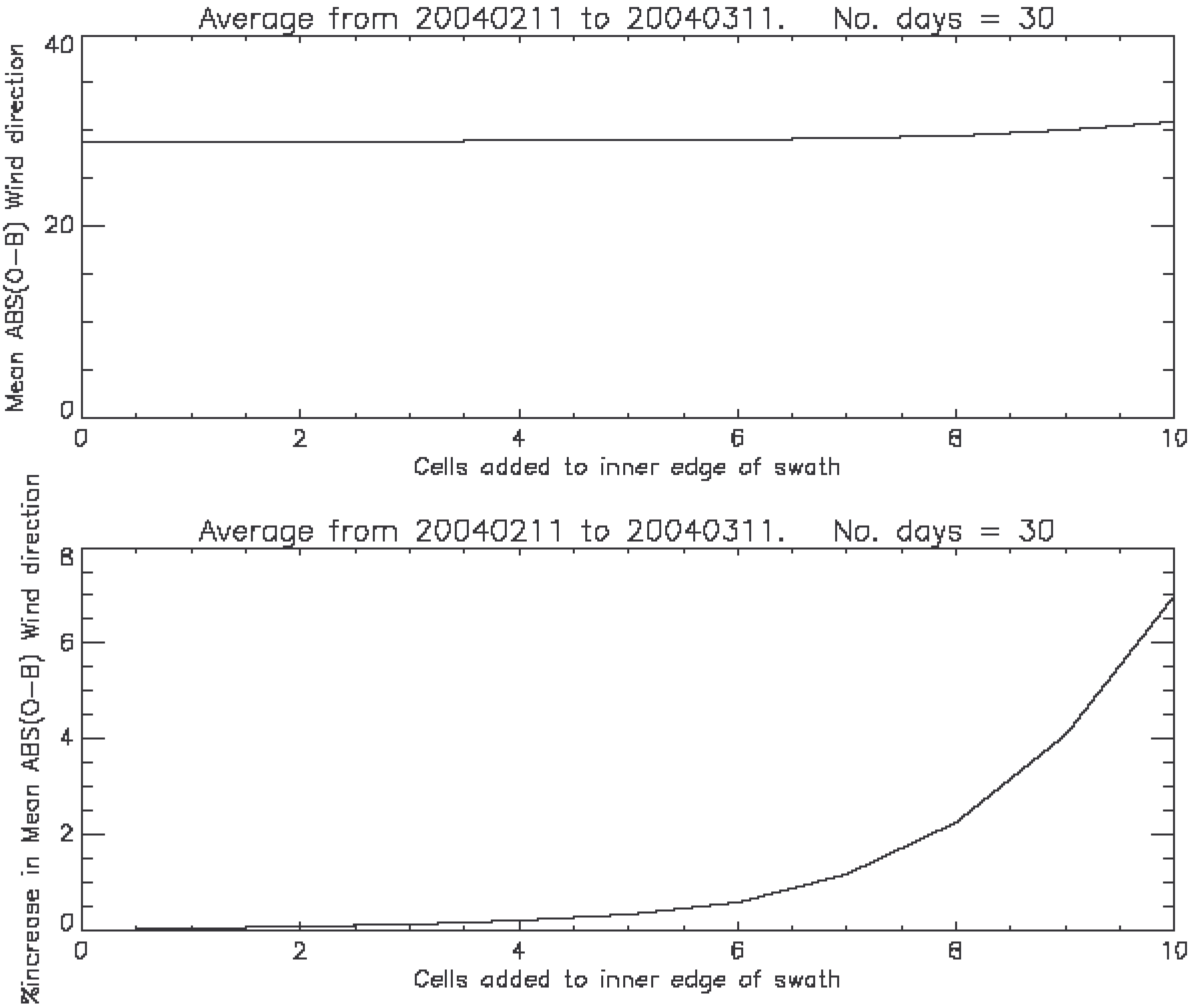


Figure 12. The effect of adding extra cells to the outer part of the swath on the mean ABS(O-B) wind direction.

The above plot is an important one as the primary value of QuikSCAT data is that it provides valuable surface wind direction data. It can be seen from the above plot that extending the inner edge of the swath inwards towards the centre increases the mean ABS(O-B) wind direction. The growth of the mean ABS(O-B) values is very slow at first with little difference arising by adding two cells. After four cells have been added though, the growth becomes more rapid. After four cells are added the %increase in the mean ABS(O-B) values is less than 0.5%.

4. Discussion and forecast trial.

It appears that the effects of extending the swath are less severe in terms of the effect on the overall quality of the wind speed and direction data if the inner edge of the swath is extended rather than the outer edge. This is what is expected given the results plotted earlier between the wind parameters and node number. Table 1 and 2 illustrate this point clearly.

Table 1. Effects of extending outer edge of swath.

Number of Cells Added	% Extra observations	% increase mean O-B wind speed	% increase in mean ABS(O–B) wind direction
0	0.0	0.0	0.0
1	6.3	0.5	1.1
2	12.5	1.0	3.7
3	18.2	1.8	8.6
4	24.7	5.2	17.8
5	31.2	9.9	26.1
6	37.7	16.0	33.8
7	44.3	24.0	40.9
8	50.9	34.0	47.5
9	54.3	39.1	50.8

Table 2. Effects of extending inner edge of swath.

Number of Cells Added	% Extra observations	% increase mean O-B wind speed	% increase in mean ABS(O–B) wind direction
0	0.0	0.0	0.0
1	5.7	0.2	0.03
2	11.5	0.3	0.07
3	17.2	0.6	0.11
4	23.0	0.9	0.20
5	28.8	1.2	0.32
6	34.6	1.6	0.59
7	40.3	2.1	1.15
8	46.1	2.6	2.23
9	51.8	3.0	4.08
10	57.8	3.3	6.96

A baseline figure of 9.4×10^6 observations were used in the 'no cells added' case and it is easy to see how this figure can be increased by large percentages if even a few cells are added to the inner part of the swath.

It would be interesting to perform this analysis again later when merged back analysis values are available from the MetDB. It would also be interesting to perform this analysis again using a different MLE upper threshold value (instead of 1.80) to look at the effects on the quality of the data when varying the number of cells used. It may be that we can increase the number of observations available by adding cells and reduce the effects of the extra cells on the O-B difference by lowering the MLE upper threshold.

A forecast trial (SCAT006) was run on the SX6 to look at the impact on the NWP index of extending the inner part of the scatterometer swath be extended by 5 cells on either side. This change was expected to give an increased amount of data for NWP with only a negligible effect on the overall data quality. The verification of the results against observations gave a neutral impact (Table 3). However, the results of the trial were negative when verified against analysis (Table 4).

