

Benefit of tracking GNSS satellites with SLR

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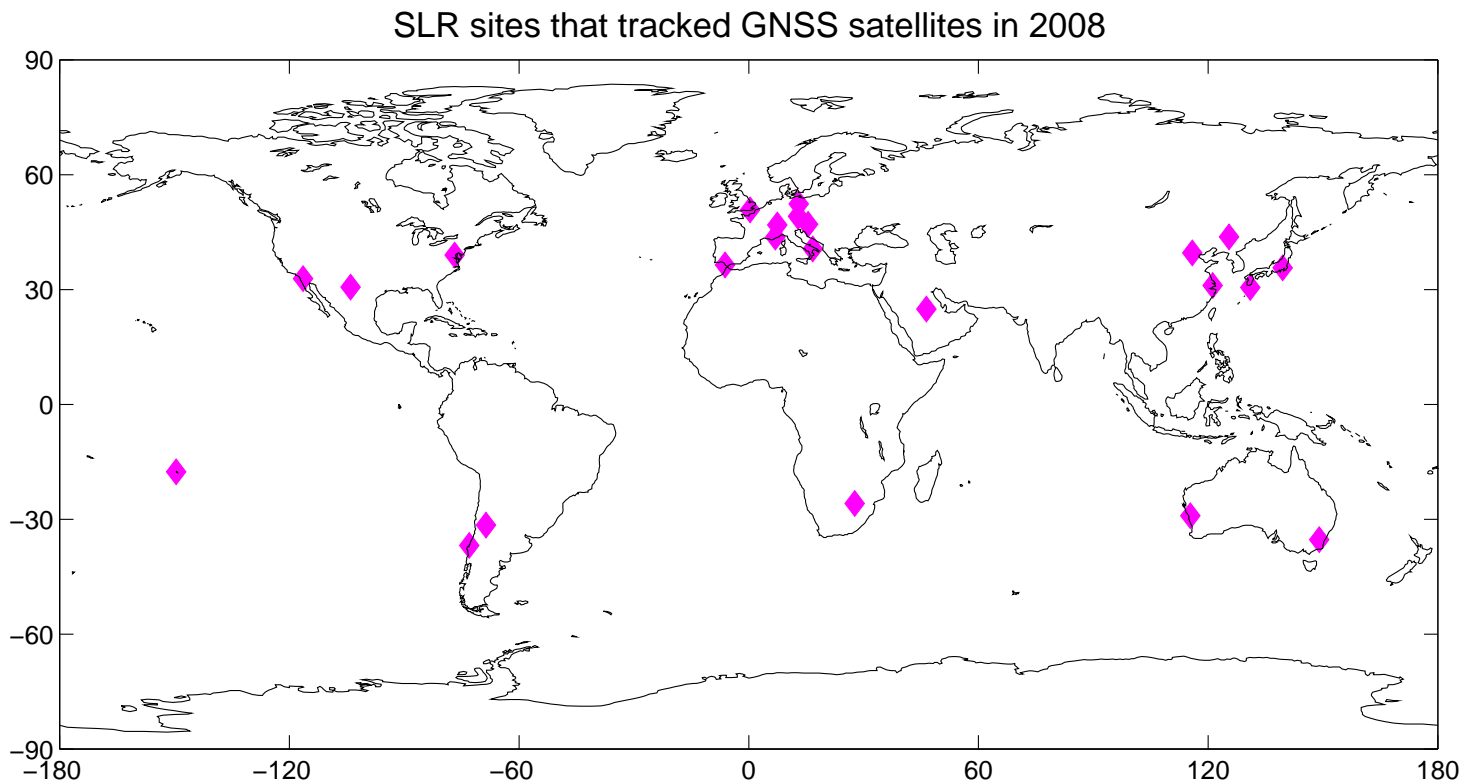
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Overview

1. **Statistics**
2. Two major applications:
 1. GNSS orbit validation using SLR
 2. **Combined GNSS+SLR solution**
3. **Expectation** from a combination GNSS and SLR@GNSS
4. **Results** from one year of combining GNSS and SLR@GNSS
5. Conclusions and outlook

Network in 2008

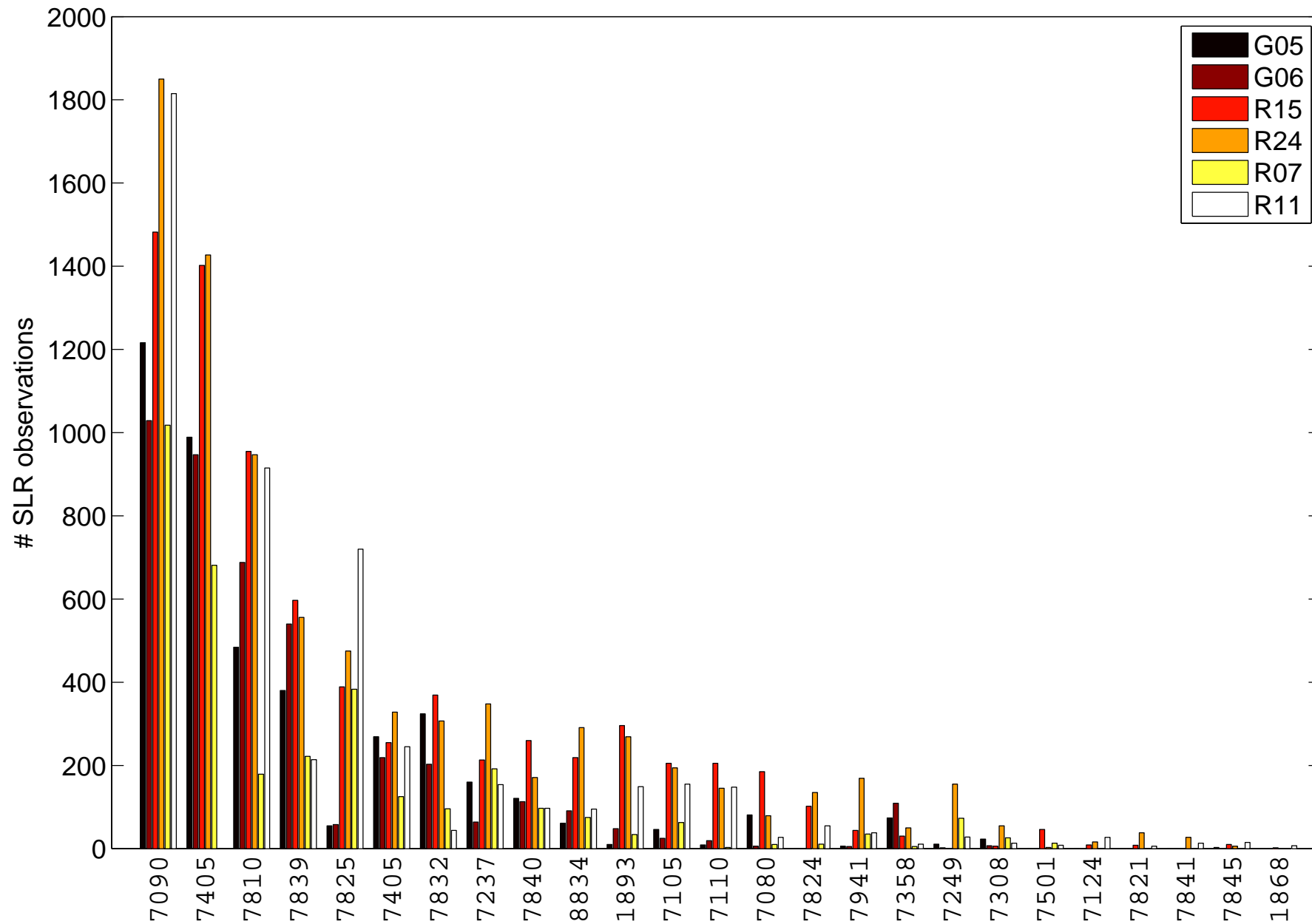


Altogether:
25 SLR sites
32165 normal points (NP)

8 sites with > 1000 NP
5 sites with > 500 NP
6 sites with > 100 NP
6 sites with < 100 NP

