

First comparison of GRACE-FO-derived gravity variations and superconducting gravity observations at the Argentine-German Geodetic Observatory (AGGO)

Pedro Granovsky^{1,2} , Ezequiel D Antokoletz^{3,4} 

Abstract Continuous monitoring of gravity variations has been contributing to the study of a wide range of geophysical and geodynamic phenomena. In particular, satellite gravity missions such as GRACE and its follow-up mission, GRACE-FO, play an essential role not only for the development of global gravity models but also for the analysis of temporal variations of the Earth's gravity field related to, for example, climate change. On the other hand, superconducting gravimeters (SGs) allow for a precise and stable monitoring of gravity variations at particular stations. In this sense, SGs have a great potential as a ground-truth observation useful for the validation of satellite-derived products. In this study, a first comparison of nine different satellite gravity solutions from GRACE-FO with the SG time series recorded at the Argentine-German Geodetic Observatory (AGGO) is performed. Spherical harmonic coefficients from GRACE-FO were used to derive gravity variations at AGGO's location after applying different isotropic and non-isotropic de-stripping filters. Results show correlations up to 80% between the SG time series and several GRACE-FO solutions. A spectral analysis complemented by an Empirical Orthogonal Function (EOF) analysis shows that annual signals are well represented especially by non-isotropic solutions. Longer periods are also present in both observations, although the SG presents larger amplitudes, which could be related to local effects not captured by the lower spatial resolution of GRACE-FO.

Keywords Superconducting gravimetry, GRACE-FO, AGGO

Primera comparación de las variaciones de gravedad derivadas de GRACE-FO y las observaciones de gravedad superconductora en el Observatorio Argentino-Alemán de Geodesia (AGGO)

Resumen El monitoreo continuo de variaciones de gravedad contribuye al estudio de una gran cantidad de efectos geofísicos y geodinámicos. En particular, misiones satelitales de gravedad como GRACE y su continuación, GRACE-FO, juegan un rol fundamental no solo para el desarrollo de modelos globales de gravedad, sino también para el análisis de variaciones temporales del campo de gravedad terrestre relacionado a, por ejemplo, cambio climático. Por otra parte, los gravímetros superconductores (SGs) permiten el monitoreo preciso y estable de variaciones de gravedad en estaciones puntuales. En este sentido, los SGs tienen un gran potencial para la validación de productos derivados de observaciones satelitales. En este estudio, se realiza una primera comparación de nueve soluciones diferentes de GRACE-FO con observaciones del SG ubicado en el Observatorio Argentino-Alemán de Geodesia (AGGO). Se utilizaron los coeficientes armónicos esféricos de GRACE-FO para derivar las variaciones de gravedad en la ubicación de AGGO tras aplicar diferentes filtros de *de-stripping* isotrópicos y no-isotrópicos. Los resultados muestran correlaciones de hasta el 80% entre la serie temporal observada con el SG y algunas soluciones de GRACE-FO. Un análisis espectral, complementado con análisis de Funciones Ortogonales Empíricas (EOF), muestra que las señales anuales están bien representadas especialmente por las soluciones no-isotrópicas. Ambas observaciones también presentan periodos más largos, aunque el SG presenta mayores amplitudes, lo que podría estar relacionado con efectos locales no captados por la menor resolución espacial de GRACE-FO.

Palabras clave Gravimetría superconductora, GRACE-FO, AGGO

INTRODUCTION

The Gravity Recovery and Climate Experiment (GRACE; Tapley and Reigber, 2001) and its continuation, GRACE Follow-On (GRACE-FO; Kornfeld et al., 2019), are satellite gravity missions that provide essential information to study the Earth's gravity field and its temporal variability with a global coverage and an approximate spatial resolution of 200–300 km (Barthelmes, 2009; Tapley et al., 2019). Over the past two decades, this data has contributed to the development of global geopotential models and the

¹ Centro de Meteorología espacial, Atmósfera terrestre, Geodesia, Geodinámica, diseño de Instrumental y Astrometría (MAGGIA), Universidad Nacional de La Plata, Argentina

² Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina

³ Bundesamt für Kartographie und Geodäsie (BKG), Germany

⁴ Centro de Investigaciones Geofísicas (CIGEOF), Universidad Nacional de La Plata, Argentina

* Contacto: pedrog@fcaglp.unlp.edu.ar

investigation of temporal variations of the gravity field of the Earth related to hydrological processes, sea level changes or ice-mass variations in polar regions (e.g., Luthcke et al., 2006; Tamisiea et al., 2007; Velicogna and Wahr, 2006). The GRACE mission was operated during the period 2002-2017 and, due to its success, GRACE-FO was launched in 2018.

Superconducting gravimeters (SGs) are the most sensitive relative sensors offering high temporal resolution and stability with exceptional precision (Hinderer et al., 2015; Neumeyer, 2010). Although they provide measurements at single points (stations), their high-sensitivity has allowed not only to investigate geophysical processes but also to validate mass variations in the Earth system as represented through atmospheric, ocean and/or hydrological models (e.g., Antokoletz, Wziontek, Dobsław, et al., 2024; Antokoletz et al., 2026; Creutzfeldt et al., 2008).