Table 3. Effect of adding 5 cells to each side of inner swath – **verified against Observations**.

Green--> Better; Red--> Worse; White--> Neutral

Parameter Details				No of Values	Control Data			Test Data			Differences		
Area	Field Code	Fc Range	Wt	12Z	Fc RMS	Per RMS	Wted Skill	Fc RMS	Per RMS	Wted Skill	Fc RMS Diff (%)	Skill Diff	UnWted Diff
NH	PMSL	T+24	10	22	1.767	7.602	9.460	1.772	7.603	9.457	0.30	0.00	0.00
NH	PMSL	T+48	8	21	2.610	10.232	7.479	2.615	10.234	7.478	0.19	0.00	0.00
NH	PMSL	T+72	6	20	3.735	11.078	5.318	3.781	11.076	5.301	1.22	-0.02	0.00
NH	PMSL	T+96	4	19	5.035	12.184	3.317	5.058	12.184	3.311	0.45	-0.01	0.00
NH	PMSL	T+120	4	18	6.231	13.387	3.133	6.307	13.386	3.112	1.21	-0.02	-0.01
NH	H500	T+24	6	22	16.036	75.692	5.731	16.045	75.725	5.731	0.06	0.00	0.00
NH	H500	T+48	4	21	23.704	108.464	3.809	23.802	108.483	3.807	0.42	0.00	0.00
NH	H500	T+72	2	20	34.020	123.345	1.848	34.364	123.351	1.845	1.01	0.00	0.00
NH	W250	T+24	12	22	6.348	20.844	10.887	6.337	20.846	10.891	-0.17	0.00	0.00
Trop	W850	T+24	5	22	4.145	4.682	1.082	4.124	4.668	1.099	-0.51	0.02	0.00
Trop	W850	T+48	3	21	4.617	5.852	1.133	4.607	5.858	1.144	-0.21	0.01	0.00
Trop	W850	T+72	2	20	5.002	6.448	0.797	4.985	6.447	0.804	-0.34	0.01	0.00
Trop	W250	T+24	6	22	6.268	9.115	3.163	6.237	9.128	3.199	-0.50	0.04	0.01
SH	PMSL	T+24	5	22	1.488	5.013	4.559	1.489	5.010	4.558	0.03	0.00	0.00
SH	PMSL	T+48	4	21	2.066	6.540	3.601	2.071	6.537	3.598	0.25	0.00	0.00
SH	PMSL	T+72	3	20	2.681	7.248	2.590	2.680	7.246	2.589	-0.01	0.00	0.00
SH	PMSL	T+96	2	19	3.277	7.682	1.636	3.272	7.680	1.637	-0.14	0.00	0.00
SH	PMSL	T+120	2	18	4.121	8.162	1.490	4.095	8.159	1.496	-0.63	0.01	0.00
SH	H500	T+24	3	22	14.160	46.137	2.717	14.160	46.127	2.717	0.00	0.00	0.00
SH	H500	T+48	2	21	18.000	64.237	1.843	17.932	64.206	1.844	-0.38	0.00	0.00
SH	H500	T+72	1	20	24.548	70.737	0.880	24.605	70.677	0.879	0.23	0.00	0.00
SH	W250	T+24	6	22	6.759	16.788	5.028	6.783	16.772	5.019	0.37	-0.01	0.00

Total Weighted Mean Skill (total weight = 100)
Control Case = 81.499
Test Case = 81.516
Test - Control = 0.017

Estimated Obs Based Global Index
(36 Month, normalised to March 2000)
Control Case = 119.304
Test Case = 119.358
Test - Control = 0.054 (0.046 %)

Table 4. Effect of adding 5 cells to each side of inner swath – **verified against <u>Analysis</u>**.

Green--> Better; Red--> Worse; White--> Neutral

Parameter Details				No of Values	Control Data			Test Data			Differences		
Area	Field Code	Fc Range	Wt	12Z	Fc RMS	Per RMS	Wted Skill	Fc RMS	Per RMS	Wted Skill	Fc RMS Diff (%)	Skill Diff	UnWted Diff
NH	PMSL	T+24	10	23	1.354	6.860	9.610	1.362	6.859	9.606	0.55	0.00	0.00
NH	PMSL	T+48	8	22	2.274	9.288	7.520	2.286	9.286	7.515	0.54	-0.01	0.00
NH	PMSL	T+72	6	21	3.297	10.040	5.353	3.338	10.038	5.337	1.23	-0.02	0.00
NH	PMSL	T+96	4	20	4.334	10.849	3.362	4.369	10.847	3.351	0.80	-0.01	0.00
NH	PMSL	T+120	4	19	5.416	11.665	3.138	5.417	11.664	3.137	0.01	0.00	0.00
NH	H500	T+24	6	23	11.957	70.647	5.828	11.986	70.657	5.827	0.24	0.00	0.00
NH	H500	T+48	4	22	21.039	99.076	3.820	21.212	99.078	3.817	0.82	0.00	0.00
NH	H500	T+72	2	21	31.749	111.249	1.837	32.083	111.240	1.834	1.05	0.00	0.00
NH	W250	T+24	12	23	4.187	20.045	11.476	4.179	20.048	11.479	-0.19	0.00	0.00
Trop	W850	T+24	5	23	2.113	3.460	3.136	2.131	3.461	3.105	0.84	-0.03	-0.01
Trop	W850	T+48	3	22	2.850	4.637	1.867	2.853	4.643	1.867	0.10	0.00	0.00
Trop	W850	T+72	2	21	3.369	5.099	1.127	3.366	5.098	1.128	-0.09	0.00	0.00
Trop	W250	T+24	6	23	3.672	7.422	4.531	3.672	7.428	4.534	-0.01	0.00	0.00
SH	PMSL	T+24	5	23	1.311	6.593	4.802	1.320	6.581	4.799	0.64	0.00	0.00
SH	PMSL	T+48	4	22	2.255	8.651	3.728	2.265	8.639	3.725	0.45	0.00	0.00
SH	PMSL	T+72	3	21	3.242	9.517	2.652	3.289	9.500	2.641	1.43	-0.01	0.00
SH	PMSL	T+96	2	20	4.281	9.989	1.633	4.341	9.972	1.621	1.39	-0.01	-0.01
SH	PMSL	T+120	2	19	5.526	10.193	1.412	5.587	10.173	1.397	1.11	-0.02	-0.01
SH	H500	T+24	3	23	12.238	71.905	2.913	12.281	71.876	2.912	0.35	0.00	0.00
SH	H500	T+48	2	22	21.627	97.053	1.901	21.701	97.013	1.900	0.34	0.00	0.00
SH	H500	T+72	1	21	32.414	109.243	0.912	32.757	109.169	0.910	1.06	0.00	0.00
SH	W250	T+24	6	23	4.215	18.673	5.694	4.235	18.671	5.691	0.45	0.00	0.00

