Combination at the Observation Level
IERS Working Group

COL Working Group Kick-off Meeting

21-22 October 2009 – Polish Academy of Science, Warsaw

Wednesday 21 October 16:15 – 18:15

16:15 presentation of the COL WG

16:20 presentation of current combination activities and of software packages used

expected presentations (~10 mn each):

1. *M. Seitz: Combination of space geodetic techniques in order to compute TRF solutions, NEQ handling, constraints, local tie handling, weighting of the techniques, aspects concerning daily TRFs*
2. *D. Thaller: EOP estimation and combination aspects of daily resolution, constraints on EOP (advantages, disadvantages, CODE strategy, densification of UT1, subdaily EOP*
3. *M. Seitz, D. Thaller: Software packages Bernese and DOGS*
4. *R. Gross: Presentation of GIPSY.*
5. *R. Biancale, J.Ch Marty, J.M. Lemoine: Presentation of GINS/DYNAMO*
6. *J.Y. Richard: Strategy and analyses performed at GRGS using DYNAMO*
7. *F. Lemoine: GEODYN &Multitechnique Processing for the Reference Frame*
8. *other spontaneous interventions*

18:15 adjourn

Combination at the Observation Level
IERS Working Group

COL Working Group Kick-off Meeting

21-22 October 2009 – Polish Academy of Science, Warsaw

Thursday 22 october 9:00 to 12:00

9:00 discussion on strategies according to the charter of the WG

1. *promoting the approach within groups and the capability of processing jointly two or more techniques.*
2. *establishing common processing standards for all techniques in order to guarantee homogeneity and consistency.*
3. *studying appropriate weighting between techniques and the interest of using local ties or satellites tracked by several techniques.*
4. *optimizing and unifying parameterization for instance for tropospheric parameters in order to minimize globally the degree of freedom of the whole inverse system.*
5. *elaborating benchmarks to intercompare results between groups from the same data set.*
6. *insuring SINEX compatibility between techniques and with the international technique services and IERS.*
7. *studying stabilization methods and looking for high temporal resolution of parameters.*
8. *evaluating and comparing results to search for compatibility between groups.*
9. *organizing routine operations*

11:00 list of actions and schedule

12:00 *end of the kick-off meeting*

Commutativity question

$$\sum_{CC}^{4}\left(\sum_{AC}^{n} individual\ technique\right) \overset{?}{\Leftrightarrow} \sum_{CC'}^{n'}\left(\sum_{COL}^{\geq 2} multi-technique\right)$$

Changing our approach by searching for homogeneity “at the level of observations” in terms of :

- precision *(considering systematisms and common parameters)*
- resolution *(considering observation densification)*
- consistency *(wrt modelling standard, software…)*

should increase accuracy ?

Mutual information from the different techniques should complement and improve global products tacking advantage of strengths of each technique through a homogeneous processing

COL-WG Charter

1) promoting the approach within groups and the capability of processing jointly two or more techniques.
2) establishing common processing standards for all techniques in order to guarantee homogeneity and consistency.
3) studying appropriate weighting between techniques
and the interest of using local ties or satellites tracked by several techniques.
4) optimizing and unifying parameterization
for instance for tropospheric parameters in order to minimize globally the degree of freedom of the whole inverse system.
5) elaborating benchmarks
to intercompare results between groups from the same data set.
6) insuring SINEX compatibility
between techniques and with the international technique services and IERS.
7) studying stabilization methods
and looking for high temporal resolution of parameters.
8) evaluating and comparing results
to search for compatibility between groups.
9) organizing routine operations for a new TRF realization, either in the framework of the next ITRF or as ITRF assessment

Proposal for discussion

1) *Registering a list of participants (with respective software) on the Paris Observatory' forum (for exchanging information and for file delivering)*

2) *Describing models used in processing (for each software package)*

3) *Fixing a priori weighting between techniques*

4) *Defining the parameters to be kept in NEQ (EOP and nutation, drifts, stations, troposphere…) and to which frequency (1hr – 1d – 1w)*

5) *Elaborating benchmarks: test week(s), list of stations and satellites*

6) *Describing SINEX and testing compatibility; defining name file convention*

7) *Dealing with additional information (a priori constraints, ties…) and continuity constraints*

