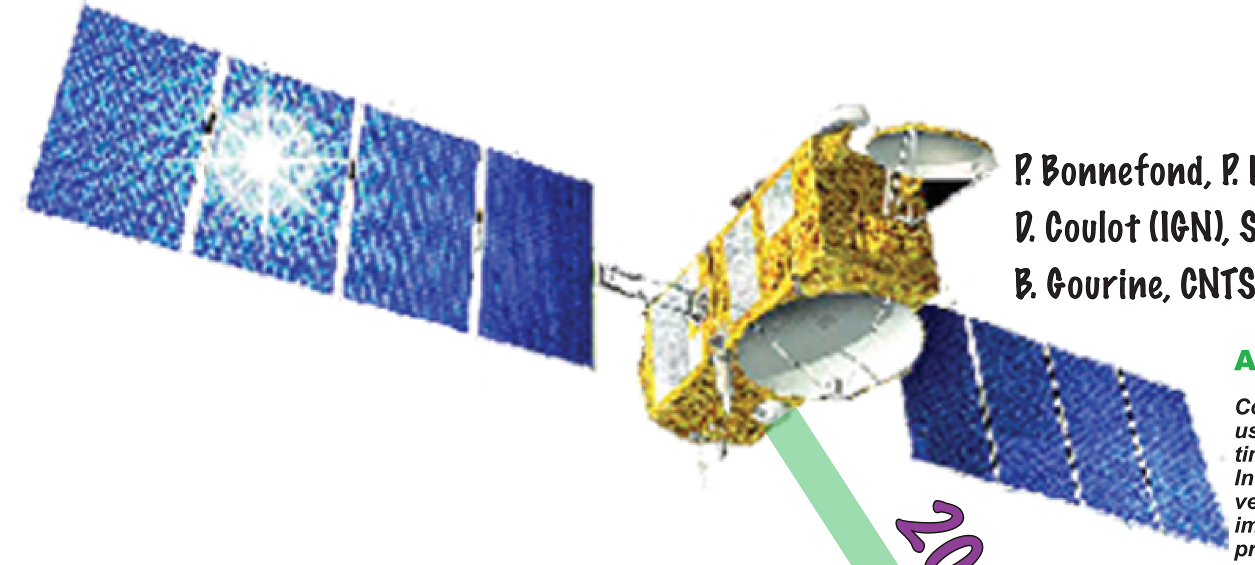

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Validation Activities for Jason-1 and Topex/Poseidon Precise Orbits

ABSTRACT

Considering the 1 cm challenge to be reach for the global determination of the orbit of altimeter satellites using DORIS and/or GPS measurements, we plan to evaluate the accuracy of the Jason-1 and TOPEX/Poseidon (T/P) precise orbits using Satellite Laser Ranging (SLR) data. Above the Europe area and, as a consequence, above the Mediterranean sea where several calibration/validation sites have been or will be installed in the next future, the fact that the orbit of both altimeters is largely covered by SLR is a very interesting aspect for altimetry.
In the frame of the Jason-1 GDR-B products, orbit validation of the new CNES precise orbit strategy (SLR+DORIS+GPS, GRACE gravity field, …) as well as new GPS-Reduced dynamic orbits (JPL) has been performed and analyzed. Moreover, in 2005, the French Transportable Laser Ranging System has been settled again for 6 months at Ajaccio. The goal with such a mobile SLR system, particularly with the choice of the Corsica Island as on site verification area, is to improve the orbit determination at the level of less than 1cm; and on a long-term basis, the goal is to maintain this accuracy. Results on the station coordinates determination and on the use of short-arc orbit determination in the calibration process will be presented.

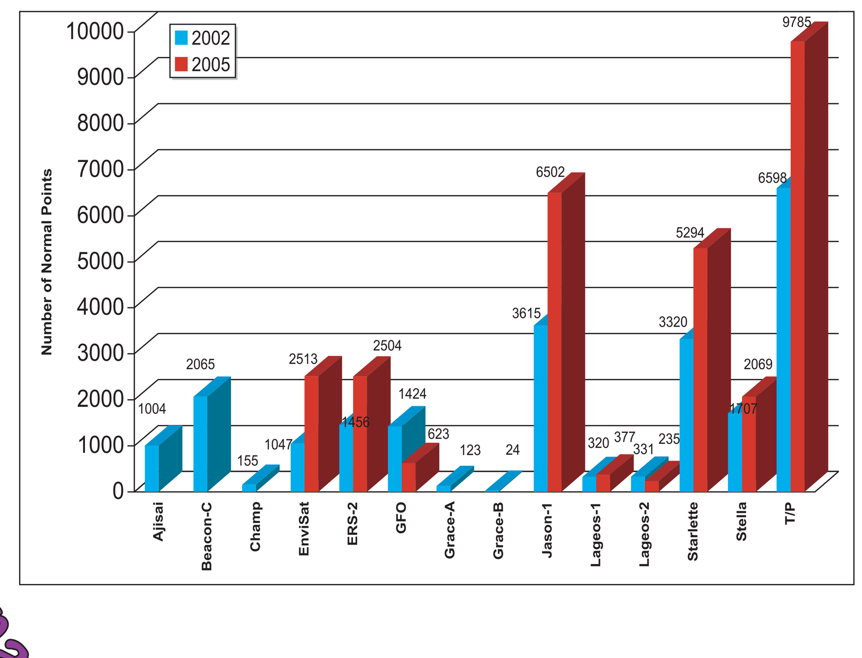
2005 FTLRS Laser Tracking Campaign at Ajaccio

