

Calibration and Validation of the Precise Orbits for OSTM - Extending the Climate Data Record for MSL Studies

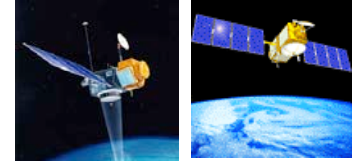
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OSTST Meeting
November 10-12, 2008
Nice, FRANCE



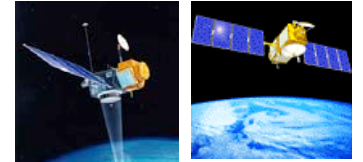
Outline



- **Status as of Hobart (pre-Jason-2 launch).**
- **Outstanding issues.**
- **Development of New Standards.**
- **Results for Jason-1.**
- **Results for TOPEX/Poseidon.**
- **Jason-2**
 1. *(Validation of LPOD2005)*
 2. **Impact of quaternions on SLR/DORIS POD.**
 3. **Tuning of A priori Macromodel.**
 4. **Tuning the Offsets (SLR, DORIS)..**
 5. **Orbit Comparisons (internal vs external).**
- **Outstanding issues.**



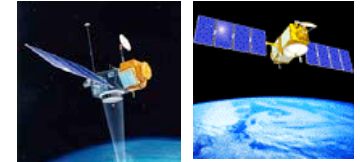
Objectives of Investigation



- 1. Develop a consistent time series of orbits across all altimeter missions (TOPEX/Poseidon, Jason-1, Jason-2) Using unified geophysical modelling.**
- 2. Examine modelling issues which impact the orbit performance and which might cause spurious signals in the altimetry.**
e.g.
 - Reference frame (changes) & impact on MSL.
 - Solar radiation pressure & 120-day (beta-prime) stationary signals.
 - SLR station performance & bias stability; DORIS station performance.
- 3. Process all tracking types during CalVal to validate the tracking systems and POD performance on Jason-2**
- 4. Supply consistent POE orbits for J1 & J2 during the Tandem phase.**



Status as of Hobart OSTST, 2007

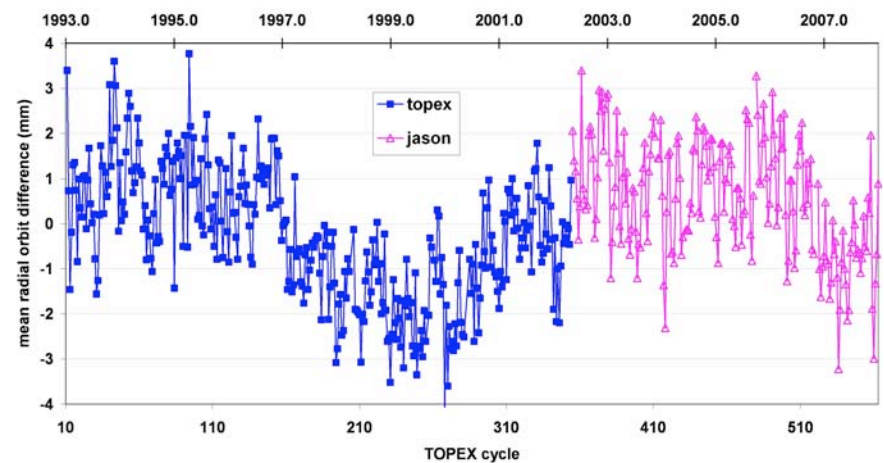
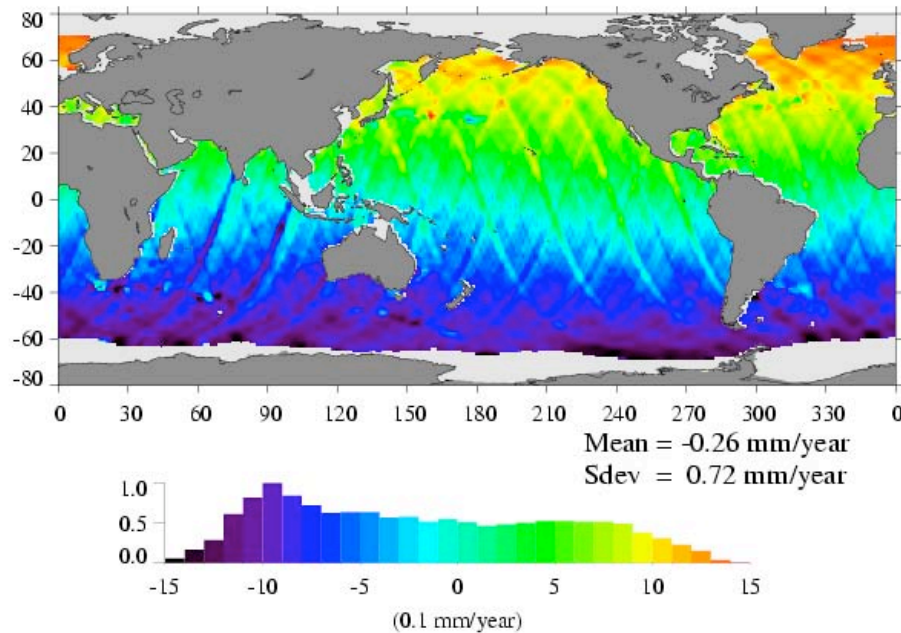


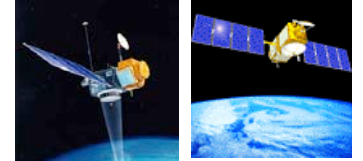
Recomputation of T/P & J1 orbits

TOPEX Precision Orbit Determination Results: Cycles 1-364

Orbits	DORIS RMS (mm/s)	SLR RMS (cm)	Xover RMS ¹ (cm)
GDR	0.5348	2.21	5.713
ITRF2005	0.5104	1.87	5.472

Time-variable Z-shift in orbits due to reference frame (CSR+ITRF2000 vs ITRF2005) affects MSL calculations.





Outstanding Modelling Issues for Jason-2

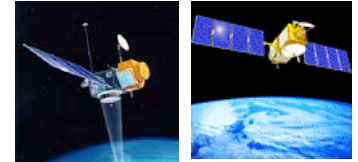
- **New Gravity Models (EIGEN-GL04S1, EGM2008).**
- **New SLR Reference Frame Solution (SLRF2005) (+SLR Station bias modelling) (+ LPOD2005).**
- **Update to ITRF2005 for DORIS (DPOD2005).**
- **Nonconservative Force Modelling.**
- **Other model updates (such as):**
 1. **GOT4.7 Ocean Tide Model.**
 2. **ECMWF-6hr.**
 3. **LRA Phase Map for Jason-1.**
 4. **Tidal EOP & Tidal COM.**
 5. **Ocean Pole Tide.**
 6. **Testing of UCL/Jason-1 RP Model in GEODYN.**



