RAEGE: Exploring Geodetic Capabilities and Applications

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Abstract RAEGE (Red Atlántica de Estaciones Geodinámicas y Espaciales / Rede Atlântica de Estações Geodinâmicas e Espaciais) is a strategic project focused on establishing four multi-technique stations to strengthen the geodetic infrastructure within Spain and Portugal and to contribute to the Global Geodetic Observing System. This project not only aims to amplify the scope of geodetic observations within the observatories but also fosters strengthening of VLBI analysis and multi-technique combination through the formation of a dedicated RAEGE analysis group.

A comprehensive evaluation of RAEGE's future geodetic capabilities is underway through simulations of observations. Currently, only two of the four stations, Yebes and Santa María, are operational. Several simulations have been conducted to explore the full network's potential once the Gran Canaria and Flores stations are operative.

In the past, promising results arose from the first simulations. These simulations were done for specific sessions and two configurations, RAEGE-network in "stand-alone" mode and evaluating the performance when expanding the network with additional VGOS antennas of the International VLBI Service network. Subsequently, we have extended the simulation period, increasing the number of sessions simulated. The results of this extended study are presented.

Additionally, RAEGE is actively investigating new possibilities for observations and applications. The RAEGE project is intended for Geodesy and Geophysics; therefore, we want to explore new possibilities of observing focused on geodynamic purposes. First results of VLBI sessions processed with this objective are presented.

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1 Introduction

RAEGE (Red Atlántica de Estaciones Geodinámicas y Espaciales / Rede Atlântica de Estações Geodinâmicas e Espaciais) is focused on strengthening the geodetic infrastructure within Spain and Portugal and on contributing to the Global Geodetic Observing System. Currently only two of the four stations, Yebes (RAEGYEB, Yj) and Santa María (RAEGSMAR, Sa) are operational. Several simulations have been conducted to explore the full network's potential, once the Gran Canaria (RAEGGCA, Ga (non-official name)) and Flores (RAEGFLR, Fl (non-official name)) stations are operative.

In the past, promising results arose from the first simulations. These simulations were done for specific sessions and two configurations, RAEGE-network in "stand-alone" mode and evaluating the performance when expanding the network with additional VGOS antennas of the IVS network. Subsequently, we have extended the simulation period to one year, increasing the number of sessions simulated. The results of this extended study are presented.

Table 1 Different configurations used for the simulations.

Color	Session Configurations	Code in legends
● (pink)	IVS 2023 VGOS-OPS (RAEGYEB included)	Original VO session
● (green)	VGOS-OPS + Santa María	+ Sa
● (yellow)	VGOS-OPS + Santa María + Gran Canaria	+ Sa + Ga
● (blue)	VGOS-OPS + Santa María + Gran Canaria + Flores	+ Sa + Ga + Fl
● (purple)	VGOS-OPS + Santa María + Gran Canaria + Flores + Simulated VGOS station in HartRAO (Hv)	+ Sa + Ga + Fl + Hv
● (red)	VGOS-OPS + Simulated VGOS station in HartRAO	Orig. VO session + Hv
● (black)	RAEGE-alone	

2 RAEGE Simulations

2.1 Simulations

VieSched++ was used to simulate the integration of RAEGE into existing VGOS sessions for EOP estimation and for RAEGE-alone performance for coordinates. 24 VGOS-OPS sessions during 2023 were selected and simulated with seven configurations. The different configurations are shown in Table 1.

A simulated HartRAO VGOS station was introduced in two of the session configurations because we want to study the relation between RAEGE and southern hemisphere stations. For each configuration 79 schedules were tested, varying the weight factors (number of observations, duration, sky-coverage, and idle time), and for each of these 79 schedules, 1,000 simulations were done, and the best was selected in terms of minimum Mean Formal Error (MFE) and Repeatability (REP). A total of 168,000 simulations were done in this test.

2.2 Earth Orientation Parameters

Mean Formal Errors and Repeatabilities were obtained and are shown in Figure 1 and Figure 2.

The configuration that minimizes MFE and REP is VGOS-OPS + Sa + Ga + Fl + Hv, as expected due to the larger number of observations and the increment of the volume of the network which is caused by the VGOS HartRAO simulated station. We can see that adding only a VGOS HartRAO station has a strong impact on EOPs, bigger than adding stations in the northern hemisphere; this remarks on the importance of strengthening the networks in the southern hemisphere.

2.3 RAEGE Coordinates

RAEGE-alone sessions were simulated to coincide with the 2023 VGOS-OPS. The network's performance in estimating coordinates is notably strong, Table 2, achieving millimeter-level accuracy and even finer precision for RAEGYEB.

Table 2 RAEGE mean MFE and REP of coordinates, observing RAEGE alone.

