EUMETSAT OSI SAF
OCEAN AND SEA ICE

Scientific Validation Report (SVR) for the HY-2 winds

HY-2B 25 km wind vectors (OSI-114-a)

HY-2B 50 km wind vectors (OSI-114-b)

HY-2C 25 km wind vectors (OSI-115-a)

HY-2C 50 km wind vectors (OSI-115-b)

HY-2D 25 km wind vectors (OSI-116-a)

HY-2D 50 km wind vectors (OSI-116-b)

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Document Change record

Document version	Software version	Date	Author	Change description
0.9 draft		Mar 2021	AV	First version for Operational Readiness Review
1.0		May 2021	AV	Changes according to ORR RIDs
1.1		Nov 2022	AV	Added information for HY-2D ORR

Table of contents

1. Introduction

The HSCAT scatterometer instrument is mounted on the HY-2B satellite which was launched on October 25th, 2018 by the Chinese National Satellite Ocean Application Service (NSOAS). The same instrument is mounted on the HY-2C satellite which was launched on September 21th, 2020, and on the HY-2D satellite which was launched on May 19th, 2021. The Ku-band HSCAT instruments on the three satellites are identical and are similar to HSCAT on HY-2A which was launched in 2011. The level 1b files from NSOAS are processed by KNMI into 25 km and 50 km level 2 wind products.

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 level 2 wind products with 25 and 50 km Wind Vector Cell (WVC) spacing in near-real time [3], based on the HSCAT scatterometer level 1b products, kindly provided by NSOAS. See the NSOAS documentation [4], [5] for more information on the level 1b product characteristics.

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. In this version (1.1) of the report, the validation information for HY-2D was added on top of HY-2B and HY-2C which already have an operational status. In order to make a good comparison of the new product with the existing HY-2B and HY-2C products, data for the same period was used for all three products. Thus, the HY-2B and HY-2C information will slightly differ from the information of previous report versions. The results presented in this report are encouraging and warrant the release of the HY-2D 25 and 50 km wind products.

1.1. Acknowledgement

NSOAS kindly provides the HSCAT level 1b 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.

1.2. Reference and applicable documents

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[2] OSI SAF,
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[4] National Satellite Ocean Application Service,
HY-2A Microwave Scatterometer Data Format User's Guide
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[5] National Satellite Ocean Application Service (NSOAS),
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Reprocessed SeaWinds L2 winds validation report
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High resolution data assimilation guide
Version 1.3, SAF/OSI/CDOP3/KNMI/SCI/GUI/388, 2020 (link)

[14] OSI SAF,
Algorithm Theoretical Basis Document for the scatterometer wind products,
SAF/OSI/CDOP2/KNMI/SCI/MA/197, 2022 (link)

2. Product characteristics and comparison with NWP model wind data

Figure 1 shows an example of a HY-2D wind field, as visualized on https://scatterometer.knmi.nl/. It is clear that the Quality Control (QC) mechanism is well capable to flag rainy WVCs: the black arrows generally well correspond to the cloudy areas where heavy rain can be expected. The QC is optimised to reduce the number of misses and false alarms, in order to keep high-quality winds and reject winds of inferior quality.

