Data accuracy analysis of Chinese SLR stations in the first half of 2021

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Shanghai Astronomical Observatory

2021.11

Directory

- Data processing strategy
- The results from Lageos1

The slr data from:

7237：Changchun

7249：Beijing

7396：Wuhan

7819：Kunming

7821：shanghai

Data processing strategy and models

- **Strategy:**
  - **Use precise orbit products from ilrsb. Not Orbit Determination.**
  - **Calculate O-C of SLR data (np), and give the time series of residuals of each station.**
  - **For each station, calculate:**
    - **ratio of good data.**
    - **mean, represents the bias of measurement**
    - **std, represents the precision**
    - **rms, represents the accuracy**

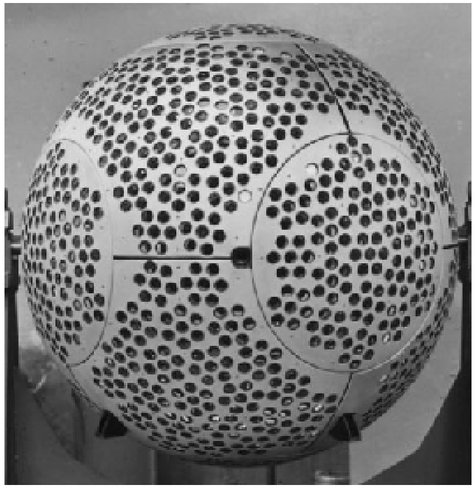
- **Software: EODP**

- **Models**
  - **Station coordinates: SLRF2014**
  - **Center of Mass (CoM) correction: 0.251 m for Lageos1**
  - **Tropospheric delay correction: Marini-Murray**
  - **Solid Earth tides/Ocean tides/Solid Earth pole tides for station displacement**
  - **Shapiro time delay**
  - **Model accuracy: < 1 cm**

ILRS orbit products

- Sp3c format.
- One file per week/satellite, update every week.
- Sample rate：120s(L)/900s(E)，Coordinates system：Earth Center Earth Fix (ECEF)

	Etalon-1	Etalon-2	LAGEOS-1	LAGEOS-2
Sponsor:	Russia	Russia	United States	United States and Italy
Expected Life:	hundreds of years	hundreds of years	many decades	many decades
Primary Applications:	geodesy	geodesy	geodesy	geodesy
COSPAR ID:	8900103	8903903	7603901	9207002
SIC Code:	0525	4146	1155	5986
Satellite Catalog (NORAD) Number:	19751	20026	8820	22195
Launch Date:	January 10, 1989	May 31, 1989	May 4, 1976	October 22, 1992
RRA Diameter:	1.294 m	1.294 m	60 cm	60 cm
RRA Shape:	circular	circular	sphere	sphere
Reflectors:	2146 corner cubes	2146 corner cubes	426 corner cubes	426 corner cubes
Orbit:	Circular	Circular	circular	circular
Inclination:	64.9 degrees	65.5 degrees	406.965 Kg	405.38 kg
Eccentricity:	0.00061	0.00066	0.0045	0.0135
Perigee:	19,120 km	19,120 km	5,860 km	5,620 km
Period:	676 minutes	675 minutes	225 minutes	223 minutes
Weight:	1415 kg	1415 kg	109.84 degrees	52.64 degrees



Lageos1 orbit products

- ilrsb as the reference.

Analysis Centers (ACs)			
Center	**Code**	**Contact**	**E-mail**
Bundesamt für Kartographie und Geodäesie (BKG) Germany (log)	bkg	Dr. Daniela Thaller Dr. Daniel Koenig	Daniela.Thaller@bkg.bund.de Daniel.Koenig@bkg.bund.de
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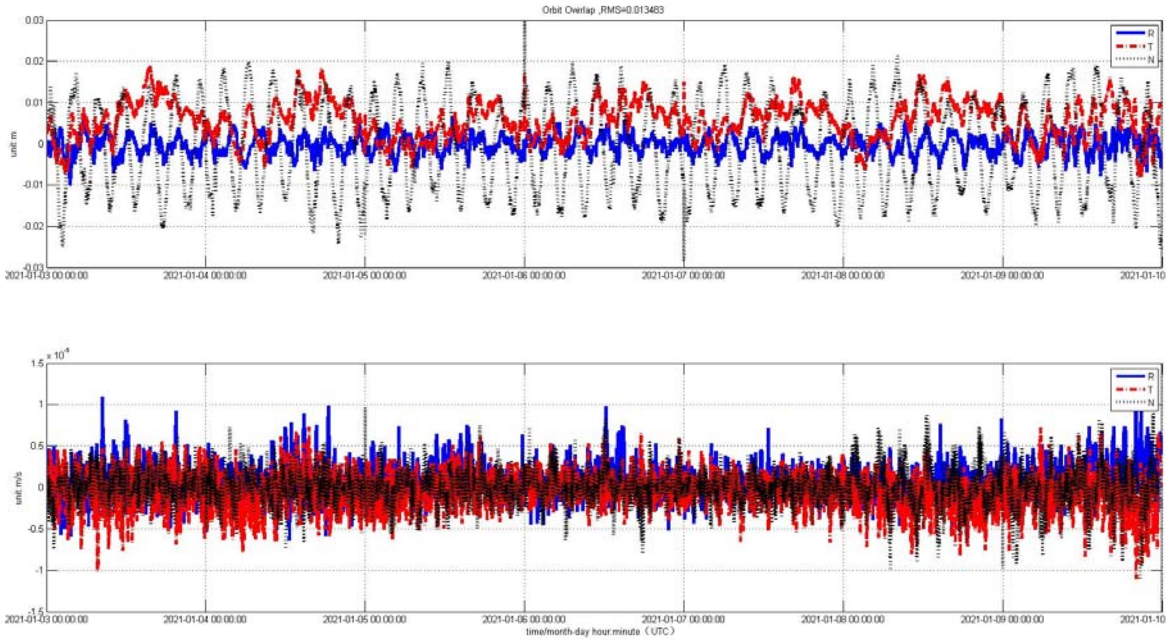
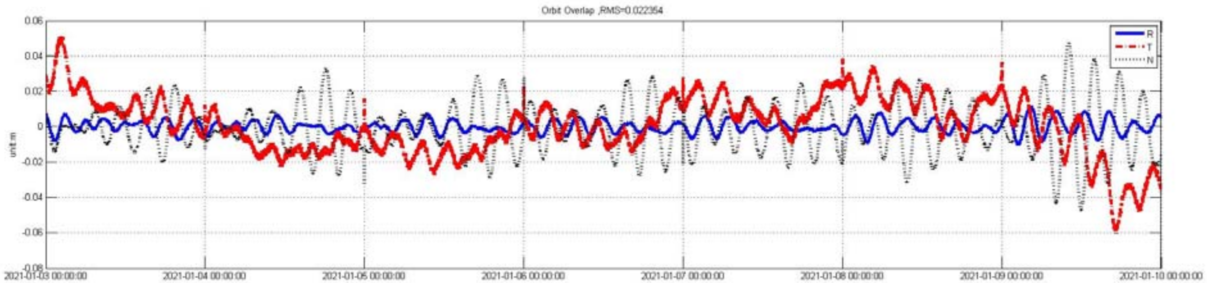
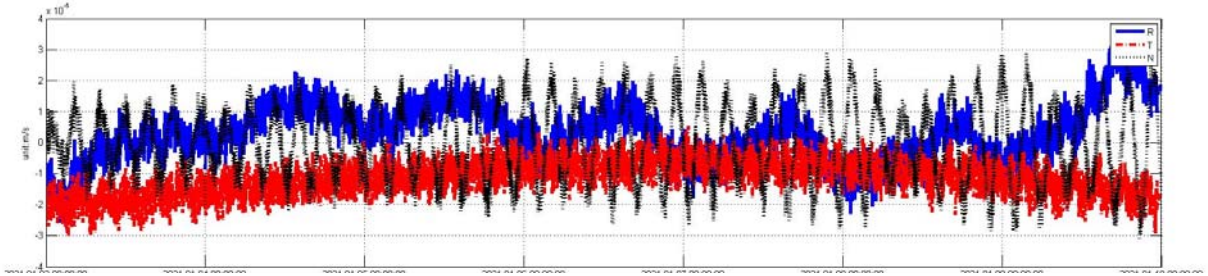
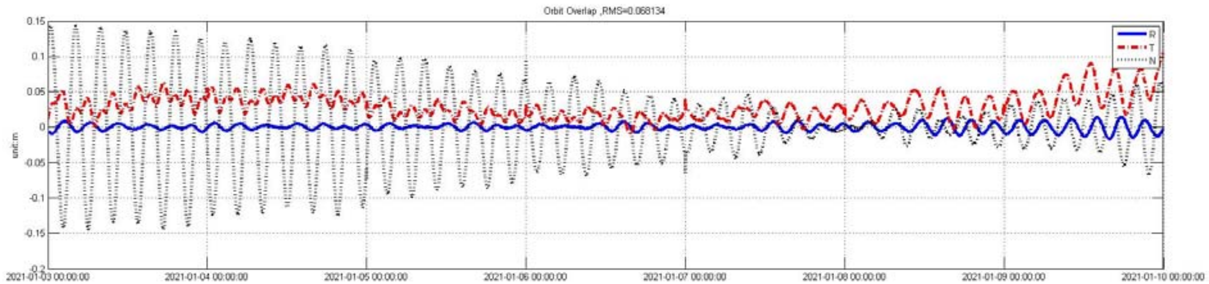
NERC Space Geodesy Facility (NSGF) formely RGO Satellite Laser Ranging Group, United Kingdom (log)	ngsf	Dr. Graham Appleby	gapp@nerc.ac.uk

