Combination of GNSS and SLR using satellite co-location

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Session 2: Strengths, weaknesses, modelling standards and processing strategies of space geodetic techniques

Overview

1. **Co-location** of GNSS and SLR at GNSS satellites

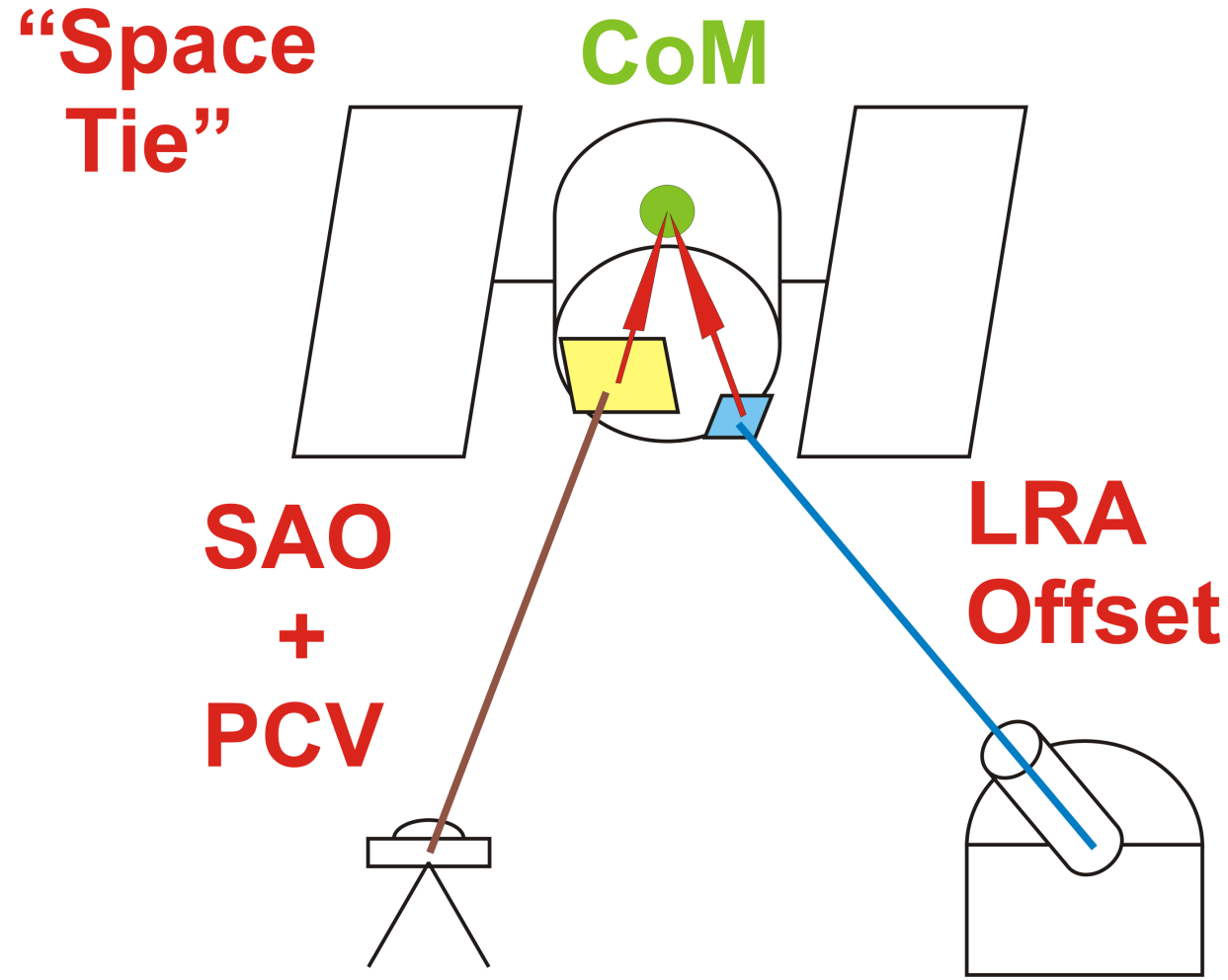
2. **Results** from combined GNSS-SLR analysis using satellite co-location:
   - Station coordinates / TRF
   - GNSS satellite antenna offsets
   - Biases between GNSS and SLR

