

Simulation of realistic SLR observations to optimize tracking scenarios

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Introduction

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	Satellite Name	Satellite ID	SIC Code	NORAD Number	NP Indicator	Bin Size (Seconds)	Altitude (Km)	Inclination (deg)	First Tracked Date
	Ajisai	8606101	1500	16908	5	30	1485	50	1986-Aug-13
	Apollo11 Sea of Tranquility	0000100	N/A	N/A	2	variable	356,400	5	1969-Aug-20
	Apollo14 Fra Mauro	0000102	N/A	N/A	2	variable	356,400	5	1971-Feb-07
GLONASS-123	Apollo15 Hadley Rille	0000103	N/A	N/A	2	variable	356,400	5	1971-Sep-01
GLONASS-125	Beacon-C	6503201	0317	1328	3	15	927	41	1976-Jan-02
GLONASS-128	COMPASS-G1	1000101	2002	36287	9	300	35,786	55.5	2012-Apr-28
GLONASS-129	COMPASS-I3	1101301	2003	37384	9	300	35,786	55.5	2012-Apr-27
GLONASS-133	COMPASS-I5	1107301	2005	37948	9	300	35,786	55.5	2012-Jul-06
GLONASS-134	COMPASS-IS1	1501901	2006	40549	9	300	35,786	55.5	2015-Sep-08
GRACE-A	COMPASS-IS2	1505301	2010	40938	9	300	35,786	55.5	2015-Sep-29
GRACE-B	COMPASS-M3	1201801	2004	38250	9	300	21,528	55.0	2012-Jul-11
Luna17 Sea of Imbrium	COMPASS-MS1	1503702	2007	40749	9	300	21,528	55.0	2015-Jul-25
Luna21 Sea of Serenity	COMPASS-MS2	1503701	2008	40748	9	300	21,528	55.0	2015-Jul-25
PN-1A	IRNSS-1A	1001301	8006	36508	3	15	720	92	2010-Apr-20
QZS-1	IRNSS-1B	1401301	0525	19751	9	300	19,105	65	1989-Jan-26
RadioAstron	IRNSS-1C	1401301	4146	20026	9	300	19,135	65	1989-Jul-13
SARAL	IRNSS-1D	1501301	7101	37846	9	300	23,220	56	2011-Nov-29
Sentinel-3A	IRNSS-1E	1601301	7102	37847	9	300	23,220	56	2011-Nov-29
Starlette	IRNSS-1F	1601301	7103	38857	9	300	23,220	56	2012-Nov-07
SpinSat	Jason-2	1205501	7104	38858	9	300	23,220	56	2012-Nov-07
Stella	Jason-3	1405001	7201	40128	9	300	17,000 - 26,210	~ 50	2014-Dec-05
STPSat-2	KOMPSAT-5	1405002	7202	40129	9	300	17,000 - 26,210	~ 50	2015-Mar-17
STSAT-2C	LAGEOS-1	1501701	7203	40544	9	300	23,220	56 +/- 2 deg	2015-Mar-27
Swarm-A	LAGEOS-2	1501702	7204	40545	9	300	23,220	56 +/- 2 deg	2015-Mar-27
Swarm-B	LARES	1504501	7205	40889	9	300	23,220	56 +/- 2 deg	2015-Sep-11
Swarm-C	Larets	1504502	7206	40890	9	300	23,220	56 +/- 2 deg	2015-Sep-11
TanDEM-X	Luna17 Sea of Rains	1507902	7208	41175	9	300	23,220	56 +/- 2 deg	2015-Dec-17
TerraSAR-X	Luna21 Sea of Serenity	1507901	7209	41174	9	300	23,220	56 +/- 2 deg	2015-Dec-17

Introduction– ILRS Tracking Campaigns

- **Campaign 1: August 01 – September 30, 2014**
 - All GNSS satellites (on ILRS priority list, 18 satellites); more if able.
 - Three sets of two normal points distributed over transit; normal point includes 1000 FR points or last 5 minutes, whichever is shorter.
- **Campaign 2: November 22, 2014– February 28, 2015**
 - Six GLONASS as first priority, Beidou and Galileo as second priority, remaining GLONASS as third priority.
 - minimum three segments along each pass with three NPTs in each segment.
- **Campaign 3: August 20 – October 16, 2015**
 - Six GLONASS as first priority, Beidou and Galileo as second priority, remaining GLONASS as third priority.
 - Nine NPTs over the pass; 3 during the ascending/early region, 3 in the central region, 3 in the descending/late region of the pass.

