SeaWinds Product User Manual

Ocean and Sea Ice SAF

Version 1.6

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Version 1.1	Oct 2005	Minor	Adaptation to SDP, included file name convention
Version 1.2	Apr 2006	Minor	Adapted web location of [Ref-6]
Version 1.3	Sep 2006	Minor	Use of ECMWF NWP data
Version 1.4	Sep 2007	Minor	Introduction of 25-km product
Version 1.5	Jan 2008	Minor	Version prepared for 25-km SeaWinds DRI
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Reference: SAF/OSI/KNMI/TEC/MA/134

CONTENTS

1. Introduction

1.1. Overview

The Ocean and Sea Ice Satellite Application Facility (OSI SAF) is producing 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).

This document is the SeaWinds product user manual dedicated to the OSI SAF wind product users. It describes the global SeaWinds products available at KNMI. Quality monitoring information on this product and more general information on the whole OSI SAF project, is available on the OSI SAF web site at the following address: http://www.osi-saf.org/. The user is strongly encouraged to register on this web site in order to receive the service messages and the latest information about the OSI SAF products.

KNMI has a long experience in scatterometer processing and is developing generic software for this purpose. Processing systems for the ERS scatterometers were adopted for NSCAT, SeaWinds and ASCAT.

The scatterometer is an instrument that provides information on the wind field near the ocean surface, and scatterometry is the knowledge of extracting this information from the instrument's output. Space-based scatterometry has become of great benefit to meteorology and climate in the past years (e.g., Isaksen and Stoffelen, 2000).

NASA and NOAA put available SeaWinds products; the former produces science products, whereas NOAA provides a near-real time wind product that is used as basis for further processing at KNMI. Our SeaWinds products are different from the NASA and NOAA products, since special emphasis is put on

- increasing the **reliability** of the wind vectors by Quality Control and rejection of rain-contaminated Wind Vector Cells (WVC);

- improving **accuracy** by noise reduction through spatial averaging (100-km product) and meteorological filtering;

- Guaranteeing **correctness** by monitoring of the operational SeaWinds data and KNMI processing; and

- **Reduce** wind direction selection **errors** by meteorologically-balanced wind direction Ambiguity Removal (AR).

These wind quality issues are further elaborated in this manual and discussed in section 6.

Over the whole globe 80% of SeaWinds products are available within 3 hours after the last satellite data acquisition. Availability includes the processing time at KNMI which is less than 10 minutes and a not very substantial part of the total delay.

The OSI SAF products are delivered on request through the FTP server to all users and through EUMETCast. See also http://www.knmi.nl/scatterometer/osisaf/ for real-time graphical examples of the products and up-to-date information and documentation.

The easiest access to the SeaWinds products is through the OSI SAF as described in this manual. Alternatively, in the context of the Numerical Weather Prediction SAF (see http://www.metoffice.gov.uk/research/interproj/nwpsaf/index.html) software is developed and maintained to produce scatterometer winds from raw backscatter data which may be implemented at the user site if special processing features are desired. The NWP SAF software is used by the OSI SAF production system. In the context of the climate (CM) SAF KNMI is developing the Scatterometer Ocean Stress (SOS) product from the OSI SAF wind product.

This user manual outlines user information for the OSI SAF products based on the SeaWinds scatterometers [Ref-2], [Ref-4]. Section 2 presents a brief description of the SeaWinds instruments, section 3 the processing algorithms, and section 4 gives an overview of the data processing configuration. Section 5 provides detailed information on the file content and format, while in section 6 the product quality is elaborated.

1.2. Purpose and use of 100 km and 25 km products

The OSI SAF SeaWinds scatterometer winds are available in two resolutions: 100 km and 25 km. The 100 km product is especially suitable for assimilation in Numerical Weather Prediction models. It provides up to 4 wind solutions in each Wind Vector Cell. The 25 km product is more suitable for nowcasting: it contains more detail in the wind field that is not present in the 100 km product. However, the 25 km winds may contain spatial correlation structures in the errors that have not been investigated in full detail and may prove detrimental when the product is assimilated in an NWP model. Hence, we do not recommend to use SeaWinds at 25 km for data assimilation.

1.3. Access to data and helpdesk

These wind products are disseminated through the EUMETCast system; for access please contact EUMETSAT (http://www.eumetsat.int/). The products are also available on a password protected FTP server. Contact the KNMI OSI SAF team (scat@knmi.nl) for access.

For a swift response management procedure, user requests on these data products should be issued at the Ocean and Sea Ice SAF website (http://www.osi-saf.org/).

1.4. Disclaimer

All intellectual property rights of the OSI SAF products belong to EUMETSAT. The use of these products is granted to every interested user, free of charge. If you wish to use these products, EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used.

The OSI SAF is much interested in receiving your feedback, would appreciate your acknowledgment in using and publishing about the data, and like to receive a copy of any publication about the application of the data. Your feedback helps us in maintaining the resources for the OSI SAF wind services.

1.5. References

[Ref-1] KNMI OSI SAF web site: http://www.knmi.nl/scatterometer/osisaf/

[Ref-2] O&SI SAF wind product documentation on http://www.osi-saf.org/:

[Ref-3] NWP SAF website: http://www.metoffice.gov.uk/research/interproj/nwpsaf/index.html

[Ref-4] NASA SeaWinds Documentation: http://podaac.jpl.nasa.gov/quikscat/qscat_doc.html

[Ref-5] Thesis "Wind Field Retrieval from Satellite radar systems" by Marcos Portabella, available on http://www.knmi.nl/scatterometer/publications/

[Ref-6] Thesis "Scatterometry" by Ad Stoffelen, available on http://igitur-archive.library.uu.nl/dissertations/01840669/inhoud.htm

[Ref-7] Leidner, M., Hoffman, R., and Augenbaum, J., "SeaWinds scatterometer real-time BUFR geophysical data product", version 2.3.0, *NOAA/NESDIS*, June 2000, available on ftp://metroweb.nesdis.noaa.gov/seawinds/bufr_v2.3.0.ps.gz.
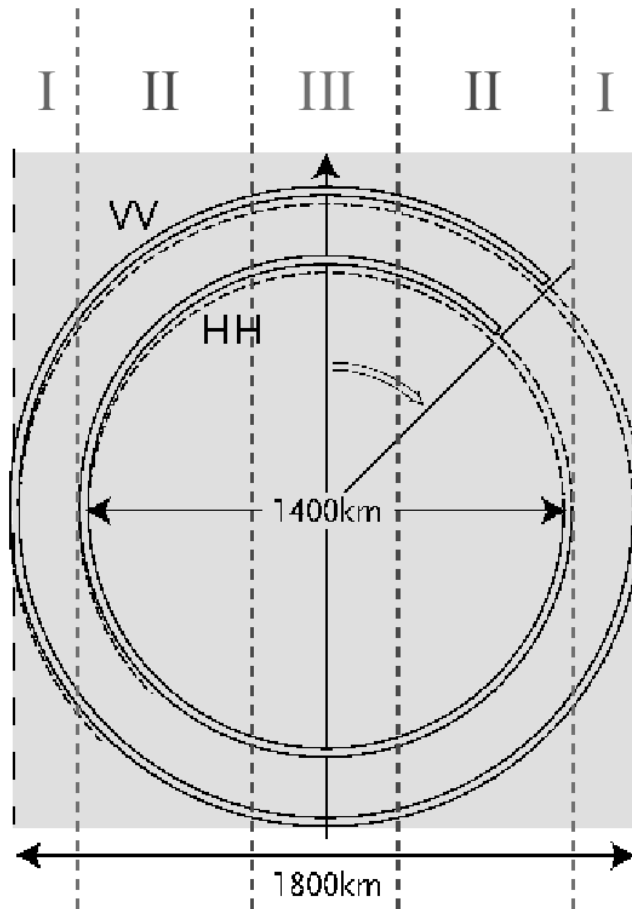
2. SeaWinds Instruments

Figure 1: *Earth surface coverage of the scans of the horizontal (HH) and vertical polarisation (VV) pencil-beams of SeaWinds. As the satellite propagates towards the top of the page the swath (in grey) is illuminated, and three areas are discriminated:*

I: Outer swath: only viewed once by the VV beam in the forward direction, and once in the aft direction (2 views);

II: Sweet (inner) swath: Viewed both by the VV and HH beam, both in fore and aft direction (4 views);

III: Nadir (inner) swath: As II, but the azimuth view direction is close to the satellite propagation direction, or just opposite to it.

Scatterometers fly on polar-orbiting satellites, for SeaWinds these are the NASA/NOAA QuikSCAT and Japanese ADEOS-II platforms. Data are read out once per orbit usually, which lasts about 100 minutes. This means that a delay of up to 100 minutes is already present at read-out. Dedicated transmission lines and fast processing are needed to limit further delays.

2.1. SeaWinds-I and SeaWinds-II

Two SeaWinds scatterometers are developed and flown. The SeaWinds on QuikSCAT mission (from NASA/NOAA) is a "quick recovery" mission to fill the gap created by the loss of data from NSCAT, when the ADEOS-1 satellite lost power in June 1997. It was launched in June 1999 and is still operational. A similar version of the instrument (SeaWinds-2) flew on the Japanese ADEOS-2 satellite, launched in December 2002, which was regrettably lost in October 2003. For detailed information on the QuikSCAT instrument and data we refer to Spencer et al. (1997), JPL (1997, 2001), and [Ref.7]. A brief description is given below.

The SeaWinds instrument is a conically scanning pencil-beam scatterometer, as depicted in figure 1. It uses a rotating 1-meter dish antenna with two "spot" beams of about 25-km size on ground, a horizontal polarisation beam (HH) and a vertical polarisation beam (VV) at incidence angles of 46° and 54° respectively, that sweep the surface in a circular pattern. Due to the conical scanning, a WVC is generally viewed when looking forward (fore) and a second time when looking aft. As such, up to four measurement classes (called "beam" here) emerge: HH fore, HH aft, VV fore, and VV aft, in each wind vector cell (WVC). The 1800-km-wide swath covers 90% of the ocean surface in 24 hours and represents a substantial

improvement compared to the side-looking scatterometers, where the largest coverage, given by NSCAT, is only half of SeaWinds coverage, i.e. 90% of the ocean surface within 48 hours.

