OSTM/Jason-2 Products Handbook

References:	
CNES :	SALP-MU-M-OP-15815-CN
EUMETSAT :	EUM/OPS-JAS/MAN/08/0041
JPL :	OSTM-29-1237
NOAA/NESDIS :	Polar Series/OSTM J400

Issue: 1 rev 11

Date: January 13th, 2017

Chronology Issues:

Issue:	Date:	Reason for change:
1rev0	June 17, 2008	Initial Issue
1rev1	July 31, 2008	Adding NOAA doc id, JASON2 launch date, and correction of SSH, SLA terms
1rev2	November 28, 2008	Update for the OGDR data distribution to users (inline with product version ‘c’).
1rev3	January 20, 2009	Update for the IGDR data distribution to users and adding the information included in document ‘Access_to_Jason-2_data’
1rev4	August 3, 2009	Update for the GDR data distribution to users and of the editing procedure
	October 14, 2009	Introduction of the document in configuration management process at 4-partners level (Change request SALP-FT-7147).
1rev5	November 15th, 2010	4 partner change request #7365 Correction on BUFR filenames; update of the Jason-2 BUFR descriptor sequence number’ (e.g. from 005 to 010)
1rev6	January 13th, 2001	4 partner change request #7974 : Location indicator in upper case for BUFR filenames
1rev7	September 9th, 2011	Update to take into account version ‘d’ product (Change request SALP-FT-7233 and SALP-FT-8014)
1rev8	December 1st, 2011	4-partner change request #8346 : - New Mean Sea Surface: MSS_CNES-CLS-2011 - New Mean Dynamic Topography : MDT_CNES-CLS-2009 - Documentation update (new table on GDR-D orbit, new MSS&MDT, etc.) 4-partner change request #8379 : Implementation of NetCDF extension (.nc) on all Jason-2 level 2 products filenames (OGDR and OGDR-SSHA, IGDR, IGDR-SSHA and S-IGDR, GDR, GDR-SSHA and S-GDR)
1rev9	May 13rd, 2015	- Modification of the AVISO+ contact/address. - Correction on information given on tides models and load tides. - Update of NRT & offline data access for NOAA. 4-partner change request #10022 : Modification of orbit information to take into account the operational change to MOE and POE at “GDR-E” orbit standard.
1rev10	October 17th, 2016	- Modification of orbit paragraph to introduce OSTM/Jason-2 interleaved orbit (SALP-FT-10555).

Chronology Issues:

Issue:	Date:	Reason for change:
1rev11	13 January 2017	- Modification of GDR latency after OSTST 2016 recommendation. Latency extended from 60 to 90 days in order to allow cold sky calibration processing and use in radiometer calibrations. (SALP-FT-10763). - Update of Jason-2 orbit parameters (SALP-FT-10563).

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List of tables and figures

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Applicable documents / reference documents

AD 1 : OSTM/Jason-2 System Requirements
TP3-J0-STB-44-CNES

AD 2 : OSTM/Jason-2 Science and Operational Requirements
TP3-J0-SP-188-CNES

AD 3 : Algorithm Definition, Accuracy and Specification – Bibli_Alti : Altimeter Level 1b Processing
SALP-ST-M2-EA-15596-CN

AD 4 : Algorithm Definition, Accuracy and Specification – Bibli_Alti : Radiometer Level 1b Processing
SALP-ST-M2-EA-15597-CN

AD 5 : Algorithm Definition, Accuracy and Specification – Bibli_Alti : Altimeter Level 2 Processing
SALP-ST-M2-EA-15598-CN

AD 6 : Algorithm Definition, Accuracy and Specification – Bibli_Alti : Off-Line Control Processing
SALP-ST-M2-EA-15599-CN

AD 7 : Algorithm Definition, Accuracy and Specification – Bibli_Alti : Altimeter/Radiometer Verification Processing
SALP-ST-M2-EA-15703-CN

AD 8 : Algorithm Definition, Accuracy and Specification – Bibli_Alti : Mechanisms
SALP-ST-M2-EA-15600-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 : Rain Flag Modification for Version B Jason GDRs
Doc. Techni/ DOPS/LOS, 2006-01

Contents

1. Introduction

OSTM/Jason-2 is a follow-on mission to Jason-1. The satellite is named after the leader of the Argonauts' famous quest to recover the Golden Fleece. The OSTM/Jason-2 mission takes over and continues the TOPEX/Poseidon and Jason-1 missions. While the TOPEX/Poseidon and Jason-1 missions were conducted under a cooperation between the French Space Agency, "*Centre National d'Etudes Spatiales*" (CNES) and the United States National Aeronautics and Space Administration (NASA), OSTM/Jason-2 involves CNES, NASA and 2 new partners : the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the National Oceanic and Atmospheric Administration (NOAA) in order to facilitate the transition towards a fully operational altimetry mission, able to satisfy the data timeliness and reliability requirements of operational applications.

1.1. Overview of the OSTM/Jason-2 product family

The purpose of this document is to assist users of the OSTM/Jason-2 products (Operational Geophysical Data Record : OGDR, Interim Geophysical Data Record : IGDR, and Geophysical Data Record : GDR) by providing a comprehensive description of product content and format. We will so refer to (O)(I)GDR in this document when the information is relevant for all the products.

(O)(I)GDR products are identical except for the following differences regarding the auxiliary data used in the processing:

Auxiliary Data	Impacted Parameter	OGDR	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, …	Predicted	Restituted	
Pole Location	Pole tide height	Predicted		Restituted
Mog2D	HF ocean dealiasing correction	Not available	Preliminary	Precise
GIM	Ionosphere correction	Not available	Available	
Radiometer antenna temperatures coeff.	Wet tropospheric correction, Sigma0 rain attenuation, …	Preliminary		Precise (accounting for radiometer calibration)

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

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

1.1.1. Product contents

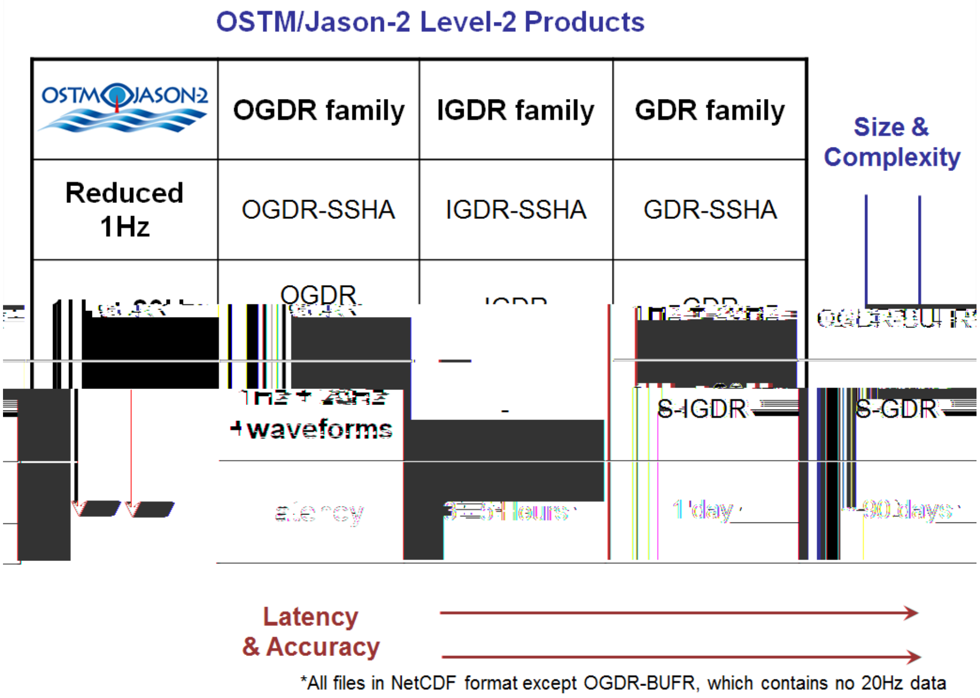
The Level-2 products from this mission comprise a family of nine different types of geophysical data records (GDRs). As illustrated in Table 1 below, there are three families of GDRs, distinguished by increasing latency and accuracy, going from the Operational GDR (OGDR), to the Interim GDR (IGDR), to the final GDR. Within each of these three families there are up to three types of files in NetCDF format, with increasing size and complexity:

1. a reduced 1 Hz subset of the full dataset in NetCDF format (O/I/GDR-SSHA);

2. the native NetCDF formatted datasets (O/I/GDRs) which contain 1Hz records as well as 20 Hz high-rate values;

3. an expert sensor product containing the full radar-echo waveforms in NetCDF format (S-IGDR/S-GDR, not applicable to the OGDR).

For the OGDR family, a specific product in BUFR format containing exclusively 1 Hz data is available, designed to cover the needs of the operational community for near real time observations in World Meteorological Organisation (WMO) standardised formats for assimilation in Numerical Weather Prediction (NWP) models.



OSTM/Jason-2 Level-2 Products

	OGDR family	IGDR family	GDR family
Reduced 1Hz	OGDR-SSHA	IGDR-SSHA	GDR-SSHA
[illegible]	OGDR	[illegible]	[illegible]
1Hz + 20Hz + waveforms	-	S-IGDR	S-GDR
Latency	3-5 hours	1 day	[illegible]

*All files in NetCDF format except OGDR-BUFR, which contains no 20Hz data

Table 2. Summary of operational, interim, and final geophysical data record products (O/I/GDR) from the Jason-2 / Ocean Surface Topography Mission (OSTM).

All nine files contain sea surface height, ocean surface wind speed, significant wave height information and all required corrections. The NetCDF files differ in the amount and type of auxiliary data included but the product format is the same.

1.1.2. Filename conventions

The product names are based on the following convention:

JA2_<O/I/G>P<N/R/S>_2P<v><S/P><ccc>_<ppp>_<yyyymmdd_hhnnss>_<yyyymmdd_hhnnss>.nc

With :

<O/I/G> : product family (O : OGDR, I : IGDR, G: GDR)
<N/R/S> : product type (N : native, R: reduced, S : sensor)
<v> : product version (set to 'T' during CalVal phases,
set to 'c', the current Jason-1 data standards, for the first delivery of OSTM/Jason-2 products to users, set to 'd' for the reprocessed delivery)
<S/P> : product duration (S : segment for OGDR, P : pass for I/GDR)
<ccc>: cycle number of 1st product record
<ppp> : pass number of 1st product record (1-254)
<yyyymmdd_hhnnss> : date of 1st product record
<yyyymmdd_hhnnss> : date of last product record

So for the OGDR we have:

OGDR: JA2_OPN_2PvSccc_ppp_yyyymmdd_hhnnss_yyyymmdd_hhnnss.nc
OGDR-SSHA: JA2_OPR_2PvSccc_ppp_yyyymmdd_hhnnss_yyyymmdd_hhnnss.nc

for the OGDR-BUFR, the filename is not relevant if your are accessing the files via GTS (see below for details on access to NRT data). Otherwise, if you are accessing the files from the archives (CLASS or UMARF) or EUMETCast, the filenames of the OGDR-BUFR are:

at the NOAA/CLASS:
JA2_OPB_2PvSccc_ppp_yyyymmdd_hhnnss_yyyymmdd_hhnnss

at the EUMETSAT/UMARF and on EUMETCast:
W_US-NOAA-Washington,SURFACE+SATELLITE,JASON2+OGDR_C_KNES_yyyymmddhhnnss_v_ccc_ppp_yyyymmddhhnnss.bin
W_XX-EUMETSAT-Darmstadt,SURFACE+SATELLITE,JASON2+OGDR_C_EUMS_yyyymmddhhnnss_v_ccc_ppp_yyyymmddhhnnss.bin

for the IGDR:

IGDR: JA2_IPN_2PvPccc_ppp_yyyymmdd_hhnnss_yyyymmdd_hhnnss.nc
IGDR-SSHA: JA2_IPR_2PvPccc_ppp_yyyymmdd_hhnnss_yyyymmdd_hhnnss.nc
S-IGDR: JA2_IPS_2PvPccc_ppp_yyyymmdd_hhnnss_yyyymmdd_hhnnss.nc

and for the GDR:

GDR: JA2_GPN_2PvPccc_ppp_yyyymmdd_hhnnss_yyyymmdd_hhnnss.nc
GDR-SSHA: JA2_GPR_2PvPccc_ppp_yyyymmdd_hhnnss_yyyymmdd_hhnnss.nc
S-GDR: JA2_GPS_2PvPccc_ppp_yyyymmdd_hhnnss_yyyymmdd_hhnnss.nc

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 (O)(I)GDR and this document

Section 3 is an overview of the OSTM/Jason-2 mission

Section 4 is an introduction to using the OSTM/Jason-2 data

Section 5 is an introduction to the OSTM/Jason-2 altimeter algorithms

Section 6 provides a description of the content and format of the OSTM/Jason-2 (O)(I)GDRs

Appendix A contains references

Appendix B contains acronyms

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

1.3. Document reference and contributors

When referencing this document, please use the following citation:

"OSTM/Jason-2 Products Handbook",

CNES :	**SALP-MU-M-OP-15815-CN**
EUMETSAT :	**EUM/OPS-JAS/MAN/08/0041**
JPL :	**OSTM-29-1237**
NOAA/NESDIS :	**Polar Series/OSTM J400**

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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

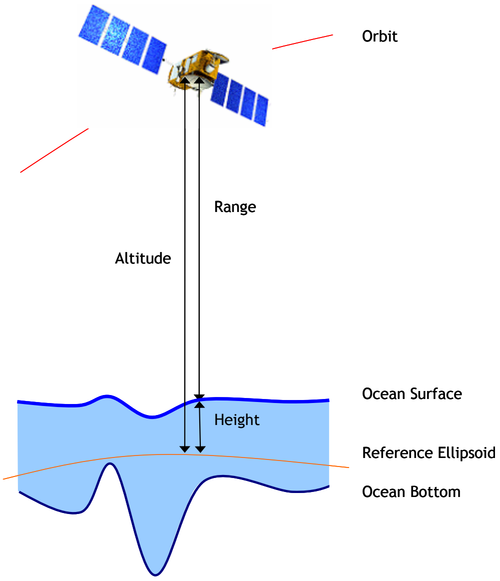


Figure 1 : Altimetric distances – Altitude, Range and Height

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 OGDR data is organized into files (“segments”) which corresponds 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 OSTM/Jason-2, 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). The passes are numbered from 1 to 254 representing a full repeat cycle of the OSTM/Jason-2 ground track. Ascending passes are odd numbered and descending passes are even numbered.

