## Ocean and Sea Ice SAF

Technical Note

SAF/OSI/CDOP2/KNMI/TEC/RP/194

# Quality Control of Ku-band scatterometer winds

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# Contents

# 1 Introduction

A good assessment of the information content of scatterometer winds is particularly important in order to assimilate them in weather analysis or use them in climate analyses. Besides retrieval problems in cases of a confused sea state, a particularly acute problem of Ku-band scatterometry is the sensitivity to rain. Elimination of poor quality data is therefore very important for the successful use of the wind data of the OSCAT instrument on Oceansat-2 [1] and the SeaWinds instrument on QuikSCAT [2]. The process of discriminating between good and bad quality Wind Vector Cells (WVCs) winds is called Quality Control (QC).

The OSCAT scatterometer is one of the three instruments carried on-board the Oceansat-2 polar satellite, launched and operated by the Indian Space Research Organisation (ISRO). It was launched on 23 September 2009. A similar instrument is planned to be launched in 2013 on ScatSat. The OSCAT instrument is a conically scanning pencil-beam scatterometer. It uses a 1-meter dish antenna rotating at 20 rpm with two "spot" beams of about 25 km × 55 km size on the ground. A horizontal polarisation beam (HH) and a vertical polarisation beam (VV) at incidence angles of 43º and 49º respectively, sweep the surface in a circular pattern. The OSCAT Wind Data Processor (OWDP) was developed in the Numerical Weather Prediction Satellite Application Facility (NWP SAF) to compute winds from the 50-km level 2a OSCAT backscatter data. The OSCAT level 2a data are available in near-real time and OWDP is used at KNMI to produce the Ocean and Sea Ice (OSI) SAF wind product which is made available to users. A beta version of OWDP is also available to the public. Moreover, the National Oceanic and Atmospheric Administration (NOAA) developed software to convert the OSCAT level 1b product from ISRO into a 25-km level 2a product; the software package was kindly provided to KNMI. The 25-km level 2a product can be used to create a 25-km OSCAT wind product with OWDP.

The OSCAT instrument very much resembles the SeaWinds scatterometer which has been operational until November 23, 2009; it operates in the same frequency band and uses the same polarisations. KNMI has developed a QC mechanism for SeaWinds that is based on the wind inversion residual (MLE or Maximum Likelihood Estimator), which proved to be very effective in detecting rainy or otherwise distorted backscatter measurements [3, 4, 5]. It was implemented in the SeaWinds Data Processor (SDP) software package that is (still) available in the NWP SAF. SDP was also used to produce the near-real time OSI SAF SeaWinds wind products until the end of the QuikSCAT mission. In this report, we assess the usability of this QC method for OSCAT and we propose some refinements in the algorithm that appear to be also profitable for SeaWinds.

## 1.1 References

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[3] Portabella, M. and A. Stoffelen, 2001
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## 1.2 Abbreviations and acronyms

| | |
|---|---|
| ASCAT | Advanced SCATterometer |
| ECMWF | European Centre for Medium-Range Weather Forecasts |
| EUMETSAT | European Organisation for the Exploitation of Meteorological Satellites |
| JPL | Jet Propulsion Laboratory |
| KNMI | Royal Netherlands Meteorological Institute |
| MLE | Maximum Likelihood Estimator |
| NOAA | National Oceanic and Atmospheric Administration |
| NWP | Numerical Weather Prediction |
| OSCAT | Scatterometer onboard the Oceansat-2 satellite |
| OSI | Ocean and Sea Ice |
| OWDP | OSCAT Wind Data Processor |
| QC | Quality Control |
| RMS | Root Mean Square |
| SAF | Satellite Application Facility |
| SDP | SeaWinds Data Processor |
| WVC | Wind Vector Cell |

# 2 Quality Control method

Quality Control is performed in several steps of the scatterometer wind processing. Before the wind inversion step, WVCs containing a significant portion of land or ice are filtered out. After that, in the wind inversion, a set of ambiguous wind vector solutions is computed using a Geophysical Model Function (GMF). The GMF is an empirical function representing the radar backscatter as a function of wind speed and direction, given the incidence and azimuth angles of the radar beam on the ocean surface. When the set of backscatter measurements in a WVC is not consistent with the GMF, then a large residual (Maximum Likelihood Estimator or MLE) will result from the wind retrieval process. This report is devoted to the Quality Control procedure that is part of the wind inversion step and based on evaluation of the MLE. The Ambiguity Removal (AR) is the next step in the wind processing: in each WVC one of the ambiguous wind solutions is selected in order to obtain a consistent and unambiguous wind field. Quality Control is also part of the AR step in order to achieve spatial consistency.

