# Readme file for

# ERS-2 Wind Scatterometer Products

| Field: | Contents: | Filled by: |
|---|---|---|
| Title | Readme file for ERS-2 Wind Scatterometer Products | SPPA Engineer |
| Reference | ENVI-GSOP-EOGD-QD-15-0130, issue 1.0 Date: 26 March2015 | SPPA Manager |
| Affected data sets | This readme file applies to the following products:<br>• ASPS20_N (reprocessed data in nominal resolution)<br>• ASPS20_H (reprocessed data in high resolution)<br>• UWI (reprocessed operational data in nominal resolution)<br>generated by the Advanced Scatterometer Processing System version 10.04 | SPPA Engineer |
| Product specification references | • Product Specification:<br>ERSE-GSEV-EOPG-RS-06-0002 , Issue 2, Revision 3, 29/03/2009 | SPPA Engineer |
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| | | |
|---|---|---|
| Summary |  | SPPA Engineer |

# 1. ERS-2 Wind Scatterometer Mission Overview

The European Remote-sensing Satellite (ERS)-2 was launched in July 1995 as the follow-on mission to ERS-1 and was concluded with the deorbiting of the satellite on February 2011.

Scatterometers send microwave pulses under an incidence angle θ to the Earth's surface, and measure the power scattered back, allowing estimation of the normalised radar cross section ($\sigma_o$) of the Earth's surface. Over Ocean, the radar cross-section $\sigma_0$ mainly depends on the sea roughness, which in turn depends on wind speed and direction (it increases when the wind speed increases). Multiple, collocated, nearly simultaneous $\sigma_o$ measurements acquired from three directions (i.e. one looking perpendicular to the satellite ground track, one looking forward and one looking backwards at 45° azimuth projection angle with respect to the ground track) can be used to solve simultaneously the minimization of a cost function to retrieve the wind speed and direction. The most widely adopted forward models, used in the cost function, relating $\sigma_o$ to the wind speed are empirical and are periodically updated and improved based on real satellite measurements.

The ERS-2 Active Microwave Instrument (AMI) operated in wind scatterometer mode has a spatial resolution of about 25 – 50 Km depending on the incidence angle over a swath of about 500 km. The acquisition repeat cycle is 3 days at the equator. Table 1 lists the operating characteristics of the Wind Scatterometer.

*Table 1: Operating Characteristics of ERS-2 AMI in Wind Scatterometer mode*

| | |
|---|---|
| Time Period | 21 April 1995 – 5 July 2011 |
| Frequency | 5.3 GHz (C band) |
| Antenna Azimuth Orientations | Three fixed |
| Polarizations | V Only |
| Beam Resolution | Range Gate |
| Resolution | 25/50 km |
| Number of pulses per 50 km | 256 |
| Swath width | 500 km |
| Incidence Angle | $18 – 59^o$ |
| Orbit | Sun-synchronous<br>780 km altitude<br>98.52° inclination |

During the 16 years of operations, the ERS-2 mission underwent a number of failures (platform and AMI) and consequent changes of both the acquisition plan and the ground segment configuration. A brief summary of the main events of the ERS-2 mission is presented in the Table 2 below:

*Table 2: Main Events of ERS-2 mission [Crapolicchio et al., 2012]*

| Period | Event |
|---|---|
| 1995, Apr. | ERS-2 is launched on April 21, 1995. |
| 1995, Nov. | The first Scatterometer measurement is achieved by setting the antenna circulator system into an intermediate position to avoid arcing in the AMI transmitter. In this new configuration the transmitted power is reduced by a factor of 3 dB if compared with ERS-1. |
| 1996, Aug. | Due to an anomaly in the internal calibration unit, the calibration sub-system is switched from side A (nominal) to side B (redundant). |
| 2000, Jan | Three of the six gyroscope fail, the operation mode is changed from Nominal to Mono-Gyro Mode. In Mono-Gyro configuration the accuracy of the satellite attitude was degraded in particular for the yaw angle. |
| 2001, Jan. | Other two gyroscopes fail, leading to the so-called Zero-Gyro Mode; the single operating gyroscope is only used for important orbital manoeuvres.<br>Scatterometer operational data is degraded and are not disseminated to the users. More details can be found in the list of events affecting ERS-2 Scatterometer mission at https://earth.esa.int/web/sppa/mission-performance/esa-missions/ers-2/scatterometer/mission-highlights. |
| 2001,Jun. | To test a way to compensate for the gyroscopes failure, ERS-2 AMI starts operating only in Wind-Wave acquisition mode. |
| 2003, May | Nominal Wind Scatterometer acquisition mode is resumed. |
| 2003, Aug. | ERS Scatterometer Attitude Corrected Algorithm (ESACA) is included in the processing chain to compensate for the switching off of the gyroscopes. |
| 2010, Sep. | Due to an irrecoverable transponder failure, the calibration acquisition mode is removed from the orbital planning and substituted by nominal acquisition. |
| 2011, Feb. | ERS-2 is lowered by a series of orbit manoeuvres. As a consequence of that, the repeat cycle changes from 35 to the 3 day. |
| 2011, Jul. | ERS-2 is decommissioned. |

# 2. ERS-2 Wind Scatterometer processor ASPS Version 10.04

To satisfy the needs of high quality and homogeneous set of Scatterometer measurements, the European Space Agency (ESA) has developed the processor Advanced Scatterometer Processing System (ASPS) with which a long-term dataset of new ERS-2 wind products, with an enhanced resolution of 25km square, has been generated for the entire ERS mission [Crapolicchio et al., 2004].
The Wind Scatterometer/ERS-2 ASPS processor version 10.04 introduces a number of upgrades that are detailed in this document. Detailed information can be found at https://earth.esa.int/web/sppa/mission-performance/esa-missions/ers-2/scatterometer/products-and-algorithms/products-information.

## 2.1 Processor upgrades

The new ASPS Level 2 data set includes significant quality improvements with respect to the previous UWI operational data version:

- re-fined calibration of the 3 backscattering measurements (sigma noughts),
- retrieved wind vectors characterized in terms of CMOD5N [Hersbach, 2008] (neutral wind) geophysical forward model derived by ECMWF, 4 aliased wind vector solutions (Rank 1-4) and de-aliased wind vector flag,
- sea-ice probability and sea-ice flag,
- YAW error angle flag to be used as quality indicator filter during the Zero Gyro Mode (ZGM) period from 2001 till the end of the ERS-2 mission.

The auxiliary files which have been used as inputs for processing wind-scat data are the following:

- Geophysical information files
- LUT Look Up Table

The following geophysical auxiliary files have been used as background information for the wind ambiguity removal:

ERA-40 (ECMWF 40 Year Re-analysis) until August 2002
OPAN (ECMWF OPerational ANalysis) from September 2002

The ERA-40 project is a global atmospheric reanalysis provided by ECMWF of many conventional observations and satellite data streams for the period September, 1957 -August, 2002. Analyses were produced daily at 00, 06, 12 and 18 UTC. The atmospheric model was run with the following resolution:

- 60 levels in the vertical;
- T159 spherical-harmonic representation for basic dynamic fields;
- a reduced Gaussian grid with approximately uniform 125km spacing for surface and other grid-point fields.

The OPAN files are equivalent to the ERA-40 and are operational forecasts computed using the same model on daily basis.

The Look Up Tables (LUTs) contain auxiliary parameters used in the ground stations processing, configuration and calibration parameters.

The above files permit to generate ASPS15, ASPS20, UWI, and HEY products.

