Calibration and Validation of the Precise Orbits for OSTM – Extending the TOPEX, Jason-1 and Jason-2 Climate Data Record for MSL Studies

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ABSTRACT

The quality and the precision of the satellite orbit is a critical component of the OSTM mission and provides the central reference frame for the altimeter data. The analysis of OSTM altimeter data and data from TOPEX/Poseidon and Jason-1 requires that the orbits for all three missions be in a consistent reference frame, and calculated with the best possible standards to minimize error and maximize the data return from the 15+ year time series, particularly with respect to the demanding application of measuring mean sea level change. We discuss the (1) the validation of the tracking systems on OSTM by processing data from all available tracking systems on the spacecraft (SLR, DORIS, GPS and altimeter crossovers); (2) the production of a consistent set of orbits for GFO, TOPEX/Poseidon Jason-1 and the OSTM using updated orbit and geophysical model standards. Issues associated with the quality of the models and the tracking systems are explored, and which include time varying gravity, the terrestrial reference frame, orbit centering, and OSTM model tuning.

Extending the TOPEX, Jason-1, Jason-2 accurate and consistent orbit time series

GSFC POD Model Standards May 2009: std0905 (changes from std0809 in red)			
Reference frame and displacement of reference points			
SLR	SLRF2005 + LPOD2005 (version 11)		
DORIS	DPOD2005 (version 1.4)		
Earth tide	IERS2003		
Ocean loading	Got4.7 all stations		
Tidal CoM &EOP	Got4.7; VLBI high frequency terms		
EOP	IERS Bulletin A daily (consistent with ITRF2005)		
Precession / Nutation	IAU2000		
Gravity			
Static	Eigen-Gl04s		
Time varying	Linear C20-dot, C21-dot, S21-dot (IERS2003) + 20x20 annual terms from GRACE		
Atmospheric	ECMWF, 50x50@6hrs		
Tides	Got4.7 20x020 (ocean); IERS2003 (Earth)		
Satellite Surface Forces and attitude			
Albedo /IR	Knocke-Ries-Tapely (1988)		
Atmospheric drag	MSIS86		
Radiation pressure	*TOPEX*	*Jason-1*	*Jason-2*
	tuned 8-panel	UCL	Jason-1 8-panel
Radiation scale coeff.	C_R = 1.0	C_R = 1.0	C_R = 0.916 (tuned)
Attitude	Nominal Yaw; Quaternions off-nominal	Nominal Yaw	Quaternions
Tracking data and parameterization			
Tracking data	SLR/DORIS (Jason1 DORIS corrected for SAA)		
Troposphere model	SLR: Mendez-Pavlis; DORIS: GPT + GPS/Neill		
Parameterization	Drag/8 hrs + opr along & cross-track /24 hrs + DORIS time bias /arc; 10-day arc dynamic solution		
Antenna reference	*TOPEX*	*Jason-1*	*Jason-2*
SLR	LRA model	tuned offset	pre-launch
DORIS	pre-launch	pre-launch	pre-launch
SLR/DORIS weight	10-cm / 2-mm/s	10-cm / 3-mm/s; down-weight 14 SAA stations	10-cm / 2-mm/s

