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Abstract

The ILRS contribution to ITRF2020 is a time series of weekly/bi-weekly SINEXs with station position estimates and EOP, from 7-day arcs (1993.0 – 2021.0) and 15-day arcs over 1983.0- 1993.0. Each solution was obtained as the combination of loosely constrained individual solutions from the seven ILRS Analysis Centers: ASI, BKG, DGFI, ESA, GFZ, JCET and NSGF. Everyone followed strict standards agreed within the ILRS Analysis Standing Committee (ASC) and used SLR data from LAGEOS, LAGEOS-2, Etalon-1 and Etalon-2, (LAGEOS-only from 1983 to 1992). The ILRS ASC devised an innovative approach in handling systematic errors in the network, never before utilized. After a 5-year pilot-project documented in Luceri et al., (2019). The Station Systematic Error Monitoring PP (SSEM), delivered a series of long-term mean bias estimates for each station, the time intervals of applicability and their statistics. They were derived from freely adjusted station position and EOP solutions for the period 1993.0 to 2020.5, using the latest satellite CoG model. The simultaneous estimation of the station heights and measurement biases resulted in a self-consistent set of weekly bias estimates for each site. Breaks and “jumps” were used to define the periods of applicability and to calculate the mean bias and its standard deviation. The mean biases were pre-applied in the re-analysis, limiting the remaining jitter of the bias to negligible level. This approach strengthened the estimation process without a compromise of the final results’ accuracy. As a result, the ILRS contribution to ITRF2020 minimized the scale difference between SLR and VLBI to below 2 mm (ITRF2014 ~9 mm). We present an overview of the procedures, models, the improvement over previous ILRS products, focusing especially on the Core ILRS sites, and an overview of how the new model has been implemented in support of the ILRS official products.



ITRF2020: The ILRS Contribution and Operational Implementation

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AGU FALL
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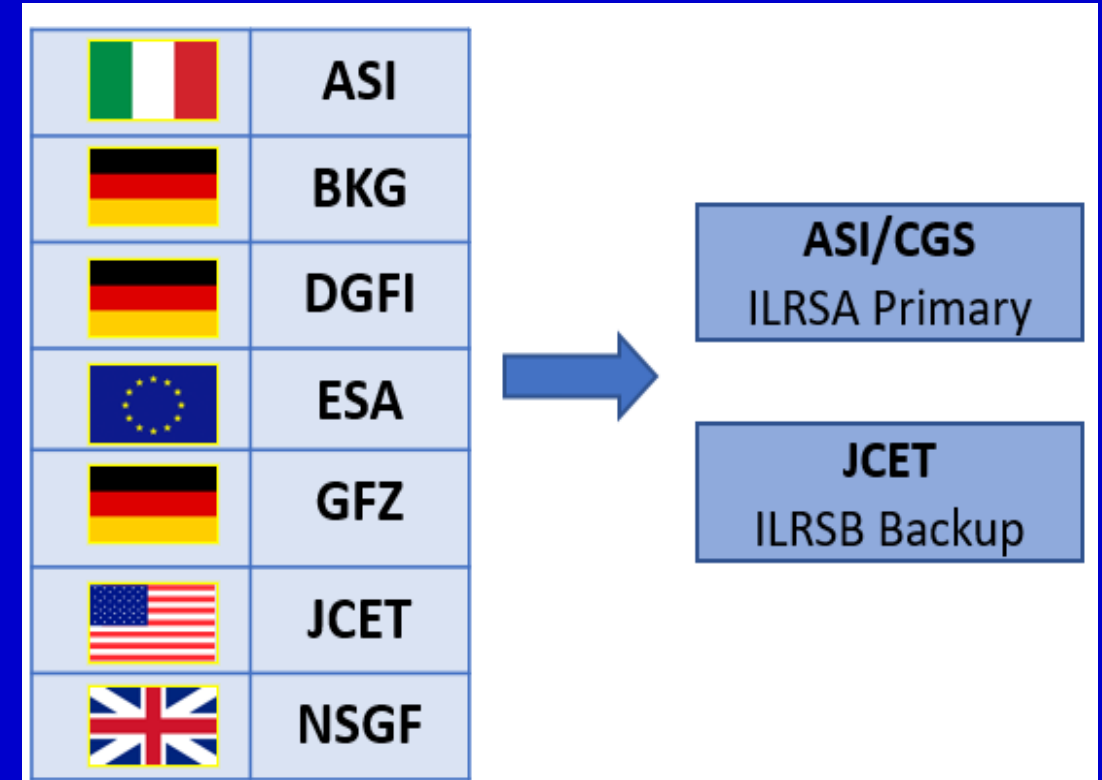
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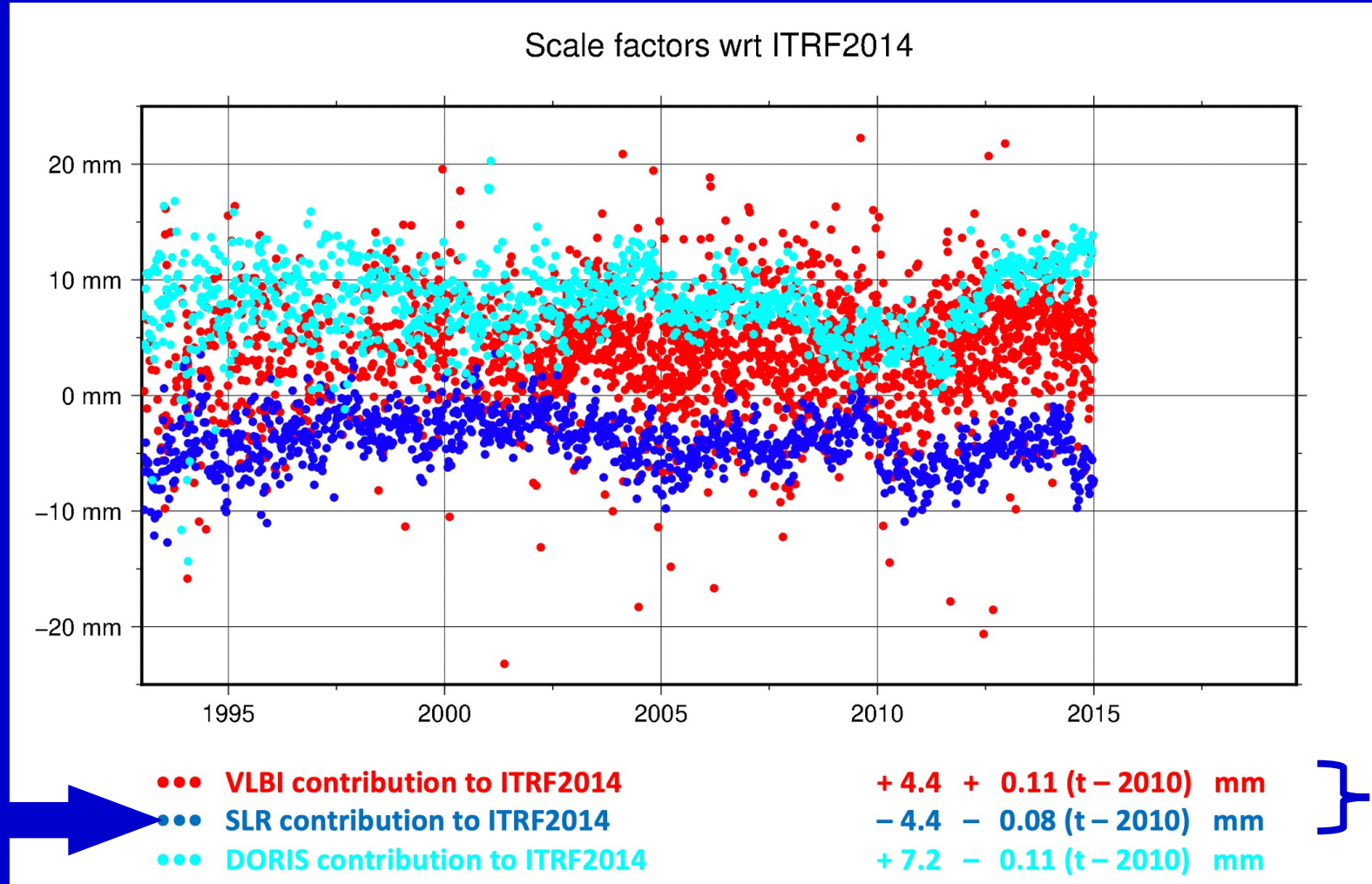


