Project

Near-shore scatterometer wind product

Reference: MyWave-D2.1

Project N°: FP7-SPACE-2011-284455	**Work programme topic:** SPA.2011.1.5.03 – R&D to enhance future GMES applications in the Marine and Atmosphere areas
Start Date of project : 01.01-2012	**Duration**: 36 Months

WP leader: Deltares	**Issue:** 1.1
Contributors : KNMI	
MyWave version scope : D2.1 version 1.2	
Approval Date :March 28 2014	**Approver: O. Saetra**
Dissemination level: PU	

DOCUMENT

VERIFICATION AND DISTRIBUTION LIST

	Name	Work Package	Date
Checked By:	M. Verlaan	WP2	February 3 2015
Distribution			
	public		

CHANGE RECORD

Issue	Date	§	Description of Change	Author	Checked By
0.1	31/3/2013	all	First draft of document	G.J. Marseille	A. Stoffelen
1.0	4/6/2013	all	Document finalization	G.J. Marseille	A. Stoffelen, S. Caires
1.1	28/3/2014	Front	Finalize cover pages	G.J. Marseille	S. Caires
1.2	5/2/2015	Various	Changes after review	G.J. Marseille	M. Verlaan

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY AND ABREVIATIONS

2D-Var	: 2-dimensional Variational analysis
ASCAT	: Advanced scatterometer
BUFR	: Binary Universal Format
CNSCAT	: Chinese scatterometer
ECMWF	: European Centre for Medium-Range Weather Forecasting
EUMETSAT	: European organization for the exploitation of Meteorological satellites
HARMONIE	: HIRLAM ALADIN Research on Meso-scale Operational NWP in Euromed
HIRLAM	: High resolution limited area model
ISRO	: Indian Space Research Organization
NWP	: Numerical Weather Prediction
NRT	: Near Real Time
OSCAT	: OceanSat-2 scatterometer (India)
OSI-SAF	: Ocean and Sea Ice Satellite Application Facility
SWAN	: Simulation Waves Nearshore
TBD	: To be decided
WP	: Work Package
WVC	: Wind Vector Cell

Table I-3

APPLICABLE AND REFERENCE DOCUMENTS

Applicable Documents

	Ref	Title	Date / Issue
DA 1	MyWave-A1	MyWave: Annex I – "Description of Work"	September 2011
DA 2	MyWave-A2	Updated high-resolution wind-fields available for use in impact-studies	Expected December 2013

Reference Documents

	Ref	Title	Date / Issue
DR 1	MyWave-R1	Verhoef, A., Portabella, M., Stoffelen, A., High-Resolution ASCAT scatterometer Winds near the coast, IEE Trans. On GeoSc. And rem. Sens., vol. 50, No. 7.	July 2012
DR 2	MyWave-R2	Figa-Saldaña, J., J. J.W. Wilson, E. Attema, R. Gelsthorpe, M. R. Drinkwater, and A. Stoffelen, 2002: The advanced scatterometer (ASCAT) on the meteorological operational (MetOp) platform: A follow on for the European wind scatterometers, Can. J. Remote Sens., 28(3), 404–412, doi:10.5589/m02-035	2002
DR 3	MyWave-R3	Stoffelen, A. and D. Anderson, 1997: Scatterometer Data Interpretation: Measurement Space and Inversion, J. Atmos. and Oceanic Technol. 14, 1298-1313	1997
DR 4	MyWave-R4	Vogelzang, J., A. Stoffelen, A. Verhoef, J. de Vries and H. Bonekamp, 2009: Validation of two-dimensional variational ambiguity removal on SeaWinds scatterometer data, J. Atm. Oceanic Technol., 7, 26, 1229-1245, doi:10.1175/2008JTECHA1232.1	2009
DR 5	MyWave-R5	Verhoef, A., and A. Stoffelen, ASCAT coastal winds validation report, OSI SAF Report, SAF/OSI/CDOP/KNMI/TEC/RP/176	2011

I INTRODUCTION

This document describes the work done for Task 2.2 (Coastal wind products and their impact on wave forecasts) subtask 2.2.1: Near-shore scatterometer wind product, as part of MyWave WP2: Data assimilation and improvement of both model and satellite near shore winds and waves. The main objective of subtask 2.2.1 is to collect satellite winds, from scatterometer instruments, near European coastal regions for selected periods. The resulting dataset is used in subtasks 2.2.2 (Near-shore forecasts with assimilation of near-shore scatterometer) and 2.2.3 (Cross-validation of satellite data, in-situ observations and wave-forecasts).

Section II discusses the selected periods for evaluation and the availability of scatterometer winds for these periods. Section III discusses the relatively new ASCAT scatterometer coastal product with optimal coverage in coastal regions. Section IV shows some typical examples of model and observed wind fields for the selected periods.