Introduction– ILRS Tracking Campaigns

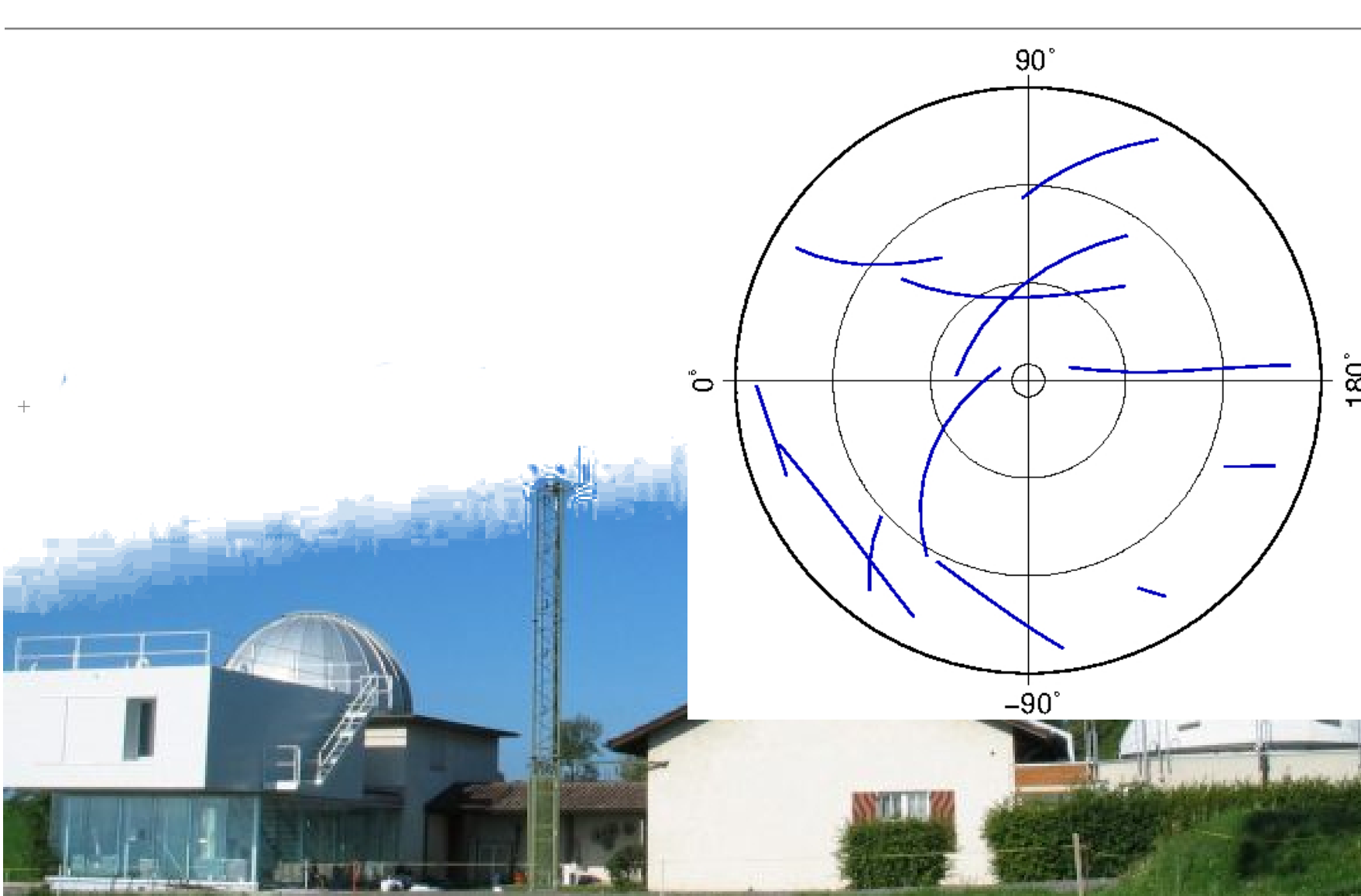
- **Common results**
 - Need more data
 - Few stations could fulfill requirements all the time
 - More daylight data
- **ILRS can handle tracking of all the required satellites (for now).**
- **Motivation for simulation!**

Introduction: Overview

- **Simulation of Satellite Laser Ranging measurements to GNSS and geodetic satellites.**
- **Calculation of pseudorange due to geometry, then apply:**
 - +
 - **Corrections**
 - **Noise.**
- **Synthetic observations upon which comparison and optimization can be done.**
 - **SLR+GNSS combination.**
 - **Impact of target selection and observation distribution.**

Introduction: Procedure

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Simulation– Design Goals

- Ability to generate synthetic SLR measurements to satellites in form of NP.
- Include station/satellite specific noise handling.
- Based on final orbit products .
- Possibility to alter observations as needed.
- Consider differences between stations
 - Operating times, day/night capabilities, ...

Introduction: Procedure

- **Realistic station behaviour**
 - Resemblance what stations have done.
- **Independent noise generation for each observation.**
 - Adding/removing satellites at other epochs.
 - Exchanging satellites at specific epoch.
- **Observation selection separated from simulation.**

