ILRS QCB Meeting

August 18, 2020
13:00 UT

Agenda

• Herstmonceux Open-source Normal Point Program Testing	Randy (15 min)
• Analysis of SLR normal points from new normal pointing software	John R. (20 min)
• Further discussion on examination of data	Van (30 min)
• Questions and discussion	All (30 min)

Herstmonceux Open-source Normal Point Program Testing

R. Ricklefs
UT/CSR
18 August, 2020

Purpose

- The Herstmonceux normal point software was created as reference code for those testing or updating existing normal point software.
- By use of large data set, it is hoped to show that the Herstmonceux normal point software produces demonstrably acceptable results.
- Use the test(s) to quantify the performance of the Hx software vs stations' software
- Use the tests to highlight errors or issues with the Hx software
- Ultimately hope to use the software to critique stations' software and procedures

Software

- orbitNP.py
- available on the ILRS web site software page
- written by Matt Wilkinson in Python
- several changes were made in the course of these test due to problems found
- Running under Linux, although Python code should run anywhere

Data

- January 2020 full rate and normal point data from the ILRS website
- multiple stations
- LAGEOS I
  - about 750 passes with a total of about 3846 normal points
- LARES data
  - About 515 passes with a total of about 5279 normal points
  - This presentation shows comparisons of the normal points at a very basic level – no orbits
  - Single point normal points created for compatibility with many stations
  - Sigma for filtering taken from site logs

LAGEOS Results - I

- almost 2/3 of the normal points ranges agreed to 0.5 mm
- about 3/4 agreed to better than 1 mm

- Normal point range comparisons:
  - number closer than 0.5 mm: 2268
  - number closer than 1.0 mm: 565
  - number closer than 2.0 mm: 311
  - number closer than 5.0 mm: 138
  - number closer than 10.0 mm: 60
  - number closer than 15.0 mm: 15
  - number > or = 15.0 mm: 489

LAGEOS Results – II

For normal points with >= 15 mm difference:

- Difference in number of returns (std-test):
- return difference = 0: 292 => picked different points and have different epoch
- return difference = 1: 67
- return difference = 2: 36
- return difference = 3: 17
- return difference = 4: 8
- return difference = 5: 11
- return difference > 5: 31

Number of returns (std):

- returns <= 2: 23 => one or two-point normal points
- returns <= 5: 3
- returns <= 10: 1
- returns <= 25: 7
- returns <= 50: 11
- returns <= 100: 29
- returns <= 500: 104
- returns > 500: 284 => khz stations

Total “really bad” normal points: 462

LAGEOS Results - III

- averages, skew, and kurtosis are not quite the same as for the "standard" normal points
- Some ideas for large differences
  - Differences in hardware, OS, compilers can affect round off, filtering, etc.
    - Different points selected can change epoch appreciably
  - Extra normal points from Hx software
    - Differences in filtering?
    - Data fitting filter data differently at beginning and end of pass segments
    - Stations sometimes manually filter data

LARES Results - I

- About 1/2 of the normal point ranges agreed to 0.5 mm
- Almost 2/3 agreed to better than 1 mm
- Normal point comparisons:
  - number closer than 0.5 mm: 2116
  - number closer than 1.0 mm: 645
  - number closer than 2.0 mm: 653
  - number closer than 5.0 mm: 263
  - number closer than 10.0 mm: 42
  - number closer than 15.0 mm: 15
  - number > or = 15.0 mm: 566
- Total normal points: 4300 for same npt bin – and 131 unmatched (new in Hx files, only)

LARES Results – II

For normal points with >= 15 mm difference:

- Difference in number of returns (std-test):
- return difference = 0: 429 => picked different points and have different epoch
- return difference = 1: 47
- return difference = 2: 12
- return difference = 3: 5
- return difference = 4: 3
- return difference = 5: 3
- return difference > 5: 35

Number of returns (std):

- returns <= 2: 43 => one or two-point normal points
- returns <= 5: 2
- returns <= 10: 6
- returns <= 25: 17
- returns <= 50: 17
- returns <= 100: 49
- returns <= 500: 128
- returns > 500: 272=> khz stations

Total “really bad” normal points: 534

DISTRIB vs Python Functions I

Perfect match

1873_lageos1_crd_200113_1746_0.npt – Simeiz

							RMS	SKEW	Kertosis	P-M		
Native Python Functions												
11	64009.800159999999	0.041877336485	KS	2	120.0	10	50.1	0.820	0.521	0.0	1.2	0
11	64127.000161999997	0.042611809914	KS	2	120.0	14	72.5	-0.452	-1.092	0.0	1.4	0
11	64266.000161000004	0.043816952935	KS	2	120.0	7	35.8	-0.270	-1.334	0.0	31.8	0
11	64366.000160000003	0.044889945476	KS	2	120.0	14	81.7	0.302	-1.072	0.0	1.8	0
11	64497.200160000000	0.046532086431	KS	2	120.0	16	91.5	0.063	-1.610	0.0	1.7	0
11	64597.600172999999	0.047948944640	KS	2	120.0	2	8.5	0.000	-2.000	0.0	0.4	0
11	64712.600170999998	0.049720936346	KS	2	120.0	3	52.7	-0.439	-1.500	0.0	2.8	0
DISTRIB.f converted to Python												
11	64009.800159999999	0.041877336485	KS	2	120.0	10	50.1	0.820	0.521	4.327	1.2	0
11	64127.000161999997	0.042611809914	KS	2	120.0	14	72.5	-0.452	-1.092	-20.173	1.4	0
11	64266.000161000004	0.043816952935	KS	2	120.0	7	35.8	-0.270	-1.334	-9.790	31.8	0
11	64366.000160000003	0.044889945476	KS	2	120.0	14	81.7	0.302	-1.072	13.930	1.8	0
11	64497.200160000000	0.046532086431	KS	2	120.0	16	91.5	0.063	-1.610	35.244	1.7	0
11	64597.600172999999	0.047948944640	KS	2	120.0	2	8.5	0.000	-2.000	0.000	0.4	0
11	64712.600170999998	0.049720936346	KS	2	120.0	3	52.7	-0.439	-1.500	-16.799	2.8	0
Station Normal Point Records												
11	64009.8001600	0.041877336466	std	2	120.0	10	50.0	-1.000	-1.000	-1.0	0.0	0
11	64127.0001620	0.042611810092	std	2	120.0	14	72.0	-1.000	-1.000	-1.0	0.0	0
11	64266.0001610	0.043816952906	std	2	120.0	7	35.0	-1.000	-1.000	-1.0	0.0	0
11	64366.0001600	0.044889945518	std	2	120.0	14	81.0	-1.000	-1.000	-1.0	0.0	0
11	64497.2001600	0.046532086313	std	2	120.0	16	91.0	-1.000	-1.000	-1.0	0.0	0
11	64597.6001730	0.047948944655	std	2	120.0	2	7.0	-1.000	-1.000	-1.0	0.0	0
11	64712.6001710	0.049720936450	std	2	120.0	3	51.0	-1.000	-1.000	-1.0	0.0	0

DISTRIB vs Python Functions II

Imperfect match

7090_lageos1_crd_200125_1414_0.npt – Yarragadee

							RMS	SKEW	KURT	P-M		
Native Python Functions												
11	51283.000561100002	0.046956311431	KS	2	120.0	42	37.2	0.756	0.020	0.0	14.0	0
11	51475.000560200002	0.044692369665	KS	2	120.0	16	23.5	-0.030	-0.482	0.0	28.6	0
11	51518.600558600003	0.044248163945	KS	2	120.0	107	39.0	0.556	-0.211	0.0	18.0	0
11	51601.800560099997	0.043479769791	KS	2	120.0	1	OK 0.0	0.000	-3.000	0.0	0.2	0
11	51829.200559800003	0.041960922449	KS	2	120.0	36	37.6	0.513	-0.568	0.0	35.3	0
11	51862.200557400000	0.041816481380	KS	2	120.0	19	30.1	0.819	0.160	0.0	6.0	0
DISTRIB.f converted to Python												
11	51283.000561100002	0.046956311431	KS	2	120.0	42	31.6	0.452	-0.624	11.753	14.0	0
11	51475.000560200002	0.044692369665	KS	2	120.0	16	23.5	-0.030	-0.482	3.620	28.6	0
11	51518.600558600003	0.044248163945	KS	2	120.0	107	35.8	0.393	-0.465	4.454	18.0	0
11	51601.800560099997	0.043479769791	KS	2	120.0	1	OK 0.0	0.000	-3.000	0.000	0.2	0
11	51829.200559800003	0.041960922449	KS	2	120.0	36	34.5	0.329	-1.026	9.342	35.3	0
11	51862.200557400000	0.041816481380	KS	2	120.0	19	30.1	0.819	0.160	2.879	6.0	0
Station Normal Point Records												
11	51283.000561100002	0.046956311434	std	2	120.0	42	37.0	0.681	-0.083	-1.0	7.00	0
11	51475.000560200002	0.044692369665	std	2	120.0	16	23.0	-0.153	-0.544	-1.0	2.67	0
11	51518.600558600003	0.044248163949	std	2	120.0	107	39.0	0.497	-0.305	-1.0	17.83	0
11	51601.800560099997	0.043479769791	std	2	120.0	1	BAD! 36.0	0.000	-3.000	-1.0	0.17	0
11	51829.200559800003	0.041960922449	std	2	120.0	36	38.0	0.508	-0.549	-1.0	6.00	0
11	51862.200557400000	0.041816481378	std	2	120.0	19	29.0	0.814	0.064	-1.0	3.17	0

DISTRIB vs Python Functions III

Imperfect match

7810_lageos1_crd_200107_1515_0.npt – Zimmerwald

Native Python Functions

							RMS	SKEW	KURT	P-M		
11	55023.332522335077	0.054587345161	KS	2	120.0	861	77.4	0.395	-0.613	0.0	7.2	0
11	55136.981252328987	0.052815484071	KS	2	120.0	952	72.0	0.420	-0.527	0.0	8.0	0
11	55258.065992333133	0.051075100427	KS	2	120.0	1193	71.8	0.433	-0.441	0.0	10.0	0
11	55378.161752328364	0.049521359979	KS	2	120.0	1257	65.9	0.454	-0.473	0.0	10.5	0
11	55500.562022333921	0.048138108828	KS	2	120.0	1255	67.1	0.521	-0.143	0.0	10.5	0

DISTRIB.f converted to Python

11	55023.332522335077	0.054587345161	KS	2	120.0	861	77.4	0.395	-0.613	12.317	7.2	0
11	55136.981252328987	0.052815484071	KS	2	120.0	952	72.0	0.420	-0.527	12.261	8.0	0
11	55258.065992333133	0.051075100427	KS	2	120.0	1193	71.6	0.429	-0.447	10.134	10.0	0
11	55378.161752328364	0.049521359979	KS	2	120.0	1257	65.8	0.449	-0.481	9.922	10.5	0
11	55500.562022333921	0.048138108828	KS	2	120.0	1255	62.2	0.361	-0.388	7.724	10.5	0

Station Normal Point Records

11	55023.332522335077	0.054587345155	sys1	2	120	860	78.0	0.368	-0.629	181.3	-1.00	0
11	55136.887952329431	0.052816886466	sys1	2	120	953	71.7	0.409	-0.524	176.2	-1.00	0
11	55258.065992333133	0.051075100430	sys1	2	120	1193	71.9	0.421	-0.495	174.5	-1.00	0
11	55378.161752328364	0.049521359982	sys1	2	120	1257	66.1	0.436	-0.509	161.5	-1.00	0
11	55500.487382326137	0.048138885940	sys1	2	120	1254	67.0	0.527	-0.121	184.1	-1.00	0

DISTRIB vs Python Functions IV

Imperfect match

1888_lageos1_crd_200111_0941_0.npt – Svetloe

							RMS	SKEW	Kurt	P-M		
Native Python Functions												
11	34902.511098230003	0.048932092051	KS	2	120.0	66	259.2	0.258	0.076	0.0	0.6	0
11	34989.374760929997	0.047635292917	KS	2	120.0	537	217.3	0.626	-0.021	0.0	1.5	0
11	35068.696228280001	0.046520052118	KS	2	120.0	104	276.8	0.537	0.031	0.0	0.3	0
11	35183.454451550002	0.045037238866	KS	2	120.0	11	5503.1	-0.569	-1.668	0.0	0.8	0
11	35492.701953789998	0.041962377771	KS	2	120.0	1229	229.6	0.565	-0.060	0.0	7.1	0
11	35577.271298460000	0.041392550441	KS	2	120.0	2318	234.5	0.517	-0.201	0.0	6.4	0
11	35701.706201319997	0.040790975708	KS	2	120.0	2905	240.1	0.531	-0.130	0.0	8.1	0
11	35822.817827940002	0.040489131378	KS	2	120.0	3605	247.5	0.588	0.012	0.0	10.0	0
11	35880.118682870001	0.040446447012	KS	2	120.0	6	241.0	0.051	-1.310	0.0	10.5	0
DISTRIB.f converted to Python												
11	34902.511098230003	0.048932092051	KS	2	120.0	66	243.8	0.617	-0.505	-3.793	0.6	0
11	34989.374760929997	0.047635292917	KS	2	120.0	537	200.8	0.441	-0.413	4.682	1.5	0
11	35068.696228280001	0.046520052118	KS	2	120.0	104	266.5	0.430	-0.194	0.860	0.3	0
11	35183.454451550002	0.045037238866	KS	2	120.0	11	5503.1	-0.569	-1.668	-1069.040	0.8	0
11	35492.701953789998	0.041962377771	KS	2	120.0	1229	212.5	0.402	-0.431	4.587	7.1	0
11	35577.271298460000	0.041392550441	KS	2	120.0	2318	224.1	0.395	-0.495	3.304	6.4	0
11	35701.706201319997	0.040790975708	KS	2	120.0	2905	226.3	0.395	-0.489	2.102	8.1	0
11	35822.817827940002	0.040489131378	KS	2	120.0	3605	227.2	0.386	-0.470	1.934	10.0	0
11	35880.118682870001	0.040446447012	KS	2	120.0	6	241.0	0.051	-1.310	76.447	10.5	0
Station Normal Point Records												
11	34901.735252359998	0.048944005493	std	2	120.0	64	233.0	0.581	2.418	(-0.582)	-1.0	-1.0 0
11	34989.135008570003	0.047638767226	std	2	120.0	526	202.2	0.447	2.594	(-0.406)	-1.0	-1.0 0
11	35068.696228280001	0.046520052048	std	2	120.0	87	193.5	0.396	3.189	(+0.189)	-1.0	-1.0 0
11	35492.825149980003	0.041961456492	std	2	120.0	1211	217.9	0.429	2.627	(-0.373)	-1.0	-1.0 0
11	35576.881770590000	0.041394882848	std	2	120.0	2275	220.6	0.367	2.465	(-0.535)	-1.0	-1.0 0
11	35701.609644229997	0.040791329536	std	2	120.0	2849	225.2	0.395	2.493	(-0.507)	-1.0	-1.0 0
11	35822.637993529999	0.040489367220	std	2	120.0	3498	224.2	0.370	2.499	(-0.501)	-1.0	-1.0 0
11	35880.118682870001	0.040446447012	std	2	120.0	6	241.0	0.052	1.690	(-1.31)	-1.0	-1.0 0

DISTRIB vs Python Functions – Conclusion

- Native Python mean, rms, skew, and kurtosis functions and DISTRIB.py:
  - give the same results much of the time, mainly for n < 100.
  - At n > 1000, they are usually close, with the epoch and range often being different
  - Usually, the results differ for unknown reasons
- Implies a bug in the conversion of DISTRIB to Python?
- Probably just use the native Python functions for efficiency
- Looking into computing Peak – Mean with native python functions.

Where to go from here

- Orbital tests
  - Matt Wilkinson did some tests and didn't find any systematic problems. He is now making more checks.
  - John Ries has done tests on this LAGEOS data set. Results will be presented here.
- Move to Python routines for statistics. Peak-Mean still needs work.
- Suggestions?

Analysis of SLR normal points from new normal pointing software

John C. Ries

8/18/2020

LAGEOS

Analysis method (V1 vs V2 for Jan 2020)

- Two variations were looked at
  - Compute residuals for V1 (nominal NPT software) and V2 (new NPT software) separately for stations that provided V2 data
    - In some cases, there were more V2 NPTs than V1 for a given pass
    - New normal point SW sometimes accepts more data for normal pointing
      - In some of those cases, the extra points were problematic
    - Some passes looked at in more detail
  - Process V1 and V2 data in same run (resulting in duplicates)
    - Plotted individual normal point residuals on pass-by-pass basis
    - V1 and V2 data show up side by side

Basic statistics V1 vs V2 (1)

Station	V1 passes	# obs	V2 passes	# obs
1824	1	6	1	6
1873	9	48	9	48
1884	4	28	4	28
1888	7	45	7	71
1890	27	129	27	176
1891	19	86	21	105
1893	9	71	9	73
7090	108	964	108	975
7105	31	291	31	294
7110	41	324	41	325
7119	13	125	13	126
7237	43	301	43	398
7249	3	17	3	20
7501	11	103	11	104
7810	88	1042	88	1124
7811	9	98	9	98
7821	8	90	8	102
7824	4	11	4	14
7825	12	44	12	65
7827	40	218	40	383
7838	24	241	24	243
7839	48	307	48	327
For example: 7840	39	478	39	479
7841	29	144	29	145
7845	35	392	35	411
7941	62	500	62	505
8834	36	230	36	236
TOTALS	760	6333	762	6881

V1 = original data from CDDIS

V2 = replace V1 data where there is a match with V2.

There are more NPTS for some stations compared to to the original release.

Caveat: By doing this, any new points/passes in V2 are included, but any pass missing in V2 remains V1. Some passes do seem to be missing in V2 compared to V1. Is this on purpose?

Closer look in next slides

```
STATION: 7840 HERL__   PASS:   1  RESIDS:   14  UTOPIA ED:    0  RMS:    0.004  MID-PASS TIME:  1/ 9/20 19:55:40  DURATION:  29.90

          GOOD      FLAGGED       RAW      OBS     SIGMA     TIME    SIGMA     CORR      B/TB        POLYNOMIAL FIT          POLY      EDIT
 ITER      OBS        OBS         RMS     BIAS       M      BIAS     MSEC     COEF       RMS      A(1)     A(2)     A(3)     RMS      CRIT
   0        14          0      0.0044  -0.0024    0.014  -0.0014    0.008  -0.588    0.0013   -0.002    0.000 -0.0000  0.0009    0.030

                I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
    1.580E-03 H                                        :                                                  *                  H  PASS RISE
    1.431E-03 H                                        :                                                                     H  ELEVATION
    1.282E-03 H                                        :                                                                     H 49 DEGREES
    1.132E-03 H*                                       :                                                                     H
    9.830E-04 H                                        :                                        *                            H
    8.336E-04 H                                        :                                                                     H
    6.843E-04 H                                        :                                                  *                  H
    5.350E-04 H                                        :                                        *                            H
    3.857E-04 H                                        *          *                                                          H
    2.363E-04 H                                        :                                                                     H
    8.702E-05 H                                        :    *                                                                H  MAXIMUM
   -6.231E-05 H--------------------------------------------------------------------------------------------------------------H  ELEVATION
   -2.116E-04 H                                        :                                                                     H 68 DEGREES
   -3.610E-04 H                                        :                                                                     H
   -5.103E-04 H                                        :                                                                     H
   -6.596E-04 H                                        :                         *                                           H
   -8.089E-04 H                                        :                                                            *        H
   -9.582E-04 H                        *               :                         *                                           H
   -1.108E-03 H                                        :                                                                    *H  PASS SET
   -1.257E-03 H                                        :                                                                     H  ELEVATION
   -1.406E-03 H                           *            :                                                                     H 27 DEGREES
                I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
               0.00       2.99       5.98       8.97      11.96      14.95      17.94      20.93      23.92      26.91      29.90
                                        POLY RESID VS TIME (MINUTE) FOR  STA 78401

STATION: 7840 HERL__   PASS:   1  RESIDS:   15  UTOPIA ED:    0  RMS:    0.006  MID-PASS TIME:  1/ 9/20 19:54:29  DURATION:  30.85

          GOOD      FLAGGED       RAW      OBS     SIGMA     TIME    SIGMA     CORR      B/TB        POLYNOMIAL FIT          POLY      EDIT
 ITER      OBS        OBS         RMS     BIAS       M      BIAS     MSEC     COEF       RMS      A(1)     A(2)     A(3)     RMS      CRIT
   0        15          0      0.0057  -0.0044    0.012    0.0000    0.007  -0.466    0.0036   -0.004    0.001 -0.0000  0.0027    0.030

                I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
    6.884E-03 H   *                                    :                                                                     H  PASS RISE
    6.185E-03 H                                        :                                                                     H  ELEVATION
    5.487E-03 H                                        :                                                                     H 47 DEGREES
    4.788E-03 H                                        :                                                                     H
    4.090E-03 H                                        :                                                                     H
    3.391E-03 H                                        :                                                                     H
    2.693E-03 H                                        :                                                                     H
    1.994E-03 H                                        :                                                                     H
    1.296E-03 H                           *            :                                                                     H
    5.971E-04 H                             *          *   *                                                  * *            H
   -1.014E-04 H--------------------------------------------*-------------------------**-----------------------*---*H  MAXIMUM
   -8.000E-04 H                                        :                                                                     H  ELEVATION
   -1.499E-03 H                                        :                                                                     H 68 DEGREES
   -2.197E-03 H                                        :                         **                                          H
   -2.896E-03 H                                        :                                                                     H
   -3.594E-03 H                                        :                                                                     H
   -4.293E-03 H                                        :                                                                     H
   -4.991E-03 H                                        :                                                                     H
   -5.690E-03 H                                        :                                                                     H  PASS SET
   -6.388E-03 H                                        :                                                                     H  ELEVATION
   -7.087E-03 H*                                       :                                                                     H 27 DEGREES
                I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
               0.00       3.09       6.17       9.26      12.34      15.43      18.51      21.60      24.68      27.77      30.85
                                        POLY RESID VS TIME (MINUTE) FOR  STA 7840
```

V1

V2

This new NPT has only 1 shot; probably a good reason it was excluded in V1

This is the only pass from 7840 that had an extra point; extra point looks inconsistent with remainder of pass, which affects PolyRMS and the scale of the plot

V1

```
STATION: 7840 HERL__  PASS:   1  RESIDS:   14  UTOPIA ED:    0  RMS:    0.004  MID-PASS TIME:  1/ 9/20 19:55:40  DURATION:  29.90

          GOOD      FLAGGED        RAW       OBS     SIGMA      TIME    SIGMA     CORR      B/TB        POLYNOMIAL FIT          POLY      EDIT
ITER      OBS       OBS            RMS      BIAS       M      BIAS     MSEC     COEF       RMS      A(1)     A(2)    A(3)     RMS      CRIT
  0        14         0         0.0044   -0.0024    0.014   -0.0014    0.008   -0.588    0.0013    -0.002    0.000 -0.0000  0.0009    0.030

                I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
   1.580E-03 H                                    :                                                                  H  PASS RISE
   1.431E-03 H                                    :                                                                  H  ELEVATION
   1.282E-03 H                                    :                                                                  H 49 DEGREES
   1.132E-03 H*                                   :                                                                  H
   9.830E-04 H                                    :                                                                  H
   8.336E-04 H                                    :                                                                  H
   6.843E-04 H                                    :                                                                  H
   5.350E-04 H                                    :                                                                  H
   3.857E-04 H                                    :                                                                  H
   2.363E-04 H                                    :                                                                  H
   8.702E-05 H                                    :                                                                  H  MAXIMUM
  -6.231E-05 H------------------------------------------------------------------------------------------------------H  ELEVATION
  -2.116E-04 H                                    :                                                                  H 68 DEGREES
  -3.610E-04 H                                    :                                                                  H
  -5.103E-04 H                                    :                                                                  H
  -6.596E-04 H                                    :                                                                  H
  -8.089E-04 H                                    :                                                                  H
  -9.582E-04 H                                    :                                                                  H
  -1.108E-03 H                                    :                                                                 *H  PASS SET
  -1.257E-03 H                                    :                                                                  H  ELEVATION
  -1.406E-03 H                                    :                                                                  H 27 DEGREES
                I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
               0.00      2.99      5.98      8.97     11.96     14.95     17.94     20.93     23.92     26.91     29.90
                                  POLY RESID VS TIME (MINUTE) FOR  STA 78401
```

V2

```
STATION: 7840 RGO___  PASS:   1  RESIDS:   14  UTOPIA ED:    0  RMS:    0.004  MID-PASS TIME:  1/ 9/20 19:55:40  DURATION:  29.90

          GOOD      FLAGGED        RAW       OBS     SIGMA      TIME    SIGMA     CORR      B/TB        POLYNOMIAL FIT          POLY      EDIT
ITER      OBS       OBS            RMS      BIAS       M      BIAS     MSEC     COEF       RMS      A(1)     A(2)    A(3)     RMS      CRIT
  0        14         0         0.0042   -0.0024    0.014   -0.0012    0.008   -0.588    0.0013    -0.002    0.000 -0.0000  0.0010    0.030

                I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
   1.287E-03 H                                    :                                                                  H  PASS RISE
   1.146E-03 H*                                   :                                                                  H  ELEVATION
   1.004E-03 H                                    :                                                                  H 49 DEGREES
   8.623E-04 H                                    :                                                                  H
   7.207E-04 H                                    :                                                                  H
   5.790E-04 H                                    :                                                                  H
   4.373E-04 H                                    :                                                                  H
   2.956E-04 H                                    :                                                                  H
   1.539E-04 H                                    :                                                                  H
   1.225E-05 H------------------------------------------------------------------------------------------------------H
  -1.294E-04 H                                    :                                                                  H  MAXIMUM
  -2.711E-04 H                                    :                                                                  H  ELEVATION
  -4.128E-04 H                                    :                                                                  H 68 DEGREES
  -5.545E-04 H                                    :                                                                  H
  -6.962E-04 H                                    :                                                                  H
  -8.378E-04 H                                    :                                                                  H
  -9.795E-04 H                                    :                                                                  H
  -1.121E-03 H                                    :                                                                  H
  -1.263E-03 H                                    :                                                                  H  PASS SET
  -1.405E-03 H                                    :                                                                 *H  ELEVATION
  -1.546E-03 H                                    :                                                                  H 27 DEGREES
                I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
               0.00      2.99      5.98      8.97     11.96     14.95     17.94     20.93     23.92     26.91     29.90
                                  POLY RESID VS TIME (MINUTE) FOR  STA 7840
```

Extra point removed; PolyRMS is similar now

In the following, only NPTs present in both data sets are compared

Using 4019 matching NPTs(after editing and excluding stations 1891,1824,7838,7824), the RMS was 7.02 mm for V1 and 6.89 mm for V2

Orbits were based on full original data set, then fixed

No other parameters were estimated
(No EOP, biases, station coordinates, etc.)