II SELECTED PERIODS AND SATELLITE DATA AVAILABILITY

Four periods have been selected to evaluate the additional value of scatterometer winds for wave modelling and forecasting. The criteria for period selection are (i) extreme events with substantial flooding and societal impact and (ii) availability of a substantial amount of observations for monitoring the events and for use in data assimilation to evaluate wave model forecast performance. The selected periods and their main characteristics are summarized below.

II.1 Periods

1. Horses storm: 28/10/2006 – 3/11/2006

The area of interest is the Northern coast of the Netherlands. The (NW-W) storm is marked as a surge- and swell record in the city Delfzijl and well known in the Netherlands as “Allerheiligenvloed” (flooding at All Saints Day) or the “Horses storm”, because 227 horses were isolated due to flood in the small village Marrum. 25 Horses drowned, the rest was saved in a spectacular rescue operation. Figure II-1 provides an indication of the increased water level near the city Delfzijl.

Figure II-1. Photograph of the Delfzijl harbour, showing increased water levels.

The left panel of Figure II-2 shows that both the regional HIRLAM model winds and the global ECMWF model winds may under predict the storm surge when compared to the ocean surface satellite winds from the QuikScat scatterometer, i.e., the observed winds are stronger with respect to ECMWF and more directed into the harbour with respect to HIRLAM. The performance of the meso-scale HARMONIE model for this event is discussed in [DA2].

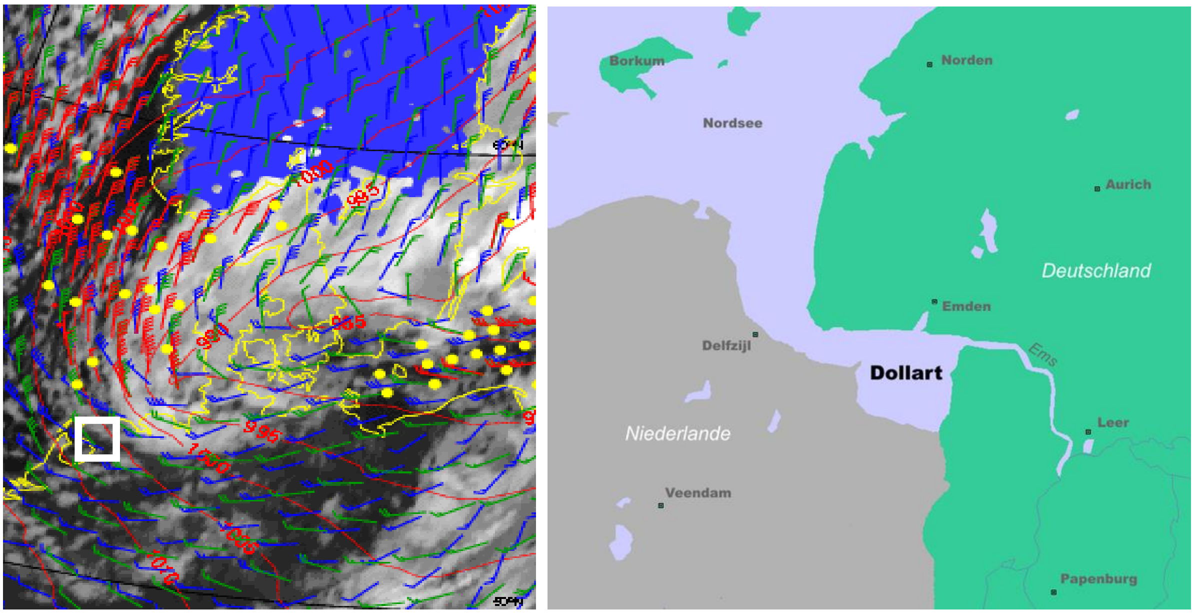

Figure II-2. Left panel: surface wind on 1/11/2006 at 04UTC. The Netherlands is located on the left hand side of the figure. The white square marks the North-Eastern part of the Netherlands that is displayed in the right panel. The city Delfzijl is located near the Dollard estuary, close to the "Waddenzee". On the left panel HIRLAM model winds are denoted with blue barbs, ECMWF model winds with green barbs and the OSI-SAF QuikScat satellite winds with red barbs.

2. North-Westerly storm: 5/11/2007 – 11/11/2007

This is the first storm since the building of the "Nieuwe Waterweg" and the "Maeslantkering" that led to closure of the waterway due to water levels in "Hoek van Holland" exceeding the threshold value at the Dutch west coast, see Figure II-3.

Figure II-3. Left panel: river the "Nieuwe Waterwaterweg" with the "Maeslantkering". The center panel shows the Maeslantkering closed. The right panel shows a model of the Maeslantkering that is demonstrated at the local visitor center.

3. North-Eastern storm: 11/7/2011 – 17/7/2011

Not a very common but an interesting event, because it is one of the periods used in the assessment of the operational SWAN† model for the North Sea.

