Ocean and Sea Ice SAF

Technical Note
SAF/OSI/CDOP2/KNMI/TEC/RP/228

RapidScat wind validation report

25 and 50 km wind products (OSI-109)

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Contents

1 Introduction

The EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI SAF) produces a range of air-sea interface products, namely: wind, sea ice characteristics, Sea Surface Temperatures (SST) and radiative fluxes, Surface Solar Irradiance (SSI) and Downward Long wave Irradiance (DLI). The Product Requirements Document [1] provides an overview of the committed products and their characteristics in the current OSI SAF project phase, the Service Specification Document [2] provides specifications and detailed information on the services committed towards the users by the OSI SAF in a given stage of the project.

The OSI SAF delivers development status level 2 wind products with 25 and 50 km Wind Vector Cell (WVC) spacing in near-real time [3], based on the RapidScat scatterometer level 2a products, kindly provided by the NASA Jet Propulsion Laboratory (JPL). See the JPL documentation [4], [5] for more information on the level 2a product characteristics. The products are available with two different timeliness's [3], the results in this report are based on the 3 hours (delayed) products. The 2 hours products have the same properties but have more missing parts in the orbits.

In this report, we assess the quality of the OSI SAF wind products. We compare the scatterometer wind data with ECMWF model data in section 2 and with in situ wind data from moored buoys in section 3. A triple collocation exercise is done as well and presented in section 4. Section 5 summarises the main conclusions.

The results presented in this report are encouraging and warrant the release of the 25 and 50 km wind products.

Acknowledgement

JPL kindly provides the RapidScat level 2a data which are used as input for the OSI SAF wind products. We are grateful to Jean Bidlot of ECMWF for helping us with the buoy data retrieval and quality control.

2 Product characteristics and comparison with NWP model wind data

Figure 1 shows an example of a RapidScat wind field. It is clear that the Quality Control (QC) mechanism is well capable to flag rainy WVCs: the orange dots generally well correspond to the cloudy areas where heavy rain can be expected. Some winds near the centre of the cyclonic structure are considered as meteorologically inconsistent and flagged by the variational QC flag (orange coloured arrows). The global fraction of WVCs rejected by the KNMI QC flag is approximately 8% which is comparable to the rejection rates of the OSI SAF SeaWinds and OSCAT wind products.

