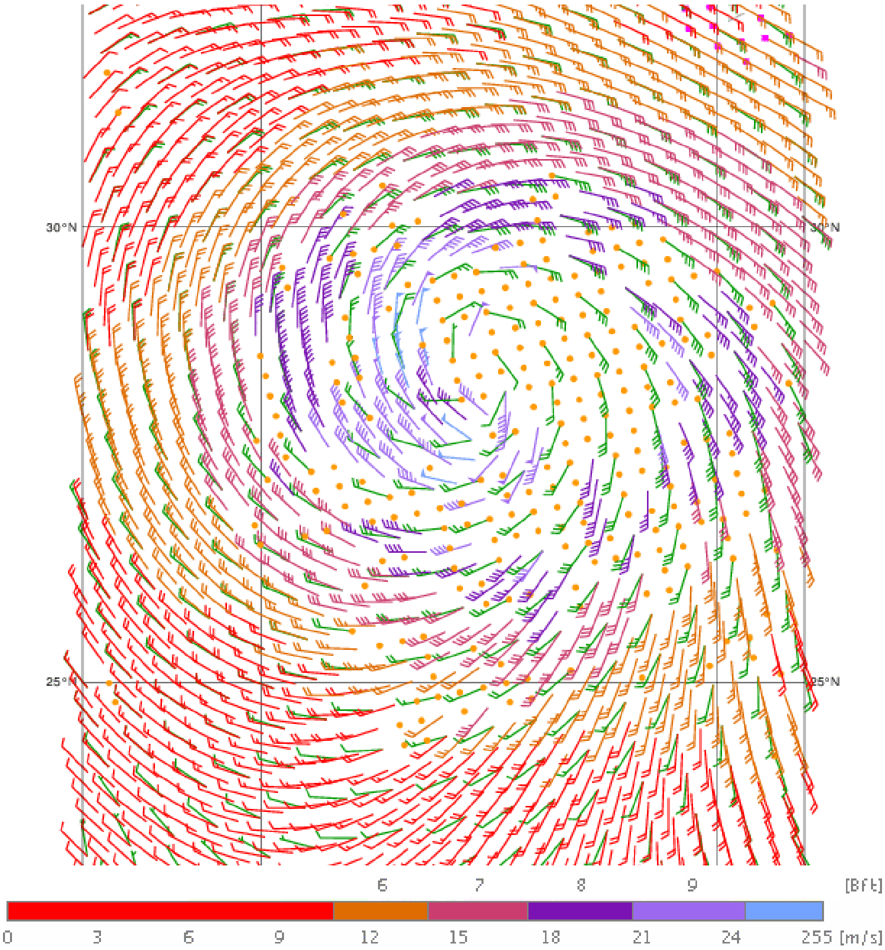
Ocean and Sea Ice SAF

Oceansat-2 L2 winds Data Record Product User Manual



25 km and 50 km wind products (OSI-153-a and OSI-153-b)

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DOCUMENTATION CHANGE RECORD

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Version 1.0	Apr 2017		Initial version
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KNMI, De Bilt, the Netherlands
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Cover illustration: Oceansat-2/OSCAT wind field of hurricane Katia retrieved in the western Atlantic (28° N, 68° W) at 25 km Wind Vector Cell (WVC) spacing on 7 September 2011, approximately 4:15 UTC. The scatterometer wind arrows are coloured according to their Beaufort force, the ECMWF ERA-Interim NWP winds are plotted in green. Orange dots indicate Wind Vector Cells flagged by the Quality Control due to e.g. heavy rain or confused sea state. In the NWP wind field the cyclonic structure is too weak and located at the wrong position, indicating that scatterometer winds may help to improve the wind field analysis.

Contents

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 as the centre where the level 1 to level 2 scatterometer wind processing is carried out. This document is the Product User Manual to the Oceansat-2 OSCAT scatterometer climate data record. More general information on the OSI SAF project is available on the OSI SAF web site: 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. More information about this product can also be found on http://www.knmi.nl/scatterometer/.

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 Baseline 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 developed in the EUMETSAT Numerical Weather Prediction Satellite Application Facility (NWP SAF), whereas wind processing is performed operationally in the Ocean and Sea Ice SAF (OSI SAF).

The archived near-real time ISRO Oceansat-2 level 1b files [4], spanning the period of 15th December 2009 to 20th February 2014 have been provided by NASA’s Jet Propulsion Laboratory (JPL) from their archive. Note that in the near-real time processing we used level 2a input data but for the reprocessing we used level 1b since level 2a was not available on 25 km swath grid spacing. The data have been processed using the Pencil beam Wind Processor (PenWP) software version 2.1, as available in the NWP SAF [5]. The ambiguity removal and product monitoring are done using the ECMWF re-analysis (ERA) Interim winds rather than the archived ECMWF operational winds. The ERA-Interim winds are much more uniform over time than the operational winds. The OSI SAF Climate Data Records (CDRs) can be obtained from the EUMETSAT Data Centre.

