BeiDou Orbits and Clocks

P. Steigenberger, O. Montenbruck, DLR/GSOC
Z. Deng, GFZ Potsdam
J. Guo, Wuhan University
L. Prange, AIUB
S. Song, Shanghai Observatory
Current BeiDou Constellation

BDS-2 MEO (3)
BDS-2 IGSO (7)
BDS-2 GEO (5)

BDS-3 MEO (24)
BDS-3 IGSO (3)
BDS-3 GEO (2+1)

BDS-3S (0+4)
BeiDou-3 MEO Satellites

MEO CAST
(China Academy of Space Technology)

MEO SECM
(Shanghai Engineering Center for Microsatellites)

Images: CSNO/TARC; SECM
BeiDou-3 IGSO and GEO Satellites

Images: CSNO/TARC
MGEX Analysis Centers

Five out of seven analysis center of the Multi-GNSS Pilot Project (MGEX) provide BeiDou-2 and BeiDou-3 orbit and clock products.

<table>
<thead>
<tr>
<th>Abb.</th>
<th>Institution</th>
<th>Type</th>
<th>MEO</th>
<th>IGSO</th>
<th>GEO</th>
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<td>CODE</td>
<td>Center for Orbit Determination in Europe</td>
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<td>RAP</td>
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<td>Information and Analysis Center</td>
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<td>WU</td>
<td>Wuhan University</td>
<td>FIN</td>
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# Selected BDS-3 Modeling Options

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<tr>
<td>Arc length</td>
<td>72 h</td>
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<td>48 h</td>
<td>24 h</td>
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<td>A priori SRP</td>
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<td>None</td>
<td>Box-wing</td>
<td>Box-wing</td>
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<td>SRP param.</td>
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<td>ECOM</td>
<td>ECOM-based</td>
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<td></td>
<td>D0,Y0,B0,BC,BS, D2C, D2S</td>
<td>D0,Y0,B0,BC,BS</td>
<td>Sc,Y0,BC,BS (</td>
<td>\beta</td>
<td>&lt; 5^\circ) D0, B0 (</td>
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<tr>
<td>Albedo/IR</td>
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<td>X</td>
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Orbit Signal-in-Space Range Error

\[ \text{SISRE}_{\text{orb}} = \sqrt{w_1^2 R^2 + w_2^2 (A^2 + C^2)} \]

computed from RMS orbit differences:

- \( R \) radial
- \( A \) along-track
- \( C \) cross-track

and weighting factors \( w_1, w_2 \)

between pairs of analysis centers
BeiDou-3 Satellite Laser Ranging Residuals

[Diagram showing SLR residuals for different satellites and centers]
BeiDou-3 Satellite Clocks
BeiDou-3 Satellite Clocks

IGSO

GEO

Integration time [s]

Median ADEV C226

Median ADEV C217

COD GFZ IAC SHA WUM

GFZ IAC SHA
BeiDou-3 Satellite Clocks

Median clock RMS [ps]

MEO CAST

MEO SECM

IGSO

GEO

RAFS

PHM
Signal-in-Space Range Error

\[
SISRE = \sqrt{w_1 R^2 - 2w_1 R T + T^2 + w_2 (A^2 + C^2)}
\]

\(T\) clock differences

compensation of orbit-related errors by corresponding errors in the estimated satellite clocks
Precise Point Positioning Performance

- December 2021
- 30 stations
- BDS-3 MEO
- Daily coordinates

Average 1-σ repeatability per AC:
- N: 2 – 4 mm
- E: 3 – 7 mm
- U: 5 – 11 mm
- 3D: 7 – 13 mm

COD  GFZ
IAC  SHA
WUM  WUM
Summary and Conclusions

• 5 IGS analysis center provide BeiDou orbit and clock products
• Processing options not as homogeneous as for other constellations
• BDS-3 MEO orbit consistency on the 4-8 cm level, SLR residuals have RMS values of 3-9 cm
• Extended coverage of SLR tracking of the BDS-3 constellation is strongly encouraged
• Solar radiation pressure modeling is challenging, in particular for IGSO and GEO satellites
• Incomplete set of satellite metadata available, publication of further data encouraged
• BeiDou-3 is a complement to GPS and other GNSSs and can already make valuable contributions to geodesy and precise positioning
Resources

• IGS MGEX Products: https://igs.org/mgex/data-products/#orbit_clock