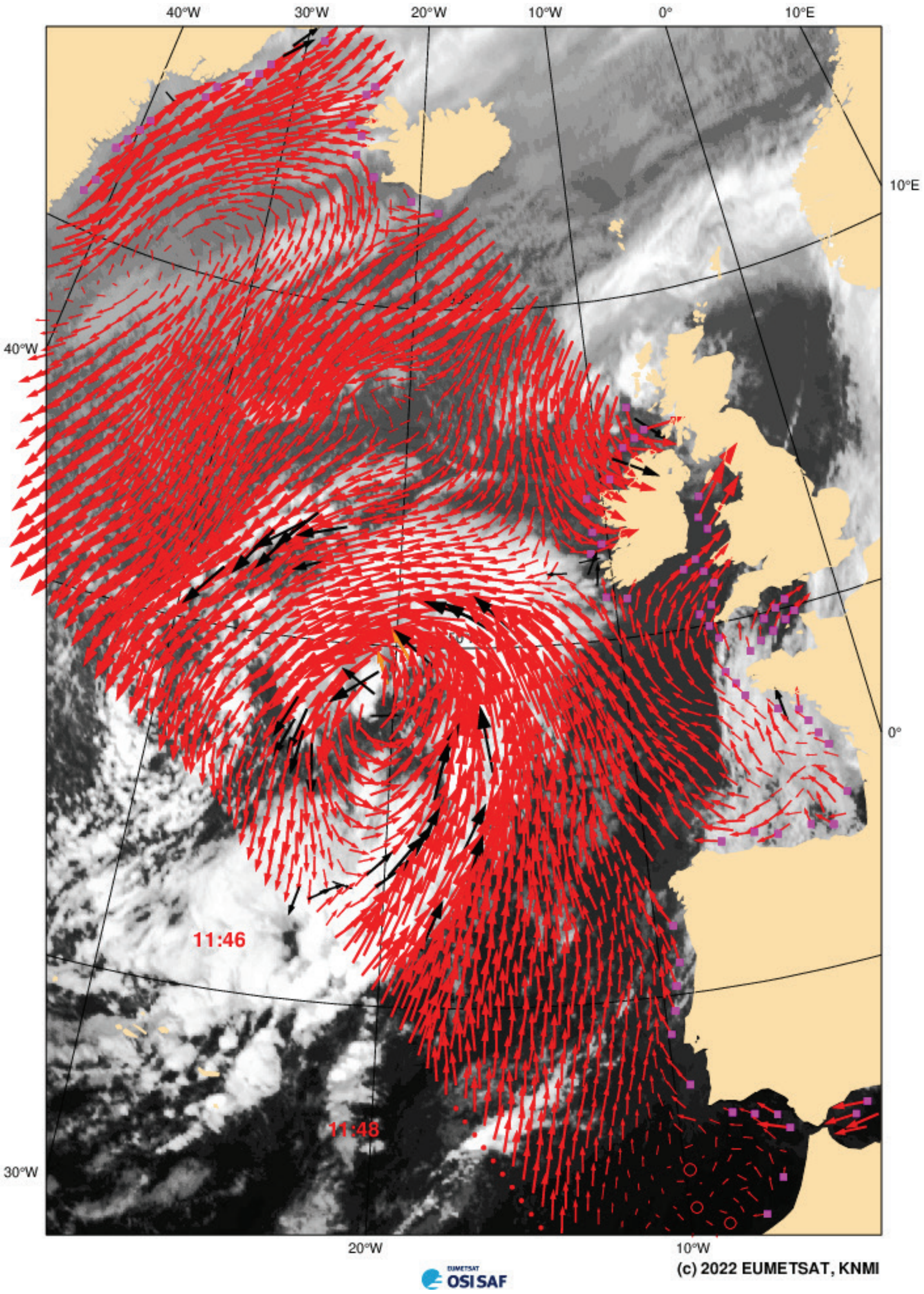

Figure 1: Example of 25 km HY-2D product, thinned to 50 km, over the Atlantic Ocean at 17 October 2022 11:45 UTC, overlaid on a Meteosat IR satellite image at 11:30 UTC. The black arrows correspond to WVCs that have been rejected by the "Quality Control data rejection for visualisation and nowcasting" flag.

Figure 2 shows two-dimensional histograms of the retrieved winds versus ECMWF 10 m wind background for the HY-2B 25 km wind product, after rejection of Quality Controlled (KNMI QC flagged) wind vectors. The data for these plots are from 1 to 2 October 2022. 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].

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. The ECMWF winds are stress equivalent 10 m winds to best represent the retrieved scatterometer winds. Figure 3 shows the comparisons of 25 km HY-2C winds with ECMWF winds in the same way as in Figure 2 and Figure 4 shows the 25 km HY-2D comparisons.