On the other hand, the wind retrieval from SeaWinds data is not trivial. In contrast with the side-looking scatterometers, the number of measurements and the beam azimuth angles vary with the sub-satellite cross-track location (see figure 1). A detailed discussion is provided in [Ref-5; pages 22-23]. The wind retrieval skill will therefore depend on the position in the swath as illustrated in figure 2.
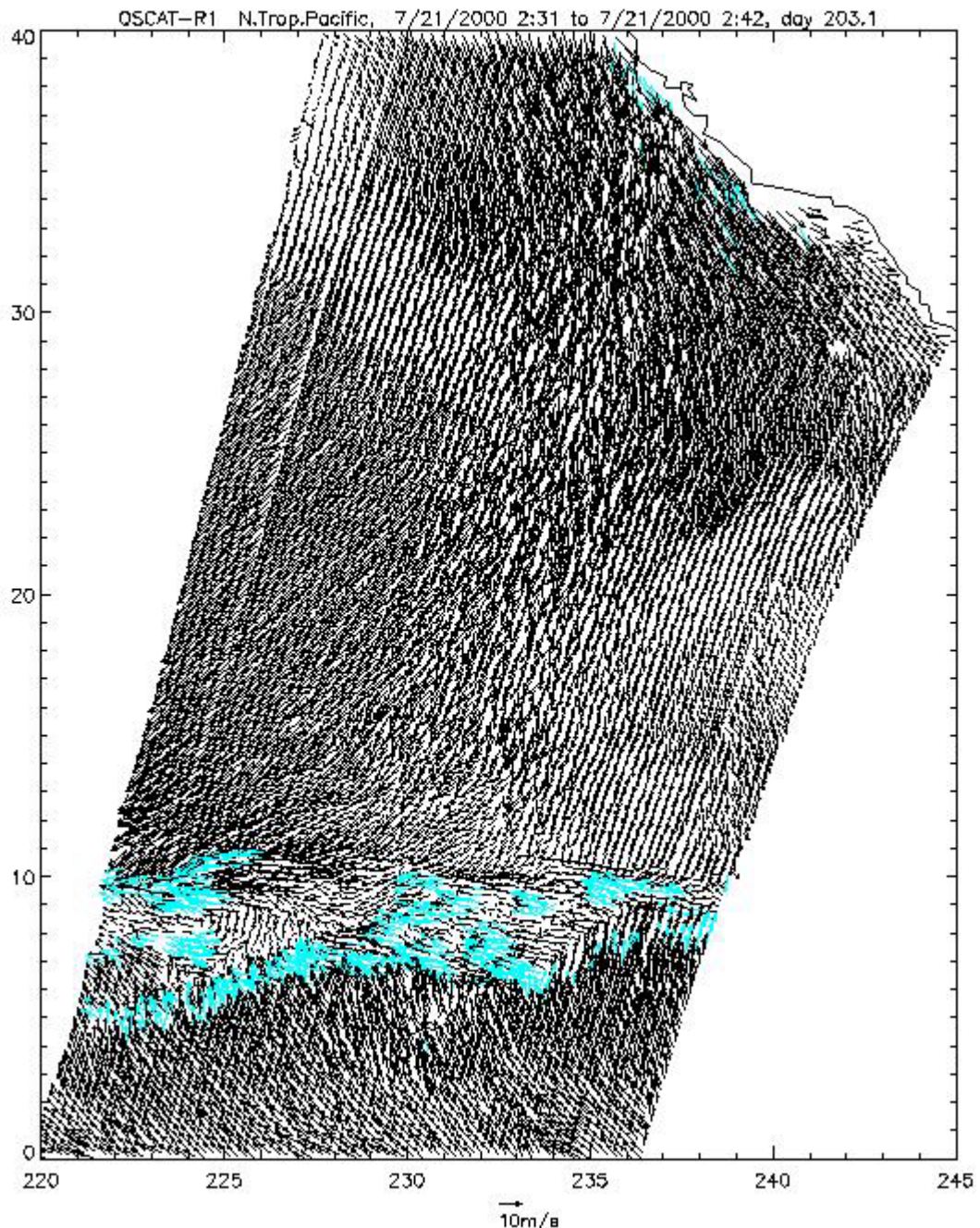

Figure 2: *SeaWinds product processed on a 25-km grid. The wind retrieval on the grid results in four solutions of which one is selected by the ambiguity removal procedure. Note the varying noise properties in the parts of the swath indicated in Figure 1. The blue patches are flagged as rain contaminated.*

In the outer swath (region I in figure 1) the two looks result in an ambiguous set of generally four wind solutions with an equal probability of about 25%. Measurement noise here results in systematic wind direction errors, which is why the outer swath is often well visible is figure 2. In the nadir swath (region III in figure 1) insufficient azimuth views are available for wind retrieval and the measurement noise causes a rather noisy wind field. As we enter the sweet swath, this noise becomes smaller, but does generally not disappear altogether. At KNMI a spatially averaged product was developed at 100 km, which strongly reduces the measurement noise, as shown in section 6. Rather uniform and high quality winds are then obtained in regions II and III. Due to a more difficult QC in region I, this region is not processed in the OSI SAF product at the time of writing this manual.

2.2. Rain problem

The NASA scatterometers work at a Ku-band radar wavelength. The atmosphere is not transparent at these wavelengths and in particular rain is detrimental for wind computation. In fact, moderate and heavy rain cause bogus wind retrievals of 15-20 m/s wind speed which need to be eliminated by a quality control step. Wind-rain discrimination is easiest to manage in the sweet swath, performs acceptable in nadir, but is problematic in the outer swath.
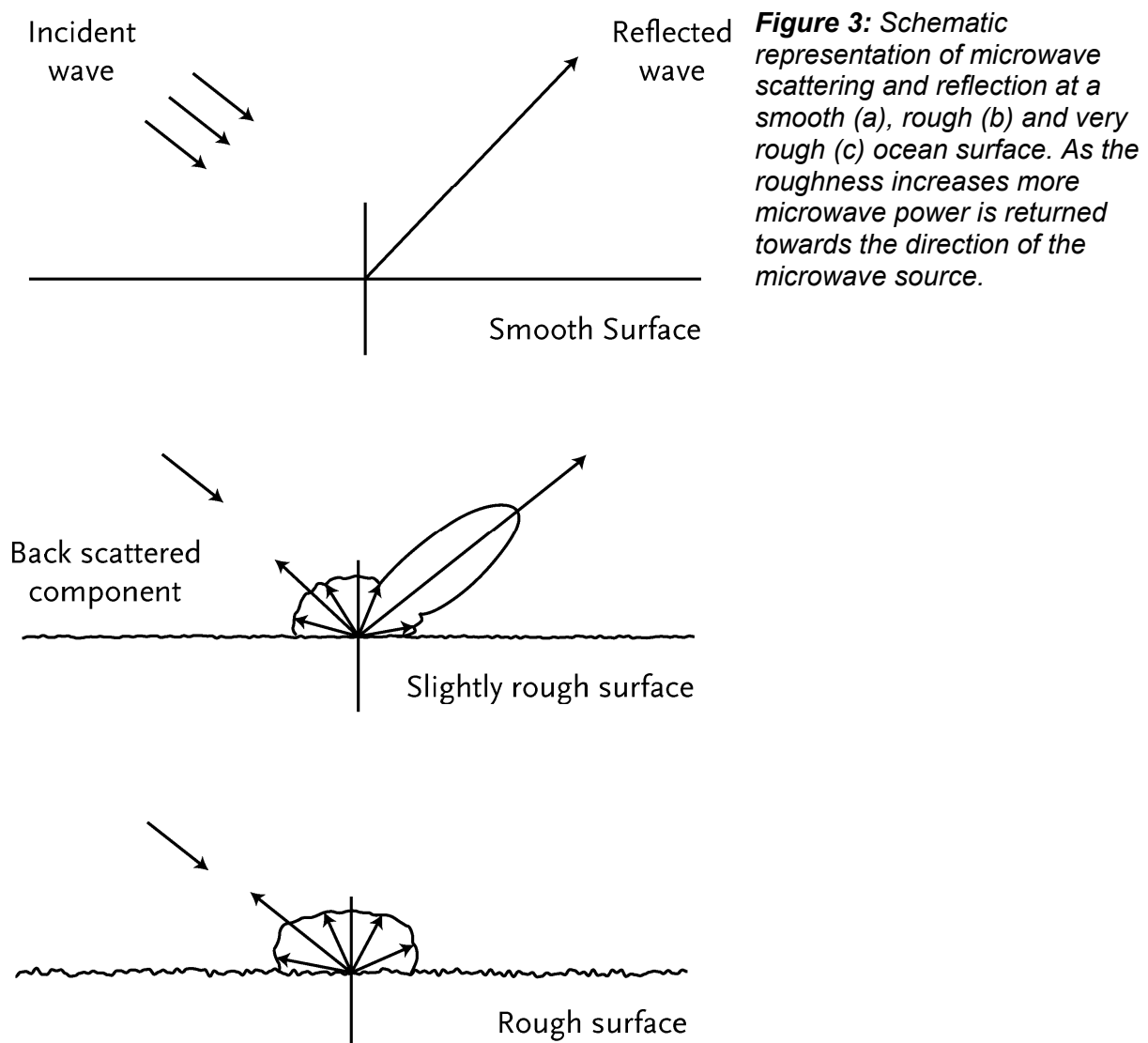
2.3. Sea ice detection

Due to the availability of VV and HH polarisation measurements, discrimination of water and ice surfaces is generally well possible and performed by NOAA [Ref-7]. On top of this, an additional filter based on NWP Sea Surface Temperature is applied to prevent erratic winds over sea ice surfaces in case the NOAA ice screening fails.

3. Algorithms

Scatterometry was developed heuristically. It was found experimentally that the sensitivity to wind speed and direction describe well the changes in backscatter over the ocean at moderate incidence angles due to changes in surface roughness, as depicted in figure 3 (Valenzuela, 1978). In return, backscatter measurements can be used to determine the wind speed and wind direction in a WVC.

In the NWP SAF development phase the ERS scatterometer (SCAT) processing has been successfully extended to SeaWinds. A schematic illustration of the processing is given in figure 4. After defining the wind output and motivating the Geophysical Model Function that is used, the algorithms developed at KNMI are described.

Figure 3: Schematic representation of microwave scattering and reflection at a smooth (a), rough (b) and very rough (c) ocean surface. As the roughness increases more microwave power is returned towards the direction of the microwave source.

3.1. Wind definition

A scatterometer measurement relates to the ocean surface roughness (see figure 3), while the scatterometer product is represented by the wind at 10m height over a wind vector cell (WVC). It is important to realize that in the approach followed here the radar backscatter measurement σ_0 is related to the wind at 10 meter height above the ocean surface, simply

because such measurements are widely available for validation. This means that any effect that relates to the mean wind vector at 10 meter height is incorporated in the backscatter-to-wind relationship. As such, air stability, the appearance of surface slicks, and the amplitude of gravity or longer ocean waves, depend to some degree on the strength of the wind and may, to the same degree, be fitted by a geophysical model function, GMF ([Ref-6]; Chapter I). Stoffelen ([Ref-6]; Chapter IV) discusses a unique method to determine the accuracy of scatterometer, buoy, and NWP model winds.

