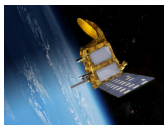
Status SARAL POD processing at GSFC and orbit sensitivity to time-varying gravity



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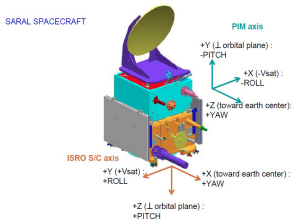
Correcting satellite CM and tuning the DORIS/SLR antenna offsets improves Saral POD

SARAL ISRO axis: X (nadir), Y (along-track), Z (cross-track)



1) Initial SLR and DORIS antenna offset estimates suggest SARAL CM position is in error by about 4-cm cross-track (Z)

SARAL SLR / DORIS tuning 130317-131215		DORIS antenna offset (m) X	Y	Z	SLR antenna offset (m) X	Y	Z	LRA (m)
a-priori** (cnes)		0.8050	-0.3040	-1.1290	0.4735	0.0000	-0.9400	
tune1	correct.	0.0031	---*	-0.0406	0.0158	---*	-0.0456	-0.03748
	sigma	±0.0012	---*	±0.0019	±0.0016	---*	±0.0014	(Arnold)

* note: DORIS/SLR antenna Y offset estimates show 0.997 correlation and are suppressed
** CM: X(nadir)= -.0112, Y(along track)= -.0067, Z(cross track)= -.6183 (m)

2) Correct SARAL CM and re-estimate DORIS/SLR antenna offsets

SARAL SLR / DORIS antenna offset re-tuning over 130317-131222 data. (CM corrected using mean of tune1 SLR+DORIS Z estimates)		Offset (m) X (nadir)	Y (along-trk)	Z (cross-trk)
CM (Center of Mass)	CNES a-priori	-0.0112	-0.0067	-0.6583
	Corrected	-0.0112	-0.0067	-0.6152
LRA antenna offset re-tune	a-priori	0.4735	0.0000	-0.9400
	correction to a-priori	0.0157	---	-0.0025
	estimate sigma	±0.0016		±0.0014
DORIS antenna offset re-tune	a-priori	0.8050	-0.3040	-1.1290
	correction to a-priori	0.003	---	0.002
	estimate sigma	±0.001		±0.002

Note: LRA OBSCOR = -0. 03748 m (Arnold); DORIS phase map correction

3) Final SLR and DORIS tuned antenna offset values using corrected CM

Source	DORIS antenna offset (m) X	Y	Z	SLR antenna offset (m) X	Y	Z
a-priori** CNES	0.805	-0.304	-1.129	0.4735	0.0000	-0.9400
final tune	0.825	-0.304	-1.127	0.4859	0.0000	-0.9409

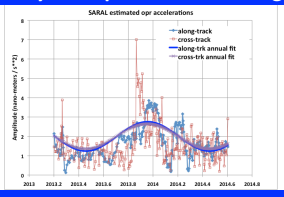
CM: X= -.0112, Y= -.0067, Z= -.6152 (m); LRA OBSCOR = -0. 03748 m

Evaluate tuning SLR/DORIS SARAL antenna offsets Residual summary 140105-140810 (independent data)

test	DORIS (mm/s)	SLR (cm) Mean	RMS
std1404 (pre-tune)	0.4328	-0.153	1.857
std1404 (post-tune)	0.4315	0.067	1.389

RMS orbit differences (mm)	radial	cross-trk	along-trk
pre_tune – post_tune	1.4	20.3	12.5

Annual signals (~ draconitic) in estimated opr acceleration amplitudes suggest SRP model may be improved with tuning

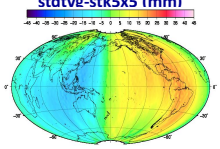


Some higher degree/order (> L=5) Time Varying Gravity (TVG) coefficients strongly affect Saral POD, but show discrepancy in the SLR/Xover residual performance

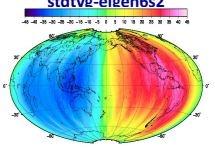
TVG model	Description (all forward model atmosphere gravity using ECMWF 6-hour data and apply the IERS2010 C21/S21 model)
stdtvg (std1007)	3 linear coefficient terms (IERS2010), 20x20 annual (GRACE); static EIGEN GL04s
stk4x4 (std1204)	4x4 linear+periodic fit to previous tvg4x4 series, 5x20 annual (GRACE); static GOCO02s (from 5x5)
tvg5x5_gsfc	7-day SLR/DORIS 5X5 estimates with relative weights for 21 satellites in solution calibrated using subset analysis (SPOT-2, SPOT-4 down-weighted), 6x20 annual (GRACE); static GOCO02s (from 6x6)
stk5x5 (std1404)	stacked tvg5x5_gsfc 5x5 solutions of static, periodic, linear terms in periods: 1) 1993-2002 and 2003-2013, 2) 1993-2002 and 2003-2006 and 2007-2013; ; static GOCO02s (from 6x6)
eigen-6s2	GRACE, LAGEOS, GOCE solutions of static, periodic, linear terms in periods: 1) 2x2 1986-2002, 2) 50x50 2003-2013; static EIGEN6s2
tvg5x5_csr	5x5 from monthly CSR GRACE RL05 60x60 solutions; 6x20 annual (GRACE); static GGM05s
tvg60x60_csr	60x60 from monthly CSR GRACE RL05 60x60 solutions; static GGM05s
tvg60x60_gfz	60x60 from monthly GFZ GRACE RL05 90x90 solutions; static EIGEN-6c