Simulation - Observation Selection

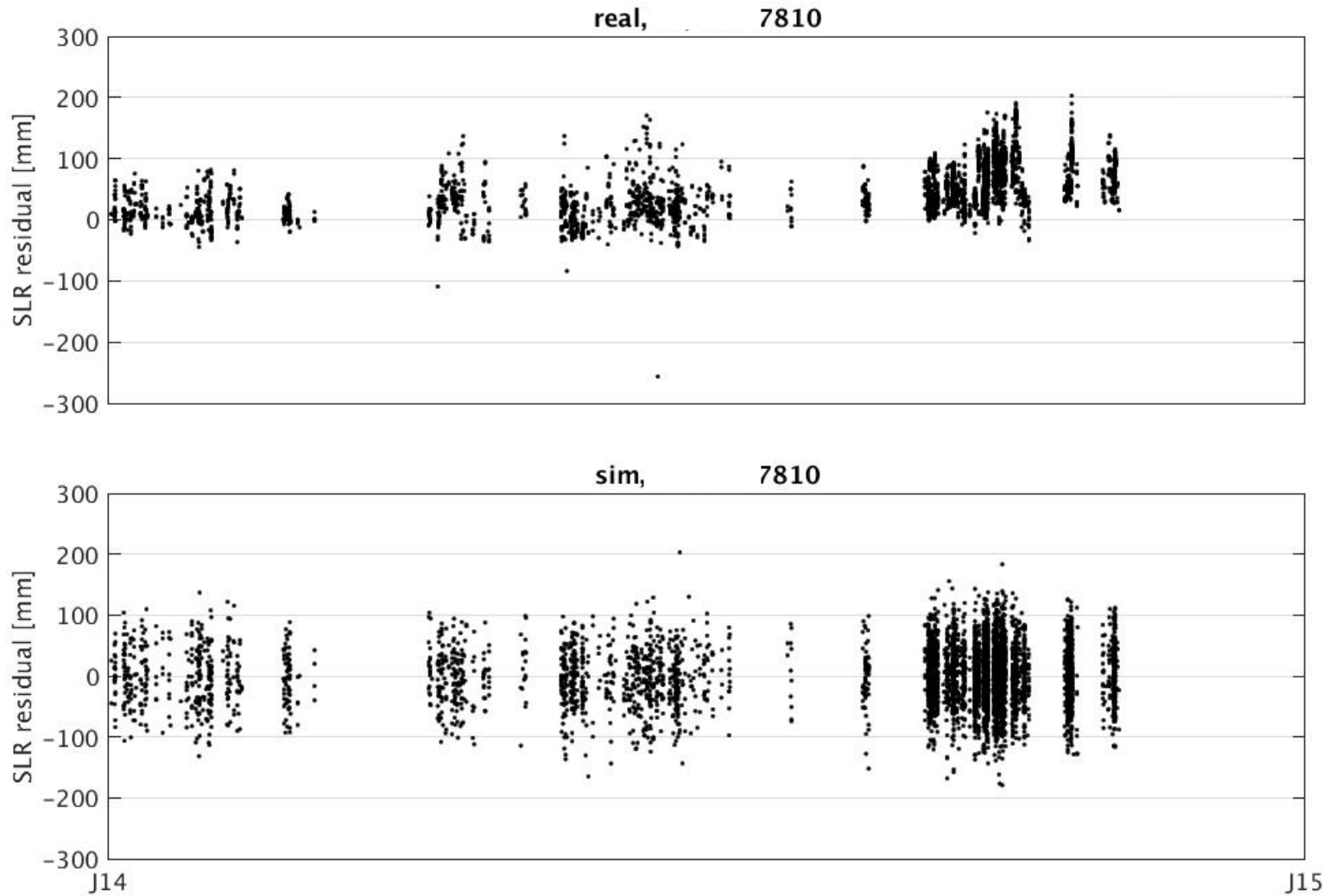
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YYYY MM DD STAT TIME IN SECONDS PRN
**** ** ** **** *
2015 05 06 7810 32046.185902247878 108 1
2015 05 06 7810 32126.060302248032 108 1
2015 05 06 7810 34742.648702320352 107 1
2015 05 06 7810 34862.552302311269 107 1
2015 05 06 7810 35154.578702318162 107 1
2015 05 06 7810 36243.455102316861 108 1
2015 05 06 7810 36376.229502318871 108 1
2015 05 06 7810 40050.113102219737 111 1
2015 05 06 7810 50219.056302341145 111 1
2015 05 06 7810 51928.352112342225 121 1
2015 05 06 7810 51932.583932335045 121 1
2015 05 06 7810 51936.500912335854 121 1
2015 05 06 7810 51942.945872333563 121 1
2015 05 06 7810 51946.872112332734 121 1
2015 05 06 7810 51951.641012342428 121 1
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2015 05 06 7810 51962.188152332608 121 1
2015 05 06 7810 51967.808972341074 121 1
2015 05 06 7810 51972.374152341465 121 1
2015 05 06 7810 51977.856072334798 121 1
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2015 05 06 7810 51992.042392342613 121 1
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2015 05 06 7810 52007.451032332443 121 1
2015 05 06 7810 52018.155592334660 121 1
2015 05 06 7810 52022.054052340201 121 1
2015 05 06 7810 52027.526712332408 121 1
2015 05 06 7810 52031.951052338896 121 1
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2015 05 06 7810 52047.119922336395 121 1
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2015 05 06 7810 52056.818052335875 121 1
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2015 05 06 7810 61700.233082270584 124 1
2015 05 06 7810 62868.262582268966 113 1
2015 05 06 7810 63549.433102269177 113 1
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2015 05 06 7810 63903.531902260132 113 1
2015 05 06 7810 78878.631902225781 103 1
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2015 05 06 7810 79286.484302322424 102 1
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Simulation – First Results

