Status of the geodetic VLBI analysis at the National Geographic Institute of Spain

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Introduction

In the last years, National Geographic Institute of Spain (IGE) has been strongly involved in technical aspects of geodetic VLBI. In this sense, it should be highlighted RAEGE project which foresees the installation of an Atlantic Network of geodynamical and space stations. The aim of this project is setting up a Spanish-Portuguese network of four Geodetic Fundamental Stations, two in Spain (Yebes Observatory and Gran Canaria), and two in Azores Archipelago (Santa María –Figure 1– and Flores) which cover three tectonic plates.

Fig. 1: RAEGE VLBI antenna in Santa María (Azores).

IGE is committed to expand its contribution to geodetic VLBI. At this aim, a VLBI analysis team has been set up in order to contribute as much as possible to IVS analysis activities. In this respect, a bid to become potential analysis center was submitted to the IVS Combination Center in January 2019. In this contribution we present the VLBI analysis activities that have been carried out so far.

VLBI analysis

The International VLBI Service for Geodesy and Astrometry (Nothnagel et al. 2017) is in charge of providing VLBI data and products for the scientific community. Among others, IVS products are terrestrial reference frame (TRF), the international celestial reference frame (ICRF), and Earth Orientation Parameters (EOP). Solutions in SINEX format estimated by individual Analysis Centers (AC) are combined by the IVS Combination Center and later used to produce consolidated products, for instance ITRF14, ICRF3 or IERS EOP 14 C04 series.

The selection of the VLBI analysis software package is a choice of the AC. At IGE, two VLBI software packages are currently being used. Software package Where (Kirkvik et al. 2017) has been used for the reprocessing of 17 years of 24-hours VLBI sessions (from 2002 to 2019). This software package has been selected as part of the bid submitted in January 2019 to become IVS analysis center in test. Where is a project of the Norwegian Mapping Authority (NMA) which is coded in Python and that can be retrieved freely through GitHub.

The other software package that is being employed at IGE for research activities is VieVS (Böhm et al. 2018). This software is written in MATLAB and it is also accessible through GitHub. VieVS is managed by the Department of Geodesy and Geoinformation of the Technical University of Vienna. Some experiments using VieVS were presented in EVGA 2019 (Puente et al. 2019). In particular, the usage of GNSS-based Zenith Total Delays in VLBI processing was tested. For this analysis, VieVS 3.1 was modified to read and use GNSS-based troposphere delays. The dataset used correspond to CONT17 campaign, in which 15 days of continuous VLBI data are available.

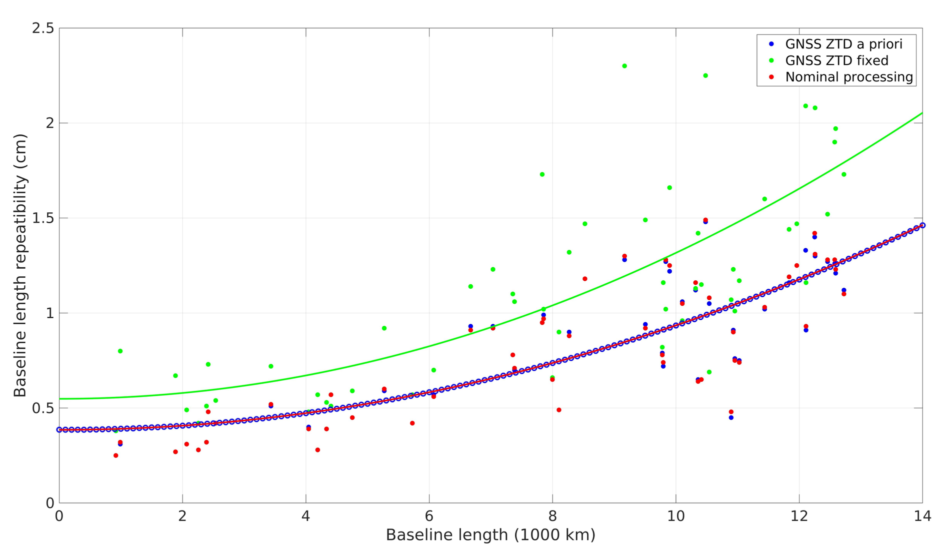

Fig. 2: CONT17 repeatability using different troposphere modelling.

No difference was found between using GNSS-based ZTD as a priori value or using an a priori model (Figure 2). Results worsen if GNSS-based ZTDs are used as a priori value and not estimated. In any case, the evolution of the software presented could be used in the frame of VLBI intensive sessions analysis, since GNSS-based gradients improve UT1 estimation (Teke et al. 2015).

Results in CONT17 campaign

We used CONT17 data to assess the level of agreement of our solutions with respect to other IVS ACs solutions. We analysed the 15 sessions corresponding to CONT17 and we retrieved SINEX files from individual solutions of 7 IVS ACs and the IVS combined solution. The reference products used for the comparison were IGS final Earth Rotation Parameters. We provide in Table 1 the metadata of the solutions produced using VieVS and Where software packages.

