**DUE GlobWave**

**Deliverable D.7**  
*Product User Guide Phase 3*

<table>
<thead>
<tr>
<th>Customer</th>
<th>ESA / ESRIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author</td>
<td>SatOC</td>
</tr>
<tr>
<td>ESRIN Contract Number</td>
<td>21891/08/I-EC</td>
</tr>
<tr>
<td>Logica Project Reference</td>
<td>UK EC230943</td>
</tr>
<tr>
<td>Document Reference</td>
<td>GlobWave/DD/PUG</td>
</tr>
<tr>
<td>Version/Rev</td>
<td>1.0</td>
</tr>
<tr>
<td>Date of Issue</td>
<td>25th January 2013</td>
</tr>
<tr>
<td>Category</td>
<td>A/I/P</td>
</tr>
</tbody>
</table>

| Prepared by       | Ellis Ash            |
| (SatOC)           | SatOC Lead           |
| Reviewed by       | Geoff Busswell       |
| (Logica)          | GlobWave Project Manager |
| Accepted by       | Simon Pinnock        |
| (ESA/ESRIN)       | ESA Technical Officer |
Amendment History

<table>
<thead>
<tr>
<th>Issue</th>
<th>Date</th>
<th>Status</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.5 1.0</td>
<td>08/03/10</td>
<td>Formal Release for ESA Review</td>
<td>Ellis Ash</td>
</tr>
<tr>
<td>D.5 1.1</td>
<td>22/04/10</td>
<td>Update following review comments</td>
<td>Ellis Ash</td>
</tr>
<tr>
<td>D.5 1.2</td>
<td>03/08/10</td>
<td>Inclusion of SAR Quality Info and Terms and Conditions</td>
<td>Geoff Busswell</td>
</tr>
<tr>
<td>D.5 1.3</td>
<td>22/11/10</td>
<td>Updates for inclusion of error statistics in new L2P release and additional release notes (version 1.3)</td>
<td>Geoff Busswell</td>
</tr>
<tr>
<td>D.5 1.4</td>
<td>16/12/10</td>
<td>Updates for release of NRT data</td>
<td>Geoff Busswell</td>
</tr>
<tr>
<td>D.6 2.0</td>
<td>13/02/12</td>
<td>Updates for phase 2</td>
<td>Geoff Busswell</td>
</tr>
<tr>
<td>D.7 0.1</td>
<td>15/01/13</td>
<td>Updates for phase 3</td>
<td>Ellis Ash</td>
</tr>
<tr>
<td>D.7 1.0</td>
<td>25/01/13</td>
<td>Logica Approval</td>
<td>Geoff Busswell</td>
</tr>
</tbody>
</table>

Distribution

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simon Pinnock</td>
<td>ESA Technical Officer</td>
<td>ESA</td>
</tr>
<tr>
<td>Geoff Busswell</td>
<td>GlobWave Project Manager</td>
<td>Logica</td>
</tr>
<tr>
<td>Clive Farquhar</td>
<td>GlobWave Team, Logica</td>
<td>Logica</td>
</tr>
<tr>
<td>Jean-François Piolle</td>
<td>GlobWave Team, Ifremer Lead</td>
<td>Ifremer</td>
</tr>
<tr>
<td>Fabrice Collard</td>
<td>GlobWave Team, CLS Lead</td>
<td>CLS</td>
</tr>
<tr>
<td>Helen Snaith</td>
<td>GlobWave Team, NOC Lead</td>
<td>NOC</td>
</tr>
<tr>
<td>Maureen Pagnani</td>
<td>GlobWave Team, NOC Scientist</td>
<td>NOC</td>
</tr>
<tr>
<td>Ellis Ash</td>
<td>GlobWave Team, SatOC Lead</td>
<td>SatOC</td>
</tr>
</tbody>
</table>

© 2013 Logica UK Ltd

This document contains information which is confidential and of value to Logica. It may be used only for the agreed purpose for which it has been provided.
Contents

1 EXECUTIVE SUMMARY ......................................................................................... 6
2 INTRODUCTION .................................................................................................... 7
  2.1 The GlobWave Project ................................................................................. 7
  2.2 The Level 2 Preprocessed (L2P) dataset ..................................................... 8
  2.3 Document Structure .................................................................................... 8
  2.4 Definitions and Acronyms .......................................................................... 8
3 ESSENTIAL INFORMATION: SUMMARY OF PRODUCTS, PRODUCT ACCESS, CONTACT DETAILS .......................................................... 11
  3.1 L2P products ............................................................................................... 11
  3.1.1 Near real-time (NRT) products .............................................................. 11
  3.1.2 Delayed mode (GDR) products .............................................................. 12
  3.1.3 Terms & Conditions ............................................................................. 13
  3.2 Demonstration products ............................................................................ 14
  3.3 Contact details ............................................................................................ 15
4 L2P DATA PRODUCTS .......................................................................................... 16
  4.1 Level 2 source data .................................................................................... 16
  4.1.1 Near real-time source data .................................................................... 16
  4.1.2 Delayed mode source data .................................................................... 16
  4.2 L2P format and file naming ....................................................................... 17
  4.3 L2P content .................................................................................................. 18
  4.3.1 Dimensions ............................................................................................ 18
  4.3.2 Variables ................................................................................................ 19
  4.3.3 Variable Attributes ................................................................................ 24
  4.3.4 Global Attributes .................................................................................. 25
  4.3.5 Data ....................................................................................................... 26
  4.4 Variable calculation .................................................................................... 26
  4.4.1 Calibrated variables .............................................................................. 27
  4.4.1.1 SAR calibration ................................................................................. 27
  4.4.1.2 Altimetry calibration ......................................................................... 27
  4.4.2 Quality variables .................................................................................... 29
  4.4.2.1 SAR quality variables ....................................................................... 29
  4.4.2.2 Altimetry quality variables ................................................................. 30
  4.4.3 Hs standard error variable ..................................................................... 31
  4.4.4 Rejection flags variable ......................................................................... 31
  4.4.4.1 SAR rejections flags variable ............................................................. 31
  4.4.4.2 Altimeter rejections flag variable ....................................................... 31
  4.4.4.3 Altimeter rain flag .............................................................................. 32
  4.4.5 Ancillary variables .................................................................................. 33
  4.5 Known issues .............................................................................................. 34
  4.5.1 NRT ......................................................................................................... 34
  4.5.1.1 SAR Processor Version 1.8 ................................................................. 34
  4.5.1.2 Altimeter Processor Version 1.2 ........................................................ 34
  4.5.2 GDR ........................................................................................................ 34
5 DEMONSTRATION DATA PRODUCTS ........................................ 36
   5.1 Hs-Tz scatterplots ............................................... 36
   5.2 Fireworks .................................................................. 39
   5.3 Soprano ..................................................................... 40
   5.4 GlobWave lesson ....................................................... 41
   5.5 Merged Altimeter Wave Heights .................................... 42
   5.6 Global Sea State from SAR data .................................... 42
   5.7 Related Projects ........................................................ 43
   5.7.1 COASTALT ........................................................... 43
   5.7.2 PISTACH ............................................................... 44
   5.7.3 eSurge .................................................................. 44

ANNEX A : L2P DIMENSION, VARIABLE AND ATTRIBUTE LISTINGS ..... 45

ANNEX B : CALCULATION OF QUALITY VARIABLES .................. 56
   B.1 : Altimetry ............................................................... 56
   Introduction 56
   Sources 56
   Handbooks 56
   Other references .......................................................... 57
   Validation checks ........................................................ 58
   Envisat 58
   ERS-1 58
   ERS-2 59
   Geosat 59
   Geosat Follow-On .......................................................... 60
   Jason-1 60
   Jason-2 61
   Poseidon 62
   Topex 62
   B.2 : SAR 63
   Introduction 63
   Azimuth Cut-Off ............................................................. 63
   Confidence 68
   Wave partition quality flag calculation .............................. 69
   Sigma0 quality flag calculation ....................................... 69

ANNEX C : CALCULATION OF THE SWH_STANDARD_ERROR VARIABLE .............................................. 70

ANNEX D : SPECIFIC CONTENT OF THE ALTIMETRY REJECTION_FLAGS VARIABLE ......................................... 73
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 (SAR) data. The historical archive contains altimeter data from 8 satellites, ranging from Geosat (operating between 1985 and 1989) through to Cryosat, Jason-1 and Jason-2, still operating in 2013. The historical data is continuous in time from 1991 to 2012, and real-time data is made available from Cryosat, 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 demonstration products are described together with information on how to access them.