4. Storm Ulli: 6/12/2011 – 6/1/2012

A 1 month period that includes storm Ulli that was characterized by a rapid development over the UK on the 3rd of January 2012.

II.2 Scatterometer data availability

A scatterometer is a satellite radar-instrument which provides a measure of wind speed and direction near the sea surface. Scatterometers measure the electromagnetic microwave backscatter by the wind-roughened ocean surface [DR2]. Scatterometer wind information is organised in Wind Vector Cells (WVCs) projected on the instrument swath. The number of WVCs determines the sampling resolution for the surface wind field and the wind information is considered to be independent from one WVC to the next. Each WVC contains between two and four ambiguous wind vector solutions that are the result of the inversion of the CMOD5 wind cone, i.e., the Geophysical Model Function, for a given set of backscatter values and a given scanning geometry [DR3]. Each wind ambiguity is characterised by a solution probability that is determined based on the distance-to-cone residual in the inversion.

The wind ambiguities, solution probabilities and prior information from the ECMWF model 10-m background wind are used in a 2D variational (2D-Var) ambiguity removal procedure [DR4] to produce an analysed surface wind field. This wind field is then used to select the wind vector ambiguity in each WVC that is closest to the analysis, based on vector difference, as the solution for the observed surface wind. A wind vector solution flag is set to the index of the selected wind ambiguity in each WVC. Finally, the backscatter measurements, wind ambiguities, scanning geometry and wind vector solution flag among others are made available as a scatterometer wind product‡ in BUFR and NetCDF format.

A number of scatterometers have been launched in the last couple of decades. The first European scatterometer, the AMI on ERS-1 was launched in July 1991 and was operational until 10 March 2000. In the meantime, ERS-2 was launched in April 1995 and operational until 5 September 2011. The scatterometers on board the ADEOS-1 Satellite, called NSCAT, and the SeaWinds-2 scatterometer on board ADEOS-2, measured near-surface ocean wind for about one year. After the unexpected failure of NSCAT, a quick recovery satellite (QUIKSCAT) was launched in June 1999 with a SeaWinds scatterometer to fill the emerged gap between ADEOS-1 and ADEOS-2. This satellite had a lifetime of over 10 years. The launch in 2006 of the European METOP-A satellite with the ASCAT scatterometer, started an era with guaranteed and operational scatterometer observations. Follow-up satellite METOP-B was successfully launched in 2012 and METOP-C is scheduled for launch in 2018. All METOP satellites have a scatterometer on board. Furthermore, an Indian scatterometer,

† For more information see: http://www.swan.tudelft.nl/

‡ See http://www.knmi.nl/scatterometer

OSCAT, on board the OceanSat-2 satellite is operational in NRT since June 2011. A recently established collaboration between EUMETSAT and the Indian Space Research Organization (ISRO) guarantees the constant data flow and access to OSI SAF OSCAT wind data. The Chinese scatterometer, HSCAT, on board Haiyang-2 was launched in August 2011. At the time of writing, collaboration and data access to HSCAT is both under way and under negotiation.

Table II-1 provides an overview[§] of the main characteristics of above-mentioned scatterometers. All scatterometers are located on polar orbiting satellites with a satellite orbit period of about 100 minutes, as such each yielding twice daily (incomplete) global coverage of ocean surface winds. The Ku-band scatterometers are more sensitive to rain contamination.

Instrument	Country	satellite	operational	type	LTAN
No longer operational					
ERS AMI	Europe	ERS 1/2	1991 – 5 Sept. 2011	fan-beam/ C-band	9:30
NSCAT	USA/Japan	ADEOS-1	Aug. 1996 – June 1997	fan-beam/ Ku-band	6:00
SeaWinds-2	USA/Japan	ADEOS-2	Dec 2002 – Oct 2003	Pencil beam /Ku-band	6:00
SeaWinds	USA	QuikScat	1999 – 23 Nov. 2009	Pencil beam /Ku-band	6:00
Still operational					
ASCAT-A	Europe	METOP-A	19 Oct. 2006 - 2018	fan-beam/ C-band	10:30
OSCAT	Indian	OceanSat-2	June 2011 - ??	Pencil beam /Ku-band	12:00
HSCAT	China	Haiyang-2	Aug. 2011 - ??	Pencil beam /Ku-band	06:00
ASCAT-B	Europe	METOP-B	17 Sept. 2012 - ??	C-band	10:30
Scheduled future satellites					
OSCAT-2	Indian	OceanSat-3	2014	Pencil beam /Ku-band	12:00
MSCAT	Russia	Meteor-M3	2013	Ku-band pencil-beam	TBD
ASCAT-C	Europe	METOP-C	2018	C-band	10:30

§ An overview is also found at http://www.ceos.org/index.php?option=com_content&view=category&layout=blog&id=73&Itemid=72

CFOSAT	China/France	TBD	2015	Ku-band rotating fan-beam	TBD
HSCAT-2	China	HaiYang-2	2016	Ku-band pencil-beam	TBD

Table II-1. Main scatterometer characteristics. Question marks in the period column means that the instruments are still operational and the final date not yet known. LTAN means Local (equator crossing) Time of Ascending Node. TBD means to be determined.