Precise Orbit Analysis Through Short-Arc Technique

OVERVIEW

We have developed a short-arc orbit technique [Bonnefond et al., 1995] for the validation of altimeter satellite precise orbits. It is based on SLR data, and on rigorous geometrical adjustment criterions. These developments and capacities have been installed on a dedicated Internet site: http://grasse.obs-azur.fr/cerga/gmc/calval/pod/. The goal is to permit the quasi-immediate validation of Jason-1 and T/P orbits. Since the beginning of the Jason-1 mission, it is possible to use this site to evaluate a given orbit cycle or results of the overall missions; orbit and/or SLR residuals (eventually per station) are presented "permanently". The proper error budget of the method, being at the level of less than 1 cm, this has allowed us to study the radial orbit error, which appears above a given site. Thanks to a selective choice of SLR measurements, taking into account their intrinsic precision/accuracy, and the precision of the station coordinates of the SLR network (ITRF2000 solution), the error budget of the orbit validation has been reduced to 1 cm.

Bonnefond, P., P. Exertier, P. Schaeffer, S. Bruinsma and F. Barlier, Satellite Altimetry From a Short-Arc Orbit Technique: Application to the Mediterranean, J. Geophys. Res., 100 (C12), 25365-25382, 1995.



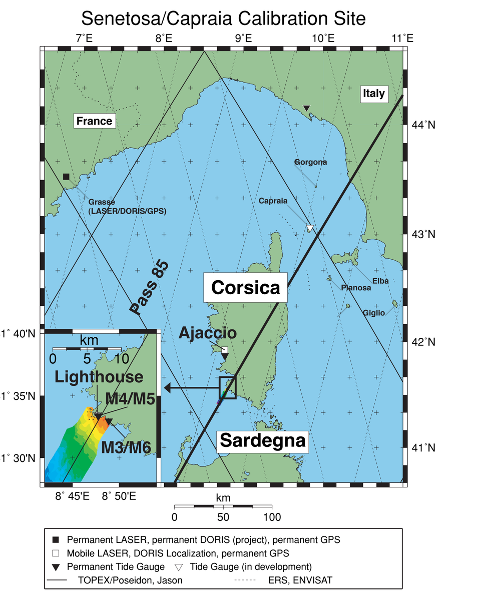
OVERVIEW

The French Transportable Laser Ranging System has been settled at Ajaccio from may to october 2005. This second campaign at the same location follows the 2002 campaign which has been realized during the Jason-1 validation phase. This aim of the 2005 is two-fold: first is to maintain the geodetic accuracy of this location and second is to provide high accuracy local orbits for the Jason-1 altimeter calibraton (Figure to the right).
The FTLRS is a highly transportable system and was set-up in about two days above the same marker than in 2002 (respective exentricities are given in Table 1).
In term of tracking measurements the 2005 campaign was very successfull with very short outages periods. The number of normal points acquired during the 2002 and 2005 periods are shown on the Figure to the left. For most of the satellites and especially for the ones with high priority (Jason-1, T/P, EnviSat, ERS-2) the number of observations is close to twice what we obtained in 2002.
In term of internal accuracy, the FTLRS was at the same level than in 2002 (no major modifications). Moreover, all the local geodetic mesurements have been realized (distance from the calibration target, link to permanent GPS, …).
In the following we will present results about the coordinates and range bias determination as well as an analysis of the FTLRS laser residuals using Jason-1 orbits.