## 2.2 ASPS version 10.04 data set

Three different kinds of products are generated with ASPS:

- *Level 1.5* products, that are engineering products not available to the end users;
- *Level 2.0 nominal resolution* products (ASPS20_N), which contain, for each node, the three values of σ0 related to the three beams of the instrument, the retrieved wind (up to 4 solutions for each node) using the CMOD5N, the ambiguity removed wind solutions, the sea-ice probability, the sea-ice flag and the yaw error flag. The grid spacing of the nodes is 25 Km and the node spatial resolution is 50x50 km square;
- *Level 2.0 high resolution* products (ASPS20_H), which has the same content of the nominal resolution products. The grid spacing of the nodes is 12.5 Km and the node spatial resolution is about 25x25 km square;
- *User Wind* products *(UWI)*, which contain, for each node, the three values of σ0 related to the three beams of the instrument, the retrieved ambiguity removed wind solution using the CMOD5N. The grid spacing of the nodes is 25 Km and the node spatial resolution is 50x50 km square.

The standard ASPS product available for the users is the *Level 2.0 product*. ASPS generates an intermediate product for Quality control (QC) and instrument assessment called ASPS level 1.5. To maintain the compatibility with the actual ERS ground segment one additional output from ASPS is the nominal UWI product generated in NRT since the beginning of the mission.

## 2.3 HEY (Helpful ESOC Yaw product)

The HEY (Helpful ESOC Yaw) product represents the "near real time" yaw error angle information retrieved by using Scatterometer raw data plus some auxiliary data generated by the WS processor.
The yaw error angle estimation is computed on-ground by the ESACA processors. The full set of results of the Yaw processing is stored in an internal ESA product named HEY (Helpful ESA Yaw). The estimation of the Yaw error angle is based on the Doppler shift measured on the received echo (first three plots for the Fore, Mid

and Aft antenna) and aims to compute the correct acquisition geometry for the three Scatterometer antenna throughout the entire orbit. The Yaw error angle information is used in the radar equation to derive the calibrated backscattering (sigma nought) from the Earth surface and to select the echo samples associated to each node in the spatial filter.
Strong degradation in the evolution of the Yaw angle impacts the quality of the sigma noughts. In such cases a flag in the product allows user to discard the measurements. It was also noted that a strong solar activity impacts the Yaw performances.

### 2.4 ASPS Product Format

The Level 2.0 product is generated for both *nominal* and *high resolution* and is structured as follow [Crapolicchio and Lecomte, 2004]:
• MPH (Main Product Header)
• SPH (Specific Product Header)
• DSR (Data Set Record)

The detailed description of the product format is available here:
ERSE-GSEV-EOPG-RS-06-0002, Issue 2, Revision 3, 29/03/2009.

## 3. ERS-2 Wind Scatterometer Calibration Performance

A calibration activity over ERS-2 data has been performed in order to compute a refined in-orbit antenna pattern to be used for the Scatterometer mission reprocessing. The refined in-orbit antenna pattern computed has been compared with the previous one.

### 3.1 Reference Area

The tropical rain forest in the South America has been used as reference distributed target to monitor the relative calibration and antenna pattern of ERS-2 scatterometer. The target at the working frequency (C band) of ERS-2 Scatterometer acts as a very rough surface, and the transmitted signal is equally scattered in all directions. Consequently, for the angle of incidence used by ERS-2 Scatterometer, the normalized backscattering coefficient (sigma nought) will depend solely on the surface effectively seen by the instrument:

$$S^0 = S \bullet \cos\theta$$

With this hypothesis it is possible to define the following formula:

$$\gamma^0 = \frac{\sigma^0}{\cos\theta}$$

Using the above equation, the gamma nought backscattering coefficients over the rain forest is independent of the incident angle, allowing the measurements from each of the three beams to be compared. The test area used for monitoring ERS lies within 60.5 degrees West and 70.0 degrees West in longitude and 2.5 degrees North and 5.0 degrees south in latitude. That area was only partially covered by the Regional mission scenario during a period close to the end of the mission allowing a long-term comparison of the antenna profile.

