Input data
and
first combination results

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2nd COL Working Group Meeting
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DGFI

Outline

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

Input data

- 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

			used
SLR-GPS	ESOC	(GNSS+SLR to GPS targets)	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)	x
		the same as for SLR-GPS	

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 ⟺ pwl (unstacked)

Which EOP can be combined?

	AC	pole	UT1	nutation (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	nutation (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

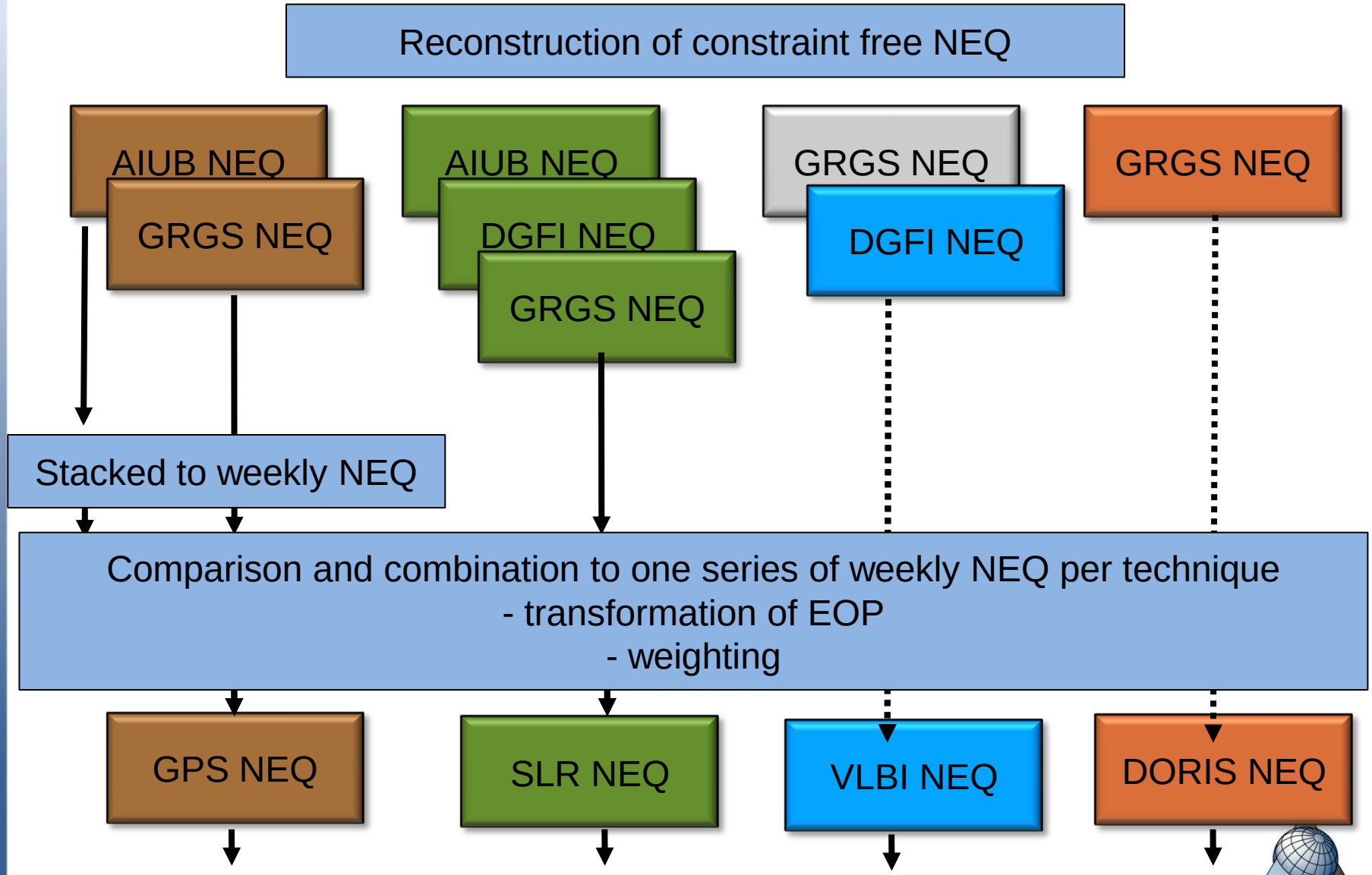
- Step by step

Per technique: daily to weekly (AIUB_GPS)
Comparison and combination of input files

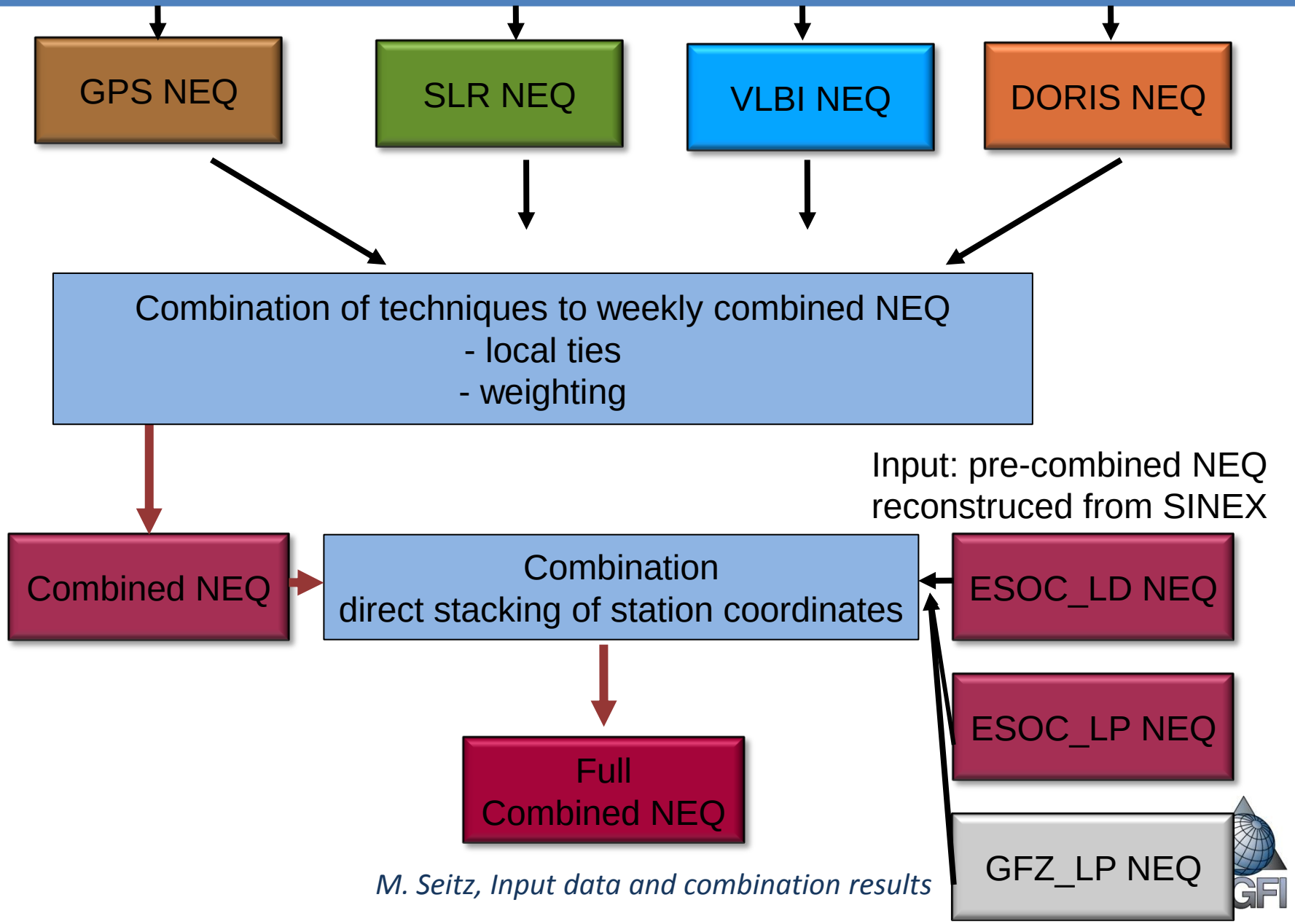
inter-technique 1: Comparison and combination of
VLBI-, SLR- and GPS-only contributions

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)

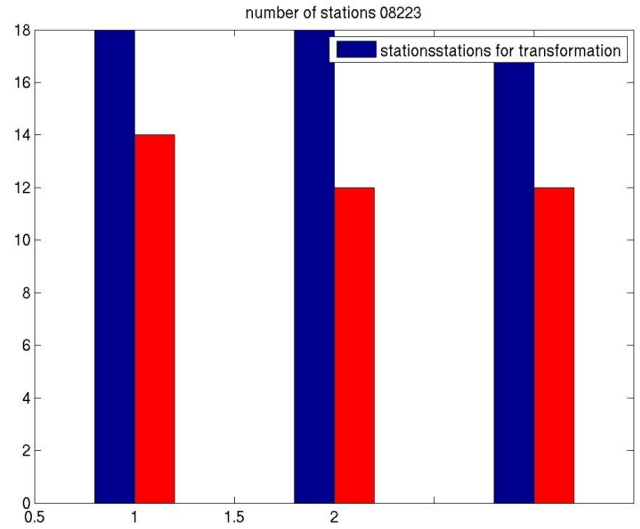


Intra-technique combination: SLR

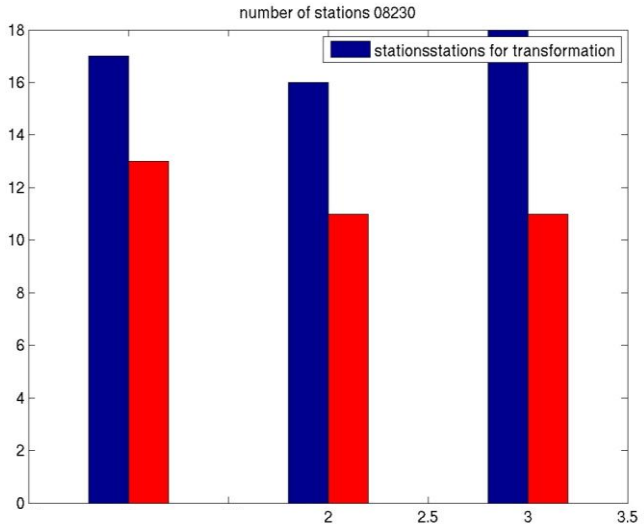
- SLR intern comparisons
  - 3 SLR only contributions(AIUB, DGFI, GRGS)
  - and 2 pre-combined (ESOC_LP, ESOC_LD)

Intra-technique combination: SLR

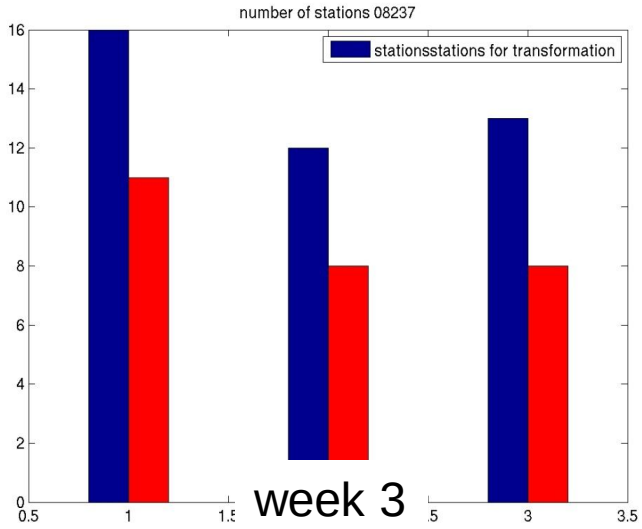
- Comparison of AIUB, DGFI and GRGS: number of stations



week 1



week 2



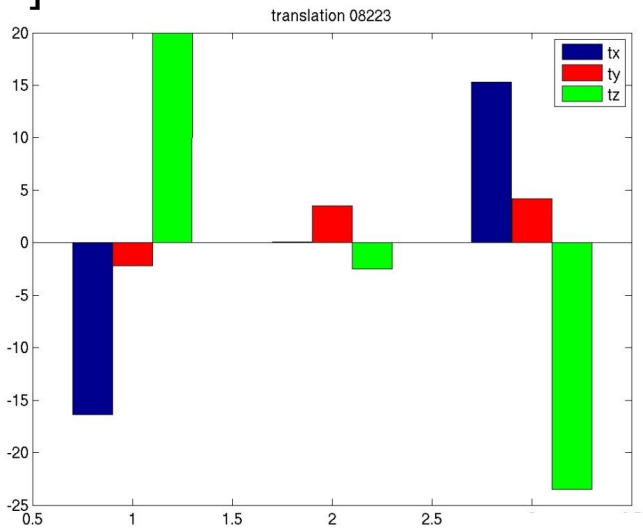
week 3

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

available
used

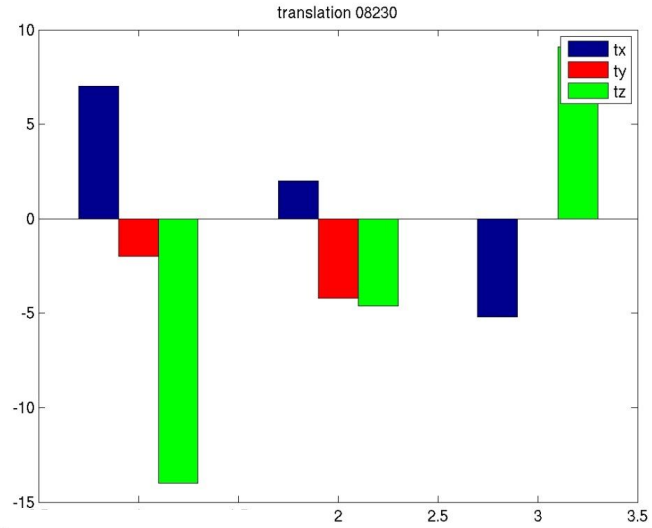
Translation parameters between SLR contributions

