GRGS ILRS ANALYSIS CENTER

OPERATIONAL ACTIVITIES AND RESEARCH

AWG Meeting, Wien, EGU 2009

International Laser Ranging Service

Observatoire de la CÔTE d'AZUR

IGN INSTITUT GEOGRAPHIQUE NATIONAL

LAREG

GeoAzur TERRE - OCÉAN - ESPACE

GRGS GROUPE DE RECHERCHE DE GEODESIE SPATIALE

GRGS Analysis center

- Staff:
  - OCA/Geoazur: F. Deleflie, O. Laurain, P. Exertier, B. de Saint-Jean
  - IGN/LAREG: D. Coulot
- Software:
  - GINS/DYNAMO (CNES/GRGS)
  - MATLO (IGN/LAREG/OCA/GRGS)
- Operational activities:
  - For ILRS: Weekly, and now daily, submissions
    - *pos+eop*
    - *based on LA1+LA2*
  - For GRGS internal validation and combinations: Weekly arcs
    - *Accounting as well for loading effects*
    - *Additionnaly: Gravity field time series*
- Other activities:
  - Reanalyses, over long periods of time
  - Specific projects: T2L2, calibration/validation altimetric measurements
  - Other satellites: STA, STE, AJI, ET1 & 2, *JAS1* and *JAS2*

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GRGS ILRS PROJECT STATUS

- Beginning of 2009: Reassessment of internal procedures, and environment GRGS files
  - Eccentricities
  - Biases
  - Corrections to be applied by ACs
- Operational submissions:
  - Weekly « v20 »: ok
  - Daily « v120 »: ok
- Specific studies:
  - Historical data: pb with old format *(MERIT2)*
  - New stations in operation: Golosiiv, Grasse, Burnie *(see hereafter)*
  - Gravity field estimation: to be discussed
- Next steps:
  - SP3c format: *almost ready, (ORBEX ?)*
  - ET1, ET2
  - Implementation of the CRD format: OK for T2L2 data, *work in progress for Gins/Matlo.*

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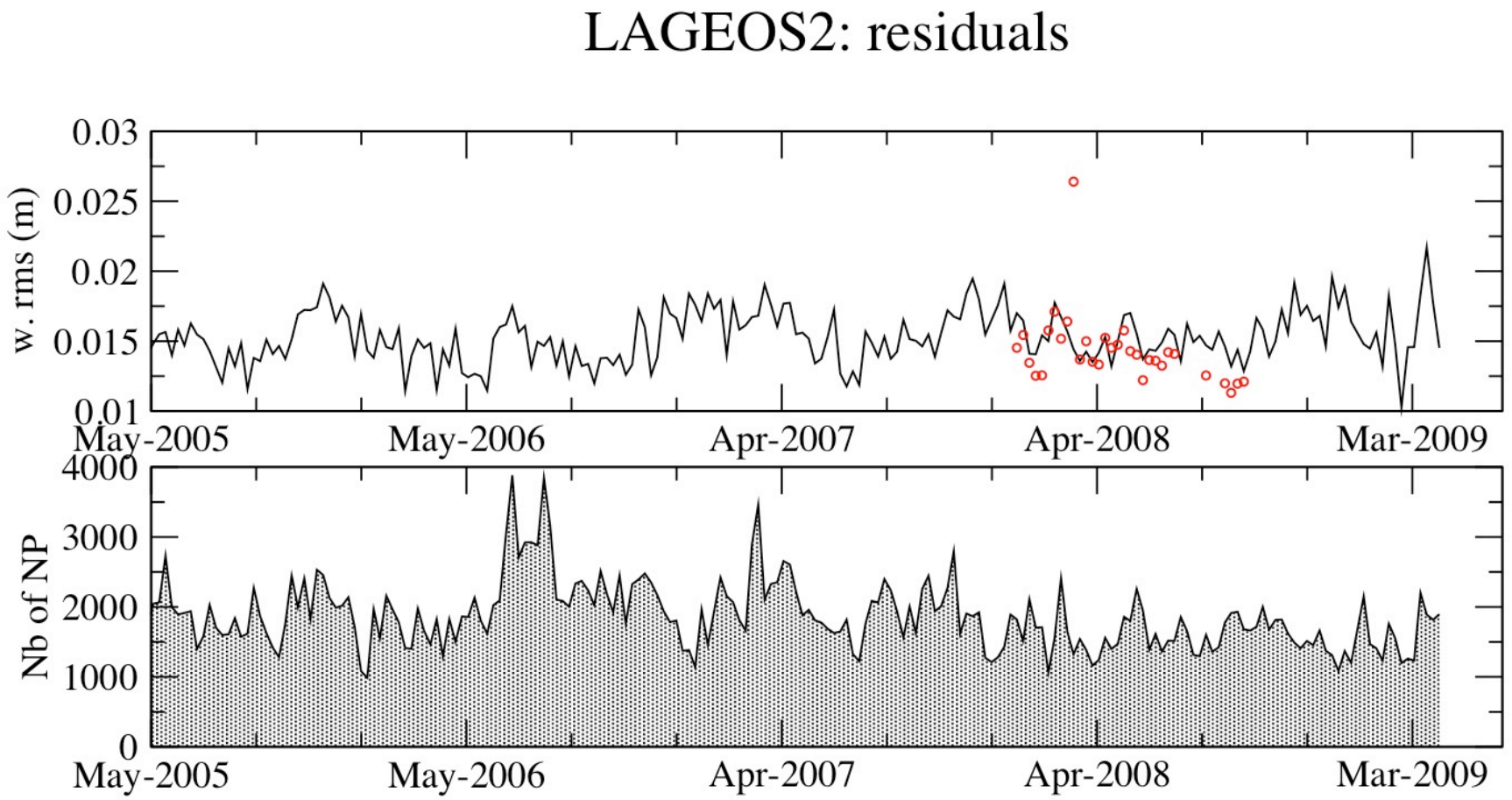
Post-fit residuals level



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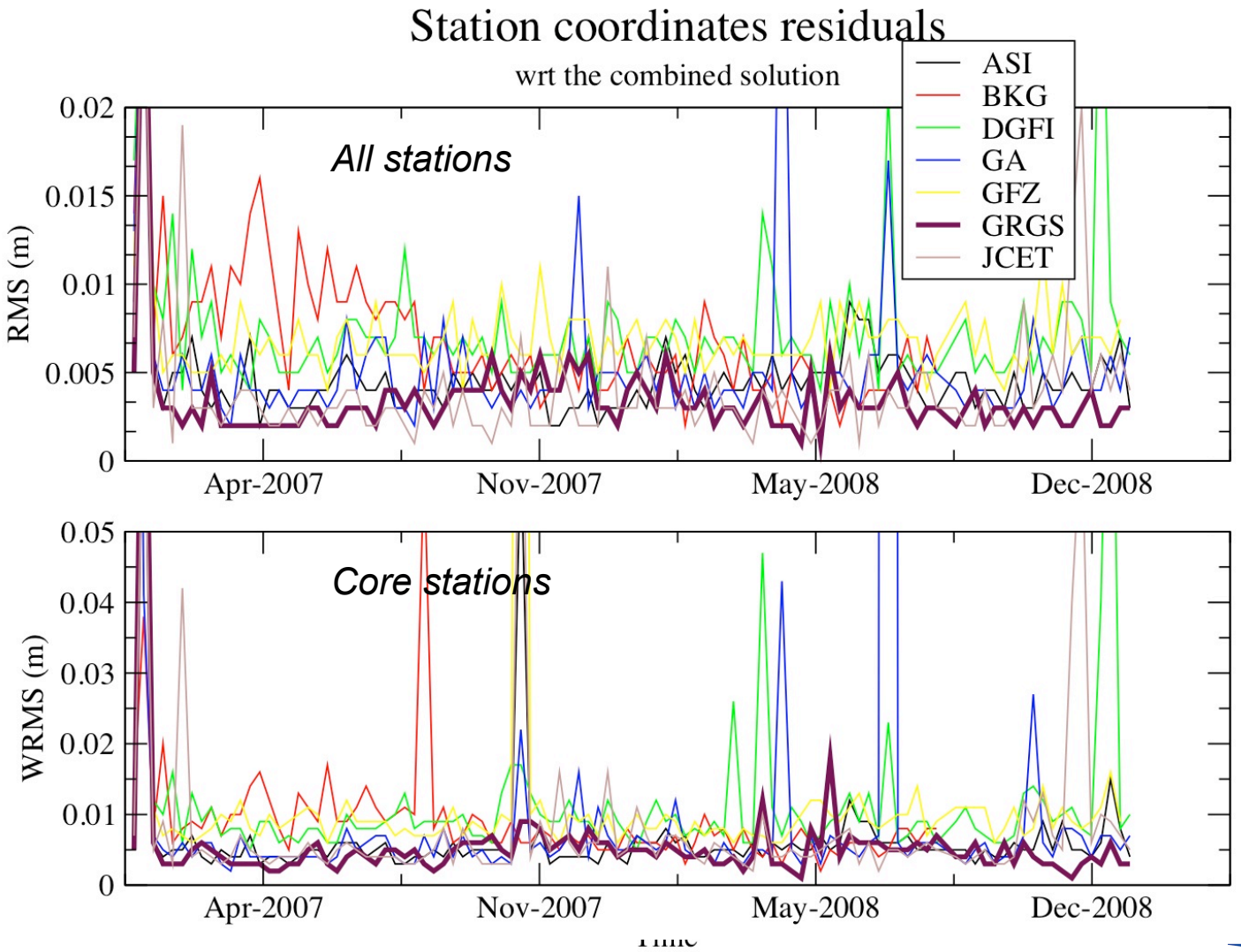
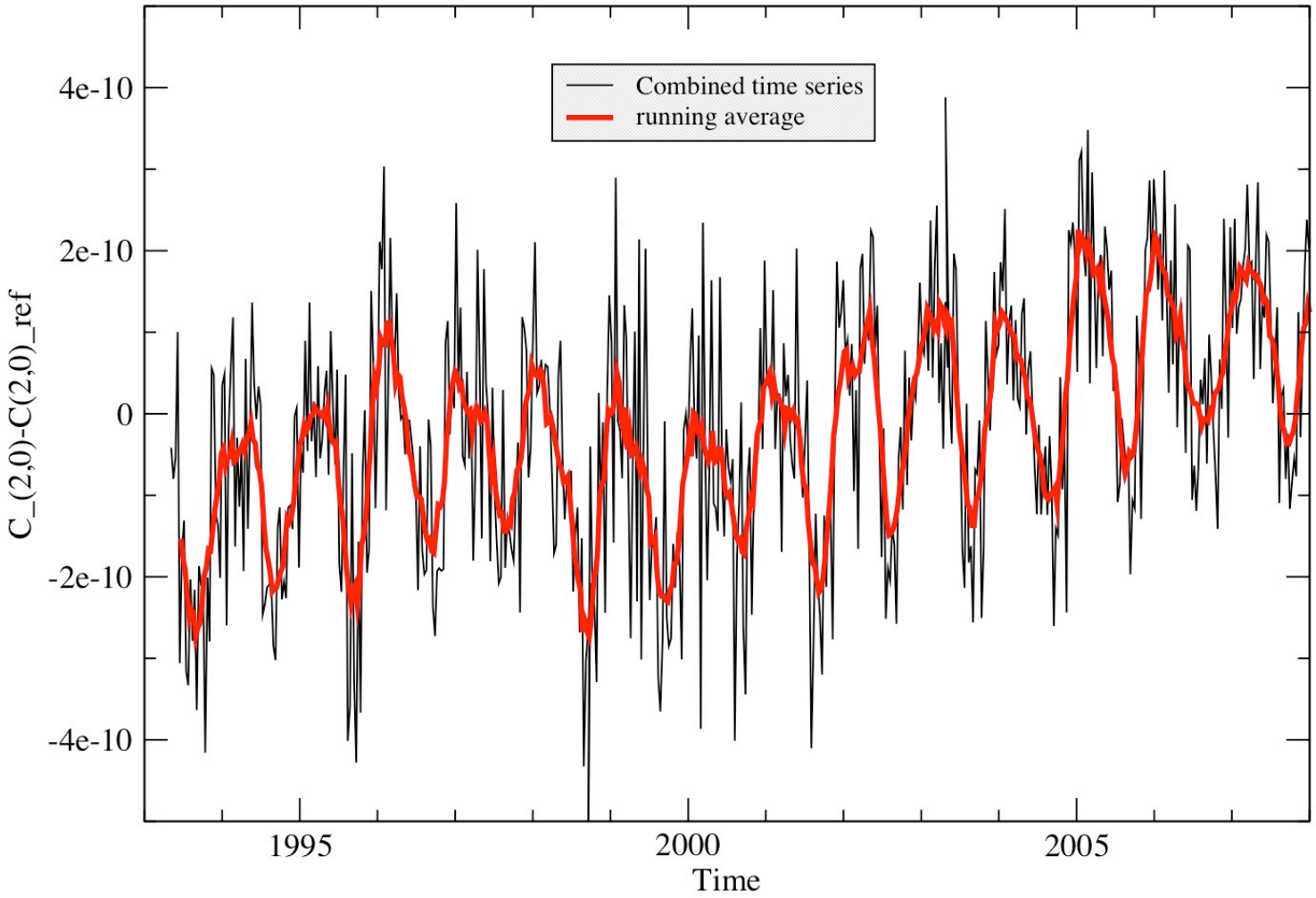
Comparisons from weekly reports