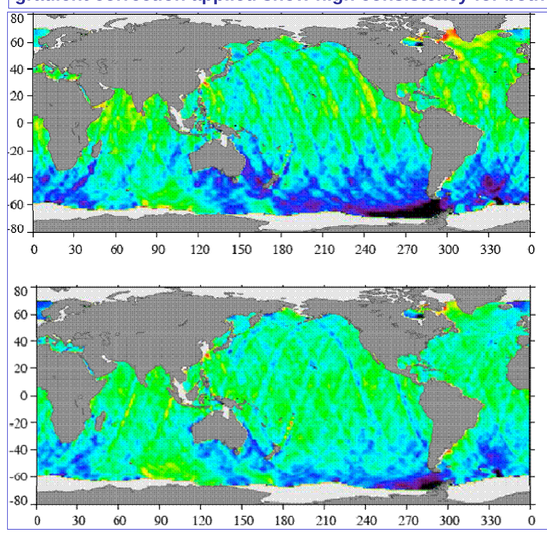
NEW POD STANDARDS DEVELOPED AND TESTED FOR OSTM

Evaluation of new TOPEX 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*	---
ITRF2005 SLR-rescaled (2007 release)	*0.5111*	*1.828*	*0.347*	---
std0809 (2008 release)	*0.5110*	*1.824*	*0.415*	---
std0905 (2009 release)	*0.5104*	*1.791*	*0.386*	---
Subset Analysis: 21 TOPEX Cycles (344-364)				
ITRF2005 SLR-rescaled	*0.4682*	*1.553*	*0.198*	*5.526*
std0809	*0.4677*	*1.544*	*0.255*	*5.521*
std0905	*0.4668*	*1.558*	*0.266*	*5.508*

Evaluation of new Jason-1 orbits						
Jason-1 SLR/DORIS Orbits cycles 1-259	DORIS		SLR			Xover rms (cm) cyc 1-176
	points	rms (mm/s)	points	mean (cm)	rms (cm)	
std0809 (release 2008)	112067	0.3727	4105	0.010	1.120	5.585
std0905 (release 2009)	110664	0.3732	4111	0.177	1.057	5.584

GSFC TP, J1, and J2 orbit Release anonymous ftp dirac.gsfc.nasa.gov				
path (pub/earth)	orbit name	cycles	description	release date
TP repro_topex/swt09	gsfc_poe_std0905.$cycle.Z	001-446	LPOD2005/DPOD2005 stations, 0905 standard	summer 2009
Jason-1 repro_jason/swt09	gsfc_ja1_poe_ld_std0905.$cycle.Z	240-259	LPOD2005/DPOD2005 stations, 0905 standard	summer 2009
Jason-2 repro_jason/ostm/swt09	gsfc_ja2_poe_ld_std0905.$cycle.Z	001-030	LPOD2005/DPOD2005 stations, 0905 standard	summer 2009

OSTM-Jason1 Sea Surface Height Differences (OSTM cycles 1-20) with only cross-track gradient correction applied show high consistency for both GDRC and GSFC orbits



GDRc orbits

Mean = 83.4 mm (83.8)
Sdev – 3.3 mm (9.5)

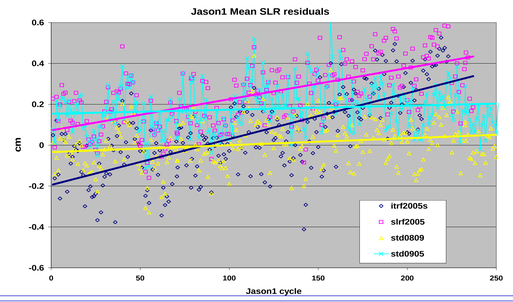
GSFC replacement std0905 orbits

Mean – 83.8 mm (84.1)
Sdev = 2.4 mm (9.3)

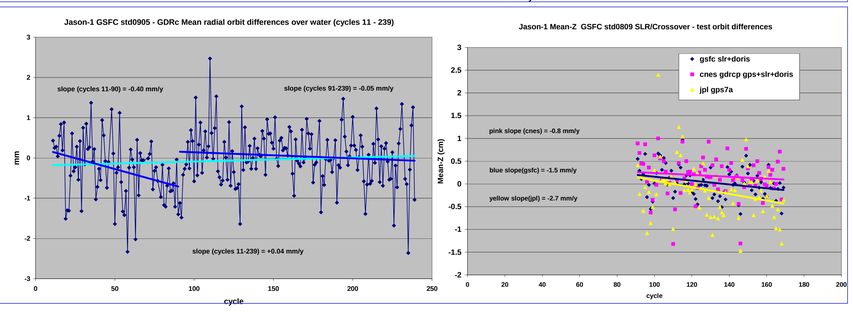
Sources of orbit error

TRF Terrestrial Reference Frame accuracy is essential to POD and altimeter data science. The DPOD2005 and SLRF2005/LPOD2005 have been critical for achieving and maintaining highly accurate orbits. The continuation of such a service for ITRF2008 should be considered.

