

# SLR DATA PROCESSING OF SPHERICAL SATELLITES AT AIUB

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from

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COSPAR-2021-Hybrid, 29 January 2021

# OUTLINE

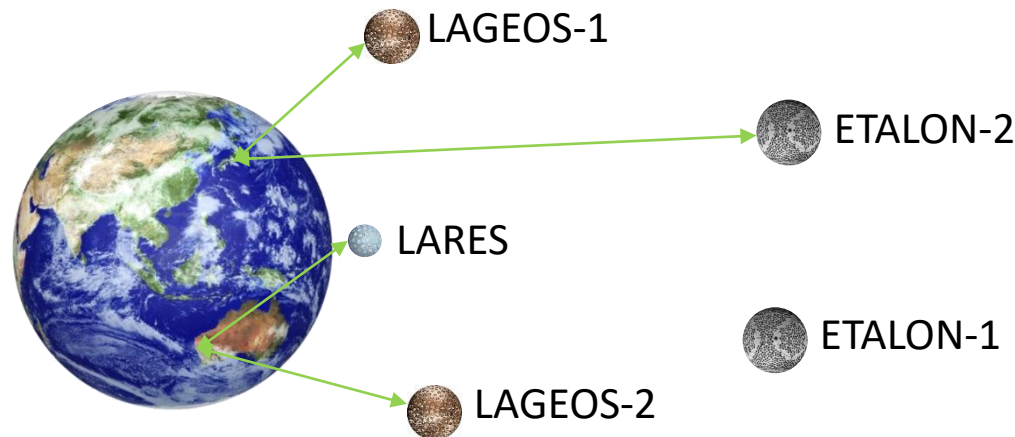
- Introduction
  - What is SLR
  - Parametrization
- Analysis
  - Compare estimated geodetic parameters of different SLR solutions
- Summary and Outlook

# WHAT IS SATELLITE LASER RANGING

## Outline:

- Introduction
- Analysis
- Summary and Outlook

- Runtime measurement of a laser beam (e.g.  $\lambda: 532/1064 \text{ nm}$ ) from a station to a satellite with retroreflectors
- To determine geodetic parameters, e.g. Earth rotation parameters (ERPs), station coordinates, geocenter



Zimmerwald in Switzerland

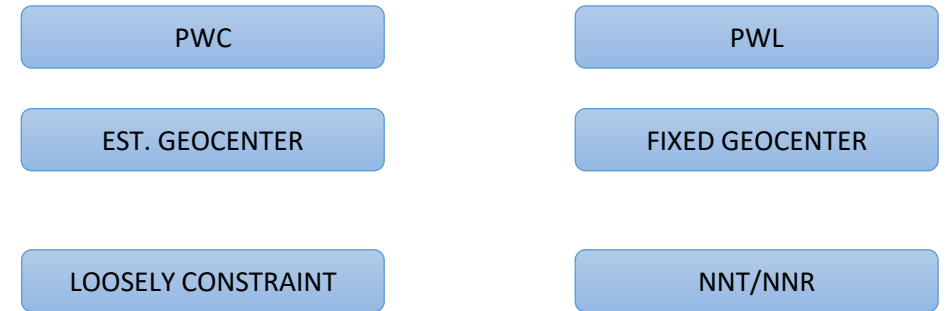
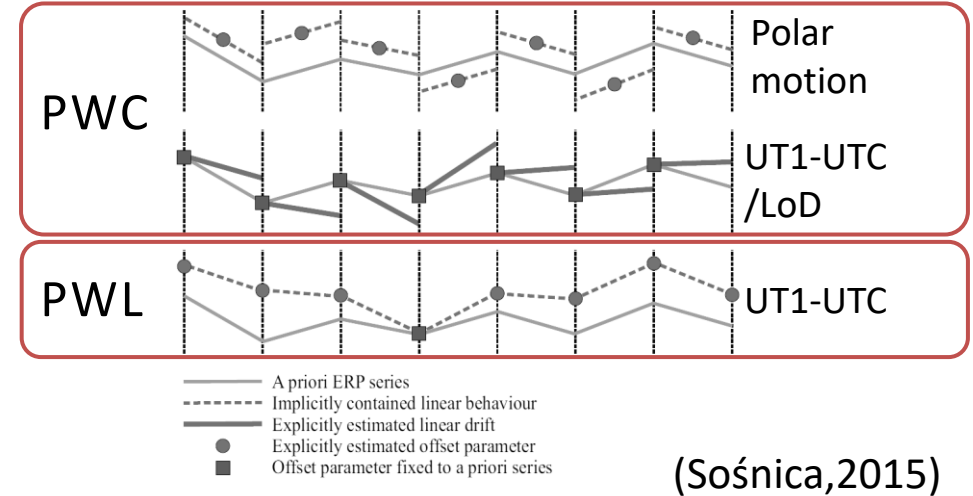


