Combination Strategies for ILRS Products

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The ILRS Analysis Centers

The ILRS AC contributions

	EOP / SSC weekly	**EOP / SSC** daily	**SP3c L / E** weekly	**ITRF2008** 1983-2008	SW
ASI	Nov 03	Feb 08	May 08	May 09	**GEODYN II / SOLVE**
BKG	May 05	Feb 08	May 08	-	**UTOPIA / SOLVE**
DGFI	Nov 03	-	Jun 08	May 09	**DOGS_OC / DOGS_CS**
GA	May 07	-	Aug 08	May 09	**GEODYN II / SOLVE**
GFZ	Nov 03	Feb 08	Sep 08	May 09	**EPOSOC**
GRGS	Dec 07	Mar 09	Jun 08	Jun 09 *	**INS / MATLO**
JCET	Jan 04	Feb 08	-	May 09	**GEODYN II / SOLVE**
NSGF	Nov 03	Feb 08	-	Jul 09	**SATAN**

The ILRS Combined Products

ilrsa/ilrsb	arc length	issue start	latency	SSC	EOP	SV
“pos+eop” weekly	7day	Nov 03	4-10day	1/week	1/day	-
“pos+eop” daily	7day	Feb 08	2-8day	1/week	1/day	-
“pos+eop” ITRF05	15-7day **1993-2005**	Dec 05	-	1/week 1/15day	1/day 1/3day	-
“pos+eop” ITRF08	15-7day **1983-2008**	Aug 09	-	1/week 1/15day	1/day 1/3day	-
“orbit” L/E weekly	7day		4-10day			1/2’ 1/15’

The ILRS data processing flow

- The official ILRS AC weekly/long term solutions and the pre-operational daily solutions are combined by ASI and DGFI CCs
- Solutions contain SSC and daily EOP, using Lageos and Etalon data, according to the **ILRS/AWG guidelines**

