

GNSS satellites as co-locations for a combined GNSS and SLR analysis

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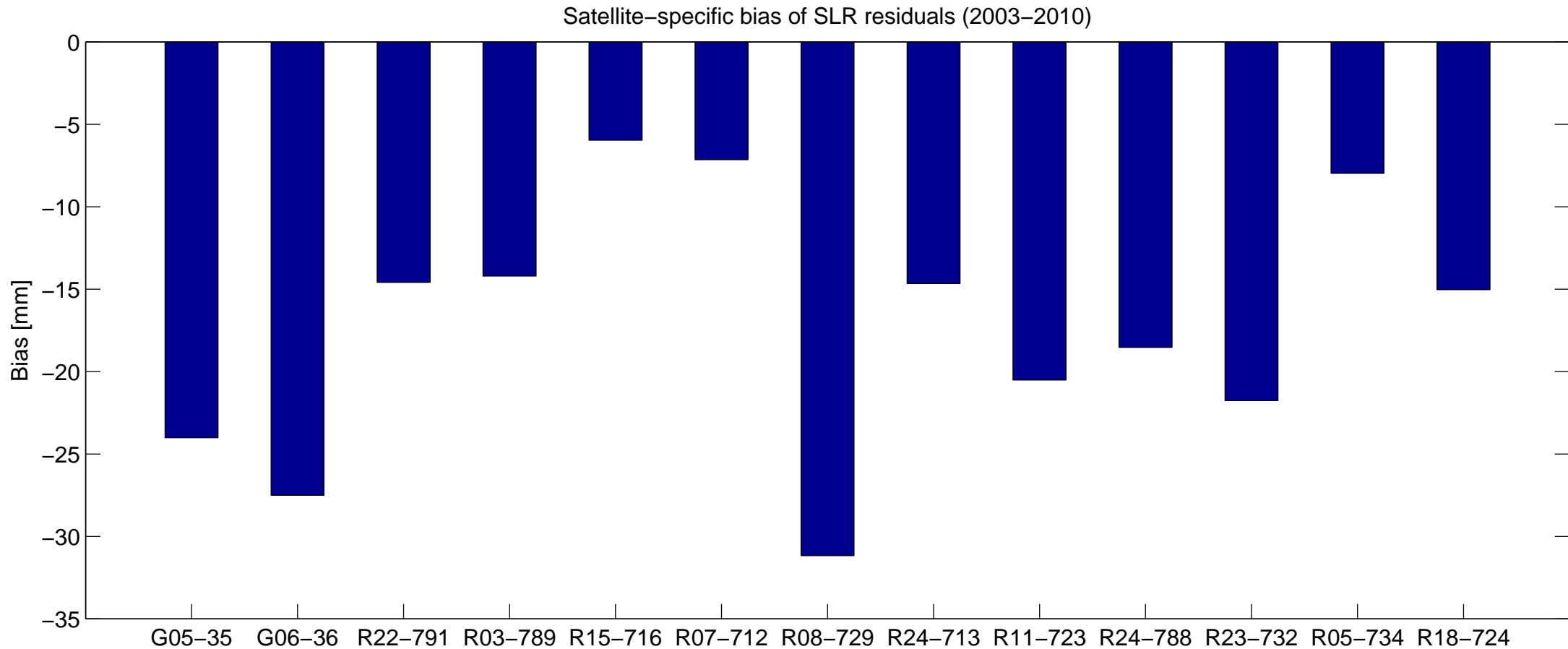
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Overview

1. **SLR range residuals** to GPS/GLONASS satellites
⇒ Biases
2. **Results** from combining microwave data and SLR data to GPS, GLONASS:
 - GNSS-SLR „range“ bias parameters
 - Offsets of Laser Reflector Array (LRA)
 - GNSS Satellite Antenna Offsets (SAO)
3. **Conclusions**

