QUALITY ASSESSMENT OF CERSAT ALTIMETER PRODUCTS

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[PERIODICAL REPORT]

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DRAFT

1 - BACKGROUND

The french processing and archiving facility (F-PAF: CERSAT center) processes the ERS-1 altimeter data over ocean, by using data recorded on-board the satellite and telemetered to the ground when the satellite flies over receiving stations.

The first step of the processing consists in transforming raw data in physical quantities, dated, located and corrected for the instrumental effects, and storing them in an "off-line intermediate product" (OIP). The computed physical quantities are mainly the altitude of the satellite above the sea surface, the significant waveheight and the backscatter coefficent of the sea surface.
The second step of the processing mainly consists in computing the environmental corrections, using the best available orbit to provide the altitude of the satellite above ellipsoïd, and computing the wind speed modulus from the backscatter coefficient. The resulting product is the "ocean product" (OPR).
Note that the microwave radiometer data are processed in order to provide the "microwave brightness temperatures" product (MBT), which allows the computation in OPR, of a wet tropospheric correction on the altitude.

Processings and products are described in CERSAT document : "Altimeter products, user manual" (C1-EX-MUT-A21-01-CN, issue 2.0).

First results of OIP and OPR quality assessments are presented in this report. Further results will be provided by the way of periodical reports.

2 - PROCESSINGS STATUS

2.1 - OIP processing status

- **Version 1.9 and 2.0**: these versions are compatible.

- **Version 2.1**: this version is not compatible with preceeding ones.

  The instrumental bias on the altitude, derived from the Venice external calibration campaign, is added to the raw altitude to provide the altitude corrected for instrumental effects. The corresponding field in OPR takes this bias into account (+ 192 mm). A bias of 2.8 dB is removed from the backscatter coefficient estimates. The corresponding field in OPR takes this bias into account (- 2.8 dB). The significant waveheight estimate is affected by a correction in the width of the altimeter point target response (histograms of this parameter are now more consistent than previously).

- **Version 2.2**: this version is compatible with the previous one (minor corrections without impact on altimeter parameters).

  Measurement generation over land for longitudes between 357 and 360 degrees are removed (some measurements were previously located on African continent coasts). Bits of the measurement confidence data are modified (the cause of invalidation is now set to "other operation mode" state when the altimeter is in ice mode). The default value of the backscatter coefficient corrected for instrumental effects is modified (this value was not a constant because corrections were applied, while it is now -327 dB).

- **Version 2.3**: this version incorporates a refined datation of altimeter measurements. Version 2.3 products may be used with previous ones, since an enhancement of altimeter altitude estimation results from this modification.

  Previous datation was computed from one on-board/on-ground time relation (by calculating the time since this relation). Due to the on-board clock resolution (1 ns), this method led to an error of several ms, when a gap occured between successive time relations. Now, an interpolation between two time relations is done to obtain the measurement datation. Previously, the time relation preceeding measurements was stored in the main header (fields 14, 15, 16), while now these fields are filled with the interpolated relation (in both OIP and OPR).

- **Version 2.4**: this version is compatible with the preceeding one. It should be applied for products since 21-10-1991. A software error in the on-board time handling is corrected. It occured when satellite time exceeded 2^{31}. Processing of data earlier than 21-10-1991 provides the same products with version 2.4 and 2.3.

2.2 - MBT processing status

All following software versions changes, do not imply modification on the corresponding microwave brightness temperatures data.

- **Version 2.0 and 2.1**: these versions are compatible. Modification were made to be able to handle telemetry when erroneous data were found (inconsistencies between on-board time and sequence counter).
- **Version 2.2:** this version is compatible with the previous one. Datation is obtained from an interpolation between two successive time relations (see OIP version 2.3).
- **Version 2.3:** this version is compatible with the previous one. Products later than 21-10-1991 should be generated with this version (see OIP version 2.4).

2.3 - OPR processing status

- **Version 2.0 to 2.5**: these versions are compatible (correction of software errors which stopped the processing. No modification is done on geophysical parameters).

3 - ALTIMETER "INSTRUMENTAL LEVEL" VALIDATION

Four steps of validation, contractually planned with the "European Space Agency" (ESA) were carried out:

- The ANALYSIS OF RAW DATA (telemetry), necessary to evaluate the validity of data, their continuity, the occurence and duration of functionning modes, the on-board estimations and their evolution
- The ALGORITHMIC VALIDATION, consisting in checking the internal coherency of the processing and setting parameters, and requiring the analysis of direct or intermediate outputs of the processing
- The MONITORING OF OIP in different contextes, with a view to estimate performances
- The COMPARISON BETWEEN OIP AND FDP ("Fast delivery products"), planned to identify and characterize the possible differences.

3.1 - Analysis of raw data

About 9000 source packets of 9 August 1991 were analysed (1 source packet corresponding to 0.98 second). Although measurements and telemetry are globally consistent with expected ones, three remarks concerning waveforms may be pointed out:

- On-board constraints involve a systematically null level of thermal noise on waveforms. As a part of the information contained in the leading edge of waveforms is lost, the impact on the waveform's parameters estimation could be not negligible. On the other hand, signal to noise ratio, which cannot be estimated from waveforms, is set to a default value, and the off-line instrumental corrections by look-up tables may become slightly erroneous.
- In ocean tracking mode, different kinds of waveforms were observed, even null ones. OIP processing has been protected so that it becomes able to process any waveform.
- Waveforms are not consistent with conventionnal return power models (Brown's model or similar), when the waveheight is null over the sea surface. In this case, altimetric parameters should be taken with care, because both on-board and off-line estimation algorithms are based on the coïncidence between waveforms and Brown's model.

Telemetry over the calibration site of Venice has also been processed, in order to point out the advantage of an on-ground estimation of waveforms parameters. Figure 1 shows the estimation of the satellite altitude above the sea surface, from which a bias and a slope (modelising the orbit) are removed, for three paths over the calibration site.

On the left, it concerns the on-board estimation (20 Hz), derived from the height tracking loop (HTL) outputs. On the right, it concerns the off-line estimation (10 Hz), obtained from the on-ground estimation of the waveforms parameters. Due to biases removal, only a relative comparison is available. The off-line estimation provides a smoothed measurement of the "geoïd", while high drifts coming from a bad choice of HTL gain values, are visible for on-board estimation. A new set of gains is used since 24 January 1991, but the on-board compromise between tracking and estimation functions remains inevitable.

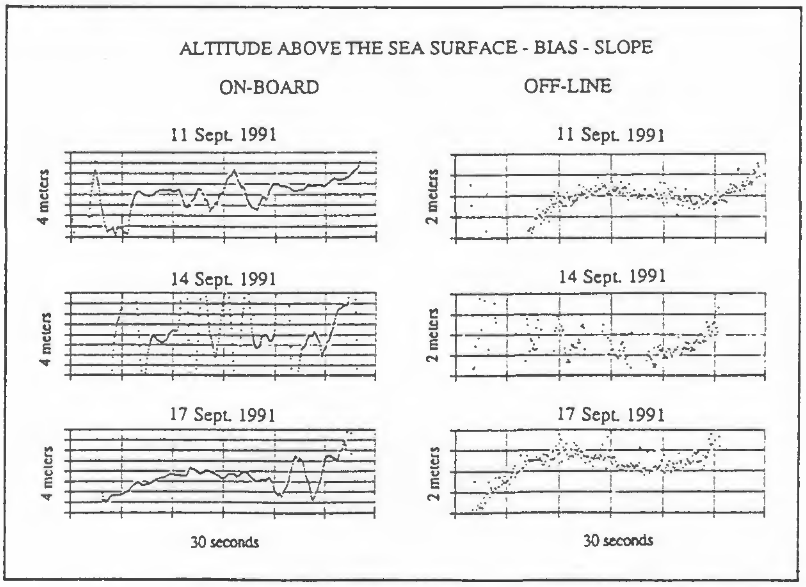

Figure 1

3.2 - Algorithmic validation

Algorithmic validation mainly refers to the estimation of waveforms parameters and to ocean-non ocean sorting. These two algorithms have been set and validated from the previous analysed raw data set. Validation of the other algorithms will be described in next sections.

