SLR residuals to GPS / GLONASS and combined GNSS-SLR analysis

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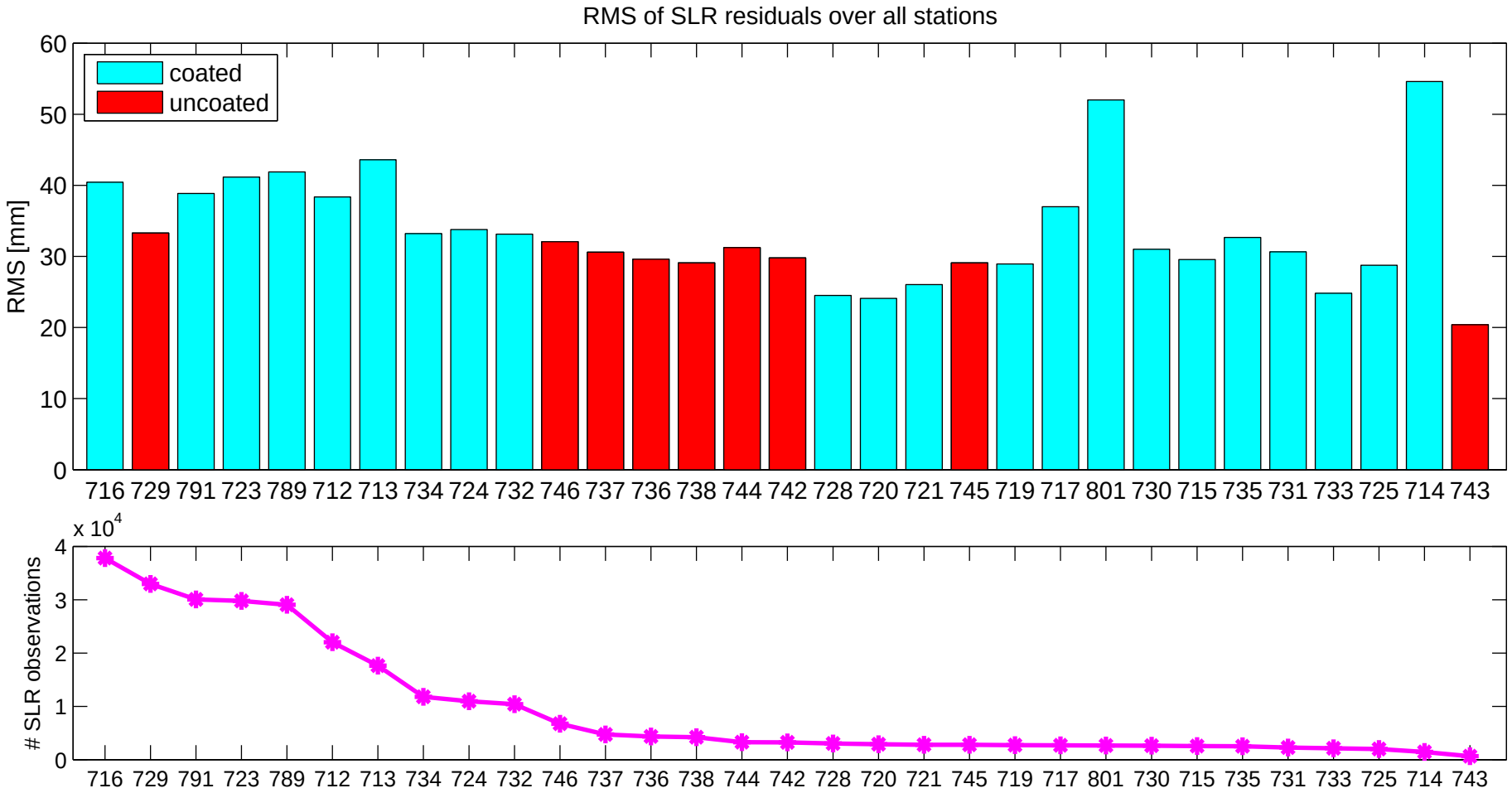
Overview

- GPS/GLONASS tracking 1996 – now:
  - SLR residuals to microwave orbits
  - Any difference between coated and uncoated arrays?
- Combined GNSS-SLR analysis 2000 – 2010:
  - Combination strategy
  - Range biases, antenna / reflector offsets (microwave and SLR)
  - Geocenter, scale
  - Orbits

GPS / GLONASS: SLR residuals w.r.t. MW orbit

- Microwave (MW) orbits from CODE reprocessing (1996–2010) + routine CODE-IGS processing (since 2011)
- 1996 – «now»
  - GPS: 2 satellites (mostly 1 satellite since 2009)
  - GLONASS since June 2003 (start for CODE MW orbits)
- 3–6 GLONASS satellites in ILRS tracking list
- Few stations track «full» GLONASS constellation:
  - 7840: since Dec. 2009
  - 7810, 7090, 7839, 7237, 7821, 7841, 1873: since mid-2011

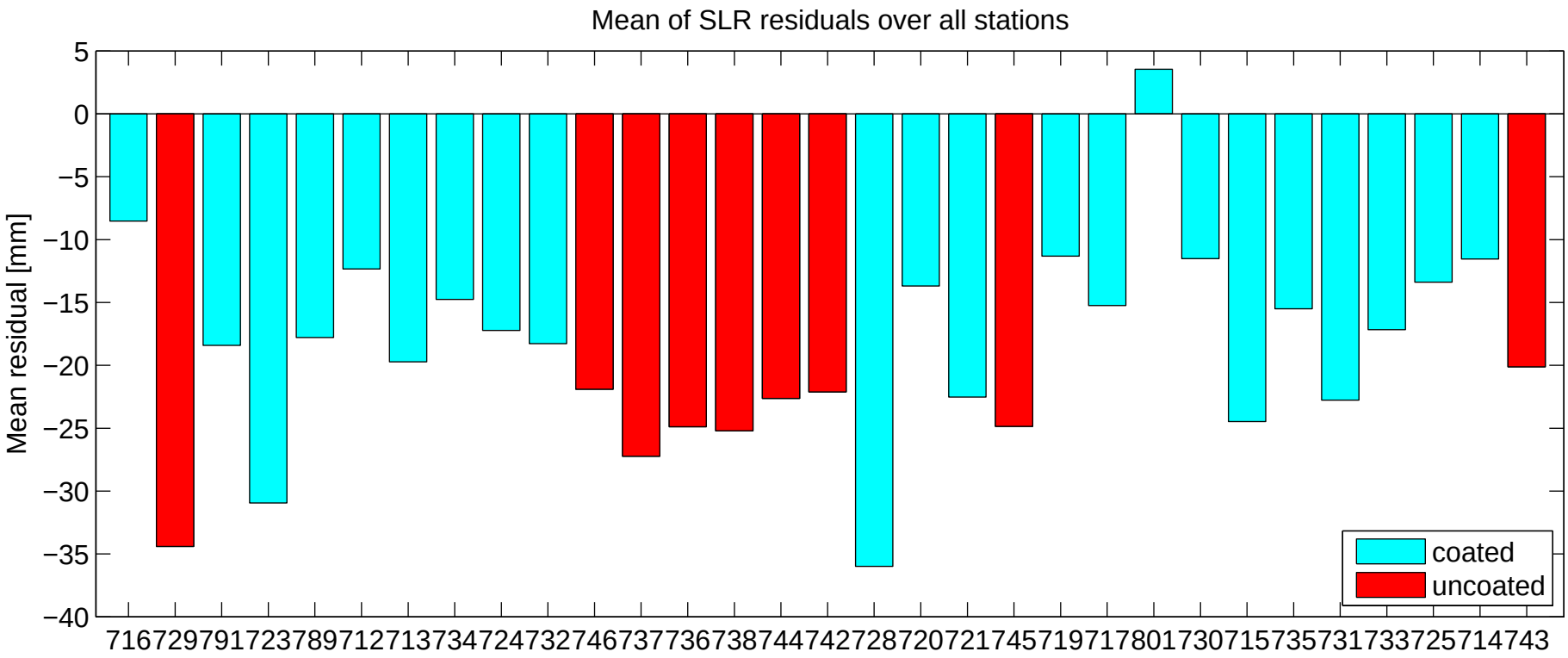
GLONASS: Coated vs. uncoated LRA



RMS over all stations:

- Slightly smaller RMS for uncoated reflectors (?)