GRAVITY FIELD

Time series of C_(2,0): combined solution



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First Analysis of Golosiiv Data

- Done: weekly 3D-position for the station, 1 range bias for LA1&2 over the period

Satellite bias	Correction to a priori value (cm)	+/- (cm)	Nb of NP
LA1	1.103530	1.746424	227
LA2	0.636086	1.861462	107

Estimation epoch (JJ 1950)	Correction to a priori X-value (cm)	Y-value (cm)	Z-value (cm)	Nb of NP
21479.442165	0.1614 (±1.9126)	0.6710 (± 2.1930)	1.9763 (±2.2536)	54
21485.841062	4.7525 (±2.2356)	2.2960 (±2.7115)	1.9813(±2.4958)	31
21498.716706	-1.1665 (±1.5087)	0.3279 (±1.2767)	-0.8799 (±1.8335)	133
21506.231237	-3.9819 (±2.3491)	1.5547 (±1.5789)	-4.6702(± 2.1510)	50
21513.026388	-10.0416 (±8.7184)	0.7537 (±2.7115)	14.561 (±3.5480)	12
21523.835923	4.293 (±3.3401)	2.1454 (±4.7418)	5.4103 (± 3.8702)	12
21528.937161	4.5857 (±2.7219)	10.6279 (±4.1660)	12.4439 (±2.9875)	14
21561.814345	-121.2363 (±5.0564)	0.5466 (±2.4895)	56.7890(±3.3133)	13
21632.046286	-1.9699 (±10.9994)	0.5217 (±6.0220)	15.1424(±4.8986)	15

- To be done: one 3D-position for the station over the period, 1 range bias per week for the satellites

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To be discussed, and possible inputs from our group…

- Preanalysis of ILRS contribution to ITRF2008
- Stability of daily solution
- Gravity field time series: lumped coeff ?
- NP formula and rules…
- Impact of atmospheric effects and ECMWF files
- Weekly bias report ?
- Other satellites signatures
- Possible impact of DPOD2005 ?

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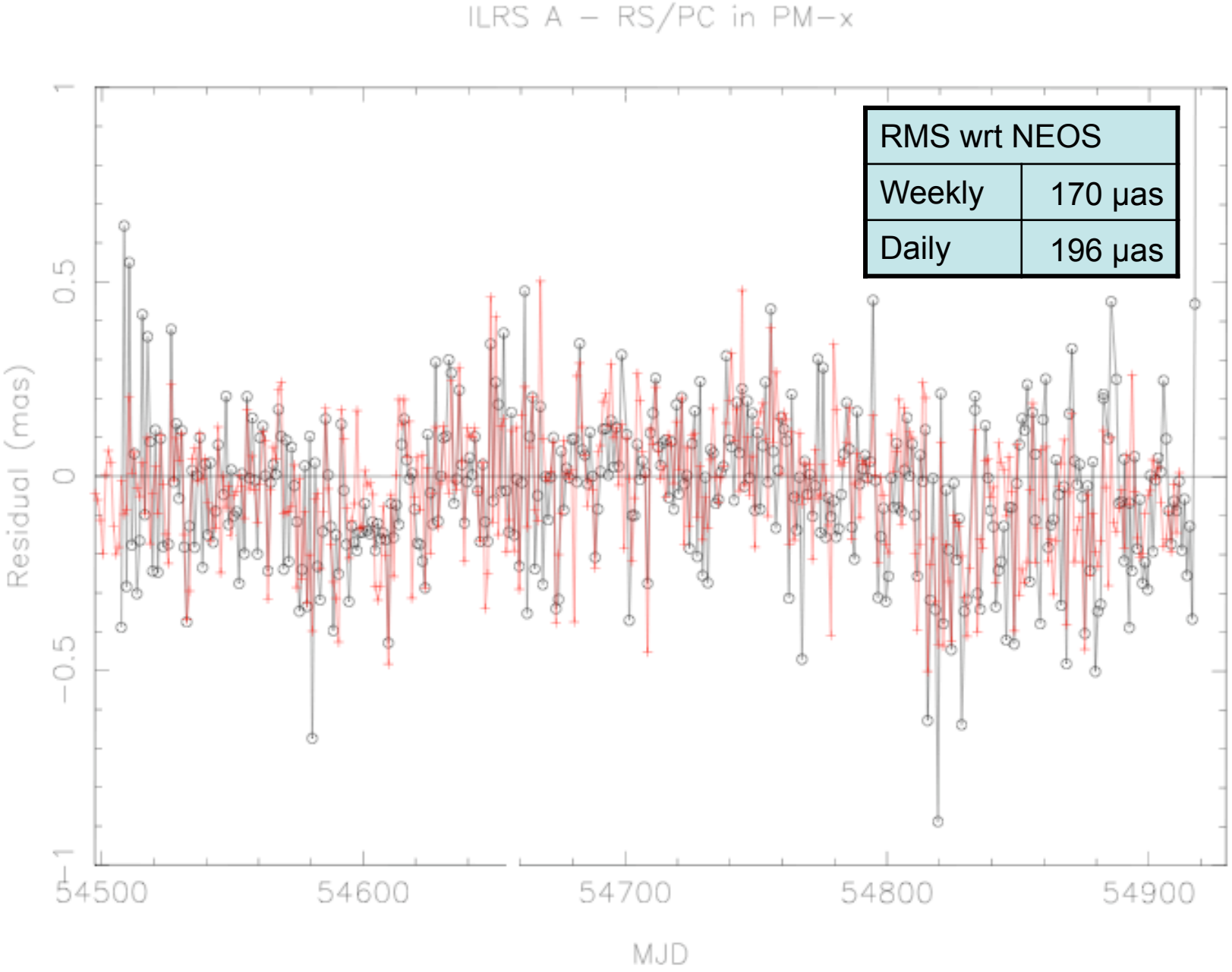
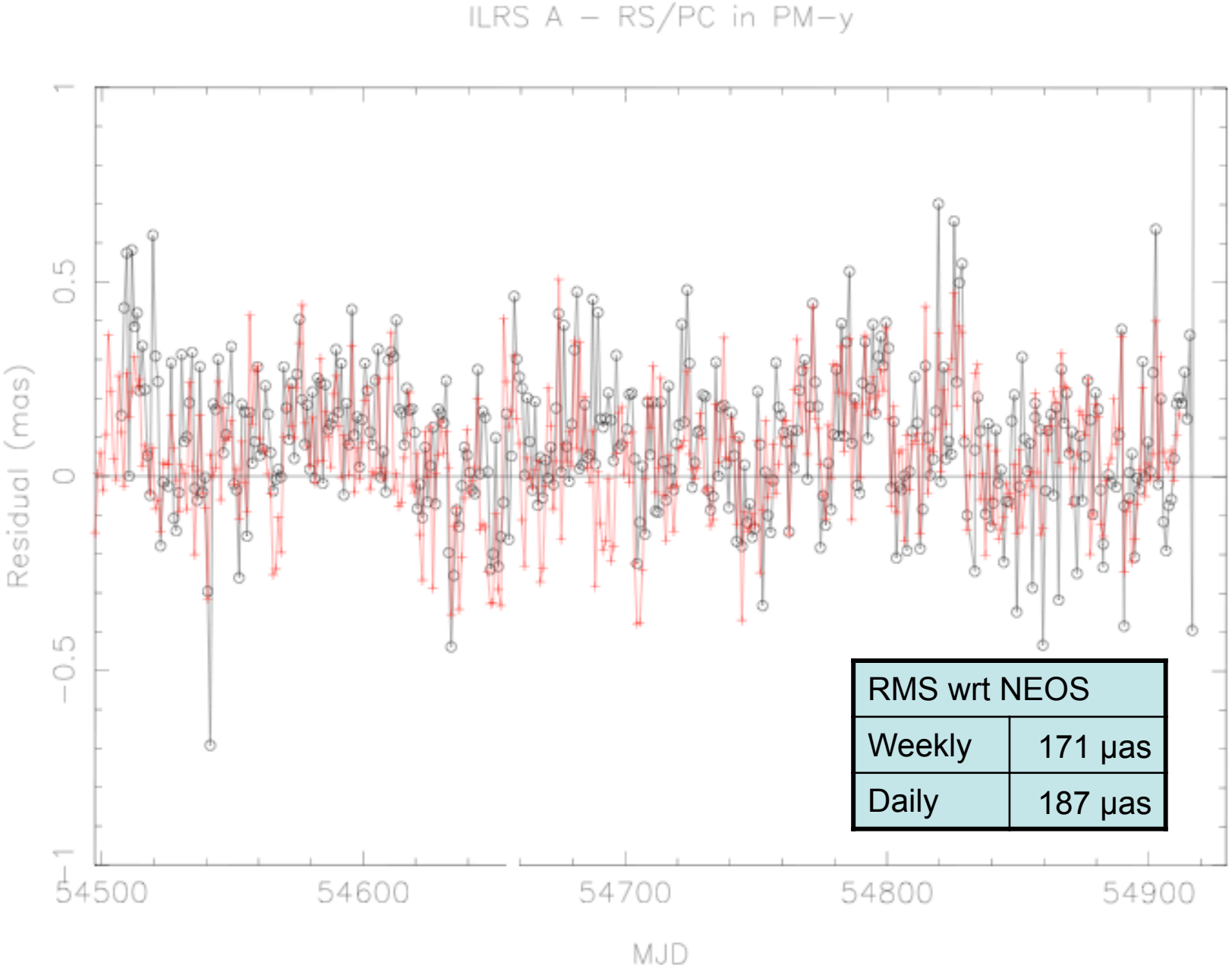
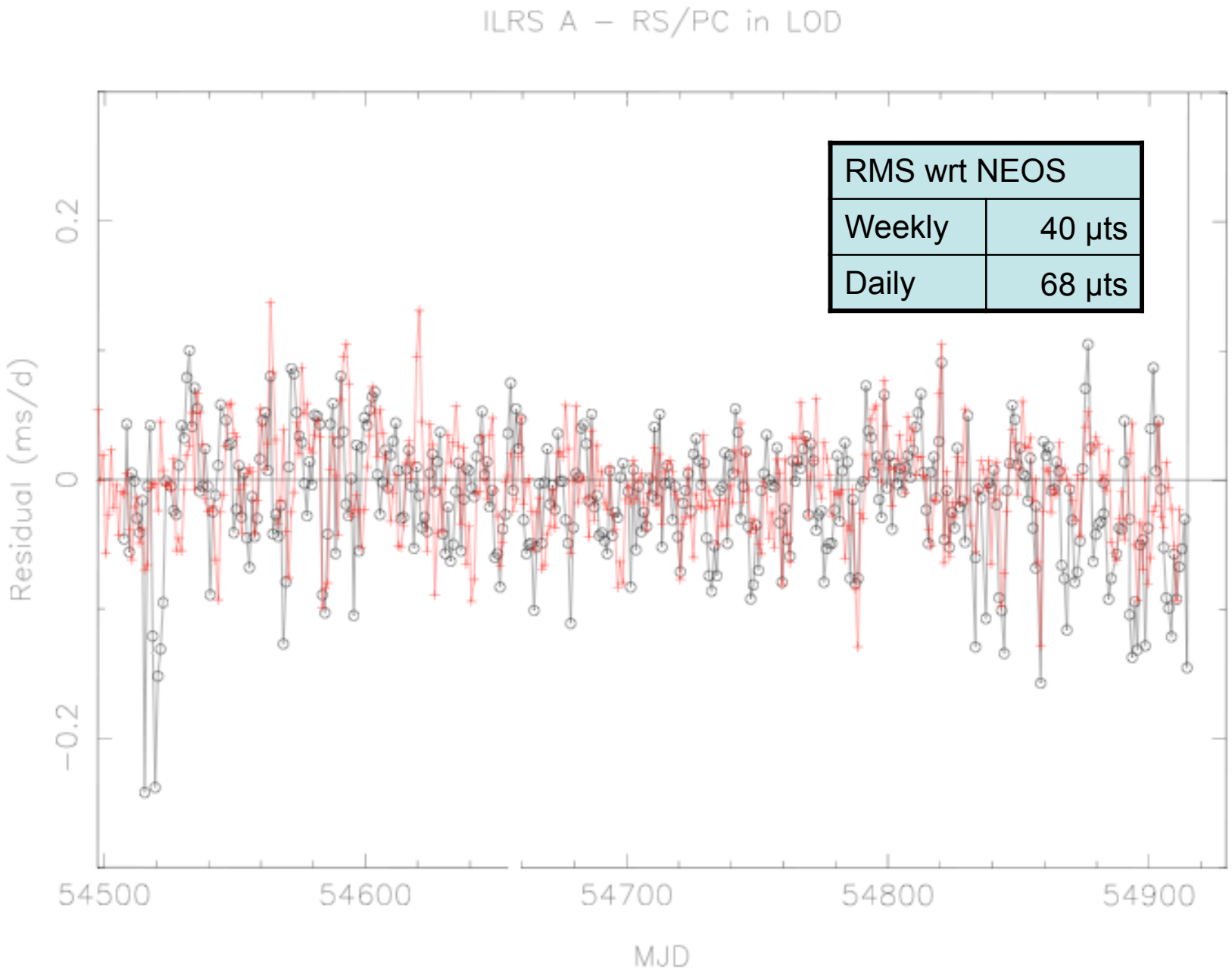
ILRS DAILY EOP vs. NEOS