This user manual outlines user information for the OSI SAF Oceansat-2 winds on 25 km and 50 km grid spacing, OSI-153-a and OSI-153-b, respectively. Section 2 presents a brief description of the OSCAT 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. The product quality is elaborated in the validation report to these products [6].

1.2. Acknowledgement

ISRO has kindly provided the near-real time OSCAT level 1b data which were used as input for the OSI SAF wind products.

JPL have kindly provided their archived OSCAT data record to the OSI SAF.

1.3. Disclaimer

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.

1.4. Useful links

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

Information on OSI SAF activities at KNMI: http://www.knmi.nl/scatterometer/osisaf/

OSI SAF wind product documentation on http://www.osi-saf.org/

NWP SAF website: http://nwpsaf.eu/

EUMETSAT Data Centre:
http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETSATDataCentre/index.html

Oceansat-2 information on ISRO website: http://www.isro.gov.in/Spacecraft/oceansat-2

1.5. Limitations and remaining issues

The beam azimuth angles in the level 1b data are not correct. These have been successfully corrected in the wind processing, see section 3.1.

WVC and beam dependent NWP Ocean Calibration (NOC) corrections have been applied to correct for the skew azimuth and WVC dependency of the backscatter calibrations, see section 3.2.

An instrument calibration change occurred between 19^{th} and 20^{th} August 2010, this was corrected for in the wind processing, see section 3.2.

The Bayesian ice screening used in the processing is done using the algorithm developed for SeaWinds, with some minor parameter adaptations. This yields ice extent maps which are very close to those from ASCAT but refinements could be done. This was not further explored in the scope of this work.

2. The OSCAT scatterometer

The scatterometer is one of the three instruments carried on-board the Oceansat-2 polar satellite, launched and operated by the Indian Space Research Organisation (ISRO). It was launched on 23 September 2009. The spacecraft is in a sun-synchronous orbit of 720 km altitude with an inclination of 98.2° and a repeat cycle of 2 days. The local time of ascending Equator crossing is 0:00. For detailed information on the OSCAT instrument and data we refer to [4]. A brief description is given below.

The OSCAT instrument is a conically scanning pencil-beam scatterometer, as depicted in figure 1. It uses a 1-meter dish antenna rotating at 20 rpm with two ‘spot’ beams on the ground. The horizontal polarisation beam (HH) has an incidence angle of 49º and a footprint size of approximately 26 x 42 km and the vertical polarisation beam (VV) has an incidence angle of 57º and a footprint size of approximately 31 x 65 km. The beams sweep the surface in a circular pattern as depicted in Figure 1. Note that the egg-shaped beam footprints are divided into slices by applying a modulated chirp signal, the inner beam footprint has 7 slices, the larger outer beam footprint has 12 slices. 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 WVC. The 1800-km-wide swath covers 90% of the ocean surface in 24 hours which is substantially higher than side-looking scatterometers like ERS, NSCAT and ASCAT.

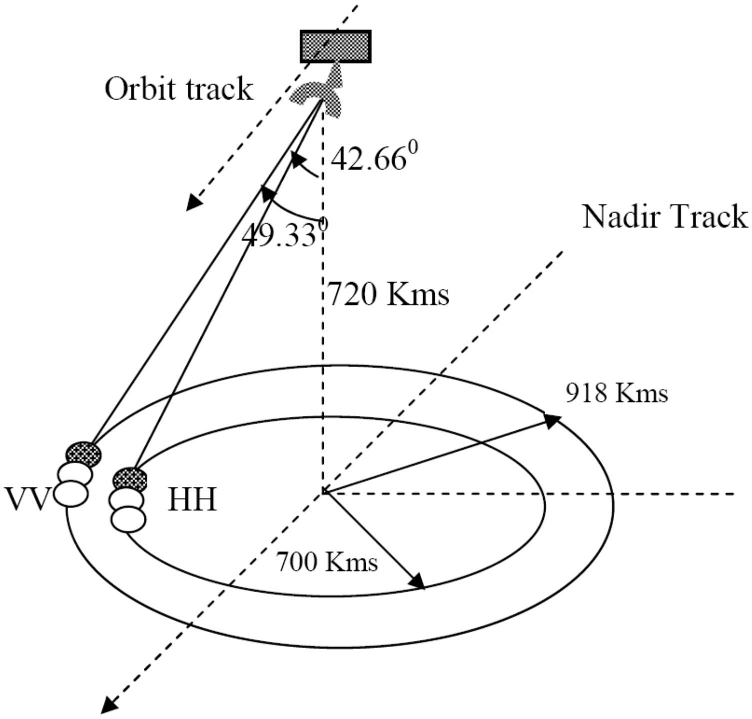

Figure 1: OSCAT pencil beam geometry (source: [4]).

