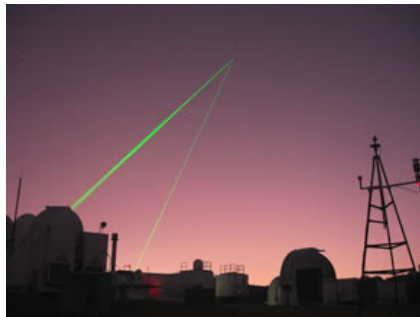
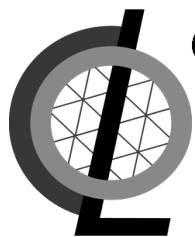




GEODYN & Multitechnique Processing for the Reference Frame



*F.G. Lemoine, D.S. Chinn, N.P. Zelensky,
S. Melachroinos, D.S. Macmillan,
D.E. Pavlis, D.D. Rowlands,
S. B. Luthcke, K. Le Bail*



*Combination at the
Observation Level
IERS Working Group*

*21-22 Novembre 2011
Observatoire de Paris,
Paris, France*





RECENT DEVELOPMENTS

(since ITRF2008 & 2009 COL meeting)

- **Developed new time series of orbits for TOPEX, Jason-1, Jason-2 in consistent reference frame (SLR+DORIS):**
 - (1) ITRF2005 (*std0905*) (*Lemoine et al., 2010, Adv. Space Res.*)
 - (2) ITRF2008 (*std1007*)
 - (3) ITRF2008 + time series low deg adjustments (4x4, 1993-2011) (*std1110, experimental*).
- **Developed 2-year time series of GPS orbits for Jason2 (documented in posters at EGU2011, OSTST2011).**



RECENT DEVELOPMENTS (2)

(since ITRF2008 & 2009 COL meeting)



Continuing testing between CALC/SOLVE (GSFC VLBI software) & GEODYN. Getting sufficiently good agreement -- but there are still models and parameter estimation that must be introduced into GEODYN:

- (1) VMF** (*GMF introduced previously after completion of ITRF2008*).
- (2) Need to introduce estimation of nutations.**

• Continued routine delivery of SINEX series to IDS combination center (*gscwd11, SP4+SP5+ENV+J2; gscwd12, same+CR2*).

---> Most recent SINEX submissions (2011) completed using DPOD2008; This is important because the latest DORIS stations are not in ITRF2008 (*Willis et al., 201X, manuscript in preparation*).

---> Documented in various DORISReports.

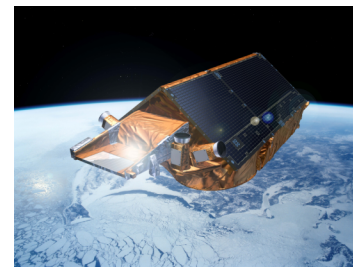
---> Agreement between DORIS-only & SLR+DORIS orbits routinely calculated for each of the altimeter satellites.



Average & Median of RMS Orbit Differences per arc Between SLR+DORIS & DORIS-only Orbits for Altimetry Satellites

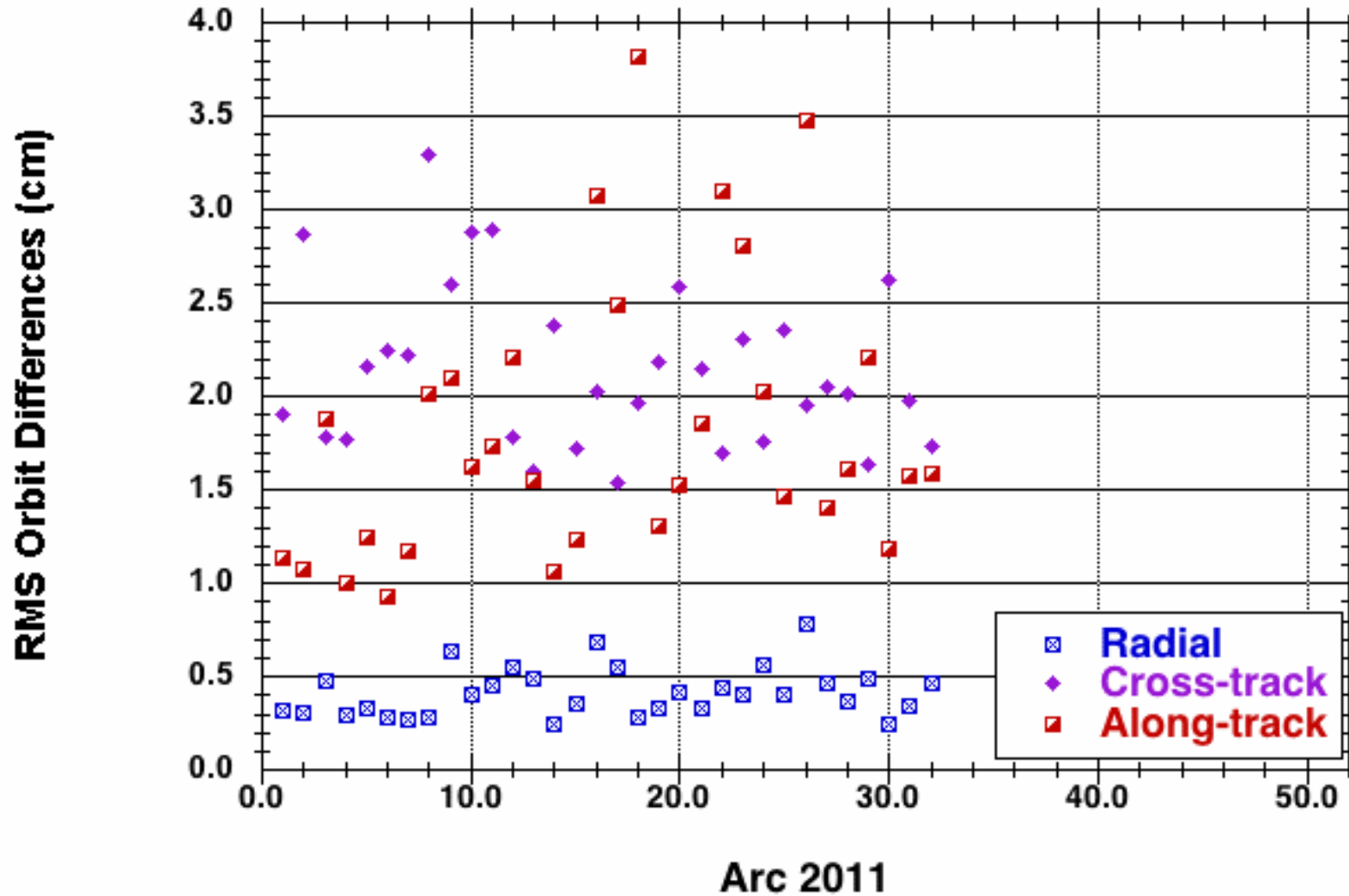
(arcs in 2011, only, for gsc12wd IDS SINEX series)