After one **repeat cycle** of 254 passes, OSTM/Jason-2 revisits the same ground-track within a margin of ±1 km. That means that every location along the OSTM/Jason-2 ground-track is measured every approximately 9.9 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 Jason-1 and 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

Corrected Quantity = Measured Value + 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

Times are UTC and referenced to **January 1, 2000 00:00:00.00**.

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. OSTM/Jason-2 Mission Overview

2.1. Background

Two previous high-accuracy altimetric missions, TOPEX/POSEIDON (T/P, launched in August 1992 and which last until October 2005) and Jason-1 (launched in December 2001) have been the key elements of a major turning point in physical oceanography, in terms of both scientific research and applications. Exceeding most initial specifications in terms of accuracy, T/P quickly became a unique tool to make significant progress in the understanding and modeling of ocean circulation and consequently on its climatic impact. The success of the T/P mission was mainly due to an appropriate optimization of the system: instruments, satellite, and orbit parameters were all specifically designed to fulfill the objectives of the mission. The T/P follow-on mission, Jason-1, was engaged soon after with the aim to provide the same level of performance, but with a significant decrease in weight and power needs, hence a much lower mission cost. In addition, near-real time applications were included in the main objectives of the mission.

Both missions, individually as well as combined have made essential contributions in other domains, like mean sea level surveys, tides, marine meteorology, geophysics and geodesy. Most notably the tandem mission phase, where Jason-1 and T/P were flying on the same orbit separated by only 70 s, provided a unique opportunity for intercalibration of both systems, hence improving further the scientific data quality. High accuracy radar altimeter missions are uniquely capable to globally and continuously observe the ocean and to better understand the short to long term changes of ocean circulation. They are now considered as essential components of global ocean observation systems. These systems integrate altimetric and other satellite and in-situ data into models and require the continuity and permanence of ocean measurements to produce time series over several decades.

The near-real time and short term capability of Jason-1 as well as ENVISAT (from ESA, launched in March 2002) have fed several pilot experiments that demonstrated the growing importance of operational ocean observation products and short-range ocean prediction for a variety of applications (ship routing, environmental hazards, support to maritime industries).

Also worth mentioning is the importance of wave and wind data provided by altimeter systems over oceans. This information is routinely used in meteorological and research entities, either for calibration of other data sets, assimilation in weather and wave models, or for statistical analysis.

2.2. OSTM/Jason-2 Mission

The OSTM/Jason-2 mission is built on the heritage of T/P and Jason-1, with two driving ambitions:

- Ensuring continuity of high quality measurements for ocean science
- Providing operational products for assimilation and forecasting applications

The main participation of the agencies is the following:

- CNES has provided the platform and payload module (see section 2.4)
- NASA and CNES have jointly provided the payload instruments (see section 2.4)
- NASA has provided launch services for the satellite
- CNES provides a command and control center for the satellite, a European Earth Terminal and data processing, archiving and distribution infrastructure for the mission
- NOAA provides a control center for the satellite, command and data acquisition (CDA) stations and data processing, archiving and distribution infrastructure for the mission
- EUMETSAT provides a site and infrastructure for accommodation of the European Earth terminal, to be integrated into the EUMETSAT Ground Segment infrastructure and data processing, archiving and near real time products distribution infrastructure for the mission

OSTM/Jason-2 was launched on **20 June 2008 at 7:46 GMT** and reached its **nominal repetitive orbit** on 4 July 2008. The start of cycle 1 occurred on 12 July 2008 at 01:20:05 GMT.

OSTM/Jason-2 was moved from nominal ground track early October 2016. After a series of maneuvers, the satellite reached the **interleaved orbit on October 14th 2016** in the middle of cycle 305.

The Jason missions support research programs such as the Climate Variability and Predictability program (CLIVAR) and the Global Ocean Data Assimilation Experiment (GODAE).

2.3. OSTM/Jason-2 Requirements

The major elements of the mission include:

- **An Earth orbiting 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
- **A Principal Investigator program** for feedback from operational applications and scientific studies based on the satellite observations

The sea-surface height measurement must be made with an accuracy of 3.4 cm or better (at 1 Hz) in order to meet the mission objectives. The OSTM/Jason-2 satellite is specified and designed to fulfill the mission objectives (AD 1) and to take over from the Jason-1 mission. As for Jason-1, distribution of altimetric products (non-validated) in near real time is planned. The interim (IGDR) and definitive (GDR) science products are delivered later (see Table 18 in section 6), following the model used for Jason-1.

To ensure that science and mission goals are accomplished by the OSTM/Jason-2 mission, the following requirements were established.

2.3.1. Accuracy of Sea-level Measurements

Generally speaking OSTM/Jason-2 has been specified based on the Jason-1 state of the art, including improvements in payload technology, data processing and algorithms or ancillary data (e.g: precise orbit determination and meteorological model accuracy). The sea-surface height shall be provided with a globally averaged RMS accuracy of 3.4 cm (1 sigma), or better, assuming 1 second averages.

The instrumental and environmental corrections are provided with the appropriate accuracy to meet this requirement. In addition to these requirements, a set of measurement-system goals was established based on the anticipated impact of off-line ground processing improvements. These improvements are expected to enable reduction of sea-surface height errors to 2.5 cm RMS. Knowledge of the stability of the system is especially important to the goal of monitoring the change in the global mean sea level, hence a specification on the system drift with a 1 mm/year goal.

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

Parameter	OGDR 3 hours		IGDR 1 to 1.5 days		GDR 40 days		
[redacted]							
Altimeter Noise[1]	1.7	1.8	1.7	1.8	1.7	1.5	1.8
[redacted]							
Sea State Bias[3]	3.5	2	2	2	2	1	2
[redacted]							
Wet Troposphere	1.2	0.8	1.2	0.8	1.2	1	0.8
[redacted]							
RMS Orbit (Radial Component)	10(4)	3.0(4)	2.5	1.5	1.5	1.0	1.0
[redacted]							
Signficant Wave Height[5]	10% or 0.5 m	TBD % or 0.12 m	10% or 0.4m	TBD % or 0.12 m	10% or 0.4m	5% or 0.25m	TBD % or 0.12 m
[redacted]							
Sigma Naught (absolute)	0.7 dB	0.1(6) dB	0.7 dB	0.1(6) dB	0.7 dB	0.5 dB	0.1(6) dB
[redacted]							

(1) – Ku-Band after ground retracking, averaged over 1 second, assuming 320 MHz C-Band bandwidth.
(2) – Filtered over 100 km assuming 320 MHz bandwidth.
(3) – Can also be expressed as 1% of SWH.
(4) – Real-time DORIS onboard ephemeris.
(5) – Whichever is greater.
(6) – After calibration to Jason-1.
(7) – On global mean sea level, after calibration.

Table 3 : Summary of error budget at the end of the verification phase

2.3.2. Sampling Strategy

As for Jason-1, sea level shall be measured along a fixed grid of subsatellite 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

As for Jason-1, 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 five years, with the potential to extend this period for an additional two years.

The OSTM/Jason-2 satellite shall overfly the reference Jason-1 ground tracks.

2.4. Satellite Description

The 500 kg satellite consists of a multi-mission PROTEUS platform and an OSTM/Jason-2 specific payload module. Both are provided by CNES. 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 OSTM/Jason-2 instruments.

The OSTM/Jason-2 payload (see Figure 2) includes the following components:

- **An Altimeter (Poseidon-3)**, provided by CNES – the main mission instrument
- **A Microwave Radiometer (AMR),** 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,** provided by NASA – to calibrate the orbit determination system
- **A precision GPS receiver (GPSP),** 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
- Three experimental passengers:

- **CARMEN-2 Radiation Detectors,** provided by CNES - to measure high-energy particles that could disturb the ultra-stable oscillator in the DORIS positioning unit
- **A Light Particle Telescope (LPT) detection unit,** provided by JAXA under CNES responsibility - complementing the measurement of radiation received by the DORIS instrument
- **Time Transfer by Laser Link (T2L2)** detectors, provided by CNES - for ultra-precise time transfer, to monitor the clock in the DORIS instrument

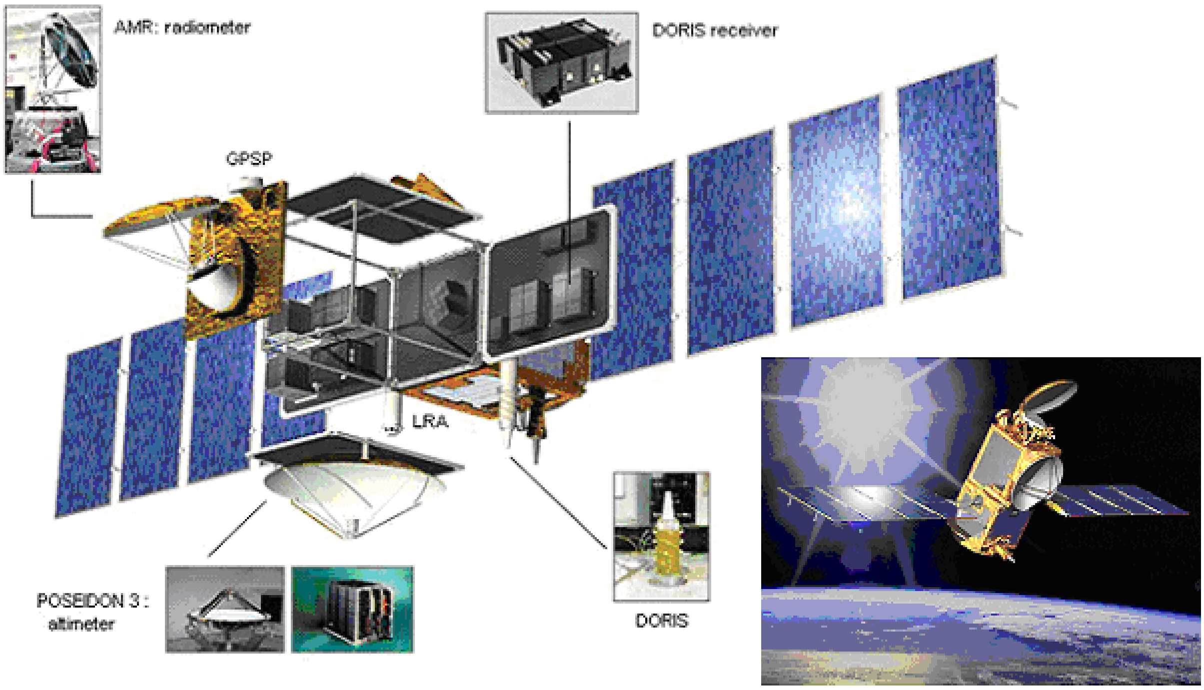


Figure 2 : OSTM/Jason-2 satellite (main components and artist view)

2.4.1. Satellite Characteristics

The main features of the OSTM/Jason-2 satellite are summed up in the following table.

Satellite mass	525 kg
Satellite power	511 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	Delta II (7320)
Launch Site	Vandenberg Air Force Base (AFB)

Table 4 : Main features of the OSTM/Jason-2 satellite

2.4.2. Sensors

2.4.2.1. Poseidon-3 Altimeter

The two-frequency solid-state altimeter, measuring range with accurate ionospheric corrections, is derived from the two-frequency Poseidon-2 altimeter embarked on Jason-1 mission and from the SIRAL altimeter. It operates at 13.575 GHz (Ku-band) and 5.3 GHz (C-band). Poseidon-3 electronics are configured in two boxes: the processing unit (PCU) and the radiofrequency unit (RFU).

- The processing unit includes the digital chirp generator, base-band demodulator, spectrum analyzer, instrument control unit and interfaces.
- The RF unit includes the up-conversion to the Ku and C bands, high power amplifier (solid state), low noise amplification of the received echoes and mixing with a reference chirp. The peak output powers are 6 to 8 W for the Ku band and 25 W for the C band.
- Poseidon-3 is dual string (in cold redundancy) without cross strapping and connected to the antenna through a switching box.
- Poseidon-3 antenna is of centered type (1.2 meter diameter) and located on the nadir face of the satellite.

Figure 3 : OSTM/Jason-2 Posidon-3 Instrument

2.4.2.2. Advanced Microwave Radiometer (AMR)

The three frequency microwave radiometer, named the Advanced Microwave Radiometer, consists of three separate channels at 18.7, 23.8 and 34 GHz. The radiometer is functionally equivalent to the Jason Microwave Radiometer found on Jason-1. The 23.8 GHz channel is the primary water vapor sensing channel, meaning higher water vapor concentrations leads to larger 23.8 GHz brightness temperature values. The addition of the 34 GHz channel and the 18.7 GHz channel, which have less sensitivity to water vapor, facilitate the removal of the contributions from cloud liquid water and excess surface emissivity of the ocean surface due to wind, which also act to increase the 23.8 GHz brightness temperature.

The AMR design is based on Monolithic Millimeter-wave Integrated Circuit (MMIC) technology and represents a giant leap forward from its predecessors (TMR and JMR) in both mass and size. Three redundant temperature controlled noise diodes are used for operational gain calibration in all the radiometers channels. The use of noise diodes eliminates the need for a cold sky calibration horn, which was employed on TMR. The JMR was the first space-borne radiometer to use noise diodes for calibration and the AMR is the second.

Another significant improvement in the AMR design is the addition of a 1-m reflector, compared to a 0.6 m reflector for TMR and JMR, which nearly doubles the spatial resolution of the AMR. The AMR is expected to produce reliable path delay measurements to within 15-20 km from the coast. The antenna is a fixed offset paraboloid (1 meter diameter) fed by a single three frequency coaxial corrugated horn feed. It is be located on the front of the satellite (+ X axis) and its beam is co-aligned with the altimeter footprint.