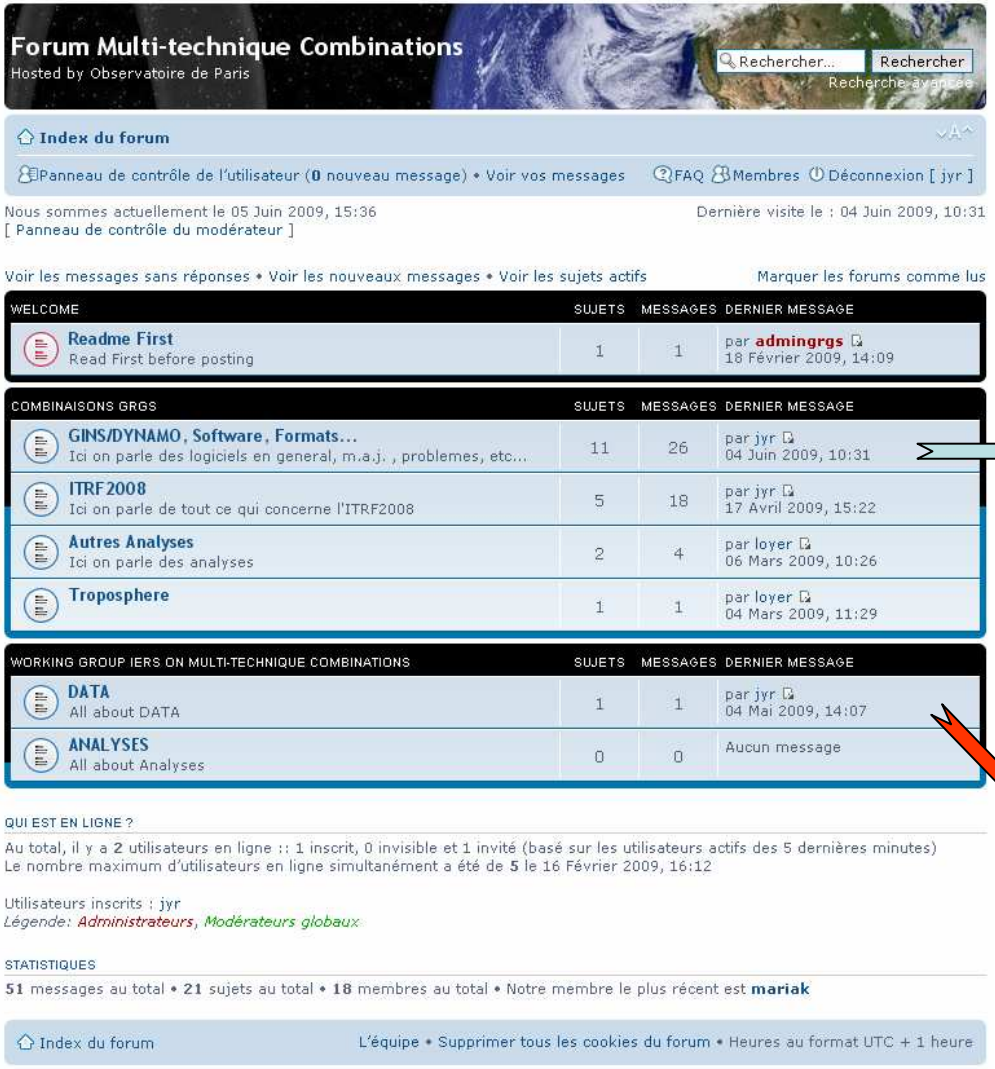
8) *Proposing two or more centres making combinations and results comparisons (relative, wrt to C04, ITRF…)*