Applications of the data are not included in this guide, but are 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 is an update to deliverable D.5 and D.6 for phase 3 of GlobWave and represents deliverable D.7 of the 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 co-located 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

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASAR</td>
<td>Advanced Synthetic Aperture Radar</td>
</tr>
<tr>
<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
</tr>
<tr>
<td>AVISO</td>
<td>Archiving, Validation and Interpretation of Satellite Oceanographic Data</td>
</tr>
<tr>
<td>CD</td>
<td>Compact Disc</td>
</tr>
<tr>
<td>CDIP</td>
<td>Coastal Data Information Program</td>
</tr>
<tr>
<td>CLS</td>
<td>Collecte Localisation Satellites</td>
</tr>
<tr>
<td>CNES</td>
<td>Centre National d’Etudes Spatiales</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
</tr>
<tr>
<td>CSV</td>
<td>Comma Separated Value</td>
</tr>
<tr>
<td>DUE</td>
<td>Data User Element</td>
</tr>
<tr>
<td>DVD</td>
<td>Digital Versatile Disc</td>
</tr>
<tr>
<td>ECMWF</td>
<td>European Centre for Medium-Range Weather Forecasts</td>
</tr>
<tr>
<td>ENVISAT</td>
<td>ESA’s Environmental Satellite</td>
</tr>
<tr>
<td>EO</td>
<td>Earth Observation</td>
</tr>
<tr>
<td>ERS</td>
<td>European Remote-Sensing Satellite</td>
</tr>
<tr>
<td>ESA</td>
<td>European Space Agency</td>
</tr>
<tr>
<td>ESRIN</td>
<td>ESA Space Research Institute</td>
</tr>
<tr>
<td>ESTEC</td>
<td>European Space Research and Technology Centre</td>
</tr>
<tr>
<td>GDR</td>
<td>Geophysical Data Record</td>
</tr>
<tr>
<td>GEOSAT</td>
<td>GEOdetic SATellite</td>
</tr>
<tr>
<td>GFO</td>
<td>GEOSAT Follow On</td>
</tr>
<tr>
<td>GHRSSST</td>
<td>GODAE High Resolution Sea Surface Temperature</td>
</tr>
<tr>
<td>GODAE</td>
<td>Global Ocean Data Assimilation Experiment</td>
</tr>
<tr>
<td>GOES</td>
<td>Geostationary Operational Environment Satellites</td>
</tr>
<tr>
<td>HR-DDS</td>
<td>High Resolution Diagnostic Data Set</td>
</tr>
<tr>
<td>Hs</td>
<td>Significant Wave Height</td>
</tr>
<tr>
<td>I/O</td>
<td>Input/Output</td>
</tr>
<tr>
<td>JCOMM</td>
<td>Joint Technical Commission for Oceanography and Marine Meteorology</td>
</tr>
<tr>
<td>L2P</td>
<td>Level-2-Preprocessed</td>
</tr>
<tr>
<td>MATLAB</td>
<td>MATrix LABoratory</td>
</tr>
<tr>
<td>MDB</td>
<td>Match Up Database</td>
</tr>
<tr>
<td>MERSEA</td>
<td>Marine Environment and Security for the European Area</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautical Space Administration</td>
</tr>
<tr>
<td>NCOF</td>
<td>National Centre for Ocean Forecasting</td>
</tr>
<tr>
<td>NDBC</td>
<td>National Data Buoy Center</td>
</tr>
<tr>
<td>NERSC</td>
<td>Nansen Environmental and Remote Sensing Center</td>
</tr>
<tr>
<td>NetCDF</td>
<td>Network Common Data Form</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>NOCS</td>
<td>National Oceanography Centre Southampton</td>
</tr>
<tr>
<td>NODC</td>
<td>National Oceanographic Data Center</td>
</tr>
<tr>
<td>NRT</td>
<td>Near Real Time</td>
</tr>
<tr>
<td>PDF</td>
<td>Portable Document Format</td>
</tr>
<tr>
<td>PM</td>
<td>Progress Meeting</td>
</tr>
<tr>
<td>RADS</td>
<td>Radar Altimeter Database System</td>
</tr>
<tr>
<td>RB</td>
<td>Requirements Baseline</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
</tr>
<tr>
<td>RMS</td>
<td>Root Mean Square</td>
</tr>
<tr>
<td>SAR</td>
<td>Synthetic Aperture Radar</td>
</tr>
<tr>
<td>SatOC</td>
<td>Satellite Oceanographic Consultants</td>
</tr>
<tr>
<td>SHOM</td>
<td>Service Hydrographique et Océanographique de la Marine</td>
</tr>
<tr>
<td>SQL</td>
<td>Structured Query Language</td>
</tr>
<tr>
<td>SSALTO</td>
<td>Segment Sol multi-missions d’ALTimetrie, d’orbitographie et de location précise</td>
</tr>
<tr>
<td>SST</td>
<td>Sea Surface Temperature</td>
</tr>
<tr>
<td>TBC</td>
<td>To Be Confirmed</td>
</tr>
<tr>
<td>THREDDS</td>
<td>Thematic Real-time Environmental Distributed Data Services</td>
</tr>
<tr>
<td>UKMO</td>
<td>United Kingdom Meteorological Office</td>
</tr>
<tr>
<td>WAM</td>
<td>Wave Analysis Model</td>
</tr>
<tr>
<td>WFVS</td>
<td>Wave Forecast Verification Scheme</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>L2P product</th>
<th>Description</th>
<th>Typical file size</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW_L2P_ALT_CRYO_NRT_*</td>
<td>Near real-time L2P product from Cryosat altimeter</td>
<td>~550 KB</td>
</tr>
<tr>
<td>GW_L2P_ALT_JAS1_NRT_*</td>
<td>Near real-time L2P product from Jason-1 altimeter</td>
<td>~450 KB</td>
</tr>
<tr>
<td>GW_L2P_ALT_JAS2_NRT_*</td>
<td>Near real-time L2P product from Jason-2 altimeter</td>
<td>~650 KB</td>
</tr>
</tbody>
</table>

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


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.

<table>
<thead>
<tr>
<th>L2P version</th>
<th>Date</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>16/12/10</td>
<td>Initial release of L2P products NRT version</td>
</tr>
</tbody>
</table>

### 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.

<table>
<thead>
<tr>
<th>L2P product</th>
<th>Description</th>
<th>Typical file size</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW_L2P_SAR_ENVI_NRT_ *</td>
<td>L2P product from Envisat synthetic aperture radar (format is unchanged from formerly available NRT product)</td>
<td>&lt; 100 KB</td>
</tr>
<tr>
<td>GW_L2P_ALT_ERS1_GDR_ *</td>
<td>L2P product from ERS-1 altimeter</td>
<td>212 KB</td>
</tr>
<tr>
<td>GW_L2P_ALT_ERS2_GDR_ *</td>
<td>L2P product from ERS-2 altimeter</td>
<td>216 KB</td>
</tr>
<tr>
<td>GW_L2P_ALT_ENVI_GDR_ *</td>
<td>L2P product from Envisat altimeter</td>
<td>264 KB</td>
</tr>
<tr>
<td>GW_L2P_ALT_GEOS_GDR_ *</td>
<td>L2P product from Geosat altimeter</td>
<td>3.7 MB</td>
</tr>
<tr>
<td>GW_L2P_ALT_GFO_GDR_ *</td>
<td>L2P product from Geosat Follow-On altimeter</td>
<td>188 KB</td>
</tr>
<tr>
<td>GW_L2P_ALT_TOPX_GDR_ *</td>
<td>L2P product from TOPEX/Poseidon altimeter</td>
<td>264 KB</td>
</tr>
<tr>
<td>GW_L2P_ALT_JAS1_GDR_ *</td>
<td>L2P product from Jason-1 altimeter</td>
<td>256 KB</td>
</tr>
<tr>
<td>GW_L2P_ALT_JAS2_GDR_ *</td>
<td>L2P product from Jason-2 altimeter</td>
<td>308 KB</td>
</tr>
<tr>
<td>GW_L2P_ALTCRYO_GDR_ *</td>
<td>L2P product from CryoSat-2 altimeter</td>
<td>168 KB</td>
</tr>
</tbody>
</table>

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

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:


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

<table>
<thead>
<tr>
<th>L2P version</th>
<th>Date</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>22/04/10</td>
<td>Initial release of L2P products GDR version</td>
</tr>
<tr>
<td>1.3</td>
<td>22/11/10</td>
<td>Inclusion of error statistics, update to Jason-2 calibration</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Demonstration product</th>
<th>Description</th>
<th>Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hs-Tz scatterplots</td>
<td>Plots of significant wave height against altimeter-derived wave period for selected locations coincident with in-situ data positions.</td>
<td>GlobWave portal: <a href="http://www.globwave.org/Products/Demo-Products/Hs-Tz-scatterplots">http://www.globwave.org/Products/Demo-Products/Hs-Tz-scatterplots</a></td>
</tr>
<tr>
<td>Fireworks</td>
<td>Swell tracking animations of SAR-observed swell snapshots at several successive dates from observations back or forward in time after simple linear wave propagation.</td>
<td>Through Soprano website at: <a href="http://soprano.cls.fr/L3/fireworks.html">http://soprano.cls.fr/L3/fireworks.html</a></td>
</tr>
<tr>
<td>Soprano</td>
<td>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.</td>
<td>Soprano website: <a href="http://soprano.cls.fr">http://soprano.cls.fr</a></td>
</tr>
<tr>
<td>GlobWave lesson</td>
<td>Murray Brown from the UNESCO/IOC Intergovernmental Oceanographic Data and Information Exchange’s (IODE) OceanTeacher program has developed an online tutorial using GlobWave data. The lesson teaches users how to access the GlobWave portal and download Near Real Time (NRT) ENVISAT and JASON 1&amp;2 Altimeter data, open the netCDF files using the Integrated Data Viewer and display multiple datasets of altimeter point data with a range of visualisations.</td>
<td>Marine Data Literacy exercise: <a href="http://marinedataliteracy.org/ops/globwave_pts.htm">http://marinedataliteracy.org/ops/globwave_pts.htm</a></td>
</tr>
<tr>
<td>Measuring Global Sea State</td>
<td>The German Aerospace Center (DLR) have recently published their work on Global Sea State Measurements using ENVISAT ASAR</td>
<td>Documentation: <a href="http://earth.eo.esa.int/works">http://earth.eo.esa.int/works</a></td>
</tr>
<tr>
<td>Demonstration product</td>
<td>Description</td>
<td>Access</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------</td>
<td>--------</td>
</tr>
<tr>
<td>using SAR data</td>
<td>Wave Mode Data. This work focuses on developing an empirical algorithm, known as CWAVE, that derives integral ocean wave parameters from SAR data without first guess information. CWAVE derived total SWH measurements have been validated for both ERS and ENVISAT ASAR Wave Mode Data against both models and buoys, with a scatter index of 24% against buoys. ENVISAT ASAR CWAVE measurements have also been compared to Jason and GFO Altimeter measurements with a scatter index of 13% and 17% respectively.</td>
<td>hops/seasar2010/participants/345/pres_345_brusch.pdf</td>
</tr>
<tr>
<td>eSurge</td>
<td>The DUE eSurge project has been set up by ESA to promote the use of Earth Observation data for Storm Surge applications. A storm surge is an abnormally high sea level produced by severe atmospheric conditions, lasting for a period ranging from a few minutes to a few days. Storm surges can be extremely destructive, causing extensive flooding, severe damage to property and infrastructure, and in extreme cases significant loss of life. For example, most fatalities during tropical storms are due to the associated storm surges.</td>
<td>eSurge website: <a href="http://www.storm-surge.info/data-access">http://www.storm-surge.info/data-access</a></td>
</tr>
</tbody>
</table>

### 3.3 Contact details

<table>
<thead>
<tr>
<th>Product / service</th>
<th>Name, organisation</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altimetry L2P This L2P User Guide Hs-Tz scatterplots</td>
<td>Ellis Ash, SatOC</td>
<td><a href="mailto:e.ash@satoc.eu">e.ash@satoc.eu</a></td>
</tr>
<tr>
<td>SAR L2P Fireworks Soprano</td>
<td>Fabrice Collard (“dr.fab”), CLS</td>
<td><a href="mailto:dr.fab@cls.fr">dr.fab@cls.fr</a></td>
</tr>
<tr>
<td>Data access / GlobWave portal</td>
<td>Jean-Francois Piolle, IFREMER</td>
<td><a href="mailto:Jean.Francois.Piolle@ifremer.fr">Jean.Francois.Piolle@ifremer.fr</a></td>
</tr>
<tr>
<td>GlobWave Project Manager</td>
<td>Geoff Busswell, Logica</td>
<td><a href="mailto:geoff.busswell@logica.com">geoff.busswell@logica.com</a></td>
</tr>
</tbody>
</table>
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) have been used to generate the NRT L2P products since December 2010:

<table>
<thead>
<tr>
<th>Source</th>
<th>L2 Product</th>
<th>Type</th>
<th>Dates</th>
<th>Official Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESA Envisat</td>
<td>RA2_WWV_2P</td>
<td>Altimeter</td>
<td>26/08/2002 onwards</td>
<td>ESA <a href="http://www.esa.int">www.esa.int</a></td>
</tr>
<tr>
<td>ESA Envisat</td>
<td>ASA_WWV_2P</td>
<td>SAR</td>
<td>17/12/2002 onwards</td>
<td>ESA <a href="http://www.esa.int">www.esa.int</a></td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Source</th>
<th>L2 Product</th>
<th>Type</th>
<th>Dates</th>
<th>Official Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESA Envisat</td>
<td>RA2_GDR_2P</td>
<td>Altimeter</td>
<td>26/08/2002 onwards</td>
<td>ESA</td>
</tr>
</tbody>
</table>
### Table 4-2: Space Agency L2 Archived Satellite Data for GlobWave

<table>
<thead>
<tr>
<th>Source</th>
<th>L2 Product</th>
<th>Type</th>
<th>Dates</th>
<th>Official Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESA/NOAA CryoSat</td>
<td>IGDR</td>
<td>Altimeter</td>
<td>28/01/2011 onwards</td>
<td>ESA <a href="http://www.esa.int">www.esa.int</a> NOAA <a href="http://ibi.s.grdl.noaa.gov">http://ibi.s.grdl.noaa.gov</a></td>
</tr>
</tbody>
</table>

#### 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](http://www.unidata.ucar.edu/software/netcdf/index.html)

For more information on Climate and Forecast conventions visit:


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:

<table>
<thead>
<tr>
<th>Label</th>
<th>File name components</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>instr</td>
<td>one of:</td>
<td>Gives satellite instrument type:</td>
</tr>
</tbody>
</table>
### 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:

<table>
<thead>
<tr>
<th>Name</th>
<th>Length</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>variable</td>
<td>This dimension is variable in length according to the number of data points in time in the L2 data.</td>
</tr>
<tr>
<td>n_partitions</td>
<td>variable</td>
<td>This dimension is variable in length according to the number of partitions</td>
</tr>
</tbody>
</table>
### 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:

<table>
<thead>
<tr>
<th>Name</th>
<th>Length</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>variable</td>
<td>This dimension is variable in length according to the number of data points in time in the L2 data.</td>
</tr>
</tbody>
</table>

