

Input data and first combination results

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2nd COL Working Group Meeting
9.-10. December 2010

- Input data
- Comparison and Combination results
 - Intra-technique combination
 - Inter-technique combination
- Summary and “to do”

- normal equations (SINEX 2.xx) are provided by all AC
- at least two contributions per technique
- Check of SINEX files
 - Does SINEX can be read?
 - Does a first solution run and look okay?

Input data

■ Single technique

			used
SLR	AIUB :	okay	x
	DGFI:	x-,y-rotation are constrained (few Centimetres)	x
	ESOC :	vtpv becomes negative if NEQ is tried to be solved in DOGS the vtpv is solved together with the other parameters. So, the NEQ cannot be inverted	/
	GRGS:	okay	x
VLBI	DGFI :	okay, relativistic scale: model must be improved	x
	GRGS:	troposphere parameters not related to stations	/
GPS	AIUB:	okay	x
	GRGS:	okay, but nutation needs special constraints	x
DORIS	GRGS:	no rates for pole and UT1 (even if in the readme)	x



Input data

Pre-combined

SLR-GPS

ESOC (GNSS+SLR to GPS targets)

used
x

orientation fixed to 1-2 cm is the NEQ stored in SINEX
constraint free or are the constraints from the
“a priori” NEQ also stored in SINEX are added to the
NEQ?

GFZ (GNSS incl. GRACE A/B + SLR to GPS-5, GPS-6, GRACE A/B)
okay, but 6 NEQ cannot be solved /

origin of GPS network part shows a large scatter, but
standard deviations are very small (1mm / component)
scale of GPS and SLR network parts show also a large
scatter but standard deviations are small

SLR-DORIS

ESOC (DORIS + SLR to ENVISAT and JASON-2)
the same as for SLR-GPS

x

Which parameters can be combined?

■ Station coordinates

Existing inhomogenities:

- Ocean loading / Atmospheric loading
- Antenna phase centre correction (?)
- Troposphere correction
- Elevation cut off, elevation dependent weighting

■ EOP

Existing inhomogenities:

- Parametrization
- Interpolation of a priori values (?)
- Subdaily pole model

Which parameters can be combined?

- EOP
 - Different types of parameterization
 - O: Offset
 - D: Drift
 - O+D: Offset + Drift
 - pwl: piece-wise linear polygon

Possible transformation

O+D $\longleftrightarrow$ pwl (unstacked)

Which EOP can be combined?

	AC	pole	UT1	nutration (3)
DORIS	GRGS	4d pwl O		
GPS	AIUB (4)	pwl	pwl	pwl
	GRGS n5 (1)	O	O	O
SLR	AIUB	O	D	
	GRGS	O	O (pwl?)	
	ESOC	O+D	D	
	DGFI	pwl stacked (2)	pwl stacked (2)	
VLBI	DGFI	O+D	O+D	O+D
	GRGS	O	O	O
SLR-GPS	ESOC	O+D	D	
	GFZ	O+D	D	
SLR-DORIS	ESOC	O+D	D	

(1) n4 would be O+D but cannot be inverted because of nutation

(2) daily pwl stacked at day boundaries

(3) nutation can be combined if rates are constrained to zero

(4) transf. of AIUB in O+D; AIUB-only seems okay, but 2 week of combined solution cannot be solved

Which EOP can be combined?

	AC	pole	UT1	nutration (3)
DORIS	GRGS	4d pwl O		
GPS	AIUB (4)	pwl	pwl	pwl
	GRGS n5 (1)	O	O	O
SLR	AIUB	O	D	
	GRGS	O	O (pwl?)	
	ESOC	O+D	D	
	DGFI	pwl stacked (2)	pwl stacked (2)	
VLBI	DGFI	O+D	O+D	O+D
	GRGS	O	O	O
SLR-GPS	ESOC	O+D	D	
	GFZ	O+D	D	
SLR-DORIS	ESOC	O+D	D	

(1) n4 would be O+D but cannot be inverted because of nutation

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(3) nutation can be combined if rates are constrained to zero

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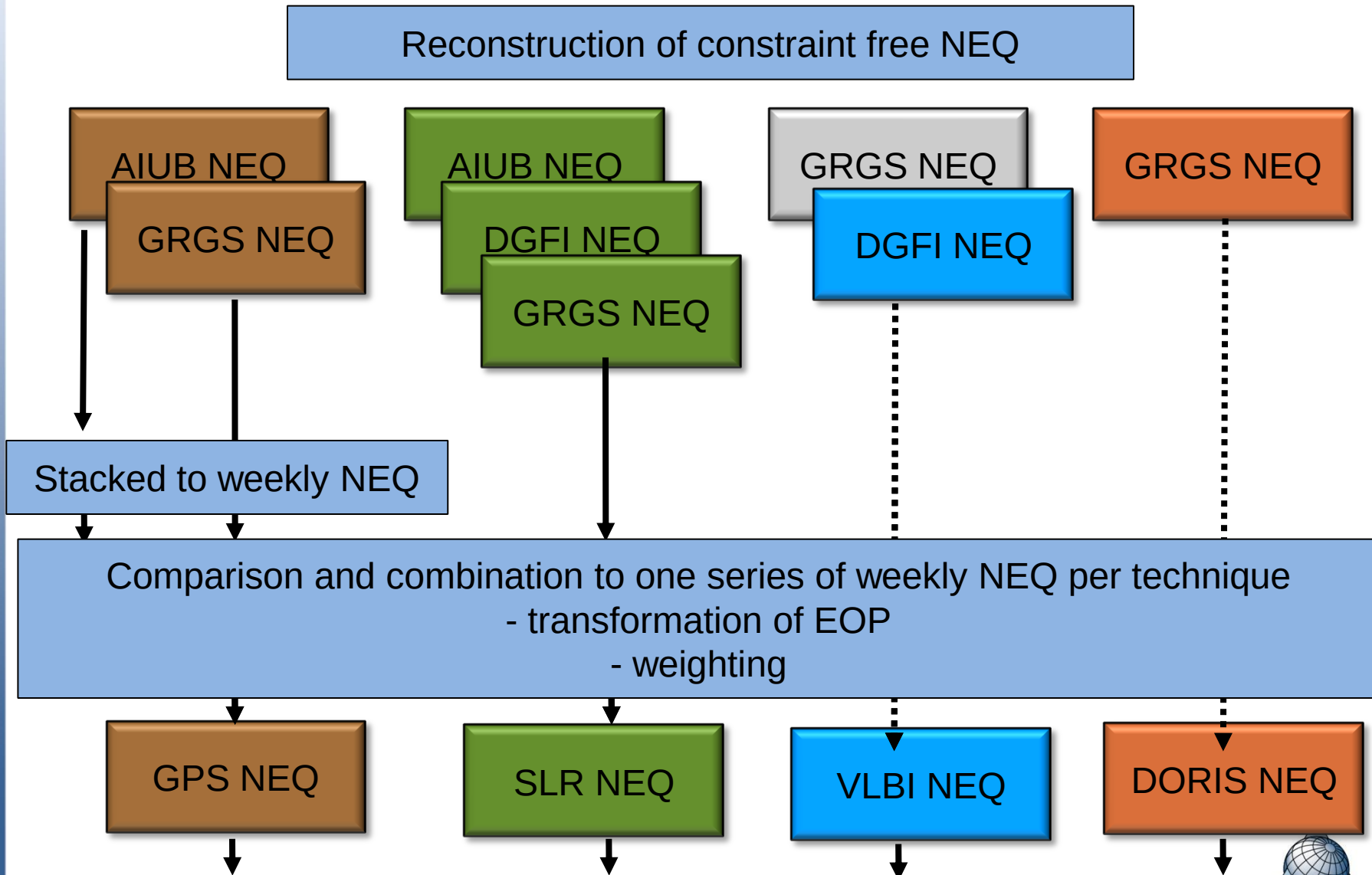


Combination

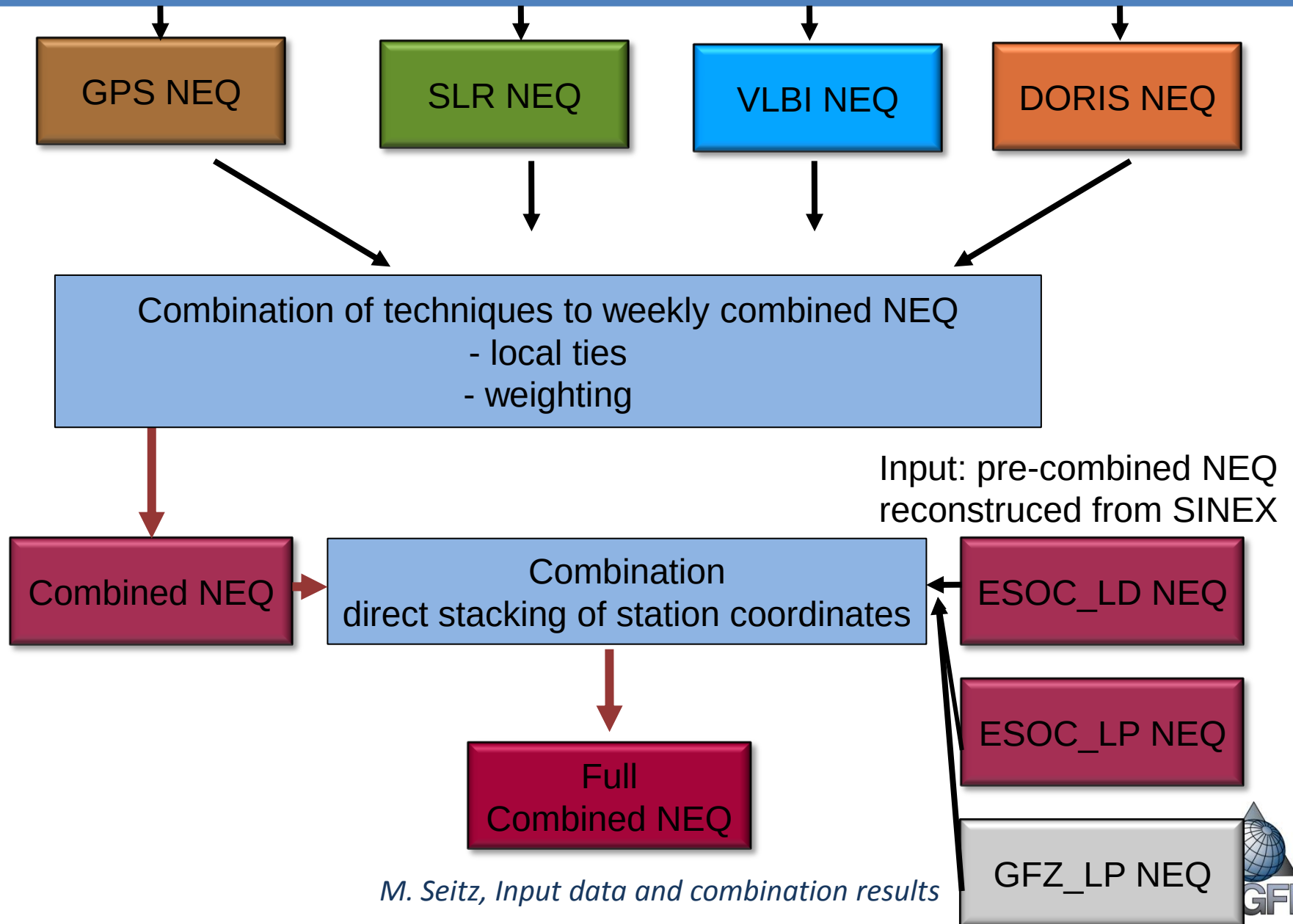
- Step by step

- Per technique:** daily to weekly (AIUB_GPS)
Comparison and combination of input files
- inter-technique 1:** Comparison and combination of
VLBI-, SLR- and GPS-only contributions
- inter-technique 2:** Comparison and combination of
inter-technique 1 with
pre-combined SLR-DORIS and SLR-GPS

Combination scheme for weekly combination (I)



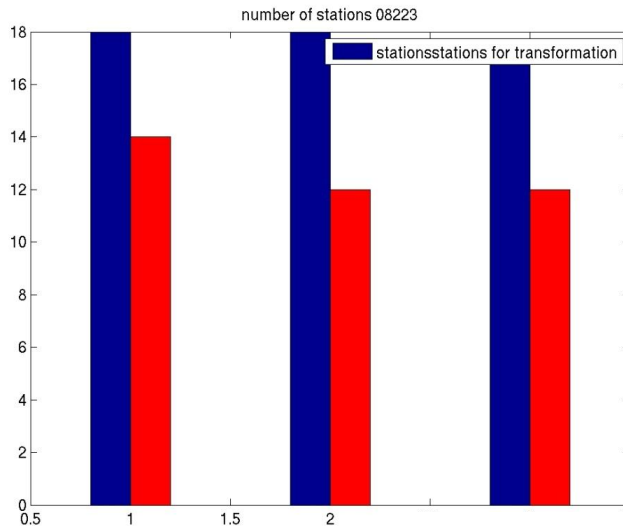
Combination scheme for weekly combination (II)



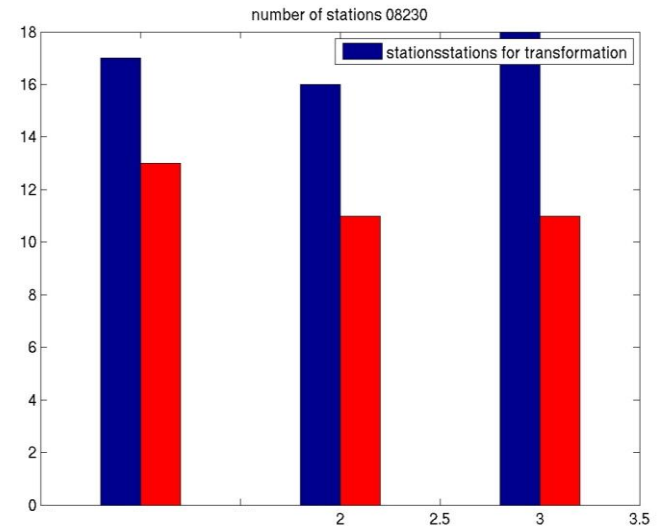
- SLR intern comparisons
 - 3 SLR only contributions (AIUB, DGFI, GRGS)
 - and 2 pre-combined (ESOC_LP, ESOC_LD)