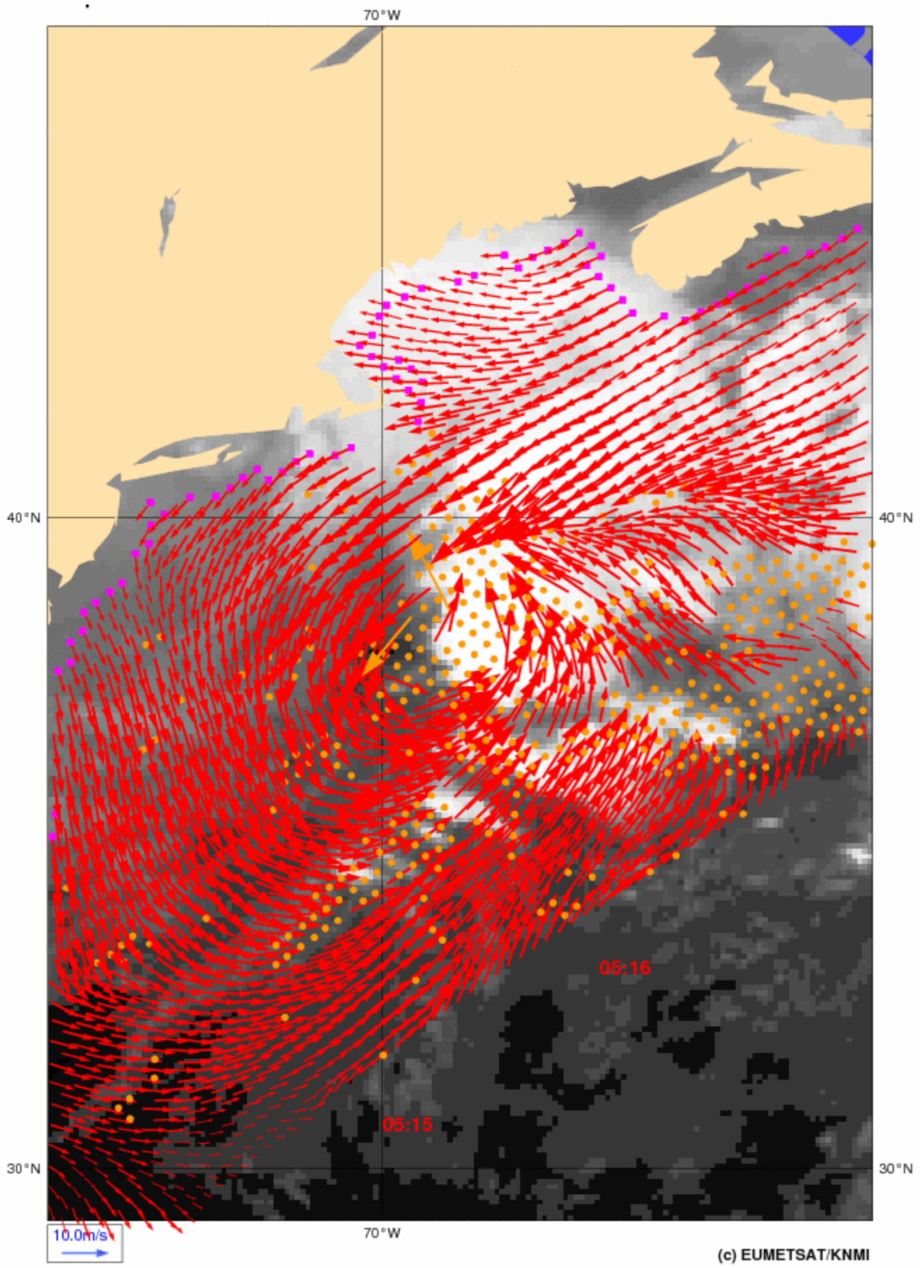

Figure 1: Example of 25 km RapidScat product near the United States east coast and Nova Scotia at 22 January 2015 5:15 UTC, overlaid on a GOES IR satellite image at 5:00 UTC. The purple squares correspond to WVCs where the land flag is set, but where reliable winds can still be computed, the orange dots correspond to WVCs that have been rejected by QC due to inconsistencies between backscatter data and wind GMF, and the orange arrows correspond to WVCs where the variational QC flag is set due to spatial inconsistencies.

Figure 2 shows two-dimensional histograms of the retrieved winds versus ECMWF 10 m wind background for the 25 km wind product, after rejection of Quality Controlled (KNMI QC flagged) wind vectors. The data for these plots are from 28 consecutive orbits from 25 and 26 January 2015. Due to the large daily number of collocations with the model data, two days is sufficient to obtain reliable statistics. The seasonal oscillations are also known to be quite small for these type of comparisons [6]; those can be further reduced by using data only from a delimited period of the year.

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 only 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. Figure 3 shows the comparisons of 50 km RapidScat winds with ECMWF winds in the same way as in Figure 2.