Table 1. Excentricity (from marker to SRP)

	2002	2005
North [m]:	0.000	0.000
East [m]:	0.000	0.000
Up [m]:	1.8260	1.8504

Senetosa/Capraia Calibration Site



IMPROVEMENT FOR ALTIMETER CALIBRATION

Table 1. Impact of orbits on the statistics on Jason-1 altimeter bias

Orbit	Bias	Standard Deviation	Standard Error	Number
Old CNES POE	85	26	12	5
New CNES POE	90	19	8	5
JPL GPS-RD 06	94	16	7	5
Short-Arc	88	19	8	5

Table 2. Impact of orbits on the statistics on T/P altimeter bias

Orbit	Bias	Standard Deviation	Standard Error	Number
Old NASA POE	-10	29	8	14
New NASA POE	-23	26	7	14

Absolute calibration is very sensitive to systematic errors that affect the vertical components of the whole closure equation. In this study we have compared same altimetric data using different kind of orbits for Jason-1 and TOPEX/Poseidon satellites on the formation flight phase period (cycles 1-21 and 344-364 respectively):
Jason-1
- The old Precise Orbit Ephemerid (POE, GDR-A), CNES (SLR and DORIS data, JGM3 gravity field)
- The new Precise Orbit Ephemerid (POE, GDR-B), CNES (SLR, DORIS and GPS data, GGM02C gravity field)
- The GPS Reduced-Dynamic (GPS-RD 06), JPL (GPS data, GGM02C gravity field)
- The Short-Arc Orbit (SAO), GEMINI (SLR data)

TOPEX/Poseidon
- The old NASA POE (M-GDR, JGM3 gravity field)
- The new NASA POE (future GDR reprocessing, GGM02C gravity field)

Table 1 shows statistics on the Jason-1 altimeter bias for the different studied orbits. First of all the new CNES POE really shows an improvement in term of standard deviation with a decrease of 18 mm in term of root square difference compared to the old one. The same level of improvement is obtained with the Short-Arc orbits. The GPS Reduced-Dynamic orbits have the lower standard deviation with decrease of 10 mm compared to the new CNES POE or the Short-arc orbits.
Concerning the altimeter bias value itself, results are coherent at few millimeters (6 mm at maximum) for the new generation of orbits.
The maximum difference (9 mm) is obtained when comparing the old CNES POE and the latest realease of GPS Reduced-Dynamic orbits.
Table 2 shows the same statistics on the TOPEX/Poseidon altimeter bias (ALT-B) for the two studied orbits.
The level of improvement on the standard deviation is a little less (13 mm) than for Jason-1. Concerning the value of the altimeter bias itself, it decreases by -13mm so 8 mm more than between the old and new POE for Jason-1.
This study needs to be extended to a longer period of time to really state the real level of improvement and quantify the impact of the Geographically Orbit Errors.

COORDINATES DETERMINATION

Table 2. Geographical Coordinates Differences from published ones [Exertier et al., 2004]

	δφ	δλ	δh
2002	+0.5 ±0.7	2.7 ±0.7	-1.2 ±0.8
2005	+4.1 ±0.4	-2.9 ±0.4	+4.0 ±0.4

Table 3. AJACCIO 7848 10077M002 Coordinates (epoch 1997.0)

	X	Y	Z
Coordinates (m)	4696992.026	724001.507	4239671.545
Velocities (m/year)	-0.014	+0.020	+0.011

Table 4. 7848 Range Bias (mm)

	Lageos-1	Lageos-2	Mean Lageos 1&2	Starlette	Stella	Mean Starlette/Stella	Global Mean
2002	-5	-7	-6	-13	-13	-13	-10
2005	+5	+3	+4	-5	-4	-5	0

The method used for determining the coordinates and range bias is described in detail in [Exertier et al., 2004]. For this analysis the satellites used are: Lageos 1&2, Starlette and Stella. Concerning the orbit determination process, the GINS software (GRGS, Toulouse) has been used and the chosen gravity fields are respectively GRIM5-C1 and EIGEN-GRACE-03S for Lageos and Starlette/Stella satellites. On the average the standard deviation of the laser residuals are 11 mm and 18 mm for respectively Lageos and Starlette/Stella satellites. The standard deviation improvement thanks to the use EIGEN-GRACE-03S instead of GRIM5-C1 for Starlette/Stella satellites is 14 mm.

Table 2 presents the differences of the 2002 and 2005 solutions relatively to the published coordinates [Exertier et al., 2004]. This differences in term of geographical coordinates are very small and at the level of remaining errors in the velocities. Because no significant differences have been found between 2002 and 2005 coordinates, we just averaged the both sets of coordinates (Table 3). Comparisons with the published coordinates show negligeable differences in the X and Y components and +3 mm in the Z axis.