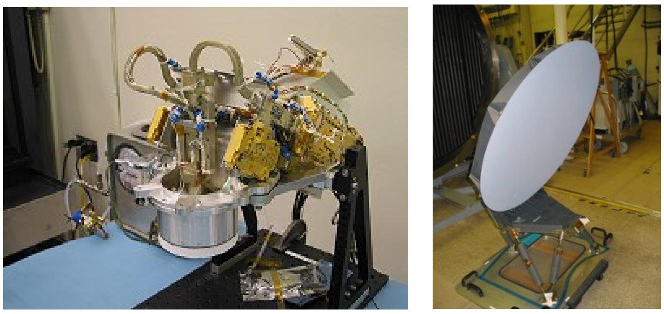


Figure 4 : OSTM/Jason-2 AMR Instrument and Antenna

2.4.2.3. DORIS System

The complete DORIS system includes the DORIS on board package, a network of approximately 50 beacons located around the world and a ground system.

The on board package includes the receiver itself, the ultrastable oscillator and an omnidirectional antenna located on the nadir face of the satellite.

The DORIS on board package is a new version of the DORIS instrument (all the functions included in a single unit). It includes a 8-beacons receiving capability and an on-board real time function (DIODE = "*Détermination Immédiate d'Orbite par DORIS Embarqué*") to compute the orbit ephemeris.

The DORIS on board package is also dual string (in cold redundancy) without cross strapping and connected to the single antenna through a switching box. Each receiver is connected to its own ultra stable oscillator.

The DORIS antenna is located on the nadir side of the satellite.

Figure 5 : OSTM/Jason-2 DORIS Receiver Antenna and Instrument

2.4.2.4. Laser Reflector Array

The laser reflector array is placed on the nadir face of the satellite. It consists of several quartz corner cubes arrayed as a truncated cone with one in the center and the others distributed azimuthally around the cone.

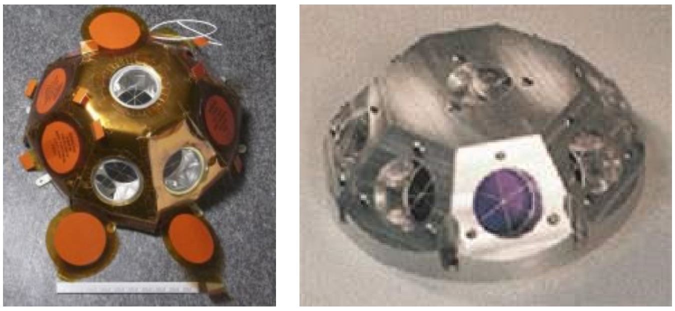


Figure 6 : OSTM/Jason-2 Laser Reflector Array

2.4.2.5. GPS Receiver

The GPS Payload receiver is a twelve channel Global Positioning system receiver. The on board package is comprised of a down-converter processor assembly, two antennas and interconnecting RF cables.

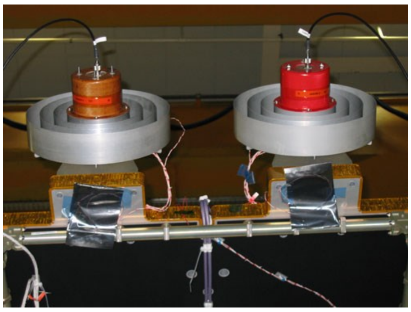


Figure 7 : OSTM/Jason-2 Precision GPS Receiver

2.4.2.6. CARMEN-2 Radiation Detectors

CARMEN-2 is the mission name for the ICARE-NG instrument aboard OSTM/Jason-2 satellite.

This instrument is dedicated to study the influence of space radiation on advanced components to measure e-, p+ and ion fluxes in the energy ranges responsible for component effects (as ionizing dose, single event effect and displacement damage), to measure associated effects on test components, to characterize the local radiation environment for DORIS USO and to evaluate its potential drifts inside the SAA.

The on board package includes only ICARE-NG box that is composed of a CPU, data processing & TM/TC unit, a custom DC/DC converter, a Data acquisition unit for the set of three radiation detectors and the component test bed.

Figure 8 : OSTM/Jason-2 CARMEN-2 Instrument

2.4.2.7. LPT Detection Unit

The LPT Detection Unit is composed of one detector box (LPT) and one electronic box (LPT-E). All the electrical interfaces with the satellite are through the LPT-E.

The detectors are placed on the satellite in order to see the same radiation environment and at the vicinity of DORIS BDR. The LPT-S is an assembly of four sensors, each adapted to different particles and energy band.

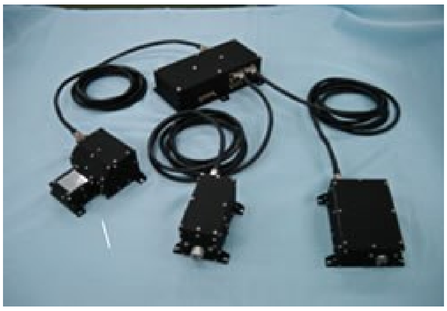


Figure 9 : OSTM/Jason-2 LPT

2.4.2.8. T2L2 Detectors

The T2L2 experiment onboard equipment is constituted of a photo-detection device, a time tagging unit and uses the Laser Reflector Array (LRA). The laser station emits light pulses in the OSTM/Jason-2 direction. The LRA returns a fraction of the received photons to the station.

The T2L2 onboard instrument is organized in 2 main subsystems: the optical one and the electronic one.

Two Optical Units collect a part of the laser pulse, one for the time dating and the other one for detection and amplitude measurement of the pulse.

The Electronic Unit ensures the conversion of the laser pulse into an electronic signal which is dated with a very high precision and the management of the whole instrument.

Figure 10 : OSTM/Jason-2 T2L2 Optics Unit

2.4.3. Orbit

2.4.3.1. Repetitive orbit on historical ground track (June 2008 – October 2016)

The OSTM/Jason-2 satellite flies on the same ground-track as Jason-1 and the original T/P with a 254 pass, 10-day exact repeat cycle. As during the Jason-1 Cal/Val phase, Jason-2 was placed close to Jason-1 (1 minute apart) in order to allow inter-calibration of all systems. Then Jason-1 was moved to an interleaved ground track (as was T/P in August 2002).

Orbital characteristics and the equator crossing longitudes for OSTM/Jason-2 are given in Tables 10 and 11. Figure below is a plot of the ground track on a world map.

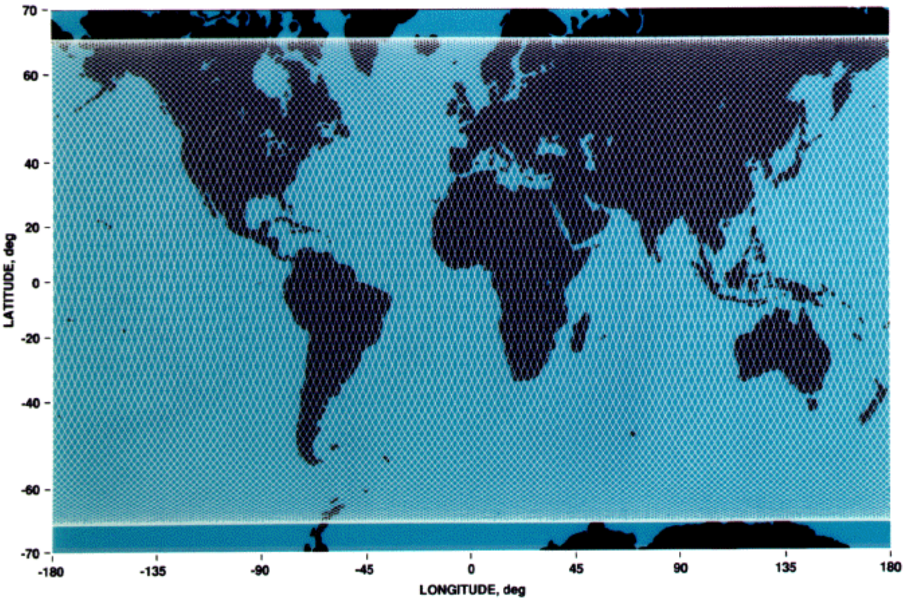


Figure 11 : T/P, Jason-1 and OSTM/Jason-2 ground track coverage every 10 days

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

Orbit element	Value
Semi-major axis	7,714.432 km
Eccentricity	0.000098
Inclination	66.042 deg
Argument of periapsis	90.0 deg
Inertial longitude of the ascending node	116.56 deg
Mean anomaly	253.13 deg

Table 5. Mean classical orbit elements

The orbit auxiliary data are given in the table below.

Auxiliary Data	Values
Reference (Equatorial) altitude	1,339 km
Nodal period	6,745.7605 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	39.4 deg
Longitude of Equator crossing of pass 1	99.9242 deg

Inertial nodal rate	- 2.07707 deg/day
Orbital speed	7.2 km/s
Ground track speed	5.8 km/s

Table 6 : Orbit auxiliary data

This orbit overflies two verification sites funded by NASA and CNES. The prime CNES verification site is located at Cape Senetosa on the island of Corsica (8°48' E, 41°34' N, ascending pass 85). The prime NASA verification site is located on the Harvest oil platform near Pt. Conception, California (239° 19' E, 34° 28' N, ascending pass 43).

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 using only one thrust to minimize impacts on the ground orbit solution. Orbit computation is optimized to minimize the orbit error during such periods. Science data are taken during orbit maintenance maneuvers and are 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	Pass	Longitude	Pass	Longitude	Pass	Longitude	Pass	Longitude	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 7 : Equator Crossing Longitudes (in order of Pass Number)

2.4.3.1.2. Equator Crossing Longitudes (in order of Longitude)

Pass	Longitude	Pass	Longitude	Pass	Longitude	Pass	Longitude	Pass	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 8 : Equator Crossing Longitudes (in order of Longitude)

2.4.3.2. Repetitive orbit on interleaved orbit (October 2016-Nowadays)

After approval by the Joint Steering Group (held on 12 Sept 2016), the OSTM/Jason-2 satellite was moved to a new ground track early October 2016 after the end of repeat cycle 303, after more than 8 years of service on the nominal ground track.

The satellite was moved to the same interleaved orbit that was used by Topex from 2002-2005 and Jason-1 from 2009-2012. Several maneuvers were performed between October 2nd, 2016, and October 14th, 2016.

Regarding the interleaved OSTM/Jason-2 orbit.

- OSTM/Jason-2 uses the same pass numbering scheme adopted by Topex and Jason-1 in the interleaved ground track. However, the start time of the OSTM/Jason-2 and Jason-3 repeat cycles differs by approximately 5 days.
- The first OSTM/Jason-2 repeat cycle on the new interleaved ground track is cycle 305.
- The OSTM/Jason-2 altimeter was placed in wait mode and data production (OGDR, IGDR and GDR) was stopped during the transit to the interleaved orbit. It was restarted during cycle 305 with the same requirements for data latency and quality.

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

Pass	Longitude	Pass	Longitude	Pass	Longitude	Pass	Longitude	Pass	Longitude	Pass	Longitude
1	98.51	**44**	29.06	**87**	319.62	**130**	250.17	**173**	180.72	**216**	111.27
2	264.34	**45**	194.89	**88**	125.44	**131**	55.99	**174**	346.55	**217**	277.10
3	70.17	**46**	0.72	**89**	291.27	**132**	221.82	**175**	152.37	**218**	82.92
4	235.99	**47**	166.54	**90**	97.10	**133**	27.65	**176**	318.20	**219**	248.75
5	41.82	**48**	332.37	**91**	262.92	**134**	193.48	**177**	124.03	**220**	54.58
6	207.65	**49**	138.20	**92**	68.75	**135**	359.30	**178**	289.85	**221**	220.40
7	13.47	**50**	304.03	**93**	234.57	**136**	165.13	**179**	95.68	**222**	26.23
8	179.30	**51**	109.85	**94**	40.40	**137**	330.95	**180**	261.51	**223**	192.06
9	345.13	**52**	275.68	**95**	206.23	**138**	136.78	**181**	67.33	**224**	357.89
10	150.96	**53**	81.51	**96**	12.06	**139**	302.61	**182**	233.16	**225**	163.71
11	316.78	**54**	247.33	**97**	177.88	**140**	108.44	**183**	38.99	**226**	329.54
12	122.61	**55**	53.16	**98**	343.71	**141**	274.26	**184**	204.81	**227**	135.36
13	288.43	**56**	218.99	**99**	149.54	**142**	80.09	**185**	10.64	**228**	301.19
14	94.26	**57**	24.81	**100**	315.37	**143**	245.91	**186**	176.47	**229**	107.02
15	260.09	**58**	190.64	**101**	121.19	**144**	51.74	**187**	342.29	**230**	272.85
16	65.92	**59**	356.47	**102**	287.02	**145**	217.57	**188**	148.12	**231**	78.67
17	231.74	**60**	162.29	**103**	92.84	**146**	23.40	**189**	313.95	**232**	244.50
18	37.57	**61**	328.12	**104**	258.67	**147**	189.22	**190**	119.78	**233**	50.32
19	203.39	**62**	133.95	**105**	64.50	**148**	355.05	**191**	285.60	**234**	216.15
20	9.22	**63**	299.77	**106**	230.33	**149**	160.88	**192**	91.43	**235**	21.98
21	175.05	**64**	105.60	**107**	36.15	**150**	326.71	**193**	257.25	**236**	187.81
22	340.88	**65**	271.43	**108**	201.98	**151**	132.53	**194**	63.08	**237**	353.63
23	146.70	**66**	77.25	**109**	7.80	**152**	298.36	**195**	228.91	**238**	159.46
24	312.53	**67**	243.08	**110**	173.63	**153**	104.18	**196**	34.73	**239**	325.29
25	118.36	**68**	48.91	**111**	339.46	**154**	270.01	**197**	200.56	**240**	131.11
26	284.18	**69**	214.73	**112**	145.29	**155**	75.84	**198**	6.39	**241**	296.94
27	90.01	**70**	20.56	**113**	311.11	**156**	241.66	**199**	172.21	**242**	102.77
28	255.84	**71**	186.39	**114**	116.94	**157**	47.49	**200**	338.04	**243**	268.59
29	61.66	**72**	352.22	**115**	282.77	**158**	213.32	**201**	143.87	**244**	74.42
30	227.49	**73**	158.04	**116**	88.59	**159**	19.14	**202**	309.70	**245**	240.24