Intra-technique combination: SLR

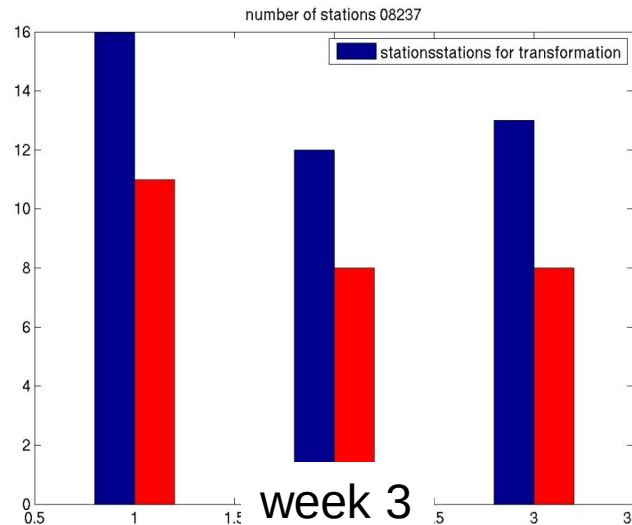
■ Comparison of AIUB, DGFI and GRGS: number of stations



week 1



week 2

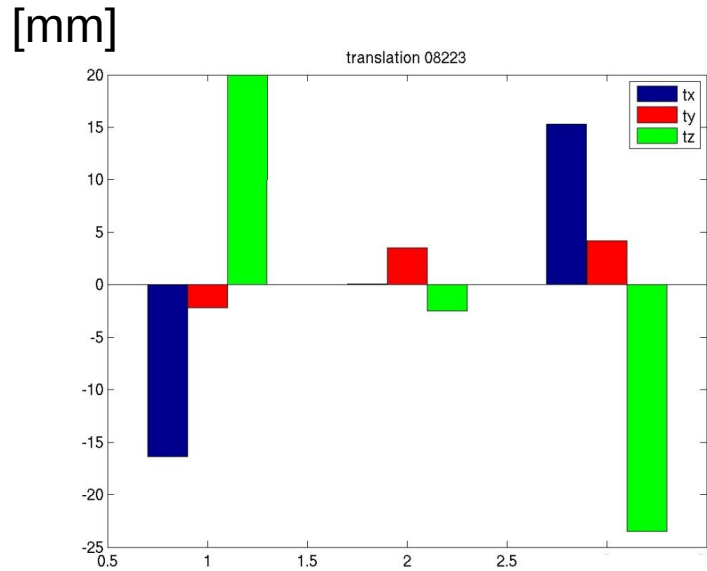


week 3

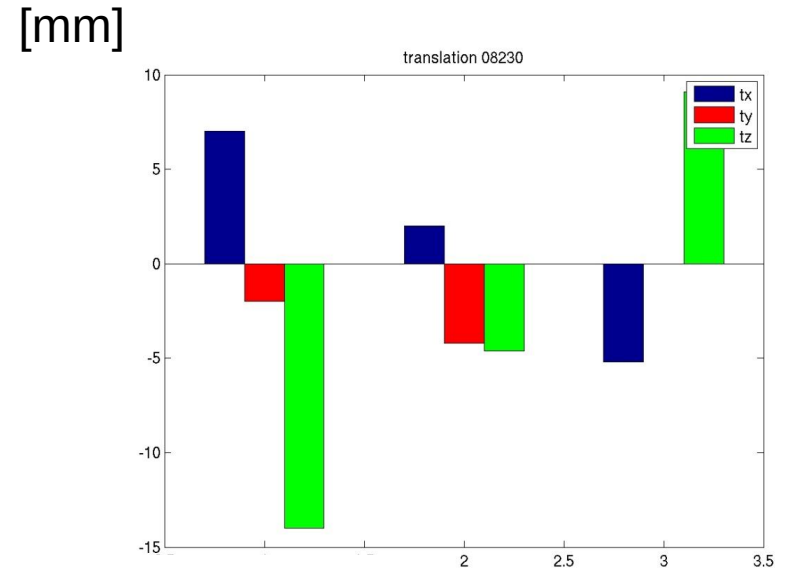
- 1 AIUB-DGFI
- 2 AIUB-GRGS
- 3 DGFI-GRGS

■ available
■ used

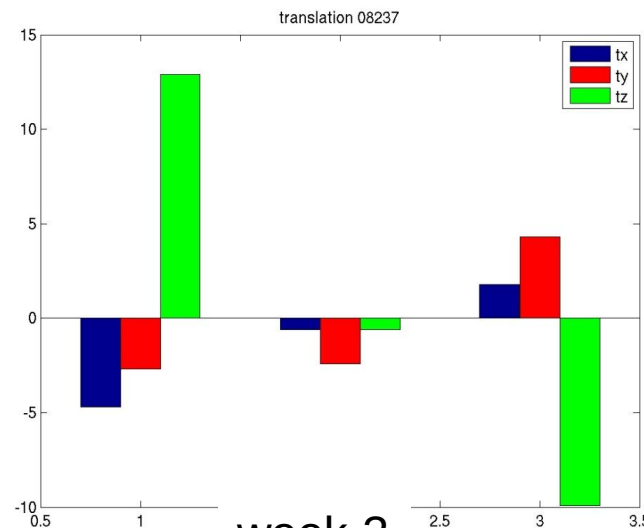
Translation parameters between SLR contributions



week 1



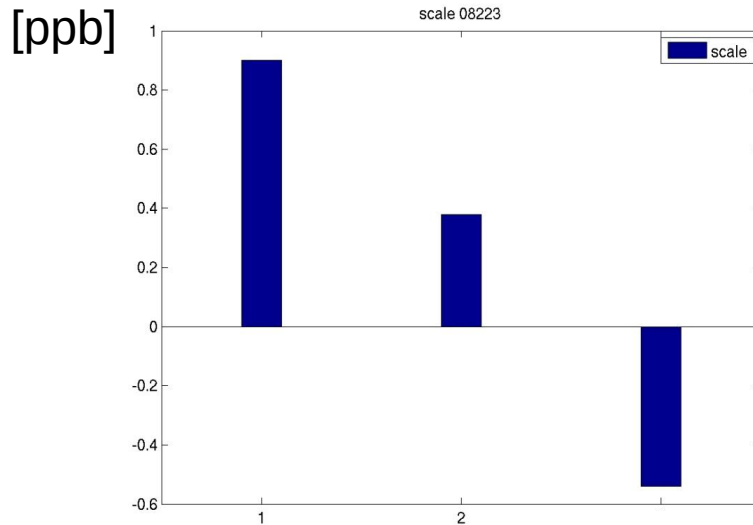
week 2



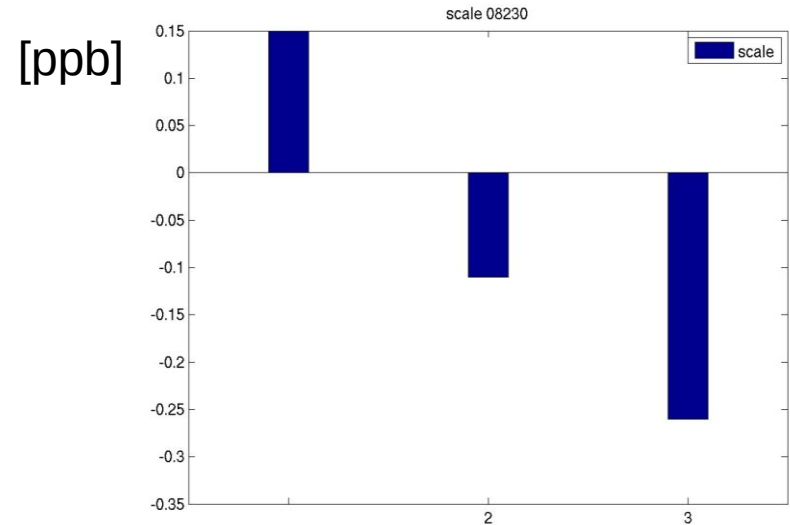
week 3

- 1 AIUB-DGFI
- 2 AIUB-GRGS
- 3 DGFI-GRGS

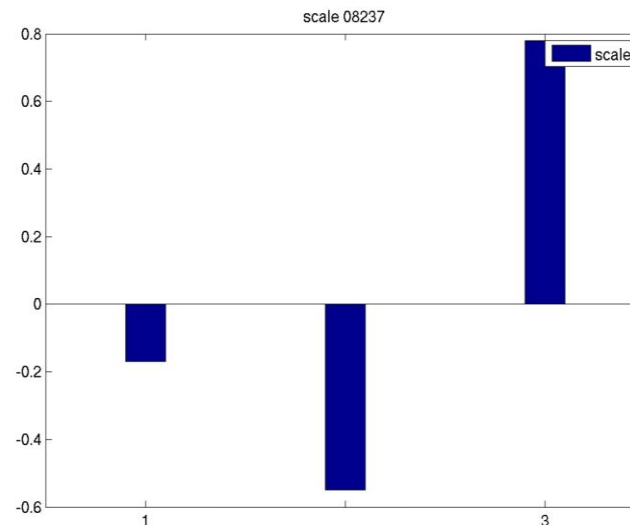
Scale parameters between SLR contributions



week 1



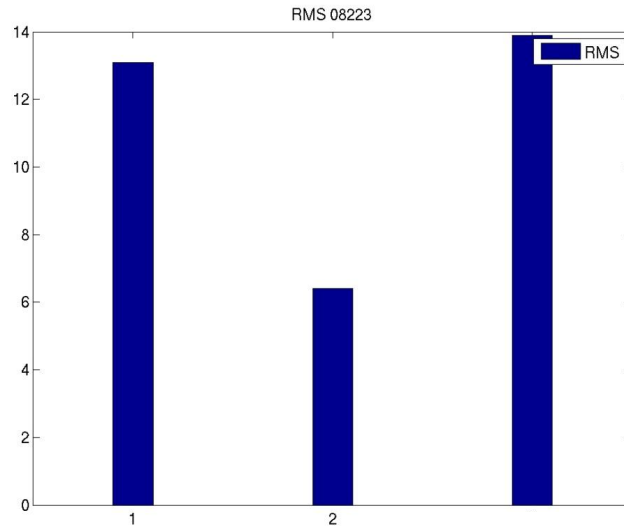
week 2



week 3

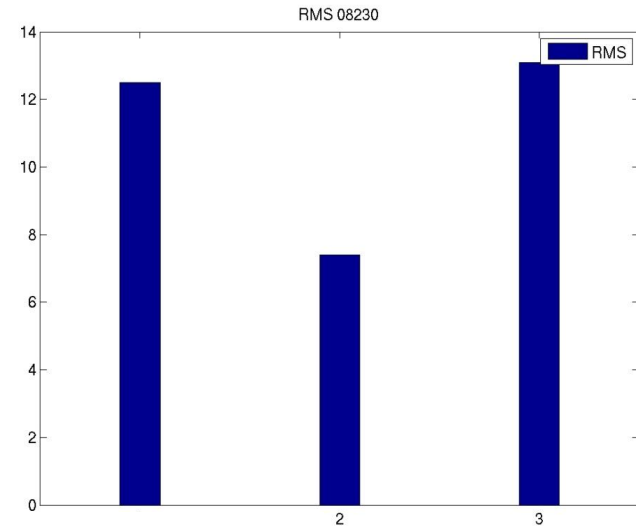
1 AIUB-DGFI
2 AIUB-GRGS
3 DGFI-GRGS

RMS of transformation: SLR

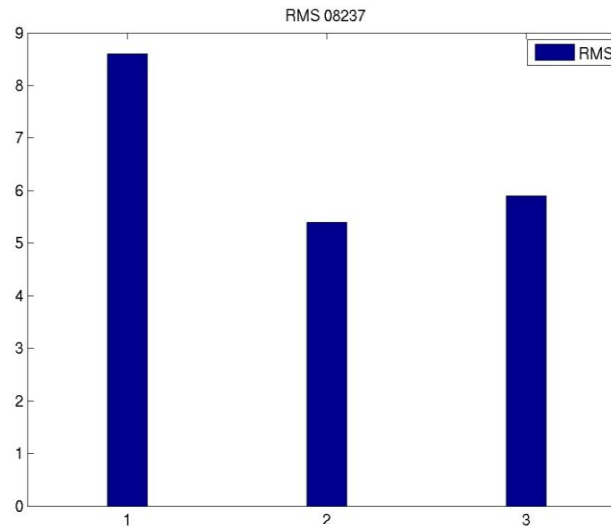


week 1

[mm]



week 2

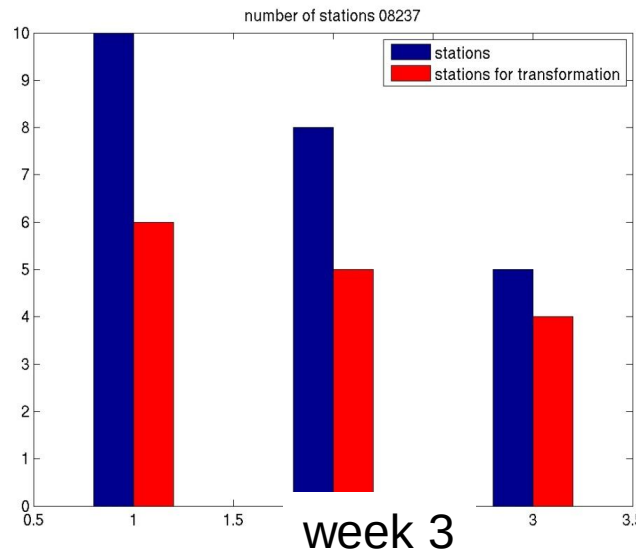
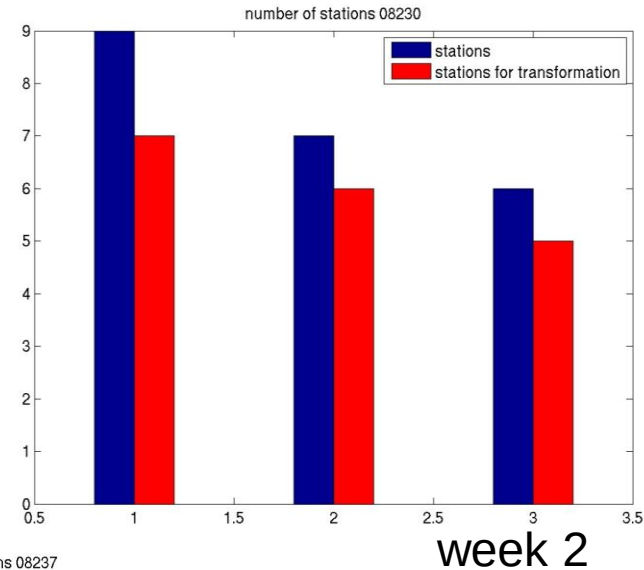
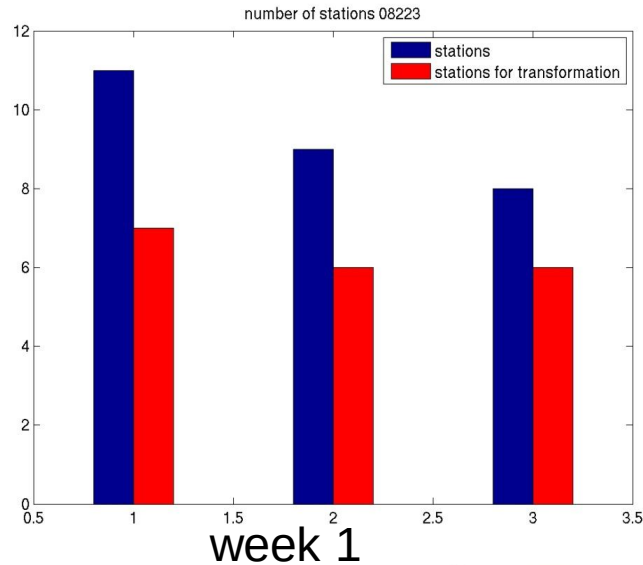


