Combination at the Observation Level

IERS Working Group

GRGS Combinations
Earth Orientation Parameters Strategy
Analyses Performed at GRGS

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Outline of Presentation

EOP Determination: Pole, UT at 6h, Nutation at 12h using
Combination at the Observation Level

- Processing
- Pole Coordinates solution
- Nutation solution

Station Space Coordinates Determination & daily EOP using
Combination at the Observation Level
Contribution to the realization of ITRF2008

- Processing
- Transformation Parameters
- Station Space Coordinates Solution
- Pole Coordinates solution
- Nutation solution

FORUM on multi technique Combinations

•Conclusion & Outlook

GRGS Program

Global Combination of Terrestrial Frame & Earth Orientation parameters at Observation Level

Techniques

SLR	*F. Deleflie*	OCA Géo-Azur
GPS	*S. Loyer*	*CNES/CLS*
DORIS	*L. Soudarin*	*CNES/CLS*
VLBI	*G. Bourda*	*Obs Bordeaux*

Combinations

J.Y Richard	*Observatoire de Paris*
C. Bizouard	
D. Gambis	
T. Carlucci	

Software

GINS	J.C. Marty	*CNES, Toulouse*
DYNAMO	J.M. Lemoine	CNES
Compsta		
Compcont		
CATREF	*Z. Altamimi*	*IGN LAREG*
SINEXTOOL	*S. Loyer*	*CNES/CLS*

