Ocean and Sea Ice SAF

Technical Note

SAF/OSI/CDOP2/KNMI/TEC/RP/196

OSCAT winds validation report

Product OSI-105

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Contents

1 Introduction

The Ocean and Sea Ice Satellite Application Facility (OSI SAF) delivers a demonstration status level 2 wind product with 50-km Wind Vector Cell (WVC) spacing in near-real time [1], based on the Oceansat-2 scatterometer (OSCAT) level 2a products from the Indian Space Research Organisation (ISRO). See the ISRO documentation [2] for more information on the level 2a product characteristics.

In this report, we asses the quality of the OSI SAF wind product. We compare the scatterometer wind data with ECMWF model data and with in situ wind data from moored buoys. A triple collocation exercise is done to asses the quality of the products.

The results presented in this report are encouraging and warrant the release of the 50-km wind product.

1.1 References

Note that all publications with KNMI authors are also available at www.knmi.nl/publications.

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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
FR	Full Resolution
GTS	Global Telecommunication System
ISRO	Indian Space Research Organisation
KNMI	Royal Netherlands Meteorological Institute
MSS	Multiple Solution Scheme
NASA	National Aeronautics and Space Administration (USA)
NOAA	National Oceanic and Atmospheric Administration (USA)
NOC	NWP Ocean Calibration
NSCAT	NASA Scatterometer
NWP	Numerical Weather Prediction
OSCAT	Scatterometer onboard the Oceansat-2 satellite
OSI	Ocean and Sea Ice
QC	Quality Control
SAF	Satellite Application Facility
SeaWinds	Scatterometer on-board QuikSCAT platform (USA)
WVC	Wind Vector Cell

1.3 Acknowledgement

We are grateful to Jean Bidlot of ECMWF for helping us with the buoy data retrieval and quality control. ISRO and EUMETSAT kindly provide the OSCAT level 2a data in near-real time. Jur Vogelzang of KNMI provided the wind spectra plots and the triple collocation computations.

2 Test data

The validations of the OSCAT product are done using 3 months of data (1 January to 31 March 2012) which were received through EUMETCast. The ISRO level 2a data (version 1.3) have been reprocessed using the latest version of OWDP (1.0.01), which is used in the near-real time processing of the OSI SAF OSCAT development status product. However, the code was changed in several ways to improve the wind quality:

- The MLE normalisations are recomputed using version 1.3 level 2a data rather than version 1.2 level 2a data in the near-real time processing.
- A correction was applied to the backscatter values to correct for the latitude dependent wind biases which have been reported by several users. A negative wind speed bias was found in the southern hemisphere, most notably at latitudes south of -50°. The latitude dependent correction coefficients have been derived from the orbit height as a function of latitude which can be computed from the orbit information in the OSCAT level 1b files. From the orbit height, the slant range R is computed and the attenuation corrections can be calculated from this assuming that the received power is proportional to R^4. In this way, we obtain latitude dependent wind speed biases that are comparable to those found for QuikSCAT in the past. The issue is reported to ISRO.
- Outer swath processing was implemented. In those WVCs where no HH-polarised (inner beam) backscatter data are available (generally WVC numbers 1 to 4 and 33 to 36), the VV-polarised slice data from the level 2a product are divided into four independent WVC views, all VV-polarised. This is done to provide more than two independent measurements as input to the wind retrieval and thus obtain a more meaningful retrieval [3]. The division of the slices is done based on azimuth angle, to obtain some azimuth angle separation after averaging the slices into WVC-based backscatter information. The WVCs containing more than two VV-polarised beams can easily be recognised by the corresponding flag bit in the Wind Vector Cell Quality flag.
- The NSCAT-2 Geophysical Model Function was adapted for wind speeds above 15 m/s. The new GMF is called NSCAT-3. Below 15 m/s nothing was changed and the NSCAT-3 winds are identical to the NSCAT-2 retrieved winds. Above 15 m/s, a linear scaling of the wind speed was applied, starting with zero correction at 15 m/s, 2.5 m/s downward correction at 20 m/s, 5 m/s downward correction at 25 m/s and so on. This means that if a certain backscatter value results in a wind of 22.5 m/s in NSCAT-2, the same backscatter value will result in a wind of 20 m/s in NSCAT-3. The NSCAT-2 GMF lookup table was adapted in this way for all combinations of incidence and azimuth angles. This ensures that the fit in measurement space (see e.g. [4]) of the backscatter quadruplets to the GMF will not change. The high speed correction was tuned by comparing scatterometer wind speeds with ECMWF and buoy winds. We looked at the scatterometer wind speed bias versus the average scatterometer and background wind speed, background being ECMWF or buoy winds. Using the proposed GMF change, we obtain a rather flat bias, not only for OSCAT as will be shown in this report, but also for SeaWinds as we verified. Note that precise tuning of high speed winds is not easy. Due to the limited amount of available data above 15 m/s, the errors in the ECMWF and buoy winds are not very well known. Comparison to NOAA hurricane flight data is ongoing within the International Ocean Vector Winds Science Team (IOVWST).

