CENTRE NATIONAL D'ÉTUDES SPATIALES

Coastal and Hydrology Altimetry product (PISTACH) handbook

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1. Introduction

1.1. Overview of this document

This document is the Coastal and Hydrology Altimetry product handbook.

Those products were conceived in the frame of the PISTACH (Prototype Innovant de Système de Traitement pour les Applications Côtières et l'Hydrologie) project. Basically, those products are conceived as **an experimental evolution** of the Jason-2 Level-2 products.

Since the prototype is operated on a pseudo-operational basis in Near Real Time, **the Coastal and Hydrology Altimetry products should be considered, in a first approximation, as an evolution of the official Jason-2 I-GDR products** in the sense that most of the scientific/technological content of the official Jason-2(I)GDR is included in the products (variable names are unchanged). Extra fields derived from the various state-of-the-art processes are then added to form the products.

The standard Jason-2 products are extensively described in the official handbook that is found on the AVISO web site:

http://www.aviso.oceanobs.com/fileadmin/documents/data/tools/hdbk_j2.pdf

It is thus highly recommended that the user of the Coastal and Hydrology Altimetry products first reads the official Jason-2 products handbook to which the present document mainly adds information relative to the specific PISTACH processes and additional outputs.

1.2. The PISTACH project: Altimetry for coastal areas and hydrology

1.2.1. Rationale

Many crucial issues for science, society or the economy arise in coastal zones and near continental waters. However, altimeter and radiometer instrument observations are perturbed by emerged lands (50 km off the coasts for radiometers, about 10 km for altimeters). This leads to missing or degraded data in the distributed datasets, mostly meant for open ocean studies. However, the instruments do give measurements which contain useful information for areas between 50 km offshore and the coastline, over continental water bodies and over emerged land as well!

This is why CNES funded the PISTACH project *(Prototype Innovant de Système de Traitement pour les Applications Côtières et l'Hydrologie*, or Innovative Processing System Prototype for Coastal and Hydrology Applications), as part of the Jason-2 Project, to improve satellite radar altimetry products over coastal areas and continental waters.

1.2.2. The PISTACH Project in few words

The PISTACH project was organized around 3 phases:

- Phase 1: user needs and structure of coastal/hydrological products
- Phase 2: development of new dedicated algorithms: retracking of the waveforms, wet and dry tropospheric corrections, local models or high resolution, global models for topography, geoid, tides, land cover classification, land water mask, data editing.

- Phase 3: prototype implementation, validation and exploitation. Generation of the products.

The implementation of the prototype was completed in October 2008 while the exploitation of the prototype is ongoing, up to December 2010, at least.

The products are freely distributed via FTP since early November 2008.

The PISTACH project is:

- funded by CNES
- led by CLS (http://www.cls.fr/) with the support of:
  - LEGOS (http://www.legos.obs-mip.fr/)
  - CEMAGREF (http://www.montpellier.cemagref.fr/umrtetis/)
  - IRD/HyBAM (http://www.mpl.ird.fr/hybam/)

The input for the prototype consists of Jason-2 Level 2 S-IGDR altimeter products. The PISTACH products include new retracking solutions, several state-of-the-art geophysical corrections as well as higher resolution global/local models, in addition to the content of standard Jason2 IGDRs (NetCDF, with the nomenclature of variables and files similar to that for IGDRs). The prototype has now been commissioned and products are accessible through the Aviso web site. The products have the same format and structure as Jason-2 standard IGDR to facilitate their adoption and assessment by expert users, with data provided as high-resolution along-track products (20 Hz sampling rate, with fields which are either interpolated or copied), and about 80 extra fields. Two products are available:

- one for **coastal applications**, covering the whole ocean plus a 25-km fringe over land,
- the other for **hydrology**, with all emerged lands plus a 25-km fringe over oceans.

Products that will be simpler and easier to use are already being envisioned for wider dissemination to non-expert users.

1.2.3. Overview of the main PISTACH achievements and processings

Waveform retracking

The effective footprint of a pulse-limited altimeter is controlled by the pulse bandwidth and by the width of the analysis window (corresponding to the number of gates of the altimeter waveforms). Over water, after the leading edge of the altimeter pulse strikes the sea surface, the area illuminated by the pulse becomes a circle that expends with time until the trailing edge of the pulse reaches the calm sea surface a time later. Thereafter, the area illuminated by the short pulse becomes an expending annulus spreading on the earth surface.
In the case of land/sea or sea/land transitions, the altimeter footprint can be partly over ocean and partly over land as represented in Figure 1. Consequently, the power received by a radar antenna in each of its sampling gates, is linked to the relative proportion of sea and land surfaces in the corresponding annulus and also to the relative sigma naught coefficients of each of these surfaces. The top panel of Figure 1 shows how, when the nadir of the satellite is still over ocean (during an ocean to land transition for example), the last samples of the waveform are contaminated by land returns. The closer the satellite nadir position is from the coastline, the more the last samples of the waveforms are contaminated. Similarly, during a land to sea transition, the closer the satellite nadir position is from the coastline, the more the returns from ocean cells contaminate the last samples of the waveform.
The lower panel of Figure 1 is a view of the altimeter footprint showing the importance of the relative ocean and land surfaces in each of the annulus foot-prints. The number of contaminated gates depends on the height and areal extent of the land, as well as its proximity to the nadir

point. Moreover, how the waveform is affected depends on a weighted average of the scattering coefficient of land and ocean i.e. "SurfaceLand x sigma0Land" relative to "SurfaceOcean x sigma0Ocean" where SurfaceLand (respectively SurfaceOcean) is the surface of land (resp. ocean) in the altimeter footprint. If sigma0Land < sigma0Ocean (often true), the effect will be small. In some environments however (coral atolls), sigma0Land > sigma0Ocean and the land effect is significant.
From this, it is clear that the geometry of the coastline, the relief, the nature of the terrain, all characteristics of the coast that are extremely diverse all over the world, will all contribute to the shape of the waveform. An equivalent reasoning can be done for hydrologic surfaces.

In order to account for these various waveforms shapes, dedicated retracking algorithms are required to precisely estimate the altimetric range and, if possible, the other waveform parameters. The retracking strategy involves a classification of the waveforms, plus the application of four different retracking algorithms, in order to provide users with several possibilities and enable them to choose the most appropriate one for their case.

Waveforms are classified according to their shapes: Brown echoes (for ocean and ocean-like surfaces); peak echoes, linear, very noisy, etc. A number is assigned to each class, and included as a flag in the dataset, thus enabling users to automate their processing, for example by using a different retracking output depending on the class.

The 20Hz retracking ouput (ranges, sigma0, SWH, classes etc.) are included in the PISTACH products.

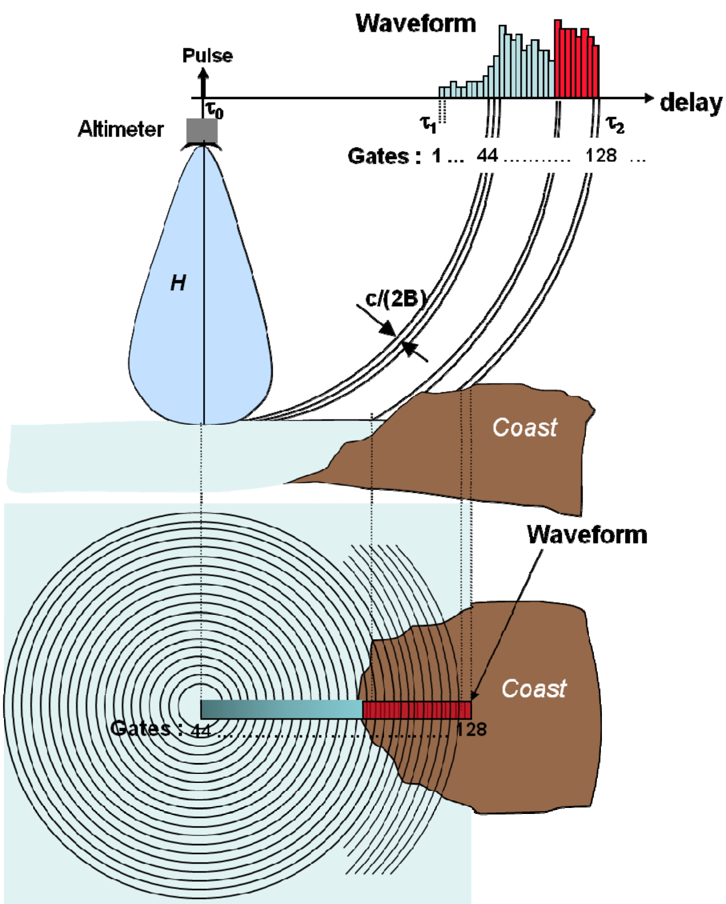

Figure 1: Perturbation of the radar waveform by the emerged lands within the altimeter footprint

Coastal applications

Two different wet tropospheric corrections are implemented in the PISTACH prototype for coastal oceans:

- A composite correction, whereby the model correction (ECMWF) replaces the radiometer near the coasts (<50 km), or the ECMWF correction is shifted to the nearest valid radiometer value in the transition case. Interpolation and detrending are also applied in complex cases.
- A decontamination correction, probably more suitable than the composite correction for areas where large and rapid fluctuations of air masses are observed, the composite correction being too smooth. On the contrary, decontamination may be less precise over areas with complex shorelines

A study was performed in order to assess the performances of empirical estimation of regional Sea State Bias (SSB) models. Three zones were selected: the Mediterranean Sea, Bay of Biscay and Gulf of Maine, because they represent different types of sea state regimes (dominated by young seas, short or long fetch etc.). Different SSB models were obtained on the three zones. It was shown that such estimations performed on very small regions are too affected by the oceanic signal, which prevents the real sea-state bias being retrieved. The PISTACH products will use the SSB model of Jason-2 GDR products.

Hydrology

The hydrology altimetry products are enriched with state-of-the-art geophysical parameters (geoid, DEM, land cover class, Land/water mask, etc.).

The wet tropospheric correction, crucial over continental waters, cannot be computed from the onboard radiometer because the land emissivity drowns out the signal coming from water bodies. The model backup correction included in the standard altimetry products has proved to be insufficiently accurate over continental waters. For PISTACH we therefore developed a new wet tropospheric model correction based on a more accurate integration of the atmospheric parameters. Moreover, over land, the ECMWF model geometry does not reconstruct small-scale topography, especially over water bodies in mountainous terrains. The wet and dry tropospheric corrections are recomputed from ECMWF 3D meteorological fields with the bottom (and thus thickness) of the atmosphere column given by each altimetric measurement (to be included in the next version of the PISTACH products).

1.3. Access to the PISTACH Coastal and Hydrology Altimetry products

Data files are freely accessible at the following FTP address:

ftp://ftp.aviso.oceanobs.com/pub/oceano/pistach/J2/IGDR/

However, we recommend that users register on Aviso web site (http://www.aviso.oceanobs.com/en/data/registration-form/) in order to be kept informed of any and every news about those products.

Users can then go either to the "**coastal**" or the "**hydro**" sub-directory according to their topic of interest.

Then go to the "**cycle_CCC**" sub-directory. Information and tools relative to the conversion between Jason-2 orbital cycle numbers and calendar dates can be found on the Aviso web site.

Remember however that:

- cycle 001 was acquired in early july 2008

- each cycle lasts ~10 days (i.e. ~36 cyles are acquired each year)
- cycle 037 was thus acquired in July 2009, ... etc

The file names are defined according to the example below:

JA2_IPX_2PTPCCC_PPP_YYYYMMDD_HHMMSS_YYYYMMDD_HHMMSS.nc

Where:

- JA2_IPC_2PTP = Jason-2 **Coastal** product
- JA2_IPH_2PTP = Jason-2 **Hydro** product
- CCC: cycle number
- PPP: pass number
- First YYYYMMDD_HHMMSS block: acquisition start time (YearMonthDay_HourMinutesSecondes)
- Second YYYYMMDD_HHMMSS block: acquisition end time (YearMonthDay_HourMinutesSecondes)

1.4. Conventions

The vocabulary and conventions for the time, units, corrections,... etc., are strictly identical to the ones described in the official OSTM/Jason-2 Products Handbook (§1.4). Cf. this document for any further information.

Variable names that appears in blue in the following paragraphs refers to variable names that users will find in the standard GDR Jason-2 products while those printed in green are specific to the Coastal and Hydrology Altimetry Products.

1.5. User's feedback

The Coastal and Hydrology Altimetry products are **experimental** products.

Therefore, we consider that each and every question, comment, example of use, suggestion will help us improve the product and will thus be welcome at aviso@oceanobs.com.

2. Using the Coastal and Hydrology Altimetry I-GDR data

2.1. Overview

Level-2 GDR altimetry products are obviously rich data sets but that can appear complex especially to newcomers to altimetry. However, the use of the wide spread self-described NetCDF format plus the publication of dedicated toolboxes, such as the **BRAT** (Basic Radar Altimetry Toolbox: http://www.altimetry.info/html/data/toolbox_en.html), make it possible to quickly and efficiently visualize and handle these data.

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,
- 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.

The Coastal and Hydrology Altimetry products (IGDR-like) contains all relevant corrections needed to calculate the water (sea, lake, river, …) surface height. For the other "geophysical variables" in the PISTACH data sets: 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.

As indicated above, **the Coastal and Hydrology Altimetry products are experimental products**. Following that guideline, it is frequent that several alternative solutions may be proposed for some data fields. As an example, the user will find 4 different altimeter ranges and 4 different wet tropospheric corrections. **Even if this handbook can eventually recommend one given solution, the user is strongly advised to test them on its own study area.**

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

2.2. Typical computation from altimetry data over ocean

N.B.: The“Coastal” products contain data over the open ocean and can thus be used on these areas. This section is entirely reproduced from the OSTM/Jason-2 Products Handbook

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.

WARNING

Default values are given to data when computed values are not available (See section 6.1.2 Erreur ! Source du renvoi introuvable. of OSTM/Jason-2 Products Handbook**) 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 Erreur ! Source du renvoi introuvable.**, of OSTM/Jason-2 Products Handbook**) although some discussion of flags appears in this section.**

2.2.1. 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) 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 and C band ranges (net_instr_corr_range_ku and 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 altimeter ionosphere correction (iono_corr_alt_ku to correct range_ku).

IMPORTANT: See Section 2.2.4 "Smoothing the Ionosphere Correction".

Sea State Bias Correction:

Use sea state bias correction (sea_state_bias_ku to correct range_ku).

NOTE: The ionosphere and sea state bias corrections are both frequency dependent. Therefore Ku band corrections should only be applied to Ku band ranges, and C band corrections should only be applied to C band ranges. Section 2.2.5 explains how the C band ionosphere correction can be derived from the Ku band ionosphere correction (iono_corr_alt_ku), while the C band sea state bias correction is provided as sea_state_bias_c.

2.2.2. 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 2.2.1.

Tide effects (solid earth tide height, geocentric ocean tide height, pole tide height)**:**

See sections 2.2.2.1 and 3.73.8.

Inverted Barometer Height Correction:

Use inv_bar_corr (see also section 3.8).

HF Fluctuations of the Sea Surface Topography:

Use hf_fluctuations_corr (see also section 3.8).

Mean Sea Surface:

See sections 2.2.2.2 and 3.4.

2.2.2.1. 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 3.7 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.

2.2.2.2. 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 3.3 and 3.4.

2.2.3. 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 $\pm$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, §6.2 of OSTM/Jason-2 Products Handbook) 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.

2.2.4. 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 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

2.2.5. 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)
- 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.

2.3. Typical computation from altimetry data over coastal areas

2.3.1. Corrected Altimeter Range

The principle of the computation of the Corrected Altimeter Range is identical to the one described in 2.22.2 for open ocean areas, at the exception of:

Range:

Depending on the user's study area, use standard altimeter range (range_ku) or PISTACH ranges: range_oce3_ku for areas where the altimeter is not too much polluted by emerged lands i.e. at least 15 km offshore,
or range_red3_ku for areas including near shore zones.

Wet Troposphere Correction:

The radiometer is perturbed by land emerged at a distance up to 50 km from nadir. Therefore, the AMR correction should not be used in coastal areas. Two alternative solutions are issued from the PISTACH prototype.

Use the composite correction (composite_wet_tropo_corr) or the decontaminated correction (decontaminated_wet_tropo_corr) instead of the AMR correction (rad_wet_tropo_corr).

Ionosphere Correction:

The dual-frequency ionosphere correction is deduced from range differences between Ku and C bands. The emerged lands do not affect in the same way the 2 bands. Therefore, the dual-frequency ionosphere correction should be used with caution in the 0-20 km coastal zones.

Use standard altimeter ionosphere correction (iono_corr_alt_ku to correct standard range_ku) or PISTACH ionosphere correction (iono_corr_alt_oce3_ku to correct range_oce3_ku) or even the GIM model correction (iono_corr_gim_ku) for studies in the immediate vicinity of lands.

IMPORTANT: See Section 2.2.4 "Smoothing the Ionosphere Correction".

Sea State Bias Correction:

Use standard sea state bias correction (sea_state_bias_ku to correct range_ku) or PISTACH sea state bias correction (sea_state_bias_oce3_ku to correct range_oce3_ku).

2.3.2. Sea Surface Height and Sea Level Anomaly

The principle of the computation of the Sea Surface Height and Sea Level Anomaly is identical to the one described in 2.2.2 for open ocean areas, at the exception of:

Tide effects (solid earth tide height, geocentric ocean tide height, pole tide height)**:**

A most recent geocentric ocean tide height (global model GOT 4.7) is provided in the Coastal and Hydrology Altimetry products (ocean_tide_sol3) in addition to the 2 existing solutions.

Regional solutions are to be included in the next version of the products (North East Atlantic, Mediterranean Sea).

Mean Sea Surface:

Two alternative solutions (GOCINA for the North Atlantic Ocean and DSNC08 global) are provided in the Coastal and Hydrology Altimetry products (respectively mss2 and mss3) in addition to the existing solution (MSS CLS01V1).

Geoid:

A most recent geoid solution (EGM2008) is provided in the Coastal and Hydrology Altimetry products (geoid_EGM2008) in addition to the existing solution (geoid_EGM96).

2.4. Typical computation from altimetry data over hydrologic areas

Over continental water bodies (or even "dry" lands where altimeter echoes can be exploitable), users seeking for water surface heights should proceed as described below.

2.4.1. Corrected Altimeter Range

Range:

At the exception of some large water bodies that can exhibit ocean-like waveforms in their central parts, users are advised to use the Ice1 standard altimeter range solution (ice_range_ku) or PISTACH Ice3 range (range_ice3_ku). The PISTACH range_red3_ku range solution can eventually be used over medium-size water targets.

Wet Troposphere Correction:

At the exception of the central parts of some very very large water bodies, the radiometer is usually perturbed by emerged lands. Therefore, the AMR correction (rad_wet_tropo_corr) should not be used over continental waters. The standard model solution (model_wet_tropo_corr) is not optimal over non ocean areas due to a possibly inaccurate knowledge of the atmosphere thickness above each altimeter data point. But it should nevertheless be used since the new solution developed in PISTACH (model_wet_tropo_corr_direct_sol) is not computed yet because of difficulties to access the ECMWF meteo model outputs.

Dry Troposphere Correction:

The standard model solution (model_dry_tropo_corr) is not optimal over non ocean areas due to a possibly inaccurate knowledge of the surface pressure above each altimeter data point. But it should nevertheless be used since the new solution developed in PISTACH (model_dry_tropo_corr_direct_sol) is not computed yet because of difficulties to access the ECMWF meteo model outputs.

Ionosphere Correction:

The dual-frequency ionosphere correction is deduced from range differences between Ku and C bands. The emerged lands do not affect in the same way the 2 bands. Additionally, the dual-frequency ionosphere correction must be smoothed over long distances. Therefore, the dual-frequency ionosphere correction should not be used over continental waters and we recommend using the GIM iono correction (iono_corr_gim_ku) instead.

Sea State Bias Correction:

The sea state bias correction remains mostly enigmatic over continental water bodies and we recommend not to include this correction in the water surface height computation at the exception of central parts of very large water bodies. In that case, use standard sea state bias correction (sea_state_bias_ku to correct range_ku) or PISTACH sea state bias correction (sea_state_bias_oce3_ku to correct range_oce3_ku).

2.4.2. Water Surface Height

Water Surface Height (WSH) is the height of the surface of a given water body above the reference ellipsoid. It is calculated by subtracting the corrected range from the Altitude:

Water Surface Height = Altitude - Corrected Range

Where

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

The Water Surface Altitude is calculated above the geoid. It is given by:

Water Surface Altitude = Water Surface Height - Geoid
- Solid Earth Tide Height
- Pole Tide Height

3. Altimetry data

This section presents a short discussion of the main quantities on the (O)(I)GDR. It is reproduced from the OSTM/Jason-2 Products Handbook. Specificities introduced by the PISTACH processing and outputs are added.

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

3.1. 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 10 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).

PISTACH Processing and Outputs: **None. Being an evolution of the OSTM/Jason-2 IGDRs, the PISTACH products contain the preliminary orbit with radial accuracies better than 2.5 cm (RMS).**

3.2. Altimeter Range - Retracking

The altimeter transmits a short pulse of microwave radiation with known power toward the sea surface and measures the time for the pulse to travel round trip between the satellite and the sea surface.

. The distance between the satellite and the sea surface, called altimeter range is deduced from this time delay between emission and reception 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 instrumental effects, including calibration errors, center of gravity motion, and terms related to the altimeter acceleration such as Doppler shift and oscillator drift. The total sum 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).

PISTACH Processing and Outputs for Coastal and Continental Water Areas: Due to the heterogeneity of the backscattering surfaces in coastal and continental water areas, many different waveform shapes can be observed. A classification of these waveforms has been achieved (neural network algorithm). The result of this classification is provided in the Coastal and Hydrology Altimetry products. Knowing, for each waveform the classification number (see Figure 4) can also be very useful to choose which retracking output has to be preferably considered (the 4 retrackers are applied simultaneously on each waveform). Moreover, editing criteria using WF classification can be used to discard some retracking output knowing that each retracking cannot be efficient whatever the shape of the waveform. As an example, waveforms of class 2 or class 21 (peaky waveforms) cannot be efficiently retracked by a deep ocean retracking (based on a Brown model as the one used for nominal GDR products).

