The ILRS Analysis Standing Committee (ASC)

Contribution to ITRF2020

REFAG 2022
THESSALONIKI - GREECE

E. C. Pavlis, M. Kuzmicz-Cieslak, K. Evans
GESTAR II/UMBC – Baltimore, MD

V. Luceri, A. Basoni, D. Sarrocco
e-GEOS S.p.A., ASI/CGS - Matera

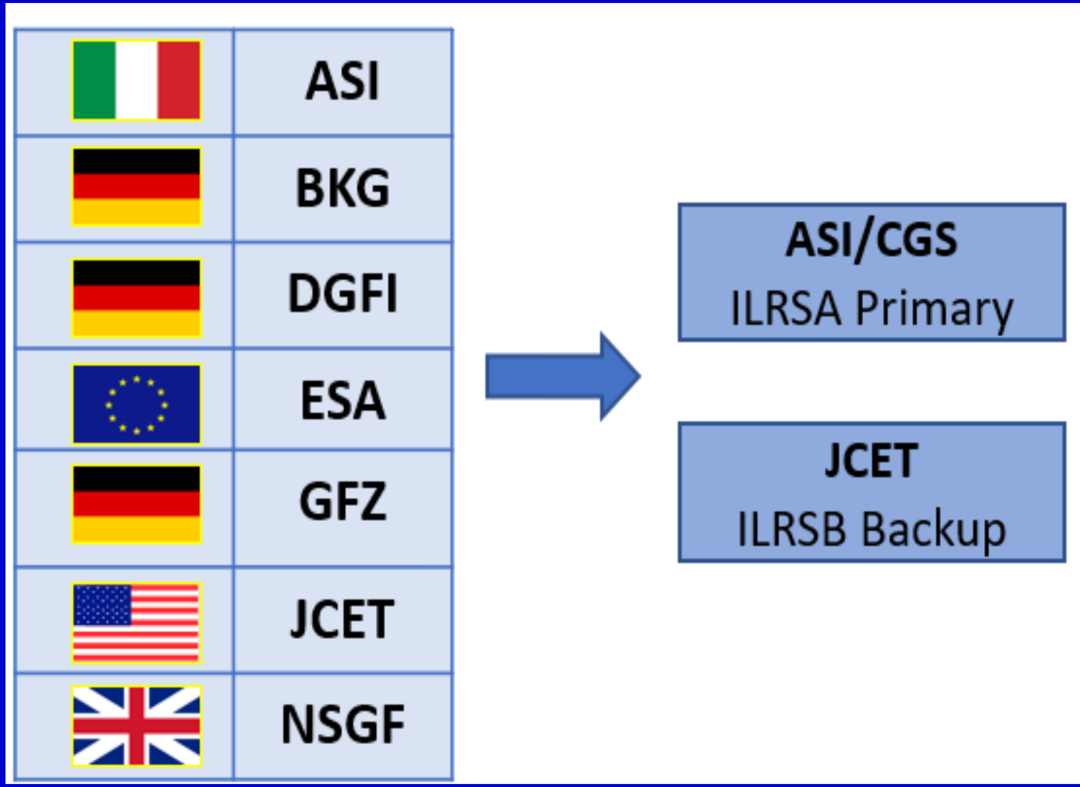
G. Bianco
Agenzia Spaziale Italiana, CGS - Matera

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.



The REPRO2020 ILRS ASC Team Members:

ASI (AC/CC)

Giuseppe Bianco
Agenzia Spaziale Italiana
Matera, Italy

Vincenza Luceri
e-GEOS SpA
Matera, Italy

Antonio Basoni
e-GEOS SpA
Matera, Italy

David Sarrocco
e-GEOS SpA
Matera, Italy

BKG (AC)

Daniela Thaller
Bundesamt für Kartographie und Geodäsie
Frankfurt am Main, Germany

Daniel König
Bundesamt für Kartographie und Geodäsie
Frankfurt am Main, Germany

Ulrich Meyer
Astronomical Institute, University of Bern (AIUB)
Bern, Switzerland

Rolf Dach
Astronomical Institute, University of Bern (AIUB)
Bern, Switzerland

DGFI (AC)

Mathis Bloßfeld
Deutsches Geodätisches Forschungsinstitut (DGFI)
der Technischen Universitaet Muenchen (TUM)
Munich, Germany

ESA (AC)

Erik Schönemann
European Space Operation Centre (ESOC)
Darmstadt, Germany

Tim Springer
PosiTim UG (haftungsbeschränkt)
Seeheim-Jugenheim, Germany

GFZ (AC)

Rolf König
Deutsches GeoForschungsZentrum - GFZ
Section 1.2: Global Geomonitoring and Gravity Field
Oberpfaffenhofen , Germany

Margarita Vei
Deutsches GeoForschungsZentrum - GFZ
Section 1.2: Global Geomonitoring and Gravity Field
Oberpfaffenhofen , Germany

Karl Hans Neumayer
Deutsches GeoForschungsZentrum - GFZ
Section 1.2: Global Geomonitoring and Gravity Field
Oberpfaffenhofen , Germany

JCET (AC/CC)

Erricos C. Pavlis
Goddard Earth Sciences Technology and Research II (GESTAR II)
University of Maryland, Baltimore County (UMBC) & NASA Goddard 61A

Magda Kuzmicz-Cieslak
Goddard Earth Sciences Technology and Research II (GESTAR II)
University of Maryland, Baltimore County (UMBC) & NASA Goddard 61A

Keith Evans
Goddard Earth Sciences Technology and Research II (GESTAR II)
University of Maryland, Baltimore County (UMBC) & NASA Goddard 61A
Baltimore, Maryland, USA