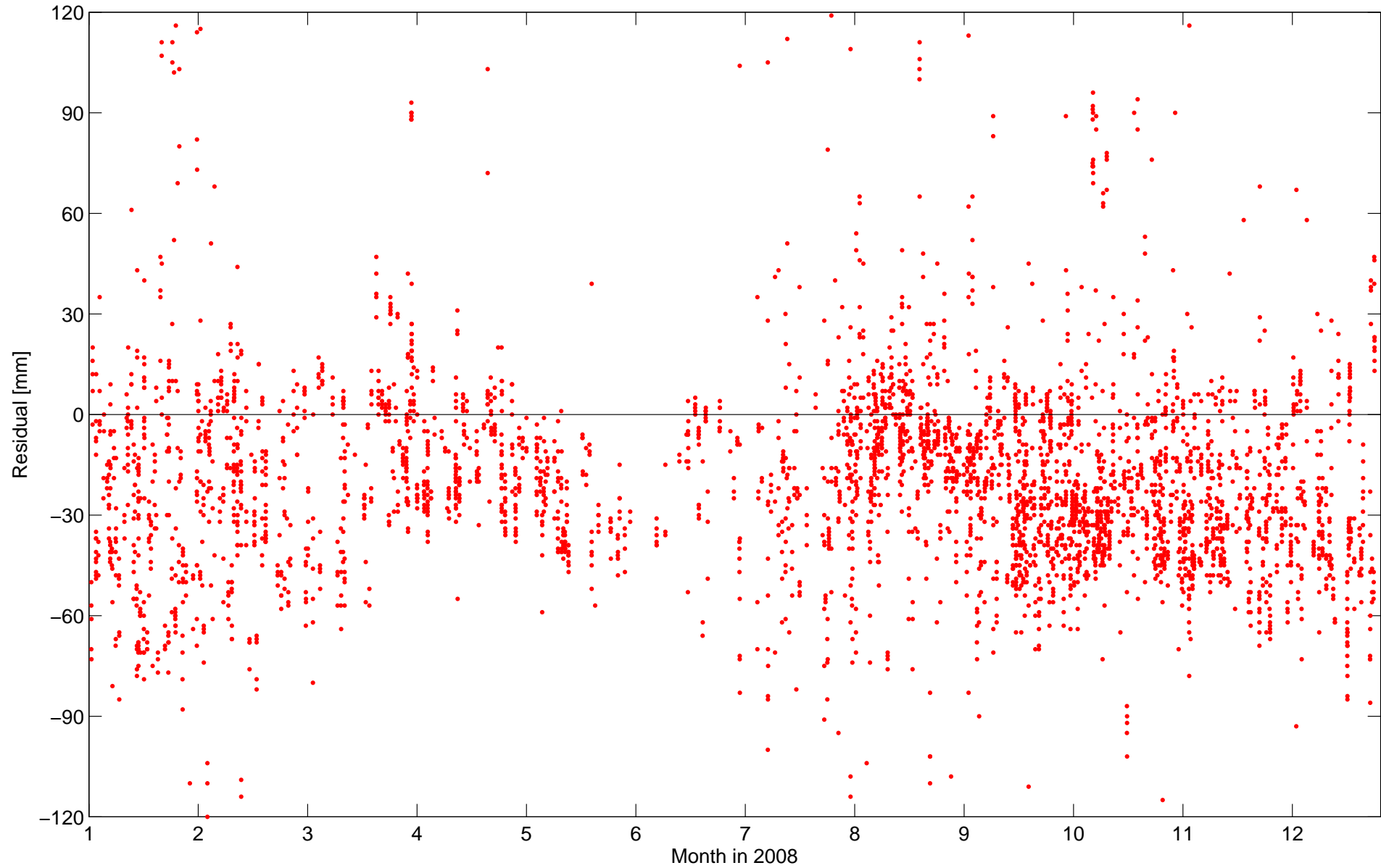
Number of observations in 2008

Number of SLR observations

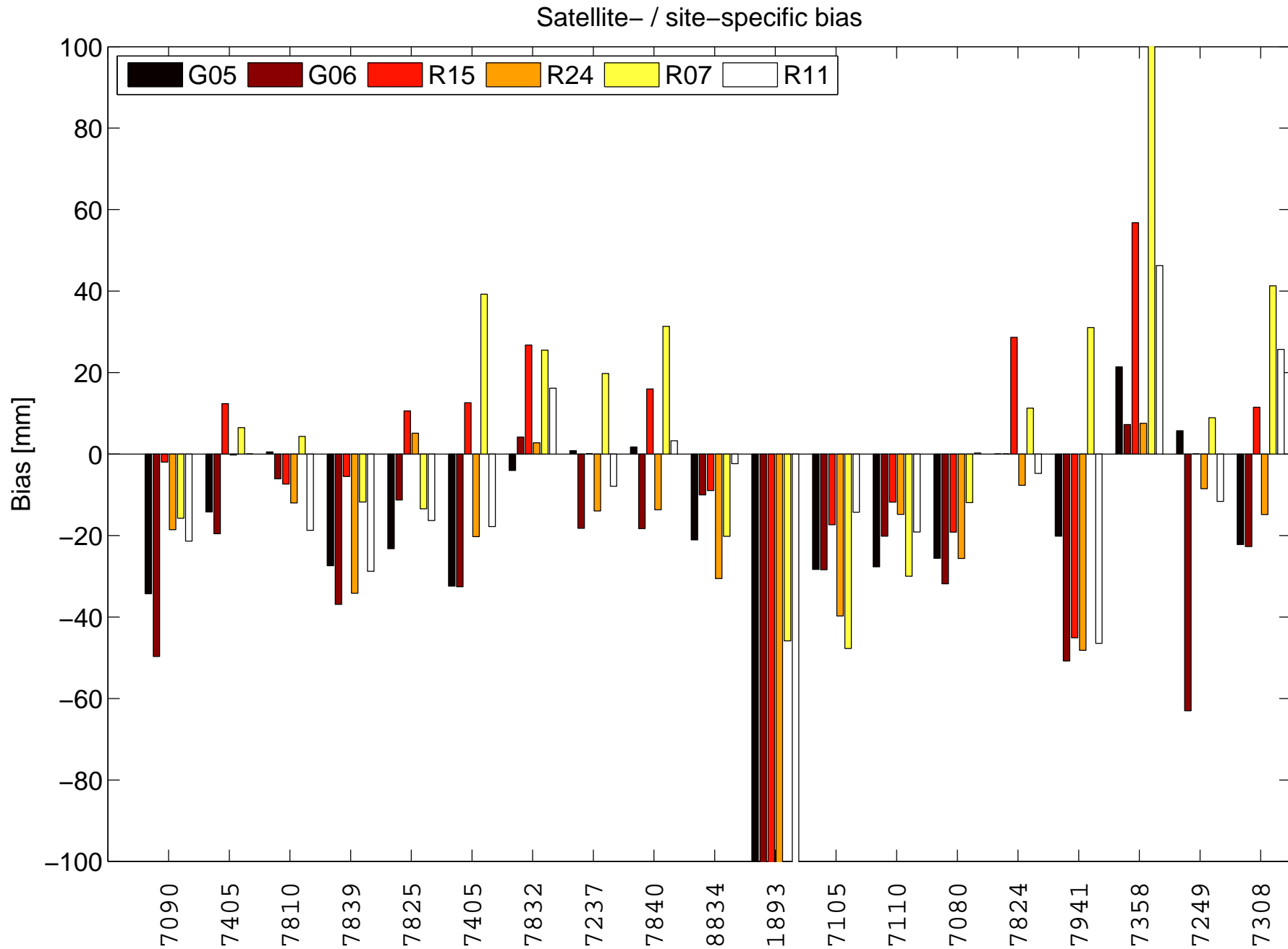


SLR residuals

SLR residuals for satellite G05, Orbit G3

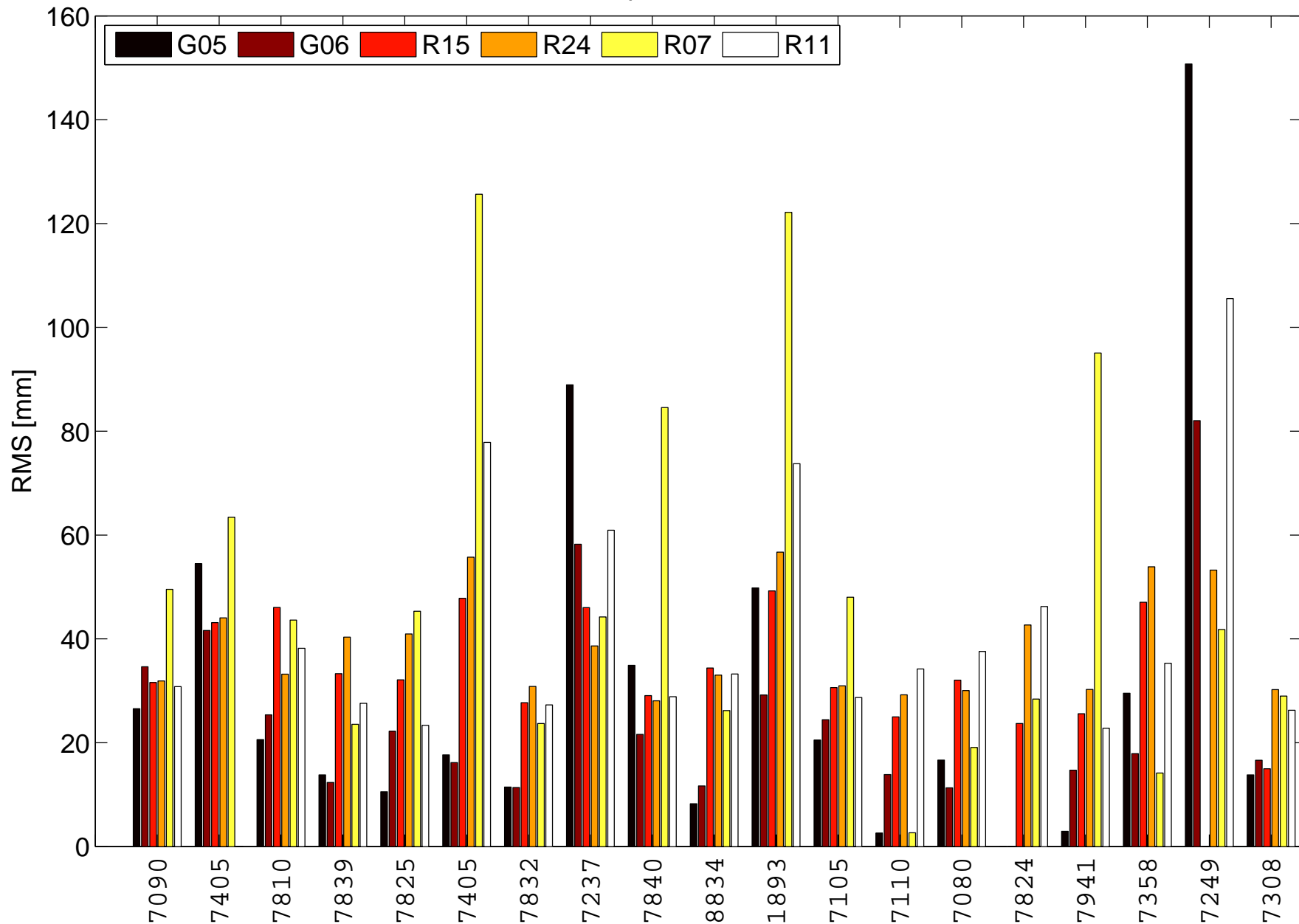


SLR residuals: Mean Bias



SLR residuals: RMS

Satellite- / site-specific RMS of SLR residuals



Expectation from combined analysis

Strength of *SLR to geodetic satellites* (Lageos,...): Reference frame scale and geocenter

⇒ **Applicable as well for SLR @ GNSS?**

GNSS deficiencies: modeling of radiation pressure and satellite antenna phase center

- Radiation pressure (RPR) correlated with **geocenter**

- Antenna phase center correlated with **scale**

⇒ GNSS scale and geocenter not “true”

SLR@GNSS:

- RPR parameters have to be estimated from SLR as well

⇒ Geocenter is affected as well

- SLR observations independent from GNSS antenna phase center

⇒ Scale can be gained from SLR

Expectation from combined analysis

	GNSS @GNSS	SLR @GNSS	SLR @Lageos
Radiation pressure ↔ Geocenter	Problems in RPR modelling	Problems in RPR modelling	RPR well modelled
