Combination of techniques at CC DGFI

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DGFI Munich
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Outline

- Input data
- New SINEX files
- Intra-technique combination
  - Comparison of SLR files
- Inter-technique combination

Input data

Status and changes since November 2011

	AIUB	DGFI	ESOC	GFZ	GRGS	MAO	OPA	TUW
GPS	**n2**				**n7**			
SLR	**n3(11)**	**w2(11)**	**w1**		**n3**			
VLBI		**n2**			**n6**	**n1**	**n1**	**n2(11)**
DORIS					**n5**			
L-P			**n1**	**n1**				
L-D			**n1/n2**					

New SINEX files

SINEX files Nov. 2011

Information about new models and parametrizations often missed!

Input data

Remarks on the new SINEX files

GPS

GRGS: orientation constrained (n7)

discussion with Sylvain in Nov. last year
one SINEX file for test purposes: okay

SLR

GRGS: okay;

What are the changes compared to Nov. 2011?

EOP: now pwl representation with offsets at 0 h

Input data

Remarks on the new SINEX files

VLBI

TUW: 11/269: 4-char. ID of WARK12m in SINEX missed

GRGS: station names related troposphere parameters (**ZBIAS**) do not correspond to the station names in block SITE/ID

OPA: discussion with Sebastien Lampert on the lTPl values given in SINEX which seem to be not reduced

→ Dan MacMillan would look at this problem in Calc/Solve

→ All NEQ provide the expected number of eigenvalues = 0 (except of [GPS/GRGS])

Reduction of $l^T P l$

$$l_1{}^T P_{11} l_1 = l^T P l - y_2{}^T N_{22}{}^{-1} y_2$$

1… remaining
2… reduced parameters

if N_{22} is the part of the Normal quation matrix related to the parameters, which should be reduced. y_2 is the corresponding right hand side of NEQ.

(see also App. II of the new SINEX format description, which will be provided very soon by Daniela Thaller/SINEX WG)

$l^T P l$ is needed for the computation of the a posteriori variance factor

$$v^T P v = l^T P l - y^T \hat{x}$$

$$\sigma = \sqrt{\frac{v^T P v}{n - u}}$$

→ A large $l^T P l$ leads to large standard deviations.

Earth Orientation Parameters

dUT1

- OPA (UT1-TAI) ; all the others UT1-UTC

Nutation

- only TUW provides [X,Y] representation
- GRGS/DORIS: 12-hourly resolution
- a priori values are not 0.0 (IAU2000 model values?):
  - GRGS (all techniques)
  - MAO
  - OPA
  - TUW (a priori values, but very small)

Pole

- No inconsistencies

→ EOP parameterization must be further homogenized.

Tropospheric parameters in SINEX

GPS:

AIUB TROTOT (a priori=dry ZD), TGNTOT, TGETOT

GRGS ZBIAS, TGNTOT, TGETOT

VLBI:

GRGS ZBIAS

TUW TROWET (a priori=0), TGNTOT, TGETOT

DORIS

GRGS ZBIAS

→ Consistency is needed for comparisons and combination:
TROTOT, TGNTOT, TGETOT

→ All AC (GNSS; VLBI; DORIS) should provide the tropospheric parameters for the co-location sites

Tropospheric parameters in SINEX

ZBIAS: tropospheric bias at zenith

What does it exactly mean?

TROTOT: total tropospheric delay

- a priori value: ~ dry part
- estimated value: ~ wet part

→ the use of TROTOT with: a priori values = dry ZD would be necessary for comparisons

Corresponding gradients:

TGNTOT

TGETOT

Tropospheric parameters in SINEX

ZBIAS: tropospheric bias at zenith

What does it exactly mean?

COL specs

TROTOT: total tropospheric delay

- a priori value: ~ dry ZD → *GPT model, GMF mapping function*
- estimated value: ~ wet ZD *(GMF mapping function)*

→ the use of TROTOT with: a priori values = dry ZD *(GPT/GMF)* would be necessary for comparisons

Corresponding gradients:

TGNTOT
TGETOT

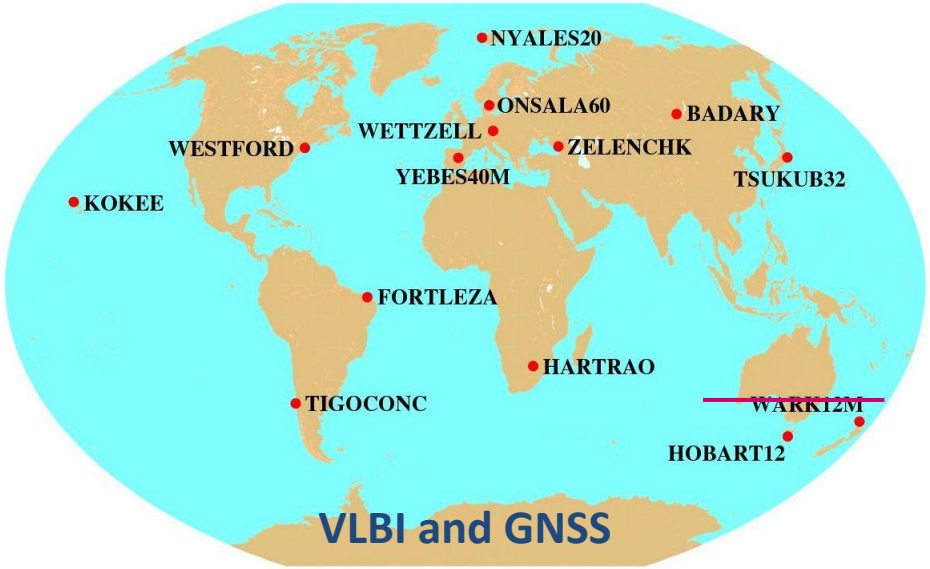
} a priori values = 0 (or standardized values for COL)

Tropospheric parameters in SINEX

Stations CONT08

DORIS
NyAlesund
Hartebeesthoek
Kokee Park

Stations CONT11



DORIS
NyAlesund
Hartebeesthoek
Kokee Park

Seitz: Combination at the

Comparison of SLR input series

- AIUB: CONT08, CONT11
- DGFI: CONT08, (CONT11)
- GRGS: CONT08

Comparison CONT08

	RMS	Tran. [mm]	Scale [mm]
AIUB-GRGS	7 - 12	4 - 6	1 - 4
DGFI-GRGS	5 - 10	3 - 10	0 - 5
AIUB-DGFI	10	3 - 20	1 - 7

Stations with large residuals are excluded from the transformation

- Station lists are not identical
- Number of common stations 14-19

Comparison of SLR input series

Comparison CONT08: Stations with large residuals [mm]

station	code	AIUB-GRGS	DGFI-GRGS	AIUB-DGFI
Borowiec	7811	70	50	70
Riyadh	7832	30		44
Shanghai		/	/	35
Changchun	7237			40
Koganei	7308	/	/	60
Fort Davis	7406	1600	1600	
Maui	7119			50
Washington	7105	1700	1700	
Mon. Peak	7110	200	200	100
San Juan	7406	70	70	30
Arequipa	7403	3400	3400	30

→ A SLR internal comparison/homogenization is necessary

Comparison of SLR input series

Comparison CONT11

AIUB-DGFI (number of common stations: 20-22)

RMS: 10 mm

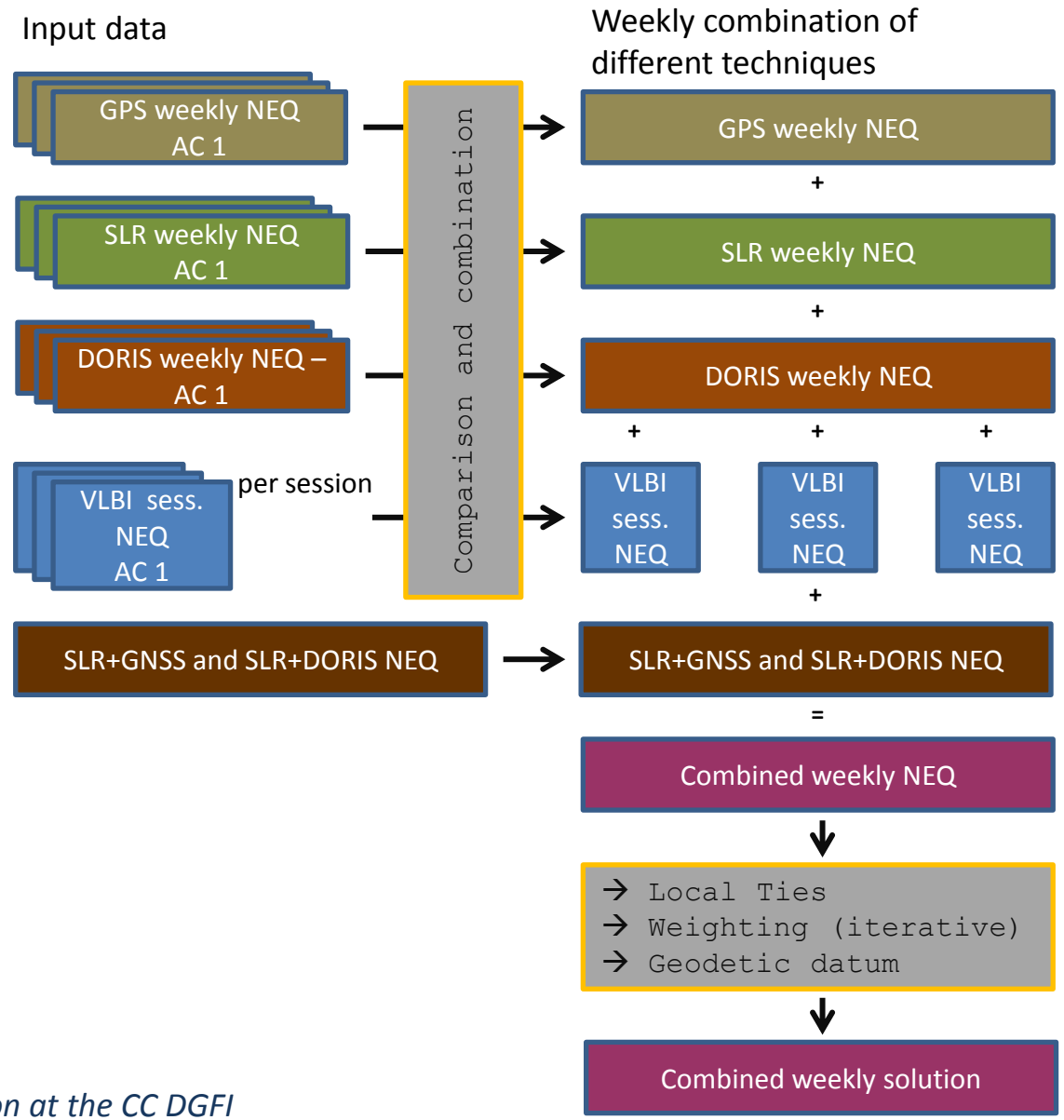
Tran: 0-5 mm

Scale: 4-7 mm

Stations with large residuals

Station	code	Max. residual [mm]
Kiev	1824	60
Potsdam	7841	30
Washington	7105	30
Arequipa	7403	30
Mt. Stromlo	7825	30

Combination procedure at DGFI



Local ties

CONT11 contains the co-location sites

- 12338 Badary GPS-VLBI
- 13420 Yebes GPS-VLBI
- 50116 Hobart GPS-VLBI (new antenna HOBART12)

for which no local ties were available so far (ITRF2008/DTRF2008).