Table 1. IGE solutions metadata.

Feature	VieVS 3.1	Where 0.21.2
Input data	vgosDB	vgosDB
A priori EOP	IERS Bulletin B	IERS Bulletin A
Geophysical models	IERS Conventions 2010	IERS Conventions 2010
TRF	ITRF14	ITRF14
CRF	ICRF3	ICRF3
Mapping function	VMF1	VMF1
Estimation model	Weighted least squares	Kalman Filter

To assess the inter-technique EOP accuracy we computed the weighted mean (WM) and weighted RMS (WRMS) with the formulation proposed by Nilsson et al. (2014). IGS final solution was used as reference value and VLBI solutions were linearly interpolated at the GNSS estimate epochs (12:00 UTC).

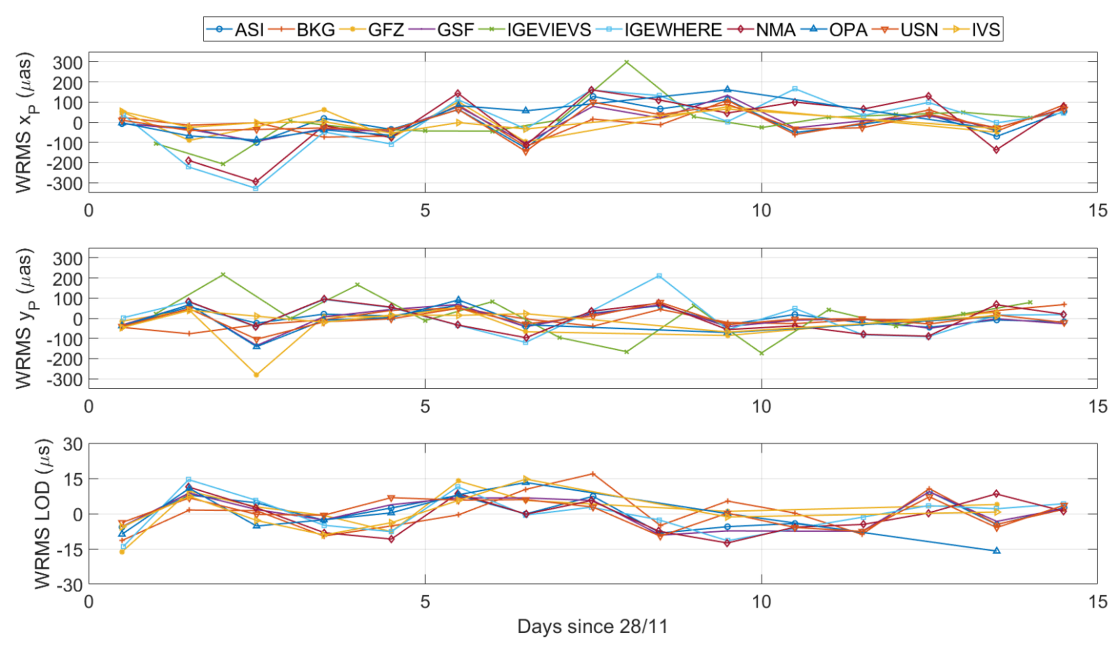

Fig. 3: ERP comparison for different VLBI solutions.

The median WRMS of the differences with respect to IGS final solution is 72.0 μas for x component of polar motion, 47.4 μas for y component of pole motion and 7.5 μs for LOD. IGE solutions are in the same level of agreement than official IVS ACs. Daily WRMS values for each EOP analysed are plotted in Figure 3.

Table 2. EOP differences of single VLBI solutions vs. IGS final.

	x_P		y_P		LOD		
Solution	WM (μas)	WRMS (μas)	WM (μas)	WRMS (μas)	WM (μs)	WRMS (μs)	sessions
ASI	41.8	71.3	-33.7	37.9	0.8	6.2	15
BKG	54.4	69.8	355.8	40.5	0.4	8.0	15
GFZ	-48.6	73.1	41.7	49.1	5.3	10.3	9
GSF	30.6	62.2	27.9	45.7	1.2	6.5	15
IGE-VieVS	34.1	102.1	8.9	105.6	-	-	15
IGE-Where	71.0	106.8	-16.6	76.7	3.7	9.1	15
NMA	38.8	122.0	-18.7	70.8	6.9	7.5	14
OPA	64.2	72.7	16.5	58.9	3.7	9.3	9
USN	6.6	62.8	14.1	34.9	0.8	5.7	15
IVS	1.9	37.0	-63.4	33.4	1.4	6.4	9
Median	36.5	72.0	11.5	47.4	1.4	7.5	15

Gravitational deformation modelling of Yebes radio telescopes

The effect of gravity in VLBI antennas is one of the errors that should be taken into account in the analysis of VLBI data. This effect can reach several millimeters and it has to be determined specifically for each radio telescope (Sarti et al. 2009). Taking this fact into account, it is expected to perform a land survey of Yebes radiotelescopes using a terrestrial laser scanner attached to the antenna. In order to anticipate these activities, a simulation has been carried out to develop the routines needed for the modelling of the gravitational deformation.