GNSS satellite antenna phase center ↔ Scale	Problems in phase center modelling	independent	-
Range biases ↔ Scale	-	To be defined	For a few sites only

Other topics to be considered:

- “Local ties” and “space ties”

GNSS+SLR combination

- Studies using one year of data: 2008
- Analysis and combination with the *Bernese GPS Software*
- **GNSS-only NEQs (daily):**
 - Combined GPS+Glonass analysis performed at CODE
- **SLR-only NEQs (daily):**
 - SLR data to GPS and Glonass satellites
 - Parameterization identical to GNSS analysis (orbits, ERP, geocenter)
 - In addition: Range biases
- **Combination on normal equation level:**
 - Daily combination
 - Accumulation to annual solution
 - Use of “space ties” only, no “local ties”!

Validation of estimated coordinates and of datum definition:

- Comparison of coordinate differences at co-located GNSS–SLR sites using **local tie values**
- Helmert transformation of combined solution to GNSS-only and SLR-only solutions: **Scale**

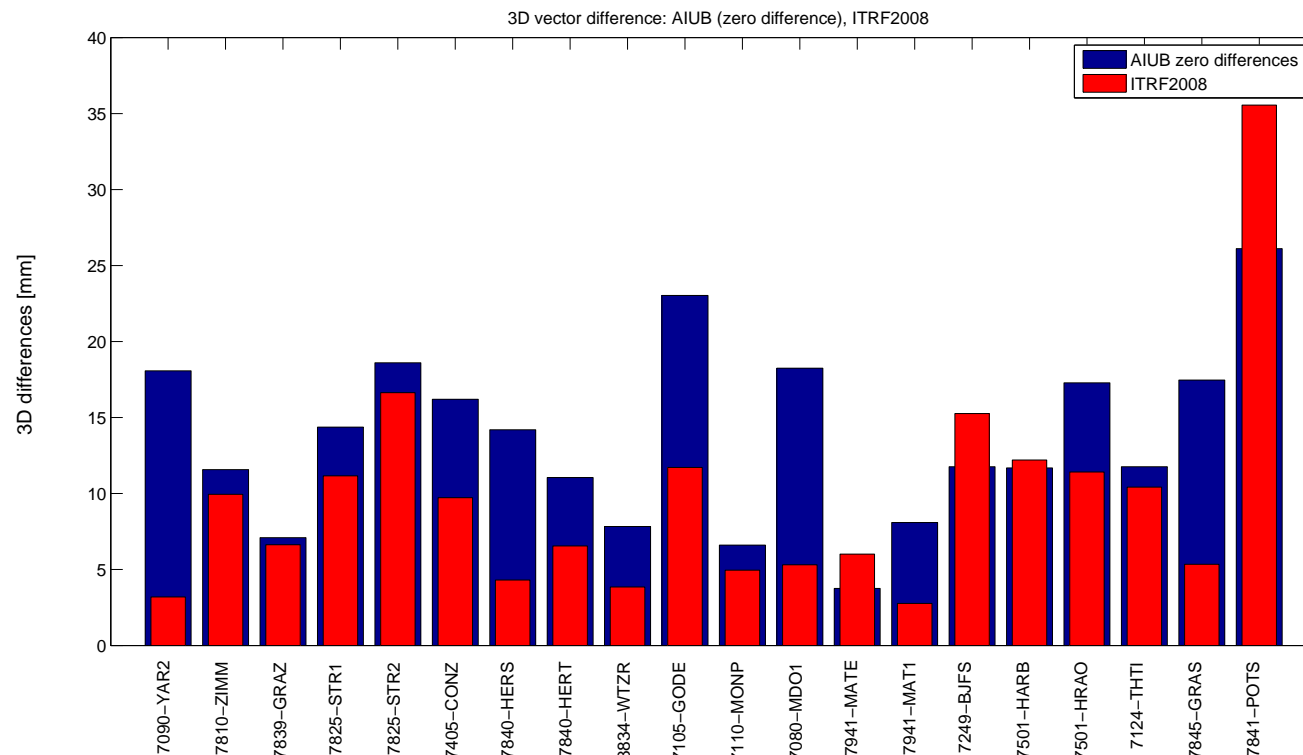
Parameters to be checked:

- **SLR range biases**
- GNSS satellite antenna offsets
- Geocenter
- Orbits
- ...