ASI
BKG
DGFI
GA
GFZ
GRGS
JCET
NSGF

CDDIS
EDC

ASI
ILRSA solution

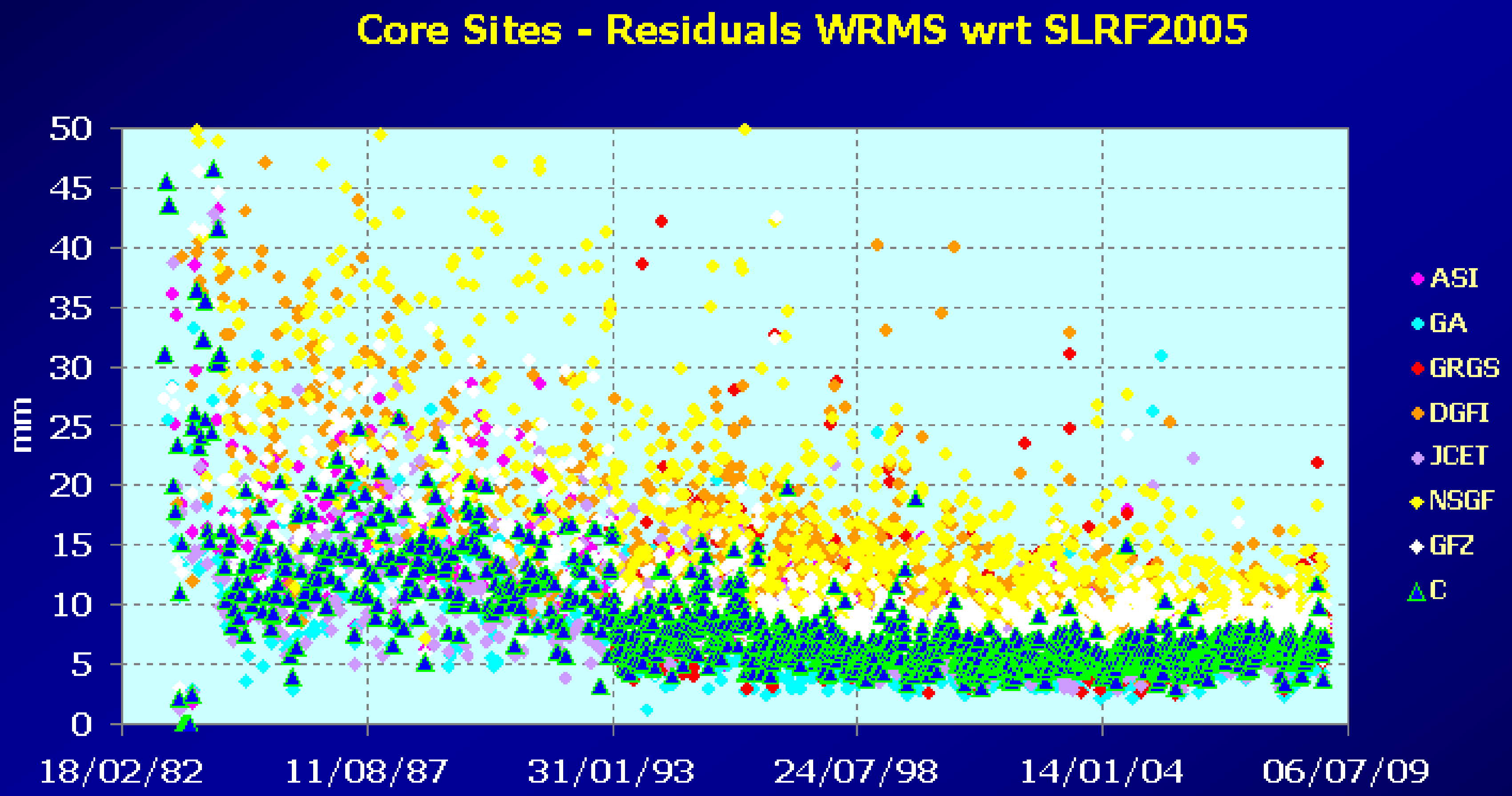
DGFI
ILRSB solution

Database
Data&Solutions

ILRS ACs

ILRS CCs

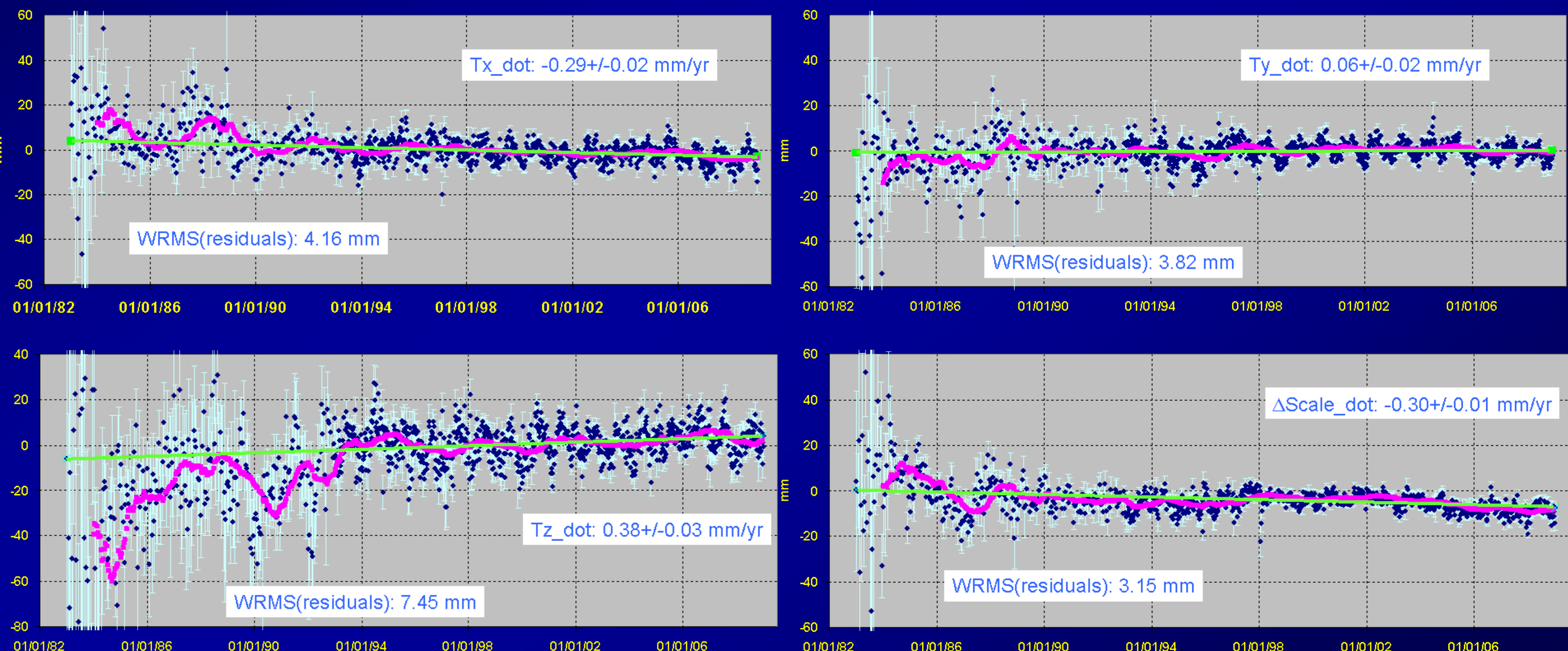
ILRSA ITRF2008 solution overall quality



mm	ASI	GA	GRGS	GFZ	DGFI	JCET	NSGF	C
All Sites	13+/-8	8+/-6	15+/-9	16+/-9	26+/-30	11+/-7	22+/-12	13+/-18
Core Sites	10+/-6	7+/-4	8+/-4	11+/-7	16+/-20	8+/-5	17+/-10	8+/-6

ILRSA ITRF2008 solution Reference Frame stability

- Ty shows the stablest behavior, slope << 0.1 mm/yr; WRMS res < 4mm
- Tx shows a clear slope of -0.3 mm/yr, WRMS res ~ 4mm
- Tz shows a slope ~ 0.4 mm/yr, WRMS res ~ 8 mm
- Δ_scale shows a very clear slope of -0.3 mm/yr, WRMS res ~ 3mm



The quality of the final product

The final product quality depends from different factors, such as:

data analysis

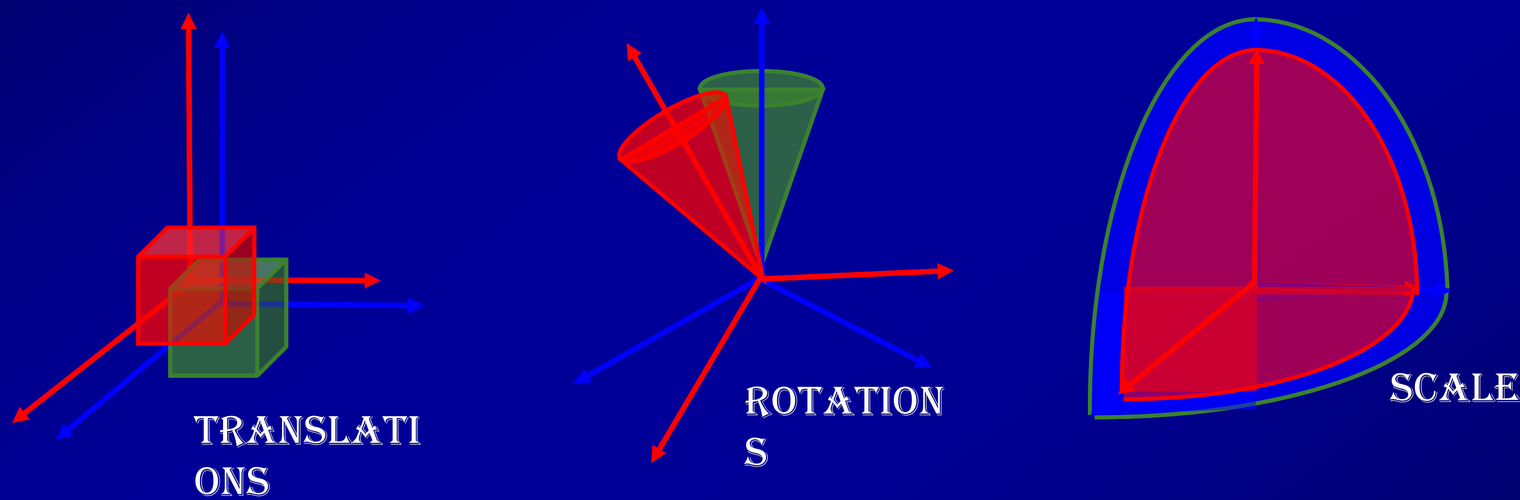
- Conventions adopted
- Application/estimation of system biases
- Satellite Center of Mass correction
- Data coverage
- SW “biodiversity”

combination

- Balance in the contribution of all the ACs solutions
- Hidden constraints
- Outlier editing, which affects the iterative computation of the solution scaling factors in the combination process

The ILRSA combination approach

The ASI-CGS combination procedure is based on the direct combination of loose constrained solutions (*"Methodology for global geodetic time series estimation: A new tool for geodynamics*", Davies and Blewitt, 2000).



Under these conditions the reference frame biases are no more estimable and the Helmert transformation parameters could be treated stochastically:

- no inversion problems for the solution covariance matrix
- no need to know *a priori* values for the estimates
- no relative rotation between the reference frames should be estimated

The combination equations

The general design equations are very simple

"x"
combined solution as solve-for parameters

Site Coordinates
Site Velocities
E.O.P.
E.O.P. Rates

$$\begin{pmatrix} \mathbf{X}_1(t_1) \\ \dot{\mathbf{X}}_1 \\ \mathbf{Y}_1(t_{1j}) \\ \dot{\mathbf{Y}}_1(t_{1j}) \end{pmatrix} = A \begin{pmatrix} \mathbf{X}_0(t_0) \\ \dot{\mathbf{X}}_0 \\ \mathbf{Y}_0(t_{0j}) \\ \dot{\mathbf{Y}}_0(t_{0j}) \end{pmatrix} = \begin{pmatrix} \mathbf{I} & (t_1 - t_0)\mathbf{I} & 0 & 0 \\ 0 & \mathbf{I} & 0 & 0 \\ 0 & 0 & \mathbf{I} & (t_{1j} - t_{0j})\mathbf{I} \\ 0 & 0 & 0 & \mathbf{I} \end{pmatrix} \begin{pmatrix} \mathbf{X}_0(t_0) \\ \dot{\mathbf{X}}_0 \\ \mathbf{Y}_0(t_{0j}) \\ \dot{\mathbf{Y}}_0(t_{0j}) \end{pmatrix}$$

