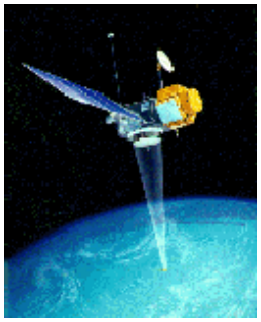
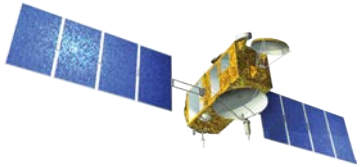
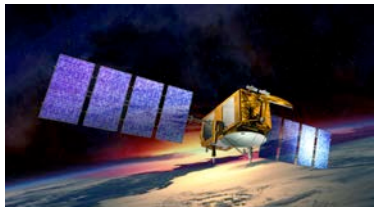


Improvement of the Complete TOPEX and Jason Orbit Time Series (1992-2017): GSFC Status

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(2) SGT Inc., Greenbelt, Maryland, USA

(3) Observatoire de la Côte d'Azur

Introduction:

From the previous OSTST (2016): The outstanding issues pertained to:

(1) Evaluation of ITRF2014 reference frame (all variants).

(2) Development of a CoM model with Atmosphere Loading modeled a priori.

(3) Characterization of systematic errors in DORIS & SLR w.r.t. altimeter satellites.

(4) Expressed concern about pole-tide modeling and impact on altimeter satellite POD.

Accomplishments in the past year:

(1) Evaluated reference frame realizations (ITRF2014/IGN, DTRF2014, JTRF2014) as well as prototype DPOD2014 (DORIS-only) realization.

(2) Retuned POD parameters for Jason-3 (Cr=0.98584).

(3) Evaluated Jason-2 DORIS/USO and SLR/Timing bias effects on POD.

→ see A. Belli presentation in this session.

In addition we have implemented specific improvements:

(1) Estimated a (preliminary) geocenter model from L1/L2 for satellite altimetry includes atmospheric loading. → **see N. Zelensky presentation in this session.**

TP, J1, J2, J3 Orbits Delivered

All the orbits are available via anonymous FTP, and are in the standard POE format (**version, std1504_dpod2014**)

TOPEX/Poseidon: **std1504_dpod2014, cycles 1-481** (**ITRF2014**)
Jason-1: **std1504_dpod2014, cycles 1-259** (**ITRF2014**)
Jason-2: **std1504_dpod2014, cycles 1-300a** (**ITRF2014**)
Jason-3: **std1504_dpod2014, cycles 1-58** (**ITRF2014**)

- TP Orbits delivered to JPL to support retracking effort.
- All new ITRF2014-based orbits are delivered to MEASURES for Sea Level ESDR Product.

All orbit will be available via the NASA CDDIS in early November 2017 using a new delivery address and when (hopefully) a doi number can be arranged.

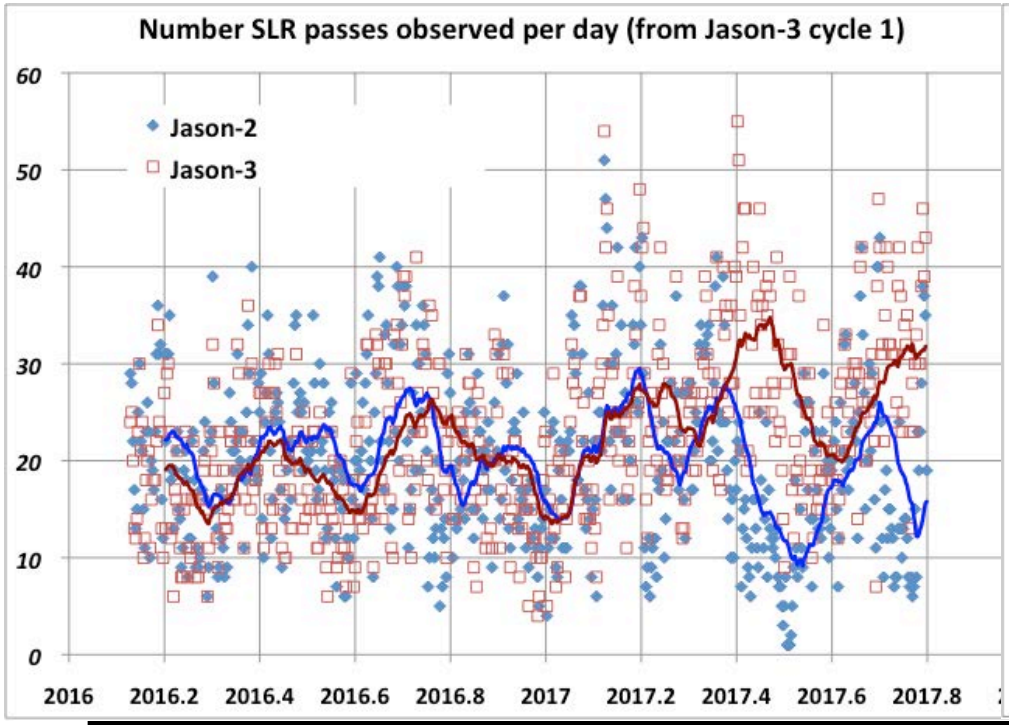
GSFC POE Description

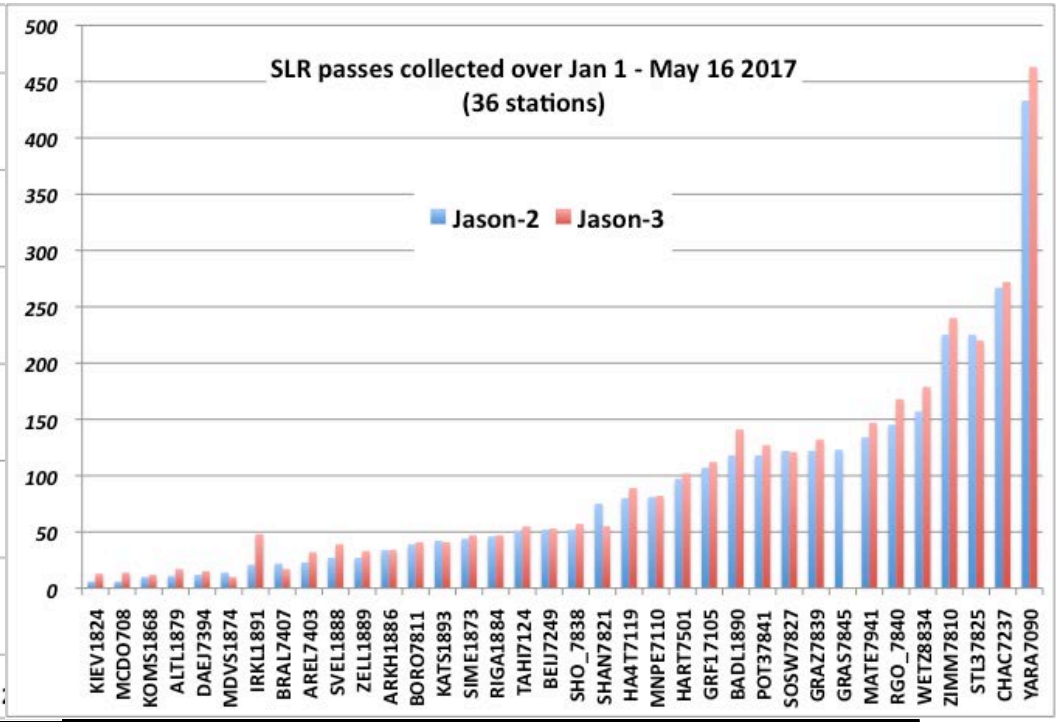
GSFC SLR + DORIS orbits	Description
std1504_dpod2014	ITRF2014: GDR-F comparable. Includes SLRF2014 (SLR), DPOD2014 (DORIS). (SLR+DORIS dynamic)
SLR+DOR+XOVER (std1504)	Test Series for orbit comparisons (J3).
SLR+XOVER (std1504)	Test Series for orbit comparisons (J3).