Comparison with local ties

Level of agreement when using one year of data only

- Coordinate differences from GNSS-only and SLR-only solutions (1 year)
- Datum definition for both solutions using NNR+NNT (core sites)
- Velocities from ITRF2005



Red:
ITRF2008 (prelim.)

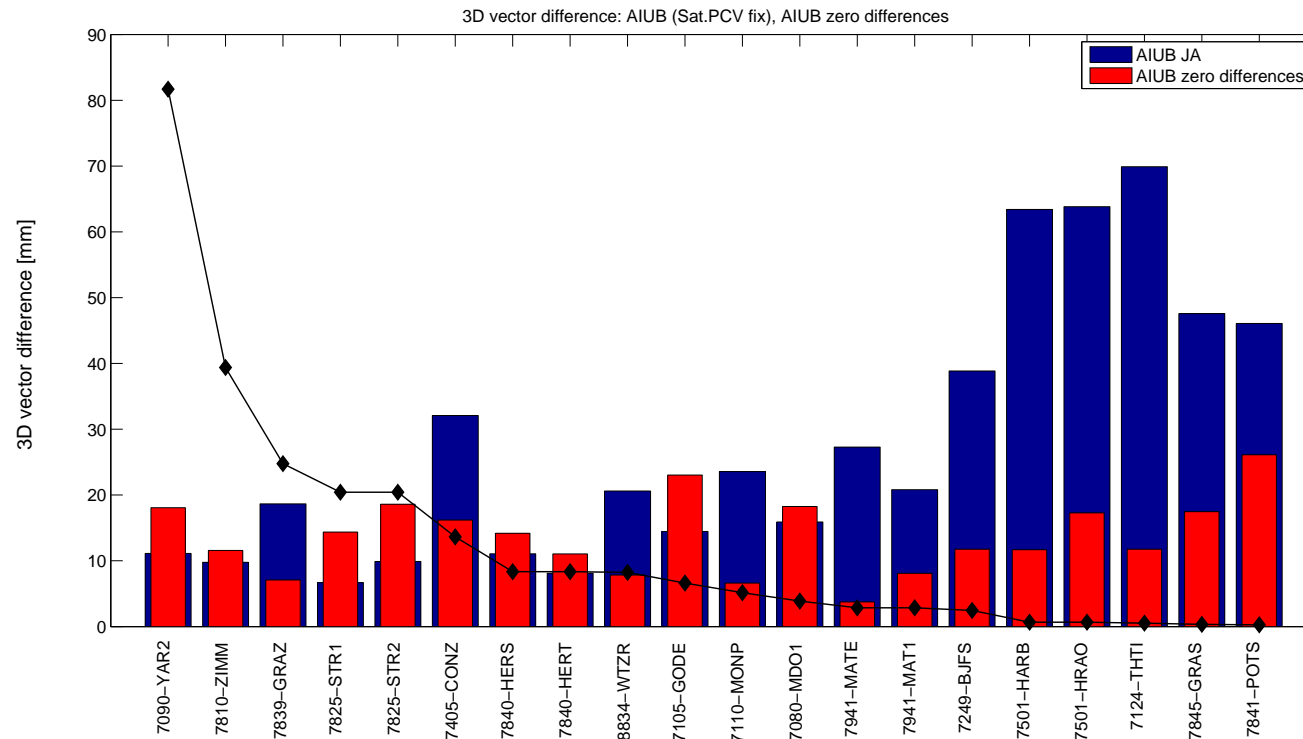
Blue:
From annual
single-technique
solutions

Plot provided by M. Seitz, DGFI

Comparison with local ties

Changes when combining GNSS and SLR@GNSS using „space ties“ only

- Combined yearly GNSS+SLR solution
- Datum definition: NNR+NNT (GNSS core sites), **no Local ties**
- **GNSS antenna phase center (SAO) fixed** = Scale defined by GNSS and SLR



Red:
From annual
single-technique
solutions

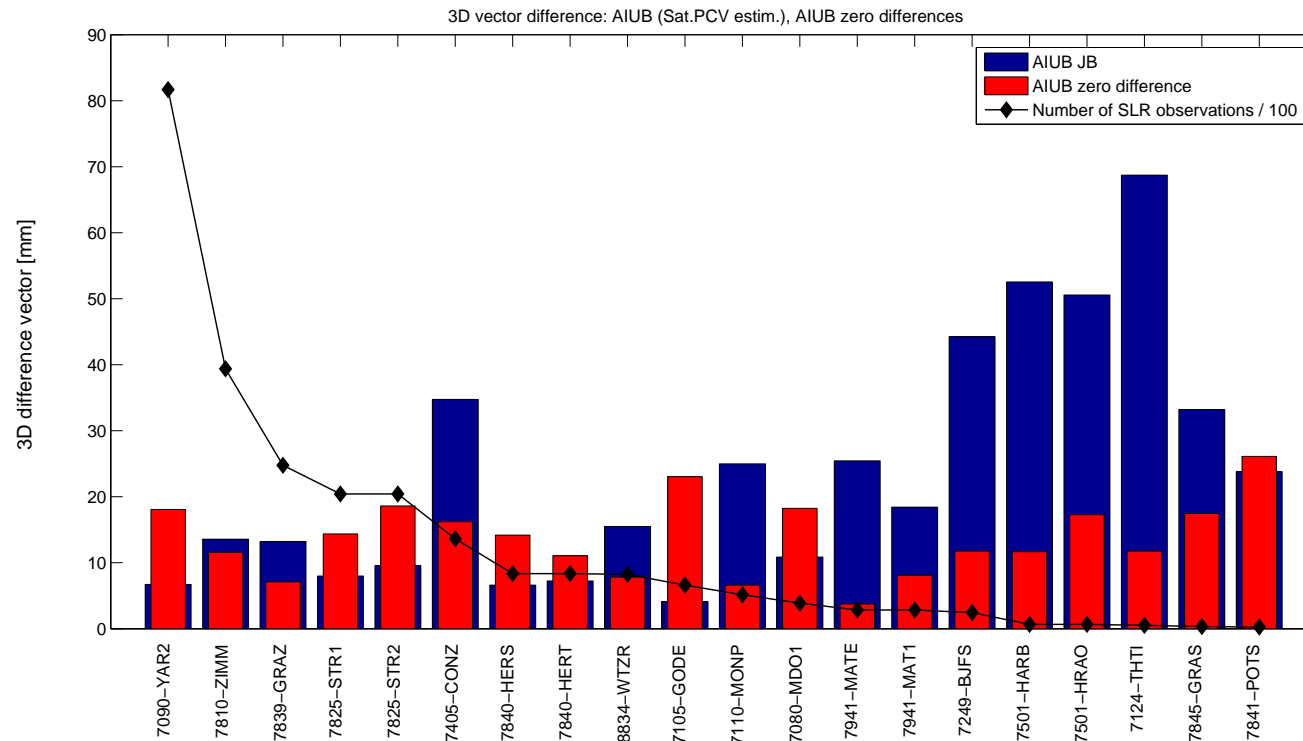
Blue:
Combined solution,
GNSS SAO fixed

Plot provided by M. Seitz, DGFI

Comparison with local ties

Changes when combining GNSS and SLR@GNSS using „space ties“ only

- Combined yearly GNSS+SLR solution
- Datum definition: NNR+NNT (GNSS core sites), **no Local ties**
- **GNSS antenna phase center (SAO) estimated** = Scale defined by SLR only!