3. **Conclusions** and **outlook**

Co-location for GNSS and SLR

Co-location at GNSS satellites = Common orbit parameters from GNSS microwave and SLR range data

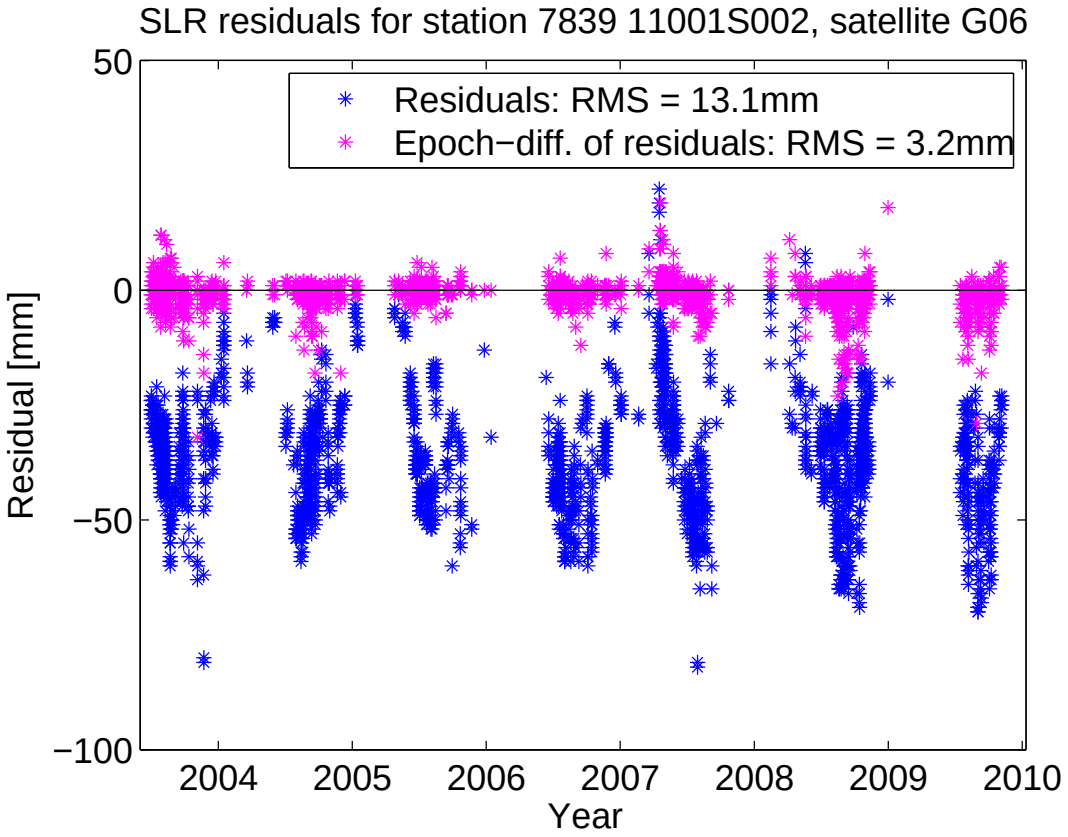
→ **Vectors** of GNSS and SLR reference points **w.r.t. satellite CoM** needed

