Combination of Space Geodetic Techniques for ITRF computation

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Workshop on combination on observation level,
21./22.10.09, Warsaw

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

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Combination on NEQ level

GGOS-D http://www.ggos-d.de **project** - a project of GFZ, DGFI, IGG and BKG

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**

GPS	Bernese GPS Software 5.0 @ GFZ	EPOS @ GFZ
VLBI	OCCAM @DGFI	Calc/Solve@IGG, Bonn
SLR	EPOS@GFZ	DOGS-OC@DGFI

- models and parameterizations are identical (homogenized software packages)
- combination on NEQ level **≈ combination on observation level**

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Combination on NEQ level

Comparison of combination on NEQ and on observation level

- if analysis softwares are homogenized

NEQ level	Observation level
Consistent processing of the data using the same models and parameterization	
Appropriate **relative weighting** of the techniques	
Corrections to the **original observations** are estimated	
Outlier detection and **weighting** of observations technique-wise	Outlier detection and weighting of observations within the combination process
A priori **reduced parameter** cannot be handled anymore	All parameters are available

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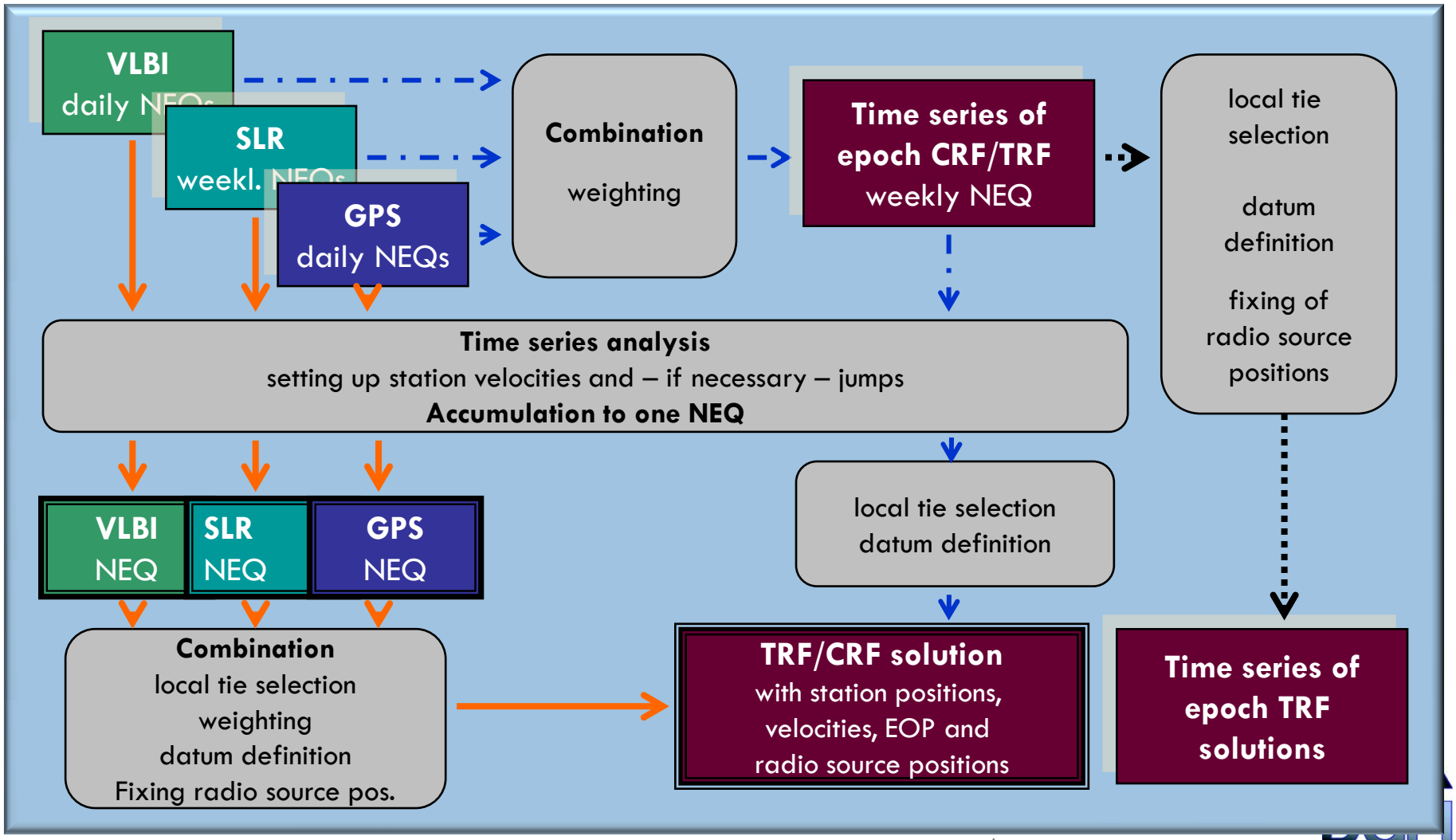
Combination strategy at DGFI



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
- vc estimat
- unconside
  considere