TEST (external ephemeris residuals)	SARAL 34 arcs span Mar-Sep 2013 DORIS (mm/s)	SLR (cm)	Xover (cm)
stdtvg (std1007)	0.4155	1.815	5.951
stk4x4 (std1204)	0.4142	1.683	5.916
stk5x5 (std1404)	0.4096	1.450	5.864
eigen-6s2	0.4110	1.201	6.054
tvg5x5_gsfc	0.4113	1.444	5.892
tvg60x60_gfz	0.4102	1.194	6.033
tvg60x60_csr	0.4100	1.189	6.021
tvg5x5_csr	0.4105	1.337	5.953

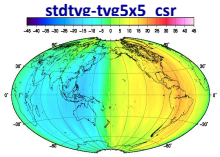
stdtvg-stk5x5 (mm)



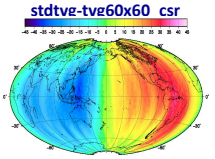
stdtvg-eigen6s2



stdtvg-tvg5x5_csr



stdtvg-tvg60x60_csr



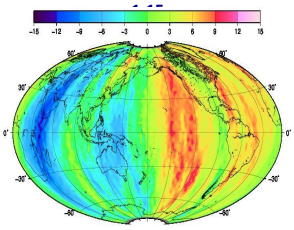
GSFC std1404 orbits have been computed for Saral, as well as for TOPEX, Jason1, and Jason2, and compare well with the CNES GDRD

Model Summary	std1404
Station coordinates	SLRF2008, DPOD2008
Dynamic tides	GOT4.8
Ocean loading	GOT4.8
SRP (6 panel CNES)	un-tuned
DORIS Troposphere	VMF1
OPR / Drag	48-hr / 4-hr
Pole Model	IERS2010
Static gravity	GOCO2S (> L=5)
TVG	Harmonic piecewise fit to 5X5 weekly solutions
Satellite CM, SLR/ DORIS antenna off.	tuned
DORIS corrections	beacon phase map

SLR+DORIS ORBIT (external ephemeris residuals)	SARAL cycles 1-15 March 14 2013 – August 10 2014 DORIS (mm/s)	SLR (cm) Mean	RMS	Xover (cm)
std1404	0.4261	+0.123	1.378	5.782
gdrd	0.4149	+0.290	1.581	5.837

orbit difference cycles 1-15 (Mar 2013 – Aug 2014)	RMS Inertial (mm) radial	cross-track	along-track	Mean ECF (mm) X	Y	Z
std1404 - gdrd	9.7	23.5	35.2	-0.9	-5.4	1.8

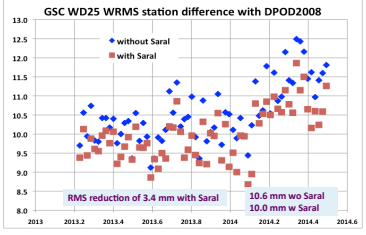
std1404-gdrd (mm) cycles

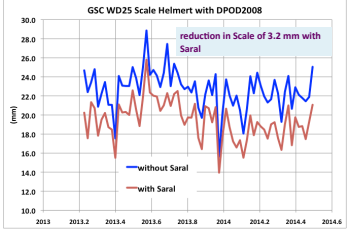


DORIS beacon phase map correction improves DORIS modeling, and orbit as shown with SLR residuals, but not with Crossover residuals

Evaluate VMF1 / phase map Saral SLR+DORIS POD (March 2013 – February 2014)	average RMS Residuals doris (mm/s)	slr (cm)	xover (cm)
1) stk5x5, GMF/GPT	0.4110	1.498	5.869
2) as 1) + VMF1	0.4109	1.498	5.870
3) as 1) + beacon phase map	0.4102	1.467	5.880
4) all combined	0.4101	1.468	5.881
5) re-tune offsets with phase map (std1404)	0.4089	1.338	5.883

Including Saral in the GSC DORIS station solution improves the WRMS station difference with DPOD2008 and moves the Scale closer to zero





Helmert parameter mean difference (mm) with Saral – without Saral

Tx	Ty	Tz	Scale
0.8 ± 1.2	-0.5 ± 1.4	0.8 ± 2.7	-3.2 ± 0.9

SUMMARY

- Based on gravity field, Saral measurement modeling, and other improvements, the std1404 orbits have been computed.
- Although the std1404 orbits compare to within 1-cm with the GDRD, they also show systematic differences at the cm level.
- Future work will include:
  - to better understand the SLR/Xover performance discrepancy as seen with the phase map correction and gravity tests
  - tune SRP model
  - continue gravity field improvement

IDS October 27-28, 2014
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