Combination method of different space geodesy techniques for EOP and terrestrial reference frame determination

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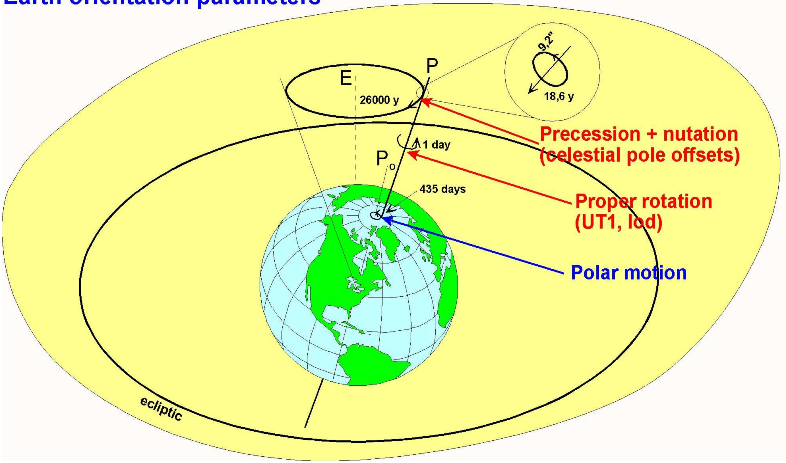
ICRS, *ITRS* and their frames:

- International Celestial Reference System (*ICRS*)
  - *ICRS* is realized by International Celestial Reference Frame (*ICRF*) that contains a set of adopted coordinates and uncertainties of extragalactic sources;
- International Terrestrial Reference System (*ITRS*)
  - *ITRS* is realized by International Terrestrial Reference Frame (*ITRF*) based upon estimated coordinates and velocities of a set of stations observed by geodesy techniques (*VLBI*, *GPS*, *DORIS*, *SLR* and *LLR*);

These systems are related to each other by five Earth Orientation Parameters (*EOP*), i.e. precession-nutation, polar motion and $UT1$.

Earth orientation parameters



Observation techniques:

Rigorous and non-rigorous solution:

- Each technique has analysis centers whose products are published (positions and velocities of stations, Earth orientation parameters etc.);
- Products of techniques can only be combined for stations equipped with more then one techniques;
- There are two approaches to combination :
  - rigorous combination - combined are original observation equations or results of individual techniques using covariance matrices;
  - non-rigorous combination is much simpler because the covariance matrices are not used; the presented method belongs to this kind.

Combination method:

The method is based on combining station vectors in the *ICRF*, where they are function of both the *EOP* and the station coordinates:

$$x_C = Q(t)R_3(ERA)R_3(-s')R_1(y_P)R_2(x_P)x_T. \tag{1}$$

The system consists of observation equations as derivatives of (1) with respect to any unknowns :

$$\sum_j \frac{\partial x_C}{\partial U_j} dU_j = x_C|_{obs} - x_C|_0 + v. \tag{2}$$

The system as it was presented is singular. To remove singularity two additional sorts of constraints have to be added.

1^{st} type of constraints:

$$
\begin{aligned}
translation : \sum_{i}^{N} dU_i &= 0, \\
rotation : \sum_{i}^{N} U_i^0 \times dU_i &= 0, \qquad (3) \\
scale : \sum_{i}^{N} (dU_i^0) \bullet dU_i &= 0.
\end{aligned}
$$

The no-net-rotation constraints were applied on coordinates to satisfy the minimization of the relative kinematic energy of the system.

2^{nd} type of constraints:

$$L_i''' = \sum_{k=0}^{3} \left(6 \prod_{j=0, i \neq k}^{3} \frac{1}{x_{i+k} - x_{i+j}} \right) E_{i+k}. \quad (4)$$

The constraint is third derivative of third-order Lagrange polynomial running through the four adjacent epoch; it was applied on *EOP* in order to tie them.

The constraint was derived from smoothing method proposed by J. Vondák also well used to smooth C04 2005 by D. Gambis.

By weighting, the degree of smoothness of *EOP* can be controled.

All constrants entered into system in the form of pseudo-observations.

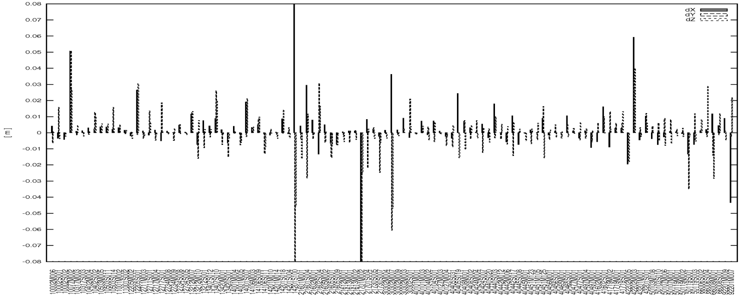
Intput of the method:

- daily station coordinates measuared by *GPS*, *SLR* and *VLBI* at colocation stations;
- daily *EOP* (x_P, y_P and $UT1-UTC$) extracted from SINEX files; values of *LOD* measured by *GPS* and *SLR* had to be integrated with respect to *VLBI*.

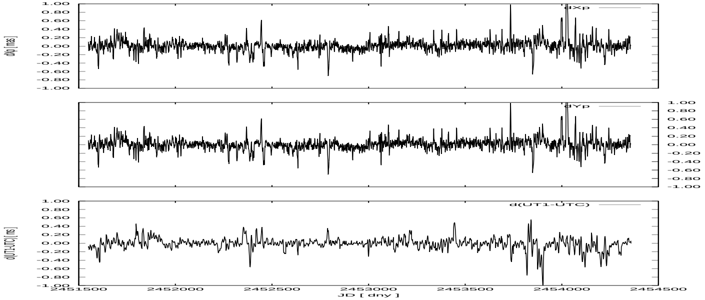
Output of the method:

- daily corrected *EOP* (x_P, y_P and $UT1-UTC$);
- daily corrected station coordinates.

Comparison of computed coordinates with ITRF 2005:



Comparison of computed EOP with ones published by ITRF 2005:



The differences are 0.162 *mas*, 0.156 *mas*, and 0.138 *ms* for x_p, y_p, and $UT1-UTC$, respectively.

Conclusions :

The combination method of results of geodetic techniques gives two kinds of products, namely, corrected stations coordinates and the Earth orientation parameters for each epoch.

Approximately eight-year data was successively procesed and results were compared with ITRF 2005. The differences were 0.162 *mas*, 0.156 *mas*, and 0.138 *ms* for x_p, y_p, and $UT1-UTC$, respectively. In case of coordinates, most differences didn't exceed level of 2 cm.

The computed station coordinates as results of presented method were also used to estimete $\overrightarrow{\omega}$ of main tectonic plates; this topis is not covered by this presentation.

Thank you for your attention !!!