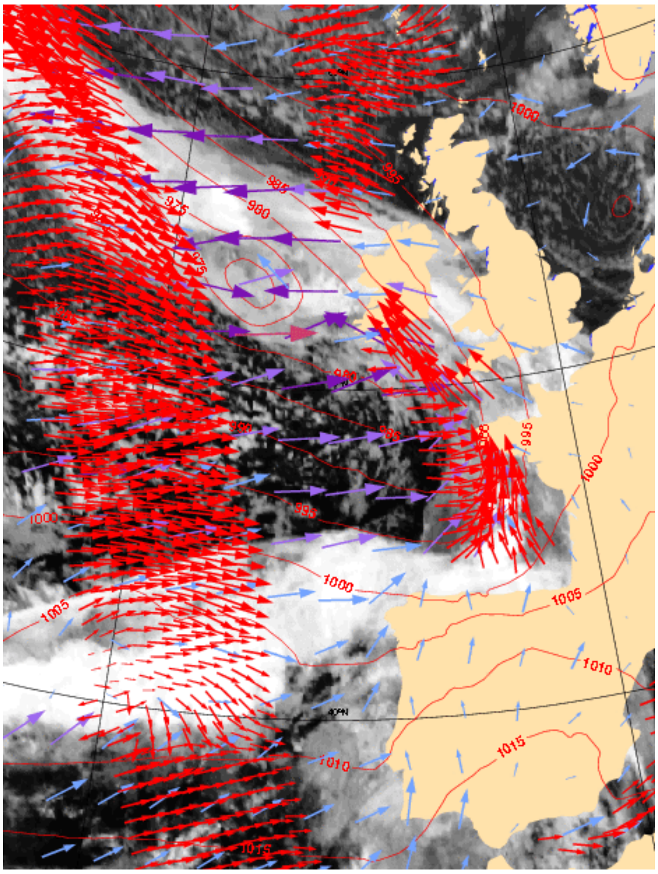
ASCAT Wind Product User Manual



Ocean and Sea Ice SAF

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DOCUMENT SIGNATURE TABLE

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DOCUMENTATION CHANGE RECORD

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Version 1.0	Mar 2007	Minor	First external version
Version 1.1	Sep 2007	Minor	Added release note (sec. 1.4)
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KNMI, De Bilt, the Netherlands

Reference: SAF/OSI/CDOP/KNMI/TEC/MA/126

Cover illustration: ASCAT winds over the Atlantic on 12 February 2007, around 21 hour UTC (red arrows). In this picture, only half of the ASCAT wind vectors, with 25-km cell spacing, are plotted. The blue and purple arrows show a 3-hour forecast of the winds by the KNMI High-Resolution Limited Area Model (HiRLAM). In the background, a METEOSAT infrared image is shown in black and white.

Contents

1. Introduction

1.1. Overview

The 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 Longwave Irradiance (DLI).

KNMI is involved in the OSI SAF and the EUMETSAT Advanced Retransmission Service (EARS) ASCAT service as the centre where the Level 1b to Level 2 processing is carried out. This document is the Product User Manual to the ASCAT wind products. The wind products will be distributed in two resolutions: a 50-km resolution product with 25-km cell spacing and a 25-km resolution product with 12.5-km cell spacing. Both resolutions will be available as a regional EARS product with a timeliness of approximately 30 minutes from sensing time and as a global OSI SAF product with a timeliness of approximately 2.5-3 hours from sensing time.

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, see e.g. [Ref-1].

KNMI has a long experience in scatterometer processing and is developing generic software for this purpose. Processing systems have been developed for the ERS, NSCAT, SeaWinds and ASCAT scatterometers. Scatterometer processing software is developed in the EUMETSAT Numerical Weather Prediction Satellite Application Facility (NWP SAF), whereas wind processing is performed (semi-)operationally in the Ocean and Sea Ice SAF (OSI SAF) and in the EARS project.

EUMETSAT makes available near real-time Level 1b scatterometer products from the MetOp satellite through EUMETCast (global data) and through a private network (regional data). These products are used as basis for further processing at KNMI.

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

This user manual outlines user information for the KNMI products based on the ASCAT scatterometer. Section 2 presents a brief description of the ASCAT instrument, section 3 the processing algorithms, and section 4 gives an overview of the data processing configuration. Section 5 provides details on how to access the products. Detailed information on the file content and format is given in section 6, while in section 7 the product quality is elaborated.

1.2. References

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[Ref-18] Stoffelen, A., A Generic Approach for Assimilating Scatterometer Observations, ECMWF seminar, 2000, available on http://www.knmi.nl/scatterometer/publications/

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[Ref-20] Portabella, M. and Stoffelen, A., Development of a Global Scatterometer Validation and Monitoring, Visiting Scientist report for the Ocean & Sea Ice SAF, January 2007.

