Comparison between a 20-year terrestrial and satellite gravity data at Mt. Etna volcano (Italy)

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Introduction

Gravity measurements are increasingly used for high-precision and high-resolution Earth investigation. Recent times reveal the intention to combine both terrestrial and satellite data in order to reach higher accuracy for several purposes such as geological structures determination and geoid models construction.

Here we present results of a comparison between a twenty-year (2002-2022) absolute gravity data collected through the Microg LaCoste FG5#238 absolute gravimeter (AG) in the framework of repeated measurements at Mt. Etna-Serra La Nave station (SLN) at about 1750m above sea level, another in the city of Catania (CTA) (*Figure 1*), and satellite gravity data provided by CNES/GRGS Earth gravity field models from GRACE and SLR data.

The comparison allowed to estimate the long-term correlation between the two dataset and a remarkably good fit was found in the long-term trend, revealing gravity changes most likely due to hydrological and volcanological effects.

Our study shows how the combination of terrestrial and satellite data seems promising to obtain a broader estimation of the temporal characteristics of the studied processes. The combined use of these dataset results crucial especially in a harsh, unsteady and changing environment as well as active volcanoes.

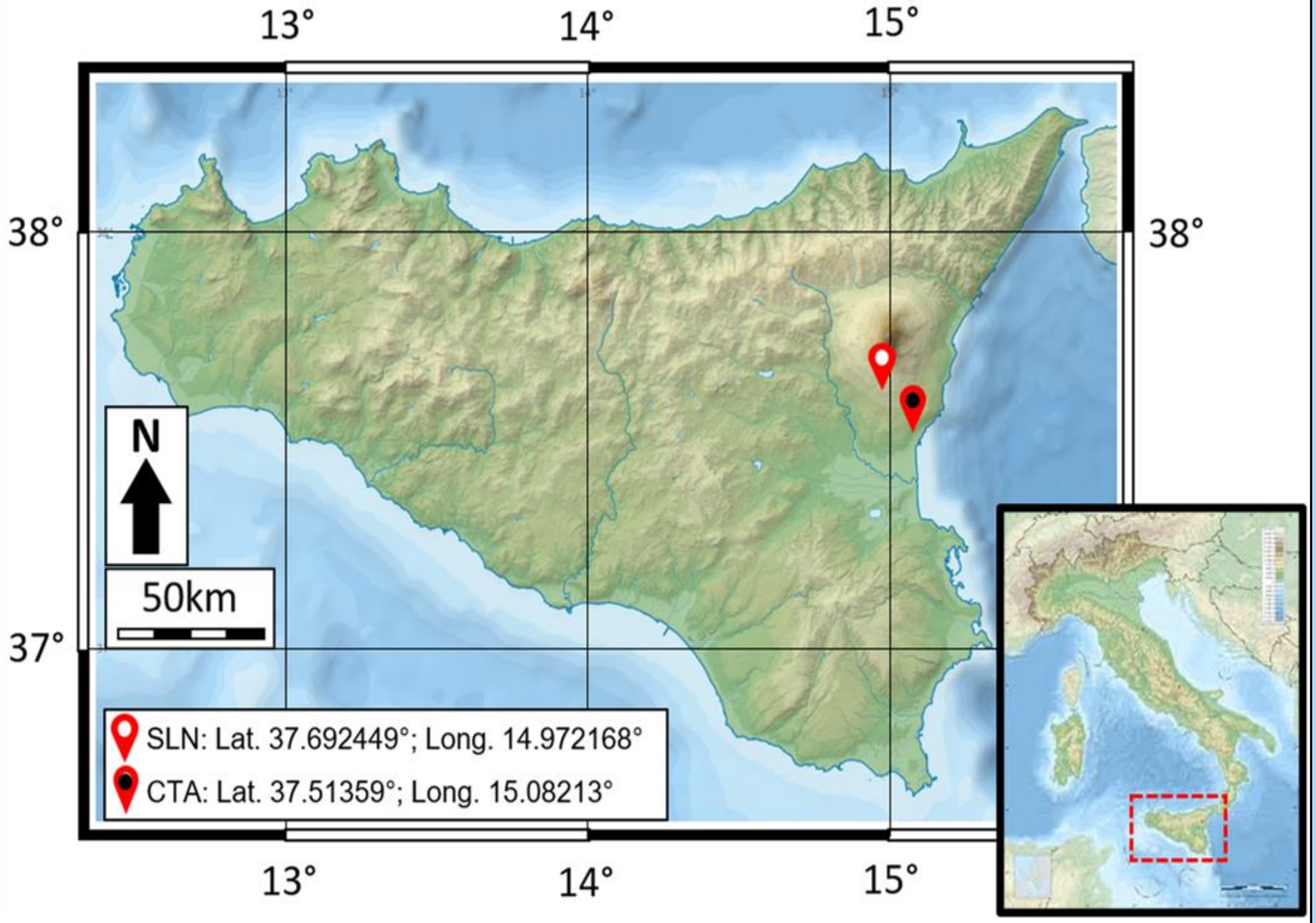

Figure 1: absolute gravity stations measured and compared with GRACE satellite data.