3.1.1. Geophysical Model Function

For the OSI SAF SeaWinds product the NSCAT-2 geophysical model function (GMF) for calculating equivalent neutral winds is used (Wentz and Smith, 1999). Portabella ([Ref.5]; page 153) compares the QSCAT-1 (Freilich et al, 2002) and NSCAT-2 Ku-band GMFs and found that the latter is of better quality, since the former leads to more wind solutions during wind retrieval, i.e., is more ambiguous.

At low wind speeds the wind direction and speed may vary considerably within the WVC. Locally, below a speed of roughly $2\,\mathrm{ms}^{-1}$ calm areas are present where little or no backscatter occurs, perhaps further extended in the presence of natural slicks that increase the water surface tension (Donelan and Pierson, 1987). However, given the variability of the wind within a footprint area of 25 or 50 km it is, even in the case of zero mean vector wind, very unlikely that there are no patches with roughness in the footprint. As the mean vector wind increases, the probability of a calm patch will quickly decrease, and the mean microwave backscatter will increase. Also, natural slicks quickly disappear as the wind speed increases, and as such the occurrence of these is correlated to the amplitude of the mean vector wind over the footprint, as modelled by the GMF. Low scatterometer wind speeds are thus providing useful information.

Figure 4: Overview of SeaWinds algorithms
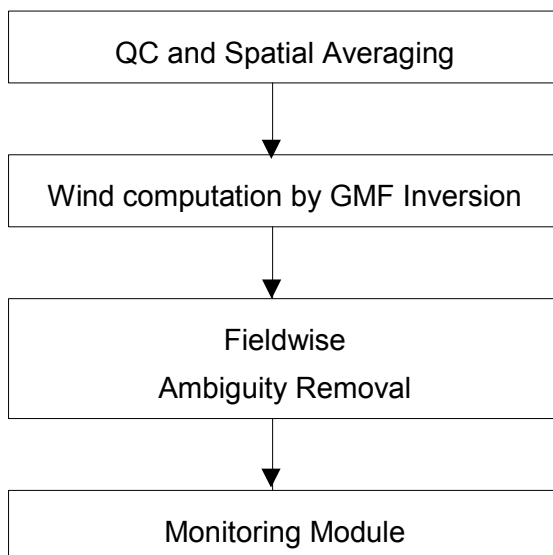
At high wind speeds wave breaking will further intensify, causing air bubbles, foam and spray at the ocean surface, and a more and more complicated ocean topography. Although theoretically not obvious, it is empirically found that σ_0 keeps increasing for increasing wind speed up to 25 m/s and even higher, and that a useful wind direction dependency remains (Donelly et al, 1999).

3.2. Wind Retrieval

The GMF has two unknowns, namely wind speed and wind direction, so, if more than two backscatter measurements are available then these two unknowns may be estimated using a maximum-likelihood estimator (MLE) as the objective function for determining wind vector solutions (Pierson, 1989; 1990). The MLE is defined by

$$J = -\sum_{i=1}^{N} \frac{(\sigma_{oi} - \sigma_m(u, \chi_i))^2}{Var(\sigma_m)_i}$$
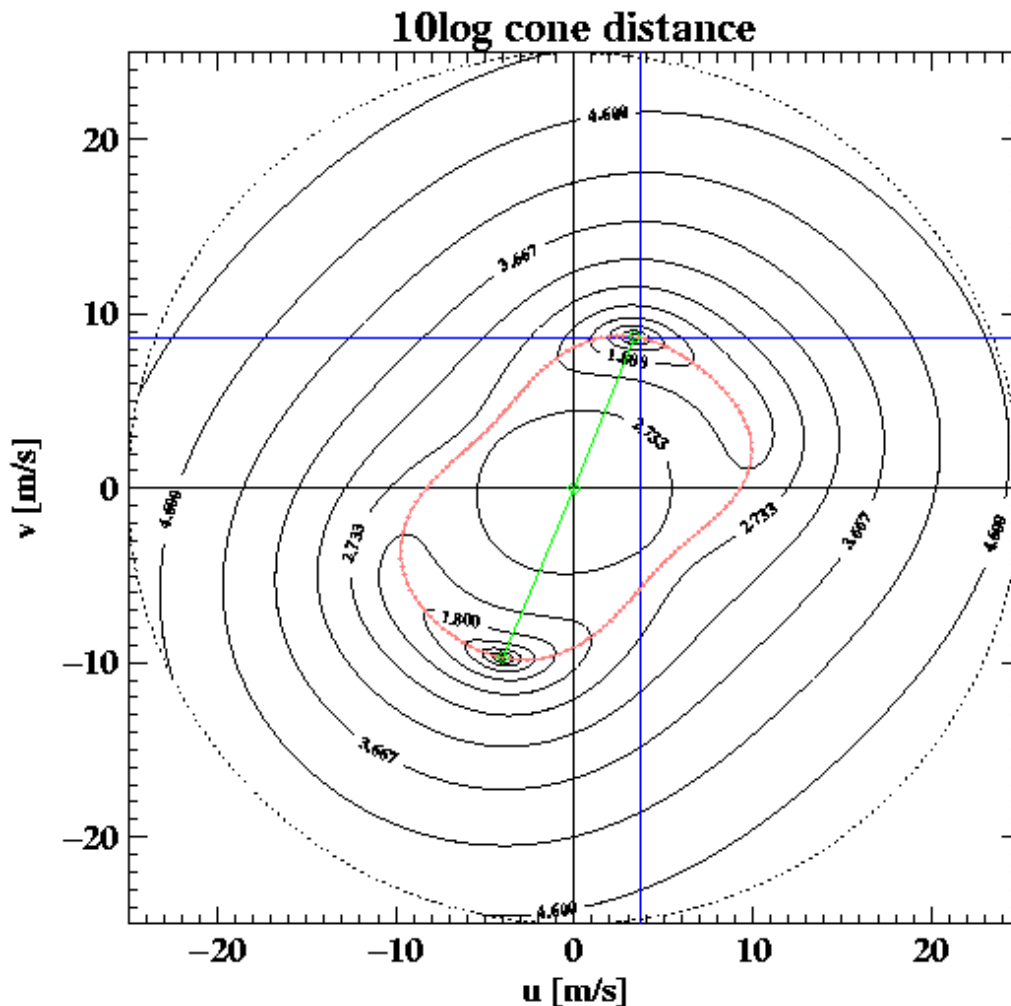
Figure 5: *The wind retrieval objective function J as a function of wind vector components u and v for four collocated fore and aft beam measurement of radar backscatter. The cross indicates the position of the most likely ambiguous solution. The other solution is opposite.*

where σ_{oi} are the backscatter measurements, $\sigma_m(u, \chi_i)$ are the model backscatter values corresponding to the measurements, and $Var(\sigma_m)_i = (K_{pi}^2 \sigma_{oi}^2)$ are the measurement variances. Note that in the NOAA product $Var(\sigma_m)_i = (K_{pi}^2 \sigma_{mi}^2)$ is used, i.e., the noise variance estimated by the modelled rather than the observed backscatter. We [Ref-5] found the latter to perform better. The local minima of *J* correspond to wind vector solutions. The three or more independent measurements should well sample the azimuth variation of the GMF in order to resolve the wind direction, albeit ambiguously.

The problem of ambiguity illustrated in figure 5 does generally not disappear if more measurements become available. However, multiple azimuth views and polarisation measurements do increase the probability that one of the ambiguous solutions becomes more likely than the other ones. Stoffelen, de Vries and Voorrips (2001) describe that SeaWinds retrievals at 100 km resolution are much less ambiguous than retrievals at 25 km due to this (see also section 6).

3.2.1. Ambiguity Removal

SeaWinds scatterometer winds have a multiple ambiguity and there are up to four wind solutions in each wind vector cell (WVC) on the earth's surface. These ambiguities are removed by applying constraints on the spatial characteristics of the output wind field, such as on rotation and divergence. Several ambiguity removal (AR) schemes were evaluated for ERS data (Stoffelen, de Haan, Quilfen and Schyberg, 2000). In the OSI SAF Development Phase some schemes that were developed for the SCAT were compared. In addition to the subjective comparison of AR schemes, a method for the objective comparison of AR performance among the different schemes was used. Stoffelen et al (2002) show that this way of comparison is effective to evaluate the shortcomings of AR schemes, but also reveals a more general way forward to improve AR, which is followed up during IOP by tuning 2D-VAR. For SeaWinds this tuned version of 2D-VAR is used.

For the 25-km wind product, a somewhat different approach called MSS (Multiple Solution Scheme) is used. In this approach, the full circle of possible wind directions is divided in 144 equal sectors of 2.5° and for each wind direction an optimal wind speed with its corresponding probability is calculated in the wind retrieval step. Subsequently, the 144 solutions of each WVC are used in the AR to select the optimal solution. In this way, the full probability density function of the wind solutions is used (Portabella and Stoffelen, 2004).

3.2.2. Quality Control

Since the scatterometer wind retrieval problem is over determined, this opens up the possibility of quality control (QC) by checking the inversion residual J. The inversion residual is in theory inversely proportional to the log probability that a node is affected solely by a uniform wind. Generally this probability is low when rain affects the WVC, or there is substantial wind variability within the cell;

As such, Portabella and Stoffelen (2002) found that the inversion residual is well capable of removing cases with extreme wind variability (at fronts or centres of lows), or with other geophysical variables affecting the radar backscatter, such as rain. QC is performed on the 25-km NASA or NOAA grids and rejection percentages vary between 1-5%. In the nadir WVCs **both** the JPL rain flag and the KNMI residual check are used for QC.

3.3. Detailed SeaWinds algorithm description

SeaWinds processing is described in some detail in [Ref-4]. The OSI SAF extensions to the NOAA and NASA SeaWinds processing are described in Stoffelen (2000) and in Portabella [Ref-5].

3.4. Monitoring

Automatic ways of monitoring backscatter data quality and wind products is of the utmost importance for using the data, in particular for routine use in NWP, for example. The way of monitoring at KNMI is reported in de Vries, Stoffelen and Beysens (2005). In short, a multi-step check is used for each product (half orbit), and if
- the number of QC rejections is above a threshold, or
- the mean normalised residual J is above a threshold for those data where a wind solution can be calculated, or

- the wind speed bias against the NWP reference is above a threshold,

then the monitoring flag is raised and the output is suspicious. The false alarm rate of the monitoring flag is about 0,001 %.