Over continental waters, the altimeter waveforms are highly perturbed by emerged lands within the radar footprint. Multi-peak or quasi-specular echoes are frequently encountered. Thus, the implementation of dedicated retracking algorithms is required as a key issue to precisely estimate the altimetric ranges and, when possible, the other waveform parameters. operations

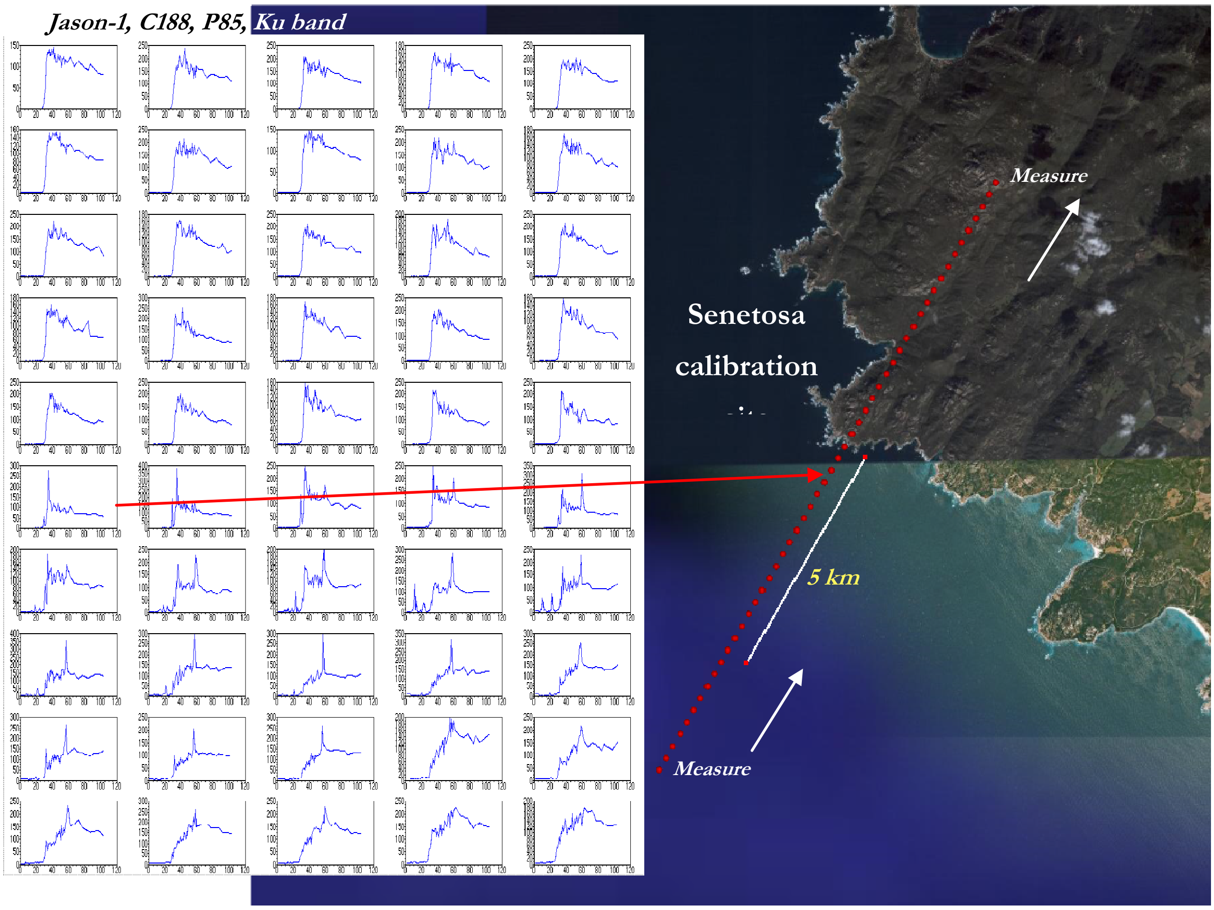

Figure 2: Examples of waveforms near the Senetosa calibration site (Corsica island) (Jason-1, Cycle 188, pass 85, Ku band). Note how ocean-like echoes are progressively altered.

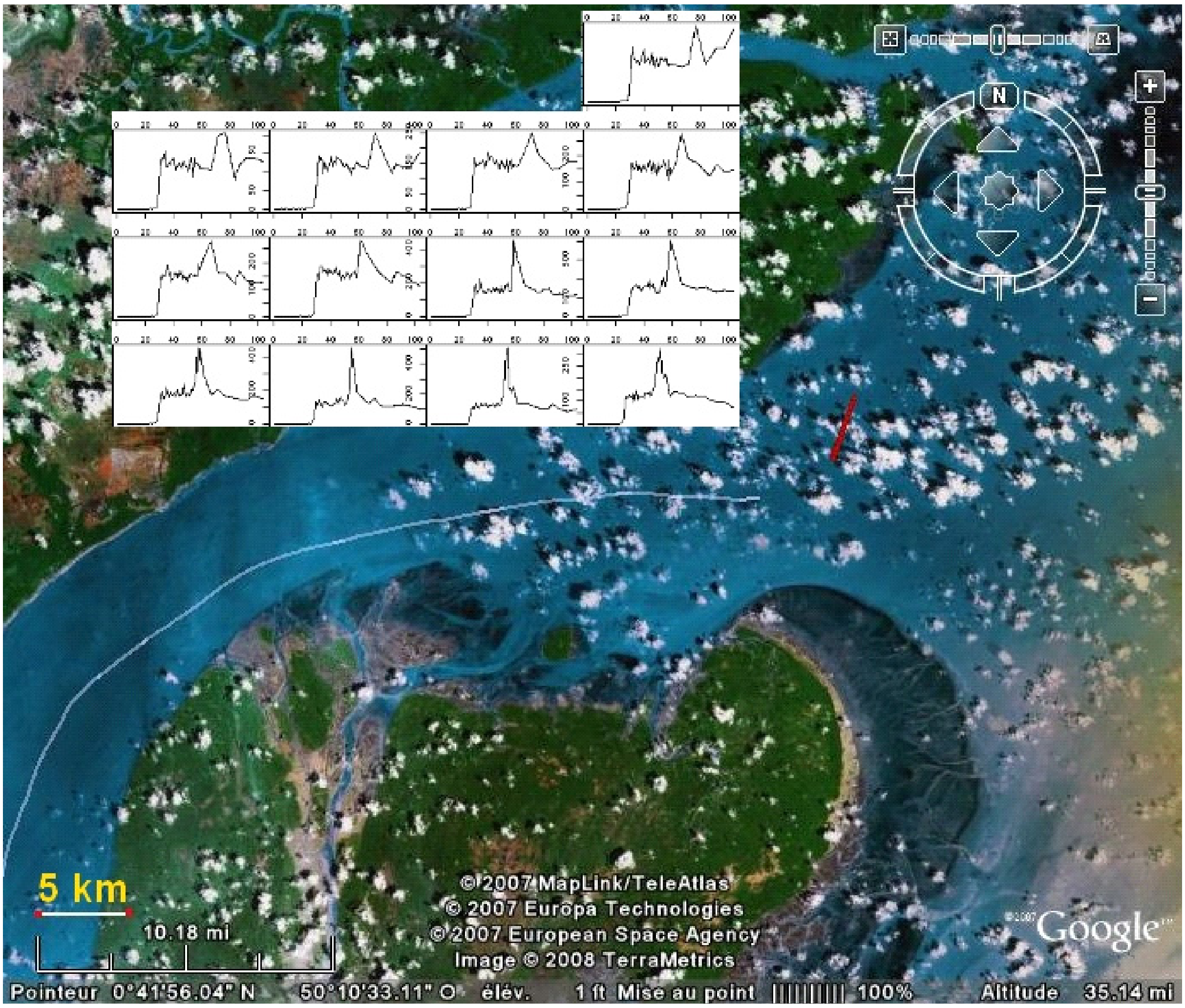

Figure 3: Examples of waveforms over the Amazon river (Jason-1, Cycle 188, pass 37, Ku band)

Classification of the waveforms

The waveforms are classified according to the shape of the waveform: Brown echoes (for ocean and ocean-like surfaces); peak echoes, linear, very noisy, etc. These classes are shown in Figure 7.

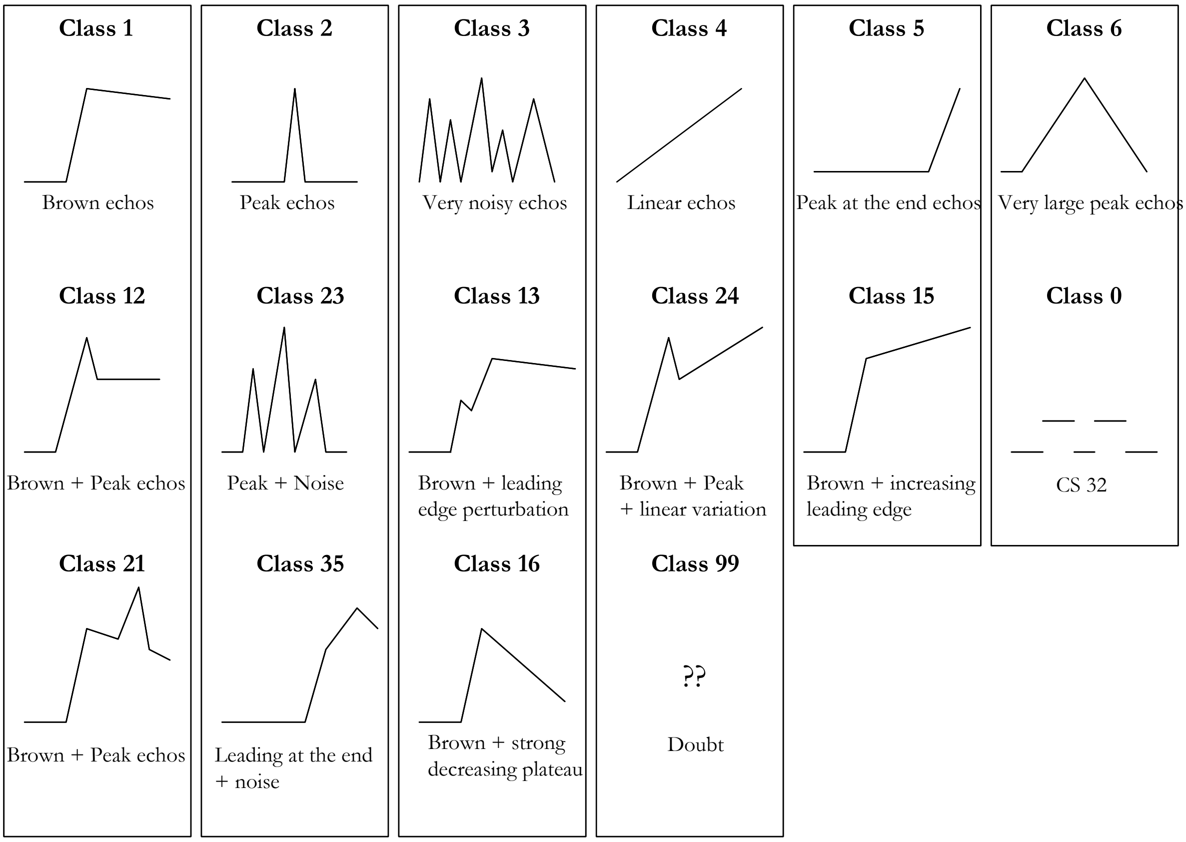

Figure 4: Schematic representation of the waveforms classes within the PISTACH processing

A number is assigned to each class and users can find within the Coastal and Hydrology Altimetry products the value of this class number associated to each data point (wf_class_ku and wf_class_c parameters for Ku and C band respectively). This information is provided to enable users to automate their processing, for example by using a specific retracking output depending on the class and/or for editing the data.

As shown on Figure 5for coastal areas, the altimeter waveforms usually start deviating from the Brown model echo around about 10km from the coast.

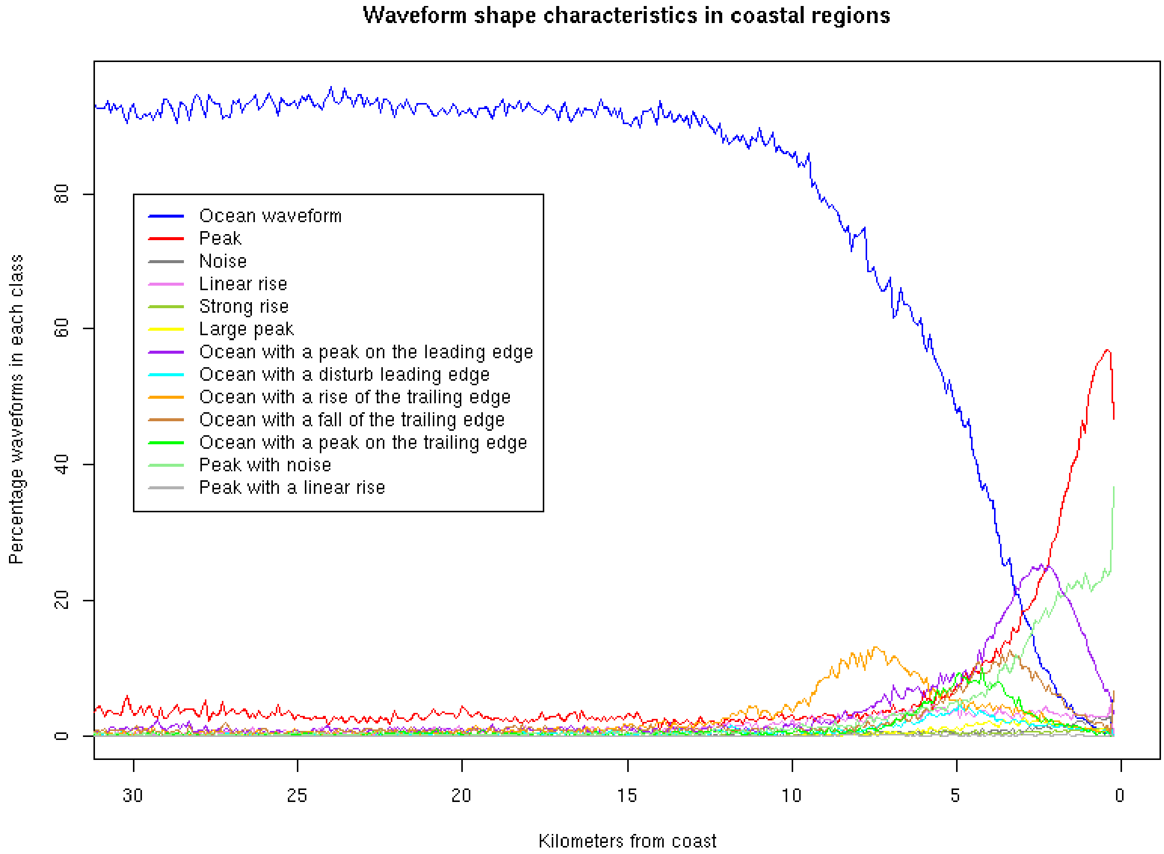

Figure 5: Percentage of occurrence for each waveform class as a function of the distance to the coast (coastal ocean areas). Typical ocean waveforms are generally encountered above 10 km from the coast.

Retracking strategies

During the PISTACH project, 3 new retracking algorithms have been developed, providing with the unchanged Ice1 algorithm a set of 4 alternative ranges since all 4 retrackers are applied simultaneously to each waveform. PISTACH being an experimental prototype, we consider that it is the responsibility of the user to determine which retracker output is appropriate to his specific data set.

- **Ice1** retracking is based on the Offset Centre of Gravity (OCOG, Wingham et al. 1986) method that consists in fitting to the waveform a rectangle which center of gravity coincides with the COG of the waveform. The ice1 range is given by the abscissa of the first sample which power reaches a given percentage of the COG amplitude (30% in this case). The following parameters are estimated by the Ice1 retracker and included in the Coastal and Hydrology Altimetry products:
    - amplitude_ice1_ku and amplitude_ice1_c: Ku and C band amplitudes for Ice1 retracker (in FFT Power unit)
    - ice_range_ku and ice_range_c: Ku and C band ranges for Ice1 retracker
    - ice_sig0_ku and ice_sig0_c: Ku and C band altimeter backscatter coefficients computed from the amplitude_ice1.
    - retracking_flag_ice1_ku and retracking_flag_ice1_c: Ku and C band processing flags for Ice1 retracker

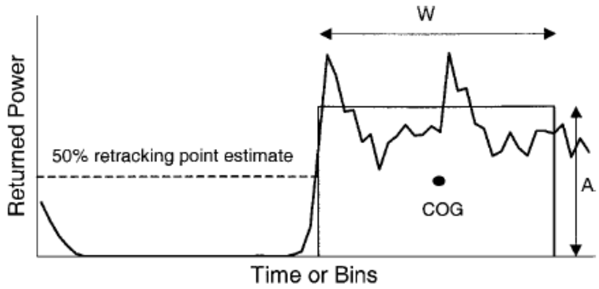

Figure 6: Principle of an OCOG algorithm (from Deng et al., 2002)

- **Ice3** : The ice3 retracker is deduced from the ice1 retracker. Its principle is exactly the same than the ice1 one except that computations are done in a smaller window selected around the main leading edge of the waveform [-10;+20 samples]. This processing is more robust than ice1 in particular when small peaks can be observed at the beginning of the waveform. This algorithm catches better than ice1 the main leading edge of the waveform. The following parameters are issued by the Ice3 retracker and are provided in the PISTACH products:
  - range_ice3_ku and range_ice3_c: Ku and C band ranges for Ice3 retracker
  - retracking_flag_ice1_ku and retracking_flag_ice1_c: Ku and C band processing flags for Ice3 retracker

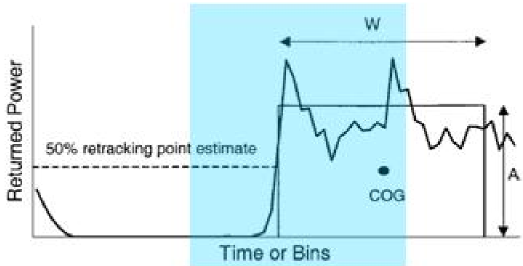

Figure 7: Principle of the Ice3 algorithm

- **Red3** As previously described, bumps in the waveforms are often observed in the trailing edge when approaching the shorelines. This algorithm works as ice3 does selecting an analysis window centered on the main leading edge of the waveform and retracking parameters in this reduced window [-10;+20 samples] with a Maximum Likelihood Estimator (solving for 3 parameters : range, amplitude and Sigma composite). The following parameters are issued by the Red3 retracker and provided in the PISTACH products:
  - amplitude_red3_ku and amplitude_red3_c: Ku and C band amplitudes for Red3 (in FFT Power unit)
  - range_red3_ku and range_red3_c: Ku and C band ranges for Red3 retracker
  - sig0_red3_ku and sig0_red3_c: Ku and C band altimeter backscatter coefficients from Red3 retracker
  - retracking_flag_red3_ku and retracking_flag_red3_c: Ku and C band processing flag for Red3 retracker
  - swh_red3_ku and swh_red3_c: significant wave height from Red3 retracker in Ku and C band
  - thermal_noise_red3_ku and thermal_noise_red3_c: Thermal noise for Red3 retracker in Ku and C band
  - width_leading_edge_red3_ku and width_leading_edge_red3_c: width of the leading edge of the waveform in Ku and C band from Red3 retracker

- mqe_red3_ku and mqe_red3_c: Mean Quadratic Error between the Ku and C waveforms samples and the corresponding model samples built from the red3n retracking output

- Oce3 :This algorithm is an classical MLE3 retracking algorithm but it is performed on **filtered waveforms**. The filtering that has been applied is a SVD filtering (Singular Value Decomposition Filtering) allowing to reduce the multiplicative speckle noise on the waveform and thus to reduce the estimation noise for each parameter.

For these 4 retracking algorithms, the 20Hz retracking ouput (ranges, sigma0, SWH, classes etc.) are provided in the Pistach products.

3.3. 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.

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

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

PISTACH Processing and Outputs (coastal areas and continental water areas)

In the Coastal and Hydrology Altimetry Jason-2 IGDRs, we took advantage of the recent release of the EGM2008 geopotential to compute an alternative geoid solution (the EGM96 geoid is also present in the Coastal and Hydrology Altimetry products). The EGM2008 geopotential model has been used to calculate point values of geoid undulation on a 1/12° by 1/12° degree grid. The EGM2008 model is complete to spherical harmonic degree and order 2159. More information on EGM2008 can be found at http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/index.html

3.4. 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.

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

The OSTM/Jason-2 (O)(I)GDR provides a global MSS model (CLS01_MSS) that is generated from multiple satellite altimetry missions. The CLS01_MSS grid used is defined on a regular 1/30°x 1/30° grid. Refer to http://www.cls.fr/html/oceano/projets/mss/cls_01_en.html for more details on this model.

PISTACH Processing and Outputs (valid for coastal and open ocean areas)

In the Coastal and Hydrology Altimetry Jason-2 IGDRs, we introduced 2 alternative solutions to the CLS01_MSS (mss1):

- The regional GOCINA model solution (http://geodesy.spacecenter.dk/~gocina/)(mss2)
- The global DNSC08 model solution (mss3) that is generated from multiple satellite altimetry missions and with a dedicated processing of the oceanic variability. It is defined on a regular 1/60°x 1/60° grid. Refer to the following link for more info on this model: http://www.space.dtu.dk/upload/institutter/space/data_og_modeller/global_mean_sea_surface_model/dnsc08mss.pdf
- Error on the various mss values (err_mss1, err_mss2 and err_mss3 respectively), which gives indication to the confidence to the data, especially valuable information in coastal areas.

3.5. 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).