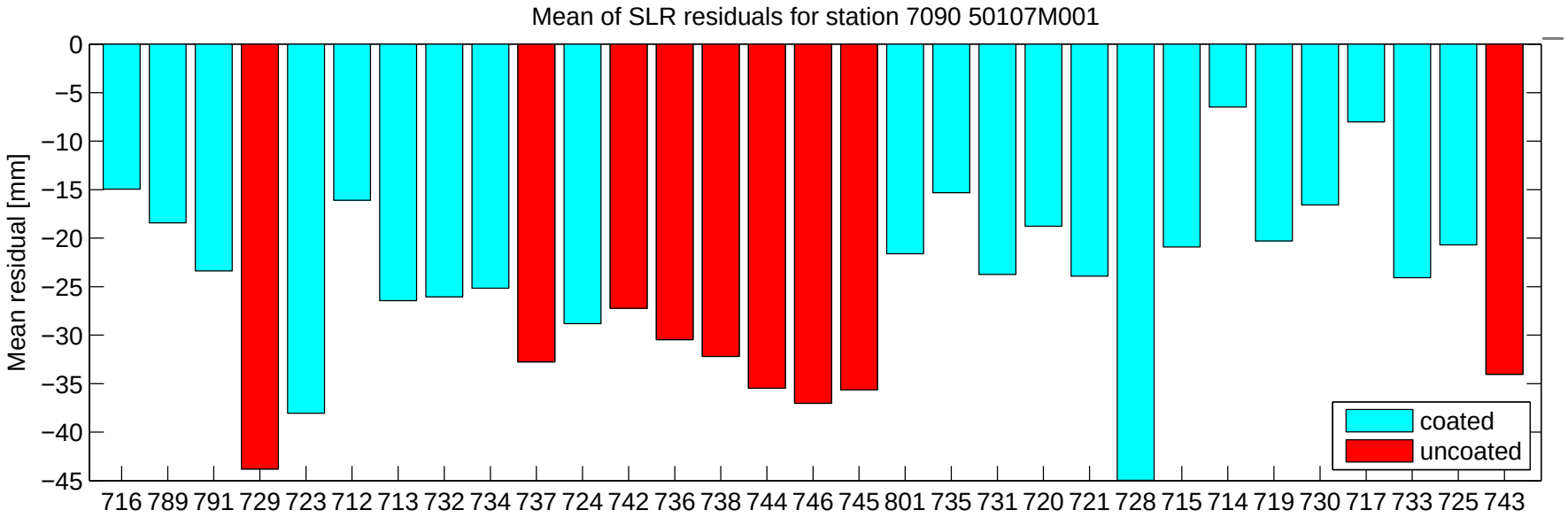
GLONASS: Coated vs. uncoated LRA

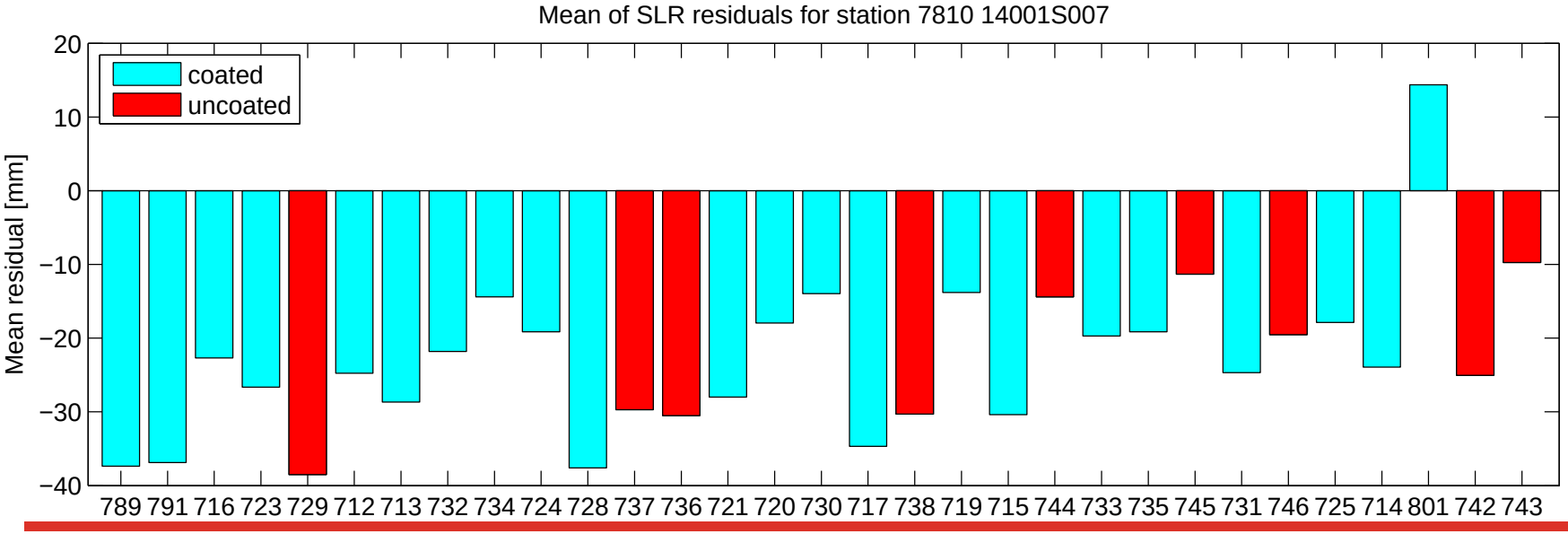


Mean over all stations:

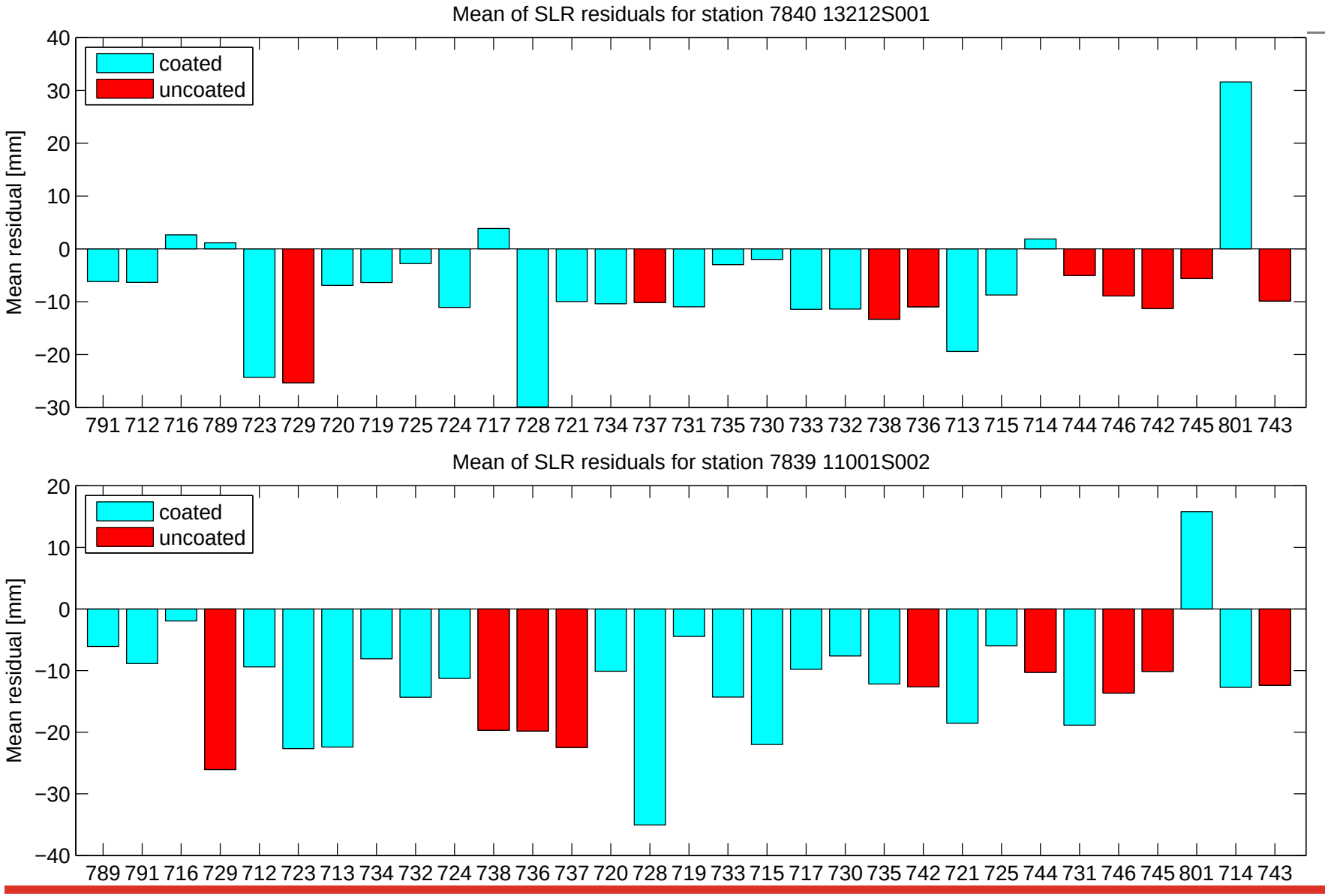
- Slightly bigger mean bias for uncoated reflectors (?)
- Closer to GPS mean bias: ~ −30 mm