Total Weighted Mean Skill (total weight = 100)
Control Case = 88.251
Test Case = 88.133
Test - Control = -0.119

Estimated Analysis Based Global Index
(36 Month, normalised to March 2000)
Control Case = 124.538
Test Case = 123.914
Test - Control = -0.624 (-0.501 %)

5. Conclusion.

It is clear from these results that extending the swath, whilst giving more observations for NWP, would have a negative impact on the forecast quality. Despite a neutral impact against observations the change showed a negative impact when verified against analyses. It is therefore not recommended that the inner part of the swath be extended by 5 cells on either side during the next operational change to the Met Office Observation Processing System but that instead it be left as it is.

Annex 2. Study of the effects of varying the QuikSCAT distance to cone limit.

Simon J. Keogh and Dave Offiler

13th August 2004

Summary.

The aim of this study is to ascertain a) if the MLE limit can be raised to allow more scatterometer observations to be available for NWP and b) if the MLE is uniform across the used range of wind speeds. Data from 10th August and 1st – 21st July were analysed. It was found the mean MLE seemed to be approximately uniform across the range 0-25m/s, being slightly higher for lower wind speeds (<7m/s). It is not recommended that the MLE be renormalized as data from <2m/s are not used anyway. It is also not recommended that the MLE limit be raised from 1.80 in order to make more observations available for NWP. This is because the O-B values for MLEs greater 1.80 were found to be greater than those in the sub 1.80 MLE range. It was also evident however that for MLEs > 2.00 the O-B values rose rapidly.

1. Introduction.

In the OPS the distance to cone limit is currently set to 1.80 (ref. (i) Candy and Offiler). This value was conservatively chosen so as to filter out the majority of poor QuikSCAT observations. The main aim of this study is to determine what effect raising the MLE limit might have on the quality and quantity of the resulting observations that would be passed to VAR. Another aim of this study is to look at the distribution of MLEs across the wind speed range 0-25m/s to see if there is any trend. There should be no trend if the MLE is properly normalised across the wind speed range.

2. Method.

Two approaches are taken for this study using data extracted from the MetDB, which are saved every day on a local linux machine.

Firstly, a single day of data is scrutinised to look at the relationship between distance to cone and wind speed. This was done in PV Wave.

Secondly, 21 days of QuikSCAT data are analysed to look at the effect of varying the MLE limit on the O-A values in a large data set. A second analysis of 21 days of data was also performed to look at the distribution of MLE values in the 0-25m/s wind speed range and how these distributions change for different maximum MLE limits.

It is worth noting that for both of the above steps the rain probability limit was kept at 0.10 (as in the current version of OPS) and the used scatterometer swath was also kept the same without the extension of the inner part of the swath, that is the subject of an earlier report (ref (ii)), being applied. The maximum wind speed was also set to 25m/s.

3. Results and discussion.

First of all, before analysing 21 days of data, a single day of data (10th August 2004) was analysed to explore the behaviour of the MLE. Figures 3.2 and 3.2 show what happens to the daily mean O-B and observed wind speed as the MLE limit is varied from 0 to 3.9.

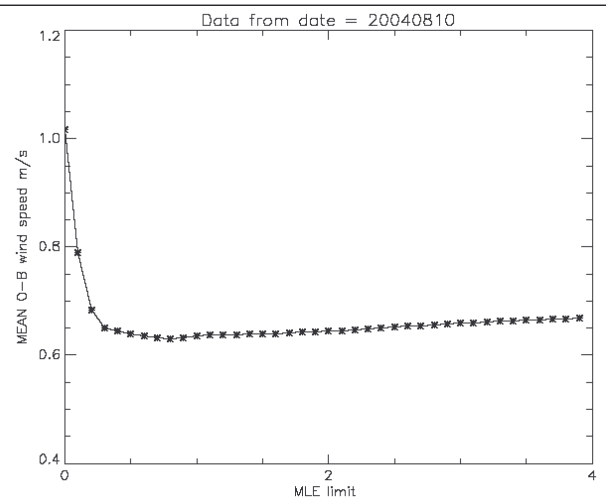


Figure 3.1 This plot shows what happens to the average O-B wind speed when the MLE limit is varied. Initially the O-B values are high and drop to a minimum corresponding to an MLE limit of approximately 0.9. At present the MLE limit is set to 1.80 in OPS. As the MLE is raised from 0.9 the O-B average increases slowly from a minimum of ~0.62 to ~0.66 at an MLE limit of 3.9. MLE bin size=0.10.

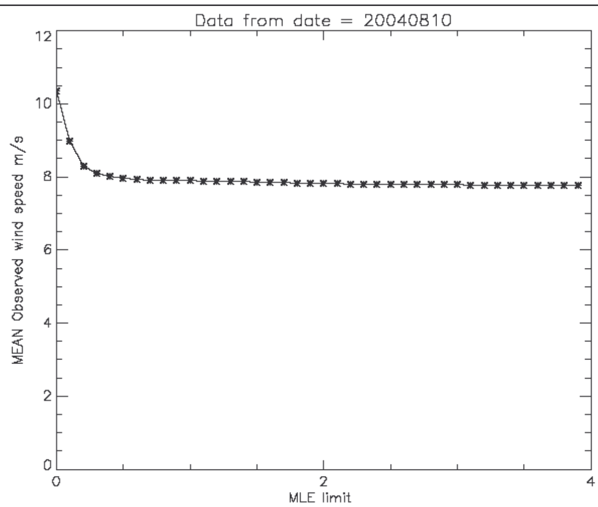


Figure 3.2 This plot demonstrates what happens to the mean observed wind speed as the MLE limit is raised. It appears that the mean observed wind speed is highest at very low MLE limit values. Beyond an MLE limit of approximately 0.5 there is little change in the mean observed wind speed. MLE bin size=0.10.

