Ocean and Sea Ice SAF

EUMETSAT Advanced Retransmission Service

ASCAT Wind Product User Manual

Global OSI SAF 25 km wind product (OSI-102 and OSI-102-b)

Global OSI SAF 12.5 km wind product (OSI-103 - discontinued)

Global OSI SAF coastal wind product (OSI-104 and OSI-104-b)

Regional EARS 25 km wind product

Regional EARS coastal wind product

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1.5	Nov 2008	AV	Change to neutral winds
1.6	Jan 2009	AV	Comments of 12.5-km DRI included
1.7	Aug 2009	AV	NetCDF product format included
1.8	Jan 2010	AV	Editorial changes, included section 1.7.
1.9	Feb 2011	AV	Included coastal product and changes for merging of soil moisture and winds
1.10	Aug 2011	AV	Some editorial changes
1.11	Feb 2012	AV	Changes for timeliness and EARS coverage
1.12	Aug 2012	AV	Implementation of Bayesian ice screening
1.13	May 2013	AV	Removed information which is now in the ATBD; include Metop-B; include comments from Metop-B ORR
1.14	Mar 2016	AV	Discontinuation of 12.5 km Hamming filter products
1.15	May 2018	AV	Change to CMOD7 and stress-equivalent model winds

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1. Introduction

1.1. Overview

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

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 wind processing is carried out. This document is the Product User Manual to the ASCAT wind products. Quality monitoring information on this product and more general information on the whole OSI SAF project, is available on the OSI SAF web site: http://osi-saf.eumetsat.int/. 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.

The wind products are distributed in two resolutions: a 50-km resolution product with 25-km cell spacing and a 25-km resolution coastal product with 12.5-km cell spacing. In the coastal products the individual backscatter observations are not averaged using a Hamming spatial filtering (like in the 25 km grid spacing product) but using a boxcar filtering. The boxcar spatial filtering yields comparable wind characteristics in full sea regions and additionally more wind data closer to the coast. Both resolutions are available as a regional (mainly covering the Northern Hemisphere) EARS product with a timeliness of approximately 25 minutes from sensing time and as a global OSI SAF product with a timeliness of approximately 1.5-2 hours from sensing time. A global 12.5-km Hamming filter product was available for Metop-A only and it was discontinued in April 2015.

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. This is extensively described in the Algorithm Theoretical Basis Document; see [3].

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, ASCAT, OSCAT and RapidScat scatterometers. Scatterometer processing software is distributed through the EUMETSAT Numerical Weather Prediction Satellite Application Facility (NWP SAF) website, whereas wind processing is performed 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-A and Metop-B satellites through EUMETCast (global data) and through a private network (regional data). These products are used as basis for further processing at KNMI.

The OSI SAF and EARS 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 OSI SAF and EARS products based on the ASCAT scatterometer. Section 2 presents a brief description of the ASCAT instrument and section 3 gives an overview of the data processing configuration. Section 4 provides details on how to access the products. Detailed information on the file content and format is given in section 5, while in section 6 the product quality is elaborated.

This manual covers the following products:

- OSI SAF ASCAT 25-km wind product (OSI-102, OSI-102-b, acronym ASCAT25).
- OSI SAF ASCAT 12.5-km wind product (OSI-103, acronym ASCAT12), for Metop-A only, discontinued in April 2015, but still available from archive.
- OSI SAF ASCAT 12.5-km coastal wind product (OSI-104, OSI-104-b, acronym ASCAT12+)
- EARS ASCAT 25-km wind product (acronym EARS-ASCAT-25)
- EARS ASCAT 12.5-km coastal wind product (acronym EARS-ASCAT-12).

Products OSI-102/OSI-102-b and OSI-103 also contain soil moisture information over land, the coastal and EARS products do not contain soil moisture information.

1.2. Disclaimer

The OSI SAF and EUMETSAT are much interested in receiving your feedback, would appreciate your acknowledgment in using and publishing about the data, and we like to receive a copy of any publication about the application of the data. Your feedback, e.g., directed to scat@knmi.nl, helps us in maintaining the resources for the OSI SAF wind services.

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_osi_co_prod/,
http://www.knmi.nl/scatterometer/ascat_ear_25_prod/,
http://www.knmi.nl/scatterometer/ascat_ear_12_prod/,
http://www.knmi.nl/scatterometer/ascat_b_osi_25_prod/,
http://www.knmi.nl/scatterometer/ascat_b_osi_co_prod/,
http://www.knmi.nl/scatterometer/ascat_b_ear_25_prod/,
http://www.knmi.nl/scatterometer/ascat_b_ear_co_prod/

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

OSI SAF wind product documentation on http://osi-saf.eumetsat.int/

NWP SAF website: http://nwp-saf.eumetsat.int/

EUMETSAT ASCAT documentation (including ASCAT product guide): http://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Metop/MetopDesign/ASCAT/index.html

1.4. Limitations of the ASCAT winds

The following restrictions and limitations hold:

1) The backscatter data and noise values (K_p) in the coastal product are computed as part of the level 2 wind processing and they are not scientifically validated, other than by validation of the wind retrieval properties in the coastal products.

