Status of the IGS-MGEX Project

R. Dach¹, O. Montenbruck², L. Prange¹

(1) Astronomical Institute, University of Bern, Switzerland
(2) DLR, German Space Operations Center, Oberpfaffenhofen, Wessling, Germany

EUREF Symposium – EUREF 2014
June 3-7, 2014 in Vilnius, Lithuania
The International GNSS Service is ...

... a federation of more than 200 institutions and organizations worldwide
... a Service of the International Association of Geodesy (IAG) founded in 1994
... operational since more than 20 years
... the premier source of the highest-quality GNSS data, products, and related standards and conventions
... in support of many applications that benefit the scientific community and society
... following an open data policy
... open to everybody to participate
## Constellation Status (May 2014)

<table>
<thead>
<tr>
<th>System</th>
<th>Blocks</th>
<th>Signals</th>
<th>Sats(^*)\</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
<td>IIA</td>
<td>L1 C/A, L1/L2 P(Y)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>IIR-A/B</td>
<td>L1 C/A, L1/L2 P(Y)</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>IIR-M</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>IIF</td>
<td></td>
<td>5(+1)</td>
</tr>
<tr>
<td>GLONASS</td>
<td>M</td>
<td>L1/L2 C/A + P</td>
<td>24</td>
</tr>
</tbody>
</table>

\(^*)\) brackets indicate satellites not yet declared healthy/operational
## Constellation Status (May 2014)

<table>
<thead>
<tr>
<th>System</th>
<th>Blocks</th>
<th>Signals</th>
<th>Sats*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
<td>IIA</td>
<td>L1 C/A, L1/L2 P(Y)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>IIR-A/B</td>
<td>L1 C/A, L1/L2 P(Y)</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>IIR-M</td>
<td>+L2C</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>IIF</td>
<td>+L5</td>
<td>5(+1)</td>
</tr>
<tr>
<td>GLONASS</td>
<td>M</td>
<td>L1/L2 C/A + P</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>+L3</td>
<td>(1)</td>
</tr>
</tbody>
</table>

*) brackets indicate satellites not yet declared healthy/operational
## Constellation Status (May 2014)

<table>
<thead>
<tr>
<th>System</th>
<th>Blocks</th>
<th>Signals</th>
<th>Sats*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
<td>IIA</td>
<td>L1 C/A, L1/L2 P(Y)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>IIR-A/B</td>
<td>L1 C/A, L1/L2 P(Y)</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>IIR-M</td>
<td>+L2C</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>IIF</td>
<td>+L5</td>
<td>5(+1)</td>
</tr>
<tr>
<td>GLONASS</td>
<td>M</td>
<td>L1/L2 C/A + P</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>K</td>
<td>+L3</td>
<td>(1)</td>
</tr>
<tr>
<td>BeiDou</td>
<td>GEO</td>
<td>B1, B2, B3</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>IGSO</td>
<td>B1, B2, B3</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>MEO</td>
<td>B1, B2, B3</td>
<td>4</td>
</tr>
<tr>
<td>Galileo</td>
<td>IOV</td>
<td>E1, (E6), E5a/b/ab</td>
<td>(4)</td>
</tr>
<tr>
<td>QZSS</td>
<td>IGSO</td>
<td>L1 C/A, L1C, SAIF</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L2C, E6 LEX, L5</td>
<td></td>
</tr>
<tr>
<td>IRNSS</td>
<td>IGSO</td>
<td>L5, S</td>
<td>(2)</td>
</tr>
</tbody>
</table>

*) brackets indicate satellites not yet declared healthy/operational

http://igs.org
Multi-GNSS Experiment (MGEX)

- Multi-GNSS Experiment (MGEX)
  - MGEX call-for-participation released mid-2011 (ongoing)
  - Steered by Multi-GNSS Working Group (MGWG)
- Some 27 contributing agencies from 16 countries
- Global tracking network, mostly real-time
  - State-of-the-art receivers and antenna
  - Tracking of Galileo, BeiDou, QZSS, SBAS (but no IRNSS, yet)
- Free and open access
  - Data archives at CDDIS, IGN, BKG (RINEX 3.x)
  - Real-time NTRIP caster (RTCM3-MSM)
  - Product archive at CDDIS
The IGS MGEX Network

