Evaluation of ITRF2014 for Altimeter Satellite POD

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10 point Summary

1) Compare ITRF2014-IGN, DTRF2014, JTRF2014, DPOD2014 to ITRF2008-based SLR+DORIS POD. ITRF2014 realizations also differ in their modeling of station motion & station number.

2) Following 2009/2010, ITRF2008 DORIS/SLR station position extrapolation error dominates comparison with ITRF2014 stations and orbits.

3) Crossovers show statistically significant improvement in accuracy of all ITRF2014-based orbits starting in 2002 and increasing with time.

4) Beginning Jason-3 (2016) statistically significant improvement only seen for DPOD2014, which has the most complete station set.

5) Routinely updated ITRF2014 complements essential to POD.

10 point Summary (continued)

6) Any orbit improvement over 1992–2008 due to small improvements in ITRF2014 DORIS stations.

7) Linear station motion model serves POD as well as the other non-linear models.

8) JTRF2014 series also accurately represent non-tidal station loading and geocenter motion which impact the J2 orbit with a 15 mm peak-to-peak annual variation in Z, & is important to POD.

9) ITRF2008/ITRF2014-IGN DORIS network drift in Z as computed with arc time series of Helmert estimates of stations used in POD, is twice as steep as the IGN rate in Z, and confirms the Morel and Willis (2005) orbit transfer function.

10) ITRF2008/ITRF2014 radial orbit drift stability is very high, but will not necessarily accommodate the Ablain et al (2015) altimeter accuracy requirements.

In addition to station coordinates and the network frame, ITRF realizations differ in their modeling of station motion and in station number (Point 1).

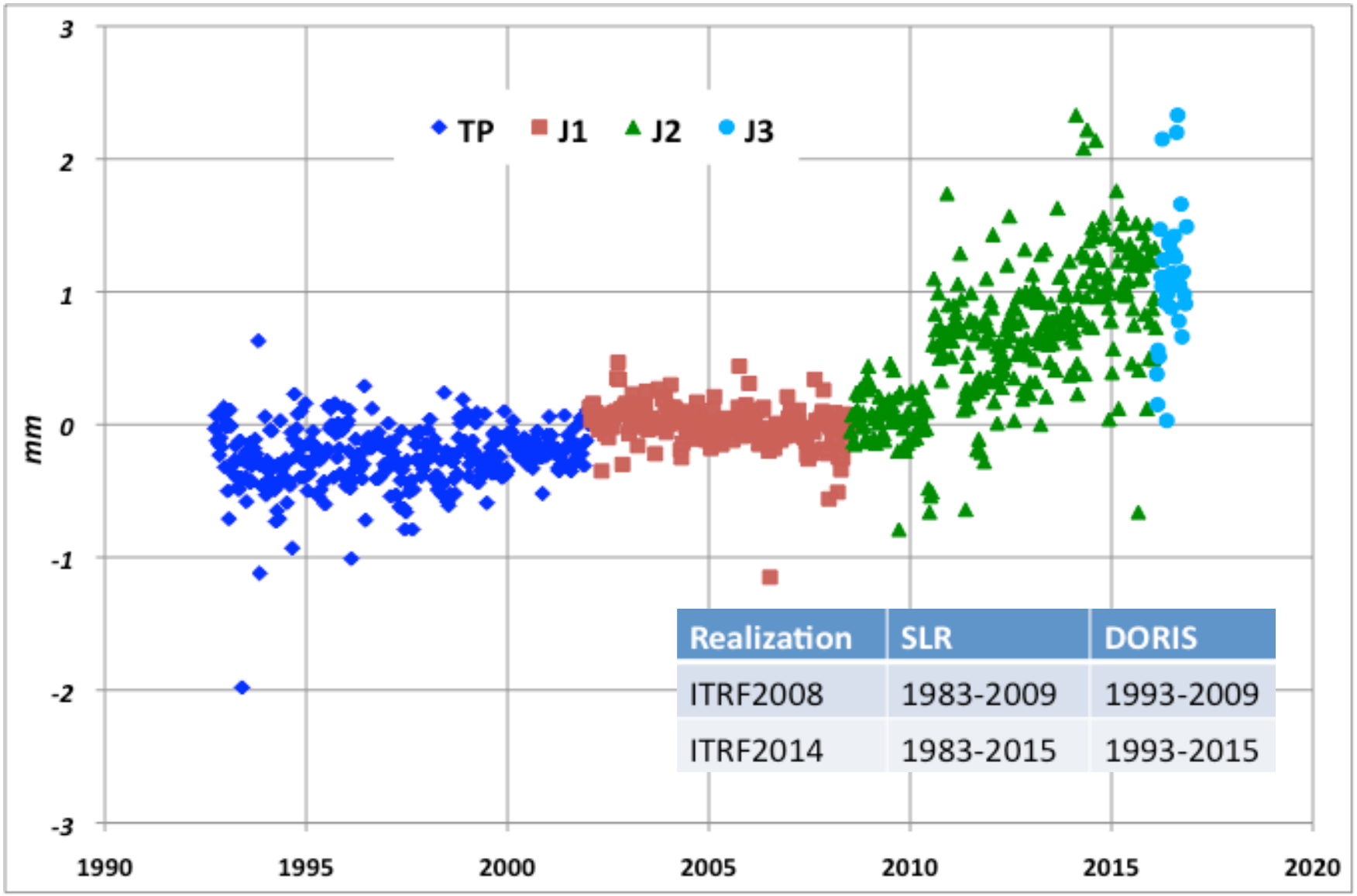
DORIS + SLR ITRF tests

DORIS+SLR Tests	Complement (DORIS + SLR)	DORIS/SLR stations	Station motion models
itrf2008	DPOD2008 + SLRF2008	189 / 168	linear
itrf2014	ITRF2014-IGN	160 / 137	linear, PSD
dtrf2014	DTRF2014 (DGFI)	153 / 97	linear
jtrf2014	JTRF2014 (JPL)	159 / 71	time series
itrf2014_aug	ITRF2014_aug	192 / 173	linear, PSD
dpod2014	DPOD2014 (IGN update) + ITRF2014_aug	195 / 173	DORIS linear SLR linear, PSD

Note. All tests adhere to the GSFC std1504 POD standards

itrf2008 – itrf2014 change in SLR RMS fit per arc;