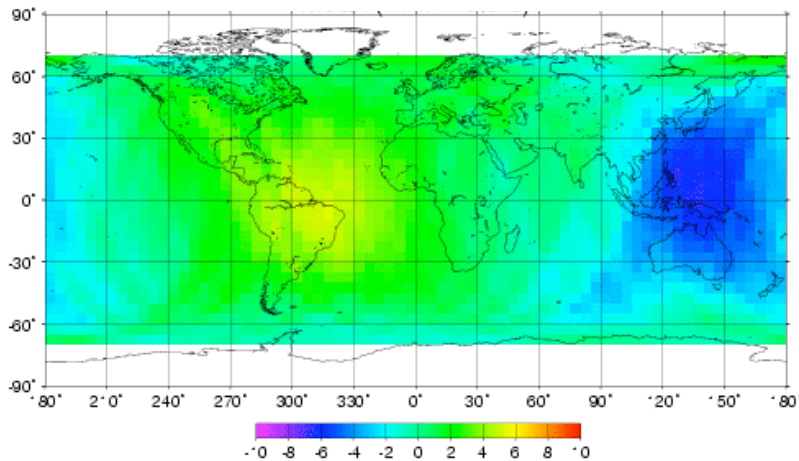
Gravity Model Comparisons for J1:

Jason1 radial orbit differences ($5^\circ \times 5^\circ$ bins)

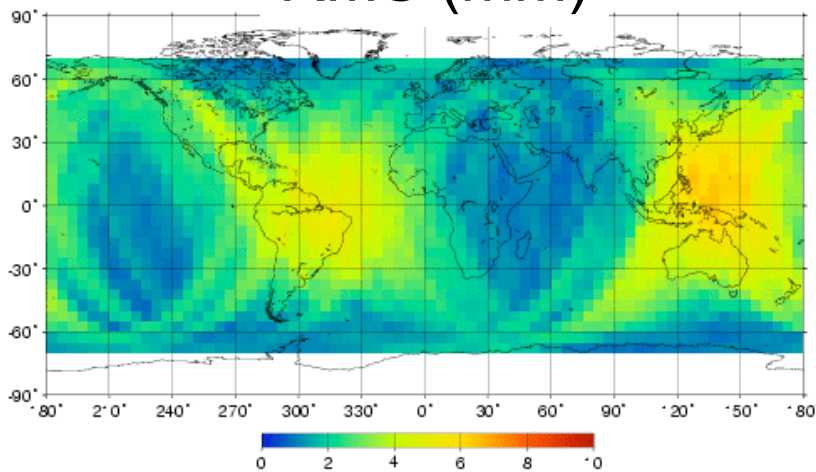
EIGEN-GL04S1 (IERS c21/s21) vs. GGM02C



Mean (mm)



RMS (mm)



**Jason-1 Cycles 1-21:
RMS of fit**

GGM02C:

Doris: 0.3979 mm/s

SLR: 1.508 cm (0.086 mean)

Xover: 5.732 cm

EIGEN-GL04S1:

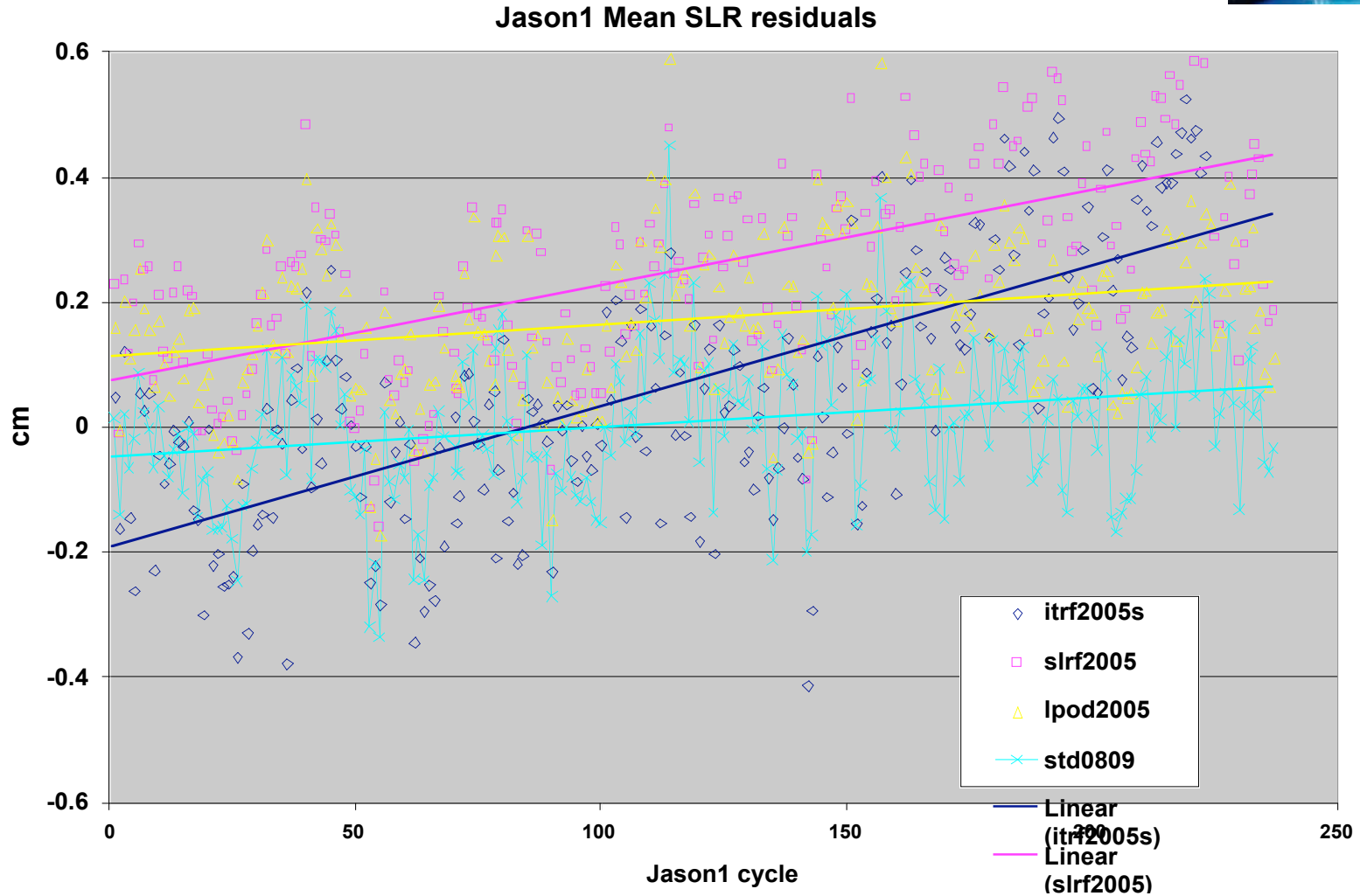
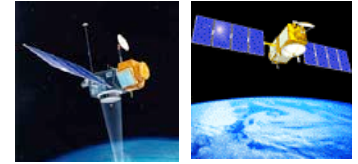
Doris: 0.3979 mm/s

SLR: 1.479 cm (0.081 mean)