These restrictions and limitations are subject to further study.

1.5. History of product changes

Here is an historical overview of the changes in the ASCAT wind products:

28-Mar-2007	OSI SAF ASCAT 25-km demonstration wind product available on EUMETCast. ASCAT Wind Data Processor software version is 1_0i.
23-May-2007	Processing transferred to operational KNMI server.
10-Oct-2007	AWDP version 1_0k: adapted to the improved calibration of the Level 1 product. Wind product status is pre-operational now.
12-Dec-2007	AWDP version 1_0l: OSI SAF ASCAT 25-km winds are available on the GTS.
18-Mar-2008	AWDP version 1_0_13: adapted to the three-transponder calibration of the Level 1 product.
20-Nov-2008	AWDP version 1_0_15: change to neutral winds (0.2 m/s added to the wind speeds) and improved calibration of the level 1 product (activated at 2 December).
03-Dec-2008	OSI SAF ASCAT 25-km wind product has the operational status.
11-Dec-2008	EARS ASCAT 25-km and 12.5-km winds are available to all users.
03-Mar-2009	OSI SAF ASCAT 12.5-km wind product is available with the operational status.
21-Apr-2009	AWDP version 1_0_17: upgrades in BUFR encoding.
01-Sep-2009	AWDP version 1_0_18: wind products are available in NetCDF now on the KNMI FTP server.
08-Sep-2009	EARS ASCAT data are available on the GTS.
12-Jan-2010	AWDP version 1_0_19: products in BUFR Edition 4 and up to four wind solutions present in 25-km BUFR products.
02-Feb-2010	OSI-SAF products disseminated on EUMETCast are also available to users in Africa and the Americas now.
28-Feb-2011	Both wind and soil moisture information are available in a multi-parameter BUFR product.

16-Aug-2011	AWDP version 2_1_00: up to four wind solutions present in the 12.5-km and coastal BUFR products, use of NWP Ocean Calibration for more uniform wind characteristics across the swath.
23-Aug-2011	AHRPT data from a number of ground stations are now available in addition to the EARS ASCAT data acquired at Svalbard.
18-Sep-2012	Implementation of Bayesian ice screening.
14-Nov-2012	First development version of ASCAT-B 25-km and coastal global wind products. AWDP version is 2_1_01.
14-May-2013	AWDP version 2_2_00: preparation for level 1b data format change.
19-Jun-2013	AWDP version 2_2_01: preparation for ASCAT-B backscatter calibration change.
12-Feb-2014	AWDP version 2_3_00: preparation for change of Metop-A level 1 calibration (activated at 12 March).
28-Apr-2015	The Metop-A global 12.5-km wind product was discontinued.
29-Mar-2016	The EARS 12.5-km wind products have been replaced by 12.5-km coastal wind products. ASCAT-A backscatter data correction to compensate for the instrument anomalies that occurred in autumn 2014.
25-Sep-2018	Introduction of CMOD-7 Geophysical Model Function and stress-equivalent background model winds.

2. The ASCAT scatterometer

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, Metop-B was launched on 17 September 2012. Metop-C is planned to be launched in autumn 2018.

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 approximately 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, i.e. each swath is divided into 21 or 41 so-called Wind Vector Cells (WVCs). This brings the effective swath width to 525 km (21x25) or 512.5 km (41x12.5) for the 25-km and 12.5-km products, respectively. For the left and right swaths together, this results in 42 WVCs per row for 25-km and 82 WVCs per row for 12.5-km products. For each WVC, we obtain three independent backscatter measurements 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.

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

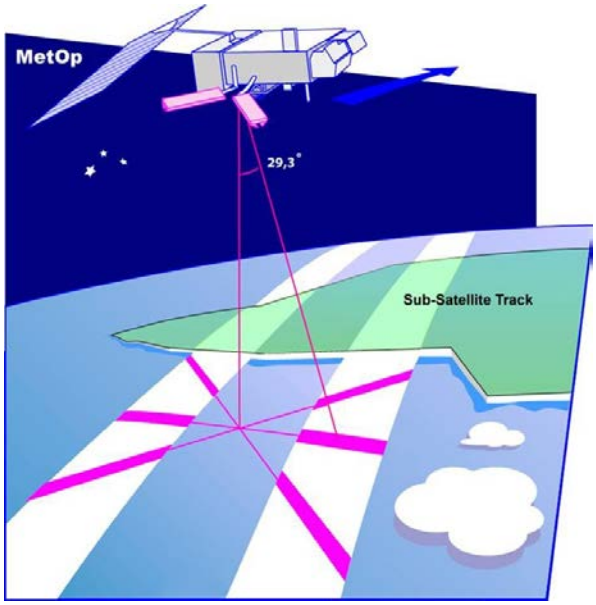

Figure 1: ASCAT wind scatterometer geometry (source: EUMETSAT web site).