Zuheir Altamimi provides us local vectors (with standard deviations) for Badary and Yebes.

→ will be provided in the forum

To do

Data Series

- CONT11 series

Models

- ✓ Jean Michel provided the gravity field model for CONT11 → COL forum
- ✓ Ocean loading (FES2004): tabeled values from Scherneck provided by Rolf König (→ forum)
- ✓ Atmospheric tides: Ray-Ponte model (→ COL forum or GGFC website)
- Models applied by all ACs

To do

Parameterization

EOP

- Homogenization of EOP parameterization
  - daily piece-wise-linear representation (0h) or offset and drift
  - Nutation [X,Y]
  - Nutation parameters: correction to nutation model

    a priori values = 0.0
  - UT1-UTC (OPA: UT1-TAI)
  - Same a priori values and a priori interpolation

To do

Parameterization

Troposphere

- Homogenization of troposphere parameters (microwave techniques)
  (GPT/GMF -> TROTOT, TGNTOT, TGETOT)
- Tropospheric parameters should be provided for all CONT08 and CONT11 VLBI stations and the co-located GPS and DORIS stations

Solution related

- MAO: RMS w.r.t. DTRF2008 much larger than for the other VLBI contributions (20-30mm)
- OPA: standard deviations (ITPI)

→ Currently not used in the combination

To do

Combination

- Combination of the new series
- Combination of all parameters
- Investigation of individual co-location sites
- VCE
- Pre-combined data should be included (more discussion is needed)

END

Analysis and combination procedure at DGFI

Step by step

Per technique:
- daily to weekly [GPS/AIUB]
- comparison and combination of input files

Inter-technique1:
- comparison and combination of VLBI-, SLR-, and GPS-only contributions

Inter-technique2:
- comparison and combination of inter-technique 1 and pre-combined SLR-DORIS, SLR-GPS data

Analysis and combination of VLBI data

Contributions: DGFI, MAO, OPA, TUW (GRGS could not be read from SINEX)

Analysis:

	A posteriori Sigma	Transformation DTRF2008 (scale)	RMS of transformation
DGFI	1.0	<= 9 mm	5 – 7 mm
MAO	20.0	20-30 mm	20-30 mm
OPA	800000.0	<= 10 mm	5 – 7 mm
TUW	1.0	<= 10 mm	5 – 7 mm

→ DGFI, OPA and TUW are combined.

→ standard deviations of OPA very large (ltpl of 1*10^15 vs. 1*10^4 for DGFI and TUW) → contribution to combined solution is very small

Analysis and combination of VLBI data

Combination aspects

- Consideration of variance components is necessary
- DGFI, OPA: EOP transformed from O+D -> pwl
- Troposphere parameters (TUW): have to be stabilized
- Sources (TUW): fixed to ICRF2

- dUT1: DGFI and TUW (UT1-UTC); OPA (UT1-TAI)

  -> **dUT1 combined for DGFI and TUW only**
- Nutation: TUW[X,Y]; DGFI and OPA [PSI, EPS]

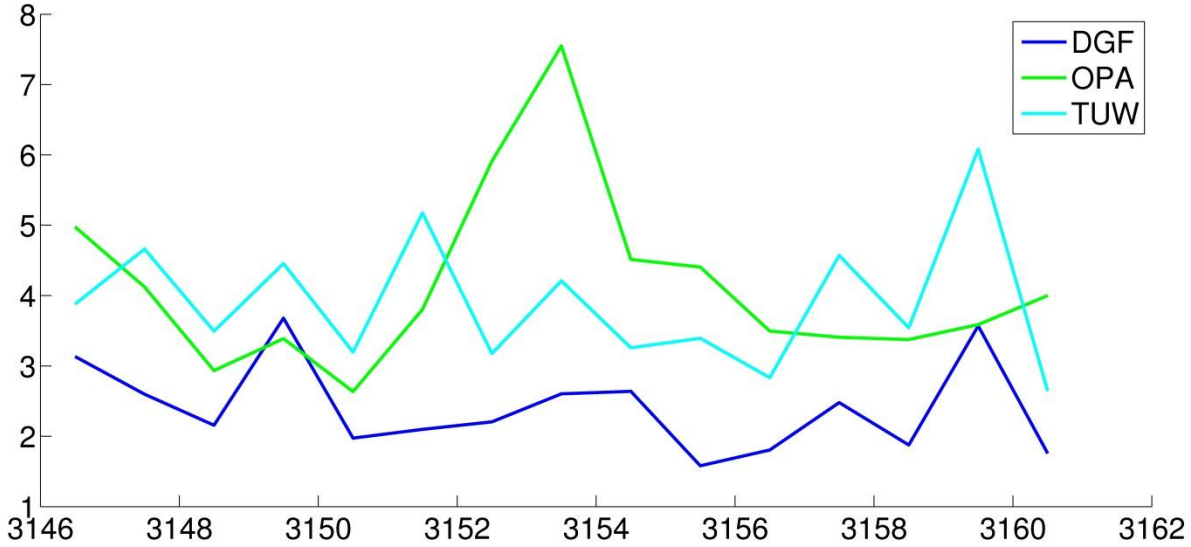
  - OPA: a priori values are not 0.0 (model values?)

  -> **nutation is not combined**

→ Parameterization of VLBI contributions must be further homogenized.

Combination results

RMS of similarity transformation between combined and single AC solutions

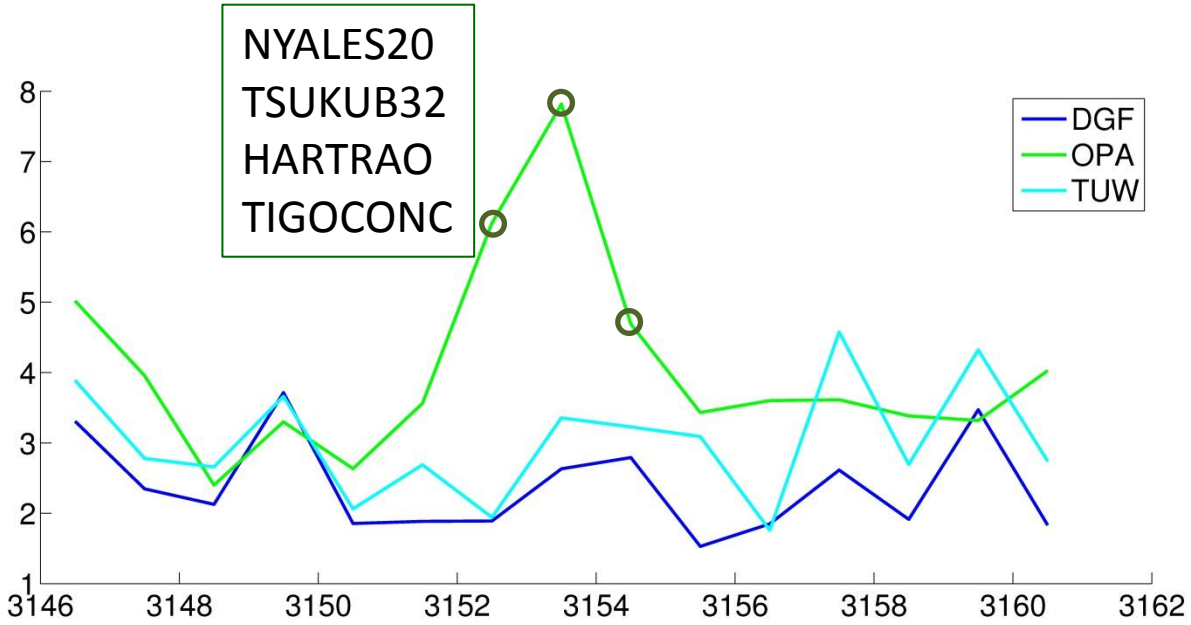


→ Offsets between the AC contributions

Analysis and combination of VLBI data

Combination results

RMS of similarity transformation between combined and single AC solutions

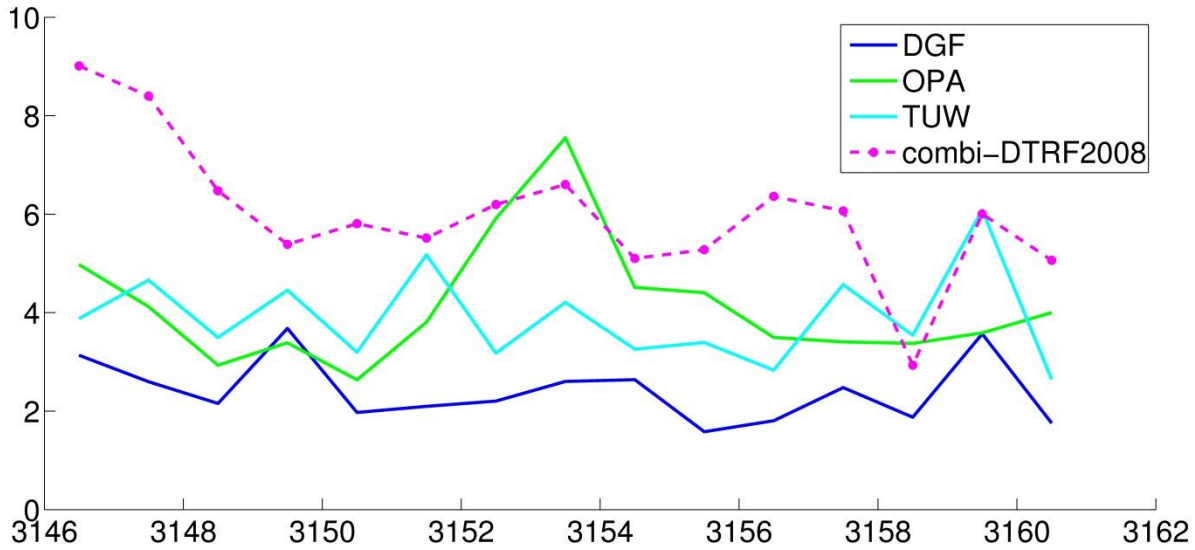


→ NYALES20 not used in transformation: offset between DGF and TUW removed. What are the reasons? Modell differences? (→height component)