## 3.2 The refined in-orbit antenna pattern

A refined in-orbit antenna pattern has been computed (in 2003) using the software TOSCA (Tools for Scatterometer Calibration) with the data of cycle 41.
To compare the new with the previous one (in use since 1996), cycle 31 and cycle 51 have been processed with both antenna patterns. The two data sets have been analysed and compared.
The results of the comparison have been used for the improvement of the following calibration quality parameters:

- the antenna profiles
- the gamma nought's histogram

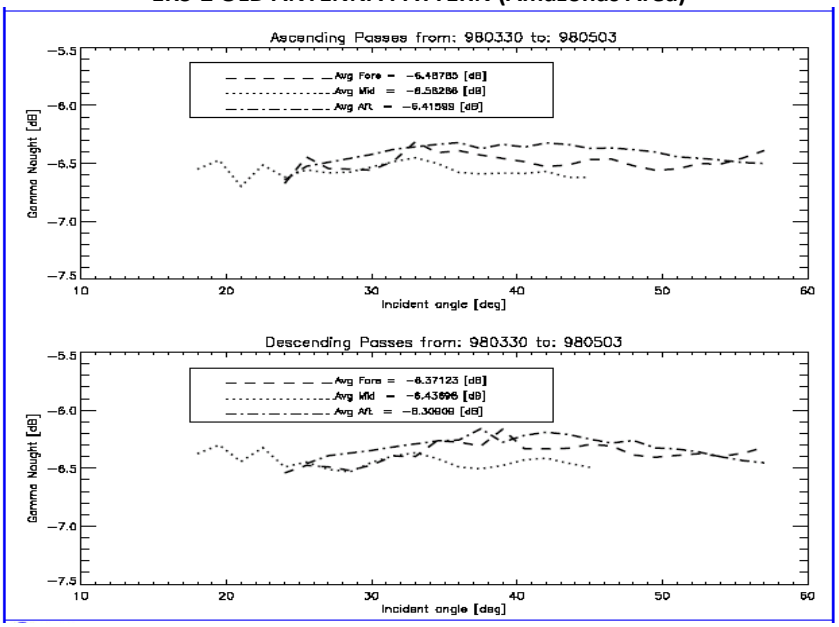
### 3.2.1 Antenna pattern: Gamma-nought as a function of incidence angle

Figure 1 shows the antenna patterns as a function of the incidence angle for respectively cycle 31 processed with the previous (upper plot) and the refined (lower plot) antenna patterns. Figure 2 shows the same for cycle 51.
The antenna patterns have been computed with a bin size for incidence angle of 1.5 deg. in order to have roughly 19 values across track. The results for both cycle 31 and 51 show that the re-processed data has a better radiometric accuracy, flatter profile, and a better inter-beam calibration.

For the cycle 31 the mid beam profile is flatter within a range of around 0.25 dB (both for ascending and descending passes) for the refined antenna pattern against the 0.4 dB of the previous pattern. Also the Fore and Aft beam show a shorter range for the refined antenna pattern (about 0.2 dB against 0.4 dB of the previous one).