### 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.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Description</th>
<th>NetCDF Type</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>time</td>
<td>Seconds since 1985-01-01</td>
<td>double</td>
<td>s</td>
</tr>
<tr>
<td>2</td>
<td>lat</td>
<td>Latitude</td>
<td>int</td>
<td>$10^{-6}$ deg</td>
</tr>
<tr>
<td>3</td>
<td>lon</td>
<td>Longitude, range -180 to 180</td>
<td>int</td>
<td>$10^{-6}$ deg</td>
</tr>
<tr>
<td>4</td>
<td>track_angle</td>
<td>Local satellite heading</td>
<td>short</td>
<td>$10^{-3}$ deg</td>
</tr>
<tr>
<td>5</td>
<td>incidence_angle</td>
<td>Local incidence angle</td>
<td>short</td>
<td>$10^{-3}$ deg</td>
</tr>
<tr>
<td>6</td>
<td>polSpec</td>
<td>Estimated Directional wave spectra : spectral energy for each direction/wavenumber</td>
<td>Short x n_wavenumbers x n_directions</td>
<td>10-3 m2</td>
</tr>
<tr>
<td>7</td>
<td>indPart</td>
<td>Directional wave spectra partition index : 0 for the most energetic partition, 1 for the</td>
<td>byte x n_wavenumbers x n_directions</td>
<td>n/a</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Description</td>
<td>NetCDF Type</td>
<td>Units</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------</td>
<td>--------------------------------------------------</td>
<td>-------------</td>
<td>-----------</td>
</tr>
<tr>
<td>8</td>
<td>k</td>
<td>wavenumbers for polar spectra</td>
<td>short</td>
<td>m-1</td>
</tr>
<tr>
<td>9</td>
<td>phi</td>
<td>angular values for polar spectra</td>
<td>short</td>
<td>deg</td>
</tr>
<tr>
<td>10</td>
<td>area</td>
<td>Polar spectral bin area</td>
<td>short</td>
<td>m-2</td>
</tr>
<tr>
<td>11</td>
<td>snr</td>
<td>signal/noise ratio</td>
<td>short</td>
<td>10^-3 m2</td>
</tr>
<tr>
<td>12</td>
<td>swh</td>
<td>Total significant wave height</td>
<td>short</td>
<td>10^3 m</td>
</tr>
<tr>
<td>13</td>
<td>swh_calibrated</td>
<td>Calibrated significant wave height</td>
<td>short</td>
<td>10^3 m</td>
</tr>
<tr>
<td>14</td>
<td>swh_standard_error</td>
<td>HS best estimate of standard error</td>
<td>short</td>
<td>10^3 m</td>
</tr>
<tr>
<td>15</td>
<td>swh_part</td>
<td>Significant wave height for each spectral partition</td>
<td>short</td>
<td>10^-3 m</td>
</tr>
<tr>
<td>16</td>
<td>dwl_part</td>
<td>Dominant wavelength for each spectral partition</td>
<td>short</td>
<td>10^3 m</td>
</tr>
<tr>
<td>17</td>
<td>ddr_part</td>
<td>Dominant direction for each spectral partition</td>
<td>short</td>
<td>10^-3 deg</td>
</tr>
<tr>
<td>18</td>
<td>sigma0</td>
<td>Mean backscatter coefficient</td>
<td>short</td>
<td>10^-2 dB</td>
</tr>
<tr>
<td>19</td>
<td>nv</td>
<td>Normalized backscatter coefficient variance</td>
<td>short</td>
<td>N/A</td>
</tr>
<tr>
<td>20</td>
<td>sigma0_calibrated</td>
<td>Calibrated backscatter coefficient</td>
<td>short</td>
<td>10^-2 dB</td>
</tr>
<tr>
<td>21</td>
<td>sigma0_quality</td>
<td>sigma0 quality (3 levels)</td>
<td>byte</td>
<td>N/A</td>
</tr>
<tr>
<td>22</td>
<td>wind_speed_sar</td>
<td>SAR wind speed</td>
<td>short</td>
<td>10^-2 m/s</td>
</tr>
<tr>
<td>23</td>
<td>wind_speed_sar_calibrated</td>
<td>Calibrated sar wind speed</td>
<td>short</td>
<td>10^-2 m/s</td>
</tr>
<tr>
<td>24</td>
<td>wind_speed_model_u</td>
<td>U component of model wind vector</td>
<td>short</td>
<td>10^-2 m/s</td>
</tr>
<tr>
<td>25</td>
<td>wind_speed_model_v</td>
<td>V component of model wind vector</td>
<td>short</td>
<td>10^-2 m/s</td>
</tr>
<tr>
<td>No.</td>
<td>Name</td>
<td>Description</td>
<td>NetCDF Type</td>
<td>Units</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------</td>
<td>-----------</td>
</tr>
<tr>
<td>26</td>
<td>swh_rms</td>
<td>RMS/std of total significant wave height</td>
<td>short</td>
<td>$10^{-3}$ m</td>
</tr>
<tr>
<td>27</td>
<td>swh_rms_part</td>
<td>RMS/std of significant wave height for each partition</td>
<td>short x n_partitions</td>
<td>$10^{-3}$ m</td>
</tr>
<tr>
<td>28</td>
<td>dwl_rms_part</td>
<td>RMS/std of dominant wavelength for each partition</td>
<td>short x n_partitions</td>
<td>$10^{-3}$ m</td>
</tr>
<tr>
<td>29</td>
<td>ddr_rms_part</td>
<td>RMS/std of dominant direction for each partition</td>
<td>short x n_partitions</td>
<td>$10^{-3}$ deg</td>
</tr>
<tr>
<td>30</td>
<td>sigma0_rms</td>
<td>RMS/std of backscatter coefficient</td>
<td>short</td>
<td>$10^{-2}$ dB</td>
</tr>
<tr>
<td>31</td>
<td>azimuth_cutoff</td>
<td>Azimuth cutoff wavelength</td>
<td>short</td>
<td>$10^{-3}$ m</td>
</tr>
<tr>
<td>32</td>
<td>range_cutoff</td>
<td>Range cutoff wavelength</td>
<td>short</td>
<td>$10^{-3}$ m</td>
</tr>
<tr>
<td>33</td>
<td>quality_flag</td>
<td>Wave inversion quality (3 levels)</td>
<td>byte x n_partitions</td>
<td>N/A</td>
</tr>
<tr>
<td>34</td>
<td>rejections_flag</td>
<td>Bundled flags including spare bits</td>
<td>int</td>
<td>N/A</td>
</tr>
<tr>
<td>35</td>
<td>bathymetry</td>
<td>Bathymetry extracted from GEBCO_08 Grid</td>
<td>int</td>
<td>m</td>
</tr>
<tr>
<td>36</td>
<td>land_coverage</td>
<td>percentage of land coverage within a cell</td>
<td>short</td>
<td>%</td>
</tr>
<tr>
<td>37</td>
<td>distance_to_coast</td>
<td>Distance to coast extracted from GSHHS shoreline</td>
<td>short</td>
<td>km</td>
</tr>
<tr>
<td>38</td>
<td>sea_surface_temperature</td>
<td>SST from model</td>
<td>short</td>
<td>K</td>
</tr>
<tr>
<td>39</td>
<td>surface_temperature</td>
<td>Surface air temperature from model</td>
<td>short</td>
<td>K</td>
</tr>
<tr>
<td>40</td>
<td>surface_air_humidity</td>
<td>Surface air humidity from model</td>
<td>short</td>
<td>%</td>
</tr>
<tr>
<td>41</td>
<td>surface_air_pressure</td>
<td>Surface air pressure from model</td>
<td>short</td>
<td>Pa</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Description</th>
<th>NetCDF Type</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>time</td>
<td>Seconds since 1985-01-01</td>
<td>double</td>
<td>s</td>
</tr>
<tr>
<td>2</td>
<td>lat</td>
<td>Latitude</td>
<td>double</td>
<td>deg</td>
</tr>
<tr>
<td>3</td>
<td>lon</td>
<td>Longitude, range 0 to 360</td>
<td>double</td>
<td>deg</td>
</tr>
<tr>
<td>4</td>
<td>swh</td>
<td>Significant wave height (primary, e.g. Ku band)</td>
<td>short</td>
<td>$10^{-3}$ m</td>
</tr>
<tr>
<td>5</td>
<td>swh_calibrated</td>
<td>Calibrated significant wave height.</td>
<td>short</td>
<td>$10^{-3}$ m</td>
</tr>
<tr>
<td>6</td>
<td>swh_quality</td>
<td>Significant wave height quality (3 levels).</td>
<td>byte</td>
<td>N/A</td>
</tr>
<tr>
<td>7</td>
<td>swh_standard_error</td>
<td>Significant wave height best estimate of standard error.</td>
<td>short</td>
<td>$10^{-3}$ m</td>
</tr>
<tr>
<td>8</td>
<td>swh_2nd</td>
<td>Significant wave height 2nd frequency (e.g. S or C band)</td>
<td>short</td>
<td>$10^{-3}$ m</td>
</tr>
<tr>
<td>9</td>
<td>swh_2nd_calibrated</td>
<td>Calibrated significant wave height 2nd frequency.</td>
<td>short</td>
<td>$10^{-3}$ m</td>
</tr>
<tr>
<td>10</td>
<td>swh_2nd_quality</td>
<td>Significant wave height quality 2nd frequency (3 levels).</td>
<td>byte</td>
<td>N/A</td>
</tr>
<tr>
<td>11</td>
<td>sigma0</td>
<td>Backscatter coefficient (primary, e.g. Ku band)</td>
<td>short</td>
<td>$10^{-2}$ dB</td>
</tr>
<tr>
<td>12</td>
<td>sigma0_calibrated</td>
<td>Calibrated backscatter coefficient.</td>
<td>short</td>
<td>$10^{-2}$ dB</td>
</tr>
<tr>
<td>13</td>
<td>sigma0_quality</td>
<td>Sigma0 quality (3 levels).</td>
<td>byte</td>
<td>N/A</td>
</tr>
<tr>
<td>14</td>
<td>sigma0_2nd</td>
<td>Backscatter coefficient 2nd frequency (e.g. S or C band)</td>
<td>short</td>
<td>$10^{-2}$ dB</td>
</tr>
<tr>
<td>15</td>
<td>sigma0_2nd_calibrated</td>
<td>Calibrated significant wave height 2nd frequency.</td>
<td>short</td>
<td>$10^{-2}$ dB</td>
</tr>
<tr>
<td>16</td>
<td>sigma0_2nd_quality</td>
<td>sigma0 quality 2nd frequency (3 levels).</td>
<td>byte</td>
<td>N/A</td>
</tr>
<tr>
<td>17</td>
<td>wind_speed_alt</td>
<td>Altimeter wind speed</td>
<td>short</td>
<td>$10^{-2}$ m/s</td>
</tr>
<tr>
<td>18</td>
<td>wind_speed_alt_calibrated</td>
<td>Calibrated Altimeter wind speed.</td>
<td>short</td>
<td>$10^{-2}$ m/s</td>
</tr>
<tr>
<td>19</td>
<td>wind_speed_rad</td>
<td>Radiometer wind speed</td>
<td>short</td>
<td>$10^{-2}$ m/s</td>
</tr>
<tr>
<td>20</td>
<td>wind_speed_model_u</td>
<td>U component of model wind</td>
<td>short</td>
<td>$10^{-2}$</td>
</tr>
</tbody>
</table>