Comparisons from B. Luzum/USNO-NEOS


ILRS A – RS/PC in PM–x
RMS wrt NEOS
Weekly 170 µas
Daily 196 µas
Residual (mas)
1
0.5
0
−0.5
−1
54500
54600
54700
54800
54900
MJD


ILRS A – RS/PC in PM–y
Residual (mas)
1
0.5
0
−0.5
−1
54500
54600
54700
54800
54900
MJD
RMS wrt NEOS
Weekly 171 µas
Daily 187 µas


ILRS A – RS/PC in LOD
RMS wrt NEOS
Weekly 40 µts
Daily 68 µts
Residual (ms/d)
0.2
0
−0.2
54500
54600
54700
54800
54900
MJD

Validating the new CRD data format

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UMBC

Tests performed

- Tested data submitted by MLRS in CRD and ILRS NP format for the past few months
- We convert the CRD data back to a quasi-ILRS FR format, which is directly readable by our analysis s/w (GEODYN)
  - All quantities were converted using the CRD precision
  - Met data are used without interpolation

CRD to ILRS FR (MERIT2)

```
h1 CRD  0 2007  9  5 13
h2 MDOL       7080 24 19 4
h3 LAGEOS1     7603901 1155     8820 0 0
h4  1 2007  5 11 23 53 33 2007  5 11  0  2 14  0 0 0 0 1 0 2
c0 0 532.000 std ml1 mcp mt1
c1 0 ml1 Nd-Yag 1064.00 10.00 -1.00 200.0 -1.00 1
c2 0 mcp mcp 532.000 -1.00 3800.0 0.0 unknown -1.0 3.00 -1.0 35.0 none
c3 0 mt1 TAC TAC MLRS_CMOS_TMRB_TD811 na 467300000.0
60 std 5 2
40 86013.4523810 0 std 47 46 -1.000 -831.7 0.0 59.4 0.118 -0.837 203.4 3 3
20 86023.457  803.09 296.26  32.                                  > MET RECORD for next 2 data
11 86023.456666973740     0.045600077128 std  2  120     22   92.5   1.503  -0.308  -47.9   1.83
11 86090.485491141153     0.044884749423 std  2  120     89  109.7   1.519  -0.342   17.3   7.42
20 86338.192  803.09 296.06  32.                                  > MET RECORD for 1 data
11 86338.192059406327     0.042824226301 std  2  120     99   85.0   1.588  -0.002  -60.8   8.25
20    71.549  803.09 296.26  33.                                  > MET RECORD for next 2 data
11    71.549406949766     0.042137743997 std  2  120     47   84.2   1.551  -0.110  -73.2   3.92
11   131.175048712525     0.041934327881 std  2  120      2   46.1   0.354  -2.750  -29.3   0.17
50 std    94.1   1.616   0.060   22.9 0
h8
h9
MERIT from CRD file:
760390107131860234566670702419      0     00456000771280000092532008031296203 2     0     0
760390107131860904854911702419      0     00448847494230000109532008031296203 2     0     0
760390107131863381920594702419      0     00428242263010000085532008031296003 2     0     0
760390107132000715494070702419      0     00421377439970000084532008031296203 3     0     0
760390107132001311750487702419      0     00419343278810000046532008031296203 3     0     0
```

ILRS NP to ILRS FR-X

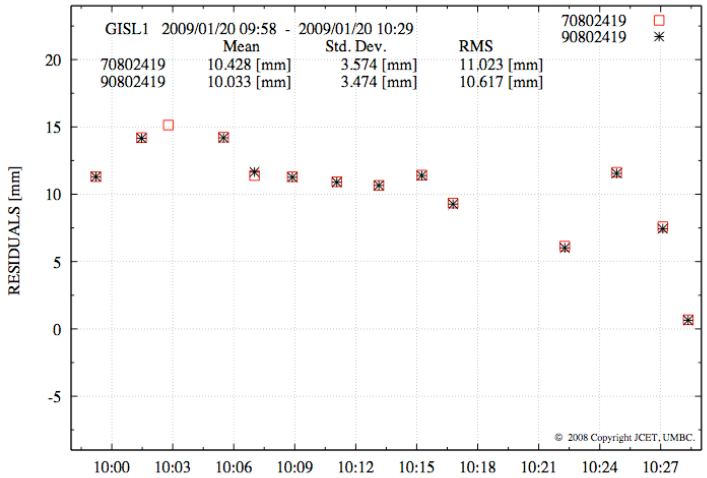
FR from ILRS QL NP file below:

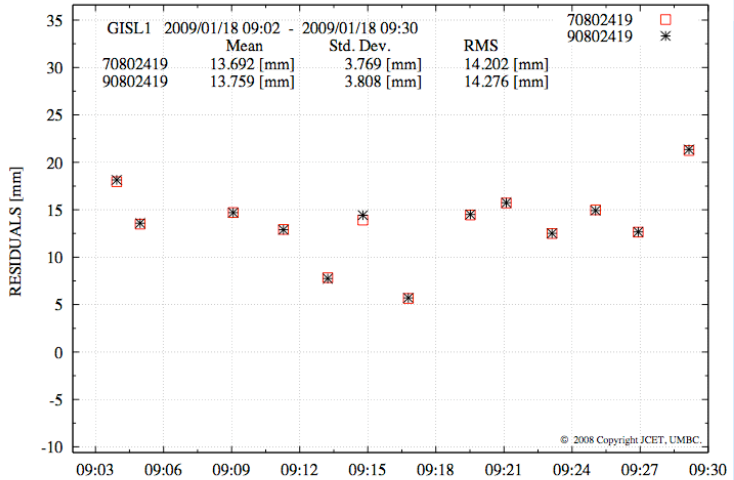
```
7603901081512336356239847080241905166975787700000795320080092929042-0000927000000004770011240111652107603901081512342939070887080241905093552953200000915320080092929042-0000927000000004770012240111652107603901081512362867649867080241904899772996800000103532008009292904 2-0000927000000004770006240111652107603901081512364998566127080241904881811221900000082532008009292904 2-0000927000000004770012240111652107603901081512384857079497080241904742912087700000755320080092929042-0000927000000004770025240111652107
```

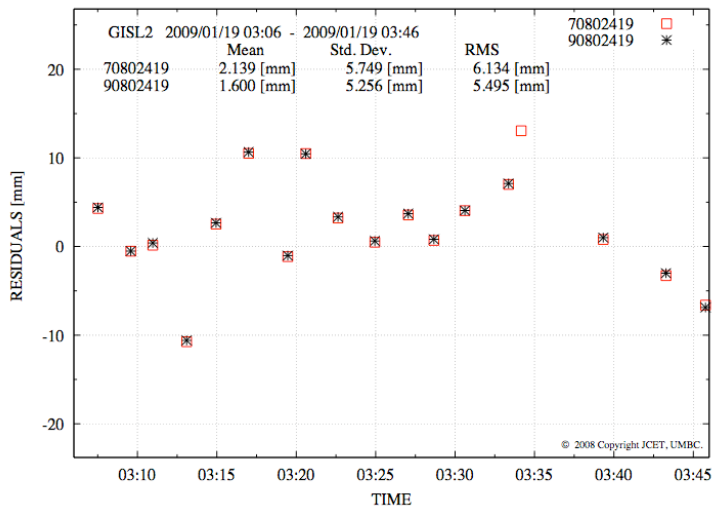
```
MERIT from CRDX
7603901081510233635623983593690000008024190000000000000005166975787700000008000532000080088292950420000000000000000000-0000926800000000467001124011165230
7603901081510234293907087690460000008024190000000000000050935529534000000080005320000800882929504200000000000000000000-0000926800000000467001224011165230
7603901081510236286764986288940000008024190000000000000048997729967000000080005320000800882929504200000000000000000000-0000926800000000467000624011165230
7603901081510236499856611704640000008024190000000000000048818112218000000080005320000800882929504200000000000000000000-0000926800000000467001224011165230
7603901081510238485707949091080000008024190000000000000047429120877000000080005320000800882929504200000000000000000000-0000926800000000467002524011165230
```

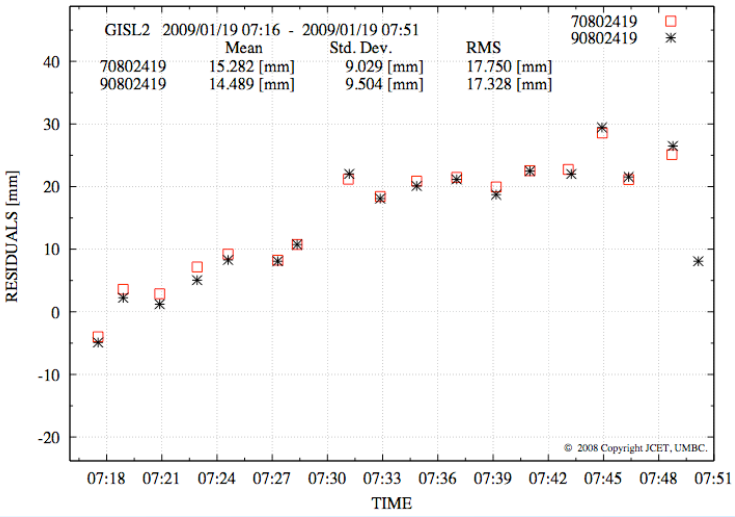
FR-X from CRD NP file above:

LAGEOS 1 & 2 Examples

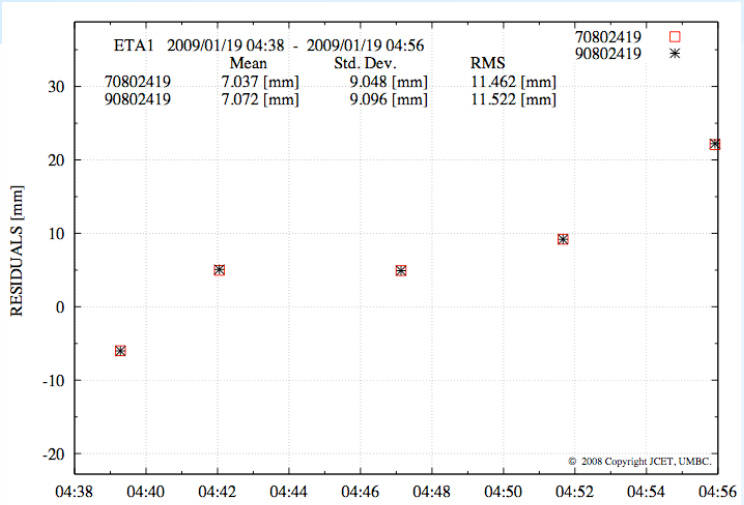


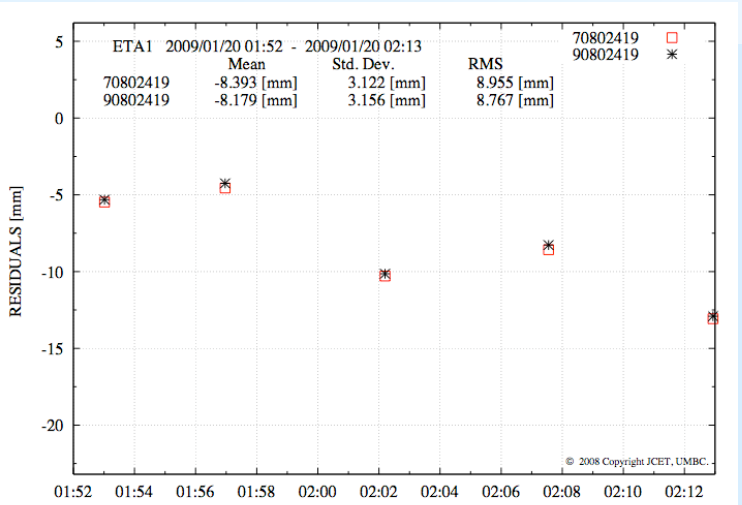


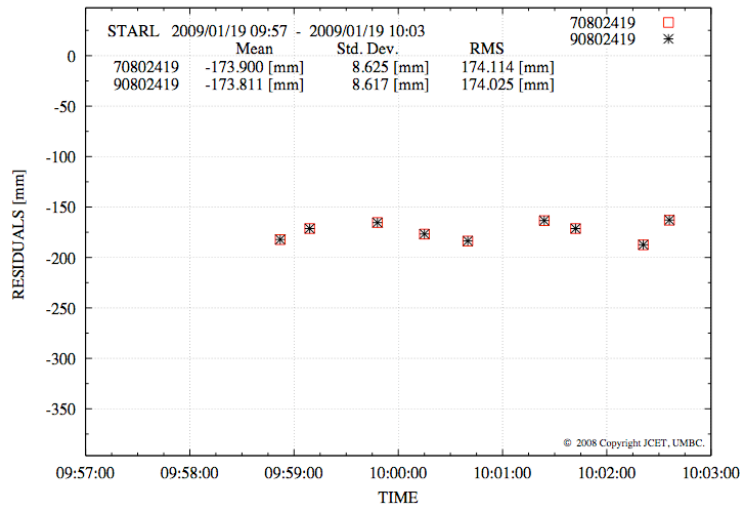


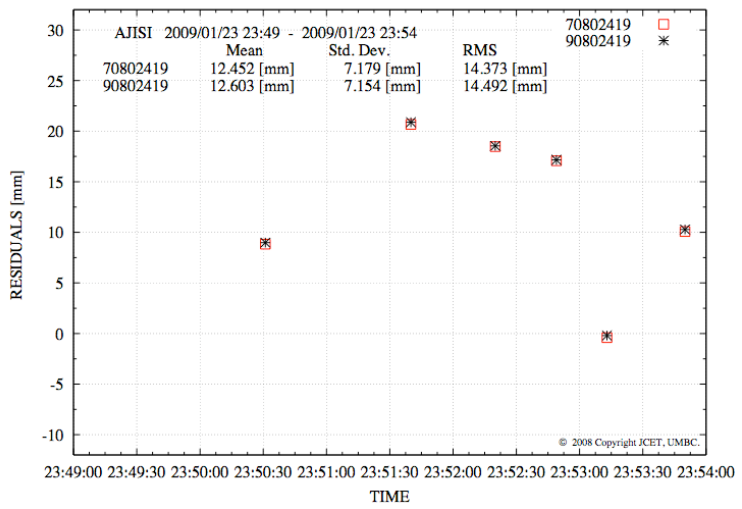


E-1, Starlette, & Ajisai Examples









Summary

- We successfully tested the new CRD format data from MLRS in GEODYN
- We tested only LAGEOS 1 & 2, ETALON 1 & 2, Starlette & Ajisai data only
- No major issues with the format, nearly identical results, $|\Delta v_R| \leq 0.5\ mm$
- Questions to the WG:
  - Adopt rules of use, e.g. should met data be interpolated linearly or not?
  - Should other data types in CRD be examined? (FR, QL, engineering data)
- Procedure runs automatically once a week (Tuesday) for available sites