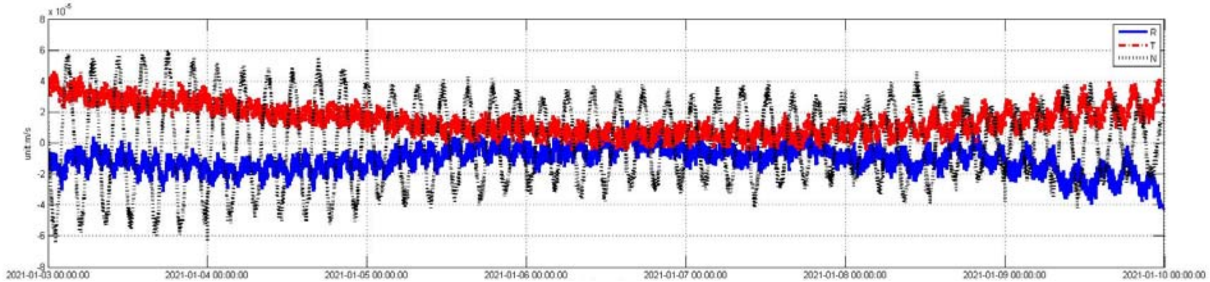


Ilrsa:1.3cm

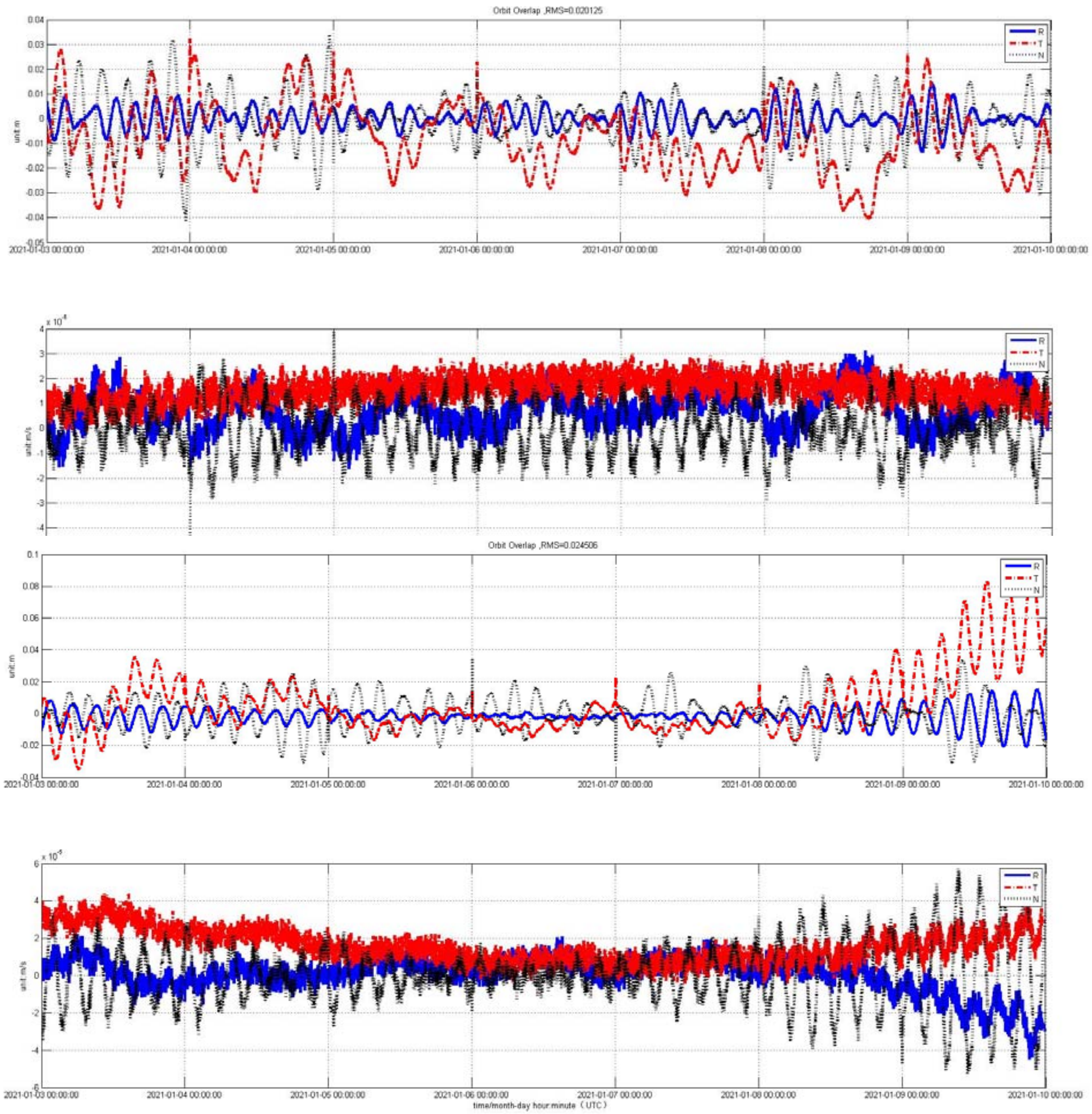




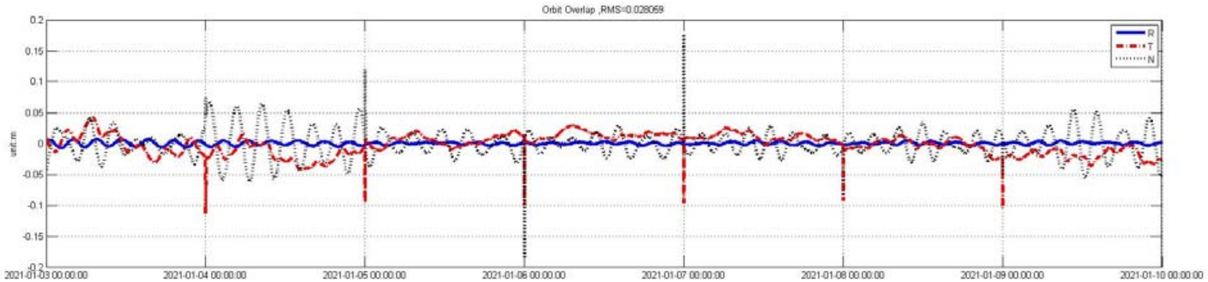


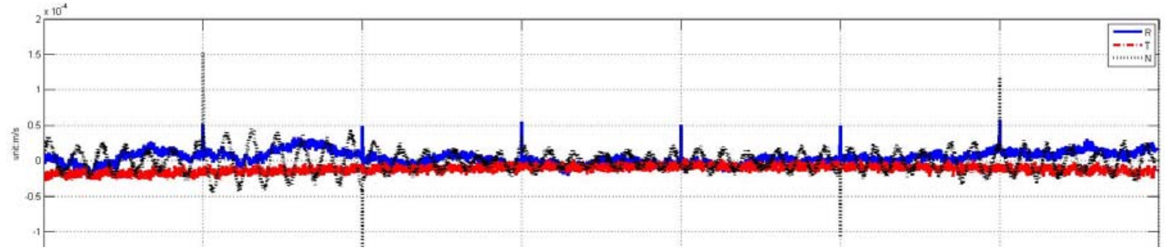


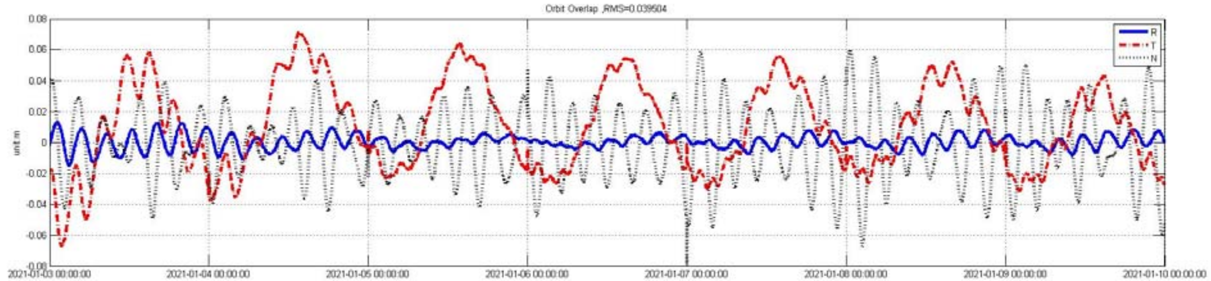
Bkg:2.2cm
Dgfi:6.8cm

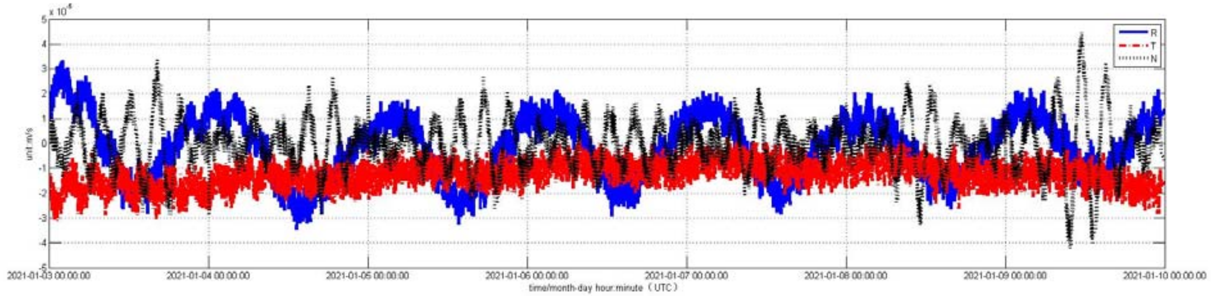


Esa:2.0cm
GFZ:2.4cm

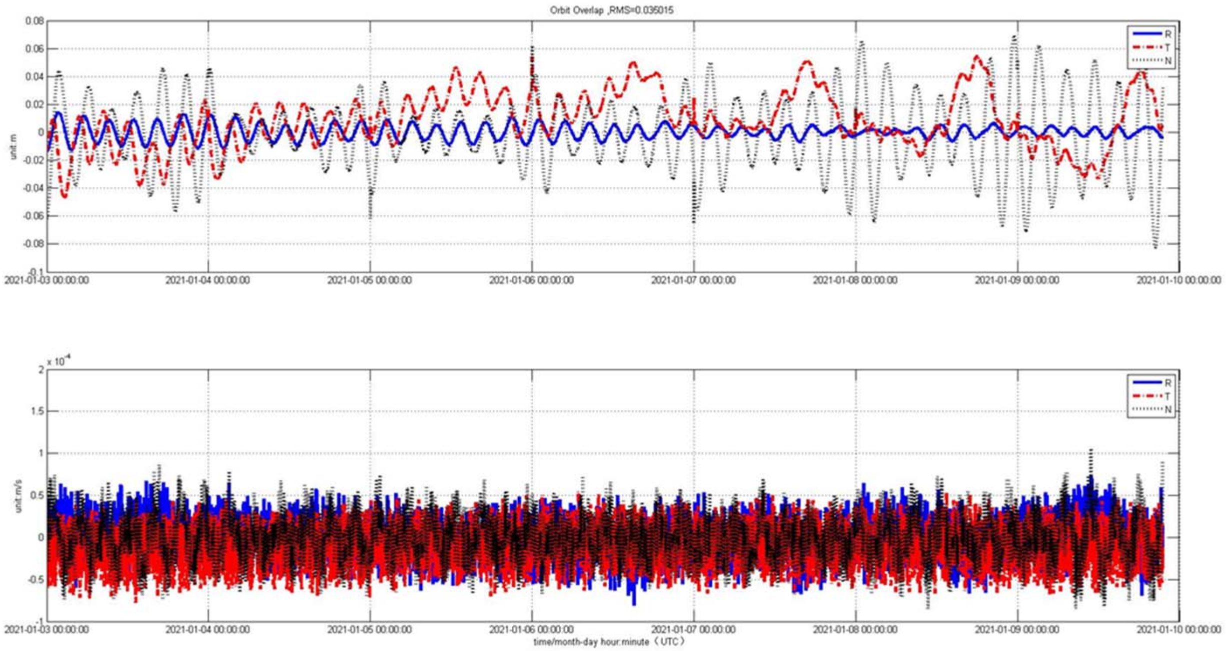








Asi: 2.8cm
Jcet:4.0cm

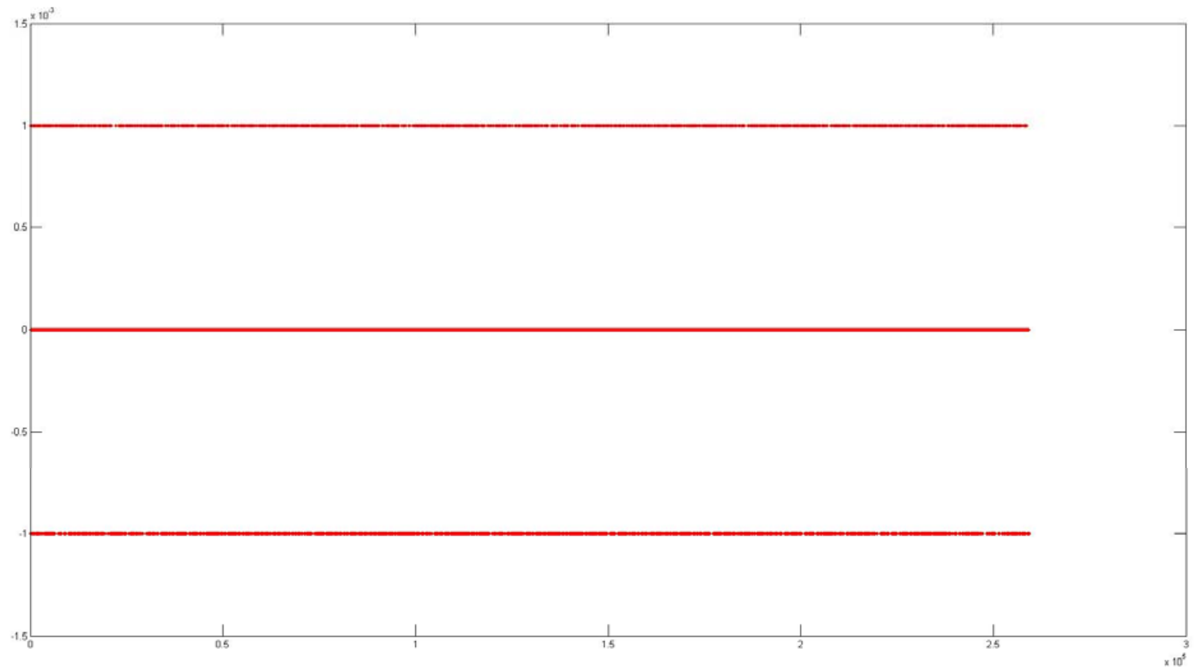


- Nsgf： 3.5cm

The position difference between Acs is about several cm, < 1 cm in radial direction.

Interpolate satellite’s position

- **Chebyshev polynomial method**
  - **120s → 1s，better than 1 mm**

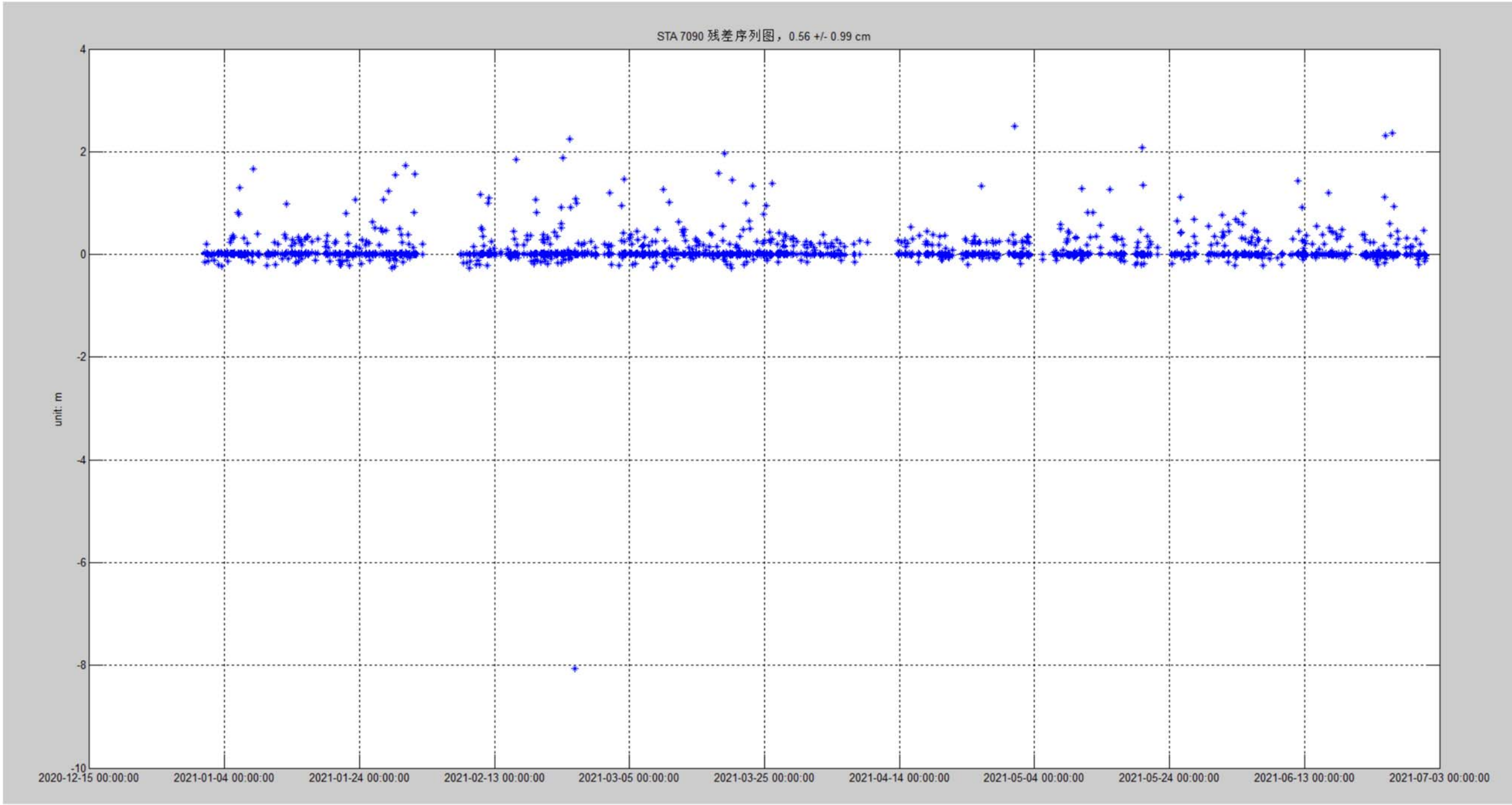


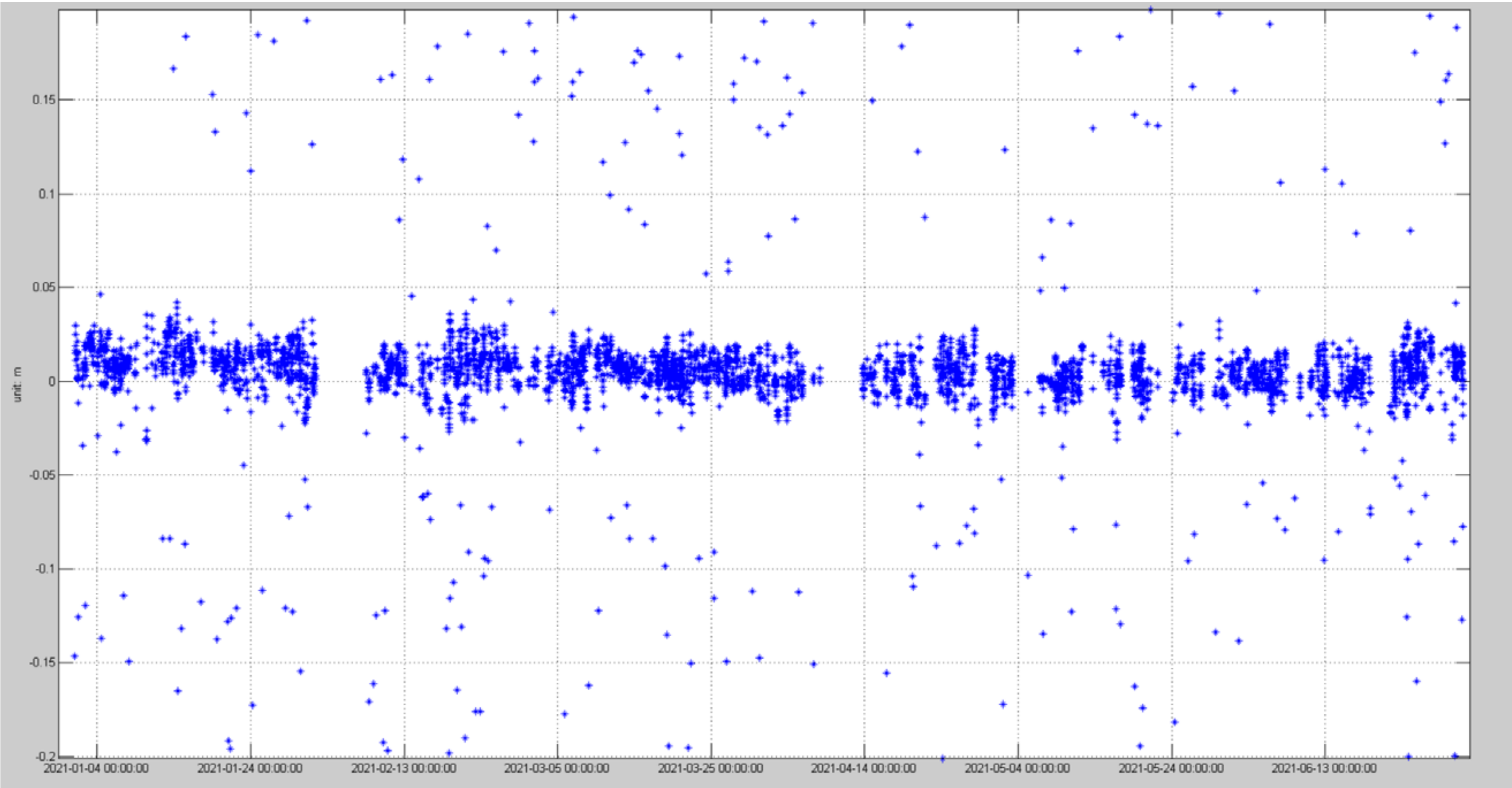
The results of Lageos1 from 2021.1 to 2021.6