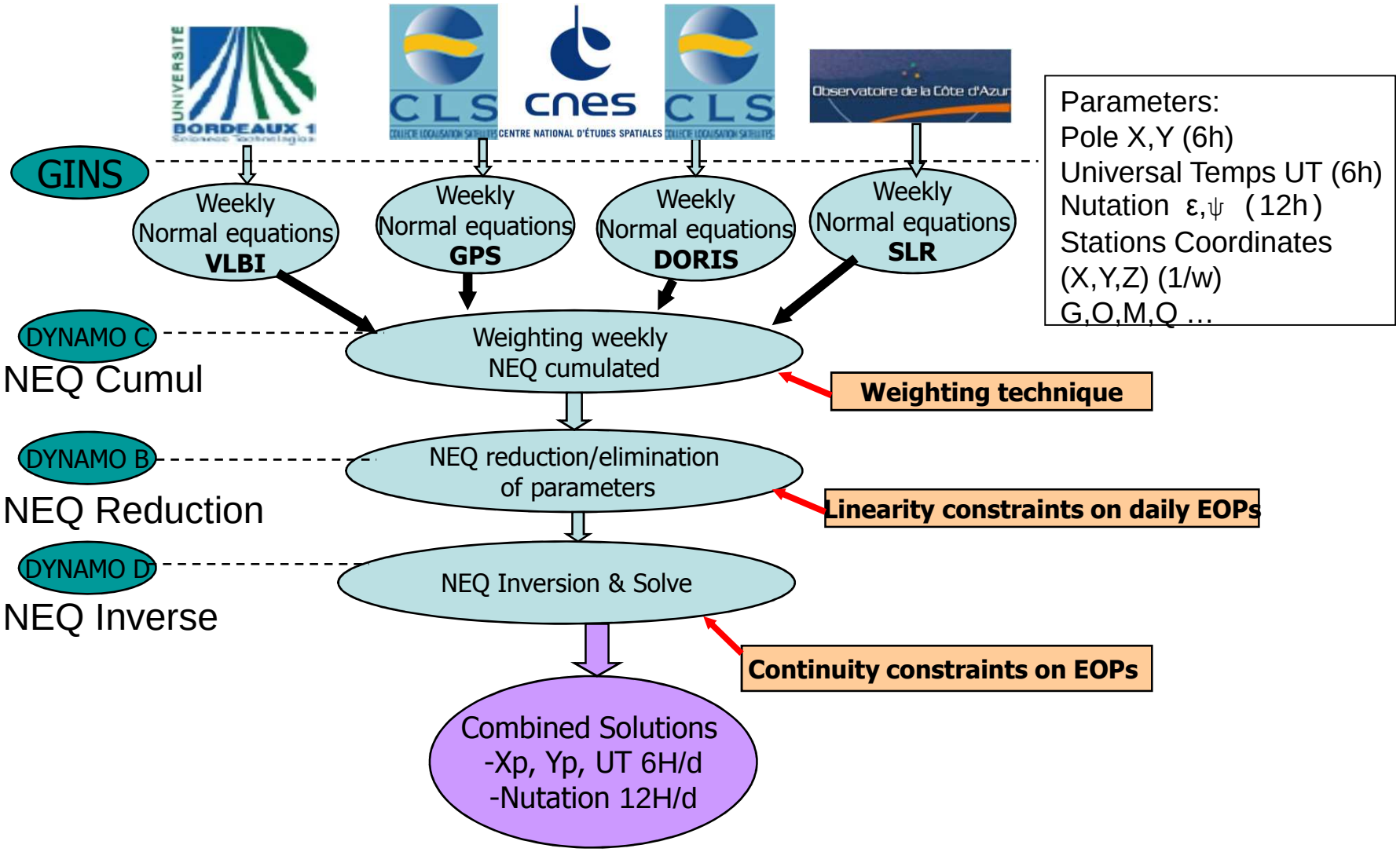
COMBINAISON

VLBI

SLR

GPS and DORIS Combination

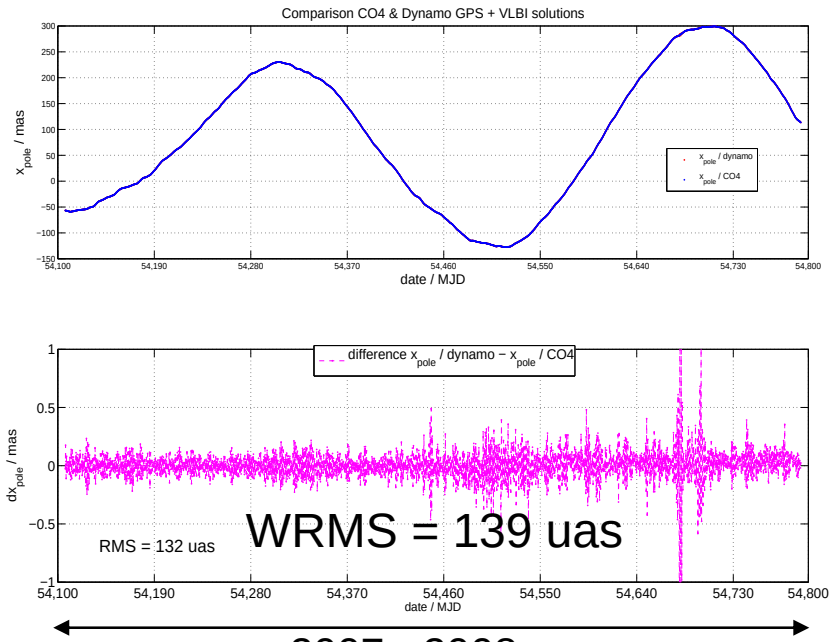
EOP Determination : Pole (X,Y), UT1, Nutation obtained by combination of weekly Normal Equation



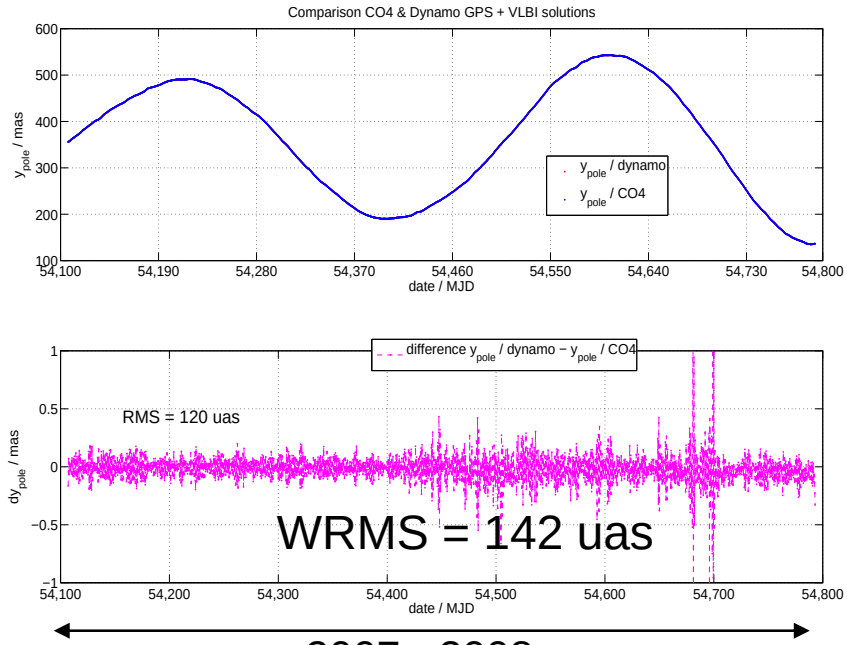
POLE Coordinates by Combination of VLBI+GPS (6h) week by week 2007-2008

Weekly Normal Equations GPS + VLBI from Analysis Centers **CLS** (GPS) et **OB** (VLBI)
Pole Parameters (XP, YP) determination every 6h

A priori EOP C04 05
Continuity Constraints on pole coordinates **: 1.3** cm
UT& Nutation & Stations FIXED
Weighting : 5,212 **GPS** & 1.102 **VLBI**



2007 - 2008



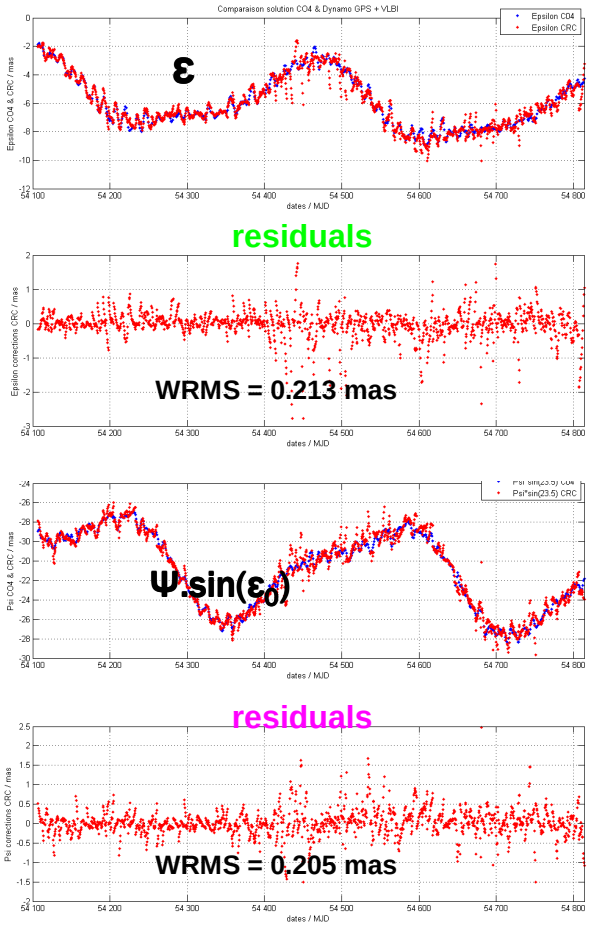
2007 - 2008

2829 points for X pole solutions with mean of 4.4 uas
2829 points for Y pole solutions with mean of -18 uas

NUTATION parameters by Combination of GPS + VLBI week by week 2007 – 2008

Weekly Normal Equations **GPS** et **VLBI** from analyses services CLS (**GPS**) et OB (**VLBI**)
Nutation Parameters (ε, ψ) determination every 12h

VLBI + GPS : 1515 points



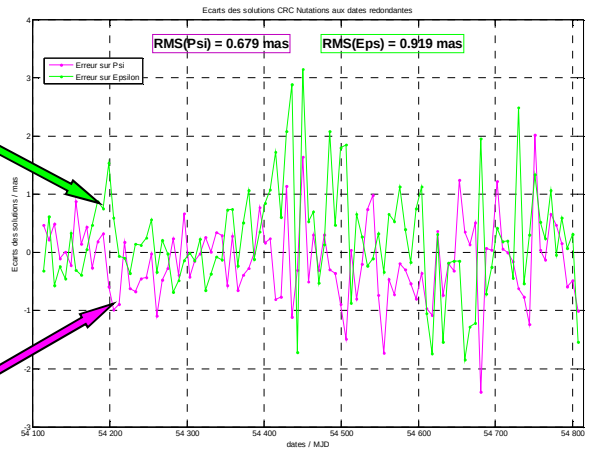
EOP C04 series
Interpolated at 12h
&
Nutation solutions
By combination