Red:
From annual
single-technique
solutions

Blue:
Combined solution,
GNSS SAO estimated

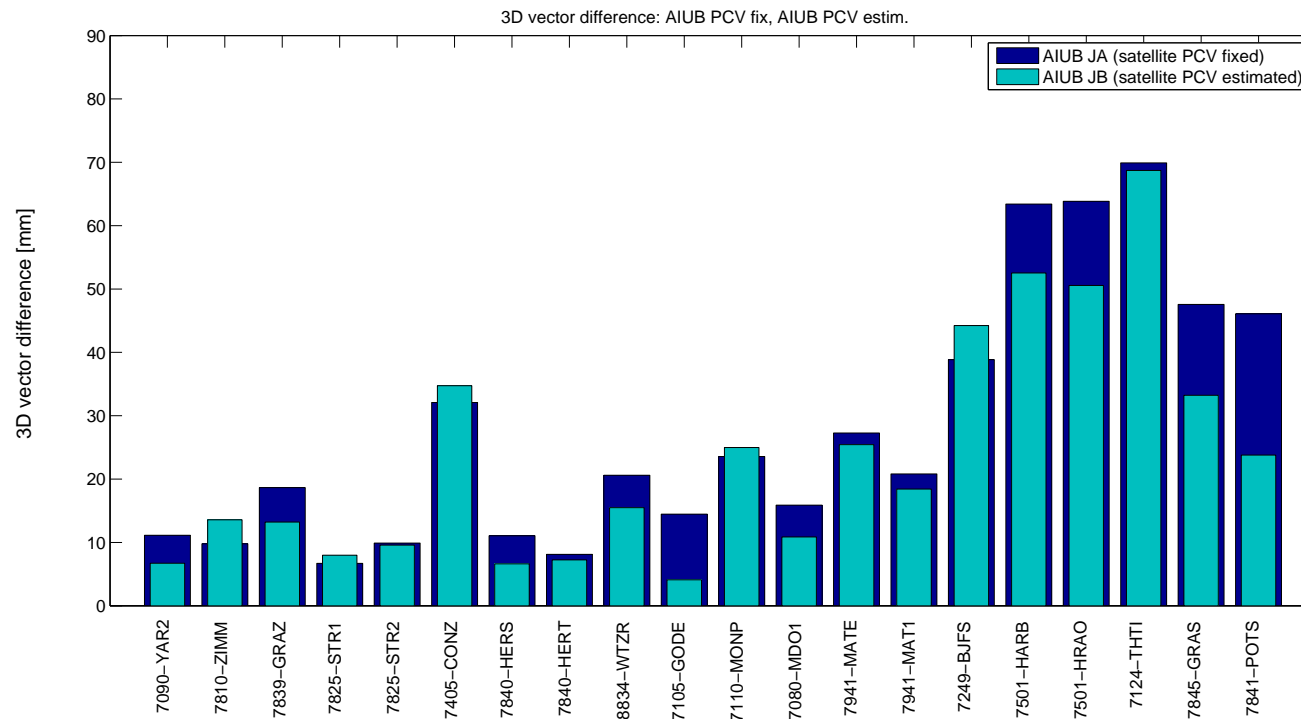
Plot provided by M. Seitz, DGFI

Comparison with local ties

Impact of GNSS antenna phase center (SAO) estimation:

→ No big differences \Rightarrow Estimation of SAO is possible

→ Slightly better agreement with local ties if scale is NOT defined by GNSS (has to be verified using longer time span of data!)



Blue:
Combined solution,
GNSS SAO fixed

Green:
Combined solution,
GNSS SAO estimated

Plot provided by M. Seitz, DGFI

SLR range biases

Question 1:

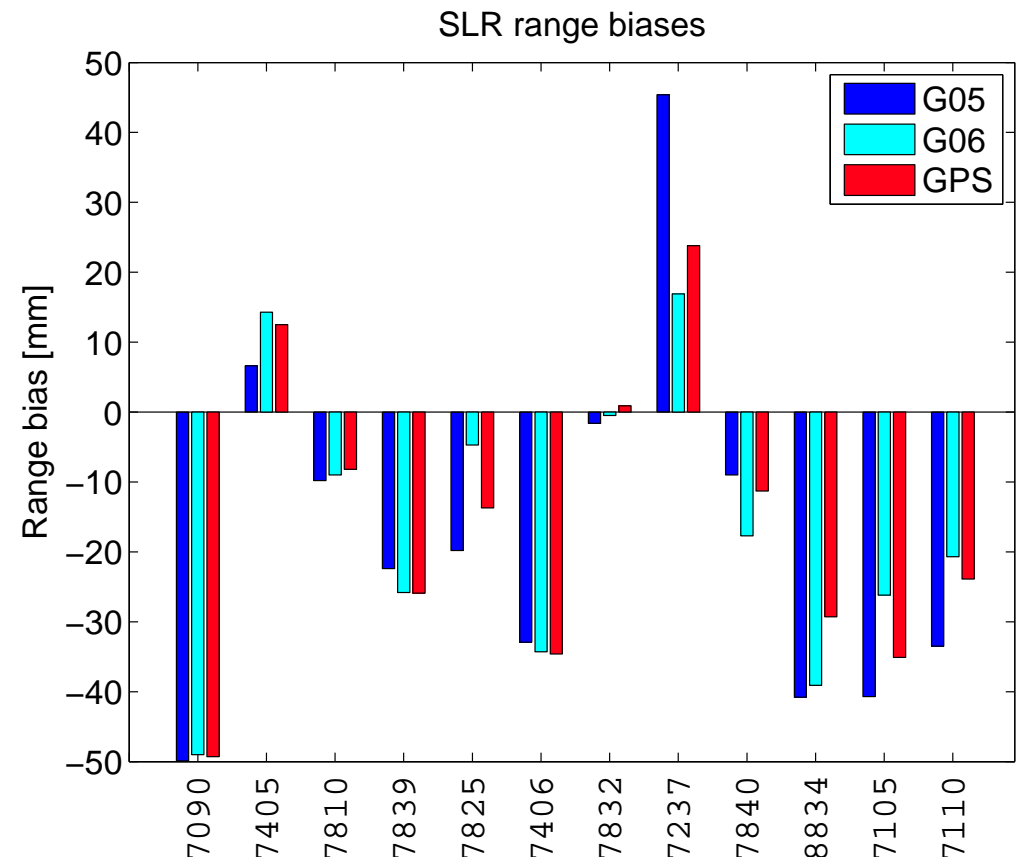
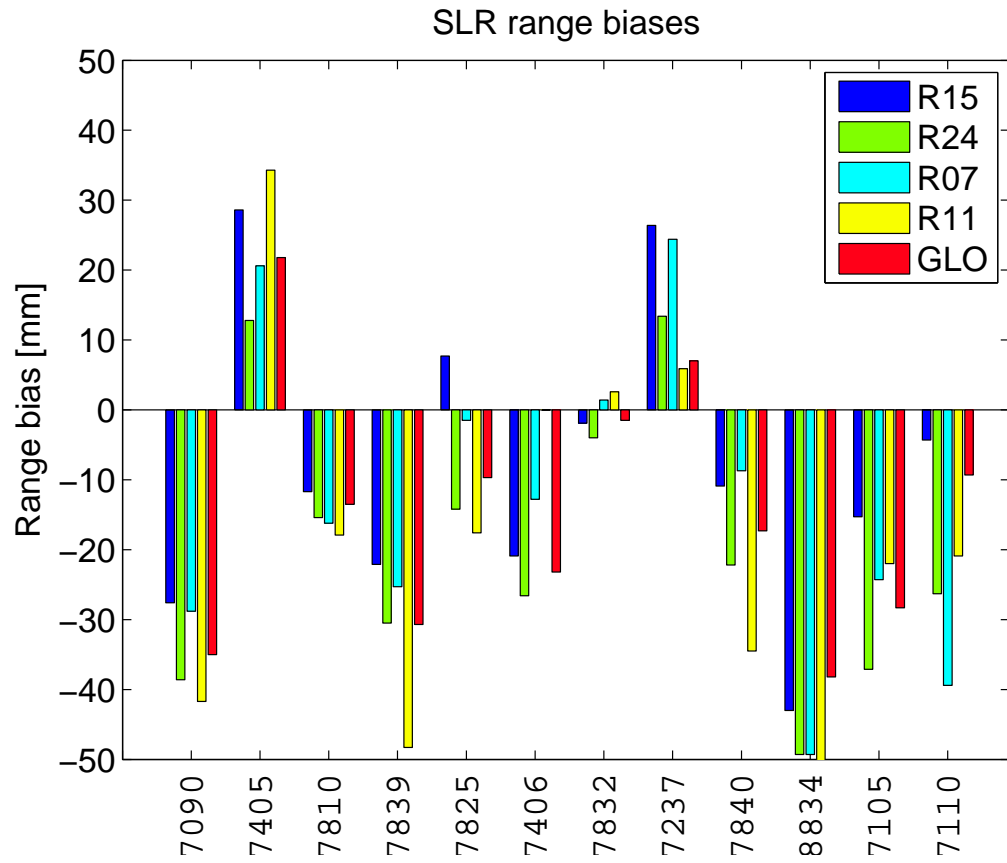
What is reasonable from technical point of view?

