Determination of Station Coordinates and EOP from Combination of Different Techniques

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Description of the method

The method is designed to combine "non-SINEX" solutions for different techniques, where the normal equations matrix can not be restored. Input data: For each technique one or more sets of (x_p, y_p, UT1–UTC, dψ, dε) – Earth orientation parameters, EOP_m, and X_t – station coordinates, SSC_m. Result: "representative" set of orientation parameters (x_p, y_p, UT1–UTC, dψ, dε) for epochs T_i and seven transformation parameters $\mathbf{p} = p_1, ...,p_7$ for each input solution of station coordinates.

The method is based on combining fictitious observations – position vectors of the stations, transformed into the celestial reference frame, i.e. $\mathbf{X}_t \rightarrow \mathbf{X}_c$:

$$\mathbf{X}_c = \mathrm{PN(t)\ R3(-GST)\ R1}(y_p)\ \mathrm{R2}(x_p)\ \mathbf{X}_t$$

where PN, R1, R2, R3 are transformation matrices. The transformation yields observation equations

$$\sum_j \frac{\partial \mathbf{X}_c}{\partial \xi_j} d\xi_j = \mathbf{X}_c\big|_{obs} - \mathbf{X}_c\big|_0 + \mathbf{v} \ ,$$

with $\xi_j \equiv x_p$, y_p, UT1, ψ, ε, **p**. Singularity of the system is removed using constraint of no-net rotation

$$\sum \mathbf{p}^T \mathbf{p} = 0 \ .$$

Corrections to nutation angles dψ, dε can be separated from the pole coordinates x_p, y_p by introducing the fictitious observations of the second kind, which are shifted from the basic epoch by ±8 hours, i.e. three observation equations correspond to each input data. The length of day, LOD, as produced by SLR and GPS, is converted to UT1–UTC by integration and parabolic fit to the VLBI data

$$\{UT1-UTC\}(t) = \int_0^t LOD + c_0 + c_1 t + c_2 t^2 \ .$$

The EOPs for a particular epoch are derived independently of the other epochs, what results in false oscillations especially in UT1–UTC. Thus, to accomplish a tie of the LOD data to VLBI time corrections, "condition" observation equations

$$\mathrm{d}\xi_i - \mathrm{d}\xi_{i-1} = 0 + \mathrm{v}, \qquad \xi \equiv x_p, y_p, \mathrm{UT1-UTC}, \psi, \varepsilon,$$

are added for each non-VLBI epoch. Strength of the tie depends on the weight of these equations.

Only stations equipped by at least two techniques are included into the combination. Instruments are centered to one reference point. One day data referred to 12 h UT are created for all EOPs. Due to the constraints, the result of combination depends on the adopted preliminary values of the unknowns. As we expect only subtle effects arising from simultaneous processing of EOP and station coordinates, the weighted mean derived from all contributing individual solutions would be the most probable approximate value of the respective unknown.

Data and numerical solution

The method is tested using following VLBI, GPS and SLR input solutions:

GAOUA	97 R 01	EOP and SSC	x_p, y_p, UT1–UTC, dψ, dε
GIUB	97 R 01	EOP and SSC	x_p, y_p, UT1–UTC, dψ, dε
SHA	97 R 01	EOP and SSC	x_p, y_p, UT1–UTC, dψ, dε
GSFC1122	97 R	EOP and SSC	x_p, y_p, UT1–UTC, dψ, dε
GSFC	97 L 01	EOP and SSC	x_p, y_p and LOD
CODE	97 P ?	EOP	x_p, y_p and LOD
CODE	98 P 01	SSC	SSC do not correspond to EOP

Systematic differences of particular input EOP solutions cause false oscillations and steps. Hence, it is necessary to homogenize the data prior to the combination by removing

- biases and trends (determined from epochs containing all input solutions),
- long periodic variations in the GPS and SLR data.

The daily values of EOP were derived over the interval of 275 days between MJD 49724 and 49999. Dispersion of station coordinates decreased after the adjustment from 0.050 m to 0.024 m when VLBI and GPS were combined, and from 0.047 m to 0.029 m for combination of VLBI, GPS and SLR.

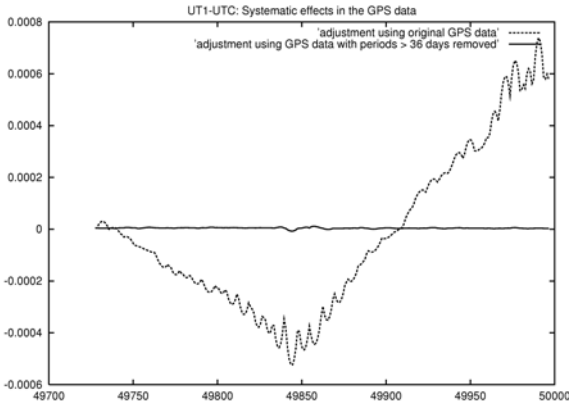

Fig. 1

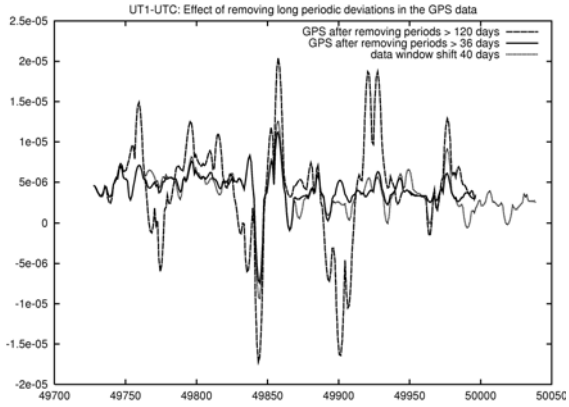

Fig. 2

Systematic deviations in the GPS data cause false quasi-periodic oscillations between VLBI epochs, to which GPS data are fitted as seen in Fig. 1. These false oscillations remain even when the condition equations are introduced to tie the solution to VLBI time corrections (dotted line). They disappeared after removing biases and long periodic terms from the GPS data (full line). (Displayed are in seconds, the increments to the adopted approximate values, as obtained from the adjustment).

The result of the combination gets the more stable the shorter periods are removed from the GPS data – see Fig. 2. To check stability of the solution, the data window was shifted by 40 days (dotted line).

Acknowledgement

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