Backscatter calibration using NWP Ocean Calibration method [4] was considered but there are some issues which result in residual biases of OSCAT winds versus buoys and model winds. The issues need to be clarified first before we can implement the ocean calibration in the wind product. We are currently working on this. For now, a constant +0.65 dB bias is applied to all backscatter data which results which effectively removes the biases against model winds.

3 Product characteristics and comparison with model wind data

Figure 1 shows an example of an OSCAT wind field. It is clear that the QC mechanism is well capable to flag rainy WVCs: the orange dots generally well correspond to the cloudy areas where rain can be expected. The wind field in the outer swath looks consistent, although some of the strong winds in the upper right part of the image seem unrealistic. These winds are considered as meteorologically inconsistent and flagged by the variational QC flag (orange coloured arrows).

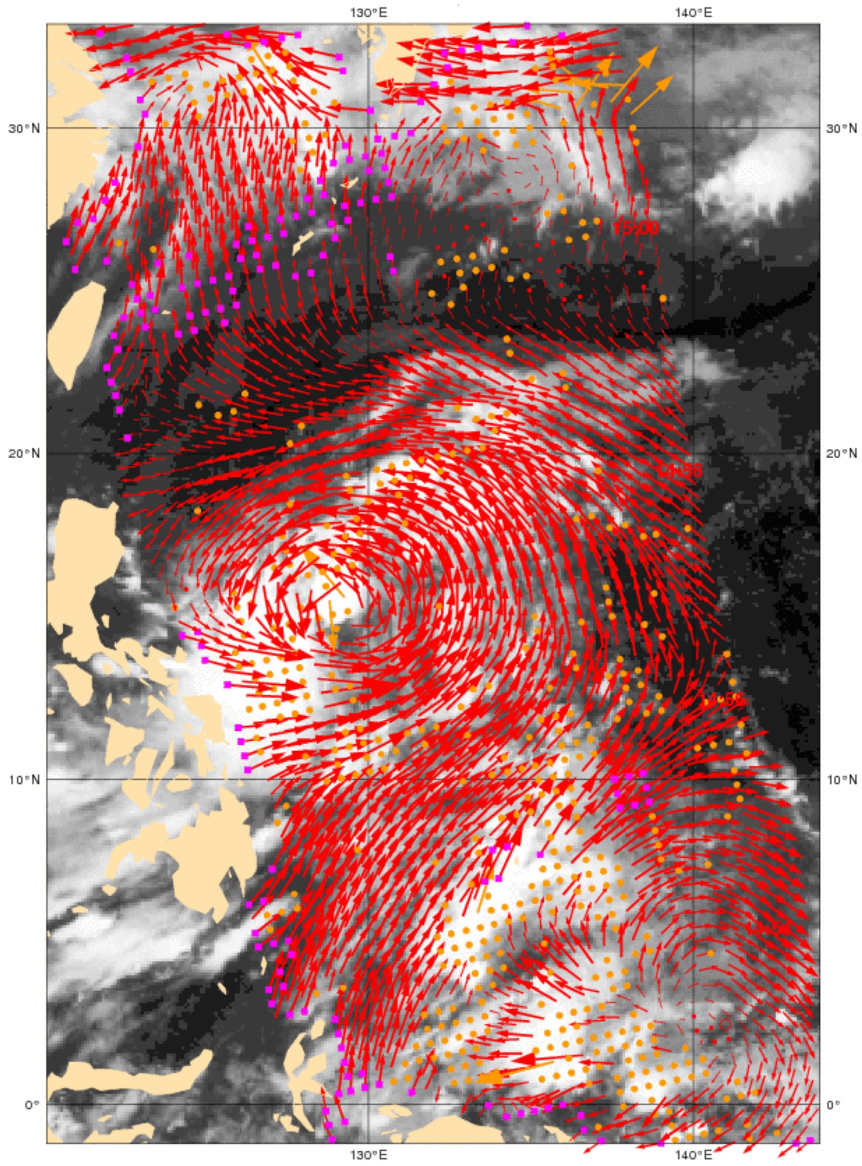
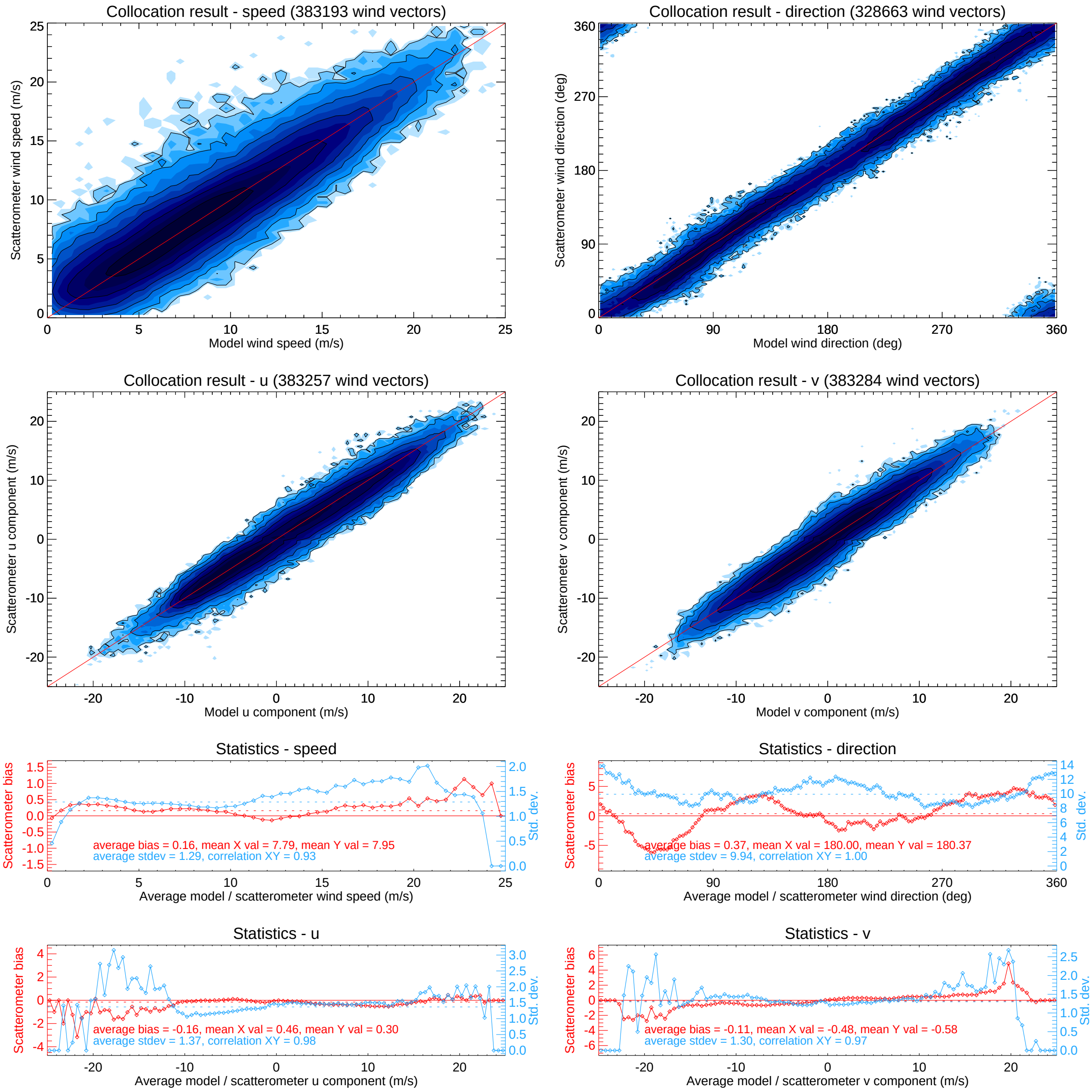