- **Estimation of waveforms parameters**

For each elementary measurement (20 Hz) in ocean tracking mode, the following altimetric parameters are estimated from waveforms (see figure 2):

- the signal epoch τ
  (position of the waveform with respect to the center of the observation window, allowing a fine estimate of the pulse's round trip time, and hence of the satellite altitude)
- the significant waveheight H1/3
  (derived from the slope of the leading edge, directly related to the standart deviation of the heights distribution of the surface reflectors)
- the level of the trailing edge P_u
  (allowing the backscatter coefficient estimate, depending on the surface roughness on a small scale)
- the level of the first plateau P_b
  (it means the thermal noise level)

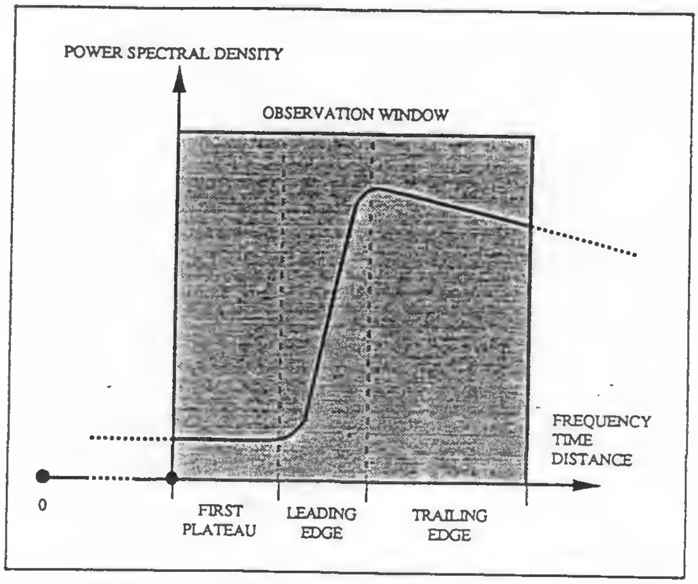

Figure 2

τ, H1/3 and P_u are estimated from an iterative algorithm derived from maximum likelihood estimators (MLE), while P_b is an average of samples of the first plateau.
As an example, figure 3 represents altimetric parameters estimation as a function of the elementary measurements row, for a raw data set of 1520 source packets. These estimations are satisfactory.

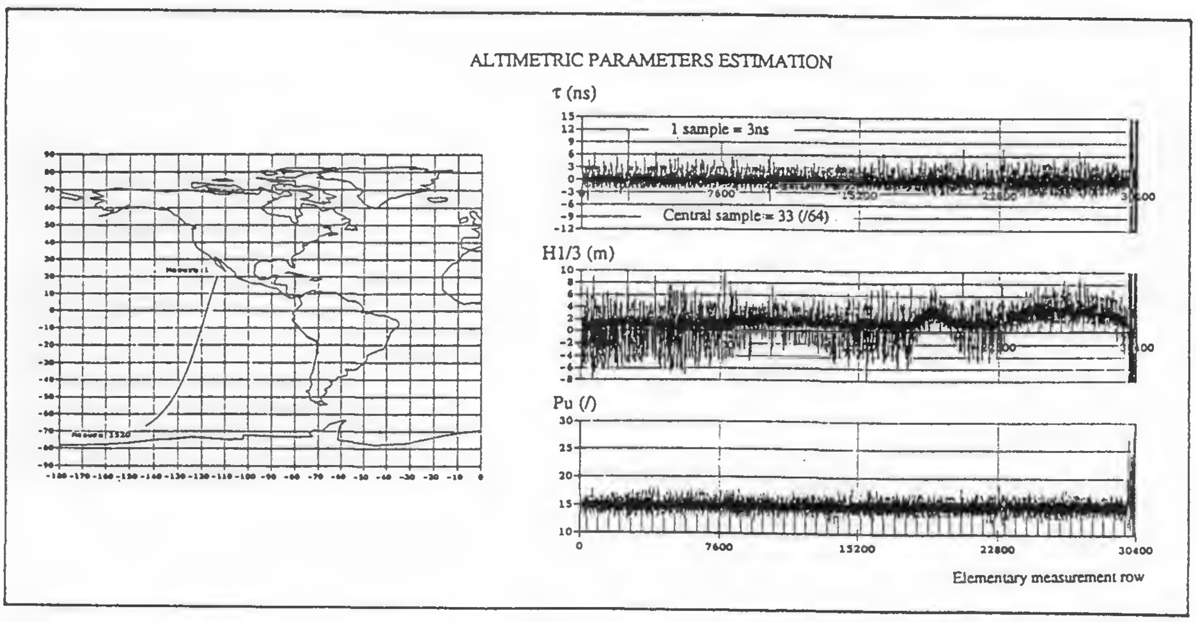

Figure 3

Out-lying data at the end of the data set are due to measurements over ice (corrresponding waveforms being no more consistent with Brown's model). The **epoch**, globally centered on zero, expresses a slight bias of the on-board tracker. The peak to peak variation is about 2 samples (90 cm). Due to speckle and spectrum sampling, the **significant waveheight** variability increases with the leading edge slope (a high slope of the leading edge corresponding to a small waveheight). Negative estimations will become positive after averaging and correcting. The **power level** is globally centered on 15 FFT units, which is correct as the on-board tracker aims at holding the center of the leading edge at $P_{ref} = 7.5$. Periodical null values correspond to internal calibration sequences. As for thermal noise, it is always null as explained previously, and the number of iterations is globally centered between its minimal and maximal values (3 and 10), the convergence criterion being a difference smaller than 5 mm between two sucessive estimates of the epoch.

- **Ocean-non ocean sorting**

It is done for each elementary measurement (20 Hz) considered as "ambiguous" by the continent file, or considered as "ocean" with a latitude out of [-45°,45°]. Previously, the processing consisted in comparing four estimates with respect to couples of thresholds. It concerned: the automatic gain control (AGC); the normalised mean quadratic error (NMQE) between the measured waveform and its corresponding model built from (off-line) altimetric parameters estimation; the resulting pitch and roll mispointing derived from the waveform trailing edge slope (attitude); and its temporal evolution. Due to instrumental errors which cannot be accurately corrected (as the anti-aliasing filter effects on waveforms), and to a too high noise level, the estimate of attitude from waveforms is foresaken.

So, on one hand, ocean-non ocean sorting is based on two criterions only (AGC, NMQE); on the other hand, corrections of the effect of a mispointing error on waveforms, will not be applied to the estimated physical quantities (altitude, waveheight, backscatter coefficient). A measurement is "non ocean" if AGC or NMQE values exceed stated brackets. Thresholds were set thanks to a rough theorical knowledge of corresponding validity fields, and to the analysis of temporal evolutions of AGC and NMQE, and of waveforms. Ocean-non ocean sorting is satisfactory.

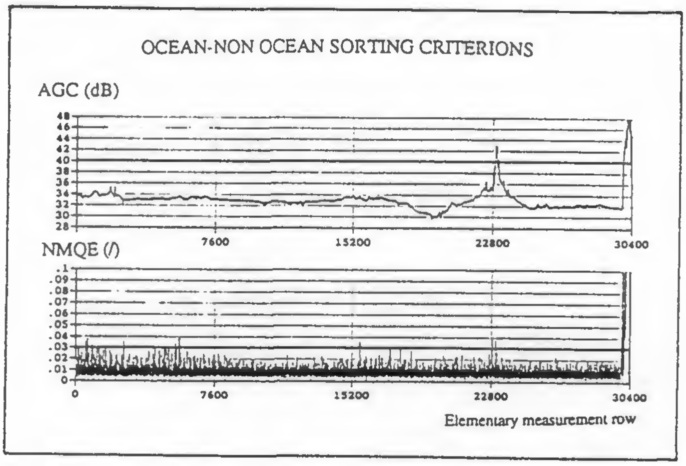

Figure 4

As an example, figure 4 represents AGC (dB) and NMQE, as a function of the elementary measurement row, for the data set mentionned in previous section. Threshold values are set to 27 and 40 dB for AGC, 0 and 0.03 for NMQE. Periodical null values are due to internal calibration sequences. Some examples of measured waveforms and their model are given in figure 5. It concerns ocean and ice measurements (due to aliasing, models are defined on 54 samples only, instead of 64).