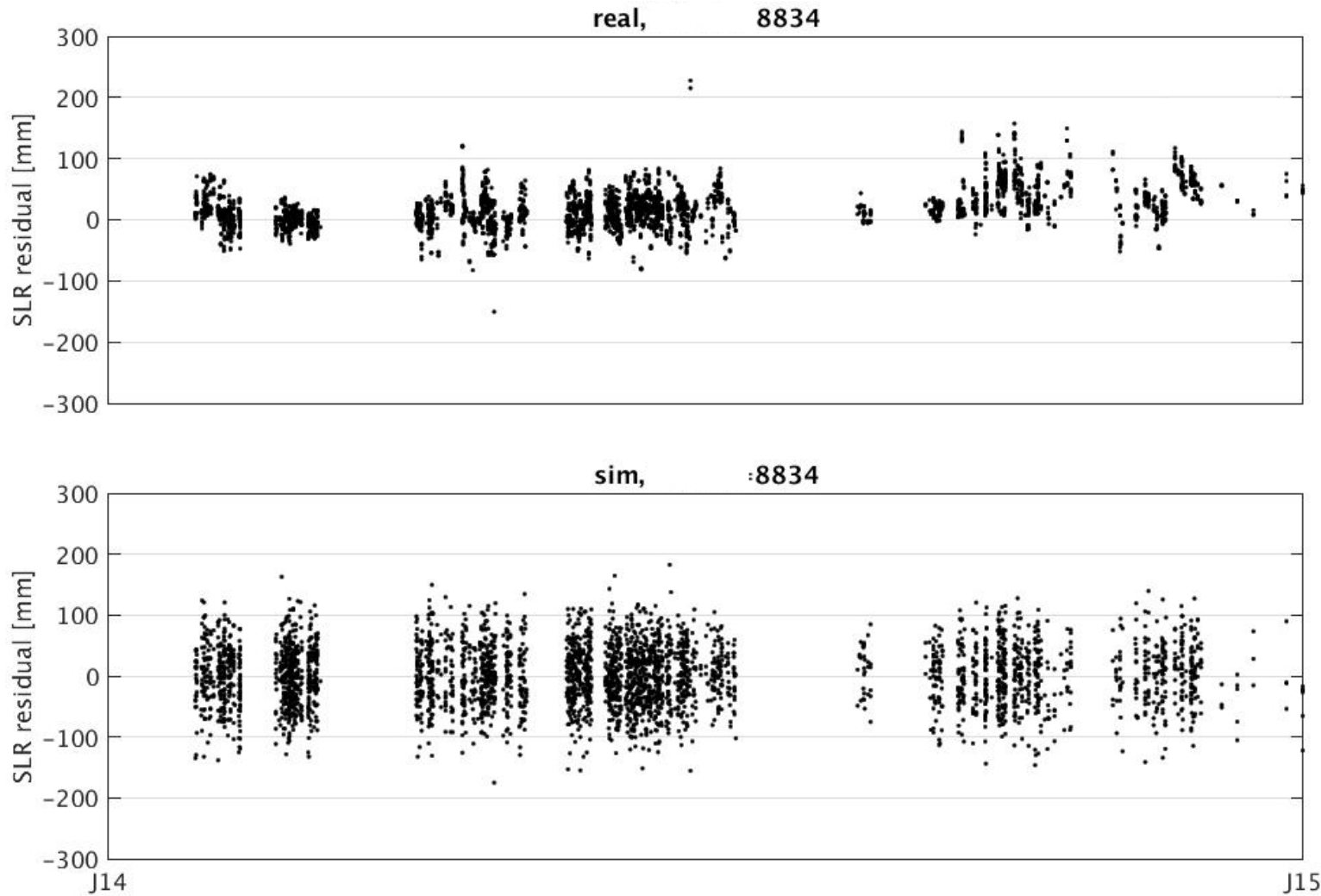
- **Simulating the real observations between January 2013 and January 2016.**
- **No noise**
- +
- **White noise**
 - **Elevation dependent sigmas**
 - **Repeatable**
- **Realistic noise**