31	33.32	**74**	323.87	**117**	254.42	**160**	184.97	**203**	115.52	**246**	46.07
32	199.14	**75**	129.69	**118**	60.25	**161**	350.80	**204**	281.35	**247**	211.90
33	4.97	**76**	295.52	**119**	226.07	**162**	156.63	**205**	87.18	**248**	17.73
34	170.80	**77**	101.35	**120**	31.90	**163**	322.45	**206**	253.00	**249**	183.55
35	336.62	**78**	267.18	**121**	197.72	**164**	128.28	**207**	58.83	**250**	349.38
36	142.45	**79**	73.00	**122**	3.55	**165**	294.10	**208**	224.66	**251**	155.21
37	308.28	**80**	238.83	**123**	169.38	**166**	99.93	**209**	30.48	**252**	321.04
38	114.11	**81**	44.65	**124**	335.21	**167**	265.76	**210**	196.31	**253**	126.86
39	279.93	**82**	210.48	**125**	141.03	**168**	71.59	**211**	2.14	**254**	292.69
40	85.76	**83**	16.31	**126**	306.86	**169**	237.41	**212**	167.96		
41	251.58	**84**	182.14	**127**	112.69	**170**	43.24	**213**	333.79		
42	57.41	**85**	347.96	**128**	278.52	**171**	209.06	**214**	139.62		
43	223.24	**86**	153.79	**129**	84.34	**172**	14.89	**215**	305.44		

Table 9 : Equator Crossing Longitudes (in order of Pass Number)

2.4.3.2.2. Equator Crossing Longitudes (in order of Longitude)

Pass	Longitude	Pass	Longitude	Pass	Longitude	Pass	Longitude	Pass	Longitude	Pass	Longitude
46	0.72	**29**	61.66	**12**	122.61	**249**	183.55	**232**	244.50	**215**	305.44
211	2.14	**194**	63.08	**177**	124.03	**160**	184.97	**143**	245.91	**126**	306.86
122	3.55	**105**	64.50	**88**	125.44	**71**	186.39	**54**	247.33	**37**	308.28
33	4.97	**16**	65.92	**253**	126.86	**236**	187.81	**219**	248.75	**202**	309.70
198	6.39	**181**	67.33	**164**	128.28	**147**	189.22	**130**	250.17	**113**	311.11
109	7.80	**92**	68.75	**75**	129.69	**58**	190.64	**41**	251.58	**24**	312.53
20	9.22	**3**	70.17	**240**	131.11	**223**	192.06	**206**	253.00	**189**	313.95
185	10.64	**168**	71.59	**151**	132.53	**134**	193.48	**117**	254.42	**100**	315.37
96	12.06	**79**	73.00	**62**	133.95	**45**	194.89	**28**	255.84	**11**	316.78
7	13.47	**244**	74.42	**227**	135.36	**210**	196.31	**193**	257.25	**176**	318.20
172	14.89	**155**	75.84	**138**	136.78	**121**	197.72	**104**	258.67	**87**	319.62
83	16.31	**66**	77.25	**49**	138.20	**32**	199.14	**15**	260.09	**252**	321.04
248	17.73	**231**	78.67	**214**	139.62	**197**	200.56	**180**	261.51	**163**	322.45
159	19.14	**142**	80.09	**125**	141.03	**108**	201.98	**91**	262.92	**74**	323.87
70	20.56	**53**	81.51	**36**	142.45	**19**	203.39	**2**	264.34	**239**	325.29
235	21.98	**218**	82.92	**201**	143.87	**184**	204.81	**167**	265.76	**150**	326.71
146	23.40	**129**	84.34	**112**	145.29	**95**	206.23	**78**	267.18	**61**	328.12
57	24.81	**40**	85.76	**23**	146.70	**6**	207.65	**243**	268.59	**226**	329.54
222	26.23	**205**	87.18	**188**	148.12	**171**	209.06	**154**	270.01	**137**	330.95
133	27.65	**116**	88.59	**99**	149.54	**82**	210.48	**65**	271.43	**48**	332.37
44	29.06	**27**	90.01	**10**	150.96	**247**	211.90	**230**	272.85	**213**	333.79
209	30.48	**192**	91.43	**175**	152.37	**158**	213.32	**141**	274.26	**124**	335.21
120	31.90	**103**	92.84	**86**	153.79	**69**	214.73	**52**	275.68	**35**	336.62
31	33.32	**14**	94.26	**251**	155.21	**234**	216.15	**217**	277.10	**200**	338.04
196	34.73	**179**	95.68	**162**	156.63	**145**	217.57	**128**	278.52	**111**	339.46
107	36.15	**90**	97.10	**73**	158.04	**56**	218.99	**39**	279.93	**22**	340.88
18	37.57	**1**	98.51	**238**	159.46	**221**	220.40	**204**	281.35	**187**	342.29
183	38.99	**166**	99.93	**149**	160.88	**132**	221.82	**115**	282.77	**98**	343.71
94	40.40	**77**	101.35	**60**	162.29	**43**	223.24	**26**	284.18	**9**	345.13
5	41.82	**242**	102.77	**225**	163.71	**208**	224.66	**191**	285.60	**174**	346.55

170	43.24	**153**	104.18	**136**	165.13	**119**	226.07	**102**	287.02	**85**	347.96
81	44.65	**64**	105.60	**47**	166.54	**30**	227.49	**13**	288.43	**250**	349.38
246	46.07	**229**	107.02	**212**	167.96	**195**	228.91	**178**	289.85	**161**	350.80
157	47.49	**140**	108.44	**123**	169.38	**106**	230.33	**89**	291.27	**72**	352.22
68	48.91	**51**	109.85	**34**	170.80	**17**	231.74	**254**	292.69	**237**	353.63
233	50.32	**216**	111.27	**199**	172.21	**182**	233.16	**165**	294.10	**148**	355.05
144	51.74	**127**	112.69	**110**	173.63	**93**	234.57	**76**	295.52	**59**	356.47
55	53.16	**38**	114.11	**21**	175.05	**4**	235.99	**241**	296.94	**224**	357.89
220	54.58	**203**	115.52	**186**	176.47	**169**	237.41	**152**	298.36	**135**	359.30
131	55.99	**114**	116.94	**97**	177.88	**80**	238.83	**63**	299.77		
42	57.41	**25**	118.36	**8**	179.30	**245**	240.24	**228**	301.19		
207	58.83	**190**	119.78	**173**	180.72	**156**	241.66	**139**	302.61		
118	60.25	**101**	121.19	**84**	182.14	**67**	243.08	**50**	304.03		

Table 10 : Equator Crossing Longitudes (in order of Longitude)

2.4.4. The OSTM/Jason-2 Project Phases

The satellite mission has two phases:

The calibration/validation phase (9 months) began shortly after launch, when the satellite reached the operational (nominal repetitive) 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. Unlike Jason-1, the Cal/Val phase is divided in 2 phases which overlap:

1. One dedicated to the validation of the near real time products (OGDRs). An OSTST meeting in November 2008 was organized to validate those products and to provide the validation status required to allow data dissemination to end users. Since Jason-1 was to be moved to the interleaved orbit in early 2009, and taking into account the very good data quality of Jason-2 IGDR products, it was also decided to disseminate IGDR off-line products to end users in January 2009.
2. The second phase was dedicated to the validation of the off-line products (IGDR and GDR). An OSTST meeting in June 2009 was organized to validate those products and to provide the validation status required to allow data dissemination to end users.

The operational phase begins after the successful validation of each product type, and when all necessary algorithm and processing changes are implemented to have OSTM/Jason-2 performances at the same level as Jason-1.

2.5. Data Processing and Distribution

Processing centers perform functions such as science data processing, data verification and orbit determination.

There are three levels of processed data:

- Telemetry data (raw data or level0)
- Sensor Data Records (engineering units or level1)
- Geophysical Data Records (geophysical units or level2)

There are two kinds of data processing and distribution:

- Real-time processing and distribution (EUMETSAT and NOAA)

The operational geophysical data record (OGDR) is available with a latency of 3-5 hours. Note that this is a non-validated product that uses orbits computed by the on-board DORIS Navigator (DIODE) and that it does not contain all the environmental/geophysical corrections.

- Delayed-mode processing (CNES) and distribution (CNES and NOAA)

The interim geophysical data record (IGDR) is available per pass with a latency of 2 days. Note that this is not a fully validated product, although it uses a preliminary orbit and includes all the environmental/geophysical corrections (preliminary for some of them).

The geophysical data record (GDR) is a fully validated product that uses a precise orbit and the best environmental/geophysical corrections. This product is available per repeat cycle with a latency of 90 days. Validation is performed by two teams at CNES and NASA/JPL to ensure in depth validation.

Geophysical data records are disseminated to users as they become available, as well as ingested in two main archives (at CNES and NOAA), where they are made available to the scientific community.

The NRT and offline data are provided through different sources and means as discussed below. Note that the telemetry acquisition strategy, designed to minimize the risk of science data loss, sometimes results in files containing data which overlaps in time. The NRT ground processing does not remove these overlaps, so it is possible to encounter two or more OGDR products which have overlapping start and stop sensing times. CNES-EUMETSAT-NOAA centers are disseminating Jason-2 products according to the interagency agreement.

- **CNES via AVISO+ data services:** http://www.aviso.altimetry.fr

“Archiving, Validation and Interpretation of Satellite Oceanographic data” is the French multi-satellite data distribution center dedicated to space oceanography, developed by CNES.

AVISO+ distributes and archives Jason-2 delayed-time data ((I)GDR).

- **EUMETSAT**: http://www.eumetsat.int

EUMETSAT is the European Organisation for the Exploitation of Meteorological Satellites. Its role is to deliver weather and climate-related satellite data, images and products– 24 hours a day, 365 days a year.

EUMETSAT distributes operational data (OGDR)

- **NOAA**: http://www.noaa.gov

The mission of the US National Oceanic and Atmospheric Administration is to understand and predict changes in Earth’s environment and conserve and manage coastal and marine resources to meet USA’s economic, social, and environmental needs

NOAA distributes operational data, and distributes and archives delayed-time data ((O)(I)GDR)

2.5.1. Access to NRT data

The OGDR, OGDR-SSHA, and OGDR-BUFR files are produced at NOAA and EUMETSAT. Telemetry data downlinked to NOAA’s ground stations at Wallops, VA and Fairbanks, AK are used to produce NOAA OGDR products, while telemetry data downlinked to the EUMETSAT earth terminal at Usingen, Germany are used to produce EUMETSAT OGDRs. NOAA and EUMETSAT exchange their products so that both agencies have a complete set.

In near real time, NOAA disseminates the complete set of OGDR files via ftp and EUMETSAT disseminates the complete set of OGDR files on EUMETCast. The complete set of OGDR files consists of OGDR, OGDR-SSHA and OGDR-BUFR, both generated at EUMETSAT and NOAA.

Note that the OGDR-BUFR files available from NOAA/CLASS use a filename similar to the native and reduced-SSHA filenames, beginning with ‘JA2_OPB’. The UMARF archive at EUMETSAT utilizes the WMO/GTS filenames indicated above, beginning with ‘W_US’ for NOAA OGDR-BUFR files and ‘W_XX” for the EUMETSAT generated OGDR-BUFR files.

The OGDR-BUFR data are additionally available in near real-time from the Global Telecommunications System (GTS). NOAA and EUMETSAT inject only their own OGDR-BUFR files onto GTS, to avoid duplication.

Details on data dissemination services from NOAA and EUMETSAT agencies are described below.

2.5.2. Access to off-line data

The IGDR and GDR families of files are produced solely by CNES, and are available to users from NOAA's Comprehensive Large Array-Data Stewardship System (CLASS; http://www.class.noaa.gov), and from the French Archiving, Validation, and Interpretation of Satellite Oceanographic data (AVISO; http://www.aviso.oceanobs.com) ftp server. Both of these archival facilities also provide a variety of auxiliary files used to produce the O/I/GDR datasets, and NOAA also provides the OGDR family of datasets.

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

2.5.3. Documentation and Sample Reader Software

This Jason-2 User's Handbook document describes only the native product format. A description of the O/I/GDR product format and contents is provided in the CNES document "SALP-ST-M-EA-15704-CN: SALP Products Specification - Volume 1: Jason-2 User Products". All documents are available through the data dissemination services.

NOAA has developed sample reading routines in Fortran-90, C, and IDL. Those tools are also available through the data dissemination services.

A BUFR reading software library can be obtained from:
http://www.ecmwf.int/products/data/software/bufr.html

2.6. Access to data via NOAA

2.6.1. Access to NRT data

Individual users who require science data in near-real-time can access the O/I/GDR at the National Oceanographic Data Center (NODC): http://www.nodc.noaa.gov/SatelliteData/. Supported access methods include direct ftp, http, and OPeNDAP and THREDDS. Helpdesk support is available during normal business hours via NODC.services@noaa.gov. Users with specific technical questions about Jason-2 data products may also write to NODC.SatelliteTeam@noaa.gov. Subscriptions to specified data streams as well as access to ancillary, auxiliary, orbital and other types of Jason-3 data are available via the NOAA CLASS system, as described under "2.6.2: Offline Data Access" below.

Operational users who demonstrate a need for minimum latency near real-time access will need to register with NOAA's Product Distribution & Access server (PDA). Please contact the PDA administrator (PDA_Administrator@noaa.gov) to determine if PDA access is needed for your use. Online registration will be provided once approval has been given to use the PDA.

