DUE GlobWave

Deliverable D5
Product User Guide

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1.1	22/04/10	Update following review comments	Ellis Ash
1.2	03/08/10	Inclusion of SAR Quality Info and Terms and Conditions	Geoff Busswell
1.3	22/11/10	Updates for inclusion of error statistics in new L2P release and additional release notes (version 1.3)	Geoff Busswell
1.4	16/12/10	Updates for release of NRT data	Geoff Busswell

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Contents

1 EXECUTIVE SUMMARY

This document gives the User Guide for GlobWave level 2 preprocessed (L2P) and demonstration products.

The L2P products give a consistent set of satellite wave data from all available satellite altimeter data and from ESA synthetic aperture radar data. The historical archive contains altimeter data from 8 satellites, ranging from Geosat (operating between 1985 and 1989) through to Envisat, Jason-1 and Jason-2, still operating in 2010. The historical data is continuous in time from 1991 to 2009, and near real-time data is made available from Envisat, Jason-1 and Jason-2 within a few hours of measurement time.

Details of the content of the L2P netCDF files are given. The dataset includes data transcribed from the space agency native products together with information derived during the GlobWave project on data quality and errors. Also included are ancillary parameters obtained from the numerical weather models of ECMWF.

The GlobWave demonstation products are described together with information on how to access them.

Applications of the data are not included in this guide, but will be described in a separate document, the GlobWave Wave Data Handbook.

2 INTRODUCTION

This document is the Product User Guide for GlobWave L2P (level 2 preprocessed) and demonstration data products. It is a reference guide for anyone using GlobWave L2P data products and also a reference for the GlobWave demonstration products. It represents deliverable D.5 of the DUE GlobWave Project.

2.1 The GlobWave Project

The GlobWave project seeks to improve the uptake of satellite-derived wind-wave and swell data by the scientific, operational and commercial user community. The project covers the development of an integrated set of information services based on satellite wave data, and the operation and maintenance of these services for a demonstration period. The project includes the following components:

- Development and maintenance of a GlobWave web portal providing a single point of reference for satellite wave data and associated calibration and validation information. The web portal shall include access to satellite wave data sets, a directory of different sources of wave data including their main characteristics, online tools providing graphical and statistical diagnostics based on comparison between satellite data streams and with in situ data, and a handbook for new users providing information on the characteristics of the various types of satellite wave data and how to access and utilise them.

- Provision via the GlobWave web portal of a uniform, harmonised, quality controlled, multi-sensor set of satellite wave data and ancillary information, in a common format, with consistent characterisation of errors and biases. This is achieved through the L2P dataset. The data provision shall also include the demonstration of new types of satellite wave data products, such as those based on new retrieval techniques, new types of satellite data, merged data from different sensors, or combinations of model and satellite data.

- Inter-comparison of SAR and altimeter wave data with colocated in situ measurements, and cross characterisation between different satellite data streams, and between satellite and wave model data.

- Development and demonstration of a pilot extension of the JCOMM Wave Forecast Verification Scheme to include spatial inter-comparison with satellite wave data sets.

These activities are intended to make it easier for the global user community to use satellite wave data, to facilitate routine comparisons with wave models, and to stimulate the development of model assimilation.

The GlobWave Project is funded by the Data User Element (DUE), which is a programmatic element of the 3rd period of the Earth Observation Envelope

Programme (EOEP-3), an optional programme of the European Space Agency (ESA). In addition, CNES funding has also contributed.

2.2 The Level 2 Preprocessed (L2P) dataset

The Level 2 Preprocessed (L2P) satellite wave data set is one of the fundamental elements of the GlobWave and was defined following the approach pioneered for satellite sea surface temperature data by ESA's Medspiration project. The L2P data consists of Level-2 data from multiple SAR and altimetry sensors which has been transcribed into a common netCDF format, and which has been augmented with error estimates for each wave measurement.

The common format of L2P products allows data users to code with the security that as new satellite derived wave data sets are brought online, very minimal code changes are required to make full use of the data. Time previously spent on coding different input-output routines and on trying to understand the different characteristics of each satellite data set can instead be spent working with the data to produce results.

2.3 Document Structure

The document structure is as follows:

- Section 1 – Executive Summary.
- Section 2 – Introduction: This section.
- Section 3 – Essential information: A summary of the products, how to access them, and contact details.
- Section 4 – L2P data product products: A detailed description of the content of the L2P data products.
- Section 5 – Demonstration data products: A summary of GlobWave demonstration products and how to access them.
- ANNEX A – Example netCDF header listings
- ANNEX B – Calculation of the L2P quality variables
- ANNEX C – Calculation of the swh_standard_error variable
- ANNEX D – Specific content of the altimetry rejection_flags variable.

2.4 Definitions and Acronyms

Acronym	Definition
ASAR	Advanced Synthetic Aperture Radar
ASCII	American Standard Code for Information Interchange
AVISO	Archiving, Validation and Interpretation of Satellite Oceanographic Data
CD	Compact Disc

Acronym	Definition
CDIP	Coastal Data Information Program
CLS	Collecte Localisation Satellites
CNES	Centre National d'Etudes Spatiales
CSV	Comma Separated Value
DUE	Data User Element
DVD	Digital Versatile Disc
ECMWF	European Centre for Medium-Range Weather Forecasts
ENVISAT	ESA’s Environmental Satellite
EO	Earth Observation
ERS	European Remote-Sensing Satellite
ESA	European Space Agency
ESRIN	ESA Space Research Institute
ESTEC	European Space Research and Technology Centre
GDR	Geophysical Data Record
GEOSAT	GEOdetic SATellite
GFO	GEOSAT Follow On
GHRSST	GODAE High Resolution Sea Surface Temperature
GODAE	Global Ocean Data Assimilation Experiment
GOES	Geostationary Operational Environment Satellites
HR-DDS	High Resolution Diagnostic Data Set
Hs	Significant Wave Height
I/O	Input/Output
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology
L2P	Level-2-Preprocessed
MATLAB	MATrix LABoratory
MDB	Match Up Database
MERSEA	Marine Environment and Security for the European Area
NASA	National Aeronautical Space Administration
NCOF	National Centre for Ocean Forecasting
NDBC	National Data Buoy Center
NERSC	Nansen Environmental and Remote Sensing Center
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NOCS	National Oceanography Centre Southampton
NODC	National Oceanographic Data Center
NRT	Near Real Time

Acronym	Definition
PDF	Portable Document Format
PM	Progress Meeting
RADS	Radar Altimeter Database System
RB	Requirements Baseline
RMS	Root Mean Square
SAR	Synthetic Aperture Radar
SatOC	Satellite Oceanographic Consultants
SHOM	Service Hydrographique et Océanographique de la Marine
SQL	Structured Query Language
SSALTO	Segment Sol multi-missions d'ALTimetrie, d'orbitographie et de location précise
SST	Sea Surface Temperature
TBC	To Be Confirmed
THREDDS	THematic Real-time Environmental Distributed Data Services
UKMO	United Kingdom Meteorological Office
WAM	Wave Analysis Model
WFVS	Wave Forecast Verification Scheme

3 ESSENTIAL INFORMATION: SUMMARY OF PRODUCTS, PRODUCT ACCESS, CONTACT DETAILS

This section gives a summary of GlobWave data products and information on how to access them, as well as relevant contacts. There are separate sections containing more detailed information on the L2P data products and demonstration products.

3.1 L2P products

3.1.1 Near real-time (NRT) products

An overview of the NRT products is given in Table 3-1. Details of the data availability and file structure are available in Section 4.

L2P product	Description	Typical file size
GW_L2P_SAR_ENVI_NRT_*	Near real-time L2P product from Envisat synthetic aperture radar	< 100 KB
GW_L2P_ALT_ENVI_NRT_*	Near real-time L2P product from Envisat altimeter	~550 KB
GW_L2P_ALT_JAS1_NRT_*	Near real-time L2P product from Jason-1 altimeter	~450 KB
GW_L2P_ALT_JAS2_NRT_*	Near real-time L2P product from Jason-2 altimeter	~650 KB

Table 3-1: Overview of NRT L2P product file types (* is a generic marker for date, time, cycle and orbit information)

Access to NRT products

To access NRT data products:

1. Obtain login details by emailing CERSAT help desk: fpaf@ifremer.fr

2. Access data by ftp at: ftp://eftp.ifremer.fr/waveuser/globwave/data/

The data are made available on the ftp server as soon as they are produced. The typical delay for NRT L2P products to become available is 1 to 4 hours from measurement time, depending on satellite. The L2P products are organised in a hierarchy to enable ease of access to files and to satisfy the user requirement of making the data available as files per orbit and files per day.

The hierarchy is structured as follows with the ROOT_PATH being at the top level:

- ROOT_PATH (waveuser/globwave/data/)
- Type (l2p)
- Acquisition type (sar or altimeter)

- Mode (nrt)
- Satellite (e.g. envisat)
- Year (e.g. 2010)
- Day (e.g. day 1 which would signify 1st January)

An example of the full path of a file for an Envisat ASAR SAR acquisition on 1st January, 2010 would be:

ftp://eftp.ifremer.fr/waveuser/globwave/data/l2p/sar/nrt/envisat/2010/001/

This ensures it is easy to get the data from a single day (though still into multiple orbit files) by copying all files in the appropriate directory for a particular day.

Note that the ECMWF ancillary fields (sea surface temperature, surface air temperature, surface air pressure, surface air humidity) arrive every 6 hours and the rest of the product is ready to distribute before then. Therefore we have decided to release the GlobWave L2P product as soon as it is available and then add the ECMWF fields 24 hours later.

L2P version	Date	Status
1.0	16/12/10	Initial release of L2P products NRT version

3.1.2 Delayed mode (GDR) products

An overview of the delayed mode products is given in Table 3-2. Details of the data availability and file structure are available in Section 4.

L2P product	Description	Typical file size
GW_L2P_SAR_ENVI_NRT_*	L2P product from Envisat synthetic aperture radar (format is unchanged from NRT product)	< 100 KB
GW_L2P_ALT_ERS1_GDR_*	L2P product from ERS-1 altimeter	212 KB
GW_L2P_ALT_ERS2_GDR_*	L2P product from ERS-2 altimeter	216 KB
GW_L2P_ALT_ENVI_GDR_*	L2P product from Envisat altimeter	264 KB
GW_L2P_ALT_GEOS_GDR_*	L2P product from Geosat altimeter	3.7 MB
GW_L2P_ALT_GFO__GDR_*	L2P product from Geosat Follow-On altimeter	188 KB
GW_L2P_ALT_TOPX_GDR_*	L2P product from TOPEX/Poseidon altimeter	264 KB
GW_L2P_ALT_JAS1_GDR_*	L2P product from Jason-1 altimeter	256 KB
GW_L2P_ALT_JAS2_GDR_*	L2P product from Jason-2 altimeter	308 KB

Table 3-2: Overview of delayed mode L2P product file types (* is a generic marker for date, time, cycle and orbit information)

Access to delayed mode products

To access GDR data products:

1. Obtain login details by emailing CERSAT help desk: fpaf@ifremer.fr

2. Access data by ftp at: ftp://eftp.ifremer.fr/waveuser/globwave/data/

The data are made available on the ftp server as soon as they are produced. The L2P products are organised in a hierarchy to enable ease of access to files and to satisfy the user requirement of making the data available as files per orbit and files per day.

The hierarchy is structured as follows with the ROOT_PATH being at the top level:

- ROOT_PATH (waveuser/globwave/data/)
- Type (l2p)
- Acquisition type (sar or altimeter)
- Mode (gdr)
- Satellite (e.g. envisat)
- Year (e.g. 2010)
- Day (e.g. day 1 which would signify 1st January)

An example of the full path of a file for an Envisat ASAR SAR acquisition on 1st January, 2009 would be:

ftp://eftp.ifremer.fr/waveuser/globwave/data/l2p/sar/gdr/envisat/2009/001/

This ensures it is easy to get the data from a single day (though still into multiple orbit files) by copying all files in the appropriate directory for a particular day.

Release history

L2P version	Date	Status
1.0	22/04/10	Initial release of L2P products GDR version
1.3	22/11/10	Inclusion of error statistics, update to Jason-2 calibration

Table 3-3: Release history of the delayed mode L2P

3.1.3 Terms & Conditions

After users request access to the GlobWave data via e-mail to the CERSAT help desk, they will receive an automated reply. This reply contains the ftp login details as well as a set of terms and conditions. The user is informed that by accessing the data they are agreeing to these terms and conditions. The terms and conditions are as follows:

"*GlobWave data is public domain and may be used, copied and distributed free of charge. GlobWave data may be exploited commercially to develop revenue-generating services where measurable value is added to the GlobWave data by a service provider. Distribution or copying of unmodified GlobWave data for commercial purposes or financial gain is strictly prohibited. Users are required to acknowledge GlobWave in any resulting papers, products, presentations or other* *outreach material.*

Any data made available through GlobWave is not guaranteed to be: up to date, true, not misleading, free from viruses (or anything else which may have a harmful effect on any technology), or to always be available for use.

No liability shall be accepted for any losses incurred as a result of the use of this data."

3.2 Demonstration products

Demonstration product	Description	Access
Hs-Tz scatterplots	Plots of significant wave height against altimeter-derived wave period for selected locations coincident with in-situ data positions.	GlobWave portal: http://www.globwave.org/Products/Demo-Products/Hs-Tz-scatterplots
Fireworks	Swell tracking animations of SAR-observed swell snapshots at several successive dates from observations back or forward in time after simple linear wave propagation.	Through Soprano website at: http://soprano.cls.fr/L3/fireworks.html
Soprano	SAR wave spectra extracted from a subset of a full SAR image. It also contains significant wave height and dominant wavelength and direction for the three most energetic wave partitions detected in each SAR wave spectrum.	Soprano website: http://soprano.cls.fr

3.3 Contact details

Product / service	Name, organisation	Email
Altimetry L2P This L2P User Guide Hs-Tz scatterplots	Ellis Ash, SatOC	e.ash@satoc.eu
SAR L2P Fireworks Soprano	Fabrice Collard ("dr.fab"), CLS	dr.fab@cls.fr
Data access / GlobWave portal	Jean-Francois Piolle, IFREMER	Jean.Francois.Piolle@ifremer.fr
GlobWave Project Manager	Geoff Busswell, Logica	geoff.busswell@logica.com

4 L2P DATA PRODUCTS

The L2P data products are based on both near real-time and archive wave data from altimeter and synthetic aperture radar (SAR) satellites.

4.1 Level 2 source data

4.1.1 Near real-time source data

The following data sources available in near real-time (NRT) will be used to generate the NRT L2P products from early 2010:

Source	L2 Product	Type	Dates	Official Source
ESA Envisat	RA2_WWV_2P	Altimeter	26/08/2002 onwards	ESA www.esa.int
ESA Envisat	ASA_WVW_2P	SAR	17/12/2002 onwards	ESA www.esa.int
CNES/NASA Jason-1	OSDR	Altimeter	15/01/2002 onwards	AVISO www.aviso.oceanobs.com, PODAAC http://podaac.jpl.nasa.gov
CNES/NASA Jason-2	OGDR	Altimeter	/12/2008 onwards	NOAA www.noaa.gov, EUMETSAT www.eumetsat.int

Table 4-1: Space Agency L2 NRT Satellite Data for GlobWave

4.1.2 Delayed mode source data

The following archive data sources have been used to generate the delayed mode (GDR) L2P data products:

Source	L2 Product	Type	Dates	Official Source
ESA ERS-1	ERS.ALT.OPR	Altimeter	01/02/1992 – 02/06/1996	CERSAT http://cersat.ifremer.fr
ESA ERS-2	ERS.ALT.OPR	Altimeter	15/05/1995 – 22/06/2003[1]	CERSAT http://cersat.ifremer.fr

[1] ERS-2 is still operational. However, the data coverage has reduced since 22/06/2003, and is still interesting for specific regions. It should also be noted that the coverage has improved since mid 2008 due to new acquisition stations.

Source	L2 Product	Type	Dates	Official Source
ESA ERS-1	ERS_WVW_2P	SAR	/01/1991– /12/1996	CERSAT http://cersat.ifremer.fr
ESA ERS-2	ERS_WVW_2P	SAR	/01/1996 onwards	CERSAT http://cersat.ifremer.fr
ESA Envisat	RA2_GDR_2P	Altimeter	26/08/2002 onwards	ESA www.esa.int
CNES/NASA Topex/POSEIDON	MGDR	Altimeter	25/09/1992-08/10/2005	AVISO www.aviso.oceanobs.com, PODAAC http://podaac.jpl.nasa.gov
CNES/NASA Jason-1	GDR	Altimeter	15/01/2002 onwards	AVISO www.aviso.oceanobs.com, PODAAC http://podaac.jpl.nasa.gov
CNES/NASA Jason-2	GDR	Altimeter	/12/2008 onwards	NOAA www.noaa.gov, EUMETSAT www.eumetsat.int
US Navy GEOSAT	GDR	Altimeter	31/03/1985-30/12/1989	NOAA www.noaa.gov
US Navy/NOAA GEOSAT Follow On	GDR and I-GDR	Altimeter	08/01/2000 - 23/07/2008	NOAA www.noaa.gov

Table 4-2: Space Agency L2 Archived Satellite Data for GlobWave

4.2 L2P format and file naming

The L2P format is netCDF-3 and the convention Climate and Forecast CF-1.4.