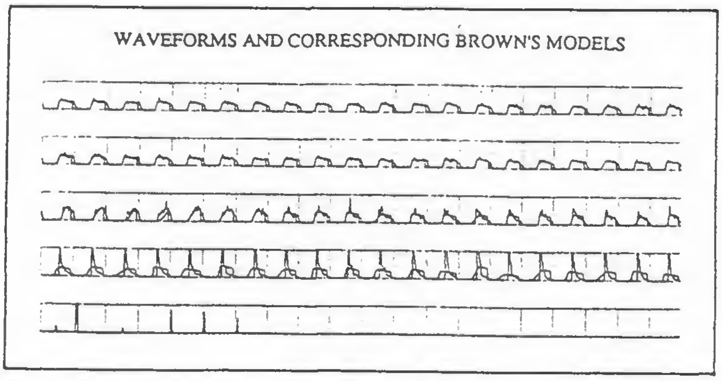

Figure 5

3.3 - Monitoring of OIP

Several checks were applied to OIP parameters. It concerns statistics over measurements and analysis of physical quantities (histograms of raw parameters, corrected parameters and corrections; along track visualizations). Processed data were composed of the OIP derived from the 9000 analysed source packets (see previous sections), and of about 100000 measurements from 8 to 10 August 1991 (OIP version 1.7). The main results are described in this section.

- **Statistics over measurements**

Figure 6 represents the valid measurements between 8 and 10 August 1991. Three reasons explain the small amount of data. Firstly, a lot of raw data were not received in CERSAT center (pass file lacking). Secondly, the continent file was erroneous, and several data were eliminated by the processing (longitudinal strips holes). These problems are solved today, exepted for the acquisition of raw data from Prince Albert station. Thirdly, an ice mode sequence begun on 9 August 1991 (21h.).

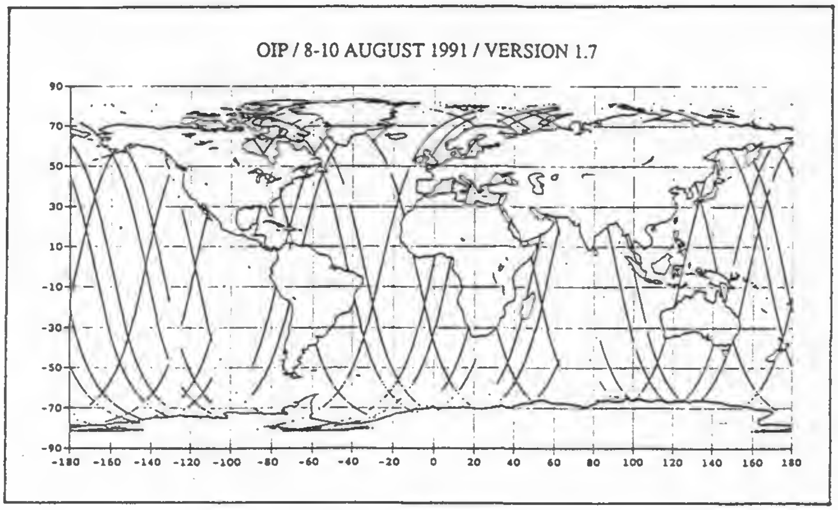

Figure 6

1262 OIP were analysed, corresponding to 92958 effective measurements (small amount because of ice mode). The averaged number of "ocean" elementary measurements (20 Hz) per 0,98 second measurement is about 19,2.

The cause of invalidation of a measurement may be:

- acquisition
- non acquisition / over land
- non acquisition / non over land / declared as non ocean
- other functionning mode
- telemetry lacking or invalid

Invalid measurements being not located (version 1.7), we represent as an example on figure 7, the location of the last measurement preceeding "non acquisition / non over land / declared as non ocean" sequences. It leads to confirm the accuracy of ocean-non ocean sorting.

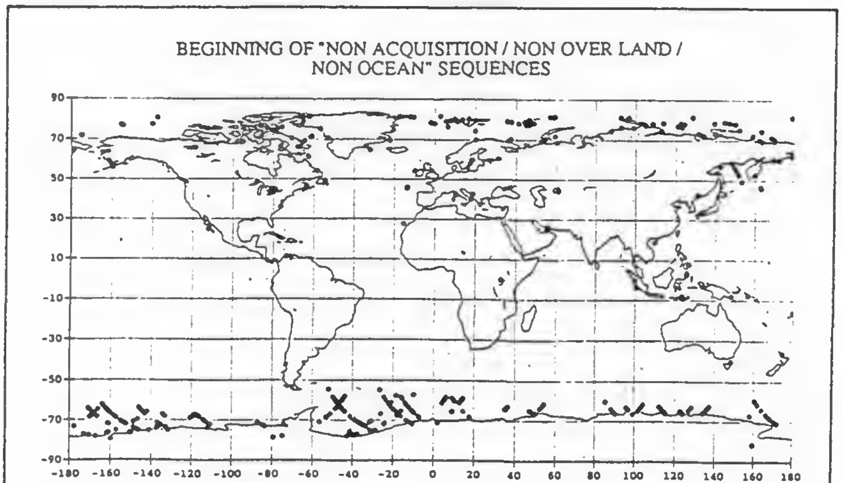

Figure 7

This kind of analysis was applied to each cause of invalidation, and allowed the correction of some errors (for example ice mode measurements which were considered as "non ocean" instead of "other functionning mode"). Processing will be modified in order to locate invalid measurements, and further investigations will be the managed to validate the assigning of invalidation causes.

- **Satellite altitude above the sea surface**

Figure 8 represents the histogram of the altitude standard deviation, computed from ocean elementary measurements (20 Hz) over 0,98 second. Processed data are OIP from 8 to 10 August 1991.

The altitude standard deviation is globally centered on 13 cm, which expresses a standard deviation over 1s. averaged measurements of about **13/√20 = 3 cm**, under the assumption that elementary estimates are totally decorrelated. In fact, on-board Hamming weighting correlates measurements by increasing the point target response width, and the value of 3 cm must be considered as an optimum. A precise estimation of the measurements noise level should be derived from spectra, computed from the height difference between two repetitive paths (see section "geophysical level validation").

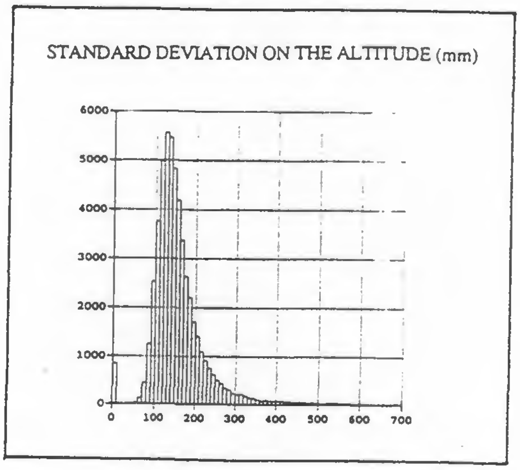

Figure 8

Figure 9 represents the histograms of the internal calibration corrections, and of the instrumental corrections by look-up tables, on the altitude. Open loop calibration aims at measuring thermal effects on the altitude and backscatter coefficient measurements, by the way of the point target response, while look-up tables take into account the effect of the (uncalibrated) anti-aliasing filter on waveforms. The histogram of internal calibration corrections expresses a high thermal stability of the instrument (the peak to peak variation of the correction being about 2,5 cm). As for the instrumental correction, its nominal value is about 2 or 3 cm, and reaches 10 cm for high waveheights (greater than 10 meters).

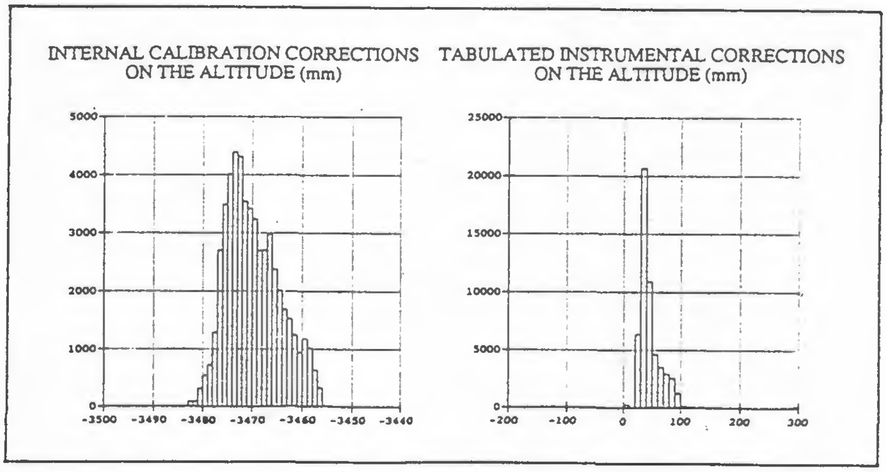

Figure 9

About stability, the ultra-stable oscillator (USO) drift will be further taken into account, as well as the measured position of the satellite center of gravity (COG) with respect to the satellite. Anyway, the USO drift does not seem to be significant since the first two months of the mission, and the COG position remains relatively stable. In terms of precision, the instrumental biais derived from the Venice calibration campaign (192 mm) is taken into account in OIP processing since version 2.1.

