Systematic Range Error 2014-2015

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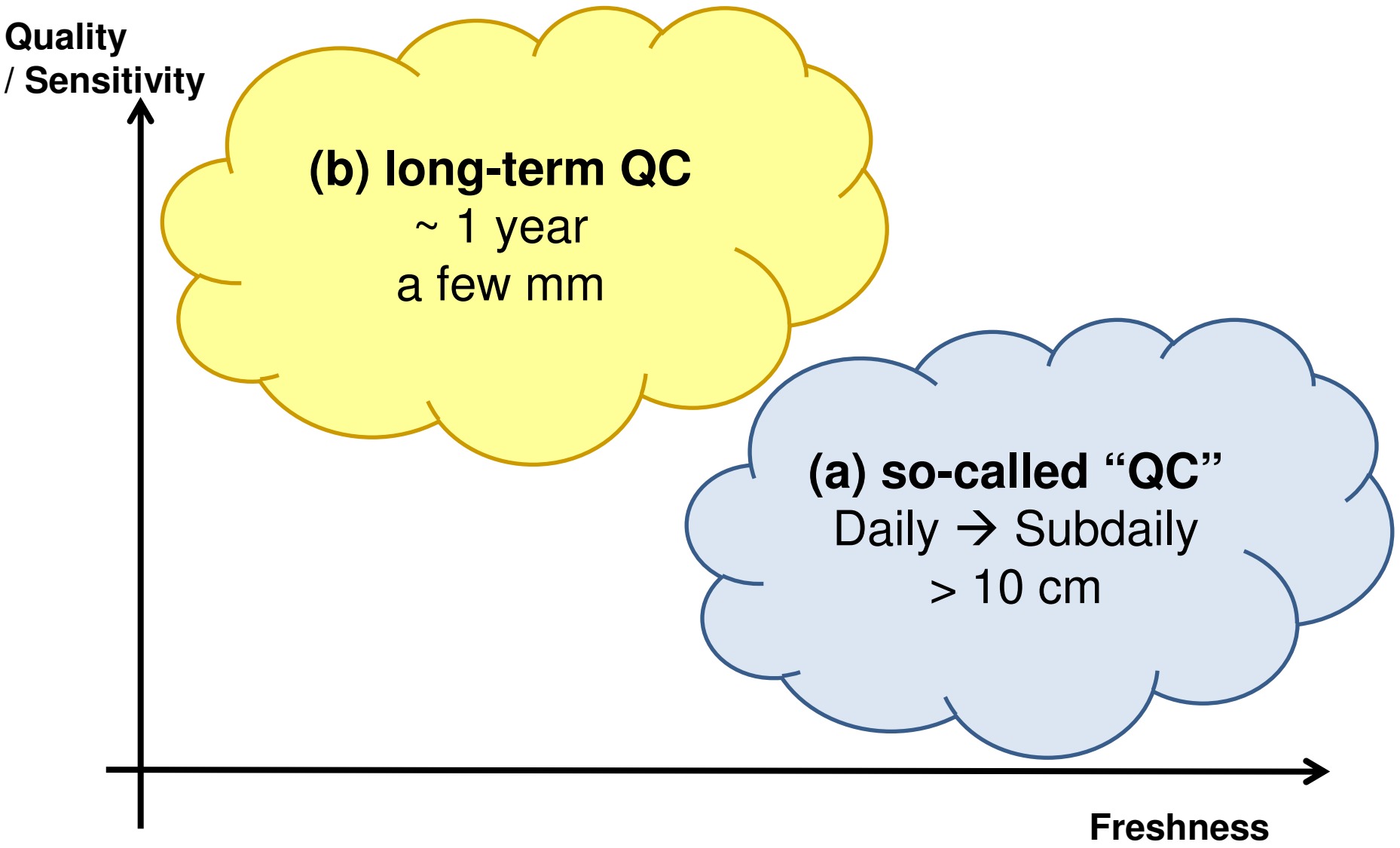
Lots of things to do to achieve the 1 mm precision.

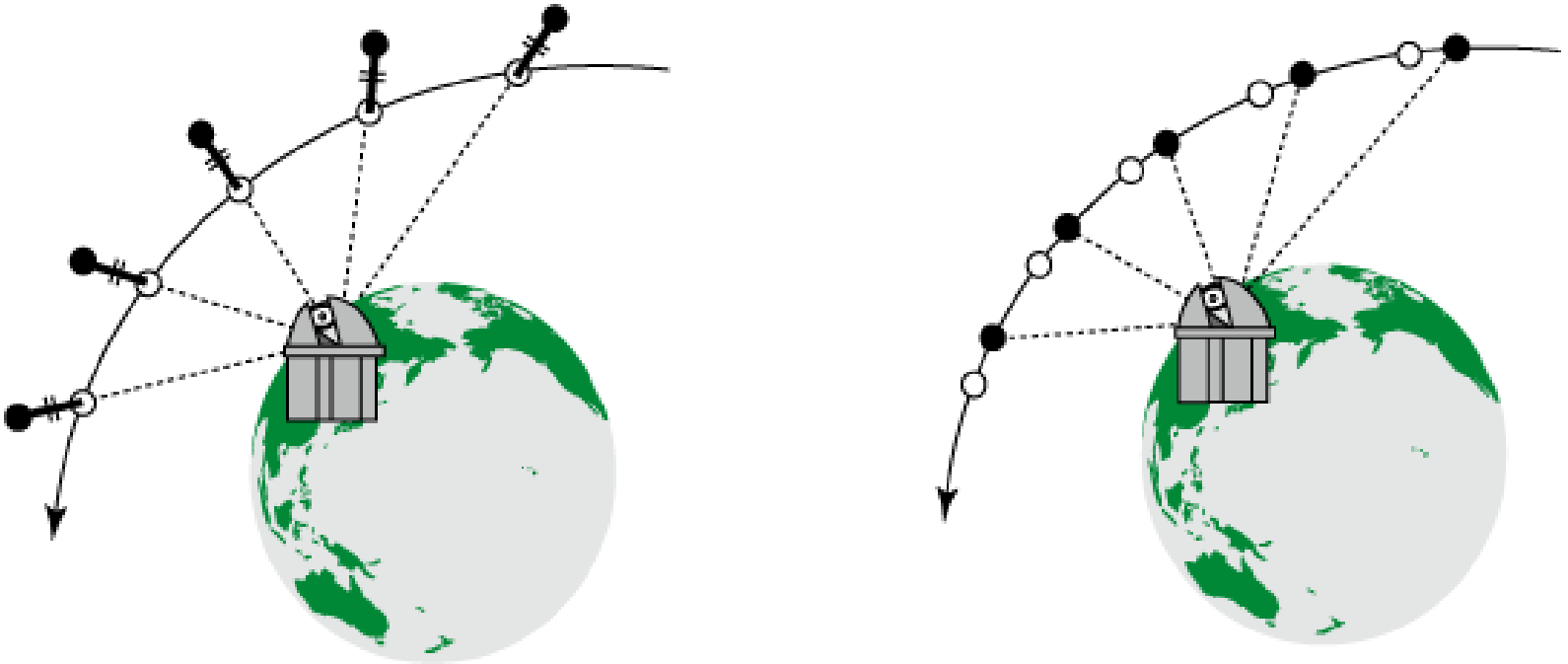
HITOTSUBASHI UNIVERSITY

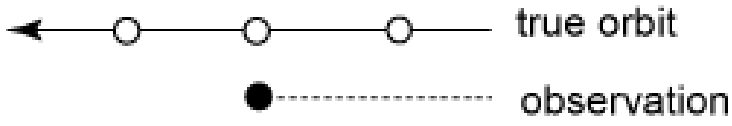
2015 ILRS Technical Workshop, Matera, 29 Oct 2015

Quick QC and "Slow" QC



Range Bias and Time Bias






```
# 7838 = SIMOSATO
# sat site date       time dur rb mm err tb us err prec bad total
LAG2 7838 2015/10/02 13:25 49  -6 (  5 )  11.1 ( 2.9 ) 3 0 / 20
AJI1 7838 2015/10/02 14:31 10 -30 ( 10 )   7.5 ( 4.0 ) 4 0 / 22
LARS 7838 2015/10/05 00:25  4  -3 ( 12 )  11.0 ( 5.3 ) 3 0 / 11
AJI1 7838 2015/10/06 12:54  7  19 ( 12 ) -10.5 ( 6.1 ) 5 0 / 15
:
```

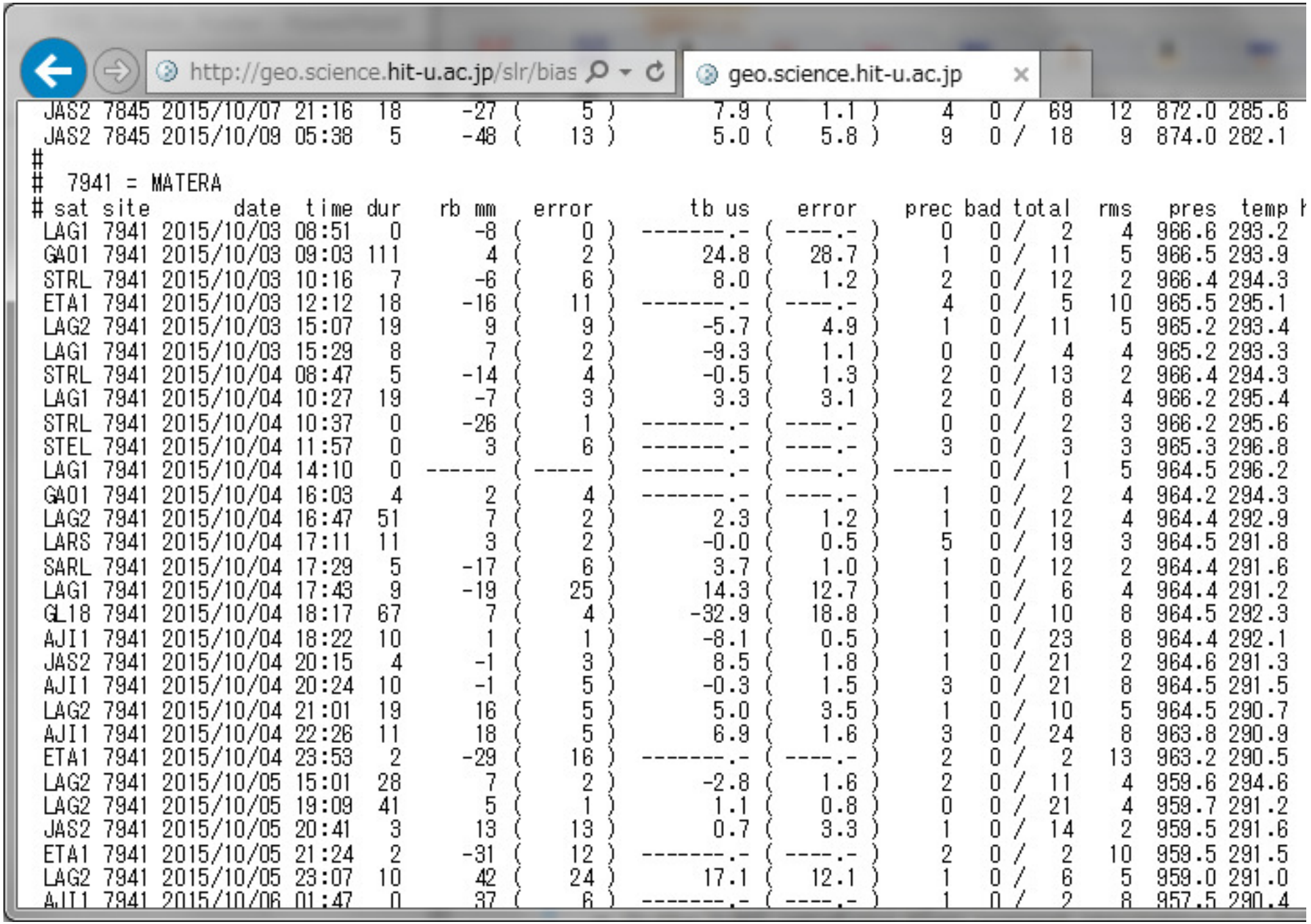
Quick QC

Quick feedback to the stations

- Range bias and time bias per pass derived from post-fit residuals.
- 12 incidents reported via RapidServiceMail (operated at DGFI) in the last 1 year. 9 from HITU & 3 from DGFI.
- 1 false alarm sent from HITU to Wettzell: time bias mapped by Zimmerwald's.
- Soon to use ITRF2014. Discontinuity expected.

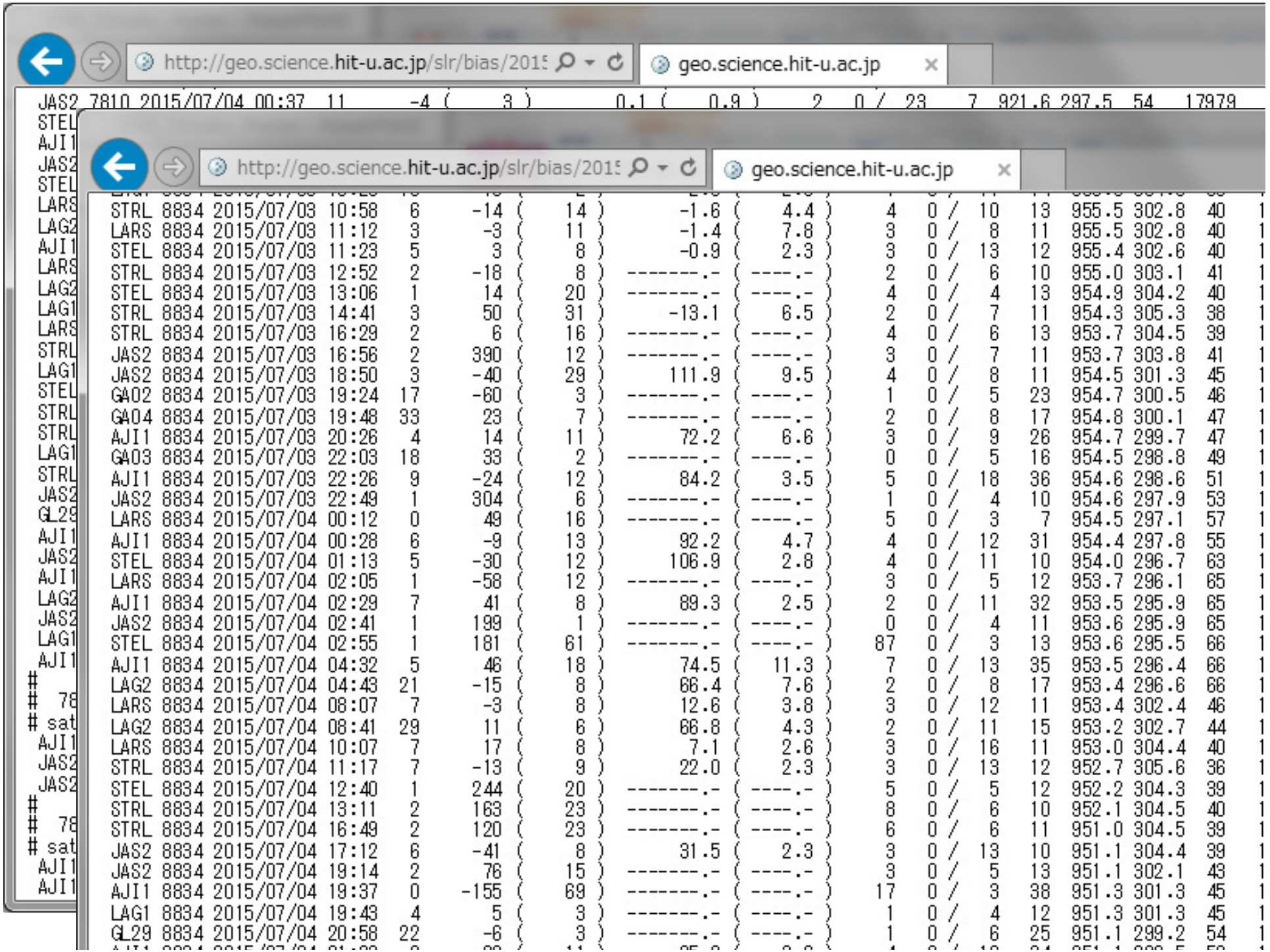
Visualization & Combination/Comparison

- NERC, JCET, ASI: Web Tools
- AIUB: Combined RB Report (← DGFI, MCC, HITU, SAO, JCET)
- ILRS CB: Global Performance Card



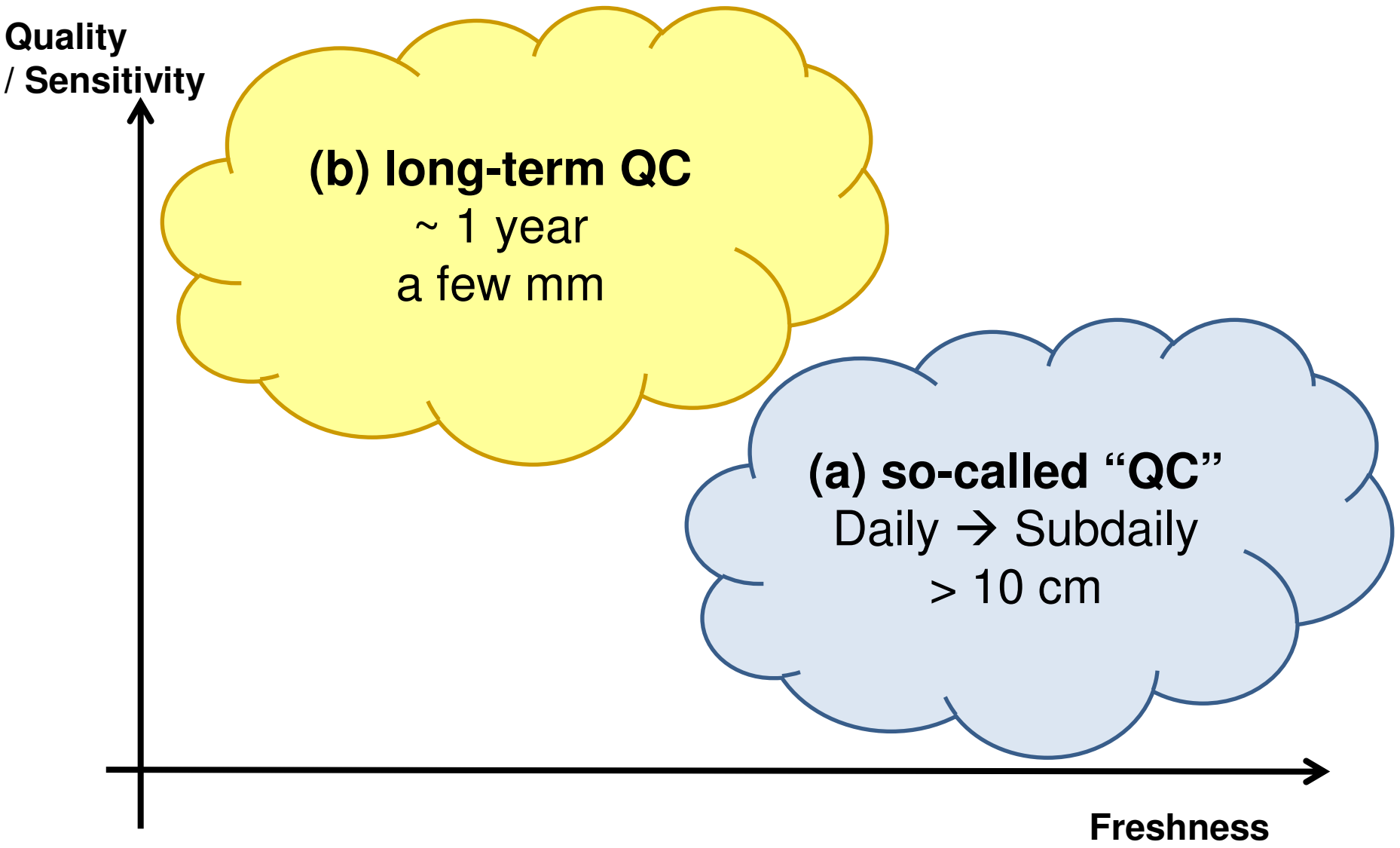

```
 JAS2 7845 2015/10/07 21:16  18     -27 (     5 )       7.9 (    1.1 )     4   0 /  69   12  872.0 285.6
 JAS2 7845 2015/10/09 05:38   5     -48 (    13 )       5.0 (    5.8 )     9   0 /  18    9  874.0 282.1
#
#  7941 = MATERA
# sat site       date  time dur    rb mm    error        tb us    error    prec bad total  rms   pres  temp h
 LAG1 7941 2015/10/03 08:51   0      -8 (     0 )  -------.- ( ----.- )     0   0 /   2    4  966.6 293.2
 GA01 7941 2015/10/03 09:03 111       4 (     2 )      24.8 (   28.7 )     1   0 /  11    5  966.5 293.9
 STRL 7941 2015/10/03 10:16   7      -6 (     6 )       8.0 (    1.2 )     2   0 /  12    2  966.4 294.3
 ETA1 7941 2015/10/03 12:12  18     -16 (    11 )  -------.- ( ----.- )     4   0 /   5   10  965.5 295.1
 LAG2 7941 2015/10/03 15:07  19       9 (     9 )      -5.7 (    4.9 )     1   0 /  11    5  965.2 293.4
 LAG1 7941 2015/10/03 15:29   8       7 (     2 )      -9.3 (    1.1 )     0   0 /   4    4  965.2 293.3
 STRL 7941 2015/10/04 08:47   5     -14 (     4 )      -0.5 (    1.3 )     2   0 /  13    2  966.4 294.3
 LAG1 7941 2015/10/04 10:27  19      -7 (     3 )       3.3 (    3.1 )     2   0 /   8    4  966.2 295.4
 STRL 7941 2015/10/04 10:37   0     -26 (     1 )  -------.- ( ----.- )     0   0 /   2    3  966.2 295.6
 STEL 7941 2015/10/04 11:57   0       3 (     6 )  -------.- ( ----.- )     3   0 /   3    3  965.3 296.8
 LAG1 7941 2015/10/04 14:10   0  ------ ( ----- )  -------.- ( ----.- ) -----   0 /   1    5  964.5 296.2
 GA01 7941 2015/10/04 16:03   4       2 (     4 )  -------.- ( ----.- )     1   0 /   2    4  964.2 294.3
 LAG2 7941 2015/10/04 16:47  51       7 (     2 )       2.3 (    1.2 )     1   0 /  12    4  964.4 292.9
 LARS 7941 2015/10/04 17:11  11       3 (     2 )      -0.0 (    0.5 )     5   0 /  19    3  964.5 291.8
 SARL 7941 2015/10/04 17:29   5     -17 (     6 )       3.7 (    1.0 )     1   0 /  12    2  964.4 291.6
 LAG1 7941 2015/10/04 17:43   9     -19 (    25 )      14.3 (   12.7 )     1   0 /   6    4  964.4 291.2
 GL18 7941 2015/10/04 18:17  67       7 (     4 )     -32.9 (   18.8 )     1   0 /  10    8  964.5 292.3
 AJI1 7941 2015/10/04 18:22  10       1 (     1 )      -8.1 (    0.5 )     1   0 /  23    8  964.4 292.1
 JAS2 7941 2015/10/04 20:15   4      -1 (     3 )       8.5 (    1.8 )     1   0 /  21    2  964.6 291.3
 AJI1 7941 2015/10/04 20:24  10      -1 (     5 )      -0.3 (    1.5 )     3   0 /  21    8  964.5 291.5
 LAG2 7941 2015/10/04 21:01  19      16 (     5 )       5.0 (    3.5 )     1   0 /  10    5  964.5 290.7
 AJI1 7941 2015/10/04 22:26  11      18 (     5 )       6.9 (    1.6 )     3   0 /  24    8  963.8 290.9
 ETA1 7941 2015/10/04 23:53   2     -29 (    16 )  -------.- ( ----.- )     2   0 /   2   13  963.2 290.5
 LAG2 7941 2015/10/05 15:01  28       7 (     2 )      -2.8 (    1.6 )     2   0 /  11    4  959.6 294.6
 LAG2 7941 2015/10/05 19:09  41       5 (     1 )       1.1 (    0.8 )     0   0 /  21    4  959.7 291.2
 JAS2 7941 2015/10/05 20:41   3      13 (    13 )       0.7 (    3.3 )     1   0 /  14    2  959.5 291.6
 ETA1 7941 2015/10/05 21:24   2     -31 (    12 )  -------.- ( ----.- )     2   0 /   2   10  959.5 291.5
 LAG2 7941 2015/10/05 23:07  10      42 (    24 )      17.1 (   12.1 )     1   0 /   6    5  959.0 291.0
 AJI1 7941 2015/10/06 01:47   0      37 (     6 )  -------.- ( ----.- )     1   0 /   2    8  957.5 290.4
```

http://geo.science.hit-u.ac.jp/slr/bias



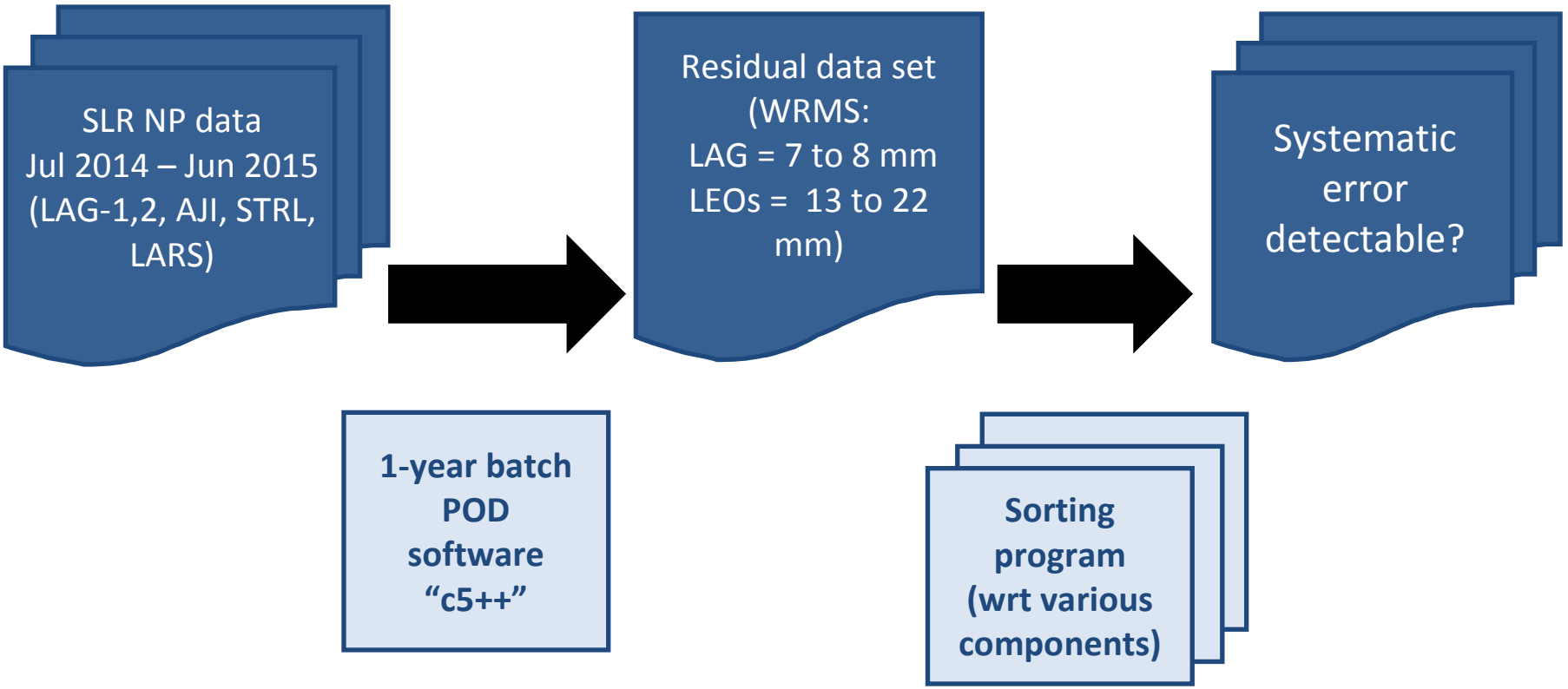
STRL	8834	2015/07/03	10:58	6	-14	14	-1.6	4.4	4	0	10	13	955.5	302.8	40	1
LARS	8834	2015/07/03	11:12	3	-3	11	-1.4	7.8	3	0	8	11	955.5	302.8	40	1
STEL	8834	2015/07/03	11:23	5	3	8	-0.9	2.3	3	0	13	12	955.4	302.6	40	1
STRL	8834	2015/07/03	12:52	2	-18	8	-------.-	----.-	2	0	6	10	955.0	303.1	41	1
STEL	8834	2015/07/03	13:06	1	14	20	-------.-	----.-	4	0	4	13	954.9	304.2	40	1
STRL	8834	2015/07/03	14:41	3	50	31	-13.1	6.5	2	0	7	11	954.3	305.3	38	1
STRL	8834	2015/07/03	16:29	2	6	16	-------.-	----.-	4	0	6	13	953.7	304.5	39	1
JAS2	8834	2015/07/03	16:56	2	390	12	-------.-	----.-	3	0	7	11	953.7	303.8	41	1
JAS2	8834	2015/07/03	18:50	3	-40	29	111.9	9.5	4	0	8	11	954.5	301.3	45	1
GA02	8834	2015/07/03	19:24	17	-60	3	-------.-	----.-	1	0	5	23	954.7	300.5	46	1
GA04	8834	2015/07/03	19:48	33	23	7	-------.-	----.-	2	0	8	17	954.8	300.1	47	1
AJI1	8834	2015/07/03	20:26	4	14	11	72.2	6.6	3	0	9	26	954.7	299.7	47	1
GA03	8834	2015/07/03	22:03	18	33	2	-------.-	----.-	0	0	5	16	954.5	298.8	49	1
AJI1	8834	2015/07/03	22:26	9	-24	12	84.2	3.5	5	0	18	36	954.6	298.6	51	1
JAS2	8834	2015/07/03	22:49	1	304	6	-------.-	----.-	1	0	4	10	954.6	297.9	53	1
LARS	8834	2015/07/04	00:12	0	49	16	-------.-	----.-	5	0	3	7	954.5	297.1	57	1
AJI1	8834	2015/07/04	00:28	6	-9	13	92.2	4.7	4	0	12	31	954.4	297.8	55	1
STEL	8834	2015/07/04	01:13	5	-30	12	106.9	2.8	4	0	11	10	954.0	296.7	63	1
LARS	8834	2015/07/04	02:05	1	-58	12	-------.-	----.-	3	0	5	12	953.7	296.1	65	1
AJI1	8834	2015/07/04	02:29	7	41	8	89.3	2.5	2	0	11	32	953.5	295.9	65	1
JAS2	8834	2015/07/04	02:41	1	199	1	-------.-	----.-	0	0	4	11	953.6	295.9	65	1
STEL	8834	2015/07/04	02:55	1	181	61	-------.-	----.-	87	0	3	13	953.6	295.5	66	1
AJI1	8834	2015/07/04	04:32	5	46	18	74.5	11.3	7	0	13	35	953.5	296.4	66	1
LAG2	8834	2015/07/04	04:43	21	-15	8	66.4	7.6	2	0	8	17	953.4	296.6	66	1
LARS	8834	2015/07/04	08:07	7	-3	8	12.6	3.8	3	0	12	11	953.4	302.4	46	1
LAG2	8834	2015/07/04	08:41	29	11	6	66.8	4.3	2	0	11	15	953.2	302.7	44	1
LARS	8834	2015/07/04	10:07	7	17	8	7.1	2.6	3	0	16	11	953.0	304.4	40	1
STRL	8834	2015/07/04	11:17	7	-13	9	22.0	2.3	3	0	13	12	952.7	305.6	36	1
STEL	8834	2015/07/04	12:40	1	244	20	-------.-	----.-	5	0	5	12	952.2	304.3	39	1
STRL	8834	2015/07/04	13:11	2	163	23	-------.-	----.-	8	0	6	10	952.1	304.5	40	1
STRL	8834	2015/07/04	16:49	2	120	23	-------.-	----.-	6	0	6	11	951.0	304.5	39	1
JAS2	8834	2015/07/04	17:12	6	-41	8	31.5	2.3	3	0	13	10	951.1	304.4	39	1
JAS2	8834	2015/07/04	19:14	2	76	15	-------.-	----.-	3	0	5	13	951.1	302.1	43	1
AJI1	8834	2015/07/04	19:37	0	-155	69	-------.-	----.-	17	0	3	38	951.3	301.3	45	1
LAG1	8834	2015/07/04	19:43	4	5	3	-------.-	----.-	1	0	4	12	951.3	301.3	45	1
GL29	8834	2015/07/04	20:58	22	-6	3	-------.-	----.-	1	0	6	25	951.1	299.2	54	1

Quick QC and "Slow" QC



“Slow QC” Procedure

Different from “Quick” QC



POD Configuration

Software “c5++”

-5 satellites combined (LAGEOS 1+2, AJISAT, STRLETTE & LARES). One-year single batch.

-Orbit: 5-day arc for LAGEOS-1 and -2. 3-day arc for LEOs.

-Station-dependent CoM correction for LAG1+2 & AJI.

-Acceleration parameters: Gravity field 4x4 as 1-year common params, and 5 empirical params twice per arc.

-Station coordinates: all solved for with loose constraints. Velocity fixed to SLRF2008.

-Per-site atm loading (L Petrov’s) applied.

-Range bias: solved for per station per satellite types (“LAG1+2”, “AJI”, “STRL”, “LARS”).

“Slow” QC (@ HIT-U): Key parameters

Test #1:
Single-shot returns per NP bin

Test #2:
Single-shot RMS in a NP bin

Test #3:
System delay (calibration)

Test #4:
Time to the nearest calibration

Test #5:
Range rate

NEW!!

Test #6:
Month

NEW!!

Test #7:
Day of week

Test #8:
Local time

#1: Single-shot returns

#2: Single-shot RMS

#3: System delay

#4: Time to the nearest cal.

#5: Range rate

#6: Month

#7: Day of week

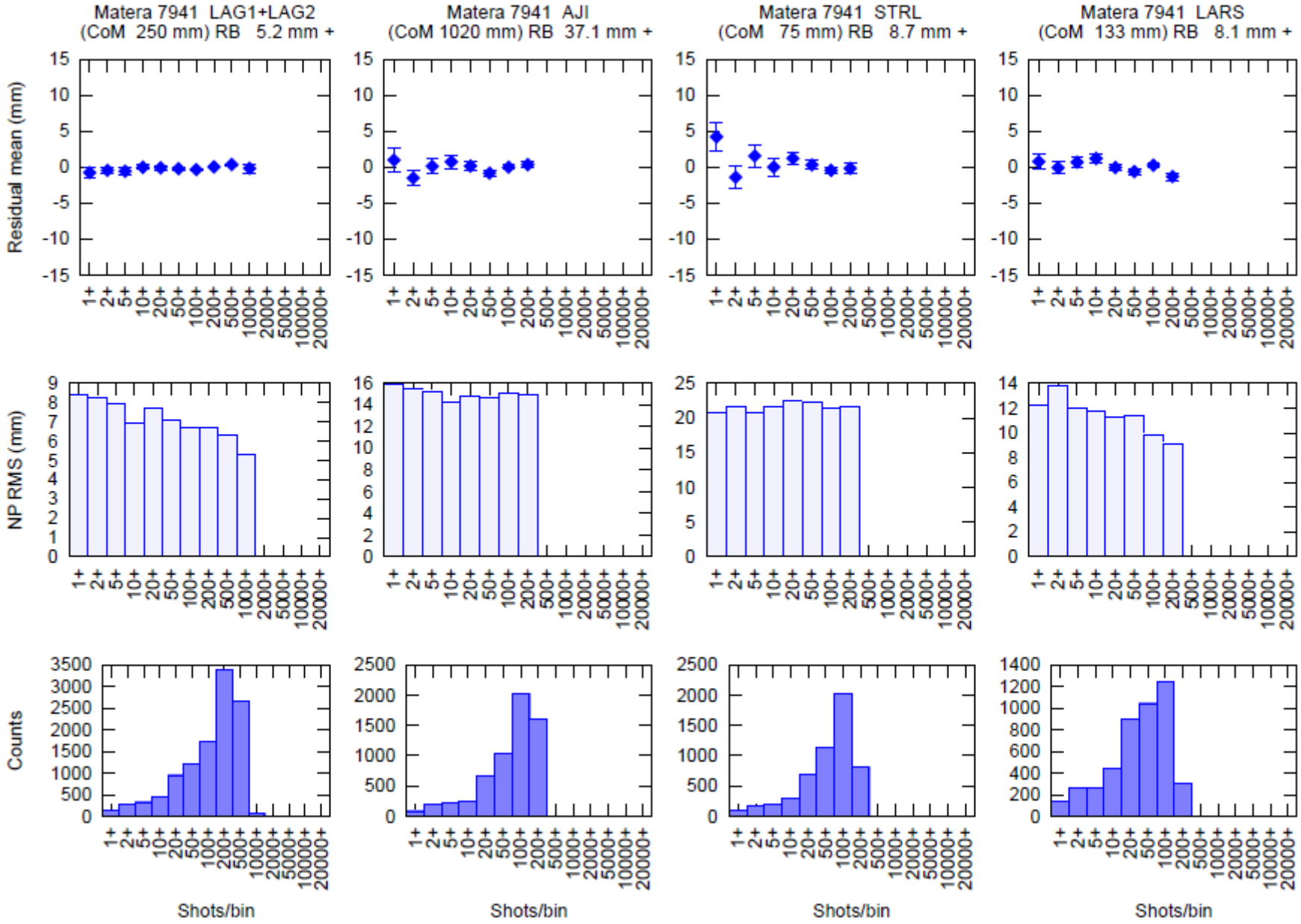
#8: Local time

Site Information		Data Volume					
Column 1	2	3	4	5	6	7	
Location	Station Number	LEO pass Tot	LAGEOS pass Tot	High pass Tot	Total passes	LEO NP Total	LAGE NP T
Baseline		1000	400	100	1500		
Yarragadee	7090	14253	2782	7275	24310	270567	23
Changchun	7237	9834	1234	6452	17520	83312	6
Mount_Stromlo_2	7825	7223	1458	3679	12360	105658	13
Greenbelt	7105	5756	1108	1602	8466	112001	10
Matera_MLRO	7941	3590	1456	3177	8223	41470	12
Herstmonceux	7840	3795	835	3016	7646	51367	7
Monument_Peak	7110	4975	906	1280	7161	92166	7
Zimmerwald_532	7810	3872	674	2411	6957	64433	8
Graz	7839	3550	609	2686	6845	66392	3
Wettzell	8834	2824	308	2160	5292	25684	2

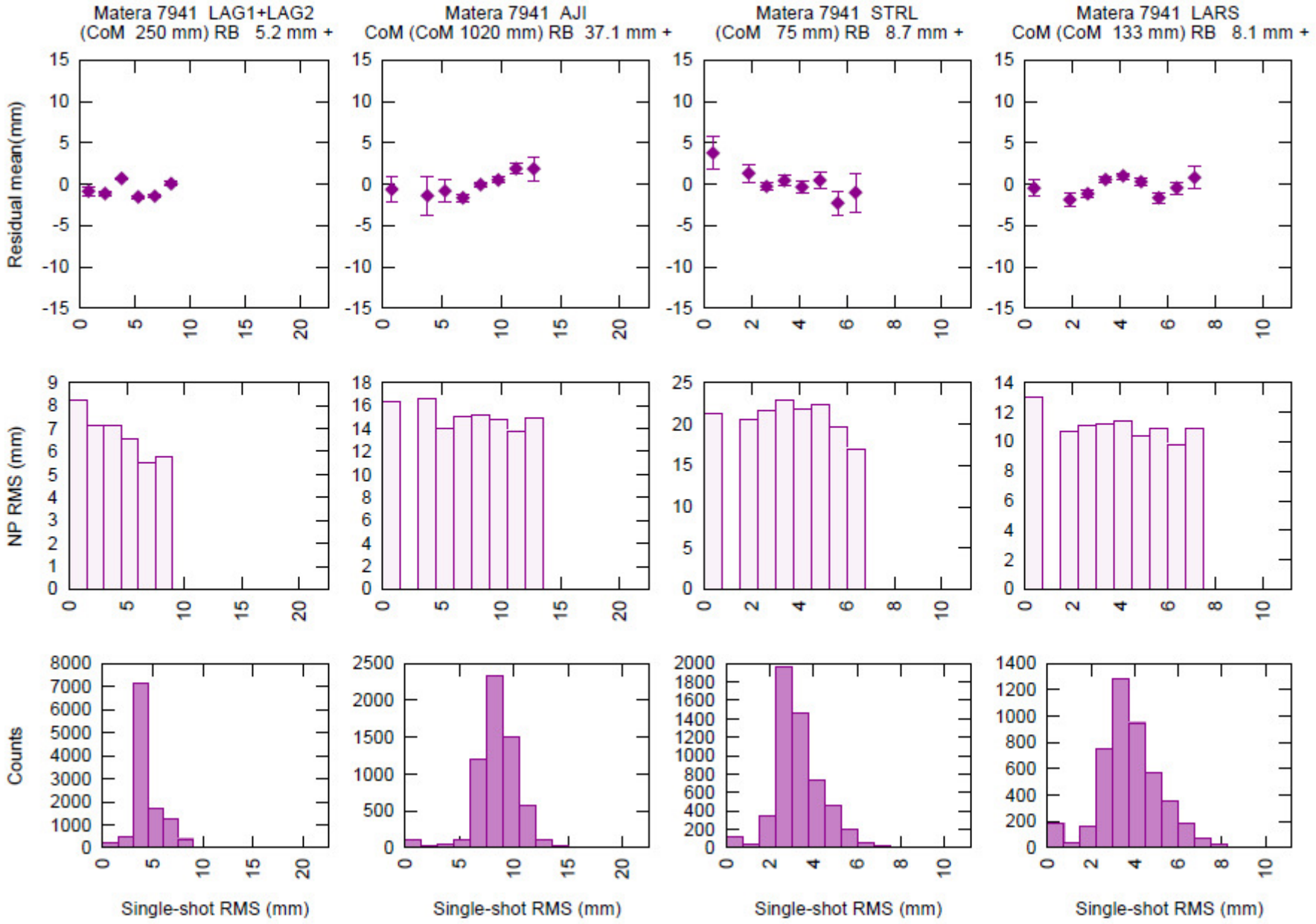
SLR Global Performance Report Card (2015 Q3)

7941+

#1: Single-shot returns



#2: Single-shot RMS



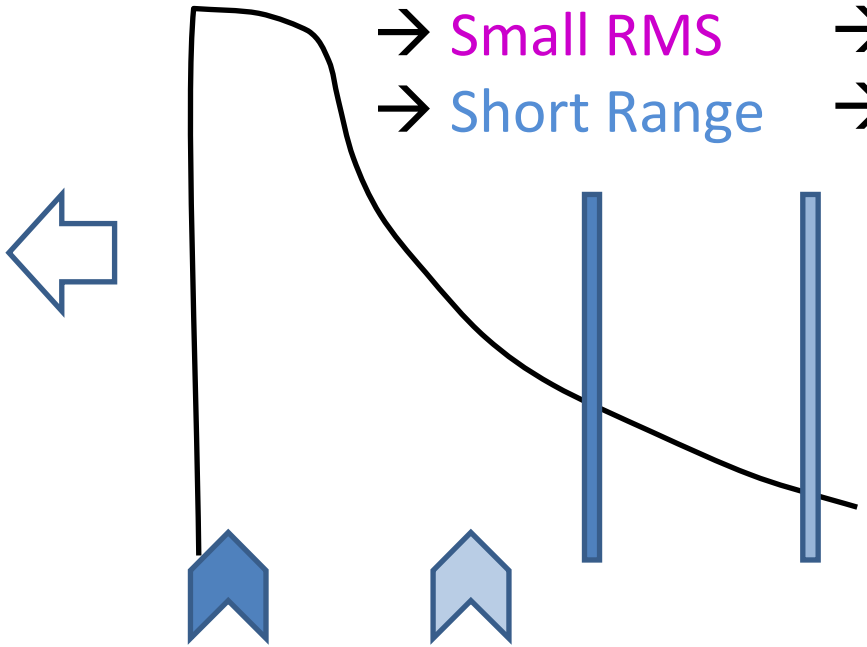
Test #1:
Single-shot returns per NP bin

Test #2:
Single-shot RMS in a NP bin

Detector time walk
Target signature
etc

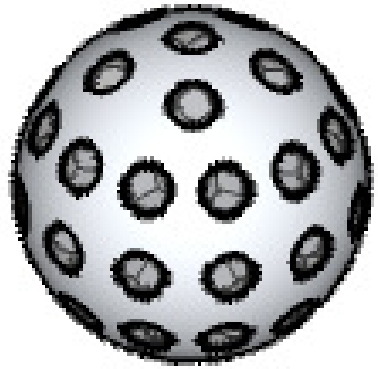
Tight clipping
→ Small RMS
→ Short Range

Loose clipping
→ Large RMS
→ Long Range



Strong
→ Small RMS
→ Short Range

Weak
→ Large RMS
→ Long Range



Discussion

Test #1:
Single-shot returns per NP bin

Test #2:
Single-shot RMS in a NP bin

Intensity-dependent error

→ Elevation-dependent error

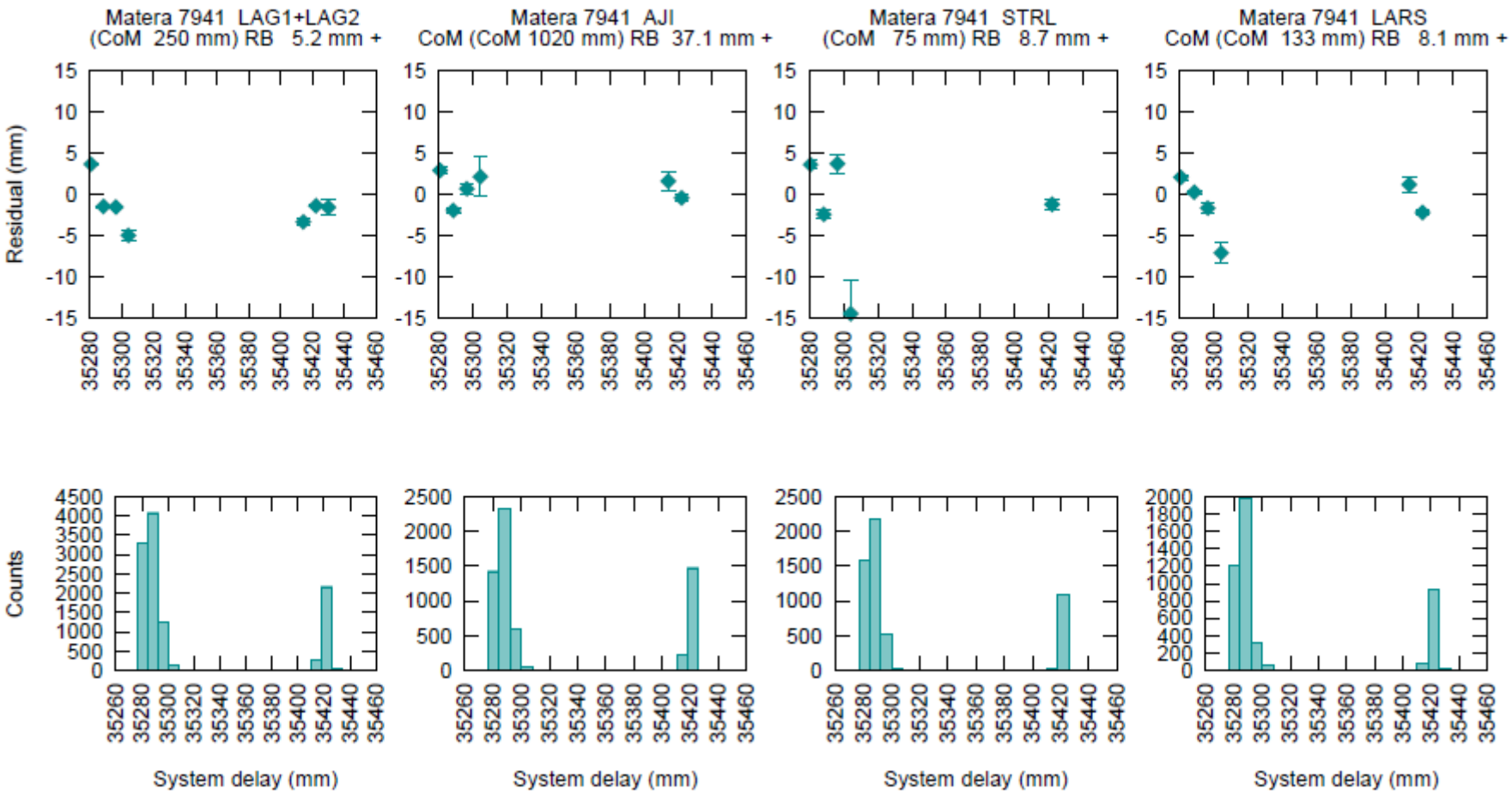
→ Systematic error in station height & other params

Eliminate intensity-dependent (or clipping-dependent) variation

Intensity robustness or intensity control.