For more information on the netCDF format visit:

http://www.unidata.ucar.edu/software/netcdf/index.html

For more information on Climate and Forecast conventions visit:

http://cf-pcmdi.llnl.gov/

The L2P data files are named in the following way:

GW_L2P_instr_satid_type_startdate_starttime_enddate_endtime_cycle_orbit.nc

where the lower case word labels are substituted as follows:

Label	File name components	Comments
instr	one of: **SAR** **ALT**	Gives satellite instrument type: SAR altimeter
satid	one of: **GEOS** **ERS1** **ERS2** **ENVI** **TOPX** **GFO_** **JAS1** **JAS2**	Gives satellite: Geosat (altimeter only) ERS1 ERS2 Envisat Topex/Poseidon (altimeter only) Goesat Follow-on (altimeter only) Jason-1 (altimeter only) Jason-2 (altimeter only)
type	one of: **GDR** **NRT**	Gives type of L2 source data used: Delayed mode data products (often called Geophysical Data Records, GDR) Near real-time data products
startdate	8 digit date in the form YYYYMMDD	Data start date
starttime	6 digit time in the form hhmmss	Data start time
enddate	8 digit date in the form YYYYMMDD	Data end date
endtime	6 digit time in the form hhmmss	Data end time
cycle	3 digit number	Cycle of satellite mission
orbit	3 or 4 digit number	Orbit or pass within the cycle

4.3 L2P content

A netCDF file contains Dimensions, Variables, Variable Attributes, Global Attributes and Data. The content of the L2P data are described with respect to these below.

4.3.1 Dimensions

For SAR data (GW_L2P_SAR) there are 4 dimensions:

Name	Length	Notes
time	variable	This dimension is variable in length according to the number of data points in time in the L2 data.
n_partitions	variable	This dimension is variable in length according to the number of partitions

Name	Length	Notes
		in the L2 data.
n_wavenumbers	variable	This dimension is variable in length according to the number of wavenumbers in the L2 data.
n_directions	variable	This dimension is variable in length according to the number of directions in the L2 data.

Table 4-3: SAR Variable Dimensions

For altimetry data (GW_L2P_ALT) data are one-dimensional along the satellite track and there is just the time dimension:

Name	Length	Notes
time	variable	This dimension is variable in length according to the number of data points in time in the L2 data.

Table 4-4: Altimeter Variable Dimensions

4.3.2 Variables

The SAR variables are described in Table 4-5. Variables in blue type are those derived or manipulated within the GlobWave processing, while those in black are transcribed directly from the L2 data products.

No.	Name	Description	NetCDF Type	Units
1	time	Seconds since 1985-01-01	double	s
2	lat	Latitude	int	10^{-6} deg
3	lon	Longitude	int	10^{-6} deg
4	track_angle	Local satellite heading	short	10^{-3} deg
5	incidence_angle	Local incidence angle	short	10^{-3} deg
6	polSpec	Estimated Directional wave spectra : spectral energy for each direction/wavenum ber	Short x n_wavenumbersx n_directions	10-3 m2
7	indPart	Directional wave spectra partition index : 0 for the most energetic partition, 1 for the	byte x n_wavenumbersx n_directions	n/a

No.	Name	Description	NetCDF Type	Units
		second, etc...		
8	k	wavenumbers for polar spectra	short	m-1
9	phi	angular values for polar spectra	short	deg
10	area	Polar spectral bin area	short	m-2
11	snr	signal/noise ratio	short	10-3 m2
12	swh	Total significant wave height	short	10^{-3} m
13	swh_calibrated	Calibrated significant wave height	short	10^{-3} m
14	swh_standard_error	HS best estimate of standard error	short	10^{-3} m
15	swh_part	Significant wave height for each spectral partition	short x n_paritions	10-3 m
16	dwl_part	Dominant wavelength for each spectral partition	short x n_paritions	10^{-3} m
17	ddr_part	Dominant direction for each spectral partition	short x n_paritions	10-3 deg
18	sigma0	Mean backscatter coefficient	short	10^{-2} dB
19	nv	Normalized backscatter coefficient variance	short	
20	sigma0_calibrated	Calibrated backscatter coefficient	short	10^{-2} dB
21	sigma0_quality	sigma0 quality (3 levels)	byte	
22	wind_speed_sar	SAR wind speed	short	10^{-2} m/s
23	wind_speed_sar_calibrated	Calibrated sar wind speed	short	10^{-2} m/s
24	wind_speed_model_u	U component of model wind vector	short	10^{-2} m/s
25	wind_speed_model_v	V component of model wind vector	short	10^{-2} m/s

No.	Name	Description	NetCDF Type	Units
26	swh_rms	RMS/std of total significant wave height	short	10-3 m
27	swh_rms_part	RMS/std of significant wave height for each partition	short x n_paritions	10-3 m
28	dwl_rms_part	RMS/std of dominant wavelength for each partition	short x n_paritions	10-3 m
29	ddr_rms_part	RMS/std of dominant direction for each partition	short x n_paritions	10-3 deg
30	sigma0_rms	RMS/std of backscatter coefficient	short	10-2 dB
31	azimuth_cutoff	Azimuth cutoff wavelength	short	10-3 m
32	range_cutoff	Range cutoff wavelength	short	10-3 m
33	quality_flag	Wave inversion quality (3 levels)	byte x n_paritions	
34	rejections_flag	Bundled flags including spare bits	int	
35	bathymetry	Bathymetry extracted from GEBCO_08 Grid	int	m
36	land_coverage	percentage of land coverage within a cell	short	%
37	distance_to_coast	Distance to coast extracted from GSHHS shoreline	short	km
38	sea_surface_temperature	SST from model		
39	surface_temperature	Surface air temperature from model		
40	surface_air_humidity	Surface air humidity from model		
41	surface_air_pressure	Surface air pressure from model		

Table 4-5: SAR Variables

The altimetry variables are described in Table 4-6. Variables in blue type are those derived or manipulated within the GlobWave processing, while those in black are transcribed directly from the L2 data products. This is a list of all variables, but for each individual satellite the included variables are a subset of this. The variables included for each satellite are summarized in Table 4-7.

No.	Name	Description	NetCDF Type	Units
1	time	Seconds since 1985-01-01	double	s
2	lat	Latitude	double	deg
3	lon	Longitude	double	deg
4	swh	Significant wave height (primary, e.g. Ku band)	short	10^{-3} m
5	swh_calibrated	Calibrated significant wave height.	short	10^{-3} m
6	swh_quality	Significant wave height quality (3 levels).	byte	
7	swh_standard_error	Significant wave height best estimate of standard error.	short	10^{-3} m
8	swh_2nd	Significant wave height 2^{nd} frequency (e.g. S or C band)	short	10^{-3} m
9	swh_2nd_calibrated	Calibrated significant wave height 2^{nd} frequency.	short	10^{-3} m
10	swh_2nd_quality	HS quality 2^{nd} frequency (3 levels) .	byte	
11	sigma0	Backscatter coefficient (primary, e.g. Ku band)	short	10^{-2} dB
12	sigma0_calibrated	Calibrated backscatter coefficient.	short	10^{-2} dB
13	sigma0_quality	Sigma0 quality (3 levels).	byte	
14	sigma0_2nd	Backscatter coefficient 2^{nd} frequency (e.g. S or C band)	short	10^{-2} dB
15	sigma0_2nd_calibrated	Calibrated significant wave height 2^{nd} frequency.	short	10^{-2} dB
16	sigma0_2nd_quality	sigma0 quality 2^{nd} frequency (3 levels) .	byte	
17	wind_speed_alt	Altimeter wind speed	short	10^{-2} m/s
18	wind_speed_alt_calibrated	Calibrated Altimeter wind speed.	short	10^{-2} m/s
19	wind_speed_rad	Radiometer wind speed	short	10^{-2} m/s

No.	Name	Description	NetCDF Type	Units
20	wind_speed_model_u	U component of model wind vector	short	10^{-2} m/s
21	wind_speed_model_v	V component of model wind vector	short	10^{-2} m/s
22	rejection_flags	32 bundled flags, all relevant flags included with spare bits for future missions.	int	
23	swh_rms	RMS/std of significant wave height (primary, e.g. Ku band)	short	10^{-3} m
24	swh_rms_2nd	RMS/std of significant wave height 2nd frequency (e.g. S or C band)	short	10^{-3} m
25	swh_num_valid	Number of valid points used to compute Hs (primary, e.g. Ku band)	short	
26	swh_num_valid_2nd	Number of valid points used to compute Hs 2nd frequency (e.g. S or C band)	short	
27	sigma0_rms	RMS/std of backscatter coefficient (primary, e.g. Ku band)	short	10^{-2} dB
28	sigma0_rms_2nd	RMS/std of backscatter coefficient 2nd frequency (e.g. S or C band)	short	10^{-2} dB
29	sigma0_num_valid	Number of valid points used to compute sig0 (primary, e.g. Ku band)	short	
30	sigma0_num_valid_2nd	Number of valid points used to compute sig0 2nd frequency (e.g. S or C band)	short	
31	peakiness	Pulse peakiness (primary, e.g. Ku band, Envisat only)	short	10^{-3}
32	peakiness_2nd	Pulse peakiness 2nd frequency (e.g. S band, Envisat only)	short	10^{-3}
33	off_nadir_angle_wf	Off nadir angle from waveforms	short	Deg(^{2})
34	off_nadir_angle_pf	Off nadir angle from platform	short	Deg(^{2})
35	range_rms	RMS/std of range (primary, e.g. Ku band)	short	10^{-4} m
36	range_rms_2nd	RMS/std of range 2nd frequency (e.g. S or C band)	short	10^{-4} m
37	bathymetry	Bathymetry from GEBCO 08 / DTM2000.1	short	m

No.	Name	Description	NetCDF Type	Units
38	distance_to_coast	Distance to coast.	short	km
39	sea_surface_temperature	SST from model.	short	K
40	surface_temperature	Surface air temperature from model.	short	K
41	surface_air_humidity	Surface air humidity from model.	short	%
42	surface_air_pressure	Surface air pressure from model.	short	Pa

Table 4-6: Altimetry Variables

Satid	Included variable numbers
ERS1	1-7, 11-13, 17-18, 20-23, 25, 27, 33, 35, 37-42
ERS2	1-7, 11-13, 17-18, 20-23, 25, 27, 33, 35, 37-42
ENVI	1-18, 20-42
GEOS	1-7, 11-13, 17-18, 20-22, 33, 35, 37-42
GFO_	1-7, 11-13, 17-18, 20-23, 25, 27, 33, 35, 37-42
TOPX	1-18, 20-25, 27, 29, 33-35, 37-42
JAS1	1-30, 33-42
JAS2	1-30, 33-42

Table 4-7: Altimetry variables included for each satellite

4.3.3 Variable Attributes

The variable attributes used in the L2P are described in Table 4-8. The attributes associated with specific variables are given in the example L2P header listings in ANNEX A: L2P dimension, variable and attribute listings.

Variable Attribute	Description	Comment
_FillValue	Default value for missing or undefined data	
long_name	A descriptive name that indicates a variable's content. This name is not standardized	
standard_name	A standard name that references a description of a variables content in the standard name table	
units	Unit of a variable's content	
calender	Reference time calender	
source	Data source (e.g. model)	

Variable Attribute	Description	Comment
institution	Institution which provides the data	
calibration_formula	Formula used in applying calibration	
calibration_reference	Reference for calibration formula	
quality_flag	Name of variable or quality flag representing quality of current variable	
valid_min	Smallest theoretical valid value of a variable (this is not the maximum of actual data)	
valid_max	Largest theoretical valid value of a variable (this is not the maximum of actual data)	
flag_values	Provide a list of the flag values. Use in conjunction with flag_meanings	
flag_masks	Use in conjunction with flag_meanings to allocate variable bit settings	
flag_meanings	Use in conjunction with flag_values to provide descriptive words or phrase for each flag value	
scale_factor	Scale factor to be applied to integer to achieve correct units	
add_offset	Offset to be applied to integer to achieve correct value	
coordinates	Identified auxiliary coordinate variables	
comment	Miscellaneous information about the data or the methods used to produce it	

Table 4-8: Variable Attributes

4.3.4 Global Attributes

The global attributes used in the L2P are described in Table 4-9.

Global Attribute	Description
Conventions	CF-1.4
title	GlobWave L2P
source	radar altimeter
project	ESA GlobWave
institution	GlobWave
history	Date and time of product creation
contact	Contact information
references	GlobWave Product User Guide
processing_center	Ifremer

Global Attribute	Description
software_version	GlobWave product user guide
source_provider	
mission_name	
source_name	
source_version	
source_software	
altimeter_sensor_name	
radiometer_sensor_name	
acq_station_name	Acquisition station
cycle_number	Mission cycle number
pass_number	Pass or orbit within cycle
equator_crossing_time	
equator_crossing_longitude	
start_time	Date and time of first measurement in file
stop_time	Date and time of last measurement in file

Table 4-9: Global Attributes

4.3.5 Data

The data themselves are of the specified binary type and presented in blocks in the order of the variables listing, however this order is not normally relevant when reading netCDF files. The number of data points for a variable corresponds to the product of the dimension values of that variable.

4.4 Variable calculation

This section describes the calculation of all variables that are not transferred directly from the L2 source data but either derived from this or from external sources.

4.4.1 Calibrated variables

4.4.1.1 SAR calibration

SAR calibration is done solely on integrated wave parameters for each wave partitions and is based on comparison of SAR wave spectra with buoy wave spectra after partitioning both spectra and cross association of partitions.

For instance

swh_calibrated = swh +0.1 swh * max (0, U10SAR -7) -0.11 with the wind speed U10SAR is in m/s

References :

Johnsen, H., and F. Collard (2004), ASAR wave mode processing — Validation of reprocessing upgrade, Tech. Rep. 168, North. Res. Inst., Troms, Norway.

Collard, F., F. Ardhuin, and B. Chapron (2009), Monitoring and analysis of ocean swell fields from space: New methods for routine observations, J. Geophys. Res., doi:10.1029/2008JC005215.

4.4.1.2 Altimetry calibration

Recommended corrections have been applied to the altimeter 1Hz estimates of significant wave height (swh) to derive the calibrated values (swh_calibrated).

For near real-time data (NRT) they are taken from Durrant et al. (2009).

For historical data (GDR) they are taken from Queffeulou & Croizé-Fillon (2009), except for Geosat which has the swh values on the revised data set Geosat Altimeter JGM-3 GDRs on CD-ROM already increased by 13% in accordance with Carter et al. (1992). The corrections are given in Table 4-10 for near real-time data and Table 4-11 for historical data.

Satellite (satid)	Correction	Comments
Envisat (ENVI)	swh_calibrated = 1.093 x swh - 0.233	
Jason1 (JAS1)	swh_calibrated = 1.041 x swh - 0.076	
Jason2 (JAS2)	swh_calibrated = 1.041 x swh - 0.076	As Jason-1 until new calibration performed.

Table 4-10: Calibration correction values for near real-time altimeter data

Satellite (satid)	Correction	Comments
Geosat (GEOS)	swh_calibrated = swh	JGM-3 version has calibrations applied
ERS-1 (ERS1)	swh_calibrated = 1.1259 x swh + 0.1854	
ERS-2 (ERS2)	swh_calibrated = 1.0642 x swh + 0.0006	
Envisat (ENVI)	swh_calibrated = 1.0585 x swh – 0.1935	
Topex (TOPX)	Side A: swh_calibrated = 1.0539 x swh - 0.0766 + dh with: dh = 0 for cycle < 98	Side A operated up to cycle 235. There was a drift in the measured swh values beginning in cycle 98, which is corrected for in the calibration.

Satellite (satid)	Correction	Comments
Poseidon (TOPX)	dh = poly3(98) - poly3(cycle) for 98 <= cycle <= 235 with a0 = 0.0864 ; a1= -6.0426 x 10-4 ; a2 = -7.7894 x 10-6 ; a3 = 6.9624 x 10-8 Side B: swh_calibrated = 1.0237 x swh - 0.0476 swh_calibrated = 0.9914 x swh – 0.0103	Side B operated after cycle 235 Poseidon operated throughout the mission approximately 5% of the time.
Geosat Follow-On (GFO_)	swh_calibrated = 1.0625 x swh + 0.0754	
Jason-1	swh_ calibrated = 1.0250 x swh + 0.0588	L2 data version b.
Jason-2	swh_ calibrated = 1.041 x swh - 0.042	New Jason-2 calibration from error analysis

Table 4-11: Calibration correction values for historical altimeter data

In the version 1.3 of the L2P (October 2010), calibrations are only provided for primary frequency significant wave height. Variables for calibrated values are also provided for second frequency significant wave height, primary and secondary frequency sigma0 and altimeter wind speed. These may be filled in future releases of the l2p.

References

Carter D J T, Challenor P G & Srokosz M A 1992
An assessment of Geosat wave height and wind speed measurements
J. Geophys. Res. 97 (C7), 11383-11392.

Durrant T H, Greenslade D J M & Simmonds I 2009
Validation of Jason-1 and Enivsat remotely sensed wave heights
J. Atmos, Oce. Tech. 26, 123-134.

Queffeulou P & Croizé-Fillon D June 2009
Global altimeter SWH data set
IFREMER (pierre.queffeulou@ifremer.fr)

4.4.2 Quality variables

4.4.2.1 SAR quality variables

Quality variables are included for overall wave spectra and backscatter coefficient (sigma0). The quality variables are:

- quality_flag (one quality flag per spectral partition)
- sigma0_quality

The values and corresponding meanings of the quality flag for each partition are given in Table 4-12.

Value (decimal)	Meaning
0	Probably good partition
1	Probably good but 180° ambiguous partition
2	Probably bad partition (ie azimuth cutoff affected or spurious dataset)

Table 4-12: Quality variables values

In the present version of the SAR L2P product (April 2010), this flag is set for each partition but has a common value for all partitions representing an overall ability to remove the 180 ambiguity estimated over all wavenumbers and directions. There is no way to set it separately starting from the existing L2 products. In future L2 reprocessing, each partitions will be treated separately and the quality values in the L2P will subsequently reflect the actual quality of each partitions.

