3.7 IERS Working Groups

3.7.2 Working Group on Combination at the Observation Level

This Working Group COL was created in 2009. Its main objective is to bring together groups able to perform combinations of space geodetic techniques (DORIS, GNSS, SLR and VLBI) at the level of observations (similar to the Normal Equation level) searching for an optimal strategy to simultaneously solve for geodetic parameters, in particular Earth Orientation Parameters, terrestrial and celestial reference frames and tropospheric delays. This implies to improve the accuracy, the time resolution and the overall consistency of the geodetic products derived.

The activities of the Working Group over 2014 were mainly focused to the participation of the French COL/GRGS to the ITRF2014 realization. At an internal meeting, the GRGS discussed on the strategy to apply at the different levels of analysis: processing of the individual techniques and the combinations.

- Organization of storage space for the normal equations delivery
- Test on the exchange of binary files between centers
- Update on the preparation of the normal equations derived from the processing of the individual techniques: VLBI, SLR, GPS, DORIS
- Update on the adoption of the IERS Conventions for models
- Particular point on the construction of DORIS weekly solutions from solutions initially derived over 3.5 days, keeping information on satellites for further studies (SAA)
- Test period: each technique is required to provide the NEQs on the test period of 2009 if possible before the end of 2014
- List of stations to take into account (DOME numbers)
- Compatibility of DYNAMO with the file containing the discontinuities of station positions and what is the procedure for the database management.

In the beginning of 2014, different GRGS groups involved for each technique have made available 12 years (2002 – 2013) of weekly normal equations (NEQs) which were then processed at the Paris combination center. Table 1 shows the different techniques delivered by the GRGS Analysis Centers and their contribution to this campaign. Table 2 shows the parameters to be considered for this comparison campaign and their a priori values.
3.7.2 Working Group on Combination at the Observation Level

Table 1: Techniques used for combination, GRGS Normal Equations (NEQs) and Parameters

<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>NEQ per 3,5d arc length &amp; per satellite: 106/106 Jason-1, 99/99 Jason-1, 104/104 Envisat, 58 Spot2, 104 Spot2, 107 Spot5 over the whole year 2009</td>
<td>From week 48B of 2008 to week 5B of 2010 session R1 (RX &amp; RF DE) producing 125 weekly NEQ</td>
<td>2009: 74 weekly NEQ LAGEOS-1, 74 NEQ LAGEOS-2, 74 NEQ ETALON-1, 74 NEQ ETALON-2</td>
<td>7-January-1990 to 8-December-2013 820 weekly NEQ</td>
<td></td>
</tr>
<tr>
<td>GPS – Glonass constellation, between 23 and 55 satellites</td>
<td>Doris Laser: Envisat, Jason-1, Jason-2</td>
<td>Doris Doppler: Envisat, Jason-1, Jason-2, Spot2,4,5</td>
<td>Lages1R2</td>
<td>Etolon-1R2</td>
<td></td>
</tr>
<tr>
<td>Pole, PX, PY and Rates PKR, PPR, 1pt/d @12h, UT1-TAI, LOD 1pt/d @ 12h, Nutation corrections IAU2000A NN, NY 1pt/d @ 12h</td>
<td>Station coordinates SX, SY, SZ 1/week</td>
<td>Tropospheric parameters for collocated sites [zenith delays &amp; N(L) gradients] 12pt/d @ 12h</td>
<td>Time station bias 1pt/arc</td>
<td>Doppler frequency offset 2h</td>
<td></td>
</tr>
<tr>
<td>Pole, PX, PY, UT1-TAI 1pt/d @ 0h, 12h, 18h, Nutation NN, NY 1pt/d @ 00, 12h Stations SX, SY, SZ 1/week</td>
<td>Tropospheric Zenithal Delays M2B 12pt/d @ 2h East &amp; North gradients 1pt/d Center of mass correction CDX, COY, COZ on satellites 1pt/sat</td>
<td>*Global station bias 1pt/arc</td>
<td>*Doppler frequency offset 2h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Orbital elements SX, EY, EZ, EXP, EYP, E2 1pt/arc</td>
<td>*Atmospheric drag and lift</td>
<td>*Solar pressure 1pt/arc</td>
<td>*Orbit Bias</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiation forces 1 to 8: -specular reflectivity of panel</td>
<td>-diffuse reflectivity of panel</td>
<td>-emittance of panel 1 pt per arc</td>
<td>-Gravity field coefficients normalized: GCN cosinus, GSR sinus degree 0 to 40</td>
<td></td>
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</tr>
</tbody>
</table>

Table 2: Recommended geodetic parameters for the GRGS multi-technique combination

<table>
<thead>
<tr>
<th>Parameters</th>
<th>SINEX format</th>
<th>GINS format</th>
<th>Sampling</th>
<th>Initial values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polar motion</td>
<td>XPO, YPO</td>
<td>PX, PY</td>
<td>PWL @ 12Hr</td>
<td>IERS EOP 08-C04 series Interpolated @12h</td>
</tr>
<tr>
<td>Delta time UT1-TAI</td>
<td>UT</td>
<td>PT</td>
<td>PWL @ 12Hr</td>
<td>IERS EOP 08-C04 series Interpolated @12h</td>
</tr>
<tr>
<td>Nutation angles X, Y corrections to the IAU2000A/2006 model</td>
<td>NUT_X, NUT_Y</td>
<td>NX, NY</td>
<td>PWL @ 12Hr</td>
<td>Set to 0.0</td>
</tr>
<tr>
<td>Station coordinates</td>
<td>STAX, STAY, STAZ</td>
<td>SX, SY, SZ</td>
<td>1/w @ mid epoch</td>
<td>ITRF2008</td>
</tr>
<tr>
<td>Radio sources coordinates right ascension &amp; declination</td>
<td>RS_RA, RS_DE</td>
<td>QRA, QDE</td>
<td>1/w @ mid epoch</td>
<td>ICRF2</td>
</tr>
</tbody>
</table>

