HF EOP Model Tests with SLR Data in Geodyn

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Outline

- We analyzed one year (2017) of LAGEOS and LAGEOS-2 global SLR data
- Modeling of the data followed the ILRS ASC standards for operational products, with only exception the substitution of the HF EOP model
- The very first test reduced the data without any correction for HF EOP
- The second test used the default set of corrections used at GSFC, a variant of the IERS 2010 model without libration modeled
- For the models provided by the WG, we reduced the data using each model with and without modeling libration (except for the Gipson model that includes libration by default)
- When the tests were completed we added a test of a hybrid model that we devised using the PM part of the Gipson model and the LOD part of the VLBI+GPS (Artz et al.).
- The results were evaluated on the basis of the weekly RMS of fit, the annual TRF solution and the resultant EOP vs. the IERS C04 series

Table 1: HF EOP Models Tested with Geodyn

Model	Tides included	Libration	Description
None	---	---	No correction model used
GSFC-IERS_2018	71	No	IERS2010 tidal correction model (GSFC implementation of 2018)
Desai	159	No/Yes	Desai and Sibois model
EOT11a	71	No/Yes	Tidal correction model based on EOT11a (Jan Hagedoorn, GFZ)
FES2012	71	No/Yes	Tidal correction model based on FES2012 (Jan Hagedoorn, GFZ)
Hamtide	71	No/Yes	PREM tidal correction model by Jan Hagedoorn (GFZ) - Hamtide
IERS_2010	71	No/Yes	IERS2010 tidal correction model (IERS Conventions 2010)
Madzak	28	No/Yes	Altimetry-based ocean model tidal correction (Madzak et al. 2016, DOI: 10.1007/s00190-016-0919-4)
Artz_2011	96	No/Yes	VLBI model (Artz et al., 2011, DOI 10.1007/s00190-011-0457-z)
Artz_2012	96	No/Yes	GPS+VLBI model (Artz et al., 2012, DOI 10.1007/s00190-011-0512-9)
Gipson	70	Yes	John Gipson's VLBI tidal model including libration
Gipson (no lib.)	70	No/Yes	John Gipson's VLBI tidal model (libration modeled acc. to IERS Conv. 2010 within Geodyn)

Table 2: HF EOP Models Tested with Geodyn

Model Designator	Model Name	Model Designator	Model Name
HFEOP00	GSFCiers2018	**HFEOP11**	DESAIwLib
HFEOP01	DESAI	**HFEOP12**	EOT11AwLib
HFEOP02	EOT11A	**HFEOP13**	FES2012wLib
HFEOP03	FES2012	**HFEOP14**	NONE
HFEOP04	GIPSON	**HFEOP15**	GIPSON-LwLib
HFEOP05	GIPSON-L	**HFEOP16**	HAMTIDEwLib
HFEOP06	HAMTIDE	**HFEOP17**	IERS2010wLib
HFEOP07	IERS2010	**HFEOP18**	MAZDAKwLib
HFEOP08	MAZDAK	**HFEOP19**	VLBIwLib
HFEOP09	VLBI	**HFEOP20**	VLBI+GPSwLib
HFEOP10	VLBI+GPS	**HFEOP21**	GIPSON-L+VLBI+GPSwLib