- **Chinese SLR station:**
  - **7237：Changchun**
  - **7249：Beijing**
  - **7396：Wuhan**
  - **7819：Kunming**
  - **7821：shanghai**

- **for comparison，7090-YARRAGADEE，7839-GRAZ，are also analyzed**

7090: YARRAGADEE

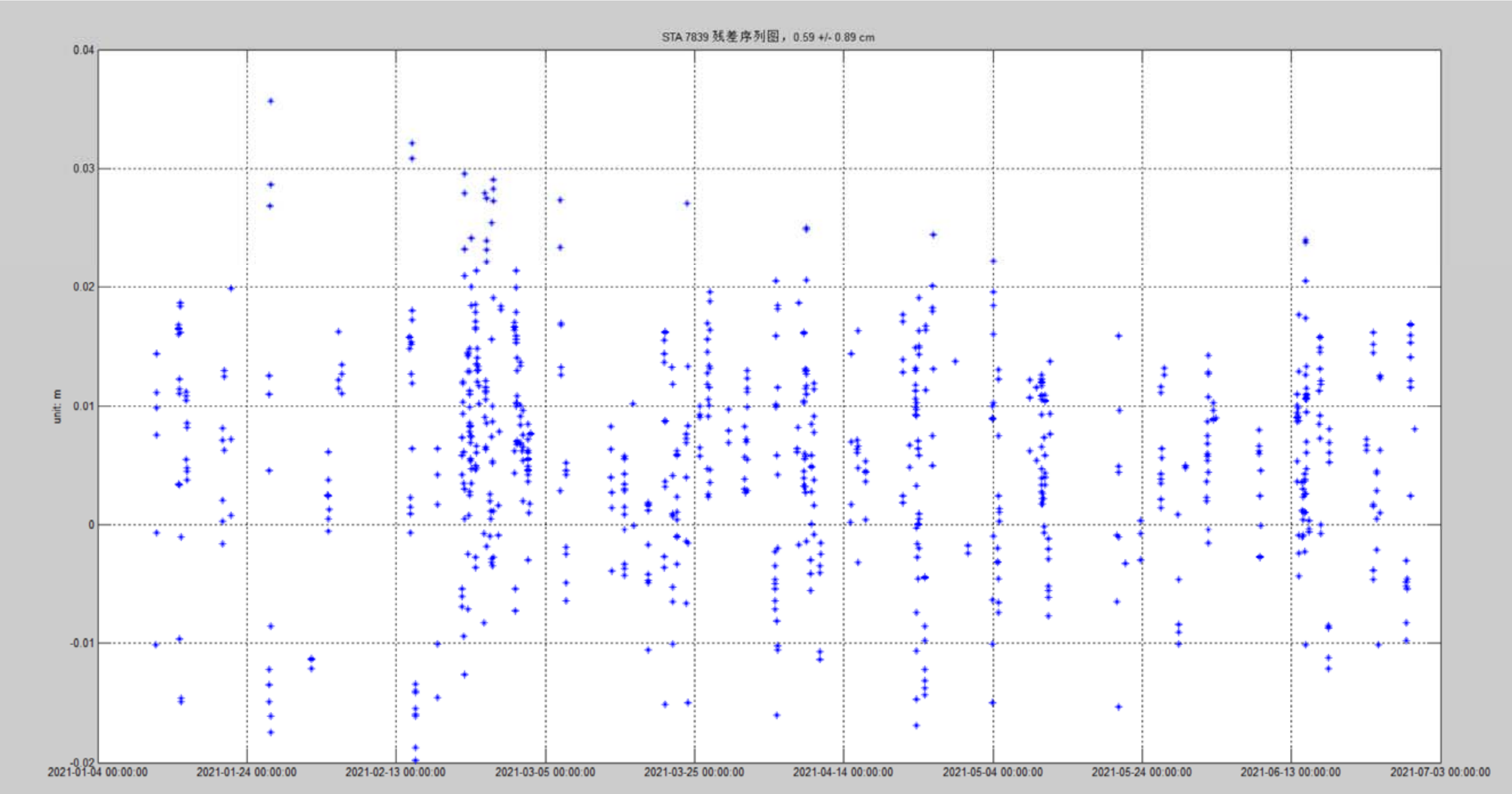




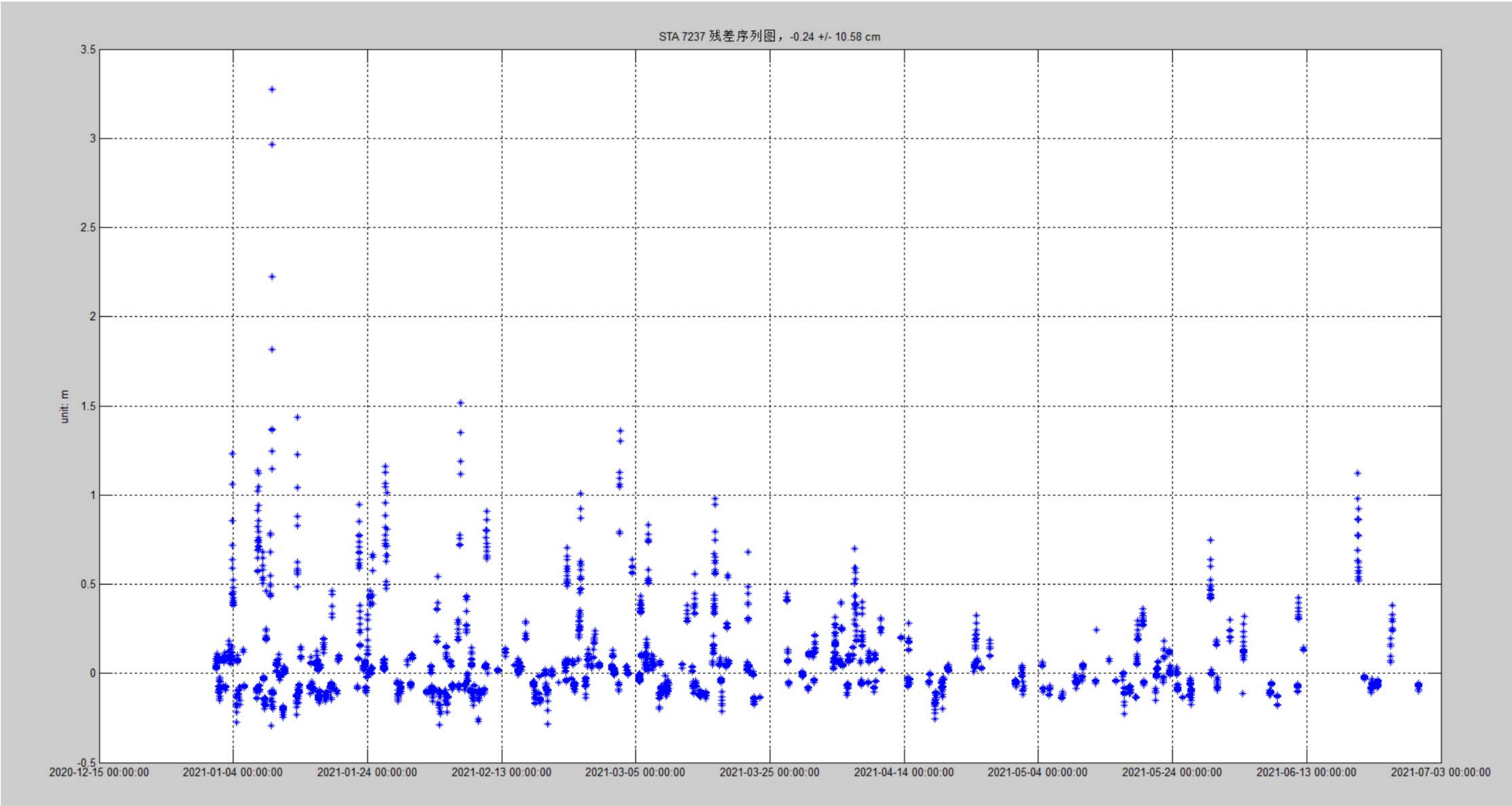
- **Most residuals are less than 3 cm, std： 0.99 cm**
- **Outlier data， max 8 m， mostly 1-2 m**
- **Most outlier data appears in the beginning of every pass**