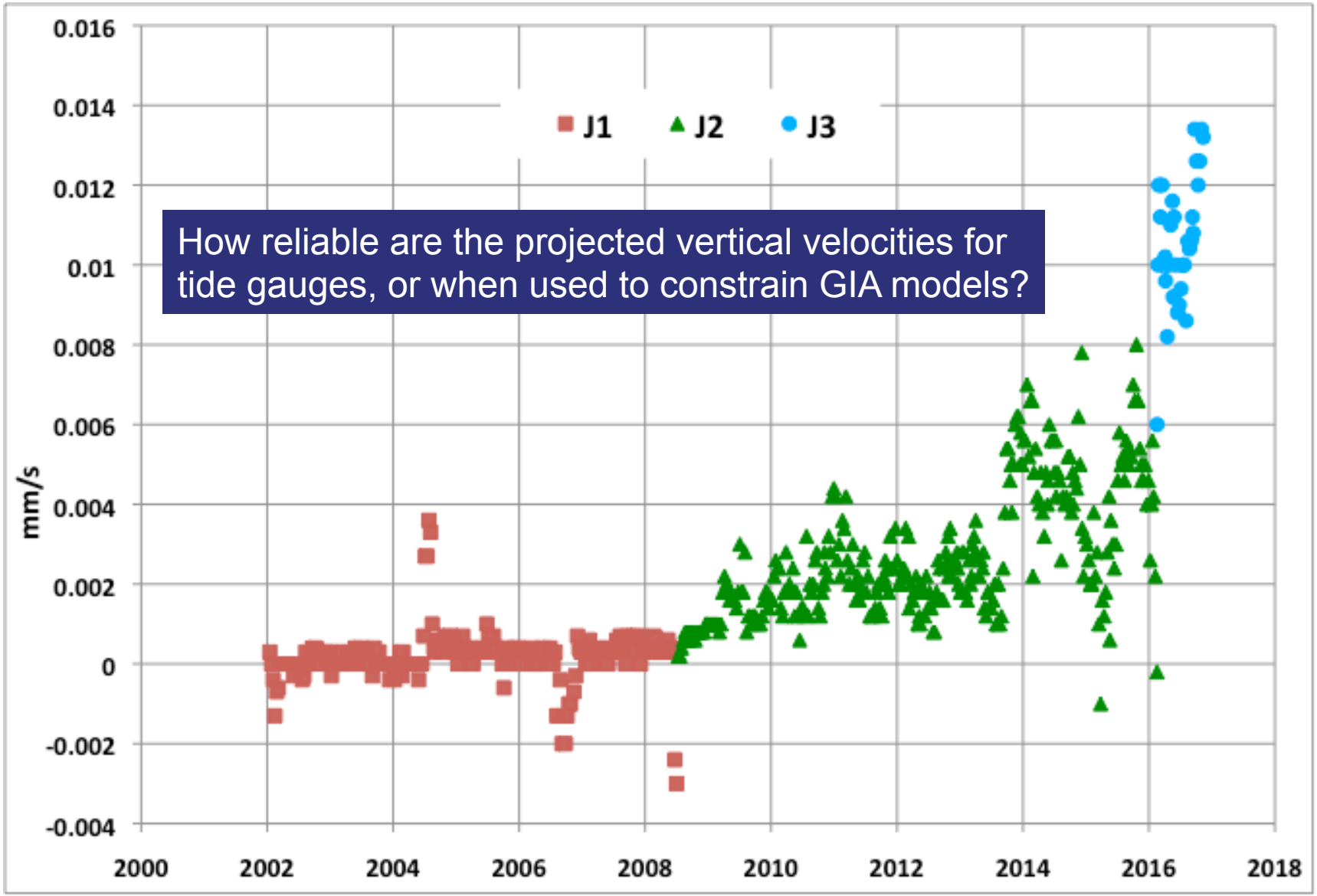
Positive implies an improvement for itrf2014 (IGN); (Point 2)



Realization	SLR	DORIS
ITRF2008	1983-2009	1993-2009
ITRF2014	1983-2015	1993-2015

itrf2008 – itrf2014 change DORIS RMS fit per arc;

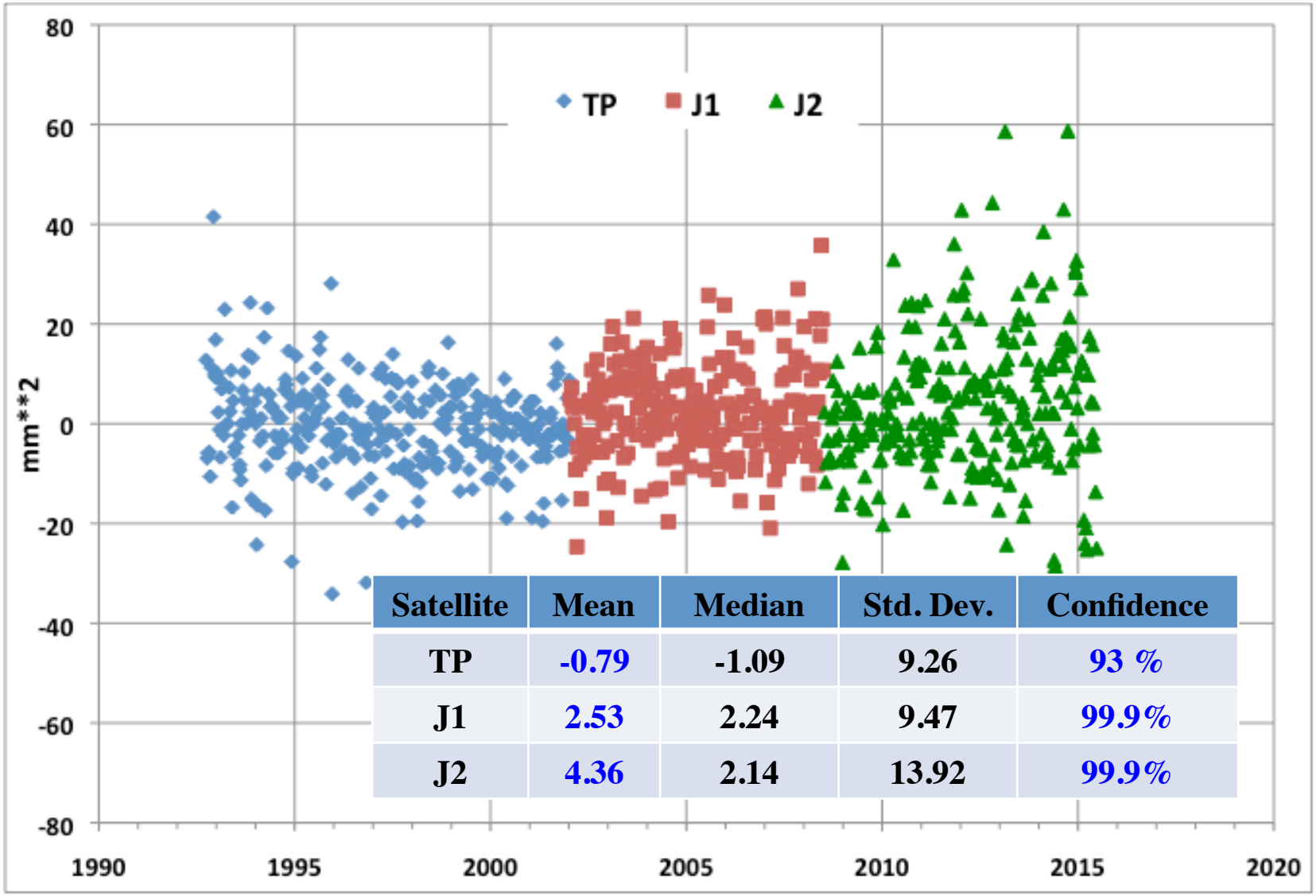
Positive implies an improvement for itrf2014 (IGN); (Point 2)



How reliable are the projected vertical velocities for tide gauges, or when used to constrain GIA models?

itrf2008 – itrf2014 Xover residual variance differences;

Positive implies an improvement for itrf2014 (IGN); (Point 3)



Satellite	Mean	Median	Std. Dev.	Confidence
TP	-0.79	-1.09	9.26	93 %
J1	2.53	2.24	9.47	99.9%
J2	4.36	2.14	13.92	99.9%

ITRF2008–ITRF2014 Xover residual variance differences;

Positive implies an improvement for ITRF2014; (Points 3-5)

ITRF Test	Mean	Median	Stnd. Dev.	Confidence
TOPEX/Poseidon (1992/09/25 – 2002/01/15)				
itrf2014	-0.79	-1.09	9.26	93 %
dtrf2014	2.58	2.10	21.66	98 %
dpod2014	0.47	-1.15	20.47	66 %
itrf2014_aug	-0.19	-1.06	7.77	66 %
jtrf2014	0.72	0.54	13.4	83 %
Jason-1 (2002/01/15 – 2008/07/12)				
itrf2014	2.53	2.23	9.37	99.9%
dtrf2014	0.91	0.00	12.85	96 %
dpod2014	0.68	0.00	10.51	91 %
itrf2014_aug	2.54	2.23	9.37	99.9%
jtrf2014	4.68	4.05	14.09	99.9%
Jason-2 (2008/07/12 – 2015/02/15)				
itrf2014	4.36	2.14	13.92	99.9%
dtrf2014	5.22	2.21	17.30	99.9%
dpod2014	4.20	2.63	16.18	99.9%
itrf2014_aug	4.04	2.11	14.99	99.9%
jtrf2014	4.27	2.15	16.63	99.9%
Jason-3 (2016/02/17 – 2016/11/21)				
itrf2014	6.87	8.29	34.22	83 %
dtrf2014	0.35	-2.73	37.19	52 %
dpod2014	8.17	2.71	20.70	97 %
itrf2014_aug	4.40	-1.52	21.12	84 %
dtrf2014_aug	6.36	-1.65	26.13	87 %