Test DORIS-only orbit	DORIS number of stations	DORIS RMS (mm/s)	SLR RMS (cm)	Orbit difference RMS (cm) radial	Orbit difference RMS (cm) 3-D total
T/P cycles 1-21 from September 1992					
ITRF2005 original	42	0.5437	7.3		
DPOD2005	48	0.5403	7.3	0.50	3.95
Jason-1 cycles 1-21 from January 2002					
ITRF2005 original	53	0.3970	3.0		
DPOD2005	54	0.3970	3.0	0.12	0.96
Jason-1 cycles 240-253 from July 2008					
ITRF2005 original	35	0.3752	4.3		
DPOD2005	55	0.3514	3.4	0.47	4.67
Jason-2 cycles 001-014 from July 2008					
ITRF2005 original	35	0.3876	3.9		
DPOD2005	56	0.3638	3.2	0.60	3.34

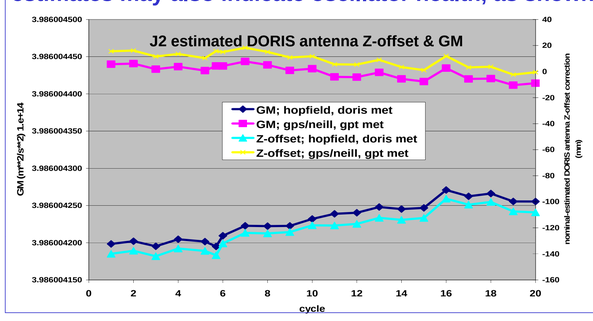


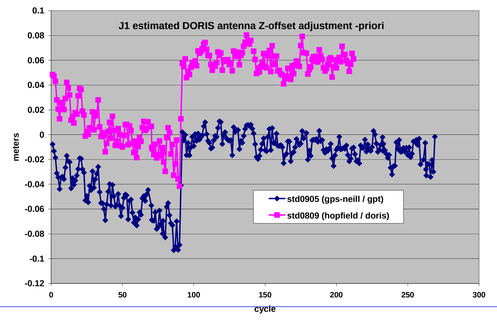
Orbit Centering Trends in mean-Z orbit centering contribute about 20% of that error to global MSL trend estimates. Orbit centering error appears to add about 0.4 mm/y to the MSL linear trend estimate error budget.



DORIS sensitivity

Estimated antenna Z-offset and GM (scale) show high sensitivity to troposphere model error. Trends in the Z-offset estimates may also indicate oscillator health, as shown over J1 cycles 1-90 of known oscillator degradation



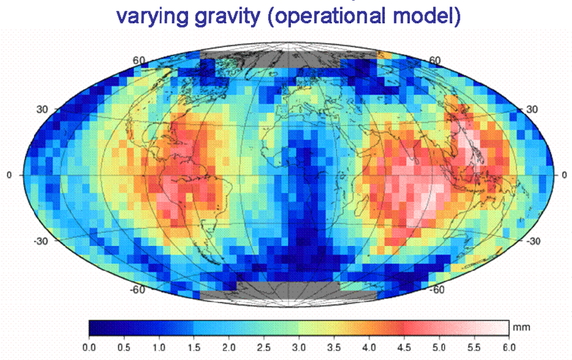


Conclusions & Future Work

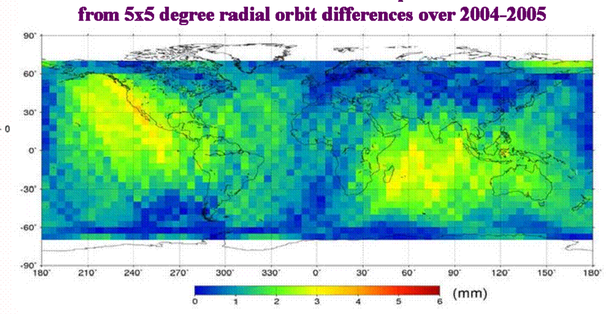
- We have delivered a consistent time series of our latest and most accurate SLR/DORIS orbits for TP, Jason-1, and OSTM.
- We will investigate use of GPS data for Jason-1 and OSTM POD, and refine OSTM model tuning.
- Future analysis, as well as model and solution strategy improvements will be made in 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.