From Table II-1 and the selected periods in section II.1 it is concluded that the focus of scatterometer observations is limited to ERS 1/2, QuikScat, ASCAT-A, OSCAT and potentially HSCAT. Note that no near-real-time (NRT) access to the data of the latter has yet been accomplished. A more detailed summary of the data products from these instruments is provided in Table II-2.

	ERS 2	QuikScat	ASCAT-A	OSCAT	HSCAT
Period 1 28/10/2006 – 3/11/2006	TBD	Y	N	N	N
Period 2 5/11/2007 – 11/11/2007	TBD	Y	Y	N	N
Period 3 11/7/2011 – 17/7/2011	TBD	N	Y	Y	N
Period 4 6/12/2011 – 6/1/2012	N	N	Y	Y	N
Swath width (km)	500	1800	1100	1800	1800
Spatial sampling (km)	TBD	100/25	25/12.5/coastal /6.25[**]	50/25[††]	TBD
Wind quality (ms^{-1}) Buoy/ECMWF	TBD	1.73/1.37 (25 km)	1.50/1.65 (coastal)	1.90/1.34 (50 km)	TBD

Table II-2. Scatterometer data availability (Y for available, N for non-available) and main characteristics for the selected periods. Wind quality here is the RMSE of the wind vector validated against buoys and the ECMWF model respectively. ERS 2 availability has not yet been checked.

Current ASCAT-A products include wind speed and direction information at either 25 km or 12.5 km spacing. A 6.25 km product is currently under investigation but not yet available. In

[**] Under investigation as part of the EUMETSAT OSI-SAF work at KNMI. Not yet available
[††] Under investigation as part of the EUMETSAT OSI-SAF work at KNMI. Not yet available

addition a coastal product is available that is further discussed in the next section. Also, an experimental OSCAT 25-km product is available.

Note that the wind quality in the last column of Table II-2 should be considered with great care because area mean (scatterometer) observations are compared with point observations (buoy) and model grid size values (ECMWF). In addition, the footprints of the various scatterometer instruments are different. The representativeness error thus contributes substantially in these numbers. For instance, ASCAT winds (12.5 km coastal product) are best when compared to buoy winds but worst when compared against the ECMWF model. In a triple collocation analyses these uncertainties are largely resolved [DR4].

In summary, the following scatterometer datasets have been collected for the selected periods:

- QuikScat 25-km product
- ASCAT-A coastal product
- OSCAT 50-km product

All datasets are available in BUFR and NetCDF format. The BUFR files include all ambiguous solutions that are needed as input for assimilation in NWP models (ECMWF and HARMONIE). The NetCDF dataset only includes a single wind solution, i.e., the one selected by 2D-VAR. For more detailed information we refer the reader to the related user manuals[‡‡]. The retrieved winds from the abovementioned scatterometers are monitored continuously to detect potential instrument or processing issues[§§].

[‡‡] http://www.knmi.nl/scatterometer/publications/#user_manuals

[§§] http://www.knmi.nl/scatterometer/ascat_osi_25_prod/ascat_app.cgi and http://www.knmi.nl/scatterometer/ascat_osi_25_prod/ascat_app.cgi?cmd=monitoring&period=week&day=0&flag=yes

III COASTAL PRODUCT

A relatively new product developed at KNMI as part of the EUMETSAT OSI-SAF activities is the ASCAT coastal product. Away from coastal regions this product is almost identical too the nominal 12.5 km product. However, an enhanced processing is applied to the beam footprints to calculate the wind in coastal WVCs [DR1]. As such it is possible to compute winds as close as ~15 km from the coast, while in the nominal 12.5-km product, WVCs closer than ~35 km from the coast are flagged because of land contamination, see [DR1, DR5]. [DR1] show that the quality of coastal winds is similar to those in the open ocean. Figure III-1 shows the locations of the coastal product in red and overlaid the 12.5 km ASCAT product in grey. Away from the coastal regions, the locations of the coastal and 12.5 km product overlap, but near the coasts, the coastal product produces substantially more winds than the 12.5 km product. For instance, the coverage is about doubled in the Irish sea.