SLR residuals to GNSS-only orbits

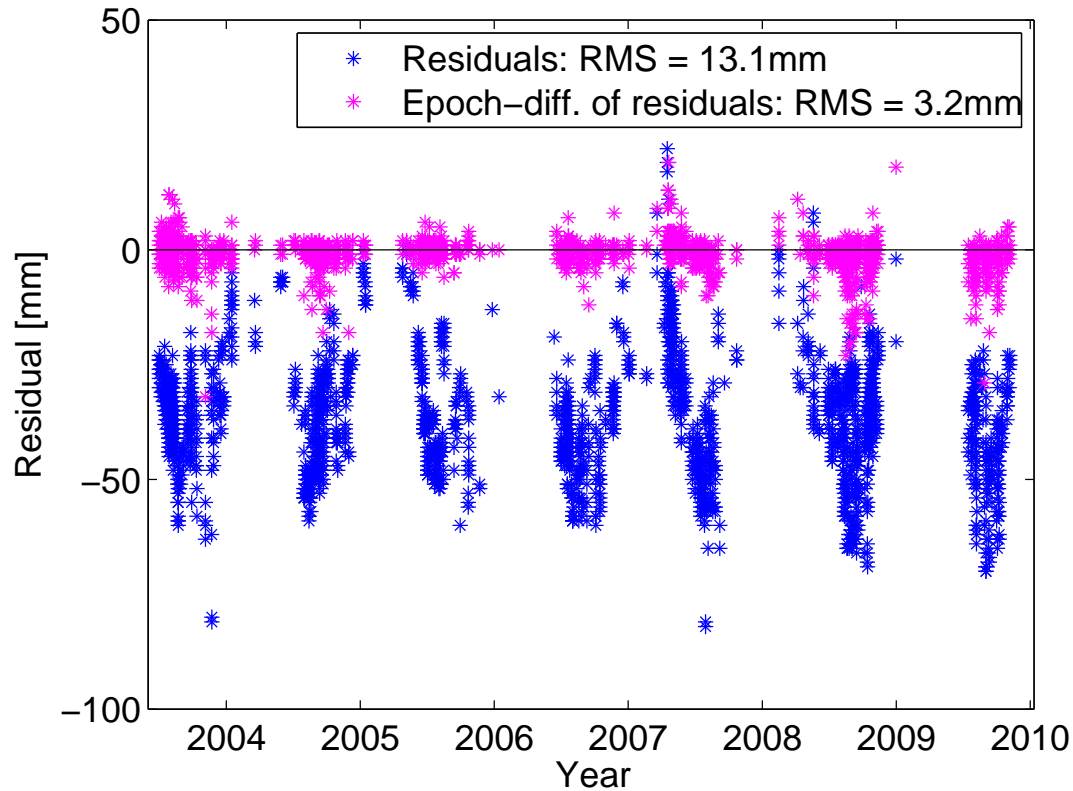


(GLONASS satellites are grouped in descending order of the amount of SLR data)

- **Biases in SLR range residuals** are at the **cm**-level
 - **All biases** in SLR range residuals are **negative**
- ⇒ **Systematic differences between microwave and range data to GNSS satellites**

SLR residuals to GNSS-only orbits

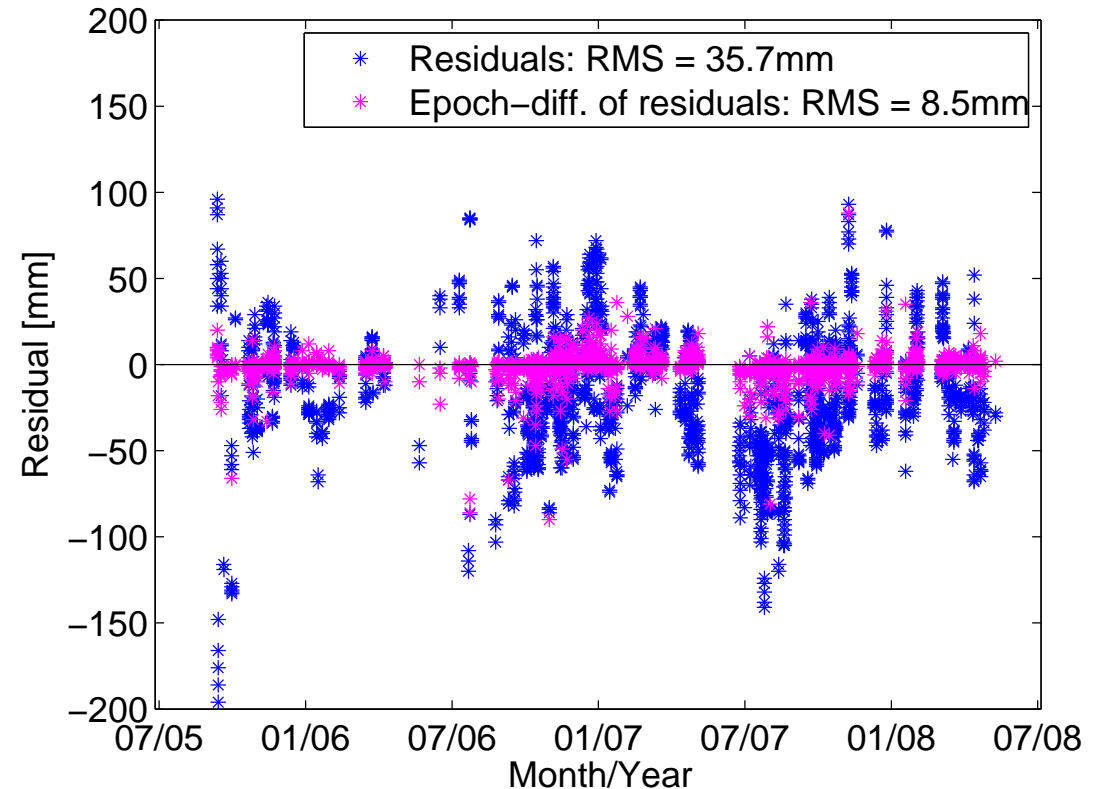
SLR residuals for station 7839 11001S002, satellite G06