2.6.2. Access to off line data

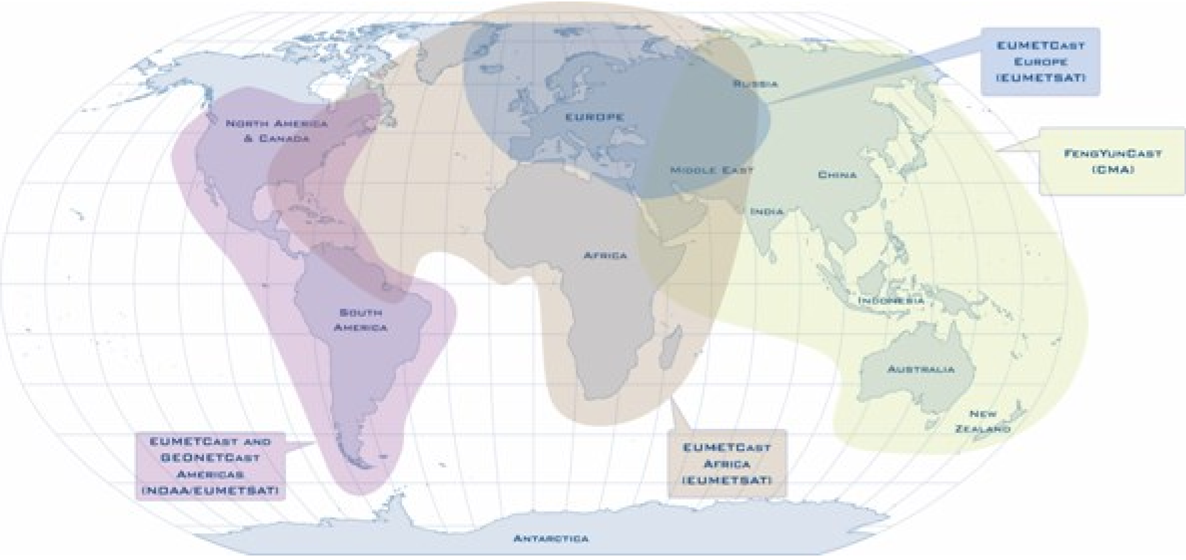
To access Jason-2 data from CLASS, a user must first register for an account at: http://www.class.noaa.gov/saa/products/user_profile. Further instructions on using CLASS to search for and retrieve data, and to optionally set up user subscription services, can be found on the CLASS help pages at: http://www.class.noaa.gov/notification/demo.htm. CLASS latency for data provision ranges from a few hours for data by subscription, to a few days for one-off orders, to a week or more for a large (bulk) order.

2.7. Access to data via EUMETSAT

2.7.1. NRT data access

Operational users requiring near real-time access (within a few hours of acquisition) can receive data via EUMETCast, which is the prime dissemination mechanism for EUMETSAT satellite data and meteorological products. EUMETCast is also used to deliver data supplied by several external data providers.

EUMETCast is an environmental data and product dissemination system based on standard Digital Video Broadcast (DVB) technology. It uses commercial telecommunication geostationary satellites to broadcast data and products to a wide user community. EUMETSAT operates three EUMETCast broadcasts: EUMETCast Europe in Ku-band via Hotbird-6 EUMETCast Africa in C-band via AtlanticBird-3 and EUMETCast South America in C-band via NewSkies-806. The coverage zones of these broadcasts are shown in Figure below. The OSTM/Jason2 OGDR products are currently disseminated over all beams.



GEONETCast Coverage Zones

EUMETCast is part of a wider data dissemination cooperation network known as GEONETCast, defined as a global network of satellite based data dissemination systems providing environmental data to a world-wide user community. The current partners within the GEONETCast initiative include the National Oceanic and Atmospheric Administration (NOAA), the World Meteorological Organization (WMO) and EUMETSAT, as well as many prospective data provider partners.

EUMETCast is a multi-service dissemination mechanism and other environmental data streams and products are also delivered via EUMETCast :

- Space-based observations from the Meteosat, Metop, GOES, MT-SAT and FY2 satellites – at their most frequent, these data are delivered to Users within 5-minutes of processing
- MODIS level 1and 2 products covering selective geographical regions
- Numerical Weather Forecasts
- In-situ observational data
- Land application products covering Europe, Africa and South America
- Marine meteorological and ocean surface products covering the Atlantic, Mediterranean Sea and Yellow Sea
- Atmospheric chemistry products

EUMETCast has an installed user base of over 2500 stations worldwide.

A typical EUMETCast reception station comprises a standard PC with DVB card inserted and a satellite off-set antenna fitted with a digital universal V/H LNB. All components of the reception station are commercially available. The hardware costs for a single PC station for EUMETCast Europe (Ku-band) reception start at around €1,500. In addition, EUMETCast Client Software package is required for handling the incoming DVB and storing it as data files. This package is available directly from EUMETSAT at a one of fee of €100and forms part of any registration process.

Further information on EUMETCast can be found on the EUMETSAT Web site at:

http://www.eumetsat.int/Home/Main/What_We_Do/EUMETCast/index.htm?l=en or alternatively follow the links to 'What We Do'-'EUMETCast'. Note that the coverage of EUMETCast is achieved through different beams, and the user location will determine the technical requirements of the EUMETCast reception station equipment.

The Jason-2 products available via EUMETCast are the EUMETSAT and NOAA injected OGDR, OGDR-SSHA and OGDR-BUFR. To access these on EUMETCast, users are requested to register online via the EUMETSAT Web site, or to contact the EUMETSAT User Service Helpdesk. As for Jason-1 near real-time products, already disseminated by EUMETSAT via EUMETCast, the Jason-2 products will be disseminated on all EUMETCast channels (Europe, Americas and Africa).

All enquiries related to EUMETCast can be addressed to the EUMETSAT User Helpdesk, email ops@eumetsat.int, who will be happy to assist with information on reception station manufacturers, reception station setup and data access registration to the Jason-2 service, or indeed to other near real-time EUMETSAT data services.

2.7.2. Access to archived data

The Jason-2 products generated and distributed by EUMETSAT in near real-time (i.e., OGDR, OGDR-SSHA and OGDR-BUFR) are also archived in the multi-mission EUMETSAT Archive. Any user can access Jason-2 data from the EUMETSAT archive upon registration. Information on registration, the archive itself and how to use it can be found at http://archive.eumetsat.org/umarf or follow the links to 'Access to Data' and then 'Archive Service'. Data delivery media include, among others, direct ftp push to a provided IP address, including the possibility of establishing standing orders, or download by the user from an html page. Note however that this is not a near real-time data access, but that it can take up to several hours and occasionally even days to get the data.

2.8. Access to data on GTS

2.8.1.1. GTS access for OGDR-BUFR files

All of the OGDR-BUFR data, whether injected by NOAA or EUMETSAT, will appear on the World Meteorological Organization's GTS network. End users with a GTS presence (typically large meteorological agencies) can retrieve the data by keying on the WMO/GTS headers specific to the Jason-2 data: 'ISZX01 KNES' for NOAA OGDR-BUFR files, and 'ISZX01 EUMS' for EUMETSAT OGDR-BUFR files. The original files are comprised of approximately 15 minute BUFR 'messages' which will appear separately on the GTS.

It is also possible to scour the NOAA National Weather Service's GTS ftp server for the individual messages, by searching for 'ISZX01' strings. At this time, the OGDR-BUFR messages have been appearing at the following location, but future access at this specific site cannot be guaranteed:

http://tgftp.nws.noaa.gov/SL.us008001/DF.bf/DC.sfsat/DS.qscat

2.9. CNES data distribution

2.9.1. Details of off line data access via CNES

Users have access to Jason-2 public data through a dedicated AVISO+ ftp server with an anonymous account. Off line IGDR and GDR products are available on the following server:

IP address: avisoftp.cnes.fr

User account: anonymous

Home directory : /AVISO/pub/jason-2

With the following ftp server directory tree:

documentation → directory containing product spec, product handbook, reading tools, …

igdr → directory containing IGDR native products (with a sub directory for each cycle and sub directory containing the latest data)

sigdr → directory containing S-IGDR (with a unique sub directory containing the latest data)

ssha_igdr → directory containing IGDR reduced products (with a sub directory for each cycle and a sub directory containing the latest data)

gdr_d → directory containing GDR native products (with a sub directory for each cycle)

sgdr_d → directory containing S-GDR (with a sub directory for each cycle)

ssha_gdr_d → directory containing GDR reduced products (with a sub directory for each cycle)

gdr_d_validation_report → directory containing GDR-D validation reports

For any questions on Jason-2 data dissemination on AVISO+ servers please contact:

aviso@altimetry.fr

2.10. Jason-1 Data Products at AVISO and PODAAC

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 on the AVISO and PODAAC ftp servers.

2.10.1. Jason-1 Products on AVISO FTP Server.

The AVISO server for Jason-1 products is:

avisoftp.cnes.fr

Login anonymous

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

/AVISO/pub/jason-1/igdr_netcdf/igdr → directory containing IGDR native products
/AVISO/pub/jason-1/igdr_netcdf/sigdr → directory containing S-IGDR
/AVISO/pub/jason-1/igdr_netcdf/ssha → directory containing IGDR reduced products
/AVISO/pub/jason-1/gdr_c_netcdf/gdr → directory containing GDR native products (with a sub directory for each cycle)
/AVISO/pub/jason-1/gdr_netcdf/ssha → directory containing GDR reduced products (with a sub directory for each cycle)

Jason-1 products in their original format continue to be available in the following directories:

/AVISO/pub/jason-1/igdr → directory containing IGDR products

/AVISO/pub/jason-1/gdr_c → directory containing GDR native products

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

aviso@altimetry.fr

2.10.2. Jason-1 Products on PODAAC FTP Server.

The PODAAC server for Jason-1 products is:

podaac.jpl.nasa.gov

Login anonymous

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

/pub/sea_surface_height/jason/igdr_netcdf → directory containing IGDR native products
/pub/sea_surface_height/jason/igdr_ssha_netcdf → directory containing IGDR reduced products

/pub/sea_surface_height/jason/gdr_netcdf_c → directory containing GDR native products (with a sub directory for each cycle)

/pub/sea_surface_height/jason/gdr_ssha_netcdf_c→ directory containing GDR reduced products

Jason-1 products in their original format continue to be available in the following directories:

/pub/sea_surface_height/jason/osdr → directory containing OSDR products

/pub/sea_surface_height/jason/igdr → directory containing IGDR products

/pub/sea_surface_height/jason/gdr_c → directory containing GDR native products

/pub/sea_surface_height/jason/j1_ssha → directory containing GDR reduced products

/pub/sea_surface_height/jason/j1_atg→ directory containing GDR reduced products

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 Product Version "T" and O/IGDR Product Version "c"

3.1.1.1. Models and Standards

The version of the data produced during the Cal/Val phase of the Jason-2 mission is identified by the version letter "T" in the name of the data products.

This product version adopts models and standards that are consistent with version "c" of the Jason-1 (I)GDR products (see RD 2). Since the OSTST meeting held in November 2008, OGDR and IGDR products are available to end users and identified by the version letter "c" in the name of the data products. The version 'T' calibration/validation GDRs have been extensively validated by the Ocean Surface Topography Science Team (OSTST) during the OSTST meeting held in June 2009, who found that these GDRs are demonstrating excellent data quality, and consistency with the Jason-1 version 'c' GDRs. The OSTST recommended so release of the Jason-2/OSTM Version 'T' GDRs as is. There are a few known minor issues with some fields in the version 'T' GDRs (see Jason-2 GDR_T release note). These issues are corrected in the Jason-2 version 'd' GDRs.

The table below summarizes the models and standards that are adopted in this version of the OSTM/Jason-2 (O)(I)GDRs. Section 3.2 provides more details on some of these models.

Model	GDR Product Version "T" and O/IGDR Product Version "c"
Orbit	Based on Doris onboard navigator solution for OGDRS. DORIS tracking data for IGDRs DORIS+SLR+GPS tracking data for GDRs.
Altimeter Retracking	“Ocean” retracking MLE4 fit from 2nd order Brown analytical model : MLE4 simultaneously retrieves the 4 parameters that can be inverted from the altimeter waveforms: - Epoch (tracker range offset) ⇒ altimeter range - Composite Sigma ⇒ SWH - Amplitude ⇒ Sigma0 - Square of mispointing angle (Ku band only, a null value is used in input of the C band retracking algorithm) “Ice” retracking Geometrical analysis of the altimeter waveforms, which retrieves the following parameters: - Epoch (tracker range offset) ⇒ altimeter range - Amplitude ⇒ Sigma0
Altimeter Instrument Corrections	Consistent with MLE4 retracking algorithm
Jason-2 Advanced Microwave Radiometer (AMR) Parameters	Using calibration parameters derived from long term calibration tool developed and operated by NASA/JPL
Dry Troposphere Range Correction	From ECMWF atmospheric pressures and model for S1 and S2 atmospheric tides
Wet Troposphere Range Correction from Model	From ECMWF model
Ionosphere correction	Based on Global Ionosphere TEC Maps from JPL
Sea State Bias	Empirical model derived from 3 years of MLE4 Jason-1 altimeter data with version "b" geophysical models
Mean Sea Surface	CLS01
Mean Dynamic Topography	CLS Rio 05
Geoid	EGM96
Bathymetry Model	DTM2000.1
Inverse Barometer Correction	Computed from ECMWF atmospheric pressures after removing S1 and S2 atmospheric tides
Non-tidal High-frequency Dealiasing Correction	Mog2D High Resolution ocean model on (I)GDRs. None for OGDRs. Ocean model forced by ECMWF atmospheric pressures after removing S1 and S2 atmospheric tides
Tide Solution 1	GOT00.2 + S1 ocean tide . S1 load tide ignored
Tide Solution 2	FES2004 + S1 and M4 ocean tides. S1 and M4 load tides ignored
Equilibrium long-period ocean tide model	From Cartwright and Taylor tidal potential
Non-equilibrium long-period ocean tide model	Mm, Mf, Mtm, and Msqm from FES2004
Solid Earth Tide Model	From Cartwright and Taylor tidal potential
Pole Tide Model	Equilibrium model
Wind Speed from Model	ECMWF model
Altimeter Wind Speed Model	Derived from TOPEX/POSEIDON data

Model	GDR Product Version "T" and O/IGDR Product Version "c"
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 AGCs
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 11 : Models and standards (Jason-2 GDR Product Version "T" and O/IGDR Product Version **"c")**

3.1.1.2. Sea Surface Height Bias

The estimate of the absolute bias in the OSTM/Jason-2 sea-surface height measurements (SSH) is one of the goals of the Cal/Val phase and was therefore not fully consolidated.

The CalVal studies show a JA2 absolute range difference of the order of 17.0 cm during the tandem phase, obtained from global analyses or from the in-situ CalVal sites. Most of this range bias comes from an error in some parameterization files Jason-2 discovered by the project before the Seattle OSTST meeting in June 2009. There are 2 main components which contribute to this bias:

- A lack of accuracy of the altimeter PRF (Pulse Repetition Frequency) that is applied today in the ground segment (truncation effect). If applied correctly, the JA2 range will be shorten by 25 mm, so increasing the absolute bias to 19.5 cms.
- A wrong antenna reference point for the computation of the Jason-2 range. If applied correctly, the JA2 range will be increased by 180 mm, so decreasing the absolute bias to about 1.5 cms.

These two errors (Jason-2 PRF value and antenna reference point) are corrected in the Jason-2 GDR-D products version.