week 3

- 1 AIUB-DGFI
- 2 AIUB-GRGS
- 3 DGFI-GRGS

Comparison with pre-combined NEQ

Number of common stations



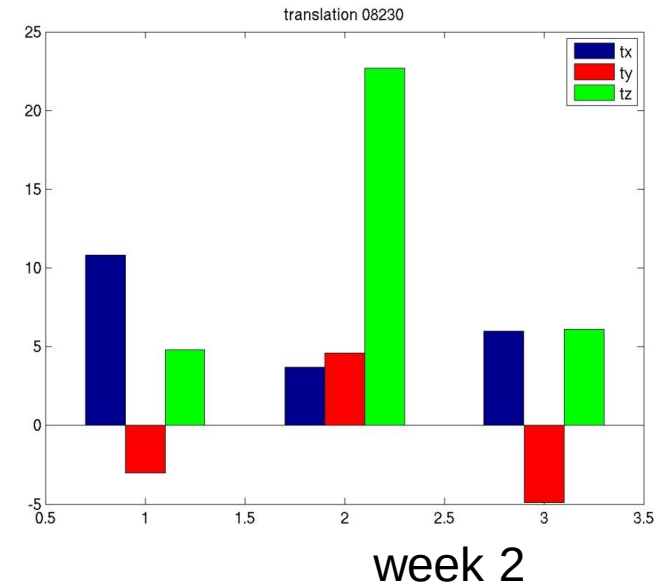
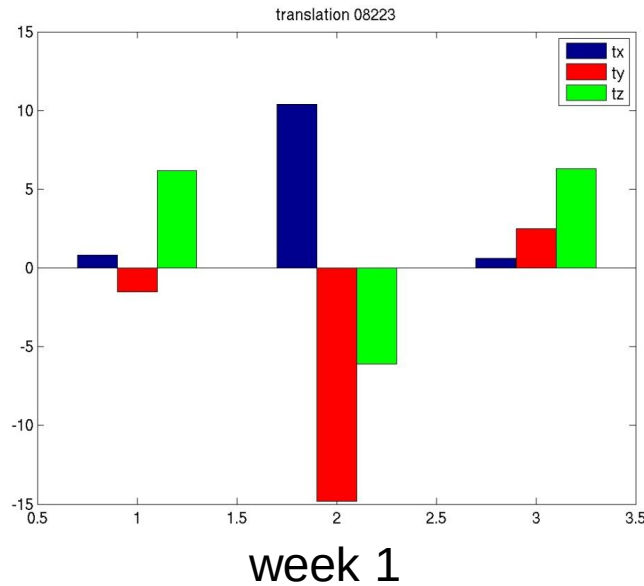
- 1 AIUB-ESOC_PL
- 2 DGFI-ESOC_PL
- 3 GRGS-ESOC_PL

available
used

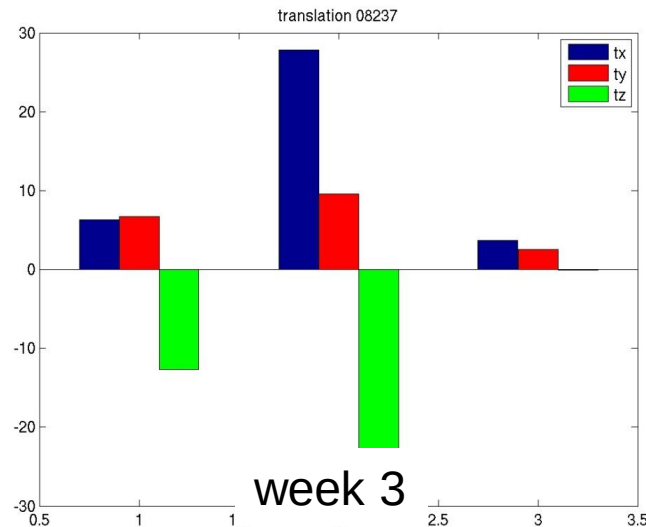
Not done:
comparisons with
ESOC_LP
because of the small
number of common
stations

ts

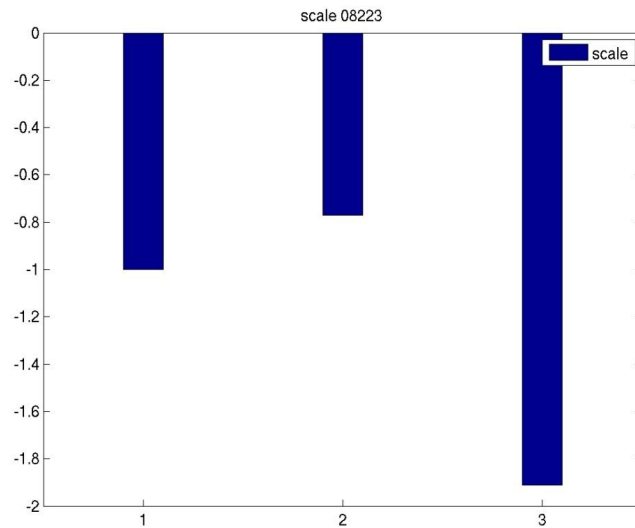
SLR with pre-combined: translations



- 1 AIUB-ESOC_PL
- 2 DGFI-ESOP_PL
- 3 GRGS-ESOC_PL

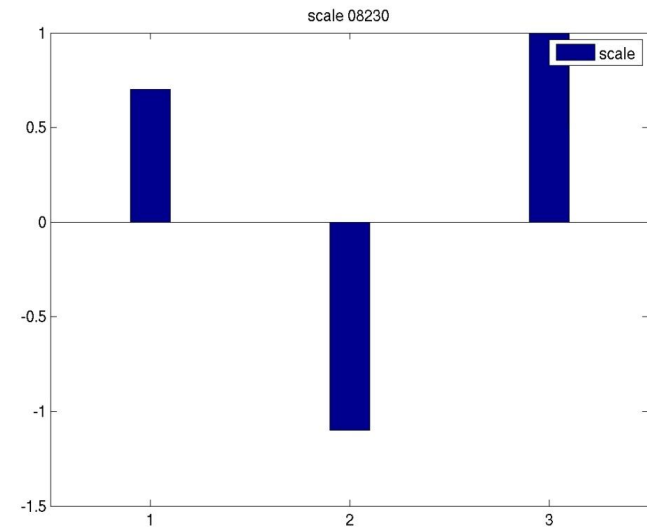


SLR with pre-combined: scale



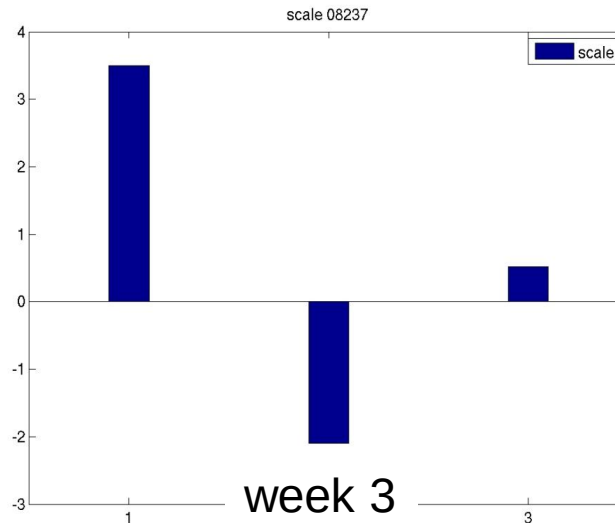
week 1

[ppb]



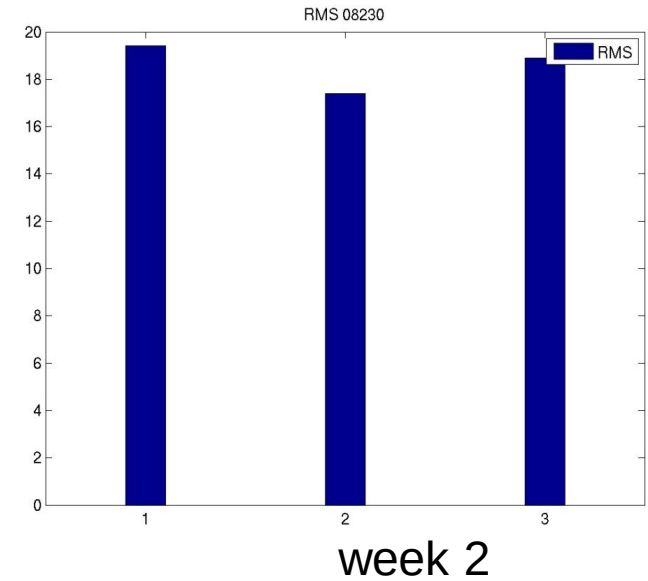
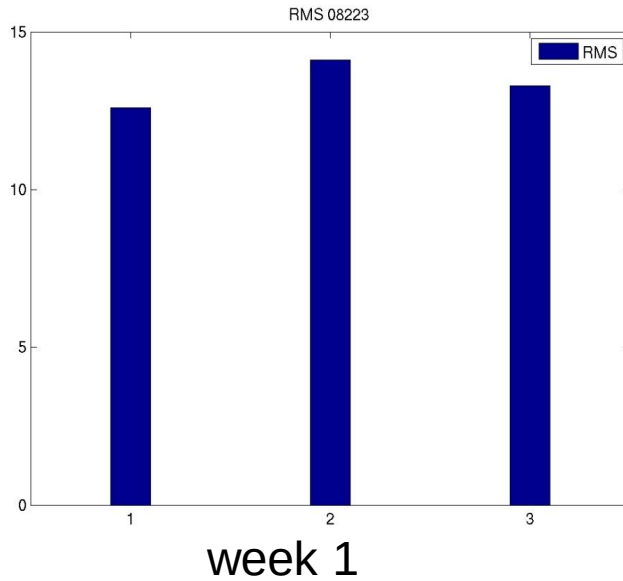
week 2

