DGFI part of project PN 5: status report

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DFG Research Unit FOR1503
Bonn, 13.06.2016
VLBI processing software DOGS-RI

- participation in the "VLBI Analysis Software Comparison Campaign 2015" organized by the Chalmers University of Technology with OCCAM and DOGS-RI
- submission of DOGS-RI test solutions (one year of data?) to the IVS Combination Center for validation
- parallel submission of OCCAM and DOGS-RI solutions for the routine R1 and R4 sessions
- switch from OCCAM to DOGS-RI
- reprocessing with DOGS-RI using the OCCAM preprocessing options
VLBI Analysis Software Comparison Campaign (1)

- initiated by the Chalmers University of Technology (Sweden)
- comparison of theoretical delays computed by different software packages:
  \[ \tau_{\text{computed}} = \tau_{\text{geometric}} + \tau_{\text{grav}} + \tau_{\text{trop}} + \tau_{\text{AO}} + \tau_{\text{therm_def}} \]
- 11 institutions with 11 different software packages participated
- first results were presented at the IVS General Meeting in March 2016
### VLBI Analysis Software Comparison Campaign (2)

<table>
<thead>
<tr>
<th></th>
<th>Calc11(GSFC)</th>
<th>c5++</th>
<th>DOGS-RI</th>
<th>ivg::ASCOT</th>
<th>SCORR</th>
<th>VieVS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calc11(GSFC)</td>
<td>x</td>
<td>0.43</td>
<td>-</td>
<td>0.38</td>
<td>0.57</td>
<td>0.44</td>
</tr>
<tr>
<td>c5++</td>
<td>-</td>
<td>x</td>
<td>0.61</td>
<td>0.17</td>
<td>0.44</td>
<td>0.22</td>
</tr>
<tr>
<td>DOGS-RI</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>0.59</td>
<td>0.71</td>
<td>0.59</td>
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<tr>
<td>ivg::ASCOT</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>0.41</td>
<td>0.17</td>
</tr>
<tr>
<td>SCORR</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>0.44</td>
</tr>
<tr>
<td>VieVS</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
</tr>
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</table>

#### RMS of residuals between delays from different software packages for a fictitious 2-week campaign (Klopotek et al. 2016)
OCCAM reprocessing (1)

significant DGFI bias (green) prior to 2009 (Hannover meeting, Feb 2015)
OCCAM reprocessing (2)

reduced bias after reprocessing (2005-2009)
## Combined multi-year reference frame

<table>
<thead>
<tr>
<th></th>
<th>GNSS</th>
<th>SLR</th>
<th>VLBI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Institution</strong></td>
<td>CODE</td>
<td>DGFI-TUM</td>
<td>DGFI-TUM</td>
</tr>
<tr>
<td><strong>Software</strong></td>
<td>Bernese</td>
<td>DOGS-OC</td>
<td>OCCAM</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>daily</td>
<td>weekly</td>
<td>session-wise</td>
</tr>
<tr>
<td><strong>Time span</strong></td>
<td>January 2005 - December 2015</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Datum conditions (station coord.)</strong></td>
<td>NNR/NNT/NNS</td>
<td>NNR</td>
<td>NNR/NNT</td>
</tr>
<tr>
<td><strong>Coord. jumps</strong></td>
<td>according to DTRF2014 processing</td>
<td></td>
<td></td>
</tr>
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</table>
Solution characteristics

GNSS:
- CODE contribution to repro2/ITRF2014 ("cf2"), complemented by operational solutions ("cof") for the latest months

SLR:
- DGFI-TUM solution based on LAGEOS-1/2
- 7-day orbits
- stations with less than 10 normal points excluded

VLBI:
- DGFI-TUM solution considering more than 1550 24-hour sessions (all types of sessions)
- stations contained in less than 10 sessions excluded
- NNR condition w.r.t. ICRF2 defining sources
- special handling sources treated as arc parameters
Second epoch VLBA Calibrator Survey (VCS-II)

- 8 Very Long Baseline Array (VLBA) sessions observed between January 2014 and March 2015
- data made available in March 2016
- about 2400 VCS-only sources reobserved (> 300 sources per session)
- position uncertainties reduced by a factor of about 5 compared to VCS-I (Gordon et al. 2016)

Petrov et al. (2009)
Radio sources (1)

Frankfurt meeting: 1851 sources
Radio sources (2)

Frankfurt meeting: 1851 sources
Bonn meeting: 3518 sources
Coordinate corrections (compared to a priori values)
Standard deviations

VLBI-only TRF/CRF

- STD (DE) [mas]
- STD (RA) * cos(DE) [mas]

- n(obs) <= 2
- n(obs) >= 3
- defining sources

declination DE [deg]
## Local tie (LT) selection (1)

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<tr>
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<th>$\Delta LT &lt; 3,\text{cm}$</th>
<th>$\Delta LT &lt; 5,\text{cm}$</th>
<th>$\Delta LT &lt; 10,\text{cm}$</th>
<th>$\Delta LT &lt; 100,\text{cm}$</th>
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<td>Intra-technique</td>
<td>34</td>
<td>40</td>
<td>44</td>
<td>50</td>
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<tr>
<td>GPS/VLBI</td>
<td>20</td>
<td>44</td>
<td>51</td>
<td>116</td>
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<td>21</td>
<td>46</td>
<td>53</td>
<td>81</td>
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<td>SLR/VLBI</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>79</td>
<td>136</td>
<td>155</td>
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## Local tie (LT) selection (1)

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### Weighting:

- $\sigma_{LT} = 0.2 \cdot \Delta LT$
- $\lambda_{GPS} = 0.34$
- $\lambda_{VLBI} = \lambda_{SLR} = 1.0$
Local tie (LT) selection (2): $\Delta LT < 5 \text{ cm}$
Local tie (LT) selection (3): $\Delta LT < 100$ cm
Combination: impact on standard deviations

For the combination of TRF/CRF (A) and (B) with VLBI-only, the impact on standard deviations is shown. The plots illustrate the difference in declination DE for different observing conditions and source numbers.
Combination: impact on source positions

- **comb. TRF/CRF (A) – VLBI-only**
  - $\Delta \text{DE [mas]}$ vs. declination $\text{DE [deg]}$
  - $\Delta \text{RA \times cos(DE) [mas]}$ vs. declination $\text{DE [deg]}$

- **comb. TRF/CRF (B) – comb. TRF/CRF (A)**
  - $\Delta \text{DE [mas]}$ vs. declination $\text{DE [deg]}$
  - $\Delta \text{RA \times cos(DE) [mas]}$ vs. declination $\text{DE [deg]}$

Legend:
- $\text{n(obs) } \leq 2$
- $\text{n(obs) } \geq 3$
- **defining sources**
Conclusions

• DOGS-RI ready for validation by the IVS Combination Center
• reduced biases for the reprocessed VLBI solution (back to August 2004) in the IVS combination
• combined 11-year TRF/CRF solution available (including > 3500 sources)
• inter-technique combination results in reduced standard deviations for the source positions
• combination has biggest impact on poorly observed sources
• further studies: impact of local tie selection/weighting; impact of combining Earth rotation parameters; impact of seasonal station motions; etc.