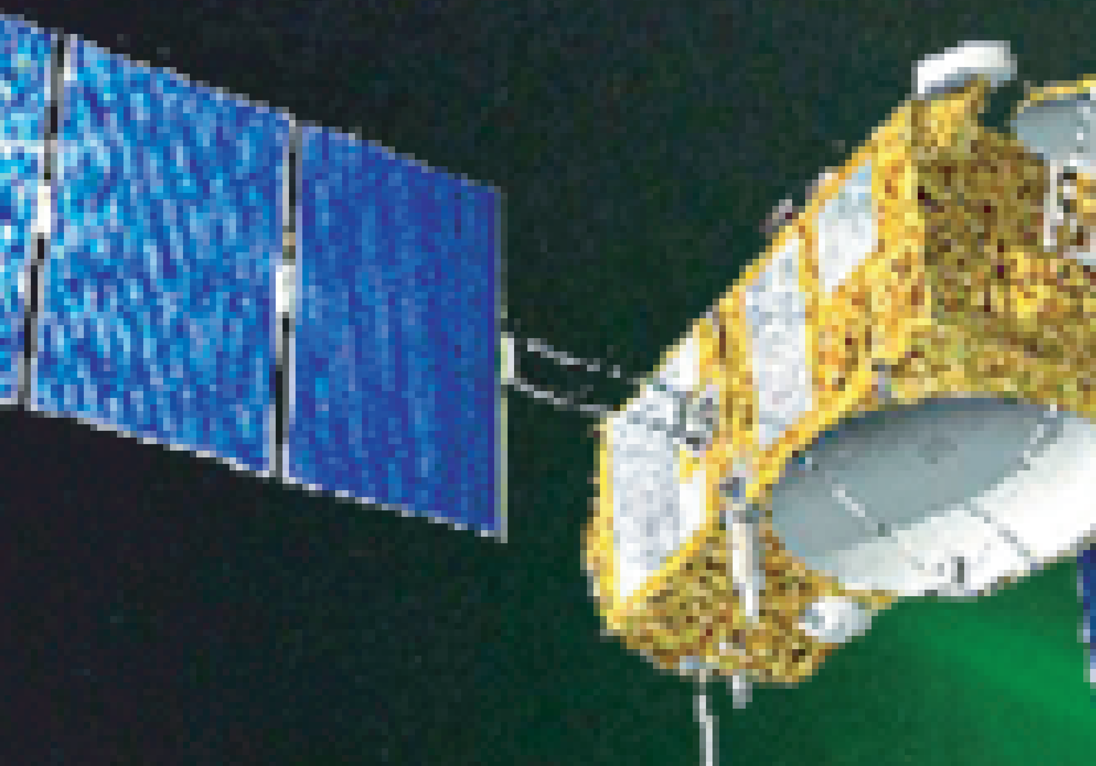
Validation Activities for Jason-1 and TOPEX/Poseidon Precise Orbits