[mm]

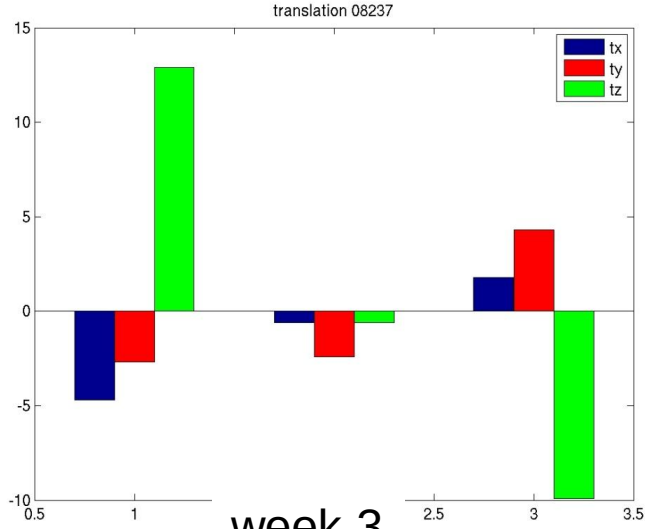


week 1

[mm]



week 2

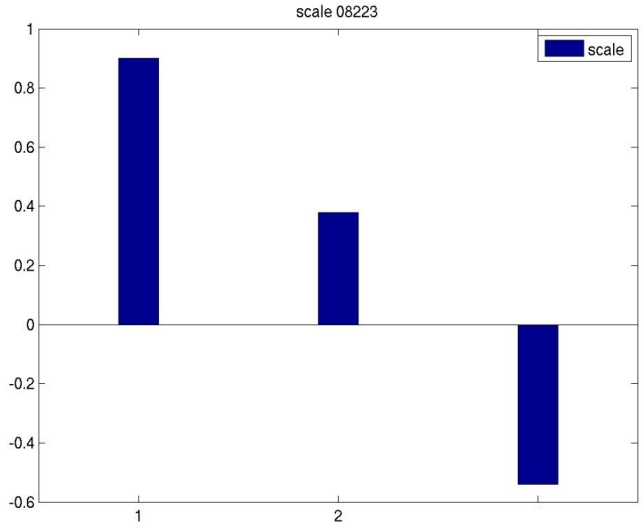


week 3

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

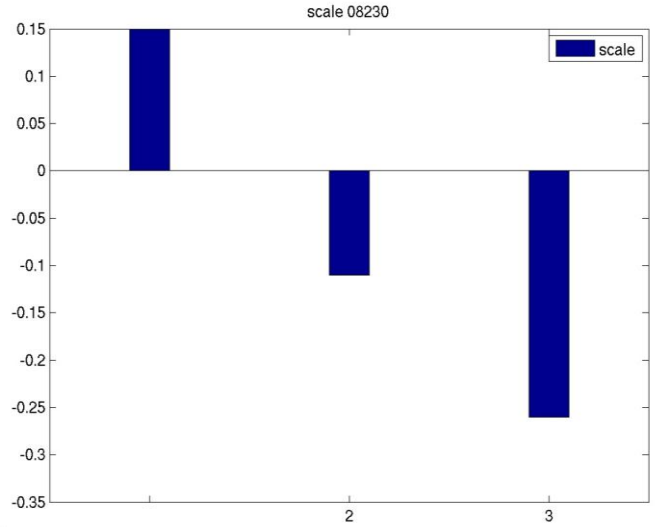
Scale parameters between SLR contributions

[ppb]

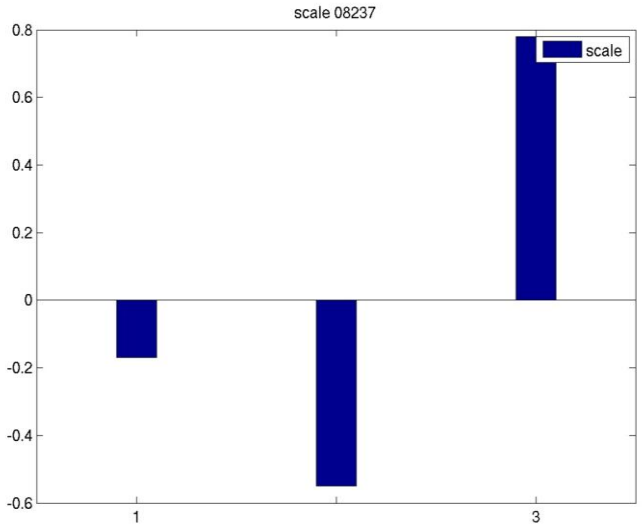


week 1

[ppb]



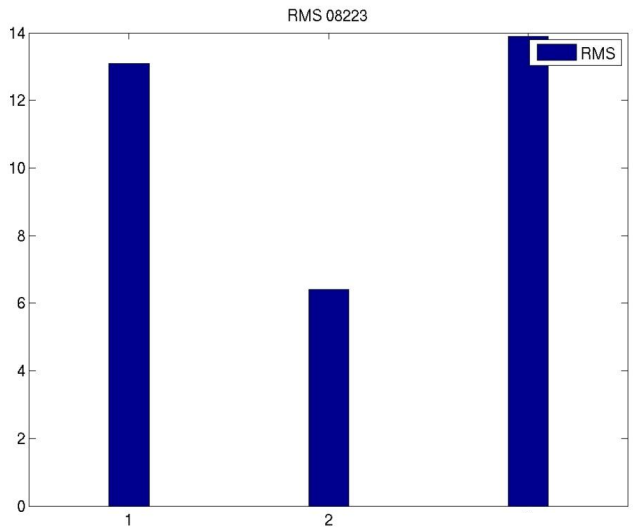
week 2



week 3

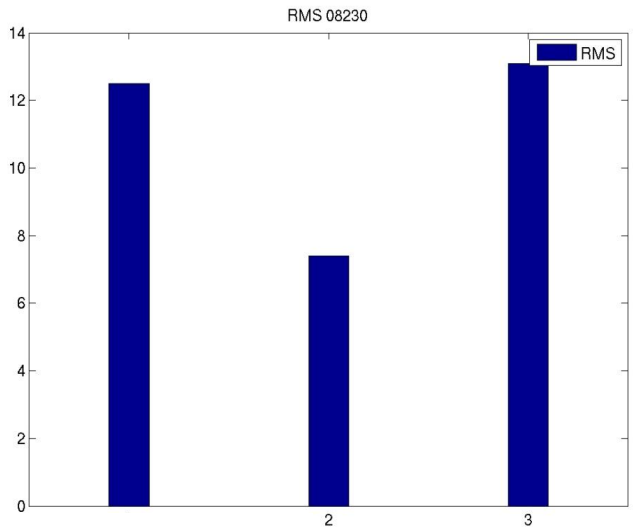
1 AIUB-DGFI
2 AIUB-GRGS
3 DGFI-GRGS

RMS of transformation: SLR

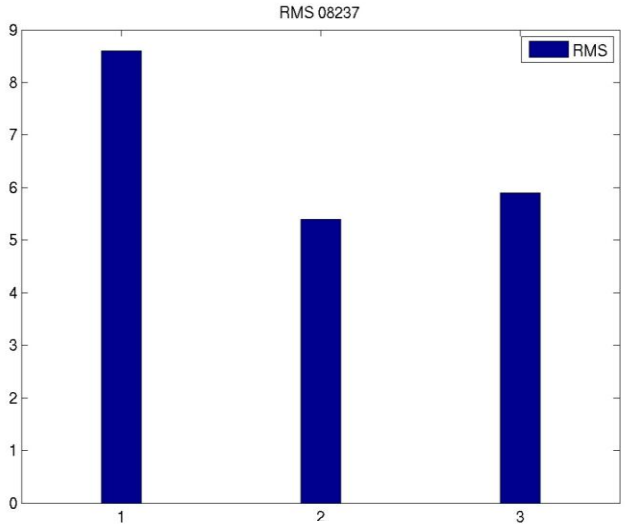


week 1

[mm]