Any orbit improvement over 1992–2008 is due to small improvements in ITRF2014 DORIS stations. (Point 6)

Summary TOPEX/Poseidon SLR+DORIS POD

(1992/09/25 – 2002/01/15; cycles 1-343)

Test	Total stations		Average RMS residuals		
	DORIS	SLR	DORIS (mm/s)	SLR (cm)	Xover (cm)
itrf2008	96	76	0.5113	1.587	5.644
itrf2014	89	75	0.5100	1.611	5.644
jtrf2014	89	49	0.5103	1.602	5.643
dtrf2014	89	67	0.5093	1.580	5.641
itrf2014_aug	96	76	0.5116	1.616	5.644
dpod2014	94	76	0.5110	1.615	5.643

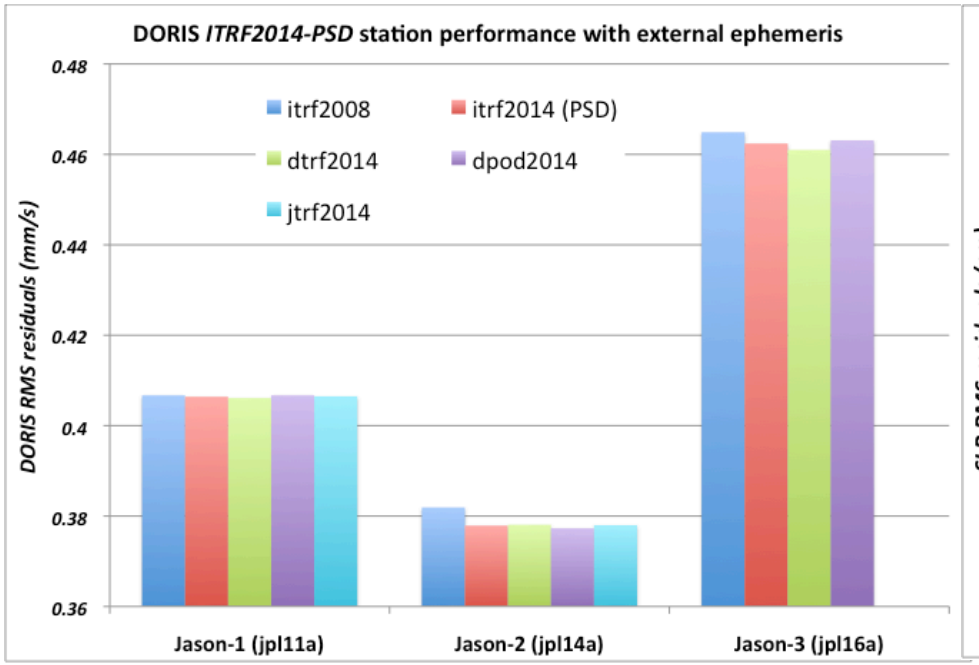
Summary Jason-1 SLR+DORIS POD

(2002/01/15 – 2008/07/12; cycles 1-239)

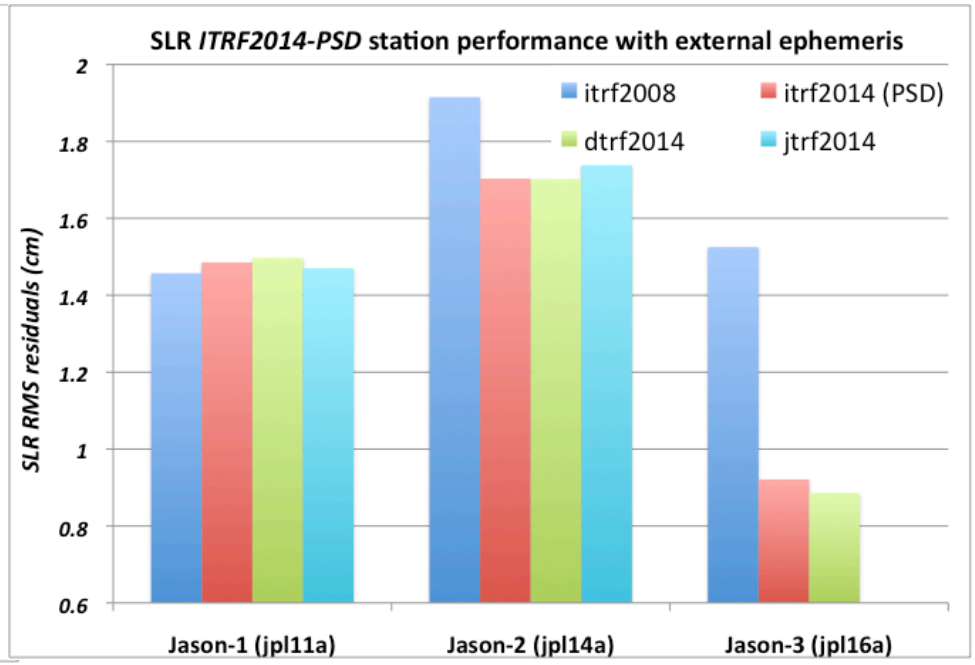
Test	Total stations		Average RMS residuals		
	DORIS	SLR	DORIS (mm/s)	SLR (cm)	Xover (cm)
itrf2008	97	52	0.3691	0.744	5.515
itrf2014	96	50	0.3689	0.744	5.512
jtrf2014	94	41	0.3665	0.737	5.510
dtrf2014	94	45	0.3684	0.750	5.514
itrf2014_aug	97	52	0.3689	0.744	5.514
dpod2014	97	52	0.3688	0.744	5.514

Non-linear station motion model does not show improvement; PSD-only stations; JPL GPS Jason1-3 orbits (Point 7)

