CONTENTS

HISTORY

Version	***Date***	***Comments***
1.0	18/05/1995	First version.
1.1	08/06/1995	Rewriting of the chapter 2. Minor corrections in all other chapters.
1.2	20/07/1995	Minor corrections in all chapters. § 3.1.3. added.
2.0	15/01/1996	Second version. Major corrections issued from OPR validation and evolutions of the OPR/VLC processing softwares.
2.1	11/03/1996	Minor corrections issued from the ERS-2 OPR validation.
2.2	21/10/1996	Modification of coefficient in micro-wave correction computation
2.3	06/07/2001	Update of the OPR product (2 fields are added), accounting for the estimation of the square of the off-nadir angle from altimeter waveforms in the altimeter processing software.

1. INTRODUCTION

CERSAT is the acronym for "Centre ERS d'Archivage et de Traitement", the French Processing and Archiving Facility for ERS-1 and ERS-2 (described in section 2.3).

1.1. PURPOSE

The purpose of this document is to assist users of ERS OPR and VLC CERSAT products (respectively altimeter and microwave sounder GDR), by providing a comprehensive description of products formats and contents. This document also provides an overview of ERS missions, and comments on measurements accuracy and use. More information on data, algorithms and sensors can be found in ERS project documents.

1.2. CONTENT OVERVIEW

Section 1 provides background information about the document. Note particularly that it defines the conventions used for building or describing the products (vocabulary - time, location, ellipsoid references - corrections - flagging and editing - default values - bits numbering).

Section 2 gives an overview of ERS missions, including a description of objectives, orbit, satellite, sensors and ground segment facilities. Most of the information provided in this section is issued from ESA Ref. 2, 3 and 4.

Section 3 provides an overview of CERSAT products, and a description of files (nomenclature, contents overview and format).

Sections 4 and 5 provide a detailed descriptive form for each OPR field (section 4) and VLC field (section 5).

Section 6 regroups comments on measurement accuracy and use, and comments about flags and default values.

Section 7 includes a glossary and references, and gives points of contact for more information.

1.3. CONVENTIONS

1.3.1. Glossary

In order to reduce confusion in discussing altimeter measurements and corrections, it is desirable that the following terms be used consistently. It is understood that the usage required is somewhat different from past unconstrained usage.

- "Range" is the distance from the centre of gravity of the satellite to the surface of the earth, as measured by altimeters. Thus, the altimeter measurement is referred as "range" or "altimeter range", not height or altitude.

- "Altitude" refers to the distance of the centre of gravity of the satellite above a reference point. The reference point will usually be either the reference ellipsoid, or the centre of the earth. This distance is computed from the satellite ephemeris data.

- "Height" refers to the distance of the sea surface above the reference ellipsoid. The sea surface height is computed from altimeter range and satellite altitude above the reference ellipsoid.

- "Distance" and "Length" are generic terms.

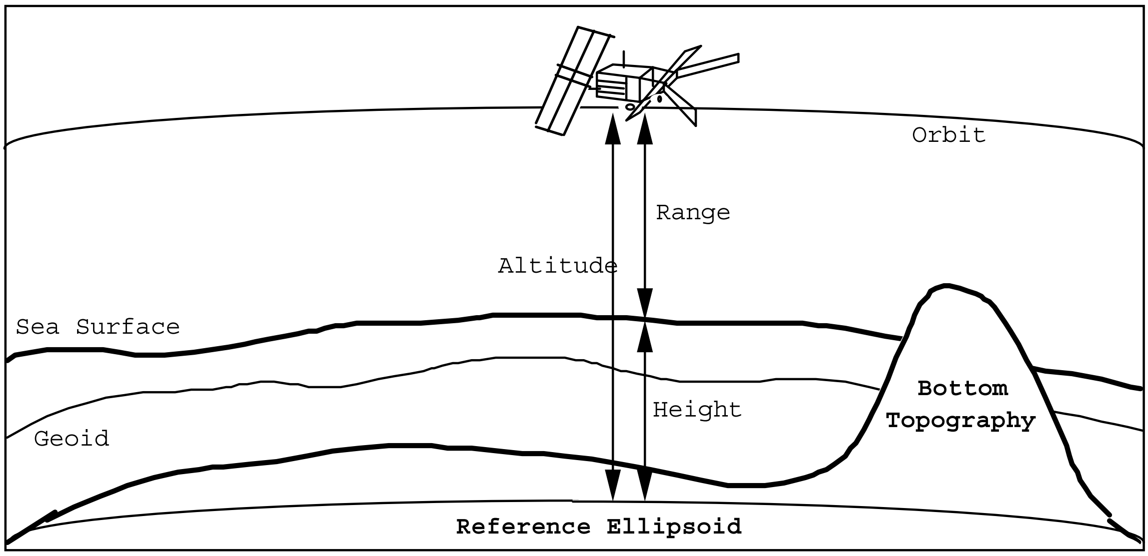


Figure 1.3.1-a : Altitude, range and height

1.3.2. Reference ellipsoid

The reference ellipsoid is the WGS84 ellipsoid, defined by the following parameters :

- equatorial radius = 6378.137 km
- flattening coefficient = 1/298.257223563

1.3.3. Time

Times are UTC.

1.3.4. Location

The longitude reference is the Greenwich meridian (longitude is positive and increases towards the East within a range of [0, 360]). The latitude reference is the Equator (latitude is positive in the northern hemisphere, and negative in the southern hemisphere).

1.3.5. Corrections

All corrections are additive to the quantity to be corrected, to revise the value to the truth. That is, an error is removed from a measurement by :

Corrected quantity = Measured value + Correction

This means that a correction to the altimeter range for an effect which lengthens the apparent signal path will be presented as a negative number. Adding this negative number to the measured (uncorrected) range will reduce it from its original value to the correct value.

<u>Examples</u>

Corrected range	= Altimeter range + corrections
Corrected sea surface height	= Altimeter orbit - Altimeter range - corrections

(Note that instrumental corrections are already applied on the altimeter range. Corrections to be applied are errors due to the environment).

1.3.6. Flagging and editing

Quality of measurements is described by a set of binary flags called Measurement Confidence Data (MCD), provided for each 1-Hz measurement in the product.

MCD provides three information levels :

- instrument level information, as measurement validity or invalidity, cause of invalidity, or simultaneity of altimeter and radiometer measurements
- engineering level information, i.e. quality of altimeter and radiometer estimates, as altimeter range or brightness temperatures
- geophysical level information, i.e. presence / absence of orbital manoeuvre or environmental parameters (as ocean tide correction or mean sea surface).

Generally speaking, the altimeter processing does not filter input data, with the following exceptions :

- data not in ocean tracking mode
- data not over ocean

(see MCD description in section 4.2.1).

1.3.7. Binary data and default values

Fields of product measurements are recorded as signed integers in a limited number N of bytes (N = 2 or 4) in IEEE (No_Dec) format. Default values are given when the field is unavailable (missing data, data out of range ...). The default value of a field is its maximum value (2^{N-1} - 1 for a N-byte signed integer).

1.3.8. Bits numbering

Bits are numbered from 0 to N, bit 0 being the MSB. Bits 0 and 7 are respectively the left and right bits of a byte in its binary representation. Bits 8 and 15 are bits 0 and 7 (as previously defined) of the next byte ...

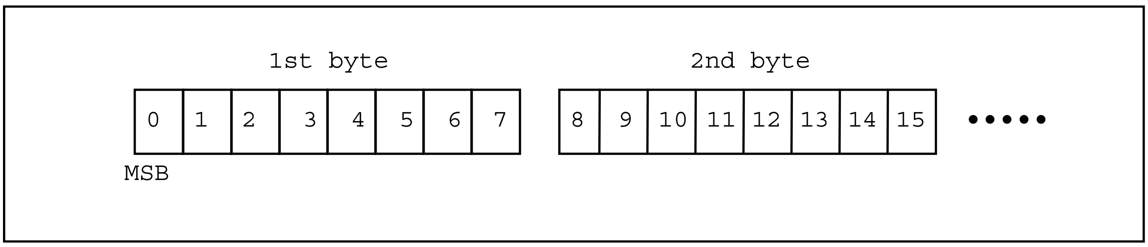


Figure 1.3.8-a : Bits numbering

2. ERS MISSIONS OVERVIEW

2.1. DESCRIPTION

2.1.1. Objectives

The ERS missions consist of two remote sensing satellites launched in the 1990s. The first of the series, ERS-1, was launched in July 1991. ERS-2 was launched in April 1995 in order to ensure the long term continuity of the data which is essential for many of its operational applications as well as for research purposes. These satellites are devoted entirely to global remote sensing from a polar orbit.

The ERS satellites provide global and repetitive observations of the environment, using advanced microwave techniques which enable measurements to be made and imaging to take place irrespective of cloud and sunlight conditions.

The satellites measure many parameters not provided by other existing satellite systems, related to sea state, sea-surface winds, ocean circulation phenomena, sea/ice and land features. Sea-surface temperature can also be measured to a greater degree of accuracy than with any other current space borne system. Much of the data collected is from remote areas such as the polar regions and southern oceans, for which little comparable information is available.

ERS-2 is also intended to make a significant contribution to atmospheric chemistry by the inclusion of an additional instrument (GOME).

Data generated by the ERS missions will make a substantial contribution to :

- improved understanding of ocean-atmosphere interactions
- major advances in knowledge of ocean circulation and the transfer of energy
- more reliable estimates of the mass balance of the Arctic and Antarctic ice sheets
- better monitoring of dynamic coastal processes and pollution
- improved detection and management of land use change.

The system has also been designed to satisfy operational requirements for data products needed within a few hours of the observations. This is expected to make significant contributions to operational meteorology, sea-state forecasting and monitoring of sea-ice distribution - all of which are important for shipping and offshore activities.

Finally, the altimetric and precise tracking data provide valuable geodetic information.

2.1.2. Orbit

The ERS satellites have sun-synchronous, near polar, quasi-circular repeating orbits with a mean altitude of about 785 km and an inclination of about 98.5°. The orbit repetitivity is normally maintained to keep the ground track within +/- 1 kilometer with respect to nominal position. This objective is achieved implementing ad-hoc manoeuvres.

ERS-1 has flown a number of repeat cycles optimised for particular mission objectives. Each period spent on a given cycle is called "mission phase". The history of the ERS-1 mission phases is :

- Commissioning phase (31-jul-91, 20-dec-91)

The satellite flew a 3-day repeat cycle aimed at observing very frequently the calibration sites

- Ice phase 1 (28-dec-91, 30-mar-92)

The satellite flew a 3-day repeat cycle aimed at observing very frequently specific ice zones

- Multidisciplinary phase (14-apr-92, 20-dec-93)

The satellite flew a 35-day repeat cycle aimed at satisfying most of the applications in particular the land/ice mapping with the SAR

- Ice phase 2 (23-dec-93, 10-apr-94)

The satellite flew a 3-day repeat cycle aimed at repeating the obsevations of ice phase 1, after a two year period.

- Geodetic phase 1 (10-apr-94, 27-sep-94)

The satellite flew a 168-day repeat cycle aimed at providing very dense altimeter observations for mapping the geoid.

- Geodetic phase 2 (27-sep-94, 21-mar-95)

The satellite flew the same 168-day repeat cycle, but shifted longitudinally of 8 Km to double the geoid resolution.

- Multidisciplinary phase 2 (from 21-mar-95)

The satellite entered into the ultimate orbit, 35-day repeat cycle , to perform its multidiciplinary mission and to permit ERS-2 cross-calibration.

For ERS-2, a 35-day cycle is foreseen covering the entire mission.

2.1.3. ERS system segments

The ERS programmes are composed of two satellites, with their ground support equipment; a launch vehicle; and a ground segment consisting of a control centre and facilities for data acquisition, processing, archiving and dissemination. The overall ground segment encompasses facilities controlled by ESA, as well as a number operated by other organisations (see section 2.3).

2.2. SPACE SEGMENT

2.2.1. Satellite

The satellite concept is based on the re-utilisation of the Multi-mission platform, developed within the French SPOT programme. This platform provides the major services for the satellite and payload operation, in particular attitude and orbit control, power supply, monitoring and control of payload status, and housekeeping and telecommanding data links.

The satellite payload consists of :

- Radar Altimeter (RA)
- Along Track Scanning Radiometer (ATSR)
- Active Microwave Instrument (AMI), combining the functions of two separate radars :
  . Synthetic Aperture radar (SAR)
  . Wind Scatterometer
- Precise Range and Range-rate Equipment (PRARE)
- Laser retroreflector
- Global Ozone Monitoring Experiment (GOME) on ERS-2 only
- Instrument Data Handling and Transmission (IDHT) to downlink the measurement data to ground.

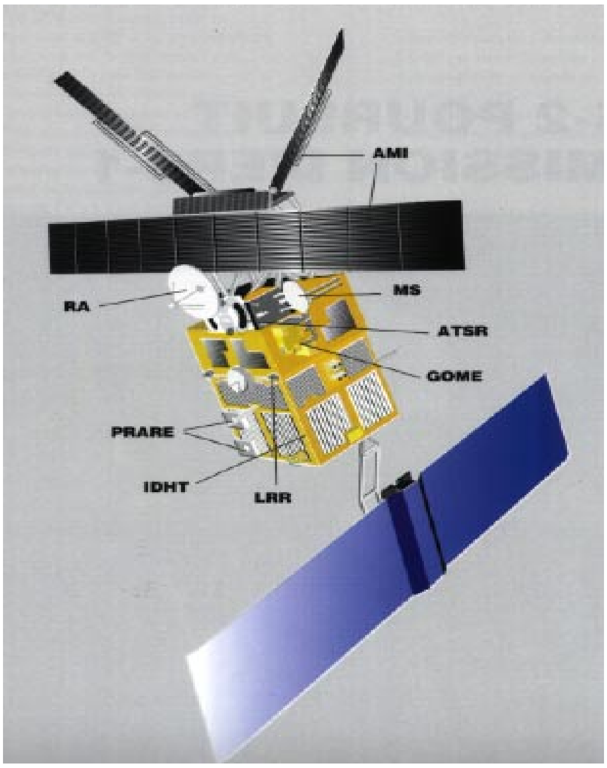


Figure 2.2.1-a : View of ERS-2 satellite

2.2.2. Radar Altimeter (RA)

2.2.2.1. General description

ERS-2 and ERS-1 instruments are identical. The onboard software has been continuously improved during the ERS-1 life and all the changes have been implemented in ERS-2 as well.

The radar altimeter is a Ku band (13.8 GHz) nadir-pointing active microwave sensor, designed to measure the echoes from ocean and ice surfaces. It has two measurement modes (tracking modes), optimised for measurements over ocean and ice, respectively. In ocean mode, it is used to measure wave height, surface wind speed modulus and sea surface elevation, the last of which is appropriate to the study of ocean topography, currents, tides and geoid. In ice mode the instrument provides the same type of measurements with a coarser resolution, allowing to extract informations on ice/land topography and other surface features.

During tracking modes, short internal calibration cycles (about 150 msec) are automatically and regularly performed, to measure the instrument behaviour changes due to thermal effects and ageing. The internal calibration is performed by feeding the transmit signal into the receiver via an adequate calibration coupler.

In tracking mode the instrument uses the current measurement to program the receiver in a way to catch the coming echoes. The loop initialisation is obtained via a special acquisition mode which performs a sequence aimed exclusively at finding the target. The switch between acquisition and tracking modes is automatic and is based on the analysis of the return echo.

2.2.2.2. Measurement principles

The key principle behind the altimeter is that the information required is in the shape and timing of the returned radar pulse. Figure 2.2.2.2-a shows a pulse being reflected from a flat surface. As the pulse advances, the illuminated area grows rapidly from a point to a disc, and then it becomes an annulus growing in size as the pulse energy vanishes. The annulus area remains approximately constant. The return signal level, which is proportional to the reflecting area, grows rapidly until the annulus is formed, remains constant until the annulus reaches the edge of the radar beam, point where it starts to decrease.

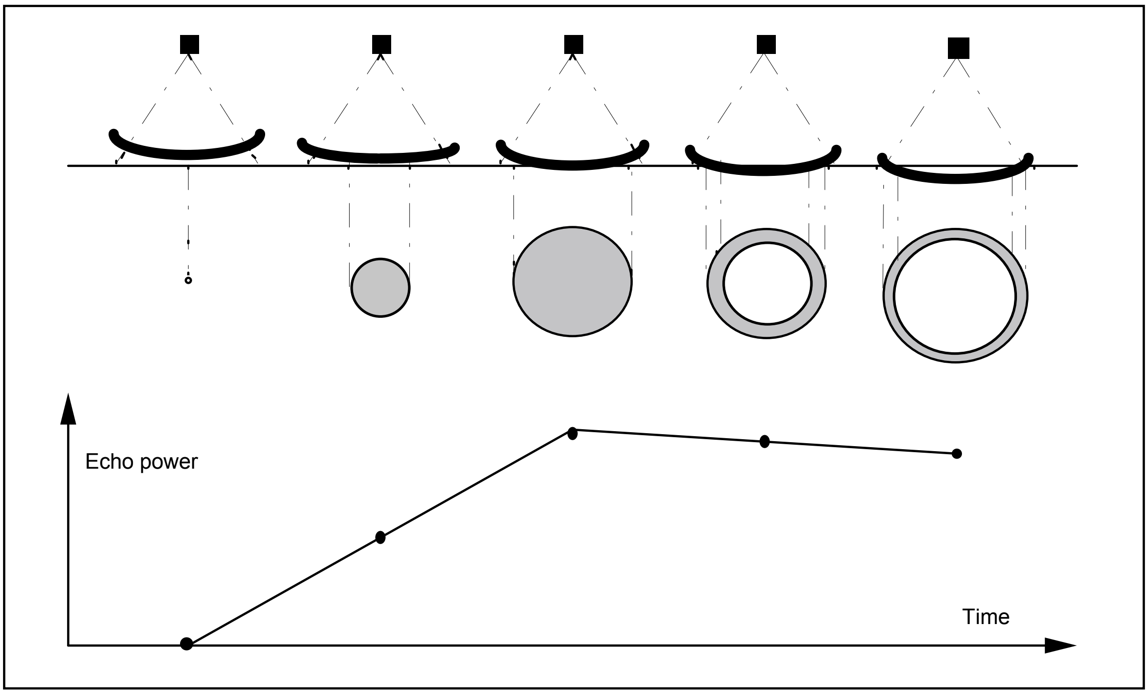


Figure 2.2.2.2-a : Intersection of an altimeter pulse with the surface

If the surface is not flat but is composed of point scatterers with elevation normally distributed, the echo rise time is longer as the pulse needs longer time to hit all the scatterers.

Applying this concept to the ocean surface, it is possible to see that the echo slope is directly related to the significant wave height (SWH). The slope mid point marks the surface elevation and the total echo power is proportionnal to the backscatter coefficient ($\sigma 0$), in turn related to the small scale surface roughness ultimately related to the wind speed.

Real echoes are composed of the sums of return signals from many point scatterers each with random phase and amplitude. The individual echoes are therefore affected by statistical fluctuations (cf fig 2.2.2.2-b). In order to perform real time tracking and to compress the amount of data to be sent to ground, the instrument averages the echoes by packs of 50, reducing also the noise.

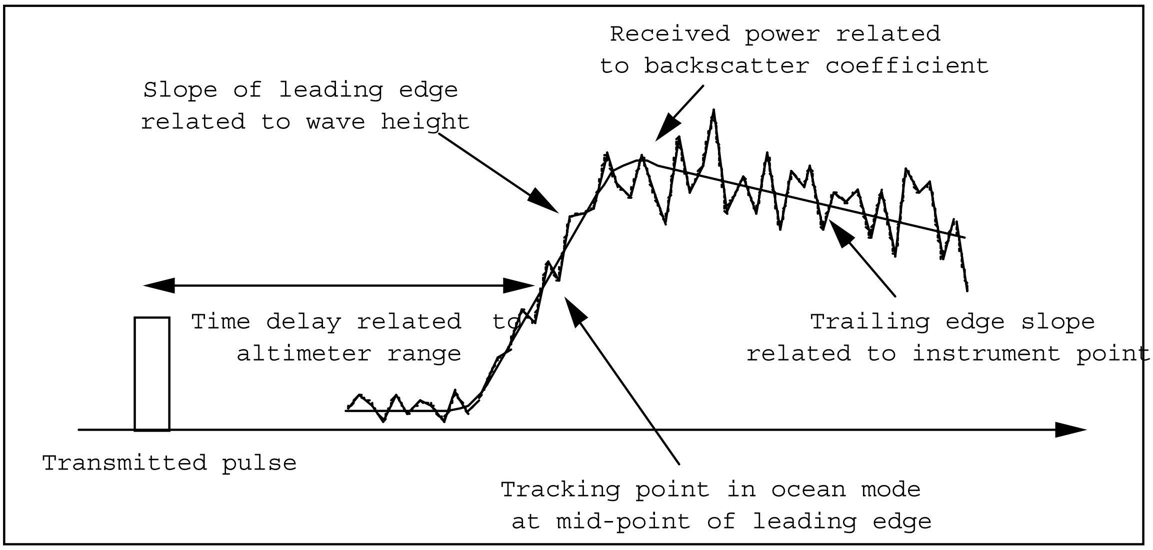


Figure 2.2.2.2-b : Profile of an ocean return waveform

2.2.2.3. Functional description

A meaningful sampling of the echo demands a pulse width too short to be achieved by conventionnal techniques. For this reason, modern altimeters implement the so-called "full deramp" technique which operates in the frequency domain.

A schematic block diagram of the altimeter is shown in figure 2.2.2.3-a. In this diagram, a representation of the frequency-time characteristics of the chirp is shown at the transmitter. A representation of the echoed signal is shown at the front end of the receiver. This is a series of many overlapping chirps, each echoed from an individual scatterer. The density of these chirps along a cut parallel to the time axis would have the shape of the returned power envelope. Individual chirps vary from this idealised waveform because of the interference effect between the echoes from different scatterers.

The instrument transmits a linear frequency modulated (FM) pulse to the ground, and expects to receive echoes composed of a number of linear FM pulses with offset in time corresponding to the scatterers relative elevation. At the time of the reception a local oscillator pulse, identical to the tansmit pulse is generated and used to mix with the echo. The output is fed into a spectrum analyser and it is easy to see that after mix, the power level of a spectral component is proportionnal to the relative delay of the relevant scatterer.

The echo shapes derived in that way are averaged by blocks of 50 and delivered to a parameter estimation processor, which extracts the radar parameters needed by the tracking loop, and detect the loss of signal needed to trigger the acquisition mode. The tracking loops are also implemented in the on-board software.

The telemetry contains tracking parameters, onboard estimations, as well as all the averaged waveforms and associated information, allowing on-ground re-processing.

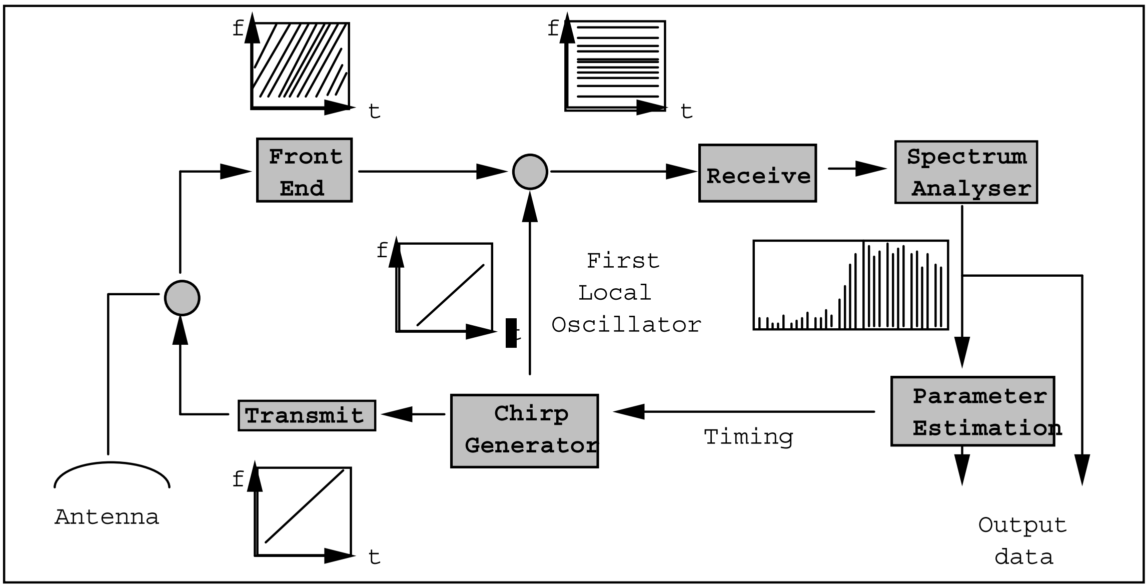


Figure 2.2.2.3-a : Schematic diagram of the RA operation

2.2.2.4. Main characteristics

The main instrument parameters and technical characteristics of the altimeter are listed below:

Antenna diameter	1.2 m
Beamwidth	1.3 °
Frequency	13.8 GHz
Bandwidth	330 MHz or 82.5 MHz (ocean or ice mode)
Transmit pulse duration	20 µs (ocean and ice modes)
Pulse repetition frequency	1020 Hz
Transmitted power (peak)	50 W
Echo waveform samples	64 samples x 16 bits at 20 Hz
	3.03 or 12.12 ns / sample (ocean or ice mode)
Equivalent window width	30 m ocean mode, 120 m ice mode

Over 1-Hz ocean measurement, the performance specifications are:

Range measurement	10 cm (1 σ, SWH = 16 m)
Significant wave height	0.5 m or 10 % (1 σ) whichever is smaller
Backscatter coefficient	0.7 dB (1 σ)

2.2.3. Along Track Scanning Radiometer / Microwave Sounder (ATSR/MW)

2.2.3.1. General description

The ATSR consists of two instruments, an Infra-red Radiometer (IRR) briefly described in section 2.2.4.1, and a Microwave Sounder (MWS) described hereafter.

The ERS-1 Microwave Sounder has been designed and built under the responsibility of CNET/CRPE, with the support of CNES, IFREMER and the Danish Ministry of Research (nationally funded experiment resulting from an ESA Announcement of Opportunity for a scientific add-on package). The ERS-2 instrument is identical, but designed and built under ESA responsibility.

The Microwave Sounder is a nadir-viewing passive radiometer providing measurements of the total water content of the atmosphere within a 20 km footprint. This is used to provide an accurate tropospheric range correction for the Radar Altimeter, and also to improve the accuracy of sea-surface temperature measured by the Infra-red Radiometer.

2.2.3.2. Measurement principles

The main purpose of the microwave radiometer is the measurement of the tropospheric path delay for the altimeter through the measurement of the atmospheric integrated water vapor content and the estimate of the attenuation of the altimetric signal by the liquid water content of the clouds.

This is achieved by measuring the brightness temperature at 23.8 and 36.5 Ghz which are, over ocean, very sensitive to the content of water vapor and liquid water in the troposphere. The water vapor is related to the excess pathlength as the liquid water is to the attenuation. The relation between brightness temperature and geophysical parameters, ie liquid water and water vapor, is of statistical nature and is obtained by linear regression using a radiative transfer mode. Basics for retrieval of ocean surface and atmospheric parameter from satellite microwave radiometry can be found in Ref. 27 (Wilheit and Chang, 1980).

This information can be used also in radiation budget studies (e.g. surface energy budget associated with the surface temperature measured by the ATSR infra-red channels and the scatterometer wind, ground humidity, surface emissivity etc.), in ice formations studies(the limits of the ice, in association with the altimeter) and for studying the properties of the continental ice pack.