- 1 AIUB-ESOC_PL
- 2 DGFI-ESOP_PL
- 3 GRGS-ESOC_PL

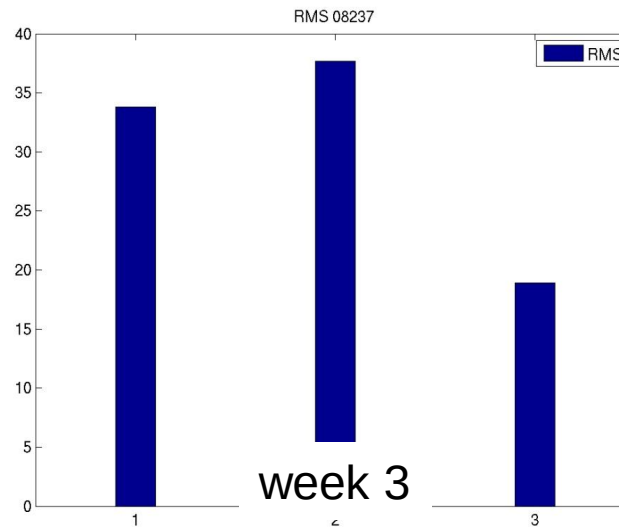


week 3

SLR with pre-combined: RMS



- 1 AIUB-ESOC_PL
- 2 DGFI-ESOP_PL
- 3 GRGS-ESOC_PL

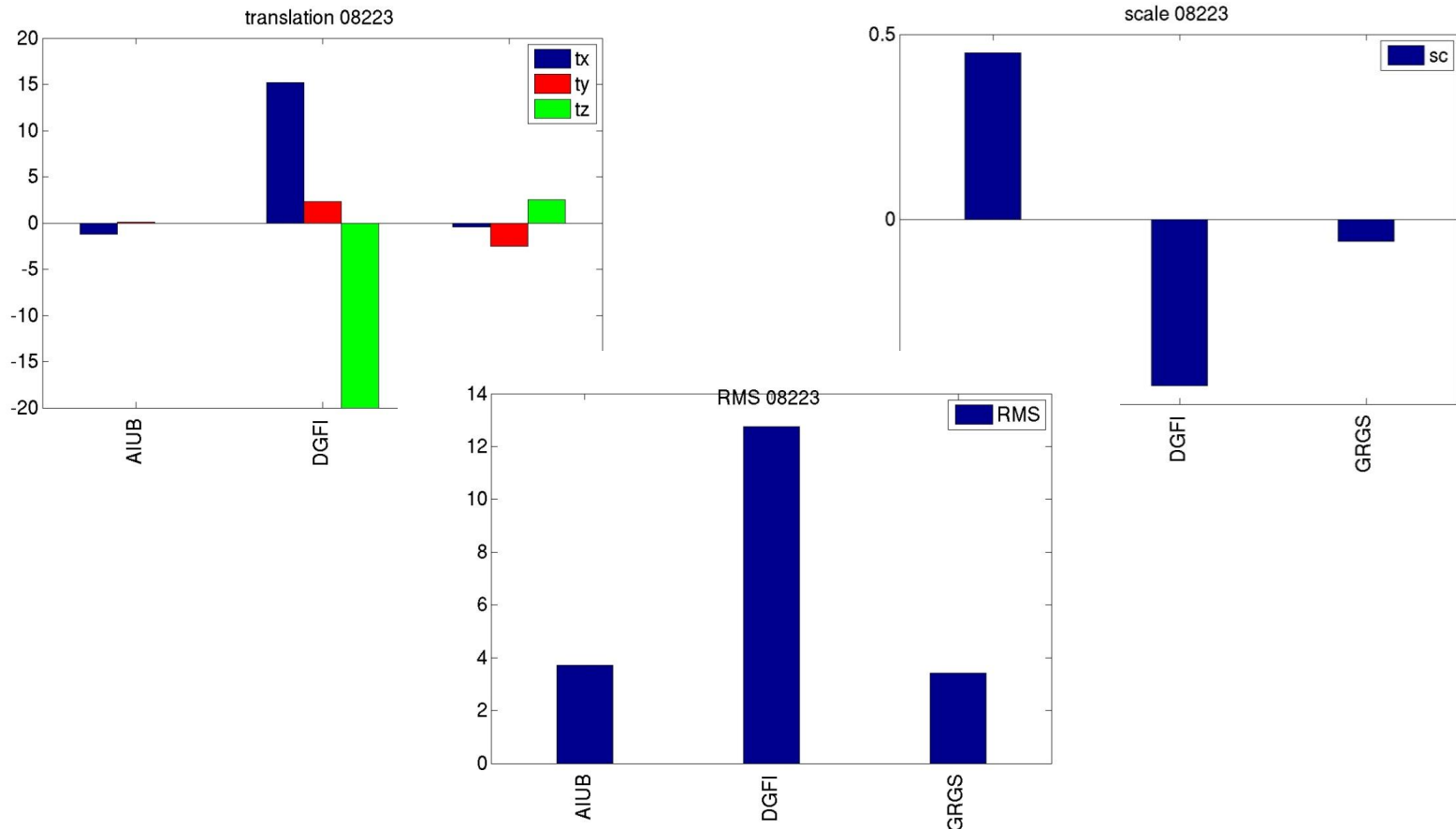


Combination of the SLR-only weekly solutions AIUB+DGFI+GRGS

Comparison of combined with AC solutions

■ Week 1

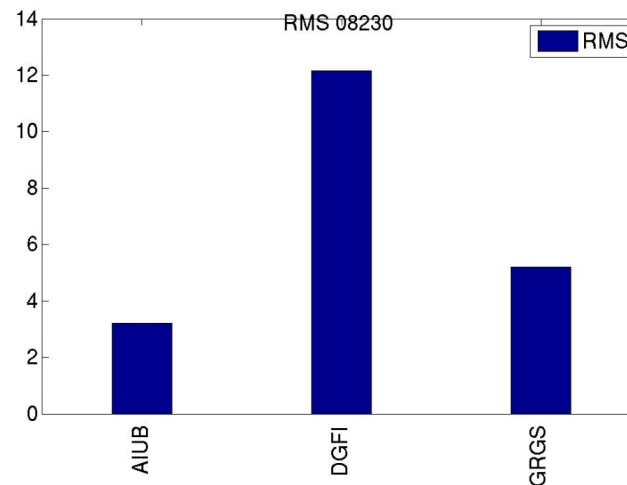
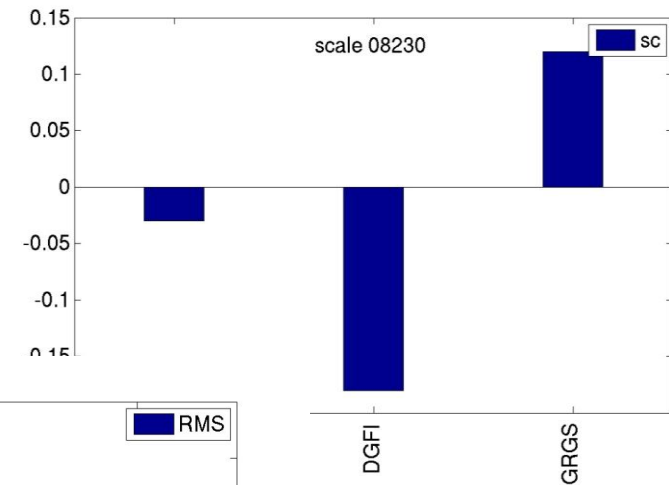
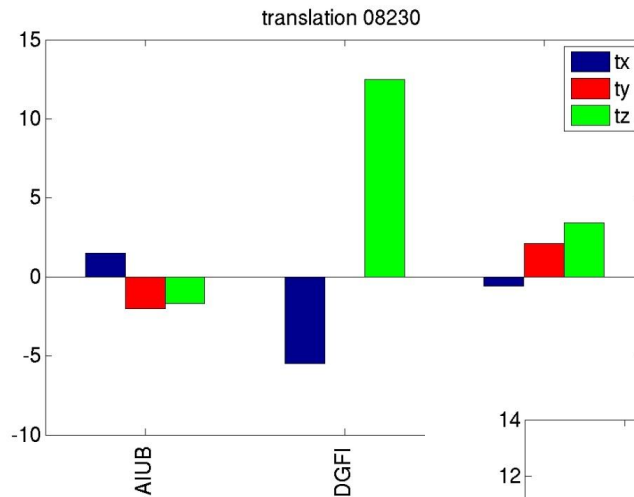
Weights: 1.00 for all three contributions



Comparison of combined with AC solutions

■ Week 2

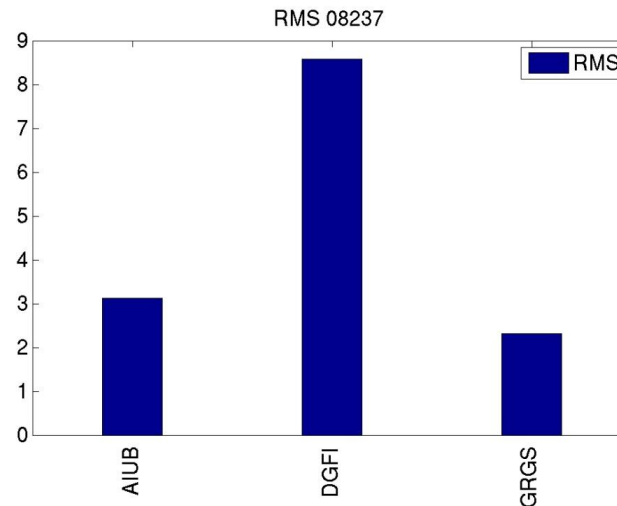
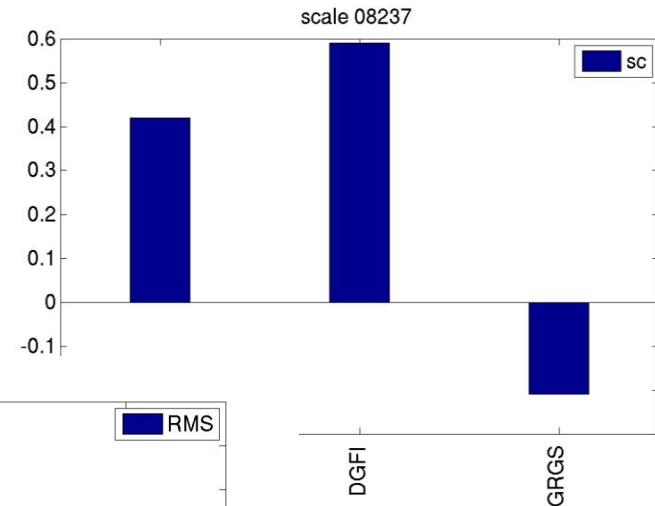
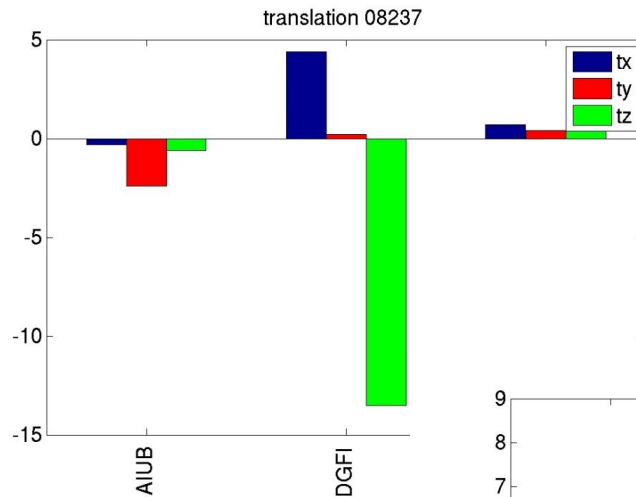
Weights: 1.00 for all three contributions



Comparison of combined with AC solutions

■ Week 3

Weights: 1.00 for all three contributions



Comparison with DTRF2008

Week1

tx [cm]:	-0.70 +- 0.25		
ty [cm]:	-0.58 +- 0.25		
tz [cm]:	-0.55 +- 0.25		
rx [μ rad]:	0.00010 +- 0.00052	[cm]:	0.07
ry [μ rad]:	-0.00011 +- 0.00044	[cm]:	-0.07
rz [μ rad]:	-0.00014 +- 0.00050	[cm]:	-0.09
sc [ppm]:	-0.00067 +- 0.00038	[cm]:	-0.42
estimated standard deviation [cm]:	0.93525		

Week2

tx [cm]:	-0.22 +- 0.24		
ty [cm]:	0.07 +- 0.24		
tz [cm]:	-0.55 +- 0.24		
rx [μ rad]:	-0.00068 +- 0.00048	[cm]:	-0.43
ry [μ rad]:	0.00027 +- 0.00045	[cm]:	0.17
rz [μ rad]:	0.00025 +- 0.00046	[cm]:	0.16
sc [ppm]:	-0.00026 +- 0.00037	[cm]:	-0.17
estimated standard deviation [cm]:	0.92424		

Week 3

tx [cm]:	-0.48 +- 0.28		
ty [cm]:	0.14 +- 0.28		
tz [cm]:	-0.31 +- 0.27		
rx [μ rad]:	0.00023 +- 0.00055	[cm]:	0.15
ry [μ rad]:	0.00048 +- 0.00050	[cm]:	0.30
rz [μ rad]:	-0.00003 +- 0.00052	[cm]:	-0.02
sc [ppm]:	-0.00021 +- 0.00042	[cm]:	-0.14
estimated standard deviation [cm]:	0.97954		

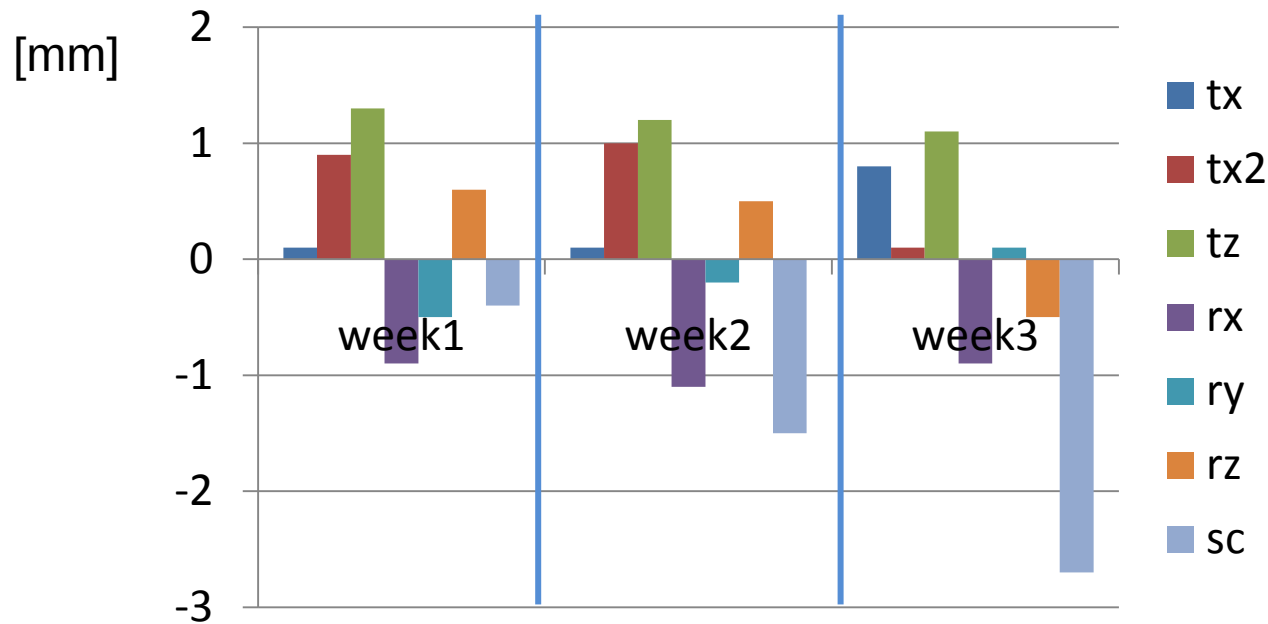
Transformation parameters for single AC w.r.t. DTRF2008 are comparable, each week another AC ist the "best one"

- GPS intern comparisons

- solutions: AIUB, GRGS
- pre-combined: ESOC_PL

(not shown: transformation parameters and residuals reach some cm, but the standard deviations of ESOC_PL are also large)

GPS: AIUB – GRGS (AIUB accumul. to weekly NEQ)



Origin and scale are set up
as parameters

NNT -

NNR – conditions are used

NNS -

GPS: Combination of AIUB and GRGS

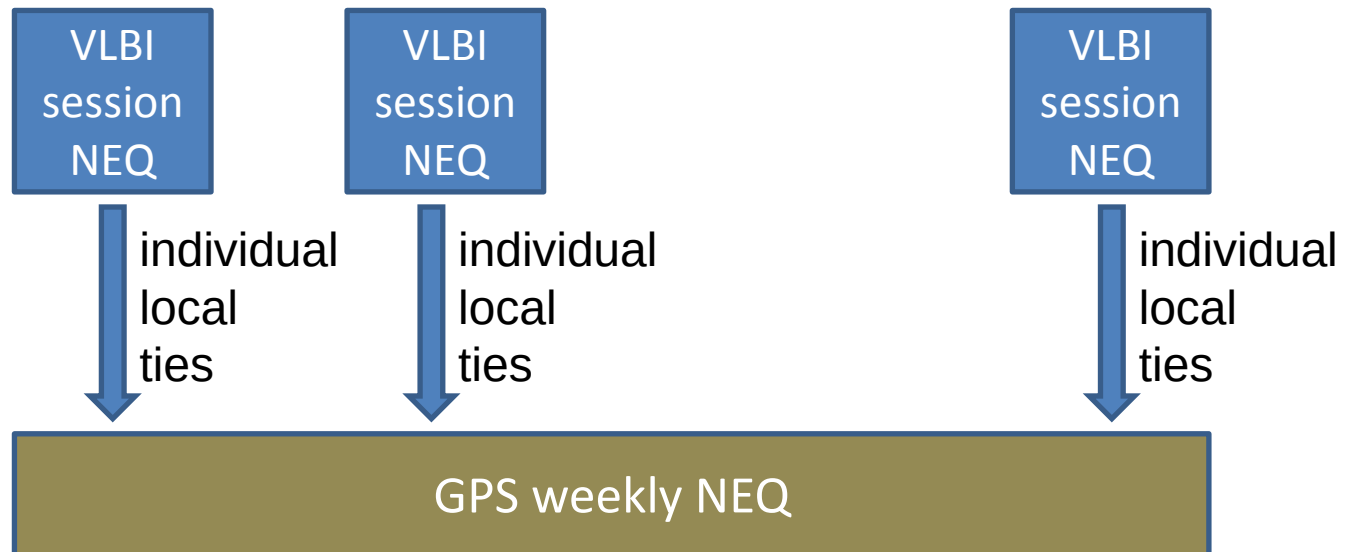
- **relative weighting necessary** as GRGS has a smaller mean STD than AIUB. What can be the reason? Sampling?
- **Weights:**
AIUB: 1.00
GRGS: 15.3 ($=3.9^2$)
-> both reach the same amount of deformation in the combination
- transformation parameters < 1mm / component
- RMS values [mm]:

	week1	week2	week3
AIUB [mm]	2.70	2.52	2.32
GRGS [mm]	2.36	2.48	1.81

Combination of techniques without pre-combined

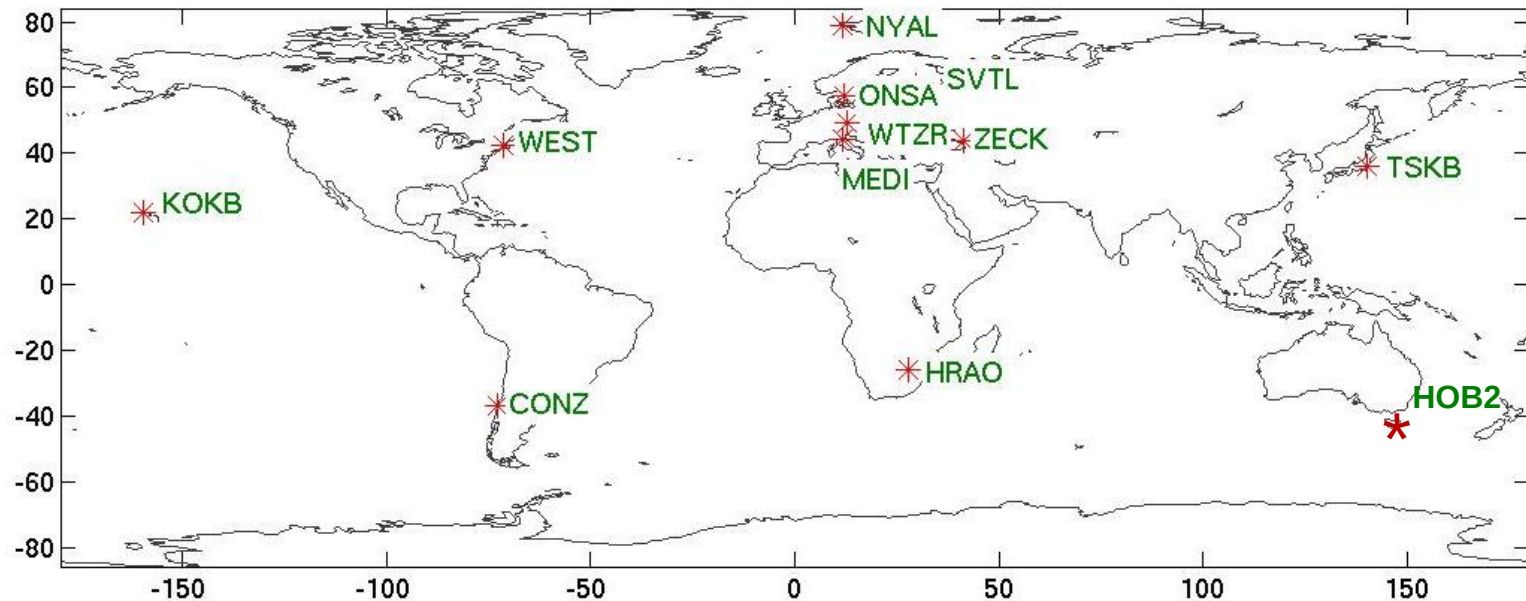
Combination of GPS and VLBI

- session wise combination, otherwise singularities can occur



Combination of GPS and VLBI

- CONT08: distribution of co-location sites



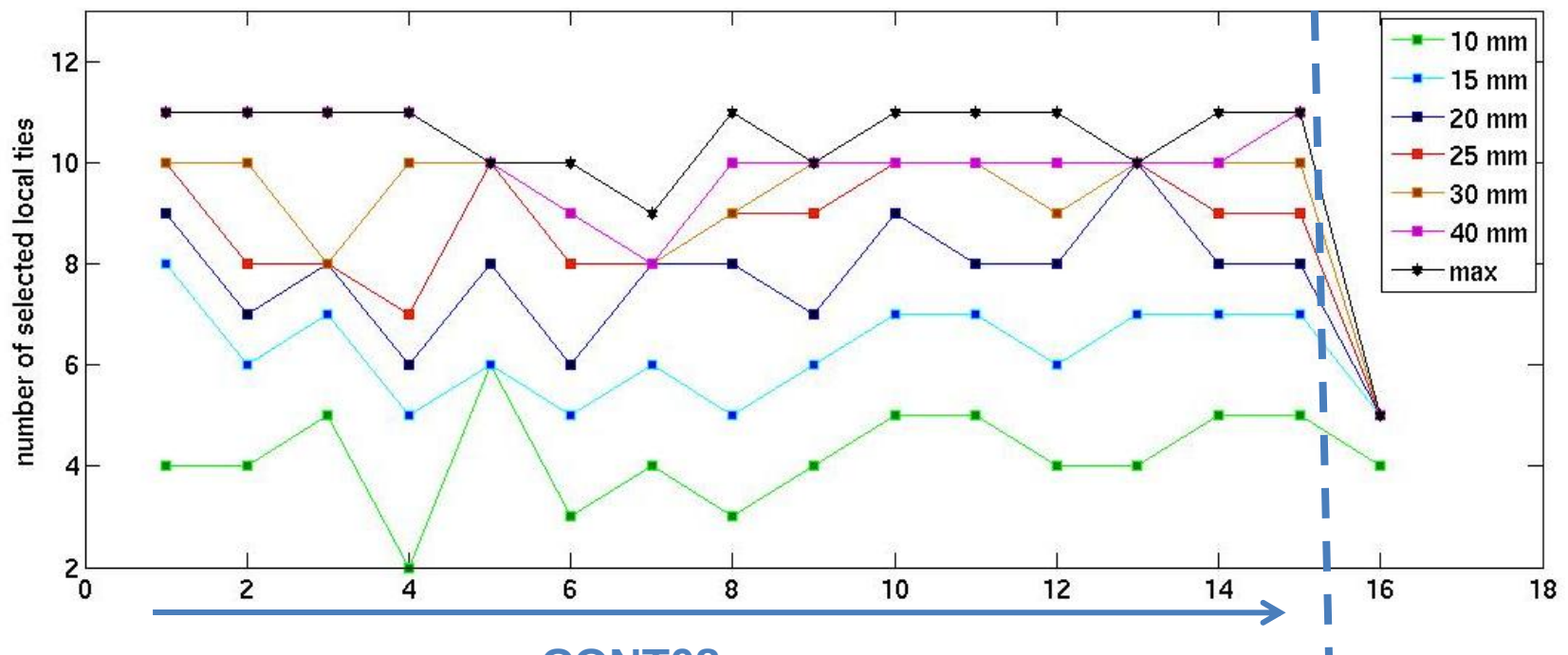
12 co-location sites

Selection of local ties

- In DTRF2008 computation (ITRF2008 contribution of DGFI)
 - Two criteria are used:
 - Deformation of networks shall be small
 - Offset between (not combined EOP) shall be small
 - Local ties and their STD are selected w.r.t. the criteria
- In COL
 - Because of differences in EOP parametrization and the short time series:
 - Good global coverage of co-locations
 - Small threshold for local tie fit (→ small deformation)

Combination of GPS and VLBI

- Number of local ties per session using different thresholds for the local tie fit