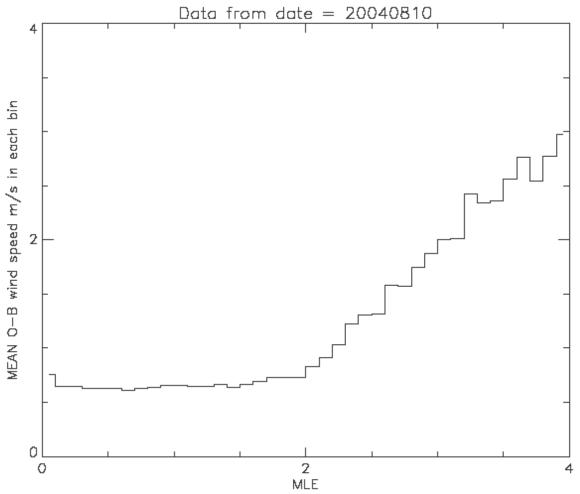


Figure 3.3 This plot shows the mean O-B wind speed after it has been binned by MLE intervals of 0.1. In the range 0<MLE<2 the mean O-B wind speeds are uniform. At higher MLE values MLE>2 it is clear that there is more disagreement between the QuikSCAT wind speed and the model background field.

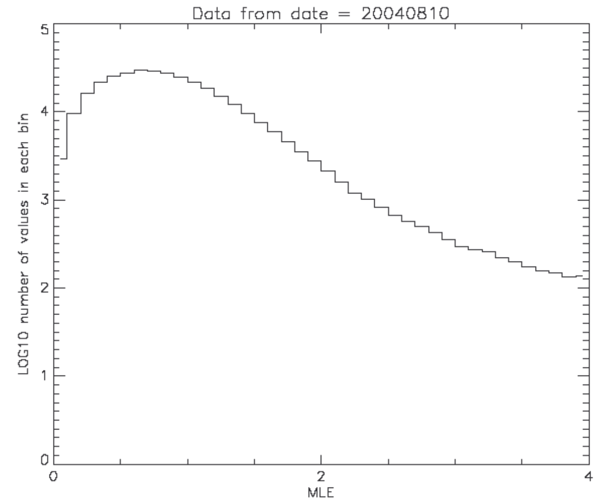


Figure 3.4 This plot demonstrates that if the MLE limit is extended from 1.80 to a higher value (e.g. 2.0) that there will be extra observations available for NWP.

These results are interesting as they show that beyond and MLE limit of ~0.9 the mean O-B wind speed difference increases and the mean observed wind speed decreases, which implies that at higher MLE values more (erroneous) low wind speed data is being included.

Figures 3.3 and 3.4 are histograms that demonstrate that a) the mean O-B wind speed is approximately uniform for MLE<1.80 and b) that by extending the MLE from 1.80 (the current value) there would only be a few % more observations available for NWP purposes (before thinning) which are of good quality.

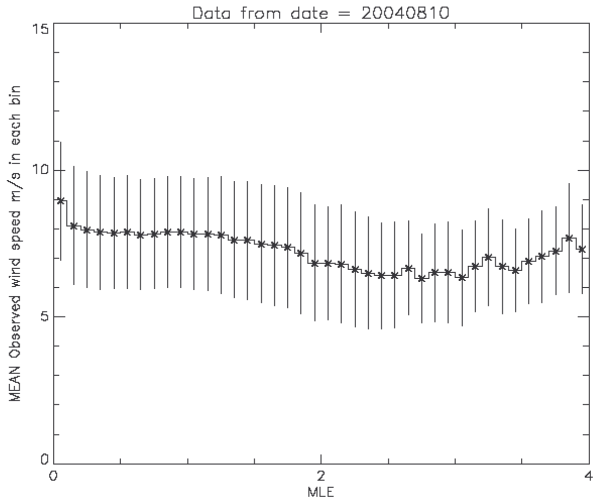


Figure 3.5 Here the mean observed wind speed is shown by MLE bin (intervals of 0.1). Error bars are of one standard deviation in length.

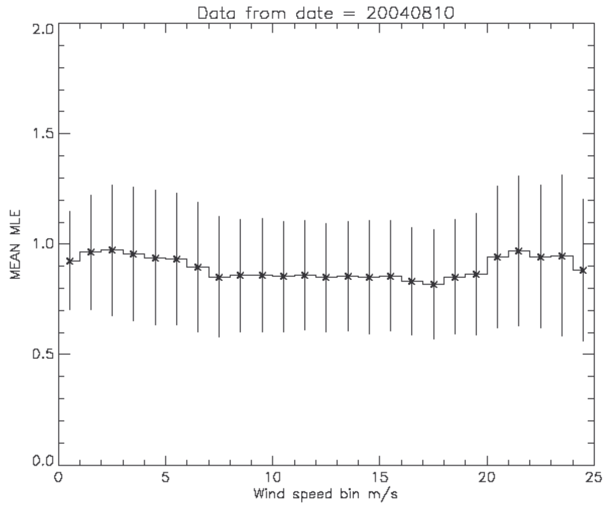


Figure 3.6 Here the wind speed is binned in 1m/s intervals and plotted against the mean MLE for each interval. Where the mean MLE is higher appears to correspond to larger values of the MLE standard deviations, which are plotted here as error bars.

Figures 3.5 and 3.6 demonstrate that the mean observed wind speed generally becomes smaller with MLE value but the mean MLE value is not so variable with wind speed bin. Where the mean MLE is higher seems to correspond to a larger scatter in the data (increased standard deviation and therefore error bar size). Figure 3. shows how the wind speeds were distributed in the data set, peaking at 6-7m/s.

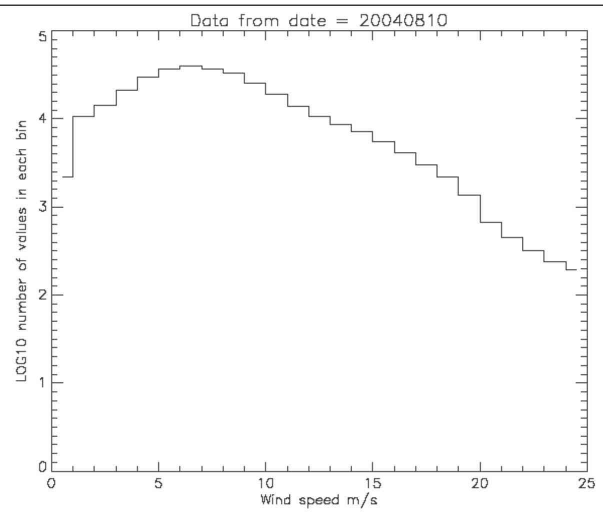


Figure 3.7 This figure demonstrates how the wind speeds are distributed over the range 0-25m/s.

To explore these results further, 21 days of data from 1st – 21st July 2004 were analysed. Figures 3.8 and 3.9 show the variation of the O-A wind speeds over time for various MLE limits. The mean O-A changes only slightly over the range 1.80<MLE<2.60, although the RMS O-A increases by approximately 0.03m/s.