Each channel, 23.8 and 36.5 Ghz, has a bandwidth of ±200 Mhz wide and operates in Dicke mode by comparing the antenna temperature to an internal reference source with a switching frequency of 1 kHz. The output signal from the sensor is integrated and sampled every 150 ms (synchronised with the Infra-red Radiometer scan rate), and is transmitted to the ground as a numerical count together with the temperatures of the microwave components. Internal calibration is achieved every 38.4 s by either connecting the receiver input to a skyhorn observing the cold temperature of space, or to a second internal reference load. The temperatures of the microwave components are monitored every 4.8 s using precise resistance measurements of platinum thermistances. As some drift of the resistance measurement system may occur with temperature variations, four precisely calibrated reference resistances are measured to calibrate the system. The main antenna is an offset antenna, with one feed horn for each frequency. Each channel is then pointing at an angle close to the nadir, with the channel 36.5 in the forward direction and the channel 23.8 in the backward direction. Each channel is linearly polarised in the orbit plane (vertical polarisation). The 3 dB footprint diameter for both channels is about 21 km.

2.2.3.3. Functional description and main characteristics

A complete description of the characteristics and performances of the ERS-1 instrument and of the antenna pattern is given by Bernard et al., 1993 (Ref. 5). The validation of the ERS-1 radiometer geophysical parameters can be found in Eymard et al., 1994 (Ref. 6).

2.2.4. Other sensors

2.2.4.1. Along Track Scanning Radiometer / Infra-red Radiometer (ATSR/IRR)

The Infra-red Radiometer is a four-channel infra-red radiometer providing measurements of sea-surface and cloud-top temperatures with higher accuracy than similar instruments flown on previous satellites. The scanning technique enables the Earth's surface to be viewed at two different angles (0° and 52°) in two curved swaths 500 km wide and separated along-track, by about 700 km. Data from the two swaths are combined to eliminate atmospheric influence in the calculation of sea-surface temperature. The instrument has been designed to provide an absolute accuracy in sea-surface temperature of better than 0.5 K when averaged over areas of 50 km x 50 km and in conditions of up to 80% cloud cover. For cloud-free pixels, each 1 km x 1 km, the relative accuracy is about 0.1 K.

The ERS-2 satellite carry an enhanced version of the ATSR, called ATSR-2. In addition to the four infra-red channels, ATSR-2 will carry three new channels. Two of these new channels are in the visible, and one in the near infra-red part of the spectrum.

2.2.4.2. Active Microwave Instrument (AMI)

The AMI combines two separate functions: the SAR and the Wind Scatterometer. The SAR can be operated in two modes:

- image mode,
- wave mode.

In image mode, the SAR obtains strips of high resolution imagery, 100 km in width, to the right of the satellite track. The 10 m long antenna, aligned parallel to the flight track, directs a narrow radar beam on the Earth's surface over the swath. Imagery is built up from the time delay and strength of the return signals, which depend primarily on the roughness and dielectric properties of the surface and its range from the satellite. Power and thermal considerations limit SAR image mode operations to a maximum of 12 minutes per orbit. The operation of all other AMI modes are inhibited during the image mode operation. The data rate of the SAR image mode is 105 Mbit/s, which is too high for on-board recording.

Consequently, images can only be acquired within the reception zones of suitably equipped ground stations.

In wave mode, the SAR obtains high resolution images of small size (5 Km by 5 Km) at intervals of 200 km along track. These imagettes are transformed into spectra providing information about wavelength and direction of wave systems. Series of power spectra can be used to determine the evolution of swell wave systems.

The wind scatterometer uses three sideways looking antennae, one pointing normal to the satellite flight path, one pointing 45° forward and the third pointing 45° backwards. These antenna beams illuminate a swath 500 km wide as the satellite advances along its orbit, and each provides measurements of radar backscatter from the sea surface for overlapping 50 km resolution cells using a 25-km grid spacing. The result is three independent backscatter measurements relating to cell centre nodes on a 25-km grid, which have been obtained using the three different viewing directions and are separated by only a very short time delay. Calculation of the surface wind vector in terms of speed and direction takes place using this so-called "triplets" within a mathematical model which defines the relationship between backscatter, wind speed, wind direction and incidence angle of the observation.

2.2.4.3. Precise Range and Range-rate Equipment (PRARE)

The PRARE is an all-weather microwave tracking system designed to perform high-precision two-way microwave range and range-rate measurements using ground-based transponder stations. These measurements are used for orbit determination and for geodetic applications. Unfortunately, the PRARE on ERS-1 suffered fatal damage after a few hours of nominal operations. An improved version of PRARE was built for ERS-2.

2.2.4.4. Laser retroreflector

The Laser Retroreflector is a passive device, used as a target by ground-based laser ranging stations for accurate tracking of the satellite.

2.2.4.5. Global Ozone Monitoring Experiment (GOME)

The instrument, present for the first time on ERS-2, is a nadir-viewing spectrometer which will observe solar radiation transmitted through or scattered from the Earth's atmosphere or surface. The instrument collects light arriving from the Earth's Sun-illuminated atmosphere and decomposes it into its spectral components. This decomposition is done in two steps in order to provide the required spectral coverage from 240 to 790 nm, as well as the exceptional spectral resolution of 0.2 to 0.4 nm. The GOME exploits the classical backscatter technique as well as the novel "Differential Absorption Spectroscopy" technique. The recorded spectra will be used to measure a range of trace constituents including ozone, but also nitrogen dioxide, water vapour, oxygen/oxygen dimmer and bromine oxide, in the troposphere as well as in the stratosphere. It is necessary to measure all these other constituents in order to be able to monitor ozone chemistry. The GOME instrument's instantaneous field-of-view is 40 km x 2 km or 2.8° x 0.14°. The instantaneous field-of-view is scanned across the satellite track, enabling global coverage within 3 days except for a small gap around the poles. The gap is filled by the inclusion of a special pole-viewing mode.

2.3. GROUND SEGMENT

2.3.1. Overview

The overall ground segment for ERS is concerned with all aspects of the satellite operations and the instrument data acquisition, processing, distribution and archiving. It comprises all ground segment components forming part of an end-to-end remote sensing system. The main elements of the ERS ground segment are:

- **Earthnet ERS1 Central Facility** (EECF) in Italy, carries out all user interface functions, including cataloguing, handling of user requests, payload operation planning, scheduling of data processing and dissemination, quality control of data products and system performance monitoring.

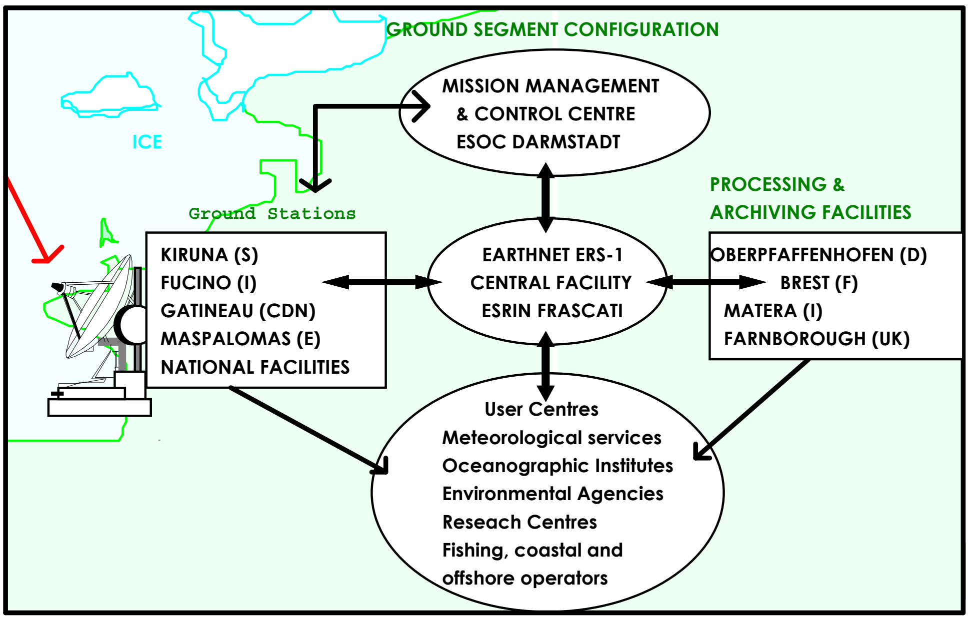
- **Mission Management and Control Centre** (MMCC) in Germany carries out all satellite operations control and functional management, including overall satellite and payload operational scheduling. It also controls the Kiruna ground station.

- **ESA ground stations** at Kiruna (Sweden), Fucino (Italy), Gatineau and Prince Albert (Canada) and Maspalomas (Canary Islands, Spain), provide the main network for data acquisition and the processing/dissemination of fast-delivery products.

- **National ground stations** around the world will receive ERS high rate data by arrangement with ESA, extending the coverage potential of the SAR imaging mission.

- **Processing and Archiving Facilities** (PAFs) located in Germany, France, Italy and the UK are the main centres for the generation of off-line precision products and the archiving and distribution of ERS data and products.

- **User centres and individuals**, such as national and international meteorological services, oceanographic institutes, various research centres and individual users.



2.3.2. The French PAF mission

Part of the ERS Ground Segment, the French PAF, also called CERSAT, is located at Brest in the most important establishment of the French Ocean Research Institute (IFREMER).

The CERSAT is in charge of archiving :

- the radar altimeter and ATSR/MW raw data for ERS1,
- the fast delivery products generated in the ground stations for ERS1 and ERS2,
- the auxiliary data necessary for the radar altimeter and ATSR/MW processing (orbits, on-board time relations, meteorological fields) for ERS1 and ERS2.

All these data are archived as well as products generated at CERSAT.

The processing mission of CERSAT, as defined by ESA, is :

- the processing of Radar Altimeter over the oceans,
- the processing of ATSR/MW over the world.

CERSAT houses a wind processing facility not part of the PAF. It is operated under IFREMER responsability.

All the products generated at CERSAT as well as fast delivery products are distributed to users either on CDROM or on exabyte.

3. CERSAT PRODUCTS OVERVIEW AND FORMATS

3.1. OVERVIEW

3.1.1. Products definition

The processing of Radar Altimeter and ATSR/MW (microwave radiometer) data is performed in two steps.

The first step of the processing consists in transforming raw data (recorded on board the satellite) in physical quantities, time tagged, located and corrected for the instrumental effects, and in storing the following internal products :

- OIP (off-line intermediate product) for the radar altimeter :
  altimeter range, backscatter coefficient, significant wave height over oceansurfaces, and all instrumental corrections.

- MBT (microwave Brightness temperatures) for the ATSR/MW : microwave brightness temperatures at 23.8 and 36.5 GHz.

The second step of the processing consists in computing the environmental corrections and merging the precise orbit. The resulting data are :

- OPR (Ocean Product) for the radar altimeter : Same as OIP but enhanced with all geophysical corrections and precise orbit altitude. All the geophysical corrections are supplied together with the uncorrected measures, to allow the user the possibility of applying different corrections.

- VLC (Vapor Liquid Content) for the ATSR/MW : geophysical parameters water vapour and liquid water content.

The processing schematic is presented in figure below :

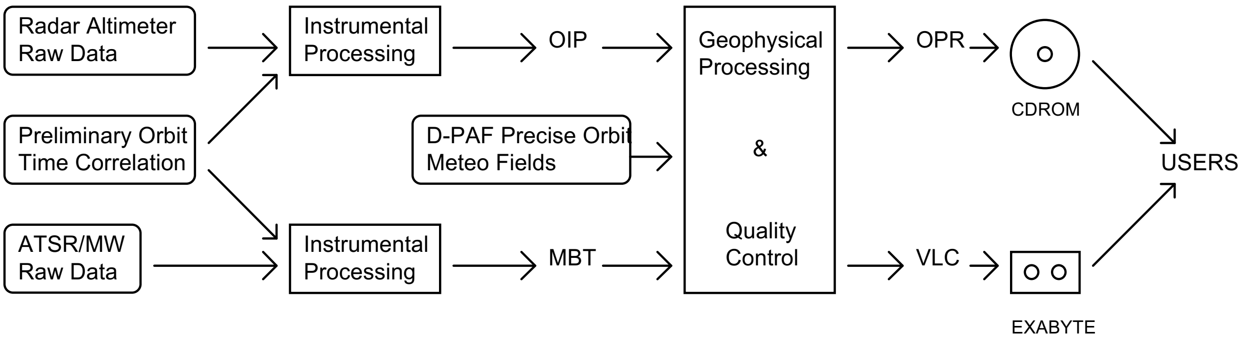


Figure 3.1.1-a : Processing and Distributing diagram

Only the OPR and VLC data are distributed to users.

An OPR or VLC user product is provided in passes, which are half orbits extending from pole to pole. A pass is fully defined by:

- an absolute orbit number (since the beginning of satellite operations),
- a relative orbit number within a cycle, which repeats at each cycle,
- a direction : ascending for a pass from south to north pole, or descending otherwise.

3.1.2. Products distribution

The OPR products are distributed on CDROM. They can also be distributed on exabyte cassette to users which have no available means to read CDROM. The VLC products are distributed only on exabyte cassette.

The format of data files on a medium follows a convention named CCSDS described in section 3.2. It is a format convention largely used in satellite data distribution.

The medium content in term of data consists in:

- a cycle for 35-day cycle phase,
- 30 days for 3-day cycle phase (ERS1 only),
- 37 days "sub-cycle" for 168-day cycle phase (ERS1 only).

The maximum number of passes distributed on a medium is 1059 for 37 days of data, and the maximum number of measurements per pass is 3061.

A user will get more than the data itself on the medium, namely:

- general information,
- information enabling data extraction conforming to a time window and/or geographical criteria,
- programs for the extraction and reading of the data, only if the medium is a CDROM.
- information on quality control performed at CERSAT, only if the medium is a CDROM.

The programs and information on the quality control are not written on the exabytes but could be made available separately.

A paper report named "Quality Assessment" is also distributed together with the medium.

3.1.3 The ERS2 35-day cycle phase characteristics

<u>The phase characteristics are</u> :

. ascending node longitude of first orbit in the phase : 288.2772 degrees East
. ascending node longitude of relative orbit number 1 in the phase : 0.1335 degrees
. 35-day repeat cycle
. 501 orbits per cycle
. 1002 passes per cycle

<u>The orbit number characteristics are</u> :

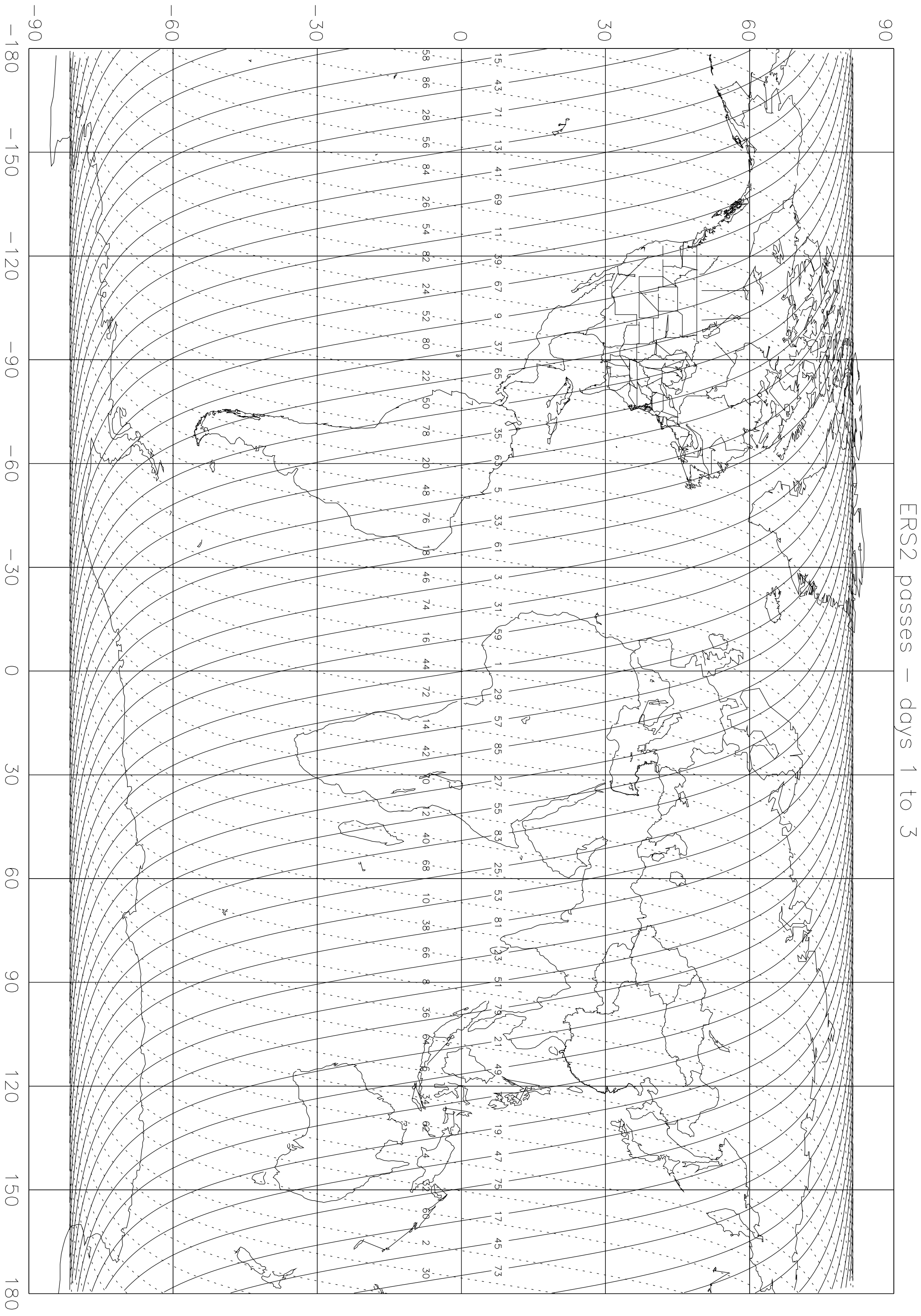
. first absolute orbit number is : 1 on 21-APR-1995 03:16:54.739 UTC
. relative orbit number (internal track) : 147

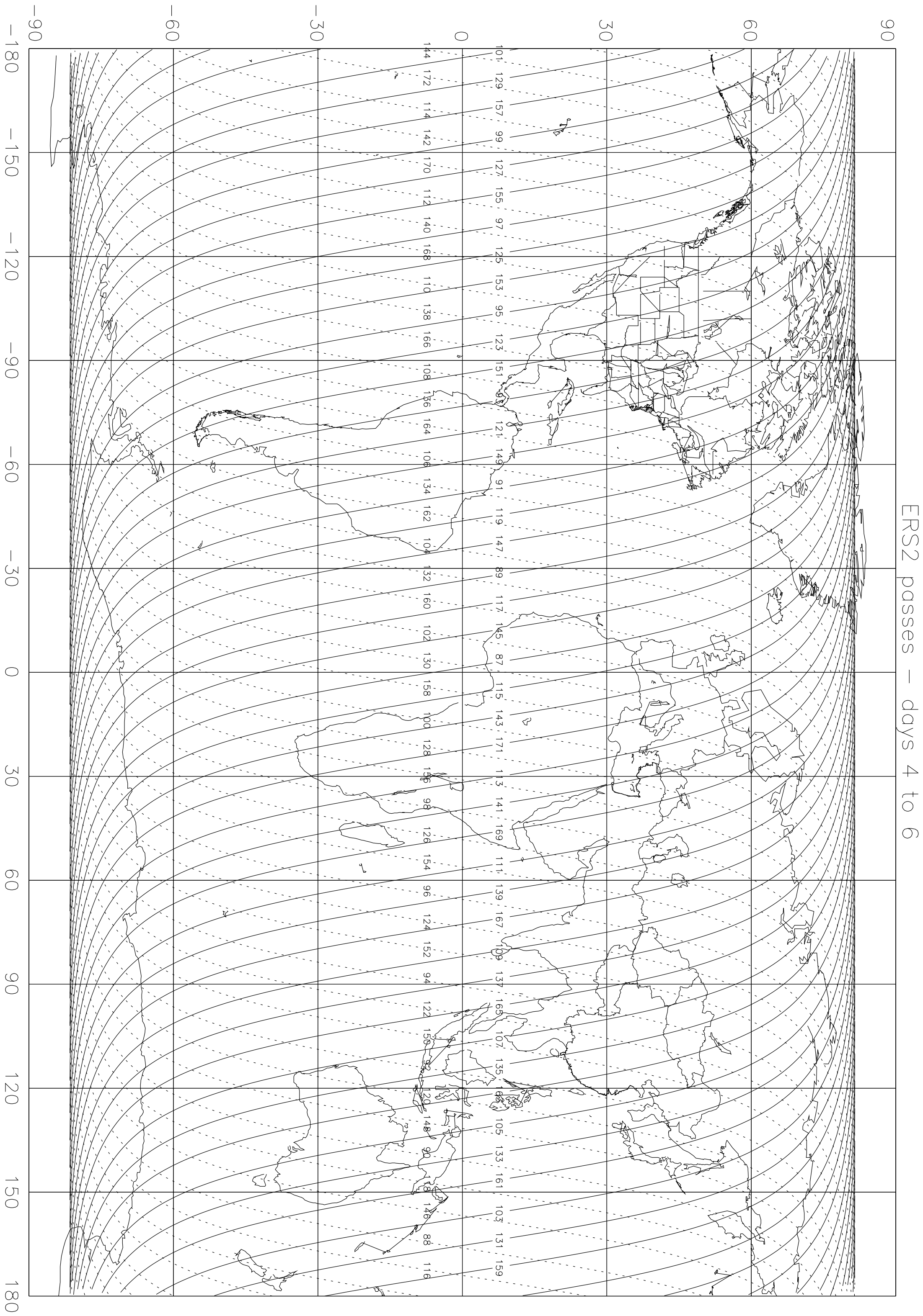
<u>The orbit parameters are</u> :

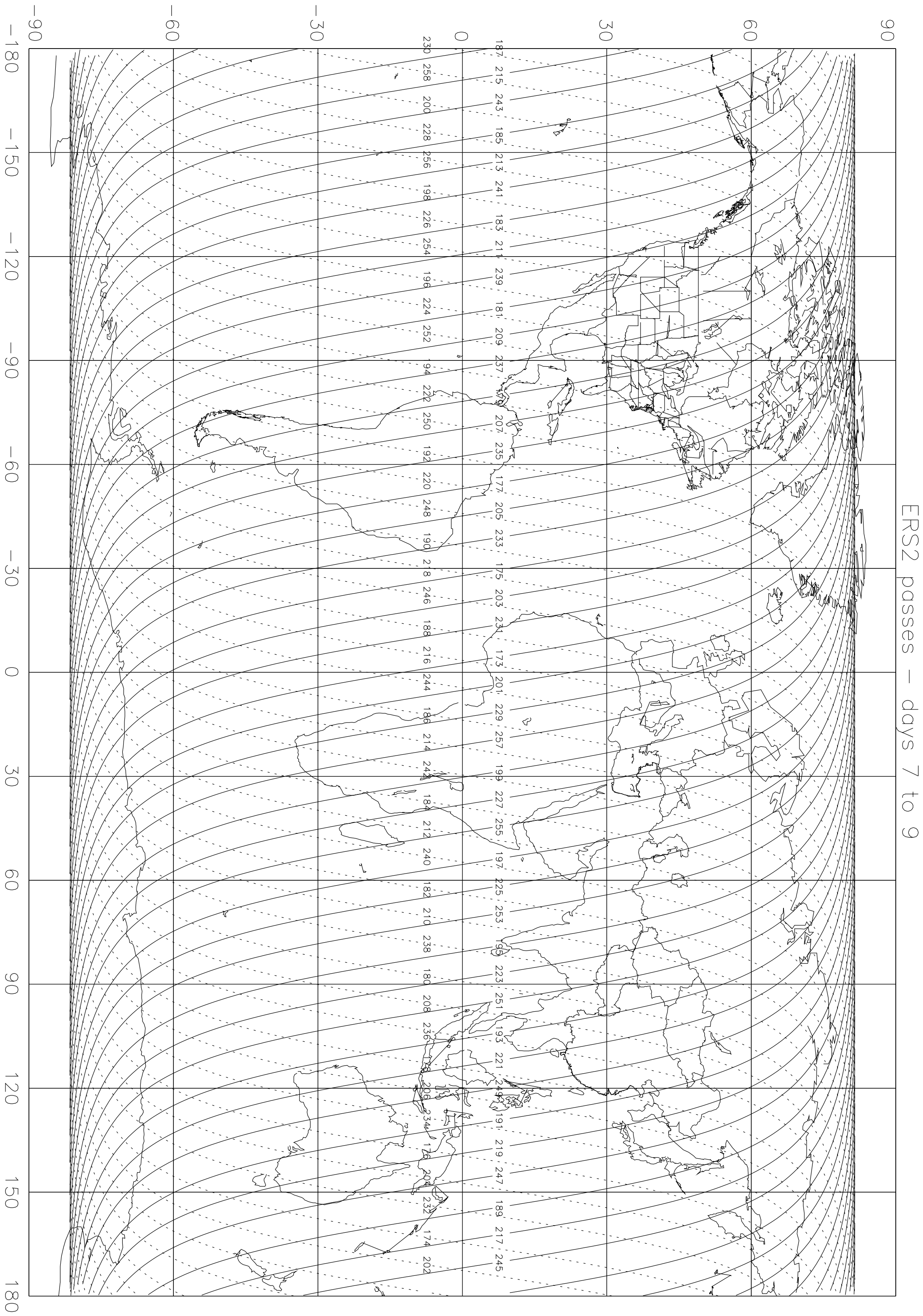
. orbit eccentricity : 0.001165 degrees
. orbit inclination : 98.5421
. semi-major axis : 7159495.96 m
. mean nodal period : 6035928.144 ms
. mean anomaly : 270.1334 degrees
. argument of perigee : 90 degrees

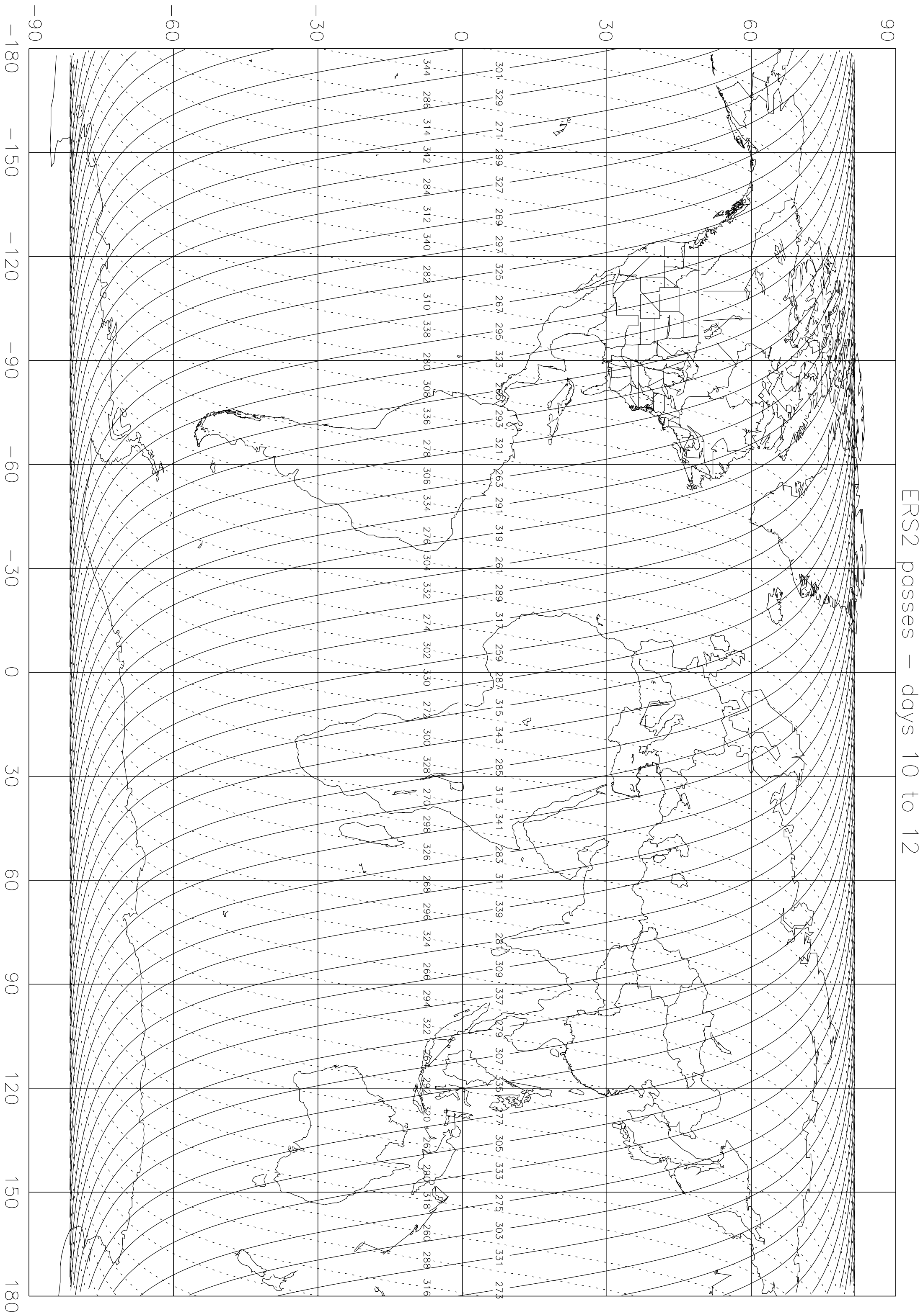
The passes of the ERS2 35-day cycle phase are represented on seperate graphics, each one corresponding to a 3-day period of a cycle (except for the last period containing only 2 days data).