# PARAMETRIZATION

**Outline:**

- Introduction
- Analysis
- Summary and Outlook

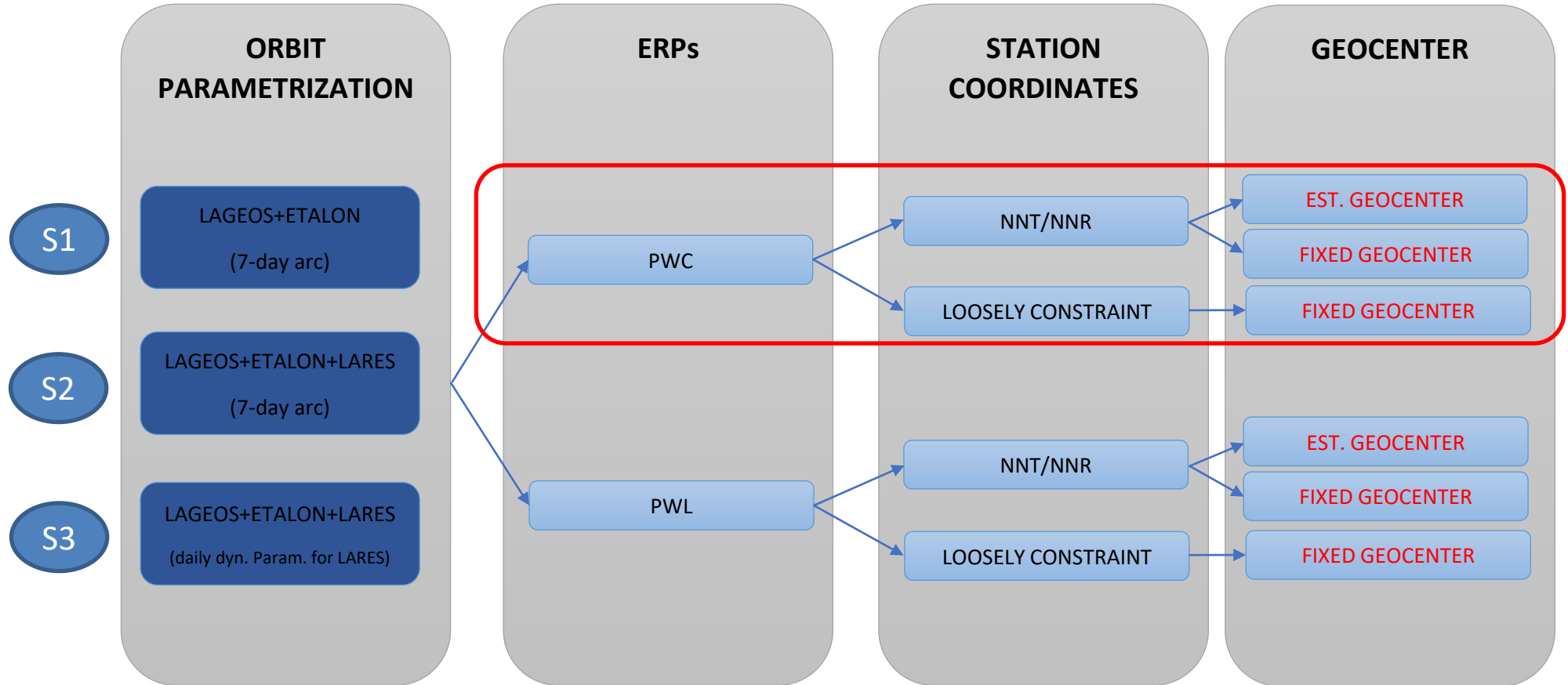
Satellites	LAGEOS-1/2 ETALON-1/2	LARES
<b>Parametrization</b>		
<b>Osculating elements</b>	$a, e, i, \Omega, \omega, u_0$ 1 set per 7 days	
<b>Constant and once-per-rev accelerations</b>	$S_0, S_S, S_C, W_S, W_C$ 1 set per 7 days   1 set per 7 days 1 set per 7 days   1 set per day	
<b>Pseudo-stochastic pulses</b>	No pulses	In along-track (twice per day)
<b>Earth rotation parameters</b>	$X_p, Y_p, UT1 - UTC$ Piecewise-constant Piecewise-linear	
<b>Geocenter coordinates</b>	1 set per 7 days Fixed Geocenter	
<b>Station coordinates</b>	1 set per 7 days Loosely constrained NNR and NNT solution	
<b>Range biases</b>	1 set per 7 days for selected stations   all stations	



# DIFFERENT SLR-SOLUTIONS

## Outline:

- Introduction
- Analysis
- Summary and Outlook



**Outline:**

- Introduction
- Analysis (PWC)
  - ERPs
  - Station coord.
  - Geocenter
- Summary and Outlook

