An Operational EOP Series by Combination of GNSS & VLBI

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Abstract

The Earth orientation parameters (EOP), the regular products of IERS Earth Orientation Centre, are computed at daily bases by combination of EOP solutions by different astro-geodetic techniques. At SYRTE we have developed a new strategy of combination using the Global Navigation Satellite Systems (GNSS) and Very Long Baseline Interferometry (VLBI) techniques at normal equation level thanks to the IERS COL-WG [1]. This approach allows to produce the EOP at the daily bases, polar coordinates (x,y) and rates (xr,yr), universal time UT1 and rate LOD, and corrections from IAU200A/2006 precession-nutation mode (dX,dY), simultaneously with station coordinates constituting the terrestrial frame (TRF) and possibly the quasar coordinates constituting the celestial frame (CRF). For studying these EOP solutions continuously with respect to the IERS EOP products, we have developed an operational process which take the recently solution files produced respectively by IGS and IVS international services which are converted at normal equation level. The recorded solutions obtained from GNSS and VLBI combination at weekly bases is recently maintained by SYRTE. The process of this combination are presented and results are analysed.

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Summary

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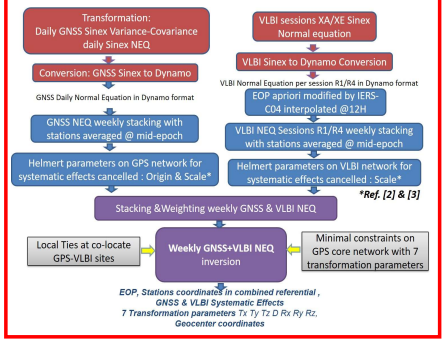
For studying these EOP solutions continuously with respect to the IERS EOP products, we have developed an operational process which take the recently solution files produced respectively by IGS and IVS international services which are converted at normal equation level. The recorded solutions obtained from GNSS and VLBI combination at weekly bases is recently maintained by SYRTE. The process of this combination are presented and results are analysed.

Strategy



Data

	GNSS	VLBI
origin	**IGS**	**IVS**
ftp	ftp://igs.ign.fr/pub/igs/products	ftp://cddis.gsfc.nasa.gov/vlbi/ivsproducts
SINEX format	daily GNSS solution with variance-covariance Matrix	Normal Equation Matrix & Normal Equation Vector
SINEX files	**5513 daily files** GPS week repro2: 1043 - 1832 **1465 daily files** GPS week 1832 - 2041	**2540** VLBI R1 / R4 sessions from January 2nd 2000 to December 29th 2018

Combined Series GNSS+VLBI @ EOP-PC produced

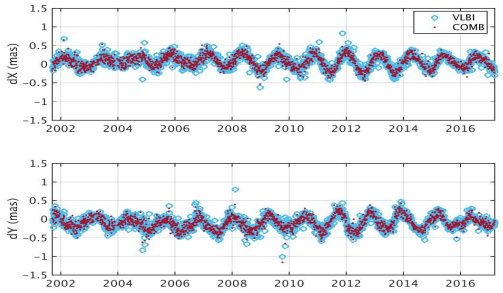
series	Pole & LOD	UT & dX, dY
971 GPS week from 1043 to 2033 **20** missing weeks	**7014** points January 2nd 2000 to December 29th 2018	**2249** points January 5th 2000 to December 28th 2018

Parameters

Parameters	GNSS daily		VLBI R1/R4 sessions	
	Sinex parameters	Initial values	Sinex parameters	Initial values
Polar coordinates	**XPO, YPO** @12h	IERS EOP 08-C04	**XPO, YPO** @~04-06h	IERS EOP 14-C04
Polar motion rate	**XPOR, YPOR** @12h	IERS EOP 08-C04	**XPOR, YPOR** @~04-06h	0.0
Delta time UT1-UTC	-		**UT** @~04-06h	IERS EOP 14-C04
Length of Day LOD	**LOD** @12h	IERS EOP 08-C04	**LOD** @~04-06h	IERS EOP 14-C04
Nutation offset dX, dY IAU2000/2006 model	-		**NUT_X, NUT_Y** @~05-07h	0.0
Station coordinates	**STAX, STAY, STAZ ~500 stations** @12h	IGb08 & IGS14 from February 2017	**STAX, STAY, STAZ ~5 stations /session** @~04-06h	ITRF14
Geo-centre	**XGC, YGC, ZGC** @12h	Set to 0.0	-	