Analysis and combination of VLBI data

Combination results

RMS of similarity transformation between combined and single AC solutions

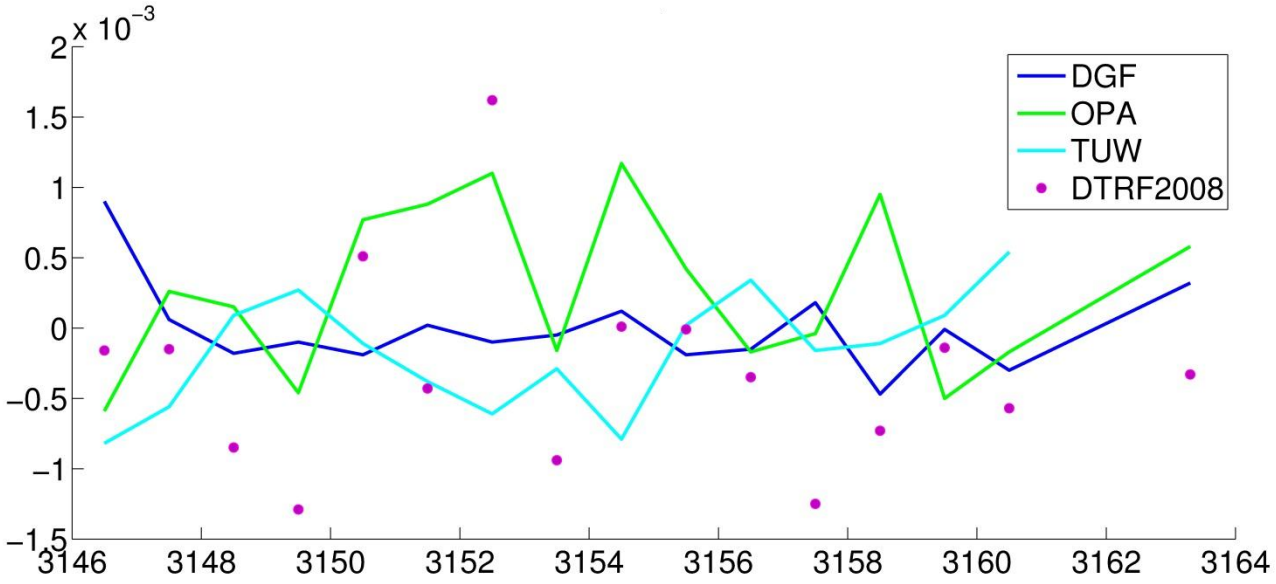


→ Agreement of AC better than agreement to DTRF2008 (model differences; epoch vs. multi-year solution)

Analysis and combination of VLBI data

Combination results

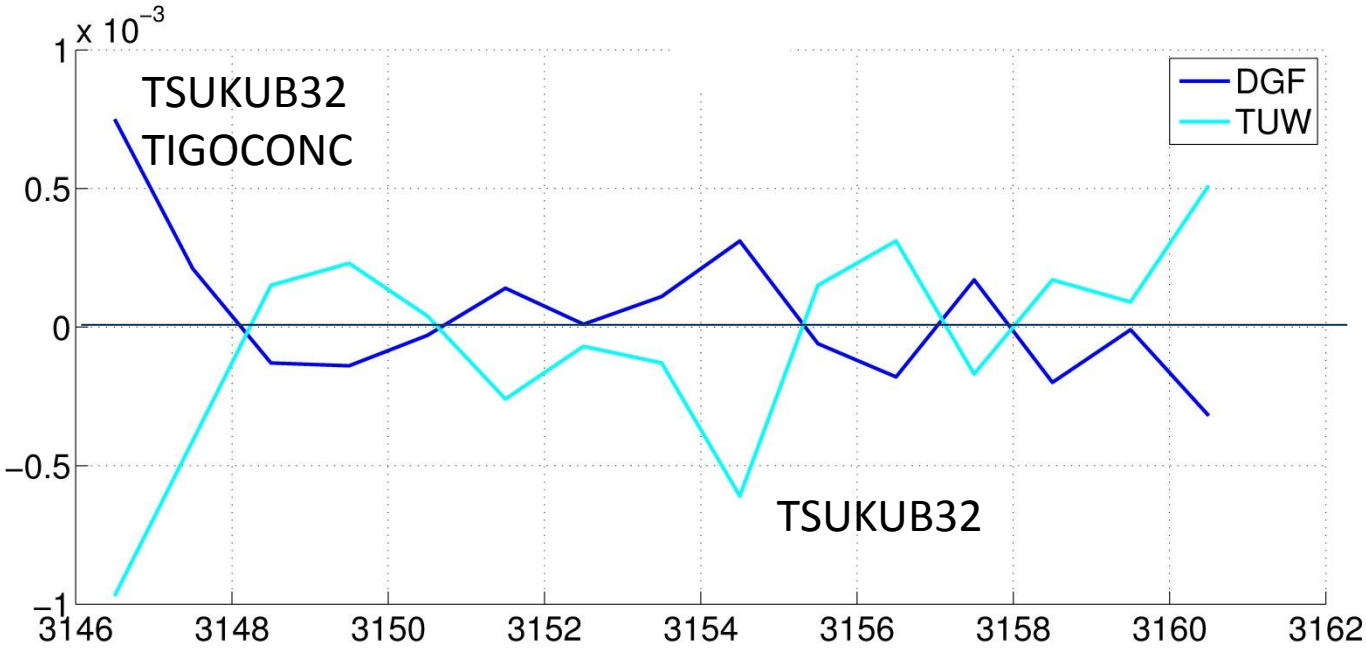
Scale differences [ppm] derived from transformation between combined and single AC solutions (and DTRF2008)



- Contribution of OPA very small (due to large STD).
- RMS of scale differences between AC comparable to comparison of combined solution and DTRF2008 (Offset: -0.5 ppb)

Combination results

Scale differences [ppm] derived from transformation between combined and single AC solutions



→ Scale is weighted mean of DGF and TUW.

Analysis and combination of VLBI data

Summary:

- Good agreement (MAO should be analyzed in detail)
- EOP parameterization must be homogenized (Nutation, dUT1)
  - DGF, MAO and OPA -> [X,Y]
  - Nutation parameters: correction to nutation model
    a priori values = 0.0
  - OPA -> UT1-UTC
  - Same a priori values, interpolation
- SINEX completed (GRGS)
- Standard deviations of OPA must be investigated
- What are the reasons for the disagreements between the ACs?

Analysis and combination of SLR data

Contributions: AIUB, DGFI, GRGS

Analysis:

	A posteriori Sigma	Transformation DTRF2008 (tra, sc)	RMS of transformation
AIUB	0.01	<= 5 mm	15 mm
DGFI	1.3	<= 10 mm	15 mm
GRGS	0.5	<= 10 mm	15 mm

→ Homogeneous SLR input data

→ Second week slightly worse than weeks 1 and 3

Analysis and combination of SLR data

Combination aspects

- Consideration of variance components is necessary
- Geocentre coordinates (AIUB) fixed to 0.0

- EOP:
  - CODE: O+D -> pwl
  - GRGS provides pwl values at noon (cannot be transformed)

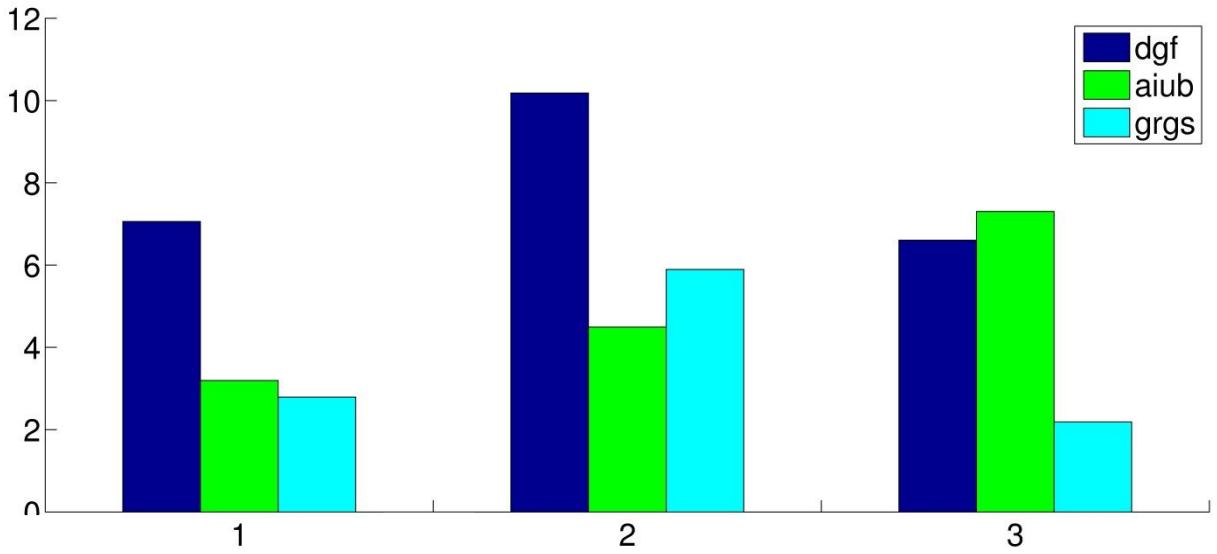
  -> only the EOP of AIUB and DGFI are combined
  - week 3 cannot be solved if EOP are combined (ITPI) !!