http://grasse.obs-azur.fr/cerga/gmc/calval/pod/

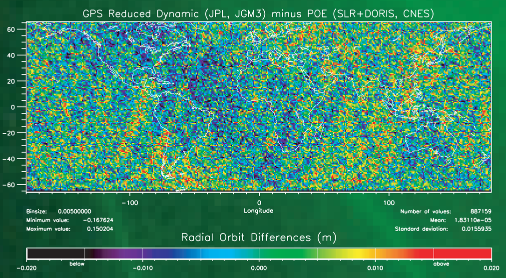


P. Bonnefond, P. Exertier, O. Laurain, P. Berio and D. Coulot

OCA/CERGA
avenue N.Copernic, F-06130 Grasse

E-mail: Pascal.Bonnefond@obs-azur.fr

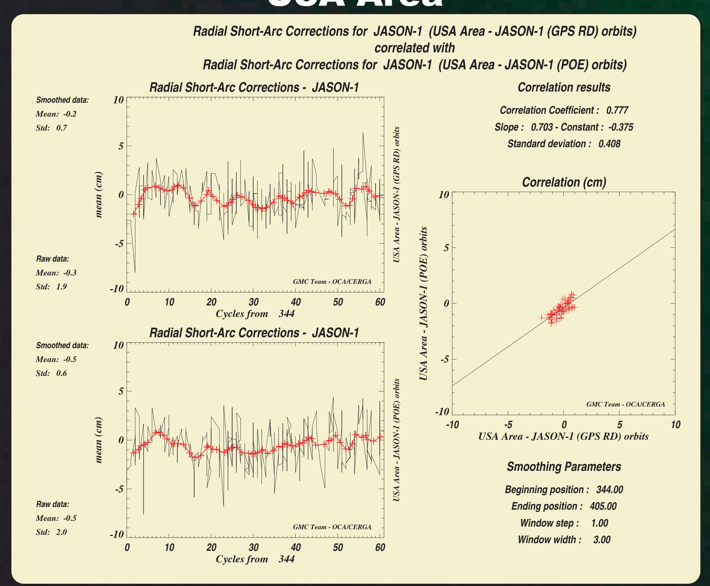
Regional Studies



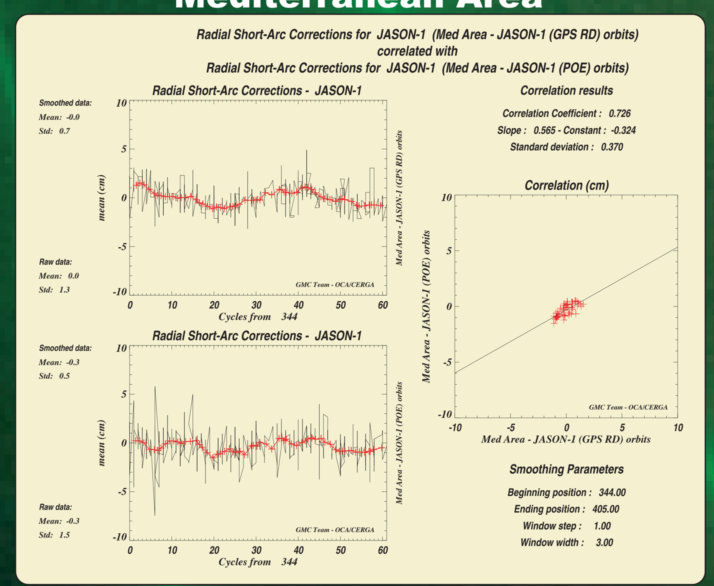
Large patterns of Geographically Correlated Errors (GCE) can affect ocean circulation studies. We have tried to quantify the improvement in terms of GCE thanks to the use of the GRACE gravity field. The Plate at right shows that the radial orbit differences from 62 cycles between POE and GPS RD are relatively small (below 1 cm) when both used JGM3 gravity field. However, largest patterns are revealed (Plate below) when comparing POE (JGM3) and GPS RD (GRACE).