1.3. Useful links

KNMI scatterometer web site: http://www.knmi.nl/scatterometer/

- Information on OSI SAF activities at KNMI: http://www.knmi.nl/scatterometer/osisaf/
- Information on EARS activities at KNMI: http://www.knmi.nl/scatterometer/ears/
- ASCAT visual products: http://www.knmi.nl/scatterometer/ascat_osi_25_prod/, http://www.knmi.nl/scatterometer/ascat_ear_25_prod/, http://www.knmi.nl/scatterometer/ascat_osi_12_prod/, http://www.knmi.nl/scatterometer/ascat_ear_12_prod/ (not all products and links are available yet)

Information on EARS and EUMETCast: http://www.eumetsat.int/

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

Scientific documents:

- 2D Variational Ambiguity Removal

Technical documents

- Science Plan
- OSI SAF User Requirements Document
- OSI SAF Project Plan
- OSI SAF Report on Algorithm Development and Prototyping Activities
- OSI SAF top-level Configuration Management Plan
- OSI SAF Output Products Format Document
- OSI SAF Software Requirements Document
- ICD for the wind production of the OSI SAF
- SVVP for the wind production of the OSI SAF

NWP SAF website: http://www.metoffice.gov.uk/research/interproj/nwpsaf/index.html

EUMETSAT ASCAT documentation: http://www.eumetsat.int/Home/Main/What_We_Do/Satellites/EUMETSAT_Polar_System/Space_Segment/SP_1139325735344?l=en and http://www.eumetsat.int/Home/Main/Publications/Technical_and_Scientific_Documentation/Technical_Notes/SP_1126189367518?l=en

1.4. Limitations of the 25-km ASCAT winds

Currently, although we have good confidence in the quality of the products, the demonstration status is still reflected in the use of the “t” (for “test”) in the file names (see section 6.2). Product quality parameters are available in near-real time if you click on the ‘Monitoring information’ link on (http://www.knmi.nl/scatterometer/ascat_osi_25_prod/).

The following restrictions and limitations hold:

1) The Level 1 product is still in its calibration phase. Currently the backscatter values are temporarily corrected using a calibration table, derived from a geophysical wind model. The backscatter values in the Level 2 wind product are however plain copies of those in the Level 1 product. At the end of the commissioning phase the corrections will be removed and the ASCAT Wind Data Processor (AWDP) will be adapted to ingest the commissioned backscatter data without loss of wind quality (expectedly a further gain).

2) The Sigma-0 Usability Flag in the Level 1 product is set to “unusable” in all Wind Vector Cells. Therefore, this flag is neglected in the wind processing.

3) The normalisation of the Maximum Likelihood Estimator (MLE), which is reflected in “Backscatter Distance” in the output product, is to be adjusted and will change after the commissioning phase.

4) The Quality Control (threshold for setting of the KNMI quality control flag) needs to be tuned.

5) The Product Monitoring flag is not yet implemented (see section 7.2).

These restrictions and limitations are subject to further study during the ASCAT commissioning phase in the next few months.

2. The ASCAT scatterometer instrument

The Advanced SCATterometer (ASCAT) is one of the instruments carried on-board the Meteorological Operational (MetOp) polar satellites launched by the European Space Agency (ESA) and operated by the EUropean organisation for the exploitation of METeorological SATellites (EUMETSAT). MetOp-A, the first in a series of three satellites, was launched on 19 October 2006 and two successors are planned to be launched approximately 4-5 years after each other.

ASCAT is a real aperture radar using vertically polarised antennas. It transmits a long pulse with Linear Frequency Modulation ('chirp'). Ground echoes are received by the instrument and, after de-chirping, the backscattered signal is spectrally analysed and detected. In the power spectrum, frequency can be mapped into slant range provided the chirp rate and the Doppler frequency are known. The above processing is in effect a pulse compression, which provides range resolution.

Two sets of three antennas are used to generate radar beams looking 45 degrees forward, sideways, and 45 degrees backwards with respect to the satellite's flight direction, on both sides of the satellite ground track. These beams illuminate 550 km-wide swaths (separated by about 700 km) as the satellite moves along its orbit, and each provide measurements of radar backscatter from the sea surface on a 25 km or 12.5 km grid. The result is three independent backscatter measurements for each grid point, obtained using the three different viewing directions and separated by a short time delay. As the backscatter depends on the sea surface roughness as a function of the wind speed and direction at the ocean surface, it is possible to calculate the surface wind speed and direction by using these 'triplets' within a mathematical model.