Standard deviation from station time series

Standard deviation from COV matrix

Variance components are derived empirically using the condition:

$$\frac{\partial_{GPS\,TS}}{\partial_{VLBI\,TS}} = \frac{\partial_{GPS\,COV}}{\partial_{VLBI\,COV}}$$

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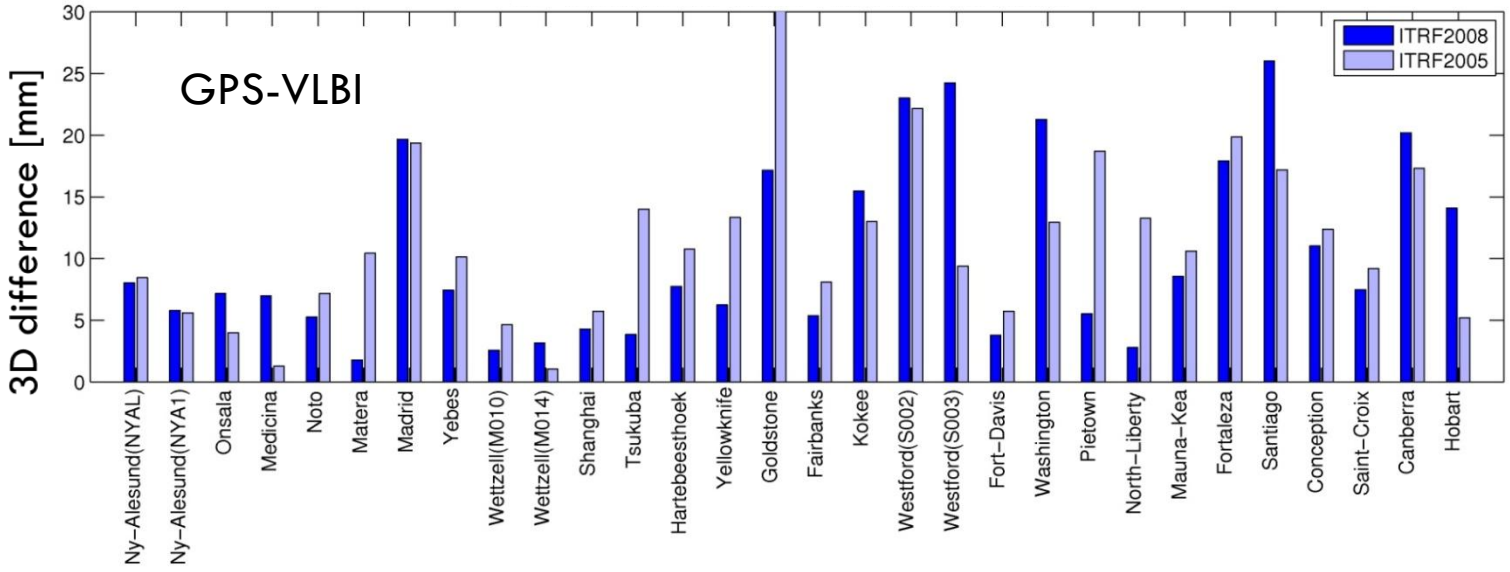
Local Tie selection

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?

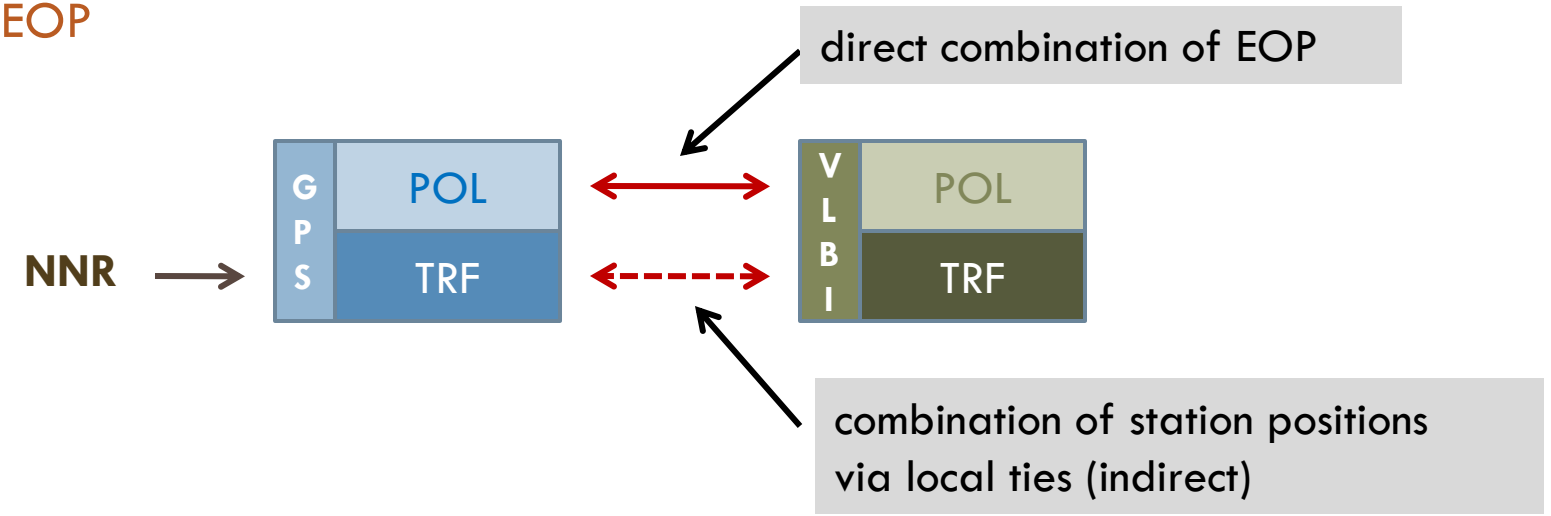
- NO, they cannot. Discrepancies between tie and techniques will always lead to a deformation of the networks (the station with the larger formal error will be more shifted, close stations will be affected)