The Argentine-German Geodetic Observatory (AGGO) is a fundamental geodetic observatory located close to the city of La Plata, Argentina. AGGO integrates the main space geodetic techniques—Very Long Baseline Interferometry (VLBI), Global Navigation Satellite Systems (GNSS), and Satellite Laser Ranging (SLR)—together with a time laboratory with three cesium clocks and two hydrogen masers, and a gravity laboratory. In addition, meteorological and hydrological sensors provide complementary measurements at the station.

The gravity laboratory operates the superconducting gravimeter SG038, which has been recording gravity variations continuously since December 2015, and the absolute gravimeter FG5-227, which was operated during the period 2018-2022 and recently resumed in July 2025. Several studies have been conducted using this gravity series. Antokoletz et al. (2020) investigated instrumental parameters of SG038 by combining them with absolute gravity measurements and hence, defined a gravity reference function for the station. Antokoletz et al. (2022, 2017) determined local tidal models for the station, and Antokoletz, Wziontek, Dobsław, et al. (2024) and Oreiro et al. (2018) investigated non-tidal ocean loading effects from the Río de La Plata estuary and globally, respectively. Also, hydrological effects have been analyzed at the station by Mikolaj et al. (2019), J. Pendiuk et al. (2023), and J. E. Pendiuk et al. (2020).

Since the establishment of GRACE, various studies have sought to validate GRACE observations through superconducting gravity time series in Europe (Abe et al., 2012; Neumeyer et al., 2006; Weise et al., 2009). However, one of the main limitations for this type of comparison is the treatment of local effects for SGs, as they are more sensitive to mass redistribution nearby the station (Weise et al., 2012). Van Camp et al. (2014) argued that SGs are mainly affected by local effects and due to this, no significant correlation is found between SG and GRACE observations. Yet, when selecting SG stations to validate satellite observations, the processing involved in each observable and the compatibility of the corrections applied in each case are critical aspects to make such comparison feasible (Crossley et al., 2014). Nevertheless, the need for validation of satellite gravity observations by means of ground-based measurements remains a challenge and it is the subject of current investigation (Chen et al., 2022).

In this study, we compare, for the first time in the region, nine different processing solutions from GRACE-FO Level-2 datasets with the SG038 gravity time series recorded at AGGO. The next section describes both the satellite gravity and SG data used together with the processing applied in each case. For the GRACE-FO data, the methodology applied to compute gravity disturbances from Stokes coefficients is also described. Results from the comparison are later presented and discussed, and the main findings are summarized in the CONCLUSIONS.

MATERIALS AND METHODS

In this section, we describe the satellite gravity data and superconducting gravimeter observations used in this study. Firstly, different solutions from GRACE-FO and their characteristics are clarified, together with the corrections and filtering techniques applied in each case. Moreover, the methodology used to derive gravity disturbances from the GRACE-FO monthly solutions at AGGO is explained. Secondly, the processing steps and corrections applied to the SG time series are described.

Satellite gravity data

GRACE-FO data is routinely processed by various scientific centers that comprise the Scientific Data System (SDS) and provided in different processing levels. For this study, Level-2 Release 06 (RL06; Dahle et al., 2019) products processed by the GFZ Helmholtz Centre for Geosciences and Level-2B Release 02.1 (RL02.1; Dahle et al., 2025) products from the International Combination Service for Time-variable Gravity Fields (COST-G; Jäggi et al., 2020) are used. The time span from October 2018 to April 2025 is considered, and all data were obtained through the International Center for Global Earth Models (ICGEM; Ince et al., 2019).

Level-2 data from GFZ consist of monthly sets of gravity field Stokes coefficients up to degree and order 96, obtained from the GFZ Information System and Data Center (ISDC). The data are available at <https://isdc-data.gfz.de/grace/> (accessed January 15, 2026). In the RL06 processing standards (Dahle et al., 2019), all main contributions to gravity variations are removed. Atmospheric and non-tidal ocean loading effects are considered and subtracted based on the AOD1B de-aliasing products (Dobslaw, Bergmann-Wolf, Dill, Poropat, & Flechtner, 2017; Dobslaw, Bergmann-Wolf, Dill, Poropat, Thomas, et al., 2017). Solid Earth tides and pole tide effects are considered based on the International Earth Rotation and Reference Systems Service (IERS) Conventions 2010 (Petit & Luzum, 2010) and ocean tide loading effects are removed based on the FES2014b model (Egbert & Ray, 2003; Lyard et al., 2021).

Level-2B products from COST-G include the monthly sets of the Stokes coefficients up to degree and order 90. These products are derived as a combined solution from various analysis centers (Jäggi et al., 2020): the Astronomical Institute, University of Bern (AIUB), the Centre National d'Etudes Spatiales (CNES/GRGS), the GFZ Helmholtz Centre for Geosciences, and the Institute of Geodesy, Graz University of Technology (IfG/ITSG). As described by Meyer et al. (2024), these are post-processed Level-2 products which, in addition to the geophysical corrections mentioned above, a long-term mean gravity signal is subtracted, low-degree spherical harmonics coefficients are replaced and corrections for Glacial Isostatic Adjustment (GIA) are applied.