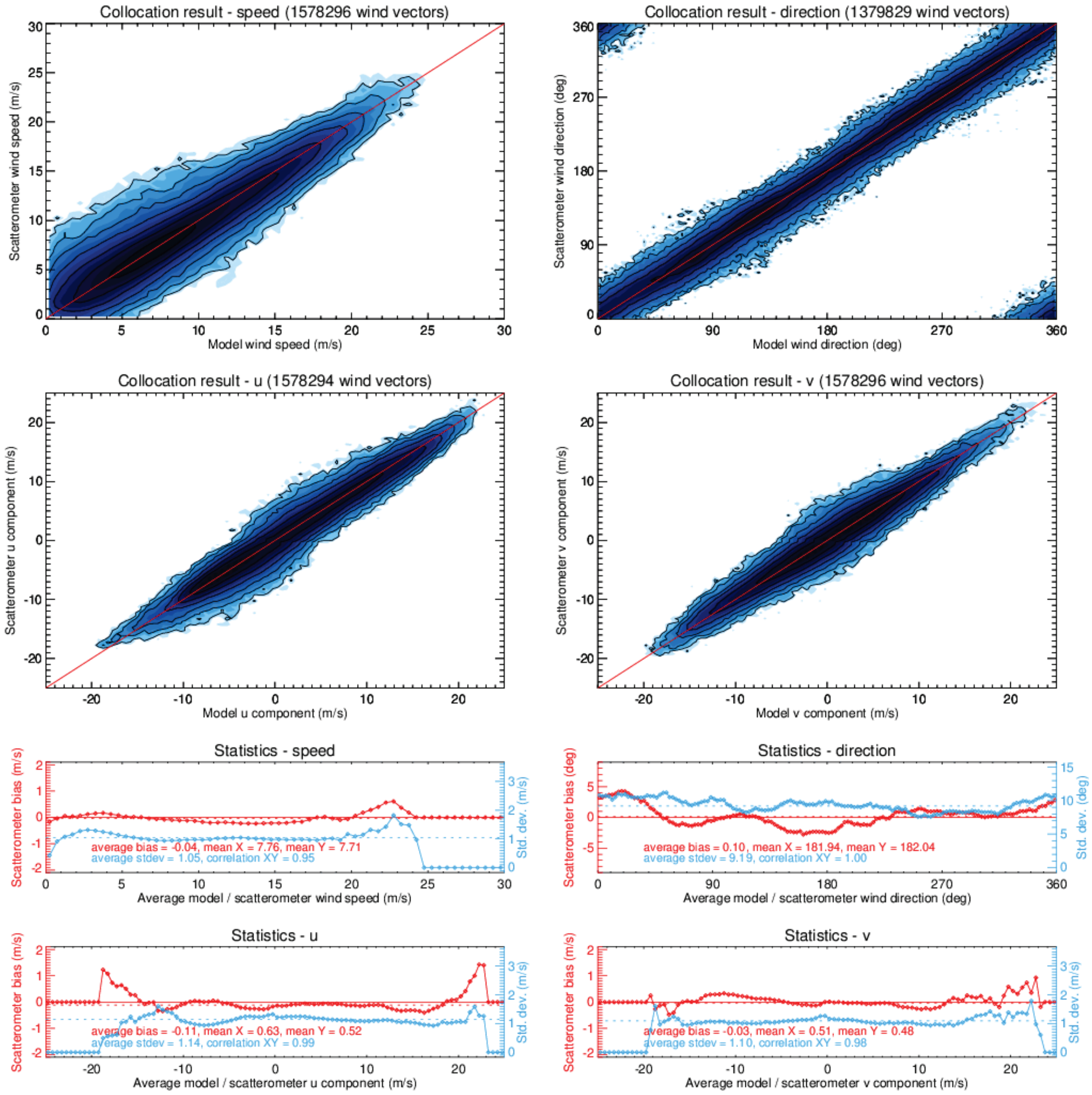

Figure 2: Two-dimensional histograms of wind speed, direction (w.r.t. wind coming from the North), u and v components of HY-2B 25 km wind product versus the ECMWF model forecast stress-equivalent winds from 1-2 October 2022 (top panels). The corresponding biases (red) and standard deviations (blue) as a function of the average scatterometer and model winds are shown in the bottom. The bias is set to 0 for empty bins, and standard deviation is set to 0 if bins contain less than two data points.

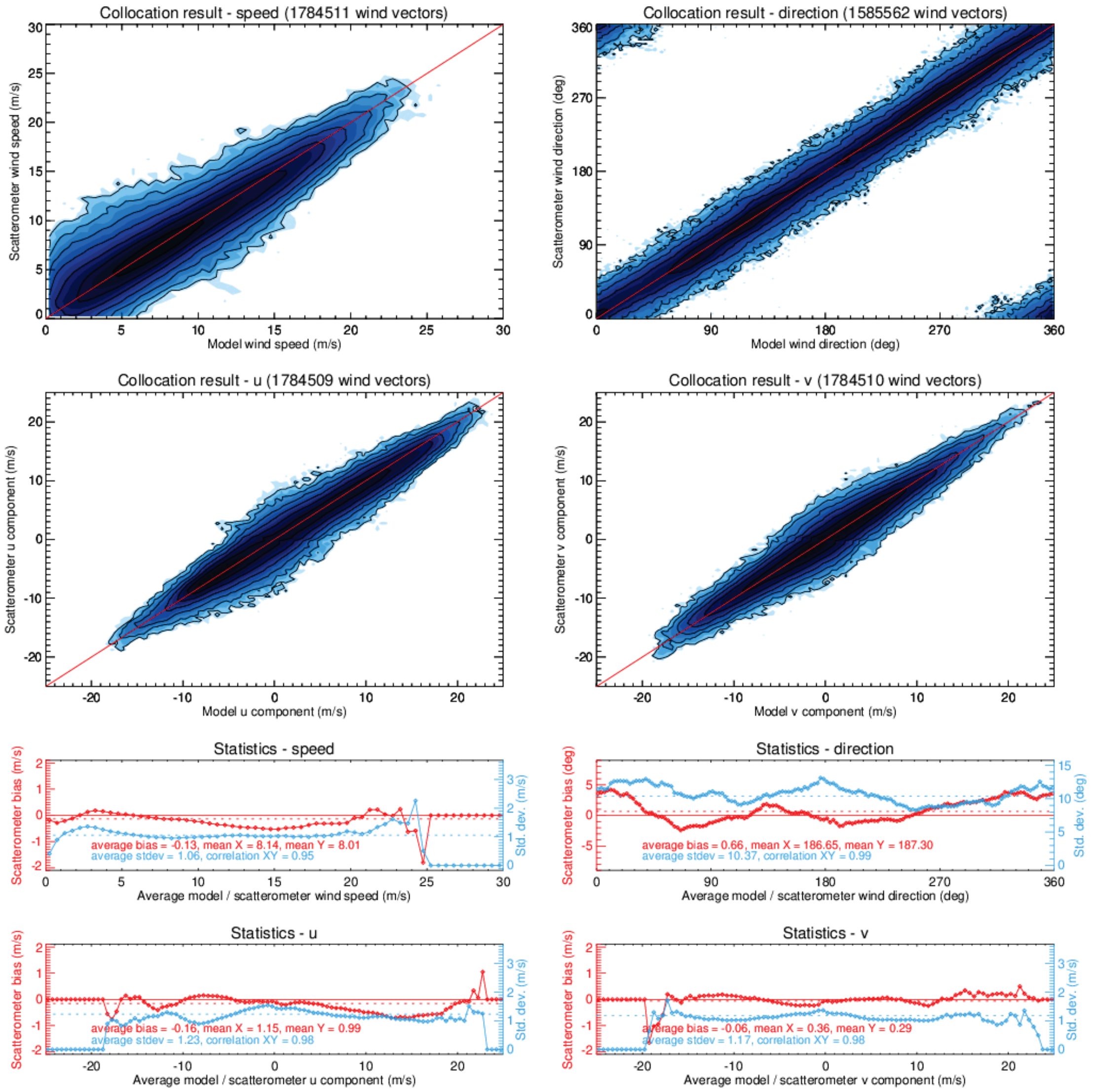

Figure 3: HY-2C 25 km wind product versus the ECMWF model forecast winds from 1-2 October 2022.