Xover: 5.728 cm



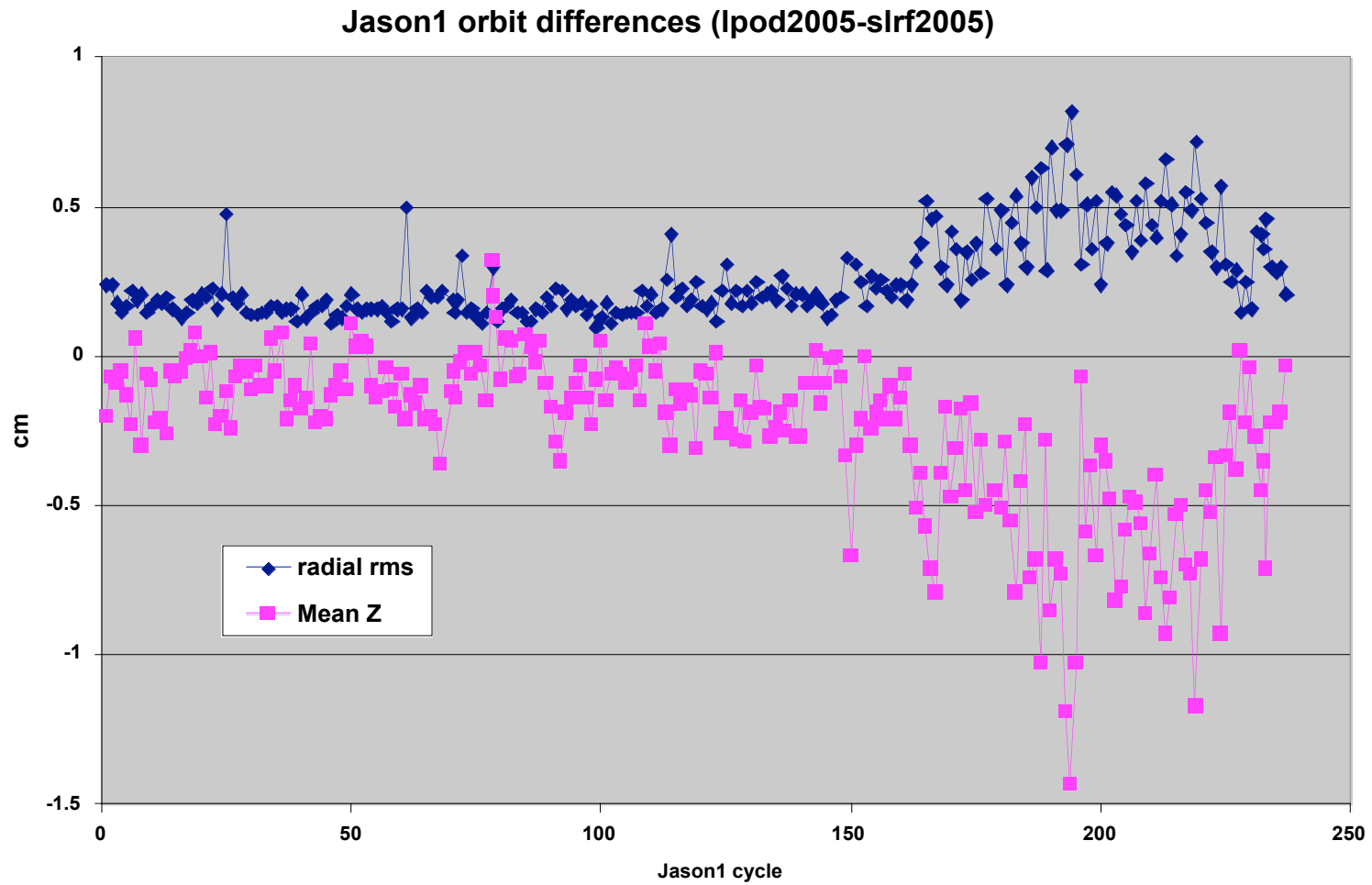
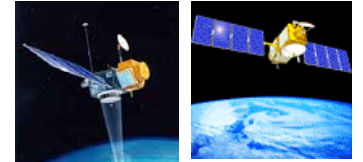
SLR Residual Analysis with Jason-1



Evidence of SLR station bias / position error, the LPOD2005 solution, and effect on the Jason-1 orbit.

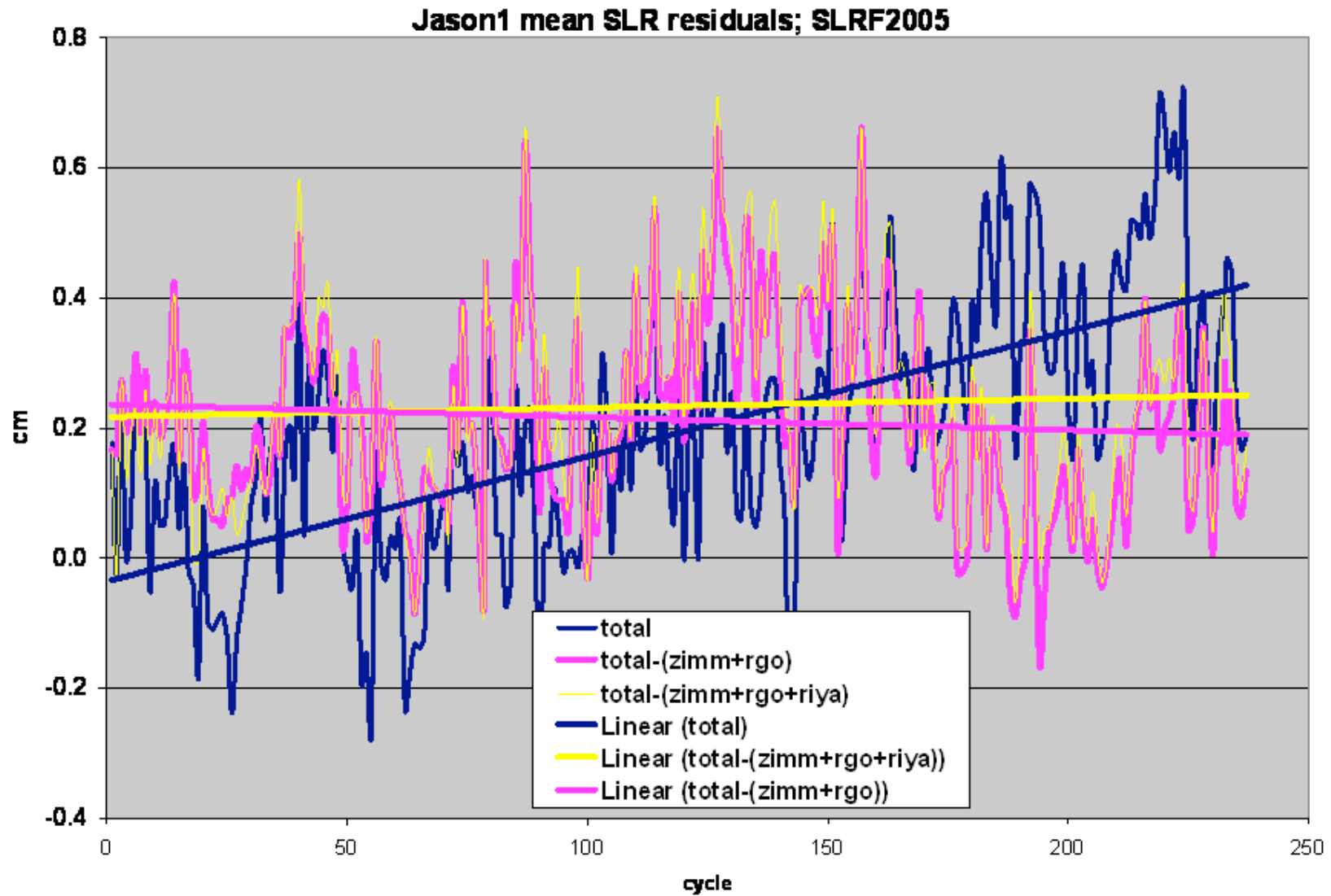
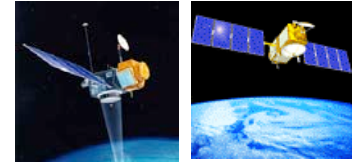