Figure 1: LAGEOS RMS of Weekly Arcs

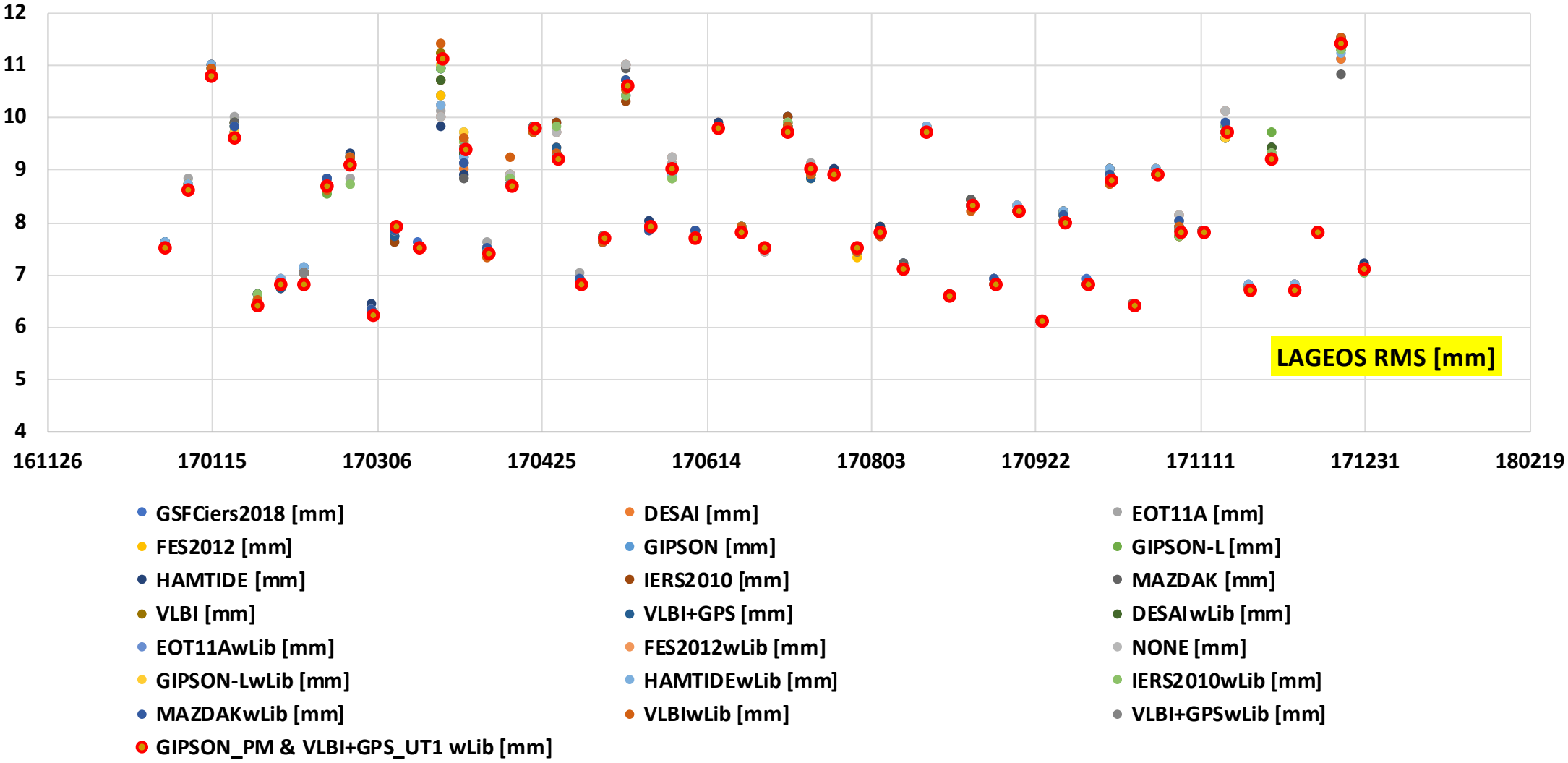


Figure 2: LAGEOS-2 RMS of Weekly Arcs

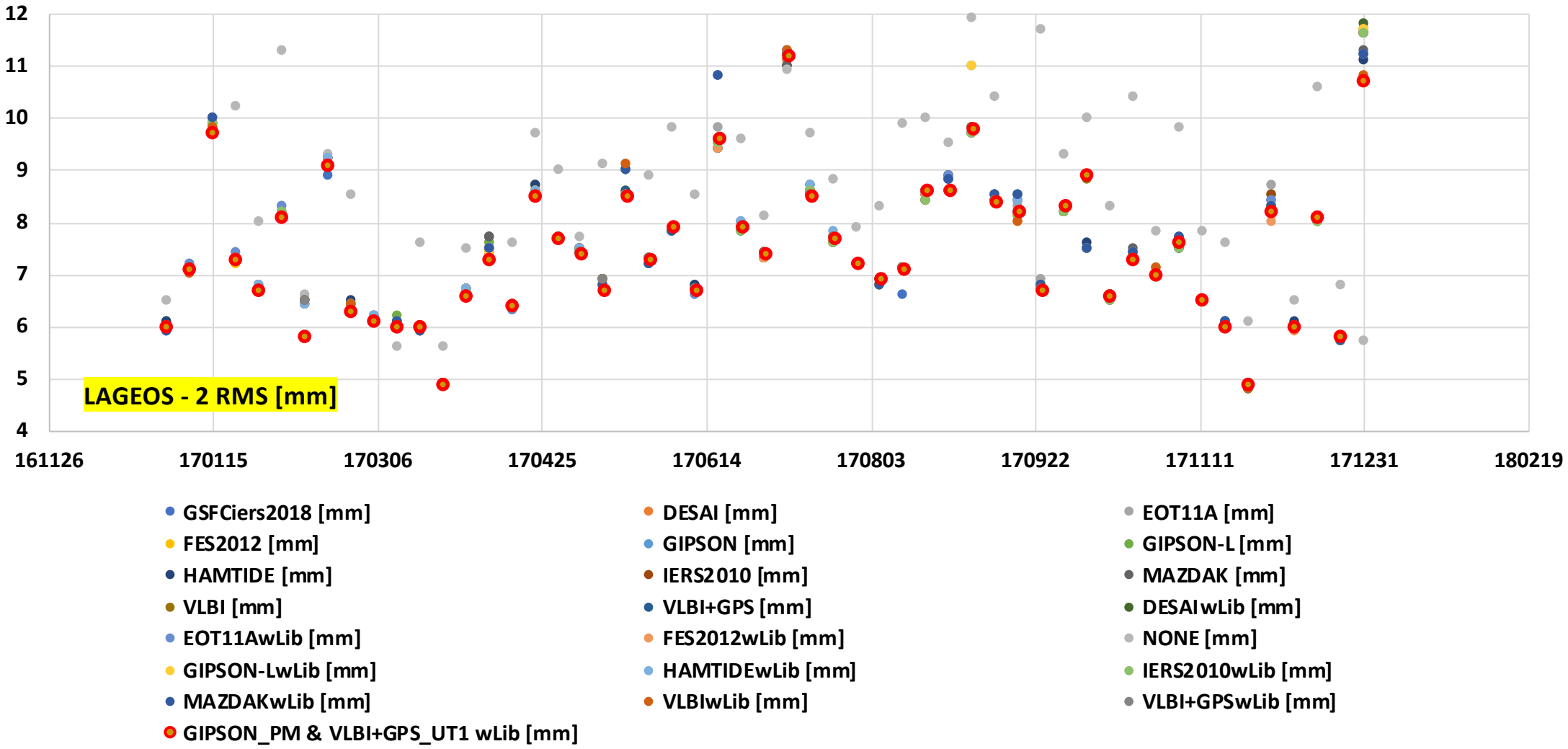
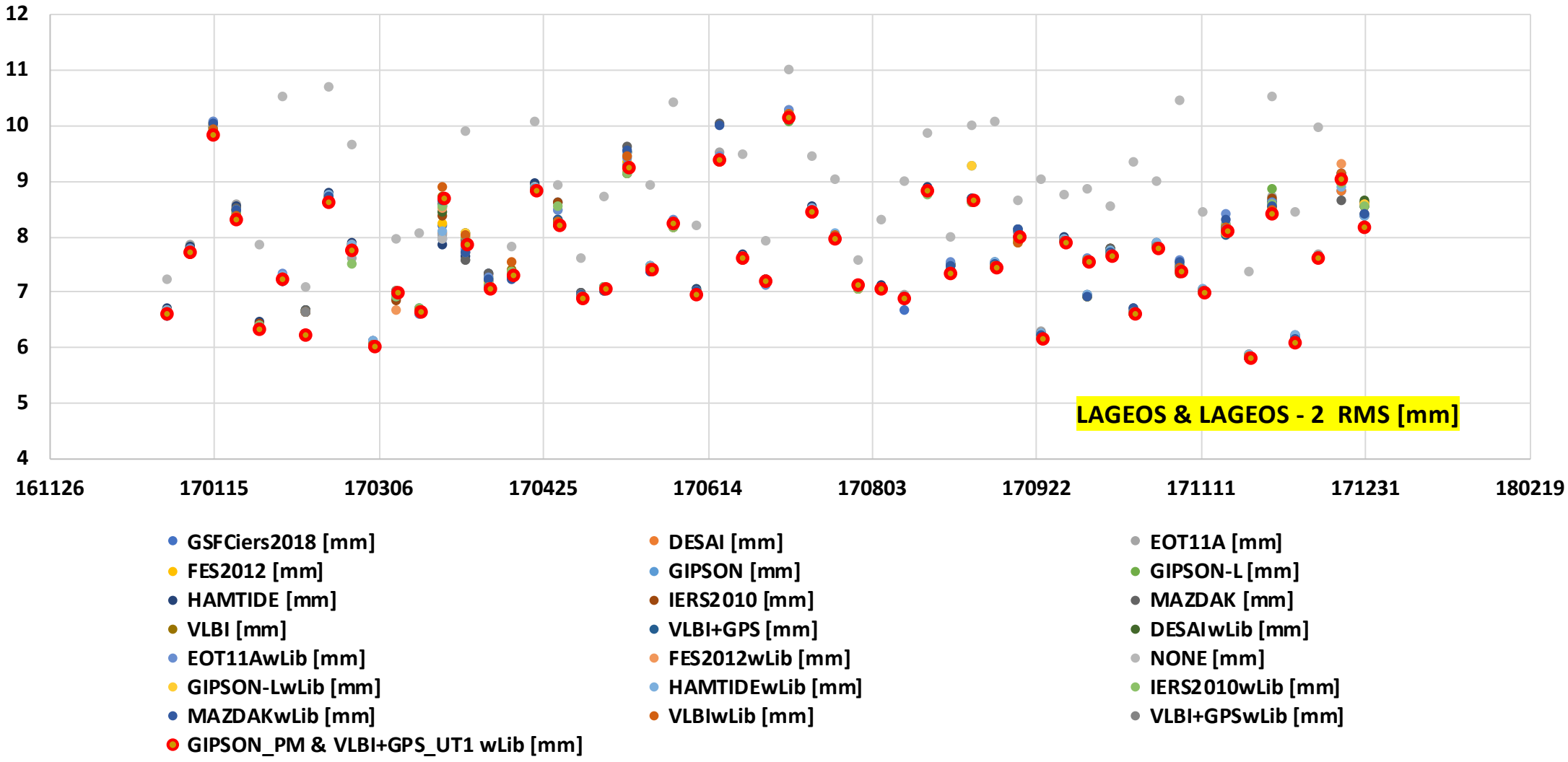


