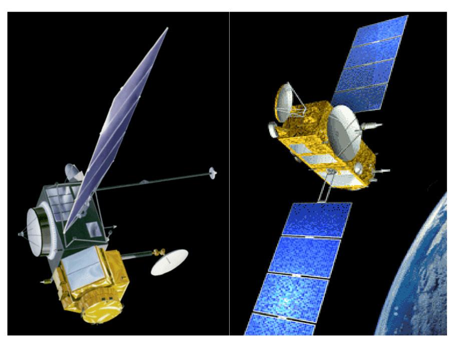
Improvement of the Complete TOPEX/POSEIDON and Jason-1 Orbit Time Series: Current Status OSTST 2007 meeting



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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 significant improvement over what is currently being achieved for TOPEX/Poseidon (TP). Studies have demonstrated this goal is being met and that the orbit accuracies can be improved *(Luthcke et al.*, 2003 and *Haines et al.,* 2004). However, the challenge is to continually achieve this high accuracy, verify the perfor mance, 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 the complete TP and Jason-1 orbit time series using all available tracking data including altimetry. Our 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 c limate data records. 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. Our evolving POD strategy using improved models (*Lemoine et al*., 2006) promise even further improvement in orbit accuracy and long term consistency for both TP and Jason (*Beckley et al*., 2004). In this presentation we summarize the curre nt status of our research effort which includes evaluation of the ITRF2005 reference frame and a new time varying gravity model.

Improvement of the Complete TP Orbit Time Series : Results from a recent reprocessing

Overview: **T able 1 presents the current modeling upgrades used to compute our latest complete TP (and Jason) orbit time series based on a dynamic solution reduction of SLR+DORIS data. While several additional improvements are planned, the following Tables and Figures demonstrate the new TP orbits represent a considerable improvement over the TP GDR orbits.**

Table 1. TOPEX & Jason-1 Modeling Summary

Models	TOPEX GDR orbits	GSFC Replacement Orbits: March 2007
Gravity (static)	JGM3 (70x70)	GGM02C (120x120) *(Tapley et al., 2004)*
Gravity (time-variable)	C20dot, C21dot, S21dot	C20dot, C21dot, S21dot + 20x20 annual terms from GRACE KBRR data. *(Luthcke et al., 2006)*
Atmospheric gravity	Not applied	NCEP, 50x50 @6 hrs (22-year mean removed) *(Petrov and Boy, 2004)*
Ocean Tides	Ray 94 + GEMT3X	(T/P-derived) GOT00.2 (20x20) *(Ray and Ponte, 2003)*
Solid Earth tides	k_2= 0.300; k_3=0.093 + FCN special handling	IERS2003
Station Coordinates	CSR95L02 (c001-359) ITRF2000 (c360-481)	ITRF2000 / DPOD2000 or ITRF2005
Tracking data	SLR / DORIS	same (+ Jason/DORIS SAA correction)
Parameterization	C_D/8-hrs + opr along+ cross track/day	Same: dynamic

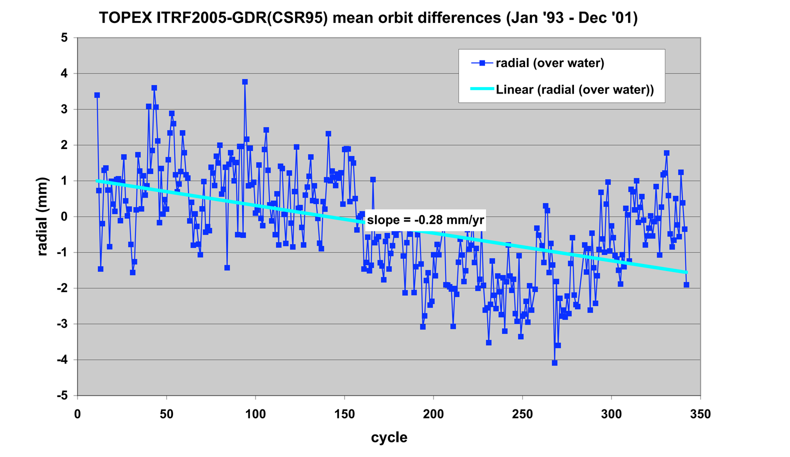
Table 2. Topex/Poseidon Orbit Performance Summary