Basic statistics V1 vs V2 (2)

STATION	PASSES	TOTAL OBS	EDITED OBS	PCT EDITED	GOOD OBS	RAW RMS	B/TB RMS	POLY RMS
1824 GLSL__	1	6	0	0.0	6	4.177	2.82	2.73
1824 GLSL__	1	6	6	100.0	0	0.000	0.00	0.00
1873 SIMEIZ	9	48	0	0.0	48	4.327	2.96	2.12
1873 SIMEIZ	9	48	0	0.0	48	4.088	2.51	1.44
1884 RIGA__	2	10	0	0.0	10	3.822	0.64	0.40
1884 RIGA__	2	10	0	0.0	10	3.843	0.63	0.34
1888 SVETLO	7	23	0	0.0	23	1.288	0.94	0.93
1888 SVETLO	7	23	0	0.0	23	1.203	0.82	0.82
1890 BADARY	26	87	7	8.0	80	1.207	0.71	0.61
1890 BADARY	26	87	7	8.0	80	1.030	0.61	0.46
1891 IRKUTS	15	39	6	15.4	33	1.621	1.01	0.69
1891 IRKUTS	15	39	15	38.5	24	1.570	1.05	0.60
1893 KATZIV	7	56	7	12.5	49	3.696	1.13	0.97
1893 KATZIV	7	56	7	12.5	49	3.667	1.13	0.98
7090 YARAG_	89	780	0	0.0	780	0.632	0.28	0.24
7090 YARAG_	89	780	0	0.0	780	0.631	0.28	0.23
7105 GRF105	31	288	0	0.0	288	0.837	0.32	0.23
7105 GRF105	31	288	0	0.0	288	0.830	0.32	0.21

First line is V1

Second line is V2

PolyRMS is estimate of NPT precision

Favorable change in green

Unfavorable change in red

No significant change in black

Basic statistics (3)

STATION	PASSES	TOTAL OBS	EDITED OBS	PCT EDITED	GOOD OBS	RAW RMS	B/TB RMS	POLY RMS
7110 MONPK1	34	282	0	0.0	282	0.778	0.42	0.26
7110 MONPK1	34	282	0	0.0	282	0.773	0.41	0.25
7119 HA4T__	11	116	4	3.4	112	0.855	0.68	0.67
7119 HA4T__	11	116	4	3.4	112	0.621	0.38	0.33
7237 CHACHU	34	159	6	3.8	153	1.571	0.84	0.54
7237 CHACHU	34	159	6	3.8	153	1.483	0.65	0.38
7249 BEIL__	3	17	0	0.0	17	0.841	0.59	0.27
7249 BEIL__	3	17	0	0.0	17	0.858	0.43	0.16
7501 HARL__	10	84	1	1.2	83	0.807	0.27	0.16
7501 HARL__	10	84	1	1.2	83	0.804	0.28	0.15
7810 ZIMMBG	40	360	1	0.3	359	0.697	0.24	0.17
7810 ZIMMBG	40	360	1	0.3	359	0.702	0.23	0.17
7811 BOROWC	4	46	0	0.0	46	0.949	0.27	0.25
7811 BOROWC	4	46	0	0.0	46	0.932	0.23	0.20
7821 SHA2__	7	67	0	0.0	67	0.841	0.21	0.14
7821 SHA2__	7	67	0	0.0	67	0.807	0.22	0.14
7824 SANF_B	2	5	0	0.0	5	1.064	0.04	0.04
7824 SANF_B	2	5	5	100.0	0	0.000	0.00	0.00

First line is V1

Second line is V2

PolyRMS is estimate of NPT precision

Favorable change in green

Unfavorable change in red

No significant change in black

Ambiguous in blue

Basic statistics (4)

STATION	PASSES	TOTAL OBS	EDITED OBS	PCT EDITED	GOOD OBS	RAW RMS	B/TB RMS	POLY RMS
7825 STROM2	12	44	4	9.1	40	0.579	0.36	0.34
7825 STROM2	12	44	4	9.1	40	0.535	0.27	0.25
7838 SISL__	21	216	40	18.5	176	1.365	0.82	0.53
7838 SISL__	21	216	29	13.4	187	1.342	0.76	0.45
7839 GRAZ__	38	248	0	0.0	248	0.535	0.20	0.11
7839 GRAZ__	38	248	0	0.0	248	0.536	0.19	0.10
7840 HERL__	26	330	0	0.0	330	0.528	0.26	0.14
7840 HERL__	26	330	0	0.0	330	0.530	0.26	0.15
7841 POTSD3	22	103	0	0.0	103	0.732	0.24	0.13
7841 POTSD3	22	103	0	0.0	103	0.731	0.24	0.12
7845 GRASSM	28	312	0	0.0	312	0.850	0.61	0.40
7845 GRASSM	28	312	0	0.0	312	0.844	0.60	0.40
7941 MLRO__	48	382	0	0.0	382	0.569	0.19	0.14
7941 MLRO__	48	382	0	0.0	382	0.572	0.20	0.13
8834 WETZL2	31	207	0	0.0	207	0.635	0.20	0.14
8834 WETZL2	31	207	0	0.0	207	0.631	0.20	0.14

First line is V1

Second line is V2

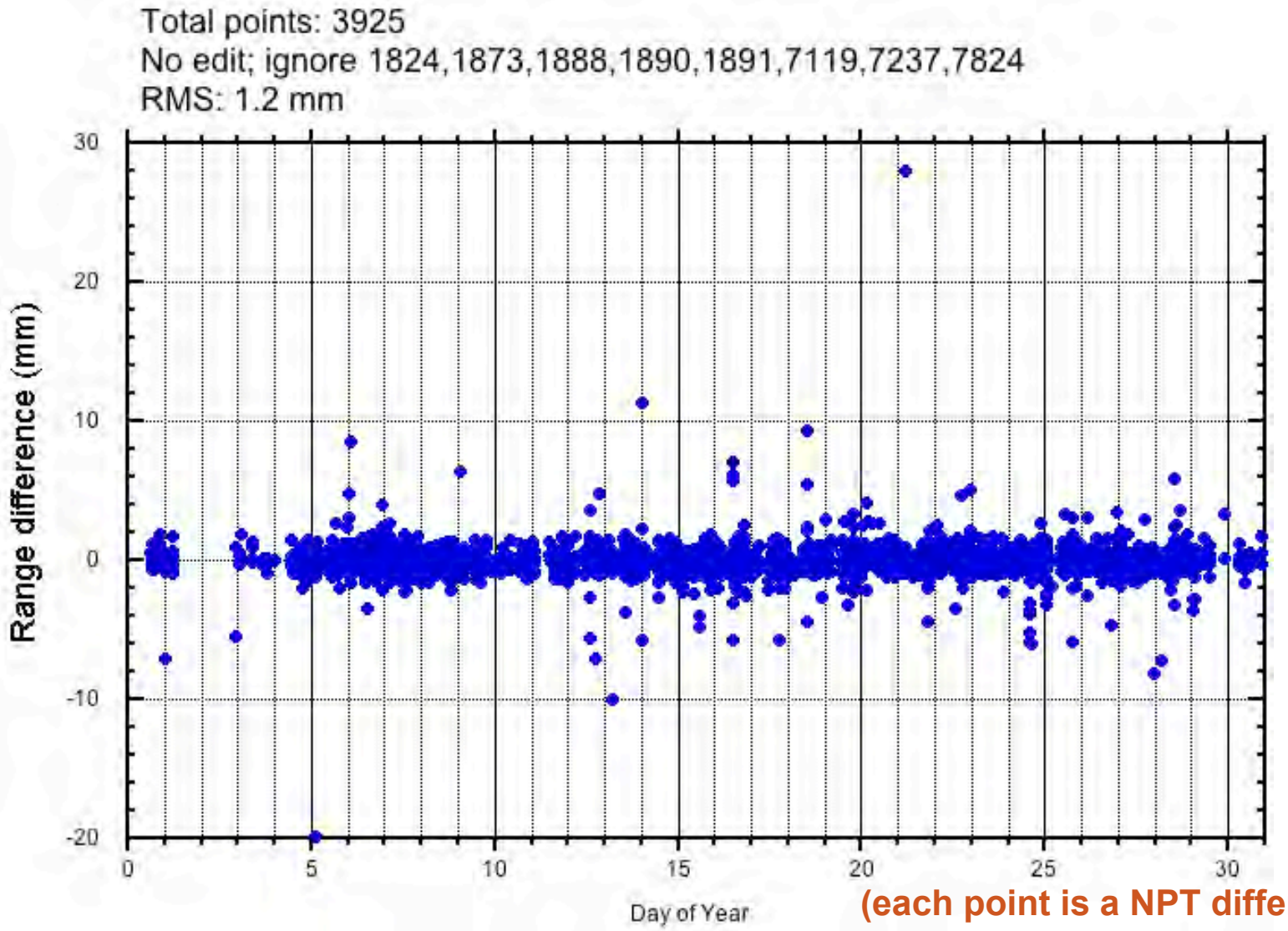
PolyRMS is estimate of NPT precision

Favorable change in green

Unfavorable change in red

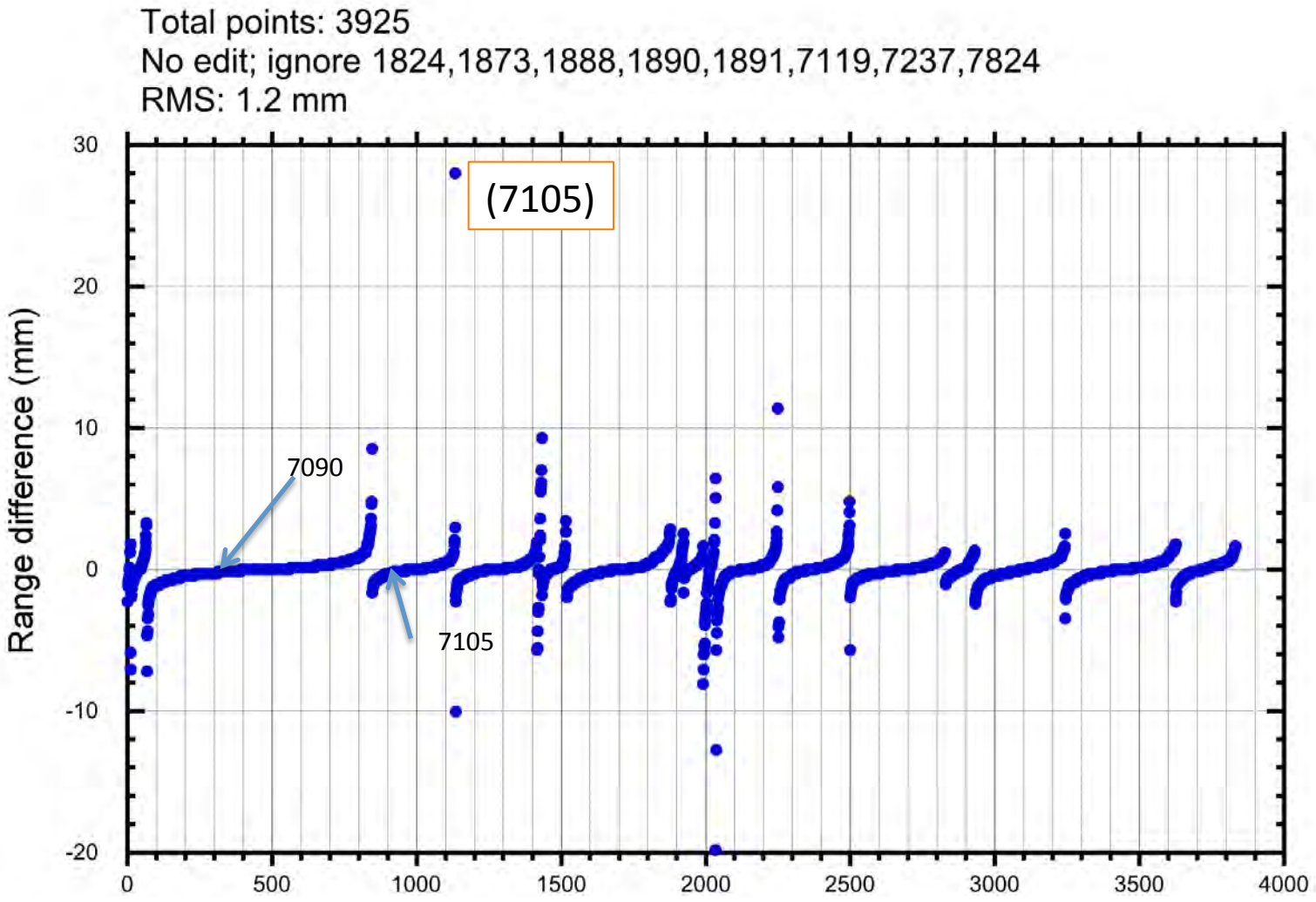
No significant change in black

Normal point differences ('good' sites with sub-cm fits)



(each point is a NPT difference)

Normal point differences (same but sorted by station/delta range)



Outlier for 7105

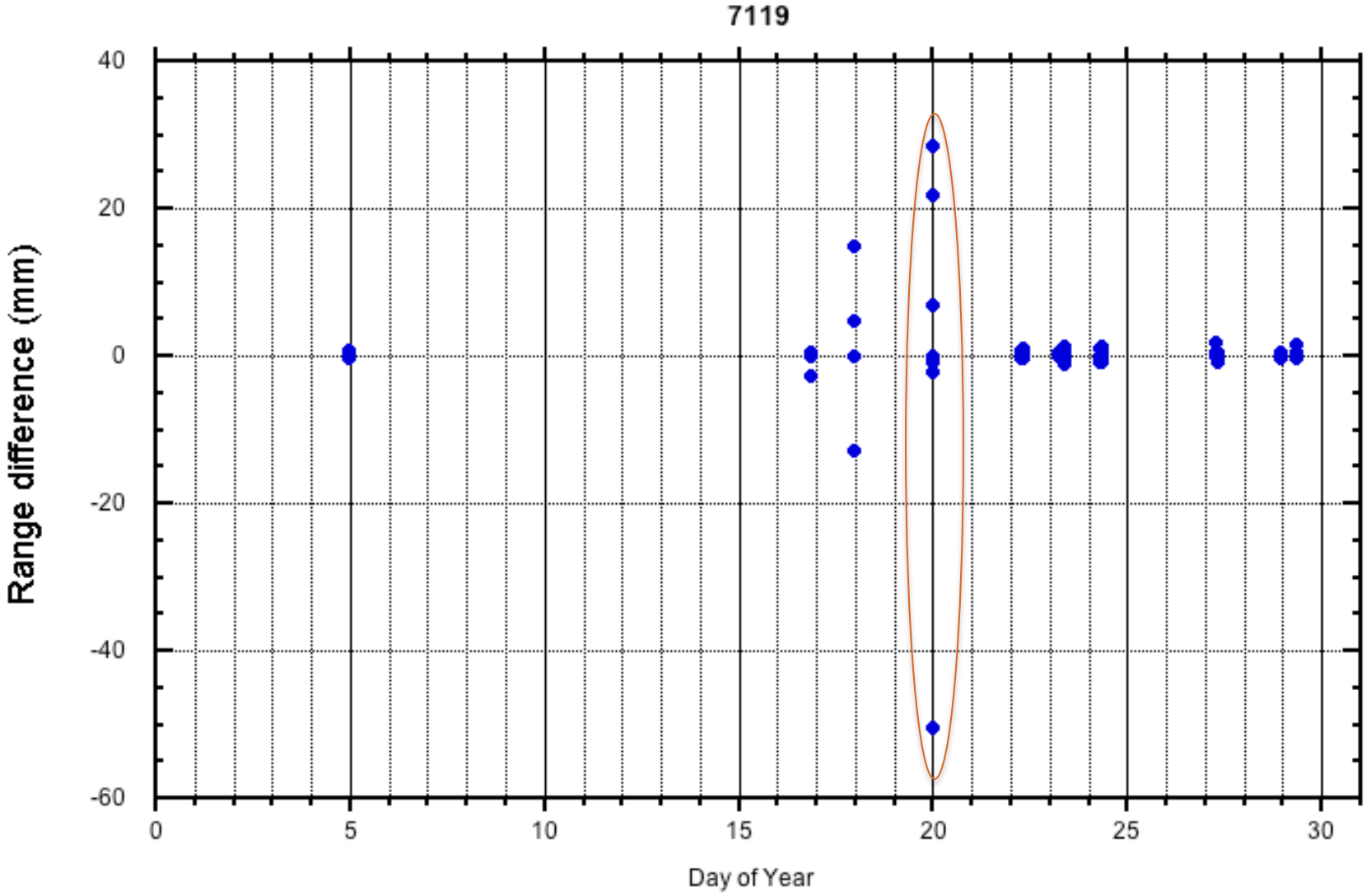
```
760390120370710520022145416286260500000008417180728735701026270059078
760390120370710520022145416286265500000008417180700704701026270059071
                                                  ^^                  ^^^^^
                                                  28 mm diff          NPT RMS(mm)
```

Difference of 2.8 cm in range, and also a large increase in the NPT rms

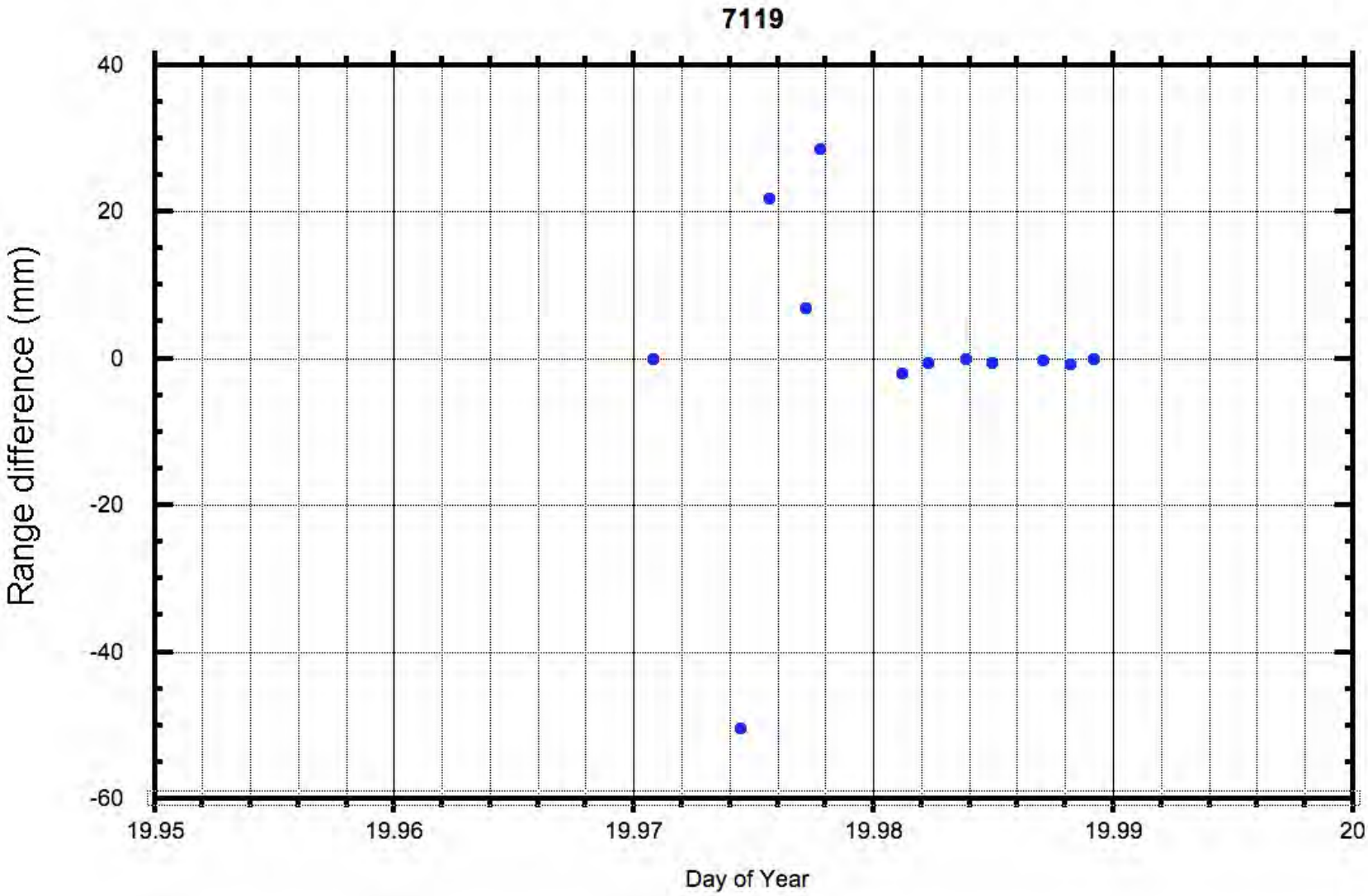
This observation had only 4 shots; old and new SW compute very different RMS values

Such a large difference in the NPT range seems unexpected for a station of this quality, but we will see later that the new NPT appears to perform better.

Normal point differences (7119)

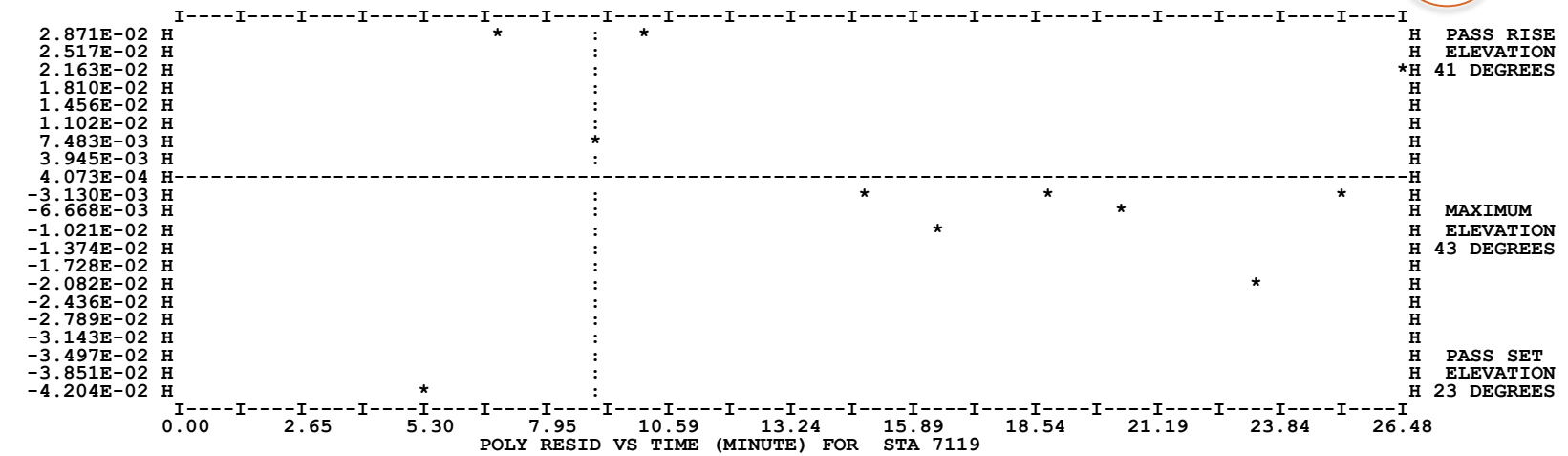


Normal point differences (7119) (Zoom in)



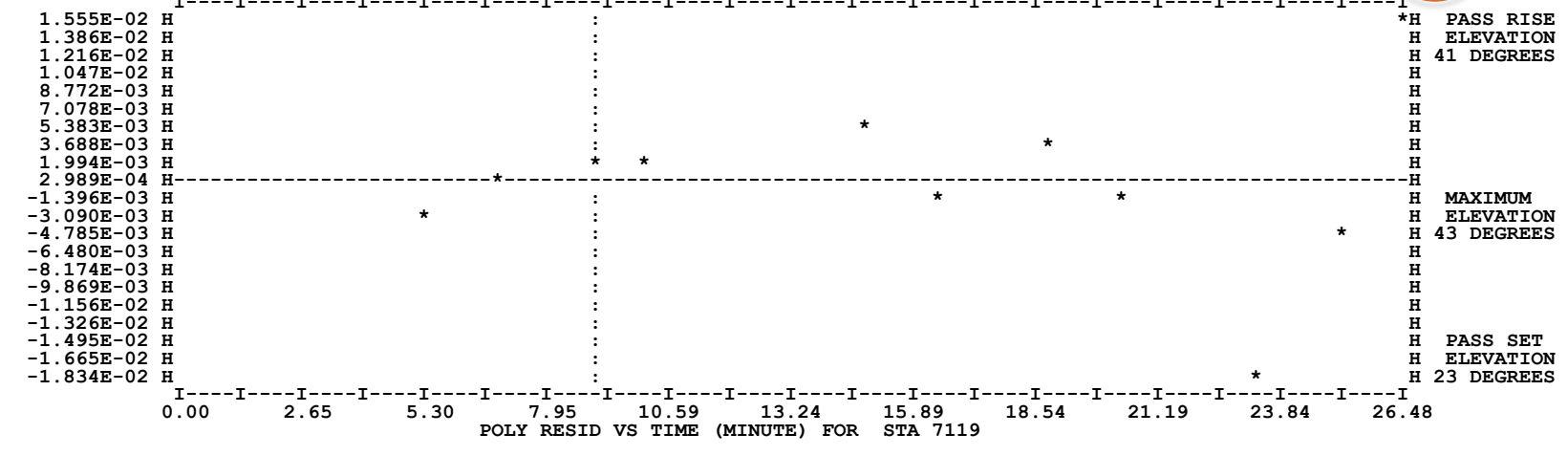
STATION: 7119 HOLTL4 PASS: 4 RESIDS: 12 UTOPIA ED: 1 RMS: 0.023 MID-PASS TIME: 1/20/20 23:34: 3 DURATION: 21.25

ITER	GOOD OBS	FLAGGED OBS	RAW RMS	OBS BIAS	SIGMA M	TIME BIAS	SIGMA MSEC	CORR COEF	B/TB RMS	POLYNOMIAL FIT A(1)	A(2)	A(3)	POLY RMS	EDIT CRIT
0	11	1	0.0231	-0.0152	0.019	0.0083	0.014	-0.711	0.0205	-0.007	0.001	-0.0000	0.0204	0.055



V1

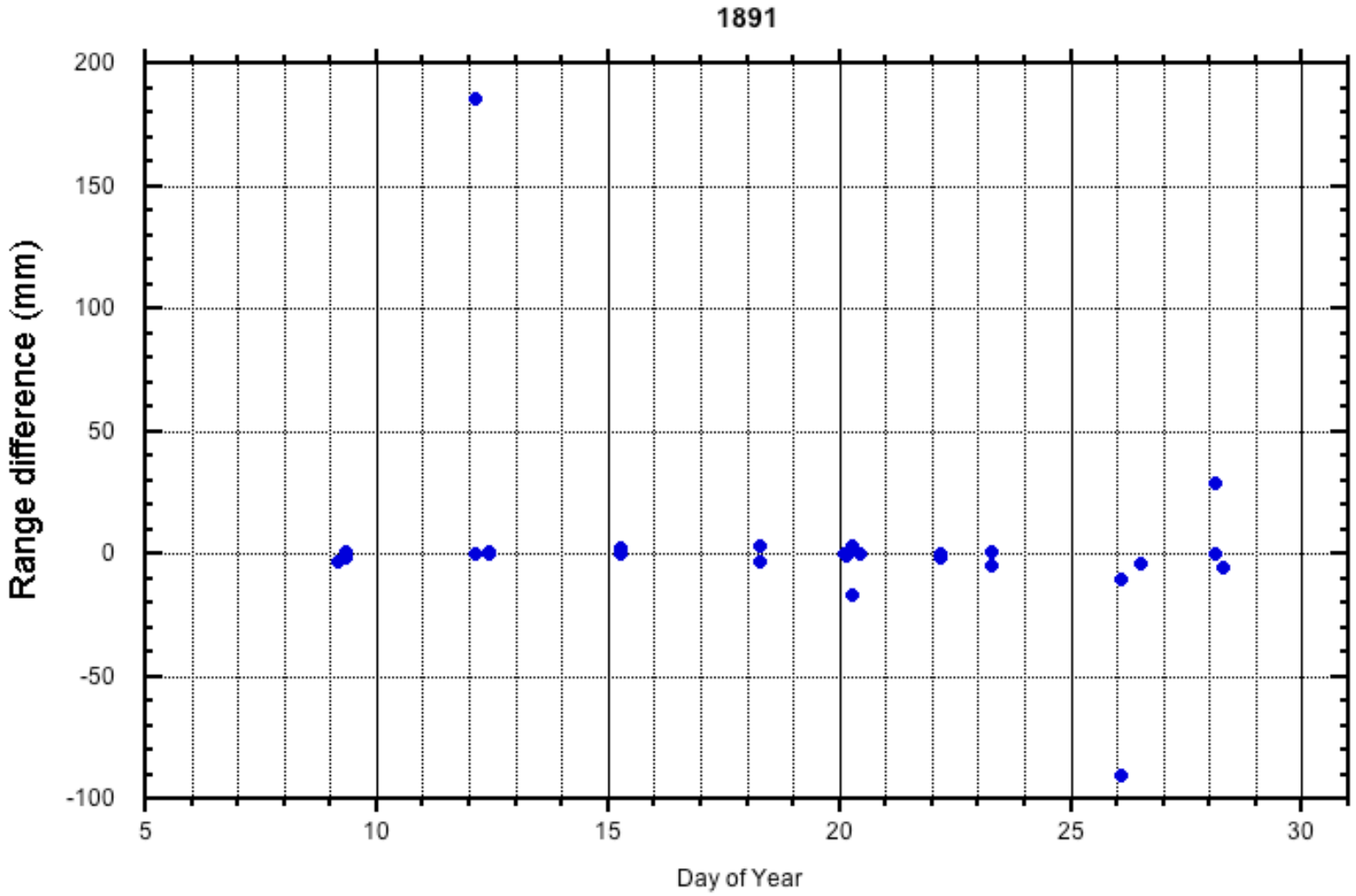
ITER	GOOD OBS	FLAGGED OBS	RAW RMS	OBS BIAS	SIGMA M	TIME BIAS	SIGMA MSEC	CORR COEF	B/TB RMS	POLYNOMIAL FIT A(1)	A(2)	A(3)	POLY RMS	EDIT CRIT
0	11	1	0.0132	-0.0132	0.019	0.0063	0.014	-0.711	0.0093	0.023	-0.004	0.0001	0.0079	0.030