Figure 1: Example of 50-km OSCAT product in the western Pacific at 26 June 2012 15:00 UTC, overlaid on a GMS IR satellite image. The purple squares correspond to WVCs where the land flag is set, but where reliable winds can still be computed, the orange dots correspond to WVCs that have been rejected by the Quality Control due to wind GMF inconsistencies and the orange arrows correspond to WVCs where the variational Quality Control flag is set due to spatial inconsistencies.

The fraction of WVCs rejected by the KNMI QC flag is pretty constant across the swath and is approximately 8%. This is somewhat higher than the rejection rate of SeaWinds which is around 5%. This difference is probably connected to differences in instrument characteristics.

Figure 2 shows two-dimensional histograms of the retrieved winds versus ECMWF 10-m wind background for the 50-km wind product, after rejection of Quality Controlled (KNMI QC flagged) wind vectors. The data for these plots are from 28 consecutive orbits from 9 and 10 February 2012.

The top left plot corresponds to wind speed (bins of 0.5 m/s) and the top right plot to wind direction (bins of 2.5°). The latter are computed for ECMWF winds larger than 4 m/s. The bottom plots show the *u* and *v* wind component statistics (bins of 0.5 m/s). The contour lines are in logarithmic scale. Note that the ECMWF winds are real 10-m winds, whereas the scatterometer winds are equivalent neutral 10-m winds, which are on average 0.2 m/s higher.


Collocation result - speed (383193 wind vectors)

Collocation result - direction (328663 wind vectors)

Collocation result - u (383257 wind vectors)

Collocation result - v (383284 wind vectors)

Statistics - speed

average bias = 0.16, mean X val = 7.79, mean Y val = 7.95
average stdev = 1.29, correlation XY = 0.93

Statistics - direction

average bias = 0.37, mean X val = 180.00, mean Y val = 180.37
average stdev = 9.94, correlation XY = 1.00

Statistics - u

average bias = -0.16, mean X val = 0.46, mean Y val = 0.30
average stdev = 1.37, correlation XY = 0.98

Statistics - v

average bias = -0.11, mean X val = -0.48, mean Y val = -0.58
average stdev = 1.30, correlation XY = 0.97

Figure 2: Two-dimensional histograms of wind speed, direction (w.r.t. wind coming from the North), *u* and *v* components of OSCAT wind product versus the ECMWF model forecast winds from 9 and 10 February 2012 (top panels). The corresponding biases (red) and standard deviations (blue) as a function of the average scatterometer and model winds are shown in the bottom.

It is clear from Figure 2 that the wind speed bias for wind speeds above 15 m/s is small and that a fairly constant bias as a function of wind speed is obtained with the NSCAT-3 GMF. This is contrary to earlier results from NSCAT-2 where an increasing wind speed bias above 15 m/s was observed.