Streams: http://mgex.igs-ip.net
## Receivers and Tracked Signals

<table>
<thead>
<tr>
<th>Receiver Type</th>
<th>Sites</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>E: 1X,5X</td>
</tr>
<tr>
<td>Javad TRE_G3TH (v8 board)</td>
<td>1</td>
<td>G: 1C,1W,2X,2W,5X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E: 1X,5X,7X,8X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C: 2I,7I</td>
</tr>
<tr>
<td>Trimble NETR9</td>
<td>36</td>
<td>G: 1C,2X,2W,5X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E: 1X,5X,7X,8X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C: 2I,6I,7I</td>
</tr>
<tr>
<td>Leica GR10/25, GRX1200+GNSS</td>
<td>17</td>
<td>G: 1C,2S,2W,5Q</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E: 1C,5C,7C,8Q</td>
</tr>
<tr>
<td>NovAtel OEM6</td>
<td>1</td>
<td>G: 1C,2W,5Q</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E: 1C,5Q</td>
</tr>
<tr>
<td>Septentrio PolaRxS/4/4TR, AsteRx3</td>
<td>15</td>
<td>G: 1C,1W,2L,2W,5Q</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E: 1C,5Q,7Q,8Q</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C: 2I,7I</td>
</tr>
</tbody>
</table>
# MGEX Analysis Centers and Products

<table>
<thead>
<tr>
<th>Institution</th>
<th>ID</th>
<th>Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNES/CLS, France</td>
<td>grm</td>
<td>GAL</td>
</tr>
<tr>
<td>CODE(AIUB), Switzerland</td>
<td>com</td>
<td>GPS+GLO+GAL(+BDS)</td>
</tr>
<tr>
<td>ESA/ESOC, Germany</td>
<td>esm(^{(1)})</td>
<td>GPS+GAL(+GLO+BDS+QZS)</td>
</tr>
<tr>
<td>GFZ, Germany</td>
<td>gfm</td>
<td>GPS+GAL</td>
</tr>
<tr>
<td></td>
<td>gbm</td>
<td>GPS+BDS</td>
</tr>
<tr>
<td>JAXA, Japan</td>
<td>qzf(^{(2)})</td>
<td>QZS</td>
</tr>
<tr>
<td>TUM, Germany</td>
<td>tum</td>
<td>GAL+QZS</td>
</tr>
<tr>
<td>Wuhan Univ., China</td>
<td>wum</td>
<td>GPS+BDS</td>
</tr>
</tbody>
</table>

Products provided at ftp://cddis.gsfc.nasa.gov/pub/gps/products/mgex/

Remarks:
(1) Selected short campaigns, only
(2) Copy of JAXA precise orbit and clock product
MGEX Product Availability

Status: 30-May-2014
Satellite system IDs according to the content of the precise orbit files at ftp://cddis.gsfc.nasa.gov/pub/gps/products/mgex/
http://igs.org
Galileo Orbit and Clock Products

• Routine products from 4 ACs
  • Different s/w packages and processing strategies

• Orbit performance assessment
  • 3-day solutions (COD, GFZ, TUM) 2-3x better than 1-day (CNES)
  • 10-15 cm level (3D rms) consistency
  • 5-8 cm day boundary discontinuities
  • 10 cm rms SLR residuals

(Steigenberger et al., ASR, submitted)
Galileo IOV – SLR Residuals

- Bias -5 cm
- 1/rev radial orbit errors with up to +/- 20 cm amplitude
- Amplitude varies with Sun-angle above orbital plane (β-angle)
  - Best results for high β-angles

(Steigenberger et al., ASR, submitted)
BeiDou Orbit and Clock Products

• Products from 3 ACs
  • Different s/w packages (PANDA\(^{(1)}\), EPOS, BSW) and processing strategies
  • Different networks
    (MGEX-only vs. MGEX+BETS\(^{(2)}\))
  • Only short overlapping periods available
    (CODE-WUH/CODE-GFZ)

• Orbit performance assessment
  • SLR residuals (10 cm MEO/IGSO; 0.5m GEO?)

