



精勤司天
诚信修文

Shanghai Astronomical Observatory
Chinese Academy of Sciences



Overview of SLR missions at Shanghai Observatory and Laser Ranging

Haifeng Zhang, **Zhi'en Cheng**, Zhongping Zhang, Xuhua Zhou

Shanghai Astronomical Observatory, Chinese Academy of Sciences, Shanghai, China.

cze@shao.ac.cn

2023 Virtual International Workshop on Laser Ranging , 16-20 October 2023



Outline



- 1. Satellite missions for SLR at Shanghai Observatory**
- 2. Beidou satellites laser ranging and applications**
- 3. HY satellites laser ranging and applications**
- 4. Future SLR missions**

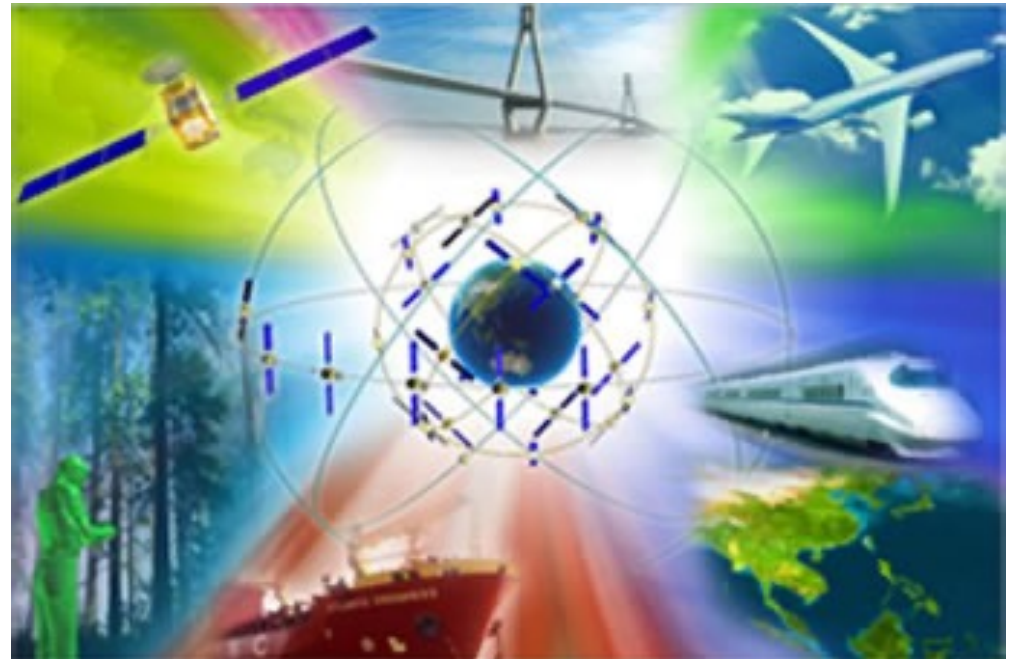


1. Satellite missions for SLR at Shanghai Observatory



(1) Beidou satellite constellation

- The China's Beidou Navigation Satellite System (BDS) is one of Global Navigation Satellite Systems (GNSS), which consists of three kinds of satellite orbits, GEO, IGSO and MEO, with wide positioning applications. The orbital altitudes for GEO and IGSO are 36,000 km, and 21,500 km for MEO.
- For improving the accuracy of satellites orbit determination to calibrate the microwave measuring techniques and provide better navigation service, Satellite Laser Ranging (SLR) technique is applied to the Beidou satellites.



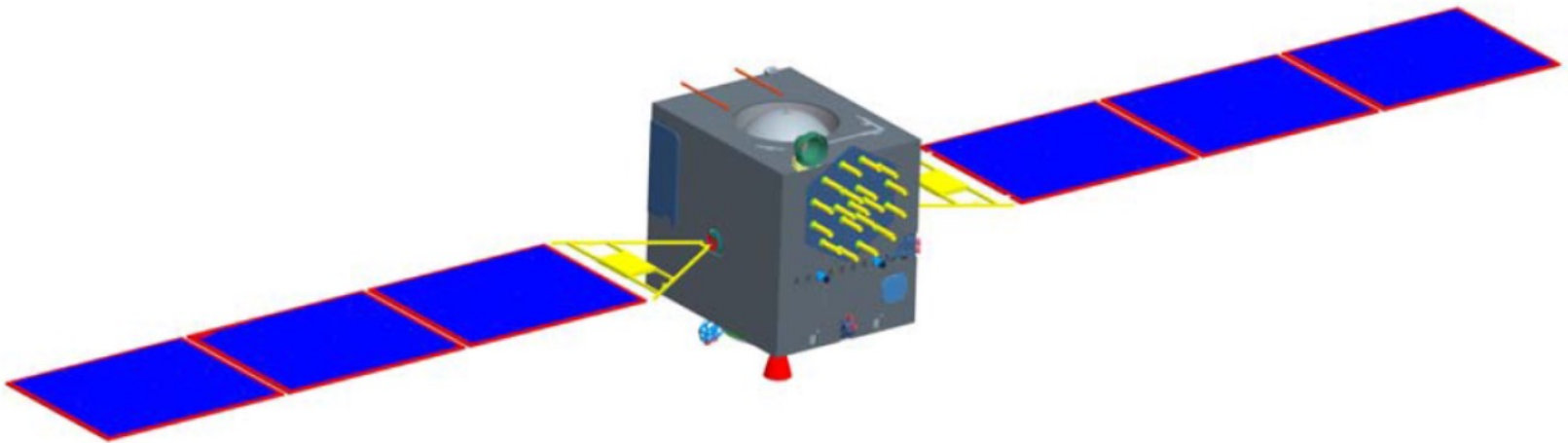


1. Satellite missions for SLR at Shanghai Observatory



Compass-m1 satellite

- **Compas-M1** is the first satellite launched on April 14, 2007 for the Beidou Navigation system.
- This satellite carried a set of laser retro-reflector array (LRA) with 42 cube corners for SLR.
- The satellite was added into the priority list of ILRS in Nov. 2008 and was tracked by ILRS stations since Dec.2008.



COMPASS-M1 Navigation Satellite



1. Satellite missions for SLR at Shanghai Observatory

- Now there are 27 Beidou satellites are being tracked by ILRS stations.
- 23 MEO satellites, 3 IGSO satellites and 1 GEO satellite.