Overview of the ILRS ASC REPRO2020 Effort

- The seven Analysis Centers comprising the ILRS ASC worked diligently since 2015 to prepare for the development of the SLR contribution to ITRF2020.
- This summary provides an overview of the work performed and the key results that shaped the final product and must be understood by SLR analysts using ITRF2020, to ensure they obtain the best results in their applications.
- We firstly review the main areas of modeling updates that resulted in the major improvement seen in the SLR contribution to ITRF2020.



SLR - VLBI Scales Systematically Different in ITRF2014



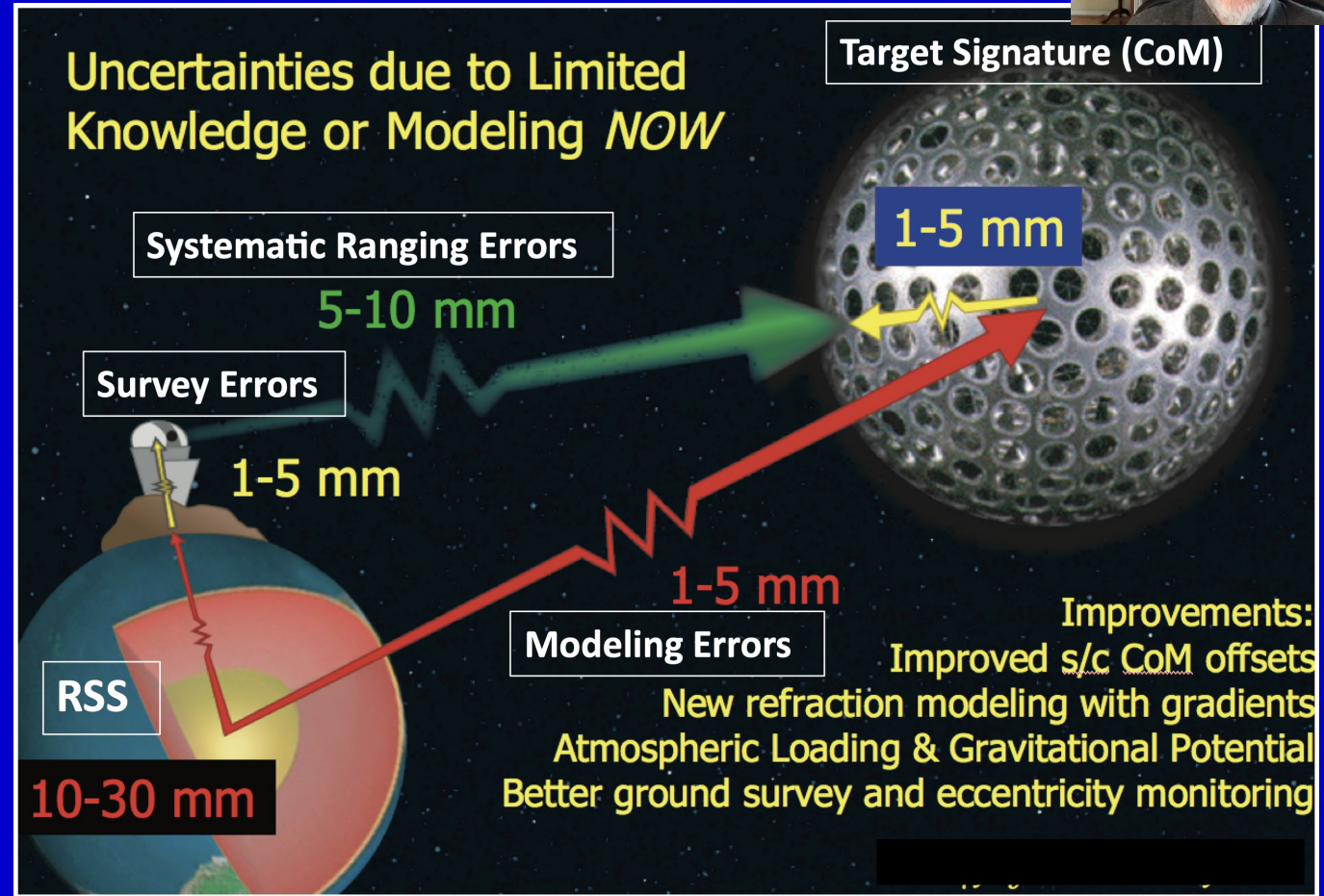
In 2015 ILRS launched a multi-year effort to address and resolve the SLR scale issue: Station Systematic Error Modeling Pilot Project (**SSEM PP**).