Satellite gravity data present a spatial-domain noise predominantly oriented in a north-south direction, known as "striping", due to the satellite's near-polar orbit and aliasing effects. These effects can be attenuated or mitigated by applying de-striping filters over the Stokes coefficients. In this study, several isotropic and non-isotropic filters are used and compared to the SG time series. The isotropic filter was considered through a low-pass Gaussian filter (Jekeli, 1981; J. Wahr et al., 1998), characterized by several radii: 500, 750, and 1000 km commonly used in the literature (Abe et al., 2012; Kusche et al., 2009; Kusche, 2007; J. Wahr et al., 1998). These filters were implemented following Chambers (2006). As the radius of the filter increases, the filter is stronger, meaning that the coefficients are more attenuated. Gaussian filters are effective but they may diminish the geophysical signal, especially at high frequencies, when considering larger values than 500 km. On the other hand, a shorter radius contains higher frequencies, but it does not properly diminish stripping effects.

Within the non-isotropic filters, Kusche et al. (2009) and Kusche (2007) developed the de-correlation (DDK) filters and Horvath et al. (2018) the time-variable de-correlation filters (VDK). These filters attenuate the Stokes coefficients heterogeneously (i.e., not only as a function of degree/order), considering the covariance error of the data and depending on a smoothing factor. DDK and VDK filters are usually more efficient than the Gaussian filters (Kusche, 2007). In this study, three different sets of smoothing factors are used as provided by ICGEM: DDK₁, DDK₃, and DDK₅ from the GFZ Level-2 data; and the VDK₁, VDK₃ and VDK₅ datasets from COST-G Level-2B. These filters are characterized by a smoothing factor, going from stronger (DDK₁/VDK₁) to softer (DDK₅/VDK₅) filters.

Based on the sets of filtered Stokes coefficients, it is possible to infer the gravity disturbances at a certain location on the Earth's surface, applying a spherical harmonic expansion of the gravity potential

through (Abe et al., 2012):

$$\begin{aligned}\delta g(\varphi, \lambda) &= \delta g_G + \delta g_{load} \\ &= \frac{GM}{R^2} \sum_{l=0}^{l_{max}} (l+1 - 2h_l') \times \sum_{m=0}^l [\Delta C_{lm} \cos(m\lambda) + \Delta S_{lm} \sin(m\lambda)] P_{lm}(\sin(\varphi)),\end{aligned}\quad (1)$$

where (φ, λ) are the spherical geocentric latitude and longitude of the computation point. δg_{load} accounts for the additional height-induced loading effect which is measured by SGs but not by satellite gravity observations (Abe et al., 2012; Neumeyer et al., 2006). l and m are the degree and order of the Stokes coefficients, respectively, with l_{max} the maximum degree. GM is the Earth's gravitational constant, R the Earth's radius, h_l' are the load Love numbers of degree l , and P_{lm} are the associated Legendre functions. ΔC_{lm} and ΔS_{lm} are the variations of the Stokes coefficients from GRACE-FO with respect to the reference ellipsoid GRS80 (Moritz, 1980).

For each monthly dataset of Stokes coefficients derived from GRACE-FO, the gravity disturbance is obtained considering the equation 1 at the location of AGGO $(\varphi, \lambda) = (-34^\circ 52' 26.0'', -58^\circ 08' 23.5'')$.

Superconducting gravity time series

The superconducting gravimeter time series from the SG038 at AGGO was processed by Antokoletz (2022) to obtain hourly gravity residuals from October 2018 to April 2025. Solid Earth tides as well as ocean tide loading effects related to daily and sub-daily tidal components were removed through a harmonic analysis with the ETERNA-X software (<https://eterna.bkg.bund.de/>), while long-periodic signals were taken into account based on the theoretical model from Dehant et al. (1999). Atmospheric loading effects were removed based on the atmospheric attraction computation service (Atmacs) of BKG (Antokoletz, Wziontek, Klügel, et al., 2024; Klügel & Wziontek, 2009) combined with the local atmospheric pressure recorded at the station. Non-tidal ocean loading corrections were also applied as computed by Atmacs (Antokoletz, Wziontek, Klügel, et al., 2024). Polar motion effects were removed using the EOP C04 polar coordinates as published by IERS with an amplitude factor of 1.16 (J. M. Wahr, 1985).

Instrumental long-term gravity variations, i.e. instrumental drift, were corrected based on Antokoletz et al. (2020). This was obtained through the combination of absolute gravity measurements of the FG5-227 and the observations of the SG038 over a period of more than one year. Consequently, a linear drift correction with a coefficient of $-110 \text{ nm s}^{-2} \text{ yr}^{-1}$ was applied to the time series.