BeiDou-3M1	1706901	2013	43001	9	300	21,500	55	773	2018-03-24
BeiDou-3M2	1706902	2014	43002	9	300	21,500	55	773	2018-08-04
BeiDou-3M3	1801802	2015	43208	9	300	21,500	55	773	2018-08-10
BeiDou-3M4	1801801	2016	43207	9	300	21,500	55	773	
BeiDou-3M5	1806201	2017	43581	9	300	21,500	55	773	
BeiDou-3M6	1806202	2018	43582	9	300	21,500	55	773	
BeiDou-3M9	1802901	2019	43245	9	300	21,500	55	773	2018-08-04
BeiDou-3M10	1802902	2020	43246	9	300	21,500	55	773	2018-08-03
BeiDou-3M11	1806702	2023	43603	9	300	21,500	55	773	
BeiDou-3M12	1806701	2024	43602	9	300	21,500	55	773	
BeiDou-3M13	1807201	2025	43622	9	300	21,500	55	773	
BeiDou-3M14	1807202	2026	43623	9	300	21,500	55	773	
BeiDou-3M15	1807802	2027	43648	9	300	21,500	55	773	
BeiDou-3M16	1807801	2028	43647	9	300	21,500	55	773	
BeiDou-3M17	1809301	2029	43706	9	300	21,500	55	773	
BeiDou-3M18	1809302	2030	43707	9	300	21,500	55	773	
BeiDou-3M19	1909001	2031	44864	9	300	21,500	55	773	
BeiDou-3M20	1909002	2032	44865	9	300	21,500	55	773	
BeiDou-3M21	1907802	2033	44794	9	300	21,500	55	773	
BeiDou-3M22	1907801	2034	44793	9	300	21,500	55	773	
BeiDou-3M23	1906102	2035	44543	9	300	21,500	55	773	
BeiDou-3M24	1906101	2036	44542	9	300	21,500	55	773	
COMPASS-G8	1902701	2037	44231	9	300	35,769	1.59	1,436	2020-03-31
COMPASS-I3	1101301	2003	37384	9	300	35,786	55.5	773.39	2012-04-27
COMPASS-I5	1107301	2005	37948	9	300	35,786	55.5	773.39	2012-07-06
COMPASS-I6B	1602101	2012	41434	9	300	35,677	55.5	773.39	2016-03-29
COMPASS-M3	1201801	2004	38250	9	300	21,528	55.0	773.2	2012-07-11



1. Satellite missions for SLR at Shanghai Observatory



MEO LRA



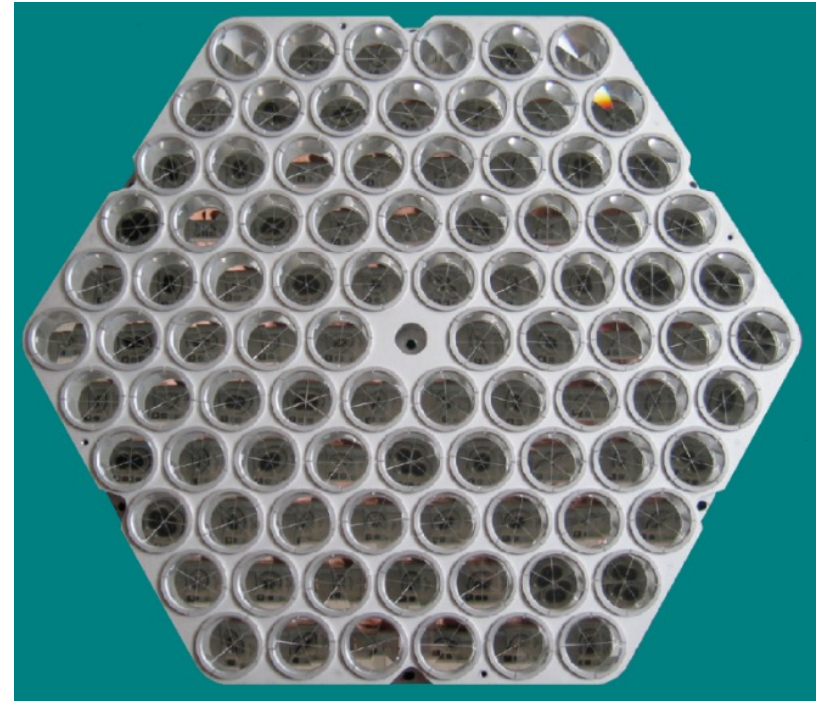
Size: $31.2 \times 28 \times 3$ cm

Weight: 2.4kg

CCR clear aperture: 33mm

CCR number: 42

GEO/IGSO LRA



Size: $48 \times 43 \times 3$ cm

Weight: 5kg

CCR clear aperture: 33mm

CCR number: 90



1. Satellite missions for SLR at Shanghai Observatory

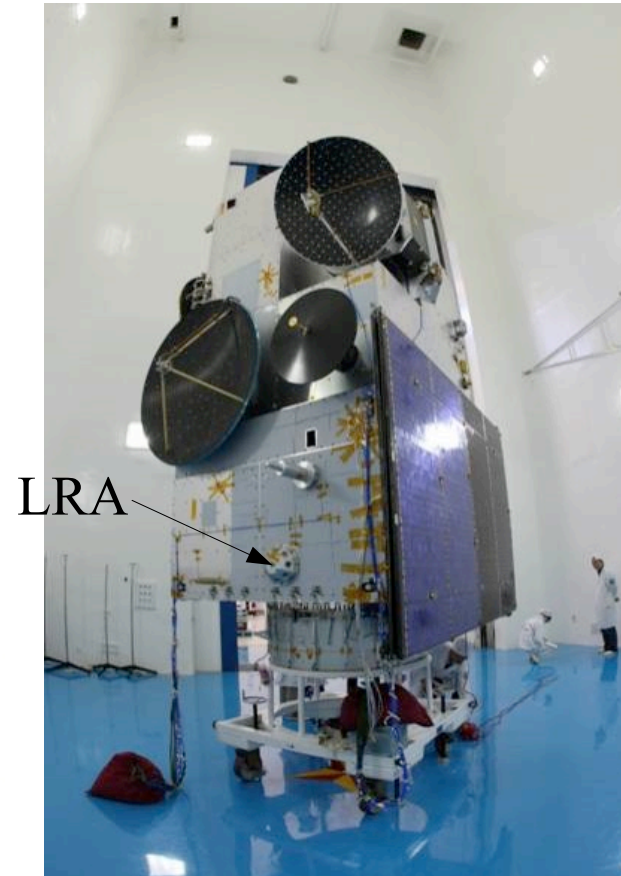
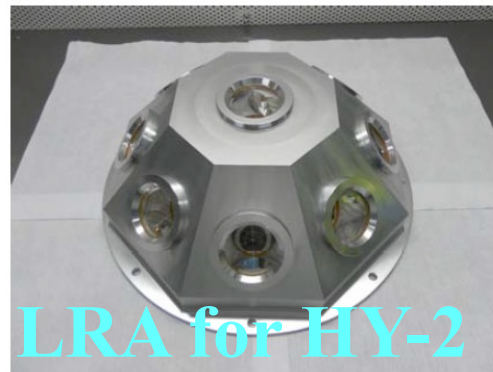


(2) HY-2 Satellite constellation

- The HY constellation is an oceanographic remote sensing satellite series hosted by China's National Satellite Ocean Application Service (NSOAS).
- HY-2 satellites which are an oceanographic remote sensing satellite series are focused on the marine dynamic environments.

