

Combination of techniques at CC DGFI

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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!

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

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 ITPI 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 equation 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: $\sim$ dry part
- estimated value: $\sim$ 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: $\sim$ dry ZD $\rightarrow$ *GPT model, GMF mapping function*
- estimated value: $\sim$ wet ZD (*GMF mapping function*)

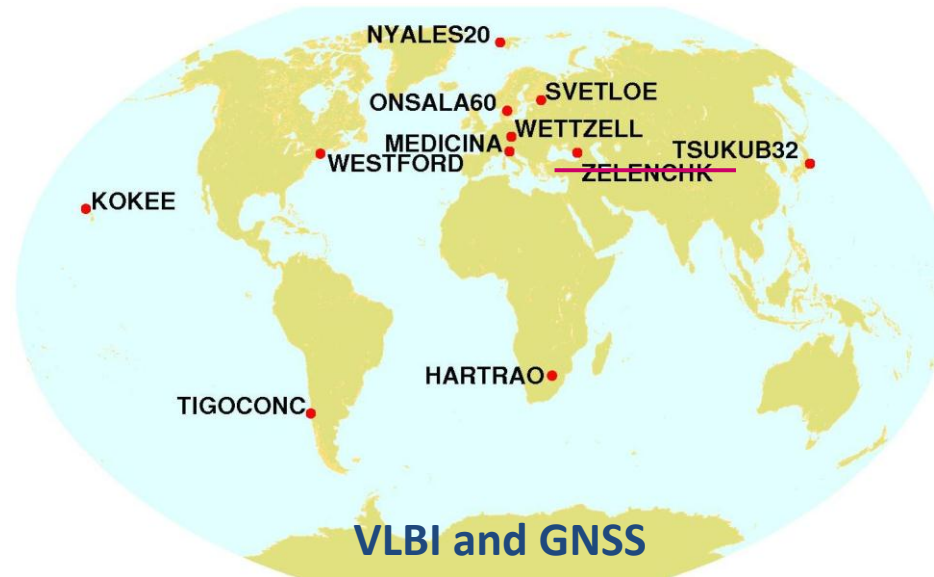
$\rightarrow$ the use of TROTOT with: a priori values = dry ZD (*GPT/GMF*)
would be necessary for comparisons

Corresponding gradients:

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

Tropospheric parameters in SINEX

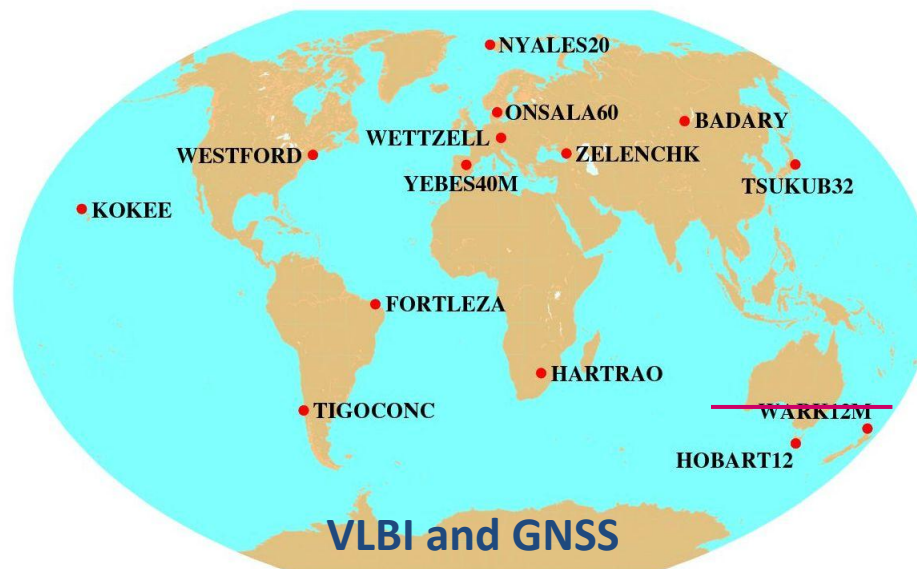
Stations CONT08



DORIS

NyAlesund
Hartebeesthoek
Kokee Park

Stations CONT11



DORIS

NyAlesund
Hartebeesthoek
Kokee Park

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

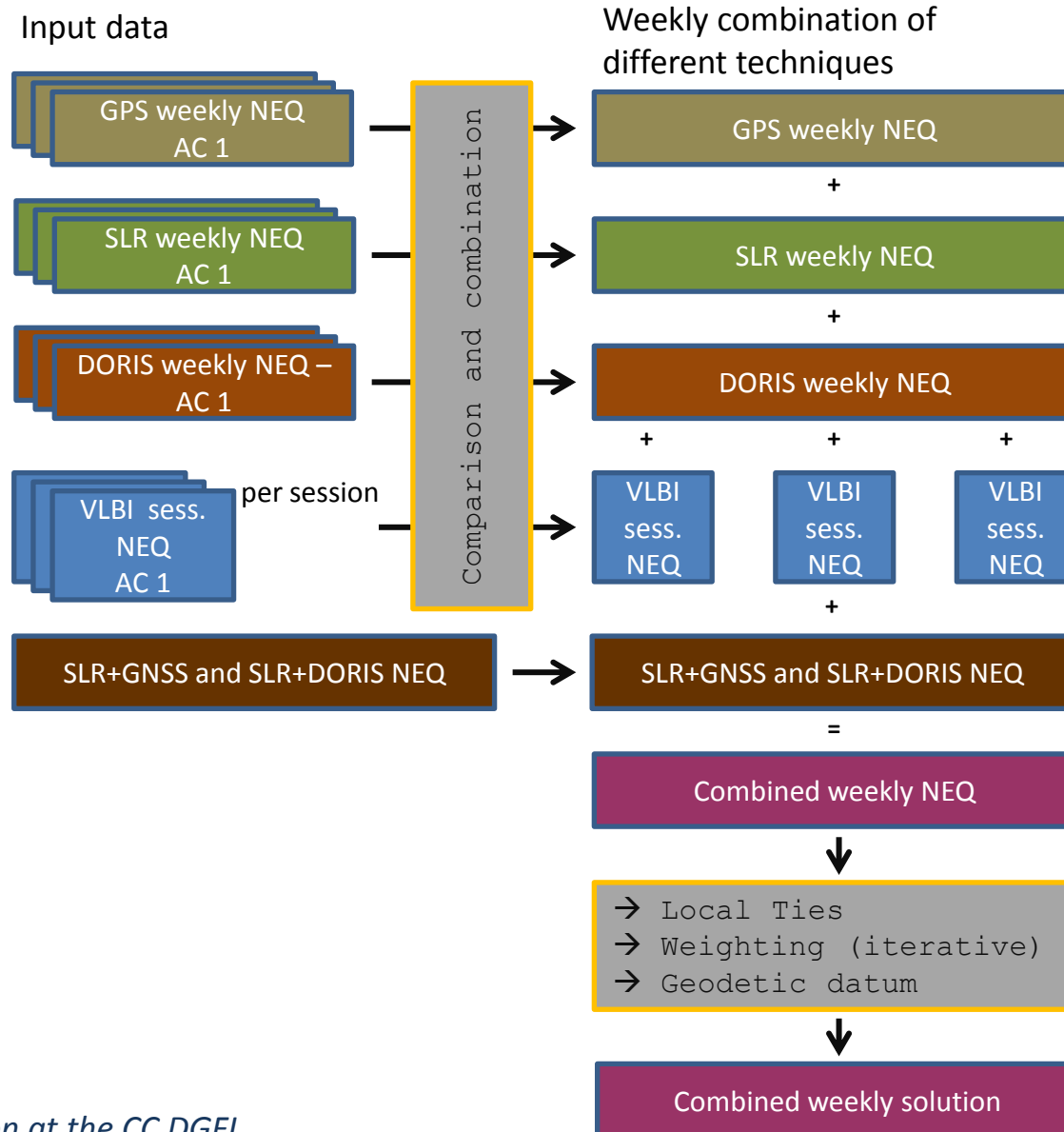
Tran: 0-5 mm

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 $1 \cdot 10^{15}$ vs. $1 \cdot 10^4$ for DGFI and TUW) → contribution to combined solution is very small