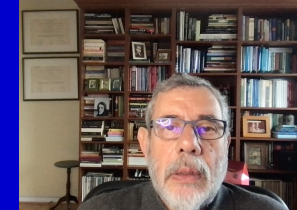
$$\text{VLBI} - \text{SLR} = 8.8 \text{ mm} \approx 1.375 \text{ ppb}$$

Credits: ITRS Center, ILRS ASC Meeting, Oct. 1st, 2019, Observatoire de Paris

Pre-Analysis Investigations:

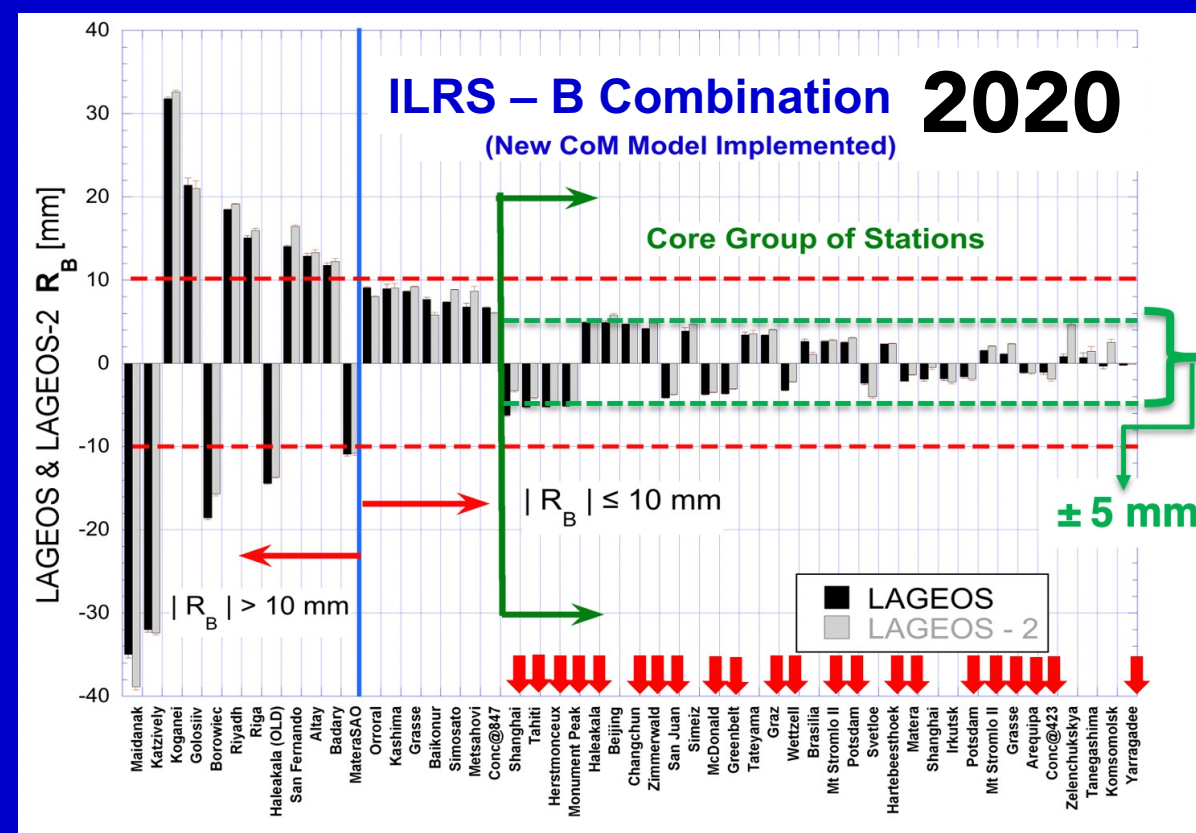
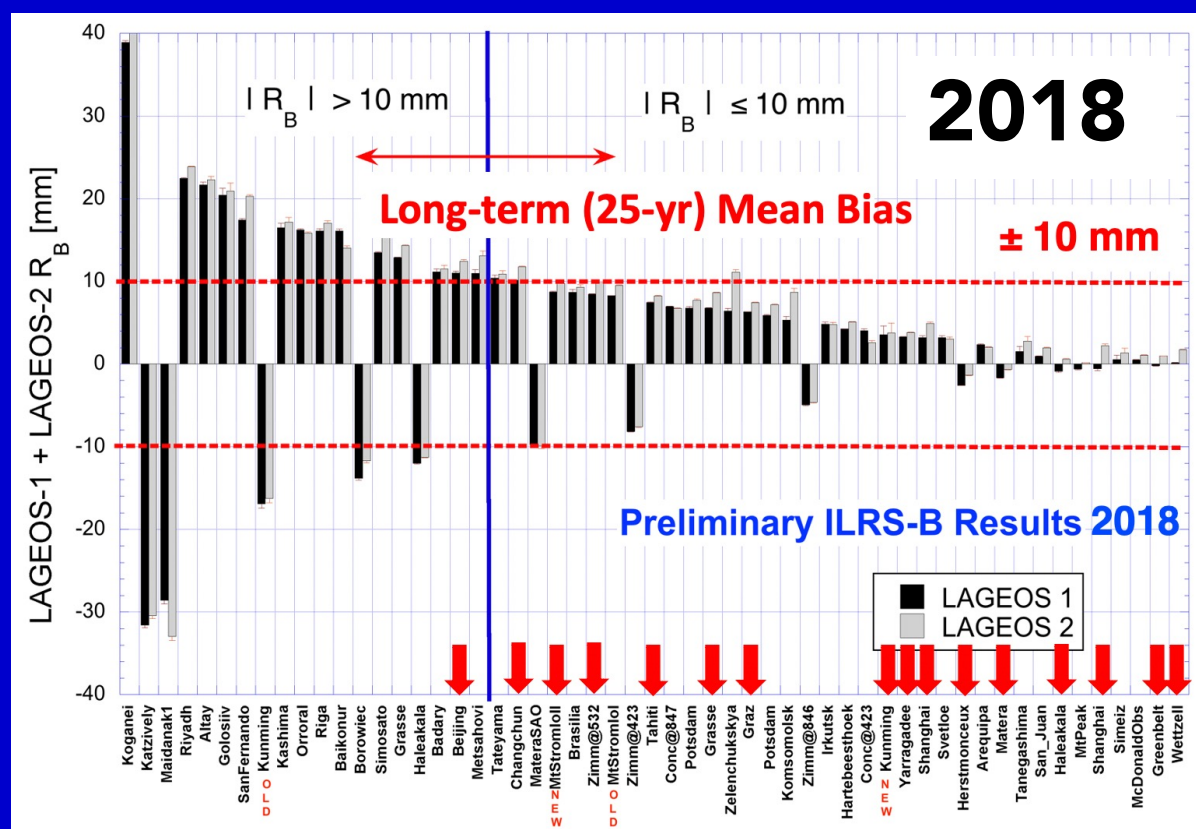
- Complete re-evaluation of stations' operating practices and recalculation of all station- and satellite-specific (time dependent) "target signature corrections"
- Simultaneous estimation of station positions and systematic errors (weekly resolution) adopted
- Review of station surveys and correction of eccentricity errors



