GFZ Analysis Centre:
Multi-GNSS Processing and Products

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DeutschesGeoforschungsZentrum GFZ

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Outline

I. GFZ contributions to IGS
II. Multi-GNSS Experiment
III. Multi-GNSS Processing Results
I. GFZ contributions to IGS

GFZ Global Multi-GNSS Station Network:
I. GFZ contributions to IGS

GFZ Analysis Center:

• Processing of GNSS data from global network (~ 200 stations)

• Primary products:
  – Satellite orbits and clocks
    IGS products: GPS, GLONASS
    MGEX products: additionally Galileo, BeiDou, QZSS
  – Reference frame products (station position and Earth rotation parameters)

• Related products:
  – Tropospheric delay estimates (Precise Point Positioning)
  – Broadcast of real-time GPS corrections for satellite orbits and clocks
## I. GFZ contributions to IGS

Satellite orbit/clock product availability for different satellite systems:

<table>
<thead>
<tr>
<th>Product</th>
<th>GPS</th>
<th>GLONASS</th>
<th>Galileo</th>
<th>BeiDou</th>
<th>QZSS</th>
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<td>Final</td>
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<td>Rapid</td>
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MGEX
IGS’ Multi-GNSS Experiment:

• Focus: track, collate and analyze all available GNSS signals
• Support all GNSS: modernized GPS/GLONASS and new systems BeiDou, Galileo, QZSS
• Official call for participation in the Multi-GNSS Experiment in mid 2011
• Approx ~ 140 stations at the moment
• Open data archives at CDDIS, IGN, BKG in RINEX 3.x
  
ftp://cddis.gsfc.nasa.gov/pub/gps/data/campaign/mgex/
ftp://cddis.gsfc.nasa.gov/pub/gps/products/mgex/

• analysis centres: CODE, GFZ, GRGS, TUM, ESOC, WHU, JAXA
II. Multi-GNSS Experiment

Global Multi-GNSS Station Network:

- GAL (138)
- BDS (87)
- QZSS (59)
II. Multi-GNSS Experiment

Total number of MGEX-tracking stations:
# II. Multi-GNSS Experiment

GNSS constellation status (September, 2015):

<table>
<thead>
<tr>
<th>Constellation</th>
<th>Revolution period</th>
<th>Actual number of satellites</th>
<th>Signal carriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galileo</td>
<td>14h 05min</td>
<td>IOV(3): E11, E12, E19 (E20) FOC (4): E14, E18, E22, E26 (E24, E30)</td>
<td>E1, E5a, E5b, E5(E5a+E5b), E6</td>
</tr>
<tr>
<td>BeiDou</td>
<td>12h 53min</td>
<td>GEO (5): C01, C02, C03, C04, C05 IGSO (5): C06, C07, C08, C09, C10 MEO (3): C11, C12, C14 (C13)</td>
<td>B1, B2 (B3)</td>
</tr>
<tr>
<td>QZSS</td>
<td>23h 56min</td>
<td>IGSO (1): J01</td>
<td>L2, L2, L5, L6</td>
</tr>
</tbody>
</table>
II. Multi-GNSS Experiment

Galileo IOV satellite tracking: number of stations per satellite

- E11
- E12
- E19
- E20

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II. Multi-GNSS Experiment

Galileo FOC satellite tracking: number of stations per satellite

E14

E18

E22

E26

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II. Multi-GNSS Experiment

BeiDou MEO satellite tracking: number of stations per satellite
III. Multi-GNSS Processing Results

Multi-GNSS data processing:

- GNSS systems: GPS, GLONASS, Galileo, BeiDou, QZSS
- IGS-Rapid like processing configuration, i.e. daily solutions
- Roughly ~ 100 sites, IGS + MGEX data archives
- Regular processing since January 2014
- Major processing settings:

<table>
<thead>
<tr>
<th>Orbit model:</th>
<th>empirical CODE orbit model (5 parameter)</th>
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<tbody>
<tr>
<td>Ambiguity fixing:</td>
<td>GPS, GAL, BDS (IGSO, MEO)</td>
</tr>
<tr>
<td>Antenna PCO/PCV:</td>
<td>IGSwwww.atx + MGEX conventional values</td>
</tr>
<tr>
<td>Observation model:</td>
<td>undifferenced ionosphere-free linear combination</td>
</tr>
<tr>
<td>Intersystem-bias setup:</td>
<td>GLO per sta/sat-link, GAL/BDS/QZSS per station</td>
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III. Multi-GNSS Processing Results

Multi-GNSS data processing:

- Observation type selection

<table>
<thead>
<tr>
<th>System</th>
<th>Signal carrier</th>
<th>RX3 modulations (code/phase)</th>
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<tbody>
<tr>
<td>GPS</td>
<td>L1/L2</td>
<td>L1: WC</td>
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<tr>
<td></td>
<td></td>
<td>L2: W</td>
</tr>
<tr>
<td>GLONASS</td>
<td>G1/G2</td>
<td>L1: PC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L2: PC</td>
</tr>
<tr>
<td>Galileo</td>
<td>E1/E5a</td>
<td>L1: CX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L5: QX</td>
</tr>
<tr>
<td>BeiDou</td>
<td>B1/B2</td>
<td>L1: I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L7: I</td>
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<tr>
<td>QZSS</td>
<td>L1/L2</td>
<td>L1: CX</td>
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<td></td>
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<td>L2: X</td>
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</table>
III. Multi-GNSS Processing Results

Multi-GNSS station selection for IGS rapid-like solution:

- **GPS/GLO (119)**
- **GAL (59)**
- **BDS (36)**
- **QZSS (16)**

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III. Multi-GNSS Processing Results

Galileo, BeiDou, QZSS ground-track characteristics:
III. Multi-GNSS Processing Results

Galileo / BeiDou / QZSS site-specific visibility:

![Graphs showing visibility of Galileo, BeiDou, and QZSS satellites at Jiufeng (China) and Arequipa (Peru).]
III. Multi-GNSS Processing Results

GNSS satellites included in data processing:

- GAL median: 4
- BDS median: 13
- GLO median: 23
- GPS median: 31
III. Multi-GNSS Processing Results

Quality of GPS and GLONASS satellite positions:

Similarity transformation of daily satellite positions w.r.t. official IGS-Rapid solution

![Graph showing GPS and GLONASS orbit differences.](Image)
III. Multi-GNSS Processing Results

GPS, GLONASS, Galileo, BeiDou, QZSS satellite position overlaps:

Position differences at same epochs derived from independent observations
III. Multi-GNSS Processing Results

GNSS orbit validation using Satellite Laser Ranging (SLR):

![Graph showing SLR residuals for different satellites and orbital types.](image)
III. Multi-GNSS Processing Results

Satellite clock performance:

Clock stability [ps/s]

September–2015

G03 (IIF)
E11 (IOV)
E18 (FOC)
E22 (FOC)
C03 (GEO)
C11 (MEO)
J01
### III. Multi-GNSS Processing Results

<table>
<thead>
<tr>
<th>BIAS/SOLUTION</th>
<th>SVN</th>
<th>PRN</th>
<th>SITE</th>
<th>DOMES</th>
<th>OBS</th>
<th>OBS2</th>
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<td>C</td>
<td>BRST</td>
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</table>
Open/known issues:

- Clock reference system reporting (GPS!)
- C1W-C1C satellite bias handling (cc2noncc)
- Galileo C1C-C1W / C2Q-C2X satellite biases
Next steps / future developments:

- Switch to ECOM2 orbit parameterisation (extended ECOM)
- Extend station selection to improve multi-GNSS observation data coverage (time and geometry)
- Generation of consistent GAL clock / DCB product
- Provide all processing chains (Ultra/Rapid/Final) in multi-GNSS mode
Many thanks for your attention