Homogeneous formation of SLR Normal Point data

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22nd INTERNATIONAL WORKSHOP ON LASER RANGING, 8 November 2022

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Outline

- Introduction
  - Data flow of SLR Normal Points
  - How to build SLR Normal Points
  - SLR processing at AIUB
- First results
  - Compare different screening techniques
  - SLR solutions using Variance Component Estimation
- Summary & Outlook

DATA FLOW OF NORMAL POINTS

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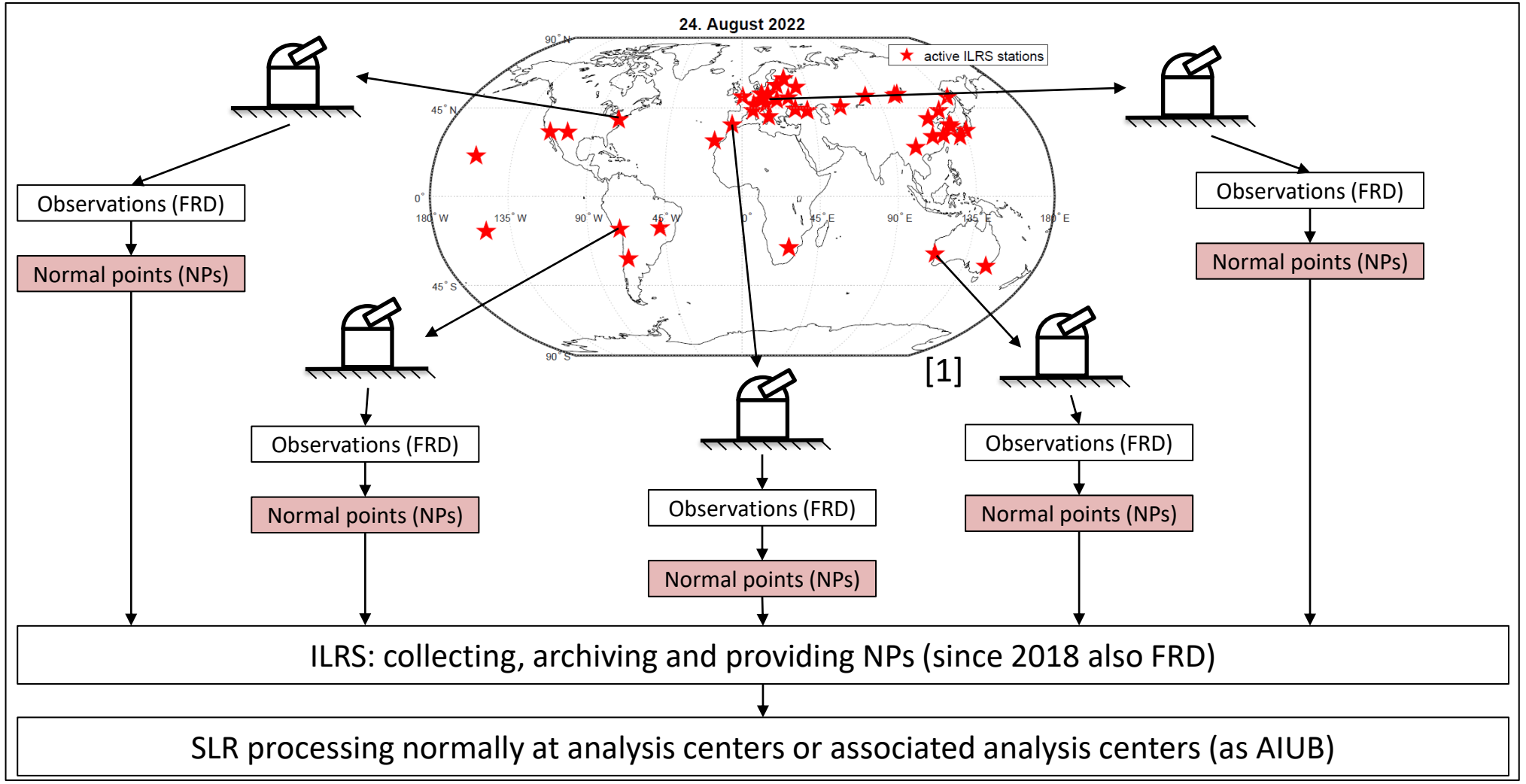

Sources:

[1] https://ilrs.gsfc.nasa.gov

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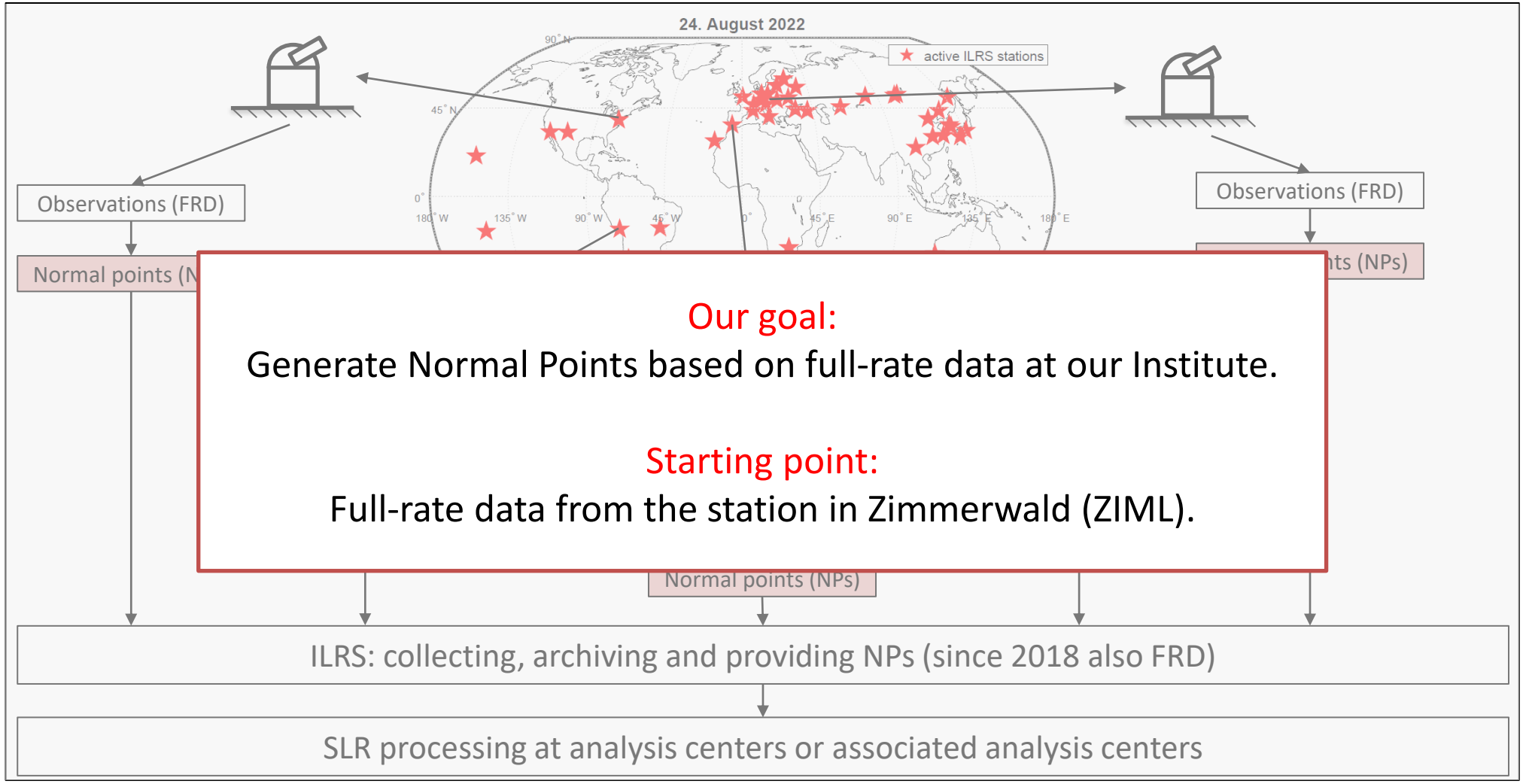

ILRS NORMAL POINT ALGORITHM

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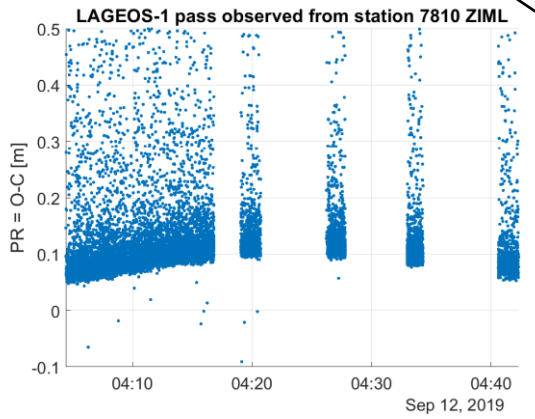
https://ilrs.gsfc.nasa.gov/data_and_products/data/npt/npt_algorithm.html