The results in terms of wind speed bias and *u* and *v* wind component standard deviations are shown in Table 1. The statistics of inner swath (where both HH and VV-polarised backscatter information is present), outer swath (only VV-polarised backscatter data) and the entire swath are shown separately. As reference, the statistics of the OSI SAF QuikSCAT/SeaWinds wind products (25-km and 100-km) from the same dates in 2009 are shown as well. Note that the OSI SAF SeaWinds wind products do not contain wind data in the outer swath, where no HH-polarised backscatter data are available. Note also that in the SeaWinds products, no ocean calibration was used so wind speed biases were not corrected for. For OSCAT, we apply a simple bias of +0.65 dB to all σ^0 values which effectively removes the biases against model winds. This is why the OSCAT wind speed bias is close to the expected value of 0.20 m/s and the SeaWinds bias deviates from this value.

The OSCAT wind speed biases and wind component standard deviations are all well within the OSI SAF requirements, even in the outer swath where the lowest wind quality can be expected. It is clear however that the standard deviations are higher in the outer swath. The OSCAT wind components compare slightly better to ECMWF than SeaWinds 25-km, in line with the relatively coarse effective resolution of the ECMWF model data used [5].

Contrary to the 25-km SeaWinds and the OSCAT product, the OSI SAF 100-km SeaWinds product did not use the Multiple Solution Scheme (MSS, [6]) in the Ambiguity Removal step. MSS is known to reduce the noise in the scatterometer wind product considerably. This explains why the *u* and *v* wind component standard deviations are higher for the OSI SAF 100-km SeaWinds winds. To show the effect of MSS, we reprocessed the 100-km data and it is clear from Table 1 that this yields much lower standard deviations, even lower than those of OSCAT.

	# wind vectors	speed bias	stdev *u*	stdev *v*
WVC 1-36 (all)	383284	0.16	1.37	1.30
WVC 5-32 (inner)	298751	0.18	1.33	1.28
WVC 1-4, 33-36 (outer)	84533	0.08	1.46	1.31
SeaWinds 25-km, 9 and 10 February 2009	1943847	-0.20	1.36	1.38
SeaWinds 100-km, 9 and 10 February 2009	126736	-0.01	1.57	1.50
SeaWinds 100-km, MSS, 9 and 10 February 2009	88533	-0.05	1.14	1.17

Table 1: ECMWF comparison results of OSCAT 50-km wind products from 9 and 10 February 2012, compared with the OSI SAF SeaWinds products from the same period in 2009.

4 Buoy validations

In this section, scatterometer wind data are compared with in situ buoy wind measurements. The buoy winds are distributed through the Global Telecommunication System (GTS) and have been retrieved from the ECMWF MARS archive. The buoy data are quality controlled and (if necessary) blacklisted by ECMWF [7]. We used a set of approximately 150 moored non-coastal buoys spread over the oceans (most of them in the tropical oceans and near Europe and North America) which are also used in the buoy validations that are routinely performed for the OSI SAF wind products (see the links on http://www.knmi.nl/scatterometer/osisaf/). Most of these buoys are located more than 50 kilometres from the coast.

See Figure 3 for the locations of the buoys used in the comparisons. A scatterometer wind and a buoy wind measurement are considered to be collocated if the distance between the Wind Vector Cell (WVC) centre and the buoy location is less than the WVC spacing divided by √2 and if the acquisition time difference is less than 30 minutes.

The buoy winds are measured hourly by averaging the wind speed and direction over 10 minutes. The real winds at a given anemometer height have been converted to 10-m equivalent neutral winds using the LKB model [7], [8] in order to enable a good comparison with the 10-m scatterometer winds.