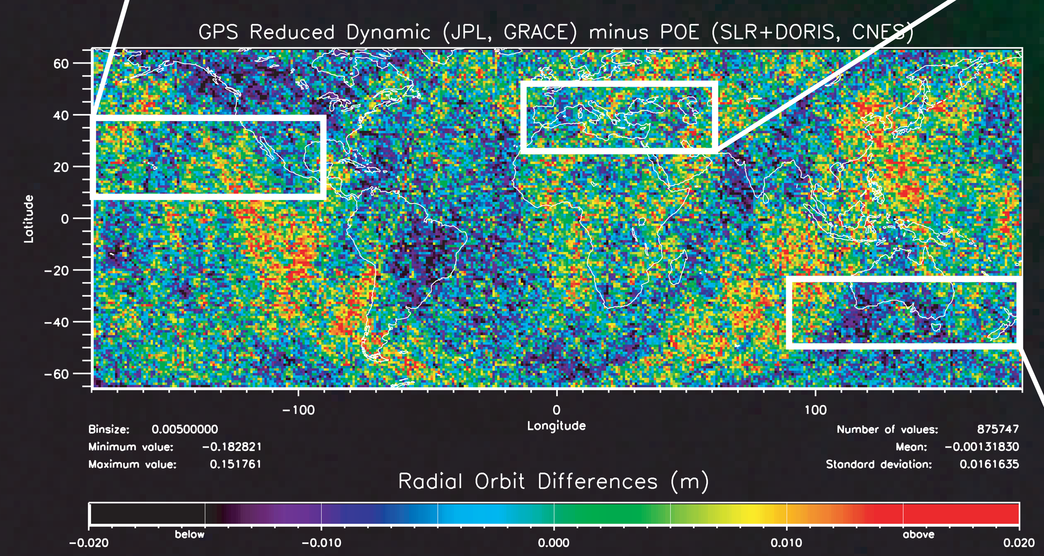
This study is based on the use of the geometrical laser-based short-arc technique which is not sensitive to gravity field. We have compared the radial orbit corrections for POE (JGM3) and GPS Reduced-Dynamic (GRACE) orbits. Due to the inhomogeneous distribution of station in the SLR network we cannot performe the short-arc technique everywhere. Three areas (USA, Mediterranean and Australian) have then been chosen for their high density and quality of SLR data. If on the average the USA and the Mediterranean area do not reveal clear GCE patterns, the Australian area clearly reveals GCE at the level of -19 mm in the POE orbit. This GCE is considerably reduced thanks to GRACE and GPS RD process (-6 mm).

