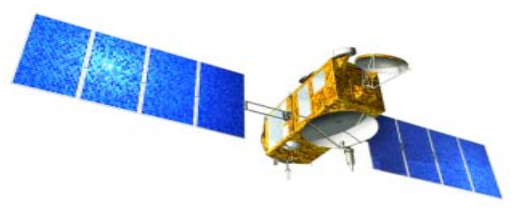

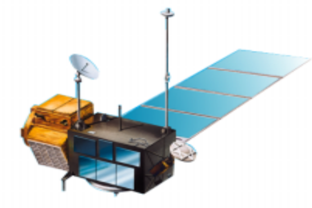

Jason-1 and TOPEX/POSEIDON Precision Orbit Determination: Initial Results

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Introduction

TOPEX/POSEIDON continues to achieve an unprecedented level of orbit accuracy for an altimeter mission, and Jason-1 promises to continue that legacy. We will examine two main POD verification issues: (1) the impact of the transition to the ITRF2000 reference frame for T/P, and (2) a preliminary assessment of the accuracy and consistency of POD for Jason-1 by various institutions.

Transition to the ITRF2000 Reference Frame

Station coordinates from the recent ITRF2000 reference frame solution will be used for Jason-1 POD, and it is essential that the T/P orbit production system transitions to the same reference frame. The system currently being used (based on CSR95L01/D02) has been quite stable and has produced good results, but errors in the station velocities are becoming a problem, especially for the DORIS stations, which were estimated with only a few years of data. In addition, there is no equivalent set of coordinates for the GPS stations. The concerns with ITRF2000 for T/P are: (1) the determination of coordinates for stations not represented in ITRF2000 (stations which did not track previously or tracked very little), (2) stations with coordinate problems in ITRF2000, and (3) any systematic trend in ITRF2000 with respect to the CSR95 system that would introduce undesirable artifacts in the long sea level time series from T/P.

The first two concerns appear to be minimal. We have found that as new DORIS beacons are deployed, we are being provided accurate position determinations consistent with the ITRF2000 system, usually adopting the ITRF2000 velocities where possible. The new beacon at Arequipa, for example, which suffered a horizontal displacement due to a recent earthquake, could be positioned accurately through a tie to a nearby GPS station (H.Fagard, 2002). These new coordinates appear to be reliable, based on post-fit residuals from T/P (Jason-1 could not verify the accuracy due to an anomaly in the DORIS data that has recently come to light). For new SLR stations, Lageos-1, Lageos-2 and even Jason-1 are able to quickly provide accurate position determinations consistent with the ITRF2000 frame. For example, the new SLR station located at Ajacio has difficulty tracking the high altitude Lageos satellites, but we were able to determine good coordinates after just several cycles of tracking of Jason-1. The small laser reflector array (LRA) on Jason-1 is well suited for this, since biases introduced by the interaction between the laser detector and the target is much smaller than with the large LRA on T/P. However, accurate knowledge of the antenna phase center and center of mass locations is required for the highest accuracy results.

The impact of a reference frame change on mean sea level time series is a more serious concern. Previous studies have demonstrated that the orbit is unaffected by a small miscentering of the station network in the equatorial plane (along the X and Y Earth-fixed axes). The parameters typically estimated for most orbit determination methods are unable to accommodate a miscentering or other motion of the reference system in these directions because the Earth rotates in inertial space once per day. (This would not be true for very short arcs or if a large number of subarc empirical acceleration parameters per day were estimated or when estimating order 1 gravity coefficients.) It is clear, however, that the orbit responds quite strongly, about one for one, with a reference system bias in Z. Because of the asymmetry in the distribution of the oceans between the northern and southern hemispheres, about 10% of the Z-drift is reflected in the global mean sea level (GMSL) estimates (Nerem et al., 2000). Regional sea level may be affected by as much as 40-50% of the Z-drift. As a consequence, a shift or drift in the Z-direction between the ITRF2000 and CSR95L01 reference systems could have an undesirable effect on the T/P sea level time series.