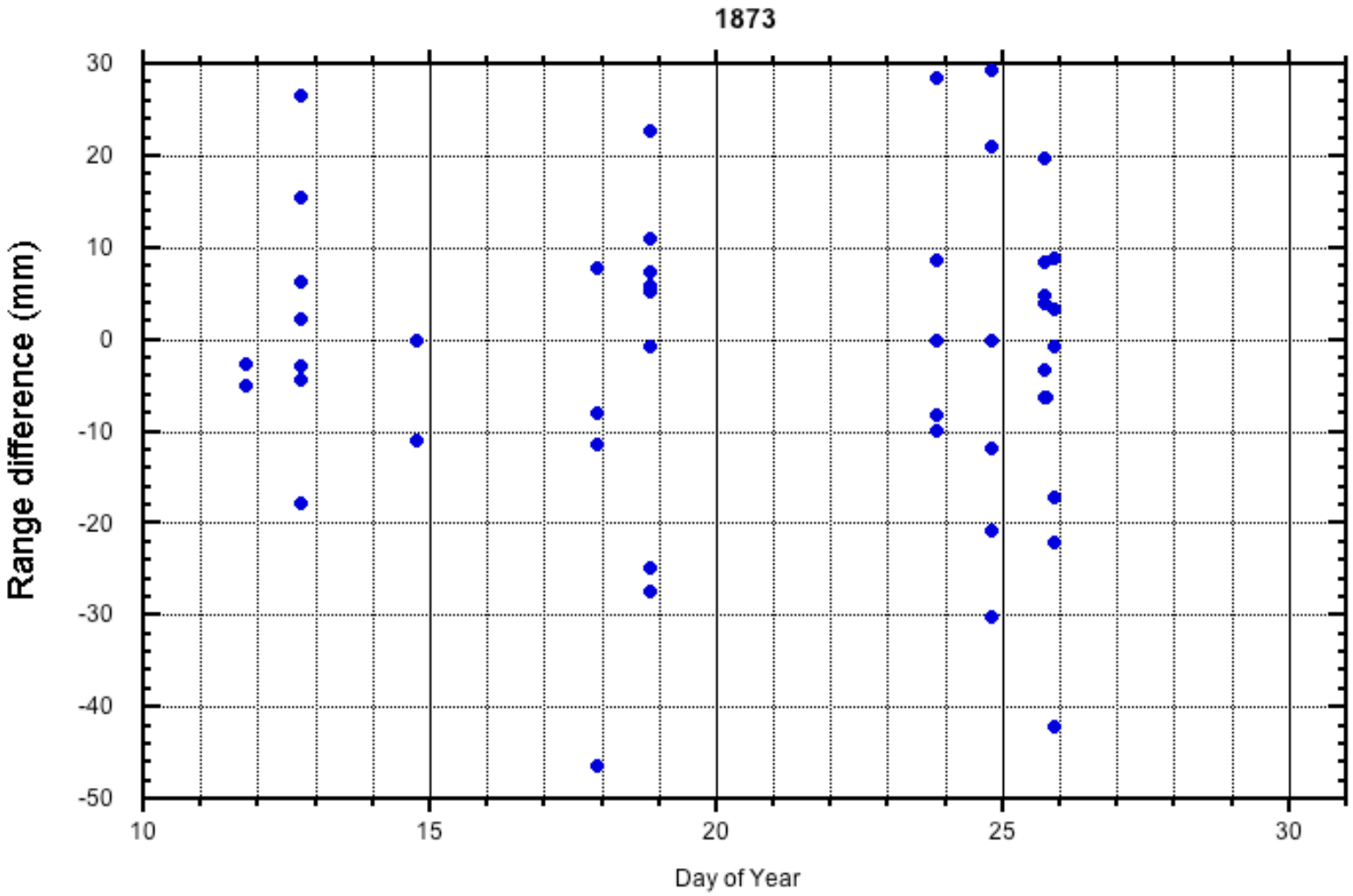
V2

In this case, the new NPTs are a clear improvement over the original (8 mm vs 20 mm)

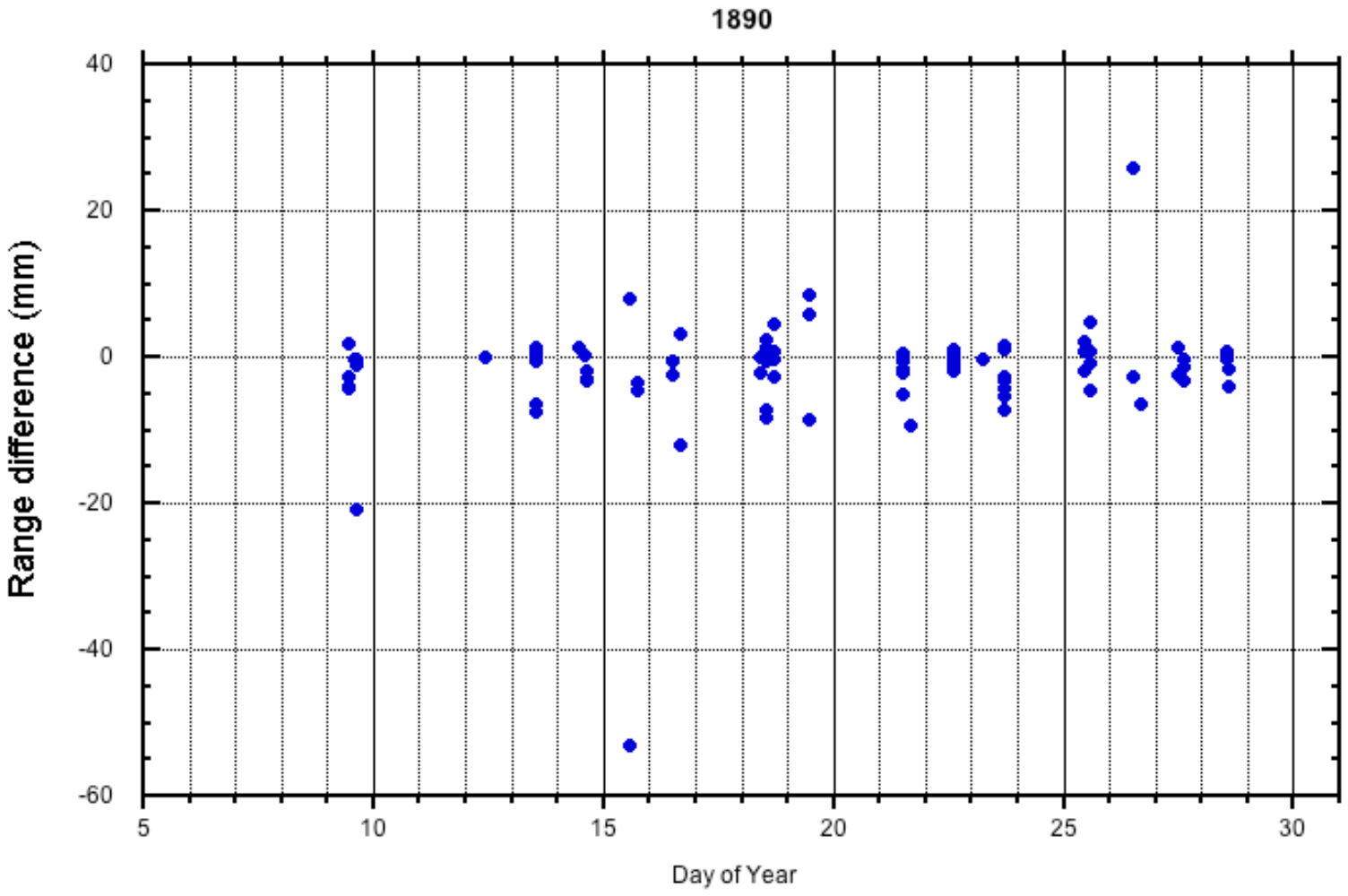
Normal point differences (1891)



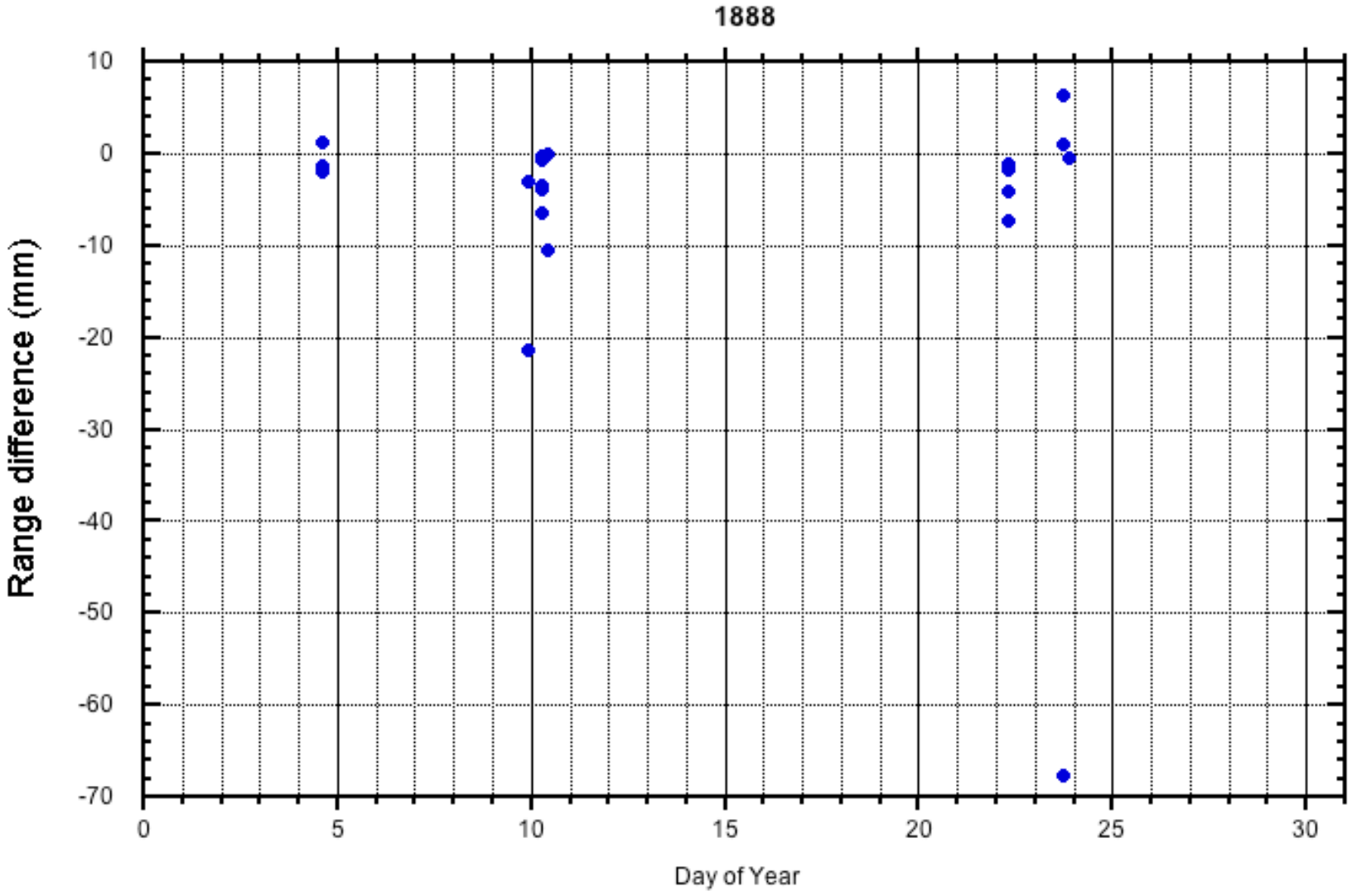
Normal point differences (1873)



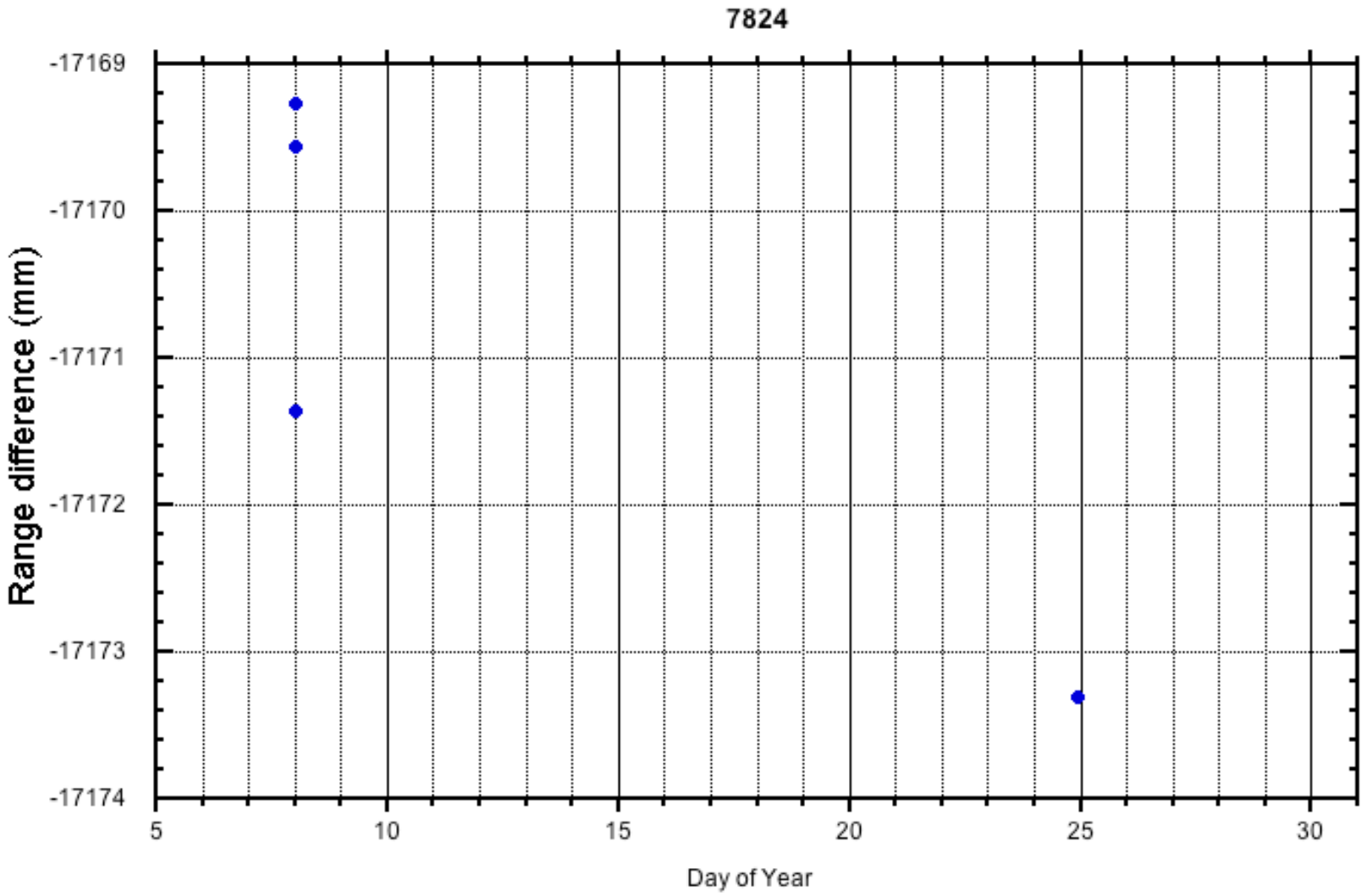
Normal point differences (1890)



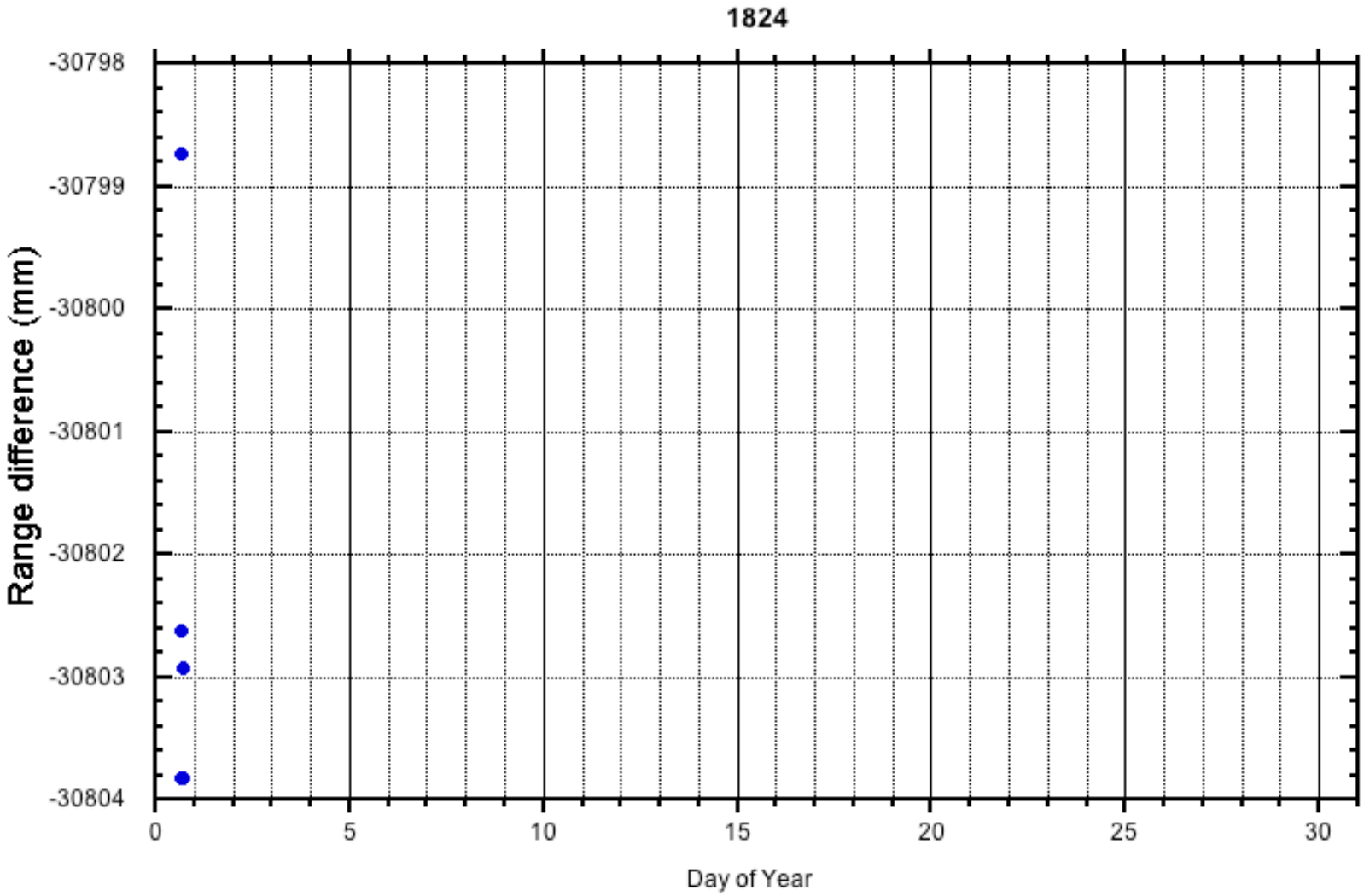
Normal point differences (1888)



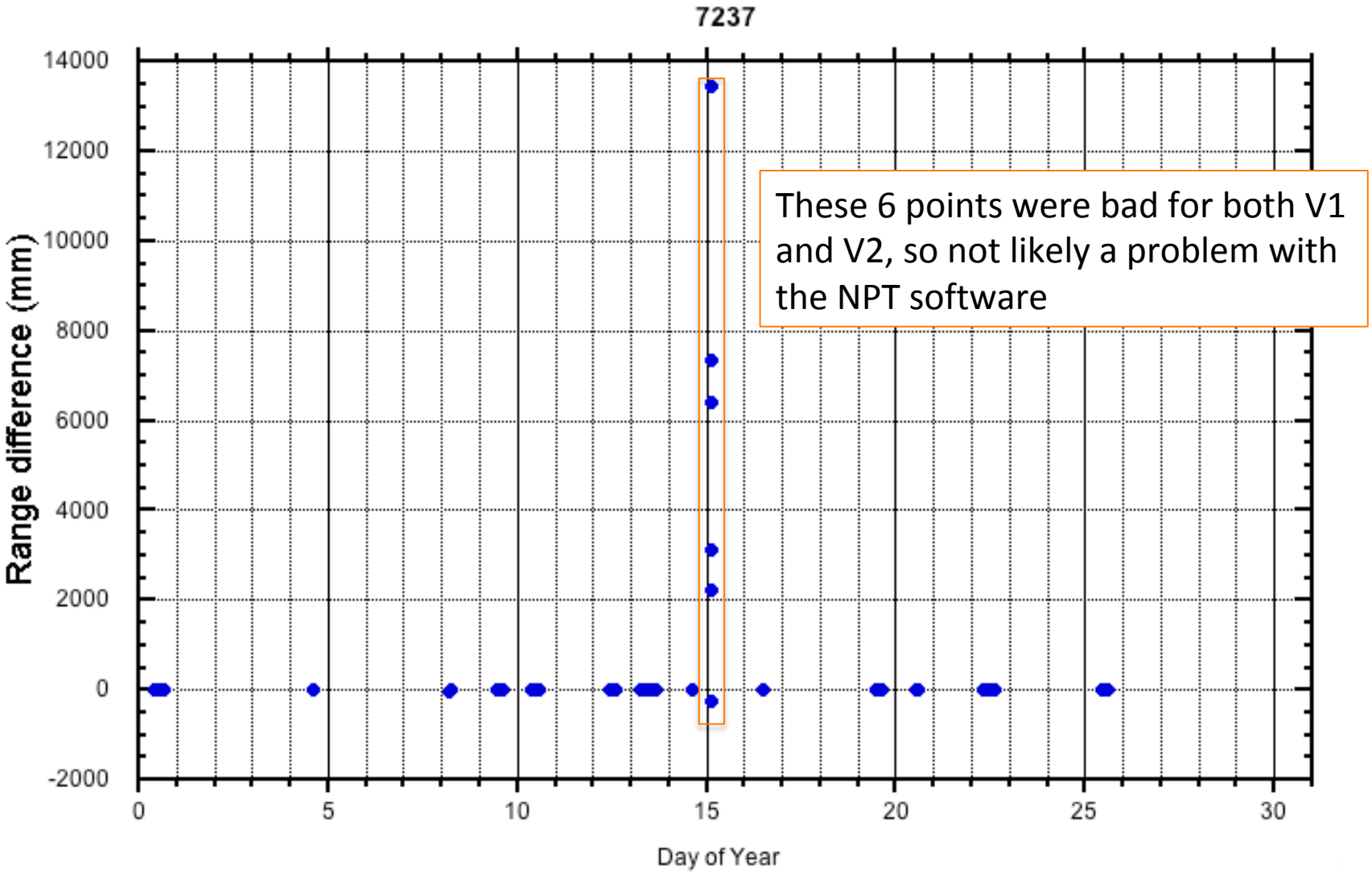
Normal point differences (7824)



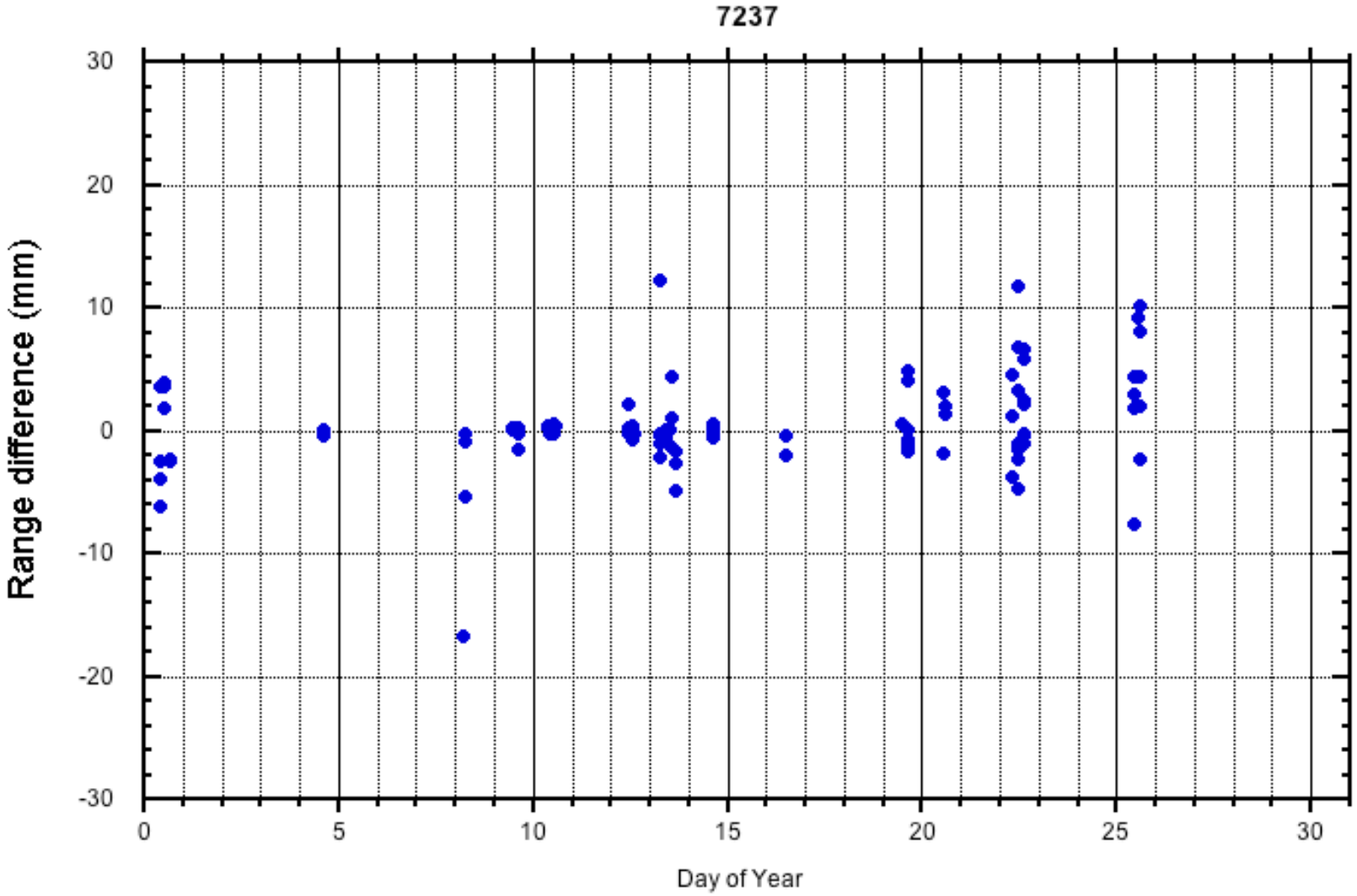
Normal point differences (1824)