    What is the reason?

Analysis and combination of SLR data

Combination results

RMS [mm] of similarity transformation between combined and single AC solutions

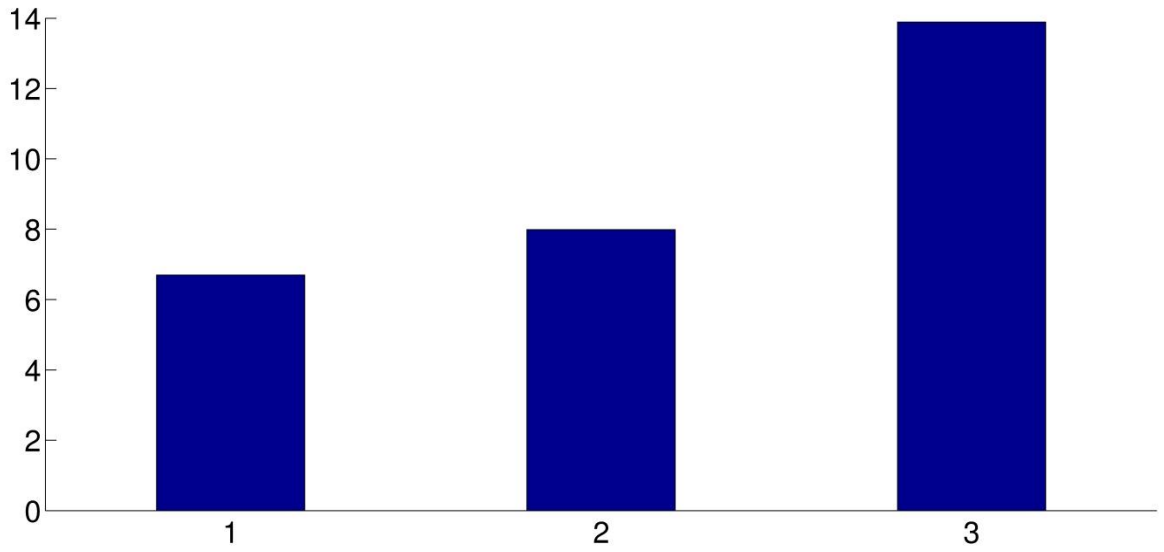


→ Comparable RMS values, DGFI values (weeks 1 and 2) slightly larger (improved compared to first DGFI solution)

Analysis and combination of SLR data

Combination results

RMS of similarity transformation between combined solution and DTRF2008

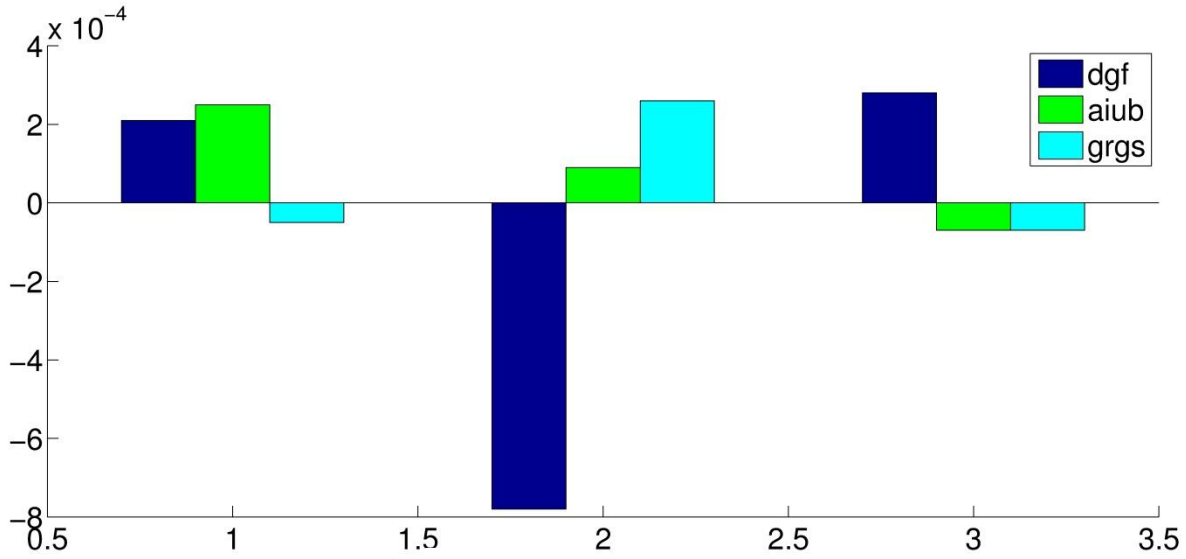


→ Comparable to RMS for single AC w.r.t. DTRF2008 (15 mm); week 1 and 2 benefit from combination