week 2

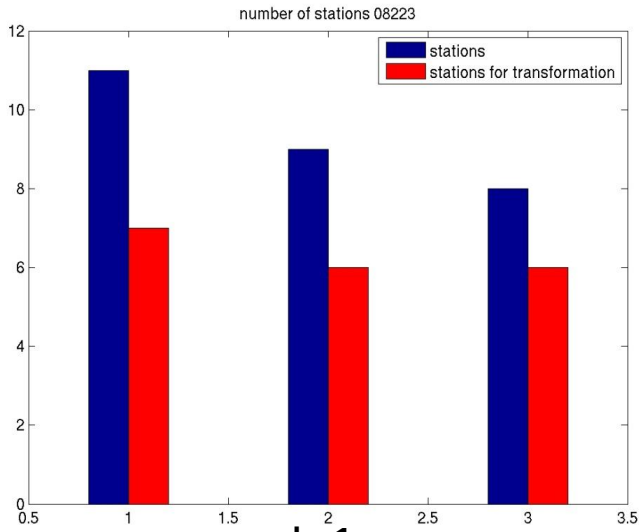


week 3

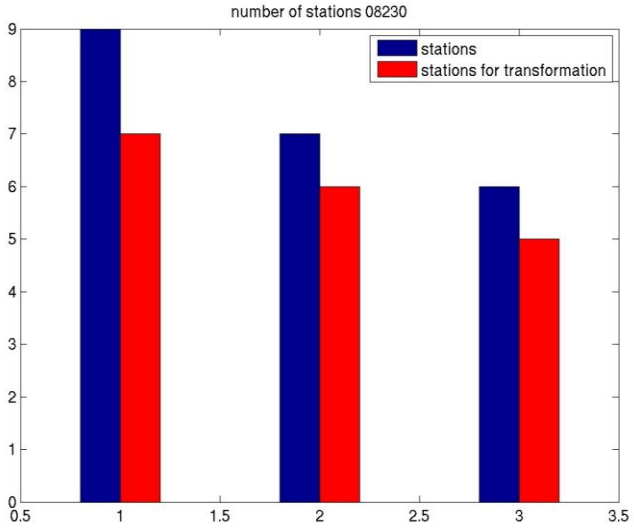
1 AIUB-DGFI
2 AIUB-GRGS
3 DGFI-GRGS

Comparison with pre-combined NEQ

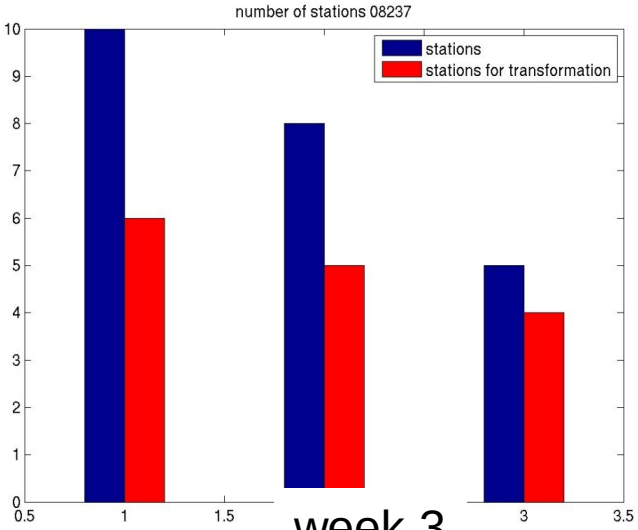
Number of common stations



week 1



week 2



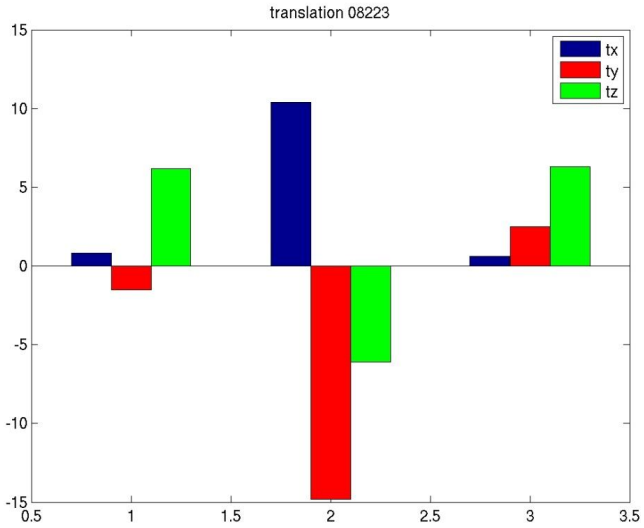
week 3

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

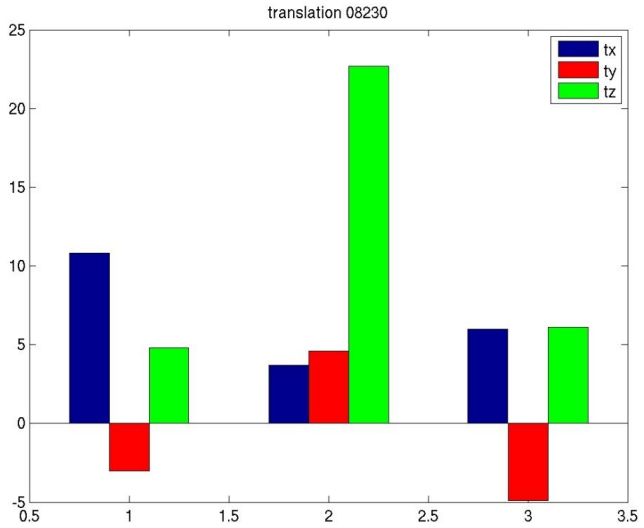
available
used

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

SLR with pre-combined: translations

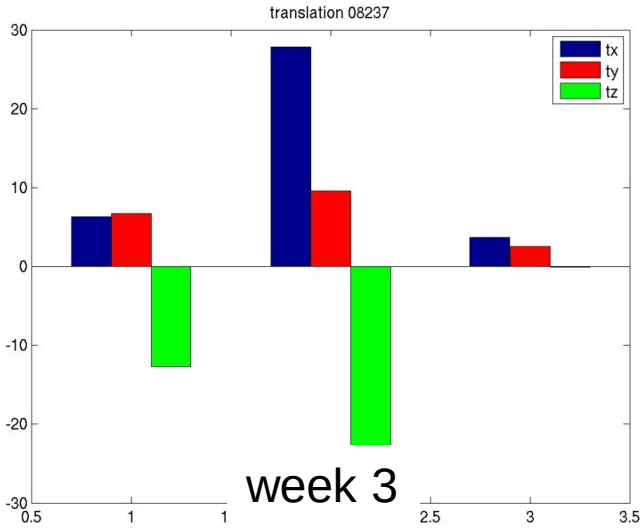


week 1



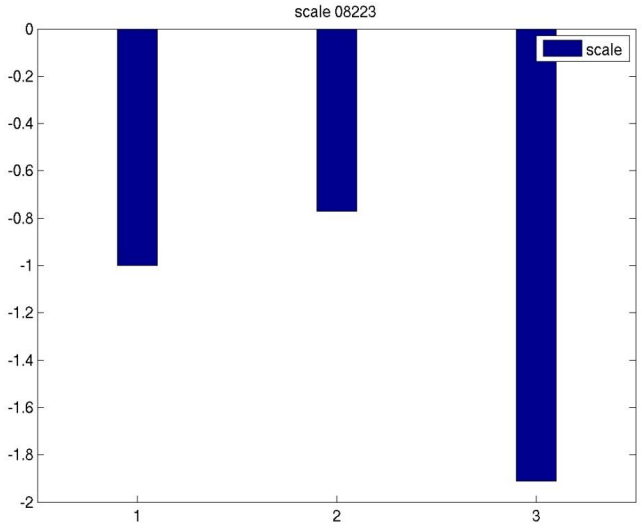
week 2

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



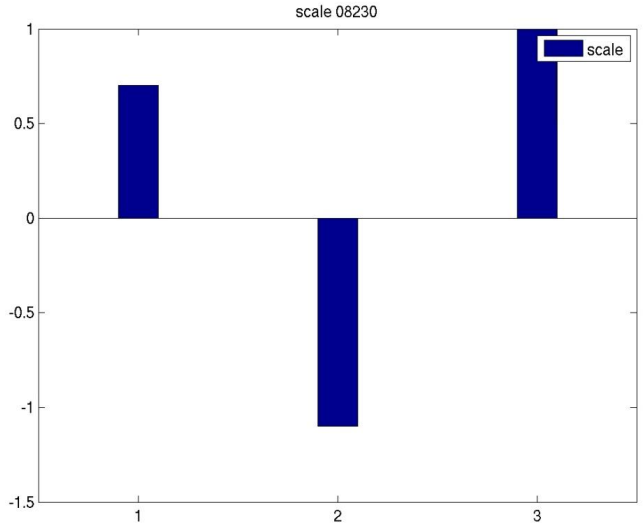
week 3

SLR with pre-combined: scale



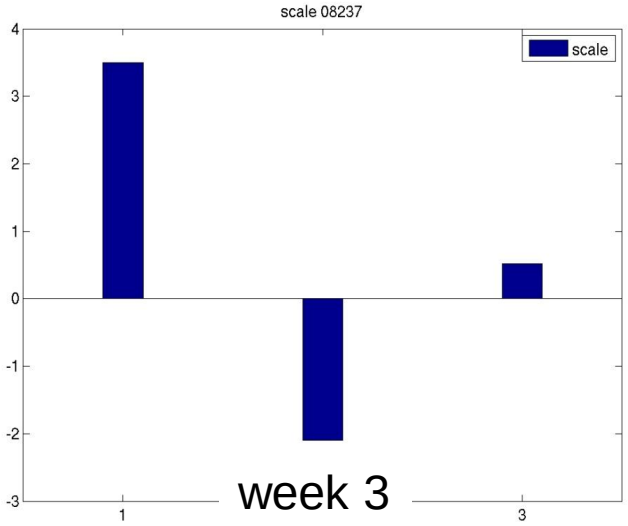
week 1

[ppb]



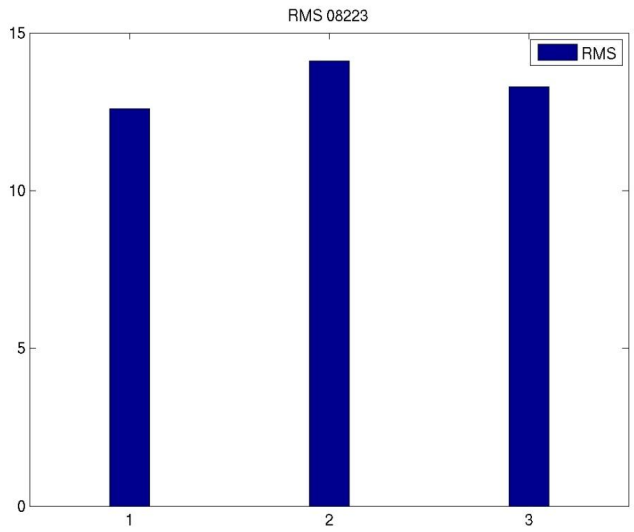
week 2

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

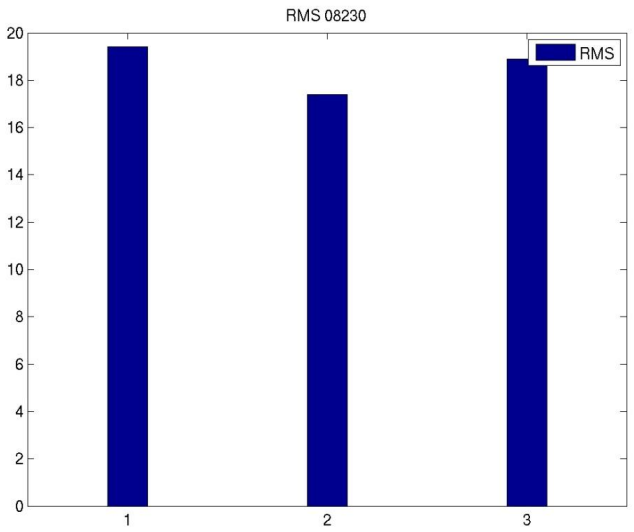


week 3

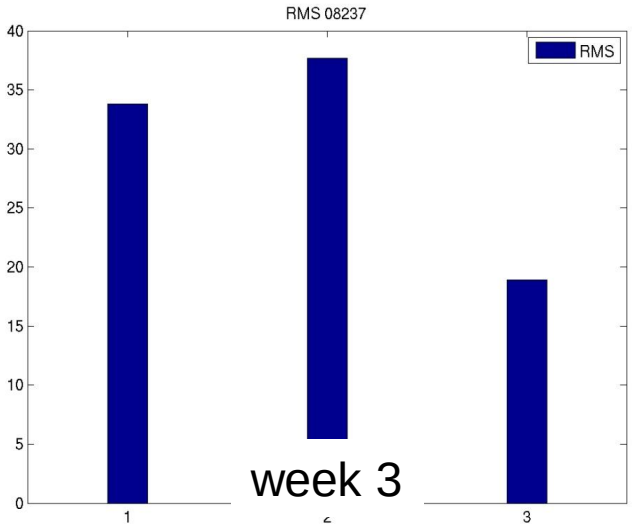
SLR with pre-combined: RMS



week 1



week 2



week 3

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

SLR intra-technique combination

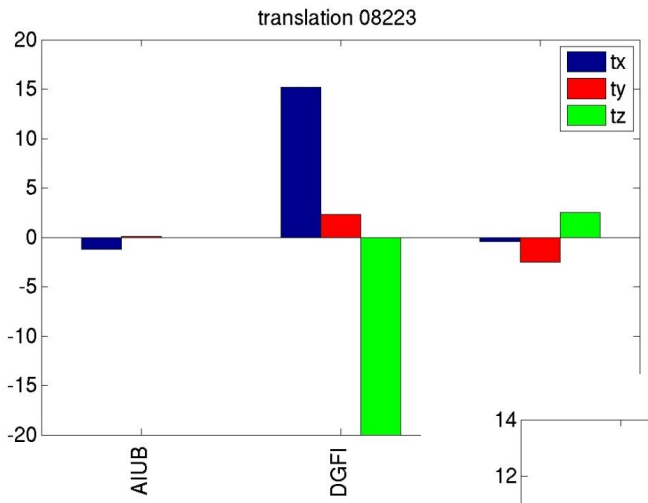
Combination of the SLR-only weekly solutions

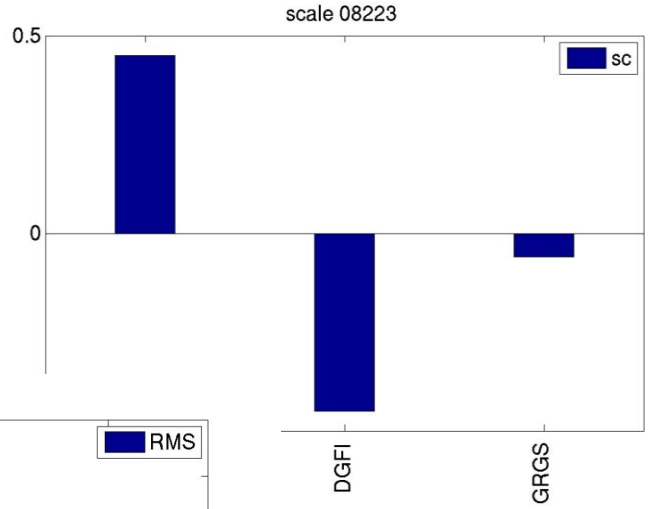
AIUB+DGFI+GRGS

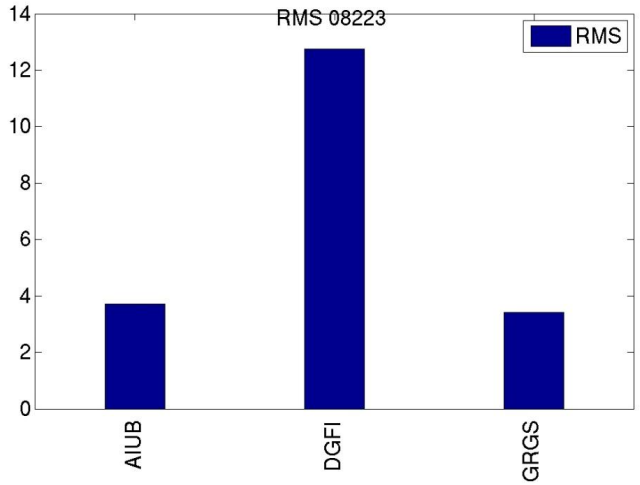
Comparison of combined with AC solutions