- HY-2 satellites (including 4 satellites) have the following instrumentation:

- Micro-Wave Radiometer
- **GNSS receiver**
- **DORIS**
- **LRA**
- Ku-band Rotating Pencil-beam Scatterometer
- Ku- and C-band Pulsed-Limited Nadir Radar Altimeter





1. Satellite missions for SLR at Shanghai Observatory



(2) HY-2 Satellite constellation

- HY-2A is the first satellite launched in July 2011 for constructing HY-2 satellite constellation.
- Its objective is to monitor the dynamic ocean environment with microwave sensors to detect sea surface wind field, sea surface height and sea surface temperature.
- The precise orbit determination (POD) of the satellite is a key support for this objective and SLR technique is important method of POD.
- The satellite was added into the priority list of ILRS in Nov. 2011 and was tracked by ILRS stations since Nov. 2011.
- Now HY-2B, HY-2C, HY-2D is being tracked by ILRS stations.

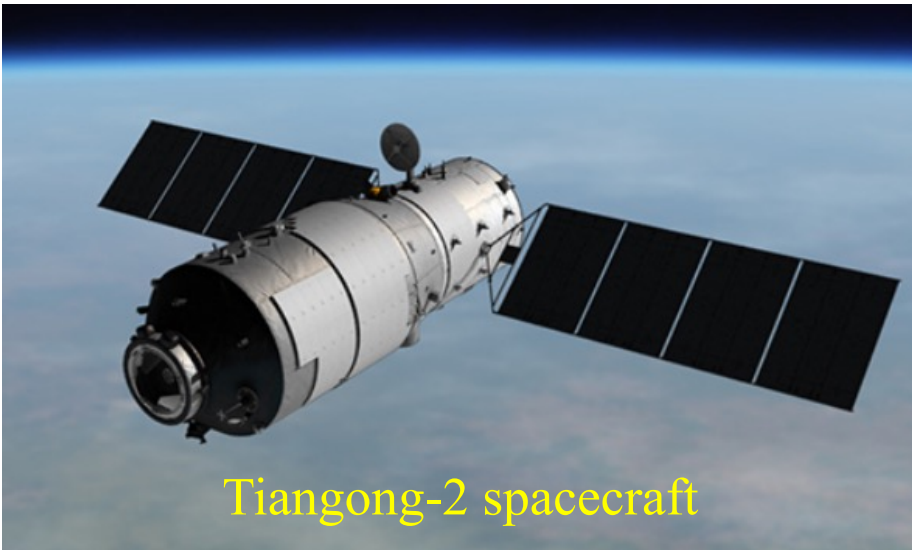


1. Satellite missions for SLR at Shanghai Observatory

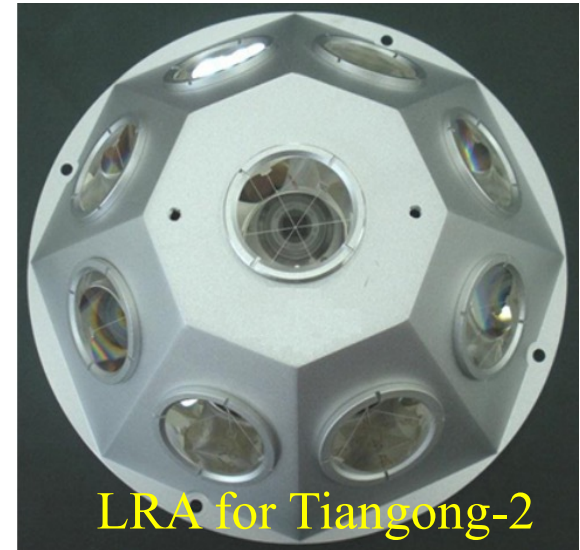


(3) Tiangong-2 mission

- Tiangong-2 (TG-2) is the second Chinese manned spacecraft with the payload of GPS receiver for POD.
- The SLR role of the mission is to validate the accuracy of the TG-2 precise orbits that are computed by GPS observations.



Tiangong-2 spacecraft



LRA for Tiangong-2



1. Satellite missions for SLR at Shanghai Observatory



(3) Tiangong-2 mission

- The SLR observations were from August 2018 to Jun. 2019.

Satellite	Site Name	Station	Start Date	End Date	No. Passes	No. Points
TIANGONG-2	Arequipa	7403	2018-08-10 06:55:44	2018-11-04 06:40:45	7	75
TIANGONG-2	Beijing	7249	2018-08-23 19:52:08	2018-11-02 12:44:33	29	328
TIANGONG-2	Changchun	7237	2018-08-09 02:12:08	2019-01-01 09:23:55	165	3,932
TIANGONG-2	Graz	7839	2018-08-13 06:03:16	2018-12-28 17:44:52	34	974
TIANGONG-2	Greenbelt	7105	2018-08-07 16:27:37	2018-12-20 05:33:31	113	3,484
TIANGONG-2	Haleakala	7119	2018-09-06 03:17:54	2018-10-11 19:56:28	8	165
TIANGONG-2	Hartebeesthoek	7501	2018-08-03 19:10:25	2018-10-10 20:08:38	9	172
TIANGONG-2	Katziwely	1893	2018-08-19 01:59:24	2018-12-27 15:36:01	9	146
TIANGONG-2	Kunming	7819	2018-08-13 21:16:00	2018-11-05 14:37:00	10	135
TIANGONG-2	Matera	7941	2018-08-14 09:59:21	2018-09-29 11:08:06	6	84
TIANGONG-2	Monument Peak	7110	2018-08-03 16:53:27	2019-01-03 01:22:19	94	1,956
TIANGONG-2	Mount Stromlo	7825	2018-09-19 15:00:00	2018-11-03 00:22:00	13	157
TIANGONG-2	Shanghai	7821	2018-08-29 18:54:44	2018-10-31 14:44:54	11	182
TIANGONG-2	Simeiz	1873	2018-09-09 17:37:14	2018-11-04 16:57:09	6	58
TIANGONG-2	Tahiti	7124	2018-09-12 20:27:35	2018-10-19 18:45:47	7	81
TIANGONG-2	Wettzell	8834	2018-10-30 18:35:22	2018-10-30 18:35:22	1	5
TIANGONG-2	Yarragadee	7090	2018-08-01 21:26:09	2019-01-02 16:40:33	312	4,478

- The succession of Tiangong-2 is the Chinese Space Station. However, it has no plan of SLR tracking campaign because of resident astronauts in space.