Normal point differences (7237)



Normal point differences (7237; apply 30 mm editing)



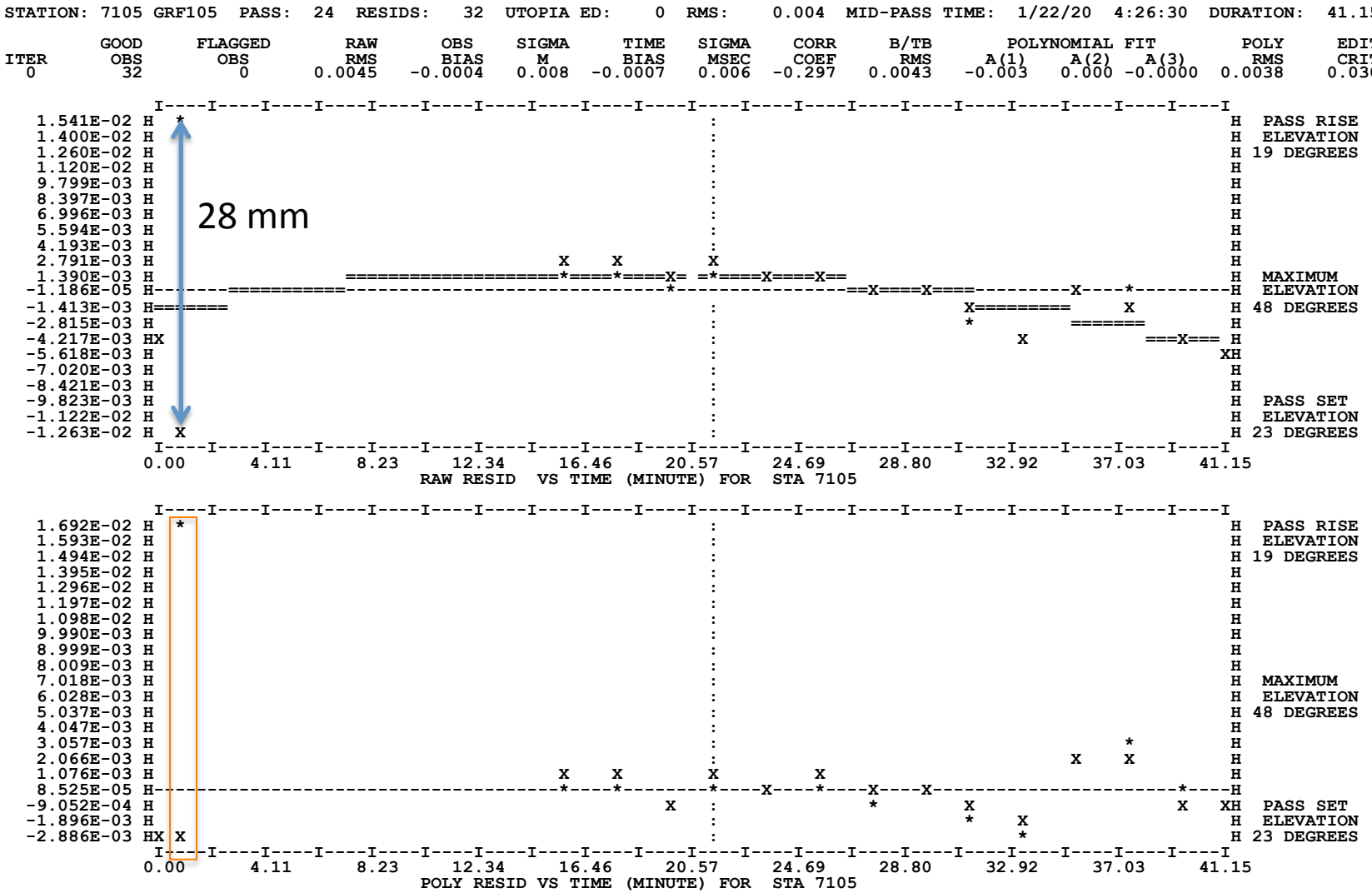
Side-by-side residual comparisons

Both versions plotted together (*=V1, X = V2)

Each plot shows the residuals before and after systematic signal has been removed

Statistics for the pass are included in the header information

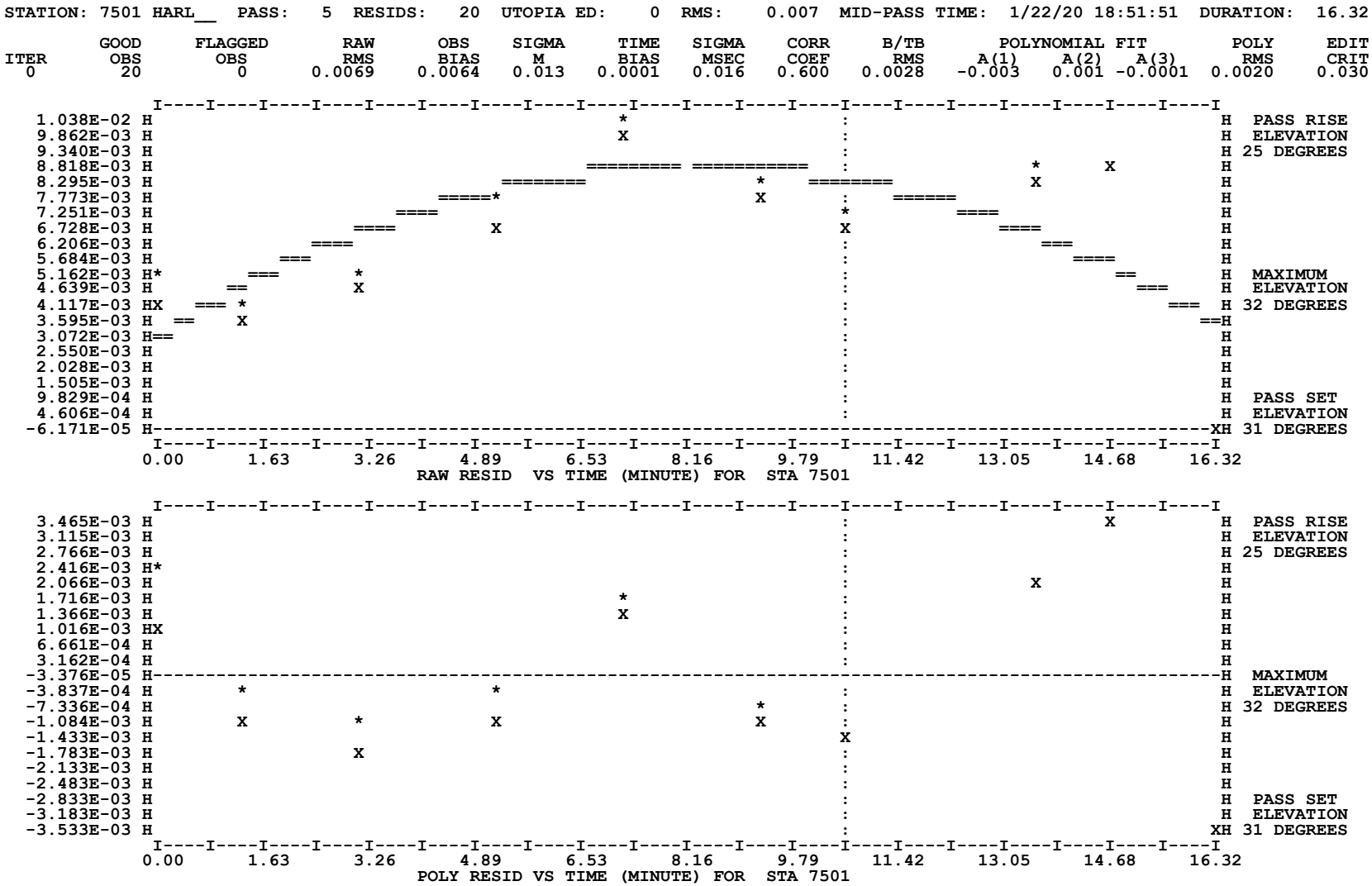
PolyRMS represents best estimate of NPT noise



Raw residuals

After removing systematics

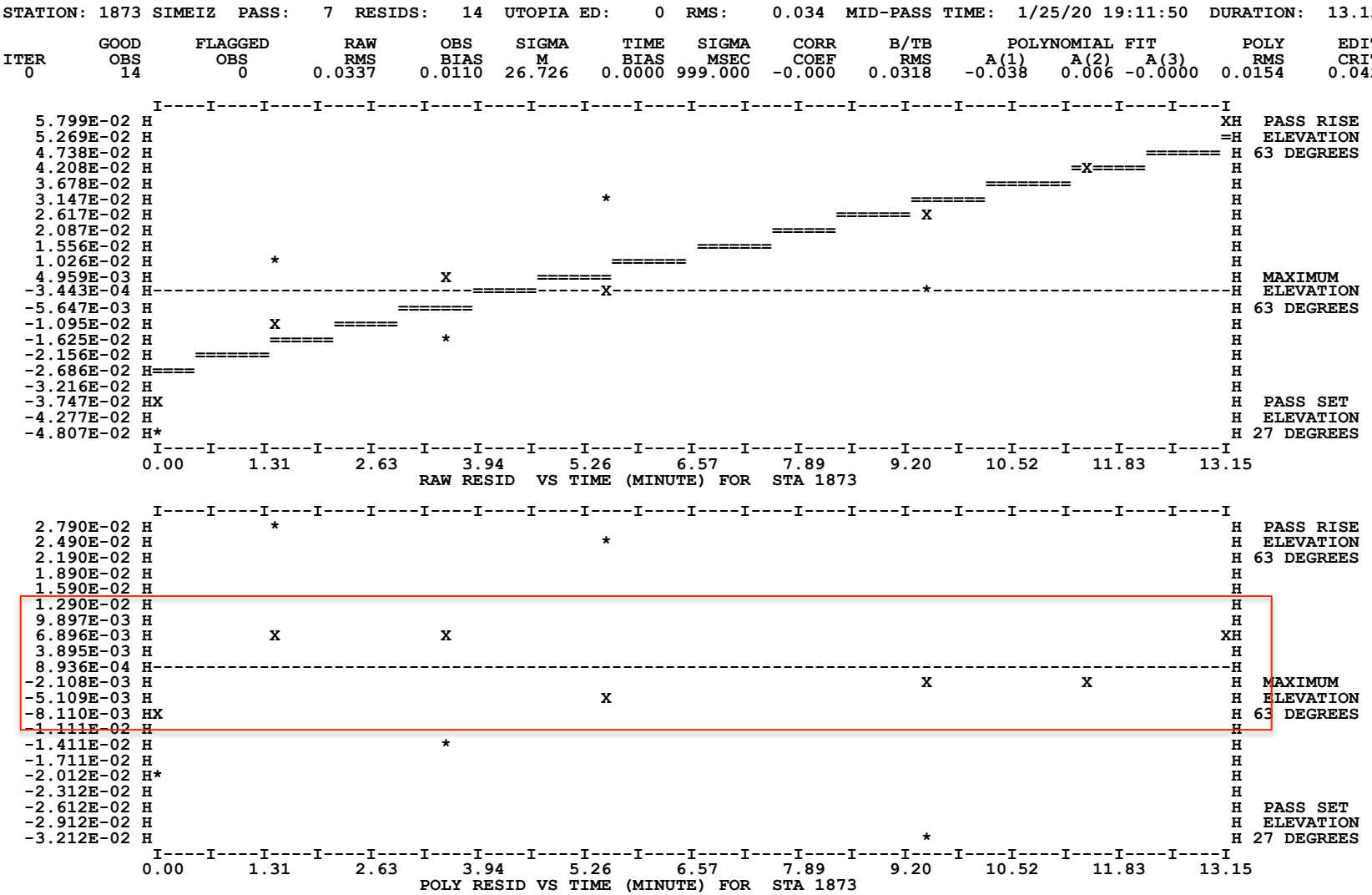
New NPT appears to be more consistent than old one



Raw residuals

After removing systematics

Where only one symbol is present means that the residuals are the same (within the resolution of the plot)

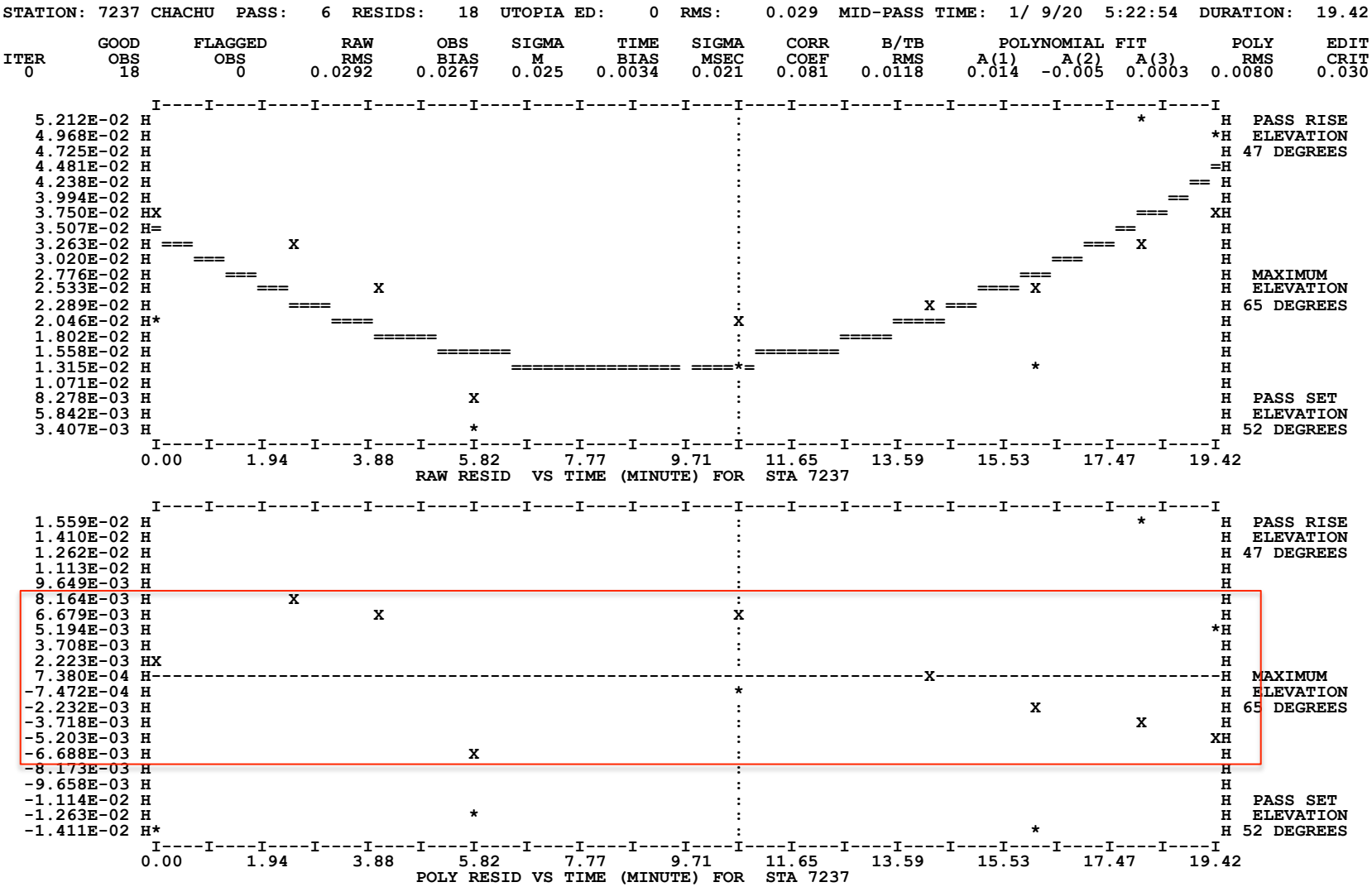


Raw residuals

After removing systematics

Where only one symbol is present means that the residuals are the same (within the resolution of the plot)

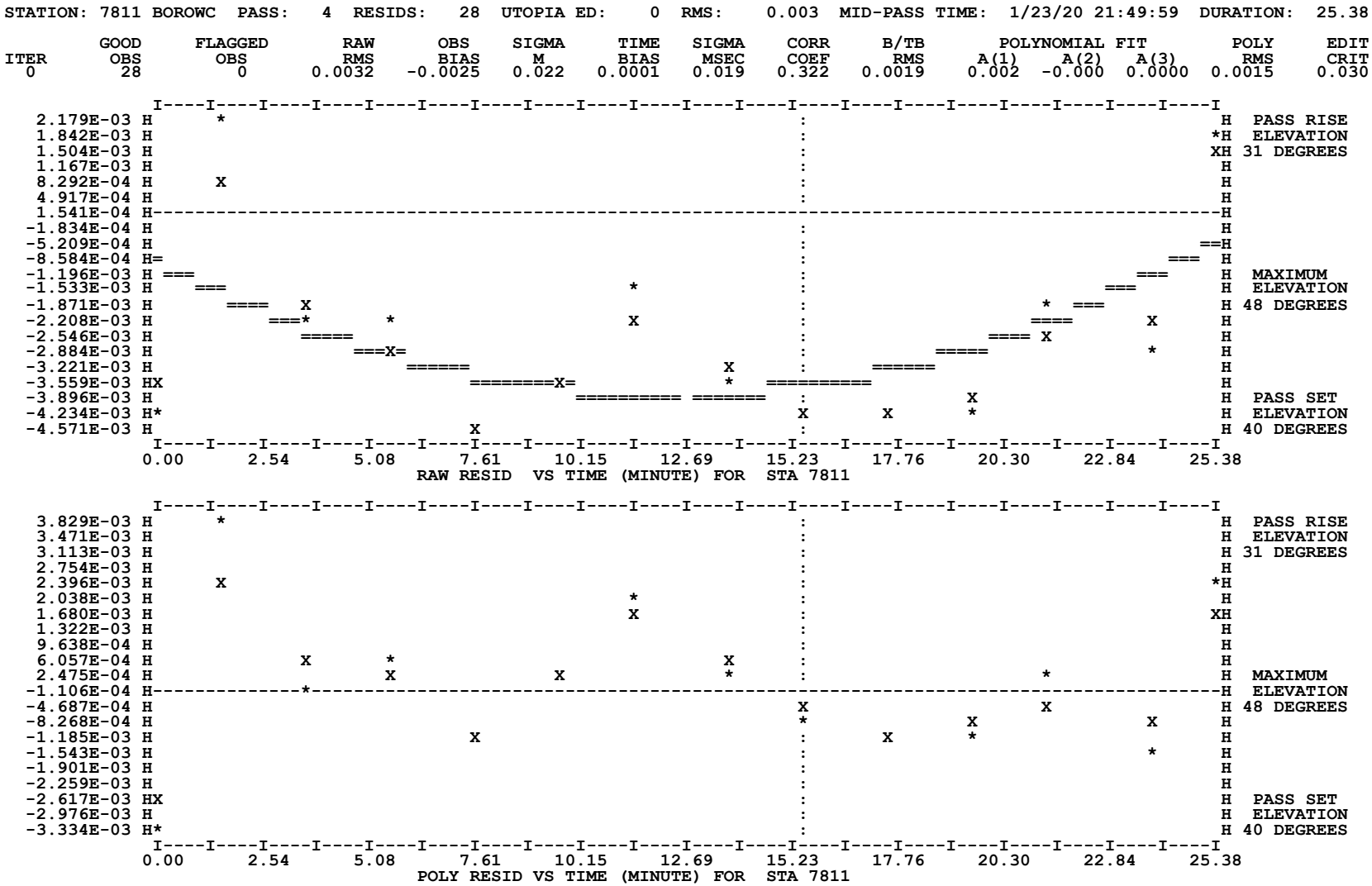
New NPTS (V2) appear to be better than original NPTS (V1)



Raw residuals

After removing systematics

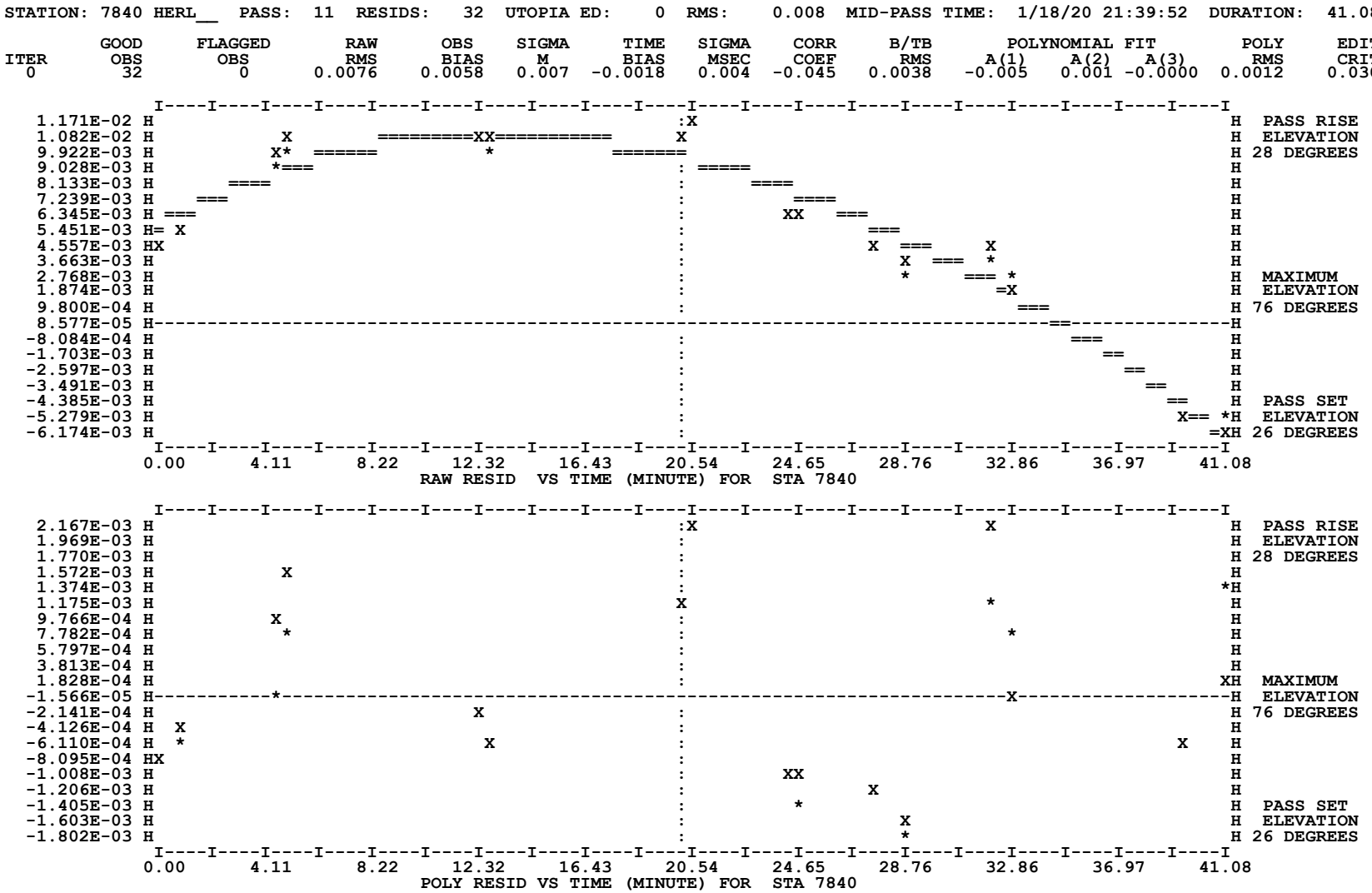
New NPTS (V2) appear to be better than original NPTS (V1)



Raw residuals

After removing systematics

New NPTS (V2) appear to be about the same quality as the original NPTS (V1)



Raw residuals and fit curve

After removing systematics

New NPTS (V2) appear to be about the same quality as the original NPTS (V1)

Summary for LAGEOS

- In most cases, no significant difference in NPTs
  - Slight improvement in overall fit RMS
  - In a few cases, the new NPTs are clearly an improvement
  - In a few cases, some new NPTs (not present in V1) seem inconsistent
  - Most NPT differences under 3 mm; 1.2 mm RMS overall (considering only better precision stations)
  - Differences tend to be larger for lower precision station
  - Observation epochs appear to be identical generally; no epoch differed by more than 0.1 microsec (the resolution of the format)
- Very large differences for 7824 and 1824
- Plots for every pass are available upon request

LARES

Basic statistics V1 vs V2 (1)

Station	V1 passes	# obs	V2 passes	# obs
1873	2	13	2	14
1884	6	90	6	90
1888	9	56	9	93
1890	20	108	20	147
1891	4	14	5	19
1893	1	5	1	5
7090	91	930	91	958
7105	31	447	31	448
7110	24	258	24	261
7119	10	106	10	111
7237	63	510	63	639
7501	9	67	9	67
7810	77	1146	77	1188
7811	10	72	10	72
7821	4	28	4	33
7824	1	1	1	1
7825	7	56	7	68
7827	37	371	37	687
7838	2	15	2	16
7839	30	426	31	488
7840	40	439	40	446
7841	37	291	37	305
For example: 7845	11	159	11	179
7941	37	331	37	336
8834	40	388	40	410

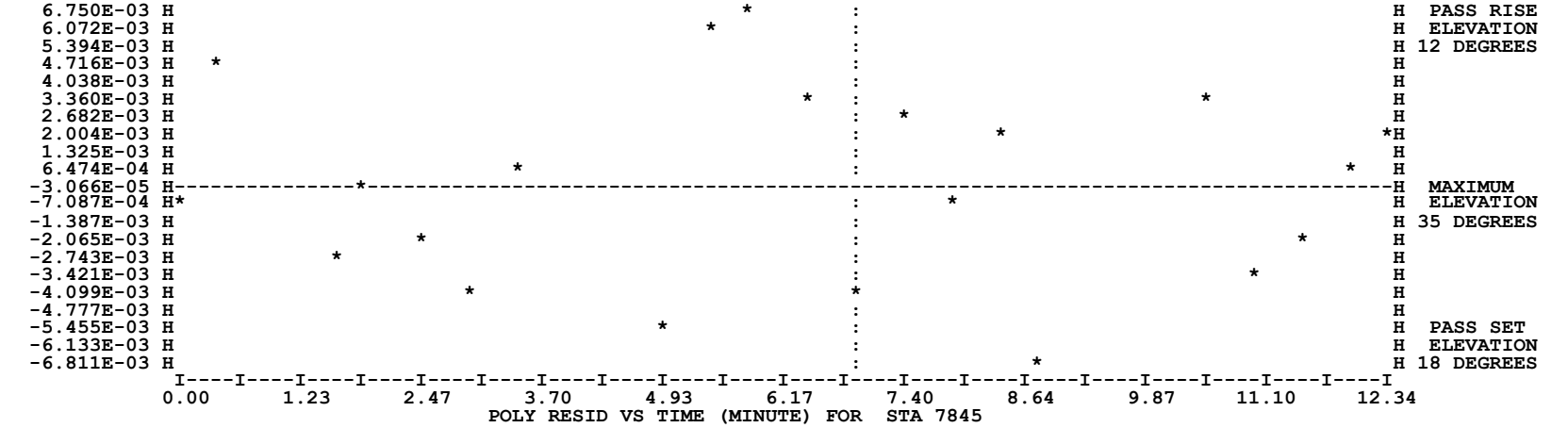
V1 = original data from CDDIS

V2 = replace V1 data where there is a match with V2.

There are more NPTS for most of the stations compared to to the original release.