PWC

LOOSELY CONSTRAINT

**Abbreviations:**

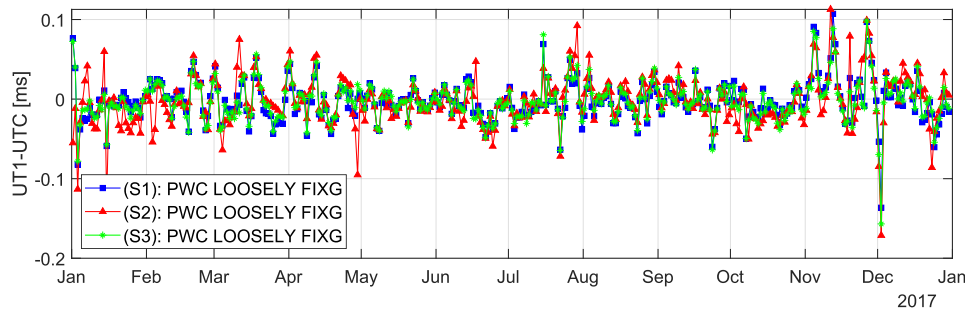
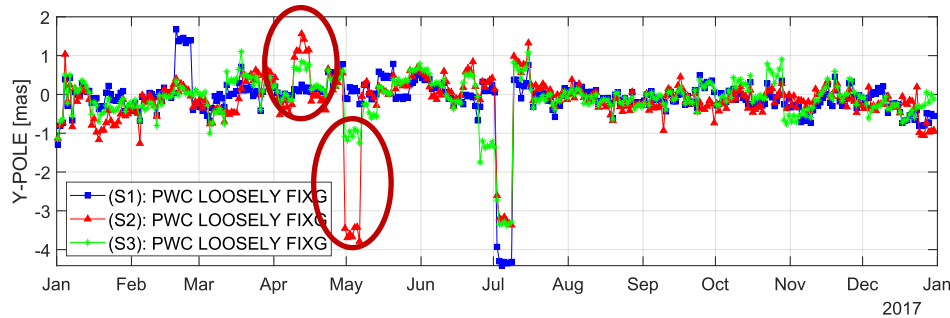
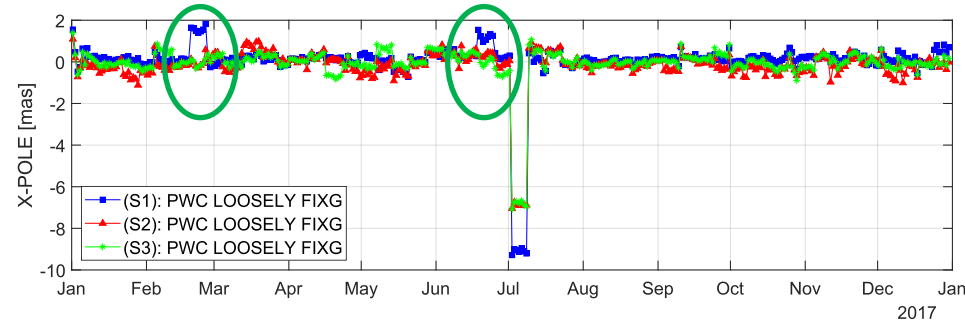
**(S1):** LAGEOS+ETALON  
(7-day arcs)

**(S2):** LAGEOS+ETALON+  
LARES (7-day arcs)

**(S3):** LAGEOS+ETALON+  
LARES (daily dyn. Param.  
for LARES)

# COMPARISON OF EARTH ROTATION PARAMETERS

COMPARISON OF ESTIMATED ERPS W.R.T. C04-SERIES (ITRF14) AT 12H-EPOCH  
W OUTLIERS



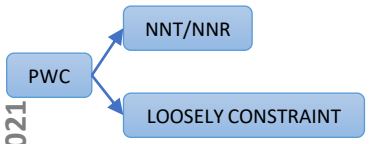
- Several outliers
  - LARES can stabilize
  - caused by LARES
- Sensitive to the a priori orbits through the screening

# COMPARISON OF EARTH ROTATION PARAMETERS

## Outline:

- Introduction
- Analysis (PWC)
  - ERPs
  - Station coord.
  - Geocenter
- Summary and Outlook