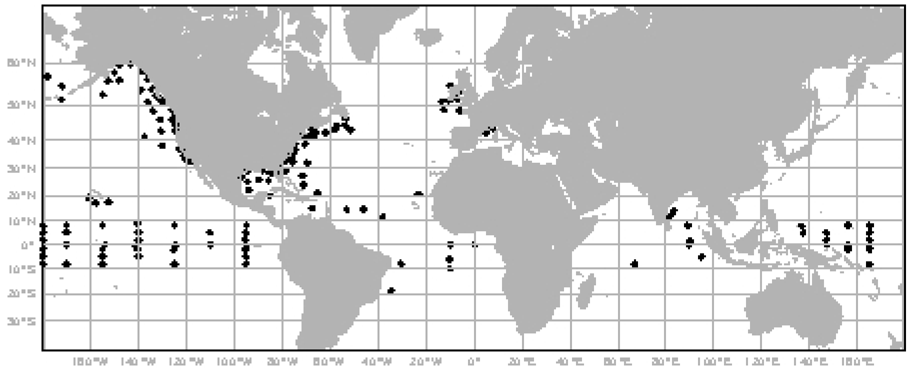


Figure 3: Locations of the moored buoys used in the comparisons.

In Table 2 we compare the various parts of the swath in the OSCAT wind product. The wind speed bias and the standard deviations of the *u* and *v* wind components are shown in this table. For comparison, we also show the results of the OSI SAF SeaWinds 25-km and 100-km products as they were produced in near-real time until November 2009. The same (winter) period was chosen for SeaWinds as for OSCAT, but then for 2009 rather than 2012.

	# wind vectors	speed bias	stdev *u*	stdev *v*
WVC 1-36 (all)	10158	0.02	1.86	1.97
WVC 5-32 (inner)	8202	0.04	1.88	1.98
WVC 1-4, 33-36 (outer)	1956	-0.04	1.76	1.87
SeaWinds 25-km, January - March 2009	9536	-0.54	1.75	1.71
SeaWinds 100-km, January - March 2009	10172	-0.32	2.07	1.94

Table 2: Buoy collocation results of OSCAT 50-km wind products from January to March 2012, compared with SeaWinds data from the same period in 2009.

The results show that the OSCAT wind component standard deviations do not vary much across the swath and compared to buoys, the quality of the winds appears to be quite uniform in inner and outer swath. The OSCAT wind component standard deviations are better than those of the SeaWinds 100-km product but worse than those of the SeaWinds 25-km product. This can be expected since the buoy data are point measurements, whereas the scatterometer samples a larger area, dependent on the product resolution. The better the resolution, the better the scatterometer can resolve the small scale wind variability and the smaller the expected wind component standard deviations. The results in Table 2 confirm that the OSCAT 50-km product has characteristics in between those of the SeaWinds 25-km and 100-km products and as such the OSCAT instrument performance is comparable to the SeaWinds instrument performance.

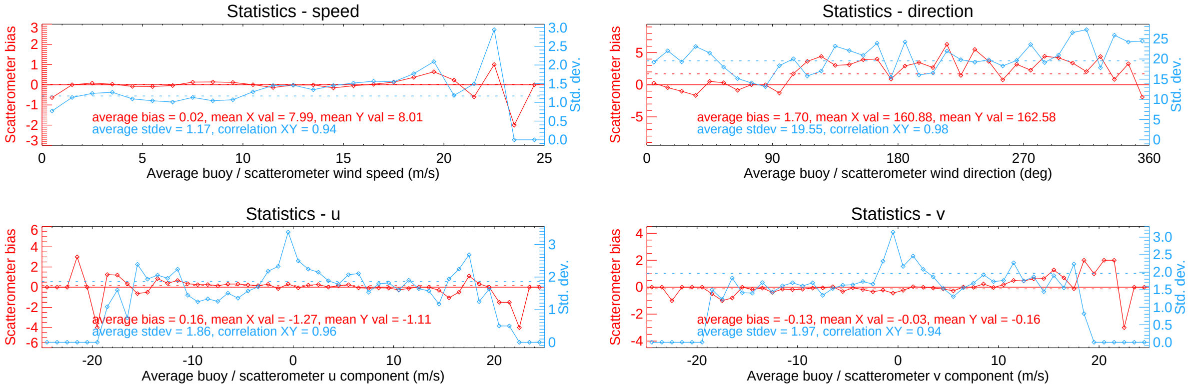


Figure 4: Biases of wind speed, direction (w.r.t. wind coming from the North), *u* and *v* components of OSCAT wind product versus the buoy winds from January to March 2012. The biases (red) and standard deviations (blue) as a function of the average scatterometer and model winds are shown.