The method used allows a better decorrelation between range bias and up component (from 80% with classical approach to about 50% in this analysis). Table 4 shows the different range biases obtained in fonction of satellites and studied periods. Results clearly show differences between Lageos and Starlette/Stella range biases (respectively -1 mm and -9 mm) which are probably due to the target response and the FTLRS detection process (signal to noise ratio is significantly worse for Lageos satellites). On the other hand the 10 mm difference of the mean bias (for all satellites) between 2002 and 2005 is mainly due to transfer between coordinates and range bias (correlation with the up component remains at the 50% level). In conclusion, when using our new set of coordinates (Table 3) users who do not want to distinguish satellites should use a range bias of -5 mm (in our convention a negative bias means that the system ranges too short). The published range bias was -7 mm so very closed to the new determination.

Exertier, P., J. Nicolas, P. Berio, D. Coulot, P. Bonnefond, and O. Laurain, The Role of Laser Ranging for Calibrating Jason-1: The Corsica Tracking Campaign, Mar. Geod., Special Issue on Jason-1 Calibration/Validation, Part 2, Vol. 27, No. 1-2, 2004.

ESTIMATION OF THE ORBIT ACCURACY

Mediterranean Area | **USA Area**

Mean of laser residuals (cm)

Figure 1a

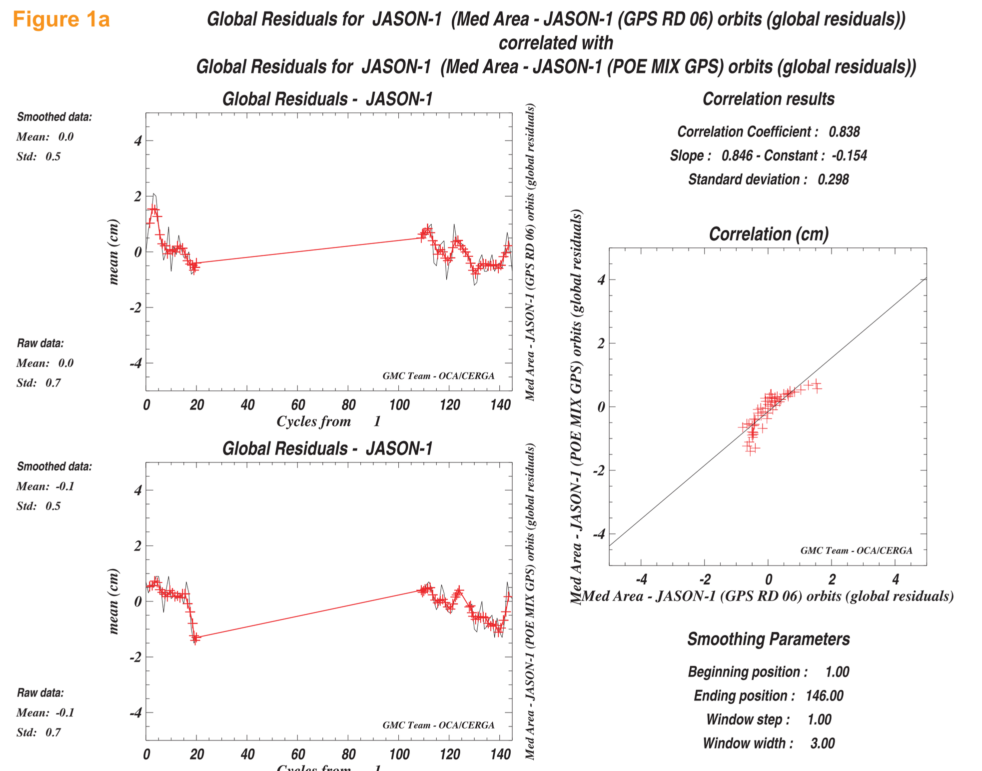
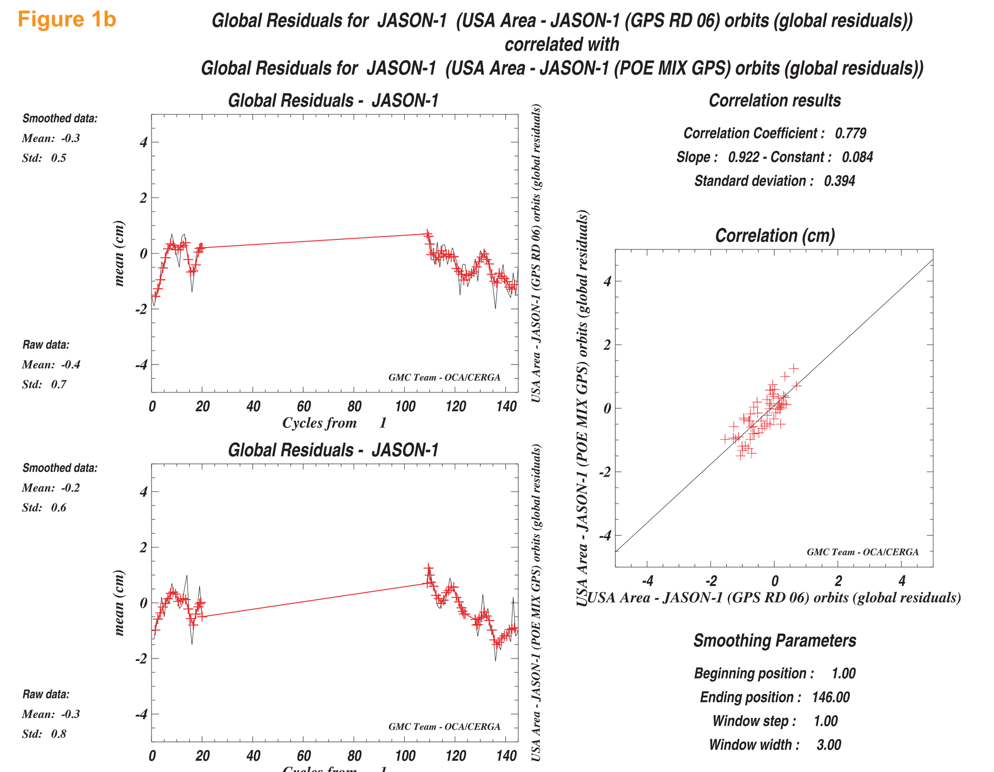