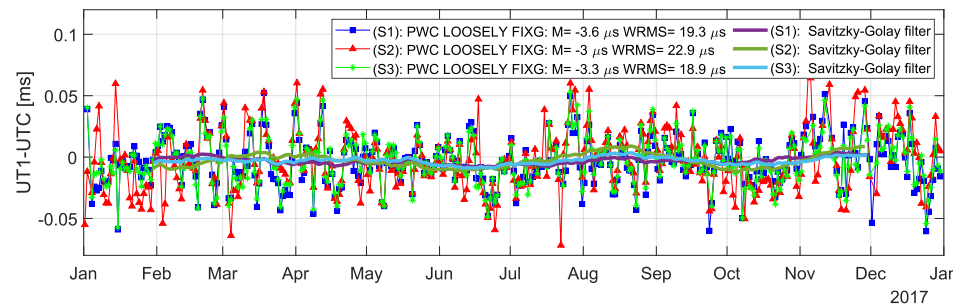
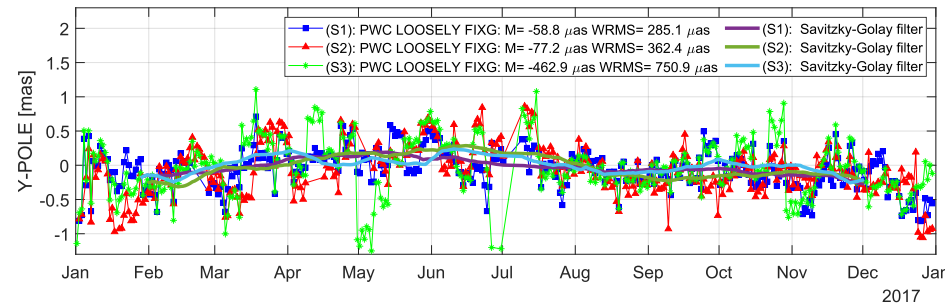
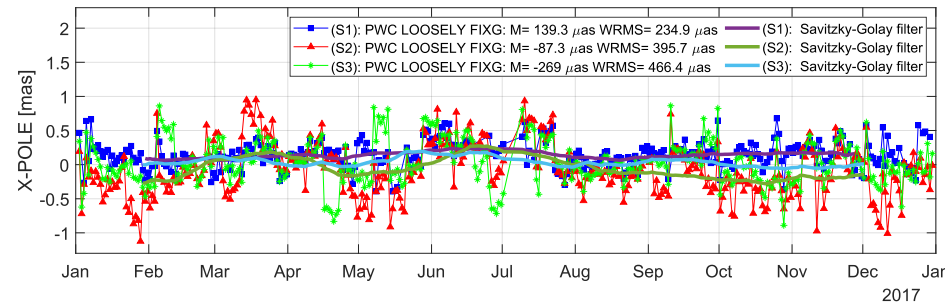
COSPAR-2021-Hybrid, PSD.1, 29 January 2021



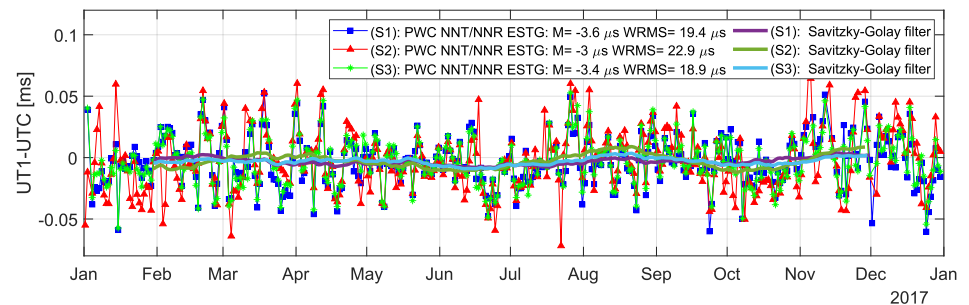
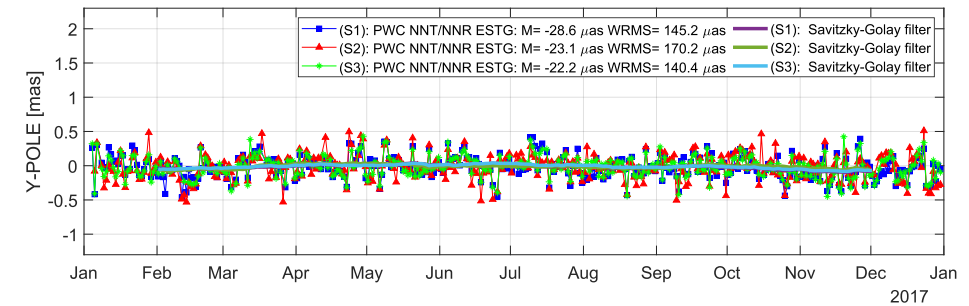
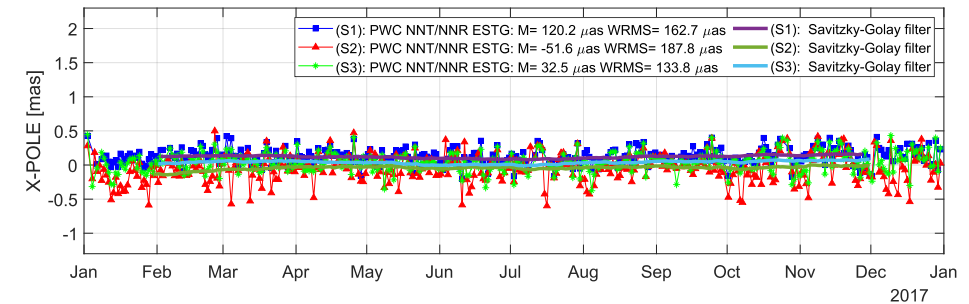
## Abbreviations:

- (S1):** LAGEOS+ETALON (7-day arcs)
- (S2):** LAGEOS+ETALON+ LARES (7-day arcs)
- (S3):** LAGEOS+ETALON+ LARES (daily dyn. Param. for LARES)