A simple introduction of SLR data auto-processing and results analysis in Shanghai Astronomical Observatory

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Shanghai Astronomical Observatory, Chinese Academy of Sciences

2009-04-10

2009 ILRS Analysis Workshop

Outline

- Introduction of our work as ILRS Associate Analysis Center
- Foundation of China continental environment monitor network and the role of SLR
- Present status and results
- Conclusions
- Future development

Introduction of our work as ILRS Associate Analysis Center

表 5　LAGEOS-1 快速资料的残差分析报告

Table 5　LAGEOS-1 quicklook residual analysis report

站号 ista	弧段开始时间 年 / 月 / 日时：分 starting time year/m/d h:mi	弧长分 Long/pass min	观测数 Obs/pass	被剔数 Edited obs	距离偏差 Range Bias mm	时间偏差 Time bias Us	精度 Raw rms mm	精度 Prec est mm
1864	1999/05/02 18:26	7.6	5	2	88	14	80	0
1864	1999/05/02 21:46	23.4	9	1	63	19	64	6
1864	1999/05/03 20:21	27.2	9	5	51	16	38	5
7090	1999/05/01 06:23	24.7	14	1	2	-2	3	1
7090	1999/05/02 11:37	29.5	16	0	12	3	13	2
7090	1999/05/03 13:45	8.1	6	0	3	-3	7	2
7110	1999/05/01 08:11	43.1	17	2	4	0	4	1
7110	1999/05/01 11:51	15.1	9	0	-2	3	3	2
7110	1999/05/02 10:29	25.1	14	1	-4	2	4	1
7124	1999/05/21 18:59	25.0	14	1	30	1	28	3
7124	1999/05/28 07:41	5.2	4	0	7	-33	45	3
7210	1999/05/04 08:05	3.4	3	0	62	34	17	0
7210	1999/05/11 08:57	43.5	19	2	-10	1	10	3
7210	1999/05/12 07:59	10.9	7	0	-9	-1	11	1
7210	1999/05/13 09:47	3.0	3	0	-42	-11	12	1
7237	1999/05/03 16:37	24.8	10	6	25	5	26	1
7237	1999/05/04 15:19	24.7	14	6	-3	33	33	7
7237	1999/05/06 16:27	5.4	4	2	43	29	87	0
7237	1999/05/09 15:35	25.0	14	9	-5	44	34	5
7249	1999/05/03 16:37	13.2	8	3	-92	-20	57	11
7249	1999/05/05 17:33	15.8	8	4	-20	-20	17	6
7249	1999/05/10 17:42	9.9	6	2	-10	-4	15	14
7403	1999/05/04 04:29	29.2	10	8	77	-41	4	0
7403	1999/05/05 03:33	4.9	4	1	-68	68	83	2
7403	1999/05/06 01:49	28.5	14	2	18	-18	23	8
7403	1999/05/06 05:19	8.6	5	0	-4	20	20	4
7820	1999/05/02 18:13	22.8	13	6	90	10	77	9
7820	1999/05/12 15:04	29.5	16	4	16	5	20	16
7837	1999/05/06 12:45	8.7	6	2	-84	1	76	11
7837	1999/05/06 16:03	28.8	12	2	36	16	29	5
7837	1999/05/07 14:51	24.9	28	0	27	7	32	6
7849	1999/05/01 02:45	11.0	7	0	-8	-5	7	2
7849	1999/05/01 06:15	18.1	6	1	-5	3	6	5
7849	1999/05/02 15:06	9.5	6	1	-12	-7	8	1
7849	1999/05/02 23:49	7.0	5	1	71	37	7	1
7849	1999/05/03 10:02	37.4	19	0	3	8	17	10
7849	1999/05/03 13:35	37.4	20	2	-2	4	8	4

(注意：　1.Us 是时间单位为微秒；　mm 是长度单位毫米；　2. 弧长表示每次卫星通过该站的时间长度，单位分钟；3. 观测数表示该站每次卫星通过的观测数.)

(Note: 1. Us is one 10^{-6} s; mm is millimeter ;　2. Long/pass shows that a pass of a satellite by a site is time length, its unit is a minute ;　3.Obs/pass shows a number in every pass.)

Introduction of our work as ILRS Associate Analysis Center

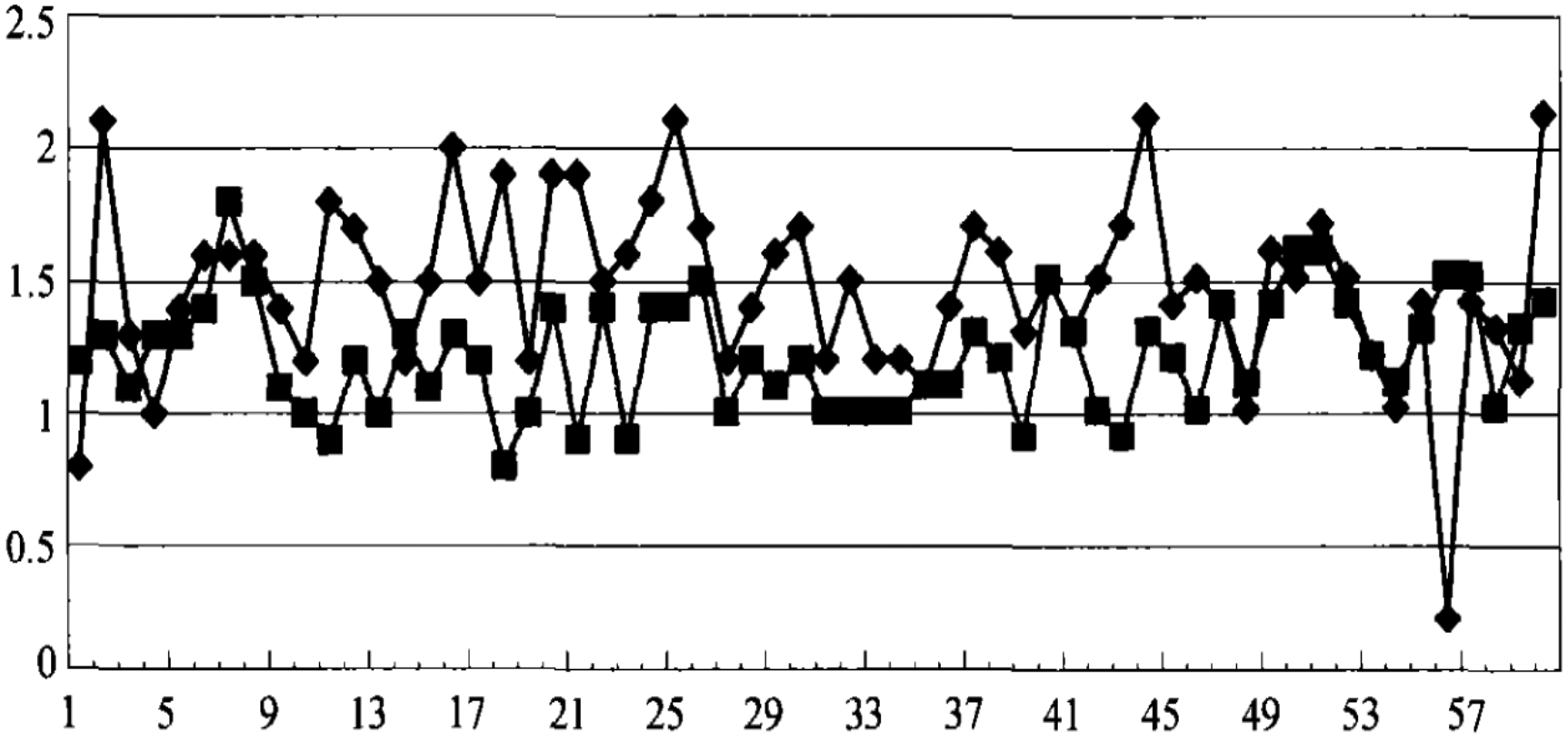

图 1　LAGEOS-1 卫星 3 天弧段定轨残差 rms

Fig. 1　The rms with respect to determining LAGEOS-1 Satellite's orbits

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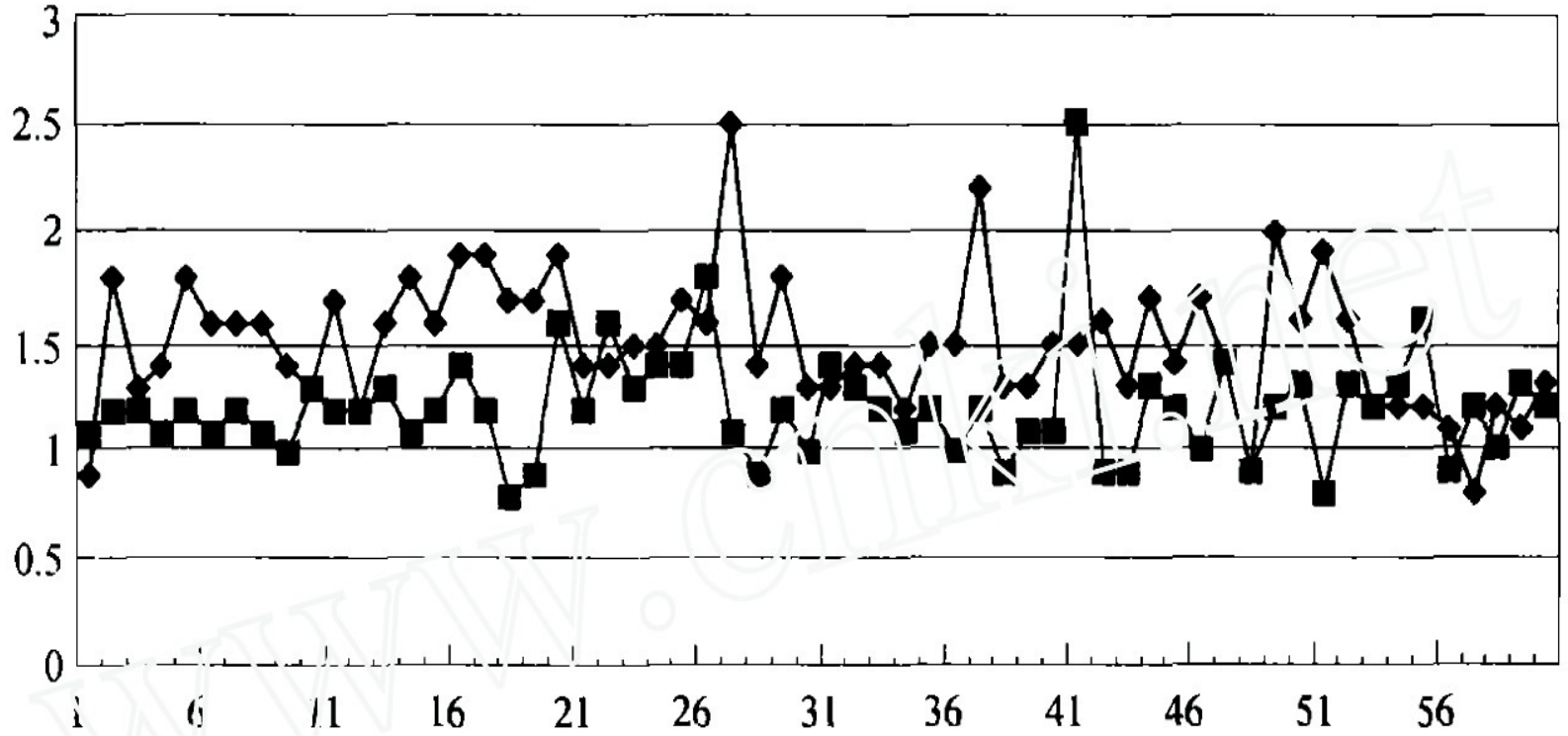