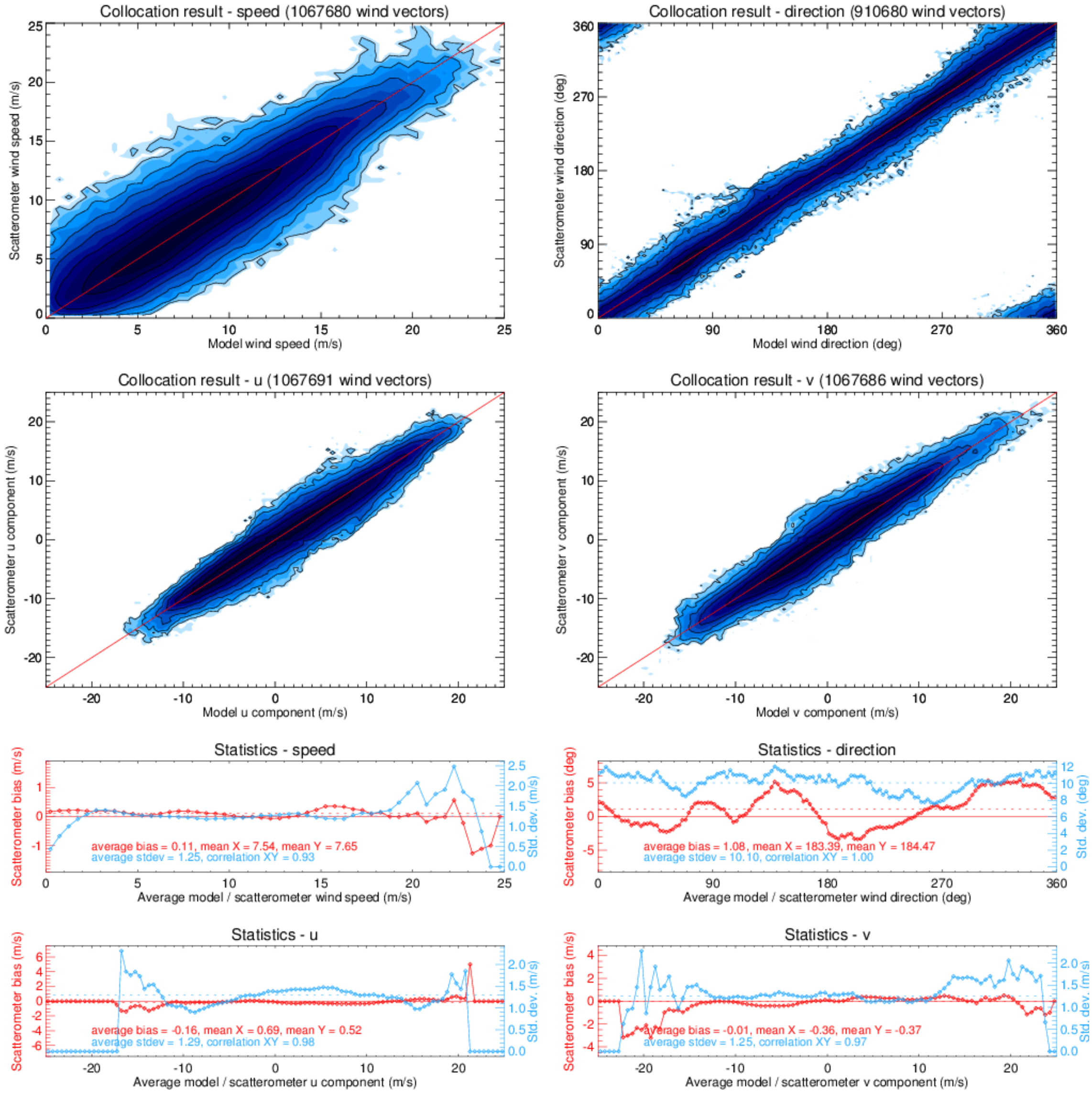

Figure 2: Two-dimensional histograms of wind speed, direction (w.r.t. wind coming from the North), *u* and *v* components of 25 km RapidScat wind product versus the ECMWF model forecast winds from 25 and 26 January 2015 (top panels). The corresponding biases (red) and standard deviations (blue) as a function of the average scatterometer and model winds are shown in the bottom.