"y"
contributing solution staked as pseudo-observations

"A"
design matrix

The iterative least square technique

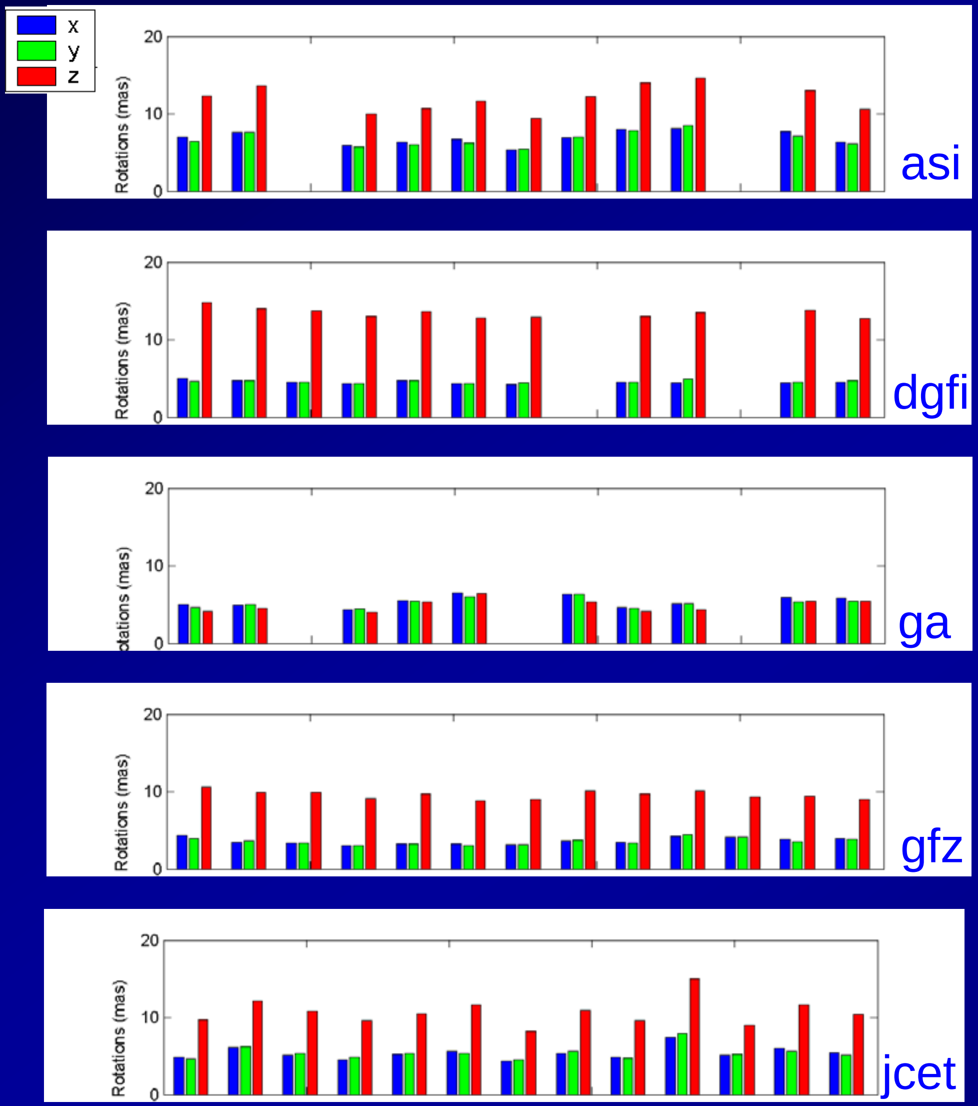
The combination is performed along the lines of the iterative Weighted Least Square technique: each contributing solution plays the role of an 'observation' whose residuals with respect to the combined solution must be minimized; each solution is stacked using its full covariance matrix rescaled by a factor f_i by imposing

$$\chi_{Norm}{}^{2} = R_1^T (f_1 C_1)^{-1} R_1 + \ \ldots + R_i^T (f_i C_i)^{-1} R_i = 1$$

$$R_1^T \left(f_1 C_1 \right)^{-1} R_1 = \ldots = R_i^T \left(f_i C_i \right)^{-1} R_i$$

The first guess for the combination is obtained with f_i=1 for each solution. In the combination step, outliers with respect to combined solution are edited, following a 5σ criterion