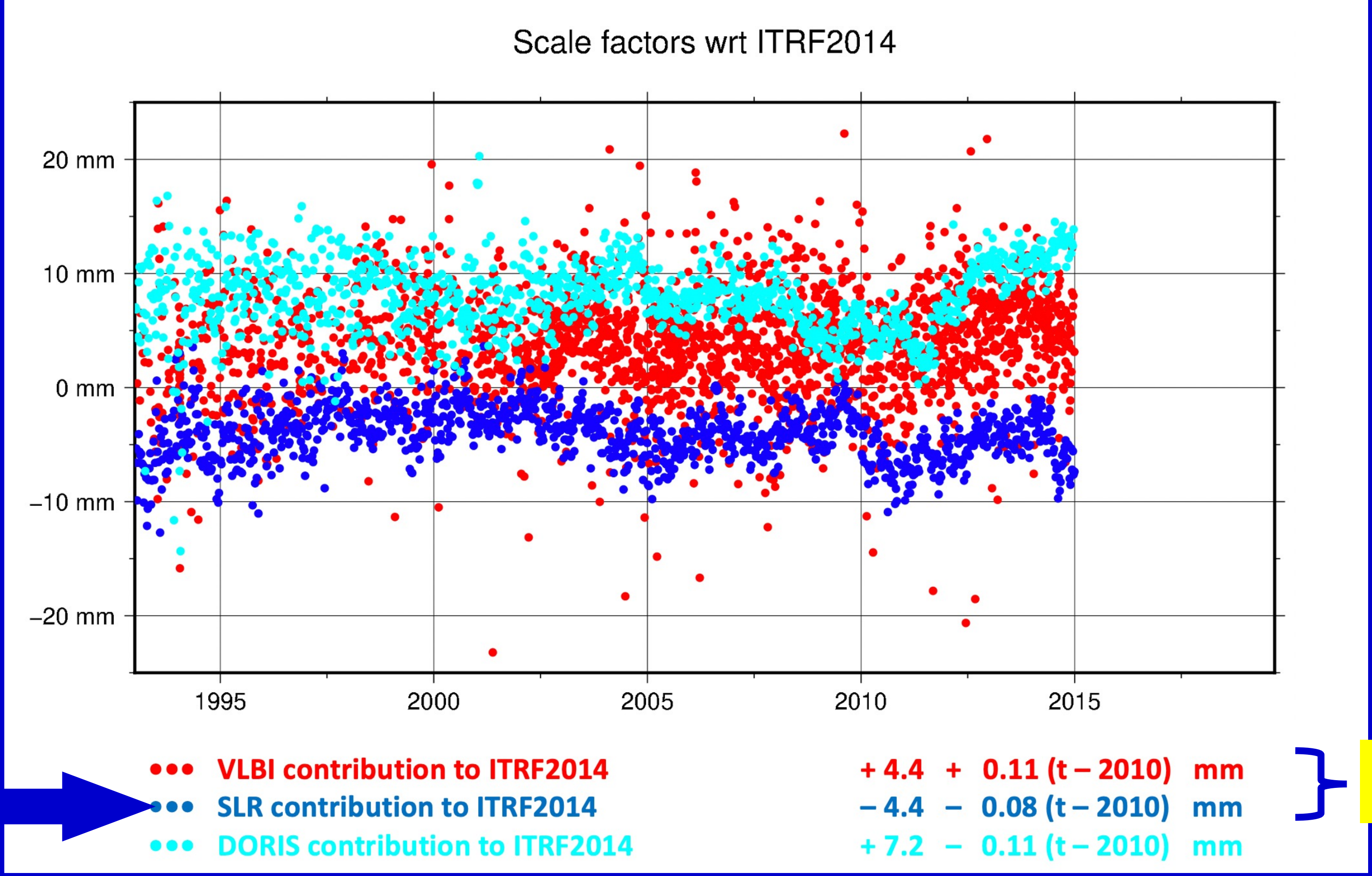
NSGF (AC)

Andreja Susnik
British Geological Survey (BGS), Space Geodesy Facility
Herstmonceux, United Kingdom

José Carlos Rodríguez
Instituto Geográfico Nacional, Observatorio de Yebes, Spain
IGN Yebes AAC

Graham Appleby
British Geological Survey (BGS) Honorary Research Associate,
Space Geodesy Facility,
Herstmonceux, United Kingdom