## 2.1 SeaWinds QC method

The Quality Control algorithm used in the OSI SAF SeaWinds wind processing at KNMI is extensively described in [5]. The wind processing is based on the SeaWinds level 2 wind products as developed by Jet Propulsion Laboratory (JPL) and provided by the National Oceanic and Atmospheric Administration (NOAA). Both the Maximum Likelihood Estimator (MLE) and the JPL rain flag, present in the BUFR input from NOAA, are used. The MLE is defined as:

$$\mathrm{MLE} = \frac{1}{N}\sum_{i=1}^{N}\frac{(\sigma_{mi}^{0} - \sigma_{si}^{0})^{2}}{K_{p}(\sigma_{mi}^{0})}$$

where $N$ is the number of measurements, $\sigma^0_{mi}$ is the backscatter measurement, $\sigma^0_{si}$ is the backscatter simulated through the GMF and $K_p(\sigma^0_{mi})$ is the measurement error variance. The MLE can be interpreted as the distance between a set of radar backscatter measurements and the solution set lying on the GMF manifold in an N-dimensional space. The normalised MLE or Rn is defined as Rn = MLE/<MLE>, where <MLE> is the expected MLE value of a particular WVC number and wind solution.

In the QC algorithm, the following steps are performed in order to assess the quality of the radar backscatter data in a WVC.

1. The MLE value of the KNMI wind solution closest to the selected wind that is provided by JPL in the SeaWinds BUFR product is normalised using an <MLE> function that depends on both wind speed and WVC number (1-76). This expected MLE is a 2D function fitted to the computed mean MLEs as a function of WVC number and wind speed. A normalisation table containing the <MLE> surface for the KNMI solutions closest to the JPL selected winds is necessary. This table was obtained by processing three weeks of QuikSCAT data and averaging the MLE values after KNMI inversion for each WVC number and wind speed bin [5].
2. The normalised MLE is compared to a wind speed dependent threshold value that has a constant value of 2 for wind speeds above 15 m/s and has a parabolic shape with a maximum of 4 at 5 m/s for wind speeds below 15 m/s. See equation 3 in [3]. When the normalised MLE exceeds the threshold, the KMNI QC flag is set.
3. In WVC numbers 29-48, the so-called nadir part of the swath, the JPL rain flag provided in the input product is taken into account as well. If in a WVC the rain flag is set, the KNMI QC flag is set. It is shown in [4] that the QC based on the JPL MLE value is less efficient in the nadir swath, and here the evaluation of the JPL rain flag helps to improve the Quality Control.

The KNMI QC algorithm was originally based on the MLE of the JPL-selected wind [3, 4], but since JPL and NOAA changed their MLE formulations, it was decided to rely on the MLE after KNMI wind inversion. This change in approach slightly improved the QC skill (i.e., the ability to discern good quality winds from bad quality winds and to flag the WVCs accordingly) but the changes were very small [5].

## 2.2 Adaptations for OSCAT

The SeaWinds QC algorithm as described in the previous section needs some modifications before it can be used for OSCAT. The OSCAT level 2a products that are used in the OSI SAF wind processing at KNMI neither contain wind information nor a rain flag. Therefore, it was decided to use the MLE of the KNMI wind closest to the ECMWF model forecast wind. Moreover, the 3rd step in the above described algorithm (i.e., the rain flag evaluation) had to be skipped.

In [3] and [5] it was shown that the QC skill improves when the Rn of the wind solution closest to a meteorologically consistent wind field (like the JPL-selected scatterometer wind) is evaluated, as compared to the situation where the Rn of the first rank wind solution (the one with the lowest Rn) is evaluated. Therefore, in absence of a scatterometer wind field, we choose the ECMWF winds as reference. The ECMWF wind forecasts are available on a grid twice a day (00 and 12 GMT analysis time) and used with forecast time steps of +3h, +6h, et cetera. The model wind data are linearly interpolated with respect to WVC location and a parabolic interpolation using three time steps with respect to WVC data acquisition time is done.