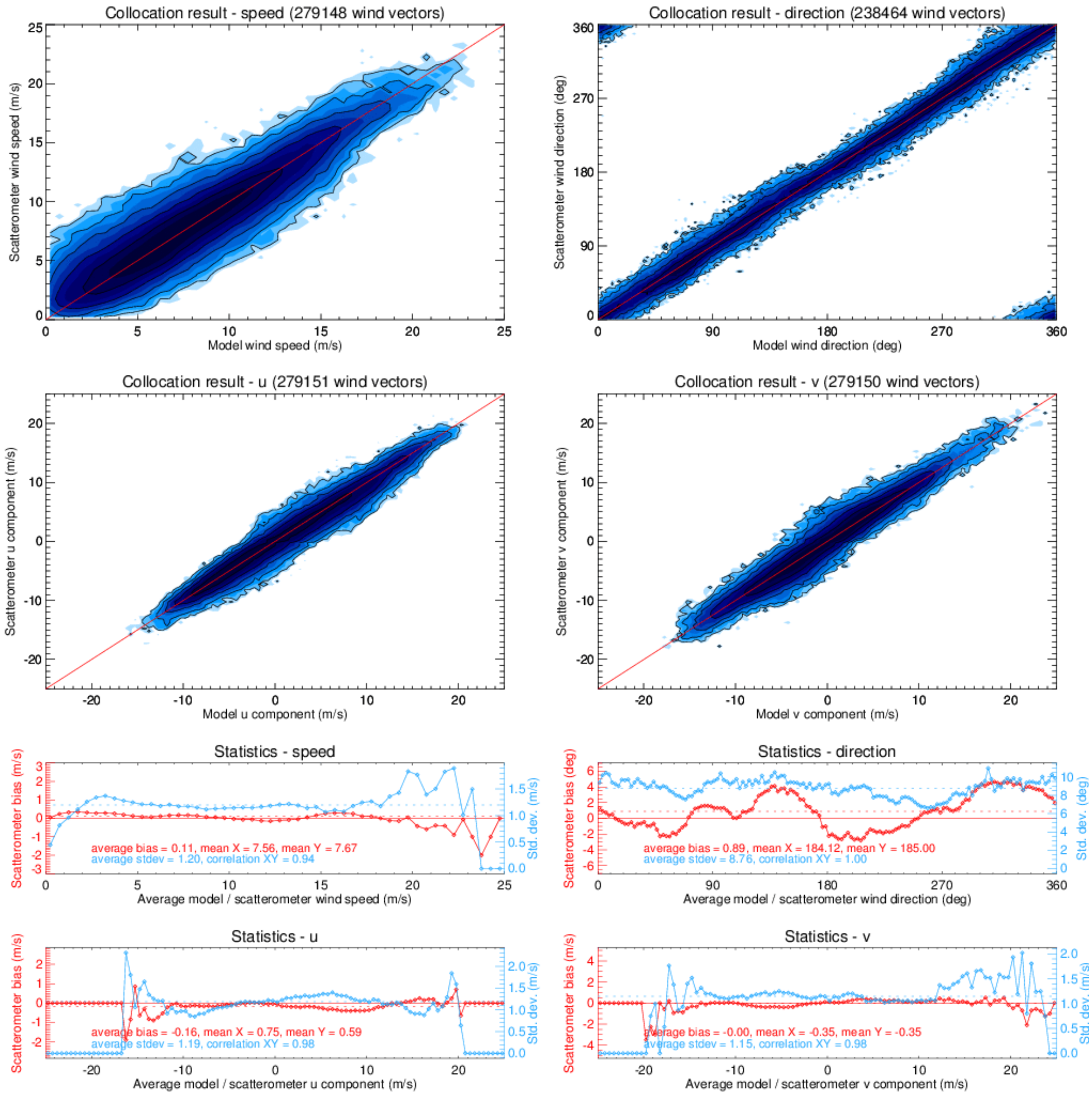

Figure 3: Two-dimensional histograms of wind speed, direction (w.r.t. wind coming from the North), *u* and *v* components of 50 km RapidScat wind product versus the ECMWF model forecast winds from 25 and 26 January 2015 (top panels). The corresponding biases (red) and standard deviations (blue) as a function of the average scatterometer and model winds are shown in the bottom.

The results in terms of wind speed bias and *u* and *v* wind component standard deviations are summarised in Table 1 for the 25 km and 50 km wind products. As reference, the statistics of the OSI SAF QuikSCAT/SeaWinds wind product (25 km) and Oceansat-2/OSCAT wind product (50 km) from comparable periods in 2009 and 2012 are shown as well. The RapidScat wind speed biases are close to the expected value of 0.20 m/s. The 50 km RapidScat wind components compare slightly better to ECMWF than the 25 km RapidScat wind components. This is in line with the relatively coarse effective resolution of the ECMWF model data used [10].

