IGS08: Elaboration, consequences and maintenance of the IGS realization of ITRF2008

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History of IGS reference frames

- Since 2000, the IGS has used its own realizations of the successive ITRFs as reference for its products.
- A new reference frame (RF) based on ITRF2008, IGS08, will be adopted as of week 1632 (17 April 2011).
Elaboration of IGS08

• Initially intended to be a subset of « good » GNSS stations from ITRF2008
  (Their actual positions should remain close to the ITRF2008 linear model.)

• A selection was made based on the ITRF2008 results:
  - Data span (> 5 yr)
  - Maximum time span between two discontinuities (> 3 yr)
  - Number of discontinuities (< 5)
  - Absence of velocity discontinuities
  - Standard deviation of velocity (< 0.3 mm/yr)
  - Residual time series (RMS + visual inspection)

• When possible, preference was given to stations with special equipment:
  - Robot-calibrated antennas
  - GPS+GLONASS capability
  - External atomic clock
  - Co-location with other techniques
Full IGS08 network: 232 stations; global coverage, but heterogeneous density
Ground antenna calibration updates

- An updated set of antenna calibrations, igs08.atx, will be adopted together with IGS08.
  - 15 new robot calibrations (+9 copies for similar antenna types)
  - 46 updated robot calibrations
  - All converted calibrations updated
  - ... (more in IGSMAIL-6355)

- Implication for IGS08:
  - ITRF2008 made indirect use of the igs05.atx calibrations.
  - But IGS08 has to be consistent with the latest igs08.atx calibrations.
  - Stations affected by calibration updates should either be dropped from IGS08 or have their ITRF2008 coordinates corrected.

- Remark:
  - The same problem had to be solved with the transition from (ITRF2005; relative calibrations) to (IGS05; absolute calibrations).
  - Differences are much smaller from (ITRF2008; igs05.atx) to (IGS08; igs08.atx).
  - Future convergence of ground antenna calibrations is expected but uncertain.
Ground antenna calibration updates

• Impact on IGS08 station coordinates assessed by:
  - PPP tests (IGN, ESA, CNES)
  - Parallel solutions from 8 Analysis Centers

• Good overall agreement
  (Although fixing ambiguities has a noticeable impact for some antenna types.)
Ground antenna calibration updates

- Corrections derived from the IGN PPP tests were finally applied to the ITRF2008 coordinates of 65 stations (87 different time spans).
- IGS08 was NOT re-aligned to ITRF2008.
IGS05 → IGS08 transformation

• Total transformation =

  Global Helmert transformation due to the ITRF2005 → ITRF2008 datum change \((1)\)
  + Station-specific corrections due to ground antenna calibration updates \((2)\)

• IGS05 → IGS08 transformation parameters estimated using 118 stations:
  - *** These parameters only describe part (1) of the total transformation. ***
    (A version of IGS08 in which coordinate corrections had NOT been applied was used.)
  - ITRF2005 → ITRF2008 transformation parameters are given in blue for comparison.

<table>
<thead>
<tr>
<th>Transformation parameters at epoch 2005.0</th>
<th>TX (mm)</th>
<th>TY (mm)</th>
<th>TZ (mm)</th>
<th>SC (ppb)</th>
<th>RX (mas)</th>
<th>RY (mas)</th>
<th>RZ (mas)</th>
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</thead>
<tbody>
<tr>
<td>TX (mm)</td>
<td>1.5</td>
<td>-0.0</td>
<td>5.8</td>
<td>-1.04</td>
<td>-0.012</td>
<td>0.014</td>
<td>0.014</td>
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<tr>
<td>TY (mm)</td>
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<td>0.9</td>
<td>4.7</td>
<td>-0.94</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
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<tr>
<td>TZ (mm)</td>
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<td>0.2</td>
<td>0.2</td>
<td>0.04</td>
<td>0.009</td>
<td>0.009</td>
<td>0.010</td>
</tr>
<tr>
<td>Rates of transformation parameters</td>
<td>dTX (mm/y)</td>
<td>dTY (mm/y)</td>
<td>dTZ (mm/y)</td>
<td>dSC (ppb/y)</td>
<td>dRX (mas/y)</td>
<td>dRY (mas/y)</td>
<td>dRZ (mas/y)</td>
</tr>
<tr>
<td></td>
<td>-0.1</td>
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<td>-0.1</td>
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<td>0.04</td>
<td>0.009</td>
<td>0.009</td>
<td>0.010</td>
</tr>
</tbody>
</table>
IGS05 → IGS08: Advice to users

- How to transform results from the (IGS05; igs05.atx) framework to the (IGS08; igs08.atx) framework?