© 2013 Logica UK Ltd
<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Description</th>
<th>NetCDF Type</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>wind_speed_model_v</td>
<td>V component of model wind vector</td>
<td>short</td>
<td>m/s</td>
</tr>
<tr>
<td>22</td>
<td>rejection_flags</td>
<td>32 bundled flags, all relevant flags included with spare bits for future missions.</td>
<td>int</td>
<td>N/A</td>
</tr>
<tr>
<td>23</td>
<td>swh_rms</td>
<td>RMS/std of significant wave height (primary, e.g. Ku band)</td>
<td>short</td>
<td>10⁻³ m</td>
</tr>
<tr>
<td>24</td>
<td>swh_rms_2nd</td>
<td>RMS/std of significant wave height 2nd frequency (e.g. S or C band)</td>
<td>short</td>
<td>10⁻³ m</td>
</tr>
<tr>
<td>25</td>
<td>swh_num_valid</td>
<td>Number of valid points used to compute Hs (primary, e.g. Ku band)</td>
<td>short</td>
<td>N/A</td>
</tr>
<tr>
<td>26</td>
<td>swh_num_valid_2nd</td>
<td>Number of valid points used to compute Hs 2nd frequency (e.g. S or C band)</td>
<td>short</td>
<td>N/A</td>
</tr>
<tr>
<td>27</td>
<td>sigma0_rms</td>
<td>RMS/std of backscatter coefficient (primary, e.g. Ku band)</td>
<td>short</td>
<td>10⁻² dB</td>
</tr>
<tr>
<td>28</td>
<td>sigma0_rms_2nd</td>
<td>RMS/std of backscatter coefficient 2nd frequency (e.g. S or C band)</td>
<td>short</td>
<td>10⁻² dB</td>
</tr>
<tr>
<td>29</td>
<td>sigma0_num_valid</td>
<td>Number of valid points used to compute sig0 (primary, e.g. Ku band)</td>
<td>short</td>
<td>N/A</td>
</tr>
<tr>
<td>30</td>
<td>sigma0_num_valid_2nd</td>
<td>Number of valid points used to compute sig0 2nd frequency (e.g. S or C band)</td>
<td>short</td>
<td>N/A</td>
</tr>
<tr>
<td>31</td>
<td>peakiness</td>
<td>Pulse peakiness (primary, e.g. Ku band, Envisat only)</td>
<td>short</td>
<td>10⁻³</td>
</tr>
<tr>
<td>32</td>
<td>peakiness_2nd</td>
<td>Pulse peakiness 2nd frequency (e.g. S band, Envisat only)</td>
<td>short</td>
<td>10⁻³</td>
</tr>
<tr>
<td>33</td>
<td>off_nadir_angle_wf</td>
<td>Off nadir angle from waveforms</td>
<td>short</td>
<td>Deg(°)</td>
</tr>
<tr>
<td>34</td>
<td>off_nadir_angle_pf</td>
<td>Off nadir angle from platform</td>
<td>short</td>
<td>Deg(°)</td>
</tr>
<tr>
<td>35</td>
<td>range_rms</td>
<td>RMS/std of range (primary, e.g. Ku band)</td>
<td>short</td>
<td>10⁻⁴ m</td>
</tr>
<tr>
<td>36</td>
<td>range_rms_2nd</td>
<td>RMS/std of range 2nd frequency (e.g. S or C band)</td>
<td>short</td>
<td>10⁻⁴ m</td>
</tr>
<tr>
<td>37</td>
<td>bathymetry</td>
<td>Bathymetry from GEBCO 08 / DTM2000.1</td>
<td>short</td>
<td>m</td>
</tr>
<tr>
<td>38</td>
<td>distance_to_coast</td>
<td>Distance to coast.</td>
<td>short</td>
<td>km</td>
</tr>
</tbody>
</table>
### Table 4-6: Altimetry Variables

<table>
<thead>
<tr>
<th>Satid</th>
<th>Included variable numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERS1</td>
<td>1-7, 11-13, 17-18, 20-23, 25, 27, 33, 35, 37-42</td>
</tr>
<tr>
<td>ERS2</td>
<td>1-7, 11-13, 17-18, 20-23, 25, 27, 33, 35, 37-42</td>
</tr>
<tr>
<td>ENVI</td>
<td>1-18, 20-42</td>
</tr>
<tr>
<td>GEOS</td>
<td>1-7, 11-13, 17-18, 20-22, 33, 35, 37-42</td>
</tr>
<tr>
<td>GFO_</td>
<td>1-7, 11-13, 17-18, 20-23, 25, 27, 33, 35, 37-42</td>
</tr>
<tr>
<td>TOPX</td>
<td>1-18, 20-25, 27, 29, 33-35, 37-42</td>
</tr>
<tr>
<td>JAS1</td>
<td>1-30, 33-42</td>
</tr>
<tr>
<td>JAS2</td>
<td>1-30, 33-42</td>
</tr>
</tbody>
</table>

### 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.

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

<table>
<thead>
<tr>
<th>Global Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventions</td>
<td>CF-1.4</td>
</tr>
<tr>
<td>title</td>
<td>GlobWave L2P</td>
</tr>
<tr>
<td>source</td>
<td>radar altimeter</td>
</tr>
<tr>
<td>project</td>
<td>ESA GlobWave</td>
</tr>
<tr>
<td>institution</td>
<td>GlobWave</td>
</tr>
<tr>
<td>history</td>
<td>Date and time of product creation</td>
</tr>
<tr>
<td>contact</td>
<td>Contact information</td>
</tr>
<tr>
<td>references</td>
<td>GlobWave Product User Guide</td>
</tr>
<tr>
<td>processing_center</td>
<td>Ifremer</td>
</tr>
<tr>
<td>software_version</td>
<td>GlobWave product user guide</td>
</tr>
<tr>
<td>Global Attribute</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-----------------------------------------------------------</td>
</tr>
<tr>
<td>source_provider</td>
<td></td>
</tr>
<tr>
<td>mission_name</td>
<td></td>
</tr>
<tr>
<td>source_name</td>
<td></td>
</tr>
<tr>
<td>source_version</td>
<td></td>
</tr>
<tr>
<td>source_software</td>
<td></td>
</tr>
<tr>
<td>altimeter_sensor_name</td>
<td></td>
</tr>
<tr>
<td>radiometer_sensor_name</td>
<td></td>
</tr>
<tr>
<td>acq_station_name</td>
<td>Acquisition station</td>
</tr>
<tr>
<td>cycle_number</td>
<td>Mission cycle number</td>
</tr>
<tr>
<td>pass_number</td>
<td>Pass or orbit within cycle</td>
</tr>
<tr>
<td>equator_crossing_time</td>
<td></td>
</tr>
<tr>
<td>equator_crossing_longitude</td>
<td></td>
</tr>
<tr>
<td>start_time</td>
<td>Date and time of first measurement in file</td>
</tr>
<tr>
<td>stop_time</td>
<td>Date and time of last measurement in file</td>
</tr>
</tbody>
</table>

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. The subsections are structured as follows:

1. Calibrated variables
2. Quality variables
3. Hs standard error variable
4. Rejection flags variable
5. Ancillary variables
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

\[
\text{swh\_calibrated} = \text{swh} + 0.1 \text{swh} \times \max (0, \text{U10SAR} - 7) - 0.11 \text{ with the wind speed U10SAR is in m/s}
\]

References:


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) the calibrations of Envisat and Jason-2 should be the same as for the historical data (GDR), though for Envisat calibrations to date (January 2012) have been taken from Durrant et al. (2009). This will be addressed in an update to the NRT processor for Envisat in January 2012. For Jason-1 the calibrations are different and are taken from Durrant et al. (2009).

For historical data (GDR) calibrations are taken from Queffeulou & Croizé-Fillon (2009), except for Geosat, Envisat and Jason-2. Geosat has the swh values from the revised data set Geosat Altimeter JGM-3 GDRs on CD-ROM already increased by 13% in accordance with Carter et al. (1992). Envisat has new calibrations since the update to L2 source processing in January 2010 (and for all reprocessed data before then). These calibrations are taken from Queffeulou et al. (2011). For Jason-2 calibrations are taken from the GlobWave error analysis.

