Simulation of realistic SLR observations to optimize tracking scenarios

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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.
- Impact of target selection.

Introduction: Procedure

- Bernese GNSS Software.
- Independent noise generation for each observation.
  - Adding/removing satellites at other epochs.
  - Exchanging satellites at specific epoch.
- Observation selection separate from simulation.

Introduction– ILRS Tracking Campaigns

- **Campaign1: 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
- **Campaign2: 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
- **Campaign3: August 20 – October 16, 2015**
  - Six GLONASS as first priority, Compass-M3 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 satellits (for now).

- Simulation might give a definite answer in future.

Simulation– Requirements

- Ability to generate synthetic SLR measurements to satellites in form of NP.
- Include station/satellite specific noise handling.
- Based on final orbit products (or predictions).
- Possibility to alter observations as needed.
- Lie within the accuracy requirements of the ILRS.

Simulation – Implementation

- Separate SLR mode within Bernese GNSS Software Simulation tool.
  - Selectable noise
  - Selectable stations
  - Selectable observation list

- Result are range observation files.

Simulation – Observation Selection

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
2015	05	06	7810	51958.623052340256	121	1
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
2015	05	06	7810	51982.106412339985	121	1
2015	05	06	7810	51987.792052336998	121	1
2015	05	06	7810	51992.042392342613	121	1
2015	05	06	7810	51997.524312334826	121	1
2015	05	06	7810	52001.691312335461	121	1
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
2015	05	06	7810	52037.587572334320	121	1
2015	05	06	7810	52042.560972338986	121	1
2015	05	06	7810	52047.119922336395	121	1
2015	05	06	7810	52052.738022335390	121	1
2015	05	06	7810	52056.818052335875	121	1
2015	05	06	7810	52061.561202337041	121	1
2015	05	06	7810	54224.806702237183	123	1
2015	05	06	7810	61700.233082270584	124	1
2015	05	06	7810	62868.262582268966	113	1
2015	05	06	7810	63549.433102269177	113	1
2015	05	06	7810	63843.317902267241	113	1
2015	05	06	7810	63903.531902260132	113	1
2015	05	06	7810	78878.631902225781	103	1
2015	05	06	7810	79022.709502223472	103	1
2015	05	06	7810	79281.893502318562	102	1
2015	05	06	7810	79286.484302322424	102	1

Simulation – Noise

- White noise
  - Selectable
  - Elevation dependent sigmas
  - Repeatable

- Normal distributed noise
  - Different parameters for each station/satelite combination.
  - Resembling bin RMS found in NP files.

