Combination of Space Geodetic Techniques for ITRF computation

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Outline

- Differences between combination on NEQ level and on observation level
- Combination strategy at the IERS CC at DGFI
- Special aspects of the combination
  - Weighting
  - Local tie selection
  - Daily TRF
    - Troposphere combination
- New combination technologies - space co-locations
Combination on NEQ level

Goal: combination of different space geodetic techniques using **consistently processed** observation data

- each data type (GPS/SLR/VLBI) is processed with two special analysis softwares, **but**

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<th>Bernese GPS Software 5.0 @ GFZ</th>
<th>EPOS @ GFZ</th>
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<tr>
<td>GPS</td>
<td>OCCAM @DGFI</td>
<td>Calc/Solve@IGG, Bonn</td>
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<tr>
<td>VLBI</td>
<td></td>
<td>DOGS-OC@DGFI</td>
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<tr>
<td>SLR</td>
<td>EPOS@GFZ</td>
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</tbody>
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- models and parameterizations are identical (homogenized software packages)

- combination on NEQ level ≈ **combination on observation level**
## Combination on NEQ level

### Comparison of combination on NEQ and on observation level
- if analysis softwares are homogenized

<table>
<thead>
<tr>
<th>NEQ level</th>
<th>Observation level</th>
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<td><strong>Consistent processing</strong> of the data using the same models and parameterization</td>
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<td>Appropriate <strong>relative weighting</strong> of the techniques</td>
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<td>Corrections to the <strong>original observations</strong> are estimated</td>
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<th><strong>Outlier detection</strong> and <strong>weighting</strong> of observations technique-wise</th>
<th>Outlier detection and weighting of observations within the combination process</th>
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<tr>
<td><strong>A priori reduced parameter</strong> cannot be handled anymore</td>
<td>All parameters are available</td>
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Combination strategy at DGFI

**Combination strategy at DGFI**

- **VLBI daily NEQs**
- **SLR weekly NEQs**
- **GPS daily NEQs**

**Time series analysis**
- Setting up station velocities and – if necessary – jumps
- Accumulation to one NEQ

**Combination**
- Local tie selection
- Weighting
- Datum definition
- Fixing radio source pos.

**Time series of epoch CRF/TRF**
- Weekly NEQ

**Local tie selection**
- Datum definition
- Fixing of radio source positions

**TRF/CRF solution**
- With station positions, velocities, EOP and radio source positions

**Time series of epoch TRF solutions**
Weighting

Necessary, because of “errors“ in the stochastic models
(differences between the estimated standard deviations
do not reflect the real precision differences)

Variance component estimation is not reliable:
- Only few common parameters (station coordinates) are available
- \(\text{vc} \) estimated via EOP must not be “valid“ for TRF
- unconsidered correlations between GPS observations cannot be considered

Variance components are derived empirically using
the condition:

\[
\frac{\partial_{\text{GPS}_{\text{TS}}}}{\partial_{\text{VLBI}_{\text{TS}}}} = \frac{\partial_{\text{GPS}_{\text{COV}}}}{\partial_{\text{VLBI}_{\text{COV}}}}
\]
Local Tie selection

A selection is necessary, because:

- partly large differences occur between local ties and coordinate solutions from GPS, VLBI and SLR

Reasons for the differences not clear: local tie? GPS? VLBI?

Changes from ITRF2005 to ITRF2008:

- GPS: switch from relative to absolute PCV
- VLBI: change of the mean pole for pole tide correction
Local Tie selection

Two points that have to be discussed:

1. Can local ties “correct“ a GPS, SLR, VLBI, DORIS derived station position?

- NO, they cannot. Discrepancies between tie and techniques will always lead to a deformation of the networks (the station with the larger formal error will be more shifted, close stations will be affected)

Local Ties are only used to connect the techniques. The network geometry resulting from the GPS, SLR, VLBI, DORIS should not be changed due to combination.

Criteria for local tie selection: deformation shall be minimized
Local Tie selection

2. If space geodetic techniques are combined, the information about the orientation of the networks is transferred via station coordinates and via EOP.