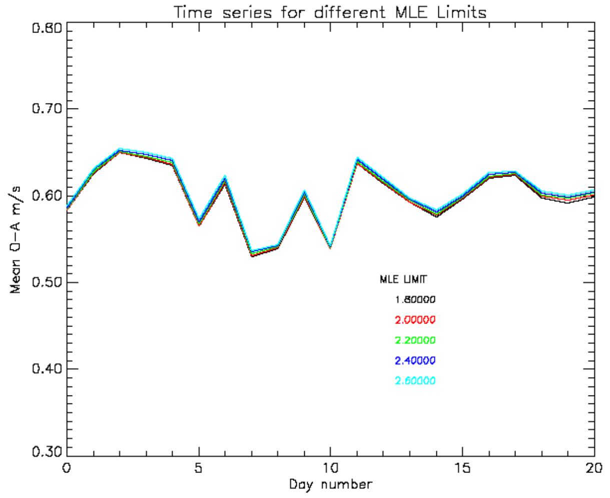


Figure 3.8 Variation in mean O-A wind speeds for 21 days of QuikSCAT data using 5 different MLE limits. As MLE limit is increased there is a small increase on the daily mean O-A values.

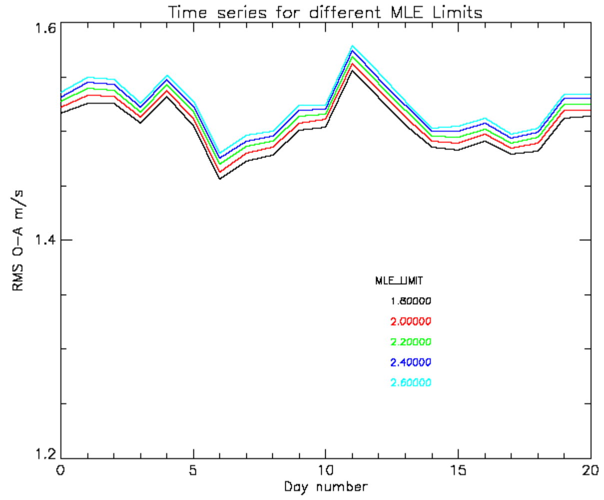


Figure 3.9 Variation in RMS O-A wind speeds for 21 days of QuikSCAT data using 5 different MLE limits. As MLE limit is increased so the daily mean O-A values become larger, i.e. RMS bias between observations and analysis increases.

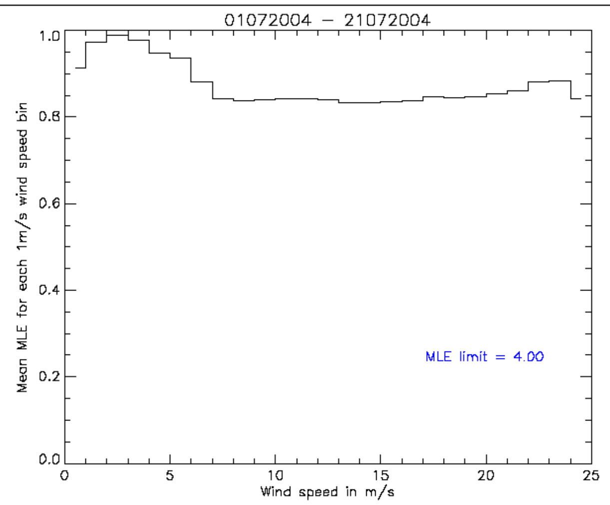


Figure 3.10 This plot shows MLE binned by wind speed in 1m/s bins. The MLE's used range from 0-4.0. The mean MLE appears to be approximately uniform over the range 7-22m/s but higher at wind speeds less than 7m/s. The data used for this plot span 21 days.

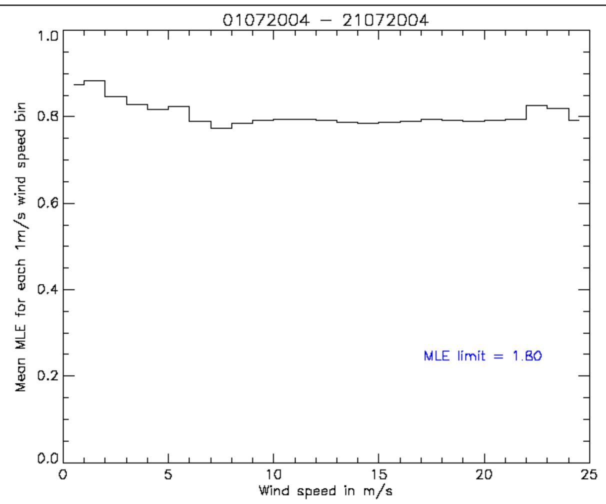


Figure 3.11 Similar to the last figure except that the Maximum allowed MLE is 1.8. It is evident that the the overall mean MLE is lower than in the previous case and that this is most evident at wind speeds less than 7m/s. The data used for this plot span 21 days.

Figures 3.10 and 3.11 show what happens to the mean MLE with wind speed when data from 0<MLE<4.0 and 0<MLE<1.80 are considered respectively. In the wind speed range 7-21m/s the mean MLE is relatively constant, being slightly less than 0.80. However in the range 0-7m/s the mean MLE increases with decreasing wind speed. However, the effect is much reduced in figure 3.11 because the MLE limit is set to 1.80 rather than 4.0 in figure 3.10. This has the effect of filtering some of the poorer quality low wind speed data, although data <2m/s is not used anyway for NWP.

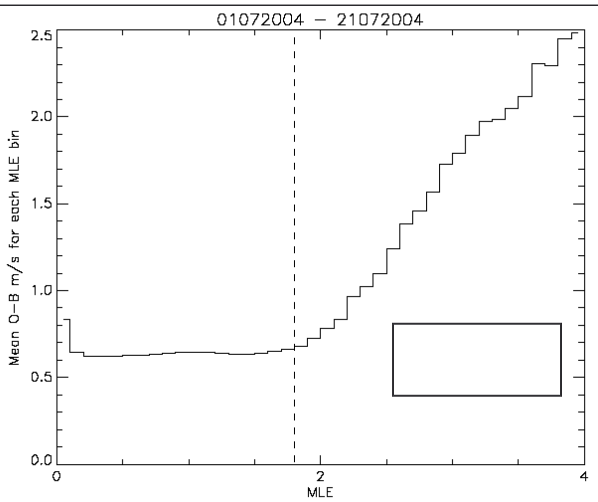


Figure 3.12 The same as figure 3.3 except for 21 days of data. Vertical dashed line shows current MLE limit of 1.80. O-B data are plotted for MLE bins of 0.1 up to a value of 4.0.