### COMPARISON OF ESTIMATED ERPS W.R.T. C04-SERIES (ITRF14) AT 12H-EPOCH W/O OUTLIERS



### COMPARISON OF ESTIMATED ERPS W.R.T. C04-SERIES (ITRF14) AT 12H-EPOCH W/O OUTLIERS

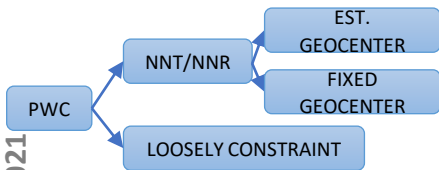




# COMPARISON OF EARTH ROTATION PARAMETERS

## Outline:

- Introduction
- Analysis (PWC)
  - ERPs
  - Station coord.
  - Geocenter
- Summary and Outlook



## Abbreviations:

**(S1):** LAGEOS+ETALON  
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**(S3):** LAGEOS+ETALON+  
LARES (daily dyn. Param.  
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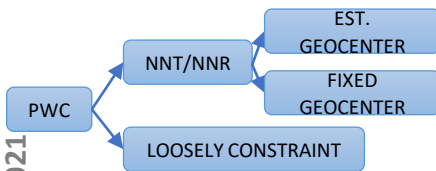
Solutions			X pole [ $\mu$ as]		Y pole [ $\mu$ as]		UT1-UTC [ $\mu$ s]	
Used satellites	Station coordinates	Geocenter	Bias	WRMS	Bias	WRMS	Bias	WRMS
(S1): LAGEOS+ETALON	Loosely	fixed	139.3	234.9	-58.8	285.1	-3.6	19.3
	NNT/NNR	estimated	120.2	162.7	-28.6	145.2	-3.6	19.4
		fixed	144.8	181.8	-34.4	149.8	-3.2	18.9
(S2): LAGEOS+ETALON+ LARES (7-day arcs)	Loosely	fixed	-87.3	395.7	-77.2	362.4	-3.0	22.9
	NNT/NNR	estimated	-51.6	187.8	-23.1	170.2	-3.0	22.9
		fixed	-16.2	179.9	-3.4	165.1	-2.1	22.5
(S3): LAGEOS+ETALON+ LARES (daily dyn. Parameters for LARES)	Loosely	fixed	-269	466.4	-462.9	750.9	-3.3	18.9
	NNT/NNR	estimated	32.5	133.8	-22.2	140.4	-3.4	18.9
		fixed	61.3	151.3	-13.7	146.8	-2.7	18.6



# COMPARISON OF EARTH ROTATION PARAMETERS

## Outline:

- Introduction
- Analysis (PWC)
  - ERPs
  - Station coord.
  - Geocenter
- Summary and Outlook



## Abbreviations:

- (S1): LAGEOS+ETALON (7-day arcs)
- (S2): LAGEOS+ETALON+LARES (7-day arcs)
- (S3): LAGEOS+ETALON+LARES (daily dyn. Param. for LARES)

Solutions			X pole [ $\mu as$ ]		Y pole [ $\mu as$ ]		UT1-UTC [ $\mu s$ ]	
Used satellites	Station coordinates	Geocenter	Bias	WRMS	Bias	WRMS	Bias	WRMS

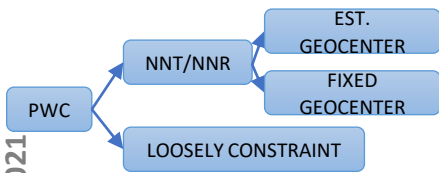
## Conclusion:

- Use a good datum definition
- LARES parametrization has to be extended as for example in (S3)
- If a good parametrization is used, the estimation of geocenter coordinates can slightly improve the ERPs

# COMPARISON OF HELMERT TRANSFORMATION

## Outline:

- Introduction
- Analysis (PWC)
  - ERPs
  - Station coord.
  - Geocenter
- Summary and Outlook