Figure 1b



Standard deviation of laser residuals (cm)

Figure 2a

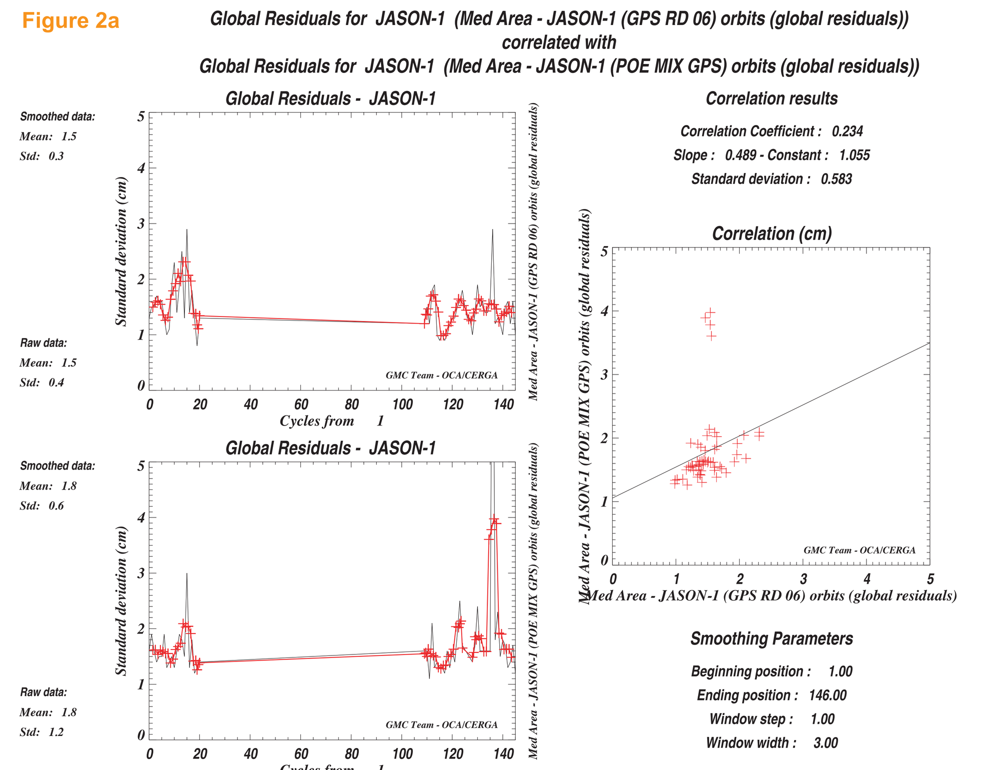
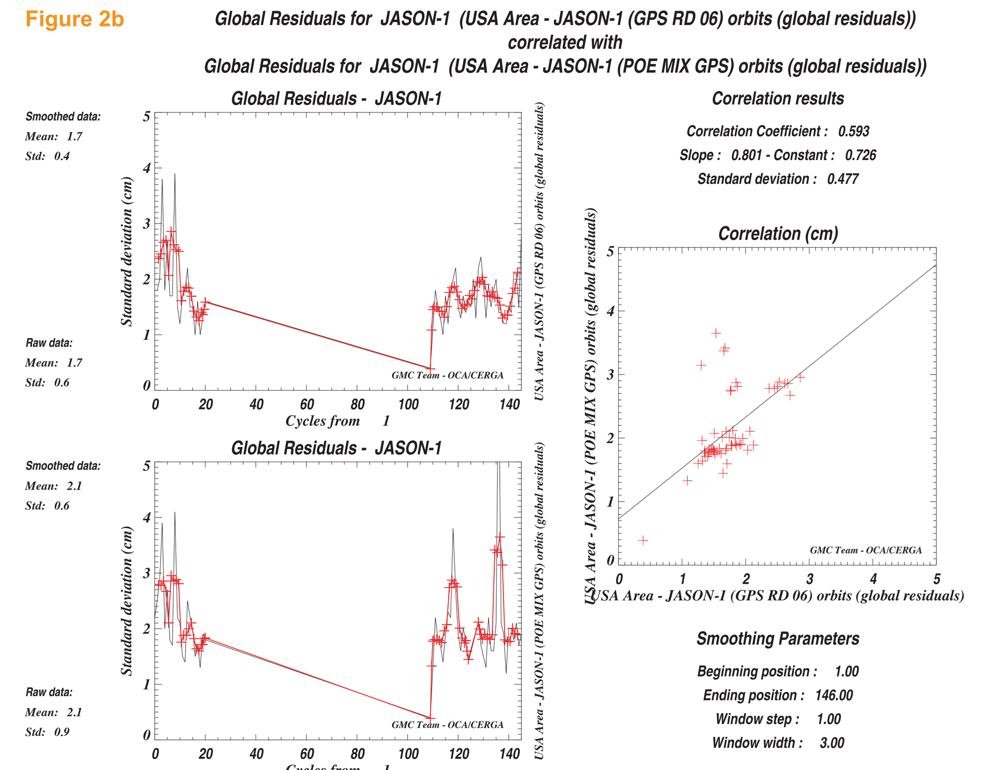