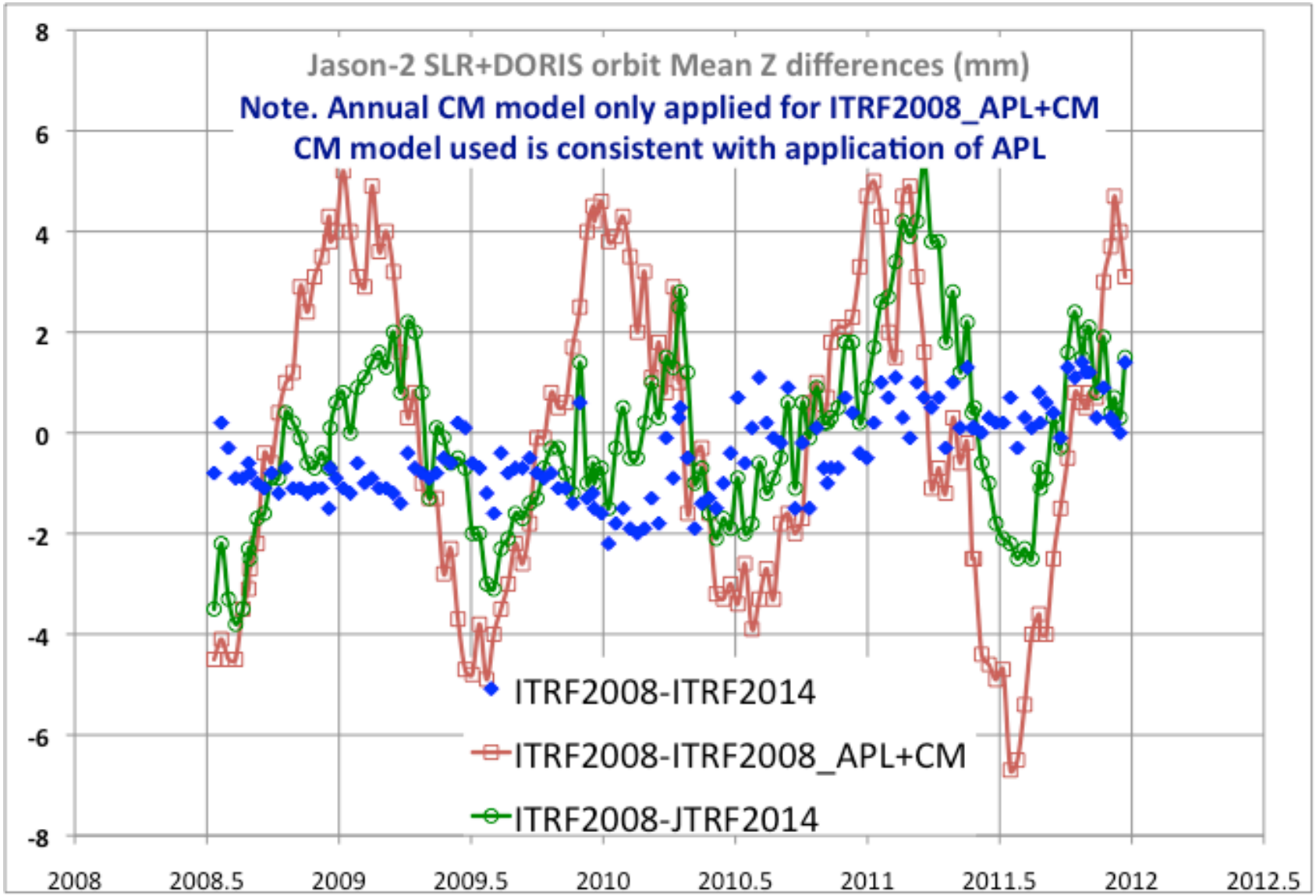
DORIS



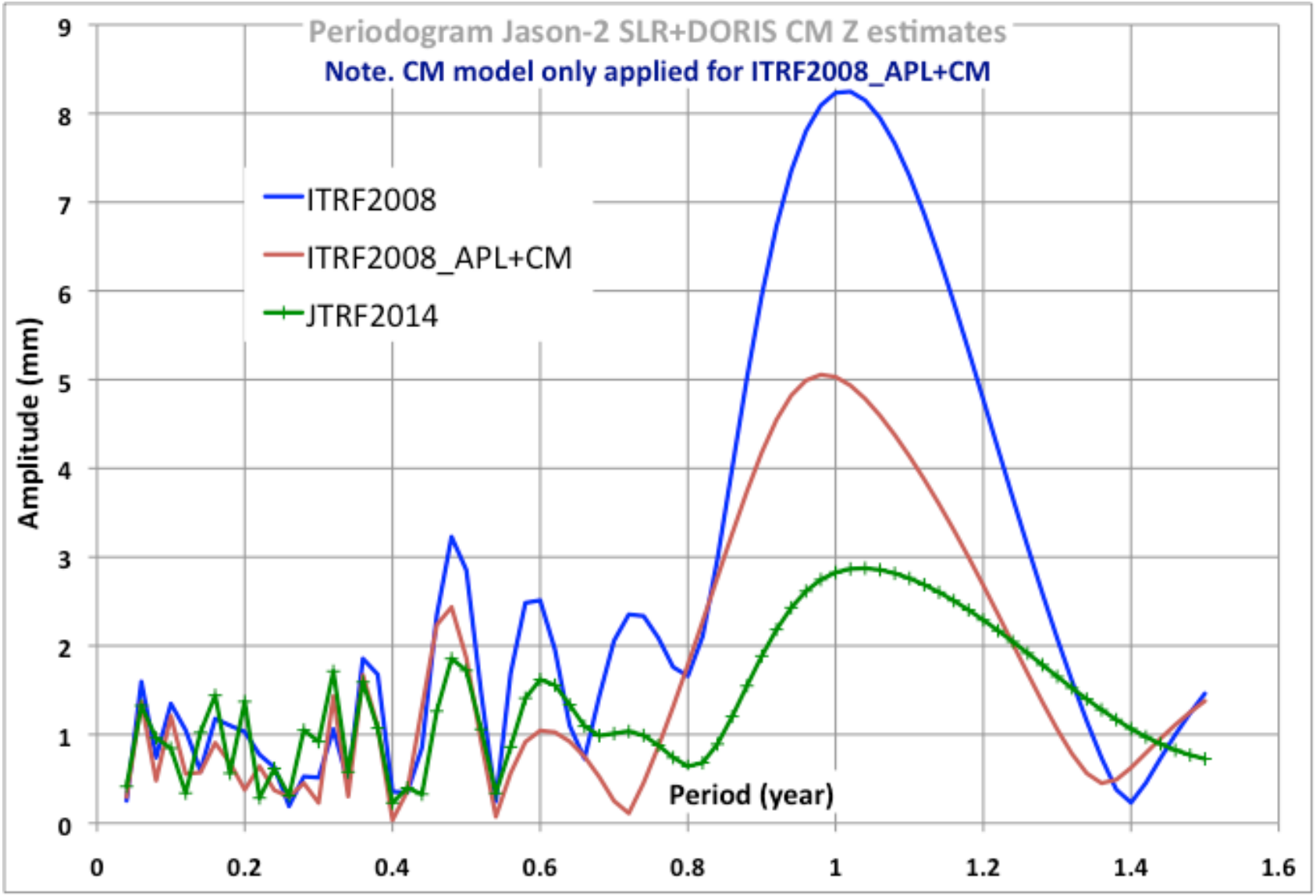
SLR



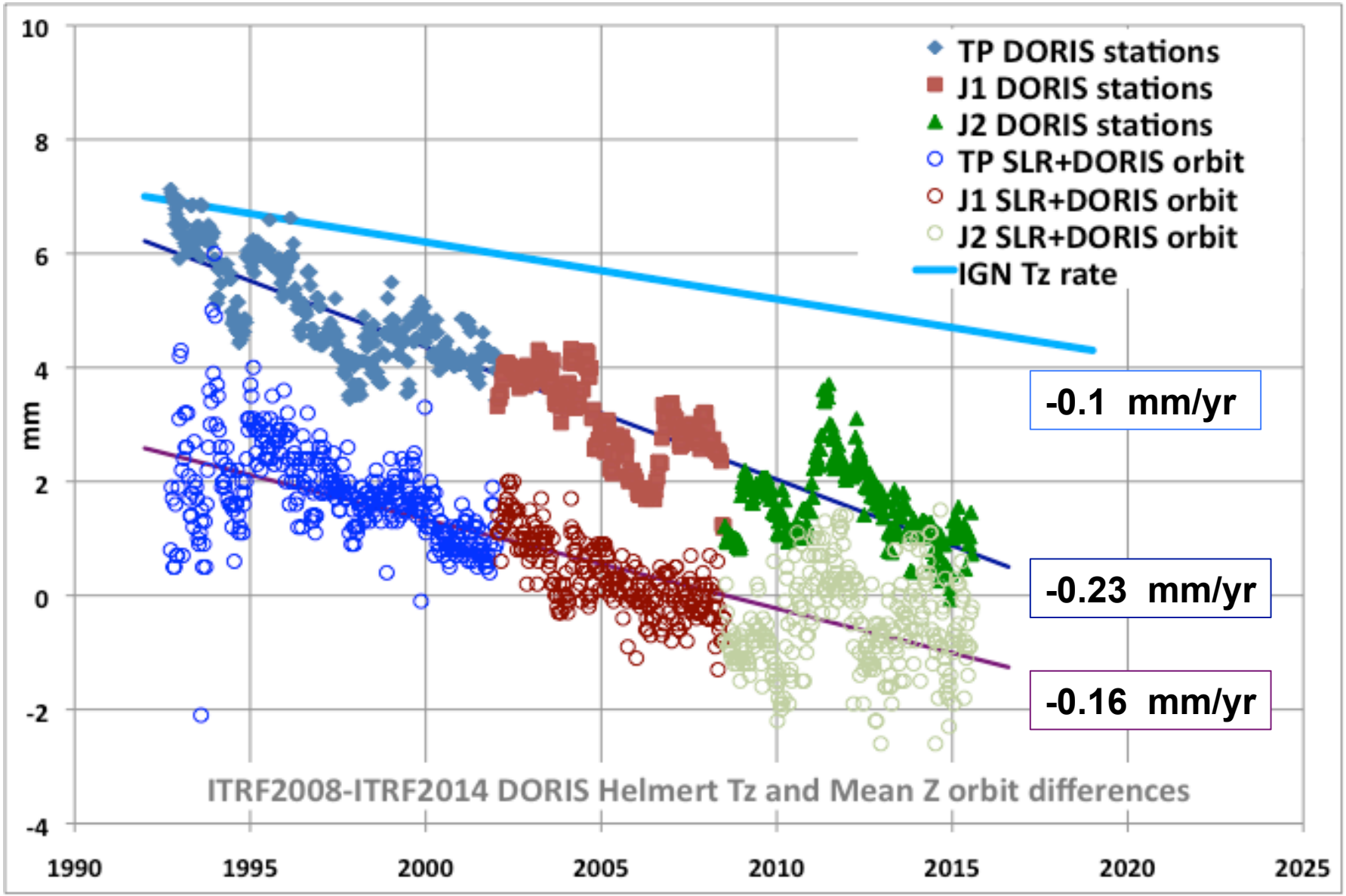
JTRF2014 orbit centering in Z is similar in phase and amplitude to orbit when geocenter motion and atmospheric station loading are modeled