4. Processing scheme

KNMI has an operational processing chain running in near real-time with SeaWinds data, including visualisation on the web: http://www.knmi.nl/scatterometer/qscat_prod/ (100-km product) and http://www.knmi.nl/scatterometer/qscat_25_prod/ (25-km product). This processing is performed using the NWP SAF software. The processing includes monitoring and archiving functionalities. A global overview of the modules of our SeaWinds scatterometer processor is given below. Figure 6 gives an overview of the entire processing system of SeaWinds.

4.1. NWP collocation

KNMI receives NWP model data from ECMWF twice a day through the RMDCN.

NWP model sea surface temperature data is used to provide information about possible ice presence in the WVCs. WVCs with a sea surface temperature below 271.56 K (-1.6 °C) are assumed to be covered with ice and no wind information is calculated. This ice check, which is usually inactive, is done in addition to the evaluation of the JPL ice flags which are present in the NOAA input product. If the JPL ice screening fails, the ice is still detected by the SST check.

NWP forecast wind data are necessary in the ambiguity removal step of the processing. ECMWF wind forecasts are available twice a day (00 and 12 GMT analysis time) with forecast time steps of +3h, +6h, …, +36h. The 10-m model wind data are averaged with respect to time and location and put into the model wind part of each WVC, where they replace the NCEP 1000-hPa forecast winds that are present in the NOAA input product. This has a positive input on the output product quality and eases the product monitoring and validation; see Verhoef and Stoffelen (2006). Note that the ECMWF winds stored in the wind products are real winds rather than neutral winds.

4.2. Validation

Each step in the processing is validated separately and also the product as a whole by a quality control and monitoring scheme. The product validation step is controlled by visual inspection, and a statistical analysis is performed to control the validation steps. The inversion step is controlled in the same way. For ambiguity removal schemes an objective scheme exists that relies on initialisation with a one-day lead NWP forecast and validation of the ambiguity selection against NWP analyses, as in Stoffelen et al (2002). Moreover, Stoffelen, de Vries and Voorrips (2001) describe subjective comparison of the 2D-VAR and PreScat schemes by routine operational meteorologists.

4.3. Quality control and monitoring

The quality of the delivered products is controlled through an ad hoc visual examination of the graphical products and the automatic production of control parameters.

The examination of the products is done at KNMI by experts. Specific tools have been developed to help this analysis. User queries obviously lead to the inspection of suspect products. The ad hoc and user queried inspections are used for quality assurance.

An information file is made for each product. The content of the file is identical whatever the product and results from a compilation of all the global information concerning this product. From these files, various graphs are produced to visually display the confidence levels of the products and their evolution with time, some of these graphs are available on the WWW site for product quality monitoring by the users.

4.4. Software Configuration

To keep record of system configuration and releases and the history of the source files in the processing system, the development team at KNMI uses the Concurrent Version System (CVS).

4.5. Dissemination and archive

SeaWinds BUFR and NetCDF products are put available on a password-protected FTP site. This password is provided to new users by E-mail request to scat@knmi.nl. A BUFR reader is available at www.knmi.nl/scatterometer/bufr_reader/. BUFR Data are available also through the EUMETCast system. Please consult http://www.eumetsat.int/, under 'Access to Data' for more information on EUMETCast dissemination and how to receive these and other EUMETSAT meteorological satellite products, or contact ops@eumetsat.int.

The data will be archived in the EUMETSAT Unified Meteorological Archive and Retrieval Facility (UMARF), see http://archive.eumetsat.org/umarf/. For data not (yet) present in UMARF, KNMI also keeps an off line archive of the products. You can send a request to scat@knmi.nl.

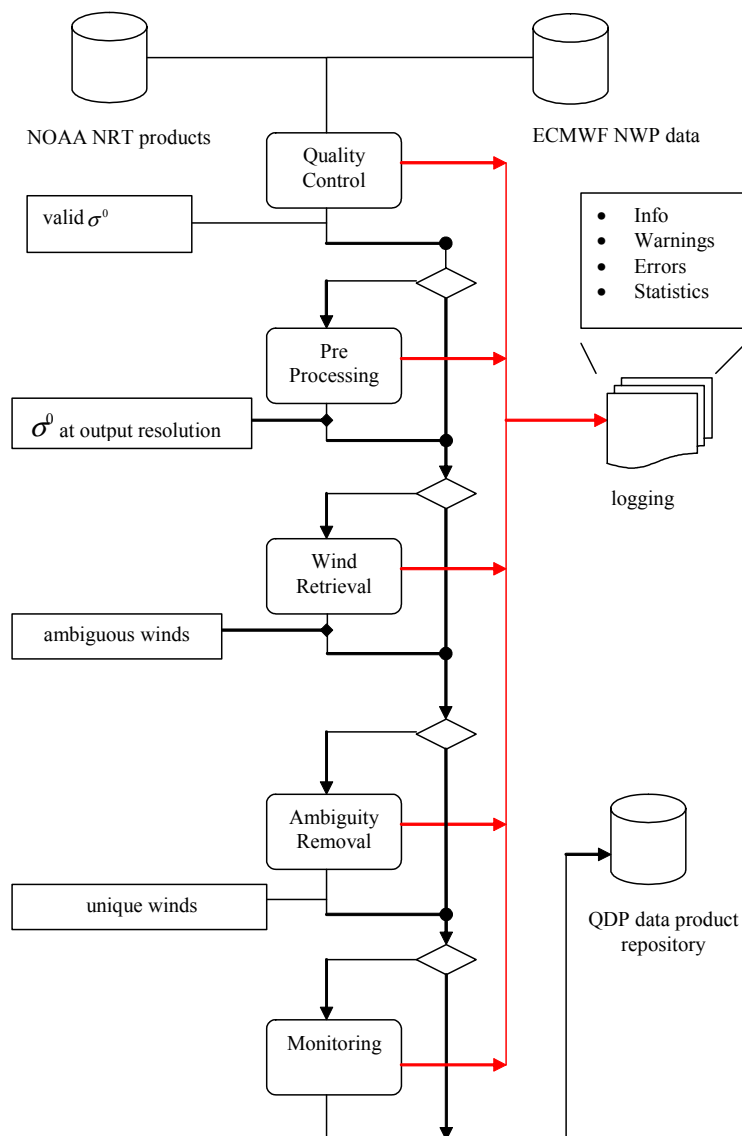*Figure 6:* SeaWinds Data Processor (de Vries, 2003).

5. Data description

5.1. Wind product characteristics

Physical definition

Horizontal equivalent neutral wind vector at 10 m height.

Units and range

Wind speed is measured in m/s. The wind speed range is from 0-50 m/s, but wind speeds over 25 m/s are generally not reliable (cf Donelly et al, 1999). In the BUFR products, the wind direction in *meteorological* (WMO) convention relative to North: 0 degrees corresponds to a wind flowing to the *South* with a clockwise increment. In the NetCDF products, the wind direction is in *oceanographic* convention: 0 degrees corresponds to a wind flowing to the *North* with a clockwise increment.

Input satellite data

SeaWinds BUFR data from NOAA are described in their user manual (see [Ref-7]).

Product computed from FTPed BUFR messages issued by NOAA to the UK Met Office, and by the UK Met Office to KNMI, containing geo-located measurement quadruplets on a satellite swath grid of 25 km size. Portabella ([Ref-5]; section 2.4) shows that the backscatter data in the BUFR and the off-line product are of similar quality despite processing differences. The delay of the input SeaWinds data is up to 3 hours delay from observation time

Geographical definition

Satellite swath projection. Swath is located below the satellite. The QuikSCAT satellite proceeds in a near-polar orbit at 98 degrees inclination at 800 km orbit height. Equator ascending crossing time is 10 UTC. Swath width is 76 (19) 25-km (100-km) size WVC each side. At KNMI we currently only use WVC for which four backscatter measurements are available (WVCs 9-68), nominally resulting in 15 100-km size WVCs. This substantially reduces the overlap of subsequent files. Products are organised in batches of about half an orbit along track.

Time resolution

Polar satellites have the capability to provide data twice daily. The SeaWinds swath width of 1800 km provides full coverage twice a day for latitudes above 50 degrees. KNMI processes a 1400 km swath where above 60 degrees full coverage at least twice daily is provided. The dissemination frequency of the scatterometer data is about every 50 minutes in half orbit files. Every useful input backscatter product has a corresponding output wind product.

Coverage

Global (see web visualisation).

Output product

The input product in BUFR is processed into a BUFR output product with a unique wind solution (chosen) and its corresponding ambiguities, quality information (probability of solution, quality flag, e.g., monitoring bit). The products are also available in NetCDF format, see section 10 for more details.

Delivery time

A wind product is available for distribution 10 minutes after the input product reception.

Expected accuracy

The expected accuracy is defined as the expected bias and standard deviation of the primary calculations. The accuracy is validated against in situ wind measurements from buoys, platforms, or ship, and against NWP data. Even better, the errors of all NWP model winds, in situ data, and scatterometer winds are computed in a triple collocation exercise ([Ref-6], Djepa, 2002). The performance is pretty constant over the globe and depends mainly on the sub-footprint wind variability. The performance of the products issued by the OSI SAF is characterised by a wind vector RMS error smaller than 3 m/s.

5.2. File formats

Wind products are in BUFR or NetCDF format. A complete description of BUFR can be found in WMO publication No 306, Manual on Codes. The graphical display of the wind products is available and explained on the web: http://www.knmi.nl/scatterometer/qscat_prod/ and http://www.knmi.nl/scatterometer/qscat_25_prod/.

The 100-km and 25-km OSI SAF wind products are stored in exactly the same BUFR format as described in the SeaWinds BUFR manual from NOAA [Ref-7], a list of descriptors (fields) contained in each WVC is provided in section 9. Data are organised in files containing approximately 75-90 minutes of data.

The file name convention for SeaWinds 100-km BUFR data is:

QS100_Dyyddd_Shhmm_Ehhmm_Bxxxxxxx

QS100_ - is a fixed prefix, denoting 'QuikSCAT' and 100-km resolution

Dyyddd_ - yyddd contain year (two digits) and day of year (001 - 366) at start of data acquisition in this file (GMT)

Shhmm_ - hhmm contains hour and minute of start of data acquisition in this file (GMT)

Ehhmm_ - hhmm contains hour and minute of end of data acquisition in this file (GMT)

Bxxxxxxx - contains information about satellite orbit number

Examples of file names are QS100_D05186_S2352_E0107_B3148182 or QS100_D05187_S1123_E1251_B3148889. The file name convention is applicable to the files which are available on the KNMI FTP server. The files which are disseminated through EUMETCast have a fixed prefix 'S-OSI_-KNMI-' before this file name, for example S-OSI_-KNMI-QS100_D05186_S2352_E0107_B3148182.