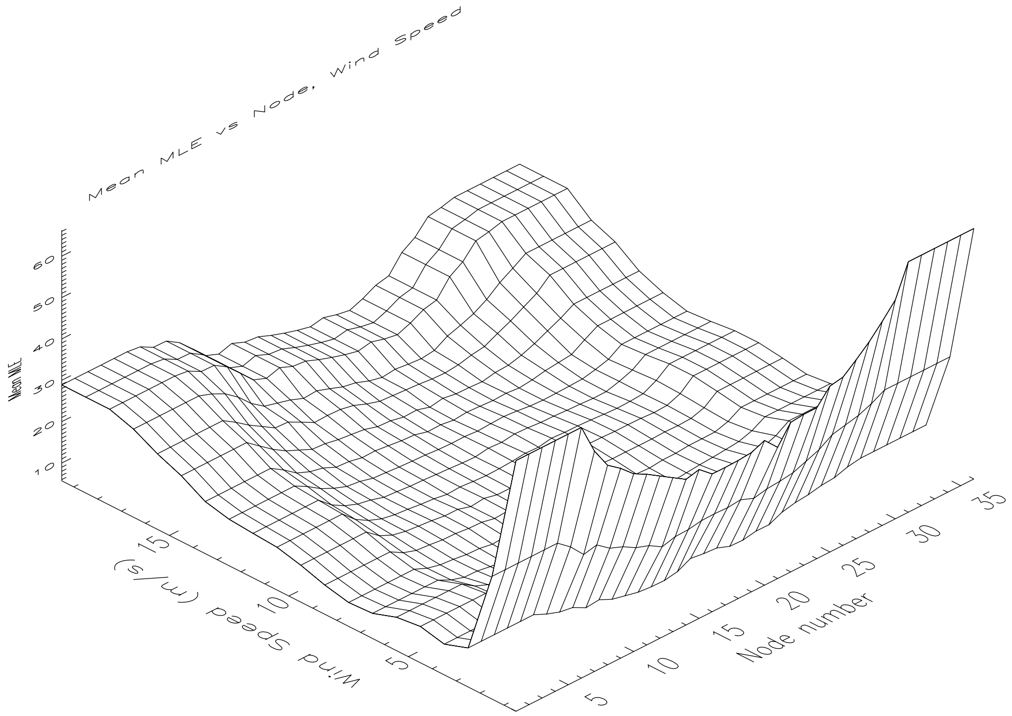

**Figure 1: <MLE> surface of the KNMI OSCAT wind solutions closest to the ECMWF forecast model winds (50-km product).**

A normalisation table containing the <MLE> surface for the KNMI solutions closest to the ECMWF forecast winds was obtained by processing 30 days of OSCAT data (6 January to 5 February 2012) and averaging the MLE values after KNMI inversion for each WVC number and wind speed bin. The resulting surface is shown in Figure 1. Note that this surface is “filtered” to remove noise. For each bin, MLEs higher than 5 times the mean MLE value are rejected and with the remaining data, a new mean MLE value is computed. This process is repeated iteratively and the <MLE> surface appears to converge after 9 steps. After the 9 iterations, approximately 4% of the data is rejected. The computation of the <MLE> surface was done in the same way as was done for SeaWinds.

The <MLE> surfaces were obtained separately for the 50-km and 25-km products. The 25-km surface is not shown here but has a comparable shape to the 50-km surface.

# 3 Quality Control analysis

Following the approach in [3], scatterometer data, both from OSCAT and from SeaWinds for comparison, were collocated with satellite radiometer rain data. However, in this work we used TMI (TRMM Microwave Imager) data from the Tropical Rainfall Measuring Mission (TRMM) satellite rather than the Special Sensor Microwave Imager (SSM/I) data used in earlier work. The reason is that none of the currently available satellites carrying SSM/I instruments are in an orbit that provides many daily collocations with OSCAT. Only few collocations, restricted to the Polar Regions, are obtained. Unlike SSM/I on DMSP platforms, the TRMM satellite travels west to east in a semi-equatorial orbit. This produces data collected at changing local times for any given earth location between 40S and 40N and the number of daily collocations for OSCAT and SeaWinds will be approximately identical. The SeaWinds orbit provides also significant numbers of collocations with SSM/I, but these were not used here in order to restrict the collocations to the tropical regions for both scatterometers and to reduce geographical influences on the wind and rain characteristics as much as possible.

For OSCAT, the period of 6 January to 18 February 2012 was used, for SeaWinds we used the period of 1 to 15 January 2008. We used the same period of the year to rule out seasonal effects as much as possible. Note however that the QuikSCAT orbit (18h local time descending Equator crossing) and Oceansat-2 orbit (12h local time descending Equator crossing) differ, so there may be small wind or rain climate differences due to diurnal effects. TMI data on a 0.25° grid were obtained from the public Remote Sensing Systems FTP server ftp.ssmi.com. The TMI rain rates were used if they were less than 30 minutes in time and less than 0.25° in space apart from the SeaWinds or OSCAT WVC centre. This means that effectively the closest TMI grid point to the 25-km or 50-km WVC was used. The number of daily SeaWinds collocations is four times as high as the number of OSCAT collocations since SeaWinds data are on a 25×25 km$^2$ WVC grid and OSCAT data are on a 50×50 km$^2$ WVC grid.