Satellite	Radial	Cross-tr.	Along-tr.
	(mean, median, cm)		
Envisat	0.41, 0.40	2.14, 2.04	1.82, 1.60
Jason2	0.66, 0.60	2.29, 2.25	2.58, 2.53
Cryosat2	0.58, 0.57	2.29, 2.24	3.01, 2.83



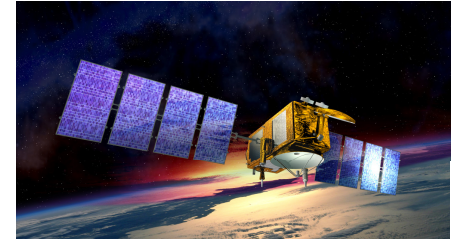


Envisat (2011)
GSCWD12, DORIS-only vs SLR+DORIS





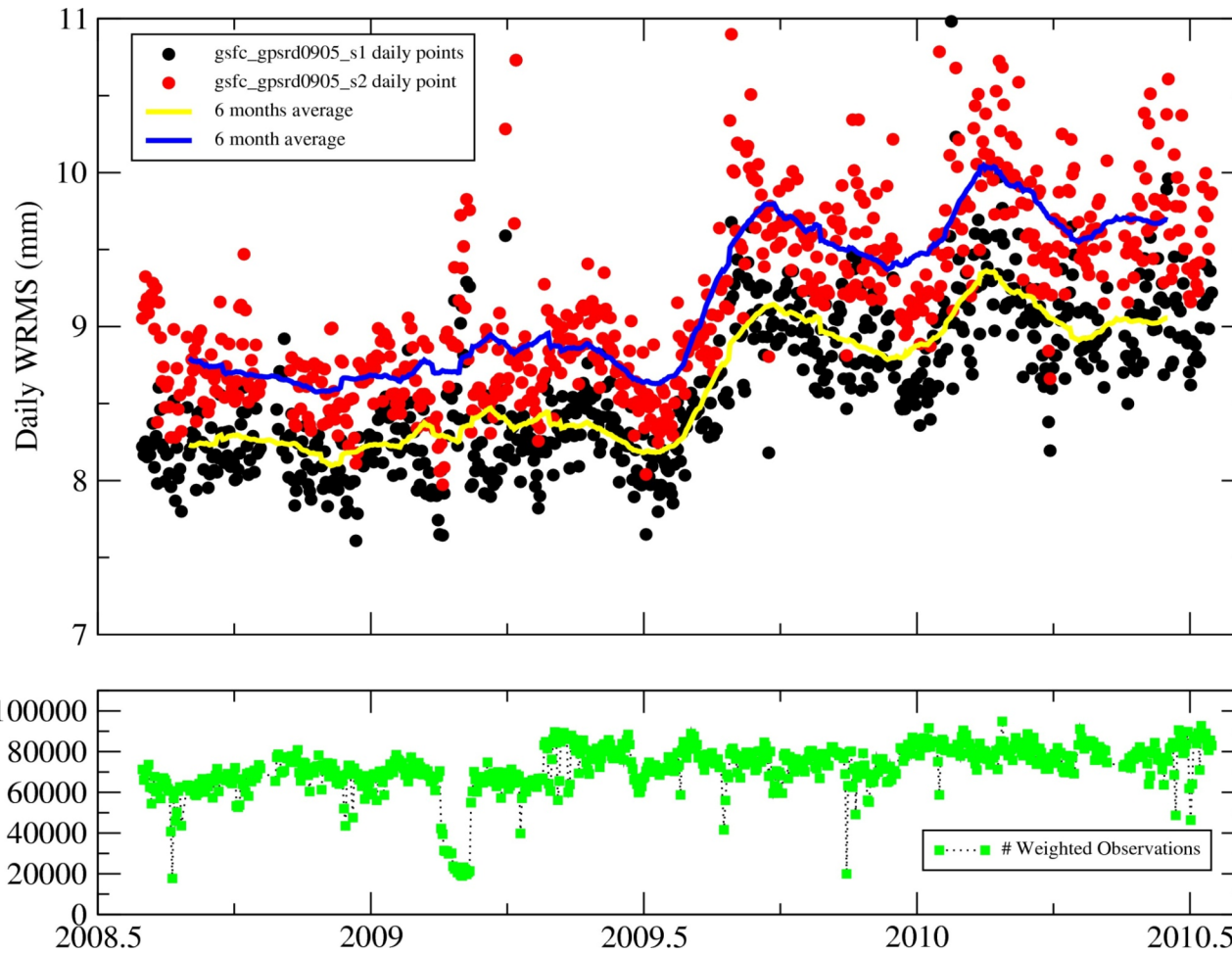
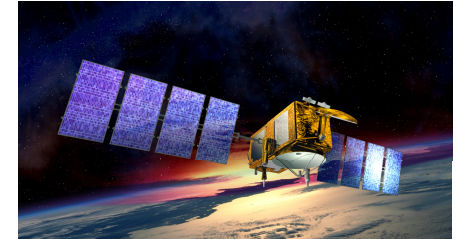
GPS Processing Summary