- Satellite-dependent? → Separate for every satellite
- System-dependent? → Average over GPS, over Glonass, ...
- Station-dependent? → Average over all GNSS satellites

Question 2:

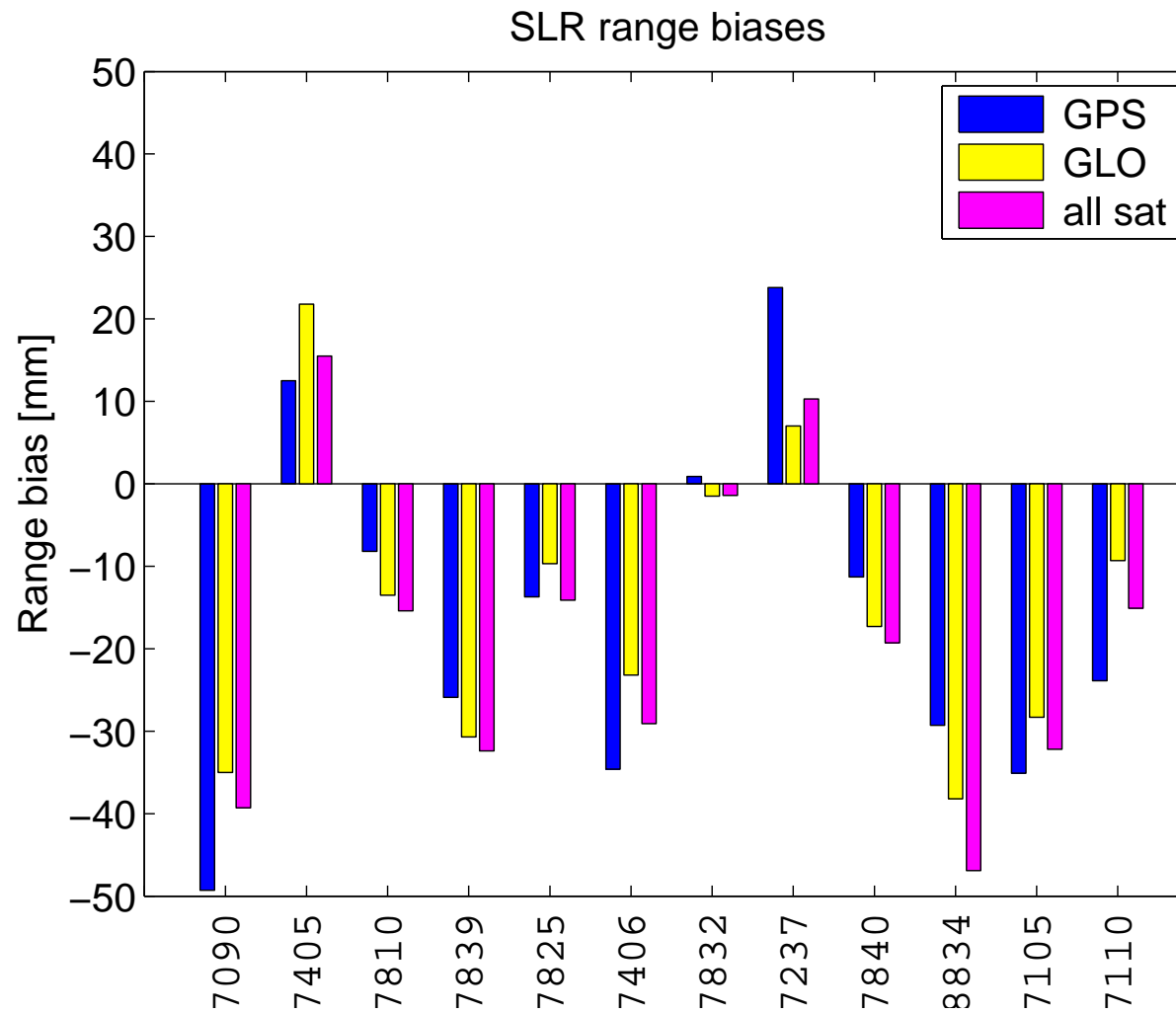
Are the SLR range bias estimates influenced by estimating GNSS satellite antenna offsets?

SLR range biases



System-specific range biases seem to be sufficient for most sites

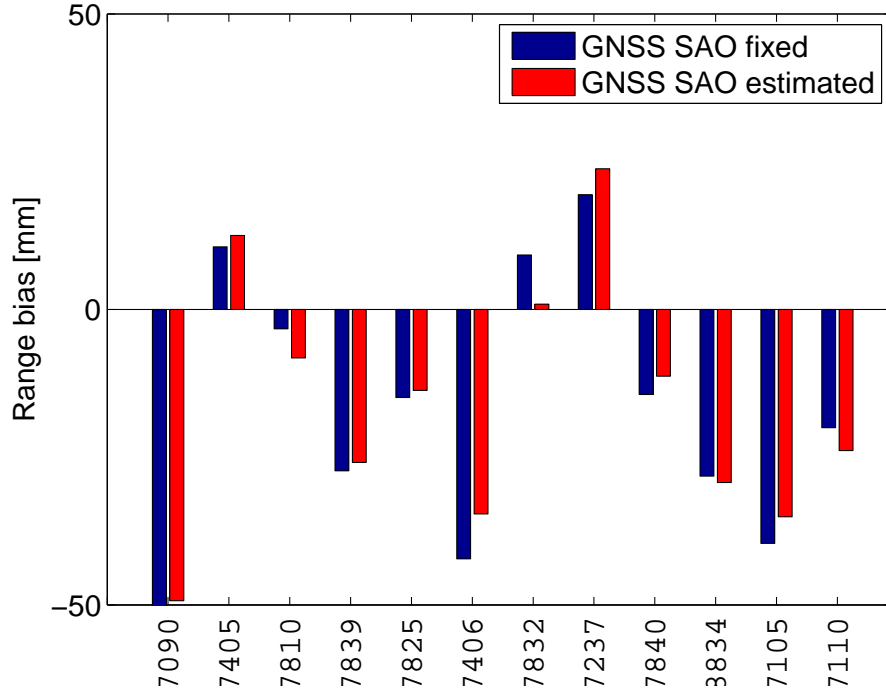
SLR range biases



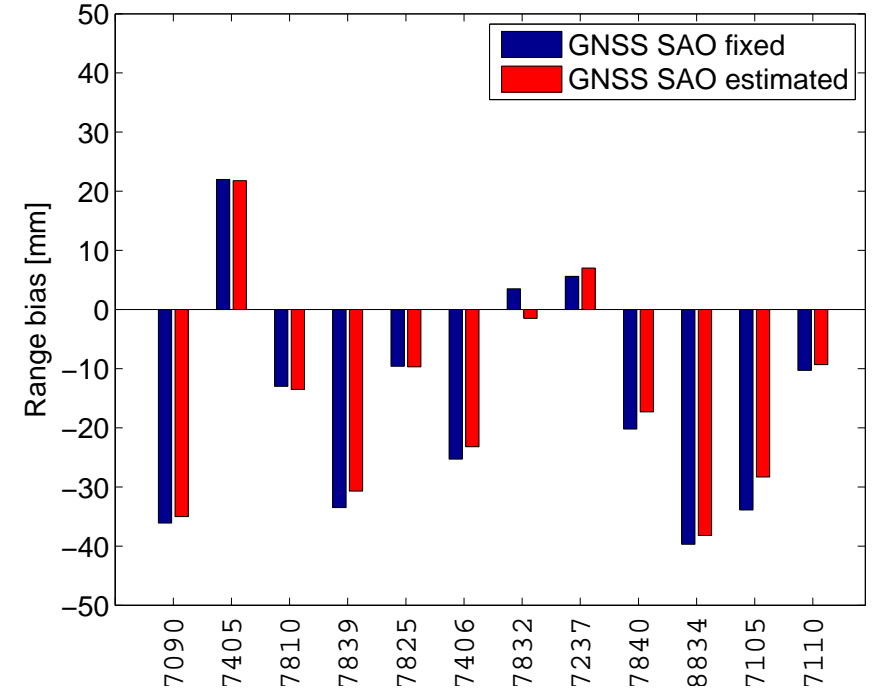
Station-specific range biases seem to be sufficient