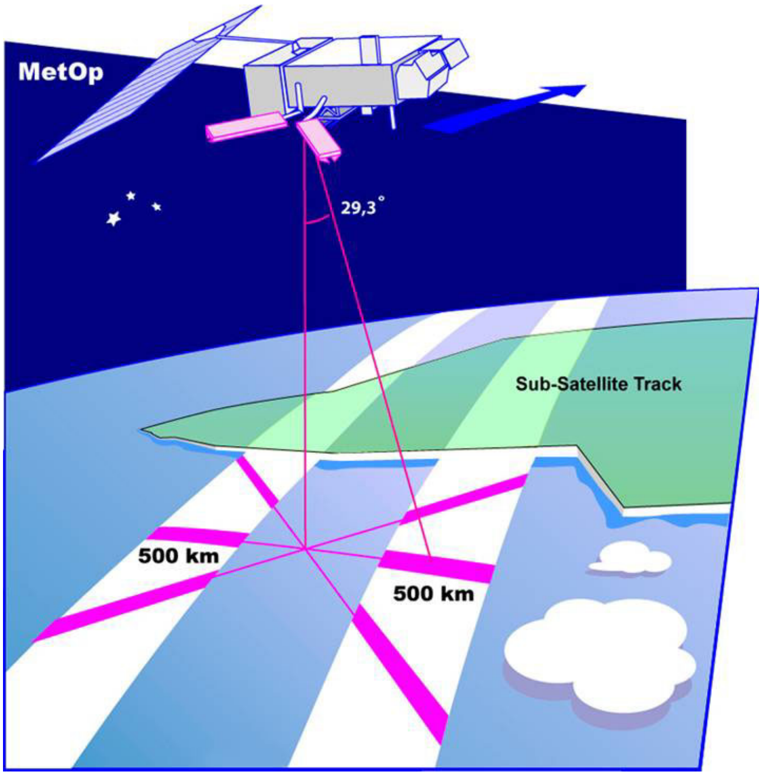

Figure 1: *ASCAT wind scatterometer geometry (source: EUMETSAT web site).*

The instrument operates at a frequency of 5.255 GHz (C-band), which makes it rather insensitive to rain.

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 2 [Ref-2]. In return, backscatter measurements can be used to determine the wind speed and wind direction in a Wind Vector Cell (WVC).

A schematic illustration of the processing is given in figure 3. After defining the wind output and motivating the Geophysical Model Function that is used, the algorithms developed at KNMI are described.

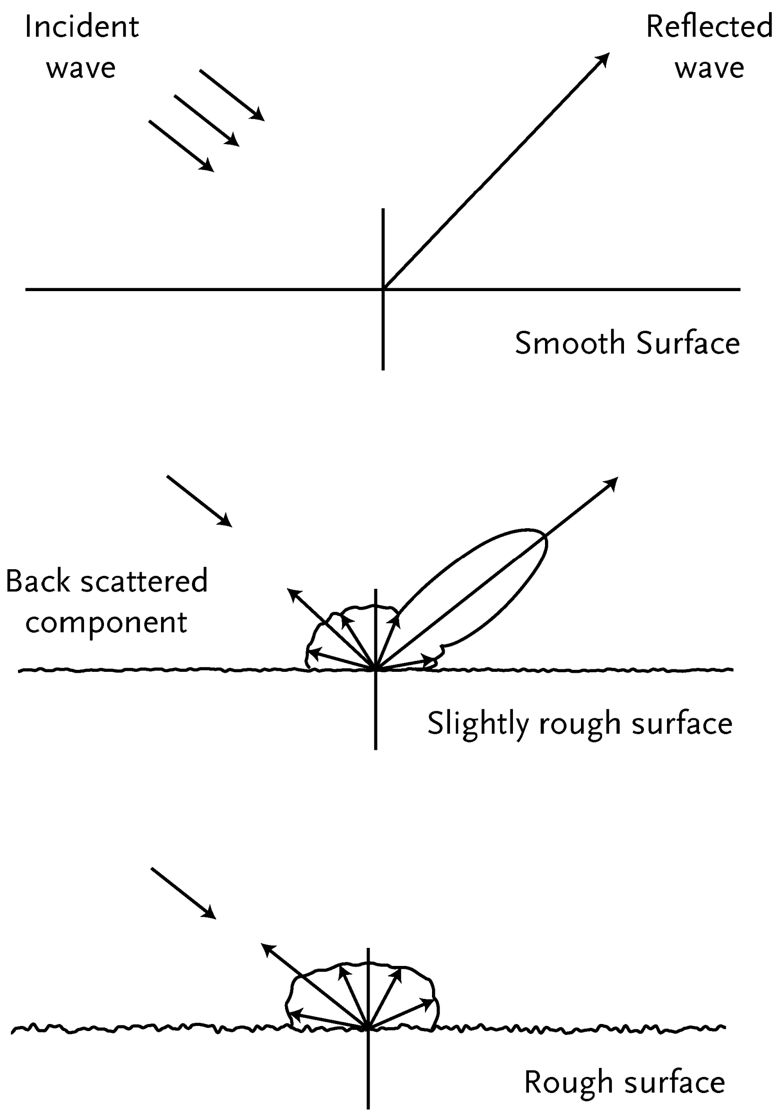

***Figure 2:** Schematic representation of microwave scattering and reflection at a smooth (a), rough (b) and very rough (c) ocean surface. As the roughness increases more microwave power is returned towards the direction of the microwave source.*

3.1. Wind definition

A scatterometer measurement relates to the ocean surface roughness (see figure 2), while the scatterometer product is represented by the wind at 10m height over a 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-3]; Chapter I). Stoffelen ([Ref-3]; 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 KNMI ASCAT wind product the CMOD5 geophysical model function (GMF) is used [Ref-4]. This model function enables the calculation of wind speeds meeting the product requirements between 0 and 25 m/s. It is known from validation work on ERS that a bias of 0.5 m/s persists for all wind speeds [Ref-20]. This bias is applied in the ASCAT wind product.