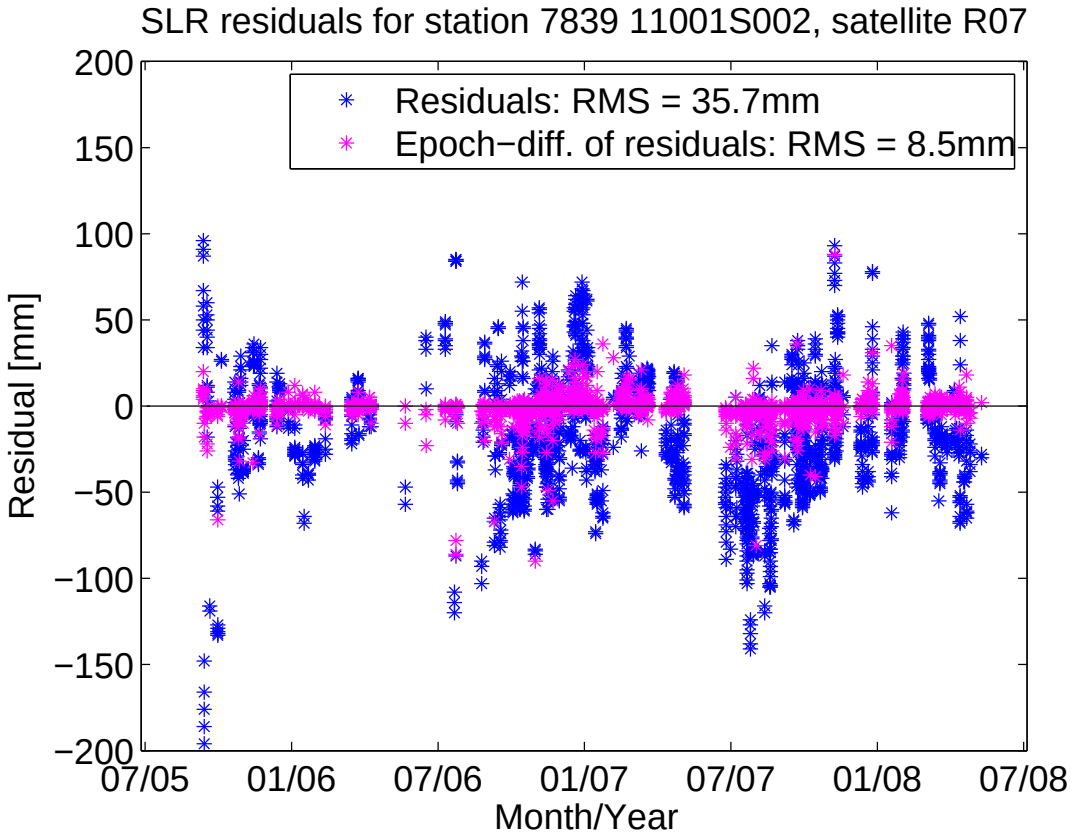


***Space Tie* =**

1. GNSS Satellite Antenna Offsets (**SAO**) w.r.t. CoM
2. GNSS Phase Center Variations (**PCV**)
3. Offsets for Laser Retroreflector Array (**LRA**) w.r.t. CoM

SLR residuals to GNSS-only orbits





1) Biases in SLR range residuals (cm-level)

2) Epoch-differences of SLR range residuals have a much smaller RMS

$\Rightarrow$ **systematic effects**

Systematic effects between SLR and GNSS

Possible reasons for systematic effects in SLR range residuals:

SLR station coordinates (fixed to SLRF2005)

TRF (scale, geocenter)

Offset for GNSS satellite antenna (SAO from igs05.atx)

Offset for laser reflector array (LRA from ILRS web site)

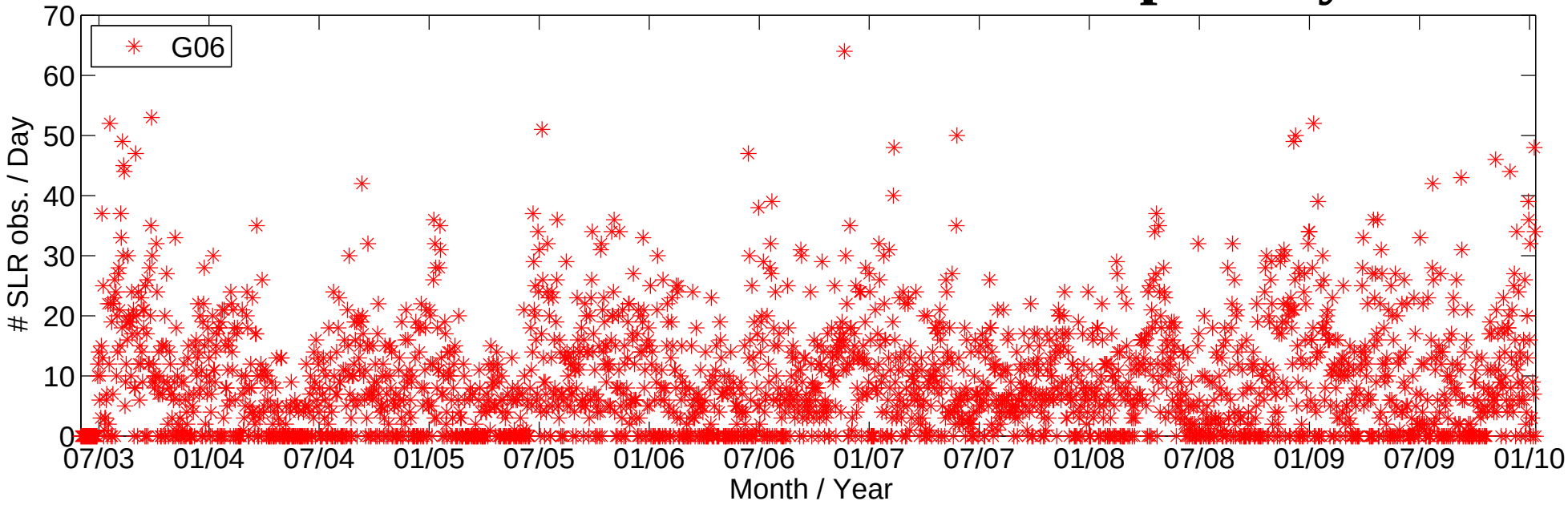
SLR range biases (unknown for GNSS satellites)