It is also clear from Table 1 that the wind component standard deviations are smaller for RapidScat than for SeaWinds and for OSCAT. This is most probably due to the limited geographical coverage of RapidScat. The storm tracks at higher latitudes where high wind speeds occur and larger differences between model winds and observations can be expected, are included in the SeaWinds and OSCAT statistics but excluded in the RapidScat statistics. Some evidence for this explanation is shown in the lines of Table 1, where the SeaWinds and OSCAT statistics for latitudes corresponding to the RapidScat coverage are shown. The *u* and *v* standard deviations are significantly lower in this latitude domain.

Other explanations for the lower RapidScat standard deviations may be differences in instrument design and set-up, and improvements in the wind processing, in particular the Quality Control, which have been made lately in the processing of Ku-band scatterometer data. Another issue is that no backscatter calibration was used for SeaWinds back in 2009. This leads to negative wind speed biases for the SeaWinds winds in Table 1. Lower wind speeds also lead to smaller values for the wind component standard deviations and hence the tabled values for SeaWinds are somewhat lower than they would be if SeaWinds wind speeds would have been calibrated in the same way as OSCAT and RapidScat. So it is hard to directly compare the numbers in Table 1, but they clearly indicate that RapidScat winds show at least the same or even better statistics as compared to those of earlier Ku-band instruments.

The RapidScat wind speed biases and wind component standard deviations are all well within the OSI SAF requirements: better than 2 m/s in wind component standard deviation with a bias of less than 0.5 m/s in wind speed.

	# of wind vectors	speed bias	stdev *u*	stdev *v*
25 km RapidScat	1,067,691	0.11	1.29	1.25
50 km RapidScat	279,151	0.11	1.19	1.15
25 km SeaWinds	1,921,796	-0.24	1.35	1.34
25 km SeaWinds, between + and - 55°	1,597,224	-0.18	1.32	1.33
50 km OSCAT	404,936	0.14	1.35	1.33
50 km OSCAT, between + and - 55°	335,326	0.21	1.29	1.27

Table 1: ECMWF comparison results of RapidScat 25 km and 50 km wind products from 25 and 26 January 2015, compared with OSI SAF SeaWinds 25 km wind products from 25 and 26 January 2009 and OSCAT 50 km wind products from 25 and 26 January 2014. The SeaWinds and OSCAT results are shown for all latitudes and for those WVCs which are between +55° and -55° separately.

3 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 buoys spread over the oceans, most of them in the tropical oceans and near Europe and North America. These buoys are also used in the validations that are routinely performed for the OSI SAF wind products; see the links on http://www.knmi.nl/scatterometer/osisaf/. 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 Liu, Katsaros and Businger (LKB) model ([7], [8]) in order to enable a good comparison with the 10-m scatterometer winds.

See Figure 4 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 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.

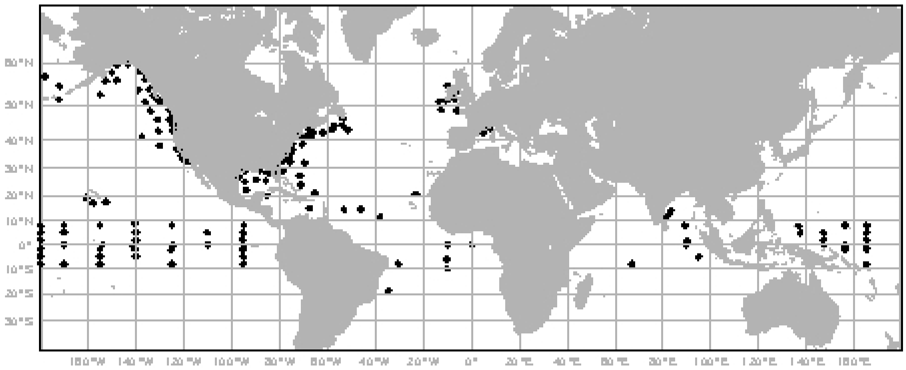

Figure 4: Locations of the moored buoys used in the comparisons.

In Table 2 we show the wind speed bias and wind component standard deviations of the 25 km and 50 km RapidScat wind products. For comparison, we also show the results of the OSI SAF SeaWinds 25 km wind product as it was produced until November 2009 and the OSCAT 50 km wind product as it was produced until February 2014. The same autumn/winter period was chosen for SeaWinds and OSCAT as for RapidScat, but then for different years.