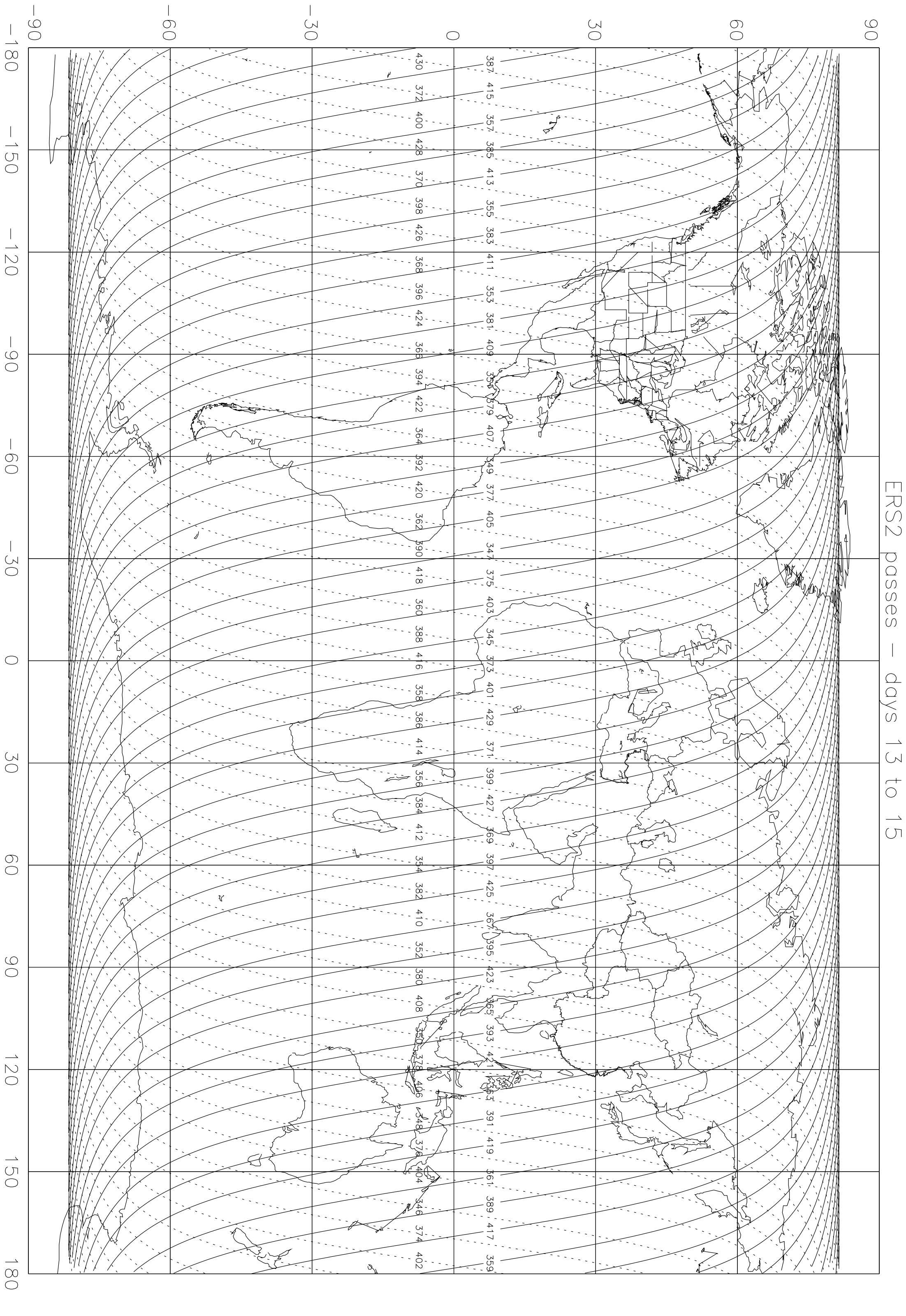
The passes are numbered from 1 to 1002 (i.e. relative pass number within the cycle). The ascending passes are the lines, anoted with odd pass numbers above the equator. The descending passes are the doted lines anoted with even pass numbers under the equator.

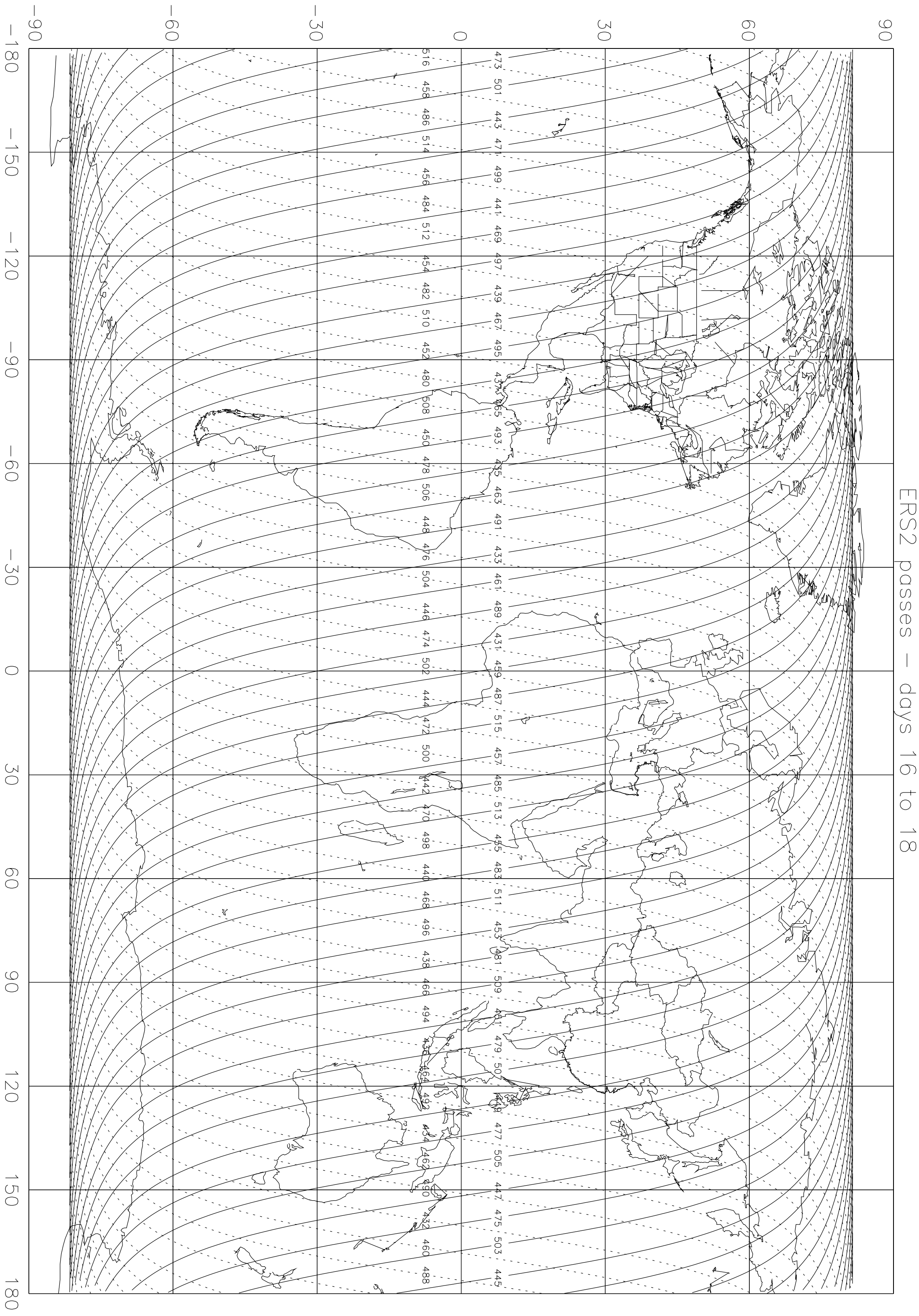

ERS2 passes – days 1 to 3

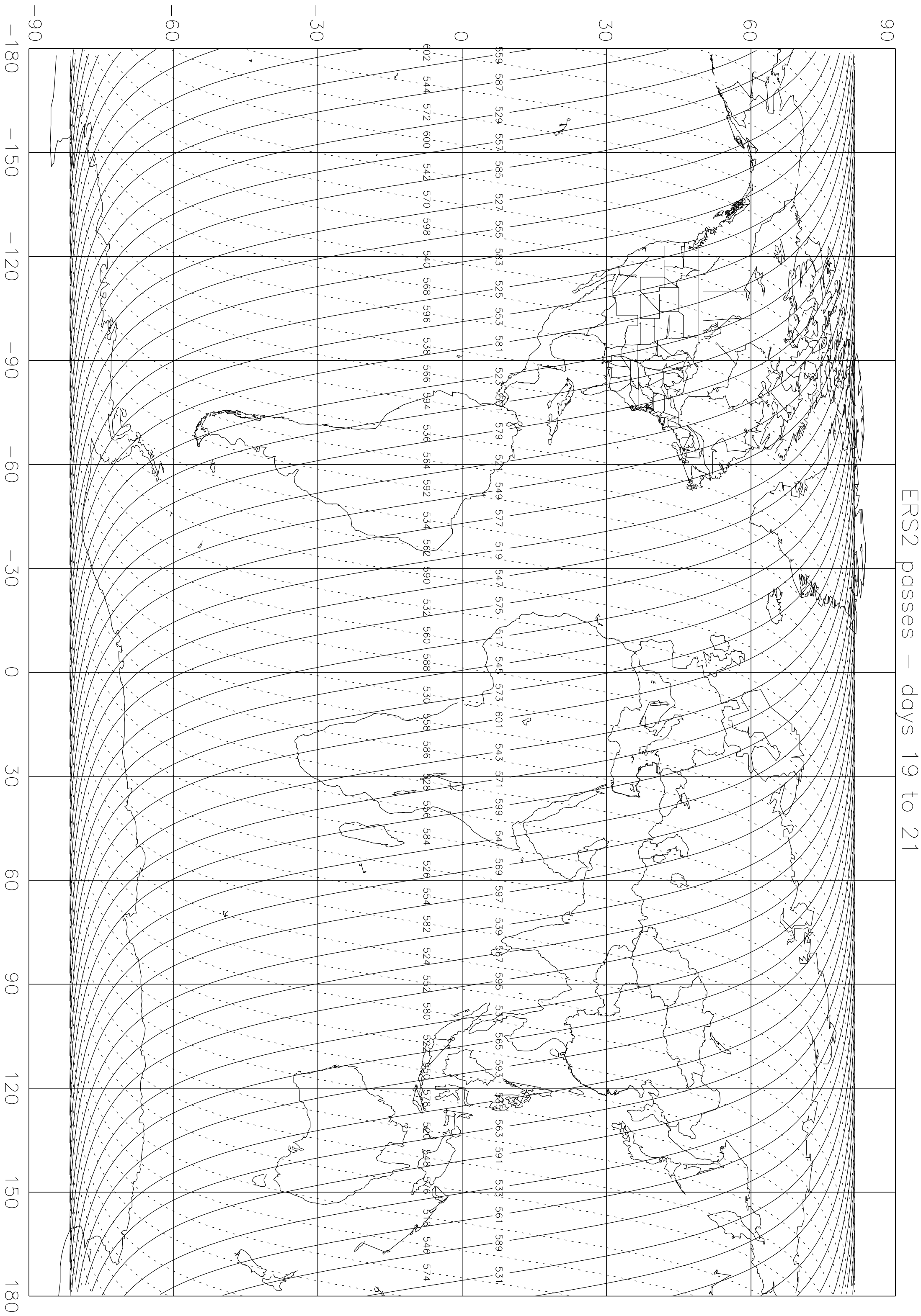

ERS2 passes - days 4 to 6
-90
-60
-30
0
30
60
90
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180

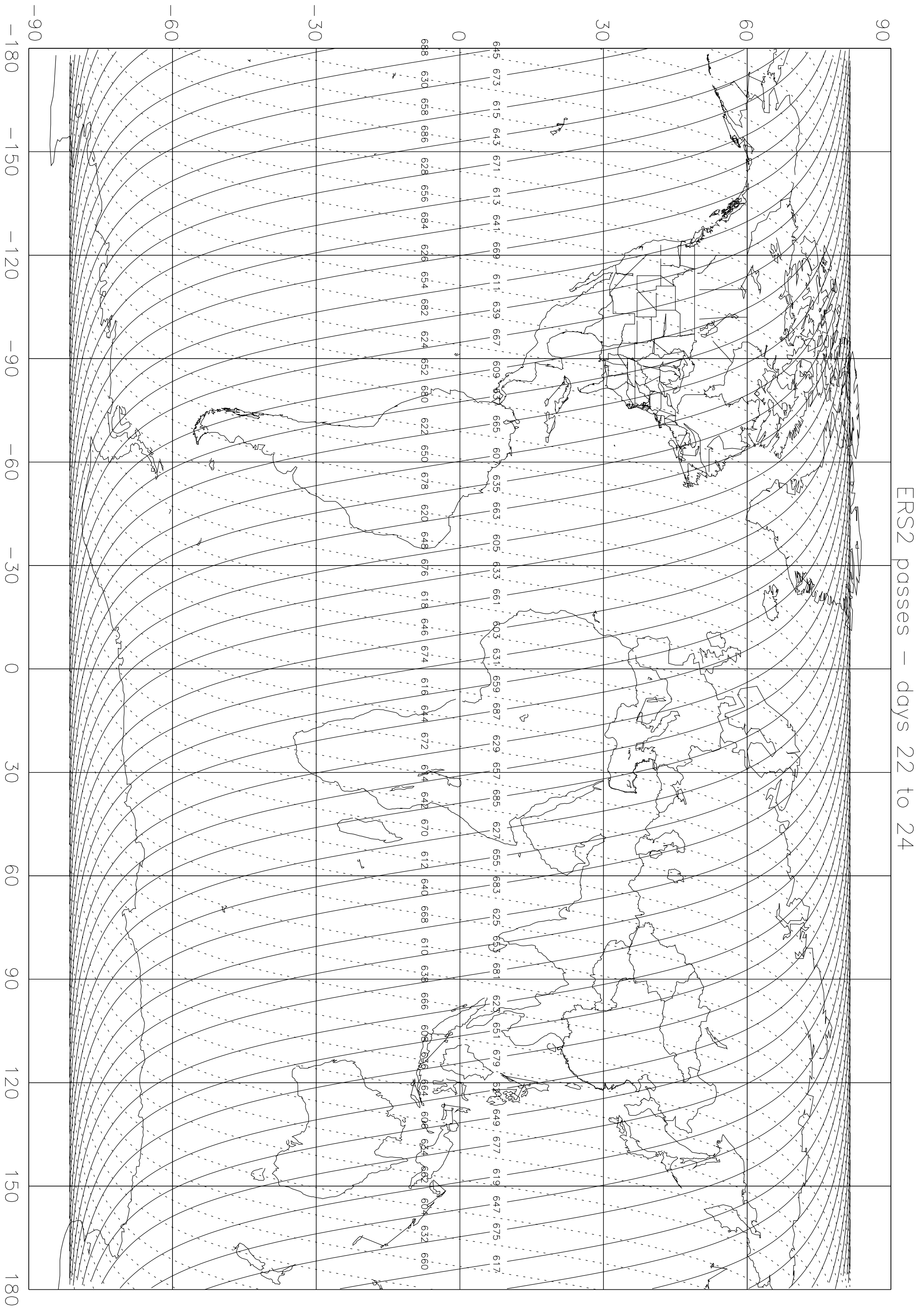

ERS2 passes - days 7 to 9
-90
-60
-30
0
30
60
90
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180

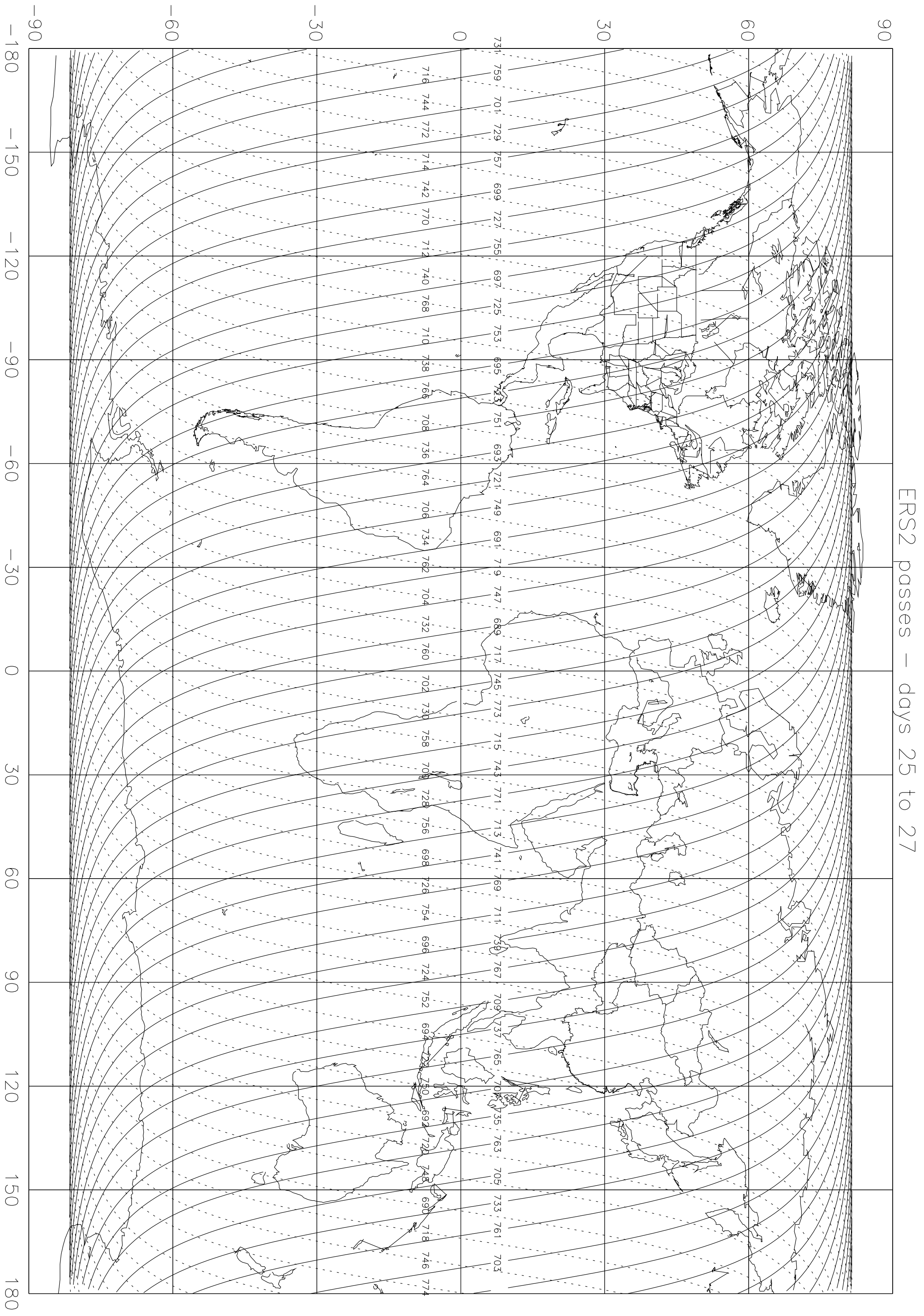

ERS2 passes – days 10 to 12
−90
−60
−30
0
30
60
90
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180

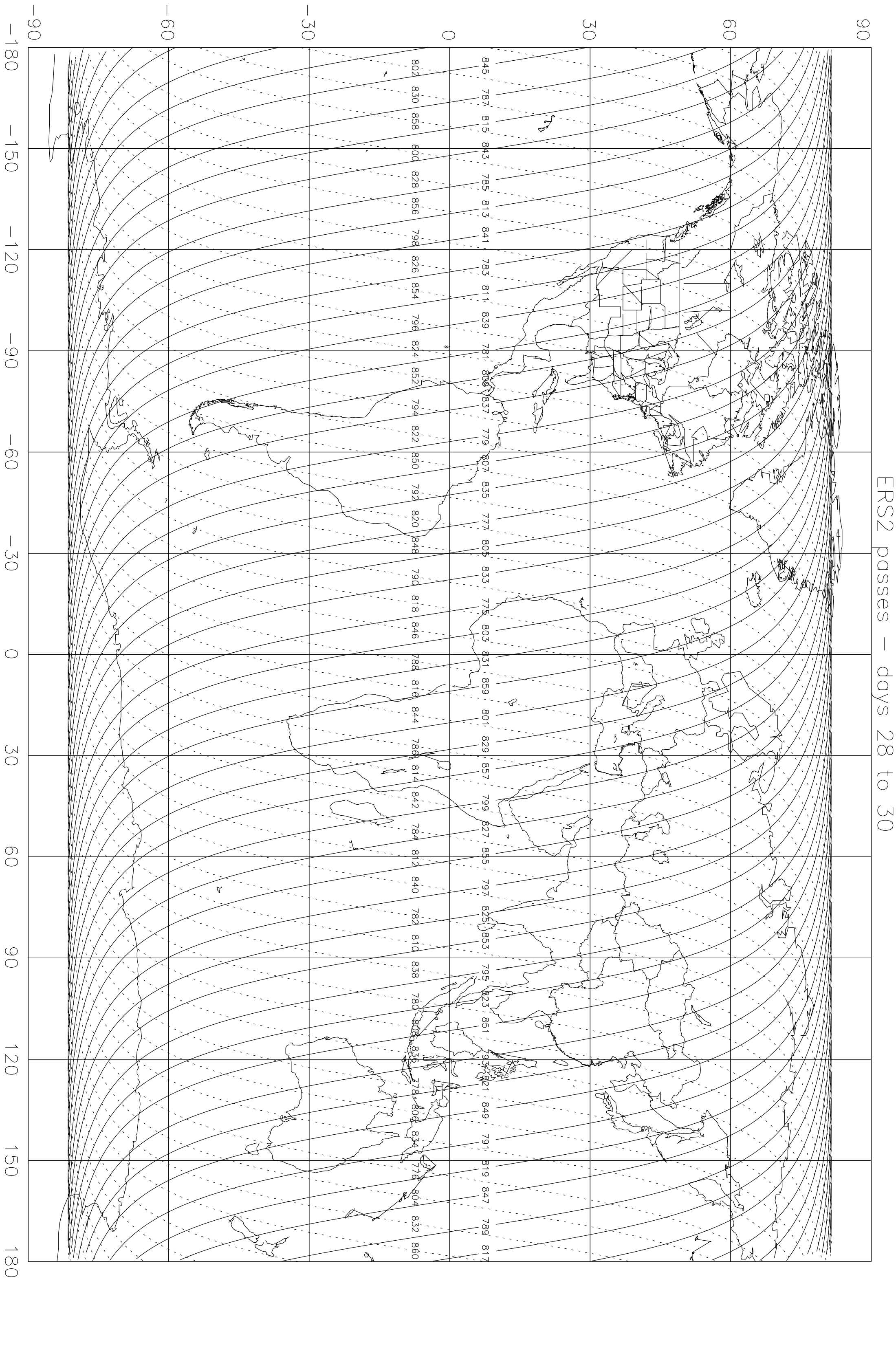

ERS2 passes – days 13 to 15
−90
−60
−30
0
30
60
90
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180