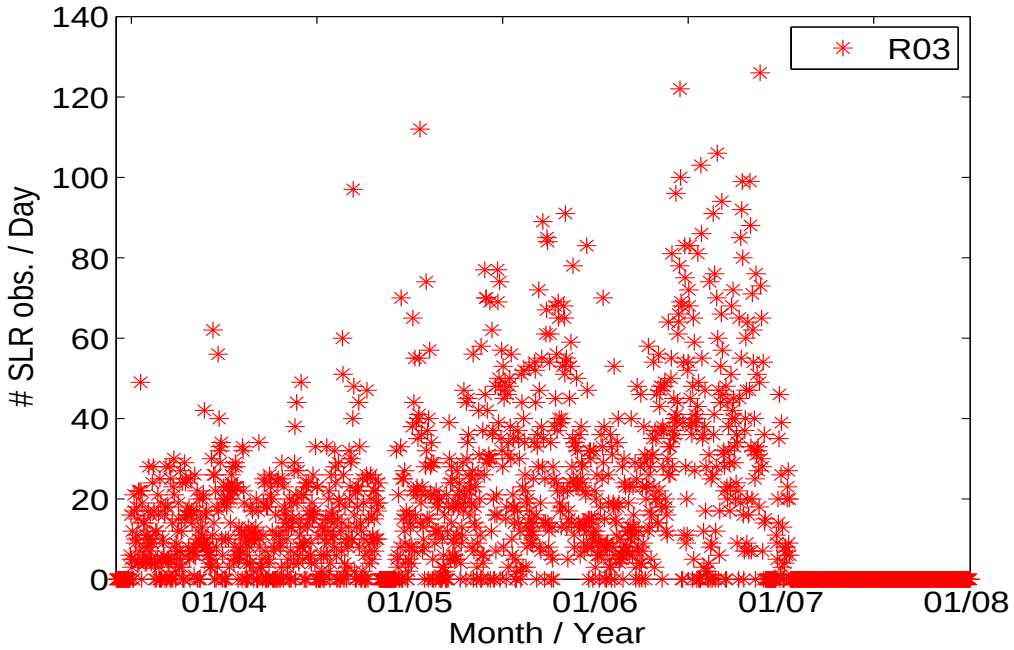
GNSS orbit modelling (solar radiation pressure)