## 3.1 Characterisation of Rn

In [3], it was shown that the Rn is a good quality indicator and that the retrieved wind speeds are too large in rainy circumstances. This was clearly shown using two-dimensional histograms of Rn versus the retrieved wind speeds. Such plots for SeaWinds and OSCAT in different TMI rain rate intervals are shown in Figure 2.

In the absence of rain (top plots), we see fairly low Rn values in most WVCs (darkest contours). A relatively small fraction of the WVCs shows higher Rn values, these data are most probably connected to confused sea states or sub-WVC wind variability. The differences between SeaWinds (top left plot) and OSCAT (top right plot) are quite small although for OSCAT there is a slightly higher fraction of the WVCs showing higher Rn values. We also observe a higher fraction of WVCs with wind speeds between 15 and 20 m/s for OSCAT. This can be connected to the difference in overpass times of QuikSCAT and OSCAT. A different time of the day may be connected to different daily wind and rain climatology. We excluded that the high Rn value occurrence is associated with the larger WVC aggregation area of OSCAT. Although a larger WVC more likely includes an atmospheric rain cell, we found that the statistics of 25-km OSCAT Rn's are very similar to the 50-km distributions. It remains to be seen whether the slightly larger incidence angles of OSCAT play a role. Moreover, we observe an increase of OSCAT wind speed bias versus ECMWF winds for wind speeds above 15 m/s, which is less pronounced in the SeaWinds data. This bias is most probably connected to a different backscatter calibration of OSCAT.

The results for moderate rain rates of up to 6 mm/hr (middle plots in Figure 2) are also quite comparable for SeaWinds and OSCAT. Again we observe the somewhat higher population of wind speeds above 15 m/s in the OSCAT plot (middle right hand side plot). Another difference between SeaWinds and OSCAT is that in this rain regime, the number of WVCs with high Rn values is somewhat higher for SeaWinds. The latter observation is contrary to the dry regime (top plots) where OSCAT shows a higher fraction of WVCs with high Rn values.

Finally, the results for heavy rain (more than 6 mm/hr) are shown in the bottom plots of Figure 2. For these rain rates it can be expected that the scatterometer wind speeds will be heavily biased due to the strong backscatter of the radar signal by rain droplets, leading to bogus high wind speeds. For SeaWinds, most of these wind speeds are between 10 and 20 m/s (bottom left plot), for OSCAT they tend to be somewhat higher, between 13 and 23 m/s. Another difference between SeaWinds and OSCAT is that the SeaWinds Rn values are higher on average.