Analysis and combination of SLR data

Combination results

Scale differences [ppm] between combined solution and single AC solutions

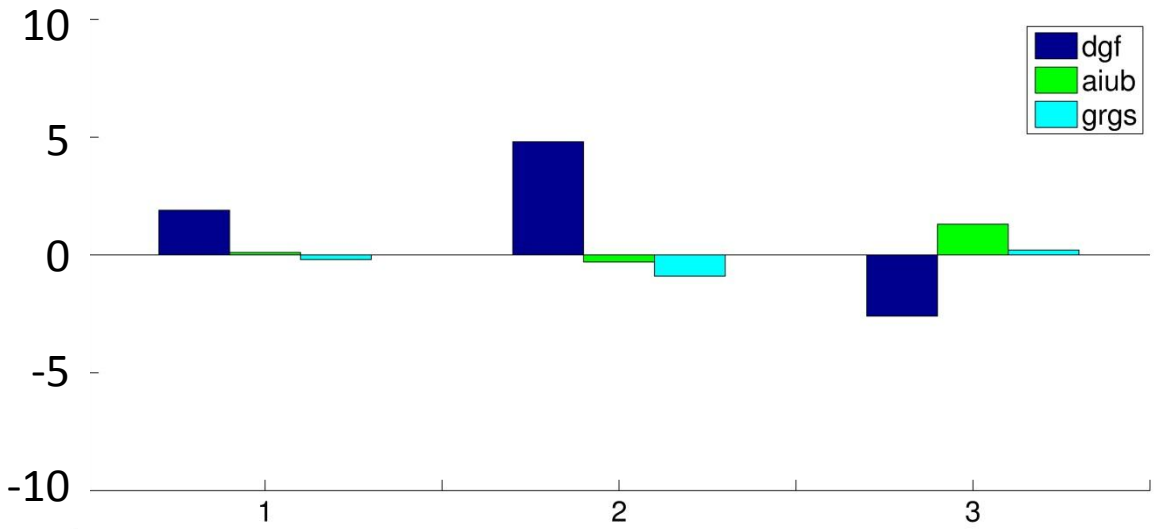


→ Agreement: 0.2 ppb (~ 1.5 mm) ; except of week 2 / DGFI

Analysis and combination of SLR data

Combination results

X-Translations [mm] between combined solution and singe AC solutions

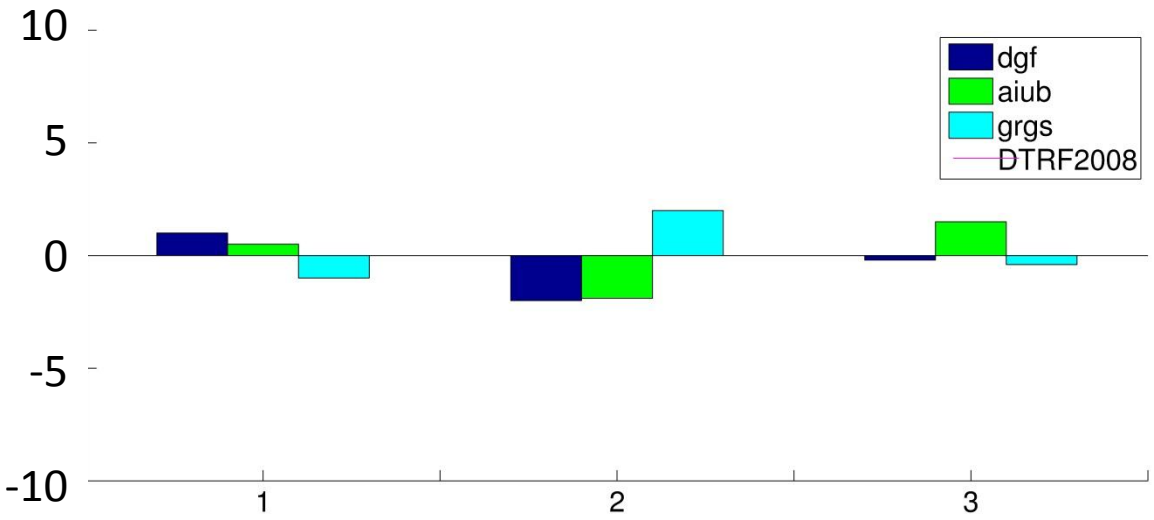


→ Agreement within 5.0 mm

Analysis and combination of SLR data

Combination results

Y-Translations [mm] between combined solution and singe AC solutions

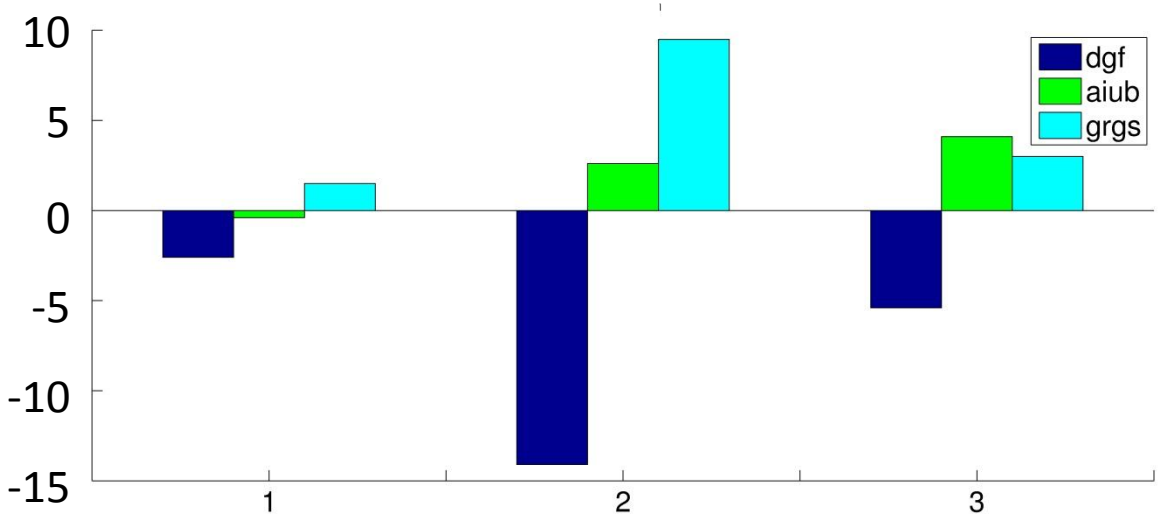


→ Agreement within 2.0 mm

Analysis and combination of SLR data

Combination results

Z-Translations [mm] between combined solution and singe AC solutions



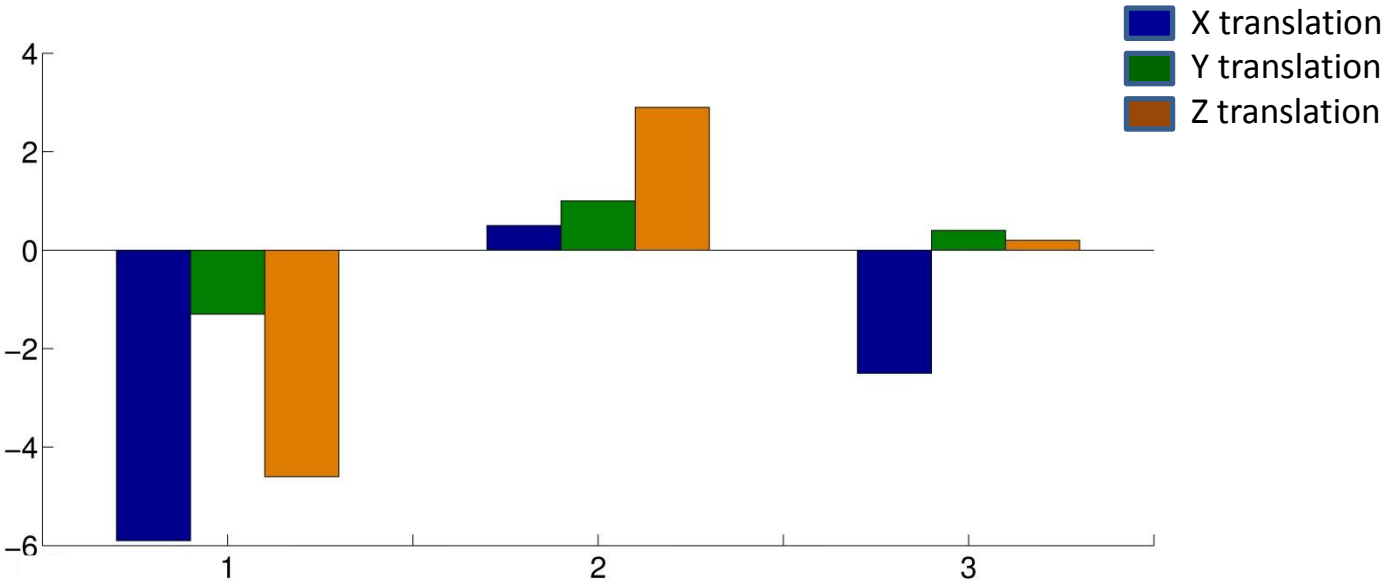
→ Agreement within 5.0 mm for week 1 and 3

→ Summarizing: homogeneous SLR input data

Analysis and combination of SLR data

Combination results

Translations of combined solution w.r.t. DTRF2008 [mm]

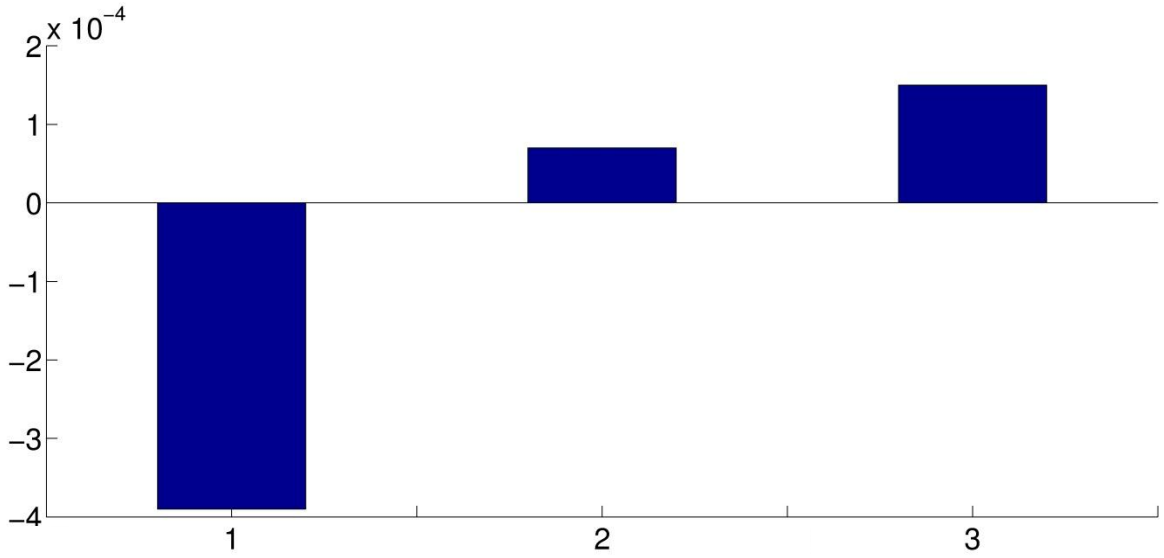


→ Agreement within 6 mm.

Analysis and combination of SLR data

Combination results

Scale of combined solution w.r.t. DTRF2008 [ppm]



→ Agreement: 0.4 ppb (~ 2.5 mm)

Analysis and combination of GPS data

Contributions: AIUB, GRGS

Analysis:

	A posteriori Sigma	Transformation DTRF2008	RMS of transformation
AIUB	0.01	datum parameters set up	7.0 mm
GRGS	2.0	datum parameters set up	6.0 mm

Combination:

RMS values (combined / single AC): 2-5 mm

RMS w.r.t. DTRF2008: 4-5 mm (Improvement compared to single AC)

→ Good agreement

Analysis and combination of DORIS data

Contributions: GRGS

Analysis:

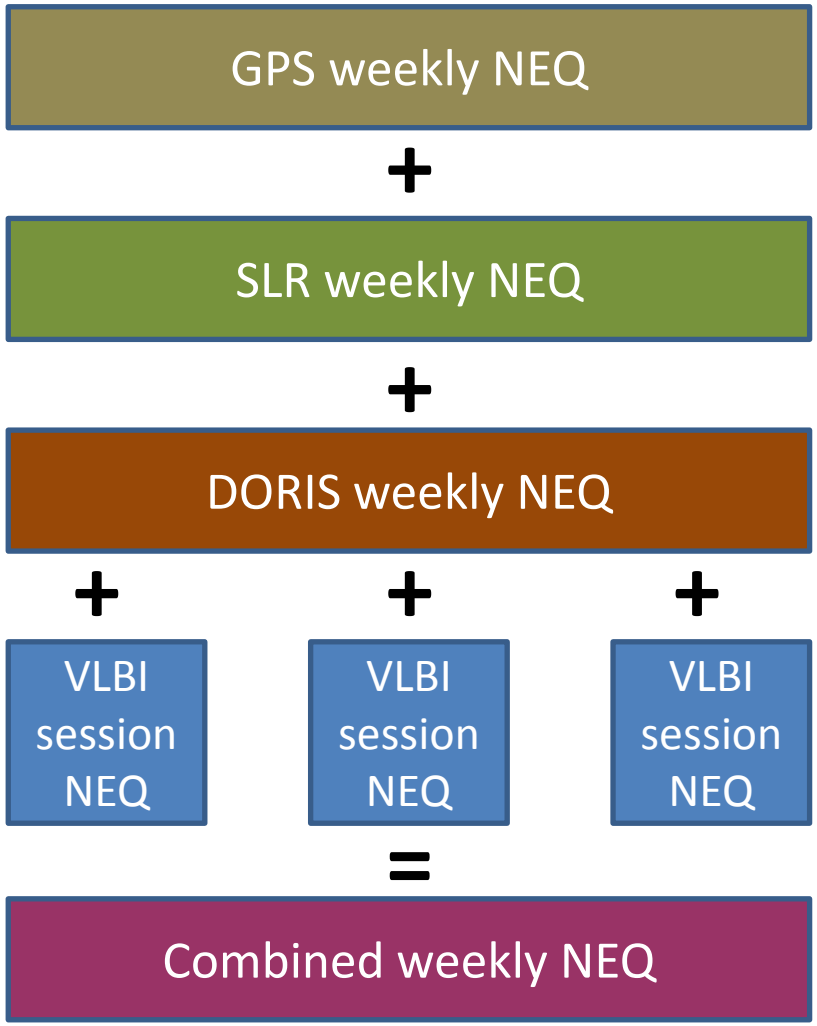
	A posteriori Sigma	Transformation DTRF2008	RMS of transformation
GRGS	1.0	datum parameters set up	10-20 mm

Combination:

→ No intra-technique combination for DORIS

Inter-technique combination

Flowchart of weekly combination

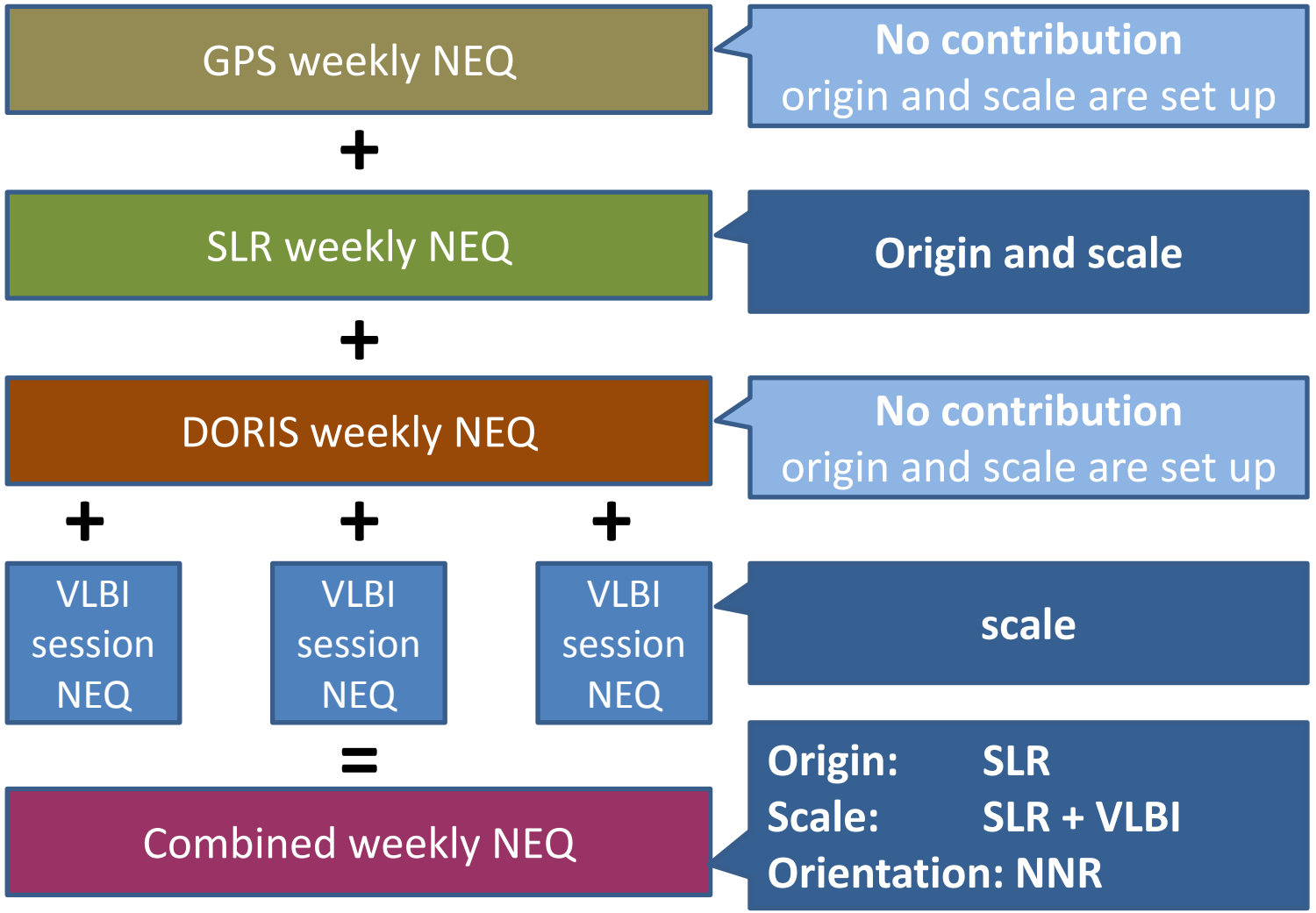


Selection of local ties
Max. local tie misfit : 25 mm

σ local ties
1.0 mm / component

Seitz: Combination at the CC DGFI

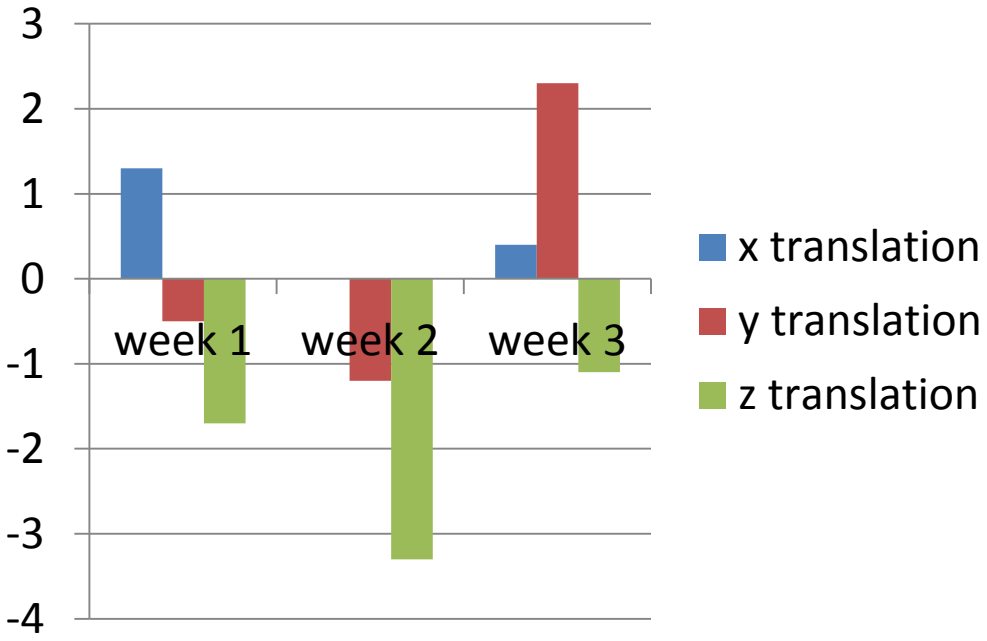
Combination: Datum realization



Combination: Datum realization

Conservation of the origin

Translation between combined (P+R+L+D) and SLR only [mm]

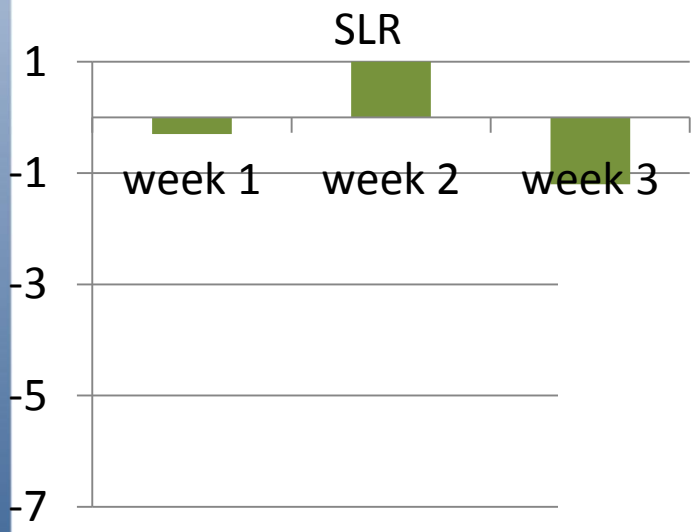


→ Good agreement between SLR only and combined solution

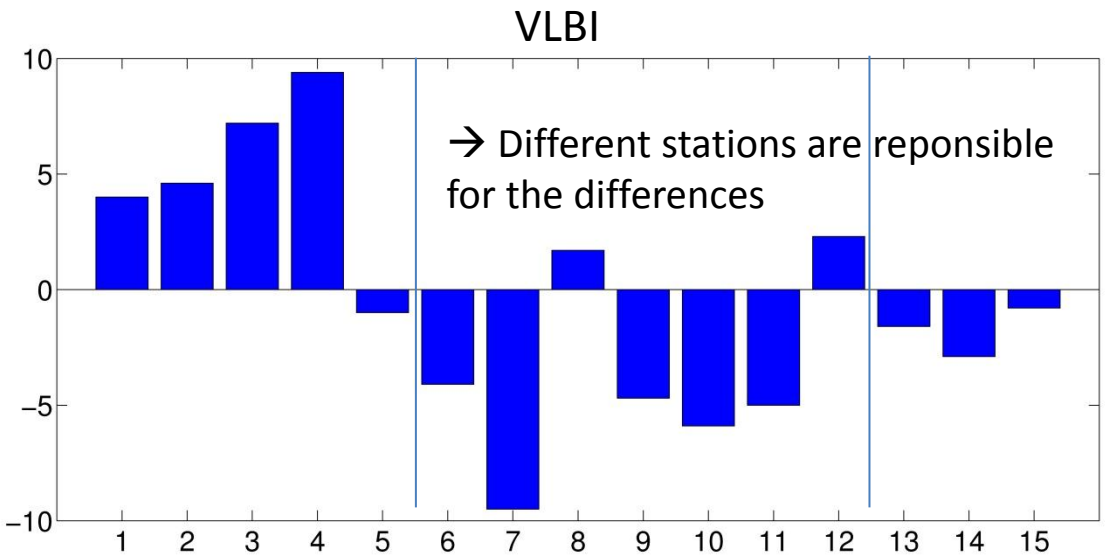
Combination: Datum realization

Conservation of the scale

Scale parameters between combined and VLBI/SLR only [mm]