The wind retrieval from OSCAT data is not trivial. In contrast with side-looking scatterometers like ASCAT, the number of measurements and the beam azimuth angles vary with the sub-satellite cross-track location. The wind retrieval skill will therefore depend on the position in the swath. A detailed discussion is provided in [3]. Here we only summarise some issues specific to OSCAT.

In the outer swath (where only VV beam data are available), the individual backscatter measurements (‘slices’) contributing to the VV fore or aft beam in a specific WVC are re-distributed to form four more or less independent backscatter observations. Slices are accumulated and averaged based on their azimuth angles. The outer swath winds have slightly reduced quality but they are still very well usable. These winds are flagged in the product and can be filtered out easily if requested, see section 5.2.

The OSCAT scatterometer operates at a Ku-band radar frequency (13.5 GHz corresponding to ~2 cm 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 (QC) step. Wind-rain discrimination is easiest to manage in the sweet swath, but still performs acceptably in nadir and outer swath.

The processing algorithms for the OSCAT wind processing are heavily based on the algorithms as developed for SeaWinds and RapidScat [3]. When calibrated geophysical backscatter measurements are available, the wind processing of the different Ku-band pencil-beam scatterometers is very similar. The wind processing software which is used, the Pencil beam Wind Processor (PenWP), is the successor of the SeaWinds Data Processor (SDP) and the OSCAT Wind Data Processor (OWDP). PenWP is capable to process data from SeaWinds, OSCAT, RapidScat and HY-2A scatterometers and replaces all former pencil beam Ku-band wind processing software packages in the NWP SAF.

Differences between the various rotating pencil beam scatterometers are to a great extent on a technical (data formats and handling) level. Moreover, due to different orbits and antenna geometries, incidence angles differ. PenWP utilises the NSCAT-4 Geophysical Model Function (GMF) [3], which is available for all prevailing incidence angles. In order to handle instrument differences well, particularly noise characteristics, some parts of the processing were re-tuned for Oceansat-2, mainly the normalisation of the Maximum Likelihood Estimator (MLE) and the tuning of the Quality Control [7].

3. Processing scheme

Figure 2 shows the system architecture to generate the wind data sets. The processing environment consists of a set of software components to collocate scatterometer data with ECMWF model data, to generate the wind data and to convert the output BUFR data into level 2 (swath) NetCDF data and level 3 (gridded to a regular lat/lon grid) NetCDF data. General information about the scatterometer wind processing algorithms can be found in the Algorithm Theoretical Basis Document (ATBD) [3].