Figure 5, Figure 6, and Figure 7 show the same plots for the 50 km wind products of HY-2B, HY-2C, and HY-2D, respectively.

We note from the plots that wind speed and wind component biases are generally small. On the other hand there is a clear wind direction bias modulation of a few degrees, which is partially related to systematic biases in global NWP models [10], [11]. There are also wind direction retrieval difficulties in the nadir swath due to poor beam azimuth separation. This leads to wind direction 'attractors' in the retrievals and hence biases. As compared to earlier products from Ku-band systems like ScatSat-1, the modulations have been considerably reduced due to improvements in the NSCAT-4DS Geophysical Model Function and refinements in the backscatter calibration. Another feature in the plots is a slight positive tendency in the wind speed biases above 20 m/s, in particular for HY-2B and HY-2D. This may be due to a small non-linearity in the instrument backscatter calibration, although it is hard to draw conclusions based on the small number of high speed winds in this dataset. Note that high wind speed calibration is also uncertain due to lacking consistent in-situ wind speed references [12].

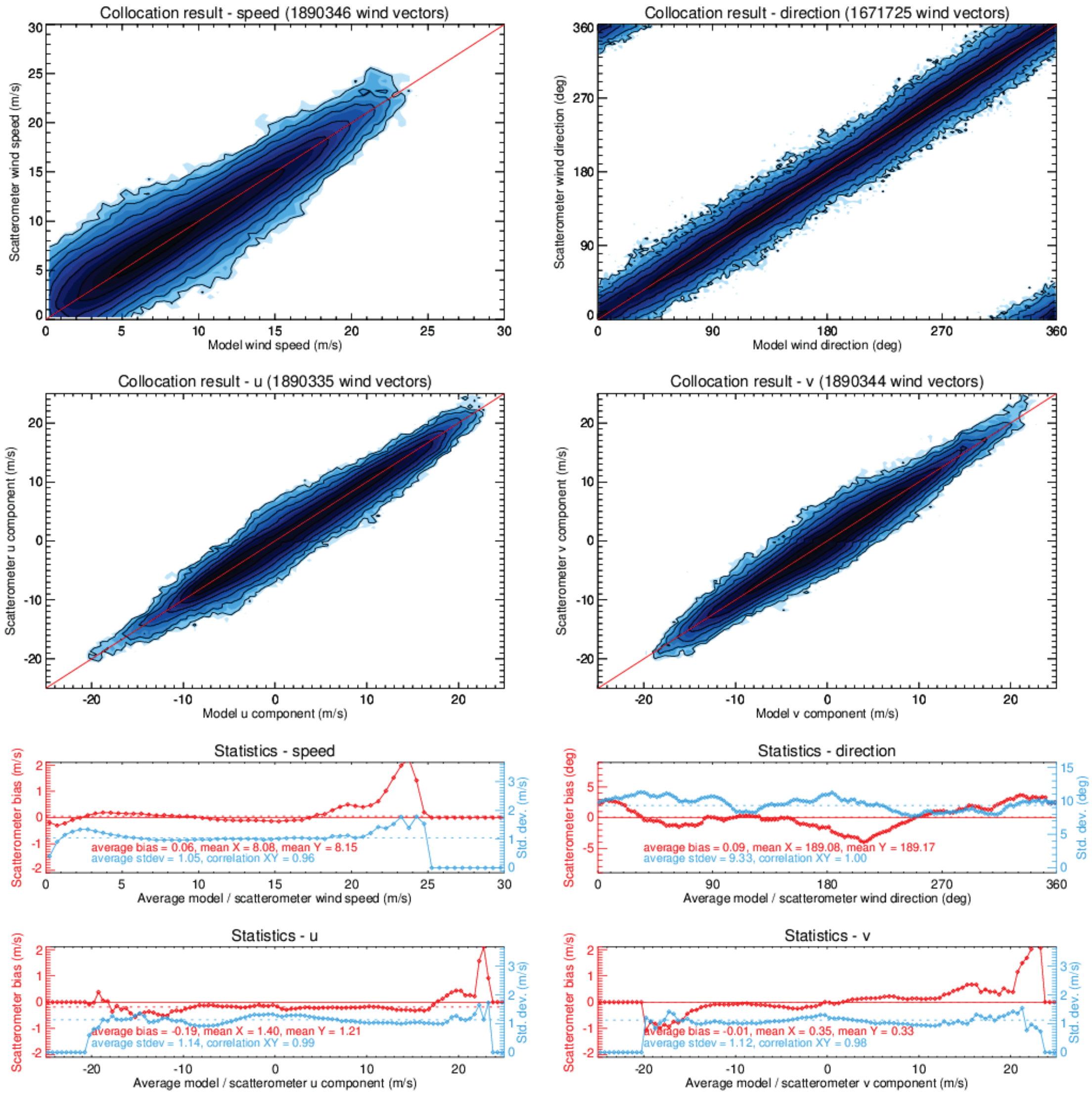

Figure 4: HY-2D 25 km wind product versus the ECMWF model forecast winds from 1-2 October 2022.