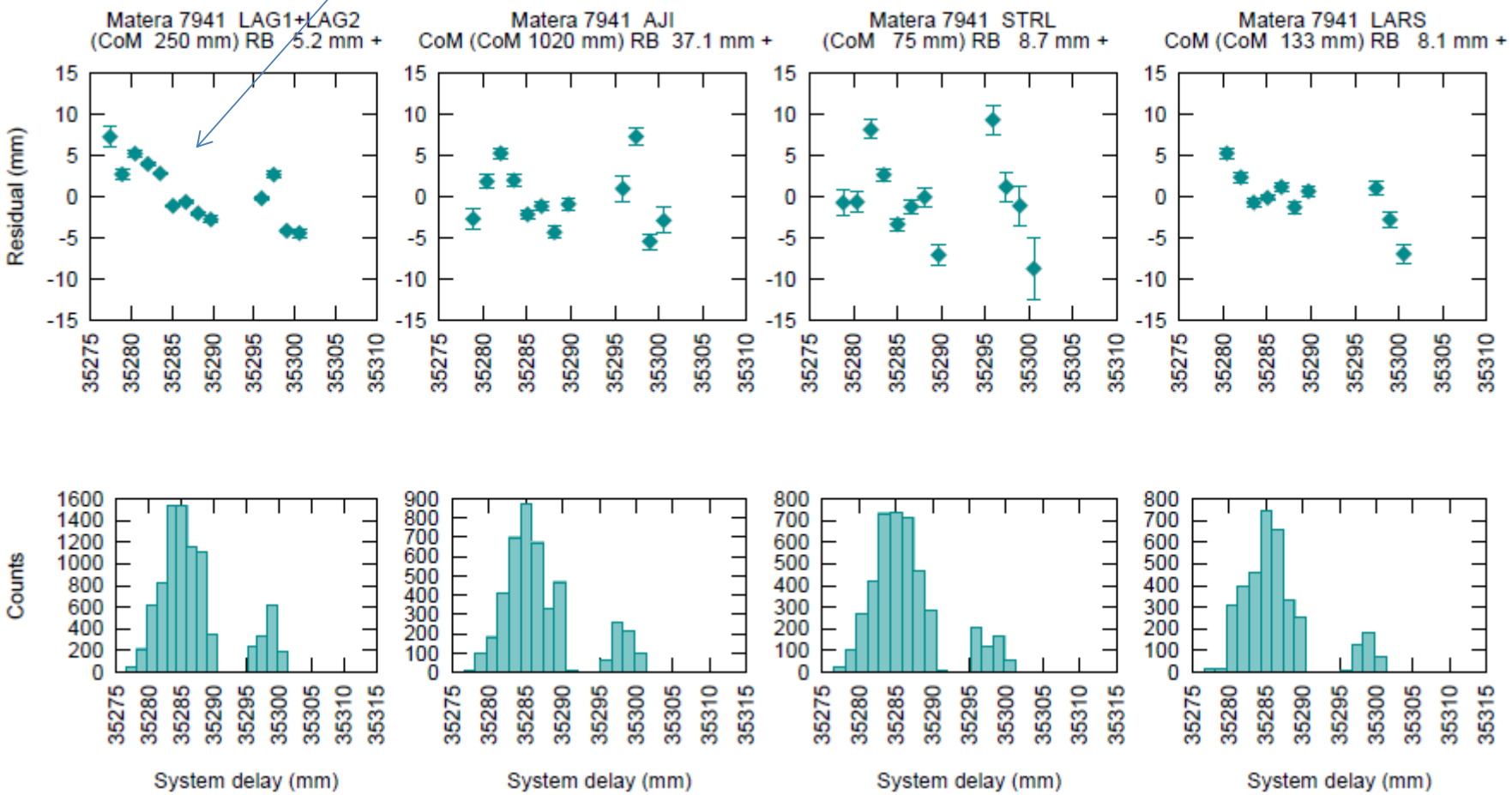
Do not mix high & low energy returns, esp. SPAD)

#3: System delay

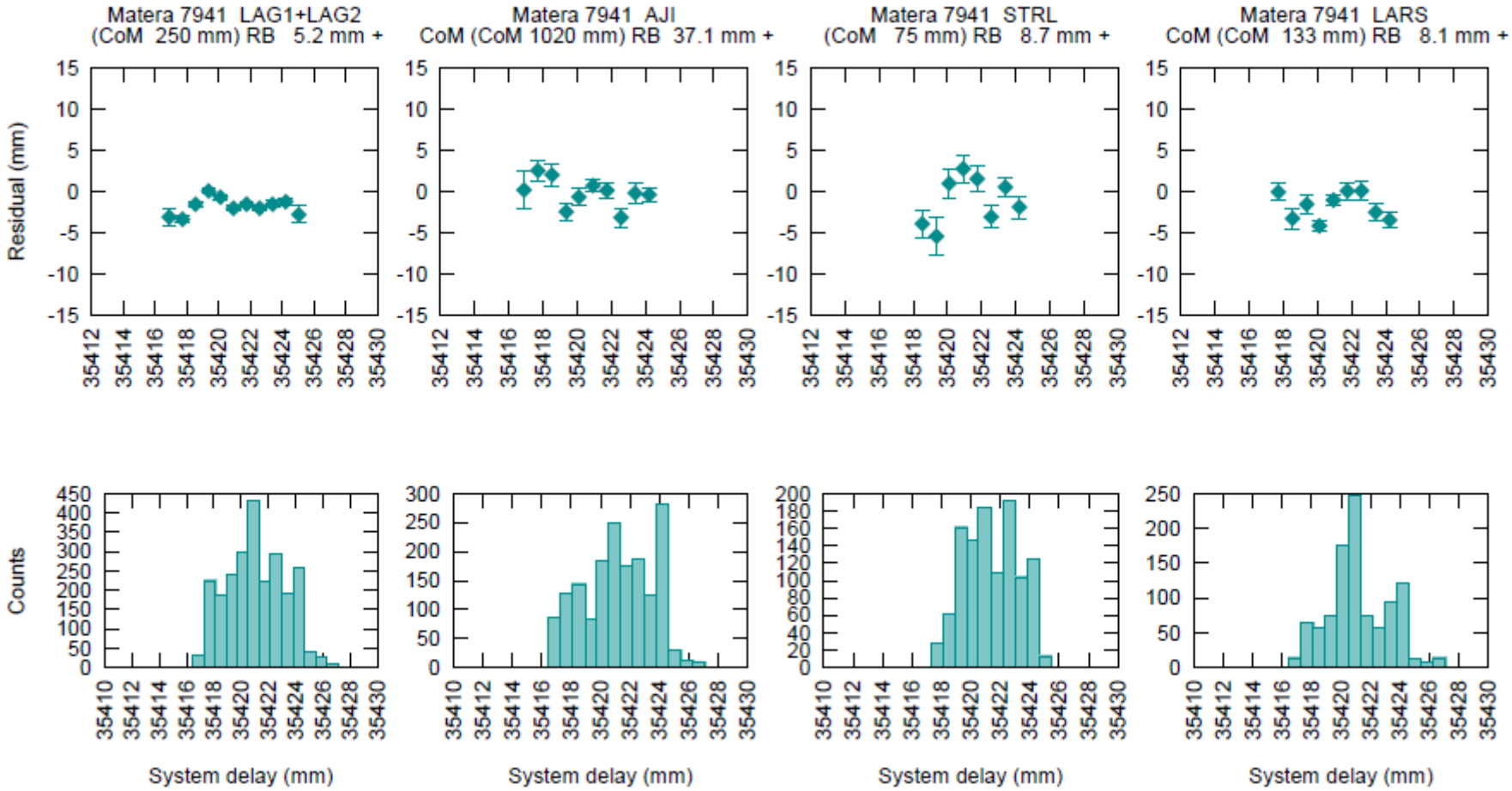


Zoomed (1)

Negative 1:1 trend?



Zoomed (2)


Matera 7941 LAG1+LAG2
(CoM 250 mm) RB 5.2 mm +
Matera 7941 AJI
CoM (CoM 1020 mm) RB 37.1 mm +
Matera 7941 STRL
(CoM 75 mm) RB 8.7 mm +
Matera 7941 LARS
CoM (CoM 133 mm) RB 8.1 mm +
Residual (mm)
Counts
System delay (mm)
System delay (mm)
System delay (mm)
System delay (mm)

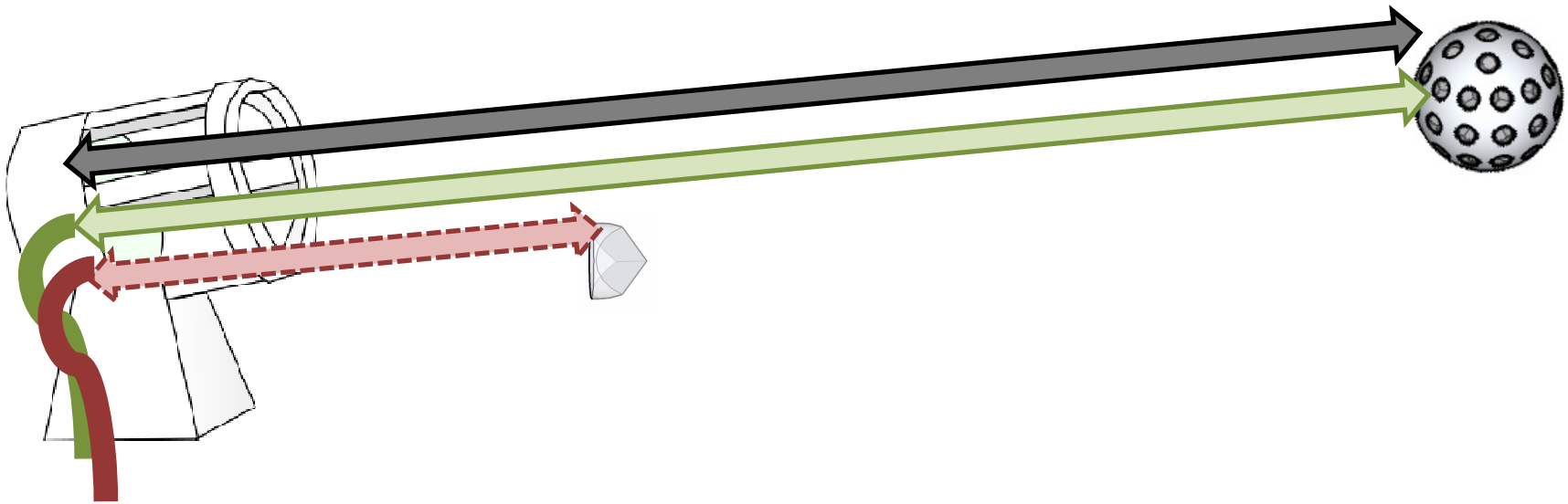
Test #3:
System delay (calibration)

← Calibration variation real?

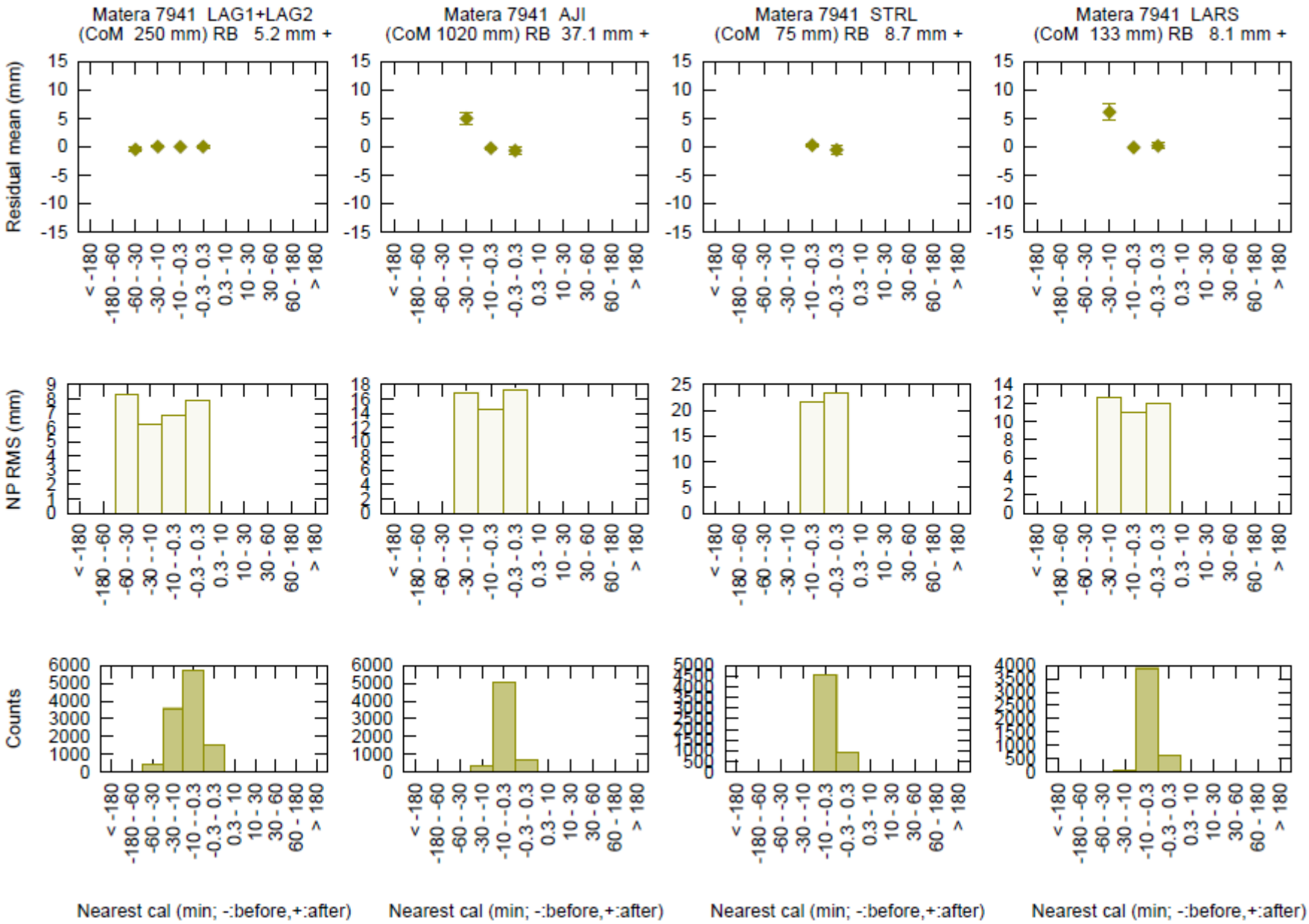
$$\rho_{\text{Released data}} \downarrow$$

$$= \rho_{\text{Satellite-measured}} - \rho_{\text{TR-measured}} \uparrow$$

$$+ \rho_{\text{TR-surveyed}}$$

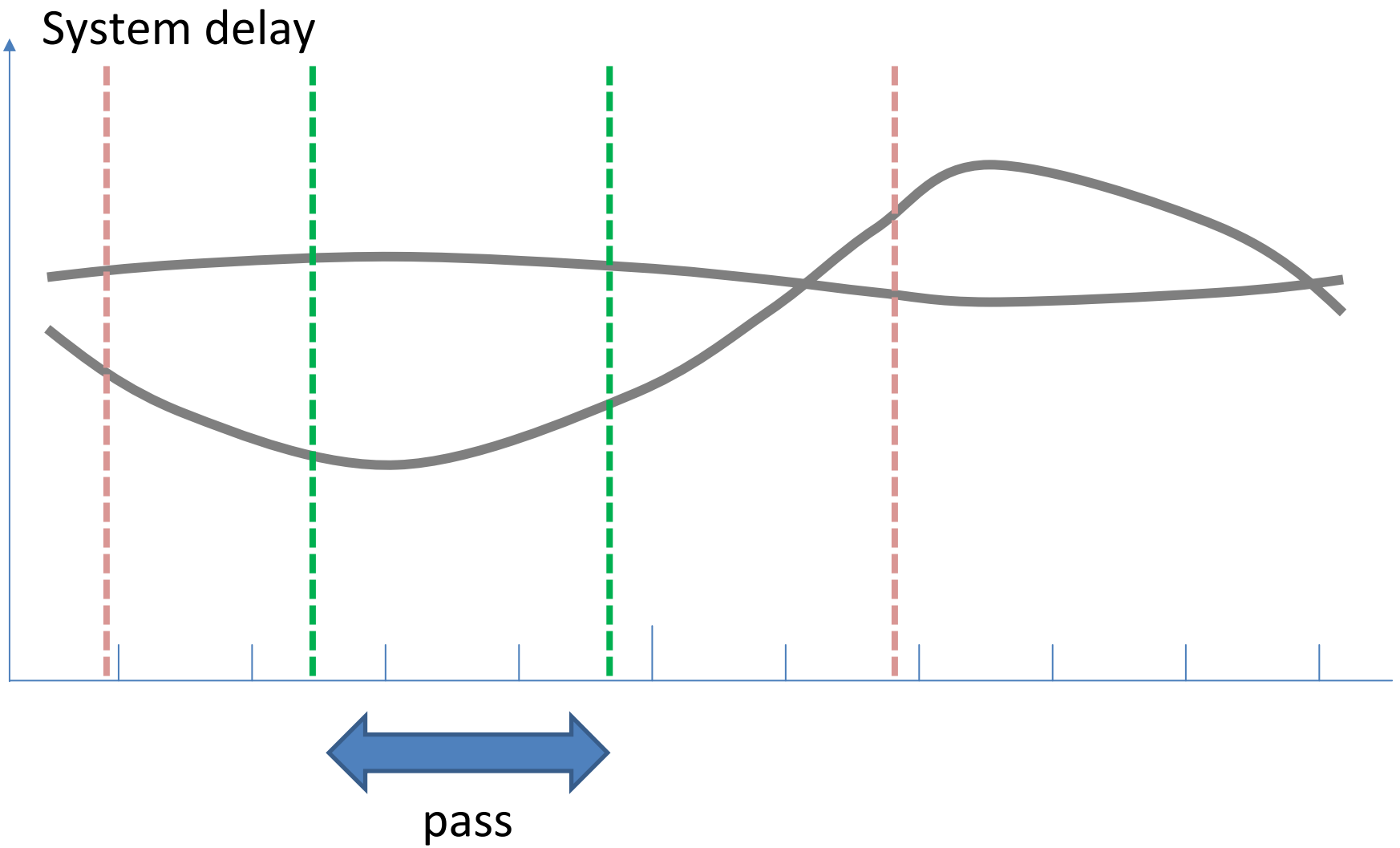


#4: Time to the nearest cal.



Test #4:
Time to the nearest calibration

← **Calibrated frequently enough?**



Discussion

Test #3:
System delay (calibration)

Test #4:
Time to the nearest calibration

How stable is your ground target ranging?

- Minimise the variation.
- The best case (Mt Stromlo) stays within 5 mm throughout the year.
- [?] Only pre-cal data are recorded in CRD files for many stations.

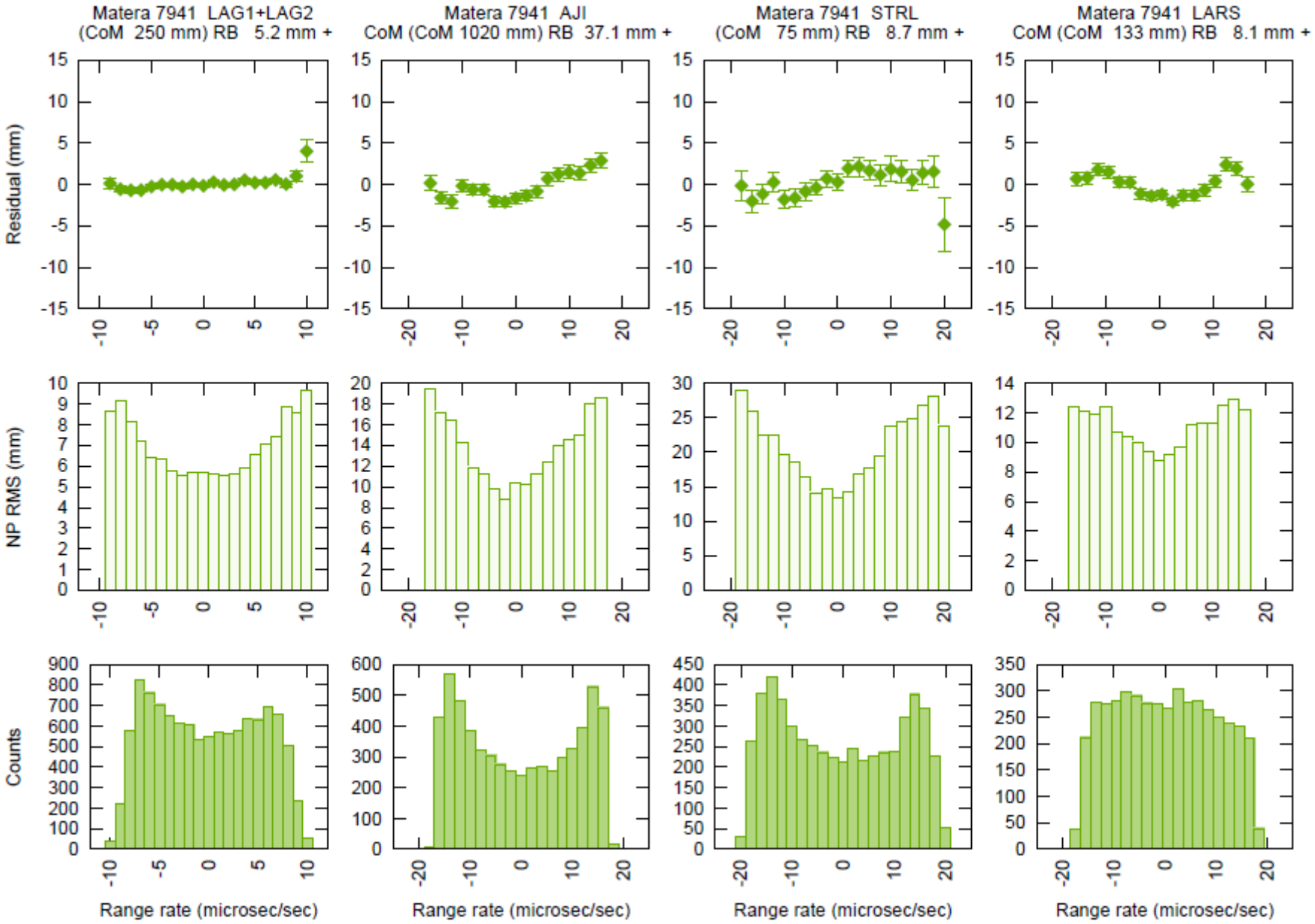
Understand why the measurement varies.

- Is the variation true (i.e. common to satellite ranging)?
- Do you apply an atm delay for ground target ranging > 3 m? ($n_{\text{atmosphere}} - 1$) ~ 1.0003.
- Do you apply a temp/pres-dependent atm delay for ground target ranging > 10 m? ($n_{\text{atmosphere}} - 1$) varies a lot.

Possible false alarm

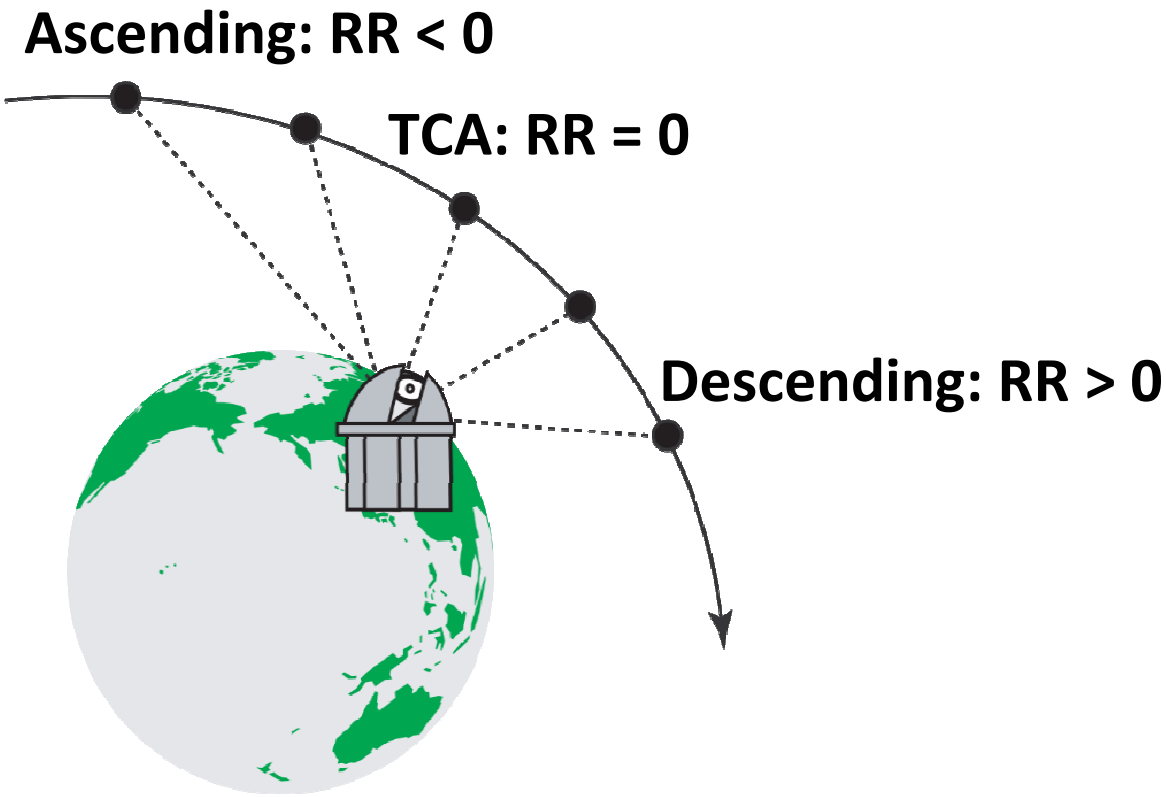
- Correlated with long-term station coordinates variation.

#5: Range rate


Matera 7941 LAG1+LAG2
(CoM 250 mm) RB 5.2 mm +
Matera 7941 AJI
CoM (CoM 1020 mm) RB 37.1 mm +
Matera 7941 STRL
(CoM 75 mm) RB 8.7 mm +
Matera 7941 LARS
CoM (CoM 133 mm) RB 8.1 mm +
Residual (mm)
NP RMS (mm)
Counts
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)

Test #5:
Range rate

← Pass coverage. Time bias.



$$\Delta\rho = -\,\mathbf{RR \times TimeBias}$$

Discussion

Test #5:
Range rate

Keep tracking to the horizon unless necessary

- SLR network is sparse → full pass coverage is ideal.

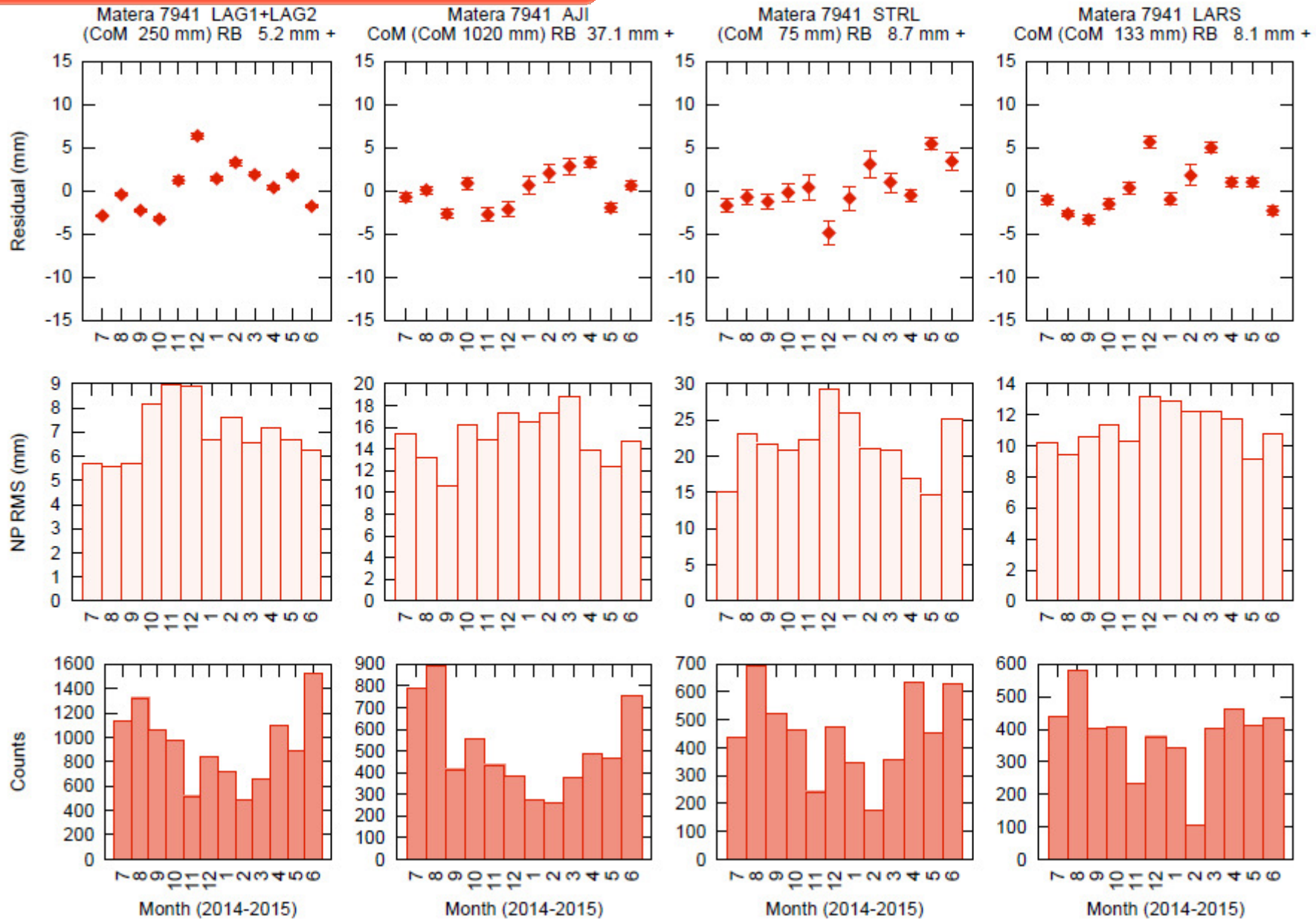
Time bias?

- More sensitive than “quick” QC.

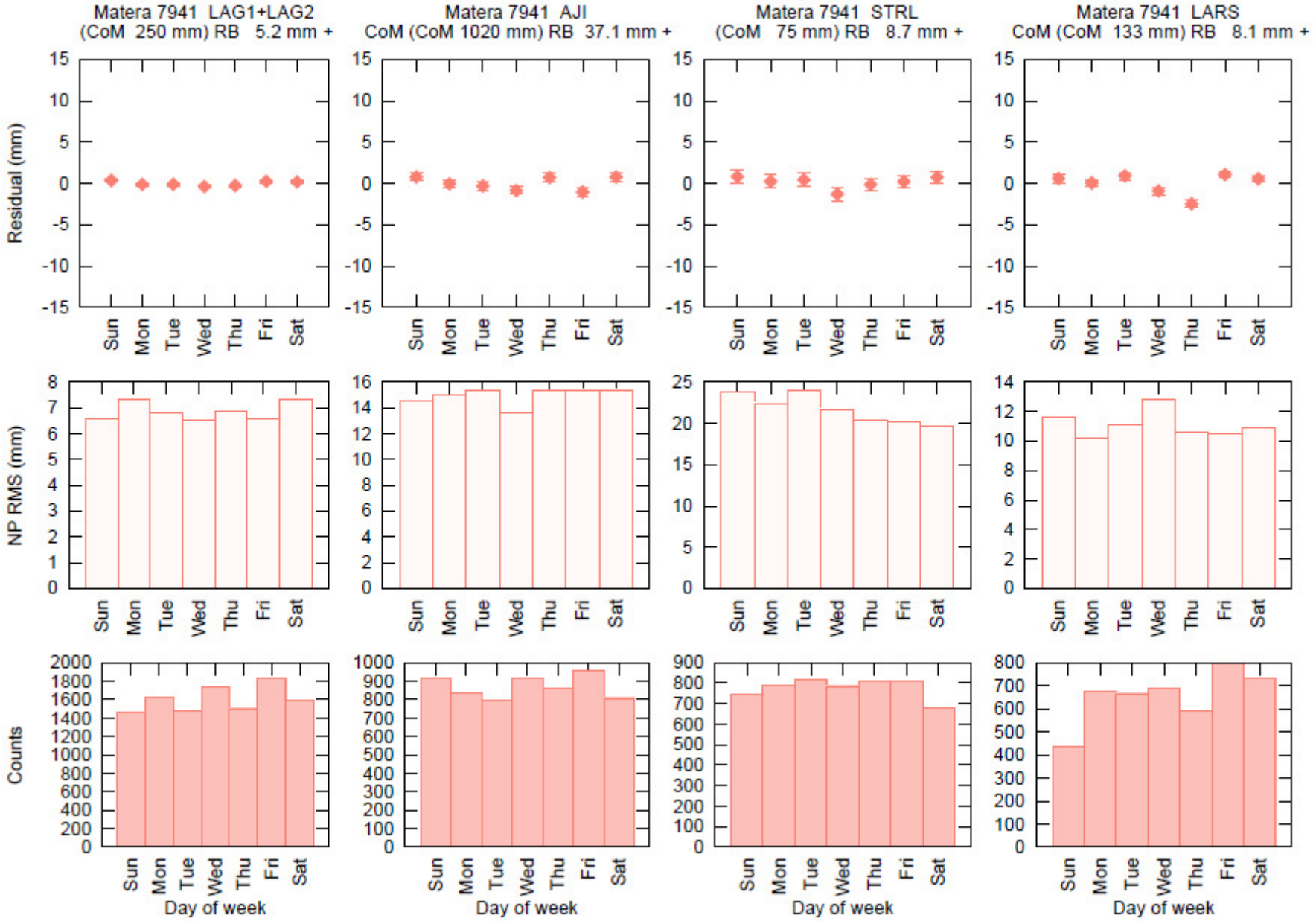
Possible false alarm/caution

- Systematic (regional-dependent) variation remains esp in LEO.
- Easily affected by other station’s time bias.
- Time resolution is poor: one-year average.

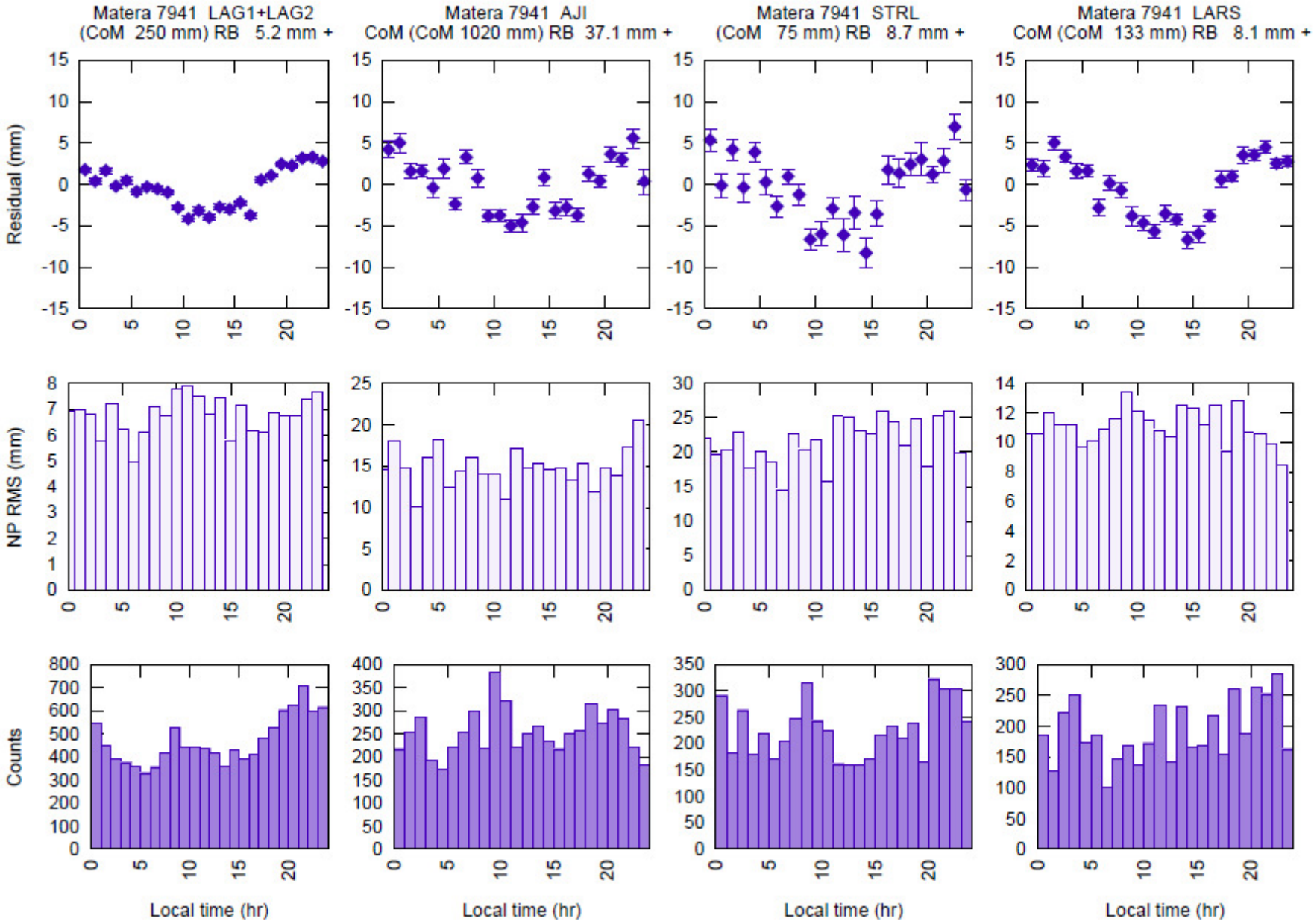
#6: Month


Matera 7941 LAG1+LAG2
(CoM 250 mm) RB 5.2 mm +
Matera 7941 AJI
CoM (CoM 1020 mm) RB 37.1 mm +
Matera 7941 STRL
(CoM 75 mm) RB 8.7 mm +
Matera 7941 LARS
CoM (CoM 133 mm) RB 8.1 mm +
Residual (mm)
NP RMS (mm)
Counts
Month (2014-2015)
Month (2014-2015)
Month (2014-2015)
Month (2014-2015)

#7: Day of week


Matera 7941 LAG1+LAG2
(CoM 250 mm) RB 5.2 mm +
Matera 7941 AJI
CoM (CoM 1020 mm) RB 37.1 mm +
Matera 7941 STRL
(CoM 75 mm) RB 8.7 mm +
Matera 7941 LARS
CoM (CoM 133 mm) RB 8.1 mm +
Residual (mm)
NP RMS (mm)
Counts
Sun Mon Tue Wed Thu Fri Sat
Day of week

#8: Local time


Matera 7941 LAG1+LAG2
(CoM 250 mm) RB 5.2 mm +
Matera 7941 AJI
CoM (CoM 1020 mm) RB 37.1 mm +
Matera 7941 STRL
(CoM 75 mm) RB 8.7 mm +
Matera 7941 LARS
CoM (CoM 133 mm) RB 8.1 mm +
Residual (mm)
NP RMS (mm)
Counts
Local time (hr)
Local time (hr)
Local time (hr)
Local time (hr)

Test #6:
Month

Test #7:
Day of week

Test #8:
Local time

Long-term to short-term variation.
Observers' shift, etc.
Daytime/nighttime configuration.

Discussion

Test #6:
Month

Test #7:
Day of week

Test #8:
Local time

Long-term to short-term periodic variation

- **Quantity & Quality should be stable.**

Day/Night bias?

- **Different ranging configuration (filter, detector, cal.)?**

Possible false alarm

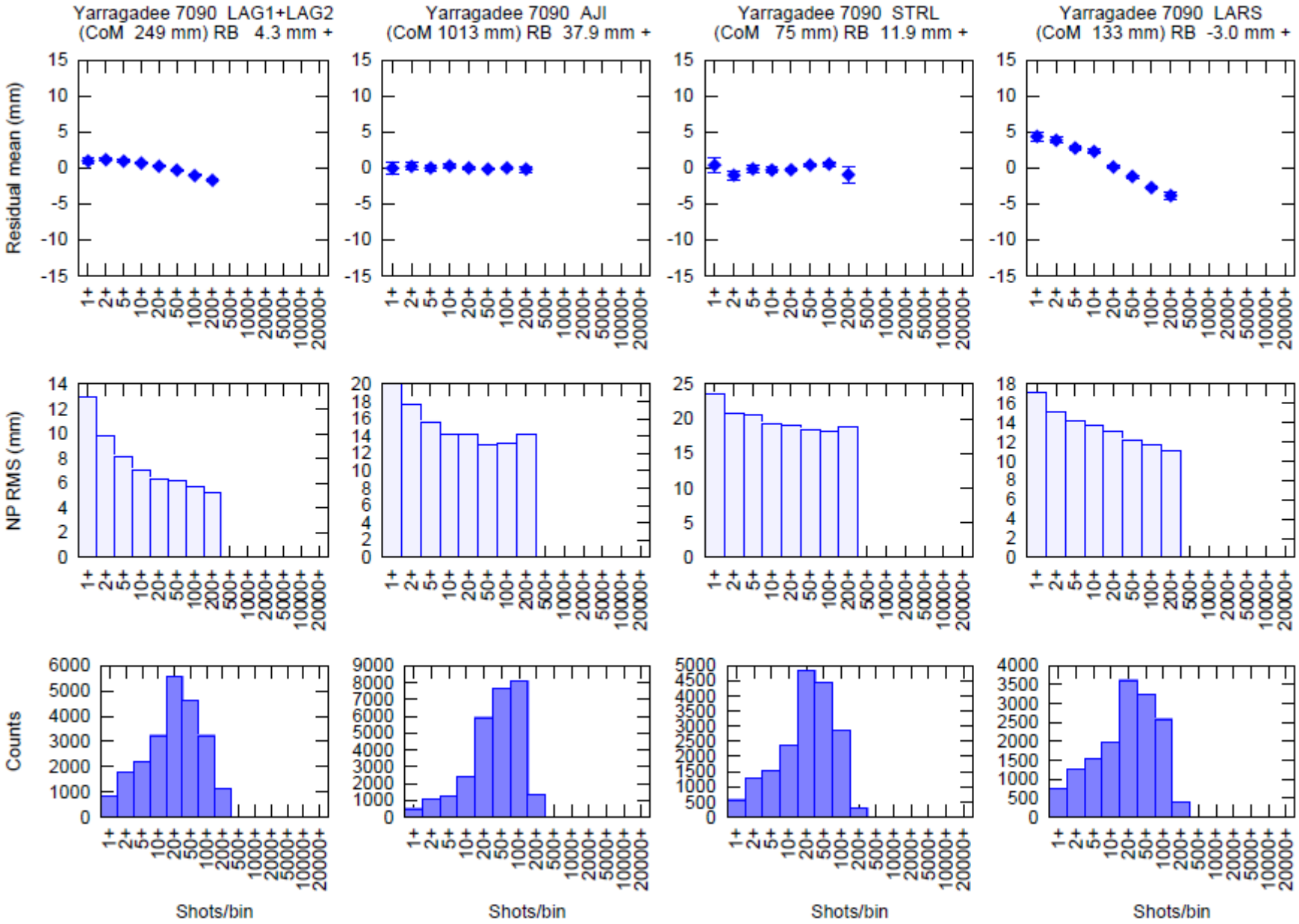
- **Correlated with long-term station coordinates variation.**
- **Correlated with calibration variation.**

Site Information		Data Volume					
Column 1	2	3	4	5	6	7	
Location	Station Number	LEO pass Tot	LAGEOS pass Tot	High pass Tot	Total passes	LEO NP Total	LAGE NP T
Baseline		1000	400	100	1500		
Yarragadee	7090	14253	2782	7275	24310	270567	23
Changchun	7237	9834	1234	6452	17520	83312	6
Mount_Stromlo_2	7825	7223	1458	3679	12360	105658	13
Greenbelt	7105	5756	1108	1602	8466	112001	10
Matera_MLRO	7941	3590	1456	3177	8223	41470	12
Herstmonceux	7840	3795	835	3016	7646	51367	7
Monument_Peak	7110	4975	906	1280	7161	92166	7
Zimmerwald_532	7810	3872	674	2411	6957	64433	8
Graz	7839	3550	609	2686	6845	66392	3
Wettzell	8834	2824	308	2160	5292	25684	2

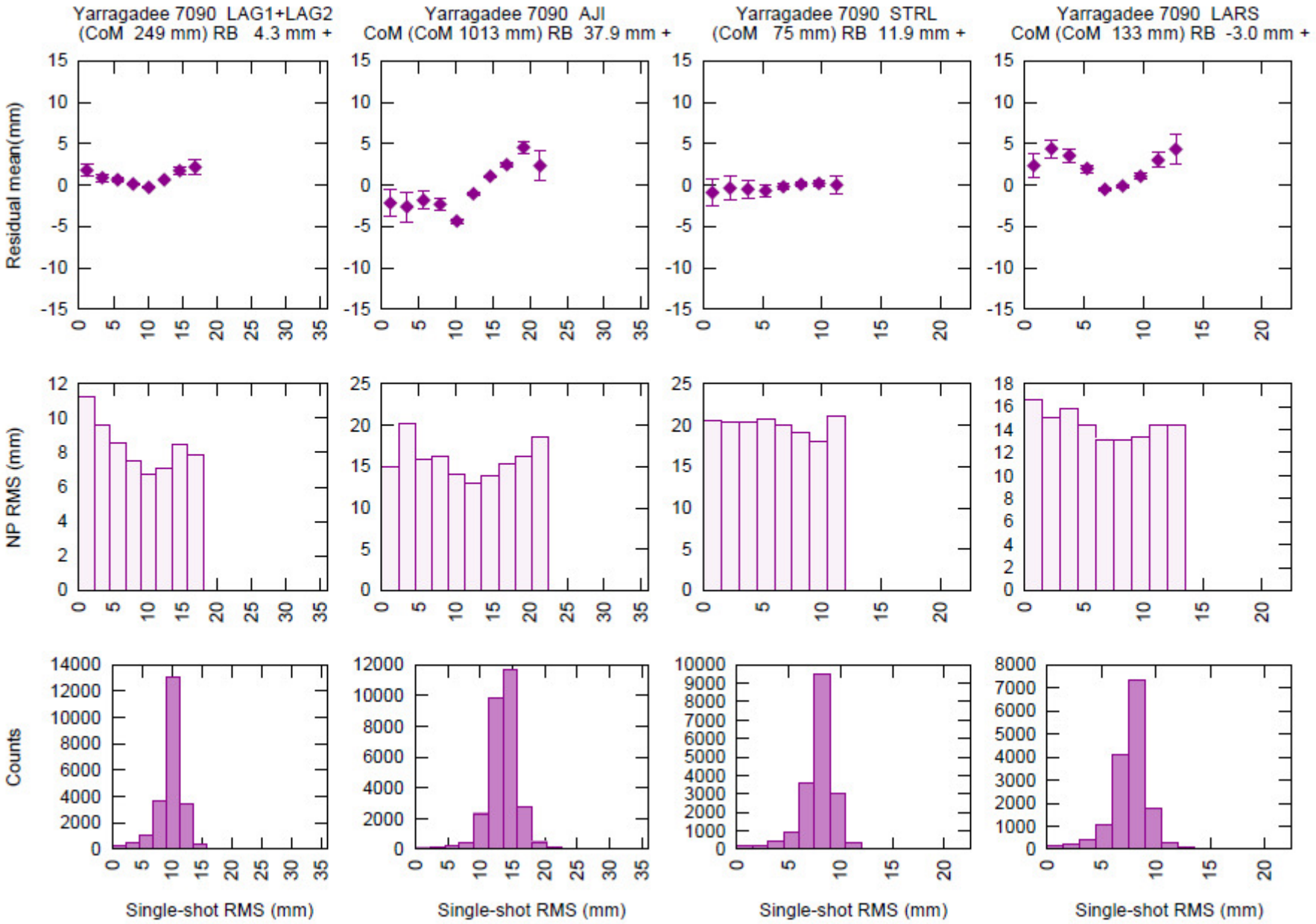
SLR Global Performance Report Card (2015 Q3)