Impact on Jason-1 Orbit



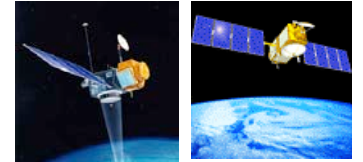


SLR Mean Residuals with SLRF2005



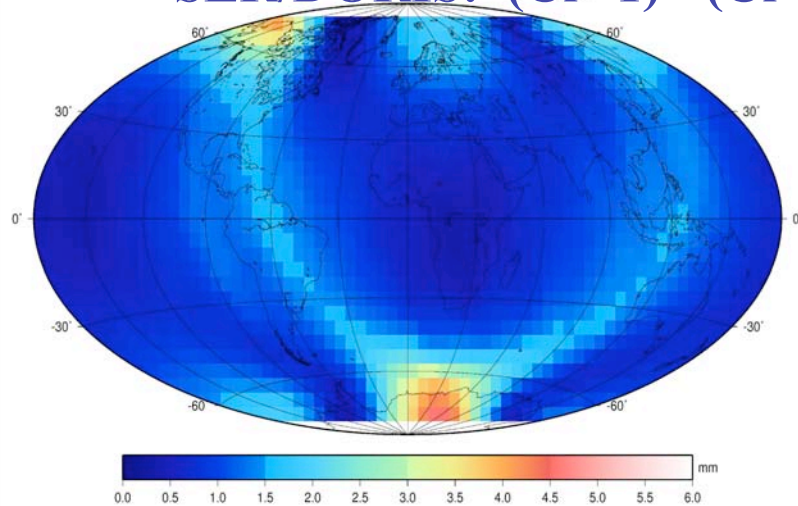


Nonconservative Force Modelling for Jason-1



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

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

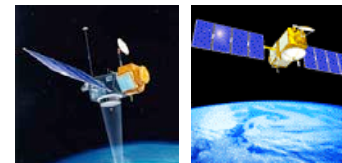


Test Models for Jason-1

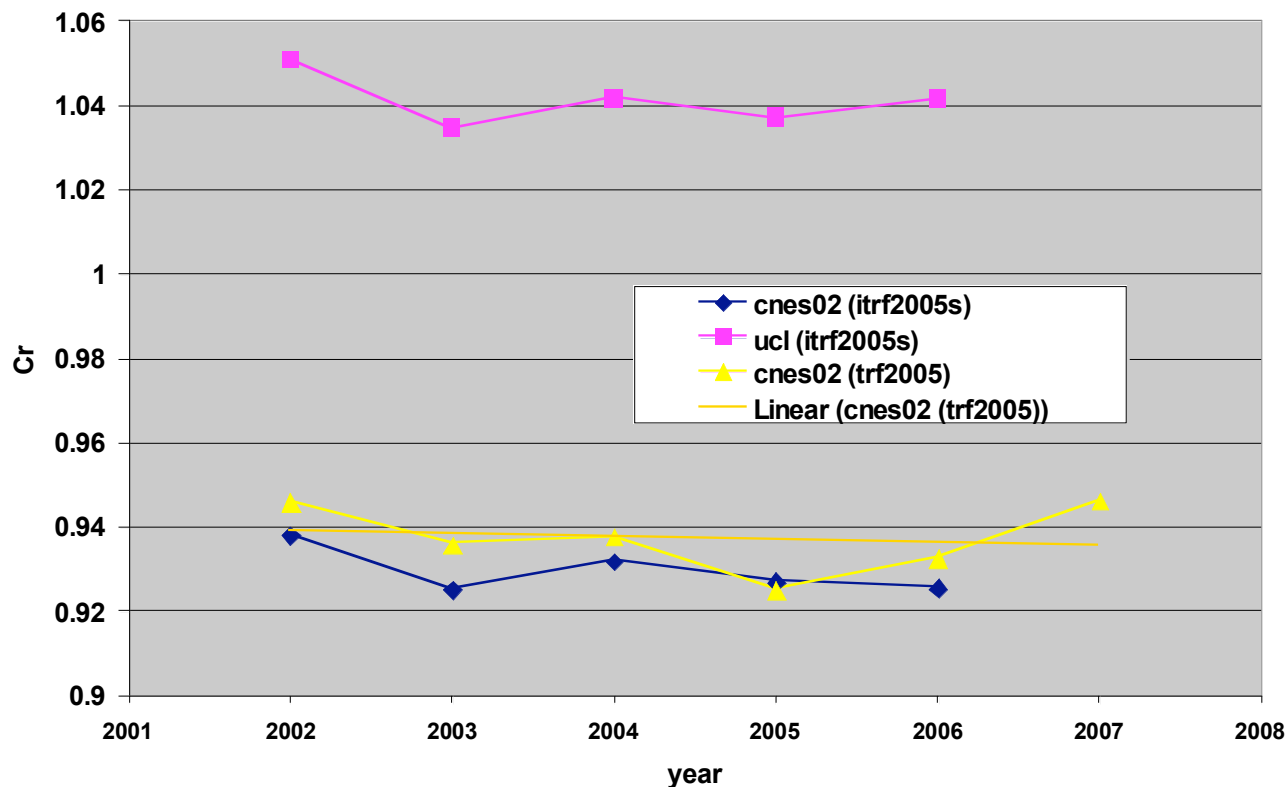
1. CNES2002 Macromodel.
2. CNES2007 Macromodel.
3. UCL Jason-1 Model (as implemented in GEODYN).



Recovered Cr Values with SLR/DORIS for Jason-1



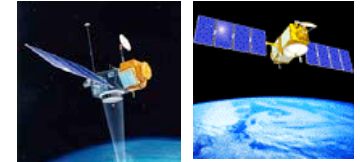
Jason1 recovered SRP coefficient of reflectivity (Cr) with SLR/DORIS