- Significant waveheight and backscatter coefficient

The analysis of these parameters (OIP version 1.7) pointed out a problem relative to their computation. Indeed, although the histogram of significant waveheights is globally centered on 2 meters, a lot of values remain null (negative or null before storing in OIP), even after correcting by the instrumental look-up table. On the other hand, the backscatter coefficient distribution seems to be globally consistent, but biased. The backscatter coefficient could be overestimated of about 3 dB, since its averaged value for 2 meters waveheights reaches 14 dB.

Further investigations are managed by the way of comparing OIP and FDP (see concerned section).

About stability, figure 10 represents the histogram of the internal calibration corrections on the backscatter coefficient. Its peak to peak variation is about 0,1 dB, which expresses a high thermal stability of the instrument.

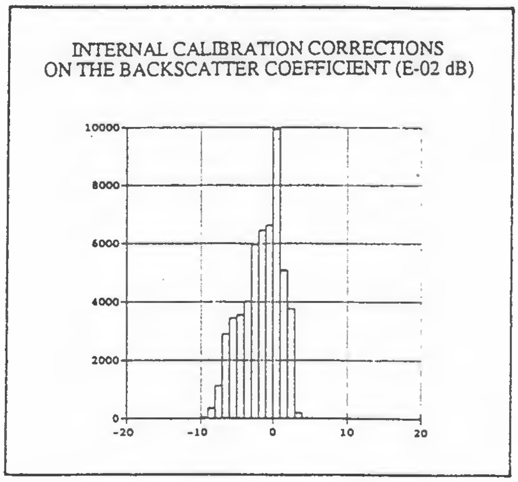

Figure 10

Finally, figure 11 provides an example of along track visualization of both significant waveheights and backscatter coefficients. Excepted for the problems above-mentionned, the global behaviour of these estimates is satisfactory.

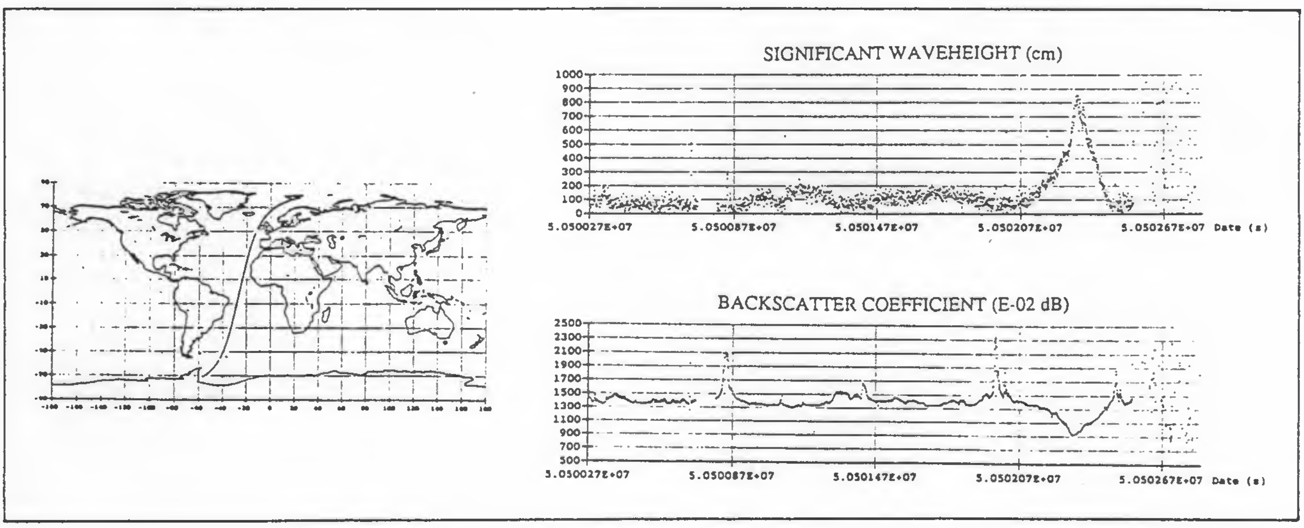

Figure 11

3.4 - Comparison between OIP and FDP

Processed data consist of two consistent data sets, recovering the period from 27 November 1991 to 30 November 1991. It concerns 1968 OIP (version 1.8) and 3783 FDP (found validated by ESA).

- Backscatter coefficient

OIP and FDP measurements are consistent (both being corrected for instrumental effects), and are therefore directly comparable after co-locating.

In consideration of the temporal evolution of backscatter coefficients, co-location simply limits to associate OIP and FDP measurements, whose temporal discrepancy is smaller than half a measurement (about 0,49 s). Only valid measurements, built from 20 ocean elementary measurements, and such as the backscatter coefficient belongs to [-10, 40] dB, are taken into account. That leads to a co-located data set composed of about 86000 measurements, whose location is represented in figure 12 (data gaps were explained in a previous section).

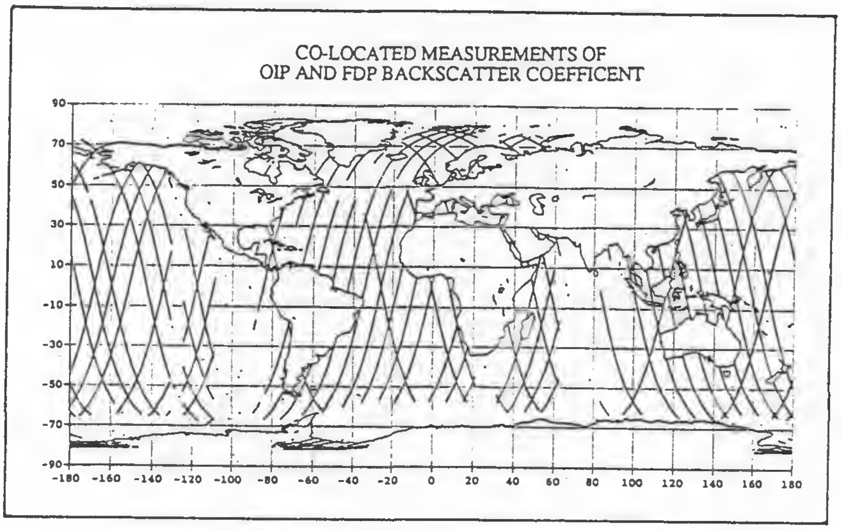

Figure 12

Figure 13 represents the histogram of OIP and FDP backscatter coefficients, of the corresponding discrepancies, as weel as the correlation between OIP and FDP measurements. A non negligible amount of differences between OIP and FDP measurements are centered on about 1,8 dB. It finds expression in a small peak on the corresponding histogram, and in a paralell curve on the correlation plot.

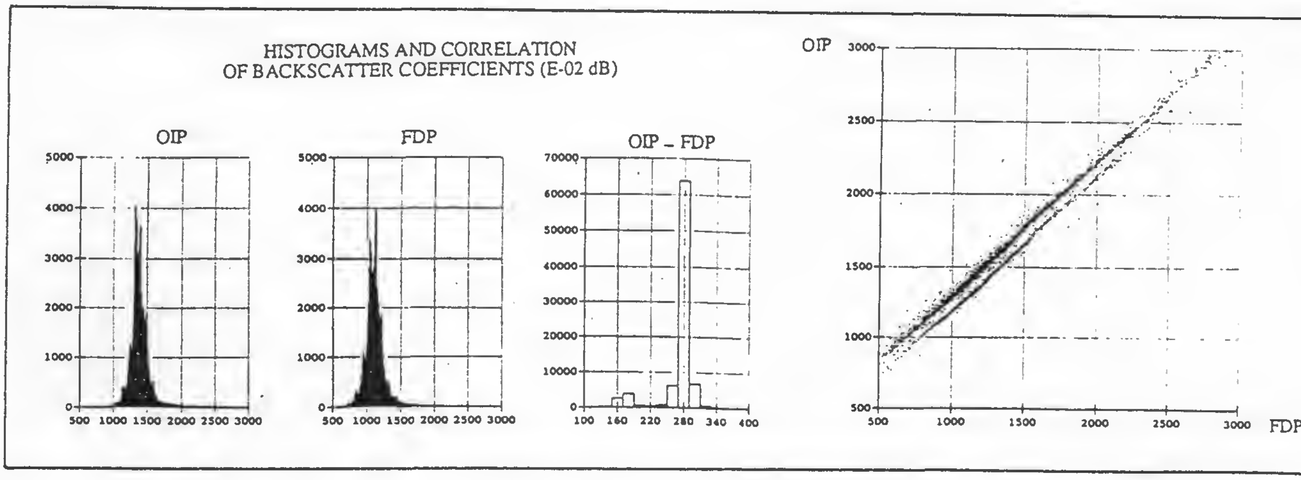

Figure 13

The analysis of FDP pointed out an inconsistency between software versions (according to stations). As shown in figure 14, all the above-mentionned discrepancies correspond to an out-of-date software version of FDP processing.