USA Area

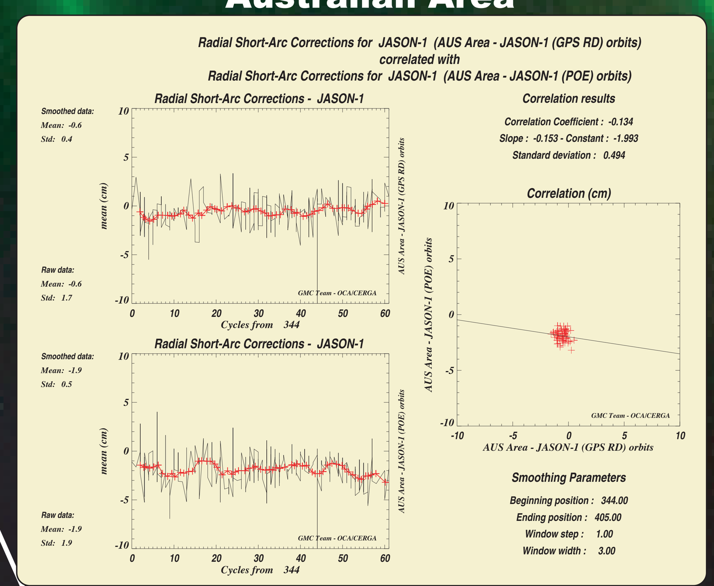


Mediterranean Area

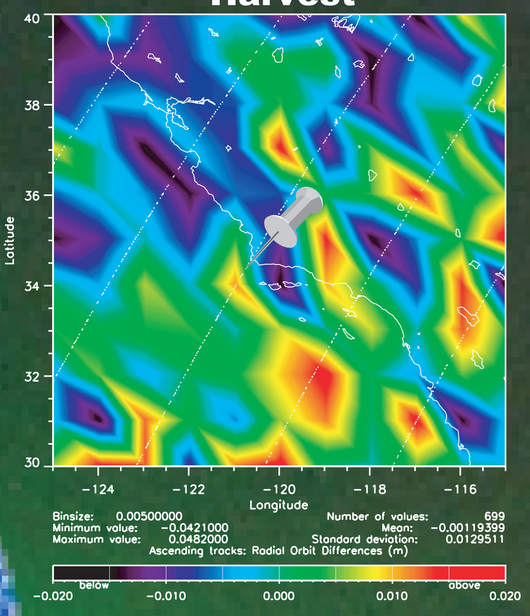




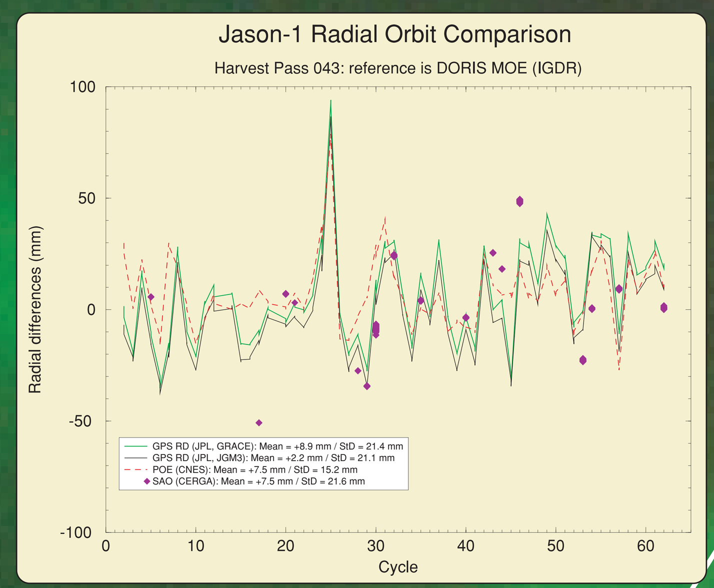
Australian Area



Harvest



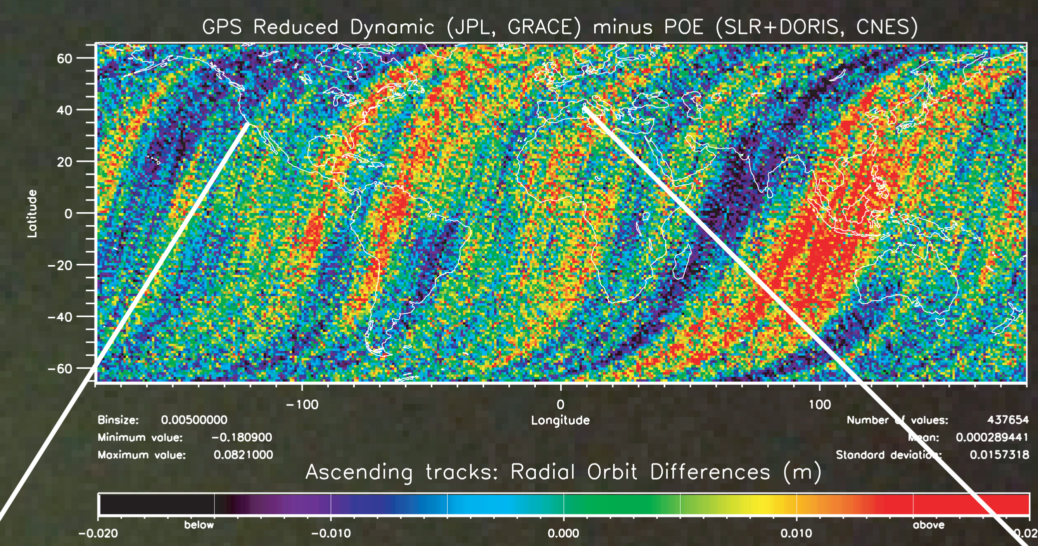
Radial orbit accuracy shows a very good consistency between POE, GPS RD (with GRACE) and Short-Arc. These three kinds of orbit reveal clearly that MOE is biased by about 8 mm.
However, GPS RD based on JGM3 is closer to MOE and then exhibit a Geographically Correlated Error at the level of 6 mm.