PISTACH Processing and Outputs (valid for coastal and open ocean areas)

In the Coastal and Hydrology Altimetry Jason-2 IGDRs, we introduced the RIO2007 regional MDT (mean_topography2) for the Mediterranean Sea as an alternative solution to the global RIO2005 MDT (mean_topography1). (Rio 2007)

3.6. 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].

3.6.1. 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 over surfaces at sea level altitude. 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).

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

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. **Over open ocean surfaces**, 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].

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).

PISTACH Processing and Outputs - Coastal areas

In the Coastal and Hydrology Altimetry Jason-2 IGDRs, we introduced 2 alternative solutions to the wet tropospheric correction for coastal areas:

- **The decontaminated wet tropo correction** (decontaminated_wet_tropo_corr) (Obligis et al., 2010) aims at removing the contamination of land within the brightness temperatures (TB) measured by the radiometer, taking into account the antenna pattern of each channel:
  - TBcorr(f)=TB(f)-corr(p,f)
  - corr (*p* , *f*) = [TBland(*f*) - TBsea (*f*)] × ***p*** (*f*)
  - dh =f(TBcorr(f))

- p= land proportion in the pixel (taking into account the antenna pattern), see 3.12.3

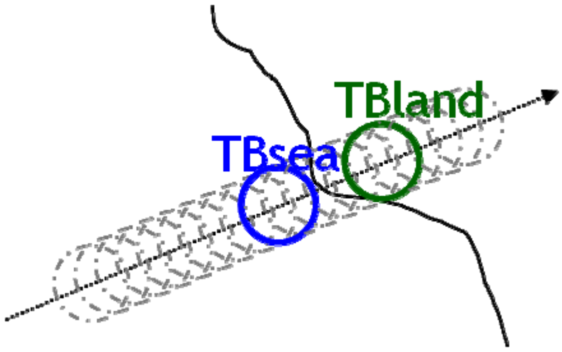

Figure 8: Exemple of a sea-land transition with the positions of full land and full sea radiometer footprints. All measurements located between these 2 extreme data points are corrected.

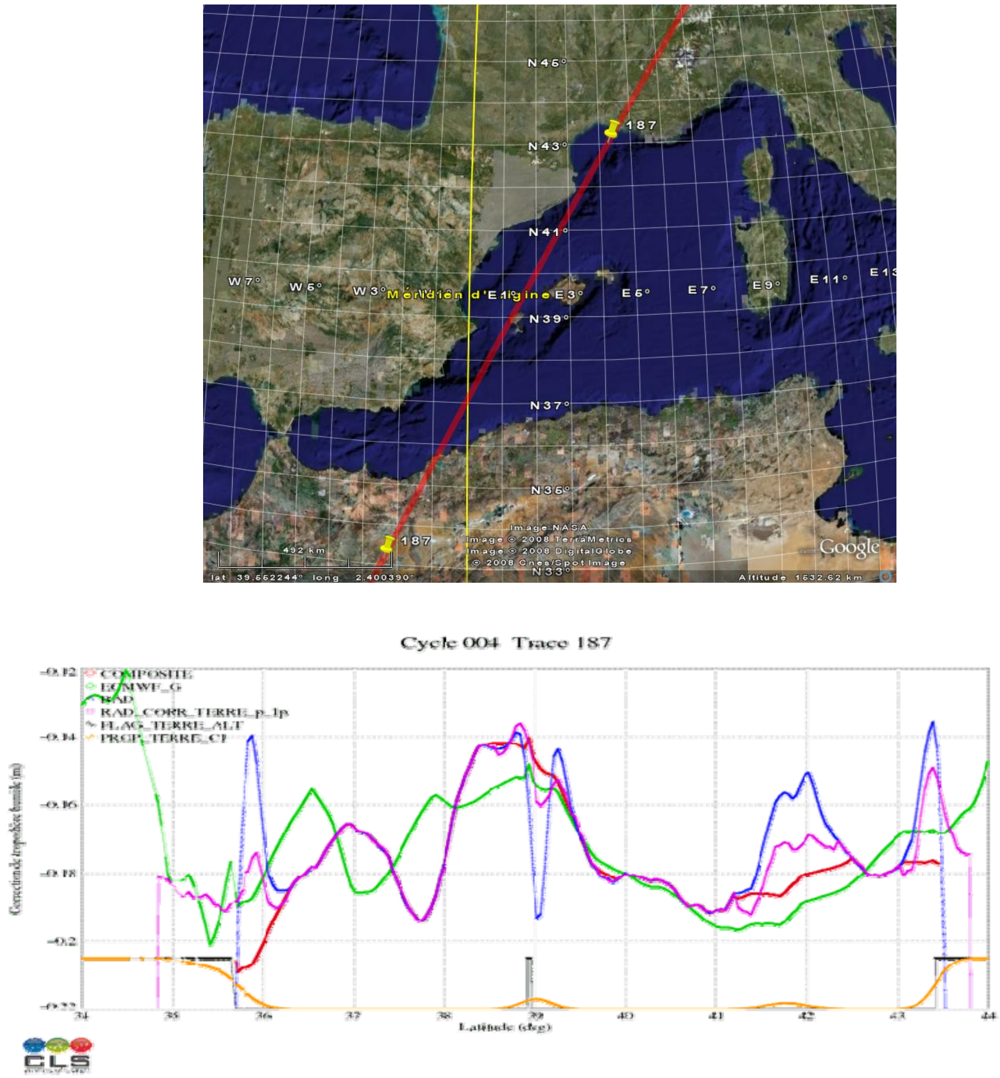

Figure 9a (top) and 9b (bottom): location of the ground track #187 (top) and fluctuations (bottom) of the various wet tropo corrections along that track as a function of latitude (blue: radiometer; green: ECMWF model ; pink: decontaminated correction; red: composite correction). The proportion of land within the radiometer (channel 1) footprint is shown in orange.

- The **composite correction** (composite_wet_tropo_corr) smartly merging the radiometer correction where it is valid and the model correction, considering several coastal configurations:
  - The composite correction takes the value of the radiometer correction when far enough from the coast (>50 km)
  - the model correction (ECMWF) replaces the radiometer for a track segment always near the coasts (<50 km)
  - simplest case ("transition"): ECMWF corr. is shifted at the nearest valid radiometer corr.
  - more complicated cases: idem + interpolation and detrending of the ECMWF corr.

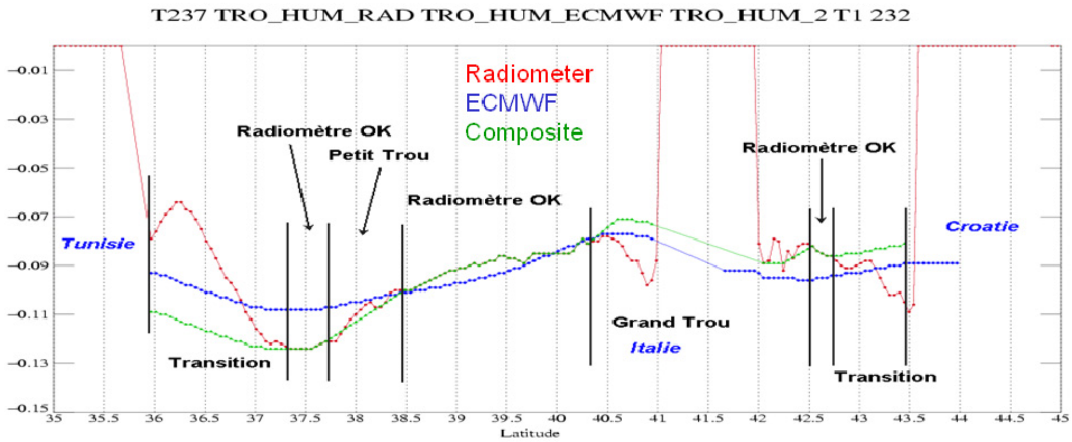

Figure 10: Fluctuations of the composite wet tropo correction along track #232 in the Mediterranean Sea. (Red: radiometer; blue: ECMWF model; green: composite correction)

PISTACH Processing and Outputs - Continental surfaces

In the Coastal and Hydrology Altimetry Jason-2 IGDRs for continental surfaces, we introduced 1 alternative solution to the wet tropospheric correction and 1 alternative to the dry tropospheric correction. Both corrections are model corrections based on outputs from the ECMWF model. ***Note however that this correction is not computed in the V1.0 of the Coastal and Hydrology Altimetry products since the ECMWF model output are not yet accessible to the PISTACH prototype on an operational basis.***

In the standard processing, 6-hourly 2D grids of the **model wet tropospheric correction** (model_wet_tropo_corr) are computed via the vertical integration of 3D meteo parameters (humidity, temperature, …) above a topography grid which resolution is the one of the ECMWF model (~0.25°x0.25°). The correction associated to each along-track data point is computed by interpolation in space and time at the date and location of the measurement. A similar process is applied for the **dry tropo correction** (model_dry_tropo_corr) that is computed from the 6-hourly surface pressure grids.

The PISTACH approach is based on the fact that the rather crude resolution of the model topography grid cannot be representative of small scale topography variations along the satellite track. Differences of several hundred of meters between the real altitude at the altimeter data point and the surrounding model grid nodes are possible, keeping in mind that water bodies are located in terrain lows. Therefore, the thickness of the atmosphere on which the integration of the meteo parameters is performed is often not very accurate over continental surfaces. The PISTACH approach ("direct solution") uses the altimeter range to derive a more accurate atmosphere thickness above the measurement points. This information is then used for the vertical integration of the 3D meteo fields at each data point for wet tropo correction (model_wet_tropo_corr_direct_sol) and for the dry tropo correction (model_dry_tropo_corr_direct_sol) via the computation of a refined surface pressure.

3.6.2. 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 2.2.4 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.).

PISTACH Processing and Outputs - Coastal areas

For the dual-frequency ionosphere correction, we decided to compute a raw correction directly from 20Hz Oce3 retracking parameters and then to apply a 150-km filter. This has been chosen in order to avoid a 20Hz/1Hz compression step. This strategy is reinforced by the fact that the SVD filtering of the waveforms significantly reduces the noise on the range measurements in Ku and C bands, even if the signal to noise ratio is rather unfavorable, especially during low solar activity periods, as it was the case during the PISTACH developments.

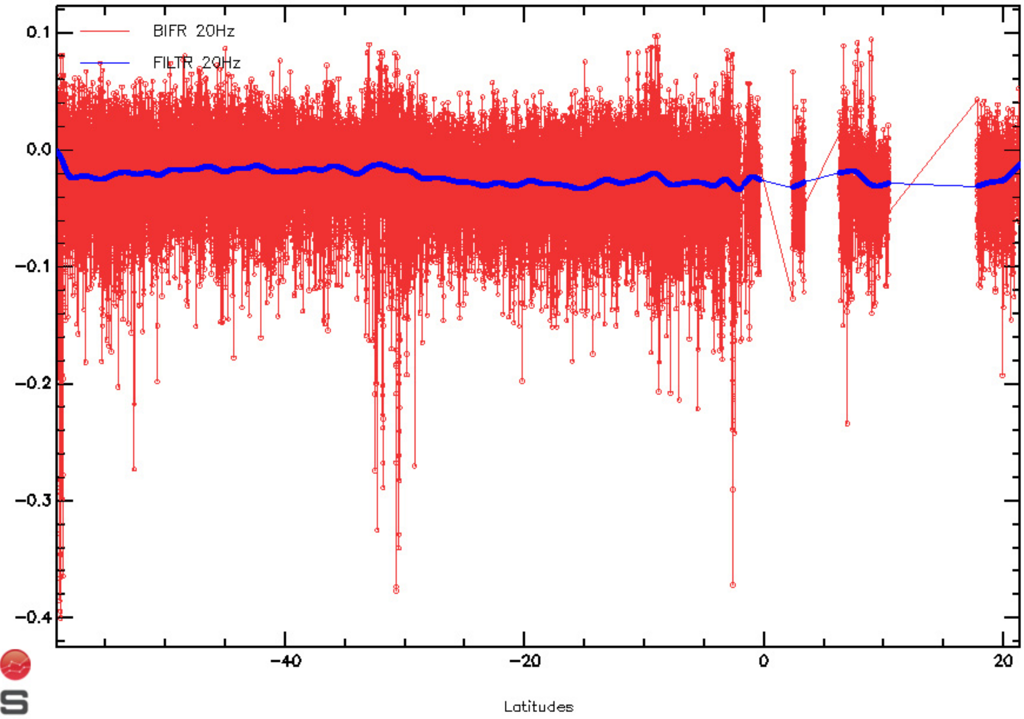

Figure 11: 20Hz dual-frequency iono correction from Oce3 retracking parameters before filtering (red) and after filtering (blue, data field iono_corr_alt_oce3_ku to correct PISTACH range_oce3_ku), Cycle 13, pass 1, Jason-2.

PISTACH Processing and Outputs - Continental water areas: none

Due to the important alteration of the waveforms over continental water areas, it has not been possible to compute an altimeter-derived ionospheric correction for those areas. We recommend using the GIM iono correction.

3.6.3. 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.

PISTACH Processing and Outputs - Coastal areas

Several regional SSB models have been estimated and analyzed during the development of the PISTACH prototype. They all differ between each other and also with respect to the open ocean SSB model which has been taken as a reference. The tricky point is to decide whether such differences may be explained by the physics of the EM bias phenomena or these differences should be attributed to the poor relevancy of the direct method used over all these regions.

The analysis of SSB performed over several regions during the development of the PISTACH prototype has shown that the empirical estimation, as it is performed for the open ocean, is difficult to apply to regional data sets. The main difficulty is that the ocean variability signal becomes preponderant when studying areas of limited extent: it is necessary to separate SSB and oceanic signals from the SSH information. Note that over the open ocean, it is possible to separate the 2 signals when working on a global scale and by considering the ocean variability as a noise mainly uncorrelated from sea state: this approach is not possible over coastal areas.

The PISTACH products contain two 20-Hz SSB corrections:

- One is directly deduced from the standard MLE4 retracking algorithm (sea_state_bias_ku to correct range_ku, equivalent to the SSB correction contained in the standard Jason-2 products)
- The other is deduced from the Oce3 retracker (sea_state_bias_oce3_ku to correct PISTACH range_oce3_ku)

These 2 corrections usually contains relevant information up to 10km from the coast, since it has been shown that waveform are mostly ocean-like up to that distance from the coasts.

PISTACH Processing and Outputs - Continental water areas: none

3.7. 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 too 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.

3.7.1. 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.

PISTACH Processing and Outputs

- **Coastal areas:** A most recent geocentric ocean tide height (global model GOT 4.7) is provided in the PISTACH products (ocean_tide_sol3) in addition to the 2 existing solutions. The corresponding load tide is also included in the products (load_tide_sol3). Regional solutions are to be included in the next version of the products (North East Atlantic, Mediterranean Sea).

- Continental water areas: none

3.7.2. 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.

PISTACH Processing and Outputs:

The new geocentric ocean tide provided in the PISTACH products (ocean_tide_sol3) already include the equilibrium long-period ocean tide.

3.7.3. 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.

PISTACH Processing and Outputs: None

3.7.4. 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.

PISTACH Processing and Outputs: None

3.8. Inverse Barometer Effect

PISTACH Processing and Outputs

- **Coastal areas:** none
- Continental water areas: none

3.8.1. 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:

$$inv\_bar\_corr = -9.948 * (P_{atm} - P)$$

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.

3.8.2. High frequency barotropic 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 has energy at periods shorter than the 20 day and thus this signal aliases into longer periods due to the ~10 day repeat cycle of OSTM/Jason-2. This high frequency correction can be thought of as a departure from the IB static response to pressure, although strictly it is the difference between the high frequency dynamic response to wind and pressure minus the IB. This dynamic atmospheric correction is computed with a global barotropic finite element model (MOG2D-G; Carrère and Lyard 2003) forced by ECMWF operationnal wind and pressure fields. The model outputs are filtered in time to keep only high frequencies (periods lower than 20 days). See also *Stammer et al*. [2000] 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.

3.9. 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.

PISTACH Processing and Outputs

The Coastal and Hydrology Altimetry products include the following altimeter backscatter coefficients derived by the various retracking algorithms:

- sig0_ice3_ku and sig0_ice3_c for the ice3retracking
- sig0_red3_ku and sig0_red3_c for the Red3 retracking
- ice_sig0_ku and ice_sig0_c for the Ice1 algorithm

3.10. Wind Speed

The model functions developed to date for altimeter wind speed have all been purely empirical. The model function establishes a relation between the wind speed, and the sea surface backscatter coefficient and significant wave height. 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. 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 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.

PISTACH Processing and Outputs - Coastal areas

The Coastal and Hydrology Altimetry products include the wind speed parameter (wind_speed_alt_oce3) deduced from the Ocean3 retracking algorithm, in addition to the standard wind speed value (wind_speed_alt). This parameter is suitable only for ocean-like echoes.

3.11. Bathymetry and Topography Information

The OSTM/Jason-2 (O)(I)GDR provides a parameter bathymetry (bathymetry_topography) that gives the ocean depth or land elevation of the data point. It is derived from the GSFC DTM2000.1 data set. 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.

PISTACH Processing and Outputs - Coastal zones

In the PISTACH products, we included the regional_bathy parameter that is filled with values derived from several regional bathymetry models. Since the models do not overlap, we created only one common field in the product that contains either:

- Bathymetry Etopo2v2
  - resolution=1/30°
  - reference = http://www.ngdc.noaa.gov/mgg/fliers/06mgg01.html
  - Black Sea : 27°E/40°N à 42°E/47.5°N
  - Baltic Sea : 9°E/53°N à 15°E/61°N and 15°E/53°N à 31°E/66.5°N
  - Florida Coasts : 87°W/24°N à 79°W/31°N
- Bathymetry GEBCO

- Resolution= 1/60°
- reference = Pharaoh and Weatherall, 2007.
- Indian's coasts : 62° 18'E-87° 45'E; 6° 29'N - 25° 43'N
- Andaman Islands's coasts: 91° 40'E - 95° 53'E; 3° 35'N - 15°N
- Korea's coasts : 124°E-133°E; 32°N-43.3°N

- Bathymetry Webtide model
  - Resolution= 1/40°
  - reference = Dupont et al. 2002, Saucier et al. 2004.
  - Hudson bay
  - North-western Atlantic
    - North of 52.5°, |depth| < 1400 m
    - St Laurent's river mouth (45°N/290°E to 52.5°N/307.5°E

PISTACH Processing and Outputs - Continental surfaces

In the Coastal and Hydrology Altimetry products, we included a more recent and precise land topography information (topography) derived from the SRTM mission. Although we initially intended to use the ACE2 DEM (Altimetry Corrected Elevation, more info on http://tethys.eaprs.cse.dmu.ac.uk/ACE2/shared/overview), the PISTACH V1.0 products actually contains the SRTM GCIAR_V3 DEM (more info on http://srtm.csi.cgiar.org/) values since ACE2 was not available at the time of delivery of the PISTACH prototype. The resolution of the SRTM CGIARV3 DEM grid is 3"x3" whereas the grid resolution of the DEM used for the standard Jason-2 GDRs is 30"x30".

3.12. Additional parameters of interest in the Coastal and Hydrology Altimetry products

In the Coastal and Hydrology Altimetry products, we introduced several new ancillary parameters that we estimated of interest for coastal and inland water studies. This new parameters are neither range nor geophysical corrections but should be considered as indicators of the measurements environment.

3.12.1. Distance to the shoreline

The parameter shoreline_distance gives an estimation of the distance between the nadir of each altimeter data point to the closest shoreline point. It is computed using coastline position information from the GMT software Full-Resolution coastline database (http://gmt.soest.hawaii.edu/gmt/doc/gmt/html/GMT_Docs/node216.html). Positive values on oceans and major inland water bodies, negative or default values over continents are found in the PISTACH products.

3.12.2. Land cover classification

The parameter Land_cover_class associates a value of the land cover classification to each altimeter data point. This information is extracted from the GLOBCOVER/ESA data set (http://postel.mediasfrance.org/en/PROJECTS/Preoperational-GMES/GLOBCOVER/). The objective of the GLOBCOVER / ESA initiative is to develop a service to produce a global land-cover map for the year 2005-2006, using the fine resolution (300 m) mode data acquired over the full year 2005 by the MERIS sensor on-board the ENVISAT satellite. The thematic legend of the final product is compatible with the FAO-UNEP Land Cover Classification System (LCCS, http://www.fao.org/docrep/003/x0596e/x0596e00.htm). The GLOBCOVER product is developed with an international network of partners, in particular, FAO, GOFC, IGBP, EEA, JRC and UNEP.

The class values found in the Coastal and Hydrology Altimetry Products are defined and described in the GLOBCOVER Products Description Manual: http://postel.mediasfrance.org/IMG/pdf/GLOBCOVER_PDM_I2.2.pdf

3.12.3. Land proportion in the radiometer footprint

The 3 parameters land_prop_c187, land_prop_c238, land_prop_c340 give an estimation of the proportion of land within the footprint of the radiometer antenna for the 18.7, 23.8 and 34GHz channels respectively. This information is used in the processing of the decontaminated_wet_tropo_cor parameter.

Appendix A - 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
DEM	Digital Elevation Model
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
GMT	Generic Mapping Tools
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 télécommuncations 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

Appendix B - References

Chelton, D. B., J. C. Ries, B. J. Haines, L. L. Fu, and P. S. Callahan, 2001, “Satellite Altimetry”, *Satellite Altimetry and Earth Sciences*, ed. L.L. Fu and A. Cazenave, pp. 1-131.

Brenner, A. C., C. J. Koblinsky, and B. D. Beckley, 1990, A Preliminary Estimate of Geoid-Induced Variations in Repeat Orbit Satellite Altimeter Observations, *J. Geophys. Res.*, 95(c3), 3033-3040.

Callahan, P. S., 1984, Ionospheric Variations affecting Altimeter Measurements: A brief synopsis *Marine Geodesy*, 8, 249-263.

Carrère, L. and F. Lyard (2003). "Modelling the barotropic response of the global ocean to atmospheric wind and pressure forcing - comparisons with observations." *GRL* 30(6).