7090

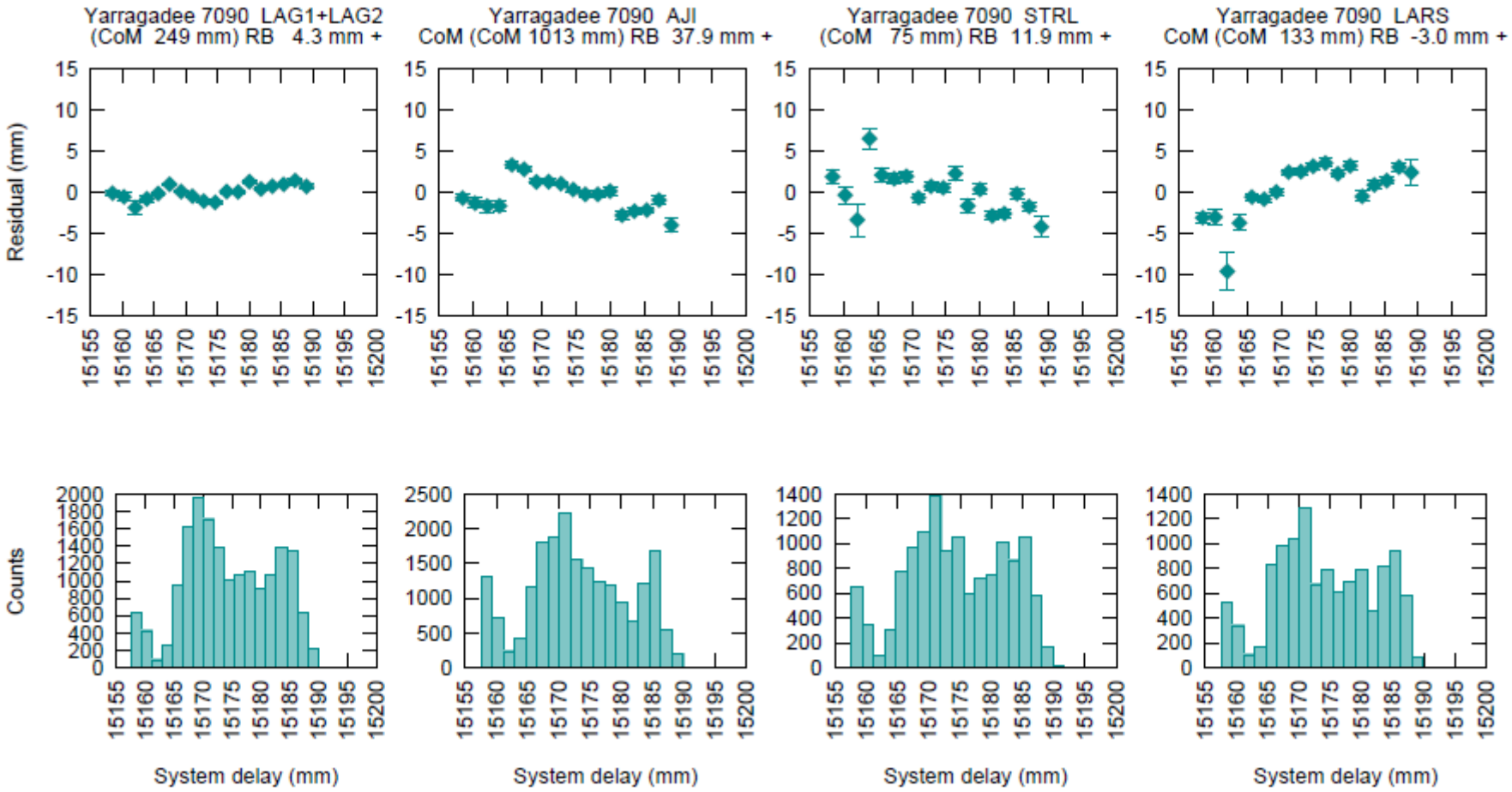
#1: Single-shot returns



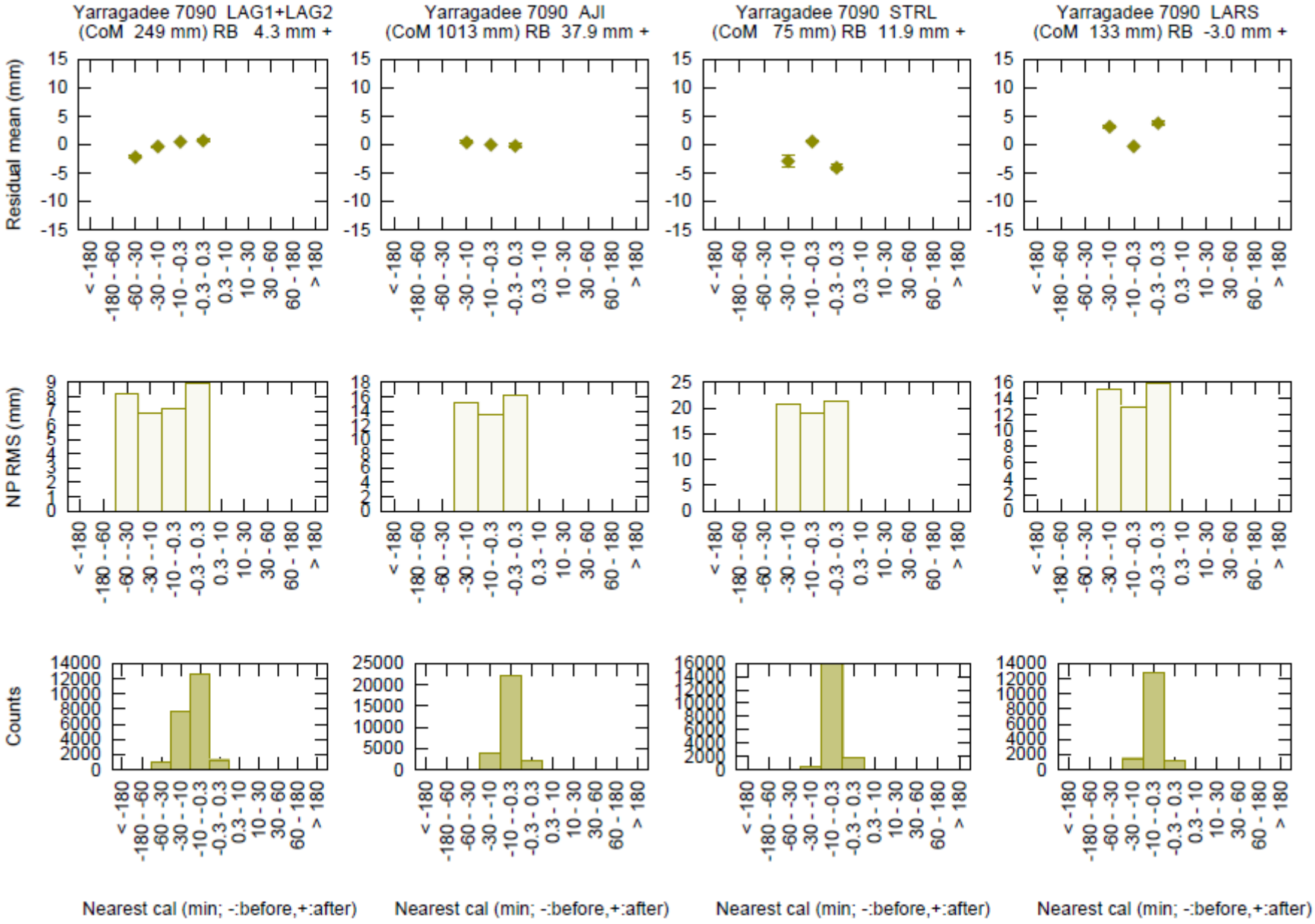
#2: Single-shot RMS



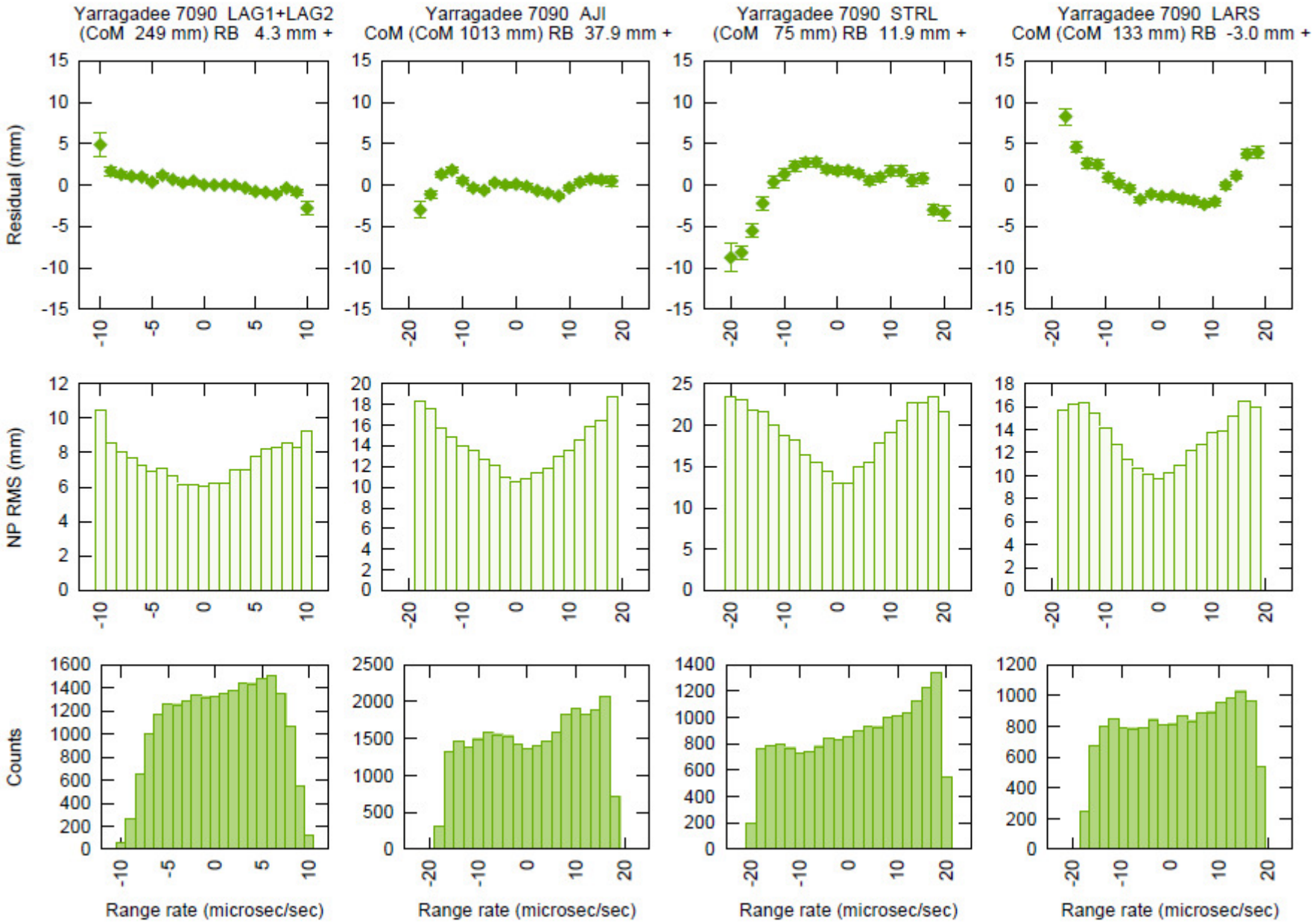
#3: System delay



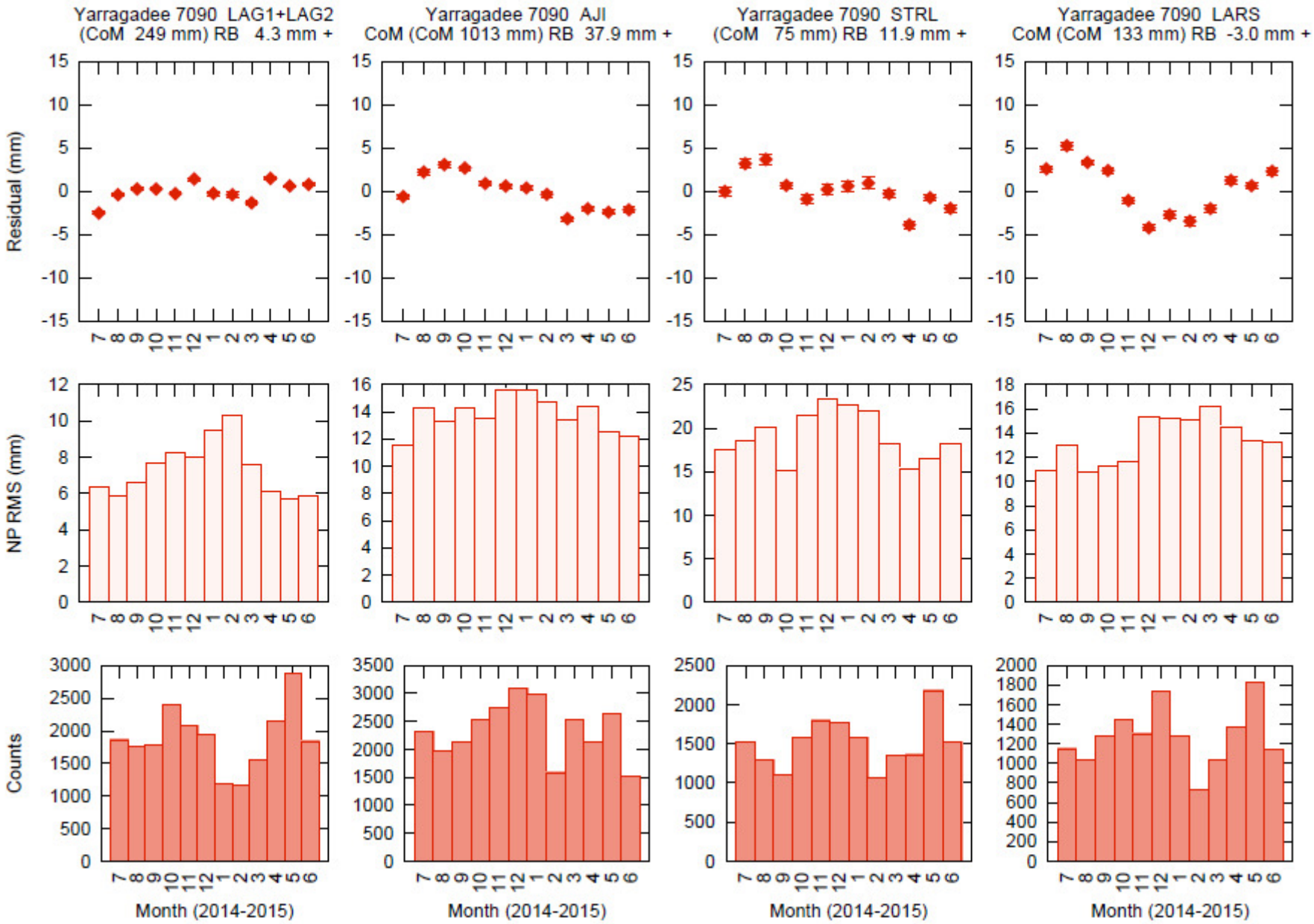
#4: Time to the nearest cal.



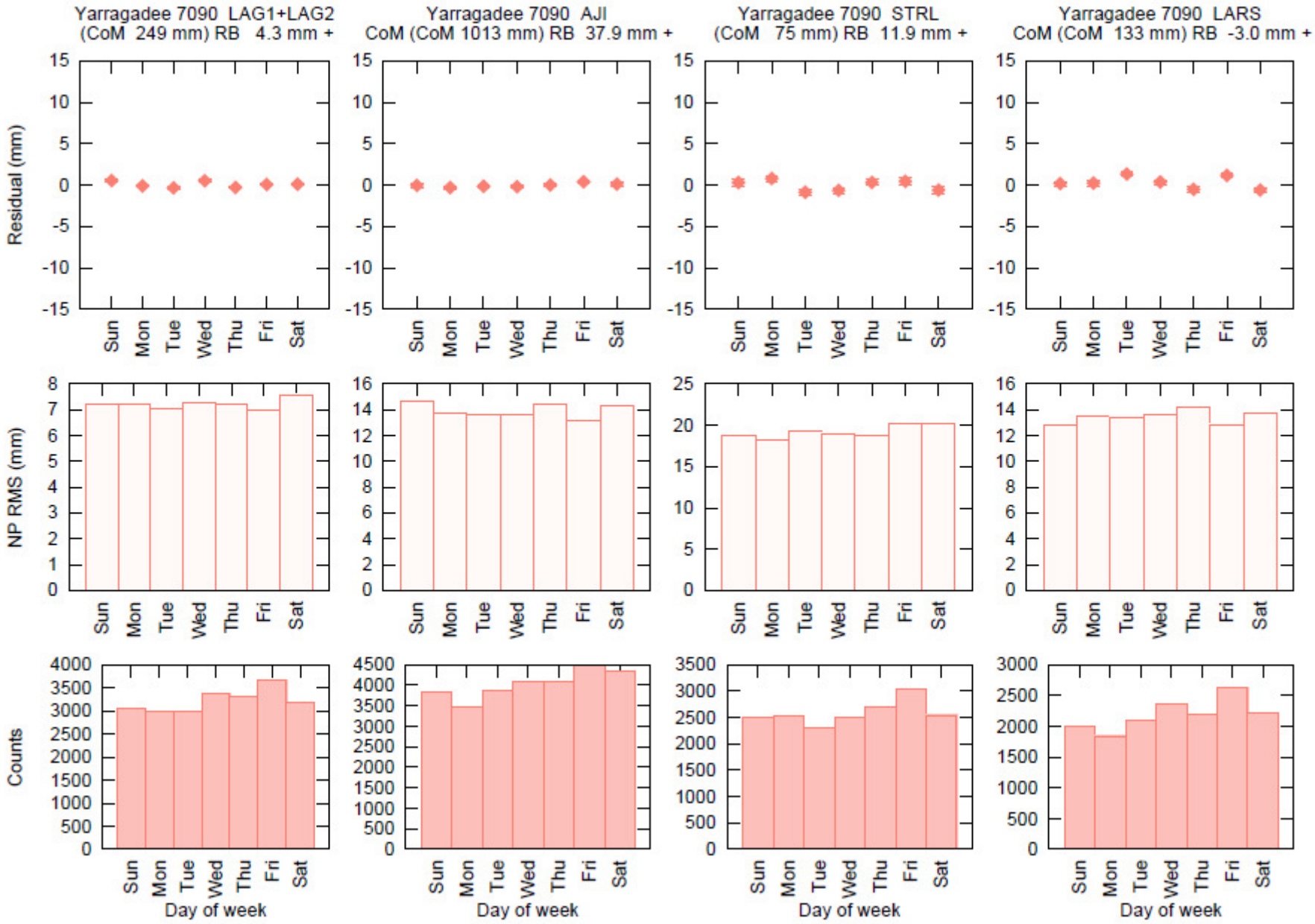
#5: Range rate


Yarragadee 7090 LAG1+LAG2
(CoM 249 mm) RB 4.3 mm +
Yarragadee 7090 AJI
CoM (CoM 1013 mm) RB 37.9 mm +
Yarragadee 7090 STRL
(CoM 75 mm) RB 11.9 mm +
Yarragadee 7090 LARS
CoM (CoM 133 mm) RB -3.0 mm +
Residual (mm)
NP RMS (mm)
Counts
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)

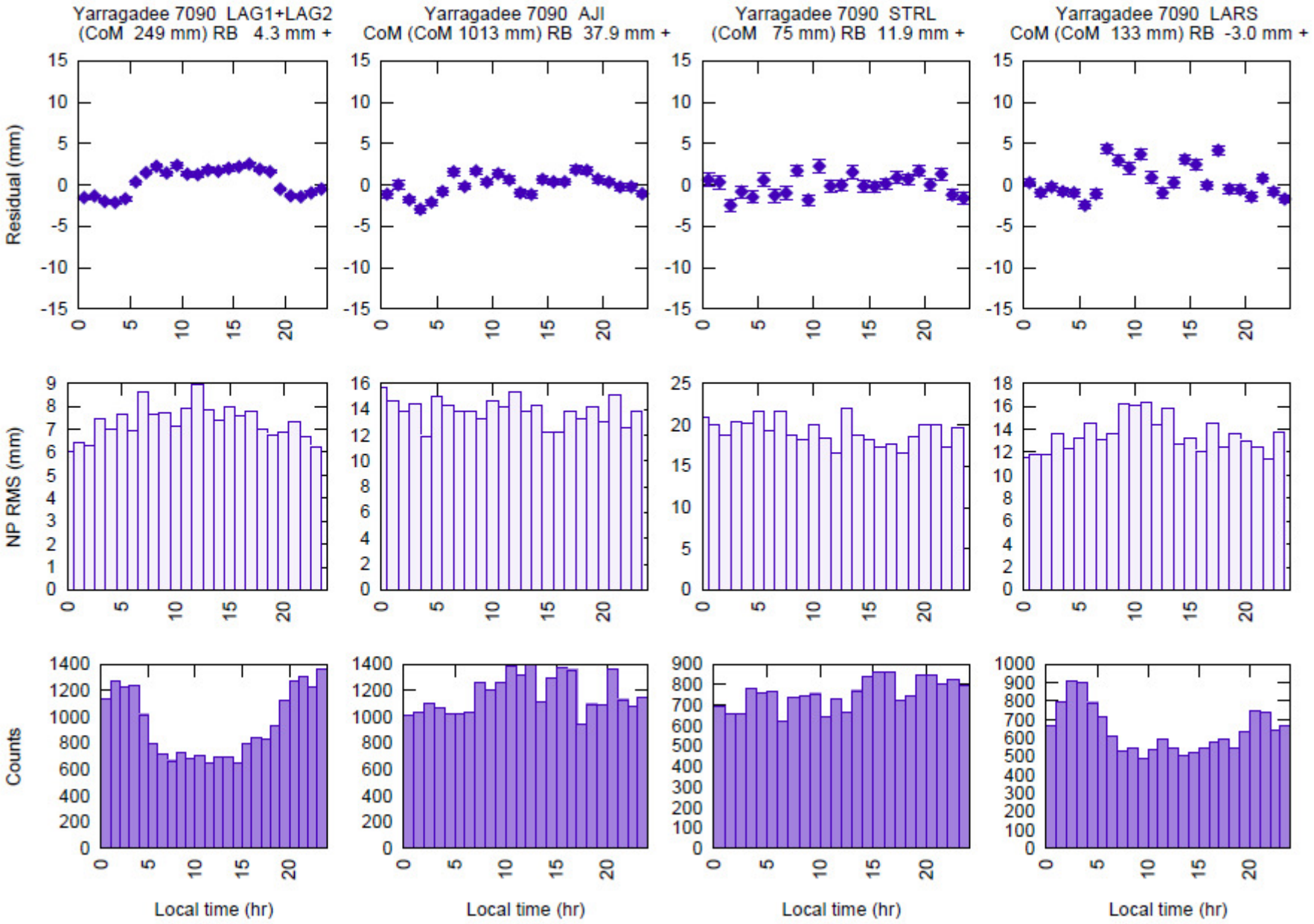
#6: Month


Yarragadee 7090 LAG1+LAG2
(CoM 249 mm) RB 4.3 mm +
Yarragadee 7090 AJI
CoM (CoM 1013 mm) RB 37.9 mm +
Yarragadee 7090 STRL
(CoM 75 mm) RB 11.9 mm +
Yarragadee 7090 LARS
CoM (CoM 133 mm) RB -3.0 mm +
Residual (mm)
NP RMS (mm)
Counts
Month (2014-2015)
Month (2014-2015)
Month (2014-2015)
Month (2014-2015)

#7: Day of week

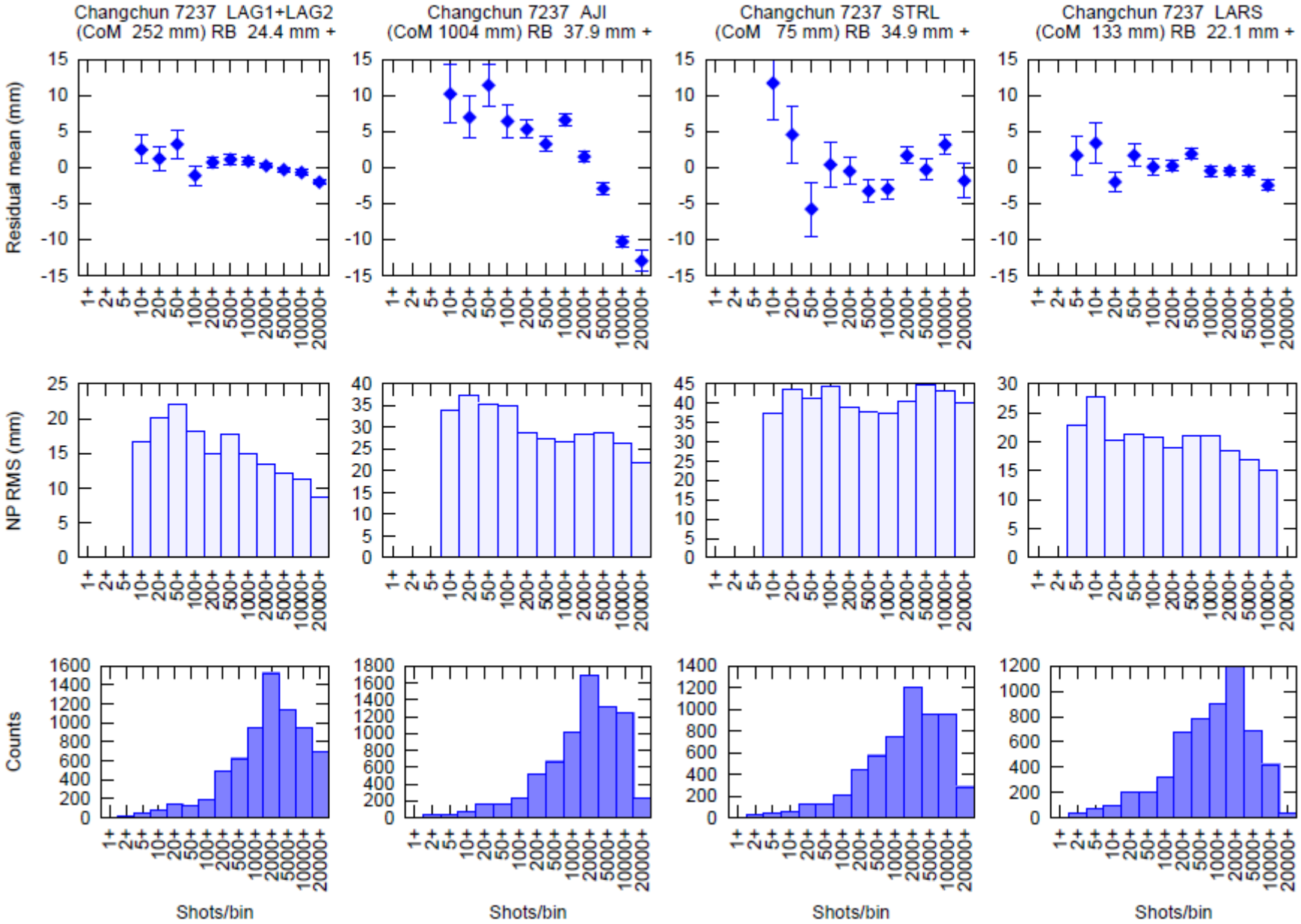

Yarragadee 7090 LAG1+LAG2
(CoM 249 mm) RB 4.3 mm +
Yarragadee 7090 AJI
CoM (CoM 1013 mm) RB 37.9 mm +
Yarragadee 7090 STRL
(CoM 75 mm) RB 11.9 mm +
Yarragadee 7090 LARS
CoM (CoM 133 mm) RB -3.0 mm +
Residual (mm)
NP RMS (mm)
Counts
Sun Mon Tue Wed Thu Fri Sat
Day of week

#8: Local time

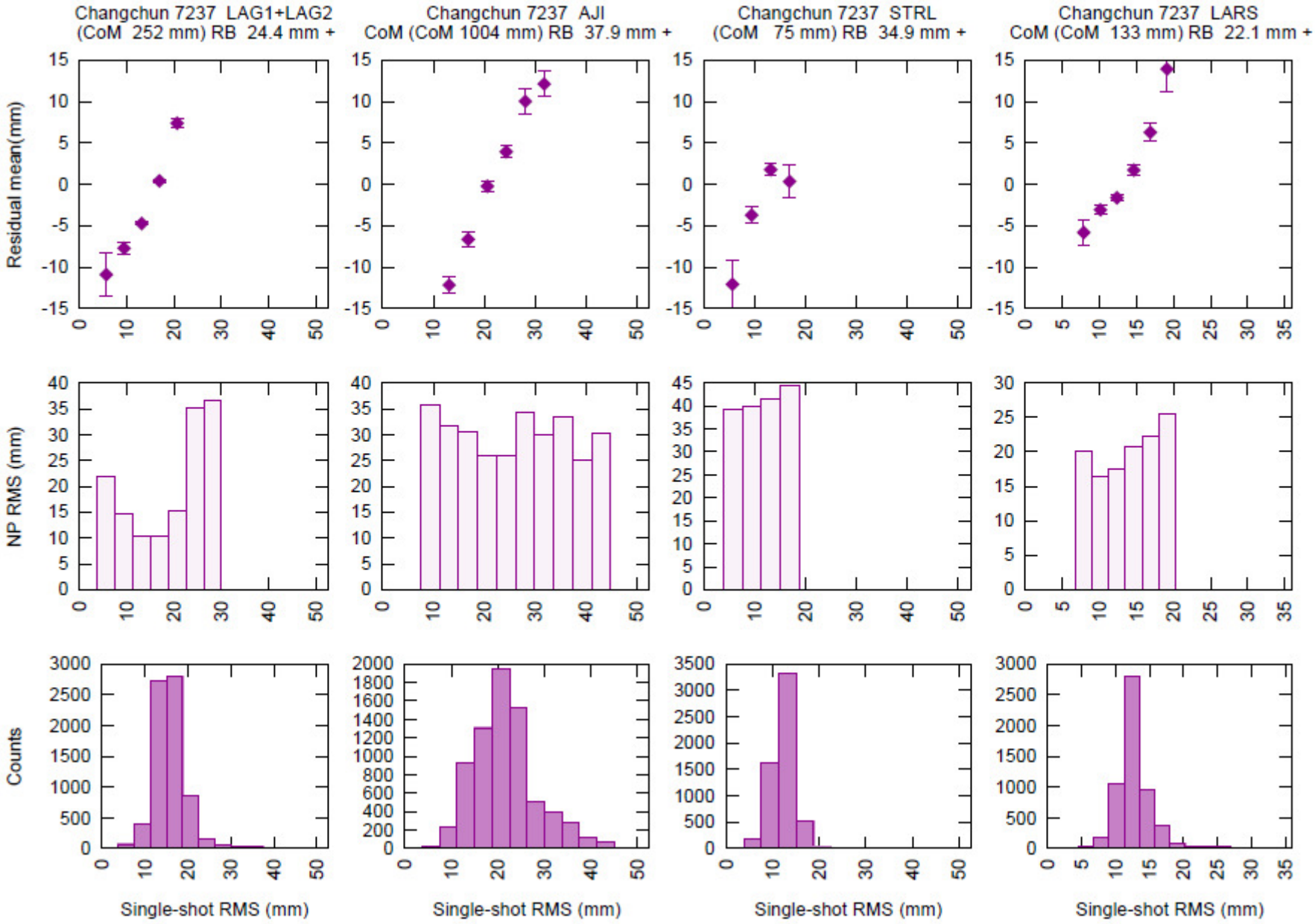

Yarragadee 7090 LAG1+LAG2
(CoM 249 mm) RB 4.3 mm +
Yarragadee 7090 AJI
CoM (CoM 1013 mm) RB 37.9 mm +
Yarragadee 7090 STRL
(CoM 75 mm) RB 11.9 mm +
Yarragadee 7090 LARS
CoM (CoM 133 mm) RB -3.0 mm +
Residual (mm)
NP RMS (mm)
Counts
Local time (hr)
Local time (hr)
Local time (hr)
Local time (hr)

7237

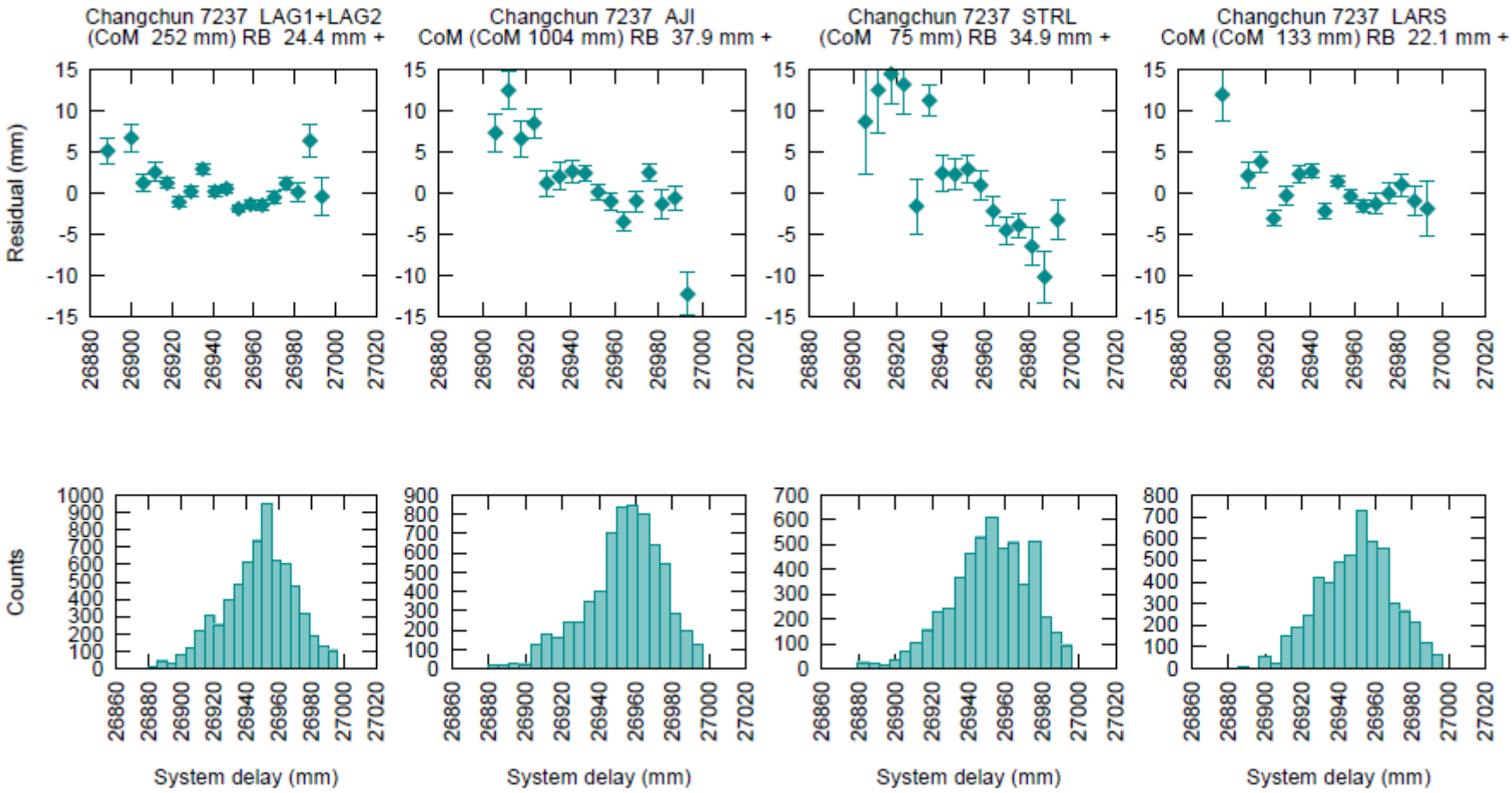
#1: Single-shot returns



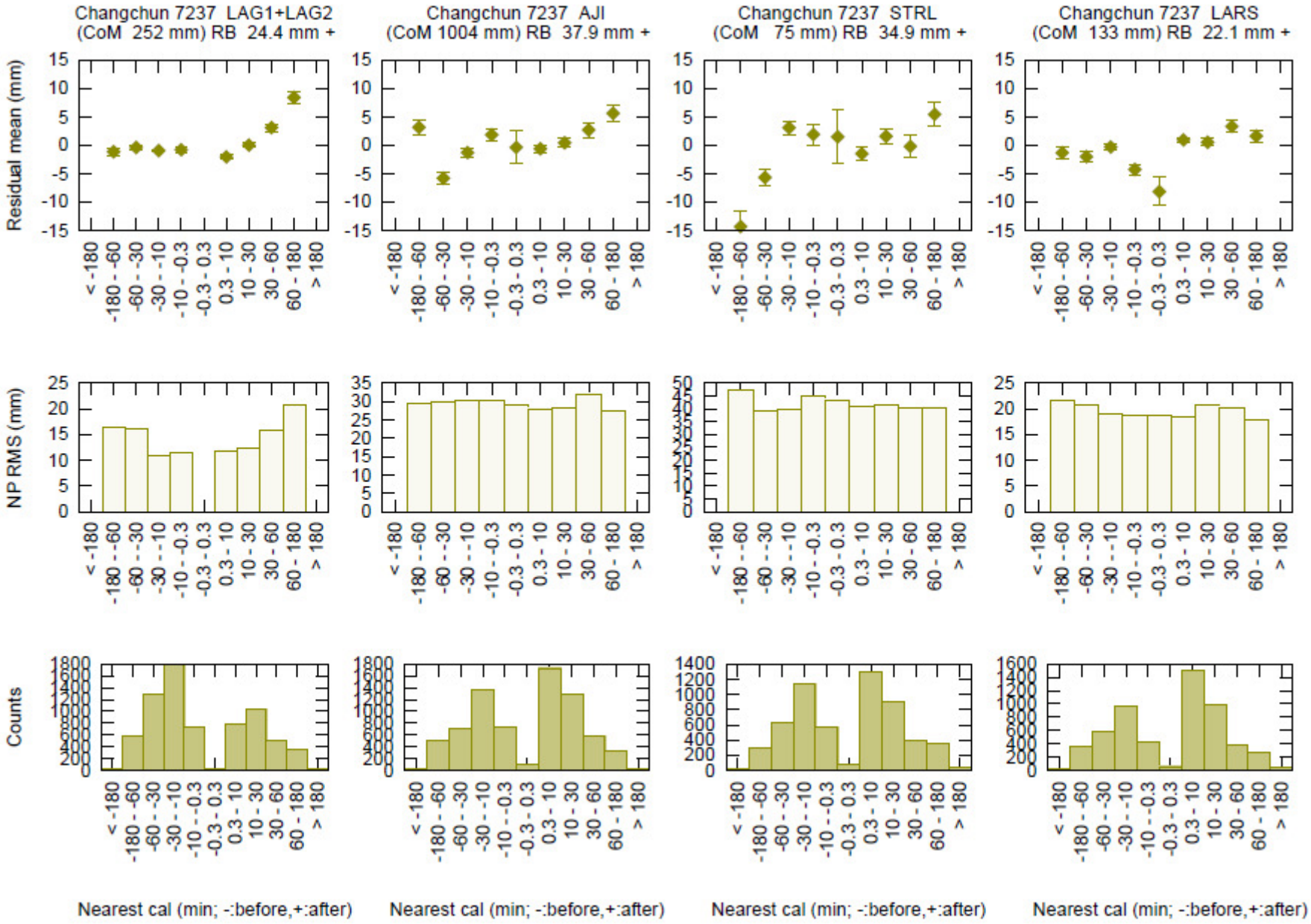
#2: Single-shot RMS



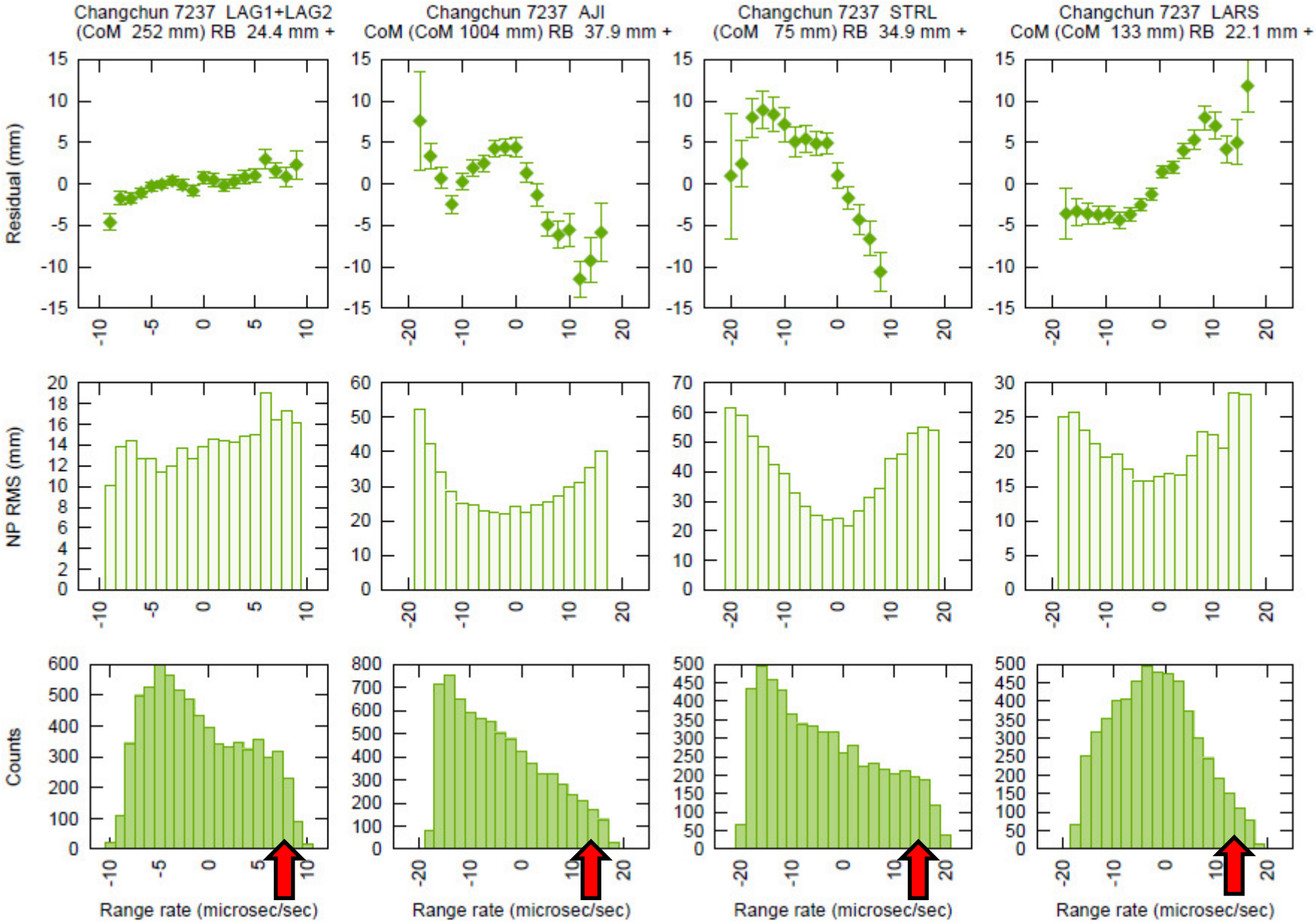
#3: System delay



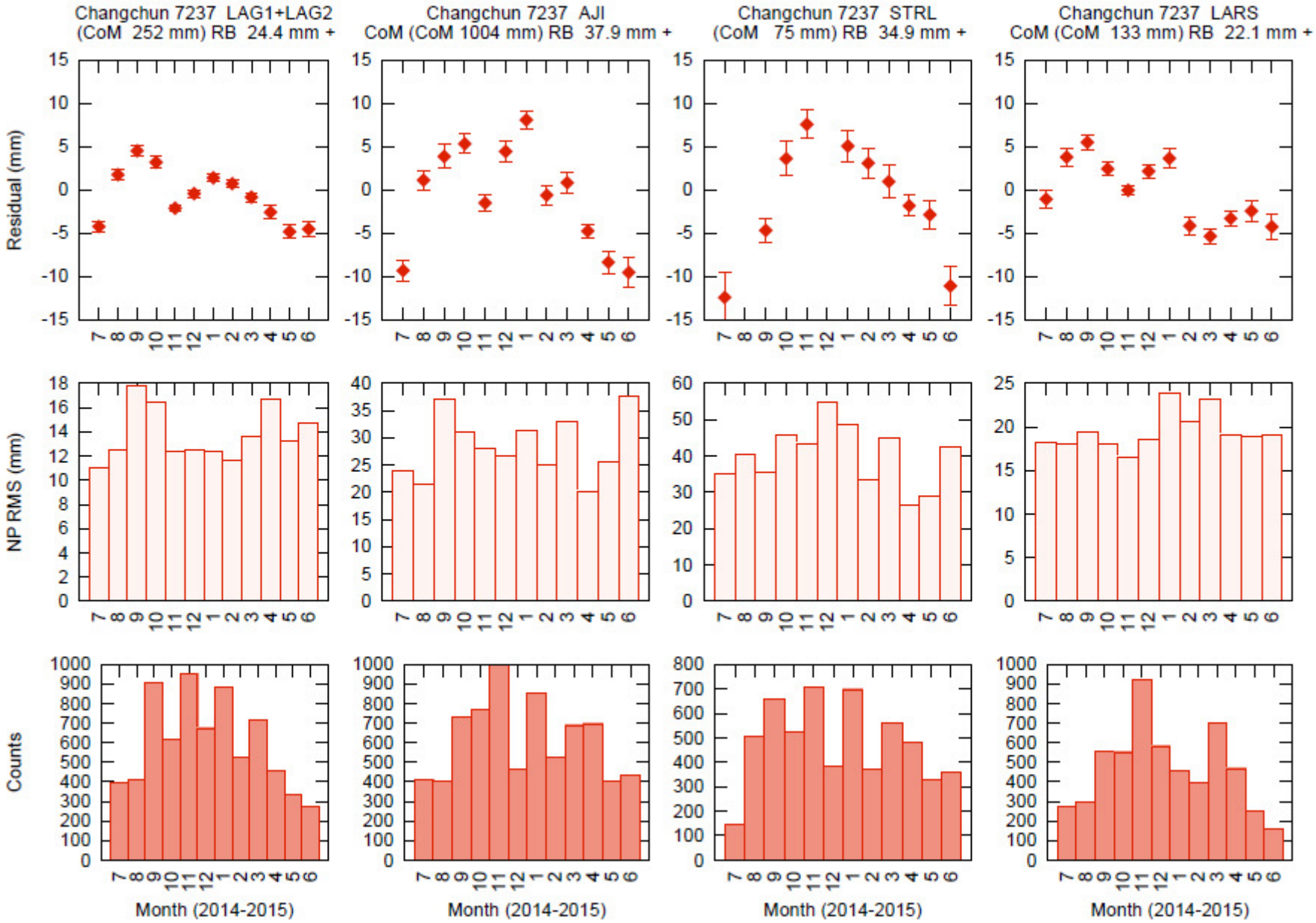
#4: Time to the nearest cal.