Satellite Measurements

GRACE

GRACE (Gravity Recovery And Climate Experiment, 2002-2017), and its successor GRACE-FO (Follow On, since 2018), are satellite gravimetric missions that provide models that reflect the temporal variations of the Earth's gravitational field, which are mainly due to transportation and mass exchange processes (*Figure 2*) [1].

The time series of gravity field models are expressed in normalized spherical harmonic coefficients.

Level 3 GRACE Plotter [2] products were used, where gravitational variations such as Earth tides, ocean tides, 3D-atmospheric pressure fields and barotropic ocean response model were taken into account.

The RL05 data version featured GRACE & GRACE-FO monthly and 10-day solutions up to spherical harmonic degree 90, obtaining a spatial resolution about 300km².

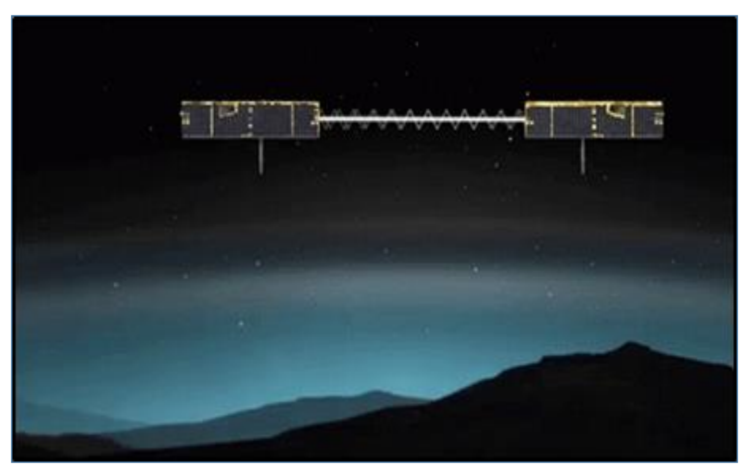

Figure 2: GRACE satellites.

Terrestrial Measurements

ABSOLUTE GRAVIMETER - Microg LaCoste FG5#238

The FG5 is designed for measurements in laboratory or like-laboratory sites; it is not well-suited for portable use on the field, but it is feasible when specific precautions are taken.

Instrumental characteristics:

Accuracy 2 µGal
Precision 1 µGal in ~ 4 min, 0.1 µGal in 6.25 h;
Repeatability within 2-3 µGal
The FG5's weight is approximately 300 kg and requires about 3m² floor space.

Procedures:

The absolute measurements were carried out at SLN and CTA stations almost monthly, from 2002 to 2022. Generally the g values were measured to a variable height (~1.3 m) through 20 sets including 100 drops in about 15-20 hours. Dedicate software undertakes the automatic data acquisition, the real time processing, and the automatic data storage. It also automatically corrects the measured g value for gravity changes due to solid-earth tides, ocean tide loadings, polar motion, and local air pressure changes.

Figure 3: FG5 Absolute gravimeter during measurements

Methods/Research workflow

A twenty-year (2002-2022) gravity anomaly comparison among four GRACE data processing centers (CNES/GRGS, CSR, GFZ, JPL) has been held at Serra La Nave station (Mt. Etna) in order to find the response that adjust better the terrestrial absolute gravity signal (*Figure 4a*). For the CNES/GRGS, the filtered and the truncated signals were both used in the analysis. Also, the average of the five gravity anomalies signals was calculated and compared with the other time series (*Figure 4b*).

The CNES/GRGS RL05 TSDV monthly gravity anomalies data [3] was chosen to continue with the analysis, due to its best long-term fit regarding the terrestrial data. Throughout the GRACE Plotter processing, reference field grid was removed, coefficients converted into 1°x1° gravity anomalies grids, and grid values were computed at the center of pixels. No smoothing or filtering was necessary since they have already been stabilized during the generation process.