	RAEGYEB	RAEGSMAR	RAEGGCA	RAEGFLR
MFE [mm]	0.4189	1.345	0.535	0.9694
REP [mm]	0.7696	2.8589	1.0689	2.0651

3 From Simulations to Reality: VGOS-INT-G (RAEGE + GSI + SHAO)

A new VGOS Intensive session type was included in the 2024 Master Schedule: VGOS-INT-G.

A joint test between RAEGE, the Geospatial Information Authority of Japan, and the Shanghai Astronomical Observatory started on the 15th of February 2024 and is observed every Thursday at 17:30 UTC.

There is double motivation:

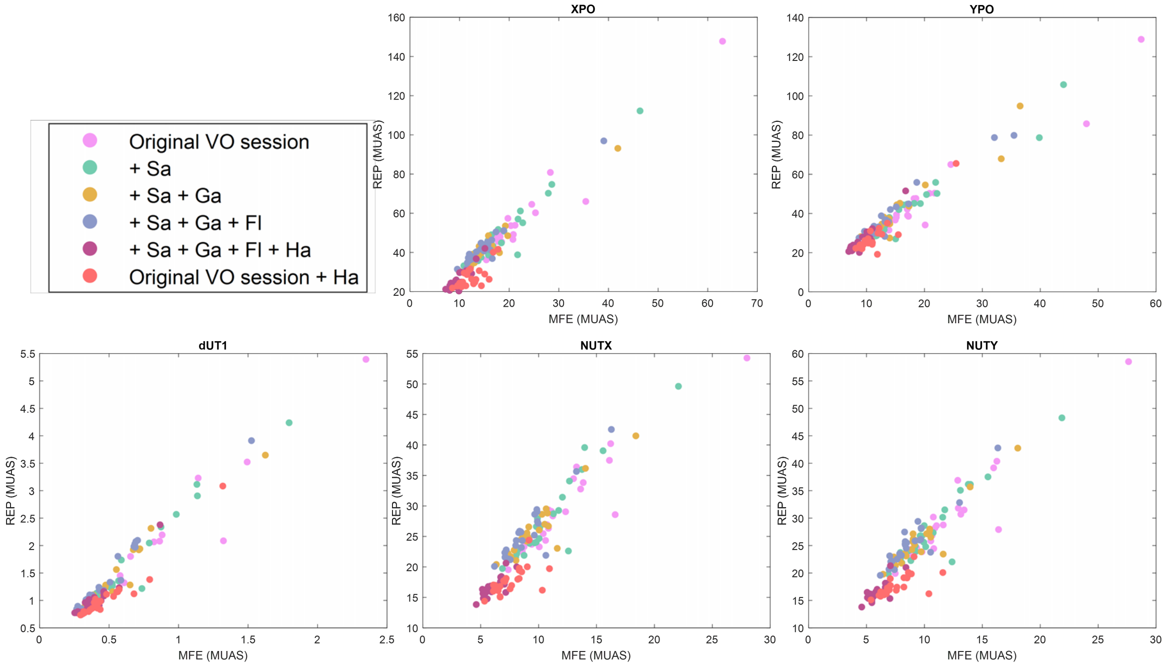

Fig. 1 MFE vs. REP, for each session configuration (different colors) and EOPs. MFE and repeatabilities for 1,000 simulations of the 24 sessions during 2023 are computed. Point clouds closer to 0 have minor MFE and REP.

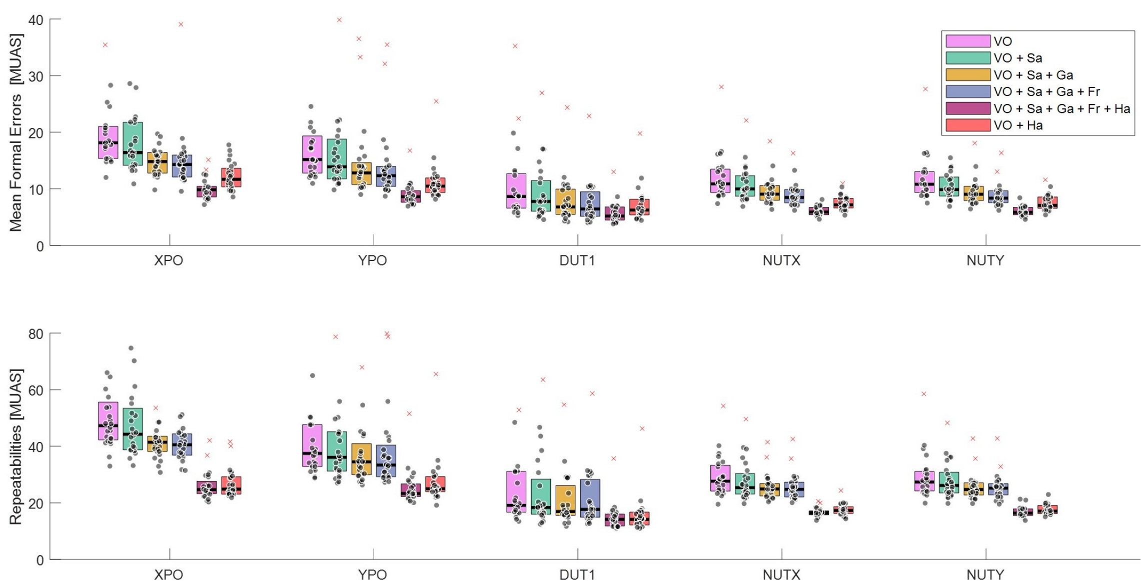

Fig. 2 MFE and REP box plots for each session configuration (different colors) and EOPs. MFE and repeatabilities for 1,000 simulations of the 24 sessions during 2023 are computed.