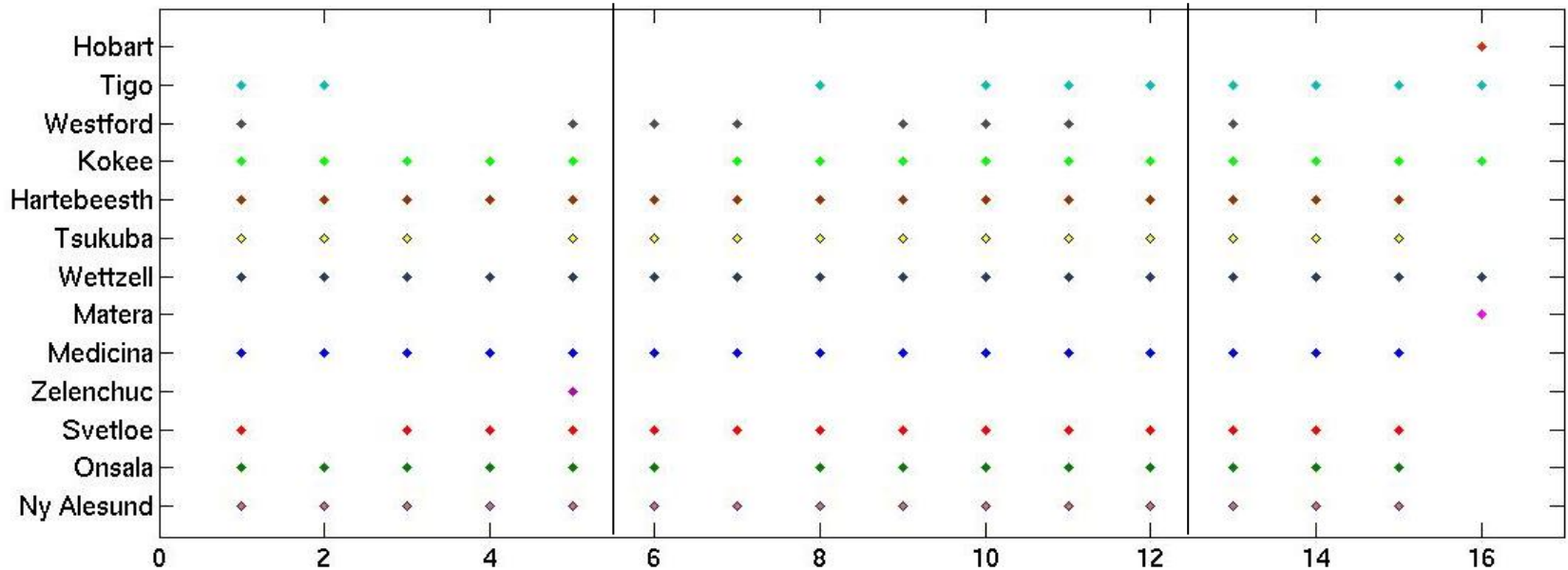
CONT08

12.8.2008, 0 UTC – 26.8.2008, 23:59:59 UTC

Combination of GPS and VLBI

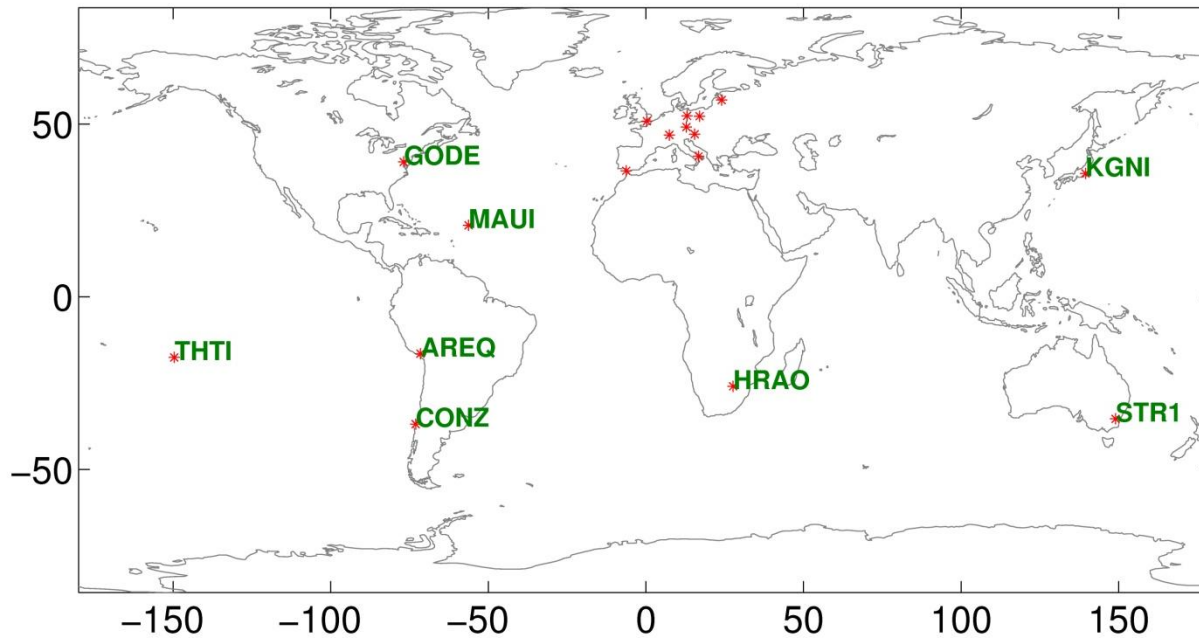
■ Global distribution of co-locations

GPS-VLBI: 25 mm threshold

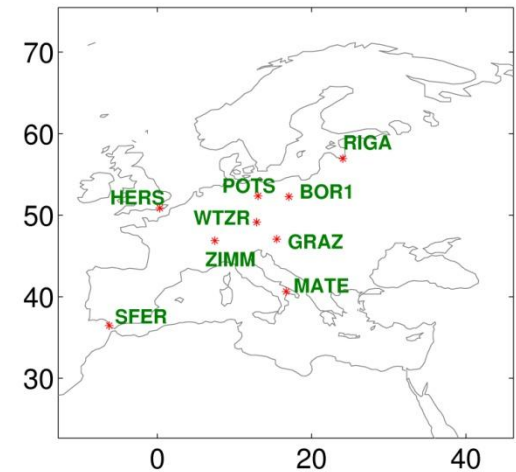


Combination of GPS and SLR

■ Co-locations GPS-SLR

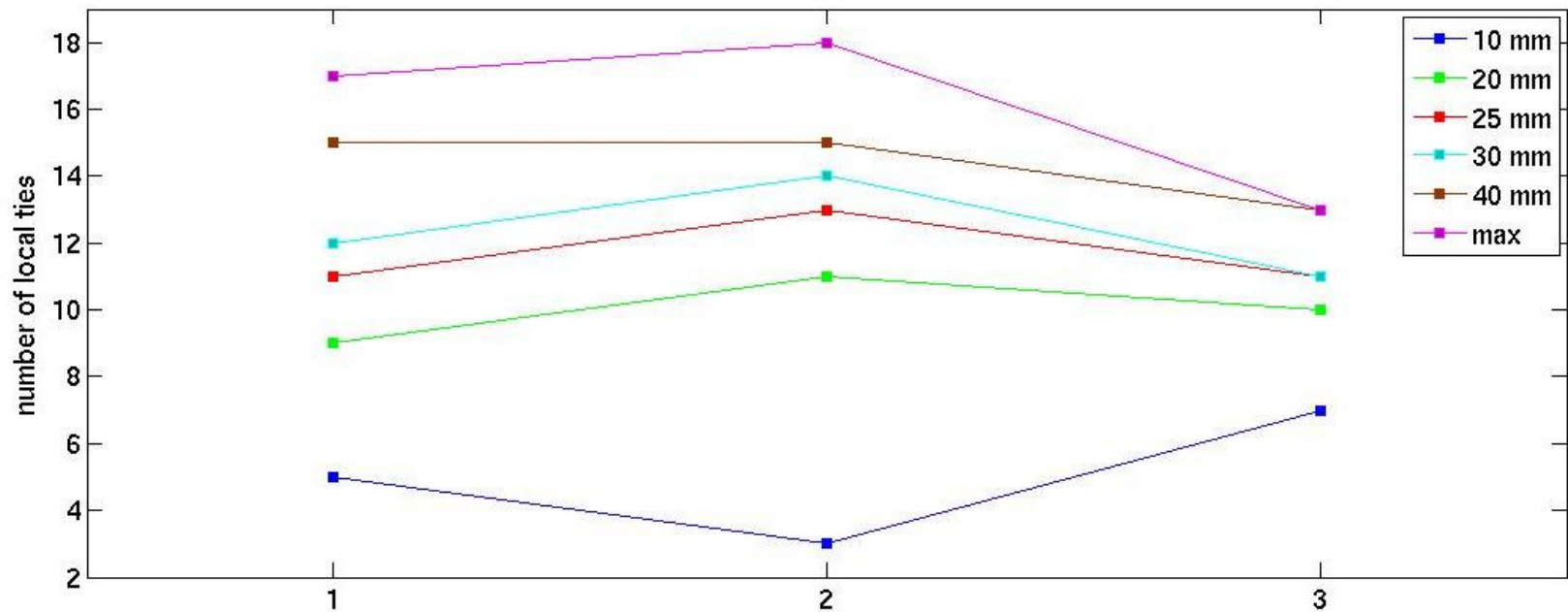


17 co-location sites



Combination of GPS and SLR

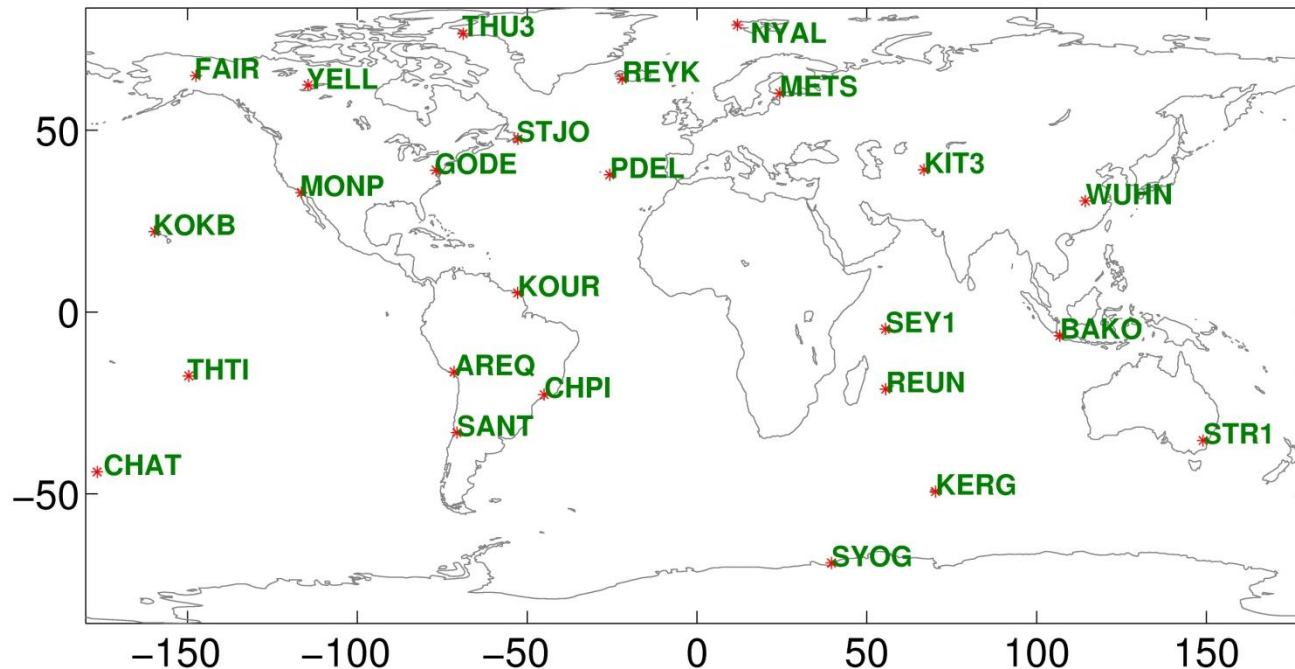
- Number of local ties per week using different thresholds for the local tie fit



A threshold of 25 mm seems to be a good compromise.

Combination of GPS and DORIS

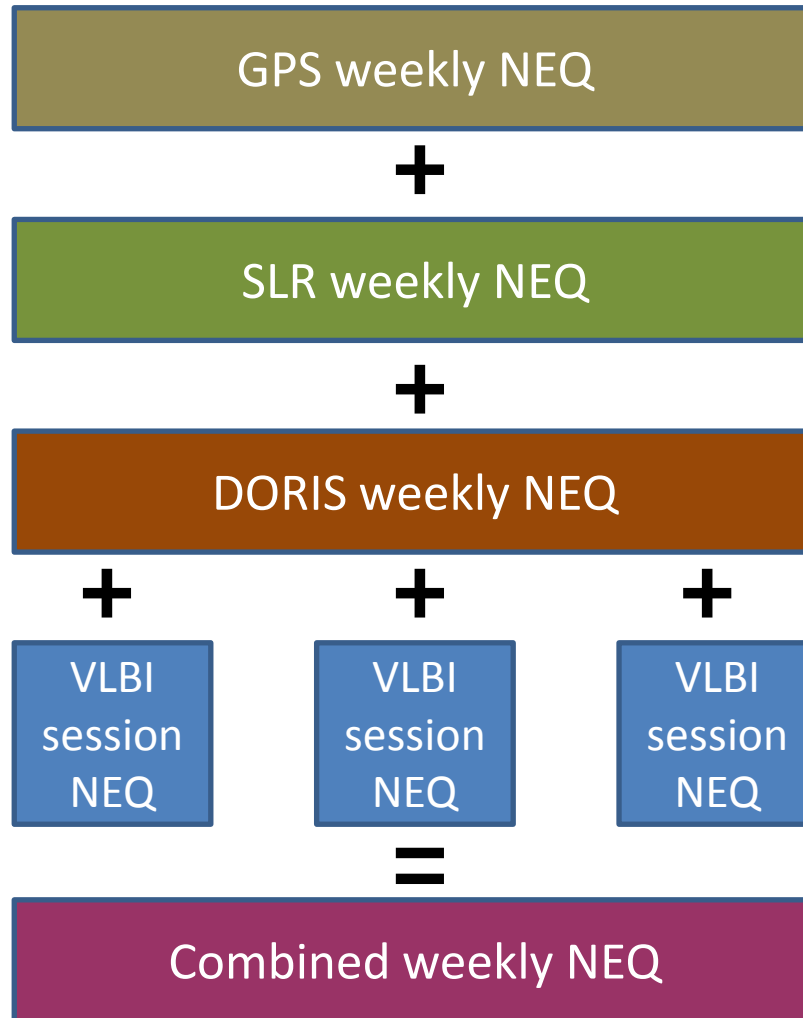
■ GPS-DORIS co-locations



Very good global distribution: 25 co-locations

Combination of GPS+SLR+DORIS+VLBI

■ Flowchart of weekly combination



Weighting:

SLR	1.00
DORIS	1.00
VLBI	1.00
GPS	0.25*

*according to DTRF2008

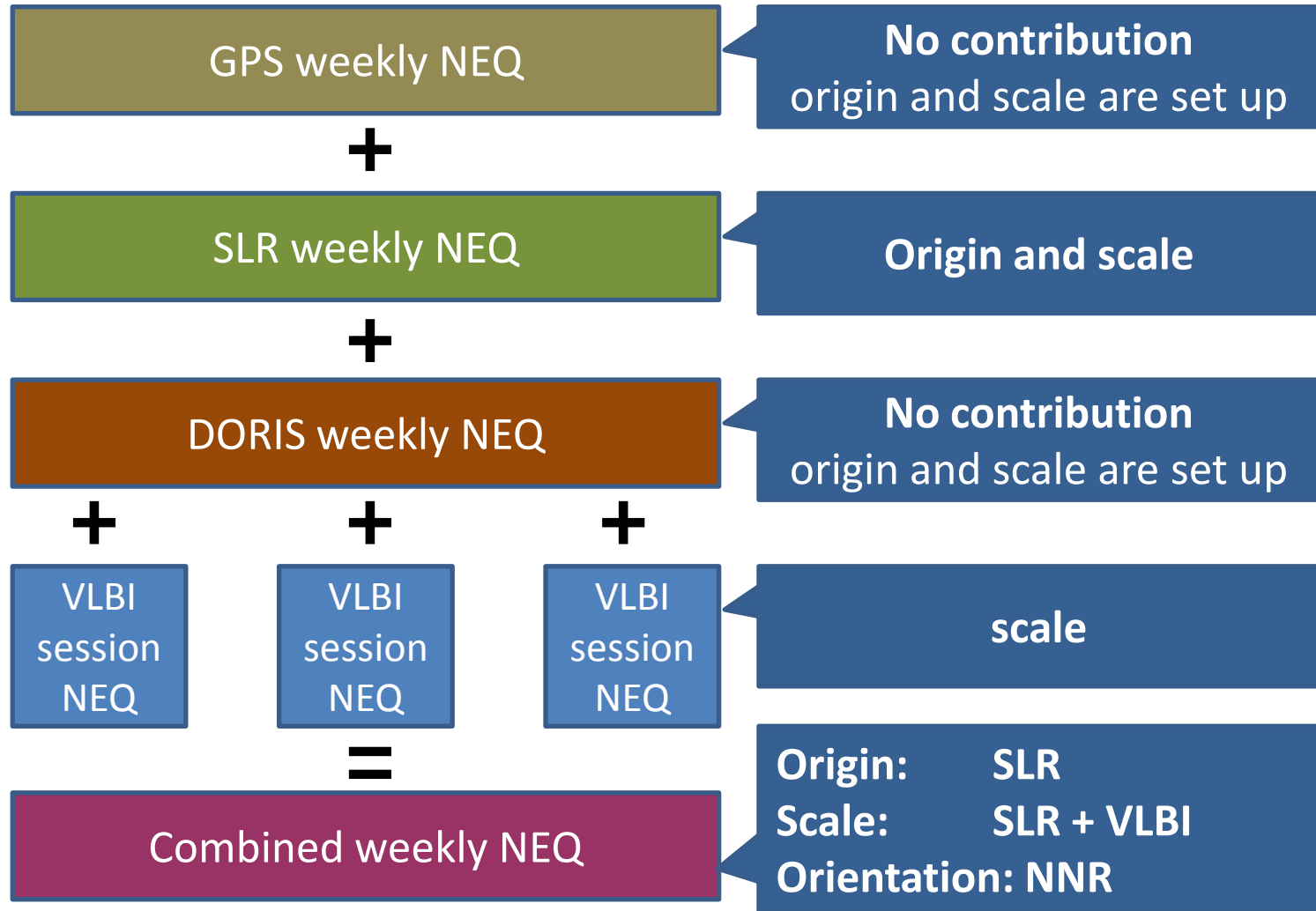
For a sophisticated weighting longer time series are necessary.

σ local ties

1.0 mm / component

Combination of GPS+SLR+DORIS+VLBI

■ Datum realization



Combination of GPS+SLR+DORIS+VLBI

■ Conservation of datum

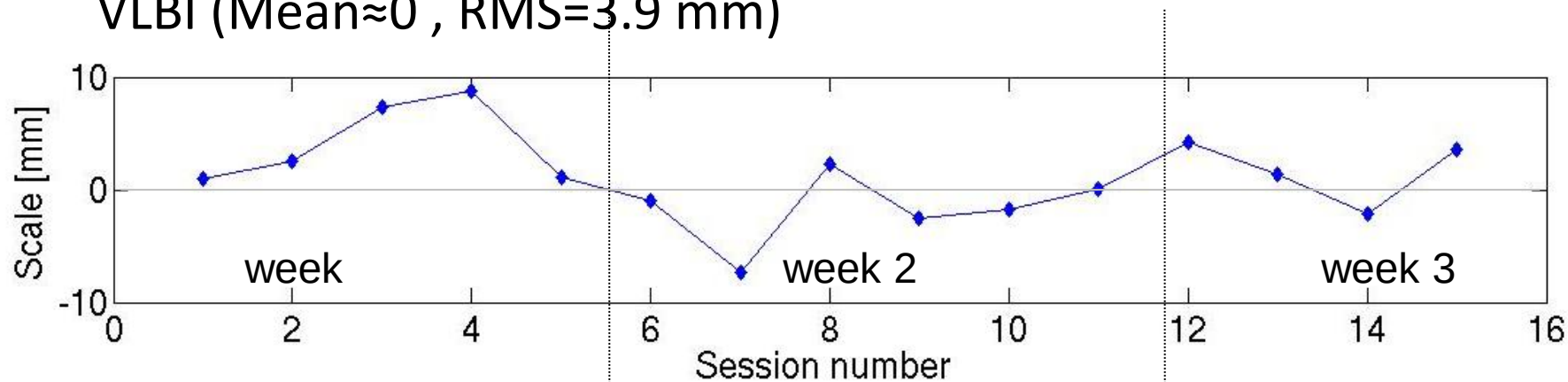
Origin

Conserved to 3.0 mm (all three components) (transformation via 20 SLR stations)