Figure 3: Combined LAGEOS & LAGEOS-2 RMS



Discussion of 2017 Annual Solution Results - 1

- We generated annual solutions with respect to ITRF2014 and allowing simultaneous height and system bias adjustment for all sites
- Naturally, the worst result was obtained when we had not corrected at all for HF EOP (case *HFEOP14*) with the largest change in the RMS of the fit and the biggest change in accepted observations (Fig. 4)
- In Fig. 5 we removed the extreme case HFEOP14 in order to bring the relative changes between the tested models to the forefront. We note that the change in RMS is not dramatic for any choice of model. As for the number of accepted observations, the Desai and Gipson models accept the least while EOT11a, FES2012, HAMTIDE, MAZDAK and the IERS2010, accept the most (Fig.5)

Figure 4: HFEOP Model Annual Solution Statistics

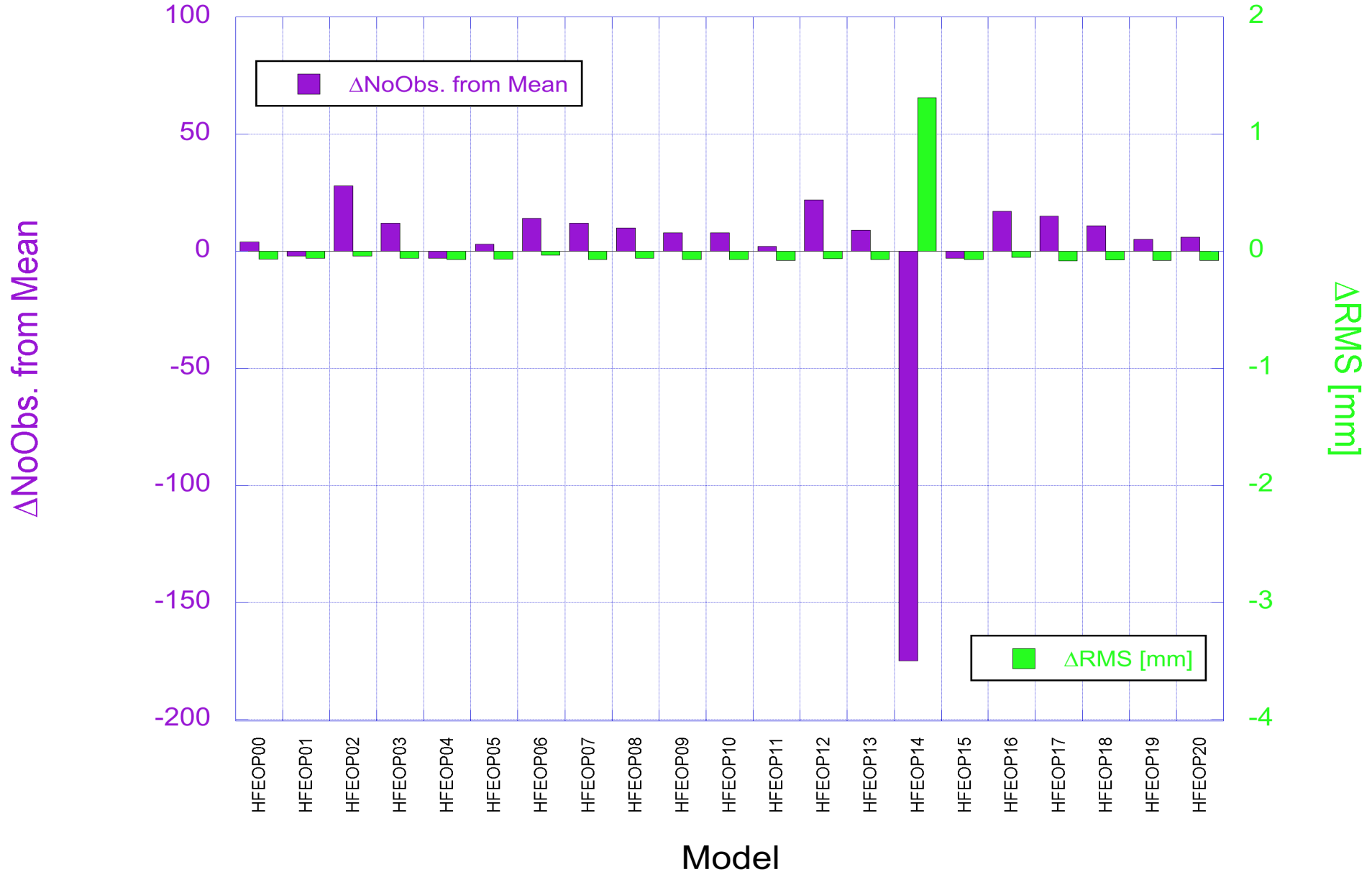
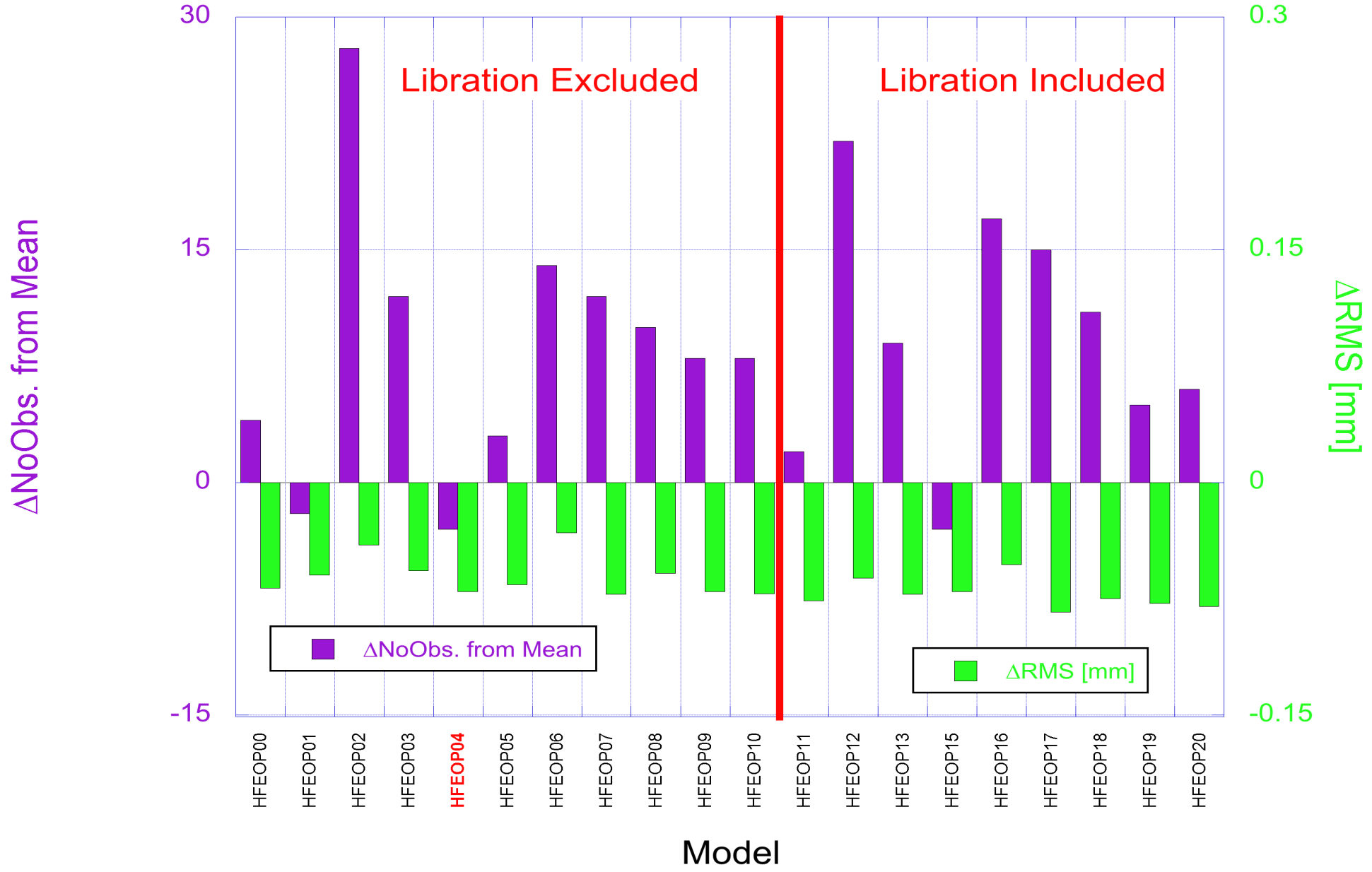


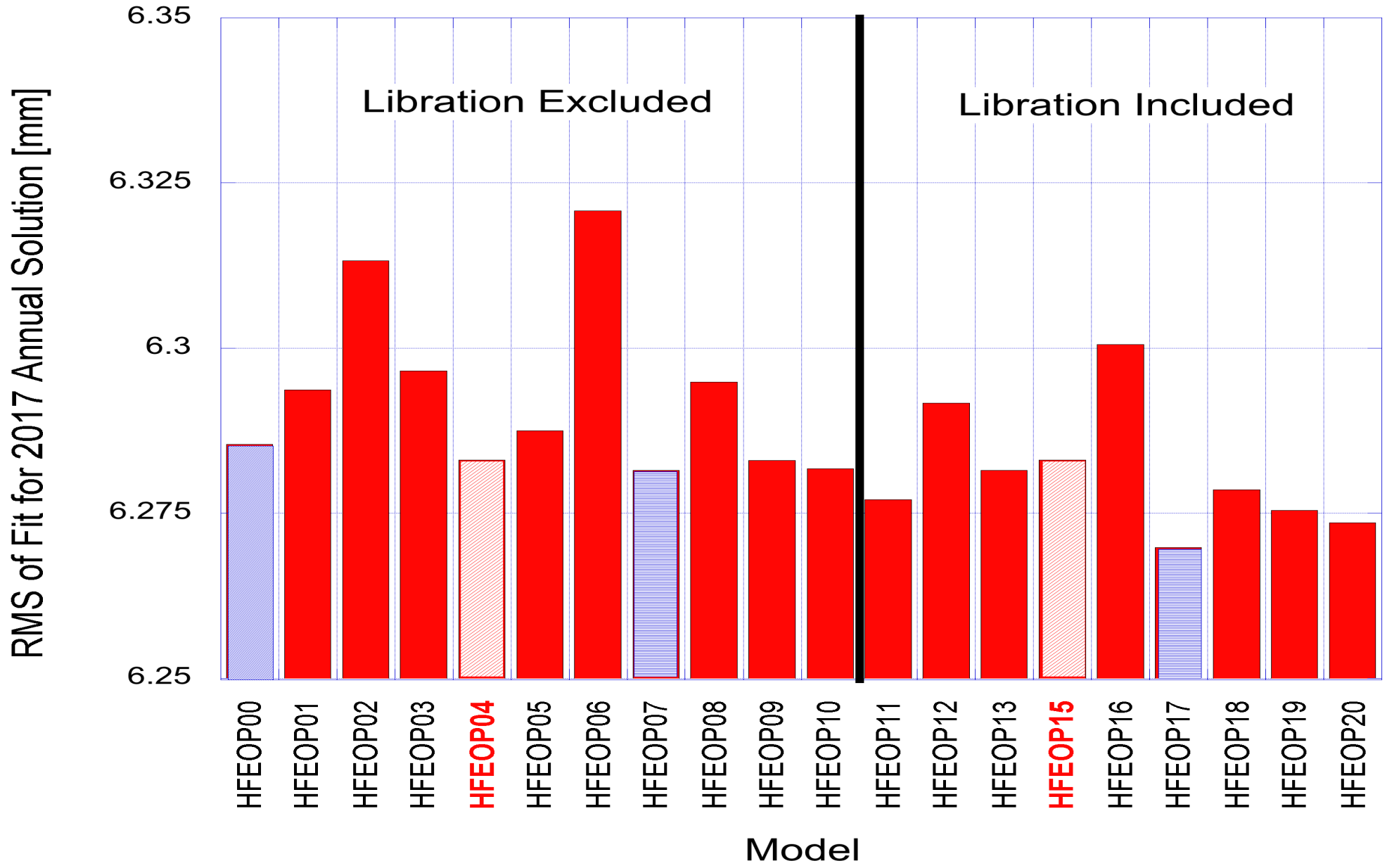
Figure 5: HFEOP Model Annual Solution Statistics-2