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

⇒ systematic effects

SLR residuals for station 7839 11001S002, satellite R07



SLR residuals to GNSS-only orbits

Possible reasons for biases in SLR range residuals:

- SLR station coordinates (fixed to SLRF2005)
- TRF (scale, geocenter)
- GNSS orbit modelling (albedo, solar radiation pressure)
- 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)

⇒ Use **known/better values** or **estimation**

SLR residuals to GNSS-only orbits

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Combined analysis: 2006.0 – 2011.0

GNSS microwave data

+ **SLR** range data **to GNSS** satellites (GPS, GLONASS)

+ **SLR** observations to **LAGEOS, ETALON**

(→ stable station coordinates; no range biases for most stations)

Solutions to be tested

	<i>Solution 1</i>	<i>Solution 2</i>	<i>Solution 3</i>	<i>Solution 4</i>
<i>GNSS-SLR "range" bias</i>	1 parameter per station estimated	1 parameter per station estimated	1 parameter per station estimated	1 parameter per station estimated
<i>LRA offset</i>	fixed	fixed	correction for <i>z-component</i> estimated	correction for <i>z-component</i> estimated
<i>Microwave SAO</i>	fixed	correction for <i>z-component</i> estimated	fixed	correction for <i>z-component</i> estimated



⇒ all GNSS-SLR discrepancies
might show up in
„range“ bias parameters

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⇒ **LRA errors
might show up in
“range “ bias parameters**

Solutions to be tested

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<i>GNSS-SLR "range" bias</i>	1 parameter per station estimated	1 parameter per station estimated	1 parameter per station estimated	1 parameter per station estimated
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⇒ **SAO errors might show up in SLR-related parameters**

Solutions to be tested

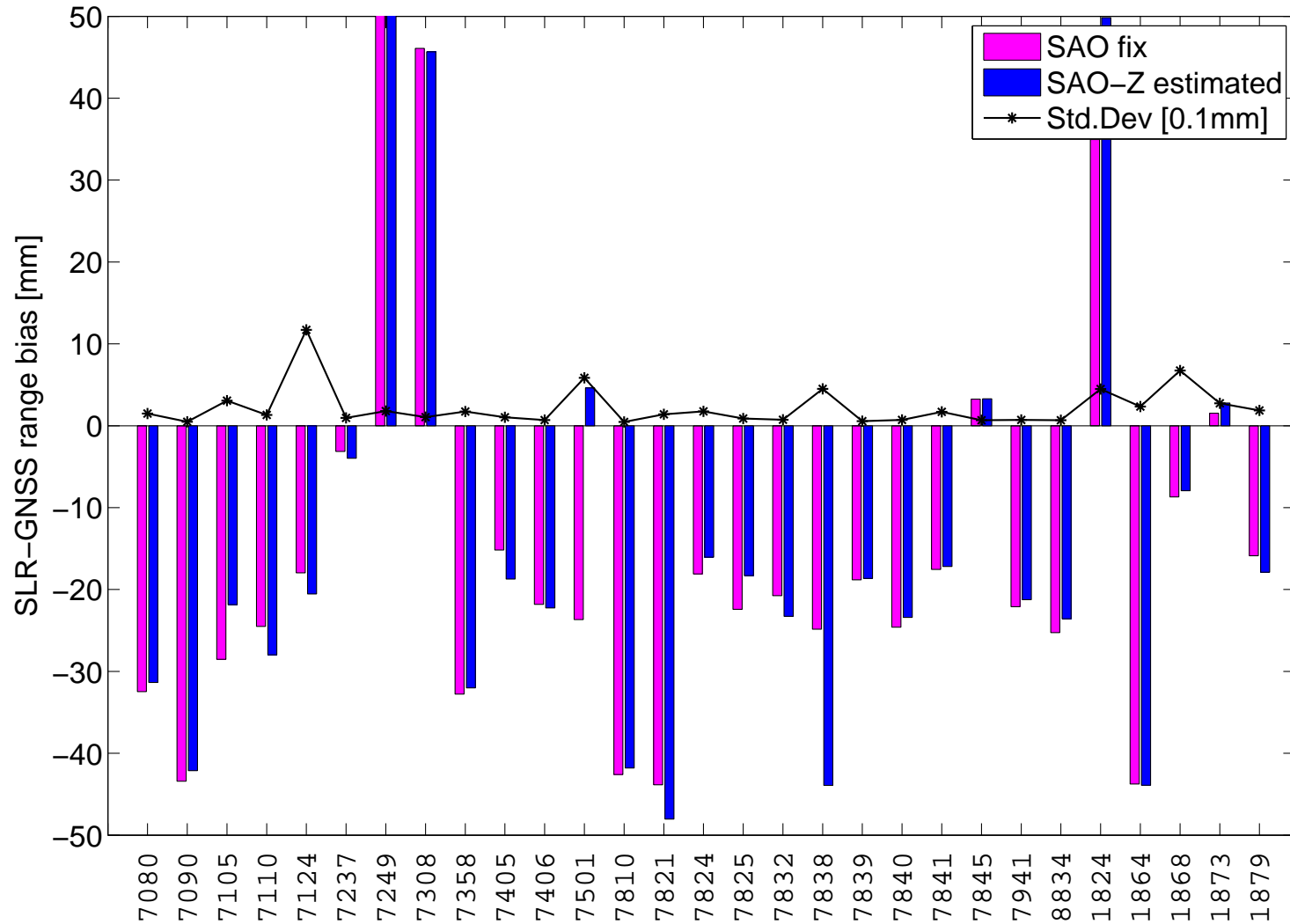
	<i>Solution 1</i>	<i>Solution 2</i>	<i>Solution 3</i>	<i>Solution 4</i>
<i>GNSS-SLR "range" bias</i>	1 parameter per station estimated	1 parameter per station estimated	1 parameter per station estimated	1 parameter per station estimated
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⇒ Parameters for all error sources estimated separately.
BUT: Correlations?

