

3.6.2.7 Groupe de Recherches de Géodésie Spatiale (GRGS)

The main points concerning the GRGS activities in the combination domain are:

- New server at OP SYRTE, a Dell PowerEdge 1950 bi-quad core Xeon E5335 2Ghz 16 Go RAM and 1 To disc, was installed in 2008 and geodesy software such as GINS, DYNAMO and CATREF were tested at the beginning of 2009.
- A discussion forum (<http://grgs.obspm.fr/forum/>) on the combination at observation level was created for our community concerning geodetic techniques for GRGS participants and extended to all other analyses centres in English language.
- SINEXtool software was upgraded in order to convert normal equation in GINS format to SINEX format. SINEXtool is managed by Sylvain Loyer (CNES-CLS Toulouse).
- Test of daily linearity constraints procedure of Dynamo software applied to the solutions or to the corrections on polar motion and universal time.
- Test of the influence of the continuity constraints on celestial offset solutions derived from GRGS VLBI observations. We observed the discrepancy of the celestial pole offset correction with respect to IAU1980 model with linearity constraint equal to various values $0 \pm \sigma$ ($\sigma \in [3\text{m}, 30\text{cm}, 3\text{cm}, 3\text{mm}]$). We noted the decreasing of RMS on correction for the celestial pole offset corrections (ϵ, ψ) from 2.7mas to 125 μas .
- Weekly VLBI normal equations from GRGS have been analysed with the new quasar coordinates parameters with respect to ICRF2 reference frame, complemented by the hourly troposphere parameters and the Earth Orientation Parameters, polar motion and Universal Time at 6h intervals and celestial pole offset at 12h intervals. Troposphere parameters estimated contribute to increase the RMS of EOP corrections with respect to C04 series as a priori reference solution.
- Participation to the realization of the new terrestrial reference frame ITRF2008 with the combination of GPS, VLBI, SLR, DORIS geodetic techniques at the normal equations level. GPS, DORIS, SLR and VLBI normal equations, over 2007–2008 period, were processed on a weekly basis (100 weeks). Atmospheric loadings are removed, tropospheric parameters are reduced, EOP 6h intervals are linearly constrained over each successive day and the weekly reduced normal equations weighted by an empirical factor are stacked. These successive steps were collected in a routine to generate the

unconstraint multi-technique combined normal equations, with daily EOP and weekly station coordinates parameters. All these normal equations of multi technique combination spanning the 2007–2008 period were converted into the SINEX format and delivered to the ITRF2008 contribution and put on the ftp server <ftp://hpiers.obspm.fr/iers/eop/grgs/GRGS/itrf2008/>. The GRGS contribution to the new realization ITRF2008 was analysed by the ITRS Center for techniques alone (SLR, VLBI, DORIS) as well as for global combination. The transformation parameters, i.e. translation, scale and rotation, were weekly estimated with respect to ITRF2005.

- EOP solutions: polar motion, universal time, nutation offset and station coordinates solutions were calculated from unconstrained weekly normal equations issued from GPS, DORIS, SLR and VLBI combination over 2007–2008 period.
- Transformation parameters for geodetic techniques GPS, DORIS, SLR, VLBI were determined over 2007–2008 period to estimate the consistency between the geodetic space reference frame versus ITRF2005.
- Zenithal Bias Delays (ZTD) were estimated by multi technique combination at the normal equation level. GPS, DORIS and VLBI geodetic techniques allow the determination of this troposphere parameter. Nutation offsets and polar motion were fixed in the process.
- Combination at normal equation level of GPS and VLBI have been made over 2 years to estimate the polar motion and universal time UT1 at 6h intervals and nutation offsets at 12h intervals.
- Combination of GPS normal equation and VLBI normal equation spanning the same 2 years period for estimation of nutation offsets parameters 12h intervals.
- Station coordinates and transformation parameters weekly determined by combination of GPS, DORIS, SLR and VLBI at normal equation level for the 2007–2008 period. Cartesian positions versus ITRF2005 of collocated techniques at Hartebeesthoek station (4 techniques) and Wettzell (3 techniques) were compared.
- 26 EOP solutions of combined geodetic techniques were produced in 2009 and 144 EOP solutions in 2010, put on the ftp server <ftp://hpiers.obspm.fr/iers/eop/grgs/GRGS/solutions/>.
- DYNAMO routine computed the weight of combined normal equations “dynamo_w” using Helmert’s algorithm have been tested and a new routine “sigmas_et_residus_moyens” was

applied to the DYNAMO output files resulting from normal equation processing. This new routine estimates for each type of measurements their uncertainty (a priori RMS), the weighting associated and the sum squared of the weighting observation minus calculated.

