Several aspects concerning EOP combination

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Overview

1. Different parameterizations and continuity

2. Problem of reference epochs (VLBI vs. GNSS/SLR/DORIS) and impact of combination strategy

3. Daily vs. multi-year solutions for deriving EOP time series

4. UT/LOD: VLBI + GPS

All studies are based on the data of the
→ CONT02 campaign
→ project GGOS-D (for long time series)
Parameterization of EOPs

**Offset-only**
Piece-wise constant

- **n** parameters
- no continuity at boundaries
- continuity constraints not reasonable

**Piece-wise linear Offset+Drift**

- **2*n** parameters
- no continuity at boundaries
- continuity constraints reduce #parameters to **n+1**

**Piece-wise linear Polygon**

- **n+1** parameters
- “real” continuity at boundaries
- no continuity constraints needed
- not distinguishable from “offset-only” in SINEX
**Problems:**

a) 24-h VLBI Sessions **NOT 00:00 – 24:00 UTC**

⇒ Epoch of „daily“ EOPs different from 12:00 UTC

⇒ No clear correspondence to daily GPS-/SLR- EOP

b) **changing** reference epoch from session to session
EOP combination: Problem of reference epoch

No clear correspondence between validity intervals of *daily EOPs* derived from GPS/SLR and from VLBI 24-h sessions.

```
<table>
<thead>
<tr>
<th>Day</th>
<th>GPS</th>
<th>VLBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>0 h</td>
<td>Day 1</td>
</tr>
<tr>
<td>Day 2</td>
<td>0 h</td>
<td>Day 2</td>
</tr>
<tr>
<td>Day 3</td>
<td>0 h</td>
<td>Day 3</td>
</tr>
<tr>
<td></td>
<td>18 h</td>
<td>18 h</td>
</tr>
</tbody>
</table>
```
Reference epoch of EOP: Combination strategy

No clear correspondence between validity intervals of *daily EOPs* derived from GPS/SLR and from VLBI 24-h sessions.

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**Use offset only:**
- Offset is correctly included into time series
- „Mixture“ of validity intervals
- Contribution to one day only
- ERP drift is ignored

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**Use offset + drift:**
- Offset and drift information are used
- „Mixture“ of validity intervals
- Contribution to one day only
No clear correspondence between validity intervals of daily EOPs derived from GPS/SLR and from VLBI 24-h sessions

⇒ Can be avoided if higher temporal resolutions are used in the individual contributions:
→ At least splitting up at midnight (or even higher resolution)
→ Full ERP information is correctly included into time series
→ Equivalent to correct distribution of observations to individual ERPs
Reference epoch of EOP: Combination strategy

Comparing different solutions for y-pole

<table>
<thead>
<tr>
<th></th>
<th>Combination w.r.t. C04</th>
<th>Combination w.r.t. GPS-only</th>
<th>&quot;Correct&quot; Combination w.r.t. &quot;offset+drift&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRMS x-pole</td>
<td>89.8 μas</td>
<td>43.1 μas</td>
<td>18.2 μas</td>
</tr>
<tr>
<td>WRMS y-pole</td>
<td>82.0 μas</td>
<td>39.8 μas</td>
<td>18.3 μas</td>
</tr>
<tr>
<td>WRMS UT</td>
<td>18.4 μs</td>
<td>8.4 μs</td>
<td>6.6 μs</td>
</tr>
</tbody>
</table>
Daily vs. multi-year solutions

- **Daily solutions**: daily realization of TRF (station coordinates) → TRF slightly different from day to day

- **Multi-year solution**: TRF (station coordinates + velocities) together with EOPs → fully consistent time series

What is the impact on the time series of EOPs?
Daily vs. multi-year solutions for PM: GPS

Daily GPS – multi-year GPS: Bias = $-11.3 \, \mu\text{as}$, drift = $4.90 \, \mu\text{as/y}$, WRMS = $70.7 \, \mu\text{as}$

WRMS vs. IERS-C04:
- X-Pole 112.7 $\mu\text{as}$ (daily) $\rightarrow$ 98.0 $\mu\text{as}$ (multi-year)
- Y-Pole 109.9 $\mu\text{as}$ (daily) $\rightarrow$ 99.5 $\mu\text{as}$ (multi-year)

$\Rightarrow$ Early epochs benefit most from multi-year solution: small network, weak daily TRF
**Daily vs. multi-year solutions for PM: VLBI**