The discrepancy between OIP and FDP measurements may therefore be considered as a **2,8 dB bias.** As FDP backscatter coefficients are calibrated by ESA, (FDP winds computed from backscatter coefficients with "Witter & Chelton" model, being consistent with ECMWF WAM global meteorological model), we consider that OIP backscatter coefficients are over-estimated.

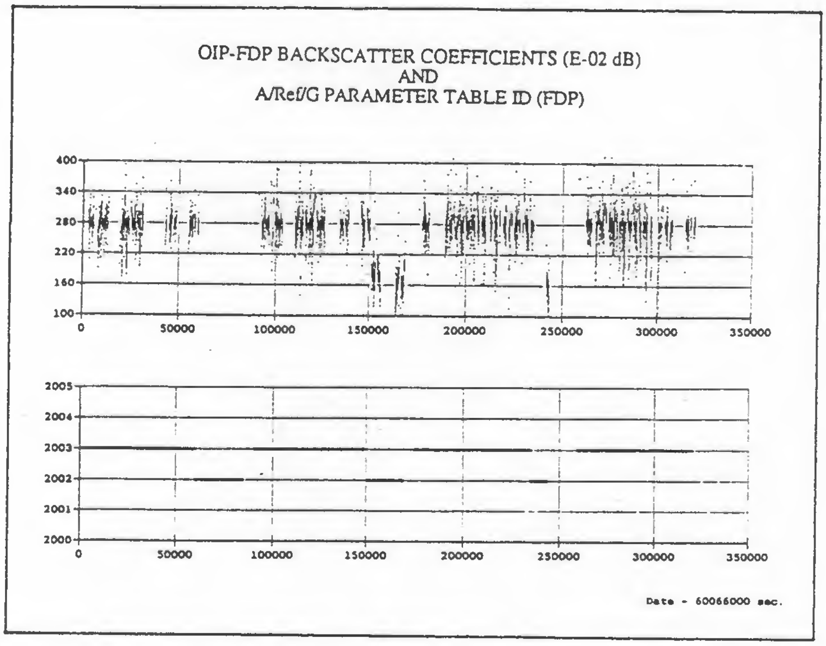

Figure 14

This over-estimation seems to come from an inaccurate or incomplete measurement of instrumental features. Since version 2.1, a bias of 2,8 dB is systematically removed to OIP backscatter coefficient estimates, which become globally consistent with FDP estimates.

- **Significant waveheight**

The comparison principle is quite similar to the one described for backscatter coefficients. The resulting co-located data set (built from valid measurements, containing 20 ocean elementary measurements, and such as the significant waveheight belongs to [0,20] m), is composed of about 85000 measurements. Their location is roughly consistent with figure 12.

Figure 15, which represents the histogram of OIP and FDP significant waveheights, and of the corresponding discrepancies, expresses a great difference between OIP and FDP measurements. FDP measurements being validated (it means consistent with ECMWF WAM global meteorological model, as demonstrated by ESA), we looked for and found an error in OIP processing. It concerned the value of the point target response half-width (σ_p), which was set to 2,3124 ns instead of 1,9295 ns (value provided by ESA).

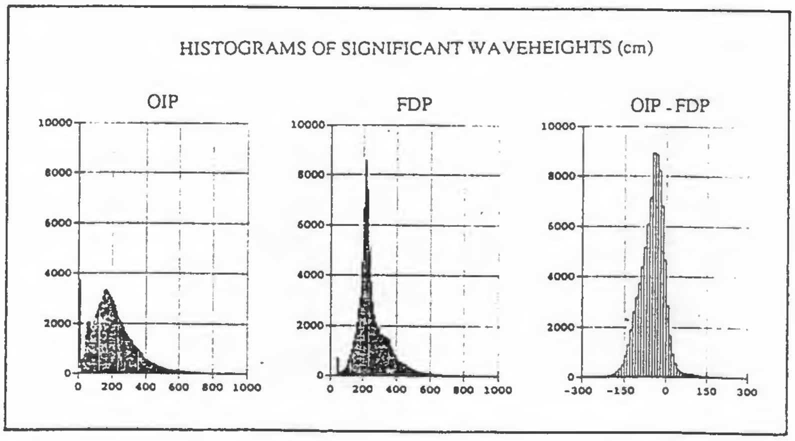

Figure 15

The impact of the corresponding correction is shown in figure 16 from a reference data set corresponding to 116 OIP. Its main features consist of a decrease of the amount of null and small significant waveheight estimates, of a slight shift to the right, as well as an increase of the histogram peak.

These observations, applied to OIP histograms represented in figure 15, tend to make OIP measurements consistent with FDP ones.

This correction is taken into account in OIP processing since version 2.1. (Note that instrumental correction look-up tables were updated, but remained sensibly identical with previous ones). Further comparisons will be done from up-to-date OIP, in order to confirm the consistency between OIP and validated FDP measurements.

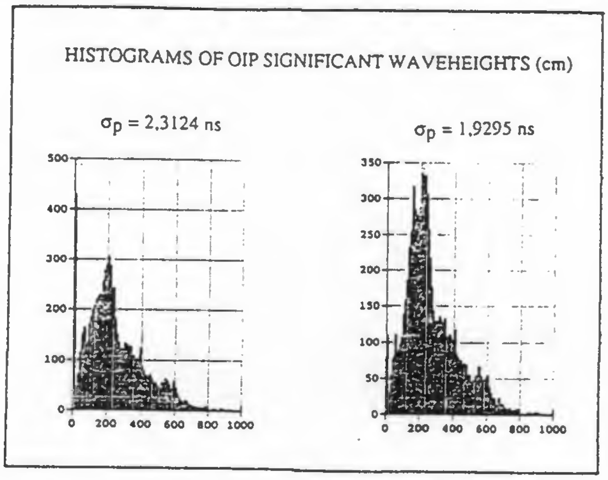

Figure 16

- **Satellite altitude above the sea surface**

The comparison is done from two data sets (OIP and FDP) composed of valid measurements, containing 20 ocean elementary measurements, and such as the altitude belongs to [740, 830] km. In consideration of the temporal evolution of altitude (dh/dt varying between -25 and +25 m/s), co-location of measurements must be very accurate. OIP and FDP measurements such as the corresponding temporal discrepancy does not exceed 98 ms (the duration of two elementary measurements), are associated. For each so-built couple of measurements, OIP altitude is computed again at the FDP measurement date, by linear regression from 10 Hz elementary measurements. The consistency between OIP and FDP estimates is obtained thanks to four operations: correction of the OIP datation over-estimation (about 4,9 ms in version 1.8), removal from FDP estimates of ionospheric and (wet and dry) tropospheric corrections, adding to FDP estimates of the distance between the antenna reference point and the satellite COG, and adding to OIP estimates of the USO drift correction. A co-located data set of about 86000 measurements was built in that way.

A comparison of OIP and FDP measurements in a restricted area (Aleoutian islands / North Pacific) allowed us to verify the accuracy (due to the off-line estimation of waveforms parameters) of OIP estimates nearness coastal areas, and to monitor all the OIP parameters related to altitude (10 Hz elementary measurements, corrections ..).

The difference between OIP and FDP altitude estimates over the whole data set is represented in figure 17. It globally varies between 10 and 20 cm, exepted for three sequences where its averaged value is about - 50 cm. It concerns the problem of inconsistencies between FDP software versions according to stations (already mentionned in the backscatter coefficient comparisons section) .