- Weighting factors applied for GPS, DORIS, SLR and VLBI for generation of weekly unconstraint combined normal equations, were estimated using the rate of the sigma a priori and the square of the empirical weighting. These weighting factors were used by IGN for the calculation of our contribution to ITRF2008 realization.
- Using the “COMPSTA” software in order to compare the station coordinates and rates for each geodetic technique versus to ITRF2005 the space reference frame used and to estimate the seven transformation parameters (TX, TY, TZ, S, RX, RY, RZ) during the 2007–2008 periods of available measurements and solutions extracted.
- Analysis of local ties constraints applied to the station coordinates estimation for weekly unconstraint normal equations. 26 collocated stations were used to constraint the normal equation for station coordinates parameters spanning the 2007-2008 period. Station coordinates corrections in Cartesian (X, Y, Z) and spherical coordinates (φ , λ , h) and rates for Wettzell site with VLBI, SLR, GPS collocated stations and for Ny-Alesund site with VLBI, DORIS, GPS collocated stations have been compared over the 2007–2008 period with respect to ITRF2005.
- Weekly transformation parameters were estimated for each technique and for combination techniques. The stability of these parameters has been compared using the Allan variance. For translation and scale transformation parameters the combination technique exhibits the best long term stability (> 100d). For rotation parameters the stability of combined referential frame shows a good compromise.
- Stacking of VLBI weekly normal equations during the period of 2007-2008 was performed to estimate UT1 and nutation offsets at 12h. The same stacking of weekly normal equations was performed to GPS, DORIS and SLR to estimate the polar coordinates. The following table shows the results obtained.

Table 1: Statistics for EOP corrections in respect to C04 series at 12h obtained by stacking the weekly NEQ derived from the different techniques over 2007-2008

	GPS	VLBI	SLR	DORIS
Number of weeks	97	97	89	97
Number of unknowns	27269	4742	6858	18131
X-Pole WRMS / μs	41.6	—	281	463
Y-Pole WRMS / μs	38.4	—	220	350
UT1 WRMS / μs	—	18.3	—	—
Eps WRMS / μs	—	389	—	—
Psi.sin(ϵ_0) WRMS / μs	—	345	—	—

References

- Bizouard Ch., Gambis D., Richard J.Y., Becker O., 2009, Combination of earth orientation parameters from different techniques, Proc. Journées Systèmes de Référence 2008, M. Soffel and N. Capitaine (eds.), p. 153.
- Gambis D., Biancale R., Carlucci T., Lemoine J.M., Marty J.C., Bourda G., Charlot P., Loyer S., Lalanne, L., Soudarin, L., 2009, Combination of Earth Orientation Parameters and terrestrial frame at the observation level, Springer Verlag series, Series International Association of Geodesy Symposia, Vol. 134, Drewes (Ed), pp. 3–9.
- Gambis D., Richard J.Y., 2009, Multi-technique combination of Earth rotation parameters and terrestrial reference frame, Proc. of the 6th Orlov Conference, Study of the Earth as a planet by methods of geophysics, geodesy and astronomy, Ukrainian Academy of Sciences, p. 38.
- Gambis D., 2009, Monitoring Earth Orientation variations; State of the art and prospective, in Transactions IAU, Volume XXVII B, Proc. XXVII IAU General Assembly, August 2009, Ian F. Corbett (ed.), p. 126.
- Richard J.Y., Gambis D., Lemoine J.M., Bizouard C., Biancale R., 2008, Global combination of station coordinates and Earth rotation parameters, Series of the Research Institute of Geodesy, Topography and Cartography, Volume 54, 45, Zdiby, Prague East, P. Holota (ed.).
- Richard J.Y., Gambis D., Bizouard Ch., Lemoine J.M., Biancale R., Loyer S., Soudarin L., Deleflie F., Bourda G., 2009, “Global Combination of the Terrestrial Frame and Earth Orientation Parameters at the Observation Level. Contribution to ITRF2008 realization”, EGU 2009.

Richard J.Y., Gambis D., Biancale R., 2010, "Combination of Space Geodetic Techniques at the Normal Equation Level", EGU 2010.

Richard J.Y., Gambis D., Bizouard Ch., 2010, Earth rotation parameters determined over CONT08 VLBI campaign by the GRGS from the combination of space geodetic techniques, subm. to Proc. Journées Systèmes de Référence 2010, N. Capitaine (ed.).

Richard J.-Y., Bizouard C., Bourda G., Deleflie F., Gambis D., Loyer S., Soudarin L., 2009, GRGS combination of the terrestrial frame and Earth orientation parameters at the observation level. Contribution to ITRF2008 realization, SF2A Proceedings. 2009, GRAAPH session, pp. 115–119.

*Jean-Yves Richard, Daniel Gambis, Christian Bizouard,
Teddy Carlucci (Observatoire de Paris)
Richard Biancale, Jean Michel Lemoine (CNES Toulouse)
Géraldine Bourda, Sylvain Loyer, Laurent Soudarin,
Florent Deleflie*