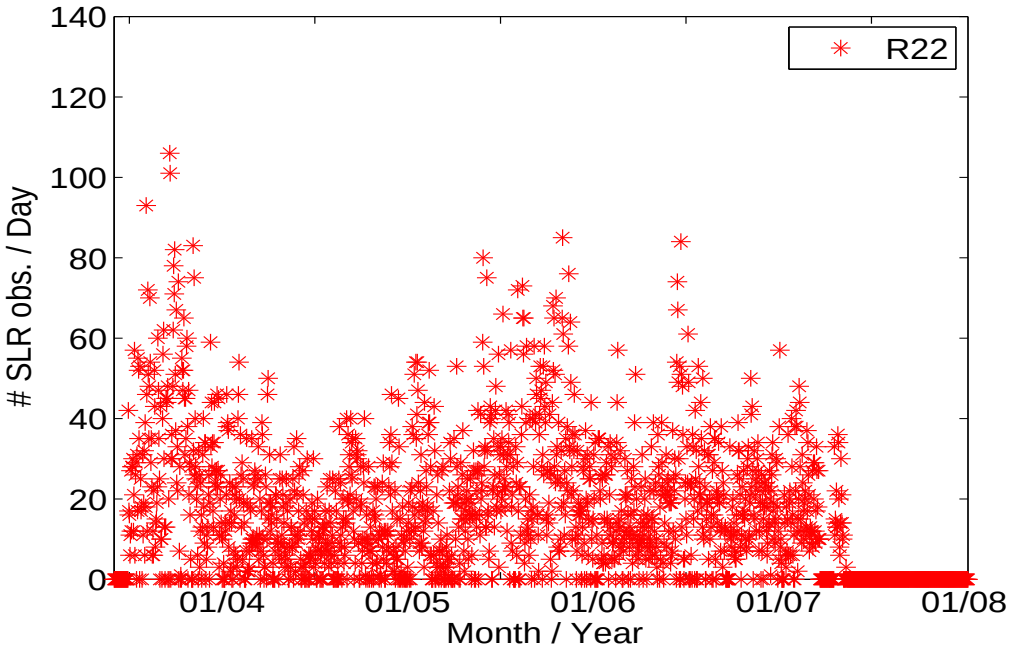
⇒ **Must be handled in combined solution:**

- use known / better values
- **Estimation**

Number of SLR observations per day







Combined analysis of GNSS and SLR

SLR station coordinates
→ **estimate + inclusion of LAGEOS**

TRF scale (and geocenter)
→ **use from SLR**

Offset for GNSS satellite antenna (SAO from igs05.atx)
→ **estimate**

GNSS has rank-deficiency w.r.t. scale if SAO are estimated

Offset for laser reflector array (LRA from ILRS web site)
→ **estimate**

SLR range biases (unknown for GNSS satellites)
→ **estimate + inclusion of LAGEOS**

Estimation of 1 bias parameter per station / per GNSS satellite

⇒ GNSS-microwave + SLR@GNSS + SLR@LAGEOS for 2006-2009

SLR station coordinates

SLR station network

- Not included in the datum definition (no-net-rotation, no-net-translation)
- No local ties applied

→ Only appended via the „space ties“ (common orbit parameters)

Validation of SLR station coordinates: Helmert transformation

		SLRF2005	Lageos-only	
RMS	**Comb: SLR@GNSS**	**54.40**	54.22	[mm]
	Comb: + Lageos	**6.70**	2.95	[mm]
	Lageos-only	**7.49**		[mm]

→ Agreement is at the **cm-level** if only SLR@GNSS is used

→ **Inclusion of Lageos** improves the coordinate estimates

→ Connection by using space ties only is feasible

SLR station coordinates

SLR station network:
- Not included in the datum definition (no-net-rotation, no-net-translation)
- No local ties applied
→ Only appended via the „space ties“ (common orbit parameters)

Validation of SLR station coordinates: Helmert transformation

		SLRF2005	Lageos-only	
Scale	**Comb: SLR@GNSS**	**1.06 +- 2.76**	2.34 +- 2.75	[ppb]
	Comb: + Lageos	**1.02 +- 0.34**	0.25 +- 0.15	[ppb]
	Lageos-only	**1.28 +- 0.38**		[ppb]