At low wind speeds the wind direction and speed may vary considerably within the WVC. Locally, below a speed of roughly 2 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 [Ref-5]. However, given the variability of the wind within a footprint area of 25 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.

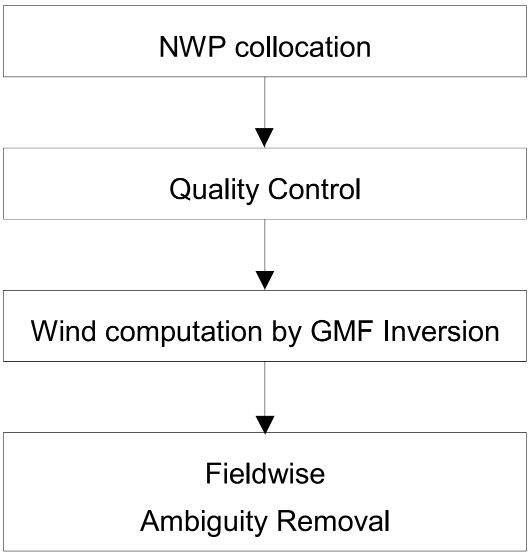

Figure 3: *Overview of wind retrieval algorithm*

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 from 25 m/s to 40 m/s, and that a useful wind direction dependency remains [Ref-6], albeit gradually weakening.

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 [Ref-7]. The MLE is defined by ([Ref-3]; Chapter II)

$$J = (z_{oi} - z_m(u, \chi_i))^2,$$

where $z = (\sigma_0)^{0.625}$ are the transformed backscatter data, z_{oi} are the backscatter measurements, $z_m(u,\chi_i)$ are the model backscatter values corresponding to the measurements. The local minima of J correspond to wind vector solutions. The three independent measurements (fore, mid and aft beam) well sample the azimuth variation of the GMF in order to resolve the wind direction, albeit ambiguously.

3.2.1. Ambiguity removal

ASCAT scatterometer winds have a multiple ambiguity and there are up to two wind solutions in each 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 [Ref-8] in the OSI SAF Development Phase. In addition to the subjective comparison of AR schemes, a method for the objective comparison of AR performance among the different schemes was used. In [Ref-8] it is shown 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 by tuning 2D-VAR. For ASCAT this tuned version of 2D-VAR is used.

3.2.2. Quality control

Since the scatterometer wind retrieval problem is overdetermined, this opens up the possibility of quality control (QC) by checking the inversion residual J. If J is normalised by the expected isotropic error variance then it is in theory inversely proportional to the log probability that a WVC is affected solely by a uniform wind. If $Var(\sigma_m)_i = (K_{pi}^2 \sigma_{oi}^2)$ are the measurement variances then the norm for the inversion residual is √3 times the RMS of $(Var(\sigma_m)_i)^{0.625}$ (Stoffelen, 1998). Generally this normalised MLE is substantial and, as a consequence, the inferred probability low, when there is substantial wind or sea state variability within the WVC.

As such, Stoffelen [Ref-3] and Portabella and Stoffelen [Ref-9] found that the inversion residual is well capable of removing cases with extreme variability (at fronts or centres of lows), or with other geophysical variables affecting the radar backscatter.

4. Processing scheme

KNMI has an experimental processing chain running in near real-time with ASCAT data, including visualisation on the internet. This processor is based on the NWP SAF software and runs in the KNMI operational environment. The processing includes monitoring and archiving functionalities. A global overview of the modules of the ASCAT scatterometer processor is given below.

4.1. Backscatter calibration

During the calibration/validation period, the backscatter values in the Level 1 product are calibrated by adding a WVC and beam dependent bias in dB to the incoming σ_0s. The calibration table was obtained by fitting the actual measurements to the theoretical GMF function. More details are provided in [Ref-14]. Note that the calibrated backscatter values are only available within the wind processing software; the σ_0 data in the wind product are identical to those in the Level 1 product.

4.2. NWP collocation

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

NWP model sea surface temperature and land-sea mask data are used to provide information about possible ice or land presence in the WVCs. WVCs with a sea surface temperature below 272.16 K (-1.0 °C) are assumed to be covered with ice and no wind information is calculated. Land presence within each WVC is determined by using the land-sea mask available from the model data. The weighted mean value of the land fractions of all model grid points within 80 km of the WVC centre is calculated and if this mean value exceeds a threshold of 0.02, no wind retrieval is performed. Also the land fractions present in the beam information in the level 1b product are considered: if any land fraction in the fore, mid or aft beam exceeds 0.02, no wind retrieval is performed.