A priori EOP C04 05
Daily linearity Constraints : 10cm
apply to corrections nutation
Continuity Constraints nutation
NE, NP : 0,3135 x 10^{-9} ➔ 2cm
UT& Pole & Stations FIXED
Weighting : 0.5 **GPS**
1.0 **VLBI**

Solutions differences in the joint of the weeks

RMS(ε)= 0.679 mas

RMS(ψ)=0.919 mas

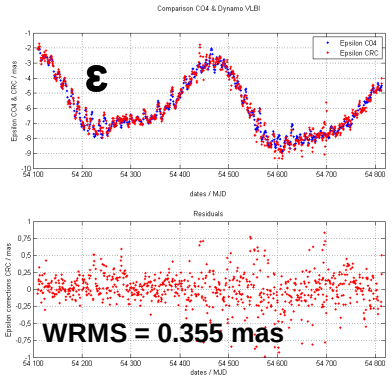


NUTATION by Combination of GPS + VLBI
Cumulated weeks 2007 2008

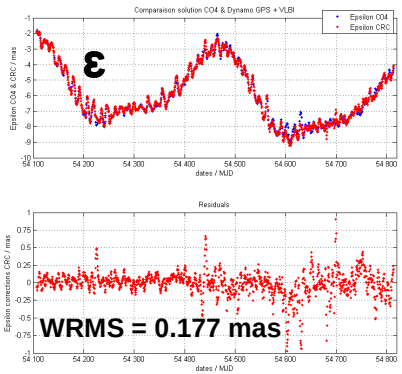
Stacked weekly Normal Equations over the period 2007-2008 are cumulated (100 NEQ **GPS** and 100 NEQ **VLBI**),
Combination of the 2 resultant NEQ cumulated
Weighting : 0.5 **GPS**, 1.0 **VLBI**
Nutation Parameters (ε, ψ) determination every 12h →

Continuity Constraints for Nutation: 2cm
Daily linearity Constraints de : 10cm
UT& Pole & Stations are FIXED to their a priori