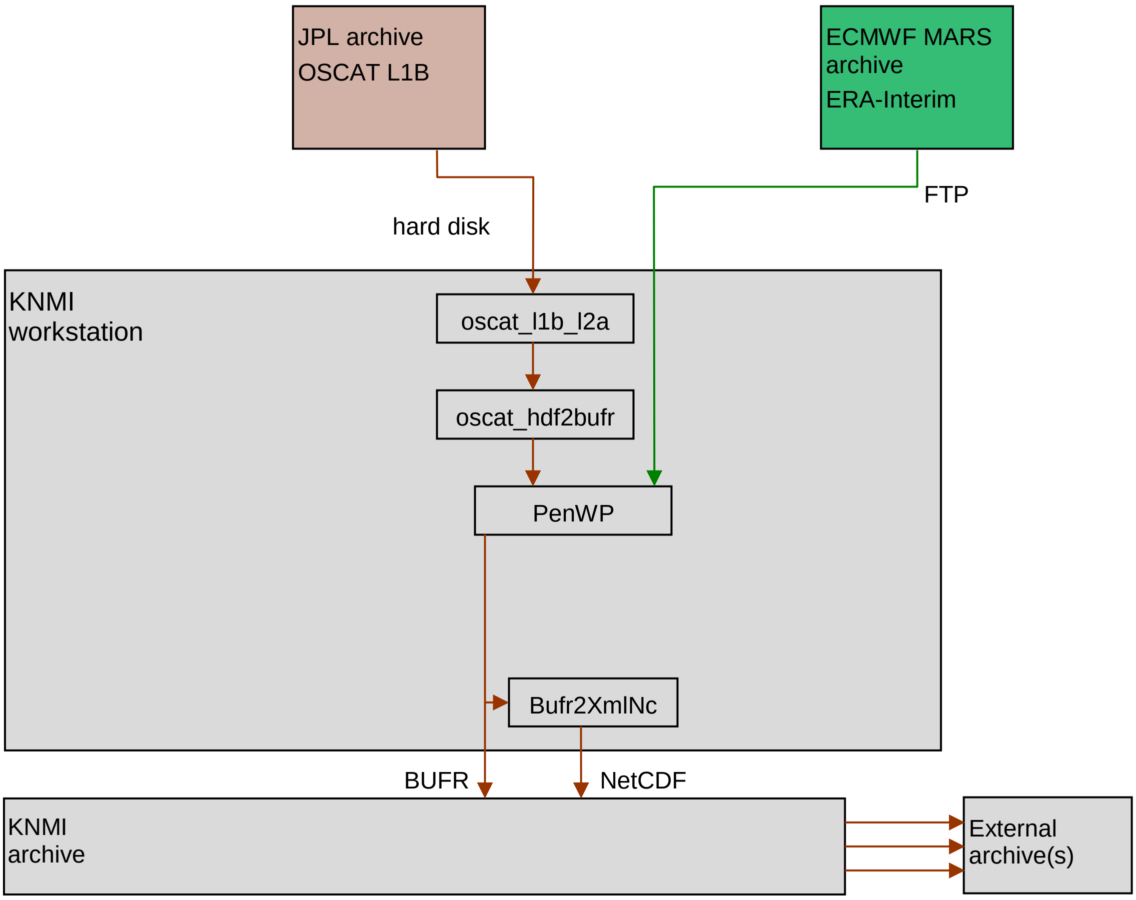

Figure 2: System architecture of reprocessing chain

The following components are shown in Figure 2.

- PenWP is the wind processing software for OSCAT, SeaWinds and other Ku-band scatterometer data. It is publicly available in the NWP SAF, see [5].
- oscat_l1b_l2a is a tool which converts the OSCAT level 1b HDF5 data into level 2a HDF. It is part of the PenWP software package.
- oscat_hdf2bufr is a tool to convert OSCAT level 2a data from HDF5 into BUFR format. PenWP cannot handle HDF5 data, only BUFR. It is part of the PenWP software package.
- Bufr2XmlNc is a program to convert BUFR scatterometer data into level 2 NetCDF data. It is currently used in the near-real time OSI SAF processing.

3.1. Backscatter slice processing

The level 1b backscatter data from ISRO are organised in slices [4] The slices are beam-wise accumulated to a WVC level before wind inversion is done. The slice weights are proportional to the estimated transmitted power contained in a slice, i.e., inversely proportional to the K_p value. The Sigma0 Quality Flag present in the level 1b data is evaluated and slice data with one of the following flags set are skipped:

- Bit 4: Sigma0 is poor
- Bit 5: K_p (noise value) is poor
- Bit 6: Invalid footprint
- Bit 7: Footprint contains saturated slice

It was discovered that the beam azimuth angles reported in the level 1b data are not correct. In particular at high latitudes, significant deviations from the expected values occur. The azimuth angles were re-computed from the WVC location and sub-satellite point using formula (5.23) in [4]. These re-computed values replaced the original azimuth level 1b angles.

3.2. Backscatter calibration

No absolute instrumental calibration exists for Ku-band pencil-beam scatterometers. Ku-band pencil-beam backscatter distributions should however be matched to achieve wind intercalibration of all space-borne scatterometer instruments. We thus developed methods that calibrate the winds of each scatterometer effectively to the mean winds at collocated moored buoys. For most Ku-band pencil beam scatterometers like QuikSCAT and RapidScat, no significant signs of azimuth (or WVC) dependent instrument biases have been found. Also the beam incidence angles are constant and hence we have chosen to apply backscatter corrections that are only dependent on the beam polarisation. The goal of applying backscatter corrections is to minimise wind speed biases between scatterometer winds on the one hand and buoy and NWP winds on the other hand. This has turned out to work out very well for most instruments.

However, for Oceansat-2 the situation is more complicated since the OSCAT instrument flies at a 9° yaw off-angle with respect to the flight path. This leads to a skew azimuth (and WVC) dependency of the backscatter calibrations [8]. WVC and beam dependent NWP Ocean Calibration (NOC) corrections have been computed and applied to correct for this.

An instrument calibration change occurred between 19th and 20th August 2010, which was also reported in literature [9]. For an unknown reason, the σ^0 values dropped by approximately 0.5 dB. On top of the NOC corrections, an extra constant correction of -0.47 dB on HH and -0.56 dB on VV was applied both for 25 km and 50 km data from before 20th August 2010 to correct for this.

Note that the calibrated backscatter values are only available within the wind processing software; the σ^0 data in the BUFR wind product are uncorrected values.