↷ 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 ($GPS_{comb\ TRF}$, $VLBI_{comb\ TRF}$) are not allowed to show systematic differences!

Criteria for local tie selection: pole offsets must be minimized

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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

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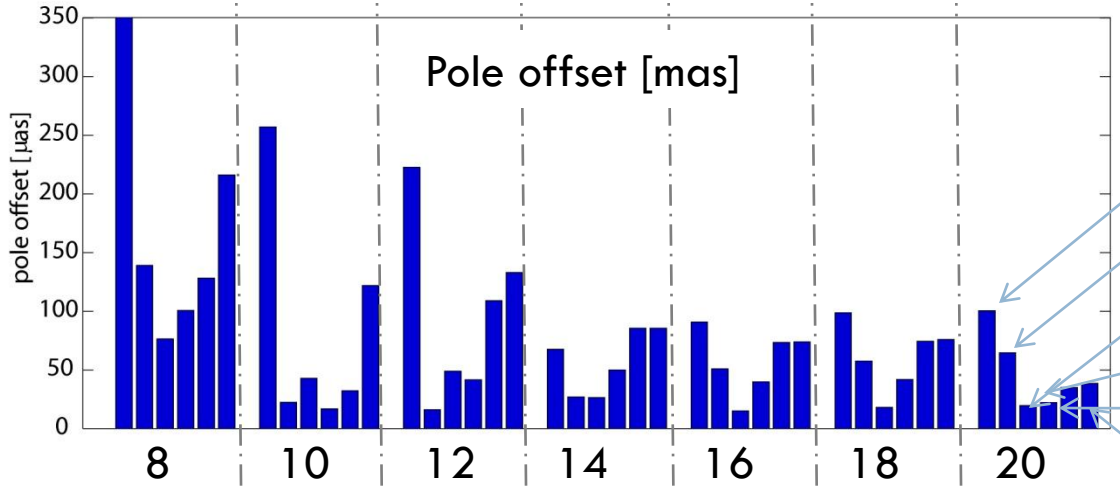
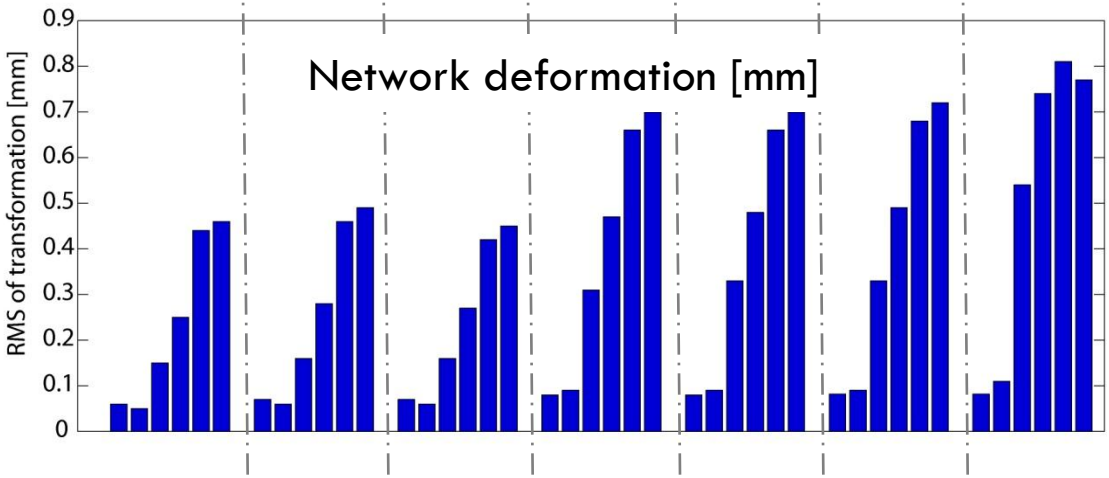
Local Tie selection

Local tie selection for ITRF2008 (GPS-VLBI)