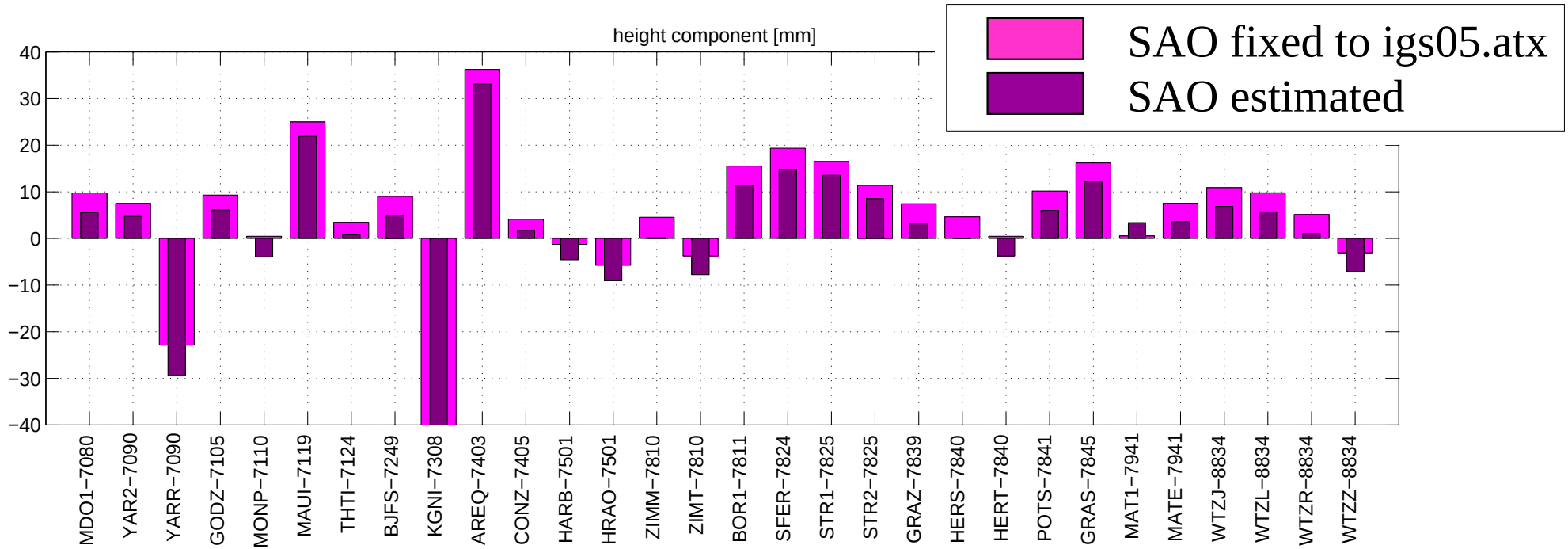
→ Scale of SLR is defined well
→ **Inclusion of Lageos** improves the coordinate estimates

Comparison with local ties