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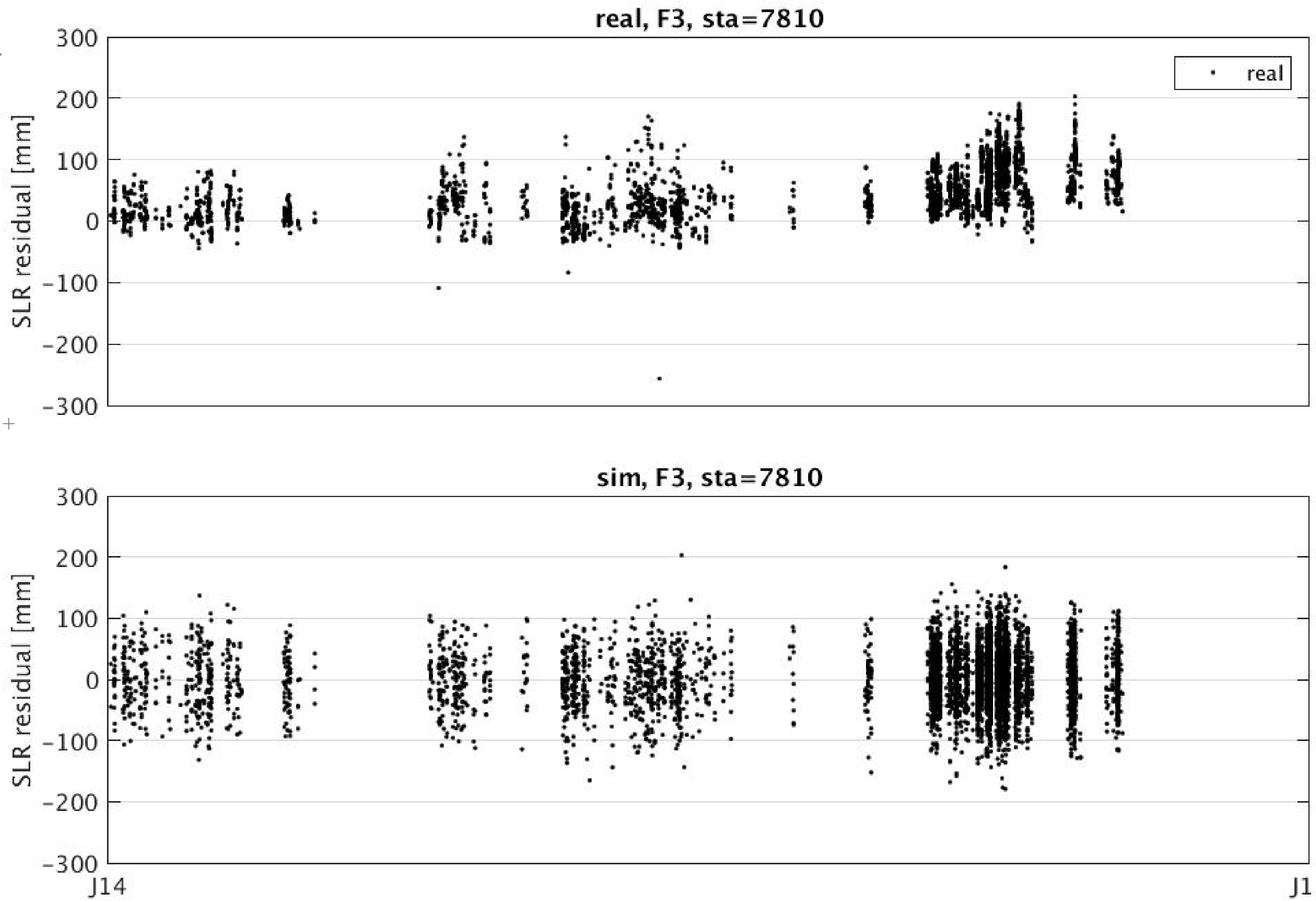
Simulation – First Results

- First Results
  - Without noise
  - White noise
  - Normal distributed noise

Simulated observation file

```
GPSSIM2          :  simulate SLR data to GNSS satellites 18433

MEASUREMENT TYPE:  RANGE                      CREATED :  26-MAY-16 15:37
REFERENCE EPOCH :  2015-05-06  0:37:43 (126)  MODIFIED:  26-MAY-16 15:37

# DIFFERENCES    :      0           FORMAT NUMBER      :      6
# FREQUENCIES    :      1           SESSION IDENTIFIER :   126S
# SATELLITES     :      0           SUBSESSION IDENTIF.:      S
# EPOCHS         :  77051           OBS. INTERVAL (S)  :      1.000000
# FLAGGED EPOCHS:       0           REMARK NUMBER      :      0

STATION NAME     :  ZIMM 14001S007
OPERATOR NAME    :
RECEIVER TYPE    :  SIMULA DEFAULT
ANTENNA TYPE     :  SIMULA          NONE
RECEIVER/ANTENNA:       0  /       0

CLOCK CORRECTION:  POLYNOMIAL DEG 0

POS.ECCENTR. (M):   0.0000  0.0000  0.0000
                                                          Station1            Station2
SAT    #L1-OBS OK  #L1-OBS BAD  #L2-OBS OK  #L2-OBS BAD  Obstype1  Obstype2  Obstype1  Obstype2

L1,L2 OBSERVATIONS:
   OBS.N    TIME    F #S   RANGE (M)   FFS SA       ...          AT THE END:  DATE, FRACT.(S), CLOCK (S)
       1    8:54:06    1  21468293.625  0 108 15-05-06  0.000000000 -0.000000000

     121    8:55:26    1  21555114.393  0 108 15-05-06  0.000000000 -0.000000000

     413    9:39:02    1  21771033.657  0 107 15-05-06  0.000000000 -0.000000000

     903    9:41:02    1  19687406.544  0 107 15-05-06  0.000000000 -0.000000000

     983    9:45:54    1  19660905.183  0 107 15-05-06  0.000000000 -0.000000000

    5100   10:04:03    1  19554801.692  0 108 15-05-06  0.000000000 -0.000000000

    5233   10:06:16    1  19595476.023  0 108 15-05-06  0.000000000 -0.000000000

   19701   11:07:30    1  19678965.284  0 111 15-05-06  0.000000000 -0.000000000

   26550   13:56:59    1  21223037.746  0 111 15-05-06  0.000000000 -0.000000000

   26555   14:25:28    1  21225342.651  0 121 15-05-06  0.000000000 -0.000000000

   26562   14:25:32    1  21228575.446  0 121 15-05-06  0.000000000 -0.000000000

   26576   14:25:36    1  21235060.791  0 121 15-05-06  0.000000000 -0.000000000

   26582   14:25:42    1  21237848.203  0 121 15-05-06  0.000000000 -0.000000000

   26586   14:25:46    1  21239709.436  0 121 15-05-06  0.000000000 -0.000000000
```

