Towards a Multi-Constellation combination

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Combination Software

- Combination software based on the method developed by Springer & Beutler (1993), and Kouba et al. (1994)

- The current IGS final products are GPS-only

- A strong limitation for end users who want to perform Multi-GNSS processing

\[ x, y, z, \delta t \] ?
# MGEX Analysis Centers Used

<table>
<thead>
<tr>
<th>intern. ID</th>
<th>Name</th>
<th>Country</th>
<th>GNSS processed</th>
<th>1st epoch used</th>
</tr>
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<tbody>
<tr>
<td>com</td>
<td>CODE</td>
<td>Swi./Ger.</td>
<td>G,R,E,C,J</td>
<td>w1690 (2012/05)</td>
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<td>G,R,E</td>
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<td>jam</td>
<td>JAXA</td>
<td>Japan</td>
<td>G,R,J</td>
<td>w1945 (2017/04)</td>
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<tr>
<td>wum</td>
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<td>China</td>
<td>G,R,E,C,J</td>
<td>w1722 (2013/01)</td>
</tr>
</tbody>
</table>
RMS for Orbit Combination

Final Orbits RMS - All Satellites

NB : No pole alignment for some ACs
RMS for Orbits Combination

Final Orbits RMS - GPS Satellites

Final Orbits RMS - Galileo Satellites
Prototype for a new combination strategy

- Developed in Python 3
- Based on the same theory so far
- Designed to add easily new functionalities
RMS for Orbit Combination
RMS for Orbits Combination
Further developments

- Weights according to the constellations
- Considering the different ACs' processing parameters (Orbit modeling ...) as annex weight information.
- Alignment to the ITRF based on ground station coordinates (Needs of SINEX)
- Combination of clocks
New combination software

Final Orbits RMS - All Satellites

Preliminary results

cmg = Combination Multi-GNSS

reference: Multi-GNSS Combination produced with the official software
Summary & Perspectives

- Orbit combination: ~30mm RMS w.r.t individual ACs
  ~10mm RMS w.r.t. IGS Final Combi.
- Can be improved with pole alignment for all ACs
- Clock combination is unstable so far
- Instabilities during recent weeks (lot of exclusions)

- A new software is under development, for an easier implementation of new features

But …

- What is the level of “emergency”?
- Should be the result of a collective discussion
RMS for Orbit Combination

Final Orbits RMS - All Satellites

Days
RMS (mm)

2014-08 2015-02 2015-08 2016-02 2016-08 2017-02 2017-08 2018-02

com gbm igs wum grm jam
Clock offsets Combination Summary

- **Step 1**: Radial correction (Ferland, 1999)
- **Step 2**: Alignment to a reference AC clock
- **Step 3**: Combination (weighted mean)
- **Step 4**: Outlier detection & weight computation
  - Iterative process: back to Step 3 while there is still outliers
RMS for Orbit Combination

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Final Orbits RMS - All Satellites

NB: No pole alignment for some ACs
RMS for Orbits Combination

"historical" constellations
RMS for Orbits Combination

"historical" constellations
RMS for Orbit Combination

"New" constellations

Final Orbits RMS - Galileo Satellites

Final Orbits RMS - BeiDou Satellites

Final Orbits RMS - QZSS Satellites
RMS for Orbit Combination

“New” constellations
Orbit Combination Summary

- **Step 1:** Alignment of each AC pole to the ITRF Combination Center one

- **Step 2:** First unweighted combination
  - Get a mean position for each satellite & epoch
  - Perform an Helmert Transformation b/w the mean and each AC
  - Compute **weights** for each **AC & Satellite**, based on differences between mean and the Helmert-transformed AC

- **Step 3:** weighted combination
  - Compute a new mean based on the weights
  - Perform an Helmert Transformation b/w the weighted mean and each AC, using the satellite weights
  - Compute a final mean based on the 2nd Helmert-transformed AC and AC weights