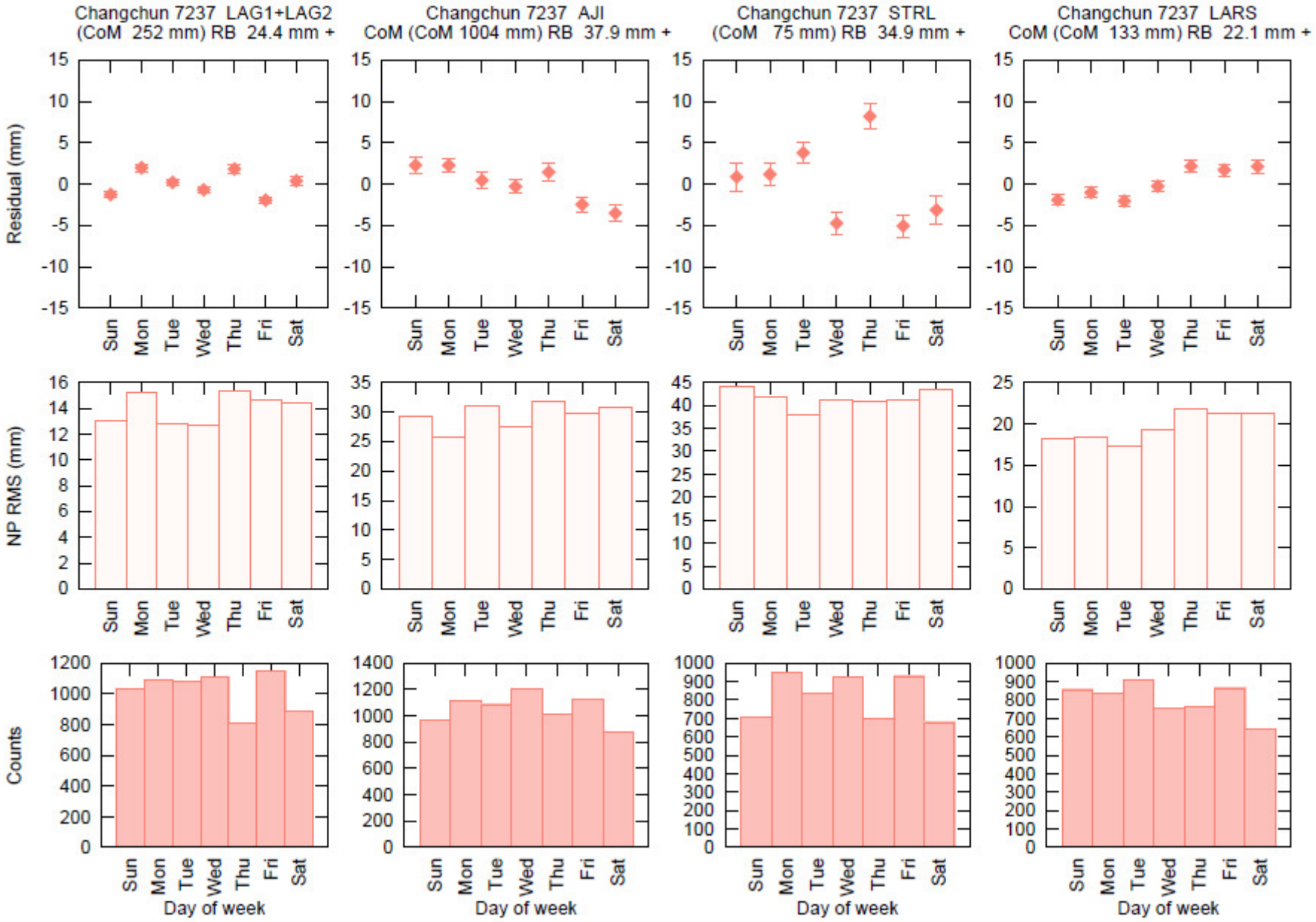
#5: Range rate


Changchun 7237 LAG1+LAG2
(CoM 252 mm) RB 24.4 mm +
Changchun 7237 AJI
CoM (CoM 1004 mm) RB 37.9 mm +
Changchun 7237 STRL
(CoM 75 mm) RB 34.9 mm +
Changchun 7237 LARS
CoM (CoM 133 mm) RB 22.1 mm +
Residual (mm)
NP RMS (mm)
Counts
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)

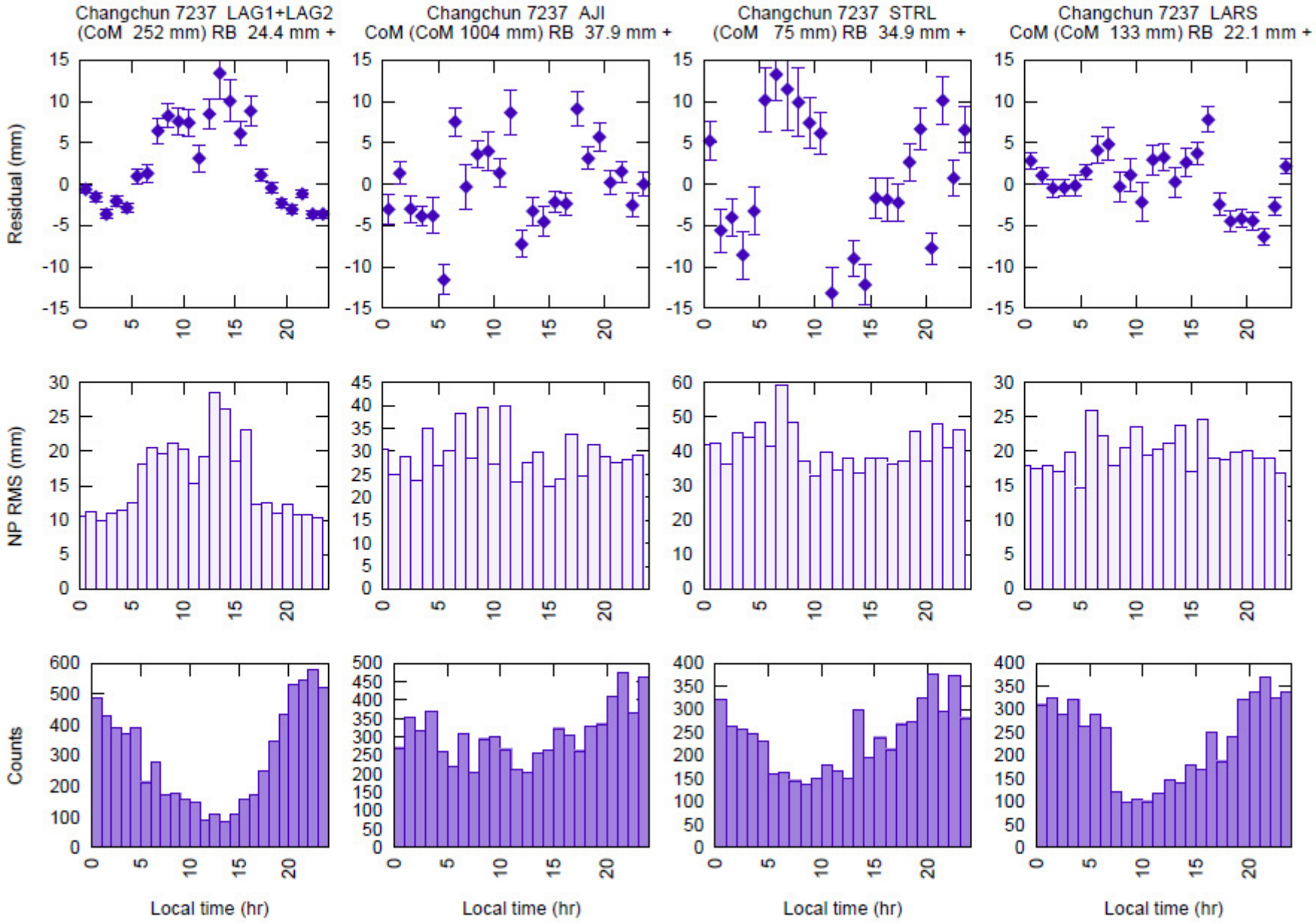
#6: Month


Changchun 7237 LAG1+LAG2
(CoM 252 mm) RB 24.4 mm +
Changchun 7237 AJI
CoM (CoM 1004 mm) RB 37.9 mm +
Changchun 7237 STRL
(CoM 75 mm) RB 34.9 mm +
Changchun 7237 LARS
CoM (CoM 133 mm) RB 22.1 mm +
Residual (mm)
NP RMS (mm)
Counts
Month (2014-2015)
Month (2014-2015)
Month (2014-2015)
Month (2014-2015)

#7: Day of week

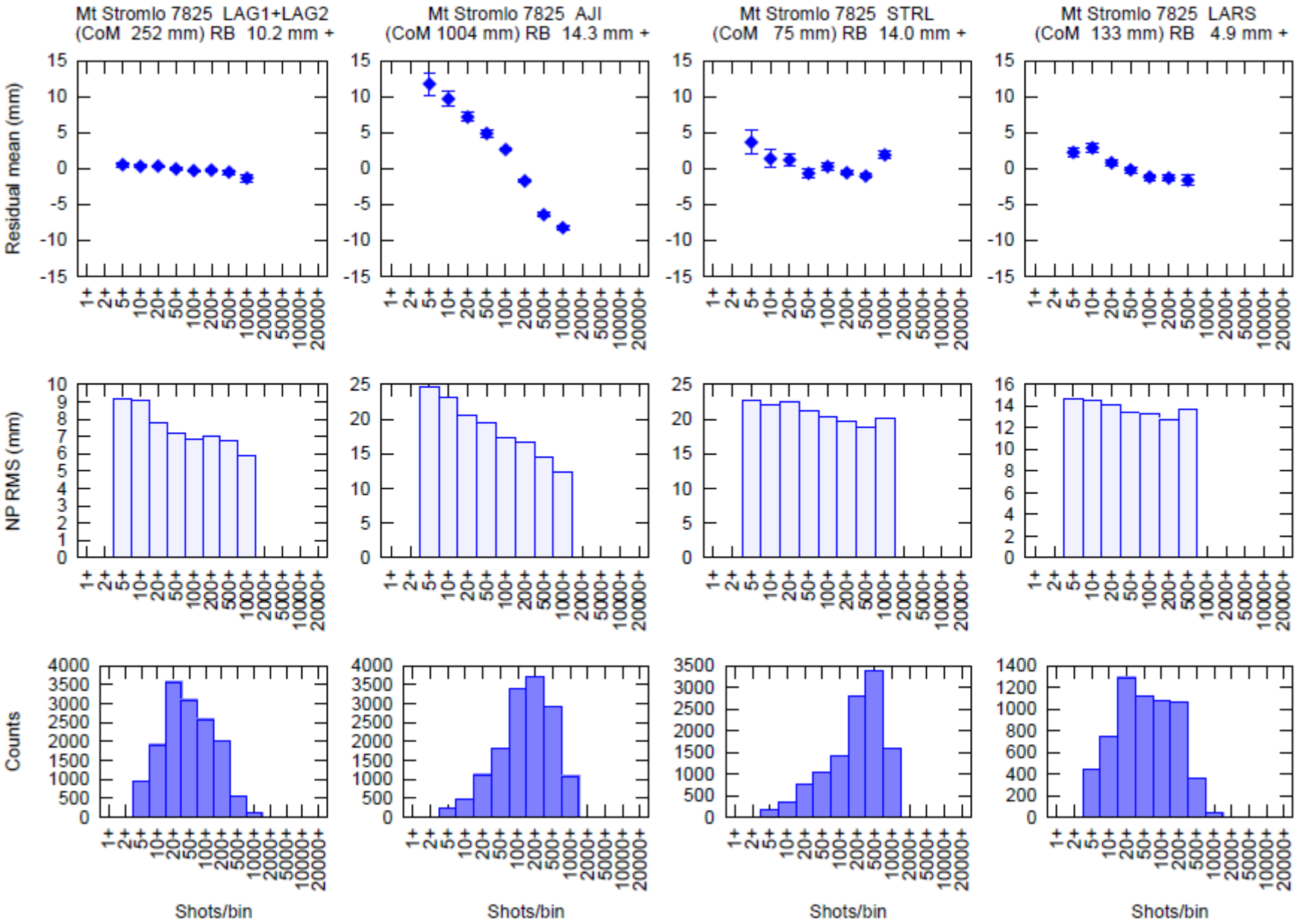

Changchun 7237 LAG1+LAG2
(CoM 252 mm) RB 24.4 mm +
Changchun 7237 AJI
CoM (CoM 1004 mm) RB 37.9 mm +
Changchun 7237 STRL
(CoM 75 mm) RB 34.9 mm +
Changchun 7237 LARS
CoM (CoM 133 mm) RB 22.1 mm +
Residual (mm)
NP RMS (mm)
Counts
Sun Mon Tue Wed Thu Fri Sat
Day of week

#8: Local time

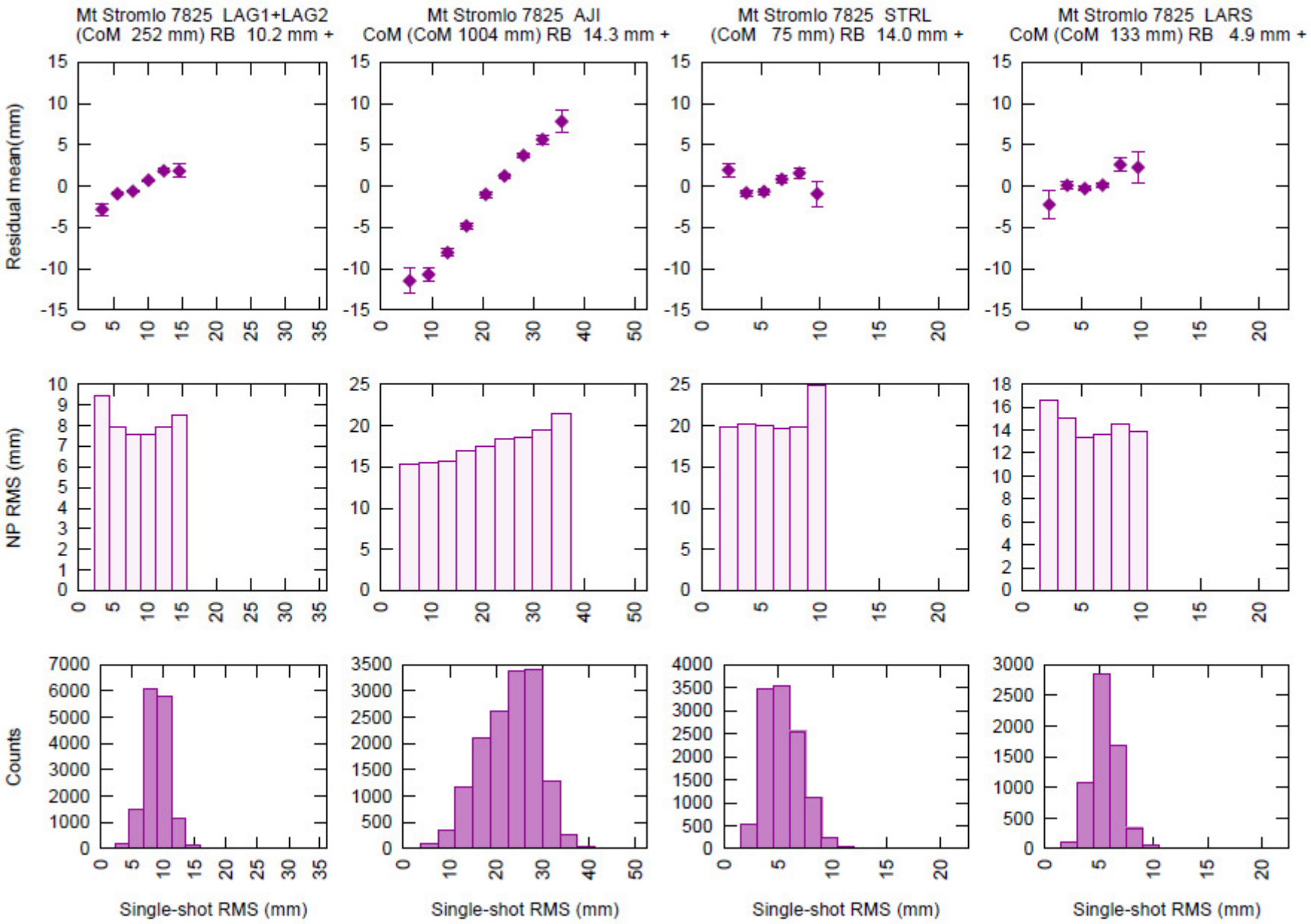

Changchun 7237 LAG1+LAG2
(CoM 252 mm) RB 24.4 mm +
Changchun 7237 AJI
CoM (CoM 1004 mm) RB 37.9 mm +
Changchun 7237 STRL
(CoM 75 mm) RB 34.9 mm +
Changchun 7237 LARS
CoM (CoM 133 mm) RB 22.1 mm +
Residual (mm)
NP RMS (mm)
Counts
Local time (hr)
Local time (hr)
Local time (hr)
Local time (hr)

7825

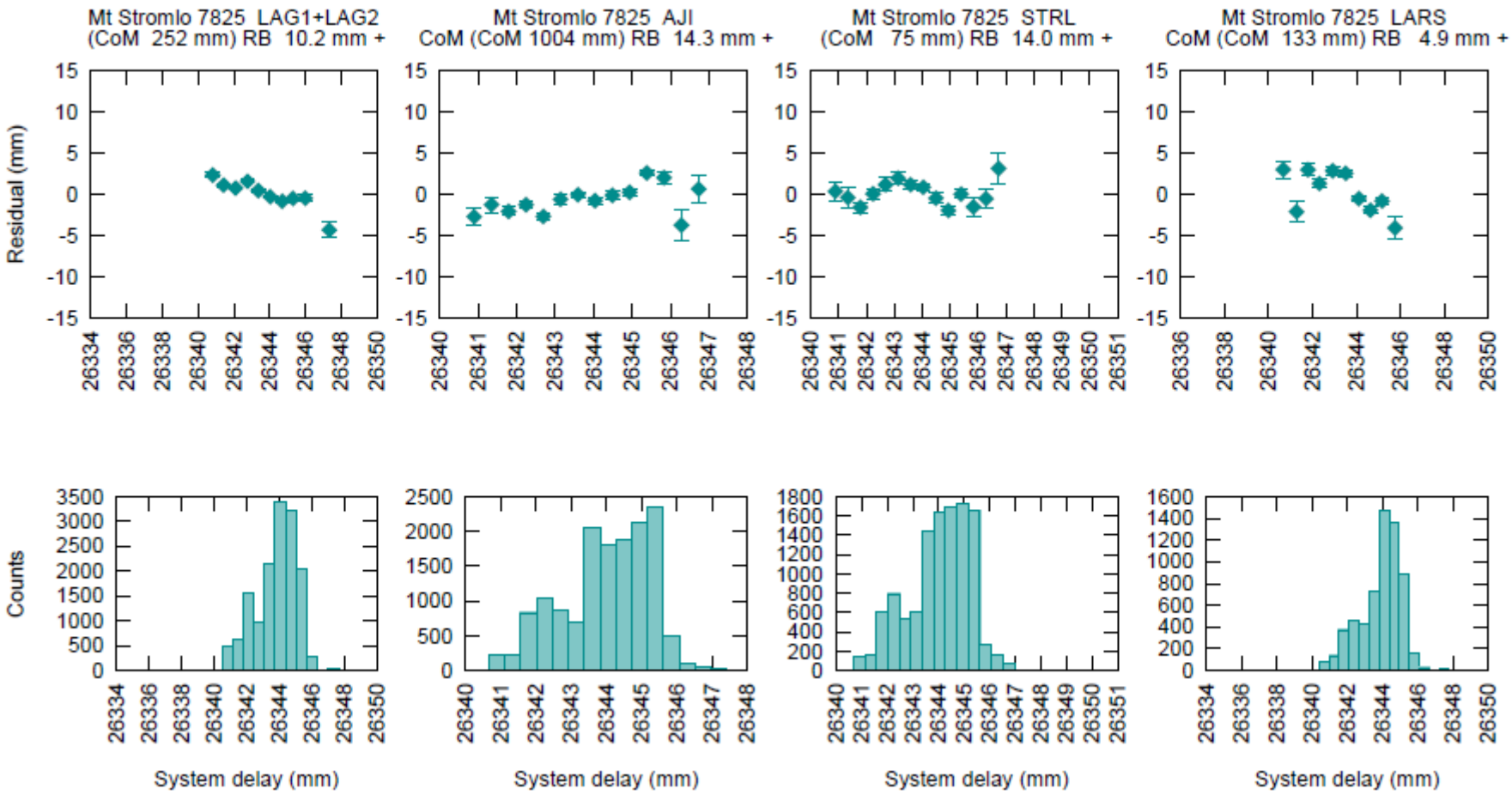
#1: Single-shot returns



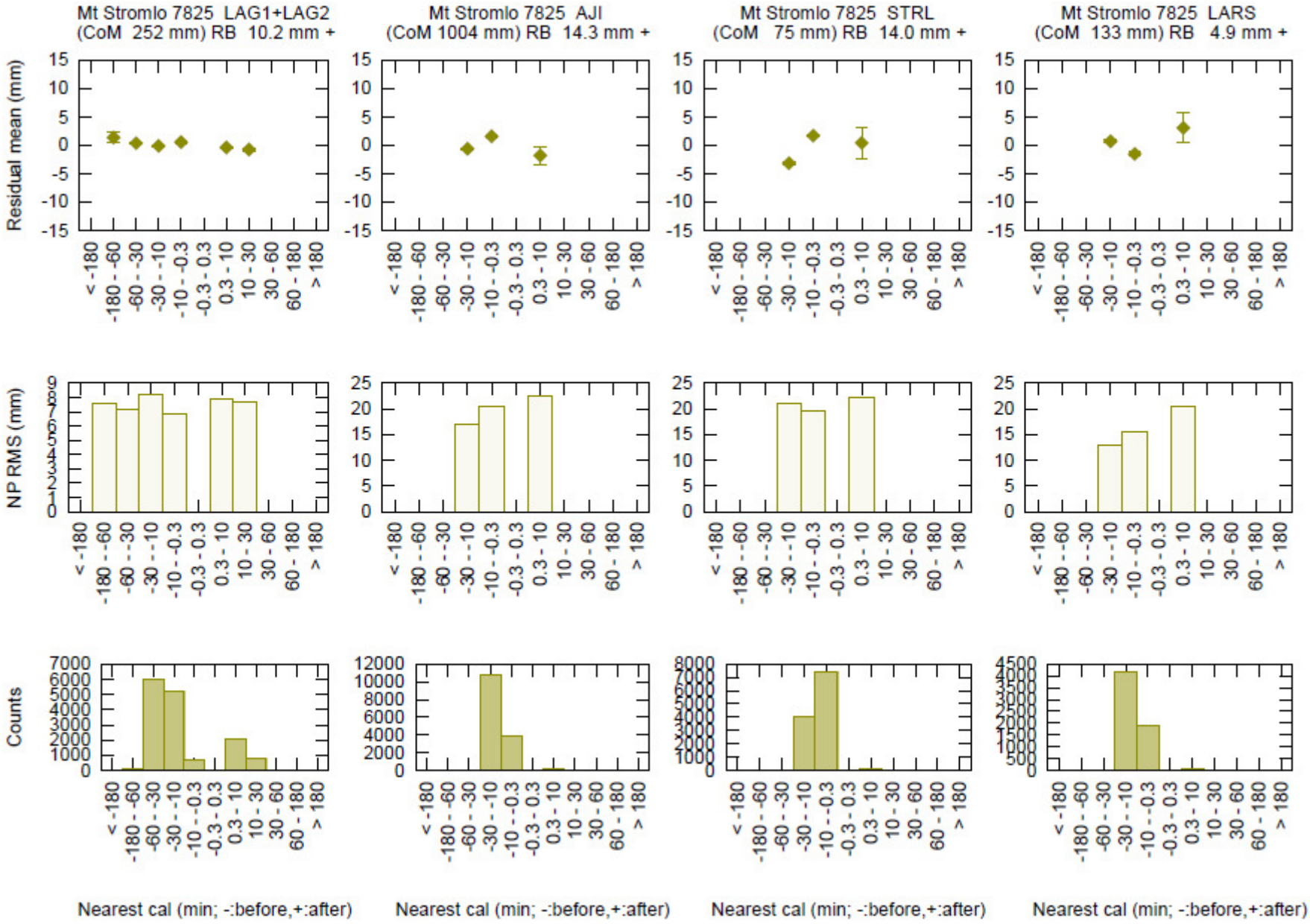
#2: Single-shot RMS



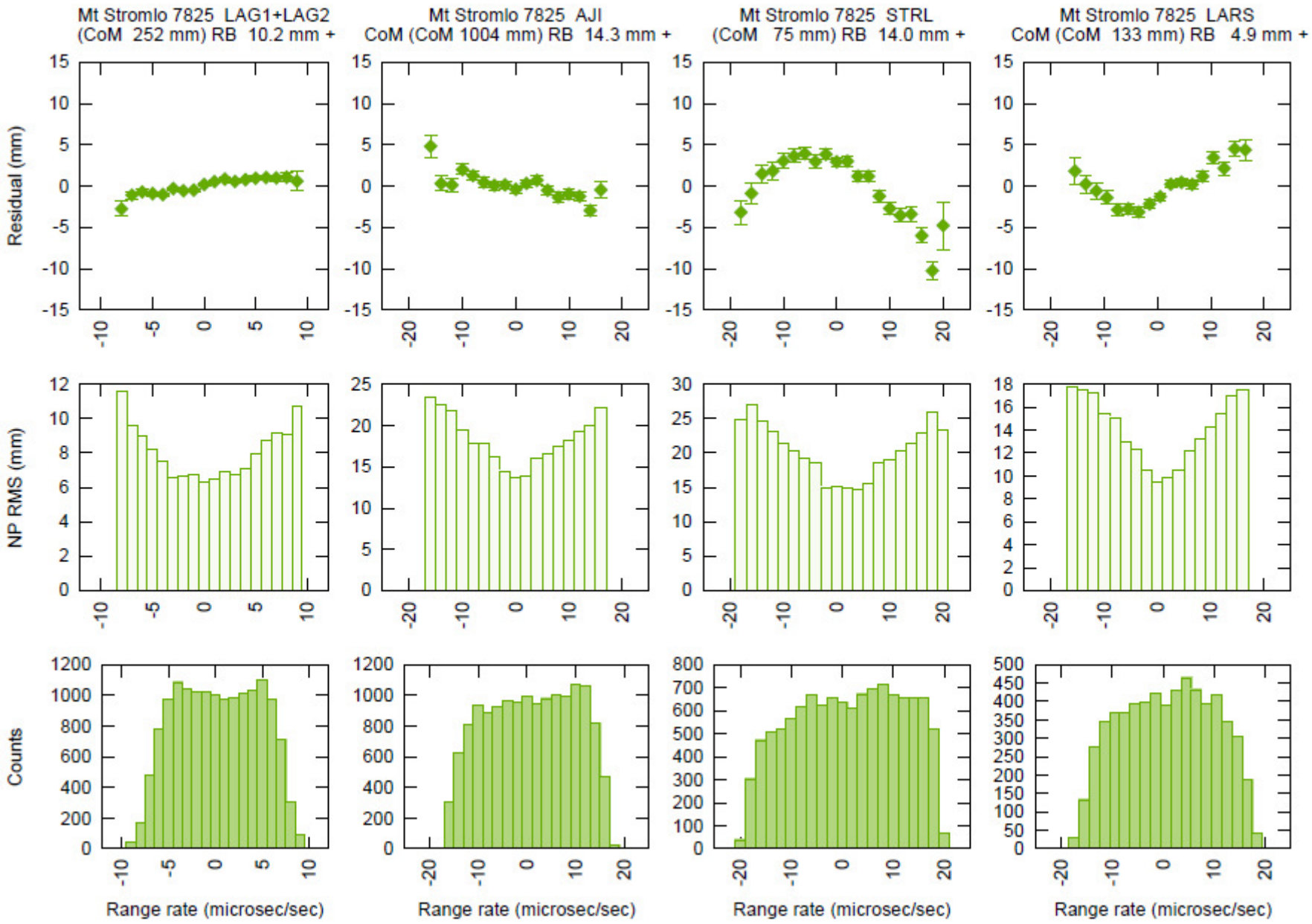
#3: System delay



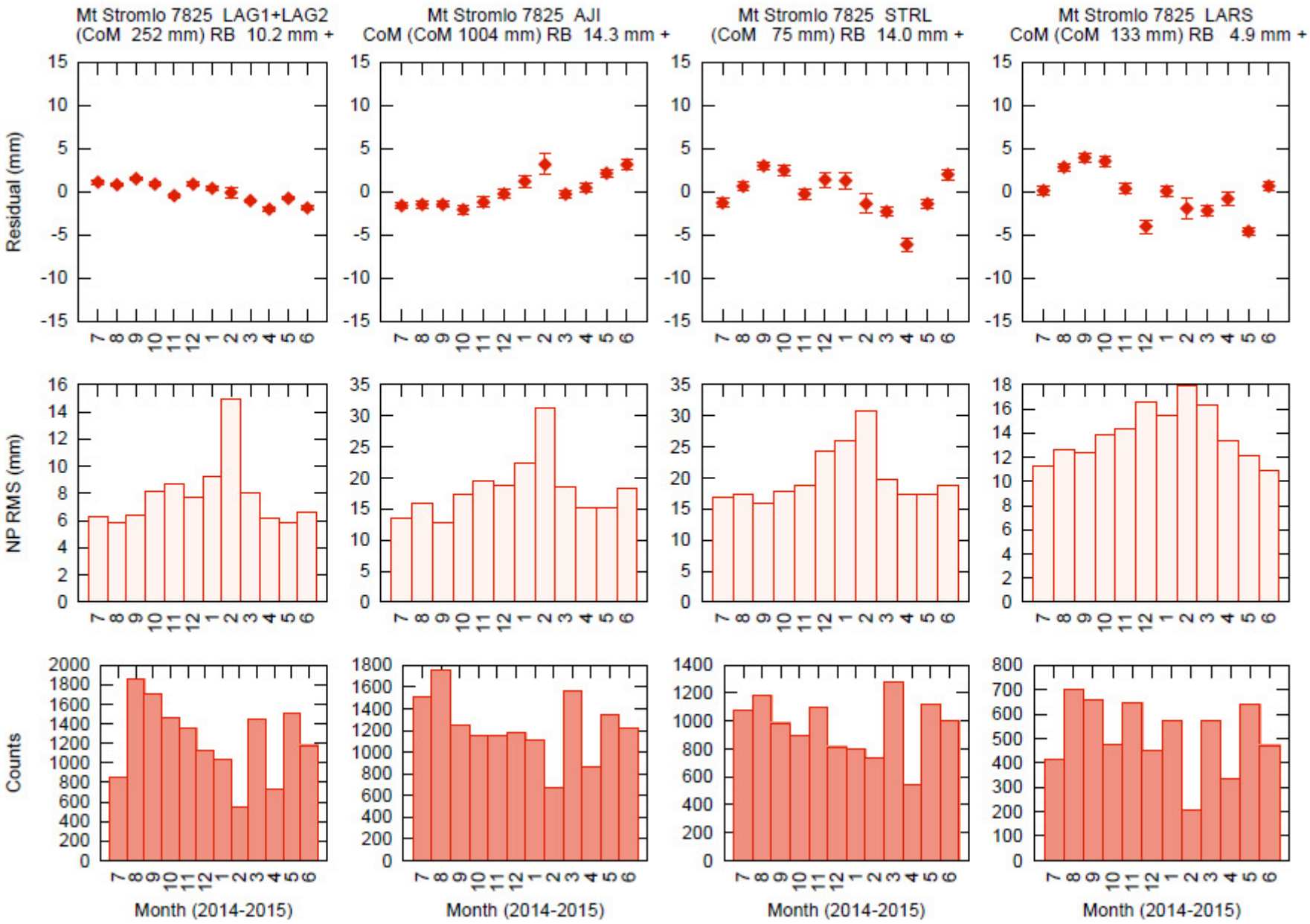
#4: Time to the nearest cal.



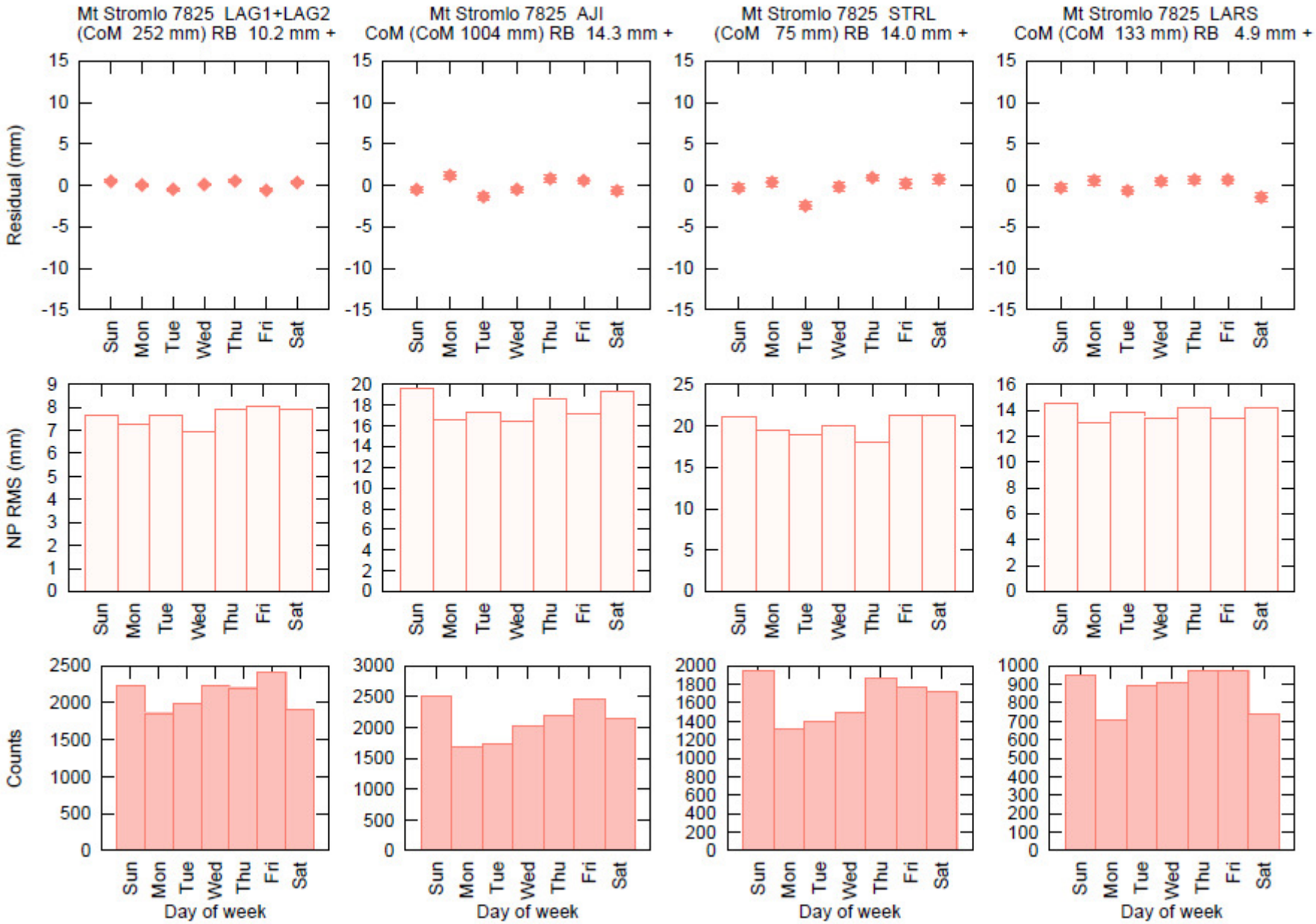
#5: Range rate


Mt Stromlo 7825 LAG1+LAG2
(CoM 252 mm) RB 10.2 mm +
Mt Stromlo 7825 AJI
CoM (CoM 1004 mm) RB 14.3 mm +
Mt Stromlo 7825 STRL
(CoM 75 mm) RB 14.0 mm +
Mt Stromlo 7825 LARS
CoM (CoM 133 mm) RB 4.9 mm +
Residual (mm)
NP RMS (mm)
Counts
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)

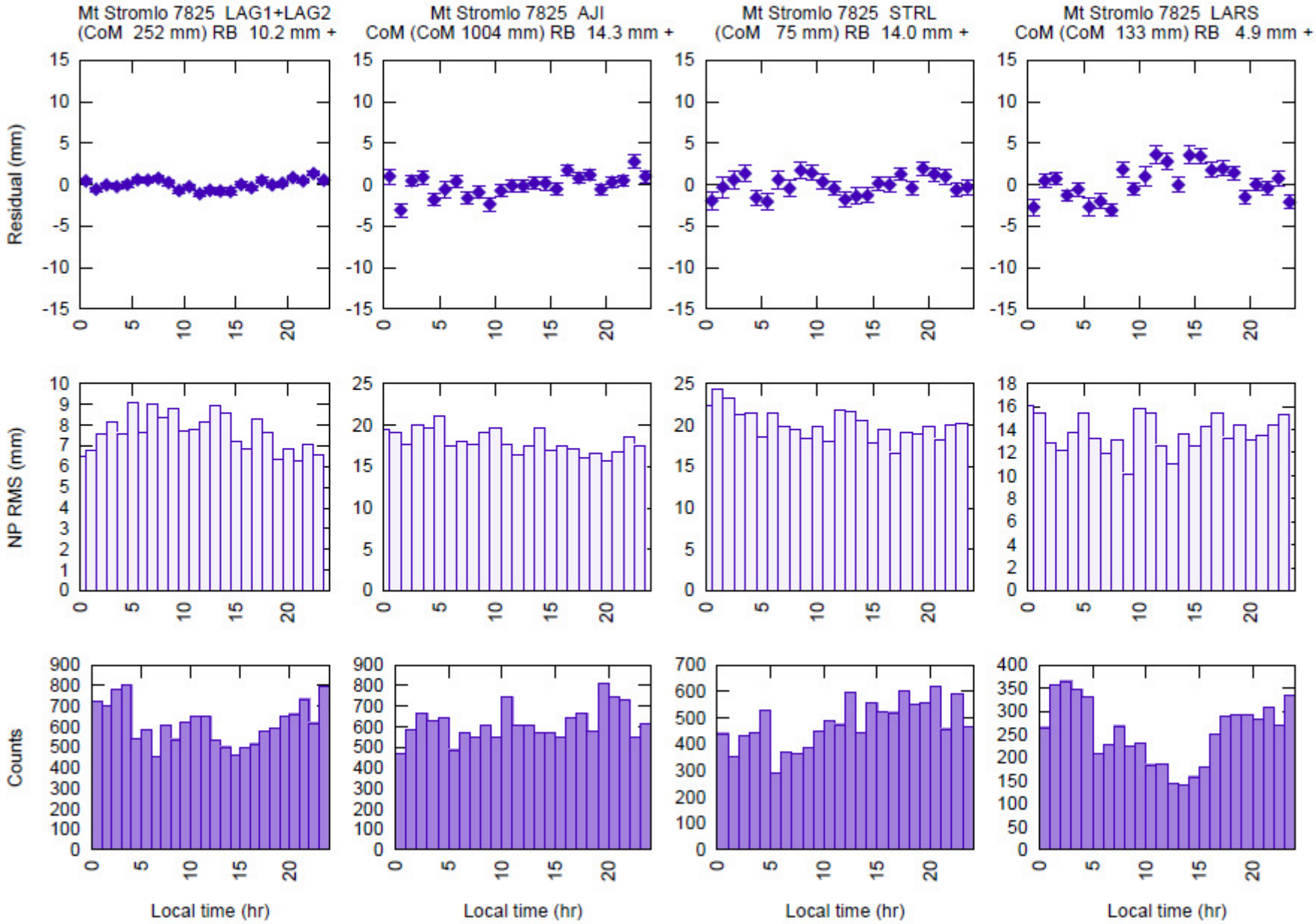
#6: Month


Mt Stromlo 7825 LAG1+LAG2
(CoM 252 mm) RB 10.2 mm +
Mt Stromlo 7825 AJI
CoM (CoM 1004 mm) RB 14.3 mm +
Mt Stromlo 7825 STRL
(CoM 75 mm) RB 14.0 mm +
Mt Stromlo 7825 LARS
CoM (CoM 133 mm) RB 4.9 mm +
Residual (mm)
NP RMS (mm)
Counts
Month (2014-2015)

#7: Day of week

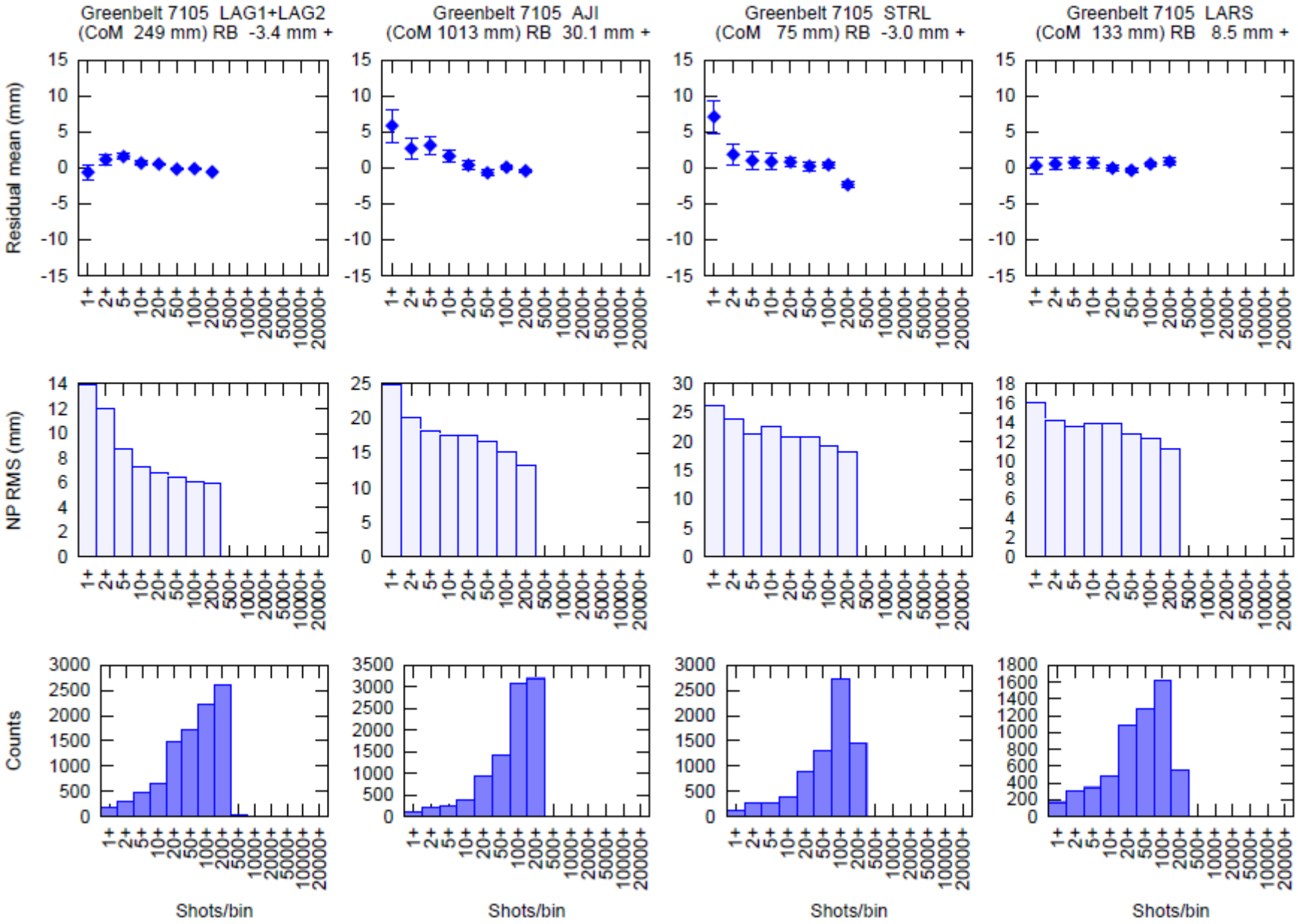

Mt Stromlo 7825 LAG1+LAG2
(CoM 252 mm) RB 10.2 mm +
Mt Stromlo 7825 AJI
CoM (CoM 1004 mm) RB 14.3 mm +
Mt Stromlo 7825 STRL
(CoM 75 mm) RB 14.0 mm +
Mt Stromlo 7825 LARS
CoM (CoM 133 mm) RB 4.9 mm +
Residual (mm)
NP RMS (mm)
Counts
Sun Mon Tue Wed Thu Fri Sat
Day of week

#8: Local time

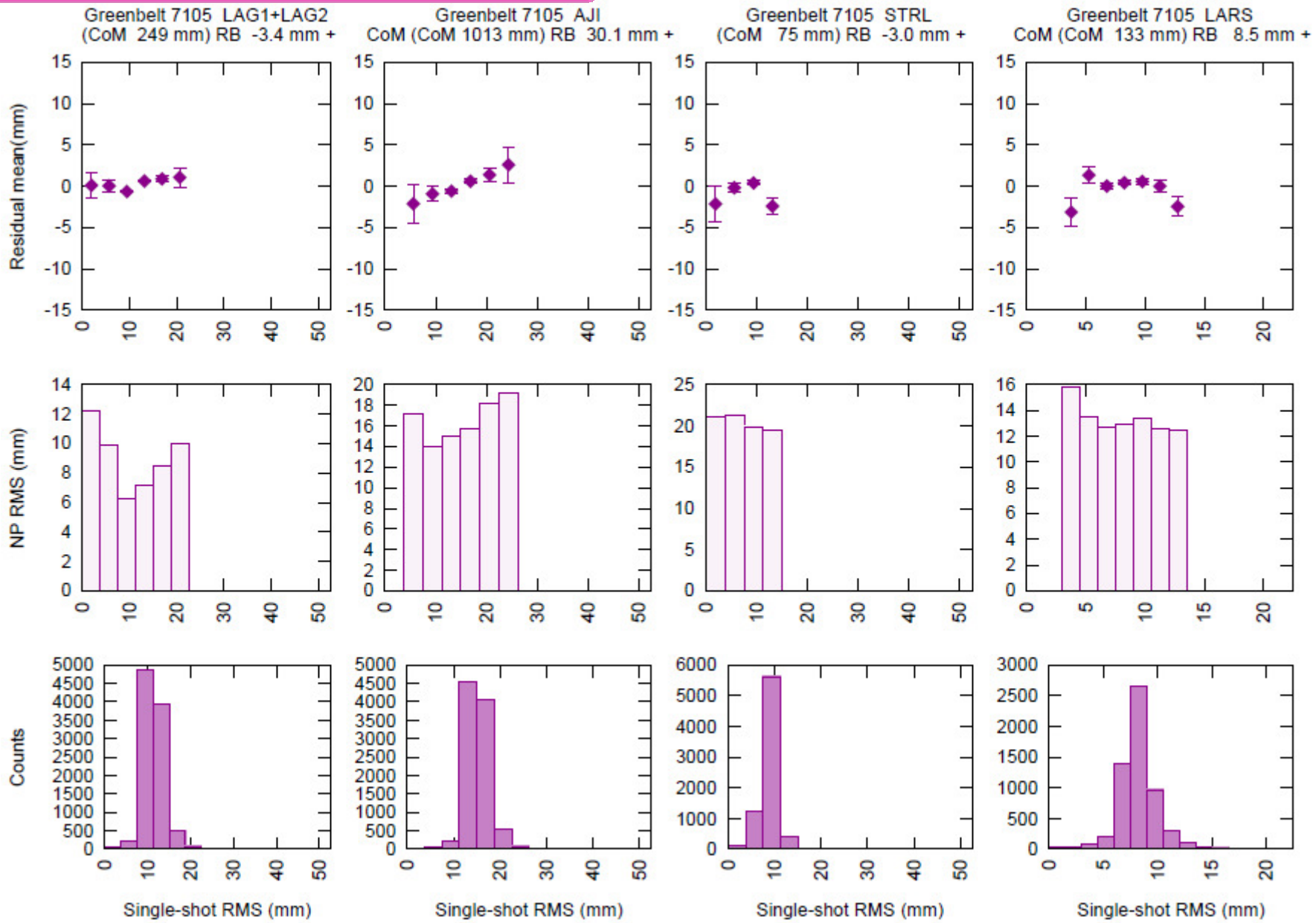

Mt Stromlo 7825 LAG1+LAG2
(CoM 252 mm) RB 10.2 mm +
Mt Stromlo 7825 AJI
CoM (CoM 1004 mm) RB 14.3 mm +
Mt Stromlo 7825 STRL
(CoM 75 mm) RB 14.0 mm +
Mt Stromlo 7825 LARS
CoM (CoM 133 mm) RB 4.9 mm +
Residual (mm)
NP RMS (mm)
Counts
Local time (hr)
Local time (hr)
Local time (hr)
Local time (hr)