Actions and schedule

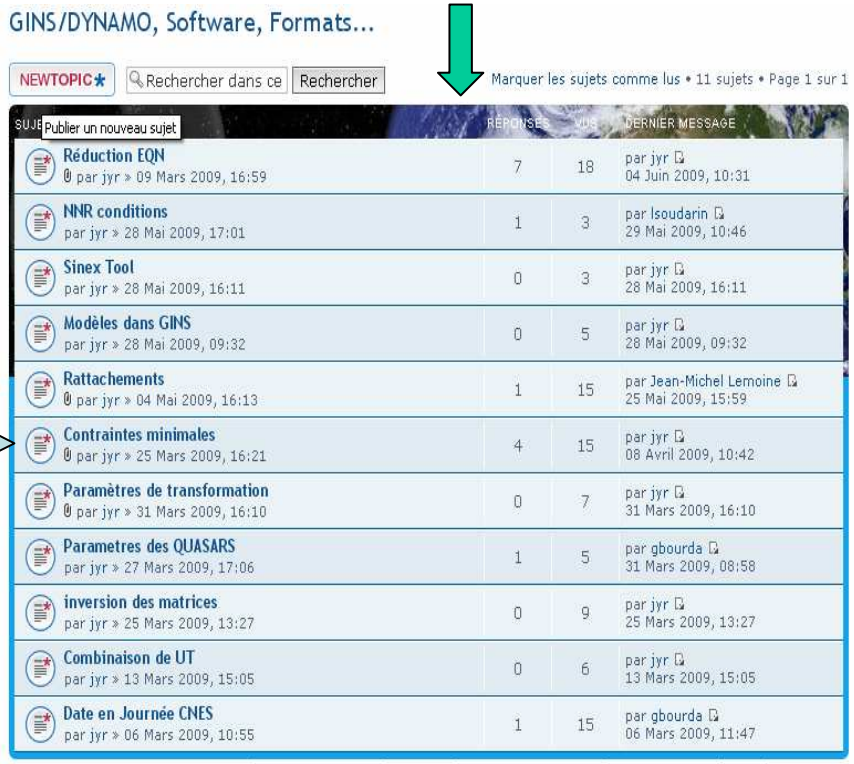
- *Keeping in touch through the forum*
- *Till November: list of participants*
- *Till December: discussion on a priori models and parameters*
- *Till February: delivery of SINEX*
- *Till April: results of combinations*
- *In May 2010 during next EGU : 2nd COL meeting*

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/

Basic principle of Combination:

1. Merging all sources of pertinent space information
2. Searching for homogeneity through the same a priori models:
    - Geodetic and geophysical
    - But technique dependent modeling (centre of phase, empirical…)
3. Getting resolution through the same parameterization:
    - Daily or sub-daily EOP (Xp, Yp, UT1); need of LOD?
    - Daily nutation
    - Weekly stations coordinates
    - Quasar coordinates
    - Tropospheric parameters
4. Helping decorrelation through additional constraints between techniques
    - Helmert’s constraints
    - Ties

A priori dynamical models:

Gravitational:

1. Gravity field (actually based on GRACE + LAGEOS models)
2. Third body
3. Tides
    1. Earth
    2. Ocean (FES2004, GOT00…)
    3. Atmosphere (B&B, Ray…)
    4. Pole (solid and oceanic)
4. Non tidal
    1. Ocean (barotropic models, i.e. MOG2D, AODOC GRACE products)
    2. Atmosphere (ECMWF, NCEP pressure variations – need of a unique mean model)
    3. Hydrology (LaD, WGHM, ECMWF…)

A priori dynamical models:

Non gravitational:

1. Drag (new DTM-2009 based on space accelerometry)
2. Solar radiation
3. Earth radiation (albedo and IR models or from ECMWF)
4. Satellite thermal thrust (based upon surface temperature models)
5. Antenna power thrust
6. Magnetic (ignored)
7. Accelerometry (need calibration)

A priori geometrical models:

1. Earth orientation in space (precession, nutation)
2. Terrestrial reference frame
3. Geocentre (connected to s.h. degree 1 → gravity modelling) (up to 5 mm)
4. Earth tides (up to 30 cm)
5. Pole tide (solid, up to 1 cm)
6. Loading (consistent with gravitational models)
    1. Ocean tides (up to 5 cm)
    2. Atmosphere mass variations (up to 1 cm)
    3. Ocean non tidal mass variations (a few mm)
    4. Hydrology mass variations

Satellite models

1. “Box & wing” macro or micro models (with self shadowing function) (cf. UCL)
2. CoM definition and variations
3. Electronic antenna pattern (azimuth/elevation)
4. Attitude (quaternions) knowledge

Propagation

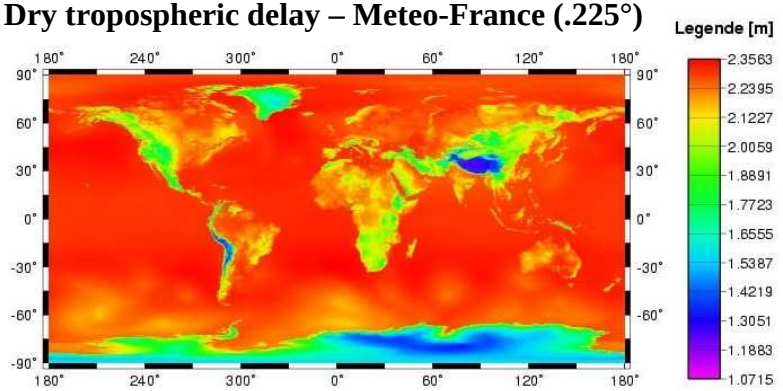
1. Ionosphere (second order correction in $1/f^3$)
2. Troposphere (same a priori → ground data, ECMWF dry and wet delays, new mapping function with zenithal gradients)