General Model Summary (std1504)

Model Summary	Std1504_dpod2014
Station coordinates	**ITRF2008 (**SLRF2014, DPOD2014v4**)**
Geocenter motion	annual model (Ries, 2013)
Dynamic tides	GOT4.10 (50x50)
Ocean loading	GOT4.10
J2 & J3 Cr	Previously tuned for Jason-2. **Tuned for Jason-3**
Solar array orientation	**Quaternions (Jason-1,2,3)**
DORIS Troposphere	VMF1
J1/J2/J3 OPR	12-hr
Pole Model	IERS2010
Static gravity	GOCO2S (> L=5)
TVG	Harmonic piecewise fit to 5x5 weekly solutions
DORIS SAA stations	Downweight by 3X (Jason-3 only). (ARFB,ASEB, CADB, EASB, HEMB, KRWB, LIBB, SAQC, SAOB, SCRB)

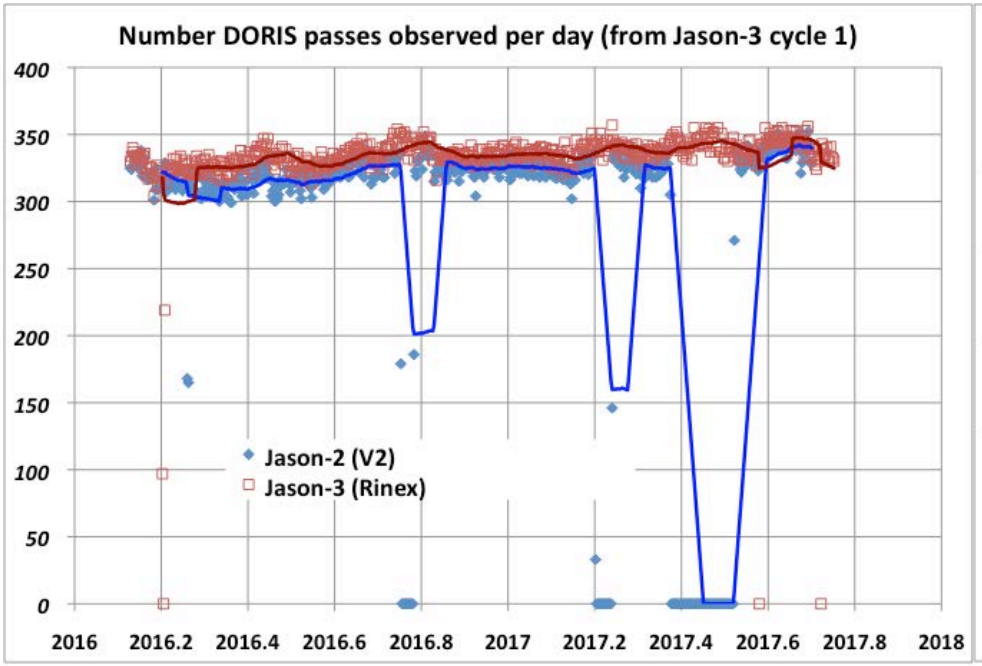
SLR Tracking Status (Jason-2 & 3)

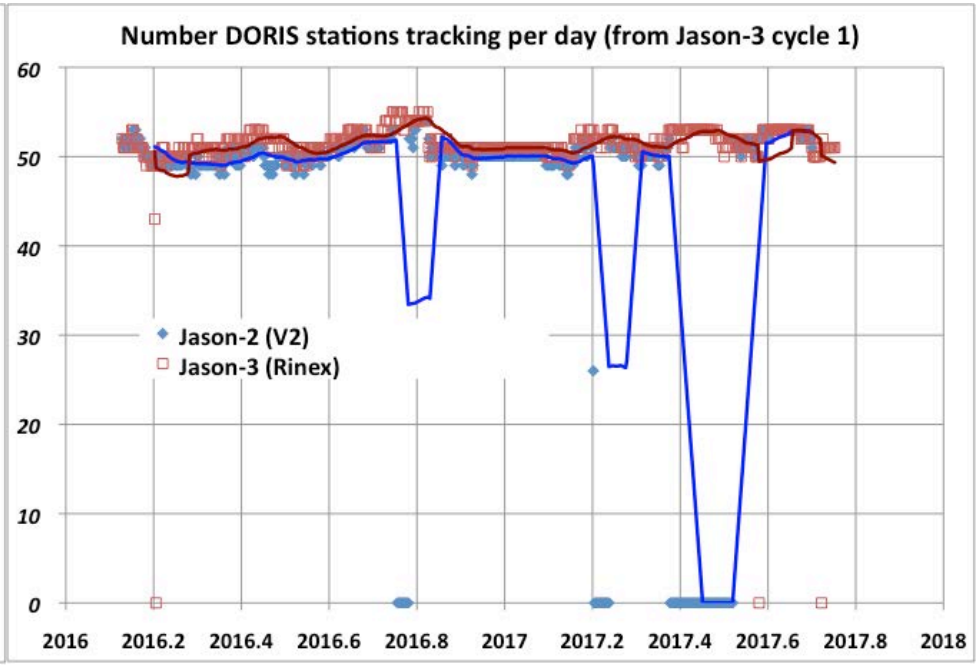




SLR Tracking for J2, J3 (2016-2017) similar to that provided for earlier missions;