σ tie

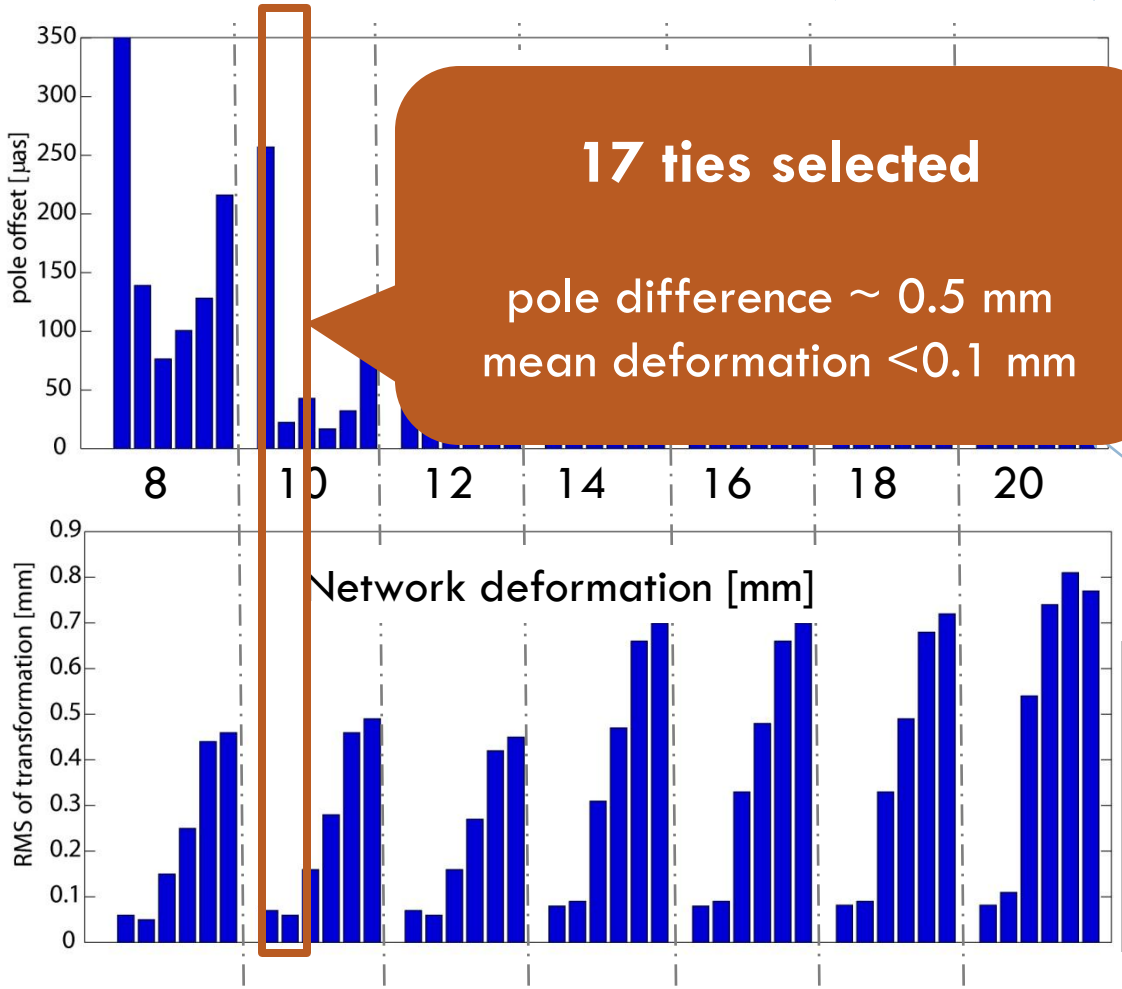
2.00 mm
1.00 mm
0.50 mm
0.10 mm
0.05 mm
0.01 mm

- 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

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

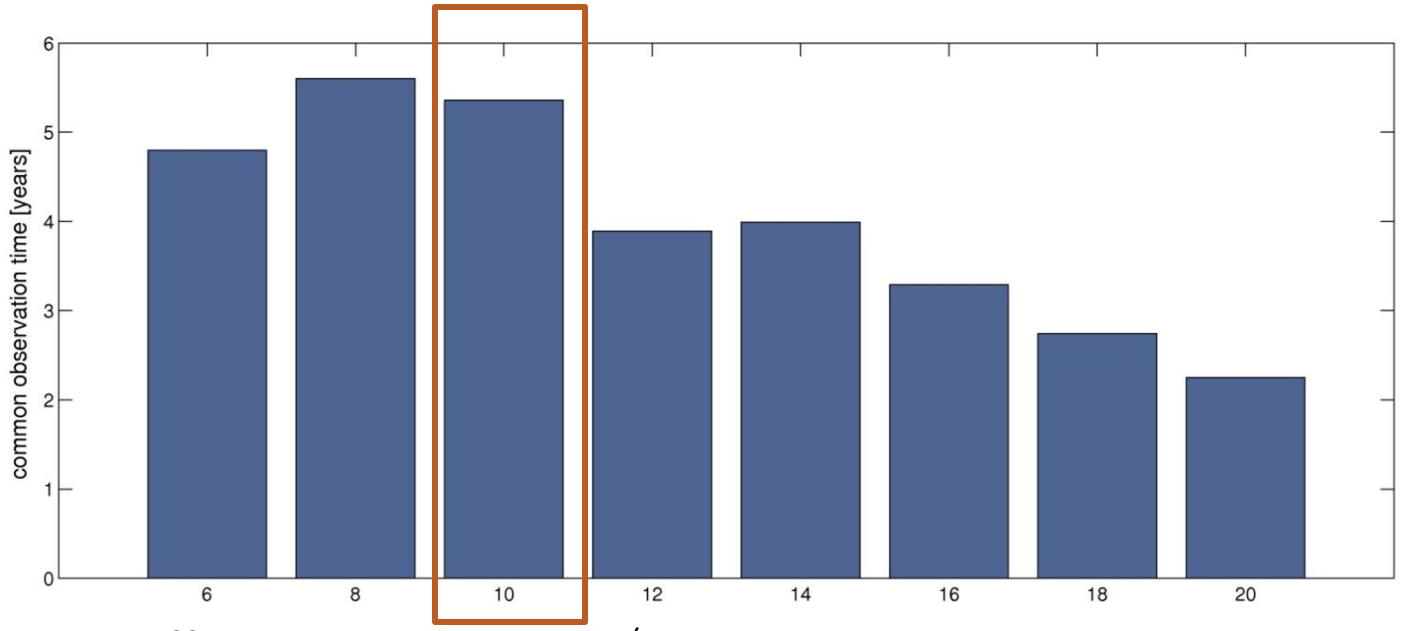
- σ tie not well known and
- network deformation shall be minimized