SLR range biases

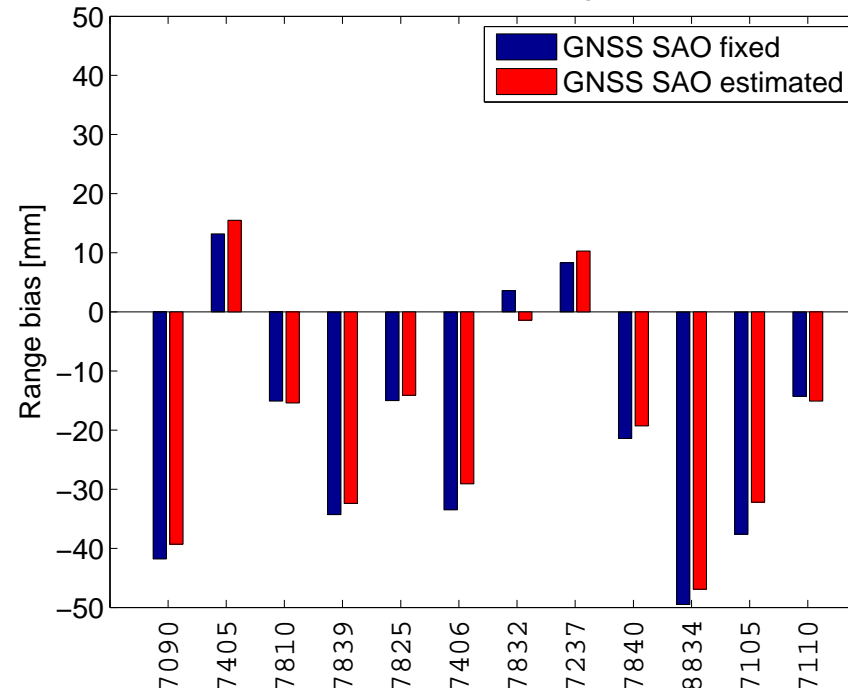
System-specific SLR range biases for GPS satellites



System-specific SLR range biases for Glonass satellites



Station-specific SLR range biases



Simultaneous estimation of GNSS antenna phase center offsets and SLR range biases is possible

Scale between solutions (GNSS core sites)

L = Satellite-specific SLR range biases
K = System-specific SLR range biases
J = Station-specific SLR range biases

	L1A	K1A	J1A		L1B	K1B	J1B
GNSS-only	0.0	0.0	0.0		0.9	0.9	0.9
L1A		0.0	0.0		0.9	0.9	0.9
K1A			0.0		0.9	0.9	0.9
J1A					0.9	0.9	0.9
L1B						0.0	0.0
K1B							0.0
Lageos	0.0 ±0.9	-0.8 ±0.7	-0.4 ±0.7		0.3 ±1.0	-0.6 ±0.6	-0.3 ±0.7

[ppb]

„**A**“: GNSS Sat.ant. fixed
 = Scale fixed

„**B**“: GNSS Sat.ant. estimated
 = Scale free ⇒ from SLR

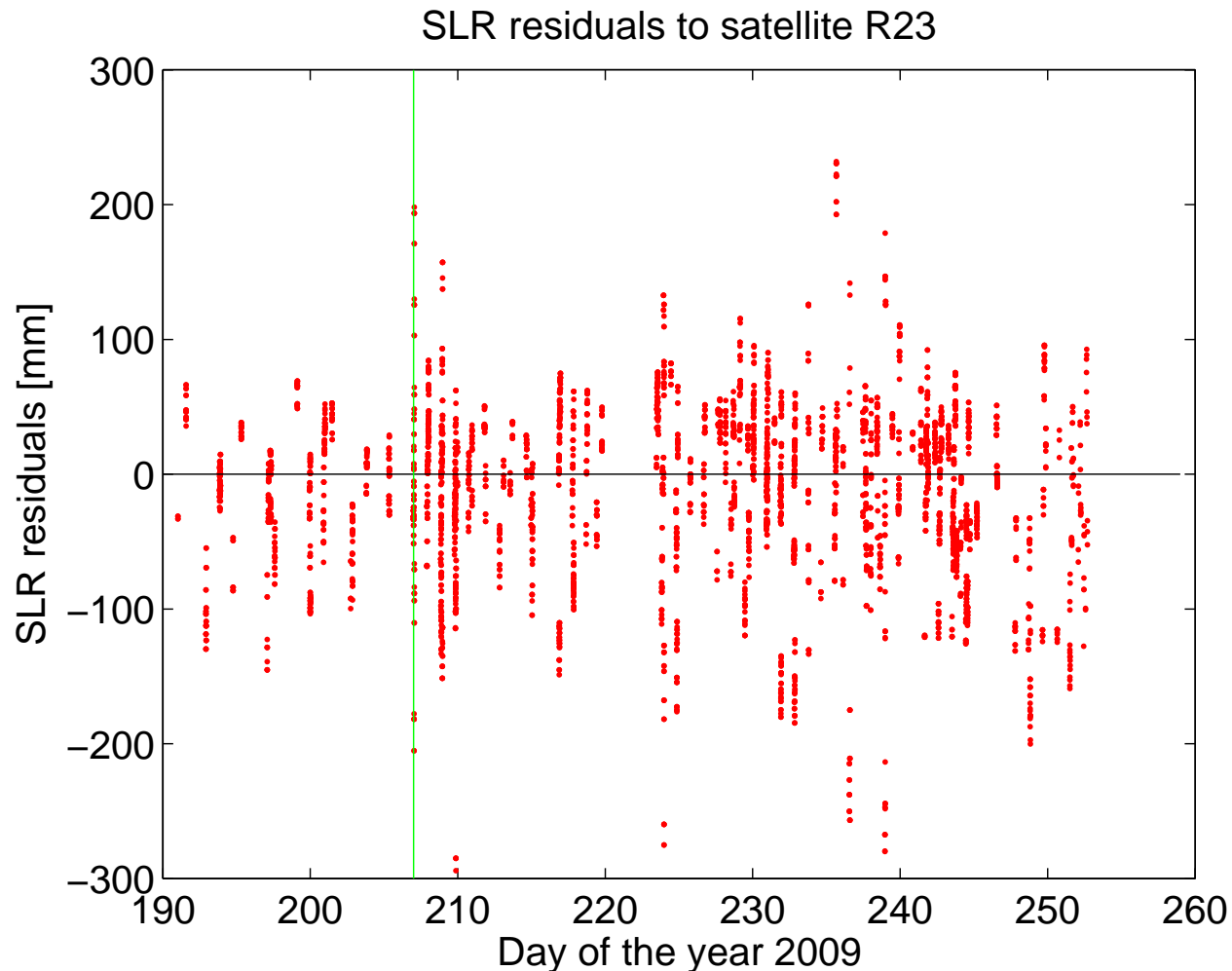
Conclusions and outlook

- Combination on *observation level* using SLR@GNSS works fine
- Connection via „*space ties*“ is possible (without local ties)
BUT:
Accurate ties (in space and on sites) required for combination
- *Scale from SLR* can be transferred to GNSS (estimation of GNSS SAO)
- Open question: Best *handling of SLR range biases* to GNSS satellites?
- Studies have to be extended to *longer time span*

- Thanks to Manuela Seitz from DGFI for providing comparisons with local tie values!