The calibration corrections are given in Table 4-10 for near real-time data and Table 4-11 for historical data.

<table>
<thead>
<tr>
<th>Satellite (satid)</th>
<th>Correction</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Envisat (ENVI)</td>
<td>swh_calibrated = 1.093 x s–h - 0.233</td>
<td>Version 1 calibration from Durrant et al. (2009)</td>
</tr>
<tr>
<td></td>
<td>[swh &gt; 3.41m] swh_calibrated = 1.0095 x swh + 0.0192</td>
<td>Version 2 calibration from Queffeulou et al. (2011)</td>
</tr>
<tr>
<td></td>
<td>[swh &lt; 3.41m] swh_calibrated =</td>
<td></td>
</tr>
</tbody>
</table>

© 2013 Logica UK Ltd
Table 4-10: Calibration correction values for near real-time altimeter data

<table>
<thead>
<tr>
<th>Satellite (satid)</th>
<th>Correction</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jason1 (JAS1)</td>
<td>swh_calibrated = 1.041 x s – h - 0.076</td>
<td>Calibration derived from GlobWave error analysis.</td>
</tr>
<tr>
<td>Jason2 (JAS2)</td>
<td>swh_calibrated = 1.041 x s – h - 0.042</td>
<td></td>
</tr>
<tr>
<td>Geosat (GEOS)</td>
<td>swh_calibrated = swh</td>
<td>JGM-3 version has calibrations applied</td>
</tr>
<tr>
<td>ERS-1 (ERS1)</td>
<td>swh_calibrated = 1.1259 x swh + 0.1854</td>
<td></td>
</tr>
<tr>
<td>ERS-2 (ERS2)</td>
<td>swh_calibrated = 1.0642 x swh + 0.0006</td>
<td></td>
</tr>
<tr>
<td>Envisat (ENVI)</td>
<td>swh_calibrated = 1.0585 x swh – 0.1935</td>
<td>Version 1, used for initial L2P release.</td>
</tr>
<tr>
<td></td>
<td>[swh &gt; 3.41m] swh_calibrated = 1.0095 x swh + 0.0192</td>
<td>Version 2, applies to all data since Jan 15th 2010 and all reprocessed data before then. See L2P release notes.</td>
</tr>
<tr>
<td></td>
<td>[swh &lt; 3.41m] swh_calibrated = -0.021 x swh³ + 0.1650 x swh² + 0.5693 x swh + 0.4358</td>
<td></td>
</tr>
<tr>
<td>Topex (TOPX)</td>
<td>Side A: swh_calibrated = 1.0539 x s – h - 0.0766 + dh with: dh = 0 for cycle &lt; 98 dh = poly3(9-) - poly3(cycle) for 98 &lt;= cycle &lt;= 235 with a0 = 0.0864; a1 = -6.0426 x 10^-4; a2 = -7.7894 x 10^-6; a3 = 6.9624 x 10^-8</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>Side B: swh_calibrated = 1.0237 x s – h - 0.0476</td>
<td>Side B operated after cycle 235</td>
</tr>
<tr>
<td>Poseidon (TOPX)</td>
<td>swh_calibrated = 1.0237 x s – h - 0.0476</td>
<td>Poseidon operated throughout the mission</td>
</tr>
<tr>
<td>Satellite (satid)</td>
<td>Correction</td>
<td>Comments</td>
</tr>
<tr>
<td>------------------</td>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>Geosat Follow-On (GFO_)</td>
<td>swh_calibrated = 0.9914 x swh – 0.0103</td>
<td>approximately 5% of the time.</td>
</tr>
<tr>
<td>Jason-1</td>
<td>swh_calibrated = 1.0625 x swh + 0.0754</td>
<td></td>
</tr>
<tr>
<td>Jason-2</td>
<td>swh_calibrated = 1.0250 x swh + 0.0588</td>
<td>L2 data version b.</td>
</tr>
<tr>
<td>CryoSat-2</td>
<td>swh_calibrated = 1.041 x swh - 0.042</td>
<td>Calibration derived from GlobWave error analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not yet calibrated</td>
</tr>
</tbody>
</table>

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, or can be used by Users to include their own calibrated values of these quantities.

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 Envisat 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)

Wave Height Measurements from altimeters: Validation status and applications.
Presentation at GlobWave User Consultation Meeting, Cork, October 2011

Additional references are given in a bibliography on the Globwave Portal at http://www.globwave.org/Validation/Calibration-Validation-Bibliography.

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.
<table>
<thead>
<tr>
<th>Value (decimal)</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Probably good partition</td>
</tr>
<tr>
<td>1</td>
<td>Probably good but 180° ambiguous partition</td>
</tr>
<tr>
<td>2</td>
<td>Probably bad partition (ie azimuth cutoff affected or spurious dataset)</td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Value (decimal)</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Probably good measurement</td>
</tr>
<tr>
<td>1</td>
<td>Suspect, probably okay for some applications. For example this is set when sigma0 over SAR imagette is very inhomogeneous</td>
</tr>
<tr>
<td>2</td>
<td>Probably bad measurement</td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th>Value (decimal)</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Probably good measurement</td>
</tr>
<tr>
<td>1</td>
<td>Suspect, probably okay for some applications. For example this is set when rain is detected for an otherwise good measurement.</td>
</tr>
</tbody>
</table>
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:

- \textit{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 \textit{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:

- \textit{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.

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
<th>Satellites</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Hardware status</td>
<td>TOPX JAS1 JAS2 ENVI</td>
</tr>
<tr>
<td>1</td>
<td>Satellite on track</td>
<td>ERS1</td>
</tr>
</tbody>
</table>

Table 4-14: Quality variables values

The calculation of the quality variables varies by satellite and sensor, and details are given Annex B.
<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
<th>Satellites</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Attitude status</td>
<td>ERS2 GEOS TOPX GFO_ JAS1 JAS2</td>
</tr>
<tr>
<td>2</td>
<td>spare</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>spare</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Altimeter land flag</td>
<td>all</td>
</tr>
<tr>
<td>5</td>
<td>Altimeter ocean / non-ocean flag</td>
<td>all</td>
</tr>
<tr>
<td>6</td>
<td>Radiometer land flag</td>
<td>all except GEOS</td>
</tr>
<tr>
<td>7</td>
<td>Corruption of Altimeter measurement</td>
<td>TOPX JAS1 JAS2 GFO_ ENVI CRYO</td>
</tr>
<tr>
<td>8</td>
<td>Corruption of radiometer measurement</td>
<td>ERS1 ERS2 TOPX JAS1 JAS2 ENVI</td>
</tr>
<tr>
<td>9</td>
<td>spare</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>spare</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Quality of the range estimate</td>
<td>all</td>
</tr>
<tr>
<td>12</td>
<td>Quality of the wave height estimate</td>
<td>ERS1 ERS2 TOPX GFO_ JAS1 JAS2 CRYO GEOS</td>
</tr>
<tr>
<td></td>
<td>Sea state bias</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Quality of sigma0 estimate</td>
<td>all except GEOS</td>
</tr>
<tr>
<td></td>
<td>Quality of windspeed measurement</td>
<td>GEOS</td>
</tr>
<tr>
<td>14</td>
<td>spare</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Quality of the orbit</td>
<td>ERS1 ERS2 TOPX JAS1 JAS2 ENVI</td>
</tr>
<tr>
<td>16</td>
<td>Quality of the wave height estimate 2nd frequency</td>
<td>JAS2</td>
</tr>
<tr>
<td>17</td>
<td>Quality of sigma0 estimate 2nd frequency</td>
<td>JAS2</td>
</tr>
<tr>
<td>18</td>
<td>Quality of off nadir angle from waveforms</td>
<td>JAS2</td>
</tr>
<tr>
<td>19</td>
<td>Quality of off nadir angle from platform</td>
<td>JAS2</td>
</tr>
<tr>
<td>20</td>
<td>Ice flag from database</td>
<td>all</td>
</tr>
<tr>
<td>21-30</td>
<td>spare</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Flag rejection</td>
<td>all</td>
</tr>
</tbody>
</table>

**Table 4-15: Rejection Flags**

### 4.4.4.3 Altimeter rain flag

For GFO, TOPEX/Poseidon, Jason-1, Jason-2 and Envisat Bit 8 of the rejection_flags variable (corruption of radiometer) is equivalent to the rain flag and will be set if rain is detected.
This flag is taken into account when calculating the quality level. If Bit 8 of the rejection_flags is set then quality level will be set to “1” for an otherwise good measurement. See section 4.4.2.2.

### 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 using the high resolution OSI-SAF dataset later in the project.