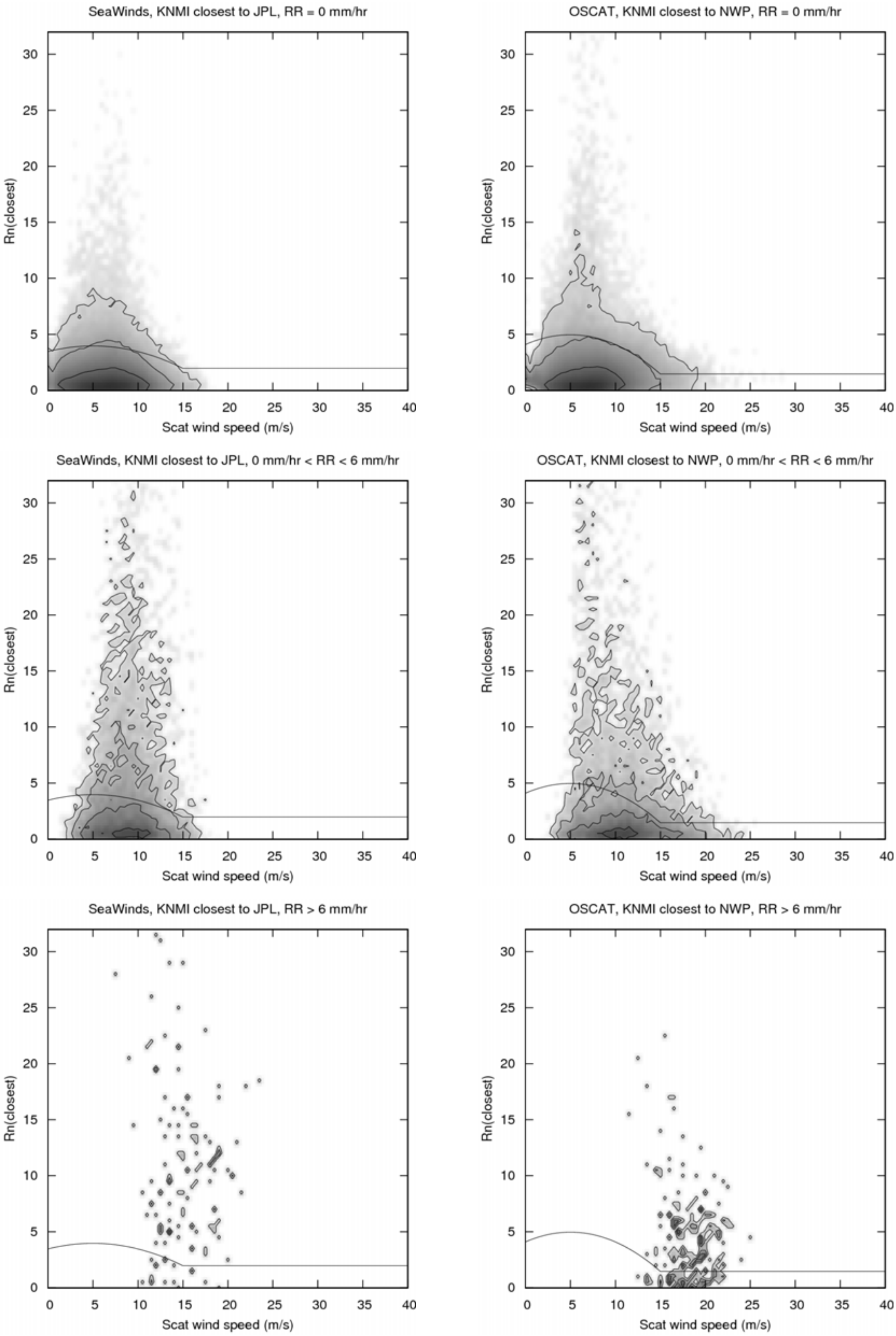

**Figure 2: Two-dimensional histograms of (left) Rn versus KNMI 25-km SeaWinds wind speed of solution closest to the JPL-selected wind and (right) KNMI OSCAT 50-km wind speed of solution closest to the ECMWF model forecast wind. The plots are for rain-free data (top), for rain rates between 0 and 6 mm/hr (middle) and for rain rates above 6 mm/hr (bottom).**

The results in Figure 2 show that the characteristics of OSCAT are quite comparable to those of SeaWinds. Hence we can expect that the QC formulation as developed for SeaWinds will be usable for OSCAT as well. However, since the number of high Rn values for OSCAT is higher in dry conditions and lower in rainy conditions, it can be expected that the QC will be slightly less effective for OSCAT. For dry conditions, the OSCAT rejection rate will be higher, whereas it will be lower for rainy conditions. An optimal QC would accept as many dry WVCs as possible (low false-alarm rate, FAR) and it would reject as many rainy WVCs as possible (high probability of detection, POD).

Finally, in order to check if the differences between SeaWinds and OSCAT are connected with the product resolution, we also made the plots like in Figure 2 for the OSCAT 25-km wind product (not shown here). OSCAT 25-km winds were made with OWDP from a 25-km OSCAT level-2a product which in its turn was made using the level 1b to level 2a conversion software package kindly provided by NOAA. It appears that the plots based on the 25-km OSCAT product are not significantly different from those on the right hand side of Figure 2. Hence, differences in Rn behaviour are inherent to the instruments and not to the product resolution.

## 3.2 Validation and improvement of Rn threshold

In order to assess the skill of the QC algorithms, we have computed the number of accepted and rejected WVCs with their vector RMS and wind speed bias values with respect to the ECMWF background winds and segregated the results according to rain rate. If the QC algorithm performs well, we expect low RMS and bias values for the accepted WVCs and large RMS and bias values for the rejected WVCs. Moreover, the WVCs with high rain rates (> 6 mm/hr) should have high rejection rates since it is know that Ku-band scatterometers are not reliable in rainy conditions.

