13-0211

The Accuracy Verification for GPS Receiver of ZY-3 Satellite by SLR

ZHAO Chunmei(1), TANG Xinming(2), WEI Zhibin(1), LI Qian(1)

(1). Chinese Academy of Surveying and Mapping, Beijing, China;
(2). Satellite Surveying and Mapping Application Center, NASG, Beijing, China
zcm@casm.ac.cn

Abstract. *The ZY-3 satellite provides stereo and multispectral imagery for topographic mapping, remote sensing and environmental applications. ZY-3 has two dual-frequency homemade GPS receivers to determine the satellite orbit. Based on the satellite dynamics principle and batch processing mode, the orbit of ZY-3 satellite was determined using zero-difference GPS data. In order to verify the orbit accuracy by GPS, we carried out a laser restricted ranging campaign with the support of the International Laser Ranging Service (ILRS). Compared with SLR data, the distance bias between the satellite and SLR stations was less than 4cm, which revealed that ZY-3 satellite orbit accuracy can meet the requirement of satellite mission.*

Introduction

ZY-3 satellite orbit has been determined using dual-frequency GPS data since it was launched last year. The position accuracy of overlapping arcs is around 5 cm. In order to verify onboard GPS receiver newly developed by China, we need to check ZY-3 orbit by SLR.

Overview of ZY-3

ZY-3 satellite was launched from Taiyuan Satellite Launch Center on 9 January 2012. It is expected to provide stereo and multispectral imagery for topographic mapping, remote sensing and environmental applications. The orbit parameters and related information of ZY-3 satellite are described in Table 1.

Table 1. The Value of the Orbit

Orbit Type	Solar synchronous circle orbit
Height	505.984km
Inclination	97.421deg
Recurrent days	59 days
Revisit period	5 days
Local time of descending node	10:30 AM
Operating life in orbit	4 years
Weight	2630 kg

ZY-3 satellite, which is equipped with four cameras, can perform seamless imaging within 84 degrees and south latitudes by side-swing function. ZY-3 satellite has two dual-frequency GPS receivers and a laser reflector as tools for orbit determination.

Orbit determination using GPS data

Compared with general remote sensing satellite, ZY-3 satellite requires higher positioning accuracy. In order to perform accurate mapping, ZY-3 satellite orbit should be determined precisely. The orbit position accuracy is required to be superior to 20 cm after post-processing. In the process of orbit determination, we eliminated the influence of first-order term of ionospheric delay by ionosphere-free linear combination and calculated satellite orbit parameters based on statistical theory and least-square batch processing algorithm (Zhao Chunmei, 2013). Various types of data used in orbit determination are described in Table 2. The dynamical model and estimated parameters are shown in Table 3.

Table 2. Various Types of Data used in Orbit Determination

Data Items	Source	Description
Spaceborne GPS data	Satellite Surveying and Mapping Application Center, NASG	Raw data of 1s sampling rate
GPS precise ephemeris and satellite clock corrections	ftp://ftp.unibe.ch/aiub/CODE/	Precise ephemeris and satellite clock corrections of 30s sampling rate
SLR data	ILRS	Normal point data
GPS receiver antenna phase center offset	ZY-3 satellite development file	Biases between receiver antenna phase center and satellite mass center in satellite-fixed coordinate system
SLR reflector offset	ZY-3 satellite development file	Biases between SLR reflector geometric center and satellite mass center in satellite-fixed coordinate system

Table 3. Dynamical Model and Estimated Parameters

Perturbative force and Estimated Parameters		**Description**
Perturbative force	Earth gravity field	GGM02c（100×100）
	Planetary ephemeris	DE405
	Solid earth tide	IERS2003
	Ocean tide	CSR3.0
	Solar radiation pressure	BERN 9-parameter model
	Stochastic pulse parameter	A group parameters every 15 minutes in R、T、N direction, a total of 96 groups
Estimated Parameters	Initial orbit	Position and velocity
	Solar radiation pressure parameters	9 parameters
	Stochastic pulse parameter	96 groups every day