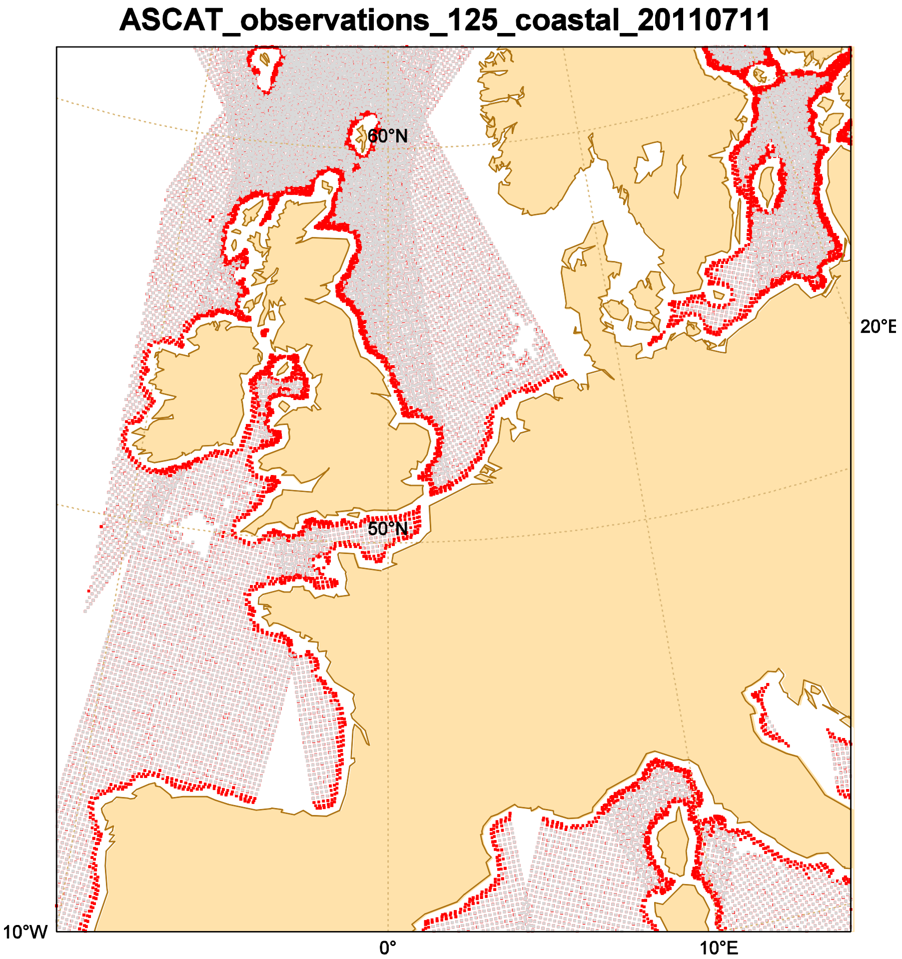

Figure III-1. ASCAT observation locations over sea for the coastal product (red) and overlaid the 12.5 km product (grey) for all satellite overpasses on 11 July 2011 in the HARMONIE domain. The red band following the European coastline shows the additional ASCAT observations of the coastal product relative to the 12.5 km product.

Figure III-2 zooms in to North Sea between the UK and The Netherlands. The distance of adjacent observations near the coast is clearly smaller than 12.5 km, due to the advanced processing near the coast. On average the distance of observations from the coast has been reduced from about 50 km to about 35 km by evolving from the 12.5 km to the coastal product. The additional observations are potentially very useful for collocation with buoys that are positioned close to the coasts, as part of the triple collocation study in subtask 2.2.3. Moreover, these additional observations may improve the modelled wind field near the coast to better forecast storm surge. This is further investigated in subtask 2.2.2 and discussed in [Ad2].

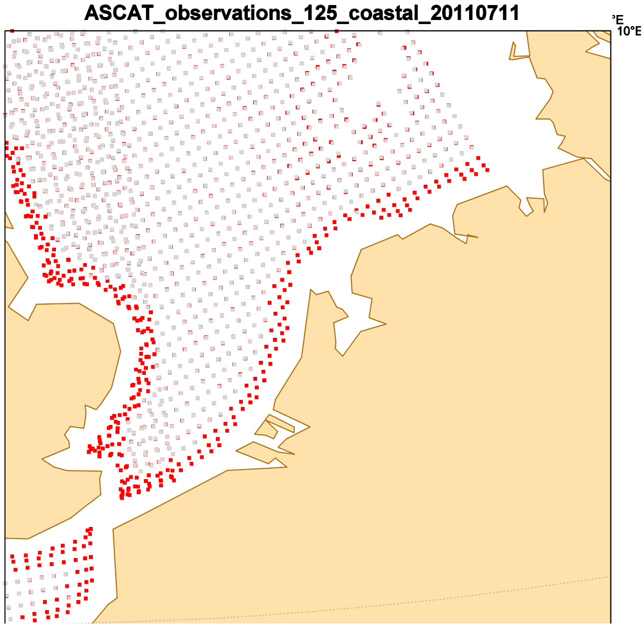

Figure III-2. Same as Figure III-1 but now zoomed in to the North Sea region between the UK and the Netherlands. White spots, e.g. at the top of the figure, indicate data void regions where the quality control procedure has flagged the corresponding observations as low quality.