3. Processing scheme

KNMI has a processing chain running in near real-time with ASCAT data, including wind maps displayed on the OSI SAF web site. This processor is based on the OSI SAF ASCAT Wind Data Processor (AWDP) software and runs in the KNMI operational environment. The processing includes monitoring and archiving functionalities. A brief overview of the modules of the ASCAT scatterometer processor is given below. General information about the scatterometer wind processing algorithms can be found in the ATBD [3]. The products are distributed through several means (e.g., FTP, EUMETCast, see section 4) and the software packages are available on the NWP SAF software portal.

3.1. Backscatter slice averaging

In this step, which is performed only for the coastal product, the full resolution ASCAT level 1 product is used to re-compute backscatter values (σ^0s) in the Wind Vector Cells. The full resolution backscatter data are averaged using a spatial box filter rather than the Hamming filter that is used in the spatial averaging of the σ^0s of the nominal level 1 products. All full resolution σ^0s within 15 km from the Wind Vector Cell centre are used in the averaging [4]. Also the time difference between the Wind Vector Cell time and the full resolution data acquisition time is considered to prevent mixing up of data from different orbits which may be close to the same location. Moreover, in Wind Vector Cells close to the coast, only those full resolution σ^0s are used that are entirely over sea. As the position of the averaged σ^0 is an averaged value of the positions of the full resolution σ^0s, the coastal Wind Vector Cell is slightly displaced away from the coast. On the other hand, it is possible to compute winds as close as ~15 km from the coast, while in the nominal 12.5-km product, Wind Vector Cells closer than ~35 km from the coast are flagged because of land contamination. See [4] for more information on the coastal product.

3.2. Backscatter calibration

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 [5] and [6]. 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.

3.3. NWP collocation

KNMI receives NWP model data from ECMWF twice a day through the Regional Meteorological Data Communication Network (RMDCN).

NWP model sea surface temperature (SST) data are used to support the Bayesian sea ice discrimination [3]. The SST values of the four surrounding model grid points around the WVC location are bi-linearly interpolated. Note that the ECMWF model data do not contain SST values over land; if one or more of the four surrounding grid points has missing SST data, the SST value of the grid point closest to the WVC is taken. WVCs with a sea surface temperature above 5 °C are assumed to be always open water. The Bayesian ice screening procedure may sometimes assign rainy WVCs erroneous as ice; using the extra SST criterion, WVCs in areas warmer than 5 °C will never be labelled as ice. Due to its rather ‘warm’ threshold value, the NWP-based SST ice screening will only be active in regions far away from the ice extents.

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. The weight of each grid point scales with $1/r^2$, where r is the distance between the WVC centre and the model grid point. If this mean land fraction 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 hourly forecast time steps of +3h, +4h, +5h, …, +30h. The model wind data are quadratically interpolated with respect to time and bi-linearly interpolated with respect to location and put into the level 2 information part of each WVC (see section 5.2). The ECMWF winds stored in the wind products are stress-equivalent winds [8] which have been computed from the equivalent neutral model winds.

3.4. Quality control and monitoring

In each WVC, the σ^0 data is checked for quality and completeness and the inversion residual [3], called MLE, is checked. Degraded WVCs are flagged; see section 5.2 for more details.

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 have been produced to visually display the confidence levels of the products and their evolution with time. Any deviations from nominal behaviour would be immediately visible as steps in these graphs. Data and overall product quality is also available to the users within the products; see section 5 for a description of quality flags.

4. Helpdesk and data availability

For a swift response management procedure, user requests on the OSI SAF data products should be issued at the Ocean and Sea Ice SAF website (http://osi-saf.eumetsat.int/). User requests on the EARS products can be sent to scat@knmi.nl. User requests on the Soil Moisture content in the products can be sent to ops@eumetsat.int.

The ASCAT BUFR L2 products are 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, or contact ops@eumetsat.int.

The BUFR and NetCDF products are also made available on a password-protected ftp site (data from the last three days only). The access details are provided to new users by email request. Please send your requests to scat@knmi.nl.

The Metop-A ASCAT 25-km global winds in BUFR format are disseminated on the GTS. The messages are distributed to the Exeter node and can be identified by: header (T1T2A1A2ii) = ISXX[01-06]; CCCC = EHDB. The coastal winds are available on the GTS with identification header (T1T2A1A2ii) = ISXX[11-16]; CCCC = EHDB. The EARS Metop-A ASCAT winds are also available on the GTS with identification header (T1T2A1A2ii) = ISXN[01-06]; CCCC = EHDB (25-km winds) and header (T1T2A1A2ii) = ISXN[11-16]; CCCC = EHDB (coastal winds).

A BUFR reader is available at www.knmi.nl/scatterometer/bufr_reader/.

