

17th Meeting of the International Committee on Global Navigation Satellite Systems



BeiDou Coordinate System(BDCS) Status and Accuracy Assessment

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4 SUMMARY





BDCS Maintenance Strategy: \succ

- Daily network solutions with loose constraints are obtained by \checkmark estimating GNSS satellite orbital parameters and stations coordinates and then align to ITRF.
- Station coordinates will be updated when the difference \checkmark between the estimated value and current used value exceeds the threshold (3cm).
- BDCS accuracy is evaluated using ITRF and IGS products. \checkmark







Accuracy Evaluation

Selected stations to evaluate the alignment accuracy

ABPO	GLPS	OUS2		
ASCG	IISC	REUN		
BJFS	KERG	SANT		
CRO1	KOUG	UNSA		
DGAR	MKEA			
FAIR	OHI3			

Coordinate Difference between BDCS and ITRF



	Trans_X	Trans_y	Trans_z	Rotate_x	Rotate_y	Rotate_z	Scal
	mm	mm	mm	mas	mas	mas	dqq
estimation	0.87	-0.93	-1.86	0.01	0.02	0.01	0.02
sigma	1.47	1.44	1.44	0.06	0.06	0.06	0.02

The alignment accuracy of BDCS to ITRF is consistent with BDCS (2019V01)

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1. BDCS STATUS

Coordinate Comparison



BDCS aligned to ITRF2020 with accuracy better than 1cm



Transformation parameters between BDCS and ITRF (BDCS align to ITRF2020)

	Trans_X	Trans_y	Trans_z	Rotate_x	Rotate_y	Rotate_z	Scal
	0.07	0.02	1.00	0.01			ppp
estimation	0.87	-0.93	-1.86	0.01	0.02	0.01	0.02
sigma	1.47	1.44	1.44	0.06	0.06	0.06	0.02

Transformation parameters between BDCS and ITRF (BDCS align to ITRF2014)

	Trans_X mm	Trans_y mm	Trans_z mm	Rotate_x mas	Rotate_y mas	Rotate_z mas	Scal ppb
estimation	2.98	-2.68	4.90	-0.14	-0.41	0.07	0.102
sigma	3.59	3.53	3.72	0.25	0.25	0.27	0.080

BDCS aligned to ITRF2020 with accuracy better than 1cm



Velocity Accuracy Evaluation





Velocity difference between BDCS and co-located CORS station is better than 1mm/y.

ACCURACY ASSESSMENT



2. ACCURACY ASSESSMENT

Helmert transformation parameters between $X_{brdc}(BDCS)$ and $X_{sp3}(ITRF/IGS)$:

 $X_{brdc} = T + (1+D) * R * X_{sp3}$

Root-Sum-Square (RSS) at the mean Earth radius:

$$RSS_{7} = \sqrt{T_{x}^{2} + T_{y}^{2} + T_{z}^{2} + R_{x}^{2} + R_{y}^{2} + R_{z}^{2} + \Delta S^{2}}$$

SISRE(orb): Orbit errors in user line-of-sight direction

$$SISRE_{RMS}^{orb} = \sqrt{w_{R}^{2}R^{2} + w_{AC}^{2}(A^{2} + C^{2})}$$

BDS satellite antenna offsets: http://www.beidou.gov.cn/yw/gfgg/201912/t20191209_ 19613.html

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2	2 A							PCV TYPE / REFANT
3	The satell	ite ante	nna phase	e cente	er file com	ntains	the PCO	COMMENT
4	referenced	to the	mass cent	ter of	BDS satel	lite		COMMENT
5	provided b	y the sa	tellite r	nanufac	turers.			COMMENT
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7								START OF ANTENNA
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17	NOAZT	0.00	0.00	0.00	0.00	0.00	0.00	0.00 0.00 0.00 0.00
18	C02							END OF FREQUENCY
19	C06							START OF FREQUENCY
20	608.70	-3.	60 1196	5.40				NORTH / EAST / UP
21	NOAZI	0.00	0.00	0.00	0.00	0.00	0.00	0.00 0.00 0.00 0.00
22	C06							END OF FREQUENCY
23	C07							START OF FREQUENCY
24	606.40	-3.	20 1073	3.90	10.5 J. 1.0 C. 10.0	6777 No. 6 (1977	NO. 7535 - 1275-453.8	NORTH / EAST / UP
25	NOAZI	0.00	0.00	0.00	0.00	0.00	0.00	0.00 0.00 0.00 0.00
26	C07							END OF FREQUENCY
27								END OF ANTENNA

Ref:

Malys S, Solomon R, Drotar J et al.(2021). Compatibility of terrestrial reference frames used in GNSS broadcast messages during an 8 week period of 2019. Adv Space Res 67:834-844.
 Igor Gusev, CURRENT STATUS OF THE GLONASS TERRESTRIAL REFERENCE FRAME, ICG-16, 2022

2023/10/16



2. ACCURACY ASSESSMENT

Evaluate the accuracy of BDS-3 and GPS broadcast ephemeris terrestrial reference frame using 2023 DOY 190-260 (RSS7method)





BDS TRF coincidence with ITRF is better than 10cm.