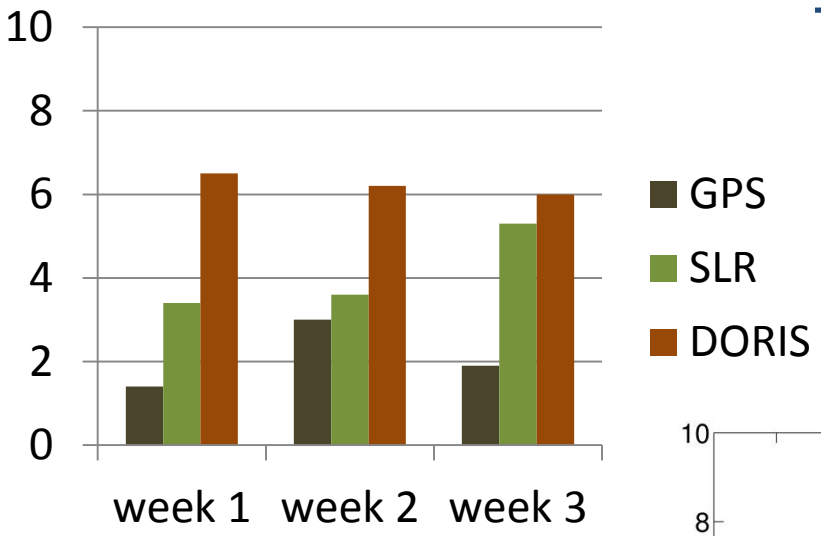


→ Variation of VLBI larger, but no mean offset between VLBI and SLR scale



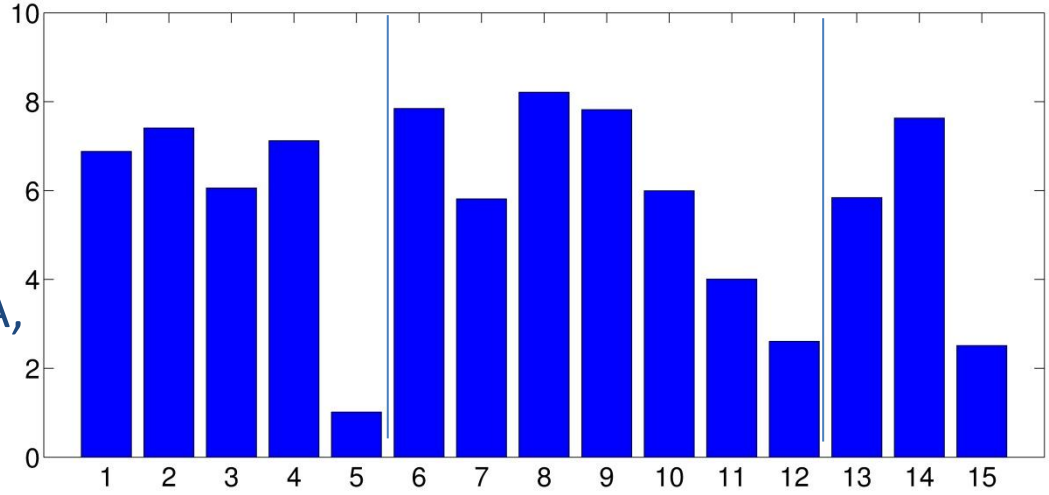
Combination: deformation of networks

RMS values of transformation between combined and single technique solution



→ Mean deformation can reach more than 5mm
SLR: Asian stations responsible for large RMS

VLBI stations with frequent residuals of 10-20 mm: NYALES20, SVETLOE, TSUKUBA, KOKEE, WESTFORD



Combination: Comparison with DTRF2008

Translations

SLR, GPS:	**-6.0 – 3.5 mm**
VLBI, DORIS:	-10.0 –6.0 mm, 5.0 – 10.0 mm

Rotations

GPS:	**-0.4 – 1.5 mm**
SLR:	-6.0 – 1.8 mm
VLBI:	-9.0 – 7.0 mm
DORIS:	-11.0 – 11.0 mm

Scale

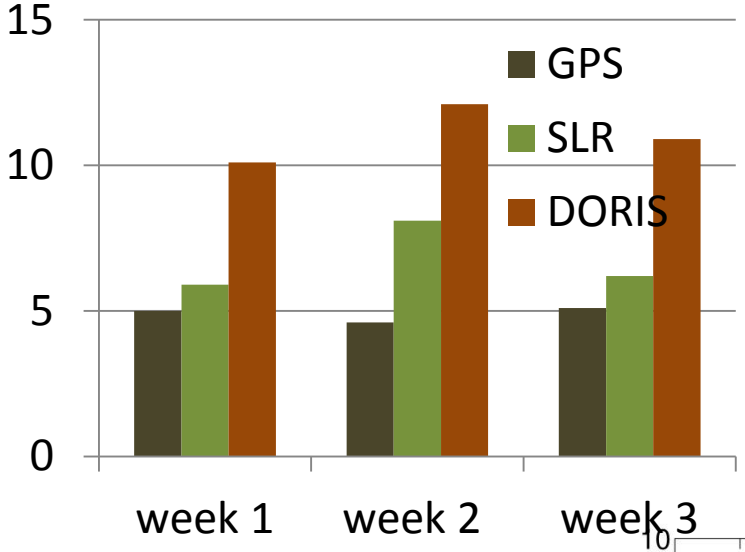
VLBI:	**-4.0 – 5.0 mm**
SLR:	**-2.3 – 1.4 mm**
GPS:	-1.6 – -2.5 mm
DORIS:	-3.7 – -5.3 mm

Datum realization w.r.t. DTRF2008
~ 5mm per component
(GPS orientation better)

Transfer into network parts
- translation/rotation : up to 11 mm
- Scale: up to ~ 5 mm

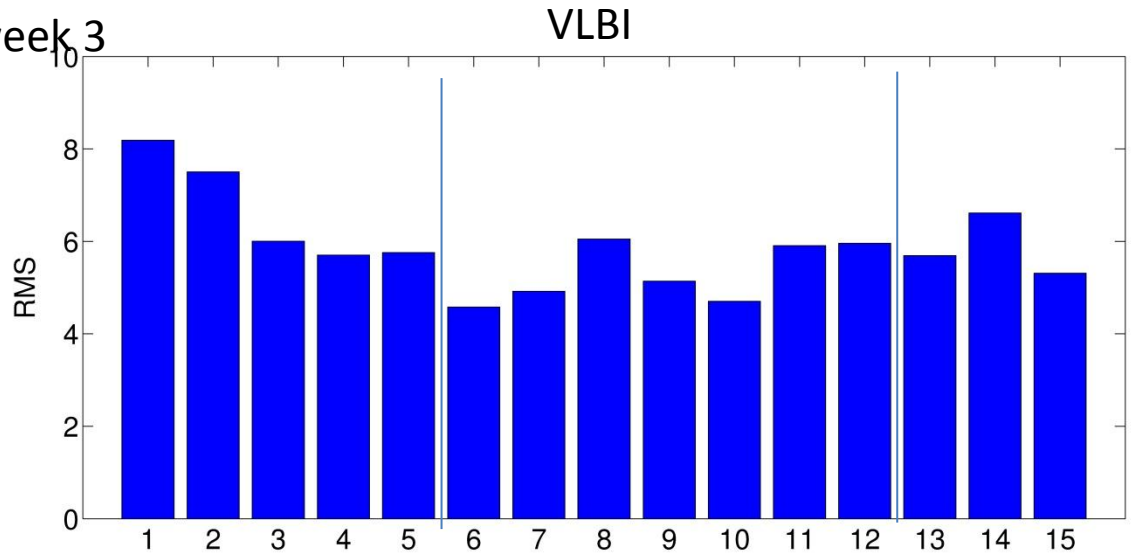
Combination: Comparison with DTRF2008

RMS values



Model differences between COL and DTRF2008 for VLBI and DORIS?

VLBI stations with frequent residuals of 10-20 mm: MEDICINA, NYALES20, TSUKU32



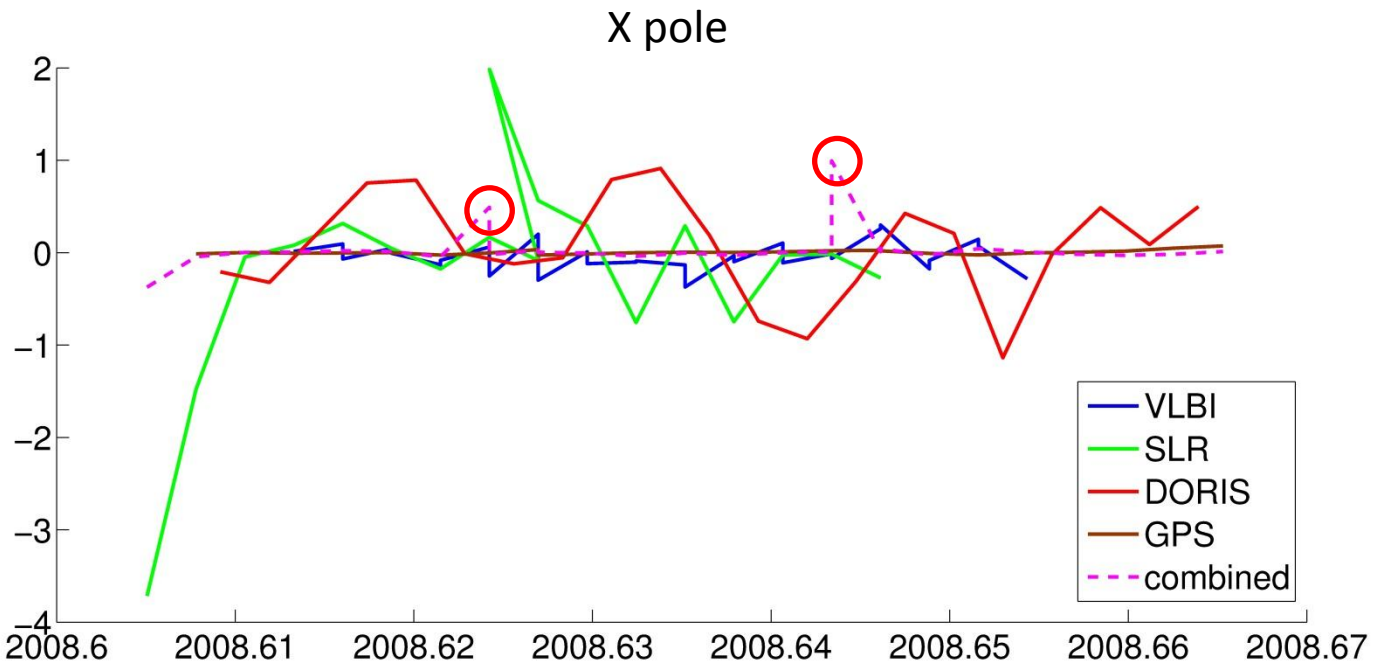
Combination: EOP

Combination of EOP (piece-wise linear at 0 h)

	pole	UT1-UTC	Nutation
GPS	**AIUB+GRGS**	**AIUB** (GRGS: UT1-TAI)	**AIUB** (GRGS: AV≠0)
SLR	**AIUB** (GRGS: pwl 12 h)	**AIUB** (GRGS: UT1-TAI; pwl 12 h)	/
VLBI	**DGFI+GRGS+ TUW**	**DGFI+TUW** (GRGS: UT1-TAI)	DGFI: mean epoch, no rates GRGS: AV≠0, mean epoch, no rates TUW: X,Y
DORIS	**GRGS**	/ (GRGS: UT1-TAI)	/ (GRGS: AV≠0)
Combined ?	yes	yes	no