Outline



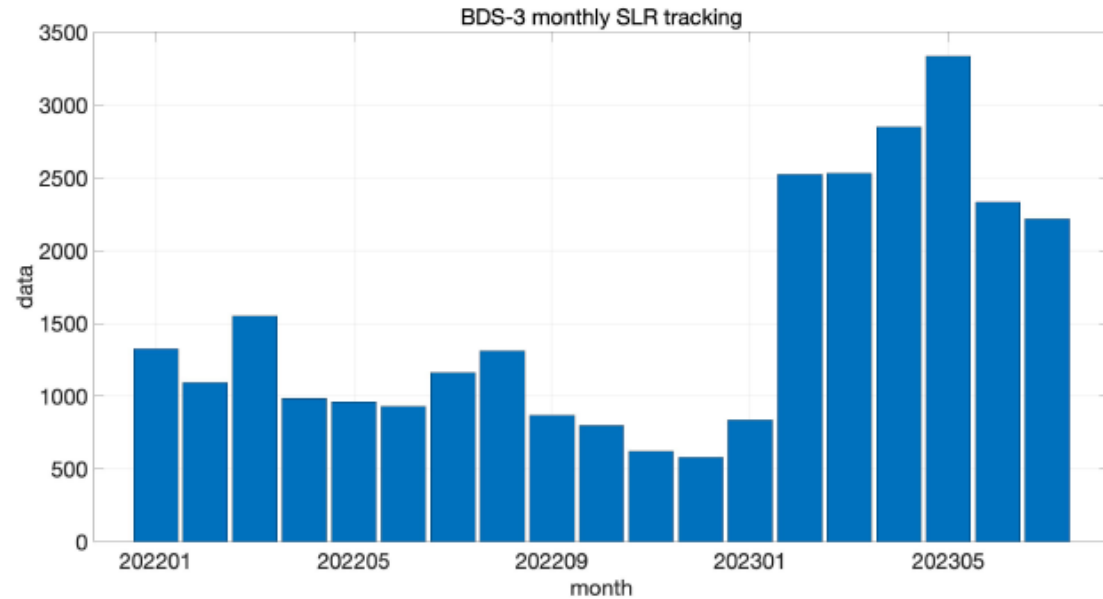
- 1. Satellite missions for SLR at Shanghai Observatory**
- 2. Beidou satellites laser ranging and applications**
- 3. HY satellites laser ranging and applications**
- 4. Future SLR missions**



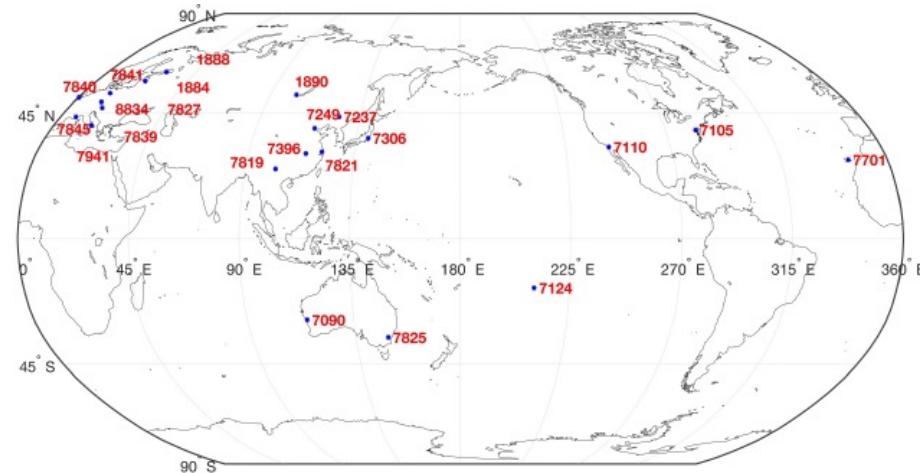
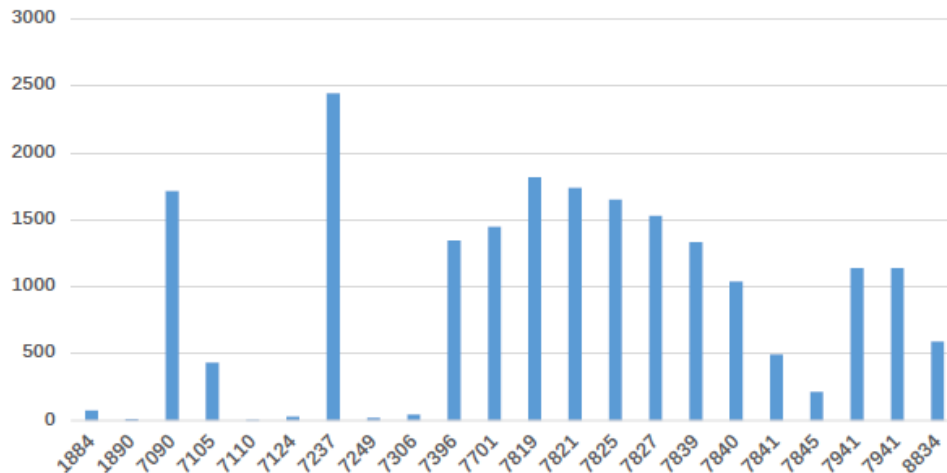
2. Beidou satellites laser ranging and applications

(1) SLR observations

- Due to a mass of Beidou3 MEO satellites, the SLR observations has been increased significantly from Feb. 2023.