Scale

SLR: ≤ 1.1 mm

VLBI (Mean ≈ 0 , RMS=3.9 mm)



cm-residuals: Tsukuba, Westford, Kokee, Ny Alesund

Combination of GPS+SLR+DORIS+VLBI

■ Conservation of datum

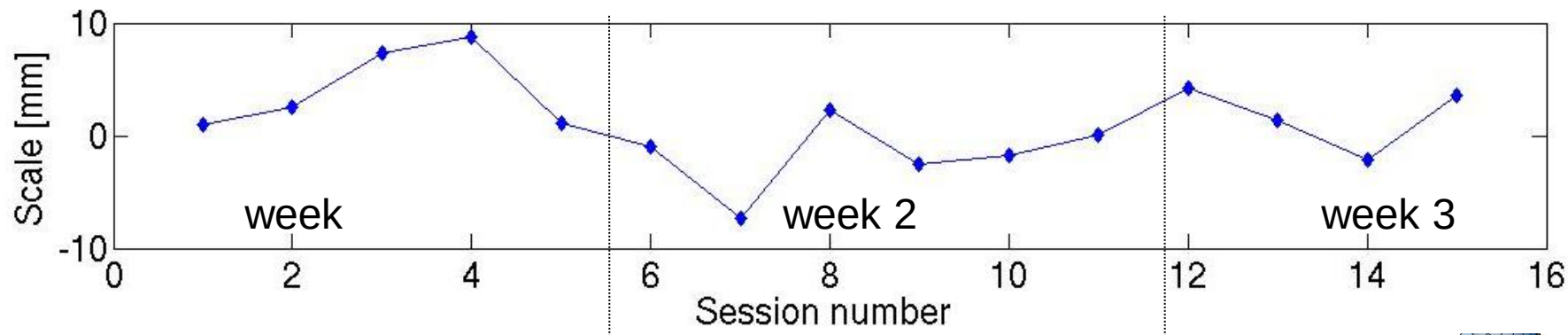
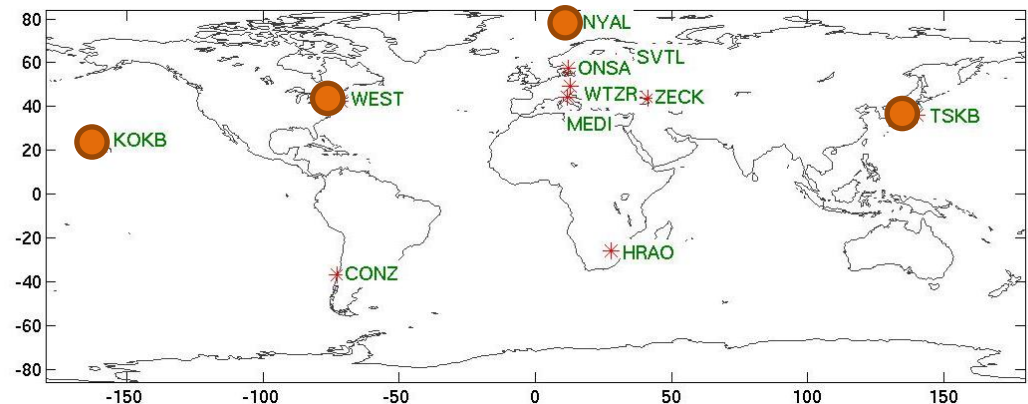
Origin

Conserved to 3.0 mm (all three components) (transformation via 20 SLR stations)

Scale

SLR: ≤ 1.1 mm

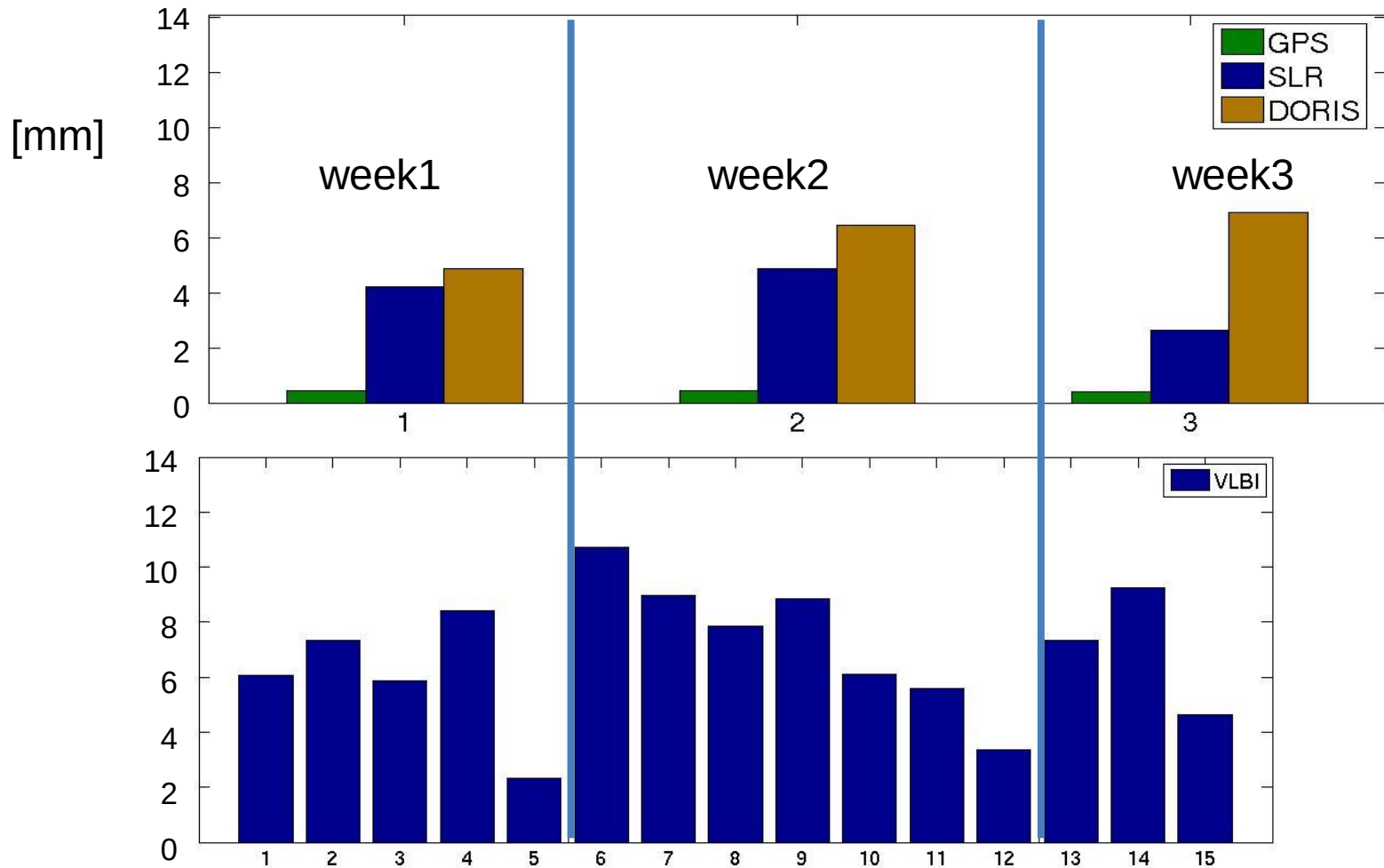
VLBI (RMS=3.9 mm)



- Conservation of datum
 - Not satisfying
 - Possible reasons / improvements
 - Consistency of techniques w.r.t. models (scale: SLR, VLBI)
 - state-of-the-art models for all techniques (abs. PCC for GPS)
 - handling of local ties
 - Including more techniques (GPS, DORIS) in the datum realization

Combination of GPS+SLR+DORIS+VLBI

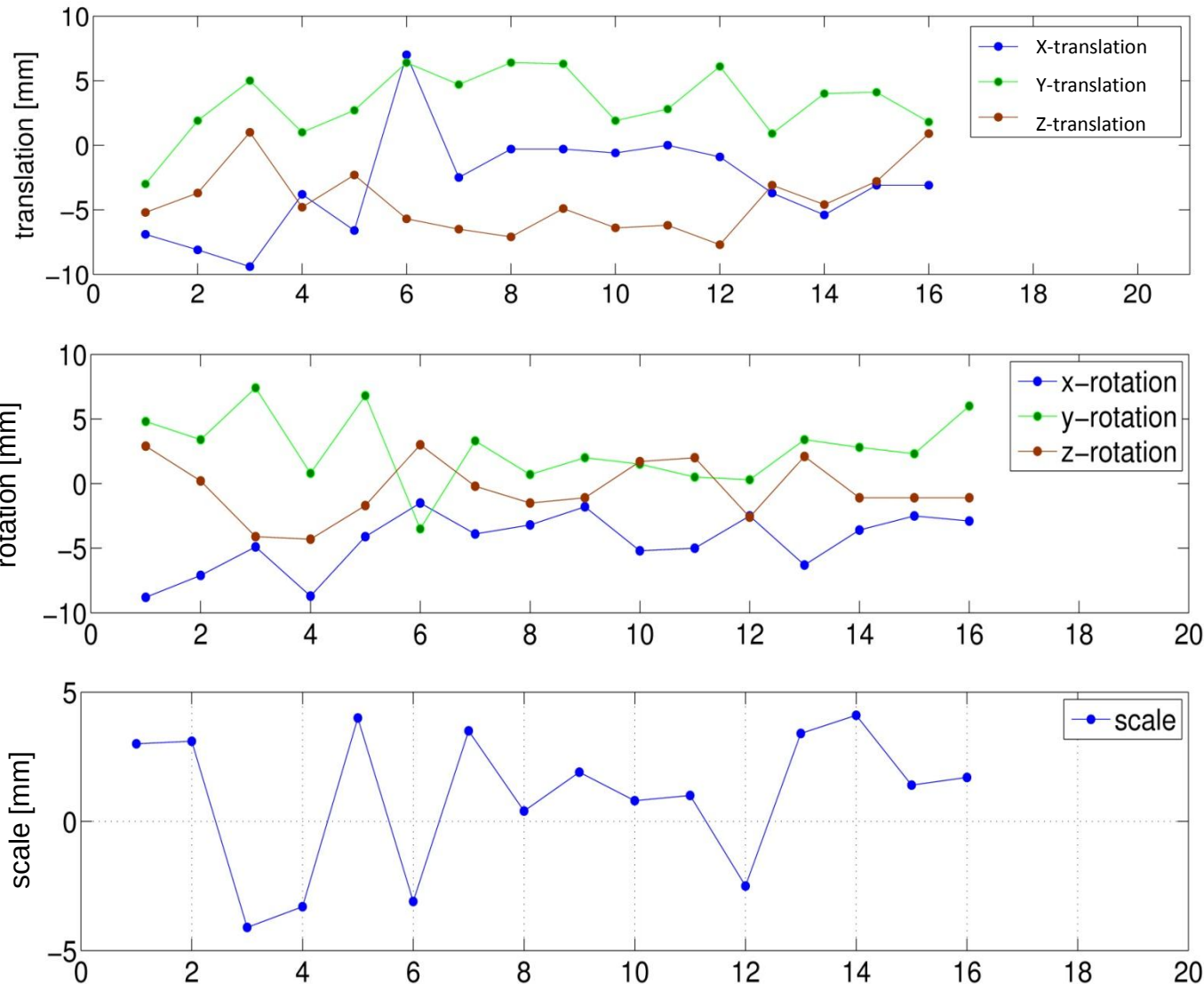
■ Deformation of the networks due to combination



M. Seitz, Input data and combination results

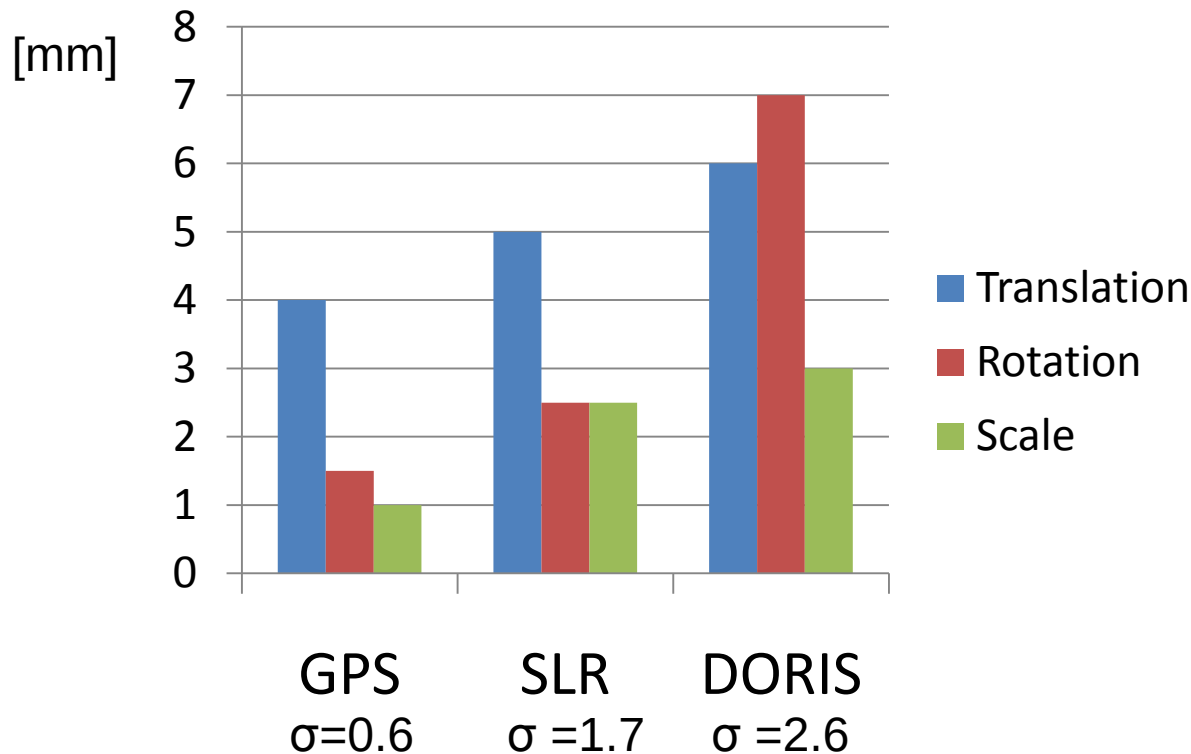
P+L+D+R: Comparison with DTRF2008

■ VLBI : How well is the datum realized?