The file name convention for the 25-km data is identical, but the QS100 part is replaced by QS025, denoting 25-km resolution.

In each node or wind vector cell (WVC) 118 data descriptors are defined. In addition some extra information/alterations have been put in place:

- In the BUFR header the value for "generating centre" is set to 99, representing KNMI.

- The value of byte 18 in BUFR section 1 identifies the generating application.

- The products contain up to four ambiguous wind solutions, with an index to the selected wind solution. These are the up to four 'normal' (non-MSS) solutions, in the selected wind solution the wind speed and wind direction have been replaced by the wind speed and wind direction of the selected MSS solution. The 'Formal Uncertainty in Wind Direction' does not contain the uncertainty, but the normalised inversion residual (referred to as Rn in [Ref-5]).

- The Wind Vector Cell Quality Flag (table 021109) is redefined and now has the following definitions:

Description	BUFR bit	Fortran bit
Not enough good sigma-0 available for wind retrieval	1	15

Description	BUFR bit	Fortran bit
Not used	2-3	14-13
Monitoring flag	4	12
Monitoring value	5	11
KNMI+JPL Quality Control (including rain)	6	10
Variational QC	7	9
Land presence	8	8
Ice presence	9	7
Not used	10	6
Reported wind speed is greater than 30 m/s	11	5
Reported wind speed is less than or equal to 3 m/s	12	4
Not used	13	3
Rain flag algorithm detects rain	14	2
Data from at least one of the four possible beam/view combinations are not available	15	1
Not used	16	0
Missing value	All 17 set	All 17 set

In Fortran, if the Wind Vector Cell Quality Flag is stored in an integer **I** then use **BTEST(I,NDW-NB-1)** to test BUFR bit **NB**, where **NDW**=17 is the width in bits of the data element in BUFR.

If the monitoring flag is set to zero, the product is monitored. If the product is monitored and the monitoring value is set to zero, the product is valid; otherwise it is rejected by the monitoring. The monitoring flag and value are the same for all WVCs in one BUFR output file.

If the KNMI+JPL QC flag is set in a 25-km WVC, then the backscatter information is not useable for various geophysical reasons like rain, confused sea-state etc, and the corresponding 100-km or 25-km WVC bit is set. JPL rain flag information is incorporated in this flag for the nadir swath Wind Vector Cells. Moreover, this flag is set when the wind speed in one or more of the wind solutions is 50 m/s. The presence of such wind solutions has proven to be a reliable indicator for sea ice in the Wind Vector Cell. WVCs, in which the KNMI+JPL QC flag is set, are not used in the calculation of the analysis field in the ambiguity removal step. However, after the ambiguity removal the wind solution closest to the analysis field is chosen (if wind solutions are present in the WVC). This means that such a WVC may contain a selected wind solution, but it is suspect.

Land/Ice presence flag is set if at least one of the 25-km WVCs in a 100-km super WVC is flagged as containing land/ice in the NOAA NRT BUFR product. This may be a flag in one of the sigma0 surface flags or in the WVC quality flag of the input. If more than half of the 25-km WVCs in a 100-km super WVC has bits 6, 8 or 9 set, the 100km WVC is rejected (no wind is calculated).

If the Variational QC flag is set, the wind vector in the WVC is rejected during ambiguity removal due to spatial inconsistency.

For recommendations on the use of the Quality Flag, see section 6.5.

6. Data Quality

NOAA provides a near-real time wind product that is used as basis for further processing at KNMI. Our SeaWinds products are different from the NASA and NOAA products, since special emphasis is put on

- increasing the **reliability** of the wind vectors by Quality Control and rejection of rain-contaminated Wind Vector Cells;

- improving **accuracy** by noise reduction through spatial averaging (100-km product) and meteorological filtering;

- Guaranteeing **correctness** by monitoring of the operational SeaWinds data and KNMI processing; and

- **Reduce** wind direction selection **errors** by meteorologically-balanced wind direction Ambiguity Removal (AR).

These wind quality issues are elaborated here.

6.1.   Reliability

QC improves the quality of winds; however, at some rejection rate useful wind information may be lost. As such, QC is a compromise between rejection of useful data and accepting inferior data quality.

[Ref-5] (chapter 2) describes a method developed at KNMI for QC of SeaWinds data at 25 km resolution, based on similar methods used for the ERS and NSCAT scatterometers. We show that these methods also work in case of SeaWinds for the rejection of cases with

- extreme sub footprint wind or wave variability; and

- rain.

Concerning the latter point we compared our QC with the JPL rain flag and found

- Despite the fact that the JPL rain flag is set, KNMI accepts a 2% category of high wind speed data. However, SSMI shows no rain in this category in about 85% of cases, even if these winds are often found in the storm track region in the vicinity of intense low pressure systems. We regard these SeaWinds data of great meteorological interest.

- In the sweet swath region (see figure 1) the QC is superior and sufficient, but in the nadir part of the swath we use both the KNMI QC **and** the JPL rain flag.

6.1.1. Usable 100 km WVC

A 100-km WVC is used if for all four beams at least eight of sixteen backscatter values are present. This choice was verified to provide satisfactory wind quality and quantity. The front cover shows an example where close to the low and close to the cold front some WVC are rejected (red dots). The only further QC at 100 km resolution is performed during AR (section 6.3).

6.2.   Accuracy - 100-km product

Figure 2 shows that SeaWinds wind variability at 25-km resolution is WVC number dependent. This is due to the effect of instrument noise dominating the wind retrieval. Obviously, we would like the true wind field to dominate the wind variability and thus a variability which is independent of WVC. At KNMI we chose to reduce the instrumental noise by spatial averaging and developed a 100-km SeaWinds product.

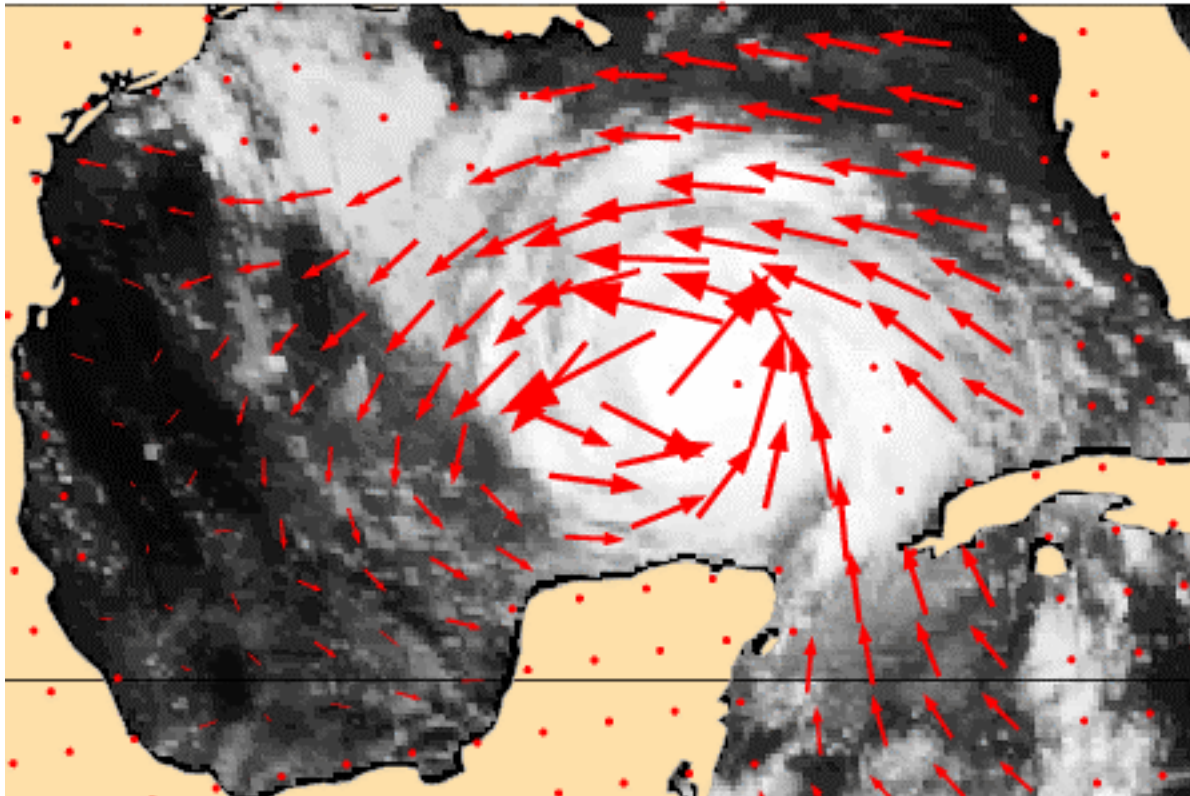QSCAT: 20021002 11:13Z HIRLAM:2002100209+3 IR: 12 IR: 12 at LAT LON:15.88

Figure 7: *OSI SAF SeaWinds product in the Gulf of Mexico for a tropical cyclone. A handful of points are rejected by our QC, but the cyclone structure remains clear.*

SD	KNMI	DIRTH
Speed	1.31	1.64
Direction	13.58	14.58
U	1.60	1.96
V	1.58	1.80

Table 1: *OSI SAF and NOAA DIRTH SeaWinds product difference with ECMWF first guess winds for a set of triple collocated wind points. Speed, direction, and wind component difference standard deviations (SD) are shown. OSI SAF winds verify better against ECMWF, in particular for wind speed.*

The 100-km resolution wind product is of reduced resolution compared to the original NOAA 25-km product, which is obtained by means of σ_0-averaging. The product is more consistent with NWP model winds than the original product, which makes it more suitable for use in NWP models. Evidence of this is given in table 1 and figures 8 and 9.