图 2　LAGEOS-2 卫星 3 天弧段定轨残差 rms. ◇ 为 CSR(美国德克萨斯大学奥斯汀分校的空间研究中心), □ 为 SHA(上海天文台)

Fig. 2　The rms with respect to determining LAGEOS-2 Satellite's orbits. ◇ is denoting CSR(Center of Space Research of University of Texas, Austin, Texas, USA), □ is denoting SHA(Shanghai Astronomical Observatory)

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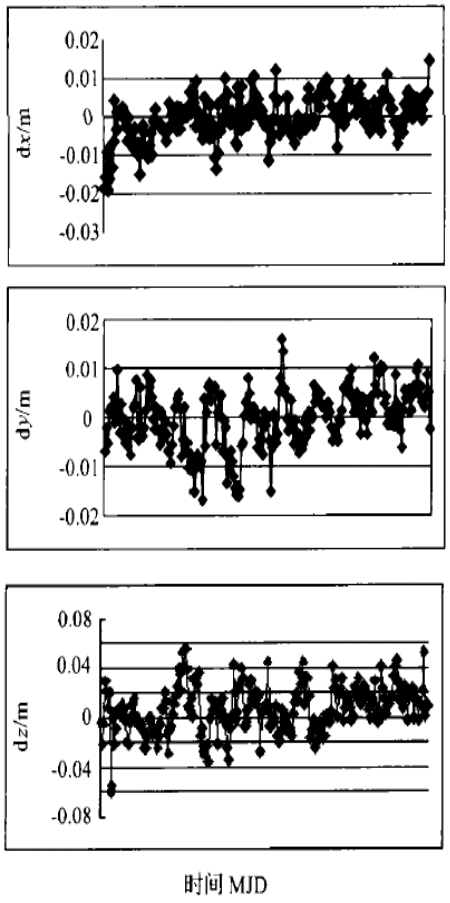


图 5　利用 Lageos 卫星 1993～2002 年激光测距资料联合解算地心的变化图

Fig. 5　The geocentric varience during 1993 ～ 2002 solved with Lageos1 SLR data

This result was obtained by SLR site coordinates. I think it is not a good means to determine the mass center variety due to less SLR sites and its coordinate precise and its distribution status in the world.

Introduction of our work as ILRS Associate Analysis Center

表 3　在 ITRF 2000 中 3 个国内 SLR 流动站站点坐标的归算 a)

站名—编号	X/m	Y/m	Z/m	ΔX/m	ΔY/m	ΔZ/m	NOBS	Rms/m
BEIJING7343(1)	-2148737.9026	4426709.9242	4044565.1287	0.05290	0.04363	0.04070	182	0.034
BEIJING7343(2)	-2148737.9030	4426709.9337	4044565.1796	0.05167	0.06504	0.04771	105	0.042
URUMQI7355(1)	184608.5227	4606775.1855	4393723.8818	0.05614	0.04203	0.02733	229	0.048
URUMQI7355(2)	184608.5516	4606775.1983	4393723.8999	0.04126	0.03264	0.02484	354	0.036
LHASA 7356(1)	-100535.6267	5550603.8251	3137037.6329	0.04274	0.02981	0.03499	274	0.036
LHASA 7356(2)	-100535.6381	5550603.8102	3137037.6332	0.03543	0.03158	0.03708	263	0.032

a) ITRF 是国际地球参考架的代码, NOBS 是观测数, Rms 是解算后残差的均方值

表 4　3 个国内 SLR 流动站站点在 ITRF 2000 中的站坐标 a)

	X/m V_x/m·s^{-1}	Y/m V_y/m·s^{-1}	Z/m V_z/m·s^{-1}	σx/m	σy/m	σz/m
北京房山站	-2148737.9027	4426709.9268	4044565.1427	0.00018	0.00424	0.02267
速度	0.0288	0.0651	-0.0340			
乌鲁木齐站	184608.5444	4606775.1960	4393723.8947	0.00942	0.00355	0.01062
速度	-0.0306	-0.0055	-0.0003			
拉萨站	-100535.6330	5550603.8169	3137037.6331	0.00567	0.00745	0.00015
速度	-0.0462	-0.0076	0.0121			

a) x, y, z 表示坐标 3 个分量, V_x, V_y, V_z 表示速度分量

These two tables show the results of the mobile SLR site coordinates and their velocities.

Single solution error:3-4 cm

Several solution error: < 2cm

The comparison of velocity from different techniques such as VLBI,SLR and GPS （ unit: m/yr ）

velocity	north	east	vertical
VLBI	-0.01433	0.03172	-0.00242
SLR	-0.01397	0.03185	-0.00117
GPS	-0.01484	0.03217	0.00103
ITRF2000	-0.0148	0.0320	-0.0014

The results from different techniques are consistent in some degree and can check system error of each other.

Foundation of China continental environment monitor network and the role of SLR

- **Introduction of China continental environment monitor network**
  - » **260 real time continuous GNSS sites**
  - » **1000 or so regional GNSS sites**
  - » **3 VLBI sites upgrade or reconstruction**
  - » **5 SLR sites (Beijing, Shanghai, Changchun, Wuhan, Kunming) and 2 mobile SLR sites upgrade or reconstruction**

    Including establishment of day ranging observation system, KHz ranging laser and control system, meteorological parameters recorder system etc…(Prof. Yang Fumin is responsible for all those sites)
  - » **InSAR data, gravity data, leveling data…**

All data are used to monitor the environment variety including crustal deformation, atmosphere monitor, ionosphere monitor and so on.

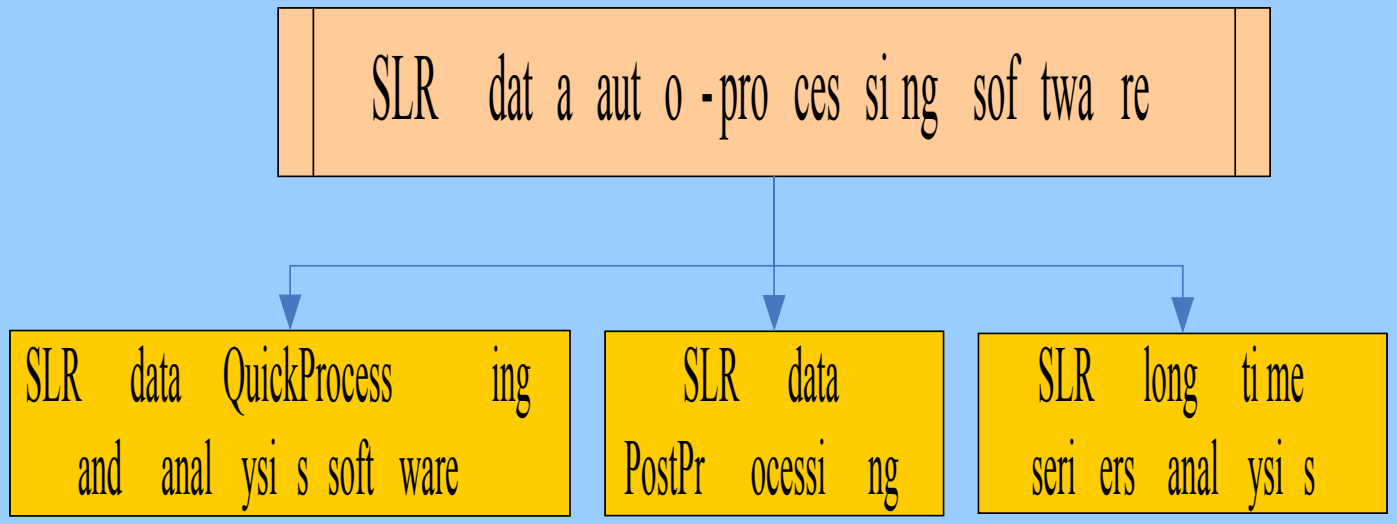
Foundation of China continental environment monitor network and the role of SLR

- **the role of SLR in this network**
  - » **The establishment of reference frame especially the determination of the mass center of the earth and the scale. It can provide a good frame with other techniques for crustal deformation.**
  - » **Orbit determination. There are many satellites with laser reflectors. So it can provide the orbit of satellites and also can be a tool to evaluate the orbit results of GNSS.**
  - » **Site coordinate and velocity. Although there are not so much SLR sites in the world it maybe can check some system errors in GNSS by collocation sites.**
  - » **EOP. GPS_EOP,VLBI_EOP,How about SLR_EOP?**
  - » **Gravity field.**
  - » **Some other parameters……**

So, we need set up software to process SLR data to finish those functions.

SLR data processing software

Applying the international SLR data and our work as the ILRS Associate Analysis Center and based on our present software, we improve the quick process of SLR data and add the special functions of SLR, and also make the results visual and make the whole process monitored. And also we carry out the auto-processing and will carry out the results share.



SLR data QuickProcessing and analysis

The functions of this part are :

- **Carry out rapid week solution to give quick residual analysis report.**
- **Evaluate those time and range biases and look for possible problem and then send the warning information to some SLR sites**
- **Provide rapid orbit and EOP**
- **Output MERIT-II format SLR data**
- **Map some results**

SLR data PostProcessing

The functions of this part are :

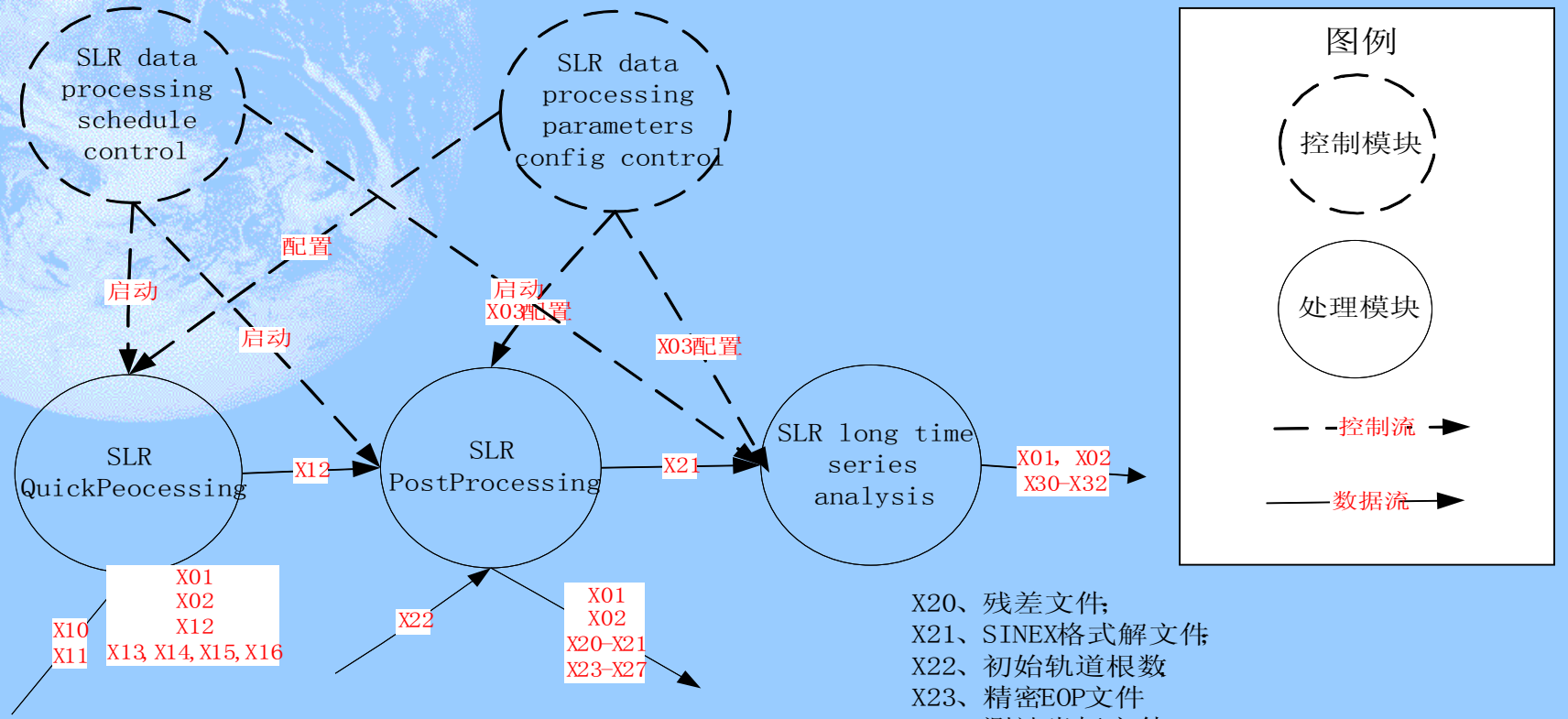
- Long arc precise orbit determination. The residual is sub cm; (Are there a uniform SLR orbit determination results such as GPS sp3 format? It is easy for us to compare our results with others one.)
- Precise EOP determination. The accuracy of pole motion is better than 0.4mas and that of LOD is better than 0.35ms under the comparison with results from IERS bulletin C, VLBI and GPS ;
- The determination of mass center of the earth.
- Site coordinates determination. Its formal error is better than 2 cm. The results are compared with those of the collocation GPS sites.
- Output of SINEX SLR solution

SLR long time series analysis

The functions of this part are :

- **Obtain site coordinate and velocity at some epoch by processing long term SLR SINEX solutions. The epoch coordinate and its velocity accuracy has got 5mm and**
- **Obtain the consistent mass center variety of the earth by long term analysis of the mass center coordinate series.**
- **Provide the satellite orbit of GNSS under enough SLR observation to some GNSS satellites or evaluate the GNSS orbit results by residuals.**

The data and control flow chart of the whole SLR data auto-processing system



X01、告警信息;
X02、日志信息;
X03、配置文件;

X10、SLR原始数据文件;
X11、测站气象文件;
X12、预处理后的MERIT—II格式文件

X13、快速轨道产品;
X14、快速EOP文件;
X15、快速分析残差文件;
X16、质量评估报告;

X20、残差文件;
X21、SINEX格式解文件;
X22、初始轨道根数
X23、精密EOP文件
X24、测站坐标文件
X25、定轨结果文件eport
X26、精密轨道产品;
X27、地球质心坐标文件

X30、ITRF框架下测站坐标速度文件;
X31、激光比对结果文件
X32、地球质心变化序列文件

Present status and results of our SLR work

- SLR data QuickProcessing and Post Processing have been finished but the results are still not automatically mapped.
- The results of PostProcessing are still in evaluation.
- SLR long time series analysis still need code and debug.