→ σ included in selection

Local Tie selection

Can other criteria corroborate the selection?

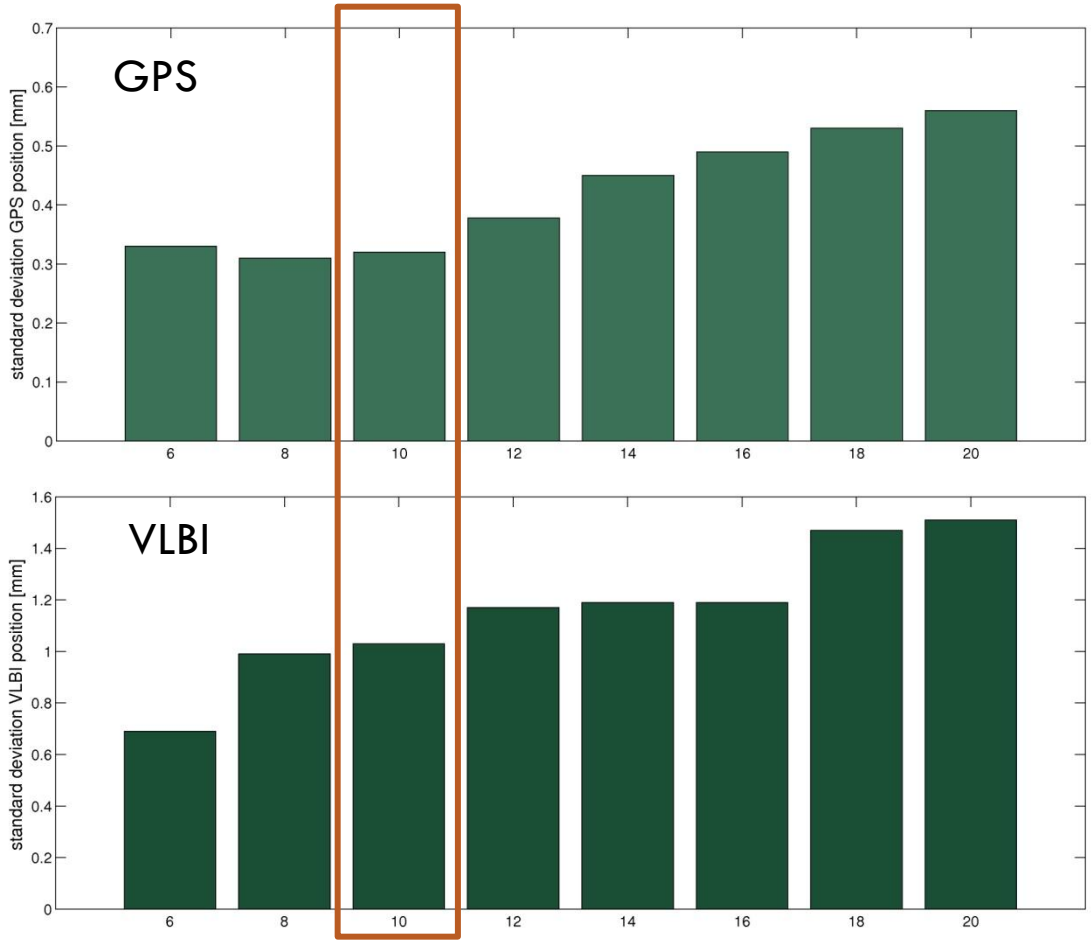
Mean common observation time



Larger differences between GPS/VLBI and local tie → shorter common observation time