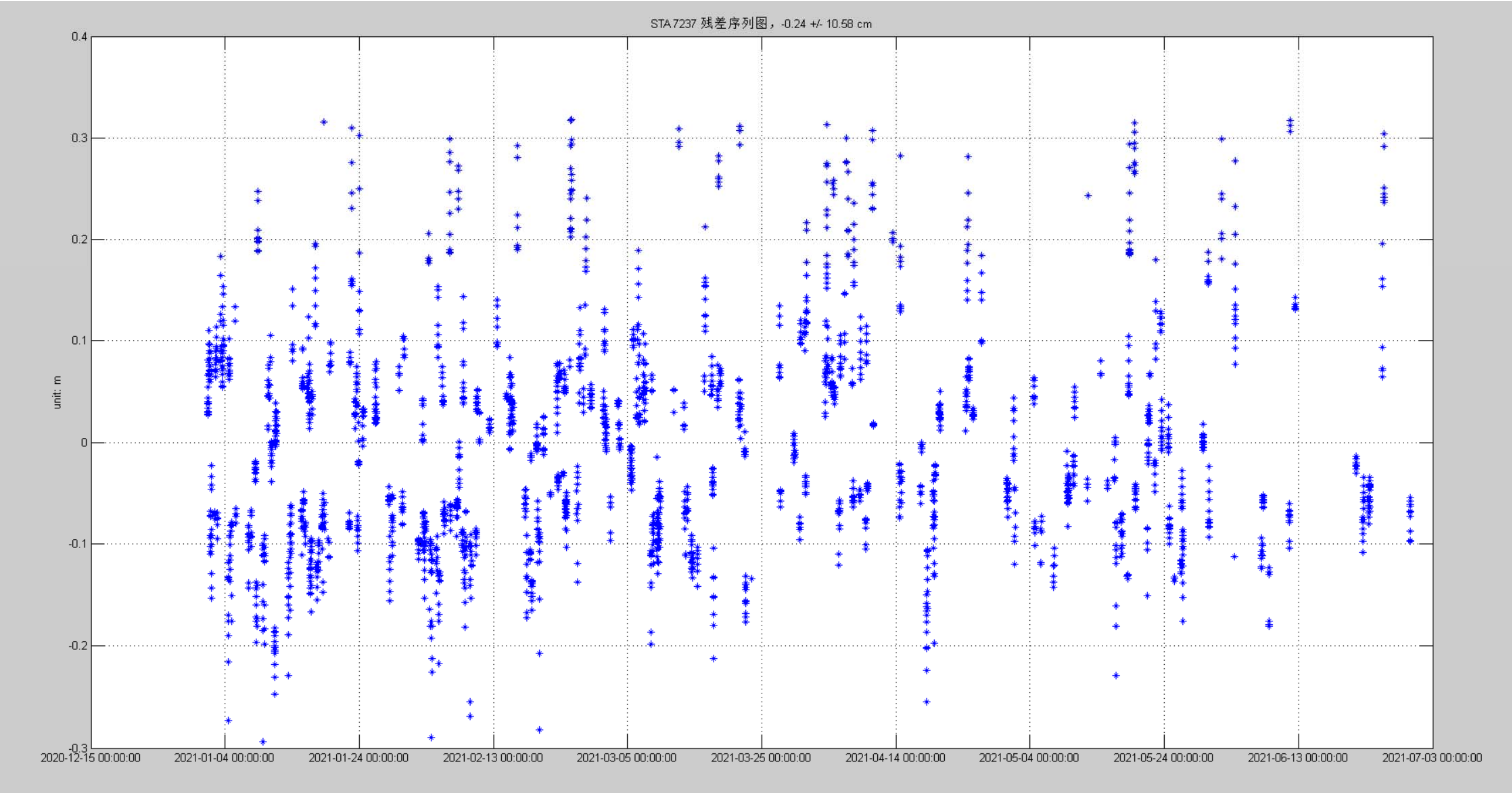
7839：GRAZ

- **No outlier data，std：0.89cm**



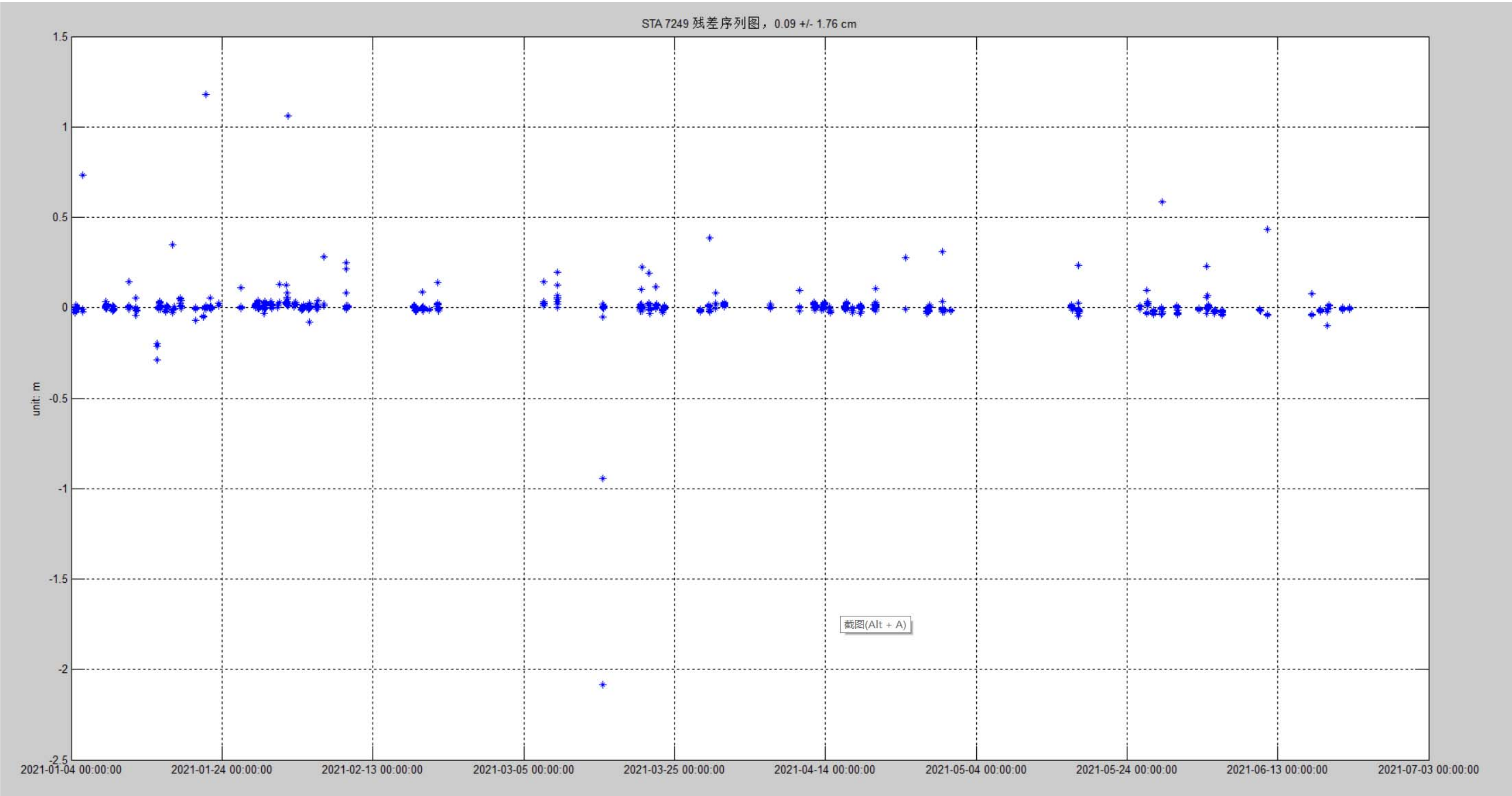
7237-Changchun

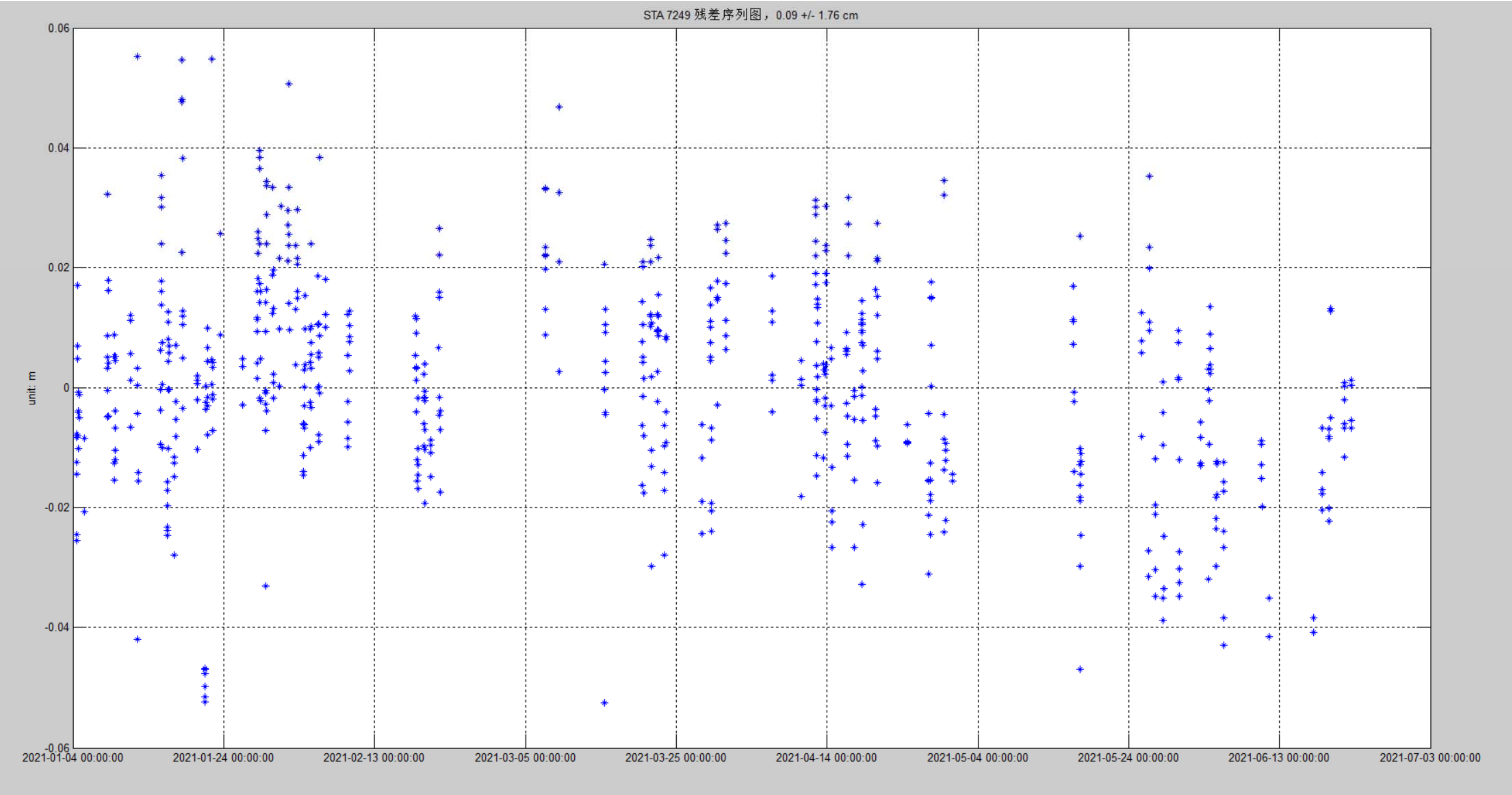




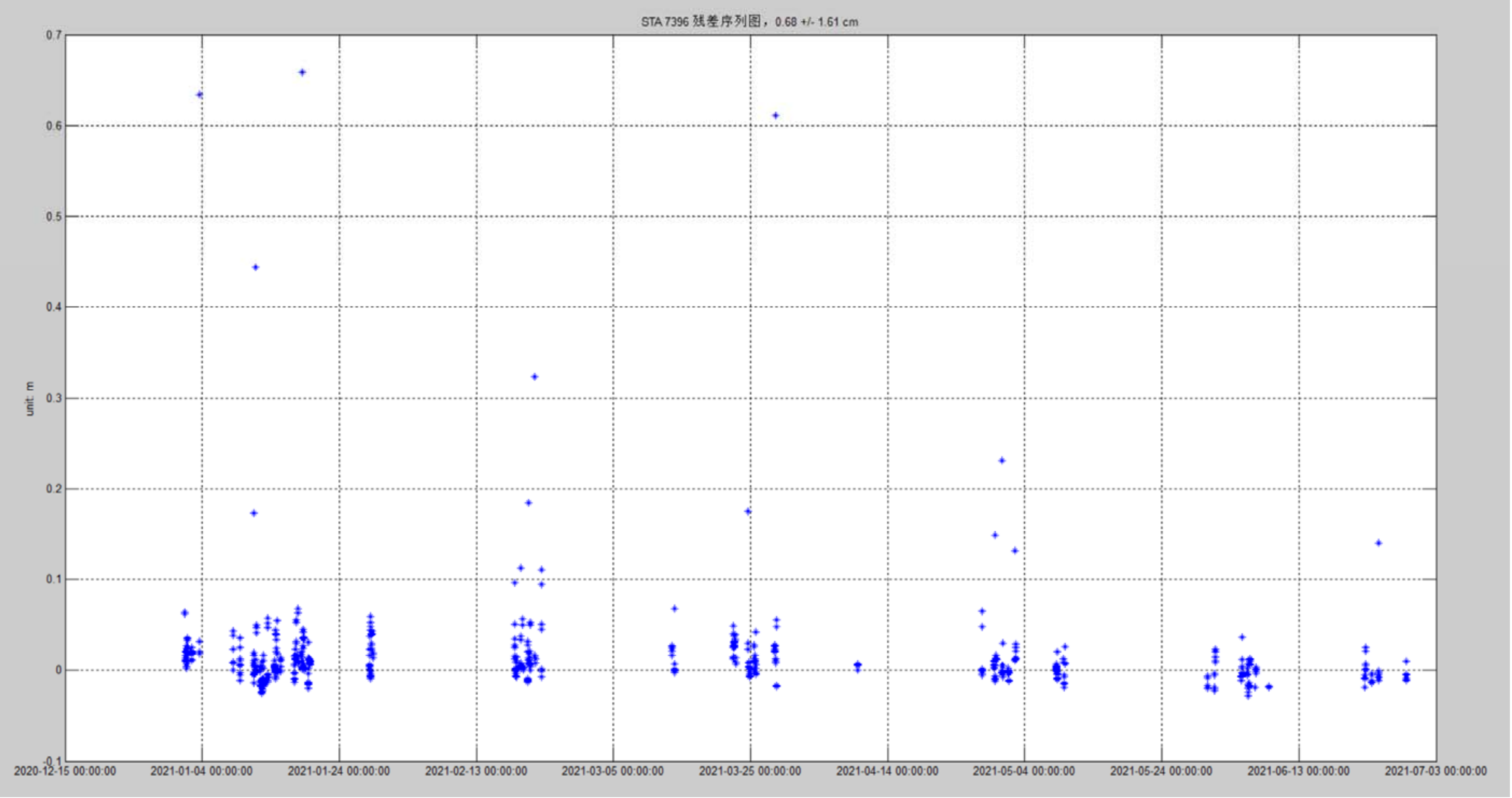
STA 7237 残差序列图，-0.24 +/- 10.58 cm
unit: m
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
2020-12-15 00:00:00
2021-01-04 00:00:00
2021-01-24 00:00:00
2021-02-13 00:00:00
2021-03-05 00:00:00
2021-03-25 00:00:00
2021-04-14 00:00:00
2021-05-04 00:00:00
2021-05-24 00:00:00
2021-06-13 00:00:00
2021-07-03 00:00:00

7249-Beijing

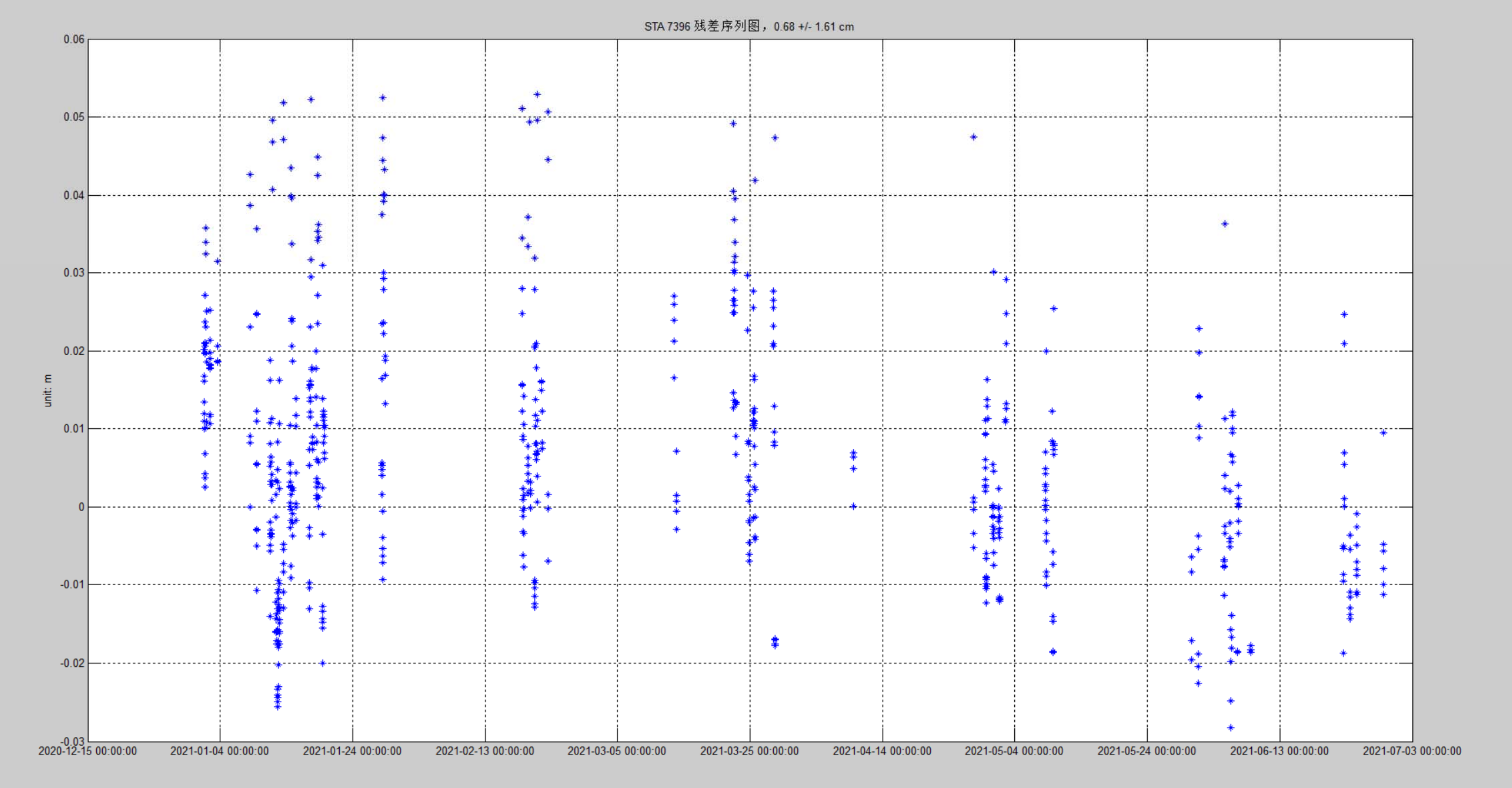



STA 7249 残差序列图，0.09 +/- 1.76 cm
unit: m
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
2021-01-04 00:00:00
2021-01-24 00:00:00
2021-02-13 00:00:00
2021-03-05 00:00:00
2021-03-25 00:00:00
2021-04-14 00:00:00
2021-05-04 00:00:00
2021-05-24 00:00:00
2021-06-13 00:00:00
2021-07-03 00:00:00