White noise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real
SLR residual [mm]
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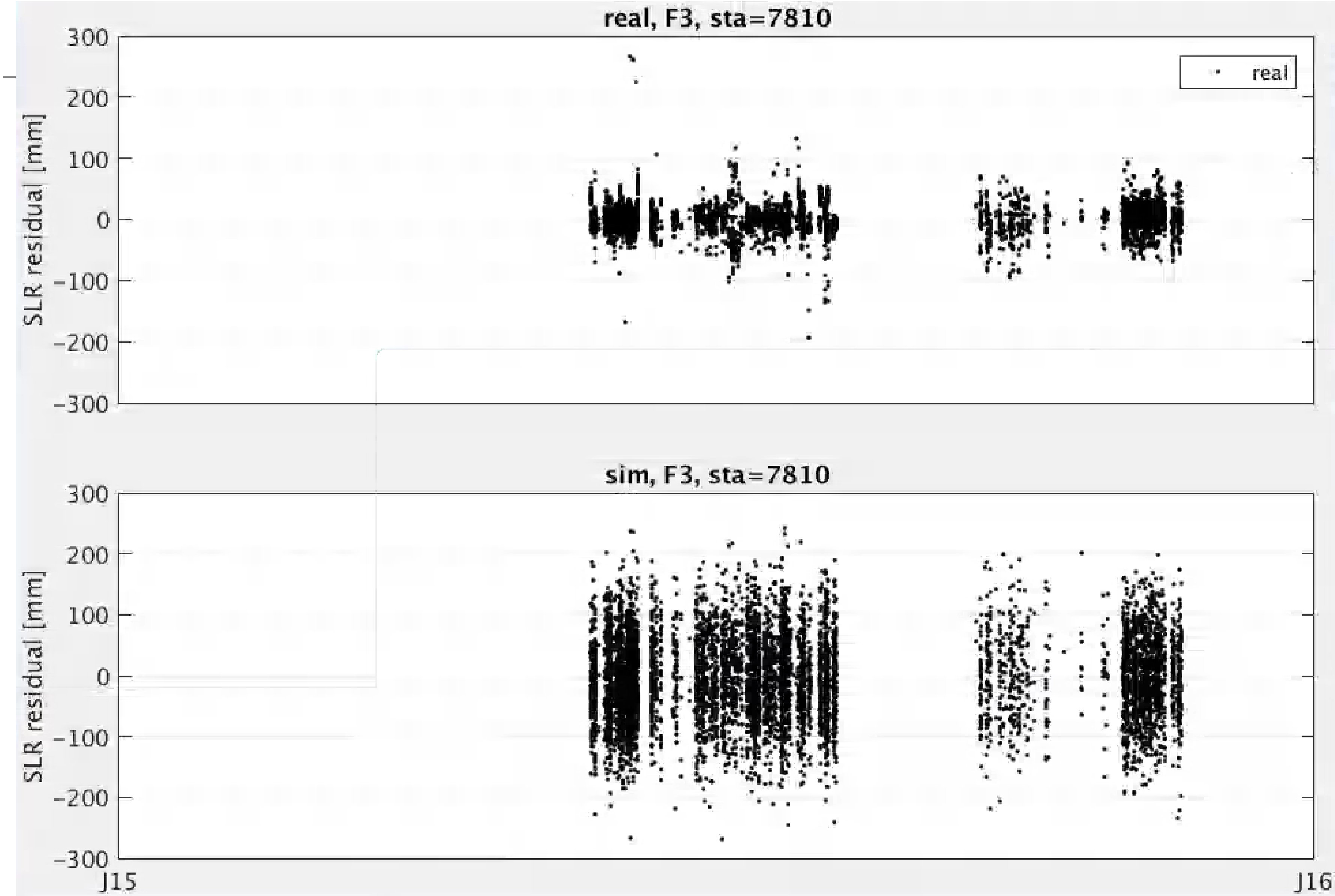
200
100
0
-100
-200
-300
sim, F3, sta=7810
SLR residual [mm]
J14