Local Tie selection

Mean standard deviation of GPS/VLBI position



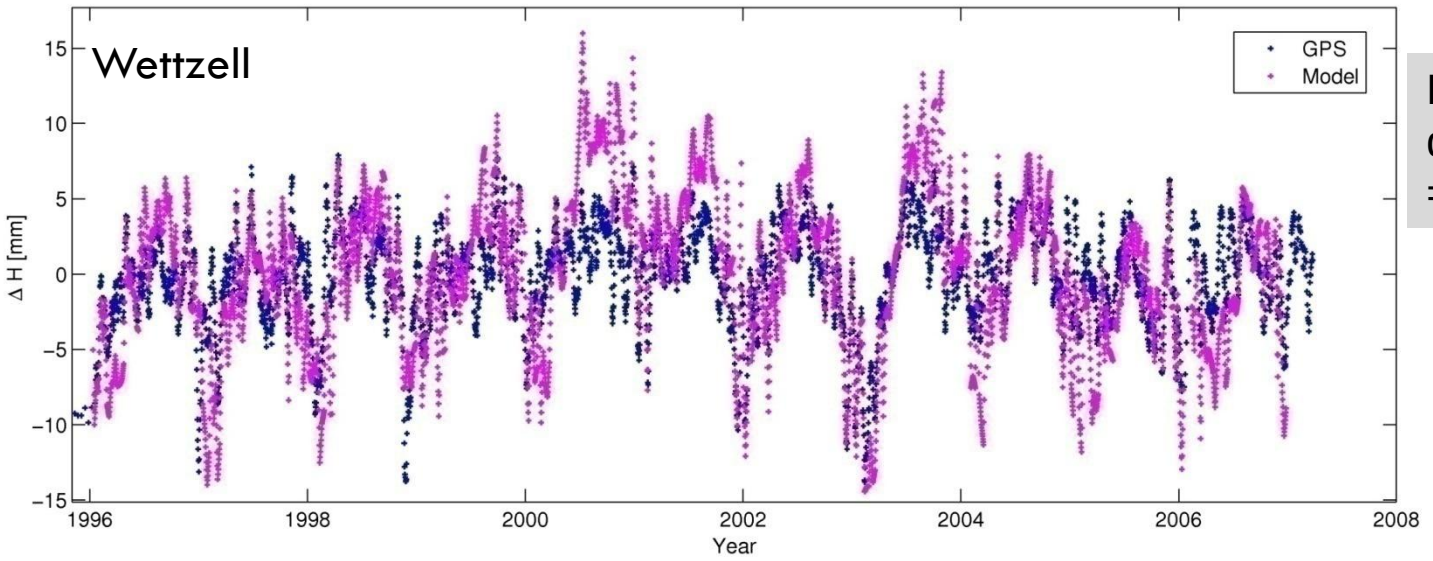
Larger differences between GPS/VLBI and local tie

Larger standard deviations for GPS and VLBI station positions

Daily TRF

Advantage

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



RMS of the difference = 3.7mm

Modeling of station displacement is not sufficient at some epochs.

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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?

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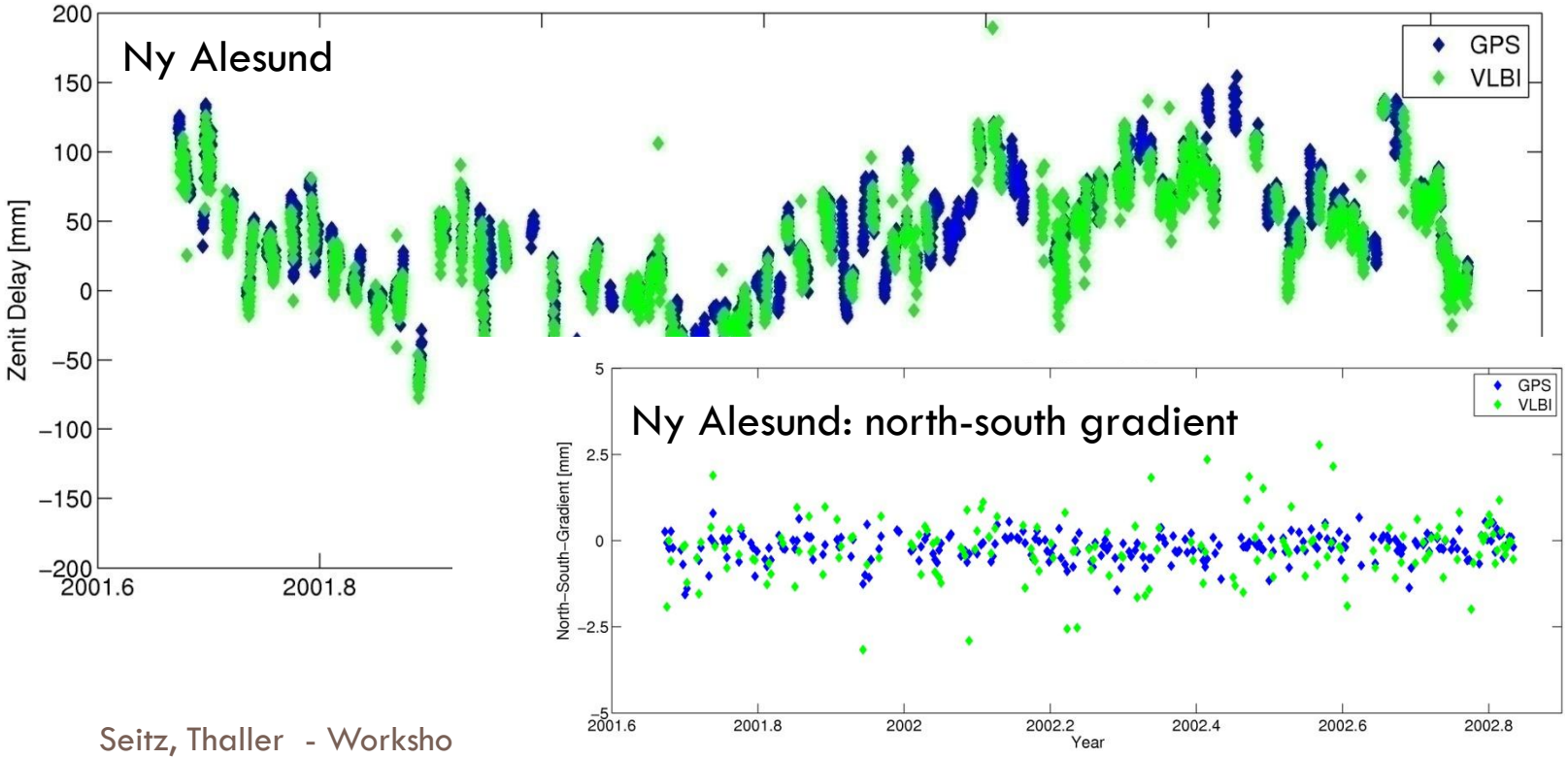
Daily TRF