Analysis and combination of VLBI data

Combination aspects

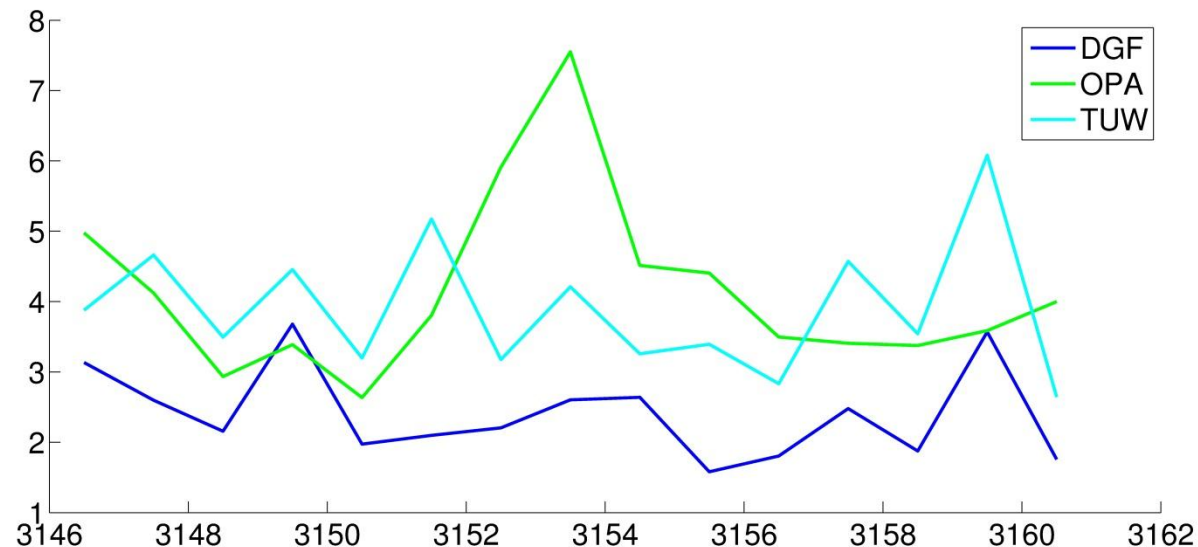
- Consideration of variance components is necessary
- DGFI, OPA: EOP transformed from O+D -> pwl
- Troposphere parameters (TUW): have to be stabilized
- Sources (TUW): fixed to ICRF2
- dUT1: DGFI and TUW (UT1-UTC); OPA (UT1-TAI)
 - > **dUT1 combined for DGFI and TUW only**
- Nutation: TUW[X,Y]; DGFI 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.

Analysis and combination of VLBI data

Combination results

RMS of similarity transformation between combined and single AC solutions

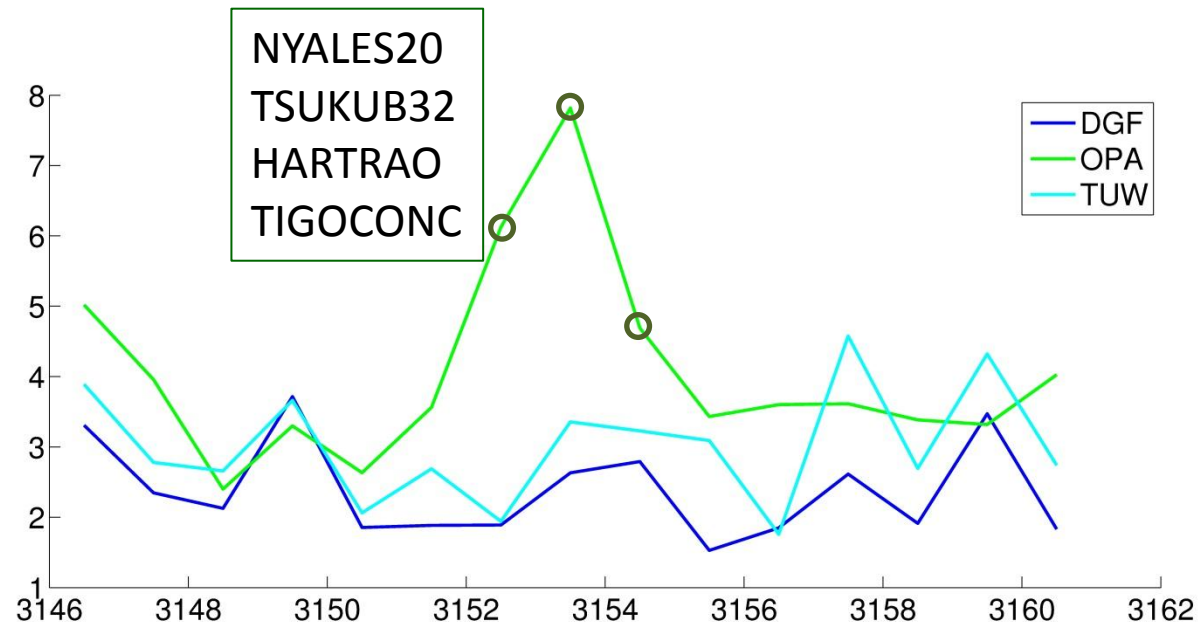


→ Offsets between the AC contributions

Analysis and combination of VLBI data

Combination results

RMS of similarity transformation between combined and single AC solutions

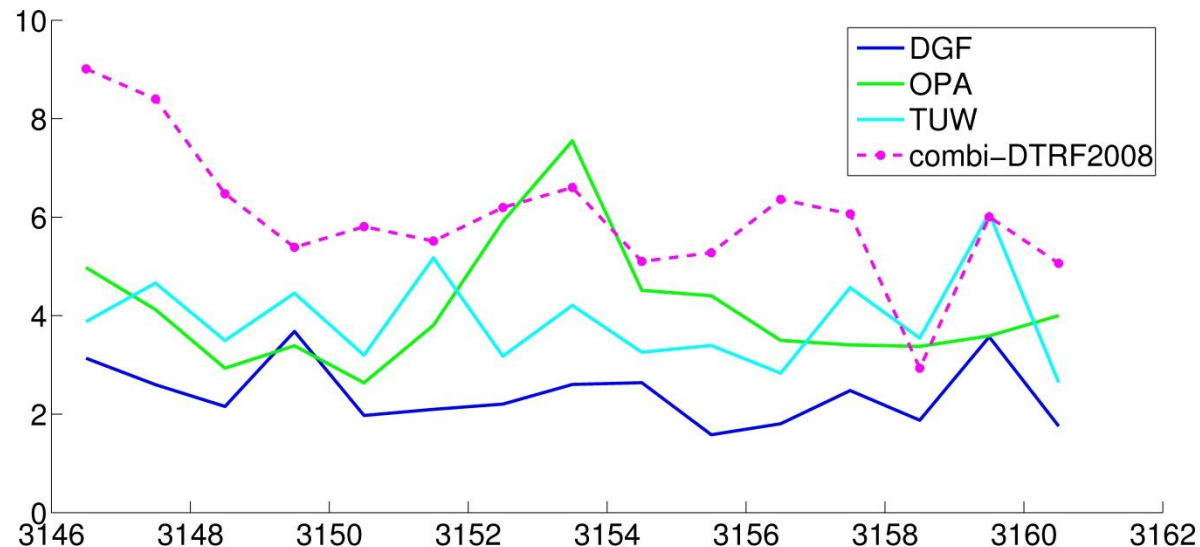


→ NYALES20 not used in transformation: offset between DGF and TUW removed. What are the reasons? Modell differences? (→height component)

Analysis and combination of VLBI data

Combination results

RMS of similarity transformation between combined and single AC solutions

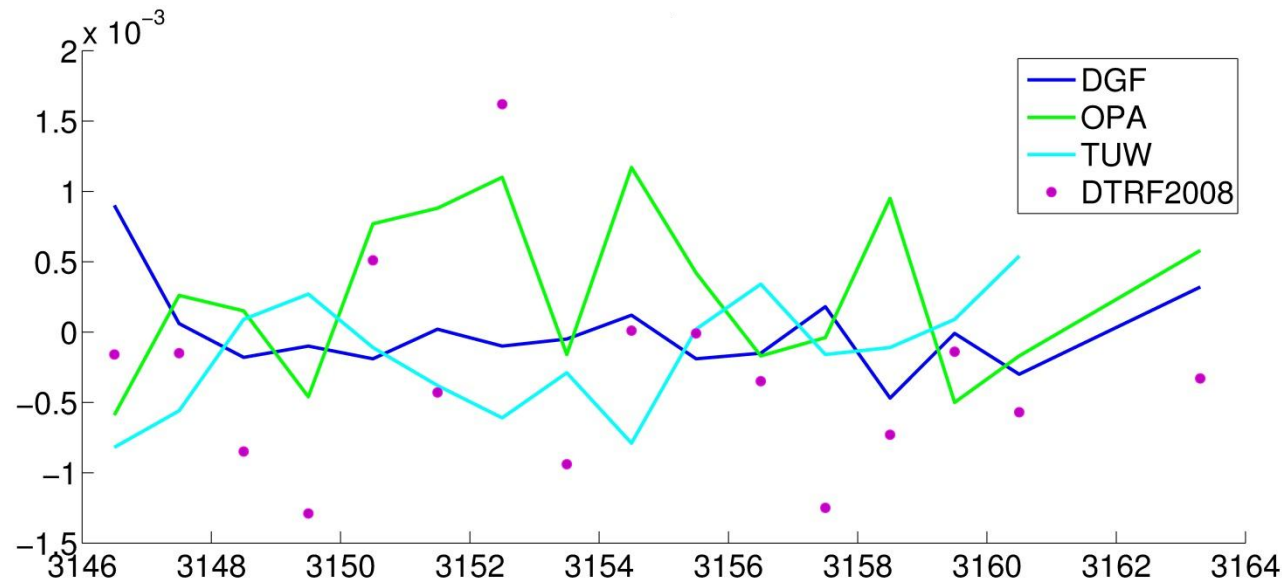


→ Agreement of AC better than agreement to DTRF2008 (model differences; epoch vs. multi-year solution)