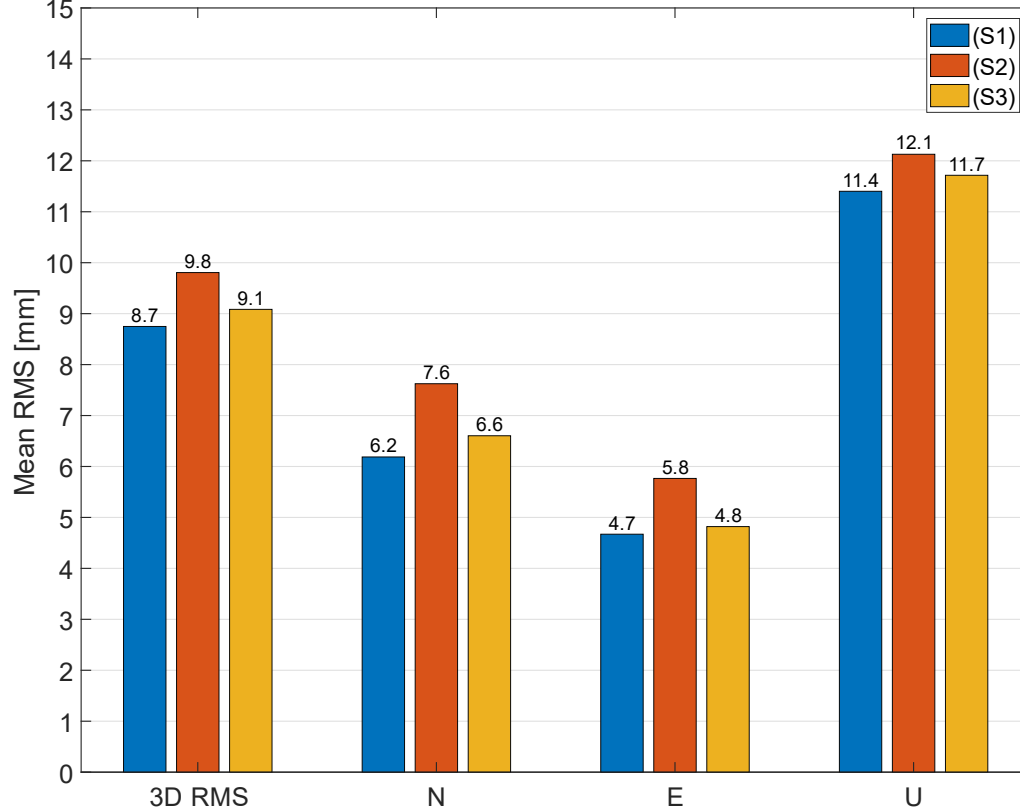
## Abbreviations:

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**(S2):** LAGEOS+ETALON+  
LARES (7-day arcs)

**(S3):** LAGEOS+ETALON+  
LARES (daily dyn. Param.  
for LARES)

Mean RMS of Helmert transformation of individual SLR solutions w.r.t. SLRF2014



- If a good LARES orbit parametrization is used, the RMS of Helmert transformations can be decreased

# COMPARISON OF THE GEOCENTER

## Outline:

- Introduction
- Analysis (PWC)
  - ERPs
  - Station coord.
  - Geocenter
- Summary and Outlook