Cartwright, D. E. and R. J. Tayler, 1971, New computations of the tide-generating potential, *Geophys. J. R. Astr. Soc.*, 23, 45-74.

Cartwright, D. E. and A. C. Edden, 1973, Corrected tables of tidal harmonics, *Geophys. J. R. Astr. Soc.*, 33, 253-264.

Cruz Pol, S. L., C. S. Ruf, and S. J. Keihm, 1998, Improved 20-32 GHz atmospheric absorption model, *Radio Science*.

Deng, X. , Featherstone, W. E. , Hwang, C. and Berry, P. A. M. (2002) Estimation of contamination of ERS-2 and POSEIDON satellite radar altimetry close to the coasts of Australia. *Marine Geodesy* **25** , pp. 249-271.

Dupond F., Hannah C.G., Greenberg D.A., Cherniawsky J.Y. and C.E. Naimie, « Modelling System for Tides for the Northwest Atlantic Coastal Ocean”, *Canadian Technical Report of Hydrology and Ocean Sciences 221*, 2002.

Gommenginger C., Thibaut P, Fenoglio-Marc L, Quartly G, Deng X, Gomez-Enri J, Challenor P, and Gao Y, « Retracking altimeter waveforms near the coasts ; A review of retracking methods and some applications to coastal waveforms”, DOI: 10.1007/978-3-642-12796-0_6, Springer-Verlag Berlin Heidelberg 2010.

Imel, D., 1994, Evaluation of the TOPEX dual-frequency Ionosphere correction, *J. Geophys. Res.*, 99 (c12), pp 24895-24906.

Keihm, S. J., M. A. Janssen, and C. S. Ruf, 1995, TOPEX/POSEIDON microwave radiometer (TMR): III. Wet troposphere range correction algorithm and pre-launch error budget, *IEEE Trans. Geosci. Remote Sensing*, 33, 147-161.

Labroue S., P. Gaspar, J. Dorandeu, O.Z. Zanife, F. Mertz, P. Vincent and D. Choquet, 2004: Non parametric estimates of the sea state bias for the Jason-1 radar altimeter. Marine Geodesy 27 (3-4), 453-481.

Le Provost, C., 2001, “Ocean Tides”, *Satellite Altimetry and Earth Sciences*, ed. L.L. Fu and A. Cazenave, pp. 267-303.

Lemoine, F. G. et al., 1998, The Development of the joint NASA GSFC and NIMA Geopotential Model EGM96, NASA/TP-1998-206861, 575 pp.

Obligis, E., Desportes, C., Eymard, L., Fernandes, J., Lazaro, C., Nunes, A., « Tropospheric corrections for Coastal Altimetry » in *Coastal Altimetry*, Vignudelli et al. (Eds), DOI: 10.1007/978-3-642-12796-0_6, Springer-Verlag Berlin Heidelberg 2010.

Pharaoh, T. and P. Weatherall (2007). Improving the GEBCO one minute grid in shallow water areas. XVII International Hydrographic conference. Monaco.

Rio, M.-H., P.-M. Poulain, et al. (2007). "A Mean Dynamic Topography of the Mediterranean Sea computed from altimetric data, in-situ measurements and a general circulation model." Journal of Marine Systems **65**: 484-508

Rodriguez, E., Y. Kim, and J. M. Martin, 1992, The effect of small-wave modulation on the electromagnetic bias, *J. Geophys. Res.*, 97(C2), 2379-2389.

Ruf, C., S. Keihm, B. Subramanya, and M. Janssen, 1994, TOPEX/POSEIDON microwave radiometer performance and in-flight calibration, *J. Geophys. Res.*, 99, 24915-24926.

Saucier, F. J., S. Senneville, et al. (2004). "Modelling the sea ice-ocean seasonal cycle in Hudson Bay, Foxe Basin and Hudson Strait, Canada." Climate Dynamics 23(3).

Stacey, F. D., 1977, *Physics of the Earth*, second ed. J. Wiley, 414 pp.

Stammer, D., C. Wunsch, and R. M. Ponte, 2000, De-aliasing of global high frequency barotropic motions in altimeter observations, *Geophys. Res. Lett.*, 27, 1175-1178.

Tierney, C., J. Wahr, F. Bryan, and V. Zlotnicki, 2000, Short-period oceanic circulation: implications for satellite altimetry, *Geophys. Res. Lett.*, 27, 1255-1258.

Wahr, J. W., 1985, "Deformation of the Earth induced by polar motion," J. Geophys. Res. (Solid Earth), 90, 9363-9368.

Wingham D.J., Rapley C.G., Griffiths H. (1986). New techniques in satellite altimeter tracking systems, *Proceedings of IGARSS'86 Symposium, Zürich, 8-11 Sept. 1986, Ref. ESA*

***SP-254*, 1339-1344.Wunsch, C., 1972**, Bermuda sea level in relation to tides, weather and baroclinic fluctuations, *Rev. Geophys. Space Phys.*, 10, 1-49.

Appendix C - Example of PISTACH product header

The text below is the result of a "ncdump –h" unix command (i.e. dump of the header of a NetCdf file) on the PISTACH Coastal Product, cycle 81, pass 170:
ftp://ftpsedr.cls.fr/pub/oceano/pistach/J2/IGDR/coastal/cycle_081/JA2_IPC_2PTP081_170_20100919_214227_20100919_223839.nc.gz