NWP forecast wind data are necessary in the ambiguity removal step of the processing. Wind forecasts are available twice a day (00 and 12 GMT analysis time) with forecast time steps of +3h, +6h, …, +36h. The model wind data are linearly interpolated with respect to time and location and put into the level 2 information part of each WVC (see section 6.2).

4.3. Validation

Each step in the processing is validated separately 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 [Ref-8]. Moreover, de Vries et al [Ref-10] describe subjective comparison of the 2D-VAR and PreScat schemes by routine operational meteorologists.

4.4. Quality control and monitoring

In each WVC, the σ_0 data is checked for quality and completeness and the inversion residual (see section 3.2.2) is checked. Degraded WVCs are flagged, see section 6.2 for more details.

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. These graphs are available on the KNMI website. Data quality is also available to the users within the products, see section 6 and 7 for a description of quality flags.

5. Dissemination

The ASCAT BUFR L2 products will be disseminated on EUMETCast. 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.

The products are also made available on a password-protected ftp site. This password is provided to new users by Email request. Please send your requests to scat@knmi.nl.

6. Data description

6.1. Wind product characteristics

Physical definition

Horizontal wind vector at 10m height.

Units and range

Wind speed is measured in m/s and wind direction in meteorological (WMO) convention relative to North: 0 degrees corresponds to a wind flowing to the South with a clockwise increment. The wind speed range is from 0-50 m/s, but wind speeds over 25 m/s are generally less reliable [Ref-6].

Input satellite data

ASCAT level 1b data from EUMETSAT are described in their technical documentation [Ref-11]. The global ASCAT data are acquired in Svalbard (Norway) and transmitted to the EUMETSAT central processing facilities in Darmstadt, where they are processed up to level 1b. Regional EARS data are acquired locally at various stations, transmitted to the EUMETSAT central processing facilities, processed up to level 1b and then transmitted to KNMI via a dedicated private network. The product contains geolocated measurement triplets on a satellite swath WVC grid of 25 km or 12.5 km size.

Geographical definition

The MetOp satellite flies in a near-polar sun synchronous orbit at 98 degrees inclination at approximately 800 km orbit height. The two satellite swaths are located to the left and to the right of the satellite ground track. The swath width is either 21 25-km size WVCs, corresponding to 525 km or 41 12.5-km size WVCs, corresponding to 512.5 km. Products are organised in messages of 42 or 82 WVCs, respectively (one row of data).

Coverage

The global OSI SAF product has a global coverage. For the regional EARS product, data is available only when the satellite is in sight of a ground station. Most ground stations are in the North Atlantic region. Actual coverage is available on the KNMI ASCAT product visualisation website (see http://www.knmi.nl/scatterometer/).

Output product

The input product in BUFR is processed into a BUFR output product including a unique wind solution (chosen), its corresponding ambiguous wind solution and quality information (distance to cone, quality flag). The 25-km cell spacing product contains two wind solutions, whereas the 12.5-km cell spacing product contains only one wind solution (the chosen one).

Delivery time

A wind product is available for distribution within 10 minutes after the input product reception at KNMI. For the global product, the delivery time between acquisition of the data and availability for the user ranges from 100 to 130 minutes. The regional product will be available within 30 minutes after data acquisition.

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-3]. The performance is pretty constant over the globe and depends mainly on the sub footprint wind variability. The performance of the products issued by KNMI is characterised by a wind component RMS error smaller than 2 m/s and a bias of less than 0.5 m/s in wind speed.

6.2. File formats

Wind products are in BUFR. A complete description of BUFR can be found in WMO publication No 306, Manual on Codes. The graphical displays of the wind products are available and explained on the web: see the links on http://www.knmi.nl/scatterometer/.

The file name convention for the Level 2 product is

acat_YYYYMMDD_HHMMSS_metopa_ORBIT_SRV_T_SMPL(_CONT).l2_bufr, where

- ascat denotes the instrument
- YYYYMMDD denotes the date of the first data in the file
- HHMMSS denotes the time (UTC) of the first data in the file
- metopa denotes the satellite name
- ORBIT is the orbit number (00000-99999)
- SRV is the service (eps for global OSI SAF or ear for regional EARS)
- T is the processing type (o for operational, t for test)
- SMPL is the WVC sampling (cell spacing): 250 or 125
- CONT (optional field) refers to the product contents: ovw for a product containing only Ocean Vector Winds and no soil moisture information, CONT is omitted if the product contains both winds and soil moisture.
- l2_bufr (l is the lowercase L) denotes Level 2 product in BUFR

Examples of file names are

ascat_20070213_021503_metopa_01653_eps_t_250.l2_bufr for a global test product containing soil moisture information, or

ascat_20070213_021503_metopa_01653_eps_o_125_ovw.l2_bufr for a regional operational product containing no soil moisture information.

The filename convention follows the EUMETSAT proposal as described in [Ref-12]. The wind product is stored in the BUFR format as proposed for ASCAT and described in [Ref-13], a list of descriptors (fields) contained in each WVC is provided in section 9.