In a previous study, we estimated the effect on the GMSL time series caused by the differences between ITRF2000 and CSR95L01 (Ries *et al.*, 2001). Figure 1 shows the GMSL differences for a subset of the cycles where the difference was only the use of the ITRF2000 reference frame. The resulting change in slope was only 0.02 mm/y, and a step of only 0.2 mm was introduced. This suggests that over this period, the two frames were consistent at the few mm level with very little drift, so that the effect of switching to ITRF2000 on the mean sea level time series appeared to be minimal. However, more recent analyses of SLR data suggests that the drift in ITRF2000 might be larger than this. In Figure 2, we see a time series of the displacement between ITRF2000 and the frame implied by the SLR tracking data, as analyzed at CSR. From these results, we might conclude that switching to ITRF2000 would introduce as much as a 0.14 mm/y change in the GMSL time series as well as a jump of ~1 mm, but as shown below, the effect is not this large. The increased slope appears to be largely due to an offset resulting from the inclusion of recent data from a number of new SLR stations, rather than a systematic drift in the reference frame. This cannot yet be determined precisely, since the uncertainty in the reference frame centering is probably still at the mm/y level. This highlights the importance of continuing to gather the high-quality, global SLR tracking needed to reduce the uncertainty in the terrestrial reference frame determination to support studies such as global mean sea level change.

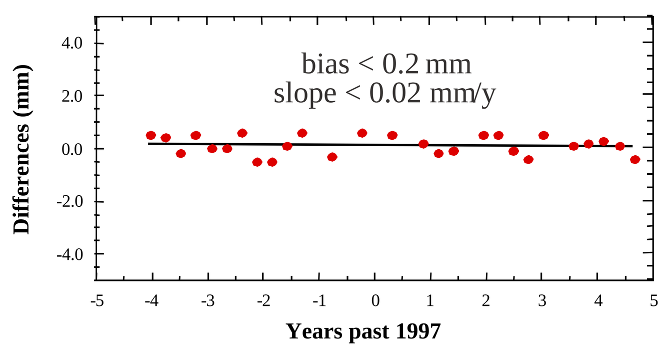

Figure 1. Global mean sea level differences due to using the ITRF2000 and CSR95L01 reference systems for POD in the UTCSR verification orbits, as presented previously in Ries *et al.* [2001].

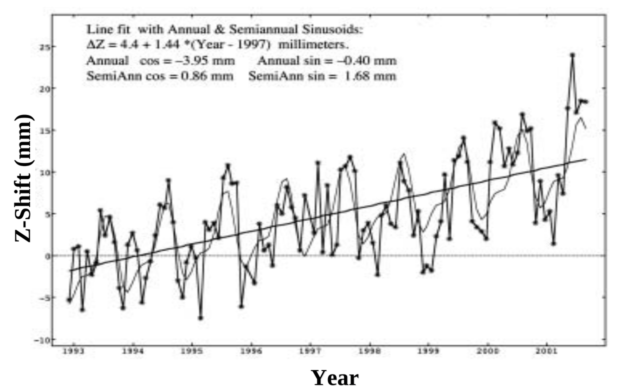

Figure 2. Recent analysis showing the amount of Z-shift required to align ITRF2000 with our SLR solution.

In a test of the preparation for the transition to ITRF2000, GSFC and CSR reprocessed cycles 344-353 using ITRF2000. The results shown in Tables 1 and 2 exhibit some effect of the Z-shift between the two reference frames, but it is not as large as predicted by Figure 2. In general, the quality of the orbits using ITRF2000 are equal to those with the previous reference system, and the internal consistency between GSFC and CSR has improved. The systematic differences caused by the change in the reference frame appear to be minor (as illustrated in Figure 3) and generally beneficial (as demonstrated by the improved tracking data fits shown in Table 3).

Topex/Poseidon Cycle	CSR mean	95L01 rms	CSR mean	ITRF rms	NASA mean	95L01 rms	NASA mean	ITRF rms
344	0	59	-8	59	8	60	-6	58
345	6	63	-2	63	7	63	-4	63
346	5	62	-5	62	5	62	-9	63
347	3	60	-3	60	6	60	-1	60
348	2	62	1	61	8	62	1	61
349	1	61	2	61	10	62	4	61
350	5	59	0	59	6	61	-2	61
351	4	62	0	62	9	62	4	62
352	5	59	4	59	10	59	6	59
353	3	59	0	58	6	59	-2	58
Mean	3	61	-1	60	8	61	-1	61

Table 1. The differences in the altimeter crossover statistics for CSR and GSFC using the two reference systems are shown here. In general, no degradation has occurred in the crossover rms, while the mean crossover has decreased. The mean crossover residual, when calculated as ascending minus descending (or the opposite), is a measure of the miscentering of the orbit in inertial space (in the equatorial plane). In this case, the orbit centering has been improved, particularly for the GSFC orbits. Crossovers are insensitive to a Z-bias in the orbit.