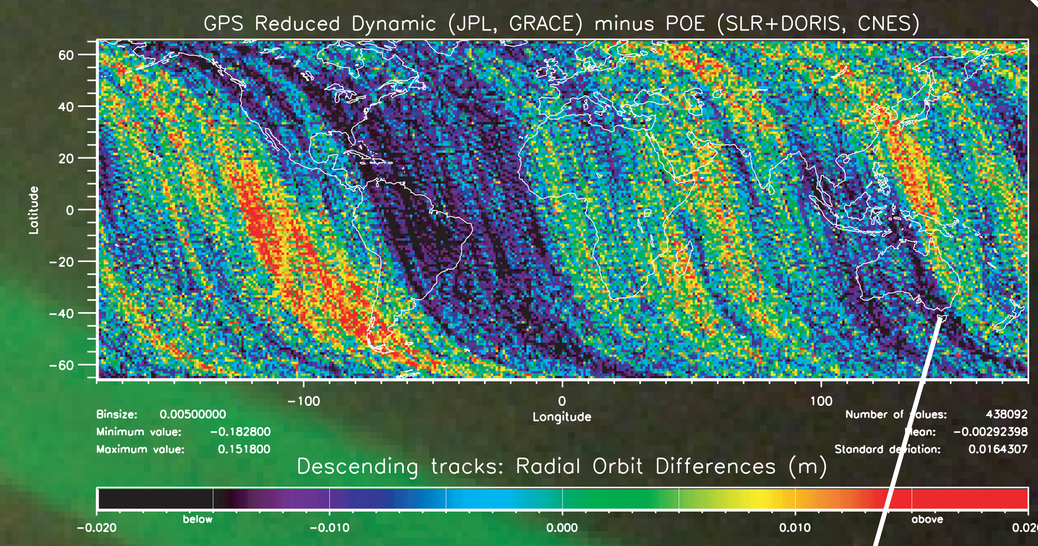


Calibration Sites Studies

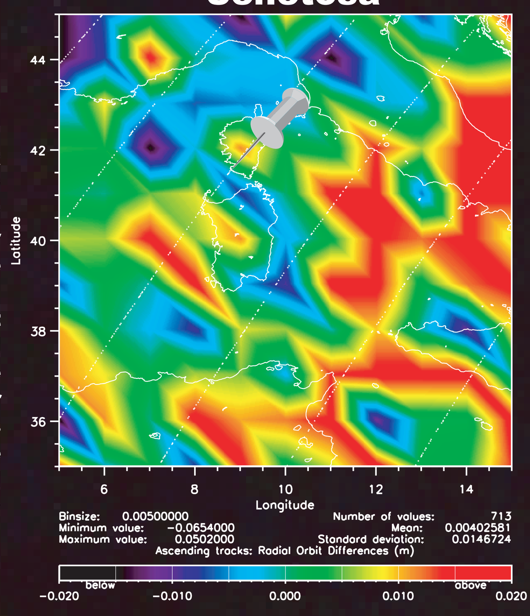
Absolute calibration is very sensitive to systematic errors that affect the vertical components of the whole closure equation. Geographically Correlated orbit Errors (GCE) studies are then of great importance to establish the overall error budget. In this study we have compared results using four kind of orbits:

- GPS Reduced-Dynamic (GPS-RD), JPL (GPS data, JGM3 and GRACE gravity fields)
- Precise Orbit Ephemerid (POE), CNES (SLR and DORIS data, JGM3 gravity fields)
- Medium precision Orbit Ephemerid (MOE), CNES (DORIS data, JGM3 gravity fields)
- Short-Arc Orbit (SAO), CERGA (SLR data)