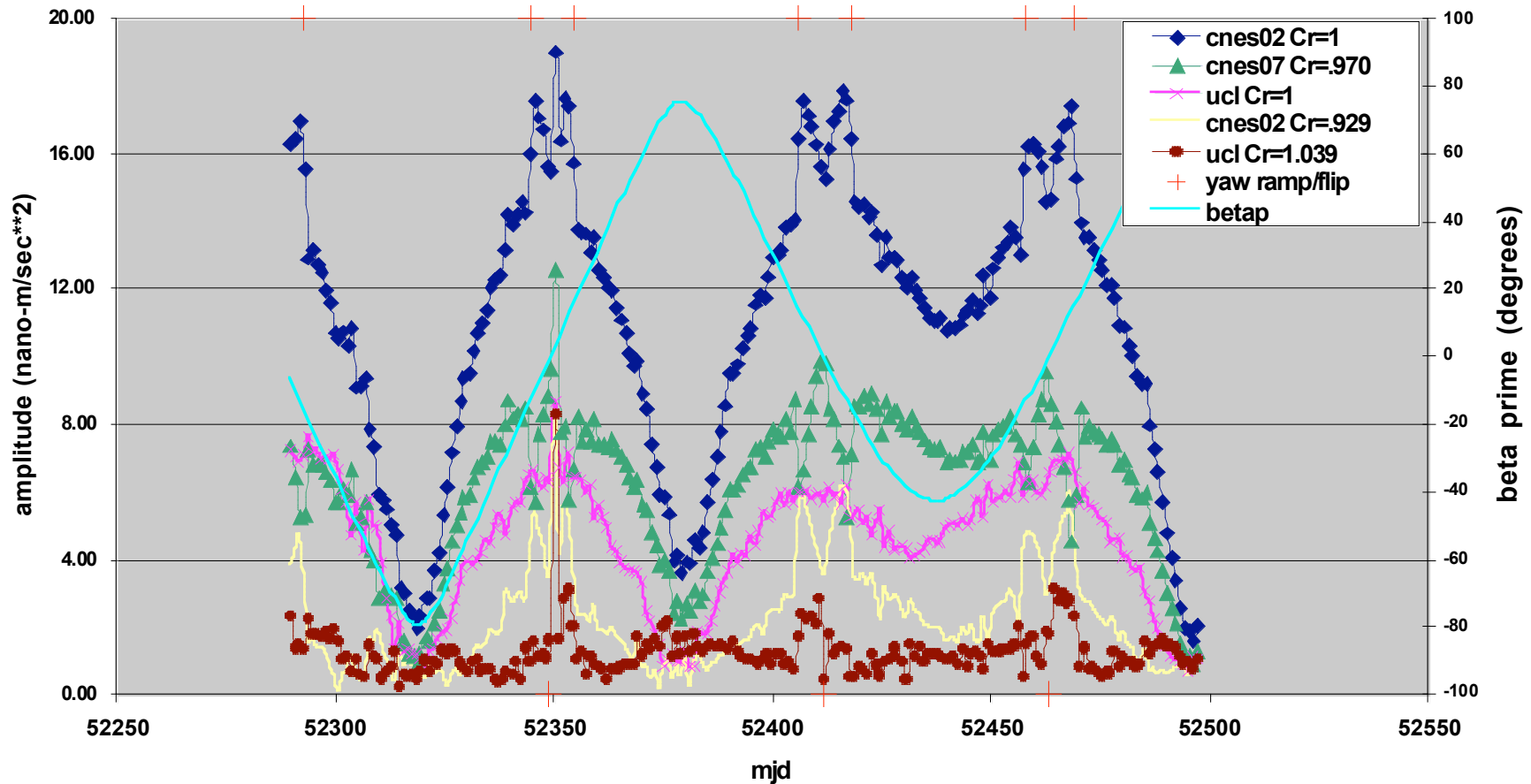
Jason-1 UCL/GEODYN Results are preliminary



Jason-1 Along-track Empirical Accelerations



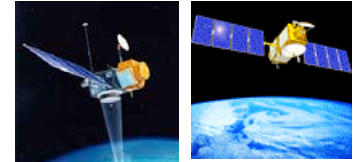
Jason estimated empirical along-track accelerations / day (cycles 1-21)



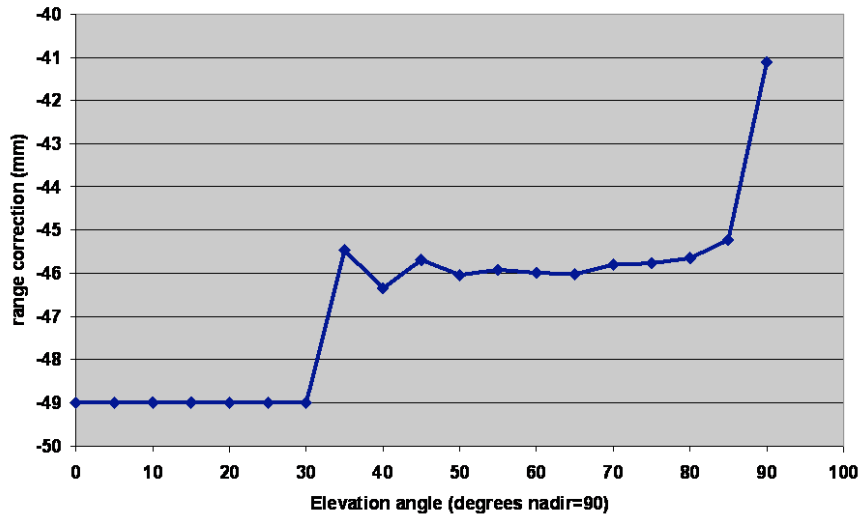
Jason-1 UCL/GEODYN Results are preliminary



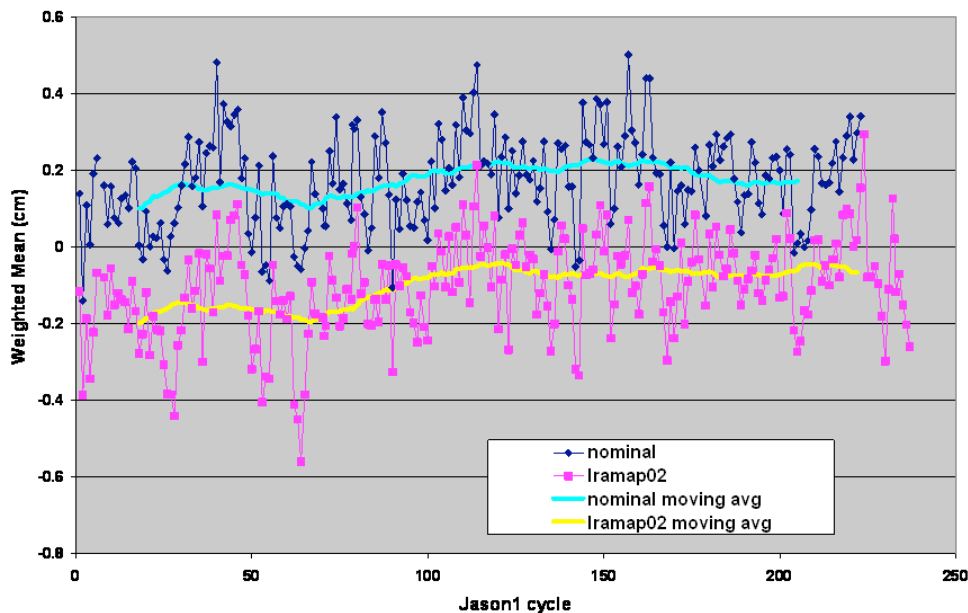
Jason-1 LRA Preliminary Phase Map Estimation



Jason-1 LRA phase map estimate



Jason1 LRA Map estimate version02 SLR residuals



1. Compute LRA phase map wrt satellite-centered azimuth & elevation, but axisymmetric using Jason1 SLR data from 2002 & 2006.
2. No data below elev = $\sim 35^\circ$.
3. (A priori) Standard OBSCOR value is -49 mm.
4. Need to repeat analysis with latest LPOD version & after verification of SLR bias strategy