Jason-3 DORIS Status

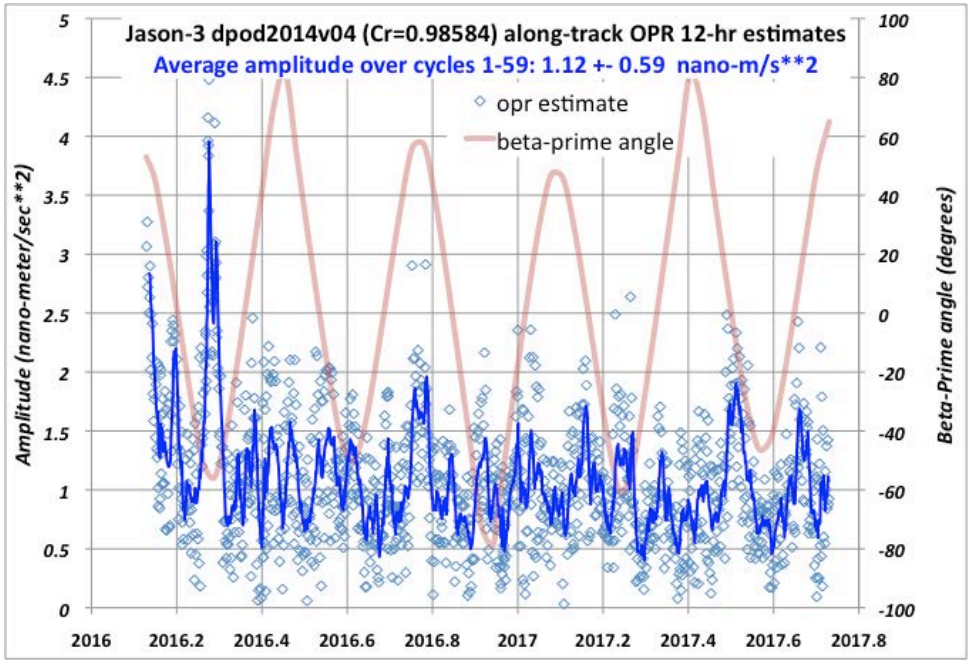




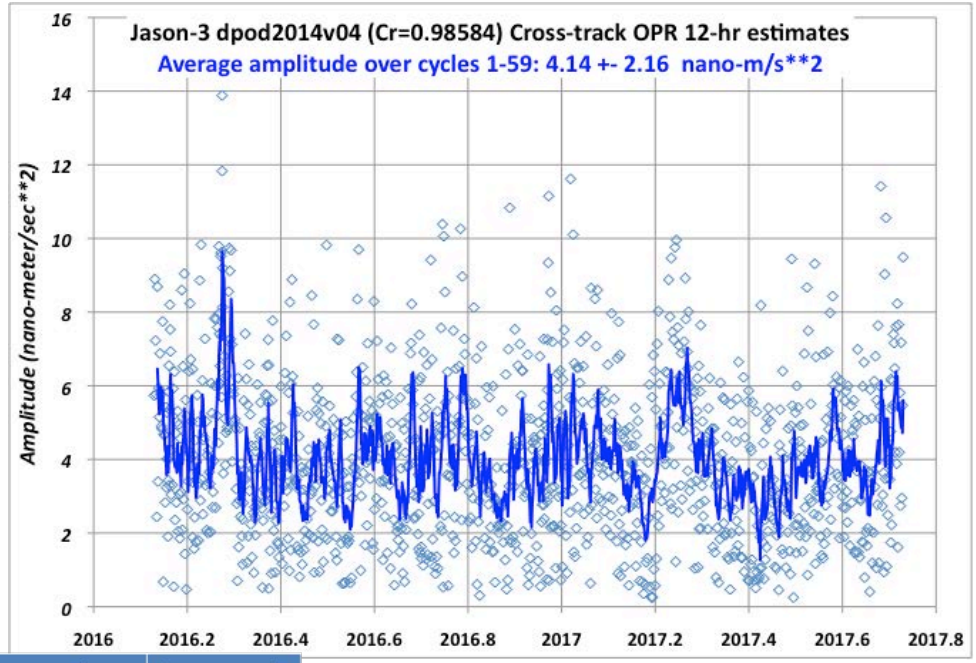
Jason-3 Macromodel Tuning

We adopt a mean Cr = 0.9854 determined over Jason-3 cycles 1-XX.

J3:Along-track OPR Amplitudes (nm/s^2)

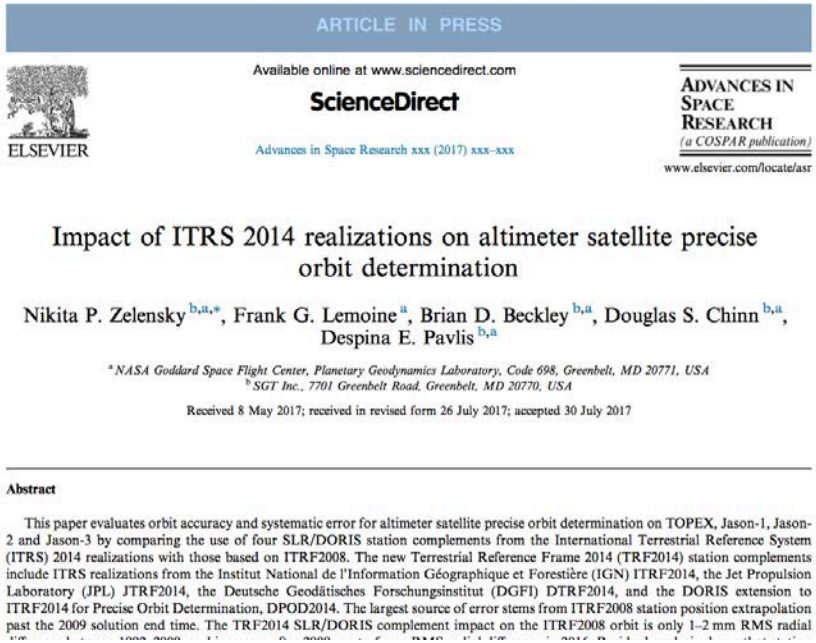


J3:Cross-track OPR Amplitudes (nm/s^2)



Satellite	Along-track (nm/sec^2)	Cross-track (nm/sec^2)
Jason-2 (2016-01-01 to 2016-10-02)	1.5 ± 0.6	4.2 ± 2.2
Jason-3 (2016-02-17 to 2017-09-24)	1.1 ± 0.6	4.1 ± 2.2

Station complement (Reference Frame), SLR+DORIS POD test sets



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Impact of ITRS 2014 realizations on altimeter satellite precise orbit determination

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Abstract

This paper evaluates orbit accuracy and systematic error for altimeter satellite precise orbit determination on TOPEX, Jason-1, Jason-2 and Jason-3 by comparing the use of four SLR/DORIS station complements from the International Terrestrial Reference System (ITRS) 2014 realizations with those based on ITRF2008. The new Terrestrial Reference Frame 2014 (TRF2014) station complements include ITRS realizations from the Institut National de l'Information Géographique et Forestière (IGN) ITRF2014, the Jet Propulsion Laboratory (JPL) JTRF2014, the Deutsche Geodätisches Forschungsinstitut (DGFI) DTRF2014, and the DORIS extension to ITRF2014 for Precise Orbit Determination, DPOD2014. The largest source of error stems from ITRF2008 station position extrapolation past the 2009 solution end time. The TRF2014 SLR/DORIS complement impact on the ITRF2008 orbit is only 1–2 mm RMS radial

Zelensky et al. (2017), Adv. Space Res., doi: 10.1016/j.asr.2017.07.044, in press.

- Evaluated all ITRS2014 complements:
  (1) ITRF2014 (IGN).
  (2) DTRF2014 (DGFI).
  (3) JTRF2014 (JPL).
  (4) DPOD2014 – DORIS-only extension.
  (5) ”Augmented versions” for DTRF2014 & ITRF2014 (due to ’missing stations’).

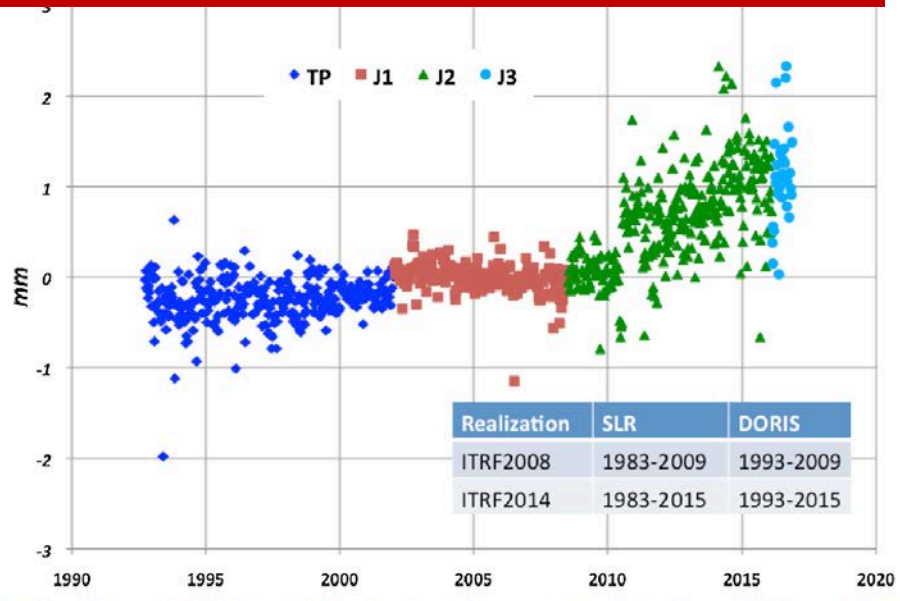
- Computed Orbits for TP, J1, J2, J3.

- Evaluated orbits and RMS of fit w.r.t.` ITRF2008.