Troposphere combination

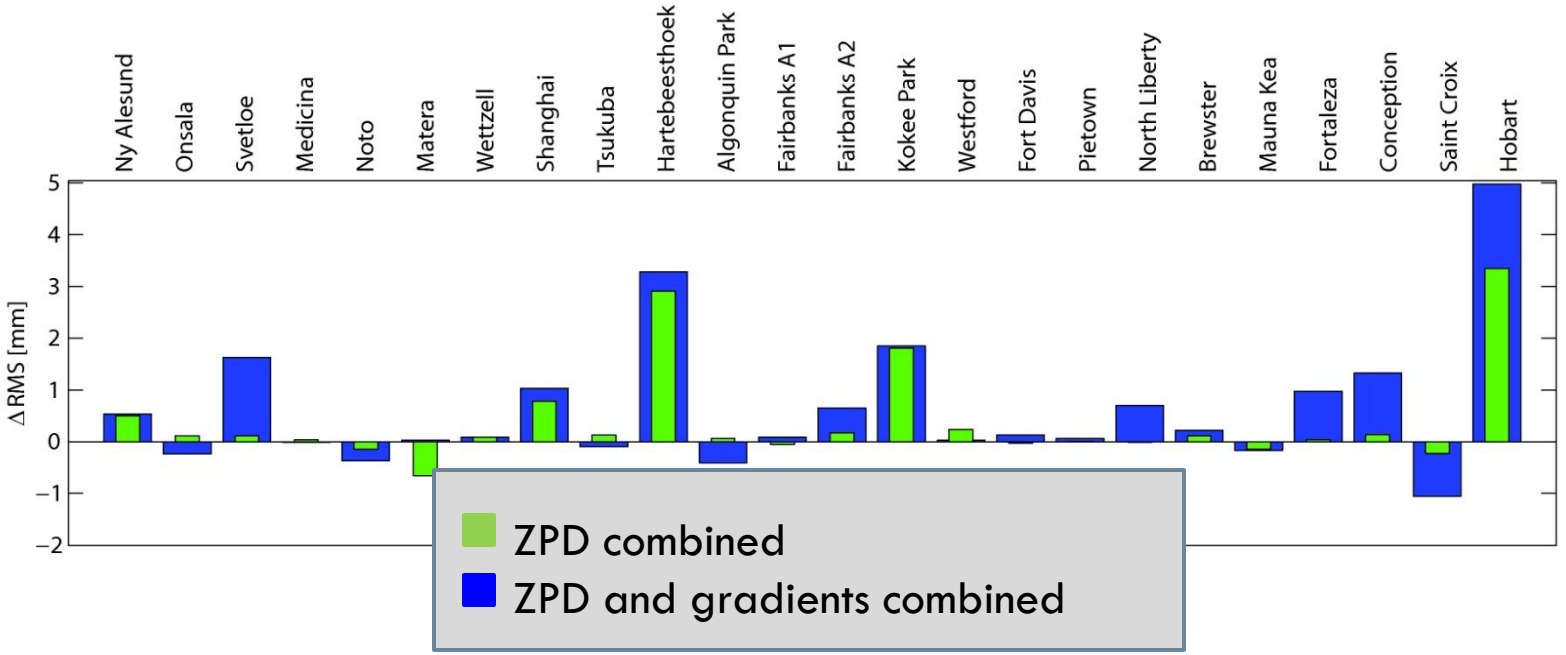
Estimated tropospheric zenith delay (wet part)



Daily TRF

Troposphere combination

Change of station height repeatabilities



RMS improved

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)