The bathymetry and distance_to_coast are calculated from the GEBCO_08 Grid — The General Bathymetric Chart of the Oceans (GEBCO) consists of an international group of experts who work on the development of a range of bathymetric data sets and data products, including gridded bathymetric data sets, the GEBCO Digital Atlas, the GEBCO world map and the GEBCO Gazetteer of Undersea Feature Names. GEBCO_08 is provided on a global grid at 30 arc-second intervals. The grid is largely based on ship track soundings with interpolation between soundings guided by satellite-derived gravity data. However, in areas where they improve on the existing GEBCO_08 grid, data sets generated by other methods have been included. See http://www.gebco.net/
4.5 Known issues

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

4.5.1 NRT

4.5.1.1 SAR Processor Version 1.8

Unfilled variables

- surface_air_humidity

4.5.1.2 Altimeter Processor Version 1.2

Unfilled variables

- surface_air_humidity

4.5.2 GDR

4.5.2.1 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.

Other variables to be updated

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

Data quality issues

- Envisat: Envisat data has now been reprocessed using version 2.1 of the L2 source data. New calibration has been applied. In the previous version certain files (e.g. Cycle 047 pass 194) have some bad latitude values in the L2 data that were not corrected for in the L2P. Envisat data are missing on a few days in 2003, 2006, 2007, 2010 and 2011. Occasional Envisat model winds have a fixed incorrect value of 1.5m/s.
• ERS2: Some negative swh values to be investigated.

• GFO: some L2 files contain no data and are omitted from the L2P. It is recommended not to use sigma0 or altimeter wind speed data after 2nd August 2006.

• TOPEX: it is recommended not to use sigma0 or altimeter wind speed data for the first 10 cycles of TOPEX, up until December 31st 1992, and cycles 433 to 437, from June 15th to August 2nd 2004 inclusive. Quality levels of sigma0 for these periods have been set accordingly and may differ from the quality levels of significant wave height.

• Jason-2: Occasional Jason-2 model winds have a fixed incorrect value of 2.5m/s

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%.

• CryoSat-2: Quality levels, error estimates and calibrations are not yet available and will be calculated once there is a suitable time series of buoy co-locations.

• Jason-1: Since 8th May 2012 Jason-1 has been moved to a Geodetic orbit and NRT data are provided in a separate folder labelled “jason1_geodetic”. The Geodetic mission was a result of a change in orbit of the Jason-1 satellite due concerns about the future of the mission after two earlier equipment failures. This orbit manoeuvre was initiated on April 23rd and the normal instrument operations began on May 7th.

4.5.2.2 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.
5 DEMONSTRATION DATA PRODUCTS

The present set of demonstration products are:

- Hs-Tz scatterplots
- Fireworks
- Soprano
- GlobWave lesson
- Merged altimeter wave heights
- Esurge
- Measuring Global Sea State using SAR data

Further demonstration products will be developed during the remainder of 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

\[ S_s = \frac{2\pi H_s}{gT_z^2} \]

![Figure 3: Hs-Tz Scatterplot using the Altimeter Wave Period Product](image)

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 \( (h/\lambda) \). 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.

<table>
<thead>
<tr>
<th>Region</th>
<th>Location</th>
<th>WMO buoy reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>N Pacific</td>
<td>55°N 175°E</td>
<td>46070</td>
</tr>
<tr>
<td>Equatorial Pacific</td>
<td>1°N 153°W</td>
<td>51028</td>
</tr>
<tr>
<td>W Pacific</td>
<td>13°N 145°E</td>
<td>52200</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>39°N 5°E</td>
<td>61197</td>
</tr>
<tr>
<td>NW Atlantic</td>
<td>49°N 13°W</td>
<td>62029</td>
</tr>
<tr>
<td>NW Atlantic</td>
<td>55°N 21°W</td>
<td>62606</td>
</tr>
<tr>
<td>NW Atlantic</td>
<td>59°N 11°W</td>
<td>64045</td>
</tr>
</tbody>
</table>

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,


### 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 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.

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

http://soprano.cls.fr

5.4 GlobWave lesson

Murray Brown from the UNESCO/IOC Intergovernmental Oceanographic Data and Information Exchange's (IODE) OceanTeacher program has developed an online tutorial using GlobWave data. The lesson teaches users how to access the GlobWave portal and download Near Real Time (NRT) ENVISAT and JASON 1&2 Altimeter data, open the netCDF files using the Integrated Data Viewer and display multiple datasets of altimeter point data with a range of visualisations.

Access the lesson at http://marinedataliteracy.org/ops/globwave_pts.htm

By the end of the lesson, the user can start to make comparisons between the various Surface Wave height point datasets displayed simultaneously within the IDV. An example visualisation for a single data file is shown below.

This lesson is hosted on the Marine Data Literacy website, http://marinedataliteracy.org/, which provides instruction for handling (managing, converting, analyzing and displaying) oceanographic station data, marine meteorological data, GIS-compatible marine and coastal data and mapped remote sensing imagery.

The lesson is part of the Operational Oceanography: Synoptic Views of the Sea (2011) course, whose goal is to demonstrate the range of ocean data resources available from operational programs, which can be assembled, synthesised and displayed in a single software platform.
The Operational Oceanography course is hosted by Ocean Teacher, a web-based training system for ocean data managers (working in ocean data centres), marine information managers (marine libraries) as well as for marine researchers who wish to acquire knowledge on data and also for individuals in other related disciplines. The courses are based on 3 resources: The annotated outlines; the resource materials (i.e. reading) in our Digital Library; and a large collection of practical exercises.

Murray Brown has been training young scientists in marine data management for UNESCO/IOC's Intergovernmental Oceanographic Data and Information Exchange's (IODE) OceanTeacher program for almost exactly 20 years now. He is also responsible for the IODE's 'help desk'.

The material described here is in the public domain. Please cite the author, Murray Brown, in any use you make of this lesson.

**5.5 Merged Altimeter Wave Heights**

A database of merged altimeter wave heights has been set up at Ifremer by Pierre Queffeulou. This provides wave height, backscatter coefficient and wind speed, together with proposed calibration corrections for all altimeters since ERS-1, spanning August 1991 to 2011. Data are in netCDF format and provided in one file for all data each day.

The Ifremer Laboratoire d'Océanographie Spatiale (LOS) is involved in several aspects of the GlobWave project. Besides these GlobWave dedicated activities an independent monitoring of the quality of significant wave height, and wind speed, measurements from the altimeters has been performed regularly for a long time.

In 2011 the merged altimeter database has been improved, with new information including C-band backscatter coefficient and 1 Hz standard deviation values for the Jason-1 & Jason-2 datasets, S-band backscatter coefficient and 1 Hz standard deviation values for ENVISAT, new SWH calibrations applied to ERS-2, Jason-1 & Jason-2 datasets, new data screening for ENVISAT, Jason-1 & Jason-2 and the ENVISAT GDR dataset reprocessed in version V2.1.


**5.6 Global Sea State from SAR data**

The German Aerospace Center (DLR) have published their work on Global Sea State Measurements using ENVISAT ASAR Wave Mode Data.

This work focuses on developing an empirical algorithm, known as CWAVE, that derives integral ocean wave parameters from SAR data without first guess information. CWAVE derived total SWH measurements have been validated for
both ERS and ENVISAT ASAR Wave Mode Data against both models and buoys, with a scatter index of 24% against buoys. ENVISAT ASAR CWAVE measurements have also been compared to Jason and GFO Altimeter measurements with a scatter index of 13% and 17% respectively.

This work was presented at the 2010 SeaSAR conference and the presentation can be downloaded at: http://earth.eo.esa.int/workshops/seasar2010/participants/345/pres_345_brusc_h.pdf

The algorithm for deriving total SWH from the SAR wave mode data is available at: http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5508398

The work is part of Dr Xiao-Ming Li’s PhD research and his published thesis can be downloaded at: http://ediss.sub.uni-hamburg.de/volltexte/2010/4492/pdf/XiaomingLi_Dissertation_2010.pdf

5.7 Related Projects

Other wave-related projects will be of interest to users of wave data and some important examples are given below.

5.7.1 COASTALT

COASTALT was a Project on “Development of Radar Altimetry Data Processing in the Coastal Zone” funded by the European Space Agency (ESA/ESRIN contract 21201/08/I-LG) whose main objective was to contribute to the transition of pulse-limited coastal altimetry towards a mature, pre-operational status, by defining and testing new coastal radar altimeter products. This is ultimately to prepare the way for a routine generation and distribution of such products by ESA, first from the RA-2 altimeter on board Envisat but then also from the instruments on ERS-1 and ERS-2 (and now also Cryosat-2, plus Sentinel-3 in the future).