Added parameters not used for ITRF2013 purposes but proposed for GRGS studies

| Zenithal Troposphere Delay for wet component limited for stations | ZBIAS: Adjustment of the wet component to the model | M2B | Every 2-hours: 00, 02, 04, ..., 20, 22h per day | GPT/GMF model for radio waves and Mendels/Pavlis for optical waves |
| Tropospheric gradient north & east limited for selected stations | TGETOT, TGINTOT | MGE, MGN | 1pt/d @ 00Hr |

Possible parameters for future investments

| Polar motion rate | XPOR, YPOR | PXR, PYR | 1pt/d @ 12Hr | Set to 0.0 |
| Length of Day LOD | LOD | PTR | 1pt/d @ 12Hr | IERS EOP 08-C04 LOD Interpolated @12h |
| Rate for nutation angle | NUTR_X, NUTR_Y | NXR, NYY | 1pt/d PWL @ 12Hr | Set to 0.0 |
3.7 IERS Working Groups

Strategy to prepare the normal equations derived from the individual techniques

1. Stacking the weekly Normal Equations for DORIS, GNSS, SLR, LLR, VLBI techniques

The daily GNSS NEQs are stacked to generate the weekly NEQs with respect to the GPS week numeration. The DORIS NEQs for satellites ENVISAT, Jason-1 and 2, SPOT-3, 4 and 5 and by arcs of 3.5 days long are stacked without any weighting. The weekly SLR and LLR NEQs are stacked using the Helmert weighting method. The VLBI NEQs session R1 and R4 are weekly stacked with respect to the GPS week numeration.

2. Reduction of parameters

For each weekly NEQ, tropospheric parameters which do not belong to a selection of tied stations and outside the list of recommended parameters are reduced (Table 3).

3. Systematic Effects

In order to combine the different geodetic techniques, we need to consider the systematic effects of their terrestrial referential frame relatively to the a priori TRF. To take into account inconsistencies between techniques, Helmert parameters are introduced, i.e translations and scale for satellites systems and scale factor for VLBI technique. Station coordinates for each technique are transformed into a common reference frame $R_c$ by applying the Helmert parameters by the transformation equation:

$$X_{tech} = X_{tech,ITRF} + A_{tech} \Theta_{tech}$$

The station parameters of each technique expressed in the ITRF2008 referential frame, $X_{tech,ITRF}$ are reduced from the normal equation, the station parameters $X_{tech}$ and systematic effects, handled by $\Theta_{tech}$, are kept for estimation. For more details see IERS Annual Report for 2012.

Combination of DORIS, GNSS, SLR/LLR, VLBI Normal Equations

1. Stacking DORIS, SLR/LLR, VLBI Normal Equations without GNSS

NEQs are stacked using the Helmert weighting algorithm. Table 3 shows for a dedicated week the weighting factors applied to the variance.

Table 3: Weighting factor computed by the Helmert algorithm for DORIS SLR/LLR and VLBI weekly NEQ available – here for GPS week 1514

<table>
<thead>
<tr>
<th>Technique</th>
<th>DORIS</th>
<th>SLR/LLR</th>
<th>VLBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighting factor</td>
<td>0.0072</td>
<td>1.246</td>
<td>0.043</td>
</tr>
</tbody>
</table>

2. Cancellation of Earth Orientation Parameters measurements outside the considered week

In order to cancel the influence of EOP measurements outside the week processed, we introduce a constraint consisting to force the outside EOP to equal to their a priori, or the EOP corrections to be null for dates outside the nominal week processed:

$$d[EOP(tk)] = 0 \pm \sigma$$ with $\sigma$ very small (0.1mm)

This process is applied on the weekly DORIS, SLR/LLR, and VLBI NEQs. GNSS weekly NEQs are not concerned by this process.
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The sub-daily EOP (sampling 6h) resulting of the weekly stacking NEQs DORIS, SLR/LLR and VLBI, are daily linearly constrained between 0h to 24h, and then all EOP except those of 12h are reduced from the NEQ. DORIS, SLR/LLR, VLBI NEQs provide daily EOP at 12h and ready for combination with GNSS NEQ containing EOP also at 12h.

DORIS, SLR/LLR, VLBI NEQs are then stacked with the GNSS NEQ using unitary weighting factor. This NEQ weekly stacked constitutes Normal Equations delivered.

Additional constraints are added to the combined NEQs before the inversion, such as the No Net Rotation condition on quasars set (NNR), minimal constraints on DORIS, GNSS, SLR and VLBI network stations respectively (7 transformation parameters: 3 Translations, 1 scale factor, and 3 Rotations), stability constraints on station coordinates and loose constraints on tropospheric parameters.

Preliminary results have been obtained over January 2009. They show a good consistency for pole components and for the terrestrial frame. The computation of combined Normal Equations over the whole period is planned for the year 2015.

Participants in the Working Group activities

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F. Lemoine, GSFC

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Richard J.-Y., Gambis D., Bizouard C., Carlucci T., Biancale R.,
Combinaison de Techniques Géodésiques au niveau des Observations, AS GRAM 2014, Bordeaux, 2–4 April 2014
Richard J.-Y., Biancale R., Gambis D., Bizouard C., Carlucci T.,
IERS COL-WG project at GRGS COMBINATION CENTRE,
17th June 2014
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Bouquillon S., Coulot D., Deleflie F., Francou G., Gambis D.,
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