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. The wind speed biases of all products are close to the expected value of 0.00 m/s. The 50 km wind components compare slightly better to ECMWF than the wind components of their 25 km equivalents. This is in line with the relatively coarse effective resolution of the ECMWF model data [13].

It is also clear from Table 1 that the wind component standard deviations are smaller for HY-2B and HY-2D than for HY-2C. The reason for this is not entirely clear but it is most probably related to an instrumental feature or issue of HY-2C.

The 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.

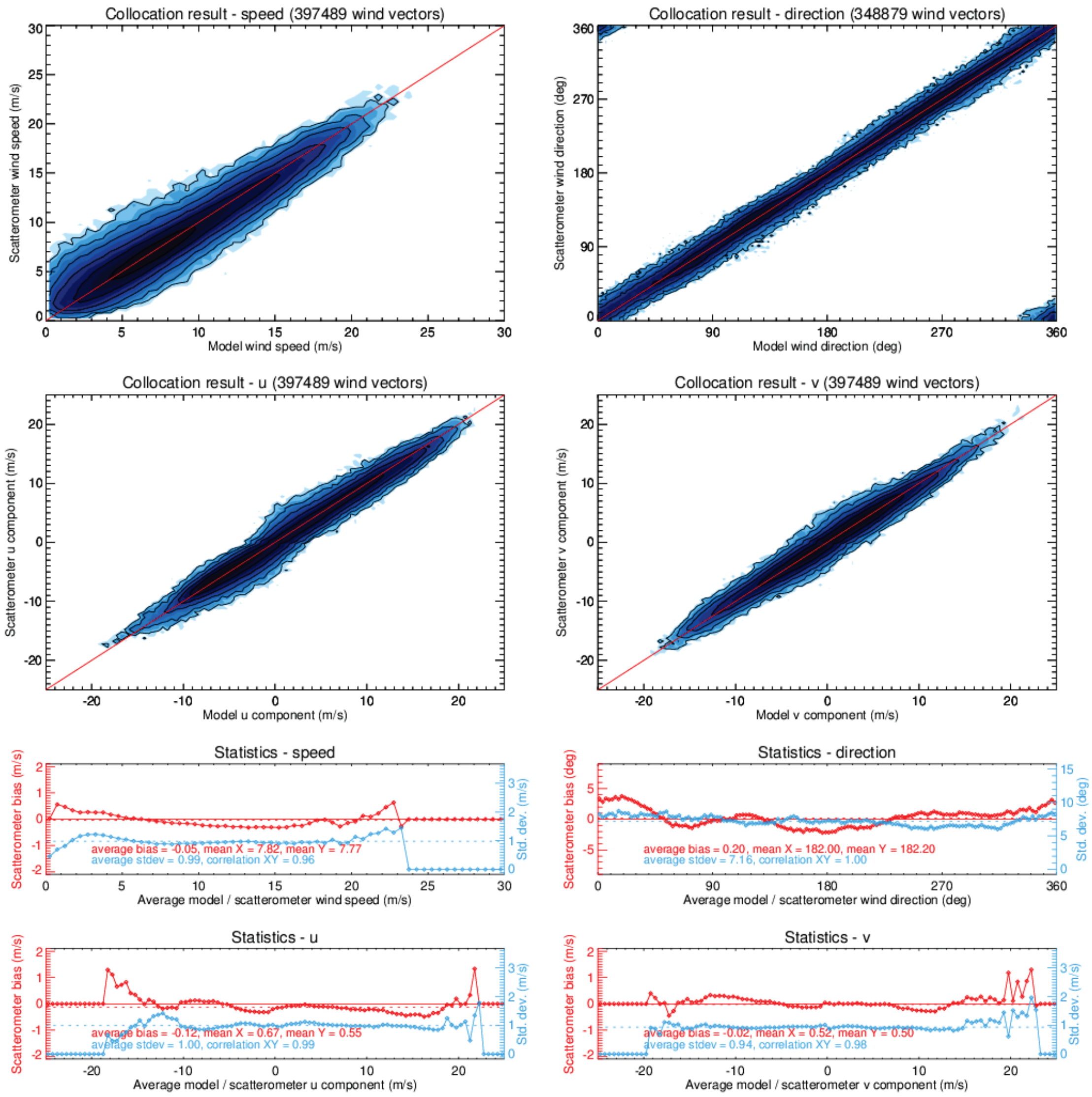

Figure 5: HY-2B 50 km wind product versus the ECMWF model forecast winds from 1-2 October 2022.