Analysis and combination of VLBI data

Combination results

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

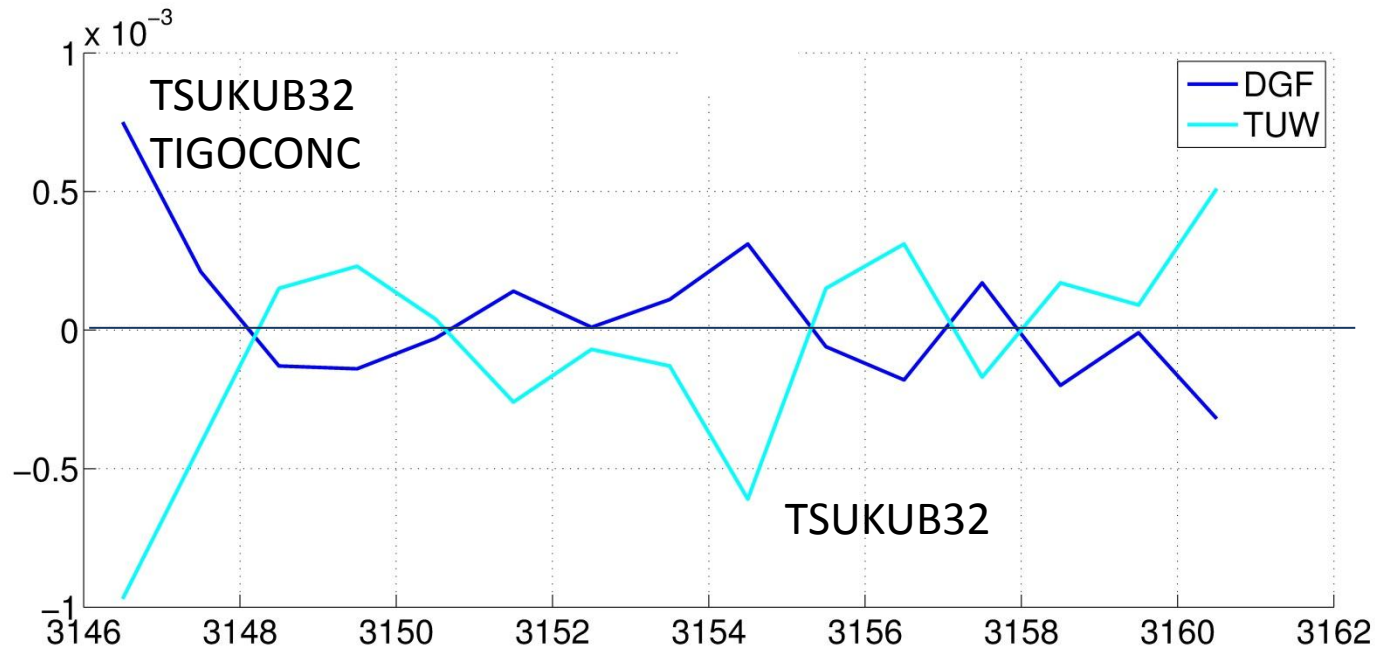


- Contribution of OPA very small (due to large STD).
- RMS of scale differences between AC comparable to comparison of combined solution and DTRF2008 (Offset: -0.5 ppb)

Analysis and combination of VLBI data

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

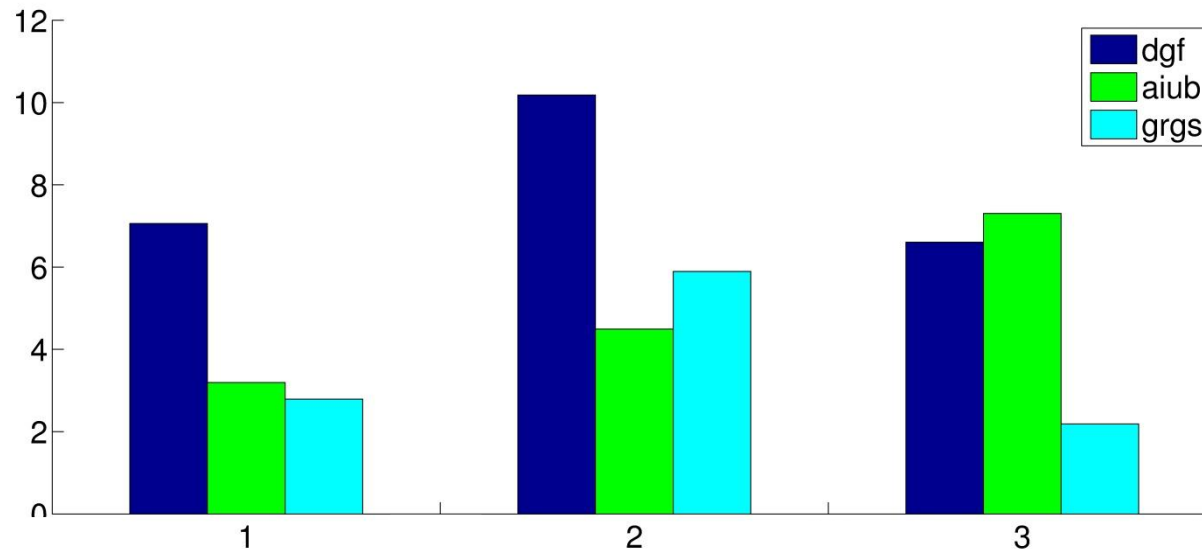
- Consideration of variance components is necessary
- Geocentre coordinates (AIUB) fixed to 0.0
- EOP:
 - CODE: O+D -> pwl
 - GRGS provides pwl values at noon (cannot be transformed)
 - > only the EOP of AIUB and DGFI are combined
 - week 3 cannot be solved if EOP are combined (ITPI) !!

What is the reason?

Analysis and combination of SLR data

Combination results

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

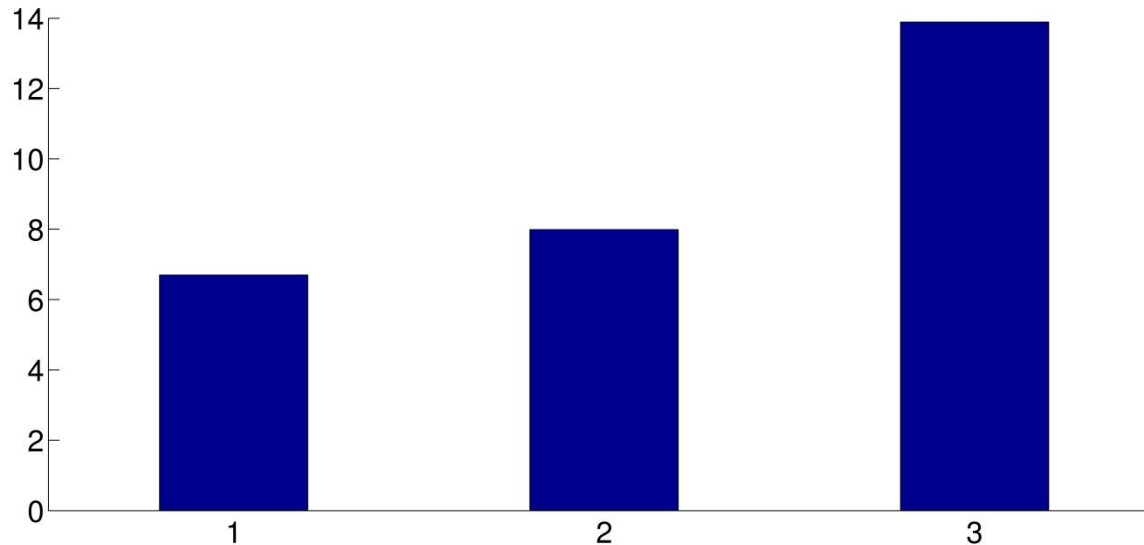


→ Comparable RMS values, DGFI values (weeks 1 and 2) slightly larger (improved compared to first DGFI solution)