Figure 2b



Radial orbit orrections (cm)

Figure 3a

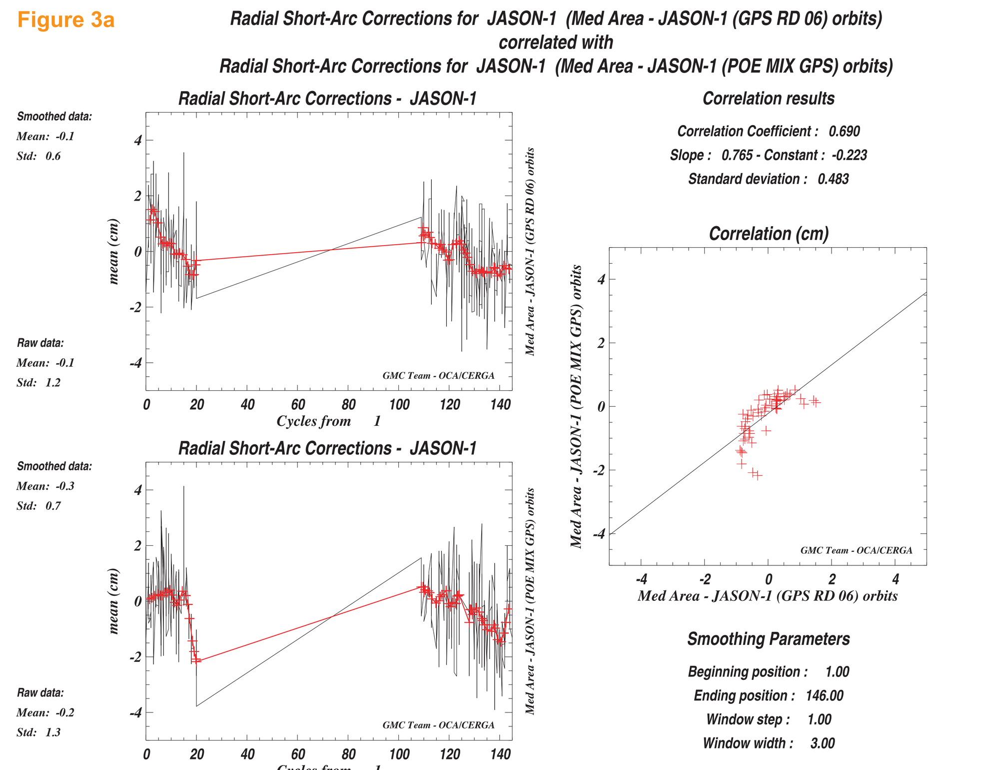
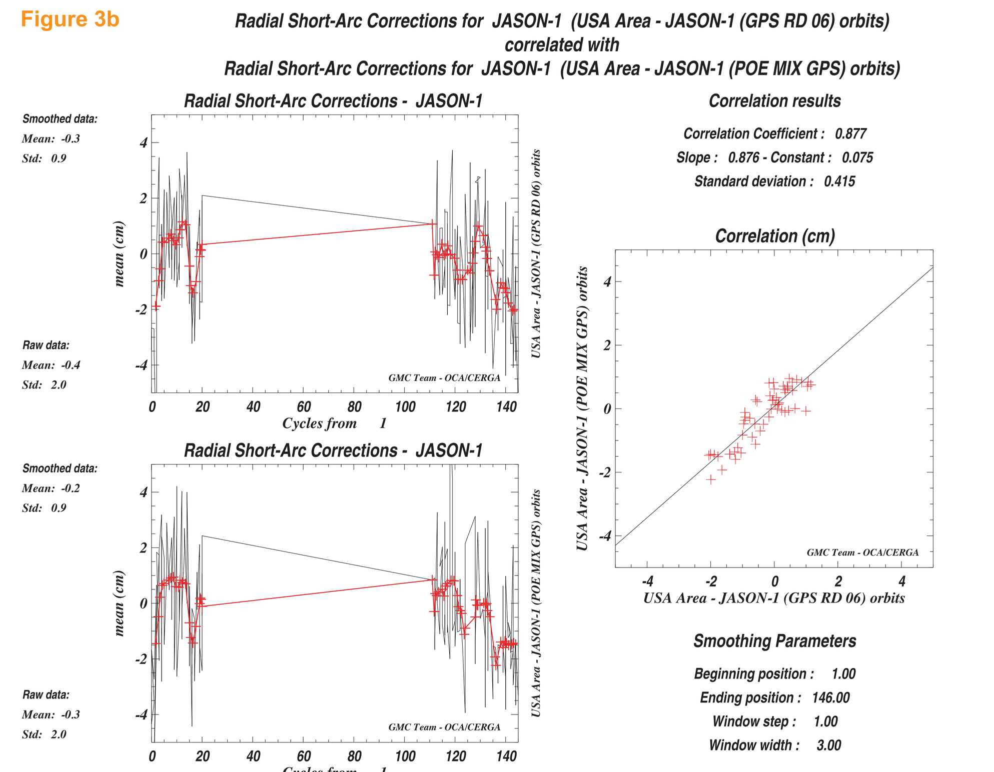