VLBI daily – VLBI multi-year: Bias = 19.2 μas, drift = −8.17 μas/y, WRMS = 177.8 μas

WRMS vs. IERS-C04:
- **X-Pole**: 155.6 μas (daily) → 109.0 μas (multi-year)
- **Y-Pole**: 195.4 μas (daily) → 100.7 μas (multi-year)

⇒ **All epochs** benefit from multi-year solution: generally small network, weak daily TRF
Daily vs. multi-year solutions for PM: Combination

Combined daily – combined multi-year: Bias = 0.6 µas, drift = 1.07 µas/y, WRMS = 76.7 µas

Δx-pole [mas]

X-pole: Differences to IERS-C04

X-pole [mas]

WRMS vs. IERS-C04:

- X-Pole 104.1 µas (daily) → 98.1 µas (multi-year)
- Y-Pole 100.4 µas (daily) → 96.0 µas (multi-year)

⇒ Early epochs benefit most from multi-year solution: small network, weak daily TRF
Daily vs. multi-year solutions for UT: VLBI

- Similar to pole coordinates
- All epochs benefit from multi-year solution: generally small network, weak daily TRF
Daily vs. multi-year solutions for UT: TRF combined

Session-wise combination: VLBI-only daily TRF weak ⇒ stabilization

UT1−UTC: Differences to IERS−C04

VLBI−only: WRMS = 8.8 µs
TRF combined: WRMS = 6.1 µs

Multi-year combination: VLBI-only TRF is already stable enough ⇒ no big impact

VLBI−only: WRMS = 5.6 µs
TRF comb: WRMS = 5.8 µs
Problems with daily realization of TRFs: *Number of Local Ties* (LT)

→ **LT per Session** in most cases very small

→ may be even reduced after selection of „good“ local ties

⇒ problematic for „VLBI-only parameters“ (*UT*, *nutation*)

⇒ Can be avoided if long-term solutions (multi-year) are computed

Total number of LT in ITRF2008 (after selection): **17**
UT/LOD combination: Continuous and sub-daily

**Continuous** VLBI contribution (CONT02) ⇒ No „GPS-only“ epochs in combination

**Sub-daily** resolution (1 h)

- **RMS VLBI-only:** 15.1 µs

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<th>Combined Parameters</th>
<th>RMS [µs]</th>
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<tr>
<td>TRF</td>
<td>15.2</td>
</tr>
<tr>
<td>TRF+Pole</td>
<td>14.8</td>
</tr>
<tr>
<td>TRF+Pole+UT/LOD</td>
<td>11.9</td>
</tr>
<tr>
<td>TRF+Pole+UT/LOD +Nut.+Trop.</td>
<td>11.6</td>
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⇒ Combination UT/LOD works fine ⇒ benefit for the resulting UT time series
UT/LOD combination: 24-h sessions

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**UT/LOD combination: 24-h sessions**

- **VLBI**: Epochs mid of session
- **VLBI**: Epochs 00:00 UTC
- **Combination**: Epochs stabilized by VLBI

The chart above illustrates the difference between UT1 and UTC over a period from January 2004 to May 2005. The table below summarizes the results for different solution types, including the number of epochs, mean bias, and WRMS.
UT/LOD combination: 24-h sessions

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<td>-0.6</td>
<td>11.3</td>
</tr>
<tr>
<td>Combination: All epochs</td>
<td>365</td>
<td>2.0</td>
<td>22.6</td>
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Summary

- Problem of different *reference epochs* (VLBI vs. satellite-techniques):
  → combination strategy is important

- ERPs from *long-term solutions* are more stable than *daily solutions*
  → especially if daily network is weak

- *Combination of UT/LOD* from VLBI and GPS is possible
  → continuous VLBI data (CONT campaigns)
  → epochs with contribution by VLBI
  → problems with “GPS-only” epochs (Densification: Intensive sessions)

**Further aspects** (not covered here):
- Densification for UT using VLBI Intensive sessions
- Nutation (similar to UT, but lower temporal resolution possible)
- Correlation between sub-daily polar motion and nutation
- EOP useful for selection of good local ties (→ Manuela)
Daily combination: Problems with „GPS-only“ epochs (similar to UT) ⇒ Use lower temporal resolution (7d, 14d, 28d); main signal is Free-Core Nutation (~432 d)