	# of wind vectors	speed bias	stdev *u*	stdev *v*
25 km RapidScat	9648	0.07	1.61	1.72
50 km RapidScat	9738	0.09	1.62	1.73
25 km SeaWinds	9858	-0.48	1.84	1.80
50 km OSCAT	10375	0.07	2.04	1.98

Table 2: buoy comparison results of RapidScat 25 km and 50 km wind products from November 2014 to January 2015, compared with OSI SAF SeaWinds 25 km wind products from November 2008 to January 2009 and OSCAT 50 km wind products from November 2012 to January 2013.

The table shows that the RapidScat results for 25 km and 50 km do not differ significantly. On the other hand, the wind component standard deviations are significantly lower for RapidScat than for SeaWinds and OSCAT. The differences between RapidScat and the other instruments are more distinct in the buoy comparisons than in the NWP model comparisons (Table 1). This cannot be a matter of geographical coverage since almost all buoys are located between 55° south and 55° north latitude and hence covered both by OSCAT and RapidScat. Apart from the possible causes mentioned in the previous section (instrument and wind processing algorithm), larger variations may be expected for buoy comparisons than for model comparisons due to weather variations and its limited sampling. A smaller number of collocations leads to a less precise determination of the standard deviations.

4 Triple collocation results

A triple collocation study was performed to initially assess the errors of the RapidScat, ECMWF and buoy winds independently. The triple collocation method was introduced by Stoffelen [9]. 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, from the intermediate resolution scatterometer perspective, or from the fine resolution buoy perspective when using the specified local buoy measurement error. How to deal with errors of spatial representation is extensively introduced by Vogelzang et al. [10].

Collocated data sets of RapidScat 25 km and 50 km, ECMWF and buoy winds spanning three months were used in the triple collocation. Table 3 lists the error variances of the buoy, RapidScat and ECMWF winds from the intermediate resolution scatterometer perspective. When we compare the 50 km RapidScat product with the 25 km RapidScat product, we see an increase of the buoy wind error standard deviations and a decrease of the ECMWF wind standard deviations. This is due to the coarser resolution of the 50 km product, which contains less small scale information and in this respect resembles better the ECMWF winds and resembles worse the local buoy winds. The errors of the 25 km RapidScat winds are larger than those of the 50 km winds. This is most probably due to the larger noise in the 25 km wind retrievals.

For comparison, some triple collocation results from OSCAT and SeaWinds are shown in Table 3 as well. Note that in the scope of this validation report we have re-used SeaWinds and OSCAT triple collocations results that were already available from earlier publications and we did not re-compute them for comparable periods to comply with the RapidScat period. It appears that the error values for RapidScat 50 km are lower than those for OSCAT 50 km and that the error values for RapidScat 25 km are lower than those for SeaWinds 25 km. Apart from instrument specific characteristics and differences in sampling period, this may be due in part to the improvements in wind retrieval and quality control implemented in the latest version of the Pencil beam Wind Processor (PenWP) software. The RapidScat scatterometer winds are of good quality: at 25 km scale the error in the wind components is less than 0.7 m/s; at 50 km scale it is less than 0.6 m/s.

	Scatterometer		Buoys		ECMWF	
	ε_u (m/s)	ε_v (m/s)	ε_u (m/s)	ε_v (m/s)	ε_u (m/s)	ε_v (m/s)
25 km RapidScat	0.64	0.67	1.33	1.38	1.17	1.15
50 km RapidScat	0.56	0.53	1.41	1.47	1.06	1.07
50 km OSCAT	0.69	0.54	1.46	1.57	1.03	1.09
25 km SeaWinds	0.79	0.63	1.40	1.44	1.19	1.27

Table 3: Error standard deviations in *u* and *v* wind components from triple collocation of RapidScat 25 km and 50 km wind products with buoy and ECMWF forecast winds, seen from the scatterometer perspective. The results were obtained for the limited period of November 2014 to January 2015. The OSCAT results over January to March 2012 and the SeaWinds results over the whole year 2009 [10] are shown for comparison.