STATION: 7845 GRASSM PASS: 11 RESIDS: 21 UTOPIA ED: 0 RMS: 0.019 MID-PASS TIME: 1/29/20 23:39:36 DURATION: 12.34

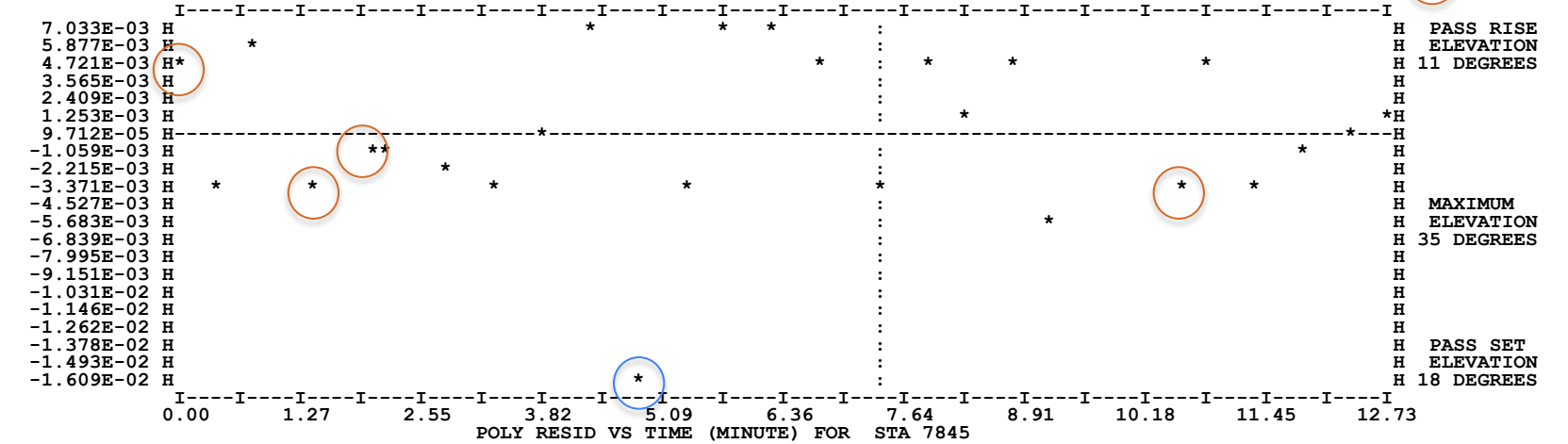
ITER	GOOD OBS	FLAGGED OBS	RAW RMS	OBS BIAS	SIGMA M	TIME BIAS	SIGMA MSEC	CORR COEF	B/TB RMS	POLYNOMIAL FIT A(1)	A(2)	A(3)	POLY RMS	EDIT CRIT
0	21	0	0.0187	0.0182	0.011	0.0000	0.003	0.140	0.0044	-0.005	0.002	-0.0002	0.0037	0.030



V1

STATION: 7845 GRASSM PASS: 11 RESIDS: 26 UTOPIA ED: 0 RMS: 0.018 MID-PASS TIME: 1/29/20 23:39: 7 DURATION: 12.73

ITER	GOOD OBS	FLAGGED OBS	RAW RMS	OBS BIAS	SIGMA M	TIME BIAS	SIGMA MSEC	CORR COEF	B/TB RMS	POLYNOMIAL FIT A(1)	A(2)	A(3)	POLY RMS	EDIT CRIT
0	26	0	0.0185	0.0177	0.010	-0.0000	0.003	0.247	0.0053	-0.003	0.002	-0.0001	0.0050	0.030



V2

This is one of the passes for GRASSE (7845) that had extra points (circled); most look consistent except for the new one circled in blue. As a result, the POLYRms (NPT noise estimate) increases from 3.7 to 5.0 mm.

```
STATION: 7845 GRASSM  PASS:  11  RESIDS:   21  UTOPIA ED:    0  RMS:    0.019  MID-PASS TIME:  1/29/20 23:39:36  DURATION:  12.34

         GOOD      FLAGGED        RAW      OBS     SIGMA      TIME    SIGMA     CORR      B/TB        POLYNOMIAL FIT          POLY      EDIT
ITER      OBS        OBS          RMS     BIAS       M      BIAS     MSEC     COEF       RMS      A(1)     A(2)    A(3)      RMS      CRIT
  0        21          0       0.0187   0.0182   0.011    0.0000   0.003    0.140    0.0044    -0.005    0.002 -0.0002   0.0037    0.030

                I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
   6.750E-03 H                                                  *        :                                                  H  PASS RISE
   6.072E-03 H                                                 *         :                                                  H  ELEVATION
   5.394E-03 H                                                           :                                                  H 12 DEGREES
   4.716E-03 H   *                                                       :                                                  H
   4.038E-03 H                                                           :                                                  H
   3.360E-03 H                                                    *      :                    *                             H
   2.682E-03 H                                                           :    *                                             H
   2.004E-03 H                                                           :          *                                      *H
   1.325E-03 H                                                           :                                                 H
   6.474E-04 H                          *                                :                                          *      H
  -3.066E-05 H----------------*-------------------------------------------------------------------------------------------H  MAXIMUM
  -7.087E-04 H*                                                          :         *                                       H  ELEVATION
  -1.387E-03 H                                                           :                                                 H 35 DEGREES
  -2.065E-03 H                     *                                     :                                          *      H
  -2.743E-03 H               *                                           :                                                 H
  -3.421E-03 H                                                           :                                    *            H
  -4.099E-03 H                        *                                 :                                                 H
  -4.777E-03 H                                                          *:                                                 H
  -5.455E-03 H                                  *                        :                                                 H  PASS SET
  -6.133E-03 H                                                           :                                                 H  ELEVATION
  -6.811E-03 H                                                           :              *                                  H 18 DEGREES
                I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
               0.00      1.23      2.47      3.70      4.93      6.17      7.40      8.64      9.87     11.10     12.34
                                  POLY RESID VS TIME (MINUTE) FOR  STA 7845

STATION: 7845 GRASSM  PASS:  11  RESIDS:   26  UTOPIA ED:    0  RMS:    0.018  MID-PASS TIME:  1/29/20 23:39: 7  DURATION:  12.73

         GOOD      FLAGGED        RAW      OBS     SIGMA      TIME    SIGMA     CORR      B/TB        POLYNOMIAL FIT          POLY      EDIT
ITER      OBS        OBS          RMS     BIAS       M      BIAS     MSEC     COEF       RMS      A(1)     A(2)    A(3)      RMS      CRIT
  0        26          0       0.0185   0.0177   0.010   -0.0000   0.003    0.247    0.0053    -0.003    0.002 -0.0001   0.0050    0.030

                I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
   7.033E-03 H                                    *          *   *        :                                                  H  PASS RISE
   5.877E-03 H       *                                                   :                                                  H  ELEVATION
   4.721E-03 H*                                                 *         :    *       *                 *                   H 11 DEGREES
   3.565E-03 H                                                           :                                                  H
   2.409E-03 H                                                           :                                                  H
   1.253E-03 H                                                           :       *                                         *H
   9.712E-05 H----------------------------------*-------------------------------------------------------------------------*---H
  -1.059E-03 H                   **                                     :                                          *       H
  -2.215E-03 H                      *                                   :                                                  H
  -3.371E-03 H    *       *                 *               *           *                          *      *               H
  -4.527E-03 H                                                          :                                                  H  MAXIMUM
  -5.683E-03 H                                                          :                 *                                H  ELEVATION
  -6.839E-03 H                                                          :                                                  H 35 DEGREES
  -7.995E-03 H                                                          :                                                  H
  -9.151E-03 H                                                          :                                                  H
  -1.031E-02 H                                                          :                                                  H
  -1.146E-02 H                                                          :                                                  H
  -1.262E-02 H                                                          :                                                  H
  -1.378E-02 H                                                          :                                                  H  PASS SET
  -1.493E-02 H                                                          :                                                  H  ELEVATION
  -1.609E-02 H                                  *                       :                                                  H 18 DEGREES
                I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I----I
               0.00      1.27      2.55      3.82      5.09      6.36      7.64      8.91     10.18     11.45     12.73
                                  POLY RESID VS TIME (MINUTE) FOR  STA 7845
```

V1

V2

Also, one of the new NPTs is very close to a old one; why?

Closer look at this pass (1)

NPT	STATION	MJD	NSHOTS	RMS	MJD	NSHOTS	RMS
1	7845				58877.98121	2	49
2	7845	58877.98148	33	18	58877.98148	33	16
3	7845	58877.98177	9	29	58877.98177	9	29
4	7845				58877.98216	3	59
5	7845	58877.98262	6	27	58877.98262	6	21
6	7845	58877.98275	39	14	58877.98275	39	13
7	7845	58877.98316	21	20	58877.98316	21	18
8	7845	58877.98354	17	22	58877.98354	17	20
9	7845	58877.98385	16	29	58877.98385	16	28
10	7845				58877.98418	5	42
11	7845				58877.98455	2	33
12	7845	58877.98490	54	12	58877.98490	54	11
13	7845	58877.98521	20	19	58877.98521	20	16
14	7845	58877.98554	22	24	58877.98554	22	22
15	7845	58877.98590	16	25	58877.98590	16	22
16	7845	58877.98630	46	14	58877.98630	46	13
17	7845	58877.98665	45	14	58877.98665	45	13
18	7845	58877.98699	36	14	58877.98699	36	12
19	7845	58877.98727	23	20	58877.98727	23	18
20	7845	58877.98760	6	26	58877.98760	6	20
21	7845				58877.98851	1	13
22	7845	58877.98875	13	27	58877.98875	13	24
23	7845	58877.98906	15	24	58877.98906	15	21
24	7845	58877.98943	22	27	58877.98943	22	25
25	7845	58877.98977	22	20	58877.98977	22	17
26	7845	58877.99005	23	20	58877.99005	23	18

V1 (on the left) 21 npts

V2 (on the right) 26 npts

NSHOTS is the number of shots in the NPT

RMS is the RMS assigned by the normal pointing software

Five new NPTs where there were none previously; RMS is well above average for most of them. Is this beneficial?

NPT #11 is the outlier in the previous plot and is based on only 2 shots.

Software appears to be more aggressive in finding normal points.

Closer look at this pass (2)

NPT	STATION	MJD	NSHOTS	RMS	MJD	NSHOTS	RMS
1	7845				58877.98121	2	49
2	7845	58877.98148	33	18	58877.98148	33	16
3	7845	58877.98177	9	29	58877.98177	9	29
4	7845				58877.98216	3	59
5	7845	58877.98262	6	27	58877.98262	6	21
6	7845	58877.98275	39	14	58877.98275	39	13
7	7845	58877.98316	21	20	58877.98316	21	18
8	7845	58877.98354	17	22	58877.98354	17	20
9	7845	58877.98385	16	29	58877.98385	16	28
10	7845				58877.98418	5	42
11	7845				58877.98455	2	33
12	7845	58877.98490	54	12	58877.98490	54	11
13	7845	58877.98521	20	19	58877.98521	20	16
14	7845	58877.98554	22	24	58877.98554	22	22
15	7845	58877.98590	16	25	58877.98590	16	22
16	7845	58877.98630	46	14	58877.98630	46	13
17	7845	58877.98665	45	14	58877.98665	45	13
18	7845	58877.98699	36	14	58877.98699	36	12
19	7845	58877.98727	23	20	58877.98727	23	18
20	7845	58877.98760	6	26	58877.98760	6	20
21	7845				58877.98851	1	13
22	7845	58877.98875	13	27	58877.98875	13	24
23	7845	58877.98906	15	24	58877.98906	15	21
24	7845	58877.98943	22	27	58877.98943	22	25
25	7845	58877.98977	22	20	58877.98977	22	17
26	7845	58877.99005	23	20	58877.99005	23	18

V1 (on the left) 21 npts

V2 (on the right) 26 npts

NSHOTS is the number of shots in the NPT

RMS is the RMS assigned by the normal pointing software

NPT #21 made from a single shot; perhaps unwise?

Also, how is an RMS of 13 mm calculated when there is only 1 point?

If 2 points get an RMS of 33 or 49 mm, 1 point should get something larger to reflect unreliability of NPT.

Closer look at this pass (3)

NPT	STATION	MJD	NSHOTS	RMS	MJD	NSHOTS	RMS
1	7845				58877.98121	2	49
2	7845	58877.98148	33	18	58877.98148	33	16
3	7845	58877.98177	9	29	58877.98177	9	29
4	7845				58877.98216	3	59
5	7845	58877.98262	6	27	58877.98262	6	21
6	7845	58877.98275	39	14	58877.98275	39	13
7	7845	58877.98316	21	20	58877.98316	21	18
8	7845	58877.98354	17	22	58877.98354	17	20
9	7845	58877.98385	16	29	58877.98385	16	28
10	7845				58877.98418	5	42
11	7845				58877.98455	2	33
12	7845	58877.98490	54	12	58877.98490	54	11
13	7845	58877.98521	20	19	58877.98521	20	16
14	7845	58877.98554	22	24	58877.98554	22	22
15	7845	58877.98590	16	25	58877.98590	16	22
16	7845	58877.98630	46	14	58877.98630	46	13
17	7845	58877.98665	45	14	58877.98665	45	13
18	7845	58877.98699	36	14	58877.98699	36	12
19	7845	58877.98727	23	20	58877.98727	23	18
20	7845	58877.98760	6	26	58877.98760	6	20
21	7845				58877.98851	1	13
22	7845	58877.98875	13	27	58877.98875	13	24
23	7845	58877.98906	15	24	58877.98906	15	21
24	7845	58877.98943	22	27	58877.98943	22	25
25	7845	58877.98977	22	20	58877.98977	22	17
26	7845	58877.99005	23	20	58877.99005	23	18

V1 (on the left) 21 npts

V2 (on the right) 26 npts

NSHOTS is the number of shots in the NPT

RMS is the RMS assigned by the normal pointing software

In many cases, the same number of shots are used but the calculated RMS is different (always lower).

Not necessarily a cause for concern; just an observation.

Point by Point analyses

In the following, only obs present in both data sets are compared

Using 4525 matching obs (after editing and excluding stations 1891, 7838, 7824), the RMS was the same for V1 and V2 (17.2 mm)

Orbits were based on full original data set, then fixed

No other parameters were estimated
(No EOP, biases, station coordinates, etc.)

Basic statistics V1 vs V2 (2)

STATION	PASSES	TOTAL OBS	EDITED OBS	PCT EDITED	GOOD OBS	RAW RMS	B/TB RMS	POLY RMS
7810 ZIMMBG	40	568	0	0.0	568	1.366	0.38	0.35
7810 ZIMMBG	40	568	0	0.0	568	1.360	0.37	0.34
7237 CHACHU	50	304	3	1.0	301	2.548	0.79	0.45
7237 CHACHU	50	304	3	1.0	301	2.572	0.77	0.41
7841 POTSD3	30	231	0	0.0	231	1.471	0.48	0.37
7841 POTSD3	30	231	0	0.0	231	1.470	0.47	0.35
7090 YARAG_	75	744	0	0.0	744	2.338	0.46	0.36
7090 YARAG_	75	744	0	0.0	744	2.345	0.46	0.36
7827 SOSW__	2	2	0	0.0	2	2.389	0.00	0.00
7827 SOSW__	2	2	0	0.0	2	2.327	0.00	0.00
7825 STROM2	7	56	0	0.0	56	3.430	0.55	0.55
7825 STROM2	7	56	0	0.0	56	3.390	0.51	0.51
7840 HERL__	38	418	0	0.0	418	1.098	0.38	0.26
7840 HERL__	38	418	0	0.0	418	1.097	0.38	0.26
7941 MLRO__	31	279	0	0.0	279	1.221	0.31	0.23
7941 MLRO__	31	279	0	0.0	279	1.218	0.31	0.23
8834 WETZL2	37	359	0	0.0	359	1.198	0.34	0.22
8834 WETZL2	37	359	0	0.0	359	1.202	0.34	0.22

First line is V1

Second line is V2

PolyRMS is estimate of NPT precision

Favorable change in green

Unfavorable change in red

No significant change in black

Basic statistics V1 vs V2 (3)

STATION	PASSES	TOTAL OBS	EDITED OBS	PCT EDITED	GOOD OBS	RAW RMS	B/TB RMS	POLY RMS
1884 RIGA__	3	49	0	0.0	49	4.721	1.34	1.34
1884 RIGA__	3	49	0	0.0	49	4.783	1.39	1.38
7839 GRAZ__	25	341	0	0.0	341	1.063	0.31	0.28
7839 GRAZ__	25	341	0	0.0	341	1.065	0.31	0.28
7119 HA4T__	8	83	0	0.0	83	1.567	0.64	0.35
7119 HA4T__	8	83	0	0.0	83	1.565	0.65	0.37
7105 GRF105	30	442	0	0.0	442	1.893	0.47	0.39
7105 GRF105	30	442	0	0.0	442	1.903	0.47	0.39
7110 MONPK1	18	214	0	0.0	214	1.686	0.47	0.45
7110 MONPK1	18	214	0	0.0	214	1.695	0.49	0.46
7845 GRASSM	11	159	2	1.3	157	1.266	0.45	0.45
7845 GRASSM	11	159	2	1.3	157	1.269	0.45	0.45
7403 ARELA2	1	6	0	0.0	6	3.379	0.79	0.79
7403 ARELA2	1	6	0	0.0	6	3.351	0.78	0.78
1893 KATZIV	1	5	0	0.0	5	4.738	1.44	1.29
1893 KATZIV	1	5	0	0.0	5	4.997	1.53	1.50
1888 SVETLO	8	31	0	0.0	31	2.143	1.22	0.72
1888 SVETLO	8	31	8	25.8	23	2.454	1.81	1.64

First line is V1

Second line is V2

PolyRMS is estimate of NPT precision

Favorable change in green

Unfavorable change in red

No significant change in black

Basic statistics V1 vs V2 (4)

STATION	PASSES	TOTAL OBS	EDITED OBS	PCT EDITED	GOOD OBS	RAW RMS	B/TB RMS	POLY RMS
1873 SIMEIZ	2	12	0	0.0	12	5.759	3.71	3.11
1873 SIMEIZ	2	12	0	0.0	12	5.577	1.97	1.79
7501 HARL__	8	50	0	0.0	50	1.483	0.27	0.26
7501 HARL__	8	50	0	0.0	50	1.482	0.28	0.27
1890 BADARY	18	86	0	0.0	86	2.252	0.97	0.88
1890 BADARY	18	86	1	1.2	85	2.220	1.23	1.07
7811 BOROWC	8	54	0	0.0	54	2.703	0.89	0.59
7811 BOROWC	8	54	0	0.0	54	2.613	0.70	0.42
7821 SHA2__	2	12	0	0.0	12	2.112	0.28	0.25
7821 SHA2__	2	12	0	0.0	12	1.991	0.35	0.33

First line is V1

Second line is V2

PolyRMS is estimate of NPT precision

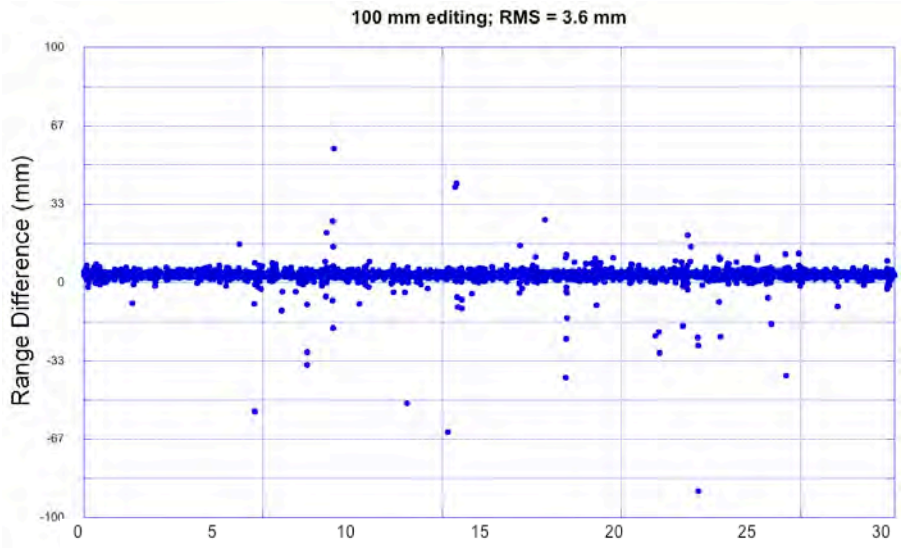
Favorable change in green

Unfavorable change in red

No significant change in black

RMS for 1873 and 7811 improve slightly but fits are still poor

Range differences (in time order)

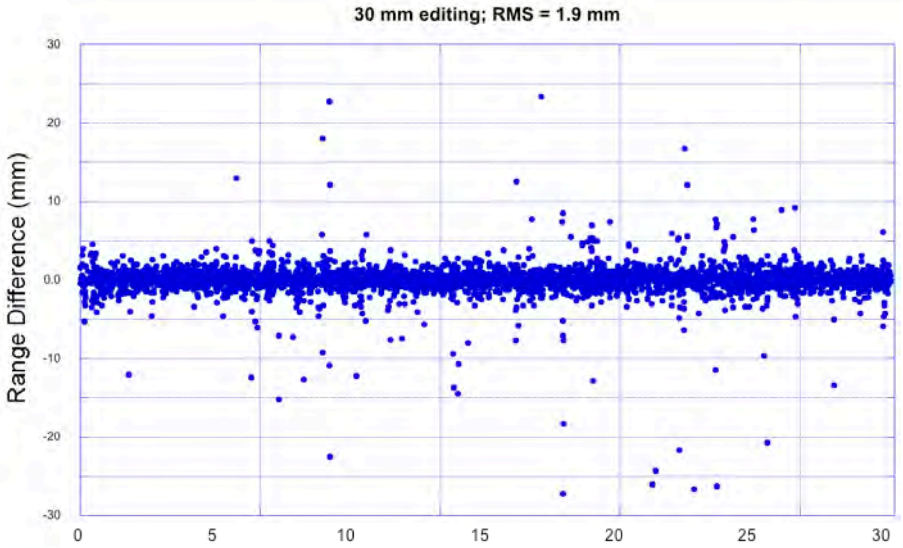


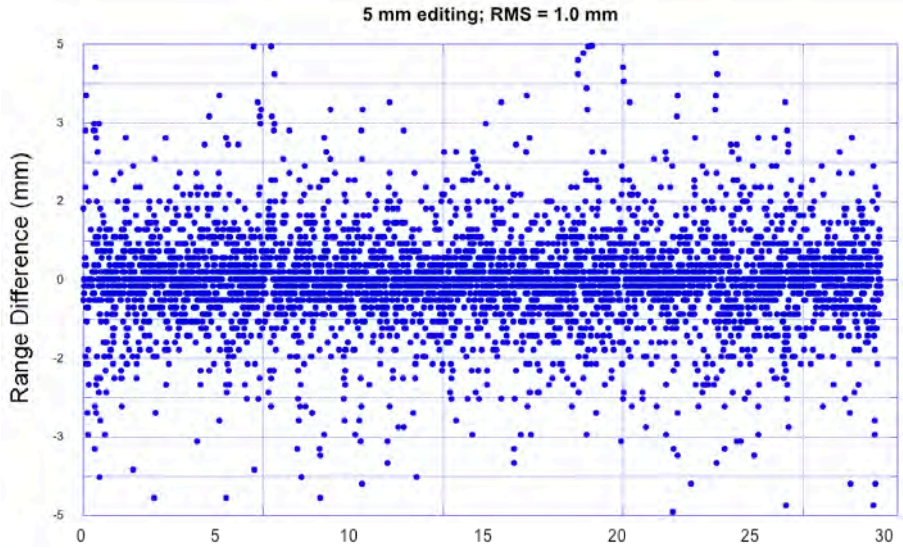
Each point is range difference between V1 and V2

7 points exceed 100 mm and not plotted:

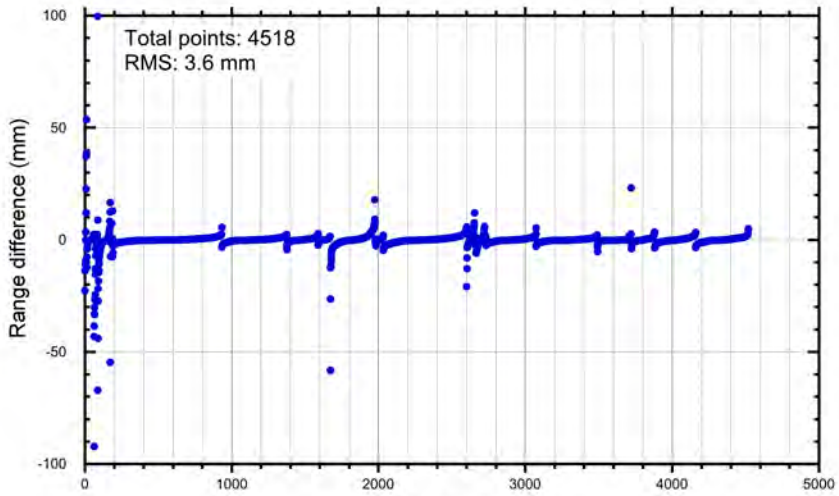
DoY	Station_ID	Range_difference (mm)
8.89046	1888	4280.586
14.08038	7824	-17116.950
20.93477	1888	-462.580
20.93593	1888	1188.528
23.54939	1888	1436.306
24.91534	1888	-179.576
25.54921	1890	-3606.803

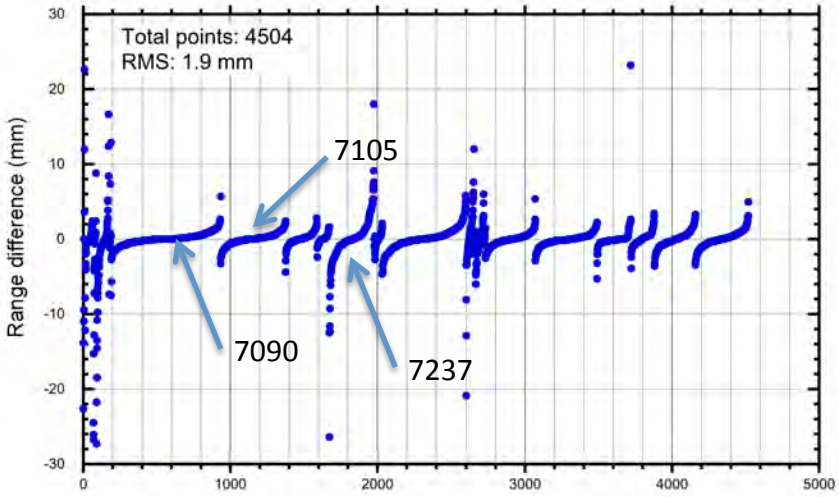
Only 215 points differed in epoch by 0.1 microsec; none exceeded that.