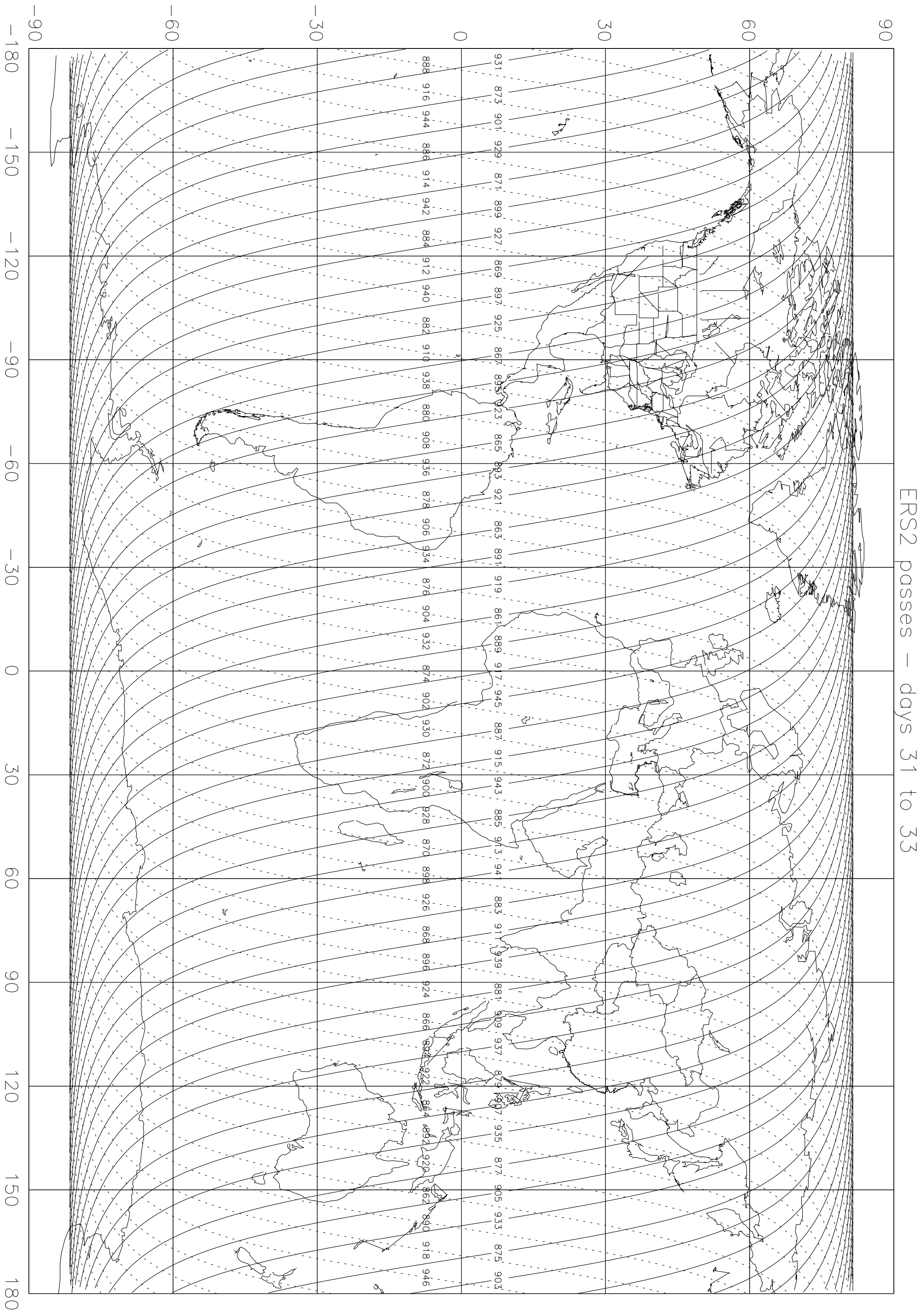

ERS2 passes – days 16 to 18

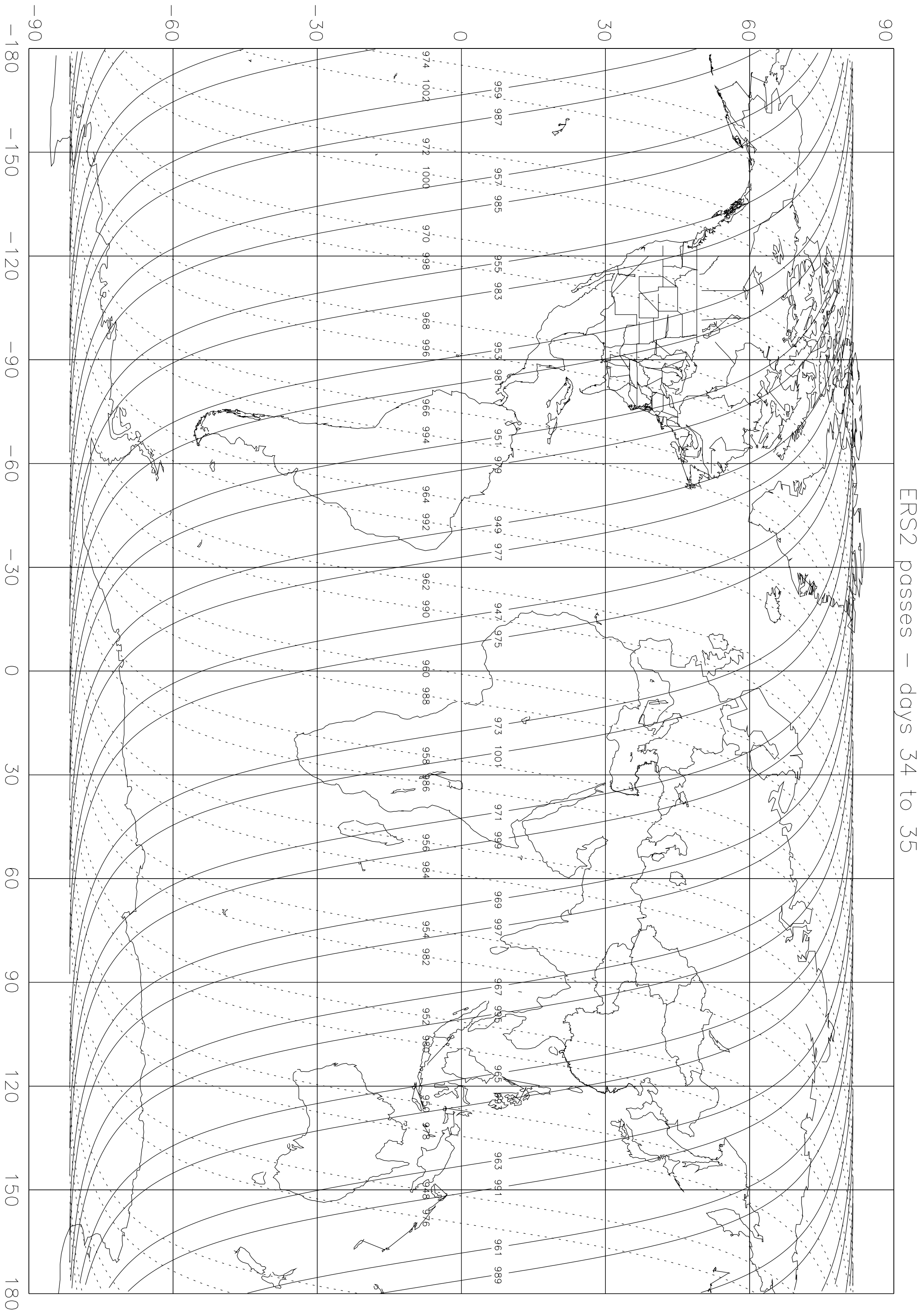

ERS2 passes – days 19 to 21


ERS2 passes – days 22 to 24


ERS2 passes – days 25 to 27
–90
–60
–30
0
30
60
90
–180
–150
–120
–90
–60
–30
0
30
60
90
120
150
180


ERS2 passes – days 28 to 30


ERS2 passes – days 31 to 33
-90
-60
-30
0
30
60
90
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180


ERS2 passes - days 34 to 35
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180
-90
-60
-30
0
30
60
90

3.2. CCSDS FORMAT CONVENTION

CCSDS stands for Consultative Comittee on Space Data System, and this format is normalized (ISO 12175) since October 1993.

The following explanations are issued from the CCSDS recommandation defined in three documents:

- Unités de données à structuration normalisée (SFDU)
  Règle de structure et de construction

- Standard Formatted Data Units - - A Tutorial - CCSDS 621.0-G-1

- Parameter Value Language specification (CCSD0006) - CCSDS 641.0-B-1

3.2.1. CCSDS header format convention

Each file contains a header composed of fixed length records. All file headers are coded in ASCII and follow the CCSDS format convention. Headers provide identification, processing history and content information.

A header include SFDU identifiers (Standard Formatted Data Unit). The SFDU label is coded as one line (ascii record), and is recorded with 20 characters padded with ascii spaces to maintain a fixed length equal to the record length of the header.

All other header entries follow a "KEYWORD = VALUE"syntax as defined below:

KEYWORD assignment_symbol VALUE stmt_terminator

Where :

- **KEYWORD** is the leftmost component term and is made up with a character string that describes the keyword. It is of variable length.

- **Assignment_symbol** is the ASCII equal sign character " = ". It is coded as three characters.

- **VALUE** is the rightmost component term and is made up of a character string containing the value of the data object described by the keyword. It is of variable length.

- **stmt_terminator** is the ASCII semicolon character ";". It is coded as one character.

Each record is then padded with ascii spaces (blanks) to the record length minus two characters to end with a carriage return and line feed pair (CR + LF).

3.2.2. CCSDS time formats

Time has two formats in CCSDS headers:

- **UTC1** format gives time in seconds and is recorded with 17 characters:

YYYY-DDD**T**HH:MM:SS

- **UTC2** format gives time in microseconds and is recorded with 24 characters:

YYYY-DDD**T**HH:MM:SS.XXXXXX

With :

YYYY = year
DDD = day of the year (001 to 366)
HH = hours (00 to 23)
MM = minutes (00 to 59)
SS = seconds (00 to 59)
XXXXXX = microseconds

3.2.3. CCSDS header content description

Each CCSDS header will be described in this chapter in a table with the following items.

Record	KEYWORD		VALUE		
N°	SIZE	CONTENT	POS	SIZE	FORMAT/CONTENT

- **record number** (or line number)
- **keyword size** = number of bytes of the keyword
- **value pos** = position in bytes of the value
- **value size** = number of bytes of the value
- **value content** = when the value of the keyword is determined
- **value format** = specifies the format used to express the value, it follows the convention :
  - the value is expressed between a pair of "quotes",
  - the value indicates the number of positions occupied by each element of the format,
  - If the element is ascii numeric, the value indicates the size as Nx.

example : "xxxxx.yyy" where xxxxx = absolute orbit number (N5), yyy = relative orbit number in the cycle (N3)

NB : The value of a numeric element shall be :
- a default value when the element cannot be determined,
- padded with digits '9' when it is greater than the element size.

3.3. GEOGRAPHIC AND TIME INFORMATIONS

Those informations are only of internal use of an extraction program that can be run on a medium to extract data regarding a time window and/or geographic criteria.

The tables below are present on CDROM and exabyte.

3.3.1. Geographic tables

The world is cut up in 4 strips in latitude by 12 sectors in longitude that form geographic boxes regarding the following gridding:

90° (AC)	1	2	3	4	5	6	7	8	9	10	11	12
LIN	13	14	15	16	17	18	19	20	21	22	23	24
0°	25	26	27	28	29	30	31	32	33	34	35	36
LIS -90° (AC)	37	38	39	40	41	42	43	44	45	46	47	48
	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300	330°

<u>The values for north intermediate latitude and south intermediate latitude are</u> :

LIN = 78° et LIS = -78°

Each geographic box is called a <u>cell</u> numbered from 1 to 48.

Each pass on a medium is recorded in each cell it is crossing. In each cell, the pass are recorded in a chronologic order, i.e. increasing orbit numbers and ascending pass before descending pass.

A medium contains exactly 48 geographic table files.

3.3.2. Time table

All the pass files present on a medium are recorded in another table regarding their date and in a chronologic order. Each record of this table contains the pass identification together with its start and stop date.

The program extracts the data using the geographical criteria first anf the time filter after.

3.4. NAMING CONVENTION

The labelling of files and directory referred in this chapter uses the following naming convention:

F	French PAF
e	Satellite (=1 for ERS1, =2 for ERS2)
A	Altimeter data type
S	Microwave radiometer data type
volu	volume identifier coded as 4 digits = cycle number or *mmaa* for month and year
v	Volume issue number
HDR	Header file extension
cc	type of cycle code as two characters with : SC = 3-day cycle (short cycle) IC = 35-day cycle (intermediate cycle) LC = 168-day cycle (long cycle)
xxxxx	absolute orbit number coded as 5 digits
s	pass (A=ascending, D=descending) coded as one character
yyy	relative orbit number within a cycle coded as 3 digits and being a hexadecimal value for 168-day cycle
TAB	Tables directory suffix
DAT	Dates table file extension
GEO	Geographic table file extension
nn	Geographic cell number coded as 2 digits (from 01 to 48)

3.5. MEDIA SUMMARIZED CONTENT

3.5.1. OPR CDROM

An OPR CDROM contains :

- a CDROM header file following an ascii CCSDS format.
- a directory containing source programs, one for extracting data according a time tag and/or geographic criteria and one for reading the data.
- a data directory containing one file per pass, each one beginning with a CCSDS header.
- a table directory containing :
  - the dates table file
  - the 48 geographic table files
- a quality control results directory containing postscript graphic files

CDROM organization :

CDROM Label
FeAvolu_v_cc

CDROM header file *FeAvoluv.HDR*
Programs directory *FeA_SRC* Contains the extraction package
Data directory *FeAvoluv* **Pass files (1002 maximum)** *eAxxxxxs.yyy*
Quality control results directory *FeA_CQ* **PostScript files**

Tables directory *FeA_TAB* **Dates table file** *FeA.DAT* **Geographic table files (48 files)** *FeA_nn.GEO*

3.5.2. OPR exabyte

A OPR exabyte contains the following files :

- one exabyte header file (ascii CCSDS format),
- one file per pass, each one beginning with an ascii CCSDS header,
- one dates table file,
- the 48 geographic table files.

Here after, the exabyte files organization :

Exabyte header file **EOF**
First geographic table file (n=1) **EOF** .... **Last geographic table file(n=48)** **EOF**
Dates table file **EOF**

First pass file **EOF** ... **Last pass file** **EOF**
EOF
EOF

3.5.3. VLC exabyte

An VLC exabyte contains the following files :

- one exabyte header file (ascii CCSDS format),
- one file per pass, each one beginning with an ascii CCSDS header,
- one dates table file,
- the 48 geographic table files.

Hereafter, the exabyte files organization :

Exabyte header file **EOF**
First geographic table file (n=1) **EOF** .... **Last geographic table file (n=48)** **EOF**

Dates table file **EOF**
First pass file **EOF** ... **Last pass file** **EOF**
EOF
EOF

3.5.4. The extraction package

An "extract" package is provided to ease extraction of the products you really need. It enables you to specify the time period and geographic area you want and it copies only the revelvant data products from the medium (CD ROM or exabyte).

You may either ask for a complete pass or only selected measurements. The extraction is split in two steps :

- selection of a list of pass (later referred to as the raw list) according to the information contained into the dates and geographic table files.
- if you have asked for complete extraction of the products, all the passes from the previous list are scanned to determine for each measurement if it fits the requirements you specified.

For more information read the "read_me.opr" or "ex_read.me" file which comes with the package.

How do you get this package ?

1) on OPR CDROM : you will find the extraction package (all the files names "ex_*") into the FeA_SRC directory.

The CDROM are made under ISO9660 format. It means that all the names are in upper case, but some CDROM drivers (HSFS on SUN for example) convert the upper case in lower case !

2) on a FTP server for OPR or VLC exabyte : The C sources files are available on a server by ftp anonymous at Ifremer as described after.

First, go to the directory where you want to install the program Extractexa and then type the following commands (in bold face):

ftp ftp.ifremer.fr

name : **anonymous**

password : **<your name>**

ftp>**cd pub/ifremer/cersat/Extractexa**

ftp>**mget ***

ftp>**quit**

3.6 OPR CDROM FILES DESCRIPTION

3.6.1 CDROM header file

- **Content overview**

File name :	FeAvoluv.HDR
Format :	ASCII CCSDS
Acces :	sequential or direct
Record length (fixed) :	80 bytes
Size :	1 680 bytes

This file is only a header following CCSDS convention. It provides organization and data product identification, i.e. identification of the entity in charge of the CDROM, and information about the CDROM content.

- **Format**

File content is given the table below:

Record	KEYWORD		VALUE		
N°	**SIZE**	**CONTENT**	**POS**	**SIZE**	**FORMAT/CONTENT**
1	20	CCSD3ZF0000100000001	/	/	/
1	20	CCSD3KS00006CDROMHDR	/	/	/
1	40	38 blanks + CR + LF	/	/	/
2	20	Producer_Agency_Name	24	8	ESA
3	22	Producer_Facility_Name	26	12	FRENCH-PAF
4	11	Source_Name	15	4	ERS1 or ERS2
5	11	Sensor_Name	15	9	ALTIMETER
6	23	Data_Handbook_Reference	27	14	C2-MUT-A-01-IF
7	16	Handbook_Version	20	3	"x.y" with x issue number (N1) and y revision number (N1)
8	25	Product_Create_Start_Time	29	17	UTC1 format
9	23	Product_Create_End_Time	27	17	UTC1 format
10	9	Volume_Id	13	12	"FeAvolu_v_cc"
11	14	Version_Number	18	1	"v" (N1)
12	20	Facility_Software_Id	24	14	C2-DSL-D-04-IF
13	25	Facility_Software_Version	29	3	"x.y" with x issue number (N1) and y revision number (N1)
14	23	Package_Data_Start_Time	27	24	UTC2 format
15	21	Package_Data_End_Time	25	24	UTC2 format
16	18	Start_Orbit_Number	22	9	"xxxxx.yyy" xxxxx = absolute orbit number (N5) yyy = relative orbit number in the cycle (N3)
17	16	End_Orbit_Number	20	9	"xxxxx.yyy"
18	10	Pass_Count	14	4	"nnnn" (N4)
19	20	CCSD$$MARKERCDROMHDR	/	/	/
19	20	CCSD3RF0000300000001	/	/	/
19	40	38 blanks + CR + LF	/	/	/
20	13	ReferenceType	17	7	$CCSDS1
21	9	Reference	13	8	"FeAvoluv"

- **Header element description**

Producer_Agency_Name :	Producer Agency Name
Producer_Facility_Name :	Processing Facility Name
Source_Name :	Satellite Name
Sensor_Name :	Sensor Name
Data_Handbook_Reference :	Reference of OPR products user handbook
Handbook_Version :	Version number of the above handbook
Product_Create_Start_Time :	Production start date of the medium
Product_Create_End_Time :	Production stop date of the medium
Volume_Id :	Volume identification of the medium
Version_Number :	Issue number of the volume
Facility_Software_Id :	Producing facility software reference
Facility_Software_Version :	Producing facility software issue
Package_Data_Start_Time :	Start date of the data
Package_Data_End_Time :	Stop date of the data
Start_Orbit_Number :	Start orbit number of the data
End_Orbit_Number :	Stop orbit number of the data
Pass_Count :	Number of pass files
ReferenceType :	Type of reference defined by keyword **Reference**
Reference :	Name of the data directory

3.6.2. OPR pass file

- **Content overview**

File name :	**eAxxxxxs.yyy**
Format :	*header* : ASCII CCSDS *data* : binary
Access :	sequential or direct
Record length (fixed) :	180 bytes
Size :	*header* : 3960 bytes *measurement records* : n*180, n<=3061 *total :* 554940 bytes

There is one file per pass. It contains one header following the CCSDS convention and n measurements records that belong to the pass.

- **Header format**

Header content is given below. See chapter 4 for more details on each element.

Record	KEYWORD		VALUE		
N°	**SIZE**	**CONTENT**	**POS**	**SIZE**	**FORMAT/CONTENT**
1	20	CCSD3ZF0000100000001	/	/	/
1	20	CCSD3KS00006PASSFILE	/	/	/
1	140	138 blanks + CR + LF	/	/	/
2	14	Pass_File_Name	20	12	"eAxxxxxs.yyy"
3	12	Pass_Station	16	2	among FS,GS,KS,MS,ES and PS
4	15	Pass_Start_Date	19	24	UTC2 format
5	20	Pass_Generation_Date	24	17	UTC1 format
6	10	Pass_Nbmes	14	4	"nnnn" (N4)
7	23	Pass_Start_End_Latitude	27	19	"ddddddddd_ffffffff" (2*N9 +1)
8	24	Pass_Start_End_Longitude	28	19	"ddddddddd_ffffffff" (2*N9 +1)
9	12	Pass_Version	16	19	"xxxx_yyyy_zzzz_oooo" (4*N4+3)
10	18	Nbmes_Sea_Land_MBT	22	9	"mmmm_tttt" (2*N4+1)
11	11	Nbmes_Valid	15	4	"nnnn" (N4)
12	19	Nbmes_Valid_OIP_MBT	23	4	"nnnn" (N4)
13	21	Type_Orbit_Height_Geo	25	11	"hhhhh_ooooo" (2*N5+1)
14	18	Min_Max_Wind_Speed	22	11	"nnnnn/xxxxx" (2*N5+1)
15	22	Min_Max_Vapour_Content	26	11	"nnnnn/xxxxx" (2*N5+1)
16	22	Min_Max_Liquid_Content	26	11	"nnnnn/xxxxx" (2*N5+1)
17	16	Min_Max_Altitude (1)	20	21	"nnnnnnnnnn/xxxxxxxxxx" (2*N10+1)
18	19	Min_Max_Wave_Height	23	11	"nnnnn/xxxxx" (2*N5+1)
19	20	Min_Max_Sigma_Naught	24	11	"nnnnn/xxxxx" (2*N5+1)
20	10	Parameters	14	15	"iii/ooooo/aaaaa (N3+N5+N5+2)
21	23	Calibration_Corrections	27	22	"nnnnnnnnnn/vvvvv/ccccc" (N10+N5+N5+2)
22	140	140 blanks (2)	/	/	/
22	20	CCSD$$MARKERPASSFILE	/	/	/
22	20	FCST3IF0010300000001	/	/	/

(1) : the term altitude must be interpreded as range
(2) : at the end of record 22, there is no CR + LF pair.

- **Header elements description :**

See chapter 4 for more details on elements of records 02 to 21.

- **OPR measurement data record format**

The OPR measurement format is given in the table hereafter : it is a 180-byte record, containing 67 fields, each being described with the following items :

- Number of the field in the record
- Type: SI2 (signed 2-byte integer in IEEE format), SI4 (signed 4-byte integer in IEEE format) or BF4 (4-byte bitfield)
- Position of the field in the record (in bytes)
- Mnemonic
- Content
- Unit

The detailed description of fields is provided in section 4.2.

N°	Type	Postion (bytes)	Mnemonic	Content	Unit
				... Identification and characterization ...	
1	SI4	1	Nb	Measurement number	/
2	BF4	5	MCD	Measurement Confidence Data	/
3	SI4	9	Tim_1	Time (seconds)	s
	SI4		Tim_2	Time (microseconds)	10^{-6} s
4	SI4	17	Lat	Latitude	10^{-6} degree
5	SI4	21	Lon	Longitude	10^{-6} degree
6	SI4	25	Nval	Number of averaged 20-Hz measurements	/
				... Altimeter range and altitude ...	
7	SI4	29	H_Alt_Raw	Range : raw value	10^{-3} m
8	SI4	33	Std_H_Alt	Standard deviation on range	10^{-3} m
8+i	SI2	37-55	H_Alt_SME(i)	Difference of the i^{th} 10-Hz range from H_Alt_Raw (i=1,10)	10^{-3} m
18+i	SI2	57-75	Tim_SME(i)	Difference of the i^{th} 10-Hz time from Tim_1, Tim_2	10^{-4} s
29	SI4	77	H_Alt	Range corrected for instrumental effects	10^{-3} m
30	SI2	81	H_Alt_LUT_Cor	Look-up table correction to range	10^{-3} m
31	SI2	83	H_Alt_Dop_Cor	Doppler correction to range	10^{-3} m
32	SI4	85	H_Alt_Cal_Cor_1	Internal calibration correction to range	10^{-3} m
33	SI4	89	H_Alt_Cal_Cor_2	Initial setting for internal calibration correction to range	10^{-3} m
34	SI2	93	Range_Deriv	Range first derivative	10^{-2} m/s
35	SI2	95	Dry_Cor	Dry tropospheric correction to range	10^{-3} m
36	SI2	97	Wet_Cor	Meteorological wet tropospheric correction to range	10^{-3} m
37	SI2	99	Pres_Err	Pressure field error	10^{2} Pa
38	SI2	101	Wet_H_Rad	Radiometer wet tropospheric correction to range	10^{-3} m
39	SI2	103	Iono_Cor	Ionospheric correction to range	10^{-3} m
40	SI2	105	SSB_Cor	Sea state bias correction to range	10^{-3} m
41	SI2	107	H_Eot	Elastic ocean tide	10^{-3} m
42	SI2	109	H_Lt	Tidal loading effect	10^{-3} m
43	SI2	111	H_Set	Solid earth tide	10^{-3} m
44	SI4	113	H_Geo	Geoid height	10^{-3} m
45	SI4	117	H_MSS_DPAF	DPAF mean sea surface height	10^{-3} m
46	SI4	121	H_Sat	Altitude above the reference ellipsoid	10^{-3} m
47	SI4	125	Orb_Err	Orbit error	10^{-3} m
				... Significant wave height ...	
48	SI2	129	SWH_Raw	Significant wave height : raw value	10^{-2} m
49	SI2	131	Std_SWH	Standard deviation on significant wave height	10^{-2} m
50	SI2	133	SWH	Significant wave height corrected for instrumental effects	10^{-2} m
51	SI2	135	SWH_Lut_Cor	Look-up table correction to significant wave height	10^{-2} m
				... Backscatter coefficient and wind speed ...	
52	SI2	137	Sigma0_Raw	Backscatter coefficient : raw value	10^{-2} dB
53	SI2	139	Std_Sigma0	Standard deviation on backscatter coefficient	10^{-2} dB
54	SI2	141	Sigma0	Backscatter coefficient corrected for instrumental effects	10^{-2} dB
55	SI2	143	Sigma0_LUT_Cor	Look-up table correction to backscatter coefficient	10^{-2} dB
56	SI2	145	Sigma0_Cal_Cor	Internal calibration correction to backscatter coefficient	10^{-2} dB
57	SI2	147	Sigma0_LW	Sigma0 corrected for cloud liquid water path attenuation	10^{-2} dB
58	SI2	149	Wind_Sp	Wind speed	10^{-2} m/s
59	SI2	151	Wind_Sp_LW	Wind speed corrected for cloud liquid water path attenuation	10^{-2} m/s
				...Radiometer ...	
60	SI2	153	TB_23	23.8 GHz brightness temperature	10^{-1} K
61	SI2	155	TB_36	36.5 GHz brightness temperature	10^{-1} K
62	SI2	157	WV_Cont	Water vapour content	10^{-2} g/cm^2
63	SI2	159	WV_Cont_WS	Precise water vapour content (wind speed included)	10^{-2} g/cm^2
64	SI2	161	LW_Cont	Liquid water content	10^{-2} kg/m^2
65	SI2	163	LW_Cont_WS	Precise liquid water content (wind speed included)	10^{-2} kg/m^2

66	SI4	165	H_MSS_OSU	OSU Mean sea surface height	10^{-3} m
67	SI4	169	Square_Off_Nad	Waveform-derived square of the off-nadir angle (1-Hz estimate)	10-6 degree^2
68	SI4	173	Square_Off_Nad_ Smoothed	Waveform-derived square of the off-nadir angle (smoothed estimate)	10-6 degree^2
69	/	177	/	Spare (4 bytes)	/

OPR measurement format

3.7. OPR EXABYTE FILES DESCRIPTION

3.7.1. Exabyte header file

• **Content overview** :

Format :	ASCII CCSDS
Access :	sequential
Record length	80 bytes
Volume :	1 600 bytes

This file is only a header following CCSDS convention. It provides organisation, and data product identification, i.e. identification of the entity in charge of the exabyte and information about the exabyte content

The file is written on exabyte as only one block of 1600 bytes.

Header of 20 records (80 bytes each)

• **Format** :

File content is given below :

Record	**KEYWORD**		**VALUE**		
N°	**SIZE**	**CONTENT**	**POS**	**SIZE**	**FORMAT/CONTENT**
1	20	CCSD3ZF0000100000001	/	/	/
1	20	CCSD3KS00006EXABTHDR	/	/	/
1	40	38 blanks + CR + LF	/	/	/
2	20	Producer_Agency_Name	24	8	ESA
3	22	Producer_Facility_Name	26	12	FRENCH-PAF
4	11	Source_Name	15	4	ERS1 ou ERS2
5	11	Sensor_Name	15	9	ALTIMETER
6	23	Data_Handbook_Reference	27	14	C2-MUT-A-01-IF
7	16	Handbook_Version	20	3	"x.y"
8	25	Product_Create_Start_Time	29	17	format UTC1
9	23	Product_Create_End_Time	27	17	format UTC1
10	9	Volume_Id	13	12	"FeAvolu_v_cc"
11	14	Version_Number	18	1	"v" (N1)
12	20	Facility_Software_Id	24	14	C2-DSL-D-04-IF
13	25	Facility_Software_Version	29	3	"x.y"
14	23	Package_Data_Start_Time	27	24	format UTC2
15	21	Package_Data_End_Time	25	24	format UTC2
16	18	Start_Orbit_Number	22	9	"xxxxx.yyy"
17	16	End_Orbit_Number	20	9	"xxxxx.yyy"
18	10	Pass_Count	14	4	"nnnn" (N4)
19	16	Pass_Bloc_Size	20	5	32400
20	20	CCSD$$MARKEREXABTH DR	/	/	/
20	60	58 blanks + CR + LF	/	/	/

• **Header element description :**

See section 3.6.1. for description of elements for the records from 02 to 18.