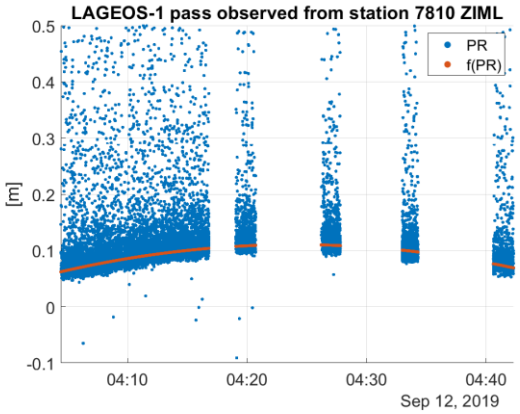
Observations (O)

Predictions (C)

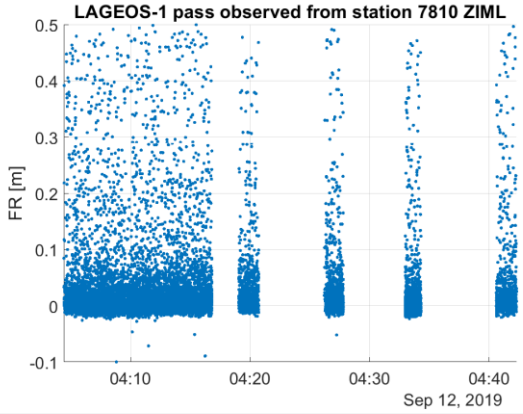


PR = O-C

Trend function f (e.g., orbital function or low degree polynomials)



FR = PR – f(PR)



NORMAL POINTS

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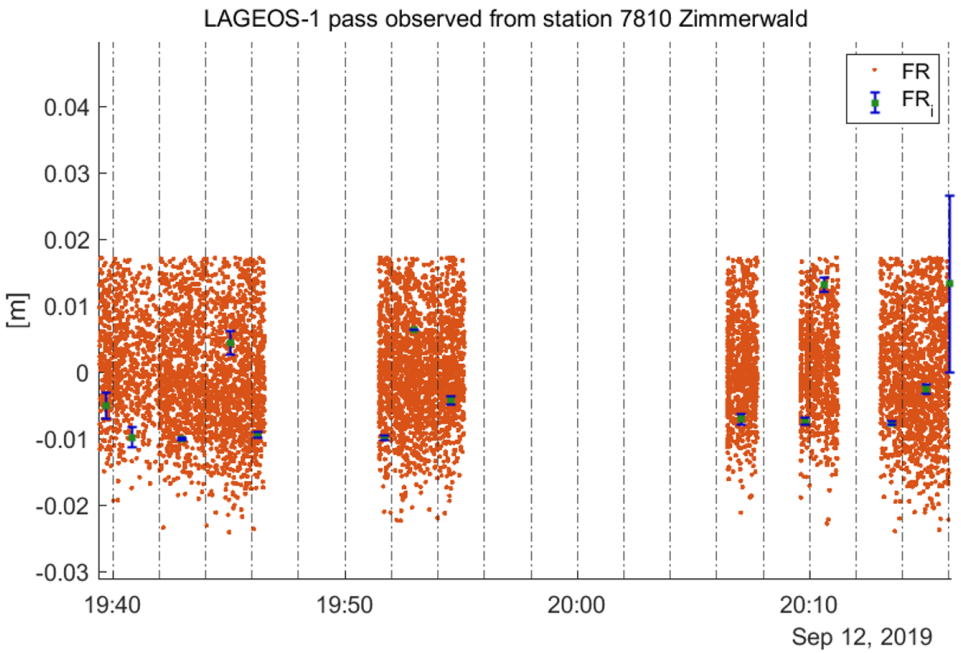
- Use only selected observations
- For each bin i:

$$NP_i = O_i - FR_i + \overline{FR_i}$$



O_i: Observation closest to the mean epoch of the bin i

FR_i: Fit residual of this observation O_i

$\overline{FR_i}$: Mean of fit residuals in the bin i

TWO SCREENING TECHNIQUES

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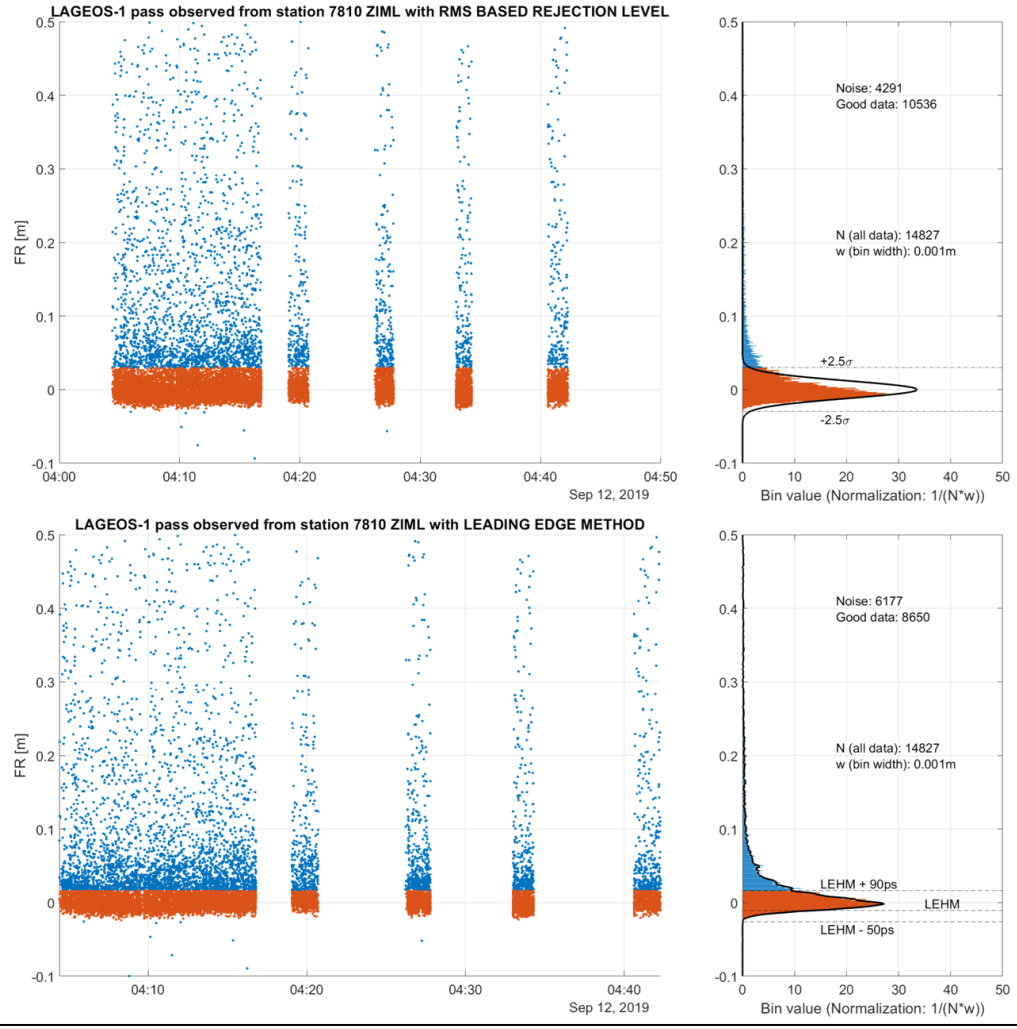
- RMS based rejection level [1]
- Leading edge method [Kirchner et al., 2008] [Wilkinson et al., 2018]



Sources:

[1]https://ilrs.gsfc.nasa.gov/data_and_products/data/npt/npt_algorithm.html

SLR PROCESSING AT AIUB

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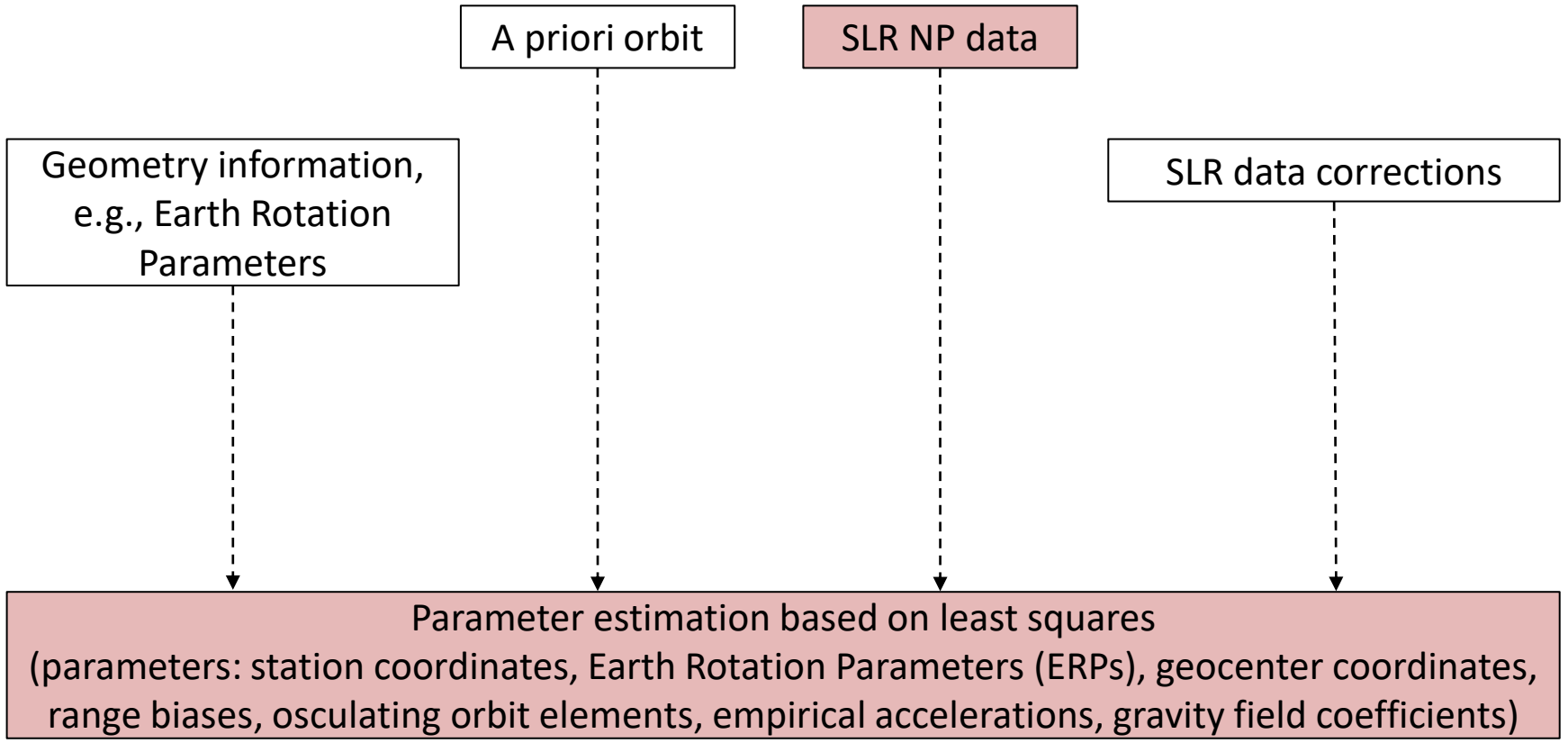
- Using the Bernese GNSS Software



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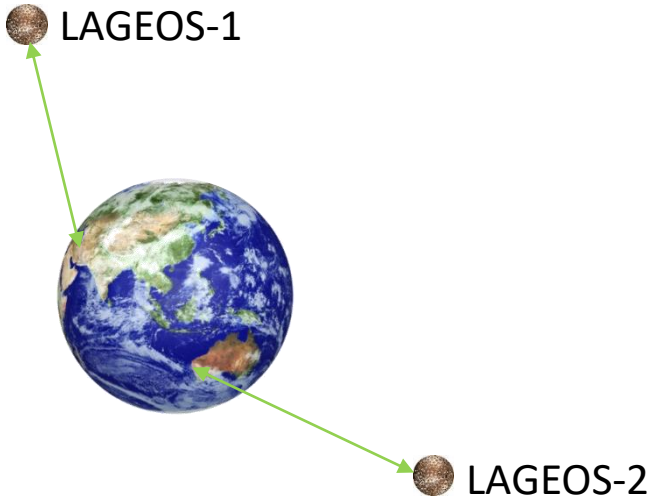
Glossary:

- S: along-track
- W: cross-track

• Parametrization

Parametrization \ Satellites	LAGEOS-1/2
Osculating elements	$a, e, i, \Omega, \omega, u_0$
	1 set per 7 days
Constant and once-per-revolution accelerations	S_0, S_S, S_C, W_S, W_C
	1 set per 7 days
Pseudo-stochastic pulses	no pulses
Earth Rotation Parameters	$X_P, Y_P, UT1 - UTC$
	piecewise-linear
Geocenter coordinates	1 set per 7 days
	free geocenter
Station coordinates	1 set per 7 days
	NNR and NNT
Range biases	1 set per 7 days for
	selected stations + ZIML