T/P Cycle	CSR (95L01 vs ITRF2000) RMS Radial	Mean Radial	Mean X	Mean Y	Mean Z	NASA (95L01 vs ITRF2000) RMS Radial	Mean Radial	Mean X	Mean Y	Mean Z	NASA vs CSR (ITRF2000) RMS Radial	Mean Radial	Mean X	Mean Y	Mean Z
344	6	0	0	0	-1	12	0	0	0	-4	17	0	1	1	-5
345	7	0	0	0	4	11	0	0	-1	9	10	-1	-3	1	4
346	8	0	0	0	3	9	0	-1	0	3	7	-1	0	1	0
347	7	0	0	0	5	6	0	0	0	5	8	-1	0	0	-1
348	4	0	0	0	4	7	0	0	0	7	8	-1	0	1	0
349	6	0	0	0	1	7	0	0	0	10	9	0	0	-1	-4
350	5	0	0	0	0	9	0	0	0	7	13	0	0	2	-1
351	6	0	0	0	7	8	0	0	0	11	8	0	0	2	-3
352	6	0	0	0	6	6	0	0	0	7	9	0	0	1	-3
353	6	0	0	0	6	11	0	0	0	13	8	0	0	0	5
Mean	6	0	0	0	3	8	0	0	0	7	10	0	0	1	0

Table 2. The systematic differences between the CSR and GSFC orbits using the old and new reference systems. There is a mean Z-shift of 3 mm for the CSR orbits and 7 mm for the GSFC orbits. However, both orbits appear to have shifted to the same center, as evidenced by a mean of 0 in Z averaged over these ten cycles (last column), as well as a reduced cycle-to-cycle scatter. The average RMS radial difference between the GSFC and CSR orbits using ITRF2000 was 10 mm, which is slightly better than the 11 mm obtained for these same cycles using CSR95L01.

Topex/Poseidon Cycle	SLR (cm) CSR95L01	SLR (cm) ITRF2000	DORIS (mm/s) CSR95L01	DORIS (mm/s) ITRF2000
344	2.58	2.03	0.471	0.462
345	2.56	2.26	0.469	0.458
346	2.46	2.04	0.466	0.456
347	2.47	2.09	0.474	0.466
348	2.30	2.15	0.477	0.468
349	2.62	2.19	0.462	0.455
350	2.02	1.74	0.465	0.459
351	2.55	2.35	0.471	0.463
352	2.61	2.54	0.453	0.449
353	2.38	2.19	0.468	0.461
Average	2.46	2.16	0.468	0.460

Table 3. The SLR and DORIS tracking data fits for the CSR orbits are improved using ITRF2000 as compared to the older CSR95L01 system. Updated DORIS coordinates for AREB appear to perform well. There are a few DORIS stations in ITRF2000 that may need additional adjustment, since it appears that they may have position errors that exceed 10 cm (ADEA, DIOA, MANA, ROTA, MARB, YARB, DJIB).

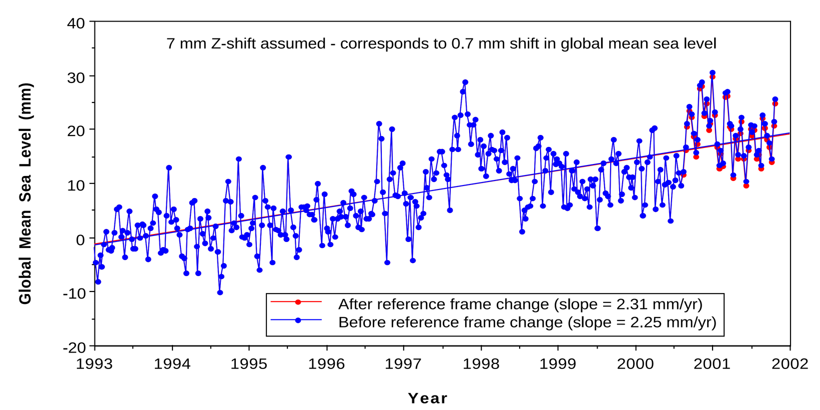

Figure 3. The simulated effect of a 7 mm Z-shift in the POE orbits on global mean sea level time series. With the current level of uncertainties, the effect is insignificant. However, this is only the difference between the new ITRF2000 and the older CSR95L01 reference systems. Ongoing analysis is required to determine the true drift in the terrestrial reference frame.