The BUFR data contain three main sections: level 1 information (fields 1-62), level 2 Soil Moisture (SM) information (fields 63-82) and level 2 wind information (fields 83 and up). The L1 information is simply copied into the L2 data. Currently, the SM information is not provided in the wind product and the corresponding fields are set to missing values.

Field 84 (‘Generating Application’) contains the value 91 which means that first guess model winds are used for ambiguity removal. The interpolated model winds are in the fields 85-86.

The Wind Vector Cell Quality Flag (field 89, table 021155) has the following definitions:

Description	BUFR bit	Fortran bit
Not enough good sigma-0 available for wind retrieval	1	22
Poor azimuth diversity among sigma-0 for wind retrieval	2	21
Any beam noise content above threshold	3	20
Product monitoring not used	4	19
Product monitoring flag	5	18
KNMI quality control fails	6	17

Description	BUFR bit	Fortran bit
Variational quality control fails	7	16
Some portion of wind vector cell is over land	8	15
Some portion of wind vector cell is over ice	9	14
Wind inversion not successful for wind vector cell	10	13
Reported wind speed is greater than 30 m/s	11	12
Reported wind speed is less than or equal to 3 m/s	12	11
Rain flag for the wind vector cell is not usable	13	10
Rain flag algorithm detects rain	14	9
No meteorological background used	15	8
Data are redundant	16	7
Distance to GMF too large	17	6
Reserved	18-23	5-0
Missing value	All 24 set	All 24 set

In Fortran, if the Wind Vector Cell Quality is stored in an integer **I** then use **BTEST(I,NDW-NB-1)** to test BUFR bit **NB**, where **NDW**=24 is the width in bits of the data element in BUFR.

If the 'monitoring not used' bit (BUFR bit 4) is set to zero, the product is monitored. If the product is monitored and the 'monitoring flag' bit (BUFR bit 5) is set to zero, the product is valid; otherwise it is rejected by the monitoring, see section 7.2. The monitoring bits are set to the same value in all WVCs in one BUFR output file.

If the KNMI QC flag (BUFR bit 6) is set in a WVC this means that the backscatter information is of poor quality for various reasons, such as a too large inversion residual, or a too high noise value in the input product. WVCs, in which the KNMI 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 presence flag is set if a land fraction (see section 4.2) larger than zero is calculated for the WVC. As long as the land fraction is below the limit value, a reliable wind solution may however still be present.

Ice presence flag is set if the SST calculated for the WVC (see section 4.2) is below 272.16 (-1.0 °C).

If the variational QC flag is set, the wind vector in the WVC is rejected during ambiguity removal due to spatial inconsistency. A wind solution is present, but it may be suspect.

It is recommended not to use WVCs with the monitoring flag, the KNMI quality control flag or the variational quality control flag set. See section 7.2 for more information on product reliability.

The 'likelihood computed for solution' (descriptor 021104) actually contains the $\log_{10}$ of the calculated likelihood for the wind solution. This is done since otherwise values close to zero will be rounded to zero in the BUFR encoding. In order to recalculate the probability, the user should compute 10 to the power <value from BUFR>.

7. Data quality

7.1. Accuracy

As introduced in section 6.1, the accuracy should be better than 2 m/s in wind component RMS with a bias of less than 0.5 m/s in wind speed.