Pass_bloc_size : size of a pass file block

3.7.2. OPR pass file

- **<u>Content overview</u> :**

Format :	*header* : ASCII CCSDS *data* : binary
Access :	sequential
Record length (fixed) :	180 bytes
Size :	*header* : 4320 bytes *data records :* n * 180, n < = 3061 *total :* 555300 bytes *i.e. exabyte :* 615600 bytes (18 blocks * 32400 bytes)

There is one file per pass. It contains one header following CCSDS convention and n measurements records that belong to the pass.

The file is written by block of 180 records on the exabyte ; the record length being 180 bytes the block size is then 32400 bytes.

One OPR pass file contains 3085 records maximum (24 in the header + 3061 measurements records) , i.e. 18 blocks of measurements maximum. The number of measurements in the last block depends on the number of measurments in the pass. If the last block does not exactly contain 180 measurements then it is padded with fillers (blanks) up to 32400 bytes.

<u>The file is written on exabyte as described below</u> :

Block 1 = header of 24 records + 154 measurements records

IRG

Block 2 = 180 measurements records (180 bytes each)

IRG

...

Last block B = 32 400 bytes, (Max 18 blocks)

• **Header format :**

Header content is given bellow:

Record	KEYWORD		VALUE		
N°	**SIZE**	**CONTENT**	**POS**	**SIZE**	**FORMAT/CONTENT**
1	20	CCSD3ZF0000100000001	/	/	/
1	20	CCSD3KS00006PASSFIL E	/	/	/
1	140	138 blanks + CR + LF	/	/	/
2	14	Pass_File_Name	20	12	"eAxxxxxs.yyy"
3	12	Pass_Station	16	2	among FS,GS,KS,MS,ES and PS
4	15	Pass_Start_Date	19	24	UTC2 format
5	20	Pass_Generation_Date	24	17	UTC1 format
6	10	Pass_Nbmes	14	4	"nnnn" (N4)
7	23	Pass_Start_End_Latitude	27	19	"ddddddddd_fffffffff" (2*N9 +1)
8	24	Pass_Start_End_Longitude	28	19	"ddddddddd_fffffffff" (2*N9 +1)
9	12	Pass_Version	16	19	"xxxx_yyyy_zzzz_oooo" (4*N4+3)
10	18	Nbmes_Sea_Land_MBT	22	9	"mmmm_tttt"(2*N4+1)
11	11	Nbmes_Valid	15	4	"nnnn" (N4)
12	19	Nbmes_Valid_OIP_MBT	23	4	"nnnn" (N4)
13	21	Type_Orbit_Height_Geo	25	11	"hhhhh_ooooo" (2*N5+1)
14	18	Min_Max_Wind_Speed	22	11	"nnnnn/xxxxx"(2*N5+1)
15	22	Min_Max_Vapour_Content	26	11	"nnnnn/xxxxx" (2*N5+1)
16	22	Min_Max_Liquid_Content	26	11	"nnnnn/xxxxx"(2*N5+1)
17	16	Min_Max_Altitude (1)	20	21	"nnnnnnnnnn/xxxxxxxxxx" (2*N10+1)
18	19	Min_Max_Wave_Height	23	11	"nnnnn/xxxxx" (2*N5+1)
19	20	Min_Max_Sigma_Naught	24	11	"nnnnn/xxxxx"(2*N5+1)
20	10	Parameters	14	15	"iii/ooooo/aaaaa (N3+2*N5+2)
21	23	Calibration_Corrections	27	22	"nnnnnnnnnn/vvvvv/ccccc" (N10+2*N5+2)
22	13	Pass_Nb_Blocs (2)	17	2	"bb" (N2)
23	14	Pass_Last_Bloc	18	3	"nnn" (N3)
24	140	140 blanks	/	/	/
24	20	CCSD$$MARKERPASSFI LE	/	/	/
24	20	FCST3IF0010300000001	/	/	/

(1) : the term altitude must be interpreded as range
(2) : at the end of record 22, there is no CR + LF pair.

• **Header elements description** :

See chapter 4 for more details on elements of records 02 to 21.

Pass_Nb_Blocs : number of blocks written on exabyte for the pass file

Pass_Last_Bloc : number of records in the last block of the pass file

3.8. VLC EXABYTE FILES DESCRIPTION

3.8.1. Exabyte header file

• **Content overview**

Format :	ASCII CCSDS
Access :	sequential
Record length	80 bytes
Volume :	1 600 bytes

This file is only a header following CCSDS convention. It provides organisation, and data product identification, i.e. identification of the entity in charge of the exabyte and information about the exabyte content

The file is written on exabyte as only one block of 1600 bytes.

Header of 20 records (80 bytes each)

• **Format**

The file content is given as bellow

Record	KEYWORD		VALUE		
N°	**SIZE**	**CONTENT**	**POS**	**SIZE**	**FORMAT/CONTENT**
1	20	CCSD3ZF0000100000001	/	/	/
1	20	CCSD3KS00006EXABTHDR	/	/	/
1	40	38 blanks + CR + LF	/	/	/
2	20	Producer_Agency_Name	24	8	ESA
3	22	Producer_Facility_Name	26	12	FRENCH-PAF
4	11	Source_Name	15	4	ERS1 ou ERS2
5	11	Sensor_Name	15	9	ATSR/MW
6	23	Data_Handbook_Reference	27	14	C2-MUT-A-01-IF
7	16	Handbook_Version	20	3	"x.y"
8	25	Product_Create_Start_Time	29	17	UTC1 format
9	23	Product_Create_End_Time	27	17	UTC1 format
10	9	Volume_Id	13	12	"FeSvolu_v_cc"
11	14	Version_Number	18	1	"v" (N1)
12	20	Facility_Software_Id	24	14	C2-DSL-D-04-IF
13	25	Facility_Software_Version	29	3	"x.y"
14	23	Package_Data_Start_Time	27	24	UTC2 format
15	21	Package_Data_End_Time	25	24	UTC2 format
16	18	Start_Orbit_Number	22	9	"xxxxx.yyy"
17	16	End_Orbit_Number	20	9	"xxxxx.yyy"
18	10	Pass_Count	14	4	"nnnn" (N4)
19	16	Pass_Bloc_Size	20	5	32760
20	20	CCSD$$MARKEREXABTHDR	/	/	/
20	60	58 blanks + CR + LF	/	/	/

- **Header elements description**

See section 3.6.1 for description of elements for the record from 02 to 18

Pass_Bloc_Size : size of a pass file block

3.8.2. VLC pass file

• **Content overview**

Format :	*header* : ASCII CCSDS *data* : binary
Access :	sequential
Record length (fixed) :	52 bytes
Size :	*header* : 988 bytes *measurement records* : n*52, n<=3061 *total :* 160160 bytes *i.e. exabyte :* 163800 (5 block * 32760 bytes)

There is one file per pass. It contains one header following CCSDS convention and n measurements records that belong to the pass.

The file is written by block of 630 records on the exabyte ; the record length being 52 bytes the block size is then 32760 bytes.

One VLC pass file contains 3080 records maximum (19 in the header + 3061 measurements records), i.e. 5 blocks of measurements maximum. The number of measurements in the last block depends on the number of measurements in the pass. If the last block does not contain exactly 630 measurements then it is padded with fillers (blanks) up to 32760 bytes.

This file is written on exabyte as described below :

Block 1 = header of 19 records + 611 measurement records

IRG

Block 2 = 630 measurement records (52 bytes each)

IRG

...

Last block B = 32 760 bytes, B <= 5

• **Header format :**

Record	KEYWORD		VALUE		
N°	**SIZE**	**CONTENT**	**POS**	**SIZE**	**FORMAT/CONTENT**
1	20	CCSD3ZF0000100000001	/	/	/
1	20	CCSD3KS00006PASSFILE	/	/	/
1	12	10 blanks + CR + LF	/	/	/
2	14	Pass_File_Name	18	12	"eSxxxxxs.yyy"
3	12	Pass_Station	16	2	among FS,GS,KS,MS,ES and PS
4	15	Pass_Start_Date	19	24	UTC2 format
5	20	Pass_Generation_Date	24	17	UTC1 format
6	10	Pass_Nbmes	14	4	"nnnn" (N4)
7	23	Pass_Start_End_Latitude	27	19	"ddddddddd_fffffffff" (2*N9 +1)
8	24	Pass_Start_End_Longitude	28	19	"ddddddddd_fffffffff" (2*N9 +1)
9	12	Pass_Version	16	19	"xxxx_yyyy_zzzz_oooo" (4*N4+3)
10	18	Nbmes_Sea_Land_MBT	22	9	"mmmm_tttt" (2*N4+1)
11	11	Nbmes_Valid	15	4	"nnnn" (N4)
12	19	Nbmes_Valid_OIP_MBT	23	4	"nnnn" (N4)
13	18	Type_Orbit_Geo	22	11	"hhhhh_ooooo" (2*N5+1)
14	18	Min_Max_Wind_Speed	22	11	"nnnnn/xxxxx"(2*N5+1)
15	22	Min_Max_Vapour_Content	26	11	"nnnnn/xxxxx" (2*N5+1)
16	22	Min_Max_Liquid_Content	26	11	"nnnnn/xxxxx"(2*N5+1)
17	13	Pass_Nb_Blocs	17	2	"bb" (N2)
18	14	Pass_Last_Bloc	18	3	"nnn" (N3)
19	120	12 blanks	/	/	/
19	20	CCSD$$MARKERPASSFILE	/	/	/
19	20	FCST3IF0010400000001	/	/	/

NB : at the end of record number 19 there is no CR + LF pair.

• **Header elements description** :

See chapter 5 for more details on elements of records 02 to 16.

Pass_Nb_Blocs : number of blocks written on exabyte for the pass file

Pass_Last_Bloc : number of records in the last block of the pass file

• **VLC measurement data record format** :

The VLC measurement format is given hereafter : it is a 52-byte record, containing 14 fields, each being described with the following items :

- Number of the field in the record
- Type : SI2 (signed 2-byte integer in IEEE format), SI4 (signed 4-byte integer in IEEE format) or BF4 (4-byte bitfield)
- Position of the field in the record (in bytes)
- Mnemonic
- Content
- Unit

The detailed description of fields is provided in section 5.2.

N°	Type	Position (bytes)	Mnemonic	Content	Unit
				... Identification and characterization ...	
1	SI4	1	Nb	Measurement number	/
2	BF4	5	MCD	Measurement Confidence Data	/
3	SI4	9	Tim_1	Time (seconds)	s
	SI4		Tim_2	Time (microseconds)	10^{-6} s
4	SI4	17	Lat	Latitude	10^{-6} degree
5	SI4	21	Lon	Longitude	10^{-6} degree
				... Wind speed ...	
6	SI2	25	Wind_Sp	Wind speed	10^{-2} m/s
7	SI2	27	Wind_Sp_LW	Wind speed corrected for cloud liquid water path attenuation	10^{-2} m/s
				... Brightness temperatures ...	
8	SI2	29	TB_23	23.8 GHz brightness temperature	10^{-1} K
9	SI2	31	TB_36	36.5 GHz brightness temperature	10^{-1} K
				... Water vapour and liquid water contents ...	
10	SI2	33	WV_Cont	Water vapour content	10^{-2} g/cm^2
11	SI2	35	WV_Cont_WS	Precise water vapour content (wind speed included)	10^{-2} g/cm^2
12	SI2	37	LW_Cont	Liquid water content	10^{-2} kg/m^2
13	SI2	39	LW_Cont_WS	Precise liquid water content (wind speed included)	10^{-2} kg/m^2
14	/	41	/	Spare (12 bytes)	/

VLC measurement content

3.9. GEOGRAPHIC TABLE FILE DESCRIPTION

3.9.1. Content Overview

File name	**FeA_nn.GEO**
Format :	*out layer : CCSDS* *header* : binary *data* : binary
Access :	sequential or direct
Record length	out layer: 20 bytes Header and data : 8 bytes
Size :	*SFDU label : 20 bytes* *header* : 8 bytes *records : N*8, N<=270* *Total : 2188 bytes*

A geographic table file contains first a SFDU label (CCSDS out layer) , then a header followed by N data records corresponding to the N passes crossing the geographic cell. N is around 270 as at most 1/4 of the passes cross each cell.

The SFDU label coded as 20 characters (A20) beginning the file is "FCST3SF0010800000001".

3.9.2. Header format

Field No	**Type**	**Position (bytes)**	**Content**	**Unit**
1	SI2	1	cell number	/
2	SI2	3	number of pass files	/
3	SI2	5	latitude north intermediate limit	degree
4	SI2	7	latitude of south intermediate limit	degree

3.9.3. Data Record format

Field N°	**Type**	**Position (bytes)**	**Content**	**UNIT**
0+2*N	SI4	1	Absolute orbit number	/
1+2*N	A4	5	For ascending pass "A " or for descending pass "D "	/

3.9.4. File structure on exabyte

This file is written on exabyte as only one block of 2188 bytes which is the maximum size for this file. If the number of recorded passes is less than 270 then this block is padded with fillers (blanks) up to 2188 bytes.

SFDU label	(20 bytes)
Header	(8 bytes)**+ 270 data records** (8 bytes each)

3.10. DATES TABLE FILE DESCRIPTION

3.10.1. Content overview

File name :	**FeA.DAT**
Format :	*out layer : CCSDS* *header* : binary *data* : binary
Access :	sequential or direct
Record length:	out layer : 20 bytes header et data : : 28 bytes
Size :	*SFDU label: 20 bytes* *header* : 28 bytes *records : N*28, N<=1059* *Total : 29700 bytes*

The dates table file contains first a SFDU label (CCSDS out layer) then a header followed by as much data records as pass files.

The SFDU label codded as 20 characters (A20) beginning the file is "FCST3SF0010900000001".

The coded dates in this file are expressed in seconds since 01-01-1990, 0h and microseconds in the second.

3.10.2. Header format

Field No	Type	Position (bytes)	Content	Unit
1	SI4	1	Number of pass files	/
2	SI4	5	First orbit number	/
3	SI4	9	Last orbit number	/
4	2SI4	13	Start date of first orbit	/
5	2SI4	21	Stop date of last orbit	/

3.10.3. Data Record format

Field No	Type	Position (bytes)	Content	Unit
0+5*N	SI4	1	Absolute orbit number	/
1+5*N	A4	5	For ascending pass "A " or descending pass "D "	/
2+5*N	SI4	9	Number of measurements in the pass	/
3+5*N	2SI4	13	Start date of the orbit (first measurement)	/
4+5*N	2SI4	21	Stop date of the orbit (last measurement)	/

3.10.4. File structure on exabyte

This file is written on exabyte as only one block of 29700 bytes which is the maximum size for this file. If the number of recorded passes is less than 1059 then this block is padded with fillers (blanks) up to 29700 bytes.

SFDU label (20 bytes)
Header (28 bytes) **+ 1059 data records** (28 bytes each)

4. OPR DEFINITION

The OPR (Ocean Product) is built from data relative to one pass (half an orbit revolution, from pole to pole). It contains N header records, followed by a set of M measurement records. Each measurement record contains 66 fields. Header records and measurement fields are hereafter referred to as "elements". The aim of this section is to describe the header elements and the measurement elements of OPR, with the following items (if applicable):

- Record number or field number	Element record number in the file (for header elements) Element field number in the record (for measurement elements)
- Name	Element name
- Definition	Element definition
- Element type	Bitfield, integer, real or string
- Storage type	Signed or unsigned (integer) Bit (contiguous sequence of bits) Character (contiguous sequence of ASCII characters)
- Size	Element size in 8-bit bytes
- Unit	Element unit (including scale factor, UTC1, UTC2)
- Minimum value	Typical or approximate minimum element value
- Maximum value	Typical or approximate maximum element value
- Nominal value	Typical or approximate nominal element value
- Default value	Element value when the measurement is not available, or when the element is not computable
- Flags	Flags indicating the element quality
- Algorithm	Algorithm used to compute the element
- Comment	Other comment

Items without meaning for an element are not quoted in the corresponding descriptive form. Elements are described according to their chronological order in the product.

4.1. HEADER ELEMENTS

Record number 1 and records number greater than 22 do not need a detailed description. They are defined in section 3.6.2.

- **Pass_File_Name (Record number 02)**

Name of the pass-file, built from the following indicators : satellite, product type, orbit revolution number (absolute and relative number in the cycle), and pass direction (ascending or descending pass).

Element type	String
Storage type	Character
Size	12
Nominal value	eAxxxxxs.yyy

e	: satellite (1 for ERS-1, 2 for ERS-2)
A	: means Altimeter product
xxxxx	: absolute orbit revolution number
s	: pass sense (A = ascending pass, D = descending pass)
yyy	: relative orbit revolution number in the cycle

Comment

- yyy coding :
  The relative orbit revolution number yyy has a hexadecimal value for 168-day repeat cycles (2411 = $96B_H$ revolutions).

- Cycle number :
  Cycle number is not provided in the pass-file header records. It is part of "Volume_Id" in the medium header file (see chapter 3).

- Pass number :
  Please be aware that pass number is not provided in the pass-file header records. For 35-day repeat cycles, pass number N in the cycle (from 1 to 1002) may be derived as follows from the relative revolution number in the cycle (yyy) and the pass sense (s) :
  Let M be the value corresponding to the character string yyy (1 to 501) :
  N = 2.M-1 if s = A (odd number for ascending passes : 1, 3, 5 ... 999, 1001)
  N = 2.M if s = D (even number for descending passes : 2, 4, 6 ... 1000, 1002)
  So, for a 35-day repeat cycle :
  s.yyy = A.001 -> Pass number in the cycle = 1
  s.yyy = D.001 -> Pass number in the cycle = 2
  s.yyy = A.002 -> Pass number in the cycle = 3
  .../...
  s.yyy = D.500 -> Pass number in the cycle = 1000
  s.yyy = A.501 -> Pass number in the cycle = 1001
  s.yyy = D.501 -> Pass number in the cycle = 1002

- **Pass_Station (Record number 03)**

Telemetry transcription station.

Element type	String	
Storage type	Character	
Size	2	
Nominal value	6 possible values :	FS (Fucino Station)
		GS (Gatineau Station)
		KS (Kiruna Station)
		MS (Maspalomas Station)
		PS (Prince Albert Station)
		ES (EECF Station)

- **Pass_Start_Date (Record number 04)**

Time of the first data record in the pass-file.

Element type	String
Storage type	Character
Size	24
Unit	UTC2
Minimum value	1991-001T00:00:00.000000
Maximum value	2001-001T00:00:00.000000

- **Pass_Generation_Date (Record number 05)**

Local time when the pass-file was produced.

Element type	String
Storage type	Character
Size	17
Unit	UTC1
Minimum value	1995-001T00:00:00
Maximum value	2001-001T00:00:00

- **Pass_Nbmes (Record number 06)**

Number of data records in the pass-file.

Element type	String
Storage type	Character
Size	4
Minimum value	1
Maximum value	3061 (for a 50 mn nominal pass duration)

Comment

Altimeter measurements are nominally carried out every 0.98 s, on a 50 mn-duration pass.

- **Pass_Start_End_Latitude (Record number 07)**

Latitude of the first and of the last data records in the pass-file.

Element type	String
Storage type	Character
Size	19
Unit	10^{-6} degree
Minimum value	-82 000 000
Maximum value	82 000 000

Comment

Both latitudes are stored in a single string of characters, and set apart by a separator (_).

- **Pass_Start_End_Longitude (Record number 08)**

Longitude of the first and of the last data records in the pass-file.

Element type	String
Storage type	Character
Size	19
Unit	10^{-6} degree
Minimum value	0
Maximum value	359 999 999

Comment

Both longitudes are stored in a single string of characters, and set apart by a separator (_).

- **Pass_Version (Record number 09)**

Versions of OPR, OIP, MBT and orbit softwares used to build the pass-file.

Element type	String
Storage type	Character
Size	19

Comment

The four software versions are stored in a single string of characters, each of them using four characters and being set apart by a separator (_).

Let IJKL be the version of a CERSAT software (OIP, MBT or OPR software); the first two characters (IJ) are updated in case of algorithmic modifications, while the last two ones (KL) concern bugs removal.

- **Nb_Mes_Sea_Land_MBT (Record number 10)**

Number of valid radiometer measurements over the sea, and number of valid radiometer measurements over the earth (in the pass-file).

Element type	String
Storage type	Character
Size	9
Minimum value	0
Maximum value	2500 (for a 50 mn nominal pass duration)

Comment

Both numbers are stored in a single string of characters, and set apart by a separator (_). Radiometer measurements are nominally carried out every 1.2 s, on a 50 mn-duration pass, so the total number of measurements (valid and invalid) in the pass cannot exceed 2500.

- **Nbmes_valid (Record number 11)**

Number of valid 1-Hz altimeter measurements in the pass-file.

Element type	String
Storage type	Character
Size	4
Minimum value	1
Maximum value	3061 (for a 50 mn nominal pass duration)

Comment

See comments concerning measurement validity in MCD description (in section 4.2). Altimeter measurements are nominally carried out every 0.98 s, on a 50 mn-duration pass, so the total number of measurements (valid and invalid) in the pass cannot exceed 3061.

- **Nbmes_Valid_OIP_MBT (Record number 12)**

Number of simultaneous altimeter and radiometer valid measurements in the pass-file.

Element type	String
Storage type	Character
Size	4
Minimum value	0
Maximum value	3061 (for a 50 mn nominal pass duration)

Comment

See comments concerning the simultaneity of altimeter and radiometer measurements in MCD description (in section 4.2).

- **Type_Orbit_Height_Geo (Record number 13)**

Type of orbit data used to compute the altitude of the satellite above the reference ellipsoid, and type of orbit data used to locate measurements.

Element type	String
Storage type	Character
Size	11
Nominal value	For altitude : DPAFL or DPAFP For location : MMCC, DPAFL or DPAFP

Comment

DPAFL = DPAF preliminary orbit
DPAFP = DPAF precise orbit
MMCC = MMCC restituted orbit

Both types are stored in a single string of characters, and set apart by a separator (_). Location is carried out in OIP processing, while the altitude of the satellite above the reference ellipsoid is computed in OPR processing.

- **Min_Max_Wind_Speed (Record number 14)**

Minimal and maximal value of wind speed estimates (Wind_Sp) in the pass-file.

Element type	String
Storage type	Character
Size	11
Unit	10^{-2} m/s
Default value	32767

Comment

Both values are stored in a single string of characters, and set apart by a separator (_).

- **Min_Max_Vapour_Content (Record number 15)**

Minimal and maximal value of water vapour content estimates (WV_Cont) in the pass-file.

Element type	String
Storage type	Character
Size	11
Unit	10^{-2} g/cm^2
Default value	32767

Comment

Both values are stored in a single string of characters, and set apart by a separator (_).

- **Min_Max_Liquid_Content (Record number 16)**

Minimal and maximal value of liquid water content estimates (LW_Cont) in the pass-file.

Element type	String
Storage type	Character
Size	11
Unit	10^{-2} kg/m^2
Default value	32767

Comment

Both values are stored in a single string of characters, and set apart by a separator (_).

- **Min_Max_Range (Record number 17)**

Minimal and maximal value of altimeter range estimates (H_Alt) in the pass-file.

Element type	String
Storage type	Character
Size	21
Unit	10^{-3} m
Default value	2 147 483 647

Comment

Both values are stored in a single string of characters, and set apart by a separator (_). They are computed from the altimeter range corrected for instrumental effects.

- **Min_Max_Wave_Height (Record number 18)**

Minimal and maximal value of significant wave height estimates (SWH) in the pass-file.

Element type	String
Storage type	Character
Size	11
Unit	10^{-2} m
Default value	32767

Comment

Both values are stored in a single string of characters, and set apart by a separator (_). They are computed from the significant wave height corrected for instrumental effects.

- **Min_Max_Sigma_Naught (Record number 19)**

Minimal and maximal value of backscatter coefficient estimates (Sigma0) in the pass-file.

Element type	String
Storage type	Character
Size	11
Unit	10^{-2} dB
Default value	32767

Comment

Both values are stored in a single string of characters, and set apart by a separator (_). They are computed from the backscatter coefficient corrected for instrumental effects.

- **Parameters (Record number 20)**

Parameters consist of R12 sunspot number, Ultra-Stable Oscillator (USO) drift , and distance (H_Alt_COG_Cor) between the antenna reference for the altimeter range measurement and the satellite centre of gravity.

Element type	String		
Storage type	Character		
Size	15		
Unit	10^{-3} Hz (USO drift), 10^{-3} m (distance antenna / COG)		
Minimum value	R12 : 0	USO drift : -10 000	Antenna / COG : 700
Minimum value	R12 : 200	USO drift : 10 000	Antenna / COG : 1000

Comment

These three parameters are provided in the pass-file header because their value remain constant over the pass-file. They are stored in a single string of characters, and set apart by a separator (_).

- R12 sunspot number is used to compute the ionospheric correction (see Iono_Cor)

- USO drift is the difference between the nominal 5 MHz USO frequency and the in-flight measured USO frequency (nominal - measured). It is taken into account in the computation of altimeter range (see H_Alt_Raw)

- Distance antenna / centre of gravity is one of the corrections added to the raw value of altimeter range to get the altimeter range corrected for instrumental effects (see H_Alt).

- **Calibration_Corrections (Record number 21)**

These elements consist of three engineering calibration corrections (biases) related to altimeter range (H_Alt_Bias), significant wave height (SWH_Bias), and backscatter coefficient (Sigma0_Bias).

Element type	String	
Storage type	Character	
Size	22	
Unit	10^{-3} m (range), 10^{-2} m (wave height), 10^{-2} dB (backscatter coefficient)	
Nominal value	Altimeter range :	0
	Significant wave height :	0
	Backscatter coefficient :	-280 10^{-2} dB for ERS-1
		-390 10^{-2} dB for ERS-2

Comment

These values are taken into account in the computation of corresponding estimates corrected for instrumental effects (see H_Alt, SWH and Sigma0). They are provided in the pass-file header because they remain constant over the pass-file. The three values are stored in a single string of characters, and set apart by a separator (_).

4.2. MEASUREMENT ELEMENTS

4.2.1. Identification and characterization elements

- **Nb (Field number 01)**

Measurement number in the pass-file.

Element type	Integer
Storage type	Signed
Size	4
Minimum value	1
Maximum value	3061 (for a 50 mn nominal pass duration)

Comment

This element is the counter of measurement records in the pass-file. It is computed whether the measurement is valid or invalid.

- **MCD (Field number 02)**

Element type	Bitfield
Storage type	Bit
Size	4

This element is the Measurement Confidence Data, which regroups all the flags related to the 1-Hz altimeter measurement. The meaning of each flag is given hereafter :

Validity / Invalidity

Bit 0 Measurement validity
0 = Valid, 1 = Invalid

A 1-Hz measurement is valid if it contains at least one 20-Hz elementary measurement declared "ocean" in the processing; it is invalid otherwise. An elementary measurement is declared "ocean" if the following conditions are satisfied :

- Instrument operating in ocean tracking mode
- Valid telemetry
- Measurement not over a 100% land-covered area.

  A 10’x10’ land/sea mask built from a file providing the percentage of liquid extend (sea with or without ice, lakes, ponds, marshes) in the area, is used to perform a coarse sorting of measurements early in the processing, in order to reject 100% land-covered measurements. A fine sorting is performed further in the processing from each 20-Hz measurements, as explained hereafter.

- Ocean-like waveforms.

Each 20-Hz measurement is processed as follows :
- The measurement is "ocean" if it belongs to a 100 % ocean-covered measurement with a latitude belonging to ± 45 degrees (no ice).
- The measurement is "ambiguous" otherwise.

Each ambiguous 20-Hz measurement is then processed as follows :
- The measurement is "ocean" if its waveform is ocean-like, i.e. if both the mean quadratic error between the waveform and its model (built from retracking estimates), and the Automatic Gain Control, have nominal values.
- The measurement is "non ocean" and so rejected otherwise.