Discussion of 2017 Annual Solution Results - 2

- Fig. 6 displays the actual RMS of fit for each model. We note that in general the solutions when libration is included have lower RMS for all models.
- We also observe the consistency of the GSFC implementation of the IERS2010 model with the one that comes directly from the Conventions document, leading to nearly the same RMS value HFEOP00 vs. HFEOP07 cases.
- Furthermore, the IERS2010 model with the libration included, i.e. case HFEOP17, results in the lowest RMS fit of the annual solutions with all other models. We should not take this as a strong vote for the IERS2010 model since the RMS can change at that level due to various reasons. This is only an indication at this point.

Figure 6: RMS of Fit of Annual Solution 2017



Discussion of EOP Series 2017 vs. the IERS C04

- Table 3 summarizes the comparison of the annual EOP series resulting from our solutions using the various HF EOP models under test.
- On the left panel are all the results when libration was excluded, on the right panel, when we included libration.
- We only compared Polar Motion components x_p and y_p and LOD, since SLR is only sensitive to these parameters.
- The first observation is that when we omit entirely the HF EOP, the SLR results are very significantly deteriorated, at the level of 163%, 176% and 213% in x_p, y_p and LOD respectively.
- The second observation is that the spread between models is not huge, in PM 1-2 μas and in LOD less than 1 μs. This spread is more tight amongst the cases that include libration modeling.

Table 3: Statistics of ΔEOP from IERS C04 Series

Model	Libration Not Included						Libration Included					
	Xp_J - IERS C04		Yp_J - IERS C04		LOD_J - IERS C04		Xp_J - IERS C04		Yp_J - IERS C04		LOD_J - IERS C04	
	Mean [μas]	Std Deviation [μas]	Mean [μas]	Std Deviation [μas]	Mean [μs]	Std Deviation [μs]	Mean [μas]	Std Deviation [μas]	Mean [μas]	Std Deviation [μas]	Mean [μs]	Std Deviation [μs]
NONE	82.56	299.08	-18.05	313.03	-10.20	81.24	---	---	---	---	---	---
GSFC-IERS_2018	17.65	183.97	39.64	178.34	3.81	38.21	---	---	---	---	---	---
DESAI	15.19	184.19	38.50	178.54	4.55	38.34	15.67	184.31	38.73	178.05	3.92	38.04
EOT11A	15.39	184.16	39.98	179.26	5.10	38.38	15.27	184.26	39.28	178.82	4.58	38.13
FES2012	16.01	183.79	38.66	178.49	4.66	38.17	16.30	184.00	38.84	178.00	4.03	37.93
HAMTIDE	14.77	184.43	38.53	179.21	4.53	38.99	15.05	184.61	38.63	178.89	3.90	38.68
IERS2010	16.96	183.78	38.39	178.08	3.68	38.06	18.08	184.12	40.69	177.81	3.01	37.81
MAZDAK	15.12	184.26	38.73	178.13	4.93	38.33	15.51	184.42	39.02	177.70	4.31	38.05
VLBI	15.74	184.48	39.46	177.51	4.17	38.05	17.65	183.97	39.64	178.34	3.81	38.21
VLBI+GPS	16.54	184.07	39.09	177.54	3.05	38.08	17.58	184.31	39.33	177.45	2.45	37.88
GIPSON PM & VLBI+GPS UT1	---	---	---	---	---	---	18.22	184.32	39.07	177.18	2.50	37.89
GIPSON	---	---	---	---	---	---	14.96	184.42	38.61	177.46	4.08	38.18
GIPSON-L	14.05	184.35	38.24	178.07	4.74	38.35	14.98	184.41	38.64	177.48	4.05	38.19

Concluding Remarks

- Our analysis indicates that all models perform very well in SLR, given the formal errors of the resulting EOP components
- If we had to choose one model to use, it's a tossup between the Desai and Gipson models with libration included in all cases
- Trying to follow the most tight agreement with IERS C04, we picked one model for PM (Gipson's with libration) and for LOD the one based on VLBI+GPS (Artz et al.) again with libration, and we tested this hybrid model in the same way we did for the others
- As expected the results show very good agreement with IERS C04 and they are very similar to those of the parent models for all three EOP components

Detailed Weekly RMS of Fit by Satellite Group

- Figures 7 through 12 display six graphs each, in all cases the first one on the upper left corner spans the entire 2017 year and shows the individual RMS of fit for each weekly arc and for all of the tested models (except the hybrid HFEOP21 which was an afterthought)
- The second to last graphs show in higher detail a few months at a time, with the weekly results staggered in time in order to allow separate the values for each model used
- The first three figures summarize the LAGEOS, LAGEOS-2 and Combined LAGEOS & LAGEOS-2 results when **libration is excluded**
- The last three figures summarize the LAGEOS, LAGEOS-2 and Combined LAGEOS & LAGEOS-2 results when **libration is included**

Figure 7: LAGEOS RMS (Models Without Libration)

