Multi-Technique Combinations of Geodetic Observations at the level of Normal Equations

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IDS Workshop 2012, 25-26 September, Venice

MOTIVATION

The space geodetic techniques GPS, VLBI, SLR, and DORIS can been combined at the level of Normal Equations for recovering geodetic parameters such as terrestrial frame, Earth orientation parameters, troposphere delays and quasar coordinates. The potential advantage of the method is to improve the accuracy, the time resolution and the overall consistency of the products obtained in the combination. We present results derived from the combination of normal equations obtained for the different techniques over two VLBI intensive campaigns referred to as CONT08 and CONT11.

PARAMETERS & MODELS

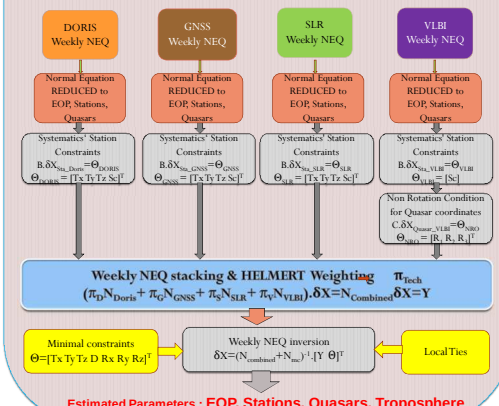
In order to combine homogenously the normal equations, the common parameters are formatted in a similar way for a-priori values, sampling and time space. Models preferences are established. Tables below summarize the list of parameters to be estimated and a priori models and parameters to be used.

Parameters	Parameters to be estimated	Initial values
Pole, UT1-UTC or UT1-TAI	XPO, YPO, UT : PWL @ 0hr	IERS EOP 08-C04
Pole Rate	XPOR, YPOR 1pt/day @ 12hr	Set to 0
LOD	LOD 1pt/day @ 12hr	Set to 0
Nutation angles	NUT_X, NUT_Y : PWL @ 0hr corrections to the model IAU2000	IERS EOP 08-C04
Station coordinates	SX, SY, SZ at mid epoch	ITRF2008
Radio sources coordinates	RS_RA, RS_DE 1pt/week	ICRF2
Zenithal Tropospheric Delay Wet component & horizontal gradients	TROWET @ {00, 02, 04, … 24} hr: Adjustment of the wet component to the model TGETOT, TGNTOT daily 00h	GPT/GMF model for radio waves & Mendes/Pavlis for optical waves

Gravity Field	EIGEN model computed from GRACE-GOCE completed by the mean gravity variations of the atmosphere and the non-IB oceanic response
Ocean Tides Loading	FES2004 check at the triple co-location sites
Troposphere Delay	GPT+GMF for radio-electrical waves, Mendes-Pavlis for optical waves
Atmospheric Tide Model	Ray-Ponte (2003)
Atmospheric Loading	Not applied

COMBINATION STRATEGY

Processing used with the Normal Equations from different techniques are described in the flowchart below. The first step consists in reducing parameters such as orbital elements, global and range biases, center of mass. The second consist in cancelling systematic effects relatively to each a priori space reference frame. For VLBI, the No-Net-Rotation is implemented to cancel the global frame rotation versus the a priori celestial reference frame. The next step allows to stack the constrained Normal Equations, applying a scale factor derived from the variance analysis component. Finally, minimal constraints are applied to the sub networks in addition to local ties.



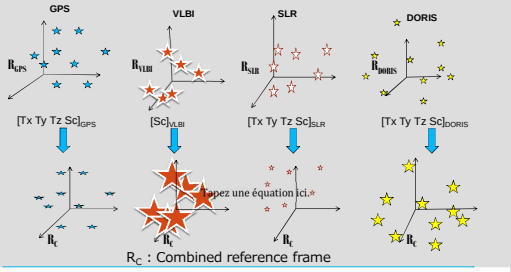
SYSTEMATIC CONSTRAINT

Each geodetic technique contains systematic effects versus the terrestrial reference frame, ITRF2008 have been chosen in this study. To combine all geodetic techniques and estimate the GPS, DORIS, SLR and VLBI stations coordinates, the first process consists to cancel the systematic effects estimated by each of them versus ITRF2008. Constraints applied by technique to the ensemble of station coordinates:

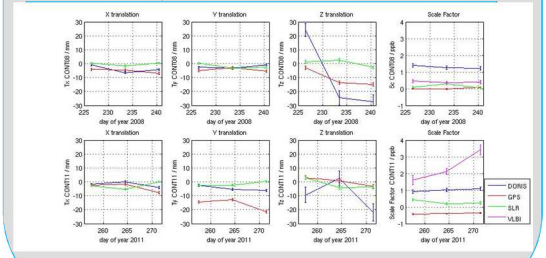
$$X_{Tech} = X_{Tech\_ITRF} + D*\Theta_{Tech}$$

X_{Tech_ITRF} means station coordinates in the reference frame ITRF2008, Θ_{Tech} the systematic effects contained in the transformation parameters $\Theta_{Tech}=[T_X\ T_Y\ T_Z\ Sc]^T$ for the satellite techniques and $\Theta_{Tech}=[Sc]$ for the VLBI technique and respectively the D matrix $\begin{bmatrix}100x^0_i\\010y^0_i\\001z^0_i\end{bmatrix}$ and $\begin{bmatrix}x^0_i\\y^0_i\\z^0_i\end{bmatrix}$.