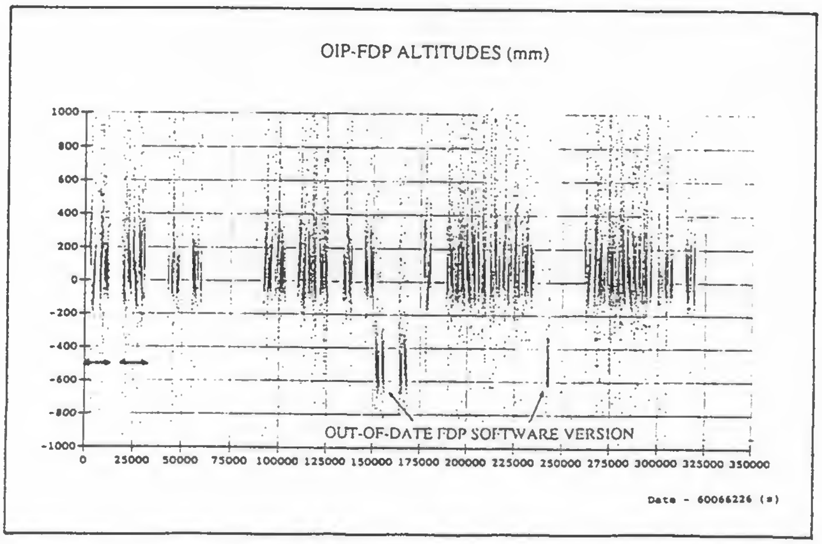

Figure 17

The likeness of remaining sequences induced us to analyse more precisely the first two ones (underlined in figure 17). Conclusions being identical for both sequences, the following section describes the results concerning the second one only, whose location is represented in figure 18.

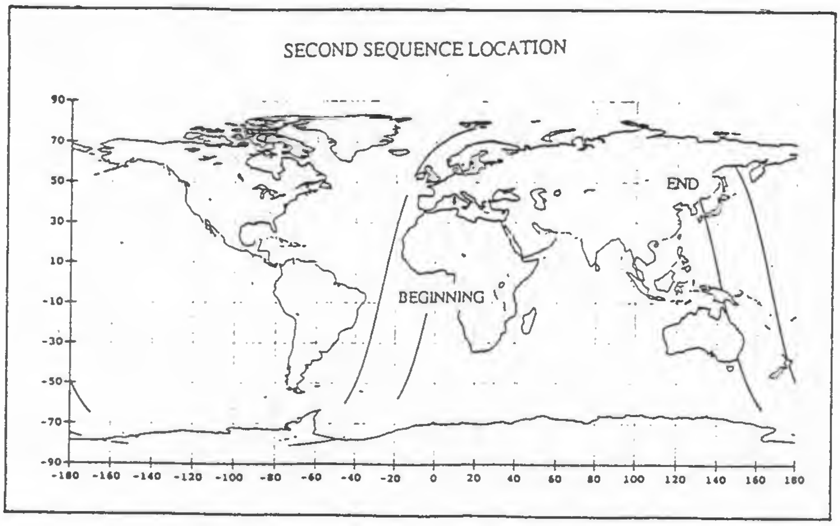

Figure 18

Figure 19 represents the differences between OIP and FDP altitude estimates, as well as the corresponding vertical speed (dh/dt). Changes in on-board / universal time relation in a processing (OIP or FDP), are marked with black points. They involve universal time relative discrepancies between OIP and FDP of about 1,71 ms, 1 ms and then 2,36 ms (see figure 19). (These kinds of discrepancies reached -6,17 ms for the first analysed sequence). To each temporal relative discrepancy between OIP and FDP, corresponds a relative dating bias, and hence a difference between altitude measurements depending on vertical speed.

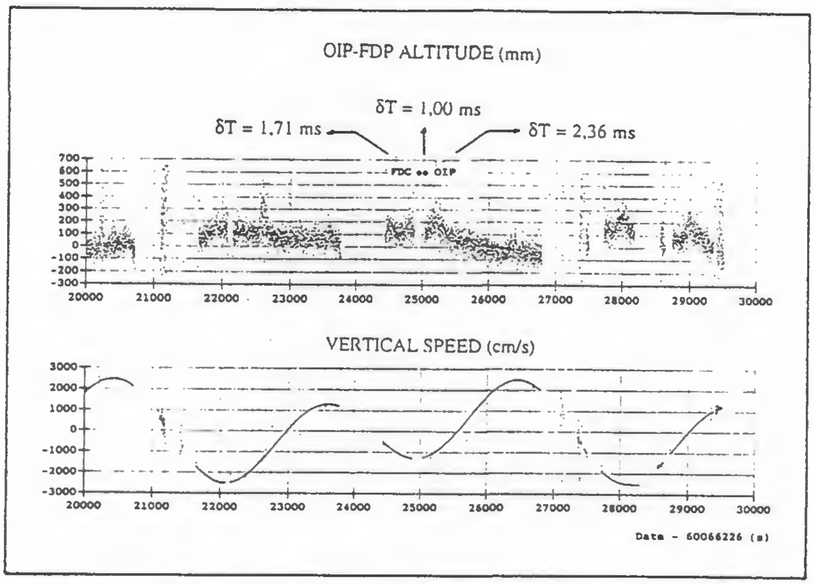

Figure 19

OIP datations are modified (by adding of a relative bias) to become consistent with FDP ones (see figure 20). On the other hand, updated OIP instrumental corrections by look-up table are applied (the correct value of the point target response half-width being taken into account: see comparison of significant waveheights). The resulting difference between OIP and FDP altitude estimates looks like a linear function of significant waveheight, as shown in figure 20 (the ratio between altitude differences and FDP significant waveheight being about 2,6 %)

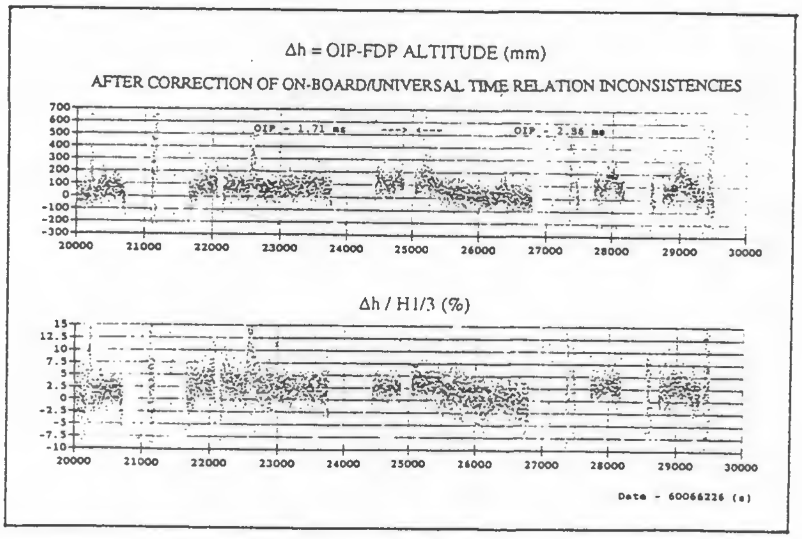

Figure 20

2,6% of significant waveheights are then removed from OIP altitude discrepancies, which become globally constant. A detailed analysis of the correlation between altitude discrepancies and vertical speed estimates, pointed out a residual dating error of about 1,5 ms.

Figure 21 represents the final result of this study. The difference between OIP and FDP altitude measurements is globally constant, centered on zero, with a peak to peak variation of about 20 cm, if:

- inconsistencies between OIP and FDP on-board/universal time relation are taken into account
- 2,6%.H1/3 are removed from OIP altitude estimates (or added to FDP ones)
- a residual dating error (about 1,5 ms) is removed from OIP measurements (or added to FDP ones).

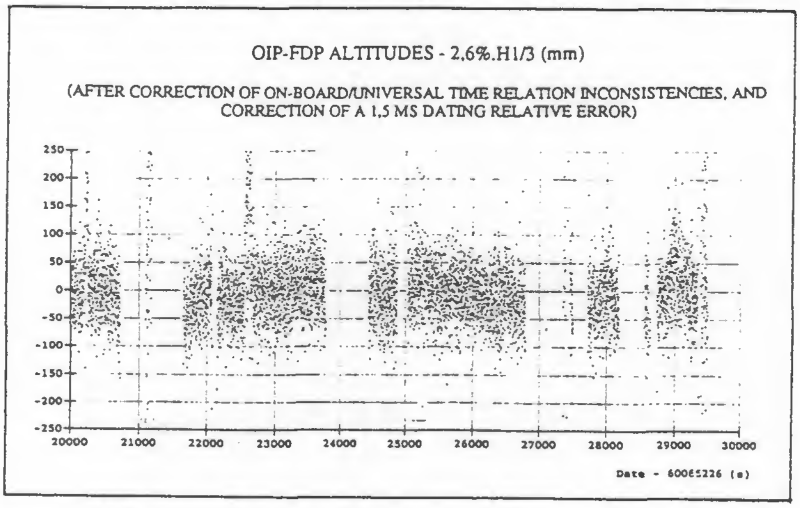

Figure 21

On-board/universal time relation inconsistencies, which express as random errors up to 10 ms, with a standart deviation of about 3 ms, seem to come from an incorrect transcription from the "European Space Operation Center" (ESOC), relations being correctly estimated at Kiruna. In order to reduce their impact on altitude estimates (a dating error of 1 ms corresponding to an altitude error varying from -2,5 cm to 2,5 cm over the orbit), an improvment is done in OIP since version 2.3 (interpolation of these relations). The true relations (from launch) are available since early October 92. They should be taken into account in CERSAT processing of 35 days measurements.