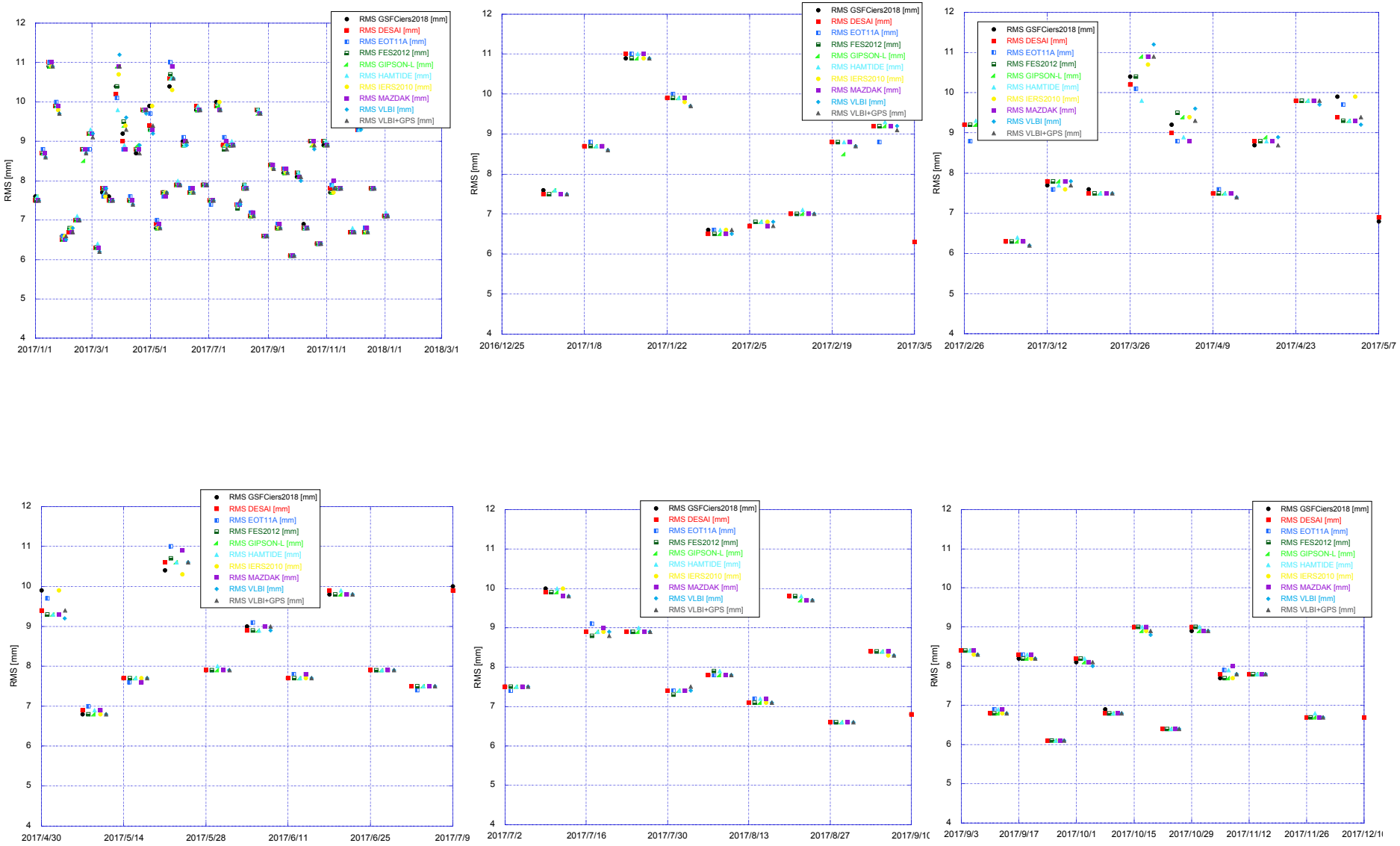


Figure 8: LAGEOS-2 RMS (Models Without Libration)