The 'looseness' issue: a real example



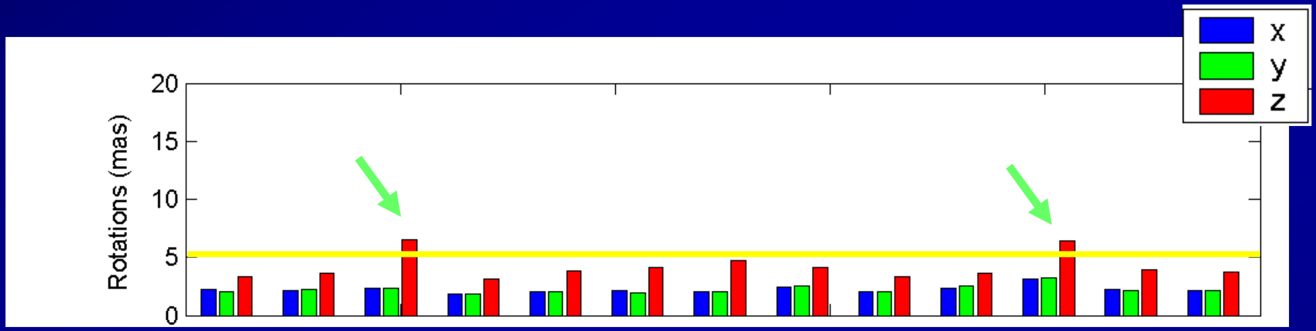
- A 3-month sample (April – June 2008) from the solutions contributing to ITRF2008 is considered.

- The selected solutions are those presenting a completely agreeable looseness level, measured projecting the loose covariance matrix of the parameters in the rotation uncertainties.

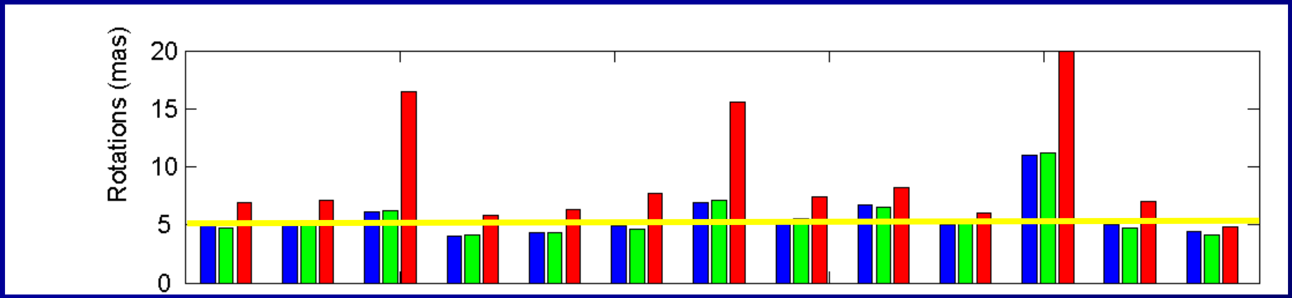
- Each solution has a characteristic 'looseness' style, recurring in the whole solution set.