7105

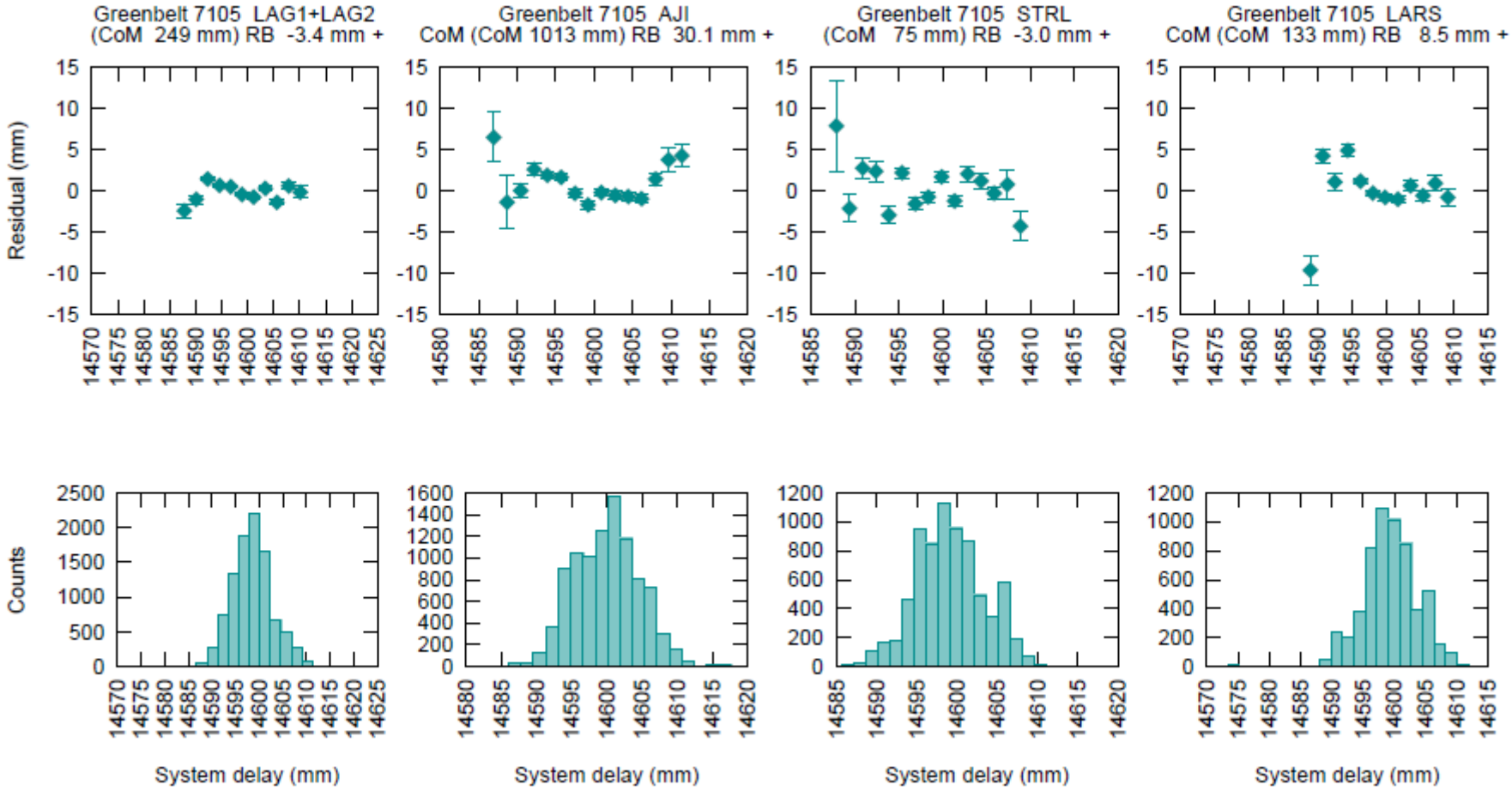
#1: Single-shot returns



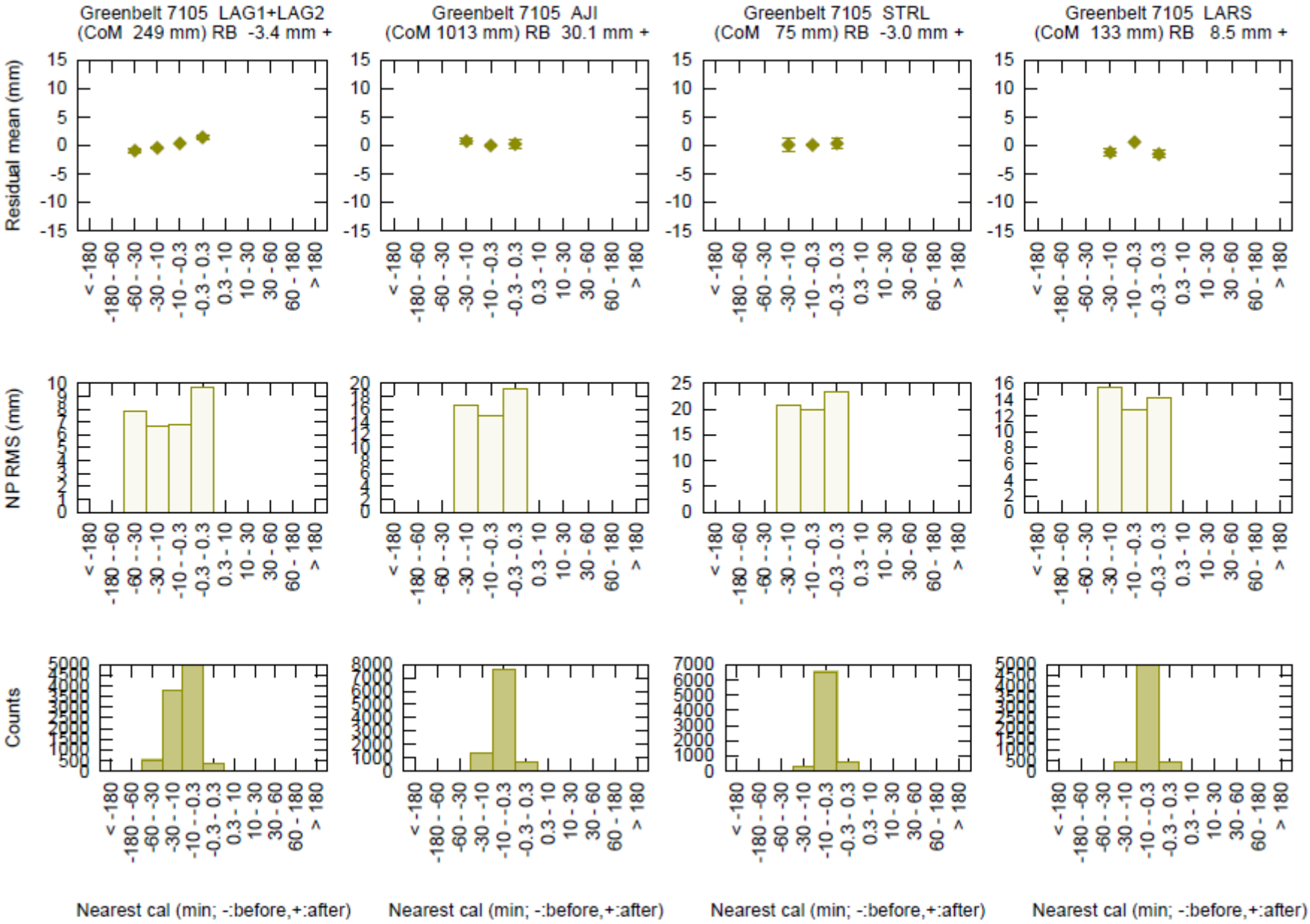
#2: Single-shot RMS



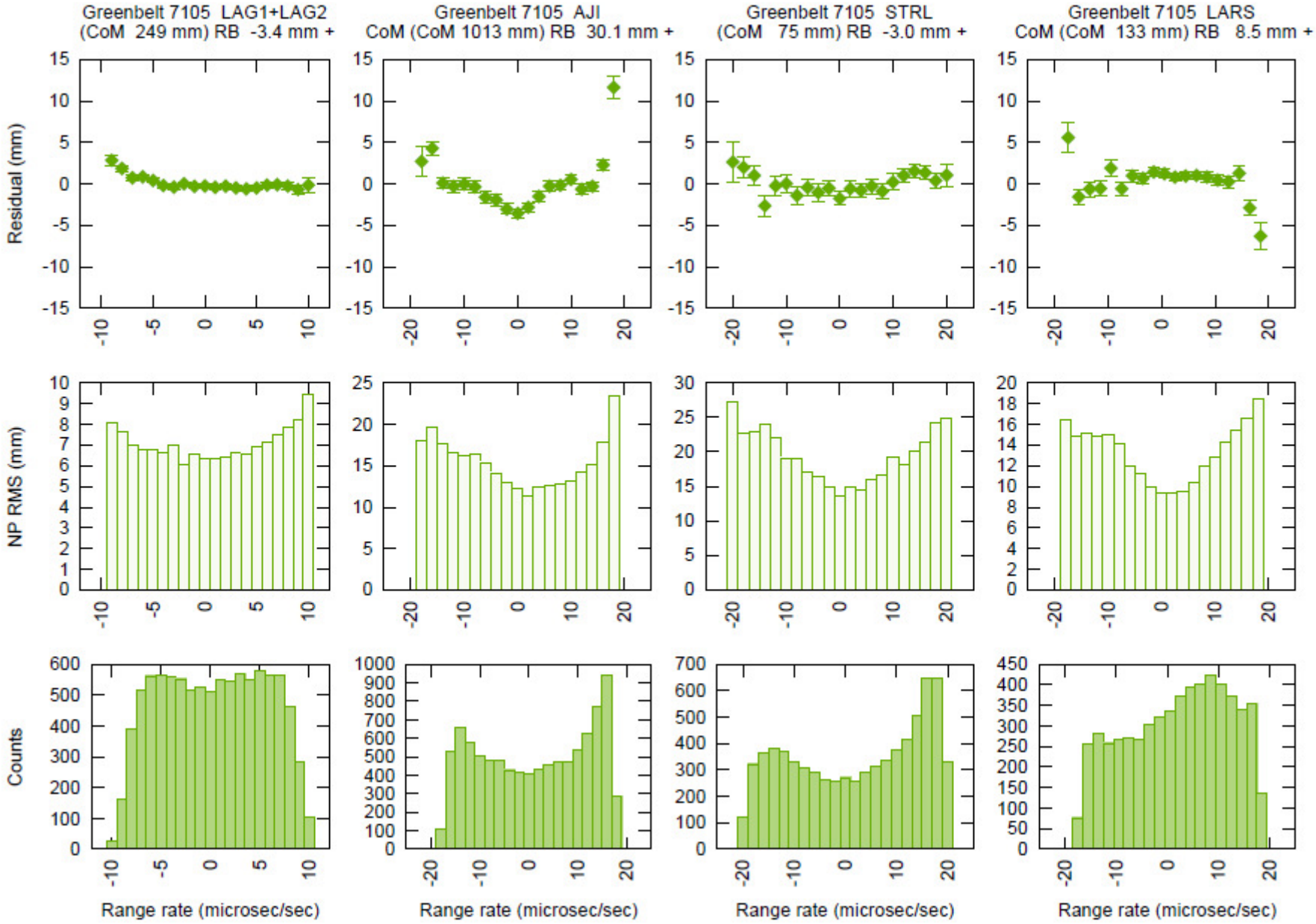
#3: System delay



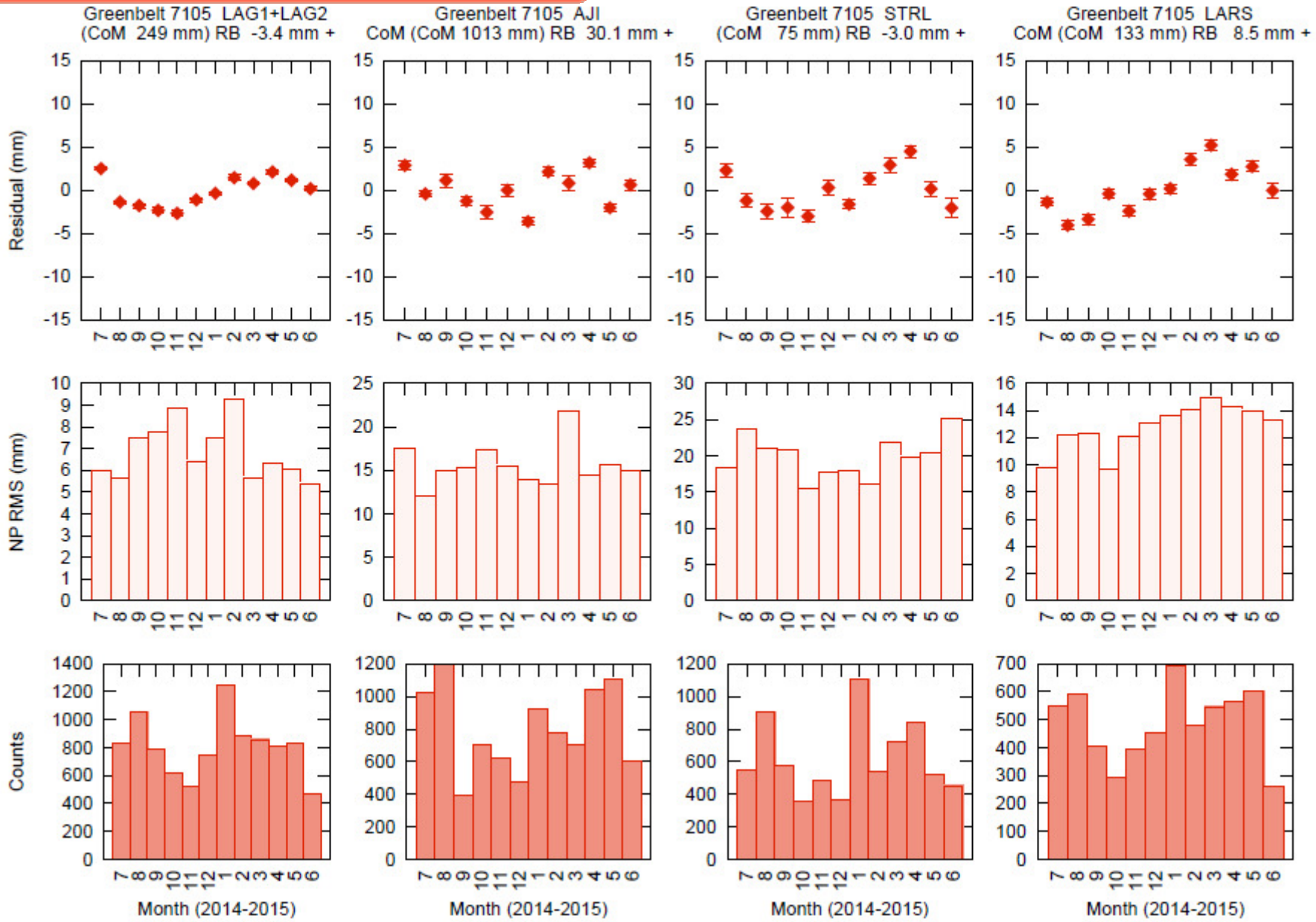
#4: Time to the nearest cal.



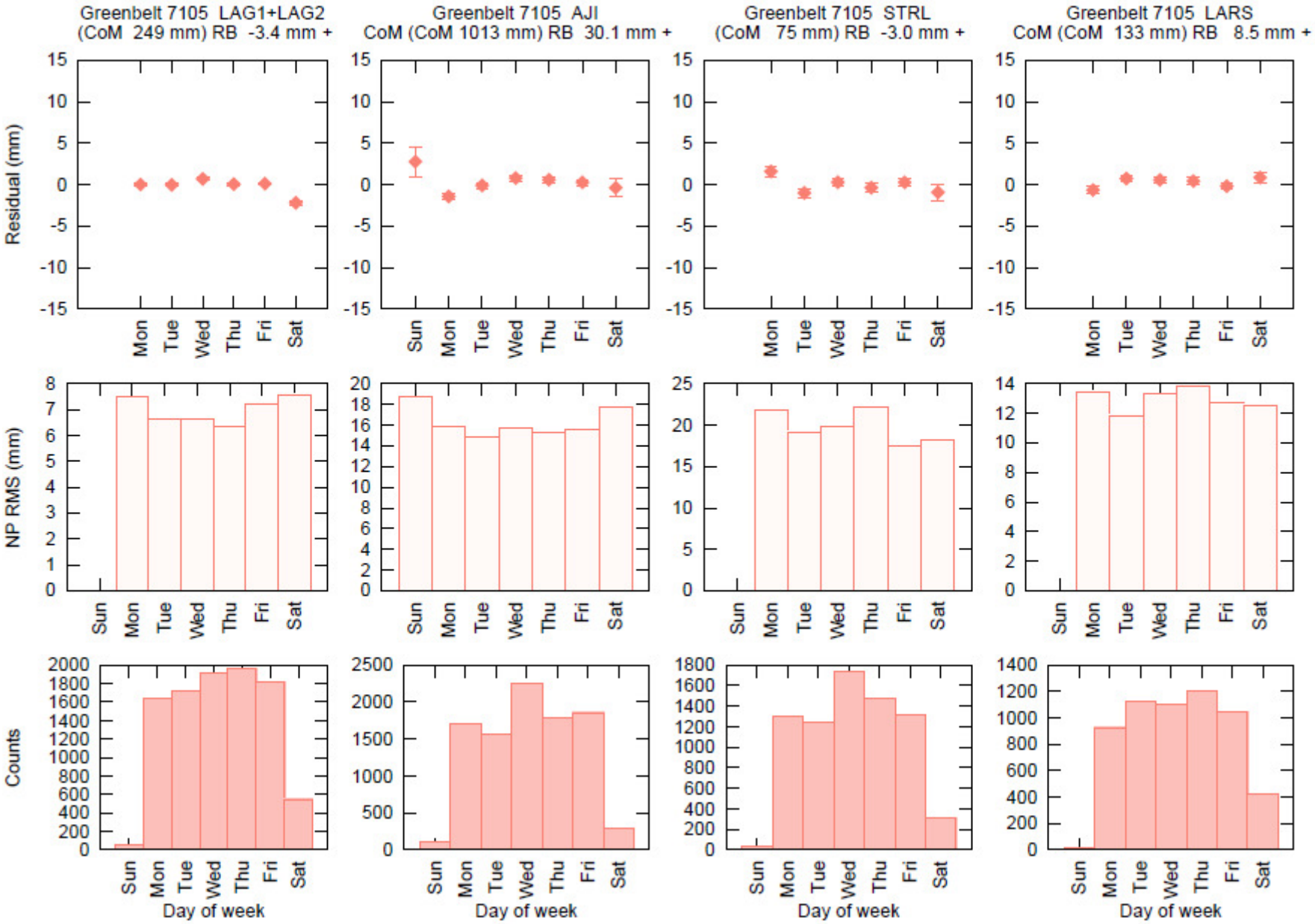
#5: Range rate


Greenbelt 7105 LAG1+LAG2
(CoM 249 mm) RB -3.4 mm +
Greenbelt 7105 AJI
CoM (CoM 1013 mm) RB 30.1 mm +
Greenbelt 7105 STRL
(CoM 75 mm) RB -3.0 mm +
Greenbelt 7105 LARS
CoM (CoM 133 mm) RB 8.5 mm +
Residual (mm)
NP RMS (mm)
Counts
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)

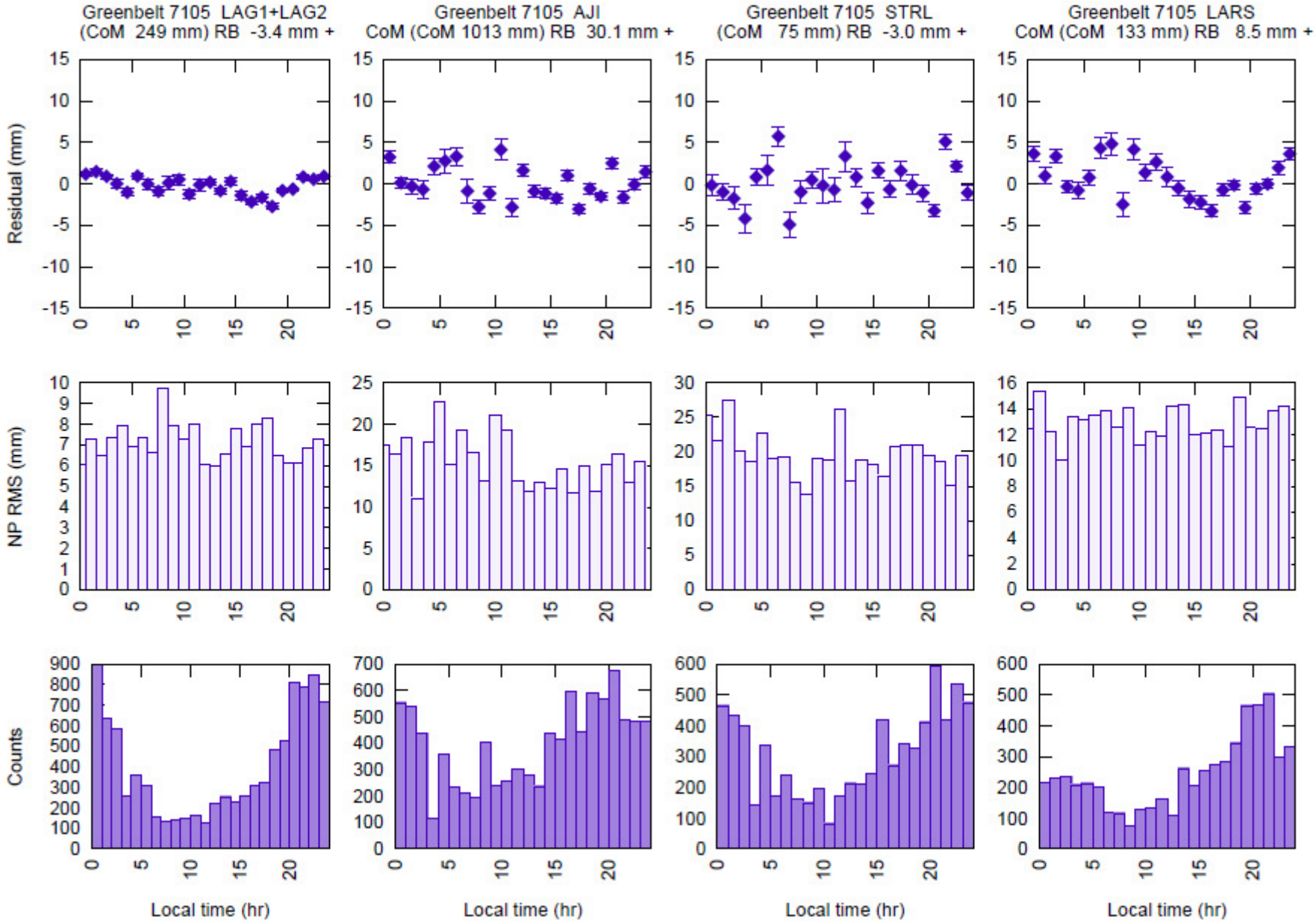
#6: Month


Greenbelt 7105 LAG1+LAG2
(CoM 249 mm) RB -3.4 mm +
Greenbelt 7105 AJI
CoM (CoM 1013 mm) RB 30.1 mm +
Greenbelt 7105 STRL
(CoM 75 mm) RB -3.0 mm +
Greenbelt 7105 LARS
CoM (CoM 133 mm) RB 8.5 mm +
Residual (mm)
NP RMS (mm)
Counts
Month (2014-2015)

#7: Day of week

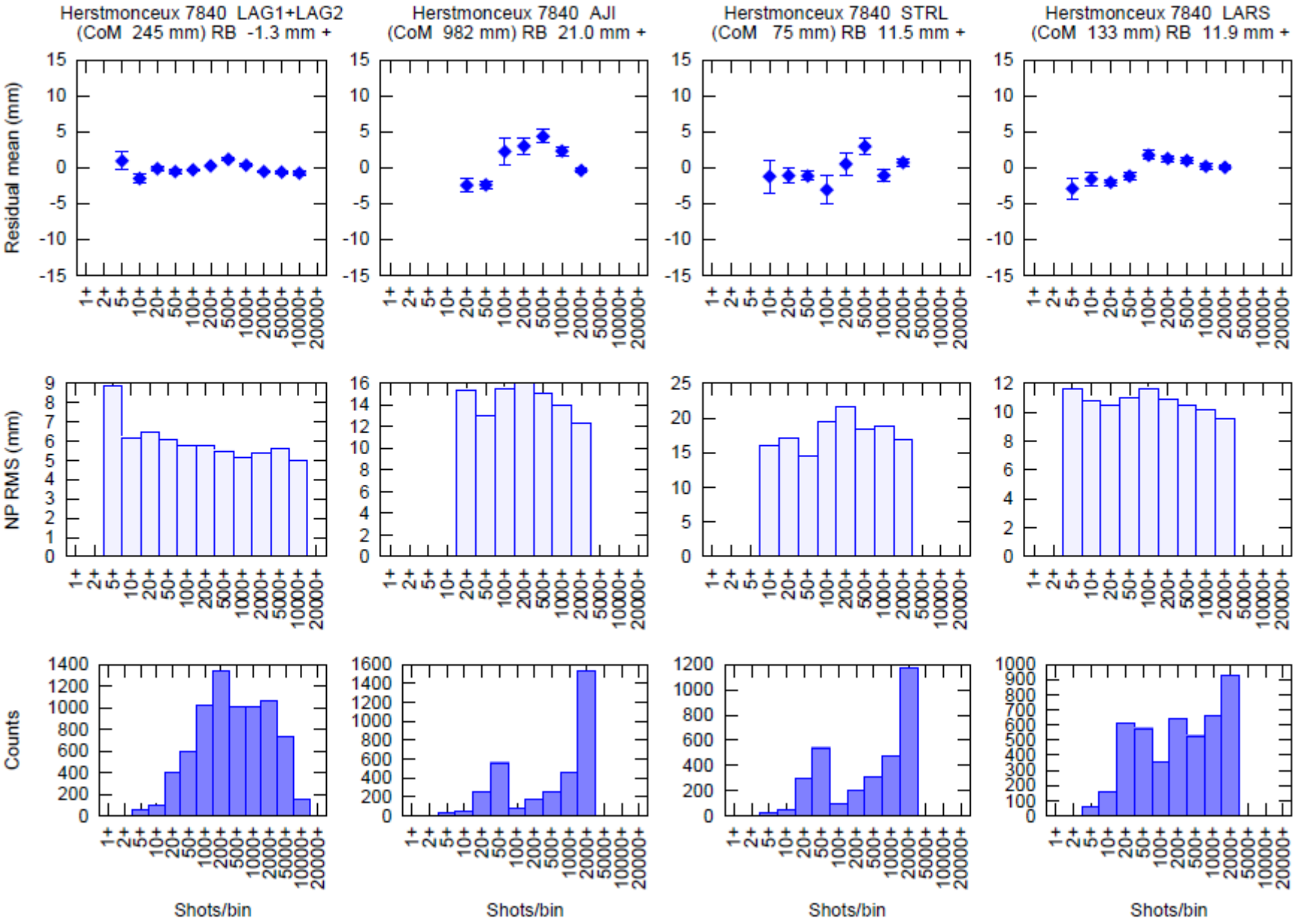

Greenbelt 7105 LAG1+LAG2
(CoM 249 mm) RB -3.4 mm +
Greenbelt 7105 AJI
CoM (CoM 1013 mm) RB 30.1 mm +
Greenbelt 7105 STRL
(CoM 75 mm) RB -3.0 mm +
Greenbelt 7105 LARS
CoM (CoM 133 mm) RB 8.5 mm +
Residual (mm)
NP RMS (mm)
Counts
Sun Mon Tue Wed Thu Fri Sat
Day of week

#8: Local time

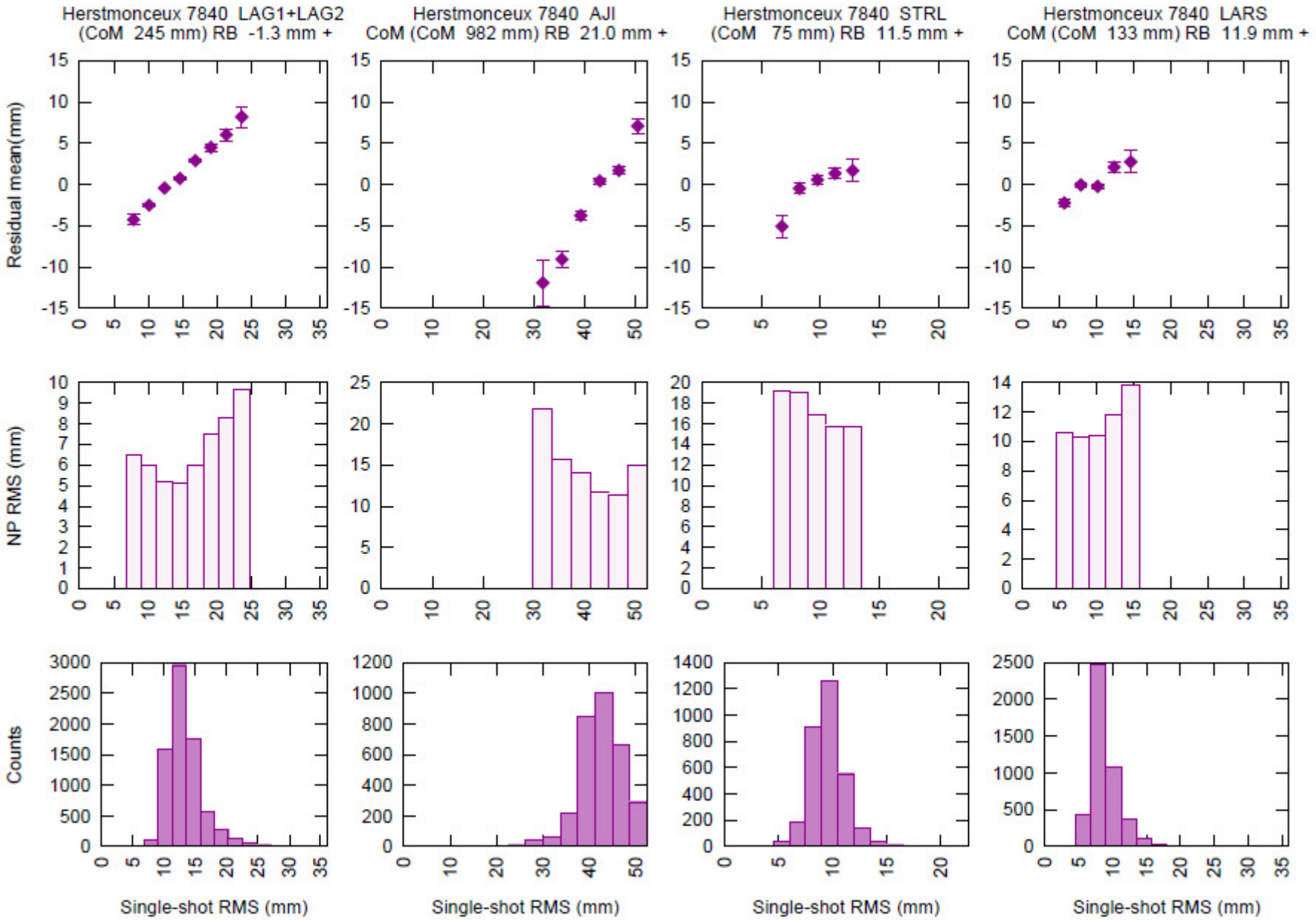

Greenbelt 7105 LAG1+LAG2
(CoM 249 mm) RB -3.4 mm +
Greenbelt 7105 AJI
CoM (CoM 1013 mm) RB 30.1 mm +
Greenbelt 7105 STRL
(CoM 75 mm) RB -3.0 mm +
Greenbelt 7105 LARS
CoM (CoM 133 mm) RB 8.5 mm +
Residual (mm)
NP RMS (mm)
Counts
Local time (hr)
Local time (hr)
Local time (hr)
Local time (hr)

7840

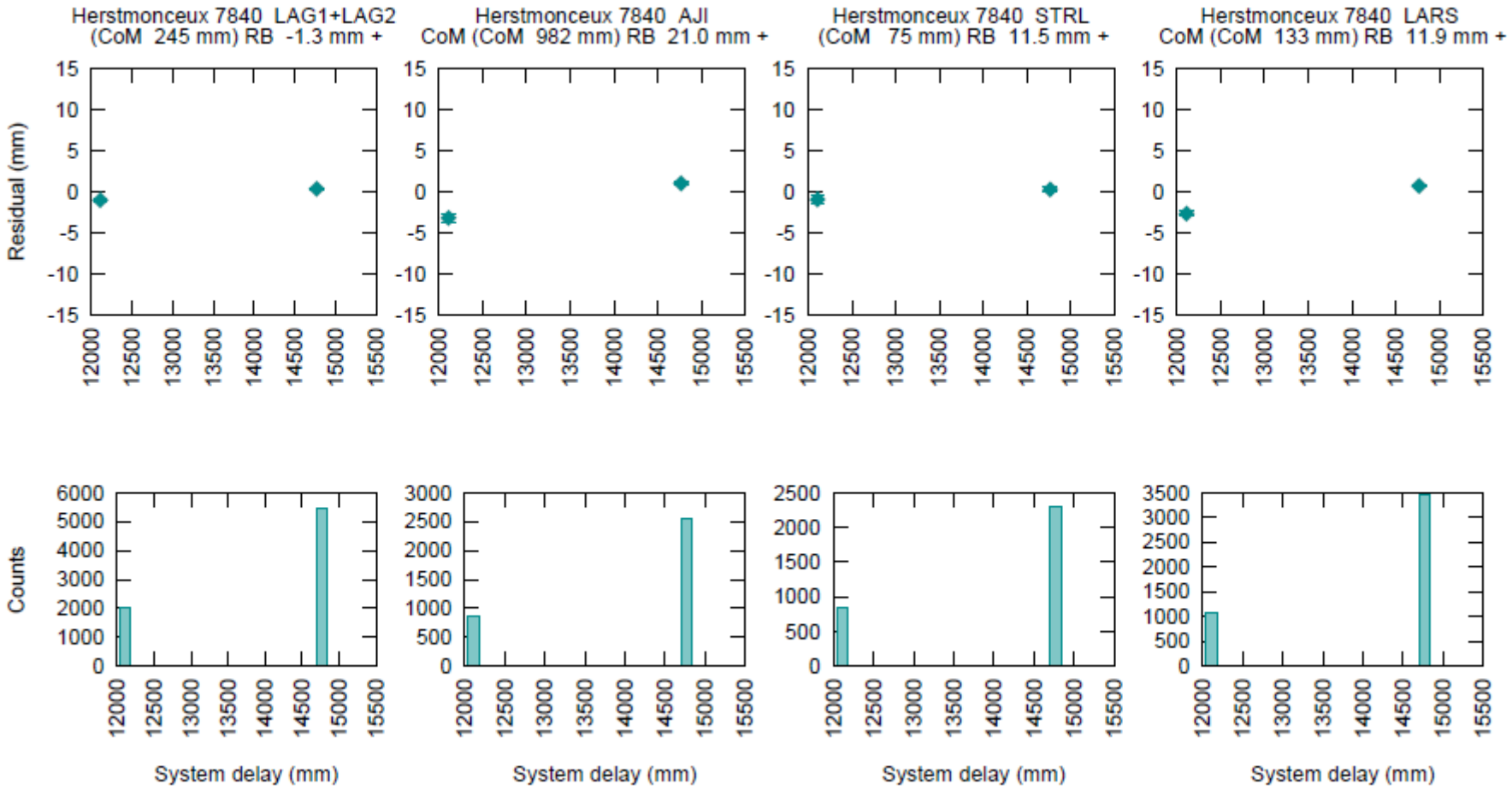
#1: Single-shot returns



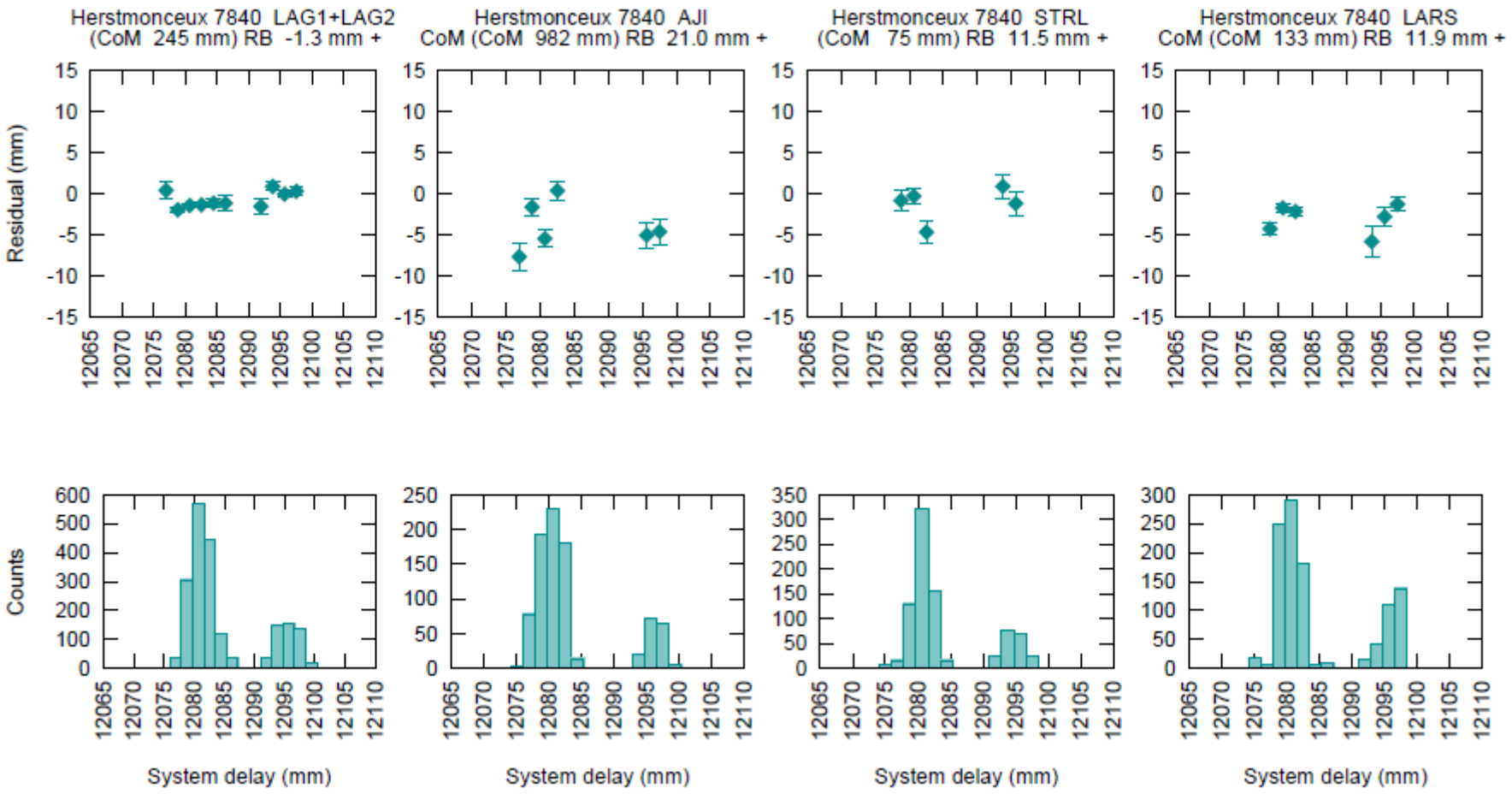
#2: Single-shot RMS



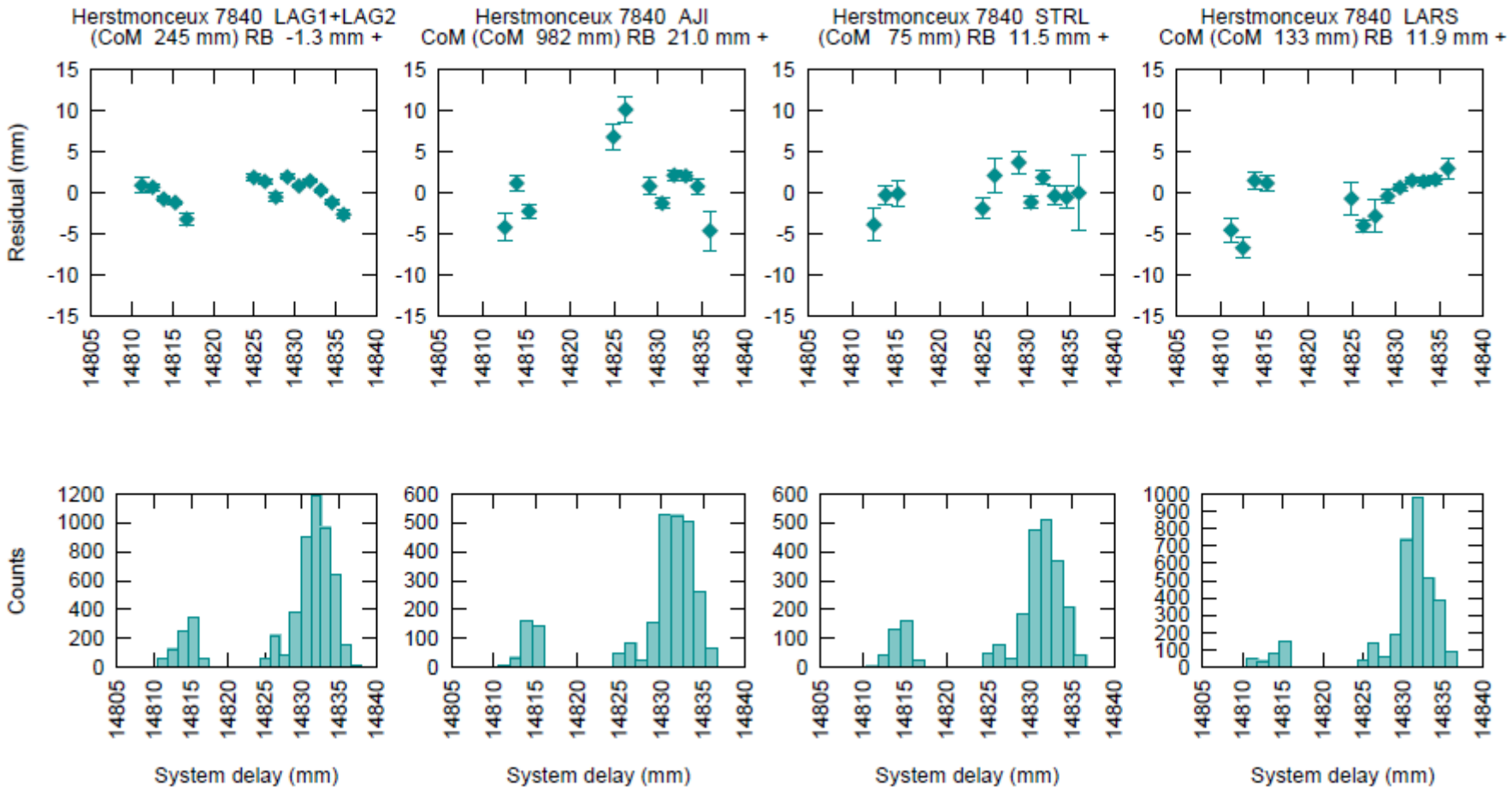
#3: System delay



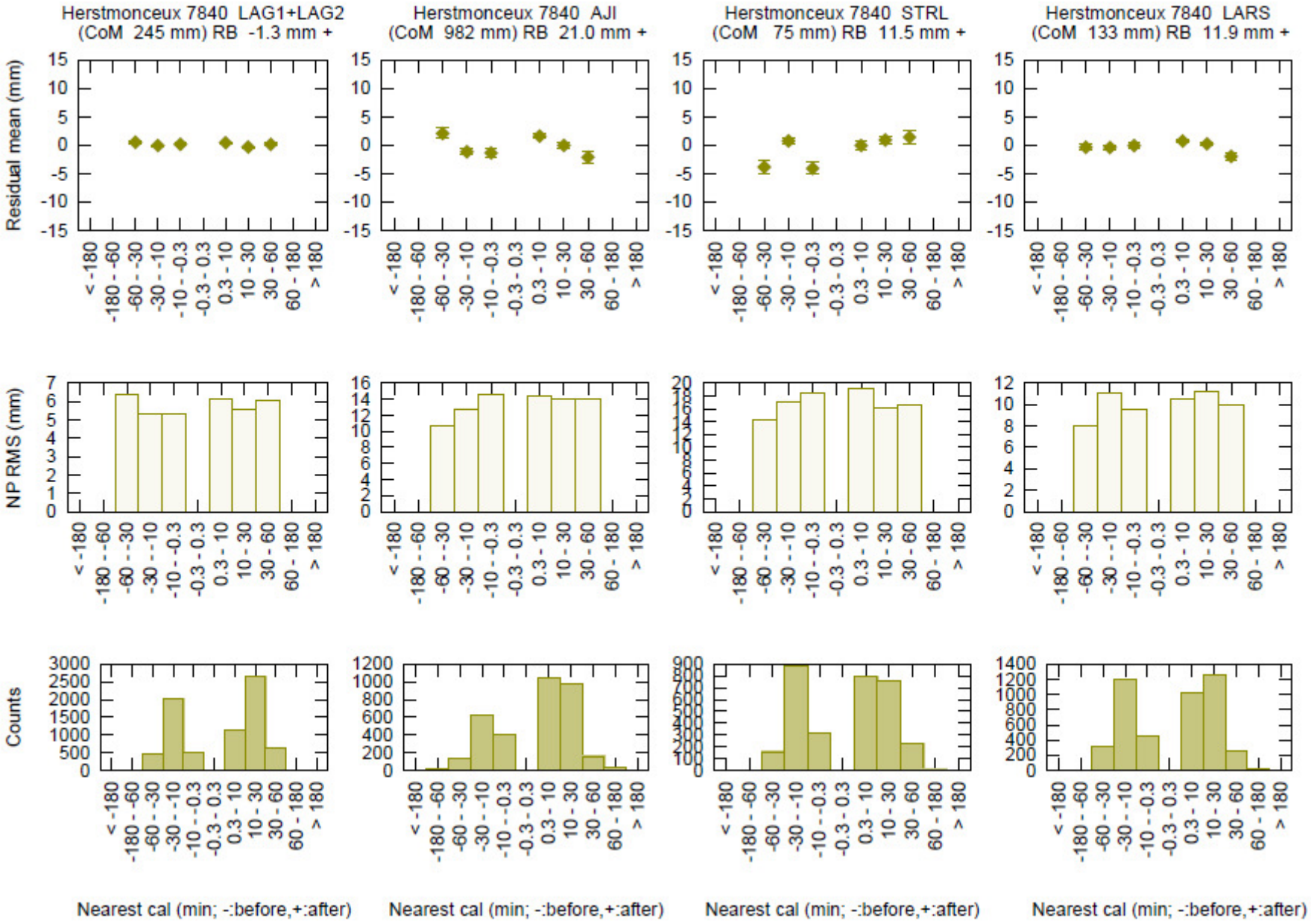
Zoomed (1)


Herstmonceux 7840 LAG1+LAG2
(CoM 245 mm) RB -1.3 mm +
Herstmonceux 7840 AJI
CoM (CoM 982 mm) RB 21.0 mm +
Herstmonceux 7840 STRL
(CoM 75 mm) RB 11.5 mm +
Herstmonceux 7840 LARS
CoM (CoM 133 mm) RB 11.9 mm +
Residual (mm)
Counts
System delay (mm)

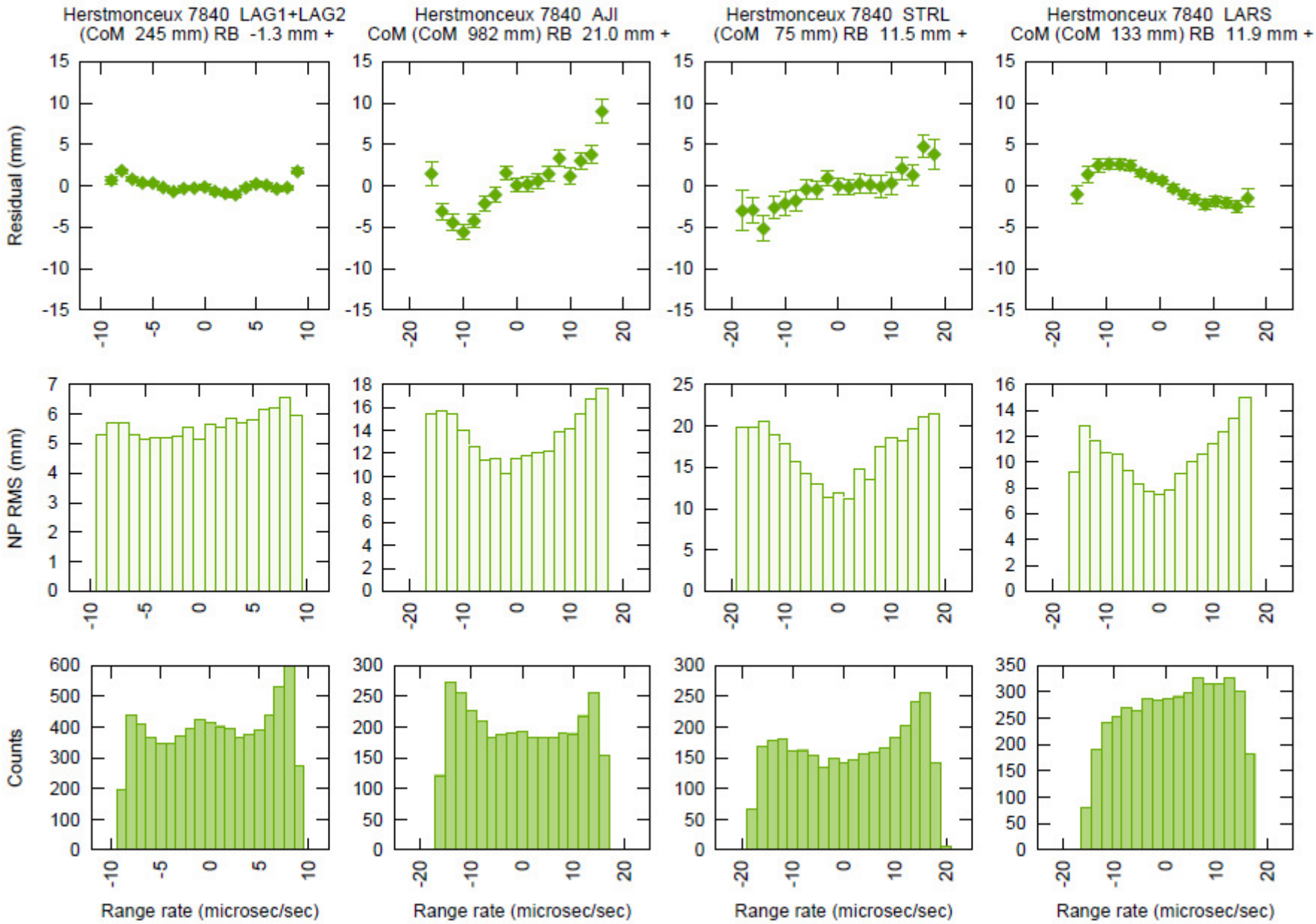
Zoomed (2)


Herstmonceux 7840 LAG1+LAG2
(CoM 245 mm) RB -1.3 mm +
Herstmonceux 7840 AJI
CoM (CoM 982 mm) RB 21.0 mm +
Herstmonceux 7840 STRL
(CoM 75 mm) RB 11.5 mm +
Herstmonceux 7840 LARS
CoM (CoM 133 mm) RB 11.9 mm +
Residual (mm)
Counts
System delay (mm)
System delay (mm)
System delay (mm)
System delay (mm)

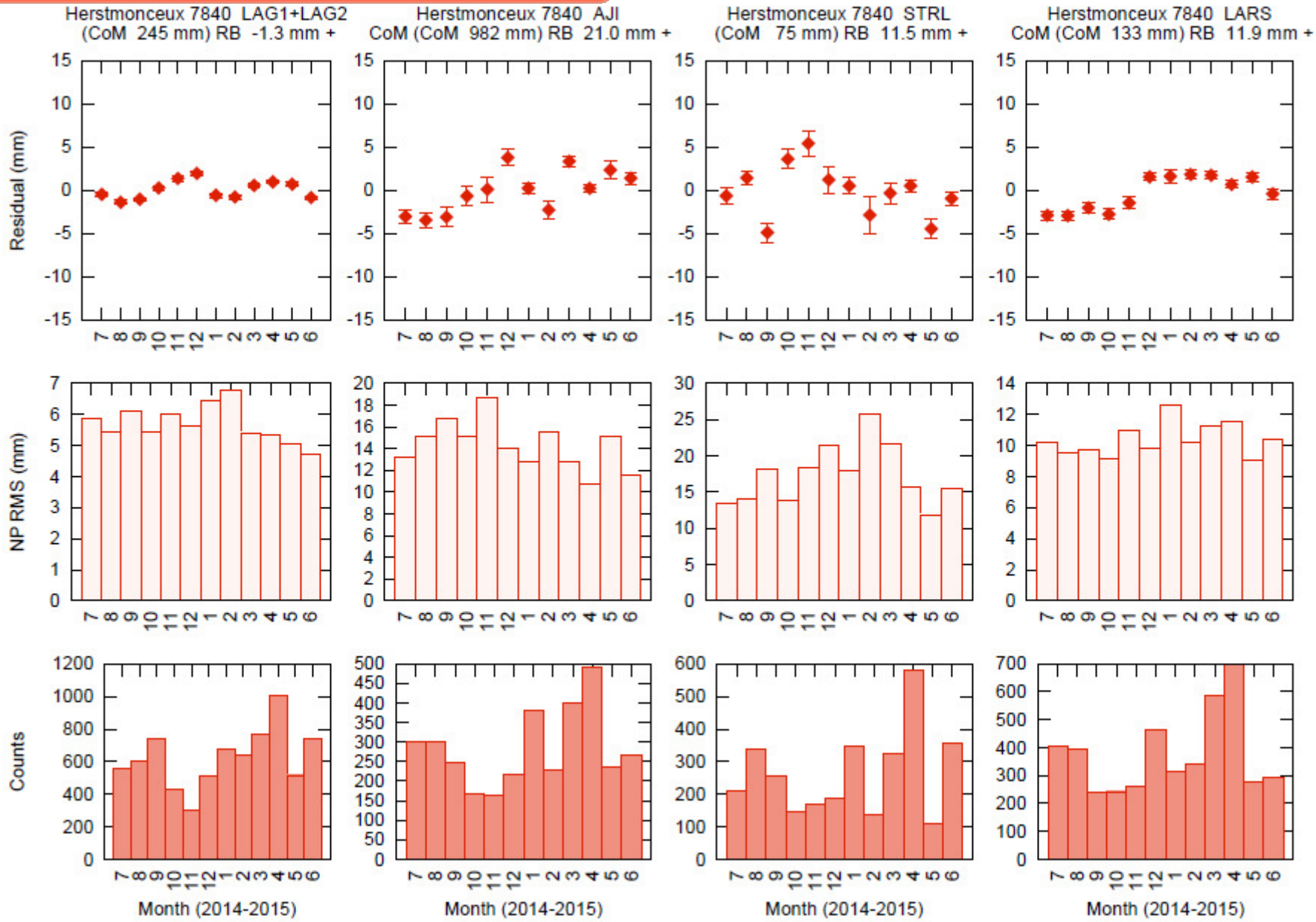
#4: Time to the nearest cal.