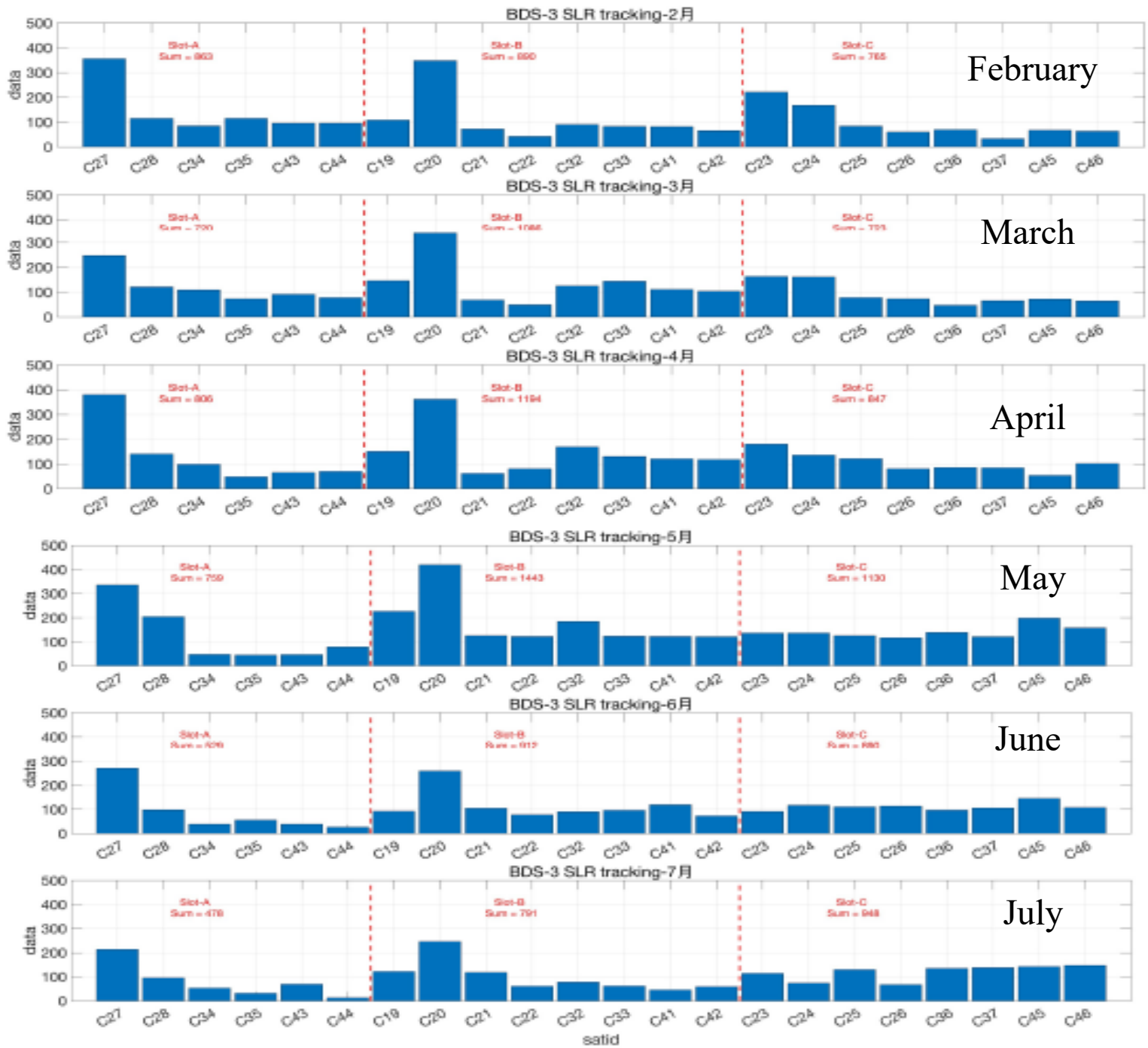


SLR Tracking Station Data Volume 2023.01-08





SLR Obs.
data from
Feb. to
July of
2023



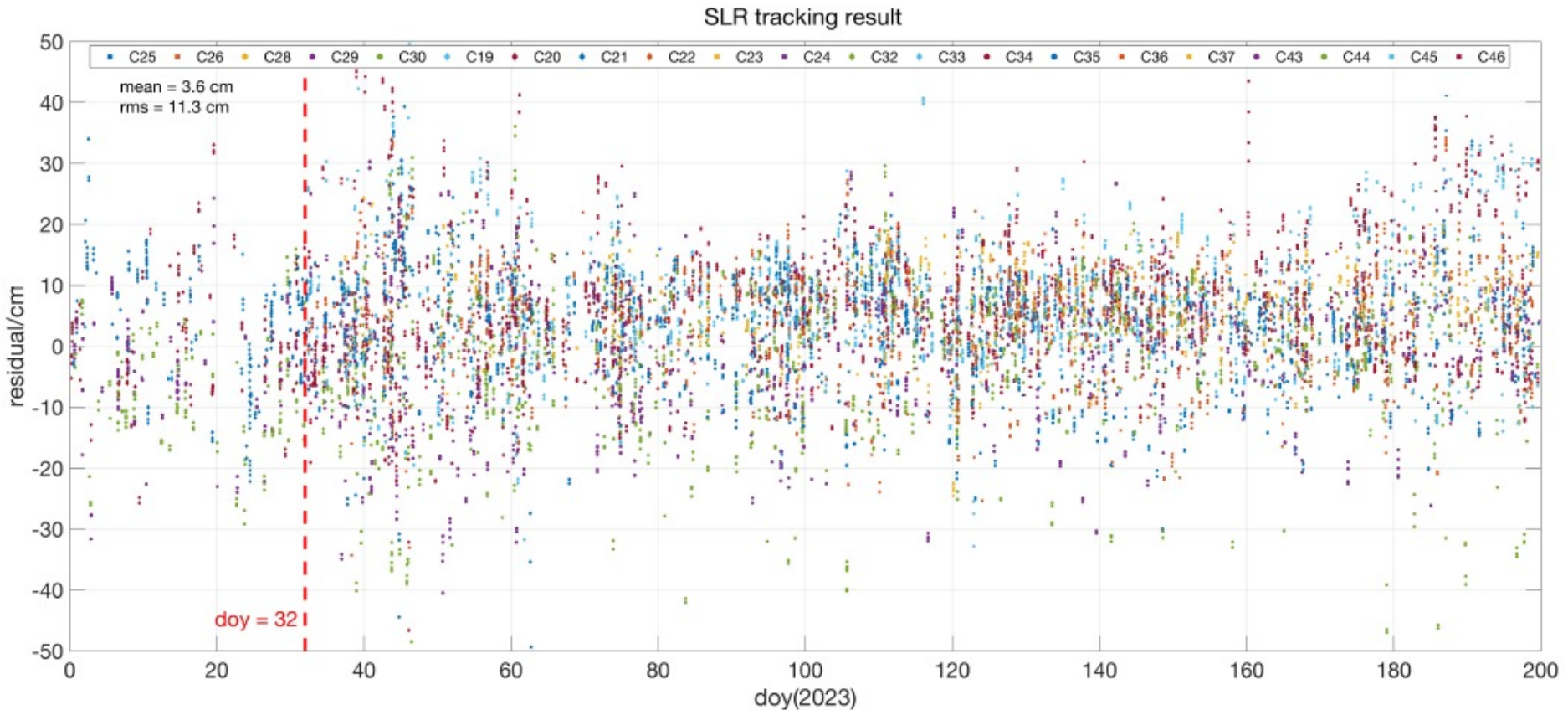


2. Beidou satellites laser ranging and applications



(2) Applications of SLR observations

- The evaluation of broadcasting ephemeris from Beidou satellites by using SLR observation data.
- The mean errors of is about 3.6cm and 11.3cm for rms.



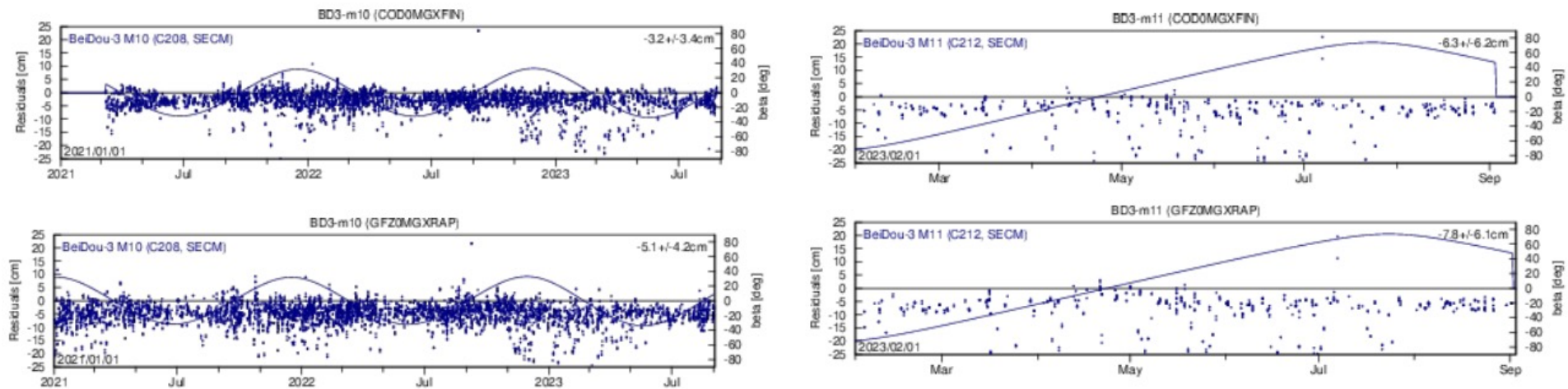


2. Beidou satellites laser ranging and applications



(2) Applications of SLR observations

- Evaluation of POD of Beidou satellites
 - Combined precise orbit determination was carried out on normal equation level and the ratio between GNSS and SLR data was 1:1.
 - Data process was carried out using 114 MGEX stations and 26 SLR stations for Beidou C08, C10 and C11 satellites. The results show that combined SLR data can improve the radial precision of BDS satellites.