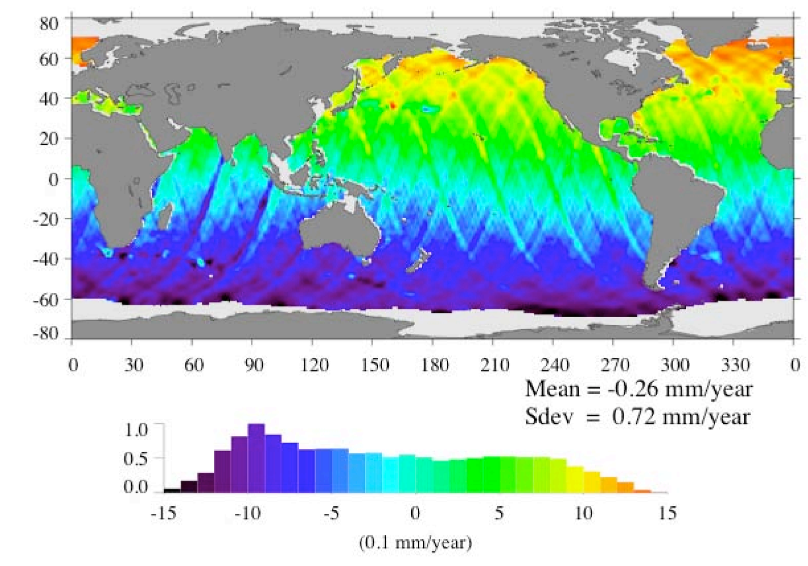
GSFC SLR/DORIS dynamic Orbits	DORIS Points	DORIS Residual (mm/s)	SLR Points	SLR Residual (cm)
GDR T/P Standards (JGM3, Ray-94 tides, CSR95 stations to cycle 359, ITRF2000 from cycle 360)	24952608	0.5246	2065219	2.218
GGMO2C+ GGM02C, ITRF2000 stations, Earth & Ocean (Got00) tides conform to IERS2003	25940300	0.5006	2415988	1.960
ATGRAV As ggm02c+, plus IAU2000 reference, forward gravity modeling of the atmosphere	25944455	0.5018	2416363	1.895
TVG As atgrav, plus Grace-derived (annual) time varying (20x20) gravity	25943984	0.5017	2415909	1.878
NCOM as tvg, plus CoM variations applied to station	25943761	0.5016	2415977	1.875

Table 3. Evaluation of new TOPEX *TVG* orbits

TOPEX SLR/DORIS Orbits Cycles 1-364	DORIS RMS (mm/s)	SLR RMS (cm)	SLR mean (cm)	Altimeter Crossover RMS (cm)
GDR	*0.5348*	*2.210*	*0.323*	---
ITRF2000	*0.5104*	*1.815*	*0.161*	---
ITRF2005	*0.5104*	*1.870*	*0.323*	---
ITRF2005 SLR-rescaled (with scale-rate)	*0.5102*	*1.771*	*0.195*	---
Subset Analysis: 21 TOPEX Cycles (344-364)				
ITRF2000	*0.4678*	*1.629*	*0.001*	*5.493*
ITRF2005	*0.4878*	*1.670*	*0.264*	*5.501*
ITRF2005 SLR-rescaled (with scale-rate)	*0.4676*	*1.572*	*0.099*	*5.494*