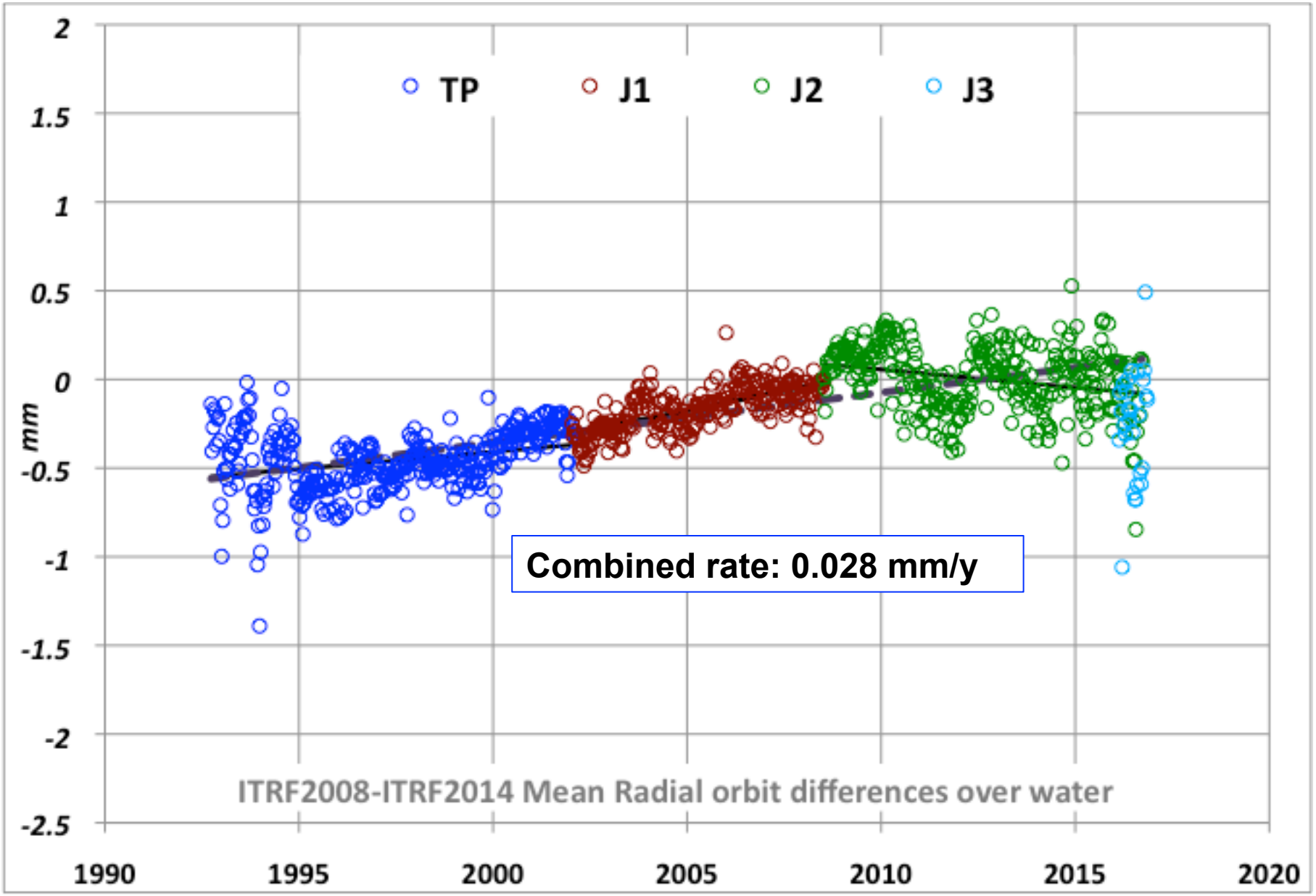
Jason-2 SLR+DORIS CM estimates in Z suggest that the effects of geocenter motion and non-tidal surface loading are well represented with JTRF2014 (Point 8)



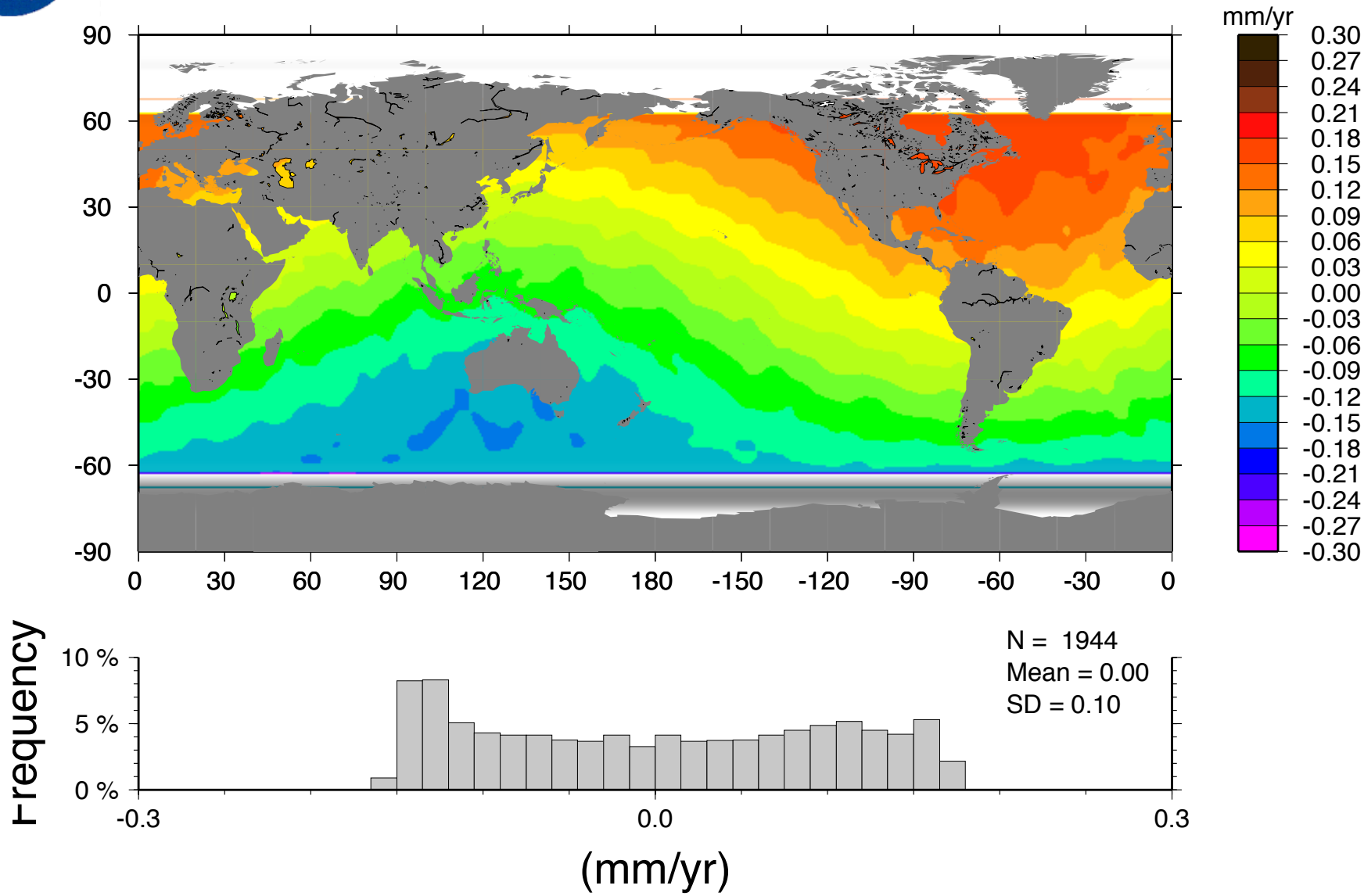
itrf2008/itrf2014 station network and orbit frame stability in Z (Point 9)



itrf2008 vs. itrf2014 (IGN) radial orbit drift stability impact on Global Mean Sea Level (GMSL) (Points 9, 10)



itrf2014_aug – itrf2008 geographic radial orbit drift computed over 1992-2016 (Points 9, 10)