	# of wind vectors	speed bias	stdev *u*	stdev *v*
25 km HY-2B	1,578,296	-0.04	1.14	1.10
25 km HY-2C	1,784,511	-0.13	1.23	1.17
25 km HY-2D	1,890,346	0.06	1.14	1.12
50 km HY-2B	397,489	-0.05	1.00	0.94
50 km HY-2C	452,656	-0.13	1.07	1.01
50 km HY-2D	478,047	0.05	0.98	0.95

Table 1: ECMWF comparison results of HY-2B, HY-2C, and HY-2D 25 km and 50 km wind products from 1 to 2 October 2022.

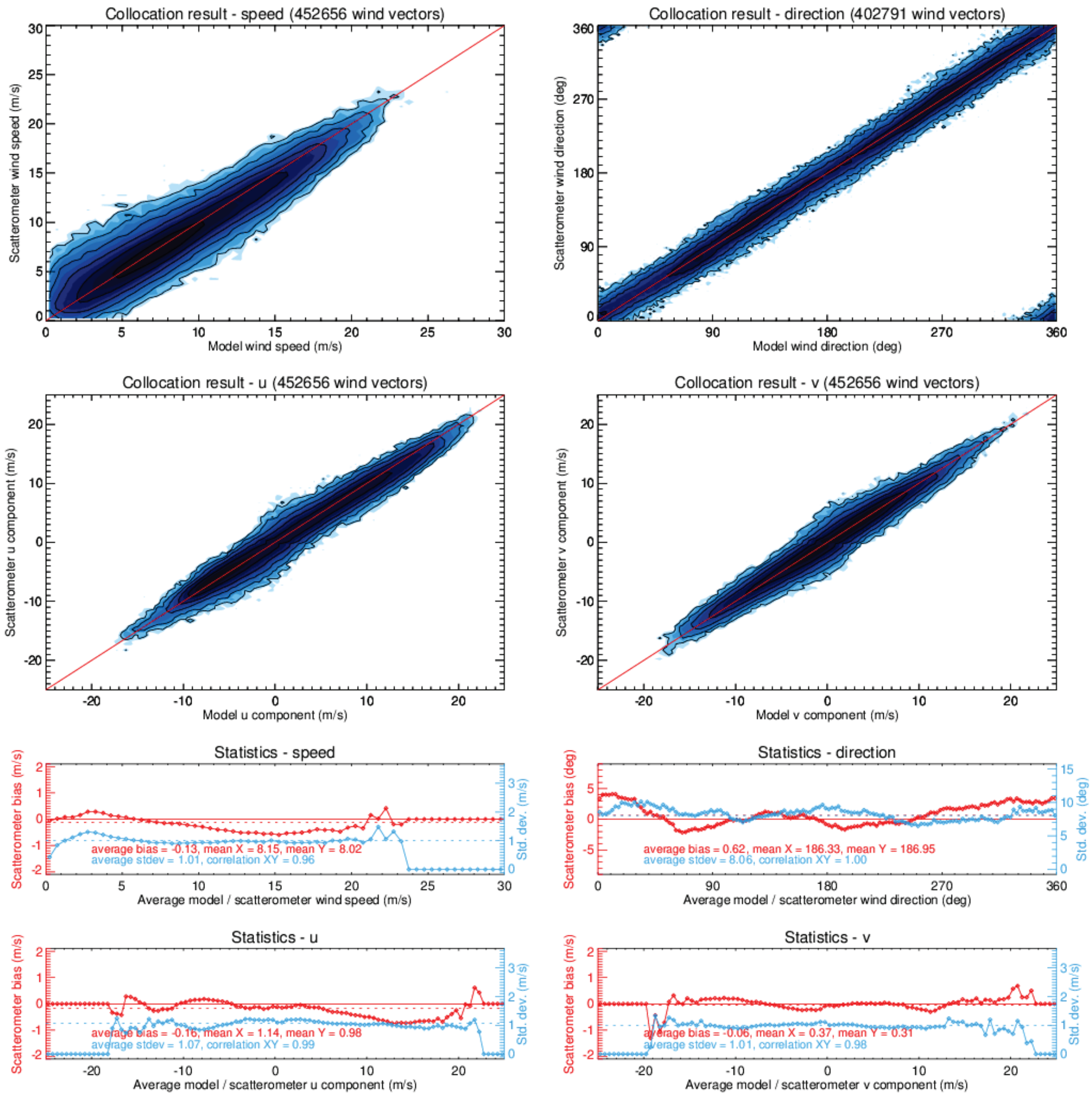

Figure 6: HY-2C 50 km wind product versus the ECMWF model forecast winds from 1-2 October 2022.