Impact on long-term sea level studies: **Orbit error due to Terrestrial Reference Frame (TRF) Z-drift directly affects MSL trend estimates on the order of 0.2 - 0.4 mm/year overall, and up to 1 - 2 mm/year regionally. Tests show ITRF2005 is the best TRF to date.**

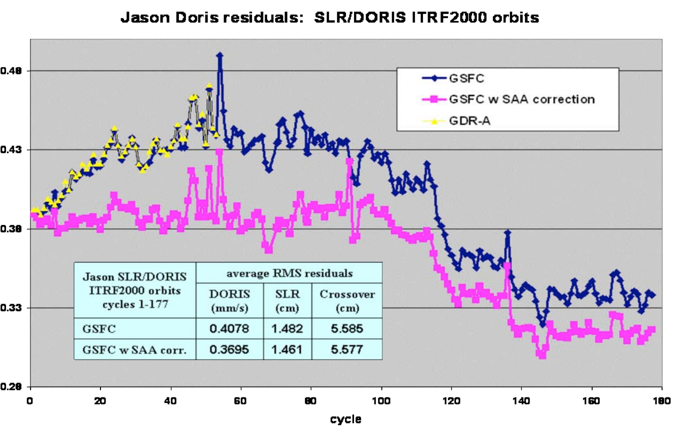


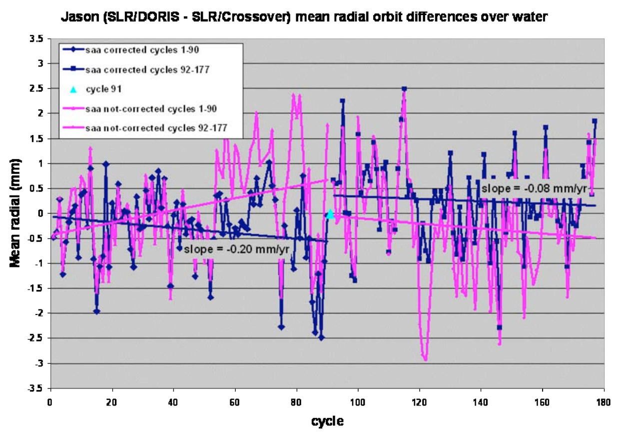


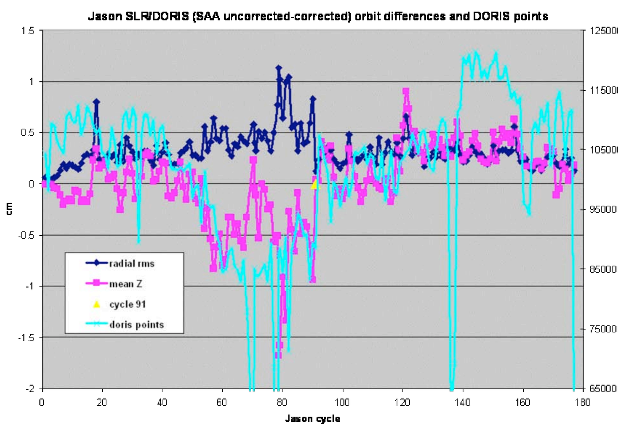
Improving the Jason-1 Orbit Time Series

Overview: **For Jason-1 the modeling upgrades described in Table 1 were implemented to update the POD solution models and strategy outlined in Luthcke et al., 2003. We have computed a new Jason-1 orbit time series (cycles 1 through 183) based on a dynamic solution reduction of SLR+DORIS data. In addition we have evaluated the DORIS SAA correction (*J.M.Lemoine and H. Capedeville* 2006) and tested several models to better understand the unexpected long-term and systematic orbit differences noted last year between centers. Our goal is to provide the most accurate Jason orbits which are most consistent with our most accurate TP orbits.**