SLR - VLBI Scales Systematically Different in ITRF2014



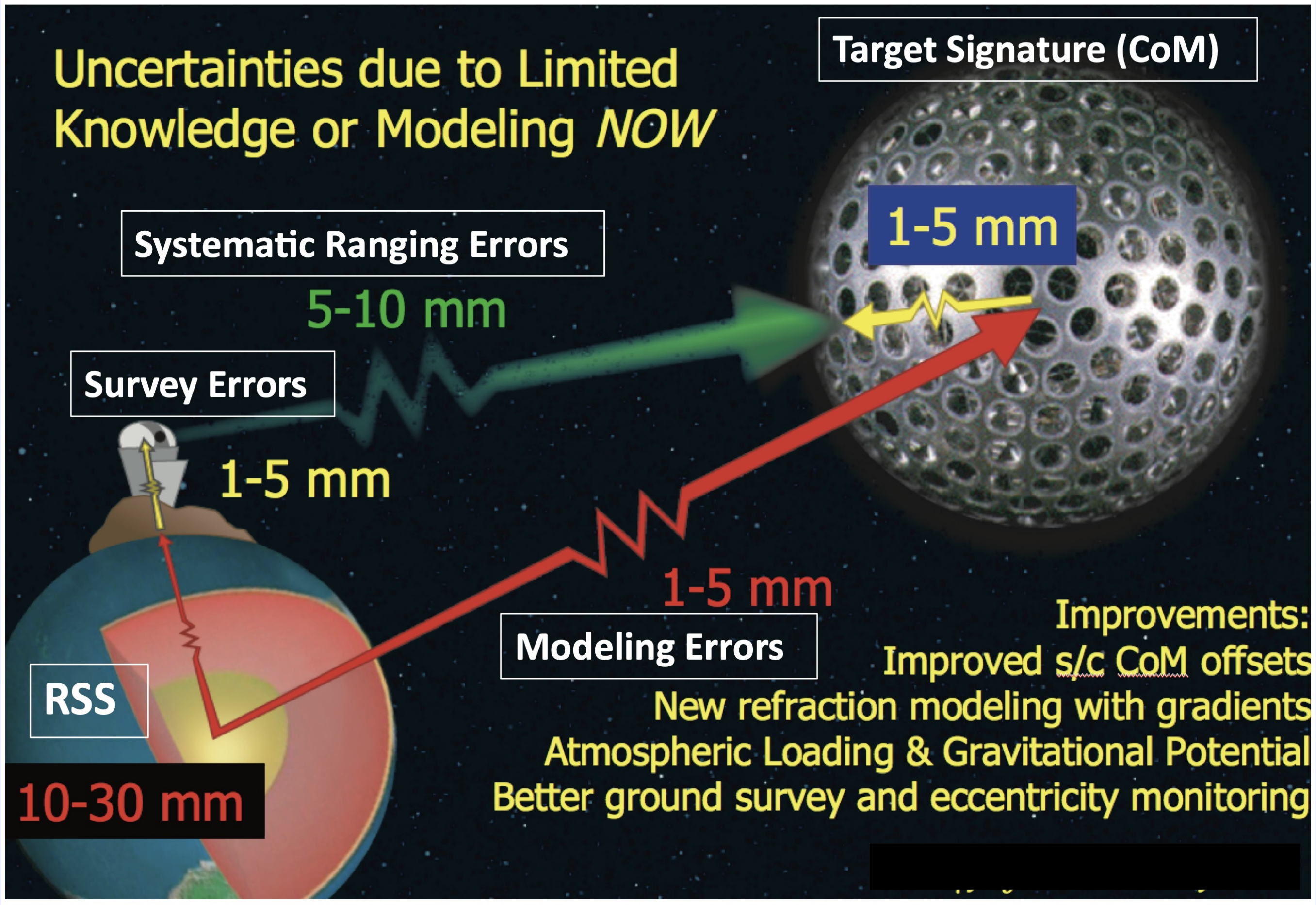
VLBI - SLR = 8.8 mm ≈ 1.375 ppb

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

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

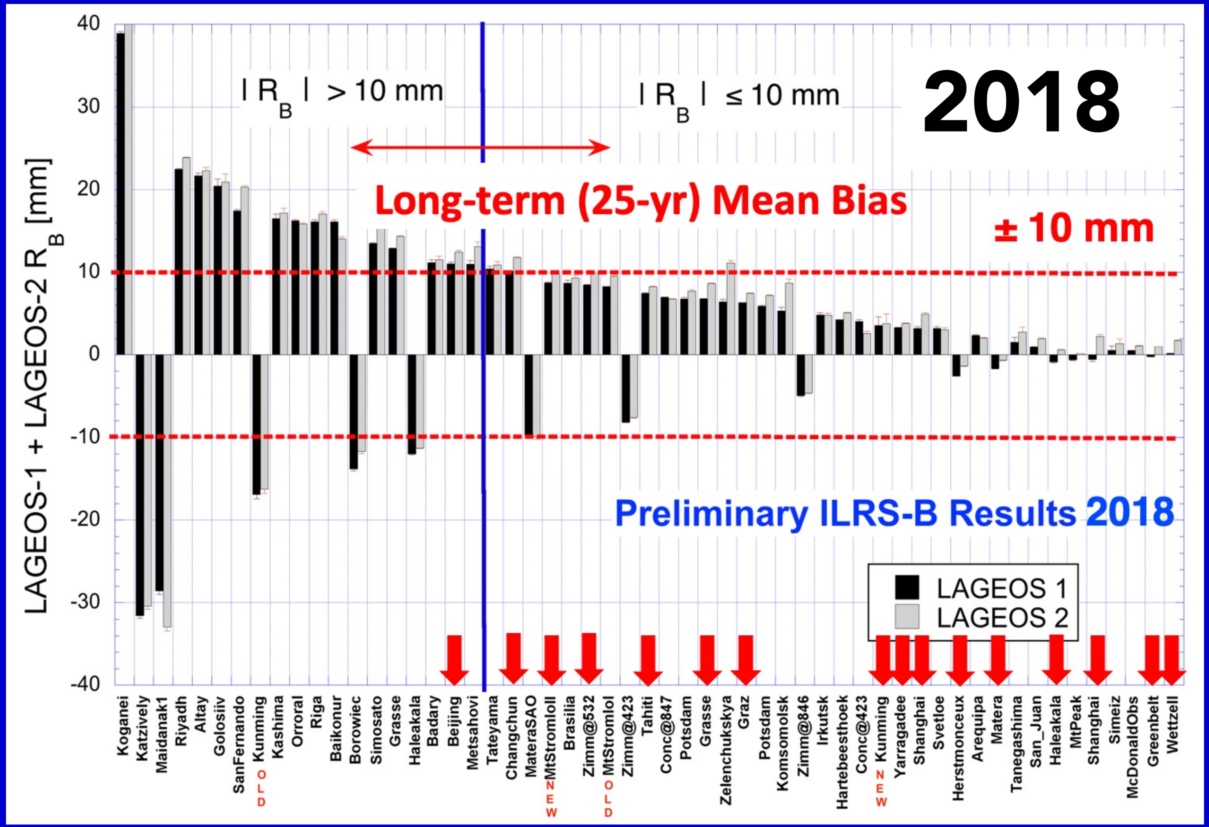
Pre-Analysis Investigations:

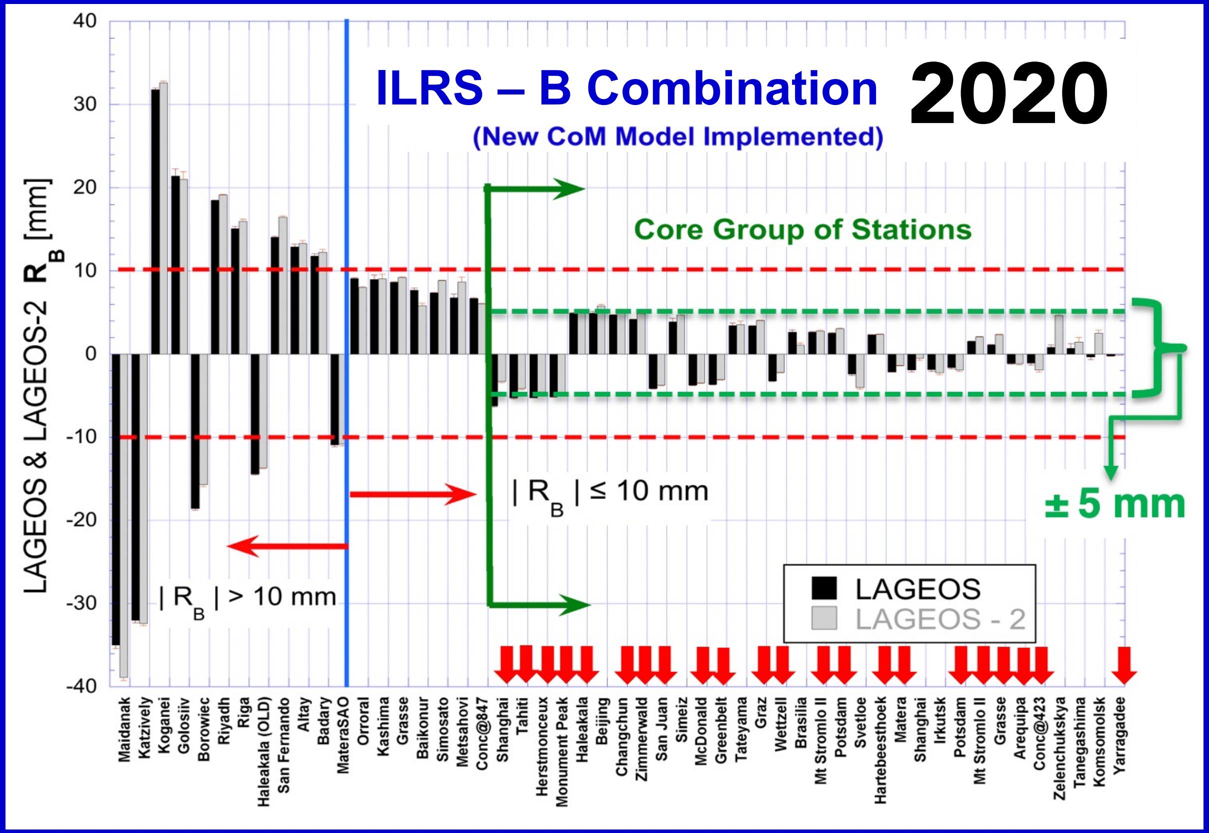
- Complete re-evaluation of stations' operating practices and recalculation of all station- and satellite-specific (time dependent) "target signature corrections"
- Simultaneous estimation of station positions and systematic errors (weekly resolution) adopted
- Review of station surveys and correction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



New modeling vastly improved the solution:

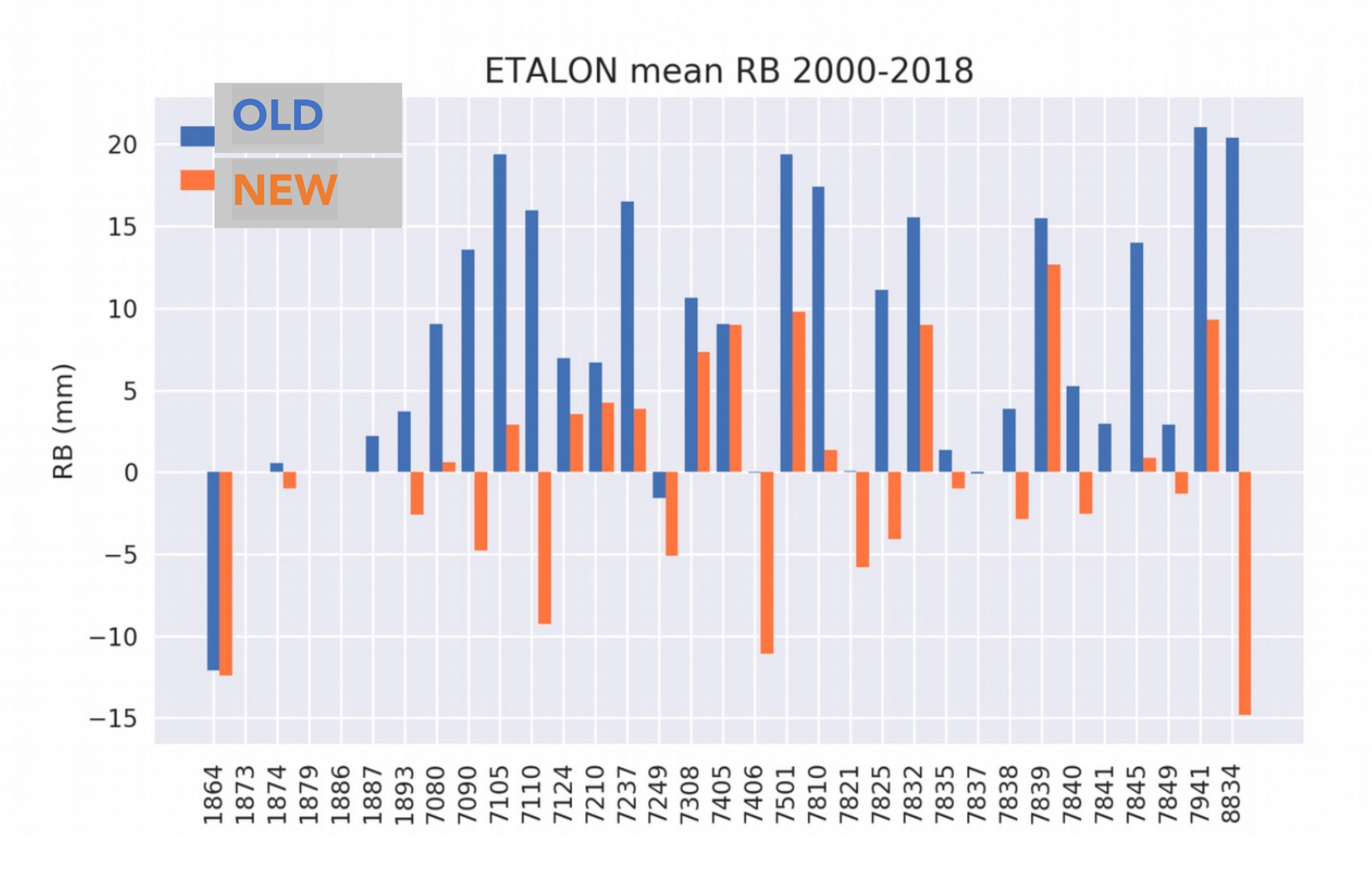
- Long-term mean biases for Core stations **reduced by > 50% !!!**
- Biases randomly distributed about zero ➠ net effect on scale ≈ 0





Improved Target Signature Corrections

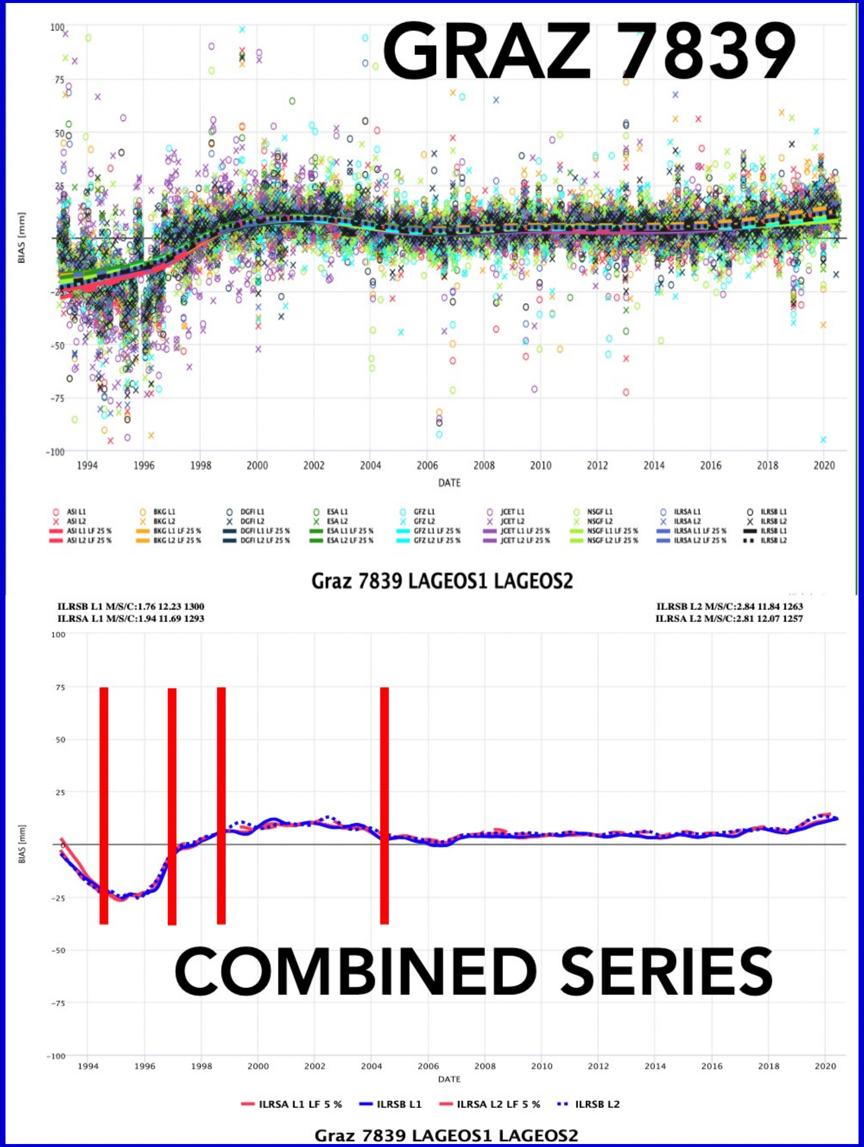
- These errors introduce a direct scale "bias"
- Most stations had inadequate modeling even at cm-level, e.g. for the Etalon satellites
- A non-random distribution in the network, resulted in significant distortion of the scale