Figure 3b



VALIDATION WITH JASON-1 ORBITS

In order to validate the new set of coordinates (Table 3) we have analyzed the laser residuals for Jason-1 using the latest precise orbits from both CNES and JPL (POE MIX GPS and GPS RD 06 respectively on the Figure to the right). The CNES orbit corresponds to the one used in the first release of Jason-1 GDR-B and the JPL one is based on the reduced dynamic technique (see *"GPS-Based Precise Orbit Determination: Jason-1 Status"* Poster for details).
For this analysis the published -7 mm FTLRS range bias has been used for Jason-1.

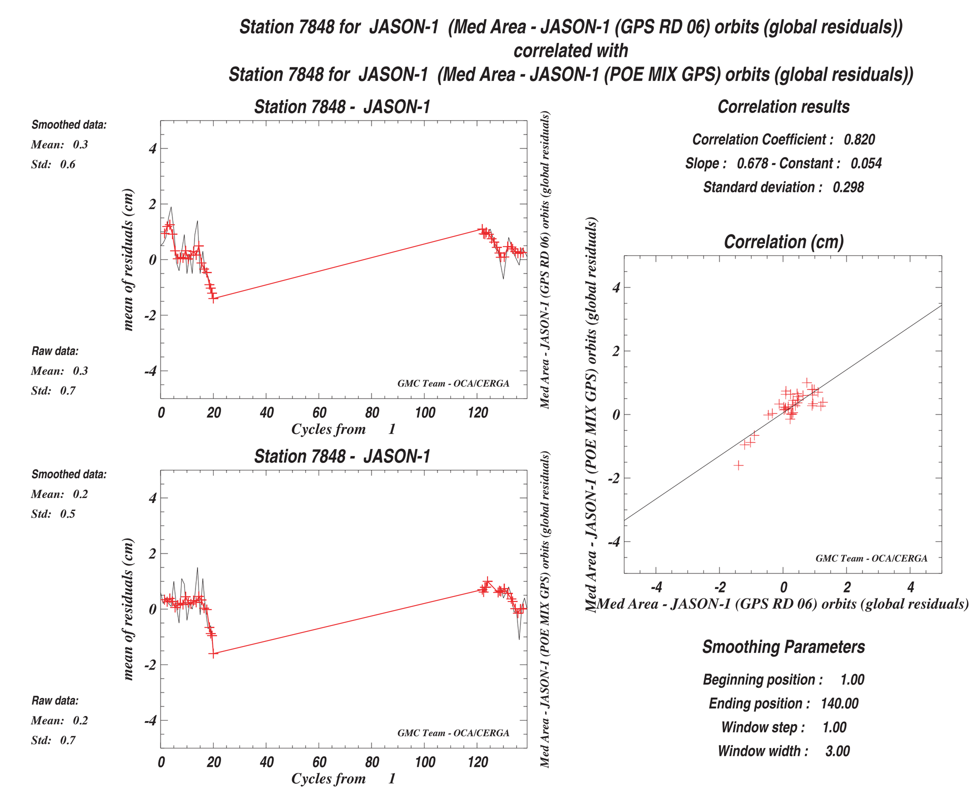


Table 5. 7848 Laser Residuals on Jason-1 POE Orbits (mm)

	2002	2005	Mean
CNES	+2	+3	+2
JPL	+2	+4	+3

The above Figure shows the 7848 mean residuals for both orbits as well as the correlation (82%) between the smoothed (30-days) time series. This shows that both orbits are at the same level of accuracy with a standard deviation of the mean at the level of 7 mm. Concerning the standard deviation of the laser residuals the values are on the average 21 and 17 mm respectively for CNES and JPL orbits (not shown in the Figure).
The averaged laser residuals either for 2002 and 2005 periods are very close to the global average and not significantly different for both orbits. Considering the introduced range bias (-7 mm) the global mean of about +2 mm reveals that the FTLRS range bias for both 2002 and 2005 campaigns should be -5 mm which is inperfect agreement with the analysis presented in the "coordinates determination" section.

This study is based on the use of the geometrical laser-based short-arc technique which is not sensitive to gravity field. We have compared the laser residuals as well as the radial orbit corrections for the new CNES POE (SLR, DORIS, and GPS, close to the future GDR-B reprocessing) and the JPL one which is based on the reduced dynamic technique (see *"GPS-Based Precise Orbit Determination: Jason-1 Status"* Poster for details). These two orbits are both based on the GRACE-based gravity field GGM02C. The studied period spans from cycle 1-21 and 110-141 because the CNES POE is only available on these cycles.
Due to the inhomogeneous distribution of station in the SLR network we cannot performe the short-arc technique everywhere. Two areas (USA and Mediterranean) have then been chosen for their high density and quality of SLR data.