White Noise

+



White Noise

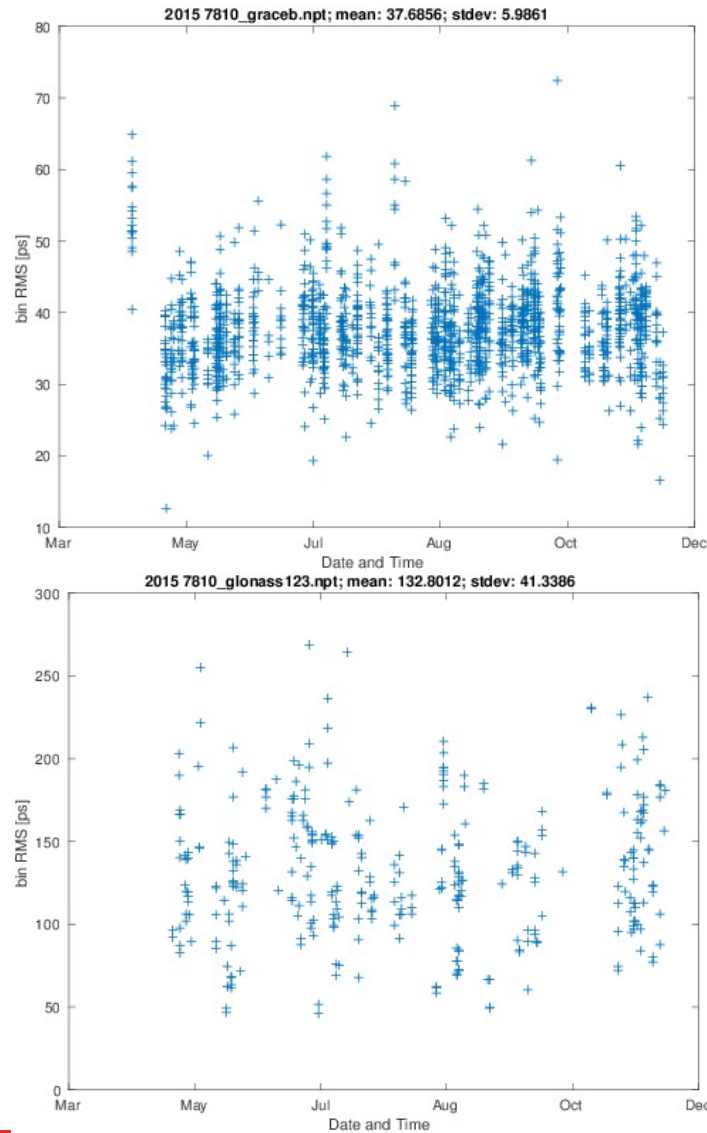


Simulation – Noise

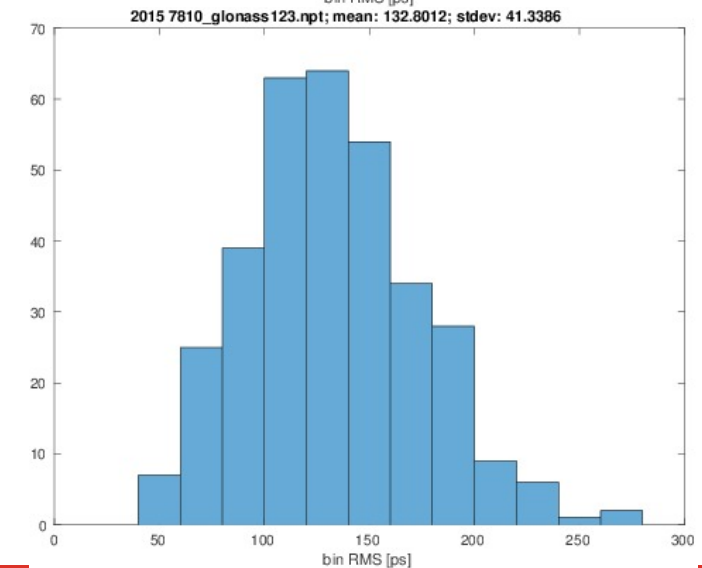
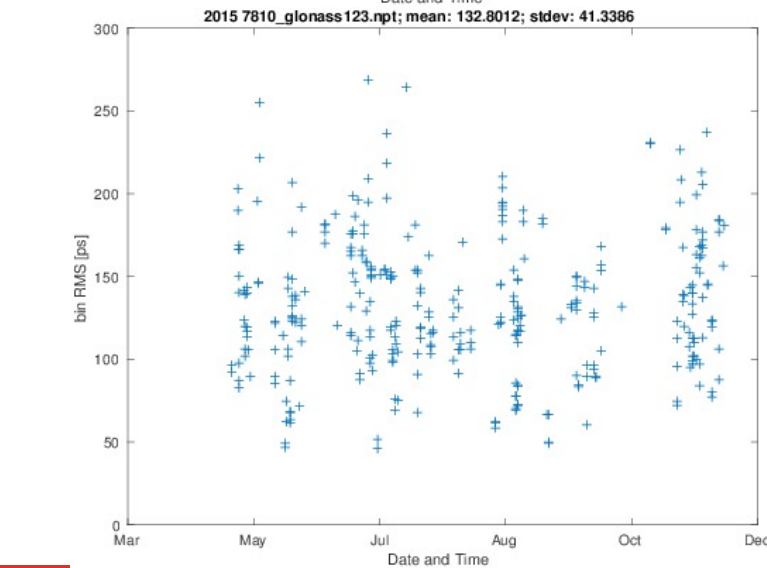
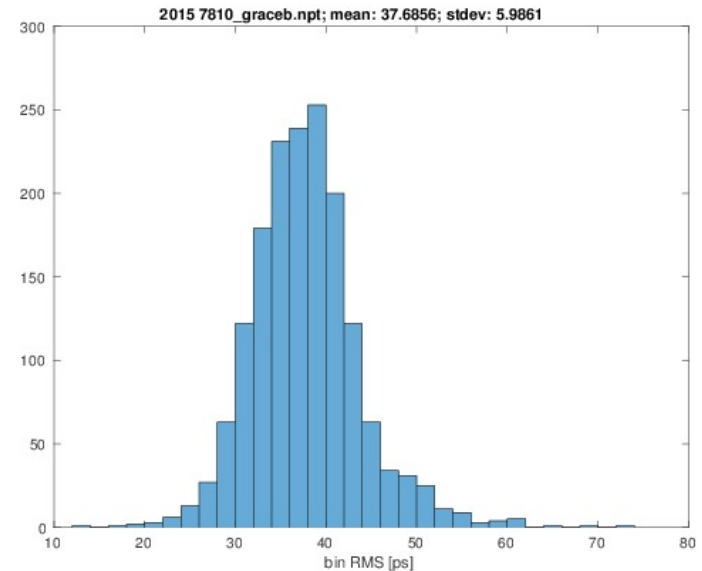
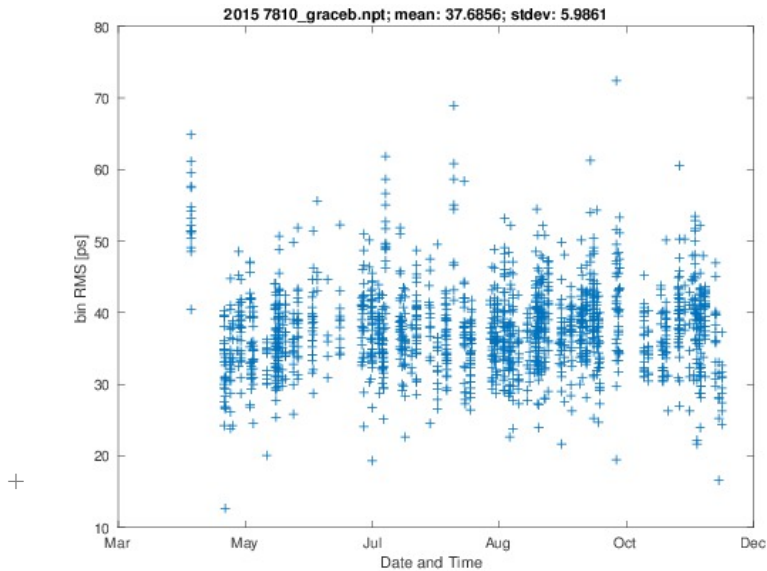
- White noise
 - Elevation dependent sigmas
 - Repeatable
- **Realistic Noise**
 - Normally distributed.
 - Different parameters for each station/satellite combination.
 - Resembling bin RMS given in NP files.
 - Repeatable.