**CYCLE 31**

**ERS-2 OLD ANTENNA PATTERN (Amazonas Area)**




**ERS-2 NEW ANTENNA PATTERN (Amazonas Area)**

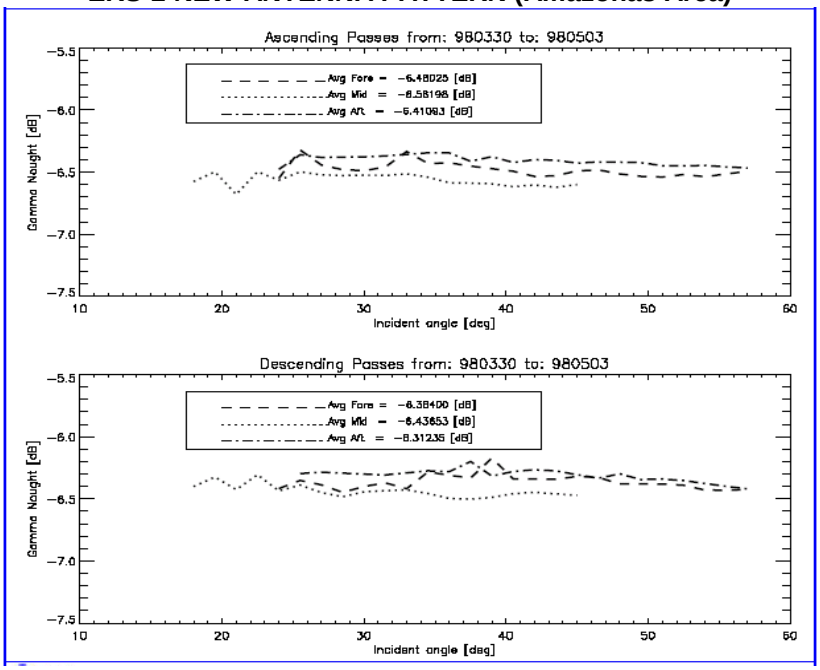
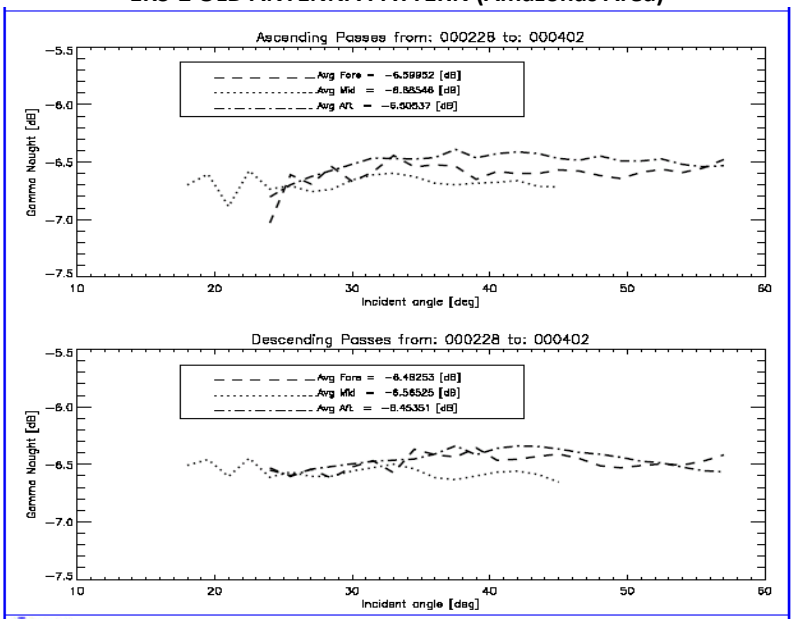



**Figure 1: Scatterometer Antenna Pattern as function of the incidence angle for the cycle 31: the old antenna pattern in the upper plot, new antenna pattern in the lower plot.**

The same behaviour is shown for the cycle 51. The mid beam profile varies in a range of 0.3 dB with the refined antenna pattern against 0.25 of the previous one. Fore beam fluctuates in a range of around 0.55/0.25 dB (respectively Ascending/Descending passes) against 0.45/0.2 dB of the previous one. Aft beam varies in a range of 0.2/0.15 dB (respectively Ascending/Descending passes) in the refined antenna pattern against 0.4/0.23 dB in the previous one.