SLR-GNSS „range“ biases

SLR-GNSS range biases per station (LRA fix)

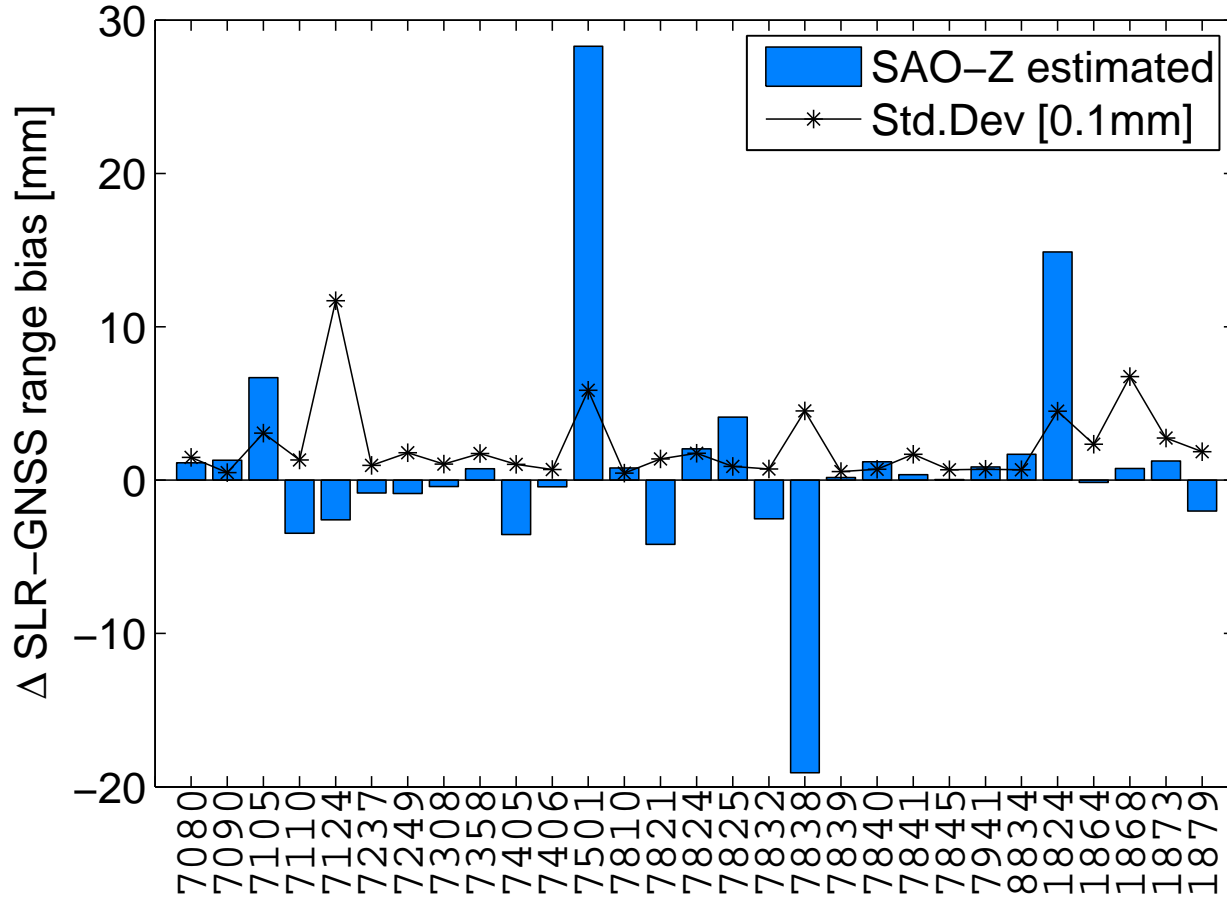


LRA
offsets
fixed

Common estimation of: GNSS Satellite Antenna Offset (z -direction)
GNSS-SLR „range“ bias parameters

SLR-GNSS „range“ biases

Difference in SLR-GNSS range biases (per station)
(LRA fixed) w.r.t. "SAO fixed"