EOP Combined solution 2000-2019

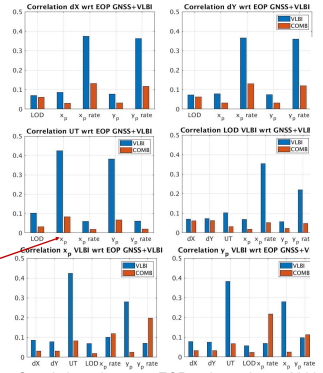
Nutation offsets to IAU2000



The nutation offsets to IAU2000: some spurious points of the VLBI solution are drawn back closer to the mean when combined to GNSS. Covariance matrices reveal that correlations between nutation parameters and other EOP are systemically – and neatly for EOP rates – improved by the combination.

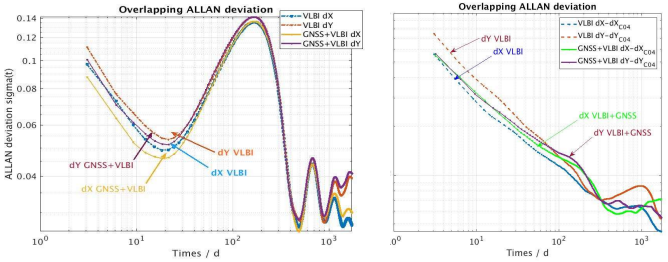
$$r_{dX,x_p} = \frac{cov(dX,x_p)}{\sqrt{var(dX).var(x_p)}}$$

EOP Correlation for VLBI & COMB



Correlations between EOP estimated over 2000-2019 for VLBI only and COMB (GNSS+VLBI)

Stability on the nutation offset corrections wrt. C04, VLBI only & COMB



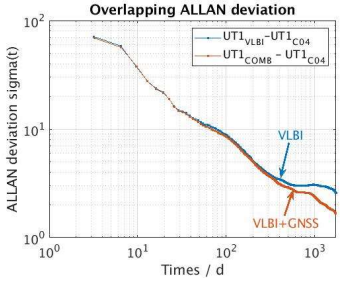
RMS of differences to C04 (µas)

	xp	yp	UT1 µs	LOD	dX	dY
GNSS	35.9	32	-	16.5	-	-
VLBI	113.0	112.2	69.8	18.7	46.8	51.6
COMB	35.2	32.0	68.8	15.5	56.3	60.7

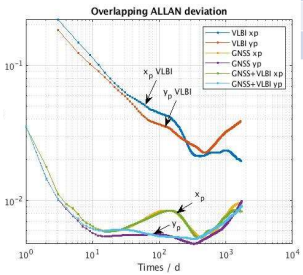
CHI square of differences to C04

	xp	yp	UT1 µs	LOD	dX	dY
GNSS	0.4	0.4	-	1.6	-	-
VLBI	4.9	6.1	2.2	2.5	1.5	2.4
COMB	0.3	0.3	1.9	1.5	2.2	3.1

Stability on the UT1-UTC corrections wrt. C04, VLBI only & COMB



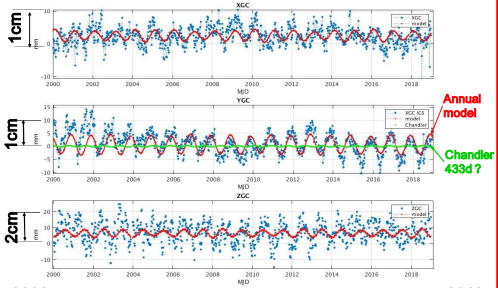
Stability on the polar motion corrections wrt. C04, VLBI only, GNSS only & COMB



Median of errors (µas)

	xp	yp	UT1 µs	LOD	dX	dY
C04	67.0	63.0	9.5	15.2	43.0	40.0
IVS					17.2	17.4
GNSS	3.8	3.9		0.8		
VLBI	27.9	27.5	1.2	2.4	15.6	15.9
COMB	3.6	3.6	1.1	0.8	14.2	14.3