Gravity variations as recorded by SGs are particularly affected by local mass variations that occur in the vicinity of the station. In particular, AGGO shows significant gravity variations related to local hydrology, mainly due to episodes of heavy rainfall and groundwater variations, as reported by Cañas (2025). A local hydrological model has been developed by Mikolaj et al. (2019) based on local hydro-meteorological observations at AGGO (Mikolaj et al., 2018) and covers a few hundred meters around the station. However, the time span of this model is currently limited to the period from April 2016 to November 2018 and it does not coincide with the time period considered in this study (October 2018 to April 2025). Therefore, this model has not been applied as a correction to the terrestrial gravity time series. Although the consideration of hydrological contributions based on a linear regression or a Bouguer plate approximation (e.g., Hinderer et al., 2015; J. E. Pendiuk et al., 2020) would help to account for local effects, the validity and spatial extension of such simple models might affect the interpretation of the results when comparing with satellite-based observations. For this reason, no local hydrological model was applied in this study, being this aspect subject of future studies.

Finally, the hourly SG residuals were down-sampled by applying a moving average window to obtain a smoothed monthly series compatible with the time series obtained from GRACE-FO. Both time series are depicted in Figure 1.

The corrections applied for the main geophysical phenomena during processing of each technique are summarized in Table 1. Such corrections need to be considered to ensure the consistency of their comparison. In all cases, all major contributions to gravity variations are removed from both



Figure 1. SG038 gravity residuals recorded at AGGO. In green, gravity residuals with 1-hour sampling. In black, the same time series down-sampled to monthly resolution after applying the moving average window.

Table 1. Applied corrections for every geophysical contribution considered in the processing of GRACE-FO (Level-2 from GFZ and Level-2B from COST-G) and the SG038. The last column shows the approximate peak-to-peak amplitude for each effect on the Earth's surface.

Process	Level-2 GFZ	Level-2B COST-G	SG038	Approximate peak-to-peak amplitude
Earth tides	IERS Conventions (2010)	*	Local model + theoretical long-period	6000 nm s ⁻²
Ocean tide loading	FES2014b	*	Local model	60 nm s ⁻²
Atmospheric loading	AOD1B Release 06	*	Atmacs + local pressure	100 nm s ⁻²
Pole tide and LOD	IERS Conventions (2010)	*	EOP 04 from IERS	50 nm s ⁻²
Non-tidal ocean loading	AOD1B Release 06	*	Atmacs	20 nm s ⁻²
Instrumental drift	—	—	Combination	110 nm s ⁻² yr ⁻¹
Other corrections	—	Low-degree coefficients, GIA	—	—

* Corrections depend on the processing center (see Meyer et al., 2024).

observations. For the SG, an additional correction for its instrumental drift is included through a linear trend. On the other hand, in the Level-2B datasets from COST-G, the low-degree coefficients of the gravity field are replaced according to Dahle et al. (2025). The aim of this replacement is to improve the representation of the long-wavelength components of the gravity field, which are better determined through other geodetic techniques such as SLR. Finally, while GIA effects are also corrected in this dataset, their amplitude at AGGO can be neglected.

RESULTS AND DISCUSSION

Firstly, all different solutions from GRACE-FO are analyzed and compared against the SG038 time series at AGGO. Secondly, results from a spectral analysis are presented and finally, common characteristics between both datasets are analyzed through Empirical Orthogonal Functions (EOF) to extract common signals between both observations.

Gravity variation comparison

To study the gravity signal time variations, both terrestrial and satellite series were detrended for the entire time span to focus on inter-annual, annual and semi-annual variations. Long-period variations