**CYCLE 51**

**ERS-2 OLD ANTENNA PATTERN (Amazonas Area)**




**ERS-2 NEW ANTENNA PATTERN (Amazonas Area)**

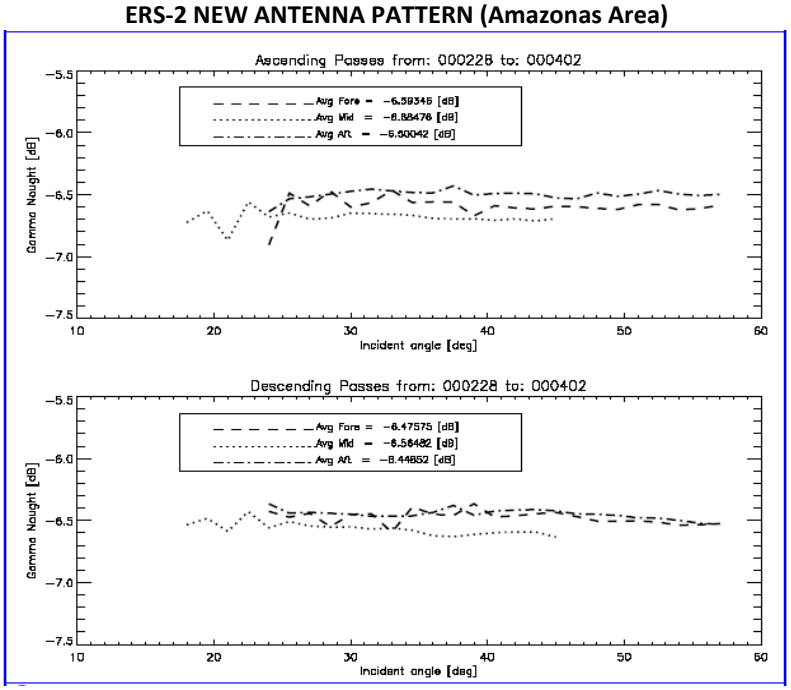



**Figure 2: Scatterometer Antenna Pattern as function of the incidence angle for the cycle 51: the old antenna pattern in the upper plot, new antenna pattern in the lower plot.**

## 3.3 Validation of ERS Scatterometer Reprocessing Products (ASPS)

A first geophysical validation of the ASPS products has been performed by ECMWF. In particular the wind validation has been performed by comparing the following three wind data sets to the ECMWF short forecast (i.e. first-guess) winds:

1) ASPS selected winds based on CMOD5.N (red)

2) ASPSD as the ambiguity solution closest to ECMWF one (black)
3) Winds inverted at ECMWF from backscattering values based on CMOD5.N (blue).

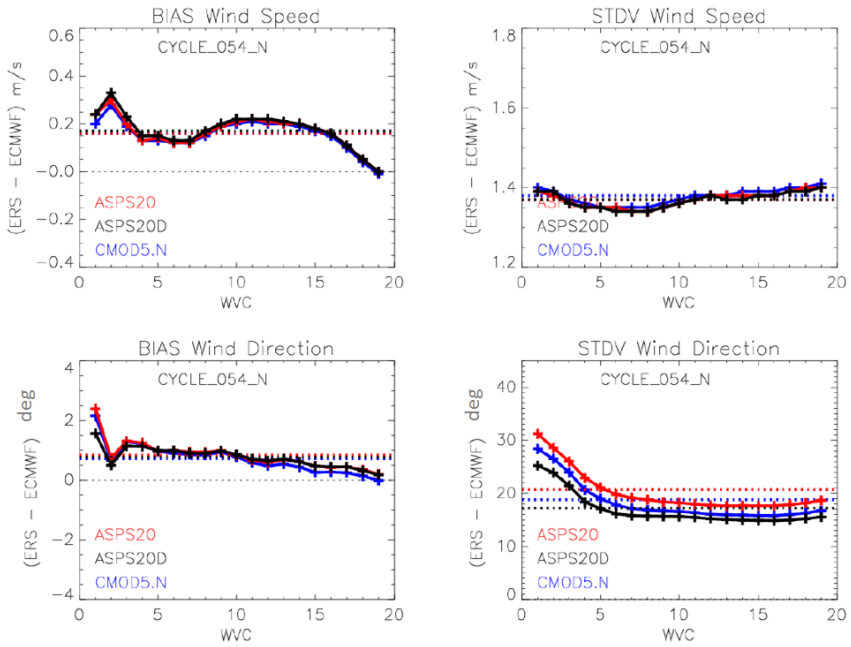



***Figure 1: Wind speed and direction bias Observation – ECMWF FG. Results are shown for ERS-2 Cycle 54 ASPS 20 N data (from 12 Jun 2000 to 17 July 2000) [from Abdalla et al., 2011].***