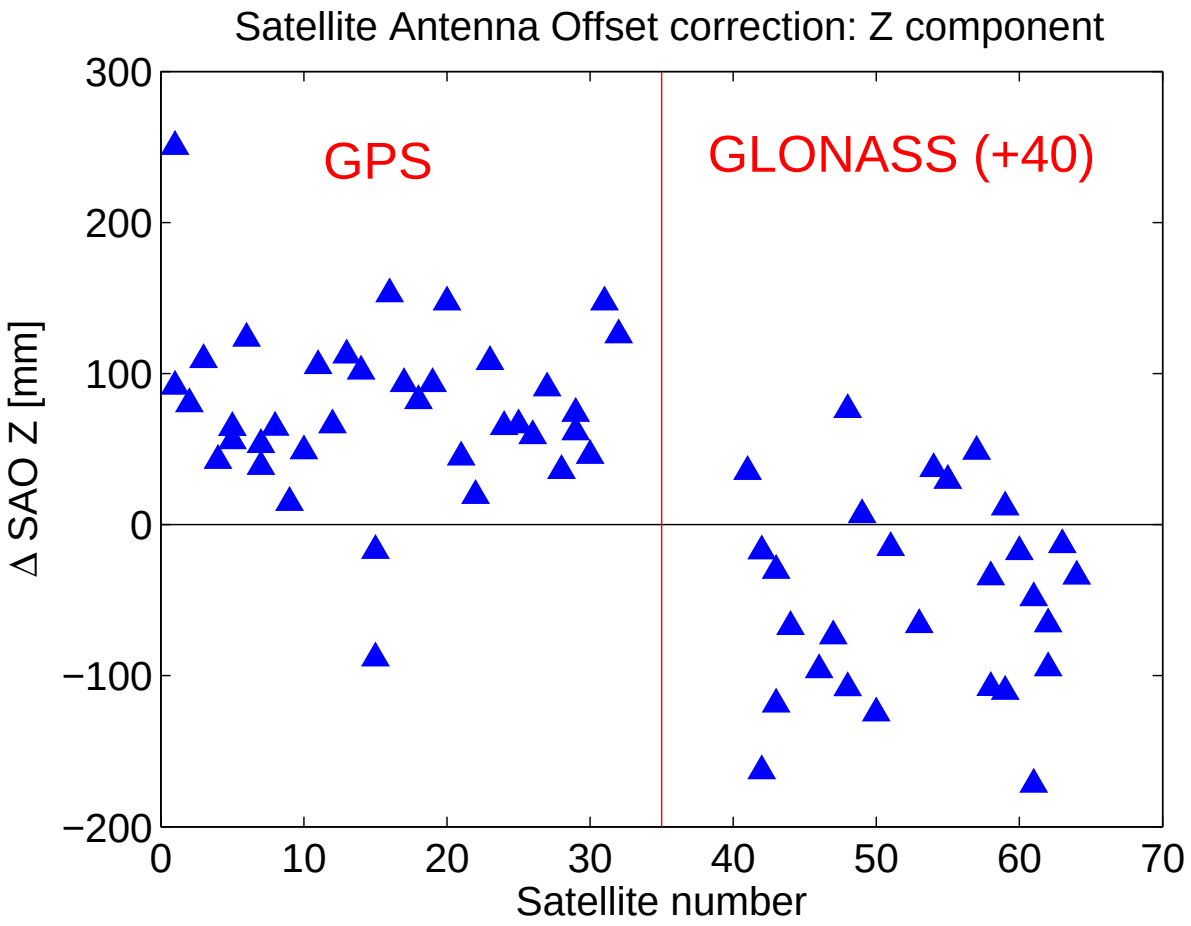
1. Estimated SLR and GNSS station coordinates ⇒ **ΔCRD_estimate**
2. Local tie between SLR and GNSS reference points: **ΔCRD_LT**