The OSI SAF ASCAT data are archived in the EUMETSAT Data Centre Archive, see http://www.eumetsat.int/Home/Main/DataAccess/EUMETSATDataCentre/index.htm?l=en (BUFR and NetCDF). For data not (yet) present in the EUMETSAT Data Centre, KNMI also keeps an off line archive of the global products. You can send a request to scat@knmi.nl.

The OSI SAF ASCAT data in NetCDF are also archived in the NASA Physical Oceanography Distributed Active Archive Center (PO.DAAC) archive, see http://podaac.jpl.nasa.gov/datasetlist?ids=Sensor&values=ASCAT&search=.

The ASCAT 25-km global winds can be explored through the Enhanced Satellite Archive Dataminer Naiad: http://www.naiad.fr/

5. Data description

5.1. Wind product characteristics

5.1.1. Physical definition

Horizontal stress-equivalent wind vector at 10 m height, obtained using the CMOD7 GMF, see [3] [8].

5.1.2. Units and range

Wind speed is measured in m/s. The wind speed range is from 0-50 m/s, but wind speeds exceeding 25 m/s are generally less reliable [3]. In the BUFR products, the wind direction is in *meteorological* (World Meteorological Organisation, 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.

5.1.3. Input satellite data

The generation of ASCAT level 1b data by EUMETSAT is described in their technical documentation [9]. 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 at Svalbard and other ground stations, processed up to level 1b and then transmitted to KNMI via a dedicated private network. The product contains geo-located measurement triplets on a satellite swath WVC grid of 25 km or 12.5 km size.

5.1.4. Geographical definition

The Metop satellites fly 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 rows of 42 or 82 WVCs, respectively.

5.1.5. Coverage

The OSI SAF products have global coverage. For the ascending Metop-A tracks, the EARS data correspond to the last 30 minutes of the X-band data dump when the satellite passes the Svalbard ground station. For the descending tracks, also AHRPT data from several ground stations are used, adding coverage in the European seas and Atlantic and Indian oceans. For Metop-B, only AHRPT data are used. An up-to-date list of ground stations in use is available on http://www.eumetsat.int/Home/Main/Satellites/GroundNetwork/EARSSystem/EARS-ASCAT/index.htm?l=en. Actual wind coverage is available on the OSI SAF and EARS ASCAT product visualisation websites (see http://www.knmi.nl/scatterometer/).

5.1.6. Output product

The input product is processed into a BUFR output product including a unique wind solution (chosen), its corresponding ambiguous wind solutions and quality information (distance to cone, quality flag). The products contain up to four wind solutions. See section 9 for an overview of the used descriptors in the BUFR data format. The products are also available in NetCDF format; see section 10 for more details.

5.1.7. 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 40 to 120 minutes. The regional product is available within 25 minutes after data acquisition. Timeliness statistics are available on the product visualisation websites, after clicking on the 'Monitoring information' link.

5.1.8. 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, 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 [10]. The performance is pretty constant over the globe and depends mainly on the sub footprint wind variability. According to the OSI SAF product requirements [2], the accuracy should be better than 2 m/s in wind component standard deviation with a bias of less than 0.5 m/s in wind speed. More validation information is available in [7], showing that the actual product accuracy well exceeds the requirements.

5.2. File formats

Wind products are in BUFR Edition 4 or in NetCDF format. A complete description of BUFR can be found in WMO publication No 306, Manual on Codes. A list of descriptors (fields) contained in each WVC is provided in section 9. The NetCDF format is described in section 10.

5.2.1. File name conventions

The file name convention for the Level 2 BUFR product is

ascat_YYYYMMDD_HHMMSS_SAT_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
- SAT denotes the satellite name: 'metopa' or 'metopb'
- 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): it contains '250' or '125', or 'coa' for the coastal product which has a WVC spacing of 12.5 km, as well.
- CONT (optional field) refers to the product contents: it contains '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_ear_o_coa_ovw.l2_bufr for a regional operational product containing no soil moisture information.

The wind product is stored in the BUFR format as proposed for ASCAT and described in the WMO Manual on Codes, a list of descriptors (fields) contained in each WVC is provided in section 9.

The NetCDF data have almost the same file name convention as the BUFR data, only the part 'l2_bufr' is replaced by '.l2.nc', for example:

ascat_20070213_021503_metopa_01653_eps_o_250_ovw.l2.nc

5.2.2. File contents

The BUFR data contain three main sections: level 1 information (fields 1-62), level 2 Soil Moisture information (fields 63-82) and level 2 wind information (fields 83 and up). The L1 information is simply copied into the L2 data, except for the coastal product, where the backscatter data are recalculated based on the data in the ASCAT full resolution level 1 product [4]. More information on the L1 data can be found in the EUMETSAT ASCAT Product Guide, see the link in section 1.3. The Soil Moisture data are produced by and under the responsibility of the EUMETSAT central facilities. The coastal product does not contain Soil Moisture information since it contains recalculated backscatter information which is not input to the Soil Moisture computations. In this way, inconsistency between the backscatter data and Soil Moisture in one product is avoided.