III.1 Validation of the coastal product

The relatively new coastal product has been evaluated extensively by comparing against in-situ observations from buoys and the ECMWF model. The results have been documented in [DR1,DR5] and are shortly summarized below.

The nominal ASCAT (12.5 km resolution) product measures winds as close as ~35 km from the coast, while the new coastal product measures as close as ~15 km from the coast. In regions far away from the coast, the ASCAT nominal and coastal products are of identical quality, but fewer WVCs pass the quality control steps for the nominal product, indicating that the coastal product better resolves sub-WVC wind variability. In the coastal region enhanced wind variability is expected due to, among others, katabatic and sea breeze effects. However, the quality of the coastal winds in terms of boy wind component difference standard deviation is almost as good as for the open sea. Figure III-3 is extracted from [DR1] and shows the locations of the buoys used in the validation of the ASCAT coastal product. Statistics of differences between buoy winds and scatterometer winds in Table III-1, also extract from [DR1] indeed show the small differences between the nominal and coastal product in both the non-coastal and coastal areas.

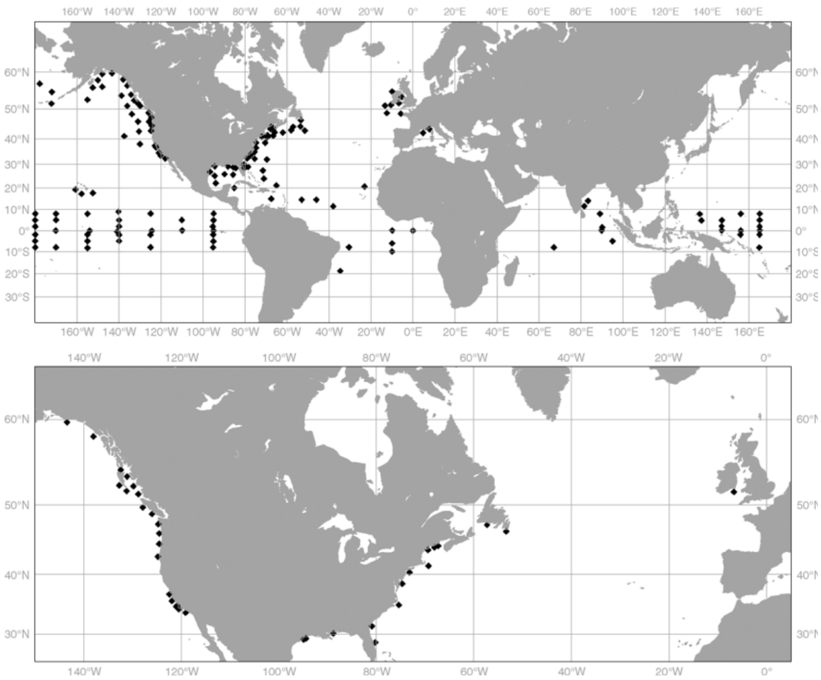

Figure III-3. Locations of the noncoastal (top) and coastal (bottom) moored buoys used in the ASCAT coastal product validation. Figure extracted from [DR1].

	number of wind vectors	wind speed bias (ms^{-1})	std.dev u (ms^{-1})	std.dev v (ms^{-1})	RMS vector (ms^{-1})
nominal	14513	-0.28	1.45	1.58	2.21
non-coastal areas	15476	-0.29	1.46	1.59	2.21
coastal areas	4768	-0.22	1.54	1.61	2.30

Table III-1. Buoy collocation results of ASCAT nominal (2nd row) product, the coastal product in the non-coastal areas (3rd row) and the coastal product in the coastal areas (4th row) for the period March to August 2009. Table extracted from [DR1].

IV TYPICAL WIND FIELD EXAMPLES

Figure IV-1 shows a typical example of the wind field of Tropical hurricane Sandy observed by ASCAT off the Eastern US coast on 29 October 2012. The left panel clearly shows the cloud patterns around the eye wall with strong winds at the ocean surface.