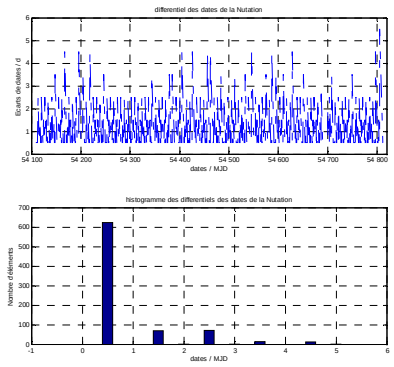
VLBI



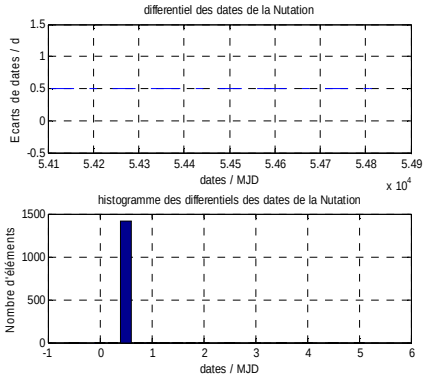
VLBI + GPS cumulated

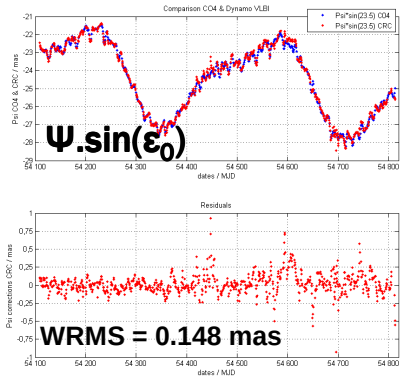


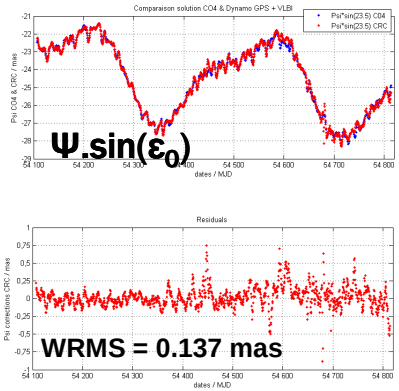
VLBI : 792 points



VLBI + GPS : 1415 points



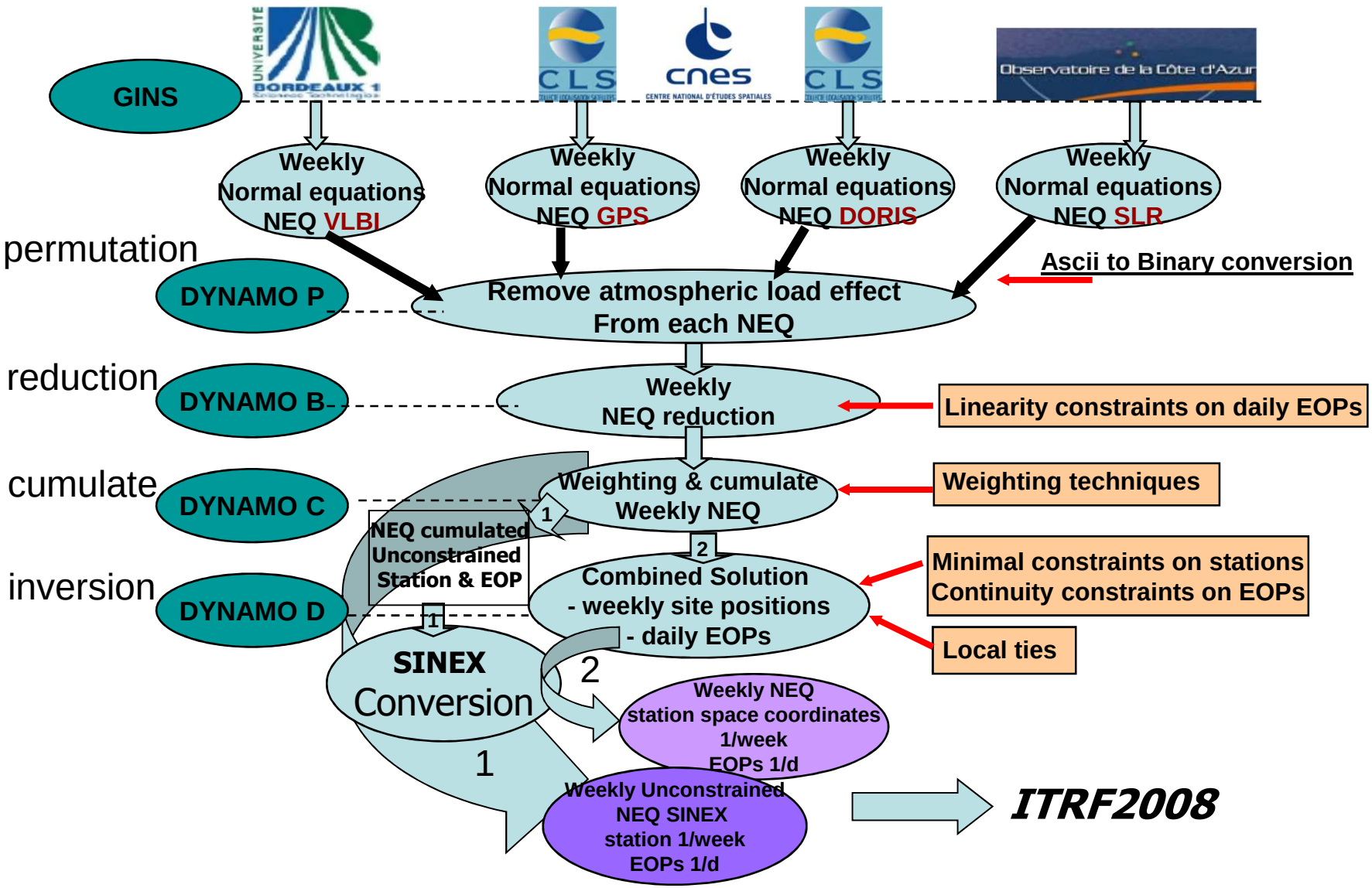




Residuals WRMS

	VLBI Cumulated weeks 792 points	GPS+VLBI Week by week 1515 points	GPS+VLBI Cumulated weeks 1415 points
ε	0.355	0.213	0.177
$\Psi.\sin(\varepsilon_0)$	0.148	0.205	0.137

Stations Coordinates Determination Contribution to ITRF2008



Combination of techniques for ITRF2008 realization (1/2)

Weekly processes for each technique (VLBI, GPS, DORIS, SLR)
Period: 2007 – 2008 using Weekly Normal Equations from GINS of each AC
format Conversion NEQs GINS ➔ Binary format

- 1- **Atmospheric loading Effect removed**

(it is requested not to correct for any geophysical fluid loading effects except for tidal ocean loading)

EOP A priori recent EOP C04

- 2- **Reduction** : **troposphere** parameters with loose constraints

σ(MZB) = 0.1E-4, σ(MTB) = 0.1, σ(MRB) = 1.0

- 3- **Reduction** / **Elimination Parameters** from NEQ before inversion
  - Free parameters
    - EOP: PX, PY, UT, NE, NP introduction of daily linear piecewise constraint on the corrections = 5mm (4 pts/d ➔ 1 pt/d at noon)
    - Stations Space coordinates SX, SY, SZ (1 point/w)
  - Reduction
    - Parameters E (orbital elements), F (non gravitational Forces), B (orbit Biases)
  - Elimination
    - Parameters Q (Quasar), G (gravity field), O (ocean tides)

Combination of techniques for ITRF2008 realization (2/2)

GPS, VLBI, SLR, DORIS **NEQ Combination** unconstrained

- 4- **Generation** of weekly files containing the list of NEQ with their weighting factor. Each technique are used with a same weight during the all period
- Example week 2007/03/04

```
5.212 1 jml /home/jml/gin/batch/eqna/CRC/gps_atm_20070304.v3_bin_journalier
1.927 1 jml /home/jml/gin/batch/eqna/CRC/vlbi_atm_20070304.v1_bin_journalier
1.102 1 jml /home/jml/gin/batch/eqna/CRC/doris_atm_20070304.v0_bin_journalier
1.709 1 jml /home/jml/gin/batch/eqna/CRC/slr_atm_20070304.v2_bin_journalier
```

- 5- **Combination** of the weekly weighted NEQs and **conversion** of the resulting weekly unconstrained NEQ in SINEX files