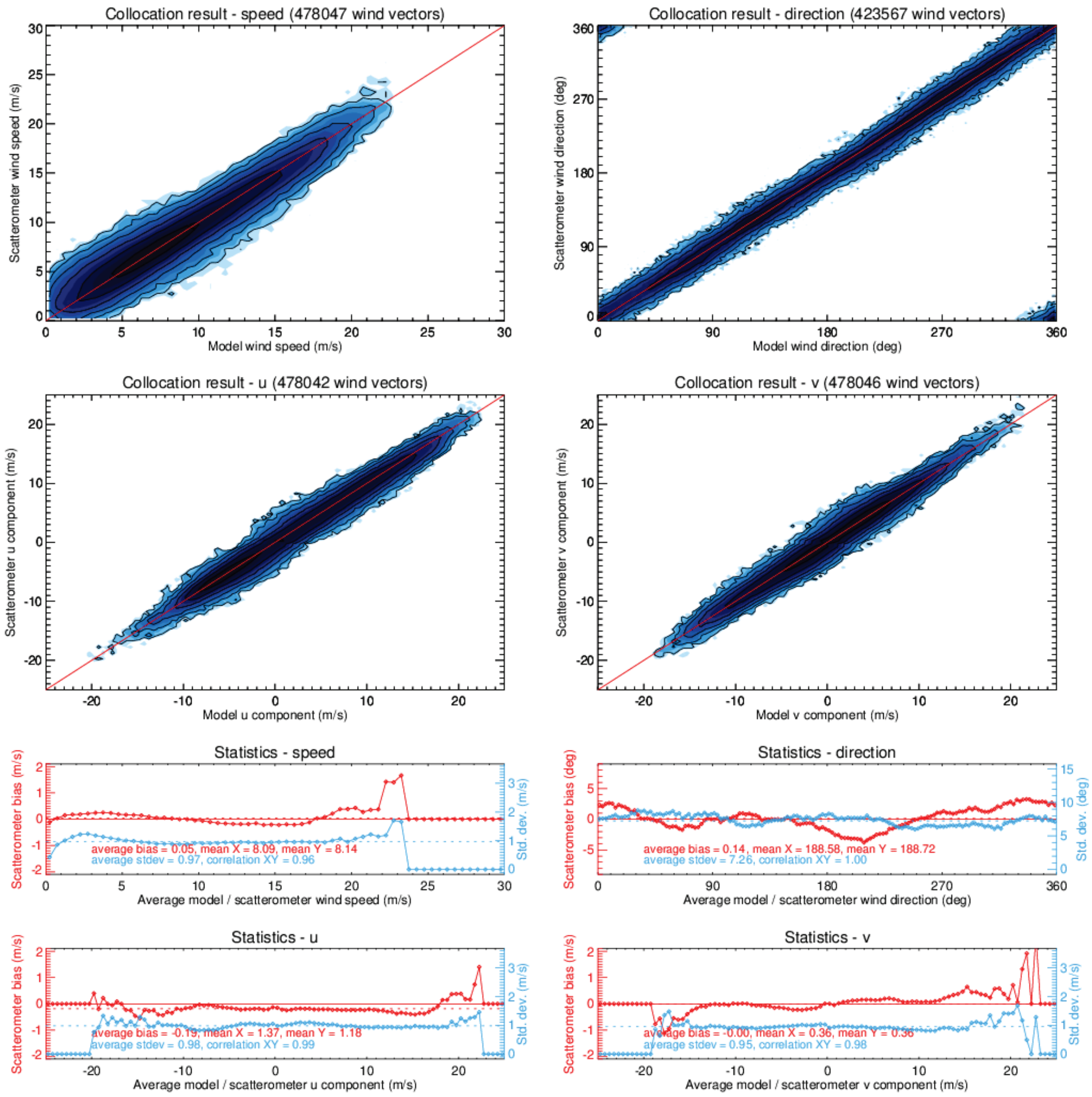

Figure 7: HY-2D 50 km wind product versus the ECMWF model forecast winds from 1-2 October 2022.

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 130 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, and presented in the half-yearly operations reports. 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. Unlike the NWP winds, the equivalent neutral buoy winds have not been further converted into stress-equivalent winds since only few buoys always report the necessary parameters (pressure, humidity and air temperature).

See Figure 8 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.

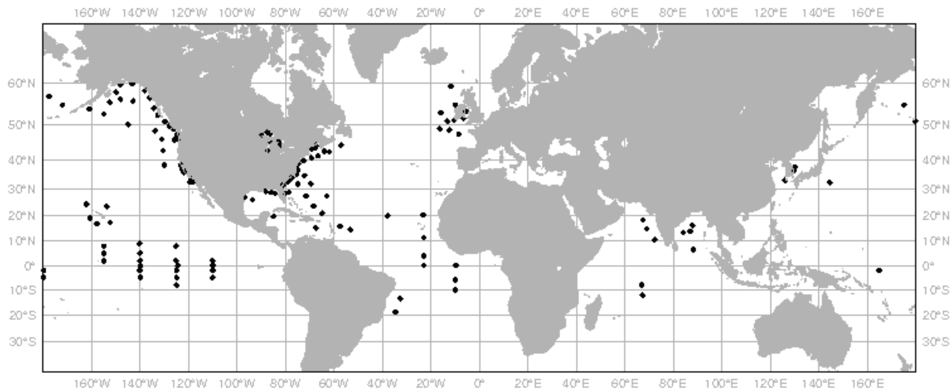

Figure 8: Locations of the moored buoys used in the comparisons.