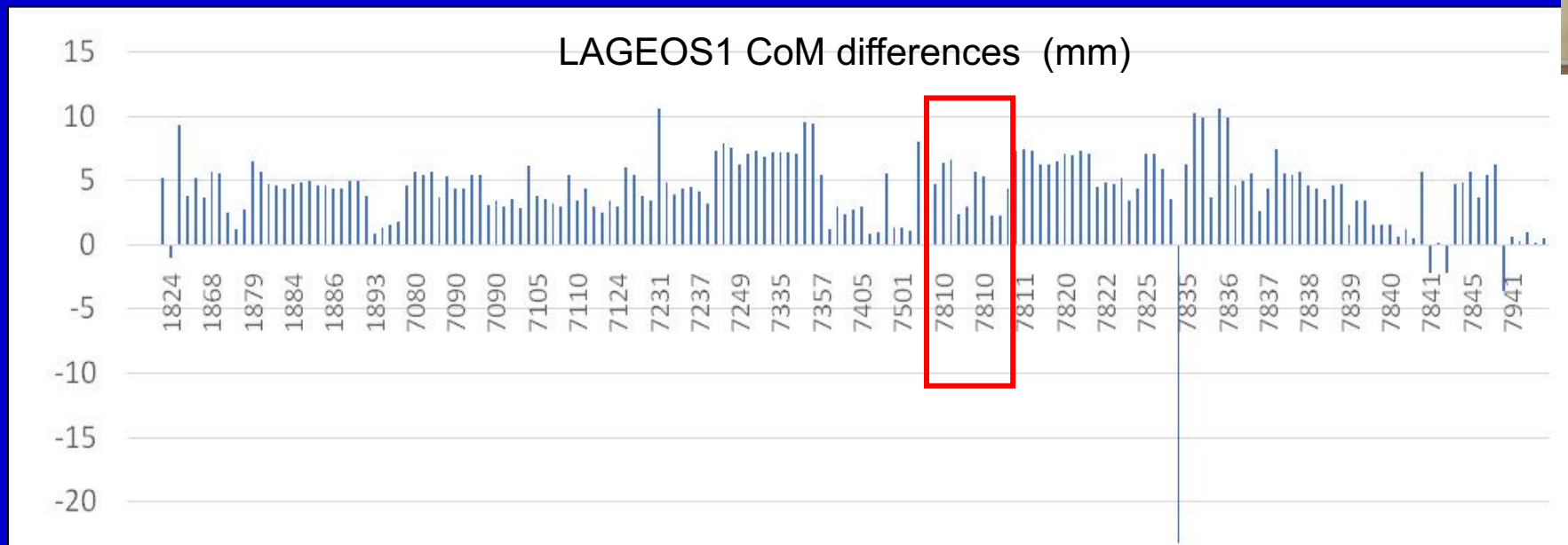


New modeling vastly improved the solution:

- Long-term mean biases for Core stations **reduced by > 50% !!!**
- Biases randomly distributed about zero $\Rightarrow$ net effect on scale ≈ 0



Improved Target Signature Corrections

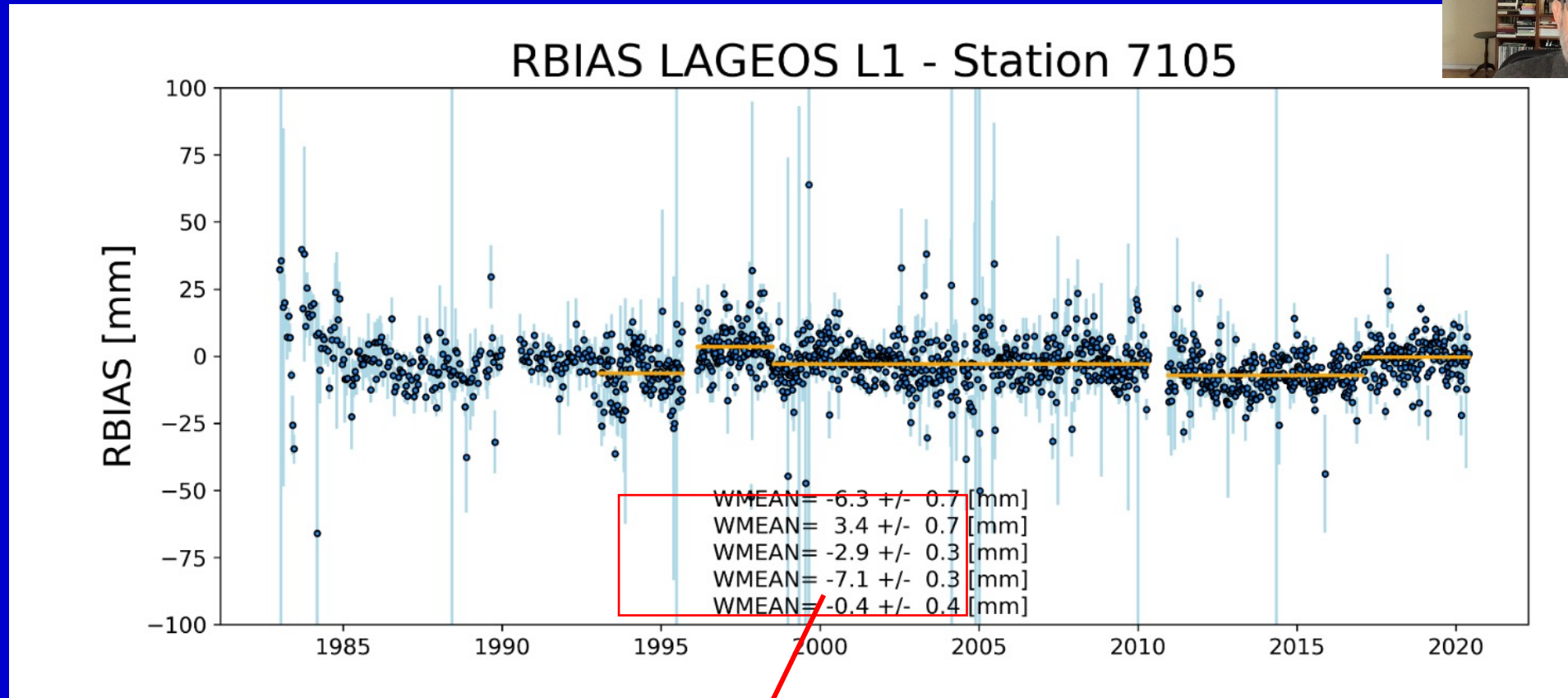


Zimmerwald, CH
(7810)

Old CoM model				New CoM model		
7810	1/1/1980	30/4/1995	251	01/01/1983	01/06/1995	244,6
				01/01/1986	01/06/1995	244,4
7810	2/1/1996	9/3/2001	245	01/01/1997	09/03/2001	242,6
7810	9/3/2001	18/2/2008	248	09/03/2001	11/03/2003	245,0
7810	4/3/2008	31/12/2050	249	11/03/2003	03/02/2006	243,4
				03/02/2006	18/02/2008	243,7
				01/01/2002	18/02/2006	246,8
				18/06/2006	18/02/2008	246,7
				18/02/2008	01/01/2050	244,7

Rodríguez, J. et al., *J Geod* **93**, (2019). <https://doi.org/10.1007/s00190-019-01315-0>

Each station series were examined to identify all breaks:



+MODEL/RANGE_BIAS

*CODE PT SOLN T START_DATE__ END_DATE__ M __E-VALUE__ STD_DEV __E-RATE__ UNIT CMNTS

.....