This can be expressed with the following pseudo code :

```
If over 100 % land-covered area then rejected
        If over 100 % ocean-covered area then
                If Lat within +/- 45 deg. (no ice) then declared "ocean"
                Else (ice)
                        If Waveform "ocean-like" then declared "ocean"
                        Else rejected
                        Endif
        Else (ambiguoug area)
                If Waveform "ocean-like" then declared "ocean"
                Else rejected
                Endif
        Endif
Endif
```

The aim of the ocean / non ocean sorting is to reject land measurements, but to keep in the processing all the measurements susceptible of bringing useful information. It is in that way consistent with the quality controls performed in the processing, which flag out-of-range values but do not reject them (flagged fields are not set to their default value), see section 6.3.

For an invalid measurement, the only computed fields are : number (Nb), Measurement Confidence Data pointing out the invalidity and its cause (bits 0-4 of MCD), time (Tim_1, Tim_2) and location (Lat, Lon). The other fields are set to their default value.

<u>Bits 1-3</u> Cause of invalidity (for invalid measurements) :

001 = Acquisition mode
010 = Not acquisition mode, but over land (*)
011 = Not acquisition mode, not over land, but not "ocean" measurement
100 = Other operating mode (generally ice tracking mode)

The purpose of the acquisition mode is to locate the surface with an accuracy sufficient to close the tracking loops, when no *a priori* information is available. This mode does not provide any useful information to OIP/OPR processing.

(*) Measurements over land are provided in OPR as invalid measurements.

Altimeter estimates

Bit 4 Quality of range estimate
Bit 5 Quality of telemetry parameters for range computation
Bit 6 Quality of internal calibration correction to range
Bit 7 Quality of significant wave height estimate
Bit 8 Quality of backscatter coefficient estimate
Bit 9 Quality of telemetry parameters for backscatter coefficient computation
Bit 10 Quality of internal calibration correction to backscatter coefficient
Bit 11 Quality of range derivative estimate
0 = Good , 1 = Bad (for bits 5 to 11)

1-Hz altimeter quality flags are derived from the quality of 20-Hz ocean elementary measurements. A 1-Hz altimeter quality flag is set to "bad" if at least one of the corresponding elementary estimates is "bad" (i.e. out-of-range); otherwise it is set to "good". These engineering level flags may be considered as useful information for software validation, but their systematic use for editing data is to consider with care.

Altimeter operating modes

Bit 12 Type of internal calibration for range correction
Bit 13 Type of internal calibration for backscatter coefficient correction
0 = Single Point Target Response , 1 = Invalid (for bits 12 and 13)
Bit 14 Type of ocean tracking
0 = Nominal , 1 = Preset

In ocean tracking mode, measurements are made and instrument control performed, expecting the average return echoes to conform to Brown's model. During this mode, there are periodic automatic transitions to a brief internal calibration mode in which a single point target response appears in the range window. Invalid internal calibration means that the correction is set to a default value close to the mean.
It is possible to bypass the acquisition mode by initializing the tracking modes with preset information and stopping the normal feedback operation of the tracking loops for a preset time. By these means, the range and range rate window can be set to a given value. Data issued from this preset tracking mode are processed by the software as nominal tracking mode data.

Wind speed

Bit 15 Backscatter coefficient value for wind speed computation
0 = Nominal , 1 = Out-of-range

Wind speed is computed using the modified Chelton and Wentz wind speed model function (Ref. 22), which is valid for a backscatter coefficient between 7 dB and 19.6 dB, giving wind speed values between 1 cm/s and 2015 cm/s.
If Sigma0 or Sigma0_LW are OUT OF RANGE (lower than 7 dB or greater than 19.6 dB) then the corresponding wind speed (Wind_Sp or Wind_Sp_LW) is set to saturation value (2 015 cm/s or 1 cm/s) and bit 15 is set to 1.

Ocean tide

Bit 16 Presence / Absence of tide corrections
0 = Presence , 1 = Absence

In some closed sea areas, the ocean tide height is not computed (H_Eot is set to its default value), as well as the tidal loading effect (H_Lt is set to its default value).

Radiometer

Bit 17 Presence / Absence of a simultaneous radiometer data
0 = Presence , 1 = Absence

Bit 17 is set to 1 if there is no radiometer measurement within a 1.2-second time interval centered on the altimeter time.

When bit 17 is set to 1 :
- all the radiometer fields are set to their default values,
- bits 18, 19 and 20 are meaningless.

Bit 18 23.8 GHz brightness temperature value (TB_23) for altimetric correction
0 = Nominal , 1 = Out-of-range

If TB_23 > 279.9 K or if one of the three computed quantities Wet_H_Rad (field 38), WV_Cont (field 62) or LW_Cont (field 64) is out of the permitted range for a signed 2-byte integer, then these quantities are set to their default values and bit 18 is set to 1.

Bit 19 36.5 GHz brightness temperature value for altimetric correction
0 = Nominal , 1 = Out-of-range

If TB_36 > 279.9 K or if one of the three computed quantities Wet_H_Rad (field 38), WV_Cont (field 62) or LW_Cont (field 64) is out of the permitted range for a signed 2-byte integer, then these quantities are set to their default values and bit 19 is set to 1.

Bit 20 Ocean / Land flag for the radiometer
0 = ocean , 1 = land

The Ocean/Land flag for the radiometer has been built using a 10' x 10' land/sea mask, and taking into account the antenna main lobe 10-dB beamwidth for considering the intrusion of land in the radiometer field-of-view.
Bit 20 is set to 1 if the radiometer measurement is located less than 28 km away from land (mean value, can vary between 18.5 and 48.5 km depending on the coast position and orientation). When bit 20 is set to 1, the corresponding radiometer geophysical parameters are computed but are wrong, except in particular cases (altimeter tracks near small islands for example) for which the land/sea mask used for building the flag may not be accurate enough, or overestimates the real percentage of land within the 10'x10' cell.

Meteorological wet tropospheric correction

Bit 21 Presence / Absence of meteorological wet tropospheric correction
0 = Presence , 1 = Absence

Bit 21 is set to 1 when the four model nearby grid points are over land. The corresponding meteorological wet tropospheric correction is set to its default value.

Mean Sea surface

Bit 22 Presence / Absence of **DPAF** mean sea surface
0 = Presence , 1 = Absence (the four MSS nearby grid points over land)

Bit 22 is set to 1 when the four nearby grid points are over land. The corresponding **DPAF** mean sea surface height is set to its default value.

Bit 24 Presence / Absence of **OSU** mean sea surface
0 = Presence , 1 = Absence (the four MSS nearby grid points over land)

Bit 24 is set to 1 when the four nearby grid points are over land. The corresponding **OSU** mean sea surface height is set to its default value.

Orbital manoeuvre

Bit 23 Orbit quality (manoeuvre)
0 = Nominal , 1 = Manoeuvre

Bit 23 is set to 1 when the orbit quality is affected by a satellite manoeuvre. The corresponding orbit altitude H_Sat is computed, but is wrong.

Radial orbit correction

Bits 25-26 Cause of invalidity of radial orbit correction
01 = radial orbit correction exceeds 60 cm
10 = altimeter data on land
11 = no OPR1 altimeter data available

Comment

Bits 27-31 = Spare

- **Tim_1 and Tim_2 (Field number 03)**

UTC time elapsed between the reference epoch (January 01, 1990 0 h.) and the time of the 1-Hz altimeter measurement (corresponding to the centre of the footprint).

Element type	Integer	
Storage type	Signed	
Size	4 (Tim_1 and Tim_2)	
Unit	s (Tim_1), 10^{-6} s (Tim_2)	
Minimum value	Tim_1 : 30 000 000	Tim_2 : 0
Maximum value	Tim_1 : 350 000 000	Tim_2 : 99 999

Algorithm

The onboard time T_b associated to a telemetry source packet (1-Hz measurement), corresponds to the transmission of the 1000^{th} and last pulse of the previous source packet. The time T_o corresponding to the centre of the footprint of the first elementary measurement (20 Hz) in the source packet, is computed as follows, where H is the satellite altitude, c the light velocity, and PRI the Pulse Repetition Interval :

T_b ->	TU	: universal time derived from on-board time
	+ H/c	: ground impact of the last pulse of the previous source packet
	+ 34.PRI	: ground impact of the 34^{th} pulse (reference pulse for range computation)
	- 50.PRI	: shift of one elementary measurement, because the waveform associated to a measurement is derived from the 50 pulses transmitted in the previous one

A shift of (19/2).50.PRI converts T_o in the time T corresponding to the centre of the footprint of the 1-Hz measurement. Thus :

$$T = TU + H/c + 459.PRI$$

Comment

Time is computed whether the measurement is valid or invalid. The complete elapsed time can be calculated by : Elapsed time (s) = Tim_1 + Tim_2 . 10^{-6}
The nominal duration of 1-Hz measurement is more precisely 0.98 s (20 elementary measurements of 50 pulses at 1020 Hz or 49 ms).

- **Lat (Field number 04)**

Geodetic latitude of the 1-Hz measurement.

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-6} degree
Minimum value	-82 000 000 (South)
Maximum value	82 000 000 (North)

<u>Comment</u>

Location is computed whether the measurement is valid or invalid. The type of orbit data used to compute the measurement location is provided in the pass-file header (see section 4.1 : Type_Orbit_Height_Geo).

- **Lon (Field number 05)**

Longitude of the 1-Hz measurement.

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-6} degree
Minimum value	0 (Greenwich meridian)
Maximum value	359 999 999 (East)

<u>Comment</u>

Location is computed whether the measurement is valid or invalid. The type of orbit data used to compute the measurement location is provided in the pass-file header (see section 4.1 : Type_Orbit_Height_Geo).

- **Nval (Field number 06)**

Number of 20-Hz elementary measurements used for computing the 1-Hz measurement.

Element type	Integer
Storage type	Signed
Size	4
Minimum value	1
Maximum value	20 (for valid measurements)
Nominal value	20 for full-ocean measurements, restricted to 17 when the measurement contains an internal calibration cycle (the first three 20-Hz measurements being ignored in the average processing).

<u>Comment</u>

Nval represents the number of elementary measurements declared "ocean" by OIP processing (see comments concerning measurement validity in the description of MCD). Indeed, averaged engineering estimates as range, significant wave height, backscatter coefficient ... are computed from ocean elementary estimates only. Nval looks like a good indicator of the global quality of measurements. Its averaged value over a complete cycle is greater than 19.

4.2.2. Range and altitude elements

- **H_Alt_Raw (Field number 07)**

Raw value of the 1-Hz altimeter range (not corrected for instrumental effects).

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-3} m
Minimum value	750 000 000
Maximum value	850 000 000
Default value	2 147 483 647
Flags	Bits 4 and 5 of MCD (see field number 02)

<u>Algorithm</u>

- Elementary estimates :
  Computation of 20-Hz altimeter range estimates from the following main parameters :
  . On-board estimates (epoch of the centre of the range window)
  . Ultra Stable Oscillator drift (see Parameters in the pass-file header, section 4.1)
  . Retracking (position of the tracking point w.r.t. the centre of the range window)

- Average :
  Computation of H_Alt_Raw from "ocean" 20-Hz estimates only (see comments concerning measurement validity in the description of MCD), by linear regression at the centre of the 1-Hz measurement (to make consistent range estimate and time of the measurement).

<u>Comment</u>

Retracking consists of an iterative algorithm, intended to make the measured waveform coincide with a return power model according to Maximum Likelihood Estimators. For each processed waveform, the outputs are :

- Position of the tracking point w.r.t. the centre of the range window (difference between the predicted and the efficient position of the waveform), used to improve the altimeter range estimate

- Slope of the waveform leading edge, from which the significant wave height is derived

- Waveform amplitude, used to compute an accurate backscatter coefficient value.

- **Std_H_Alt (Field number 08)**

Standard deviation on 20-Hz altimeter range estimates.

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-3} m
Minimum value	0
Maximum value	500
Default value	2 147 483 647

Algorithm

Std_H_Alt is the standard deviation of "ocean" 20-Hz altimeter range estimates, expressed with respect to the linear model (see H_Alt_Raw).

Comment

Due to retracking, 20-Hz altimeter range estimates are almost fully decorrelated, what increases standard deviation on 20-Hz estimates, but not 1-s noise level (Std_H_Alt / $N^{1/2}$), due to the highest number N of decorrelated points in a 1-Hz measurement. On the other hand, being normalized by $(Nval-2)^{1/2}$, Std_H_Alt is set to its default value if Nval = 2 or Nval = 1.

- **H_Alt_SME(i) (Field number 09 to 18)**

Difference of 10-Hz semi elementary altimeter ranges (i=1,10) from the averaged altimeter range (H_Alt_raw).

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-3} m
Minimum value	-20 000
Maximum value	20 000
Default value	32 767

Algorithm

Let {H_alt_Raw(j)} be the 20-Hz elementary altimeter range estimates. H_Alt_SME(i) (i=1,10) is computed from pairs of consecutive 20-Hz estimates as follows :

- If both 20-Hz estimates number 2i-1 and 2i are "ocean" :
  H_Alt_SME(i) = [H_alt_Raw(2i-1) + H_alt_Raw(2i)] / 2 - H_Alt_Raw

- If only one of the two 20-Hz estimates is "ocean" (let k be its number) :
  H_Alt_SME(i) = H_alt_Raw(k) - H_Alt_Raw

- Else, H_Alt_SME(i) is set to its default value

Comment

- "Ocean" measurement :
  See comments concerning measurement validity in the description of MCD.

- 10-Hz altimeter range estimates :
  These ten values are obtained by adding H_Alt_Raw to H_Alt_SME(i) (i=1,10)

- Step of semi elementary estimates :
  10-Hz estimates do not represent equidistant measurements, because only "ocean" 20-Hz estimates are taken into account (see Tim_SME(i)).

- **Tim_SME(i) (Field number 19 to 28)**

Difference of times related to 10-Hz semi elementary ranges (i=1,10) from the averaged time (Tim_1, Tim_2).

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-4} s
Minimum value	-5000
Maximum value	5000
Default value	32 767

Algorithm

Let δt be the duration of a 20-Hz elementary measurement (δt = 50/PRF, where PRF is the Pulse Repetition Frequency). As the averaged time (Tim_1, Tim_2) corresponds to the centre of the 1-Hz measurement, i.e. to the fictive 20-Hz measurement number 10.5, Tim_SME(i) (i=1,10) is computed as follows :

- If both 20-Hz estimates number 2i-1 and 2i are "ocean" :
  Tim_SME(i) = - [10.5 - (2i - 0.5)].δt = - (11 - 2i).δt

- If only one of the two 20-Hz estimate is "ocean" (let k be its number) :
  Tim_SME (i) = - (10.5 - k).δt

- Else, Tim_SME(i) is set to its default value

Comment

- Time of 10-Hz altimeter range estimates :
  The elapsed time between the reference epoch (January 01, 1990 0h.) and the time of the i^{th} 10-Hz semi elementary measurement (i=1,10), is the sum of the 1-Hz measurement elapsed time (Tim_1, Tim_2) and Tim_SME(i).

- Step of semi elementary estimates :
  If the twenty 20-Hz elementary measurements are "ocean", Tim_SME(i) nominally varies between -441 ms (i=1) and 441 ms (i=10), with a step of 98 ms. Actually, the duration between semi elementary measurements may be equal to x.49 ms, with x = 1, 1.5, 2, 2.5 or 3.

- **H_Alt (Field number 29)**

1-Hz altimeter range corrected for instrumental effects.

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-3} m
Minimum value	750 000 000
Maximum value	850 000 000
Default value	2 147 483 647
Flags	Bits 4, 5 and 6 of MCD (see field number 02)

<u>Algorithm</u>

The 1-Hz altimeter range corrected for instrumental effects H_Alt is the sum of the raw estimate H_Alt_Raw and the instrumental corrections :

H_Alt =		H_Alt_Raw	Altimeter range raw value	(field number 07)
	+	H_Alt_LUT_Cor	Look-up table correction	(field number 30)
	+	H_Alt_Dop_Cor	Doppler correction	(field number 31)
	+	H_Alt_Cal_Cor_1	Internal calibration correction 1	(field number 32)
	+	H_Alt_Cal_Cor_2	Internal calibration correction 2	(field number 33)
	+	H_Alt_COG_Cor	Distance antenna / COG	(pass-file header)
	+	H_Alt_Bias	Calibration correction	(pass-file header)

<u>Comment</u>

H_Alt_COG_Cor and H_Alt_Bias are stored in the pass-file header, because they are constant over the pass: see records number 20 ("Parameter") and number 21 ("Calibration_Corrections") in section 4.1. See also section 6.1.2 about the algorithm improvments performed from issue 6.0 of OIP software.

- **H_Alt_LUT_Cor (Field number 30)**

Look-up table correction to altimeter range.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-3} m
Minimum value	-500
Maximum value	500
Default value	32 767

<u>Comment</u>

The look-up table provides the error on altimeter range, due to the imperfections of the retracking algorithm. This error is a function of significant wave height (H_Alt_LUT_Cor is the output of this table corresponding to SWH) and of signal to noise ratio.

- **H_Alt_Dop_Cor (Field number 31)**

Doppler correction to altimeter range.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-3} m
Minimum value	-30
Maximum value	30
Default value	32 767
Flags	Bit 11 of MCD (see field number 02)

<u>Comment</u>

The Doppler correction is computed from the altimeter range derivative (see Range_Deriv).

- **H_Alt_Cal_Cor_1 (Field number 32)**

Internal calibration correction to altimeter range.

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-3} m
Minimum value	-4000
Maximum value	-2000
Default value	2 147 483 647
Flags	Bits 6 and 12 of MCD (see field number 02)

<u>Algorithm</u>

Each internal calibration cycle (ocean or ice transmitted chirp) provides the measurement of the altimeter Single Point Target Response (SPTR). The corresponding correction to the altimeter range is computed from internal calibration measurements with ocean chirp. It is derived from the position of SPTR in the range window, and includes the USO drift. H_Alt_Cal_Cor_1 is obtained by linear interpolation of these corrections.

<u>Comment</u>

Internal calibration is regularly performed at intervals of a few minutes. Each internal calibration cycle requires three 20-Hz elementary measurements (i.e. 147 ms).

- **H_Alt_Cal_Cor_2 (Field number 33)**

Initial setting for internal calibration correction to altimeter range.

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-3} m
Minimum value	0
Maximum value	0
Nominal value	0
Default value	2 147 483 647

<u>Comment</u>

The initial setting for internal calibration correction to altimeter range was initially expected to be a parameter of the on-board processing. Actually it is a constant, taken into account as a bias in the computation of the altimeter range, and_Alt_Int_Cal_Cor_2 is always set to 0.

- **Range_Deriv (Field number 34)**

1-Hz altimeter range first derivative.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} m/s
Minimum value	-2500
Maximum value	2500
Default value	32 767
Flags	Bit 11 of MCD (see field number 02)

<u>Comment</u>

Range_Deriv is the on-board estimate of altimeter range derivative. It is used to correct the altimeter range for Doppler effect .

- **Dry_Cor (Field number 35)**

Dry tropospheric correction to altimeter range.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-3} m
Minimum value	-3000
Maximum value	-2000
Default value	32 767

Algorithm

The correction of the dry troposphere Dry_Cor (in millimetres) is calculated with the following equation (Ref. 7 : Saastamoinen 1972) :

$$Dry\_Cor = -2.277 \cdot P_S \cdot (1 + 0.0026 \cdot \cos 2\phi)$$

with :

P_S = surface atmospheric pressure (in hPa)

ϕ = measurement latitude (in degrees)

The atmospheric pressure P_S is calculated on the satellite track by bilinear interpolation in space and linear interpolation in time, of the surface pressure field provided every 6 hours by the French Meteorological Office as regular 0.5° in latitude and 0.5° in longitude geographical grids, derived from the ECMWF model outputs.

- **Wet_Cor (Field number 36)**

Meteorological wet tropospheric correction to altimeter range.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-3} m
Minimum value	-1000
Maximum value	0
Default value	32 767
Flags	Bit 21 of MCD (see field number 02)

Algorithm

The meteorological wet tropospheric correction Wet_Cor is calculated under the satellite track, by bilinear interpolation in space and linear interpolation in time, of the meteorological wet tropospheric correction fields provided every 6 hours by the French Meteorological Office as regular 0.5° in latitude and 0.5° in longitude geographical grids. These fields are computed by Météo-France by using temperature and humidity analysis from the ECMWF model outputs, as described in Stum, 1994 (Ref. 8).

- **Pres_Err (Field number 37)**

Pressure field error.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{2} Pa
Minimum value	0
Maximum value	10
Default value	32 767

Comment

The resulting value gives the pressure field error in hPa. This is a confidence criteria for the analysed pressure field expressing both the performance of the processing scheme and the quality of the observations network used for the analysis. The pressure analysis error is calculated under the satellite path by bilinear interpolation in space, and linear interpolation in time, by using the analysis error field calculated and provided by the French Meteorological Office every 6 hours as regular 0.5° in latitude and 0.5° in longitude grids, derived from the ECMWF model outputs.

- **Wet_H_Rad (Field number 38)**

Radiometer wet tropospheric correction to altimeter range.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-3} m
Minimum value	- 500
Maximum value	0
Default value	32 767
Flags	Bits 17, 18, 19 and 20 of MCD (see field number 02)

Algorithm

The correction Wet_H_Rad of the wet troposphere by the microwave radiometer instrument, is calculated using the microwave radiometer brightness temperatures and the altimeter's wind speed :

$$Wet\_H\_Rad = a + b \,.\, \log_e(280 - T23) + c \,.\, \log_e(280 - T36) + d.(U - 7)$$

with:

T23 = 23.8 GHz brightness temperature in K
T36 = 36.5 GHz brightness temperature in K
U = altimeter wind speed in m/s

a, b, c and d have been calculated by regression on a statistically representative set of atmospheric and surface situations together with the corresponding simulated brightness temperatures :

a = 1654.35 b = - 546.68 c = 225.58 d = - 1.37

- **Iono_Cor (Field number 39)**

Ionospheric correction to altimeter range.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-3} m
Minimum value	-250
Maximum value	0
Default value	32 767

Algorithm

The ionospheric correction Iono_Cor (in millimetres) is calculated with the following expression:

$$\text{Iono\_Cor} = -\ 40250\ .\ \frac{TEC}{f^2}$$

with :

TEC = Total Electron Content in electrons/m^2
f = altimeter frequency in Hz (13.8 GHz)

TEC is calculated with Bent's model (Ref. 9 : Llewellyn and Bent 1973). The model input consists of predictions for the 12-month running average of the monthly sunspot number R12 published by CCIR. The predicted values of R12 are used to calculate the monthly median values of the critical frequency of the F2 layer foF2, according to Jones and Gallet 1962 (Ref. 10), with coefficients showing a parabolic dependency in R12. Bent's model calculates the vertical profile of the electronic concentration, which is integrated up to the satellite altitude (≈ 790 km). The TEC obtained is a monthly median for a given time of the day.

Comment

The interpolated value of R12 used to derive Iono_Cor is provided in the pass-file header (see "Parameters").

- **SSB_Cor (Field number 40)**

Sea state bias correction to altimeter range.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-3} m
Minimum value	-500
Maximum value	0
Default value	32 767
Flags	Bit 7 of MCD (see field number 02)

Algorithm

The sea state bias correction SSB_Cor (in millimetres) is computed according to Gaspar and Ogor (Ref. 11), as being equal to 0.55 times the significant wave height (in cm).

- **H_Eot (Field number 41)**

Elastic ocean tide.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-3} m
Minimum value	-15 000
Maximum value	15 000
Default value	32 767
Flags	Bit 16 of MCD (see field number 02)

Algorithm

The ocean tide H_Eot (in millimetres) is the sum of the non equilibrium ocean tide and the equilibrium ocean tide. The non equilibrium ocean tide is computed from the FES95.2.1 model by Le Provost et al. (1994) (Ref. 12). It is given by adding the 27 tide heights from the 27 tides waves M2, S2, N2, K2, K1, O1, 2N2, Q1, L2, T2, P1, NU2, MU2, EPS2, LDA2, ETA2, 2Q1, SIG1, RHO1, M11, M12, KHI1, PI1, PHI1, TTA1, J1, OO1. Only the first eight constituents (M2 to Q1) are the outputs of the model and have been provided as amplitudes and phases on a 0.5° x 0.5° geographical grid. The remaining ones are calculated by admittance from the main waves. The non-equilibrium ocean tide is computed under the satellite track by bilinear interpolation of the grid values. In the Mediterranean sea, the tide is calculated from the maps given by Canceil et al., 1993 (Ref. 13). The long period equilibrium tides are computed according to Cartwright and Tayler, 1971 (Ref. 14), and Cartwright and Edden, 1973 (Ref. 15).

Comment

Note that H_Eot does not include the tidal loading effect, which is provided in a separate record (field number 42).

- **H_Lt (Field number 42)**

Tidal loading effect.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-3} m
Minimum value	-500
Maximum value	500
Default value	32 767
Flags	Bit 16 of MCD (see field number 02)

Algorithm

The tidal loading H_Lt (in millimetres) is a correction due to the load of the ocean tide acting on the bottom of the ocean. The loading effect is calculated by evaluating a convolution integral over the loaded region (the oceans) with a kernel (so-called Green's function) which is the response of the media (the Earth) to a mass-point load (see Francis and Mazzega, 1990 (Ref. 16.)). The used ocean tides model is the FES95.2.1 model.

Comment

The tidal loading effect (H_Lt) is not computed when the elastic ocean tide (H_Eot) is not computed.

- **H_Set (Field number 43)**

Solid earth tide (or body tide).

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-3} m
Minimum value	-1000
Maximum value	1000
Default value	32 767

Algorithm

The solid earth tide H_Set (in millimetres) is computed by adding four terms :

$$H\_Set = 1000 \cdot (h_L + h_S + h_W + h_P)$$

with :

h_L = moon contribution (including permanent deformation)
h_S = sun contribution (including permanent deformation)
h_W = Wahr's radial correction
h_P = the opposite of the permanent deformation term

Consequently, the above solid earth tide H_Set does not include the permanent deformation term.

Moon contribution :

A second order expansion of the potential is used to calculate the contributions due to the Moon and the Sun, for instance, for the Moon (h_L in meters) :

$$h_L = h_2 \cdot (M_L / M_T) \cdot (R_T^4 / D_L^3) \cdot [(3 \cos^2 \theta_L - 1) / 2]$$

with :

h_2 = Love number of second order = 0.609
M_L = mass of the Moon
M_T = mass of the Earth
R_T = local terrestrial radius
$D_L = (X_L^2 + Y_L^2 + Z_L^2)^{1/2}$
$\cos\theta_L = (x.X_L^2 + y.Y_L^2 + z.Z_L^2) / D_L$

(X_L, Y_L, Z_L) are the coordinates of the Moon in the terrestrial reference frame at the time of the altimetric measurement. (x, y, z) are the coordinates of the point of the altimetric measurement in the terrestrial reference frame. X_L, Y_L, Z_L are calculated using the Moon ephemeris provided every 12 hours in the celestial reference frame in the following way :

- linear interpolation at the time of the ephemeris measurements
- calculation of the sideral time θ_G at the time of measurement
- conversion into the terrestrial reference frame by application of the θ_G rotation angle matrix

Sun contribution :

h_S is calculated in an identical way using the Sun ephemeris.

Wahr's radial correction :

h_W (in meters) is calculated according to the expression:

$$h_W = -0.0253 \cdot \sin\phi \cdot \cos\phi \cdot \sin(\theta_G + \mu)$$

with:

ϕ = latitude of subsatellite point

μ = longitude of subsatellite point

Opposite of the permanent deformation term :

h_P (in meters) is calculated according to the expression:

$$h_P = 0.198 \cdot h_2 \cdot [(3 \sin^2\phi - 1) / 2]$$

- **H_Geo (Field number 44)**

Geoid height above the reference ellipsoid.