Noise parameters

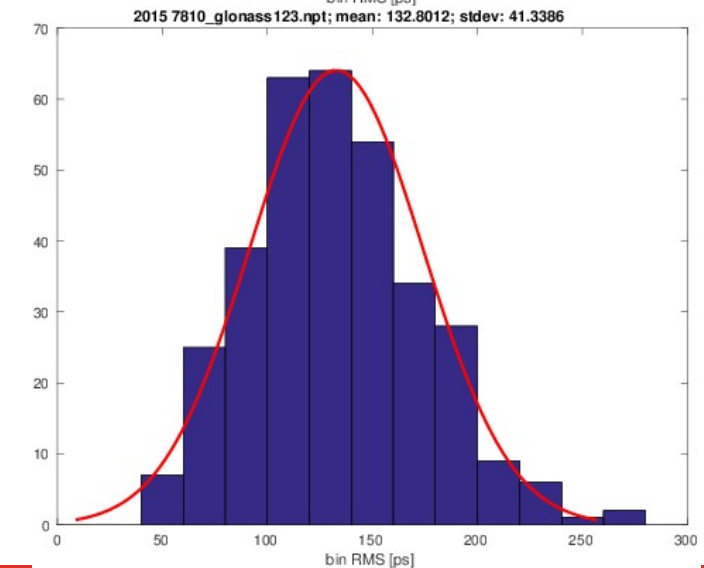
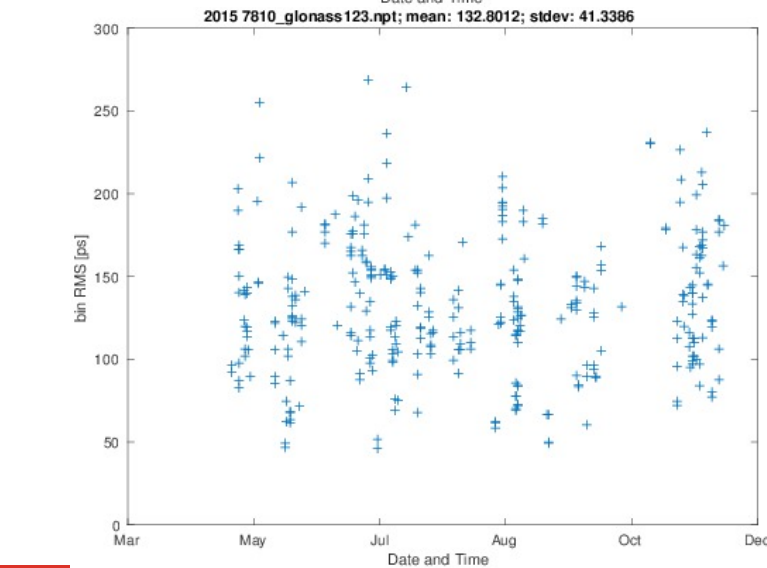
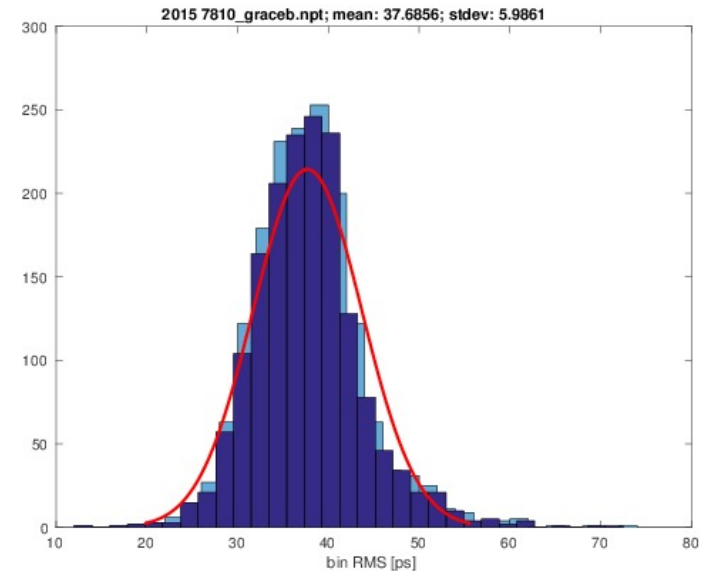