As for the other corrections, the following problems are posed :

- what is the meaning of the 2,6%.H1/3 correction ? does it express an electromagnetic bias correction in FDP ? does it concern an instrumental error inaccurately corrected in OIP or in FDP ?
- what is the meaning of the 1,5 ms dating relative error ? is it an OIP error, a FDP error, or both ?

4 - RADIOMETER "INSTRUMENTAL LEVEL" VALIDATION

CERSAT delivers two products from the Along Track Scanning Radiometer and Microwave sounder (ATSR/M): the "instrumental" MBT (Microwave Brightness Temperatures) product, and the "geophysical" VLC (Vapour and Liquid Contents) product.

VLC production is implemented in the altimeter geophysical level (OPR) processing software. Validation of the geophysical outputs of the ATSR/M is carried out by CNET/CRPE (Centre National d'Etudes des Télécommunications / Centre de Recherche en Physique de l'Environnement). Validation of the MBT processing has been made at CLS-Argos. The objectives of the validation was first, to check the quality of the input telemetry in order to be sure that the algorithms were convenient, and second, to check the direct or intermediate outputs of the processing in order to track possible software errors and correct them.

The conclusions of this "first level" assessment study is the following :

- the instrument is performing well for both 23.8 and 36.5 GHz channels : output numerical counts from antenna, sky-horn and hot load, and internal temperatures measurement system are nominal.

- high values of brightness temperatures are recorded over sea ice and (probable) rain, resulting in unrealistic values of water vapour and liquid contents in VLC product, and of wet tropospheric correction in OPR product. The present rain/ice flag in the MBT, VLC and OPR products is not efficient. However, for OPR, most of these unrealistic values can be rejected using the altimeter quality parameters (number of averaged elementary (20 Hz) measurements, standard deviation on altitude).

- liquid water content has negative values most of the time, indicating probable bias in the algorithm. Consequence is that in OPR, sigma-nought and windspeed corrected for cloud attenuation are suspect.

5 - ALTIMETER "GEOPHYSICAL LEVEL" VALIDATION

Planned validation activities were the following :

- wet tropospheric (model and radiometer) corrections intercomparison
- ionospheric correction performance evaluation
- sea surface height validation
- crossover analysis
- altimeter noise evaluation
- sigma-nought to wind transfer function study.

These activities have been performed with the first available OPR products (three 3 days cycles from August 1st to August 9th), received at the beginning of April 1992, and corresponding to the 1.8 version of OIP software. Considerable gaps exist in the data due to errors in this software version. Dramatic datation errors are present : a small part of them due to OIP software errors has been corrected in version 1.9, the largest part of them due to errors in the on-board to UTC correspondance functions, remains in the present 2.4 version. All these problems may cause the present OPR assessment not conclusive. However, as far as the OPR processing is concerned, the consistency of each parameter has been checked, so that the OPR products will be "good for use" as soon as the present remaining datation problems are corrected.

5.1 - Wet tropospheric corrections intercomparison

Figure 22 shows the radiometer wet tropospheric correction against the model wet tropospheric correction for the first three days of August 91. There is a good agreement between the two corrections, indicating that there is no systematic error on one of them (relative to the other one). RMS and STD of the difference between the two corrections are 41 mm. High radiometer values corresponding to the low model values are due to sea ice in the radiometer field of view. Most of such sea ice cases can be suitably filtered by setting thresholds on altimeter altitude standard deviation, but figure 22 shows that despite these thresholds some sea ice cases remain. High radiometer values around 300 mm model values are probably due to rain in the radiometer field of view. As these false high radiometer values are in the OPR data, the user should have to reject them using thresholds on the wet tropospheric correction itself.

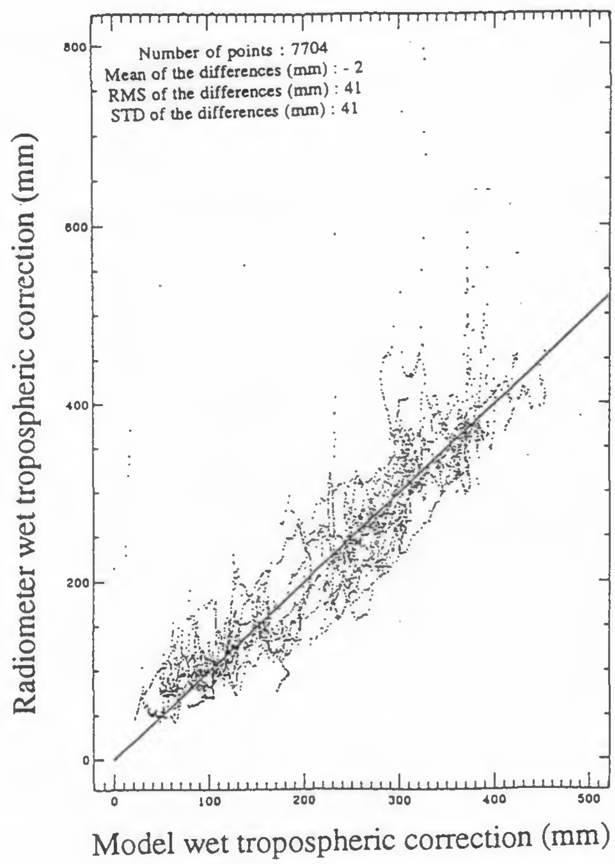

Figure 22

5.2 - Ionospheric correction evaluation

Comparisons have been made between the ERS-1 OPR ionospheric correction (use of BENT ionospheric model together with monthly mean sunspot numbers), and, first, ionospheric correction derived from 12 Faraday stations, second, ionospheric correction derived from 12 GPS stations of the CIGNET network. Conclusions confirm the well known poor representation of the ionosphere by this model, leading to errors up to 10 cm in the tropical regions.

5.3 - Sea surface height evaluation

This activity was twofold :

- compare the altimeter derived SSH with a reference mean sea surface, in order to make sure that the altitude is correctly computed
- caracterize altitude outliers.

Comparison has been made using the Marsh mean sea surface: the two SSH's showed general relative agreement excepted in regions of rapid geoid variations, where the mean sea surface does not match the real surface anymore. Figure 23 shows two maps: on bottom, measurements declared as being outliers, based on a procedure looking at the likelihood of the along track altimeter profile; on top, measurements declared as being valid by the procedure. Data used are the first three days of August 91. Percentage of outliers is 2.9%, for 50000 measurements. Most of outliers are located at sea to ice or sea to land transitions.