- Week 1

Weights: 1.00 for all three contributions



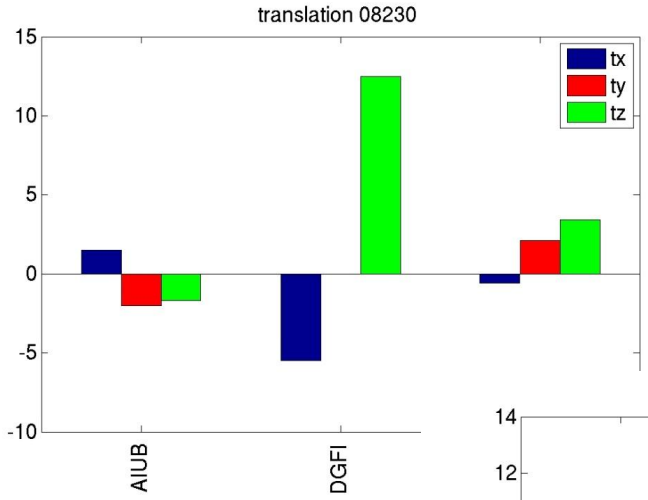


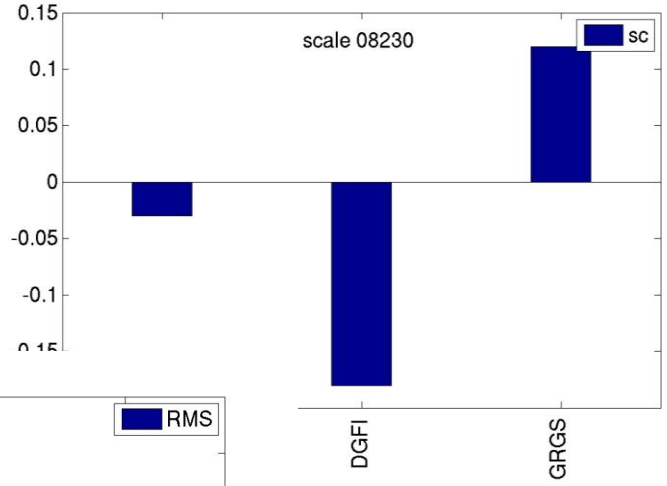


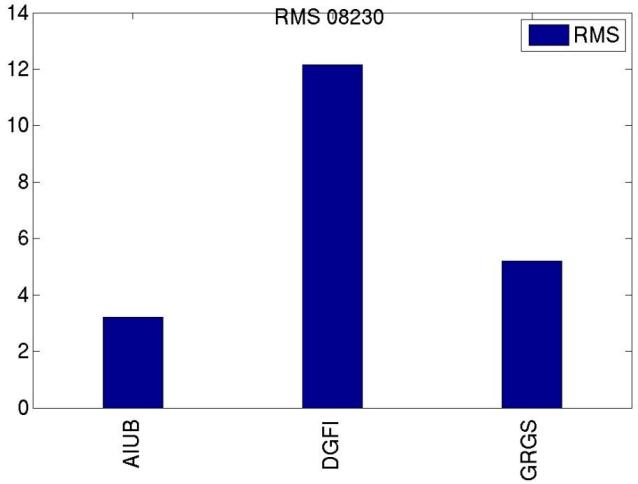
Comparison of combined with AC solutions

- Week 2

Weights: 1.00 for all three contributions



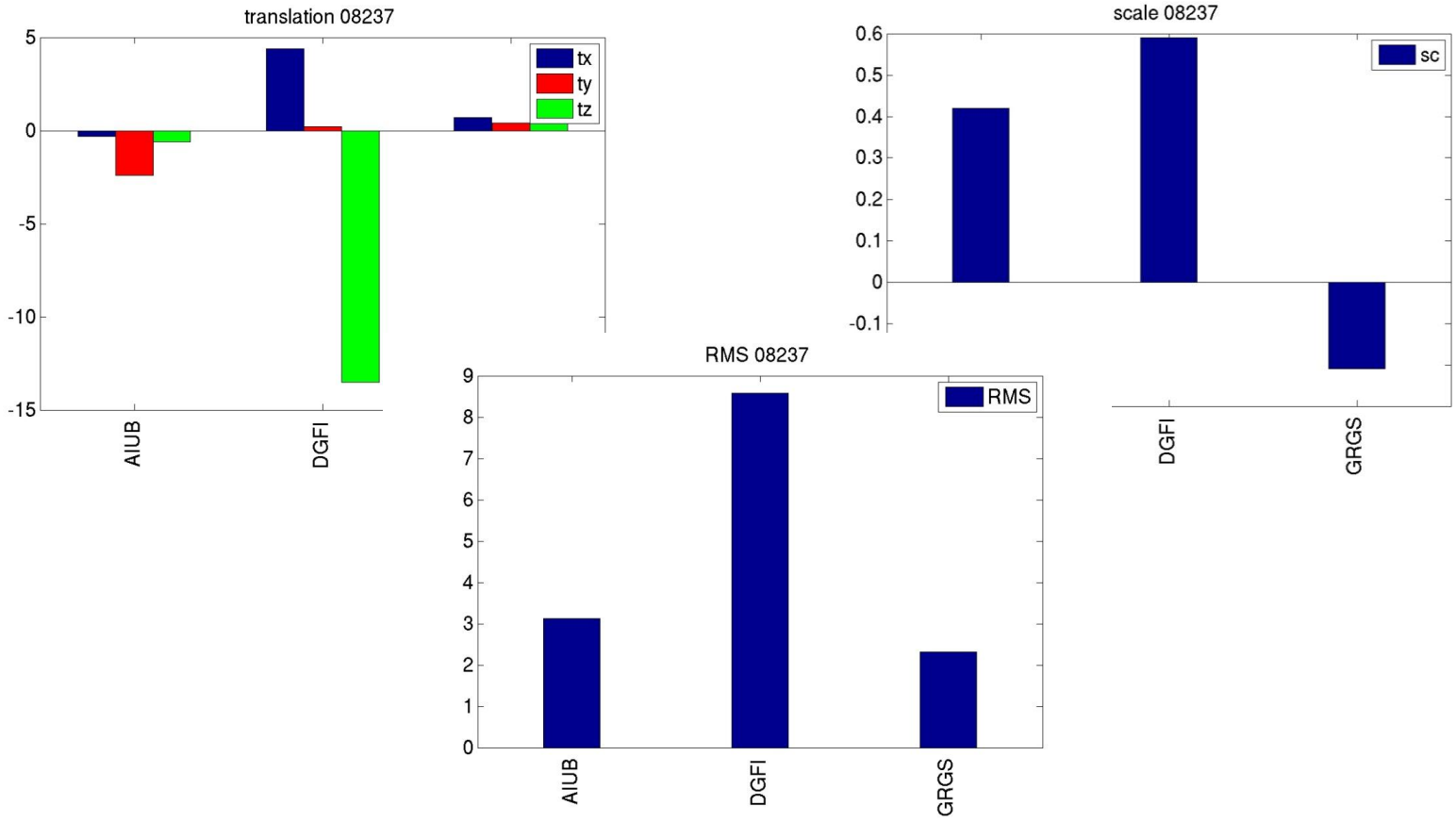




Comparison of combined with AC solutions

- 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 [µrad]:	0.00010 +-	0.00052	[cm]:	0.07
ry [µrad]:	-0.00011 +-	0.00044	[cm]:	-0.07
rz [µrad]:	-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 [µrad]:	-0.00068 +-	0.00048	[cm]:	-0.43
ry [µrad]:	0.00027 +-	0.00045	[cm]:	0.17
rz [µrad]:	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 [µrad]:	0.00023 +-	0.00055	[cm]:	0.15
ry [µrad]:	0.00048 +-	0.00050	[cm]:	0.30
rz [µrad]:	-0.00003 +-	0.00052	[cm]:	-0.02
sc [ppm]:	-0.00021 +-	0.00042	[cm]:	-0.14
estimated	standard deviation [cm]:	0.97954		

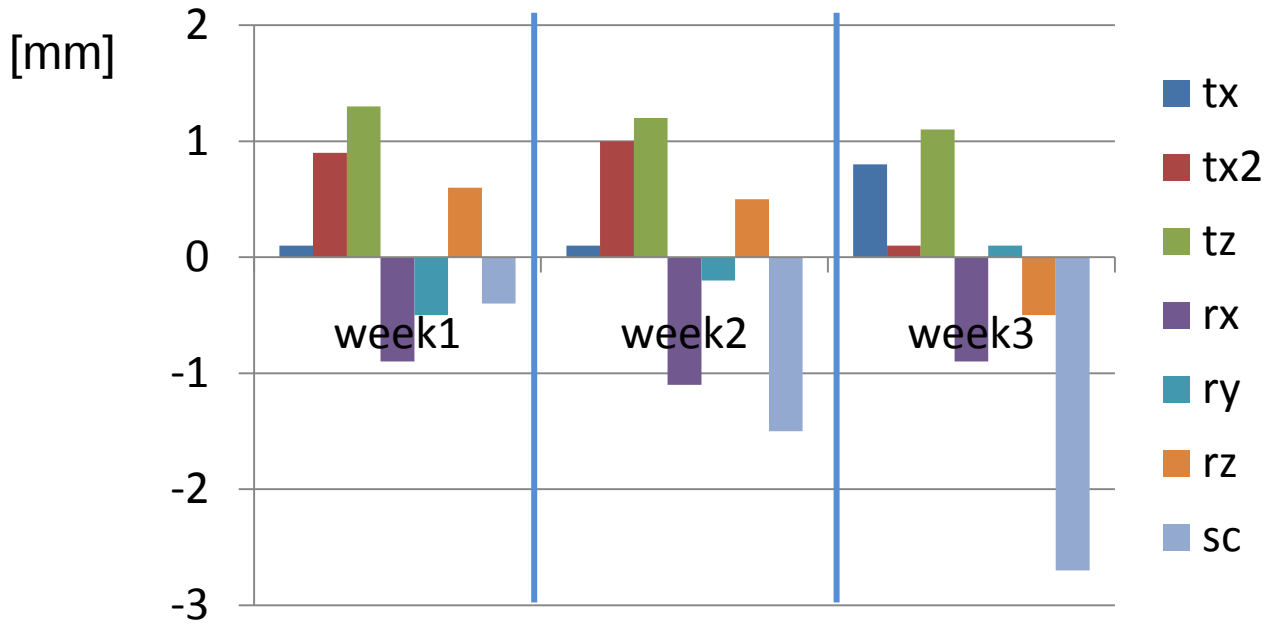
Transformation parameters for single AC w.r.t. DTRF2008 are comparable, each week another AC ist the “best one”

GPS: intra-technique

- 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 -

DGFI

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]:

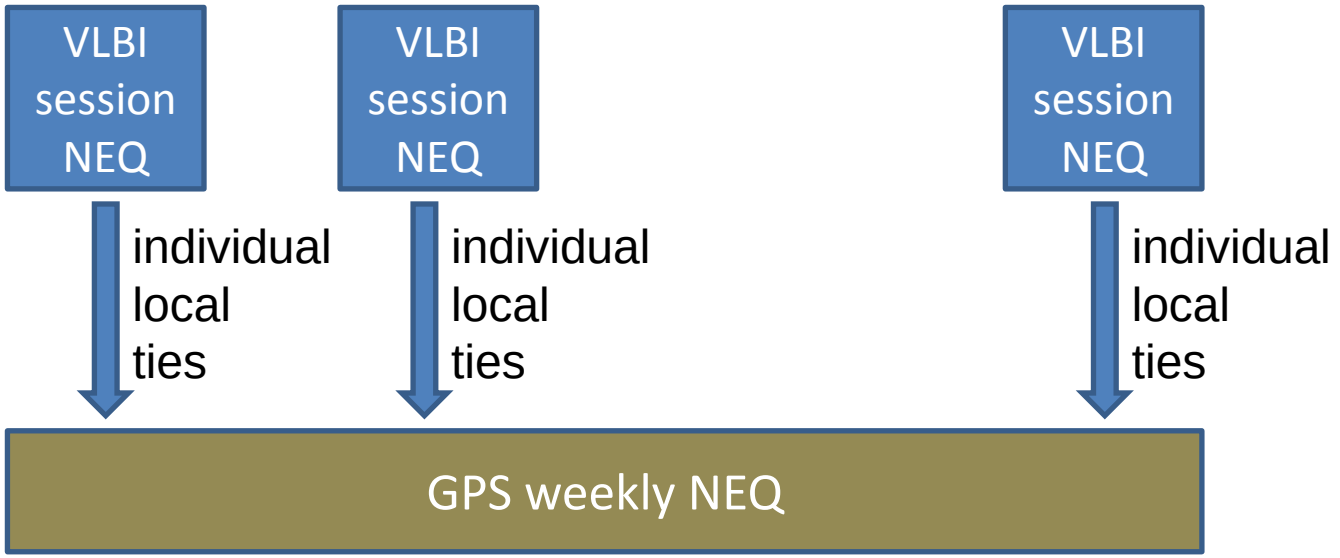
	week1	week2	week3
AIUB [mm]	2.70	2.52	2.32
GRGS [mm]	2.36	2.48	1.81