Field 2 ('Identification of originating/generating sub-centre') is set to 0 for OSI SAF products. For EARS products, a value of 1 refers to X-band data dumps from Svalbard, whereas other values refer to AHRPT ground stations. For a list of ground stations, see http://www.eumetsat.int/website/home/Data/RegionalDataServiceEARS/EARSASCAT/index.html.

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**
Reserved	1	23
Not enough good sigma-0 available for wind retrieval	2	22
Poor azimuth diversity among sigma-0 for wind retrieval	3	21
Any beam noise content above threshold	4	20
Product monitoring not used	5	19
Product monitoring flag	6	18
KNMI Quality Control data rejection	7	17
Variational Quality Control data rejection	8	16
Some portion of wind vector cell is over land	9	15
Some portion of wind vector cell is over ice	10	14

Description	BUFR bit	Fortran bit
Wind inversion not successful for wind vector cell	11	13
Reported wind speed is greater than 30 m/s	12	12
Reported wind speed is less than or equal to 3 m/s	13	11
Not used	14	10
Not used	15	9
No meteorological background used	16	8
Data are redundant	17	7
Distance to GMF too large	18	6
Reserved	19-23	5-1
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)** to test BUFR bit **NB**, where **NDW**=24 is the width in bits of the data element in BUFR. The **BTEST** function is equivalent to **(I/2^NF) modulo 2** where **NF** is the Fortran bit number.

If the 'product monitoring not used' bit, Fortran bit 19, is set to zero, the product is monitored. If the product is monitored and the 'product monitoring flag' bit, Fortran bit 18, is set to zero, the product is valid; otherwise it is rejected by the monitoring, see [3]. The monitoring bits are set to the same value in all WVCs in one BUFR output file.

If the KNMI QC flag, Fortran bit 17, is set in a WVC this means that the backscatter information is of poor usability 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, Fortran bit 15, is set if a land fraction (see section 3.3) 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 so there is normally no reason to reject WVCs with the land flag set.

Ice presence flag, Fortran bit 14, is set if the Bayesian sea ice screening algorithm calculates ice for the WVC (see [3]). Note that the products contain wind solutions also over sea ice regions. These bogus winds are flagged both by the KNMI quality control flag and by the ice flag. Hence it is important to reject any winds with the KNMI quality control flag set when ingesting the products. Note that WVCs that are rejected due to a large inversion residual (e.g., in case of rain), only have the KNMI quality control flag set. On the other hand, WVCs that are rejected due to sea ice, have both the KNMI quality control flag and the ice flag set.

If the variational QC flag, Fortran bit 16, 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.

The redundancy flag, Fortran bit 7, is set when a specific WVC has been sent out before. This is the case for WVCs which are present both in the regional EARS data stream and in the global OSI SAF

data stream. In most cases, the EARS wind vector cell will be sent out earlier than the corresponding OSI SAF wind vector cell and in such cases the redundancy flag will be set in the OSI SAF wind vector cell. Note that the OSI SAF global products still have full coverage and users not ingesting EARS-ASCAT winds can simply ignore the redundancy flag. On the other hand, users who use both data streams can simply filter out any duplicate wind vector cells by evaluating the redundancy flag.

It is recommended not to use WVCs with the product monitoring flag, the KNMI quality control flag or the variational quality control flag set. See [3] 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>.

Contrary to the BUFR products, the NetCDF data do not contain backscatter information but only the level 2 wind (selected wind solution only) and sea ice information. They are intended to be an easy to handle wind-only product, see section 10.

6. Data quality

As stated in the OSI SAF product requirements [2], the accuracy should be better than 2 m/s in wind component standard deviation with a bias of less than 0.5 m/s in wind speed.