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-3} m
Minimum value	-120 000
Maximum value	90 000
Default value	2 147 483 647

Algorithm

The height of the geoid above the WGS84 ellipsoid at the subsatellite point is obtained by linear interpolation in latitude and longitude of the JGM3/OSU91A geoid (Ref. 17 and 18), calculated on a 0.25° x 0.25° grid.

Comment

As for the solid earth tide, JGM3/OSU91A does not include the permanent deformation.

- **H_MSS_DPAF (Field number 45)**

Mean sea surface height.

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-3} m
Minimum value	-200 000
Maximum value	100 000
Default value	2 147 483 647
Flags	Bit 22 of MCD (see field number 02)

Algorithm

The height of the mean sea surface at the subsatellite point is obtained by linear interpolation in latitude and longitude of the MSS95A mean sea surface provided on a grid of 3' x 3' by DPAF. This mean sea surface has been computed using ERS-1 OPR from 14-APR-92 to 14-APR-93, ERS-1 upgraded Fast Delivery data from 10-APR-94 to 20-MAR-95, and TOPEX-POSEIDON M-GDR from 25-SEP-92 to 01-JAN-93. A description of the procedure used to compute the mean sea surface, together with comparison with other existing MSS, can be found in Anzenhofer et al., 1996 (Ref . 19).

- **H_MSS_OSU (Field number 66)**

OSU mean sea surface height

Element type	Integer
Storage type	Signed
Size	4
Unit	10-3 m
Minimum value	-200000
Maximum value	100000
Default value	2 147 483 647
Flags	Bit 24 of MCD (see field number 02)

Algorithm

The height of the OSU mean sea surface at the subsatellite point is obtained by bi-cubic spline interpolation on 5 latitude points and 5 longitude points from the OSUMSS95 mean sea surface provided on a 3.75' x 3.75' gridsize. This mean sea surface has been computed using one year mean 17-day repeat GEOSAT sea surface height based on JGM-2 orbit from cycles 1 to 22, one year mean 35-day repeat ERS-1 NOAA IGDR (Fast Delivery altimeter data upgraded by NOAA with JGM-2 orbit) sea surface height from cycles 7 to 17 (10-NOV-92 to 30-NOV-93), the first ERS-1 NOAA IGDR 168-day repeat cycle sea surface height, and one-year mean TOPEX sea surface height based on JGM-2 orbit with improved ocean tide correction from 25-SEP-92 to 01-JAN-93. A description of the procedure used to compute the mean sea surface can be found in Yi, 1995 (Ref. 20).

Comment

In order to keep the original place of the other OPR fields, the OSU MSS has been put after all already existing fields, at field number 66.

- **H_Sat (Field number 46)**

Satellite altitude above the reference ellipsoid.

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-3} m
Minimum value	700 000 000
Maximum value	900 000 000
Default value	2 147 483 647
Flags	Bit 23 of MCD (see field number 02) Type_Orbit_Height_Geo (pass-file header flag)

Algorithm

This concerns the orbit height of the satellite above the **WGS84** reference ellipsoid, defined in section 1.3.2. The satellite orbit is calculated by DPAF. The type of orbit used for computing H_Sat is provided in the pass-file header (Type_Orbit_Height_Geo). Although two types are possible (preliminary or precise orbit), OPR should be disseminated to the users with precise orbit only.

For ERS-1, the precise orbit is available with about 5 months delay. The data used for their calculation are tracking data, normal Laser points, as well as altimeter crossover points. The ephemeris are calculated every 30 seconds.

For ERS-2, the precise orbit is available within 2 months.

In any case, the ephemerides are interpolated at the altimeter time using Everett's formula. The height of the orbit above the ellipsoid is then calculated using an iterative method. An estimation of the orbit error is also given every 30 seconds in the orbit files (see Orb_Err).

- **Orb_Err (Field number 47)**

Orbit error.

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-3} m
Minimum value	-2000
Maximum value	2000
Default value	2 147 483 647
Flags	Bits 25-26 of MCD (see field number 2)

Algorithm

The radial orbit error is computed by simple linear interpolation of the orbit error field provided every 30 seconds in the DPAF orbit files. The orbit error estimation performed at DPAF is based on the minimization of crossover sea surface height differences, by the way of least squares polynomial adjustment, using the orbit altitude together with OPR01 data (OPR data with preliminary orbit). The orbit error field provided by DPAF is set to default value in the following cases :

- missing OPR01 data
- orbit state vector on land
- absolute value of radial orbit error exceeds 600 mm

In the presence of such a default value, the interpolation at OPR altimeter time simply propagates the previous valid radial orbit correction field if available within the 30 seconds time interval. If no valid radial orbit error field is available within the 30 seconds time interval, the radial orbit correction is set to its default value.

4.2.3. Significant wave height elements

- **SWH_Raw (Field number 48)**

Raw value of the 1-Hz significant wave height (not corrected for instrumental effects).

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} m
Minimum value	0
Maximum value	3000
Default value	32 767
Flags	Bit 7 of MCD (see field number 02)

<u>Algorithm</u>

- Elementary estimates :

  Computation of 20-Hz significant wave height estimates from retracking; estimates corresponding to four times the standard deviation of the height distribution of reflectors on the sea surface (assumed to be gaussian).

- Average :

  Computation of the arithmetic mean value SWH_Raw from "ocean" 20-Hz estimates only (see comments concerning measurement validity in the description of MCD).
  Negative values, when they exist are set to zero.

<u>Comment</u>

Retracking consists of an iterative algorithm, intended to make the measured waveform coincide with a return power model according to Maximum Likelihood Estimators. For each processed waveform, the outputs are :

- Position of the tracking point w.r.t. the centre of the range window (difference between the predicted and the efficient position of the waveform), used to improve the altimeter range estimate

- Slope of the waveform leading edge, from which the significant wave height is derived

- Waveform amplitude, used to compute an accurate backscatter coefficient value.

- **Std_SWH (Field number 49)**

Standard deviation on 20-Hz significant wave height estimates.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} m
Minimum value	0
Maximum value	500
Default value	32 767

Algorithm

Std_SWH is the arithmetic standard deviation of "ocean" 20-Hz significant wave height estimates.

Comment

Being normalized by $(Nval-1)^{1/2}$, Std_SWH is set to its default value if Nval = 1.

- **SWH (Field number 50)**

1-Hz significant wave height corrected for instrumental effects.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} m
Minimum value	0
Maximum value	3000
Default value	32 767
Flag	Bit 7 of MCD (see field number 02)

Algorithm

The 1-Hz significant wave height corrected for instrumental effects SWH, is the sum of the raw estimate SWH_Raw and the instrumental corrections :

SWH =		SWH_Raw	SWH raw value	(field number 48)
	+	SWH_LUT_Cor	Look-up table correction	(field number 51)
	+	SWH_Bias	Calibration correction	(pass-file header)

Negative values of SWH, when they exist are set to zero.

Comment

SWH_Bias is a "Calibration_Correction" stored in the pass-file header because constant over the pass (see record number 21 in section 4.1).

- **SWH_LUT_Cor (Field number 51)**

Look-up table correction to significant wave height.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} m
Minimum value	-5000
Maximum value	5000
Default value	32 767

Comment

The look-up table provides the error on significant waveheight, due to the imperfections of the retracking algorithm. This error is a function of significant wave height (SWH_LUT_Cor is the output of this table corresponding to SWH) and of signal to noise ratio.

4.2.4. Backscatter coefficient and wind speed elements

- **Sigma0_Raw (Field number 52)**

Raw value of the 1-Hz backscatter coefficient (not corrected for instrumental effects).

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} dB
Minimum value	400
Maximum value	3500
Default value	32 767
Flags	Bits 8 and 9 of MCD (see field number 02)

Algorithm

- Elementary estimates :

  Computation of 20-Hz backscatter coefficient estimates by expansion of the radar equation, from the following main parameters :
  . Automatic Gain Control (Attenuation applied on-board to the waveform)
  . Result of a pre-launch internal calibration (total power of the SPTR)
  . Retracking (waveform amplitude)

- Average :

  Computation of the arithmetic mean value Sigma0_Raw from "ocean" 20-Hz estimates only (see comments concerning measurement validity in the description of MCD), and conversion in dB.

Comment

Retracking consists of an iterative algorithm, intended to make the measured waveform coincide with a return power model according to Maximum Likelihood Estimators. For each processed waveform, the outputs are :

- Position of the tracking point w.r.t. the centre of the range window (difference between the predicted and the efficient position of the waveform), used to improve the altimeter range estimate
- Slope of the waveform leading edge, from which the significant wave height is derived
- Waveform amplitude, used to compute an accurate backscatter coefficient value.

- **Std_Sigma0 (Field number 53)**

Standard deviation on 20-Hz backscatter coefficient estimates.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} dB
Minimum value	0
Maximum value	100
Default value	32 767

Algorithm

Std_Sigma0 is the arithmetic standard deviation of "ocean" 20-Hz backscatter coefficient estimates. It is computed from estimates before their conversion in dB, and then converted in dB as follows (where X_bc represents the value of X before conversion in dB) :

$$Std\_Sigma0 = 10 \cdot \log_{10} (1 + Std\_Sigma0\_bc / Sigma0\_Raw\_bc)$$

Comment

Being normalized by $(Nval-1)^{1/2}$, Std_Sigma0 is set to its default value if Nval = 1.

- **Sigma0 (Field number 54)**

1-Hz backscatter coefficient corrected for instrumental effects.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} dB
Minimum value	400
Maximum value	3500
Default value	32 767
Flags	Bits 8, 9 and 10 of MCD (see field number 02)

Algorithm

The 1-Hz backscatter coefficient corrected for instrumental effects Sigma0, is the sum of the raw estimate Sigma0_Raw and the instrumental corrections :

Sigma0 =		Sigma0_Raw	Backscatter coeff. raw value	(field number 52)
	+	Sigma0_LUT_Cor	Look-up table correction	(field number 55)
	+	Sigma0_Cal_Cor	Internal calibration correction	(field number 56)
	+	Sigma0_Bias	Calibration correction	(pass-file header)

Comment

Sigma0_Bias is a "Calibration_Correction" stored in the pass-file header because constant over the pass (see record number 21 in section 4.1).

- **Sigma0_LUT_Cor (Field number 55)**

Look-up table correction to backscatter coefficient.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} dB
Minimum value	-100
Maximum value	100
Default value	32 767

Comment

The look-up table provides the error on backscatter coefficient, due to the retracking algorithm. This error is a function of significant wave height (Sigma0_LUT_Cor is the output of this table corresponding to SWH) and of signal to noise ratio.

- **Sigma0_Cal_Cor (Field number 56)**

Internal calibration correction to backscatter coefficient.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} dB
Minimum value	-100
Maximum value	100
Default value	32 767
Flags	Bit 10 of MCD (see field number 02)

Algorithm

Each internal calibration cycle (ocean or ice transmitted chirp) provides the measurement of the altimeter Single Point Target Response (SPTR). The corresponding correction to the backscatter coefficient is computed from internal calibration measurements with ice chirp. It is derived from the total power of SPTR, by comparison with a pre-launch internal calibration used as a reference for the computation of backsactter coefficient (see Sigma0_Raw). Sigma0_Cal_Cor is obtained by linear interpolation of these corrections, and converted in dB.

Comment

Internal calibration is regularly performed at intervals of a few minutes. Each internal calibration cycle requires three 20-Hz elementary measurements (i.e. 147 ms).

- **Sigma0_LW (Field number 57)**

Backscatter coefficient corrected for cloud liquid water path attenuation.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} dB
Minimum value	400
Maximum value	3500
Default value	32 767
Flags	Bits 17, 18, 19 and 20 of MCD (see field number 02)

Algorithm

The backscatter coefficient corrected for the liquid water attenuation (σ_C in dB) is calculated using the backscatter coefficient corrected for instrumental effects (σ_0 in dB) and the estimate of the liquid water content of the clouds made by the microwave radiometer, according to the expression :

$$\sigma_C = \sigma_0 + 2.\beta$$

with :

β = attenuation due to the liquid water of the clouds in a one-way trip :

$$\beta = \int_0^h \beta(z)dz, \text{and } \beta(z) = 355.\lambda^{-2}.10^{-T(z)/82}.M(z) \quad \text{(Réf. 21 : Staelin 1970)}$$

with :

$\beta(z)$ = absorption coefficient for the altitude z, in Neper/km
λ = altimeter wave length in cm (= 2.2 cm)
$T(z)$ = temperature of the cloud at altitude z in K
$M(z)$ = liquid water content in g/m^3.

Assuming an average temperature of the cloud to be 280K constant with altitude, then integration gives the following expression, where L is the integrated liquid water content in kg/m^2 :

$$\beta = 0.12 . L \text{ (dB)}$$

The integrated liquid water content is calculated using microwave radiometer brightness temperatures, by means of a statistical algorithm identical in its principle to that described for correcting the wet troposphere (see Wet_H_Rad).

Comment

As the integrated liquid water content derived from the radiometer brightness temperatures is not yet validated, Sigma0_LW is to be considered with caution.

- **Wind_Sp (Field number 58)**

1-Hz wind speed intensity.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} m/s
Minimum value	1
Maximum value	2015
Default value	32 767
Flags	Bit 15 of MCD (see field number 02)

Algorithm

The wind speed value is calculated using a table (Ref. 22 : Witter and Chelton 1991) relating the backscatter coefficient (Sigma0) to the wind.

Comment

As explained in the description of MCD (bit 15), the wind speed value is limited to [1, 2015] cm/s, in particular for the computation of the water vapour and liquid water contents corrected for excess wind speed induced surface emissivity (WV_Cont_WS and LW_Cont_WS : fields 63 and 65).

- **Wind_Sp_LW (Field number 59)**

Wind speed corrected for cloud liquid water path attenuation.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} m/s
Minimum value	0
Maximum value	3000
Default value	32 767
Flags	Bits 15, 17, 18, 19 and 20 of MCD (see field number 02).

Algorithm

The corrected wind speed value is calculated using the corrected backscatter coefficient (Sigma0_LW), in an identical way to the uncorrected wind speed value (Wind_Sp).

Comment

As the integrated liquid water content derived from the radiometer brightness temperatures is not yet validated, Sigma0_LW is to be considered with caution.

4.2.5. Radiometer elements

Radiometer brightness temperatures result from a 1.2-s averaging. Radiometer elements in OPR are those of the nearest radiometer measurement within a 1.2-second interval centered on the altimeter time. When the altimeter measurement is invalid, all radiometer elements are set to their default values in OPR, but the radiometer elements which are independant of the altimeter (field numbers 60, 61, 62 and 64) are stored in VLC product.

- **TB_23 (Field number 60)**

23.8 GHz brightness temperature.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-1} K
Minimum value	1000
Maximum value	4000
Default value	32 767
Flags	Bits 17, 18, 19 and 20 of MCD (see field number 02)

Algorithm

The brightness temperatures for each channel (23.8 and 36.5 GHz) are calculated according to the processing scheme described in Bernard et al. 1993 (Ref. 5). For the ERS-1 radiometer, they account for the recent tuning of calibration performed by Eymard et al. (Ref. 6). Brightness temperatures for both channels are nadir viewing and have the same footprint of about 21 km diameter wide (half power beamwidth).

- **TB_36 (Field number 61)**

36.5 GHz brightness temperature.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-1} K
Minimum value	1000
Maximum value	4000
Default value	32 767
Flags	Bits 17, 18, 19 and 20 of MCD (see field number 02)

Algorithm

See TB_23.

- **WV_Cont (Field number 62)**

Water vapour content.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} g/cm^2
Minimum value	-2000
Maximum value	2000
Default value	32 767
Flags	Bits 17, 18, 19 and 20 of MCD (see field number 02)

Algorithm

The water vapour content is calculated from the brightness temperatures by means of the following algorithm :

$$V = a + b.\log_e(280 - T23) + c.\log_e(280 - T36)$$

with :

T23 = 23.8 GHz channel brightness temperature in K
T36 = 36.5 GHz channel brightness temperature in K
V = integrated water vapour content in 10^{-2} g/cm^2

a, b and c have been calculated by regression on a statistically representative set of atmospheric and surface situations together with the corresponding simulated brightness temperatures :
a = 2706.19, b = - 931.12, c = 405.96

Comment

Negative values may occur, due to the statistical nature of the algorithm which is not designed to map extreme geophysical situations : they should be considered as being wrong.

- **WV_Cont_WS (Field number 63)**

Water vapour content corrected for excess wind speed induced surface emissivity.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} g/cm^2
Minimum value	-2000
Maximum value	2000
Default value	32 767
Flags	Bits 15, 17, 18, 19 and 20 of MCD (see field number 02)

<u>Algorithm</u>

The precise water vapour content V_p is calculated from the water vapour content V by the equation :

$$V_p = V + d.(U - 7)$$

with :

U = altimeter wind speed value (in m/s)

d = regression coefficient calculated together with a, b and c for WV_Cont : d = -2.25

This correction is used to take into account the emissivity variations due to the wind.

<u>Comment</u>

Negative values may occur, due to the statistical nature of the algorithm which is not designed to map extreme geophysical situations : they should be considered as being wrong.

- **LW_Cont (Field number 64)**

Liquid water content.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} kg/m^2
Minimum value	-1000
Maximum value	1000
Default value	32 767
Flags	Bits 17, 18, 19 and 20 of MCD (see field number 02)

<u>Algorithm</u>

The liquid water content is calculated in the same way as the water vapour content (WV_Cont). Only the coefficients a,b and c are different.
a = 663.05, b = 77.19, c = -215.36

Comment

Negative values may occur, due to the statistical nature of the algorithm which is not designed to map extreme geophysical situations : they should be considered as being wrong. This also may occur in clear sky situations. Such values should be understood as being zero values for liquid water content.

- **LW_Cont_WS (Field number 65)**

Liquid water content corrected for excess wind speed induced surface emissivity.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} kg/m^2
Minimum value	-1000
Maximum value	1000
Default value	32 767
Flags	Bits 15, 17, 18, 19 and 20 of MCD (see field number 02)

Algorithm

The precise liquid water content is calculated in the same way as the precise water vapour content (WV_Cont_WS). The value for the coefficient d is -0.47. As for LW_Cont, negative values may occur.

Comment

Negative values may occur, due to the statistical nature of the algorithm which is not designed to map extreme geophysical situations : they should be considered as being wrong. This also mainly occur in clear sky situations. Such values should be understood as being zero values for liquid water content.

4.2.6 - Off-nadir angle

- **Square_Off_Nad (Field number 67)**

Square of the off-nadir angle derived from the altimeter waveforms.

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-6} degree^2
Default value	2 147 483 647

Algorithm

The square of the off-nadir angle is derived from the altimeter waveforms. A linear regression of the logarithm of the slope of the trailing edge of the waveforms is performed. The 20-Hz "ocean" estimates are then averaged.

Comment

The square of the off-nadir angle should nominally be a positive value close to zero, corresponding to a mispointing smaller than some tenths of degrees. Nevertheless, negative values may be observed due to speckle affecting the altimeter waveforms.

- **Square_Off_Nad_ Smoothed (Field number 68)**

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-6} degree^2
Default value	2 147 483 647

Algorithm

The 1-Hz estimates of the square of the off-nadir angle (Square_Off_Nad) are smooted over 30 seconds.

5. VLC DEFINITION

The VLC (water Vapour and Liquid water Contents) product is built from data relative to one pass (half an orbit revolution, from pole to pole). It contains N header records, followed by a set of M measurement records. Each measurement record contains 15 fields. Header records and measurement fields are hereafter referred to as "elements". The aim of this section is to describe the header elements and the measurement elements of VLC product, with the following items (if applicable):

- Record number	Element record number in the file (for header elements)
or field number	Element field number in the record (for measurements elements)
- Name	Element name
- Definition	Element definition
- Element type	Bitfield, integer, real or string
- Storage type	Signed or unsigned (integer)
	Bit (contiguous sequence of bits)
	Character (contiguous sequence of ASCII characters)
- Size	Element size in 8-bit bytes
- Unit	Element unit (including scale factor, UTC1, UTC2)
- Minimum value	Typical or approximate minimum element value
- Maximum value	Typical or approximate maximum element value
- Nominal value	Typical or approximate nominal element value
- Default value	Element value when the measurement is not available,
	or when the element is not computable
- Flags	Flags indicating the element quality
- Algorithm	Algorithm used to compute the element
- Comment	Other comment

Items without meaning for an element are not quoted in the corresponding descriptive form. Elements are described according to their chronological order in the product.

5.1. HEADER ELEMENTS

Record number 1 and records number greater than 16 do not need a detailed description. They are defined in section 3.8.2.

- **Pass_File_Name (Record number 02)**

Name of the pass-file, built from the following indicators : satellite, product type, revolution number (absolute and relative number in the cycle), and pass sense (ascending or descending pass).

Element type	String
Storage type	Character
Size	12
Nominal value	eSxxxxxs.yyy

e	: satellite (1 for ERS-1, 2 for ERS-2)
A	: means Altimeter product
xxxxx	: absolute revolution number
s	: pass sense (A = ascending pass, D = descending pass)
yyy	: relative revolution number in the cycle

Comment

- yyy coding :
  The relative revolution number yyy has a hexadecimal value for 168-day repeat cycles (2411 = $96b_H$ revolutions).

- Cycle number :
  Cycle number is not provided in the pass-file header. It is part of "Volume_Id" in the medium header file (see chapter 3).

- Pass number :
  Please be aware that pass number is not provided in the pass-file header records. For 35-day repeat cycles, pass number N in the cycle (from 1 to 1002) may be derived as follows from the relative revolution number in the cycle (yyy) and the pass sense (s) :

  Let M be the value corresponding to the character string yyy (1 to 501) :
  N = 2.M-1 if s = A (odd number for ascending passes : 1, 3, 5 ... 999, 1001)
  N = 2.M if s = D (even number for descending passes : 2, 4, 6 ... 1000, 1002)
  So, for a 35-day repeat cycle :

  s.yyy = A.001 -> Pass number in the cycle = 1
  s.yyy = D.001 -> Pass number in the cycle = 2
  s.yyy = A.002 -> Pass number in the cycle = 3
  .../...
  s.yyy = D.500 -> Pass number in the cycle = 1000
  s.yyy = A.501 -> Pass number in the cycle = 1001
  s.yyy = D.501 -> Pass number in the cycle = 1002

- **Pass_Station (Record number 03)**

Telemetry transcription station.

Element type	String
Storage type	Character
Size	2

Nominal value	6 possible values :	FS (Fucino Station) GS (Gatineau Station) KS (Kiruna Station) MS (Maspalomas Station) PS (Prince Albert Station) ES (EECF Station)

- **Pass_Start_Date (Record number 04)**

Time of the first data record in the pass-file.

Element type	String
Storage type	Character
Size	24
Unit	UTC2
Minimum value	1991-001T00:00:00.000000
Maximum value	2001-001T00:00:00.000000

- **Pass_Generation_Date (Record number 05)**

Local time when the pass-file was produced.

Element type	String
Storage type	Character
Size	17
Unit	UTC1
Minimum value	1995-001T00:00:00
Maximum value	2001-001T00:00:00

- **Pass_Nbmes (Record number 06)**

Number of data records in the pass-file.

Element type	String
Storage type	Character
Size	4
Minimum value	1
Maximum value	3061 (for a 50 mn nominal pass duration)

Comment

Radiometer measurements are nominally carried out every 1.2 s, on a 50 mn-duration pass.

- **Pass_Start_End_Latitude (Record number 07)**

Latitude of the first and of the last data records in the pass-file.

Element type	String
Storage type	Character
Size	19
Unit	10^{-6} degree
Minimum value	-82 000 000
Maximum value	82 000 000

Comment

Both latitudes are stored in a single string of characters, and set apart by a separator (_).

- **Pass_Start_End_Longitude (Record number 08)**

Longitude of the first and of the last data records in the pass-file.

Element type	String
Storage type	Character
Size	19
Unit	10^{-6} degree
Minimum value	0
Maximum value	359 999 999

Comment

Both longitudes are stored in a single string of characters, and set apart by a separator (_).

- **Pass_Version (Record number 09)**

Versions of VLC, OIP, MBT and orbit softwares used to build the pass-file.

Element type	String
Storage type	Character
Size	19

Comment

The four software versions are stored in a single string of characters, each of them using four characters and being set apart by a separator (_).
Let IJKL be the version of a CERSAT software (OIP, MBT or VLC software); the first two characters (IJ) are updated in case of algorithmic modifications, while the last two ones (KL) concern bugs removal.

- **Nb_Mes_Sea_Land_MBT (Record number 10)**

Number of valid radiometer measurements over the sea, and number of valid radiometer measurements over the earth (in the pass-file).

Element type	String
Storage type	Character
Size	9
Minimum value	0
Maximum value	2500 (for a 50 mn nominal pass duration)

<u>Comment</u>

Both numbers are stored in a single string of characters, and set apart by a separator (_). Radiometer measurements are nominally carried out every 1.2 s, on a 50 mn-duration pass, so the total number of measurements (valid and invalid) in the pass cannot exceed 2500.

- **Nbmes_valid (Record number 11)**

Number of valid radiometer measurements in the pass-file.

Element type	String
Storage type	Character
Size	4
Minimum value	1
Maximum value	2500 (for a 50 mn nominal pass duration)

<u>Comment</u>

Radiometer measurements are nominally carried out every 1.2 s, on a 50 mn-duration pass, so the total number of measurements (valid and invalid) in the pass cannot exceed 2500.

- **Nbmes_Valid_OIP_MBT (Record number 12)**

Number of simultaneous altimeter and radiometer valid measurements in the pass-file.

Element type	String
Storage type	Character
Size	4
Minimum value	0
Maximum value	3061 (for a 50 mn nominal pass duration)

<u>Comment</u>

See comments concerning the simultaneity of altimeter and radiometer measurements in MCD description (in section 4.2).

- **Type_Orbit_Geo (Record number 13)**

Type of orbit data used to locate measurements.

Element type	String
Storage type	Character
Size	5
Nominal value	MMCC, DPAFL or DPAFP

Comment

DPAFL = DPAF preliminary orbit
DPAFP = DPAF precise orbit
MMCC = MMCC restituted orbit

Both types are stored in a single string of characters, and set apart by a separator (_).

- **Min_Max_Wind_Speed (Record number 14)**

Minimal and maximal value of wind speed estimates (Wind_Sp) in the pass-file.

Element type	String
Storage type	Character
Size	11
Unit	10^{-2} m/s
Default value	32767

Comment

Both values are stored in a single string of characters, and set apart by a separator (_).

- **Min_Max_Vapour_Content (Record number 15)**

Minimal and maximal value of water vapour content estimates (WV_Cont) in the pass-file.

Element type	String
Storage type	Character
Size	11
Unit	10^{-2} g/cm^2
Default value	32767

Comment

Both values are stored in a single string of characters, and set apart by a separator (_).

- **Min_Max_Liquid_Content (Record number 16)**

Minimal and maximal value of liquid water content estimates (LW_Cont) in the pass-file.

Element type	String
Storage type	Character
Size	11
Unit	10^{-2} kg/m^2
Default value	32767

Comment

Both values are stored in a single string of characters, and set apart by a separator (_).

5.2. MEASUREMENT ELEMENTS

5.2.1. Identification and characterization elements

- **Nb (Field number 01)**

Measurement number in the pass-file.

Element type	Integer
Storage type	Signed
Size	4
Minimum value	1
Maximum value	3061 (for a 50 mn nominal pass duration)

Comment

This element is the counter of measurement records in the pass-file. It is computed whether the measurement is valid or invalid.