- 38 IGS05 and IGS08 stations**
- Tracking data : DD LC iono-free tracking data**
- GPS PCOs and PCVs : igs05.atx and igs08_1604_woGLO_final**
- IGS05 and IGS08 (w. station corrections) TRF**
- 1/hr scale(wet+dry) troposphere (GMF/GPT-hopfield) s1**
- Float ambiguities**
- J2 JPL GPS antenna PCV map**
- J2 revised LC GPS antenna PCO values**
- Solutions S1 : troposphere is adjusted /1 hr using 2 paths (1 station + 2 GPS s/c) during the POD**
- Solutions S2 : troposphere is adjusted /1 hr using 4 paths (2 stations + 2 GPS s/c) in a ground network solution**



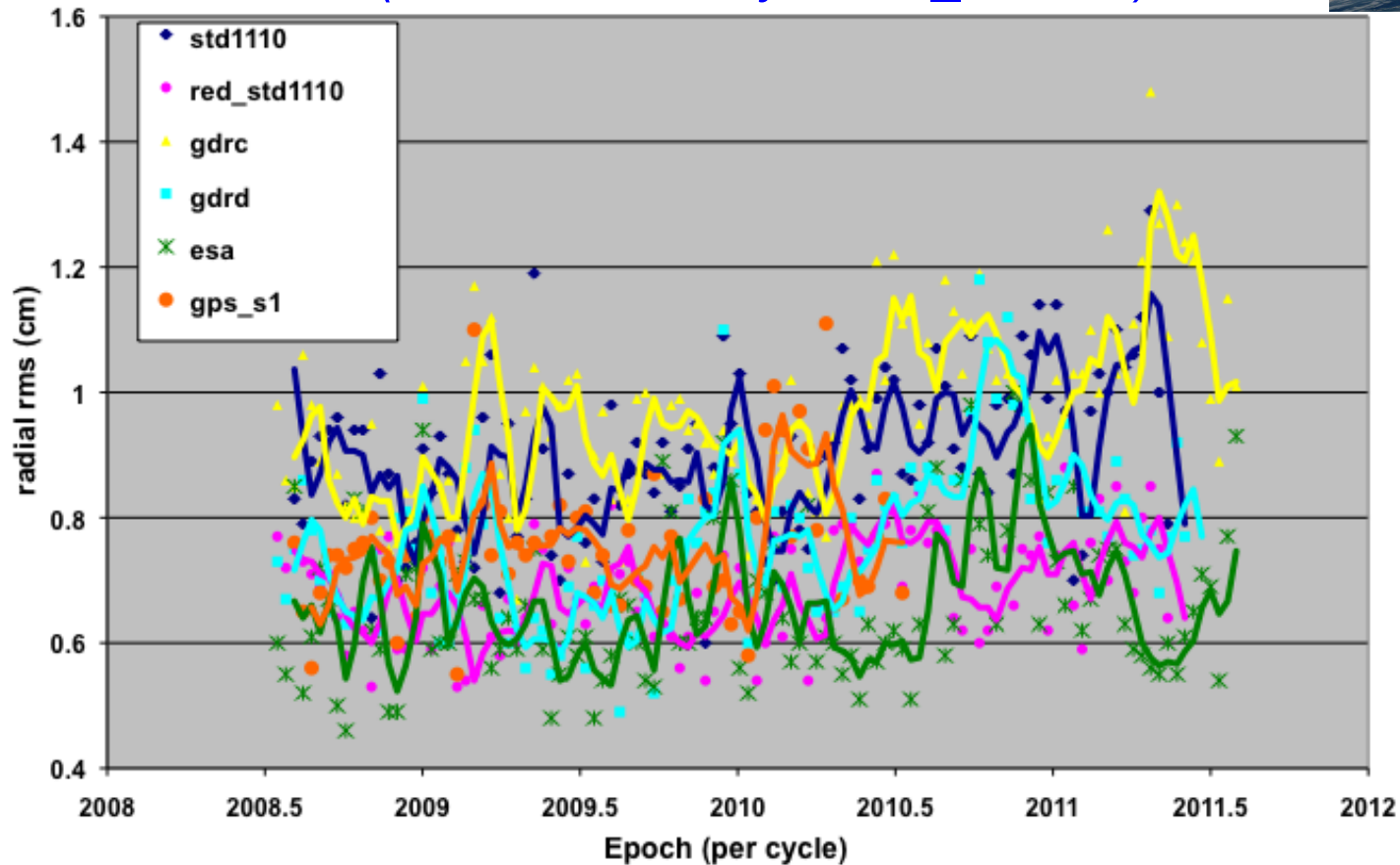
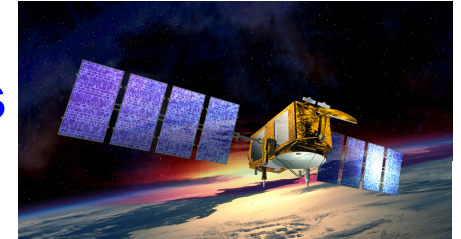
GPS Processing Results





