

Jason-1 Products Handbook

References:

CNES : SALP-MU-M5-OP-13184-CN

JPL : JPL D-21352

Issue: 5 rev 1

Date: April 4th, 2016



Chronology Issues:

| Issue: | Date: | Modifications | Visa |
|--------|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|
| 2rev0 | 14 April 2003 | Initial release to users In line with products named JA1_GDR_2Pa generated since the beginning of the mission | N Picot |
| 2rev1 | October 2004 | Modification on 20Hz field management. Implemented on IGDR data starting with cycle 102 and on GDR/SGDR data starting with cycle 91. No impact on the 1 Hz data. | N. Picot |
| 3rev0 | 07 December 2005 | Accounting for all evolutions included in GDR v2 version. In line with products named JA1_GDR_2Pb Implemented on IGDR data starting on October, 24th 2005 (i.e. first day of cycle 140) and on GDR/SGDR data starting on cycle 136 (for the routine processing) | N. Picot S. Desai |
| 4rev0 | June 2008 | Accounting for all evolutions included in GDR_C version. Accounting for evolution regarding mog2D correction inside IGDR products. In line with products named JA1_GDR_2Pc and JA1_IGD_2Pc Implemented on IGDR data starting on June, 17th (ie JA1_IGD_2PcP237_121) and on GDR/SGDR data starting on cycle 233 (for the routine processing). | N. Picot S. Desai J. Hausman |
| 4rev1 | September 2008 | POE standard modification (Time variable Gravity terms of order > 1 removed) Correction of GDR_C version scope (instrumental corrections have been updated) In line with products named JA1_GDR_2Pc and JA1_IGD_2Pc. | N. Picot S. Desai |
| 4rev2 | June 2012 | Evolutions to take into account new Jason-1 new geodetic orbit: - New orbit characteristics - Modification of cycles/tracks numbering - POD standard modification (GDR-D) - New Mean Sea Surface : CNES-CLS-2011 | E. Bronner |
| 5rev0 | September 2015 | - Update to take into account Jason-1 reprocessing of GDR products in version 'e' (Change request SALP-FT-10180) - New template of products handbook document to be in line with Jason-2 and | E. Bronner N. Picot S. Desai J. Hausman |

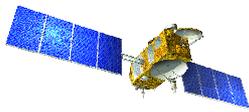


Chronology Issues:

| Issue: | Date: | Modifications | Visa |
|--------|------------|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| | | Jason-3 mission. | |
| 5rev1 | April 2016 | Update to take into account corrections of reprocessing tool and auxiliary data. | E. Bronner N. Picot L. Carrère S. Desai J-D. Desjonquères N. Tran |

People involved in this issue:

| | | |
|-------------------|-----------------|-----------------------|
| Written by (*): | | Date : |
| E. BRONNER | CNES | On behalf of the team |
| N. PICOT | CNES | 4 April 2016 |
| J-D. DESJONQUERES | CNES | <i>Bronner</i> |
| S. DESAI | NASA/JPL | |
| J. HAUSMAN | NASA/JPL/PODAAC | |
| L. CARRERE | CLS | |
| N. TRAN | CLS | |



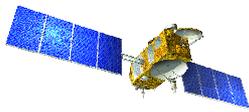
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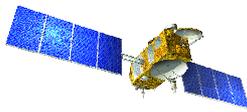
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Applicable documents / reference documents

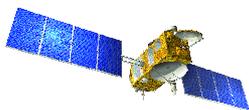
- AD 1 : **Jason-1 System Requirements**
TP2-SB-J0-100-CNES
- AD 2 : **Jason-1 Science and Operational Requirements**
TP2-SB-J0-102-CNES
- AD 3 : **ADAS, « Algorithm Definition Accuracy Specification Vol 1 : Jason real time processing »** SMM-ST-M2-EA-11002-CN
- AD 4 : **ADAS, « Algorithm Definition Accuracy Specification Vol 2 : CMA altimeter level 1B processing »** SMM-ST-M2-EA-11003-CN
- AD 5 : **ADAS, « Algorithm Definition Accuracy Specification Vol 3 : CMA radiometer level 1B processing »** SMM-ST-M2-EA-11004-CN
- AD 6 : **ADAS, « Algorithm Definition Accuracy Specification Vol 4 : CMA altimeter level 2 processing »** SMM-ST-M2-EA-11005-CN
- AD 7 : **ADAS, « Algorithm Definition Accuracy Specification Vol 5 : CMA radiometer level 2 processing »** SMM-ST-M2-EA-11006-CN
- AD 8 : **ADAS, « Algorithm Definition Accuracy Specification Vol 6 : CMA altimeter / radiometer verification processing »** SMM-ST-M2-EA-11007-CN
- AD 9 : **ADAS, « Algorithm Definition Accuracy Specification Vol 7 : Near real time control processing »** SMM-ST-M2-EA-11008-CN
- AD 10 : **ADAS, « Algorithm Definition Accuracy Specification Vol 8 : Off line control processing »** SMM-ST-M2-EA-11009-CN
- AD 11 : **ADAS, « Algorithm Definition Accuracy Specification Vol 9 : CMA mechanisms »** SMM-ST-M2-EA-11010-CN
- AD 12 : **ADAS, « Algorithm Definition Accuracy Specification Vol 11 : Visualisation processing »** SMM-ST-M2-EA-11012-CN
- AD 13 : **ADAS, « Algorithm Definition Accuracy Specification Vol 12 : CMA/DORIS » ionospheric processing »** SMM-SP-M2-EA-11013-CN

- RD 1 : **TOPEX/POSEIDON Project, 1992, "GDR-T User's Handbook"**
PD 633-721, JPL D-8944, October 18, 1993
- RD 2 : **AVISO and PODAAC User Handbook - IGDR and GDR Jason Products**
SMM-MU-M5-OP-13184-CN (AVISO), JPL D-21352 (PODAAC)
- RD 3 : **OSTM/Jason-2 Products Handbook**
SALP-MU-M-OP-15815-CN
- RD 4 : **Rain Flag Modification for Version B Jason GDRs**
Doc. Techni/ DOPS/LOS, 2006-01

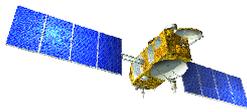


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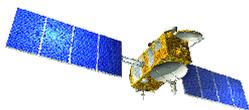
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1. Introduction

Jason-1 is a follow-on mission to the highly successful TOPEX/POSEIDON (T/P) mission. It was launched on 7 December 2001 and decommissioned on 21 June 2013. The satellite is named after the leader of the Argonauts' famous quest to recover the Golden Fleece. The Jason-1 mission is jointly conducted by the French Space Agency, "Centre National d'Etudes Spatiales" (CNES) and the United States National Aeronautics and Space Administration (NASA).

1.1. Overview of the Jason-1 product family

The purpose of this document is to assist users of the Jason-1 version E reprocessed products that have been generated after the conclusion of the mission. Reprocessed products only include the fully validated Geophysical Data Record (GDR), and supersede all prior versions and product families from the Jason-1 mission.

During mission operations, there were three product families (Operational Sensor Data Record: OSDR, Interim Geophysical Data Record: IGDR, and Geophysical Data Record : GDR) that are described in previous versions of this user handbook. The OSDR was a non-validated near-real-time (3-hour latency) product aimed towards wind/wave users. The IGDR and GDR were identical except for the following differences regarding auxiliary data used in the processing. These differences resulted from the product latencies of 2-3 days for the IGDR and 30 days for the GDR.

| Auxiliary Data | Impacted Parameter | OSDR | IGDR | GDR |
|----------------|------------------------------------------------------------------------------------------------------------------|--------------------|------------------------------------------|-----------------------------------------------------------------|
| Orbit | Satellite altitude, Doppler correction, ... | DORIS Navigator | Preliminary (MOE using DORIS data) | Precise (POE using DORIS and/or Laser and/or GPS data) |
| Meteo Fields | Dry/wet tropospheric corrections, U/V wind vector, Surface pressure, Inverted barometer correction, ... | Not available | Restituted | |
| Pole Location | Pole tide height | Not available | Predicted | Restituted |
| Mog2D | HF ocean dealiasing correction | Not available | Preliminary | Precise |
| GIM | Ionosphere correction | Not available | Available | |

Table 1 : Differences between Auxiliary Data for O/I/GDR Products

GDR products, unlike OSDR and IGDR products, are fully validated products.

1.1.1. Product contents

The version E GDR products from this mission comprise three types of files in NetCDF format, with increasing size and complexity:

1. a reduced (R) 1 Hz subset of the full dataset in NetCDF format (GDR-SSHA);
2. the native (N) NetCDF formatted datasets (GDRs) which contain 1Hz records as well as 20 Hz high-rate values;
3. an expert sensor (S) product containing the full radar-echo waveforms in NetCDF format (S-GDR).



The format of these products closely follows that from the follow-on Jason-2 mission. All files contain sea surface height, ocean surface wind speed, significant wave height information and all required corrections. The files differ in the amount and type of auxiliary data included but the product format is the same.

1.1.2. Filename conventions

The version E GDR product names are based on the following convention:

JA1_GP<N/R/S>_2P<v>P<ccc>_<ppp>_<yyyymmdd_hhnss>_<yyyymmdd_hhnss>.nc

With :

- <N/R/S> : product type (N : native, R: reduced, S : sensor)
- <v> : product version (set to 'e' for the current delivery of Jason-1 reprocessed products)
- <ccc>: cycle number of 1st product record
- <ppp> : pass number of 1st product record (1-254)
- <yyyymmdd_hhnss> : date of 1st product record
- <yyyymmdd_hhnss> : date of last product record

Offline GDR products:

GDR: JA1_GPN_2PvPccc_ppp_yyyyymmdd_hhnss_yyyyymmdd_hhnss.nc
GDR-SSHA: JA1_GPR_2PvPccc_ppp_yyyyymmdd_hhnss_yyyyymmdd_hhnss.nc
S-GDR: JA1_GPS_2PvPccc_ppp_yyyyymmdd_hhnss_yyyyymmdd_hhnss.nc

Binary formats and contents of the Jason-1 products during mission operations (versions a, b, c) are described in previous versions of "Jason-1 product handbook" and "Jason-1 user products".



1.2. Handbook Overview

This is a combination of a guide to data use and a reference handbook, so not all sections will be needed by all readers.

Section 1 provides information on product evolution history

Section 2 provides background information about the GDR and this document

Section 3 is an overview of the Jason-1 mission

Section 4 is an introduction to using the Jason-1 data

Section 5 is an introduction to the Jason-1 altimeter algorithms

Section 6 provides a description of the content and format of the Jason-1 GDRs

Appendix A contains references

Appendix B contains acronyms

Appendix C describes how to order information or data from CNES and NASA, and lists related Web sites.

1.3. Document reference and contributors

When referencing this document, please use the following citation:

“Jason-1 Products Handbook”,

CNES (AVISO+) :

JPL (PODAAC) :

SALP-MU-M5-OP-13184-CN

JPL D-21354

This document is based on “Jason-2 products handbook” and “AVISO and PODAAC User Handbook. IGDR and GDR Jason Products”.

All contributors are: N. Picot, S. Desai, P. Vincent, E. Bronner, K. Case, P. Callahan, R. Benada, and V. Zlotnicki, J. Lambin, F. Boy, T. Guinle, L. Carrère, J.P. Dumont, V. Rosmorduc, H. Bonekamp, J. Figa, J. Lillibridge, R. Scharroo, A. Couhert.



1.4. Conventions

1.4.1. Vocabulary

1.4.1.1. Altimetric distances

In order to reduce confusion in discussing altimeter measurements and corrections, the following terms are used in this document as defined below:

- **Distance** and **Length** are general terms with no special meaning in this document
- **Range** is the distance from the satellite to the surface of the Earth, as measured by the altimeter. Thus, the altimeter measurement is referred to as "range" or "altimeter range," not height
- **Altitude** is the distance of the satellite or altimeter above a reference point. The reference point used is the reference ellipsoid. This distance is computed from the satellite ephemeris data
- **Height** is the distance of the sea surface above the reference ellipsoid. The sea surface height is the difference of the altimeter range from the satellite altitude above the reference ellipsoid

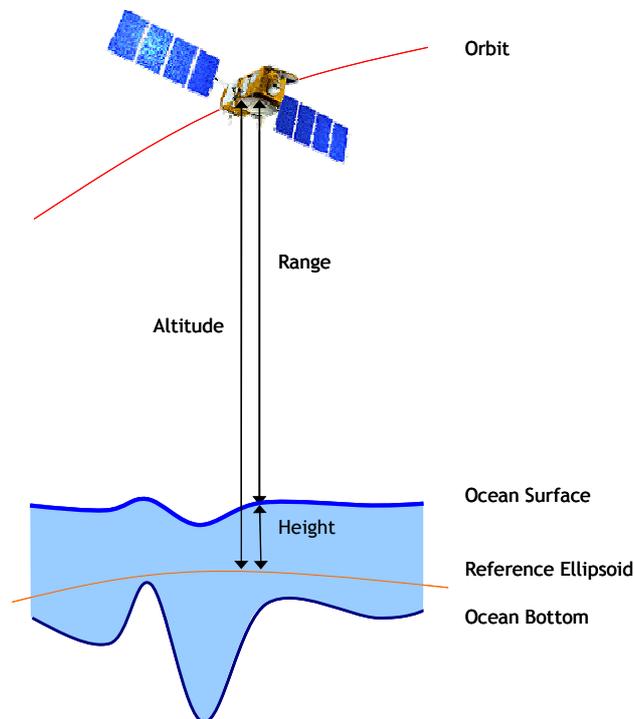


Figure 1 : Altimetric distances - Altitude, Range and Height

1.4.1.2. Orbits, Revolutions, Passes, and Repeat Cycles

An **Orbit** is one circuit of the earth by the satellite as measured from one ascending node crossing to the next. An ascending node occurs when the sub satellite point crosses the earth's equator going from south to north. A **Revolution** (REV) is synonymous with orbit.

The OSDR data were organized into files ("segments") which corresponded to the amount of data dumped over an Earth terminal (typically 2 hour-data sets).



The (I)GDR data is organized into pass files in order to avoid having data boundaries in the middle of the oceans, as would happen if the data were organized by orbit. A **Pass** is half a revolution of the earth by the satellite from extreme latitude to the opposite extreme latitude.

For Jason-1, an **Ascending Pass** begins at the latitude -66.15 deg and ends at +66.15 deg. A **Descending Pass** is the opposite (+66.15 deg to -66.15 deg).

On the **repetitive orbit**, the passes are numbered from 1 to 254 representing a full repeat cycle of the Jason-1 ground track. Ascending passes are odd numbered and descending passes are even numbered. After one repeat cycle of 254 passes, Jason-1 revisits the same ground-track within a margin of ± 1 km. That means that every location along the Jason-1 ground-track is measured every approximately 9.9 days.

On the **geodetic orbit** (from May, 2012), the passes are numbered from 1 to 280 (i.e. sub-cycle of 10.9 days).

1.4.1.3. Reference Ellipsoid

The **Reference Ellipsoid** is the first-order definition of the non-spherical shape of the Earth as an ellipsoid of revolution with equatorial radius of 6378.1363 kilometers and a flattening coefficient of 1/298.257 (same reference ellipsoid as used by the T/P missions).

1.4.2. Correction Conventions

All environmental and instrument corrections are computed so that they should be added to the quantity which they correct. That is, a correction is applied to a measured value by

$$\text{Corrected Quantity} = \text{Measured Value} + \text{Correction}$$

This means that a correction to the altimeter range for an effect that lengthens the apparent signal path (e.g., wet troposphere correction) is computed as a negative number. Adding this negative number to the uncorrected (measured) range reduces the range from its original value toward the correct value. Example: Corrected Range = Measured Range + Range Correction.

1.4.3. Time Convention

For Jason-1 products release “GDR-E”, measurement time tags are UTC and referenced to **January 1, 2000 00:00:00.00**. Note that for Jason-1 products before release “GDR-E”, measurement time tags were UTC and referenced to **January 1, 1958 00:00:00.00**, sometimes abbreviated UTC58.

A UTC leap second can occur on June 30 or December 31 of any year. The leap second is a sixty-first second introduced in the last minute of the day. Thus the UTC values (minutes:seconds) appear as: 59:58 ; 59:59 ; 59:60 ; 00:00 ; 00:01.

1.4.4. Unit Convention

All distances and distance corrections are reported in tenths of millimeters (10^{-1} mm).

1.4.5. Flagging and Editing

In general, flagging consists of three parts: instrument flags (on/off), telemetry flags (preliminary flagging and editing) and data quality flags (geophysical processing flags).

Instrument flags provide information about the state of the various instruments on the satellite.

Telemetry flags are first based on instrument modes and checking of telemetry data quality. Only severely corrupted data are not processed (i.e. data that cannot be correctly read on ground). Flag setting is designed to get a maximum amount of data into the “Sensor Data Records” (part of the SGDR data sets). Science data are processed only when the altimeter is in tracking mode.

Quality flags are determined from various statistical checks on the residuals after smoothing or fitting through the data themselves. These flags are set if gaps in the data are detected, or residuals have exceeded predetermined thresholds, or if the gradients of the data exceed predetermined thresholds.



2. Jason-1 Mission Overview

2.1. Background

Jason-1 is jointly conducted by the French Space Agency, "Centre National d'Etudes Spatiales" (CNES), and the United States' National Aeronautics and Space Administration (NASA) for studying the global circulation from space. The mission used the technique of satellite altimetry to make precise and accurate observations of sea level for several years. Jason-1 was launched on 7 December 2001 and was decommissioned on 21 June 2013.

2.2. Jason-1 Mission

Jason-1 was a follow-on mission to the highly successful TOPEX/POSEIDON (T/P) mission. The main goal of this mission was to measure the sea surface topography at least at the same performance level of T/P. This provided an extended continuous time series of high-accuracy measurements of the ocean topography from which scientists can determine the general circulation of the ocean and understand its role in the Earth's climate. In addition to the primary Jason-1 IGDR and GDR data products provided with a 2-3 and 30 day latency, respectively, Jason-1 also supported the preparation of operational ocean services by providing a non-validated near-real-time (3 hour latency) Jason-1 data product, the Operational Sensor Data Record (OSDR). Jason-1 was the first in a twenty-year series of satellites to take over from T/P, marking the start of operational satellite altimetry.

The Jason-1 mission supports new research programs such as the Climate Variability and Predictability program (CLIVAR) and the Global Ocean Data Assimilation Experiment (GODAE).