Analysis and combination of SLR data

Combination results

RMS of similarity transformation between combined solution and DTRF2008

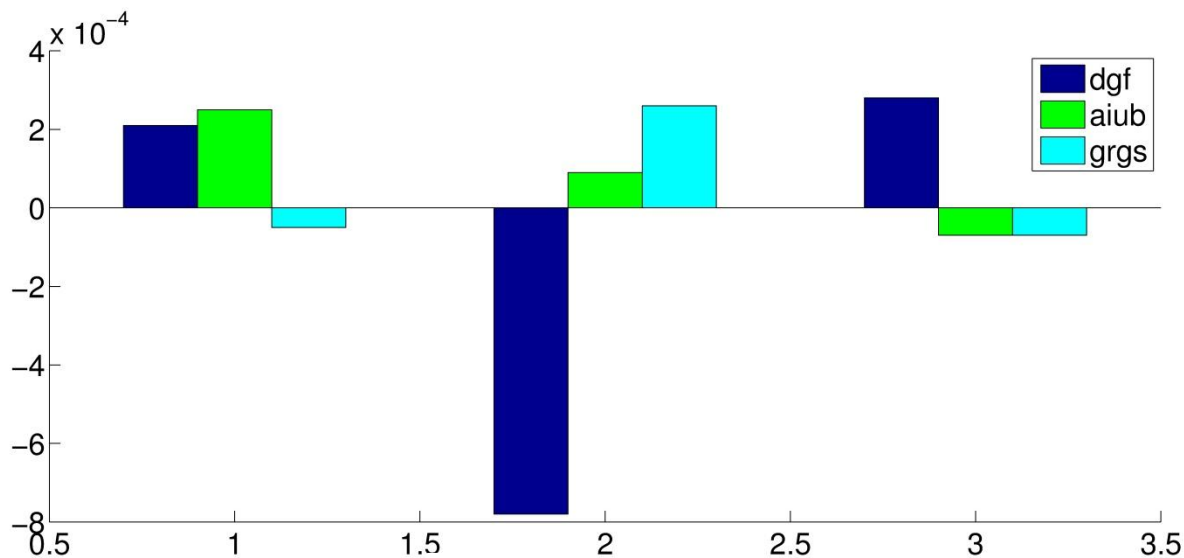


→ Comparable to RMS for single AC w.r.t. DTRF2008 (15 mm); week 1 and 2 benefit from combination