DORIS SAA: **The SAA correction model (*J.M. Lemoine and Capdeville,* 2006) reduces the DORIS residuals and removes the strong trend in the SLR/DORIS orbit mean Z (and mean radial over water). Comparison with the SLR/Crossover orbit shows a ~0.9 mm jump in Z, with the switch-over in the DORIS oscillator at cycle 91. The Z-trend observed over cycles 1-90 is about twice the trend between the ITRF2000/ITRF2005 orbits. The orbit Z-trend was likely caused by the combination of both the SAA effect and degradation in the DORIS tracking as shown.**



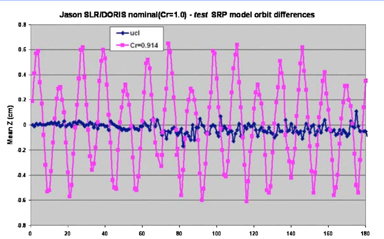


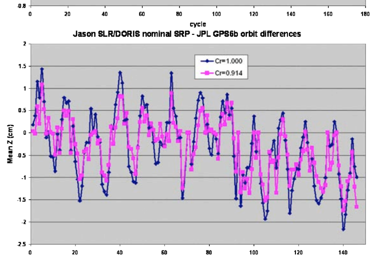


SRP: **The solar radiation pressure coefficient (C_R) for the *a priori* CNES macromodel has been estimated using 91 SLR/DORIS arcs over cycles 1-184. Also the UCL (*Ziebart et al.*, 2005) has been implemented in GEODYN but not yet tuned. Although the untuned UCL and the untuned C_R produce very similar orbits, using the C_R tuned to 0.914 produces orbits which show a 120-day signal in the mean Z difference, and explain some of the mean Z differences with the JPL GPS6b orbits. The JPL GPS6b 120-day radial orbit difference signal is not well explained.**

Jason global C_R estimate for nominal SRP model using SLR/DORIS arcs	Jason solar radiation pressure coefficient (C_R): a-priori	estimated	sigma estimate
cycles 1-90 (45 arcs)	1.0	.913100	9.E-06
cycles 92-184 (46 arcs)	1.0	.914134	8.E-06
cycles 1-184 (91 arcs)	1.0	.913634	6.E-06
use C_R = 0.914 for the estimated value in tests			

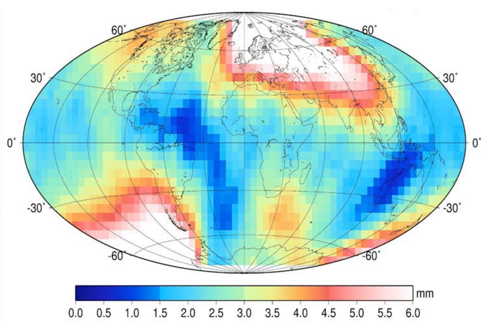
Jason SRP model performance cycles 1-180	average RMS residuals: DORIS (mm/s)	SLR (cm)	Crossovers (cm)
nominal (C_R =1.000)	0.3688	1.460	5.577
nominal (C_R =0.914)	0.3688	1.433	5.585
UCL (untuned)	0.3632*	1.445*	----
* fewer points used (dynamic editing)			



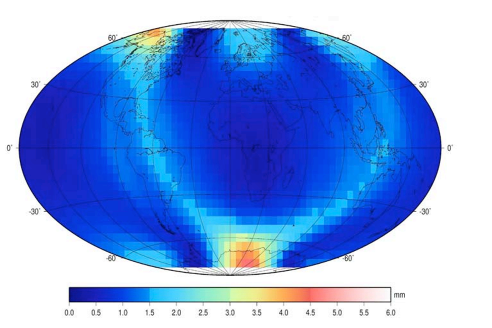


Jason-1 120-day radial orbit difference amplitude (mm)