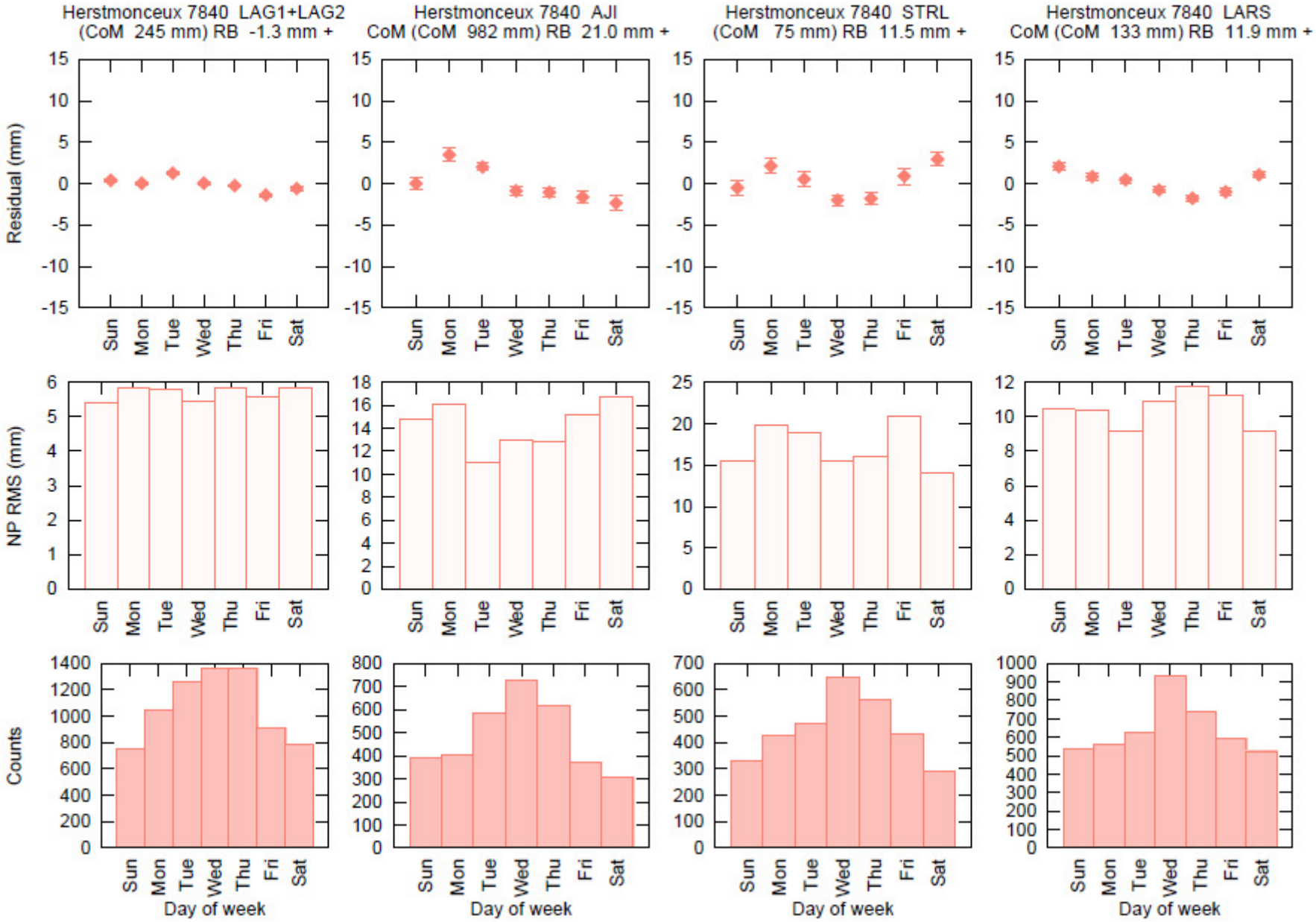
#5: Range rate


Herstmonceux 7840 LAG1+LAG2
(CoM 245 mm) RB -1.3 mm +
Herstmonceux 7840 AJI
CoM (CoM 982 mm) RB 21.0 mm +
Herstmonceux 7840 STRL
(CoM 75 mm) RB 11.5 mm +
Herstmonceux 7840 LARS
CoM (CoM 133 mm) RB 11.9 mm +
Residual (mm)
NP RMS (mm)
Counts
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)

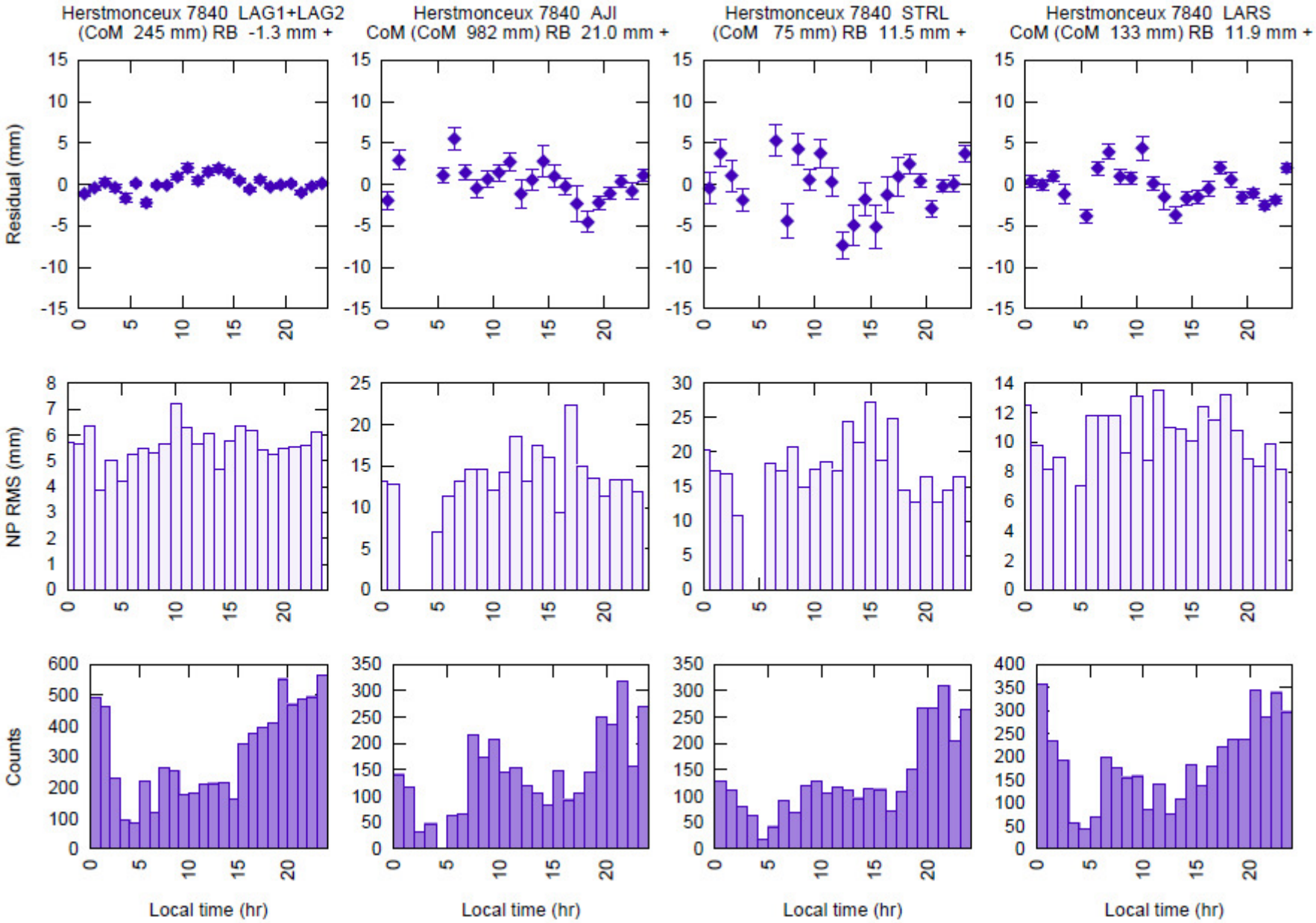
#6: Month


Herstmonceux 7840 LAG1+LAG2
(CoM 245 mm) RB -1.3 mm +
Herstmonceux 7840 AJI
CoM (CoM 982 mm) RB 21.0 mm +
Herstmonceux 7840 STRL
(CoM 75 mm) RB 11.5 mm +
Herstmonceux 7840 LARS
CoM (CoM 133 mm) RB 11.9 mm +
Residual (mm)
NP RMS (mm)
Counts
Month (2014-2015)

#7: Day of week

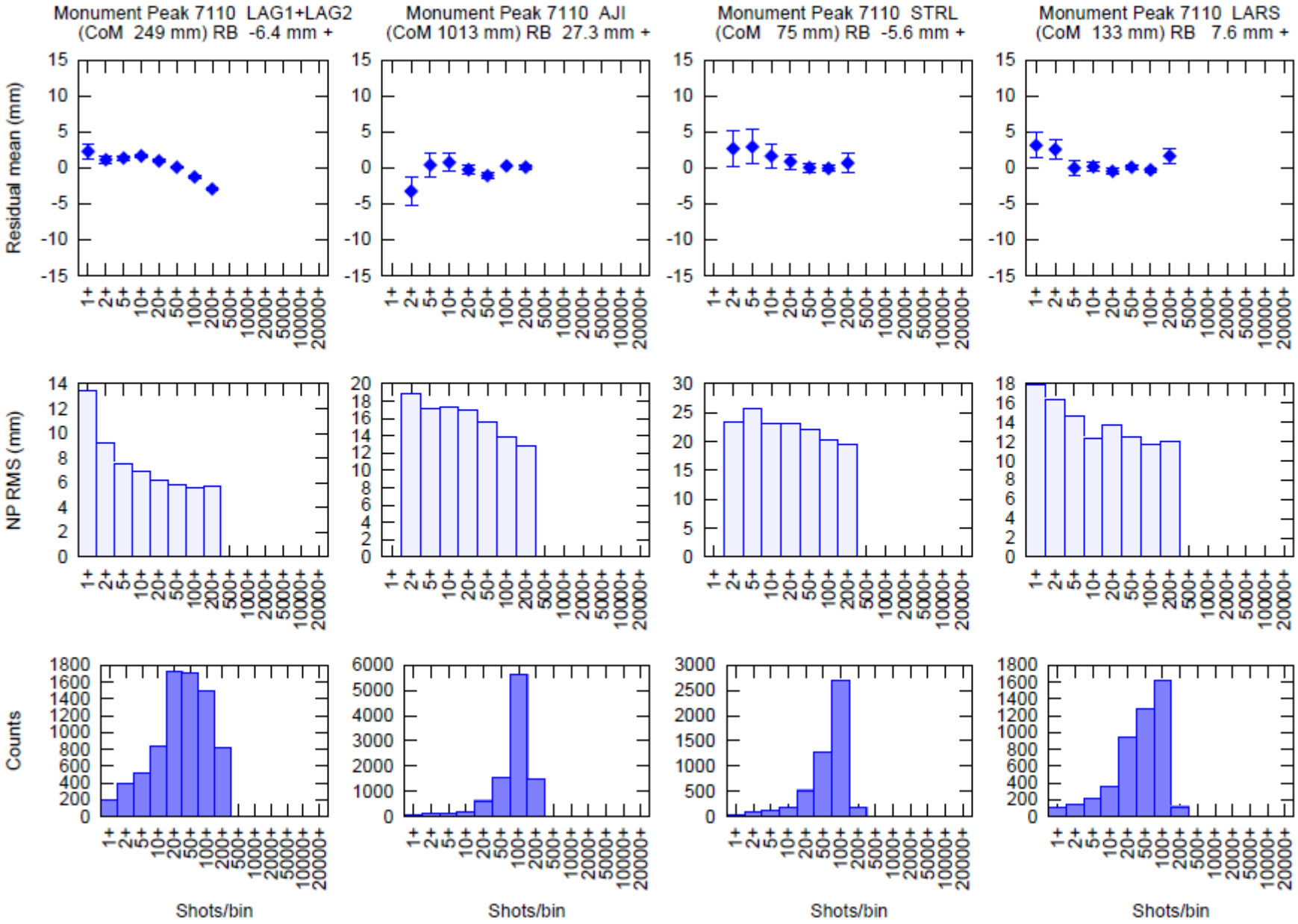

Herstmonceux 7840 LAG1+LAG2
(CoM 245 mm) RB -1.3 mm +
Herstmonceux 7840 AJI
CoM (CoM 982 mm) RB 21.0 mm +
Herstmonceux 7840 STRL
(CoM 75 mm) RB 11.5 mm +
Herstmonceux 7840 LARS
CoM (CoM 133 mm) RB 11.9 mm +
Residual (mm)
NP RMS (mm)
Counts
Sun Mon Tue Wed Thu Fri Sat
Day of week

#8: Local time

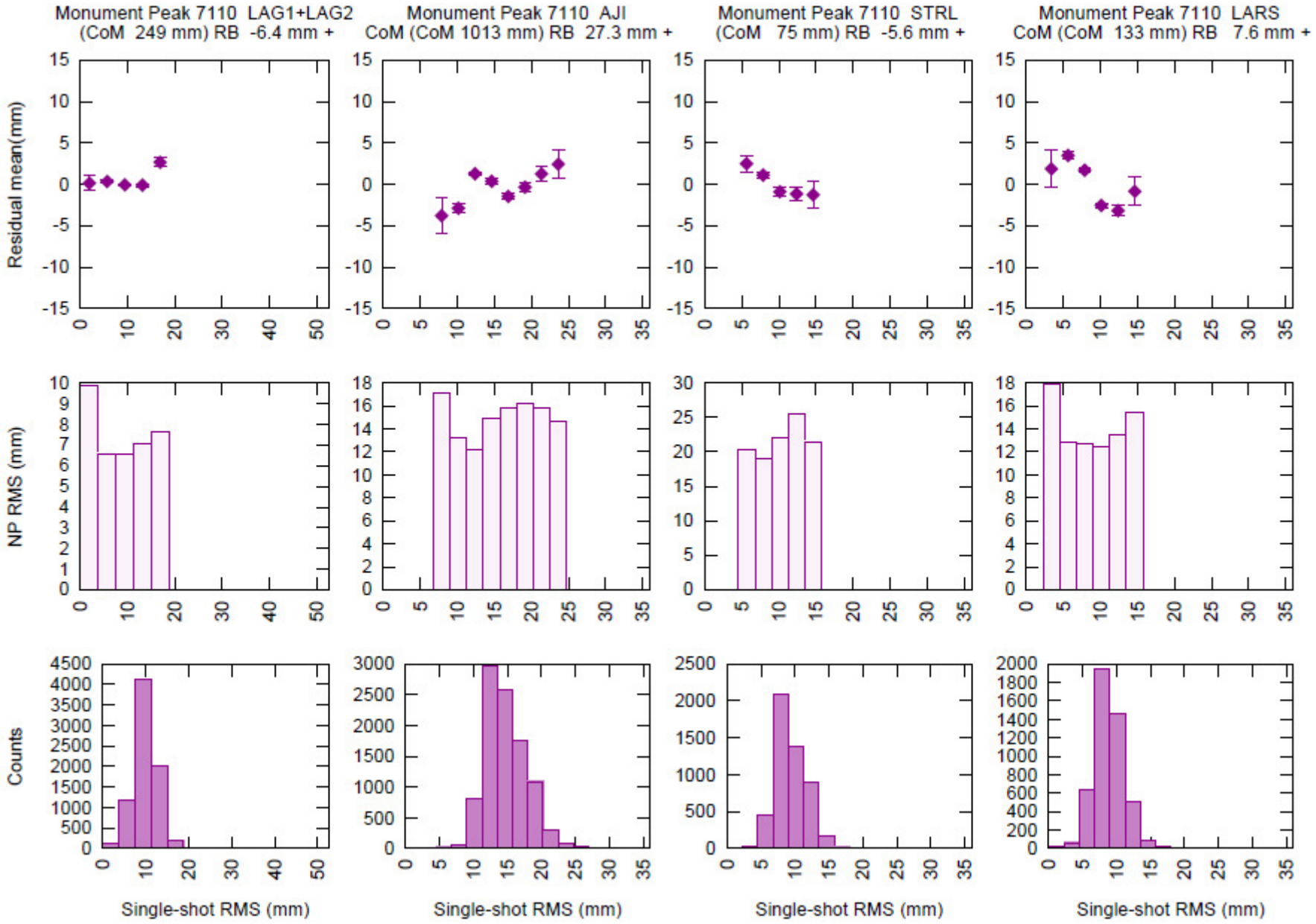

Herstmonceux 7840 LAG1+LAG2
(CoM 245 mm) RB -1.3 mm +
Herstmonceux 7840 AJI
CoM (CoM 982 mm) RB 21.0 mm +
Herstmonceux 7840 STRL
(CoM 75 mm) RB 11.5 mm +
Herstmonceux 7840 LARS
CoM (CoM 133 mm) RB 11.9 mm +
Residual (mm)
NP RMS (mm)
Counts
Local time (hr)
Local time (hr)
Local time (hr)
Local time (hr)

7110

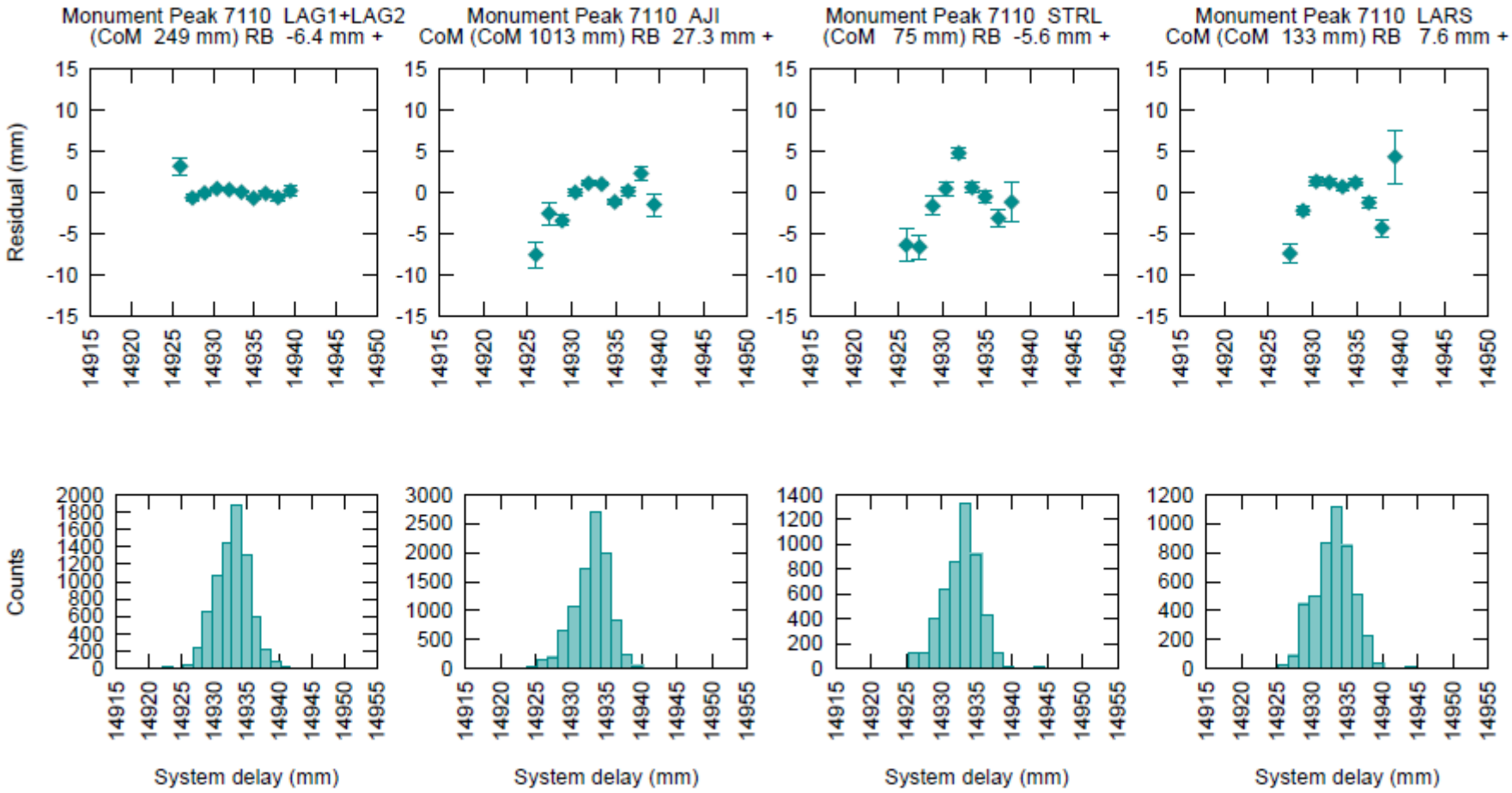
#1: Single-shot returns



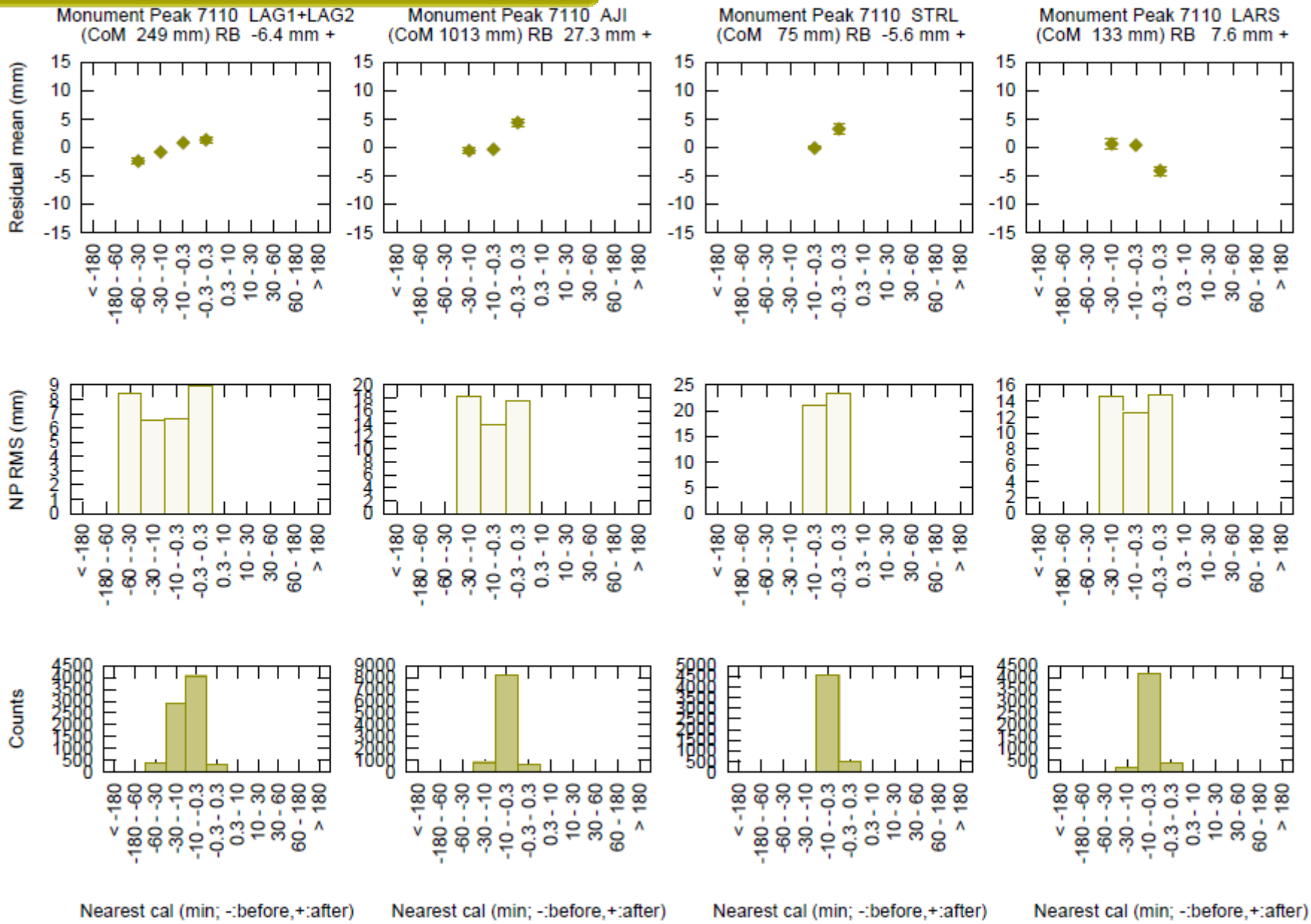
#2: Single-shot RMS



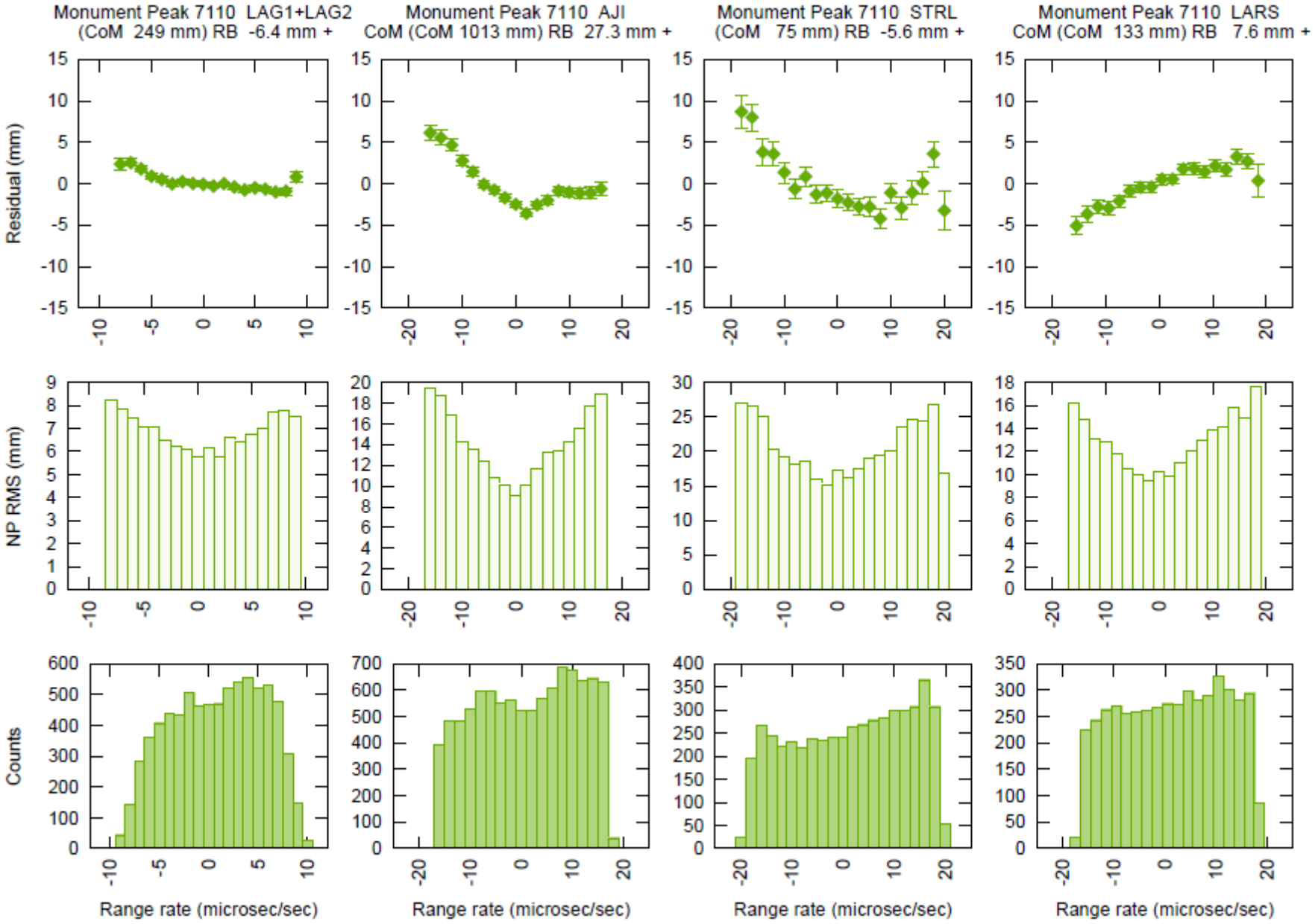
#3: System delay



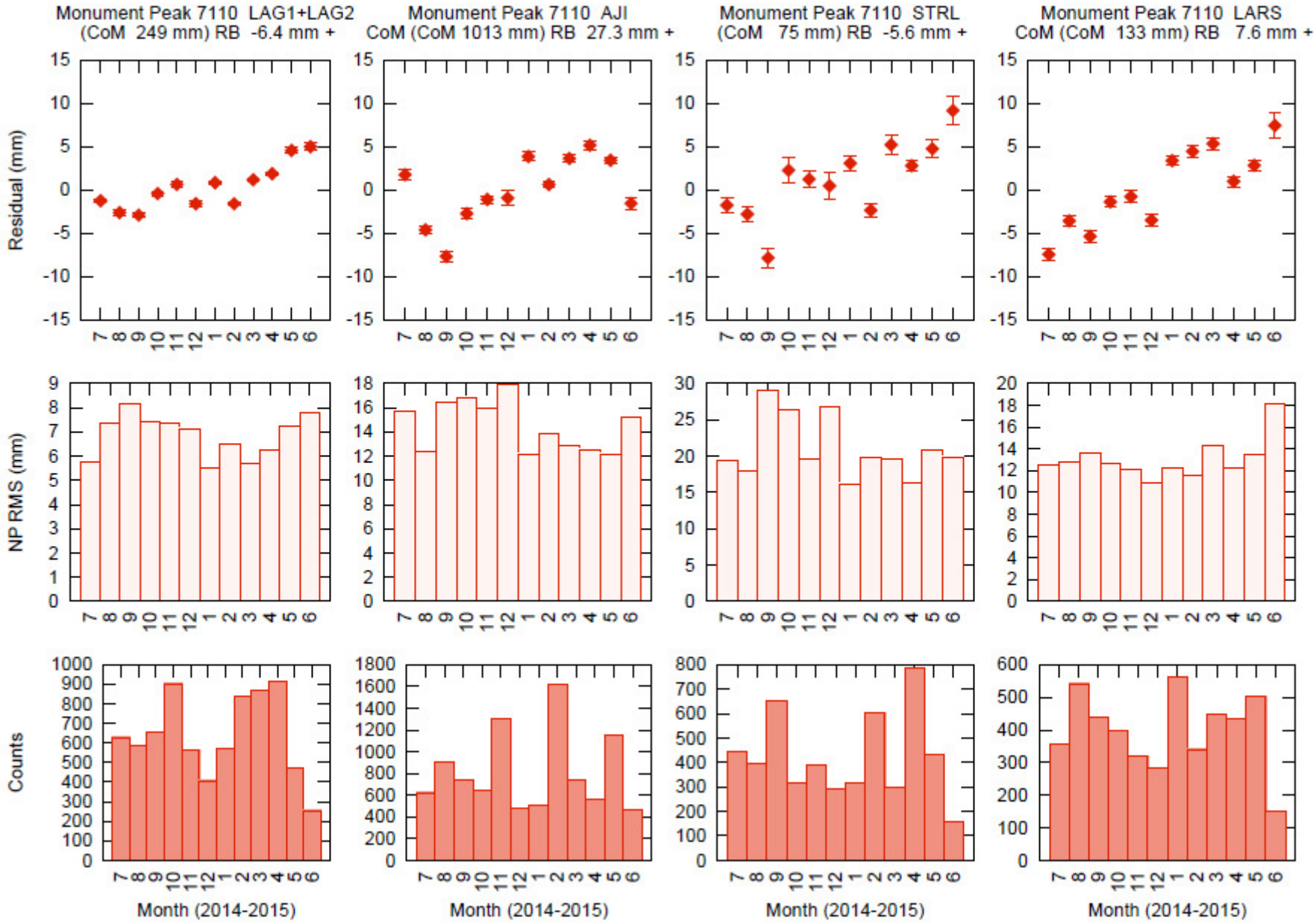
#4: Time to the nearest cal.



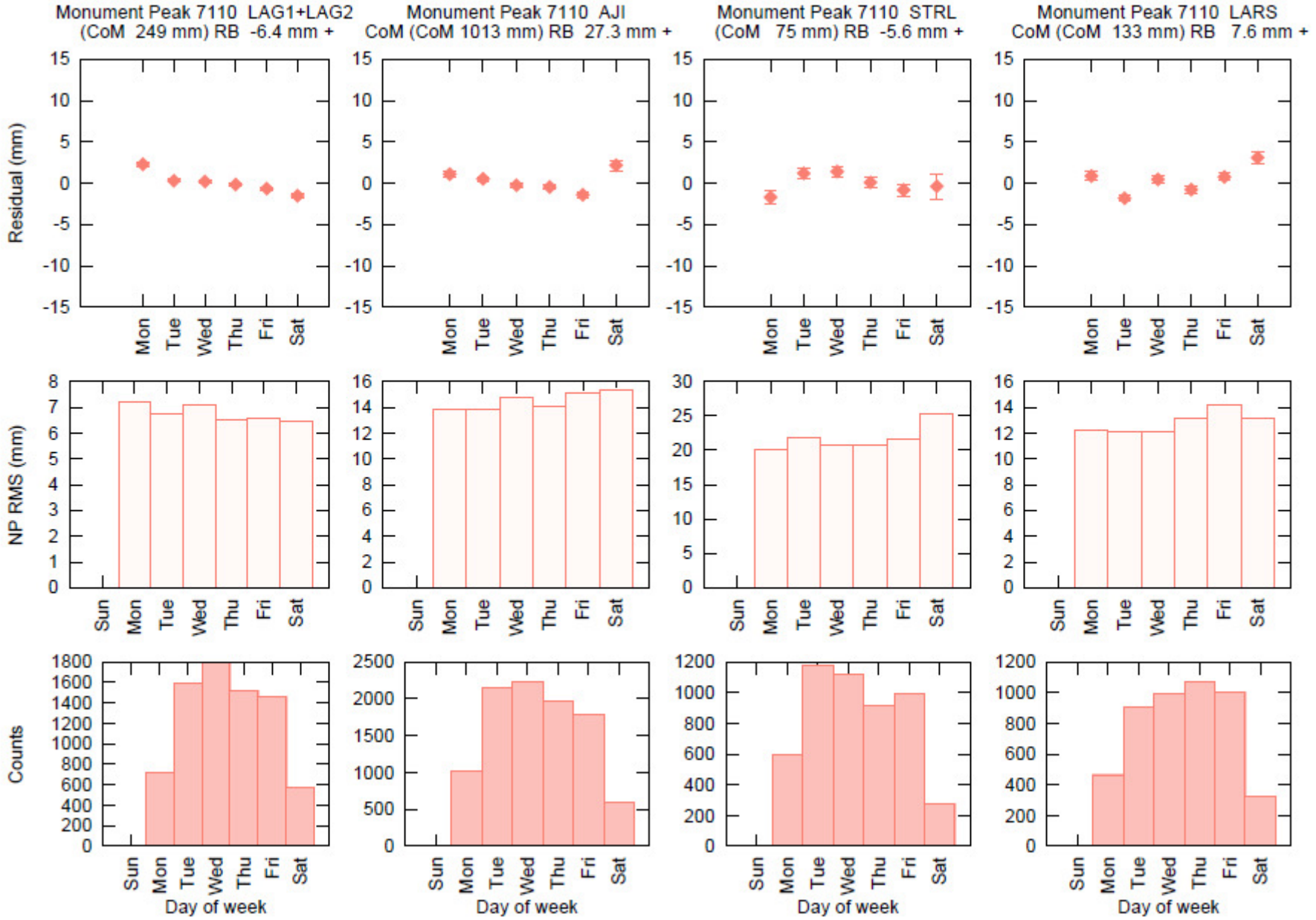
#5: Range rate


Monument Peak 7110 LAG1+LAG2
(CoM 249 mm) RB -6.4 mm +
Monument Peak 7110 AJI
CoM (CoM 1013 mm) RB 27.3 mm +
Monument Peak 7110 STRL
(CoM 75 mm) RB -5.6 mm +
Monument Peak 7110 LARS
CoM (CoM 133 mm) RB 7.6 mm +
Residual (mm)
NP RMS (mm)
Counts
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)

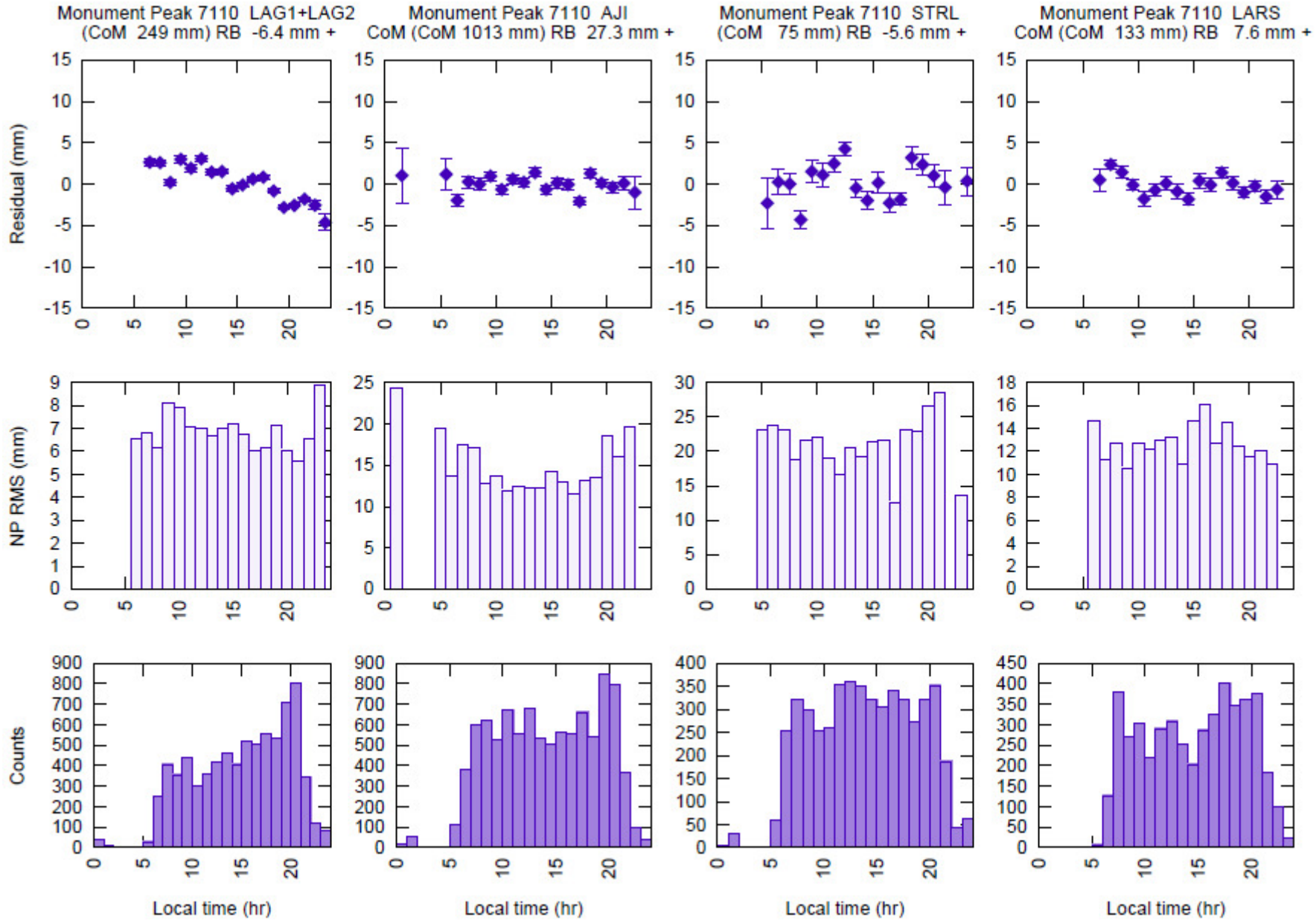
#6: Month


Monument Peak 7110 LAG1+LAG2
(CoM 249 mm) RB -6.4 mm +
Monument Peak 7110 AJI
CoM (CoM 1013 mm) RB 27.3 mm +
Monument Peak 7110 STRL
(CoM 75 mm) RB -5.6 mm +
Monument Peak 7110 LARS
CoM (CoM 133 mm) RB 7.6 mm +
Residual (mm)
NP RMS (mm)
Counts
Month (2014-2015)
Month (2014-2015)
Month (2014-2015)
Month (2014-2015)

#7: Day of week

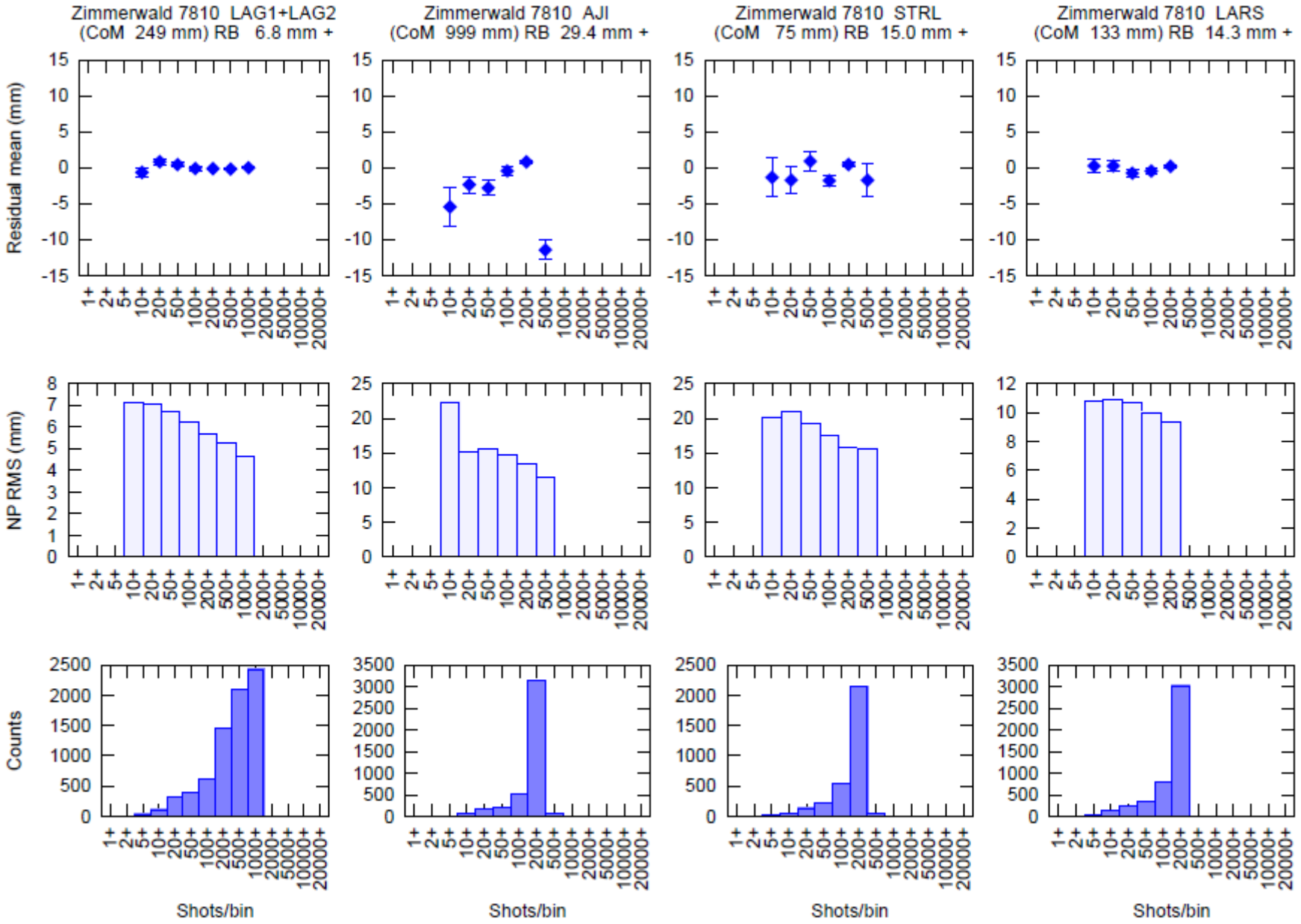

Monument Peak 7110 LAG1+LAG2
(CoM 249 mm) RB -6.4 mm +
Monument Peak 7110 AJI
CoM (CoM 1013 mm) RB 27.3 mm +
Monument Peak 7110 STRL
(CoM 75 mm) RB -5.6 mm +
Monument Peak 7110 LARS
CoM (CoM 133 mm) RB 7.6 mm +
Residual (mm)
NP RMS (mm)
Counts
Sun Mon Tue Wed Thu Fri Sat
Day of week

#8: Local time

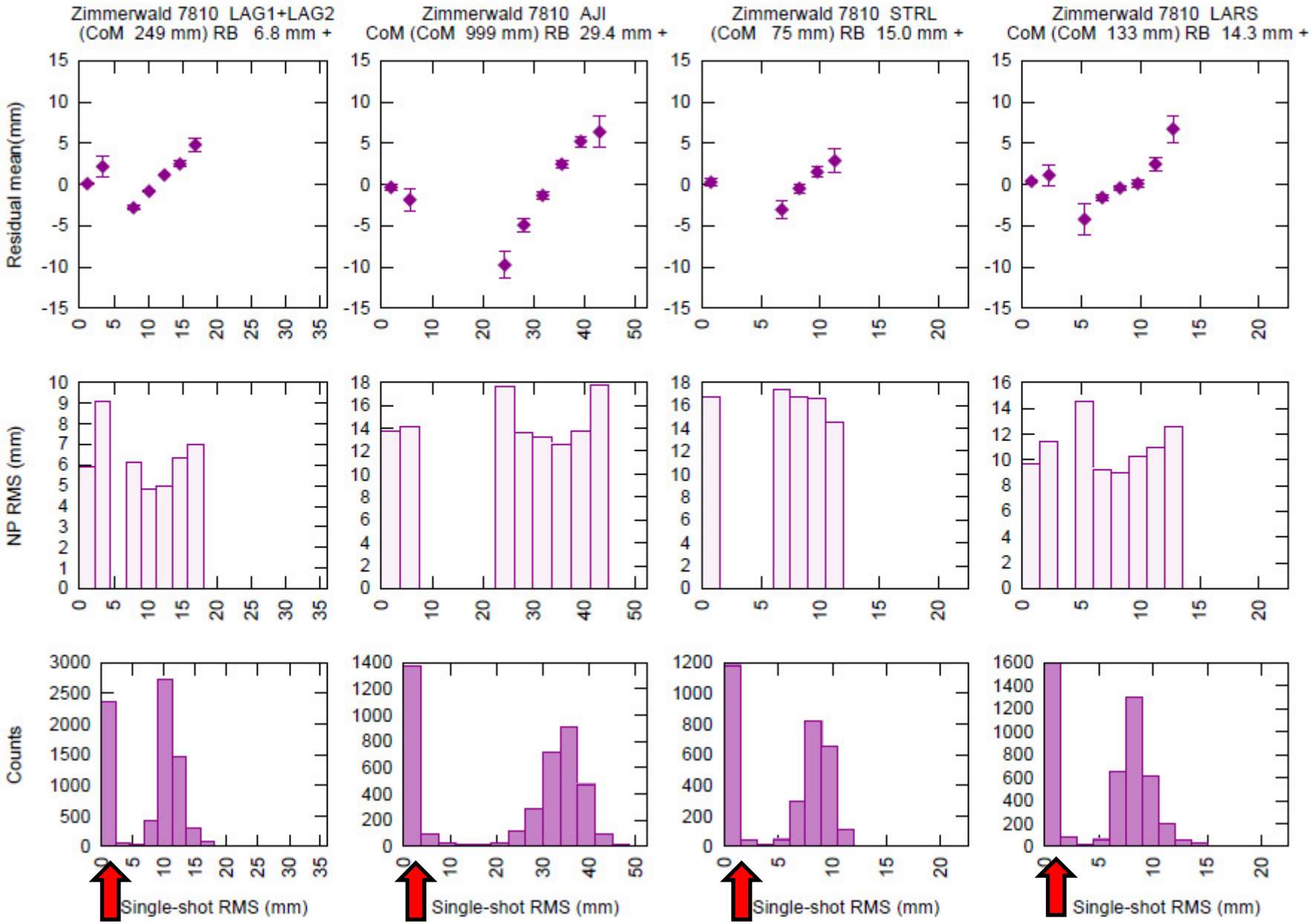

Monument Peak 7110 LAG1+LAG2
(CoM 249 mm) RB -6.4 mm +
Monument Peak 7110 AJI
CoM (CoM 1013 mm) RB 27.3 mm +
Monument Peak 7110 STRL
(CoM 75 mm) RB -5.6 mm +
Monument Peak 7110 LARS
CoM (CoM 133 mm) RB 7.6 mm +
Residual (mm)
NP RMS (mm)
Counts
Local time (hr)
Local time (hr)
Local time (hr)
Local time (hr)