Analysis and combination of SLR data

Combination results

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

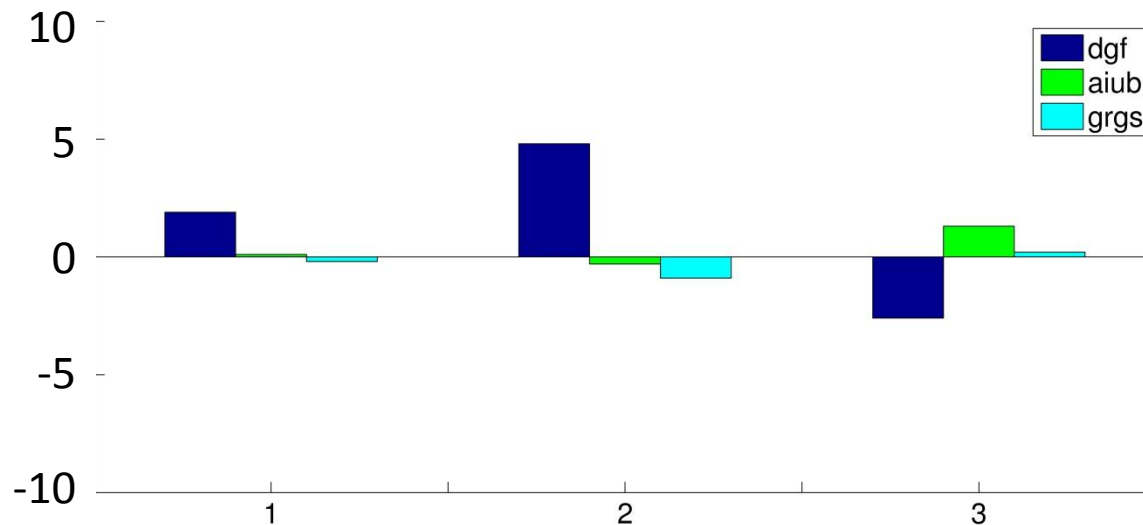


→ Agreement: 0.2 ppb (~ 1.5 mm) ; except of week 2 / DGFI

Analysis and combination of SLR data

Combination results

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

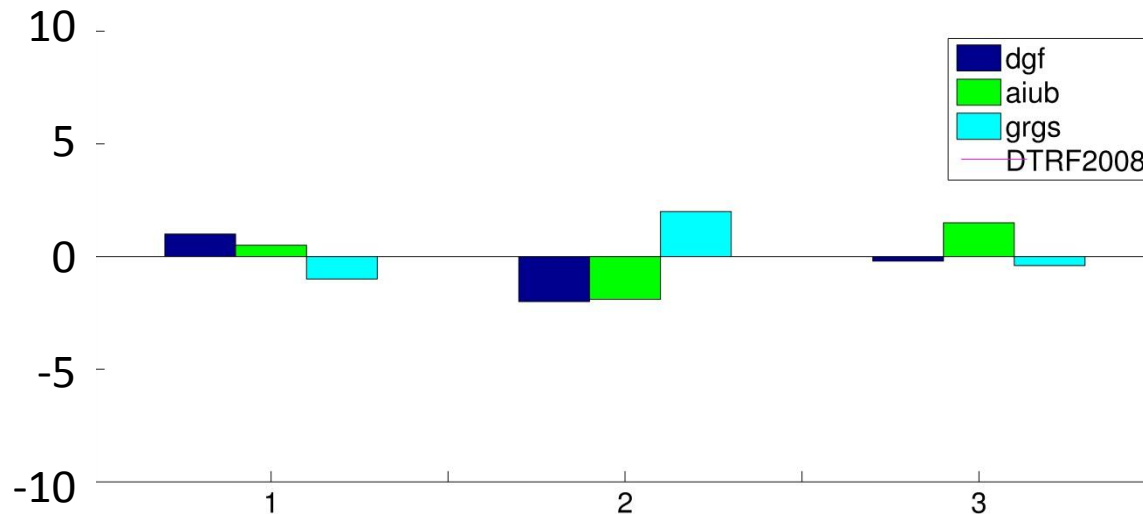


→ Agreement within 5.0 mm

Analysis and combination of SLR data

Combination results

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

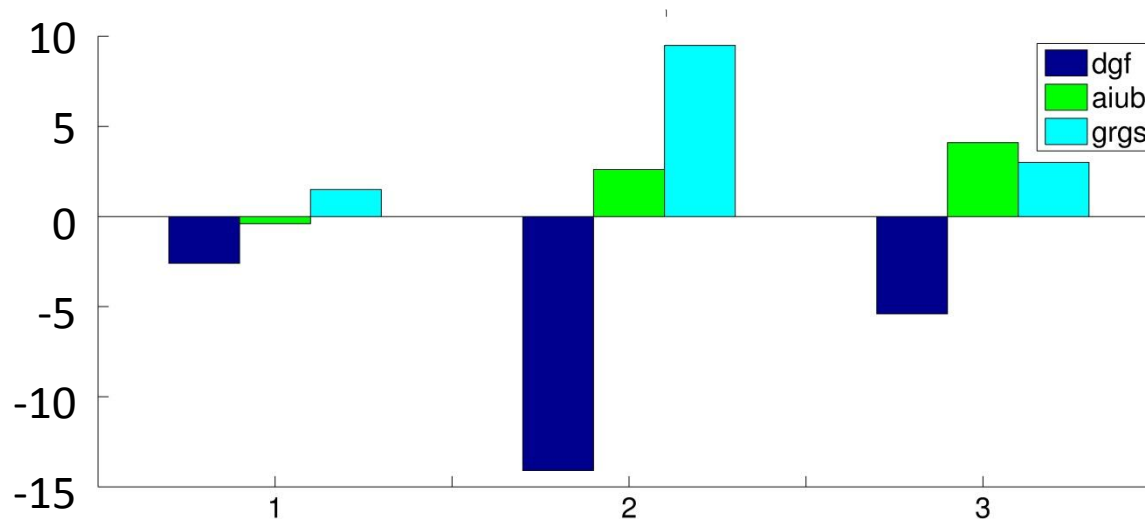


→ Agreement within 2.0 mm

Analysis and combination of SLR data

Combination results

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

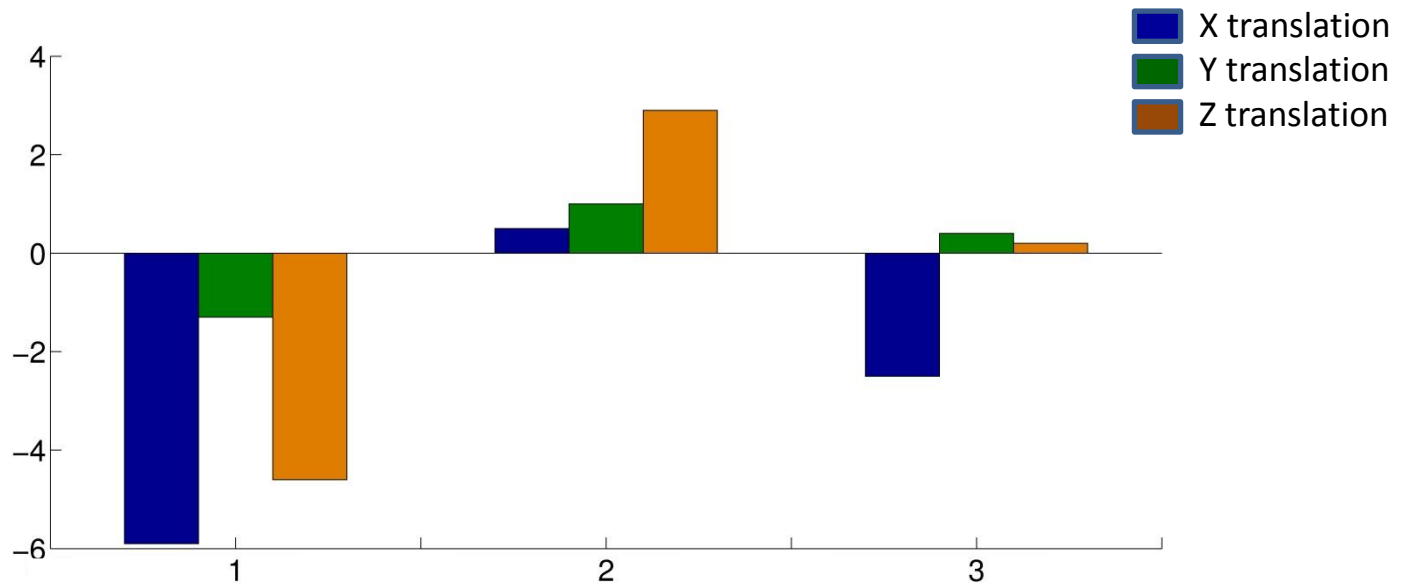


- Agreement within 5.0 mm for week 1 and 3
- Summarizing: homogeneous SLR input data

Analysis and combination of SLR data

Combination results

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

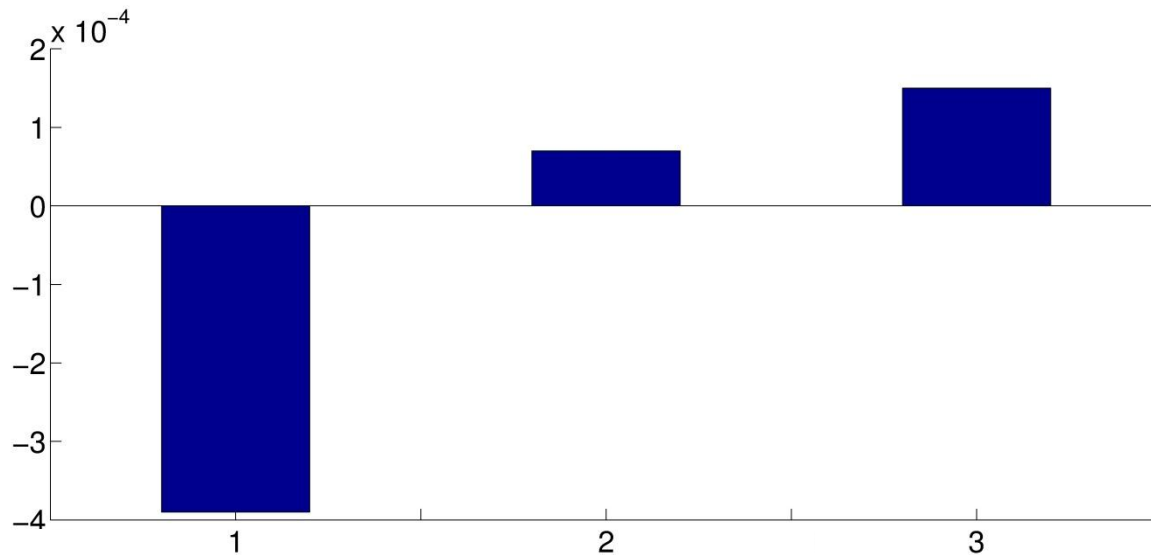


→ Agreement within 6 mm.

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:

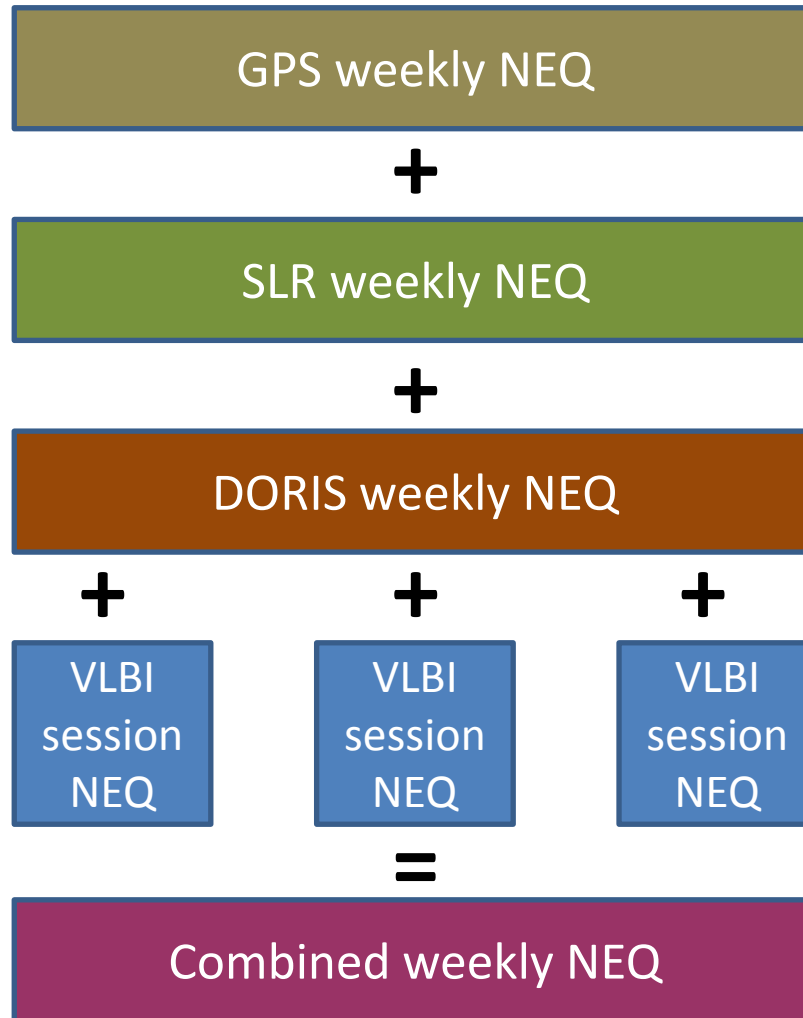
	A posteriori Sigma	Transformation DTRF2008	RMS of transformation
GRGS	1.0	datum parameters set up	10-20 mm

Combination:

→ No intra-technique combination for DORIS

Inter-technique combination

Flowchart of weekly combination



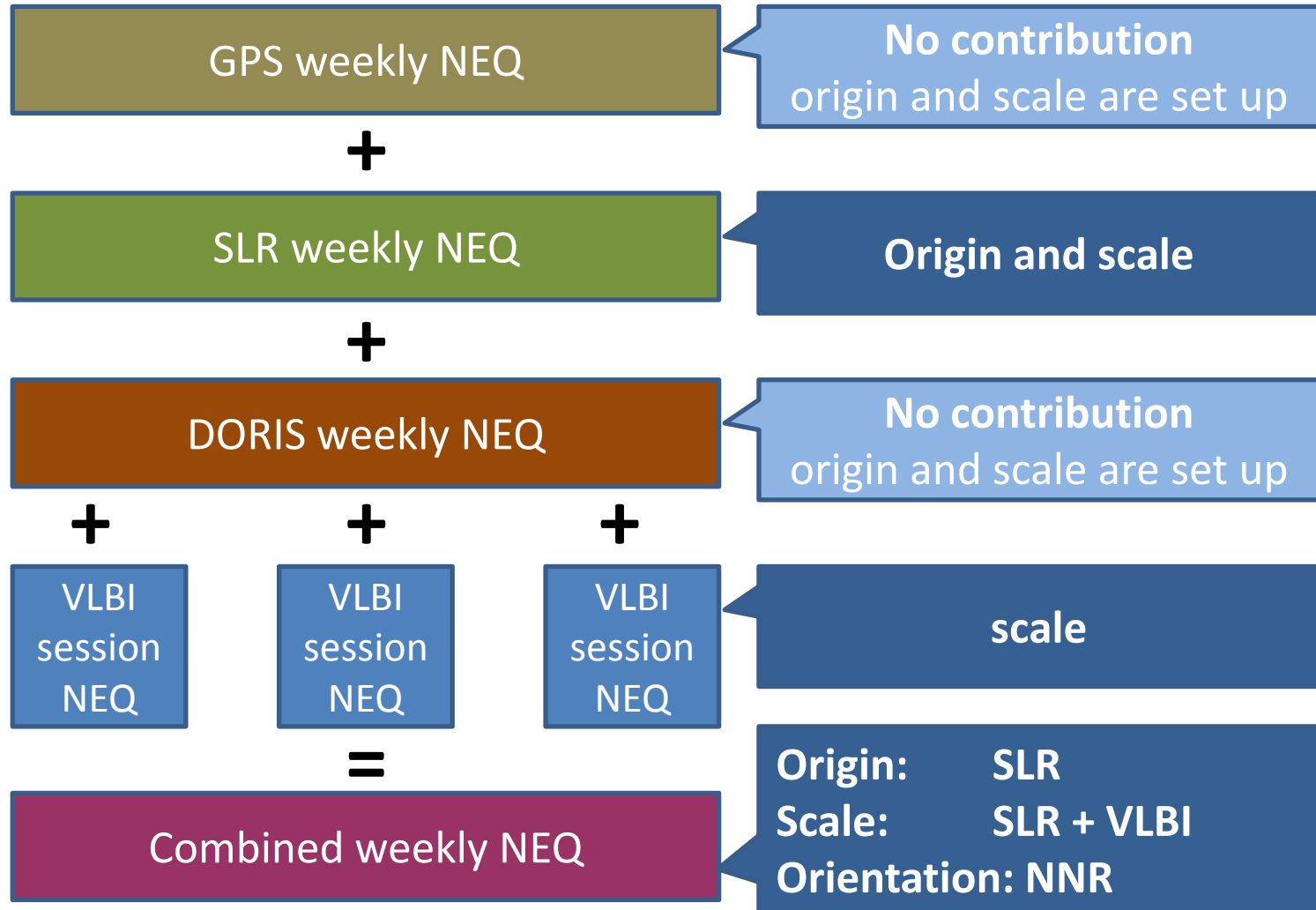
Selection of local ties

Max. local tie misfit : 25 mm

σ local ties

1.0 mm / component

Combination: Datum realization



Combination: Datum realization

Conservation of the origin

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

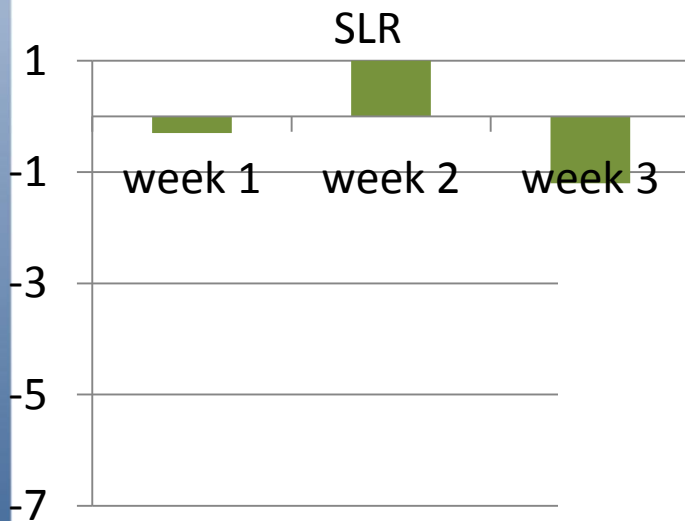


→ Good agreement between SLR only and combined solution

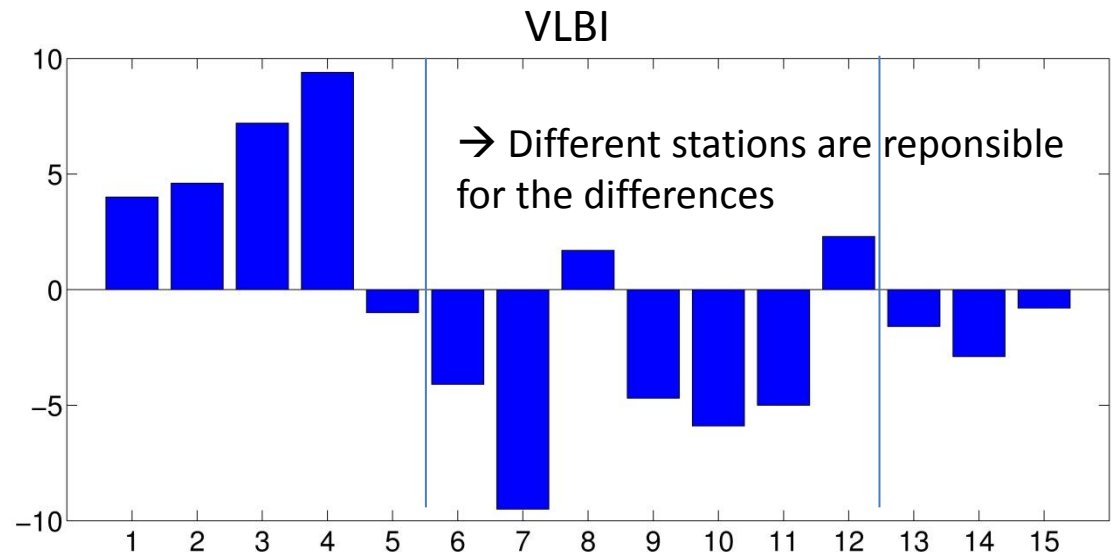
Combination: Datum realization

Conservation of the scale

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