2.3. Jason-1 Requirements

The major elements of the mission include a satellite carrying an altimetric system for measuring the height of the satellite above the sea surface; a precision orbit determination system for referring the altimetric measurements to geodetic coordinates; a data analysis and distribution system for processing the satellite data, verifying their accuracy, and making them available to the scientific community; and a Principal Investigator program for scientific studies based on the satellite observations.

The Jason-1 mission was designed in a way that allows an optimum continuation of the T/P scientific mission. This means that the error budget and orbit characteristics (repeat period, inclination, altitude) of Jason-1 were identical to those of T/P. To ensure that science and mission goals were accomplished by the Jason-1 mission, the following requirements were established.

2.3.1. Accuracy of Sea-level Measurements

Requirements for the Jason-1 (I)GDR are derived directly from the post-launch T/P error budget, with the Jason-1 system required to be at least as good as the T/P system. Each measurement of sea level shall have an accuracy of ± 4.2 cm for the GDR products and 5.2 cm for the IGDR (1 standard deviation) over 1 second averages for typical oceanic conditions of 2 m significant wave height and 11dB sigma-naught. This error budget includes the altimeter noise, uncertainties in corrections of atmospheric path delays, sea-state related biases, and orbit error.

The following table provides a summary of error budget at the end of the verification phase.



| | IGDR (3 days) | | GDR (30 days) | |
|-------------------------------------------------------------------------------|---------------|----------------|---------------|----------------|
| | Spec | Performance | Spec | Performance |
| Altimeter noise (cm) (H1/3=2m, $\sigma=11$ dB) 1Hz | 1.7 | 1.6 | 1.7 | 1.6 |
| Sea State Bias (%H1/3) | 1.2% | 1% * | 1.2% | 1% * |
| Ionosphere (cm) | 0.5** | 0.5** | 0.5** | 0.5** |
| Dry Tropo (cm) | 0.7 | 0.7 | 0.7 | 0.7 |
| Wet Tropo (cm) | 1.2 | 1.2 | 1.2 | 1.2 |
| Corrected Range (RSS, cm) (H1/3=2m, $\sigma=11$ dB) 1Hz | 3.3 | 3 | 3.3 | 3 |
| Orbit (radial component) (cm) | 4 | 2.5 | 2.5 | 1.5 |
| Corrected Sea Surface Height (RSS,cm) (H1/3=2m, $\sigma=11$ dB) 1 Hz | 5.2 | 3.9 | 4.2 | 3.3 |
| Wave Height H1/3 (m or %H1/3, whichever is greater) | 0.5 or 10% | 0.4 *** or 10% | 0.5 or 10% | 0.4 *** or 10% |
| Wind Speed (m/s) | 1.7 | 1.5 *** | 1.7 | 1.5 *** |

- * improvement studies in progress
- ** after filtering over 100 km
- *** after bias calibration

Table 2 : Summary of error budget at the end of the verification phase

2.3.2. Sampling Strategy

Sea level shall be measured along a fixed grid of sub satellite tracks such that it is possible to investigate and minimize the spatial and temporal aliases of surface geostrophic currents and to minimize the influence of the geoid on measurements of the time-varying topography.

2.3.3. Tidal Aliases

Sea level shall be measured such that tidal signals are not aliased into semiannual, annual, or zero frequencies (which influences the calculation of the permanent circulation) or frequencies close to these.

2.3.4. Duration and coverage

Sea level shall be measured for a minimum of three years, with the potential to extend this period for an additional two years.



The Jason-1 satellite shall overfly the reference T/P ground tracks. The grid of sub satellite tracks shall extend in latitude at least as far south as the southern limit of the Drake Passage (62 deg) and the sub satellite tracks that comprise the grid will cross at sufficiently large angles that the two orthogonal components of surface slope can be determined with comparable accuracy.

3.2.5. Data Reduction and Distribution

A system to process and distribute data to the Principal Investigators shall be tested, documented, and in operation at the time of launch. A minimum of 95% of the oceanic data that could be acquired by the spacecraft shall be acquired with no systematic gaps, processed and made available for scientific investigations. The intent is to collect and process all data continuously. Small amounts of data could be lost during adjustments of the satellite's orbit, during tests of the altimeter's performance, and during various other such events.

2.4. Satellite Description

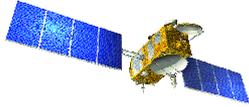
The 500 kg satellite consists of a multi-mission PROTEUS platform and a Jason-1 specific payload module. The platform provides all housekeeping functions including propulsion, electrical power, command and data handling, telecommunications, and attitude control. The payload module provides mechanical, electrical, thermal, and dynamical support to the Jason-1 instruments.

The Jason-1 payload (see Figure 2) included the following components:

- **An Altimeter (Poseidon-2)**, provided by CNES - the main mission instrument
- **A Microwave Radiometer (JMR)**, provided by NASA - to correct the altimeter measurement for atmospheric range delays induced by water vapor
- **The radio positioning DORIS system**, provided by CNES - for precision orbit determination using dedicated ground stations
- **A Laser Reflector Array (LRA)**, provided by NASA - to calibrate the orbit determination system
- **A Turbo Rogue Space Receiver (TRSR)**, provided by NASA - to provide supplementary positioning data to DORIS in support of the POD function and to enhance and/or improve gravity field models



Figure 2 : Main components of the Jason-1 satellite



2.4.1. Satellite Characteristics

The main features of the Jason-1 satellite are summed up in the following table.

| | |
|-----------------|---------------------------------|
| Satellite mass | 500 kg |
| Satellite power | 450 W |
| Platform mass | 270 kg |
| Platform power | 300 W |
| Payload mass | 120 kg |
| Payload power | 147 W |
| Altimeter mass | 55 kg |
| Altimeter power | 78 W |
| Launch Vehicle | Dual Delta II |
| Launch Site | Vandenberg Air Force Base (AFB) |

Table 3 : Main features of the Jason-1 satellite

2.4.2. Sensors

The science and mission goals are carried out with a satellite carrying five science instruments, three from CNES and two from NASA.

2.4.2.1. Poseidon-2 Altimeter

The Poseidon-2 Dual-frequency Ku/C band Solid State Radar altimeter, operating at 13.575 GHz (Ku band) and 5.3 GHz (C band), is the primary sensor for the Jason-1 mission. The measurements made at the two frequencies are combined to obtain measurements of the altimeter range, wind speed, significant wave height, and the ionospheric correction. The Poseidon-2 package consists of dual redundant altimeter units each of which has low mass and low power consumption.

2.4.2.2. Jason-1 Microwave Radiometer (JMR)

The JMR measures the sea surface microwave brightness temperatures at three frequencies (18.7 GHz, 23.8 GHz and 34.0 GHz) to provide the total water vapor content in the troposphere along the altimeter beam. The 23.8 GHz channel is the primary channel for water-vapor measurement and is a redundant channel on the JMR. The 18.7 GHz channel provides a correction for wind-induced effects in the sea surface background emissions, and the 34.0 GHz channel provides a correction for cloud liquid water. The measurements are combined to obtain the error in the satellite range measurements caused by pulse delay due to the water vapor.

2.4.2.3. DORIS System

The Doppler Orbitography and Radiopositioning by Satellite (DORIS) Precise Orbit Determination (POD) system uses a two-channel, two-frequency (401.25 MHz and 2036.25 MHz) Doppler receiver on the satellite to observe the tracking signals from a network of approximately 50 ground transmitting beacons. It provides all-weather global tracking of the satellite for POD and a correction for the influence of the ionosphere on both the Doppler signal and altimeter signals. The DORIS on-board package includes the receiver itself, the ultra-stable oscillator, and an omnidirectional antenna located on the nadir face of the satellite. It includes a dual beacon receiving capability and an on-board real time function (Détermination Immédiate d'Orbite par Doris Embarqué, or DIODE) to compute the orbit ephemeris with an accuracy of 30 cm (1 standard deviation).

2.4.2.4. Laser Reflector Array

The LRA is placed on the nadir face of the satellite and reflects signals from a network of 10 to 15 satellite laser tracking stations. It supports the Jason-1 Calibration and Validation function for POD.



2.4.2.5. Turbo Rogue Space Receiver

The TRSR is an advanced codeless sixteen-channel Global Positioning System (GPS) receiver developed by the Jet Propulsion Laboratory (JPL). The on-board package is comprised of dual redundant TRSR units and choke ring antennae. The GPS data are intended to provide supplementary positioning data in support of the POD function and/or to improve gravity field models.

2.4.3. Orbit

2.4.3.1. Repetitive Orbit (Dec. 2001 - May 2012)

The Jason-1 satellite will fly the same ground-track as the original T/P with a 254 pass, 10-day exact repeat cycle. The Jason-1 and T/P satellites were phased approximately 70 seconds apart during the calibration phase.

On August 15, 2002 (T/P cycle 365 pass 111) the T/P satellite began its “drift phase” by moving to a new orbit in preparation for the Tandem Mission. The drift phase lasted until September 16, 2002 ending with cycle 368, pass 171. Data for T/P cycle 368, pass 172 and later are on the final exact-repeat tandem mission ground track, which is interleaved with the original Jason-1 ground track, providing improved temporal and spatial coverage. Orbital characteristics and the equator crossing longitudes for the original ground track of Jason-1 are given below. Figure 3 is a plot of the ground track on a world map.

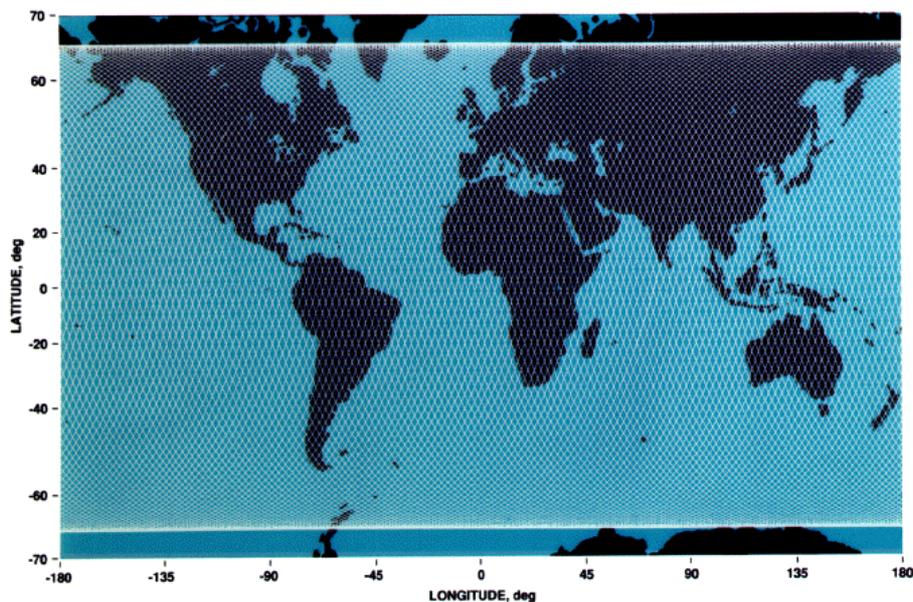
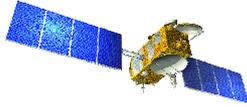


Figure 3 : T/P and Jason-1 ground track coverage every 10 days

A similar tandem mission between Jason-1 and Jason-2 became available after the launch of Jason-2 on June 20, 2008. In this case, Jason-1 and Jason-2 satellites were phased approximately 56 seconds apart on the same ground track during the Jason-2 calibration phase. Jason-1 started a drift phase on January 26, 2009 (Jason-1 repeat cycle 260) until it reached the interleaving tandem mission ground track, previously flown by T/P, on February 10, 2009 (Jason-1 repeat cycle 262).



The mean classical orbit elements are given in the table below:

| Orbit element | Value |
|------------------------------------------|-------------|
| Semi-major axis | 7,714.43 km |
| Eccentricity | 0.000095 |
| Inclination | 66.04 deg |
| Argument of periapsis | 90.0 deg |
| Inertial longitude of the ascending node | 116.56 deg |
| Mean anomaly | 253.13 deg |

Table 4 : Mean classical orbit elements

The orbit auxiliary data are given in the table below:

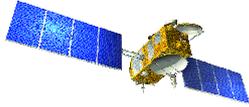
| Auxiliary Data | Values |
|-----------------------------------------|-------------------------|
| Reference (Equatorial) altitude | 1,336 km |
| Nodal period | 6,745.72 sec |
| Repeat period | 9.9156 days |
| Number of revolutions within a cycle | 127 |
| Equatorial cross-track separation | 315 km |
| Ground track control band | ± 1 km (at equator) |
| Acute angle at Equator crossings | 39.5 deg |
| Longitude of Equator crossing of pass 1 | 99.9249 deg |
| Inertial nodal rate | -2.08 deg/day |
| Orbital speed | 7.2 km/s |
| Ground track speed | 5.8 km/s |

Table 5 : Orbit auxiliary data

This orbit overflies two verifications sites. The prime CNES verification site is located at Cape Senetosa on the island of Corsica ($8^{\circ} 48' E$, $41^{\circ} 34' N$) (ascending pass 85) (*Bonnefond et al.*, 2002). The prime NASA verification site is located on the Harvest oil platform near Pt. Conception, California ($239^{\circ} 19' E$, $34^{\circ} 28' N$) (ascending pass 43) (*Haines et al.*, 2002).

A satellite orbit slowly decays due to air drag, and has long-period variability because of the inhomogeneous gravity field of Earth, solar radiation pressure, and smaller forces. Periodic maneuvers are required to keep the satellite in its orbit. The frequency of maneuvers depends primarily on the solar flux as it affects the Earth's atmosphere, and there are expected to be one maneuver (or series of maneuvers) every 40 to 200 days.

Each orbit maintenance maneuver is performed as two thrusts on pass 254 cycle N and 1 cycle N+1 (see plot below). Orbit computation is optimised to minimize the orbit error during such periods. Science data are taken during orbit maintenance maneuvers and will be distributed (an orbit state flag is provided in the products).



2.4.3.1.1. Equator Crossing Longitudes (in order of Pass Number)

| Pass | Longitude |
|------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|
| 1 | 99.9249 | 44 | 30.4744 | 87 | 321.0274 | 130 | 251.5783 | 173 | 182.1282 | 216 | 112.6813 |
| 2 | 265.7517 | 45 | 196.3012 | 88 | 126.8541 | 131 | 57.4042 | 174 | 347.9550 | 217 | 278.5075 |
| 3 | 71.5776 | 46 | 2.1280 | 89 | 292.6810 | 132 | 223.2310 | 175 | 153.7829 | 218 | 84.3343 |
| 4 | 237.4044 | 47 | 167.9557 | 90 | 98.5078 | 133 | 29.0576 | 176 | 319.6096 | 219 | 250.1600 |
| 5 | 43.2305 | 48 | 333.7825 | 91 | 264.3336 | 134 | 194.8843 | 177 | 125.4369 | 220 | 55.9867 |
| 6 | 209.0573 | 49 | 139.6102 | 92 | 70.1603 | 135 | 0.7117 | 178 | 291.2636 | 221 | 221.8129 |
| 7 | 14.8844 | 50 | 305.4370 | 93 | 235.9862 | 136 | 166.5385 | 179 | 97.0902 | 222 | 27.6397 |
| 8 | 180.7112 | 51 | 111.2637 | 94 | 41.8130 | 137 | 332.3659 | 180 | 262.9170 | 223 | 193.4666 |
| 9 | 346.5387 | 52 | 277.0905 | 95 | 207.6395 | 138 | 138.1927 | 181 | 68.7430 | 224 | 359.2934 |
| 10 | 152.3655 | 53 | 82.9167 | 96 | 13.4663 | 139 | 304.0198 | 182 | 234.5697 | 225 | 165.1212 |
| 11 | 318.1928 | 54 | 248.7435 | 97 | 179.2937 | 140 | 109.8466 | 183 | 40.3959 | 226 | 330.9479 |
| 12 | 124.0196 | 55 | 54.5694 | 98 | 345.1205 | 141 | 275.6727 | 184 | 206.2227 | 227 | 136.7755 |
| 13 | 289.8463 | 56 | 220.3962 | 99 | 150.9484 | 142 | 81.4995 | 185 | 12.0499 | 228 | 302.6023 |
| 14 | 95.6731 | 57 | 26.2229 | 100 | 316.7751 | 143 | 247.3252 | 186 | 177.8767 | 229 | 108.4290 |
| 15 | 261.4989 | 58 | 192.0497 | 101 | 122.6022 | 144 | 53.1520 | 187 | 343.7042 | 230 | 274.2558 |
| 16 | 67.3256 | 59 | 357.8771 | 102 | 288.4290 | 145 | 218.9782 | 188 | 149.5309 | 231 | 80.0819 |
| 17 | 233.1515 | 60 | 163.7039 | 103 | 94.2556 | 146 | 24.8050 | 189 | 315.3582 | 232 | 245.9087 |
| 18 | 38.9783 | 61 | 329.5313 | 104 | 260.0823 | 147 | 190.6320 | 190 | 121.1850 | 233 | 51.7347 |
| 19 | 204.8049 | 62 | 135.3580 | 105 | 65.9083 | 148 | 356.4588 | 191 | 287.0117 | 234 | 217.5614 |
| 20 | 10.6317 | 63 | 301.1851 | 106 | 231.7351 | 149 | 162.2866 | 192 | 92.8384 | 235 | 23.3883 |
| 21 | 176.4592 | 64 | 107.0119 | 107 | 37.5614 | 150 | 328.1133 | 193 | 258.6642 | 236 | 189.2150 |
| 22 | 342.2860 | 65 | 272.8379 | 108 | 203.3881 | 151 | 133.9409 | 194 | 64.4909 | 237 | 355.0425 |
| 23 | 148.1139 | 66 | 78.6647 | 109 | 9.2154 | 152 | 299.7676 | 195 | 230.3169 | 238 | 160.8693 |
| 24 | 313.9406 | 67 | 244.4904 | 110 | 175.0422 | 153 | 105.5943 | 196 | 36.1437 | 239 | 326.6966 |
| 25 | 119.7676 | 68 | 50.3172 | 111 | 340.8697 | 154 | 271.4211 | 197 | 201.9704 | 240 | 132.5234 |
| 26 | 285.5944 | 69 | 216.1435 | 112 | 146.6964 | 155 | 77.2471 | 198 | 7.7971 | 241 | 298.3504 |
| 27 | 91.4209 | 70 | 21.9702 | 113 | 312.5237 | 156 | 243.0739 | 199 | 173.6248 | 242 | 104.1772 |
| 28 | 257.2477 | 71 | 187.7974 | 114 | 118.3505 | 157 | 48.8999 | 200 | 339.4515 | 243 | 270.0031 |
| 29 | 63.0736 | 72 | 353.6242 | 115 | 284.1770 | 158 | 214.7267 | 201 | 145.2793 | 244 | 75.8299 |
| 30 | 228.9004 | 73 | 159.4520 | 116 | 90.0038 | 159 | 20.5536 | 202 | 311.1061 | 245 | 241.6556 |
| 31 | 34.7268 | 74 | 325.2788 | 117 | 255.8295 | 160 | 186.3804 | 203 | 116.9330 | 246 | 47.4824 |
| 32 | 200.5535 | 75 | 131.1062 | 118 | 61.6562 | 161 | 352.2079 | 204 | 282.7598 | 247 | 213.3088 |
| 33 | 6.3809 | 76 | 296.9330 | 119 | 227.4823 | 162 | 158.0346 | 205 | 88.5862 | 248 | 19.1355 |
| 34 | 172.2076 | 77 | 102.7596 | 120 | 33.3090 | 163 | 323.8620 | 206 | 254.4130 | 249 | 184.9628 |
| 35 | 338.0351 | 78 | 268.5864 | 121 | 199.1358 | 164 | 129.6887 | 207 | 60.2389 | 250 | 350.7896 |
| 36 | 143.8619 | 79 | 74.4124 | 122 | 4.9626 | 165 | 295.5157 | 208 | 226.0657 | 251 | 156.6174 |
| 37 | 309.6891 | 80 | 240.2392 | 123 | 170.7903 | 166 | 101.3425 | 209 | 31.8922 | 252 | 322.4442 |
| 38 | 115.5159 | 81 | 46.0652 | 124 | 336.6170 | 167 | 267.1683 | 210 | 197.7189 | 253 | 128.2715 |
| 39 | 281.3423 | 82 | 211.8920 | 125 | 142.4448 | 168 | 72.9951 | 211 | 3.5463 | 254 | 294.0983 |
| 40 | 87.1690 | 83 | 17.7190 | 126 | 308.2716 | 169 | 238.8209 | 212 | 169.3731 | | |
| 41 | 252.9947 | 84 | 183.5458 | 127 | 114.0984 | 170 | 44.6477 | 213 | 335.2005 | | |
| 42 | 58.8215 | 85 | 349.3733 | 128 | 279.9252 | 171 | 210.4741 | 214 | 141.0273 | | |
| 43 | 224.6476 | 86 | 155.2000 | 129 | 85.7515 | 172 | 16.3009 | 215 | 306.8545 | | |