3.1.1.3. Time-tag Bias

The long period crossover point residual analysis show a datation bias about 250µs, leading to a sea surface height anomaly (SSHA) error varying with latitudes. The origin of the error has been precisely determined and its value can be retrieve by the following formula:

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

Where :

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

This datation bias is corrected in the Jason-2 GDR-D product version.

3.1.2. Version "d" Products

3.1.2.1. Models and Standards

The current product version corrects a few minor issues in the version 'T' GDRs, adopts some new models, and account for inclusion of MLE-3 retracking parameters and new radiometer fields improving the coastal data quality.

The table below summarizes the models and standards that are adopted in this version of the OSTM/Jason-2 (O)(I)GDRs. Section 3.2 provides more details on some of these models.

Model	Product Version “d”
Orbit	- Based on Doris onboard navigator solution for OGDRS. - DORIS tracking data for IGDRs (orbit standard “GRD-D” until cycle 253 included and orbit standard “GRD-E” from cycle 254). - DORIS+SLR+GPS tracking data for GDRs until cycle 253 inluded (orbit standard “GRD-D”). - DORIS and/or SLR and/or GPS tracking data for GDRs from cycle 254 (orbit standard “GRD-E”).
Altimeter Retracking	“Ocean MLE4” retracking MLE4 fit from 2nd order Brown analytical model : MLE4 simultaneously retrieves the 4 parameters that can be inverted from the altimeter waveforms: - Epoch (tracker range offset) ⇒ altimeter range - Composite Sigma ⇒ SWH - Amplitude ⇒ Sigma0 - Square of mispointing angle (Ku band only, a null value is used in input of the C band retracking algorithm) “Ocean MLE3” retracking MLE3 fit from 1st order Brown analytical model : MLE3 simultaneously retrieves the 3 parameters that can be inverted from the altimeter waveforms: - Epoch (tracker range offset) ⇒ altimeter range - Composite Sigma ⇒ SWH - Amplitude ⇒ Sigma0 “Ice” retracking Geometrical analysis of the altimeter waveforms, which retrieves the following parameters: - Epoch (tracker range offset) ⇒ altimeter range - Amplitude ⇒ Sigma0
Altimeter Instrument Corrections	Two sets: - one set consistent with MLE4 retracking - one set consistent with MLE3 retracking
Jason-2 Advanced Microwave Radiometer (AMR) Parameters	Using calibration parameters derived from long term calibration tool developed and operated by NASA/JPL
Dry Troposphere Range Correction	From ECMWF atmospheric pressures and model for S1 and S2 atmospheric tides
Wet Troposphere Range Correction from Model	From ECMWF model
Ionosphere correction	Based on Global Ionosphere TEC Maps from JPL
Sea State Bias	Two empirical models: - MLE4 version derived from 1 year of MLE4 Jason-2 altimeter data with version "d" geophysical models - MLE3 version derived from 1 year of MLE3 Jason-2 altimeter data with version "d" geophysical models
Mean Sea Surface	MSS_CNES-CLS11
Mean Dynamic Topography	MDT_CNES-CLS09
Geoid	EGM96
Bathymetry Model	DTM2000.1
Inverse Barometer Correction	Computed from ECMWF atmospheric pressures after removing S1 and S2 atmospheric tides
Non-tidal High-frequency Dealiasing Correction	Mog2D High Resolution ocean model on (I)GDRs. None for OGDRs. Ocean model forced by ECMWF atmospheric pressures after removing S1 and S2 atmospheric tides

Model	Product Version “d”
Tide Solution 1	GOT4.8 + S1 ocean tide. S1 load tide ignored
Tide Solution 2	FES2004 + S1 and M4 ocean tides. S1 and M4 load tides ignored
Equilibrium long-period ocean tide model	From Cartwright and Taylor tidal potential
Non-equilibrium long-period ocean tide model	Mm, Mf, Mtm, and Msqm from FES2004
Solid Earth Tide Model	From Cartwright and Taylor tidal potential
Pole Tide Model	Equilibrium model
Wind Speed from Model	ECMWF model
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 12 : Version “d” models and standards

3.1.2.2. Sea Surface Height Bias

The precise estimate of the absolute bias in the OSTM/Jason-2 sea-surface height measurements (SSH) will be performed after the reprocessing of GDR-D products thanks to in-situ analysis and comparison to Jason-1 data during the formation flying phase. User shall refer to the project web servers for further information.

It should be noted that the bias reflects the combination of the mean errors from all of the corrections that are used to compute sea surface height. The bias provided is intended for sea surface height measurements that are computed with the standard (O)(I)GDR corrections.

3.2. Models and Editing on Version "d" Products

3.2.1. Orbit models

Jason-2 orbit standards are based on version “d” orbit model **until cycle 253 included**. Its main features are summarized below. Previous standard used on Jason-1, ENVISAT and Jason-2 missions (GDR_C) is also recalled:

	GDR-C	GDR-D
Gravity model	EIGEN-GL04S-ANNUAL (2008) Non-tidal TVG : drifts in degree 2,3,4 zonal coeffs, C21/S21; Annual and semi-annual terms up to deg/ord 50 Solid Earth Tides: from IERS2003 conventions Ocean tides FES2004 Atmospheric gravity : 6hr NCEP pressure fields + tides from Horwitz-Cowley model Pole Tide: solid Earth and ocean from IERS2003 conventions	**EIGEN-GRGS_RL02bis_MEAN-FIELD (2011)** Non-tidal TVG : Annual, Semi-annual, and **drifts up to deg/ord 50** Solid Earth Tides: from IERS2003 conventions Ocean tides FES2004 Atmospheric gravity : 6hr NCEP pressure fields + **tides from Biancale-Bode model** Pole Tide: solid Earth and ocean from IERS2010 conventions

	GDR-C	GDR-D
	Third bodies: Sun, Moon, Venus, Mars and Jupiter	Third bodies: Sun, Moon, Venus, Mars and Jupiter
Surface forces	Radiation Pressure model: thermo-optical coefficient from pre-launch box and wing model, with smoothed Earth shadow model Earth Radiation : Knocke-Ries albedo and IR satellite model Atmospheric density model : DTM-94 for Jason, and MSIS-86 for Envisat	Unchanged
Estimated dynamical parameters	Drag coefficient every 2 or 3 revolutions Along-track and Cross-track 1/rev per day or every 12 hours	Unchanged
Satellite reference	Mass and Center of gravity: Post-Launch values + variations generated by Control Center Attitude Model : For Jason-1 and Jason-2 : Quaternions and Solar Panel orientation from control center, completed by nominal yaw steering law when necessary For Envisat: nominal attitude law	Unchanged
Displacement of reference points	Earth tides: IERS2003 conventions Ocean Loading: FES2004 Pole tide : solid earth pole tides (Pole tide and ocean loading applied to both SLR stations and DORIS beacons) 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	Earth tides: IERS2003 conventions Ocean Loading: FES2004 Pole tide : solid earth pole tides (Pole tide and ocean loading applied to both SLR stations and DORIS beacons) Reference GPS constellation: JPL solution at IGS (orbits and clocks) – **fully consistent with IGS08**
Terrestrial Reference Frame	Extended ITRF2005 (SLRF/LPOD2005, DPOD2005, IGS05)	**Extended ITRF2008 (SLRF/ITRF2008, DPOD2008, IGS08)**
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

	GDR-C	GDR-D
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 13. GDR-C/GDR-D orbit standard

Jason-2 orbit standards are based on version “e” orbit model **from May 26th 2015 for IGDR products** and **from cycle 254 for GDR products.** The major updates of the new GDR-E orbit standard include the implementation of a reduced-dynamic parameterization and improved Solar Radiation Pressure (SRP) models. Other differences wrt GDR-D orbit standard are summarized in the table below:

	GDR-D	GDR-E
Gravity model	EIGEN-GRGS_RL02bis_MEAN-FIELD	**EIGEN-GRGS.RL03-v2.MEAN-FIELD**
	Non-tidal TVG: annual, semi-annual, and drift up to deg/ord 50	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**
	Solid Earth tides: from IERS2003 conventions	Unchanged
	Ocean tides: FES2004	Ocean tides: **FES2012**
	Atmospheric gravity: 6hr NCEP pressure fields (20x20) + tides from Biancale-Bode model	Atmospheric gravity: **6hr NCEP pressure fields (70x70)** + tides from Biancale-Bode model
	Pole tide: solid Earth and ocean from IERS2010 conventions	Unchanged
	Third bodies: Sun, Moon, Venus, Mars and Jupiter	Unchanged

Surface forces	Radiation pressure model: thermo-optical coefficient from pre-launch box and wing model, with smoothed Earth shadow model Earth radiation: Knocke-Ries albedo and IR satellite model Atmospheric density model: DTM-94 for Jason satellites, and MSIS-86 for other satellites	Radiation pressure model: **calibrated semi-empirical solar radiation pressure model** Unchanged Atmospheric density model: **DTM-13 for Jason satellites, HY-2A**, and MSIS-86 for other satellites
Estimated dynamical parameters	Drag coefficient every 2 or 3 revolutions Along-track and cross-track 1/rev per day or every 12 hours	**Improved stochastic solutions**
Satellite reference	Mass and center of gravity: post-launch values + variations generated by Control Center Attitude model: For Jason satellites: quaternions and solar panel orientation from control center, completed by nominal yaw steering law when necessary Other satellites: nominal attitude law	Unchanged
Displacement of reference points	Earth tides: IERS2003 conventions Ocean loading: FES2004 Pole tide: solid earth pole tides Reference GPS constellation: JPL solution at IGS (orbits and clocks) – fully consistent with IGS08	Unchanged Ocean loading: **FES2012** Pole tide: solid earth pole tides **and ocean pole tides (Desai, 2002)** **S1-S2 atmospheric pressure loading, implementation of Ray & Ponte (2003) by van Dam** 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**
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	Unchanged
	SLR range correction: constant 5.0 cm range correction for Envisat, elevation dependent range correction for Jason	Unchanged
	DORIS troposphere correction: GPT/GMF model	Unchanged
		DORIS beacons phase center correction
	GPS PCO/PCV (emitter and receiver) consistent with constellation orbits and clocks (IGS08 ANTEX)	Unchanged
	GPS: phase wind-up correction	Unchanged
Estimated measurement parameters	DORIS: one frequency bias per pass, one troposphere zenith bias per pass	Unchanged
	SLR: bias per arc solved for a few stations, bias per pass for a few stations	**Reference used to evaluate orbit precision and stability**
	GPS: floating ambiguity per pass, receiver clock adjusted per epoch	Unchanged
Tracking Data corrections	Jason-1 Doris data: South Atlantic Anomaly model (J.-M. Lemoine et al.) applied before and after DORIS instrument change	Jason-1 Doris data: **updated 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	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

3.2.2. 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	1993-2009 (16 years)
Spatial coverage	Global (80°S to 84°N) - Oceanwide where altimetric data are available. EIGEN_GRACE_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	YES (in cm) - The Optimal Interpolation method provides a calibrated formal error.
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 14 : MSS_CNES-CLS11 model characteristics

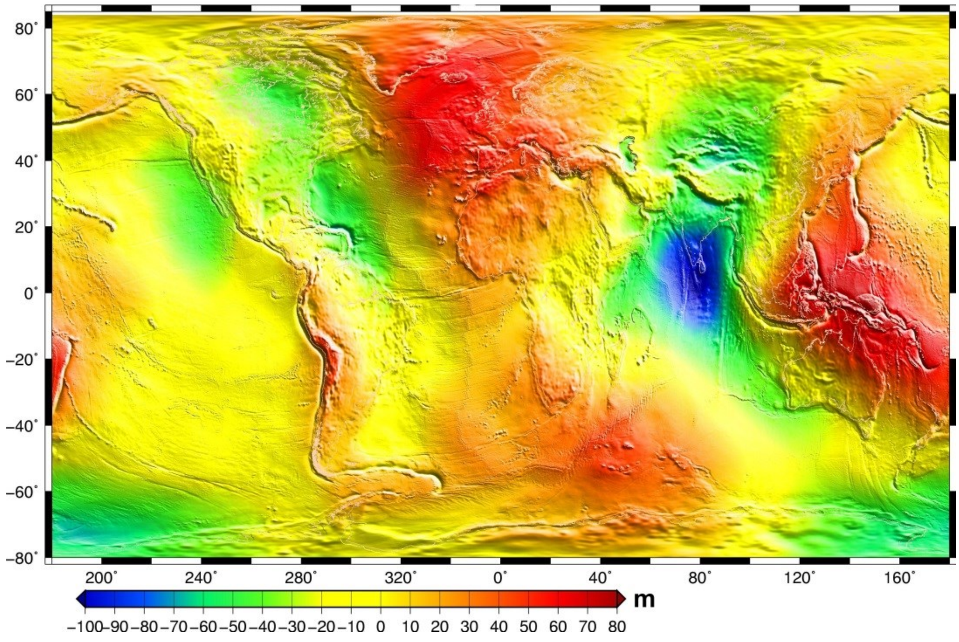


Figure 12 : Mean Sea Surface MSS_CNES-CLS11.

Refer to http://www.aviso.oceanobs.com/en/data/products/auxiliary-products/mss/index.html for more details on this model.