3.3. NWP collocation

NWP forecast wind data are necessary in the ambiguity removal step of the processing. The scatterometer winds have been collocated with ERA-Interim wind data from ECMWF [10]. Stress equivalent (U10S) winds have been computed from the real ERA-Interim forecast 10m winds, sea surface temperature, air temperature, Charnock parameter and specific humidity, using a stand-alone implementation of the ECMWF model surface layer physics [11]. The equivalent neutral winds have been converted to stress equivalent winds (U10S) by multiplying by a correction factor of $\sqrt{(\rho/\langle\rho\rangle)}$, where ρ is the air density and $\langle\rho\rangle$ is the average air density (1.225 kg/m^3).

The correction factor follows from the fact that the surface roughness as measured by the scatterometer is more closely correlated with surface stress τ than with the actual wind speed at 10 m. The surface stress τ is proportional to the air density and to the square of the equivalent neutral 10 m wind. In order to make the NWP winds equivalent to the scatterometer winds, we need to apply a correction, i.e. multiply by the square root of the normalised density.

The air density is computed from the NWP model mean sea level pressure (*msl*), specific humidity (*q*) and air temperature (*T*) as $\rho = msl / (287.04 \times (1 + 0.6078 \times q) \times T)$ [12].

Wind forecasts are available twice a day (00 and 12 GMT analysis time) with forecast time steps of +3h, +6h, …, +18h. The model wind vector component data have been 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.

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 ice screening procedure may sometimes assign rainy WVCs erroneous as ice; using the extra SST criterion, WVCs in warmer areas will never be labelled as ice. Due to its rather high threshold value, the NWP 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 50 km (60 km in the 50 km products) 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.

3.4. Quality control and monitoring

In each WVC, the σ^0 data is checked for quality and completeness and the inversion residual [3] 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 for each 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. An example of such a graph is shown in Figure 3. It shows that the average MLE values are quite constant over time showing only some seasonal fluctuations. Data quality is also available to the users within the products; see section 5 for a description of quality flags. More information on the data quality and stability over time can be found in the validation report [6].

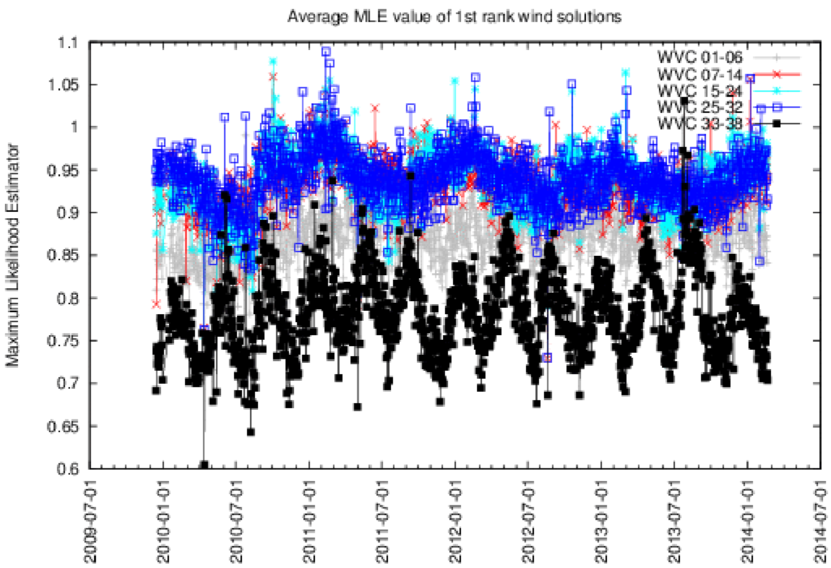

Figure 3: Daily average of MLE values (1st rank wind solution) per group of WVCs (left outer swath, left sweet swath, inner swath, right sweet swath and right outer swath) of 50 km wind products over the entire reprocessing period.

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://www.osi-saf.org/). You can also send an email to scat@knmi.nl.

A BUFR reader which is able to convert BUFR data into ASCII or NetCDF format is available at www.knmi.nl/scatterometer/bufr_reader/.

Unique Digital Object Identifiers (DOIs) are attached to the data records. A landing page containing the latest product availability information and documentation is connected to the DOI:

http://dx.doi.org/10.15770/EUM_SAF_OSI_0010 and http://dx.doi.org/10.15770/EUM_SAF_OSI_0011.

The products are available (after registration) from the EUMETSAT Data Centre, http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETSATDataCentre/index.html. The data sizes for the entire data set and per orbit file are listed in the table below. There are on average 14.5 Oceansat-2 orbits per day.

Product	**Size of one orbit file**	**Size of 4 years data record**
25 km BUFR	11 MB	220 GB
25 km NetCDF (g-zipped)	1.1 MB	22 GB
50 km BUFR	3.0 MB	55 GB
50 km NetCDF (g-zipped)	330 kB	6 GB

5. Data description

5.1. Wind product characteristics

Physical definition

Horizontal equivalent neutral wind vector at 10 m height, obtained using the NSCAT-4 GMF, see [3].