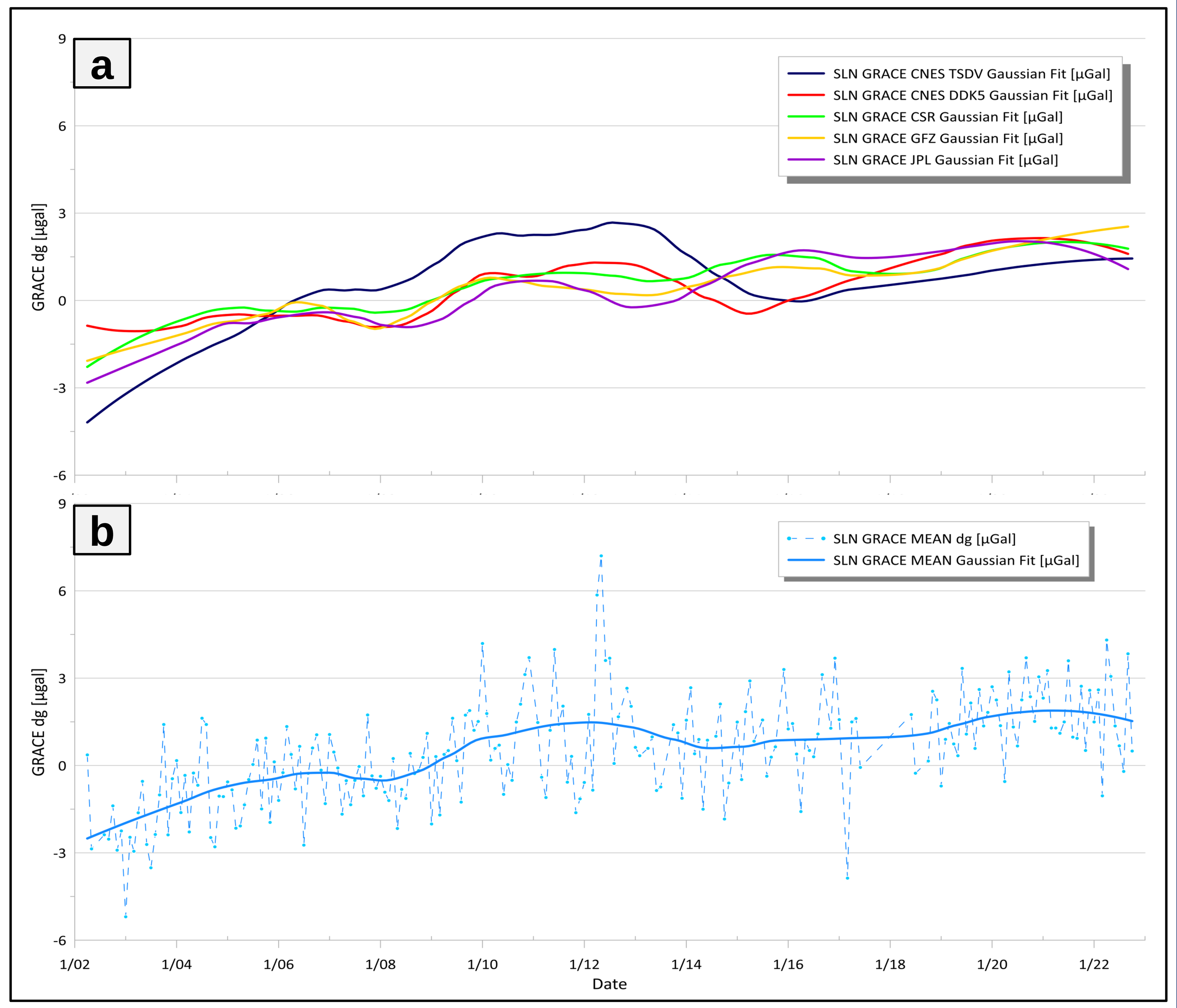

Figure 4: a)GRACE outcomes from different data centers b)GRACE data averaged using results from different data centers

Results and Conclusions

RESULTS

It is important to note that the following is a qualitative and not a quantitative analysis of the signals, since GRACE provides gravity anomalies of the terrestrial geopotential, and the terrestrial gravimeters offers the variation of absolute gravity over time. Furthermore, while GRACE data has a spatial resolution about 300km², terrestrial gravimeter provides g values directly on the measured point. Taking into account GRACE resolution, SLN and CTA gravity anomalies tend to be similar.

Moreover, periods with a strong correlation can be observed between terrestrial and satellite signals. A positive trend from 2003 to 2013 can be seen in satellite and terrestrial signals for both sites.

Presently, is being investigated the period from 2013 to 2022 where the absolute measurements show a negative trend *(Figures 5a and 5b)*, in an opposite way respect to the trend exhibited by GRACE *(Figures 5c and 5d)* which will be the analysis for further studies.