M. Seitz, Input data and combination results

Combination of techniques without pre-combined

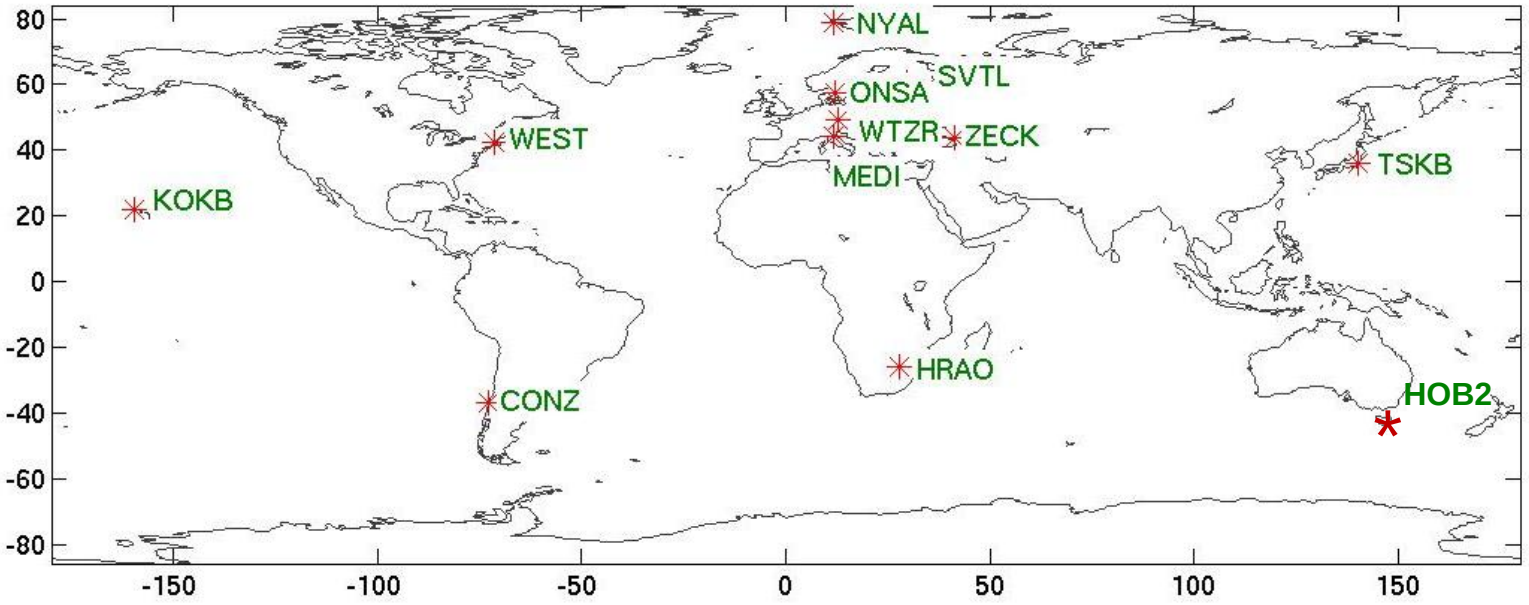
Combination of GPS and VLBI

- 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

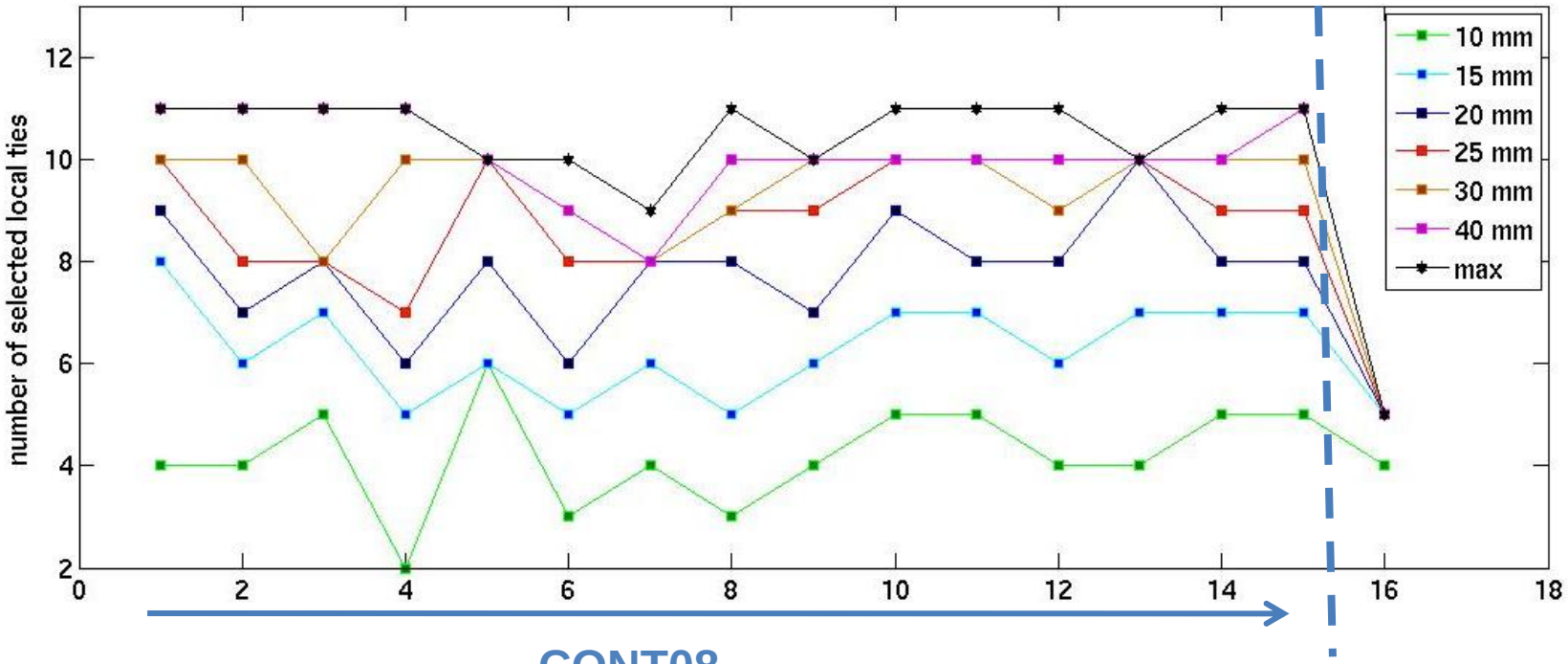
- In DTRF2008 computation (ITRF2008 contribution of DGFI)
  - Two criteria are used:
    - Deformation of networks shall be small
    - Offset between (not combined EOP) shall be small

  → 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

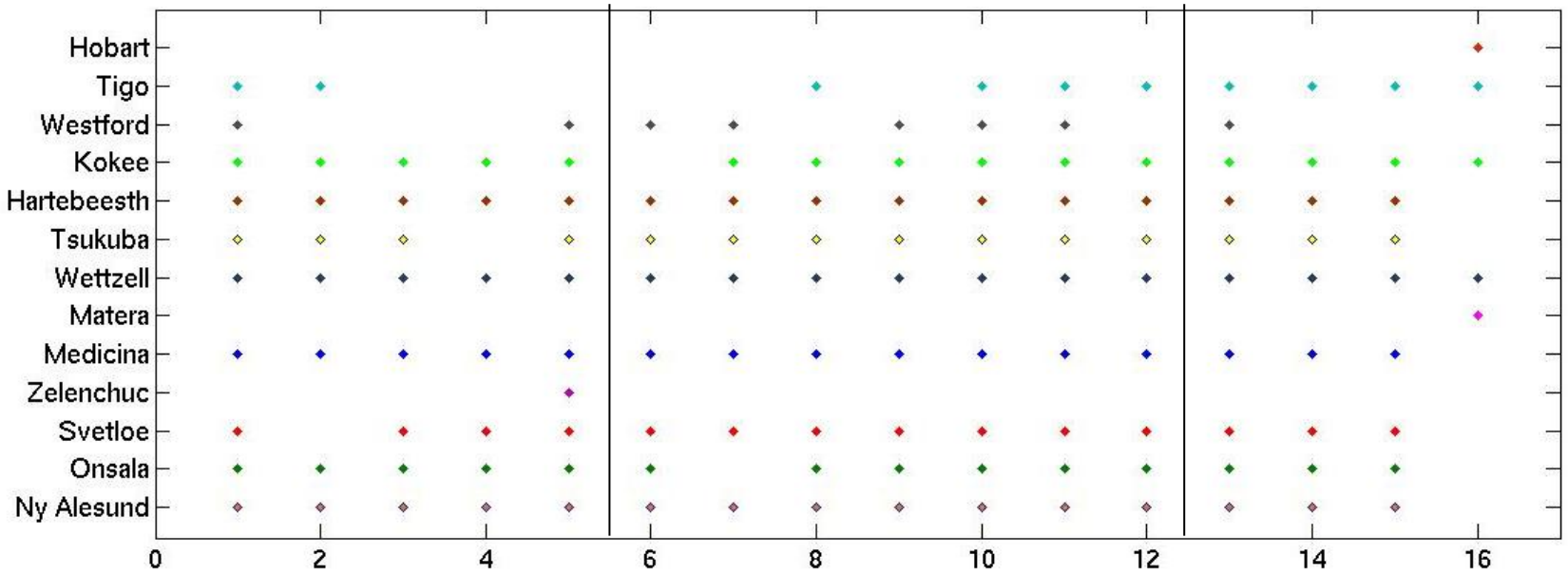
- Number of local ties per session using different thresholds for the local tie fit