| | **Old Rn threshold** | | | **New Rn threshold** | | |
|---|---|---|---|---|---|---|
| **Rain rate = 0 mm/hr** | | | | | | |
| | | RMS | bias | | RMS | bias |
| Nr. of WVCs | 219946 | | | 219946 | | |
| Accepted | 95.0% | 1.83 | 0.18 | 96.3% | 1.82 | 0.18 |
| Rejected | 5.0% | 2.62 | 0.89 | 3.7% | 2.91 | 1.13 |
| **0 mm/hr < Rain rate <= 6 mm/hr** | | | | | | |
| | | RMS | bias | | RMS | bias |
| Nr. of WVCs | 12542 | | | 12542 | | |
| Accepted | 62.7% | 3.58 | 1.81 | 63.5% | 3.50 | 1.77 |
| Rejected | 37.3% | 4.82 | 3.18 | 36.5% | 4.93 | 3.29 |
| **Rain rate > 6 mm/hr** | | | | | | |
| | | RMS | bias | | RMS | bias |
| Nr. of WVCs | 719 | | | 719 | | |
| Accepted | 23.6% | 7.19 | 5.08 | 20.0% | 7.07 | 4.92 |
| Rejected | 76.4% | 8.92 | 7.16 | 80.0% | 8.86 | 7.10 |
| **All Rain rates** | | | | | | |
| | | RMS | bias | | RMS | bias |
| Nr. of WVCs | 233207 | | | 233207 | | |
| Accepted | 93.1% | 1.93 | 0.24 | 94.3% | 1.91 | 0.24 |
| Rejected | 6.9% | 3.75 | 1.77 | 5.7% | 4.12 | 2.13 |

**Table 1: Accepted and rejected OSCAT 50-km WVCs using Quality Control based on the MLE of the KNMI wind solution closest to the ECMWF forecast wind for different TMI rain regimes. RMS and bias values are in m/s with respect to ECMWF forecast winds. The left hand columns show the results using the old Rn threshold; the right hand columns show the results using the adapted new Rn threshold (see text).**

The results for OSCAT and SeaWinds are shown in Table 1 and Table 2, respectively. In the left hand parts of the tables the Rn threshold was applied which was postulated in [3]:

$$v \leq 15\,\text{m/s} \Rightarrow y = 4 - 0.02(v - 5)^2$$
$$v > 15\,\text{m/s} \Rightarrow y = 2$$

If a WVC has an Rn value above $y$, it is rejected; otherwise the wind is accepted. The threshold value as a function of wind speed is drawn as a solid line in the left hand side (SeaWinds) plots of Figure 2. It corresponds to a parabolic threshold with a maximum value of 4 at 5 m/s, which reaches a value of 2 at 15 m/s. Above 15 m/s, a constant threshold of 2 is used. It is clear that the line does not optimally follow the contour lines in the plots, both for SeaWinds and for OSCAT. Therefore, it was decided to test the QC algorithm with a new threshold:

$$v \leq 15\,\text{m/s} \Rightarrow y = 5 - 0.035(v - 5)^2$$
$$v > 15\,\text{m/s} \Rightarrow y = 1.5$$

This new threshold is drawn as a solid line in the right hand side (OSCAT) plots of Figure 2. The parabolic threshold has a higher maximum of 5 at 5 m/s and reaches a lower value of 1.5 at 15 m/s. Note that the old Rn threshold was established in [3] based on Rn histograms of the JPL wind inversion rather than the KNMI wind inversion. The Rn threshold was not changed after the implementation of the new SeaWinds QC method based on the KNMI Rn in [5], since it seemed to be equally valid for KNMI-obtained Rn values. The results of the new Rn threshold are shown in the right hand sides of Table 1 and Table 2.

| | **Old Rn threshold** | | | **New Rn threshold** | | |
|---|---|---|---|---|---|---|
| **Rain rate = 0 mm/hr** | | | | | | |
| | | RMS | bias | | RMS | bias |
| Nr. of WVCs | 210873 | | | 210873 | | |
| Accepted | 97.1% | 1.81 | -0.14 | 98.1% | 1.81 | -0.14 |
| Rejected | 2.9% | 2.30 | 0.33 | 1.9% | 2.51 | 0.54 |
| **0 mm/hr < Rain rate <= 6 mm/hr** | | | | | | |
| | | RMS | bias | | RMS | bias |
| Nr. of WVCs | 10597 | | | 10597 | | |
| Accepted | 63.4% | 3.03 | 0.87 | 66.8% | 3.05 | 0.89 |
| Rejected | 36.6% | 4.15 | 2.29 | 33.2% | 4.24 | 2.39 |
| **Rain rate > 6 mm/hr** | | | | | | |
| | | RMS | bias | | RMS | bias |
| Nr. of WVCs | 583 | | | 583 | | |
| Accepted | 10.8% | 6.07 | 3.41 | 9.9% | 5.62 | 2.94 |
| Rejected | 89.2% | 7.67 | 5.85 | 90.1% | 7.69 | 5.87 |
| **All Rain rates** | | | | | | |
| | | RMS | bias | | RMS | bias |
| Nr. of WVCs | 222053 | | | 222053 | | |
| Accepted | 95.2% | 1.86 | -0.11 | 96.4% | 1.87 | -0.11 |
| Rejected | 4.8% | 3.51 | 1.32 | 3.6% | 3.86 | 1.71 |