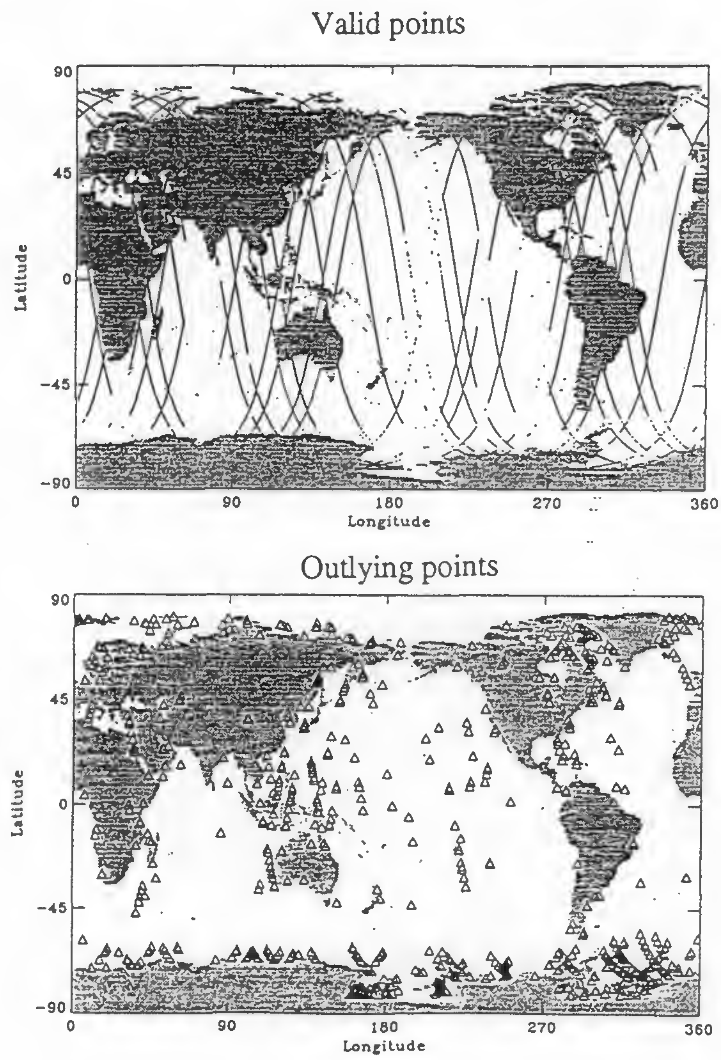

Figure 23

Figure 24 shows the same two maps obtained by simply using thresholds on the number of elementary measurements N and the altitude standard deviation Σ (if $N < 3$ or $\Sigma >$ 50 cm, point is oulier). Percentage of outliers is 3.5 %. The bottom map shows similar geographic patterns as the bottom map of figure 23, thus indicating that these two quality parameters are convenient for editing the data.

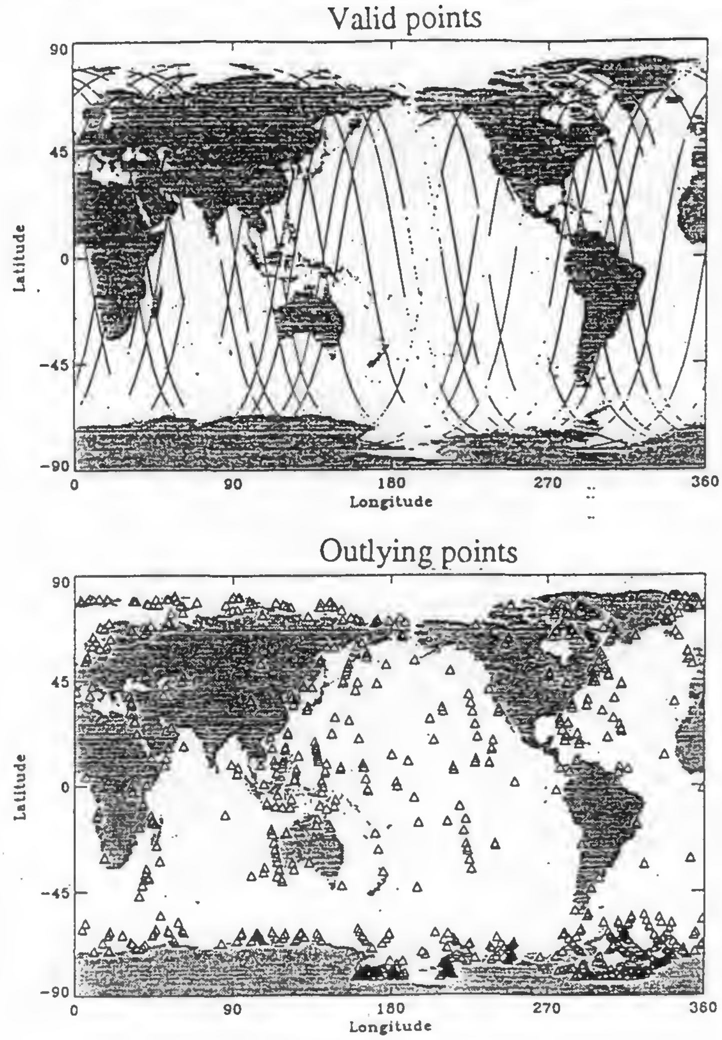

Figure 24

5.4 - Crossover analysis

A crossover analysis has been implemented in order to assess the magnitude of the orbit error together with the performance of the geophysical corrections. Figure 25 shows the histogram of the crossover differences for the first 9 days of August 91. RMS is 2.27 m. The expected accuracy of the precise orbit provided to CERSAT by G-PAF is below 1 m . Such a large RMS value is due to datation problems in the altimeter data, which are particularly dramatic in the first three days of August. Same analysis carried out using data from August 4th to 9th lead to a RMS value of 81 cm. However, only about 200 crossovers were available for this period which is too low to perform a precise analysis.

Figure 25

5.5 - Altimeter noise evaluation

An attempt has been made to evaluate the altimeter 1s averaged altitude measurements noise level. Spectra of SSH differences between three days repeat tracks for 7 different tracks have been computed and averaged together to obtain the averaged spectrum shown on figure 26 . The noise level can be estimated by considering the portion of the spectrum corresponding to white noise, associated with wavelenghts between 13 and 70 km. Integrating the spectrum below this noise floor leads to a 5.4 cm noise, which is a quite high value compared to the expected 1s noise of 3 to 4 cm which can be deduced from the altitude standard deviation. Again, datation problems may cause the present approach fail.

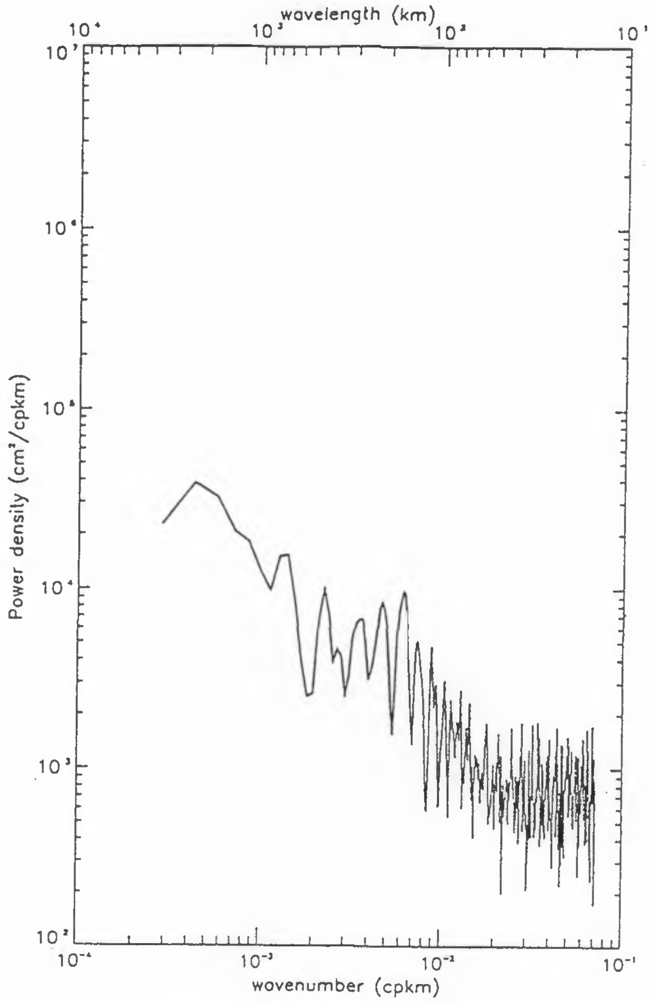

Figure 26

5.6 - Computing wind from sigma-nought

In OPR software versions up to 2.5, wind is computed from sigma-nought using the Chelton and Wentz tabulated values. A study is underway to compare the OPR wind with the french Met office PERIDOT fine mesh model wind analyses, and to calibrate the OPR sigma-nought to wind relation by using this model output. Preliminary results show that more data need to be processed to get the proper relation.

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J-P DUMONT has been in charge of the definition and specification of ERS-1 altimeter off-line instrumental level algorithms (since 1985), and involved in the follow-up of the corresponding operational software development and acceptance testing. He is now working on the validation of the OIP processing and products. He will continue to be involved in CERSAT project by performing routine data quality control and algorithms improvement.

J STUM has been in charge of the definition and specification of ERS-1 radiometer and altimeter (geophysical level) off-line algorithms (since 1985), and involved in the follow-up of the corresponding operational software development and acceptance testing. He is now working on the validation of the MBT and OPR processing and products. He will continue to be involved in CERSAT project by performing routine data quality control and algorithms improvement.