7396-Wuhan

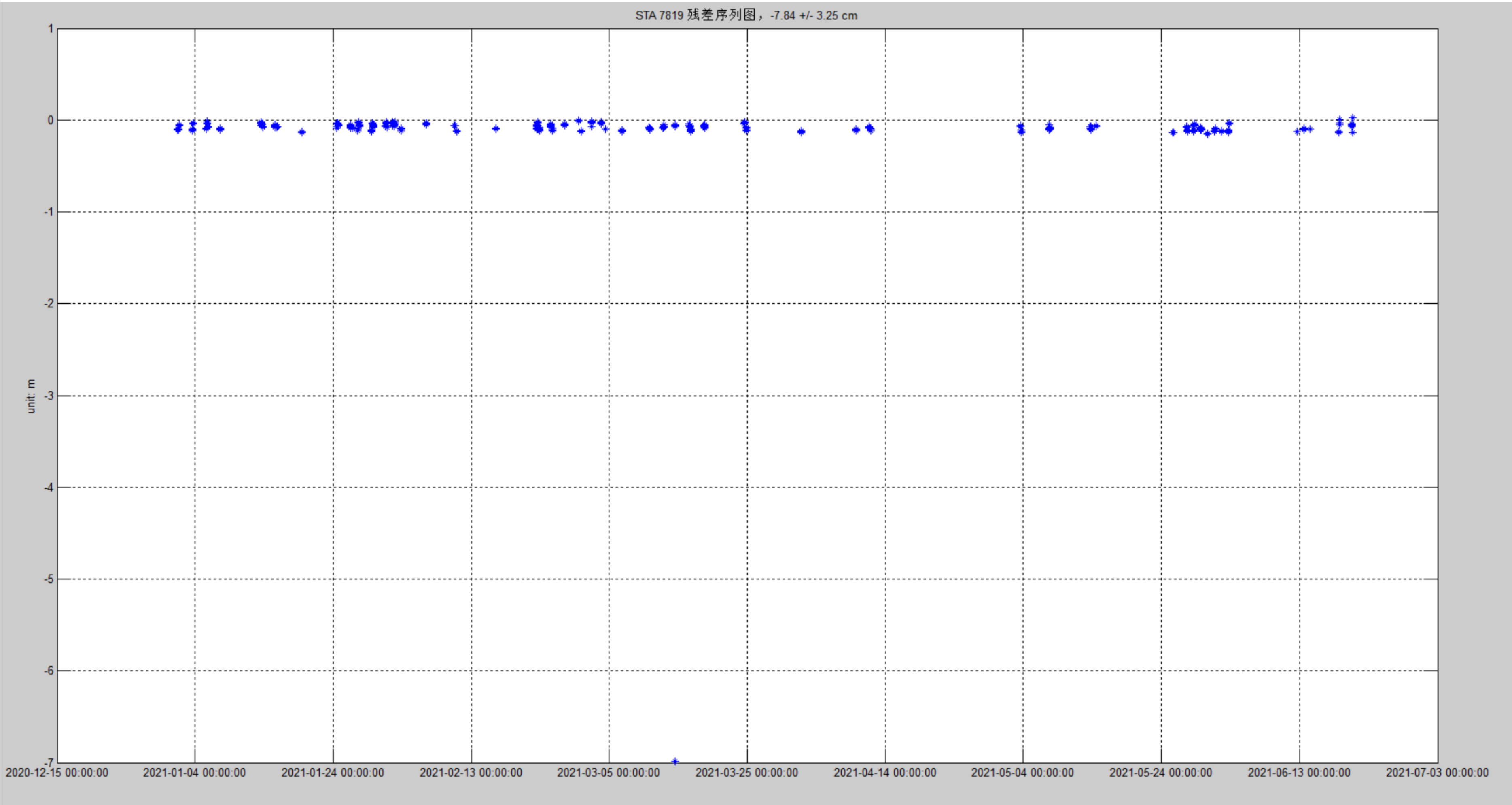


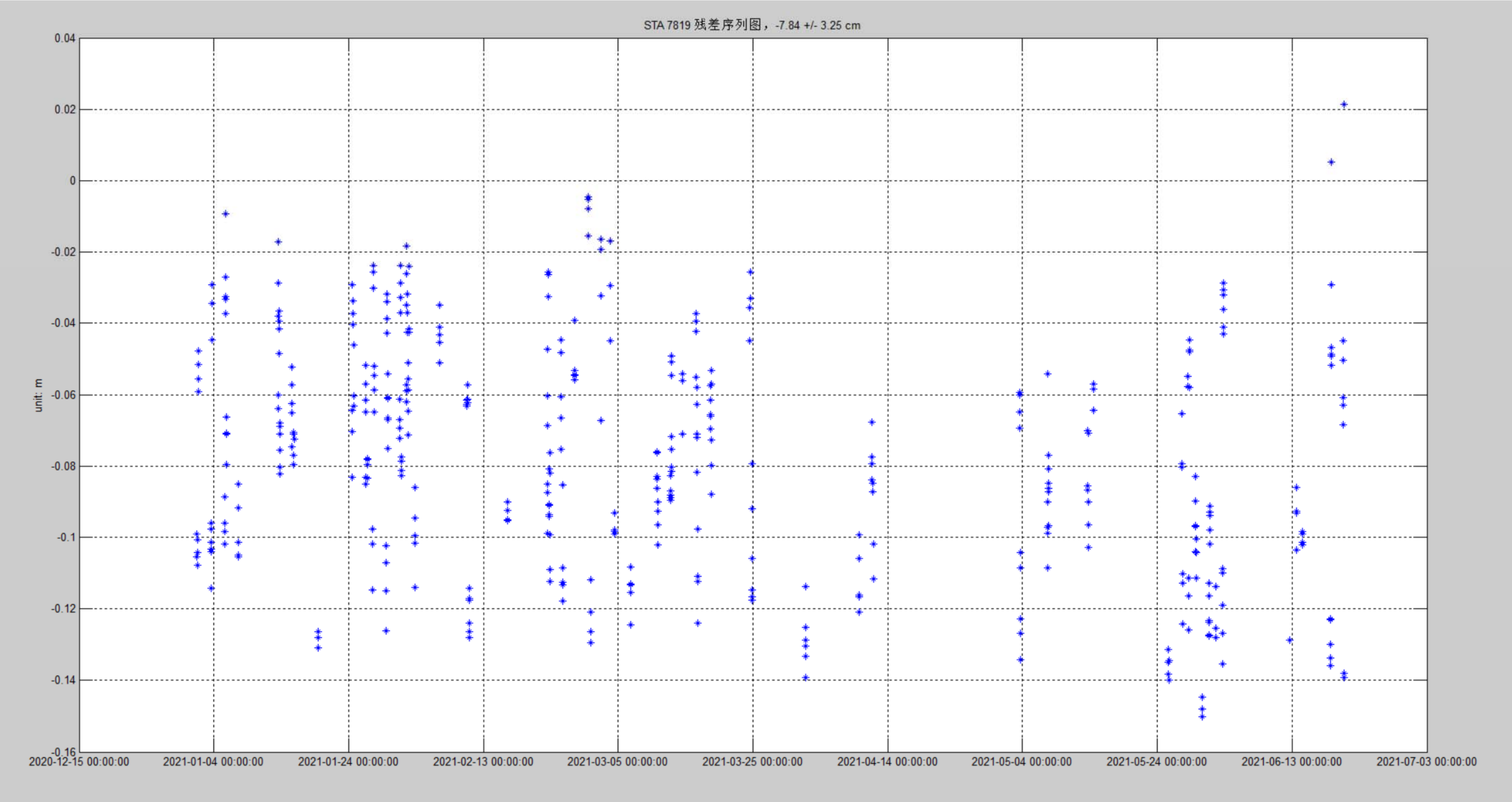
STA 7396 残差序列图，0.68 +/- 1.61 cm
unit: m
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
2020-12-15 00:00:00
2021-01-04 00:00:00
2021-01-24 00:00:00
2021-02-13 00:00:00
2021-03-05 00:00:00
2021-03-25 00:00:00
2021-04-14 00:00:00
2021-05-04 00:00:00
2021-05-24 00:00:00
2021-06-13 00:00:00
2021-07-03 00:00:00



STA 7396 残差序列图，0.68 +/- 1.61 cm
unit: m
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
2020-12-15 00:00:00
2021-01-04 00:00:00
2021-01-24 00:00:00
2021-02-13 00:00:00
2021-03-05 00:00:00
2021-03-25 00:00:00
2021-04-14 00:00:00
2021-05-04 00:00:00
2021-05-24 00:00:00
2021-06-13 00:00:00
2021-07-03 00:00:00

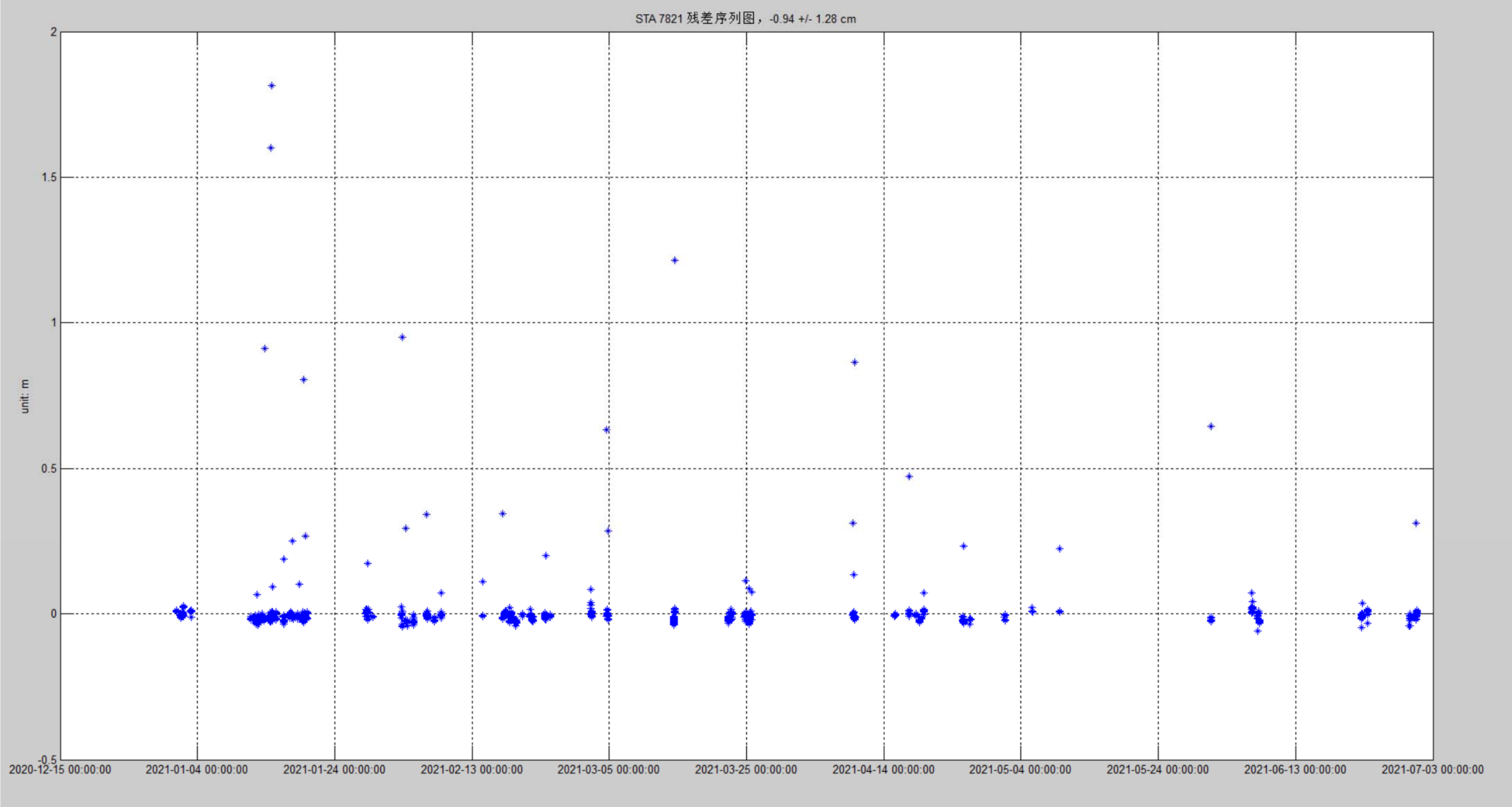
7819-Kunming

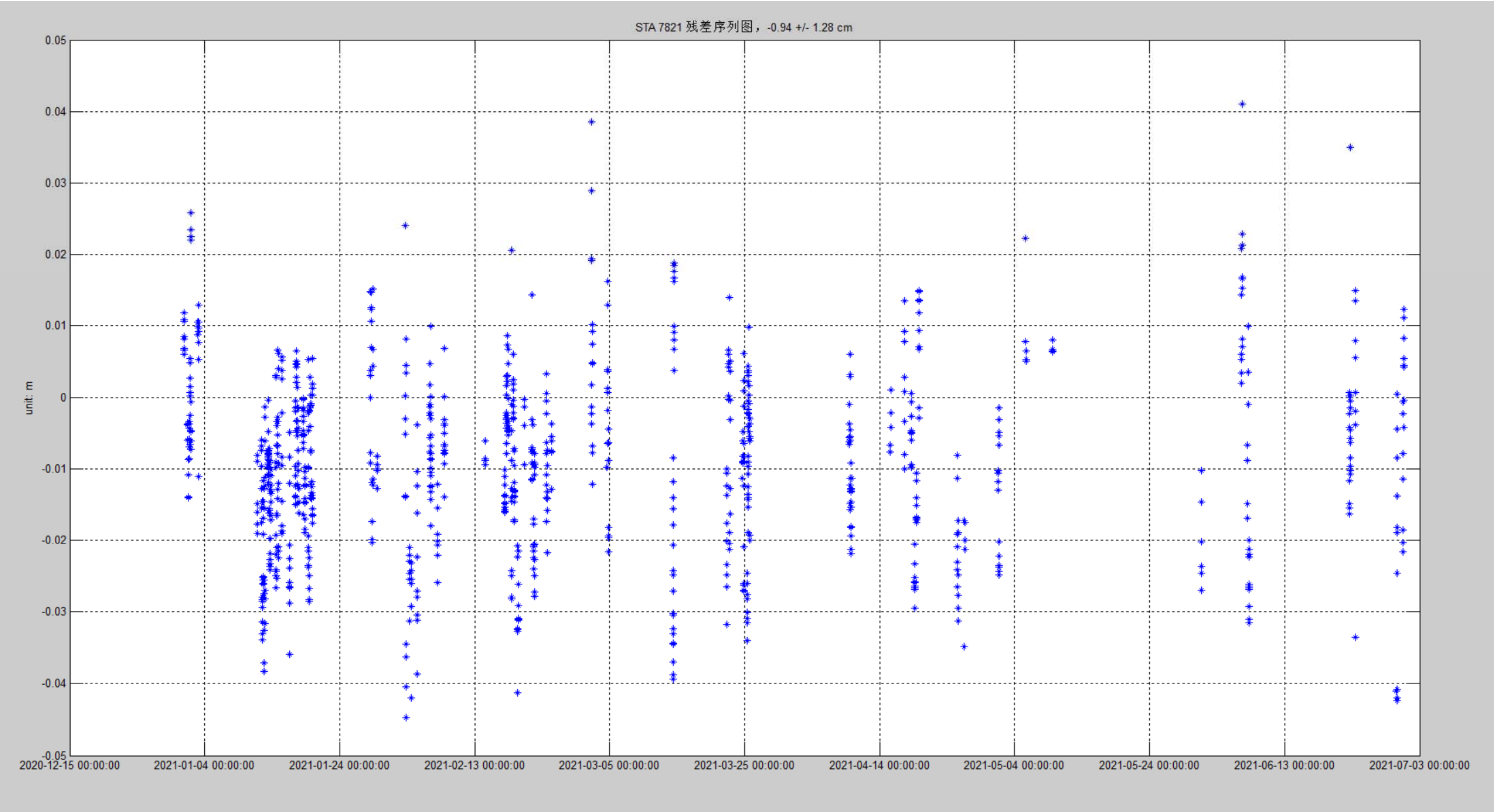




STA 7819 残差序列图，-7.84 +/- 3.25 cm
unit: m
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
-0.16
2020-12-15 00:00:00
2021-01-04 00:00:00
2021-01-24 00:00:00
2021-02-13 00:00:00
2021-03-05 00:00:00
2021-03-25 00:00:00
2021-04-14 00:00:00
2021-05-04 00:00:00
2021-05-24 00:00:00
2021-06-13 00:00:00
2021-07-03 00:00:00