- To assess the impact on UT1 data quality by raising VGOS observation frequencies above 5G, i.e., considering a new range between 4–14 GHz.
- To assess the impact of a very long West-East baseline on UT1, comparing with the VGOS-INT-A sessions.

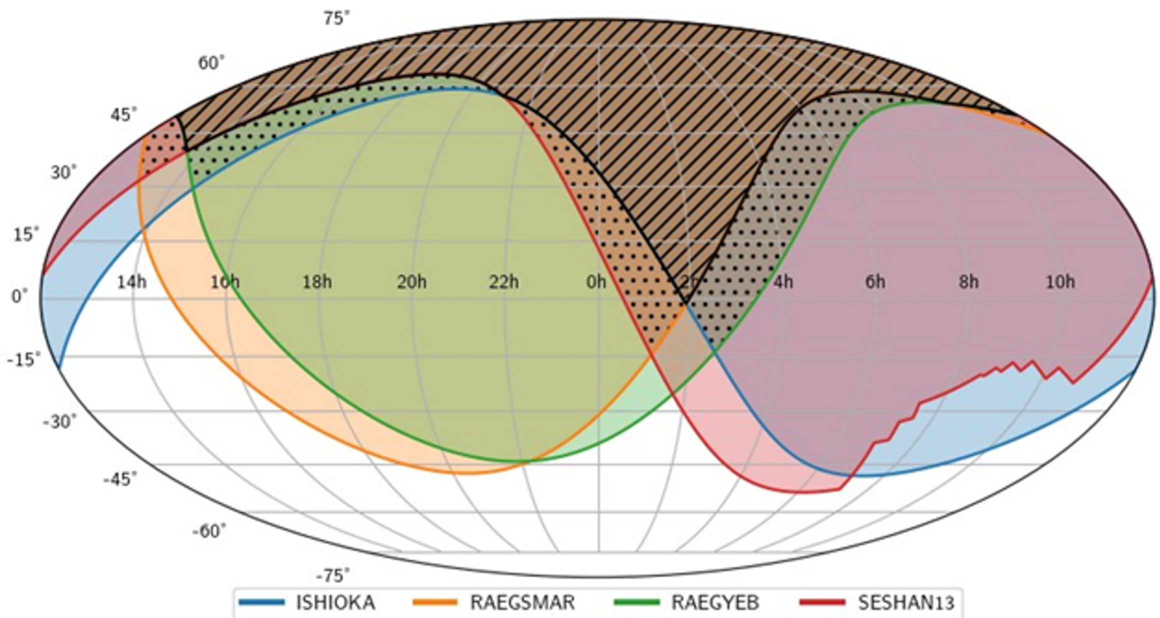

Fig. 3 VGOS-INT-G common visibility. Schedules and figure by DACH Operation Center.

There are three phases:

- Test: from 15th February to 18th April. Schedule with IVS standard Intensive configuration.
- Phase 1: from 25th April to when Phase 2 is ready for starting. Schedule optimized for VGOS observations, S/N based.
- Phase 2: A new frequency plan is defined, raising VGOS observation frequencies above 5G. Once the new plan is defined, the observations will switch weekly between an S/N schedule and the new frequency plan.

4 Conclusions

- Initial simulations of the RAEGE network yielded promising results.
- Extended simulations covering a one-year period were conducted, involving 24 VGOS-OPS sessions in 2023 with seven different configurations.
- The configuration including VGOS-OPS, Santa María, Gran Canaria, Flores, and HartRAO stations minimized Mean Formal Error (MFE) and Repeatability (REP).
- Introducing a simulated HartRAO VGOS station significantly impacted the network's performance, especially in estimating Earth Orientation Parameters (EOPs), highlighting the importance of including southern hemisphere stations.
- The RAEGE network demonstrated strong performance in estimating coordinates, achieving millimeter-level accuracy.
- A new VGOS Intensive session type, VGOS-INT-G, was included in the 2024 Master Schedule, involving RAEGE, the Geospatial Information Authority of Japan, and the Shanghai Astronomical Observatory.
- This session type aims to improve UT1 data, assessing the impact of a new very long West-East baseline and testing VGOS observation frequencies above 5 GHz.

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