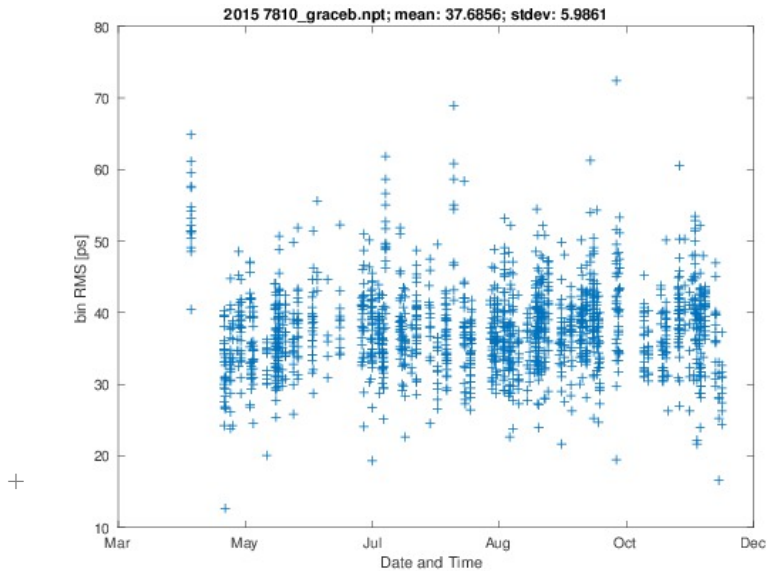
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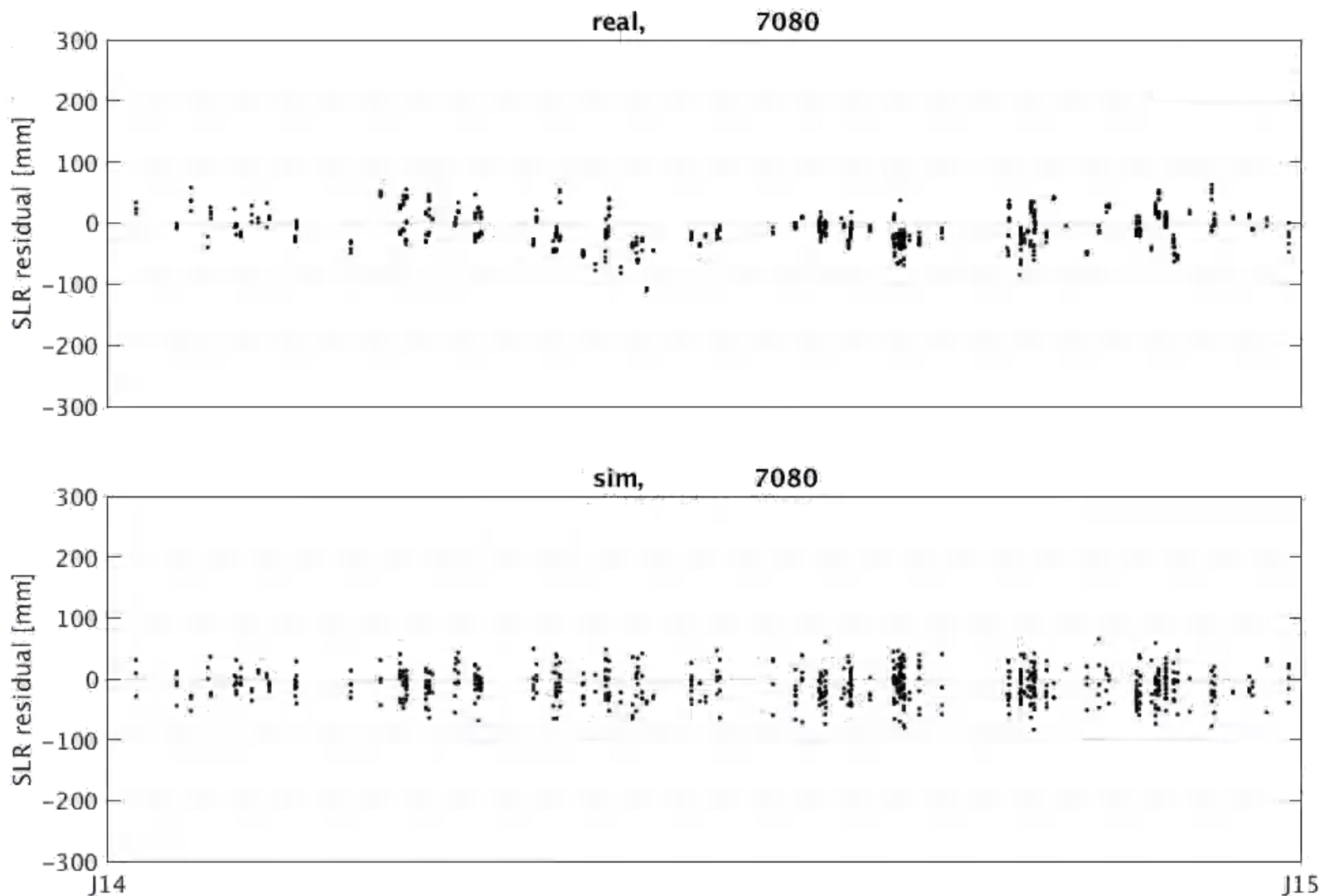
Noise parameters