Figures 1a and 1b show the mean of laser residuals for both orbits as well as the correlations between the 30-days smoothed time series. The standard deviation (cycle by cycle) of the mean residuals is ~7 mm for each orbit and each studied areas. The correlation is very high (84% and 78% respectively for the Mediterranean and USA areas) and the smoothed time series show similar behavior except for the early cycles of the GPS Reduced-Dynamic orbits in the Mediterranean sea. The two orbits exhibits a semi-annual signature and a drift for cycles higher than 110 (more clear in the USA area). The overall mean is negligeable in the Mediterranean area and 3-4 mm in the USA area showing the probably low level of Geographically Correlated Errors.

Figures 2a and 2b show the standard deviation of laser residuals for both orbits as well as the correlations between the 30-days smoothed time series. The averaged standard deviation on both areas for the GPS Reduced and CNES POE orbits are respetively 16 mm and 20 mm. However this difference seems to be mainly due to relatively high standard deviation on some cycles for the CNES POE. Semi-annuals signals also appear for both orbits and areas.

Figures 3a and 3b show the radial orbit errors derived from the Short-Arc orbit technique both orbits as well as the correlations between the 30-days smoothed time series. The overall precision is equivalent for both orbits but different for the two studied areas, respectively 13 mm and 20 mm for the Mediterranean and the USA areas. The mean of radial orbit corrections is also equivalent for both orbits with -2mm and -4mm respectively for the Mediterranean and the USA areas. This confirms the low level of Geographically Correlated Errors for both orbits at least for the studied areas.

In conclusion, the new set of coordinates (Table 3) along with a range bias of -5mm are very well suited for using the FTLRS in the Jason-1 Precise Orbit Determination process for both 2002 and 2005 campaigns. A new campaign is planned for the validation period of Jason-2 (2008?).

In conclusion, This study clearly shows the great improvement thanks to the new CNES POE compared to the one included in the GDR-A. This new generation of orbit is now at a comparable level of precision than the GPS Reduced-Dynamic orbits from JPL. Some strange signatures remain in the laser residuals and the radial orbit corrections but some refinements will be discussed during the Precise Orbit Determination and GEOID splinter to define the better strategy for the Jason-1 GDR-B processing.