GLONASS: Coated vs. uncoated LRA





GLONASS: Coated vs. uncoated LRA



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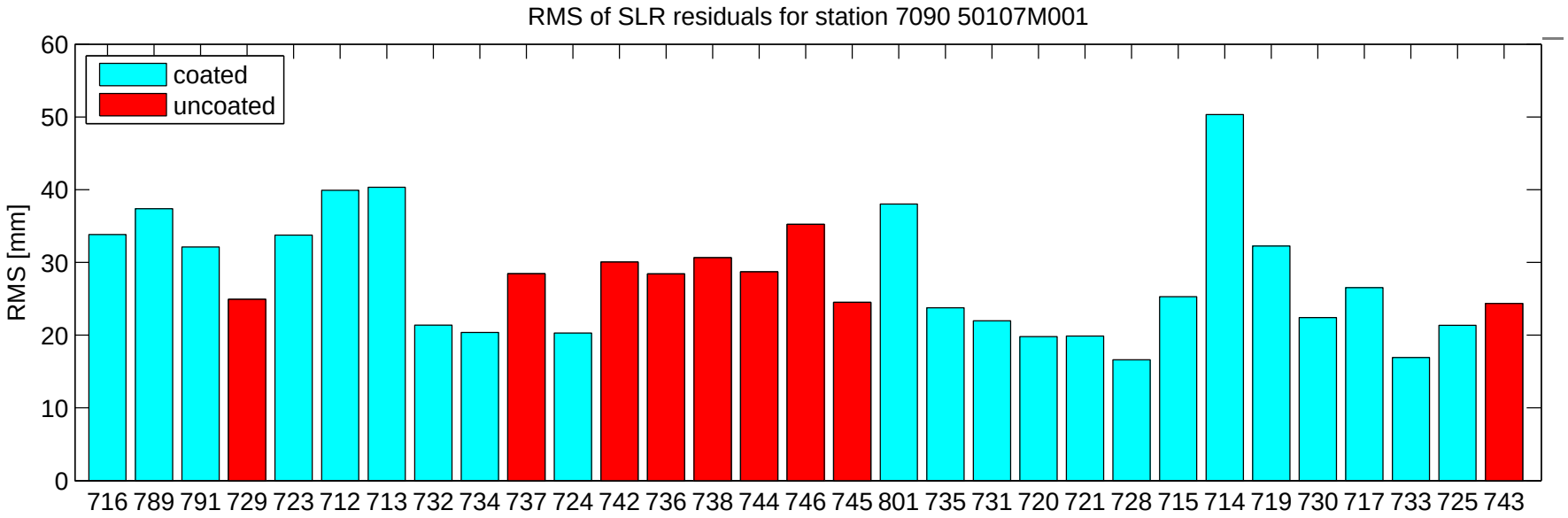
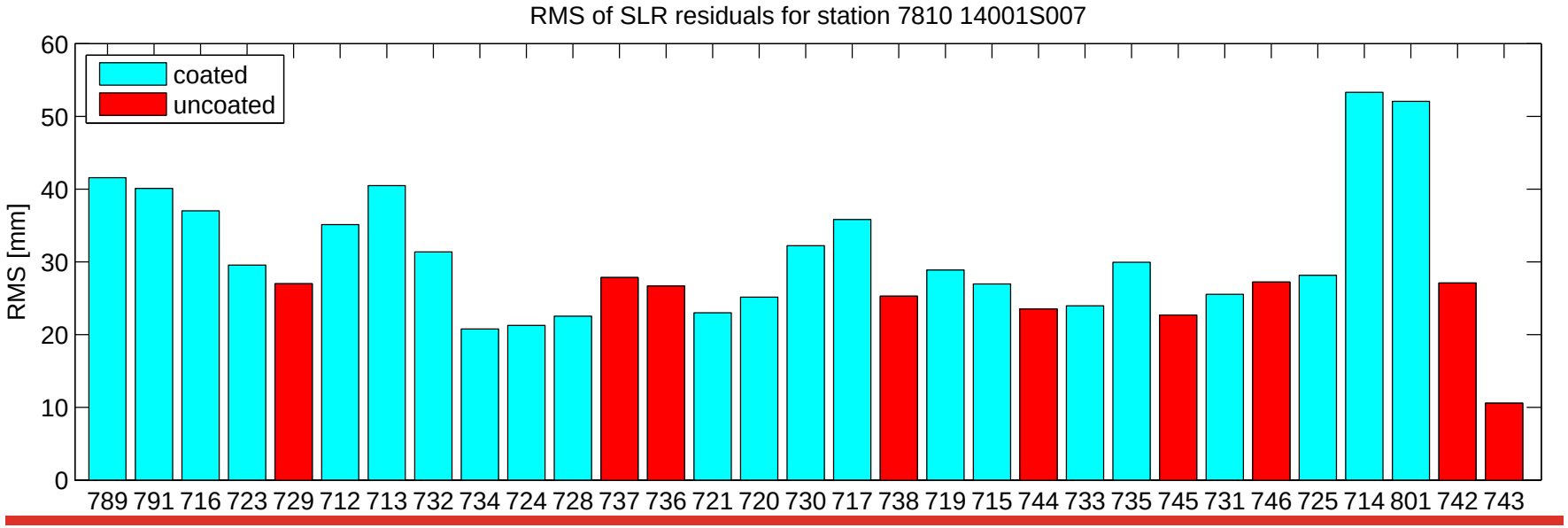
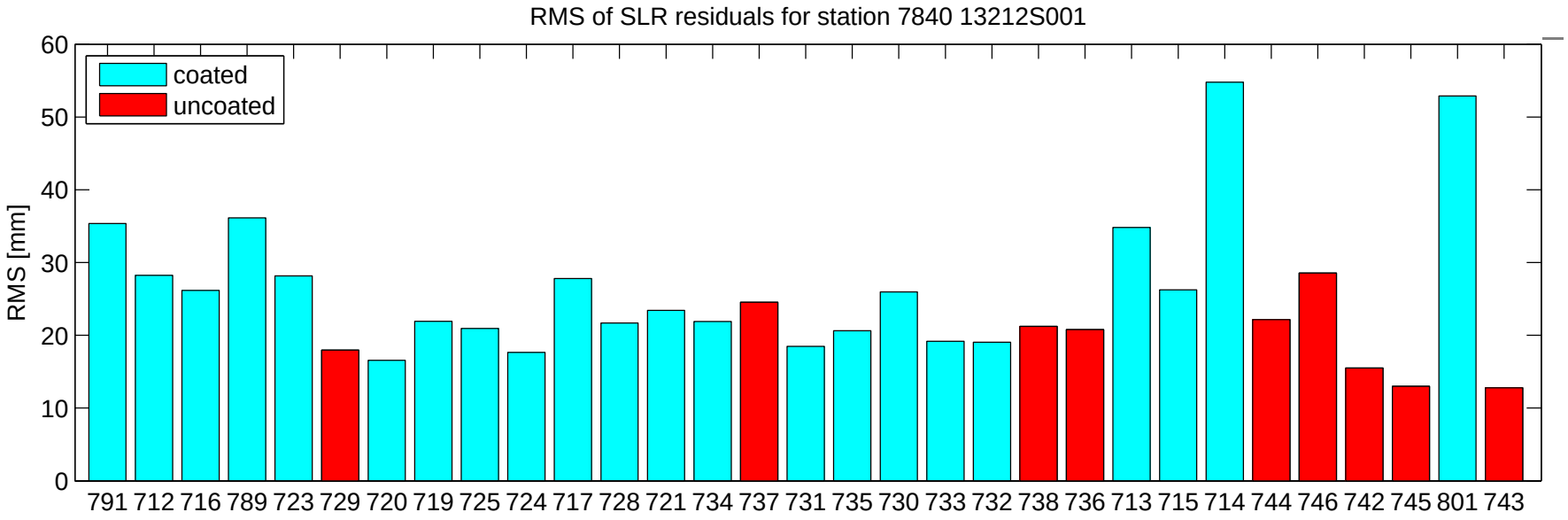
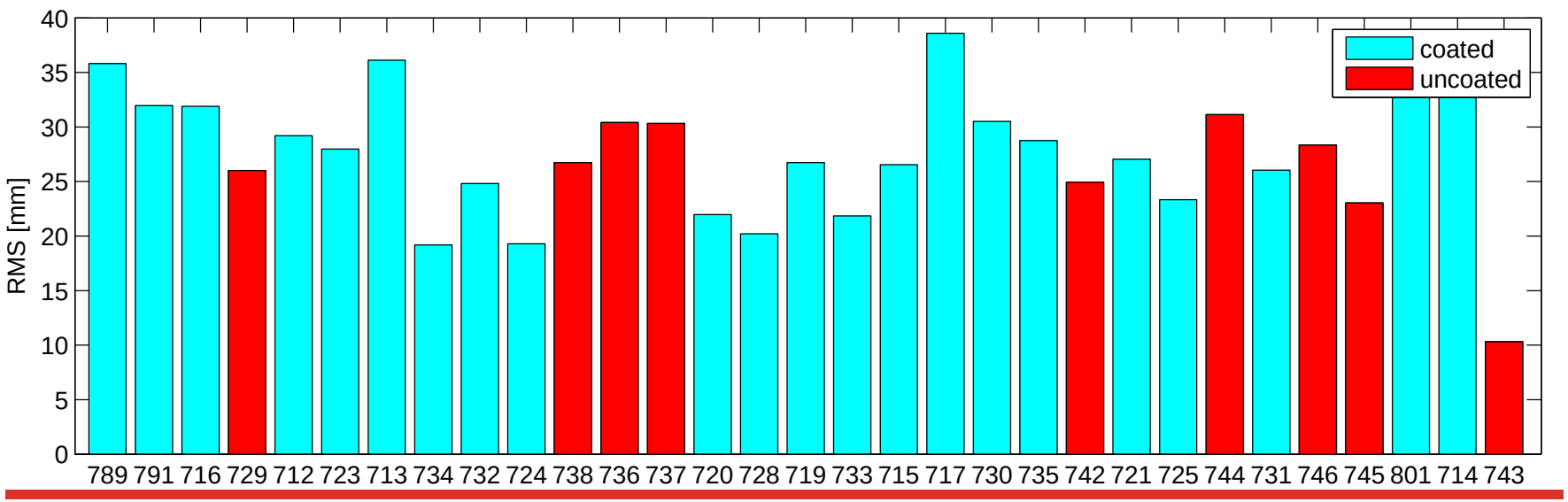