Table 6 : Equator Crossing Longitudes (in order of Pass Number)



2.4.3.1.2. Equator Crossing Longitudes (in order of Longitude)

| Pass | Longitude |
|------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|------|-----------|
| 135 | 0.7117 | 118 | 61.6562 | 101 | 122.6022 | 84 | 183.5458 | 67 | 244.4904 | 50 | 305.4370 |
| 46 | 2.1280 | 29 | 63.0736 | 12 | 124.0196 | 249 | 184.9628 | 232 | 245.9087 | 215 | 306.8545 |
| 211 | 3.5463 | 194 | 64.4909 | 177 | 125.4369 | 160 | 186.3804 | 143 | 247.3252 | 126 | 308.2716 |
| 122 | 4.9626 | 105 | 65.9083 | 88 | 126.8541 | 71 | 187.7974 | 54 | 248.7435 | 37 | 309.6891 |
| 33 | 6.3809 | 16 | 67.3256 | 253 | 128.2715 | 236 | 189.2150 | 219 | 250.1600 | 202 | 311.1061 |
| 198 | 7.7971 | 181 | 68.7430 | 164 | 129.6887 | 147 | 190.6320 | 130 | 251.5783 | 113 | 312.5237 |
| 109 | 9.2154 | 92 | 70.1603 | 75 | 131.1062 | 58 | 192.0497 | 41 | 252.9947 | 24 | 313.9406 |
| 20 | 10.6317 | 3 | 71.5776 | 240 | 132.5234 | 223 | 193.4666 | 206 | 254.4130 | 189 | 315.3582 |
| 185 | 12.0499 | 168 | 72.9951 | 151 | 133.9409 | 134 | 194.8843 | 117 | 255.8295 | 100 | 316.7751 |
| 96 | 13.4663 | 79 | 74.4124 | 62 | 135.3580 | 45 | 196.3012 | 28 | 257.2477 | 11 | 318.1928 |
| 7 | 14.8844 | 244 | 75.8299 | 227 | 136.7755 | 210 | 197.7189 | 193 | 258.6642 | 176 | 319.6096 |
| 172 | 16.3009 | 155 | 77.2471 | 138 | 138.1927 | 121 | 199.1358 | 104 | 260.0823 | 87 | 321.0274 |
| 83 | 17.7190 | 66 | 78.6647 | 49 | 139.6102 | 32 | 200.5535 | 15 | 261.4989 | 252 | 322.4442 |
| 248 | 19.1355 | 231 | 80.0819 | 214 | 141.0273 | 197 | 201.9704 | 180 | 262.9170 | 163 | 323.8620 |
| 159 | 20.5536 | 142 | 81.4995 | 125 | 142.4448 | 108 | 203.3881 | 91 | 264.3336 | 74 | 325.2788 |
| 70 | 21.9702 | 53 | 82.9167 | 36 | 143.8619 | 19 | 204.8049 | 2 | 265.7517 | 239 | 326.6966 |
| 235 | 23.3883 | 218 | 84.3343 | 201 | 145.2793 | 184 | 206.2227 | 167 | 267.1683 | 150 | 328.1133 |
| 146 | 24.8050 | 129 | 85.7515 | 112 | 146.6964 | 95 | 207.6395 | 78 | 268.5864 | 61 | 329.5313 |
| 57 | 26.2229 | 40 | 87.1690 | 23 | 148.1139 | 6 | 209.0573 | 243 | 270.0031 | 226 | 330.9479 |
| 222 | 27.6397 | 205 | 88.5862 | 188 | 149.5309 | 171 | 210.4741 | 154 | 271.4211 | 137 | 332.3659 |
| 133 | 29.0576 | 116 | 90.0038 | 99 | 150.9484 | 82 | 211.8920 | 65 | 272.8379 | 48 | 333.7825 |
| 44 | 30.4744 | 27 | 91.4209 | 10 | 152.3655 | 247 | 213.3088 | 230 | 274.2558 | 213 | 335.2005 |
| 209 | 31.8922 | 192 | 92.8384 | 175 | 153.7829 | 158 | 214.7267 | 141 | 275.6727 | 124 | 336.6170 |
| 120 | 33.3090 | 103 | 94.2556 | 86 | 155.2000 | 69 | 216.1435 | 52 | 277.0905 | 35 | 338.0351 |
| 31 | 34.7268 | 14 | 95.6731 | 251 | 156.6174 | 234 | 217.5614 | 217 | 278.5075 | 200 | 339.4515 |
| 196 | 36.1437 | 179 | 97.0902 | 162 | 158.0346 | 145 | 218.9782 | 128 | 279.9252 | 111 | 340.8697 |
| 107 | 37.5614 | 90 | 98.5078 | 73 | 159.4520 | 56 | 220.3962 | 39 | 281.3423 | 22 | 342.2860 |
| 18 | 38.9783 | 1 | 99.9249 | 238 | 160.8693 | 221 | 221.8129 | 204 | 282.7598 | 187 | 343.7042 |
| 183 | 40.3959 | 166 | 101.3425 | 149 | 162.2866 | 132 | 223.2310 | 115 | 284.1770 | 98 | 345.1205 |
| 94 | 41.8130 | 77 | 102.7596 | 60 | 163.7039 | 43 | 224.6476 | 26 | 285.5944 | 9 | 346.5387 |
| 5 | 43.2305 | 242 | 104.1772 | 225 | 165.1212 | 208 | 226.0657 | 191 | 287.0117 | 174 | 347.9550 |
| 170 | 44.6477 | 153 | 105.5943 | 136 | 166.5385 | 119 | 227.4823 | 102 | 288.4290 | 85 | 349.3733 |
| 81 | 46.0652 | 64 | 107.0119 | 47 | 167.9557 | 30 | 228.9004 | 13 | 289.8463 | 250 | 350.7896 |
| 246 | 47.4824 | 229 | 108.4290 | 212 | 169.3731 | 195 | 230.3196 | 178 | 291.2636 | 161 | 352.2079 |
| 157 | 48.9999 | 140 | 109.8466 | 123 | 170.7903 | 106 | 231.7351 | 89 | 292.6810 | 72 | 353.6242 |
| 68 | 50.3172 | 51 | 111.2637 | 34 | 172.2076 | 17 | 233.1515 | 254 | 294.0983 | 237 | 355.0425 |
| 233 | 51.7347 | 216 | 112.6813 | 199 | 173.6248 | 182 | 234.5697 | 165 | 295.5157 | 148 | 356.4588 |
| 144 | 53.1520 | 127 | 114.0984 | 110 | 175.0422 | 93 | 235.9862 | 76 | 296.9330 | 59 | 357.8771 |
| 55 | 54.5694 | 38 | 115.5159 | 21 | 176.4592 | 4 | 237.4044 | 241 | 298.3504 | 224 | 359.2934 |
| 220 | 55.9867 | 203 | 116.9330 | 186 | 177.8767 | 169 | 238.8209 | 152 | 299.7676 | | |
| 131 | 57.4042 | 114 | 118.3505 | 97 | 179.2937 | 80 | 240.2392 | 63 | 301.1851 | | |
| 42 | 58.8215 | 25 | 119.7676 | 8 | 180.7112 | 245 | 241.6556 | 228 | 302.6023 | | |
| 207 | 60.2389 | 190 | 121.1850 | 173 | 182.1282 | 156 | 243.0739 | 139 | 304.0198 | | |

Table 7 : Equator Crossing Longitudes (in order of Longitude)



2.4.3.1. Geodetic Orbit (From May 2012 until End Of Life)

Below are the characteristics of the geodetic orbit which was maintained, as before, within +/- 1km control box at the Equator.

The mean classical orbit elements are given in the table below.

| Orbit element | Value |
|-----------------|----------------|
| Semi-major axis | 7,702.437 km |
| Eccentricity | 1.3 to 2.8 E-4 |
| Inclination | 66.042 deg |

Table 8 : Mean classical orbit elements

The orbit auxiliary data are given in the table below.

| Auxiliary Data | Values |
|--------------------------------------|------------------------------------------------------|
| Reference (Equatorial) altitude | 1,324 km |
| Nodal period | 6,730 sec (1h52'10'') |
| Repeat period | 406 days (sub-cycles 3.9, 10.9, 47.5, 179.5 days) |
| Number of revolutions within a cycle | 140 revolutions in a sub-cycle of 10.9 days |

Table 9 : Orbit auxiliary data

2.4.4. The Jason-1 Project Phases

The satellite mission has two phases:

- The first phase, the calibration/validation phase, began when the satellite reached the operational orbit and the satellite and sensor systems were functioning normally. This phase continued until the data received from the sensors were satisfactorily calibrated and verified. The phase began shortly after launch. A preliminary calibration/validation workshop was held June 2002. A second calibration/validation workshop was held October 2002, where Jason-1 to TOPEX/POSEIDON cross validation was extensively discussed: recommendations were issued both on TOPEX/POSEIDON and Jason-1 science processing algorithms.
- The second phase, the operational phase, began April 2003 when all necessary algorithm and processing changes were implemented to have Jason-1 performances at the same level as TOPEX/POSEIDON.

2.5. Data Processing and Distribution

Processing centers, called respectively CNES SSALTO and NASA JPL POCC, include functions such as science data processing, data verification and precision orbit determination.

Processed data are placed in National archives for further distribution to the scientific community. There are three levels of processed data:

1. Telemetry data (raw data),
2. Sensor Data Records (engineering units),
3. Geophysical Data Records (geophysical units).

Geophysical data records are sent as they become available to AVISO and PO.DAAC for processing, archiving, managing, and distribution to PIs and the wider scientific community.



The operational sensor data record (OSDR), which was a non-validated product that used orbits computed by the on-board DORIS Navigator (DIODE) and did not perform ground retracking of the altimeter waveforms, were available with a latency of 3-5 hours. The interim geophysical data record (IGDR), which was also a non-validated product but that used a preliminary orbit and applied ground retracking, were available by pass with a latency of 2-3 days. The geophysical data record (GDR), which is a fully validated product that uses a precise orbit and applies ground retracking, were available operationally by repeat cycle with a latency of 30 days.

2.5.1. Access to NRT data

As the Jason-1 mission is no longer operational, the OSDRs are not available in version “e”. This section has been removed.

2.5.2. Access to off-line data

As the Jason-1 mission is no longer operational, only the GDR is available as version “e” products. These GDRs are available on PODAAC and AVISO ftp servers. Both of these archival facilities also provide a variety of auxiliary files used to produce the O/I/GDR dataset.

Data dissemination services from NASA and CNES agencies are described below.

Jason-1 data continue to be available in the original Jason-1 format, and are now also available in the same NetCDF format as the Jason-2 products. Jason-1 products are available in both formats for versions “a”, “b”, and “c” on the AVISO and PODAAC ftp servers. Jason-1 GDR version “e” products are only available in NetCDF format on the AVISO and PODAAC ftp servers.

2.5.3. Documentation

This Jason-1 User’s Handbook document describes only the native product. A description of the O/I/GDR product format and contents is provided in the CNES document “Jason-1 User Products”. All documents are available through the data dissemination services.

2.6. CNES data distribution

Users have access to Jason-1 public data through a dedicated AVISO+ ftp server with an anonymous account. Offline IGDR and GDR products are available on the following server:

IP address: avisoftp.cnes.fr

User account: anonymous

Home directory : /AVISO/pub/jason-1

With the following ftp server directory tree:

| | | |
|---------------|---|-------------------------------------------------------------------------------------------------|
| documentation | → | product handbook, reading tools, ... |
| gdr_e | → | directory containing GDR version ‘e’ native products (with a sub directory for each cycle) |
| sgdr_e | → | directory containing S-GDR version ‘e’ sensor products (with a sub directory for each cycle) |
| ssha_gdr_e | → | directory containing GDR version ‘e’ reduced products (with a sub directory for each cycle) |

Jason-1 products in their original binary format and in version “a”, “b” or “c” can be retrieved through AVISO CNES Data Center at the following address: <https://aviso-data-center.cnes.fr/>.



For any questions on Jason-1 data dissemination on AVISO+ servers please contact:

aviso@altimetry.fr

2.7. NASA data distribution

Users have access to Jason-1 public data through a dedicated PODAAC ftp server with an anonymous account.

The PODAAC ftp server for Jason-1 products is:

`podaac.jpl.nasa.gov`

Login anonymous

Jason-1 GDR-E products in NetCDF format are available on the following directories:

`/allData/jason1/L2/gdr_netcdf_e` → directory containing GDR native products
(with a sub directory for each cycle)

`/allData/jason1/L2/gdr_ssh_netcdf_e` → directory containing GDR reduced
products (with a sub directory for each cycle)

`/allData/jason1/L2/sgdr_netcdf_e` → directory containing SGDR products (with a sub
directory for each cycle)

Please note that from cycle 500, Jason-1 GDR-E products (on its geodetic orbit) are available on the following directories:

`/allData/jason1/L2/gdr_netcdf_e_geodetic` → directory containing GDR native products
(with a sub directory for each cycle)

`/allData/jason1/L2/gdr_ssh_netcdf_e_geodetic` → directory containing GDR reduced
products (with a sub directory for each cycle)

`/allData/jason1/L2/sgdr_netcdf_e_geodetic` → directory containing SGDR products (with a
sub directory for each cycle)

For any questions on Jason-1 data dissemination on PODAAC servers please contact:

podaac@podaac.jpl.nasa.gov.

3. Product evolution history

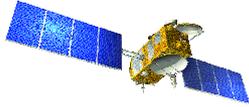
3.1. Models and Standards History

3.1.1. GDR Products Version “a”, “b” and “c”

Please refer to previous versions of “Jason-1 products handbook” for more details about old versions of Jason-1 products.

3.1.2. GDR Products Version “e”

Note: The Jason-1 mission has not been reprocessed in version “d”.



3.1.2.1. Models and Standards

The current product version is altimetric standard version “e”.