- Because of the ground antenna calibration updates, a direct Helmert alignment to IGS08 is not appropriate.

- Proposed method:
  1) Correct station positions to account for the calibration updates
     - Latitude-dependent models for the impact of calibration updates on station coordinates are available.
     - Perl scripts from J. Griffiths can be used to compute and apply corrections from these models.
     - More in IGSMAIL-6356
  
  2) Helmert alignment to IGS08
Satellite antenna calibration updates

• Computation of new satellite z-PCOs was necessary because of:
  – the -1 ppb scale difference between IGS08 and IGS05,
  – the correlation between satellite z-PCOs and the terrestrial scale.

• GLONASS PCVs were re-estimated. (But GPS PCVs are unchanged.)

• Procedure for GPS:
  – Reprocessed SINEX solutions from 5 ACs
  – Remove constraints
  – Apply constraints in scale, origin and orientation wrt ITRF2008
  – Weighted average over time and ACs

• Procedure for GLONASS:
  – Reprocessed GNSS solutions from CODE and ESA
  – Re-estimation of z-PCOs and PCVs
  – Solutions aligned to IGS08
  – GPS satellite antenna corrections kept fixed
IGS08 core network

- **Motivation:**
  - When stacking global solutions aligned to an inhomogeneous RF, parts of the geophysical or local signals are absorbed by the Helmert transformation parameters.
  - Station-dependent annual signals can be reduced/amplified and/or shifted.

- This aliasing can be reduced by using a well-distributed RF. (Collilieux et al., 2010)

- **IGS08 core network = well-distributed sub-network of IGS08**
  - 91 primary stations
  - Up to 4 substitute stations for each primary station

- Recommended for any alignment of a global solution to IGS08

- Will be used to align the IGS weekly combined solutions
IGS08 core network

The 91 primary stations of the IGS08 core network
IGS08 core network

Simulations using synthetic data:

Differences at the annual frequency between true values & residuals of a 7-parameter transformation:

\[ x(t) = \ln \cos(\omega t) + \text{Out} \sin(\omega t) \]

<table>
<thead>
<tr>
<th></th>
<th>East</th>
<th></th>
<th>North</th>
<th></th>
<th>Up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In (mm)</td>
<td>Out (mm)</td>
<td>In (mm)</td>
<td>Out (mm)</td>
<td>In (mm)</td>
</tr>
<tr>
<td>Full IGS08</td>
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<td>0.3</td>
<td>0.4</td>
<td>0.2</td>
<td>1.0</td>
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<tr>
<td>IGS08 core</td>
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<td>0.2</td>
<td>0.1</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Weekly translations and scale factors:
- **Full IGS08**
- **IGS08 core**

Annual signals are better retrieved if « IGS08 core » is used instead of the full IGS08 network.

Loading model includes:
- Atmospheric loading
- Non-tidal ocean loading
- Continental water loading

(T. van Dam, University of Luxembourg)
IGS08 decay

- Many IGS08 stations were subjected to discontinuities since 2009.5.

- Week 1627 (19 March 2011):
  - 153 / 232 usable IGS08 stations (see map)
  - 65 / 91 usable core stations

- Rate of loss seems to accelerate.
Proposal for IGS08 updates

• To avoid a future crisis situation for the IGS products, it will probably be necessary to consider regular updates of IGS08 before the next ITRF release.

• Suggestion to overcome discontinuities:
  - Some months after a discontinuity occurred, compute an offset using the IGS cumulative solution:
    \[ dX = X_{after(IGS\ cum.)} - X_{before(IGS\ cum.)} \]
  - Introduce post-discontinuity coordinates in IGS08 using this offset:
    \[ X_{after(IGS08)} = X_{before(IGS08)} + dX \]
  - Only applicable if velocity is unchanged (no post-seismic deformation).

• Suggestion to overcome station substitutions:
  - When an old station is eventually decommissioned after having run several years in parallel with a new station at the same site, compute a « local tie » using the IGS cumulative solution:
    \[ dX = X_{new(IGS\ cum.)} - X_{old(IGS\ cum.)} \]
  - Introduce the new station in IGS08 using this « local tie »:
    \[ X_{new(IGS08)} = X_{old(IGS08)} + dX \]
  - Only applicable if velocities are identical.

• In the IGS08 covariance matrix, new off-diagonal terms would be zero. But are they used by anyone?
Thanks for your attention!