From the triple collocation analysis, we can also determine the calibration of the scatterometer winds. The calibration coefficients a and b relate the observed scatterometer wind w to the ‘true’ wind t according to $t = a \times w + b$. This is done separately for the u and v wind components. The results in Table 4 show that the RapidScat winds are well calibrated, with b values close to 0 and a coefficients around 0.98. This suggests a slight (~2 %) overestimation of the winds by RapidScat. The deviation may be a seasonal effect, it will be necessary to have a full year of data before we can draw final conclusions and to determine better estimations for the RapidScat backscatter corrections.

	a_u	a_v	b_u (m/s)	b_v (m/s)
25 km RapidScat	0.983	0.978	-0.06	-0.03
50 km RapidScat	0.980	0.972	-0.07	-0.04

Table 4: Calibration coefficients *a* and *b* for *u* and *v* wind components from triple collocation of RapidScat 25 km and 50 km wind products with buoy and ECMWF forecast winds. The results were obtained for the limited period of November 2014 to January 2015.

5 Conclusions

The OSI SAF RapidScat 25 km and 50 km wind products have been validated. They provide wind quality well within the OSI SAF product requirements ([1], better than 2 m/s in wind component standard deviation with a bias of less than 0.5 m/s in wind speed on a monthly basis). The results in this report show that RapidScat winds have equal or even better quality than OSCAT winds and that RapidScat is a good successor of SeaWinds on QuikSCAT and OSCAT on Oceansat-2. It is critical to extend the Ku-band scatterometer data record over a longer period.

Moreover, due to its particular orbit characteristics, RapidScat will provide abundant collocations with the ASCAT scatterometers, the HY-2A scatterometer and probably also the Indian ScatSat scatterometer, which will be useful for improvements in intercalibration and wind processing of all these systems.

6 References

[1] OSI SAF,
Product Requirements Document,
SAF/OSI/CDOP2/M-F/MGT/PL/2-001, 2015

[2] OSI SAF,
Service Specification Document,
SAF/OSI/CDOP2/M-F/MGT/PL/2-003, 2015

[3] OSI SAF,
RapidScat wind Product User Manual,
SAF/OSI/CDOP2/KNMI/TEC/MA/227, 2015

[4] JPL,
RapidScat mission website
http://winds.jpl.nasa.gov/missions/RapidScat/

[5] JPL,
QuikSCAT Science Data Product User's Manual, version 3.0,
Jet Propulsion Laboratory D-18053-Rev A, September 2006

[6] Verhoef, A., J. Vogelzang and A. Stoffelen,
SeaWinds wind Climate Data Record validation report
SAF/OSI/CDOP2/KNMI/TEC/RP/221

[7] Bidlot J., D. Holmes, P. Wittmann, R. Lalbeharry, and H. Chen
Intercomparison of the performance of operational ocean wave forecasting systems with buoy data
Wea. Forecasting, vol. 17, 287-310, 2002

[8] Liu, W.T., K.B. Katsaros, and J.A. Businger
Bulk parameterization of air-sea exchanges of heat and water vapor including the molecular constraints in the interface
J. Atmos. Sci., vol. 36, 1979

[9] Stoffelen, A.
Toward the true near-surface wind speed: error modeling and calibration using triple collocation
J. Geophys. Res. 103, C4, 7755-7766, 1998, doi:10.1029/97JC03180

[10] Vogelzang, J., A. Stoffelen, A. Verhoef and J. Figa-Saldana
On the quality of high-resolution scatterometer winds
J. Geophys. Res., 116, C10033, 2011, doi:10.1029/2010JC006640

7 Abbreviations and acronyms

ECMWF	European Centre for Medium-Range Weather Forecasts
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GTS	Global Telecommunication System
JPL	Jet Propulsion Laboratory
KNMI	Royal Netherlands Meteorological Institute
LKB	Liu, Katsaros and Businger
NASA	National Aeronautics and Space Administration
NWP	Numerical Weather Prediction
OSI	Ocean and Sea Ice
PenWP	Pencil Beam wind Processor
QC	Quality Control
QuikSCAT	US Quick Scatterometer mission carrying the SeaWinds scatterometer
SAF	Satellite Application Facility
u	West-to-east (zonal) wind component
v	South-to-north (meridional) wind component
WVC	Wind Vector Cell