The table below summarizes the models and standards that are adopted in this version of the Jason-1 GDRs. Section 3.1 provides more details on some of these models.

| Model | Product Version “e” |
|----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Orbit | - DORIS and GPS tracking data for GDRs (laser ranging used for validation only) |
| Altimeter Retracking | <p><u>“Ocean MLE4” retracking</u> MLE4 fit from 2nd order Brown analytical model : MLE4 simultaneously retrieves the 4 parameters that can be inverted from the altimeter waveforms:</p> <ul style="list-style-type: none"> - Epoch (tracker range offset) ⇒ altimeter range - Composite Sigma ⇒ SWH - Amplitude ⇒ Sigma0 - Square of mispointing angle <p><u>“Ice-1” retracking</u> Geometrical analysis of the altimeter waveforms, which retrieves the following parameters:</p> <ul style="list-style-type: none"> - Epoch (tracker range offset) ⇒ altimeter range - Amplitude ⇒ Sigma0 |
| Altimeter Instrument Corrections | One set consistent with MLE4 retracking. Improved internal path delay correction (Repeat Orbit: +60.7 and -3.2 mm in Ku- and C-band, Geodetic Orbit: +63.9 and +0.0 mm in Ku- and C-band compared to version “c”, see below) |
| Jason-1 Microwave Radiometer (JMR) Parameters | Using JMR calibration performed at NASA/JPL in 2014 and 2015 |
| Dry Troposphere Range Correction | From ECMWF (MARS 3D and ERA-Interim) atmospheric pressures and model for S1 and S2 atmospheric tides |
| Wet Troposphere Range Correction from Model | From ECMWF model (MARS 3D and ERA-Interim) |
| Ionosphere correction | - Based on Global Ionosphere TEC Maps from JPL - Computed from updated range and SSB. |
| Sea State Bias | SSB tables (Ku and C band) derived from Jason-1 altimeter data with version “e” geophysical models and orbit |
| Mean Sea Surface | MSS_CNES-CLS11 |
| Mean Dynamic Topography | MDT_CNES-CLS13 |
| Geoid | EGM2008 |
| Bathymetry Model | DTM2000.1 |
| Added ECMWF Re-Analysis (ERA) meteorological model | The ERA model provides alternative values for the model dry troposphere delay, model wet troposphere delay, inverse barometer correction, high frequency response to the atmosphere, and model wind speeds. The ERA alternatives are indicated with “_era” in the parameter names. The corresponding values without “_era” in the parameter names are from the operational ECMWF product. |
| Inverse Barometer Correction | Computed from ECMWF atmospheric (MARS 3D and ERA-Interim) pressure after removing S1 and S2 atmospheric tides |
| Non-tidal High-frequency Dealiasing Correction | Mog2D High Resolution ocean model on GDRs. Barotropic ocean model forced by ECMWF (MARS 3D and ERA-interim) winds and pressures; S1 and S2 atmospheric tides have been removed from the pressure field. |
| Tide Solution 1 | GOT4.10c |
| Tide Solution 2 | FES2014 + using GOT4.8ac load tides |
| Equilibrium long-period ocean tide model | from <i>Cartwright and Taylor</i> [1971] and <i>Cartwright and Edden</i> [1973] tidal potential |



| Model | Product Version “e” |
|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Non-equilibrium long-period ocean tide model | Mm, Mf, Mtm, Msqm, Sa, Ssa from FES2014 |
| Load Tide solution 1 | GOT4.10c load tide (includes a tidal geocenter correction compared to GOT4.10; Desai & Ray 2014; Ray 2013) |
| Load Tide solution 2 | GOT4.8ac load tide (includes a tidal geocenter correction compared to GOT4.8; Desai & Ray 2014; Ray 2013) |
| Solid Earth Tide Model | From <i>Cartwright and Taylor</i> [1971] tidal potential |
| Pole Tide Model | Equilibrium model using mean pole of $X + iY = 0.042 + i0.293$ arcseconds. |
| Wind Speed from Model | ECMWF model (MARS 3D and ERA-interim) |
| Altimeter Wind Speed Model | Derived from Jason-1 data |
| Rain Flag | Derived from comparisons to thresholds of the radiometer-derived integrated liquid water content and of the difference between the measured and the expected Ku-band backscatter coefficient |
| Ice Flag | Derived from comparison of the model wet tropospheric correction to a dual-frequency wet tropospheric correction retrieved from radiometer brightness temperatures, with a default value issued from a climatology table |

Table 10 : Version “e” models and standards

3.1.2.2. Sea Surface Height Bias

In the GDR-E product version, corrections of +60.7 and -3.2 mm have been added to Ku- and C-band repeat orbit altimeter ranges reported in the version “c” products (e.g., version “e” Ku-band ranges are longer than those from version “c” by 60.7 mm) to take into account the correct internal path delay value. Similarly, corrections of +63.9 and 0.0 mm have been added to Ku- and C-band geodetic orbit altimeter ranges reported in the version “c” products. See section 5.2 for more details about altimetric ranges.

3.1.2.3. Time-tag Bias

A long period crossover point residual analysis on version “c” products showed a datation bias of about 400 μ s, leading to a sea surface height anomaly (SSHA) error varying with latitudes. The origin of the error has been precisely determined and its value is determined by the following formula:

$$\text{Time tag bias} = RA \times PRI - 2 \times \text{alt}/c$$

Where :

- Time tag bias = datation bias
- RA = ambiguity order (=18)
- PRI = Pulse Repetition Frequency (=1/2058.513239 or 1/ 2083.87600938 on geodetic orbit)
- alt = satellite altitude
- c = celerity

This datation bias is corrected in the Jason-1 GDR-E product version. As a result, measurement time tags on GDR-E products are slightly different to those from version “c”.

3.1.3. Orbit models

Jason-1 orbit standards for the version “e” GDRs are based on version “e” precise orbit determination (POD) standards. Its main features are summarized below. Note that version “c” GDRs used version “c” and “d” POD standards as shown in the Table below. Version “c” POD standards were applied to cycles X-Y of the version “c” GDRs, while version “d” POD standards were applied to cycles A-B of the version “c” GDRs.

| | GDR-C | GDR-D |
|--|-------|-------|
|--|-------|-------|



| | GDR-C | GDR-D |
|-----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Gravity model | <p>EIGEN-GL04S-ANNUAL (2008)</p> <p>Non-tidal TVG : drifts in degree 2,3,4 zonal coeffs, C21/S21; Annual and semi-annual terms up to deg/ord 50</p> <p>Solid Earth Tides: from IERS2003 conventions</p> <p>Ocean tides FES2004</p> <p>Atmospheric gravity : 6hr NCEP pressure fields + tides from Horwitz-Cowley model</p> <p>Pole Tide: solid Earth and ocean from IERS2003 conventions</p> <p>Third bodies: Sun, Moon, Venus, Mars and Jupiter</p> | <p>EIGEN-GRGS_RL02bis_MEAN-FIELD (2011)</p> <p>Non-tidal TVG : Annual, Semi-annual, and drifts up to deg/ord 50</p> <p>Solid Earth Tides: from IERS2003 conventions</p> <p>Ocean tides FES2004</p> <p>Atmospheric gravity : 6hr NCEP pressure fields + tides from Biancale-Bode model</p> <p>Pole Tide: solid Earth and ocean from IERS2010 conventions</p> <p>Third bodies: Sun, Moon, Venus, Mars and Jupiter</p> |
| Surface forces | <p>Radiation Pressure model: thermo-optical coefficient from pre-launch box and wing model, with smoothed Earth shadow model</p> <p>Earth Radiation : Knocke-Ries albedo and IR satellite model</p> <p>Atmospheric density model : DTM-94 for Jason, and MSIS-86 for Envisat</p> | <p>Unchanged</p> |
| Estimated dynamical parameters | <p>Drag coefficient every 2 or 3 revolutions</p> <p>Along-track and Cross-track 1/rev per day or every 12 hours</p> | <p>Unchanged</p> |
| Satellite reference | <p>Mass and Center of gravity: Post-Launch values + variations generated by Control Center</p> <p>Attitude Model :</p> <p>For Jason-1 and Jason-2 : Quaternions and Solar Panel orientation from control center, completed by nominal yaw steering law when necessary</p> <p>For Envisat: nominal attitude law</p> | <p>Unchanged</p> |
| Displacement of reference points | <p>Earth tides: IERS2003 conventions</p> <p>Ocean Loading: FES2004</p> <p>Pole tide : solid earth pole tides</p> <p>(Pole tide and ocean loading applied to both SLR stations and DORIS beacons)</p> <p>Reference GPS constellation: JPL solution at IGS (orbits and clocks) , consistent with IGS05; before GPS week 1400, JPL solution has been aligned with IGS05; IGS00 clocks are unchanged</p> | <p>Earth tides: IERS2003 conventions</p> <p>Ocean Loading: FES2004</p> <p>Pole tide : solid earth pole tides</p> <p>(Pole tide and ocean loading applied to both SLR stations and DORIS beacons)</p> <p>Reference GPS constellation: JPL solution at IGS (orbits and clocks) - fully consistent with IGS08</p> |
| Terrestrial Reference | <p>Extended ITRF2005 (SLRF/LPOD2005, DPOD2005, IGS05)</p> | <p>Extended ITRF2008 (SLRF/ITRF2008, DPOD2008, IGS08)</p> |



| | GDR-C | GDR-D |
|-----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Frame | | |
| Earth orientation | Consistent with IERS2003 conventions and ITRF2005 | Consistent with IERS2010 conventions and ITRF2008 |
| Propagations delays | SLR Troposphere correction: Mendes-Pavlis SLR range correction: constant 5.0 cm range correction for Envisat, elevation dependent range correction for Jason DORIS Troposphere correction : CNET model GPS PCO/PCV (Emitter and Receiver) consistent with constellation orbits and clocks (IGS05 Antex after GPS week 1400) GPS : Phase wind-up correction | SLR Troposphere correction: Mendes-Pavlis SLR range correction: constant 5.0 cm range correction for Envisat, elevation dependent range correction for Jason DORIS Troposphere correction : GPT/GMF model GPS PCO/PCV (Emitter and Receiver) consistent with constellation orbits and clocks (IGS08 Antex) GPS : Phase wind-up correction |
| Estimated measurement parameters | DORIS: 1 Frequency bias per pass, 1 troposphere zenith bias per pass SLR : bias per arc solved for a few stations, bias per pass for a few stations GPS: Floating ambiguity per pass, receiver clock adjusted per epoch | Unchanged |
| Tracking Data corrections | Jason-1 Doris data: South Atlantic Anomaly Model (JM Lemoine et al.) applied before and after DORIS instrument change DORIS datation bias for Envisat and Jason aligned with SLR before and after instrument change | Unchanged |
| Doris Weight | 1.5 mm/s (1.5 cm over 10 sec) For Jason-1 , Doris Weight is reduced by a factor 10 before Doris instrument change | Unchanged |
| SLR Weight | 10 cm | 15 cm |
| GPS Weight | 10 cm (phase) / 10 m (code) | 2 cm (phase) / 2 m (code) |

Table 11. GDR-C/GDR-D orbit standard

| | GDR-D | GDR-E |
|----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Gravity model | EIGEN-GRGS_RL02bis_MEAN-FIELD Non-tidal TVG: annual, semi-annual, and drift up to deg/ord 50 Solid Earth tides: from IERS2003 conventions Ocean tides: FES2004 | EIGEN-GRGS.RL03-v2.MEAN-FIELD Non-tidal TVG: one annual, one semi-annual, one bias and one drift terms for each year up to deg/ord 80; C21/S21 modeled according to IERS2010 conventions; C31/S31 estimation by arc if necessary Unchanged Ocean tides: FES2012 |



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| | | |
|-----------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | <p>Atmospheric gravity: 6hr NCEP pressure fields (20x20) + tides from Biancale-Bode model</p> <p>Pole tide: solid Earth and ocean from IERS2010 conventions</p> <p>Third bodies: Sun, Moon, Venus, Mars and Jupiter</p> | <p>Atmospheric gravity: 6hr NCEP pressure fields (70x70) + tides from Biancale-Bode model</p> <p>Unchanged</p> <p>Unchanged</p> |
| Surface forces | <p>Radiation pressure model: thermo-optical coefficient from pre-launch box and wing model, with smoothed Earth shadow model</p> <p>Earth radiation: Knocke-Ries albedo and IR satellite model</p> <p>Atmospheric density model: DTM-94 for Jason satellites, and MSIS-86 for other satellites</p> | <p>Radiation pressure model: calibrated semi-empirical solar radiation pressure model</p> <p>Unchanged</p> <p>Atmospheric density model: DTM-13 for Jason satellites, HY-2A, and MSIS-86 for other satellites</p> |
| Estimated dynamical parameters | <p>Drag coefficient every 2 or 3 revolutions</p> <p>Along-track and cross-track 1/rev per day or every 12 hours</p> | Improved stochastic solutions |
| Satellite reference | <p>Mass and center of gravity: post-launch values + variations generated by Control Center</p> <p>Attitude model:</p> <p>For Jason satellites: quaternions and solar panel orientation from control center, completed by nominal yaw steering law when necessary</p> <p>Other satellites: nominal attitude law</p> | Unchanged |
| Displacement of reference points | <p>Earth tides: IERS2003 conventions</p> <p>Ocean loading: FES2004</p> <p>Pole tide: solid earth pole tides</p> <p>Reference GPS constellation: JPL solution at IGS (orbits and clocks) - fully consistent with IGS08</p> | <p>Unchanged</p> <p>Ocean loading: FES2012</p> <p>Pole tide: solid earth pole tides and ocean pole tides (Desai, 2002)</p> <p>S1-S2 atmospheric pressure loading, implementation of Ray & Ponte (2003) by van Dam</p> <p>Reference GPS constellation: JPL solution in "native" format (orbits and clocks), referenced to the CoM of the solid Earth/Ocean system - fully consistent with IGS08</p> |



| | | |
|-----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| Geocenter variations | None | Tidal: ocean loading and S1-S2 atmospheric pressure loading Non-tidal: seasonal model from J. Ries |
| Terrestrial Reference Frame | Extended ITRF2008 (SLRF/ITRF2008, DPOD2008, IGS08) | Unchanged |
| Earth orientation | Consistent with IERS2010 conventions and ITRF2008 | Unchanged |
| Propagations delays | SLR troposphere correction: Mendes-Pavlis SLR range correction: constant 5.0 cm range correction for Envisat, elevation dependent range correction for Jason DORIS troposphere correction: GPT/GMF model GPS PCO/PCV (emitter and receiver) consistent with constellation orbits and clocks (IGS08 ANTEX) GPS: phase wind-up correction | Unchanged Unchanged Unchanged DORIS beacons phase center correction Unchanged Unchanged |
| Estimated measurement parameters | DORIS: one frequency bias per pass, one troposphere zenith bias per pass SLR: bias per arc solved for a few stations, bias per pass for a few stations GPS: floating ambiguity per pass, receiver clock adjusted per epoch | Unchanged Reference used to evaluate orbit precision and stability Unchanged |
| Tracking Data corrections | Jason-1 Doris data: South Atlantic Anomaly model (J.-M. Lemoine et al.) applied before and after DORIS instrument change DORIS time-tagging bias for Envisat and Jason aligned with SLR before and after instrument change | Jason-1 Doris data: updated South Atlantic Anomaly model (J.-M. Lemoine et al.) applied before and after DORIS instrument change Unchanged |
| Doris Weight | 1.5 mm/s (1.5 cm over 10 sec) | For Jason-1, SAA DORIS beacons weight is divided by 10 before DORIS instrument change |
| SLR Weight | 15 cm | Reference used to evaluate orbit precision and stability |
| GPS Weight | 2 cm (phase) / 2 m (code) | Unchanged |

Table 12. GDR-D/GDR-E orbit standard



3.1.4. Mean Sea Surface

The MSS_CNES-CLS11 model is computed from 16 years of satellite altimetry data from a variety of missions. Its main characteristics are the following:

| | |
|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Name | MSS_CNES-CLS11 |
| Reference ellipsoid | T/P |
| Referencing time period | 1993-2012 (~20 years) |
| Data covering period | 1993-late 2008 (16 years) |
| Spatial coverage | Global (80°S to 84°N) - Oceanwide where altimetric data are available. EIGEN_GRAVE_5C geoid elsewhere and on continents. |
| Spatial resolution | Regular grid with a 1/30° (2 minutes) spacing (i.e. ~4 km) |
| Grid | 10801 points in longitude / 4921 points in latitude |
| MSS determination technique | Local least square collocation method on a 6' grid where altimetric data in a 200-km radius are selected. Estimation on a 2' grid based on SSH-geoid values (remove/restore technique to recover the full signal). The inverse method uses local anisotropic covariance functions that witness the MSS wavelength content. |
| Estimation error level | The Optimal Interpolation method provides a calibrated formal error. Calibrated error of the Mean Sea Surface is provided in the products. |
| Altimetric dataset | T/P 10 years mean profile (first orbit), T/P tandem 3 years profile ERS-2 8 years mean profile, 1 year ERS-1 (geodetic phase) GFO, 7 years mean profile Jason-1, 7 years mean profile Envisat, 7 years mean profile |

Table 13 : MSS_CNES-CLS11 model characteristics

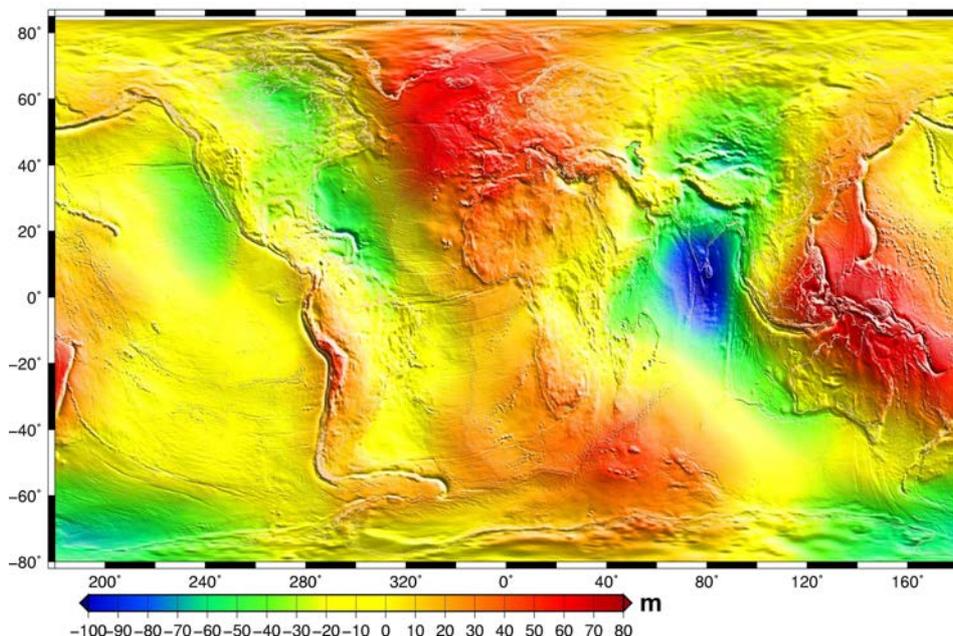


Figure 4 : Mean Sea Surface MSS_CNES-CLS11

Refer to <http://www.aviso.altimetry.fr/en/data/products/auxiliary-products/mss/index.html> for more details on this model.



3.1.5. Mean Dynamic Topography

The MDT_CNES-CLS013 model is computed from satellite altimetry data from a variety of missions. Its main characteristics are the following:

| | |
|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Name | MDT_CNES-CLS13 |
| Referencing time period | 1993-2012 (~20 years) |
| Domain | Global (78.25°S to 81.25°N) |
| Spatial resolution | Regular grid with a 1/4° (15 minutes) spacing (i.e. ~30 km) |
| Grid | 720 points in longitudes / 320 points in latitude |
| MDT determination technique | Reference the altimeter Sea Level Anomalies (SLA), computed relative to a 20 year (1993-2012) mean profile, in order to obtain absolute measurements of the ocean dynamic topography. Based on : - 2 years of GOCE data, - 7 years of GRACE data, - 20 years of altimetry and in-situ data (hydrologic and drifters data). |
| Estimation error level | Error of the Mean Dynamic Topography is provided in the products. |

Table 14 : MDT_CNES-CLS13 model characteristics

This sea surface height (mean sea surface height above geoid) corresponds to mean geostrophic currents and its changes.