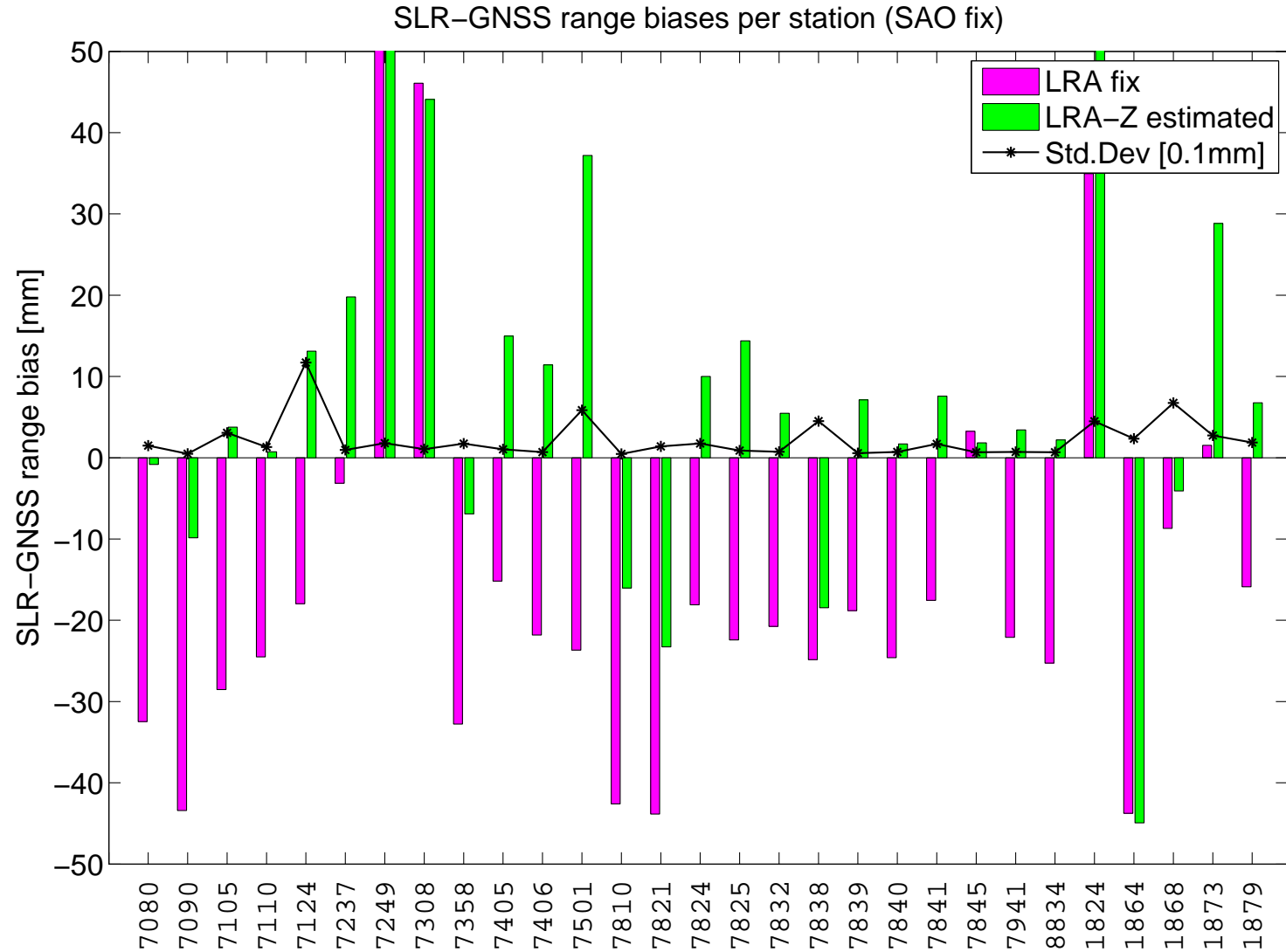


Mean diff. = 0.9 mm
Median diff. = 0.4 mm

Common estimation of: GNSS Satellite Antenna Offset (z-direction)
GNSS-SLR „range“ bias parameters
⇒ errors in SAO do not map into SLR range bias parameters