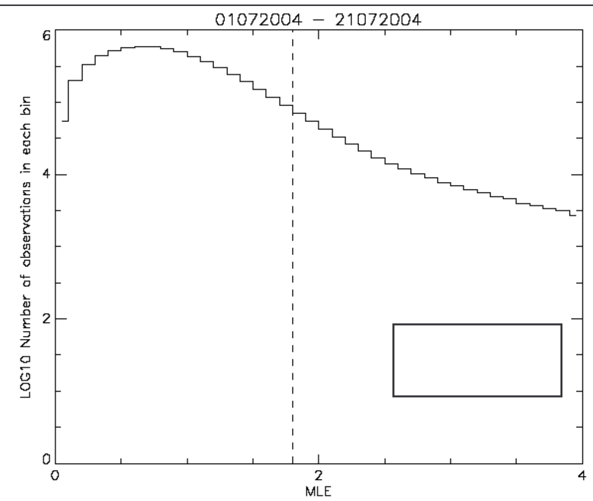


Figure 3.13 The same as figure 3.4 except for 21 days of data. Vertical dashed line shows current MLE limit of 1.80. LOG10 number of data points in each 0.1 MLE bin is plotted upto an MLE of 4.0.

Figure 3.12 and 3.13 are similar to figures 3.3 and 3.4 except that they include 21 days data rather than only data from a single day. Nevertheless the results shown are clearly similar and again demonstrate that the MLE limit of 1.80 appears to be optimal, with any increase in the limit resulting in an overall worsening of the quality of the observations being passed on to VAR.

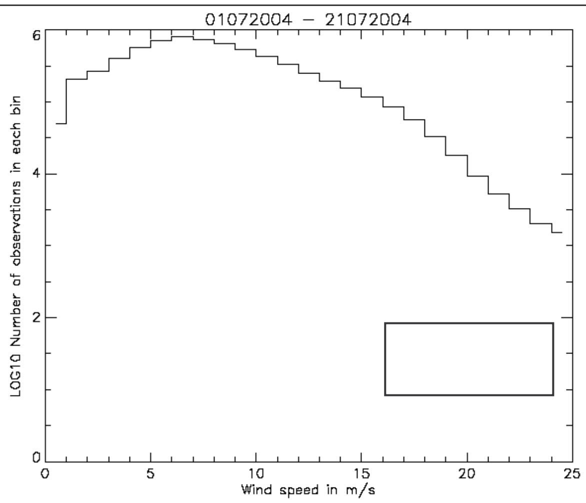


Figure 3.14 Number of observations in each QuikSCAT wind speed bin over a 21 day period.

Figure 3.14 shows the distribution of wind speeds over the 21 day period of 1st – 21st July 2004, which again peaks at 6-7m/s.

4. Recommendations.

The MLE appears to still be reasonably uniform across the 2-25 m/s range (see figure 3.11) so it is not recommended that it be renormalized across the wind speed range.

Table 1. Increase in number of observations from changes in MLE limit.

MLE limit	Number of observations	% increase in Number of observations
1.80	309808	-
1.90	313342	1.14
2.00	316117	2.03
2.10	318238	2.72
2.20	319851	3.24

It is also not recommended that the MLE limit be extended from 1.80 to make extra observations available for NWP. Table 1 demonstrates the benefit to NWP in terms of extra observations, but this must be weighted against the fact that as MLE is increased the quality of the data being added becomes poorer. Figure 3.2 demonstrates this point as the average observed wind speed becomes lower as the MLE limit is increased, which indicates that more and more (erroneous) low wind speed data is being drawn in at higher MLE values pushing down the average observed wind speed.

5. References.

(i) Candy, B. and Offiler, D., 'OSDP8: Scatterometer Processing Description', Internal Report, July 2002.

(ii) Keogh, S.J., 'Report on the broadening of the QuikScat swath', Internal Report, March 2004

Annex 3. Study of the effects of varying the scatterometer rain probability limit.

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Summary.

The OPS has a rain probability limit of 0.10 set in the scatterometer namelist (WindRetrieval.nl) to enable rain contaminated data to be filtered out of the NWP system. This document describes how scatterometer data have been examined to determine if this rain probability limit can be raised to yield improved benefits to NWP in terms of either better data coverage or quality. However, the report recommends that no change to the limit is required because a) >98% of useful data already meet the criteria and b) the remaining data are likely to be of insufficient quality to warrant their inclusion.

1. Introduction.

The QuikSCAT scatterometer works at a frequency of 13.4GHz. Unfortunately this means that the scatterometer signal is likely to be corrupted by the presence of rain. To enable NWP systems to cope with this, the OPS system has a rain probability limit (ref. (i) Candy and Offiler) that is set to filter out QuikSCAT data that have a high probability of being contaminated with rain.

The purpose of this study is to look at the effects of varying this limit (currently set to 0.10) on the values of O-A and O-B over a 21 day period. The aim is to ascertain whether or not there is likely to be any significant benefit to changing the value of the rain probability limit in the OPS system to improve NWP.

2. Method.

First of all a single day of scatterometer data is studied (9th August 2004) to see what effect choosing various rain flags might have on the O-B difference for surface wind speed.

Secondly, QuikSCAT data from 1st – 21st July 2004 were processed using PV Wave. The data was cycled through a number of times, each time with a different rain probability threshold being applied to the data set. The resulting daily O-A and O-B statistics obtained for each threshold value were stored for later analysis.

It is worth noting that for both of the above steps the MLE limit was kept at 1.80 (as in the current version of OPS) and the used scatterometer swath was also kept the same without the extension of the inner part of the swath, that is the subject of an earlier report (ref (ii)), being applied. The maximum wind speed was also set to 25m/s.

3. Results.

The figures below (figures 3.1 – 3.4) were generated using data from 9th August 2004. They show two main characteristics of interest:

- Higher probabilities of rain are associated with larger O-B wind speeds and distances to cone
- O-B wind speeds and distances to cone appear to increase in a linear fashion with increasing rain probability limit

Despite this figure 3.3 demonstrates that the overall effect on the daily mean distance to cone is negligible because there are so few occurrences of high rain probability levels in relation to low rain probability levels, which is illustrated in figure 3.5. What this essentially means is that as the rain probability limit is increased the data being added becomes worse and worse but are so few in number that it doesn't affect the mean daily statistics by very much.