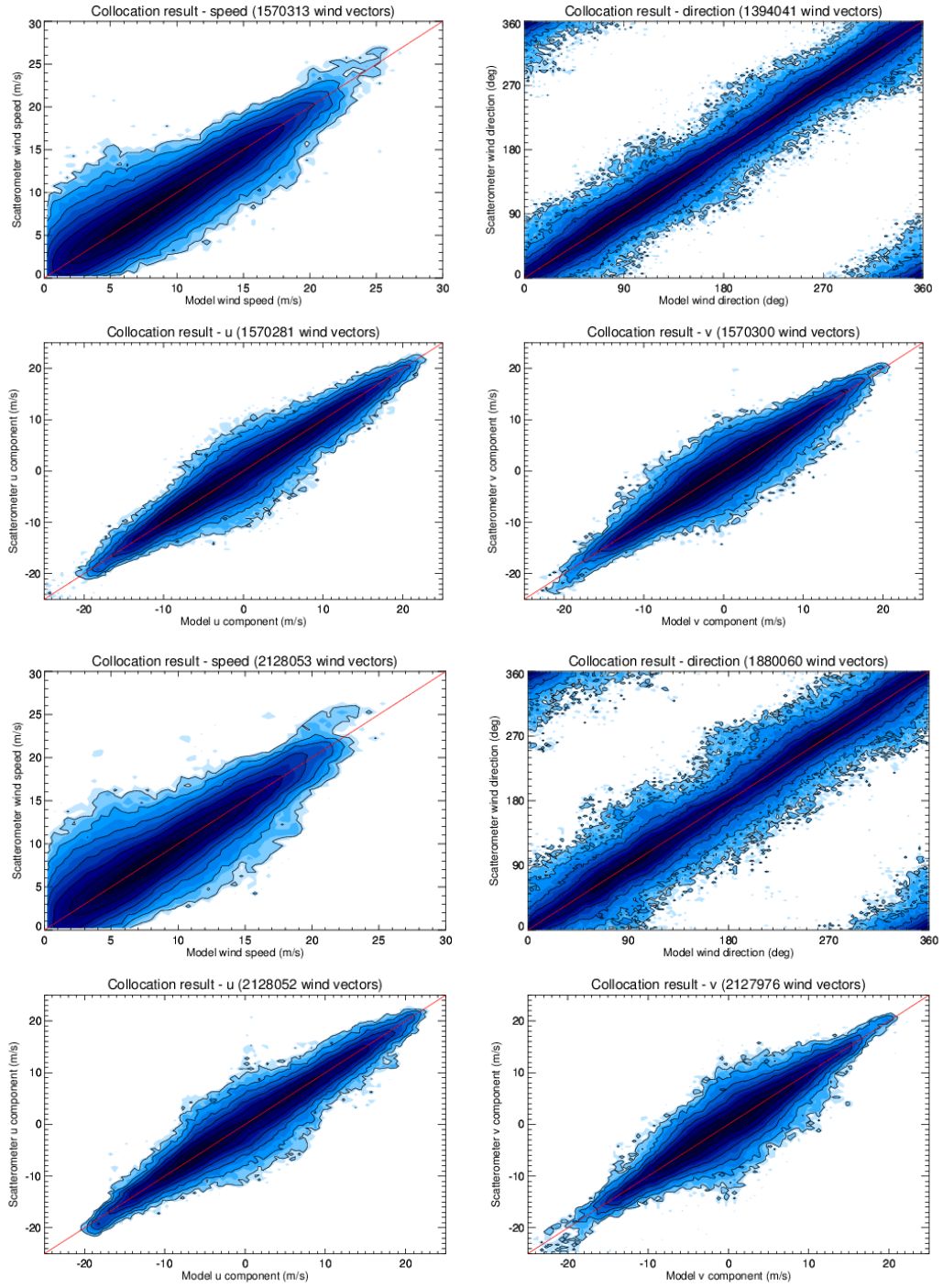

Figure 2: Two-dimensional scatter density plots of wind speed, direction (w.r.t. wind coming from the North), u and v components of 25 km (top, 1-3 March 2017) and 12.5 km (bottom, 1 March 2017) Metop-B ASCAT wind product versus the ECMWF model forecast winds.