J15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SLR residual [mm]
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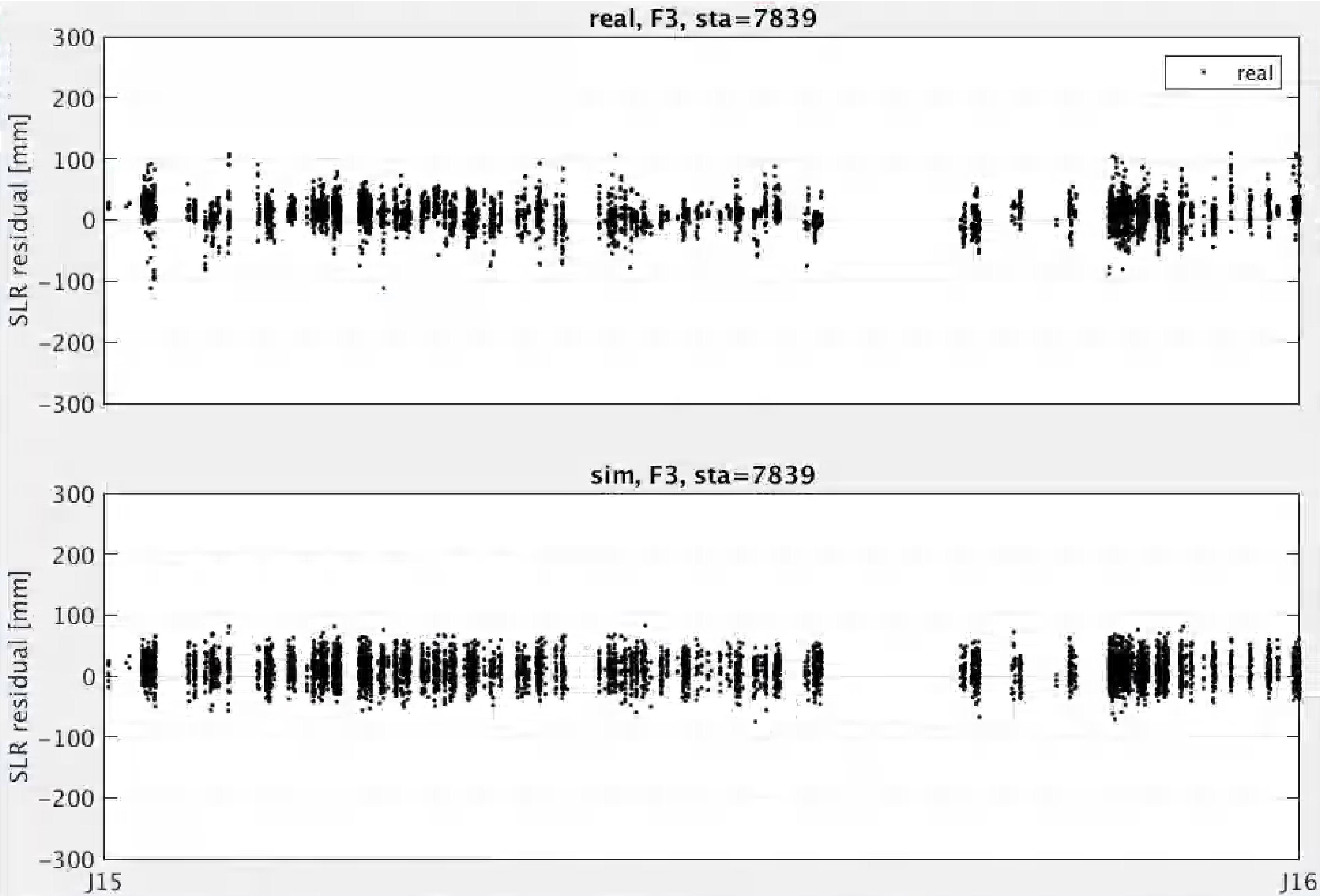
-100
-200
-300
sim, F3, sta=7810
SLR residual [mm]
300
200
100
0
-100
-200
-300
J15
J16

