New VLBI solutions at Analysis Center DGFI-TUM

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Outline

• DGFI-TUM as IVS Analysis Center
• Features of the new contribution *dgf2018a*
• Assessment of solutions
• Outlook and summary
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DGFI-TUM as IVS Analysis Center

- DGFI-TUM is an operational IVS Analysis Center (AC) since November 2008.

- Daily SINEX products:
  - dgf2007a: with DGFI-branch of OCCAM (D-OCCAM).
  - dgf2008a: D-OCCAM.
  - dgf2017b: with proprietary software DOGS-RI, for validation.
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DOGS-RI: the new VLBI software at DGFI-TUM

- DOGS-RI is part of the DGFI Orbit and Geodetic parameter estimation Software (DOGS) package written in FORTRAN:

**DOGS-RI (Radio Interferometry)**

VLBI: observation equations (O EQ), normal equations (NEQ), solutions (SOL)

**DOGS-OC (Orbit Computation)**

DORIS, SLR: O EQ, NEQ, SOL

**DOGS-CS (Combination & Solution):** combination of datum-free NEQ

SINEX: GNSS NEQ  
SINEX: VLBI NEQ  
SINEX: DORIS NEQ  
SINEX: SLR NEQ  
SINEX: . . . NEQ
DOGS-RI: workflow

**INPUT**

- classic NGS (Mk3)
- vgosDB
- Additional files:
  - observation data
  - station data
  - a-priori parameter values
  - ephemerides
  ...

**LEAST-SQUARES MINIMIZATION**

- estimates corrections to:
  - station coordinates
  - source coordinates
  - Earth orientation parameters (EOP)
  - tropospheric parameters
  - station clock parameters

- optional constraints:
  - datum (NNT / NNR / NNS)
  - ...

- three step approach:
  1) create / solve normal equation (NEQ)
  2) determine observation outliers
  3) create / solve new NEQ with reduced outlier weights

**OUTPUT**

- SINEX format: datum-free NEQ
- DOGS-CS format: datum-free NEQ
- standalone format: (constrained) NEQ observation equations solution equations
In general, DOGS-RI has a greater set of available models, observation exclusion options and mathematical parametrizations than D-OCCAM.

<table>
<thead>
<tr>
<th></th>
<th>dgf2018a</th>
<th>dgf2009a</th>
</tr>
</thead>
<tbody>
<tr>
<td>observation data format</td>
<td>NGS (Mk3)</td>
<td>NGS (Mk3)</td>
</tr>
<tr>
<td>nutation parameters</td>
<td>$\Delta X_{CIP}, \Delta Y_{CIP}$ (CIO based)</td>
<td>$\Delta \psi, \Delta \epsilon$ (equinox based)</td>
</tr>
<tr>
<td>a-priori station coord.</td>
<td>ITRF2014</td>
<td>VTRF2008</td>
</tr>
<tr>
<td>a-priori EOP</td>
<td>IERS 14 C04</td>
<td>IERS 08 C04</td>
</tr>
<tr>
<td>a-priori gradients</td>
<td>GSFC / TU Vienna</td>
<td>zero</td>
</tr>
<tr>
<td>IERS Conventions</td>
<td>2010</td>
<td>2003</td>
</tr>
<tr>
<td>atmosphere loading</td>
<td>Petrov &amp; Boy (2003)</td>
<td>n/a</td>
</tr>
<tr>
<td>delay model</td>
<td>IERS 1996</td>
<td>IERS 1992</td>
</tr>
</tbody>
</table>
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The estimated EOP values were taken directly from the AC’s *daily-sinex* files. Outliers with $\Delta x_{pol} > 10 \text{ mas}$ have been removed.
The estimated EOP values were taken directly from the AC's *daily-sinex* files. Outliers with $\Delta(UT1 - UTC) > 1\,ms$ have been removed.
Weighted mean for differences w.r.t. IERS 14 C04