The values and corresponding meanings of the sigma0 quality flag are given in Table 4-13.

Value (decimal)	Meaning
0	Probably good measurement
1	Suspect, probably okay for some applications. For example this is set when sigma0 over SAR imagette is very inhomogeneous
2	Probably bad measurement

Table 4-13: Quality variables values

4.4.2.2 Altimetry quality variables

Quality variables are included for significant wave height (Hs) and backscatter coefficient (sigma0) for both main and second altimeter frequencies where applicable. The quality variables are:

- swh_quality
- sigma0_quality
- swh_2nd_quality
- swh_2nd_quality

In the initial release of the L2P (April 2010) quality variables are only calculated for the main altimeter frequency, and have the same value for Hs and sigma0 at a data point. The values and corresponding meanings of the quality variables are given in Table 4-14.

Value (decimal)	Meaning
0	Probably good measurement
1	Suspect, probably okay for some applications. For example this is set when rain is detected for an otherwise good measurement.
2	Probably bad measurement
127	Not evaluated

Table 4-14: Quality variables values

The calculation of the quality variables varies by satellite and sensor, and details are given Annex B.

4.4.3 Hs standard error variable

The Hs standard error variable gives a measure of the standard error for significant wave height and is calculated using collocations with in situ measurements. The Hs standard error variable is:

- swh_standard_error

The error is derived from the spread of the regression of collocation measurements, and varies with altimeter and with significant wave height. The method of calculating the swh_standard_error is described in ANNEX C. This is an extract from the full reference for the error analysis, the GlobWave Wave Data Quality Report (year 1), GlobWave_D16_WDQR1.

4.4.4 Rejection flags variable

The rejections flag variable contains consolidated flags from the L2 source data together with an externally derived ice flag. The rejection flags variable is:

- rejection_flags

4.4.4.1 SAR rejections flags variable

In the present version (April 2010) of the SAR L2P product, the rejection flag has a limited number of values to account for the ice flag, SAR image quality issues, or scene inhomogeneity that can have various sources (including typically ice, land, bright targets or very low variable wind).

In the future versions, the existing flag values and related meaning will remain intact but some other values corresponding to other possible rejection criteria might be added.

4.4.4.2 Altimeter rejections flag variable

The content of the rejections flag is based loosely on the 'flags' variable used in the RADS database, and is summarised in Table 4-15. The specific flags included for each satellite are described in ANNEX D.

Bit	Description	Satellites
0	Hardware status	TOPX JAS1 JAS2 ENVI
1	Satellite on track Attitude status	ERS1 ERS2 GEOS TOPX GFO_ JAS1 JAS2
2	spare	
3	spare	
4	Altimeter land flag	all
5	Altimeter ocean / non-ocean flag	all
6	Radiometer land flag	all except GEOS
7	Corruption of Altimeter measurement	TOPX JAS1 JAS2 GFO_ ENVI
8	Corruption of radiometer measurement	ERS1 ERS2 TOPX JAS1 JAS2
9	spare	
10	spare	
11	Quality of the range estimate	all
12	Quality of the wave height estimate Sea state bias	ERS1 ERS2 TOPX GFO_ JAS1 JAS2 GEOS
13	Quality of sigma0 estimate Quality of windspeed measurement	all except GEOS GEOS
14	spare	
15	Quality of the orbit	ERS1 ERS2 TOPX JAS1 JAS2 ENVI
16	Quality of the wave height estimate 2nd frequency	JAS2
17	Quality of sigma0 estimate 2nd frequency	JAS2
18	Quality of off nadir angle from waveforms	JAS2
19	Quality of off nadir angle from platform	JAS2
20	Ice flag from database	all
21-30	spare	
31	Flag rejection	all

Table 4-15: Rejection Flags

4.4.5 Ancillary variables

Ancillary fields are quantities additional to those associated with wave measurements that may have an effect on the measurements or their application. The ancillary variables are:

- wind_speed_model_u
- wind_speed_model_v
- bathymetry
- distance_to_coast
- sea_surface_temperature
- surface_air_temperature
- surface_air_humidity
- surface_air_pressure

Some of these ancillary fields are provided within the L2 data products, but in order to maintain consistency across the L2P all the values are updated from external sources.

For the meteorological parameters (all except bathymetry and distance to coast) the values are obtained from numerical models operated at ECMWF.

For near real-time L2P data, output from the operational global 0.5 degree analysis is used.

For delayed mode data, output from the ERA40 0.75 degree reanalysis is used. This output does not include the surface_air_humidity values, so humidity values are absent from the initial release (2010) of the L2P GDR data products.

The ice flag bit of the rejections_flag variable is also taken from the ECMWF model output, but is planned to be updated from the high resolution OSI-SAF dataset later in the project.

The bathymetry and distance_to_coast are calculated from GEBCO (TBC) and (TBC) respectively.

4.4.6 Known issues

Users should be aware of the following issues with the L2P data products associated with the versions in each subsection.

4.4.6.1 NRT

4.4.6.1.1 SAR Processor Version 1.8

Unfilled variables

- surface_air_humidity

4.4.6.1.2 Altimeter Processor Version 1.2

Unfilled variables

- surface_air_humidity

4.4.6.2 GDR

4.4.6.2.1 Altimeter Product Version 1.3

Unfilled variables

- swh_2nd_calibrated, sigma0_calibrated, sigma0_2nd_calibrated, wind_speed_alt_calibrated
  These variables are included in the l2p for future use if robust calibrations become available.

- swh_2nd_quality, sigma0_2nd_quality
  These variables are included in the l2p for future use if robust quality criteria become available.

- surface_air_humidity
  This parameter was not available in the ECMWF reanalysis but may be included in a future release of the l2p.

4.4.6.2.2 Altimeter Product Version 1.2

Unfilled variables

- swh_2nd_calibrated, sigma0_calibrated, sigma0_2nd_calibrated, wind_speed_alt_calibrated
  These variables are included in the l2p for future use if robust calibrations become available.

- swh_2nd_quality, sigma0_2nd_quality
  These variables are included in the l2p for future use if robust quality criteria become available.

- surface_air_humidity
  This parameter was not available in the ECMWF reanalysis but may be included in a future release of the l2p.

Other variables to be updated

- rejections_flag
  The ice flag component of this variable will be updated with higher resolution data in a future release of the L2P.

Data quality issues

- Envisat: certain files (e.g. Cycle 047 pass 194) have some bad latitude values in the L2 data that have not yet been corrected for in the L2P.

- ERS2: Some negative swh values to be investigated.
- GFO: some L2 files contain no data and are omitted from the L2P.

Other issues

- Topex: calibration of Topex prior to cycle 98 is incorrect and has a missing zero in the offset factor. Will be corrected in v1.3 of the L2P.
- GFO: the swh_calibrated values are incorrect. Will be corrected in v1.3 of the L2P
- All satellites: the swh_standard_error value is incorrect for swh values < 1m. Will be corrected in v1.3 of the L2P.
- All satellites: some swh_calibrated values are –ve whereas to be consistent with what is planned for the NRT data they should be set to zero. Will be corrected in v1.3 of the L2P.
- Geosat: swh_calibrated values are the same as swh as the data are calibrated in the L2. The calibration reference in given incorrectly and should be Carter et al. (1992) (see section 4.4.1.2).

4.4.6.2.3 Altimeter Product Version 1.1

Unfilled variables

- swh_2nd_calibrated, sigma0_calibrated, sigma0_2nd_calibrated, wind_speed_alt_calibrated
  These variables are included in the l2p for future use if robust calibrations become available.
- swh_2nd_quality, sigma0_2nd_quality
  These variables are included in the l2p for future use if robust quality criteria become available.
- surface_air_humidity
  This parameter was not available in the ECMWF reanalysis but may be included in a future release of the l2p.

Other variables to be updated

- rejections_flag
  The ice flag component of this variable will be updated with higher resolution data in a future release of the L2P.

Data quality issues

- Envisat: certain files (e.g. Cycle 047 pass 194) have some bad latitude values in the L2 data that have not yet been corrected for in the L2P.
- ERS2: Some negative swh values to be investigated.

- GFO: some L2 files contain no data and are omitted from the L2P.

Other issues

- Geosat: swh_calibrated values are the same as swh as the data are calibrated in the L2. The calibration reference in given incorrectly and should be Carter et al. (1992) (see section 4.4.1.2).

- All satellites: the swh_standard_error variable was calculated using calibrated data instead of uncalibrated data giving a difference of <1%.

4.4.6.2.4 Altimeter Product Version 1.0

Unfilled variables

- swh_2nd_calibrated, sigma0_calibrated, sigma0_2nd_calibrated, wind_speed_alt_calibrated
  These variables are included in the l2p for future use if robust calibrations become available.

- swh_2nd_quality, sigma0_2nd_quality
  These variables are included in the l2p for future use if robust quality criteria become available.

- swh_standard_error
  This variable will be calculated and included in the next release of the L2P.

- surface_air_humidity
  This parameter was not available in the ECMWF reanalysis but may be included in a future release of the l2p.

Other variables to be updated

- rejections_flag
  The ice flag component of this variable will be updated with higher resolution data in a future release of the L2P.

Data quality issues

- Envisat: certain files (e.g. Cycle 047 pass 194) have some bad latitude values in the L2 data that have not yet been corrected for in the L2P.

- ERS2: Some negative swh values to be investigated.

- GFO: some L2 files contain no data and are omitted from the L2P.

Other issues

Geosat: swh_calibrated values are the same as swh as the data are calibrated in the L2. The calibration reference in given incorrectly and should be Carter et al. (1992) (see section 4.4.1.2).

4.4.6.2.5 SAR Product Version 1.2

Unfilled variables

- surface_air_humidity
  This parameter was not available in the ECMWF reanalysis but may be included in a future release of the l2p.

Other variables to be updated

- rejections_flag
  The ice flag component of this variable will be updated with higher resolution data in a future release of the L2P.

4.4.6.2.6 SAR Product Version 1.1

Unfilled variables

- swh_calibrated, swh_part_calibrated, dwl_part_calibrated, sddr_part_calibrated, sigma0_calibrated, wind_speed_sar_calibrated
  These variables are included in the l2p for future use if robust calibrations become available. They currently contain the uncalibrated values.

- sigma0_quality
  This variable in included in the l2p for future use if robust quality criteria become available.

- swh_standard_error, swh_part_standard_error, dwl_part_standard_error, ddr_part_standard_error, dsp_part, dsp_part_standard_error, sigma0_standard_error, range_cutoff.

These variables will be calculated and included in the next release of the L2P.

- surface_air_humidity
  This parameter was not available in the ECMWF reanalysis but may be included in a future release of the l2p.

Other variables to be updated

- rejections_flag
  The ice flag component of this variable will be updated with higher resolution data in a future release of the L2P.

4.4.6.2.7 SAR Product Version 1.0

Unfilled variables

- swh_calibrated, swh_part_calibrated, dwl_part_calibrated, sddr_part_calibrated, sigma0_calibrated, wind_speed_sar_calibrated
  These variables are included in the l2p for future use if robust calibrations become available. They currently contain the uncalibrated values.

- sigma0_quality
  This variable in included in the l2p for future use if robust quality criteria become available.

- swh_standard_error, swh_part_standard_error, dwl_part_standard_error, ddr_part_standard_error, dsp_part, dsp_part_standard_error, sigma0_standard_error, range_cutoff.

These variables will be calculated and included in the next release of the L2P.

- surface_air_humidity
  This parameter was not available in the ECMWF reanalysis but may be included in a future release of the l2p.

Other variables to be updated

- rejections_flag
  The ice flag component of this variable will be updated with higher resolution data in a future release of the L2P.

Other issues

- Envisat: the directions of the SAR partitions (ddr_part) have been incorrectly set to zero.

5 DEMONSTRATION DATA PRODUCTS

The initial set of demonstration products are:

- Hs-Tz scatterplots
- Fireworks
- Soprano

Further demonstration products will be developed during the project and described in future revisions of this document.

5.1 Hs-Tz scatterplots

Hs is significant wave height and Tz the mean zero upcrossing wave period. Hs:Tz scatterplots are widely used in offshore engineering in fatigue calculations (which require the joint distribution of individual wave heights and periods). They are also used as a visual quality check, and in wave energy applications to estimate wave power.

A scatterplot is a diagram illustrating the bivariate distribution of two parameters, such as significant wave height and zero-upcross wave period (Hs and Tz). Usually the diagram shows the data plotted on Cartesian co-ordinates. The individual pairs of data can be plotted, as in Fig.1, but more often, given a large number of pairs, the numbers in specified bins are plotted as in Fig.2 (or bins can be colour-coded). Bins here are 1 m by 1 second; they are often 0.5 m by 0.5 second and sometimes bin numbers are contoured. See for example Fig. 5.11 in Tucker & Pitt, 2001.

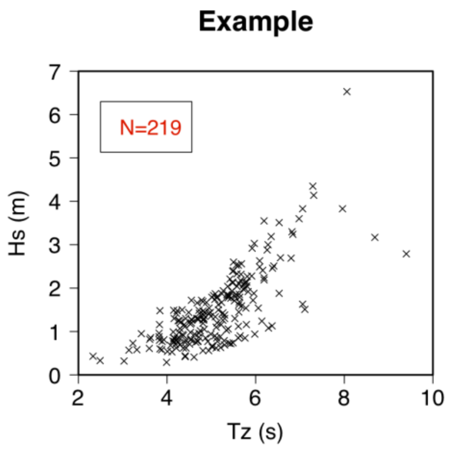

Figure 1: Example scatterplot

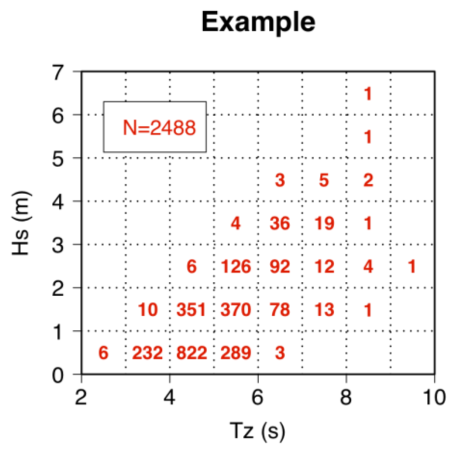

Figure 2: Grouping in bins

Often, in Hs-Tz scatterplots the numbers are converted to parts per thousand (ppt) rounded to the nearest integer; and lines of significant steepness are added. Significant steepness is defined by

$$Ss = \frac{2\pi Hs}{gTz^2}$$

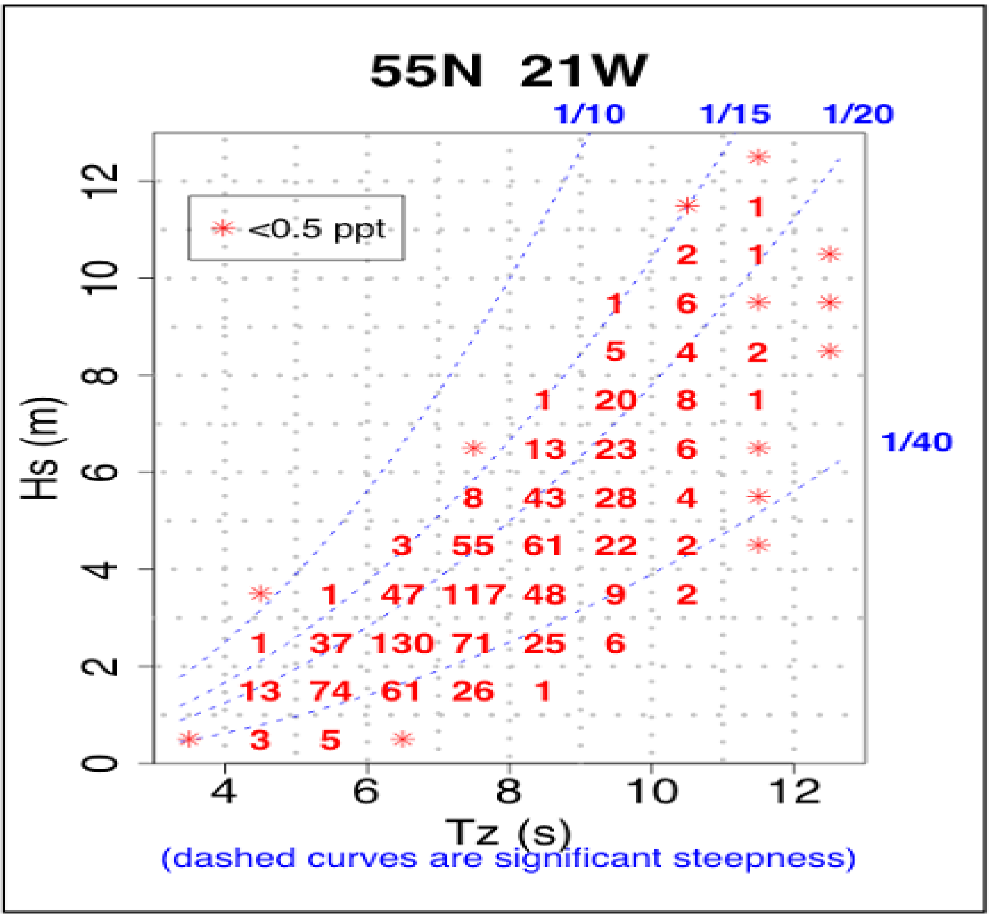

Figure 3: Hs-Tz Scatterplot using the Altimeter Wave Period Product

An example Hs-Tz plot is given above in Figure 3. This was produced from the Wavsat medians database, using all medians in a 2° squared bin centred 55°N 21°W (3795 medians) - and calculating wave period using Mackay et al. (2008). Values shown are in parts per thousand, with * for <0.5 ppt.

