Improvement of the TOPEX and Jason Orbit Time Series: Precision Orbit Determination, Calibration, Validation and Improvement through the Combined Reduction and Analysis of GPS, SLR, DORIS, and Altimetry Data

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ABSTRACT

Orbit error is a major component in the overall error budget of all altimeter satellite missions. Jason-1 is no exception and a 1 cm radial orbit accuracy goal has been set, which represents a factor of two improvement over what is currently being achieved for TOPEX/Poseidon (TP). Our current analysis suggests this goal has been met and even improved upon, but the challenge is to be able to continually achieve this high accuracy, verify the performance and characterize and quantify the remaining errors over the lifetime of the mission. The computation, verification and error characterization of such high accuracy orbits requires the reduction and analysis of all available tracking data (GPS, SLR, DORIS and altimeter). Current analysis also indicates the history of TP orbits can be further improved employing new solution strategies developed and tested on Jason-1. Our research focuses on the calibration, validation and improvement of orbit accuracies using all available tracking data including altimetry. We will compute and distribute well centered Jason orbits with an accuracy of better than 1-cm in the radial component. In addition to the orbits themselves, a characterization of the orbit error will be distributed and accumulated as a time series of orbit performance metrics to track anomalies and trends. The long time series of orbit error characterization will enable a better understanding of the remaining orbit errors and its impact on the altimeter data analysis. As part of this research effort we are also significantly improving the current level of TP orbit accuracy, re-computing new high-accuracy TP orbits from the beginning of the TP mission and continuing into the future (as long as TP is healthy). Our funded research effort will result in a complete and consistent time series of improved orbits for both TP and Jason, significantly benefiting the long time series of altimeter data analysis and the TP/Jason dual mission. The resultant high accuracy orbits and the characterization of their error will allow further improvements to the accuracy and overall quality of the altimeter measurement time series making possible further strides in radar altimeter remote sensing.

Achieving the 1-cm Orbit Goal

In *Luthcke et al. 2003* we showed the Jason 1-cm radial orbit accuracy goal has been met. Achieving this goal presented not only the challenge of producing these orbits, but also the challenge of demonstrating the accuracy of these orbits. Meeting these goals required the processing of all tracking data types available whether they were included in the orbit solution or withheld as independent data to assess orbit performance. We have computed and assessed the performance of five candidate orbit solutions determined from various combinations of the available Jason-1 tracking data and using different solution techniques. Using independent and dependent tracking data analysis, orbit difference analysis and crossover residual performance analysis we have demonstrated our GPS-based reduced dynamic orbits are achieving the 1 cm radial orbit accuracy goal. We have also demonstrated these orbits are very well centered and argued that the GPS-based orbits are as well centered or better than the SLR+DORIS orbits.

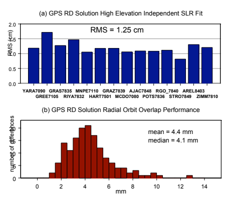


FIGURE 1 Independent SLR High Elevation performance from the GPS reduced dynamic solutions. Measurement biases estimated from high elevation pass SLR residuals offer the best single metric to gauge radial orbit accuracy. The RMS of the estimated biases indicates orbit error does not exceed 1.3 cm. The actual radial error is less because the statistic contains other error sources as well. SLR data above 60 degrees are selected for the high elevation test.

Table 1 Jason *Independent* and Dependent Data Residual Summary for Cycles 8-24

Solution Type (JGM3)	GPS DDLC RMS (cm)	DORIS RMS (mm/s)	SLR RMS (cm)	Xover RMS (cm)	Xover mean (cm)
SLR+DORIS Dyn.		0.420	1.706	*5.928*	*0.229*
SLR+DORIS RD		0.418	1.734	*5.867*	*0.219*
SLR+DORIS+Xover RD		0.418	1.914	5.780	0.049
JPL GPS RD		*0.420*	*1.586*	*5.754*	*0.035*
GPS RD	0.75	*0.419*	*1.698*	*5.766*	*-0.026*
GPS+SLR RD	0.77	*0.419*	1.341	*5.750*	*-0.029*

Table 2. Jason Orbit Difference Summary for Cycles 8-24

GPS+SLR RD minus	average rms (cm) radial	average rms (cm) 3d	ECF XY (cm) mean	ECF XY (cm) std	Z (cm) mean	Z (cm) std
SLR+DORIS Dyn	1.192	5.598	0.478	0.542	-0.005	0.301
SLR+DORIS RD	0.955	4.321	0.310	0.402	-0.009	0.330
SLR+DORIS+Xover RD	0.879	4.955	0.344	0.384	0.033	0.461
JPL GPS RD	0.779	2.575	0.026	0.177	-0.058	0.437
GPS RD	0.405	1.226	0.067	0.125	-0.075	0.119

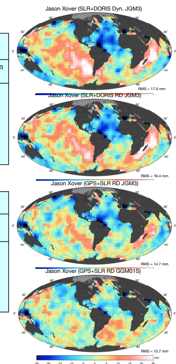
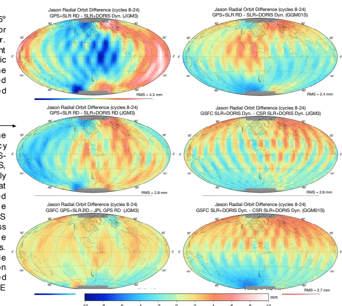


FIGURE 2 Crossover residuals averaged over 5° X 5° bins for cycles 8-24 show radial orbit error primarily due to anticorrelated gravity error. The maps show a progressive and significant reduction of error from SLR+DORIS dynamic to GPS+SLR reduced dynamic solutions. The maps also show the improvement obtained from the application of a GRACE derived gravity model (GGM01S).