Normal point differences (same but sorted by station/delta range)





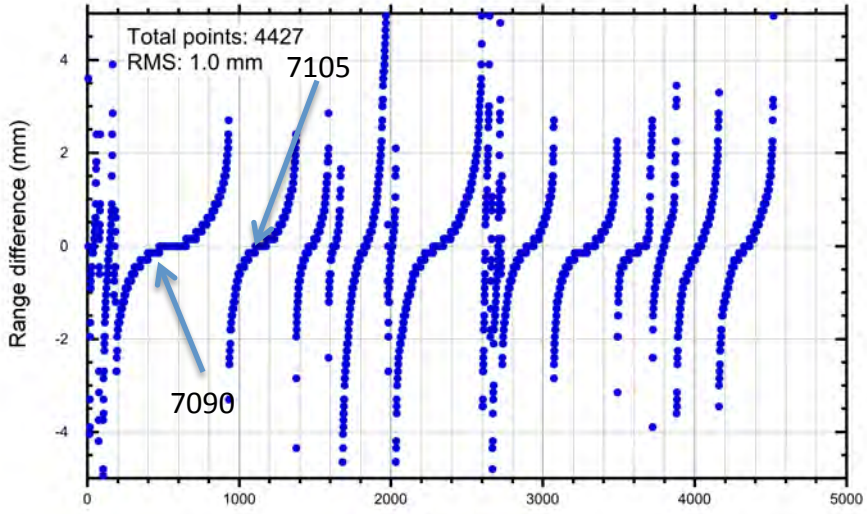
Each point is range difference between V1 and V2

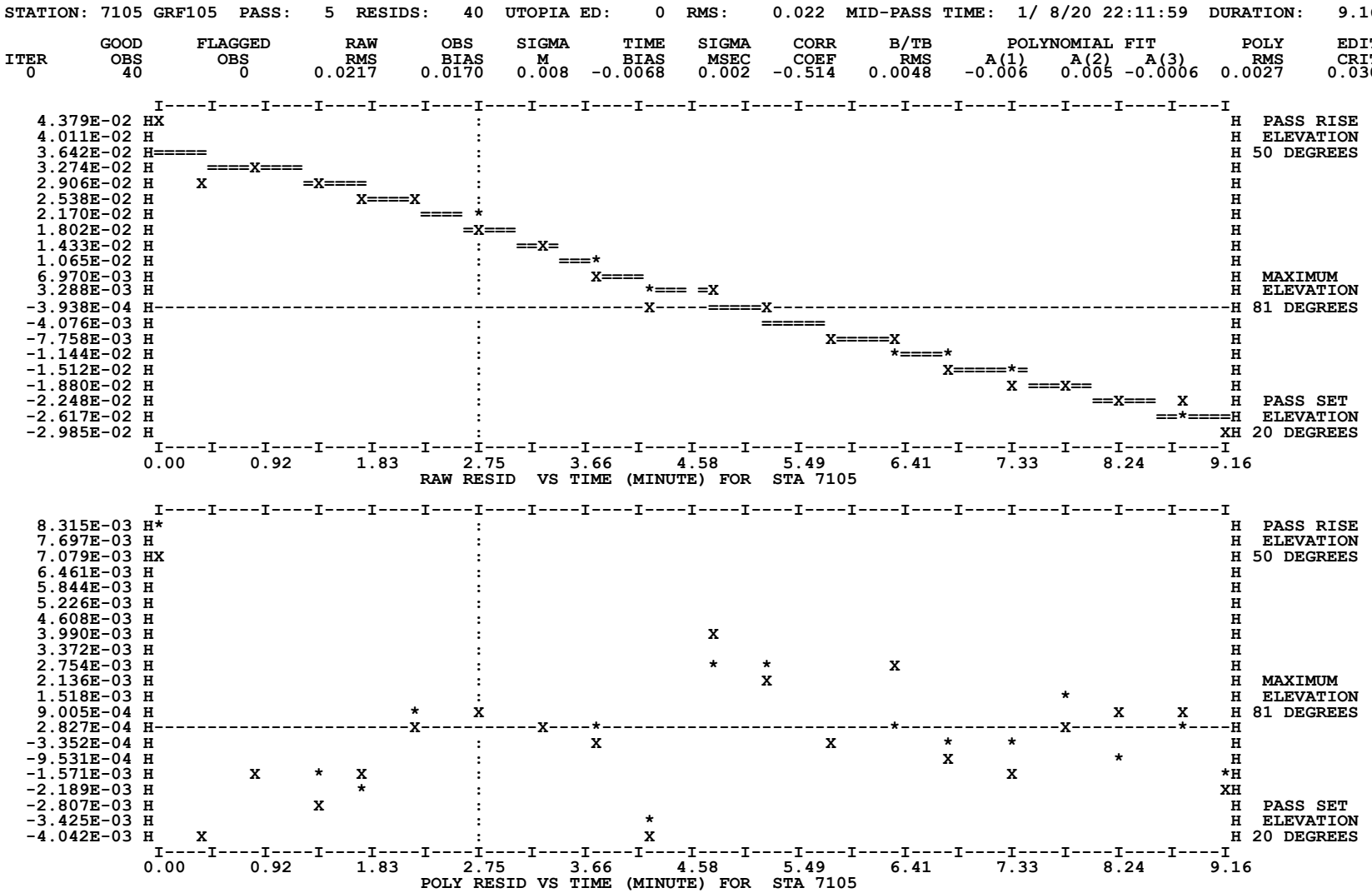
7 points exceed 100 mm and not plotted

14 additional points exceed 30 mm

77 additional points exceed 5 mm

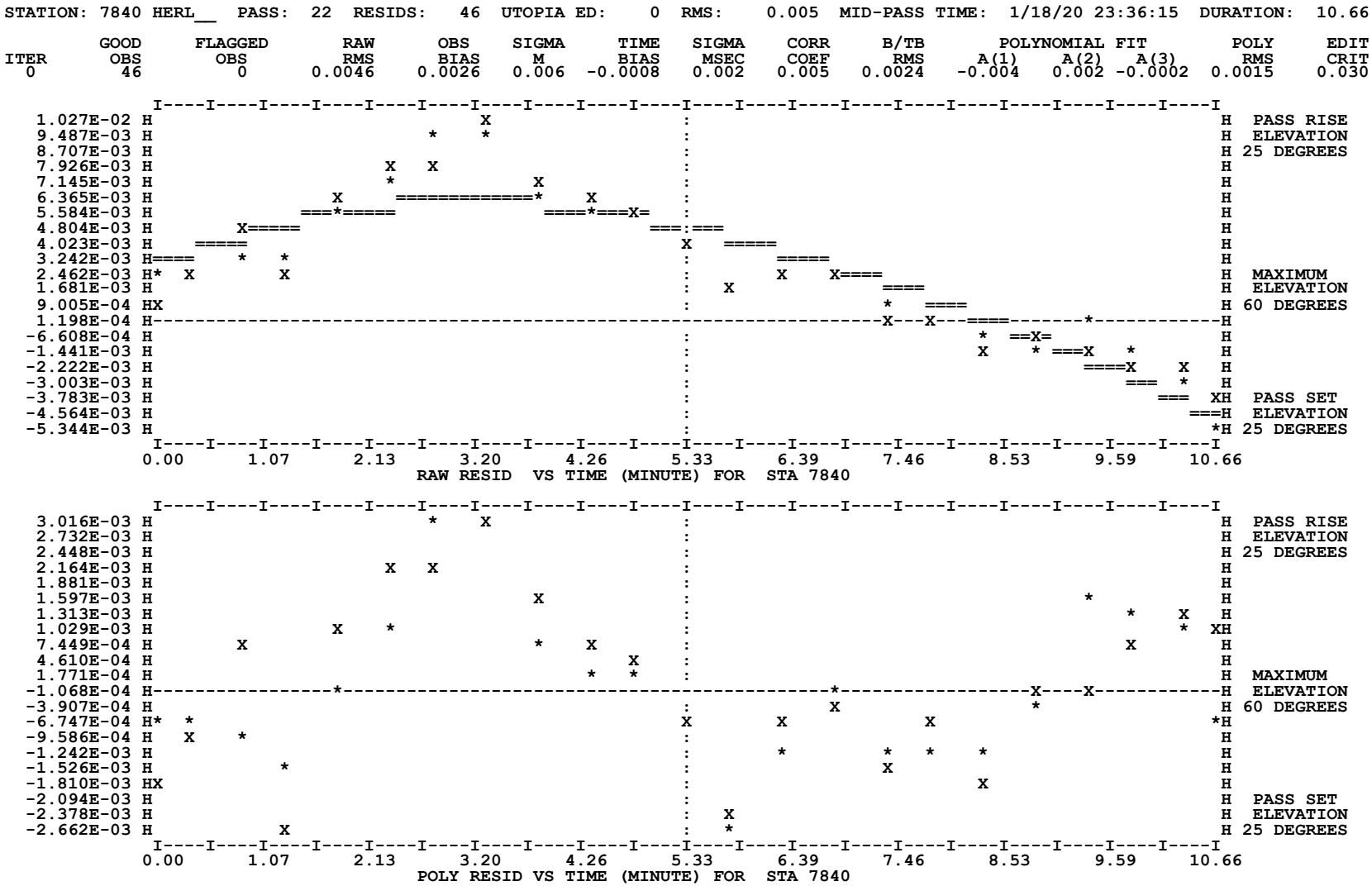
98 points exceed 5 mm in total (2.2%) but most were from poorer quality stations





Both sets of NPTs look very similar

Where only one symbol is present, the two residuals are the same (within the resolution of the plot)



Raw residuals and fit curve

After removing systematics

Both sets of NPTs look very similar

Where only one symbol is present, the two residuals are the same (within the resolution of the plot)

Summary for LARES

- Similar to LAGEOS, in most cases, no significant difference in NPTs
  - No change in overall fit RMS
  - In a few cases, the new NPTs are a slight improvement (1873,7811)
  - In a few cases, some new NPTs (not present in V1) seem inconsistent, often based on only a few shots with high RMS
  - Most NPT differences under 3 mm with a 1.0 mm RMS overall (considering only better precision stations)
  - Differences tend to be larger for lower precision stations
  - Observation epochs appear to be identical generally; no epoch differed by more than 0.1 microsec (the resolution of the format)
- Very large differences (> 100 mm) for a few sites

DoY	Station_ID	Range_difference (mm)
8.89046	1888	4280.586
14.08038	7824	-17116.950
20.93477	1888	-462.580
20.93593	1888	1188.528
23.54939	1888	1436.306
24.91534	1888	-179.576
25.54921	1890	-3606.803

Overall conclusions (and a question)

- Most V2 NPTs very close to V1
  - Stations with poorer performance tend to have larger NPT differences
  - Probably not a software issue; bad data in, unreliable NPTs out
- It seems that the new software may be trying a little too hard to find NPTs where previously no NPT was made
  - In many such cases, the new NPT is inconsistent
  - However, in cases where a new NPT replaces a previous one, the results appear to be generally better (more consistent)
- Assigned RMS for single-shot NPTs often not sensible
  - At the least, the assigned RMS should be very large for single-shot NPTs
  - However, does anyone take into account the assigned NPT RMS in their analysis?

7105 Greenbelt and 7090 Yarragadee Data Analysis

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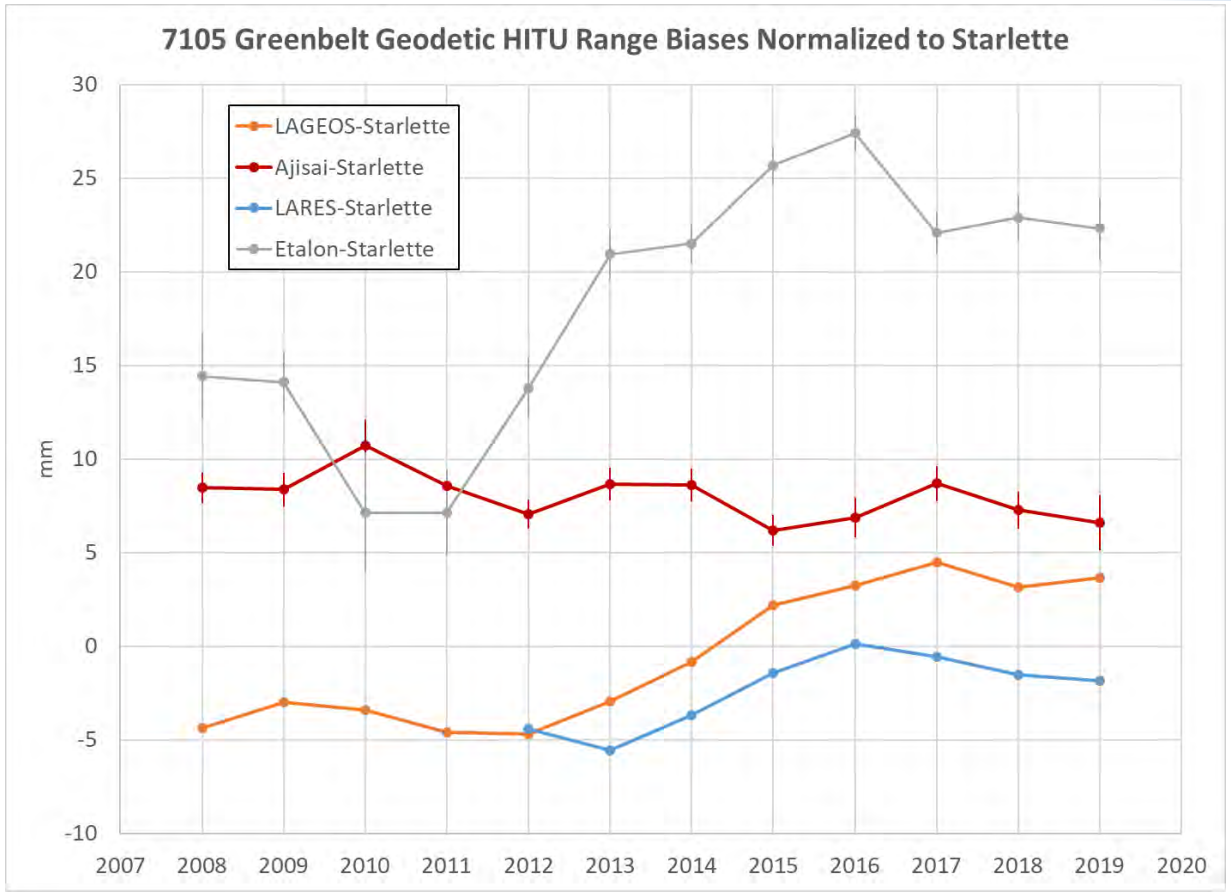
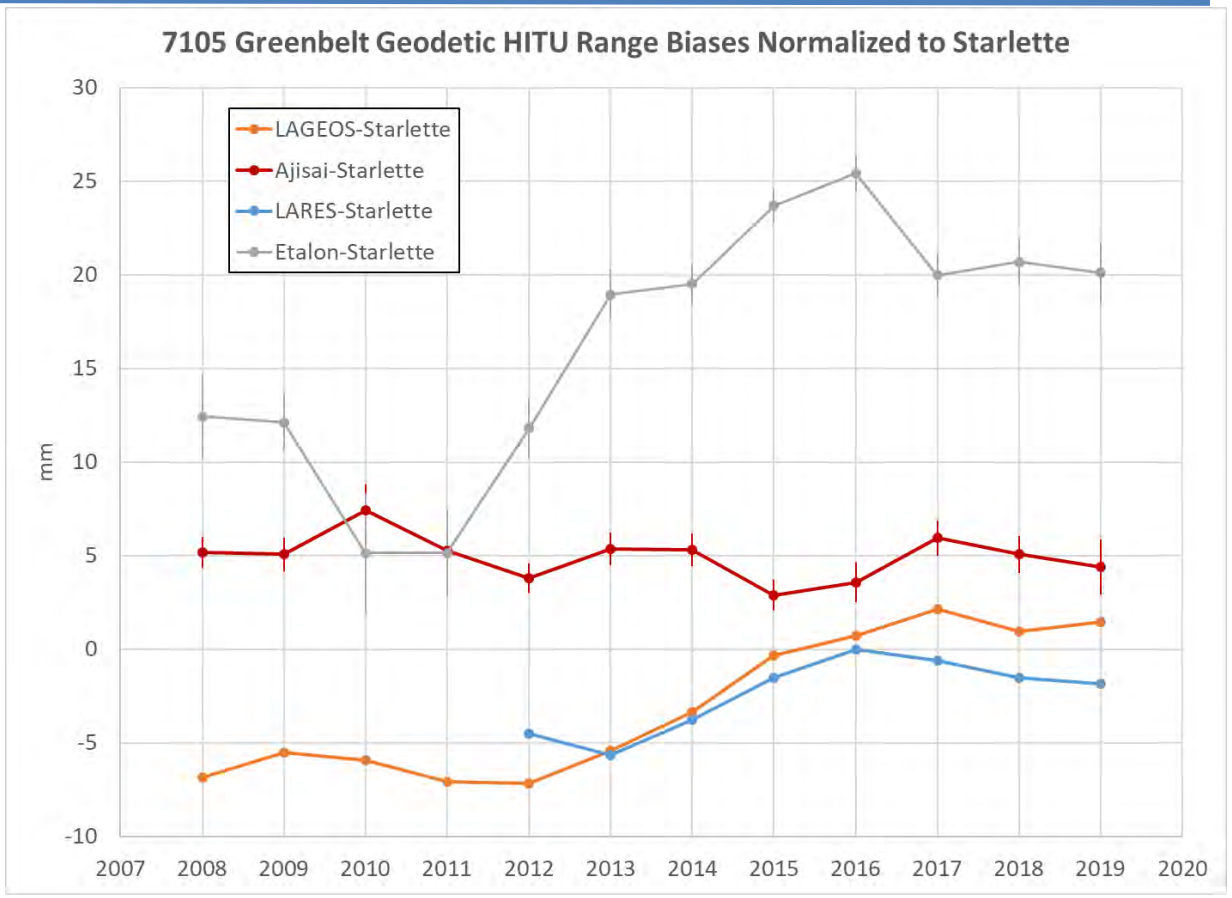
Agenda

- Recap and Update of 7105 Greenbelt Analysis
- Analysis of 7090 Yarragadee and 7110 Monument Peak
- Analysis of NASA SLR MOBLAS Center of Mass (CoM) changes
- Conclusions and Next Steps

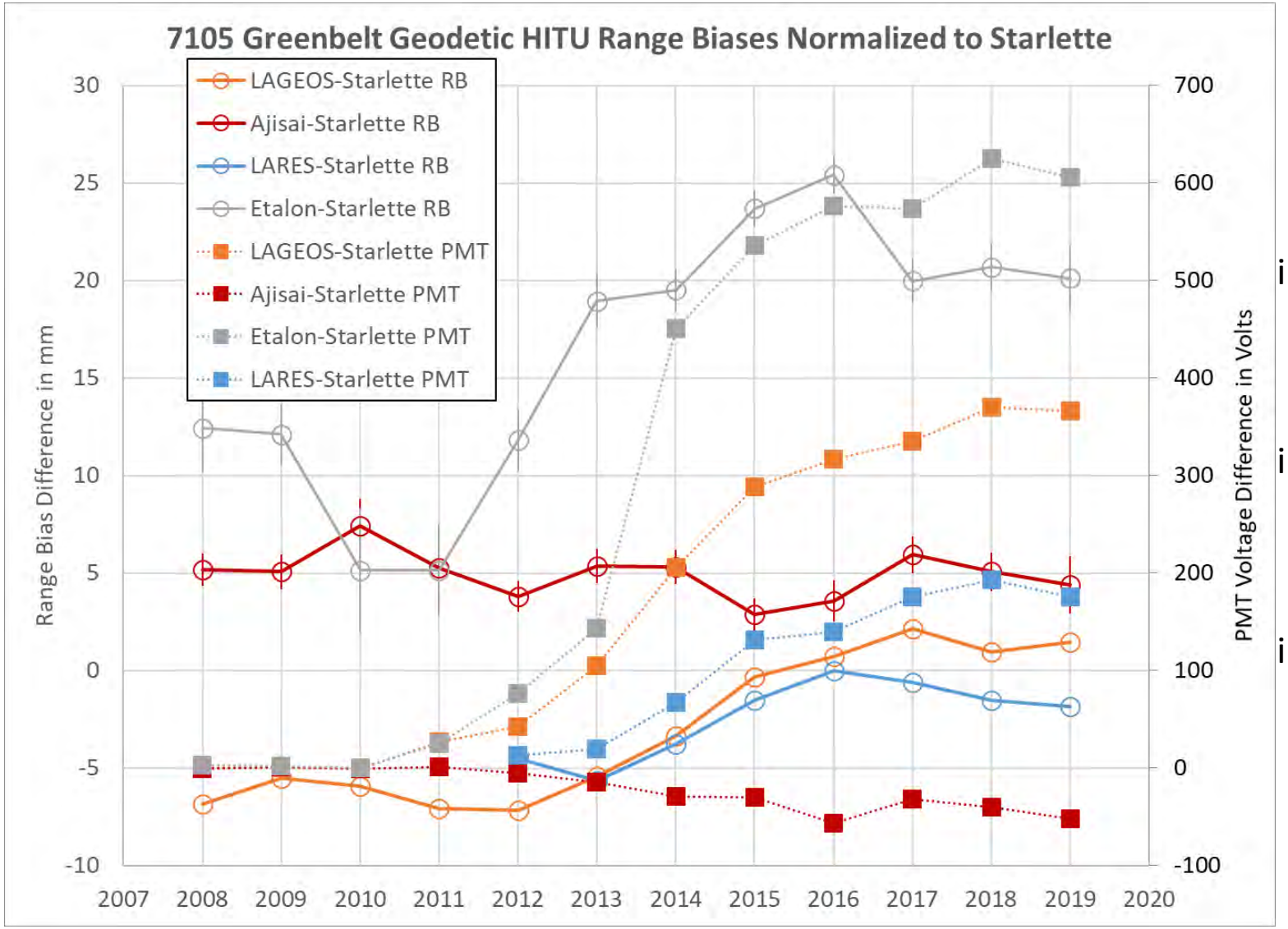
HITU 7105 Geodetic Range Biases (RB) Normalized





When I was preparing this presentation, I realized the chart on the left that I presented last time on July 15, 2020 I did not account for different CoMs before the 7105 ETM installation in 2016. Also on the chart on the left I included Stella with the Starlette data. The chart on the right accounts for CoMs changes prior to the ETM installation and only compares data relative to Starlette (Stella data not used).

7105 Yearly RB and PMT Voltages Differences



The open circles and the solid squares are the range bias and PMT voltage differences relative to Starlette; respectively.

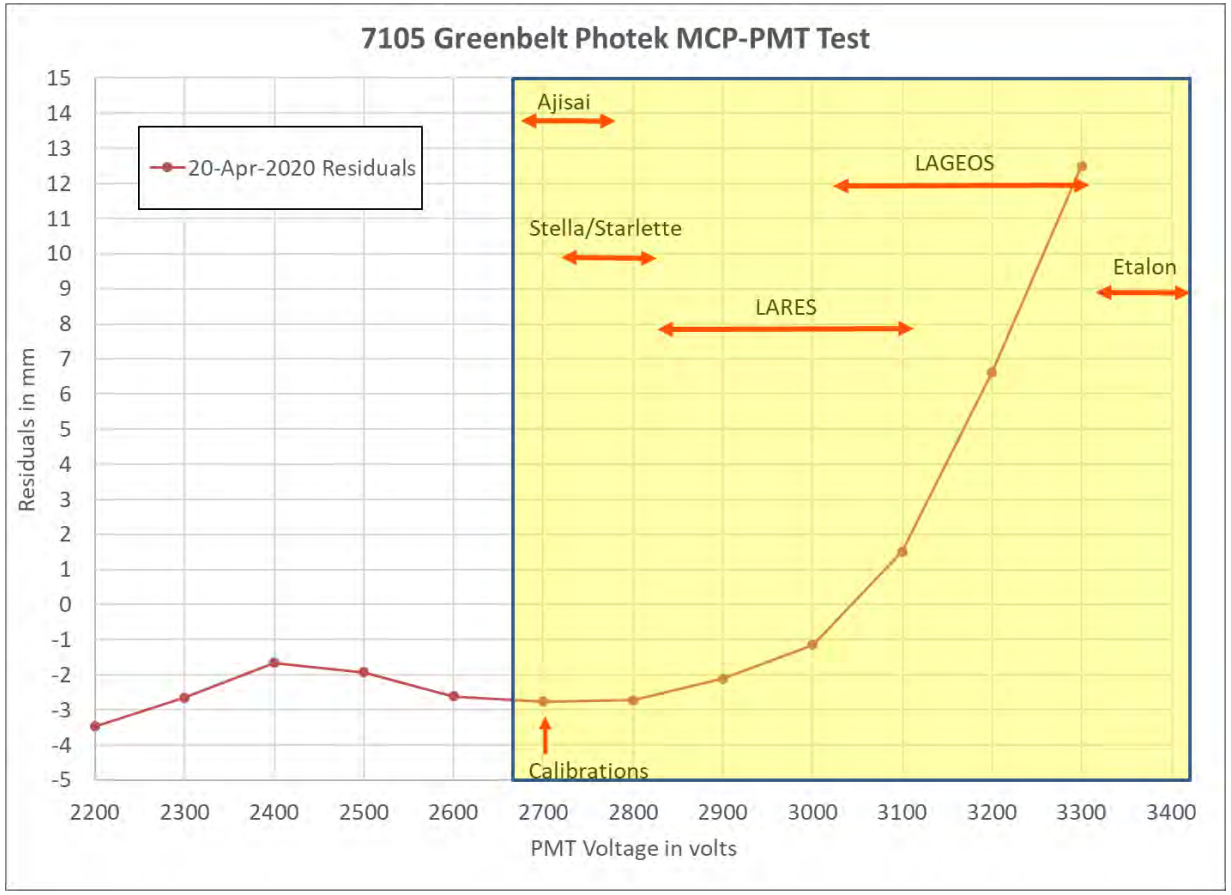
Etalon voltages differences from Starlette increased to 600 volts and as a result the relative Etalon range bias increased by ~12mm.

LAGEOS voltages differences from Starlette increased to 375 volts and as a result the relative LAGEOS range bias increased by ~7mm.

LARES voltages differences from Starlette increased to 175 volts and as a result the relative LARES range bias increased by ~3mm.

Ajisai voltages were always within 50 volts of Starlette and the reason there is little drift in the relative Ajisai range bias.

7105 Greenbelt PMT Voltage Tests



PMT voltages differences between calibrations and satellite voltages can explain most of the following range biases changes.

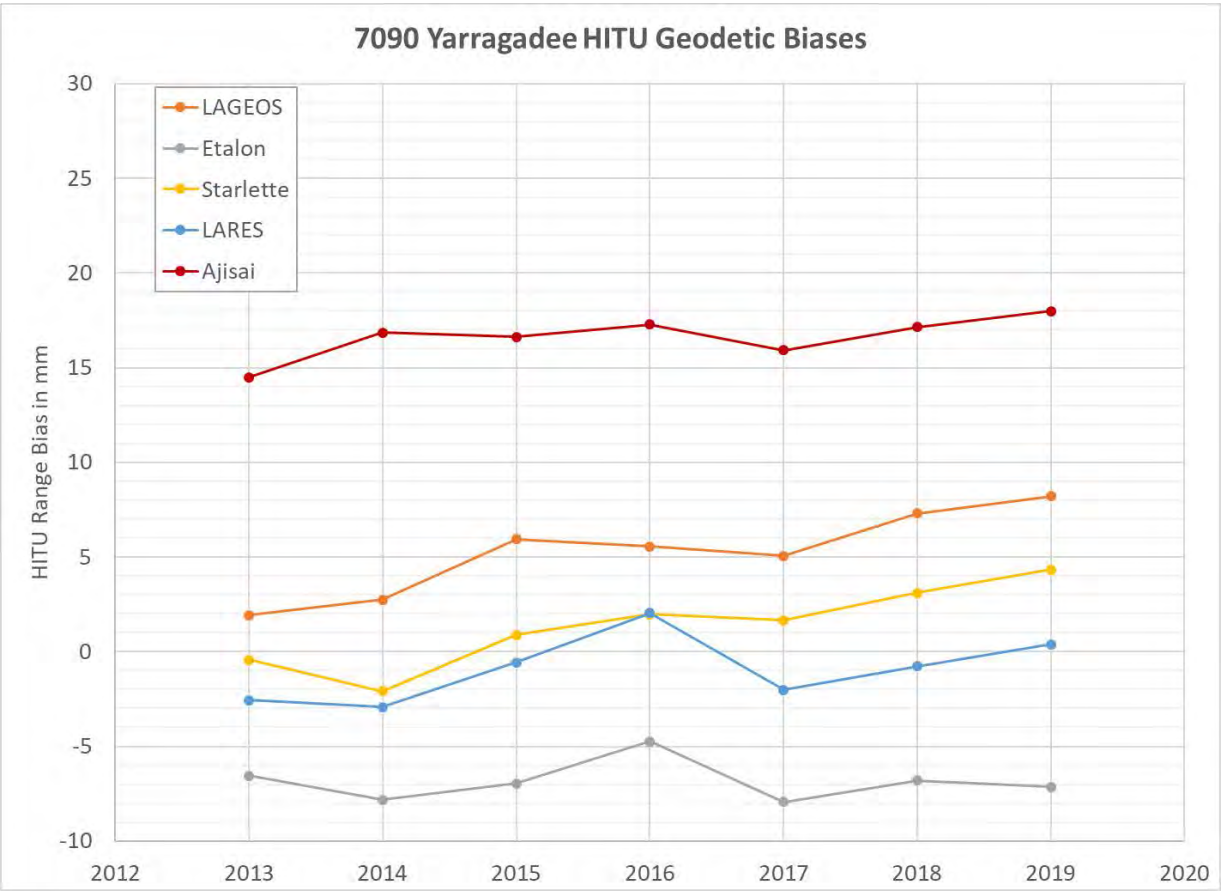
Etalon voltages differences increased to 600 volts and as a result the relative Etalon range bias increased by ~12mm.