GLONASS: Coated vs. uncoated LRA





Summary: Coated vs. uncoated LRA

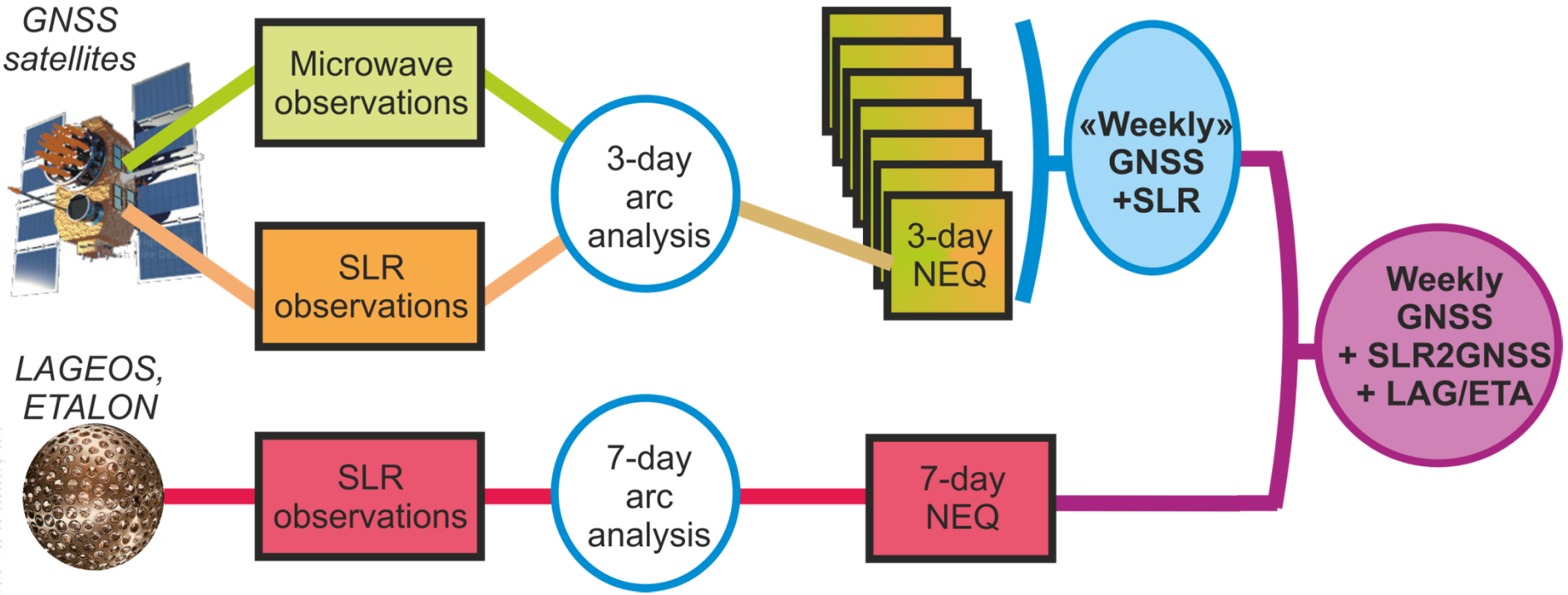
- Uncoated arrays on GLONASS are comparably new
- Small amount of SLR tracking data
- Indication that:
  - RMS becomes smaller
  - Mean bias becomes bigger (but similar to GPS)
- But: time-series should be extended

Combined GNSS-SLR solutions: Procedure

- Microwave observations to GPS / GLONASS
- SLR observations to GPS / GLONASS
- SLR observations to LAGEOS, Etalon

- Connection of SLR and GNSS at the GPS / GLONASS satellites („satellite co-location“)
- No local ties applied

Combined GNSS-SLR solutions: Procedure



- Connection of SLR and GNSS at the GPS / GLONASS satellites („satellite co-location“)
- No local ties applied

