BeiDou Coordinate System (BDCS) Status and Accuracy Assessment

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2023-10
1. BDCS STATUS

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

Accuracy Evaluation

Selected stations to evaluate the alignment accuracy

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>ABPO</td>
<td>GLPS</td>
<td>OUS2</td>
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<tr>
<td>ASCG</td>
<td>IISC</td>
<td>REUN</td>
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<tr>
<td>BJFS</td>
<td>KERG</td>
<td>SANT</td>
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<td>CRO1</td>
<td>KOUG</td>
<td>UNSA</td>
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<td>DGAR</td>
<td>MKEA</td>
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<tr>
<td>FAIR</td>
<td>OHI3</td>
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</tbody>
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Coordinate Difference between BDCS and ITRF

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

Coordinate Comparison

BDCS-ITRF2020
E/N/U(RMS): 0.8/0.3/1.2 cm

BDCS-ITRF2014
E/N/U(RMS): 3.1/0.7/1.8 cm

BDCS(ITRF2020)-IGS
E/N/U(RMS): 0.2/0.3/0.8 cm

BDCS(ITRF2014)-IGS
E/N/U(RMS): 0.5/0.5/1.2 cm

BDCS aligned to ITRF2020 with accuracy better than 1cm
1. BDCS STATUS

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

<table>
<thead>
<tr>
<th></th>
<th>Trans_X mm</th>
<th>Trans_y mm</th>
<th>Trans_z mm</th>
<th>Rotate_x mas</th>
<th>Rotate_y mas</th>
<th>Rotate_z mas</th>
<th>Scal ppb</th>
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<tbody>
<tr>
<td>estimation</td>
<td>0.87</td>
<td>-0.93</td>
<td>-1.86</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
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<tr>
<td>sigma</td>
<td>1.47</td>
<td>1.44</td>
<td>1.44</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.02</td>
</tr>
</tbody>
</table>

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

<table>
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<tr>
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<th>Trans_z mm</th>
<th>Rotate_x mas</th>
<th>Rotate_y mas</th>
<th>Rotate_z mas</th>
<th>Scal ppb</th>
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<tbody>
<tr>
<td>estimation</td>
<td>2.98</td>
<td>-2.68</td>
<td>4.90</td>
<td>-0.14</td>
<td>-0.41</td>
<td>0.07</td>
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<tr>
<td>sigma</td>
<td>3.59</td>
<td>3.53</td>
<td>3.72</td>
<td>0.25</td>
<td>0.25</td>
<td>0.27</td>
<td>0.080</td>
</tr>
</tbody>
</table>

BDCS aligned to ITRF2020 with accuracy better than 1cm
1. BDCS STATUS

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):

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

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

$$RSS = \sqrt{T_x^2 + T_y^2 + T_z^2 + R_x^2 + R_y^2 + R_z^2 + \Delta S^2}$$

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

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

Ref:
(2) Igor Gusev. CURRENT STATUS OF THE GLONASS TERRESTRIAL REFERENCE FRAME. ICG-16, 2022

BDS satellite antenna offsets:
http://www.beidou.gov.cn/yw/gfgg/201912/t20191209_19613.html
2. ACCURACY ASSESSMENT

Evaluate the accuracy of BDS-3 and GPS broadcast ephemeris terrestrial reference frame using 2023 DOY 190-260 (RSS7 method)

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 bar show the contributions of orbit errors and clock errors, respectively.

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

Ref:
Oliver Montenbruck, et. al. Comparing the ‘Big 4’ – A User’s View on GNSS Performance, 978-1-7281-0244-3/20, 2020
ILRS TRACKING APPLICATION 03
Since Feb. 2023, the entire BDS-3 MEOs have been tracked by ILRS stations.

3. ILRS TRACKING APPLICATION

- 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.
20+ SLR stations tracked BDS-3 MEOs, observations increased significantly.
Accuracy evaluation of the BDS-3 broadcast ephemeris using SLR data.
3. ILRS TRACKING APPLICATION

IGS use SLR data to evaluate MGEX precise orbit

**BDS-3 C30**

**BDS-3 C25**

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

Improve BDS-3 satellites dynamic and measurement models.
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 RSS\(_7\) 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.
Thanks