7105	51	501	A	93:017:00000	95:253:00000	R	-6.3	0.7	mm
7105	51	501	A	96:056:00000	98:193:00000	R	3.4	0.7	mm
7105	51	501	A	98:193:00000	10:122:00000	R	-2.9	0.3	mm
7105	51	501	A	10:339:00000	17:029:00000	R	-7.1	0.3	mm

.....

Data Handling File Entries

*	1	2	3	4	5	6	7	8
*234567890123456789012345678901234567890123456789012345678901234567890								

RBIAS LAGEOS L1 - Station 7840

Station bias (m) vs. Year (1992-2020). The plot shows a scatter of data points with error bars, a horizontal orange line representing the mean, and a red line at -50 m. A green box highlights the text: WMEAN= -8.4 +/- 0.2 [mm] and WMEAN= -2.4 +/- 0.2 [mm].

RBIAS LAGEOS L2 - Station 7840

WMEAN= -8.3 +/- 0.2 [mm]
WMEAN= -0.8 +/- 0.2 [mm]

[illegible]

```
+MODEL/TARGET_SIGNATURE_GEOMETRY
*SITE PT SOLN T START_DATE__ END_DATE_____ M COM_CORR STD_DEV UNIT
1873 51 501 L 08:288:00000 08:295:00000 C 0.1234 0.002 m
1879 52 501 L 08:288:00000 08:295:00000 C 0.1234 0.002 m
7810 53 501 L 08:288:00000 08:295:00000 C 0.9373 0.005 m
7810 60 501 L 08:288:00000 08:295:00000 C 0.0163 0.002 m
-MODEL/TARGET_SIGNATURE_GEOMETRY
```

The Data Handling file



+MODEL/RANGE_BIAS

- * List of mandatory systematic errors to be applied on observations by station & satellite

+SOLUTION/DATA_HANDLING

- * list of data to be deleted
- * list of mandatory arc-dependent biases to be estimated
- * meteo data corrections

+MODEL/TIME_BIAS

- * Time Biases (T_B) including the
- * T2L2 T_B and T_B -rate DATA RECORDS
- * Includes entries significant for LARES and higher orbits (range equivalent >10 mm)

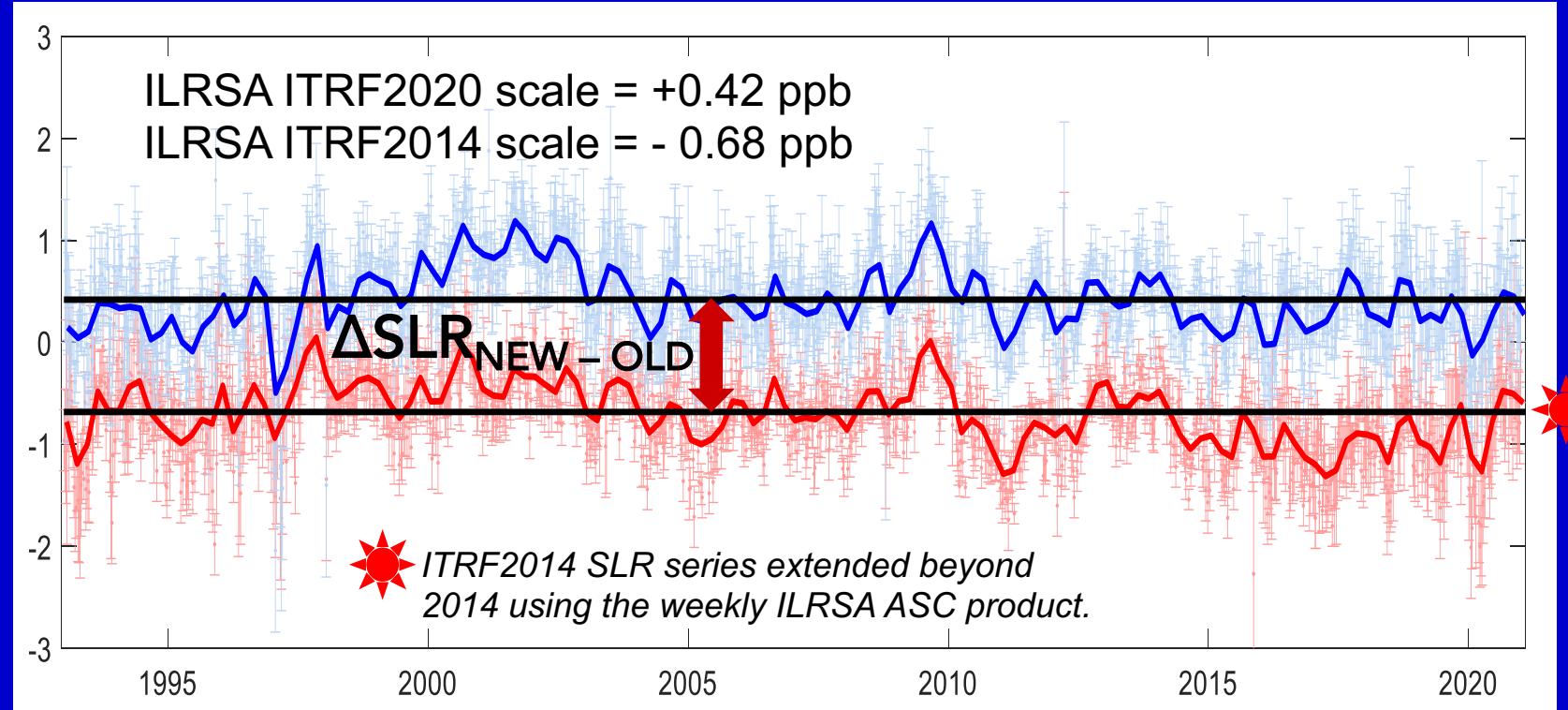
and

** SECTION WITH OPTIONAL CORRECTIONS COMMENTED with "*" for other LEO s/c

SLR Scale From the ITRF2020 Reanalysis:



- Upper curve:
 - SLR scale from SSEM
 - Mean: **+0.42 ppb**
- Lower curve:
 - SLR scale in ITRF2014
 - Mean: **- 0.68 ppb**
- Mean difference:



$$0.42 \text{ ppb} - (- 0.68 \text{ ppb}) = 1.10 \text{ ppb}$$

$$\Delta \text{SLR}_{\text{NEW} - \text{OLD}} \approx 1.10 \text{ ppb}$$

$$\bullet \text{ VLBI} - \text{SLR} \approx 0.28 \pm 0.10 \text{ ppb} \star$$

$\star$ WRT VLBI @ ITRF2014 !!!