Deposited on the web site

http://syrte.obspm.fr/~richard/ITRF2008/

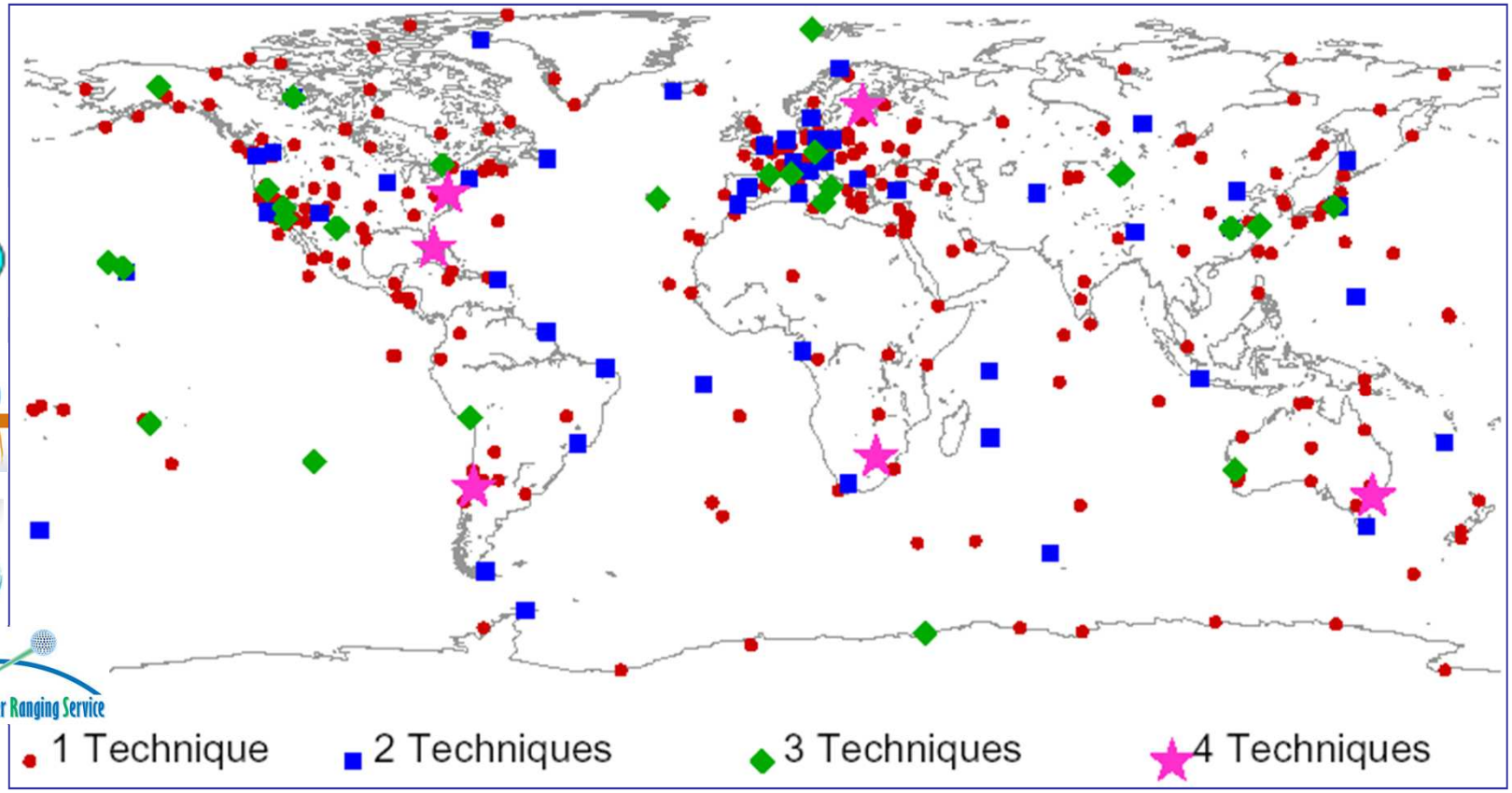
files name ➔ sem_dynamo_yyyymmdd.SNX

EOP Solutions & Stations Space coordinates are calculated by inverting the resultants Normal Equation with some constraints

Choice of parameter to estimate (FREE ou FIXED)

- **Pole X,Y** (PX, PY),
- **UT** (PT),
- **Nutation ε,ψ** (NE, NP),
- **Stations Space Coordinates** (SX, SY, SZ)

A priori Terrestrial Referential Frame : ITRF 2005



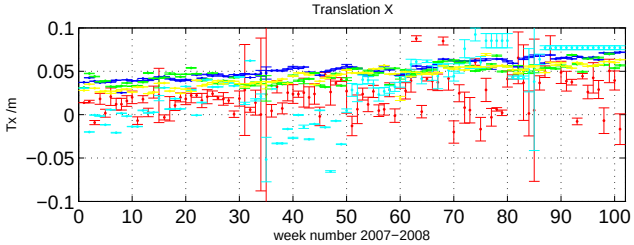
(48) (25) (6)

GRGS observations :

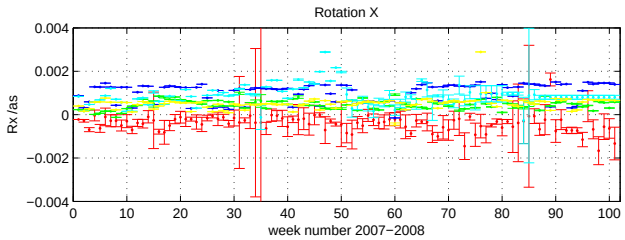
GPS	: 90 receivers
DORIS	: 50 stations Spot-2, -3, -4, -5, Topex/Poseidon, Envisat
VLBI	: 17 stations cession IVS-R1& IVS-R4 on 2007-2008
SLR	: 30 stations, satellites Lageos-1 & Lageos-2

Transformation Parameters for each technique GPS DORIS VLBI SLR and for GLOBAL technique with respect to ITRF2005