New POD Standards Testing

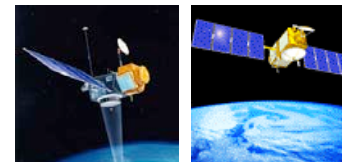


Table 1. New POD Standards Progressive Testing

test name	Jason-1 SLR/DORIS residual summary cycles 1-21	doris rms (mm/s)	slr (cm)		xover rms (cm)	include new standard
			mean	rms		
nominal 2007	itrf2005(s)_merged (itrf2000) slr/doris, got0.0 selected loads ggm02c, annual 20x20 3-yr grace model, ncep-6hr, got0.0 tides, pre-launch panel & C _R =1, Ira (-4.9 cm)	0.3976	-0.073	1.519	5.730	----
trf2005	as nominal + slrf2005/dpod2005 & complete got4.7 loads	0.3979	0.086	1.508	5.732	yes
Ira phase map(cnes)	as trf2005 + LRA phase map from pre-launch measured 3-points; (with range correction=-5mm)	.3979	0.057	1.501	5.734	no ?
eigen_gl04 s	as trf2005 + switch to eigen gl04 s	0.3979	0.081	1.479	5.728	yes
tidal_eop	as eigen_gl04s + tidal eop	0.3978	0.076	1.435	5.724	yes
tidal_com	as tidal_eop + tidal CoM (got4.7)	0.3978	0.073	1.428	5.724	yes
tv_g_4yr	as tidal_com + switch to grace annual 20x20 4-yr model	0.3979	0.075	1.428	5.724	yes
ecmwf-6hr	as tv_g_4yr + switch to ecmwf-6hr	0.3979	0.075	1.428	5.724	yes
cnes_panel	ecmwf-6hr +latest CNES macromodel	0.3979	0.056	1.411	5.738	no
got4.7	as ecmwf-6hr + got4.7 20x20 tides	0.3979	0.076	1.427	5.724	yes
cr_panel	as got4.7 + panel macromodel; tune Cr=0.929	0.3978	0.074	1.409	5.727	yes
optide	as cr_panel + ocean pole tide	0.3978	0.069	1.404	5.727	yes
lpod2005	as optide + lpod2005 (version 10)	0.3978	0.120	1.333	5.725	yes
std0809	as lpod2005 + Ira phase map estimated using 2-years SLR data	0.3978	-0.041	1.324	5.725	yes



TOPEX Orbit Evaluation for new std0809 orbits

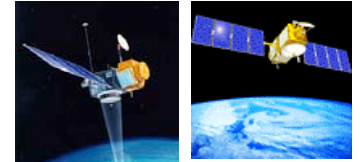
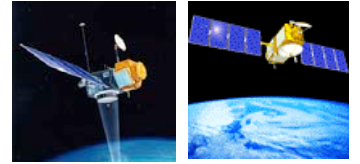
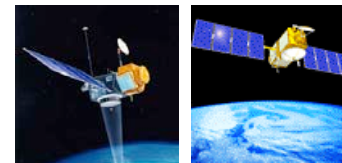


Table 3. Evaluation of new TOPEX std0809 orbits				
TOPEX SLR/DORIS Orbits Cycles 1-364	DORIS RMS (mm/s)	SLR RMS (cm)	SLR mean (cm)	Altimeter Crossover RMS (cm)
<i>GDR</i>	0.5348	2.210	0.323	---
<i>ITRF2005 SLR-rescaled (Nominal 2007)</i>	0.5111	1.828	0.347	---
<i>LPOD2005 (Std0809)</i>	0.5110	1.824	0.415	---
<u>Subset Analysis:</u> 21 TOPEX Cycles (344-364)				
<i>ITRF2005 SLR-rescaled (Nominal 2007)</i>	0.4682	1.553	0.198	5.526
<i>LPOD2005 (Std0809)</i>	0.4677	1.544	0.255	5.521

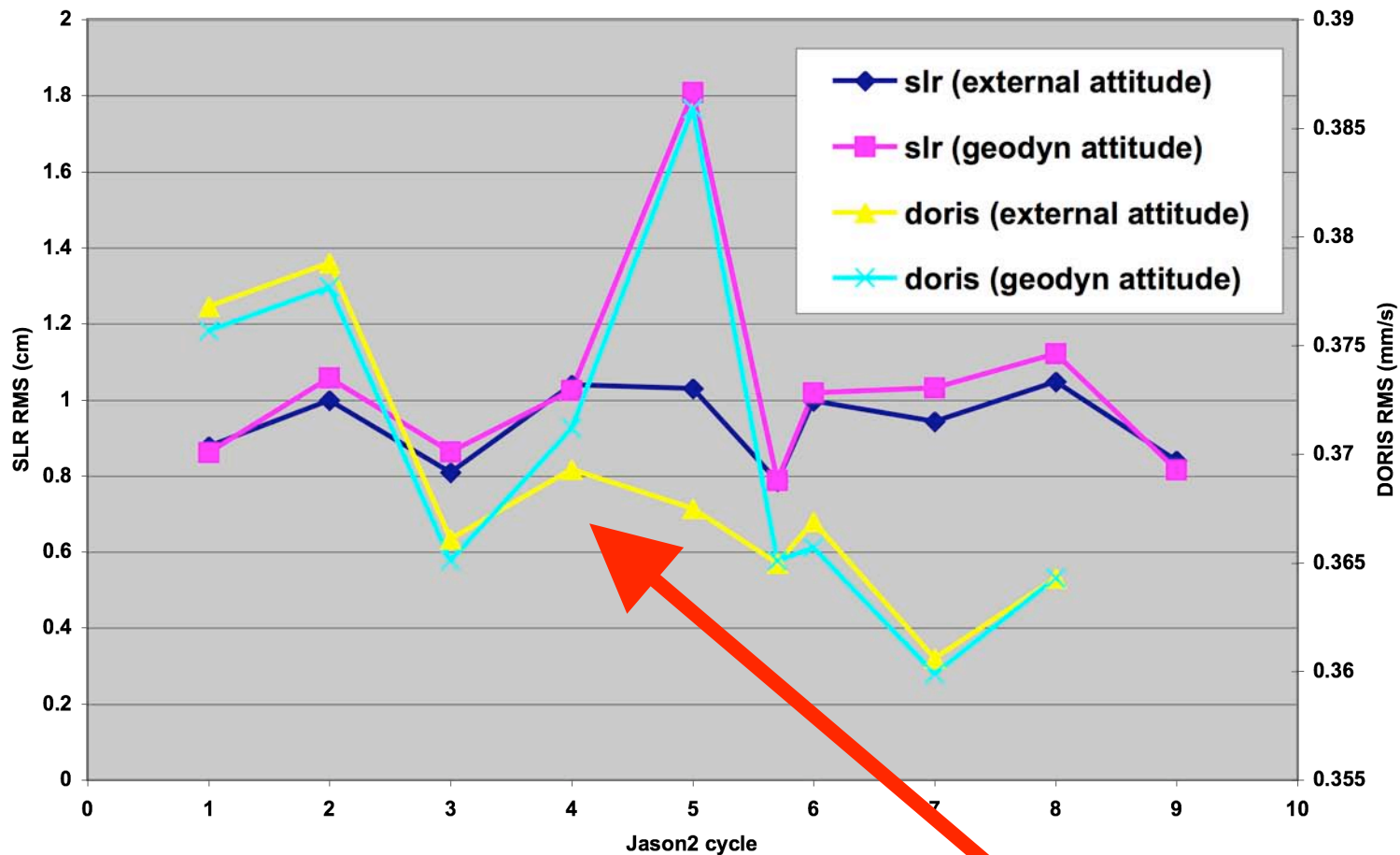


Jason-2 POD Results



Jason-2 SLR/DORIS Orbit Improvement with External Attitude

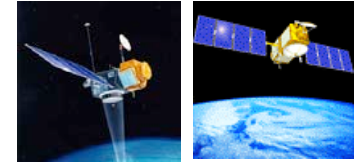
Jason-2 SLR-only / DORIS-only residuals: attitude models



Secular change in Jason-2 DORIS Oscillator since launch? (or other effect?)