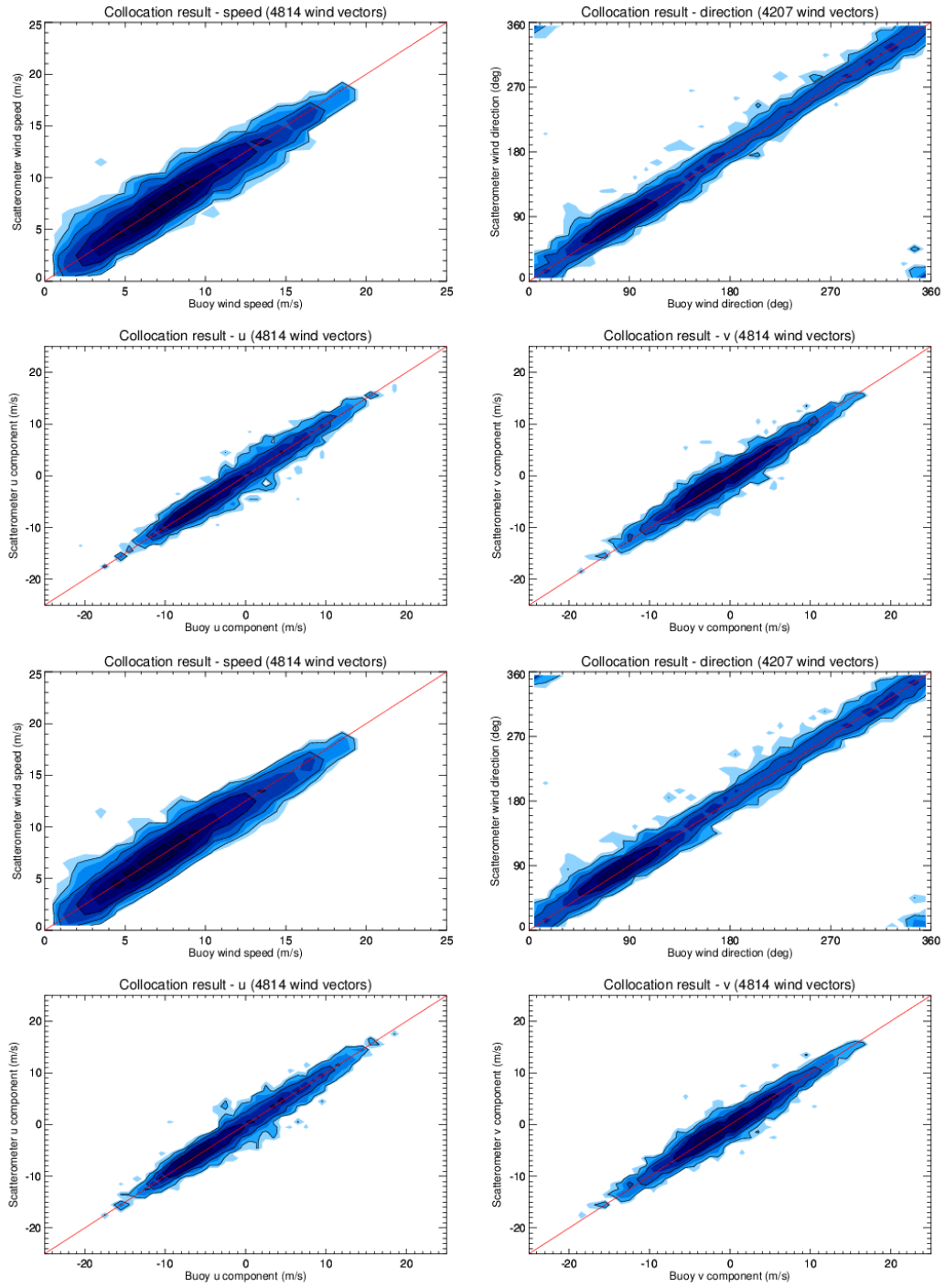

Figure 3: Two-dimensional scatter density plots of wind speed, direction (w.r.t. wind coming from the North), u and v components of 25 km (top) and 12.5 km (bottom) Metop-B ASCAT wind product versus moored buoy winds from January – March 2017.

Figure 2 shows two-dimensional scatter density plots of the retrieved winds from Metop-B versus ECMWF 10 m stress-equivalent background winds for the 25 km and 12.5 km wind products, after rejection of Quality Controlled (KNMI QC flagged) wind vectors. The top left plot in each panel corresponds to wind speed (bins of 0.5 m/s) and the top right plot to wind direction (bins of 2.5°). The latter are computed for only ECMWF winds larger than 4 m/s. The bottom plots show the *u* and *v* wind

component statistics (bins of 0.5 m/s). The contour lines are in logarithmic scale. Metop-A statistics are not shown here, but they resemble the Metop-B statistics very closely.

From these results, it is clear that the spread in the distributions is small. The wind speed bias is 0.00 m/s for 25 km and 0.02 m/s for 12.5 km, close to zero. The wind component standard deviations of the differences are around 1.4 m/s for the 25 km product and around 1.5 m/s for the 12.5 km product.

Figure 3 shows the results of collocations of ASCAT winds from Metop-B with winds from moored buoys. These results cover the period of January to March 2017 (3 months). For more details about the collocation method, please see [7]. We find a wind speed bias of 0.07 m/s for 25 km and 0.04 m/s for 12.5 km. Standard deviations of *u* and *v* wind components are 1.72 m/s and 1.78 m/s for 25 km and 1.71 m/s and 1.78 m/s for 12.5 km, respectively. These figures are all well within the OSI SAF requirements.

More validation information can be found in [7].

7. References

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8. Abbreviations and acronyms

2DVAR	Two-dimensional Variational Ambiguity Removal
AR	Ambiguity Removal
ASCAT	Advanced Scatterometer
ATBD	Algorithm Theoretical Basis Document
BUFR	Binary Universal Format Representation
DLI	Downward Long wave Irradiance
EARS	EUMETSAT Advanced Retransmission Service
ECMWF	European Centre for Medium-Range Weather Forecasts
EPS	EUMETSAT Polar System
ERS	European Remote-Sensing Satellite
EUMETCast	EUMETSAT's Digital Video Broadcast Data Distribution System
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GMF	Geophysical Model Function
HDF	Hierarchical Data Format
JPL	Jet Propulsion Laboratory (NASA)
KNMI	Royal Netherlands Meteorological Institute
Metop	Meteorological operational satellite
MLE	Maximum Likelihood Estimator
NASA	National Aeronautics and Space Administration (USA)
NetCDF	Network Common Data Form
NSCAT	NASA Scatterometer
NWP	Numerical Weather Prediction
OSCAT	Scatterometer on-board the Oceansat-2 and ScatSat-1 satellites (India)
OSI SAF	Ocean and Sea Ice SAF
QC	Quality Control
QuikSCAT	US Quick Scatterometer mission carrying the SeaWinds scatterometer
RMDCN	Regional Meteorological Data Communication Network
SAF	Satellite Application Facility
SeaWinds	Scatterometer on-board QuikSCAT platform (USA)
SM	Soil Moisture
SSI	Surface Solar Irradiance
SST	Sea Surface Temperature

u	West-to-east (zonal) wind component
v	South-to-north (meridional) wind component
WMO	World Meteorological Organisation
WVC	Wind Vector Cell