⇒ **ΔCRD_estimate - ΔCRD_LT: Height component**

⇒ Agreement between GNSS and SLR sites better if GNSS SAO are estimated (i.e. using the SLR scale)



SLR-GNSS biases and GNSS SAO



Mean **ΔZ** for GPS:
76.4 mm

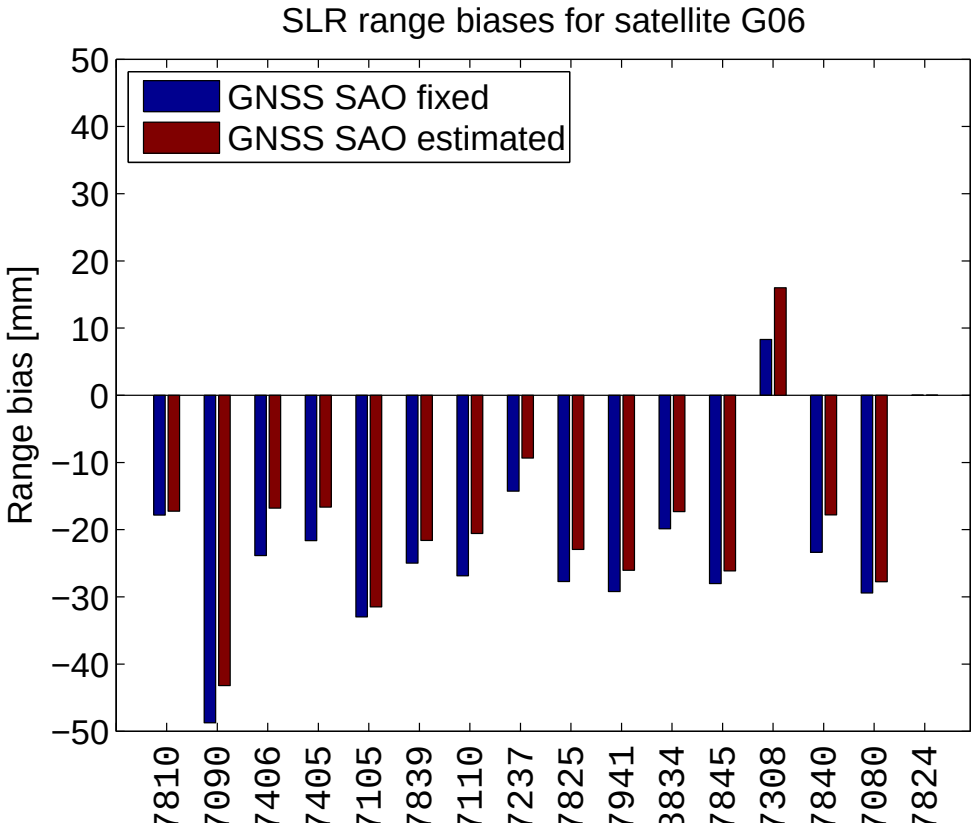
Mean **ΔZ** for GLONASS:
-47.7 mm

ΔScale for GNSS network:
0.59 ppb

ΔScale for SLR network:
0.00 ppb

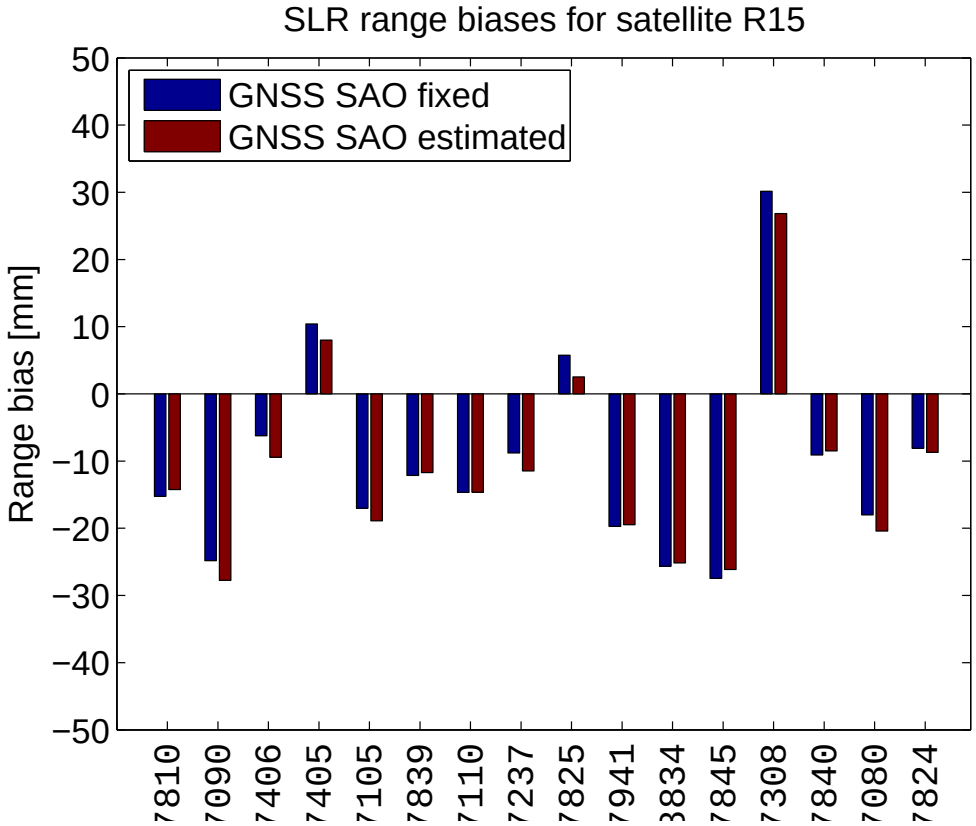
No general shift of SAO estimates
=> Scale of SLR is transferred properly to GNSS

SLR-GNSS biases and GNSS SAO



Impact of GNSS-SAO estimation on SLR-GNSS „range“ biases:

< 5 mm



Conclusions and outlook

- Inclusion of SLR@GNSS works properly

- ***LAGEOS*** data should be included in order to derive stable solutions

- ***Scale from SLR*** can be transferred to GNSS very well
  → allows the estimation of GNSS satellite antenna offsets

- GNSS SAOs from ***igs05.atx*** do not fit to the ***SLR scale*** (0.59 ppb)

- Connection via „***space ties***“ is possible (without local ties)
  BUT:
  Accurate ties (in space and on sites) required for combination

- ***Separation*** of SLR range biases and errors in ***LRA offsets*** is still needed