7821-Shanghai

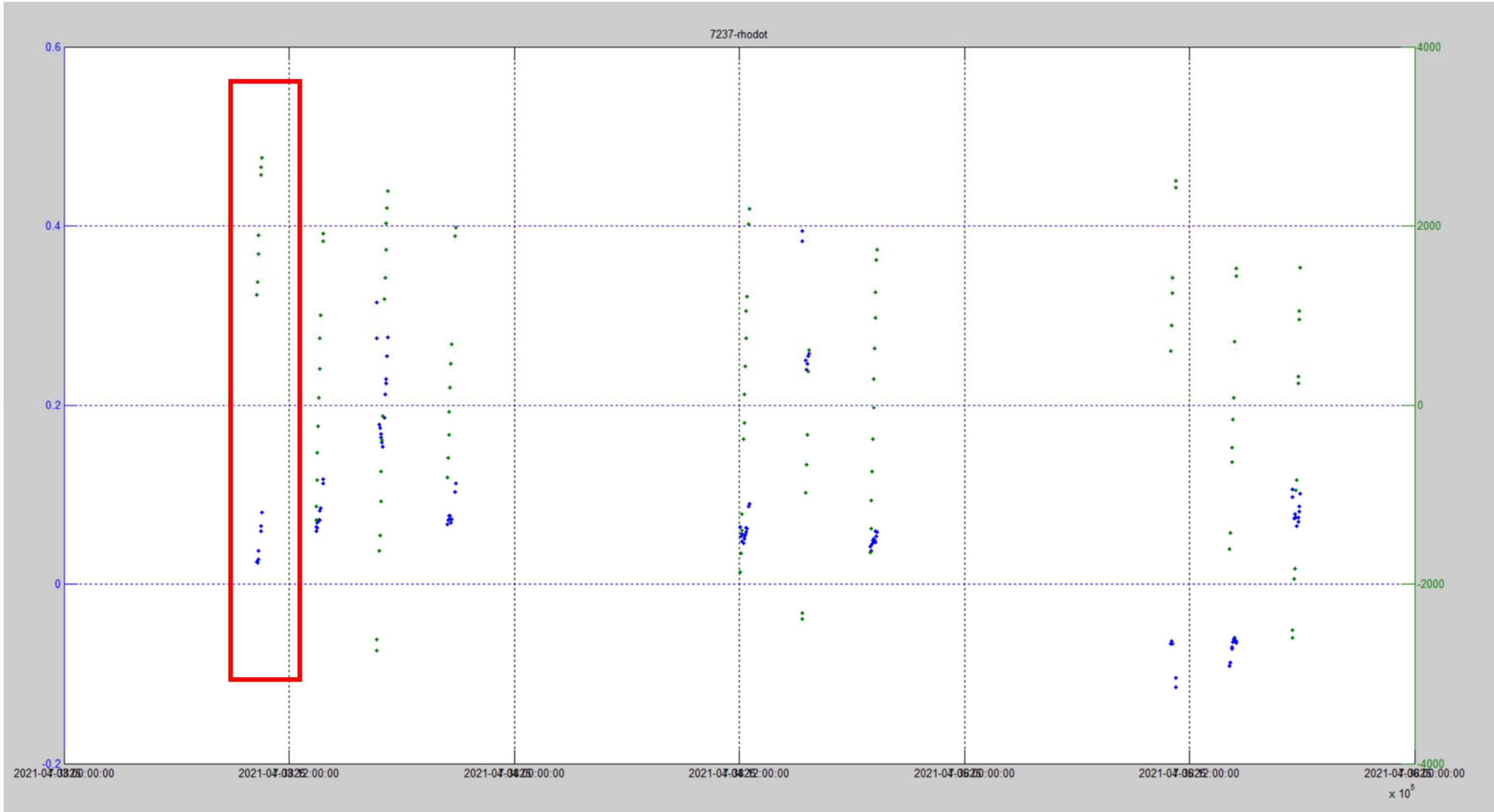



STA 7821 残差序列图，-0.94 +/- 1.28 cm
unit: m
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
2020-12-15 00:00:00
2021-01-04 00:00:00
2021-01-24 00:00:00
2021-02-13 00:00:00
2021-03-05 00:00:00
2021-03-25 00:00:00
2021-04-14 00:00:00
2021-05-04 00:00:00
2021-05-24 00:00:00
2021-06-13 00:00:00
2021-07-03 00:00:00

Accuracy summary

station	obs_all	obs_use	Ratio(%)	Mean(cm)	Std(cm)	Rms(cm)
Yarragadee(7090)	4945	4396	88.9	0.56	0.99	1.14
Graz(7839)	786	785	99.9	0.59	0.90	1.07
Changchun(7237)	2824	2484	88.0	-0.24	10.58	10.58
Beijing(7249)	665	618	92.9	0.09	1.76	1.76
Wuhan(7396)	637	609	95.6	0.68	1.61	1.75
Kunming(7819)	417	416	99.8	-7.84	3.25	8.48
Shanghai(7821)	947	910	96.1	-0.94	1.28	1.59

The systematic error in Changchun(7237)，04.03-04.06

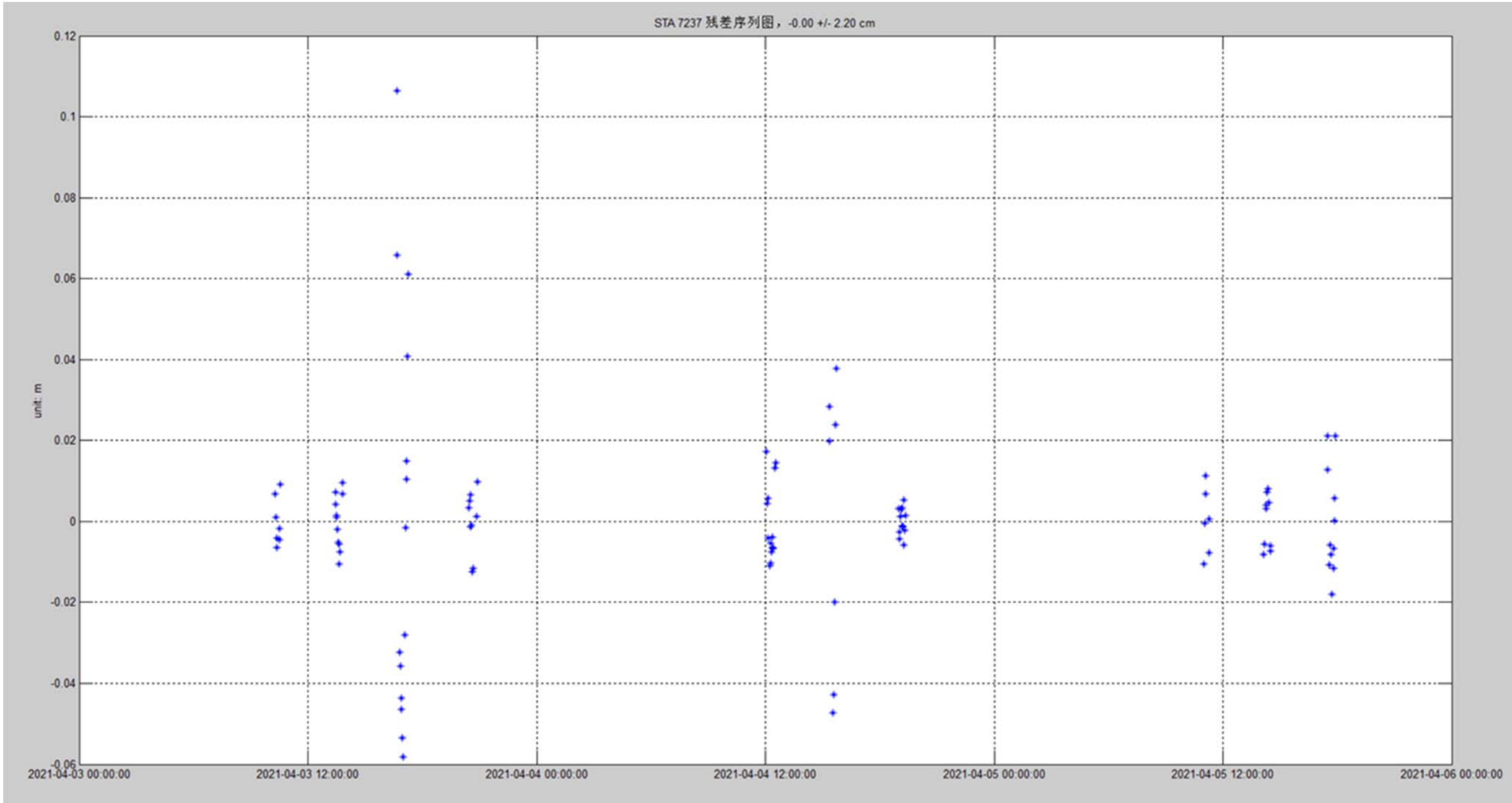


The effect of time bias: $\rho(t) = \rho(t_0) + \mathrm{b0} + \dot{\rho} \cdot \mathrm{d}t$

10 microseconds ~ 1 cm

2021	4	3	10	17	54.94953	7603901	7237	-0.0235	33.9876
2021	4	3	13	25	55.27104	7603901	7237	0.0754	16.4221
2021	4	3	16	39	5.69321	7603901	7237	0.2116	1.2073
2021	4	3	20	27	21.70750	7603901	7237	0.0745	14.0224
2021	4	4	12	3	10.72719	7603901	7237	0.0597	6.9381
2021	4	4	15	21	42.51317	7603901	7237	0.2496	-48.8590
2021	4	4	18	59	3.64149	7603901	7237	0.0470	5.2183
2021	4	5	11	0	56.21447	7603901	7237	-0.0393	-27.0073
2021	4	5	14	9	4.50855	7603901	7237	-0.0700	8.1474
2021	4	5	17	29	6.22262	7603901	7237	0.0815	-1.1363

time bias: microsecond magnitude



STA 7237 残差序列图，-0.00 +/- 2.20 cm
unit: m
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
2021-04-03 00:00:00
2021-04-03 12:00:00
2021-04-04 00:00:00
2021-04-04 12:00:00
2021-04-05 00:00:00
2021-04-05 12:00:00
2021-04-06 00:00:00

For Kunming(7819), there is no correlation between residuals and the time bias.

Summary:

- **The data quality of Chinese SLR stations in the first half of 2021 is analyzed, using the normal point data of Lageos1.**
- **Changchun(7237): may have a time bias of microsecond magnitude.**
- **Kunming(7819): may have a range bias of about 8 cm.**
- **Other Chinese SLR stations: range accuracy is about 1-2 cm. need to be improved further comparing with the best station of the world.**
- **To be continued: the data of L2，E1，E2, and of the second half of 2021**

A novel picosecond-precision timing device for SLR by integrating with high-repetition-rate range gating

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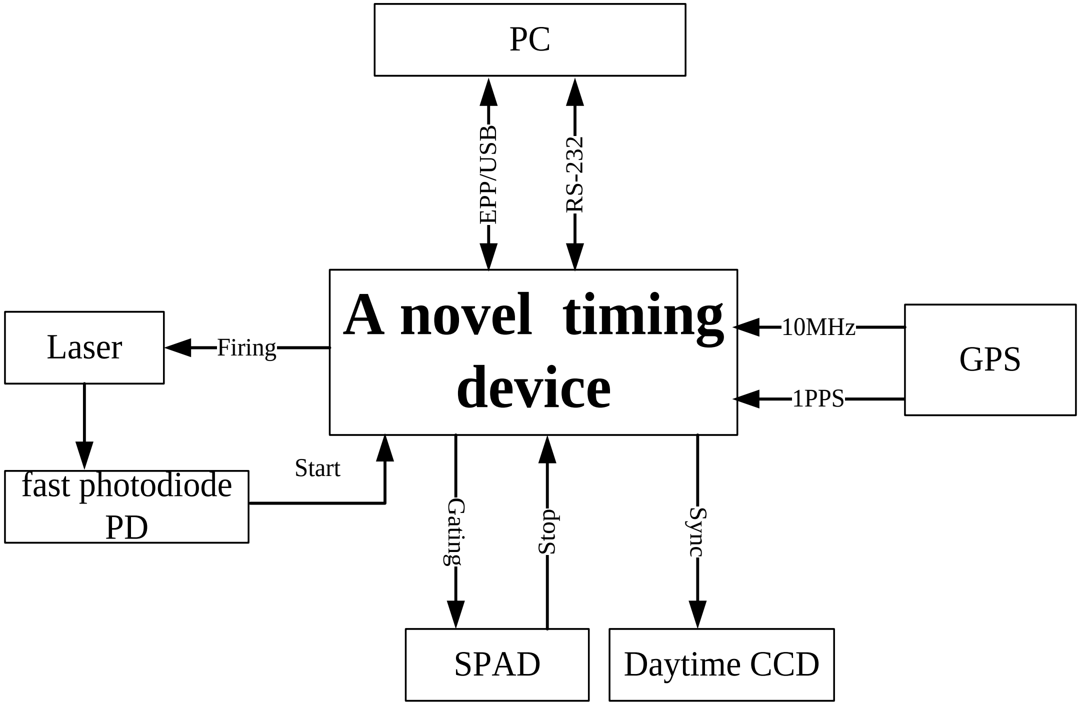
Outline

1. Introduction
2. Event timing design
3. Range gating design
4. Device application
5. Summary

1、 Introduction

- Timing and Range Gating are the keys of SLR measurement and control system, especially for SLR with high repetition rate.
- Due to including too many devices, such as interval time counter (for example SR620), constant fraction discriminator (TC454) and level conversion circuit, traditional timing system perform insufficiently.
- Traditional range gating generator is usually made up of separated components, and has insufficient programming ability and strong SW dependence, which is unsuitable for SLR with high repetition rate.
- A novel event timing device developed by SHAO will be showed in this PPT , which can meet the requirements of high-repetition-rate SLR with millimeter precision by integrating with range gating function,

1、 Introduction



- **The novel device can precisely measure the distance between ground station and satellite by collecting Start and Stop epochs, also provide control signals for laser, daytime CCD and detector simultaneously.**

1、 Introduction

Performance

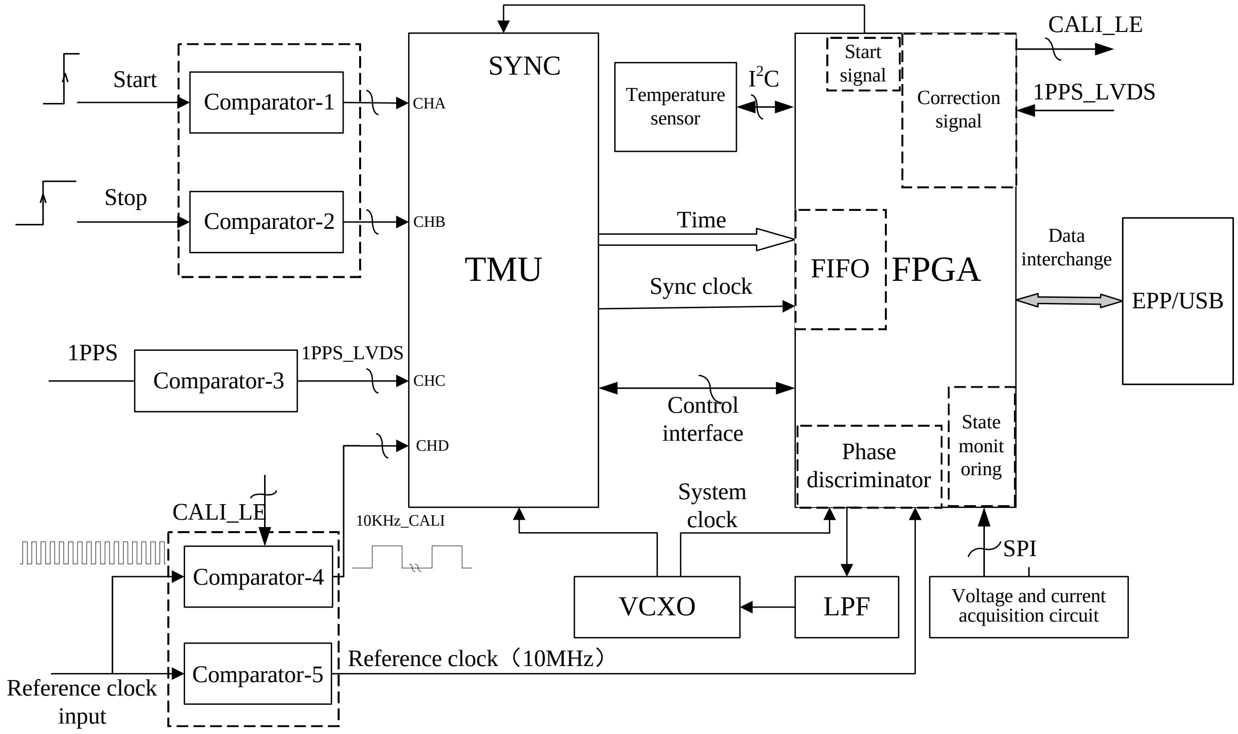
1. **Event timer:** ~8ps (precision), double channels, ＞10kHz (rate)，EPP (interface);
2. **Range Gating Generator:** 5ns (resolution), ＞ 10kHz (rate), RS-232(interface);
3. **CCD Sync Signal:** 5ns (resolution), ＞ 10kHz (rate);
4. **Laser Sync Signal:** 5ns (resolution), ＞ 10kHz (rate), programmable delay;
5. **Input Signal:** 10MHz(sine or square), 1PPS;
6. **Trigger signal for RGG:** main pulse (laser triggered internally)or fire signal (laser triggered by fire signal);
7. **Level Conversion Circuit:** TTL to NIM (double channel);