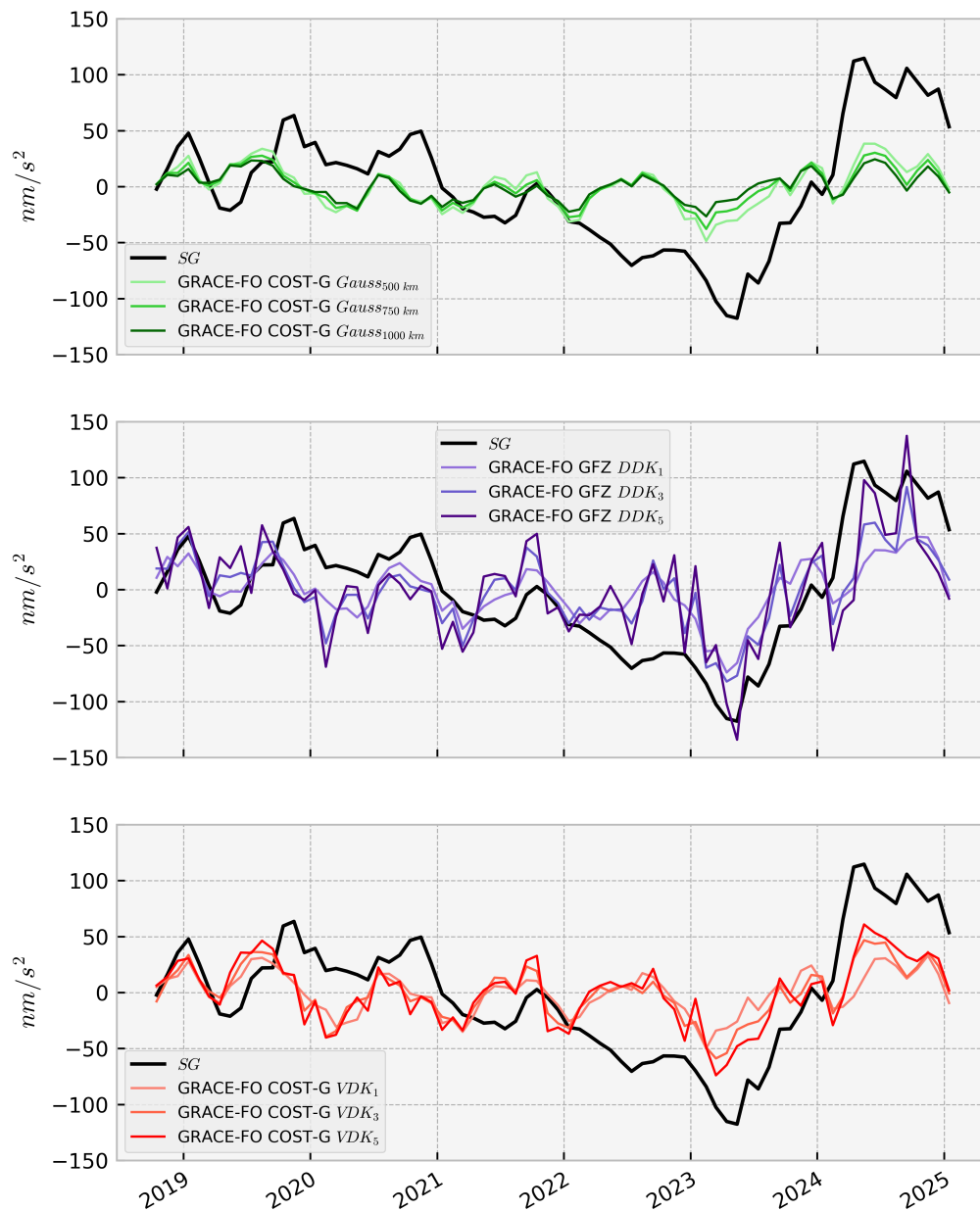


Figure 2. Terrestrial and satellite detrended gravity series. In black, the SG time series is depicted. Top panel: GRACE-FO with different Gaussian filters applied in green. Middle panel: different DDK solutions in purple. Bottom panel: different VDK solutions in red.

are not the subject of this study as the time span available is rather short to analyze them. All time series are shown in [Figure 2](#).

Most of the GRACE-FO time series show common characteristics with the gravity residuals from the SG. The correlation coefficient provides a first impression on the consistency between both observations. These are presented in [Table 2](#) and show, in general, high values of at least 60% correlation for the VDK₁, DDK₁, and DDK₅ solutions, reaching up to 80% for the solution with the Gaussian filter with radius of 500 km (Gauss₅₀₀) and 86% for the VDK₃ solution. However, in some cases, a small time or phase shift can be recognized between the local maximums or minimums as observed in both time series. This becomes clearer for the different Gauss and some of the VDK-solutions. A cross-correlation shows a lag of up to four months that can be seen for the first ones compared to the SG time series and one month for the VDK₁ and VDK₃ solutions ([Table 2](#)). For the Gaussian solutions, the lag increases with the radius of the filter and could be related to the nature of the filter. Similar behaviors have also been reported in other studies (e.g. Abe et al., [2012](#)).

Table 2. Correlation coefficients between SG and the different GRACE-FO solutions (ρ), the phase lag obtained from the cross-correlation, and the standard deviation (STD) of each signal. The STD of the difference between each GRACE-FO solution and the SG time series is also shown (STD_{diff}). The highest correlation and lowest STD_{diff} are shown in bold.

	ρ	Lag [months]	STD [nm s ⁻²]	STD _{diff} [nm s ⁻²]
SG	—	—	54.5	—
Gauss ₅₀₀	0.80	2	19.2	45.8
Gauss ₇₅₀	0.75	3	15.4	48.7
Gauss ₁₀₀₀	0.71	4	12.2	51.1
DDK ₁	0.59	0	24.8	40.1
DDK ₃	0.70	0	32.5	39.1
DDK ₅	0.61	0	42.9	44.8
VDK ₁	0.63	1	18.5	48.1
VDK ₃	0.86	1	23.4	43.1
VDK ₅	0.81	0	28.5	42.9

In general, all GRACE-FO solutions show lower amplitudes than the SG038, as reported through the standard deviation (STD) presented in Table 2 as a measure for the remaining variability of each signal. This is particularly the case for the solutions obtained with isotropic filters, i.e. Gaussian filters, where for all radii, the STDs are the lowest. It can also be seen that as the radius increases, the STD decreases, meaning that the signal is further smoothed. This is not generally the case for the non-isotropic filtered solutions (DDK and VDK), where they generally show more consistent amplitudes with each other. These results also agree with those obtained by Abe et al. (2012) and Han et al. (2005), where SG time series also show better agreement with non-isotropically filtered satellite gravity data. The higher amplitudes observed by the SG could be related to the fact that it is more exposed to local mass variations compared to GRACE-FO: SGs are highly sensitive to mass variations in a few hundred meters around the station, while GRACE-FO has a spatial resolution of 200 – 300 km (Creutzfeldt et al., 2008; Neumeyer et al., 2006; Weise et al., 2012).