3.2.3. Mean Dynamic Topography

The MDT_CNES-CLS09 model is computed from satellite altimetry data from a variety of missions. Its main characteristics are the following :

Name	MDT_CNES-CLS09
Referencing time period	1993-1999 (7 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 of the altimeter Sea Level Anomalies, computed relative to a 7 years (1993-1999) mean profile, in order to obtain absolute measurements of the ocean dynamic topography. Combined product based on 4.5 years of GRACE data, 15 years of altimetry and in situ data (hydrologic and drifters data)

Table 15 : MDT_CNES-CLS09 model characteristics

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

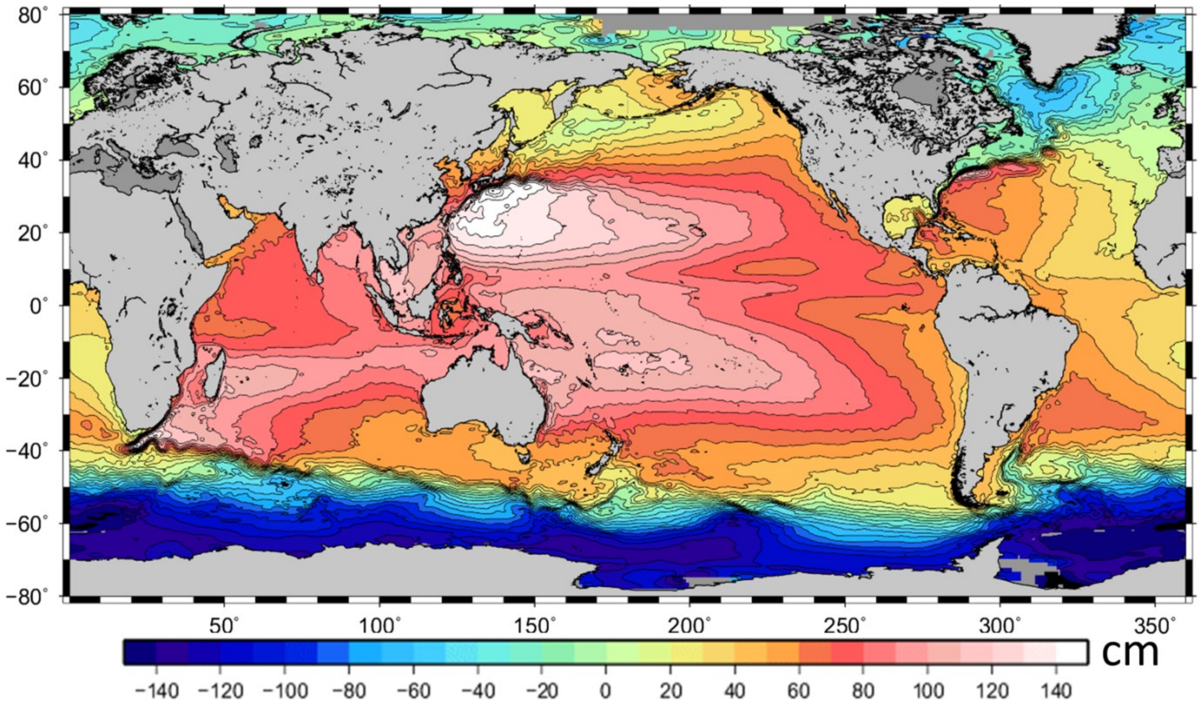


Figure 13. Mean Dynamic Topography MDT_CNES-CLS09

Refer to http://www.aviso.oceanobs.com/en/data/products/auxiliary-products/mdt/index.html for more details on this model.

3.2.4. Geoid

OSTM/Jason-2 (O)(I)GDRs use the EGM96 geopotential to compute the geoid [*Lemoine et al.*, 1998]. The EGM96 geopotential model has been used to calculate point values of geoid undulation on a 0.25 x 0.25 degree grid that spans the latitude range +85.0 deg. to -85.0 deg. The EGM96 model is complete to spherical harmonic degree and order 360, and has been corrected appropriately so as to refer to the mean tide system as far as the permanent tide is concerned [*Rapp et al.*, 1991]. The k_2 Love number used in this conversion was 0.3. The geoid undulations are given with respect to an ideal geocentric mean Earth ellipsoid, whose semi-major axis remains undefined (i.e., there is no zero-degree term in the spherical harmonic series of these geoid undulations). The flattening of this reference ellipsoid is f=1/298.257 so that values are consistent with constants adopted for T/P.

Since the geoid undulations have been computed from an expansion to degree 360, the resolution of the undulations will be on the order of 50km. Data used to derived the EGM96 model include surface gravity data from different regions of the globe, altimeter derived gravity anomalies from the GEOSAT Geodetic Mission, altimeter derived anomalies from ERS-1, direct satellite altimetry from T/P, ERS-1 and GEOSAT, and satellite tracking to over 20 satellites using satellite laser ranging, GPS, DORIS, the Tracking and Data Relay Satellite System (TDRSS), and TRANET.

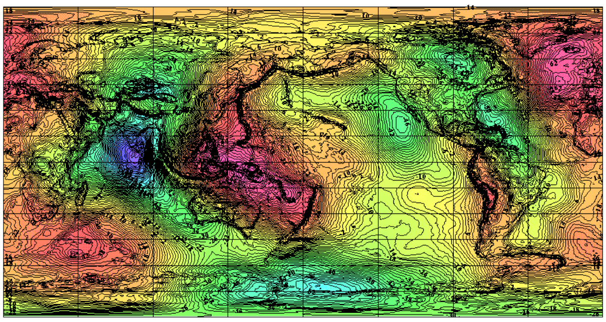


Figure 14 : EGM96 geoid

More information on EGM96 can be found at http://cddisa.gsfc.nasa.gov/926/egm96/egm96.html

3.2.5. 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.

3.2.6. Ocean Tides

The two geocentric tide values provided on the OSTM/Jason-2 (O)(I)GDR, ocean_tide_sol1 and ocean_tide_sol2, are computed with diurnal and semidiurnal ocean and load tide values predicted by the GOT4.8 and FES2004 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). These two fields (ocean_tide_sol1 and ocean_tide_sol2) also include the S1 oceanic response to atmospheric pressure based on the model from Ray and Egbert (2004). The FES2004 model also includes the M4 ocean tide. Note that the load tide fields (load_tide_sol1 and load_tide_sol2) only include the load tides from the GOT4.8 and FES2004 models, and do not contain the load tides from the S1, M4, or equilibrium long-period ocean tides.

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 (O)(I)GDRs to indicate the quality of this interpolation (see interp_flag_ocean_tide_sol1 and interp_flag_ocean_tide_sol2).

3.2.6.1. GOT4.8 Ocean Tide Model

Solution GOT4.8 [Ray 1999; Ray, personnal communication], is the last version of GOT models developed by R. Ray.

This model is identical to 4.7 in all constituents save S2.

GOT4.7 used the following data:

- 364 cycles of T/P
- 114 cycles of T/P on the interlaced orbit
- 117 cycles of ERS1 and ERS2
- 126 cycles of GFO

None Jason data has been used in this solution.

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, GOT4.8 implement the fixed-up dry troposphere correction for TP where the air tide wasn't being handled correctly (whereas it is in Jason GDRs), and this affects S2 mostly.

Another difference between GOT4.7 and GOT4.8 is that 4.7 had not applied the TP Cg correction, while 4.8 did use the Cg.

3.2.6.2. FES2004 Ocean Tide Model

The FES2004 model is a finite-element hydrodynamic model, constrained with tide gage and past altimeter data [*Le Provost*, 2001] (see ocean_tide_sol2).

It is based on the resolution of the tidal barotropic equations on a global finite element grid without any open boundary condition, which leads to solutions independent of in situ data (no open boundary conditions and no data assimilation). FES2004 is the last update of the FES solution. Tide gages and reprocessed TP and ERS crossover data are assimilated in the FES2002 hydrodynamical solution. The altimeter data reprocessing consists in a new atmospherical forcing response correction (Mog2D-G) applied to the data before the harmonic analysis. FES2004 includes the M2, S2, N2, K2, 2N2, K1, O1, P1, Q1 tides. Four hydrodynamical long period tides and the non-linear M4 tide are also included in the distribution package. A new prediction algorithm is associated with FES2004. This algorithm use an admittance method to extends the prediction spectrum up to 36 tidal constituents. The FES2004 model also provides non-equilibrium models for the Mm, Mf, Mtm, and Msqm tidal components, which are provided by parameter ocean_tide_non_equil.

See http://www.legos.obs-mip.fr/en/soa/cgi/getarc/v0.0/index.pl.cgi?donnees=maregraphie&produit=modele_fes

3.2.7. Data Editing Criteria

The following editing criteria are a recommended guideline for finding good records from the (O)(I)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 16 : Recommended editing criteria

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

Parameter	Validity conditions
range_numval_ku	10 ≤ x
range_rms_ku	0 ≤ x (mm) ≤ 200
altitude – range_ku	-130 000 ≤ x (mm) ≤ 100 000
model_dry_tropo_corr	-2 500 ≤ x (mm) ≤ - 1 900
rad_wet_tropo_corr	-500 ≤ x (mm) ≤ - 1
iono_corr_alt_ku	-400 ≤ x (mm) ≤ 40
sea_state_bias_ku	-500 ≤ x (mm) ≤ 0
ocean_tide_sol1	-5 000 ≤ x (mm) ≤ 5 000
solid_earth_tide	-1 000 ≤ x (mm) ≤ 1 000
pole_tide	-150 ≤ x (mm) ≤ 150
swh_ku	0 ≤ x (mm) ≤ 11 000
sig0_ku	7 ≤ x (dB) ≤ 30
wind_speed_alt	-0 ≤ x (m/s) ≤ 30
off_nadir_angle_wf_ku	-0.2 ≤ x (deg^2) ≤ 0.64
sig0_rms_ku	x (dB) ≤ 1
sig0_numval_ku	10 < x

Table 17 : 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.)

4. Using the (O)(I)GDR data

4.1. Overview

This section gives the reader a guide to the use of the OSTM/Jason-2 (O)(I)GDR data. While this handbook tries to be correct and complete, note that nothing can replace the information to be gained at conferences and other meetings from those using these data. The reader must proceed with caution and at his or her own risk. Further information is also available on the web servers provided in Annex C, please direct questions and comments to the contacts given there.

The instruments on OSTM/Jason-2 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. Ground based laser station and DORIS station measurements of the satellite location and speeds are used in precision orbit determination (POD). The DORIS stations also measure the ionospheric electron content along the line of sight to the satellite. 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 OSTM/Jason-2), 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 in the long term.

This (O)(I)GDR contains all relevant corrections needed to calculate the sea surface height. For the other "geophysical variables" in the (O)(I)GDR: 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 (O)(I)GDR parameters by name using the name of the variable as described in the NetCDF data sets.

In addition with the MLE-4 retracking parameters, MLE-3 retracker parameters are also included in the Jason-2 products since the GDR-D version. Altimeter parameters (e.g. Range, swh, sigma0, etc) and related geophysical parameters (e.g. Ionosphere correction, sea state bias correction, wind speed, etc) named without the "mle3" extension are derived from MLE-4 retracking, while those with the "mle3" extension are derived from MLE-3 retracking.

Most users are advised to use the MLE-4 altimeter parameters for typical scientific applications. The MLE-3 Ku-band parameters are provided for the convenience of specialized studies on the calibration and validation of the mission and impact of altimeter retracking.

WARNING

Default values are given to data when computed values are not available (See section 6.1.2.4) so you must screen parameters to avoid using those with default values. Also you must 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 (O)(I)GDR are the altimeter ranges. The (O)(I)GDR provides ranges measured at Ku band (range_ku, resp. range_ku_mle3 for MLE3) and C band (range_c). The Ku band range is used for most applications. The given ranges are corrected for instrumental effects. These corrections are separately reported for each of the Ku (net_instr_corr_range_ku, resp. net_instr_corr_range_ku_mle3 for MLE3) and C band ranges (net_instr_corr_range_c).

The given ranges must be corrected for path delay in the atmosphere through which the radar pulse passes and the nature of the reflecting sea surface. All range corrections are defined and they should be ADDED to the range. The corrected (Ku band) range is given by

Corrected Range = Range + Wet Troposphere Correction
+ Dry Troposphere Correction
+ Ionosphere Correction
+ Sea State Bias Correction

Wet Troposphere Correction :

Use AMR correction (rad_wet_tropo_corr).

Dry Troposphere Correction :

Use model correction (model_dry_tropo_corr).

Ionosphere Correction :

Use MLE4 altimeter ionosphere correction (iono_corr_alt_ku) to correct Ku range issued from MLE4 retracking (range_ku).

Use MLE3 altimeter ionospheric correction (iono_corr_alt_ku_mle3) to correct Ku range issued from MLE3 retracking (range_ku_mle3).

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

Sea State Bias Correction :

Use MLE4 sea state bias correction (sea_state_bias_ku) to correct Ku range issued from MLE4 retracking (range_ku).

Use MLE3 sea state bias correction (sea_state_bias_ku_mle3) to correct Ku range issued from MLE3 retracking (range_ku_mle3).

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 4.2.5 explains how the C band ionosphere correction can be derived from the Ku band ionosphere correction (iono_corr_alt_ku, resp. iono_corr_alt_ku_mle3 for MLE3), while the C band sea state bias correction is provided as sea_state_bias_c (resp. sea_state_bias_c_mle3 for MLE3).

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:

Sea Surface Height = Altitude - 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, namely tidal and inverse barometer. It is given by:

Sea Level Anomaly = Sea Surface Height - Mean Sea Surface
- Solid Earth Tide Height
- Geocentric Ocean Tide Height
- Pole Tide Height
- Inverted Barometer Height Correction
- HF Fluctuations of the Sea Surface Topography

The SLA contains information about:

- Real changes in ocean topography related to ocean currents
- Dynamic response to atmospheric pressure

- Differences between tides and the tide models
- Differences between the mean sea surface model and the true mean sea surface at the OSTM/Jason-2 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 OSTM/Jason-2.

Altitude :

Orbit altitude (see parameter altitude)

Corrected Range :

See section 4.2.1.

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 (see also section 5.10).

HF Fluctuations of the Sea Surface Topography :

Use hf_fluctuations_corr (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 (O)(I)GDR:

Tide Effect = Geocentric Ocean Tide + Solid Earth Tide + Pole Tide

(See also section 5.9 and subsections)

Geocentric Ocean Tide :

The geocentric ocean tide provided on the (O)(I)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.

Geocentric Ocean Tide = Ocean Tide + Load Tide

The (O)(I)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 (O)(I)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. Obviously, 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 (O)(I)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 and Koblinsky* [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 (O)(I)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 :

  ΔSSH = Interpolated POI SSH - Interpolated POI MSS
- Other geophysical corrections must be applied to dSSH, depending on the type of investigation

The geoid model in the (O)(I)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 (O)(I)GDR. The users may smooth the ionospheric correction and apply it as follows:

- Smooth iono_corr_alt_ku (resp. iono_corr_alt_ku_mle3 for MLE3) 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/m^2
- dR = Ku band ionospheric range correction from the (O)(I)GDR in meters (iono_corr_alt_ku, resp. iono_corr_alt_ku_mle3 for MLE3)
- 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-3 Ku (range_ku, resp. range_ku_mle3 for MLE3) and C band range measurements (range_c) are derived from the linear regression of the respective valid 20 Hz range measurements (range_20hz_ku, resp. range_20hz_ku_mle3 for MLE3, 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, resp. range_used_20hz_ku_mle3, range_used_20hz_c) to 1. Measurements not considered as outliers have the parameters (range_used_20hz_ku, resp. range_used_20hz_ku_mle3 for MLE3, 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 (O)(I)GDRs (range_numval_ku, resp. range_numval_ku_mle3 for MLE3, 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, resp. range_rms_ku_mle3 for MLE3 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 (O)(I)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 OSTM/Jason-2 data products. The OSTM/Jason-2 OGDRs provide a navigator orbit that has radial accuracies better than 5 cm (RMS), the OSTM/Jason-2 IGDRs provide a preliminary orbit that has radial accuracies better than 2.5 cm (RMS), while the GDRs provide a precise orbit that has radial accuracies better than 1.5 cm (RMS).