Jason2 Radial RMS Orbit Differences

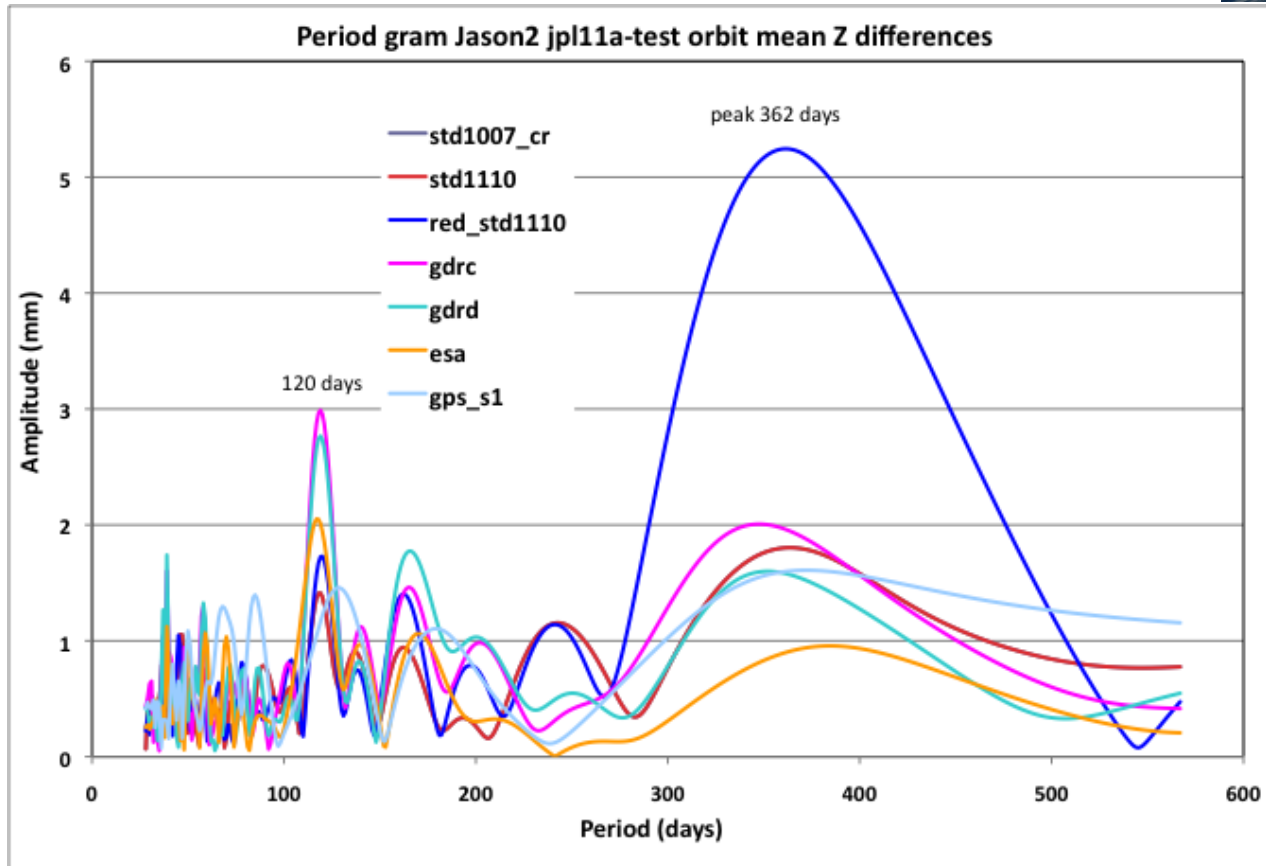
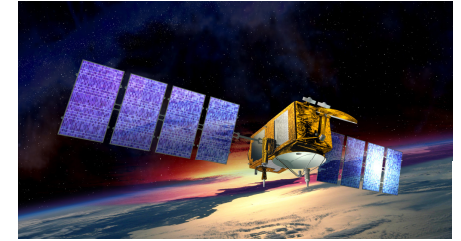
(wrt. GPS red-dyn. JPL_rlse11a)



std1110 = GSFC SLR/DORIS (dyn) or **SLR/DORIS (red_dyn)**.
GDRC, GDRD, = CNES SLR+DOR+GPS;
ESA = SLR+DOR+GPS; **GPS_S1** = GSFC GPS-only red-dyn



Periodogram, Jason2 orbit mean Z differences (orbits wrt. JPL_rlse11a)



Largest orbit differences in Z between orbits are at beta-prime period (120days) (*radiation pressure mismodelling*) and annual period (*time variable gravity; geocenter*).



Jason-2 testing SRP Model Improvements cycles 1-103

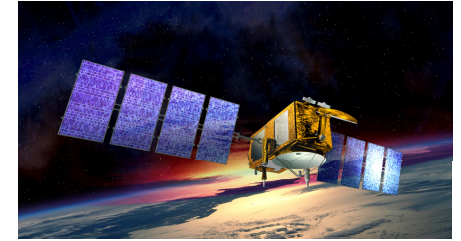


Test slr+doris ITRF2008	points		residuals		
	doris	slr	doris (mm/s)	slr (cm)	xover* (cm)
std1007 (Cr= 0.913)	158566	4386	0.3719	1.123	5.527
std1007_UCL	158566	4386	0.3719	1.132	5.523
std1007_cr (Cr= 0.945) dynamic	158566	4386	0.3719	1.127	5.519
red_std1007 (Cr=.913)	158566	4386	0.3711	1.070	5.469
red_std1007_cr (Cr= 0.945) red_dyn	158566	4386	0.3710	1.083	5.463