Troposphere

Vertical dry tropospheric delay:

$$\Delta L_d^z = 2.277 \cdot 10^{-3} \cdot P_{surf} \cdot [1 + 0.0026 \cdot \cos(2 \cdot \varphi)]$$

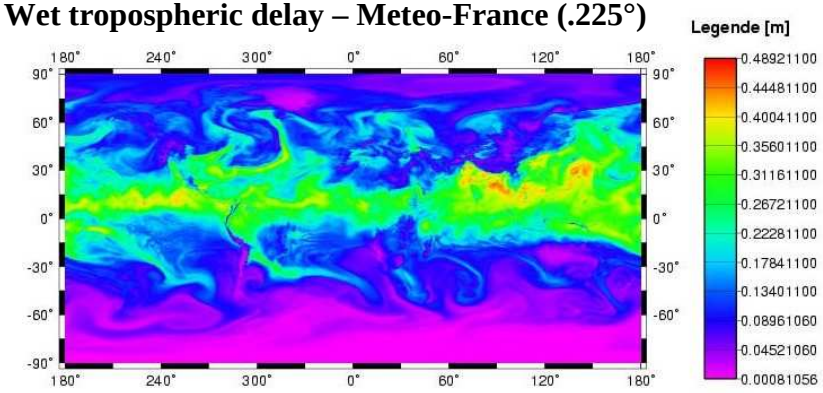
Dry tropospheric delay – Meteo-France (.225°)



Vertical wet tropospheric delay:

$$\Delta L_w^z = [1 + 0.0026 \cdot \cos(2 \cdot \varphi)] \cdot \left\{ 1.116454 \cdot 10^{-3} \cdot \int_{Psat}^{Psurf} q \cdot dP + 17.66543928 \cdot \int_{Psat}^{Psurf} \frac{q}{T} \cdot dP \right\}$$

Wet tropospheric delay – Meteo-France (.225°)



Adjusted mapping function:

(based upon ECMWF models; numerical integration of delays between all 91 layers for elevation and azimuth angles each 10 deg.)

$$f(\varepsilon) = \frac{1 + \dfrac{a_1 + a_2 \cdot z + a_3 \cdot \cos(\varphi)}{1 + \dfrac{b}{1 + c}}}{\sin(\varepsilon) + \dfrac{a_1 + a_2 \cdot z + a_3 \cdot \cos(\varphi)}{\sin(\varepsilon) + \dfrac{b}{\sin(\varepsilon) + c}}}$$

(CLS/CNES study, 2007-2008)

(Guo & Langley)

Use of vertical gradients: $\Delta L(\varphi,\lambda,H) = f_{sec}(\varepsilon) .(\Delta Lz_{sec} + H_{sec} \cot(\varepsilon) .(GE_{sec} \sin(\theta) + GN_{sec} \cos(\theta)))$
$+ f_{hum}(\varepsilon) .(\Delta Lz_{hum} + H_{hum} \cot(\varepsilon) .(GE_{hum} \sin(\theta) + GN_{hum} \cos(\theta)))$

(GE, GN derived from ECMWF models, H: reference altitude)

Ionosphere

Phase propagation: $L_0 + L_1 + L_2 + L_{31} + L_{32} + P_r$

	400Mhz			**2GHz**		
elevation angle:	**2°**	**42°**	**90°**	**2°**	**42°**	**90°**
$L_0 = \int dl$						
$L_1 = l_1/f^2 = a/f^2 \int N_l \, dl$	*486m*	*225m*	*161m*	*19m*	*9m*	*6m*
$L_2 = l_2/f^3 = b/f^3 \int N_l \, B_0 \, \lvert\cos\theta\rvert \, dl$	*1.1m*	*0.6m*	*.4m*	*.01m*	–	–
$L_{31} = l_{31}/f^4 = c/f^4 \int N_l^2 \, dl$	*.1m*	*.04m*	*.03m*	–	–	–
$L_{32} = l_{32}/f^4 = d/f^4 \int N_l \, B_0^2 \cos^2\theta \, dl$	–	–	–	–	–	–
P_r ~ *order 3 (refraction term)*	*.84m*	*.03m*	–	–	–	–

for: $N_T = 64\ 10^{16}\ m^{-2}$, $\theta = 0°$, $B_0 = 0.45$ Gauss, $L_0 = 1000$km

(CNET study)