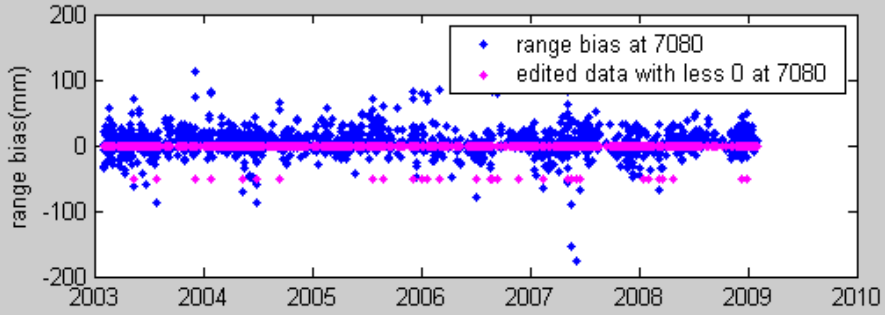
Although the software works well to GPS daily solution it doesn't work to SLR month solution. So, a good SLR velocity can not be obtained.

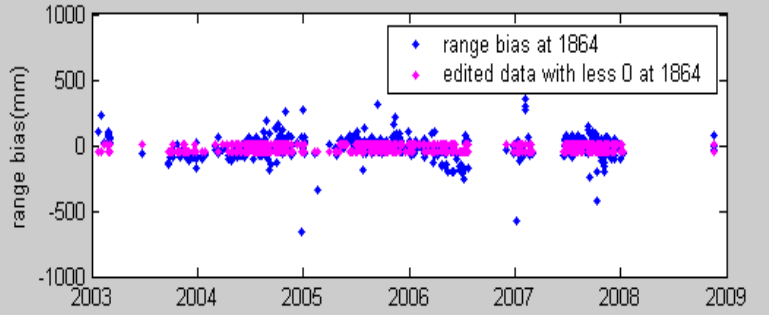
The SLR orbit evaluation have been worked and it works very well to the evaluation of COMPASS orbit.

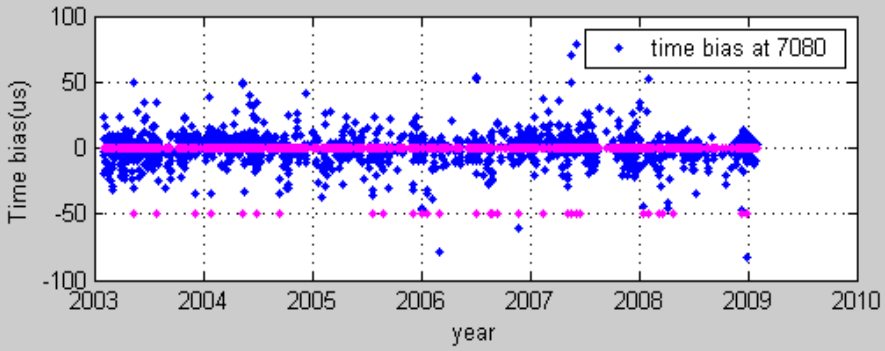
The mass center variety need be reprocessed after coordinate estimation.

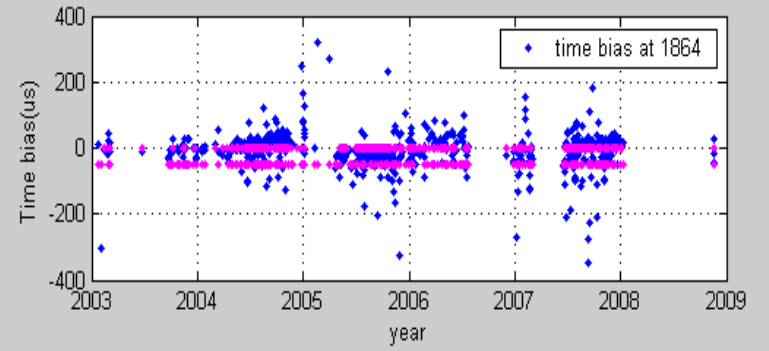
Present status and results of our SLR work

- **QuickProcessing:** Rang Bias and Time Bias series. There are a warning information to 1864 site due to too much data deleted. (Passes with range bias above 10cm or with time bias above 0.05ms or residuals above 10 cm are deleted)





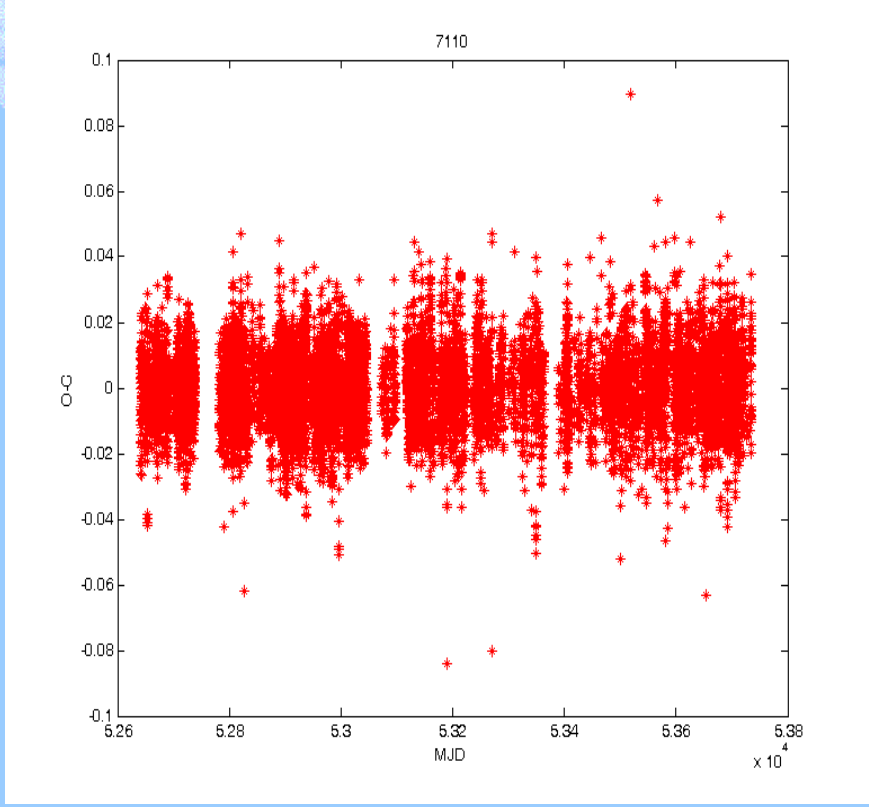


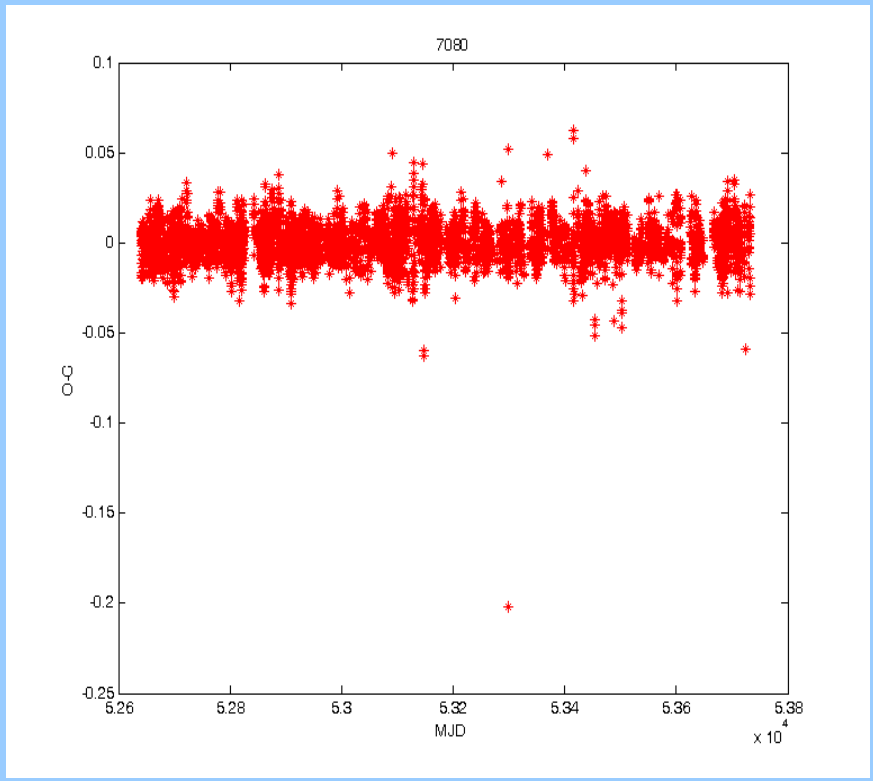


Present status and results of our SLR work

PostProcessing: Residual series.

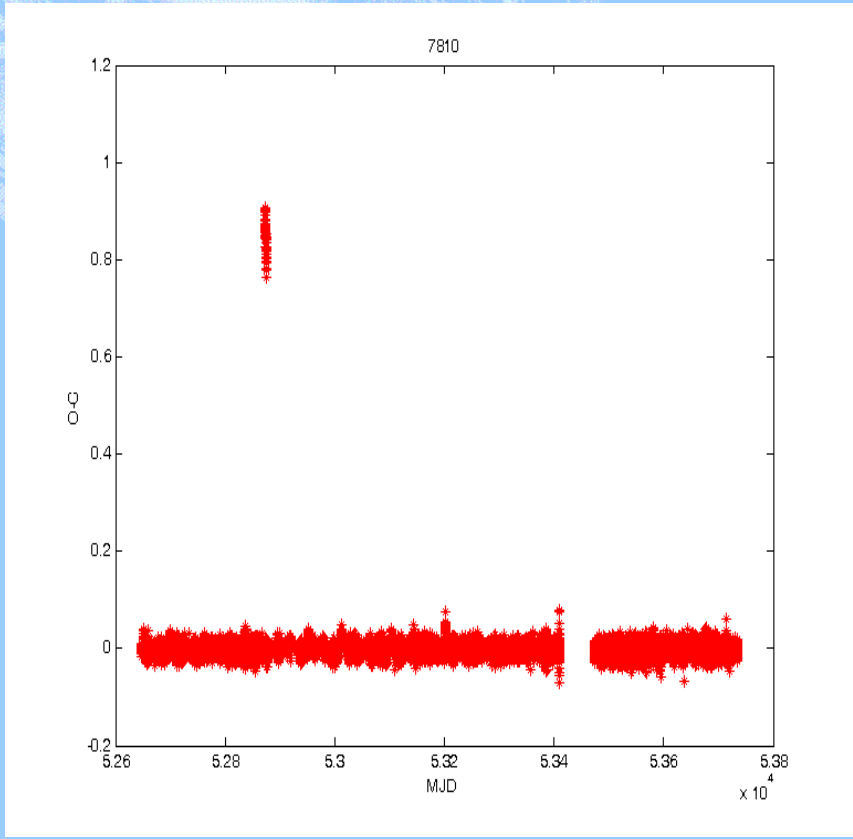
Estimate methods: The site coordinates of 7105 and 7210 are fixed; other site coordinates are estimated; RTN, Cd, Rad and EOP are estimated in one per 3 days.