**Table 2: Accepted and rejected SeaWinds 25-km WVCs using Quality Control based on the MLE of the KNMI wind solution closest to the JPL-selected wind for different TMI rain regimes. RMS and bias values are in m/s with respect to ECMWF forecast winds. The left hand columns show the results using the old Rn threshold; the right hand columns show the results using the adapted new Rn threshold (see text).**

When we first look at the results using the old Rn threshold, we see that the QC works pretty well for OSCAT. For the dry WVCs, we obtain a rejection rate of 5.0% with a good discrimination between high RMS values for rejected WVCs (2.62 m/s) and lower RMS values for accepted WVCs (1.83 m/s); see the top left part of Table 1. For high rain rates, over 6 mm/hr, we observe a high rejection rate of 76.4% and increased RMS values, both for the accepted (7.19 m/s) and rejected (8.92 m/s) WVCs. When we compare these results to those for SeaWinds using the old Rn threshold (left hand side of Table 2), we see that the QC is slightly more effective for SeaWinds: a lower rejection rate for dry WVCs (2.9% vs. 5.0% for OSCAT) and a higher rejection rate for WVCs with high rain rates (89.2% vs. 76.4% for OSCAT). It is not clear why the QC performs better for SeaWinds than for OSCAT; this may be connected to differences in instrument characteristics (e.g. the incidence angles being different for OSCAT and SeaWinds, instrument noise properties), or to differences in instrument backscatter calibration.

The use of the new Rn threshold appears to work out very well for OSCAT, when we compare the right hand side of Table 1 to the left hand side. The percentage of accepted WVCs for dry WVCs increases from 95.0% to 96.3% but their RMS value does not increase; it only changes very little, from 1.83 m/s to 1.82 m/s. The RMS value of the rejected dry WVCs increases from 2.62 m/s to 2.91 m/s when the new Rn threshold is applied, indicating that on average the rejected WVCs have a worse quality. For the rain rates over 6 mm/hr we observe an increased rejection rate of 80.0% for the new Rn threshold vs. 76.4% for the old Rn threshold, indicating a more effective screening of very rainy WVCs.

We note than Portabella et al. [6] verify ECMWF winds and ASCAT scatterometer winds in rainy tropical conditions, i.e., the conditions where TMI would detect some rain typically. They find that the quality of the ECMWF winds is much deteriorated in such conditions as compared to dry tropical conditions. The decreased discrimination of the quality of wet and dry retrievals in Table 1 and Table 2 is thus partly due to the decreased quality of the model winds used for verification.

Finally, we assess the influence of the new threshold on the SeaWinds QC; see the right hand side of Table 2 compared to the left hand side. The new Rn threshold works for SeaWinds as it does for OSCAT: it decreases the rejection rate for dry WVCs without increasing the RMS values for the accepted WVCs and it increases the rejection rate for WVCs with rain rates over 6 mm/hr.

## 3.3 QC performance in nadir swath

We looked into the QC performance in different parts of the OSCAT satellite swath. It was shown in [4] that in the nadir part of the swath (the middle part of the swath near the satellite ground track where the azimuth separation of the four scatterometer views is small), the QC proves less effective than in the sweet part of the swath (the regions where four views are available with good azimuth diversity). For SeaWinds, the nadir swath corresponds to WVCs 29-48, the sweet swath corresponds to WVCs 12-28 and 49-65. For OSCAT (50-km product), the nadir swath covers WVCs 15-22 and the sweet swath covers WVCs 7-14 and 23-30.

Table 3 shows the QC results for the OSCAT nadir swath, presented in the same way as in the previous section. The left hand side of the table contains the results using the new Rn threshold, the same as used in the right hand side of Table 1. When we compare Table 3 (left) with Table 1 (right), it appears that the rejection rates are lower in the nadir swath and that the RMS values are somewhat higher, both for the accepted and the rejected WVCs. It would be interesting to see if the RMS values of the accepted WVCs improve when we reject more WVCs by reducing the Rn threshold. Optimally, we would get lower RMS values for the accepted WVCs and higher RMS values for the rejected WVCs, i.e., a better QC skill.