As can be seen in table 1, the 100-km product clearly compares better to the independent ECMWF winds than the NOAA SeaWinds Product.
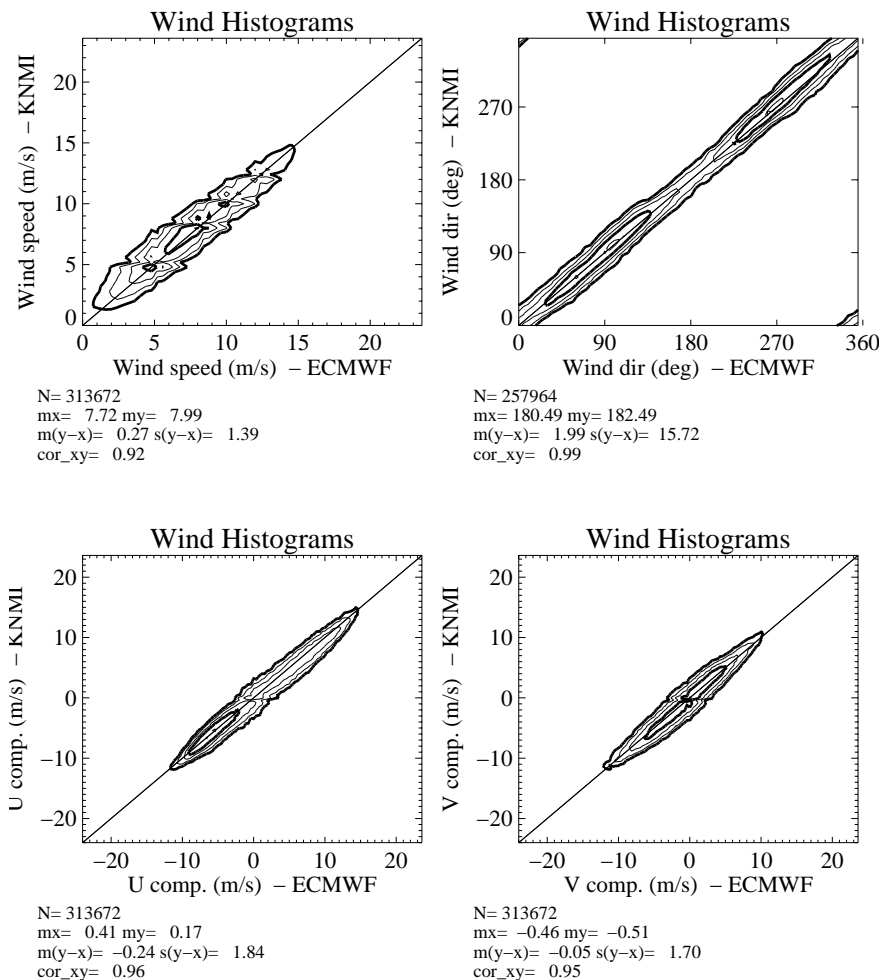
N= 313672
mx= 7.72 my= 7.99
m(y-x)= 0.27 s(y-x)= 1.39
cor_xy= 0.92

N= 257964
mx= 180.49 my= 182.49
m(y-x)= 1.99 s(y-x)= 15.72
cor_xy= 0.99

N= 313672
mx= 0.41 my= 0.17
m(y-x)= -0.24 s(y-x)= 1.84
cor_xy= 0.96

N= 313672
mx= -0.46 my= -0.51
m(y-x)= -0.05 s(y-x)= 1.70
cor_xy= 0.95

Figure 8: *Contoured histograms of the 100-km OSI SAF wind product*

Both figures 8 and 9 give the wind speed, direction and component statistics referenced against collocated ECMWF 10m wind analysis for the 100-km OSI SAF wind product and the 25-km NOAA product thinned to 100-km resolution respectively. The data for these plots are from consecutive orbits from January 27th 2002 until February 3rd 2002. The 100-km wind product was made with the QDP in default settings mode (Variational Quality Control and KNMI quality control). The thinning of the NOAA product was realized by taking winds from the nearest neighbour 25-km WVC closest to the centroid of the 100km super WVC. The wind direction statistics are based on winds with wind speeds larger than 4 m/s. From the joint distributions and accompanying statistics in all plots of both figures it is evident that the random error of the difference distribution, s(y-x), is smaller for the 100-km product. In addition the systematic error in the difference distribution, m(y-x), is also smaller for the 100-km product except for the wind direction. The asymmetric peak in the U-component distribution in both figures is due to the systematic sampling of the trade winds. The jaggedness of the wind speed distributions is due to the fact that the retrieved scatterometer wind speeds stem from the GMF lookup table. Both figures show that currently in the trade off between resolution and noise, QuikSCAT winds at 100-km resolution are the preferred product for NWP data assimilation.
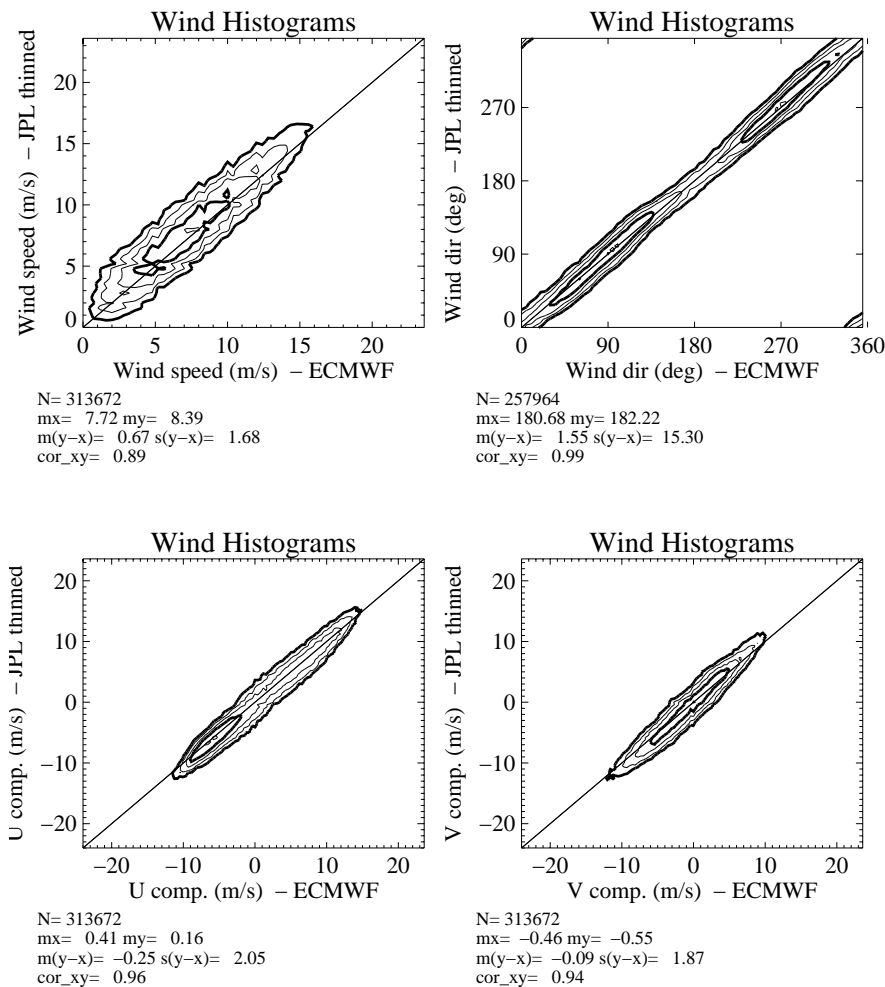
Figure 9: *As figure 8 but for the thinned NOAA product*

In our verification, the NOAA DIRTH processing tends to deliver reasonably smooth wind direction (see figure 10), but rather variable wind speeds. On the other hand, the 100-km product exhibits similar scales and variability in both wind speed and direction. This is what one may anticipate from the way both processing algorithms work.

The noise in the 100-km product is smaller than in the NOAA 25-km product and the performance more uniform over the swath, consistent with the initial objective.

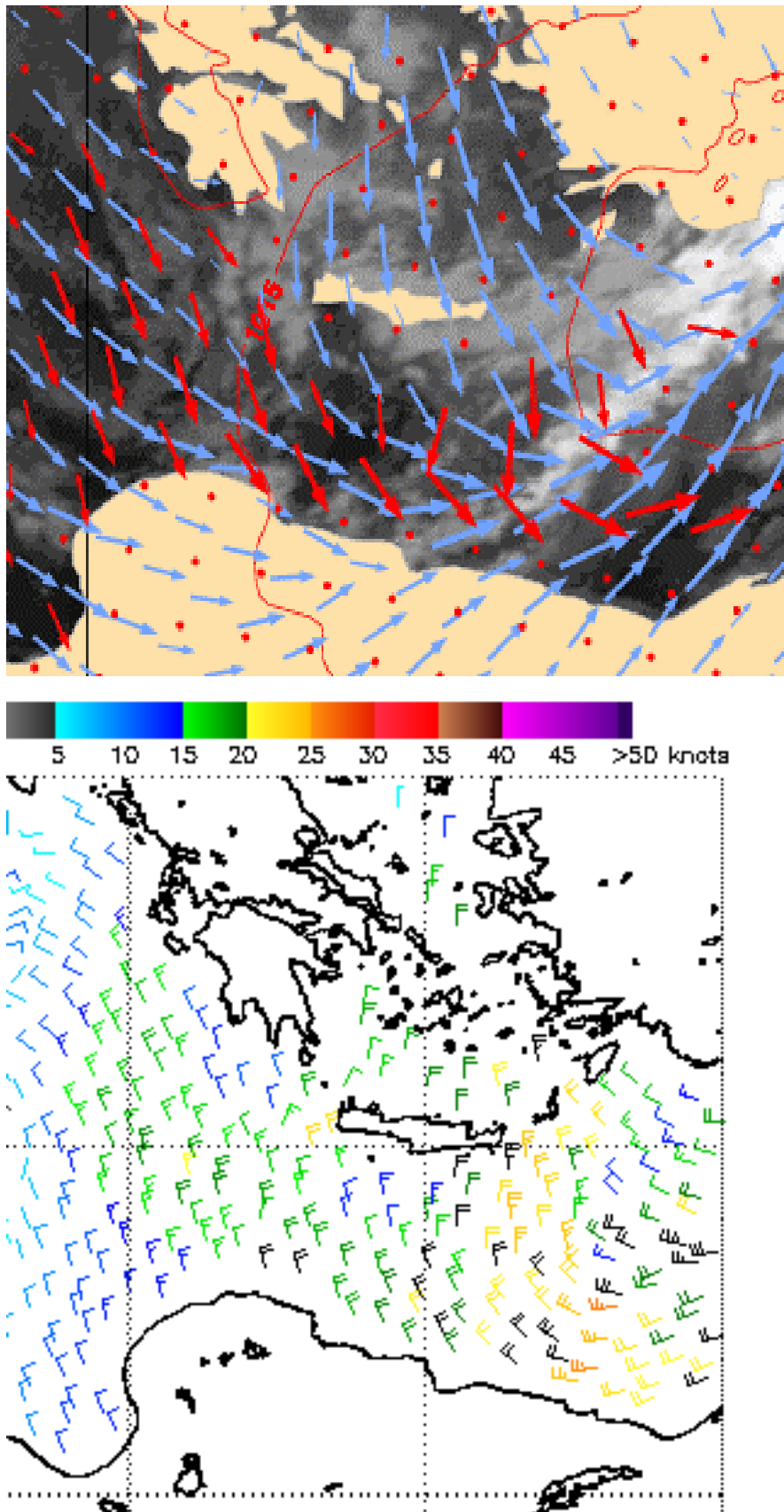**Figure 10:** *OSI SAF SeaWinds product (top) in the Mediterranean for a trough. In the DIRTH NOAA product (bottom), the trough appears weaker due to the wind direction spatial smoothing. Blue winds are HIRLAM in the top panel, while here the background image is Meteosat IR. Black winds did not pass the JPL rain check in the bottom panel.*