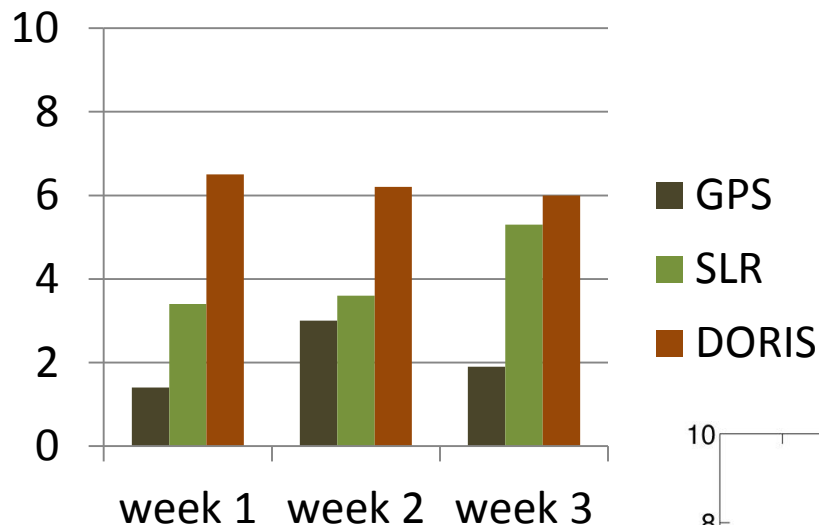


→ Variation of VLBI larger, but no mean offset between VLBI and SLR scale



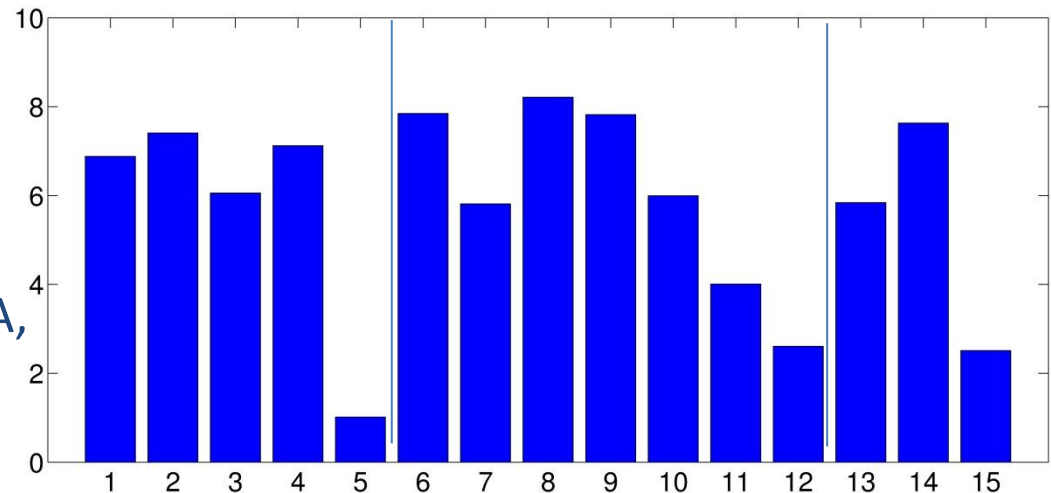
Combination: deformation of networks

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

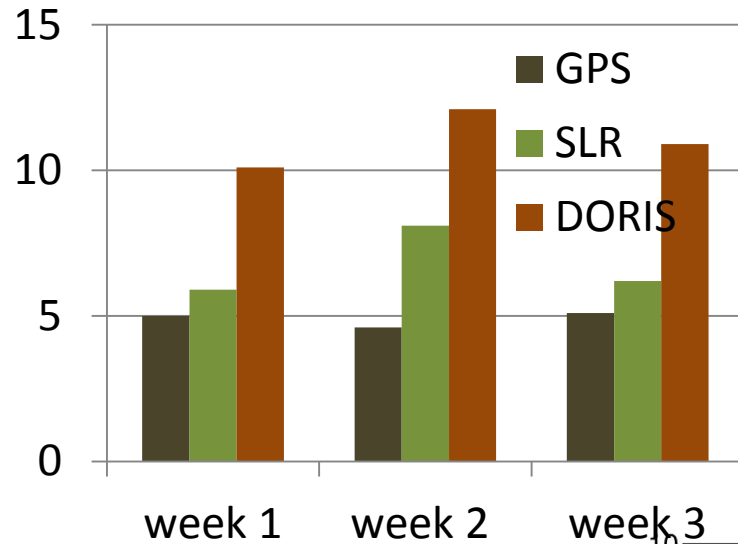
Datum realization w.r.t. DTRF2008
~ 5mm per component
(GPS orientation better)

Transfer into network parts

- translation/rotation : up to 11 mm
- Scale: up to ~ 5 mm

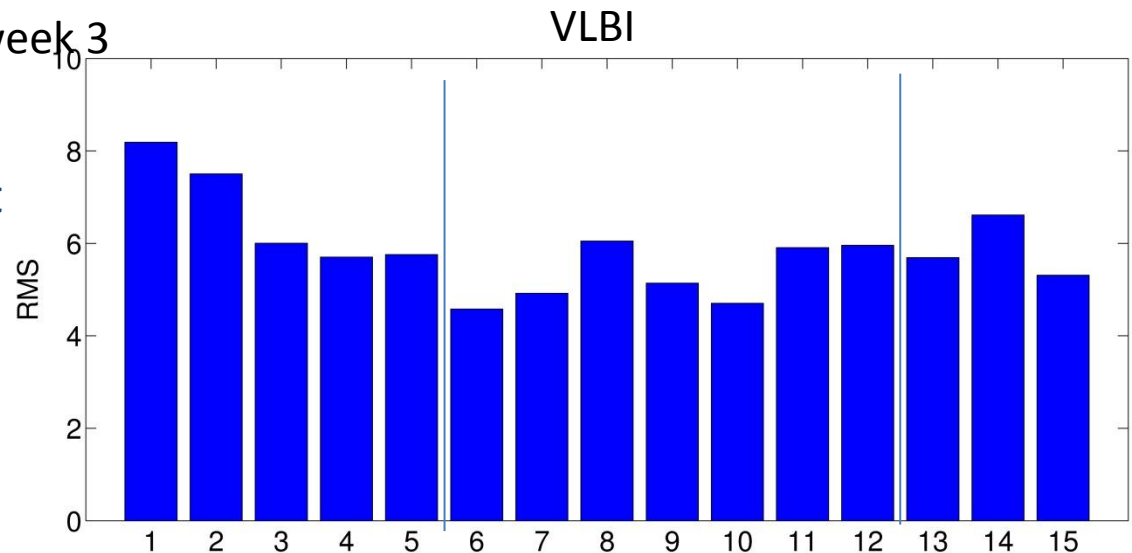
Combination: Comparison with DTRF2008

RMS values



Model differences between COL and DTRF2008 for VLBI and DORIS?