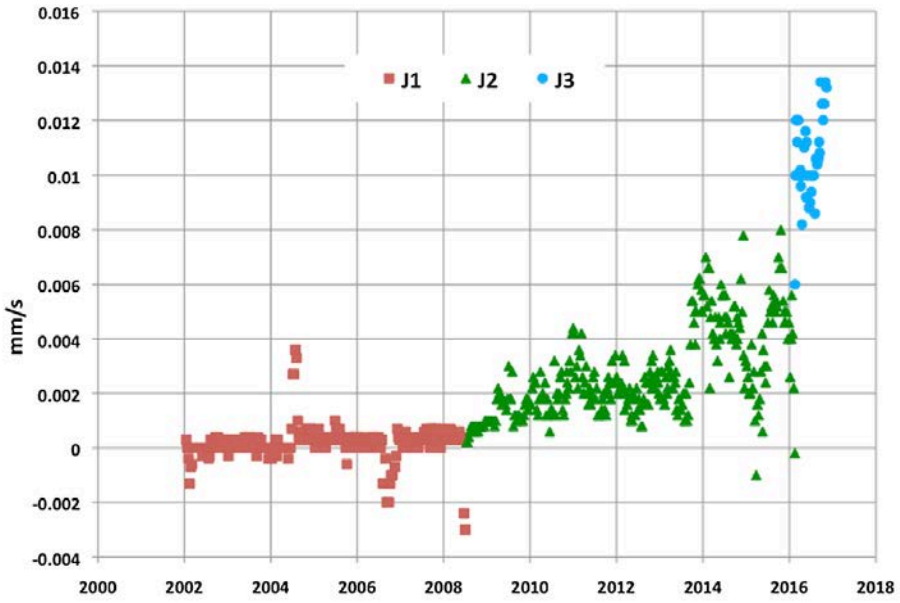
- Analyzed performance of individual stations by complement.

Evaluation of ITRS2014 complements (1)

SLR:
Improvement with ITRF2014 vs. ITRF2008



DORIS:
Improvement w. ITRF2014 vs. DPOD2008

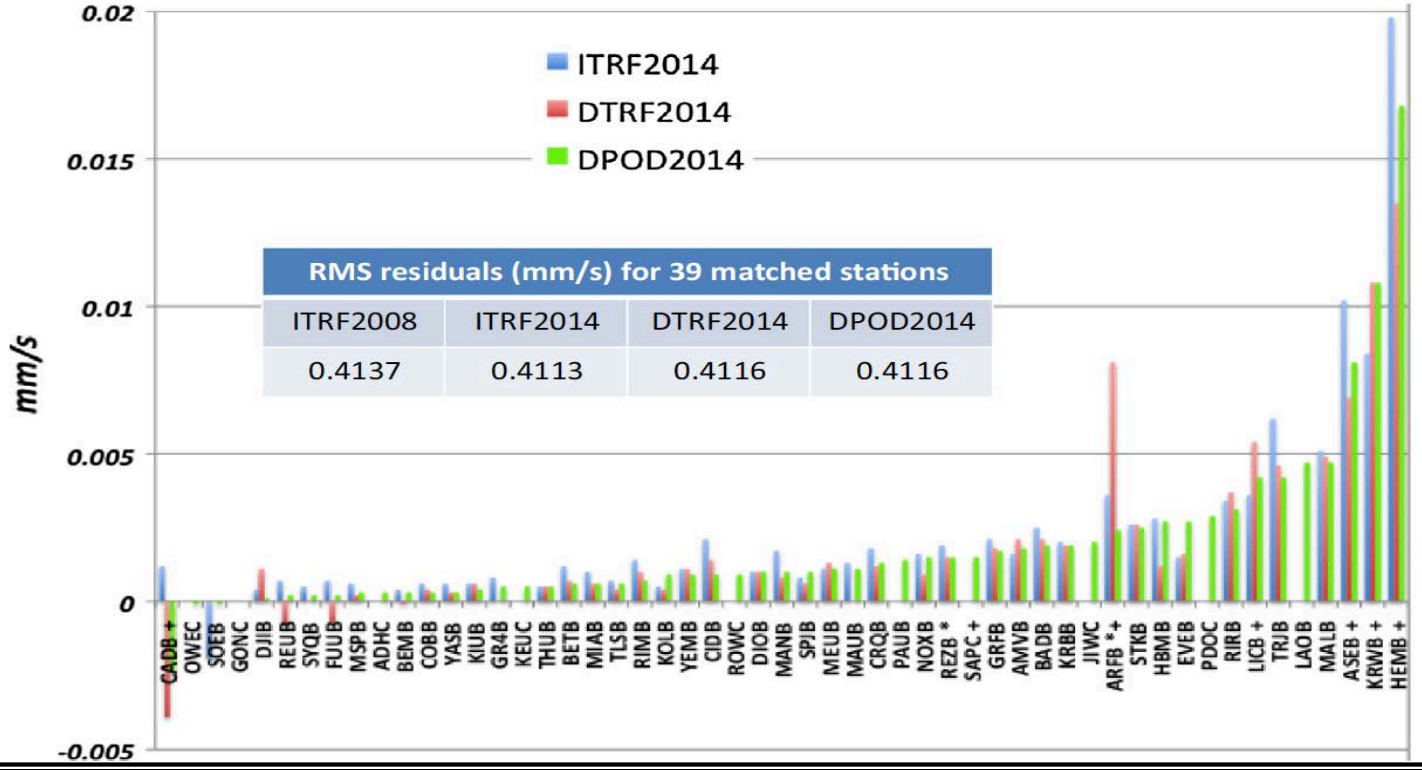


All ITRS2014 complements show improvement post-2008 (when ITRF2008 was in "extrapolation").

Zelensky et al. (2017), Adv. Space Res.,doi: 10.1016/j.asr.2017.07.044, in press.
Figures 4.2 & 4.6

Evaluation of ITRS2014 complements (2)

Jason3: Change in DORIS RMS of fit (mm/s) w. ITRS2014 complements: (*Positive shows improvement*).

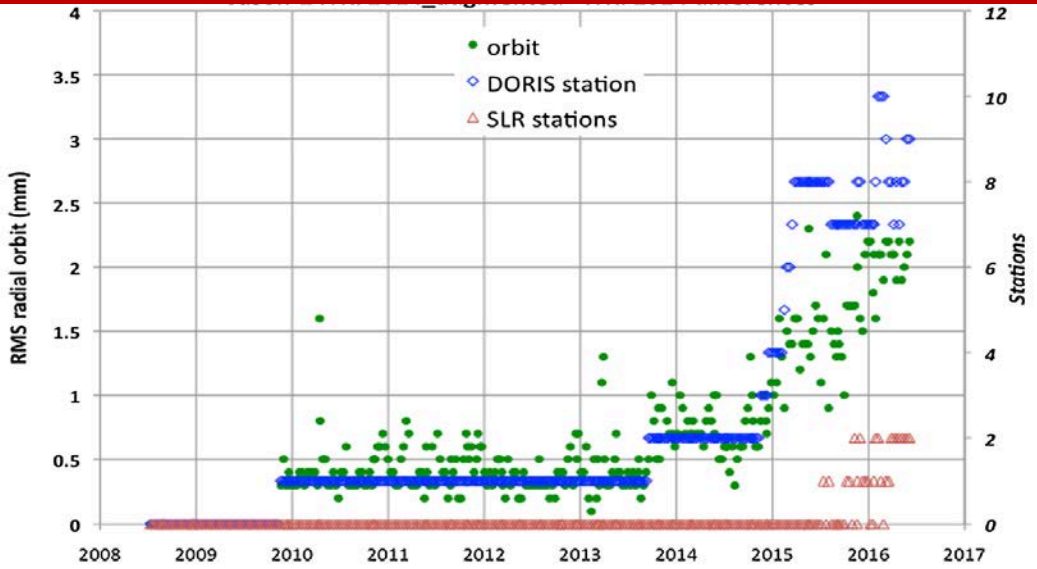


1. **Generally we see a improvement for almost all stations.**
2. **”South Atlantic Anomaly (SAA) stations” (ASEB, KRWB, HEMB) show largest improvements.**
3. **Only CADB shows slight degradation for 2/3 complements. This is the DORIS station closest to the ”center” of the SAA region.**

Zelensky et al. (2017), Adv. Space Res.,doi: 10.1016/j.asr.2017.07.044, in press. Figure 4.8a

Evaluation of ITRS2014 complements (3)

Jason-2: ITRF2014 & DPOD2014:
Radial Orbit differences vs. no. of “missing” stations.:

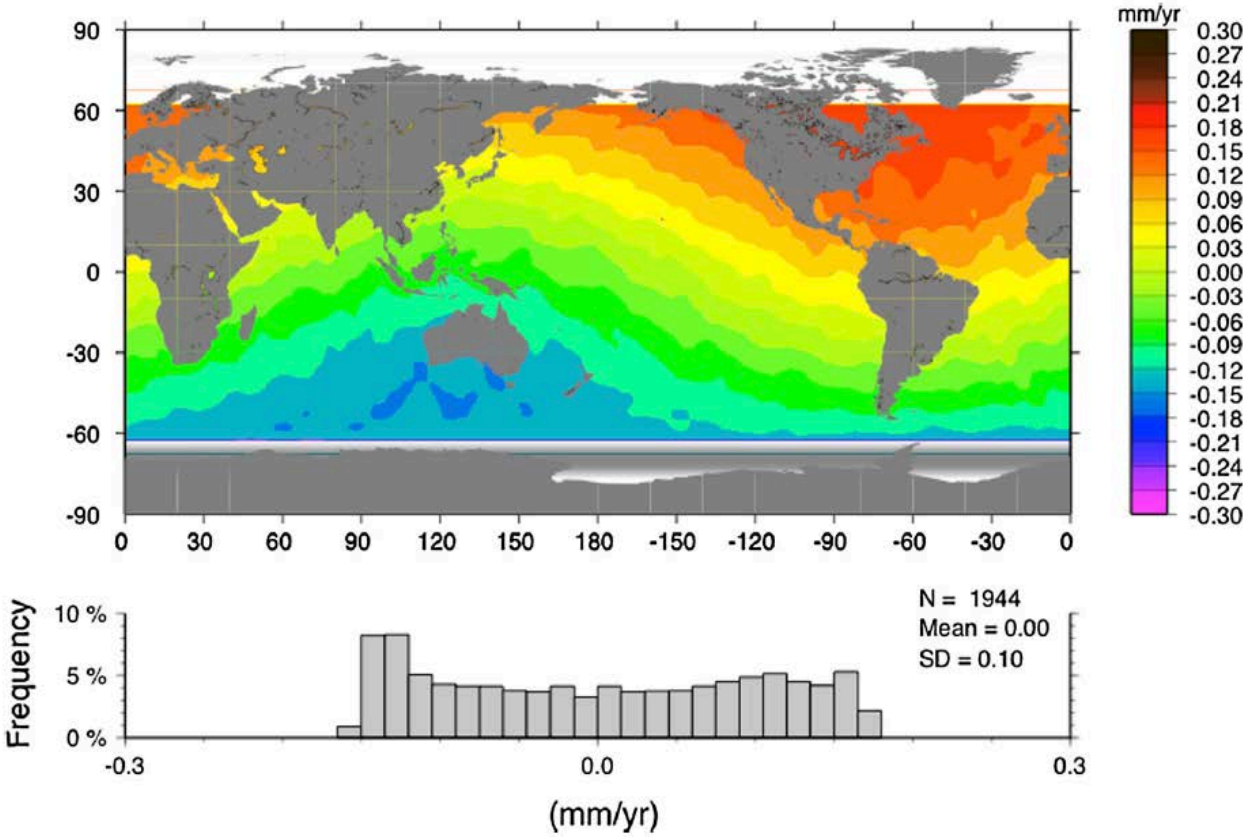


1. **New ITRF’s always contain ”missing” stations due primarily to newer stations having a time series that is too short (< 2.5 yrs).**
2. **The DORIS network operates, as we have seen at 90% or with about 50 stations, with a geometry that is optimized for nearly full tracking coverage. at TP & Jason altitudes. Therefore “missing stations” impact POD.**
3. **An ITRF complement must be operationally extended to include newest stations (SLR or DORIS). Altimeter community depends on IDS & ILRS for these updates (DPOD2014, SLRF2014).**

Zelensky et al. (2017), Adv. Space Res.,doi: 10.1016/j.asr.2017.07.044, in press.
Figure 4.1

Evaluation of ITRS2014 complements (4)

Radial orbit drift (mm/yr) : ITRF2014 – ITRF2008 (*1992-2016*)

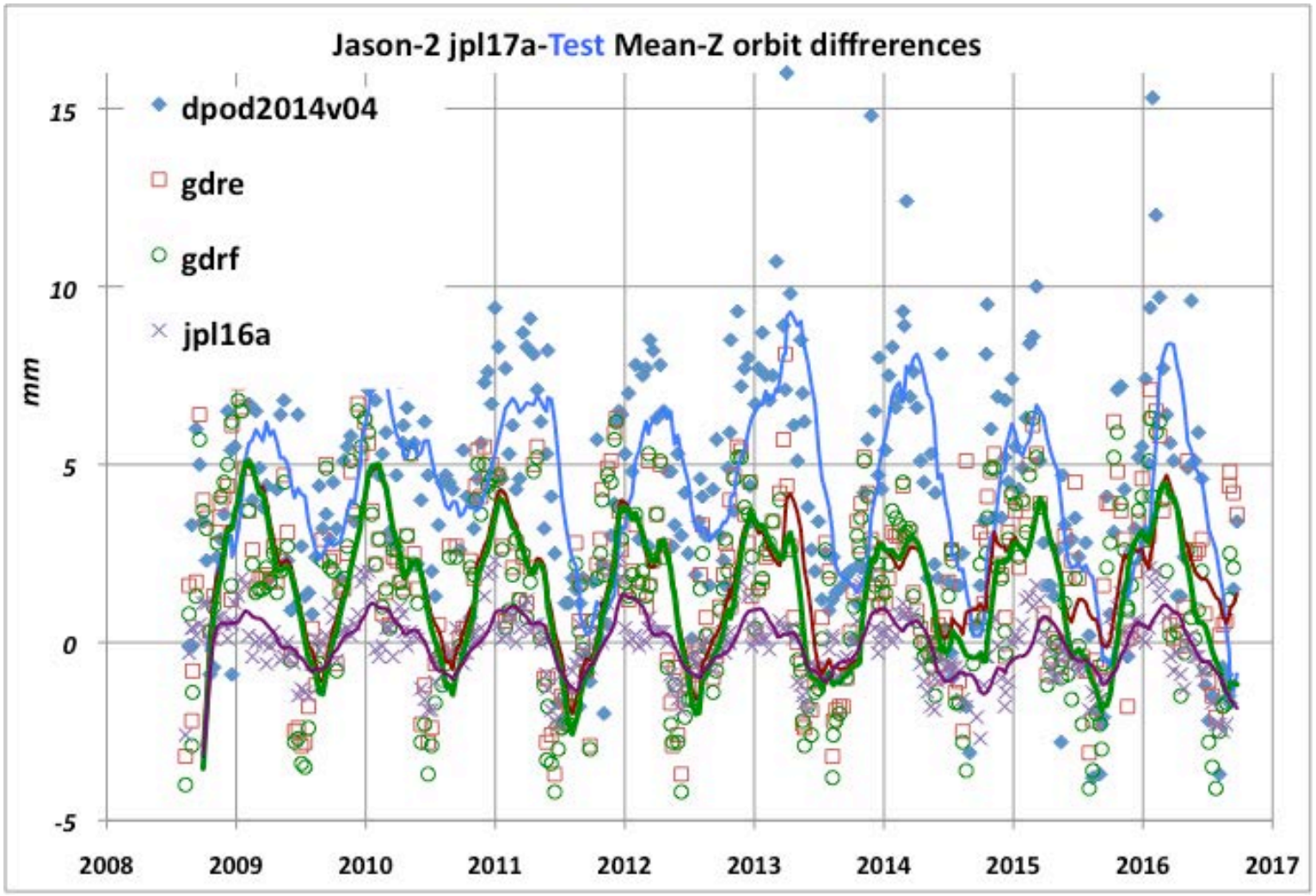


Impact on global MSL rate is 0.028 mm/yr, -- but note the regional changes of up to ± 0. 3 mm/yr.