The ‘looseness’ issue: a real example

combination
1st iteration



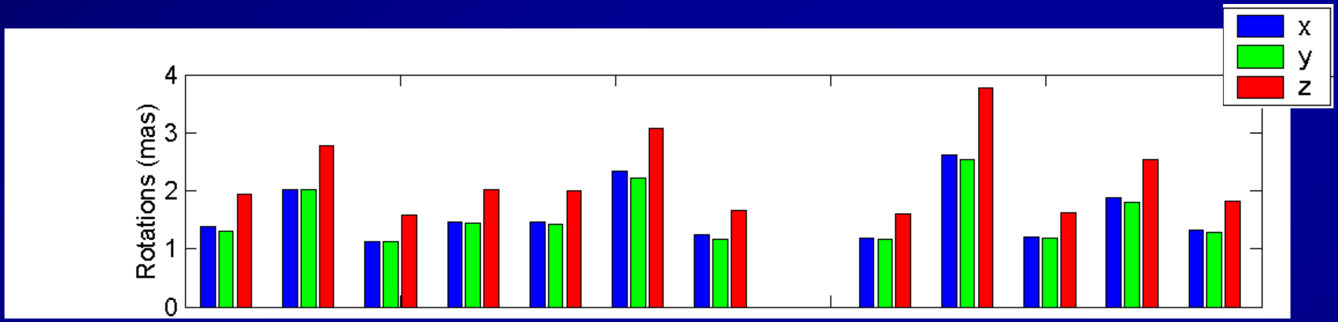
combination
>2nd iteration



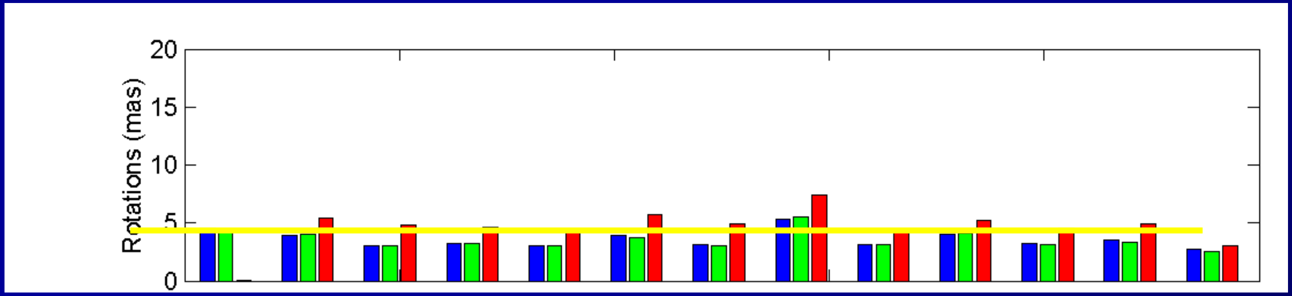
- The editing process and the re-scaling of the solutions allows to produce a combined solution with a looseness degree suitable to following inter-technique combination steps in the “loose solution only” case