7810

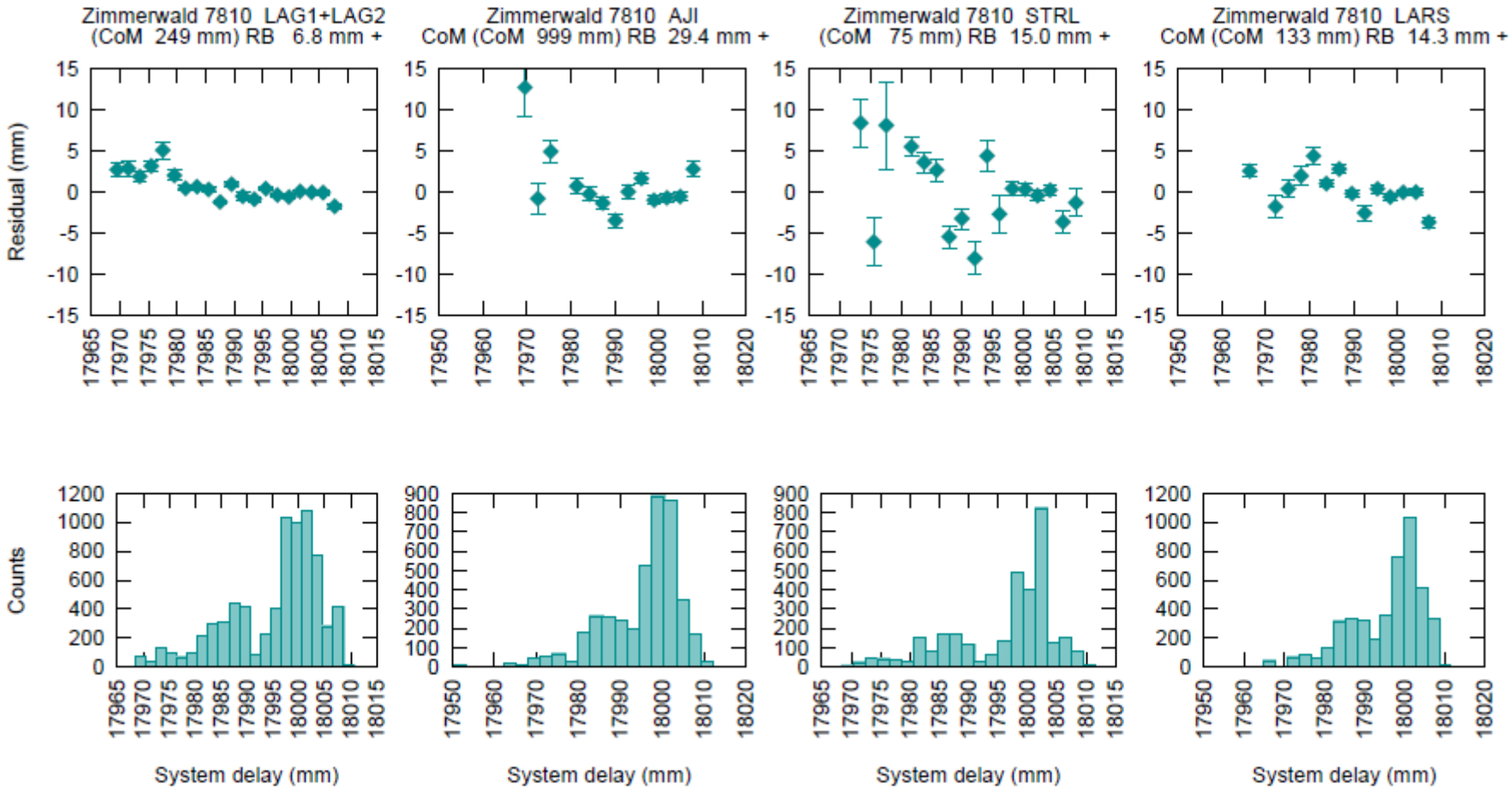
#1: Single-shot returns



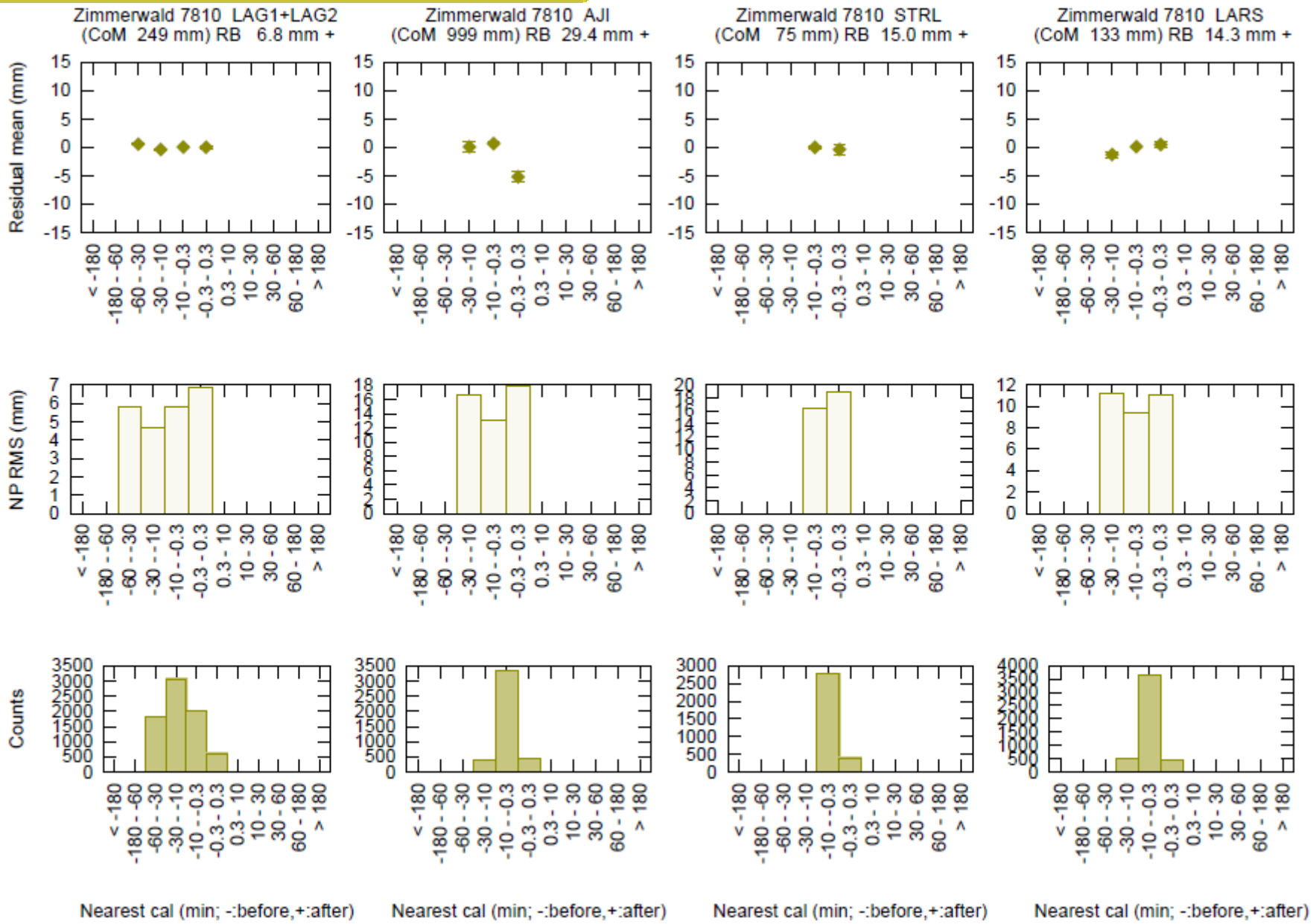
#2: Single-shot RMS



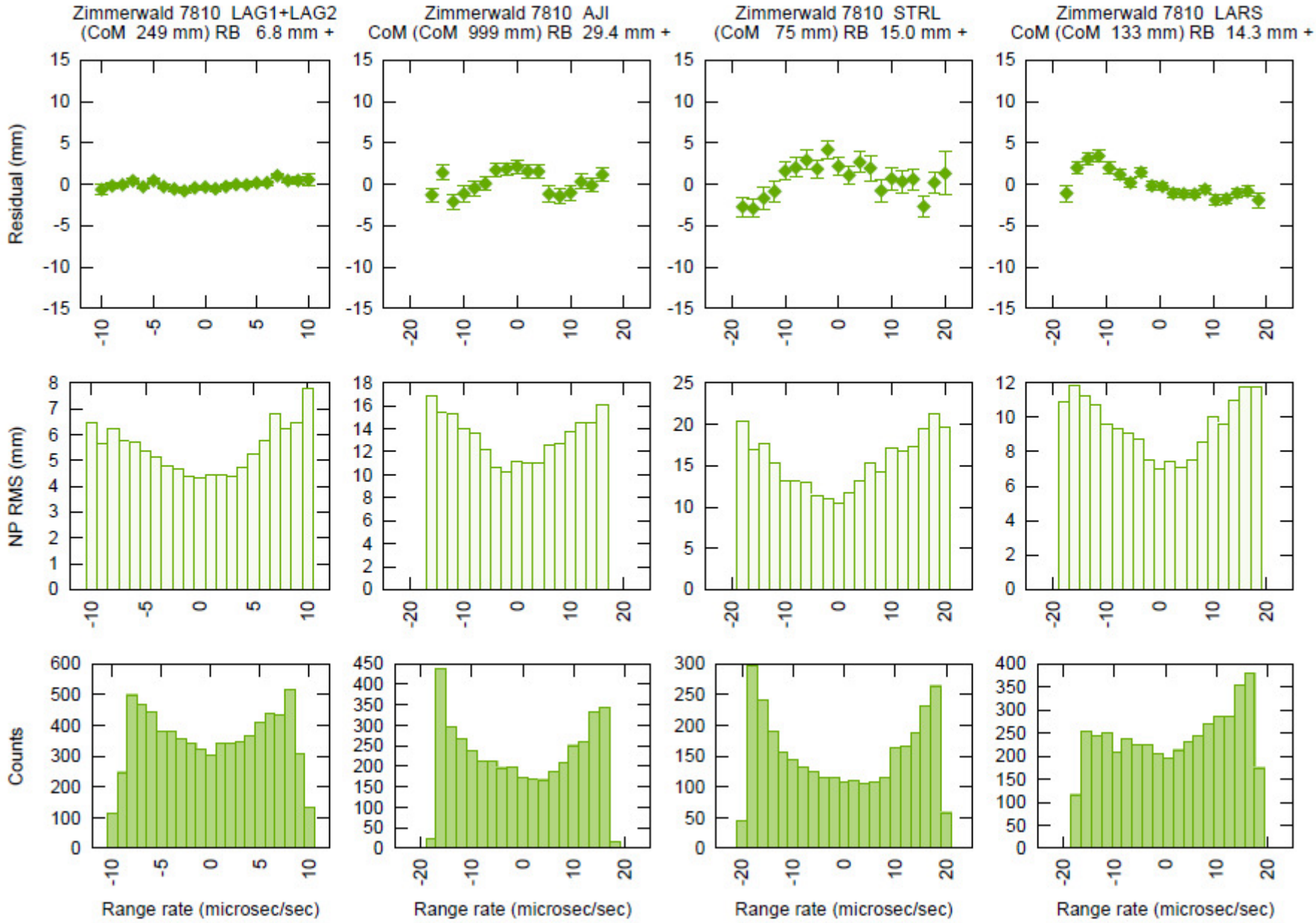
#3: System delay



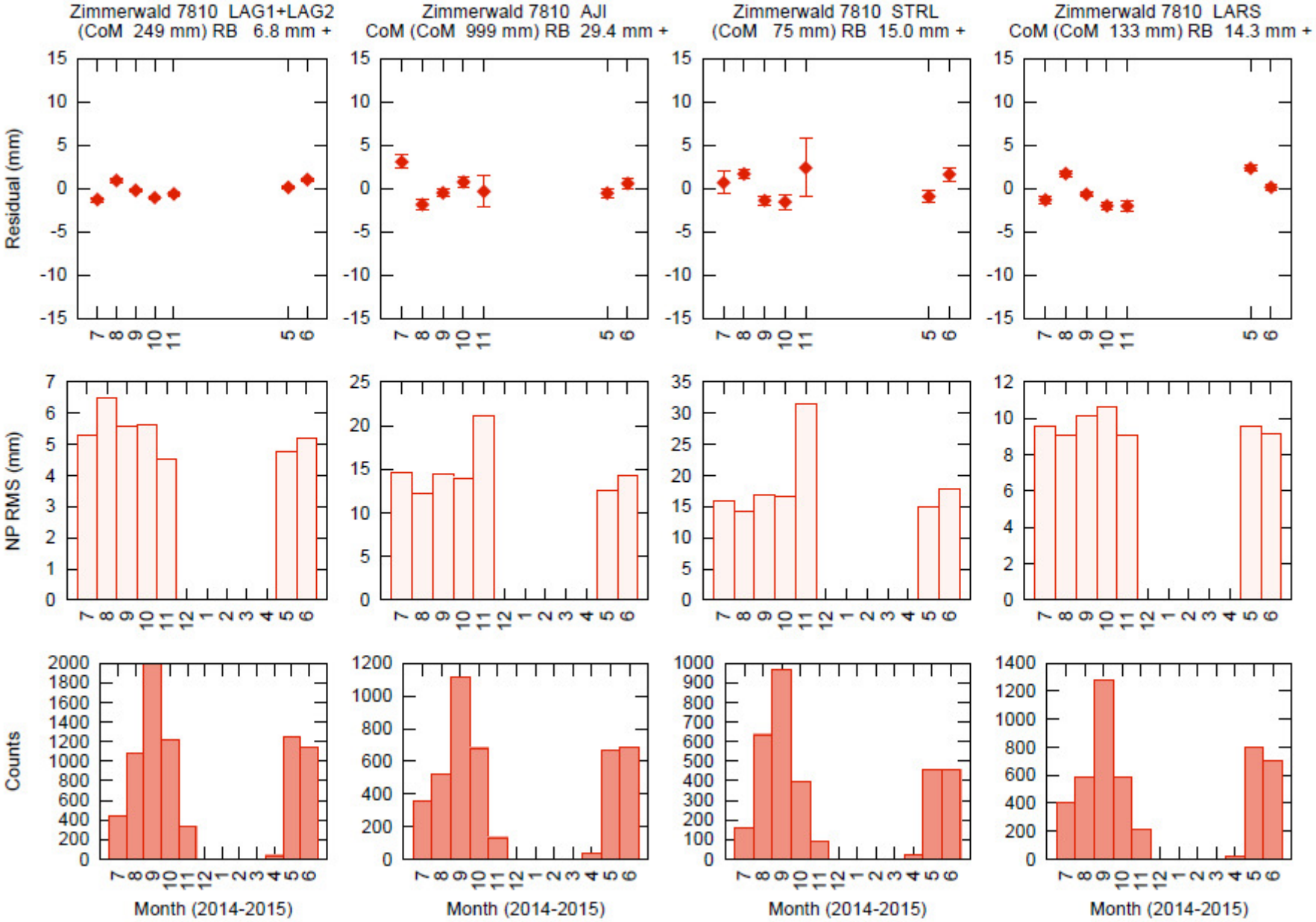
#4: Time to the nearest cal.



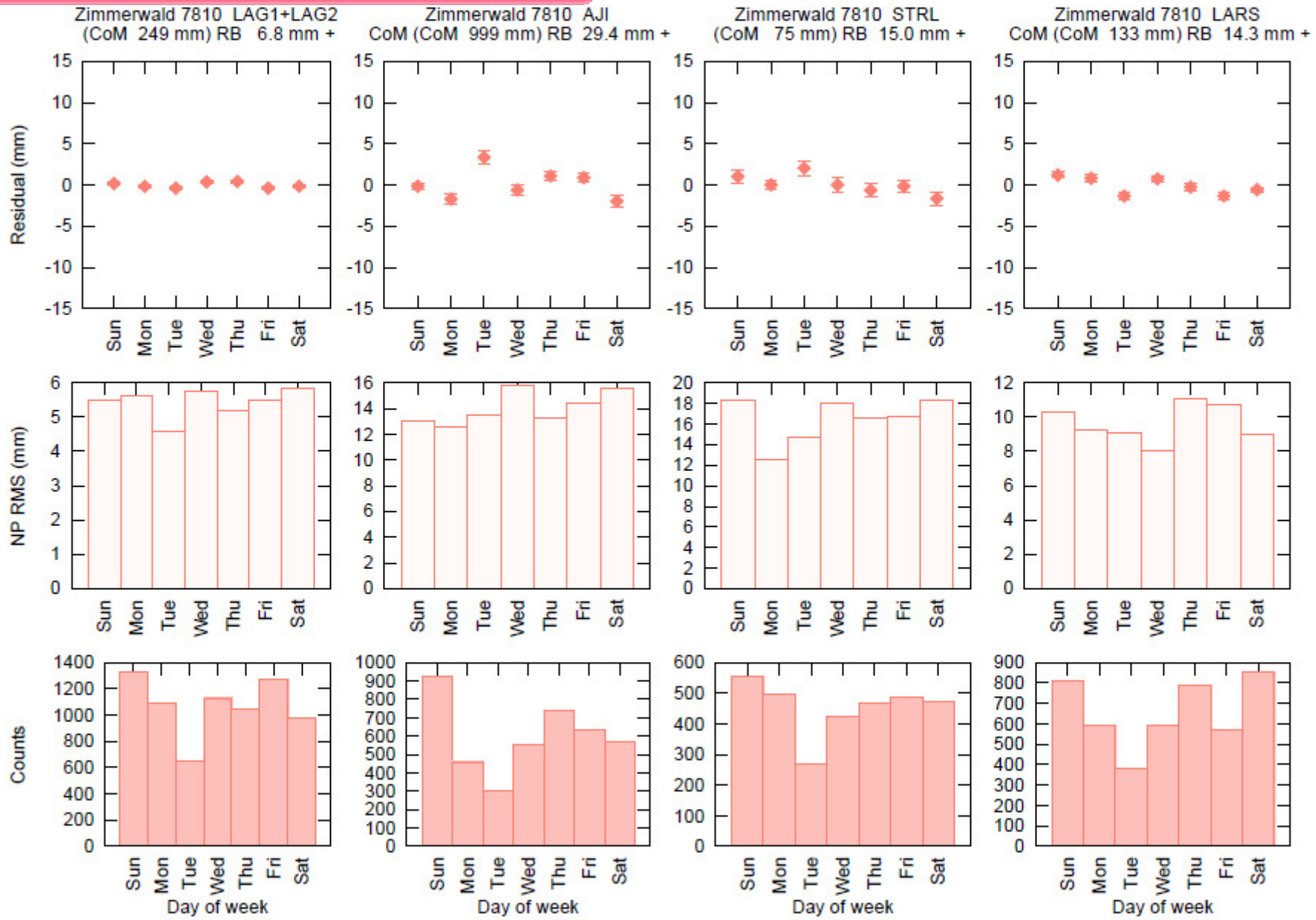
#5: Range rate


Zimmerwald 7810 LAG1+LAG2
(CoM 249 mm) RB 6.8 mm +
Zimmerwald 7810 AJI
CoM (CoM 999 mm) RB 29.4 mm +
Zimmerwald 7810 STRL
(CoM 75 mm) RB 15.0 mm +
Zimmerwald 7810 LARS
CoM (CoM 133 mm) RB 14.3 mm +
Residual (mm)
NP RMS (mm)
Counts
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)

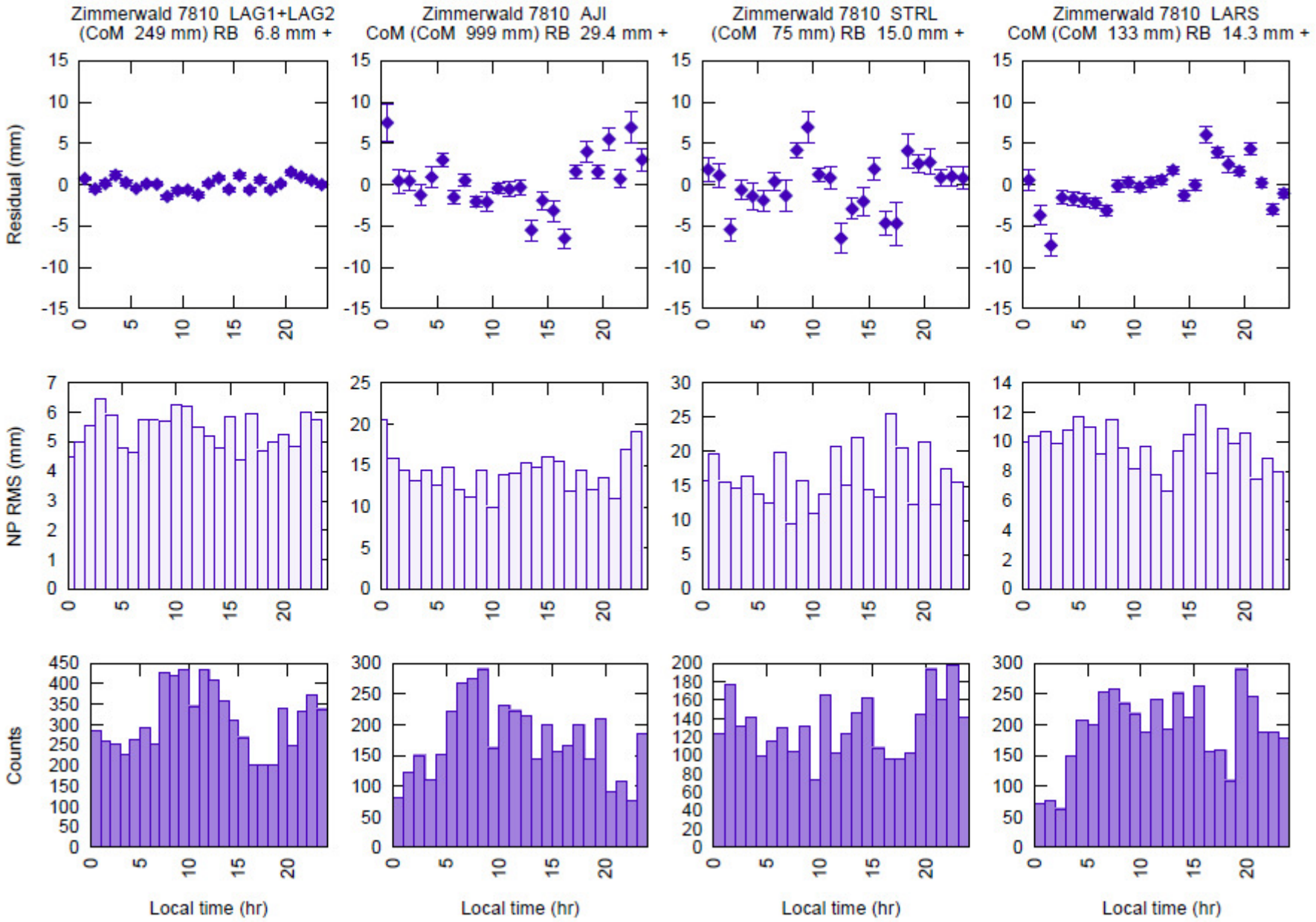
#6: Month


Zimmerwald 7810 LAG1+LAG2
(CoM 249 mm) RB 6.8 mm +
Zimmerwald 7810 AJI
CoM (CoM 999 mm) RB 29.4 mm +
Zimmerwald 7810 STRL
(CoM 75 mm) RB 15.0 mm +
Zimmerwald 7810 LARS
CoM (CoM 133 mm) RB 14.3 mm +
Residual (mm)
NP RMS (mm)
Counts
Month (2014-2015)
Month (2014-2015)
Month (2014-2015)
Month (2014-2015)

#7: Day of week

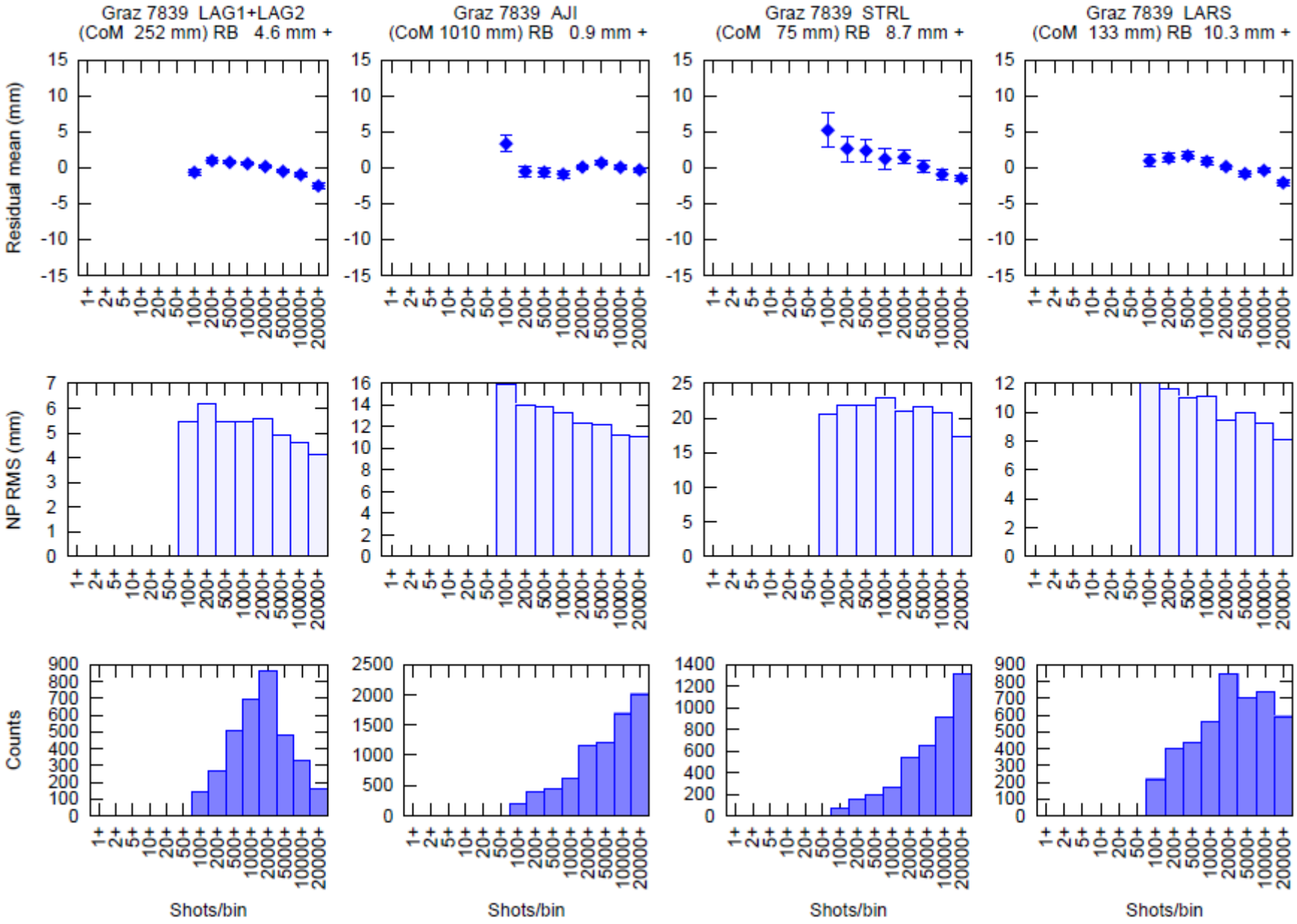

Zimmerwald 7810 LAG1+LAG2
(CoM 249 mm) RB 6.8 mm +
Zimmerwald 7810 AJI
CoM (CoM 999 mm) RB 29.4 mm +
Zimmerwald 7810 STRL
(CoM 75 mm) RB 15.0 mm +
Zimmerwald 7810 LARS
CoM (CoM 133 mm) RB 14.3 mm +
Residual (mm)
NP RMS (mm)
Counts
Sun Mon Tue Wed Thu Fri Sat
Day of week

#8: Local time

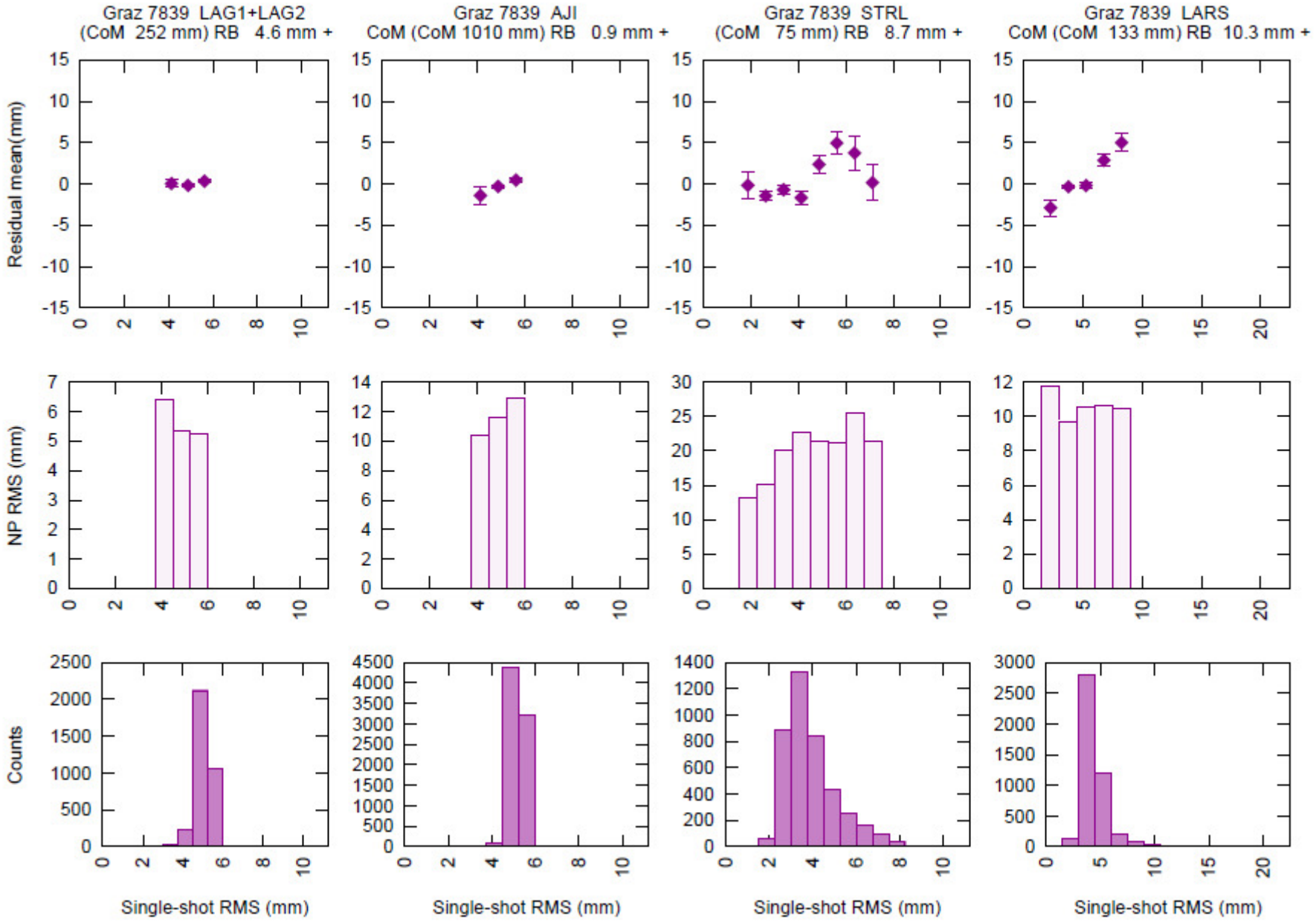

Zimmerwald 7810 LAG1+LAG2
(CoM 249 mm) RB 6.8 mm +
Zimmerwald 7810 AJI
CoM (CoM 999 mm) RB 29.4 mm +
Zimmerwald 7810 STRL
(CoM 75 mm) RB 15.0 mm +
Zimmerwald 7810 LARS
CoM (CoM 133 mm) RB 14.3 mm +
Residual (mm)
NP RMS (mm)
Counts
Local time (hr)
Local time (hr)
Local time (hr)
Local time (hr)

7839

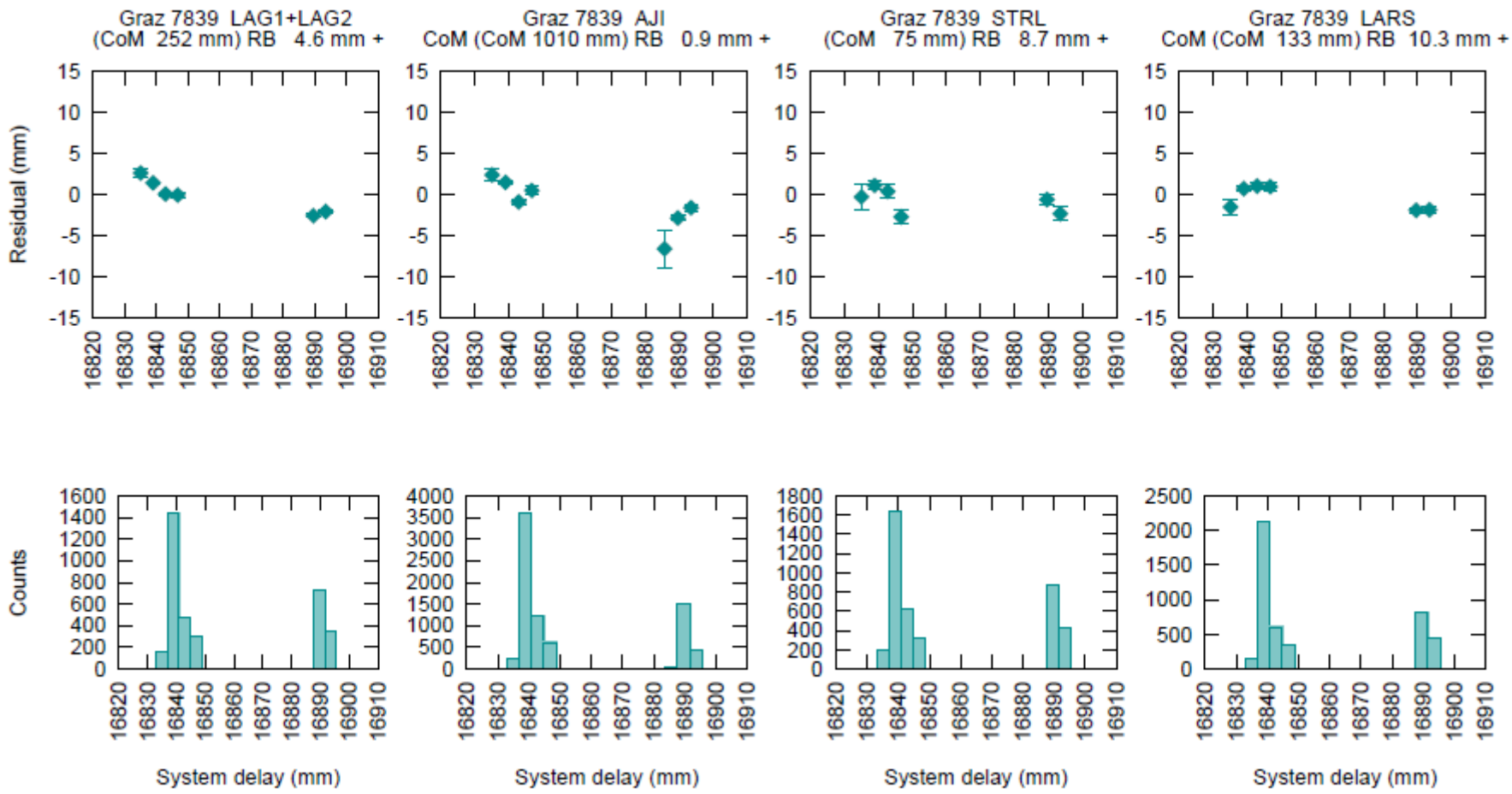
#1: Single-shot returns



#2: Single-shot RMS

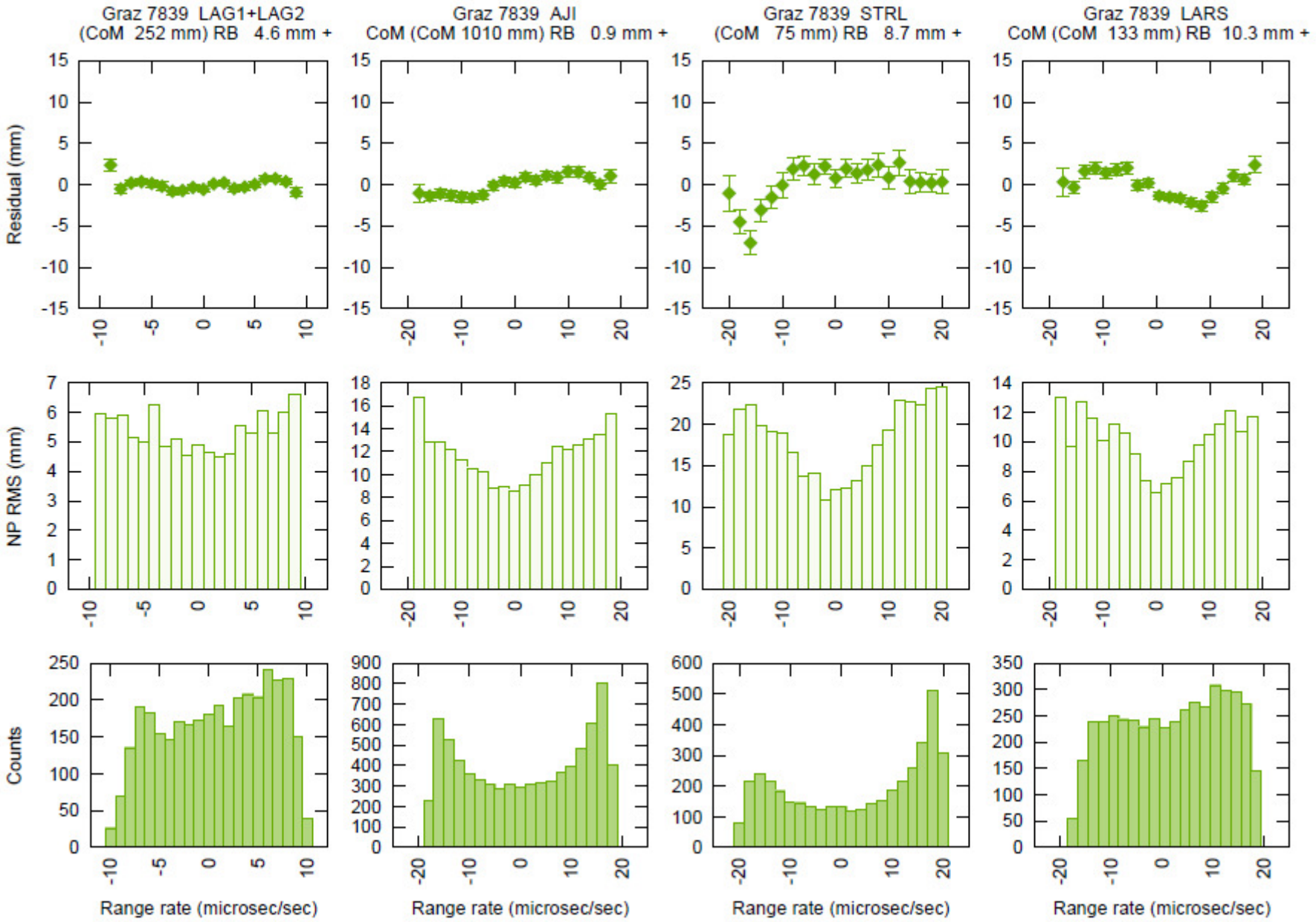


#3: System delay

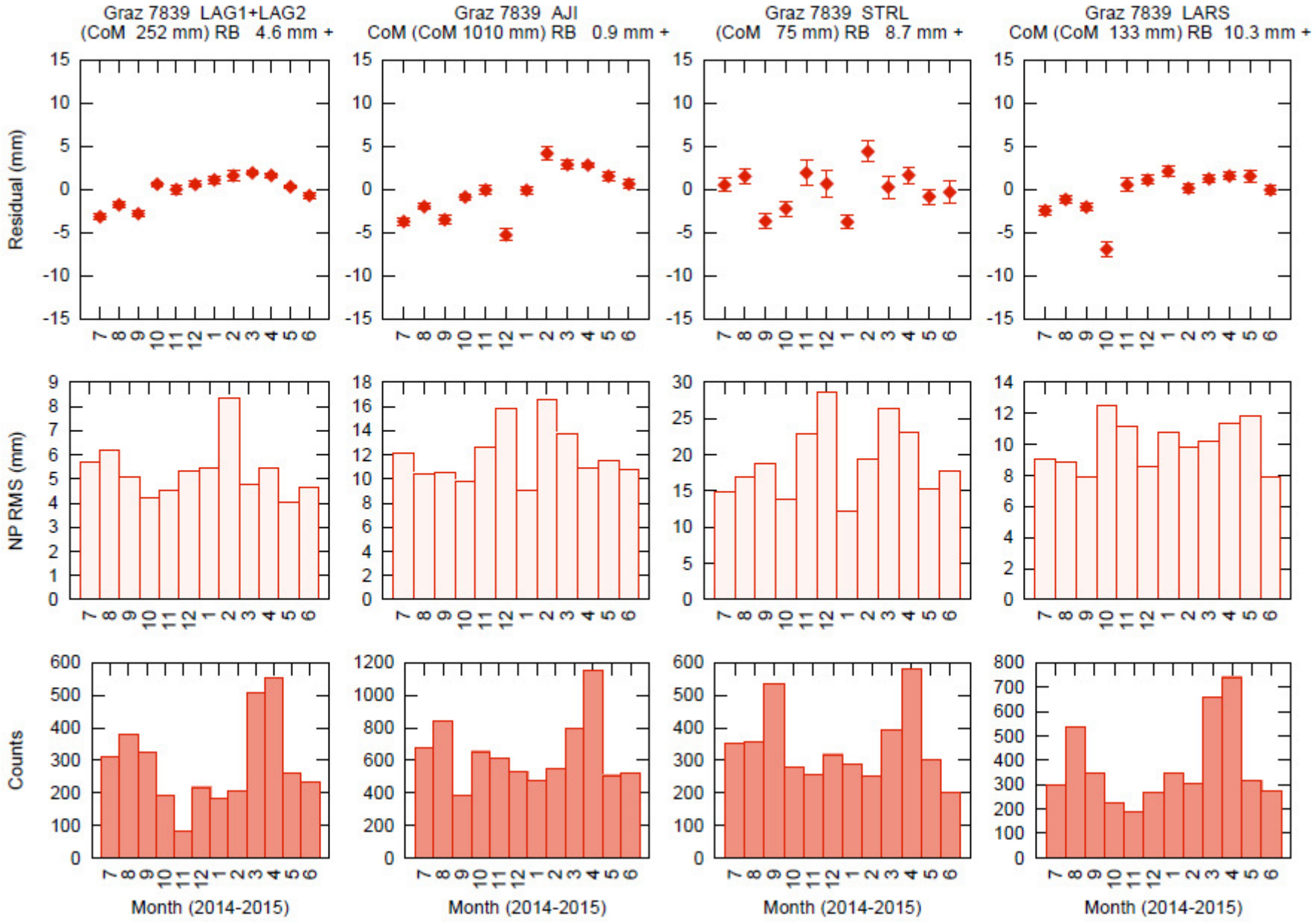


#4: Time to the nearest cal.

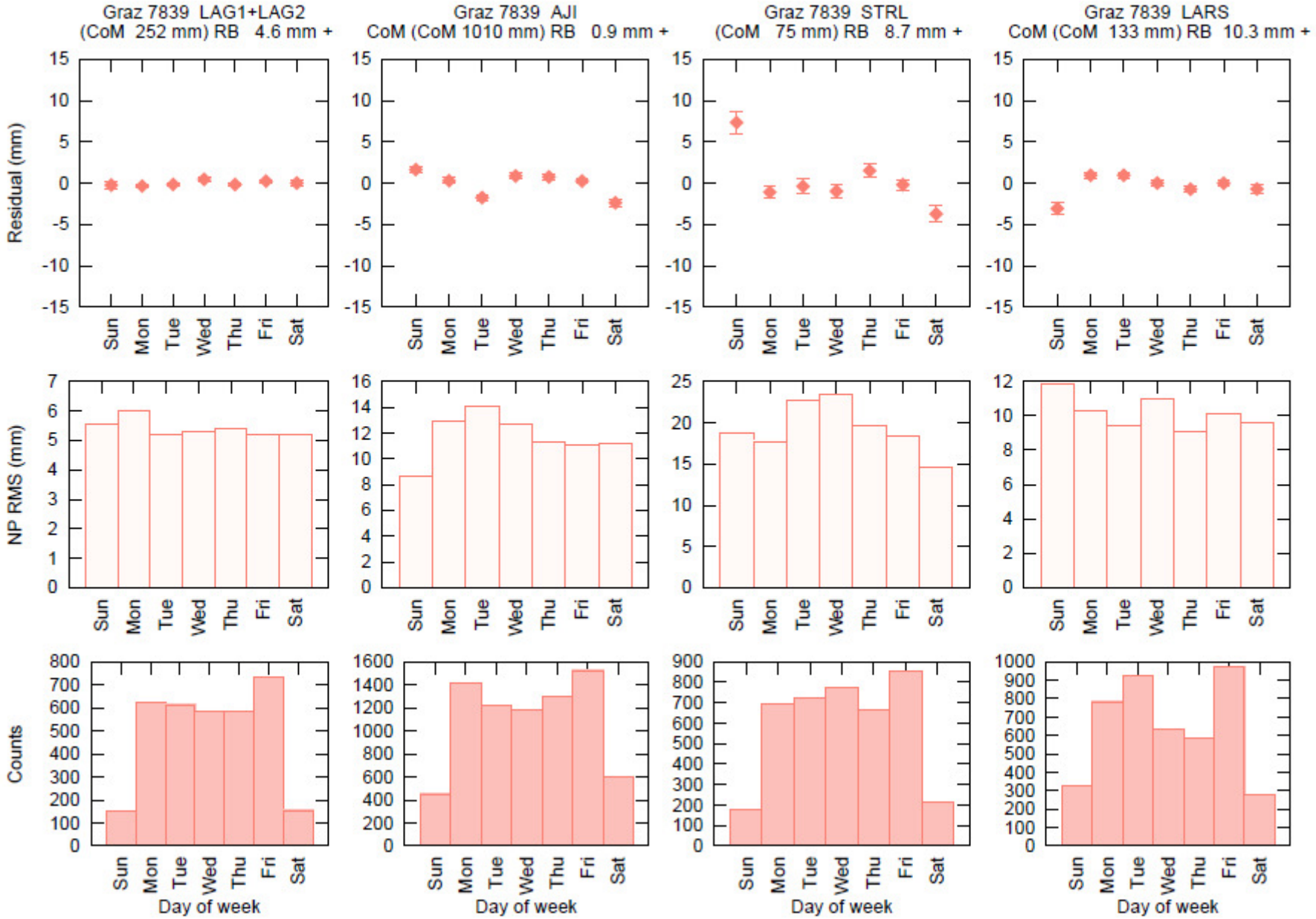
#5: Range rate


Graz 7839 LAG1+LAG2
(CoM 252 mm) RB 4.6 mm +
Graz 7839 AJI
CoM (CoM 1010 mm) RB 0.9 mm +
Graz 7839 STRL
(CoM 75 mm) RB 8.7 mm +
Graz 7839 LARS
CoM (CoM 133 mm) RB 10.3 mm +
Residual (mm)
NP RMS (mm)
Counts
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)

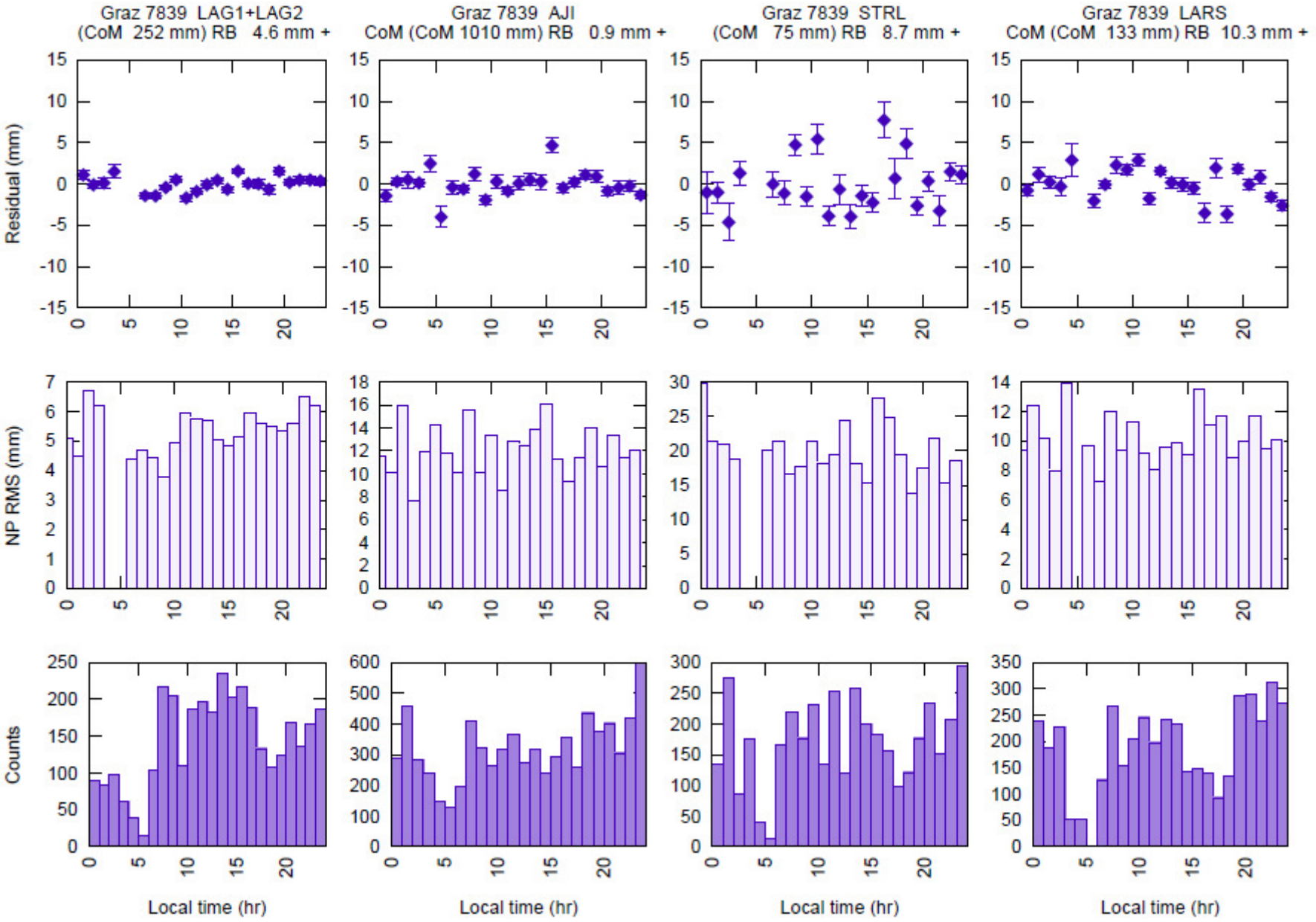
#6: Month


Graz 7839 LAG1+LAG2
(CoM 252 mm) RB 4.6 mm +
Graz 7839 AJI
CoM (CoM 1010 mm) RB 0.9 mm +
Graz 7839 STRL
(CoM 75 mm) RB 8.7 mm +
Graz 7839 LARS
CoM (CoM 133 mm) RB 10.3 mm +
Residual (mm)
NP RMS (mm)
Counts
Month (2014-2015)
Month (2014-2015)
Month (2014-2015)
Month (2014-2015)