Moreover, even though the DDK₁ and VDK₁ solutions show smaller amplitudes compared to the SG, local trends, maximums and minimums are well represented by both datasets. This is particularly true for the minimum observed in June 2023, which is well represented in these datasets, whereas this is not the case with the Gaussian solutions. DDK₅ and VDK₅, on the other hand, show high-frequency variations that are not observed in the SG time series. This may suggest that the smoothing factor is not strong enough to diminish striping effects compared to the other filters, as suggested by Abe et al. (2012). Such effects may have a significant impact at the location of AGGO as it is only 15 km away from the Río de La Plata and aliasing effects may not be correctly removed after filtering.

Theoretically, if both observables are affected by the same signals, the variability of their difference should tend to zero. The standard deviation of the difference between the SG038 time series and the different GRACE-FO solutions is also shown in Table 2 (STD_{diff}). The lowest variability is found for DDK₃ with 39.1 nm s⁻². Contributions to this variability may be caused by local mass variations affecting the SG, by remaining striping effects not properly removed during the filtering process in the GRACE-FO solutions or leakage effects (Chen et al., 2022; Lecomte et al., 2026).

Common characteristics

A spectral analysis of the SG time series and five selected satellite solutions was performed in order to study the dominant signal periods. Figure 3 depicts the normalized amplitude spectrum.

As can be appreciated, the stronger signal is present in all datasets at a period of ~ 0.2 cpy or ~ 5 years. For this period, the SG exhibits the largest amplitude followed by DDK₃. The annual cycle shows the

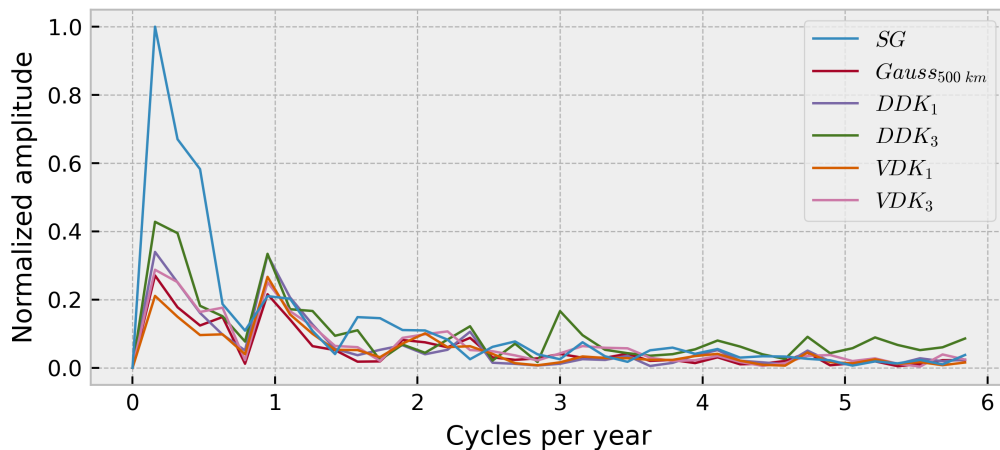


Figure 3. Amplitude spectrum of the SG time series and five selected satellite solutions.

best agreement between the different solutions and the SG, showing also a very good agreement in the observed amplitude. It is also noticeable that for the SG, a signal is present between annual and semi-annual cycles, which is not present in any of the GRACE-FO solutions. This could be related to local effects better seen by the SG. On the other hand, the DDK₃ solution shows significant amplitudes present at 3 cpy and systematically larger amplitudes above 3 cpy compared to all other solutions. This could be explained by stripping or aliasing effects not properly removed through the de-correlation filter. On the contrary, such signals are not present in the VDK₃ solution.

In order to achieve a quantitative comparison of the temporal variability of the different GRACE-FO solutions and the SG time series, an EOF analysis was performed following Preisendorfer (1988) and Wilks (2011). EOF analysis allows us to look for common signals between different observables either spatially or temporally. In this study, we apply EOF to analyze the principal components of the SG time series compared to the different satellite solutions. The series corresponding to the location of AGGO were detrended in order to isolate and study the signal variability through the EOF modes. The input data derive from gravity measurements, which can be expressed as the linear combination of both observations and, hence, they satisfy the linearity and additivity hypothesis of the method (Preisendorfer, 1988).

Figure 4 shows the percentage of representation of the two modes recovered from the EOF analysis. In general, Mode 1 for all cases allows to represent more than 65% of both observations, reaching more than 79% for three particular solutions: Gauss₅₀₀ km, DDK₁ and VDK₃. A better representation through Mode 1 is reached when the filter strength increases for the DDK and Gaussian filters. However, this behavior is not observed for the VDK filters. For DDK₁, Mode 1 represents as much as 86.6%. For these solutions, both modes were recovered and are depicted in Figure 5. In all three cases, Mode 1 is predominantly characterized by a main annual variability present in the SG time series and the different GRACE-FO solutions. On the other hand, Mode 2 represents just about 20% of the signal for the Gauss₅₀₀ km solution and even less for the other two solutions.