The ‘looseness’ issue: a real example

low looseness degree solution



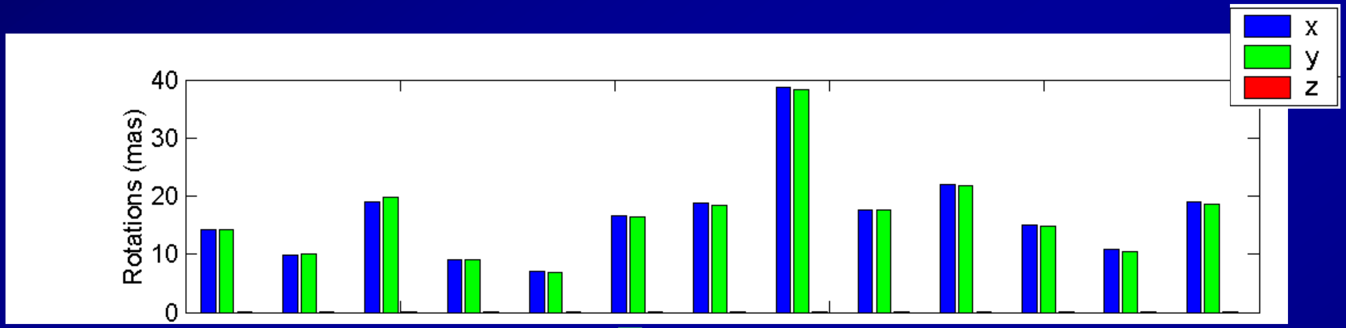
combination >2nd iteration



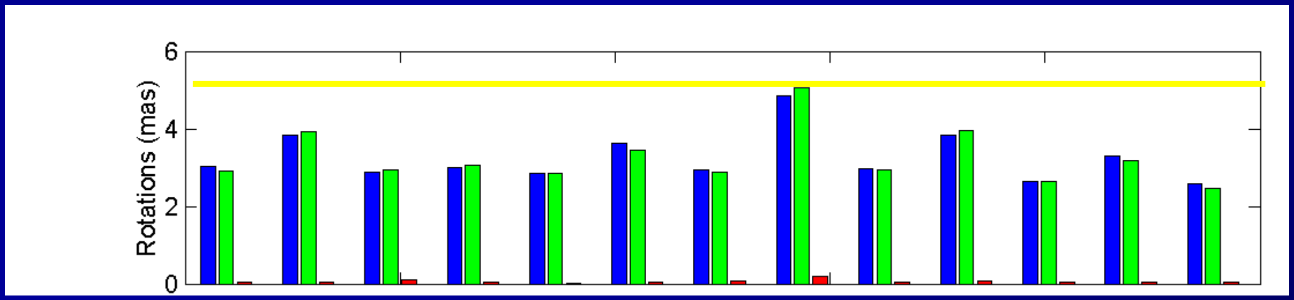
- The impact of a low looseness degree solution (in this example 1 out of 6) is in general not too heavy; however, if the combination process should be performed on huge amount of solutions, it is useful to add a loosening correction on the proper rotation components.

The ‘looseness’ issue: a real example

(hidden) constraint solution



combination >2nd iteration



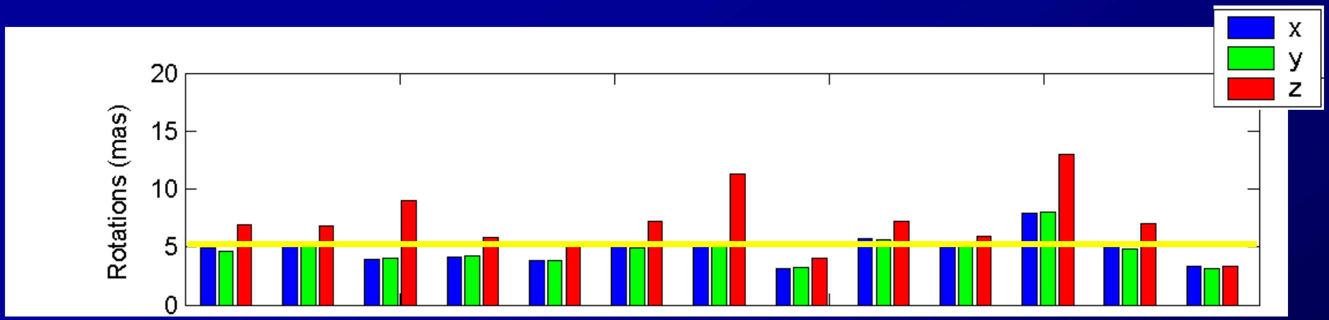
- The impact of a constraint solution (in this example 1 out of 7) cannot be mitigated by the combination process; the resulting solution turns out to be highly constrained.

The 'looseness' issue: a real example

- In ITRF2008, "ad-hoc" loosening corrections have been applied to the solution series presenting an unsatisfactorily looseness degree, affecting just the proper rotation uncertainty terms

- The looseness degree of the final ITRF2008 ILRS combined solution has been kept at the level of few mas rotation uncertainty and at the level requested by the inter-technique combination centers

"true" ILRSA
for ITRF2008
->all solutions



The ‘looseness’ issue - remarks

A preliminary verification of the looseness level of the incoming solutions is necessary: the provided covariance matrix of each solution is projected into the Helmert parameter covariance and the uncertainty of the 3 rotation parameters is verified.

If an AC solution time series shows an overall, unsatisfactorily, looseness level on one or more rotation component (due e.g. to hidden constraints), a loosening quantity should be added and the Helmert covariance matrix is projected back into the solution covariance.

Attention should be paid to the final combined solution covariance: a verification of its aptness to (e.g.) following inter-technique combination step is performed and eventual corrective actions undertaken.