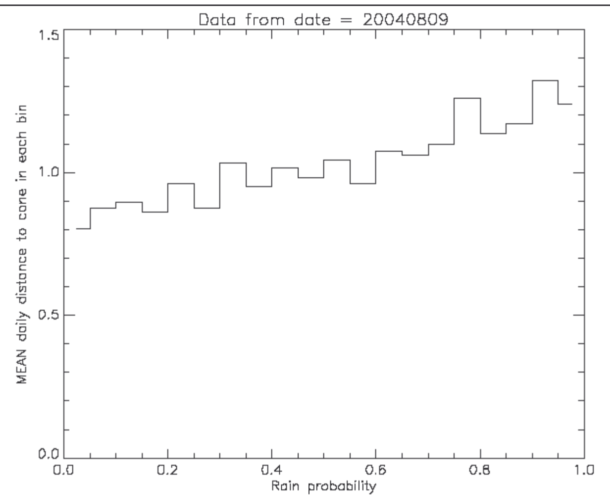

Figure 3.1 Distance to cone binned by rain probability. Distance to cone appears to increase in a near linear fashion with rain probability.

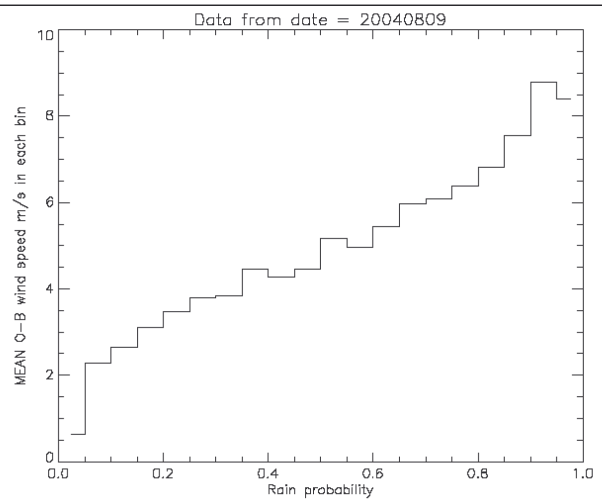

Figure 3.2 Mean O-B wind speed binned by rain probability. O-B increases with increasing rain probability.

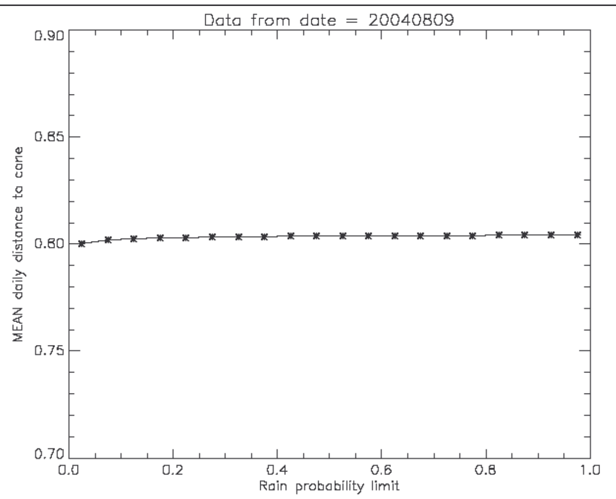

Figure 3.3 Mean distance to cone obtained using various rain probability limits.

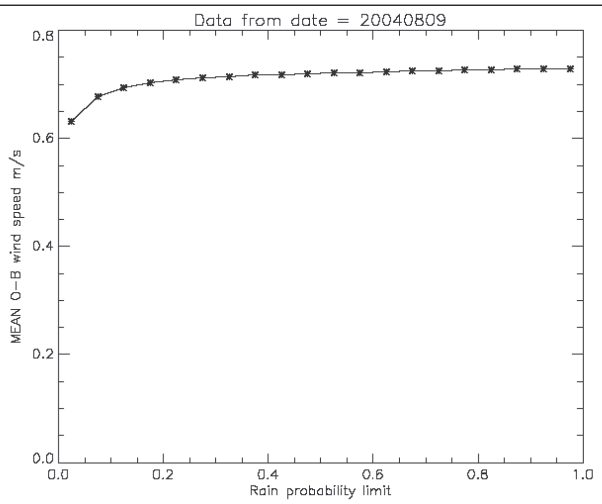

Figure 3.4 Mean O-B wind speed obtained using various rain probability limits.

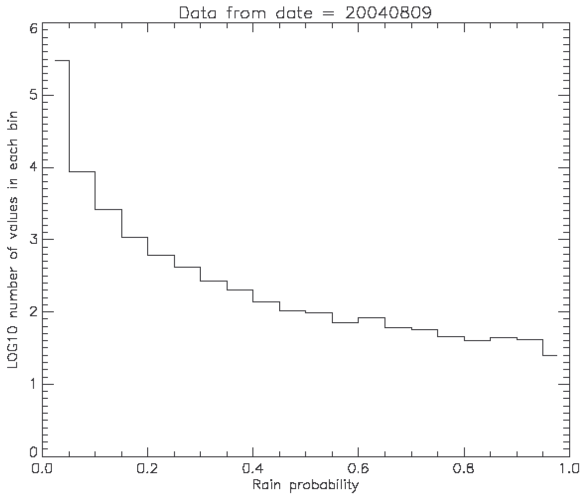

Figure 3.5 LOG_{10} Number of values in each bin from QuikSCAT data for 9th August 2004.

The findings above are reinforced when 21 days of data are analysed to produce figures 3.6 and 3.7 below. In these figures the Mean and RMS O-A wind speeds are shown colour coded for various rain probability limits. The effect of increasing the rain probability limit further and further diminishes with each increase dues to the decreasing number of observations in the higher rain probability bins.

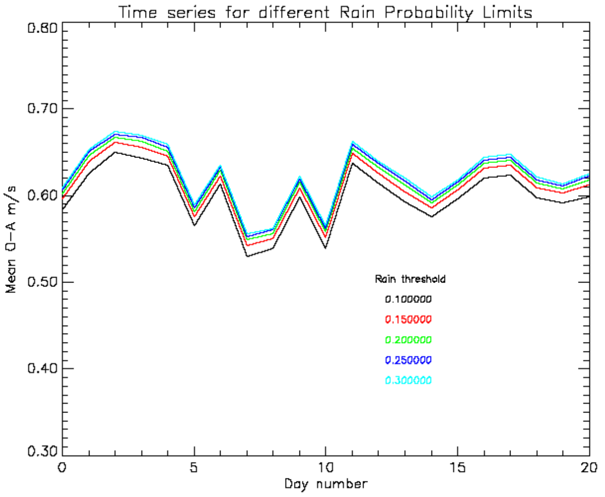

Figure 3.6 Daily mean O-A wind speed over a 21 day period for various rain probability limits.