CONCLUSIONS

In this work, nine different satellite gravity solutions from GRACE-FO are compared with high-accuracy terrestrial gravity measurements as recorded with the superconducting gravimeter SG038 at the Argentine-German Geodetic Observatory (AGGO), located close to the city of La Plata, Argentina. GRACE-FO solutions are derived from the Level-2 and 2B spherical harmonic coefficients as processed by GFZ and COST-G, respectively, before applying different isotropic and non-isotropic filters. Gaussian filters with radii of 500 km, 750 km, and 1000 km were analyzed, while for the non-isotropic filters, de-correlation (DDK₁, DDK₃, and DDK₅ from GFZ) and time-variable de-correlation (VDK₁, VDK₃, and VDK₅ from COST-G) were considered. The time span covers the period from October 2018 to April

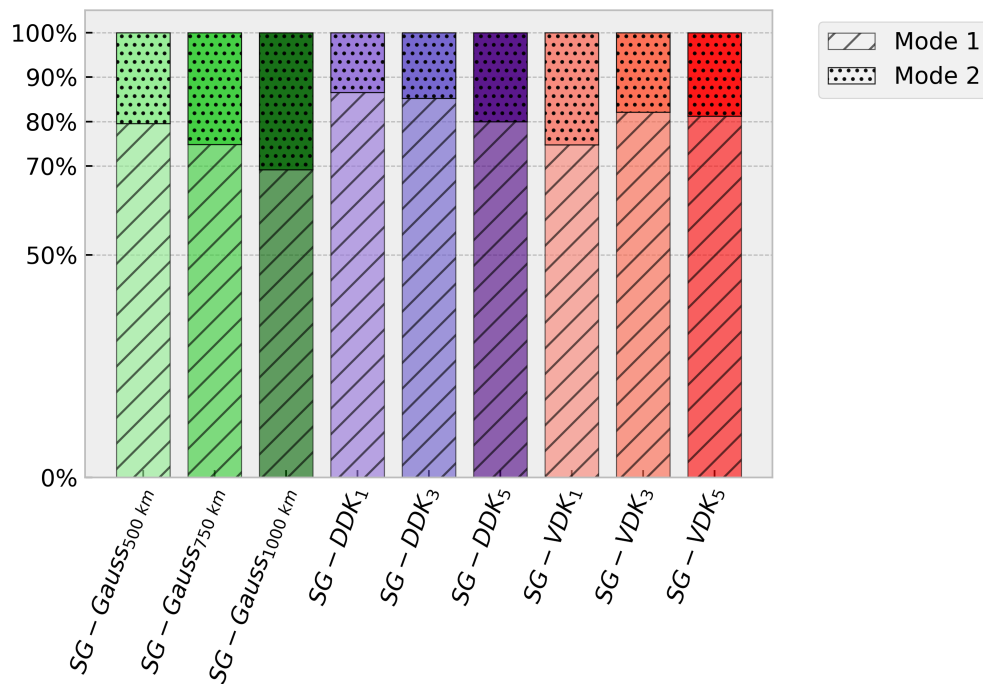


Figure 4. Percentage of representation of Modes 1 and 2 from the EOF analysis for each GRACE-FO solution and the SG time series.

2025. The SG038 time series follows the processing described in Antokoletz (2022).

The comparison was performed ensuring the compatibility of the corrections applied for each observable. A correlation of at least 60% was found between the analyzed satellite solutions and the SG time series, reaching 80% for the Gauss₅₀₀ km, and 86% for the VDK₃ solution. Observed amplitudes are significantly lower for the different Gauss solutions, which reflects the smoothness of the filter-radii as reported by the standard deviation of each signal. More consistent magnitudes are observed in the non-isotopically filtered solutions, although high-frequency variability is present in the DDK₅ solution, probably due to remaining stripping and aliasing effects not correctly removed by the filter. The SG time series still shows the largest observed amplitudes, and this may be explained by the fact that the SG is more sensitive to mass redistribution near the station, such as those associated with local hydrology. Moreover, for some solutions, a small phase between both signals is appreciated, which reaches 4 months for the Gauss₁₀₀₀ km solution.

The spectral analysis reveals a dominant component at a period of about 5 years in the SG, which is also present in the satellite solutions, although with significantly smaller amplitude. However, the time span considered might be too short to resolve such long periods and shall be further studied once a longer time span is available. The annual signal is faithfully reproduced by all solutions and the SG time series, indicating strong agreement. This is also confirmed through an EOF analysis, where Mode 1 represents more than 65% of the variance in both signals for all GRACE-FO solutions. The highest representation of Mode 1 reaches 86.6% for DDK₁ and 82.1% for the VDK₃ solution, suggesting improved agreement for the non-isotropic filters compared to the different Gauss solutions.