Jason-1 Precision Orbit Determination

Our goal was to assess the quality of the various orbits for Jason-1, particularly those from CNES, and evaluate the contribution of the various tracking systems. Jason-1 supports SLR, DORIS and GPS tracking, so a variety of orbit determination choices are available. Various institutions have used combinations of this tracking to produce precise orbits, which enable us to gain some insight into the orbit error characteristics. We can also use the altimeter data, in crossover form, as an independent check on some components of the orbit error (note that crossovers are insensitive to any orbit error that is common to ascending and descending tracks, including any miscentering in the Earth-fixed frame).

We noted that the medium precision orbits (MOE) placed on the Jason-1 IGDRs are of surprisingly good quality in many cases, as shown in Table 4. The orbits for T/P, on the other hand, are sometimes less accurate than usual, which is something to keep in mind during these Topex/Jason cross-calibration efforts. Figure 4 illustrates how the bias between Jason-1 and T/P becomes more consistent for ascending and descending tracks as the orbit accuracy, particularly the inertial centering, is improved.

Jason Cycle	Jason Mean (mm)	Jason RMS (mm)	TOPEX Mean (mm)	TOPEX RMS (mm)
3	-1.3	14.9	---	---
4	-1.6	14.1	---	---
5	0.9	15.6	---	---
6	8.6	24.1	---	---
7	9.2	34.8	---	---
8	2.8	15.7	-2.1	25.4
9	-0.3	15.2	-0.7	35.0
10	-1.1	19.4	-7.8	54.4
11	0.9	16.6	-2.8	61.6
12	9.3	26.6	5.9	33.5
Avg	2.7	19.7	-1.5	42.0

1 - Cycle 3, Passes 3-254 only because of OMM in Pass 1
2 - TOPEX Cycles 346-350 are GDR with POE

Table 4. Comparison of MOE orbits for Jason-1 and T/P with precise orbits computed by CSR using SLR and DORIS. The MOE orbits on Jason-1 appear to be competitive with the precise orbits in some cases.

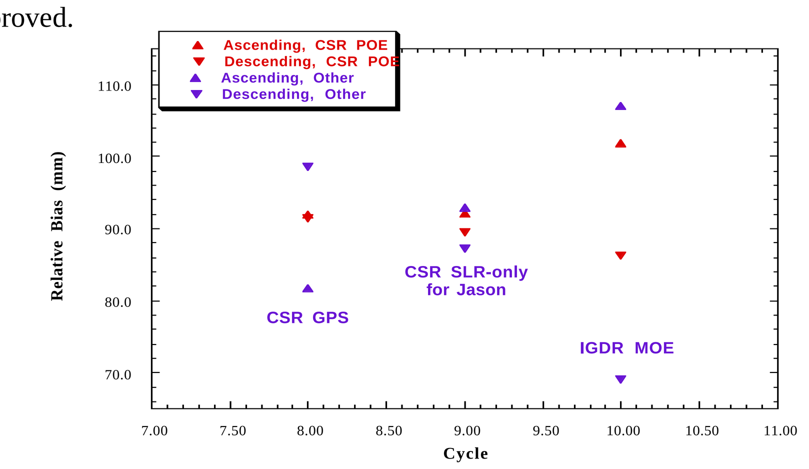

Figure 4. For cycle 8, a preliminary orbit based on GPS data did not appear to be as well-centered as a later precise orbit, leading to a significant discrepancy in the relative bias between Jason-1 and T/P for ascending and descending tracks. Using a more precise orbit, the discrepancy disappeared. For cycle 9, the SLR-only orbit was nearly as good as the combined SLR/DORIS orbit, so the bias discrepancy was fairly small. For cycle 10, a more precise orbit than the MOE considerably reduced the discrepancy, although it was not removed entirely.