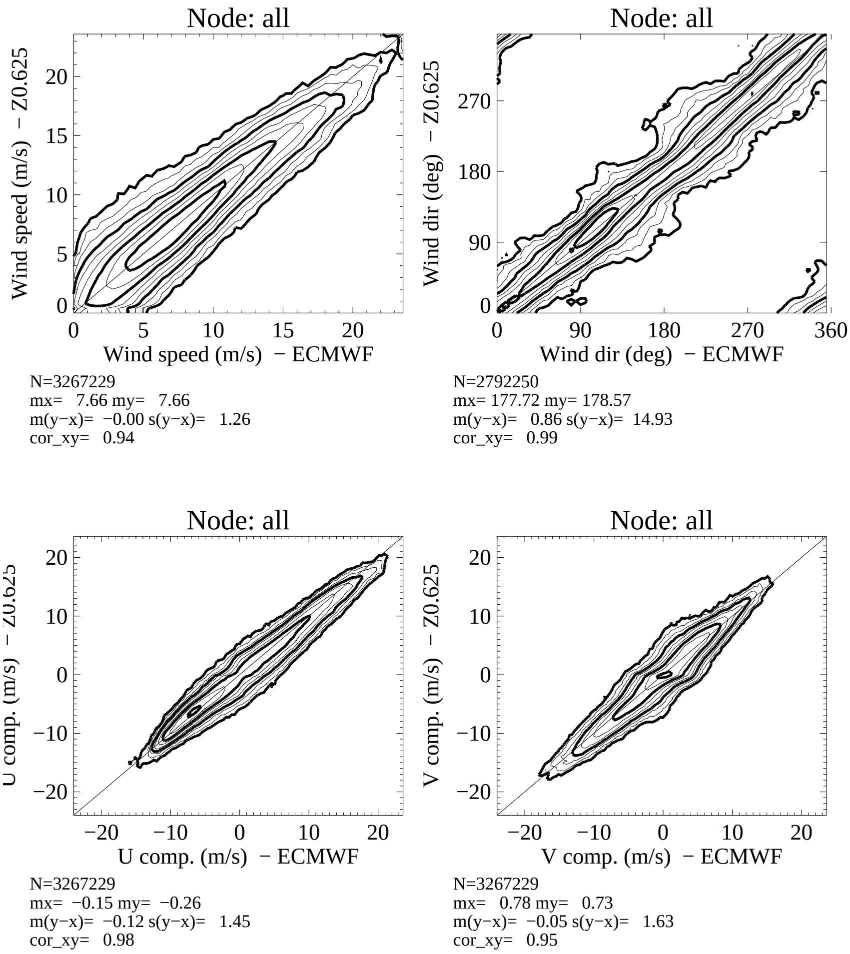

Figure 4: *Contoured histograms of the 25-km ASCAT wind product.*

Figure 4 shows two-dimensional histograms of the retrieved winds versus ECMWF 10m wind forecasts for the 25-km wind product, with the backscatter calibration (see section 4.1) applied. The data for these plots are from consecutive orbits from 23 August 2007 until 31 August 2007.

The top left plot corresponds to wind speed (bins of 0.4 m/s) and the top right plot to wind direction (bins of 2.5°). The latter are computed for ECMWF winds larger than 4 m/s. The bottom plots show the U and V wind component statistics. 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. Note that the data in the plots include WVCs that are quality controlled, i.e. have a too large inversion residual. This means that in the end product, the average quality will be even better, since WVCs of poor quality are flagged and can be filtered out.

7.2. Reliability and data use

For global coverage products, it is possible to generate a product monitoring flag, based on a multi-step check. If in one product the number of WVC Quality Control rejections, the mean residual, or the wind speed bias with respect to the NWP background is above certain threshold values, then the monitoring event flag is raised since the product is suspicious. The threshold values are based on evaluation of the product statistics over a long period [Ref-10]. Because of the granular nature of the EARS product, where files containing only a few minutes of data are generated and disseminated in real-time, this mechanism raises problems if there are not enough data in one pass for a statistically valid check. The multi-step monitoring check is sensitive to noise which is larger when mean values are calculated over fewer WVCs. If, accordingly, the thresholds are set high, many bad products will pass the check. On the other hand, if the threshold values are set too low, too many false alarms will be raised. This problem can be solved probably by evaluating not only the data of the last processed pass, but by evaluating the last 60 or 70 minutes of data present, although originating from typically 4 or 5 passes of 15 minutes. In case of instrument degradation or other problems, the monitoring event flag will be raised with some delay, inherent to the discontinuous nature of the data stream. Sensitivity tests will provide guidance on this issue. It is planned to implement the monitoring event flag in a future version of the global and regional products.

7.3. Ambiguity selection

A version of 2D-VAR is used with minimal regional performance differences [Ref-10]. This improved version was obtained after taking into account the findings of [Ref-8]. A variational QC step is performed to reject a few WVCs, which are in meteorological unbalance with their neighbours. The variational QC flagged WVCs are flagged in the output product.

8. Glossary

AR	Ambiguity Removal
ASCAT	Advanced Scatterometer
BUFR	Binary Universal Format Representation
EPS	Eumetsat Polar System
ERS	European Remote-Sensing Satellite
EUMETCast	EUMETSAT's Digital Video Broadcast Data Distribution System
HDF	Hierarchical Data Format
JPL	Jet Propulsion Laboratory (NASA)
KNMI	Royal Netherlands Meteorological Institute
MetOp	Meteorological Operational satellite
NASA	National (US) Air and Space Agency
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
RMDCN	Regional Meteorological Data Communication Network
SAF	Satellite Application Facility
SeaWinds	US scatterometer on-board QuikSCAT platform
SM	Soil Moisture
SOS	Scatterometer Ocean Stress
SST	Sea Surface Temperature
SVVP	Software Verification and Validation Plan
U	West-to-east wind component
V	South-to-north wind component
WVC	Wind Vector Cell