The steepness S of a simple, periodic wave train is defined as the crest-to–trough height divided by wavelength (h/λ). The maximum possible steepness, before the wave breaks, is about 1/7. For low amplitude sinusoidal waves of period T in deep water, from the relationship between wavelength and wave period, we get

$$S = \frac{2\pi h}{gT^2}$$

Significant steepness is defined by analogy. There is no theoretical upper limit but usually its maximum is about 1/13.

For further details on significant steepness see Tucker & Pitt, 2001. They also discuss the scatterplot, including its use in investigating structure fatigue problems in Section 5.4.

Hs-Tz scatterplots have been generated for a selection of locations where in situ data are available for comparison. The initial set of locations is given below, together with the WMO station reference for buoys located within the associated 2° squared bin.

Region	Location	WMO buoy reference
N Pacific	55°N 175°E	46070
Equatorial Pacific	1°N 153°W	51028
W Pacific	13°N 145°E	52200
Mediterranean	39°N 5°E	61197
NW Atlantic	49°N 13°W	62029
NW Atlantic	55°N 21°W	62606
NW Atlantic	59°N 11°W	64045

Access to these plots is via the GlobWave portal.

References

Mackay E B L, Retzler C H, Challenor P G & Gommenginger C P 2008, A parametric model for ocean wave period from Ku band altimeter data, J. Geophys. Res. 113, C03029,

Tucker M J & Pitt E G 2001, Waves in Ocean Engineering
Elsevier.

5.2 Fireworks

Fireworks consists of swell tracking animations of SAR observed swell snapshots at several successive dates from observations back or forward in time after simple linear wave propagation. Significant wave height is propagated from original observation using energy dissipation function derived from 3 years or wave mode data collected along several storm swell propagation trajectories. This swell tracking is performed every morning over the 3 main oceans (Atlantic, Pacific and Indian). The time step of the animation is 3 hours. The colour is coding the dominant wave length equivalent to swell period in deep water.

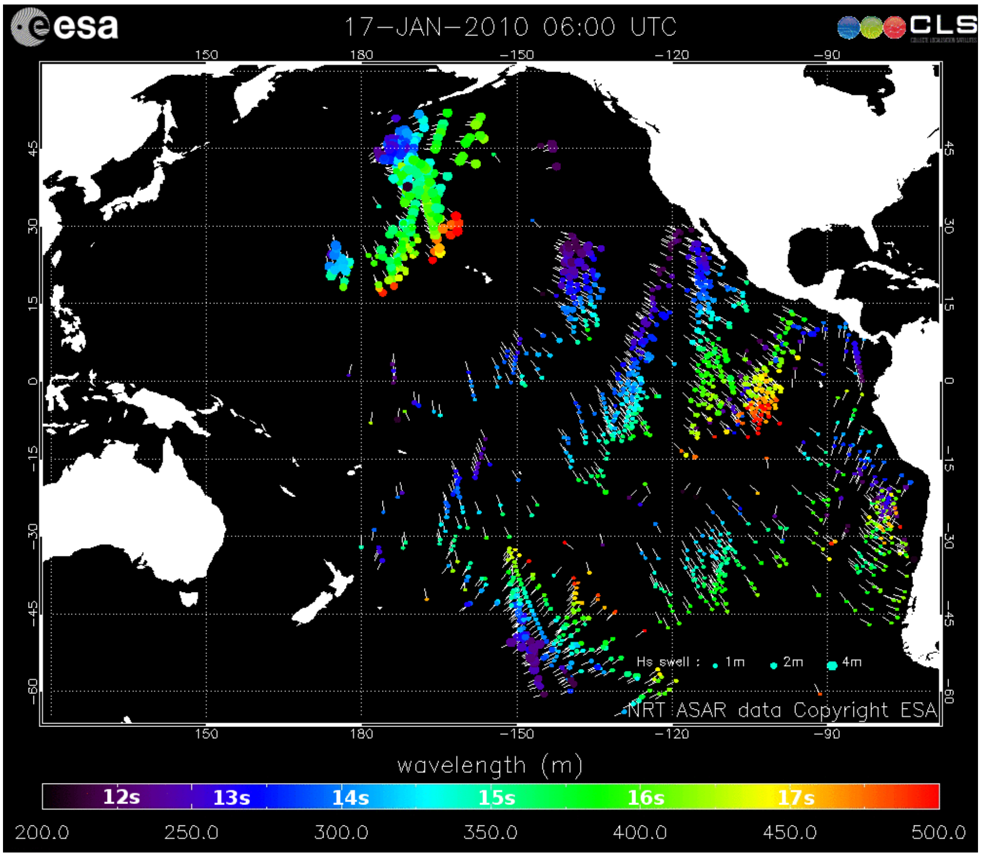

Figure 4: Snapshot of Swell Field from Fireworks Product

Figure 4 shows a still-shot of such a swell system propagation using the wave spectra measured by the Envisat ASAR instrument. The colour is proportional to the wave length of the wave systems observed. The updated animated propagation can be viewed at:

http://www.esa.int/esaEO/SEM563AATME_index_0.html under swell tracking section.

Integrated parameters of each dividual components of each swell systems (dominant period, dominant direction and significant swell wave height) at each given time step will also be shortly available in numerical format (NetCDF) from Globwave web portal.

5.3 Soprano

The SOPRANO demonstration product consists of a grid of SAR wave spectra extracted from a subset of a full SAR image. It also contains significant wave height and dominant wavelength and direction for the three most energetic wave partitions detected in each SAR wave spectrum. The spacing of the wave spectra grid is typically 5km and the SAR wave spectra has the same structure (including number of wavenumber and direction bins) as the GlobWave SAR L2P product.

Error characterisation of the SOPRANO wave product is done by extracting retrieved swell information in the SOPRANO wave product over reference buoys when images are acquired over one of the reference buoys. Significant wave height, dominant wavelength and directional error statistics are then be estimated by comparing swell partitions from the SOPRANO product to spectral partitioning of the in situ wave spectra.

Soprano is available at the following web site where further details and instructions for its use can be found:

http://soprano.cls.fr

ANNEX A :L2P DIMENSION, VARIABLE AND ATTRIBUTE LISTINGS

This Annex contains an example of the netCDF header listings for Envisat SAR and altimetry.

```
netcdf GW_L2P_SAR_ENVI_NRT_20021217_024301_20021217_024830_0012_0104 {
dimensions:
	time = 23 ;
	partitions = 2 ;
	wavenumbers = 24 ;
	directions = 36 ;
variables:
	double time(time) ;
		time:calendar = "gregorian" ;
		time:long_name = "time (seconds since 1985-01-01)" ;
		time:standard_name = "time" ;
		time:units = "seconds since 1985-01-01 00:00:00.0" ;
	double lat(time) ;
		lat:long_name = "Latitude" ;
		lat:standard_name = "latitude" ;
		lat:units = "degrees_north" ;
		lat:comment = "Positive latitude is North latitude, negative lat" ;
	double lon(time) ;
		lon:long_name = "Longitude" ;
		lon:standard_name = "longitude" ;
		lon:units = "degrees_east" ;
		lon:valid_max = -180.f ;
		lon:valid_min = 180.f ;
		lon:comment = "East longitude relative to Greenwich meridian" ;
	short track_angle(time) ;
		track_angle:long_name = "Local satellite heading" ;
		track_angle:scale_factor = 0.01f ;
		track_angle:add_offset = -180.f ;
		track_angle:units = "degree" ;
		track_angle:comment = "satellite heading direction in degrees
clockwise from North" ;
		track_angle:coordinates = "lon lat" ;
	short incidence_angle(time) ;
		incidence_angle:long_name = "Local incidence angle" ;
		incidence_angle:scale_factor = 0.01f ;
		incidence_angle:add_offset = 0.f ;
		incidence_angle:units = "degree" ;
		incidence_angle:comment = "Local incidence angle at the sea surface"
;
		incidence_angle:coordinates = "lon lat" ;
	short polSpec(directions, wavenumbers, time) ;
		polSpec:_FillValue = 32767s ;
		polSpec:long_name = "Estimated Directional wave spectra : spectral
energy for each direction/wavenumber" ;
		polSpec:standard_name =
"sea_surface_wave_directional_variance_spectral_density" ;
		polSpec:units = "m2" ;
		polSpec:coordinates = "lon lat" ;
	float k(wavenumbers) ;
		k:_FillValue = 0.f ;
		k:long_name = "wavenumbers for polar spectra" ;
		k:units = "m-1" ;
	short phi(directions) ;
		phi:_FillValue = 32767s ;
		phi:long_name = "angular values for polar spectra" ;
		phi:units = "degree" ;
		phi:comment = "Degrees clockwise from Local satellite heading" ;
	float area(wavenumbers) ;
		area:_FillValue = 0.f ;
		area:long_name = "Polar spectral bin area" ;
		area:units = "m-2" ;
		area:validation_reference = " " ;
	short snr(time) ;
		snr:_FillValue = 32767s ;
		snr:long_name = "signal/noise ratio" ;
		snr:scale_factor = 0.01f ;
```

```
           snr:add_offset = 0.f ;
           snr:units = "m2" ;
           snr:coordinates = "lon lat" ;
      short swh(time) ;
           swh:_FillValue = 32767s ;
           swh:long_name = "Total significant wave height of imaged waves" ;
           swh:standard_name = "sea_surface_wave_significant_height" ;
           swh:scale_factor = 0.001f ;
           swh:add_offset = 0.f ;
           swh:units = "m" ;
           swh:valid_max = 20000s ;
           swh:valid_min = 0s ;
           swh:coordinates = "lon lat" ;
      short swh_calibrated(time) ;
           swh_calibrated:_FillValue = 32767s ;
           swh_calibrated:long_name = "Calibrated Total significant wave height
of imaged waves" ;
           swh_calibrated:standard_name = "sea_surface_wave_significant_height"
;
           swh_calibrated:scale_factor = 0.001f ;
           swh_calibrated:add_offset = 0s ;
           swh_calibrated:units = "m" ;
           swh_calibrated:valid_max = 20000s ;
           swh_calibrated:valid_min = 0s ;
           swh_calibrated:coordinates = "lon lat" ;
      short swh_standard_error(time) ;
           swh_standard_error:_FillValue = 32767s ;
           swh_standard_error:long_name = "Significant wave height best
estimate of standard error" ;
           swh_standard_error:scale_factor = 0.001f ;
           swh_standard_error:add_offset = 0.f ;
           swh_standard_error:units = "m" ;
           swh_standard_error:coordinates = "lon lat" ;
      short swh_part(partitions, time) ;
           swh_part:_FillValue = 32767s ;
           swh_part:long_name = "Significant wave height  for each spectral
partition" ;
           swh_part:quality_flag = "quality_flag" ;
           swh_part:standard_name = "sea_surface_swell_wave_significant_height"
;
           swh_part:scale_factor = 0.001f ;
           swh_part:add_offset = 0.f ;
           swh_part:units = "m" ;
           swh_part:coordinates = "lon lat" ;
      short swh_part_calibrated(partitions, time) ;
           swh_part_calibrated:_FillValue = 32767s ;
           swh_part_calibrated:long_name = "Calibrated Significant wave height
for each spectral partition" ;
           swh_part_calibrated:standard_name =
"sea_surface_swell_wave_significant_height" ;
           swh_part_calibrated:scale_factor = 0.001f ;
           swh_part_calibrated:add_offset = 0.f ;
           swh_part_calibrated:units = "m" ;
           swh_part_calibrated:coordinates = "lon lat" ;
      short swh_part_standard_error(partitions, time) ;
           swh_part_standard_error:_FillValue = 32767s ;
           swh_part_standard_error:long_name = "RMS error of significant wave
height for each spectral partition" ;
           swh_part_standard_error:scale_factor = 0.001f ;
           swh_part_standard_error:add_offset = 0.f ;
           swh_part_standard_error:units = "m" ;
           swh_part_standard_error:coordinates = "lon lat" ;
      short dwl_part(partitions, time) ;
           dwl_part:_FillValue = 32767s ;
           dwl_part:long_name = "Dominant wavelength for each spectral
partition" ;
           dwl_part:quality_flag = "quality_flag" ;
           dwl_part:scale_factor = 0.1f ;
           dwl_part:add_offset = 0.f ;
           dwl_part:units = "m" ;
           dwl_part:valid_max = 8000s ;
           dwl_part:valid_min = 300s ;
           dwl_part:coordinates = "lon lat" ;
      short dwl_part_calibrated(partitions, time) ;
           dwl_part_calibrated:_FillValue = 32767s ;
           dwl_part_calibrated:long_name = "Calibrated Dominant wavelength for
each spectral partition" ;
```

```
          dwl_part_calibrated:quality_flag = "quality_flag" ;
          dwl_part_calibrated:scale_factor = 0.1f ;
          dwl_part_calibrated:add_offset = 0.f ;
          dwl_part_calibrated:units = "m" ;
          dwl_part_calibrated:valid_max = 8000s ;
          dwl_part_calibrated:valid_min = 300s ;
          dwl_part_calibrated:coordinates = "lon lat" ;
     short dwl_part_standard_error(partitions, time) ;
          dwl_part_standard_error:_FillValue = 32767s ;
          dwl_part_standard_error:long_name = "RMS error of dominant
wavelength for each partition" ;
          dwl_part_standard_error:scale_factor = 0.1f ;
          dwl_part_standard_error:add_offset = 0.f ;
          dwl_part_standard_error:units = "m" ;
          dwl_part_standard_error:coordinates = "lon lat" ;
     short ddr_part(partitions, time) ;
          ddr_part:_FillValue = 32767s ;
          ddr_part:long_name = "Dominant direction for each spectral
partition" ;
          ddr_part:quality_flag = "quality_flag" ;
          ddr_part:standard_name = "sea_surface_swell_wave_to_direction" ;
          ddr_part:scale_factor = 0.1f ;
          ddr_part:add_offset = 0.f ;
          ddr_part:units = "degree" ;
          ddr_part:comment = "heading of wave vector in degrees clockwise from
north" ;
          ddr_part:coordinates = "lon lat" ;
     short ddr_part_calibrated(partitions, time) ;
          ddr_part_calibrated:_FillValue = 32767s ;
          ddr_part_calibrated:long_name = "Calibrated Dominant direction for
each spectral partition" ;
          ddr_part_calibrated:quality_flag = "quality_flag" ;
          ddr_part_calibrated:standard_name =
"sea_surface_swell_wave_to_direction" ;
          ddr_part_calibrated:scale_factor = 0.1f ;
          ddr_part_calibrated:add_offset = 0.f ;
          ddr_part_calibrated:units = "degree" ;
          ddr_part_calibrated:comment = "heading of wave vector in degrees
clockwise from north" ;
          ddr_part_calibrated:coordinates = "lon lat" ;
     short ddr_part_standard_error(partitions, time) ;
          ddr_part_standard_error:_FillValue = 32767s ;
          ddr_part_standard_error:long_name = "Dominant direction for each
spectral partition" ;
          ddr_part_standard_error:scale_factor = 0.1f ;
          ddr_part_standard_error:add_offset = 0.f ;
          ddr_part_standard_error:units = "degree" ;
          ddr_part_standard_error:coordinates = "lon lat" ;
     short dsp_part(partitions, time) ;
          dsp_part:_FillValue = 32767s ;
          dsp_part:long_name = "directional spread for each spectral
partition" ;
          dsp_part:scale_factor = 0.1f ;
          dsp_part:add_offset = 0.f ;
          dsp_part:units = "degree" ;
          dsp_part:coordinates = "lon lat" ;
     short dsp_part_standard_error(partitions, time) ;
          dsp_part_standard_error:_FillValue = 32767s ;
          dsp_part_standard_error:long_name = "RMS error of directional spread
for each partition" ;
          dsp_part_standard_error:scale_factor = 0.1f ;
          dsp_part_standard_error:add_offset = 0.f ;
          dsp_part_standard_error:units = "degree" ;
          dsp_part_standard_error:coordinates = "lon lat" ;
     short sigma0(time) ;
          sigma0:_FillValue = 32767s ;
          sigma0:long_name = "Mean backscatter coefficient" ;
          sigma0:scale_factor = 0.001f ;
          sigma0:add_offset = -10.f ;
          sigma0:units = "dB" ;
          sigma0:coordinates = "lon lat" ;
     short sigma0_calibrated(time) ;
          sigma0_calibrated:_FillValue = 32767s ;
          sigma0_calibrated:long_name = "Mean backscatter coefficient" ;
          sigma0_calibrated:quality_flag = "sigma0_quality" ;
          sigma0_calibrated:scale_factor = 0.001f ;
          sigma0_calibrated:add_offset = -10.f ;
```

```
            sigma0_calibrated:units = "dB" ;
            sigma0_calibrated:coordinates = "lon lat" ;
      short sigma0_standard_error(time) ;
            sigma0_standard_error:_FillValue = 32767s ;
            sigma0_standard_error:long_name = "Mean backscatter coefficient rms
error" ;
            sigma0_standard_error:scale_factor = 0.001f ;
            sigma0_standard_error:add_offset = 0.f ;
            sigma0_standard_error:units = "dB" ;
            sigma0_standard_error:coordinates = "lon lat" ;
      byte sigma0_quality(time) ;
            sigma0_quality:_FillValue = 127b ;
            sigma0_quality:long_name = "sigma0 quality (3 levels)" ;
            sigma0_quality:coordinates = "lon lat" ;
      short nv(time) ;
            nv:_FillValue = 32767s ;
            nv:long_name = "Normalized  backscatter coefficient variance" ;
            nv:scale_factor = 0.001f ;
            nv:add_offset = 0.f ;
            nv:coordinates = "lon lat" ;
      short wind_speed_sar(time) ;
            wind_speed_sar:_FillValue = 32767s ;
            wind_speed_sar:long_name = "SAR wind speed" ;
            wind_speed_sar:standard_name = "wind_speed" ;
            wind_speed_sar:scale_factor = 0.01f ;
            wind_speed_sar:add_offset = 0.f ;
            wind_speed_sar:units = "m s-1" ;
            wind_speed_sar:valid_max = 5000s ;
            wind_speed_sar:valid_min = 0s ;
            wind_speed_sar:coordinates = "lon lat" ;
      short wind_speed_sar_calibrated(time) ;
            wind_speed_sar_calibrated:_FillValue = 32767s ;
            wind_speed_sar_calibrated:long_name = "Calibrated SAR wind speed" ;
            wind_speed_sar_calibrated:standard_name = "wind_speed" ;
            wind_speed_sar_calibrated:scale_factor = 0.01f ;
            wind_speed_sar_calibrated:add_offset = 0.f ;
            wind_speed_sar_calibrated:units = "m s-1" ;
            wind_speed_sar_calibrated:valid_max = 5000s ;
            wind_speed_sar_calibrated:valid_min = 0s ;
            wind_speed_sar_calibrated:coordinates = "lon lat" ;
      short wind_speed_model_u(time) ;
            wind_speed_model_u:_FillValue = 32767s ;
            wind_speed_model_u:institution = "ECMWF" ;
            wind_speed_model_u:long_name = "U component of 10m wind vector" ;
            wind_speed_model_u:source = "atmospheric model" ;
            wind_speed_model_u:standard_name = "wind_speed" ;
            wind_speed_model_u:scale_factor = 0.01f ;
            wind_speed_model_u:add_offset = 0.f ;
            wind_speed_model_u:units = "m s-1" ;
            wind_speed_model_u:valid_max = 5000s ;
            wind_speed_model_u:valid_min = 0s ;
            wind_speed_model_u:coordinates = "lon lat" ;
      short wind_speed_model_v(time) ;
            wind_speed_model_v:_FillValue = 32767s ;
            wind_speed_model_v:institution = "ECMWF" ;
            wind_speed_model_v:long_name = "V component of 10m wind vector" ;
            wind_speed_model_v:source = "atmospheric model" ;
            wind_speed_model_v:standard_name = "wind_speed" ;
            wind_speed_model_v:scale_factor = 0.01f ;
            wind_speed_model_v:add_offset = 0.f ;
            wind_speed_model_v:units = "m s-1" ;
            wind_speed_model_v:valid_max = 5000s ;
            wind_speed_model_v:valid_min = 0s ;
            wind_speed_model_v:coordinates = "lon lat" ;
      short azimuth_cutoff(time) ;
            azimuth_cutoff:_FillValue = 32767s ;
            azimuth_cutoff:long_name = "Azimuth cutoff wavelength or shortest
azimuth wavelength observable by the instrument" ;
            azimuth_cutoff:scale_factor = 0.1f ;
            azimuth_cutoff:add_offset = 0.f ;
            azimuth_cutoff:units = "m" ;
            azimuth_cutoff:valid_max = 8000s ;
            azimuth_cutoff:valid_min = 300s ;
            azimuth_cutoff:coordinates = "lon lat" ;
      short range_cutoff(time) ;
            range_cutoff:_FillValue = 32767s ;
```

```
          range_cutoff:long_name = "Range cutoff wavelength or shortest range
wavelength observable by the instrument" ;
          range_cutoff:scale_factor = 0.1f ;
          range_cutoff:add_offset = 0.f ;
          range_cutoff:units = "m" ;
          range_cutoff:valid_max = 8000s ;
          range_cutoff:valid_min = 300s ;
          range_cutoff:coordinates = "lon lat" ;
     byte quality_flag(partitions, time) ;
          quality_flag:_FillValue = 127b ;
          quality_flag:comment = "0 if good, 1 if 180¬∞ ambiguous spectrum, 2
if not good" ;
          quality_flag:long_name = "Wave inversion quality (3 levels)" ;
          quality_flag:valid_max = 2b ;
          quality_flag:valid_min = 0b ;
          quality_flag:validation_reference = " " ;
          quality_flag:coordinates = "lon lat" ;
     short bathymetry(time) ;
          bathymetry:_FillValue = 32767s ;
          bathymetry:institution = "IOC and IHO" ;
          bathymetry:long_name = "ocean depth" ;
          bathymetry:source = "GEBCO_08" ;
          bathymetry:scale_factor = 1.f ;
          bathymetry:add_offset = 0.f ;
          bathymetry:units = "m" ;
          bathymetry:coordinates = "lon lat" ;
     byte land_coverage(time) ;
          land_coverage:_FillValue = 127b ;
          land_coverage:institution = "University of Hawaii SOEST" ;
          land_coverage:long_name = "percentage of land coverage within a
cell" ;
          land_coverage:source = "GSHHS shoreline database" ;
          land_coverage:units = "percent" ;
          land_coverage:valid_max = 100s ;
          land_coverage:valid_min = 0s ;
          land_coverage:scale_factor = 1.f ;
          land_coverage:add_offset = 0.f ;
          land_coverage:coordinates = "lon lat" ;
     short distance_to_coast(time) ;
          distance_to_coast:_FillValue = 32767s ;
          distance_to_coast:institution = "University of Hawaii SOEST" ;
          distance_to_coast:long_name = "Distance to coast extracted from
shoreline database" ;
          distance_to_coast:source = "GSHHS shoreline database" ;
          distance_to_coast:units = "km" ;
          distance_to_coast:scale_factor = 1.f ;
          distance_to_coast:add_offset = 0.f ;
          distance_to_coast:coordinates = "lon lat" ;
     short sea_surface_temperature(time) ;
          sea_surface_temperature:_FillValue = 32767s ;
          sea_surface_temperature:institution = "ECMWF" ;
          sea_surface_temperature:long_name = "Sea Surface Temperature" ;
          sea_surface_temperature:source = "atmospheric model" ;
          sea_surface_temperature:standard_name = "sea_surface_temperature" ;
          sea_surface_temperature:scale_factor = 0.01f ;
          sea_surface_temperature:add_offset = 0.f ;
          sea_surface_temperature:units = "K" ;
          sea_surface_temperature:coordinates = "lon lat" ;
     short surface_air_temperature(time) ;
          surface_air_temperature:_FillValue = 32767s ;
          surface_air_temperature:institution = "ECMWF" ;
          surface_air_temperature:long_name = "Surface air temperature" ;
          surface_air_temperature:source = "atmospheric model" ;
          surface_air_temperature:standard_name = "surface_temperature" ;
          surface_air_temperature:scale_factor = 0.01f ;
          surface_air_temperature:add_offset = 0.f ;
          surface_air_temperature:units = "K" ;
          surface_air_temperature:coordinates = "lon lat" ;
     short surface_air_humidity(time) ;
          surface_air_humidity:_FillValue = 32767s ;
          surface_air_humidity:institution = "ECMWF" ;
          surface_air_humidity:long_name = "Surface air humidity" ;
          surface_air_humidity:source = "atmospheric model" ;
          surface_air_humidity:units = "percent" ;
          surface_air_humidity:coordinates = "lon lat" ;
          surface_air_humidity:scale_factor = 1.f ;
          surface_air_humidity:add_offset = 0.f ;
```

```
      short surface_air_pressure(time) ;
           surface_air_pressure:_FillValue = 32767s ;
           surface_air_pressure:institution = "ECMWF" ;
           surface_air_pressure:long_name = "Surface air pressure" ;
           surface_air_pressure:source = "atmospheric model" ;
           surface_air_pressure:standard_name = "air_pressure_at_sea_level" ;
           surface_air_pressure:scale_factor = 0.001f ;
           surface_air_pressure:add_offset = 0.f ;
           surface_air_pressure:units = "Pa" ;
           surface_air_pressure:coordinates = "lon lat" ;

// global attributes:
           :Conventions = "CF-1.4" ;
           :title = "GlobWave SAR L2P derived from ESA Envisat L2 product" ;
           :source = "synthetic aperture radar" ;
           :project = "ESA GlobWave" ;
           :institution = "GlobWave" ;
           :history = "2010-01-29T09:15:33 UTC : Creation" ;
           :contact = "Jean.Francois.Piolle@ifremer.fr" ;
           :references = "GlobWave Product User Guide" ;
           :processing_center = "Ifremer" ;
           :software_version = "CLS GlobWave SAR L2P processor version 1.2" ;
           :source_provider = "European Space Agency" ;
           :mission_name = "Envisat" ;
           :source_name =
"ASA_WVW_2PPIFR20021217_024301_000003292012_00104_04166_0144.N1" ;
           :source_version = "N/A" ;
           :source_software = "NORUT/2.0" ;
           :acq_station_name = "IFR" ;
           :cycle_number = "0012" ;
           :pass_number = "0104" ;
           :polarization = "VV" ;
           :equator_crossing_time = "N/A" ;
           :equator_crossing_longitude = "N/A" ;
           :start_date = "2002-12-17T02:43:01 UTC" ;
           :stop_date = "2002-12-17T02:48:30 UTC" ;
}

netcdf GW_L2P_ALT_ENVI_GDR_20030108_040514_20030108_045531_012_420 {
dimensions:
      time = 2709 ;
variables:
      double time(time) ;
           time:long_name = "time (seconds since 1985-01-01)" ;
           time:standard_name = "time" ;
           time:units = "seconds since 1985-01-01 00:00:00.0" ;
           time:calendar = "gregorian" ;
      double lat(time) ;
           lat:long_name = "latitude" ;
           lat:standard_name = "latitude" ;
           lat:units = "degrees_north" ;
           lat:comment = "Positive latitude is North latitude, negative
latitude is South latitude" ;
      double lon(time) ;
           lon:long_name = "longitude" ;
           lon:standard_name = "longitude" ;
           lon:units = "degrees_east" ;
           lon:comment = "East longitude relative to Greenwich meridian" ;
      short swh(time) ;
           swh:_FillValue = 32767s ;
           swh:long_name = "Ku band corrected significant waveheight" ;
           swh:standard_name = "sea_surface_wave_significant_height" ;
           swh:units = "m" ;
           swh:quality_flag = "swh_quality" ;
           swh:scale_factor = 0.001 ;
           swh:coordinates = "lon lat" ;
           swh:comment = "All instrumental corrections included. Uncalibrated"
;
      short swh_calibrated(time) ;
           swh_calibrated:_FillValue = 32767s ;
           swh_calibrated:long_name = "Ku band calibrated significant
waveheight" ;
           swh_calibrated:standard_name = "sea_surface_wave_significant_height"
;
           swh_calibrated:units = "m" ;
           swh_calibrated:calibration_formula = "1.0585*swh + -0.1935" ;
```

```
          swh_calibrated:calibration_reference = "Queffeulou P & Croize-Fillon
D, June 2009, Global altimeter SWH data set, IFREMER" ;
          swh_calibrated:quality_flag = "swh_quality" ;
          swh_calibrated:scale_factor = 0.001 ;
          swh_calibrated:coordinates = "lon lat" ;
          swh_calibrated:comment = "All instrumental corrections included.
Calibrated" ;
     byte swh_quality(time) ;
          swh_quality:_FillValue = 127b ;
          swh_quality:long_name = "quality of Ku band significant waveheight
measurement" ;
          swh_quality:flag_values = 0b, 1b, 2b ;
          swh_quality:flag_meanings = "good_measurement
acceptable_for_some_applications bad_measurement" ;
     short swh_standard_error(time) ;
          swh_standard_error:_FillValue = 32767s ;
          swh_standard_error:long_name = "best estimate of significant
waveheight standard error" ;
          swh_standard_error:units = "m" ;
          swh_standard_error:source = "GlobWave Wave Data Quality Report" ;
          swh_standard_error:scale_factor = 0.001 ;
          swh_standard_error:coordinates = "lon lat" ;
          swh_standard_error:comment = "Standard error calculated from buoy
colocations, see GlobWave Product User Guide" ;
     short swh_2nd(time) ;
          swh_2nd:_FillValue = 32767s ;
          swh_2nd:long_name = "S band corrected significant waveheight" ;
          swh_2nd:standard_name = "sea_surface_wave_significant_height" ;
          swh_2nd:units = "m" ;
          swh_2nd:quality_flag = "swh_2nd_quality" ;
          swh_2nd:scale_factor = 0.001 ;
          swh_2nd:coordinates = "lon lat" ;
          swh_2nd:comment = "All instrumental corrections included.
Uncalibrated" ;
     short swh_2nd_calibrated(time) ;
          swh_2nd_calibrated:_FillValue = 32767s ;
          swh_2nd_calibrated:long_name = "S band calibrated significant
waveheight" ;
          swh_2nd_calibrated:standard_name =
"sea_surface_wave_significant_height" ;
          swh_2nd_calibrated:units = "m" ;
          swh_2nd_calibrated:calibration_formula = "N/A" ;
          swh_2nd_calibrated:calibration_reference = "N/A" ;
          swh_2nd_calibrated:quality_flag = "swh_2nd_quality" ;
          swh_2nd_calibrated:scale_factor = 0.001 ;
          swh_2nd_calibrated:coordinates = "lon lat" ;
          swh_2nd_calibrated:comment = "All instrumental corrections included.
Calibrated" ;
     byte swh_2nd_quality(time) ;
          swh_2nd_quality:_FillValue = 127b ;
          swh_2nd_quality:long_name = "quality of S band significant
waveheight measurement" ;
          swh_2nd_quality:flag_values = 0b, 1b, 2b ;
          swh_2nd_quality:flag_meanings = "good_measurement
acceptable_for_some_applications bad_measurement" ;
     short sigma0(time) ;
          sigma0:_FillValue = 32767s ;
          sigma0:long_name = "Ku band corrected backscatter coefficient" ;
          sigma0:units = "dB" ;
          sigma0:quality_flag = "sigma0_quality" ;
          sigma0:scale_factor = 0.01 ;
          sigma0:coordinates = "lon lat" ;
          sigma0:comment = "All instrumental corrections included.
Uncalibrated" ;
     short sigma0_calibrated(time) ;
          sigma0_calibrated:_FillValue = 32767s ;
          sigma0_calibrated:long_name = "Ku band calibrated backscatter
coefficient" ;
          sigma0_calibrated:units = "dB" ;
          sigma0_calibrated:calibration_formula = "N/A" ;
          sigma0_calibrated:calibration_reference = "N/A" ;
          sigma0_calibrated:quality_flag = "sigma0_quality" ;
          sigma0_calibrated:scale_factor = 0.01 ;
          sigma0_calibrated:coordinates = "lon lat" ;
          sigma0_calibrated:comment = "All instrumental corrections included.
Calibrated" ;
     byte sigma0_quality(time) ;
```

```
          sigma0_quality:_FillValue = 127b ;
          sigma0_quality:long_name = "quality of Ku band backscatter
coefficient" ;
          sigma0_quality:flag_values = 0b, 1b, 2b ;
          sigma0_quality:flag_meanings = "good_measurement
acceptable_for_some_applications bad_measurement" ;
     short sigma0_2nd(time) ;
          sigma0_2nd:_FillValue = 32767s ;
          sigma0_2nd:long_name = "S band corrected backscatter coefficient" ;
          sigma0_2nd:units = "dB" ;
          sigma0_2nd:quality_flag = "sigma0_2nd_quality" ;
          sigma0_2nd:scale_factor = 0.01 ;
          sigma0_2nd:coordinates = "lon lat" ;
          sigma0_2nd:comment = "All instrumental corrections included.
Uncalibrated" ;
     short sigma0_2nd_calibrated(time) ;
          sigma0_2nd_calibrated:_FillValue = 32767s ;
          sigma0_2nd_calibrated:long_name = "S band calibrated backscatter
coefficient" ;
          sigma0_2nd_calibrated:units = "dB" ;
          sigma0_2nd_calibrated:calibration_formula = "N/A" ;
          sigma0_2nd_calibrated:calibration_reference = "N/A" ;
          sigma0_2nd_calibrated:quality_flag = "sigma0_2nd_quality" ;
          sigma0_2nd_calibrated:scale_factor = 0.01 ;
          sigma0_2nd_calibrated:coordinates = "lon lat" ;
          sigma0_2nd_calibrated:comment = "All instrumental corrections
included. Calibrated" ;
     byte sigma0_2nd_quality(time) ;
          sigma0_2nd_quality:_FillValue = 127b ;
          sigma0_2nd_quality:long_name = "quality of S band backscatter
coefficient" ;
          sigma0_2nd_quality:flag_values = 0b, 1b, 2b ;
          sigma0_2nd_quality:flag_meanings = "good_measurement
acceptable_for_some_applications bad_measurement" ;
     short wind_speed_alt(time) ;
          wind_speed_alt:_FillValue = 32767s ;
          wind_speed_alt:long_name = "altimeter wind speed" ;
          wind_speed_alt:standard_name = "wind_speed" ;
          wind_speed_alt:units = "m s-1" ;
          wind_speed_alt:scale_factor = 0.01 ;
          wind_speed_alt:coordinates = "lon lat" ;
     short wind_speed_alt_calibrated(time) ;
          wind_speed_alt_calibrated:_FillValue = 32767s ;
          wind_speed_alt_calibrated:long_name = "calibrated altimeter wind
speed" ;
          wind_speed_alt_calibrated:standard_name = "wind_speed" ;
          wind_speed_alt_calibrated:units = "m s-1" ;
          wind_speed_alt_calibrated:calibration_formula = "N/A" ;
          wind_speed_alt_calibrated:calibration_reference = "N/A" ;
          wind_speed_alt_calibrated:scale_factor = 0.01 ;
          wind_speed_alt_calibrated:coordinates = "lon lat" ;
     short wind_speed_model_u(time) ;
          wind_speed_model_u:_FillValue = 32767s ;
          wind_speed_model_u:long_name = "U component of the model wind
vector" ;
          wind_speed_model_u:standard_name = "wind_speed" ;
          wind_speed_model_u:units = "m s-1" ;
          wind_speed_model_u:source = "atmospheric model" ;
          wind_speed_model_u:institution = "ECMWF" ;
          wind_speed_model_u:scale_factor = 0.01 ;
          wind_speed_model_u:coordinates = "lon lat" ;
     short wind_speed_model_v(time) ;
          wind_speed_model_v:_FillValue = 32767s ;
          wind_speed_model_v:long_name = "V component of the model wind
vector" ;
          wind_speed_model_v:standard_name = "wind_speed" ;
          wind_speed_model_v:units = "m s-1" ;
          wind_speed_model_v:source = "atmospheric model" ;
          wind_speed_model_v:institution = "ECMWF" ;
          wind_speed_model_v:scale_factor = 0.01 ;
          wind_speed_model_v:coordinates = "lon lat" ;
     int rejection_flags(time) ;
          rejection_flags:_FillValue = 2147483647 ;
          rejection_flags:long_name = "consolidated instrument and ice flags"
;
```

```
          rejection_flags:flag_masks = 1, 2048, 4096, 8192, 16384, 32768,
65536, 262144, 524288, 1048576, 8388608, 16777216, 33554432, 67108864,
134217728, 1073741824, -2147483648 ;
          rejection_flags:flag_meanings = "flag_rejection ice_flag
quality_of_off_nadir_from_platform quality_of_off_nadir_from_waveform
quality_of_S_band_sigma0 quality_of_orbit quality_of_S_band_swh
quality_of_Ku_band_sigma0 quality_of_Ku_band_swh quality_of_range_estimate
corruption_of_radiometer_measurement corruption_of_altimeter_measurement
radiometer_land_flag altimeter_ocean_flag altimeter_land_flag attitude_status
hardware_status" ;
     short swh_rms(time) ;
          swh_rms:_FillValue = 32767s ;
          swh_rms:long_name = "RMS of the Ku band significant waveheight" ;
          swh_rms:units = "m" ;
          swh_rms:scale_factor = 0.001 ;
          swh_rms:coordinates = "lon lat" ;
     short swh_rms_2nd(time) ;
          swh_rms_2nd:_FillValue = 32767s ;
          swh_rms_2nd:long_name = "RMS of the S band significant waveheight" ;
          swh_rms_2nd:units = "m" ;
          swh_rms_2nd:scale_factor = 0.001 ;
          swh_rms_2nd:coordinates = "lon lat" ;
     byte swh_num_valid(time) ;
          swh_num_valid:_FillValue = 127b ;
          swh_num_valid:long_name = "number of valid points used to compute Ku
band significant waveheight" ;
          swh_num_valid:units = "count" ;
          swh_num_valid:valid_min = 0b ;
          swh_num_valid:valid_max = 10b ;
          swh_num_valid:coordinates = "lon lat" ;
     byte swh_num_valid_2nd(time) ;
          swh_num_valid_2nd:_FillValue = 127b ;
          swh_num_valid_2nd:long_name = "number of valid points used to
compute S band significant waveheight 2nd" ;
          swh_num_valid_2nd:units = "count" ;
          swh_num_valid_2nd:valid_min = 0b ;
          swh_num_valid_2nd:valid_max = 10b ;
          swh_num_valid_2nd:coordinates = "lon lat" ;
     short sigma0_rms(time) ;
          sigma0_rms:_FillValue = 32767s ;
          sigma0_rms:long_name = "RMS of the Ku band backscatter coefficient"
;
          sigma0_rms:units = "dB" ;
          sigma0_rms:scale_factor = 0.01 ;
          sigma0_rms:coordinates = "lon lat" ;
     short sigma0_rms_2nd(time) ;
          sigma0_rms_2nd:_FillValue = 32767s ;
          sigma0_rms_2nd:long_name = "RMS of the S band backscatter
coefficient" ;
          sigma0_rms_2nd:units = "dB" ;
          sigma0_rms_2nd:scale_factor = 0.01 ;
          sigma0_rms_2nd:coordinates = "lon lat" ;
     byte sigma0_num_valid(time) ;
          sigma0_num_valid:_FillValue = 127b ;
          sigma0_num_valid:long_name = "number of valid points used to compute
Ku band backscatter coefficient" ;
          sigma0_num_valid:units = "count" ;
          sigma0_num_valid:valid_min = 0b ;
          sigma0_num_valid:valid_max = 10b ;
          sigma0_num_valid:coordinates = "lon lat" ;
     byte sigma0_num_valid_2nd(time) ;
          sigma0_num_valid_2nd:_FillValue = 127b ;
          sigma0_num_valid_2nd:long_name = "number of valid points used to
compute S band backscatter coefficient" ;
          sigma0_num_valid_2nd:units = "count" ;
          sigma0_num_valid_2nd:valid_min = 0b ;
          sigma0_num_valid_2nd:valid_max = 10b ;
          sigma0_num_valid_2nd:coordinates = "lon lat" ;
     short peakiness(time) ;
          peakiness:_FillValue = 32767s ;
          peakiness:long_name = "Ku band pulse peakiness" ;
          peakiness:units = "count" ;
          peakiness:coordinates = "lon lat" ;
     short peakiness_2nd(time) ;
          peakiness_2nd:_FillValue = 32767s ;
          peakiness_2nd:long_name = "S band pulse peakiness" ;
          peakiness_2nd:units = "count" ;
```

```
          peakiness_2nd:coordinates = "lon lat" ;
     short off_nadir_angle_wf(time) ;
          off_nadir_angle_wf:_FillValue = 32767s ;
          off_nadir_angle_wf:long_name = "square of the off nadir angle
computed from waveforms" ;
          off_nadir_angle_wf:units = "degree2" ;
          off_nadir_angle_wf:scale_factor = 0.0001 ;
          off_nadir_angle_wf:coordinates = "lon lat" ;
     short off_nadir_angle_pf(time) ;
          off_nadir_angle_pf:_FillValue = 32767s ;
          off_nadir_angle_pf:long_name = "square of the off nadir angle
computed from platform data" ;
          off_nadir_angle_pf:units = "degree2" ;
          off_nadir_angle_pf:scale_factor = 0.0001 ;
          off_nadir_angle_pf:coordinates = "lon lat" ;
     short range_rms(time) ;
          range_rms:_FillValue = 32767s ;
          range_rms:long_name = "RMS of the Ku band range" ;
          range_rms:units = "m" ;
          range_rms:scale_factor = 0.0001 ;
          range_rms:coordinates = "lon lat" ;
     short range_rms_2nd(time) ;
          range_rms_2nd:_FillValue = 32767s ;
          range_rms_2nd:long_name = "RMS of the S band range" ;
          range_rms_2nd:units = "m" ;
          range_rms_2nd:scale_factor = 0.0001 ;
          range_rms_2nd:coordinates = "lon lat" ;
     short bathymetry(time) ;
          bathymetry:_FillValue = 32767s ;
          bathymetry:long_name = "ocean depth" ;
          bathymetry:units = "m" ;
          bathymetry:source = "GEBCO/DTM2000.1" ;
          bathymetry:institution = "IOC/IHO/GSFC" ;
          bathymetry:scale_factor = 1. ;
          bathymetry:add_offset = 0 ;
          bathymetry:coordinates = "lon lat" ;
     short distance_to_coast(time) ;
          distance_to_coast:_FillValue = 32767s ;
          distance_to_coast:long_name = "distance to nearest coast" ;
          distance_to_coast:units = "km" ;
          distance_to_coast:source = "GSHHS/DTM2000.1" ;
          distance_to_coast:institution = "University of Hawai SOEST" ;
          distance_to_coast:scale_factor = 0.001 ;
          distance_to_coast:coordinates = "lon lat" ;
     short sea_surface_temperature(time) ;
          sea_surface_temperature:_FillValue = 32767s ;
          sea_surface_temperature:long_name = "sea surface temperature" ;
          sea_surface_temperature:standard_name = "sea_surface_temperature" ;
          sea_surface_temperature:units = "K" ;
          sea_surface_temperature:source = "atmospheric model" ;
          sea_surface_temperature:institution = "ECMWF" ;
          sea_surface_temperature:scale_factor = 1. ;
          sea_surface_temperature:coordinates = "lon lat" ;
     short surface_air_temperature(time) ;
          surface_air_temperature:_FillValue = 32767s ;
          surface_air_temperature:long_name = "surface air temperature" ;
          surface_air_temperature:units = "K" ;
          surface_air_temperature:source = "atmospheric model" ;
          surface_air_temperature:institution = "ECMWF" ;
          surface_air_temperature:scale_factor = 1. ;
          surface_air_temperature:coordinates = "lon lat" ;
     short surface_air_humidity(time) ;
          surface_air_humidity:_FillValue = 32767s ;
          surface_air_humidity:long_name = "surface air humidity" ;
          surface_air_humidity:units = "percent" ;
          surface_air_humidity:source = "atmospheric model" ;
          surface_air_humidity:institution = "ECMWF" ;
          surface_air_humidity:scale_factor = 1. ;
          surface_air_humidity:coordinates = "lon lat" ;
     short surface_air_pressure(time) ;
          surface_air_pressure:_FillValue = 32767s ;
          surface_air_pressure:long_name = "surface air pressure" ;
          surface_air_pressure:standard_name = "air_pressure_at_sea_level" ;
          surface_air_pressure:units = "Pa" ;
          surface_air_pressure:source = "atmospheric model" ;
          surface_air_pressure:institution = "ECMWF" ;
          surface_air_pressure:scale_factor = 1. ;
```

```
		surface_air_pressure:add_offset = 100000 ;
		surface_air_pressure:coordinates = "lon lat" ;

// global attributes:
		:Conventions = "CF-1.4" ;
		:title = "GlobWave L2P derived from Envisat GDR Product" ;
		:source = "radar altimeter" ;
		:project = "ESA GlobWave" ;
		:institution = "GlobWave" ;
		:history = "2010-03-15T12:16:42 UTC : Creation" ;
		:contact = "SatOC e.ash@satoc.eu" ;
		:references = "GlobWave Product User Guide" ;
		:processing_center = "Ifremer" ;
		:software_version = "SatOC GlobWave Envisat GDR to L2P Processor
1.9" ;
		:source_provider = "European Space Agency" ;
		:mission_name = "Envisat" ;
		:source_name = "RA2_GDR_2POF-
P20030108_040514_00003017A012_00419_04481_5104.N1" ;
		:source_version = "N/A" ;
		:source_software = "   CMA V6.3_02" ;
		:altimeter_sensor_name = "RA2" ;
		:radiometer_sensor_name = "N/A" ;
		:acq_station_name = "PDAS-S" ;
		:cycle_number = "012" ;
		:pass_number = "420" ;
		:equator_crossing_time = "N/A" ;
		:equator_crossing_longitude = "N/A" ;
		:start_date = "2003-01-08T04:05:14 UTC" ;
		:stop_date = "2003-01-08T04:55:31 UTC" ;
}
```