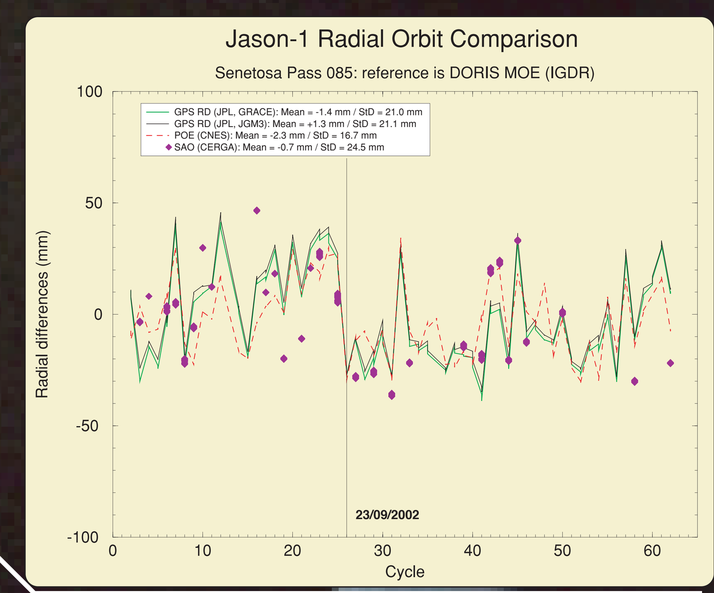




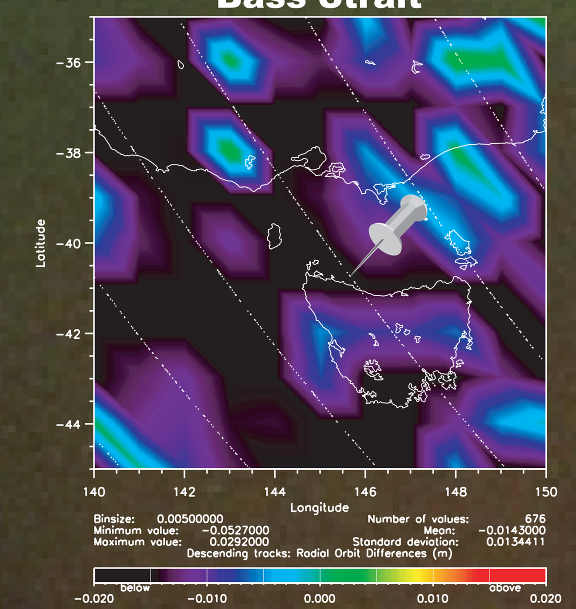
Senetosa

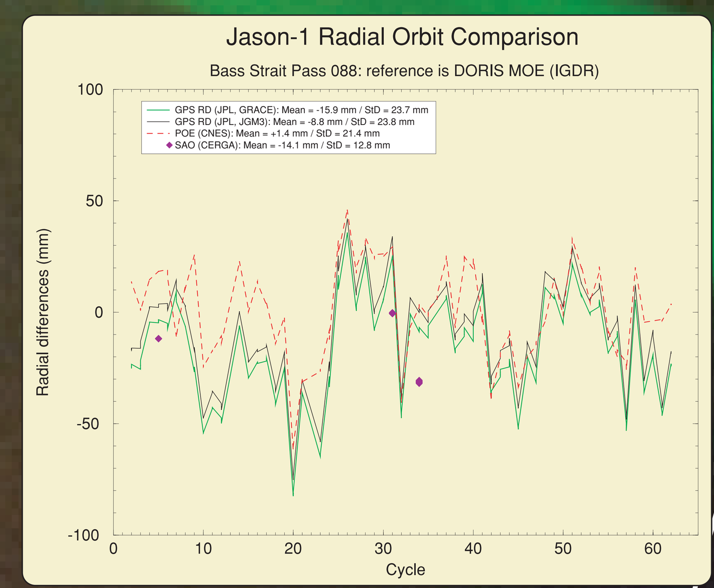


Radial orbit accuracy shows a very good consistency between POE, GPS RD and Short-Arc. In this area the Geographically Correlated Error is negligible (below 2 mm).
However, radial orbit differences from all the studied orbits reveal a change in the MOE behavior before and after the validation period. This is can be due to the fact that the Cal/Val phase was a period used to tune the orbit determination process



Bass Strait





Radial orbit accuracy shows a very good consistency between GPS RD (with GRACE) and Short-Arc. These two kinds of orbit clearly reveal that both POE and MOE are biased by about -15 mm (see also the "Regional Study" section). GPS RD based on JGM3 do not show the same mean radial orbit difference than for the GRACE solution (7 mm lower). This suggests that the Geographically Correlated Error in this area is due to JGM3 gravity field and that the reduced-dynamic technique cannot totally correct this error.
So, when using either MOE or POE orbits the Jason-1 altimeter bias determined from the Bass Strait calibration site should be too high by about 15 mm.

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.