In order to evaluate the orbit accuracy, the length of orbit arc is set to 30 hours so that there will be 6 hours' overlapping arc. Spaceborne GPS data from July 18, 2012 to July 27, 2012 were processed. And a total of 9 overlapping arcs are generated. The comparison result of 9 overlapping arcs is shown in Figure 1. As you can see, the position accuracy of overlapping arc is between 2.30 and 7.91cm. As each orbit arc is assumed to be independent and irrelevant, orbit determination accuracy of ZY-3 satellite varies between $2.3/\sqrt{2}$ and $7.91/\sqrt{2}$cm according to the law of error propagation, *i.e.* 1.63 ~ 5.59cm. The variation of orbit determination accuracy also reflects the accuracy and stability of spaceborne GPS data to some degree.

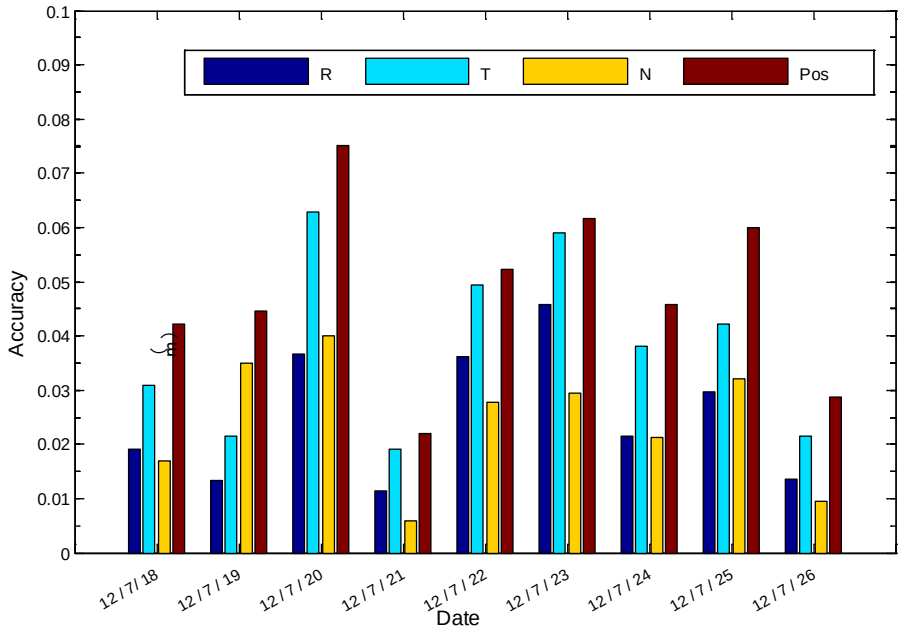

Figure 1. Accuracy of overlap comparison

Accuracy evaluation by SLR data

For orbit determination using spaceborne GPS data, the use of high-precision SLR data is another important way to verify the accuracy of orbit determination (Zhao Chunmei, 2008). With the support of ILRS, the restricted laser tracking to ZY-3 satellite was carried out. ZY-3 should only be tracked during nighttime conditions at the station to avoid damaging sensors (cameras and others). Therefore, the ILRS stations were required to only track ZY-3 starting one hour after sunset and ending one hour before sunrise. Thanks to ILRS support, twenty SLR stations (Table 4) participated in the ZY-3 SLR campaign. We obtained 184 passes and 1654 data points from 9 July, 2012 to 5 September, 2012.