FIGURE 3 The figures to the right illustrate the progressive improvement in consistency between our 1-cm reduced dynamic GPS-based orbit, and the dynamic SLR+DORIS, reduced dynamic SLR+DORIS, and finally another 1-cm GPS-based orbit computed at JPL. These figures also illustrate the reduced dynamic GPS-based orbits are internally more consistent than the dynamic SLR+DORIS orbits. In order to facilitate a seamless transition from T/P to Jason-1 we must ensure orbit consistency across the two missions. The figures to the right show that it is possible to further improve the T/P orbits (based on SLR+DORIS) by moving to our reduced dynamic solution strategy and a GRACE based gravity model.



Orbit improvement applied towards a seamless transition from TP to Jason-1

Application of GSFC Jason POD strategies to T/P SLR+DORIS (+Crossover) solutions shows significant improvement can be achieved over current GDR orbits. Table 3 indicates that reduced dynamic SLR+DORIS T/P orbits are not only superior to their dynamic counterparts, but even to the T/P reduced-dynamic GPS orbits

Table 3. TOPEX/Poseidon Collinear Altimeter Analysis

Orbit solutions T/P cycles 10-50	Number cycles	Altimeter collinear differences (cm) Mean	Altimeter collinear differences (cm) Std Dev
SLR+DORIS Dyn	38	0.014	8.454
GPS RD (JPL)	29	0.178	8.428
SLR+DORIS RD	38	0.020	8.407
SLR+DORIS+Xover RD	38	0.019	8.263

To 1st order, the discrepancy observed between the TOPEX and Jason datasets is due to GDR orbit error. Illustrated here the discrepancy is progressively and largely removed using the GSFC improved "Replacement" orbits. The "Replacement" orbits represent an initial step in our effort to improve the complete T/P and Jason-1 orbit time series. In addition to the orbits, further improvements in consistency in the altimeter datasets have been achieved and are described in the *Beckley et al. poster* (this meeting) *"Towards a Seamless Transition from TOPEX/Poseidon to Jason-1"*, and in the paper, *Beckley et al. 2004*.

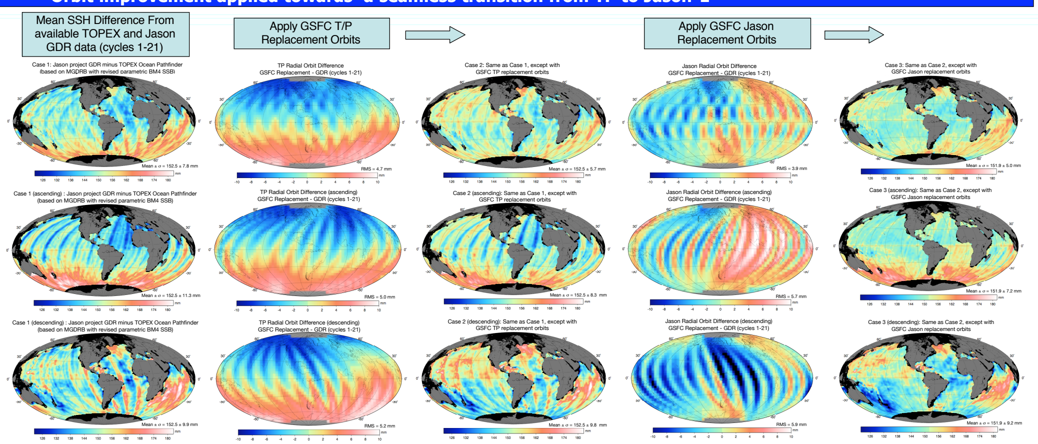


Table 4.a TOPEX JGM3 orbit performance (Jason cycles 1-21)

Orbit (TOPEX cycles 344-364)	RMS residuals DORIS (mm/s)	RMS residuals SLR (cm)	RMS residuals Crossover (cm)
GDR (NASA)	0.467	2.522	*5.618*
Replacement GSFC reduced dynamic SLR+DORIS, ITRF2000	0.465	1.979	*5.545*

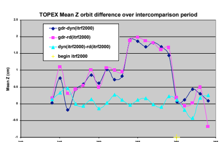
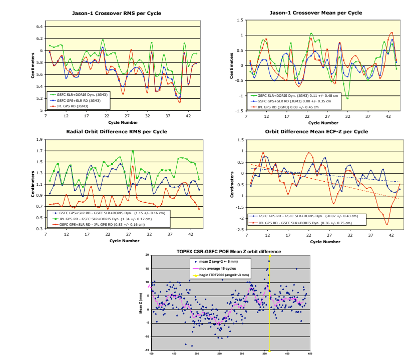


Table 4.b Jason JGM3 orbit performance (Jason cycles 1-21)

Orbit	RMS residuals DORIS (mm/s)	RMS residuals SLR (cm)	RMS residuals Crossover (cm)
GDR	0.408	2.697	*5.950*
Replacement GSFC reduced dynamic SLR+DORIS (cycles 1-7) GPS+SLR (cycles 8-21)	0.408	1.542	*5.694*

Future Work

Our Jason/TOPEX analysis over the inter-comparison period offers insight into orbit error characteristics and the means for significantly improving current orbits (*Luthcke et al. 2003*) . The GSFC improved orbits have been applied towards a seamless transition from TOPEX to Jason (*Beckley et al. 2004*), removing to 1st order, the observed TOPEX/Jason dataset discrepancy. The orbit analysis will be refined and extended over a much longer time series with the goal of identifying the optimal TOPEX/Jason POD strategies for reprocessing the entire time series of TOPEX and Jason orbits along with a detailed error characterization.



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