Operational Data Handling file extension



- Extension of the SSEM to end of 2022,
- Weekly series of SSEM-like SINEX files to routinely extend the mean R_B series
- Periodic update of the DH file as needed

DH file for ITRF2020 ended on 2021.0

Old_records.snz — Edited									
608:	1890	51	501	A	12:001:00000	21:001:00000	R	12.9	1.1
609:	1893	51	501	A	05:212:00000	21:001:00000	R	-33.4	1.6
613:	7090	51	501	A	14:208:00000	21:001:00000	R	2.3	0.2
621:	7110	51	501	A	96:287:00000	21:001:00000	R	-5.2	0.2
624:	7119	51	501	A	15:067:00000	21:001:00000	R	9.4	0.4
634:	7237	51	501	A	12:120:00000	21:001:00000	R	4.4	0.4
643:	7501	51	501	A	19:048:00000	21:001:00000	R	13.6	1.4
647:	7810	51	501	B	16:080:00000	21:001:00000	R	6.7	0.3
651:	7825	51	501	A	04:214:00000	21:001:00000	R	1.0	0.2
659:	7839	51	501	A	03:285:00000	21:001:00000	R	3.8	0.1
662:	7840	51	501	A	07:035:00000	21:001:00000	R	-2.4	0.2
663:	7841	51	501	A	04:053:00000	21:001:00000	R	1.9	0.3
668:	7845	51	501	A	15:004:00000	21:001:00000	R	-6.0	0.4
681:	1890	52	501	A	12:001:00000	21:001:00000	R	13.3	1.3
682:	1893	52	501	A	05:212:00000	21:001:00000	R	-32.7	1.6
686:	7090	52	501	A	14:208:00000	21:001:00000	R	2.5	0.2
694:	7110	52	501	A	96:287:00000	21:001:00000	R	-4.8	0.2
697:	7119	52	501	A	15:067:00000	21:001:00000	R	10.3	0.5
707:	7237	52	501	A	12:120:00000	21:001:00000	R	5.6	0.5
716:	7501	52	501	A	19:048:00000	21:001:00000	R	13.4	1.4
720:	7810	52	501	B	16:080:00000	21:001:00000	R	8.1	0.3
724:	7825	52	501	A	04:214:00000	21:001:00000	R	1.7	0.2
732:	7839	52	501	A	03:285:00000	21:001:00000	R	4.6	0.2
735:	7840	52	501	A	07:035:00000	21:001:00000	R	-0.8	0.2
736:	7841	52	501	A	04:053:00000	21:001:00000	R	3.0	0.3
741:	7845	52	501	A	15:004:00000	21:001:00000	R	-3.8	0.4