Table 4. List of Participating Station for ZY-3 Tracking

SLR Stations	ID	Nation
Simeiz	SIML	Ukraine
Katzively	KTZL	Ukraine
Yarragadee	YARL	Australia
Greenbelt	GODL	USA
Monument Peak	MONL	USA
Haleakala	HA4T	USA
Tahiti	THTL	French Polynesia
Changchun	CHAL	China
Beijing	BEIL	China
Arequipa	AREL	Peru
San Juan	SJUL	Argentina
Hartebeesthoek	HARL	South Africa
Shanghai	SHA2	China
San Fernando	SFEL	Spain
Mt Stromlo	STL3	Australia
Graz	GRZL	Austria
Herstmonceux	HERL	United Kingdom
Potsdam	POT3	Germany
Matera	MATM	Italy
Wettzell	WETL	Germany

In the process of verifying ZY-3 orbit accuracy, we calculated the distance difference (i.e. O-C) between the directly observed station-satellite distance by SLR and the calculated distance by orbit determination based on GPS. The variation and distribution of distance difference is shown in Fig.2. The average of O-Cs is only -0.002m and the standard deviation of O-Cs is only 0.039m. This means that the difference between GPS-determined orbit and SLR data is well within the margin of error and there is no significant systematic error.

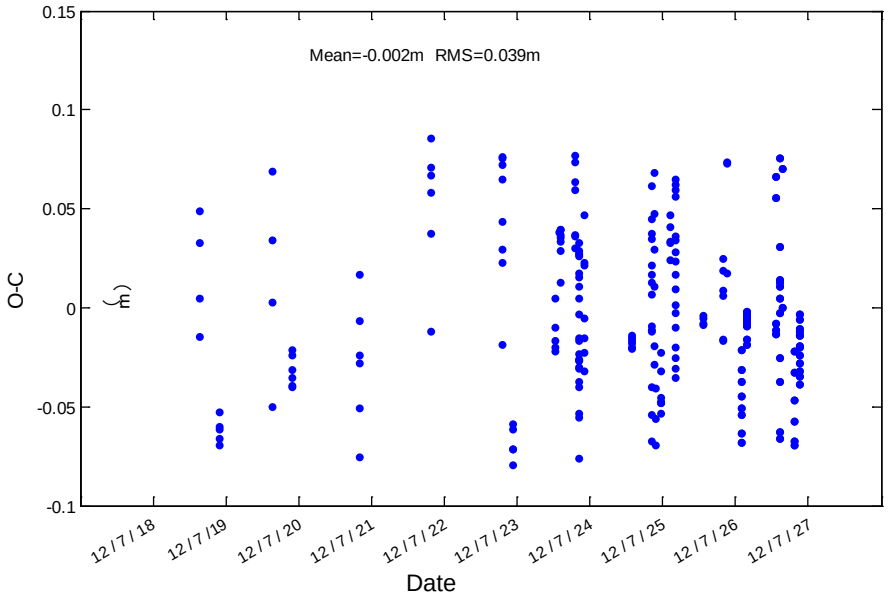

Figure 2. Comparison between SLR data and GPS-determined orbit

Conclusion

Based on the satellite dynamics principle and batch processing mode, the orbit of ZY-3 satellite was determined using spaceborne GPS data. The analysis result using the overlapping method revealed that the position accuracy of overlapping arc varies between 2.30 and 7.91cm. But the overlapping method is only a relative evaluation of orbit determination accuracy. When verified by SLR data, the standard deviation of difference between GPS-determined orbit and SLR data was superior to 4cm, which meant that there was no significant systematic error between the SLR and GPS data. The result of this analysis also shows that ZY-3 GPS receiver can provide correct positioning information and is absolutely able to meet the requirement of ZY-3 satellite mission.

Acknowledgements

ZY-3 satellite tracking campaign was performed successfully with the support of ILRS and participating SLR stations, to all of whom we would like to express our deep appreciation. The work described in this paper was also supported by the National Natural Science Foundation (Grant No. 41074012, 41274018) of China.

References

Zhao Chunmei, Tang Xinming. *Precise Orbit Determination for the ZY-3 Satellite Mission Using GPS Receiver*. Journal of Astronautics. 34(9), 2013

Zhao Chunmei, Qu Feng, Cheng Pengfei, et.al.. *Data quality analysis of Argentina San Juan laser ranging system*. Acta Geodaetica et Cartographica Sinica. 37(3), 2008