COMPARE DIFFERENT SCREENING TECHNIQUES

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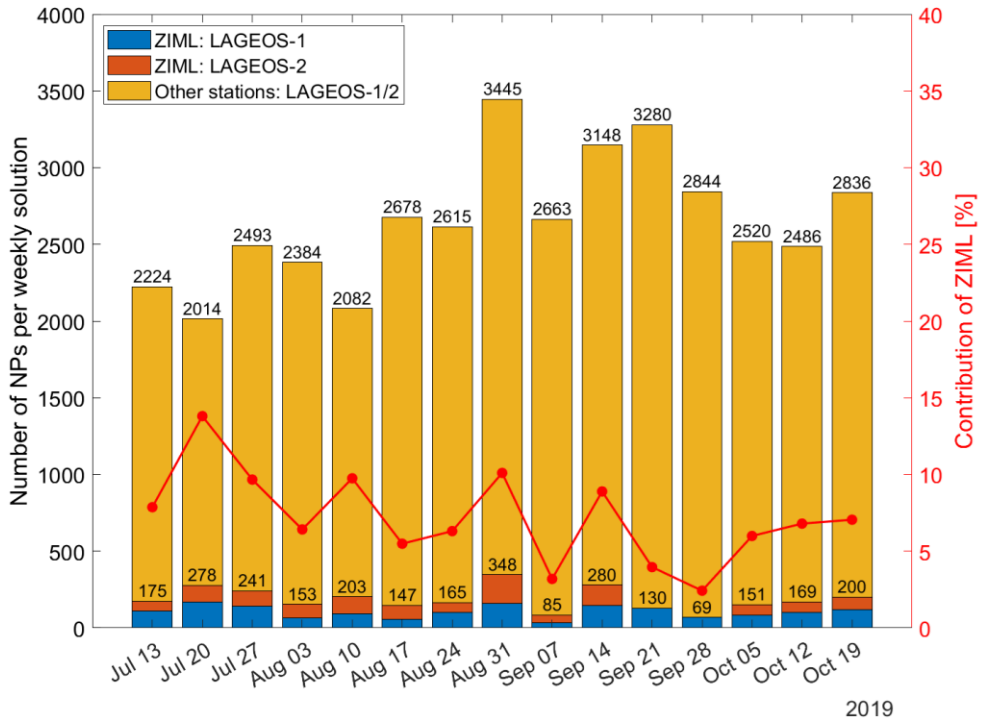
- Weekly SLR solutions based on LAGEOS-1/2 for July to October in 2019

- Different screening methods are applied
  - S1-RMS3250: RMS based rejection level with +/- 2,5σ
  - S2-LEHM-50+90: Leading edge method with [-50ps,+90ps]

(currently only on data from ZIML)

- Number of observations



→ Station ZIML provides 2-14% of the total data volume (for LAGEOS-1/2).

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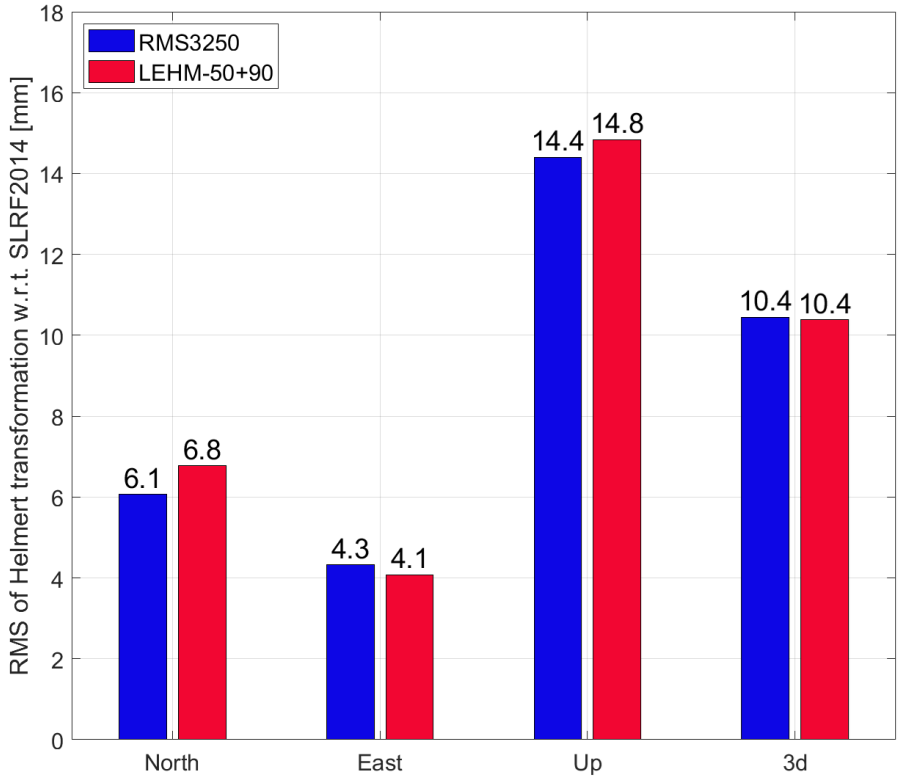
• Earth Rotation Parameters