Outline

2、 Event timing design

- ➢ **Function：**
- ✓ **precisely timing Start epoch from PD and Stop epoch from SPAD with precision of less than 10ps.**
- ➢ **Specification：**
- ✓ **level conversion (transfer TTL to NIM): in order to meet the NIM level requirements of the TDC chip.**
- ✓ **The trigger level is adjustable : to suit different level of Start and Stop signals, and adjusting knobs are mounted on the front panel.**
- ✓ **Self-check: Start and Stop signals be monitored by indicators on the front panel or Oscilloscope.**

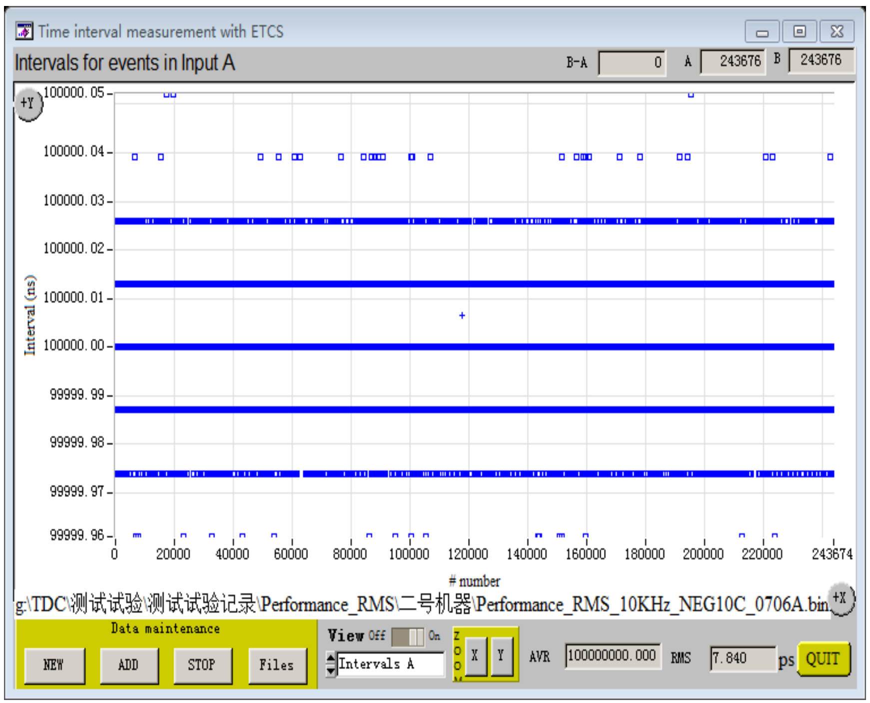
2、 Event timing design

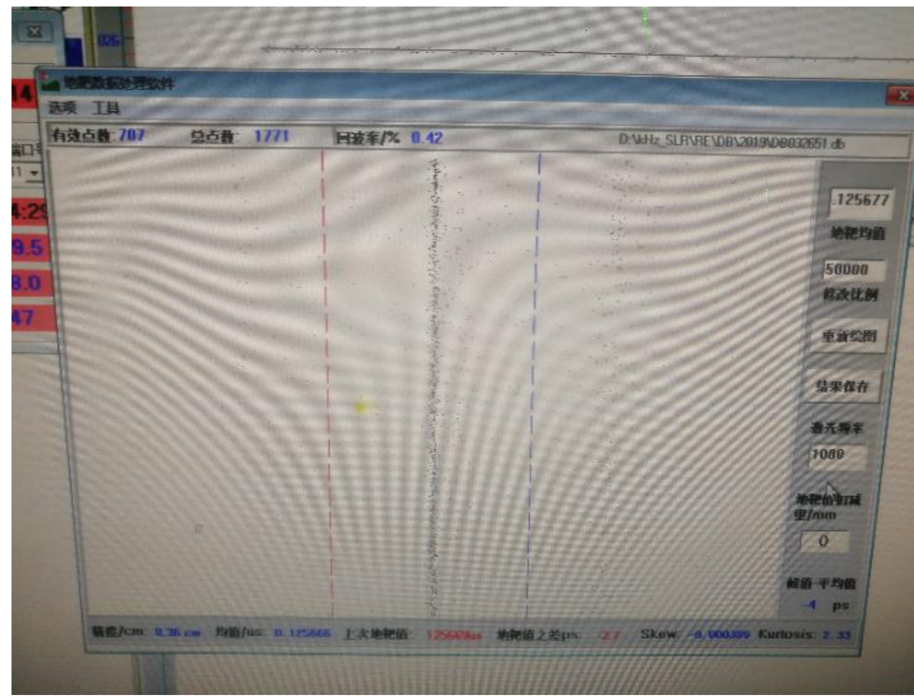


- **Based on FPGA + TDC （THS788)+ Comparators（low jitter)**
- **Using a Crystal Oscillator as system clock which sync to external clock（10Mhz)**

Shanghai Astronomical Observatory
Chinese Academy of Sciences

2、 Event timing design





RMS：～8ps

Calibration precision：4-5mm

Outline

1. Introduction
2. Event timing design
3. Range gating design
4. Device application
5. Summary

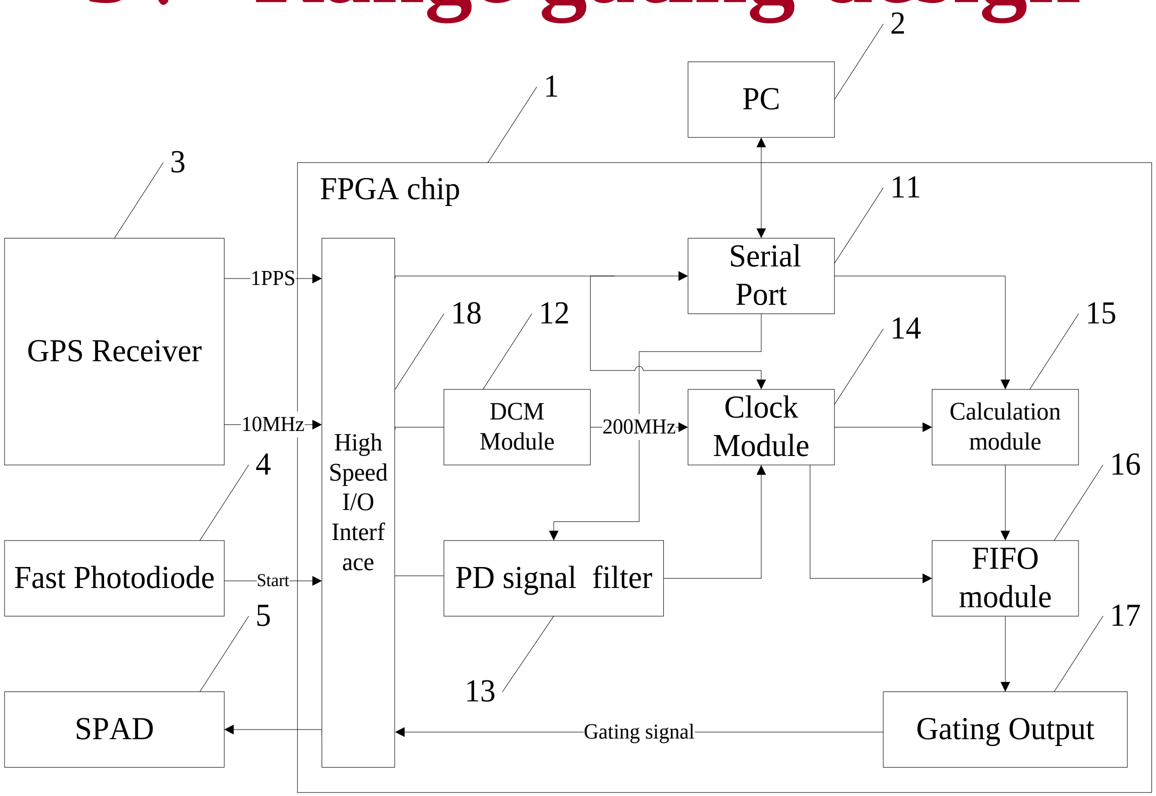
3、 Range gating design

- Function：
- ✓ **enable key devices** such as laser, detector and daytime CCD in expected time sequence.

Specification:

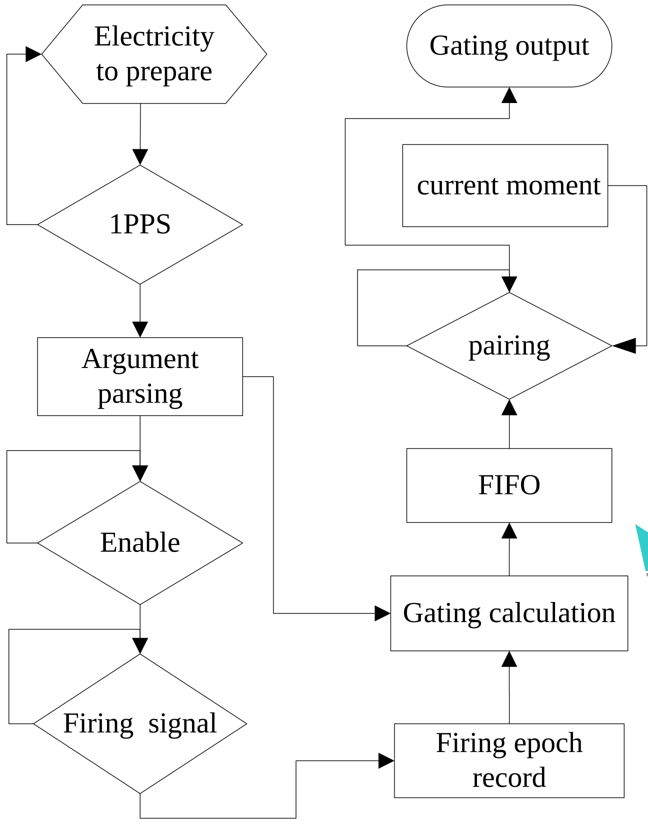
- ✓ **Real time and high repetition rate:** Automatedly generated controlling signal based on parameters per second received via RS232.
- ✓ **Different trigger modes** were developed for inner-triggering or external-triggering lasers.
- **Auto backscatter avoidance:** according to the interval between gating and firing signal, the firing signal is automatically delayed for；
- **Self-check:** all the signal including output or input signals can be monitored by indicators on the front panel or Oscilloscope.

3、 Range gating design



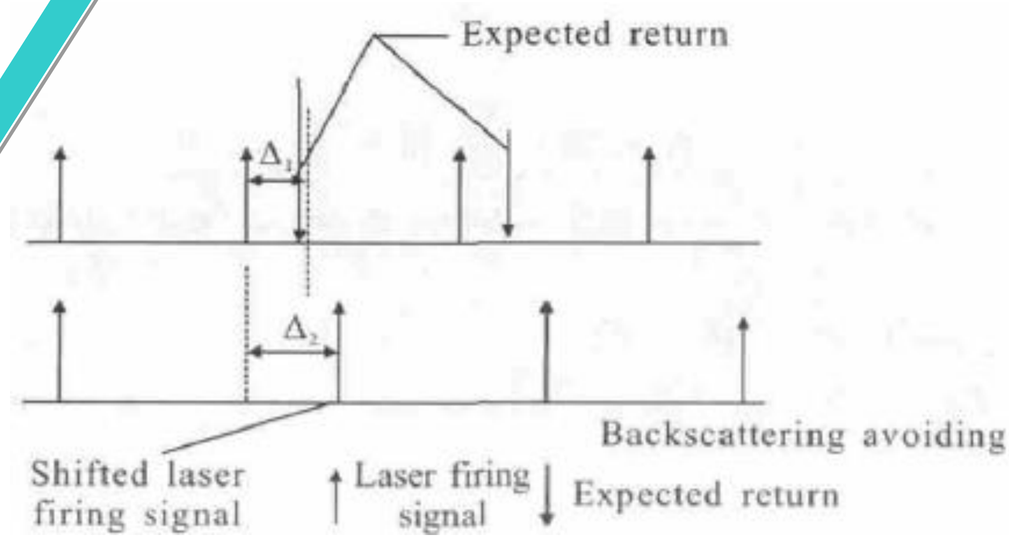
- One chip of FPGA（XC2S300）+ IO circuit.
- Real time calculating range gating epoch based on input interpolation parameters and triggering epoch.