In the following tables, we present some detailed evaluations of the various orbits submitted for comparison. We chose several statistics which capture much of the overall orbit error characteristics. The altimeter crossover rms is an obvious measure, which has the advantage of being independent of all the tracking. As noted earlier, the centering of the orbit in the inertial frame is also important for altimeter analyses. The Z-shift impacts studies of mean sea level, while miscentering of the orbit in the inertial frame within the equatorial plane create erroneous offsets between the ascending and descending tracks (the Z-shift is the same in the inertial and Earth-fixed frame). We did not explicitly compare all the orbits in the inertial frame, but rather relied on the mean crossover as an indicator of this. We did verify this with some experiments that the correlation was very strong between the crossover bias and the miscentering of an orbit in its inertial X and/or Y components; where the mean crossover is at the few mm level, the orbit is probably well centered in inertial space. We also can investigate orbit quality and consistency by intercomparing orbits. In this case, the number of possible combinations was unreasonable, and we chose to adopt our SLR/DORIS orbit as a standard for comparison. We believe our orbit is sufficiently accurate and unbiased to identify significant anomalies. Since our orbit appeared to be in good agreement with most orbits, we will assume that it is well centered in all three directions (X, Y and Z) in the Earth-fixed frame (also based on past performance on T/P). In addition, our orbit was produced with models exactly matching those we use for T/P (except those specific to each satellite), to provide a measure of orbit improvement relative to the standard T/P models. In each of the tables, our crossover statistics are included for reference. ITRF2000 was, as far as we know, used for all solutions. Individual data weighting and empirical parameterization, however, varied significantly between the various cases. Further details for some of these orbits should be available on other poster presentations.

CNES (SLR/DORIS)

Cycle	Crossover (CSR) Mean (mm)	Crossover (CSR) RMS (mm)	Crossover (CNES) Mean (mm)	Crossover (CNES) RMS (mm)	Radial Diff RMS (mm)	Radial Diff Mean (mm)	X Mean (mm)	Y Mean (mm)	Z Mean (mm)
3	-9	65	-2	64	12	2	-1	0	-2
4	-4	63	1	64	14	2	-4	-2	7
5	-3	64	4	65	16	3	-2	-3	1
6	-2	65	-3	63	17	4	0	2	4
7	3	71	-3	77	32	3	0	0	4
8	6	68	10	68	14	4	4	1	6
9	5	68	5	68	17	3	6	6	7
10	-3	68	-2	73	27	2	2	8	8
Mean	-1	66	1	68	19	3	0	2	4

CNES (GPS - DYN)

Cycle	Crossover (CSR) Mean (mm)	Crossover (CSR) RMS (mm)	Crossover (CNES) Mean (mm)	Crossover (CNES) RMS (mm)	Radial Diff RMS (mm)	Radial Diff Mean (mm)	X Mean (mm)	Y Mean (mm)	Z Mean (mm)
3	-9	65	-14	66	26	-2	-18	-15	-8
4	-4	63	8	66	18	2	-2	-3	1
5	-3	64	18	70	25	3	-1	-6	-17
6	-2	65	5	71	23	5	0	-3	-21
7	3	71	11	74	29	4	6	-1	13
8	6	68	4	68	14	4	6	-1	0
9	5	68	-3	67	18	3	8	5	7
10	-3	68	-7	64	19	2	2	7	12
Mean	-1	66	3	68	21	3	0	-2	-2

CNES (GPS - ELFE)

Cycle	Crossover (CSR) Mean (mm)	Crossover (CSR) RMS (mm)	Crossover (CNES) Mean (mm)	Crossover (CNES) RMS (mm)	Radial Diff RMS (mm)	Radial Diff Mean (mm)	X Mean (mm)	Y Mean (mm)	Z Mean (mm)
5	-3	64	18	69	25	3	9	-5	-14
6	-2	65	12	67	25	4	0	-2	-14
7	3	71	11	68	29	4	-3	1	11
8	6	68	9	68	16	4	5	-2	5
9	5	68	-2	67	17	3	2	-4	4
10	-3	68	-6	64	18	2	-3	3	12
Mean	1	67	7	67	22	3	2	-2	1

Table 5. CNES orbits based on SLR/DORIS and on GPS using dynamic and 'reduced-dynamic' (ELFE) approaches. The crossover mean is larger for the ELFE approach, and the scatter in the centering is quite large with the GPS-based solutions. There is also a few mm in the mean radial difference in all the CNES orbits which is not seen in any other case. This is a concern, since this can have an effect when linking the T/P and Jason-1 sea level time series, unless this is removed through the relative altimeter bias.