TVG residual Time Varying Gravity effect on Jason-1 orbit shows an annual amplitude of 2.5 mm compared to 5 mm for the total operationally modeled effect

Jason1 radial 5-mm annual amplitude due to time varying gravity (operational model)

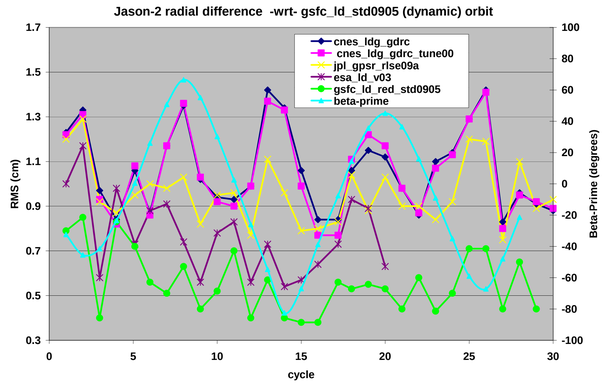


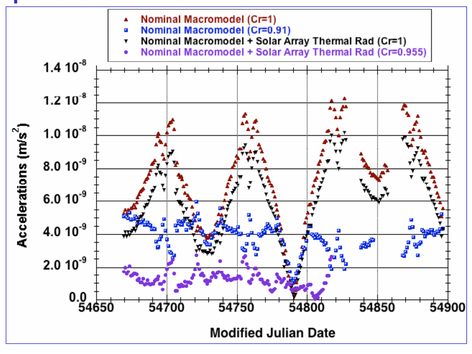
Effect of residual TVG on J1 orbit:
(operationally modeled: atgrav+annual) - (atgrav+mog2d+gldas + est. 60x60/mo Grace)
2.5 mm annual residual amplitude from 5x5 degree radial orbit differences over 2004-2005



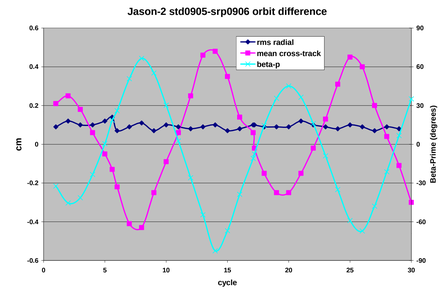
Jason-2

The orbits compare well between CNES, JPL, ESA, and GSFC. A 60-day signal in the radial differences suggests the largest remaining error is in surface force modeling. A new macromodel was constructed by including TP defined solar array thermal properties and tuning C_R to 0.955 . The new model, srp0906, reduces the recovered along-track accelerations, but has little effect on the radial orbit component.





Jason2 orbit evaluation cycles 1-20	doris (edit cyc 18) points	doris (edit cyc 18) rms (mm/s)	slr (edit cycles 18) points	slr (edit cycles 18) mean (cm)	slr (edit cycles 18) rms (cm)	xover rms (cm) (edit cyc 18,20) points	xover rms (cm) (edit cyc 18,20) rms (cm)
gsfc ld std0905	169900	0.3719	2764	-0.020	1.288	4814	5.512
gsfc ld srp0906	169900	0.3718	2764	-0.017	1.290	4814	5.505
gsfc ld red_std0905	169900	0.3711	2764	-0.075	1.242	4814	5.460
cnes ldg gdrc	167553	0.3719	2718	0.000	1.215	4812	5.523
cnes ldg gdrc tune00	167553	0.3718	2718	-0.019	1.209	4812	5.532
jpl gps rlse09a	162291	0.3720	2662	0.015	1.307	4414	5.362



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POD
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