	X pole $[\mu as]$		Y pole $[\mu as]$		UT1-UTC $[\mu s]$	
	Bias	WRMS	Bias	WRMS	Bias	WRMS
RMS3250	99,6	179,7	53,8	145,3	7,6	71,6
LEHM-50+90	93,9	170,9	53,4	140,9	5,7	71,7

• Station coordinates



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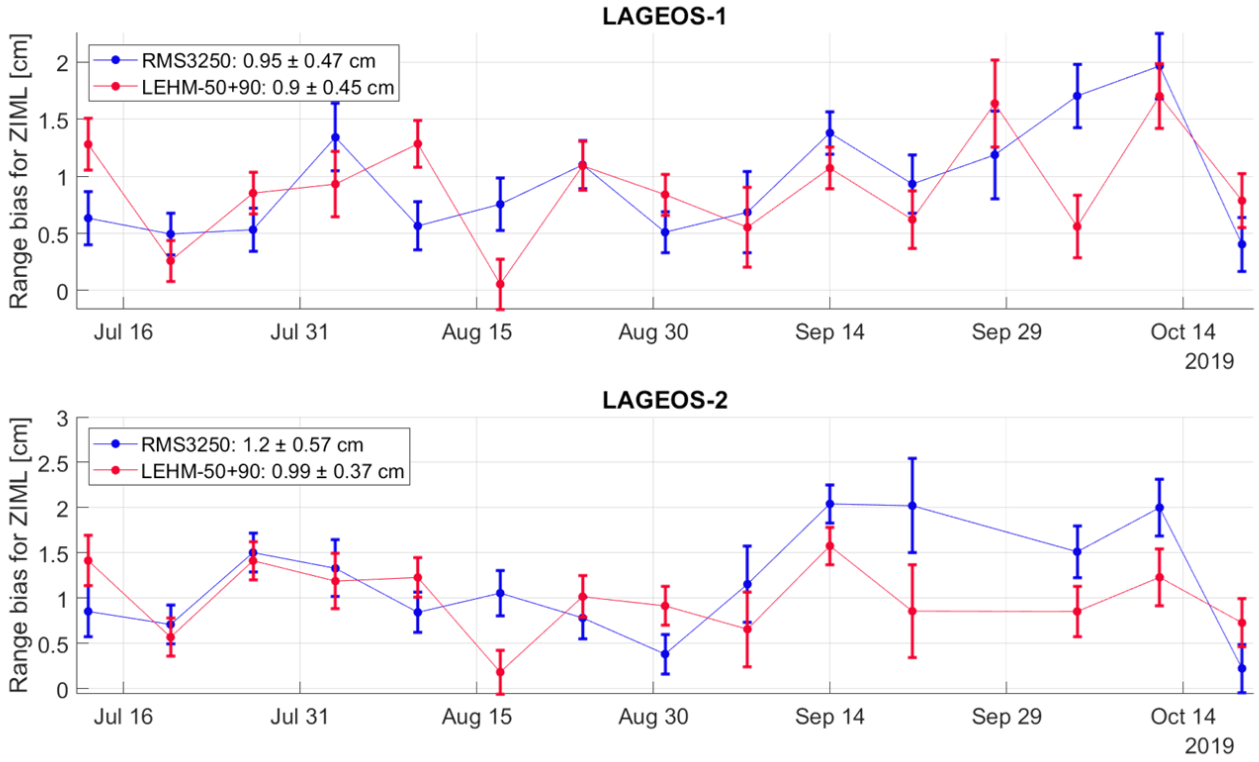
- Range biases for LAGEOS-1 and LAGEOS-2 for ZIML



→ Range biases are more stable for the NPs of the solution LEHM-50+90.

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[1] https://ilrs.gsfc.nasa.gov

SLR SOLUTIONS USING VCE

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- VCE in a nutshell

Normal equation systems per satellite group: $\boldsymbol{N}_i \boldsymbol{x}_i = \boldsymbol{b}_i$

Combined normal equation system:

$$\boldsymbol{N}_c \boldsymbol{x}_c = \boldsymbol{b}_c$$

with

$$\boldsymbol{N}_c = \sum_{i=1}^{n} \frac{\sigma_0^2}{\hat{\sigma}_i^2} \boldsymbol{N}_i \,, \boldsymbol{b}_c = \sum_{i=1}^{n} \frac{\sigma_0^2}{\hat{\sigma}_i^2} \boldsymbol{b}_i$$

where $\hat{\sigma}_i$ is the a posteriori variance factor for satellite group i:

$$\hat{\sigma}_i^2 = \frac{\boldsymbol{x}_c^T \boldsymbol{N}_i \boldsymbol{x}_c - 2\boldsymbol{x}_c^T \boldsymbol{b}_i + \boldsymbol{l}_i^T \boldsymbol{P}_i \boldsymbol{l}_i}{n_i - \frac{\sigma_0^2}{\sigma_i^2} tr\left(\boldsymbol{N}_i \boldsymbol{N}_c^{-1}\right)}$$