9. Appendix A: 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

Number	Descriptor	Parameter	Unit
48	021166	ASCAT Land Fraction	Numeric
49	008085	Beam Identifier	Code Table
50	002111	Radar Incidence Angle	Degree
51	002134	Antenna Beam Azimuth	Degree
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

Number	Descriptor	Parameter	Unit
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)

10. Appendix B: NetCDF data format

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

- The data are organised in full orbits rather than in 3-minute granules.
- The data format meets the NetCDF Climate and Forecast Metadata Convention version 1.6 (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 identical for ASCAT, SeaWinds, OSCAT and any other scatterometer data.
- The data has file sizes comparable to those of the corresponding BUFR data (e.g., one orbit of ASCAT 25-km wind data is 2.6 MB in BUFR and 2.2 MB in NetCDF). When compressed with gzip, the size of one orbit in NetCDF reduces to ~820 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

ascat_YYYYMMDD_HHMMSS_SAT_ORBIT_SRV_T_SMPL_VERS(_CONT).l2.nc.gz where the meaning of the fields is identical to those in the BUFR file names (see section 5.2). Note that in NetCDF the SRV is always “eps” (global data) and the CONT is always “ovw” (Ocean Vector Winds). The VERS part of the file name denotes the software version. A file name example is:

ascat_20090826_051502_metopa_14797_eps_o_250_1018_ovw.l2.nc.gz

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

```
dimensions:
    NUMROWS = 1581 ;
    NUMCELLS = 42 ;
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: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 = "MetOp-A ASCAT Level 2 25.0 km Ocean Surface Wind Vector Product" ;
  :title_short_name = "ASCAT-L2-25km" ;
  :Conventions = "CF-1.4" ;
  :institution = "EUMETSAT/OSI SAF/KNMI" ;
  :source = "MetOp-A ASCAT" ;
  :software_identification_level_1 = 702 ;
  :instrument_calibration_version = 0 ;
  :software_identification_wind = 1018 ;
  :pixel_size_on_horizontal = "25.0 km" ;
  :service_type = "eps" ;
  :processing_type = "O" ;
  :contents = "ovw" ;
  :granule_name = "ascat_20090826_051502_metopa_14797_eps_o_250_1018_ovw.l2.nc" ;
  :processing_level = "L2" ;
  :orbit_number = 14797 ;
  :start_date = "2009-08-26" ;
  :start_time = "05:15:02" ;
  :stop_date = "2009-08-26" ;
  :stop_time = "06:53:56" ;
  :equator_crossing_longitude = " 244.606" ;
  :equator_crossing_date = "2009-08-26" ;
  :equator_crossing_time = "05:12:26" ;
  :rev_orbit_period = "6081.7" ;
  :orbit_inclination = "98.7" ;
```

```
  :history = "N/A" ;
  :references = "ASCAT Wind Product User 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 = "08:31:31" ;
```

The interpretation of the wvc_quality_flag integer value is as follows. The flag_masks correspond to certain flag bits that may or may not be set. This means that e.g. the 'flag_mask' 64 corresponds to 'distance_to_gmf_too_large' and so on. The flag masks are powers of 2. The way to handle this is to take the integer value of the wvc_quality_flag and find out how it is composed of powers of 2. Suppose that one wants to test if the 'knmi_quality_control_fails' flag bit is set. This is the 12th item in the flag list, corresponding to an integer value of 131072 (=2^17) in the flag_masks table. You can test if this value is set using the function:

(integer flag value / 2^17) modulo 2

which gives 1 if the ‘knmi_quality_control_fails’ is set and 0 if the ‘knmi_quality_control_fails’ is not set. The other flag bits can be tested in the same way. See the table below for the flag bits present in the wvc_quality_flag.

Description	Bit number
Distance to GMF too large	6
Data are redundant	7
No meteorological background used	8
Not used	9
Not used	10
Reported wind speed is less than or equal to 3 m/s	11
Reported wind speed is greater than 30 m/s	12
Wind inversion not successful for wind vector cell	13
Some portion of wind vector cell is over ice	14
Some portion of wind vector cell is over land	15
Variational Quality Control data rejection	16
KNMI Quality Control data rejection	17
Product monitoring flag	18
Product monitoring not used	19
Any beam noise content above threshold	20
Poor azimuth diversity among sigma-0 for wind retrieval	21
Not enough good sigma-0 available for wind retrieval	22