Data fields in green are outputs of the PISTACH prototype. Other fields are found in the official IGDR Jason-2 products.

```
netcdf JA2_IPC_2PTP081_170_20100919_214227_20100919_223839 {
dimensions:
        time = 48452 ;
variables:
        double time(time) ;
            time:long_name = "time (sec. since 2000-01-01)" ;
            time:units = "seconds since 2000-01-01 00:00:00.0" ;
            time:standard_name = "time" ;
            time:calendar = "gregorian" ;
            time:tai_utc_difference = -34. ;
            time:leap_second = "0000-00-00 00:00:00" ;
            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." ;
        int lon(time) ;
            lon:long_name = "longitude" ;
            lon:units = "degrees_east" ;
            lon:standard_name = "longitude" ;
            lon:scale_factor = 1.e-06 ;
            lon:comment = "East longitude relative to Greenwhich meridian. See Jason-2 User Handbook" ;
        int lat(time) ;
            lat:long_name = "latitude" ;
            lat:units = "degrees_north" ;
            lat:standard_name = "latitude" ;
            lat:scale_factor = 1.e-06 ;
            lat:comment = "Positive latitude is North latitude, negative latitude is South latitude. See Jason-2 User Handbook" ;
        double shoreline_distance(time) ;
            shoreline_distance:_FillValue = 1.84467440737096e+19 ;
            shoreline_distance:long_name = "distance to the nearest shoreline in meters" ;
            shoreline_distance:units = "m" ;
            shoreline_distance:comment = "Distance to the closest shoreline point, derived from GMT software High-Resolution
                coastline database. Positive values on oceans and major inland water bodies, negative or default values over
                continents." ;
        byte surface_type(time) ;
            surface_type:_FillValue = 127b ;
            surface_type:long_name = "surface type" ;
            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" ;
        byte alt_echo_type(time) ;
            alt_echo_type:_FillValue = 127b ;
            alt_echo_type:long_name = "altimeter echo type" ;
            alt_echo_type:flag_values = 0b, 1b ;
            alt_echo_type:flag_meanings = "ocean_like non_ocean_like" ;
            alt_echo_type:coordinates = "lon lat" ;
            alt_echo_type:comment = "The altimeter echo type is determined by testing the rms of the high rate range
                measurements against a threshold as well as the number of valid high rate range measurements against a
                minimum value" ;
        byte rad_surf_type(time) ;
            rad_surf_type:_FillValue = 127b ;
            rad_surf_type:long_name = "radiometer surface type" ;
            rad_surf_type:flag_values = 0b, 1b ;
            rad_surf_type:flag_meanings = "ocean land" ;
            rad_surf_type:coordinates = "lon lat" ;
        byte qual_wf_ku(time) ;
            qual_wf_ku:_FillValue = 127b ;
            qual_wf_ku:long_name = "quality flag for the waveform in Ku band" ;
```

```
        qual_wf_ku:flag_values = 0b, 1b ;
        qual_wf_ku:flag_meanings = "Good Bad" ;
        qual_wf_ku:coordinates = "lon lat" ;
        qual_wf_ku:comment = "0 = no DV gate , 1 = at least one DV gate " ;
    byte qual_wf_c(time) ;
        qual_wf_c:_FillValue = 127b ;
        qual_wf_c:long_name = "quality flag for the waveform in C band" ;
        qual_wf_c:flag_values = 0b, 1b ;
        qual_wf_c:flag_meanings = "Good Bad" ;
        qual_wf_c:coordinates = "lon lat" ;
        qual_wf_c:comment = "0 = no DV gate , 1 = at least one DV gate " ;
    byte qual_rad_1hz_tb187(time) ;
        qual_rad_1hz_tb187:_FillValue = 127b ;
        qual_rad_1hz_tb187:long_name = "quality flag for 1 Hz radiometer data: 18.7 GHz brightness temperature" ;
        qual_rad_1hz_tb187:flag_values = 0b, 1b ;
        qual_rad_1hz_tb187:flag_meanings = "Good Bad" ;
        qual_rad_1hz_tb187:coordinates = "lon lat" ;
    byte qual_rad_1hz_tb238(time) ;
        qual_rad_1hz_tb238:_FillValue = 127b ;
        qual_rad_1hz_tb238:long_name = "quality flag for 1 Hz radiometer data: 23.8 GHz brightness temperature" ;
        qual_rad_1hz_tb238:flag_values = 0b, 1b ;
        qual_rad_1hz_tb238:flag_meanings = "Good Bad" ;
        qual_rad_1hz_tb238:coordinates = "lon lat" ;
    byte qual_rad_1hz_tb340(time) ;
        qual_rad_1hz_tb340:_FillValue = 127b ;
        qual_rad_1hz_tb340:long_name = "quality flag for 1 Hz radiometer data: 34 GHz brightness temperature" ;
        qual_rad_1hz_tb340:flag_values = 0b, 1b ;
        qual_rad_1hz_tb340:flag_meanings = "Good Bad" ;
        qual_rad_1hz_tb340:coordinates = "lon lat" ;
    byte alt_state_flag_acq_mode(time) ;
        alt_state_flag_acq_mode:_FillValue = 127b ;
        alt_state_flag_acq_mode:long_name = "Altimeter state flag: acquisition mode" ;
        alt_state_flag_acq_mode:flag_values = 0b, 1b, 2b ;
        alt_state_flag_acq_mode:flag_meanings = "autonomous_acq/track autonomous_DIODEacq/track
                DIODE+DEM/track" ;
        alt_state_flag_acq_mode:coordinates = "lon lat" ;
        alt_state_flag_acq_mode:comment = "0 = autonomous acquisition / tracking, 1 = autonomous DIODE acquisition /
                tracking, 2 = DIODE + Digital Elevation Model tracking" ;
    byte rain_flag(time) ;
        rain_flag:_FillValue = 127b ;
        rain_flag:long_name = "rain flag" ;
        rain_flag:flag_values = 0b, 1b ;
        rain_flag:flag_meanings = "no_rain rain" ;
        rain_flag:coordinates = "lon lat" ;
        rain_flag:comment = "See Jason-2 User Handbook" ;
    byte ice_flag(time) ;
        ice_flag:_FillValue = 127b ;
        ice_flag:long_name = "ice flag" ;
        ice_flag:flag_values = 0b, 1b ;
        ice_flag:flag_meanings = "no_ice ice" ;
        ice_flag:coordinates = "lon lat" ;
        ice_flag:comment = "See Jason-2 User Handbook" ;
    byte retracking_flag_oce3_ku(time) ;
        retracking_flag_oce3_ku:_FillValue = 127b ;
        retracking_flag_oce3_ku:long_name = "PISTACH processing flag for the Ocean3 retracking in Ku Band" ;
        retracking_flag_oce3_ku:flag_values = 0b, 1b ;
        retracking_flag_oce3_ku:flag_meanings = "Good Bad" ;
        retracking_flag_oce3_ku:coordinates = "lon lat" ;
        retracking_flag_oce3_ku:comment = "0 = Valid; 1 = Not Valid" ;
    byte retracking_flag_oce3_c(time) ;
        retracking_flag_oce3_c:_FillValue = 127b ;
        retracking_flag_oce3_c:long_name = "PISTACH processing flag for the Ocean3 retracking in C band" ;
        retracking_flag_oce3_c:flag_values = 0b, 1b ;
        retracking_flag_oce3_c:flag_meanings = "Good Bad" ;
        retracking_flag_oce3_c:coordinates = "lon lat" ;
        retracking_flag_oce3_c:comment = "0 = Valid; 1 = Not Valid" ;
    byte retracking_flag_red3_ku(time) ;
        retracking_flag_red3_ku:_FillValue = 127b ;
        retracking_flag_red3_ku:long_name = "PISTACH processing flag for the Red3 retracking in Ku Band" ;
        retracking_flag_red3_ku:flag_values = 0b, 1b ;
        retracking_flag_red3_ku:flag_meanings = "Good Bad" ;
        retracking_flag_red3_ku:coordinates = "lon lat" ;
        retracking_flag_red3_ku:comment = "0 = Valid; 1 = Not Valid" ;
    byte retracking_flag_red3_c(time) ;
        retracking_flag_red3_c:_FillValue = 127b ;
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        retracking_flag_red3_c:long_name = "PISTACH processing flag for the Red3 retracking in C band" ;
        retracking_flag_red3_c:flag_values = 0b, 1b ;
        retracking_flag_red3_c:flag_meanings = "Good Bad" ;
        retracking_flag_red3_c:coordinates = "lon lat" ;
        retracking_flag_red3_c:comment = "0 = Valid; 1 = Not Valid" ;
    byte retracking_flag_ice1_ku(time) ;
        retracking_flag_ice1_ku:_FillValue = 127b ;
        retracking_flag_ice1_ku:long_name = "PISTACH processing flag for the ICE1 retracking in Ku Band" ;
        retracking_flag_ice1_ku:flag_values = 0b, 1b ;
        retracking_flag_ice1_ku:flag_meanings = "Good Bad" ;
        retracking_flag_ice1_ku:coordinates = "lon lat" ;
        retracking_flag_ice1_ku:comment = "0 = Valid; 1 = Not Valid" ;
    byte retracking_flag_ice1_c(time) ;
        retracking_flag_ice1_c:_FillValue = 127b ;
        retracking_flag_ice1_c:long_name = "PISTACH processing flag for the ICE1 retracking in C band" ;
        retracking_flag_ice1_c:flag_values = 0b, 1b ;
        retracking_flag_ice1_c:flag_meanings = "Good Bad" ;
        retracking_flag_ice1_c:coordinates = "lon lat" ;
        retracking_flag_ice1_c:comment = "0 = Valid; 1 = Not Valid" ;
    byte retracking_flag_ice3_ku(time) ;
        retracking_flag_ice3_ku:_FillValue = 127b ;
        retracking_flag_ice3_ku:long_name = "PISTACH processing flag for the ICE3 retracking in Ku Band" ;
        retracking_flag_ice3_ku:flag_values = 0b, 1b ;
        retracking_flag_ice3_ku:flag_meanings = "Good Bad" ;
        retracking_flag_ice3_ku:coordinates = "lon lat" ;
        retracking_flag_ice3_ku:comment = "0 = Valid; 1 = Not Valid" ;
    byte retracking_flag_ice3_c(time) ;
        retracking_flag_ice3_c:_FillValue = 127b ;
        retracking_flag_ice3_c:long_name = "PISTACH processing flag for the ICE3 retracking in C band" ;
        retracking_flag_ice3_c:flag_values = 0b, 1b ;
        retracking_flag_ice3_c:flag_meanings = "Good Bad" ;
        retracking_flag_ice3_c:coordinates = "lon lat" ;
        retracking_flag_ice3_c:comment = "0 = Valid; 1 = Not Valid" ;
    byte svd_flag_ku(time) ;
        svd_flag_ku:_FillValue = 127b ;
        svd_flag_ku:long_name = "PISTACH processing flag for the SVD filtering in Ku Band" ;
        svd_flag_ku:flag_values = 0b, 1b ;
        svd_flag_ku:flag_meanings = "Good Bad" ;
        svd_flag_ku:coordinates = "lon lat" ;
        svd_flag_ku:comment = "0 = Valid; 1 = Not Valid" ;
    byte svd_flag_c(time) ;
        svd_flag_c:_FillValue = 127b ;
        svd_flag_c:long_name = "PISTACH processing flag for the SVD filtering in C Band" ;
        svd_flag_c:flag_values = 0b, 1b ;
        svd_flag_c:flag_meanings = "Good Bad" ;
        svd_flag_c:coordinates = "lon lat" ;
        svd_flag_c:comment = "0 = Valid; 1 = Not Valid" ;
    int alt(time) ;
        alt:_FillValue = 2147483647 ;
        alt:long_name = "altitude of satellite" ;
        alt:units = "m" ;
        alt:standard_name = "height_above_reference_ellipsoid" ;
        alt:add_offset = 1300000. ;
        alt:scale_factor = 0.0001 ;
        alt:coordinates = "lon lat" ;
        alt:comment = "Altitude of satellite above the reference ellipsoid" ;
    short orb_alt_rate(time) ;
        orb_alt_rate:_FillValue = 32767s ;
        orb_alt_rate:long_name = "1 Hz orbital altitude rate" ;
        orb_alt_rate:units = "m/s" ;
        orb_alt_rate:scale_factor = 0.01 ;
        orb_alt_rate:coordinates = "lon lat" ;
        orb_alt_rate:comment = "The reference surface for the orbital altitude rate is the combined MSS/geoid surface. It is
            used to compute the Doppler correction on the altimeter range (doppler_corr_ku, doppler_corr_c)" ;
    int range_ku(time) ;
        range_ku:_FillValue = 2147483647 ;
        range_ku:long_name = "Ku band corrected altimeter range" ;
        range_ku:units = "m" ;
        range_ku:standard_name = "altimeter_range" ;
        range_ku:add_offset = 1300000. ;
        range_ku:scale_factor = 0.0001 ;
        range_ku:coordinates = "lon lat" ;
        range_ku:comment = "All instrumental corrections included, i.e. distance antenna-COG (cog_corr), USO drift
            correction (uso_corr), internal path correction (internal_path_delay_corr_ku), Doppler correction
            (doppler_corr_ku), modeled instrumental errors corrections (modeled_instr_corr_ku) and system bias" ;
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int range_c(time) ;
    range_c:_FillValue = 2147483647 ;
    range_c:long_name = "C band corrected altimeter range" ;
    range_c:units = "m" ;
    range_c:standard_name = "altimeter_range" ;
    range_c:add_offset = 1300000. ;
    range_c:scale_factor = 0.0001 ;
    range_c:coordinates = "lon lat" ;
    range_c:comment = "All instrumental corrections included, i.e. distance antenna-COG (cog_corr), USO drift correction
        (uso_corr), internal path correction (internal_path_delay_corr_c), Doppler correction (doppler_corr_c), modeled
        instrumental errors corrections (modeled_instr_corr_c) and system bias" ;
int range_oce3_ku(time) ;
    range_oce3_ku:_FillValue = 2147483647 ;
    range_oce3_ku:long_name = "Ku band corrected altimeter range. PISTACH Ocean3 retracking" ;
    range_oce3_ku:units = "m" ;
    range_oce3_ku:standard_name = "altimeter_range" ;
    range_oce3_ku:add_offset = 1300000. ;
    range_oce3_ku:scale_factor = 0.0001 ;
    range_oce3_ku:coordinates = "lon lat" ;
    range_oce3_ku:comment = "All instrumental corrections included, i.e. distance antenna-COG (cog_corr), USO drift
        correction (uso_corr), internal path correction (internal_path_delay_corr_ku), Doppler correction
        (doppler_corr_ku), modeled instrumental errors corrections (modeled_instr_corr_ku) and system bias" ;
int range_oce3_c(time) ;
    range_oce3_c:_FillValue = 2147483647 ;
    range_oce3_c:long_name = "C band corrected altimeter range. PISTACH Ocean3 retracking" ;
    range_oce3_c:units = "m" ;
    range_oce3_c:standard_name = "altimeter_range" ;
    range_oce3_c:add_offset = 1300000. ;
    range_oce3_c:scale_factor = 0.0001 ;
    range_oce3_c:coordinates = "lon lat" ;
    range_oce3_c:comment = "All instrumental corrections included, i.e. distance antenna-COG (cog_corr), USO drift
        correction (uso_corr), internal path correction (internal_path_delay_corr_c), Doppler correction
        (doppler_corr_c), modeled instrumental errors corrections (modeled_instr_corr_c) and system bias" ;
int range_red3_ku(time) ;
    range_red3_ku:_FillValue = 2147483647 ;
    range_red3_ku:long_name = "Ku band corrected altimeter range. PISTACH Red3 retracking" ;
    range_red3_ku:units = "m" ;
    range_red3_ku:standard_name = "altimeter_range" ;
    range_red3_ku:add_offset = 1300000. ;
    range_red3_ku:scale_factor = 0.0001 ;
    range_red3_ku:coordinates = "lon lat" ;
    range_red3_ku:comment = "All instrumental corrections included, i.e. distance antenna-COG (cog_corr), USO drift
        correction (uso_corr), internal path correction (internal_path_delay_corr_ku), Doppler correction
        (doppler_corr_ku), modeled instrumental errors corrections (modeled_instr_corr_ku) and system bias" ;
int range_red3_c(time) ;
    range_red3_c:_FillValue = 2147483647 ;
    range_red3_c:long_name = "C band corrected altimeter range. PISTACH Red3 retracking" ;
    range_red3_c:units = "m" ;
    range_red3_c:standard_name = "altimeter_range" ;
    range_red3_c:add_offset = 1300000. ;
    range_red3_c:scale_factor = 0.0001 ;
    range_red3_c:coordinates = "lon lat" ;
    range_red3_c:comment = "All instrumental corrections included, i.e. distance antenna-COG (cog_corr), USO drift
        correction (uso_corr), internal path correction (internal_path_delay_corr_c), Doppler correction
        (doppler_corr_c), modeled instrumental errors corrections (modeled_instr_corr_c) and system bias" ;
int range_ice3_ku(time) ;
    range_ice3_ku:_FillValue = 2147483647 ;
    range_ice3_ku:long_name = "Ku band corrected altimeter range. PISTACH Ice3 retracking" ;
    range_ice3_ku:units = "m" ;
    range_ice3_ku:standard_name = "altimeter_range" ;
    range_ice3_ku:add_offset = 1300000. ;
    range_ice3_ku:scale_factor = 0.0001 ;
    range_ice3_ku:coordinates = "lon lat" ;
    range_ice3_ku:comment = "All instrumental corrections included, i.e. distance antenna-COG (cog_corr), USO drift
        correction (uso_corr), internal path correction (internal_path_delay_corr_ku), Doppler correction
        (doppler_corr_ku), modeled instrumental errors corrections (modeled_instr_corr_ku) and system bias" ;
int range_ice3_c(time) ;
    range_ice3_c:_FillValue = 2147483647 ;
    range_ice3_c:long_name = "C band corrected altimeter range. PISTACH Ice3 retracking" ;
    range_ice3_c:units = "m" ;
    range_ice3_c:standard_name = "altimeter_range" ;
    range_ice3_c:add_offset = 1300000. ;
    range_ice3_c:scale_factor = 0.0001 ;
    range_ice3_c:coordinates = "lon lat" ;
    range_ice3_c:comment = "All instrumental corrections included, i.e. distance antenna-COG (cog_corr), USO drift
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correction (uso_corr), internal path correction (internal_path_delay_corr_c), Doppler correction
        (doppler_corr_c), modeled instrumental errors corrections (modeled_instr_corr_c) and system bias" ;
int net_instr_corr_range_ku(time) ;
    net_instr_corr_range_ku:_FillValue = 2147483647 ;
    net_instr_corr_range_ku:long_name = "net instrumental correction on the Ku band range" ;
    net_instr_corr_range_ku:units = "m" ;
    net_instr_corr_range_ku:scale_factor = 0.0001 ;
    net_instr_corr_range_ku:coordinates = "lon lat" ;
    net_instr_corr_range_ku:comment = "Sum of distance antenna-COG (cog_corr), USO drift_correction (uso_corr),
        internal path correction (internal_path_delay_corr_ku), Doppler correction (doppler_corr_ku), modeled
        instrumental errors correction (modeled_instr_corr_range_ku) and system bias" ;
int net_instr_corr_range_c(time) ;
    net_instr_corr_range_c:_FillValue = 2147483647 ;
    net_instr_corr_range_c:long_name = "net instrumental correction on the C band range" ;
    net_instr_corr_range_c:units = "m" ;
    net_instr_corr_range_c:scale_factor = 0.0001 ;
    net_instr_corr_range_c:coordinates = "lon lat" ;
    net_instr_corr_range_c:comment = "Sum of distance antenna-COG (cog_corr), USO drift_correction (uso_corr),
        internal path correction (internal_path_delay_corr_c), Doppler correction (doppler_corr_c), modeled
        instrumental errors correction (modeled_instr_corr_range_c) and system bias" ;
int net_instr_corr_range_oce3_ku(time) ;
    net_instr_corr_range_oce3_ku:_FillValue = 2147483647 ;
    net_instr_corr_range_oce3_ku:long_name = "net instrumental correction on the Ku band range. PISTACH: Ocean3
        retracking" ;
    net_instr_corr_range_oce3_ku:units = "m" ;
    net_instr_corr_range_oce3_ku:scale_factor = 0.0001 ;
    net_instr_corr_range_oce3_ku:coordinates = "lon lat" ;
    net_instr_corr_range_oce3_ku:comment = "Sum of distance antenna-COG (cog_corr), USO drift_correction
        (uso_corr), internal path correction (internal_path_delay_corr_ku), Doppler correction (doppler_corr_ku),
        modeled instrumental errors correction (modeled_instr_corr_range_ku) and system bias" ;
int net_instr_corr_range_oce3_c(time) ;
    net_instr_corr_range_oce3_c:_FillValue = 2147483647 ;
    net_instr_corr_range_oce3_c:long_name = "net instrumental correction on the C band range. PISTACH: Ocean3
        retracking" ;
    net_instr_corr_range_oce3_c:units = "m" ;
    net_instr_corr_range_oce3_c:scale_factor = 0.0001 ;
    net_instr_corr_range_oce3_c:coordinates = "lon lat" ;
    net_instr_corr_range_oce3_c:comment = "Sum of distance antenna-COG (cog_corr), USO drift_correction (uso_corr),
        internal path correction (internal_path_delay_corr_c), Doppler correction (doppler_corr_c), modeled
        instrumental errors correction (modeled_instr_corr_range_c) and system bias" ;
short model_dry_tropo_corr(time) ;
    model_dry_tropo_corr:_FillValue = 32767s ;
    model_dry_tropo_corr:long_name = "model dry tropospheric correction" ;
    model_dry_tropo_corr:units = "m" ;
    model_dry_tropo_corr:standard_name = "altimeter_range_correction_due_to_dry_troposhere" ;
    model_dry_tropo_corr:source = "European Center for Medium Range Weather Forecasting" ;
    model_dry_tropo_corr:institution = "[mto_fiedls_institution]" ;
    model_dry_tropo_corr:scale_factor = 0.0001 ;
    model_dry_tropo_corr:coordinates = "lon lat" ;
    model_dry_tropo_corr:comment = "Computed at the altimeter time-tag from the interpolation of 2 meteorological fields
        that surround the altimeter time-tag. A dry tropospheric correction must be added (negative value) to the
        instrument range to correct this range measurement for dry tropospheric range delays of the radar pulse. See
        Jason-2 User Handbook" ;
short model_dry_tropo_corr_direct_sol(time) ;
    model_dry_tropo_corr_direct_sol:_FillValue = 32767s ;
    model_dry_tropo_corr_direct_sol:long_name = "model dry tropospheric correction, direct solution" ;
    model_dry_tropo_corr_direct_sol:units = "m" ;
    model_dry_tropo_corr_direct_sol:standard_name = "altimeter_range_correction_due_to_dry_troposhere" ;
    model_dry_tropo_corr_direct_sol:source = "PISTACH" ;
    model_dry_tropo_corr_direct_sol:institution = "CNES" ;
    model_dry_tropo_corr_direct_sol:scale_factor = 0.0001 ;
    model_dry_tropo_corr_direct_sol:coordinates = "lon lat" ;
    model_dry_tropo_corr_direct_sol:comment = "Computed at the altimeter time-tag from the interpolation of 2
        meteorological fields that surround the altimeter time-tag. A dry tropospheric correction must be added
        (negative value) to the instrument range to correct this range measurement for dry tropospheric range delays of
        the radar pulse. Direct solution: Surface height deduced from Jason-2 altimetric measurement.See Jason-2
        PISTACH User Handbook" ;
short model_wet_tropo_corr(time) ;
    model_wet_tropo_corr:_FillValue = 32767s ;
    model_wet_tropo_corr:long_name = "model wet tropospheric correction" ;
    model_wet_tropo_corr:units = "m" ;
    model_wet_tropo_corr:standard_name = "altimeter_range_correction_due_to_wet_troposhere" ;
    model_wet_tropo_corr:source = "European Center for Medium Range Weather Forecasting" ;
    model_wet_tropo_corr:institution = "[mto_fiedls_institution]" ;
    model_wet_tropo_corr:scale_factor = 0.0001 ;
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        model_wet_tropo_corr:coordinates = "lon lat" ;
        model_wet_tropo_corr:comment = "Computed at the altimeter time-tag from the interpolation of 2 meteorological
            fields that surround the altimeter time-tag. A wet tropospheric correction must be added (negative value) to the
            instrument range to correct this range measurement for wet tropospheric range delays of the radar pulse. See
            Jason-2 User Handbook" ;
    short model_wet_tropo_corr_direct_sol(time) ;
        model_wet_tropo_corr_direct_sol:_FillValue = 32767s ;
        model_wet_tropo_corr_direct_sol:long_name = "model wet tropospheric correction" ;
        model_wet_tropo_corr_direct_sol:units = "m" ;
        model_wet_tropo_corr_direct_sol:standard_name = "altimeter_range_correction_due_to_wet_troposhere" ;
        model_wet_tropo_corr_direct_sol:source = "PISTACH" ;
        model_wet_tropo_corr_direct_sol:institution = "CNES" ;
        model_wet_tropo_corr_direct_sol:scale_factor = 0.0001 ;
        model_wet_tropo_corr_direct_sol:coordinates = "lon lat" ;
        model_wet_tropo_corr_direct_sol:comment = "Computed at the altimeter time-tag from the interpolation of 2
            meteorological fields that surround the altimeter time-tag. A wet tropospheric correction must be added
            (negative value) to the instrument range to correct this range measurement for wet tropospheric range delays of
            the radar pulse. Direct solution: Surface height deduced from Jason-2 altimetric measurement.See Jason-2
            PISTACH User Handbook" ;
    short rad_wet_tropo_corr(time) ;
        rad_wet_tropo_corr:_FillValue = 32767s ;