ANNEX B :CALCULATION OF QUALITY VARIABLES

B.1 : Altimetry

Introduction

This note gives details of the validation checks on altimeter records that are used to derived the quality variables for significant wave height and sigma0.

The validation for each 1 second altimeter record cannot be guaranteed to separate out all bad and good records, they only indicate records which are likely to be good from those which are most likely bad. Those likely to be good are further divided into those which are generally acceptable – acceptable for most purposes – and those which are almost certainly good.

For example, if an altimeter has a rain flag then this is ignored when deciding whether a record is generally acceptable, since only very heavy rain adversely affects the altimeter radar, so frequently records with rain give good estimates of wave height and wind speed, and applying this check would remove many good records; often rain is associated with strong winds and high waves so discarding rain-flagged records for climate studies is likely to skew the results. However for some purposes, such as when calibrating wave height against buoys or studying sea state bias, it might be appropriate to use only those records which are almost certainly good.

The Globwave quality variable is set to:

2	probably bad	(abbreviated to 'bad' below).
1	generally acceptable	(abbreviated to 'acceptable' below).
0	almost certainly good	(abbreviated to 'good' below).

The checks are on the quality of both the significant wave height and the sigma-0 value (from which wind speed is derived). Often both wave height and wind speed are required for analysis, and if one is dubious the other is unlikely to be good. (An exception is that wave height is less affected by mispointing than is sigma-0.)

Only the data from the altimeter Ku-band are considered here.

Sources

The validation checks described below have been based on the following handbooks and publication, together with some unpublished checks used by Satellite Observing Systems Ltd.

Handbooks

1. AVISO User Handbook merged Topex/Poseidon Products (GDR-Ms)
AVI-NT-02-101-CN, Edition 3.0, July 1996.

2. The Geosat Altimeter JGM-3 GDRs on CD-ROM
NODC Laboratory for Satellite Altimetry
Silver Spring, Maryland 20910
May, 1997
http://ibis.grdl.noaa.gov/SAT/gdrs/geosat_handbook/index.html

3. RA/ATSR products - User Manual
C2-MUT-A-01-IF V 2.3 July 2001
Ifremer/CERSAT/CLS

4. GEOSAT Follow-On GDR User's Handbook June 2002
http://ibis.grdl.noaa.gov/SAT/gfo/gdr_hbk.htm#def_sdr

5. Picot N, Case K, Desai s and Vincent P 2003
AVISO and PODAAC User Handbook, IGDR and GDR Jason Products, (Edition 4.1, October 2008.)
SMM-MU-M5-OP-13184-CN (AVISO), JPL D-21352 (PODAAC)

6. Envisat RA2-MWR Product Handbook, Issue 2.2, 27 Feb. 2007
European Space Agency.

7. Envisat-1 Products Specifications Vol.1:RA-2 Products Specifications.
PO-RS-MDA-GS-2009. Issue 3 Rev.:0

8. OSTM/Jason-2 Products Handbook
CNES : SALP-MU-M-OP-15815-CN
EUMETSAT : EUM/OPS-JAS/MAN/08/0041
JPL : OSTM-29-1237 NOAA/NESDIS : Polar Series/OSTM J400
Issue: 1 rev 4 Date: August 3, 2009

Other references

9. Cotton P D, Carter D J T and Challenor P G 2003
Geophysical Validation of ENVISAT Altimetry Products
Final Rpt.- May 2003.
ESA Contract Report; Satellite Observing Systems Ltd.

10. Mackay E B L, Retzler C H, Challenor P G and Gommenginger C P 2008
A parametric model for ocean wave period from Ku band altimeter data
J. Geophys. Res., 113, C03029, doi:10.1029/2007JC004438

11. Mathias van den Bossche and Quan-Zan Zanife 2001
CERSAT2 off-Nadir angle evolution; validation and recommendation note
CLS/DOS/NT/01.446

12. Queffeulou P 2004
Long-term validation of wave height measurements from altimeters
Marine Geodesy 27, 495-510.

13. Queffeulou P & Croizé-Fillon D 2009a
Global altimeter SWH data set
IFREMER (pierre.queffeulou@ifremer.fr)

14. Queffeulou P 2009b
Altimeter Wave Height Measurements - Validation of Long Time Series
Poster: Ocean Surface Topography Science Team meeting, 22-24 June 2009, Seattle, Washington,USA.
http://www.aviso.oceanobs.com/en/courses/ostst/ostst-2009-seattle/posters/

Validation checks

Envisat

Sources: 6, 7, 9, 10, 12, 13.

(i) Bad if it fails any of the checks in (ii)

(ii) Acceptable if it passes all of the following:

range_rms_ku < 200 # mm Unsigned integer
18 < swh_numval_ku < 255 # Unsigned integer
0 < swh_ku < 32767 # 10^{-3}m
0 < swh_rms_ku < 32767 # 10^{-3}m
swh_rms_ku <(845.7-0.050*swh_ku+0.0000384*swh_ku^2)
0 < sig0_ku < 32767 # 10^{-2}dB
0 < sig0_rms_ku < 300 # 10^{-2}dB
wind_speed_alt < 32767 # 10^{-3}m/s
1500 < peakiness < 1800
abs(sq_off_nadir_angle_ku_wvf)<1000 # 10^{-4}deg^2
mcd bit 16 = 0
16:Ku Ocean retracking
alt_surface_type <=1 # open ocean, enclosed seas or lakes

(iii) Good if it passes checks in (ii) above and:

rain_flag= 0

Notes

a) S-band altimeter failed on 17 January 2008.
b) Wind speed algorithm gives an upper limit of 21.3 m/s
c) There is no ice flag at present but
Tran N, Girard-Ardhuin F, Ezraty R, Feng H, and Féménias P 2009
Defining a Sea Ice Flag for Envisat Altimetry Mission
IEEE GEOSCIENCE AND REMOTE SENSING LETTERS, Vol. 6, No. 1.

states that "a flag derived from this classifier will be made available in the coming soon reprocessed products of Envisat altimetry mission."

But the loss of S-band might be a problem.

d) Queffeulou (2009b) suggests that the relationship between swh_rms_ku and swh_ku needs to be re-evaluated.

ERS-1

Sources: 3, 12, 13.

(i) Bad if it fails any of the checks in (ii)

(ii) Good if it passes all of the following:

Nval>16
Std_H_Alt<400
0<SWH<3000 # 10^{-2}m
0<Std_SWH<200 # 10^{-2}m
0<Std_Sigma0<30 # 10^{-2}dB
MCD bits 0,7,8 =0
Bit 0: Measurement valid
Bit 7: SWH valid
Bit 8: sig0 valid (in range 700-1960)

Notes:

a) there is no satisfactory way of deriving a 'rain flag'.

b) If sig0<7dB then wind speeds put to 20.15 m/s; if sig0>19.6dB then wind speed put to 0.01 m/s.