Geocenter



2000 ⟶ 2019

Geocenter wrt. CM at weekly bases over 2000-2019

Conclusion & Prospects

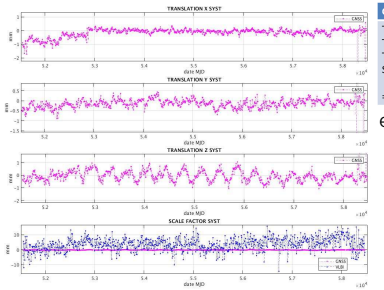
We dispose of an operational chain now available to produce GNSS and VLBI combination from IERS technique centres at the normal equation level based on the CNES/GRGS DYNAMO software. This combination shows a good consistency with ITRF14 and becomes useful to control the C04 reference series of polar motion in consistency with the official terrestrial frame. Correlations between EOP estimated by VLBI only and by combination are slightly reduced, comparable accuracy are observed on the EOP wrt. GPS & VLBI Station coordinates are simultaneously estimated in consistency with the ITRF. The long duration series of the geocenter could be useful to analyse the geophysical effect involved. Next steps of our project consist to assess the quality of the celestial reference frame, add the Laser technique (SLR, LLR) and the DORIS technique.

Combined TRF

Systematism w.r.t ITRF : Helmert parameters

Station positions with systematism: $X_{Tech\_Initial} = X_{Tech\_new} + B.\Theta_{syst}$

Estimated systematisms at weekly bases (2000 – 2019)



GPS only	VLBI only	GPS+VLBI
Tx_{syst_gps} Ty_{syst_gps} Tz_{syst_gps} Sc_{syst_gps} = 0±10cm	Sc_{syst_vlbi} = 0±10cm	Tx_{syst_gps} Ty_{syst_gps} Tz_{syst_gps} Sc_{syst_gps} Sc_{syst_vlbi} = 0±10cm

Θ_{SYST} : Translation & Scale parameters applied on GPS & VLBI core networks with loose constraints

Θ_{SYST} mean & rate wrt. ITRF over 2000-2019, on Translation & Scale for GNSS & VLBI networks

	Tx mm $\dot{T}x$ mm/y	Ty mm $\dot{T}y$ mm/y	Tz mm $\dot{T}z$ mm/y	D mm $\dot{D}x$ mm/y
GNSS	-0.185 ±0.709 +0.031	-0.136 ±0.376 -0.0006	-0.028 ±1.021 -0.010	-0.979 ±0.689 -0.767
VLBI				+3.624 ±4.205 -1.558

The systematics effects such as origin and scale for GNSS network and scale for VLBI network are estimated at weekly bases. The station positions resulting are free of these effects and put in a common referential before the combination.

Minimal constraints: 7 GNSS Transformation Parameters w.r.t. ITRF

Station positions at weekly bases

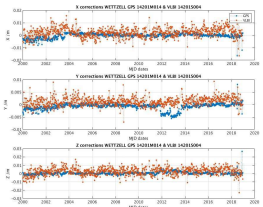
$X_{Tech} = X_{Tech\_new} + B.\Theta$ with Θ=[Tx Ty Tz D Rx Ry Rz]^T

Minimal Constraints 'Θ' on GPS core stations 2000-2019: mean & rates

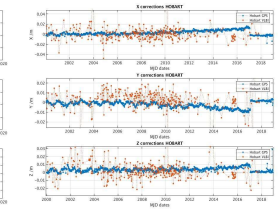
	Tx mm $\dot{T}x$ mm/y	Ty mm $\dot{T}y$ mm/y	Tz mm $\dot{T}z$ mm/y	D mm $\dot{D}x$ mm/y	Rx mm $\dot{R}x$ mm/y	Ry mm $\dot{R}y$ mm/y	Rz mm $\dot{R}z$ mm/y
GNSS	-0.012 ±0.036 -0.046	-0.014 ±0.019 +0.042	0.010 ±0.035 -0.074	-1.056 ±0.722 -2.007	-0.047 ±0.148 +0.2	0.065 ±0.188 -0.7	0.044 ±0.078 +0.3

Station coordinates estimation examples

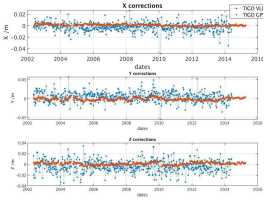
WETTZELL VLBI & GPS



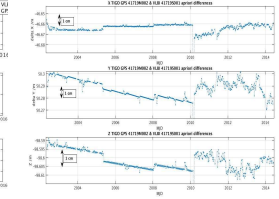
HOBART VLBI & GPS



TIGO VLBI & GPS



TIGO apriori differences GPS & VLBI



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[2] Sahin M., Variance component estimation applied to satellite laser ranging, Bul Geo Springer-Verlag 1992

[3] Arnaud Pollet IGN/LAREG thesis « COMBINAISON DE TECHNIQUES DE GÉODÉSIE SPATIALE », January 2011