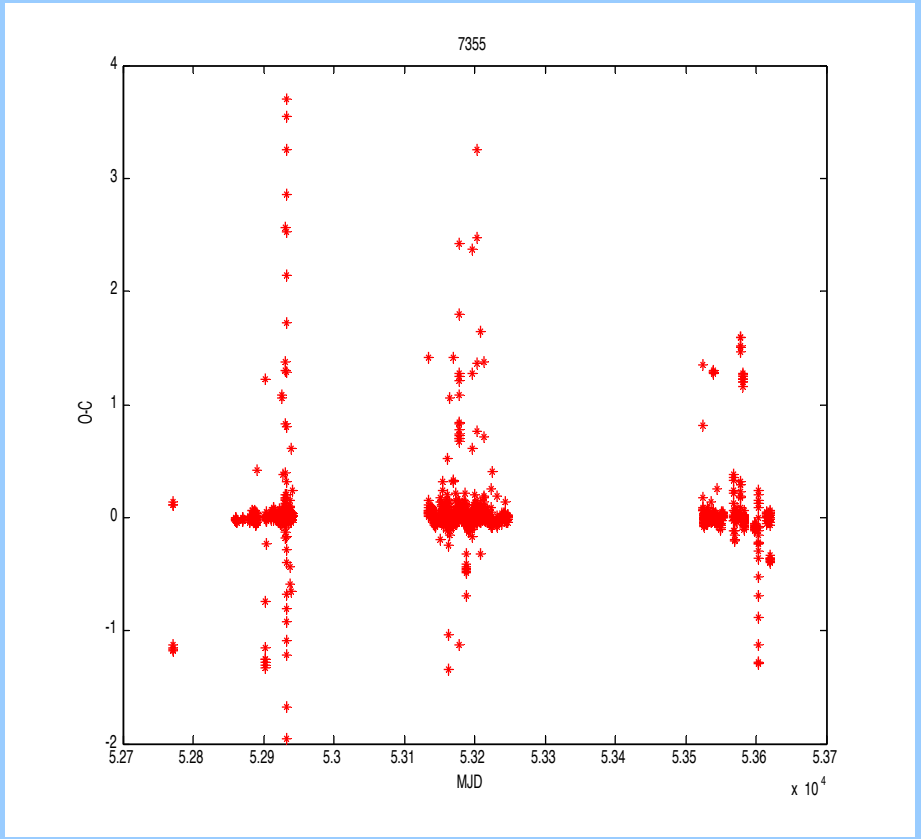




Present status and results of our SLR work

PostProcessing: Residual results

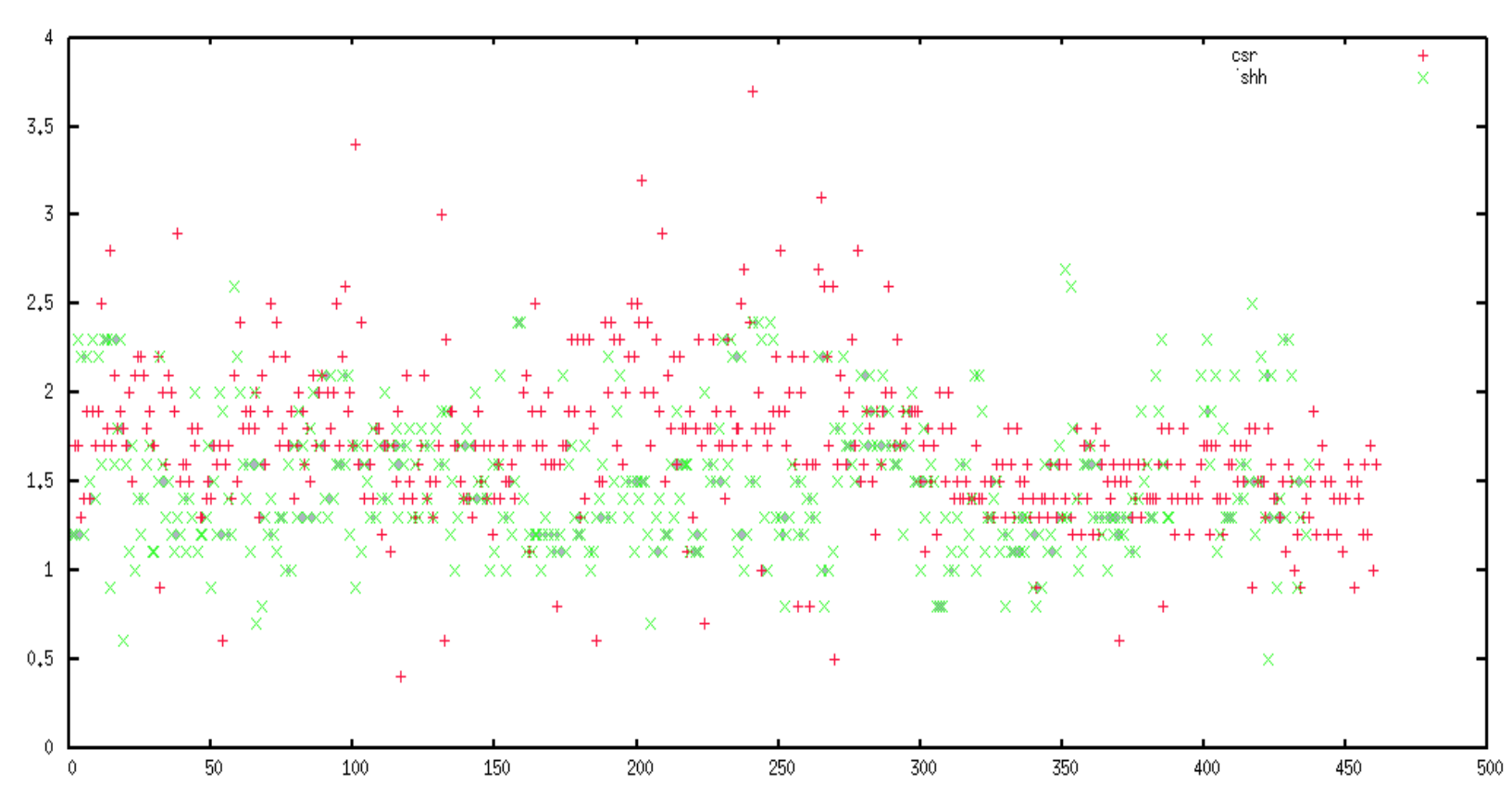




31 sites :only 19 sites show good observation!

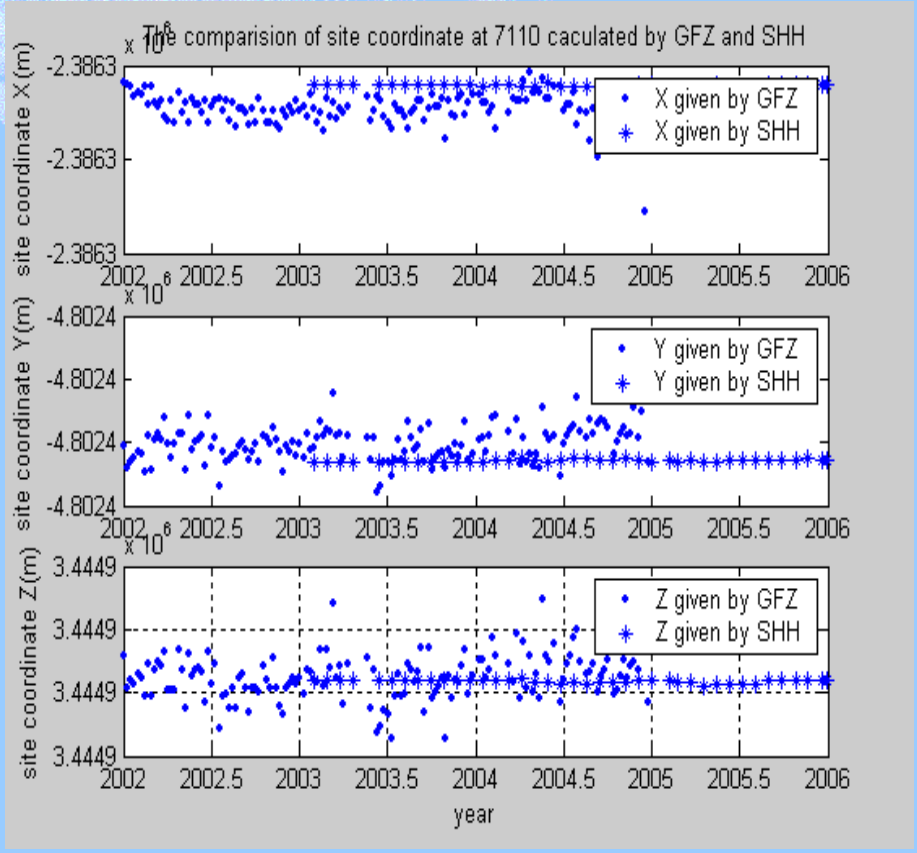
Present status and results of our SLR work

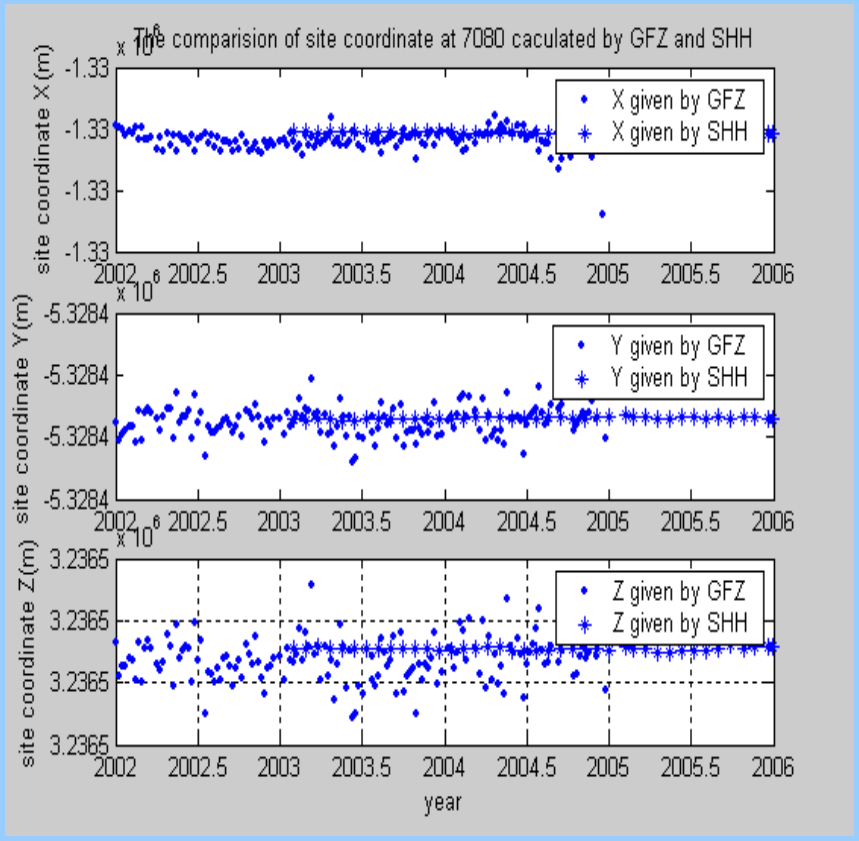
PostProcessing: Comparison of residual rms between CSR and SHH



Present status and results of our SLR work

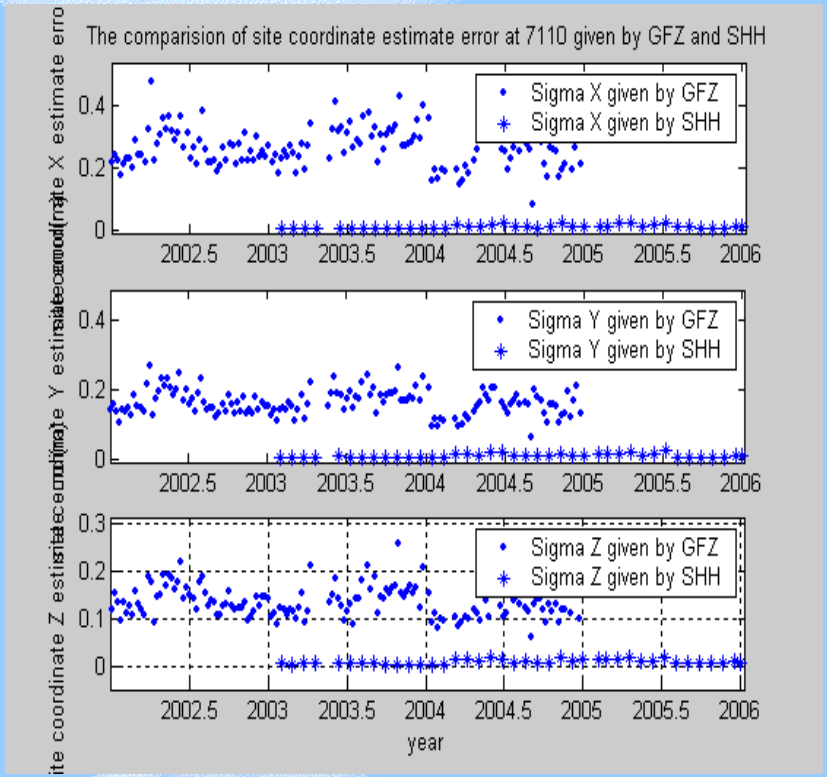
PostProcessing: The comparison of Site coordinate series with GFZ.