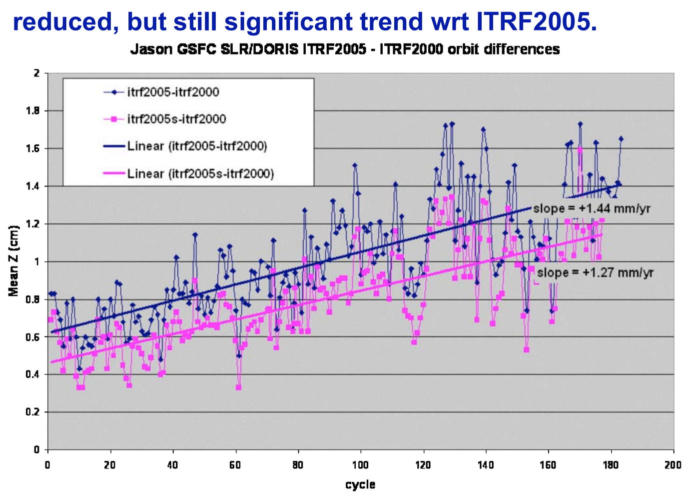
SLR/DORIS (Cr=1) - JPL/GPS6b

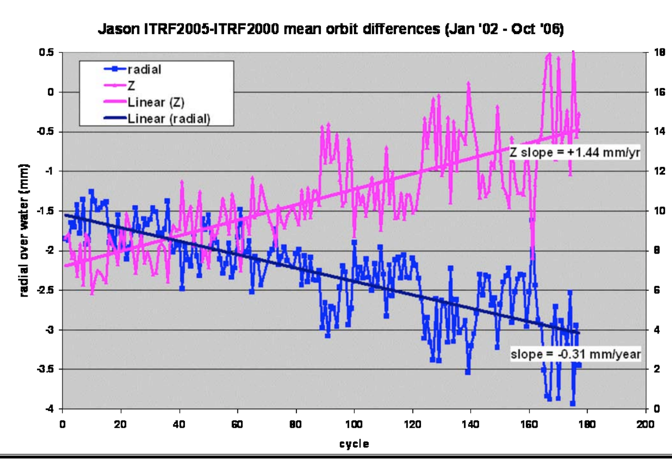


SLR/DORIS: (Cr=1) - (Cr=0.914)



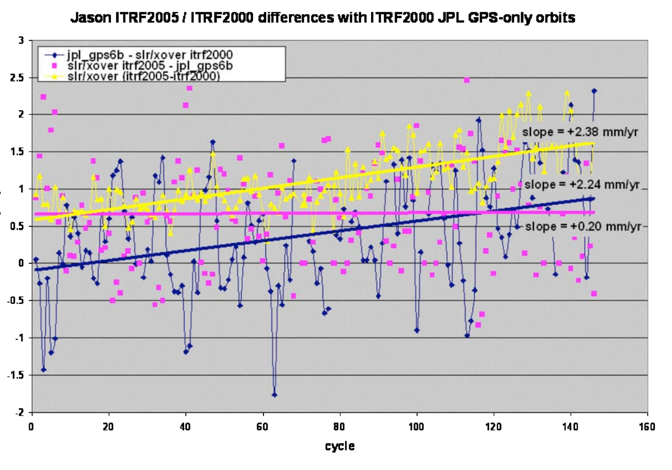
TRF: **Inconsistency in terrestrial reference frame origin definition directly results in SLR/DORIS orbit drift in Z. Use of the ITRF2005 frame will alter the estimated MSL rate by -0.31 mm/year compared to the ITRF2000 frame. Use of the ITRF2005 SLR-rescaled complement (with scale-rate) improves the SLR fits and slightly reduces the Z trend wrt. ITRF2000. The JPL GPS6b orbit shows little or no Z-trend relative to the ITRF2005 –based orbits (compared to ITRF2000). The Jason GPS6b orbits are based on GPS satellite orbits which are routinely computed as free network solutions, and rotated to ITRF2000. The GDRB GPS/DORIS/SLR ITRF2000-based orbits show a reduced, but still significant trend wrt ITRF2005.**