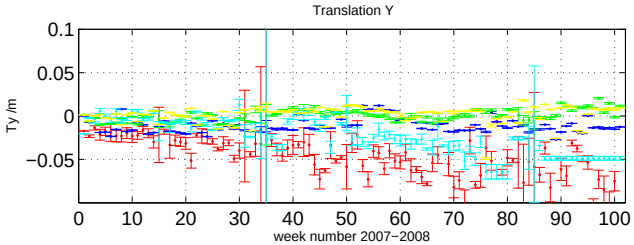
Tx /m



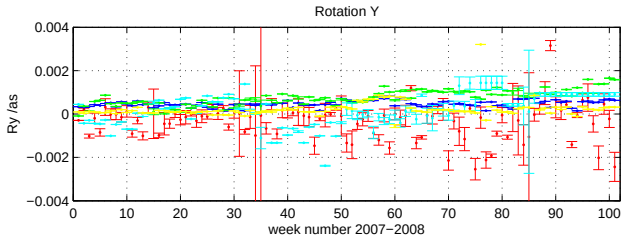
Rx /as



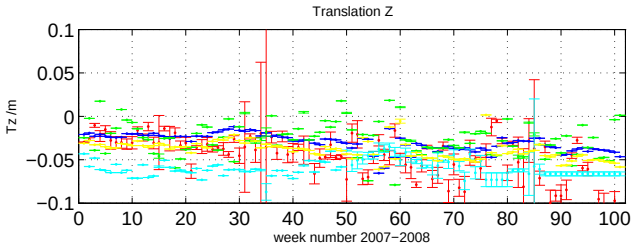
Ty /m



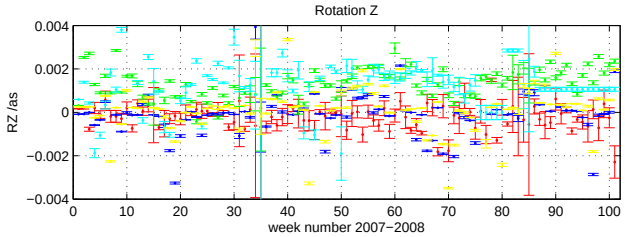
Ry /as



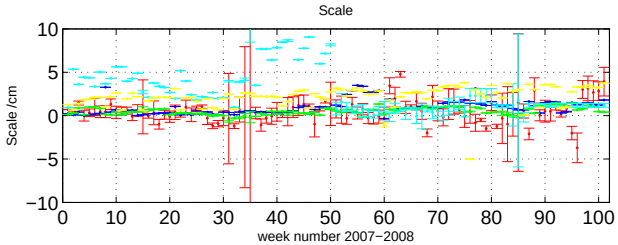
Tz /m



Rz /as



S



2007.0 - 2009.0

VLBI GPS DORIS SLR GLOBAL

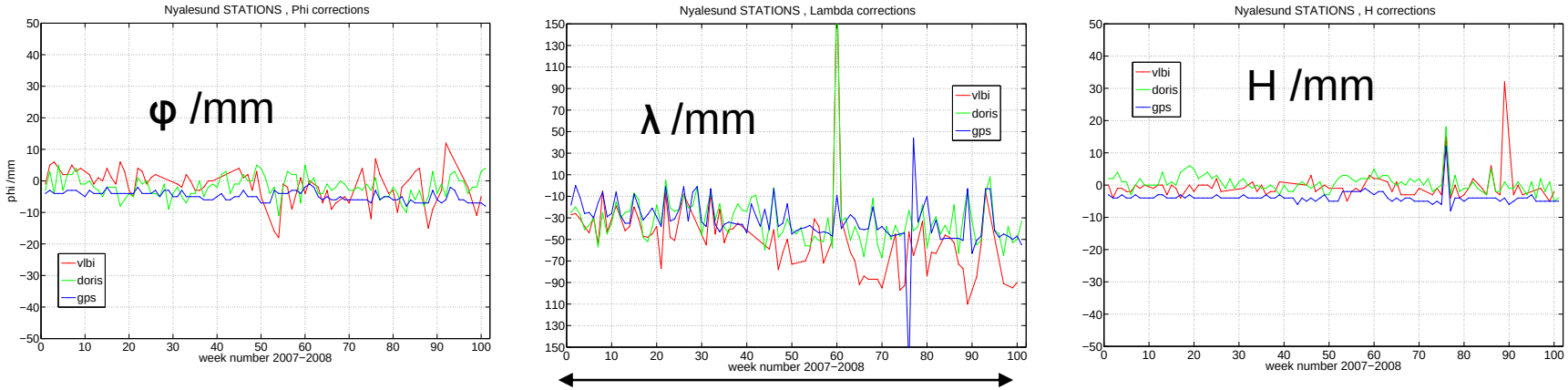
	Tx (cm)	Tx (cm)	Tx (cm)	Scale	Rx (mas)	Ry (mas)	Rz (mas)
Mean	**4.42**	**0.14**	**-3.89**	**2.19**	**0.514**	**0.222**	**0.587**
σ	**1.14**	**0.93**	**1.05**	**1.17**	**0.310**	**0.374**	**3.840**
Rate/y	**1.82±0.18**	**0.16±0..33**	**-1.01±0.32**	**0.65±0.39**	**0.133±0.107**	**0.142±0.130**	**0.419±1.361**

Global Transformation Parameters

Stations Space Coordinates using
Combination at NEQ level, contribution to ITRF2008

Solutions by inversion of weekly unconstrained combined NEQ
Pole UT & Nutation Fixed to a priori **EOP C04**
Weekly Station Space Coordinates are obtained with
Systematic Constraints : σ(Sx,Sy,Sz) = 1m
Minimal Constraints with 7 Transformations Parameters & σ(Tx,Ty,Tz,D,Rx,Ry,Rz) = 10m (loose)
Ties Constraints on co-located sites (26 actually)

Site **Ny-Alesund : 3 geodetic Co-located techniques ➔ VLBI, GPS, DORIS**



2007.0 - 2009.0

	VLBI	GPS	DORIS
φ (mm)	**5.6**	**5.0**	**3.9**
λ (mm)	**61.3**	**39.0**	**42.3**
H (mm)	**4.6**	**4.3**	**2.9**
φ rate (mm/y)	**-3.4869**	**-1.4311**	**-0.2471**
λ rate (mm/y)	**-23.6638**	**-13.7912**	**-7.3709**
H rate (mm/y)	**1.0073**	**-0.3376**	**-1.1000**