        rad_wet_tropo_corr:long_name = "radiometer wet tropospheric correction" ;
        rad_wet_tropo_corr:units = "m" ;
        rad_wet_tropo_corr:standard_name = "altimeter_range_correction_due_to_wet_troposhere" ;
        rad_wet_tropo_corr:source = "[radiometer_sensor_name]" ;
        rad_wet_tropo_corr:institution = "[radiometer_sensor_institution]" ;
        rad_wet_tropo_corr:scale_factor = 0.0001 ;
        rad_wet_tropo_corr:coordinates = "lon lat" ;
        rad_wet_tropo_corr:comment = "A wet tropospheric correction must be added (negative value) to the instrument
            range to correct this range measurement for wet tropospheric range delays of the radar pulse" ;
    short composite_wet_tropo_corr(time) ;
        composite_wet_tropo_corr:_FillValue = 32767s ;
        composite_wet_tropo_corr:long_name = "composite wet tropospheric correction" ;
        composite_wet_tropo_corr:units = "m" ;
        composite_wet_tropo_corr:standard_name = "altimeter_range_correction_due_to_wet_troposhere" ;
        composite_wet_tropo_corr:source = "PISTACH" ;
        composite_wet_tropo_corr:institution = "CNES" ;
        composite_wet_tropo_corr:scale_factor = 0.0001 ;
        composite_wet_tropo_corr:coordinates = "lon lat" ;
        composite_wet_tropo_corr:comment = "A wet tropospheric correction must be added (negative value) to the
            instrument range to correct this range measurement for wet tropospheric range delays of the radar
            pulseComposite correction: mix between model and radiometer corrections, for ocean/coastal areas onlySee
            Jason-2 PISTACH User Handbook" ;
    short decontaminated_wet_tropo_corr(time) ;
        decontaminated_wet_tropo_corr:_FillValue = 32767s ;
        decontaminated_wet_tropo_corr:long_name = "land decontaminated wet tropospheric correction" ;
        decontaminated_wet_tropo_corr:units = "m" ;
        decontaminated_wet_tropo_corr:standard_name = "altimeter_range_correction_due_to_wet_troposhere" ;
        decontaminated_wet_tropo_corr:source = "PISTACH" ;
        decontaminated_wet_tropo_corr:institution = "CNES" ;
        decontaminated_wet_tropo_corr:scale_factor = 0.0001 ;
        decontaminated_wet_tropo_corr:coordinates = "lon lat" ;
        decontaminated_wet_tropo_corr:comment = "A wet tropospheric correction must be added (negative value) to the
            instrument range to correct this range measurement for wet tropospheric range delays of the radar pulse. Land
            decontaminated correction: decontamination of the brightness temperatures before applying the retrieval
            algorithm. See Jason-2 PISTACH User Handbook" ;
    short iono_corr_alt_ku(time) ;
        iono_corr_alt_ku:_FillValue = 32767s ;
        iono_corr_alt_ku:long_name = "altimeter ionospheric correction on Ku band" ;
        iono_corr_alt_ku:units = "m" ;
        iono_corr_alt_ku:standard_name = "altimeter_range_correction_due_to_ionosphere" ;
        iono_corr_alt_ku:source = "[altimeter_sensor_name]" ;
        iono_corr_alt_ku:institution = "[altimeter_sensor_institution]" ;
        iono_corr_alt_ku:scale_factor = 0.0001 ;
        iono_corr_alt_ku:coordinates = "lon lat" ;
        iono_corr_alt_ku:comment = "An ionospheric correction must be added (negative value) to the instrument range to
            correct this range measurement for ionospheric range delays of the radar pulse. See Jason-2 User Handbook" ;
    short iono_corr_gim_ku(time) ;
        iono_corr_gim_ku:_FillValue = 32767s ;
        iono_corr_gim_ku:long_name = "GIM ionospheric correction on Ku band" ;
        iono_corr_gim_ku:units = "m" ;
        iono_corr_gim_ku:standard_name = "altimeter_range_correction_due_to_ionosphere" ;
        iono_corr_gim_ku:source = "AD" ;
        iono_corr_gim_ku:institution = "NASA/JPL" ;
        iono_corr_gim_ku:scale_factor = 0.0001 ;
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        iono_corr_gim_ku:coordinates = "lon lat" ;
        iono_corr_gim_ku:comment = "An ionospheric correction must be added (negative value) to the instrument range to
            correct this range measurement for ionospheric range delays of the radar pulse. See Jason-2 User Handbook" ;
    short iono_corr_alt_oce3_ku(time) ;
        iono_corr_alt_oce3_ku:_FillValue = 32767s ;
        iono_corr_alt_oce3_ku:long_name = "altimeter ionospheric correction on Ku band. PISTACH Ocean3 retracking" ;
        iono_corr_alt_oce3_ku:units = "m" ;
        iono_corr_alt_oce3_ku:standard_name = "altimeter_range_correction_due_to_ionosphere" ;
        iono_corr_alt_oce3_ku:source = "[altimeter_sensor_name]" ;
        iono_corr_alt_oce3_ku:institution = "[altimeter_sensor_institution]" ;
        iono_corr_alt_oce3_ku:scale_factor = 0.0001 ;
        iono_corr_alt_oce3_ku:coordinates = "lon lat" ;
        iono_corr_alt_oce3_ku:comment = "An ionospheric correction must be added (negative value) to the instrument range
            to correct this range measurement for ionospheric range delays of the radar pulse. See Jason-2 User
            Handbook" ;
    short filtered_iono_corr_alt_oce3_ku(time) ;
        filtered_iono_corr_alt_oce3_ku:_FillValue = 32767s ;
        filtered_iono_corr_alt_oce3_ku:long_name = "Filtered altimeter ionospheric correction on Ku band. PISTACH Ocean3
            retracking" ;
        filtered_iono_corr_alt_oce3_ku:units = "m" ;
        filtered_iono_corr_alt_oce3_ku:standard_name = "altimeter_range_correction_due_to_ionosphere" ;
        filtered_iono_corr_alt_oce3_ku:source = "[altimeter_sensor_name]" ;
        filtered_iono_corr_alt_oce3_ku:institution = "[altimeter_sensor_institution]" ;
        filtered_iono_corr_alt_oce3_ku:scale_factor = 0.0001 ;
        filtered_iono_corr_alt_oce3_ku:coordinates = "lon lat" ;
        filtered_iono_corr_alt_oce3_ku:comment = "An ionospheric correction must be added (negative value) to the
            instrument range to correct this range measurement for ionospheric range delays of the radar pulse. See Jason-
            2 User Handbook" ;
    short sea_state_bias_ku(time) ;
        sea_state_bias_ku:_FillValue = 32767s ;
        sea_state_bias_ku:long_name = "sea state bias correction in Ku band" ;
        sea_state_bias_ku:units = "m" ;
        sea_state_bias_ku:standard_name = "sea_surface_height_bias_due_to_sea_surface_roughness" ;
        sea_state_bias_ku:source = "Empirical solution fitted on Jason-1 GDR_C data" ;
        sea_state_bias_ku:institution = "CNES" ;
        sea_state_bias_ku:scale_factor = 0.0001 ;
        sea_state_bias_ku:coordinates = "lon lat" ;
        sea_state_bias_ku:comment = "A sea state bias correction must be added (negative value) to the instrument range to
            correct this range measurement for sea state delays of the radar pulse. See Jason-2 User Handbook" ;
    short sea_state_bias_c(time) ;
        sea_state_bias_c:_FillValue = 32767s ;
        sea_state_bias_c:long_name = "sea state bias correction in C band" ;
        sea_state_bias_c:units = "m" ;
        sea_state_bias_c:standard_name = "sea_surface_height_bias_due_to_sea_surface_roughness" ;
        sea_state_bias_c:source = "Empirical solution fitted on Jason-1 GDR_C data" ;
        sea_state_bias_c:institution = "CNES" ;
        sea_state_bias_c:scale_factor = 0.0001 ;
        sea_state_bias_c:coordinates = "lon lat" ;
        sea_state_bias_c:comment = "A sea state bias correction must be added (negative value) to the instrument range to
            correct this range measurement for sea state delays of the radar pulse. See Jason-2 User Handbook" ;
    short sea_state_bias_oce3_ku(time) ;
        sea_state_bias_oce3_ku:_FillValue = 32767s ;
        sea_state_bias_oce3_ku:long_name = "sea state bias correction in Ku band. PISTACH: Ocean3 retracking" ;
        sea_state_bias_oce3_ku:units = "m" ;
        sea_state_bias_oce3_ku:standard_name = "sea_surface_height_bias_due_to_sea_surface_roughness" ;
        sea_state_bias_oce3_ku:source = "Empirical solution fitted on Jason-1 GDR_C data" ;
        sea_state_bias_oce3_ku:institution = "CNES" ;
        sea_state_bias_oce3_ku:scale_factor = 0.0001 ;
        sea_state_bias_oce3_ku:coordinates = "lon lat" ;
        sea_state_bias_oce3_ku:comment = "A sea state bias correction must be added (negative value) to the instrument
            range to correct this range measurement for sea state delays of the radar pulse. See Jason-2 User Handbook" ;
    short sea_state_bias_oce3_c(time) ;
        sea_state_bias_oce3_c:_FillValue = 32767s ;
        sea_state_bias_oce3_c:long_name = "sea state bias correction in C band. PISTACH: Ocean3 retracking" ;
        sea_state_bias_oce3_c:units = "m" ;
        sea_state_bias_oce3_c:standard_name = "sea_surface_height_bias_due_to_sea_surface_roughness" ;
        sea_state_bias_oce3_c:source = "Empirical solution fitted on Jason-1 GDR_C data" ;
        sea_state_bias_oce3_c:institution = "CNES" ;
        sea_state_bias_oce3_c:scale_factor = 0.0001 ;
        sea_state_bias_oce3_c:coordinates = "lon lat" ;
        sea_state_bias_oce3_c:comment = "A sea state bias correction must be added (negative value) to the instrument
            range to correct this range measurement for sea state delays of the radar pulse. See Jason-2 User Handbook" ;
    short swh_ku(time) ;
        swh_ku:_FillValue = 32767s ;
        swh_ku:long_name = "Ku band corrected significant waveheight" ;
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        swh_ku:units = "m" ;
        swh_ku:standard_name = "sea_surface_wave_significant_height" ;
        swh_ku:scale_factor = 0.001 ;
        swh_ku:coordinates = "lon lat" ;
        swh_ku:comment = "All instrumental corrections included, i.e. modeled instrumental errors correction
            (modeled_instr_corr_swh_ku) and system bias" ;
    short swh_c(time) ;
        swh_c:_FillValue = 32767s ;
        swh_c:long_name = "C band corrected significant waveheight" ;
        swh_c:units = "m" ;
        swh_c:standard_name = "sea_surface_wave_significant_height" ;
        swh_c:scale_factor = 0.001 ;
        swh_c:coordinates = "lon lat" ;
        swh_c:comment = "All instrumental corrections included, i.e. modeled instrumental errors correction
            (modeled_instr_corr_swh_c) and system bias" ;
    short swh_oce3_ku(time) ;
        swh_oce3_ku:_FillValue = 32767s ;
        swh_oce3_ku:long_name = "Ku band corrected significant waveheight. PISTACH Ocean3 retracking" ;
        swh_oce3_ku:units = "m" ;
        swh_oce3_ku:standard_name = "sea_surface_wave_significant_height" ;
        swh_oce3_ku:scale_factor = 0.001 ;
        swh_oce3_ku:coordinates = "lon lat" ;
        swh_oce3_ku:comment = "All instrumental corrections included, i.e. modeled instrumental errors correction
            (modeled_instr_corr_swh_ku) and system bias" ;
    short swh_oce3_c(time) ;
        swh_oce3_c:_FillValue = 32767s ;
        swh_oce3_c:long_name = "C band corrected significant waveheight. PISTACH Ocean3 retracking" ;
        swh_oce3_c:units = "m" ;
        swh_oce3_c:standard_name = "sea_surface_wave_significant_height" ;
        swh_oce3_c:scale_factor = 0.001 ;
        swh_oce3_c:coordinates = "lon lat" ;
        swh_oce3_c:comment = "All instrumental corrections included, i.e. modeled instrumental errors correction
            (modeled_instr_corr_swh_ku) and system bias" ;
    short swh_red3_ku(time) ;
        swh_red3_ku:_FillValue = 32767s ;
        swh_red3_ku:long_name = "Ku band corrected significant waveheight. PISTACH Red3 retracking" ;
        swh_red3_ku:units = "m" ;
        swh_red3_ku:standard_name = "sea_surface_wave_significant_height" ;
        swh_red3_ku:scale_factor = 0.001 ;
        swh_red3_ku:coordinates = "lon lat" ;
        swh_red3_ku:comment = "All instrumental corrections included, i.e. modeled instrumental errors correction
            (modeled_instr_corr_swh_ku) and system bias" ;
    short swh_red3_c(time) ;
        swh_red3_c:_FillValue = 32767s ;
        swh_red3_c:long_name = "C band corrected significant waveheight. PISTACH Red3 retracking" ;
        swh_red3_c:units = "m" ;
        swh_red3_c:standard_name = "sea_surface_wave_significant_height" ;
        swh_red3_c:scale_factor = 0.001 ;
        swh_red3_c:coordinates = "lon lat" ;
        swh_red3_c:comment = "All instrumental corrections included, i.e. modeled instrumental errors correction
            (modeled_instr_corr_swh_ku) and system bias" ;
    short net_instr_corr_swh_ku(time) ;
        net_instr_corr_swh_ku:_FillValue = 32767s ;
        net_instr_corr_swh_ku:long_name = "net instrumental correction on Ku band significant waveheight" ;
        net_instr_corr_swh_ku:units = "m" ;
        net_instr_corr_swh_ku:scale_factor = 0.001 ;
        net_instr_corr_swh_ku:coordinates = "lon lat" ;
        net_instr_corr_swh_ku:comment = "Sum of modeled instrumental errors correction (modeled_instr_corr_swh_ku) and
            system bias" ;
    short net_instr_corr_swh_c(time) ;
        net_instr_corr_swh_c:_FillValue = 32767s ;
        net_instr_corr_swh_c:long_name = "net instrumental correction on C band significant waveheight" ;
        net_instr_corr_swh_c:units = "m" ;
        net_instr_corr_swh_c:scale_factor = 0.001 ;
        net_instr_corr_swh_c:coordinates = "lon lat" ;
        net_instr_corr_swh_c:comment = "Sum of modeled instrumental errors correction (modeled_instr_corr_swh_c) and
            system bias" ;
    short net_instr_corr_swh_oce3_ku(time) ;
        net_instr_corr_swh_oce3_ku:_FillValue = 32767s ;
        net_instr_corr_swh_oce3_ku:long_name = "net instrumental correction on Ku band significant waveheight. PISTACH:
            Ocean3 retracking" ;
        net_instr_corr_swh_oce3_ku:units = "m" ;
        net_instr_corr_swh_oce3_ku:scale_factor = 0.001 ;
        net_instr_corr_swh_oce3_ku:coordinates = "lon lat" ;
        net_instr_corr_swh_oce3_ku:comment = "Sum of modeled instrumental errors correction
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            (modeled_instr_corr_swh_ku) and system bias" ;
    short net_instr_corr_swh_oce3_c(time) ;
        net_instr_corr_swh_oce3_c:_FillValue = 32767s ;
        net_instr_corr_swh_oce3_c:long_name = "net instrumental correction on C band significant waveheight. PISTACH:
            Ocean3 retracking" ;
        net_instr_corr_swh_oce3_c:units = "m" ;
        net_instr_corr_swh_oce3_c:scale_factor = 0.001 ;
        net_instr_corr_swh_oce3_c:coordinates = "lon lat" ;
        net_instr_corr_swh_oce3_c:comment = "Sum of modeled instrumental errors correction (modeled_instr_corr_swh_c)
            and system bias" ;
    short sig0_ku(time) ;
        sig0_ku:_FillValue = 32767s ;
        sig0_ku:long_name = "Ku band corrected backscatter coefficient" ;
        sig0_ku:units = "dB" ;
        sig0_ku:standard_name = "surface_backwards_scattering_coefficient_of_radar_wave" ;
        sig0_ku:scale_factor = 0.01 ;
        sig0_ku:coordinates = "lon lat" ;
        sig0_ku:comment = "All instrumental corrections included, excepted the system bias, i.e. AGC instrumental errors
            correction, internal calibration correction (internal_corr_sig0_ku), modeled instrumental errors correction
            (modeled_instr_corr_sig0_ku) and atmospheric attenuation (atmos_corr_sig0_ku). See Jason-2 User
            Handbook" ;
    short sig0_c(time) ;
        sig0_c:_FillValue = 32767s ;
        sig0_c:long_name = "C band corrected backscatter coefficient" ;
        sig0_c:units = "dB" ;
        sig0_c:standard_name = "surface_backwards_scattering_coefficient_of_radar_wave" ;
        sig0_c:scale_factor = 0.01 ;
        sig0_c:coordinates = "lon lat" ;
        sig0_c:comment = "All instrumental corrections included, excepted the system bias, i.e. AGC instrumental errors
            correction, internal calibration correction (internal_corr_sig0_c), modeled instrumental errors correction
            (modeled_instr_corr_sig0_c) and atmospheric attenuation (atmos_corr_sig0_c)" ;
    short sig0_red3_ku(time) ;
        sig0_red3_ku:_FillValue = 32767s ;
        sig0_red3_ku:long_name = "Ku band corrected backscatter coefficient. PISTACH Red3 retracking" ;
        sig0_red3_ku:units = "dB" ;
        sig0_red3_ku:standard_name = "surface_backwards_scattering_coefficient_of_radar_wave" ;
        sig0_red3_ku:scale_factor = 0.01 ;
        sig0_red3_ku:coordinates = "lon lat" ;
        sig0_red3_ku:comment = "All instrumental corrections included, excepted the system bias, i.e. AGC instrumental
            errors correction, internal calibration correction (internal_corr_sig0_ku), modeled instrumental errors correction
            (modeled_instr_corr_sig0_ku) and atmospheric attenuation (atmos_corr_sig0_ku). See Jason-2 User
            Handbook" ;
    short sig0_red3_c(time) ;
        sig0_red3_c:_FillValue = 32767s ;
        sig0_red3_c:long_name = "C band corrected backscatter coefficient. PISTACH Red3 retracking" ;
        sig0_red3_c:units = "dB" ;
        sig0_red3_c:standard_name = "surface_backwards_scattering_coefficient_of_radar_wave" ;
        sig0_red3_c:scale_factor = 0.01 ;
        sig0_red3_c:coordinates = "lon lat" ;
        sig0_red3_c:comment = "All instrumental corrections included, excepted the system bias, i.e. AGC instrumental errors
            correction, internal calibration correction (internal_corr_sig0_ku), modeled instrumental errors correction
            (modeled_instr_corr_sig0_ku) and atmospheric attenuation (atmos_corr_sig0_ku). See Jason-2 User
            Handbook" ;
    short agc_ku(time) ;
        agc_ku:_FillValue = 32767s ;
        agc_ku:long_name = "Ku band corrected AGC" ;
        agc_ku:units = "dB" ;
        agc_ku:scale_factor = 0.01 ;
        agc_ku:coordinates = "lon lat" ;
        agc_ku:comment = "AGC is corrected for instrumental errors due to the imperfections of the on-board attenuators" ;
    short agc_c(time) ;
        agc_c:_FillValue = 32767s ;
        agc_c:long_name = "C band corrected AGC" ;
        agc_c:units = "dB" ;
        agc_c:scale_factor = 0.01 ;
        agc_c:coordinates = "lon lat" ;
        agc_c:comment = "AGC is corrected for instrumental errors due to the imperfections of the on-board attenuators" ;
    short net_instr_corr_sig0_ku(time) ;
        net_instr_corr_sig0_ku:_FillValue = 32767s ;
        net_instr_corr_sig0_ku:long_name = "net instrumental correction on Ku backscatter coefficient" ;
        net_instr_corr_sig0_ku:units = "dB" ;
        net_instr_corr_sig0_ku:scale_factor = 0.01 ;
        net_instr_corr_sig0_ku:coordinates = "lon lat" ;
        net_instr_corr_sig0_ku:comment = "Sum of AGC instrumental errors correction, internal calibration correction
            (internal_corr_sig0_ku) and modeled instrumental errors correction (modeled_instr_corr_sig0_ku) - system bias
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            not included" ;
    short net_instr_corr_sig0_c(time) ;
        net_instr_corr_sig0_c:_FillValue = 32767s ;
        net_instr_corr_sig0_c:long_name = "net instrumental correction on C backscatter coefficient" ;
        net_instr_corr_sig0_c:units = "dB" ;
        net_instr_corr_sig0_c:scale_factor = 0.01 ;
        net_instr_corr_sig0_c:coordinates = "lon lat" ;
        net_instr_corr_sig0_c:comment = "Sum of AGC instrumental errors correction, internal calibration correction
            (internal_corr_sig0_c) and modeled instrumental errors correction (modeled_instr_corr_sig0_c) - system bias
            not included" ;
    short net_instr_corr_sig0_oce3_ku(time) ;
        net_instr_corr_sig0_oce3_ku:_FillValue = 32767s ;
        net_instr_corr_sig0_oce3_ku:long_name = "net instrumental correction on Ku backscatter coefficient. PISTACH:
            Ocean3 retracking" ;
        net_instr_corr_sig0_oce3_ku:units = "dB" ;
        net_instr_corr_sig0_oce3_ku:scale_factor = 0.01 ;
        net_instr_corr_sig0_oce3_ku:coordinates = "lon lat" ;
        net_instr_corr_sig0_oce3_ku:comment = "Sum of AGC instrumental errors correction, internal calibration correction
            (internal_corr_sig0_ku) and modeled instrumental errors correction (modeled_instr_corr_sig0_ku) - system bias
            not included" ;
    short net_instr_corr_sig0_oce3_c(time) ;
        net_instr_corr_sig0_oce3_c:_FillValue = 32767s ;
        net_instr_corr_sig0_oce3_c:long_name = "net instrumental correction on C backscatter coefficient. PISTACH:
            Ocean3 retracking" ;
        net_instr_corr_sig0_oce3_c:units = "dB" ;
        net_instr_corr_sig0_oce3_c:scale_factor = 0.01 ;
        net_instr_corr_sig0_oce3_c:coordinates = "lon lat" ;
        net_instr_corr_sig0_oce3_c:comment = "Sum of AGC instrumental errors correction, internal calibration correction
            (internal_corr_sig0_c) and modeled instrumental errors correction (modeled_instr_corr_sig0_c) - system bias
            not included" ;
    byte atmos_corr_sig0_ku(time) ;
        atmos_corr_sig0_ku:_FillValue = 127b ;
        atmos_corr_sig0_ku:long_name = "atmospheric attenuation correction on Ku band backscatter coefficient" ;
        atmos_corr_sig0_ku:units = "dB" ;
        atmos_corr_sig0_ku:scale_factor = 0.01 ;
        atmos_corr_sig0_ku:coordinates = "lon lat" ;
    byte atmos_corr_sig0_c(time) ;
        atmos_corr_sig0_c:_FillValue = 127b ;
        atmos_corr_sig0_c:long_name = "atmospheric attenuation correction on C band backscatter coefficient" ;
        atmos_corr_sig0_c:units = "dB" ;
        atmos_corr_sig0_c:scale_factor = 0.01 ;
        atmos_corr_sig0_c:coordinates = "lon lat" ;
    short off_nadir_angle_wf_ku(time) ;
        off_nadir_angle_wf_ku:_FillValue = 32767s ;
        off_nadir_angle_wf_ku:long_name = "square of the off nadir angle computed from Ku waveforms" ;
        off_nadir_angle_wf_ku:units = "degrees^2" ;
        off_nadir_angle_wf_ku:scale_factor = 0.0001 ;
        off_nadir_angle_wf_ku:coordinates = "lon lat" ;
    short off_nadir_angle_wf_oce3_svd_ku(time) ;
        off_nadir_angle_wf_oce3_svd_ku:_FillValue = 32767s ;
        off_nadir_angle_wf_oce3_svd_ku:long_name = "square of the off nadir angle computed from Ku waveforms.
            PISTACH: SVD and Ocean3 retracking" ;
        off_nadir_angle_wf_oce3_svd_ku:units = "degrees^2" ;
        off_nadir_angle_wf_oce3_svd_ku:scale_factor = 0.0001 ;
        off_nadir_angle_wf_oce3_svd_ku:coordinates = "lon lat" ;
    short off_nadir_angle_wf_oce3_svd_c(time) ;
        off_nadir_angle_wf_oce3_svd_c:_FillValue = 32767s ;
        off_nadir_angle_wf_oce3_svd_c:long_name = "square of the off nadir angle computed from C waveforms. PISTACH:
            SVD and Ocean3 retracking" ;
        off_nadir_angle_wf_oce3_svd_c:units = "degrees^2" ;
        off_nadir_angle_wf_oce3_svd_c:scale_factor = 0.0001 ;
        off_nadir_angle_wf_oce3_svd_c:coordinates = "lon lat" ;
    short tb_187(time) ;
        tb_187:_FillValue = 32767s ;
        tb_187:long_name = "18.7 GHz main beam brightness temperature" ;
        tb_187:units = "K" ;
        tb_187:standard_name = "surface_brightness_temperature" ;
        tb_187:scale_factor = 0.01 ;
        tb_187:coordinates = "lon lat" ;
        tb_187:comment = "Brightness temperatures are unsmoothed (along-track averaging has not been performed on the
            brightness temperatures)" ;
    short tb_238(time) ;
        tb_238:_FillValue = 32767s ;
        tb_238:long_name = "23.8 GHz main beam brightness temperature" ;
        tb_238:units = "K" ;
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        tb_238:standard_name = "surface_brightness_temperature" ;
        tb_238:scale_factor = 0.01 ;
        tb_238:coordinates = "lon lat" ;