The right part of Table 3 shows what happens if we reduce the speed-dependent Rn threshold by multiplying it by 0.85. For the WVCs with no rain, we see a very small improvement of the RMS values of the accepted WVCs (1.95 vs. 1.96 m/s), but the penalty for that is a considerably higher amount of rejected WVCs (4.5% vs. 3.2%). For the WVCs with moderate rain rates (0-6 mm/hr), the RMS of both the accepted and the rejected WVCs decreases somewhat. So the QC skill (the ability to separate low RMS from high RMS data) does not improve. When we look at the WVCs with heavy rain (more than 6 mm/hr) we see that the RMS decreases for the accepted WVCs and increases for the rejected WVCs with the lower Rn threshold. So in this case we get indeed a slightly better QC skill. However, the WVCs with heavy rain contribute only marginally to the total QC since there are so few of them. In our opinion, the penalty of rejecting many dry WVCs with good quality is too heavy as compared to the slight QC improvement for the WVCs with heavy rain. Hence we keep the Rn threshold in the nadir swath at the same level as in the rest of the swath.

The conclusion obtained here is in line with what was concluded in [5] for SeaWinds. For SeaWinds we also found that the QC does not improve when the Rn threshold in the nadir swath is set to a lower value. In the SeaWinds QC, the JPL rain flag is taken into account in the nadir swath, which helps to improve the QC [5], but for OSCAT such information is regrettably not available.

| | **New Rn threshold** | | | **New Rn threshold × 0.85** | | |
|---|---|---|---|---|---|---|
| **Rain rate = 0 mm/hr** | | | | | | |
| | | RMS | bias | | RMS | bias |
| Nr. of WVCs | 63449 | | | 63449 | | |
| Accepted | 96.8% | 1.96 | 0.14 | 95.5% | 1.95 | 0.14 |
| Rejected | 3.2% | 3.31 | 1.31 | 4.5% | 3.11 | 1.15 |
| **0 mm/hr < Rain rate <= 6 mm/hr** | | | | | | |
| | | RMS | bias | | RMS | bias |
| Nr. of WVCs | 3492 | | | 3492 | | |
| Accepted | 72.3% | 3.74 | 1.99 | 69.2% | 3.69 | 1.94 |
| Rejected | 27.7% | 5.06 | 3.24 | 30.8% | 5.01 | 3.19 |
| **Rain rate > 6 mm/hr** | | | | | | |
| | | RMS | bias | | RMS | bias |
| Nr. of WVCs | 208 | | | 208 | | |
| Accepted | 29.8% | 7.32 | 5.40 | 28.8% | 7.06 | 5.20 |
| Rejected | 70.2% | 7.99 | 6.29 | 71.2% | 8.08 | 6.33 |
| **All Rain rates** | | | | | | |
| | | RMS | bias | | RMS | bias |
| Nr. of WVCs | 67149 | | | 67149 | | |
| Accepted | 95.3% | 2.08 | 0.22 | 93.9% | 2.05 | 0.21 |
| Rejected | 4.7% | 4.23 | 2.13 | 6.1% | 3.96 | 1.87 |

**Table 3: Accepted and rejected OSCAT 50-km WVCs using Quality Control based on the MLE of the KNMI wind solution closest to the JPL-selected wind for different TMI rain regimes. The results are for the nadir swath only (WVC numbers 15-22). RMS and bias values are in m/s with respect to ECMWF forecast winds. The left hand columns show the results using the new Rn threshold; the right hand columns show the results using the new Rn threshold multiplied by 0.85 (see text).**

# 4 Conclusions

The QC algorithm, as it was developed for SeaWinds, has been adapted for OSCAT wind processing and its validity is tested. Statistical analysis of the accepted and rejected WVCs reveals that the QC algorithm generally performs well and in this respect it appears to be usable for Ku-band scatterometers in general. Still, the QC performs slightly better for SeaWinds than for OSCAT; this may be connected to differences in instrument characteristics or to differences in instrument backscatter calibration.

A new function for the Rn threshold values vs. wind speed was tested and this new threshold appears to yield better QC skill both for OSCAT and for SeaWinds. It is therefore recommended to implement this new threshold in OWDP and SDP.

The performance and optimal setting of the Rn threshold values in the nadir part of the OSCAT swath was evaluated separately. It was concluded that the QC does not perform any better when the settings in the nadir swath are different from those in the rest of the swath.