<table>
<thead>
<tr>
<th>EOP</th>
<th>AC1</th>
<th>AC2</th>
<th>AC3</th>
<th>AC4</th>
<th>dgf2018a</th>
<th>ivs2017a</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_{pol}$ [mas]</td>
<td>0.05744</td>
<td>0.00606</td>
<td>0.01231</td>
<td>-0.00873</td>
<td>-0.01940</td>
<td>0.00299</td>
</tr>
<tr>
<td>$\dot{x}_{pol}$ [mas/d]</td>
<td>0.02476</td>
<td>0.02584</td>
<td>0.02015</td>
<td><strong>0.01484</strong></td>
<td><strong>0.02833</strong></td>
<td>0.02602</td>
</tr>
<tr>
<td>$y_{pol}$ [mas]</td>
<td><strong>0.25763</strong></td>
<td>-0.01996</td>
<td>-0.03460</td>
<td>-0.01763</td>
<td><strong>-0.00959</strong></td>
<td>-0.00984</td>
</tr>
<tr>
<td>$\dot{y}_{pol}$ [mas/d]</td>
<td><strong>0.01333</strong></td>
<td>-0.00026</td>
<td><strong>-0.00003</strong></td>
<td>0.01054</td>
<td>0.01322</td>
<td>0.00730</td>
</tr>
<tr>
<td>$DUT1$ [ms]</td>
<td>0.00200</td>
<td><strong>-0.00037</strong></td>
<td>-0.00132</td>
<td><strong>-0.00522</strong></td>
<td>-0.00226</td>
<td>-0.00077</td>
</tr>
<tr>
<td>$LOD$ [ms/d]</td>
<td><strong>-0.00030</strong></td>
<td>-0.00100</td>
<td>-0.00106</td>
<td><strong>0.00200</strong></td>
<td>0.00123</td>
<td>-0.00135</td>
</tr>
<tr>
<td>$\Delta X_{CIP}$ [mas]</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td><strong>0.02337</strong></td>
<td>0.01998</td>
<td><strong>0.00658</strong></td>
</tr>
<tr>
<td>$\Delta Y_{CIP}$ [mas]</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>-0.00692</td>
<td><strong>-0.00470</strong></td>
<td><strong>-0.00757</strong></td>
</tr>
</tbody>
</table>

- For each EOP, *dgf2018a* has a WMEAN similar to those of the other ACs and the combined solution *ivs2017a* (n/a = different parameter provided).
WRMS for differences w.r.t. IERS 14 C04

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<th>ivs2017a</th>
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</thead>
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<tr>
<td>$x_{pol}$ [mas]</td>
<td>0.16524</td>
<td>0.15072</td>
<td>0.13215</td>
<td>0.15584</td>
<td>0.14788</td>
<td>0.08005</td>
</tr>
<tr>
<td>$\dot{x}_{pol}$ [mas/d]</td>
<td>0.29647</td>
<td>0.25791</td>
<td>0.27315</td>
<td><strong>0.31728</strong></td>
<td>0.29105</td>
<td><strong>0.23201</strong></td>
</tr>
<tr>
<td>$y_{pol}$ [mas]</td>
<td><strong>0.19391</strong></td>
<td>0.16169</td>
<td>0.13461</td>
<td>0.17650</td>
<td>0.15703</td>
<td><strong>0.07625</strong></td>
</tr>
<tr>
<td>$\dot{y}_{pol}$ [mas/d]</td>
<td>0.28835</td>
<td>0.25398</td>
<td>0.26846</td>
<td><strong>0.32212</strong></td>
<td>0.29100</td>
<td><strong>0.23072</strong></td>
</tr>
<tr>
<td>$DUT1$ [ms]</td>
<td>0.01540</td>
<td><strong>0.01853</strong></td>
<td>0.01479</td>
<td>0.01641</td>
<td>0.01436</td>
<td><strong>0.00965</strong></td>
</tr>
<tr>
<td>$LOD$ [ms/d]</td>
<td><strong>0.01937</strong></td>
<td>0.01727</td>
<td>0.01765</td>
<td>0.01858</td>
<td>0.01890</td>
<td><strong>0.01617</strong></td>
</tr>
<tr>
<td>$\Delta X_{CIP}$ [mas]</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td><strong>0.16802</strong></td>
<td>0.13749</td>
<td><strong>0.03287</strong></td>
</tr>
<tr>
<td>$\Delta Y_{CIP}$ [mas]</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td><strong>0.15276</strong></td>
<td>0.13854</td>
<td><strong>0.03581</strong></td>
</tr>
</tbody>
</table>

- For each EOP, $dgf2018a$ has a WRMS within the range of the other ACs and the combined solution $ivs2017a$ (n/a = different parameter provided).
Assessment of station coordinates: NYALES20 (1)

- Estimated cartesian station coordinates were taken directly from the *daily-sinex* files of the ACs and transformed into spherical coordinates.
Assessment of station coordinates: NYALES20 (2)

• Greatest variation for up-coordinate, $dgf2018a$ is in line with most ACs.
The estimated source coordinates were taken directly from the *daily-sinex* files of the ACs. Again, *dgf2018a* provides matching parameters.
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NGS (Mk3) vs. vgosDB

- The vgosDB interface for DOGS-RI is basically working. However, there are some open issues.

- The conversion step between Mk3 DB and NGS file adds, for example:
  - formal error per baseline,
  - missing meteorological data.

- The corresponding routines are currently transferred to the vgosDB-DOGS-RI interface.
Summary

- *dgf2018a* is DGFI-TUM’s latest IVS contribution.

- It is computed with our proprietary VLBI software DOGS-RI, which makes use of the current IERS Conventions 2010.

- The parameters estimated with DOGS-RI are in line with those of the other IVS Analysis Centers.

- *dgf2018a* is still calculated from the NGS (Mk3) data format. There will probably be a new contribution ID with the switch to vgosDB.
Thank you for your attention!

Are there any questions?