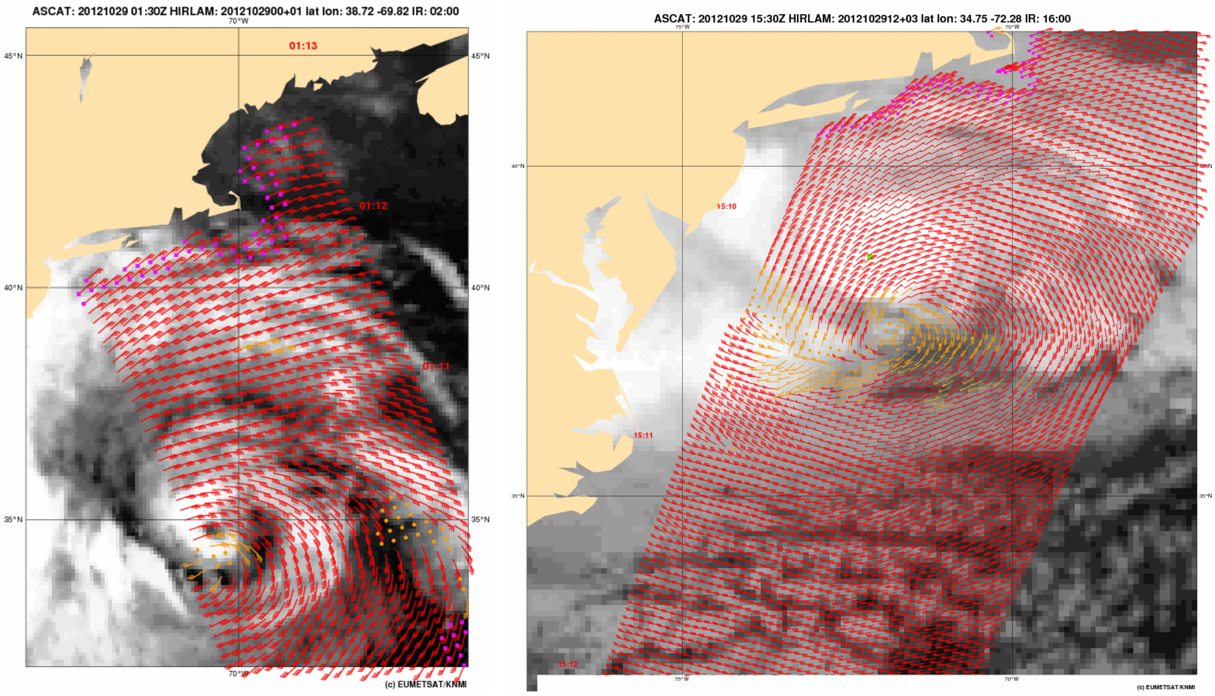

Figure IV-1. ASCAT scatterometer ocean surface winds near Tropical hurricane Sandy off the Eastern US coast on 29 October 2012 at 1:30 UTC (left) and 15:30 UTC (right). Overlaid are clouds (grey-scale) from the geostationary MeteoSat 2nd generation (MSG) satellite. Red arrows denote valid winds, red circles denote very close to zero winds, magenta markers on top of the wind arrow denote land or ice presence, orange wind arrows indicate that the variational quality control flag is set, i.e., the wind vector cell is spatially inconsistent, orange dots mean that the KNMI quality control flag is set.

Figure IV-2 and Figure IV-3 show the location of a frontal system north of Great Britain as forecasted by the HARMONIE model and observed with QuikScat. This specific case corresponds to period 2 as described in section II.1. In subtask 2.2.2, described in TN_2.3, this case is further evaluated when scatterometer observations are assimilated in HARMONIE.

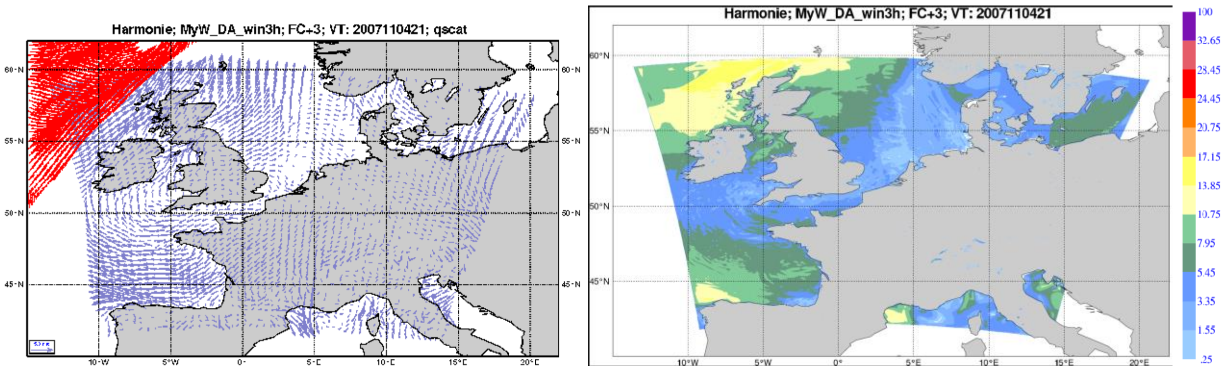

Figure IV-2. Left panel: HARMONIE surface level (10-m) wind (blue) and overlaid QuikScat 10-m wind (red) for 4 November 2007 near 21UTC. The right panel shows the HARMONIE wind field in Beaufort from 1 to 12.