Jason-2 Macromodel Tuning



Jason-2 Estimated Solar Radiation Pressure Coefficient (C_R) SLR/DORIS cycles 1-7; Jason-1 panel cards (external attitude, std0809 models)				
	a-priori	estimated increment	standard deviation	new value
C_R	1.00000	-0.08394	0.01660	0.916

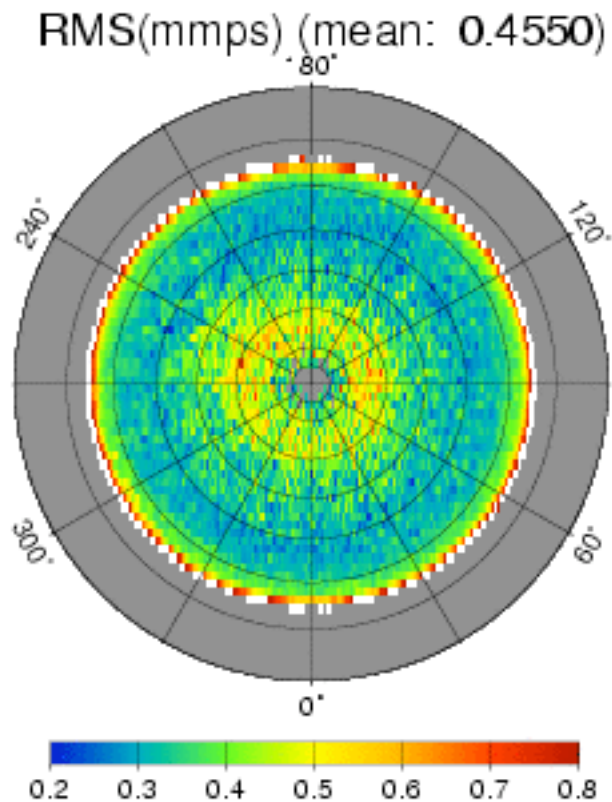
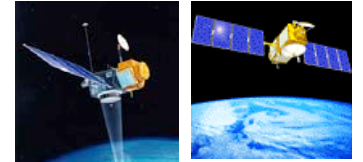
Jason-2 Offset Estimation (SLR & DORIS)

Jason-2 Estimated Laser Retro-reflector Array Offset SLR/DORIS cycles 1-7; -4.9 cm range correction (external attitude; std0809 models)				
LRA offset (m)	a-priori	estimated increment	standard deviation	new value
X	1.194	-0.00619	0.00179	1.188
Y	0.598	-0.00097	0.00172	0.597
Z	0.6838	0.00084	0.00179	0.6846

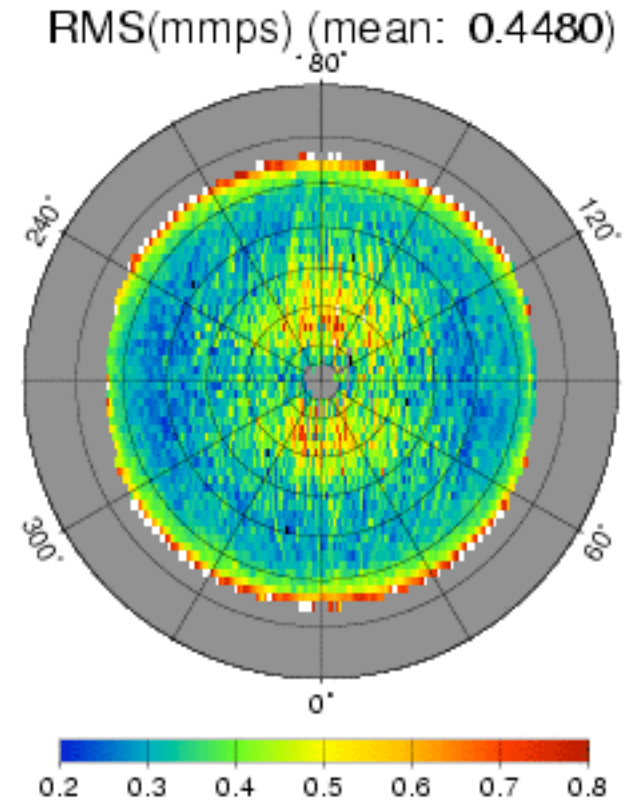
Jason-2 Estimated DORIS Antenna Phase Offset SLR/DORIS cycles 1-7; (external attitude; std0809 models)				
DORIS antenna offset (m)	a-priori	estimated increment	standard deviation	new value
X	1.194	-0.00191	0.00254	1.192
Y	-0.598	0.00626	0.00237	-0.592
Z	1.022	0.13498	0.00254	1.157



Jason-2 DORIS Residuals Mapped by Satellite Azimuth & Elevation (1°x1° bins, cycles 1-7)



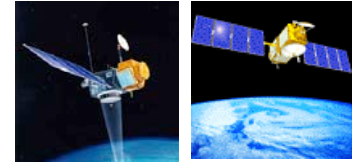
A priori Offset - Std0807



Tuned Offset



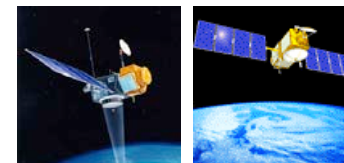
Jason-2 SLR/DORIS Model Evaluation



Jason2 Model Tuning Evaluation residual summary cycles 1-7 external attitude; std0809 models	doris		slr (cm)		xover (cm)
	rms (mm/s)	time bias (μ s)	mean	rms	
SLR/DORIS					
nominal (std0809)	0.3689	-2.35	-0.089	1.191	5.534
ld_cr: as nom+ Cr=0.916	0.3681	-2.34	-0.059	1.150	5.542
lra01: as ld_cr + est. lra offset	0.3681	-2.41	-0.033	1.137	5.545
dor01: as ld_cr + est. doris antenna offs .	0.3610	-2.19	-0.044	1.121	5.545
tune01: as ld_cr + est. lra/doris ant. offs	0.3610	-2.24	-0.020	1.102	5.550
SLR-ONLY					
nominal	----	----	-0.043	0.936	5.725
slr_cr: as nom+ Cr=0.916	----	----	-0.001	0.886	5.705
lra01: as slr_cr + est LRA off.	----	----	0.015	0.863	5.701
DORIS-ONLY					
nominal	0.3689	----	-0.4	3.6	5.571
dor_cr: as nom+ Cr=0.916	0.3677	----	-0.5	3.5	5.576
dor01: as dor_cr + est. doris antenna offs .	0.3608	----	-0.1	2.7	5.581