CONCLUSIONS

The implementation of new technologies such as satellite gravimetry, allows to obtain highly relevant information for the study and monitoring of geodynamic context, especially volcanoes.

Since GRACE is a satellite that provides information regarding the variation of the gravitational field over time, it is important to continue studying and analyzing this type of technology along with terrestrial measurements, especially when gravimetric measurements are available in situ over a long period of time and over an active volcano like Mount Etna.

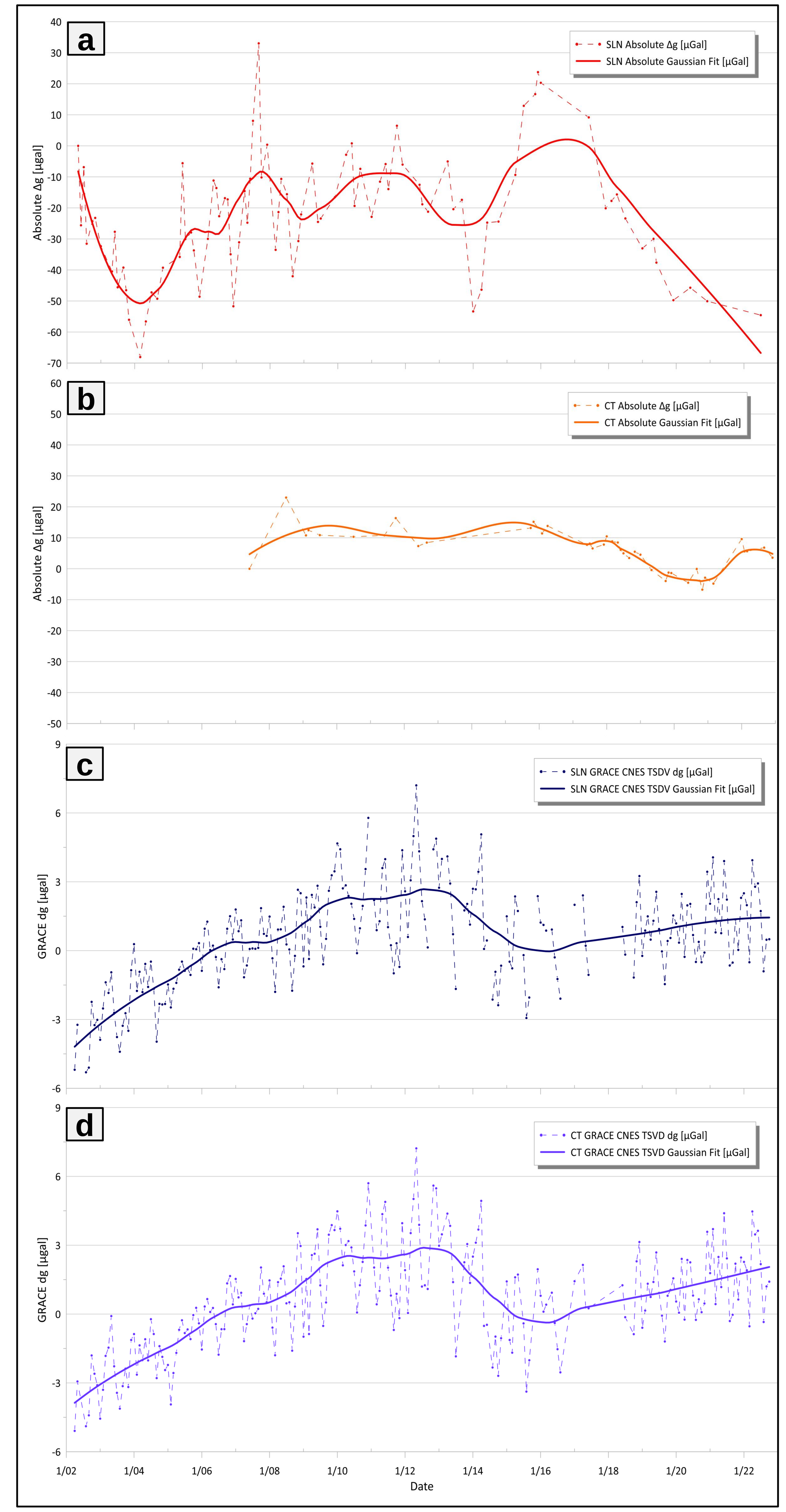

Figure 5: a) SLN Absolute data b) CTA Absolute data c) GRACE SLN data d) GRACE CTA data

References and acknowledgements

REFERENCE

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[3] Centre National d'Études Spatiales/Groupe de Recherche de Géodésie Spatiale (CNES/GRGS). Available at https://grace.obs-mip.fr/

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