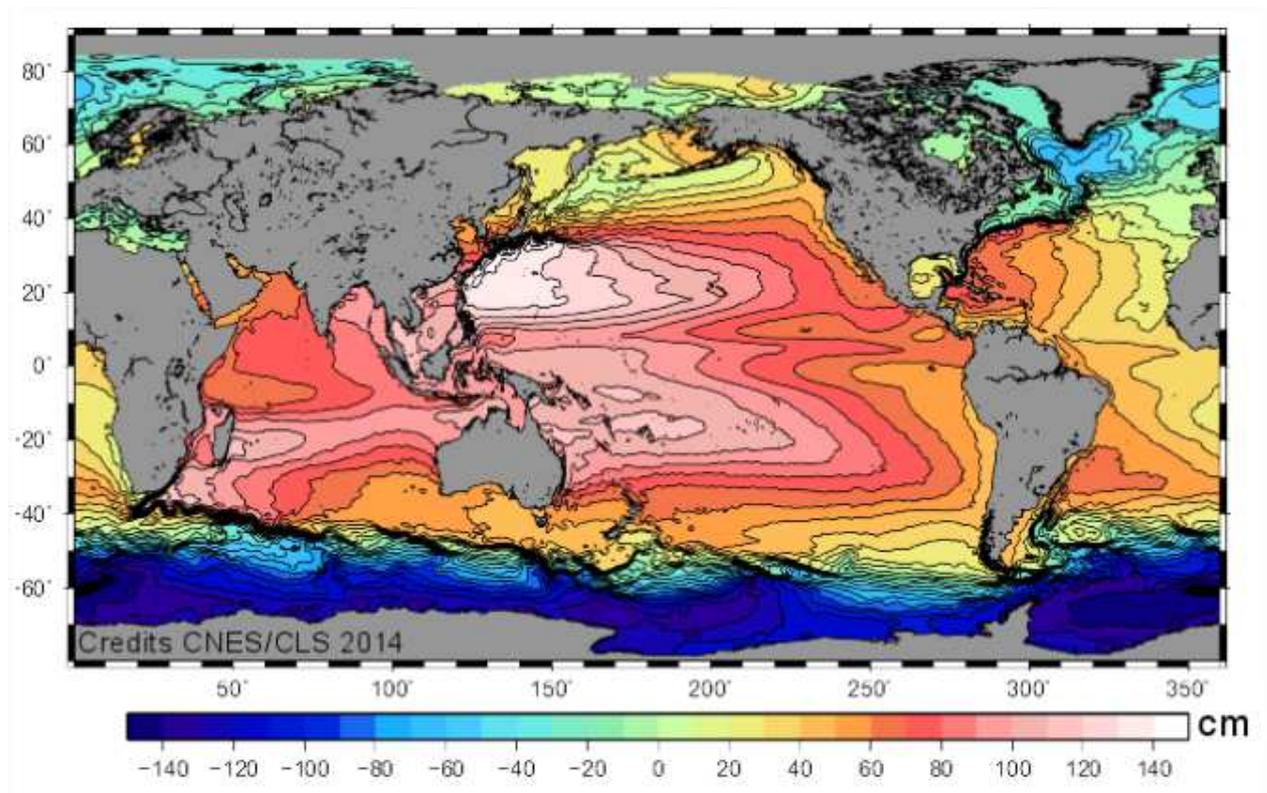


Figure 5 : Mean Dynamic Topography MDT_CNES-CLS13

Refer to <http://www.aviso.altimetry.fr/en/data/products/auxiliary-products/mdt-copy-1/mdt-description.html> for more details on this model.



3.1.6. Geoid

Jason-1 GDRs (version “e”) use the EGM2008 geopotential to compute the geoid.

The official Earth Gravitational Model EGM2008 has been publicly released by the U.S. National Geospatial-Intelligence Agency (NGA) EGM Development Team. This gravitational model is complete to spherical harmonic degree and order 2159, and contains additional coefficients extending to degree 2190 and order 2159.

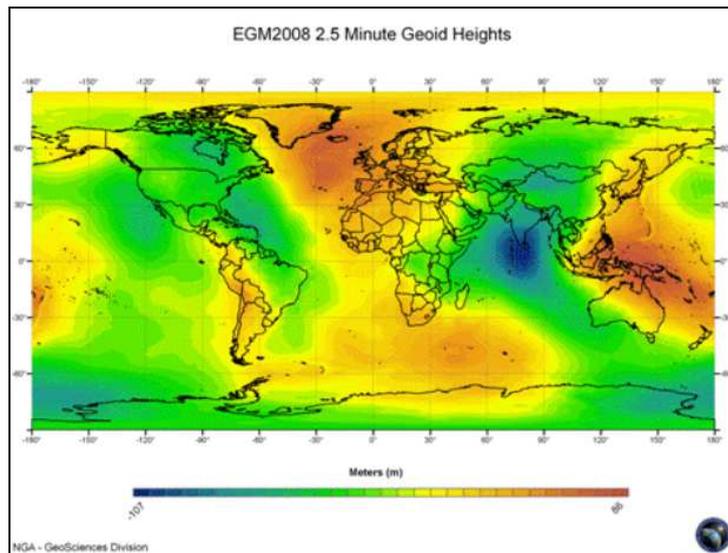


Figure 6 : EGM2008 geoid

More information on EGM96 can be found at <http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/index.html>

3.1.7. Bathymetry

The value of this parameter is determined from the DTM2000.1 model from N. Pavlis and J. Saleh [personal communication, 2000] of the Raytheon ITSS/Goddard Space Flight Center. The model is provided globally with a 2' resolution. The heritage of DTM2000.1 goes back to the OSUJAN98 database [Pavlis and Rapp, 1990] and the JGP95E database [Chapter 2 of Lemoine et al., 1998]. The bathymetric information in DTM2000.1 (originating from Smith and Sandwell's [1994] global sea floor topography) has significant differences with the ETOPO5 bathymetric model. The mean and standard deviation of these differences is 10 m and 270 m, respectively.

3.1.8. Ocean Tides

The two geocentric tide values provided on the Jason-1 GDR, `ocean_tide_sol1` and `ocean_tide_sol2`, are computed with diurnal and semidiurnal ocean and load tide values predicted by the GOT4.10c (Ray, 2013) and FES2014 (Carrere et al., 2015) models, respectively.

Both geocentric ocean tide fields (`ocean_tide_sol1` and `ocean_tide_sol2`) also include the load tides from the respective models (`load_tide_sol1` and `load_tide_sol2`), and the equilibrium long-period ocean tide (`ocean_tide_equil`).

By essence, both models include the S1 and S2 oceanic response to atmospheric pressure.

The GOT4.10c model includes the M4 ocean tide. The FES2014 model includes 9 non-linear waves : M4, M6, M8, MN4, MS4, MKS2, N4, S4, MSf.

Note that the load tide fields (`load_tide_sol1` and `load_tide_sol2`) include the load tides corresponding to GOT4.10c and FES2014 models respectively; the FES2014 loading tide is based on the GOT4.8ac loading tide. The GOT4.8ac and the GOT4.10c loading tide both include the tidal geocenter correction (Desai and Ray. 2014).



Moreover note that both models ocean tidal atlas have been extrapolated along the shores in order to avoid any altimeter missing measurement due to an undefined tidal solution: GOT4.10c model was extrapolated on 1 pixel of 0.5° , and FES2014 on 10 pixels of $1/16^\circ$. Both models are interpolated to provide the geocentric ocean and load tides at the location of the altimeter measurement, and an interpolation quality flag is provided on the GDRs to indicate the quality of this interpolation (see `interp_flag_ocean_tide_sol1` and `interp_flag_ocean_tide_sol2`).

The `ocean_tide_non_equil` field contains the difference between the dynamic (non-equilibrium) long-period ocean tide computed from FES2014 model and the equilibrium long-period ocean tide field (`ocean_tide_equil`): this parameter is computed as a correction to the parameter `ocean_tide_equil`.

3.1.8.1. GOT4.10c

The GOT4.10c model is a recent version of the GOT models developed by R. Ray (Ray, 2013).

The solution consists of independent near-global estimates of 10 constituents (K1, K2, M2, M4, N2, O1, P1, Q1, S1, S2). An a priori model was used that consisted of the hydrodynamic model FES 2004 [Lyard et al. 2006], and several other local hydrodynamic models.

GOT4.10c is identical to 4.7, 4.8, and 4.9, except that only data from Jason-1 and Jason-2 were used, with no T/P data. Otherwise, all other processing and data were kept unchanged. Note that the dry-tropospheric correction for the Jason satellites never had the S2 air-tide error that the original T/P data had. The “c” in the model name indicates that the model includes the tidal geocenter correction (Desai and Ray, 2014).

3.1.8.2. FES2014

FES2014 is the most recent version of the FES (Finite Element Solution) tide model developed in 2014-2015 (Carrere et al., 2015). It is an improved version of FES2012, which was a fully revised version of the global hydrodynamic tide solutions initiated by the works of Christian (Le Provost et al., 1995) in the early nineties. The new model has been developed, implemented and validated by LEGOS, NOVELTIS and CLS teams, within a CNES funded project.

FES2014 takes advantage of longer altimeter time series and better altimetry standards, improved modeling and data assimilation techniques, and more accurate ocean bathymetry. Special efforts have been dedicated to address the major non-linear tides issue and to the determination of accurate tidal currents.

FES2014 is based on the resolution of the tidal barotropic equations (T-UGO model) in a spectral configuration. A new original high resolution global bathymetry was built including several regional databases, and a new global finite element grid (~3 millions of nodes) is used leading to a twice more accurate 'free' solution (independent of in situ and remote-sensing data) than the FES2012 version.

Then the accuracy of this 'free' solution was improved by assimilating long-term altimetry data (Topex-Poseidon/Jason-1/Jason-2, TPN/J1N, ERS-1/ ERS-2/ ENVISAT) and tidal gauges, through an improved representer assimilation method.

The final FES2014 solution shows strong improvement compared to FES2012, GOT4.10 and DTU10 models, particularly in coastal and shelf regions, and also in some deep ocean regions and in large parts of the Arctic Ocean.

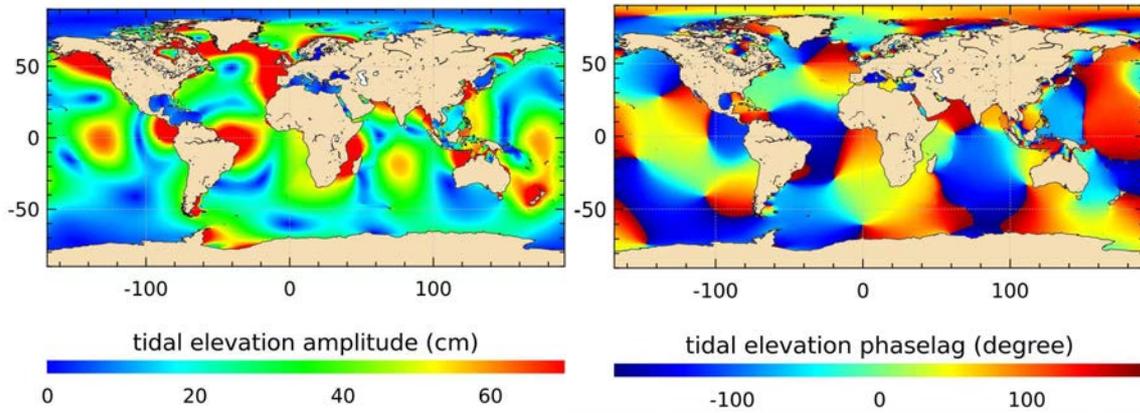
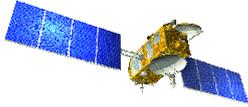


Figure 7. Amplitude and phase of the FES2014 model.



3.1.9. Data Editing Criteria

The following editing criteria are a recommended guideline for finding good records from the GDR to calculate the sea level anomaly from the Ku band range. The user should review these criteria before using them and may wish to modify them.

First, check the following conditions to retain only ocean data and remove any bad, missing, or flagged data:

| Parameter | Value | Meaning |
|--------------|-------|-----------------------------------|
| surface_type | 0 | Open oceans or semi-enclosed seas |
| ice_flag | 0 | No ice |

Table 15 : Recommended editing criteria

Then, filter the data as follows to retain only the most valid data:

| Parameter | Validity conditions |
|------------------------|-----------------------------------------------|
| range_numval_ku | $10 \leq x$ |
| range_rms_ku | $0 \leq x \text{ (mm)} \leq 200$ |
| altitude - range_ku | $-130\ 000 \leq x \text{ (mm)} \leq 100\ 000$ |
| model_dry_tropo_corr | $-2\ 500 \leq x \text{ (mm)} \leq -1\ 900$ |
| rad_wet_tropo_corr | $-500 \leq x \text{ (mm)} \leq -1$ |
| iono_corr_alt_ku | $-400 \leq x \text{ (mm)} \leq 40$ |
| sea_state_bias_ku | $-500 \leq x \text{ (mm)} \leq 0$ |
| ocean_tide_sol1 | $-5\ 000 \leq x \text{ (mm)} \leq 5\ 000$ |
| solid_earth_tide | $-1\ 000 \leq x \text{ (mm)} \leq 1\ 000$ |
| pole_tide | $-150 \leq x \text{ (mm)} \leq 150$ |
| swh_ku | $0 \leq x \text{ (mm)} \leq 11\ 000$ |
| sig0_ku | $7 \leq x \text{ (dB)} \leq 30$ |
| wind_speed_alt | $-0 \leq x \text{ (m/s)} \leq 30$ |
| sig0_rms_ku | $x \text{ (dB)} \leq 1$ |
| sig0_numval_ku | $10 < x$ |
| off_nadir_angle_ku_wvf | $-0.2 < \text{(deg}^2) < 0.5$ |

Table 16 : Recommended filtering criteria

To restrict studies to deep water, apply a limit, e.g., water depth of 1000m or greater, using the bathymetry parameter (ocean depth in meters.)

Please note that for GDR version “e”, a surface_type_globcover has been added to the product. It is a flag with 7 states computed from a mask built with MODIS and GlobCover data (0 = Open ocean; 1 = Land; 2 = Continental waters; 3 = Aquatic vegetation; 4 = Continental ice and snow; 5 = Floating ice; 6 = Salted basin). Users should use these more refined area definition for specific studies in non-open ocean (recommended filtering criteria above may not apply as they are recommended for ocean only).



4. Using the GDR data

4.1. Overview

This section will give the reader a guide to the use of the Jason-1 GDR data. Remember that this is research data. While this handbook tries to be correct and complete, nothing can replace the information to be gained at conferences and other meetings of those using these data. Information is also available on the PODAAC and AVISO+ web servers. The reader must proceed with caution and at his or her own risk. Please direct questions and comments to the contacts given on the last page of this handbook.

The instruments on Jason-1 make direct observations of the following quantities: altimeter range, ocean significant wave height, ocean radar backscatter cross-section (a measure of wind speed), ionospheric electron content in the nadir direction, tropospheric water content, and position relative to the GPS satellite constellation. The GPS data and ground-based DORIS measurements of the satellite location and speeds are used in the precision orbit determination (POD) of the satellite, and ground-based laser station measurements are used to validate the POD solution. All of these measurements are useful in themselves, but they are made primarily to derive the sea surface height with the highest possible accuracy. Such a computation also needs external data (not collected aboard Jason-1), e.g., atmospheric pressure, etc. In addition, instrument health and calibration data are collected onboard and used to make corrections to the main measurements and to monitor the instrument stability on the long term.

The GDR contains all relevant corrections needed to calculate the sea surface height. For the other "geophysical variables" in the product: ocean significant wave height, tropospheric water content, ionospheric electron content (derived by a simple formula), and wind speed, the needed instrument and atmospheric corrections have already been applied.

The following sections explain the rationale for how the corrections should be applied.

4.2. Typical computation from altimetry data

In this section references are made to specific GDR parameters by name using the name of the variable as described in the NetCDF data sets. For example, `surface_type` is a flag parameter indicating, among other things, whether or not the data point is over open ocean.

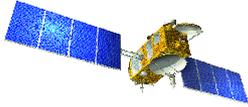
WARNING

Default values are given to data when computed values are not available (See section 6.1.2.4) so users should screen parameters to avoid using those with default values. Also users should check flag values. The related flags are given in the description of each variable (See section 6.1.2.4) although some discussion of flags appears in this section.

4.2.1. Corrected Altimeter Range

The main data of the GDR are the altimeter ranges. The GDR provides ranges measured at Ku-band (`range_ku`) and C-band (`range_c`). The Ku-band range is used for most applications. The reported ranges are corrected for instrument effects, including the instrument corrections (`net_instr_corr_ku` and `net_instr_corr_c`). Instrument corrections are separately reported for each of the Ku and C band ranges (`net_instr_corr_ku` and `net_instr_corr_c`). The reported ranges must be corrected for path delay in the atmosphere through which the radar pulse passes and the nature of the reflecting sea surface. Recall all range corrections are defined so they should be ADDED to the range. The corrected range is given by:

$$\begin{aligned} \text{Corrected Range} = & \text{Range} + \text{Wet Troposphere Correction} \\ & + \text{Dry Troposphere Correction} \\ & + \text{Ionosphere Correction} \end{aligned}$$



+ Sea State Bias Correction

Wet Troposphere Correction :

Use JMR correction (rad_wet_tropo_corr).

Dry Troposphere Correction :

Use model correction (model_dry_tropo_corr or model_dry_tropo_corr_era).

Ionosphere Correction :

Use altimeter ionosphere correction (iono_corr_alt_ku to correct range_ku).

IMPORTANT: See Section 4.2.4 "Smoothing the Ionosphere Correction".

Sea State Bias Correction : Use sea state bias correction (sea_state_bias_ku to correct range_ku).

NOTE: The ionosphere and sea state bias corrections are both frequency dependent. Therefore Ku band corrections should only be applied to Ku band ranges, and C band corrections should only be applied to C band ranges. Section 4.8 explains how the C band ionosphere correction can be derived from the Ku band ionosphere correction (iono_corr_alt_ku), while the C band sea state bias correction is provided as sea_state_bias_c.

4.2.2. Sea Surface Height and Sea Level Anomaly

Sea surface height (SSH) is the height of the sea surface above the reference ellipsoid. It is calculated by subtracting the corrected range from the Altitude:

$$\text{Sea Surface Height} = \text{Altitude} - \text{Corrected Range}$$

The sea level anomaly (SLA), also referred to as Residual Sea Surface, is defined here as the sea surface height minus the mean sea surface and minus known geophysical effects, e.g., tidal and inverse barometer. It is given by:

$$\begin{aligned} \text{Sea Level Anomaly} = & \text{Sea Surface Height} - \text{Mean Sea Surface} \\ & - \text{Solid Earth Tide Height} \\ & - \text{Geocentric Ocean Tide Height} \\ & - \text{Pole Tide Height} \\ & - \text{Inverted Barometer Height Correction} \\ & - \text{HF Fluctuations of the Sea Surface Topography} \end{aligned}$$

The SLA contains information about:

- Real changes in ocean topography related to ocean currents
- Dynamic response to atmospheric pressure
- Differences between the tide model and observed tides
- Differences between the mean sea surface model and the true mean sea surface at the Jason-1 location
- Unmodeled or mismodeled measurement effects (skewness, sea state bias, altimeter errors, tropospheric corrections, ionospheric correction, etc.)
- Orbit errors

There is naturally also random measurement noise. Understanding the first four items as a function of space and time is the purpose of Jason-1.