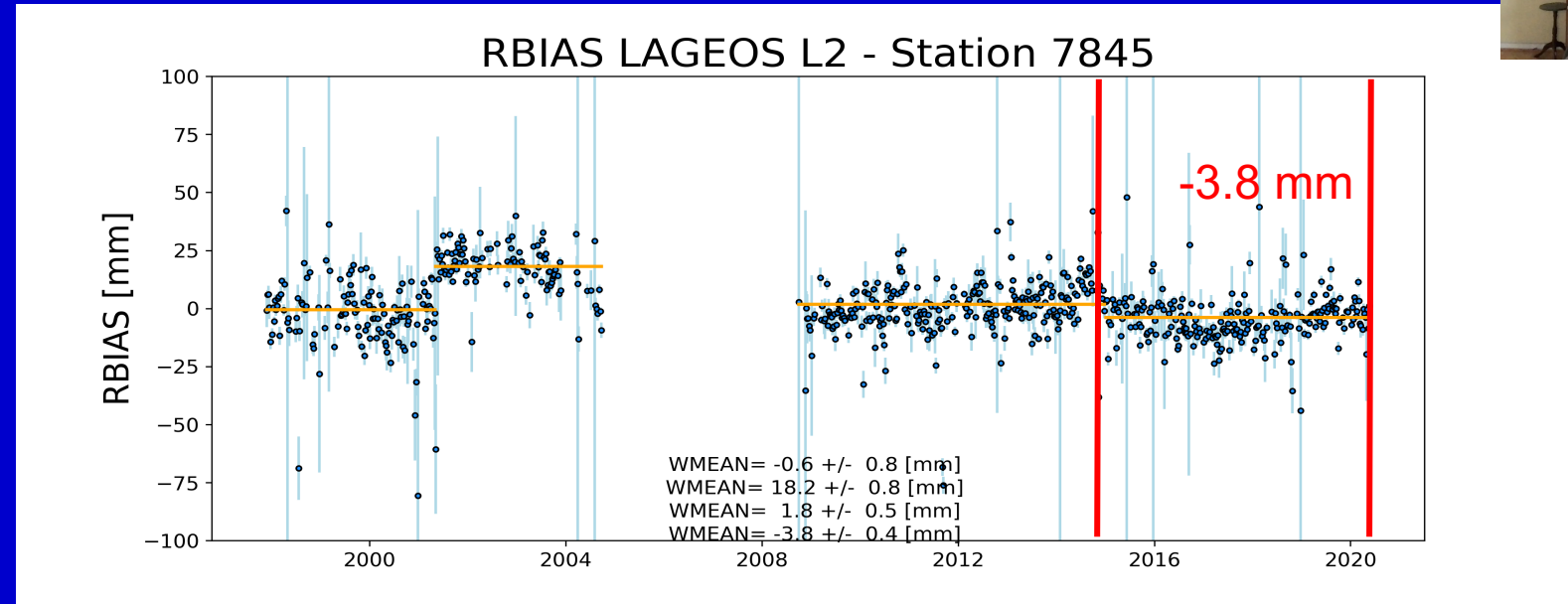
Extended DH file to June 2022

New_records.snz									
1890	51	501	A	12:001:00000	22:149:00000	R	14.0	1.0	✓
1893	51	501	A	05:212:00000	22:177:00000	R	-33.2	1.4	
7090	51	501	A	14:208:00000	22:177:00000	R	2.4	0.2	
7110	51	501	A	96:287:00000	22:177:00000	R	-5.3	0.2	
7119	51	501	A	15:067:00000	22:177:00000	R	9.8	0.4	
7237	51	501	A	12:120:00000	22:177:00000	R	5.4	0.4	
7501	51	501	A	19:048:00000	22:142:00000	R	10.9	1.1	✓
7810	51	501	B	16:080:00000	22:051:00000	R	7.0	0.3	
7825	51	501	A	04:214:00000	22:177:00000	R	0.8	0.2	
7839	51	501	A	03:285:00000	22:177:00000	R	3.9	0.1	
7840	51	501	A	07:035:00000	22:177:00000	R	-2.2	0.1	
7841	51	501	A	04:053:00000	22:177:00000	R	2.2	0.3	
7845	51	501	A	15:004:00000	22:177:00000	R	-3.3	0.4	✓
1890	52	501	A	12:001:00000	22:149:00000	R	14.0	1.1	
1893	52	501	A	05:212:00000	22:177:00000	R	-32.4	1.5	
7090	52	501	A	14:208:00000	22:177:00000	R	2.7	0.2	
7110	52	501	A	96:287:00000	22:177:00000	R	-4.9	0.2	
7119	52	501	A	15:067:00000	22:177:00000	R	10.9	0.4	
7237	52	501	A	12:120:00000	22:177:00000	R	6.5	0.4	
7501	52	501	A	19:048:00000	22:142:00000	R	10.9	1.1	✓
7810	52	501	B	16:080:00000	22:051:00000	R	8.2	0.3	
7825	52	501	A	04:214:00000	22:177:00000	R	1.4	0.2	
7839	52	501	A	03:285:00000	22:177:00000	R	4.7	0.1	
7840	52	501	A	07:035:00000	22:177:00000	R	-0.7	0.1	
7841	52	501	A	04:053:00000	22:177:00000	R	3.3	0.3	
7845	52	501	A	15:004:00000	22:177:00000	R	-2.1	0.3	✓

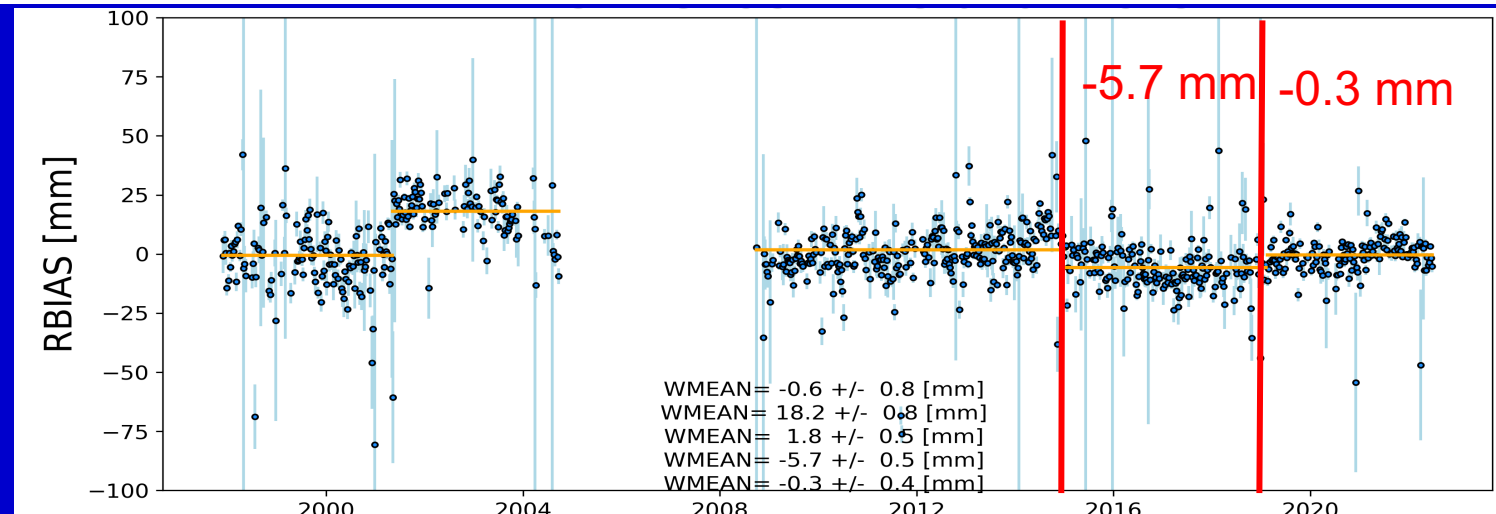
Extension of R_B series for Grasse (7845):