SLR-GNSS „range“ biases

Microwave
SAO
fixed

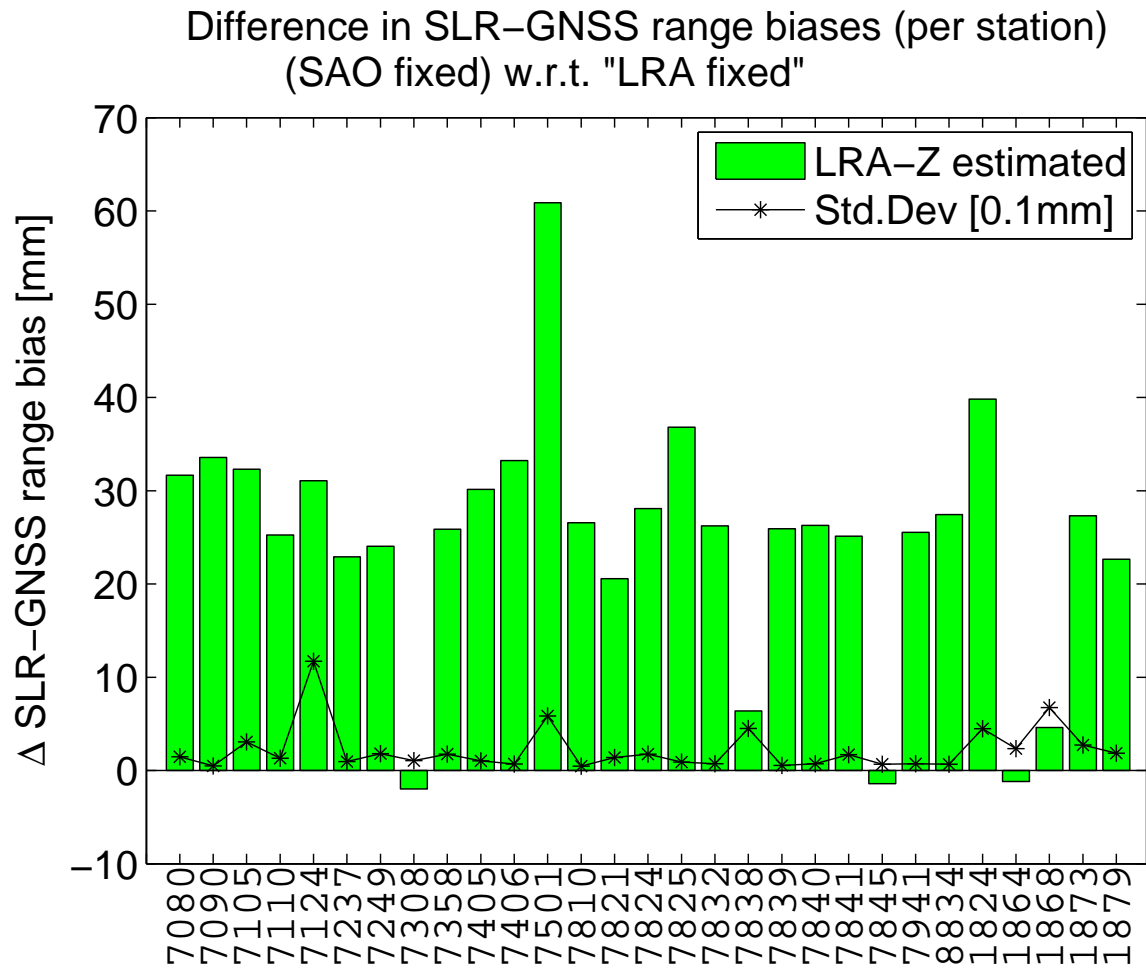


Common estimation of: LRA Offset (z -direction)
GNSS-SLR „range“ biases



- Smaller „range“ biases
- Less systematic

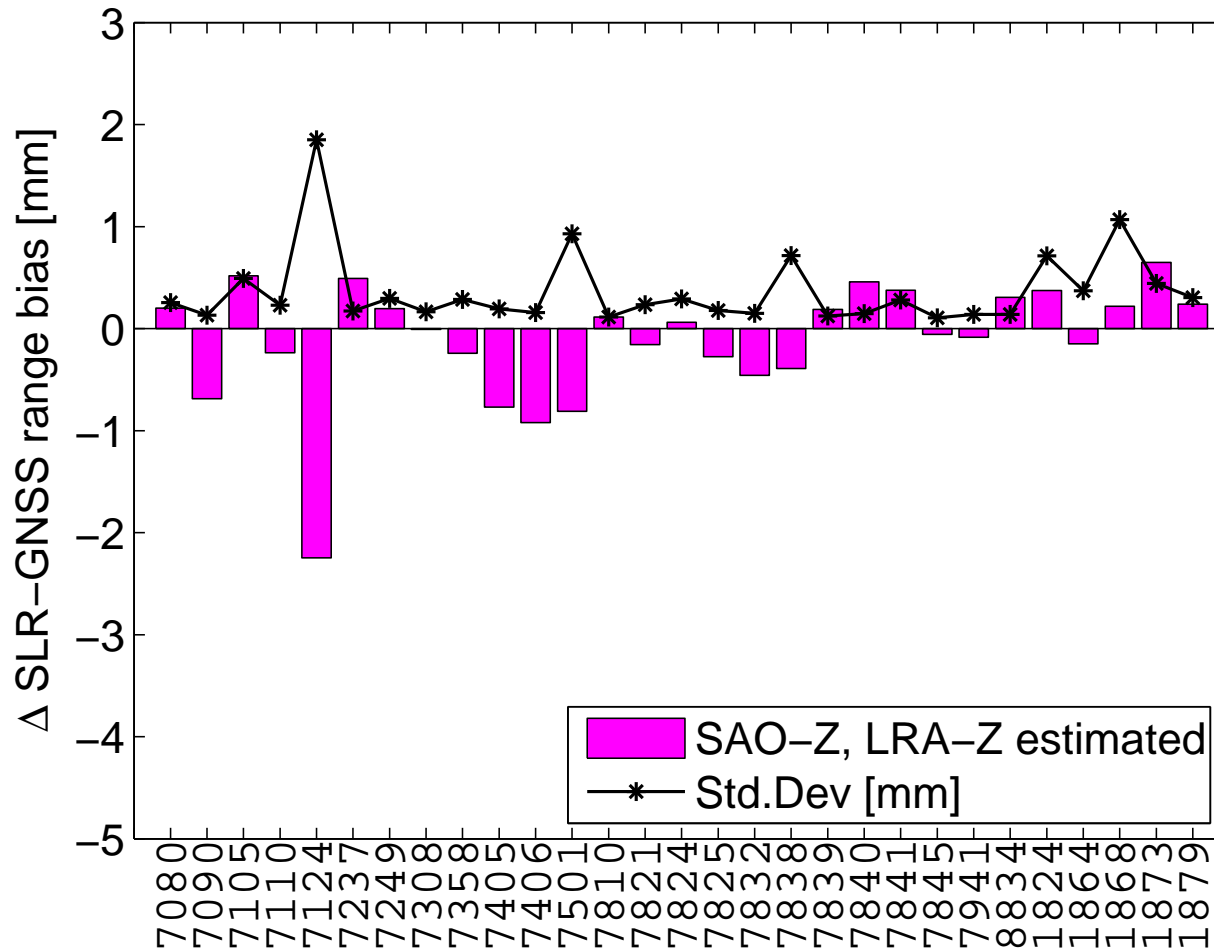
SLR-GNSS „range“ biases



GNSS-SLR bias is rather an LRA offset than an SLR range bias:
Approx. 25 mm