DEOS

Cycle	Crossover (CSR) Mean (mm)	Crossover (CSR) RMS (mm)	Crossover (DEOS) Mean (mm)	Crossover (DEOS) RMS (mm)	Radial Diff RMS (mm)	Radial Diff Mean (mm)	X Mean (mm)	Y Mean (mm)	Z Mean (mm)
3	-9	65	-4	66	17	0	-6	4	-11
4	-4	63	5	64	17	0	-4	9	-4
5	-3	64	6	65	20	1	1	9	-4
6	-2	65	0	64	19	1	2	7	-13
7	3	71	3	76	27	2	2	1	-8
8	6	68	16	72	17	2	-2	3	-5
9	5	68	9	68	16	1	-5	4	-7
10	-3	68	-2	65	17	0	-3	10	-9
Mean	-1	66	4	67	19	1	-2	6	-8

Table 8. DEOS orbits based on SLR/DORIS. There appears to be a systematic bias in the X-, Y- and Z-components.

CSR (DORIS only)

Cycle	Crossover (SLR/DORIS) Mean (mm)	Crossover (SLR/DORIS) RMS (mm)	Crossover (DORIS only) Mean (mm)	Crossover (DORIS only) RMS (mm)	Radial Diff RMS (mm)	Radial Diff Mean (mm)	X Mean (mm)	Y Mean (mm)	Z Mean (mm)
3	-9	65	-8	64	9	0	0	1	-10
4	-4	63	4	63	8	0	-1	0	-5
5	-3	64	2	64	8	0	0	0	-8
6	-2	65	-3	67	15	-1	1	1	-17
7	3	71	-2	72	13	0	1	1	-9
8	6	68	8	68	10	0	0	0	-14
9	5	68	5	68	7	0	-1	0	-5
10	-3	68	-5	65	14	0	-3	4	-4
Mean	-1	66	0	66	11	0	0	1	-9

Table 10. CSR orbits based on DORIS only. There appears to be a systematic bias in the centering in this case, also. The coherence with the DEOS orbits suggests that the DORIS data must be weighted significantly heavier than SLR in the DEOS case.

JPL (GPS)

Cycle	Crossover (CSR) Mean (mm)	Crossover (CSR) RMS (mm)	Crossover (JPL) Mean (mm)	Crossover (JPL) RMS (mm)	Radial Diff RMS (mm)	Radial Diff Mean (mm)	X Mean (mm)	Y Mean (mm)	Z Mean (mm)
8	6	68	-1	66	17	1	6	10	5
9	5	68	3	66	16	0	10	5	6
10	-3	68	5	65	21	0	6	8	4
Mean	3	68	3	66	18	0	7	8	5

Table 6. JPL orbits using GPS and a 'reduced-dynamic' approach. The crossover rms is consistently samaller. The earlier cycles from JPL were not representative of the later processing, and so they were excluded. There appears to be a significant bias in the X and Y Earth-fixed centering.

NASA (SLR/DORIS)

Cycle	Crossover (CSR) Mean (mm)	Crossover (CSR) RMS (mm)	Crossover (NASA) Mean (mm)	Crossover (NASA) RMS (mm)	Radial Diff RMS (mm)	Radial Diff Mean (mm)	X Mean (mm)	Y Mean (mm)	Z Mean (mm)
3	-9	65	-6	64	7	-1	0	-1	-4
4	-4	63	-1	63	8	-1	0	-2	0
5	-3	64	-5	63	11	0	1	-3	-4
6	-2	65	-2	64	10	1	3	1	-6
7	3	71	-2	75	23	1	4	-4	-7
8	6	68	7	67	9	1	2	-2	-4
9	5	68	5	69	13	0	1	-1	-2
10	-3	68	-2	67	12	0	1	2	-11
Mean	-1	66	-1	67	12	0	2	-1	-5

Table 7. GSFC orbits using SLR/DORIS. The GSFC models were specifically chosen to match those used at CSR to ensure a high level of internal agreement.