#7: Day of week

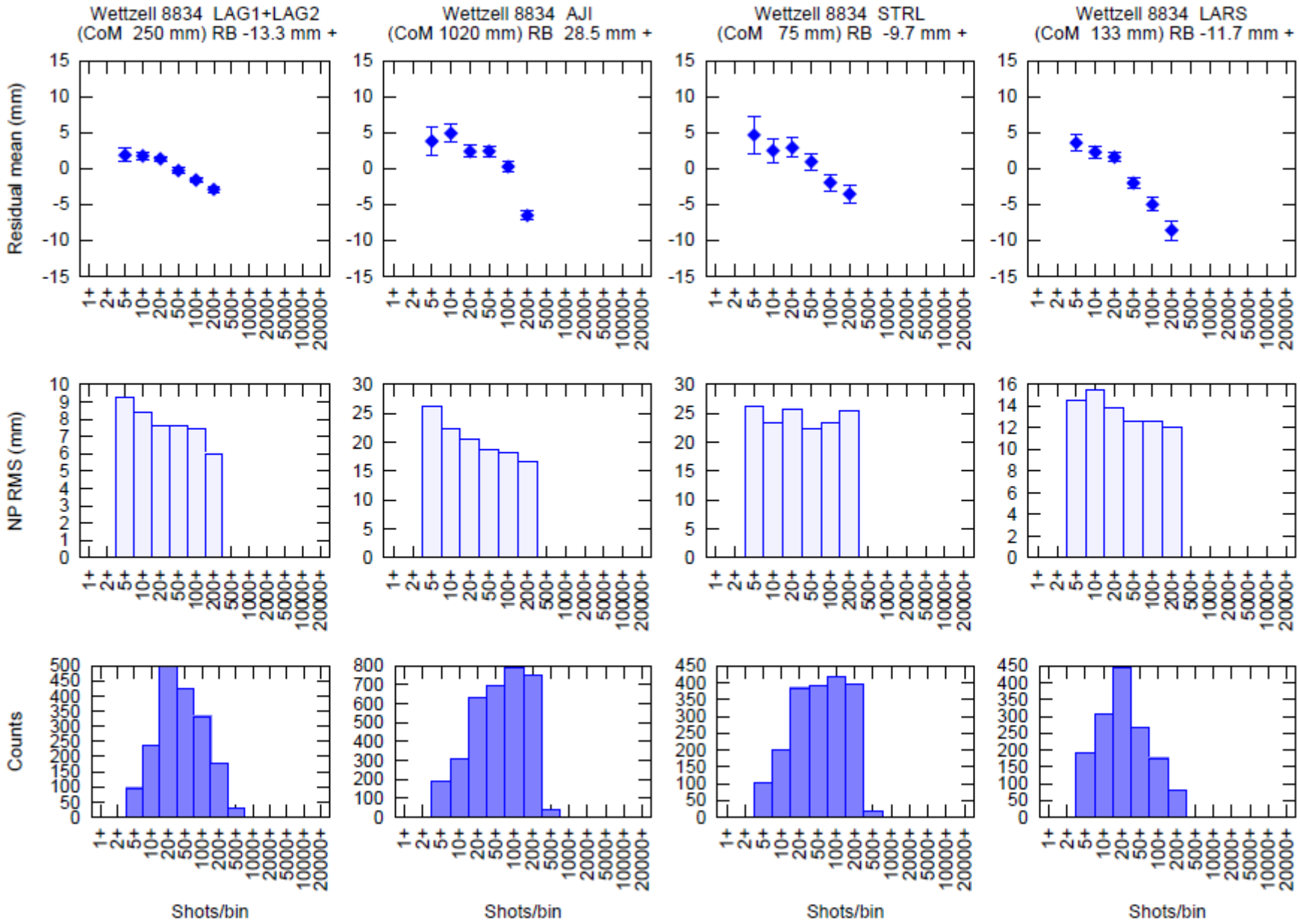

Graz 7839 LAG1+LAG2
(CoM 252 mm) RB 4.6 mm +
Graz 7839 AJI
CoM (CoM 1010 mm) RB 0.9 mm +
Graz 7839 STRL
(CoM 75 mm) RB 8.7 mm +
Graz 7839 LARS
CoM (CoM 133 mm) RB 10.3 mm +
Residual (mm)
NP RMS (mm)
Counts
Sun Mon Tue Wed Thu Fri Sat
Day of week

#8: Local time

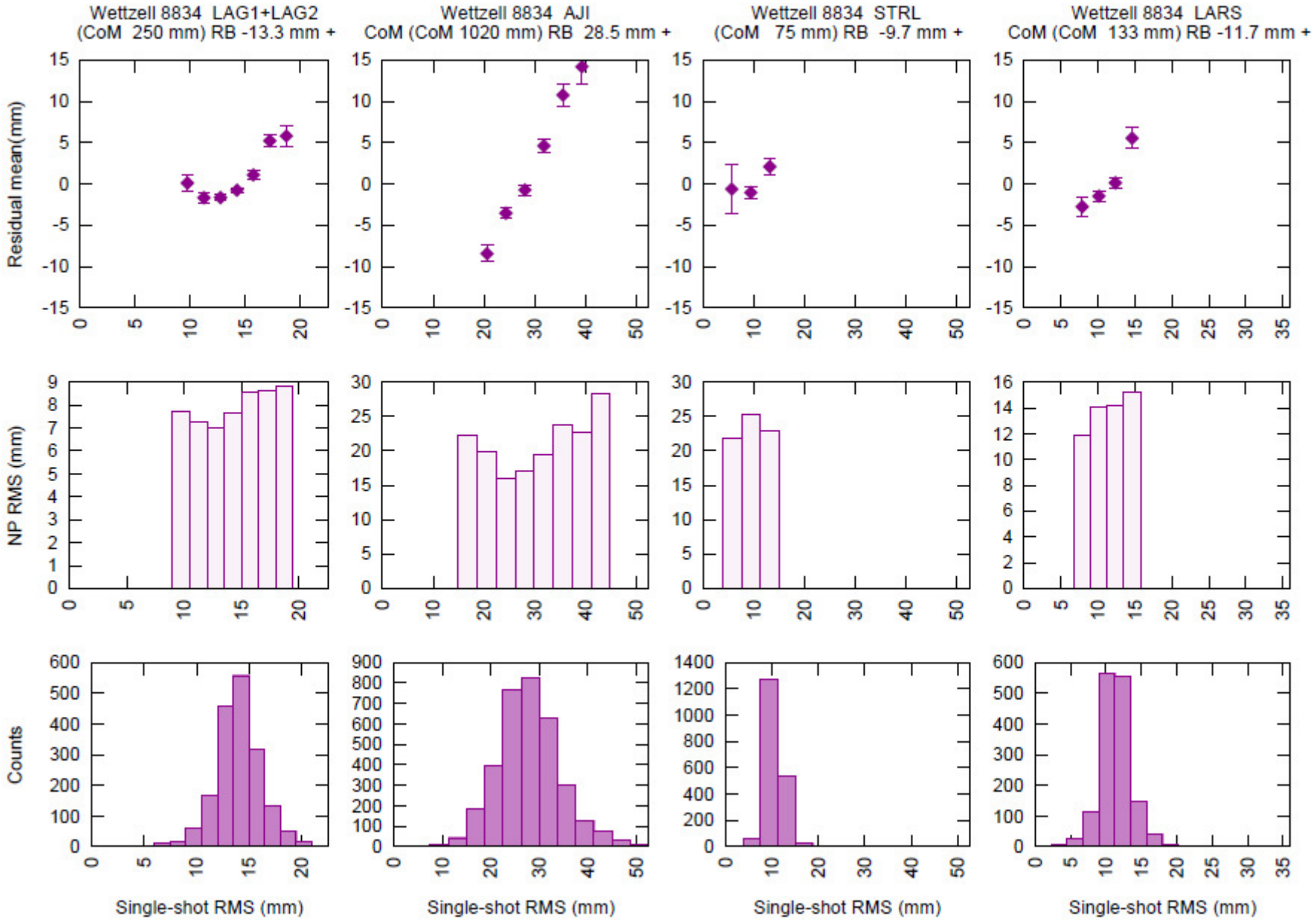

Graz 7839 LAG1+LAG2
(CoM 252 mm) RB 4.6 mm +
Graz 7839 AJI
CoM (CoM 1010 mm) RB 0.9 mm +
Graz 7839 STRL
(CoM 75 mm) RB 8.7 mm +
Graz 7839 LARS
CoM (CoM 133 mm) RB 10.3 mm +
Residual (mm)
NP RMS (mm)
Counts
Local time (hr)
Local time (hr)
Local time (hr)
Local time (hr)

8834

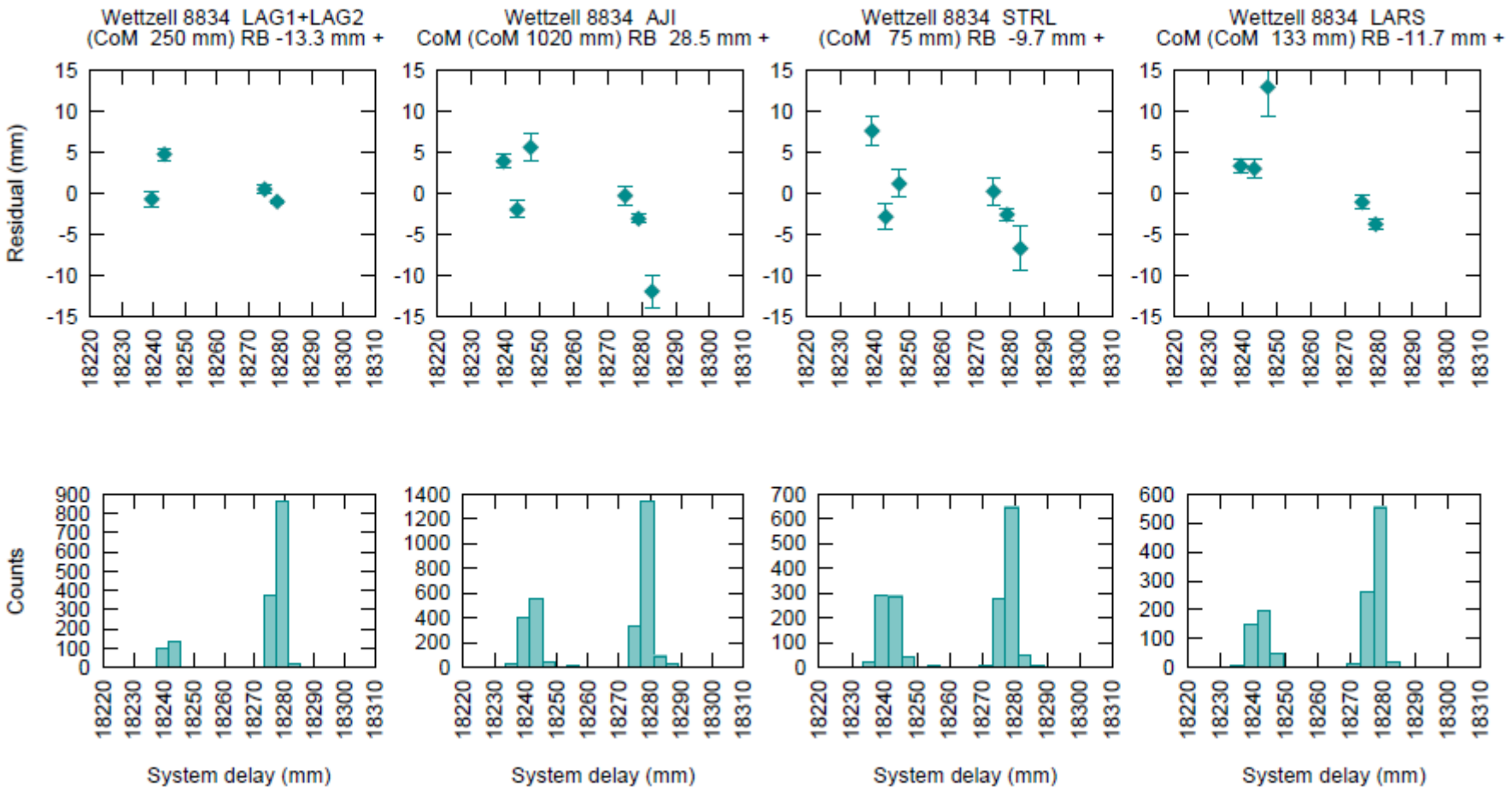
#1: Single-shot returns



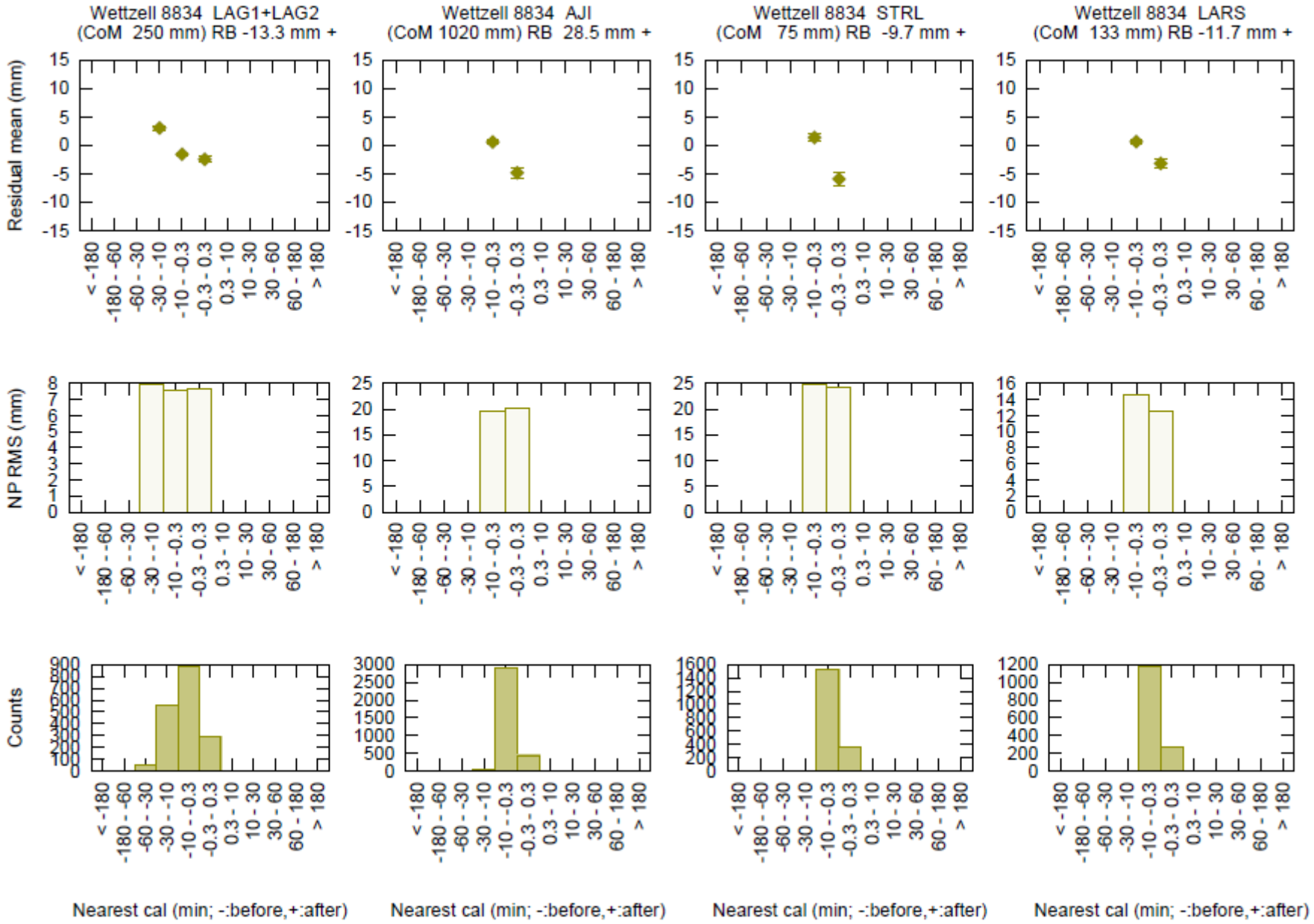
#2: Single-shot RMS



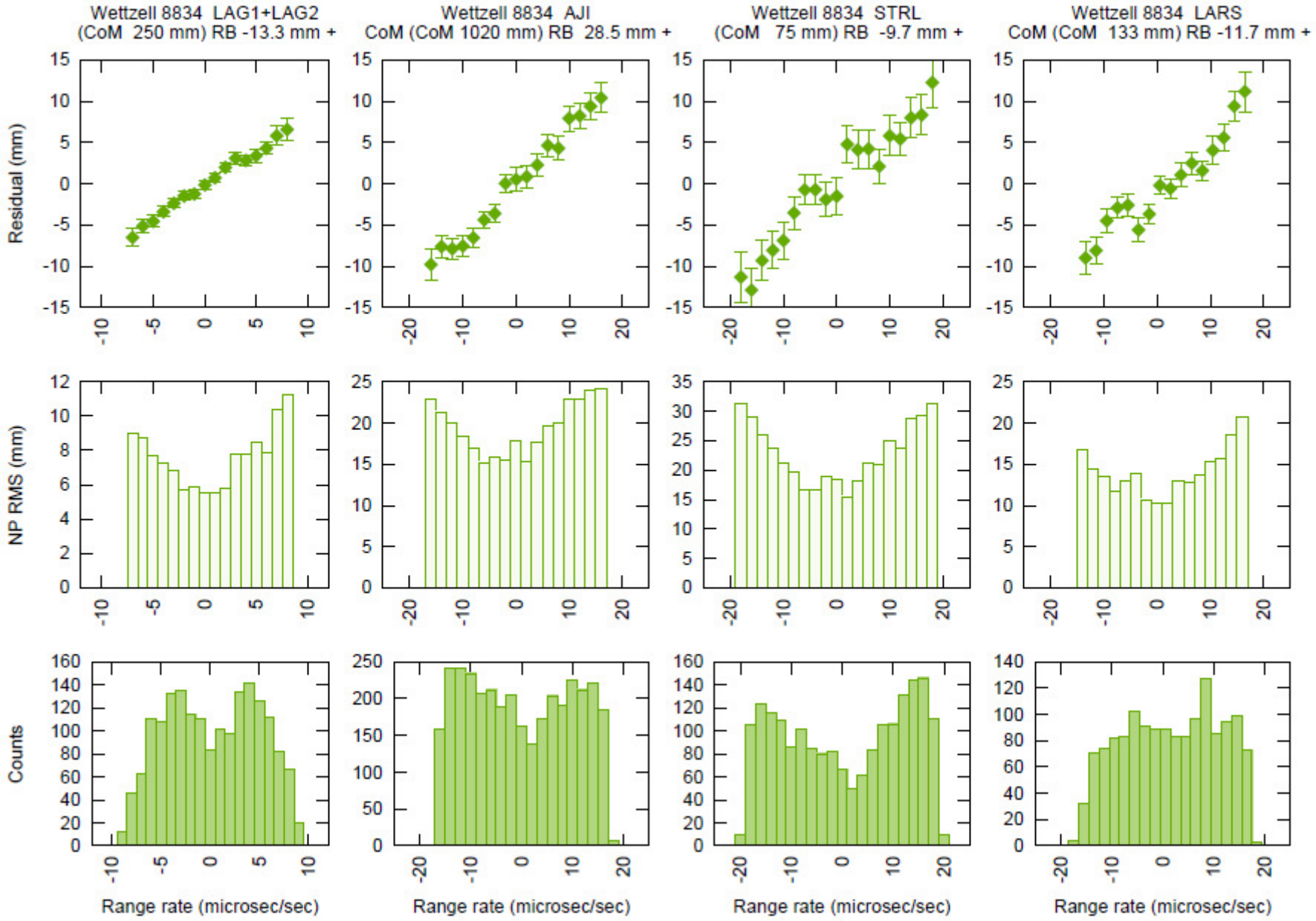
#3: System delay



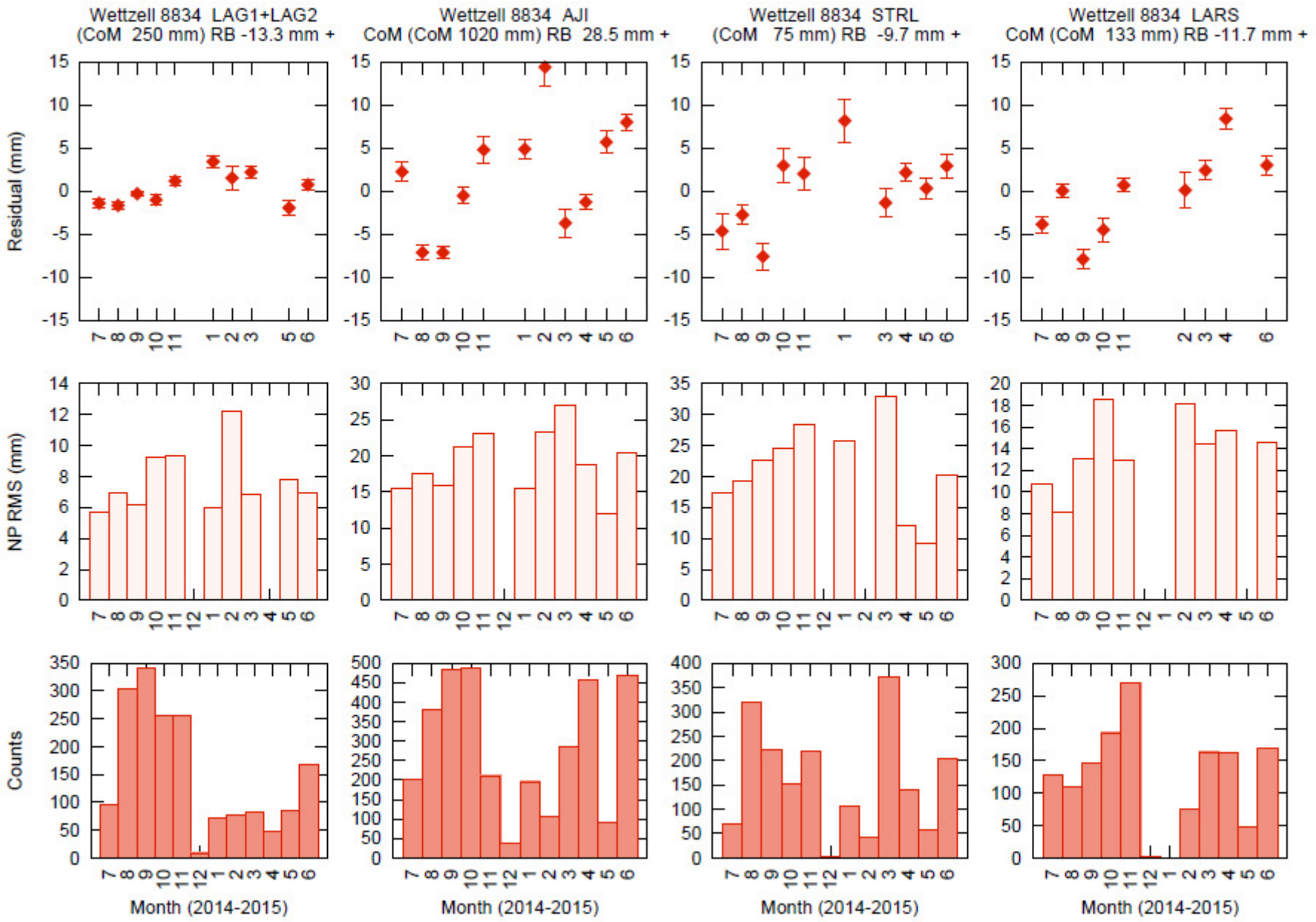
#4: Time to the nearest cal.



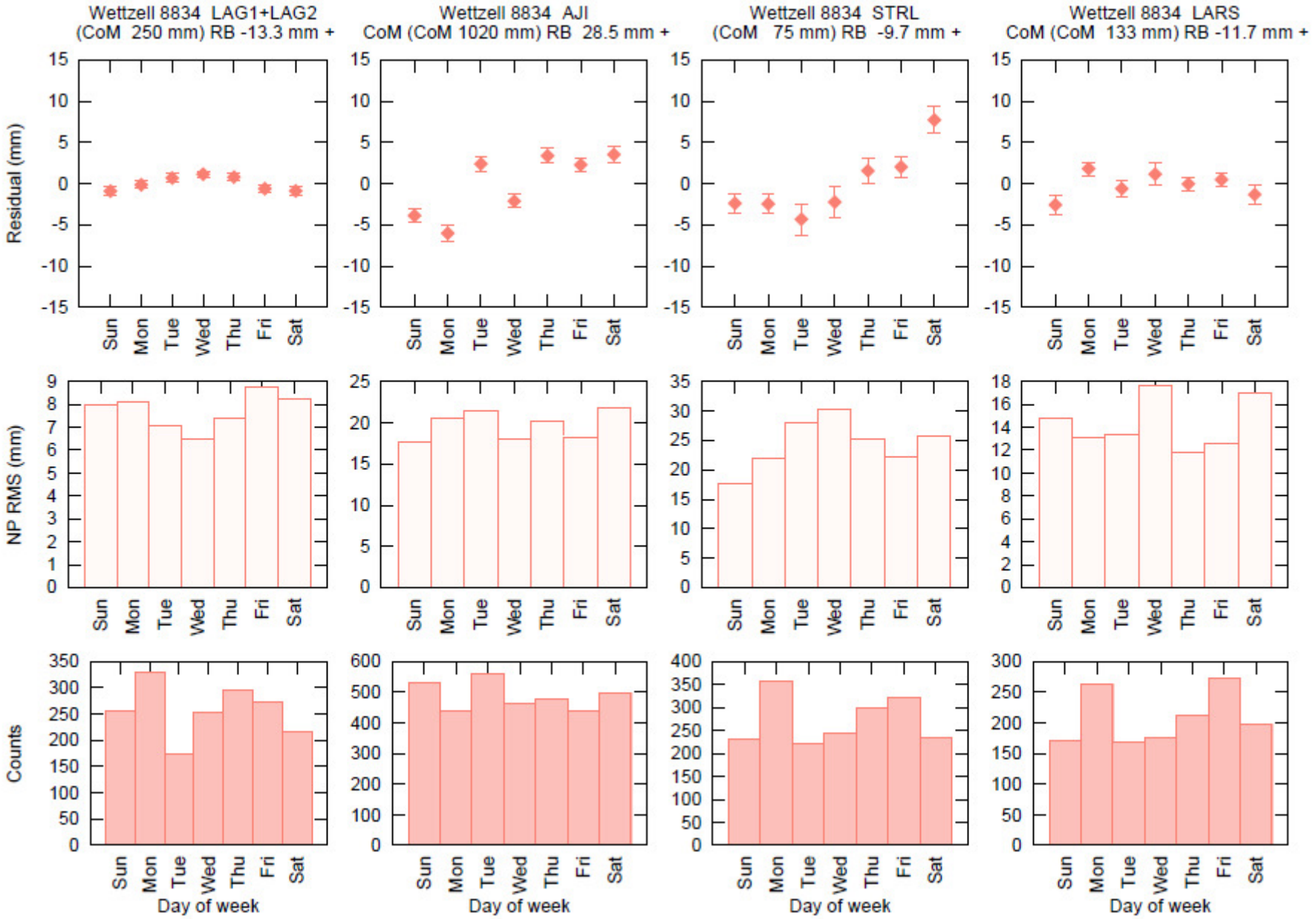
#5: Range rate


Wettzell 8834 LAG1+LAG2
(CoM 250 mm) RB -13.3 mm +
Wettzell 8834 AJI
CoM (CoM 1020 mm) RB 28.5 mm +
Wettzell 8834 STRL
(CoM 75 mm) RB -9.7 mm +
Wettzell 8834 LARS
CoM (CoM 133 mm) RB -11.7 mm +
Residual (mm)
NP RMS (mm)
Counts
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)
Range rate (microsec/sec)

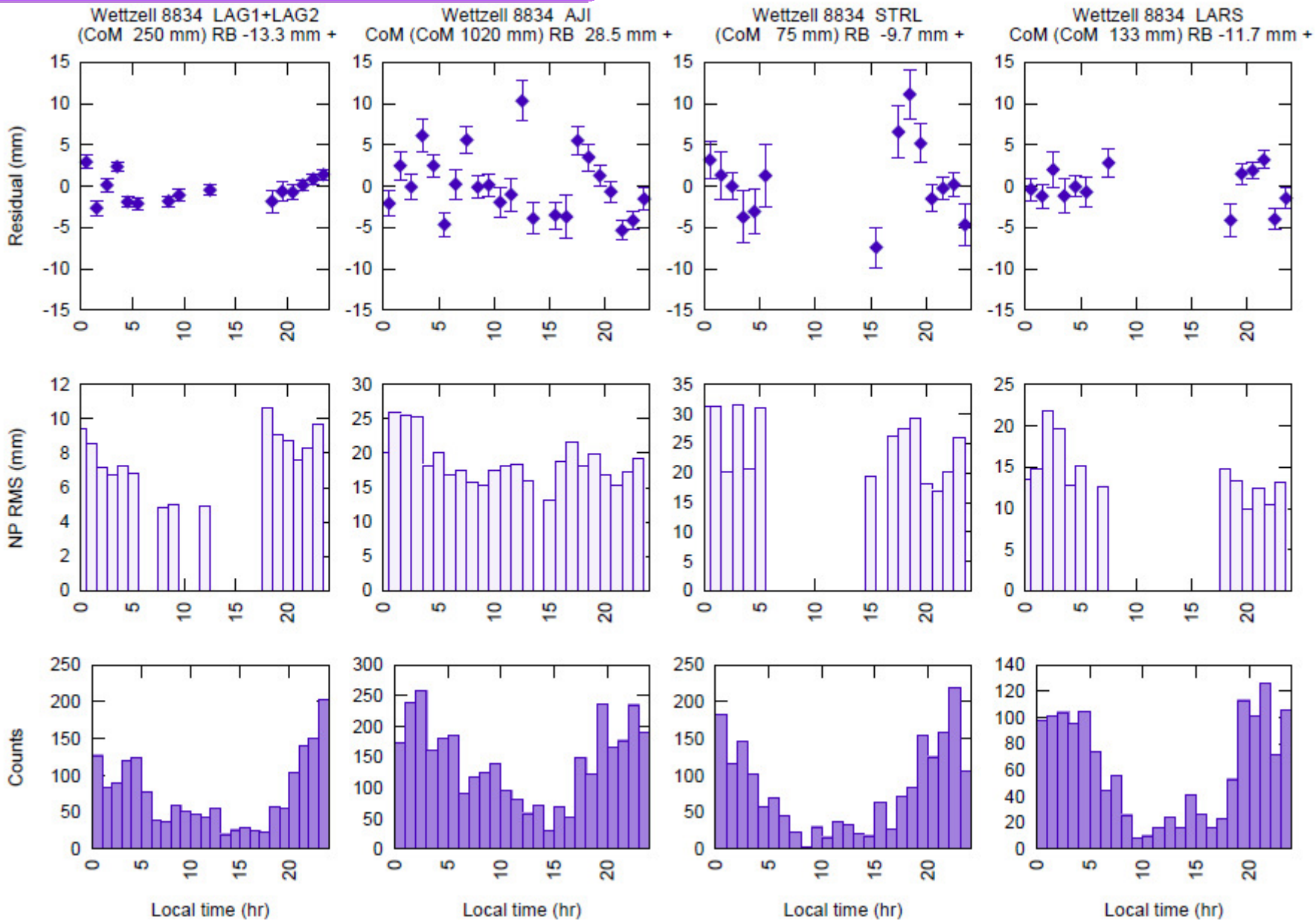
#6: Month


Wettzell 8834 LAG1+LAG2
(CoM 250 mm) RB -13.3 mm +
Wettzell 8834 AJI
CoM (CoM 1020 mm) RB 28.5 mm +
Wettzell 8834 STRL
(CoM 75 mm) RB -9.7 mm +
Wettzell 8834 LARS
CoM (CoM 133 mm) RB -11.7 mm +
Residual (mm)
NP RMS (mm)
Counts
Month (2014-2015)
Month (2014-2015)
Month (2014-2015)
Month (2014-2015)

#7: Day of week

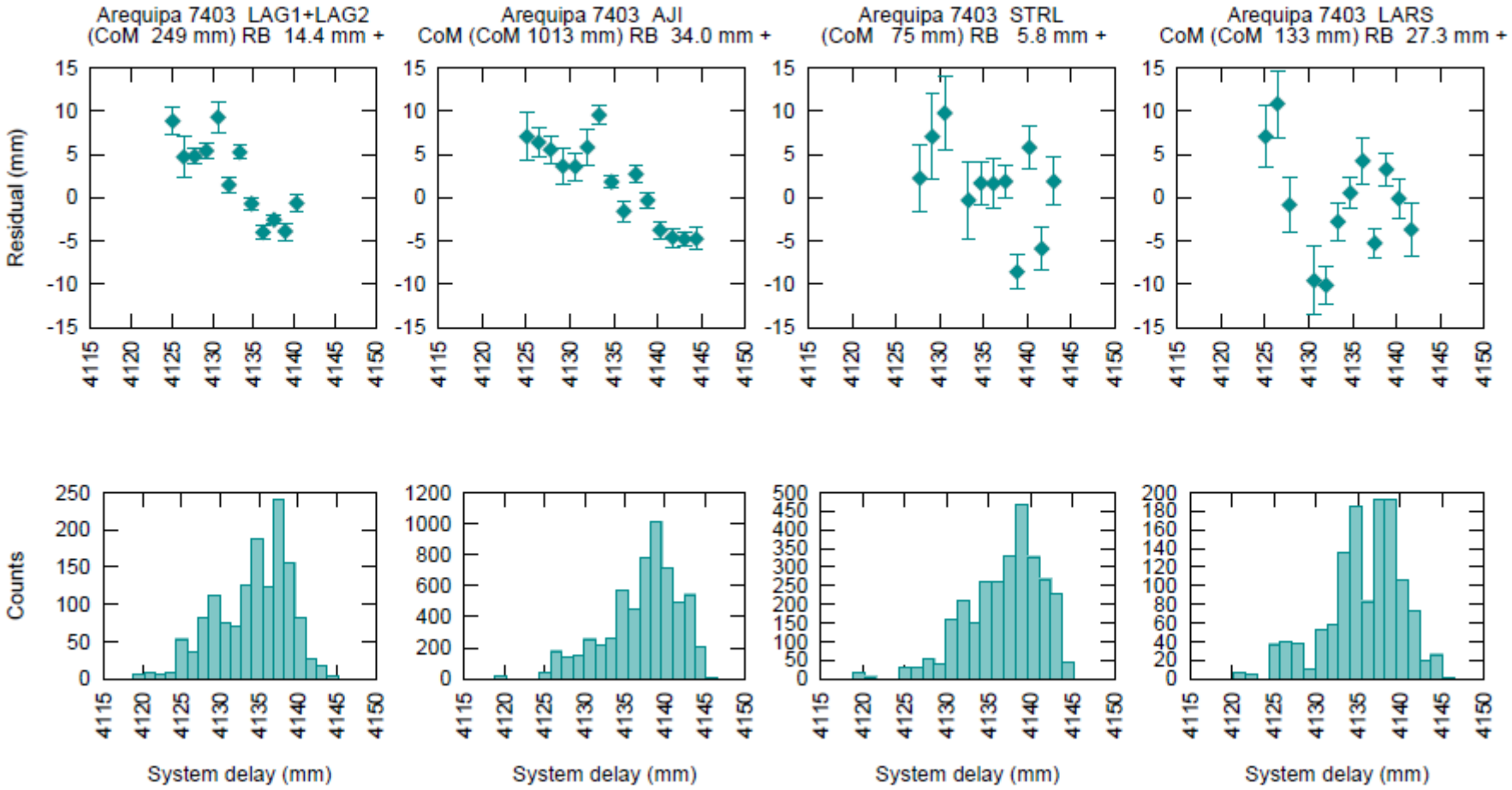

Wettzell 8834 LAG1+LAG2
(CoM 250 mm) RB -13.3 mm +
Wettzell 8834 AJI
CoM (CoM 1020 mm) RB 28.5 mm +
Wettzell 8834 STRL
(CoM 75 mm) RB -9.7 mm +
Wettzell 8834 LARS
CoM (CoM 133 mm) RB -11.7 mm +
Residual (mm)
NP RMS (mm)
Counts
Sun Mon Tue Wed Thu Fri Sat
Day of week

#8: Local time

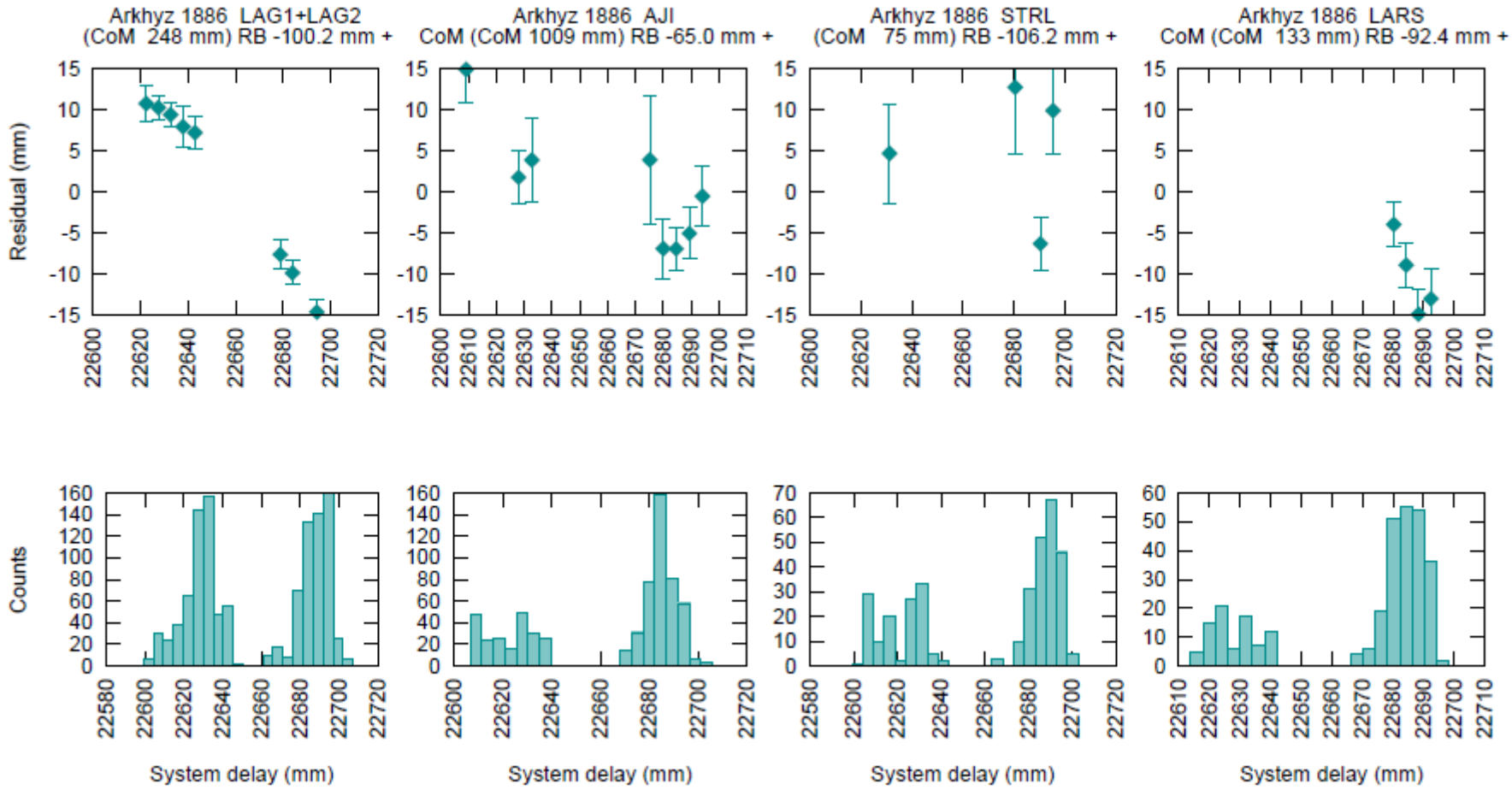

Wettzell 8834 LAG1+LAG2
(CoM 250 mm) RB -13.3 mm +
Wettzell 8834 AJI
CoM (CoM 1020 mm) RB 28.5 mm +
Wettzell 8834 STRL
(CoM 75 mm) RB -9.7 mm +
Wettzell 8834 LARS
CoM (CoM 133 mm) RB -11.7 mm +
Residual (mm)
NP RMS (mm)
Counts
Local time (hr)
Local time (hr)
Local time (hr)
Local time (hr)

#3: System delay

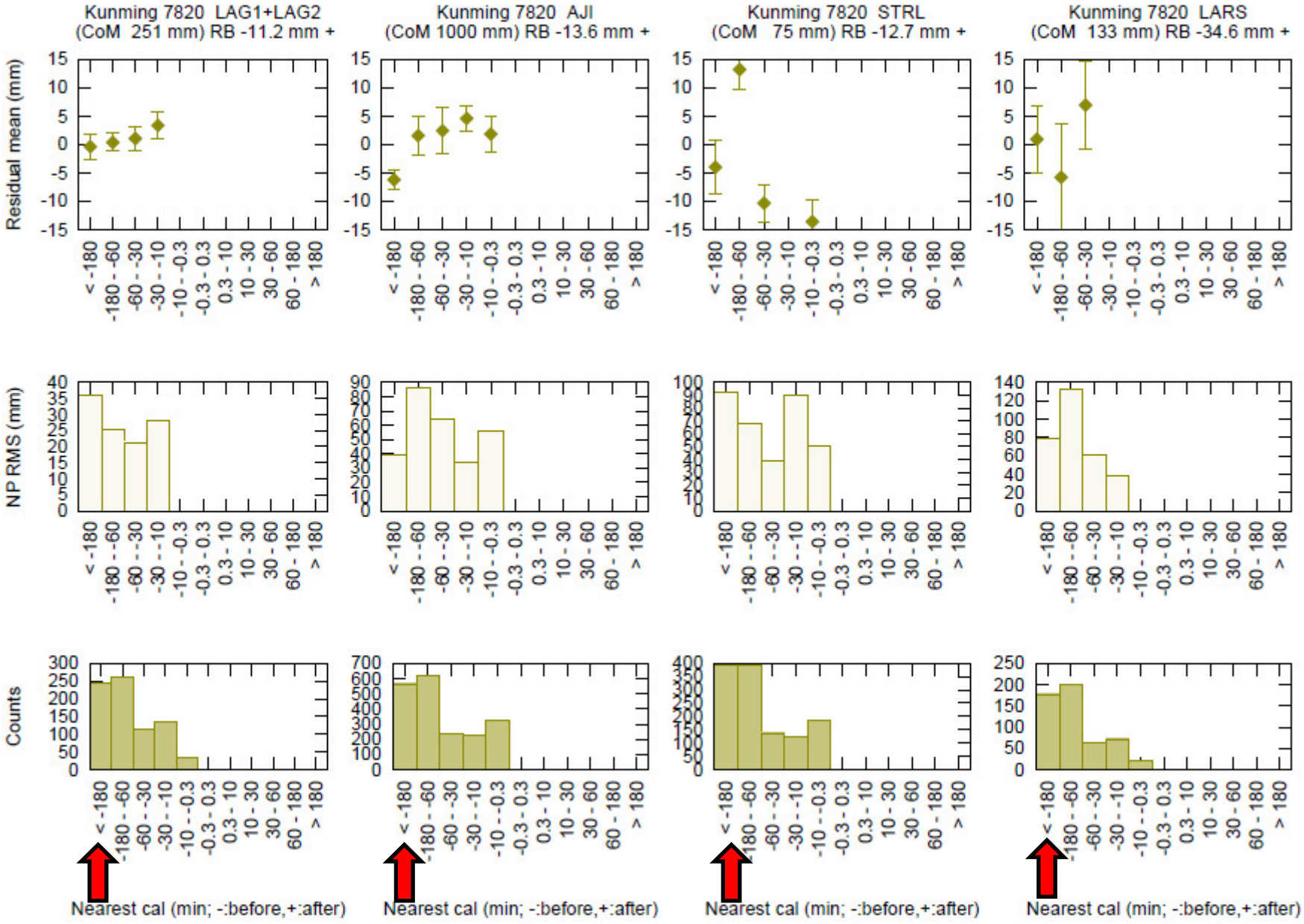
Negative 1:1 trend → Not calibrated properly



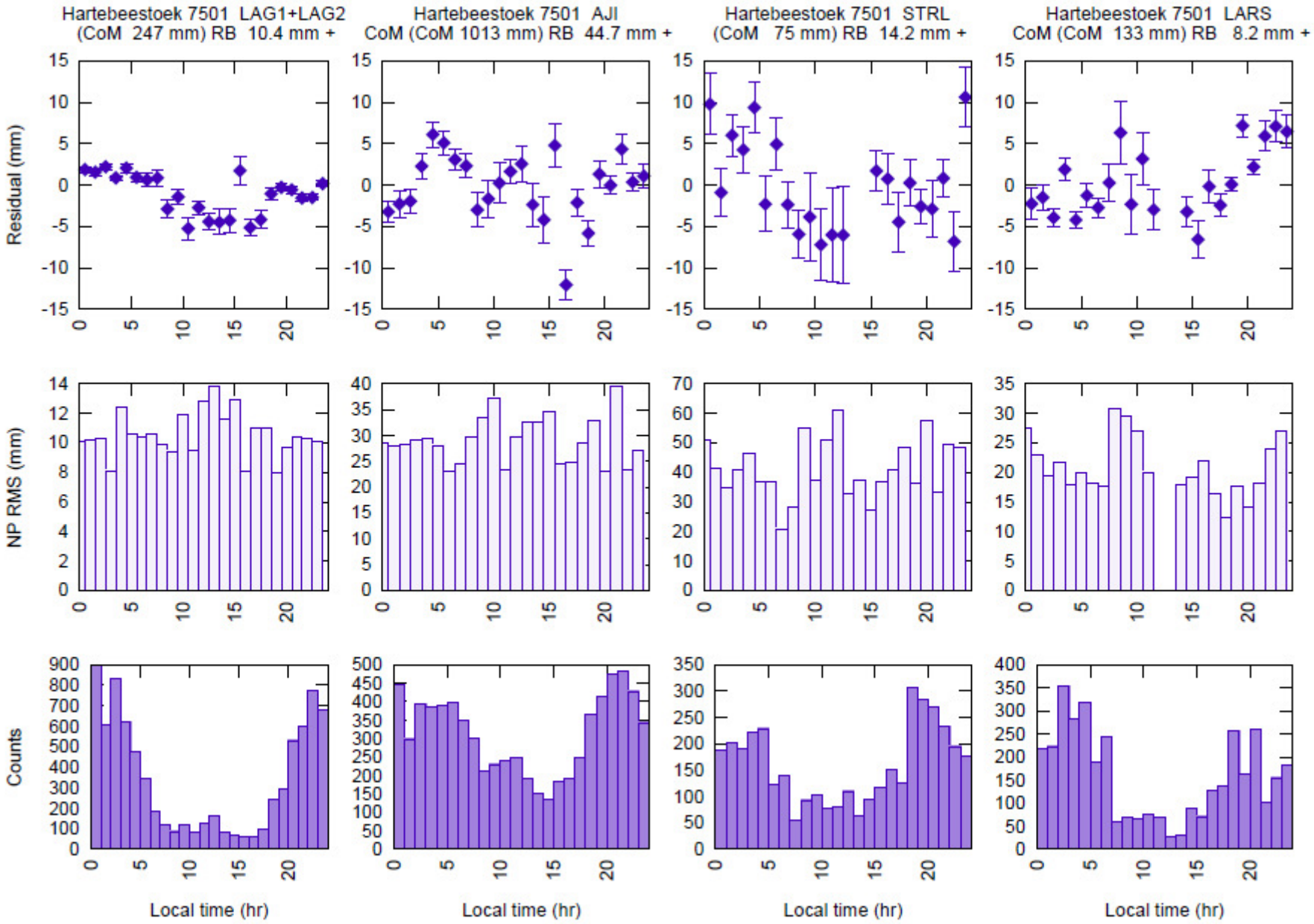
#3: System delay



#4: Time to the nearest cal.



#8: Local time


Hartebeestoek 7501 LAG1+LAG2
(CoM 247 mm) RB 10.4 mm +
Hartebeestoek 7501 AJI
CoM (CoM 1013 mm) RB 44.7 mm +
Hartebeestoek 7501 STRL
(CoM 75 mm) RB 14.2 mm +
Hartebeestoek 7501 LARS
CoM (CoM 133 mm) RB 8.2 mm +
Residual (mm)
NP RMS (mm)
Counts
Local time (hr)
Local time (hr)
Local time (hr)
Local time (hr)

Summary & Discussion

Systematic trends seen in many stations

- Understand your system's behaviour.
- On-site test is essential.
- Use this result just as a trigger.
- (There is a risk of false alarm. ← POD is not perfect.)

Station-Analyst interaction

- Enjoy this session!
- The charts for productive stations will be available on our website geo.science.hit-u.ac.jp.