3、 Range gating design



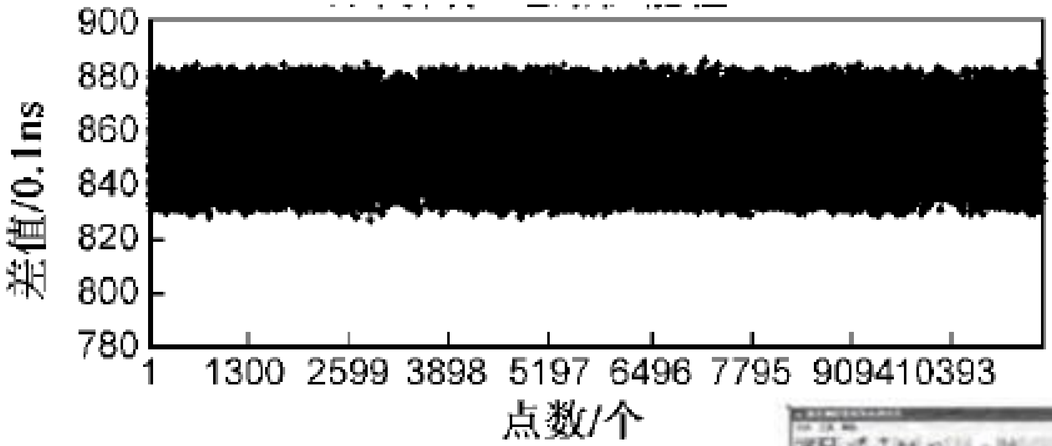
Range gating generation process

$$a_t = dt + a_0 + a_1 \cdot dt + a_2 \cdot (dt)^2 + a_3 \cdot (dt)^3$$



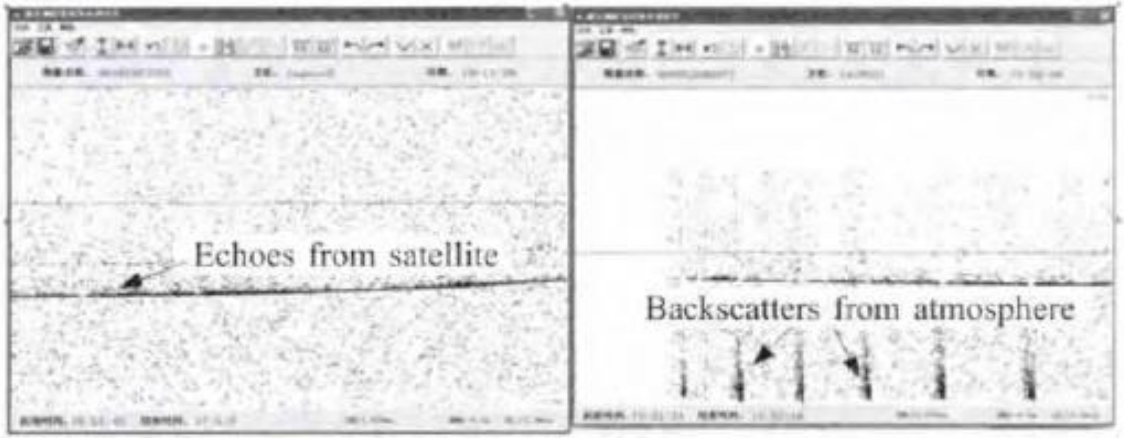
Automatic backscatter avoidance flow

3、 Range gating design



resolution： 5ns

Auto backscatter avoidance



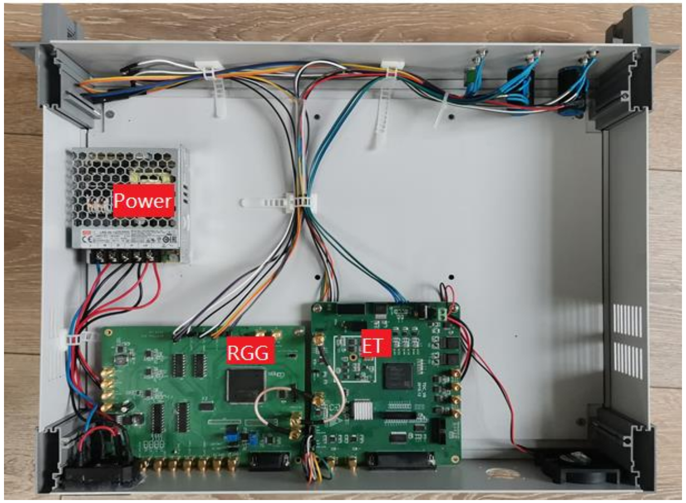
(a) 具有后向散射规避功能　(b) 没有后向散射规避功能

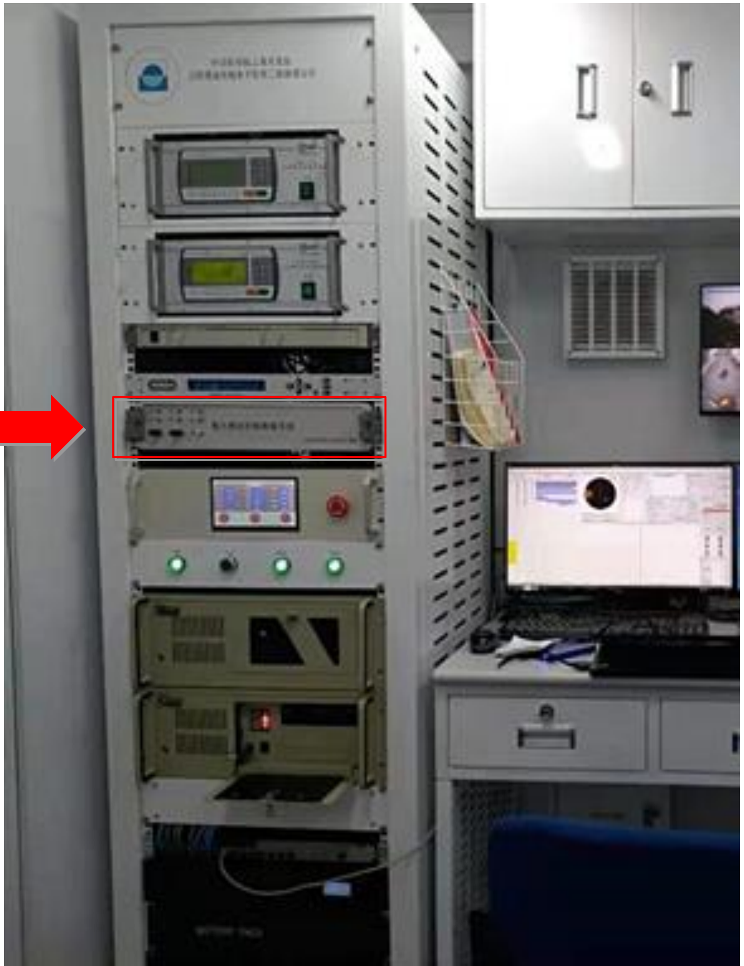
(a) With backscattering avoiding　(b) Without backscattering avoiding

Outline

1. Introduction
2. Event timing design
3. Range gating design
4. Device application
5. Summary

4、 Device application





- Standard 2U，compact installation
- Have been installed for serval SLR systems

4、 Device application

4、 Device application

# sat	site	date	time	dur	rb mm	error	tb us	error	prec	bad	total	rms	pres	temp	hum	sdelay	shft	rms	cfg	r	wlen
LAG1	7821	2018/08/07	10:41	36	-11	5	-1.5	2.2	3	0	11	8	995.4	303.2	66	13497	0	7	1	0	532
LAG2	7821	2018/08/07	12:05	29	-11	1	-0.2	1.3	0	0	12	8	996.4	302.1	71	13490	0	6	1	0	532
LAG1	7821	2018/08/07	14:21	37	-10	5	2.3	3.4	3	0	8	8	997.0	301.1	79	13480	0	6	1	0	532
LAG2	7821	2018/08/07	15:57	33	-2	5	-8.7	3.0	2	0	11	9	997.1	300.9	77	13350	0	10	1	0	532
LAG2	7821	2018/08/07	20:17	29	-14	2	-8.7	2.5	1	0	16	8	996.5	300.2	85	13457	0	4	1	0	532
LAG1	7821	2018/08/08	09:44	23	-12	7	5.6	4.6	2	0	11	9	995.7	304.3	63	13474	0	6	1	0	532
LAG1	7821	2018/08/08	13:07	30	-12	5	3.6	2.6	2	0	10	8	996.7	302.2	72	13356	0	9	1	0	532
LAG2	7821	2018/08/08	14:03	39	-9	2	-6.1	1.0	1	0	11	7	997.4	301.2	73	13457	0	4	1	0	532
LAG2	7821	2018/08/08	18:13	44	-12	5	-12.8	3.8	2	0	8	8	996.5	300.4	77	13455	0	4	1	0	532
LAG2	7821	2018/08/08	22:27	14	-10	11	-3.8	7.3	1	0	7	9	997.5	300.8	76	13491	0	6	1	0	532
LAG1	7821	2018/08/09	11:40	33	-8	5	-3.9	3.1	7	0	7	8	995.7	302.7	64	13463	0	7	1	0	532
LAG2	7821	2018/08/09	12:17	27	0	2	-5.6	2.0	1	0	12	8	996.1	302.3	65	13460	0	6	1	0	532
LAG1	7821	2018/08/09	15:13	8	-11	8	--------.-	----.-	5	0	3	9	996.5	301.1	74	13461	0	5	1	0	532
LAG2	7821	2018/08/09	16:11	14	-14	6	-12.9	4.4	1	0	7	9	996.2	300.9	73	13460	0	5	1	0	532
LAG2	7821	2018/08/09	20:27	31	-11	4	-9.7	3.9	1	0	8	8	995.2	300.2	78	13461	0	6	1	0	532
LAG1	7821	2018/08/10	03:55	4	-19	1	--------.-	----.-	0	0	4	8	995.0	309.8	43	13522	0	5	1	0	532
LAG2	7821	2018/08/10	14:46	6	13	2	--------.-	----.-	0	0	4	7	994.1	302.0	76	13449	0	6	1	0	532
LAG2	7821	2018/08/13	12:47	19	-16	7	5.1	7.0	2	0	9	9	994.0	301.4	77	13457	0	6	1	0	532
LAG1	7821	2018/08/13	13:15	18	-17	6	-2.9	4.9	2	0	7	9	994.2	301.4	78	13458	0	6	1	0	532
LAG1	7821	2018/08/15	10:37	19	-25	5	-7.8	4.1	2	0	7	9	992.6	302.2	66	13468	0	6	1	0	532
LAG1	7821	2018/08/15	14:15	8	2	6	17.6	14.3	2	0	6	9	993.3	300.8	74	13434	0	6	1	0	532

- **The novel timing device have been used our routine SLR with 2kHz repetition rate and the system range bias were stable** （[v2] Multi-satellite bias analysis v2 (hit-u.ac.jp)）
- **Calibration precision was about 5-6mm, which met the requirements of current high-repetition-rate and high-precision SLR.**

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5、 Summary

- A novel picosecond-precision timing device by integrating with RGG was developed by SHAO;
- The device can flexibly control laser, detector and daytime CCD at the same time, and precisely timing Start and Stop epochs.
- The timing precision was 8ps, and calibration RMS for SLR was 5-6mm；
- RGG signal has a 5ns resolution and working frequency of over 10kHz, with two trigger modes for different laser and auto backscattering avoidance.
- The device mounted in a 2U case has been installed for serval SLR systems and met the requirements of mm-precision SLR with high repetition rate.

Thanks for your attention !!

NESC - ILRS

Update on the travelling meteo device campaign

November 2021

C. Courde – N. Raymond

Travelling meteo device campaign

What is needed ?

1) Installing the travelling met device near the local met device(s) :

Inside/outside : How will the travelling met device be installed?
Is it necessary to send the tripod and a waterproof box?

How can you power the device?
Is an electrical connection possible everywhere?

How to download the data?
Ethernet ? USB thumbrive? SD card ?

2) Installing the travelling met device near the cross axes of the telescope
Same questions: mechanical installation and power ?

3) Are the station able to record in parallel the data from theirs met device whether or not the station is observing?

4) Where to store the data? EDC-CDDIS ?

Our solution

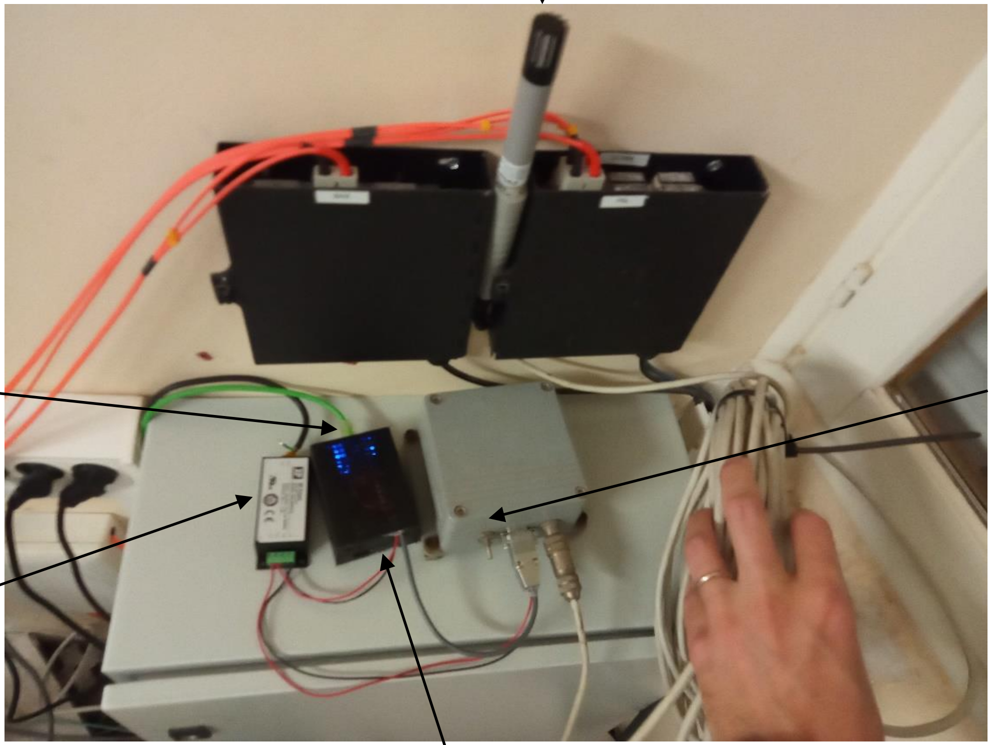
- Unpack shipping crate
- Install enclosure outside
- Plug RJ45 inside the enclosure
- Plug AC inside the enclosure
- Leave it be for a week
- Unload data with SFTP (FileZilia, …)

Inside the box

Temperature, humidity sensors

Ethernet connection

Barometer input



100-240V AC
=> 12 V
converter

Vaisala

BeagleBone, 12-5V
converter, DPS310

The enclosure

11,5 kg to
13 kg empty

Picture does not represent the actual enclosure

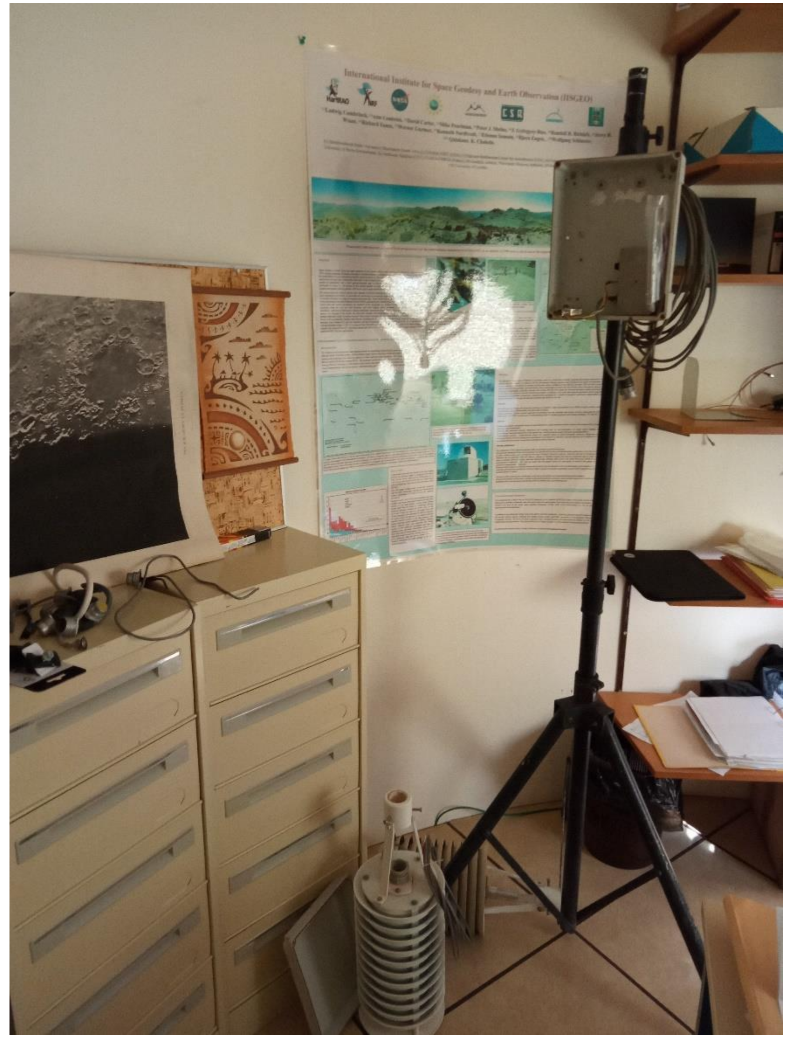
Picture does not represent the actual enclosure

What we'd like you to supply

- 100 to 240V AC on a IE C13 plug
- RJ45 ethernet (not POE)
- DHCP server ?
- NTP server (with pre-defined address)
- Enclosure mounting solution ?

Tripod

80 cm



2 m

Preliminary parts list (W links)

- AC/DC power supply (-40 80°C)
- 12 to 5V converter (-40 +80°C)
- beaglebone black industrial (-40 +80°C)
- TBD : panel mount RJ45 ethernet
- pannel mount locking IE C14 AC socket
- (supply your own IE C13 plug)
- Vaisala PTU200
- DPS310 in a syringe with tube