Backup

Radial orbit stability will not necessarily accommodate radial accuracy requirements

Altimeter error budget[1]			
Spatial scale	Temporal scale	State-of-the-art	Required
Global MSL	Long term evolution (> 10 years)	0.5 mm/year	0.3 mm/year
	Inter-annual signals (< 5 years)	< 2mm over 1 year	0.5mm over 1 year
	Annual signals	< 1mm	Not defined
Regional MSL	Long term evolution (> 10 years)	< 3 mm/year	< 1 mm/year
	Annual signals	< 1cm	Not defined
1) Courtesy of M. Ablain et al, 2015 (see Table 2).			

Non-linear station motion model does not show improvement

Jason-1 SLR, DORIS residuals using jpl11a orbit for 8 DORIS / 8 SLR stations with active PSD modeling; April 2002 – May 2006 (cycles 9-161)

Orbit	DORIS (mm/s)	SLR (cm)	
itrf2008	0.4067	1.457	DORIS PSD stations ADEB AREB FAIB GOMB REYB REZB SAKA SAKB
itrf2014 (PSD)	*0.4064*	*1.485*	SLR PSD stations
dtrf2014	0.4061	1.497	MNPE7110 BEIJ7249
jtrf2014	0.4065	1.470	CRL_7308 GMSL7358
dpod2014	0.4067	-----	AREL7403 CONC7405
Note. All stations have uniform weighting			SHAN7821 SHO_7838

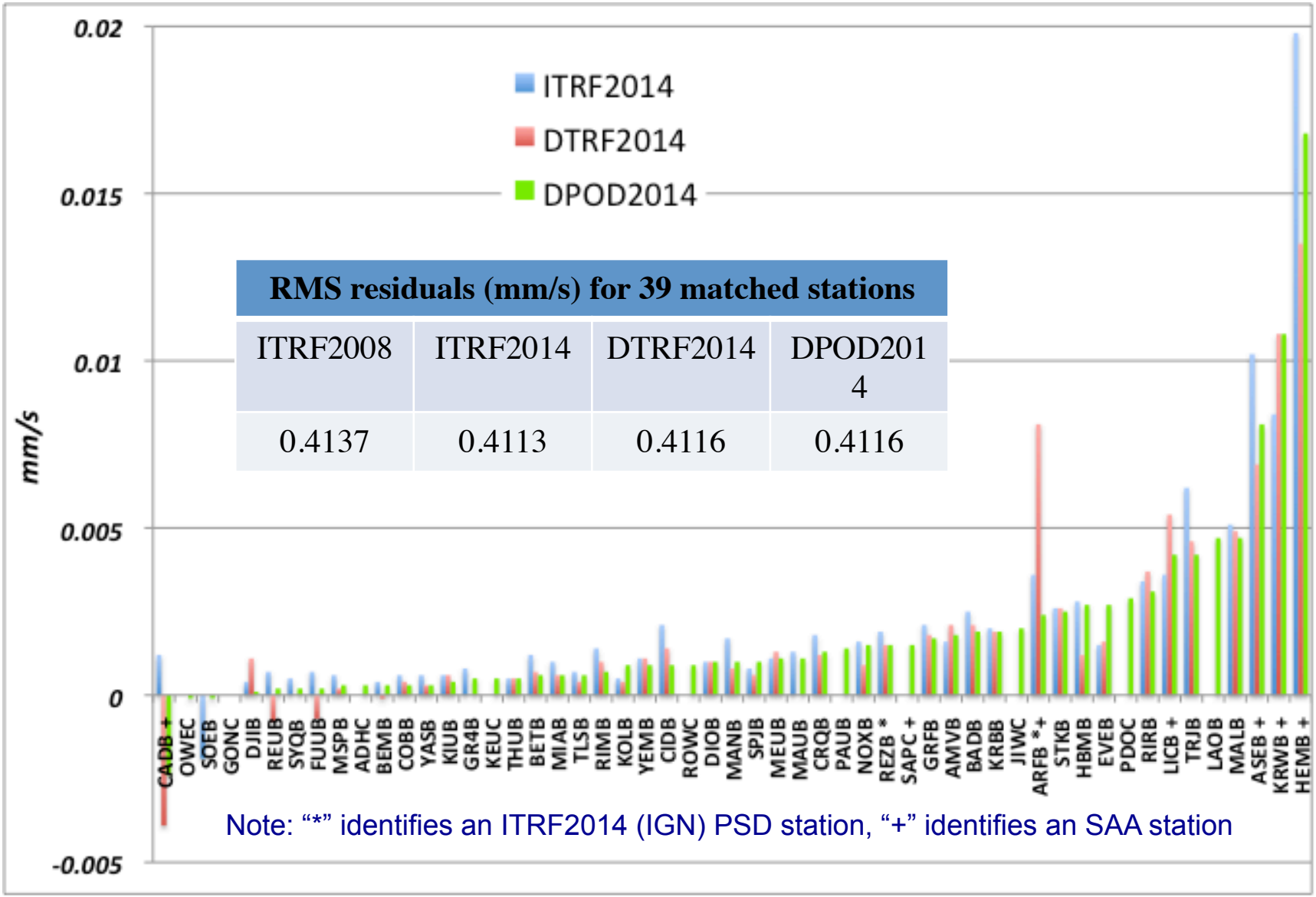
Jason-2 SLR, DORIS residuals using jpl14a orbit for 7 DORIS / 10 SLR stations with active PSD modeling; July 2008 – August 2015 (cycles 1-243)

Orbit	DORIS (mm/s)	SLR (cm)	
itrf2008	0.3819	1.915	DORIS PSD stations ADFB ADGB ARFB FAIB REZB SAKB SANB
itrf2014 (PSD)	*0.3779*	*1.703*	SLR PSD stations
dtrf2014	0.3781	1.702	MNPE7110 CHAC7237
jtrf2014	0.3780	1.738	BEIJ7249 CRL_7308
dpod2014	0.3773	-----	KOGA7328 GMSL7358
Note. All stations have uniform weighting			AREQ7403 CONC7405 SHAN7821 SHO_7838

Jason-3 SLR, DORIS residuals using jpl16a orbit for 2 DORIS / 6 SLR stations with active PSD modeling; February 2016 – August 2016 (cycles 1-20)

Orbit	DORIS (mm/s)	SLR (cm)	
itrf2008	0.4649	1.525	DORIS PSD stations ARFB REZB
itrf2014 (PSD)	*0.4624*	*0.921*	SLR PSD stations
dtrf2014	0.4610	0.886	MNPE7110 CHAC7237
dpod2014	0.4631	-----	BEIJ7249 AREQ7403
Note. All stations have uniform weighting			SHAN7821 SHO_7838