        tb_238:comment = "Brightness temperatures are unsmoothed (along-track averaging has not been performed on the
            brightness temperatures)" ;
    short tb_340(time) ;
        tb_340:_FillValue = 32767s ;
        tb_340:long_name = "34 GHz main beam brightness temperature" ;
        tb_340:units = "K" ;
        tb_340:standard_name = "surface_brightness_temperature" ;
        tb_340:scale_factor = 0.01 ;
        tb_340:coordinates = "lon lat" ;
        tb_340:comment = "Brightness temperatures are unsmoothed (along-track averaging has not been performed on the
            brightness temperatures)" ;
    short land_prop_c187(time) ;
        land_prop_c187:_FillValue = 32767s ;
        land_prop_c187:long_name = "Land proportion in the 18.7 GHz main beam footprint" ;
        land_prop_c187:units = "%" ;
        land_prop_c187:standard_name = "land_proportion" ;
        land_prop_c187:scale_factor = 0.01 ;
        land_prop_c187:coordinates = "lon lat" ;
        land_prop_c187:comment = "comuputed from the convolution of AMR antenna pattern with a global 1/10 degree land-
            sea mask" ;
    short land_prop_c238(time) ;
        land_prop_c238:_FillValue = 32767s ;
        land_prop_c238:long_name = "Land proportion in the 23.8 GHz main beam footprint" ;
        land_prop_c238:units = "%" ;
        land_prop_c238:standard_name = "land_proportion" ;
        land_prop_c238:scale_factor = 0.01 ;
        land_prop_c238:coordinates = "lon lat" ;
        land_prop_c238:comment = "comuputed from the convolution of AMR antenna pattern with a global 1/10 degree land-
            sea mask" ;
    short land_prop_c340(time) ;
        land_prop_c340:_FillValue = 32767s ;
        land_prop_c340:long_name = "Land proportion in the 34.0 GHz main beam footprint" ;
        land_prop_c340:units = "%" ;
        land_prop_c340:standard_name = "land_proportion" ;
        land_prop_c340:scale_factor = 0.01 ;
        land_prop_c340:coordinates = "lon lat" ;
        land_prop_c340:comment = "comuputed from the convolution of AMR antenna pattern with a global 1/10 degree land-
            sea mask" ;
    short ssha(time) ;
        ssha:_FillValue = 32767s ;
        ssha:long_name = "sea surface height anomaly" ;
        ssha:units = "m" ;
        ssha:standard_name = "sea_surface_height_above_sea_level" ;
        ssha:source = "[altimeter_sensor_name]" ;
        ssha:institution = "[altimeter_sensor_institution]" ;
        ssha:scale_factor = 0.001 ;
        ssha:coordinates = "lon lat" ;
        ssha:comment = "= altitude of satellite (alt) - Ku band corrected altimeter range (range_ku) - altimeter ionospheric
            correction on Ku band (iono_cor_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)
            - mean sea surface (mean_sea_surface)" ;
    int mss1(time) ;
        mss1:_FillValue = 2147483647 ;
        mss1:long_name = "mean sea surface height above reference ellipsoid" ;
        mss1:units = "m" ;
        mss1:source = "CLS01" ;
        mss1:institution = "CLS" ;
        mss1:scale_factor = 0.0001 ;
        mss1:coordinates = "lon lat" ;
        mss1:comment = "See Jason-2 User Handbook" ;
    int mss2(time) ;
        mss2:_FillValue = 2147483647 ;
        mss2:long_name = "mean sea surface height above reference ellipsoid" ;
        mss2:units = "m" ;
        mss2:source = "GOCINA" ;
        mss2:institution = "CLS" ;
        mss2:scale_factor = 0.0001 ;
        mss2:coordinates = "lon lat" ;
        mss2:comment = "See Jason-2 PISTACH User Handbook" ;
    int mss3(time) ;
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        mss3:_FillValue = 2147483647 ;
        mss3:long_name = "mean sea surface height above reference ellipsoid" ;
        mss3:units = "m" ;
        mss3:source = "DNSC08" ;
        mss3:institution = "DNSC" ;
        mss3:scale_factor = 0.0001 ;
        mss3:coordinates = "lon lat" ;
        mss3:comment = "See Jason-2 PISTACH User Handbook" ;
    int err_mss1(time) ;
        err_mss1:_FillValue = 2147483647 ;
        err_mss1:long_name = "PISTACH: Error on the mean sea surface height above reference ellipsoid." ;
        err_mss1:units = "m" ;
        err_mss1:source = "CLS01" ;
        err_mss1:institution = "CLS" ;
        err_mss1:scale_factor = 0.0001 ;
        err_mss1:coordinates = "lon lat" ;
        err_mss1:comment = "See Jason-2 User Handbook" ;
    int err_mss2(time) ;
        err_mss2:_FillValue = 2147483647 ;
        err_mss2:long_name = "PISTACH: Error on the mean sea surface height above reference ellipsoid" ;
        err_mss2:units = "m" ;
        err_mss2:source = "GOCINA" ;
        err_mss2:institution = "CLS" ;
        err_mss2:scale_factor = 0.0001 ;
        err_mss2:coordinates = "lon lat" ;
        err_mss2:comment = "See Jason-2 PISTACH User Handbook" ;
    int err_mss3(time) ;
        err_mss3:_FillValue = 2147483647 ;
        err_mss3:long_name = "PISTACH: Error on mean sea surface height above reference ellipsoid" ;
        err_mss3:units = "m" ;
        err_mss3:source = "DNSC08" ;
        err_mss3:institution = "DNSC" ;
        err_mss3:scale_factor = 0.0001 ;
        err_mss3:coordinates = "lon lat" ;
        err_mss3:comment = "See Jason-2 PISTACH User Handbook" ;
    int mean_topography1(time) ;
        mean_topography1:_FillValue = 2147483647 ;
        mean_topography1:long_name = "mean dynamic topography above geoid" ;
        mean_topography1:units = "m" ;
        mean_topography1:source = "Rio 05" ;
        mean_topography1:institution = "CLS/CNES" ;
        mean_topography1:scale_factor = 0.0001 ;
        mean_topography1:coordinates = "lon lat" ;
        mean_topography1:comment = "See Jason-2 User Handbook" ;
    int mean_topography2(time) ;
        mean_topography2:_FillValue = 2147483647 ;
        mean_topography2:long_name = "mean dynamic topography above geoid" ;
        mean_topography2:units = "m" ;
        mean_topography2:source = "Rio 07 MEDSEA" ;
        mean_topography2:institution = "CLS/CNES" ;
        mean_topography2:scale_factor = 0.0001 ;
        mean_topography2:coordinates = "lon lat" ;
        mean_topography2:comment = "See Jason-2 PISTACH User Handbook" ;
    int geoid_EGM96(time) ;
        geoid_EGM96:_FillValue = 2147483647 ;
        geoid_EGM96:long_name = "EGM96 geoid height" ;
        geoid_EGM96:units = "m" ;
        geoid_EGM96:standard_name = "EGM96 geoid_height_above_J2_reference_ellipsoid" ;
        geoid_EGM96:source = "EGM96" ;
        geoid_EGM96:institution = "GSFC" ;
        geoid_EGM96:scale_factor = 0.0001 ;
        geoid_EGM96:coordinates = "lon lat" ;
        geoid_EGM96:comment = "Computed from the EGM96 geoid model with a correction to refer the value to the mean
                tide system i.e. includes the permanent tide (zero frequency). See Jason-2 User Handbook" ;
    int geoid_EGM2008(time) ;
        geoid_EGM2008:_FillValue = 2147483647 ;
        geoid_EGM2008:long_name = "EGM2008 geoid height" ;
        geoid_EGM2008:units = "m" ;
        geoid_EGM2008:standard_name = "EGM2008 geoid_height_above_J2_reference_ellipsoid" ;
        geoid_EGM2008:source = "EGM2008" ;
        geoid_EGM2008:institution = "GSFC via BGI" ;
        geoid_EGM2008:scale_factor = 0.0001 ;
        geoid_EGM2008:coordinates = "lon lat" ;
        geoid_EGM2008:comment = "Computed from the EGM2008 geoid model with a correction to refer the value to the
                mean tide system i.e. includes the permanent tide (zero frequency). See Jason-2 User Handbook" ;
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int bathymetry_topography(time) ;
    bathymetry_topography:_FillValue = 2147483647 ;
    bathymetry_topography:long_name = "ocean depth/land elevation" ;
    bathymetry_topography:units = "m" ;
    bathymetry_topography:source = "DTM2000.1" ;
    bathymetry_topography:institution = "GSFC" ;
    bathymetry_topography:coordinates = "lon lat" ;
    bathymetry_topography:comment = "See Jason-2 User Handbook" ;
int regional_bathy(time) ;
    regional_bathy:_FillValue = 2147483647 ;
    regional_bathy:long_name = "ocean depth, regional models" ;
    regional_bathy:units = "m" ;
    regional_bathy:source = "WebTide, Etopo2v2" ;
    regional_bathy:institution = "MPO-DFO, Etopo2v2" ;
    regional_bathy:coordinates = "lon lat" ;
    regional_bathy:comment = "See Jason-2 PISTACH User Handbook" ;
int topography(time) ;
    topography:_FillValue = 2147483647 ;
    topography:long_name = "land elevation" ;
    topography:units = "m" ;
    topography:source = "ACE2" ;
    topography:institution = "DMU/ESA" ;
    topography:coordinates = "lon lat" ;
    topography:comment = "See Jason-2 PISTACH User Handbook" ;
short inv_bar_corr(time) ;
    inv_bar_corr:_FillValue = 32767s ;
    inv_bar_corr:long_name = "inverted barometer height correction" ;
    inv_bar_corr:units = "m" ;
    inv_bar_corr:standard_name = "sea_surface_height_correction_due_to_air_pressure_at_low_frequency" ;
    inv_bar_corr:source = "European Center for Medium Range Weather Forecasting" ;
    inv_bar_corr:institution = "ECMWF" ;
    inv_bar_corr:scale_factor = 0.0001 ;
    inv_bar_corr:coordinates = "lon lat" ;
    inv_bar_corr:comment = "Computed at the altimeter time-tag from the interpolation of 2 meteorological fields that
        surround the altimeter time-tag. See Jason-2 User Handbook" ;
short hf_fluctuations_corr(time) ;
    hf_fluctuations_corr:_FillValue = 32767s ;
    hf_fluctuations_corr:long_name = "high frequency fluctuations of the sea surface topography" ;
    hf_fluctuations_corr:units = "m" ;
    hf_fluctuations_corr:standard_name =
        "sea_surface_height_correction_due_to_air_pressure_and_wind_at_high_frequency" ;
    hf_fluctuations_corr:source = "AD" ;
    hf_fluctuations_corr:institution = "LEGOS/CLS/CNES" ;
    hf_fluctuations_corr:scale_factor = 0.0001 ;
    hf_fluctuations_corr:coordinates = "lon lat" ;
    hf_fluctuations_corr:comment = "Provided as a correction to the inverted barometer correction (inv_bar_corr)" ;
int ocean_tide_sol1(time) ;
    ocean_tide_sol1:_FillValue = 2147483647 ;
    ocean_tide_sol1:long_name = "geocentric ocean tide height (solution 1)" ;
    ocean_tide_sol1:units = "m" ;
    ocean_tide_sol1:standard_name = "sea_surface_height_amplitude_due_to_geocentric_ocean_tide" ;
    ocean_tide_sol1:source = "GOT00.2" ;
    ocean_tide_sol1:institution = "GSFC" ;
    ocean_tide_sol1:scale_factor = 0.0001 ;
    ocean_tide_sol1:coordinates = "lon lat" ;
    ocean_tide_sol1:comment = "Solution 1 corresponds to GOT00.2 model. Includes the corresponding loading tide
        (load_tide_sol1) and equilibrium long-period ocean tide height (ocean_tide_equil). The permanent tide (zero
        frequency) is not included in this parameter because it is included in the geoid and mean sea surface (geoid,
        mean_sea_surface). See Jason-2 User Handbook " ;
int ocean_tide_sol2(time) ;
    ocean_tide_sol2:_FillValue = 2147483647 ;
    ocean_tide_sol2:long_name = "geocentric ocean tide height (solution 2)" ;
    ocean_tide_sol2:units = "m" ;
    ocean_tide_sol2:standard_name = "sea_surface_height_amplitude_due_to_geocentric_ocean_tide" ;
    ocean_tide_sol2:source = "FES2004" ;
    ocean_tide_sol2:institution = "LEGOS/CNES" ;
    ocean_tide_sol2:scale_factor = 0.0001 ;
    ocean_tide_sol2:coordinates = "lon lat" ;
    ocean_tide_sol2:comment = "Solution 2 corresponds to FES2004 model. Includes the corresponding loading tide
        (load_tide_sol2) and equilibrium long-period ocean tide height (ocean_tide_equil). The permanent tide (zero
        frequency) is not included in this parameter because it is included in the geoid and mean sea surface (geoid,
        mean_sea_surface). See Jason-2 User Handbook " ;
int ocean_tide_sol3(time) ;
    ocean_tide_sol3:_FillValue = 2147483647 ;
    ocean_tide_sol3:long_name = "geocentric ocean tide height (solution 3)" ;
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        ocean_tide_sol3:units = "m" ;
        ocean_tide_sol3:standard_name = "sea_surface_height_amplitude_due_to_geocentric_ocean_tide" ;
        ocean_tide_sol3:source = "GOT4.7" ;
        ocean_tide_sol3:institution = "Ray/GSFC" ;
        ocean_tide_sol3:scale_factor = 0.0001 ;
        ocean_tide_sol3:coordinates = "lon lat" ;
        ocean_tide_sol3:comment = "Solution 1 corresponds to GOT4.7 model. Includes the corresponding loading tide
            (load_tide_sol1) and equilibrium long-period ocean tide height (ocean_tide_equil). The permanent tide (zero
            frequency) is not included in this parameter because it is included in the geoid and mean sea surface (geoid,
            mean_sea_surface). See Jason-2 User Handbook " ;
    short ocean_tide_equil(time) ;
        ocean_tide_equil:_FillValue = 32767s ;
        ocean_tide_equil:long_name = "equilibrium long-period ocean tide height" ;
        ocean_tide_equil:units = "m" ;
        ocean_tide_equil:standard_name = "sea_surface_height_amplitude_due_to_equilibrium_ocean_tide" ;
        ocean_tide_equil:source = "Cartwright and Taylor tidal potential" ;
        ocean_tide_equil:institution = "TBD" ;
        ocean_tide_equil:scale_factor = 0.0001 ;
        ocean_tide_equil:coordinates = "lon lat" ;
        ocean_tide_equil:comment = "This value has already been added to the two geocentric ocean tide height values
            recorded in the product (ocean_tide_sol1 and ocean_tide_sol2). The permanent tide (zero frequency) is not
            included in this parameter because it is included in the geoid and mean sea surface (geoid,
            mean_sea_surface). See Jason-2 User Handbook" ;
    short ocean_tide_non_equil(time) ;
        ocean_tide_non_equil:_FillValue = 32767s ;
        ocean_tide_non_equil:long_name = "non-equilibrium long-period ocean tide height" ;
        ocean_tide_non_equil:units = "m" ;
        ocean_tide_non_equil:standard_name = "sea_surface_height_amplitude_due_to_non_equilibrium_ocean_tide" ;
        ocean_tide_non_equil:source = "FES2004" ;
        ocean_tide_non_equil:institution = "LEGOS/CNES" ;
        ocean_tide_non_equil:scale_factor = 0.0001 ;
        ocean_tide_non_equil:coordinates = "lon lat" ;
        ocean_tide_non_equil:comment = "This parameter is computed as a correction to the parameter ocean_tide_equil.
            This value can be added to ocean_tide_equil (or ocean_tide_sol1, ocean_tide_sol2) so that the resulting value
            models the total non equilibrium ocean tide height. See Jason-2 User Handbook" ;
    short load_tide_sol1(time) ;
        load_tide_sol1:_FillValue = 32767s ;
        load_tide_sol1:long_name = "load tide height for geocentric ocean tide (solution 1)" ;
        load_tide_sol1:units = "m" ;
        load_tide_sol1:source = "GOT00.2" ;
        load_tide_sol1:institution = "GSFC" ;
        load_tide_sol1:scale_factor = 0.0001 ;
        load_tide_sol1:coordinates = "lon lat" ;
        load_tide_sol1:comment = "This value has already been added to the corresponding ocean tide height value recorded
            in the product (ocean_tide_sol1). See Jason-2 User Handbook" ;
    short load_tide_sol2(time) ;
        load_tide_sol2:_FillValue = 32767s ;
        load_tide_sol2:long_name = "load tide height for geocentric ocean tide (solution 2)" ;
        load_tide_sol2:units = "m" ;
        load_tide_sol2:source = "FES2004" ;
        load_tide_sol2:institution = "LEGOS/CNES" ;
        load_tide_sol2:scale_factor = 0.0001 ;
        load_tide_sol2:coordinates = "lon lat" ;
        load_tide_sol2:comment = "This value has already been added to the corresponding ocean tide height value recorded
            in the product (ocean_tide_sol2). See Jason-2 User Handbook" ;
    short load_tide_sol3(time) ;
        load_tide_sol3:_FillValue = 32767s ;
        load_tide_sol3:long_name = "load tide height for geocentric ocean tide (solution 3)" ;
        load_tide_sol3:units = "m" ;
        load_tide_sol3:source = "GOT4.7" ;
        load_tide_sol3:institution = "Ray/GSFC" ;
        load_tide_sol3:scale_factor = 0.0001 ;
        load_tide_sol3:coordinates = "lon lat" ;
        load_tide_sol3:comment = "This value has already been added to the corresponding ocean tide height value recorded
            in the product (ocean_tide_sol3). See Jason-2 User Handbook" ;
    short solid_earth_tide(time) ;
        solid_earth_tide:_FillValue = 32767s ;
        solid_earth_tide:long_name = "solid earth tide height" ;
        solid_earth_tide:units = "m" ;
        solid_earth_tide:standard_name = "sea_surface_height_amplitude_due_to_earth_tide" ;
        solid_earth_tide:source = "Cartwright and Taylor tidal potential" ;
        solid_earth_tide:institution = "TBD" ;
        solid_earth_tide:scale_factor = 0.0001 ;
        solid_earth_tide:coordinates = "lon lat" ;
        solid_earth_tide:comment = "Calculated using Cartwright and Tayler tables and consisting of the second and third
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            degree constituents. The permanent tide (zero frequency) is not included. See Jason-2 User Handbook" ;
    short pole_tide(time) ;
        pole_tide:_FillValue = 32767s ;
        pole_tide:long_name = "geocentric pole tide height" ;
        pole_tide:units = "m" ;
        pole_tide:standard_name = "sea_surface_height_amplitude_due_to_pole_tide" ;
        pole_tide:source = "Wahr [1985]" ;
        pole_tide:institution = "TBD" ;
        pole_tide:scale_factor = 0.0001 ;
        pole_tide:coordinates = "lon lat" ;
        pole_tide:comment = "See Jason-2 User Handbook" ;
    short Land_cover_class(time) ;
        Land_cover_class:_FillValue = 32767s ;
        Land_cover_class:long_name = "Land Cover Class according to UNEP/FAO LCCS definition" ;
        Land_cover_class:units = "count" ;
        Land_cover_class:standard_name = "Land Cover Class" ;
        Land_cover_class:source = "GLOBCOVER" ;
        Land_cover_class:institution = "ESA/MEDIAS" ;
        Land_cover_class:scale_factor = 0.0001 ;
        Land_cover_class:coordinates = "lon lat" ;
        Land_cover_class:comment =  ;
    short wind_speed_model_u(time) ;
        wind_speed_model_u:_FillValue = 32767s ;
        wind_speed_model_u:long_name = "U component of the model wind vector" ;
        wind_speed_model_u:units = "m/s" ;
        wind_speed_model_u:standard_name = "wind_speed" ;
        wind_speed_model_u:source = "European Center for Medium Range Weather Forecasting" ;
        wind_speed_model_u:institution = "ECMWF" ;
        wind_speed_model_u:scale_factor = 0.01 ;
        wind_speed_model_u:coordinates = "lon lat" ;
        wind_speed_model_u:comment = "Computed at the altimeter time-tag from the interpolation of 2 meteorological fields
            that surround the altimeter time-tag. See Jason-2 User Handbook" ;
    short wind_speed_model_v(time) ;
        wind_speed_model_v:_FillValue = 32767s ;
        wind_speed_model_v:long_name = "V component of the model wind vector" ;
        wind_speed_model_v:units = "m/s" ;
        wind_speed_model_v:standard_name = "wind_speed" ;
        wind_speed_model_v:source = "European Center for Medium Range Weather Forecasting" ;
        wind_speed_model_v:institution = "ECMWF" ;
        wind_speed_model_v:scale_factor = 0.01 ;
        wind_speed_model_v:coordinates = "lon lat" ;
        wind_speed_model_v:comment = "Computed at the altimeter time-tag from the interpolation of 2 meteorological fields
            that surround the altimeter time-tag. See Jason-2 User Handbook" ;
    short wind_speed_alt(time) ;
        wind_speed_alt:_FillValue = 32767s ;
        wind_speed_alt:long_name = "altimeter wind speed" ;
        wind_speed_alt:units = "m/s" ;
        wind_speed_alt:standard_name = "wind_speed" ;
        wind_speed_alt:scale_factor = 0.01 ;
        wind_speed_alt:coordinates = "lon lat" ;
        wind_speed_alt:comment = "Should not be used over land. See Jason-2 User Handbook" ;
    short wind_speed_alt_oce3(time) ;
        wind_speed_alt_oce3:_FillValue = 32767s ;
        wind_speed_alt_oce3:long_name = "altimeter wind speed. PISTACH Ocean3 retracking" ;
        wind_speed_alt_oce3:units = "m/s" ;
        wind_speed_alt_oce3:standard_name = "wind_speed" ;
        wind_speed_alt_oce3:scale_factor = 0.01 ;
        wind_speed_alt_oce3:coordinates = "lon lat" ;
        wind_speed_alt_oce3:comment = "Should not be used over land. See Jason-2 User Handbook" ;
    short wind_speed_rad(time) ;
        wind_speed_rad:_FillValue = 32767s ;
        wind_speed_rad:long_name = "radiometer wind speed" ;
        wind_speed_rad:units = "m/s" ;
        wind_speed_rad:standard_name = "wind_speed" ;
        wind_speed_rad:source = "[radiometer_sensor_name]" ;
        wind_speed_rad:institution = "[radiometer_sensor_institution]" ;
        wind_speed_rad:scale_factor = 0.01 ;
        wind_speed_rad:coordinates = "lon lat" ;
        wind_speed_rad:comment = "Should not be used over land. See Jason-2 User Handbook" ;
    short rad_water_vapor(time) ;
        rad_water_vapor:_FillValue = 32767s ;
        rad_water_vapor:long_name = "radiometer water vapor content" ;
        rad_water_vapor:units = "gram/cm^2" ;
        rad_water_vapor:standard_name = "atmosphere_water_vapor_content" ;
        rad_water_vapor:source = "[radiometer_sensor_name]" ;
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        rad_water_vapor:institution = "[radiometer_sensor_institution]" ;
        rad_water_vapor:scale_factor = 0.01 ;
        rad_water_vapor:coordinates = "lon lat" ;
        rad_water_vapor:comment = "Should not be used over land" ;
    short rad_liquid_water(time) ;
        rad_liquid_water:_FillValue = 32767s ;
        rad_liquid_water:long_name = "radiometer liquid water content" ;
        rad_liquid_water:units = "kg/m^2" ;
        rad_liquid_water:standard_name = "atmosphere_cloud_liquid_water_content" ;
        rad_liquid_water:source = "[radiometer_sensor_name]" ;
        rad_liquid_water:institution = "[radiometer_sensor_institution]" ;
        rad_liquid_water:scale_factor = 0.01 ;
        rad_liquid_water:coordinates = "lon lat" ;
        rad_liquid_water:comment = "Should not be used over land" ;
    int ice_range_ku(time) ;
        ice_range_ku:_FillValue = 2147483647 ;
        ice_range_ku:long_name = "Ku band altimeter range (ice retracking)" ;
        ice_range_ku:units = "m" ;
        ice_range_ku:standard_name = "altimeter_range" ;
        ice_range_ku:add_offset = 1300000. ;
        ice_range_ku:scale_factor = 0.0001 ;
        ice_range_ku:coordinates = "lon lat" ;
        ice_range_ku:comment = "Distance antenna-COG (cog_corr), USO drift correction (uso_corr) and internal path
                correction (internal_path_delay_corr_ku) included" ;
    int ice_range_c(time) ;
        ice_range_c:_FillValue = 2147483647 ;
        ice_range_c:long_name = "C band altimeter range (ice retracking)" ;
        ice_range_c:units = "m" ;
        ice_range_c:standard_name = "altimeter_range" ;
        ice_range_c:add_offset = 1300000. ;
        ice_range_c:scale_factor = 0.0001 ;
        ice_range_c:coordinates = "lon lat" ;
        ice_range_c:comment = "Distance antenna-COG (cog_corr), USO drift correction (uso_corr) and internal path
                correction (internal_path_delay_corr_c) included" ;
    short ice_sig0_ku(time) ;
        ice_sig0_ku:_FillValue = 32767s ;
        ice_sig0_ku:long_name = "Ku band backscatter coefficient (ice retracking)" ;
        ice_sig0_ku:units = "dB" ;
        ice_sig0_ku:standard_name = "surface_backwards_scattering_coefficient_of_radar_wave" ;
        ice_sig0_ku:scale_factor = 0.01 ;