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



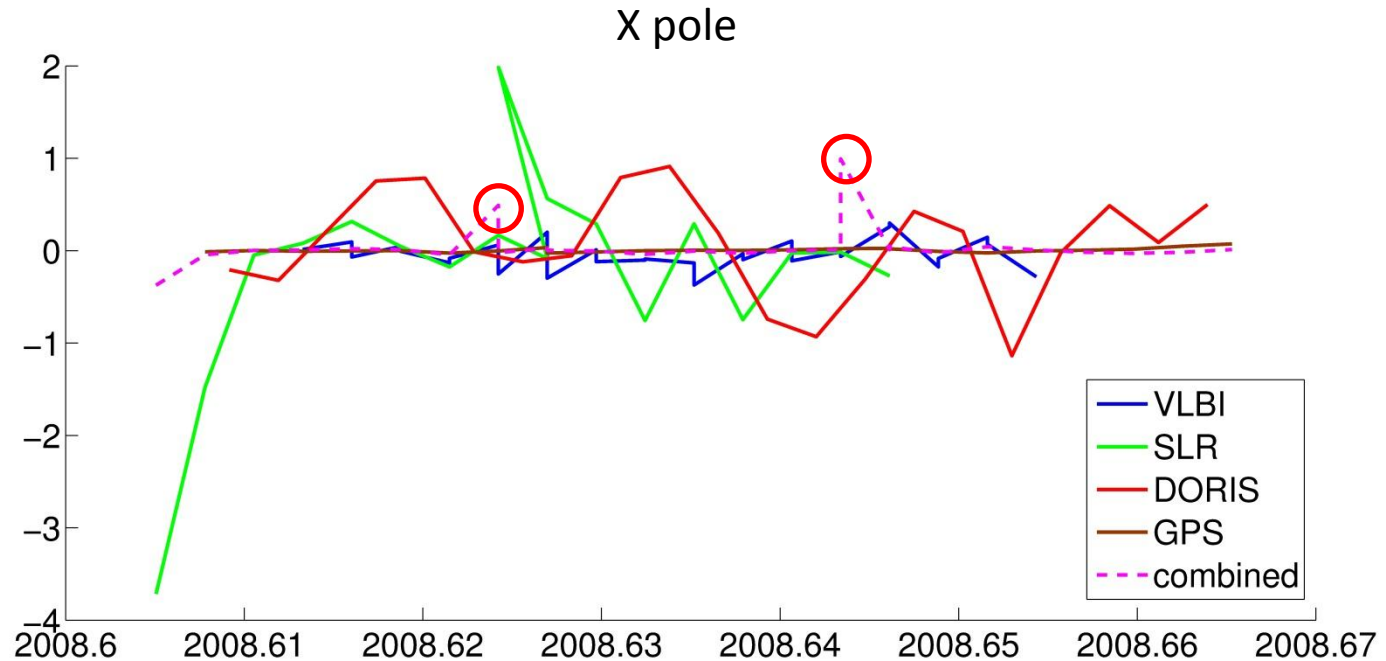
Combination: EOP

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

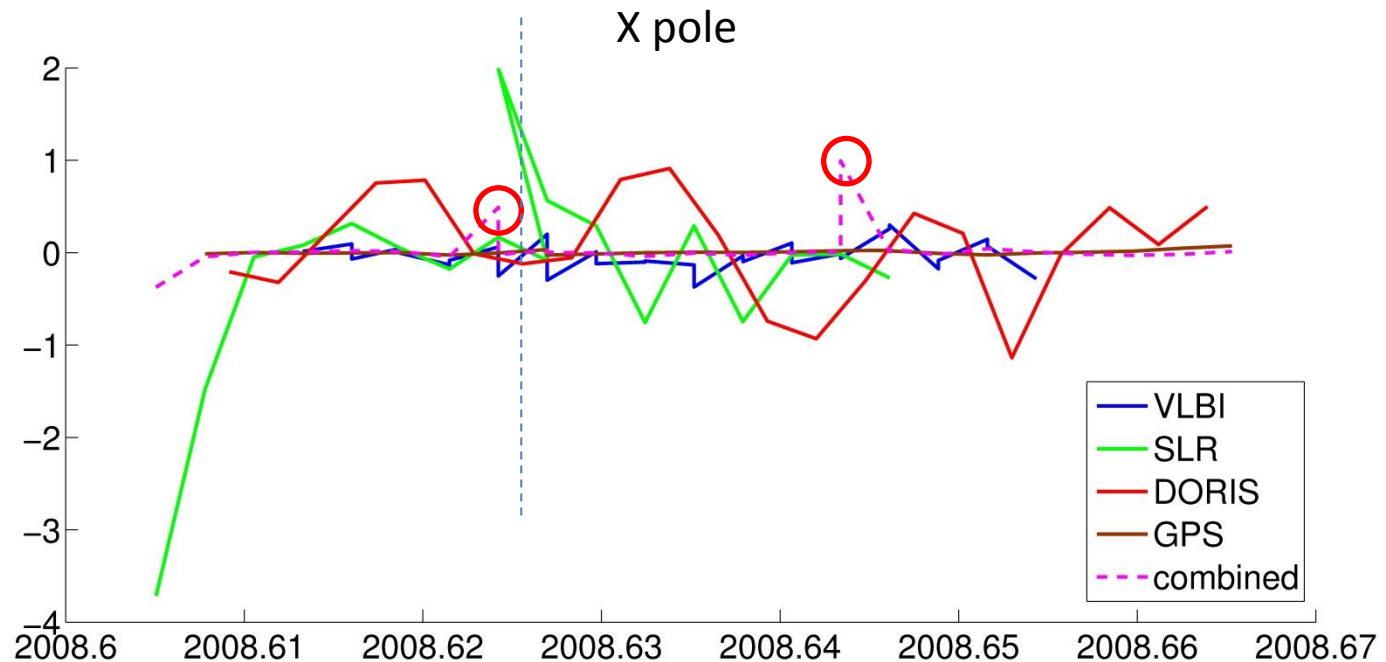
Pole coordinates (w.r.t. IERS 08 C04)



SLR week 3 cannot be solved

Combination: EOP results

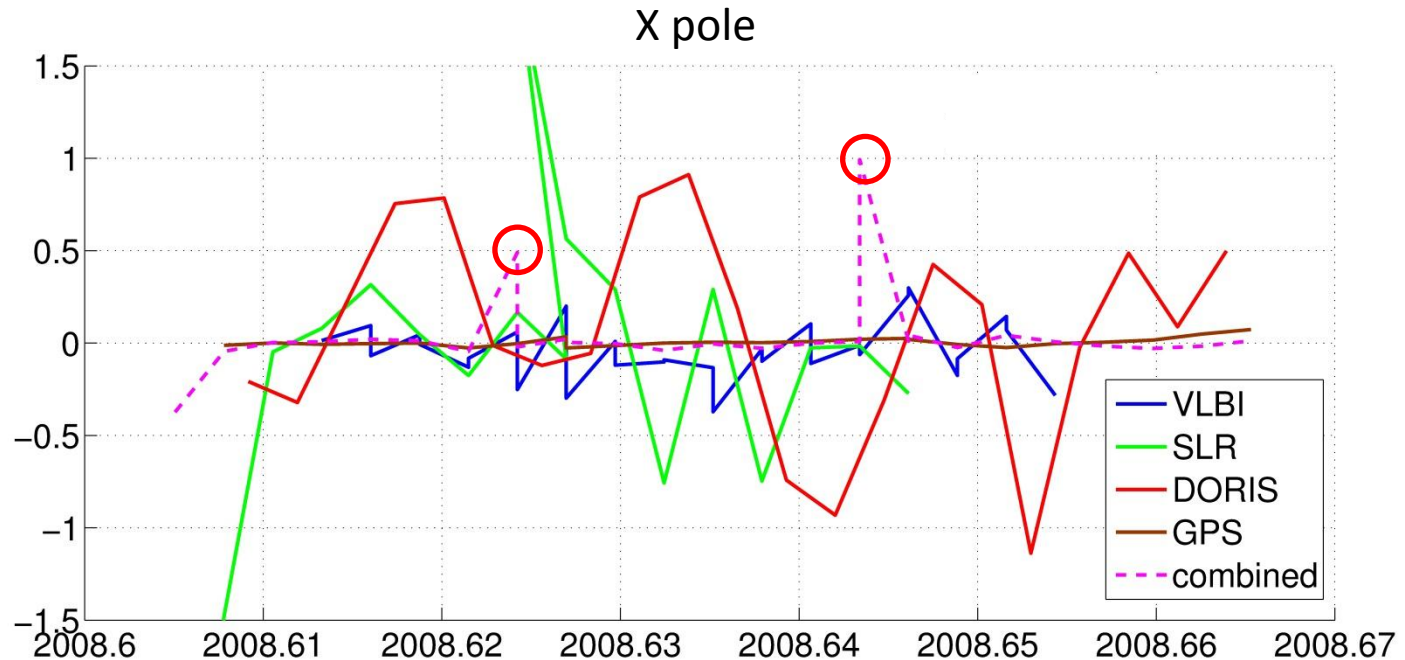
Pole coordinates (w.r.t. IERS 08 C04)



SLR week 3 cannot be solved

Combination: EOP results

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

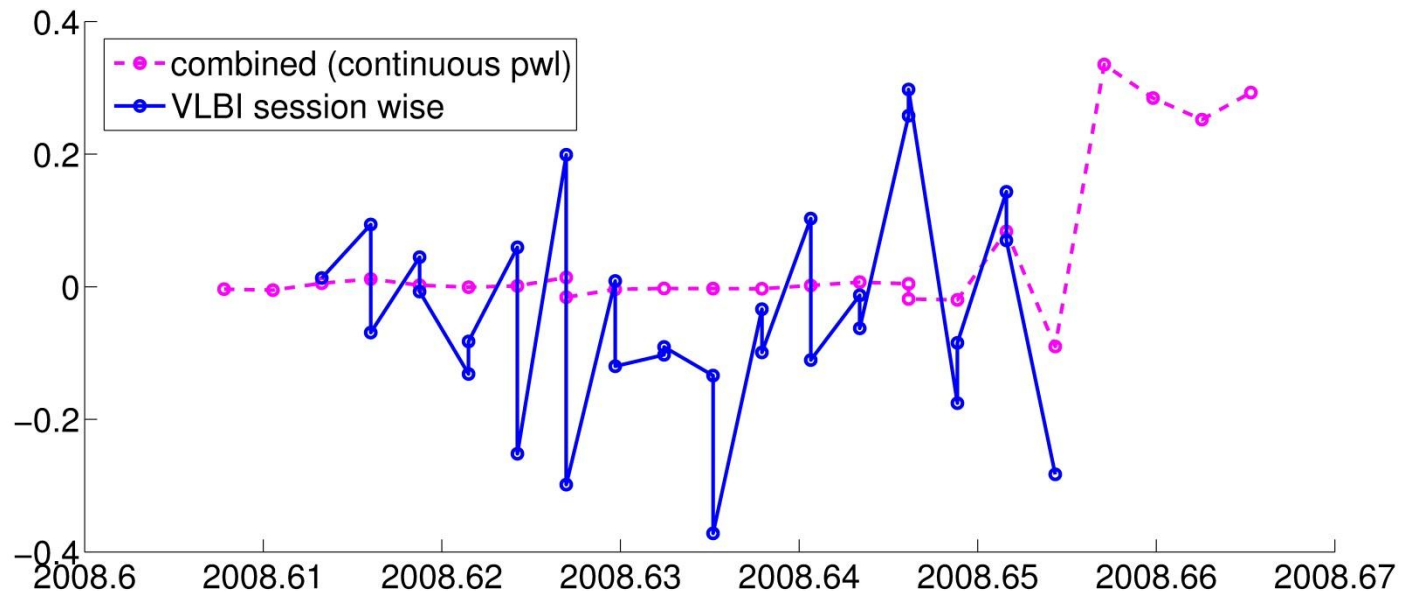


- Outliers due to SLR contribution
(AIUB values: transformation from O+D -> pwl ?)
- Y pole shows the same effects

	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)