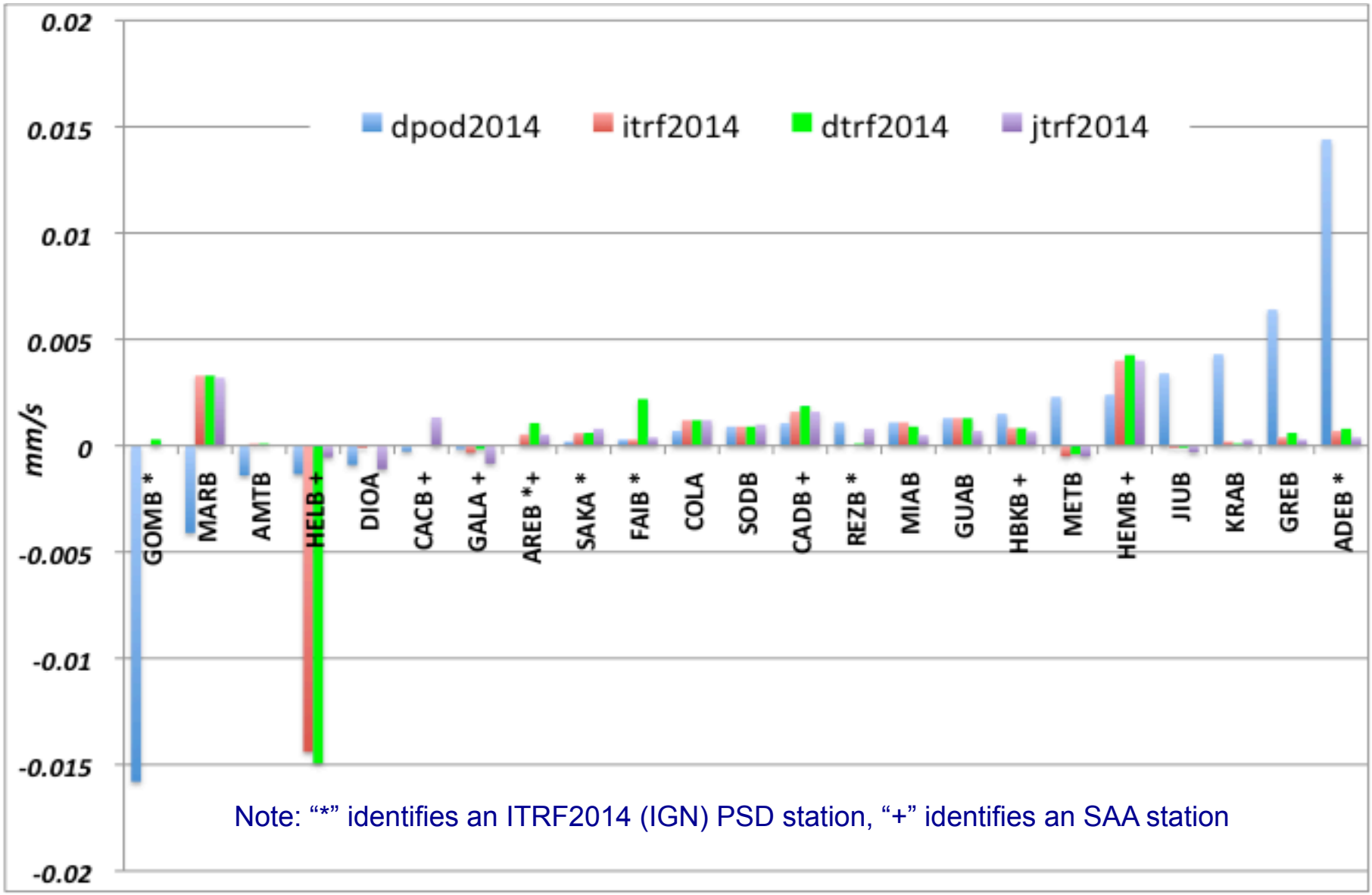
Jason-3 DORIS ITRF2008-Test residual differences computed using jpl16a orbit over 53 stations (February 2016 – August 2016).



RMS residuals (mm/s) for 39 matched stations			
ITRF2008	ITRF2014	DTRF2014	DPOD2014
0.4137	0.4113	0.4116	0.4116

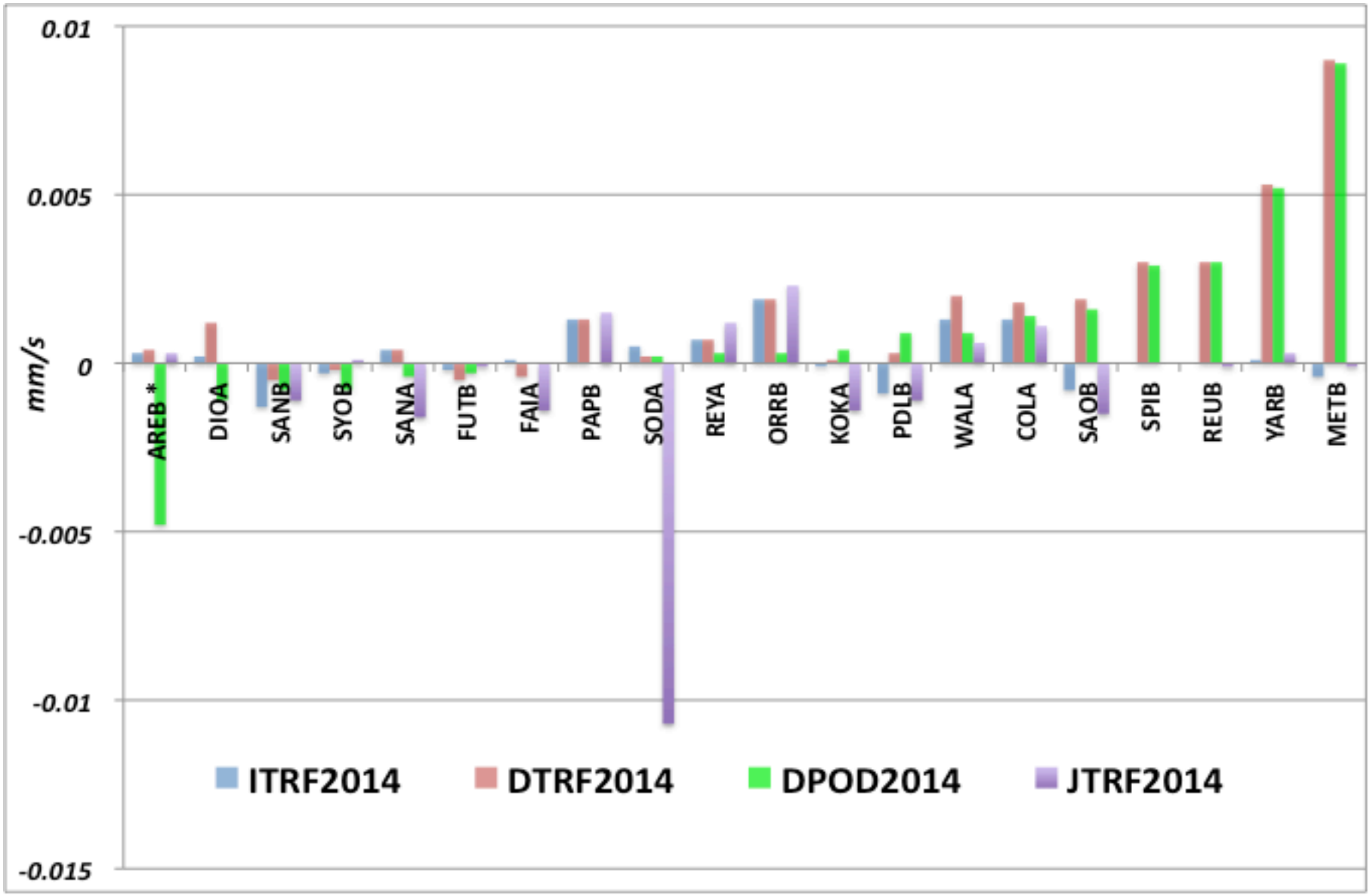
Note: "*" identifies an ITRF2014 (IGN) PSD station, "+" identifies an SAA station

Jason-1 DORIS itrf2008-Test residual differences using jpl11a orbit for best/worst performing stations; April 2002 – May 2006 (cycles 9-161)