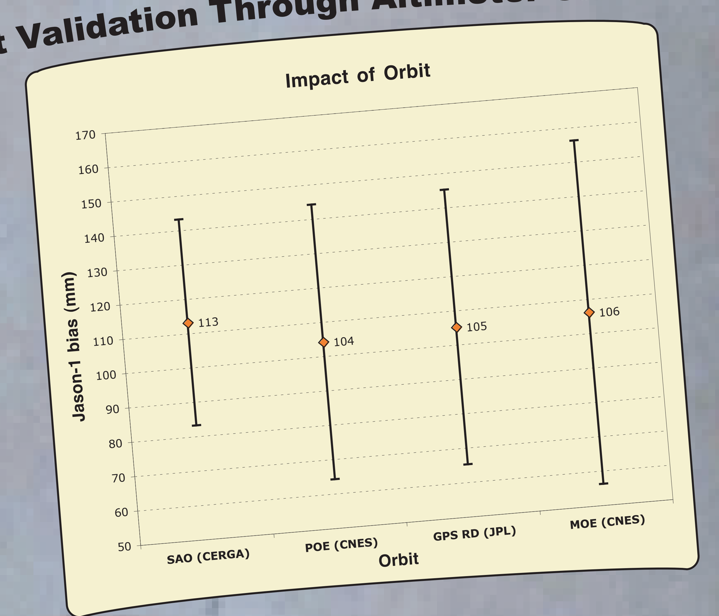
Obviously, other SLR sites around the world (US, south Pacific, mainly) largely contribute to the tracking of the tandem mission, thanks notably to the role of the International Laser Ranging Service (ILRS) through its recommendations, its data storage and distribution, and its monitoring of the up-to-date activity (qualitative and quantitative monitoring). Thus, this permits to enlarge the possibilities of CAL-VAL activities.

We have developed a short-arc orbit technique for the validation of altimeter satellite precise orbits. It is based on SLR data, and on rigorous geometrical adjustment criterions. The previous studied area has been enlarged from Mediterranean to entire network. These new 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. The differences in the shape of the Laser Reflector Array of each satellite, Jason-1 and T/P, introduce also some difficulties. Now, the situation is less difficult with Jason-1 being less sensitive than T/P to the technological features used by each SLR station (power of the laser beam, detection mode, etc).

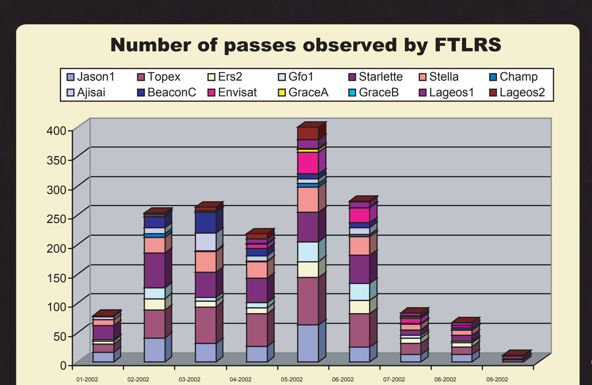
Before being settled at Ajaccio (Corsica, from January to September 2002), the data of the French Transportable Laser Ranging System have been qualified during a short campaign just before the Jason-1 launch, at the Grasse site. The goal with such a mobile SLR system, particularly with the choice of 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.

Orbit Validation Through Altimeter Calibration



By replacing the orbit in the altimeter calibration process we can monitor the level of improvement in the bias determination and then quantify the orbit quality.
This example shows Jason-1 bias determination with 4 kind of orbits: laser-based short arc orbits, DORIS+SLR POE, DORIS MOE (standard orbit in IGDR products), and GPS Reduced-Dynamic (GRACE) orbits.
Figure above shows the mean value and the standard deviation of the Jason-1 altimeter bias for each kind of orbits. All the results are within few millimeters and the relatively high value for short-arc orbits is due to the high density of determinations during the validation phase. For comparison, on cycle 1 to 26 mean bias from short-arcs and POE differs by only 4 mm. On the other hand, the short-arc solutions exhibit a standard deviation lower by 10 mm showing the high consistency and accuracy of the short-arc technique.