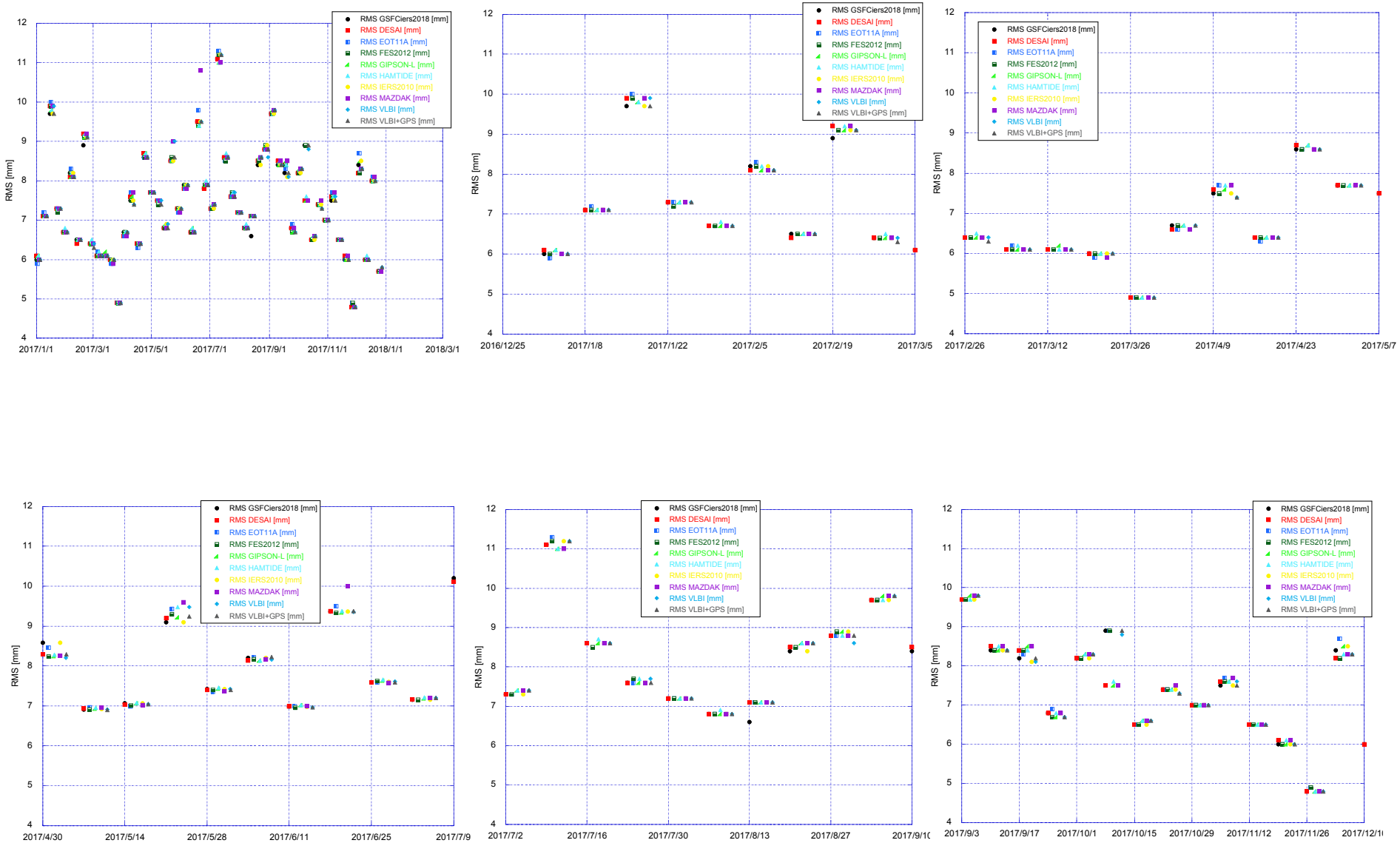


Figure 9: LAGEOS & LAGEOS-2 Combined RMS (Models Without Libration)

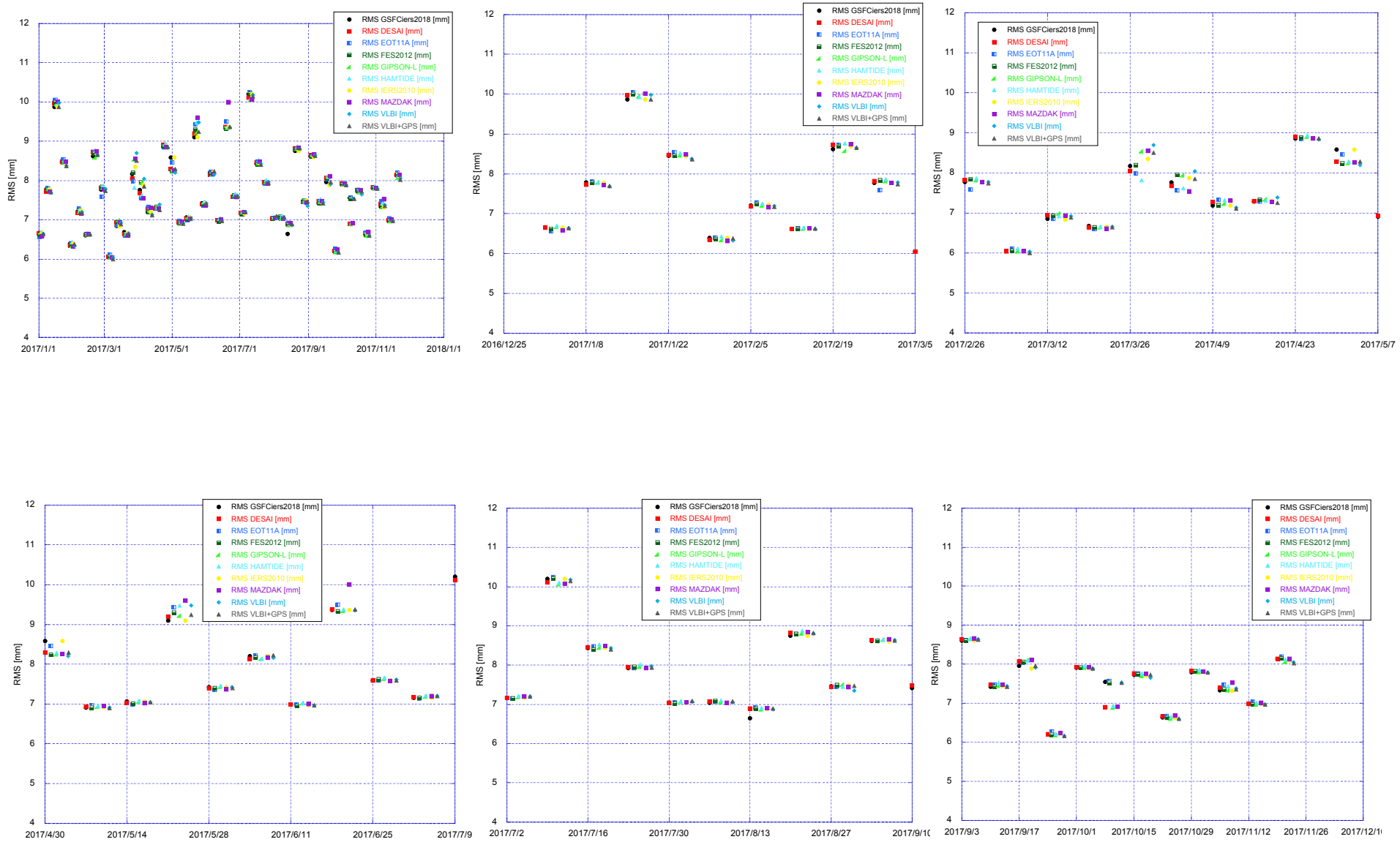


Figure 10: LAGEOS RMS (Models With Libration)