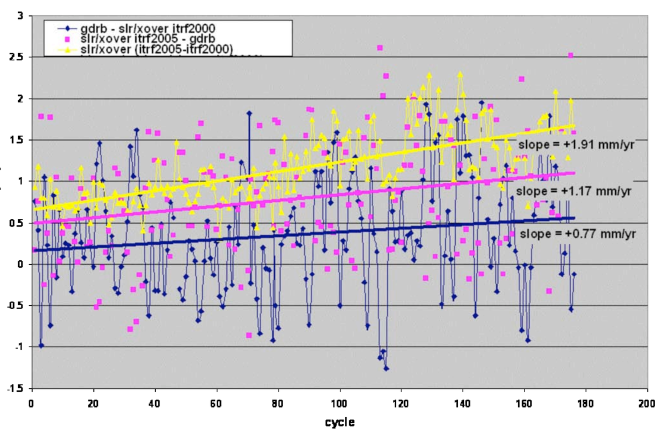




Jason (and TOPEX) radial orbit differences are driven by the difference in Z

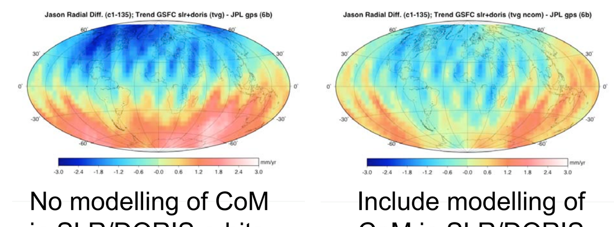
Jason Orbits SLR/DORIS Cycles 1-177	DORIS RMS (mm/s)	SLR RMS (cm)	SLR mean (cm)	Altimeter Crossover RMS (cm)
ITRF2000	*0.3740*	*1.440*	*-0.058*	*5.578*
ITRF2005	*0.3734*	*1.423*	*0.257*	*5.573*
ITRF2005 SLR-Rescaled with scale-rate	*0.3734*	*1.365*	*-0.030*	*5.576*





COM: **The JPL GPS orbits follow more closely the COM (geocenter), whereas the SLR/DORIS (ITRF2000) orbits are more CoF (center of figure). It is important to stay consistent.**

Jason-1 radial orbit trend: SLR/DORIS (gsfc) vs GPS (jpl)



No modelling of CoM in SLR/DORIS orbits. | Include modelling of CoM in SLR/DORIS orbits.

STATUS

We have completed and delivered a consistent time-series of ITRF2000 and ITRF2005-based SLR/DORIS dynamic orbits for TOPEX/Poseidon & Jason-1:

- **Jason-1 cycles 1-183 ; 01/15/02 - 01/03/07**
- **TOPEX cycles 1-481; 09/25/92 - 10/09/05**
  - **TOPEX SLR/DORIS orbits cycles 1-364, 365-446 Tandem**
  - **TOPEX SLR/Crossover orbits cycles 447-481 Tandem**

The ITRF2000-based TOPEX orbits used by Phil Callahan for GDR reprocessing ("tvg_dyn_2006aug28")

These orbits are not the GSFC final product.

- **ITRF2005-based orbits are preliminary and will soon be updated.**
- **ITRF2000-based orbits will be archived, but this series will not be extended for Jason.**

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Future: **Future analysis, as well as model and solution strategy improvements will be made in order to further reduce the orbit uncertainties. The success, in large part, will depend on the continued diligence and cooperation of the OSTM POD Team members: CNES, NASA GSFC, JPL, UT CSR…**

Acknowledgements **We wish to thank the JPL, CNES and UTCSR POD teams for the distribution of their orbits and many fruitful discussions and exchanges. We acknowledge the NASA Physical Oceanography program and the TOPEX/Poseidon project for their support. The TOPEX/Poseidon and Jason POD teams acknowledge the International Laser Ranging Service (ILRS), the International DORIS Service (IDS), and the International GNSS Service for their support.**

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