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.

Input satellite data

The Oceansat-2 level 1b input data [4] are kindly provided by ISRO. The products contain geo-located backscatter measurements, each observation corresponds to a high resolution slice in a scatterometer pulse. The input data have version 1.3 until 18th May 2013 and version 1.4 after that date. It was checked that versions 1.3 and 1.4 have the same backscatter characteristics by comparing some overlapping data. The only significant difference is in the reported brightness temperatures but those are not relevant in the OSI SAF wind retrieval process. The brightness temperatures are reported though in the level 2 BUFR data.

Geographical definition

The Oceansat-2 satellite flies in a near-polar sun synchronous orbit at 98 degrees inclination at approximately 720 km orbit height. The swath width is 1900 km and the swath is composed of 76 25 km size WVCs or 38 50 km size WVCs. Products are organised in files containing one orbit starting at the South Pole.

Output product

The input product in HDF 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 are also available in NetCDF format; see section 9 for more details.

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 [13]. The performance is pretty constant over the globe and depends mainly on the sub footprint wind variability. According to the OSI SAF product requirements [1], 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 [6], 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.

The OSI SAF wind product is stored in exactly the same BUFR format as described in the SeaWinds BUFR manual from NOAA [13], a list of descriptors (fields) contained in each WVC is provided in section 8. Data are organised in files containing approximately one orbit (100 minutes) of data.

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 9.

File name conventions

The file name convention for the level 2 BUFR product is

oscat_YYYYMMDD_HHMMSS_ocsat2_ORBIT_T_SMPL_CONT_l2.bufr or

OR1OSW025_YYYYMMDD_HHMMSS_ORBIT_OCEANSAT2.bufr (25km from the EUM Data Centre) or OR1OSW050_YYYYMMDD_HHMMSS_ORBIT_OCEANSAT2.bufr (50km from the EUM Data Centre).

- YYYYMMDD denotes the acquisition date (year, month and day) of the first data in the file
- HHMMSS denotes the acquisition time (hour, minute and second) of the first data in the file
- ORBIT is the orbit number of the first data in the file (00000-99999)
- T is the processing type (o for operational, t for test)
- SMPL is the WVC sampling (cell spacing): 250 for the 25 km and 500 for the 50 km product
- CONT refers to the product contents: always ovw for a product containing Ocean Vector Winds

Examples of file names are

oscat_20091215_192644_ocsat2_01213_o_250_ovw_l2.bufr for a 25 km product

oscat_20091215_192644_ocsat2_01213_o_500_ovw_l2.bufr for a 50 km product

File contents

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 products contain up to four ambiguous wind solutions, with an index to the selected wind solution. After the wind inversion step, we initially store the up to four solutions corresponding to the inversion residual (Maximum Likelihood Estimator, MLE) relative minima. However, subsequently the wind speed and wind direction of the after 2DVAR-selected Multiple Solution Scheme (MSS) wind solution is put at the index of the selected wind solution. This index is set to the initial wind vector solution which is closest to the MSS wind vector selection obtained after 2DVAR. Thus, the former wind vector is not provided in the product, but rather the MSS selected wind vector. The ‘Formal Uncertainty in Wind Direction’ does not contain the uncertainty, but the normalised inversion residual (referred to as Rn in [15]).
- The ‘SeaWinds Probability of Rain’ and ‘SeaWinds NOF Rain Index’ BUFR fields are not used and contain missing data values.
- The Wind Vector Cell Quality Flag (table 021109) is redefined and now has the following definitions:

Description	BUFR bit	Fortran bit
Reserved	1	16
Not enough good sigma-0 available for wind retrieval	2	15
Not used	3	14
VV polarised data in more than two beams	4	13
Product monitoring not used	5	12
Product monitoring flag	6	11
KNMI Quality Control (including rain) data rejection	7	10
Variational QC data rejection	8	9
Land presence	9	8
Ice presence	10	7
Not used	11	6
Reported wind speed is greater than 30 m/s	12	5
Reported wind speed is less than or equal to 3 m/s	13	4
Not used	14	3
Rain flag algorithm detects rain	15	2

Description	BUFR bit	Fortran bit
Data from at least one of the four possible beam/view combinations are not available	16	1
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)** to test BUFR bit **NB**, where **NDW**=17 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.

The flag indicating that more than two beams contain VV polarised data, BUFR bit 3, is active in the outer part of the swath (WVCs 1-8 and 69-76 at 25 km, WVCs 1-4 and 35-38 at 50 km). It indicates that outer beam data is used to obtain four independent σ^0 values, contrary to the middle part of the swath where two beams contain VV (outer beam) data and two beams contain HH (inner beam) data. In the outer parts of the swath, the VV backscatter data present in the level 2a product are distributed to two WVC beams based on their azimuth angle such that maximum azimuth dispersion is obtained. This generally results in slightly less optimal wind retrieval; users assimilating the data into NWP models may consider to reject WVCs for which this flag is set.