ERS-2

Sources: 3, 10, 11, 12, 13.

(i) Bad if it fails any of the checks in (ii)

(ii) Good if it passes all of the following:

Nval>16
Std_H_Alt<400
0<SWH<3000 # 10^{-2}m
Std_SWH<200 # 10^{-2}m
500<Sigma0<3000 # 10^{-2}dB
0<Std_Sigma0<30 # 10^{-2}dB
-2 10^5<Square_Off_Nad< 2 10^5 # 10^{-6}deg^2
MCD bits 0,7,8 =0
Bit 0: Measurement valid
Bit 7: SWH valid
Bit 8: sig0 valid (in range 700-1960)

Notes:

a) there is no satisfactory way of deriving a 'rain flag'.

b) If sig0<7dB then wind speeds put to 20.15 m/s; if sig0>19.6dB then wind speed put to 0.01 m/s.

Geosat

Sources: 2.

(i) Bad if it fails any of the checks in (ii)

(ii) Acceptable if it passes all of the following:

0 < SWH < 2500 # cm
500 < SIG_0 < 2000 # 0.01dB
0 < SIG_H < 10 # cm
0 < ATT < 70 # 0.01deg
FLAGS bit 0=1 # ocean (5-minute CSR land mask)
FLAGS bit 3=0 # all 10/sec heights valid
FLAGS bit 6=0 # if VATT estimate used <60 raw samples

(iii) Good if it passes checks in (ii) above and:

Cycle < 40 # Quality degraded

Notes

a) Using: Geosat Altimeter JGM-3 GDRs on CD-ROM

b) SWH values increased by 13% from earlier version using
Carter D J T, Challenor P G and Srokosz M A 1992
An assessment of Geosat wave height and wind speed measurements.
J. Geophys. Res., 97, 11383-11392.

c) Wind speeds calculated using
Freilich M H, and Challenor P 1994
A new approach for determining fully empirical altimeter wind speed model functions.
J. Geophys. Res., 99, 25051-25062.

Geosat Follow-On

Sources: 4, 10, 12.

(i) Bad if it fails any of the checks in (ii)

(ii) Acceptable if it passes all of the following:

NVals_SWH > 8 # Not available?
0< SSHU_STD < 110 # mm
SWH_STD >0 and (SWH_STD < 10 OR SWH_STD <0.1* SWH)
(SWH: cm SWH_STD: cm)
0< sigma0 < 3000 # 0.01dB
0< AGC_STD < 30 # 0.01dB
q1_n flags 4,6,10,11,19,20,21 = 0

flag	4	backscatter error
	6	VATT estimate error
	10	SWH bounds error
	11	AGC bounds error
	19	SWH STD error
	20	AGC STD error
	21	height STD error

(iii) Good if it passes checks in (ii) above and:

q2_n flag 12 = 0 # rain

Jason-1

Sources: 5, 10, 12, 13.

(i) Bad if it fails any of the checks in (ii)

(ii) Acceptable if it passes all of the following:

range_rms_ku <= 1500 # 10^{-4}m
18 < swh_numval_ku < 255 # Unsigned integer
swh_ku < 65535 # Unsigned integer
swh_rms_ku > 0 # 10^{-3}m
swh_rms_ku < 65535
swh_rms_ku <(996.1-0.0398*swh_ku+0.0000132*swh_ku^2)
(swh_ku: 10^{-3}m)
sig0_rms_ku <= 100 # 10^{-2}dB
wind_speed_alt < 65535 # cm/s
off_nadir_angle_ku_wvf >= -200 and off_nadir_angle_ku_wvf <=2500 # 10^{-4}deg^2
qual_1hz_alt_data bits 0,2,4 = 0
(Ku band range, Ku band SWH and Ku band backscatter coefficient)
surface_type <=1 # open ocean, enclosed seas or lakes
alt_echo_type = 0 # ocean-like

(iii) Good if it passes checks in (ii) above and:

rain_flag=0
ice_flag = 0

Notes

a) Jason-1 has a relatively large number of records with swh_ku=0 some of which are probably bad. Queffeulou P & Croizé-Fillon D (2009) recommend discarding all swh_ku=0.

b) Ice_flag may be set if climate map predicts ice and wind speed < 1m/s.

c) Queffeulou (2009b) suggests that the relationship between swh_rms_ku and swh_ku needs to be re-evaluated.

Jason-2

Sources: 8, 13.

(i) Bad if it fails any of the checks in (ii)

(ii) Acceptable if it passes all of the following:

18 < swh_numval_ku < 127
swh_ku < 32767 # 10^{-3}m
0 < swh_rms_ku < 32767 # 10^{-3}m
sig0_rms_ku <= 100 # 10^{-2}dB
wind_speed_alt < 32767 # 10^{-2}m/s
-200 <= off_nadir_angle_wf_ku <=2500 # 10^{-4}deg^2
qual_alt_1hz_range_ku = 0b
qual_alt_1hz_swh_ku = 0b
qual_alt_1hz_sig0_ku = 0b
surface_type <=1 # open ocean, enclosed seas or lakes
alt_echo_type = 0 # ocean-like

(iii) Good if it passes checks in (ii) above and:

rain_flag=0
ice_flag = 0

Notes

a) if alt_echo_type = 0 then it seems that range_rms_ku <= 2000

b) Ice_flag may be set if climate map predicts ice and wind speed < 1m/s.

c) Queffeulou (2009b) suggests that the acceptable range for swh_rms_ku should be a function of swh_ku, needing further research.

Poseidon

Sources: 1, 12.

(i) Bad if it fails any of the checks in (ii)

(ii) Acceptable if it passes all of the following:

0 <SWH_K < 65534 # cm # unsigned integer
700<Sigma0_K < 2500# 0.01dB
RMS_H_Alt < 200 # mm
0<Att_Wvf < 30 # 0.01deg
Geo_Bad_1 bit 1 = 0 # water (not land)
Geo_Bad_1 bit 3 = 0 # no ice
Alt_Bad_1 bits 2-3 = 0 # SWH OK
Alt_Bad_1 bits 4-5 = 0 # backscatter OK

(iii) Good if it passes checks in (ii) above and:

Geo_Bad_2 bit 0 =0 # no rain/excess liquid detected

Notes

a) Default wind speed is 255 (25.5 m/s).

b) Poseidon records include Nval_H_Alt values (but not SWH_Pts_Avg or AGC_Pts_Avg) with a maximum of 20. So an additional check might be Nval_H_Alt>15 say, if Nval_H_Alt were stored in the location for Topex SWH_Pts_Avg.

Topex

Sources: 1, 10, 12.

(i) Bad if it fails any of the checks in (ii)

(ii) Acceptable if it passes all of the following:

0<SWH_K < 65534 # cm # unsigned integer
SWH_Pts_Avg > 7
0<SWH_RMS_K < 100 or 0.1*SWH_K # cm
Sigma0_K < 65535 # 0.01dB
AGC_Pts_Avg > 15
AGC_RMS_K < 20 # 0.01dB
RMS_H_Alt < 80 # mm
Att_Wvf < 20 # 0.01deg
Geo_Bad_1 bit 1 =0 # water (not land)
Geo_Bad_1 bit 3 =0 # no ice
Alt_Bad_2 bit 6 =0 # check AGC correction and sigma0

(iii) Good if it passes checks in (ii) above and:

Geo_Bad_2 bit 0 = 0 # no rain/excess liquid detected

Notes:

Maximum wind speed is 255 (25.5 m/s) which is also the default value.

B.2 : SAR

Introduction

This note gives details of the validation checks on SAR records that are used to derive the quality variables for wave spectra partitions and sigma0.

The Globwave quality variable is set to:

2	probably bad	(abbreviated to 'bad' below).
1	generally acceptable	(abbreviated to 'acceptable' below).
0	almost certainly good	(abbreviated to 'good' below).

The sigma0 quality, propagation direction retrieval quality and the azimuth cut-off effect will vary depending on the SNR and sea-state, respectively. Below we outline approaches to deal properly with effects from product to product, in order to avoid using corrupted spectra.

Finally two flags are pre-calculated and give information on:

- quality of a given wave spectra partition
- quality of sigma0 over a given wave mode imagette.

Azimuth Cut-Off

The SAR wave spectra are always affected by the azimuth cut-off, which rolls off (Gaussian) the spectra in the azimuth direction. The width of the Gaussian function is related to the parameter λ_{cut}. The main effect of the azimuth cut-off is that the SAR imaging domain is a narrow band region centered around the range axis (radar look direction), as illustrated in Figure 1.

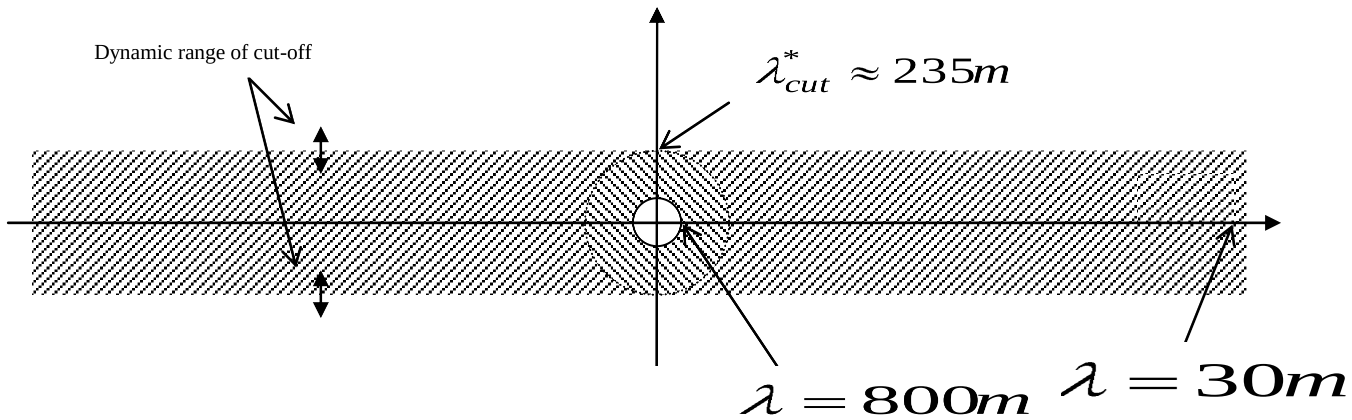

Figure 1: The shaded areas illustrate the SAR imaging spectral domain (in Cartesian wavenumbers). Inside this area the SAR detects wave spectral

information. Outside this area it is mainly noise. The azimuth is the spectral domain along the satellite flight direction, while the range is along the radar look direction. The inner circle illustrates the imaging domain left after using the Gaussian filtering function given below. The dynamic range illustrates the variations in the azimuth cut-off (i.e. the imaging region) that typically can occur from observation to observation.

The consequence of this is that the wind sea part of the spectrum is mostly not visible by the SAR, and when it appears in the spectrum it is often heavily distorted and aligned along the range axis. A typical example is shown in Figure 2 where an ASAR Image Mode spectrum from the North Sea is shown. We clearly see the alignment of the spectrum along the range axis. We thus propose to filter out the part of the ASAR Level 2 Wave Spectra outside the cut-off region. For this we need an estimate of the cut-off wavelength. The λ_{cut} given in the Level 2 product can be used for this but must be scaled according to the formula (in order to be applicable with a Gaussian roll-off function):

$$\lambda^*_{cut} = 0.5\lambda_{cut} + 90$$

to give a most correct estimate of the cut-off wavelength to be applied for filtering out the distorted part of the SAR wave spectrum. The computed cut-off value should typically be in the range $\lambda^*_{cut} \in [100m, 400m]$, with a global average value around 235m (see Figure 3).

The simplest way of filtering out the distorted part is to apply a roll-off function on the entire spectrum (all directions), given as:

$$h_n = \exp\left\{-\left(\frac{\lambda^*_{cut}}{\lambda_n}\right)^2\right\} \qquad n \in [0, N_k - 1]$$

where $\lambda_n = 2\pi / k_n$ is the wavelengths of the spectrum. To simply cut the spectrum for wavelengths above λ^*_{cut} could also be considered.

Some statistics and dependencies of λ^*_{cut} on local wind speed are shown in Figure 3 and Figure 4 respectively. More specifically, Figure 4 shows how the azimuth cut-off value varies globally and how it is correlated with the local wind speed (or more correctly the local wind sea).

More sophisticated weighting functions (using directional dependencies) can be developed in order to take into account wind sea information that sometimes are imaged along the range axis. Then you must take into account the satellite track heading as well since the spectrum is geographic oriented. This is not given here, but could be implemented since the satellite track angle is given in the L2P product.

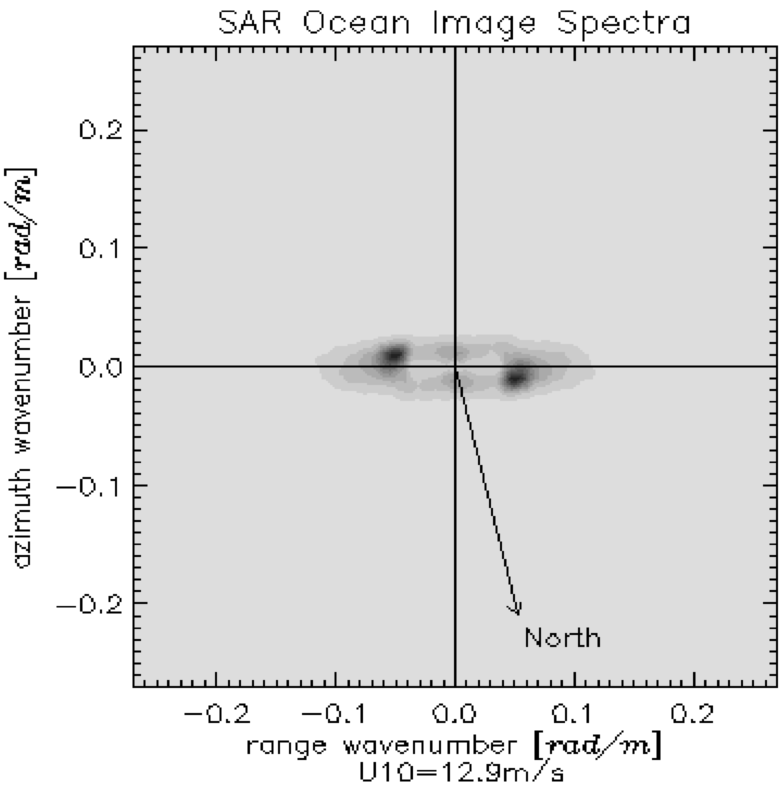

Figure 2: SAR ocean image spectra from ASAR Image Mode data in a Cartesian wave number domain from a descending track. Note the alignment of the spectral information along the range axis. The width of the spectrum in the azimuth direction is around $0.025 rad/m = 251m$.

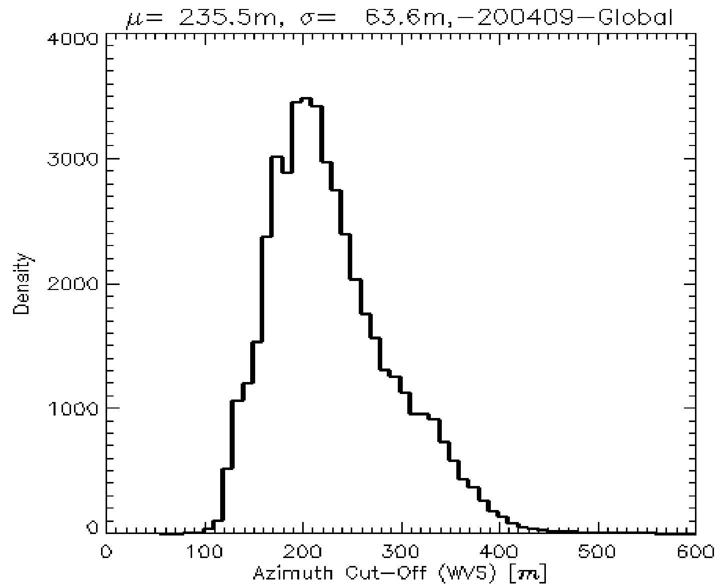

Figure 3: Histogram of ASAR Wave Mode azimuth cut-off values, λ^*_{cut} **globally collected for September 2004.**

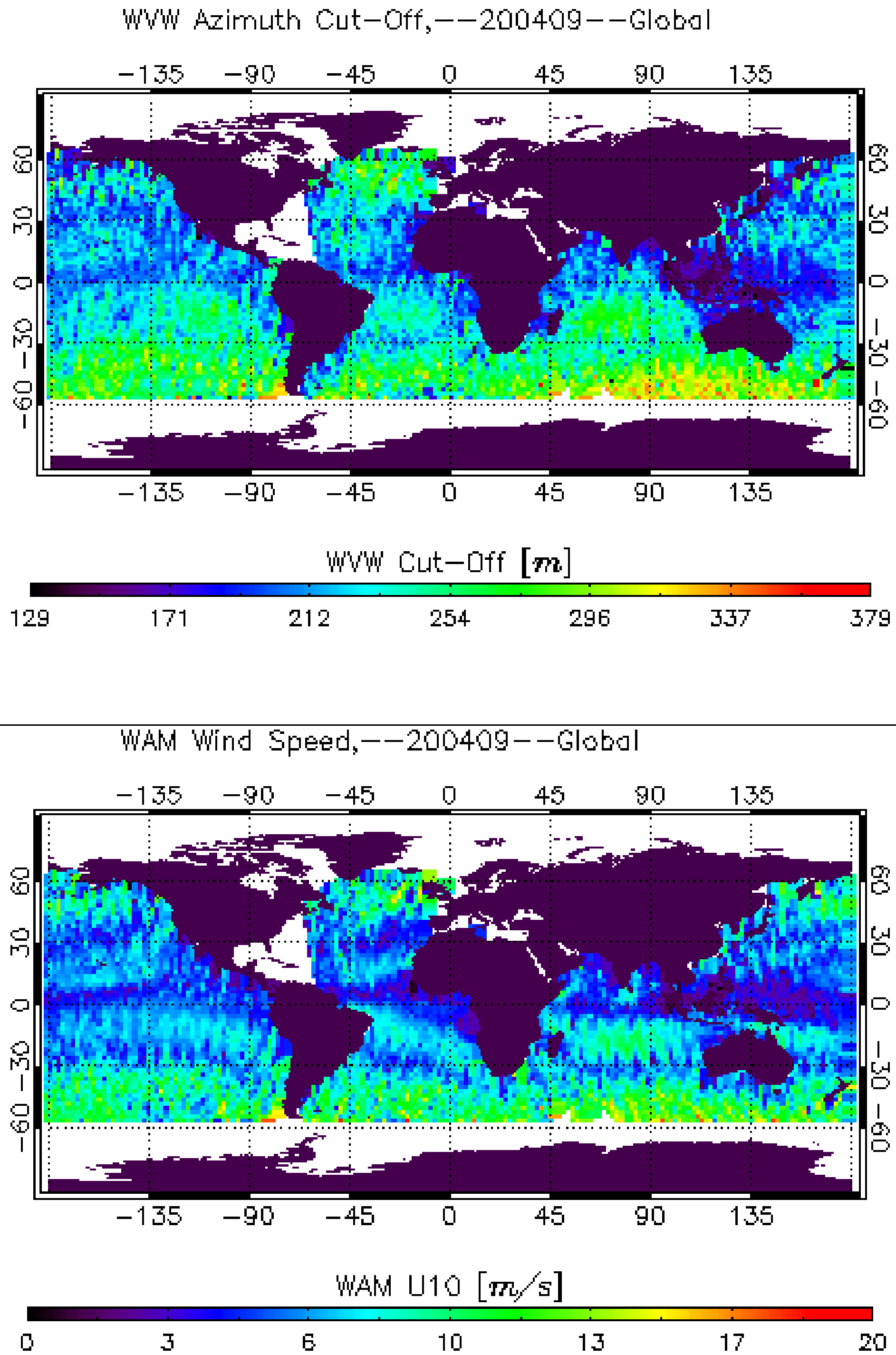

Figure 4: Upper plot: ASAR Wave Mode azimuth cut-off values, λ_{cut}^{*} for September 2004. Lower plot: Wind field from ECMWF co-located with the ASAR Wave Mode measurements.