Combination of GPS and VLBI

- Global distribution of co-locations

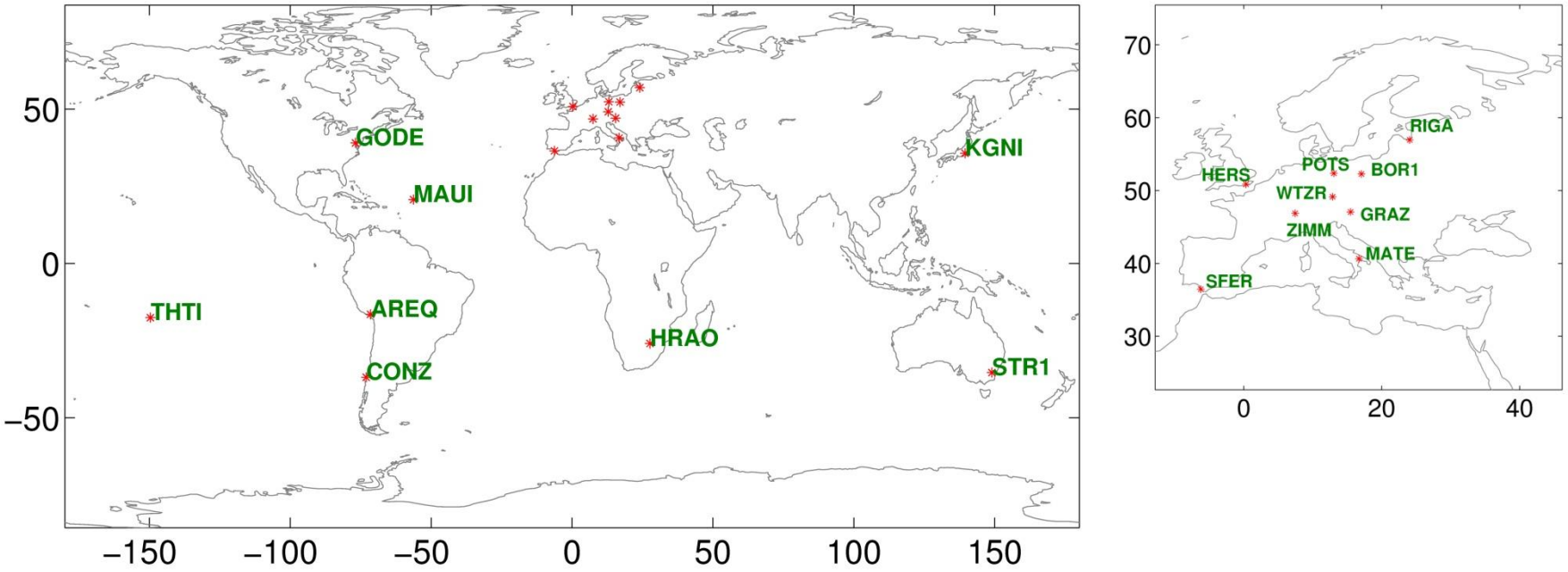
GPS-VLBI: 25 mm threshold



M. Seitz, Input data and combination results

Combination of GPS and SLR

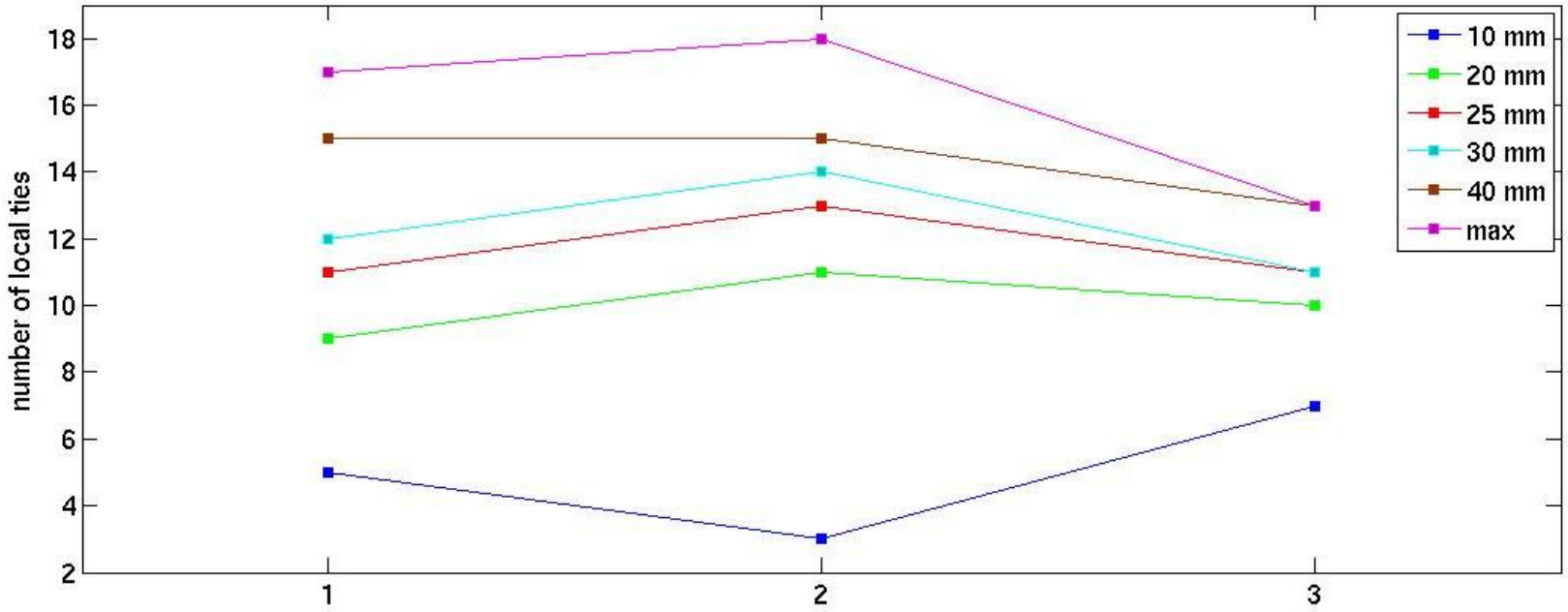
- Co-locations GPS-SLR



17 co-location sites

Combination of GPS and SLR

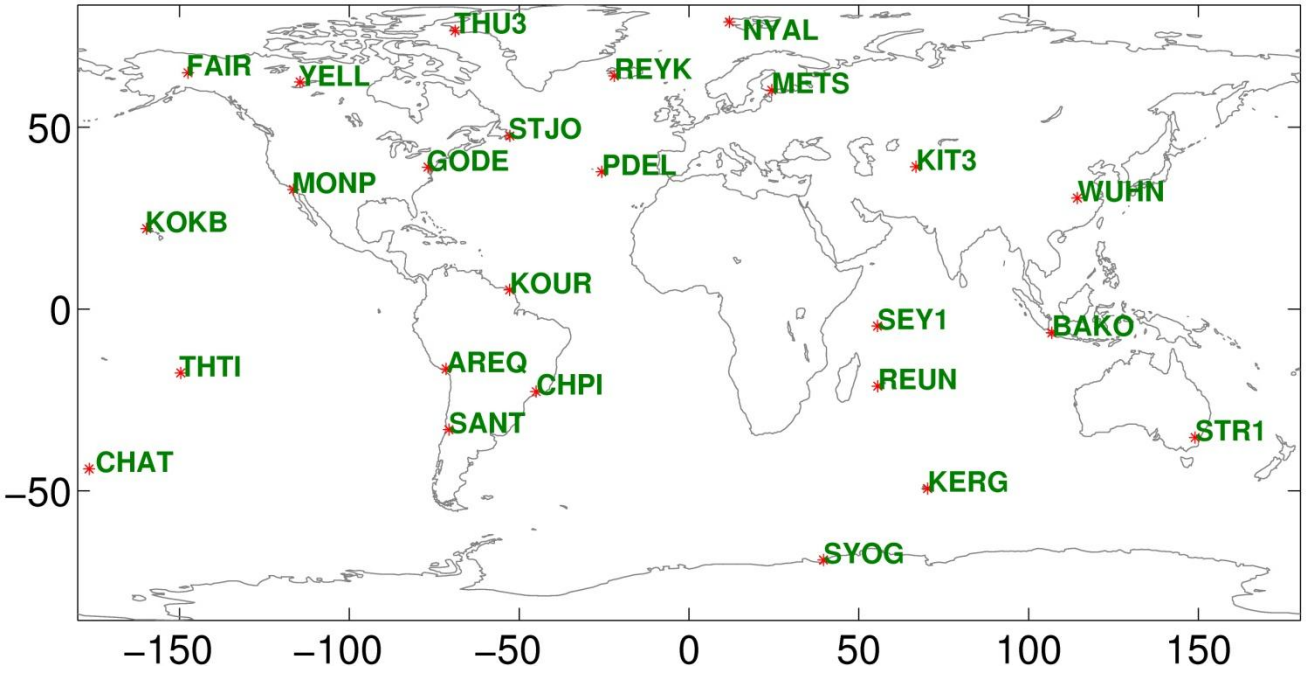
- Number of local ties per week using different thresholds for the local tie fit



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

Combination of GPS and DORIS

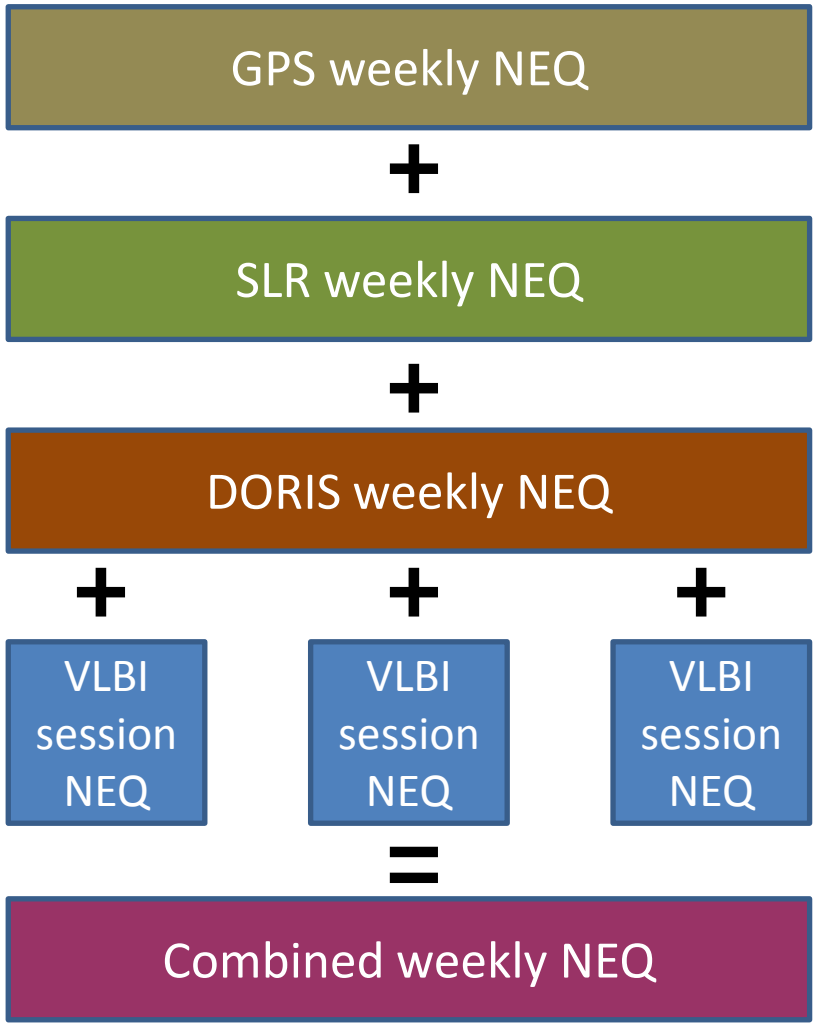
- GPS-DORIS co-locations



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*

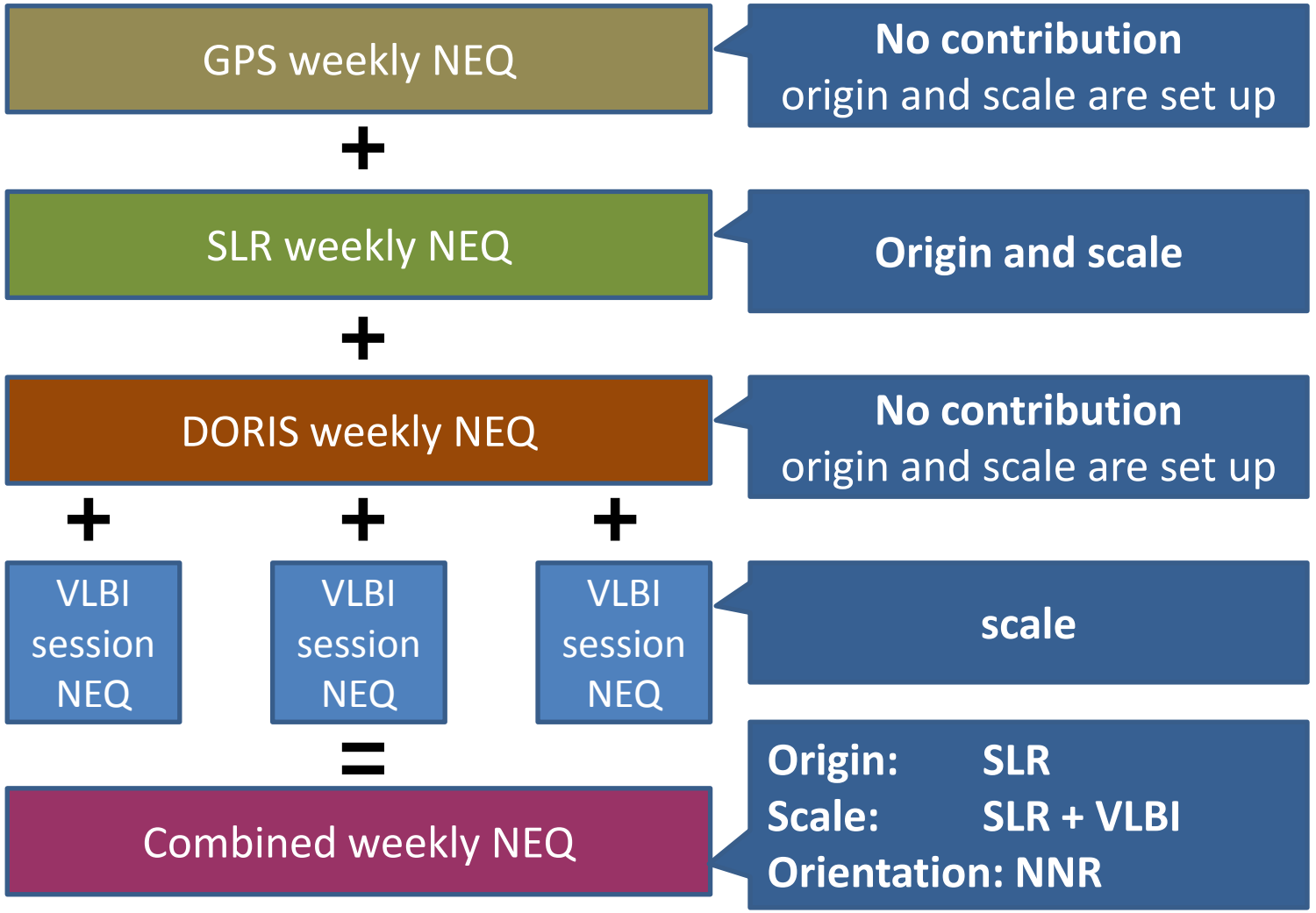
*according to DTRF2008

For a sophisticated weighting longer time series are necessary.

σ local ties
1.0 mm / component

Combination of GPS+SLR+DORIS+VLBI

- Datum realization



M. Seitz, Input data and combination results

Combination of GPS+SLR+DORIS+VLBI

- Conservation of datum

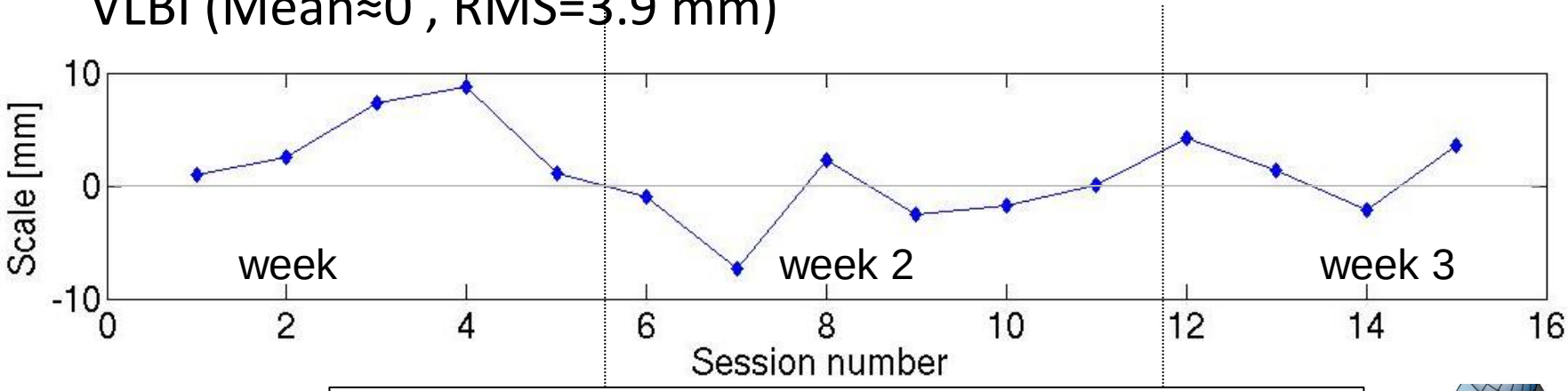
Origin

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)



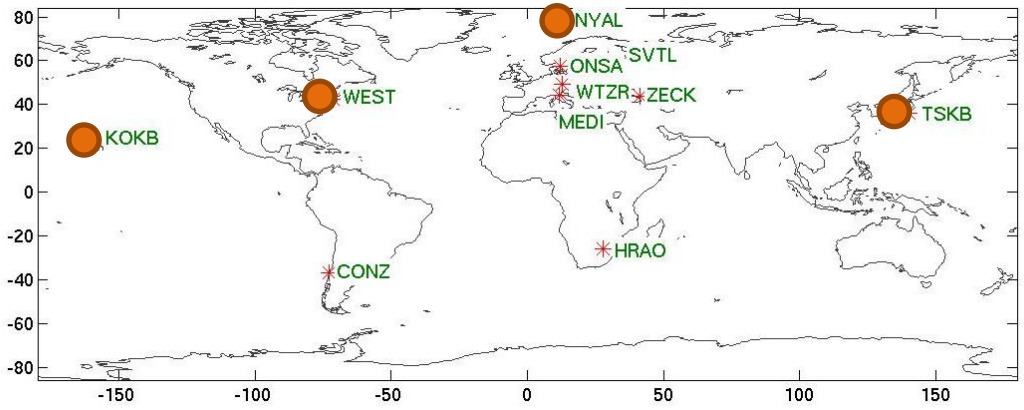
cm-residuals: Tsukuba, Westford, Kokee, Ny Alesund