Noise parameters

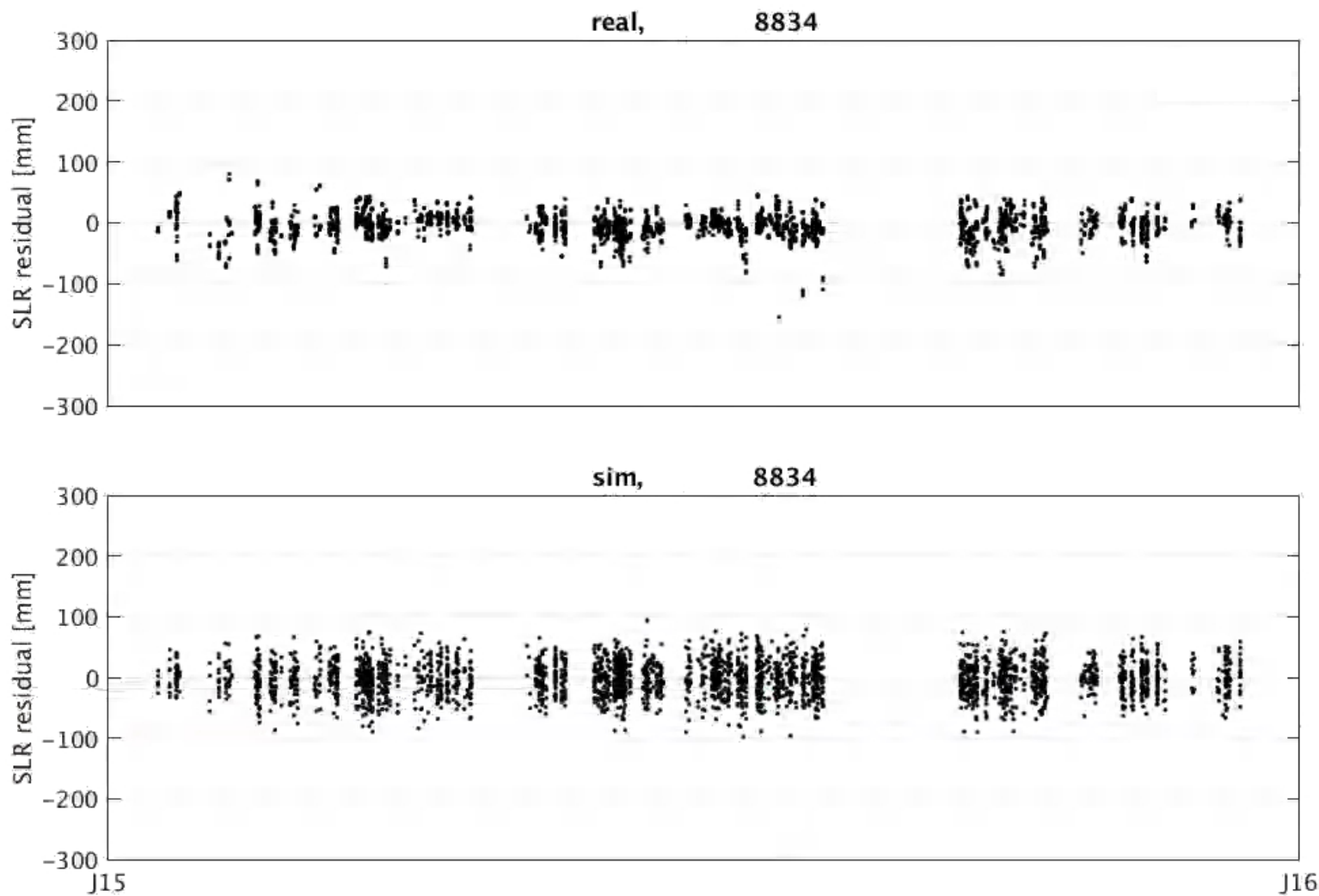


Normal distributed noise



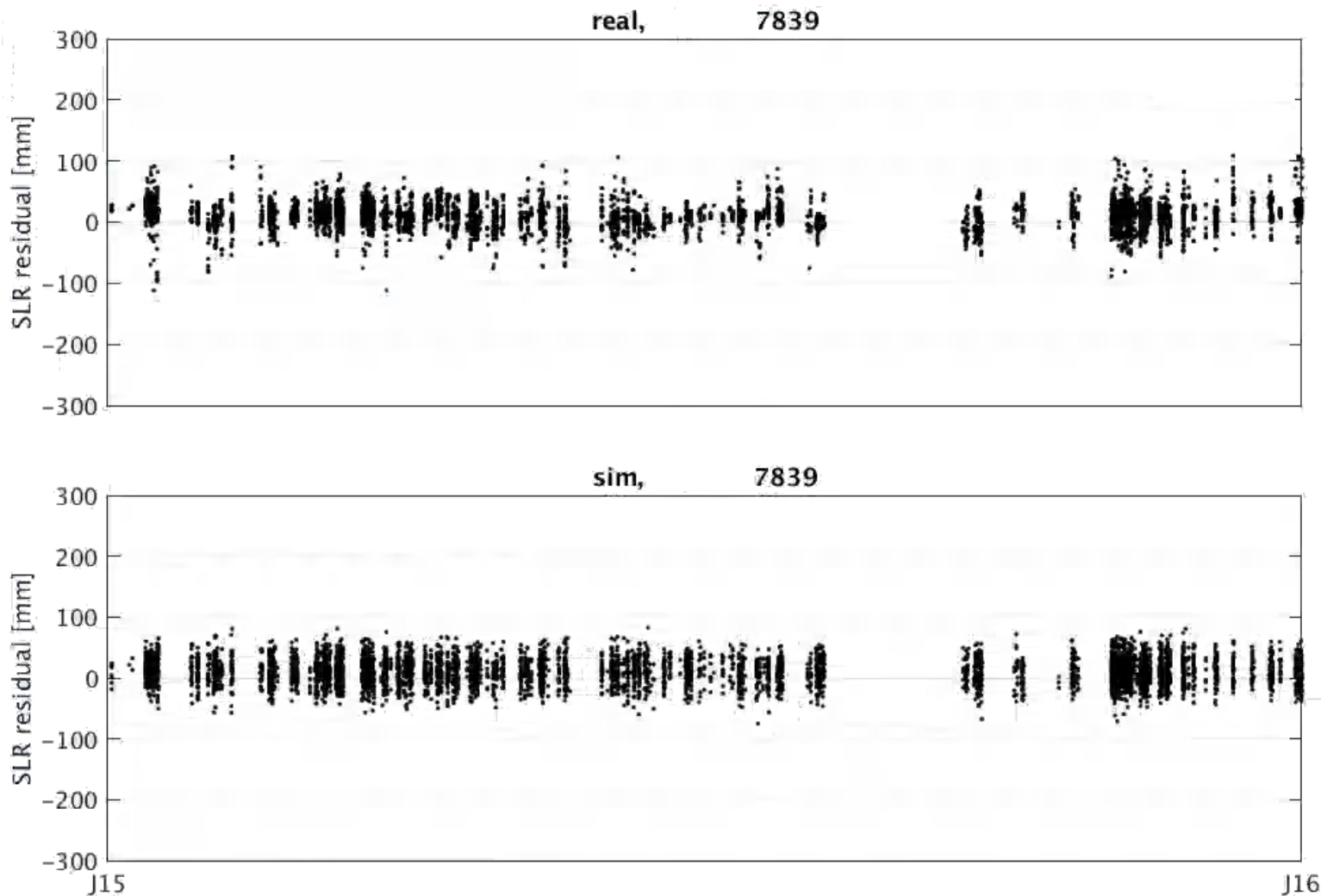
Normal distributed noise

+



Normal distributed noise

+



Summary & Outlook

- Ability to simulate additional/different SLR observations.
- Promising results that compare well in terms of residuals for existing observations.
- Different tracking strategies will be generated and used for comparison.
- + ● Investigating the impact of reducing observations to specific satellites in favor of more observations to others.
- Study the possibility of coordinated tracking among stations
- Optimized tracking.

Thank you for your attention!

References

- Dach, R., S. Lutz, P. Walser, P. Fridez (Eds); 2015: Bernese GNSS Software Version 5.2. User manual, Astronomical Institute, University of Bern, Bern Open Publishing. DOI: 10.7892/boris.72297; ISBN: 978-3-906813-05-9.
- Pearlman, M.R., Degnan, J.J., and Bosworth, J.M., "The International Laser Ranging Service", Advances in Space Research, Vol. 30, No. 2, pp. 135-143, July 2002, DOI:10.1016/S0273-1177(02)00277-6.