RMS / ITRF2005

Rate / ITRF2005

POLE COORDINATES SOLUTION obtained by NEQ combination for ITRF2008 realization

Pole 1 point/day A priori EOP C04 05 Nutation & Stations Fixed,

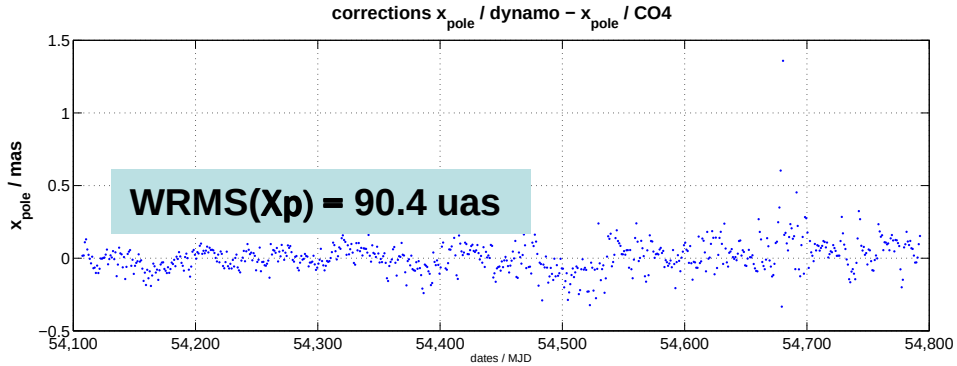
Weighting

GPS	VLBI	SLR	DORIS
5.212	1.927	1.709	1.102

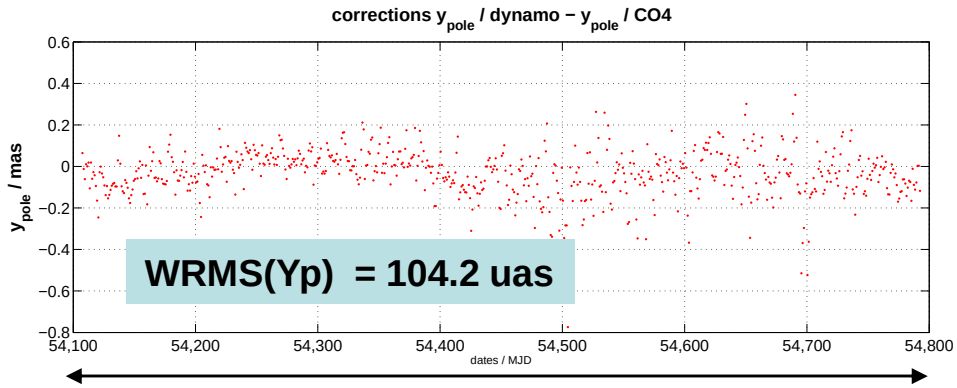
Continuity Constraints on daily Pole coordinates

PX, PY	2 x 10^{-09} rad	1.27 cm

X pole – C04



Y pole – C04



2007.0 - 2009.0

NUTATION SOLUTION obtained by NEQ combination for ITRF2008 realization

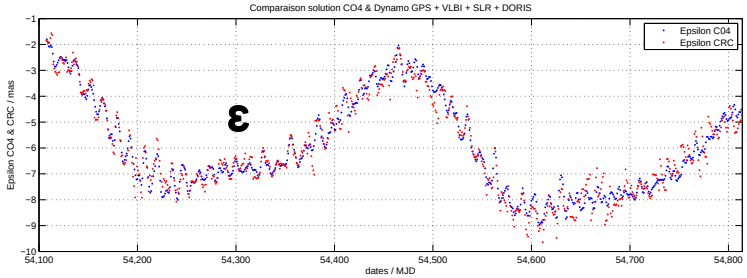
Nutation 1 point/day A priori EOP C04 05 Pole & Stations Fixed

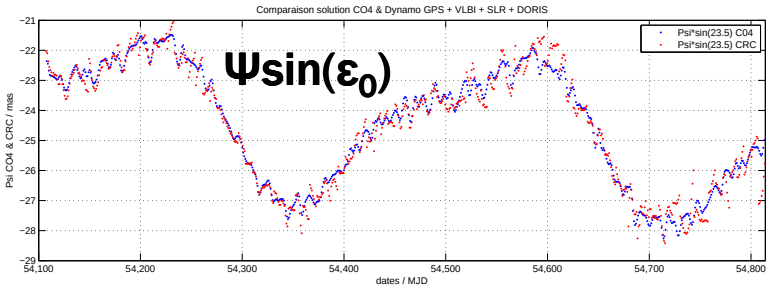
Weighting

GPS	VLBI	SLR	DORIS
5.212	1.927	1.709	1.102

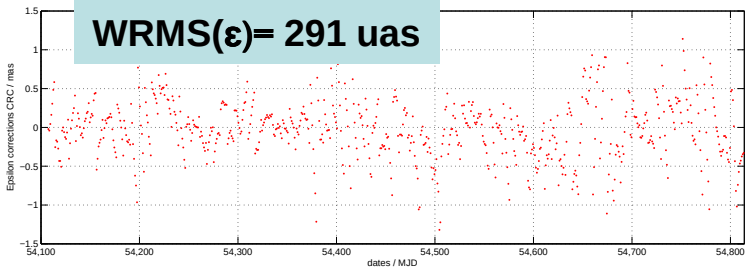
Continuity Constraints on daily nutation