Outline



- 1. Satellite missions for SLR at Shanghai Observatory**
- 2. Beidou satellites laser ranging and applications**
- 3. HY-2 satellites laser ranging and applications**
- 4. Future SLR missions**



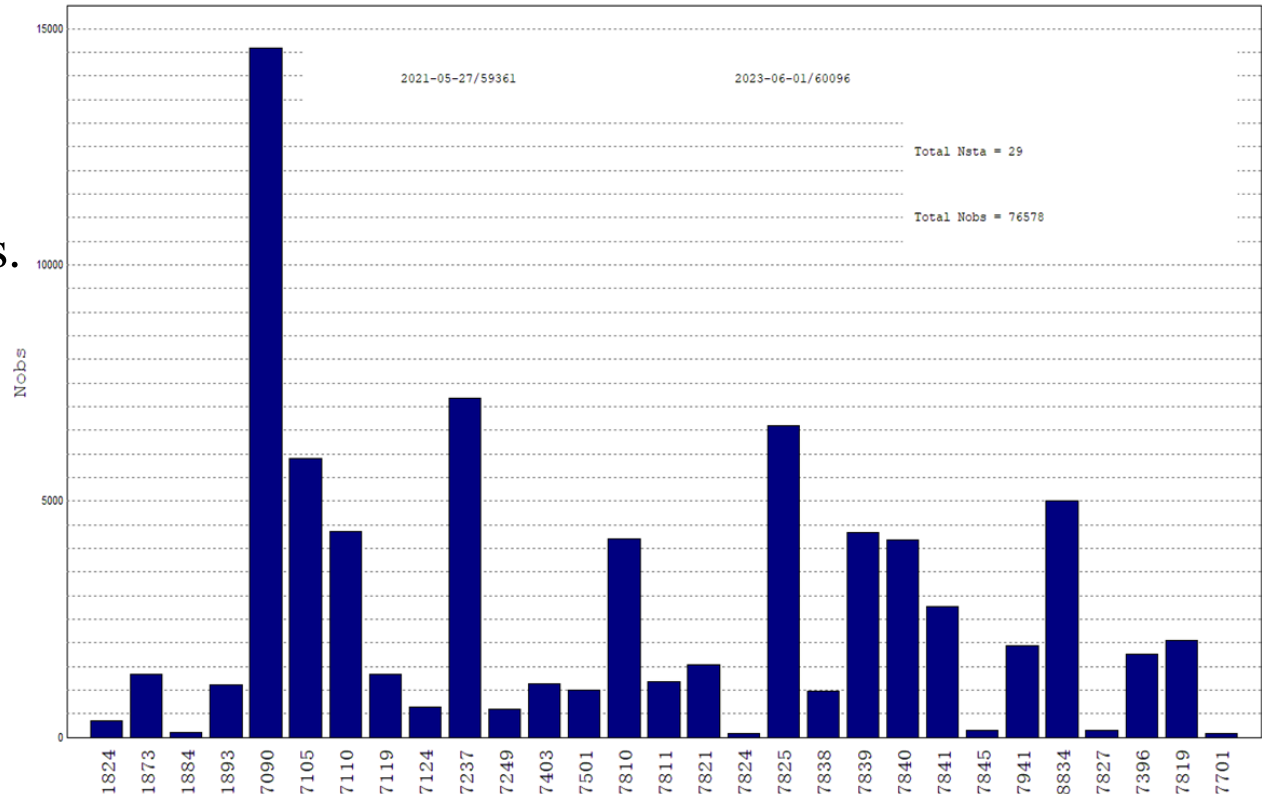
3. HY-2 satellites laser ranging and applications

(1) HY-2 satellites and Observations

- Currently there are three HY-2 satellites for SLR campaign attached the following table.

HY-2B	1808101	2208	43655	5	30	971	99.35	104.45	2018-11-01
HY-2C	2006601	2209	46469	5	30	957	66	104.45	2020-10-08
HY-2D	2104301	2211	48621	5	30	971	66	104.1	2021-05-30