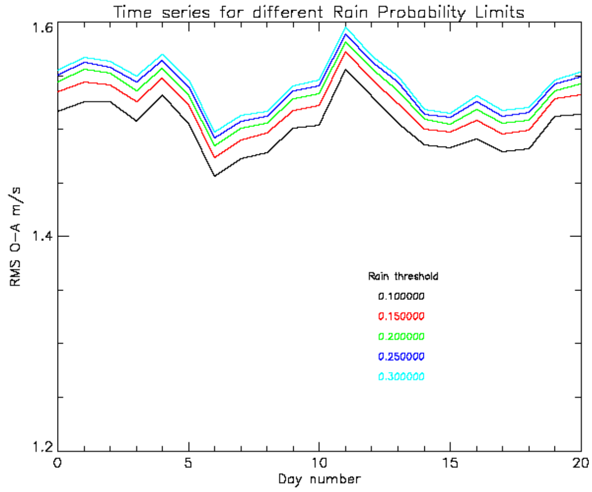

Figure 3.7 Daily RMS O-A wind speed over a 21 day period for various rain probability limits.

4. Discussion and recommendations.

The rain probability limit is currently set to 0.10. Doubling this value to 0.20 has the effect of increasing the number of observations available for NWP by only 1%. For example, for the 9th August 2004, table 1 shows the increase in the number of observations.

Table 1. Increase in number of observations from changes in rain probability limit.

Rain probability limit	Number of observations	% increase in Number of observations
0.10	308210	-
0.20	311882	1.19
0.30	312911	1.52
0.40	313386	1.68

The effect on the mean daily O-B of adding these extra values is very small even though the extra data is clearly of a lower quality. This is because so few extra values are being added. This can give a false sense of insensitivity so it is not recommended that the rain probability threshold be changed at present for the new OPS upgrade because the benefit would be very small. In fact >98% of all useful observations already fit the criteria of having a rain probability flag of less than 0.10 so an increase would not yield much benefit in terms of an increased number of observations.

5. References.

(i) Candy, B. and Offiler, D., 'OSDP8: Scatterometer Processing Description', Internal Report, July 2002.

(ii) Keogh, S.J., 'Report on the broadening of the QuikScat swath', Internal Report, March 2004.

Annex 4. Glossary and acronyms.

AMI	Active Microwave Instrument
ASCAT	Advanced SCATterometer
BUFR	Binary Universal Form for the Representation of meteorological data
C-band	Microwave band of the electromagnetic spectrum around 5 GHz
dB	decibel
DCP	Data Collection Platform
DWD	Deutscher Wetterdienst
ECMWF	European Centre for Medium-Range Weather Forecasts
EPS	EUMETSAT Polar System
ERS	European Remote-Sensing satellite
ERSURA	European Remote-Sensing satellite Radar Altimeter
ESA	European Space Agency
ESOC	European Space Operations Centre (an ESA establishment located in Darmstadt, Germany)
ESRIN	European Space Research Institute (ESA)
ESTEC	European Space Research and Technology Centre (an ESA establishment in the Netherlands)
EUMETSAT	The European Organisation for the Exploitation of Meteorological Satellites
GHz	Giga-Hertz
G/S	Ground Segment
GTS	Global Telecommunication System (of the WMO)
IFREMER	Institut Francais de Recherche pour l'Exploitation de la Mer
KNMI	Royal Netherlands Meteorological Institute
ku-band	Microwave band of the electromagnetic spectrum around 14 GHz
LAM	Local Area Model
LEO	Low Earth Orbit
LEOP	Launch and Early Orbit Phase
Metop	Meteorological Operational polar satellites of EUMETSAT
MLE	Maximum Likelihood Estimation
NASA	National Aeronautics and Space Administration (of the USA)
NESDIS	National Environmental Satellite Data and Information Service (of NOAA)
NPOESS	National Polar-orbiting Operational Environmental Satellite System (of the USA)
NSCAT	NASA Scatterometer
NWP	Numerical Weather Prediction
OPS	Observation Processing System
OSI	Ocean and Sea Ice SAF (see also SAF)
PGS	Primary Ground Station
POES	Polar-orbiting Operational Environmental Satellite (USA)
RFI	Radio Frequency Interference
RX	Receiver
QC	Quality Control
QuikSCAT	Quick SCATterometer
RA	Radar Altimeter
RMS	Root Mean Square
SAF	Satellite Application Facility
SAR	Synthetic Aperture Radar
SCAT	Scatterometer (satellite radar measuring winds over the oceans)
SFE	Scatterometer Front End
SSM/I	Special Sensor Microwave/Imager
SWI	Soil Wetness Index
TAO	Tropical Atmosphere-Ocean array of moored buoys in the Pacific
TOA	Top Of the Atmosphere

TX	Transmistter
UTC	Universal Time Coordinated
VAR	Variational Assimilation System
WMO	World Meteorological Organization
X-Band	Frequency Band 6,2 - 10,9 GHz

Annex 5. SEAWINDS error study.

As a follow on to the previous studies, it was decided that the assumed SEAWINDS U and V component error of 2m/s should be investigated to see if it was still appropriate. This was initially done by analysing O – B differences from historical SEAWINDS and Met Office model data. This study suggested that a lower observation error was appropriate for SEAWINDS except at very high winds speeds. In addition, a study by Brett Candy (personal communication) on simulating Windsat performance using SEAWINDS data had drawn a similar conclusion about SEAWINDS in that the U and V component observation error of 2m/s looked like an overestimate. Based on these collective results it was decided that a sensitivity trial should be run on the NEC to observe the effect of reducing the observation error to 1.5m/s. The results were broadly positive so the sensitivity study was extended into a full forecast trial, which again yielded broadly positive results. A second season trial also confirmed that the change from 2.0m/s to 1.5m/s would be beneficial to the NWP index. The good results from two N216 4D Var trials gave confidence that this change should be recommended for operational use. However, during a package trial with Meteosat 8 atmospheric motion vectors (AMVs) change it was found that the SEAWINDS error change was reducing the positive impact of the AMV change. The only conclusion that could be drawn about this was that somehow the benefits of the SEAWINDS error change were also being delivered by the Meteosat 8 change meaning that only the negative aspects of the SEAWINDS error change were being added into the trial forecasts. It was therefore decided that the error change should not be pursued further at this time. The recommendation was therefore to leave the U and V component observation error set to 2m/s with a view to revising this study in future if time and resources allow.