Altitude : Orbit altitude (see parameter altitude)

Corrected Range : is defined above.



Tide effects (solid earth tide height, geocentric ocean tide height, pole tide height): See sections 4.2.2.1 and 5.9.

Inverted Barometer Height Correction : Use `inv_bar_corr` or `inv_bar_corr_era` (see also section 5.10).

HF Fluctuations of the Sea Surface Topography : Use `hf_fluctuations_corr` or `hf_fluctuations_corr_era` (see also section 5.10).

Mean Sea Surface : See sections 4.2.2.2 and 5.4.

4.2.2.1. Tide Effects

The total tide effect on the sea surface height is the sum of three values from the GDR:

$$\text{Tide Effect} = \text{Geocentric Ocean Tide} + \text{Solid Earth Tide} + \text{Pole Tide}$$

(See also section 5.9 and subsections)

Geocentric Ocean Tide :

The geocentric ocean tide provided on the GDR is actually the sum total of the ocean tide with respect to the ocean bottom, and the loading tide height of the ocean bottom.

$$\text{Geocentric Ocean Tide} = \text{Ocean Tide} + \text{Load Tide}$$

The GDR provides a choice of two geocentric ocean tide values, `ocean_tide_sol1` and `ocean_tide_sol2`. Each uses a different model for the sum total of the ocean tide and loading tide heights from the diurnal and semidiurnal tides, but both include an equilibrium representation of the long-period ocean tides at all periods except for the zero frequency (permanent tide) term. Note that the GDR also explicitly provides the loading tide height from each of the two models that are used to determine the two geocentric ocean tide values, `load_tide_sol1`, `load_tide_sol2`. The geocentric ocean tide values and loading tide values should not be used simultaneously, since the loading tide height would be modeled twice.

Solid Earth Tide :

Use `solid_earth_tide`

NOTE: Zero frequency (permanent tide) term also not included in this parameter.

Pole Tide :

Use `pole_tide`

The tide values all have the same sign/sense in that positive numbers indicate that the surface is farther from the center of the Earth.

4.2.2.2. Geophysical Surface - Mean Sea Surface or Geoid

The geophysical fields Geoid (geoid) - actually geoid undulation, but called simply geoid - and Mean Sea Surface (`mean_sea_surface`) are distances above the reference ellipsoid, as is the Sea Surface Height. These values are for the location indicated by latitude and longitude. If the values of these fields are needed at a different location within the current frame, along-track interpolation may be done using the high rate (20/second) range and altitude values.

As the geoid is derived from the mean sea surface, the latter is the better-known quantity. The residual surface with respect to the geoid is sometimes called the "dynamic topography" of the ocean surface.

See also discussions of mean sea surface and geoid in sections 5.3 and 5.4.



4.2.3. Mean Sea Surface and Adjustment of the Cross Track Gradient

In order to study sea level changes between two dates, it is necessary to difference sea surface heights from different cycles at the exact same latitude-longitude, so that the not well-known time-invariant geoid cancels out. However, the GDR samples are not given at the same latitude-longitude on different cycles. They are given approximately every 1 sec along the pass (about 6 km, the time difference and distance vary slightly with satellite height above the surface), and the satellite ground track is allowed to drift by ± 1 km. This introduces a problem: on different cycles the satellite will sample a different geoid profile. This effect is the so-called cross-track geoid gradient, and *Brenner et al.* [1990] estimated it at about 2 cm/km over most of the ocean, larger over continental slopes, reaching 20 cm/km at trenches. Even if the passes repeated exactly, one would have to interpolate along the pass (say, to a fixed set of latitudes) because a 3 km mismatch in along pass position would cause approximately a 6 cm difference in the geoid, which would mistakenly be interpreted as a change in oceanographic conditions.

Both problems are simultaneously solved if the quantity one interpolates along a given pass is the difference

Residual Height - Mean Sea Surface

Then the real geoid changes across the track are automatically accounted for (to the extent the MSS model is close to the true geoid) because the MSS is spatially interpolated to the actual satellite latitude-longitude in the GDR. The residual height term above is the residual sea surface height after applying all the tidal, atmospheric and ionospheric corrections, etc. Otherwise, those need to be interpolated separately.

One possible approach is to interpolate along track to a set of common points, a "reference" track. The reference could be:

- An actual pass with maximum data and/or minimum gaps, or
- A specially constructed fixed track (see below)

The procedure is the following:

- For each common point, find neighboring points in the pass of interest (POI).
- In the POI, interpolate along track to the common point, using longitude as the independent variable, for each quantity of interest - sea surface height (see above), mean sea surface, geoid, tides, etc.
- As stated above, the quantity to compare at each common point is :
$$\Delta\text{SSH} = \text{Interpolated POI SSH} - \text{Interpolated POI MSS}$$
- Other geophysical corrections must be applied to ΔSSH , depending on the type of investigation.

The geoid model in the GDR could substitute the MSS model, but its use will result in reduced accuracy in the interpolation because the resolution of the geoid undulation is lower than that of the MSS.

Desirable features of a fixed reference track include:

- Equal spacing of points (good for FFT)
- Independent variable = (point longitude - pass equator crossing longitude)
- Equator is a point (simplifies calculation)
- Point density similar to original data density

With these specifications, it is possible to make only two fixed tracks, one ascending and one descending, which will serve for all passes. The template pass is then shifted by the equator crossing longitude (global attribute of the product, see 6.2) of each pass. Recall that the equator longitude is from a predicted orbit (not updated during GDR processing). Improved accuracy can be obtained by interpolating in the latitude, longitude values. When one interpolates to the reference



track, it is good practice to check that the interpolated latitude from the data records used is close to the latitude on the reference track.

4.2.4. Smoothing Ionosphere Correction

The ionospheric (range) correction is expected to be negative, but positive values are allowed up to +40 mm to accommodate instrument noise effects. To reduce the noise, it is recommended to average over 100 km or more [Imel, 1994], which usually results in negative numbers.

In order to provide a reversible correction, no averaging is performed on the ionospheric correction provided on the GDR. The users may smooth the ionospheric correction and apply it as follows:

- Smooth `iono_corr_alt_ku` as desired. Care should be taken regarding flagged data, editing criteria, and in the case of data (land) gaps. Typical/maximum smoothing scales are 100-150 km (20-25 frames) for local times between 06 and 24 hours and 150-200 km (25-35 frames) for local times between 00 and 06 hours. The shorter (longer) smoothing time is also more appropriate during times of high (low) solar activity.
- Apply the smoothed ionospheric correction to sea surface height as shown earlier.

4.2.5. Total Electron Content from Ionosphere Correction

To calculate Ionospheric Total Electron Content, TEC, use the following formula:

$$\text{Ionospheric Total Electron Content} = -\frac{dR * f^2}{40.3}$$

Where :

- Ionospheric Total Electron Content is in electrons/m²
- `dR` = Ku band ionospheric range correction from the GDR in meters (`iono_corr_alt_ku`)
- `f` = frequency in Hz (13.575 GHz for the Ku band)

Note that the TEC could then be converted to a C band ionosphere range correction using the same formula above, but with the C band frequency of 5.3 GHz.

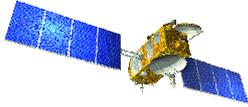
4.2.6. Range Compression

Each 1Hz frame of the Poseidon-2 Ku and C band range measurements (`range_ku` and `range_c`) are derived from the linear regression of the respective valid 20 Hz range measurements (`range_20hz_ku` and `range_20hz_c`).

An iterative outlier detection scheme is adopted in this linear regression and the resulting 20 Hz measurements are identified by setting the corresponding bit in the parameters (`range_used_20hz_ku` and `range_used_20hz_c`) to 1. Measurements not considered as outliers have the parameters (`range_used_20hz_ku` and `range_used_20hz_c`) set to 0.

The number of valid 20 Hz measurements that are used to derive each of the 1 Hz measurements is provided on the GDRs (`range_numval_ku` and `range_numval_c`), as are the root-mean-square of the differences between the valid 20 Hz measurements and the derived 1 Hz measurement (`range_rms_ku` and `range_rms_c`).

Specialized applications, such as over land, ice, lakes or rivers, may require that the users perform their own compression algorithm on the 20 Hz measurements.



5. Altimetric data

This section presents a short discussion of the main quantities on the GDR.

An excellent overview of the theoretical and practical effects of radar altimetry is the “Satellite Altimetry” Chapter by *Chelton et al* [2001].

5.1. Precise Orbits

CNES has the responsibility for producing the orbit ephemerides for the Jason-1 data products. The Jason-1 IGDRs provided a preliminary orbit that has radial accuracies better than 4 cm (RMS), while the GDRs provide a precise orbit that has radial accuracies better than 2.5 cm (RMS). DORIS tracking data were used to compute the preliminary orbit, while DORIS and GPS tracking data are used to compute the precise orbit (laser ranging data are used for validation).

5.2. Altimeter Range

An altimeter operates by sending out a short pulse of radiation and measuring the time required for the pulse to return from the sea surface. This measurement, called the altimeter range, gives the distance between the instrument and the sea surface, provided that the velocity of the propagation of the pulse and the precise arrival time are known. The dual frequency altimeter on Jason-1 performs range measurements at the Ku and C band frequencies (see `range_ku` and `range_c`), enabling measurements of the range and the total electron content (see discussion below on ionosphere). While both range measurements are provided on the GDR (see `range_ku` and `range_c`), the Ku band range measurement has much higher accuracy than the C band measurement.

The range reported on the Jason-1 GDR has already been corrected for a variety of calibration and instrument effects, including calibration errors, pointing angle errors, center of gravity motion, and terms related to the altimeter acceleration such as Doppler shift and oscillator drift. The sum total of these corrections also appears on the GDR for each of the Ku and C band ranges (see `net_instr_corr_ku` and `net_instr_corr_c`).

A change has to be noted when Jason-1 moved on its geodetic orbit (May 2012): In order to account for the altitude change to the new geodetic orbit (May 2012), the altimeter’s PRF/PRI has been updated (old value: 2059.6792 Hz / new value: 2083.87600938 Hz). Moreover, it has been decided to take the opportunity of this change to increase the accuracy of this parameter in the processing chain. This has an impact on range bias of +3.2 mm.

In the version “e” of GDR products, a datation bias has been corrected (see section 0 about time-tag bias for more details). Moreover corrections of +60.7 and -3.2 mm have been applied to the Ku- and C-band altimeter ranges, respectively, during the repeat orbit to take into account the correct internal path delay value (combination of reference plane, internal path delay and PRF/PRI truncature). During the geodetic orbit, corrections of +63.9 and 0.0 mm have been applied to the Ku- and C-band ranges as the correct value of the altimeter PRF/PRI was used in GDR-C processing.

| Nominal Orbit | Ku band | C band |
|-------------------------------|-----------|---------|
| Reference plane | 18.092 | 18.092 |
| Altimeter internal path delay | -11.70211 | -18.092 |
| PRF truncature effect | -0.316 | -0.316 |
| Sum (cms) | 6.07389 | -0.316 |

| Geodetic Orbit | Ku band | C band |
|-------------------------------|-----------|---------|
| Reference plane | 18.092 | 18.092 |
| Altimeter internal path delay | -11.70211 | -18.092 |
| PRF truncature effect | 0 | 0 |
| Sum (cms) | 6.38989 | 0 |



5.3. Geoid

The geoid is an equipotential surface of the Earth's gravity field that is closely associated with the location of the mean sea surface. The reference ellipsoid is a bi-axial ellipsoid of revolution. The center of the ellipsoid is ideally at the center of mass of the Earth although the center is usually placed at the origin of the reference frame in which a satellite orbit is calculated and tracking station positions given. The separation between the geoid and the reference ellipsoid is the geoid undulation (see geoid parameter).

The geoid undulation, over the entire Earth, has a root mean square value of 30.6 m with extreme values of approximately 83 m and -106 m. Although the geoid undulations are primarily long wavelength phenomena, short wavelength changes in the geoid undulation are seen over seamounts, trenches, ridges, etc., in the oceans. The calculation of a high resolution geoid requires high resolution surface gravity data in the region of interest as well as a potential coefficient model that can be used to define the long and medium wavelengths of the Earth's gravitational field. Surface gravity data are generally only available in certain regions of the Earth and spherical harmonic expansions of the Earth's gravitational potential are usually used to define the geoid globally. Currently, such expansions are available to degree 360 and in some cases higher.

For ocean circulation studies, it is important that the long wavelength part of the geoid be accurately determined.

5.4. Mean Sea Surface

A Mean Sea Surface (MSS) represents the position of the ocean surface averaged over an appropriate time period to remove annual, semi-annual, seasonal, and spurious sea surface height signals. A MSS is given as a grid with spacing consistent with the altimeter and other data used in the generation of the grid values. The MSS grid can be useful for data editing purposes, for the calculation of along track and cross track geoid gradients, for the calculation of gridded gravity anomalies, for geophysical studies, for a reference surface to which sea surface height data from different altimeter missions can be reduced, etc. The Jason-1 GDR provides a global MSS model that is generated from multiple satellite altimetry missions.

Longer time spans of data that become available in the future, along with improved data handling techniques will improve the current MSS models. Care must be given to the retention of high frequency signal and the reduction of high frequency noise.

The Optimal Interpolation method provides a calibrated formal error which is provided in the products.

5.5. Mean Dynamic Topography

A Mean Dynamic Topography (MDT) represents the Mean Sea Surface referenced to a geoid and corrected from geophysical effects. A MDT is given as a grid with spacing consistent with the altimeter and other data used in the generation of the grid values. The MDT provides the absolute reference surface for the ocean circulation. The Jason-1 GDR provides a global MDT model that is a combined product recovering several years based on GRACE mission, altimetry and in situ data (hydrologic and drifters data).

The error on the Mean Dynamic Topography is provided in the products.

5.6. Geophysical Corrections

The atmosphere and ionosphere slow the velocity of radio pulses at a rate proportional to the total mass of the atmosphere, the mass of water vapor in the atmosphere, and the number of free electrons in the ionosphere. In addition, radio pulses do not reflect from the mean sea level but



from a level that depends on wave height and wind speed. The errors due to these processes cannot be ignored and must be removed. Discussions of these effects are given in *Chelton et al.* [2001].

5.6.1. Troposphere (dry and wet)

The propagation velocity of a radio pulse is slowed by the "dry" gases and the quantity of water vapor in the Earth's troposphere. The "dry" gas contribution is nearly constant and produces height errors of approximately -2.3 m. The water vapor in the troposphere is quite variable and unpredictable and produces a height calculation error of -6 cm to -40 cm. However, these effects can be measured or modeled as discussed below.

The gases in the troposphere contribute to the index of refraction. In detail, the refractive index depends on pressure and temperature. When hydrostatic equilibrium and the ideal gas law are assumed, the vertically integrated range delay is a function only of the surface pressure, see *Chelton et al.* [2001]. The dry meteorological tropospheric range correction is principally equal to the surface pressure multiplied by -2.277mm/mbar, with a small adjustment also necessary to reflect a small latitude dependence (see `model_dry_tropo_corr` and `model_dry_tropo_corr_era` parameter).

$$\text{model_dry_tropo_corr} = -2.277 * P_{\text{atm}} * [1 + 0.0026 * \cos(2 * \text{phi})]$$

where P_{atm} is surface atmospheric pressure in mbar, phi is latitude, and `model_dry_tropo_corr` (or `model_dry_tropo_corr_era`) is the dry troposphere correction in mm. There is no straightforward way of measuring the nadir surface pressure from a satellite, so it is determined from the European Center for Medium Range Weather Forecasting (ECMWF) numerical weather prediction model. The uncertainty on the ECMWF atmospheric pressure products is somewhat dependent on location. Typical errors vary from 1 mbar in the northern Atlantic Ocean to a few mbars in the southern Pacific Ocean. A 1-mbar error in pressure translates into a 2.3 mm error in the dry tropospheric correction.

The amount of water vapor present along the path length contributes to the index of refraction of the Earth's atmosphere. Its contribution to the delay of the radio pulse, the wet tropospheric delay, can be estimated by measuring the atmospheric brightness near the water vapor line at 22.2356 GHz and providing suitable removal of the background. The Jason-1 Microwave Radiometer (JMR) measures the brightness temperatures in the nadir path at 18.7, 23.8 and 34.0 GHz: the water vapor signal is sensed by the 23.8 GHz channel, while the 18.7 GHz channel removes the surface emission (wind speed influence), and the 34 GHz channel removes other atmospheric contributions (cloud cover influence) [*Keihm et al.*, 1995]. Measurements are combined to obtain the path delay in the satellite range measurement due to the water vapor content (see `rad_wet_tropo_corr` parameter). The uncertainty is less than 1.2 cm RMS [e.g. *Cruz Pol et al.*, 1998 and *Ruf et al.*, 1994].

Since the 2014 recalibration of JMR data, an improved near land wet path delay algorithm is applied to improve the performance up to the coast. The algorithm error when applied to the JMR is estimated to be less than 0.8 cm up to 15 km from land, less than 1.0 cm within 10 km from land, less than 1.2 cm within 5 km from land and less than 1.5 cm up to the coastline. This is estimated from detailed simulations and validated by comparisons with measured AMR data [*Brown*, 2009]. The radiometer surface type (see `rad_surf_type` parameter) indicates the quality of this wet tropospheric correction.

The ECMWF numerical weather prediction model also provides a value for the wet tropospheric delay. An interpolated value from this model is included in the GDR, as a backup to the measurement from the JMR (see `model_wet_tropo_corr` or `model_wet_tropo_corr_era`). This backup will prove useful when sun glint, land contamination, or anomalous sensor behavior makes the JMR measurement of the wet tropospheric delay unusable.

5.6.2. Ionosphere

At the frequencies used by the Poseidon-2 altimeter, the propagation velocity of a radio pulse is slowed by an amount proportional to the density of free electrons of the Earth's ionosphere, also known as the total electron content (TEC). The retardation of velocity is inversely proportional to



frequency squared. For instance, it causes the altimeter to slightly over-estimate the range to the sea surface by typically 0.2 to 20 cm at 13.6 GHz. The amount varies from day to night (there are fewer free electrons at night), from summer to winter, and as a function of the solar cycle (there are fewer during solar minimum.) (For discussions on this correction, see *Chelton et al.* [2001], *Imel* [1994], and *Callahan* [1984]. Also, see section 4.2.4 on smoothing the ionospheric correction).