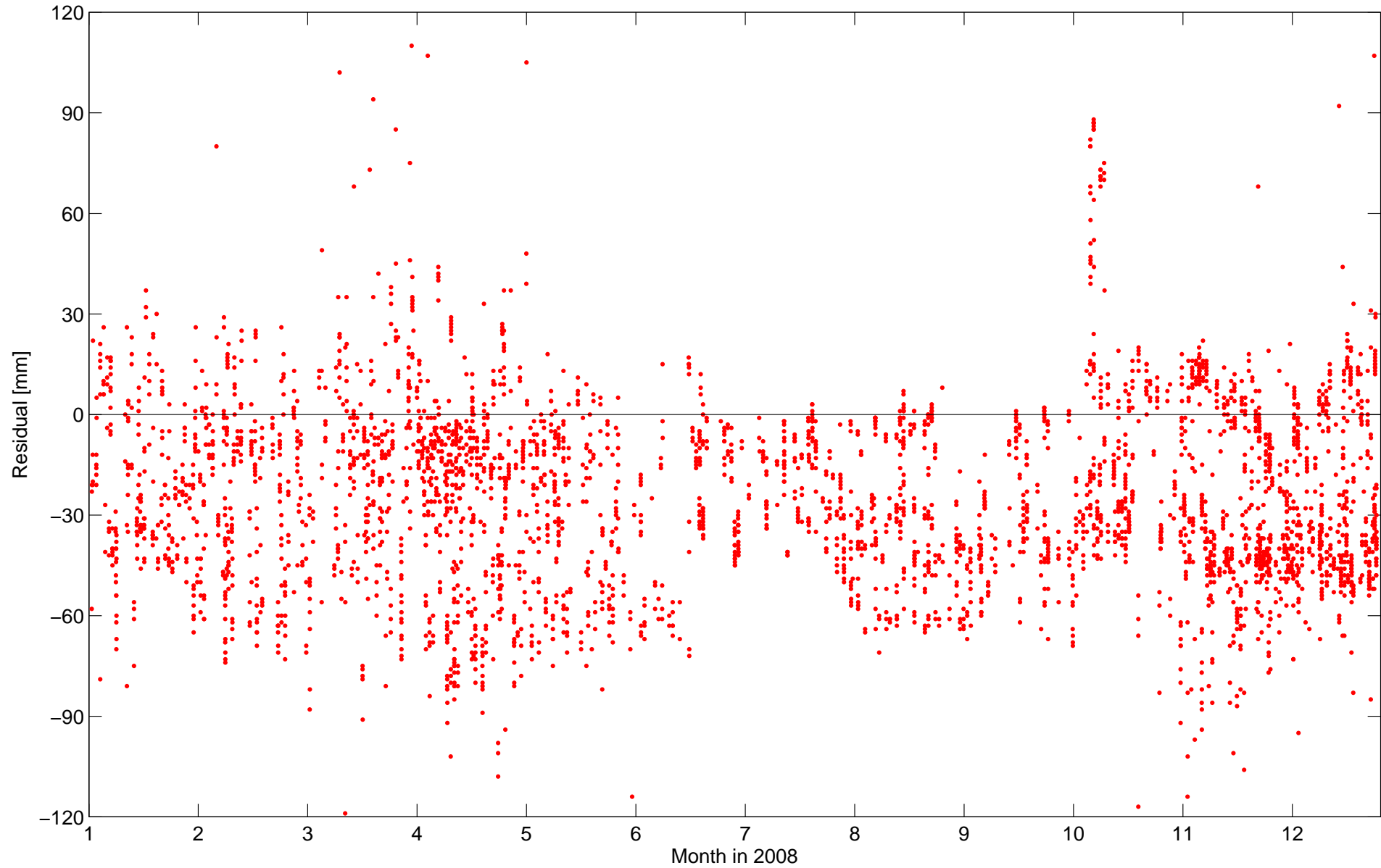
SLR orbit validation for R23

- Switch to new z-offset for GNSS antenna of Glonass satellite R23 within IGS
 - ILRS agreed to track R23 during the transition phase (10 weeks)
- ⇒ **Many thanks to all SLR sites for supporting this tracking request!**



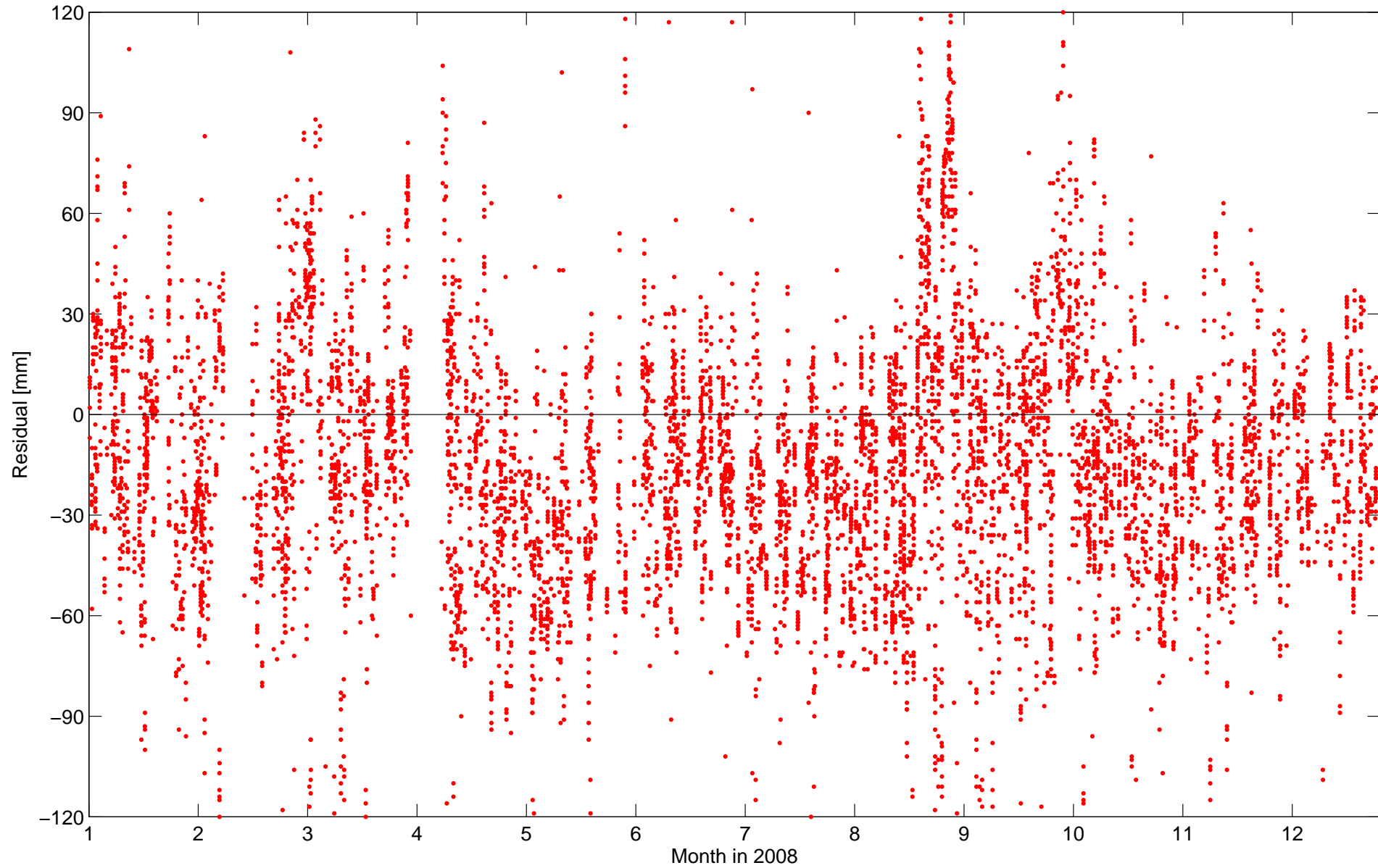
SLR residuals

SLR residuals for satellite G06, Orbit G3



SLR residuals

SLR residuals for satellite R24, Orbit G3



SLR residuals

SLR residuals for satellite R15, Orbit G3