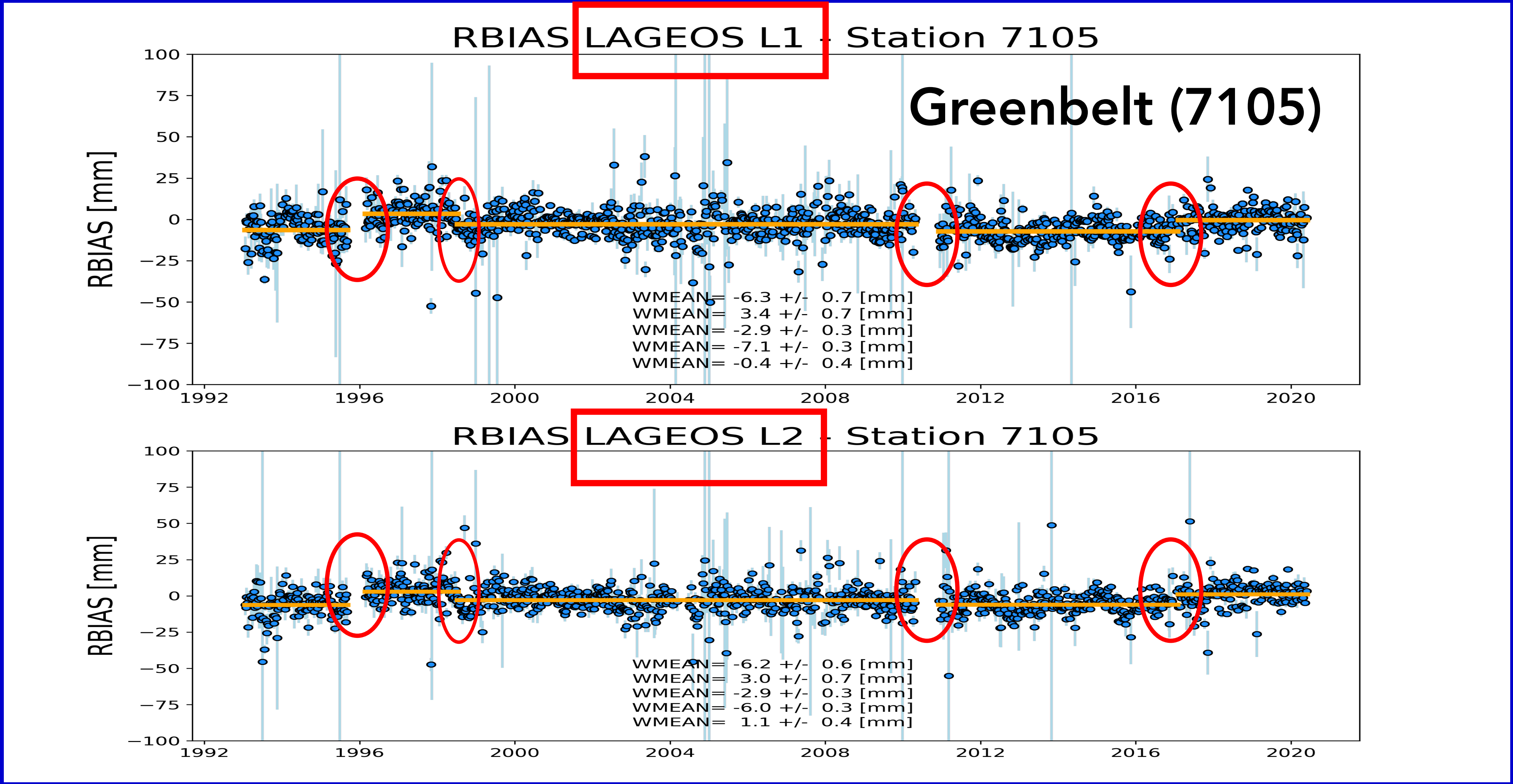
Rodríguez, J. et al., *J Geod* **93,** (2019). https://doi.org/10.1007/s00190-019-01315-0

Identifying changes in station systematic behavior:

- The 7 AC weekly series were combined for each satellite:
  - LAGEOS, LAGEOS 2 and
  - Etalon 1 & 2 (combined, common bias)
- Statistically good agreement, with the combined series showing even better agreement
- Periods of different station behavior were identified in the combined series and in consultation with available station logs
- The next step developed a set of mean estimates for each period identified, to be used *a priori* in the reanalysis for ITRF2020, resulting in a stronger and cleaner solution



Each station series were examined to identify all breaks:



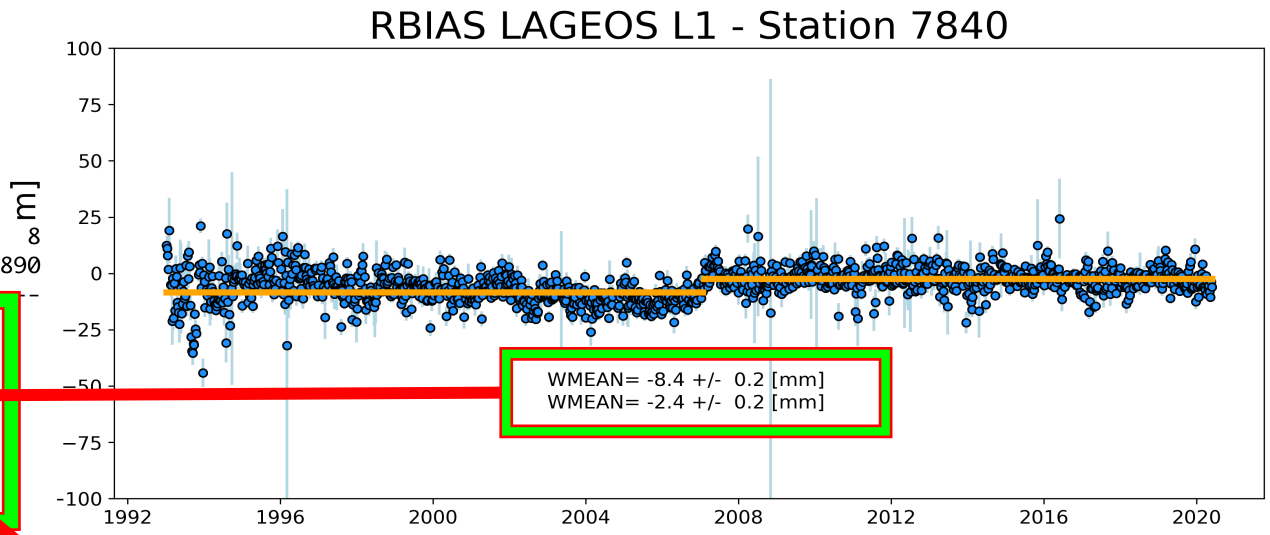
A priori range bias documentation:

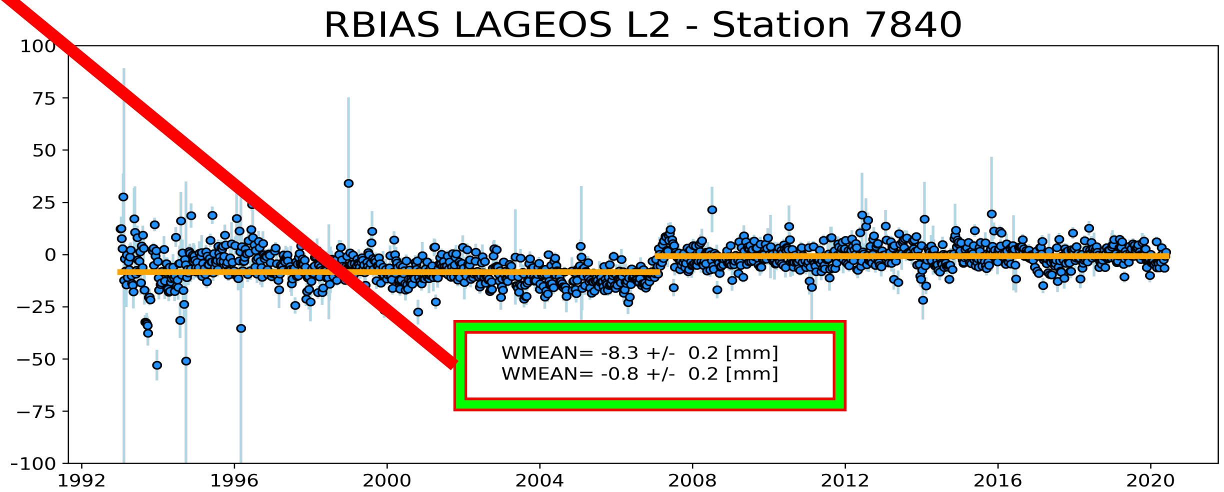
Weekly SINEXs now contain the systematics applied *a priori:*

```
*        1         2         3         4         5         6         7         8
*234567890123456789012345678901234567890123456789012345678901234567890123456789
+MODEL/RANGE_BIAS
*SITE PT SOLN T START_DATE__ END_DATE____ M RANGE_BIAS STD_DEV UNIT
 1873 51  501 L 08:288:00000 08:295:00000 R    -0.0193   0.002    m
 7810 51  501 L 08:288:00000 08:290:54321 R     0.0173   0.002    m
 7810 51  501 L 08:290:54321 08:295:00000 R     0.0183   0.002    m
 7810 60  501 L 08:288:00000 08:295:00000 R     0.0163   0.002    m
-MODEL/RANGE_BIAS
```

```
*        1         2         3         4         5         6         7         8
*234567890123456789012345678901234567890123456789012345678901234567890123456789
*-------------------------------------------------------------------------------
+MODEL/TIME_BIAS
*SITE PT UNIT T START_DATE__ END_DATE____ M __E-VALUE___ STD_DEV _E-RATE__ CMNTS
 1824 -- us   A 02:084:68460 12:085:00000 T      -24.400   5.000    0.0000 -----
 1873 -- us   A 07:059:00000 09:110:00000 T      -21.750  50.000   -0.2600 drift
-MODEL/TIME_BIAS
```

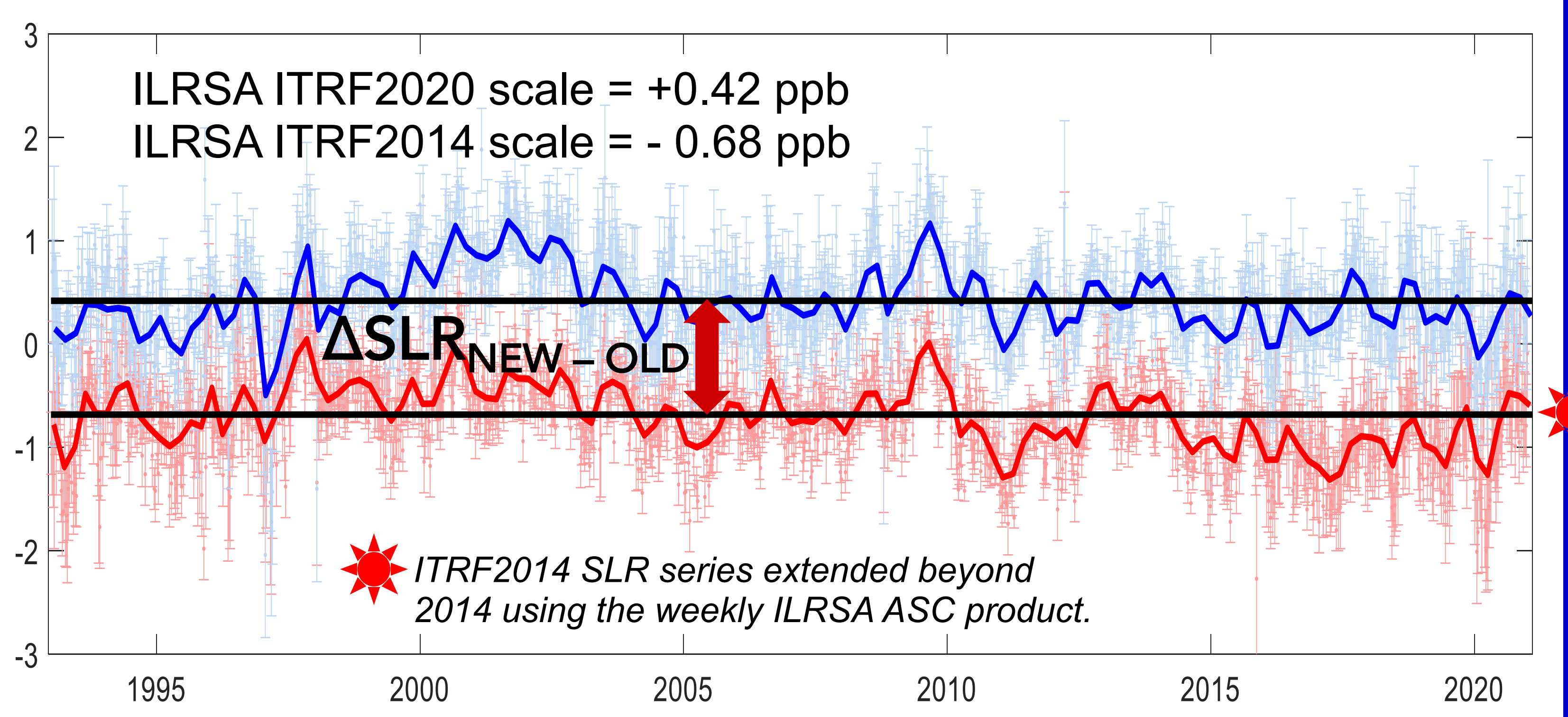
```
*        1         2         3         4         5         6         7         8
*234567890123456789012345678901234567890123456789012345678901234567890123456789
*-------------------------------------------------------------------------------
+MODEL/TARGET_SIGNATURE_GEOMETRY
*SITE PT SOLN T START_DATE__ 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
```





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:



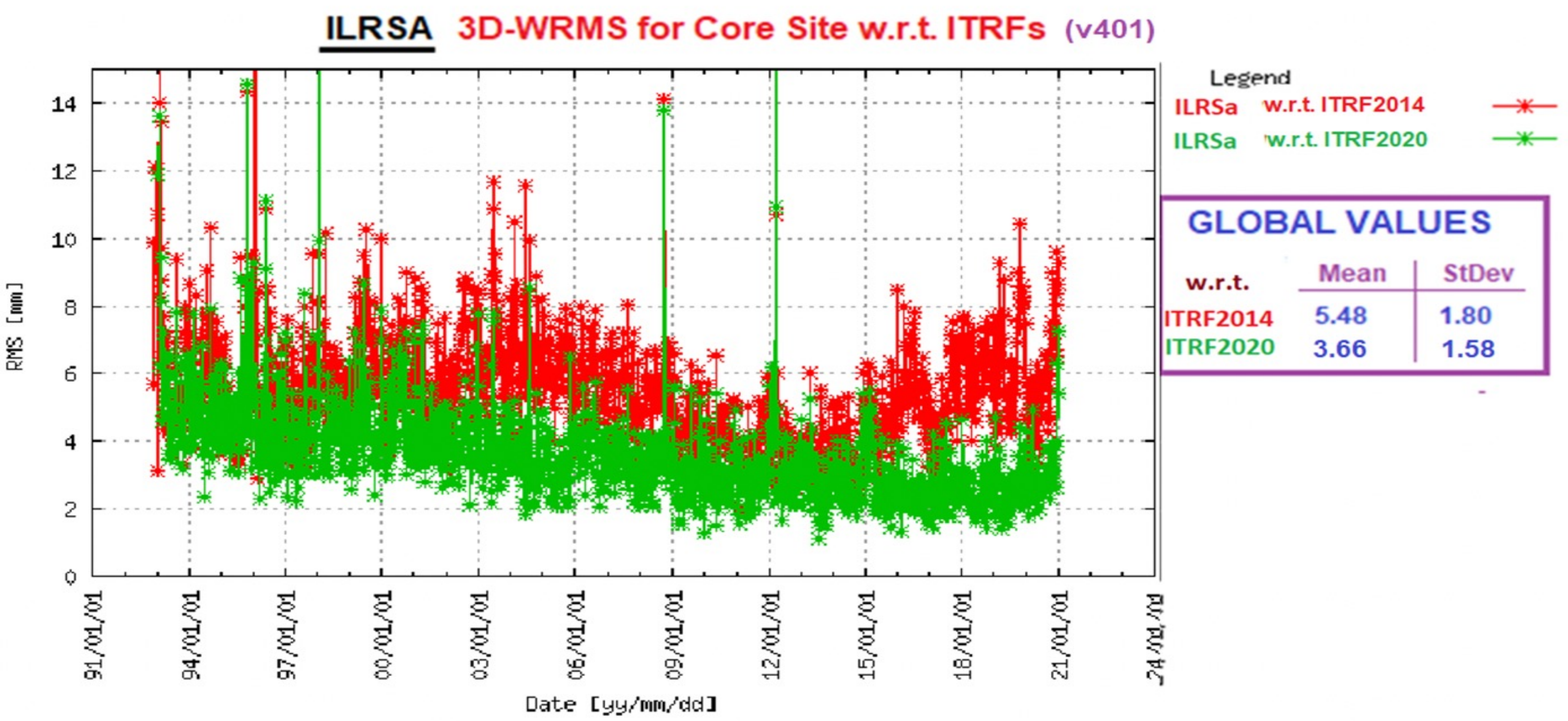
0.42 ppb – (- 0.68 ppb) = 1.10 ppb

- $\Delta SLR_{NEW-OLD} \approx 1.10$ ppb

• VLBI - SLR ≈ 0.28 ± 0.10 ppb

WRT VLBI @ ITRF2014 !!!

Core Site Position Tests: ITRF2020 vs ITRF2014



GLOBAL VALUES

w.r.t.	Mean	StDev
ITRF2014	5.48	1.80
ITRF2020	3.66	1.58

Evaluation of ITRF2020 vs ITRF2014

- New model performed well:
  - when used as *a priori* in the ASI time series for 1993-2020
  - when used as *a priori* for the ILRSA combination time series 1993-2020
- The PSD model fits well the effects of earthquakes on the coordinates
- Improvements in the 3D-WRMS for the core sites
- Improvements in coordinate offsets, for both, core and non-core stations
- Improvements in the Helmert parameters' mean values and scatter:

Scale	W_{mean} (mm)	σ- W_{Mean} (mm)	Slope (mm/yr)	σ- Slope (mm/yr)
vs ITRF2014	2,654	0,069	-0,028	0,009
vs ITRF2020	-0,743	0,063	0,084	0,008

Time Series of Origin Variations in ITRF2020 Reanalysis

T_X

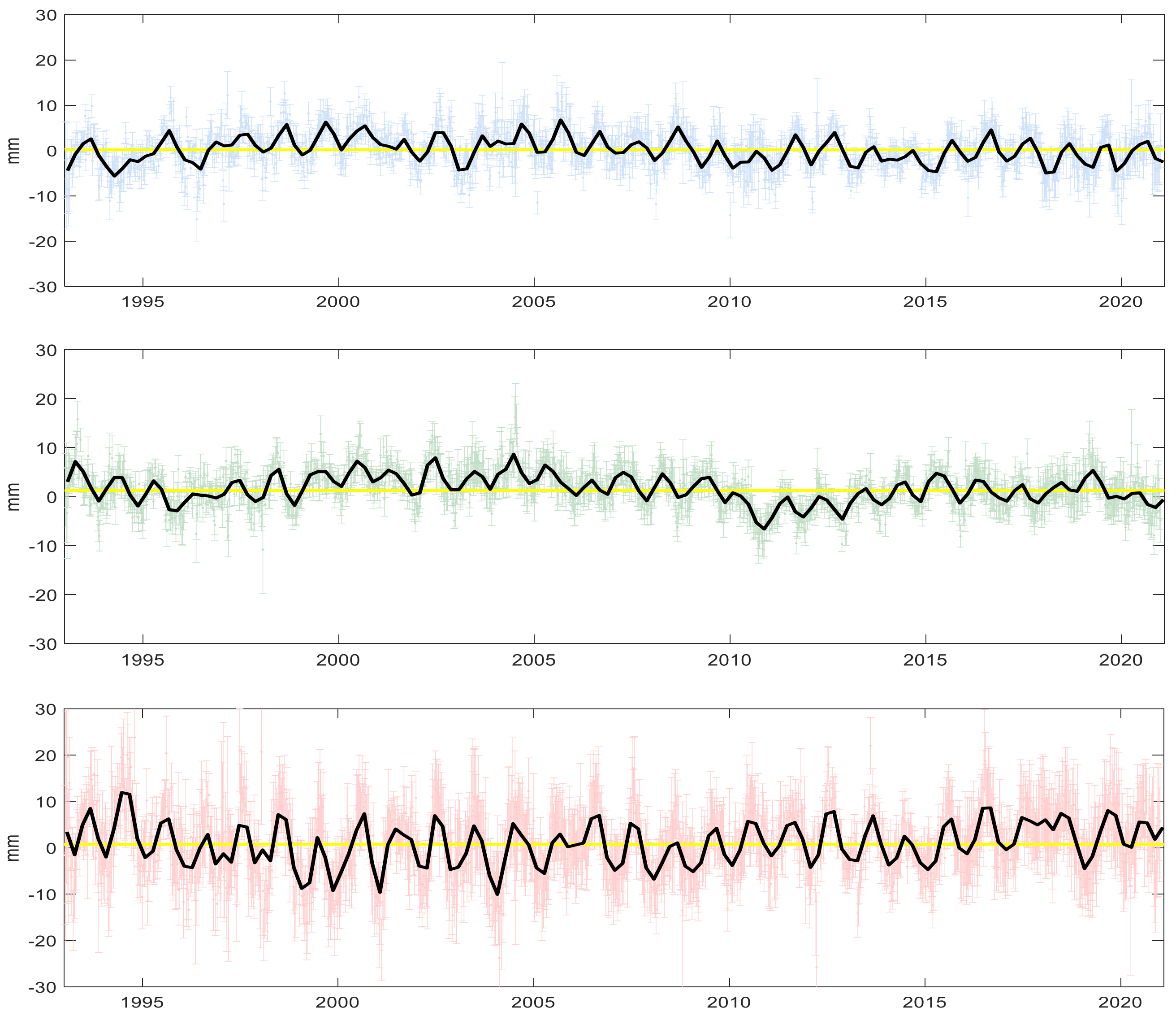
$$W_{mean} = 0.15\ mm$$
$$W_{RMS} = 3.68\ mm$$
$$Lin.rate = -0.081 \pm 0.012\ mm/y$$