	# of wind vectors	speed bias	stdev *u*	stdev *v*
25 km HY-2B	18156	-0.22	1.50	1.47
25 km HY-2C	20214	-0.23	1.59	1.59
25 km HY-2D	17729	-0.11	1.57	1.55
50 km HY-2B	17160	-0.22	1.53	1.52
50 km HY-2C	19697	-0.20	1.62	1.64
50 km HY-2D	17040	-0.10	1.61	1.60

Table 2: buoy comparison results of HY-2B, HY-2C, and HY-2D 25 km and 50 km wind products from January to June 2022.

In Table 2 we show the wind speed bias and wind component standard deviations of the 25 km and 50 km HSCAT products over a 6 months period.

The table shows that the wind component standard deviations for 25 km are slightly lower than those for 50 km. The higher resolution 25 km winds contain more small scale features and hence better mimic the local point measurements of the buoys. The differences in the wind component standard deviations between the three instruments are rather small. Like in the comparisons with ECMWF winds, HY-2C shows the highest values, although the differences between HY-2C and HY-2D are rather small.

4. Triple collocation results

A triple collocation study was performed to initially assess the errors of the scatterometer, 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 an estimated buoy observation error, mainly constituted by the spatial representativeness error of buoy data for a scatterometer WVC. How to deal with errors of spatial representation is extensively discussed in [13].

Collocated data sets (see section 3) of HY-2B, HY-2C, and HY-2D 25 km and 50 km, ECMWF and buoy winds spanning six months were used in the triple collocation. Table 3 lists the error variances of the buoy, scatterometer and ECMWF winds from the intermediate resolution scatterometer perspective. When we compare the 50 km HSCAT products with the corresponding 25 km products, 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 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. When we compare the three instruments, it again appears that the errors for HY-2B are smallest, those of HY-2D are slightly larger and those of HY-2C are largest.

All HSCAT 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 HY-2B	0.57	0.43	1.17	1.25	0.84	0.94
25 km HY-2C	0.72	0.63	1.19	1.27	0.82	0.92
25 km HY-2D	0.61	0.51	1.19	1.23	0.85	0.95
50 km HY-2B	0.43	0.28	1.26	1.33	0.78	0.85
50 km HY-2C	0.58	0.48	1.30	1.38	0.74	0.83
50 km HY-2D	0.49	0.33	1.29	1.32	0.77	0.89

Table 3: Error standard deviations in u and v wind components from triple collocation of HY-2B, HY-2C, and HY-2D 25 km and 50 km wind products with buoy and ECMWF forecast winds, seen from the scatterometer perspective. The results were obtained for the period of January to June 2022.

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 HY-2B, HY-2C, and HY-2D winds are well calibrated, with *b* values close to 0 and *a* coefficients close to 1. The *a* coefficients for HY-2D are slightly smaller than those for the other two instruments, indicating that the HY-2D wind speeds are higher, this is in line with the higher wind speed biases w.r.t. buoys and NWP winds. The wind calibration is done using only a limited period of scatterometer and ECMWF winds [3], depending on seasonal or other temporal (weather related) effects there may be small deviations from product to product.

	a_u	a_v	b_u (m/s)	b_v (m/s)
25 km HY-2B	1.009	1.031	-0.159	0.063
25 km HY-2C	1.014	1.025	-0.124	0.061
25 km HY-2D	1.000	0.997	-0.132	0.028
50 km HY-2B	1.010	1.023	-0.153	0.049
50 km HY-2C	1.008	1.016	-0.127	0.047
50 km HY-2D	0.998	0.990	-0.144	0.027

Table 4: Calibration coefficients a and b for u and v wind components from triple collocation of HY-2B, HY-2C, and HY-2D 25 km and 50 km wind products with buoy and ECMWF forecast winds. The results were obtained for the period of January to June 2022.

5. Conclusions

The OSI SAF HY-2B, HY-2C, and HY-2D 25 km and 50 km wind products have been validated. They provide wind quality well within the OSI SAF product requirements ([2], 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). It appears that the HY-2C winds have the highest deviations when compared to reference NWP and buoy winds but the differences between the three missions are quite small. The Haiyang missions are very helpful to extend the Ku-band scatterometer data record over a longer period and to improve the temporal coverage of scatterometer winds.

Moreover, due to their particular orbit characteristics, HY-2C and HY-2D provide abundant collocations with the ASCAT and other Ku-band scatterometers, which will be useful for improvements in intercalibration and wind processing of all these systems.

6. Abbreviations and acronyms

ECMWF	European Centre for Medium-Range Weather Forecasts
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GTS	Global Telecommunication System
HSCAT	Scatterometer on-board the Haiyang 2 series satellites (China)
ISRO	Indian Space Research Organisation
KNMI	Royal Netherlands Meteorological Institute
LKB	Liu, Katsaros and Businger
MARS	Meteorological Archival and Retrieval System from ECMWF
NWP	Numerical Weather Prediction
OSCAT	Scatterometer on-board the Oceansat-2 and ScatSat-1 satellites (India)
OSI	Ocean and Sea Ice
PenWP	Pencil Beam wind Processor
QC	Quality Control
SAF	Satellite Application Facility
ScatSat-1	Indian Scatterometer mission carrying an OSCAT scatterometer
u	West-to-east (zonal) wind component
v	South-to-north (meridional) wind component
WVC	Wind Vector Cell