P+L+D+R: Comparison with DTRF2008

- GPS, SLR, DORIS: mean transformation parameters



But **maximum values for translation** are:

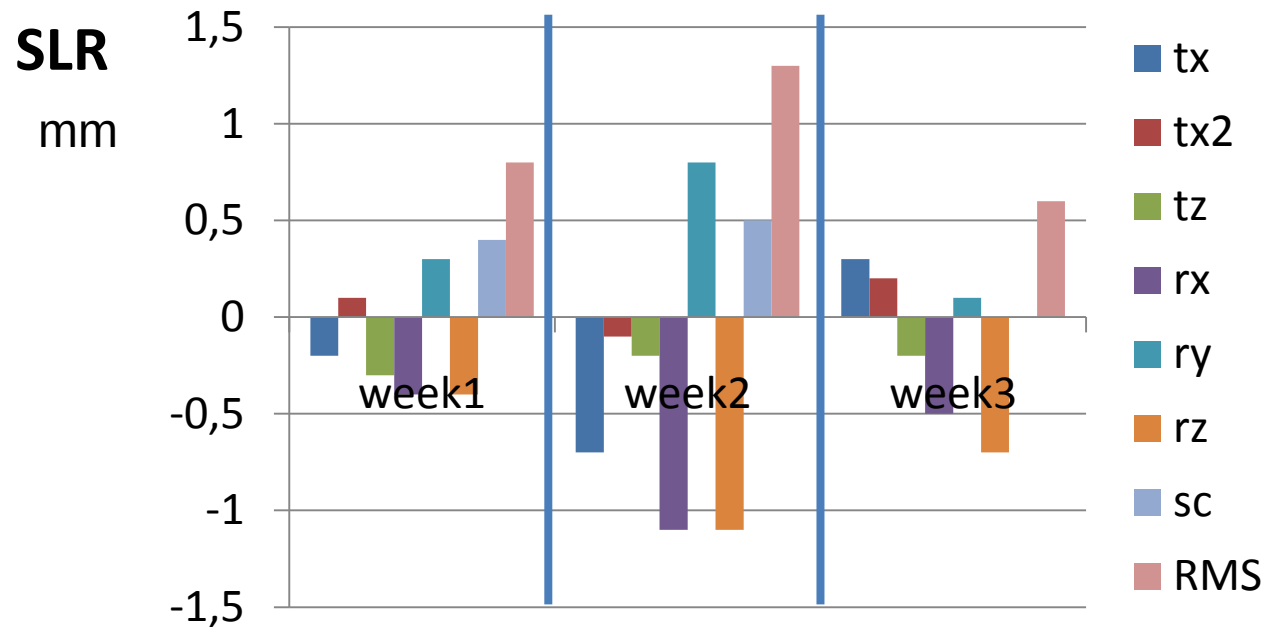
8 mm for SLR and GPS
12 mm for DORIS

Combination of GPS+SLR+DORIS+VLBI with pre-combined data

Combination with pre-combined data

- GPS+SLR+VLBI+DORIS and ESOC_LD (weight of ESOC_LD = 0.1)

Transformation between P+L+D+R+LD and P+L+D+R



Transformation parameters small

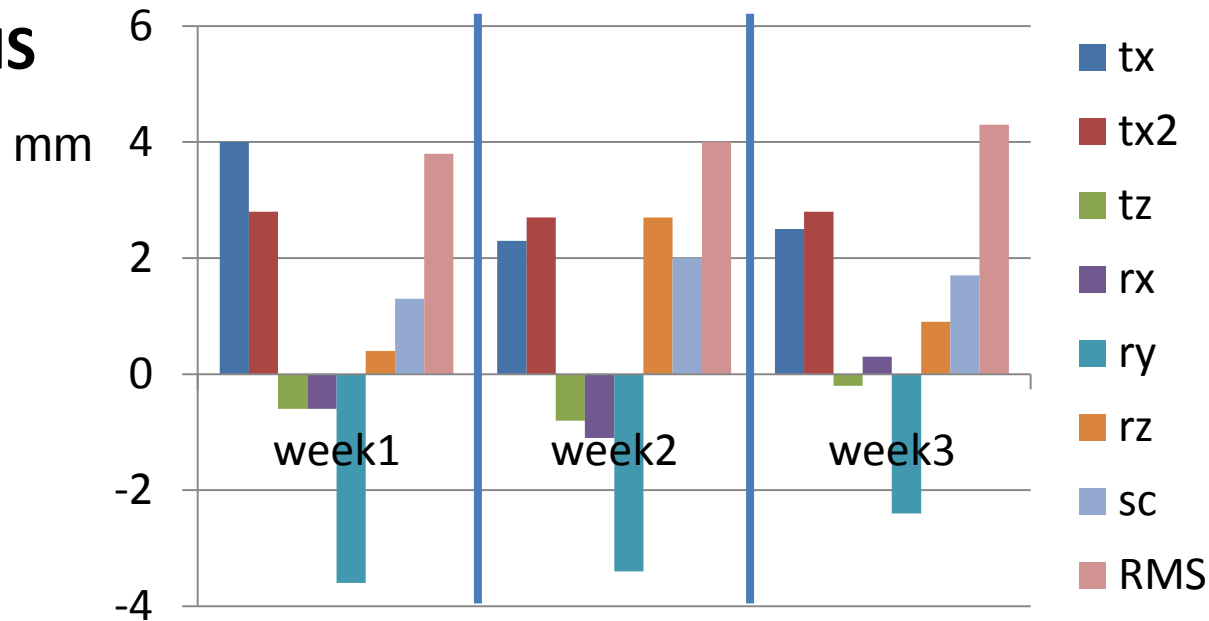
Orientation: orientation of ESOC_LD is fixed to about 2 cm

Combination with pre-combined data

- GPS+SLR+VLBI+DORIS and ESOC_LD (weight of ESOC_LD = 0.1)

Transformation between P+L+D+R+LD and P+L+D+R

DORIS



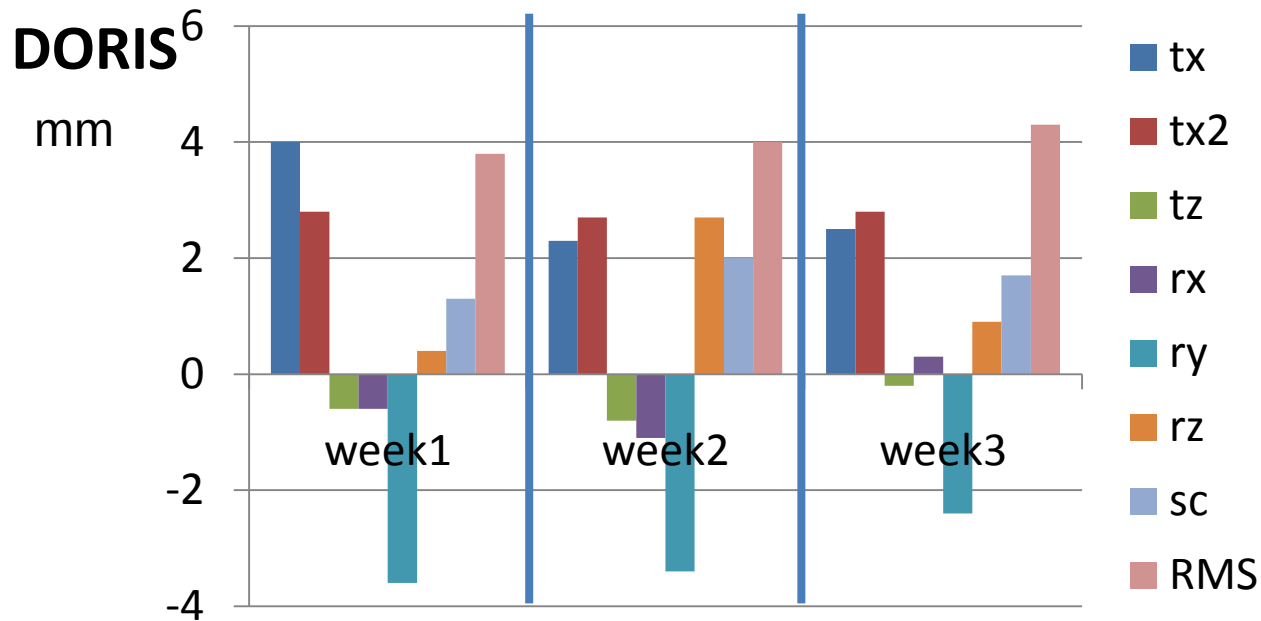
Transformation parameters of some mm

SLR is slightly, DORIS is more influenced by the combination

Combination with pre-combined data

- GPS+SLR+VLBI+DORIS and ESOC_LD (weight of ESOC_LD = 0.1)

Transformation between P+L+D+R+LD and P+L+D+R



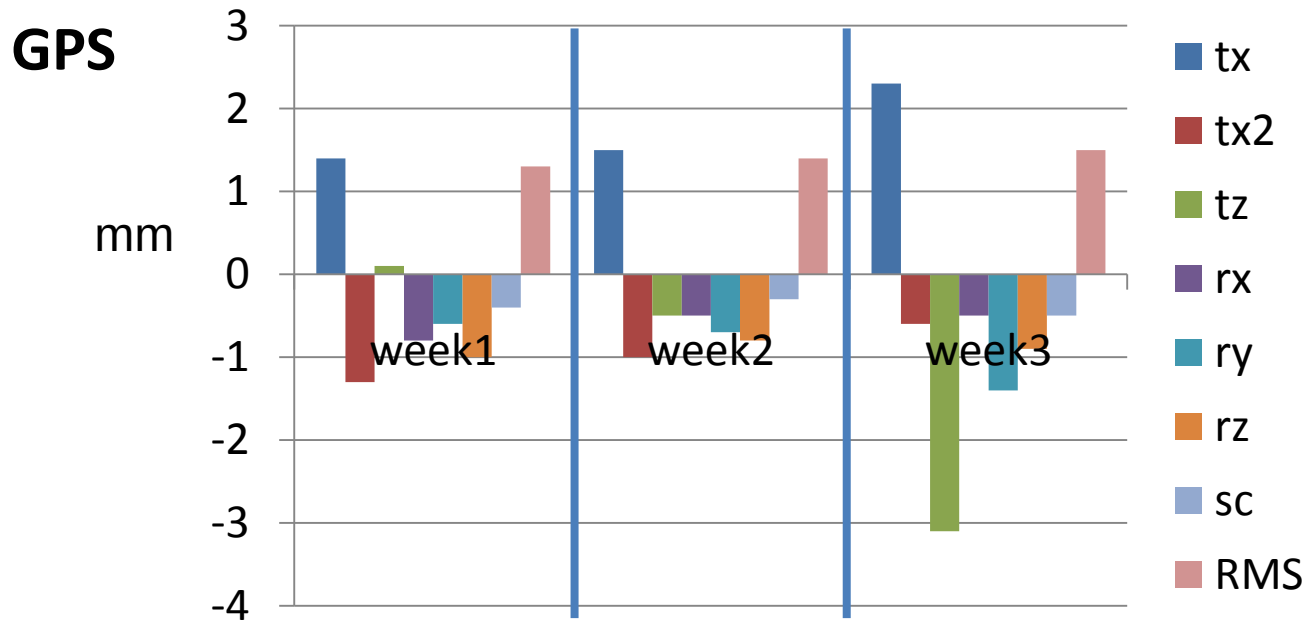
Transformation parameters of some mm

How is the datum of ESOC_LD realized?
Does DORIS contribute to origin and scale?
How the techniques are weighted?

Combination with pre-combined data

- GPS+SLR+VLBI+DORIS and ESOC_LD and ESOC_LP
(weight of ESOC_LD = 0.1, weight of ESOC_LP = 0.1)

Transformation between P+L+D+R+LD+LP and P+L+D+R



transformation parameters of up to 3 mm

orientation: orientation of ESOC_LP is fixed to 1cm

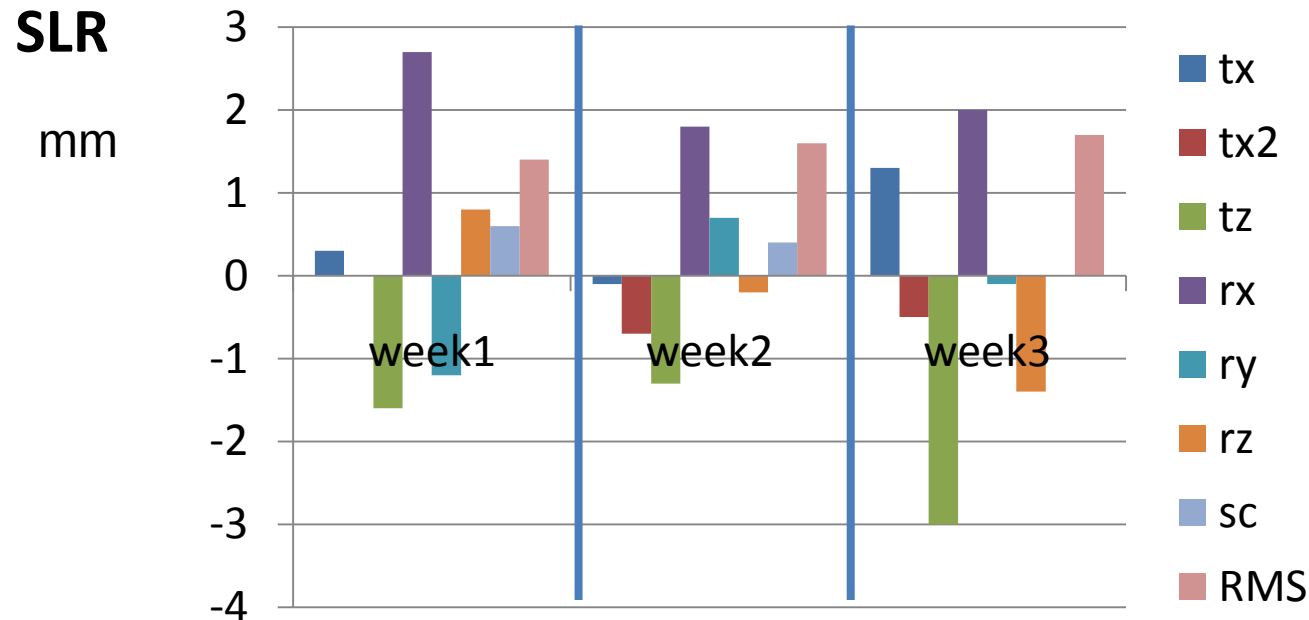
How the datum of ESOC_LP is realized? Origin realized also by GPS?

M. Seitz, Input data and combination results

Combination with pre-combined data

- GPS+SLR+VLBI+DORIS and ESOC_LD and ESOC_LP
(weight of ESOC_LD = 0.1, weight of ESOC_LP = 0.1)

Transformation between P+L+D+R+LD+LP and P+L+D+R



same characteristic for the translations. Parameters up to 3mm.

How the datum of ESOC_LP is realized? Origin realized also by GPS?

Deformation of the networks

- Summary: deformation of the networks
 - ESOC_LD (weight 0.1) / (weight 1.0)
 - SLR 0.7 mm / 1.3 mm
 - DORIS 4.0 mm / 9 mm
 - ESOC_LD and ESOC_LP (weights 0.1) / (weights 1.0)
 - SLR 1.3 mm / 6 mm
 - GPS 1.2 mm / 9 mm

- Promising results
 - Good agreement of AC contributions
 - Intra-technique combination works well
 - Inter-technique combination works well
 - Inclusion of pre-combined data works
 - Comparison with DTRF2008: good agreement

- Potential for improvement
 - Model improvements, homogenization
 - Refinement of combination strategy

To Do!

■ SINEX

- **SLR**: DGFI: orientation constraints
- **SLR**: ESOC: negative vTPv
- **VLBI**: GRGS: troposphere parameters not related to station
- **SLR-GPS**: ESOC: orientation fixed to 1cm
- **SLR-GPS**: GFZ: 6 of the daily NEQ cannot be solved
- **SLR-DORIS**: ESOC: orientation fixed to 2cm

To Do!

■ Models

- **All:** homogenization of the applied models
- **All:** homogenization of EOP parameterization
- No constraints w.r.t. orientation
- Datum realization and weighting of pre-combined NEQ

To Do!

■ Single technique

- GPS: why a weighting (AIUB/GRGS) is necessary?
- SLR, DORIS, GPS: why a weighting of ESOC pre-combined NEQ must be used w.r.t. $P+L+D+R$, if a strong deformation should be avoided?
- VLBI: combined solution (AIUB/GRGS)

To Do!

■ Combination

- Inclusion of all contributions
- all „types of ties“ implemented
- Refinement of local tie implementation
- Sophisticated weighting
- Datum realization: inclusion of GPS, DORIS?
 - Influence of ESOC_LD and ESOC_LP?
 - Weights of ESOC pre-combined contributions
- EOP combination
- Analysis of orbit parameters
- Add on: orbit combination

Troposphere combination