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 OSTM/Jason-2 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 (I)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 OSTM/Jason-2 (O)(I)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 (O)(I)GDR for each of the Ku and C band ranges (see net_instr_corr_ku and net_instr_corr_c).

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 OSTM/Jason-2 (O)(I)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.

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 OSTM/Jason-2 (O)(I)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).

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 parameter).

$$\text{model\_dry\_tropo\_corr} = -2.277 * P_{atm} * \left[1 + 0.0026 * \cos(2 * \text{phi})\right]$$

where P_{atm} is surface atmospheric pressure in mbar, phi is latitude, and model_dry_tropo_corr 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 OSTM/Jason-2 Microwave Radiometer (AMR) 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 GDR-D product version, 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 AMR 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 provides also a value for the wet tropospheric delay. An interpolated value from this model is included in the (O)(I)GDR, as a backup to the measurement from the AMR (see model_wet_tropo_corr). This backup will prove useful when sun glint, land contamination, or anomalous sensor behavior makes the AMR measurement of the wet tropospheric delay unusable.

The ECMWF meteorological fields are interpolated to provide the model dry and wet tropospheric corrections at the time and location of the altimeter measurement (see model_dry_tropo_corr and model_wet_tropo_corr) and an interpolation quality flag is provided on the (O)(I)GDR to indicate the quality of this interpolation (see interp_flag_meteo).

5.6.2. Ionosphere

At the frequencies used by the Poseidon-3 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 (I)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 (Labroue [2004]). 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.

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 OSTM/JASON-2 (O)(I)GDR is set if integrated liquid water content measured by the AMR 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 MLE3 retracking (sig0_ku_mle3 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 AMR 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 AMR. 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 OSTM/JASON-2 (O)(I)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 AMR 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 AMR 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 [*LeProvost*, 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.

OSTM/Jason-2 (O)(I)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 OSTM/Jason-2 (O)(I)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 OSTM/Jason-2 (O)(I)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 OSTM/Jason-2 (O)(I)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 (O)(I)GDR (ocean_tide_sol1 and ocean_tide_sol2) already include the equilibrium long-period ocean tide and should therefore not be used simultaneously.

The OSTM/Jason-2 (O)(I)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 OSTM/Jason-2 (O)(I)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 OSTM/Jason-2 (O)(I)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 OSTM/Jason-2 (O)(I)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.

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

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 OSTM/Jason-2. 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.* [1999] and *Tierney et al.* [2000].

The parameter hf_fluctuations_corr is provided in the (I)GDR products as a correction to the inverse barometer correction inv_bar_corr.

5.11. Sigma 0

The backscatter coefficients, sigma0 Ku and C values (see parameters sig0_ku and sig0_c), reported on the (O)(I)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 OSTM/Jason-2 data products. For some geophysical algorithms, an appropriate bias is applied to the provided sigma. These biases have been determined from comparisons to Jason-1 sigma0.

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 and the significant wave height (see wind_speed_alt) using the Gourrion algorithm [*Gourrion et al*, 2002] and Collard table [*Collard*, 2005]. A calibration bias is applied on Jason-2 Ku-band backscatter coefficient (0.28dB for MLE4 and 0.32 dB for MLE3) to match with the Jason-1 distribution and therefore allow the use of Collard table. 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 AMR [*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 OSTM/Jason-2 (O)(I)GDR (see parameters wind_speed_model_u and wind_speed_model_v). This wind speed vector is determined from an interpolation of the ECMWF model. 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 then 5 m/s and 40 degrees in the southern Pacific Ocean.

5.13. Bathymetry Information

The OSTM/Jason-2 (O)(I)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 (O)(I)GDR products are summarized in the following table.

Features	OGDR	IGDR	GDR
Primary Goal	To provide wind/wave data to meteorological users. Also designed to provide altimeter range, environmental and geophysical corrections together with a real-time orbit in order to make NRT SSHA available to ocean users	To provide sea surface height data to operational oceanography users (with a more accurate orbit and additional environmental / geophysical corrections w.r.t. OGDR)	To fulfill the project science objectives (AD 2)
Content	Geophysical level 2 product (Poseidon-3/AMR), including waveforms retracking		
	+ available environmental and geophysical corrections	+ all the environmental and geophysical corrections (preliminary for some of them)	+ all the environmental and geophysical corrections (precise)
Orbit	5 cm DORIS navigator	2.5 cm MOE (processed DORIS data)	1.5 cm POE (processed DORIS and/or GPS and/or laser data)
Delivery delay (after data acquisition)	Near-Real Time	Off-Line	Off-Line
	3-5 hours	2 calendar days	90 days
Validation	Not fully validated (elementary and automatic controls only)		Fully validated (in depth validation performed on a cycle basis before delivery)
Validation by Experts	No		Yes (NASA/JPL and CNES/SALP)
Structure	Segment (see 0)	Pole to pole pass	
Ground Processing Centre	NOAA and EUMETSAT	CNES	

Table 18 : Main characteristics of (O)(I)GDR products

The differences between Auxiliary Data used for OGDR, IGDR and GDR products is given in section3.1.2.1. The main fields recomputed for GDR with respect to IGDR are the following:

- Due to the update of orbit data:

  Latitude (“latitude”)

  Longitude (“longitude”)

  Altitude (“alt”,”orb_state_flag_rest”, “alt_20hz”)

  Orbital altitude rate (“orb_alt_rate”)

  Doppler correction (“doppler_corr_ku”, doppler_corr_c)

  Sum of the instrumental corrections (“net_instr_corr_range_ku”, “net_instr_corr_range_ku”)

  Corrected ground retracked altimeter ranges (“range_ku”, “range_c”)

  Altimeter ionospheric correction (“iono_corr_alt_ku”)

- Due to the update of platform data:

  Distance antenna-COG correction (“cog_corr”)

Sum of the instrumental corrections (“net_instr_corr_range_ku”, “net_instr_corr_range_ku”)

Corrected ground retracked altimeter ranges (“range_ku”, “range_c”)

Altimeter ionospheric correction (“iono_corr_alt_ku”)

- Due to the update of pole locations:

  Pole tide height (“pole_tide”)

- Due to the update of Mog2D data:

  High frequency dealiasing correction (“hf_fluctuations_corr”)

- Due to the update of AMR calibration coefficients:

  All the AMR-derived parameters, and mainly as far as altimeter parameters are concerned:

    Radiometer wet tropospheric correction (“rad_wet_tropo_corr”)

    Atmospheric attenuation (“atmos_corr_sig0_ku”, “atmos_corr_sig0_c”)

    Backscatter coefficient (“sig0_ku”, “sig0_c”)

    Altimeter wind speed (“wind_speed_alt”)

    Radiometer wind speed (”wind_speed_rad”)

    Sea State Bias (“sea_state_bias_ku”)

    Rain flag (“rain_flag”)

    Radiometer rain flag (“rad_rain_flag”)

    Ice flag (“ice_flag”)

    Radiometer sea ice flag (“rad_sea_ice_flag”)

6.1. Data format

OSTM/Jason-2 OGDR, IGDR and GDR products have the same information and format. The only difference is related to the auxiliary data used (orbit, meteo files, calibrations, …).

Accounting for Jason-1 heritage, products are split into three data sets :

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

The following figure shows the data sets available for each kind of product.

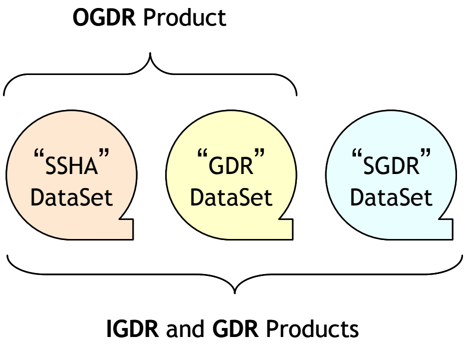


Figure 15 : Data set availability per product

OGDR products are also available in BUFR-formatted dataset for distribution via the World Meteorological Organization (WMO) Global Tele-communication System (GTS).

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 describing 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 OSTM/Jason-2 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 19 - Dimensions used in the OSTM/Jason-2 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 20 - 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 OSTM/Jason-2 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 *scale_factor* and *add_offset* 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 *flag_values* to provide descriptive words or phrase for each flag value
flag_values	Provide a list of the flag values. Use in conjunction with *flag_meanings*
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 *add_offset* 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 21 - 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_time is packed. The data are stored in 32-bit integers (long). The value of the altitude of the satellite can be recovered using:

$$alt = (alt_{long} * scale\_factor) + add\_offset$$

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
altimeter_chacterisation	Name of the altimeter characterisation data file
altimeter_ltm	Name of the altimeter Long Term Monitoring data file
radiometer_temp	Name of the file containing the antenna temperature coefficients
doris_uso	Name of the file containing the DORIS-derived USO frequency
orbit_data	Name of the file containing the orbit ephemeris
pf_data	Name of the file containing the platform data
pole_location	Name of the file containing the pole location data
orf_data	Name of the Orbit Revolution File used to create the pass file
meteorological_files	Name of the meteorological files used to create the pass file
utc_tai_data	Name of the TAI/UTC leap second offset file used to manage the leap second
radiometer_calibration	Name of the file containing the radiometer level-1 calibration
gim_data	Name of the GIM files used to create the pass file
mog2d_data	Name of the MOG2D files used to create the pass file
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);
            time:long_name = "time (sec. since 2000-01-01)";
            time:standard_name = "time";
            time:units = "seconds since 2000-01-01 00:00:00.0";
            time:calendar = "gregorian";
            time:tai_utc_difference = [GA_TAI_UTC_DIF];
            time:leap_second = [GA_LEAP_TIME];
time:comment = “[tai_utc_difference] is the difference between TAI and UTC reference time (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.”
byte meas_ind(meas_ind);
            meas_ind:long_name = "elementary measurement index";
            meas_ind:units = "count";
      meas_ind:comment = "Set to be compliant with the CF-1.1 convention";

double time_20hz(time,meas_ind);
            time_20hz:long_name = "time 20 Hz (sec. since 2000-01-01)";";
            time_20hz:standard_name = "time";
            time_20hz:_FillValue = 18446744073709551616.000000;
            time_20hz:units = "seconds since 2000-01-01 00:00:00.0";
            time_20hz:calendar = "gregorian";
            time_20hz:tai_utc_difference = [GA_TAI_UTC_DIF];
            time_20hz:leap_second = [GA_LEAP_TIME];
            time_20hz:comment = “[tai_utc_difference] is the difference between TAI and UTC reference time (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.”

byte surface_type(time);
            surface_type:long_name = "surface type";
            surface_type:_FillValue = 127b;
            surface_type:flag_values = 0b, 1b, 2b, 3b ;
            surface_type:flag_meanings = "ocean lake_enclosed_sea ice land";
            surface_type:coordinates = "lon lat";
```

```
        surface_type: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-2 User Handbook";

short ssha(time);
        ssha:long_name = "sea surface height anomaly";
        ssha:standard_name = "sea_surface_height_above_sea_level";
        ssha:source = [altimeter_sensor_name];
        ssha:institution = [altimeter_sensor_institution];
        ssha:_FillValue = 32767s;
        ssha:units = "m";
        ssha:scale_factor = 1.00e-03;
        ssha:coordinates = "lon lat";
        ssha: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, OSTM/Jason-2 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

6.5. OGDR BUFR product

The Global Telecommunications System (GTS) is the coordinated global system of telecommunication facilities and provides rapid collection, exchange and distribution of observations and processed information within the framework of the World Weather Watch. It is implemented and operated by National Meteorological Services of the World Meteorological Organisation (WMO) members and also by a few international organizations (ECMWF, EUMETSAT). The GTS consists of an integrated network of point-to-point circuits, and multi-point circuits which interconnect meteorological telecommunication centres.

Jason-2 BUFR products are designed primarily for dissemination via the GTS and they consequently follow the format conventions defined by the WMO for all data disseminated on the GTS. The WMO FM-94 BUFR (Binary Universal Form for the Representation of Meteorological data), is a binary code designed to represent, employing a continuous binary stream, any meteorological data. It has been designed to achieve efficient exchange and storage of meteorological and oceanographic data. It is self defining, table driven and a very flexible data representation system, especially for big volumes of data.

The following table summarises how to identify Jason-2 OGDR data in BUFR format on the GTS.

Product	Bulletin header	Originating station	Descriptor sequence
OGDR generated at NOAA	ISZX01	KNES	3-40-010
OGDR generated at EUMETSAT	ISZX01	EUMS	3-40-010
OGDR generated at CNES	ISZX01	LFPW	3-40-010

You will find more details on the BUFR format and the latest tables, on the WMO page:

http://www.wmo.int/pages/prog/www/WMOCodes/OperationalCodes.html

Finally, note that ECMWF offers a comprehensive introduction to understanding BUFR format and provides various well documented encoding/decoding tools. All this can be accessed on this page:

http://www.ecmwf.int/products/data/software/bufr.html.

Annexe A - References

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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
BUFR	**B**inary **U**niversal **F**orm for the **R**epresentation of Meteorological data
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
JAXA	Japan Aerospace Exploration Agency
JGM	Joint Gravity Model
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
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real Time
NWP	Numerical Weather Prediction
OGDR	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	Plate Forme Reconfigurable pour l'Observation de la TErre, les telecommuncations 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
T2L2	Time Transfer by Laser Link
TBC	To be confirmed
TBD	To be defined
TEC	Total Electron Content
TRSR	Turbo Rogue Space Receiver
UTC	Universal Time Coordinated
WMO	World Meteorological Organisation

Annexe C - Contacts

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