Combined GNSS-SLR solutions: Procedure

- 2000 – 2010
- GNSS NEQs from CODE reprocessing using the latest standards:
  - IGS08: antenna phase center model, reference frame
  - IERS Conventions 2010
  - Higher-order ionosphere terms
- SLR reprocessing for LAGEOS/Etalon at AIUB using the latest models:
  - IERS Conventions 2010
  - SLRF2008
- SLR NEQs for GPS / GLONASS have been generated consistently

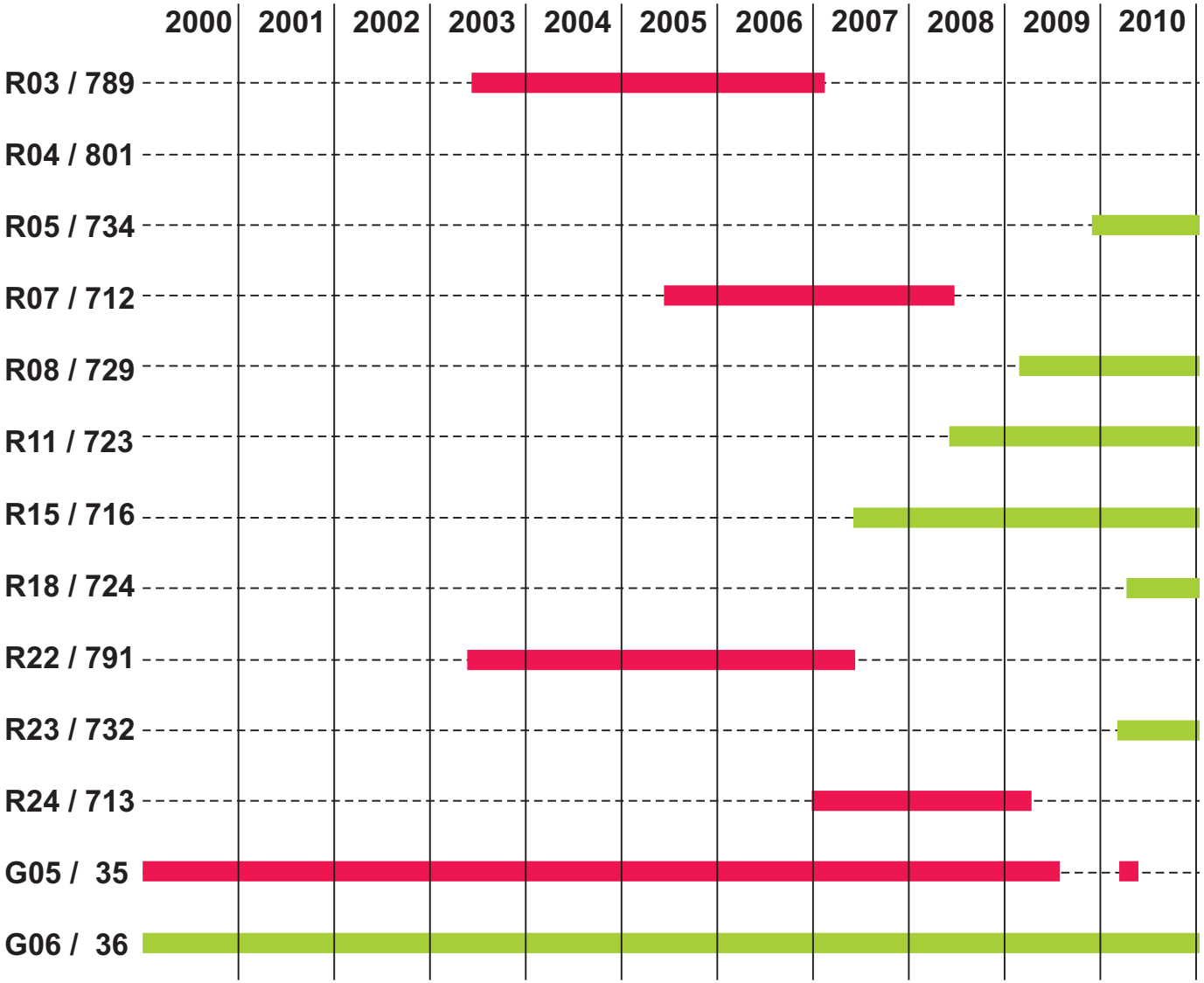
Combined GNSS-SLR solutions: Parameters

Common parameters for combination:

- Direct combination
- Indirect combination by applying correction terms («Local ties»)

Parameter	GNSS microwave	SLR@GNSS	SLR spherical satellites
Station coordinates	GNSS	SLR	SLR
Earth Rotation Params	X	X	X
Orbits GNSS satellites	X	X	
Orbits spherical satellites			X
Geocenter	X	X	X
Microwave SAO	X		
LRA offsets		X	
Range biases		X	X

Satellite co-location GPS / GLONASS



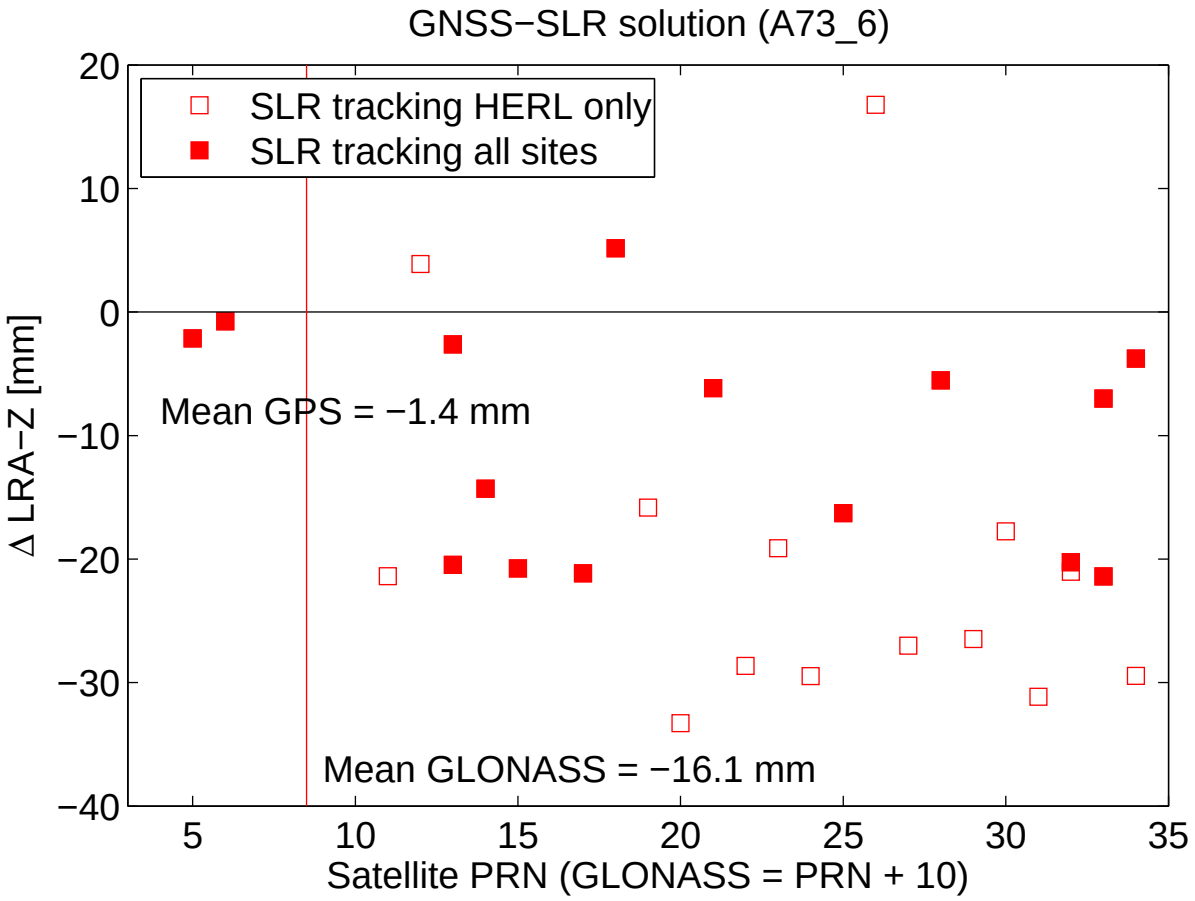
Satellite co-locations usable:

2 GPS satellites

+

2-6 GLONASS satellites

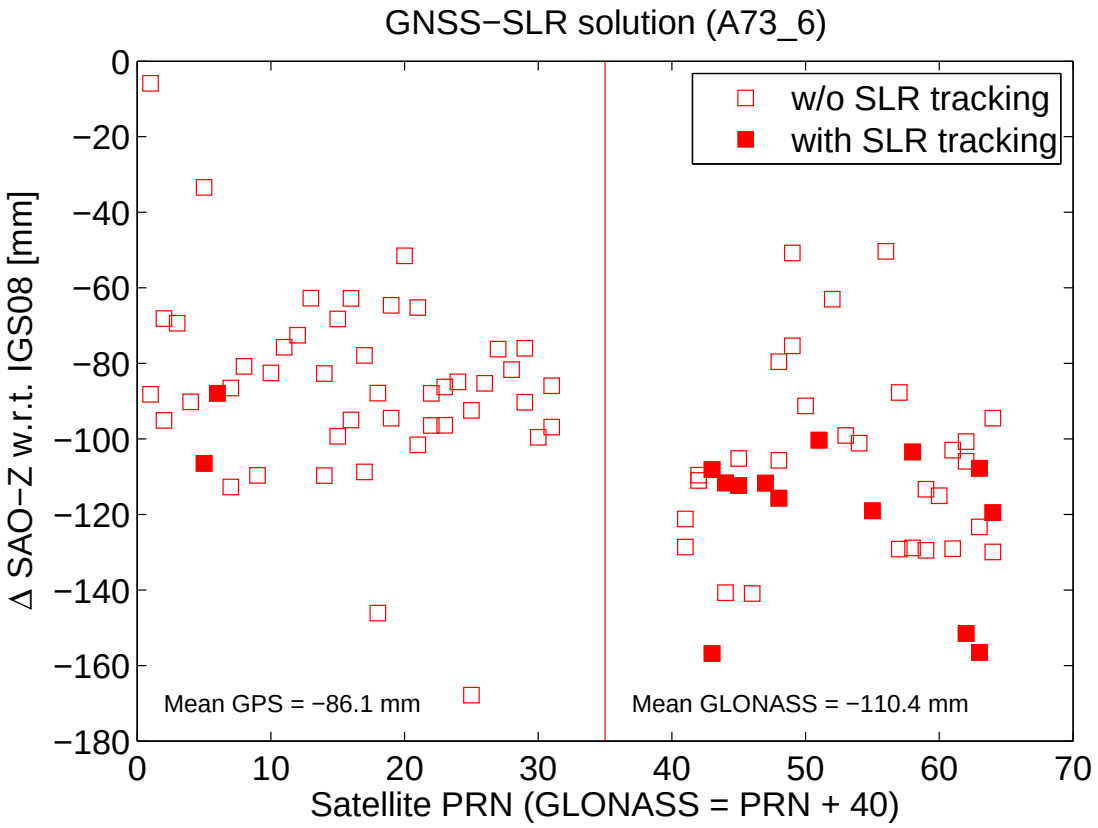
LRA from multi-year solution



⇒ see presentation on Tuesday:

The space tie between GNSS and SLR

SAO from multi-year solution



Δscale [ppb] =

$-7.8 \times \Delta SAO_Z$ [m]

Corrections to IGS08 values:

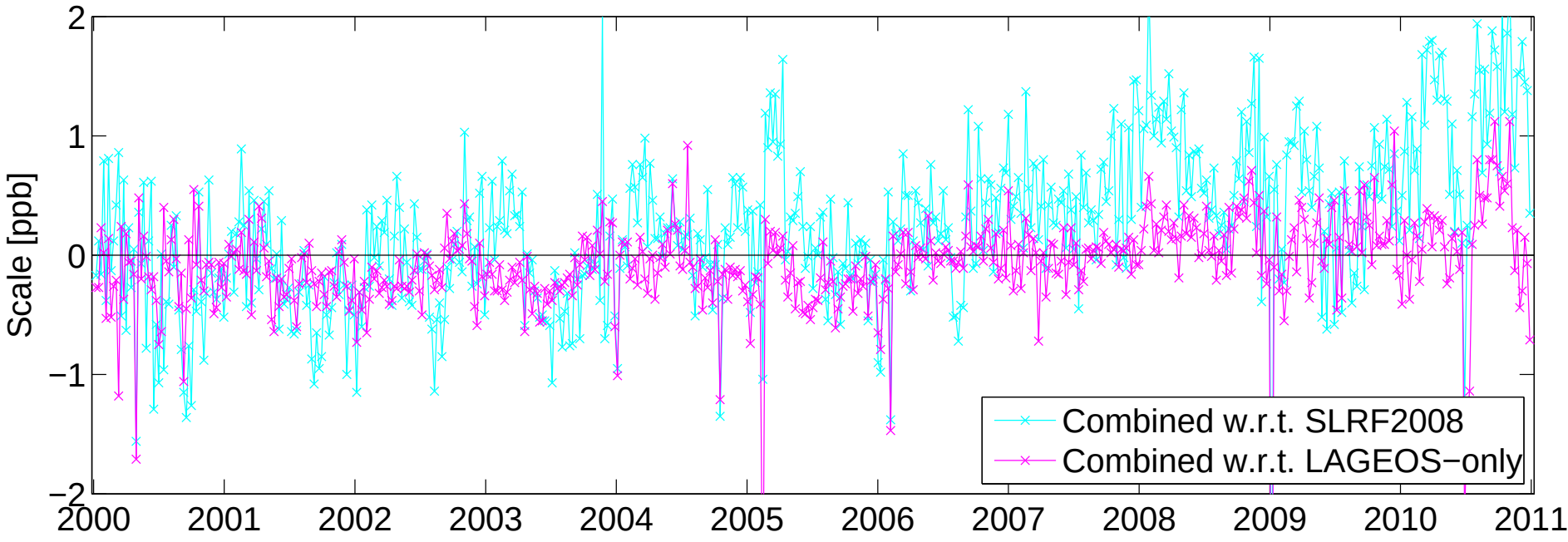
GPS: −86.1 mm

GLONASS: −110.4 mm

$\Rightarrow$ 0.67 ppb

$\Rightarrow$ 0.86 ppb

Solution verification: Scale



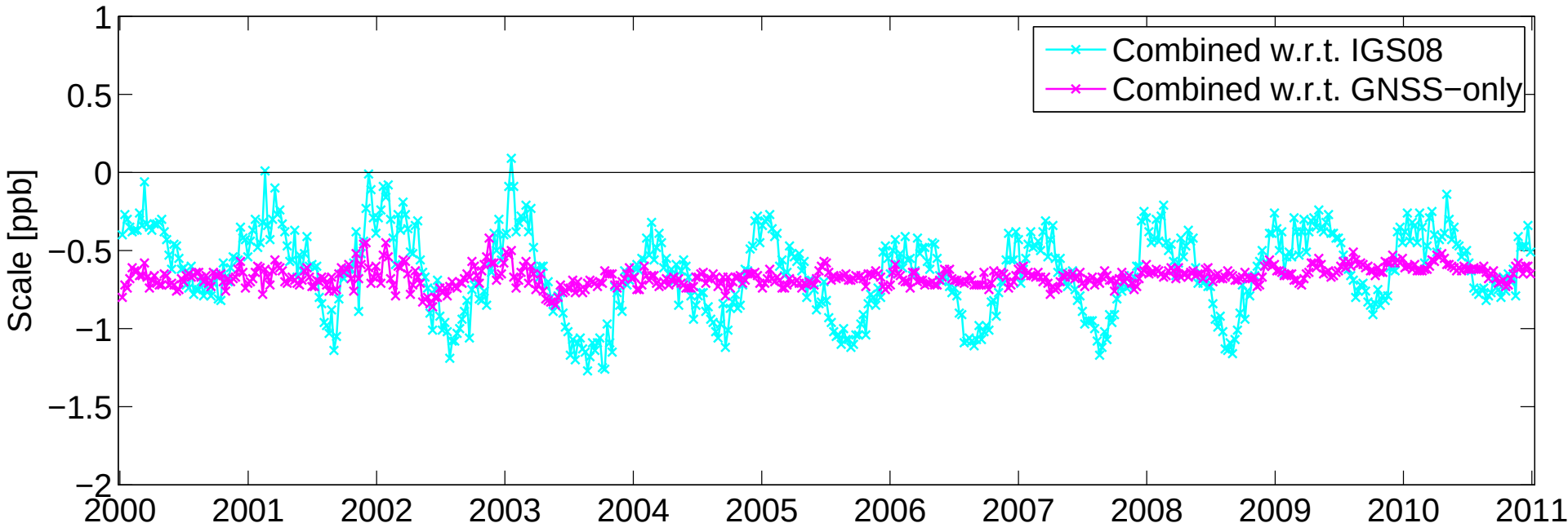
Goal for combined GNSS-SLR solution:

Scale should be dominated by LAGEOS

(GNSS: problems with antenna phase center modelling)

⇒ Differences w.r.t. LAGEOS-only solution visible, but small

Solution verification: Scale



Goal for combined GNSS-SLR solution:

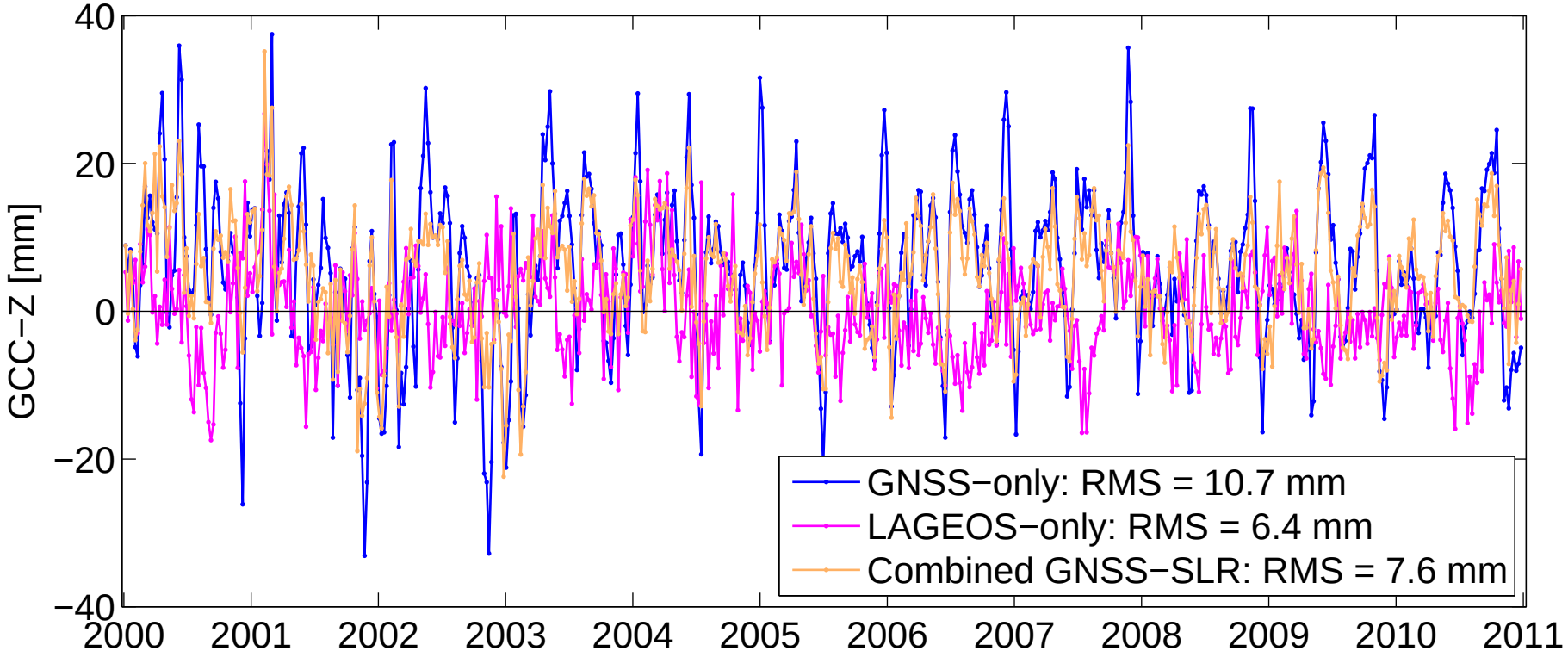
Scale should be dominated by LAGEOS

(GNSS: problems with antenna phase center modelling)

⇒ Differences w.r.t. GNSS-only: constant bias of -0.67ppb

⇒ Corresponds to corrections to microwave antenna offsets !!!

Solution verification: Geocenter



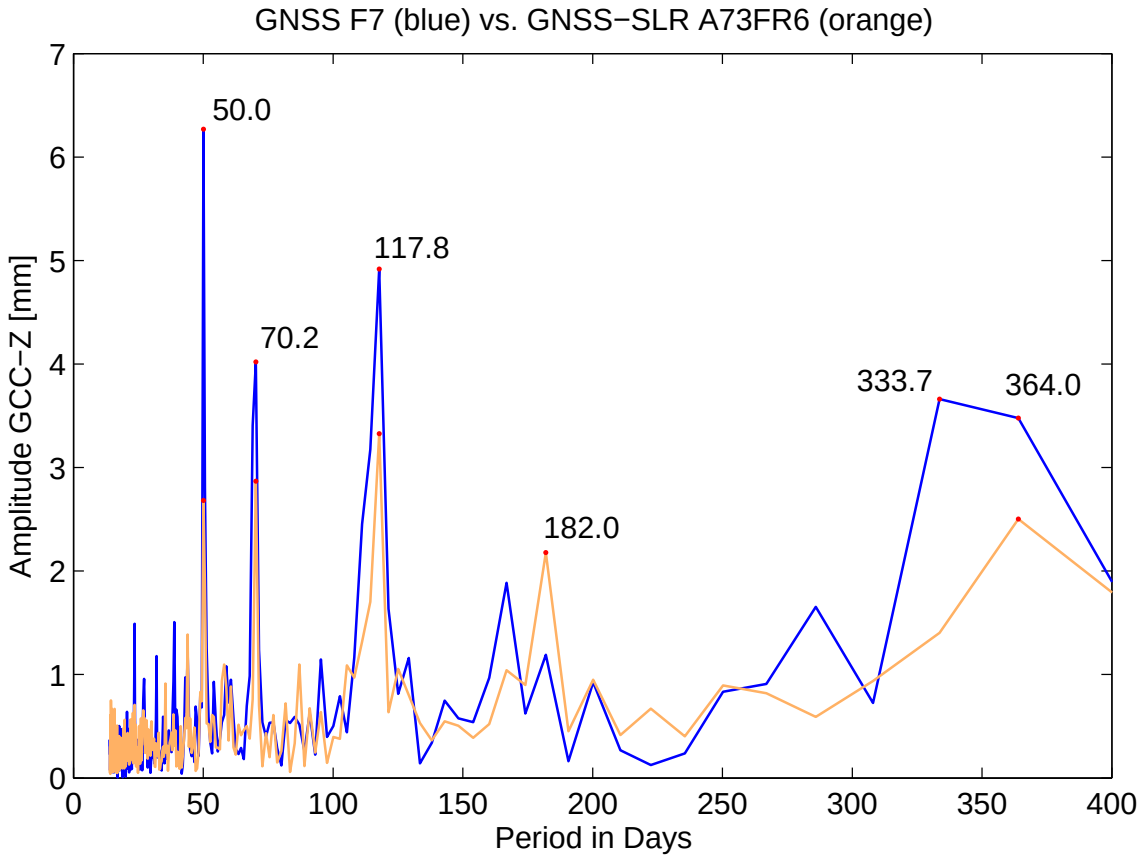
Goal for combined GNSS-SLR solution:

No artificial GNSS-related signals in z-geocenter

⇒ Noise in time series is reduced compared to GNSS-only,

⇒ But: slightly noisier than in LAGEOS-only (datum definition!)