PWC

NNT/NNR

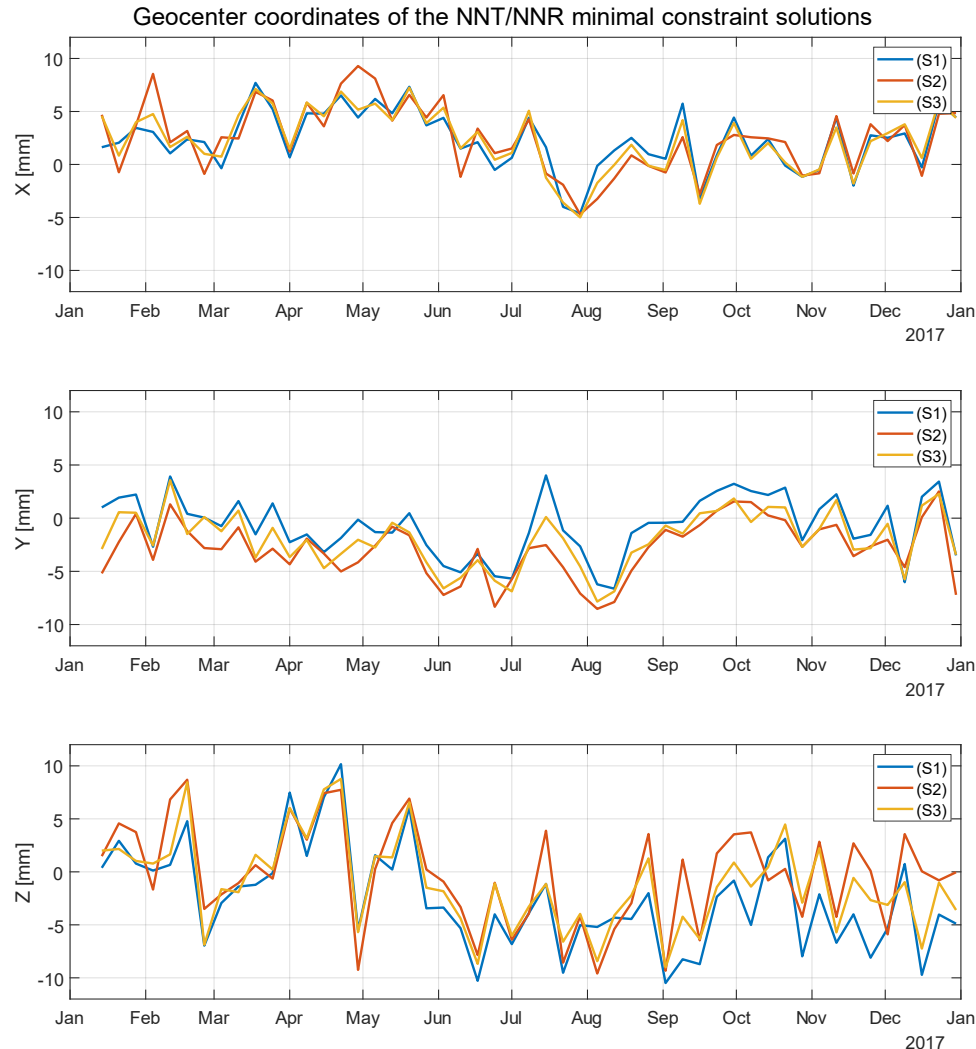
EST.  
GEOCENTER

## Abbreviations:

**(S1):** LAGEOS+ETALON  
(7-day arcs)

**(S2):** LAGEOS+ETALON+  
LARES (7-day arcs)

**(S3):** LAGEOS+ETALON+  
LARES (daily dyn. Param.  
for LARES)

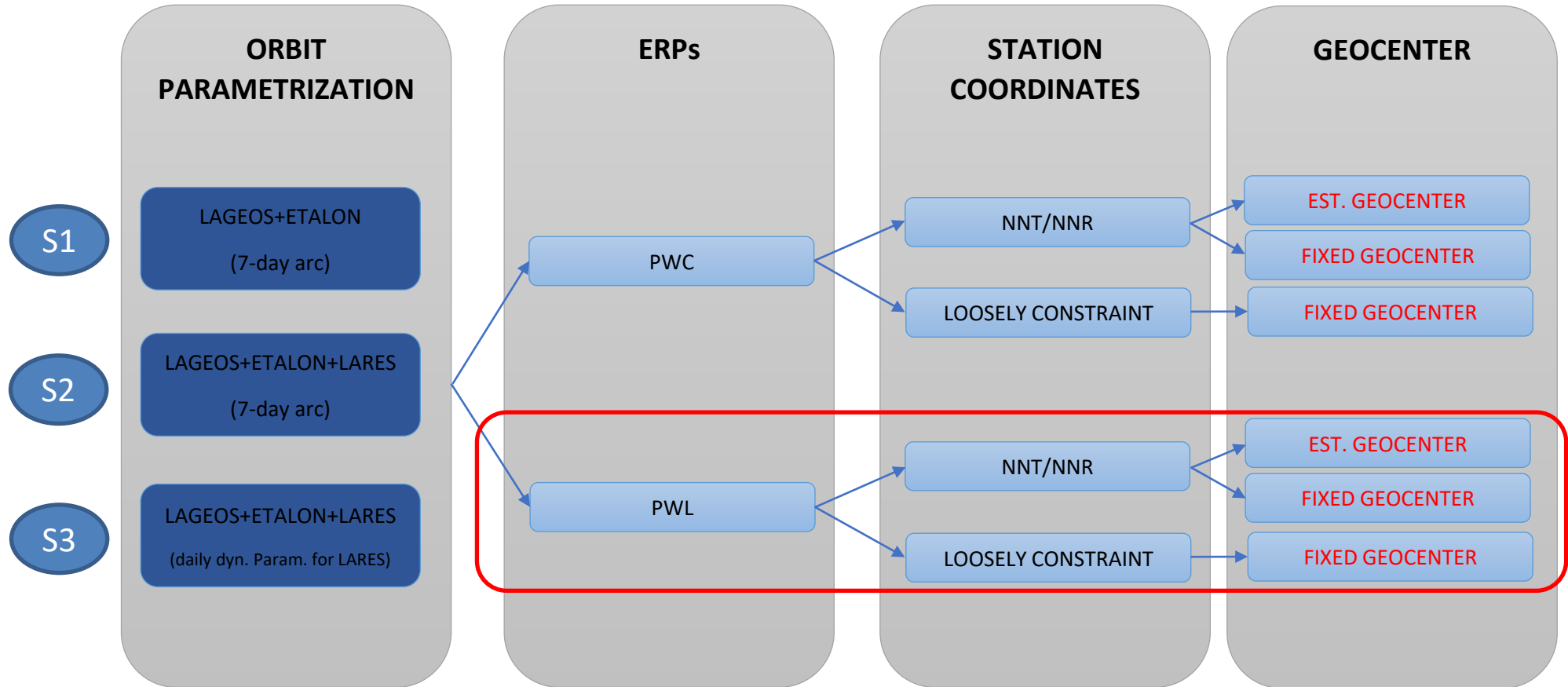


- The time series of the geocenter from solution (S3) fits better to (S1) than (S2)