        ice_sig0_ku:coordinates = "lon lat" ;
        ice_sig0_ku:comment = "AGC instrumental errors correction and internal calibration correction (internal_corr_sig0_ku)
                included" ;
    short ice_sig0_c(time) ;
        ice_sig0_c:_FillValue = 32767s ;
        ice_sig0_c:long_name = "C band backscatter coefficient (ice retracking)" ;
        ice_sig0_c:units = "dB" ;
        ice_sig0_c:standard_name = "surface_backwards_scattering_coefficient_of_radar_wave" ;
        ice_sig0_c:scale_factor = 0.01 ;
        ice_sig0_c:coordinates = "lon lat" ;
        ice_sig0_c:comment = "AGC instrumental errors correction and internal calibration correction (internal_corr_sig0_c)
                included" ;
    short mqe_ku(time) ;
        mqe_ku:_FillValue = 32767s ;
        mqe_ku:long_name = "Ku band MQE (ocean retracking)" ;
        mqe_ku:units = "count" ;
        mqe_ku:scale_factor = 0.0001 ;
        mqe_ku:coordinates = "lon lat" ;
        mqe_ku:comment = "Mean Quadratic Error between the waveforms samples and the corresponding model samples
                built from the ocean retracking outputs" ;
    short mqe_c(time) ;
        mqe_c:_FillValue = 32767s ;
        mqe_c:long_name = "C band MQE (ocean retracking)" ;
        mqe_c:units = "count" ;
        mqe_c:scale_factor = 0.0001 ;
        mqe_c:coordinates = "lon lat" ;
        mqe_c:comment = "Mean Quadratic Error between the waveforms samples and the corresponding model samples
                built from the ocean retracking outputs" ;
    short mqe_oce3_ku(time) ;
        mqe_oce3_ku:_FillValue = 32767s ;
        mqe_oce3_ku:long_name = "Ku band MQE (PISTACH Ocean3 retracking)" ;
        mqe_oce3_ku:units = "count" ;
        mqe_oce3_ku:scale_factor = 0.0001 ;
        mqe_oce3_ku:coordinates = "lon lat" ;
        mqe_oce3_ku:comment = "Mean Quadratic Error between the waveforms samples and the corresponding model
```

```
            samples built from the ocean retracking outputs" ;
    short mqe_oce3_c(time) ;
        mqe_oce3_c:_FillValue = 32767s ;
        mqe_oce3_c:long_name = "C band MQE (PISTACH Ocean3 retracking)" ;
        mqe_oce3_c:units = "count" ;
        mqe_oce3_c:scale_factor = 0.0001 ;
        mqe_oce3_c:coordinates = "lon lat" ;
        mqe_oce3_c:comment = "Mean Quadratic Error between the waveforms samples and the corresponding model
            samples built from the ocean retracking outputs" ;
    short mqe_red3_ku(time) ;
        mqe_red3_ku:_FillValue = 32767s ;
        mqe_red3_ku:long_name = "Ku band MQE (PISTACH Red3 retracking)" ;
        mqe_red3_ku:units = "count" ;
        mqe_red3_ku:scale_factor = 0.0001 ;
        mqe_red3_ku:coordinates = "lon lat" ;
        mqe_red3_ku:comment = "Mean Quadratic Error between the waveforms samples and the corresponding model
            samples built from the ocean retracking outputs" ;
    short mqe_red3_c(time) ;
        mqe_red3_c:_FillValue = 32767s ;
        mqe_red3_c:long_name = "C band MQE (PISTACH Red3 retracking)" ;
        mqe_red3_c:units = "count" ;
        mqe_red3_c:scale_factor = 0.0001 ;
        mqe_red3_c:coordinates = "lon lat" ;
        mqe_red3_c:comment = "Mean Quadratic Error between the waveforms samples and the corresponding model
            samples built from the ocean retracking outputs" ;
    short peakiness_ku(time) ;
        peakiness_ku:_FillValue = 32767s ;
        peakiness_ku:long_name = "peakiness on Ku band waveforms" ;
        peakiness_ku:units = "count" ;
        peakiness_ku:scale_factor = 0.001 ;
        peakiness_ku:coordinates = "lon lat" ;
    short peakiness_c(time) ;
        peakiness_c:_FillValue = 32767s ;
        peakiness_c:long_name = "peakiness on C band waveforms" ;
        peakiness_c:units = "count" ;
        peakiness_c:scale_factor = 0.001 ;
        peakiness_c:coordinates = "lon lat" ;
    short wf_class_ku(time) ;
        wf_class_ku:_FillValue = 32767s ;
        wf_class_ku:long_name = "most probable class for the waveform in Ku Band" ;
        wf_class_ku:units = "count" ;
        wf_class_ku:scale_factor = 0.001 ;
        wf_class_ku:coordinates = "lon lat" ;
    short wf_class_c(time) ;
        wf_class_c:_FillValue = 32767s ;
        wf_class_c:long_name = "most probable class for the waveform in C Band" ;
        wf_class_c:units = "count" ;
        wf_class_c:scale_factor = 0.001 ;
        wf_class_c:coordinates = "lon lat" ;
    int tracker_ku(time) ;
        tracker_ku:_FillValue = 2147483647 ;
        tracker_ku:long_name = "Ku band tracker range" ;
        tracker_ku:units = "m" ;
        tracker_ku:standard_name = "altimeter_range" ;
        tracker_ku:add_offset = 1300000. ;
        tracker_ku:scale_factor = 0.0001 ;
        tracker_ku:coordinates = "lon lat" ;
        tracker_ku:comment = "Ku-band operating tracker (\'Diode+DEM\' or \'Median\' or \'Slide Gate\' tracker). All
            instrumental corrections included, i.e. distance antenna-COG (cog_corr), USO drift correction (uso_corr),
            internal path correction (internal_path_delay_corr_ku), Doppler correction (doppler_corr_ku), modeled
            instrumental errors correction (modeled_instr_corr_range_ku) and system bias" ;
    int tracker_diode_ku(time) ;
        tracker_diode_ku:_FillValue = 2147483647 ;
        tracker_diode_ku:long_name = "tracker range counter from Diode+DEM" ;
        tracker_diode_ku:units = "m" ;
        tracker_diode_ku:standard_name = "altimeter_range" ;
        tracker_diode_ku:add_offset = 1300000. ;
        tracker_diode_ku:scale_factor = 0.0001 ;
        tracker_diode_ku:coordinates = "lon lat" ;
    int tracker_c(time) ;
        tracker_c:_FillValue = 2147483647 ;
        tracker_c:long_name = "C band tracker range" ;
        tracker_c:units = "m" ;
        tracker_c:standard_name = "altimeter_range" ;
        tracker_c:add_offset = 1300000. ;
```

```
        tracker_c:scale_factor = 0.0001 ;
        tracker_c:coordinates = "lon lat" ;
        tracker_c:comment = "C-band operating tracker. All instrumental corrections included, i.e. distance antenna-COG
            (cog_corr), USO drift correction (uso_corr), internal path correction (internal_path_delay_corr_c), Doppler
            correction (doppler_corr_c), modeled instrumental errors correction (modeled_instr_corr_range_c) and system
            bias " ;
    int uso_corr(time) ;
        uso_corr:_FillValue = 2147483647 ;
        uso_corr:long_name = "USO frequency correction on altimeter range" ;
        uso_corr:units = "m" ;
        uso_corr:scale_factor = 0.0001 ;
        uso_corr:comment = "Correction of the USO frequency drift on the altimeter range" ;
    int internal_path_delay_corr_ku(time) ;
        internal_path_delay_corr_ku:_FillValue = 2147483647 ;
        internal_path_delay_corr_ku:long_name = "Ku band internal path delay correction on altimeter range" ;
        internal_path_delay_corr_ku:units = "m" ;
        internal_path_delay_corr_ku:scale_factor = 0.0001 ;
        internal_path_delay_corr_ku:comment = "Internal calibration correction on the Ku-band altimeter range" ;
    int internal_path_delay_corr_c(time) ;
        internal_path_delay_corr_c:_FillValue = 2147483647 ;
        internal_path_delay_corr_c:long_name = "C band internal path delay correction on altimeter range" ;
        internal_path_delay_corr_c:units = "m" ;
        internal_path_delay_corr_c:scale_factor = 0.0001 ;
        internal_path_delay_corr_c:comment = "Internal calibration correction on the C-band altimeter range" ;
    short modeled_instr_corr_range_ku(time) ;
        modeled_instr_corr_range_ku:_FillValue = 32767s ;
        modeled_instr_corr_range_ku:long_name = "Ku band modeled instrumental correction on altimeter range" ;
        modeled_instr_corr_range_ku:units = "m" ;
        modeled_instr_corr_range_ku:scale_factor = 0.0001 ;
    short modeled_instr_corr_range_c(time) ;
        modeled_instr_corr_range_c:_FillValue = 32767s ;
        modeled_instr_corr_range_c:long_name = "C band modeled instrumental correction on altimeter range" ;
        modeled_instr_corr_range_c:units = "m" ;
        modeled_instr_corr_range_c:scale_factor = 0.0001 ;
    short modeled_instr_corr_range_oce3_ku(time) ;
        modeled_instr_corr_range_oce3_ku:_FillValue = 32767s ;
        modeled_instr_corr_range_oce3_ku:long_name = "Ku band modeled instrumental correction on altimeter range.
            PISTACH Ocean3 retracking" ;
        modeled_instr_corr_range_oce3_ku:units = "m" ;
        modeled_instr_corr_range_oce3_ku:scale_factor = 0.0001 ;
    short modeled_instr_corr_range_oce3_c(time) ;
        modeled_instr_corr_range_oce3_c:_FillValue = 32767s ;
        modeled_instr_corr_range_oce3_c:long_name = "C band modeled instrumental correction on altimeter range.
            PISTACH Ocean3 retracking" ;
        modeled_instr_corr_range_oce3_c:units = "m" ;
        modeled_instr_corr_range_oce3_c:scale_factor = 0.0001 ;
    short doppler_corr_ku(time) ;
        doppler_corr_ku:_FillValue = 32767s ;
        doppler_corr_ku:long_name = "Ku band Doppler correction on altimeter range" ;
        doppler_corr_ku:units = "m" ;
        doppler_corr_ku:scale_factor = 0.0001 ;
    short doppler_corr_c(time) ;
        doppler_corr_c:_FillValue = 32767s ;
        doppler_corr_c:long_name = "C band Doppler correction on altimeter range" ;
        doppler_corr_c:units = "m" ;
        doppler_corr_c:scale_factor = 0.0001 ;
    short cog_corr(time) ;
        cog_corr:_FillValue = 32767s ;
        cog_corr:long_name = "Distance antenna-COG correction on altimeter range" ;
        cog_corr:units = "m" ;
        cog_corr:scale_factor = 0.0001 ;
    short modeled_instr_corr_swh_ku(time) ;
        modeled_instr_corr_swh_ku:_FillValue = 32767s ;
        modeled_instr_corr_swh_ku:long_name = "Ku band modeled instrumental correction on significant waveheight" ;
        modeled_instr_corr_swh_ku:units = "m" ;
        modeled_instr_corr_swh_ku:scale_factor = 0.001 ;
    short modeled_instr_corr_swh_c(time) ;
        modeled_instr_corr_swh_c:_FillValue = 32767s ;
        modeled_instr_corr_swh_c:long_name = "C band modeled instrumental correction on significant waveheight" ;
        modeled_instr_corr_swh_c:units = "m" ;
        modeled_instr_corr_swh_c:scale_factor = 0.001 ;
    short modeled_instr_corr_swh_oce3_ku(time) ;
        modeled_instr_corr_swh_oce3_ku:_FillValue = 32767s ;
        modeled_instr_corr_swh_oce3_ku:long_name = "Ku band modeled instrumental correction on significant waveheight.
            PISTACH Ocean3 retracking" ;
```

```
        modeled_instr_corr_swh_oce3_ku:units = "m" ;
        modeled_instr_corr_swh_oce3_ku:scale_factor = 0.001 ;
    short modeled_instr_corr_swh_oce3_c(time) ;
        modeled_instr_corr_swh_oce3_c:_FillValue = 32767s ;
        modeled_instr_corr_swh_oce3_c:long_name = "C band modeled instrumental correction on significant waveheight.
            PISTACH Ocean3 retracking" ;
        modeled_instr_corr_swh_oce3_c:units = "m" ;
        modeled_instr_corr_swh_oce3_c:scale_factor = 0.001 ;
    short modeled_instr_corr_sig0_ku(time) ;
        modeled_instr_corr_sig0_ku:_FillValue = 32767s ;
        modeled_instr_corr_sig0_ku:long_name = "Ku band modeled instrumental correction on backscatter coefficient" ;
        modeled_instr_corr_sig0_ku:units = "dB" ;
        modeled_instr_corr_sig0_ku:scale_factor = 0.01 ;
    short modeled_instr_corr_sig0_c(time) ;
        modeled_instr_corr_sig0_c:_FillValue = 32767s ;
        modeled_instr_corr_sig0_c:long_name = "C band modeled instrumental correction on backscatter coefficient" ;
        modeled_instr_corr_sig0_c:units = "dB" ;
        modeled_instr_corr_sig0_c:scale_factor = 0.01 ;
    short modeled_instr_corr_sig0_oce3_ku(time) ;
        modeled_instr_corr_sig0_oce3_ku:_FillValue = 32767s ;
        modeled_instr_corr_sig0_oce3_ku:long_name = "Ku band modeled instrumental correction on backscatter coefficient.
            PISTACH Ocean3 retracking" ;
        modeled_instr_corr_sig0_oce3_ku:units = "dB" ;
        modeled_instr_corr_sig0_oce3_ku:scale_factor = 0.01 ;
    short modeled_instr_corr_sig0_oce3_c(time) ;
        modeled_instr_corr_sig0_oce3_c:_FillValue = 32767s ;
        modeled_instr_corr_sig0_oce3_c:long_name = "C band modeled instrumental correction on backscatter coefficient.
            PISTACH Ocean3 retracking" ;
        modeled_instr_corr_sig0_oce3_c:units = "dB" ;
        modeled_instr_corr_sig0_oce3_c:scale_factor = 0.01 ;
    int k_cal_factor_ku(time) ;
        k_cal_factor_ku:_FillValue = 2147483647 ;
        k_cal_factor_ku:long_name = "Scaling factor for Ku band backscatter coefficient" ;
        k_cal_factor_ku:units = "dB" ;
        k_cal_factor_ku:scale_factor = 0.01 ;
        k_cal_factor_ku:coordinates = "lon lat" ;
        k_cal_factor_ku:comment = "This scaling factor represents the backscatter coefficient for a Ku-band waveform
            amplitude equal to 1. It accounts for all the parameters of the radar equation excepted the amplitude of the
            waveform. It is a raw value accounting for atmospheric attenuation (atmos_corr_sig0_ku) only. AGC
            instrumental errors correction, internal calibration correction, modeled instrumental errors correction and system
            bias are not included" ;
    int k_cal_factor_c(time) ;
        k_cal_factor_c:_FillValue = 2147483647 ;
        k_cal_factor_c:long_name = "Scaling factor for C band backscatter coefficient" ;
        k_cal_factor_c:units = "dB" ;
        k_cal_factor_c:scale_factor = 0.01 ;
        k_cal_factor_c:coordinates = "lon lat" ;
        k_cal_factor_c:comment = "This scaling factor represents the backscatter coefficient for a C-band waveform
            amplitude equal to 1. It accounts for all the parameters of the radar equation excepted the amplitude of the
            waveform. It is a raw value accounting for atmospheric attenuation (atmos_corr_sig0_c) only. AGC instrumental
            errors correction, internal calibration correction, modeled instrumental errors correction and system bias not
            included" ;
    int epoch_ku(time) ;
        epoch_ku:_FillValue = 2147483647 ;
        epoch_ku:long_name = "Ku band epoch (ocean retracking)" ;
        epoch_ku:units = "s" ;
        epoch_ku:scale_factor = 1.e-15 ;
        epoch_ku:coordinates = "lon lat" ;
    int width_leading_edge_ku(time) ;
        width_leading_edge_ku:_FillValue = 2147483647 ;
        width_leading_edge_ku:long_name = "Ku band width of the leading edge (ocean retracking)" ;
        width_leading_edge_ku:units = "s" ;
        width_leading_edge_ku:scale_factor = 1.e-15 ;
        width_leading_edge_ku:coordinates = "lon lat" ;
        width_leading_edge_ku:comment = "The width of the leading edge corresponds to the so-called composite sigma
            (SigmaC)" ;
    int amplitude_ku(time) ;
        amplitude_ku:_FillValue = 2147483647 ;
        amplitude_ku:long_name = "Ku band amplitude (ocean retracking) [FFT power unit]" ;
        amplitude_ku:units = "count" ;
        amplitude_ku:scale_factor = 1.e-06 ;
        amplitude_ku:coordinates = "lon lat" ;
    int thermal_noise_ku(time) ;
        thermal_noise_ku:_FillValue = 2147483647 ;
        thermal_noise_ku:long_name = "Ku band thermal noise (ocean retracking) [FFT power unit]" ;
```

```
        thermal_noise_ku:units = "count" ;
        thermal_noise_ku:scale_factor = 1.e-06 ;
        thermal_noise_ku:coordinates = "lon lat" ;
    int epoch_c(time) ;
        epoch_c:_FillValue = 2147483647 ;
        epoch_c:long_name = "C band epoch (ocean retracking)" ;
        epoch_c:units = "s" ;
        epoch_c:scale_factor = 1.e-15 ;
        epoch_c:coordinates = "lon lat" ;
    int width_leading_edge_c(time) ;
        width_leading_edge_c:_FillValue = 2147483647 ;
        width_leading_edge_c:long_name = "C band width of the leading edge (ocean retracking)" ;
        width_leading_edge_c:units = "s" ;
        width_leading_edge_c:scale_factor = 1.e-15 ;
        width_leading_edge_c:coordinates = "lon lat" ;
        width_leading_edge_c:comment = "The width of the leading edge corresponds to the so-called composite sigma
            (SigmaC)" ;
    int amplitude_c(time) ;
        amplitude_c:_FillValue = 2147483647 ;
        amplitude_c:long_name = "C band amplitude (ocean retracking) [FFT power unit]" ;
        amplitude_c:units = "count" ;
        amplitude_c:scale_factor = 1.e-06 ;
        amplitude_c:coordinates = "lon lat" ;
    int thermal_noise_c(time) ;
        thermal_noise_c:_FillValue = 2147483647 ;
        thermal_noise_c:long_name = "C band thermal noise (ocean retracking) [FFT power unit]" ;
        thermal_noise_c:units = "count" ;
        thermal_noise_c:scale_factor = 1.e-06 ;
        thermal_noise_c:coordinates = "lon lat" ;
    int epoch_oce3_ku(time) ;
        epoch_oce3_ku:_FillValue = 2147483647 ;
        epoch_oce3_ku:long_name = "Ku band epoch (PISTACH Ocean3 retracking)" ;
        epoch_oce3_ku:units = "s" ;
        epoch_oce3_ku:scale_factor = 1.e-15 ;
        epoch_oce3_ku:coordinates = "lon lat" ;
    int width_leading_edge_oce3_ku(time) ;
        width_leading_edge_oce3_ku:_FillValue = 2147483647 ;
        width_leading_edge_oce3_ku:long_name = "Ku band width of the leading edge (PISTACH Ocean3 retracking)" ;
        width_leading_edge_oce3_ku:units = "s" ;
        width_leading_edge_oce3_ku:scale_factor = 1.e-15 ;
        width_leading_edge_oce3_ku:coordinates = "lon lat" ;
        width_leading_edge_oce3_ku:comment = "The width of the leading edge corresponds to the so-called composite
            sigma (SigmaC)" ;
    int amplitude_oce3_ku(time) ;
        amplitude_oce3_ku:_FillValue = 2147483647 ;
        amplitude_oce3_ku:long_name = "Ku band amplitude (PISTACH Ocean3 retracking) [FFT power unit]" ;
        amplitude_oce3_ku:units = "count" ;
        amplitude_oce3_ku:scale_factor = 1.e-06 ;
        amplitude_oce3_ku:coordinates = "lon lat" ;
    int thermal_noise_oce3_ku(time) ;
        thermal_noise_oce3_ku:_FillValue = 2147483647 ;
        thermal_noise_oce3_ku:long_name = "Ku band thermal noise (PISTACH Ocean3 retracking) [FFT power unit]" ;
        thermal_noise_oce3_ku:units = "count" ;
        thermal_noise_oce3_ku:scale_factor = 1.e-06 ;
        thermal_noise_oce3_ku:coordinates = "lon lat" ;
    int epoch_oce3_c(time) ;
        epoch_oce3_c:_FillValue = 2147483647 ;
        epoch_oce3_c:long_name = "C band epoch (PISTACH Ocean3 retracking)" ;
        epoch_oce3_c:units = "s" ;
        epoch_oce3_c:scale_factor = 1.e-15 ;
        epoch_oce3_c:coordinates = "lon lat" ;
    int width_leading_edge_oce3_c(time) ;
        width_leading_edge_oce3_c:_FillValue = 2147483647 ;
        width_leading_edge_oce3_c:long_name = "C band width of the leading edge (PISTACH Ocean3 retracking)" ;
        width_leading_edge_oce3_c:units = "s" ;
        width_leading_edge_oce3_c:scale_factor = 1.e-15 ;
        width_leading_edge_oce3_c:coordinates = "lon lat" ;
        width_leading_edge_oce3_c:comment = "The width of the leading edge corresponds to the so-called composite
            sigma (SigmaC)" ;
    int amplitude_oce3_c(time) ;
        amplitude_oce3_c:_FillValue = 2147483647 ;
        amplitude_oce3_c:long_name = "C band amplitude (PISTACH Ocean3 retracking) [FFT power unit]" ;
        amplitude_oce3_c:units = "count" ;
        amplitude_oce3_c:scale_factor = 1.e-06 ;
        amplitude_oce3_c:coordinates = "lon lat" ;
```

```
	int thermal_noise_oce3_c(time) ;
		thermal_noise_oce3_c:_FillValue = 2147483647 ;
		thermal_noise_oce3_c:long_name = "C band thermal noise (PISTACH Ocean3 retracking) [FFT power unit]" ;
		thermal_noise_oce3_c:units = "count" ;
		thermal_noise_oce3_c:scale_factor = 1.e-06 ;
		thermal_noise_oce3_c:coordinates = "lon lat" ;
	int amplitude_ice1_ku(time) ;
		amplitude_ice1_ku:_FillValue = 2147483647 ;
		amplitude_ice1_ku:long_name = "Ku band amplitude (Ice1 retracking PISTACH) [FFT power unit]" ;
		amplitude_ice1_ku:units = "count" ;
		amplitude_ice1_ku:scale_factor = 1.e-06 ;
		amplitude_ice1_ku:coordinates = "lon lat" ;
	int amplitude_ice1_c(time) ;
		amplitude_ice1_c:_FillValue = 2147483647 ;
		amplitude_ice1_c:long_name = "C band amplitude (Ice1 retracking PISTACH) [FFT power unit]" ;
		amplitude_ice1_c:units = "count" ;
		amplitude_ice1_c:scale_factor = 1.e-06 ;
		amplitude_ice1_c:coordinates = "lon lat" ;
	int amplitude_red3_ku(time) ;
		amplitude_red3_ku:_FillValue = 2147483647 ;
		amplitude_red3_ku:long_name = "Ku band amplitude (Red3 retracking PISTACH) [FFT power unit]" ;
		amplitude_red3_ku:units = "count" ;
		amplitude_red3_ku:scale_factor = 1.e-06 ;
		amplitude_red3_ku:coordinates = "lon lat" ;
	int amplitude_red3_c(time) ;
		amplitude_red3_c:_FillValue = 2147483647 ;
		amplitude_red3_c:long_name = "C band amplitude (Red3 retracking PISTACH) [FFT power unit]" ;
		amplitude_red3_c:units = "count" ;
		amplitude_red3_c:scale_factor = 1.e-06 ;
		amplitude_red3_c:coordinates = "lon lat" ;
	int width_leading_edge_red3_ku(time) ;
		width_leading_edge_red3_ku:_FillValue = 2147483647 ;
		width_leading_edge_red3_ku:long_name = "Ku band width of the leading edge (PISTACH Red3 retracking)" ;
		width_leading_edge_red3_ku:units = "s" ;
		width_leading_edge_red3_ku:scale_factor = 1.e-15 ;
		width_leading_edge_red3_ku:coordinates = "lon lat" ;
		width_leading_edge_red3_ku:comment = "The width of the leading edge corresponds to the so-called composite
			sigma (SigmaC)" ;
	int width_leading_edge_red3_c(time) ;
		width_leading_edge_red3_c:_FillValue = 2147483647 ;
		width_leading_edge_red3_c:long_name = "C band width of the leading edge (PISTACH Red3 retracking)" ;
		width_leading_edge_red3_c:units = "s" ;
		width_leading_edge_red3_c:scale_factor = 1.e-15 ;
		width_leading_edge_red3_c:coordinates = "lon lat" ;
		width_leading_edge_red3_c:comment = "The width of the leading edge corresponds to the so-called composite sigma
			(SigmaC)" ;
	int thermal_noise_red3_ku(time) ;
		thermal_noise_red3_ku:_FillValue = 2147483647 ;
		thermal_noise_red3_ku:long_name = "Ku band thermal noise (PISTACH Red3 retracking) [FFT power unit]" ;
		thermal_noise_red3_ku:units = "count" ;
		thermal_noise_red3_ku:scale_factor = 1.e-06 ;
		thermal_noise_red3_ku:coordinates = "lon lat" ;
	int thermal_noise_red3_c(time) ;
		thermal_noise_red3_c:_FillValue = 2147483647 ;
		thermal_noise_red3_c:long_name = "C band thermal noise (PISTACH Red3 retracking) [FFT power unit]" ;
		thermal_noise_red3_c:units = "count" ;
		thermal_noise_red3_c:scale_factor = 1.e-06 ;
		thermal_noise_red3_c:coordinates = "lon lat" ;

// global attributes:
		:Conventions = "CF-1.1" ;
		:title = "IGDR - PISTACH high frequency Coastal dataset" ;
		:institution = "CNES/CLS" ;
		:source = "radar altimeter" ;
		:history = "2010-09-20 20:53:20 : Creation" ;
		:contact = "TBD" ;
		:references = "TBD" ;
		:reference_document = "OSTM/Jason-2 Products Handbook,CLS-DOS-NT-08.096 and PISTACH Jason-2 Product
			Handbook,  CLS-DOS-NT-XX.XXX" ;
		:mission_name = "OSTM/Jason-2" ;
		:altimeter_sensor_name = "Poseidon-3" ;
		:radiometer_sensor_name = "AMR" ;
		:doris_sensor_name = "DGXX" ;
		:cycle_number = 81 ;
		:absolute_rev_number = 10346 ;
```

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		:pass_number = 170 ;
		:absolute_pass_number = 20490 ;
		:equator_time = "2010-09-19 22:10:33.768000" ;
		:equator_longitude = 44.65 ;
		:first_meas_time = "2010-09-19 21:42:27.123722" ;
		:last_meas_time = "2010-09-19 22:38:39.851481" ;
		:ellipsoid_axis = 6378136.3 ;
		:ellipsoid_flattening = 0.00335281317789691 ;
}
```

SERVICE

ALTIMETRIE

&

LOCALISATION

PRECISE