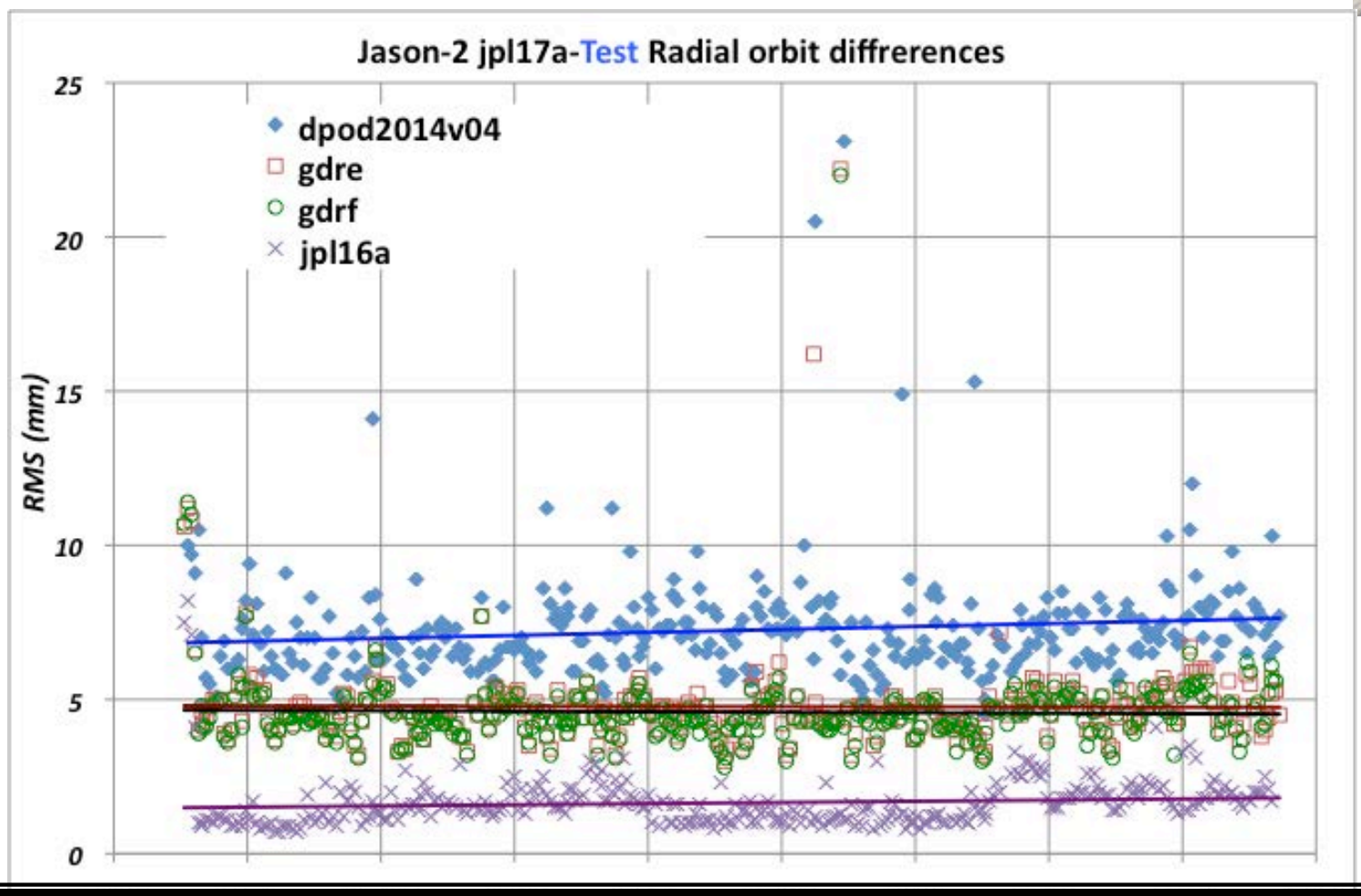
Zelensky et al. (2017), Adv. Space Res.,doi: 10.1016/j.asr.2017.07.044, in press. Figure 5.3

Next:
Jason-2 & Jason-3 Orbit comparisons

Jason-2: Mean "Z" Orbit Differences (jpl17a vs. gsfc, cnes, jpl16a)



Jason-2: Radial Orbit Differences (jpl17a vs. gsfc, cnes, jpl16a)



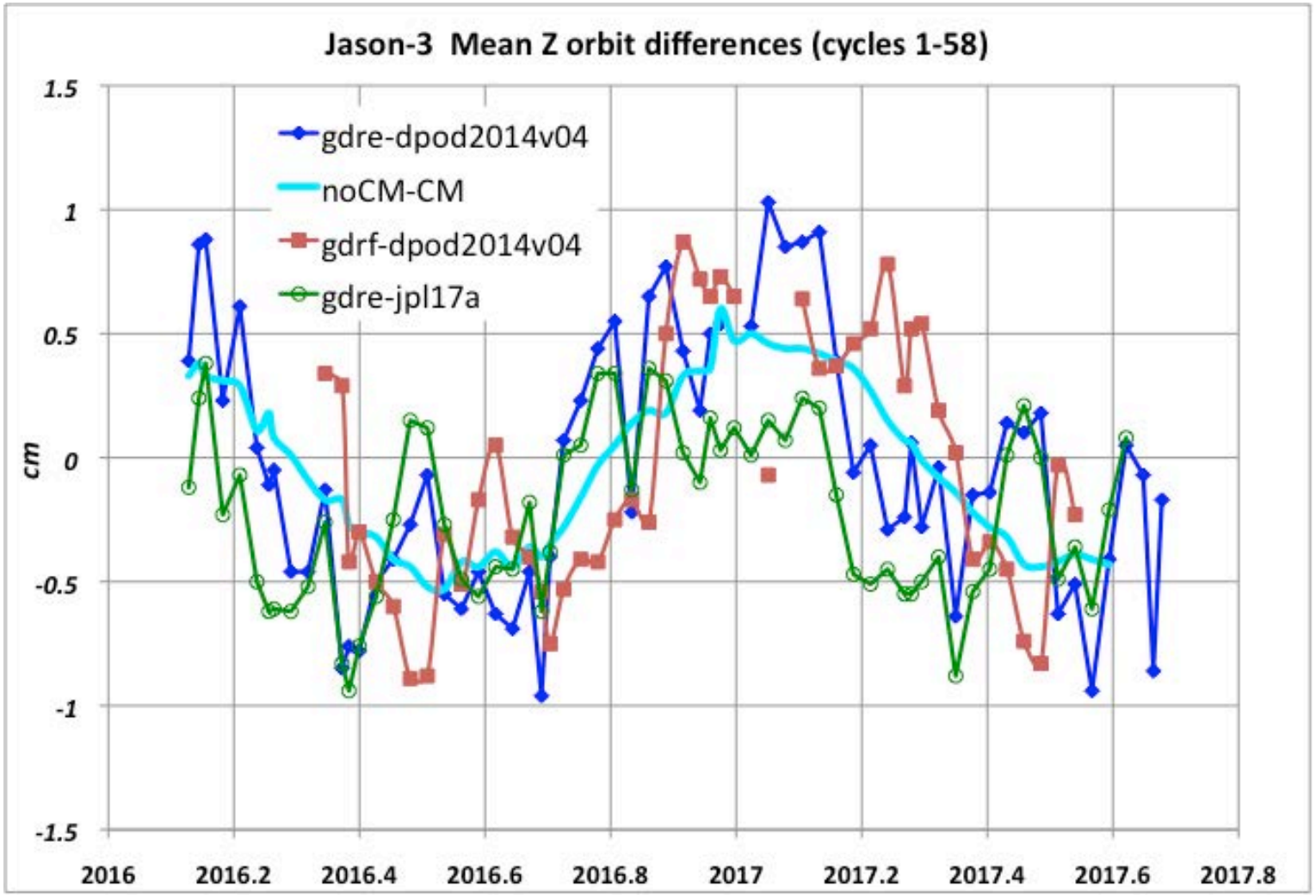
Radial Orbit consistency for Jason-2 orbits (JPL vs CNES vs GSFC; GPS vs. SLR+DORIS) < 8 mm radial RMS!