While altimetry over the open ocean is a mature discipline, incredibly useful both for process studies and operational forecasting, in the coastal zone (the strip within a few tens of km from the coast) data are often discarded (i.e. flagged as bad) simply because we do not know well how to interpret/model land effects on the altimetric waveforms, and/or lack adequate corrections for various effects such as path delays, coastal tides, high frequency atmospheric signals. But we believe that the information hidden in those 'bad data' can be recovered - and that once that is done, that information will be invaluable to study the very region where the impact of the changing ocean on society is strongest - the coastal strip. Recovering that information requires the development of ad hoc techniques for processing the raw altimetric data in proximity of the coast, but once those techniques are up and running, more than 18 years of data from several missions are ready to be reprocessed in the archives... a tantalizing prospect!

Further information can be found on the COASTALT web page at http://www.coastalt.eu/. The data that was disseminated is of particular interest to GlobWave users due to the retrieval of the significant wave height parameter.
5.7.2 PISTACH

As part of the Jason-2 project, CNES is funding a dedicated initiative called PISTACH to improve conventional satellite radar altimetry products over coastal areas and continental waters.

The PISTACH (Prototype Innovant de Systeme de Traitement pour les Applications Cotieres et l'Hydrologie) project was organized to correct the standard Jason-2 products to make them suitable for use in coastal regions. Detailed information about the PISTACH experimental coastal products can be found at http://www.aviso.oceanobs.com/index.php?id=1527, and users may be interested to link directly to the PISTACH Handbook: http://www.aviso.oceanobs.com/fileadmin/documents/data/tools/hdbk_Pistach.pdf

5.7.3 eSurge

The DUE eSurge project has been set up by ESA to promote the use of Earth Observation data for Storm Surge applications. A storm surge is an abnormally high sea level produced by severe atmospheric conditions, lasting for a period ranging from a few minutes to a few days. Storm surges can be extremely destructive, causing extensive flooding, severe damage to property and infrastructure, and in extreme cases significant loss of life. For example, most fatalities during tropical storms are due to the associated storm surges.

Storm Surge forecasting and warning systems depend upon the cooperation of different scientific disciplines and user communities. Such systems use a range of measurements including in-situ (such as tide buoys), Numerical Weather Prediction (NWP) and Numerical Ocean Prediction (NOP) systems. There are several ways in which EO data can help improve storm surge forecasting. These include tracking the progress of storms and estimating their landfall locations, using SAR data to measure wind speeds and using EO data to measure Sea Surface Temperature that can be used to estimate the intensity of a storm.

Another EO tool that can be used for storm surge monitoring is the measurement of water levels in coastal regions using coastal altimetry tools. As most satellite altimetry techniques have been developed to measure Sea Surface Height in the open ocean, some work still needs to be done for extending these measurements to the coast. The work done for this project will continue the research done in the COASTALT project.
ANNEX A :L2P DIMENSION, VARIABLE AND ATTRIBUTE LISTINGS

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

```plaintext
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" ;
    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" ;
    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";
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_cAlibrated:scale_factor = 0.1f;
dwL_part_cAlibrated:adD_offset = 0.f;
dwL_part_cAlibrated:uniTs = "m";
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:coordinates = "lon lat";
ddr_part:comment = "heading of wave vector in degrees clockwise from north";

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 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_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\textsuperscript{-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\textsuperscript{-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\textsuperscript{-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\textsuperscript{-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 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 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: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: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";

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_2PP1FR20021217_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";
short 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: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: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 ;
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;
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;
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";

short swh_rms_2nd(time);
swh_rms_2nd:_FillValue = 32767s;
short swh_rms(time);
swh_rms:_FillValue = 32767s;
swh_rms:long_name = "RMS of the Ku band backscatter coefficient";
short swh_rms_2nd(time);
swh_rms_2nd:_FillValue = 32767s;
short swh_rms(time);
swh_rms:_FillValue = 32767s;
swh_rms:long_name = "RMS of the Ku band backscatter coefficient";
short swh_rms_2nd(time);
swh_rms_2nd:_FillValue = 32767s;
short off_nadir_angle_wf(time);
off_nadir_angle_wf:_FillValue = 32767s;
short off_nadir_angle_wf(time);
off_nadir_angle_wf:_FillValue = 32767s;
short off_nadir_angle_wf(time);
off_nadir_angle_wf:_FillValue = 32767s;
short off_nadir_angle_wf(time);
off_nadir_angle_wf:_FillValue = 32767s;
short off_nadir_angle_wf(time);
off_nadir_angle_wf:_FillValue = 32767s;
short off_nadir_angle_wf(time);
off_nadir_angle_wf:_FillValue = 32767s;
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 = "IOIC/IHO/GSFC" ;
bathymetry:scale_factor = 1. ;
bathymetry:add_offset = 0 ;
bathymetry:coordinates = "lon lat" ;

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 Hawaii 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: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" ;
```json
: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_2P0F-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)
2. The Geosat Altimeter JGM-3 GDRs on CD-ROM
   NODC Laboratory for Satellite Altimetry
   Silver Spring, Maryland 20910
   May, 1997

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

   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)

   European Space Agency.

   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

   Geophysical Validation of ENVISAT Altimetry Products
   ESA Contract Report; Satellite Observing Systems Ltd.

    A parametric model for ocean wave period from Ku band altimeter data

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
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 # Unsinged 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
- med 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

b) Wind speed algorithm gives an upper limit of 21.3 m/s
c) There is no ice flag at present but
   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 \(10^5\) # \(10^9\)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.

c) Wind speeds calculated using
Freilich M H, and Challenor P 1994
A new approach for determining fully empirical altimeter wind speed model functions.

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 \leq 1500 \ # 10^4 m
18 < swh_numval_ku < 255 \ # \text{Unsigned integer}
swh_ku < 65535 \ # \text{Unsigned integer}
swh_rms_ku > 0 \ # 10^3 m
swh_rms_ku < 65535
swh_rms_ku < (996.1 - 0.0398 \times swh_ku + 0.0000132 \times swh_ku^2)
\quad (\text{swh} \text{ _k_u: } 10^3 \text{ m})
sig0_rms_ku \leq 100 \ # 10^2 \text{ dB}
wind_speed_alt < 65535 \ # \text{cm/s}
off_nadir_angle_ku_wvf >= -200 \ and \ off_nadir_angle_ku_wvf <= 2500 \ # 10^4 \text{ deg}^2
qual_1hz_alt_data bits 0,2,4 = 0
(surface_type \leq 1 \ # \text{open ocean, enclosed seas or lakes})
alt_echo_type = 0 \ # \text{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 \leq 100 \ # 10^2 \text{ dB}
wind_speed_alt < 32767 \ # 10^2 \text{m/s}
-200 \leq \text{off_nadir_angle}_\text{wf_ku} \leq 2500 \ # 10^4 \text{deg}^2
qual_1hz_range_ku = 0b
qual_1hz_swh_ku = 0b
qual_1hz_sig0_ku = 0b
surface_type \leq 1 \ # \text{open ocean, enclosed seas or lakes}
alt_echo_type = 0 \ # \text{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 $\lambda_{cut}$. 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 \( \lambda_{\text{cut}} \) 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):

\[
\lambda^*_{\text{cut}} = 0.5\lambda_{\text{cut}} + 90
\]

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 \( \lambda^*_{\text{cut}} \in [100m, 400m] \), 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:

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

where \( \lambda_n = \frac{2\pi}{k_n} \) is the wavelengths of the spectrum. To simply cut the spectrum for wavelengths above \( \lambda^*_{\text{cut}} \) could also be considered.
Some statistics and dependencies of $\lambda_{\text{cut}}$ 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 $0.025 \text{rad/m} = 25 \text{m}$. 
Figure 3: Histogram of ASAR Wave Mode azimuth cut-off values, $\lambda_{\text{cut}}^*$, globally collected for September 2004.
Figure 4: Upper plot: ASAR Wave Mode azimuth cut-off values, $\lambda^*$, 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, $\sigma_I$, 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

Table 1 – standard deviation values over 0.5m steps

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

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.

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

For CryoSat-2 only 7 bits are used as follows:

| 4 Altimeter land        | flags bit 2 |
| 5 Alt ocean / non-ocean | flags bit 4 |
| 7 Corruption alt        | flags bit 5 |
| 11 Quality range        | flags bit 11|
| 12 Quality swh / ssb    | flags bit 12|
| 13 Quality sig0 / u10   | flags bit 13|
| 31 Flag rejection       |             |
Contact person:  
Dr. Geoff Busswell  
GlobWave Project Manager  
P: +44 (0) 7595 612 392  
F: +44 (0) 1372 759 690  
E: geoff.busswell@logica.com  
www.logica.com