# DIFFERENT SLR-SOLUTIONS

## Outline:

- Introduction
- **Analysis**
- Summary and Outlook

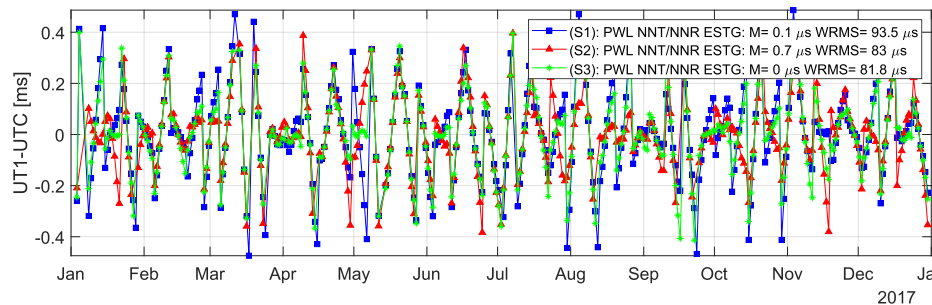
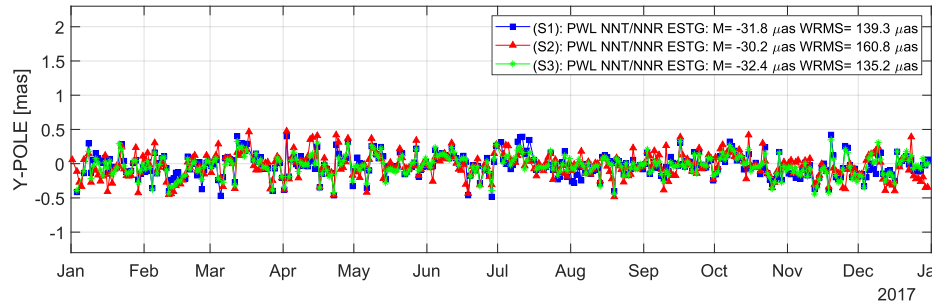
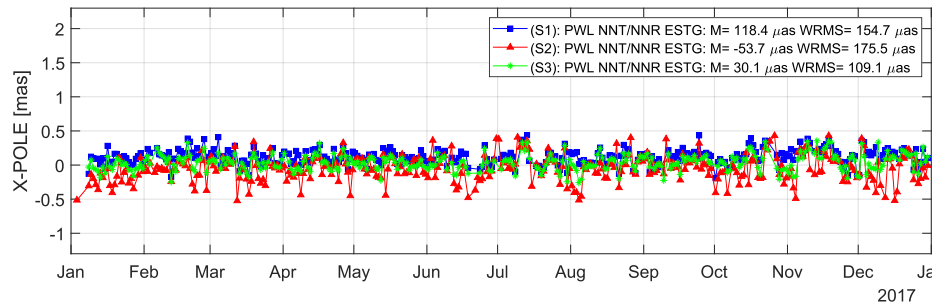


# COMPARISON OF EARTH ROTATION PARAMETERS

## Outline:

- Introduction
- Analysis (PWL)
  - ERPs
- Summary and Outlook

COMPARISON OF ESTIMATED ERPS W.R.T. C04-SERIES (ITRF14) AT 12H-EPOCH W/O OUTLIERS



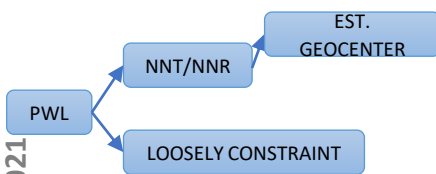
Solutions				X pole [ $\mu$ as]		Y pole [ $\mu$ as]		UT1-UTC [ $\mu$ s]	
	Station coordinates	Geo-center	ERPs	Bias	WRMS	Bias	WRMS	Bias	WRMS
(S1)	NNT/NNR	est.	PWC	123.9	190.2	-26.5	169.8	-2.7	21.5
			PWL	121.7	185.3	-28.3	153.6	1.0	105.2
(S2)	NNT/NNR	est.	PWC	-51.6	187.8	-23.1	170.2	-3.0	22.9
			PWL	-53.7	175.5	-30.2	160.8	0.7	83.0
(S3)	NNT/NNR	est.	PWC	37.1	158.5	-25.1	166.7	-2.6	21.3
			PWL	32.1	146.9	-29.1	152.6	0.2	92.1

## Conclusion:

Piecewise-linear parametrization of ERPs can improve the solution

## Abbreviations:

- (S1): LAGEOS+ETALON (7-day arcs)
- (S2): LAGEOS+ETALON+ LARES (7-day arcs)
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# SUMMARY & OUTLOOK

## Outline:

- Introduction
- Analysis
- **Summary and Outlook**

## Summary:

- We successfully included LARES with two different orbit parametrizations in our SLR solutions
- A good datum definition is needed
- Piecewise-linear parametrization of ERPs improves the quality of the ERPs

## Outlook:

- Further investigations of PWL parametrization of ERPs
- Co-estimation of low-degree gravity field coefficients

# REFERENCES

1. Sośnica, K.; 2015: **Determination of Precise Satellite Orbits and Geodetic Parameters using Satellite Laser Ranging**. Geodätisch-geophysikalische Arbeiten in der Schweiz, vol. 93.