6.3. Accuracy - 25-km product

Figure 11 shows two-dimensional histograms of the OSI SAF-retrieved 25-km winds versus ECMWF forecasts. The data are from consecutive orbits from 1-5 July 2007.
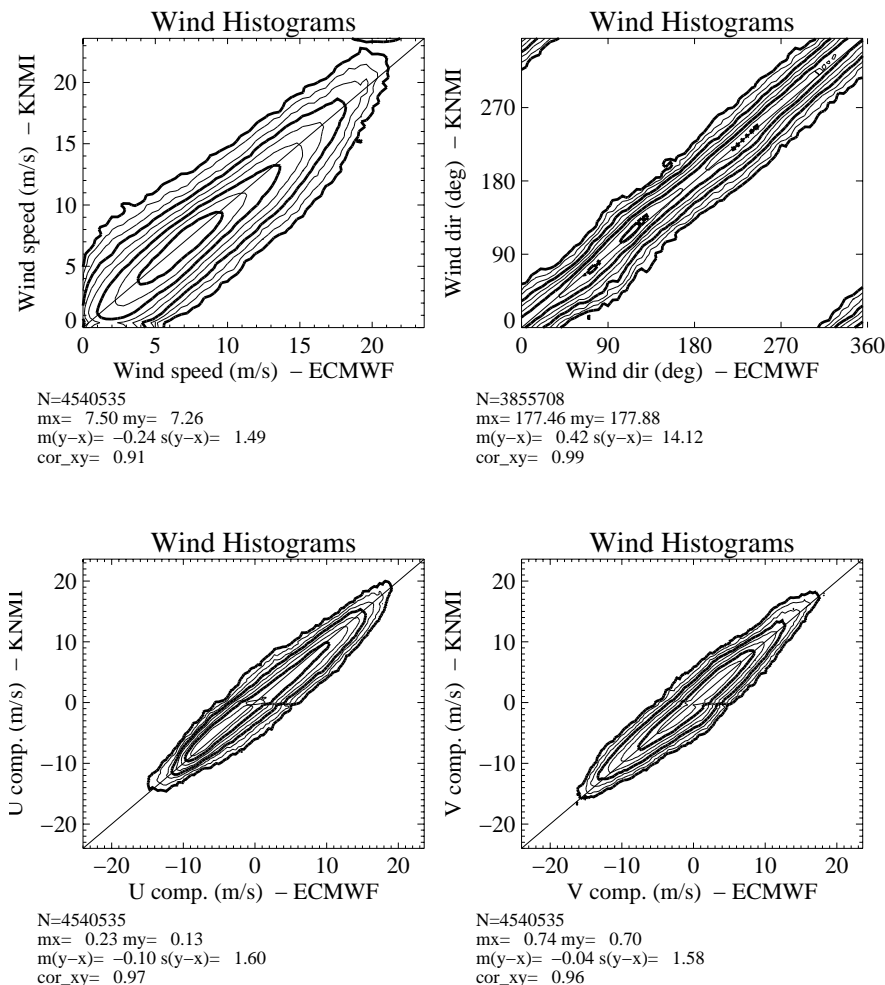

Figure 11: Contoured histograms of the 25-km OSI SAF wind product

The top left plot corresponds to wind speed (bins of 0.4 m/s) and the top right plot to wind directions (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. N is the number of data; mx and my are the mean values along the x and y axis, respectively; m(y-x) and s(y-x) are the bias and the standard deviation with respect to the diagonal, respectively; and cor_xy is the correlation value between the x- and y-axis distributions. The contour lines are in logarithmic scale: each step is a factor of 2 and the lowest level (outer-most contour line) is at N/64000 data points.

From these results, it is clear that the spread in the distributions is small. The wind speed bias is quite small and it is clear from the bottom plots that the standard deviations in the components are well below 2 m/s.

The quality of the 25-km winds is further elaborated in Verhoef, Vogelzang and Stoffelen (2007). By passing more wind and probability information from the inversion step to the ambiguity removal step, the 25-km product spatial noise filtering is effectively performed by

the meteorologically balanced 2D-VAR. This appears crucial for the wind quality that is obtained in the end product and it is shown in the above report that good quality winds showing small scale details are obtained.

6.4. Ambiguity selection

For SeaWinds a version of 2D-VAR is used with minimal regional performance differences (Vogelzang, 2007). This version is based on the work by de Vries, Stoffelen and Beysens (2005) which in turn was triggered by the findings of Stoffelen et al (2002). A variational QC step is performed to reject a few WVCs, which are in meteorological unbalance with their neighbours. This rejection rate, often called gross error rate, peaks at nadir and falls off quickly by a factor of two in the sweet swath.

6.5. Quality indices and data use

We summarise the product quality indices here:
1. Rain/sea-state, ice, and land presence, resp. bits 6, 9, and 8, of WVC_QUALITY_FLAG (section 5.2); the land flag may be ignored since it indicates land *contamination*, if a too high land fraction is present in the WVC, no winds are calculated;
2. Monitoring flag and bit, resp. bits 4 and 5 of WVC_QUALITY_FLAG (sections 5.2 and 3.4); a selected wind may be given, but it should be suspected if bits 4 **and** 5 are set;
3. Variational QC bit 7 of WVC_QUALITY_FLAG (section 5.2); if this bit is set, the selected wind is spatially inconsistent with its neighbours and suspect.

7. Glossary

ADEOS	(Japanese) Advanced Earth Observation Satellite
AR	Ambiguity Removal
ASCAT	Advanced Scatterometer
BUFR	Binary Universal Format Representation
CM SAF	Climate SAF
DLI	Downward Long wave Radiation
EPS	EUMETSAT Polar Satellite
ERS	European Remote-Sensing Satellite
EUMETCast	EUMETSAT's Digital Video Broadcast Data Distribution System
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GOES	Geostationary Operational Environmental Satellite
HDF	Hierarchical Data Format
HH	Horizontal polarisation send and receive mode
IR	InfraRed
JPL	Jet Propulsion Laboratory (NASA)
KNMI	Royal Netherlands Meteorological Institute
MSS	Multiple Solution Scheme
NASA	National (US) Air and Space Agency
NetCDF	Network Common Data Form
NOAA	National (US) Oceanic and Atmospheric Administration
NSCAT	NASA Scatterometer
NWP	Numerical Weather Prediction
OSI SAF	Ocean and Sea Ice SAF
QC	Quality Control
QuikSCAT	US dedicated scatterometer mission to bridge ADEOS-I and ADEOS-II
RMDCN	Regional Meteorological Data Communication Network
SAF	Satellite Application Facility
SeaWinds	US scatterometer on-board QuikSCAT and ADEOS-II platforms
SOS	Scatterometer Ocean Stress
SSI	Surface Solar Irradiance
SST	Sea Surface Temperature
U	West-to-east wind component
V	South-to-north wind component
VV	Vertical polarisation send and receive mode
WVC	Wind Vector Cell

8. Literature

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9. SeaWinds BUFR data descriptors

Number	Descriptor	Parameter	Unit
001	(01007)	Satellite Identifier	Code Table
002	(01012)	Direction of Flight	Degree True
003	(02048)	Satellite Instrument Identifier	Code Table
004	(21119)	Wind Scatterometer GMF	Code Table
005	(25060)	Software Identification	Numeric
006	(02026)	Cross Track Resolution	m
007	(02027)	Along Track Resolution	m
008	(05040)	Orbit Number	Numeric
009	(04001)	Year	Year
010	(04002)	Month	Month
011	(04003)	Day	Day
012	(04004)	Hour	Hour
013	(04005)	Minute	Minute
014	(04006)	Second	Second
015	(05002)	Latitude (Coarse Accuracy)	Degree
016	(06002)	Longitude (Coarse Accuracy)	Degree
017	(08025)	Time Difference Qualifier	Code Table
018	(04001)	Time to Edge	Second
019	(05034)	Along Track Row Number	Numeric
020	(06034)	Cross Track Cell Number	Numeric
021	(21109)	Seawinds Wind Vector Cell Quality Flag	Flag Table
022	(11081)	Model Wind Direction At 10 M	Degree True
023	(11082)	Model Wind Speed At 10 M	m/s
024	(21101)	Number of Vector Ambiguities	Numeric
025	(21102)	Index of Selected Wind Vector	Numeric
026	(21103)	Total Number of Sigma0 Measurements	Numeric
027	(21120)	Seawinds Probability of Rain	Numeric
028	(21121)	Seawinds NOF Rain Index	Numeric
029	(13055)	Intensity Of Precipitation	kg/m**2/sec
030	(21122)	Attenuation Correction On Sigma-0 (from Tb)	dB
031	(11012)	Wind Speed At 10 M	m/s
032	(11052)	Formal Uncertainty In Wind Speed	m/s
033	(11011)	Wind Direction At 10 M	Degree True
034	(11053)	Formal Uncertainty In Wind Direction	Degree True
035	(21104)	Likelihood Computed for Wind Solution	Numeric
036	(11012)	Wind Speed At 10 M	m/s
037	(11052)	Formal Uncertainty In Wind Speed	m/s
038	(11011)	Wind Direction At 10 M	Degree True
039	(11053)	Formal Uncertainty In Wind Direction	Degree True
040	(21104)	Likelihood Computed for Wind Solution	Numeric
041	(11012)	Wind Speed At 10 M	m/s
042	(11052)	Formal Uncertainty In Wind Speed	m/s
043	(11011)	Wind Direction At 10 M	Degree True
044	(11053)	Formal Uncertainty In Wind Direction	Degree True
045	(21104)	Likelihood Computed for Wind Solution	Numeric
046	(11012)	Wind Speed At 10 M	m/s
047	(11052)	Formal Uncertainty In Wind Speed	m/s
048	(11011)	Wind Direction At 10 M	Degree True
049	(11053)	Formal Uncertainty In Wind Direction	Degree True
050	(21104)	Likelihood Computed for Wind Solution	Numeric
051	(02104)	Antenna Polarisation	Code Table