Jason-2 Orbit Evaluation



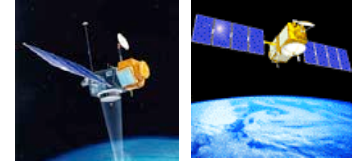
Jason2 orbit evaluation cycles 1-6	doris	slr (cm)		xover rms (cm)
	rms (mm/s)	mean	rms	
JPL_gpsr_rlse08a (gps-only)	0.3831	0.083	1.404	5.505
CNES_ldg_gdrpc_v00 (GPS,slr,doris)	0.3827	-0.163	1.518	5.544
CNES_ldg_gdrpc_v01 (gps,<u>SLR/DORIS</u>)	0.3825	-0.060	1.147	5.544
GSFC slr+doris_tune01 dynamic	0.3827	-0.043	1.222	5.551
GSFC slr+doris_tune01 reduced-dynamic	0.3820	-0.113	1.209	5.484



Jason2 Orbit Difference Comparisons

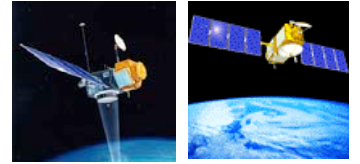


Jason-2 orbit difference summary cycles 1-7							
GSFC / CNES orbits	RMS (cm)			Mean (cm)			
	Rad	Crs Trk.	Alg. Tr.	X	Y	Z	radial
test - cnes_ldg_gdrpc_v00 (GPS,slr,doris)							
slr-only	1.76	2.47	7.49	0.18	-0.14	-1.34	0.10
doris-only	1.23	6.08	3.75	0.18	-0.19	-0.36	0.10
slr+doris	1.22	2.94	3.49	0.07	0.07	-0.44	0.10
slr+dor_tune01_dynamic	1.27	1.59	3.51	0.08	0.17	-0.64	0.06
slr+dor_tune01_reduced-dyn	1.00	1.61	3.09	0.06	0.06	-0.47	0.06
test - cnes_ldg_gdrpc_v01 (gps, SLR, DORIS)							
slr+dor_tune01_reduced-dyn	0.86	1.66	3.03	-0.02	-0.1	0.21	0.06
cnes_ldg_gdrpc_v00	0.77	0.51	2.03	-0.07	-0.16	0.68	0.00
test - jpl_gpsr_rlse08a (gps-only)							
slr+dor_tune01_reduced-dyn	0.95	1.89	3.08	-0.34	0.40	-0.25	0.04
cnes_ldg_gdrpc_v01	1.10	1.39	2.81	-0.31	0.52	-0.54	-0.02
cnes_ldg_gdrpc_v00	1.11	1.31	2.98	-0.37	0.36	0.19	-0.03



POD Summary

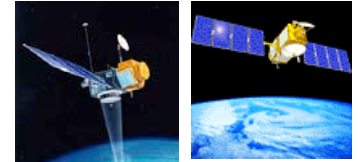
- ⇒ Established a new baseline series of geophysical models to use for entire altimeter orbit time series (TOPEX, Jason-1, Jason-2).
- ⇒ Analyzed the tracking data from Jason-2 (SLR/DORIS); 1 to 1.5 cm radial agreement with other centers; SLR/DORIS Red-dynamic orbits produce lowest Xover RMS.
- ⇒ Some satellite-specific models need to be retuned or refined (e.g. Jason-1 & Jason-2); Verify new offsets for Jason-2, particularly DORIS.
- ⇒ Outstanding issues: 1. Verify GEODYN implementation of UCL/Jason-1 model; 2. New coordinates for some DORIS sites (update to DPOD) & handling of some stations (eg. ASCB) 3. Process GPS data for Jason-2; 4: Verification of bias handling for SLR stations - needs long-term monitoring.



Backups



Access to GSFC 2008 POE orbits for Jason-1 & Jason-2



POE ORBIT AVAILABILITY

We have placed an accurate and consistent set of our latest GSFC SLR/DORIS dynamic replacement orbits for OSTM (Jason-2), Jason-1, and TOPEX on our anonymous ftp site:

[dirac.gsfc.nasa.gov](ftp://dirac.gsfc.nasa.gov)

[pub/earth/repro-jason/ostm/](ftp://pub/earth/repro-jason/ostm/)

[gsfc_ja2_poe_std0809.\\$cycle.Z](ftp://gsfc_ja2_poe_std0809.$cycle.Z)

Jason-2 \$cycle=001-007

[pub/earth/repro-jason/swt08/](ftp://pub/earth/repro-jason/swt08/)

[gsfc_poe_std0809.\\$cycle.Z](ftp://gsfc_poe_std0809.$cycle.Z)

Jason-1 \$cycle=001-246

[pub/earth/repro-topex/swt08/](ftp://pub/earth/repro-topex/swt08/)

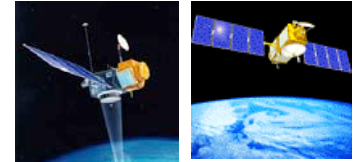
[gsfc_poe_std0809.\\$cycle.Z](ftp://gsfc_poe_std0809.$cycle.Z)

TOPEX \$cycle=001-443

These orbits are not the GSFC final product.

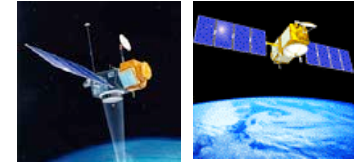


Nonconservative Force Models for Jason-1 (detail)



CNES Macromodels

Jason1 8-panel macromodel		cnes02 2002 pre-launch		cnes07 2007 tuned (C. Luca)	
surface	area (m**2)	specular ref.	diffuse ref.	specular ref.	diffuse ref.
X+	1.65	0.425	0.178	0.0938	0.2811
X-	1.65	0.408	0.186	0.434	0.215
Y+	3.0	0.334	0.342	1.188	-0.0113
Y-	3.0	0.274	0.369	1.2002	-0.0044
Z+	3.1	0.236	0.382	0.240	0.402
Z-	3.1	0.298	0.336	0.318	0.370
SA+	9.8	0.344	0.006	0.344	0.006
SA-	9.8	0.004	0.298	0.004	0.298
Scale (C _R)		1.0		0.97	
X force(μ N)/acceleration(nm/s ²)		-0.09 (μ N) / -0.184 (nm/s ²)		-0.39 (μ N) / -0.797 (nm/s ²)	
Y force(μ N)/acceleration(nm/s ²)		-0.18 (μ N) / -0.368 (nm/s ²)		-0.18 (μ N) / -0.368 (nm/s ²)	



Jason-1 SRP Model Orbit Tests

Jason-1 SLR/DORIS residual summary cycles 1-21					
test name	description	doris rms (mm/s)	slr (cm)		xover rms (cm)
			mean	rms	
ecmwf-6hr (nominal)	as tvg_4yr + switch to ecmwf-6hr	0.3979	0.075	1.428	5.724
cnes07	ecmwf-6hr +latest CNES macromodel	0.3979	0.056	1.411	5.738
ucl	ecmwf-6hr + UCL (Cr=1)	0.3978	0.113	1.420	5.743
cr_ucl	tune Cr UCL model : Cr=1.039	0.3978	0.137	1.414	5.735
cr_panel	tune Cr panel macromodel: Cr=0.929	0.3978	0.074	1.409	5.727

Jason-1 UCL/GEODYN Results are preliminary