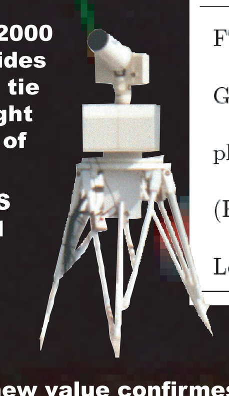
FTLRS – The Corsica Tracking Campaign



The adopted methodology to compute the FTLRS geocentric positioning is based on a multi-satellite semi-dynamical approach (using the Starlette, Stella and Lageos geodetic satellites). First, orbits are computed as precisely as possible (especially for the lower altitude satellites) without the FTLRS tracking data. Then, the normal matrices are established and the FTLRS parameters are solved through a weighted least-squares fit; the model consists of coordinate updates in the adopted terrestrial reference frame and of a range bias value (B).

To improve the accuracy of the low orbit satellites, the short-arc technique is applied above the Corsica area using the European SLR network (still without FTLRS). As a result, the Starlette and Stella corresponding orbit residuals (rms before and after the short-arc fits) decreased from 16 and 19 mm to 8 and 10 mm, respectively.

The initial mean coordinates of the FTLRS were given by the ITRF2000 solution corrected for plate velocities, and for polar and Earth tides following the IERS 96 conventions [McCarthy, 1996]. The local tie between the GPS and the FTLRS ground marker, and the height between that marker and the FTLRS reference point (cross-axes of the telescope) were measured by the IGN at the millimeter level (see values in Table).



	X	Y	Z	Epoch
FTLRS	4696993.293 ± 0.001	724001.822 ± 0.002	4239672.821 ± 0.003	2002.4
GPS	4696989.476 ± 0.001	723994.424 ± 0.001	4239678.502 ± 0.001	2002.4
plate motion (GPS)	-0.0137	0.0199	0.0109	2002.4
(FTLRS-GPS)	3.817	7.398	-5.681	
Local tie (IGN)	3.819	7.400	-5.674	

The final set of coordinates of the FTLRS in Corsica is shown in Table, as the coordinates of the permanent GPS receiver (installed at Ajaccio in 1999). Instead of ITRF2000 coordinates, this latter set was in fact re-computed using the two more recent years (2001-2002) of EUREF SINEX files with the CATREF software [Altamimi et al., 2002]. The coordinate differences between the FTLRS and the GPS were compared to the local tie measured by the IGN (taking into account the FTLRS height of 1.826 m). These differences are of (3.7mm, 1.7mm, 6.4mm), respectively in the (ϕ, λ, h) frame, showing a very good agreement between both SLR and GPS solutions particularly in the horizontal plane. The range bias has been established from an averaging of the four satellite bias values at -7 ± 2 mm. Compared to the value determined during a collocation experiment at Grasse (-5mm), this new value confirmes the great quality (stability) of the FTLRS system.

The FTLRS system confirms its place, as a unique highly mobile SLR system designed to participate to tracking campaigns on dedicated sites; in 2003, the FTLRS has been set up in Crete, Greece for a 7-month period in view of re-calibrating JASON-1. Nevertheless, the Corsica campaign, dedicated to the absolute calibration, will have to be re-iterated to estimate measurement-system drift at the 1 mm/year level; as eustatic sea-level rise over the last century is estimated to be only 1-2 mm/year which requires a minimum of 3-5 years of data.

Conclusion

The laser-based short-arc technique has been used since the beginning of TOPEX/Poseidon mission to validate orbit computed by other institute (CNES, GSFC, JPL): results are continuously updated on our web site. It has proved its capability to monitor the orbit quality at the centimeter level.

Our studies of Geographically Correlated Errors either at the local (calibration sites) or regional scale clearly reveal a large pattern in the Australian area which affects POE (GDR) and MOE (IGDR) orbits. This pattern seems to be due to JGM3 and the use of GRACE gravity field should considerably reduce the GCE even for other areas.

Thanks to the FTLRS tracking support at Ajaccio, the laser-based short-arc technique has also proved to improve the standard deviation of Jason-1 altimeter bias determination.