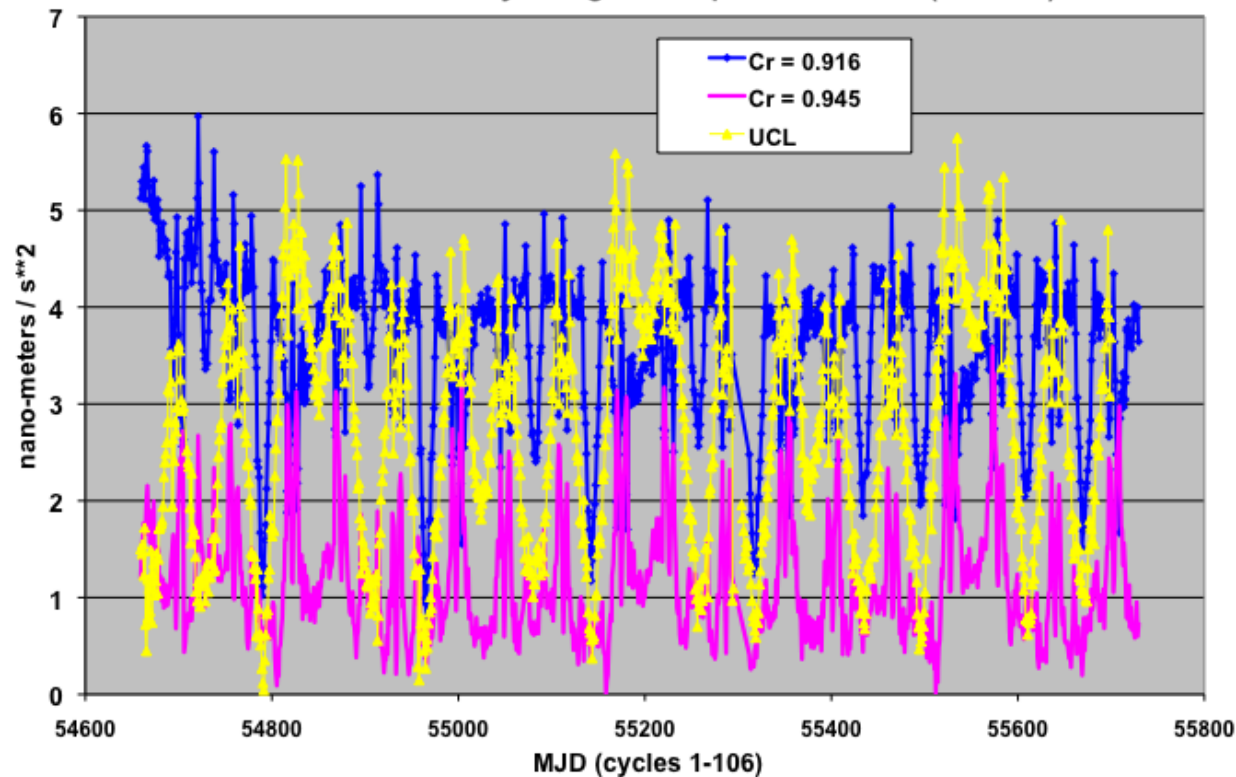
***Altimeter crossovers are independent.**



Jason-2 testing SRP Model Improvements cycles 1-103



Jason-2 estimated daily along-track opr acceleration (std1007)

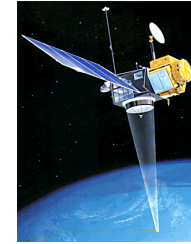


UCL model tested here is Jason-1 specific; Jason-2 UCL model is under development (by Marek Ziebart et al., *UCL*).

- *Radiation pressure mismodelling is an issue for (LEO) satellites and their use in the reference frame; --> IDS AC's are planning analysis campaign in this regard.*



Solution Strategy for SLR+DORIS test solution (1993-2010)-- I



1. Keep track of multiple solutions & and/or solution breaks as identified in ITRF2008.
2. Aggregate first yearly normal equations -- then cumulative normal equations for 1993 - 2011.
3. Solve for position & velocity of stations over the available data span.
- 4 Where appropriate, tie velocities for DORIS-DORIS, SLR-SLR occupations at a particular geodetic site:

(e.g.)

DORIS:

(*Rio Grande, Argentina*): RIOA (1987-1995), RIOB (1995-2001), RIPB (2001-2005), RIPB (2005-2008), RIQB (> 17/04/2008).

(*Koike Park, Hawaii*): KOKA (1990-2002), KOLB (> 17/11/2002)

SLR:

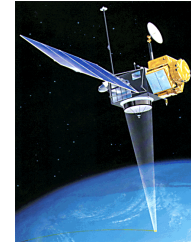
(McDonald Observatory): Many occupations with MLRS

..... From 1993: MLRS (7080), MLRS 23,24,25 +

TLRS4 (7850), 23-Jan-1993 - 01-May-1993)



Solution Strategy for SLR+DORIS test solution (1993-2010)-- II



5. Tie DORIS & SLR Velocities -- but only for sites where velocities are “sufficiently” coincident.

e.g.

Orroral (ACT, Australia)

SLR: *ORRL7843* (1989 --> 30-Nov-1998)

DORIS: *ORRA* (15-Sept-1992 --> 26-Sept-1996)

ORRB (27-Sept-1992 --> 10-Oct-1998)

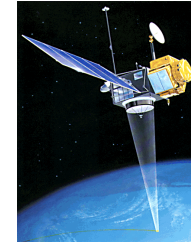
Yarragadee

SLR: *YARA7090 (70900513)*

DORIS: *YARA, YARB, YASB*



Solution Strategy: Issues



6. SPECIAL CASES (example Arequipa)

Arequipa:

SLR. AREL7403, TLRS-3. (74031303)

Six SLR solutions in ITRF2008:

ITRF2008 #1 (14-Jul-1992 ---> ~21-Jun-2001, *Earthquake*)

ITRF2008 #2 (01-Jul-2001 ---> 23-Aug-2001)

ITRF2008 #3 (23-Aug-2001 ---> 13-Sept-2001)

ITRF2008 #4 (13-Sept-2001 ---> 28-Aug-2002)

ITRF2008 #5 (28-Aug-2002 ---> 01-Jan-2004)

ITRF2008 #6 (> 01-Jan-2004)

(74031304) (01-Jan-2007 ---> 08-Aug-2008)

(74031305) (05-Aug-2009 ---> 21-Sept 2010)

(74031306) (22-Sept 2010 --->

Only three DORIS solutions in ITRF2008:

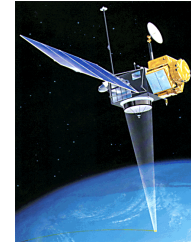
DORIS. AREA (1988 ---> (20-Nov-2001))

DORIS. AREB (21-Nov-2001 ---> 01-Aug-2006)

DORIS. ARFB (02-Aug-2006 --->



Solution Strategy: Issues



7. SPECIAL CASES: Collocated velocities not identical

JIUFENG/WUHAN

JIUB/DORIS: 10-Dec-2003 ---> ...