→ Weights: $\hat{w}_i := \frac{\sigma_0^2}{\hat{\sigma}_i^2}$

- Using the Variance Component Estimation per satellite and per station:

Station	LAGEOS-1	LAGEOS-2
1884	$\hat{w}_{1884,L1}$	$\hat{w}_{1884,L2}$
7090	$\hat{w}_{7090,L1}$	$\hat{w}_{7090,L2}$
7810	$\hat{w}_{7810,L1}$	$\hat{w}_{7810,L2}$
…	…	…

- Compare
  - Earth Rotation Parameters
  - Weights from VCE

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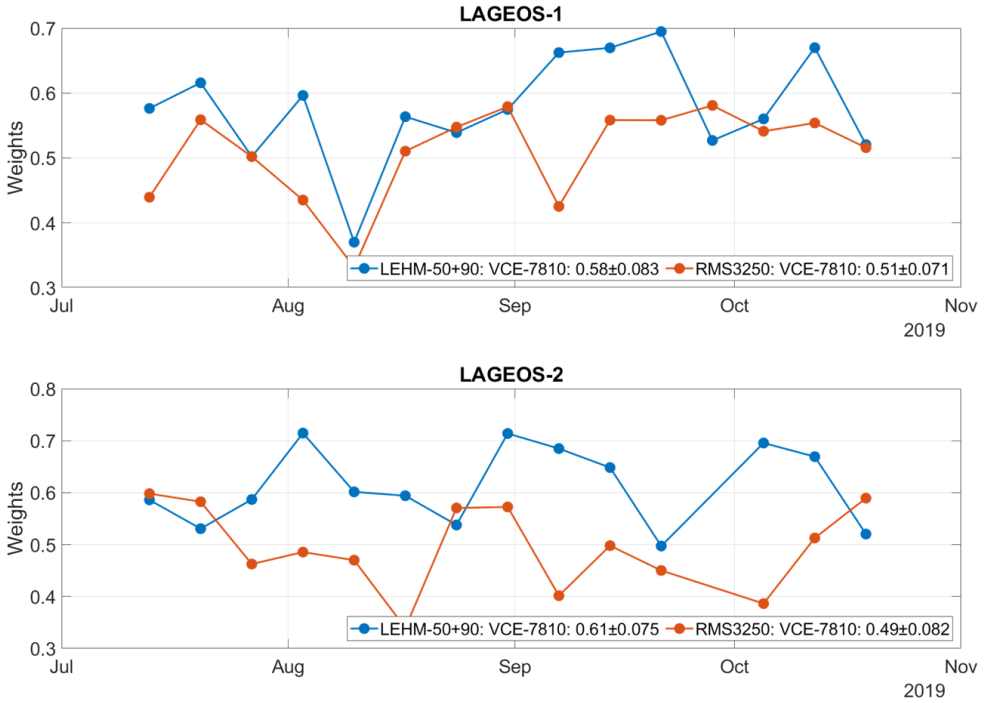
	Bias	WRMS	Bias	WRMS	Bias	WRMS
RMS3250	99,6	179,7	53,8	145,3	7,6	71,6
LEHM-50+90	93,9	170,9	53,4	140,9	5,7	71,7
RMS3250: VCE	146,1	189,1	27,4	109,7	0,2	57,6
LEHM-50+90: VCE	141,0	184,6	22,6	101,4	-0,2	57,5

Weights from VCE



→ The VCE indicates that the observations from LEHM-50+90 solution fit better to the a priori models.

SUMMARY & OUTLOOK

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SUMMARY

- Different screening techniques can be applied.
- SLR processing can be used to validate the quality of the newly generated NPs.
- VCE per satellite and per station indicates that the LEHM-50+90 solution is better.

OUTLOOK

- Develop new screening techniques.
- Apply the screening techniques also on full-rate data from other stations.

REFERENCES

1. https://ilrs.gsfc.nasa.gov/data_and_products/data/npt/npt_algorithm.html
2. Kirchner G., Kucharski D., Koidl F. (2008) *Millimeter Ranging to Centimeter Targets*. In: Proceedings of the 16th International Workshop on Laser Ranging, October 12-17, 2008, Poznan, Poland
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