Combination: EOP results

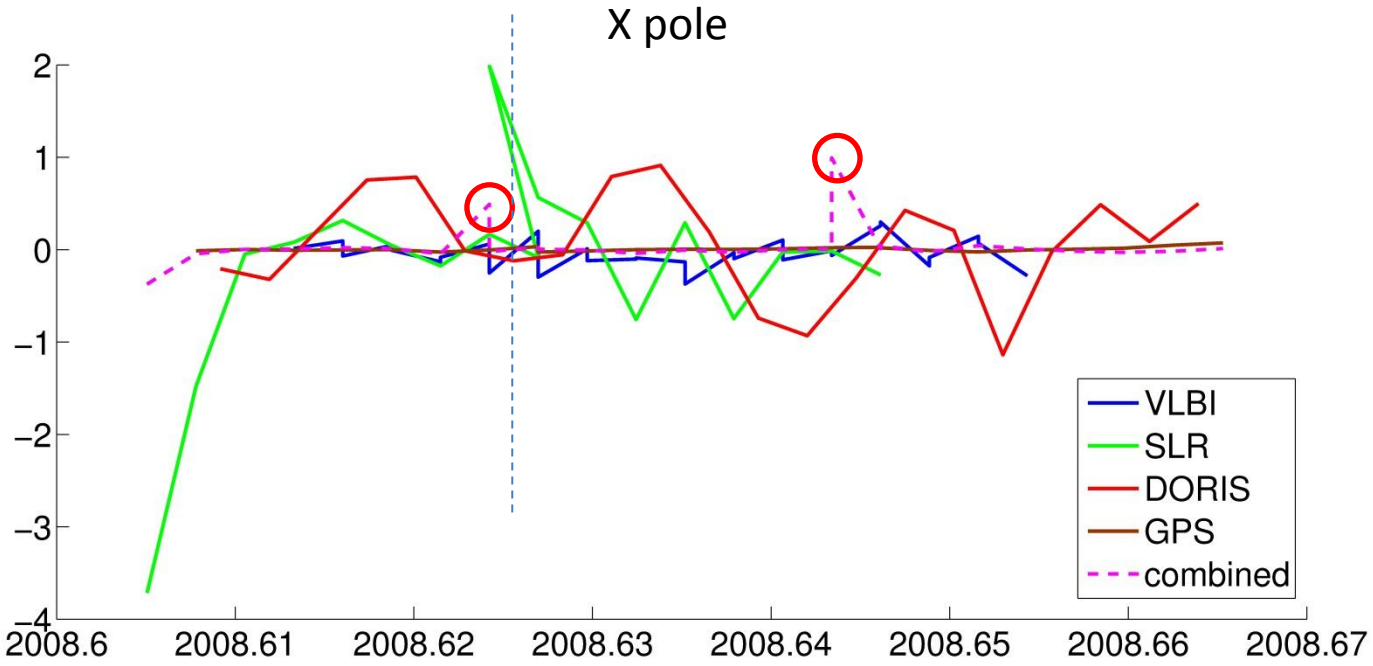
Pole coordinates (w.r.t. IERS 08 C04)



SLR week 3 cannot be solved

Combination: EOP results

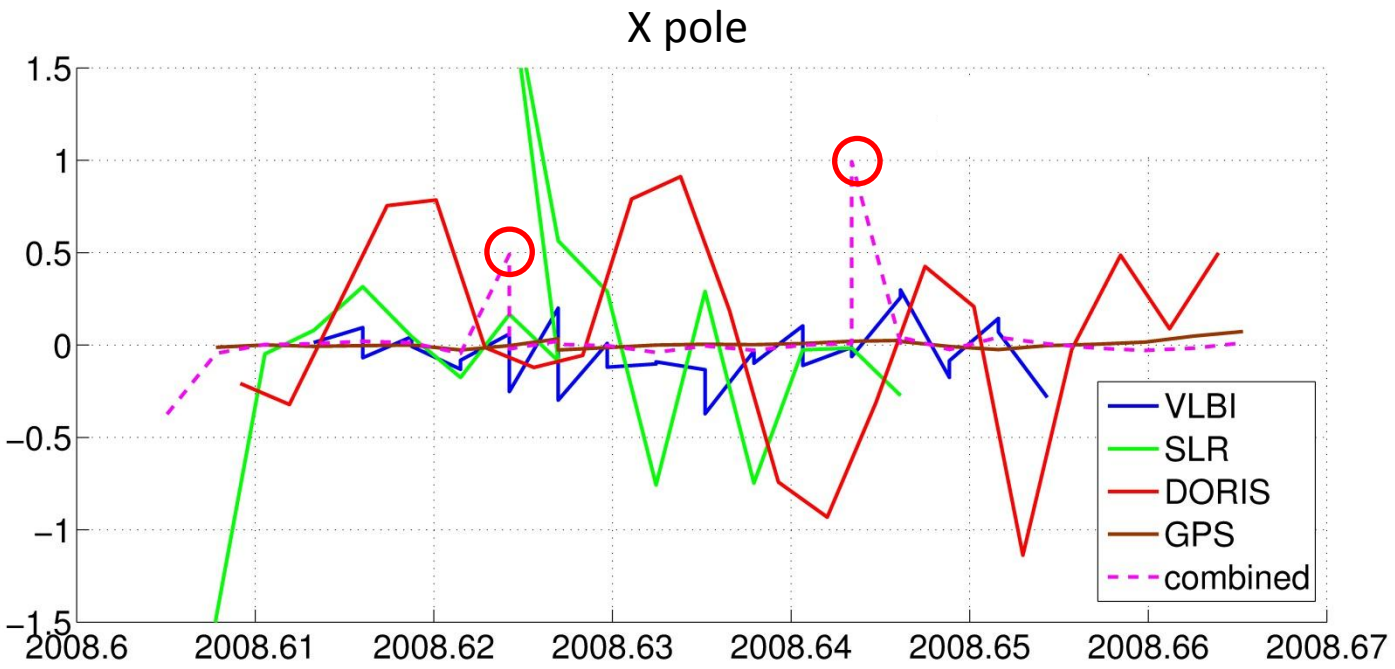
Pole coordinates (w.r.t. IERS 08 C04)



SLR week 3 cannot be solved

Combination: EOP results

Pole coordinates (w.r.t. IERS 08 C04)



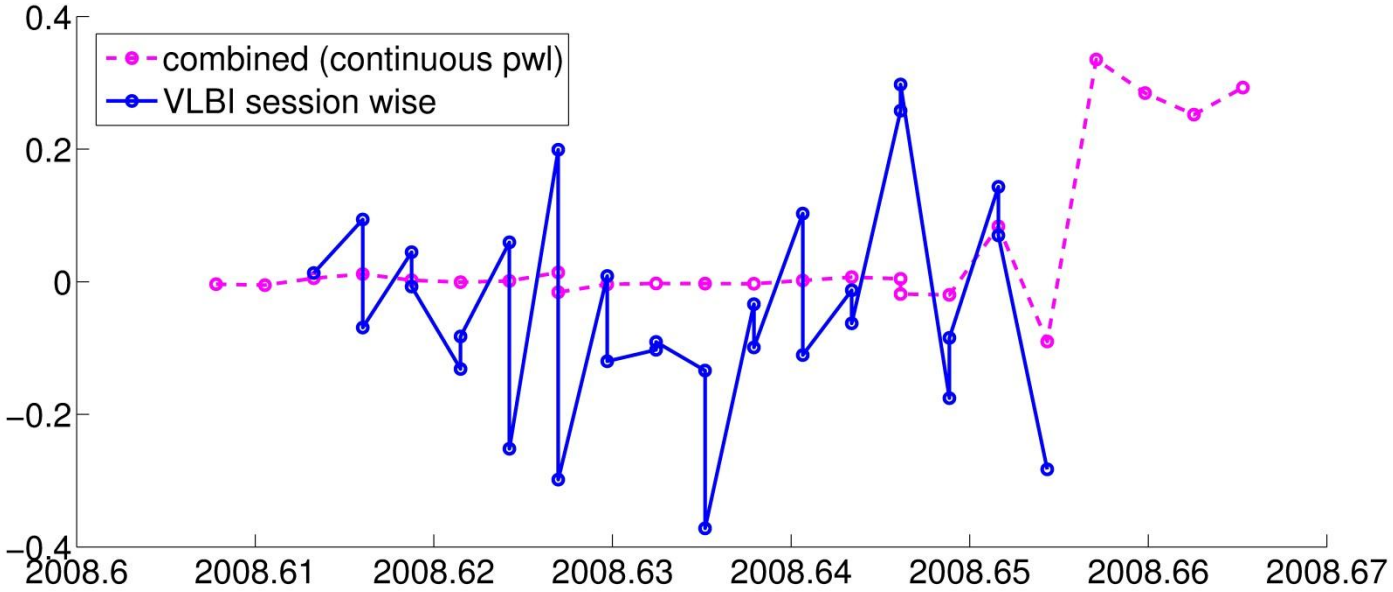
→ Outliers due to SLR contribution
(AIUB values: transformation from O+D -> pwl ?)

→ Y pole shows the same effects

	WRMS
X pole	39.4 uas
Y pole	32.8 uas

Combination: EOP results

UT1-UTC (w.r.t. IERS 08 C04)



	WRMS
UT1-UTC	20.1 us (w/o last four values)

Summary: to do

Input data

- Correct SINEX file:

  constraints, statistical information, station names (tropospheric parameters), source names, satellite names

- Parameterization:

  IERS2010 should be used (what about the new pole representation in the pole tide model?), Nutation -> [X,Y], UT1-UTC, same a priori values, for EOP: pwl at 0h or O+D

Combination

- Combination of all parameters
- Investigation of individual co-location sites
- VCE
- Pre-combined data should be included (more discussion is needed)