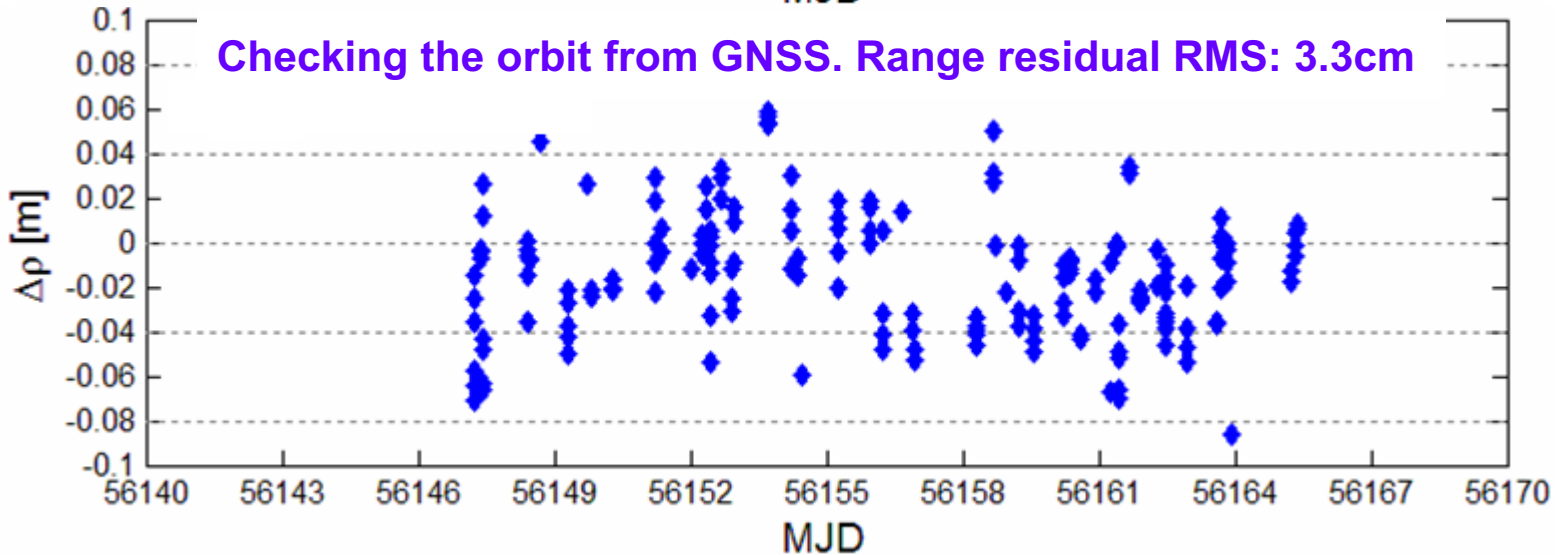
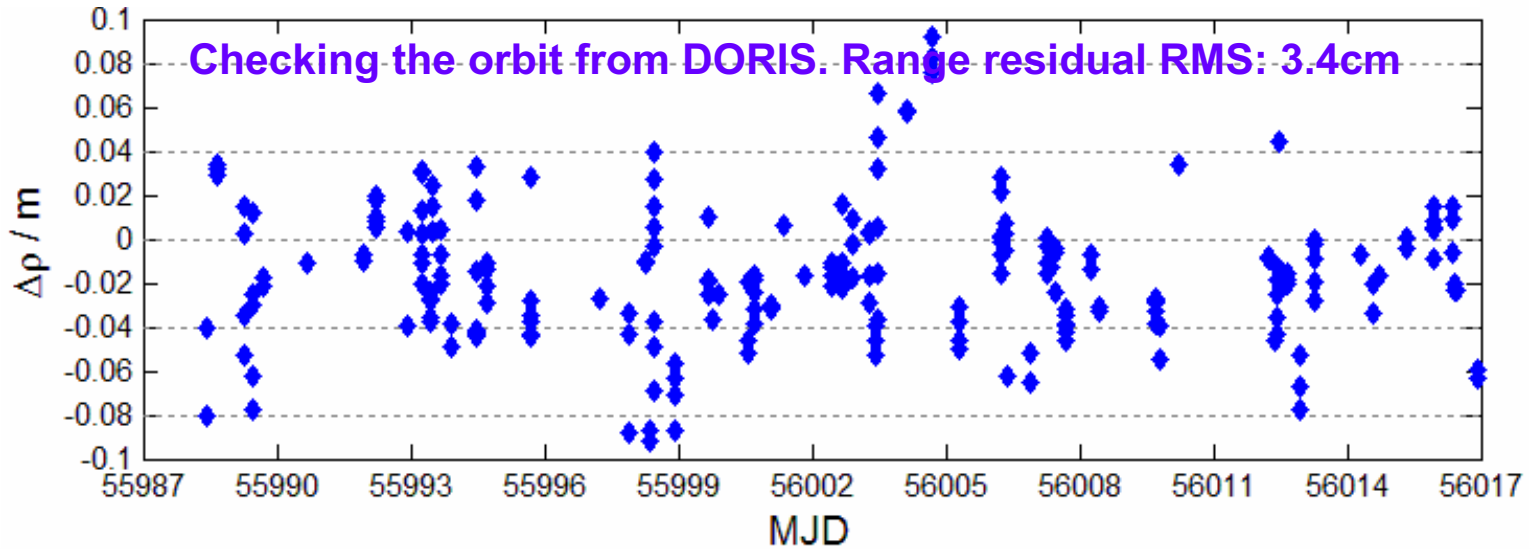
- 29 SLR stations for tracking HY-2 satellites.
- The total npts are more than 76,000 up to July 2023.





3. HY-2 satellites laser ranging and applications

(2) Applications of SLR observations to HY-2a

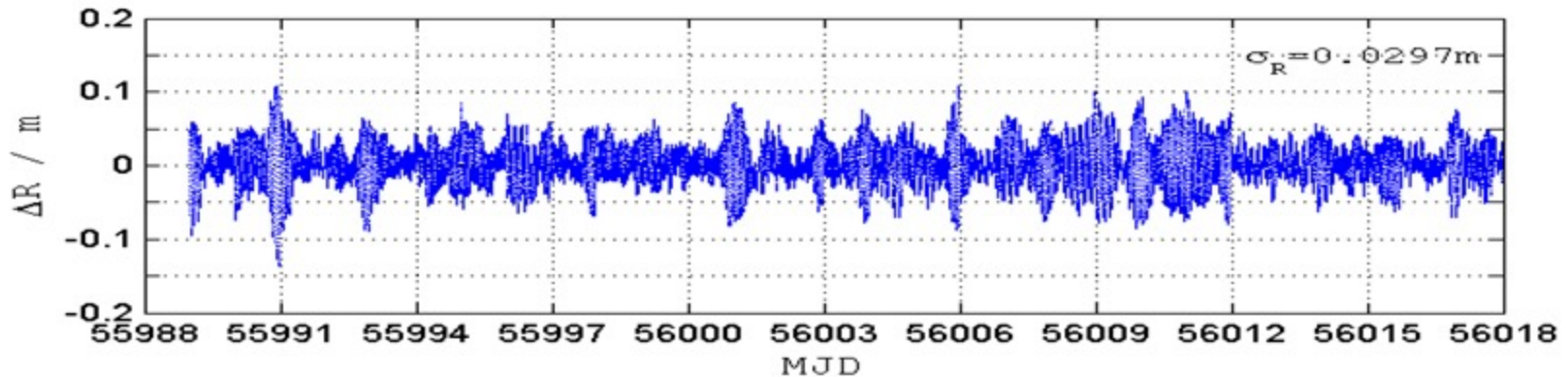
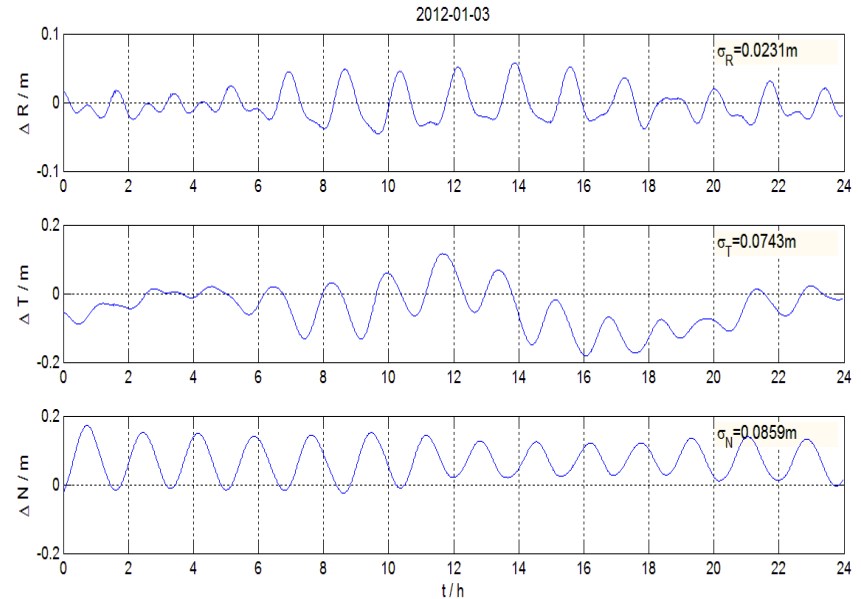
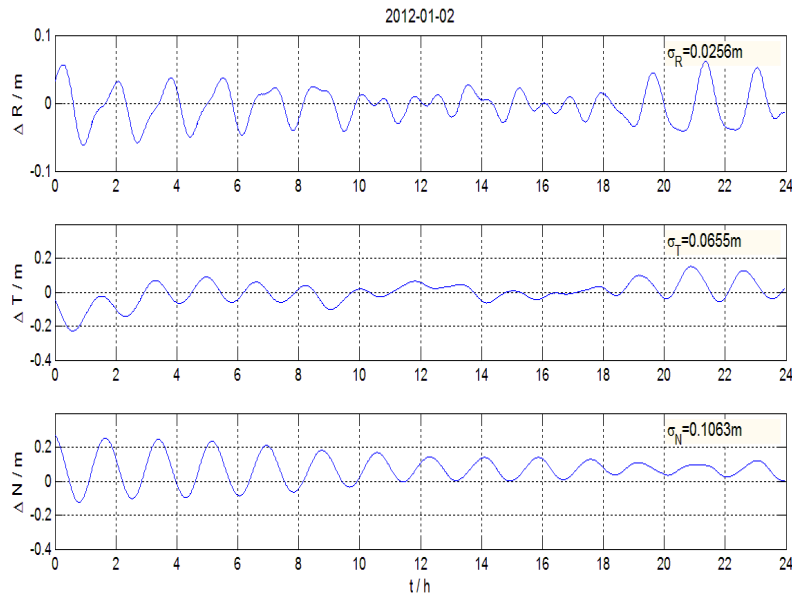