WUHAN/SLR, 72312901: 01-Jan-2001 --->

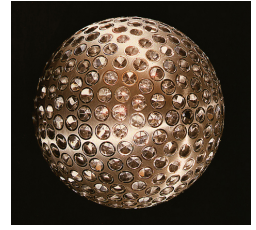
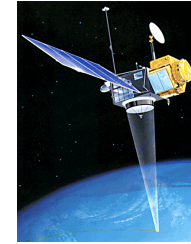
---> SLR ITRF2008 Velocity: (X, Y, Z) = (-2.97, -0.61, -1.50) cm/yr

---> DORIS ITRF2008 Velocity: = (-2.98 -1.15, -0.78) cm/yr

DORIS Shifted to SLR Velocity in GSFC2008(3a) solution



Solution Strategy: Issues



8. SPECIAL CASES: Collocated velocities not identical

SANTIAGO

SLR: TLRS-2. 74041201. 24-Apr-1995 ---> 27-Oct-1995.

74041201. 30-Oct-1995 ---> 30-Nov-1996.

DORIS: SANA. 1988 ---> 04-Dec-1996. **(29 km from SLR)**

SAOB. 05-Dec-1996 ---> 20-Feb-2001 **(~15 m from SLR)**

SANB. 28-Feb-2001 --->

--> SLR ITRF2008 Velocity (X,Y,Z) = (2.27, -1.55, 1.85) cm/yr

--> DORIS ITRF2008 Velocity: (X,Y,Z) = (1.96, 0.45, 1.53) cm/yr

--> *GPS ITRF2008 Velocity (1998-2008) = (2.39, -0.38, 1.25) cm/yr*

--> *VLBI ITRF2008 Velocity (1991-1996) = (2.23, -0.58, 1.27) cm/yr*

Occupations not coincident. Velocities incompatible. SLR & DORIS Adjusted independently