Confidence

If the modulation is weak in the image, the SNR can be too low to gain any meaningful information from the data, although some sort of spectrum is generated. In such cases the normalized variance should theoretically be $\sigma_I = 1.0$ i.e. only speckle noise is detected. On the other hand, if the image is corrupted with signatures from land, islands, sea surface slicks, current shears, atmospheric fronts etc., the normalized variance takes values larger than expected from pure wave modulation only. The variance measure, σ_I can therefore be a parameter to use to reject low SNR data and data with large inhomogenities (see Figure 5). Data with variance in the range:

$$\sigma_I \in [1.0, 1.6]$$

is usually of good quality, and covers most of the histogram taken over ocean areas (see Figure 5) (computed when landFlag = 0).

In addition to this, the use of the propagation direction retrieval confidence measured within the Level 2 product can be implemented. In order to reject 180° ambiguity from non-ambiguity data use of the confidence parameters can be helpful. For each swell system partitioned in the L2 wave spectra, a confidence parameter i_{conf} is set to 0 when an ambiguity free spectrum is produced, and to 1 when a spectrum with 180 degree ambiguity is produced. Depending on the application, these confidence measures can be used to separate the data.

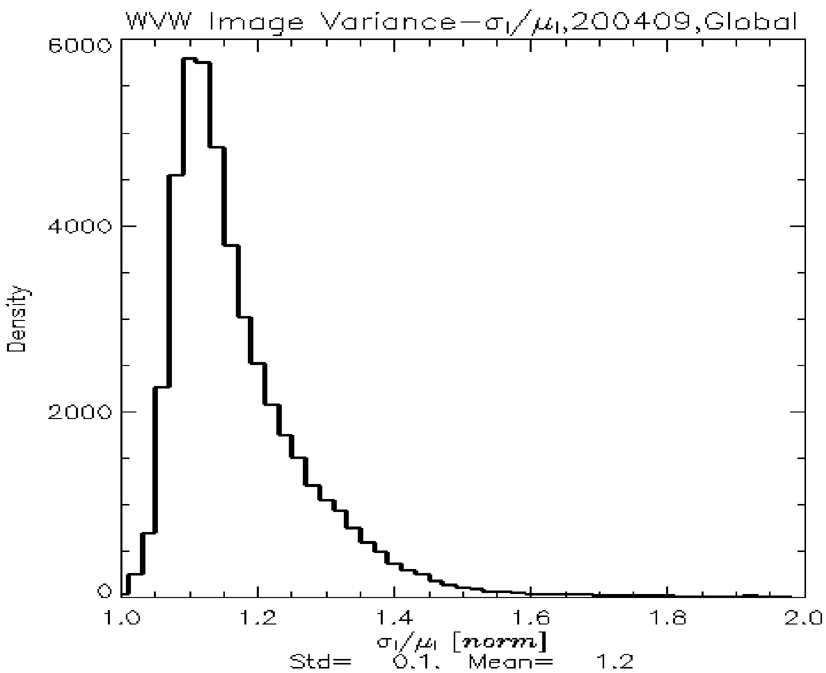

Figure 5: Histogram of ASAR Wave Mode normalized image variance for September 2004.

Wave partition quality flag calculation

The wave partition quality flag is set to

0 : when the L2 confidence flag on the considered spectral partition is set to 0 (no ambiguity on propagation direction) and normalized variance is less than 1.6 and swell azimuth wavenumber is less than 0.75 * azimuth cutoff wavenumber.

1 : when the L2 confidence flag on the considered spectral partition is set to 1 (ambiguous propagation direction) and normalized variance is less than 1.6 and swell azimuth wavenumber is less than 0.75 * azimuth cutoff wavenumber.

2 : when either normalized variance is more than 1.6 or swell azimuth wavenumber is more than 0.75 * azimuth cutoff wavenumber.

Sigma0 quality flag calculation

The sigma0 quality flag is set to

0 :.when normalized variance is less than 1.6 and mean sigma0 is more than 3db above NESZ

1 : when normalized variance is more than 1.6 but mean sigma0 is more than 3db above NESZ.

2 : when mean sigma0 is less than 3db from NESZ

ANNEX C :CALCULATION OF THE SWH_STANDARD_ERROR VARIABLE

This note describes the method of calculating the swh_standard_error variable

We begin by fitting the Orthogonal Distance Regression (ODR) to the Hs(buoy):Hs(altimeter) scatterplot:

Hs(buoy) = a + b*Hs(alt)

Then assuming no systematic errors in the buoy, we have

Hs'(alt) = Hs(alt,corrected) = a + b*Hs(alt)

This gets rid of any intercept/scale problem in Hs(alt).

Now, if V = var(Hs(buoy) – Hs'(alt)), then assuming variability of Hs(buoy) and Hs'(alt) are equal:

Var(Hs'(alt) = V/2

i.e.

Var(Hs'(alt) = var{Hs(buoy) – (a + b*Hs(alt)}/2

Assuming the ODR line is close to 45° then var{Hs(buoy) – (a + b*Hs(alt)} is equal to 2*var(d) where d is the orthogonal distance from [Hs(alt),Hs(buoy)].

So the s.e(Hs'(alt)) is the residual s.d. from the ODR – assuming that the error is constant over all Hs.

Since it is not, we can calculate sd(d) over ranges of Hs and fit a curve. This is essentially what I suggested in the annex to yesterday's note except for the division by sqrt(2).

Applying this to the ERS-1 data, gives the s.d. for 0.5 m steps as shown in Fig.1, where the line is regression of s.d. on Hs using a weighted regression, with weights equal to sqrt(number of values in each bin); the red lines are s.e.(estimated s.d.). Values are shown in Table 1.

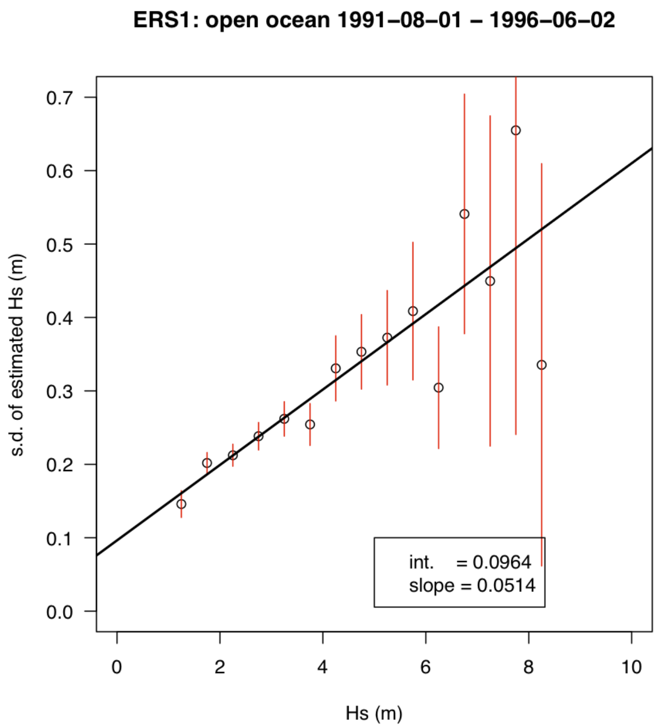

Figure 1 – standard deviation of matchup data over 0.5m steps

Hs	N	s.d	s.d./Hs
1.25	129	0.146	0.117
1.75	398	0.202	0.115
2.25	401	0.212	0.0944
2.75	324	0.238	0.0866
3.25	250	0.262	0.0806
3.75	159	0.254	0.0678
4.25	111	0.331	0.0778
4.75	97	0.353	0.0744
5.25	67	0.372	0.0709
5.75	38	0.409	0.071
6.25	27	0.304	0.0487
6.75	22	0.541	0.0802
7.25	8	0.45	0.062
7.75	5	0.655	0.0845
8.25	3	0.336	0.0407

Table 1 – standard deviation values over 0.5m steps

The result seems to be that sd is proportional to Hs except at low Hs (< about 2), which might be partly because the buoy data are only given to the nearest 0.1 m.

Taking ±2*s.d. from this straight line fit, as approximate 95% limits, gives the blue lines in Fig.2. The value of 2 s.d. gives the value used for the swh_standard_error.

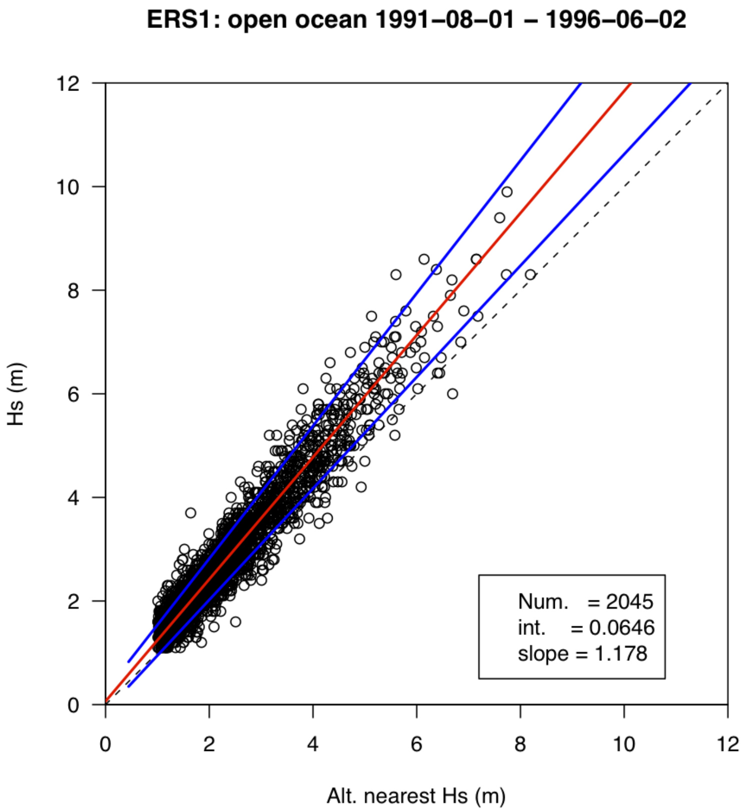

Figure 2 – ODR plot with approximate 95% confidence limits that give the swh_standard_error values

ANNEX D : SPECIFIC CONTENT OF THE ALTIMETRY REJECTION_FLAGS VARIABLE

The tables below give the specific content of the bits of the L2P rejection_flags variable. For each satellite the nomenclature of L2 variables from the respective data handbook is used, together with the L2 variable number where available.

L2P rejection_flag bits		ERS-1	ERS-2	Envisat
0	Hardware	no	no	7 MCD 3
1	On track / attitude	no	no	no
2	spare			
3	spare			
4	Altimeter land	MCD 1 = 2	MCD 1 = 2	161 altim_landocean_flag = 3
5	Alt ocean / non-ocean	MCD 0	MCD 0	161 altim_landocean_flag > 0
6	Rad land	MCD 18	MCD 18	162 radio_landocean_flag = 1
7	Corruption alt	no	no	161 altim_landocean_flag = 2
8	Corruption rad	no	no	164 rain_flag != 0
9	spare			
10	spare			
11	Quality range	MCD 2	MCD 2	7 MCD 16
12	Quality swh / ssb	MCD 5	MCD 5	no
13	Quality sig0 / u10	MCD 6	MCD 6	7 MCD 4
14	spare			
15	Qual orbit	MCD 21	MCD 21	7 MCD 27
16	Qual swh 2nd	no	no	no
17	Qual sig0 2nd	no	no	no
18	Qual off nad wf	no	no	no
19	Qual off nad pf	no	no	no
20	Ice from DB			
21	spare			
22	spare			
23	spare			
24	spare			
25	spare			
26	spare			
27	spare			
28	spare			
29	spare			
30	spare			
31	Flag rejection			

L2P rejection_flag bits		GFO	TOPEX/Poseidon TOPEX	Poseidon
0	Hardware	no	68 ALTON	
1	On track / attitude	Qual_Word_I 18	73 Lat_Err or 74 Lon_Err	
2	spare			
3	spare			
4	Altimeter land	33 NOAA_FLAGS = 3	91 Geo_Bad_1 id 3	
5	Alt ocean / non-ocean	33 NOAA_FLAGS > 0	91 Geo_Bad_1 id 4	
6	Rad land	Qual_Word_II 11	91 Geo_Bad_1 id 2	
7	Corruption alt	no	91 Geo_Bad_1 id 1	
8	Corruption rad	Qual_Word_II 12	92 Geo_Bad_2 id 3	
9	spare			
10	spare			
11	Quality range	Qual_Word_I 21	81 Alt_Bad_1 id 0	81 Alt_Bad_1 6 & 7 > 0
12	Quality swh / ssb	Qual_Word_I 19, 10	82 Alt_Bad_2 id 3	81 Alt_Bad_1 4 & 5 > 0
13	Quality sig0 / u10	Qual_Word_I 4, 11, 20	82 Alt_Bad_2 id 1	82 Alt_Bad_1 2 & 3 > 0
14	spare			
15	Qual orbit	Qual_Word_I 6	no	
16	Qual swh 2nd	no	no	
17	Qual sig0 2nd	no	no	
18	Qual off nad wf	no	no	
19	Qual off nad pf	no	no	
20	Ice from DB			
21	spare			
22	spare			
23	spare			
24	spare			
25	spare			
26	spare			
27	spare			
28	spare			
29	spare			
30	spare			
31	Flag rejection			

L2P rejection_flag bits		Jason-1	Jason-2	Geosat
0	Hardware	11 alt_state_flag id 6	alt_state_flag_oper	no
1	On track / attitude	no	no	no
2	spare			
3	spare			
4	Altimeter land	5 surface_type > 0	surface_type > 0	FLAGS 0
5	Alt ocean / non-ocean	6 alt_echo_type	alt_echo_type	no
6	Rad land	5 surface_type > 1	surface_type > 1	no
7	Corruption alt	95 ice_flag	ice_flag	no
8	Corruption rad	94 rain_flag	rain_flag	no
9	spare			
10	spare			
11	Quality range	8 qual_1hz_alt_data id 7	qual_alt_1hz_range_ku	FLAGS 3
12	Quality swh / ssb	8 qual_1hz_alt_data id 5	qual_alt_1hz_swh_ku	FLAGS 2
13	Quality sig0 / u10	8 qual_1hz_alt_data id 3	qual_alt_1hz_sig0_ku	FLAGS 7
14	spare			
15	Qual orbit	no	no	no
16	Qual swh 2nd	8 qual_1hz_alt_data id 4	qual_alt_1hz_swh_c	no
17	Qual sig0 2nd	8 qual_1hz_alt_data id 2	qual_alt_1hz_sig0_c	no
18	Qual off nad wf	8 qual_1hz_alt_data id 1	qual_alt_1hz_off_nadir_angle_wf_ku	FLAGS 6
19	Qual off nad pf	8 qual_1hz_alt_data id 0	qual_alt_1hz_off_nadir_angle_pf	no
20	Ice from DB			
21	spare			
22	spare			
23	spare			
24	spare			
25	spare			
26	spare			
27	spare			
28	spare			
29	spare			
30	spare			
31	Flag rejection			

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