Normal distributed noise

Noise parameters

+

Noise parameters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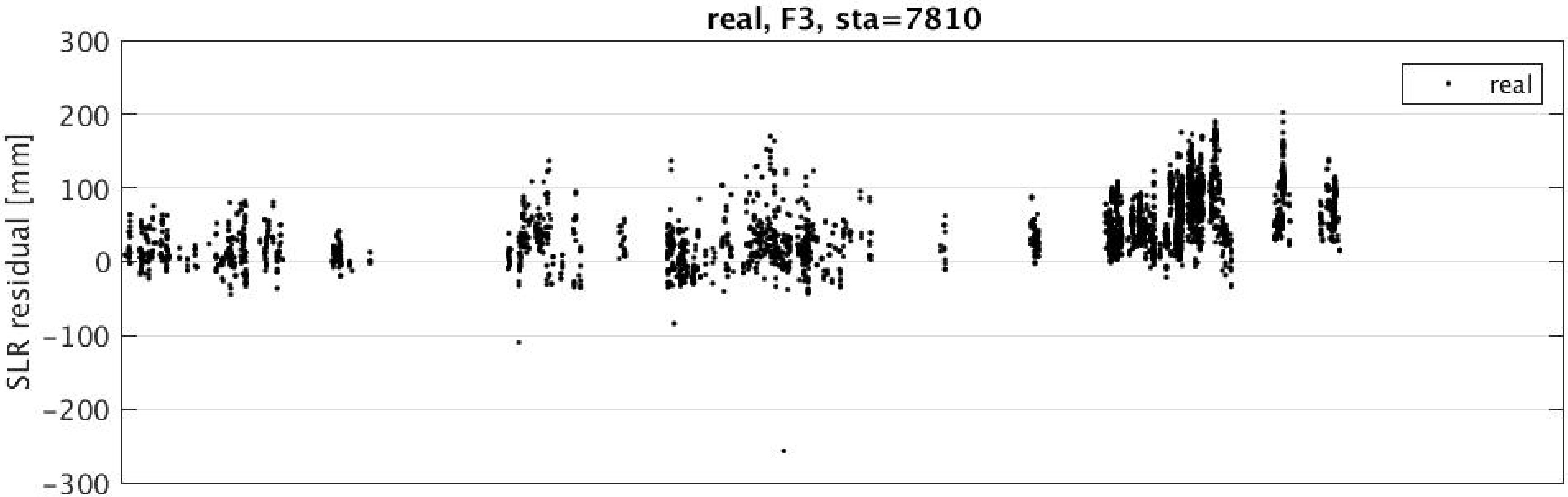
200
100
0
−100
−200
−300
J15
J16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SLR residual [mm]
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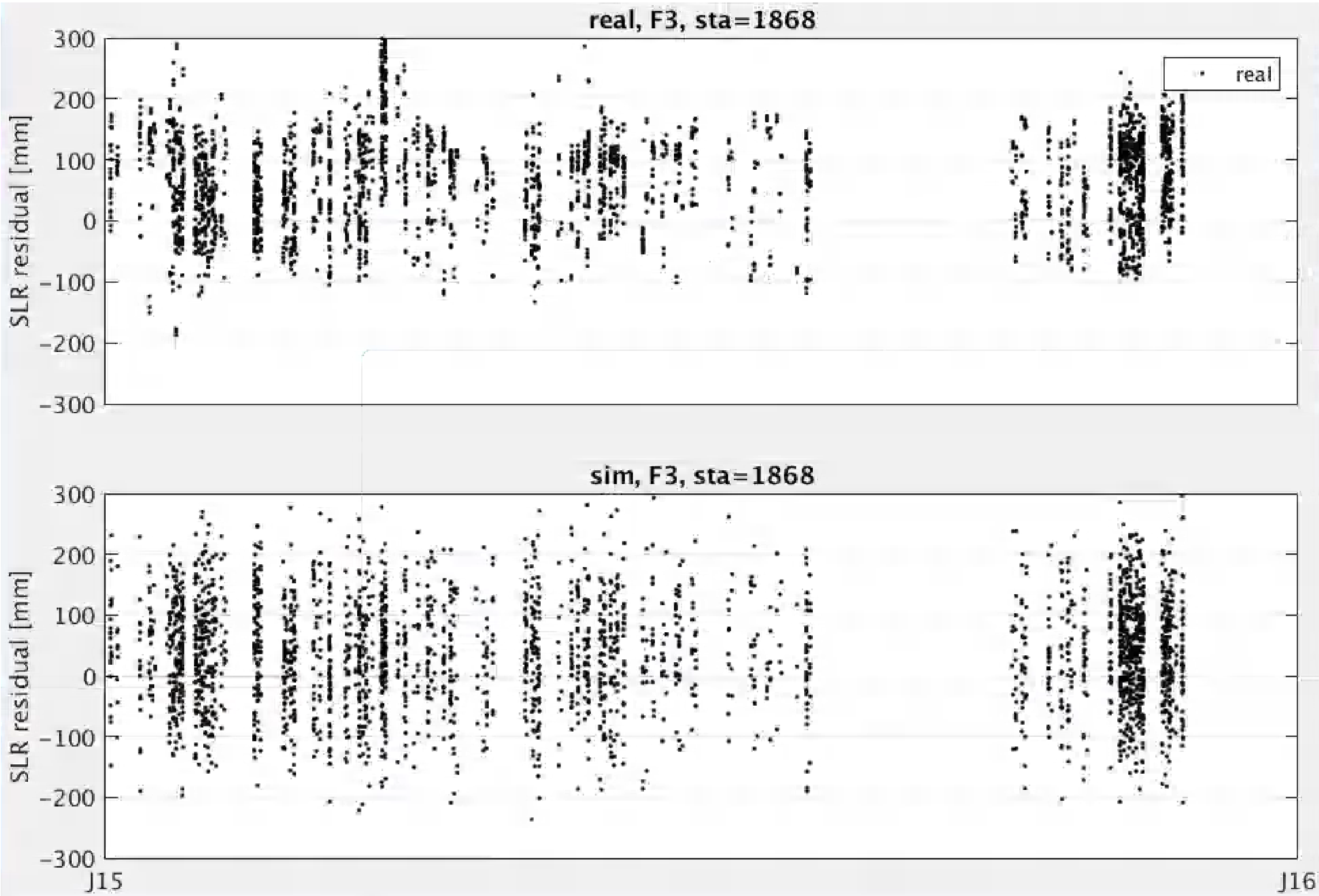