Because this effect is dispersive, measuring the range at two frequencies allows it to be estimated. Under typical ocean conditions of 2-meter significant wave height, the Ku band ionospheric range correction determined from the dual frequency measurements from the altimeter is expected to have an accuracy of ± 0.5 cm (see `iono_corr_alt_ku` parameter).

A backup ionospheric correction solution, derived from Global Ionosphere Maps (GIM), is provided in the GDR products. It may be used over non ocean surfaces (ice, land, etc.).

5.6.3. Ocean Waves (sea state bias)

Unlike the preceding effects, sea-state effects are an intrinsic property of the large footprint radar measurements. The surface scattering elements do not contribute equally to the radar return; troughs of waves tend to reflect altimeter pulses better than do crests. Thus the centroid of the mean reflecting surface is shifted away from mean sea level towards the troughs of the waves. The shift, referred to as the electromagnetic (EM) bias, causes the altimeter to overestimate the range (see *Rodriguez et al.*, [1992]). In addition, a skewness bias also exists from the assumption in the onboard algorithms that the probability density function of heights is symmetric, while in reality it is skewed. Finally, there is a tracker bias, which is a purely instrumental effect. The sum of EM bias, skewness bias, and tracker bias is called 'sea state bias' (see `sea_state_bias_ku` and `sea_state_bias_c` parameters).

The accuracy of sea state bias models remains limited and continues to be a topic of research. The current most accurate estimates are obtained using empirical models derived from analyses of the altimeter data. The sea state bias is computed from a bilinear interpolation of a table of sea state biases versus significant wave height and wind speed, based on empirical fits (*Tran et al.*[2011]). For a typical significant wave height (SWH) of 2 meters, the sea state bias is about 10 cm, and the error (bias) in the sea state bias correction is approximately 1-2 cm. The noise of the sea state bias estimates depends mainly on the noise on the significant wave height estimates.

In the version "e" of GDR products, the Jason-1 SSB (Ku and C-band) have been recomputed at the end of 2015 based on 3-year of data from cycles 1 to 111. The products used are the GDR_E 2.0 like (GDR_E 1.3 + updates (i.e. correct bias for range + GOT4.10 using all waves)). The obtained SSB tables are then biased by +0.8 mm for the Ku-band and -28.5 mm for the C-band. These biases have been provided by S. Desai to avoid positive C-band SSB corrections. For more information please refer to:

http://meetings.aviso.altimetry.fr/fileadmin/user_upload/tx_ausyclsseminar/files/GDRE_CalVal_cnesjpl.pdf

5.7. Rain Flag

Liquid water along the pulse's path reduces the energy returned to the altimeter, mainly at Ku band. In heavy rain, there are competing effects from attenuation and surface changes. The small-scale nature of rain cells tends to produce rapid changes in the strength of the echo as the altimeter crosses rain cells. Both effects degrade the performance of the altimeter. Data contaminated by rain are rare (most are located in the west equatorial pacific), flagged and should be ignored (see `rain_flag` parameter).

The rain flag on the Jason-1 GDR is set if integrated liquid water content measured by the JMR is larger than a specified threshold, AND if the difference between the expected Ku-band backscatter coefficient (estimated from the C-band backscatter coefficient which is much less affected by rain) and the measured Ku-band backscatter coefficient, is larger than either a specified threshold or a specified multiple of the uncertainty in the expected Ku-band backscatter coefficient (see `rain_flag` parameter) [*Tournadre and Morland*, 1998] (and RD 3). Ku band backscatter coefficient used for the rain flag determination is issued from MLE4 retracking (`sig0_ku` and `sig0_c`).

A radiometer derived rain flag (see `rad_rain_flag` parameter) is also computed through a comparison of the 18.7 GHz brightness temperature and the cloud liquid water observed by the JMR to specific



thresholds. Rain is very absorptive in the microwave, and, over ocean, increases significantly and proportional to the rain rate the brightness temperature and the cloud liquid water observed by the JMR. Over the ocean, only rain will cause the 18.7 GHz brightness temperature to rise above -200 K.

5.8. Ice Flag

The range measurement from the altimeter is likely to have larger errors when the pulse is reflected off ice surfaces. The ice surface is not at sea level, but at some unknown distance above it. For this reason the Jason-1 GDR provides an ice flag (see `ice_flag` parameter) to indicate when the data point is likely to be over ice.

The ice flag is set if the absolute value of the difference between the model wet tropospheric correction and the dual frequency wet tropospheric correction retrieved from 23.8 GHz and 34.0 GHz brightness temperatures exceeds a specified threshold, OR if the number of valid 20-Hz altimeter range of the processed measurement is smaller than a specified threshold. If the corresponding computations cannot be performed, then the ice flag is set if a climatological map predicts ice at the given location, and if the wind speed derived from the altimeter measurement is less than 1 m/s, i.e., the backscatter is larger than normally expected from the ocean.

A radiometer derived sea ice flag (see `rad_sea_ice_flag`) is also computed through the comparison between the JMR 34.0 GHz channels and 18.7 GHz brightness temperatures. Sea ice has an emissivity near 1 in the microwave and has a small frequency dependence. This contrasts from the open ocean brightness temperature. The difference between the JMR 34.0 GHz channels and 18.7 GHz channels is near 20-30 K in the open ocean, but generally less than 10K when sea ice is present. As the difference is also small for land, sea ice presence is assessed using the radiometer surface type flag.

5.9. Tides

Tides are a significant contributor to the observed sea surface height [*Le Provost, 2001*]. While they are of interest in themselves, they have more variation than all other time-varying ocean signals. Since they are highly predictable, they are removed from the data in order to study ocean circulation. The T/P orbit was specifically selected (inclination and altitude) so that diurnal and semidiurnal tides would not be aliased to low frequencies.

There are several contributions to the tidal effect: the ocean tide, the load tide, the solid earth tide and the pole tide. The ocean tide, load tide and solid earth tide are all related to luni-solar forcing of the earth, either directly as is the case of the ocean and solid earth tide, or indirectly as is the case with the load tide since it is forced by the ocean tide. The pole tide is due to variations in the earth's rotation and is unrelated to luni-solar forcing.

Jason-1 GDRs do not explicitly provide values for the pure ocean tide, but instead provide values for a quantity referred to as the geocentric ocean tide, which is the sum total of the ocean tide and the load tide. Values of the load tide that were used to compute the geocentric ocean tide are also explicitly provided, so the pure ocean tide can be determined by subtracting the load tide value from the geocentric ocean tide value. Note that the permanent tide is not included in either the geocentric ocean tide or solid earth tide corrections that are provided on the Jason-1 GDRs.

5.9.1. Geocentric Ocean Tide

As mentioned above, the geocentric ocean tide is a quantity sometimes used to refer to the sum total of the ocean tide and the load tide. The Jason-1 GDR provides two choices for the geocentric ocean tide, `ocean_tide_sol1` and `ocean_tide_sol2`, each of which is computed as the sum total of the diurnal and semidiurnal ocean and load tides as predicted by a particular model, and an equilibrium representation of the long-period ocean tides at all periods except for the zero frequency (constant) term. The two load tide values provided on the GDR, `load_tide_sol1` and `load_tide_sol2`, provide the respective load tide values that were used to compute `ocean_tide_sol1` and `ocean_tide_sol2`.



5.9.2. Long period Ocean Tide

The long-period ocean tides are a subject of continuing investigation. To first order, they can be approximated by an equilibrium representation. However, the true long-period ocean tide response is thought to have departures from an equilibrium response that increase with decreasing period. The two principal long-period ocean tide components, Mf and Mm, with fortnightly and monthly periods respectively, are known to have departures from an equilibrium response with magnitudes less than 1-2 cm.

The Jason-1 GDR explicitly provides a value for an equilibrium representation of the long-period ocean tide that includes all long-period tidal components excluding the permanent tide (zero frequency) component (see parameter `ocean_tide_equil`). Note that both geocentric ocean tide values on the GDR (`ocean_tide_sol1` and `ocean_tide_sol2`) already include the equilibrium long-period ocean tide and should therefore not be used simultaneously.

The Jason-1 GDR provides a parameter for a non-equilibrium representation of the long-period ocean tides (see parameter `ocean_tide_non_equil`). This parameter is provided as a correction to the equilibrium long-period ocean tide model so that the total non-equilibrium long period ocean tide is formed as a sum of `ocean_tide_equil` and `ocean_tide_non_equil`.

5.9.3. Solid Earth Tide

The solid Earth responds to external gravitational forces similarly to the oceans. The response of the Earth is fast enough that it can be considered to be in equilibrium with the tide generating forces. Then, the surface is parallel with the equipotential surface, and the tide height is proportional to the potential. The two proportionality constants are the so-called Love numbers. It should be noted that the Love numbers are largely frequency independent, an exception occurs near a frequency corresponding to the K1 tide constituents due to a resonance in the liquid core [Wahr, 1985 and Stacey, 1977].

The Jason-1 GDR computes the solid earth tide, or body tide, as a purely radial elastic response of the solid Earth to the tidal potential (see parameter `solid_earth_tide`.) The adopted tidal potential is the *Cartwright and Tayler* [1971] and *Cartwright and Edden* [1973] tidal potential extrapolated to the 2000 era, and includes degree 2 and 3 coefficients of the tidal potential. The permanent tide (zero frequency) term is excluded from the tidal potential that is used to compute the solid earth tide parameter for the Jason-1 GDR. The elastic response is modeled using frequency independent Love numbers. The effects of the resonance in the core are accounted for by scaling the tide potential amplitude of the K1 tidal coefficient and some neighboring nodal terms by an appropriate scale factor.

5.9.4. Pole Tide

The pole tide is a tide-like motion of the ocean surface that is a response of both the solid Earth and the oceans to the centrifugal potential that is generated by small perturbations to the Earth's rotation axis. These perturbations primarily occur at periods of 433 days (called the Chandler wobble) and annual. These periods are long enough for the pole tide displacement to be considered to be in equilibrium with the forcing centrifugal potential. The Jason-1 GDR provides a single field for the radial geocentric pole tide displacement of the ocean surface (see `pole_tide` parameter), and includes the radial pole tide displacement of the solid Earth and the oceans.

The pole tide is easily computed as described in Wahr [1985]. Modeling the pole tide requires knowledge of proportionality constants, the so-called Love numbers, and a time series of perturbations to the Earth's rotation axis, a quantity that is now measured routinely with space techniques. Note that the pole tide on the IGDR and GDR may differ, since the pole tide on the GDR is computed with a more accurate time series of the Earth's rotation axis.



5.10. Inverse Barometer Effect

5.10.1. Inverted Barometer Correction

As atmospheric pressure increases and decreases, the sea surface tends to respond hydrostatically, falling or rising respectively. Generally, a 1-mbar increase in atmospheric pressure depresses the sea surface by about 1 cm. This effect is referred to as the inverse barometer (IB) effect.

The instantaneous IB effect on sea surface height in millimeters (see parameter `inv_bar_corr`) is computed from the surface atmospheric pressure, P_{atm} in mbar:

$$\text{inv_bar_corr} = -9.948 * (P_{atm} - P)$$

where P is the time varying mean of the global surface atmospheric pressure over the oceans.

The scale factor 9.948 is based on the empirical value [Wunsch, 1972] of the IB response at mid latitudes. Some researchers use other values. Note that the surface atmospheric pressure is also proportional to the dry tropospheric correction, and so the parameter `inv_bar_corr` approximately changes by 4 to 5 mm as `model_dry_tropo_corr` changes by 1 mm (assuming a constant mean global surface pressure). The uncertainty of the ECMWF atmospheric pressure products is somewhat dependent on location. Typical errors vary from 1 mbar in the northern Atlantic Ocean to a few mbars in the southern Pacific Ocean. A 1-mbar error in pressure translates into a 10 mm error in the computation of the IB effect.

Note that the time varying mean global pressure over the oceans, P , during the first eight years of the T/P mission had a mean value of approximately 1010.9 mbar, with an annual variation around this mean of approximately 0.6 mbar. However, the T/P data products provided a static inverse barometer correction referenced to a constant mean pressure of 1013.3 mbar.

$$\text{IB(T/P)} = -9.948 * (P_{atm} - 1013.3)$$

Sea surface heights that are generated after applying an inverse barometer correction referenced to a mean pressure of 1013.3 mbar are therefore approximately $-9.948 * (1010.9 - 1013.3) = 23.9$ mm lower than those that are generated after applying an inverse barometer correction referenced to a time varying global mean pressure, and the difference between the two sea surface heights has an annual variation of approximately $9.948 * 0.6 = 6$ mm.

5.10.2. Barotropic/Baroclinic Response to Atmospheric Forcing

The High Frequency Wind and Pressure Response correction, `hf_fluctuations_corr`, complements the Inverted Barometer (IB) correction. Like both tides and IB, the ocean response to wind and pressure (after removing the IB part) has energy at periods shorter than the 20 day implied by the ~10 day repeat cycle of Jason-1. This correction can be thought of as a departure from the IB response to pressure, although strictly it is the difference between the response to wind and pressure minus the IB. *Ali and Zlotnicki* [2000] compute this response with a barotropic model that is forced by NCEP operational wind and pressure. The model output is filtered in time to pass frequencies shorter than 20 days. See also *Stammer et al.* [2000] and *Tierney et al.* [2000].

The parameter `hf_fluctuations_corr` (and `hf_fluctuations_corr_era`) is provided in the GDR products as a correction to the inverse barometer correction `inv_bar_corr` (and `inv_bar_corr_era`).

5.11. Sigma 0 and Atmospheric Attenuation

The backscatter coefficients, `sigma0_Ku` and `C` values (see parameters `sig0_ku` and `sig0_c`), reported on the GDR are corrected for atmospheric attenuation using `atmos_corr_sig0_ku` and `atmos_corr_sig0_c`. Note that "unbiased" `sigma0` values are recorded on the Jason-1 data products. For some geophysical algorithms, an appropriate bias is applied to the provided `sigma0`.



For defaulted atmospheric attenuation correction given by radiometer, a value of atmospheric attenuation correction has been calculated using the following formula:

$$\begin{aligned} \text{atmos_corr_sig0_c} &= 2 \times (\text{Att_Sigma0_C_Coef}[0] - \text{Att_Sigma0_C_Coef}[1] \times \text{model_wet_tropo_corr}) \\ \text{atmos_corr_sig0_Ku} &= 2 \times (\text{Att_Sigma0_Ku_Coef}[0] - \text{Att_Sigma0_Ku_Coef}[1] \times \text{model_wet_tropo_corr}) \end{aligned}$$

Where $\text{att_sigma0_C_Coef}[0] = 0.430\text{e-1 dB}$
 $\text{att_sigma0_C_Coef}[1] = 0.783\text{e-2 dB/meter}$
 $\text{att_sigma0_Ku_Coef}[0] = 0.594\text{e-1 dB}$
 $\text{att_sigma0_Ku_Coef}[1] = 0.227\text{e0 dB/meter}$

5.12. Wind Speed

The model functions developed to date for altimeter wind speed have all been purely empirical. A wind speed is calculated through a mathematical relationship with the Ku-band backscatter coefficient (corrected from atmospheric attenuation) and the significant wave height (see `wind_speed_alt`) using the Gourrion algorithm [*Gourrion et al*, 2002] and Collard table [*Collard*, 2005]. The wind speed model function is evaluated for 10 meter above the sea surface, and is considered to be accurate to 2 m/s.

A radiometer derived wind speed is also computed through an empirical relationship to brightness temperatures measured by the JMR [*Keihm et al.*, 1995] (see `wind_speed_rad`). The coefficients of this relationship have been determined from the regression of island radiosonde data computations combined with seasonal and latitude dependent wind speed statistics.

Finally, a 10-meter (above surface) wind vector (in east-west and north-south directions) is also provided on the Jason-1 GDR (see parameters `wind_speed_model_u` and `wind_speed_model_v` and `wind_speed_model_u_era` and `wind_speed_model_v_era`). This wind speed vector is determined from an interpolation of the ECMWF model (MARS 3D and ERA_interim data). The best accuracy for the wind vector varies from about 2 m/s in magnitude and 20 degrees in direction in the northern Atlantic Ocean, to more than 5 m/s and 40 degrees in the southern Pacific Ocean.

5.13. Bathymetry Information

The Jason-1 GDR provides a parameter bathymetry that gives the ocean depth or land elevation of the data point. Ocean depths have negative values, and land elevations have positive values. This parameter is given to allow users to make their own "cut" for ocean depth.



6. Data description

The main characteristics of Jason-1 level-2 products are summarized in the following table. During mission operations, three product families (OSDR, IGDR, and GDR) were available, and were provided in versions “a”, “b”, and “c”. All of those data are now superceded by the GDR version “e” product described in this handbook. Prior versions of this handbook provide more information about the OSDRs and IGDRs and their differences with respect to the GDR.

6.1. Data format

Accounting for Jason-1 heritage, the GDR version “e” products are split into three data sets:

- “SSHA” data set : One file SSHA, limited to 1Hz sampling values
- “GDR” data set : One file GDR, containing 1Hz and 20Hz values
- “SGDR” data set : One file SGDR, containing 1Hz, 20hz and waveforms values

6.1.1. NetCdf format and CF convention

The [netCDF](#) data format has been chosen to store the different data sets (one file per data set). This format is extremely flexible, self-documenting and has been adopted as a de-facto standard for many operational oceanography systems. What’s more, the files follow the Climate and Forecast NetCDF conventions CF-1.1 because these conventions provide a practical standard for storing.

6.1.2. The NetCDF Data Model

A netCDF file contains **dimensions**, **variables**, and **attributes**, which all have both a name by which they are identified. These components can be used together to capture the meaning of data and relations among data fields in an array-oriented data set.

6.1.2.1. Dimensions

A dimension may be used to represent a real physical dimension, for example, time, latitude, longitude, or height. A dimension might also be used to index other quantities (waveforms index for example). The following dimensions are used in the Jason-1 product files:

| Dimension Name | Value | SSHA Data Set | GDR Data Set | SGDR Data Set |
|----------------|----------------------------------------|---------------|--------------|---------------|
| time | Number of measurements in the file | X | X | X |
| meas_ind | 20 (number of elementary measurements) | | X | X |
| wvf_ind | 104 (number of waveform samples) | | | X |

Table 17 - Dimensions used in the Jason-1 data sets

6.1.2.2. Variables

Variables are used to store the bulk of the data in a netCDF file. A variable represents an array of values of the same type. A scalar value is treated as a 0-dimensional array. A variable has a name, a data type, and a shape described by its list of dimensions specified when the variable is created. A variable may also have associated attributes, which may be added, deleted or changed after the variable is created.