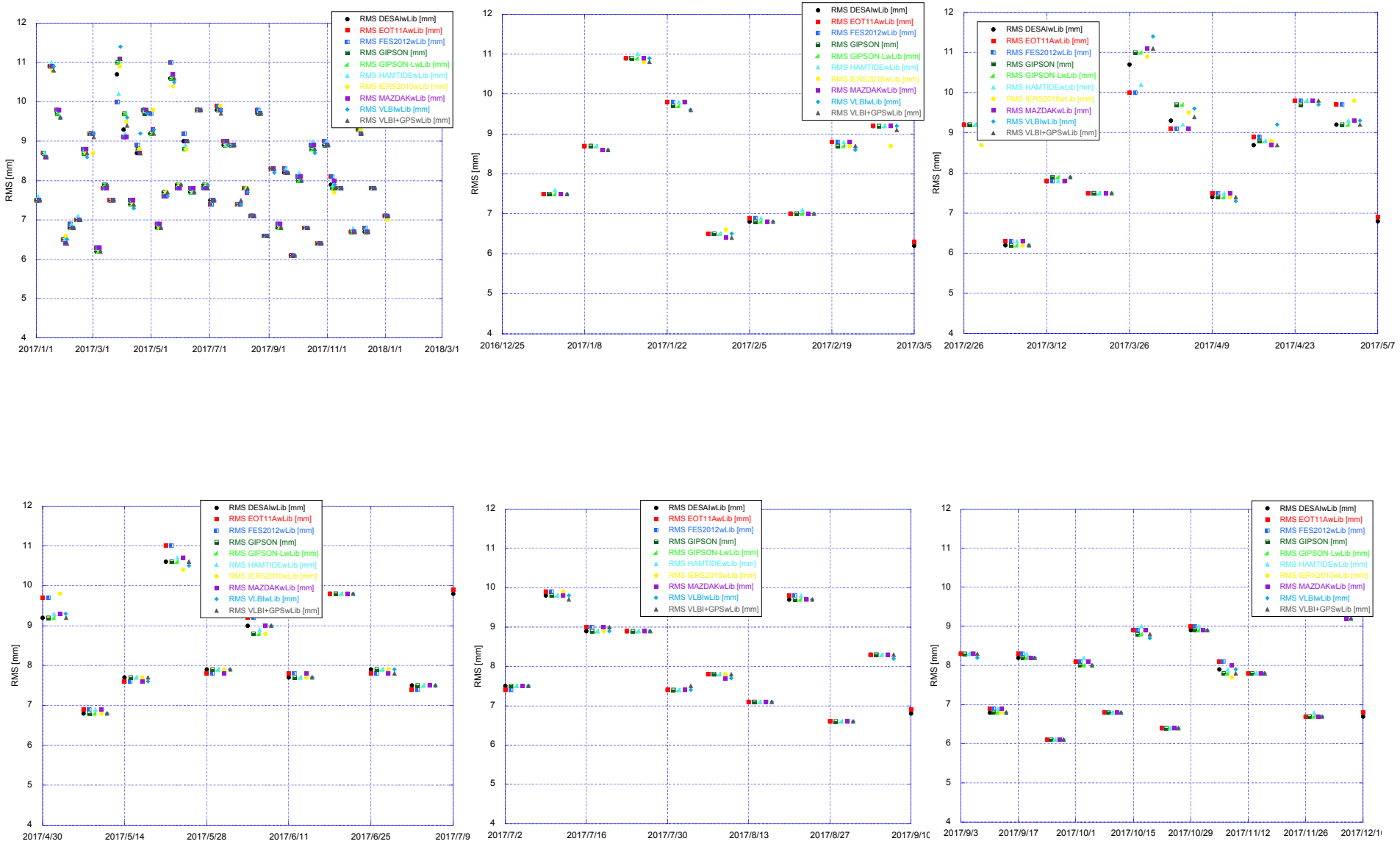


Figure 11: LAGEOS-2 RMS (Models With Libration)

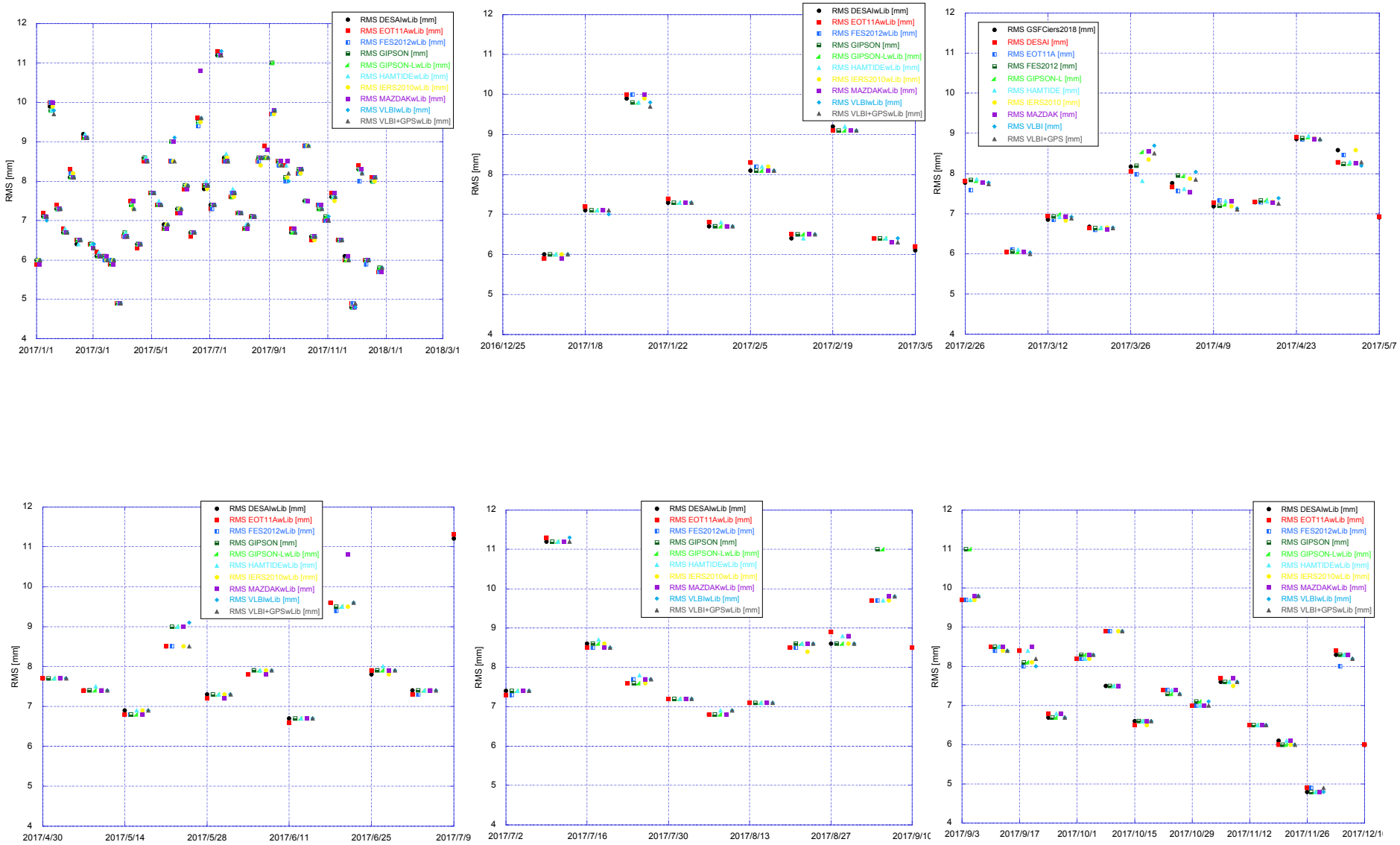


Figure 12: LAGEOS & LAGEOS-2 Combined RMS (Models With Libration)