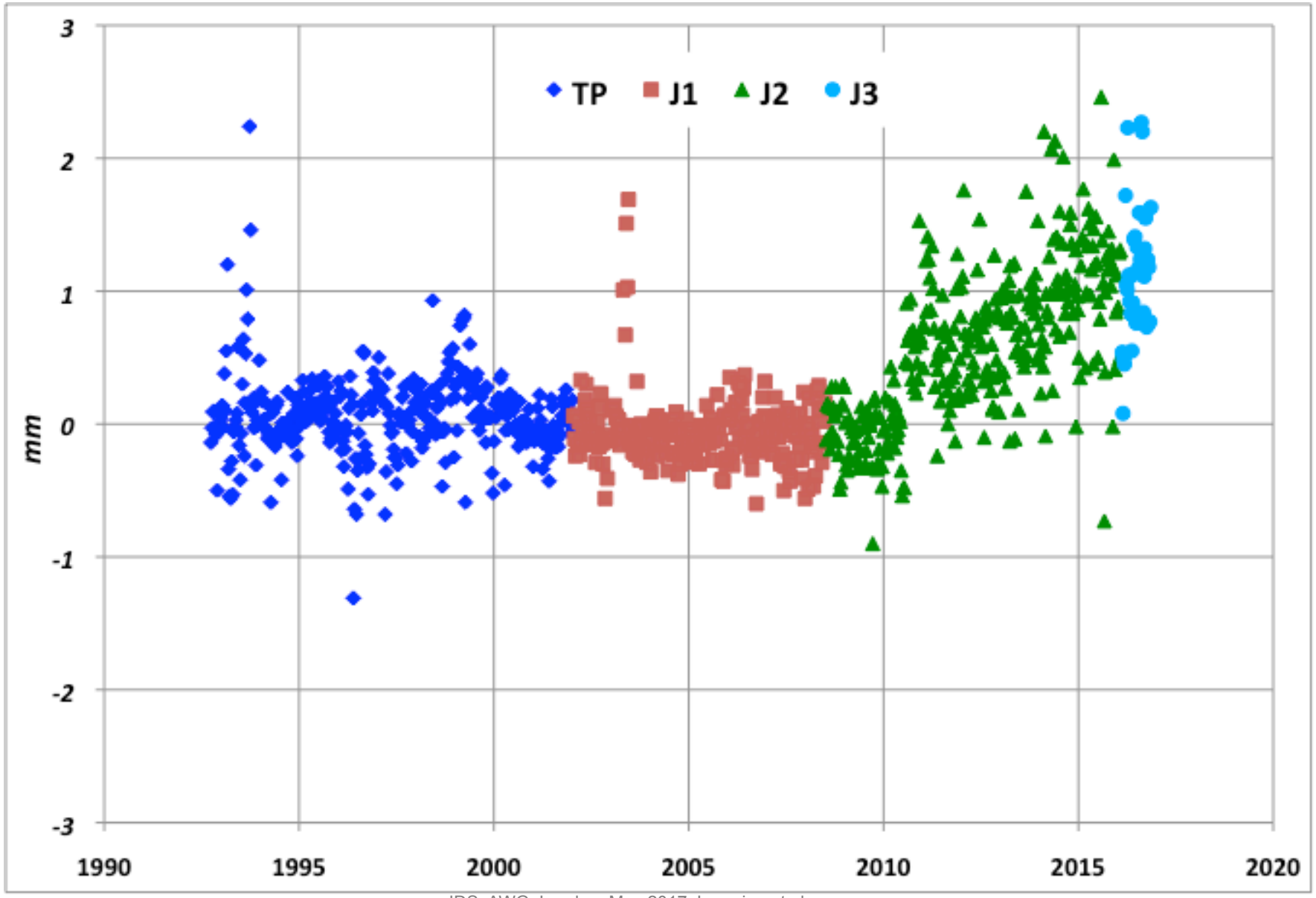


Note: "*" identifies an ITRF2014 (IGN) PSD station, "+" identifies an SAA station

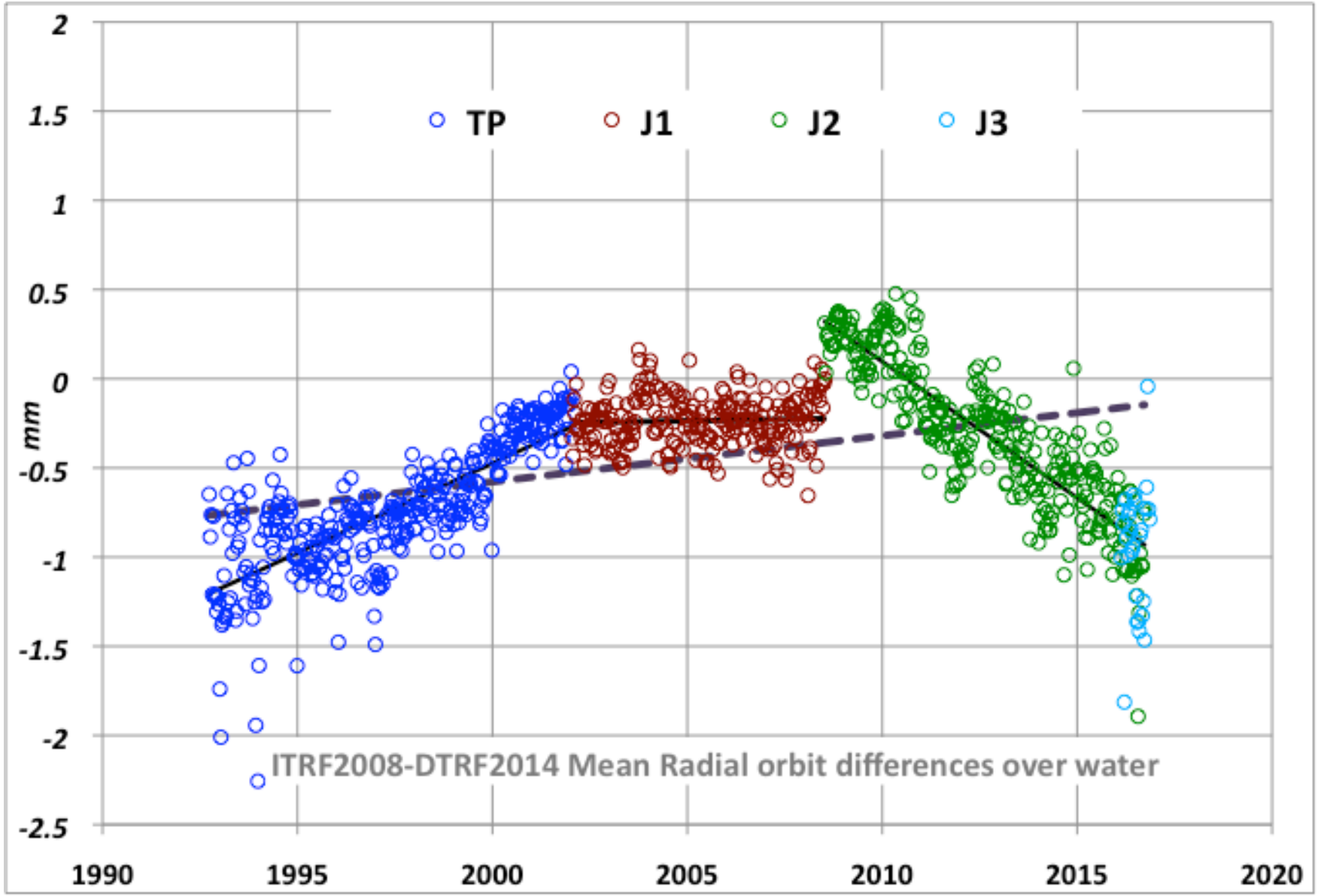
TOPEX DORIS POD itrf2008-Test residual differences for best/worst performing stations; September 1992 – January 2002 (cycles 1-343)



itrf2008 – dtrf2014 change in SLR RMS fit per arc;
Positive implies an improvement for dtrf2014; (Point 2)



itrf2008 vs. dtrf2014 radial orbit drift stability impact on Global Mean Sea Level (GMSL)



itrf2008 vs. jtrf2014 radial orbit drift stability impact on Global Mean Sea Level (GMSL)