If the ‘product monitoring not used’ bit, Fortran bit 12, is set to zero, the product is monitored. If the product is monitored and the ‘product monitoring flag’ bit, Fortran bit 11, is set to zero, the product is valid; otherwise it is rejected by the product monitoring [3]. This is based on a statistical check of the number of WVC QC rejections, the wind speed bias with respect to the NWP background, and the wind vector RMS difference with respect to the NWP background. The product monitoring bits have the same value for all WVCs in one BUFR output file. Since all problematic data due to instrument issues already have been removed from the input data set, product monitoring rejection does not occur in the wind CDRs.

If the KNMI QC flag, Fortran bit 10, is set in a WVC, then the backscatter information is not useable for various geophysical reasons like rain, confused sea-state etc, resulting in a too large inversion residual. 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.

The land presence flag, Fortran bit 8, 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.

The Bayesian ice screening algorithm as implemented in PenWP was used when creating the CDRs. The ice presence flag, Fortran bit 7, is set if the Bayesian sea ice screening algorithm calculates ice for the WVC [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 excessive local wind variability), 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 9, 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 product monitoring flag, the KNMI quality control flag or the variational quality control flag set. See [3] for more information on product reliability.

6. References

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7. Abbreviations and acronyms

2DVAR	Two-dimensional Variational Ambiguity Removal
ATBD	Algorithm Theoretical Basis Document
AR	Ambiguity Removal
ASCAT	Advanced Scatterometer
BUFR	Binary Universal Format Representation
DLI	Downward Long wave Irradiance
ECMWF	European Centre for Medium-Range Weather Forecasts
ERS	European Remote-Sensing Satellite
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GMF	Geophysical Model Function
HDF	Hierarchical Data Format
HH	Horizontal polarisation of sending and receiving radar antennas
ISRO	Indian Space Research Organisation
JPL	Jet Propulsion Laboratory
KNMI	Royal Netherlands Meteorological Institute
MLE	Maximum Likelihood Estimator
MSS	Multiple Solution Scheme
NASA	National Aeronautics and Space Administration (USA)
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration (USA)
NOC	NWP Ocean Calibration
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
OWDP	OSCAT Wind Data Processor
PenWP	Pencil beam Wind Processor
QC	Quality Control
QuikSCAT	US Quick Scatterometer mission carrying the SeaWinds scatterometer
SAF	Satellite Application Facility
SDP	SeaWinds Data Processor
SeaWinds	Scatterometer on-board QuikSCAT platform (USA)
SSI	Surface Solar Irradiance
SST	Sea Surface Temperature
u	West-to-east (zonal) wind component
v	South-to-north (meridional) wind component
VV	Vertical polarisation of sending and receiving radar antennas
WMO	World Meteorological Organisation
WVC	Wind Vector Cell

8. Appendix A: 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

9. Appendix B: NetCDF data format

The 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 1.6 (http://cf-pcmdi.llnl.gov/).
- The data contain, contrary to the BUFR data, only level 2 wind and sea ice information, no sigma0 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 OSCAT, ASCAT and any other scatterometer data.
- The data has file sizes somewhat smaller than those of the corresponding BUFR data (e.g., one orbit file of 25 km wind data is 11 MB in BUFR and 4 MB in NetCDF). When compressed with gzip, the size of one file in NetCDF reduces to 1.1 MB.

The file name convention for the gzipped NetCDF product is

oscat_YYYYMMDD_HHMMSS_ocsat2_ORBIT_T_SMPL_CONT_l2.nc.gz or

OR1OSW025_YYYYMMDD_HHMMSS_ORBIT_OCEANSAT2.nc.gz or

OR1OSW050_YYYYMMDD_HHMMSS_ORBIT_OCEANSAT2.nc.gz (the latter two from the EUM Data Centre) where the meaning of the fields is identical to those in the BUFR file names (see section 5.2). A file name example is:

oscat_20091215_192644_ocsat2_01213_o_250_ovw_l2.nc.gz.