Jason-2 external ephemeris residual comparison: cycles 1-303 (080712 - 161002)

J2 orbit cycles 1-303	DORIS (mm/s)	SLR (cm)	Xover (cm)	radial rms (mm)	cross-trk rms (mm)	along-trk rms (mm)
jpl17a	0.3834	1.149	5.243	----	----	----
gdre	0.3826	1.202	5.237	4.8	5.4	11.4
gdrf	0.3826	1.190	5.233	4.6	4.4	10.7
dpod2014v04	0.3829	1.021	5.312	7.2	22.0	27.9

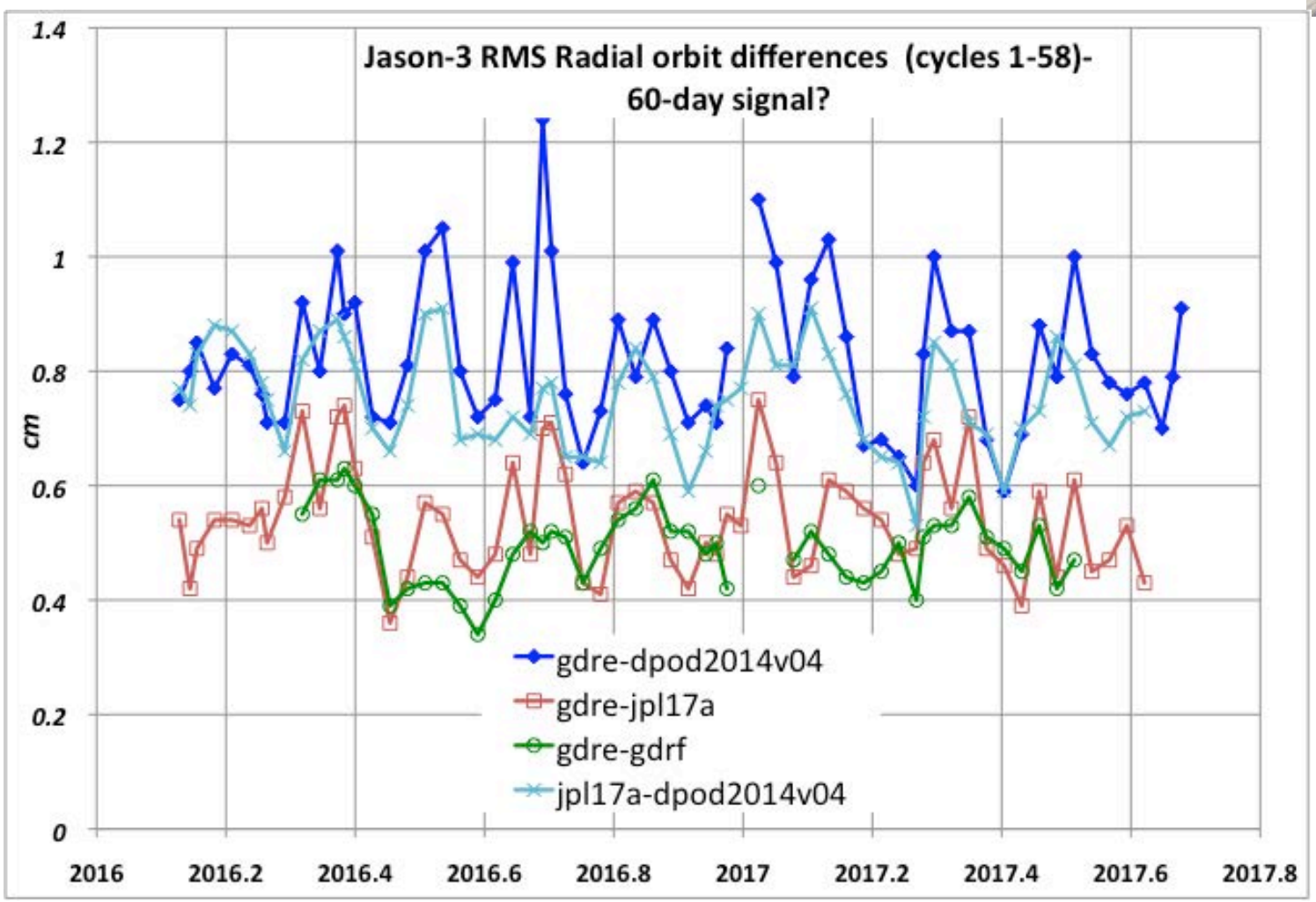
Note. There is no one-to-one match between cycles for the orbit categories. For example, several cycles are missing with gdrf.

Jason-3: Mean "Z" Orbit Differences



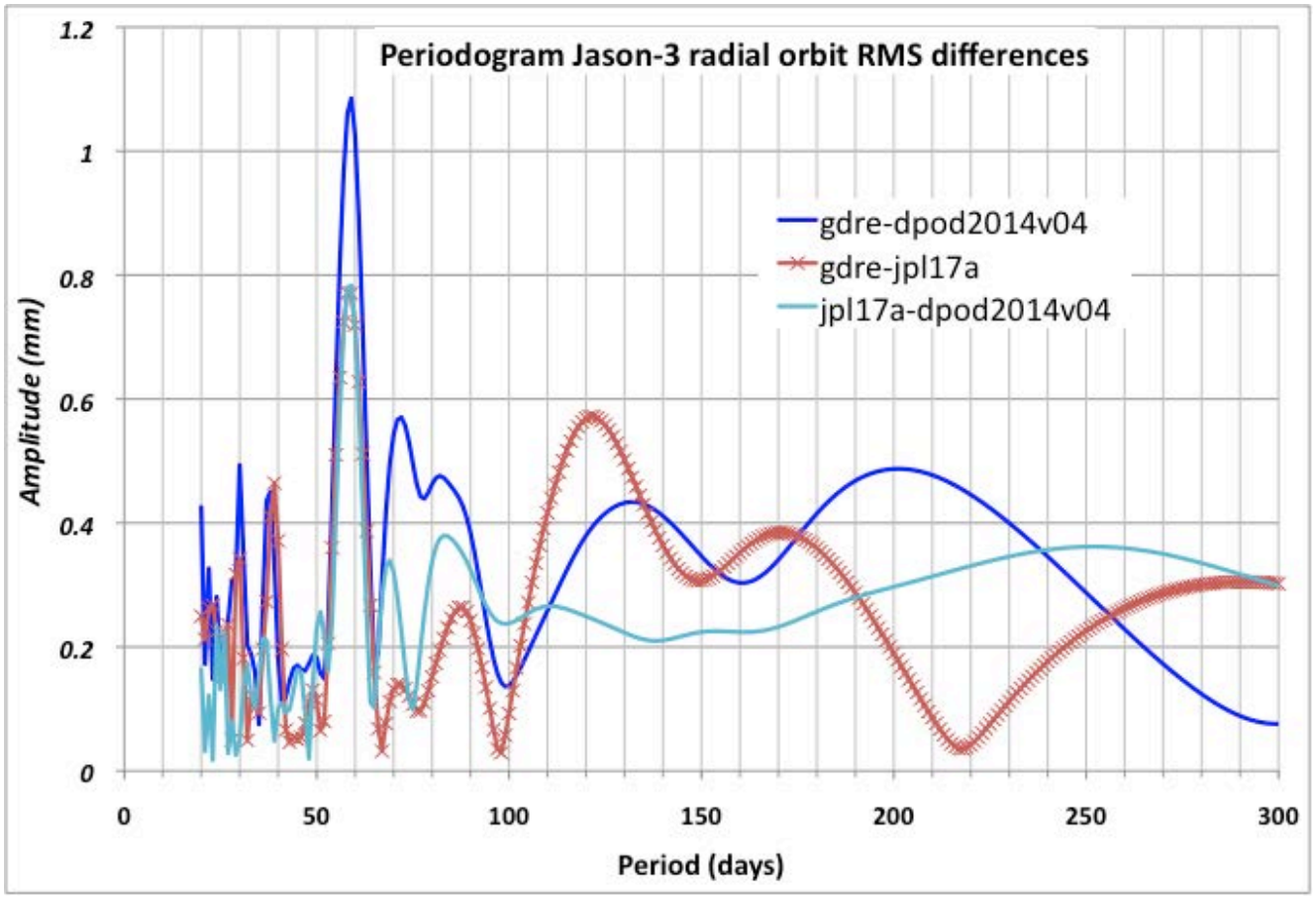
Lemoine et al., 2017; POD Status For TP, J1, J2, J3 , OSTST, October 24, 2017.