JPL/IGN (DORIS)

Cycle	Crossover (CSR) Mean (mm)	Crossover (CSR) RMS (mm)	Crossover (CNES) Mean (mm)	Crossover (CNES) RMS (mm)	Radial Diff RMS (mm)	Radial Diff Mean (mm)	X Mean (mm)	Y Mean (mm)	Z Mean (mm)
3	-9	65	-9	64	17	-1	3	1	20
4	-4	63	0	63	17	-1	1	2	24
5	-3	64	-2	64	17	0	5	0	18
6	-2	65	-10	67	17	1	6	1	8
7	3	71	-13	66	24	1	-3	6	18
8	6	68	-2	68	20	0	3	4	24
9	5	68	-7	67	22	-1	-1	2	30
10	-3	68	-14	66	21	-1	-2	4	24
Mean	-1	66	-7	65	19	0	1	2	20

JPL/IGN (DORIS+GPS)

Cycle	Crossover (CSR) Mean (mm)	Crossover (CSR) RMS (mm)	Crossover (CNES) Mean (mm)	Crossover (CNES) RMS (mm)	Radial Diff RMS (mm)	Radial Diff Mean (mm)	X Mean (mm)	Y Mean (mm)	Z Mean (mm)
8	6	68	0	66	16	1	1	6	12
9	5	68	0	66	16	0	3	4	11
10	-3	68	-2	64	20	-1	0	5	11
Mean	3	68	-1	65	17	0	1	5	11

Table 9. JPL/IGN orbits using DORIS and DORIS+GPS. The crossover RMS is very good on average. The orbit centering is considerably worse with DORIS only. There is a systematic bias in the Z-component for both cases.

CSR (SLR only)

Cycle	Crossover (SLR/DORIS) Mean (mm)	Crossover (SLR/DORIS) RMS (mm)	Crossover (SLR only) Mean (mm)	Crossover (SLR only) RMS (mm)	Radial Diff RMS (mm)	Radial Diff Mean (mm)	X Mean (mm)	Y Mean (mm)	Z Mean (mm)
3	-9	65	0	68	21	0	-3	-1	-4
4	-4	63	-7	64	5	0	1	0	1
5	-3	64	-6	67	12	0	-1	0	9
6	-2	65	-2	67	11	1	1	0	5
7	3	71	6	74	16	0	1	1	10
8	6	68	3	68	7	0	1	0	3
9	5	68	3	68	8	0	0	0	5
10	-3	68	4	71	21	1	-1	2	6
Mean	-1	66	0	69	13	0	0	0	4

Table 11. CSR orbits based on SLR only. While not as accurate as the other cases, the results are still very good. Predictably, the orbit appears to be well centered in Z.

Comparing the results among the various institutions, we note that most of the orbits have a mean X and Y that agrees with the CSR orbits within 2 mm, and within 5 mm for Z. Some orbit solutions, however, exhibit either significant biases or scatter in the centering, especially in Z. Almost all orbit solutions have a mean crossover of only 1 mm, although the cycle to cycle average is usually several mm. The radial bias in the CNES orbits is distinct from all other orbit solutions.

Conclusions:

There appears to be no problem with adopting the ITRF2000 reference frame for the T/P orbit production. While the Z-shift between ITRF2000 and the older CSR95L01 system does show up in the orbit differences, the effect on the sea level time series appears to be well within current uncertainties. However, SLR tracking and analysis is critical for maintaining and improving the terrestrial reference frame to support studies such as monitoring mean sea level from satellite altimetry.

Nearly all of the orbits produced for Jason-1, whether based on GPS only or SLR and DORIS or some combination, appear to be performing at a comparable level. If we believe that the T/P orbit accuracy is approaching the 2 cm level, it appears that the Jason-1 orbits are of a similar quality (as demonstrated by the fact that the RMS difference between the various orbits is generally less than 2 cm). The altimeter crossovers are an independent test which is particularly helpful in identifying orbit miscentering in inertial space in the equatorial plane. Crossovers are insensitive to any displacement of the orbit in the Earth-fixed frame, so the various orbit comparisons are important for testing this component of the orbit error. In general, in spite of the variety of techniques, the accuracies of the various orbits examined appear to be fairly uniform, and most orbits demonstrated consistent centering and good radial accuracy.

These results are preliminary, and it is anticipated that experience with the Jason-1 DORIS and GPS receivers will allow additional improvement of the orbit determination techniques and models. Whether the goal of 1 cm orbit accuracy is reachable remains to be seen, and it will be a challenge to quantify and verify the orbit error at this level.

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