Number	Descriptor	Parameter	Unit
052	(08022)	Total Number w.r.t. accumulation or average	Numeric
053	(12063)	Brightness Temperature	K
054	(12065)	Standard Deviation Brightness Temperature	K
055	(02104)	Antenna Polarisation	Code Table
056	(08022)	Total Number w.r.t. accumulation or average	Numeric
057	(12063)	Brightness Temperature	K
058	(12065)	Standard Deviation Brightness Temperature	K
059	(21110)	Number of Inner-Beam Sigma0 (fwd of sat.)	Numeric
060	(05002)	Latitude (Coarse Accuracy)	Degree
061	(06002)	Longitude (Coarse Accuracy)	Degree
062	(21118)	Attenuation Correction On Sigma-0	dB
063	(02112)	Radar Look (Azimuth) Angle	Degree
064	(02111)	Radar Incidence Angle	Degree
065	(02104)	Antenna Polarisation	Code Table
066	(21105)	Normalized Radar Cross Section	dB
067	(21106)	Kp Variance Coefficient (Alpha)	Numeric
068	(21107)	Kp Variance Coefficient (Beta)	Numeric
069	(21114)	Kp Variance Coefficient (Gamma)	dB
070	(21115)	Seawinds Sigma-0 Quality Flag	Flag Table
071	(21116)	Seawinds Sigma-0 Mode Flag	Flag Table
072	(08018)	Seawinds Land/Ice Surface Flag	Flag Table
073	(21117)	Sigma-0 Variance Quality Control	Numeric
074	(21111)	Number of Outer-Beam Sigma0 (fwd of sat.)	Numeric
075	(05002)	Latitude (Coarse Accuracy)	Degree
076	(06002)	Longitude (Coarse Accuracy)	Degree
077	(21118)	Attenuation Correction On Sigma-0	dB
078	(02112)	Radar Look (Azimuth) Angle	Degree
079	(02111)	Radar Incidence Angle	Degree
080	(02104)	Antenna Polarisation	Code Table
081	(21105)	Normalized Radar Cross Section	dB
082	(21106)	Kp Variance Coefficient (Alpha)	Numeric
083	(21107)	Kp Variance Coefficient (Beta)	Numeric
084	(21114)	Kp Variance Coefficient (Gamma)	dB
085	(21115)	Seawinds Sigma-0 Quality Flag	Flag Table
086	(21116)	Seawinds Sigma-0 Mode Flag	Flag Table
087	(08018)	Seawinds Land/Ice Surface Flag	Flag Table
088	(21117)	Sigma-0 Variance Quality Control	Numeric
089	(21112)	Number of Inner-Beam Sigma0 (aft of sat.)	Numeric
090	(05002)	Latitude (Coarse Accuracy)	Degree
091	(06002)	Longitude (Coarse Accuracy)	Degree
092	(21118)	Attenuation Correction On Sigma-0	dB
093	(02112)	Radar Look (Azimuth) Angle	Degree
094	(02111)	Radar Incidence Angle	Degree
095	(02104)	Antenna Polarisation	Code Table
096	(21105)	Normalized Radar Cross Section	dB
097	(21106)	Kp Variance Coefficient (Alpha)	Numeric
098	(21107)	Kp Variance Coefficient (Beta)	Numeric
099	(21114)	Kp Variance Coefficient (Gamma)	dB
100	(21115)	Seawinds Sigma-0 Quality Flag	Flag Table
101	(21116)	Seawinds Sigma-0 Mode Flag	Flag Table
102	(08018)	Seawinds Land/Ice Surface Flag	Flag Table
103	(21117)	Sigma-0 Variance Quality Control	Numeric
104	(21113)	Number of Outer-Beam Sigma0 (aft of sat.)	Numeric
105	(05002)	Latitude (Coarse Accuracy)	Degree
106	(06002)	Longitude (Coarse Accuracy)	Degree

Number	Descriptor	Parameter	Unit
107	(21118)	Attenuation Correction On Sigma-0	dB
108	(02112)	Radar Look (Azimuth) Angle	Degree
109	(02111)	Radar Incidence Angle	Degree
110	(02104)	Antenna Polarisation	Code Table
111	(21105)	Normalized Radar Cross Section	dB
112	(21106)	Kp Variance Coefficient (Alpha)	Numeric
113	(21107)	Kp Variance Coefficient (Beta)	Numeric
114	(21114)	Kp Variance Coefficient (Gamma)	dB
115	(21115)	Seawinds Sigma-0 Quality Flag	Flag Table
116	(21116)	Seawinds Sigma-0 Mode Flag	Flag Table
117	(08018)	Seawinds Land/Ice Surface Flag	Flag Table
118	(21117)	Sigma-0 Variance Quality Control	Numeric

10.   NetCDF data format

The SeaWinds wind products are also available in the NetCDF format, with the following characteristics:

- The data format meets the NetCDF Climate and Forecast Metadata Convention version 1.4 (http://cf-pcmdi.llnl.gov/).

- The data contain, contrary to the BUFR data, only Level 2 wind and sea ice information, no sigma0 nor soil moisture information. The aim was to create a compact and easy to handle product for oceanographic and climatological users.

- The data contain only the selected wind solutions, no ambiguity information.

- The wind directions are in oceanographic rather than meteorological convention (see section 5.1).

- The format is usable for ASCAT, ERS, QuikSCAT and any other scatterometer data.

- The data has file sizes comparable to those of the corresponding BUFR data (e.g., one file of SeaWinds 100-km wind data is 300 kB in BUFR and 180 kB in NetCDF). When compressed with gzip, the size of one file in NetCDF reduces to ~60 kB.

- The NetCDF data in near real-time are only available on the KNMI FTP server, but EUMETCast dissemination can be considered on user request.

The file name convention for the gzipped NetCDF product is

QS100_Dyyddd_Shhmm_Ehhmm_Bxxxxxxx.nc.gz,
QS025_Dyyddd_Shhmm_Ehhmm_Bxxxxxxx.nc.gz where the meaning of the fields is identical to those in the BUFR file names (see section 5.2).

Below are some meta data contained in the NetCDF data files:

```
dimensions:
    NUMROWS = 359 ;
    NUMCELLS = 19 ;
variables:
    int time(NUMROWS, NUMCELLS) ;
            time:long_name = "time" ;
            time:units = "seconds since 1990-01-01 00:00:00" ;
    int lat(NUMROWS, NUMCELLS) ;
            lat:long_name = "latitude" ;
            lat:units = "degrees_north" ;
    int lon(NUMROWS, NUMCELLS) ;
            lon:long_name = "longitude" ;
            lon:units = "degrees_east" ;
    short wvc_index(NUMROWS, NUMCELLS) ;
            wvc_index:long_name = "cross track wind vector cell number" ;
            wvc_index:units = "1" ;
    short model_speed(NUMROWS, NUMCELLS) ;
            model_speed:long_name = "model wind speed at 10 m" ;
            model_speed:units = "m s-1" ;
    short model_dir(NUMROWS, NUMCELLS) ;
            model_dir:long_name = "model wind direction at 10 m" ;
            model_dir:units = "degree" ;
    short ice_prob(NUMROWS, NUMCELLS) ;
            ice_prob:long_name = "ice probability" ;
            ice_prob:units = "1" ;
    short ice_age(NUMROWS, NUMCELLS) ;
            ice_age:long_name = "ice age (a-parameter)" ;
```

```
            ice_age:units = "dB" ;
    int wvc_quality_flag(NUMROWS, NUMCELLS) ;
            wvc_quality_flag:long_name = "wind vector cell quality" ;
            wvc_quality_flag:coordinates = "lat lon" ;
            wvc_quality_flag:flag_masks = 64, 128, 256, 512, 1024, 2048, 4096,
8192, 16384, 32768, 65536, 131072, 262144, 524288, 1048576, 2097152, 4194304 ;
            wvc_quality_flag:flag_meanings = "distance_to_gmf_too_large
data_are_redundant no_meteorological_background_used rain_detected
rain_flag_not_usable small_wind_less_than_or_equal_to_3_m_s
large_wind_greater_than_30_m_s wind_inversion_not_successful
some_portion_of_wvc_is_over_ice some_portion_of_wvc_is_over_land
variational_quality_control_fails knmi_quality_control_fails
product_monitoring_event_flag product_monitoring_not_used
any_beam_noise_content_above_threshold poor_azimuth_diversity
not_enough_good_sigma0_for_wind_retrieval" ;
    short wind_speed(NUMROWS, NUMCELLS) ;
            wind_speed:long_name = "wind speed at 10 m" ;
            wind_speed:units = "m s-1" ;
    short wind_dir(NUMROWS, NUMCELLS) ;
            wind_dir:long_name = "wind direction at 10 m" ;
            wind_dir:units = "degree" ;
    short bs_distance(NUMROWS, NUMCELLS) ;
            bs_distance:long_name = "backscatter distance" ;
            bs_distance:units = "1" ;

// global attributes:
  :title = "QuikSCAT SeaWinds Level 2 100.0 km Ocean Surface Wind Vector Product" ;
  :title_short_name = "SeaWinds-L2-100km" ;
  :Conventions = "CF-1.4" ;
  :institution = "EUMETSAT/OSI SAF/KNMI" ;
  :source = "QuikSCAT SeaWinds" ;
  :software_identification_level_1 = 0 ;
  :instrument_calibration_version = 0 ;
  :software_identification_wind = 0 ;
  :pixel_size_on_horizontal-1 = "100.0 km" ;
  :service_type = "N/A" ;
  :processing_type = "O" ;
  :contents = "ovw" ;
  :granule_name = "QS100_D08113_S0827_E0956_B4604546.nc" ;
  :processing_level = "L2" ;
  :orbit_number = 46045 ;
  :start_date = "2008-04-22" ;
  :start_time = "08:28:05" ;
  :stop_date = "2008-04-22" ;
  :stop_time = "09:56:57" ;
  :equator_crossing_longitude = " 332.828" ;
  :equator_crossing_date = "2008-04-22" ;
  :equator_crossing_time = "07:55:23" ;
  :rev_orbit_period = "6059.1" ;
  :orbit_inclination = "98.6" ;
  :history = "N/A" ;
  :references = "SeaWinds Product Manual, http://www.osi-saf.org/,
http://www.knmi.nl/scatterometer/" ;
  :comment = "Orbit period and inclination are constant values. All wind directions
in oceanographic convention (0 deg. flowing North)" ;
  :creation_date = "2009-08-26" ;
  :creation_time = "11:47:52" ;
```