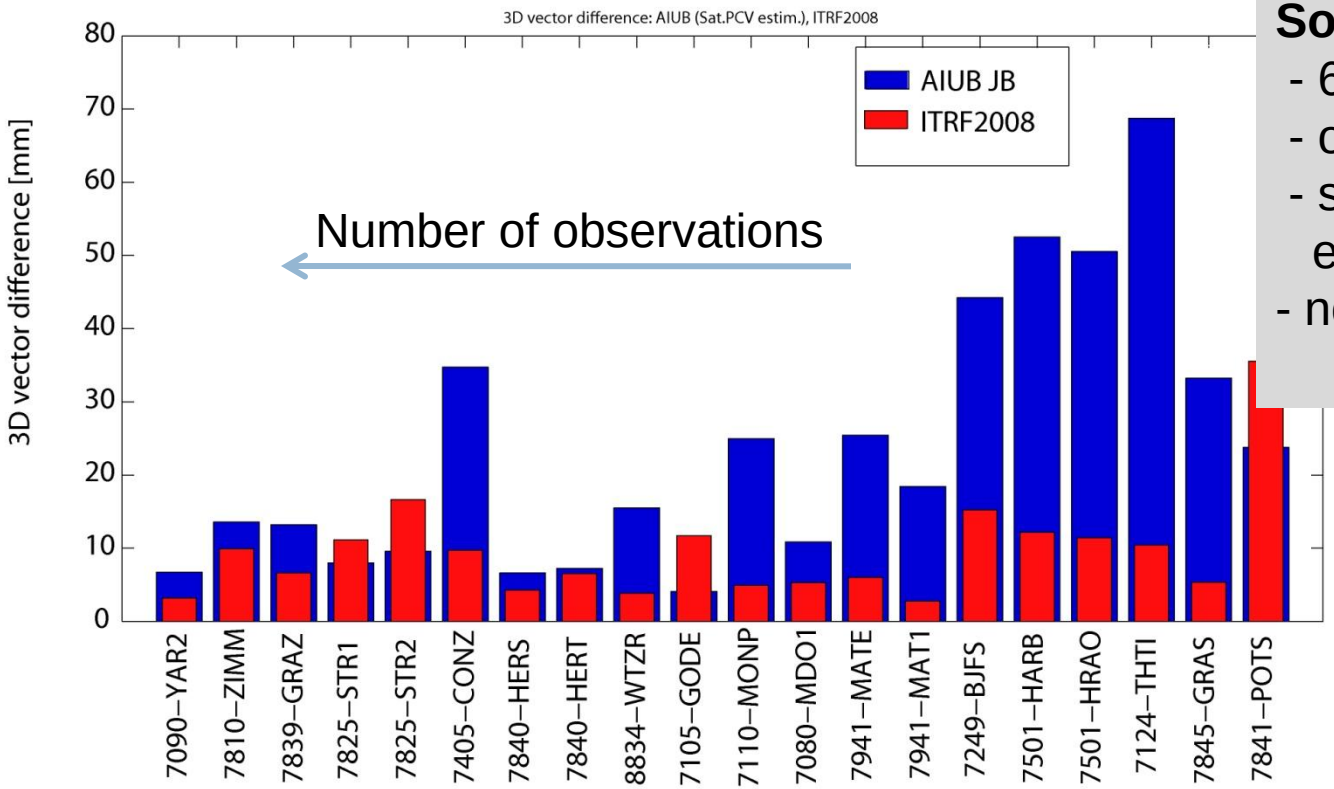
- advantage: scale can be gained from SLR

→ 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

Summary

- 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

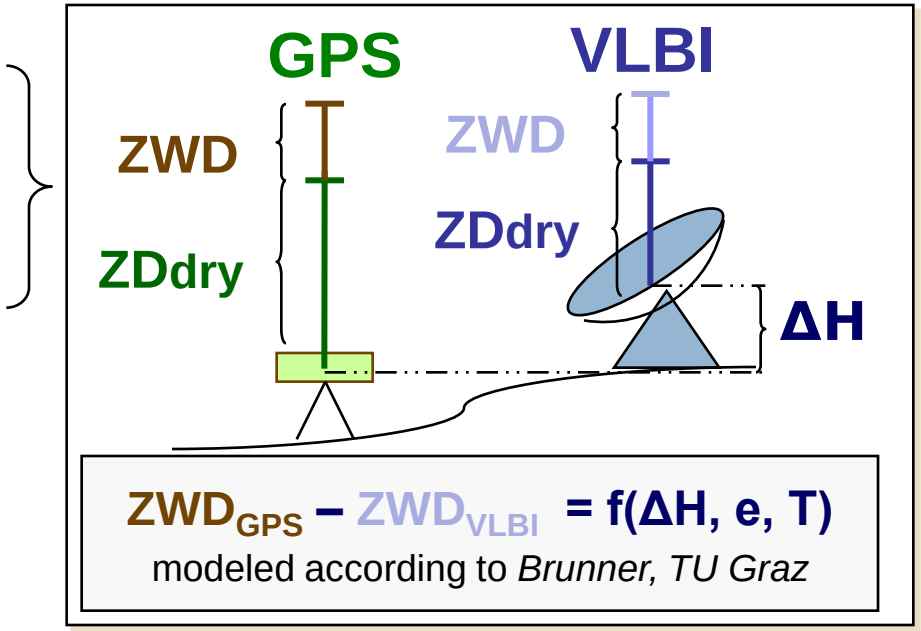
Daily TRF

Troposphere combination

$$ZD(e) = mf_{dry}\, ZD_{dry} + mf_{wet}\, ZWD \quad + G_{NS} + G_{EW}$$

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

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



Combination on NEQ level

GGOS-D project - a project of four German institutes

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