SLR-GNSS „range“ biases

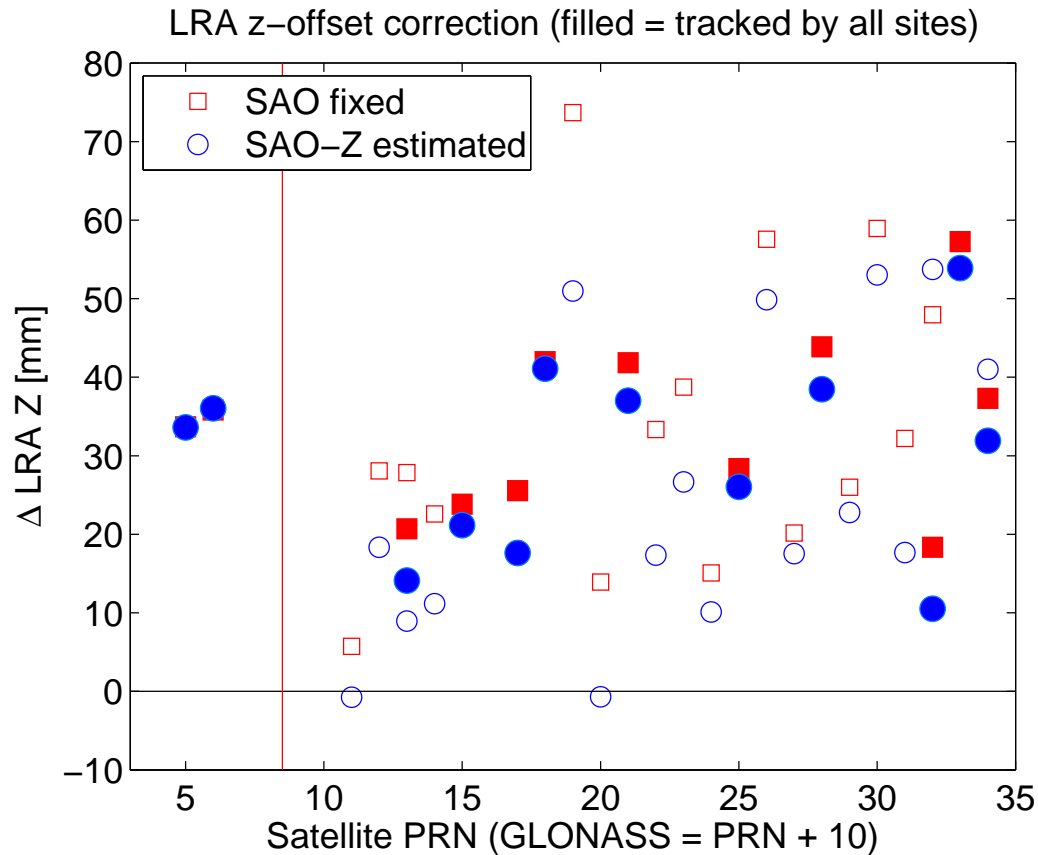
Difference in SLR-GNSS range biases per station
w.r.t. "SAO fixed, LRA-Z estimated"



Mean diff. = 0.1 mm
Median diff. = 0.0 mm

Common estimation of: GNSS Satellite Antenna Offset (z-direction)
LRA offset (z-direction)
GNSS-SLR range biases

LRA offset corrections



Filled signatures:

Satellites **tracked by all SLR sites**

Others:

Satellites tracked only by

Herstmonceux (since Dec. 2009)

Mean correction:

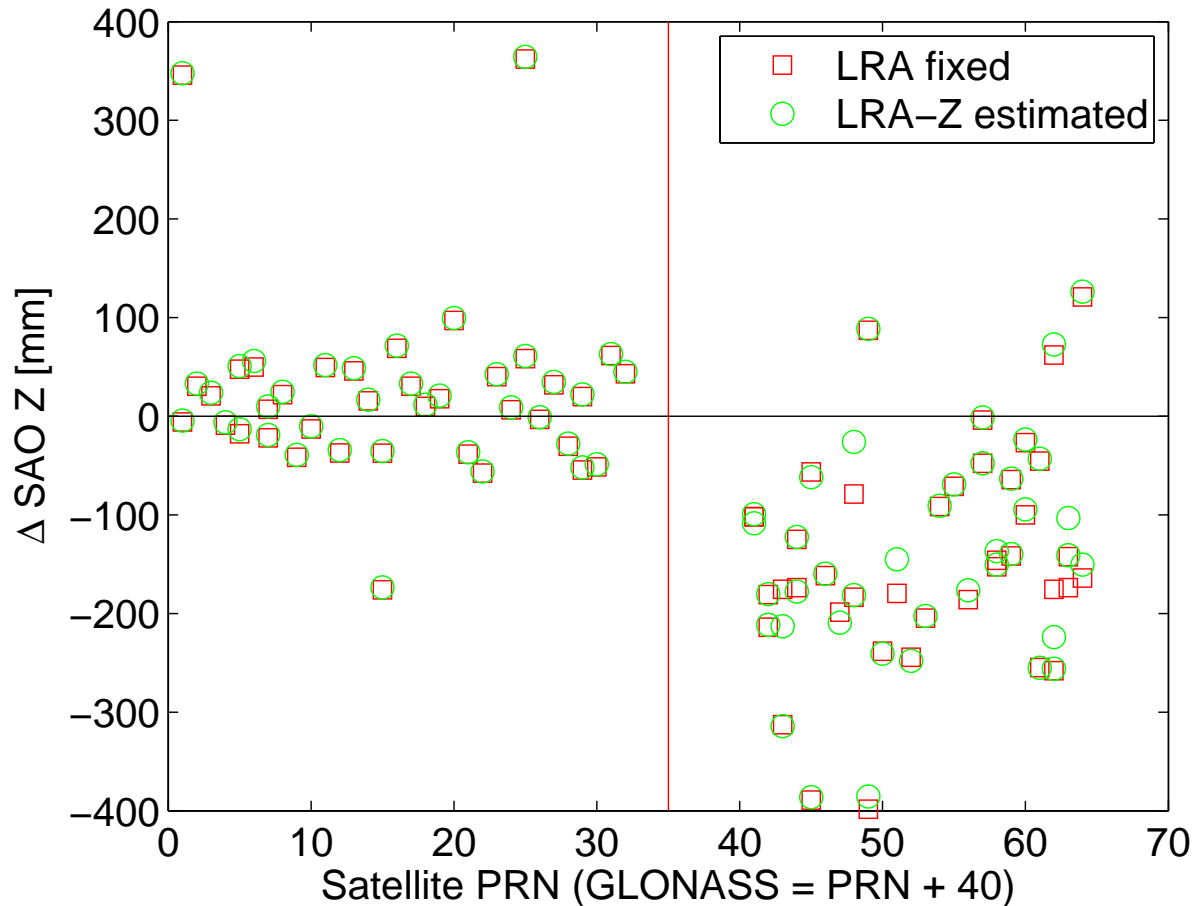
	GPS	GLONASS
SAO fixed	34.76 mm	33.56 mm
SAO-Z estimated	34.83 mm	26.52 mm
⇒ Difference	0.06 mm	7.04 mm

⇒ Significant corrections to LRA offsets

⇒ Common estimation with SAO corrections is possible

GNSS SAO corrections

Satellite antenna offset correction: Z component



⇒ Significant corrections to SAO of igs05.atx

⇒ Common estimation with LRA corrections is possible

Mean correction:

LRA fixed

LRA-Z estimated

⇒ **Difference**

GPS

23.34 mm

25.93 mm

2.59 mm

GLONASS

-142.35 mm

-138.80 mm

3.55 mm

Conclusions

- Combination of *GNSS and SLR* using *satellite co-location* in order to reduce / explain biases seen in SLR range residuals
- *Accurate ties* (in space and on sites) required for combination
- *GNSS SAOs* from *igs05.atx* do not fit to the *SLR scale*
→ improvements with *igs08.atx*?
- *LRA offsets* show significant discrepancies (*~35 mm*)
- *Separation* of SLR *range biases*, *LRA offsets* and *GNSS SAO* is feasible

Next steps / possible improvements:

- use ITRF2008 reference frame
- use GNSS antenna phase center model *igs08.atx*
- improve GNSS orbit model (albedo, solar radiation pressure)