A simulation of deformations in a generic antenna was made by using the Finite Element Method (FEM). In the model it was considered that the deformation caused by the structure's self weight is proportional to the square of the height. The deformed dish together with white noise added simulate the measurements of a terrestrial laser scanner to be used as a test point cloud.

Based on this data, a least-squares adjustment was computed to estimate six parameters: three translations to transform the origin of the model in the vertex of the paraboloid, two rotations to solve any misalignment between them and the focal length variation, which would be the potential input to VLBI analysis.

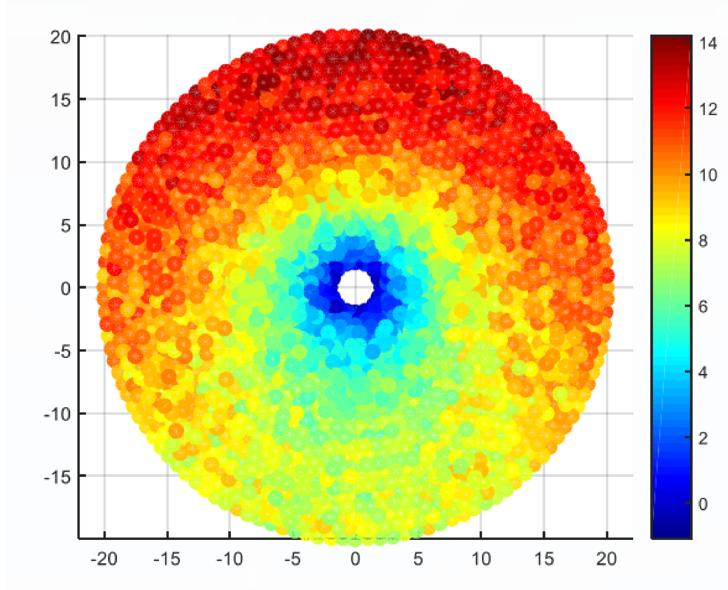

Fig. 4: Relative deformations of the dish.

Figure 4 shows the relative deformations of the dish between the model at 30º and the one at 90º based on the simulated data. Futher information can be found in Prudencio et al. (2019).

Conclusions and future work

In this contribution, VLBI analysis activities carried out at IGE have been presented. IGE VLBI analysis team is driven to gain more experience on geodetic VLBI analysis and to humbly contribute as much as possible to IVS analysis activities, both in the operational analysis part and in research tasks.

The following points will be adressed in the mid term:

- Finish the needed tasks required to become IVS Analysis Center.
- Perform the survey of Yebes radiotelescope using terrestrial laser scanner measurements and model the gravitational deformation of the antenna.
- Pursue VLBI research with special focus on the comparison with GNSS products.

Acknowledgements

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References

Böhm, J. et al., Vienna VLBI and Satellite Software (VieVS) for Geodesy and Astrometry, Publications of the Astronomical Society of the Pacific, 2018, Vol. 130(986), 044503.

Kirkvik, A.-S., Hjelle, G.A., Dähnn, M., Fausk, I., Mysen, E. Where - A new software for geodetic analysis. 23th EVGA Working Meeting 18th IVS Analysis Workshop, 2017.

Nilsson, T, Heinkelmann, R, Karbon, M et al. J Geod 88: 491. (2014) doi:https://doi.org/10.1007/s00190-014-0700-5

Nothnagel, A., Artz, T., Behrend, D., Malkin, Z. "International VLBI Service for Geodesy and Astrometry – Delivering high-quality products and embarking on observations of the next generation", Journal of Geodesy, 2017, Vol. 91(7), pp. 711–721.

Prudencio, A., Azcue, E., López-Ramasco, J., García-Espada, S., Gómez-Espada, Y., Puente, V., Valdés, M. First steps in gravitational deformation modelling of the VLBI Yebes radio telescopes. 24th Meeting of the European VLBI Group for Geodesy and Astrometry (EVGA), 2019.

Puente, V., Gómez-Espada, Y., Azcue, E., S. García-Espada, S., Valdés, M. Comparison of troposphere delays from GNSS and VLBI in R1 and R4 sessions. 24th Meeting of the European VLBI Group for Geodesy and Astrometry (EVGA), 2019.

Sarti, P., Vittuari, L., Abbondanza, C. Laser Scanner and Terrestrial Surveying Applied to Gravitational Deformation Monitoring of Large VLBI Telescopes' Primary Reflector, Journal of Surveying Engineering, 2009, Vol. 135, Issue 4

Teke, K., Böhm, J., Madzak, M., Kwak, Y., Steigenberger, P. GNSS zenith delays and gradients in the analysis of VLBI Intensive sessions. Advances in Space Research, Volume 56, Issue 8, p. 1667-1676. 2015.