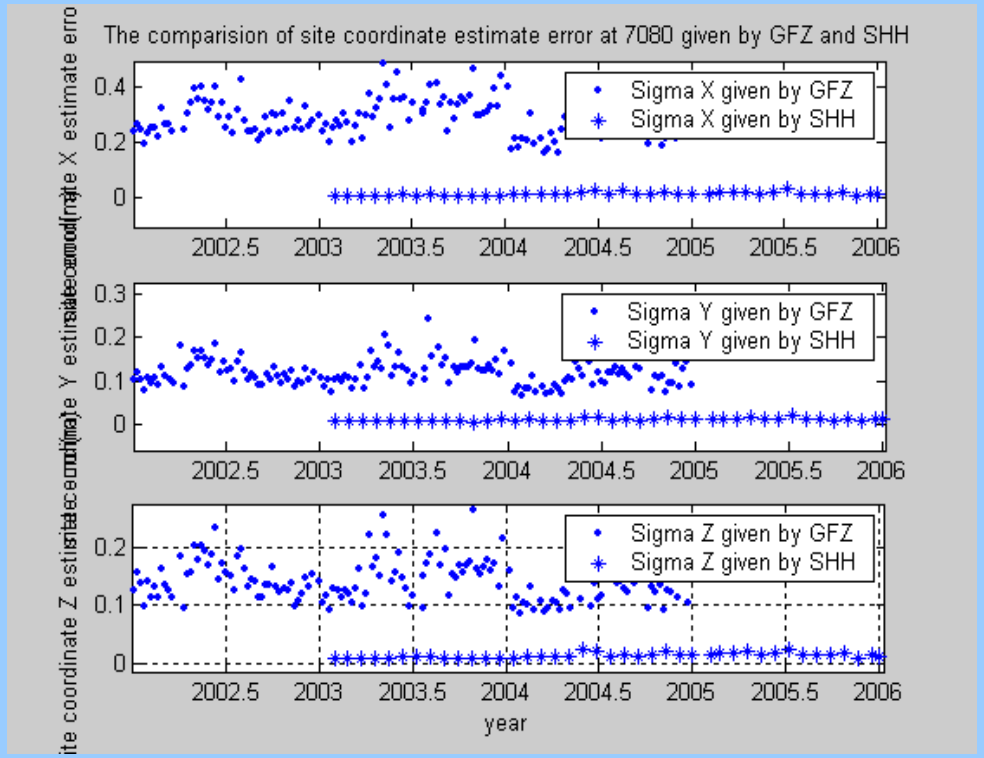




Present status and results of our SLR work

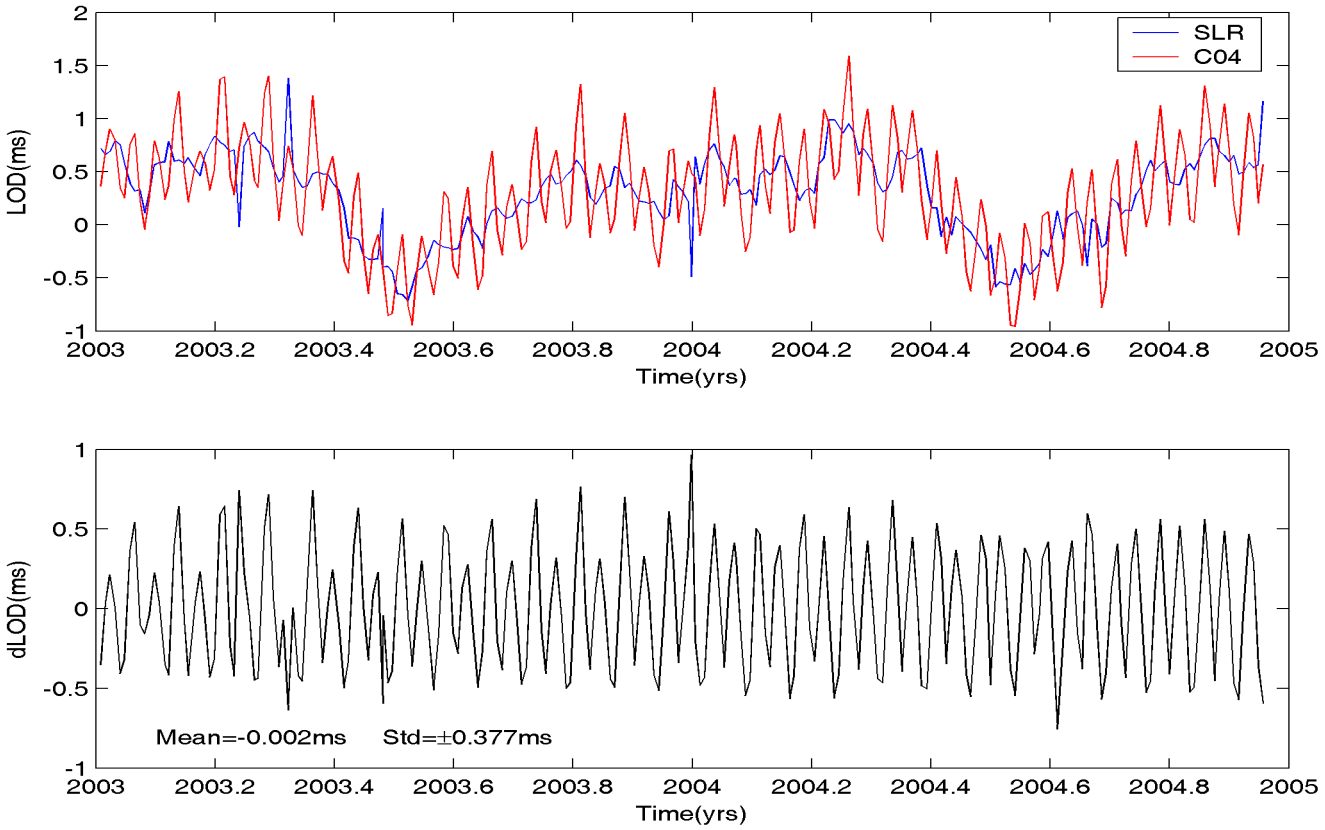
PostProcessing: The comparison of site coordinate estimate error given by GFZ and SHH. SHH:1-2cm error; GFZ:10-30cm error direction error is especially big(40cm or so). Maybe GFZ solution is more loose.





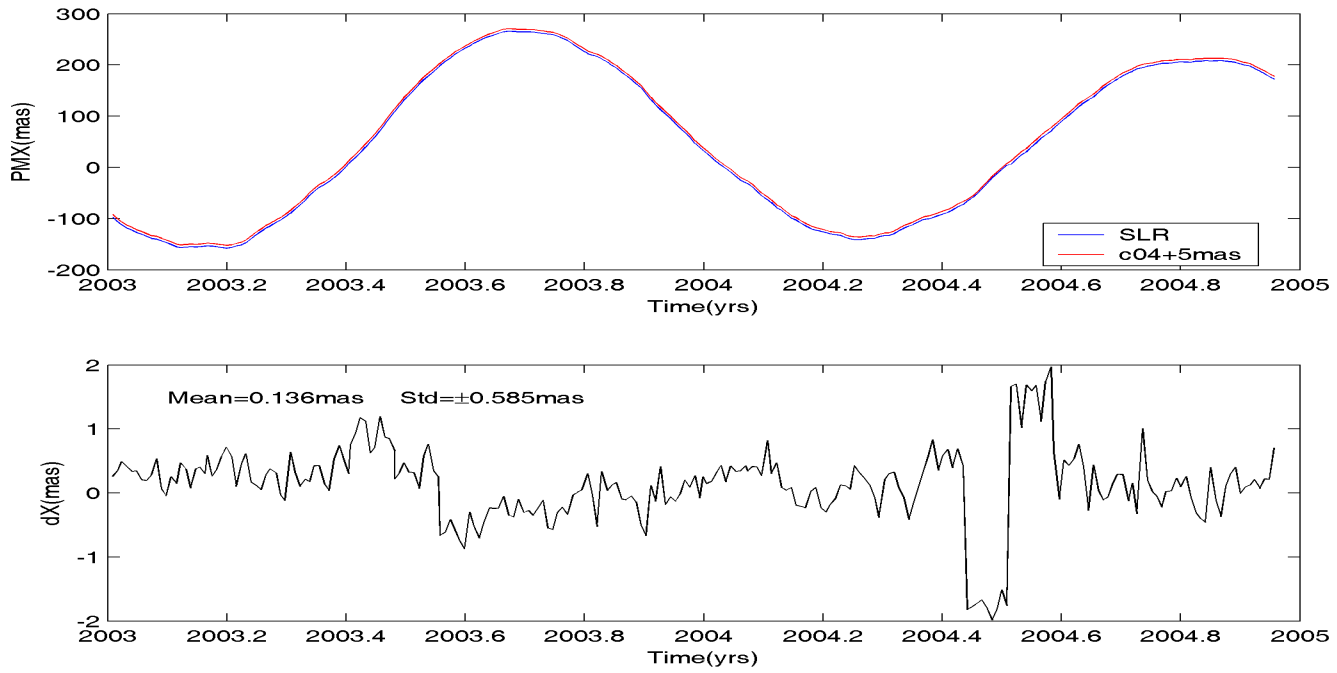
Present status and results of our SLR work

PostProcessing: LOD comparison with C04:
Mean=-0.002ms; Std=±0.377ms



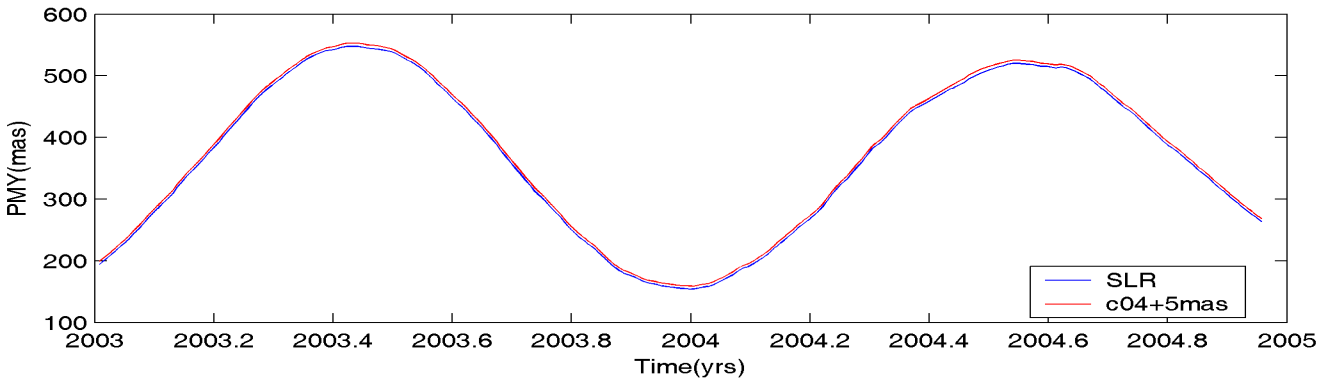
Present status and results of our SLR work

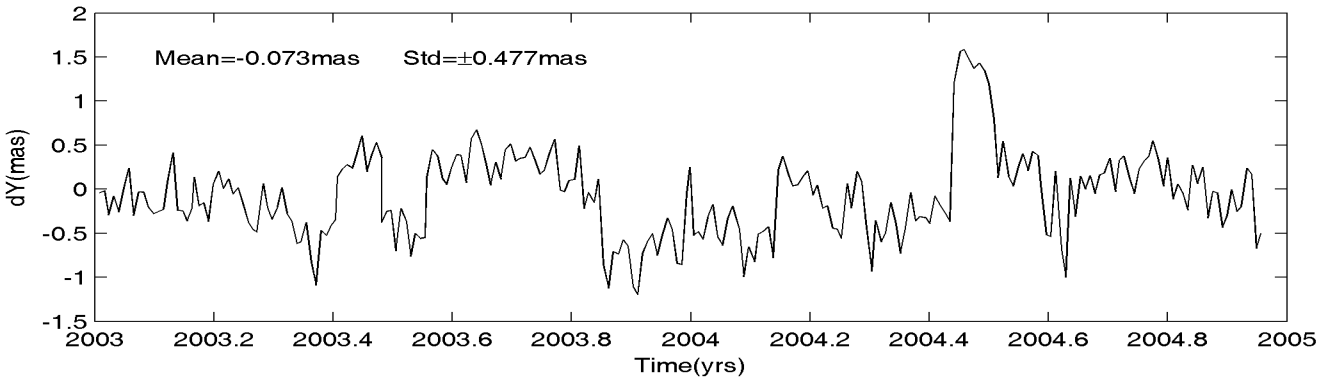
PostProcessing: PM comparison in X direction with C04: Mean=0.136mas; Std=±0.585mas. There are some data gap especially less data at 7105 and 7210 between doy 200 and 300 in 2004.



Present status and results of our SLR work

PostProcessing: PM comparison in Y direction with C04: Mean=-0.073mas; Std=±0.477mas





Conclusions

- SLR data auto-processing is very necessary for long-term study and analysis of site coordinate, EOP, satellite orbit evaluation, system error and mass center variety. It can also give a warning information to SLR sites so that they can find the problem and solve it.
- A uniform SLR orbit format is needed to compare our results with those from other techniques or other analysis center. SP3 orbit format is good?
- Reference frame unification is important for us to get uniform and consistent velocity and coordinate at reference epoch. Because the SLR sites are not so much it needs some good, stable and long-term SLR sites to control the reference frame. Once there are only few good sites the reference frame is unstable. The results are terrible! The accuracy falls down quickly.

Future development

There are more problems to study or discuss:

2) Loose solution or constrained solution is better to SLR data processing? Week solution or longer arc length solution is better?
3) How to get better and consistent mass center variety of the earth? This is one of the SLR's special characters. We should apply it very well!
4) More observations are possible? Day observation system or kHz system could significantly improve observation number? Maybe more channels observation possible? We need an observation list at first so that we can give more observation to some interesting satellites and satisfy for our study needs.
5) Gravity coefficients and tide parameters could be estimated well under not much data? Only 30 SLR sites and some still show few observation!
6) Check the consistence of our software with ILRS and IERS standards and update some modes and constants.

Thank you for your attention!