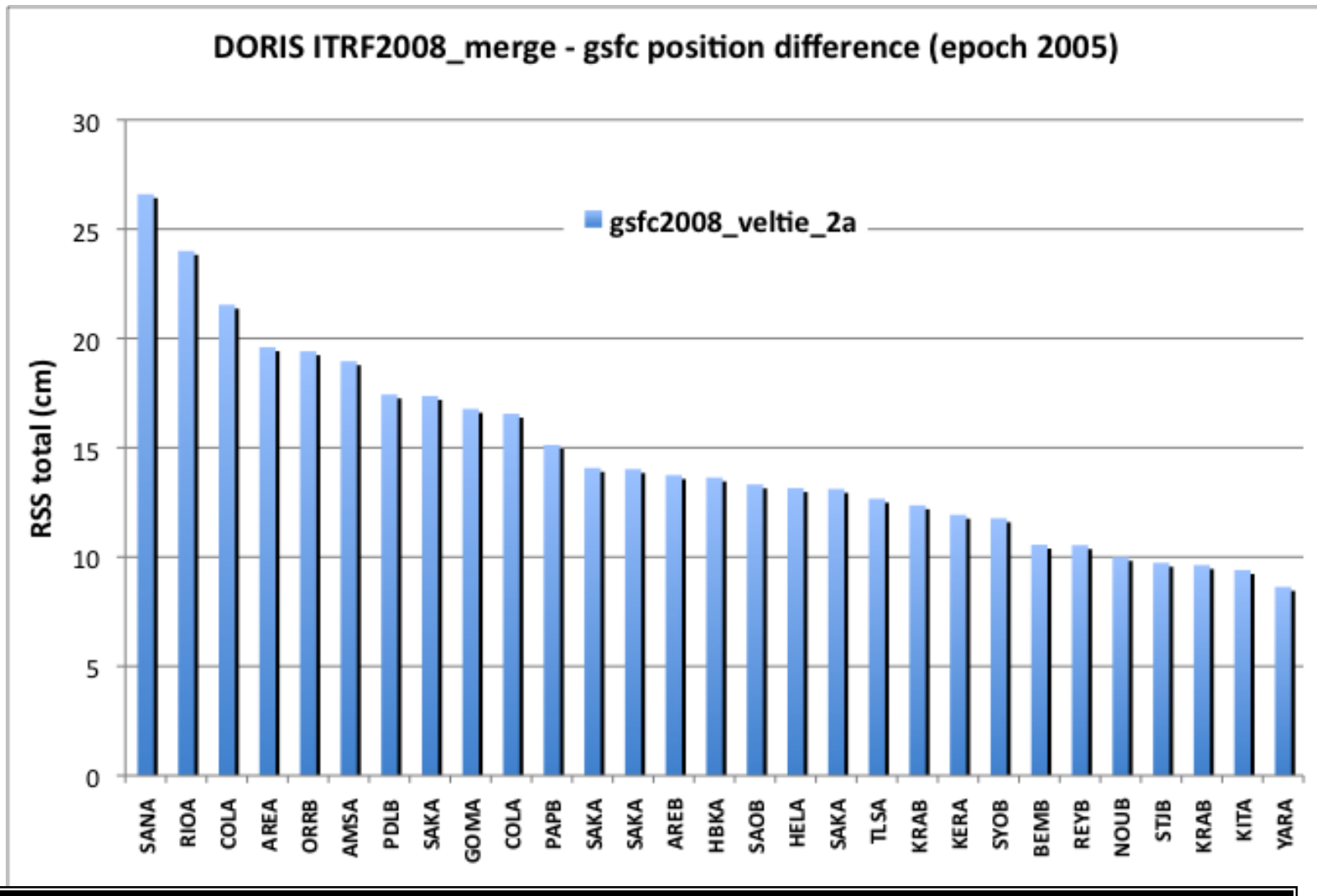
Preliminary Results



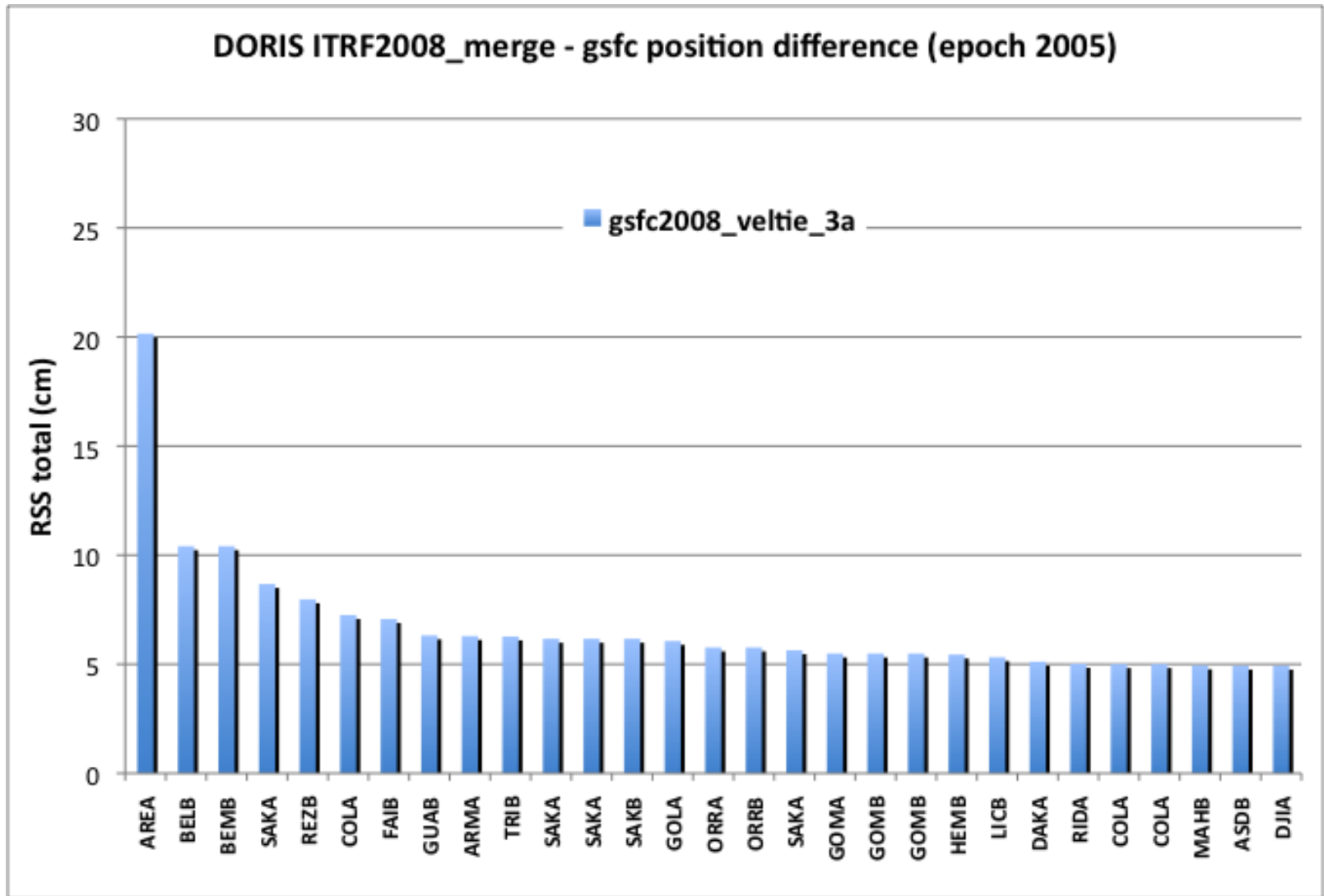
GSFC2008 average total divergence from ITRF2008_merge complement

stations	Solution	average RSS position (cm)	average RSS velocity (mm/y)
SLR	gsfc2008_2a (92 stations, 129 solutions)	9.3	10.6
	gsfc2008_3a (92 stations, 129 solutions)	8.6	9.3
DORIS	gsfc2008_2a (130 stations, 161 solutions)	6.1	10.4
	gsfc2008_3a (130 stations, 161 solutions)	4.2	5.1

Solution 2a: SLR & DORIS are independent (*no SLR+DORIS ties*).
Solution 3a: SLR & DORIS velocities are tied at (some) sites.



Solution 2a: SLR & DORIS are independent (no SLR+DORIS ties).
Solution 3a: SLR & DORIS velocities are tied at (some) sites.



Solution 2a: SLR & DORIS are independent (*no SLR+DORIS ties*).
Solution 3a: SLR & DORIS velocities are tied at (some) sites.