Solution verification: Geocenter

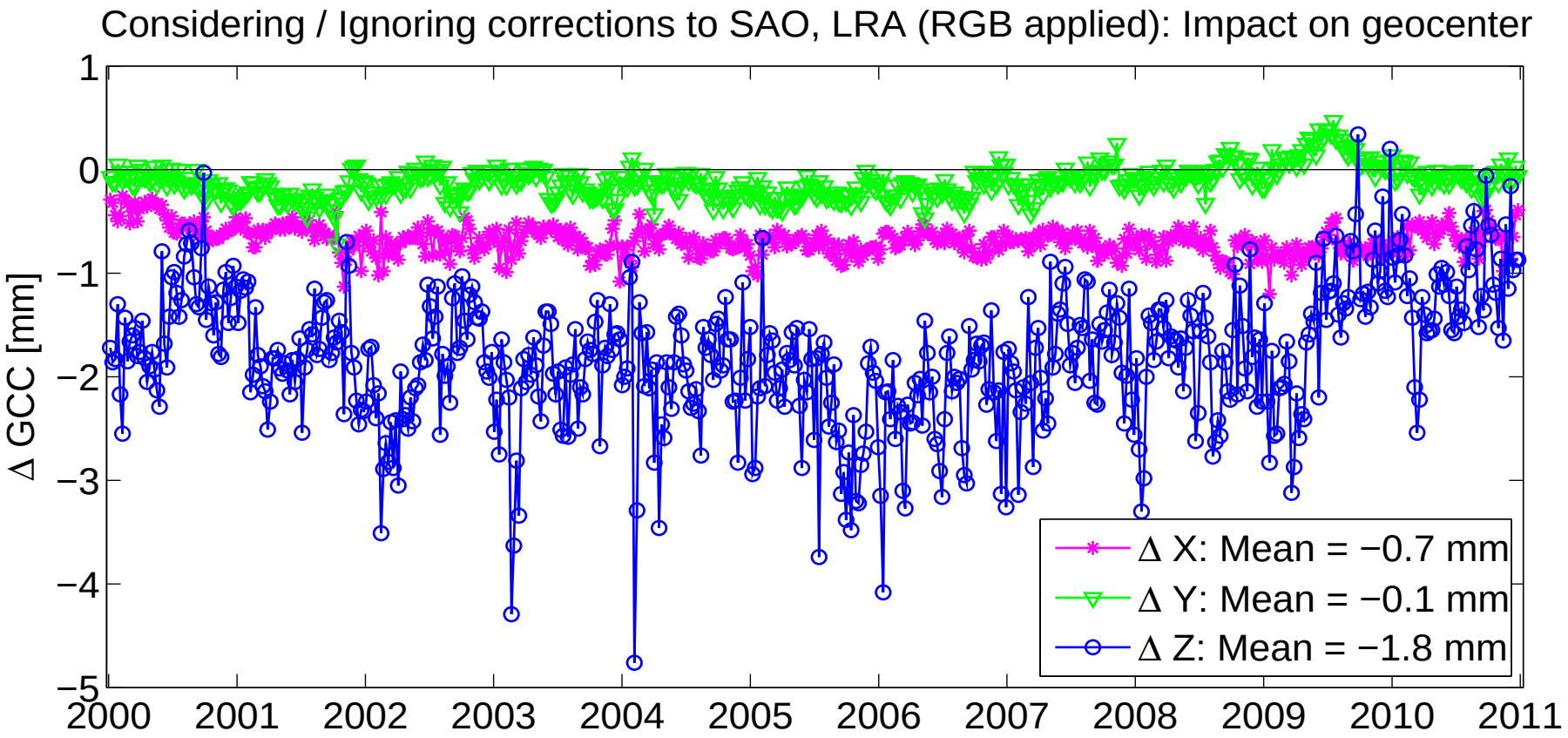


Goal for combined GNSS-SLR solution:

No artificial GNSS-related signals in z-geocenter

⇒ Periods are clearly reduced, but small effects remain

Solution verification: Geocenter



Comb 1: Range bias per station, per satellite considered

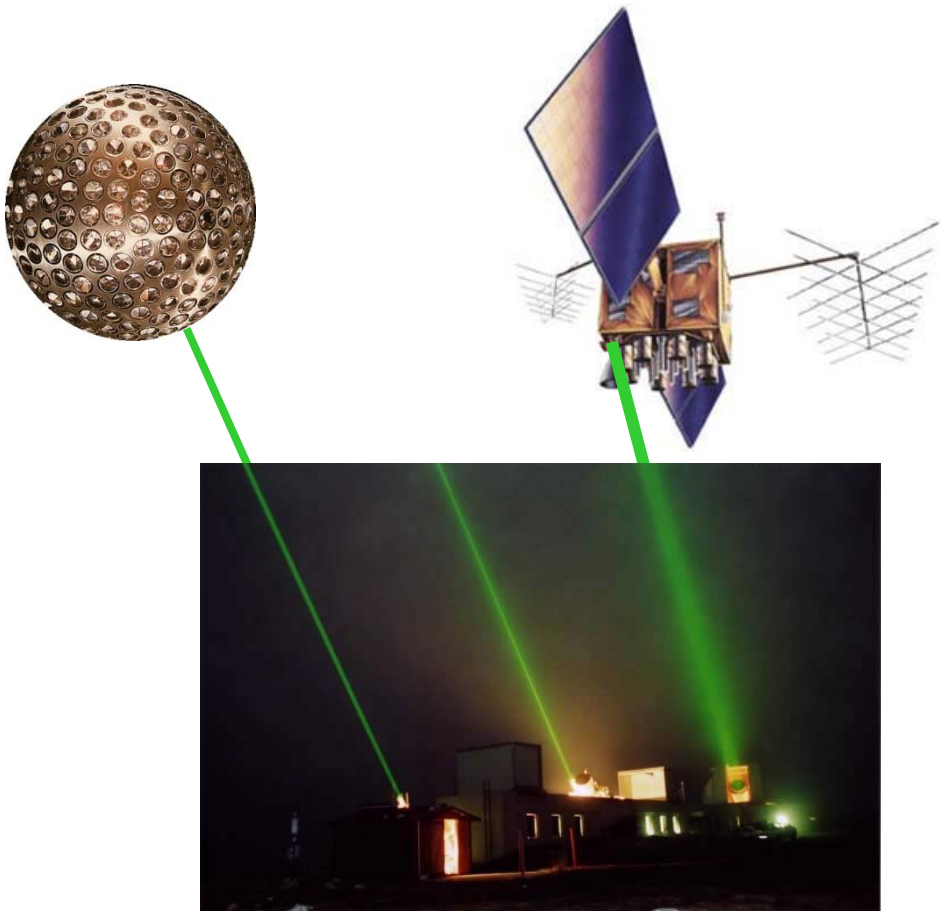
Comb 2: RGB, SAO, LRA corrections considered

⇒ **Bias** at mm-level (mainly in z-component)

Conclusions

- **Coated and uncoated reflectors** in residual analysis:
  - Bias: slightly larger for uncoated, but closer to GPS bias
  - RMS: smaller for uncoated reflectors
- **Combined GNSS-SLR analysis**:
  - Scale and geocenter are well transferred from SLR-LAGEOS to the combined solution
  - Microwave antenna offsets of IGS08 are not consistent with SLR scale: 86 mm ≙ 0.67 ppb
- **To be done**:
  - Performance of GNSS orbits from combined solution not yet satisfying
  - Extension to «now» (full GLONASS constellation since 2011)

Thank you for your attention



Especially thanks to the SLR stations for their additional effort of tracking the full GLONASS constellation

Solution verification: GNSS orbits

Goal for combined GNSS-SLR solution:

Improved orbit stability

⇒ Not yet reached!