The detailed buoy collocation results in terms of wind speed, wind direction and wind components are shown in Figure 4. A fairly constant speed bias as a function of wind speed is shown (top left panel), indicating that the NSCAT-3 is well capable to correct the NSCAT-2 positive wind speed biases above 15 m/s.

5 Spectral analysis

Wind component spectra are a means to detect noise and asses the relative amount of small scale information in a wind product [5]. Figure 5 shows the wind spectra of the OSCAT product. The $k^{-5/3}$ spectrum is also shown as a black dotted line in the plots. According to a host of measurements, among which from aircraft [9], and the 3D turbulence theory of Kolmogorov, the wind spectra follow such spectra for scales smaller than about 500 km (spatial frequency above $2 \cdot 10^{-6}$ m^{-1}). The OSCAT spectra fall off faster; this is in line with the spectra observed from the OSI SAF SeaWinds 25-km product [5], see Figure 5. The OSCAT data show a comparable amount of small scale information as compared to the SeaWinds data; this is reflected in the spectral level for spatial frequencies higher than about 500 km. Instrument-related noise that occurs at small spatial scales would be reflected in a flattening of the curves towards higher spatial frequencies, but this is not observed in the OSCAT spectra.

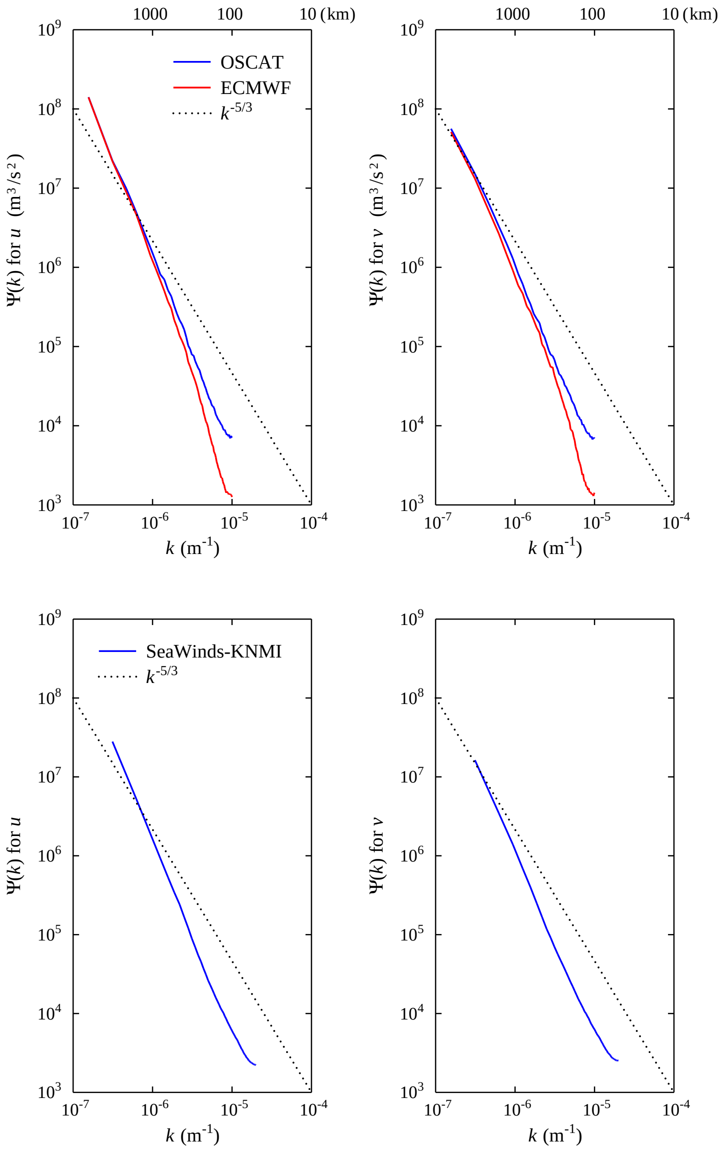


Figure 5: Wind spectra of OSCAT (top) and SeaWinds 25-km (bottom, from [5]) wind products. The results for the *u* wind components are shown in the left hand side plot and for the *v* wind component in the right hand side plot. The spectra of the ECMWF global model forecasts are also shown. The OSCAT plots cover the period of January 2012.