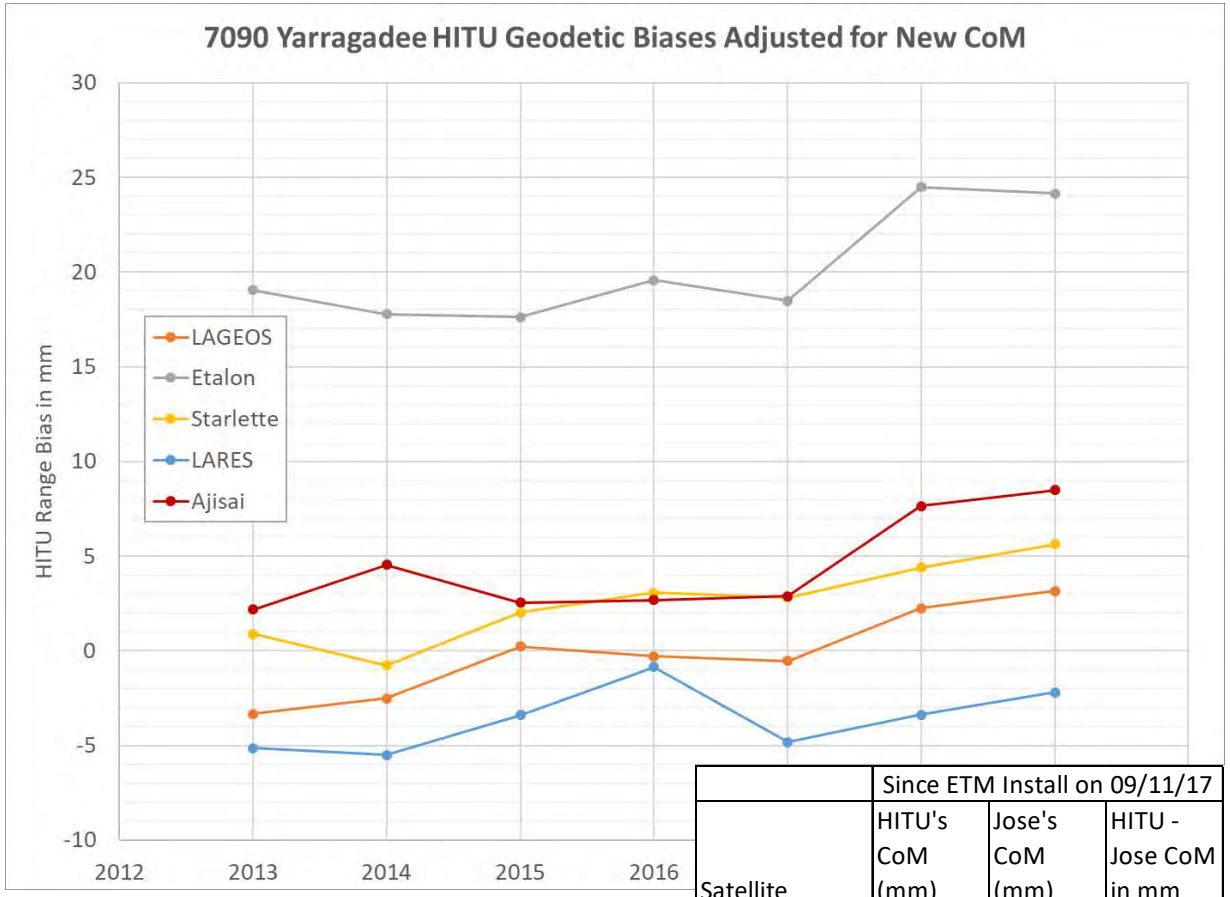
LAGEOS voltages differences increased to 375 volts and as a result the relative LAGEOS range bias increased by ~7mm.

LARES voltages differences increased to 175 volts and as a result the relative LARES range bias increased by ~3mm.

Starting on August 14, 2020, at 03:14 GMT, 7105 starting using one voltage for all satellites and calibration. Their change history was updated to reflect this.

7090 Yarragadee Yearly Geodetic Range Biases

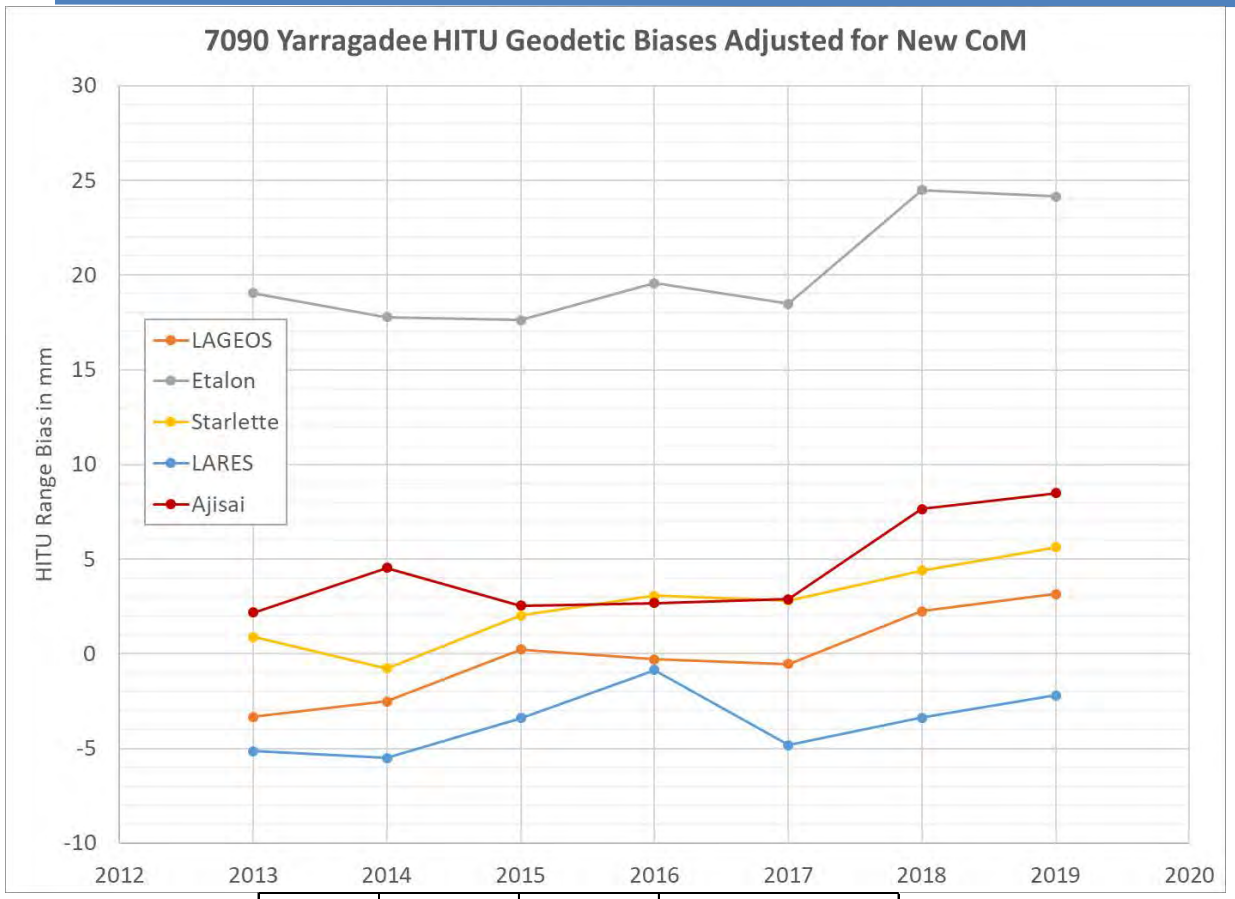




	Since ETM Install on 09/11/17		
Satellite	HITU's CoM (mm)	Jose's CoM (mm)	HITU - Jose CoM in mm
Etalon	558.0	589.3	-31.3
Stella/Starlette	75.0	76.3	-1.3
Lares	133.0	130.4	2.6
LAGEOS-1	251.0	246.2	4.8
LAGEOS-2	251.0	245.7	5.3
Ajisai	1010.0	1000.5	9.5

The right chart is adjusted for Jose's latest CoM corrections which tightened up the RBs except for Etalon. Starting in 2018, all the biases appear to be drifting positive.

7090 Yarragadee Yearly Geodetic Range Biases



Satellite	Pre ETM CoM in mm	Post ETM CoM in mm	Difference Post-Pre ETM CoM in mm
Etalon	582.3	589.3	7.0
LAGEOS-1	245.5	246.2	0.7
LAGEOS-2	244.8	245.7	0.9
Lares	130.1	130.4	0.3
Starlette	76.1	76.3	0.2
Ajisai	995.4	1000.5	5.1

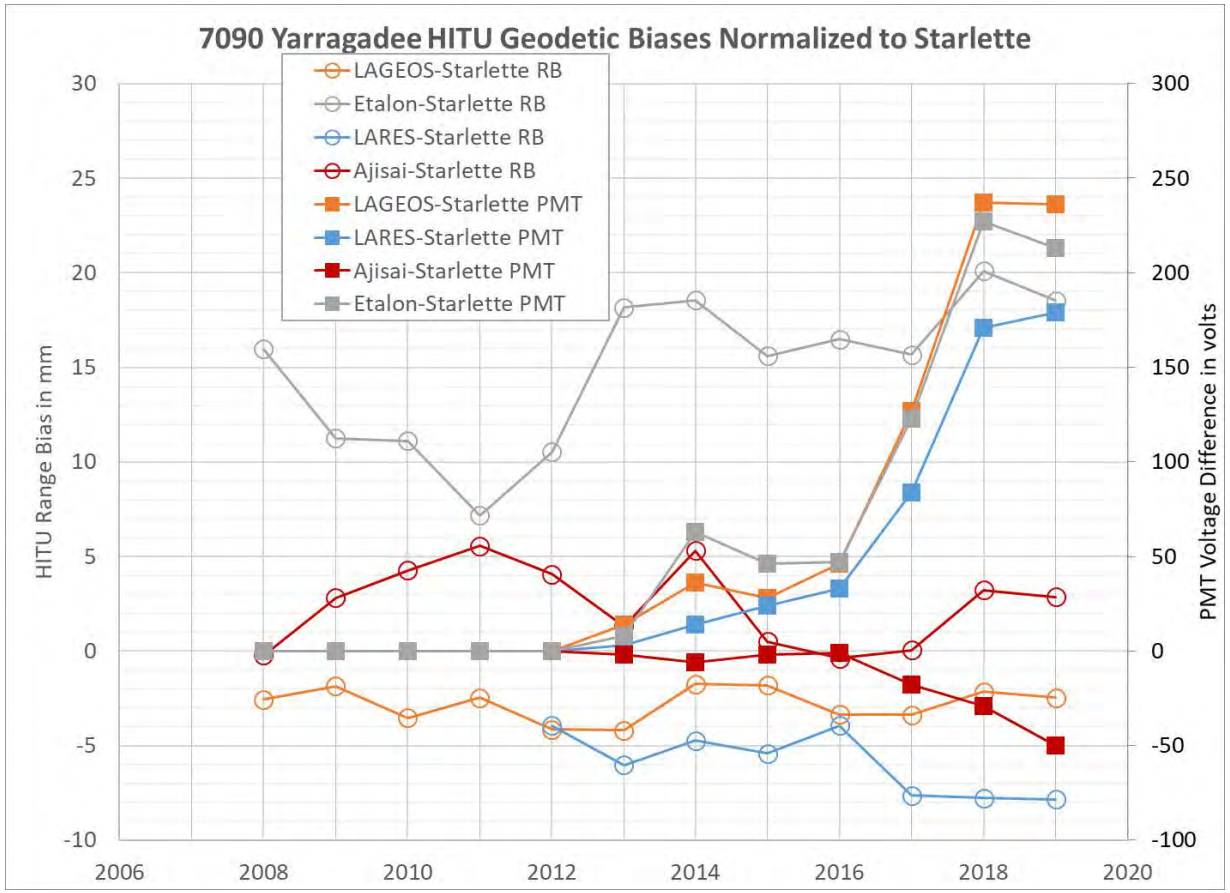
The apparent uptick in RBs in 2018 and 2019 may have multiple causes.

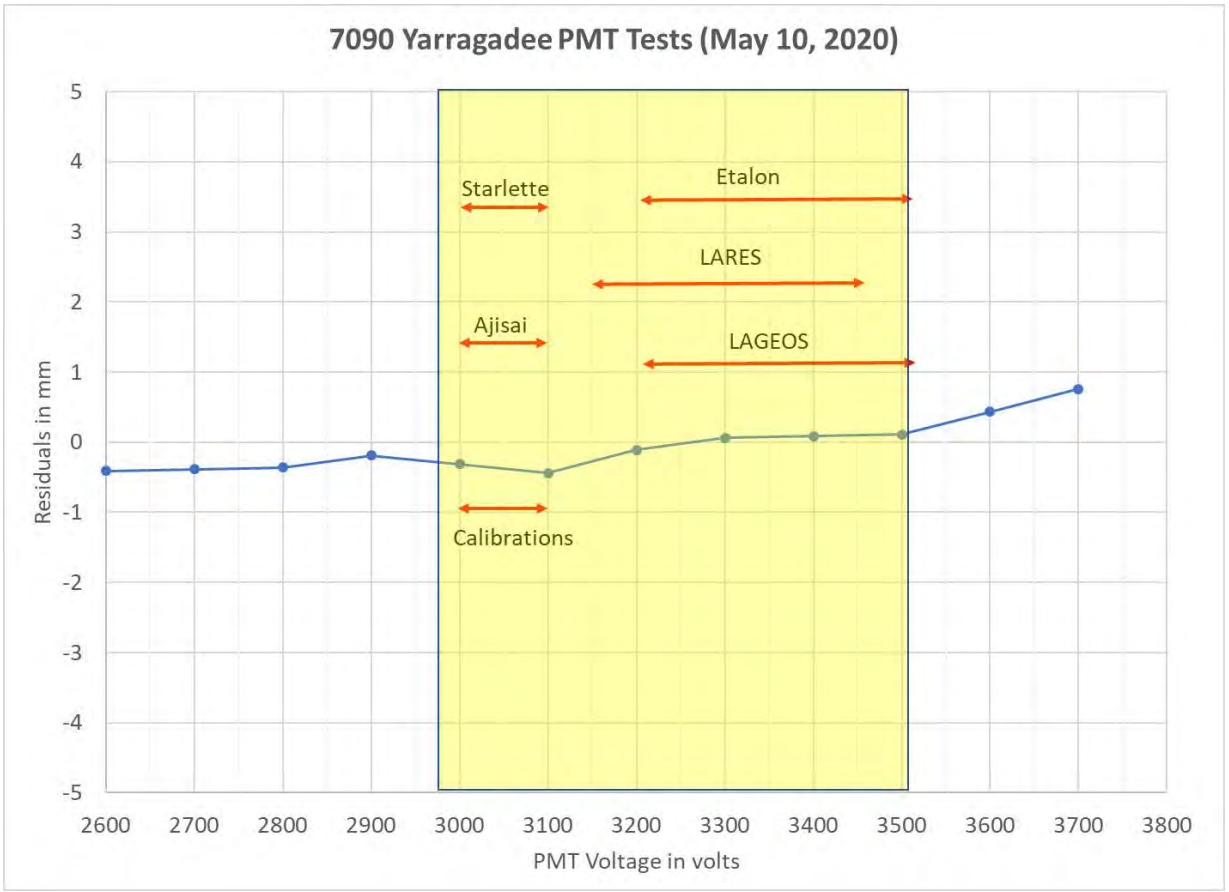
1) In June 2017, HITU updated coordinates to ITRF2014 which has a 7090 station height rate of -0.5 mm/year. Is this height rate correct?

2) On Sep 11, 2017, the ETM was installed and new CoMs were computed (see CoM table) with large changes in Etalon and Ajisai CoMs. If the 7090 HP5370 and ETM data compared favorably on all satellites, does these several mm level CoMs changes make sense?

3) Does 7090 PMT Voltage variations have any influence on these range biases?

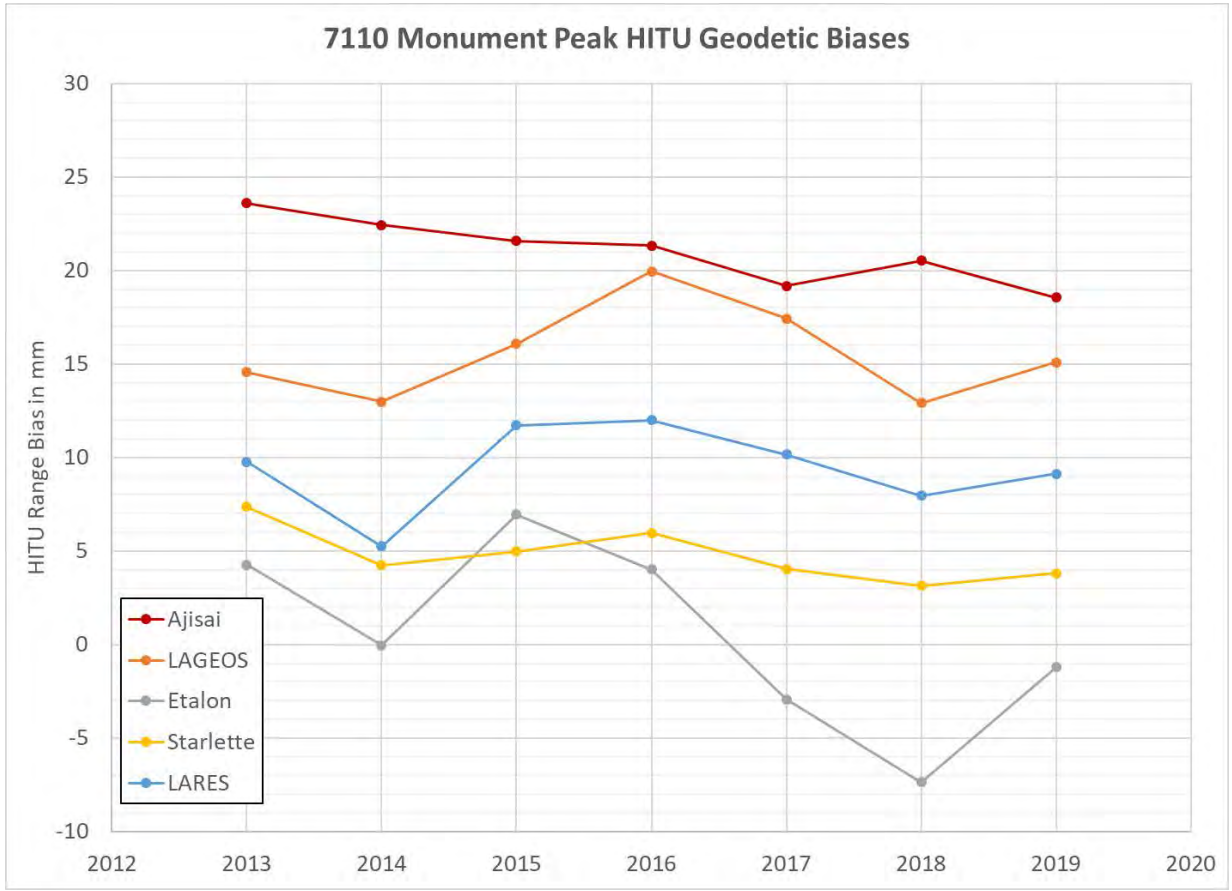
7090 Yarragadee RBs Normalized and PMT Results

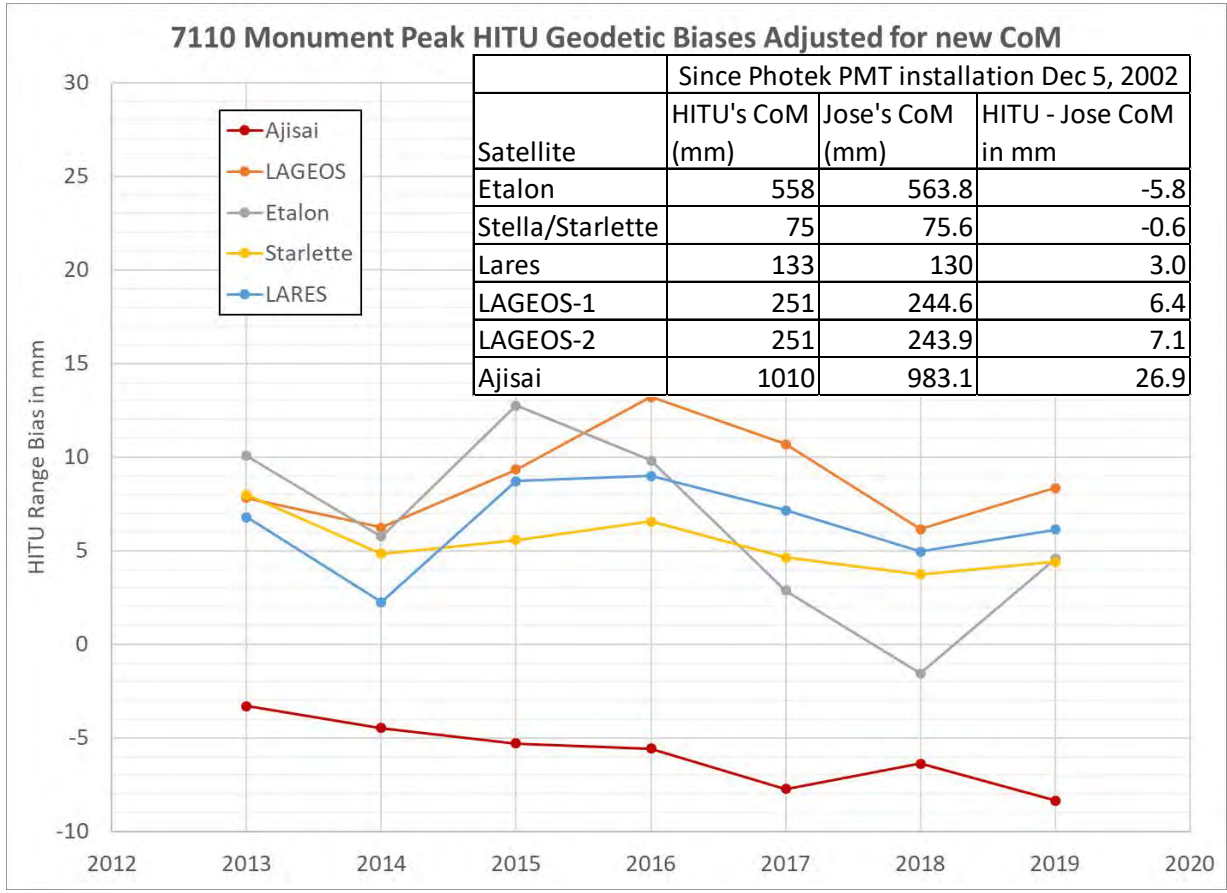




The left chart is the same analysis that we did for 7105. Based on the 7090 PMT test results on the right increasing, PMT voltage Changes have little impact in range bias changes. On June 1, 2020, 7090 uses one voltage for all satellites and calibrations.

7110 Monument Peak Yearly Geodetic Range Biases

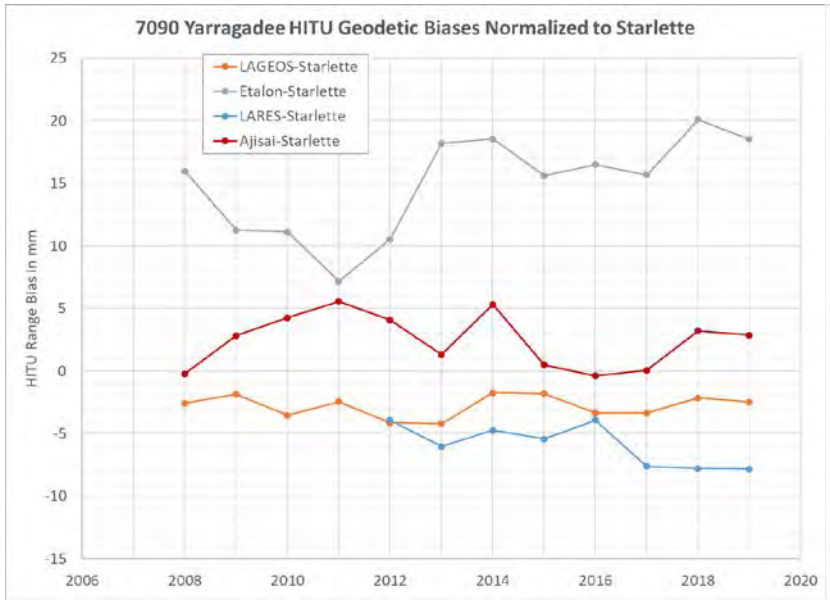


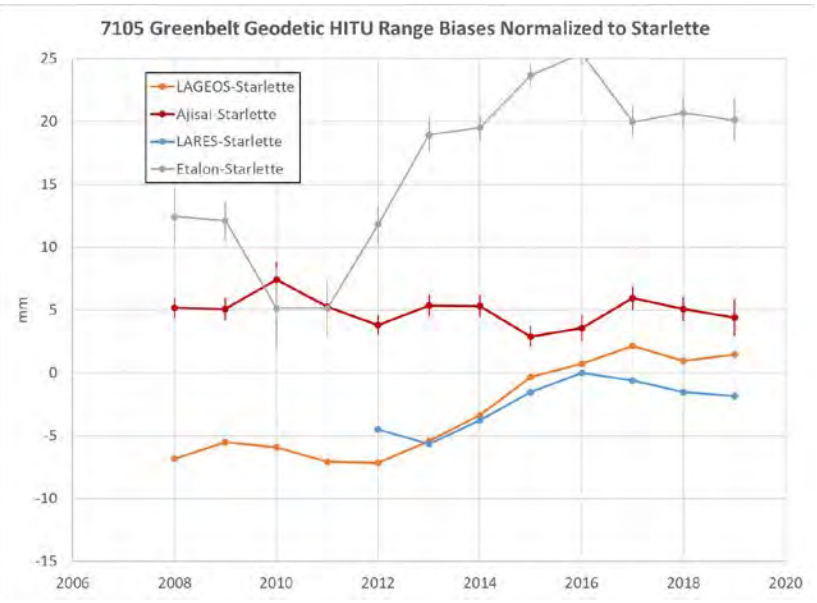


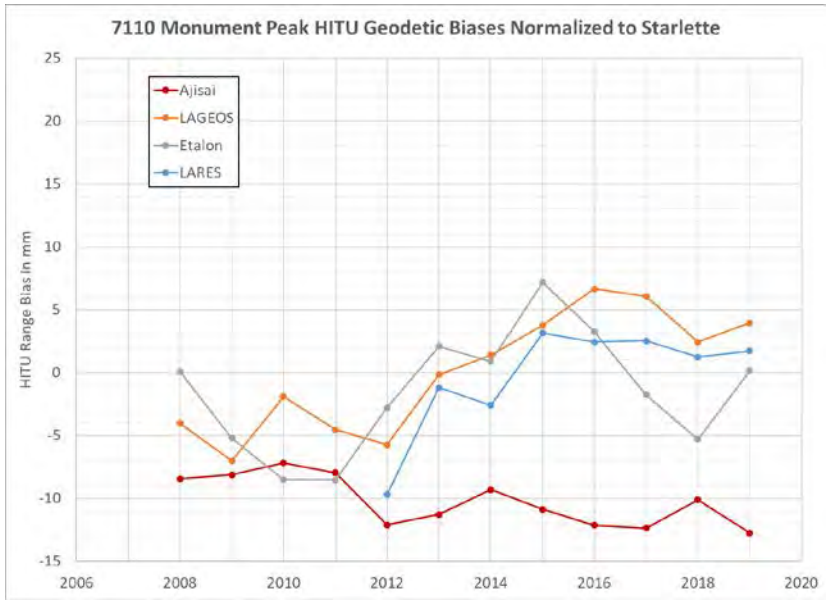
	Since Photek PMT installation Dec 5, 2002		
Satellite	HITU's CoM (mm)	Jose's CoM (mm)	HITU - Jose CoM in mm
Etalon	558	563.8	-5.8
Stella/Starlette	75	75.6	-0.6
Lares	133	130	3.0
LAGEOS-1	251	244.6	6.4
LAGEOS-2	251	243.9	7.1
Ajisai	1010	983.1	26.9

The right chart is adjusted for Jose's latest CoM corrections.
The ranage biases have a tighter grouping with the new CoM applied except for Ajisai. And Etalon is not an outlier like it was for 7105, 7110.