9. ASCAT BUFR data descriptors

Number	Descriptor	Parameter	Unit
1	001033	Identification Of Originating/Generating Centre	Code Table
2	001034	Identification Of Originating/Generating Sub-Centre	Code Table
3	025060	Software Identification	Numeric
4	001007	Satellite Identifier	Code Table
5	002019	Satellite Instruments	Code Table
6	001012	Direction Of Motion Of Moving Observing Platform	Degree True
7	004001	Year	Year
8	004002	Month	Month
9	004003	Day	Day
10	004004	Hour	Hour
11	004005	Minute	Minute
12	004006	Second	Second
13	005001	Latitude (High Accuracy)	Degree
14	006001	Longitude (High Accuracy)	Degree
15	005033	Pixel Size On Horizontal-1	M
16	005040	Orbit Number	Numeric
17	006034	Cross Track Cell Number	Numeric
18	010095	Height Of Atmosphere Used	m
19	021157	Loss Per Unit Length Of Atmosphere Used	dB/m
20	021150	Beam Collocation	Flag Table
21	008085	Beam Identifier	Code Table
22	002111	Radar Incidence Angle	Degree
23	002134	Antenna Beam Azimuth	Degree
24	021062	Backscatter	dB
25	021063	Radiometric Resolution (Noise Value)	%
26	021158	ASCAT Kp Estimate Quality	Code Table
27	021159	ASCAT Sigma-0 Usability	Code Table
28	021160	ASCAT Use Of Synthetic Data	Numeric
29	021161	ASCAT Synthetic Data Quality	Numeric
30	021162	ASCAT Satellite Orbit And Attitude Quality	Numeric
31	021163	ASCAT Solar Array Reflection Contamination	Numeric
32	021164	ASCAT Telemetry Presence And Quality	Numeric
33	021165	ASCAT Extrapolated Reference Function	Numeric
34	021166	ASCAT Land Fraction	Numeric
35	008085	Beam Identifier	Code Table
36	002111	Radar Incidence Angle	Degree
37	002134	Antenna Beam Azimuth	Degree
38	021062	Backscatter	dB
39	021063	Radiometric Resolution (Noise Value)	%
40	021158	ASCAT Kp Estimate Quality	Code Table
41	021159	ASCAT Sigma-0 Usability	Code Table
42	021160	ASCAT Use Of Synthetic Data	Numeric
43	021161	ASCAT Synthetic Data Quality	Numeric
44	021162	ASCAT Satellite Orbit And Attitude Quality	Numeric
45	021163	ASCAT Solar Array Reflection Contamination	Numeric
46	021164	ASCAT Telemetry Presence And Quality	Numeric
47	021165	ASCAT Extrapolated Reference Function	Numeric
48	021166	ASCAT Land Fraction	Numeric
49	008085	Beam Identifier	Code Table
50	002111	Radar Incidence Angle	Degree
51	002134	Antenna Beam Azimuth	Degree

Number	Descriptor	Parameter	Unit
52	021062	Backscatter	dB
53	021063	Radiometric Resolution (Noise Value)	%
54	021158	ASCAT Kp Estimate Quality	Code Table
55	021159	ASCAT Sigma-0 Usability	Code Table
56	021160	ASCAT Use Of Synthetic Data	Numeric
57	021161	ASCAT Synthetic Data Quality	Numeric
58	021162	ASCAT Satellite Orbit And Attitude Quality	Numeric
59	021163	ASCAT Solar Array Reflection Contamination	Numeric
60	021164	ASCAT Telemetry Presence And Quality	Numeric
61	021165	ASCAT Extrapolated Reference Function	Numeric
62	021166	ASCAT Land Fraction	Numeric
63	025060	Software Identification	Numeric
64	025062	Database Identification	Numeric
65	040001	Surface Soil Moisture (Ms)	%
66	040002	Estimated Error In Surface Soil Moisture	%
67	021062	Backscatter	dB
68	021151	Estimated Error In Sigma0 At 40 Deg Incidence Angle	dB
69	021152	Slope At 40 Deg Incidence Angle	dB/Degree
70	021153	Estimated Error In Slope At 40 Deg Incidence Angle	dB/Degree
71	021154	Soil Moisture Sensitivity	dB
72	021062	Backscatter	dB
73	021088	Wet Backscatter	dB
74	040003	Mean Surface Soil Moisture	Numeric
75	040004	Rain Fall Detection	Numeric
76	040005	Soil Moisture Correction Flag	Flag Table
77	040006	Soil Moisture Processing Flag	Flag Table
78	040007	Soil Moisture Quality	%
79	020065	Snow Cover	%
80	040008	Frozen Land Surface Fraction	%
81	040009	Inundation And Wetland Fraction	%
82	040010	Topographic Complexity	%
83	025060	Software Identification	Numeric
84	001032	Generating Application	Code Table
85	011082	Model Wind Speed At 10 m	m/s
86	011081	Model Wind Direction At 10 m	Degree True
87	020095	Ice Probability	Numeric
88	020096	Ice Age (A-Parameter)	dB
89	021155	Wind Vector Cell Quality	Flag Table
90	021101	Number Of Vector Ambiguities	Numeric
91	021102	Index Of Selected Wind Vector	Numeric
92	031001	Delayed Descriptor Replication Factor	Numeric
93	011012	Wind Speed At 10 m	m/s
94	011011	Wind Direction At 10 m	Degree True
95	021156	Backscatter Distance	Numeric
96	021104	Likelihood Computed For Solution	Numeric
97	011012	Wind Speed At 10 m	m/s
98	011011	Wind Direction At 10 m	Degree True
99	021156	Backscatter Distance	Numeric
100	021104	Likelihood Computed For Solution	Numeric

Note that descriptor numbers 93-96 can be repeated 1 to 144 times, depending on the value of the Delayed Descriptor Replication Factor (descriptor number 92)