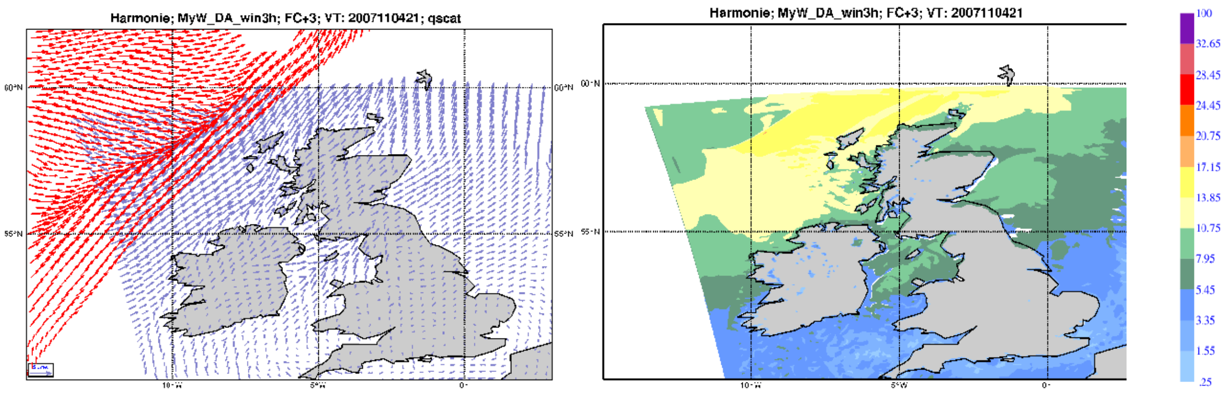

Figure IV-3. Same as Figure IV-2 but now zoomed in to the Britain area.

Figure IV-4 gives an indication of the impact of observing systems, including scatterometer, in the global ECMWF NWP model. The impact of satellite radiances (AMSU-A) is largest, both in the 2012 and 2013 ECMWF model versions, but also wind and temperature observations from aircrafts have large impact. Interestingly, the impact of scatterometer (SCAT) data has increased substantially from 2012 to 2013. This is explained by the Indian scatterometer OSCAT, whose data became available in 2013, increasing the total scatterometer data coverage by a factor of about 4.

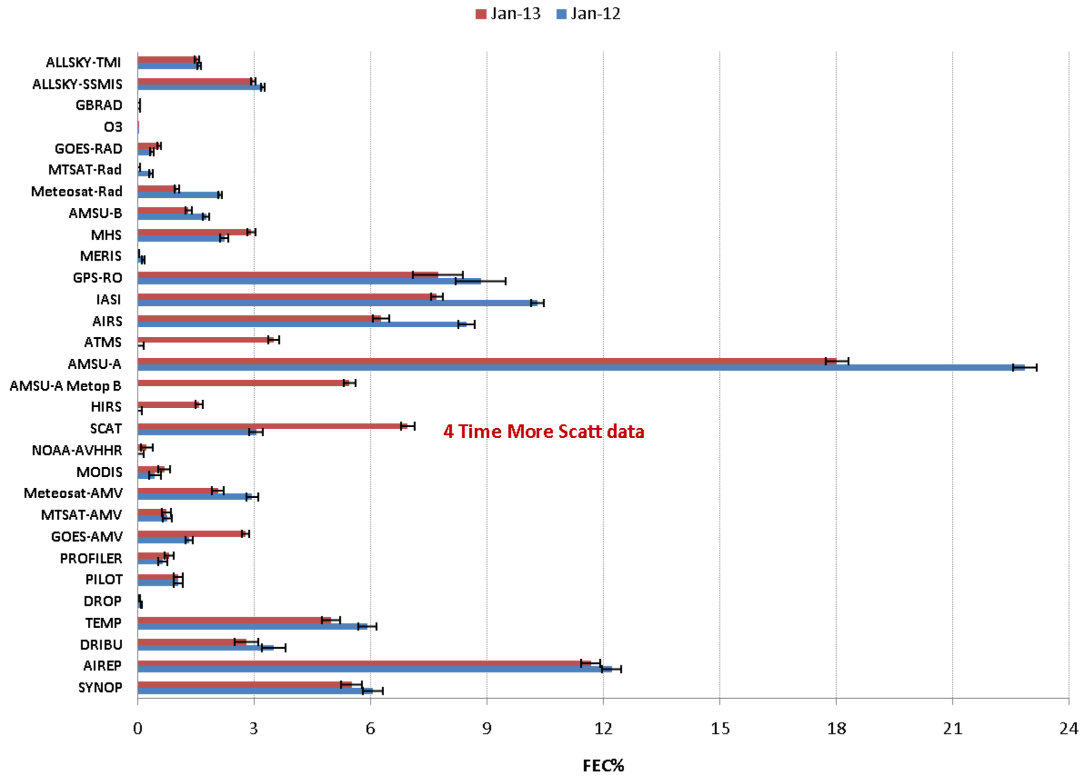

Figure IV-4. Impact of assimilated observations on forecast error reduction (FEC) from all observing systems used by the ECMWF global model. The left hand side shows the various observing systems. Blue/red bars show the impact in 2012/2013.