- **MCD (Field number 02)**

Element type	Bitfield
Storage type	Bit
Size	4

This element is the Measurement Confidence Data, which regroups all the flags related to the 1.2-s radiometer measurement. The meaning of each flag is given hereafter :

Bits 0-1 Measurement validity

00 = Valid for both channels
01 = Invalid for channel 23.8 GHz
10 = Invalid for channel 36.5 GHz
11 = Invalid for both channels

For an invalid measurement the only computed fields are : number (Nb), Measurement Confidence Data pointing out the invalidity and its cause (bits 0-3 of MCD), time (Tim_1, Tim_2) and location (Lat, Lon). The other fields are set to their default value.

Bits 2-3 Cause of invalidity (for invalid measurements)

00 = Radiometer "off"
01 = Out-of-range measurements or gap of auxiliary temperature data
10 = Radiometer in test operation mode
11 = Absence of telemetry

The most likely reason for invalidity is the absence of telemetry.

Bit 4 Infra-red Radiometer status
0 = on , 1 = off

When the Infra-Red Radiometer is off, the sampling time of the Micro-Wave radiometer may be a few milliseconds different than when it is on.

Bit 5 Ocean/Land flag
0 = ocean , 1 = land
Measurements over land are provided in VLC.

The Ocean/Land flag for the radiometer has been built using a 10'x10' land/sea mask, and taking into account the antenna main lobe 10-dB beamwidth for considering the intrusion of land in the radiometer field-of-view.
Bit 5 is set to 1 if the radiometer measurement is located less than 28 km away from land (mean value, can vary between 18.5 and 48.5 km depending on the coast position and orientation). When bit 5 is set to 1, the corresponding radiometer geophysical parameters are computed but are wrong, excepted in particular cases (altimeter tracks near small islands for example) for which the land/sea mask used for building the flag may not be accurate enough, or overestimates the real percentage of land within the 10'x10' cell.

Bit 6 Backscatter coefficient value for wind speed computation
0 = Nominal , 1 = Out-of-range
Wind speed is computed using the modified Chelton and Wentz wind speed model function (Ref. 22), which is valid for a backscatter coefficient between 7 dB and 19.6 dB, giving wind speed values between 1 cm/s and 2015 cm/s.
If Sigma0 or Sigma0_LW are OUT OF RANGE (lower than 7 dB or greater than 19.6 dB) then the corresponding wind speed (Wind_Sp or Wind_Sp_LW) is set to saturation value (2 015 cm/s or 1 cm/s) and bit 15 is set to 1.

Bit 7 Presence / Absence of a simultaneous altimeter data
0 = Presence , 1 = Absence

Bit 7 is set to 1 if there is no altimeter measurement within a 1.2-second time interval centered on the radiometer time. Fields number 7, 8, 11 and 13 are set to their default values.

Bit 8 23.8 GHz brightness temperature value
0 = Nominal , 1 = Out-of-range

If TB_23 > 279.9 K or if one of the two computed quantities WV_Cont (field 10) or LW_Cont (field 12) is out of the permitted range for a signed 2-byte integer, then these quantities are set to their default values and bit 8 is set to 1.

Bit 9 36.5 GHz brightness temperature value
0 = Nominal , 1 = Out-of-range

If TB_36 > 279.9 K or if one of the two computed quantities WV_Cont (field 10) or LW_Cont (field 12) is out of the permitted range for a signed 2-byte integer, then these quantities are set to their default values and bit 9 is set to 1.

Comment

Bits 10-31 = Spare

- **Tim_1 and Tim_2 (Field number 03)**

UTC time elapsed between the reference epoch (January 01, 1990 0 h.) and the time of the 1.2-s radiometer measurement.

Element type	Integer	
Storage type	Signed	
Size	4 (Tim_1 and Tim_2)	
Unit	s (Tim_1), 10^{-6} s (Tim_2)	
Minimum value	Tim_1 : 30 000 000	Tim_2 : 0
Maximum value	Tim_1 : 350 000 000	Tim_2 : 99 999

Comment

Time is computed whether the measurement is valid or invalid. The complete elapsed time can be calculated by : Elapsed time (s) = Tim_1 + Tim_2 . 10^{-6}

- **Lat (Field number 04)**

Geodetic latitude of the 1.2-s measurement.

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-6} degree
Minimum value	-82 000 000 (South)
Maximum value	82 000 000 (North)

Comment

Location is computed whether the measurement is valid or invalid. The type of orbit data used to compute the measurement location is provided in the pass-file header (see section 5.1 : Type_Orbit_Geo).

- **Lon (Field number 05)**

Longitude of the 1.2-s measurement.

Element type	Integer
Storage type	Signed
Size	4
Unit	10^{-6} degree
Minimum value	0 (Greenwich meridian)
Maximum value	359 999 999 (East)

Comment

Location is computed whether the measurement is valid or invalid. The type of orbit data used to compute the measurement location is provided in the pass-file header (see section 5.1 : Type_Orbit_Geo).

5.2.2. Wind speed elements (from altimeter)

- **Wind_Sp (Field number 06)**

Wind speed intensity.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} m/s
Minimum value	0
Maximum value	3000
Default value	32 767
Flags	Bits 6, 7 of MCD (see field number 02)

Algorithm

The wind speed value is calculated using a table (Ref. 22 : Witter and Chelton 1991) relating the backscatter coefficient to the wind.

Comment

As explained in the description of MCD (bit 6), the wind speed value is limited to [1, 2015] cm/s, in particular for the computation of the water vapour and liquid water contents corrected for excess wind speed induced surface emissivity (WV_Cont_WS and LW_Cont_WS : fields 11 and 13).

- **Wind_Sp_LW (Field number 07)**

Wind speed corrected for cloud liquid water path attenuation.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} m/s
Minimum value	0
Maximum value	3000
Default value	32 767
Flags	Bits 5, 6, 7, 8, 9 of MCD (see field number 02).

Algorithm

The corrected wind speed value is calculated using the corrected backscatter coefficient, in an identical way to the uncorrected wind speed value (Wind_Sp).

The backscatter coefficient corrected for the liquid water attenuation (σ_C in dB) is calculated using the backscatter coefficient corrected for instrumental effects (σ_0 in dB) and the estimate of the liquid water content of the clouds made by the microwave radiometer, according to the expression :

$$\sigma_C = \sigma_0 + 2.\beta$$

with :

β = attenuation due to the liquid water of the clouds in a one-way trip :

$$\beta = \int_0^h \beta(z)dz, \text{and } \beta(z) = 355.\lambda^{-2}.10^{-T(z)/82}.M(z) \quad \text{(Réf. 21 : Staelin 1970)}$$

with :

β(z)	= absorption coefficient for the altitude z, in Neper/km
λ	= altimeter wave length in cm (= 2.2 cm)
T(z)	= temperature of the cloud at altitude z in K
M(z)	= liquid water content in g/m^3.

Assuming an average temperature of the cloud to be 280K constant with altitude, then integration gives the following expression, where L is the integrated liquid water content in kg/m^2 :

β = 0.12 . L (dB)

The integrated liquid water content is calculated using microwave radiometer brightness temperatures, by means of a statistical algorithm identical in its principle to that described for correcting the wet troposphere (see Wet_H_Rad in section 4.2).

Comment

As the integrated liquid water content derived from the radiometer brightness temperatures is not yet validated, the corrected backscatter coefficient is to be considered with caution.

5.2.3. Brightness temperature elements

- **TB_23 (Field number 08)**

23.8 GHz brightness temperature.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-1} K
Minimum value	1000
Maximum value	4000
Default value	32 767
Flags	Bits 5, 8, 9 of MCD (see field number 02)

Algorithm

The brightness temperatures for each channel (23.8 and 36.5 GHz) are calculated according to the processing scheme described in Bernard et al. 1993 (Ref. 5). For the ERS-1 radiometer, they account for the recent tuning of calibration performed by Eymard et al. (Ref. 6). Brightness temperatures for both channels are nadir viewing and have the same footprint of about 21 km diameter wide (half power beamwidth).

- **TB_36 (Field number 09)**

36.5 GHz brightness temperature.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-1} K
Minimum value	1000
Maximum value	4000
Default value	32 767
Flags	Bits 5, 8, 9 of MCD (see field number 02)

Algorithm

See TB_23.

5.2.4. Water vapour and liquid content elements

- **WV_Cont (Field number 10)**

Water vapour content.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} g/cm^2
Minimum value	-2000
Maximum value	2000
Default value	32 767
Flags	Bits 5, 8, 9 of MCD (see field number 02).

Algorithm

The water vapour content is calculated from the brightness temperatures by means of the following algorithm :

$$V = a + b.\log_e(280 - T23) + c.\log_e(280 - T36)$$

with :

T23 = 23.8 GHz channel brightness temperature in K
T36 = 36.5 GHz channel brightness temperature in K
V = integrated water vapour content in 10^{-2} g/cm^2

a, b and c have been calculated by regression on a statistically representative set of atmospheric and surface situations together with the corresponding simulated brightness temperatures :
a = 2706.19, b = - 931.12, c = 405.96

<u>Comment</u>

Negative values may occur, due to the statistical nature of the algorithm which is not designed to map extreme geophysical situations : they should be considered as being wrong.

- **WV_Cont_WS (Field number 11)**

Water vapour content corrected for excess wind speed induced surface emissivity.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} g/cm^2
Minimum value	-2000
Maximum value	2000
Default value	32 767
Flags	Bits 5, 6, 7, 8, 9 of MCD (see field number 02).

<u>Algorithm</u>

The precise water vapour content V_p is calculated from the water vapour content V by the equation :

$$V_p = V + d.(U - 7)$$

with :

U = altimeter wind speed value (in m/s)

d = regression coefficient calculated together with a, b, and c for WV_Cont : d = -2.25

This correction is used to take into account the emissivity variations due to the wind.

<u>Comment</u>

Negative values should be considered as not reliable.

- **LW_Cont (Field number 12)**

Liquid water content.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} kg/m^2
Minimum value	-1000
Maximum value	1000
Default value	32 767
Flags	Bits 5, 8, 9 of MCD (see field number 02).

Algorithm

The liquid water content is calculated in the same way as the water vapour content (WV_Cont). Only the coefficients a, b and c are different.
a = 663.05, b = 77.19, c = -215.36

Comment

Negative values may occur, due to the statistical nature of the algorithm which is not designed to map extreme geophysical situations : they should be considered as being wrong.
This also may occur in clear sky situations. Such values should be understood as being zero values for liquid water content.

- **LW_Cont_WS (Field number 13)**

Liquid water content corrected for excess wind speed induced surface emissivity.

Element type	Integer
Storage type	Signed
Size	2
Unit	10^{-2} kg/m^2
Minimum value	-1000
Maximum value	1000
Default value	32 767
Flags	Bits 5, 6, 7, 8, 9 of MCD (see field number 02).

Algorithm

The precise liquid water content is calculated in the same way as the precise water vapour content (WV_Cont_WS). The value for the coefficient d is -0.47. As for LW_Cont, negative values may occur.

Comment

Negative values may occur, due to the statistical nature of the algorithm which is not designed to map extreme geophysical situations : they should be considered as being wrong.
This also may occur in clear sky situations. Such values should be understood as being zero values for liquid water content.

6. MEASUREMENTS ACCURACY AND USE

The following sections give an estimate of the accuracy of the OPR main fields (orbit altitude, altimeter range, geophysical corrections), and discuss the other possible sources of errors on the altimetric measurements (i.e. error due to the inverse barometer effect).

6.1. OPR MAIN FIELDS ACCURACY

6.1.1. Orbit

The precise orbit is generated at DPAF in batches of about 7 days and is delivered at CERSAT in 5-day batches. For ERS-1, the orbit was computed from satellite laser ranging measurement and altimeter crossover data (derived from OPR produced by CERSAT with shorter time delay using DPAF preliminary orbit). The orbit files are concatenated at CERSAT and merged into the OPR. Typical accuracy of the precise orbit for ERS-1 is about 12 to 15 cm in radial component. For ERS-2, the use of PRARE data will improve the radial accuracy.

6.1.2. Altimeter range

As described in section 2.2.2, the altimeter operates by sending out radar pulses and measuring the time required for the pulse echoes to return from the sea surface. This measurement called the altimeter range, provides a first estimate of the height of the instrument above the sea surface, and needs to be corrected by using instrumental and geophysical corrections.

OPR contains :

- the raw altimeter range : H_Alt_Raw
- the altimeter range corrected for instrumental effects : H_Alt
- all the instrumental corrections (added to H_Alt_Raw to get H_Alt) :
  . Look-up table correction : H_Alt_LUT_Cor
  . Doppler correction : H_Alt_Dop_Cor
  . Internal calibration corrections : H_Alt_Cal_Cor_1 (and 2)
  . Distance antenna / COG : H_Alt_COG_Cor
  . Calibration correction (bias) : H_Alt_Bias

As described in section 4.2.2, the altimeter range estimate includes a correction of the tracker error, thanks to the on-ground retracking of waveforms. Moreover, the Ultra Stable Oscillator drift is taken into account.

According to an ESA request, the calibration correction is set to 0 for both ERS-1 (the bias issued from ERS-1 Venice calibration campaign is ignored) and ERS-2 altimeters, what involves a possible bias on the altimeter range (see section 6.2.1). The 1-s noise level on the altimeter range for a typical 2-m significant wave height, is about 3 cm for ERS-1.

From issue 6.0 of OIP software :

- Waveforms are corrected for the effects of the anti-aliasing IF filtering performed on-board before FFT. In the all previous issues, these effects were taken into account through the look-up table correction on the altimeter range (field number 30). The impact of this modification on the altimeter range estimates is about some millimetres (for ERS-1 and ERS-2 data).

- The earth curvature effects in the altimeter footprint are accounted for in the retracking algorithm (through the expression of the mean return power model). The impact of this modification is a decrease of the altimeter range estimates at about 1 % of SWH (significant waveheight).

- The convergence of the iterative retracking algorithm has been improved, leading thus to an increase of the standard deviation on 20-Hz altimeter range estimates (field number 08), and to a better decorrelation of 20-Hz estimates.

The global increase of the standard deviation on 20-Hz altimeter range estimates is about 10 %.

6.1.3. Radiometer wet tropospheric correction

Work done by Eymard et al., 1994 (Ref. 6), has shown that the ERS-1 microwave radiometer wet tropospheric correction estimates matches the in-situ radiosonde estimates with a 2 cm RMS error and no bias. Comparisons between ERS-1 and TOPEX microwave radiometers also show a good agreement (1 cm RMS, no bias, see Stum, 1994 (Ref. 8)).

6.1.4. Model dry and wet tropospheric corrections

The typical accuracy of the model sea surface pressure ranges from 1 hPa in northern Atlantic up to 10 hPa in high latitudes in southern oceans. This leads to errors in dry tropospheric correction from 0.2 cm up to 2 cm. The model wet tropospheric correction has a rather good global accuracy (about 3 cm RMS error when compared with the radiometer one), but generally overestimates the humidity, particularly in the tropical areas (e.g. off the coasts of Peru). It may be used with good accuracy in high latitudes when the radiometer one is missing.

6.1.5. Ionospheric correction

The accuracy of the Bent model mainly depends on the solar activity. For low solar activity (from 1993 to 1996), the ionospheric correction is low (less than 10 cm) and the associated model error is weak (about 2 cm). For high solar activities, the ionospheric correction can be as high as 20 to 30 cm, and the model error can reach 5 to 10 cm particularly in the tropical areas.

6.1.6. Sea state bias correction

The sea state bias correction from Gaspar and Ogor (Ref. 11), was derived from OPR before the implementation of the version 6 of F-PAF altimeter processing software. Studies are needed to further investigate the dependency of sea-state bias with waveheight and windspeed for the new OPR products.

6.2. OTHER POSSIBLE SOURCES OF ERRORS

6.2.1. Altimeter bias

The ERS-1 altimeter bias derived by Francis et al., 1993 (Ref. 23) from the Venice calibration campaign is -41.5 ± 5 cm (this value should be added to the sea surface height estimate to get its true value, what means that the altimeter range is overestimated).

The relative ERS-1 altimeter bias with respect to TOPEX has been estimated by Le Traon et al, 1995 (Ref. 24) from TOPEX/Poseidon - ERS-1 dual crossover differences. Results are in very good agreement with those of Venice campaign.

6.2.2. Mispointing

Both ERS-1 and ERS-2 are three-axis stabilised earth-pointed spacecraft. The yaw axis is pointed towards the geodetic nadir on the reference ellipsoid. The nominal operation is the yaw steering mode, with the pitch axis oriented along the composite ground velocity vector, including earth rotation (the AMI SAR antenna and AMI wind scatterometer mid-beam antenna boresight are then in the zero Doppler plane at nadir).

For the Radar Altimeter, the maximum specified errors for pitch and roll axis are :

Sum of bias and long term drift	= 0.23°
Harmonic and random (3 σ)	= 0.11°
Total pointing accuracy	= 0.34°

The platform provides the capability of compensating a static bias pointing error of up to 0.2 ° on each axis. This capability may be used in particular for achieving the Radar Altimeter performances which are defined for a maximum overall pointing error of the RA antenna of 0.25° in pitch and roll combined. Actual priority performance achieved is significantly better than specified.

There is no information about mispointing in OPR, neither platform estimates (which are not provided by ESA), nor on-ground estimates from waveforms (which were expected for ERS-1 but not validated).

6.2.3. Inverse barometer effect

The atmospheric pressure variations induce variations of the sea surface height, assuming an hydrostatic response of the ocean : a 1 hPa increase in atmospheric pressure depresses the sea surface by about 1 cm. The surface pressure P_S (in hPa) can be derived from the dry tropospheric correction Dry_corr in mm (field number 35) by inverting the Saastamoinen formula (where ϕ is the latitude) :

$$P_S = Dry\_corr / [-2.277 . (1 + 0.0026 . \cos(2.\phi))]$$

The inverse barometer correction Inv_Bar (in mm) is then, as a first approximation :

$$Inv\_Bar = - 9.948 . (P_S - 1013.25)$$

6.2.4. Contamination by sea ice or rain

Sea ice or rain present in the field of view of the radiometer enhance brightness temperatures and give erroneous estimates of geophysical parameters (wet tropospheric correction, columnar water vapor content, cloud liquid water). No universaly robust flag can easily be derived from the brightness temperatures to prevent from this contamination.

6.2.5. Orbit repeatitiveness

During the 35-day repeat period of ERS-1, it was shown that the orbit has been maintained within ± 1 km, excepted near out-of-plane inclinations manoeuvres, where loss of repeatitiveness reached 2 km for some passes. Not exact repeatitiveness can induce errors on altimeter residuals when strong geoid gradients are present. To correct for this effect, the mean sea surface height H_MSS (field number 45) can be subtracted from the altimeter sea surface height before computing the residuals.

6.3. FLAGS AND DEFAULT VALUES

6.3.1. Flags

OPR 1-Hz measurements are characterised by a set of flags stored in the Measurement Confidence Data (MCD), whose precise definition is given in section 4.2.1. These flags provide information about one of the following items :

- Validity or invalidity of the 1-Hz measurement :

Bit 0 : Validity
Bits 1 to 3 : Cause of invalidity (for invalid measurements)

- Quality of estimates :

Bit 4 : Altimeter range
Bit 5 : Telemetry parameter involved in the altimeter range computation
Bit 6 : Internal calibration correction to the altimeter range
Bit 7 : Significant waveheight
Bit 8 : Backscatter coefficient
Bit 9 : Telemetry parameters involved in the backscatter coefficient computation
Bit 10 : Internal calibration correction to the backscatter coefficient
Bit 11 : Altimeter range derivative (radial velocity)
Bit 15 : Backscatter coefficient for wind speed computation
Bit 18 : 23.8 GHz brightness temperature
Bit 19 : 36.5 GHz brigthness temperature

- Presence or absence of geophysical level items :

Bit 16 : Tide corrections
Bit 21 : Meteorological wet tropospheric correction
Bit 22 : Mean sea surface (DPAF)
Bit 24 : Mean sea surface (OSU)

- Measurement characteristics :

Bit 12 : Type of internal calibration for altimeter range correction
Bit 13 : Type of internal calibration for backscatter coefficient correction
Bit 14 : Type of ocean tracking
Bit 17 : Existence of a simultaneaous radiometer data
Bit 20 : Ocean/land flag for the radiometer
Bit 23 : Orbital manoeuvre

6.3.2. Quality flags building

Quality flags are built in various levels of the OPR generation processing :

- Bit 4, 5, 7, 8, 9 and 11 :
  These flags are computed in OIP processing (instrumental level processing) from comparisons of the 20-Hz estimates with thresholds. The 1-Hz flags are set to "bad" if one at least of the corresponding 20-Hz estimates is out-of-range. They are set to "good" otherwise.

- Bit 6 and 10 :
  These flags are computed in OIP processing from comparisons of the 1-Hz corrections with thresholds. They are set to "bad" if the correction is out-of-range. They are set to "good" otherwise.

- Bits 15, 18 and 19 :
  These flags are computed in OPR processing from comparisons of the 1-Hz estimates with thresholds which correspond to the input limits of the tables used to compute the wind speed and the tropospheric corrections. They are set to "bad" if the correction is out-of-range. They are set to "good" otherwise.

Be aware that the various thresholds used in building of quality flags are not the minimum and maximum values provided together with the description of each field of the product. Indeed, flags and thresholds have mainly been designed for first-level product quality control, while minimum and maximum values represent typical or approximate minimum or maximum element value, and must be interpreted as sizing information.

6.3.3 Default values and relationship with flags

As mentioned in section 1.3.7, a field is set to its default value (2^{N-1}-1 for a N-byte signed integer) if it is unavailable, i.e. if data is missing, if the field cannot be computed, or if it is out-of-range.

- Missing data :

  In this case, the default value is pointed out by a flag (i.e. a bit of the MCD).

  Examples :

  - no radiometer data (bit 17)
  - no tide correction (bit 16)
  - no meteorological correction (bit 21)
  - no DPAF mean sea surface (bit 22)
  - no OSU mean sea surface (bit 24)

- No computation :

  In this case, there is no flag to point out the default value of the field.

Examples :

- The standart deviation on the altimeter range is set to its default value because the number of 20-Hz averaged measurements is smaller than 3.

- The 1-Hz backscatter coefficient estimate is set to its default value because it cannot be converted in dB (power estimate less or equal to zero).

- The difference of 10-Hz semi elementary altimeter ranges from the averaged altimeter range is set to its default value because the two 20-Hz measurements involved are not ocean measurements.

In these examples, one or some fields of the measurements are not available, despite of the possible global validity of the 1-Hz measurement. These cases correspond to a software protection performed at various levels of the processing, and aimed at avoiding a computer trap. The default value itself has to be considered as a quality information, equivalent to a flag.

- Field out-of-range :

Fields of the product measurements are recorded as signed integers in a limited number N of bytes (N=2 or 4). Any field of the product will be set to its default value at the end of the processing if it has such an unexpectable value that it is out of the range of the corresponding storing integer. In this case, there is no flag to point out the default value of the field.

To sum up, flags and default values represent uncorrelated quality information. A default value is not systematically flagged in the product. Flags, when they exist are aimed at providing the reason of the default value. On the other hand, be aware that flagging is a passive processing, i.e. that a flagged field is not systematically set to its default value. The computed value of the flagged field is provided in the product, and corresponding flags point out the fact that the field is out-of-range (with respect to the thresholds involved in the processing).

6.3.4. Quality controls performed at CERSAT

Two types of control are systematically performed at CERSAT from each OPR cycle :

- A first-level routine product quality control, which consists in the counting of out-of-range fields (performed from specific thresholds), and in the verification that the corresponding percentages of outliers do not exceed an acceptable threshold. Note that default values are accounted for in this control, by using thresholds for data editing.

- A scientific quality assessment (see the Quality Assessment reports provided by CERSAT together with each OPR cycle).

6.3.5. Use of flags and default values

All the flags relative to a field or to one of its components are provided in the item "flags" of the field description (see sections 4.2.2 to 4.2.5). However, the choice of the appropriate flags for data editing largely depends on the type of study the data is used for. A flag may be useless (e.g. the manoeuvre flag for a wind/wave study), or irrelevant due to the large thresholds involved in the building of quality flags.

So, generally speaking the main simple editing criteria to be performed by any user are the following :

- Validity of the 1-Hz measurement
- Non default value for the fields

Note that the test of default values may be performed alone, because all the fields of an invalid measurement, except number, time, latitude, longitude and MCD are set to their default value.

More accurate editing criteria may be built by users, either form MCD flags or measurements fields (as for example the number of 20-Hz averaged measurements), or from comparisons of fields with suitable thresholds.

As an example, the flags involved in the first-level routine control performed at CERSAT are the following (for the main processed fields) :

- H_Alt and Std_H_Alt :	bit 4 (quality of the raw estimate)
	bit 2 (manoeuvre)
- SWH :	bit 23 (quality of the raw estimate)
- Sigma0 :	bit 8 (quality of the raw estimate)
	bit 15 (out-of-range for wind speed computation)
- Wet_Corr :	bit 21 (presence/absence of meteorological correction)
- Wet_H_Rad :	bit 17 (presence/absence of a simultaneous radiometer data)
	bit 18 (quality of the 23.8 GHz estimate)
	bit 19 (quality of the 36.5 GHz estimate)
	bit 20 (ocean/land flag for the radiometer)

Be aware that this only represents an example, and that various configurations may be tested, according to the importance put on the different components of a field, the most selective sorting being performed by using all the flags mentioned in the item "flags" of the fields description.

A complete example of editing can be found in the Quality Assessment reports provided by CERSAT together with each OPR cycle. Note that using thresholds for data editing will automatically reject default values.

7. GLOSSARY, REFERENCES, CONTACT

7.1. GLOSSARY

AGC	Automatic Gain Control
AMI	Active Microwave Instrument
ASCII	American Standard Code for Information Interchange
ATSR	Along Track Scanning Radiometer
CCIR	Centre Consultatif International des Radiocommunications
CD ROM	Compact Disk Read Only Memory
CERSAT	Centre ERS d'Archivage et de Traitement
CLS	Collecte Localisation Satellites
CNES	Centre National d'Etudes Spatiales
COG	Centre Of Gravity
DPAF	German Processing and Archiving Facility
ECMWF	European Centre for Medium-range Weather Forecasting
EECF	ESRIN ERS-1 Central Facility
EOF	End of file
ERS	European Remote-sensing Satellite
ESA	European Space Agency
ESRIN	European Space Research Institute
FDP	Fast Delivery Product
FES	Finite Element Solution
FFT	Fast Fourier Transform
FM	Frquency modulation
FPAF	French Processing and Archiving Facility (CERSAT)
GDR	Geophysical Data Record
GOME	Global Ozone Monitoring Experiment
IEEE	Institut of Electrical and Electronics Ingineers
IF	Intermediate Frequency
IFREMER	Institut Français de Recherche pour l'Exploitation de la MER
IR	Infra-Red
IRG	Inter Record Gap
IRR	Infra-Red Radiometer
JGM	Joint Gravity Model
MBT	Micro-wave Brightness Temperature product
MLE	Maximum Likelihood Estimator
MMCC	Mission Management and Control Centre
MSS	Mean Sea Surface
MSB	Most Significant Bit
MW	Micro-Wave
MWS	Micro-Wave Sounder
OIP	Ocean Intermediate Product
OPR	Ocean Product

OSU	Ohio State University
PAF	Processing and Archiving Facility
PRARE	Precise RAnge and Range-rate Equipment
PRI	Pulse Repetition Interval
PRF	Pulse Repetition Frequency
RA	Radar Altimeter
RMS	Root Mean Square
SAR	Synthetic Aperture Radar
SDR	Sensor Data Record
SPOT	Satellite Pour l'Observation de la Terre
SPTR	Single Point Target Response
SWH	Significant Wave Height
TM	Telemetry
USO	Ultra-Stable Oscillator
UTC	Universal Time Coordinated
VLC	Water Vapour and Liquid water Content

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