(1) Processing details from Wuhan solution are pending
(2) BeiDou Experimental Tracking Stations (BETS)
BeiDou: Orbit Overlaps (CODE)

Difference in orbit positions in cm

BeiDou 14.3 +/- 18.8 cm

http://igs.org EUREF 2014
BeiDou: Orbit Overlaps (CODE)

<table>
<thead>
<tr>
<th></th>
<th>Difference in orbit positions in cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>BeiDou</td>
<td>14.3 ± 18.8 cm</td>
</tr>
<tr>
<td>BeiDou, MEO</td>
<td>13.6 ± 22.7 cm</td>
</tr>
<tr>
<td>BeiDou, IGSO</td>
<td>18.2 ± 22.6 cm</td>
</tr>
</tbody>
</table>

http://igs.org

EUREF 2014 15
BeiDou: Orbit Overlaps (CODE)

- GPS: 1.0 ± 1.1 cm
- GLONASS: 1.4 ± 1.4 cm
- Galileo: 5.1 ± 5.5 cm
- BeiDou, MEO: 13.6 ± 22.7 cm
BeiDou – Open Issues

- Limited coverage of GEO/IGSO satellites by current MGEX network
- Lacking information on antenna phase center offsets and attitude modes
- No maneuver information (NABUs?)
- Will B3 signal remain accessible for tracking?
- Need common standard for clock offsets
  - All receivers provide B1/B2, only a subset offers also B3
  - B3 used for broadcast clocks
  - ACs (may) employ different conventions for intersystem biases
- Support SLR tracking for all BeiDou satellites!?
Inter-System-Bias (CODE): BeiDou

CUT0

http://igs.org

EUREF 2014
Inter-System-Bias (CODE): BeiDou

http://igs.org
The CODE-MGEX solution is referring to:

- **GPS**: C1P/C2P
- **Galileo**: C1X/C5X
- **BeiDou**: C2I/C7I

If other groups are using difference observation types, the **Differential Code Biases** become relevant.

MGEX DCB Products are available in Bias SINEX format:

- **Supported constellations**: GPS, GLO, BDS, GAL
- **Available at**:
  
There are several groups of satellites that are expected only marginally relevant for EUREF because of their «location»:

- **QZSS**: Quasi Zenith Satellite System, Japan
- **IRNSS**: Indian Regional Navigation Satellite System
- **IGSO, GEO** for BeiDou

These satellites are not or at least only visible in low elevations for (Central) European stations. Their contribution to EPN products is consequently limited.
Standardization Efforts

- Continued interactions of MGWG with:
  - GNSS system providers
  - Equipment manufacturers
  - Other IGS Working Groups (Ant WG, Bias WG, RT WG)

- Recommendations, conventions and processing standards:
  - Attitude models
  - Antenna offsets and patterns
  - SRP models

- Data formats:
  - Observations and navigation data (RINEX 3.x, RTCM3.2)
  - Biases (SINEX?)
  - Orbits and attitude (ORBEX?)
IGS MGEX – http://igs.org/mgex/

- Central portal for MGEX related information
- Entry point for data and product servers

Welcome to the Home Page of the IGS Multi-GNSS Experiment!

Scope

The Multi-GNSS Experiment (MGEX) has been set-up by the IGS to track, collate and analyze all available GNSS signals. This includes signals from the BeiDou, Galileo and QZSS systems, as well as from modernized GPS and GLONASS satellites and any space-based augmentation system (SBAS) of interest. Analysis centers will attempt to estimate inter-system calibration biases, compare equipment performance and further develop processing software capable of handling multiple GNSS observation data.

MGEX News

2013/05/29 – New multi-GNSS broadcast ephemeris product made available (see section Products)
2013/05/29 – Various new stations have been added to the MGEX network by CNES (REGINA network), CLR (CONGO network), and OFZ as well as individual providers (see section Network). A total of 74 stations is now available, most of which offer real-time data streams in addition to offline RINEX data.
2012/09/01 – All participating institutions have now transitioned to the RINEX3 format for observation and navigation files submitted to the MGEX data archives. RINEX2 has been discontinued for MGEX purposes (but continues to be used for the operational IGS network).
2012/12/17 – First release of QZSS products by JAXA (see section Products)
2012/11/10 – Provision of orbit and clock products for Galileo and QZSS (see section Products)
2012/11/18 – Revised interactive network map (see section Network)
2012/11/18 – Draft parameters for BeiDou processing (see BeiDou page)
2012/11/20 – Recommended parameters for Galileo and GIOVE processing (see Galileo page)
2012/11/20 – Recommended parameters for QZSS processing (see QZSS page)

Constellation Status

Status information for the various navigation satellite systems can be obtained by clicking on the icons below. Primary attention is given to the emerging constellations that are currently deployed and undergoing initial validation.

Network

An overview of the current MGEX network is shown in the map below. For detailed information on individual stations see the MGEX station list. The latest site logs are available from the IGS MGEX site log archive.

http://igs.org