SYSTEMATIC EFFECTS ESTIMATED FOR DORIS GPS SLR and VLBI TECHNIQUES



R_C : Combined reference frame



Translation X,Y, Z and scale factor estimated over CONT08 & CONT11

NO NET ROTATION CONSTRAINT FOR CELESTIAL FRAME TIE IN VLBI ANALYSIS

In order to align the radio sources onto the a-priori catalog (ICRF2) we add transformated parameters between the a-priori and the estimated catalog, imposed to be zero. The 3-parameter transformation is represented by 3 rotations constraining the small angles for the i-th source:

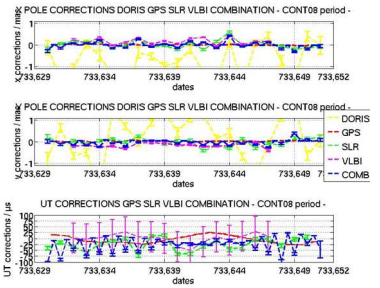
$\Delta RS\_DA_i = R_1\cos(RS\_DA_i)\tan(RS\_DE_i) + R_2\sin(RS\_DA_i)\tan(QDE_i) - R_3$

$\Delta RS\_DE_i = -R_1\sin(RS\_DA_i) + R_2\cos(RS\_DA_i)$

	R1 / µas	R2 / µas	R3 / µas
CONT08	-9,7	-3,5	35,9
CONT11	1,0	6,6	34,0

Rotation parameters estimated for CONT08 & CONT11

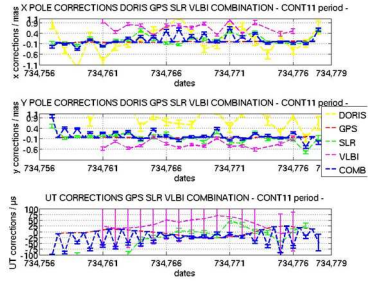
RESULTS: POLE & UT1



Pole and UT1 versus C04 series (CONT08)

Combined parameters	Weigthed Mean	Weighted Standart Deviation
X pole / µas	-3,8	45,5
Y pole / µas	14,8	47,5
UT1 / µs	-5,3	16,0

Mean and weighted RMS (CONT08)



Pole and UT1 versus C04 series (CONT11)

Combined parameters	Weigthed Mean	Weighted Standart Deviation
X pole / µas	-6,1	43,0
Y pole / µas	-27,6	47,3
UT1 / µs	-2,3	15,4

Mean and weighted RMS CONT11

Further investigations

- Pole & UT, Troposphere delay hourly resolution and combination.
- Low degree spherical harmonic coefficients of gravity field.
- Combination at observation equations level.
- Integration of spatial ties (Jason-2, GRACE).

VLBI network 12 stations

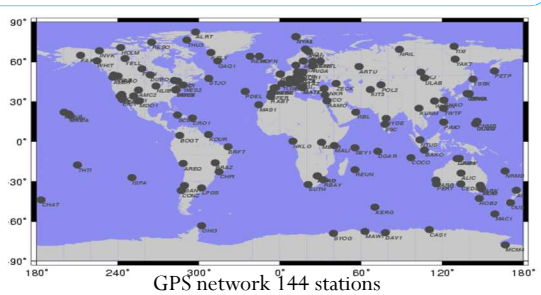
Documentation and Links

Electronic discussion FORUM http://grgs.obspm.fr/forum/

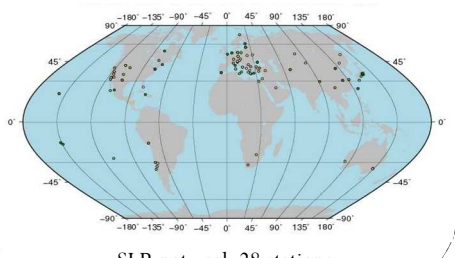
ftp server: delivery normal equations files and solutions are set on ftp server ftp://hpiers.obspm.fr/iers/eop/grgs/

Web site: a web site on Combination at Observation Level available at http://hpiers.obspm.fr/col/

DORIS network 47 stations



GPS network 144 stations



SLR network 28 stations