Combination of GPS+SLR+DORIS+VLBI

- Conservation of datum

Origin

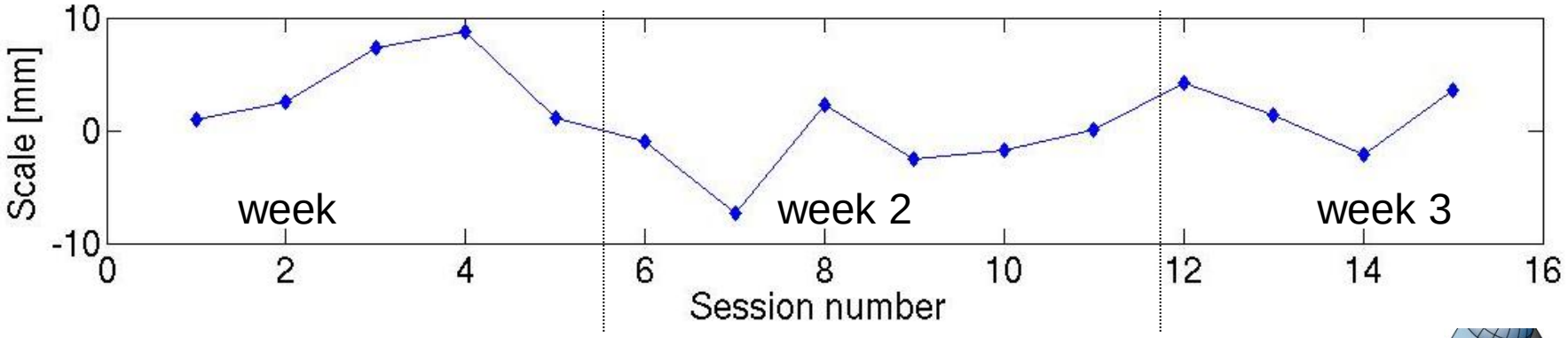
Conserved to 3.0 mm (all three components) (transformation via 20 SLR stations)



Scale

SLR: < = 1.1 mm

VLBI (RMS=3.9 mm)



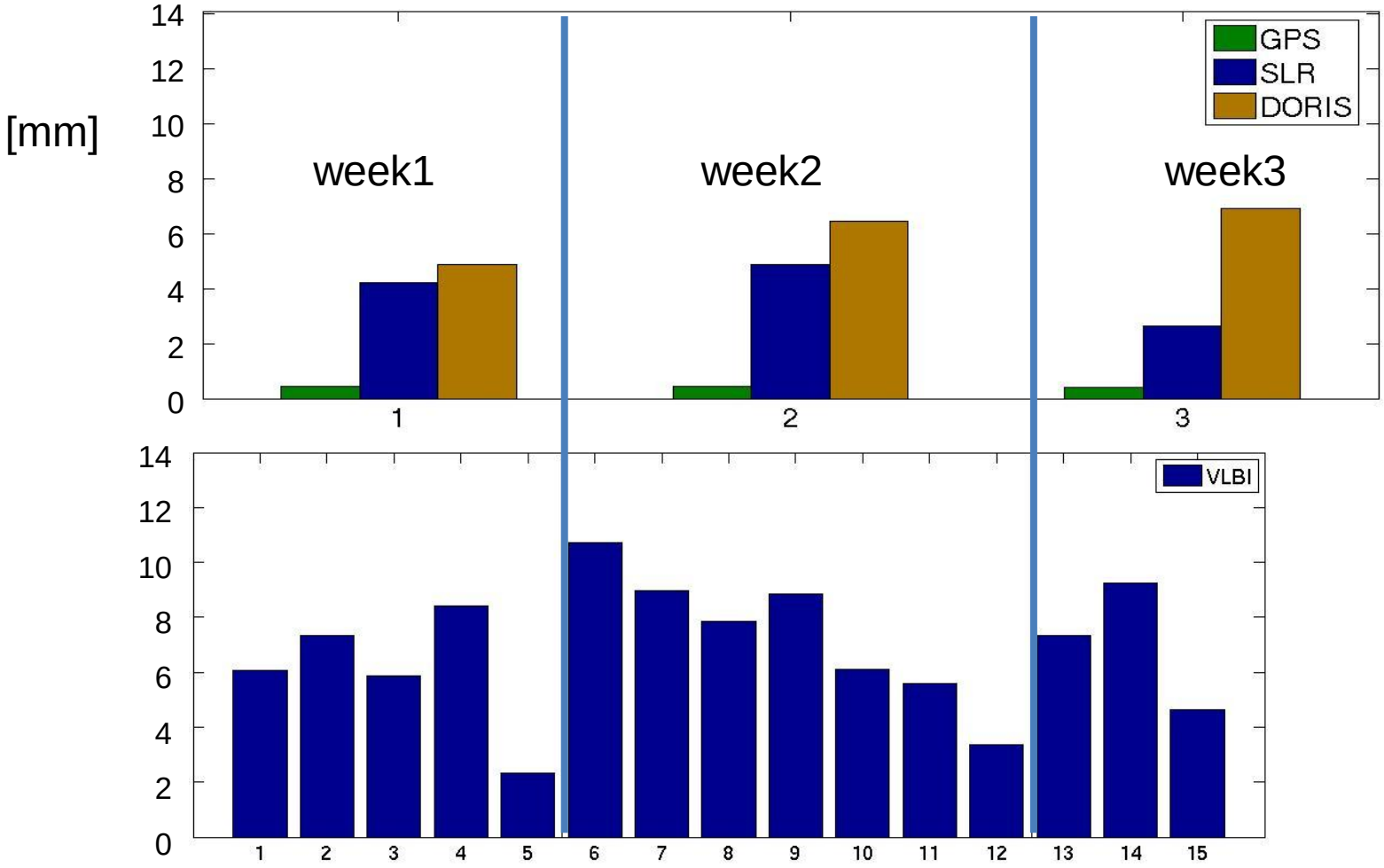
M. Seitz, Input data and combination results

Combination of GPS+SLR+DORIS+VLBI

- 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

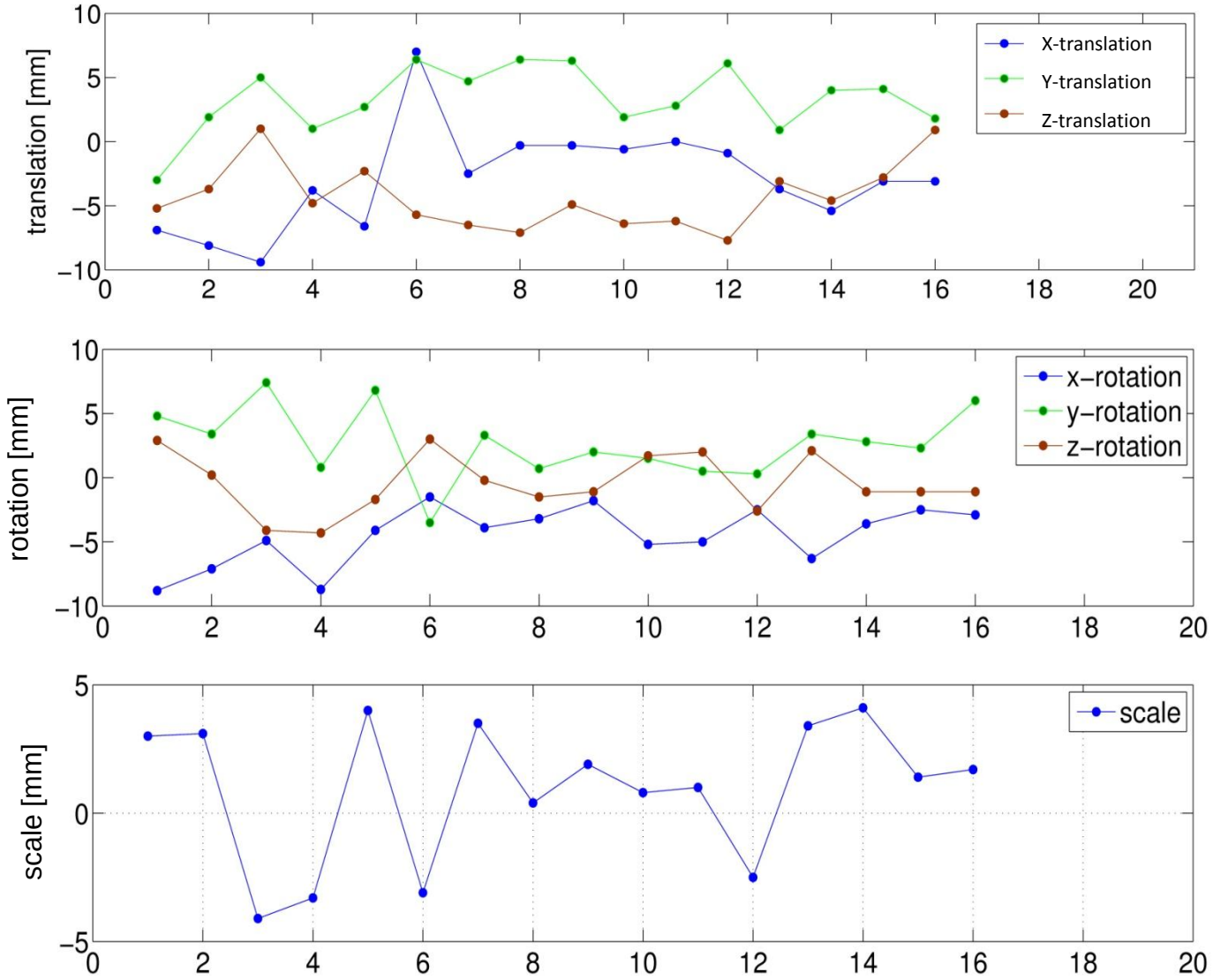
- Deformation of the networks due to combination