Below are some meta data contained in the NetCDF data files. Note that the listing below is only an excerpt of the file contents which is intended to give a global overview. The full information is in the meta data of the data files.

```
dimensions:
        NUMROWS = 1624 ;
        NUMCELLS = 76 ;
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 = "Oceansat-2 OSCAT Level 2 25.0 km Ocean Surface Wind
Vector Product" ;
                :title_short_name = "OSCAT-L2-25km" ;
                :Conventions = "CF-1.6" ;
                :institution = "EUMETSAT/OSI SAF/KNMI" ;
                :source = "Oceansat-2 OSCAT" ;
                :software_identification_level_1 = 2102 ;
                :instrument_calibration_version = 0 ;
                :software_identification_wind = 2102 ;
                :pixel_size_on_horizontal = "25.0 km" ;
                :service_type = "N/A" ;
                :processing_type = "R" ;
                :contents = "ovw" ;
                :granule_name =
"oscat_20091215_192644_ocsat2_01213_o_250_ovw_l2.nc" ;
                :processing_level = "L2" ;
                :orbit_number = 1213 ;
                :start_date = "2009-12-15" ;
                :start_time = "19:26:44" ;
                :stop_date = "2009-12-15" ;
                :stop_time = "21:05:59" ;
                :equator_crossing_longitude = "  86.341" ;
                :equator_crossing_date = "2009-12-15" ;
                :equator_crossing_time = "18:12:20" ;
                :rev_orbit_period = "5958.6" ;
                :orbit_inclination = "98.3" ;
                :history = "N/A" ;
                :references = "Oceansat-2 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 = "2017-03-08" ;
                :creation_time = "16:47:22" ;
```

10. Appendix C: Data gaps and number of files

The Oceansat-2 OSCAT Data Record starts at orbit 1212 on 15th December 2009 and ends at orbit 23371 on 20th February 2014. Quite some orbits are missing, sometimes isolated orbits and sometimes for longer periods. The tables below show the gaps with a length of at least 10 orbits in the Data Records and the number of files (orbits) per year, respectively.

The gaps reported here are based on the resulting retrieved winds from the reprocessing.

Start date	End date	Last orbit before gap	First orbit after gap	Number of missing orbits
2009-12-31	2010-01-16	1443	1665	221
2010-02-03	2010-02-06	1935	1977	41
2010-02-09	2010-02-12	2022	2067	44
2010-02-27	2010-02-28	2283	2298	14
2010-03-03	2010-03-06	2337	2381	43
2010-03-09	2010-03-12	2430	2471	40
2010-03-14	2010-03-16	2499	2529	29
2010-04-03	2010-04-06	2790	2828	37
2010-04-09	2010-04-12	2877	2922	44
2010-05-03	2010-05-06	3227	3271	43
2010-05-09	2010-05-12	3314	3358	43
2010-06-04	2010-06-06	3684	3719	34
2010-06-09	2010-06-12	3764	3807	42
2010-06-15	2010-06-16	3846	3857	10
2010-07-03	2010-07-06	4112	4154	41
2010-07-09	2010-07-12	4199	4241	41
2010-07-30	2010-08-01	4507	4532	24
2010-08-02	2010-08-06	4546	4604	57
2010-08-09	2010-08-12	4648	4691	42
2010-08-21	2010-08-23	4822	4849	26
2010-08-23	2010-08-24	4855	4869	13
2010-09-03	2010-09-06	5011	5053	41
2010-09-07	2010-09-08	5062	5075	12
2010-09-09	2010-09-12	5098	5140	41
2010-10-03	2010-10-06	5446	5489	42
2010-10-09	2010-10-12	5533	5576	42
2010-11-03	2010-11-06	5889	5939	49
2010-11-09	2010-11-12	5982	6026	43
2010-12-03	2010-12-06	6328	6373	44
2010-12-09	2010-12-12	6417	6460	42
2011-02-21	2011-02-22	7482	7505	22
2011-03-01	2011-03-02	7596	7610	13
2011-03-30	2011-03-31	8027	8040	12
2011-05-07	2011-05-09	8578	8606	27
2011-06-29	2011-07-01	9350	9365	14
2011-07-15	2011-07-16	9578	9593	14
2011-07-19	2011-07-20	9634	9650	15
2011-08-17	2011-08-18	10050	10065	14
2011-11-24	2011-11-25	11492	11507	14
2011-12-31	2012-01-02	12031	12053	21
2012-02-18	2012-02-20	12737	12768	30
2012-02-28	2012-03-01	12883	12903	19
2012-04-14	2012-04-15	13544	13556	11
2012-08-18	2012-08-19	15380	15396	15
2012-10-01	2012-10-04	16013	16050	36

Start date	End date	Last orbit before gap	First orbit after gap	Number of missing orbits
2013-03-02	2013-03-05	18212	18259	46
2013-08-28	2013-08-29	20819	20830	10
2013-10-01	2013-10-02	21302	21315	12
2013-11-28	2013-12-03	22152	22212	59
2013-12-31	2014-01-04	22631	22676	44
2014-01-31	2014-02-04	23068	23125	56

Year	Number of files
2009	218
2010	3742
2011	4842
2012	5081
2013	5110
2014	631
Total	19624