POD orbit tests with new (3a) complement

- Delete stations with large deviations from ITRF2008 complement,

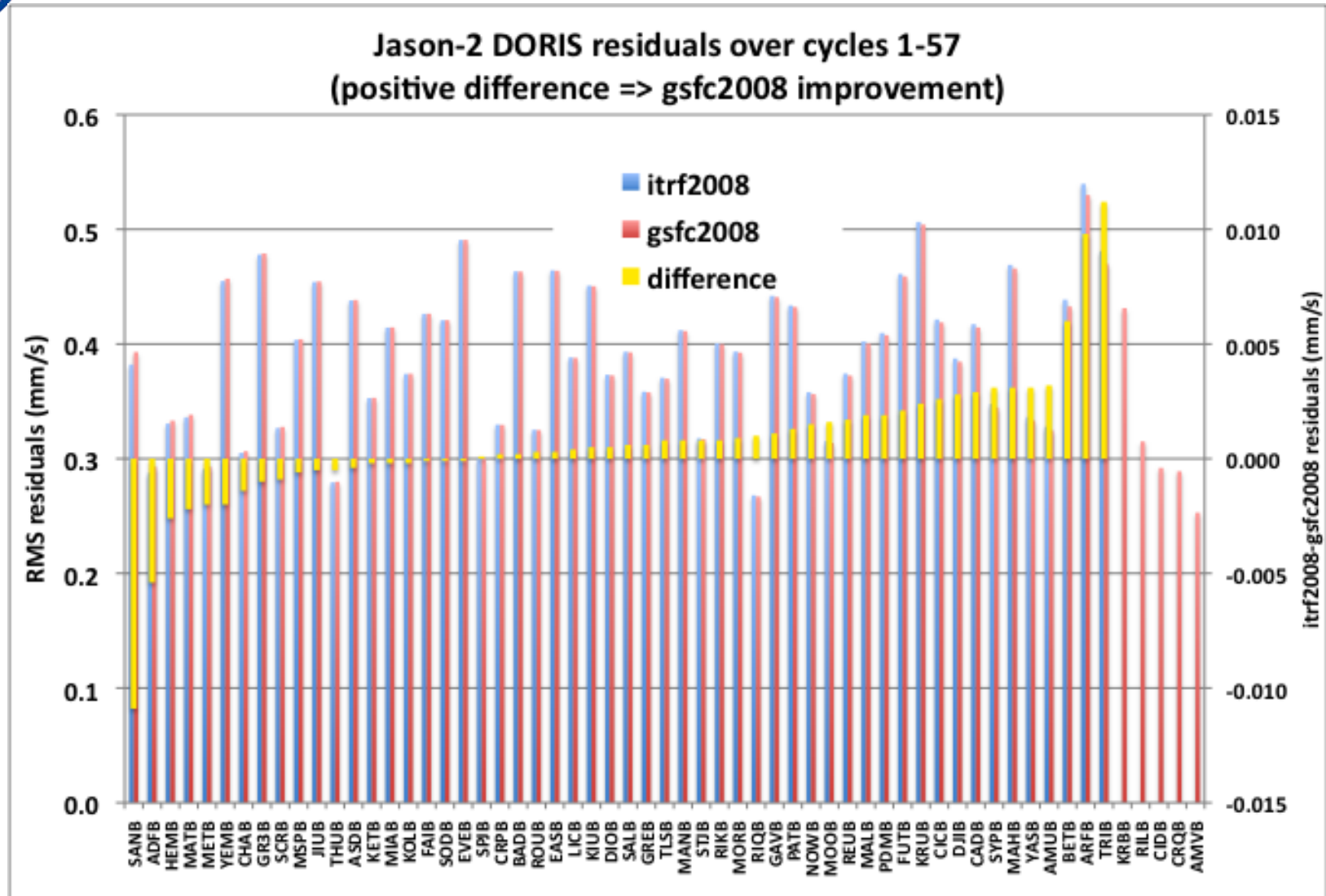
==> DORIS: 12 stations; SANA, SAOB, FAIB (> 030209); SANB; BELB; REZB; BEMB; HDMB; SODA;

==> SLR: numerous stations with short occupations; Simultaneous position+velocity adjustments not possible for many of these.

- TOPEX and Jason2 (*independent*) using SLR, DORIS & Altimeter crossovers.
- Tests with input data (L1, L2, Starlette, Stella)



GSFC2008 complement performance over the march of time						
satellite / period	test SLR/DORIS	number stations		average residuals per cycle		
		doris	slr	doris (mm/s)	slr (cm)	xover** (cm)
TP cycles 22-30 Apr 19, 1993 - Jul 17, 1993	itrf2008_merge*	44	26	0.5312	2.114	5.901
	gsfc2008_3a	44	26	0.5308	2.070	5.898
TP cycle 344-364 Jan 15, 2002 - Aug 11, 2002	itrf2008_merge	53	33	0.4740	1.498	5.506
	gsfc2008_3a	53	32	0.4735	1.484	5.511
J2 cycles 1-57 Jul 11, 2008 - Jan 28, 2010	itrf2008_merge	54	32	0.3710	1.015	5.526
	gsfc2008_3a	59	32	0.3606	1.165	5.531
* edited to not exceed number gsfc2008 stations used in POD						
** independent data						





POD orbit tests with new (3a) complement with input data

Satellite	Year	ITRF2008	Solution3a
Lageos1	1994	1.02 cm	1.05 cm
	2009	0.93 cm	1.09 cm
Lageos2	1994	1.02 cm	0.99 cm
	2009	0.89 cm	1.02 cm
Envisat	2009	1.20 cm	1.22 cm
		0.454 mm/s	0.449 mm/s
TOPEX	1993	2.09 cm	1.99 cm
		0.547 mm/s	0.544 mm/s

Conclusion: Results look promising; A recomputation of all the normal equations (1993-2011) is in progress with improvements to most of the satellites.



Future Work

Implement GPS & VLBI-specific model improvements (in GEODYN & preprocessing).

- **ambiguity fixing for double diffs;**
- **Implement (new) Jan Kouba subroutine to orient GPS satellites;**
- **Improve station selection strategy for production of daily orbits;**
- **Implement radiation model improvements (*e.g. planetary radiation pressure model by TU München*).**
- **Revamp GEODYN/GPS preprocessor to improve efficiency.**
- **Implement VMF in GEODYN for all radio data types.**
- **Implement nutation estimation capability (VLBI)**
- **Jason2: Implement half-cycle slip editing scheme -**
- **Revalidate attitude models for DORIS LEO satellites; Consider further improvements to SRP models**
- **Assess 2nd order ionosphere correction (*developed by OLC*) for DORIS and re-validate implementation in GEODYN/GPS processing.**



Satellites processed at GSFC



Lageos1 & 2



Starlette & Stella



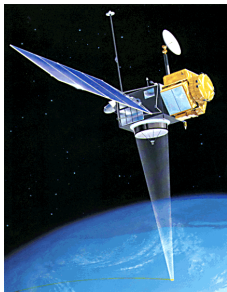
Ajisai



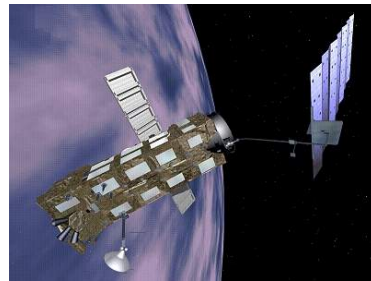
Larets



Westpac



TOPEX



Envisat



Jason1 & 2



Cryosat2



SPOT 2,3,4,5

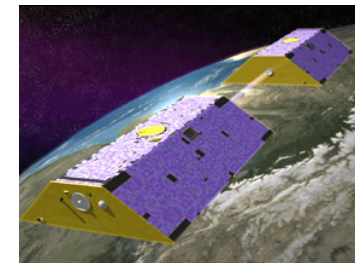
GFO



Geosat



ICESat



GRACE