HITU Geodetic Range Biases Normalized





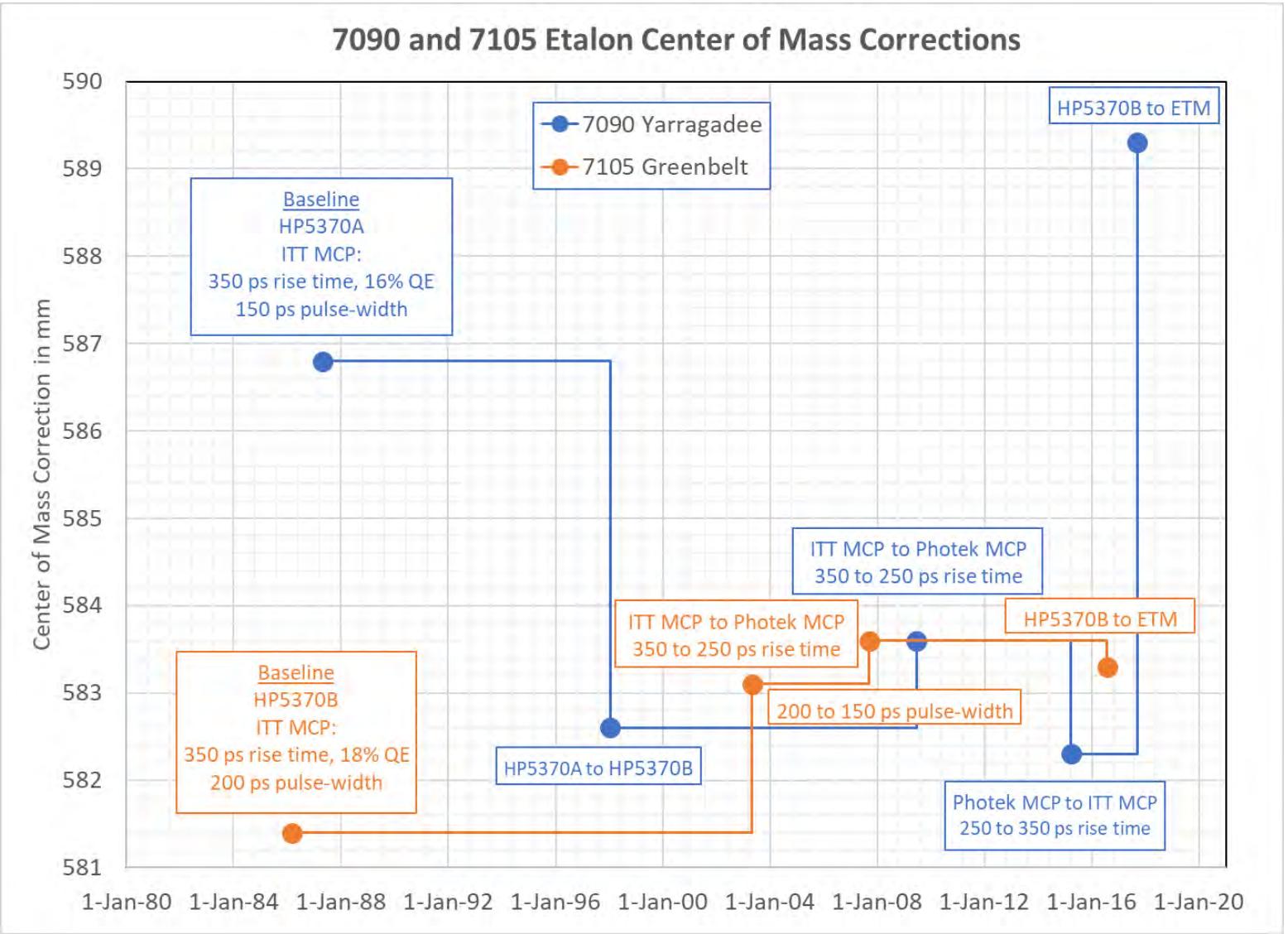


NASA SLR Center of Mass Differences						
Satellite	7090 CoM (mm)	7105 CoM (mm)	7110 CoM (mm)	7105-7090	7110-7090	7110-7105
Etalon	589.3	583.3	563.8	-6.0	-25.5	-19.5
Stella/Starlette	76.3	76.1	75.6	-0.2	-0.7	-0.5
Lares	130.4	130.1	130.0	-0.3	-0.4	-0.1
LAGEOS-1	246.2	246.0	244.6	-0.2	-1.6	-1.4
LAGEOS-2	245.7	245.6	243.9	-0.1	-1.8	-1.7
Ajisai	1000.5	998.5	983.1	-2.0	-17.4	-15.4

Range Bias Differences and new CoMs						
Satellite	7090 RB Diff (mm)	7105 RB Diff (mm)	7110 RB Diff (mm)	7105-7090	7110-7090	7110-7105
Etalon-Starlette	14.9	16.2	-1.5	1.3	-16.5	-17.8
LARES-Starlette	-5.9	-2.4	-0.3	3.5	5.6	2.1
LAGEOS-Starlette	-2.8	-3.0	0.1	-0.2	2.9	3.1
Ajisai-Starlette	2.4	4.9	-10.2	2.5	-12.7	-15.2

The Etalon and Ajisai CoM corrections are quite different between these 3 systems which have essentially the same configuration except for the detector. The differences in CoM show up in the relative differences of the Range Biases.

7090 & 7105 Etalon Center of Mass (CoM) Corrections



The chart depicts the step jumps in Etalon CoM corrections due to system configuration changes (detector, counter, laser).

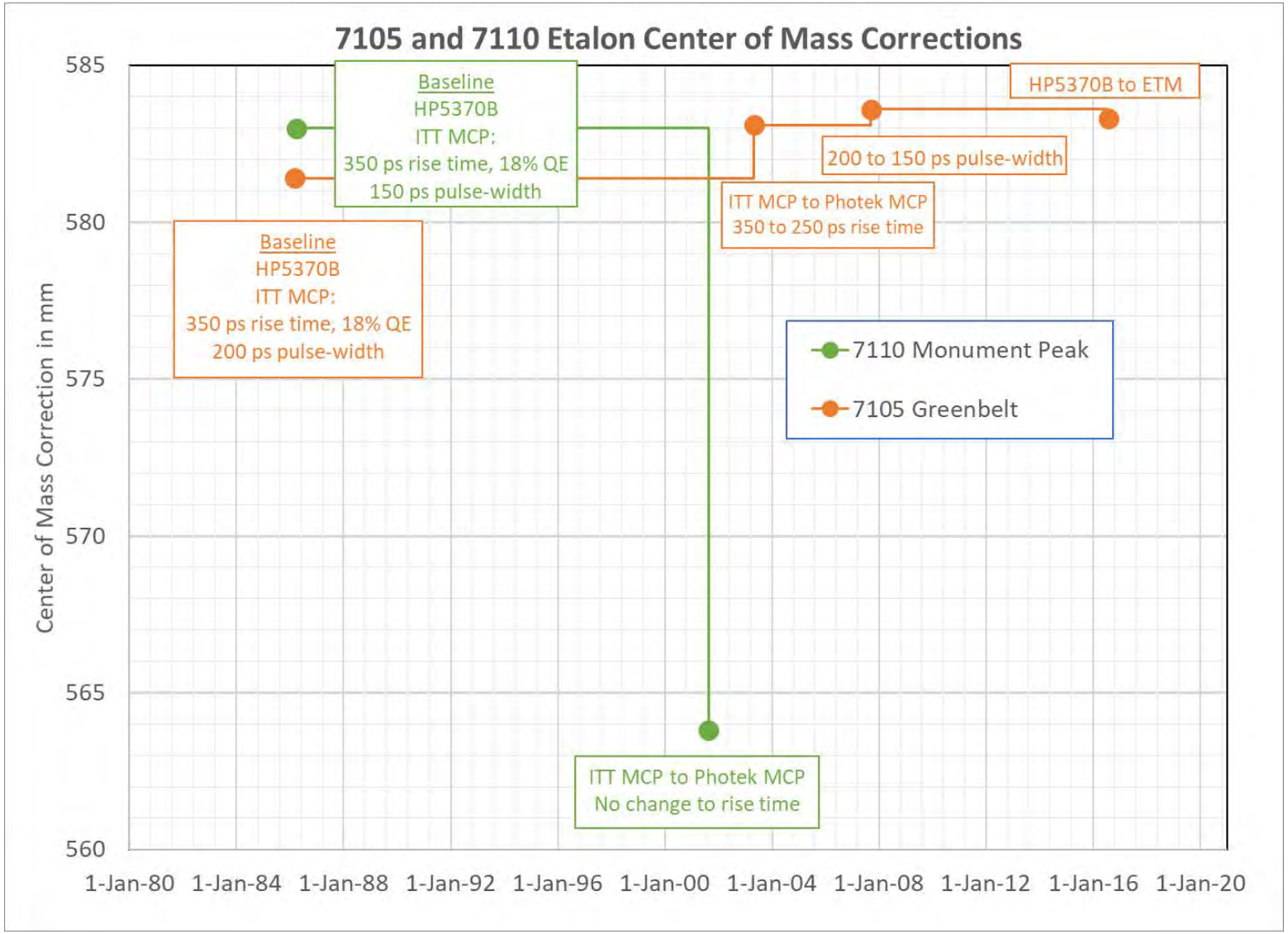
Changing MCP PMTs and laser pulse widths had <=1.7 mm impact on the CoM corrections.

In the case of 7090, there were mm level CoM changes when the counter was upgraded from HP5370A to HP5370B and from the HP5370B to the ETM.

However; 7105 CoM corrections changes were sub-mm when the counter was upgraded from the HP5370B to the ETM.

Note: 7090 and 7105 currently have different PMTs.

7105 & 7110 Etalon Center of Mass (CoM) Corrections

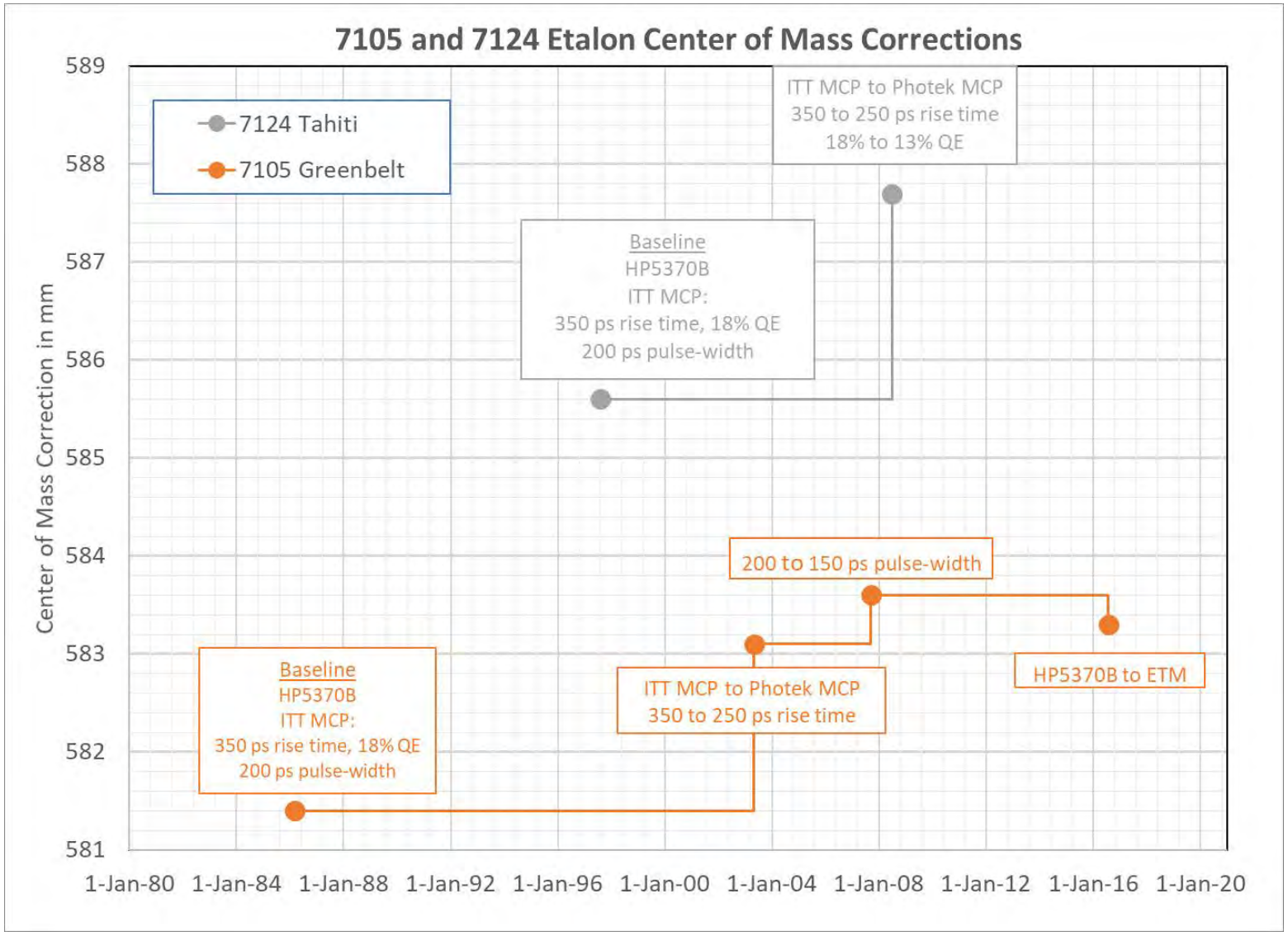


There is a 19.2 mm change in the 7110 Etalon CoM due to a detector change? The rise time of the Photek MCP is listed at 350 ps, but the other MOBLAS Photek MCPs have rise times of 250 ps. Are the Photek MCP rise time differences real?

Stations 7105 and 7090 also made the same PMT change at one point in time; however, their CoM corrections changed by <1.3 mm

Also, there are no new CoM entries for any satellite, when 7110 upgraded to the ETM on 29-Mar-2019.

7105 & 7124 Etalon Center of Mass (CoM) Corrections

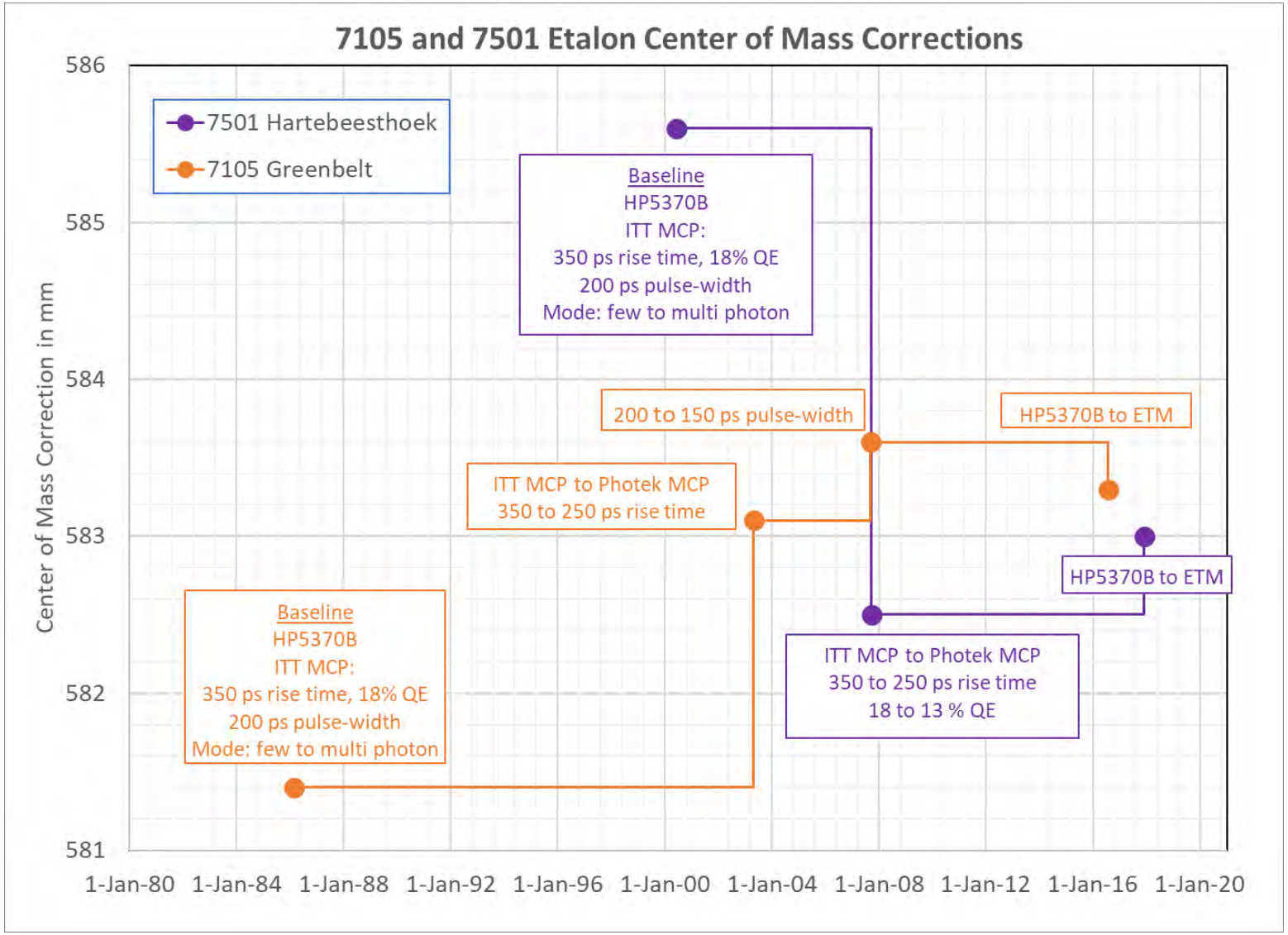


There are ~4 mm differences between 7105 and 7124 with the same HW configurations, but the mode of operations (number of photons) are listed as being different.

7124 is listed as f2m (few to multi) and 7105 is listed as s2m (single to multi)?

7124 has switched to the ETM as their prime counter effective 4-May-2020. We need to add new CoM entries.

7105 & 7501 Etalon Center of Mass (CoM) Corrections



The 7105 and 7501 baseline configurations on this chart are identical, but the Etalon CoMs differ by 4 mm different. Does than make sense; do I have an outdated set of CoMs, or does one of the baseline configurations have an error?

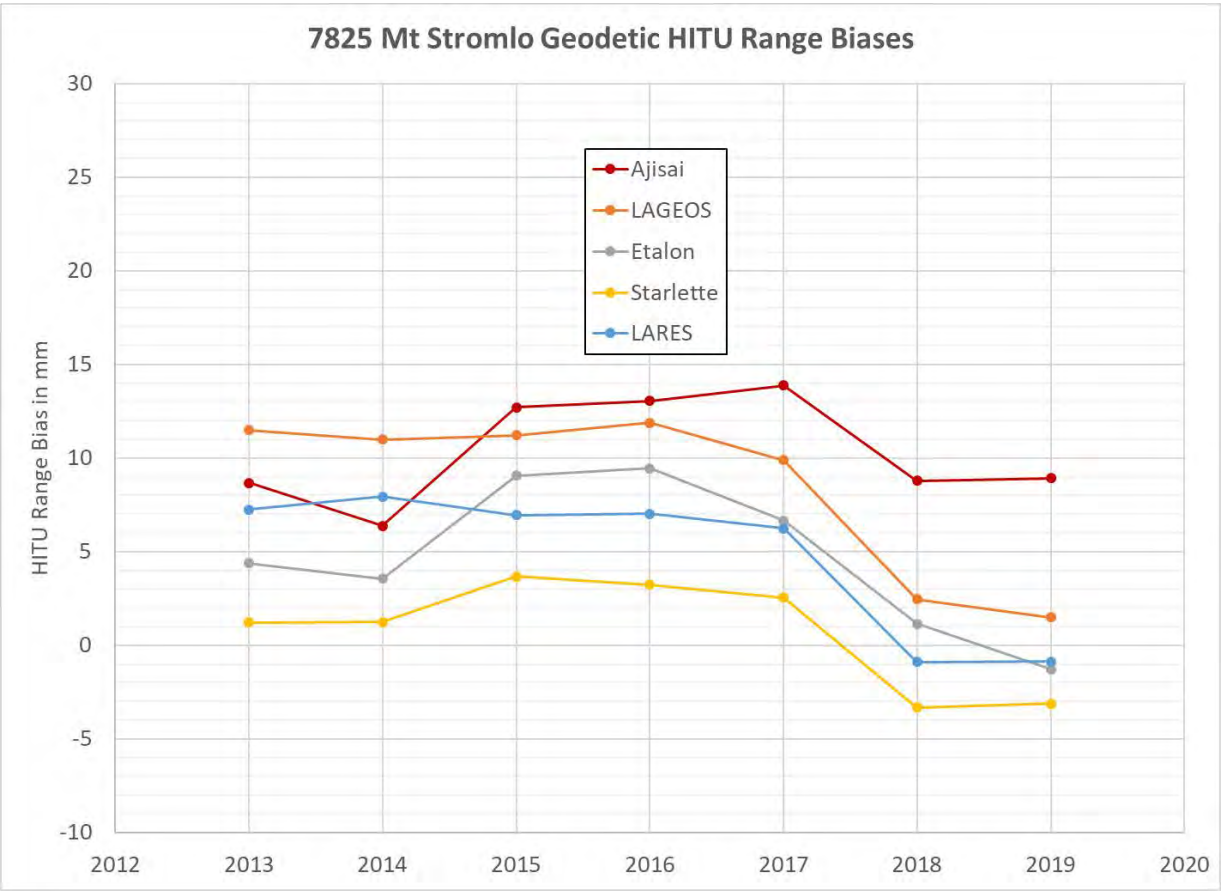
When the ETMs were installed the 7105 and 7501 Etalon CoMs changed in opposite directions.

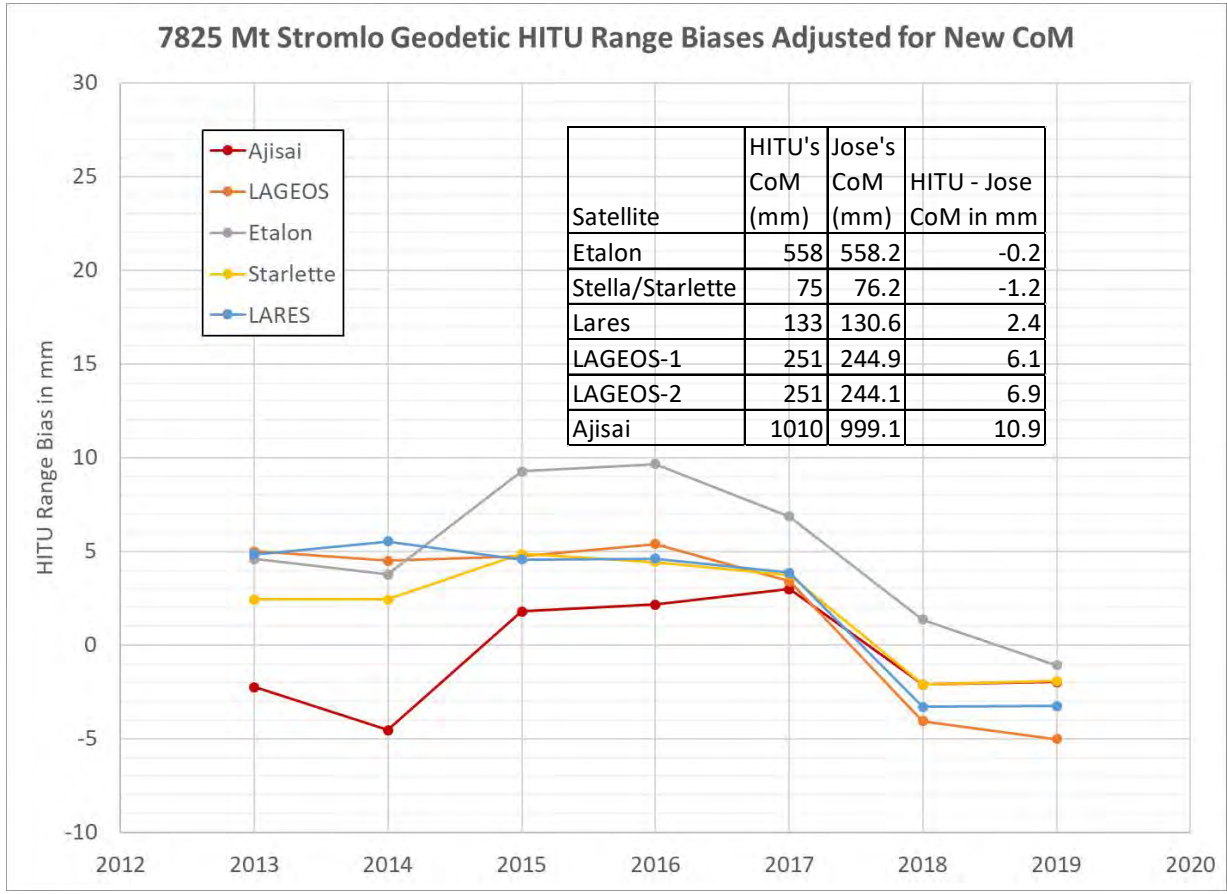
Summary/Questions and Next Steps

- Excluding Etalon, updated CoM corrections improve the HITU 7105 and 7110 range bias stability between satellites
- There appears to be a few to several mm 7090, 7105 and 7110 LAGEOS and Lares range biases differences relative to Starlette. Are these differences in the orbit; the station; the CoM corrections; or a combination?
  - Is there something in the NASA SLR systems that effect receive pulse shape that should be modeled in the CoM corrections, but currently is not.
- Are the 12-25 mm variations between the NASA SLR MOBLAS Etalon and Ajisai CoM corrections real?
- Next Steps/Actions:
  - Complete the analysis of 7110 geodetic range biases.
  - Analyze MOBLAS (7090, 7105, 7110) signal strength variations between calibrations and the geodetic satellites
  - Need some updated CoMs for ETM installations at 7110, 7124 and 7403. Is there a process in place to track system configuration changes and then update the CoMs accordingly?

BACKUP SLIDES

7825 Mt Stromlo Yearly Geodetic Range Biases





Satellite	HITU's CoM (mm)	Jose's CoM (mm)	HITU - Jose CoM in mm
Etalon	558	558.2	-0.2
Stella/Starlette	75	76.2	-1.2
Lares	133	130.6	2.4
LAGEOS-1	251	244.9	6.1
LAGEOS-2	251	244.1	6.9
Ajisai	1010	999.1	10.9

Mt Stromlo biases on LARES, LAGEOS and Starlette tighten up quite nicely with the new CoM corrections and Ajisai since 2015. All biases show a downward trend the past 2 years, where Yarragadee biases trend upwards.