J14
J15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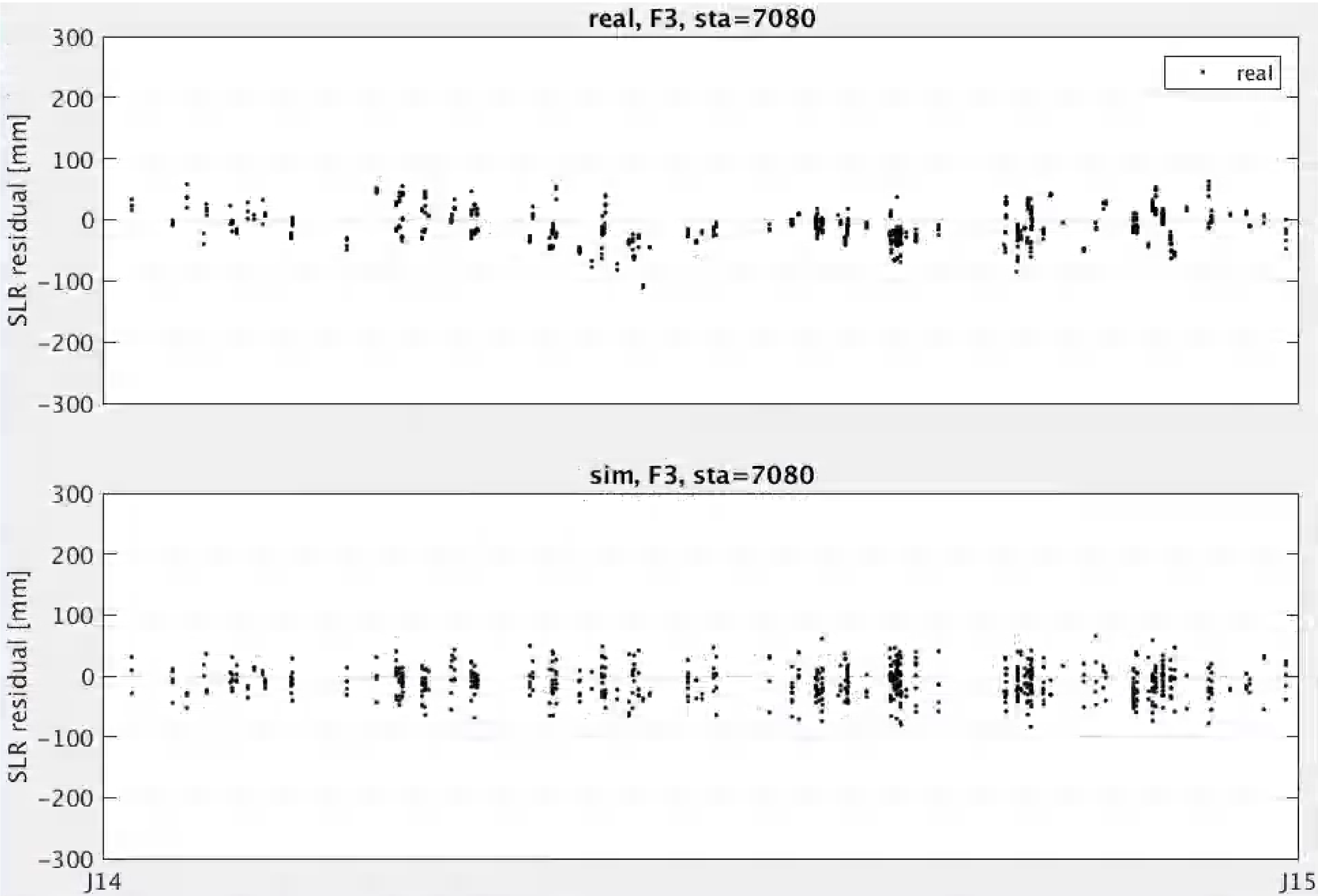
-200
-300
J15
J16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0
−100
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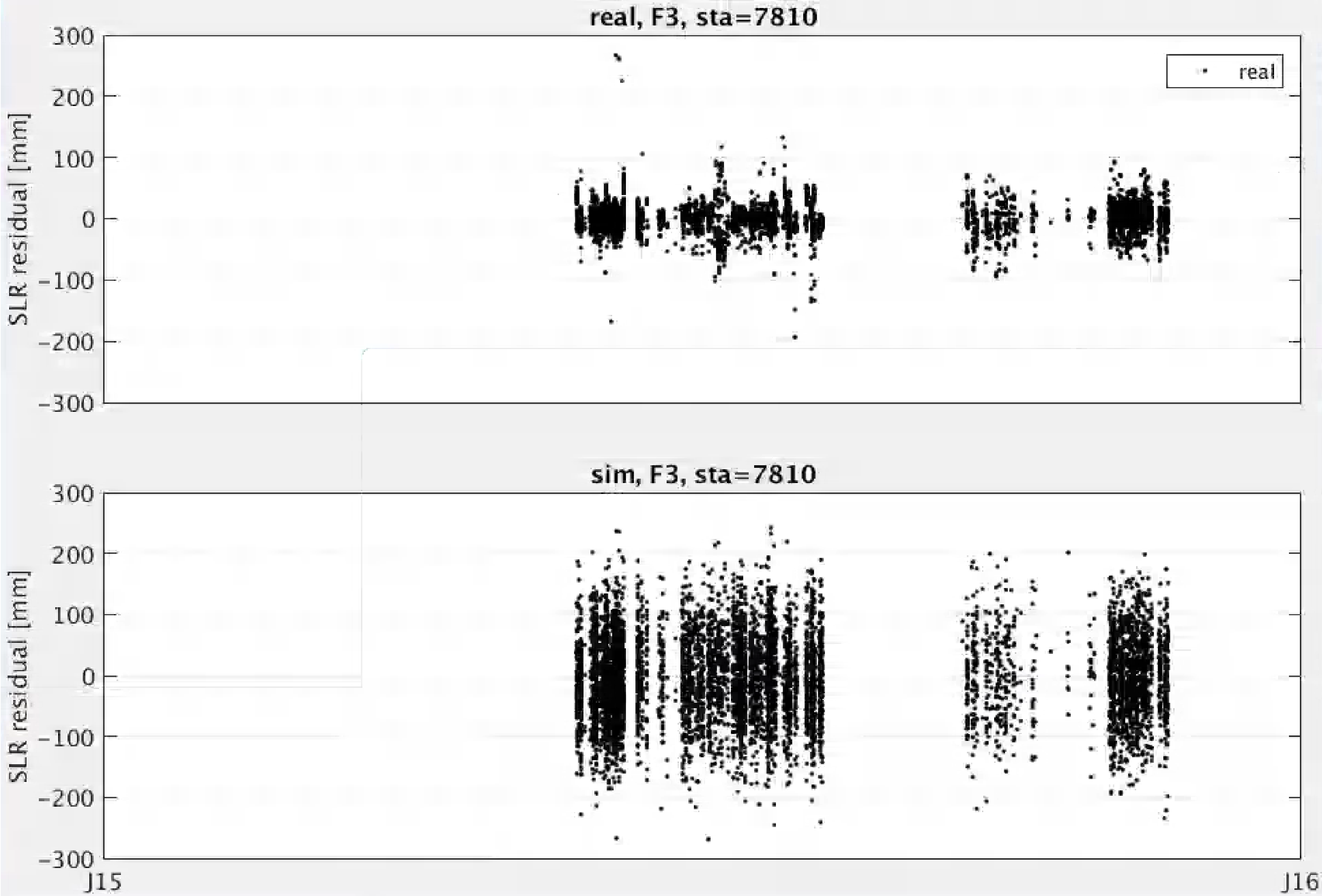
J14
J15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SLR residual [mm]
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−200
−300
real
sim, F3, sta=7810
SLR residual [mm]
300
200
100
0
−100
−200
−300
J15
J16

Conclusions & Outlook

- 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

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, Universtiy 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.