Jason-3: Radial Orbit Differences (jpl17a vs. gsfc, cnes, jpl16a)



Radial Orbit consistency for Jason-3 orbits < 9 mm RMS.

Jason-3: Radial Orbit Differences (Periodogram)



Over the 21 months since launch of J3, the largest signals in the orbit differences are at ~60 days (slr/doris & gdre vs. Jpl17a orbits); ~120 days (gdre vs jpl17a); and ~39 days (gdre vs. other orbits).

Jason-3 external ephemeris residual comparison: cycles 8-52

J3 orbit cycles 1-55	DORIS (mm/s)	SLR (cm)	Xover (cm)	radial rms (mm)	cross-trk rms (mm)	along-trk rms (mm)
gdre	0.4149	1.210	5.184	----	----	----
gdrf	0.4149	1.110	5.200	4.9	14.7	14.3
jpl17a	0.4151	0.960	5.149	5.5	6.4	16.3
dpod2014v04 (las+dor)	0.4148	0.913	5.213	7.5	28.2	29.1

* check gdrf cycle 35

Summary

(1) The new ITRF2014 realizations show consistent improvement for TP, J1, J2 & J3.
(2) A "complete" complement for SLR & DORIS is essential.
(3) Radial orbit consistency between different sets of Jason-2 & Jason-3 orbits < 7-9 mm RMS. GPS-based orbits (JPL, CNES) show (naturally) the best radial orbit consistency.
(4) Change in ITRF produces regional changes in MSL of up to $\pm$ 0. 3 mm/yr.

Future work & concerns.

(1) Continue to evaluate geocenter models that include geophysical loading *a priori.*
(2) Characterize and mitigate systematic errors in the tracking data that affect POD; DORIS USO (Jason-2, Jason-3); SLR ranging and timing biases.
(3) Improve non-conservative (radiation pressure) modelling by working with Univ. College London, U.K. (*M. Ziebart*).
(4) As recommended by IERS, we will adopt the IERS linear pole model -> impacts the calculation of the pole tide. It's implementation necessitates a complete re-computation of the orbit time series.

***N.B.*: ITRF2014 Orbits for TP, J1, J2, J3 to be distributed from NASA CDDIS by November 2017 as soon as directory structure is implemented.**

Backups

tvg5x5 time series description

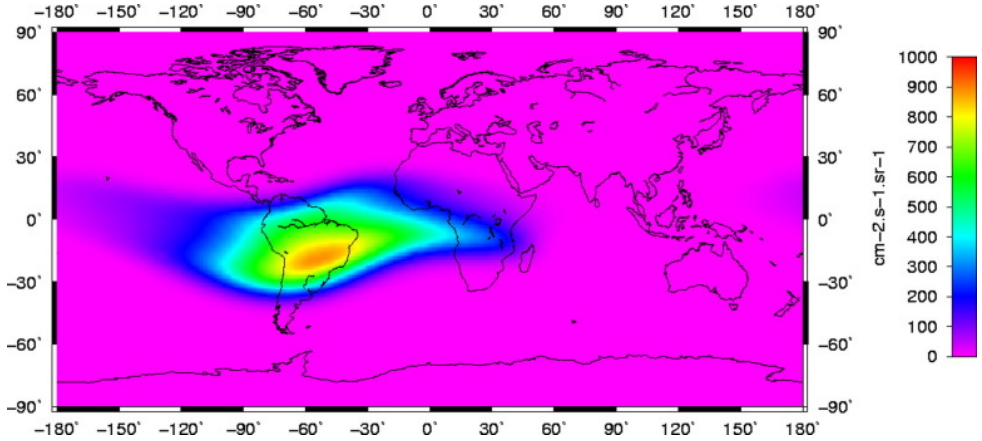
- **20 SLR+DORIS satellites, mostly 7-day arcs (1993-2014).**
(Lageos1, Lageos2, Starlette, Stella, Ajisai, TOPEX, Jason-1, Jason-2 SPOT-2, SPOT-3, SPOT4, Envisat, Larets, Cryosat-2, Blits, Westpac, Lares, Etalon-1, Etalon-2)
- **Subset solution analysis to converge on adopted weights.**
- **Smoothed with a moving window over several solution periods.**
- **Used for ITRF2013 @ NASA GSFC for IDS submission.**
- **Solution compares well with independent solutions to 4x4; Order 1 terms (C_{31}/S_{31}, C_{41}/S_{41}) not so well determined.**
- **Extended to 2016. To be udpated with ITRF2014.**

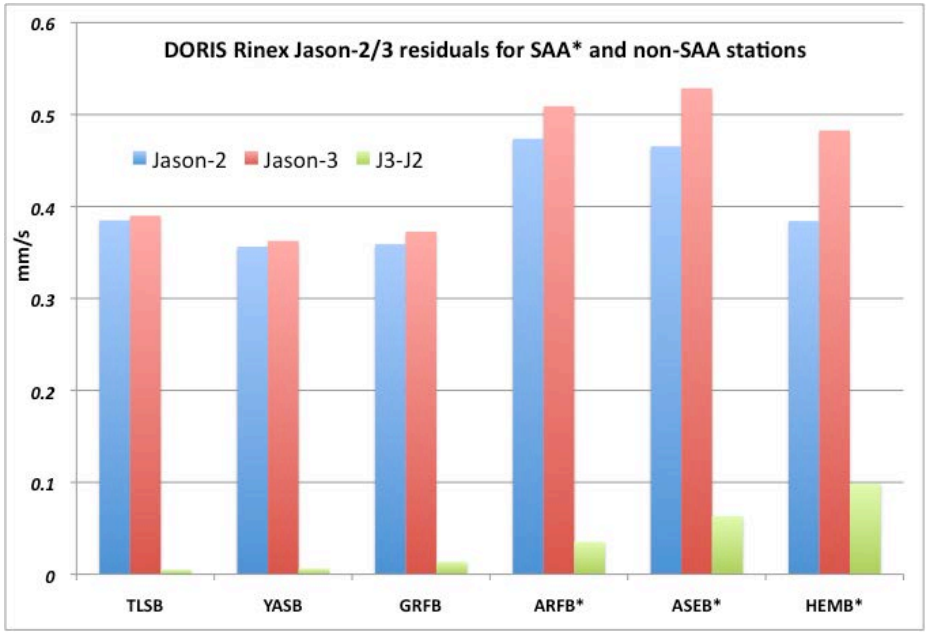
stk5x5 description

Harmonic fit to tvg5x5 time series by time period.
1992.0 to 2003.0; 2003.0 to 2007.0; 2007.0 to 2014.0

Jason-3 DORIS Status (I)

Jason-3 DORIS RMS of fit (select stations)





Jason-3 DORIS RMS of fit increases by 10-25% (*compared to Jason-2*) for stations in vicinity of the "SAA (*South Atlantic Anomaly*)"; especially CADB, HEMB.

Jason-2 CARMEN 85MeV Integrated Proton Flux Map (2009-2011) (*Fig. 11, Capdeville et al., Adv. Space Res., 2016*)