These results suggest that the application of non-isotropic de-stripping filters yields gravity signals that provide a better agreement with terrestrial observations. However, a potential limitation of this comparison is the presence of aliasing effects related to the proximity of AGGO to the Río de La Plata. This comparison could also be complemented with other GRACE-FO mascon solutions (e.g., Watkins et al., 2015) or compared with other observations, such as those derived from GNSS or through the consideration of global hydrological models. Moreover, the SG is highly sensitive to local mass redistribution, whereas GRACE-FO is limited by its coarse spatial resolution. This could also be addressed through local hydrological modeling. Although Mikolaj et al. (2018) developed such a

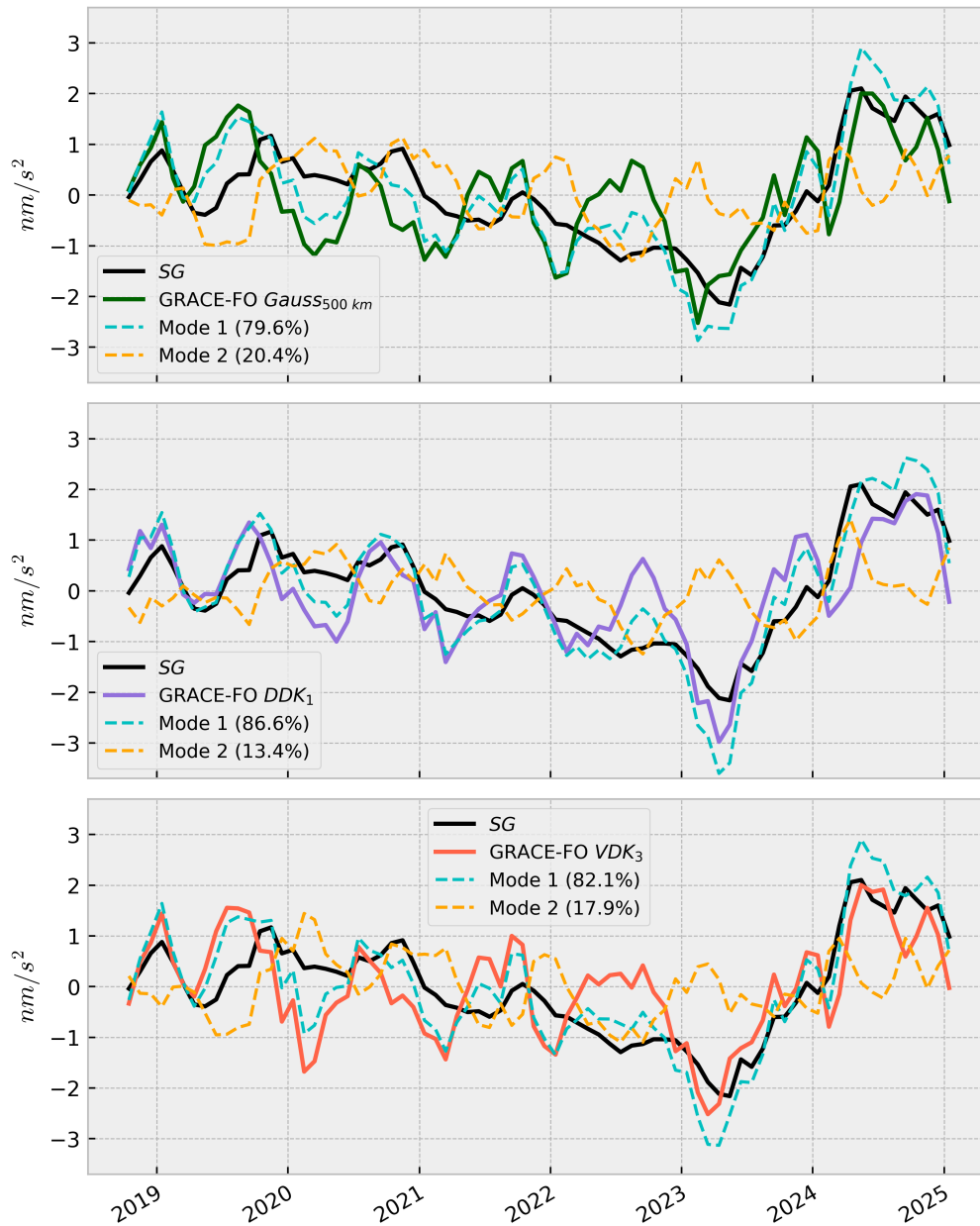


Figure 5. SG time series and three selected GRACE-FO solutions: a) $Gauss_{500}$ km, b) DDK_1 , and c) VDK_3 solution. For each of them, Modes 1 and 2 from the EOF analysis are depicted. In each case, the representative percentage is presented.

model, the time span coverage did not allow us to take it into account in this study.

Finally, with the perspective of future satellite gravity missions such as GRACE-I, the comparison and validation of satellite-derived products and processing procedures through ground-truth observations such as those performed with superconducting gravimeters will play an essential role. This study contributes to this validation and may support future investigations at AGGO, as well as comparative studies in other regions.

Acknowledgments The authors acknowledge the efforts of the operators of the SG038 at AGGO. We also thank the Editor-in-Chief, Danilo Velis, the Associate Editor, Mauricio Gende, and the two anonymous reviewers for their valuable comments and suggestions.

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