2. ACCURACY ASSESSMENT

Evaluate the accuracy of BDS-3 and GPS broadcast ephemeris terrestrial reference frame using 2023 DOY 190-260 (SISRE(orb) method)





Fig. 4. RMS signal-in-space range error of the four global navigation satellite systems (solid) in the September to November 2019 time period. Empty framed bars and hatched bars show the contributions of orbit errors and clock errors, respectively.

Ref:

Oliver Montenbruck, et. al, Comparing the 'Big 4' – A User's View on GNSS Performance, 978-1-7281-0244-3/20, 2020

BDS-3 SISRE (orb) RMS is about 8cm.

ILRS TRACKING APPLICATION

3. ILRS TRACKING APPLICATION

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- Sep. 21st 2022, SLR MISSION SUPPORT
 REQUEST (MSRs) for all BDS-3 MEOs have
 been submitted to ILRS Governing Board(GB)
- Sep. Nov. 2022, Communicated with the
 ILRS on the issue of MEO satellite information.
- Dec. 30th 2022, BDS-3 MEOs were added to the satellite observation list.
- Feb. 1st 2023, BDS-3 orbit prediction had been updated regularly.

Re: Please provide additional information about the Beidou satellites to be added to the tracking support	▶ ~ ⓒ 營 营 发起会议 2023-02-01 09:01:11
洗海峰 发送给 Carabajal, Claudia C. (GSFC-61A.0)[SCIENCE SYSTEMS AND APPLICATIONS INC]	······ · ·
▶ 发送成功 查看洋情	
Dear Claudia,	
I have noticed that the additional Beidou MEO satellites have been added to the list of ILRS webpage. The cpf fi uploaded to EDC ftp.	les are also prepared to be
Christian, please help us to check the status of receiving the cpf files. If ok, this afternoon we will upload to same way of the existed Beidou satellites.	nem to EDC ftp by the
Thank you.	
hest regards	
Now the cpt files of new Beidou satellites are uploaded to EDC ftp and The SLR stations can download them. A stations to track the new beidou satellites. Thank you. best regards zhang	fould you please inform SLR
>: ————————————————————————————————————	
wg:、次に本引引、おおひなでいたいで、 <u>生い、</u>) 後g:、收件人:"张海峰"(hfzhang@shao.ac.cn 〈 <u>mailto:hfzhang@shao.ac.cn</u> 〉)、"Carabajal, Claudia C. (GSFC-61A.0) INC] ~ (claudia.c.carabajal@nasa.gov 〈 <u>mailto:claudia.c.carabajal@nasa.gov</u> 〉) >: 抄法:	SCIENCE SYSTEMS AND APPLICATIO
また、主題: Re: Please provide additional information about the Beidou satellites to be added to the tracking 数は: 数は: Dear Zhang	g support
wst. Poar Linnis, Mgt:	
<pre>> CPFs can be uploaded to the EDC in the same way as the other CPFs. &st</pre>	
>: Thank you and best regards,	
Øgt:	

Since Feb. 2023, the entire BDS-3 MEOs have been tracked by ILRS stations.



3. ILRS TRACKING APPLICATION







2023/10/16

20+ SLR stations tracked BDS-3 MEOs, observations increased significantly.



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SLR tracking result



Accuracy evaluation of the BDS-3 broadcast ephemeris using SLR data.



BDS-3 C25

3. ILRS TRACKING APPLICATION

IGS use SLR data to evaluate MGEX precise orbit

BDS-3 C30



https://igs.org/mgex/analysis/#bd3-slr-residuals

Improve BDS-3 satellites dynamic and measurement models.

2023/10/16









- BDCS is aligned to ITRF2020. The accuracy is 0.97/-0.83/-1.76mm for transition, -0.00/0.02/0.00mas for rotation, and 0.02ppb for scale parameters, which indicate that BDCS is aligned and maintained precisely.
- The accuracy of the BDCS was evaluated using a comparison method between broadcast ephemeris and precision ephemeris, with RSS₇ of approximately 7.5cm and SISRE (orb) of approximately 8.0cm.
- After the addition of Beidou-3 to the ILRS tracking, 20+ global stations tracked BDS-3 MEOs, which providing important data sources for broadcasting ephemeris and precision ephemeris orbit accuracy verification, and promoting the scientific researches using BDS.



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Thanks