A variable data type is one of a small set of netCDF types. In this document the variable types will be represent as follows:

| Variable type | Description |
|---------------|-------------|
|---------------|-------------|



| | |
|--------|------------------------------------------------|
| char | characters |
| byte | 8-bit data signed |
| short | 16-bit signed integer |
| int | 32-bit signed integer |
| float | IEEE single precision floating point (32 bits) |
| double | IEEE double precision floating point (64 bits) |

Table 18 - netCDF variable type

6.1.2.3. Coordinate variables and auxiliary coordinate variables

A variable with the same name as a dimension is called a **coordinate variable**. It typically defines a physical coordinate corresponding to that dimension. In accordance with the Climate and Forecast conventions, we must declare a coordinate variable for each dimension. What's more, missing values are not allowed in coordinate variables and they must be strictly monotonic.

An **auxiliary coordinate variable** is a netCDF variable that contains coordinates data but is not a coordinate variable as defined above. Unlike coordinate variables, there is no relationship between the name of an auxiliary coordinate variable and the name(s) of its dimension(s).

6.1.2.4. Attributes

NetCDF attributes are used to store data about the data (ancillary data or metadata), similar in many ways to the information stored in data dictionaries and schema in conventional database systems. Most attributes provide information about a specific variable. These are identified by the name of that variable, together with the name of the attribute.

Some attributes provide information about the data set as a whole. They are called **global attributes** - similar to the header of the Jason-1 products.

The following table shows the variable attributes used in the Jason-1 product. There are no mandatory attributes.

| Attribute | Description |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| _FillValue | A default value used to represent missing or undefined data |
| add_offset | If present, this number is to be added to the data after it is read by an application. If both <i>scale_factor</i> and <i>add_offset</i> attributes are present, the data are first scaled before the offset is added |
| calendar | Reference time calendar |
| comment | Miscellaneous information about the data or the methods used to produce it |
| coordinates | Identified auxiliary coordinates variables |
| flag_meanings | Use in conjunction with <i>flag_values</i> to provide descriptive words or phrase for each flag value |
| flag_values | Provide a list of the flag values. Use in conjunction with <i>flag_meanings</i> |
| institution | Institution which provides the data |
| leap_second | UTC time at which a leap second occurs |
| long_name | A descriptive name that indicates a variable's content. This name is not standardized |
| quality_flag | Name of the variable(s) (quality flag) representing the quality of the current variable |
| scale_factor | If present, the data are to be multiplied by this factor after the data are read by an application. See also <i>add_offset</i> attribute |
| source | Data source (model features, or observation) |
| standard_name | A standard name that references a description of a variables content in the standard name table |
| tai_tuc_difference | Difference between TAI and UTC reference time |
| units | Unit of a variable's content. The value of this attribute must be a string that can be recognized by the UNIDATA's Udunits package |
| valid_max | Largest theoretical valid value of a variable (this is not the maximum of actual data) |
| valid_min | Smallest theoretical valid value of a variable (this is not the minimum of actual data) |

Table 19 - Variable's attributes



6.1.3. The Common Data Language

The Common Data Language (CDL) is used to describe the content of a data set.

The CDL is textual notation that described the netCDF object and it is human readable. The netCDF utility `ncdump` converts netCDF objects binary to CDL text. The netCDF utility `ncgen` creates netCDF binary file from CDL text file.

A CDL description of a netCDF data set takes the form:

```
netCDF name {  
  dimension: ...  
  variables: ...  
  data: ...  
}
```

where the name is used only as a default in constructing file names by the `ncgen` utility. The CDL description consists of three optional parts, introduced by the keywords `dimensions` `variables` and `data`. NetCDF dimension declarations appear after the `dimensions` keyword, netCDF variables and attributes are defined after the `variables` keyword and variable data assignments appears after the `data` keyword. CDL statement are terminated by a semicolon. Spaces, tabs and newlines can be used freely for readability. Comments in CDL follow the characters `/**` on any line.

Example

```
netcdf example {  
  dimensions:                               // dimensions name are declared first  
  time = 2680;  
  
  variables:  
  double time(time);                        // variable <type> <name>(<dimension>)  
    time:long_name = "time";                // variable attributes  
    time:units = "seconds since 2000-01-01 00:00:00.0";  
  
  int lon(time);  
    lon:long_name = "longitude";  
    lon:standard_name = "longitude";  
    lon:units = "degrees_east";  
    lon:scale_factor = 1.0e-06;  
  
  byte alt_echo_type(time);  
    alt_echo_type:long_name = "altimeter echo type";  
    alt_echo_type:_FillValue = 127b;  
    alt_echo_type:flag_values = 0b, 1b ;  
    alt_echo_type:flag_meanings = "ocean_like non_ocean_like";  
    alt_echo_type:coordinates = "lon lat";  
  
  int alt(time);  
    alt:long_name = "1 Hz altitude of satellite";  
    alt:_FillValue = 2147483647;  
    alt:units = "m";  
    alt:add_offset = 1.30e+06;  
    alt:scale_factor = 1.00e-04;  
    alt:coordinates = "lon lat";
```

- time is a coordinate variable
- alt_echo_type is a flag fully described by the flag_meanings and flag_values attributes:

```
alt_echo_type = 0    -> ocean like echo  
alt_echo_type = 1    -> non ocean like echo
```

If alt_echo_type is not computed, it will take the value 127 (_FillValue attribute).

- alt is packed. The data are stored in 32-bit integers (long). The value of the altitude of the satellite can be recovered using:

```
alt = (altlong * scale_factor) + add_offset
```



6.2. Global attributes

Global attributes (the equivalent of header parameters for Jason-1 products) may be displayed from a SSHA/GDR/SGDR data set file using “ncdump -h” command.

A list (not necessarily exhaustive) of the global attributes available in these data sets is given below (attribute name and description).

| | |
|-------------------------------|----------------------------------------------------------------------|
| Conventions | netCDF convention followed |
| title | A descriptive title for the data set |
| institution | The name of the data producer |
| source | The method of production of original data |
| history | Date and Product Create Time |
| contact | A text giving the primary contact for information about the data set |
| references | The version of the altimetric library used to produce the data set |
| processing_center | Name of the processing center |
| reference_document | Name of the reference document describing the products |
| mission_name | Name of the mission |
| altimeter_sensor_name | Name of the altimeter sensor |
| radiometer_sensor_name | Name of the radiometer sensor |
| doris_sensor_name | Name of the DORIS sensor |
| acq_station_name | Identification of the acquisition station |
| cycle_number | Cycle number |
| absolute_rev_number | Absolute number of revolution |
| pass_number | Pass number in the cycle (relative pass number) |
| absolute_pass_number | Absolute pass number (since the beginning of the mission) |
| equator_time | UTC time of equator crossing |
| equator_longitude | Longitude of equator crossing |
| first_meas_time | First measurement time |
| last_meas_time | Last measurement time |
| ellipsoid_axis | Semi-major axis of the reference ellipsoid |
| ellipsoid_flattening | Flattening coefficient of the reference ellipsoid |

6.3. Data Sets

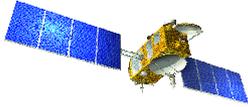
Variables attributes are identified in section 6.1.2.4 they may be displayed from a SSHA/GDR/SGDR data set file using “ncdump -h” command.

Some examples (not necessarily fully up to date) are given below:

```
double time(time=2450);
  :long_name = "time (sec. since 2000-01-01)";
  :standard_name = "time";
  :calendar = "gregorian";
  :tai_utc_difference = 32.0; // double
  :leap_second = "0000-00-00 00:00:00";
  :units = "seconds since 2000-01-01 00:00:00.0";
  :comment = "[tai_utc_difference] is the difference between TAI - UTC (i.e., leap seconds) for the first measurement of the data set. [leap_second] is the UTC time at which a leap second occurs in the data set, if any. After this UTC time, the [tai_utc_difference] is increased by 1 second. time variable is corrected from datation bias. See Jason-1 User handbook.”;
```

```
byte meas_ind(meas_ind=20);
  :long_name = "elementary measurement index";
  :units = "count";
  :comment = "Set to be compliant with the CF-1.1 convention”;
```

```
double time_20hz(time=2450, meas_ind=20);
  :FillValue = 1.8446744073709552E19; // double
  :long_name = "time 20 Hz (sec. since 2000-01-01)";
  :standard_name = "time";
  :calendar = "gregorian";
  :tai_utc_difference = 32.0; // double
```



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```
:leap_second = "0000-00-00 00:00:00";
:units = "seconds since 2000-01-01 00:00:00.0";
:comment = "[tai_utc_difference] is the difference between TAI - UTC (i.e., leap seconds) for the first measurement of
the data set. [leap_second] is the UTC time at which a leap second occurs in the data set, if any. After this UTC time, the
[tai_utc_difference] is increased by 1 second. time_20hz variable is corrected from datation bias. See Jason-1 User
handbook.";
```

```
int lat(time=2450);
:long_name = "latitude";
:standard_name = "latitude";
:units = "degrees_north";
:quality_flag = "orb_state_flag_rest";
:scale_factor = 1.0E-6; // double
:comment = "Positive latitude is North latitude, negative latitude is South latitude. See Jason-1 User Handbook.";
```

```
int lon(time=2450);
:long_name = "longitude";
:standard_name = "longitude";
:units = "degrees_east";
:quality_flag = "orb_state_flag_rest";
:scale_factor = 1.0E-6; // double
:comment = "East longitude relative to Greenwich meridian. See Jason-1 User Handbook.";
```

```
int lon_20hz(time=2450, meas_ind=20);
:_FillValue = 2147483647; // int
:long_name = "20 Hz longitude";
:standard_name = "longitude";
:units = "degrees_east";
:scale_factor = 1.0E-6; // double
:comment = "East longitude relative to Greenwich meridian. See Jason-1 User Handbook";
```

```
int lat_20hz(time=2450, meas_ind=20);
:_FillValue = 2147483647; // int
:long_name = "20 Hz latitude";
:standard_name = "latitude";
:units = "degrees_north";
:scale_factor = 1.0E-6; // double
:comment = "Positive latitude is North latitude, negative latitude is South latitude. See Jason-1 User Handbook";
```

```
byte surface_type(time=2450);
:_FillValue = 127B; // byte
:long_name = "surface type";
:flag_values = 0B, 1B, 2B, 3B; // byte
:flag_meanings = "ocean lake_enclosed_sea ice land";
:coordinates = "lon lat";
:comment = "Computed using a DTM2000 file: 0 = open oceans or semi-enclosed seas; 1 = enclosed seas or lakes; 2 =
continental ice; 3 = land. See Jason-1 User Handbook";
```

```
short ssha(time=2450);
:_FillValue = 32767S; // short
:long_name = "sea surface height anomaly";
:standard_name = "sea_surface_height_above_sea_level";
:source = "Poseidon-2";
:institution = "CNES";
:units = "m";
:scale_factor = 0.001; // double
:coordinates = "lon lat";
:comment = "= altitude of satellite (alt) - Ku band corrected altimeter range (range_ku) - altimeter ionospheric
correction on Ku band (iono_corr_alt_ku) - model dry tropospheric correction (model_dry_tropo_corr) - radiometer wet
tropospheric correction (rad_wet_tropo_corr) - sea state bias correction in Ku band (sea_state_bias_ku) - solid earth tide
height (solid_earth_tide) - geocentric ocean tide height solution 1 (ocean_tide_sol1) - geocentric pole tide height (pole_tide)
- inverted barometer height correction (inv_bar_corr) - high frequency fluctuations of the sea surface topography
(hf_fluctuations_corr for I/GDR off line products only) - mean sea surface (mean_sea_surface). Set to default if the altimeter
echo type (alt_echo_type) is set to 1 = non ocean like, the radiometer surface type (rad_surf_type) set to 2 = land, or the
rain flag (rain_flag) set to 1 = rain";
```

6.4. Software

This section lists some software that may be used to browse and use data from SSHA, GDR and SGDR data sets.



6.4.1. Software provided with netCDF : “ncdump”

< ncdump > converts netCDF files to ASCII form (CDL)

See <http://www.unidata.ucar.edu/software/netcdf/docs/ncdump-man-1.html>

The main options are the following:

- h Show only the header information in the output that is the declarations of dimensions, variables, and attributes but no data values for any variables
- c Show the values of coordinate variables (variables that are also dimensions) as well as the declarations of all dimensions, variables, and attribute values
- v *var1,...,varn* The output will include data values for the specified variables, in addition to the declarations of all dimensions, variables, and attributes
- x *var1,...,varn* Output XML (NcML) instead of CDL. The NcML does not include data values

6.4.2. Additional general software

6.4.2.1. ncbrowse

“ncBrowse” is a Java application that provides flexible, interactive graphical displays of data and attributes from a wide range of netCDF data file conventions.

See <http://www.epic.noaa.gov/java/ncBrowse/>

6.4.2.2. netCDF Operator (NCO)

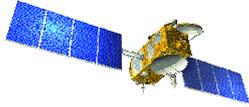
The netCDF Operators, or “NCO”, are a suite of programs known as **operators**. Each operator is a standalone, command line program which is executed at the UNIX shell-level, like, e.g., `ls` or `mkdir`. The operators take netCDF files as input, then perform a set of operations (e.g., deriving new data, averaging, hyperslabbing, or metadata manipulation) and produce a netCDF file as output. The operators are primarily designed to aid manipulation and analysis of gridded scientific data. The single command style of NCO allows users to manipulate and analyze files interactively and with simple scripts, avoiding the overhead (and some of the power) of a higher level programming environment.

See <http://nco.sourceforge.net/>

6.4.3. Additional specific software : “BRAT”

The “Basic Radar Altimetry Toolbox” is a collection of tools and tutorial documents designed to facilitate the use of radar altimetry data. It is able to read most distributed radar altimetry data from all the satellites, to do some processing, data editing and statistic over them, and to visualize the results. The Basic Radar Altimetry Toolbox is able to read ERS-1 and 2, TOPEX/Poseidon, GEOSAT Follow-on, Jason-1, ENVISAT, Jason-1 and CRYOSAT missions altimetry data from official data centers (ESA, NASA/JPL, CNES/AVISO, NOAA), and this for different processing levels, from level 1B (Sensor Geophysical Data Record) to level 3/4 (gridded merged data).

See http://www.altimetry.info/html/data/toolbox_en.html

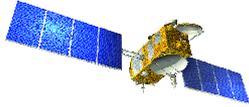


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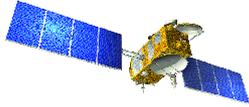


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Annexe B - List of acronyms

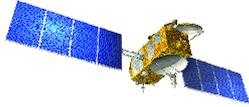
| | |
|----------|--------------------------------------------------------------------------------------------------------------------|
| AD | Applicable Document |
| AGC | Automatic Gain Control |
| AMR | Advanced Microwave Radiometer |
| AVISO | Archivage, Validation et Interprétation des données des Satellites Océanographiques |
| BRAT | Basic Radar Altimetry Toolbox |
| CLIVAR | Climate Variability and Predictability program |
| CLS | Collecte Localisation Satellites |
| CNES | Centre National d'Etudes Spatiales |
| DIODE | Détermination Immédiate d'Orbite par Doris Embarque |
| DORIS | Détermination d'Orbite et Radiopositionnement Intégrés par Satellite |
| DTM | Digital Terrain Model |
| ECMWF | European Center for Medium range Weather Forecasting |
| EGM | Earth Gravity Model |
| EM | ElectroMagnetic |
| EUMETSAT | European Organisation for the Exploitation of Meteorological Satellites |
| FES | Finite Element Solution |
| FFT | Fast Fourier Transform |
| GDR | Geophysical Data Records |
| GIM | Global Ionosphere Maps |
| GODAE | Global Ocean Data Assimilation Experiment |
| GPS | Global Positioning System |
| GTS | Global Telecommunications System |
| HF | High Frequency |
| IB | Inverse Barometer |
| IGDR | Interim Geophysical Data Records |
| JGM | Joint Gravity Model |
| JMR | JMR Jason-1 Microwave Radiometer |
| JPL | Jet Propulsion Laboratory |
| LPT | Light Particle Telescope |
| MDT | Mean Dynamic Topography |
| MLE | Maximum Likelihood Estimator |
| MSS | Mean Sea Surface |
| NASA | National Aeronautics and Space Administration |
| NetCDF | Network Common Data Form |
| NRT | Near Real Time |
| NWP | Numerical Weather Prediction |
| OSDR | Operational Geophysical Data Records |
| OSTM | Ocean Surface Topography Mission |
| OSU | Ohio State University |
| PO.DAAC | Physical Oceanography Distributed Active Archive Center |
| POD | Precision Orbit Determination |
| POE | Precision Orbit Ephemerides |
| PROTEUS | Plateforme Reconfigurable pour l'Observation de la Terre, les télécommunications et les Utilisations Scientifiques |
| RD | Reference Document |
| RMS | Root Mean Square |
| RSS | Root Sum Square |
| SLA | Sea Level Anomaly |
| SLR | Satellite Laser Ranging |
| SSALTO | Segment Sol multimissions d'ALTimétrie, d'Orbitographie et de localisation précise |
| SSB | Sea State Bias |
| SSH | Sea Surface Height |
| SSHA | Sea Surface Height Anomaly |
| SWH | Significant Wave Height |
| T/P | Topex/Poseidon |
| TBC | To be confirmed |



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| | |
|-------------|-----------------------------------|
| TBD | To be defined |
| TEC | Total Electron Content |
| TRSR | Turbo Rogue Space Receiver |
| UTC | Universal Time Coordinated |
| WMO | World Meteorological Organisation |



Annexe C - Contacts

CNES

18, avenue Edouard Belin
F-31401 Toulouse Cedex 9

Web : www.cnes.fr

AVISO+ User Service Helpdesk:

8-10 rue Hermès
F-31520 Ramonville-St-Agne, France

Phone : +33 (0) 5 61 39 47 80
Fax : +33 (0) 5 61 39 37 82
Web : www.aviso.altimetry.fr
e-mail : aviso@altimetry.fr

NASA

Web : <http://www.nasa.gov/>

PO.DAAC User Services:

Jet Propulsion Laboratory
MS T1721-202
4800 Oak Grove Drive
Pasadena, CA 91109 USA

Phone : +1 818-393-7165
Fax : +1 818-393-3405
Web : <http://podaac.jpl.nasa.gov>
e-mail : podaac@podaac.jpl.nasa.gov