Original
version used
in ITRF2020



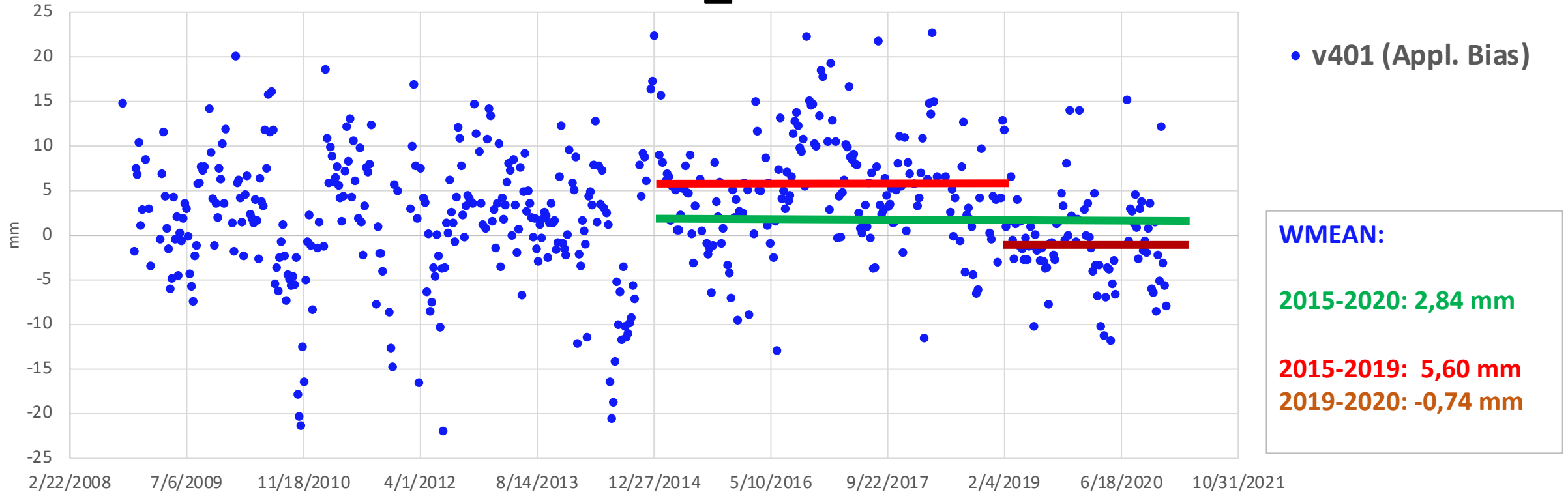
Revised
version after
the extension



Revised R_B effect on Grasse (7845) height



7845 UP_offset ILRSA



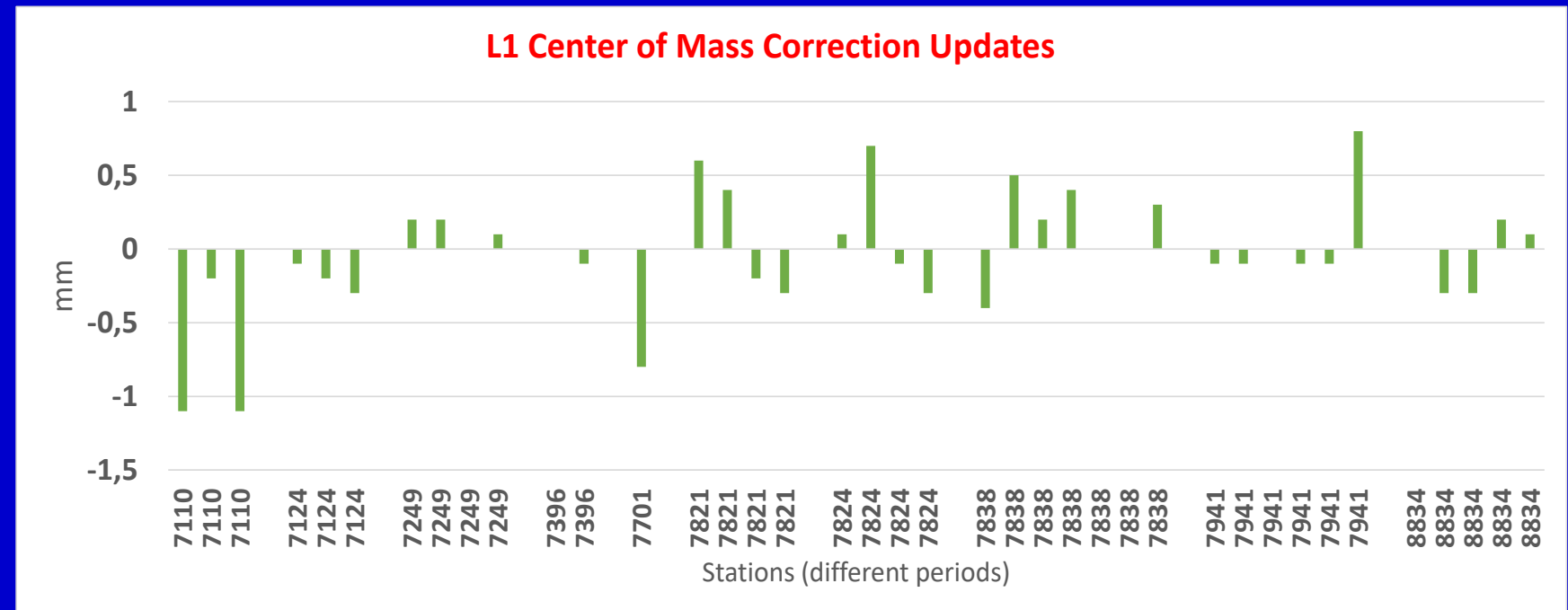
Latest Update of the Target Signature Correction Model



- Reevaluation of the operating practices of stations and computation of station and satellite specific (time-dependent) target signature corrections frequently

Latest Release:

- J. Rodriguez
11/05/2021
- Update with minor changes
- Model version is listed in every DH File release



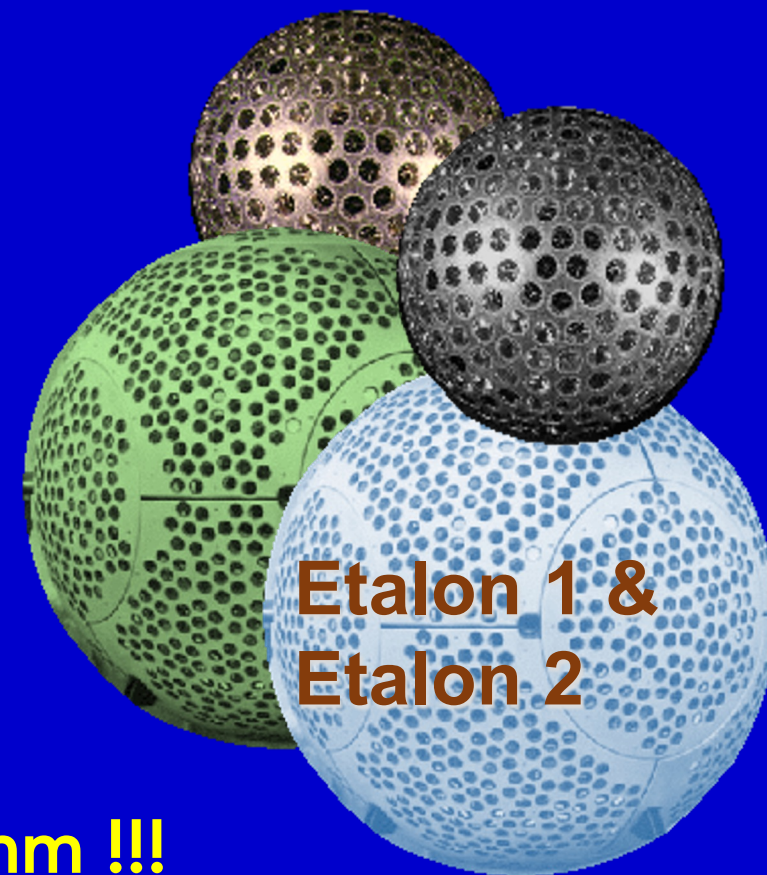
Rodríguez, J. et al., *J Geod* **93**, (2019). <https://doi.org/10.1007/s00190-019-01315-0>

Summary

- The ILRS ASC established a new analysis approach for its contribution to ITRF2020;
- It will be implemented in the operational series after adoption of ITRF2020 (2023);
- The complete SLR series for the **38-year** period **1983 – 2021** will be reanalyzed (2023);
- The new bias model (SSEM-X) will be publicly available and maintained current over the coming years.

From nearly 1 cm Δ Scale(SLR-VLBI) to 1 mm !!!

**LAGEOS &
LAGEOS 2**





Thank you!