NE, NP	2 x 10^{-09} rad	1.27 cm



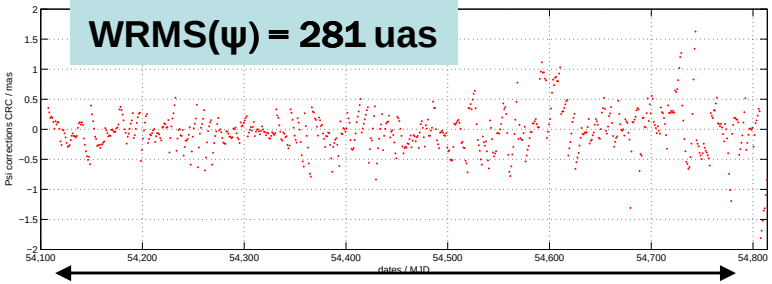


residuals



2007.0 – 2009.0

residuals

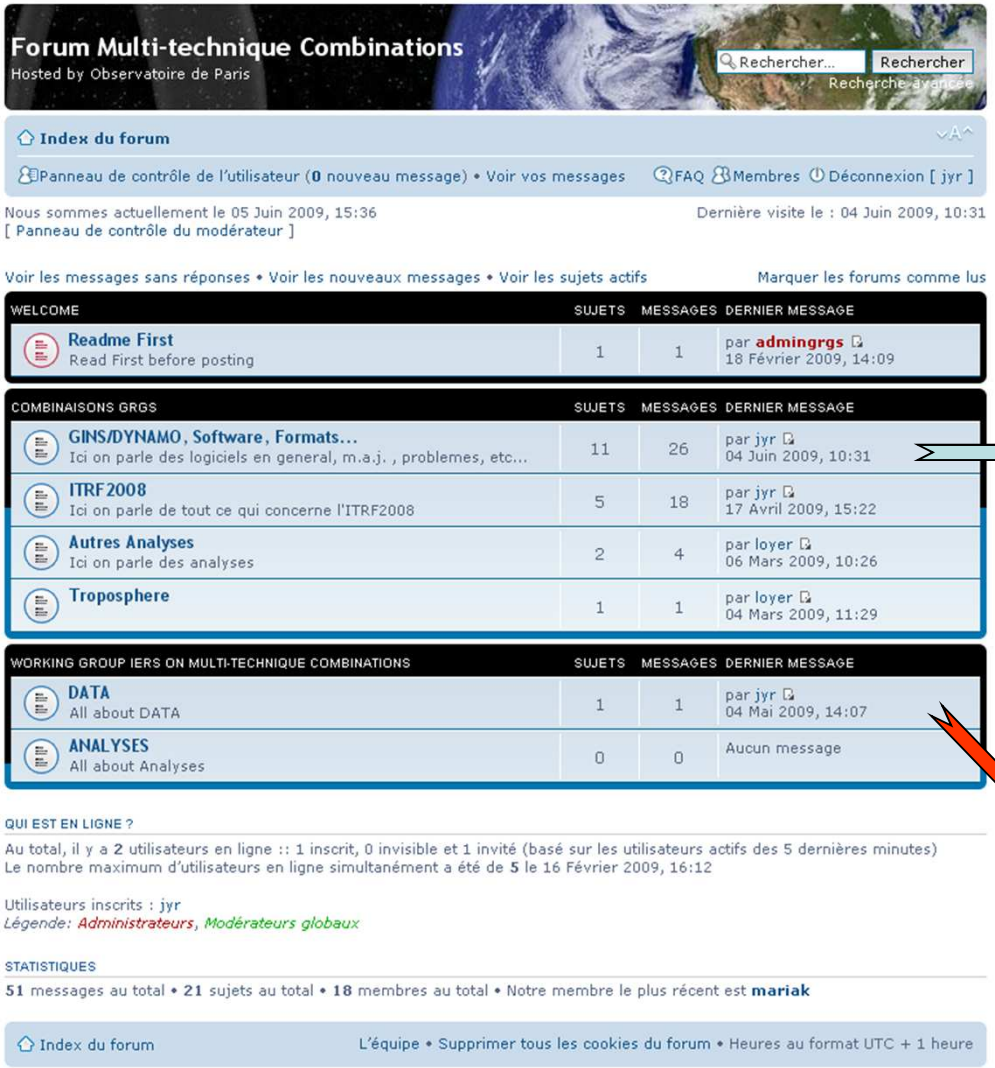


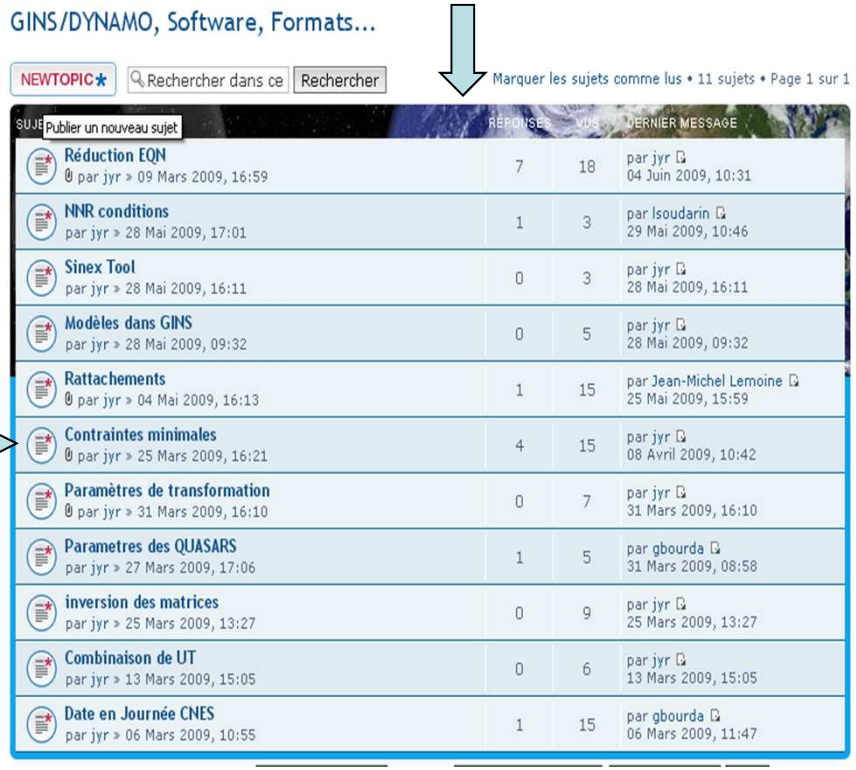
2007.0 – 2009.0

FORUM COMBINATION at the Observation Level

http://grgs.obspm.fr/forum/

Discussion for GRGS processing





Exchanges with DGFI,ORB, Ukrainian Observatory MAO …
For SINEX Matrix

Combinations Series available at
ftp://hpiers.obspm.fr/iers/eop/grgs/

CONCLUSION and Outlook

Between weekly X, Y, UT1 solutions from DYNAMO we found 2 solutions at 0h
necessity to cumulate 2 consecutives weeks with overlapping of 1 week

Possibility to compare EOP solutions with different software packages
Using SINEXTOOL GRGS software:
Convert EQN GINS format ➔ SINEX format
EQN SINEX format ➔ GINS format
Nutation parameters radian unit in SINEX ➔ mas

Local ties: how to maintain the list of co located stations in up-to-date state
and the changing during the analysis period

UT1: request LOD parameter from geodetic techniques GPS, DORIS, SLR to
combine LOD with UT1 VLBI

Weighting technique: Helmert method for the all period, week by week
or other algorithm taking time variation of uncertainties into account …

EOP measurements sampling at 3h or 1h and necessity to compare solutions with other
combinations at the same intervals of solutions

Introduction of LLR EOP measurements to combine with other techniques

Authors are grateful to Zuheir Altamimi and Xavier Collilieux (LAREG-IGN)
for your help in this contribution to ITRF2008
and
to Jean-Michel Lemoine, Jean-Charles Marty, Richard Biancale (CNES)
for their assistance and their advices to use GINS/DYNAMO software

Thanks for your Attention