CODE's multi-GNSS orbit and clock solution - status 2016

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• Satellite clock validation

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MGEX data monitoring

Number of stations providing daily RINEX3 files and included in CODE’s raw data monitoring (data sources: IGS-MGEX and EPN)
CODE MGEX orbit solution

GNSS considered: GPS + GLONASS + Galileo + BeiDou (MEO+IGSO) + QZSS (≈70 SV)

Processing mode: Post-processing (≈2 weeks latency)

Timespan covered: GPS-weeks 1689 - today

Number of stations: 130 (GPS), 110 (GLONASS), 85 (Galileo); 55 (BeiDou); 20 (QZSS)

Processing scheme: Double-difference network processing
(obsetable: phase double differences)

Signal frequencies: L1 + L2 (GPS + GLO+ QZSS);
E1 (L1) + E5a (L5) Galileo; B1 (L1) + B2 (L7) BeiDou

Orbit characteristic: 3-day long arcs; SRP: ECOM / ECOM2 (since 2015)

Reference frame: IGS08 (until week 1708); IGb08 (since week 1709)

IERS conventions: IERS2003 (until 1705); IERS2010 (since 1706)

Product list: Daily orbits (SP3) and ERPs


Designator: comwwwwd.???.Z
# CODE MGEX clock solution

<table>
<thead>
<tr>
<th>GNSS considered:</th>
<th>GPS + GLONASS + Galileo + BeiDou + QZSS (≈70 SV)</th>
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</thead>
<tbody>
<tr>
<td>Processing mode:</td>
<td>Post-processing (≈2 weeks latency)</td>
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<tr>
<td>Timespan covered:</td>
<td>GPS-weeks 1710 - today</td>
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<tr>
<td>Number of stations:</td>
<td>130 (GPS), 35 (GLO), 45 (Galileo); 50 (BeiDou); 20 (QZSS)</td>
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<td>Processing scheme:</td>
<td>Zero-difference processing</td>
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<td>(observable: code+phase undifferenced)</td>
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<td>L1+ L2 (GPS + GLO+ QZSS);</td>
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<td>E1 (L1) + E5a (L5) Galileo; B1 (L1) + B2 (L7) BeiDou</td>
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<td>A priori information:</td>
<td>Orbits, ERPs, coordinates, and troposphere from</td>
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<td></td>
<td>CODE MGEX orbit solution introduced as known</td>
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<tr>
<td>Reference frame:</td>
<td>IGb08</td>
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<td>IERS conventions:</td>
<td>IERS2010</td>
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<td>Product list:</td>
<td>Epoch-wise (300s) satellite and station clock corrections</td>
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<td></td>
<td>in daily clock RINEX files; daily inter-system biases for mixed stations in Bernese DCB and BIAS-SINEX format</td>
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<td>Distribution:</td>
<td>ftp://cddis.gsfc.nasa.gov/gnss/products/mgex/ and</td>
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<td>ftp://ftp.unibe.ch/aiub/CODE_MGEX/</td>
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Changes w.r.t. to IGS solution

- Implementation of Galileo, QZSS, BeiDou (except GEOs)
- Use of RINEX3 files from MGEX network; selection of observation types
- Improved SRP model for yaw-steering attitude (ECOM2, Arnold et al., 2015)
- Normal attitude and related SRP models for QZSS and BeiDou
- ANTEX (PCO+PCV) for Galileo, QZSS, BeiDou
- Attitude laws for GPS, GLONASS, (Galileo?) eclipses
- Proper handling of observation biases
- Ambiguity resolution for Galileo, BeiDou, QZSS
- Albedo radiation modelling for Galileo, QZSS, BeiDou
- Antenna thrust for (GLONASS), Galileo, QZSS, BeiDou
Galileo orbit validation

Significant reduction of dependency on beta-angle, when changing to the ECOM2 (attitude related?)
Galileo clock validation

- Significant reduction of dependency on beta angle
- Pronounced signal remains during eclipse season or close-by (attitude related?)
Galileo clock validation

Small beta-angle:
=> Periodic signal caused by mis-modelled orbit (ECOM1)

Large beta-angle:
=> Clock signal has small amplitude (about ±0.15 ns)

=> Significant reduction of signal amplitude from ±0.75 ns to ±0.15 ns when switching to ECOM2

Clock corrections of Galileo E11, SVN E101
QZSS orbit validation

→ Yaw-steering: ECOM2 reduces dependency on beta angle
→ Significant SLR offset remains
Normal attitude mode (|β| < 20°; marked grey): large orbit errors

Test of new ECOM versions suited for orbit normal attitude mode
QZSS orbit validation

Test of new ECOM versions suited for orbit normal attitude mode
QZSS clock validation

→ Yaw-steering: significant reduction of dependency on beta angle thanks to ECOM2
→ Orbit normal attitude mode (grey): large errors remain
QZSS clock validation

Experiments with ECOM versions better suited for orbit normal attitude mode
QZSS clock validation

Experiments with ECOM versions better suited for orbit normal attitude mode
BeiDou orbit validation

→ Yaw-steering: no significant impact of ECOM version
→ Orbit normal attitude mode (|\(\beta\)| < 4°; grey boxes; not correctly considered): large residuals
Test of new ECOM versions better suited for orbit normal attitude mode
BeiDou orbit validation

⇒ Test of new ECOM versions better suited for orbit normal attitude mode
BeiDou clock validation

**Diagram:**
- Y-axis: RMS of linear clock fit [ns]
- Beidou C11, SVN C012, ECOM 1, ECOM 2

**Notes:**
- Yaw-steering: no significant difference between ECOM versions.
- Orbit normal attitude mode ($|\beta| < 4^\circ$, marked grey; wrong attitude considered): ECOM2 may even degrade solution.
BeiDou clock validation

Experiments with ECOM versions better suited for orbit normal attitude mode
BeiDou clock validation

Experiments with ECOM versions better suited for orbit normal attitude mode
Summary

- Still a long way to go until new GNSS can contribute to CODE’s IGS solutions with the same quality as GPS
- Our current focus: correct consideration of orbit normal attitude (challenges are, e.g., SRP modelling, detection and consideration of mode-transitions, …)
- Next: use of published or own estimated transmitter antenna phase center corrections for Galileo, BeiDou, and QZSS
- Reprocessing of data from 2015 planned
Thank you for your interest!