Results of the wind speed validation show that the biases are similar between these three datasets. For wind direction validation, instead, ASPS20D values seem agree better than the others.

Further validation of ASPS winds has been performed versus PIRATA buoys (see Polverari et al., 2013).

# 4. ERS-2 ASPS version 10.04 reprocessed data set availability

ERS-2 AMI Wind Scatterometer data set has been reprocessed covering the period from 30th December 1996 to 5th July 2011 (end of mission).

The reprocessed data asset is available here through Fast Registration. The size of the available data is: 774 GB of ASPS_H, 182 GB of ASPS_N, and 91 GB of UWI.

## 4.1 ERS-2 ASPS version 10.04 reprocessed data set caveat

Please find below a list of caveats, which might affect the intended data usage.

- **Cycle 1-9:** the initial period of the ERS-2 mission from 15th May 1995 to 25th March 1996 was not reprocessed due to the limited availability of the AMI in Wind Scatterometer mode.

- **Cycle 69 to Cycle 74:** data set has been reprocessed but is not available to the users due to degraded calibration performances in the Aft beam antenna measurements. As a consequence of this issue, the Aft beam measurements for those specific cycles will be re-calibrated and the affected cycle will be reprocessed at a later stage.

- **Missing Orbits:** can be present inside a data cycle (i.e. 35 days of data acquisition). The following link (https://earth.esa.int/web/sppa/mission-performance/esa-missions/ers-2/scatterometer/quality-control-reports/products-availability) reports tables with the number of orbits available per cycle and the number of explained and unexplained missing orbits. Explained missing orbits cannot be recovered because is effectively data lost due to platform/instrument anomalies, and acquisition errors. Unexplained missing orbits might be recovered during next reprocessing campaign and are mainly due to corruption occurred during the transcription processes of the raw telemetry data from tape units to hard disks.

## 5 References


- S. Abdalla, G. De Chiara and H. Hersbach, 2011: The technical support for global validation of ERS wind and wave products at ECMWF (July 2008 – July 2011). ECMWF Technical Report.

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- F. Polverari, M. Talone, R. Crapolicchio, G. Levy, F. Marzano, 2013: characterization of ocean wind vector retrievals using ERS-2 high-resolution long-term dataset and Buoy measurements. ESA living Planet, Edimburgh (UK).

## 6 Acronyms and Abbreviations

| | |
|---|---|
| AMI | Active Microwave Instrument |
| ASPS | Advanced Scatterometer Processing System |
| CMOD-5 | C-band Model 5 |
| DPQC | Data Processing Quality control |
| DSR | Data Set Record |
| ECMWF | European Centre for Medium-term Weather Forecast |
| ERS | European Remote-sensing Satellite |
| ESA | European Space Agency |
| ESACA | ERS Scatterometer Attitude Corrected Algorithm |
| HEY | Helpful ESOC Yaw |
| IPF | Instrument Processing Facility |
| LUT | Look-Up Table |
| MDS | Measurement Data Set |
| MPH | Main Product Header |
| PIRATA | Prediction and Research Moored Array in the Tropical Atlantic |
| TOSCA | Tools for Scatterometer Calibration |
| SPH | Specific Product Header |
| UWI | User Wind products |
| WSP | Wind Scatterometer Processor |
| YSM | Yaw Steering Mode |
| ZGM | Zero Gyro Mode |

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|---|---|---|
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