6 Triple collocation results

A triple collocation study was performed to assess the errors of the OSCAT, ECMWF and buoy winds independently. The triple collocation method was introduced by Stoffelen [10]. Given a set of triplets of collocated measurements and assuming linear calibration, it is possible to simultaneously calculate the errors in the measurements and the relative calibration coefficients. The triple collocation method can give the measurement errors from the coarse resolution NWP model perspective or from the intermediate resolution scatterometer perspective, but not from the fine resolution buoy perspective without further assumptions on the local buoy measurement error. A wind signal present in buoy measurements but not in scatterometer measurements is therefore contained in the buoy error. This matter is introduced in [10] and extensively discussed in [5].

A collocated data set of OSCAT 50-km, ECMWF and buoy winds spanning three months was used in the triple collocation. Table 3 lists the error variances of the buoy, OSCAT and ECMWF winds from the intermediate resolution scatterometer perspective. The precision of the scatterometer error standard deviations is approximately 0.02 m/s, assuming that the error is Gaussian and that the representation error is known. Ideally we would expect the same error standard deviation in each column for buoys and ECMWF. This is the case when considering all WVCs and the inner swath WVCs, but for the outer swath the error standard deviations are somewhat larger; this is due to the small number of collocations (1882) in the outer swath region.

A small but significant trend showing increasing scatterometer error standard deviations for the outer swath appears when we compare the results for inner swath, all data and outer swath in Table 3. This is expected since the wind retrieval skill is less in the outer swath where only one polarisation is present and azimuth separation is poorer. The numbers in the table compare well with the results for SeaWinds as reported in [5]. The SeaWinds 25-km results from this reference are repeated in Table 3 for reference. Note that these results were obtained over a full year, whereas for OSCAT we used only 3 months of data. This may effect the results slightly.

	Scatterometer		Buoys		ECMWF	
	σ_u (m/s)	σ_v (m/s)	σ_u (m/s)	σ_v (m/s)	σ_u (m/s)	σ_v (m/s)
WVC 1-36 (all)	0.69	0.54	1.46	1.57	1.03	1.09
WVC 5-32 (inner)	0.67	0.51	1.46	1.57	0.99	1.10
WVC 1-4, 33-36 (outer)	0.74	0.61	1.47	1.59	1.16	1.01
SeaWinds 25-km, 2009	0.79	0.63	1.40	1.44	1.19	1.27

Table 3: Error standard deviations from triple collocation of OSCAT wind product with buoy and ECMWF forecast winds, seen from the scatterometer perspective. The results were obtained for the period of 1 January to 31 March 2012. The SeaWinds 25-km results over 2009 [5] are shown for comparison.

7 Conclusions

The OSI SAF OSCAT 50-km wind product has been validated. It provides wind quality well within the OSI SAF product requirements [11] (wind speed bias less than 0.5 m/s and wind component RMS better than 2.0 m/s). The winds in the outer swath region (where only VV-polarised backscatter data are available) have slightly reduced quality but they are still very well usable, especially for nowcasting. These winds are flagged in the product and can be filtered out easily. The adaptation of the NSCAT-2 GMF to NSCAT-3 is well capable to remove the positive wind speed biases above 15 m/s, as is clear from the comparison of OSCAT winds with ECMWF model winds and OSCAT winds with buoy winds.

The results in this report show that OSCAT is a good successor of SeaWinds on QuikSCAT and will help to extend the Ku-band scatterometer data record over a longer period.