T_Y

$$W_{mean} = 1.25\ mm$$
$$W_{RMS} = 3.45\ mm$$
$$Lin.rate = -0.113 \pm 0.012\ mm/y$$

T_Z

$$W_{mean} = 0.75\ mm$$
$$W_{RMS} = 6.32\ mm$$
$$Lin.rate = 0.045 \pm 0.021\ mm/y$$

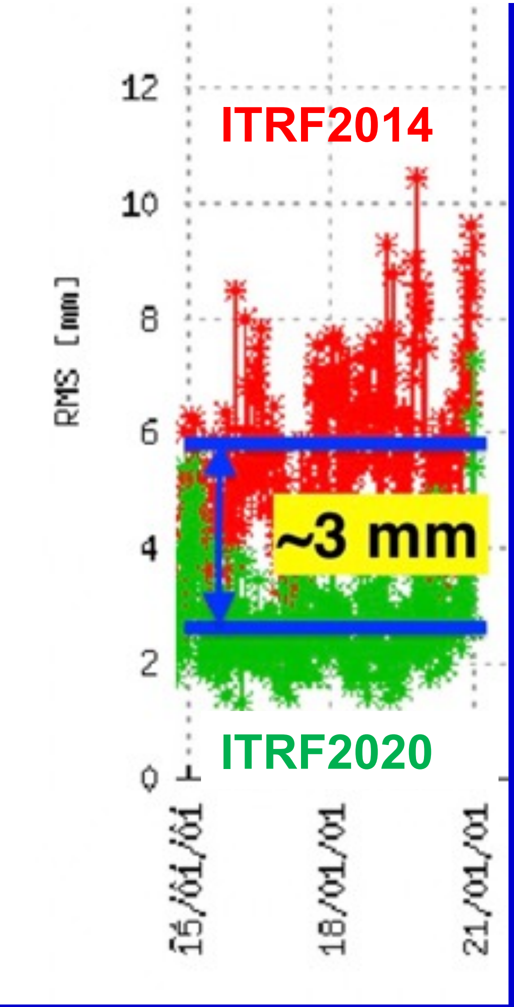


ILRS ASC Evaluation - Conclusions

- The general conclusion reached by all AC/CCs based on the performed tests, is that ITRF2020 is a significant improvement over ITRF2014.
- Over the 2015.0 – 2021.0, **a period not covered by SLR data in ITRF2014**, the new model does 100% better in Core station position 3D RMS, based on the current reanalysis.
- Based on the ITRF2020 evaluation results, the new ILRS contribution limits the systematic scale difference to **VLBI & SLR to 0.15 ppb *(~1 mm)***

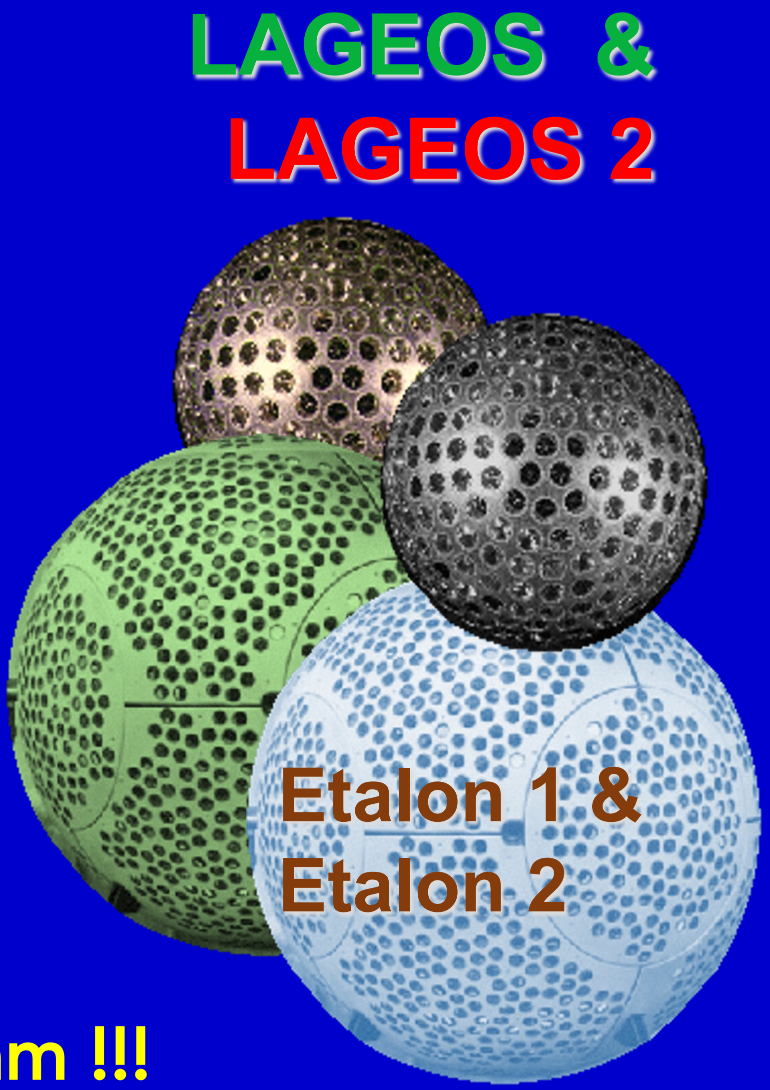
Zuheir Altamimi, IERS DB#74

Core Sites' 3D-WRMS 2015.0 - 2021.0



Summary

- The ILRS ASC stablished 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;
- The new bias model (SSEM-X) will be publicly available and maintained current over the coming years.



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

Thank you!