Orbit determination by global SLR data



(Comparison of orbit from SLR and DORIS)



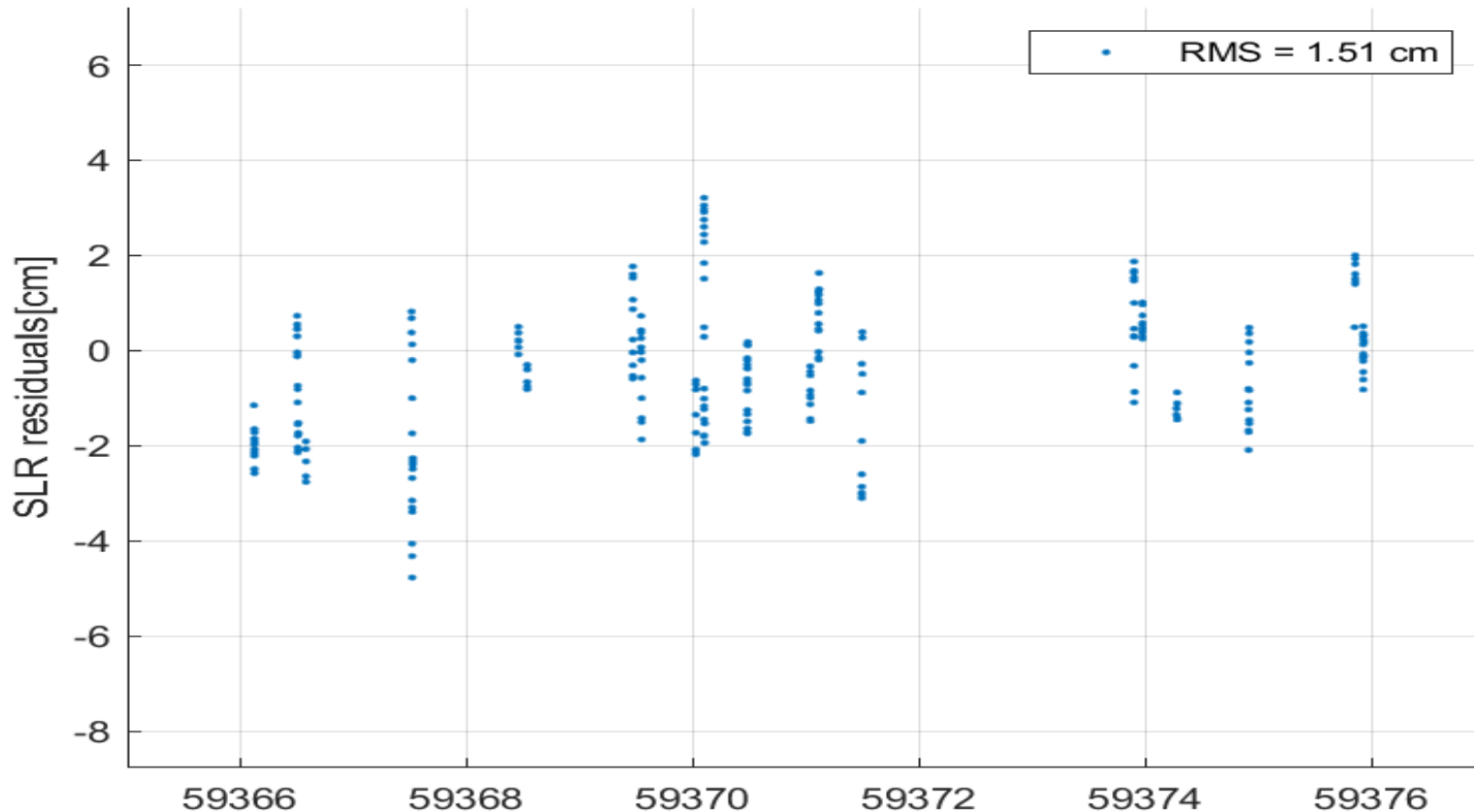
Orbit of 3D error :10cm; Radial error : 3cm



3. HY-2 satellites laser ranging and applications

(2) Applications of SLR observations to HY-2d

- SLR residual from stations # 7090, 7105, 7810, 7839, 7840, 7941, 7119, 7501 for **HY-2d satellite**.
- The RMS of residual is $\sim 1.51\text{cm}$.





4. Future SLR missions

(1) New Beidou satellites which replace with the over life ones

- Beidou navigation system will be running for long time and the new Beidou satellites will be launched in order to replace with the old ones.
- The opportunities for investigating the performance of different satellite navigation system will be provided for GNSS community.

(2) Geomagnetic survey satellites

- Mss1a satellite is one marked by a new high-precision constellation of satellites that will survey the Earth's geomagnetic and space environment. And SLR will be an importance kind of high-precision satellite orbit measurement technology.
- The procedure of application of laser tracking campaign for mss1a satellite is over and it is ready to be tracked by ILRS network.

(3) HY-3 satellite constellation

- In future, HY-3 satellite constellation will be built and will combine visible/infrared and microwave sensors for the oceanic environmental monitoring and related scientific researches.
- The new satellites will also be tracked by SLR stations.



Shanghai Astronomical Observatory

Chinese Academy of Sciences



**Thanks for SLR supports from ILRS community
of the past, current and future missions.**