M. Seitz, Input data and combination results

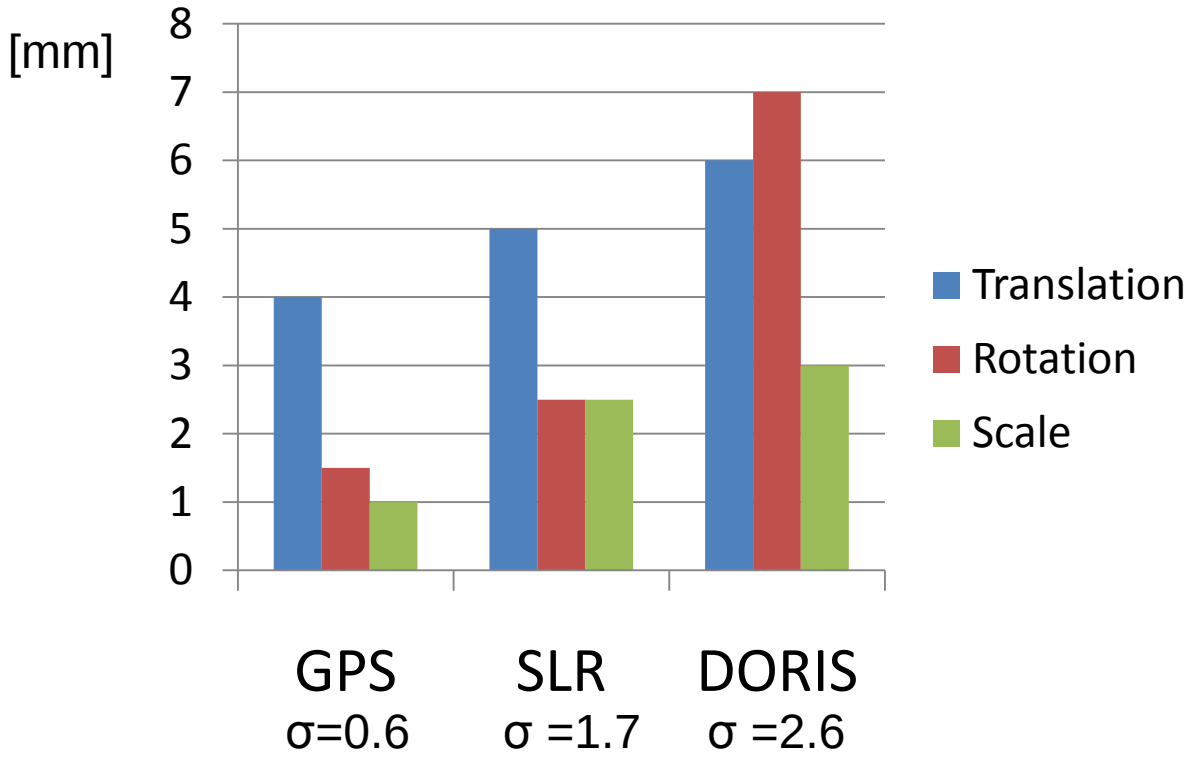
P+L+D+R: Comparison with DTRF2008

- 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

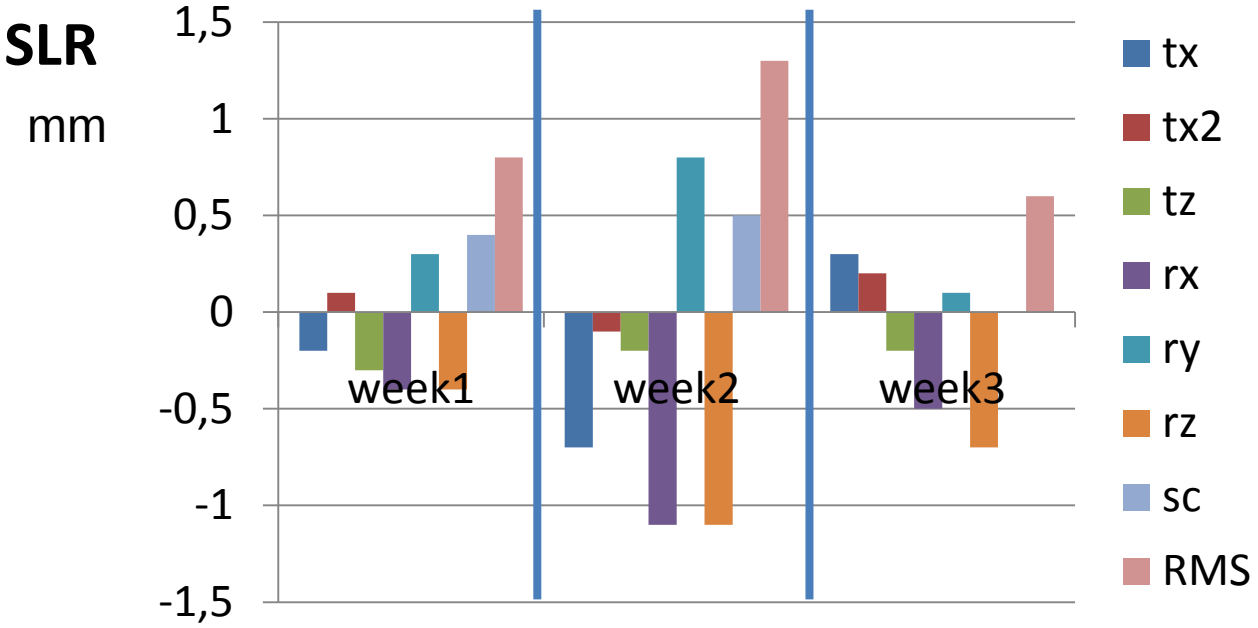
M. Seitz, Input data and combination results

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

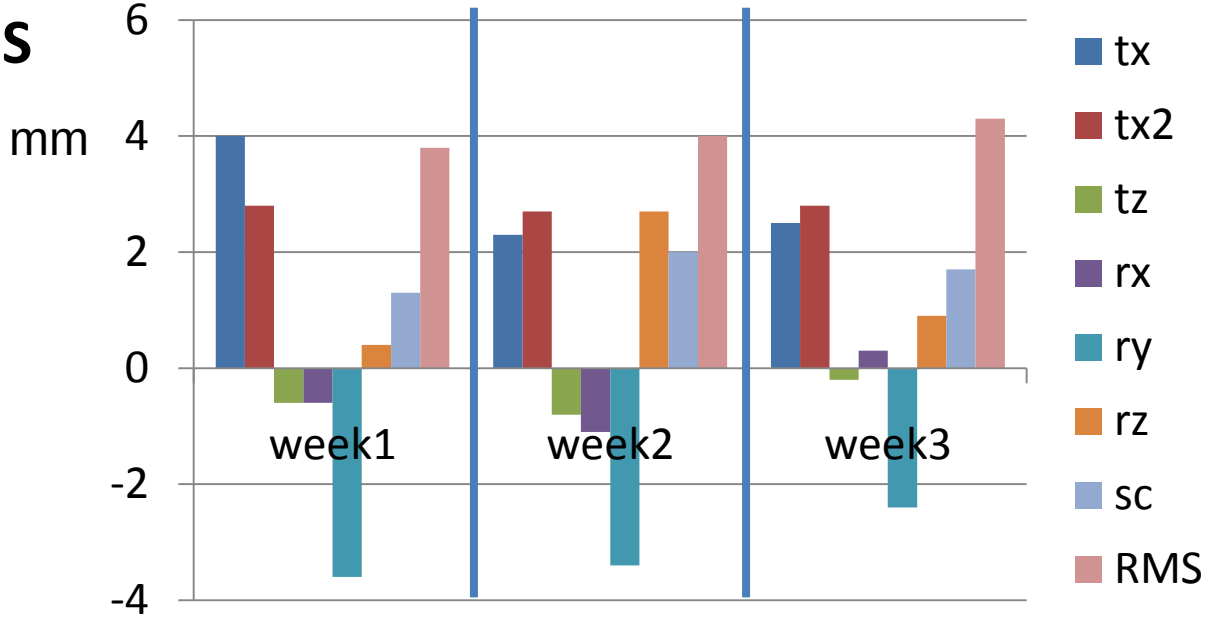
Orientation: orientation of ESOC_LD is fixed to about 2 cm

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



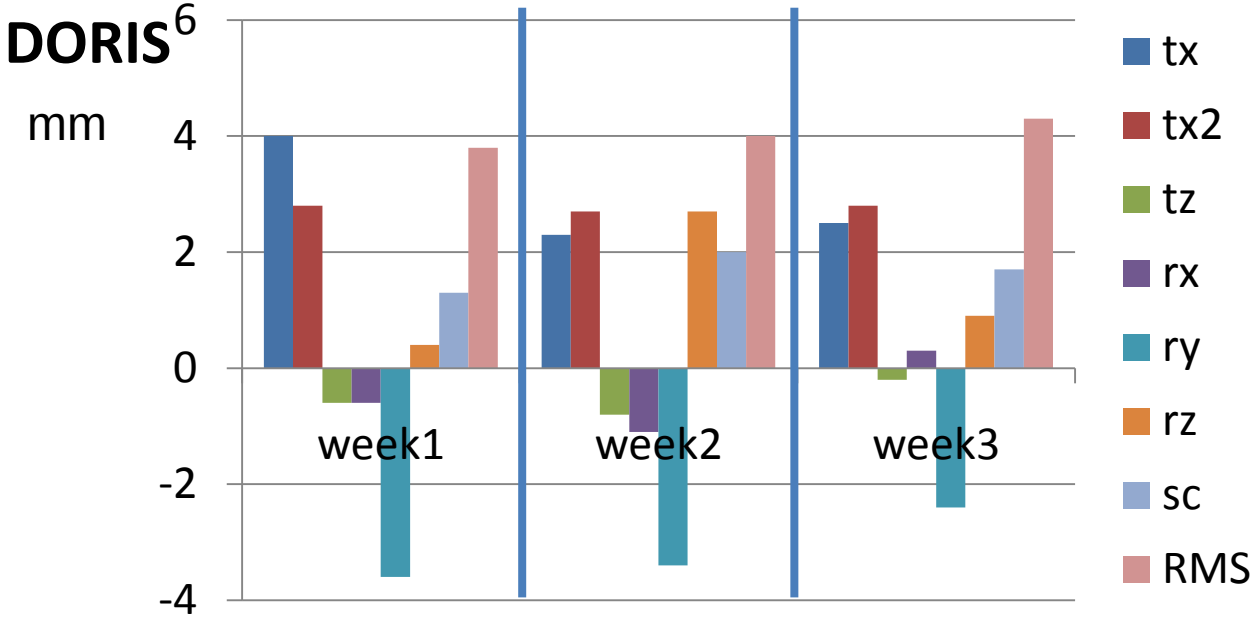
Transformation parameters of some mm

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?

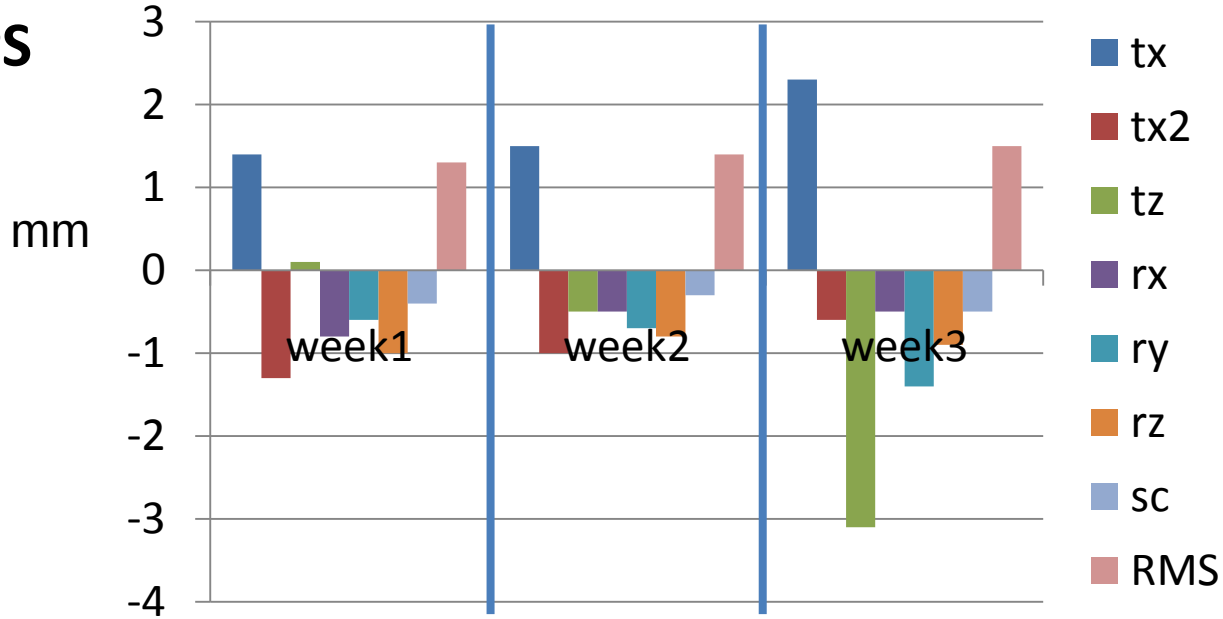
Combination with pre-combined data

- 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

GPS



transformation parameters of up to 3 mm

orientation: orientation of ESOC_LP is fixed to 1cm

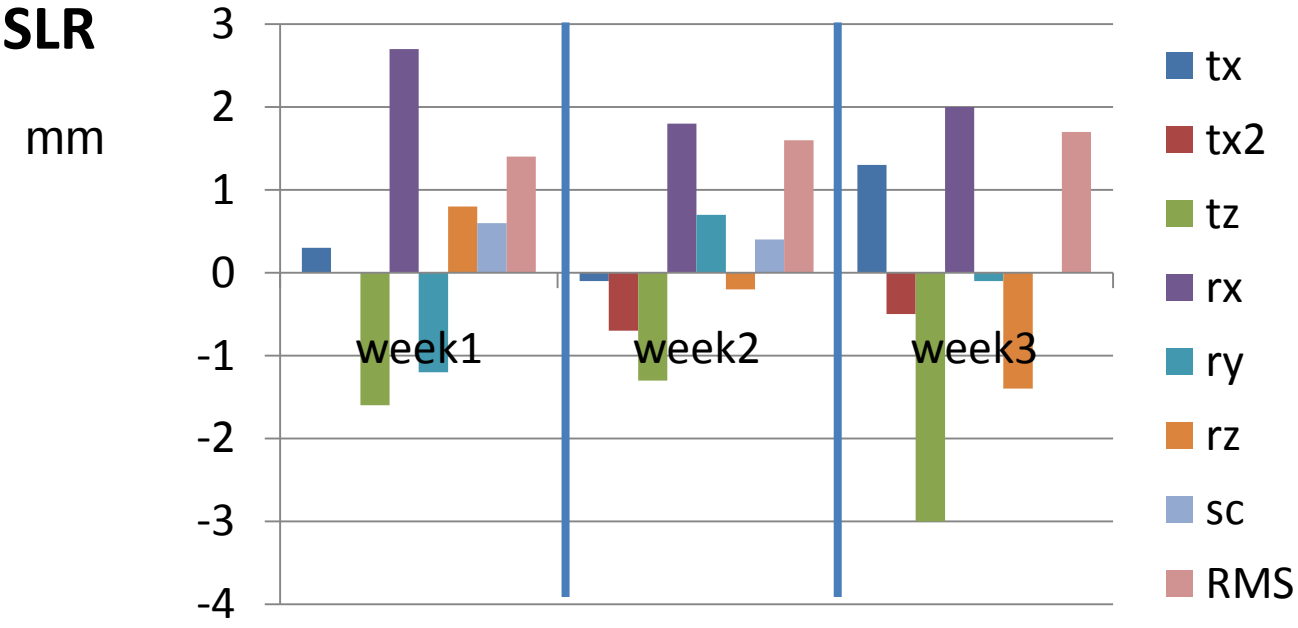
How the datum of ESOC_LP is realized? Origin realized also by GPS?

Combination with pre-combined data

- GPS+SLR+VLBI+DORIS and ESOC_LD andESOC_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

Summary

- 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 weigthing (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