Consistency of the ITRF: if station networks are combined but not the EOP, the resulting pole coordinates (GPS\textsubscript{comb} TRF, VLBI\textsubscript{comb} TRF) are not allowed to show systematic differences!

Criteria for local tie selection: pole offsets must be minimized.
Local Tie selection

How to test the local ties w.r.t. the criteria?

- **Deformation**
  - RMS of 7-parameter similarity transformation between combined and single technique solution is a measure for the deformation

- **Pole offset**
  - TRF are combined, EOP series are not combined
  - Offset of the two estimated pole series (GPS, VLBI) is analysed
Local Tie selection

Local tie selection for ITRF2008 (GPS-VLBI)

Pole offset [mas]

Network deformation [mm]

σ tie
2.00 mm
1.00 mm
0.50 mm
0.10 mm
0.05 mm
0.01 mm

- σ tie not well known and
- network deformation shall be minimized

→ σ included in selection
Local Tie selection

Local tie selection for ITRF2008 (GPS-VLBI)

17 ties selected

pole difference ~ 0.5 mm
mean deformation <0.1 mm

- $\sigma$ tie not well known and
- network deformation shall be minimized
  $\rightarrow$ $\sigma$ included in selection
Local Tie selection

Can other criteria corroborate the selection?

Mean common observation time

Larger differences between GPS/VLBI and local tie shorter common observation time
Local Tie selection

Mean standard deviation of GPS/VLBI position

- Larger differences between GPS/VLBI and local tie
- Larger standard deviations for GPS and VLBI station positions
Daily TRF

Advantage

time variability of station positions (height) can be considered with high accuracy

Modeling of station displacement is not sufficient at some epochs.

RMS of the difference = 3.7mm
Daily TRF

Disadvantages

- long term stability and precision are not as good as for the ITRF
- EOP time series show a larger noise level
- no UT1-UTC parameters for days without contributions of VLBI

presentation by Daniela Thaller

Can the daily combined TRF benefit from an additional combination of the tropospheric parameters?
Troposphere combination

Estimated tropospheric zenith delay (wet part)

Ny Alesund: north-south gradient
Daily TRF

Troposphere combination

Change of station height repeatabilities

Especially stations located far away benefit from the troposphere combination.
Space co-locations

SLR observations of GNSS satellites

- via on board co-location: vector between reflector / GNSS antenna and the center of mass of the satellite

- common adjustment of
  orbits: SLR and GNSS
  TRF: SLR and GNSS stations
  EOP
  (in Bernese @ AIUB)

- advantage: scale can be gained from SLR

→ results are very promising
Space co-locations

SLR observations of GPS satellites
3D – Differences between local ties and GNSS - SLR TRFs

Solution characteristics
- 6 GNSS satellites
- one year of data
- satellite PCO for GNSS estimated
- no local ties introduced
Combination on **NEQ level** is a good approximation of the combination on observation level if the **software packages** used for the GPS, VLBI, SLR, … analysis are **homogenized**.

Combination strategy at DGFI
- Variance factors are derived empirically
- Local tie selection is based on the
  - minimizing of pole offset and deformation of the networks
- Daily TRF
  - station variation is approximated well, but EOP have a larger noise level *(presentation by Daniela Thaller)*
  - benefit from troposphere combination

Combination of SLR and GNSS via space-ties provides promising results
Daily TRF

Troposphere combination

\[ ZD(e) = mf_{dry} ZD_{dry} + mf_{wet} ZWD + G_{NS} + G_{EW} \]

zenith delay
- a priori: hydrostatic part \( ZD_{dry} \)
- estimated: wet part \( ZWD \)

gradients
- \( G_{NS} \): north-south gradient
- \( G_{EW} \): east-west gradient

\[ ZD = ZD_{dry} + ZWD \]

\[ \Delta H = \frac{ZWD_{GPS} - ZWD_{VLBI}}{f(\Delta H, e, T)} \]

modeled according to Brunner, TU Graz
Combination on NEQ level

**GGOS-D project** - a project of four German institutes

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