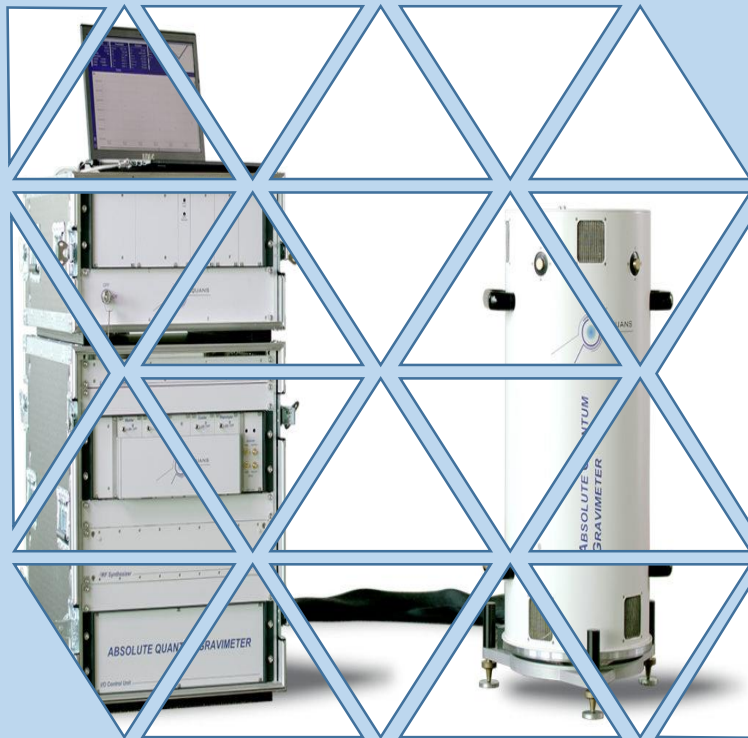




# Absolute Quantum Gravimeter

Operator Meeting

23<sup>rd</sup> – 25<sup>th</sup> January 2024  
Hannover, Germany



## Working group

### Osservatorio Etneo

Filippo Greco – Daniele Carbone– Luca Samperi  
Alfio Messina – Luca Mrabella – Danilo Contrafatto

### Osservatorio Vesuviano

Giovanna Berrino – Giuseppe Ricciardi – Alessandro Fedele

### Osservatorio Nazionale Terremoti

Federica Riguzzi



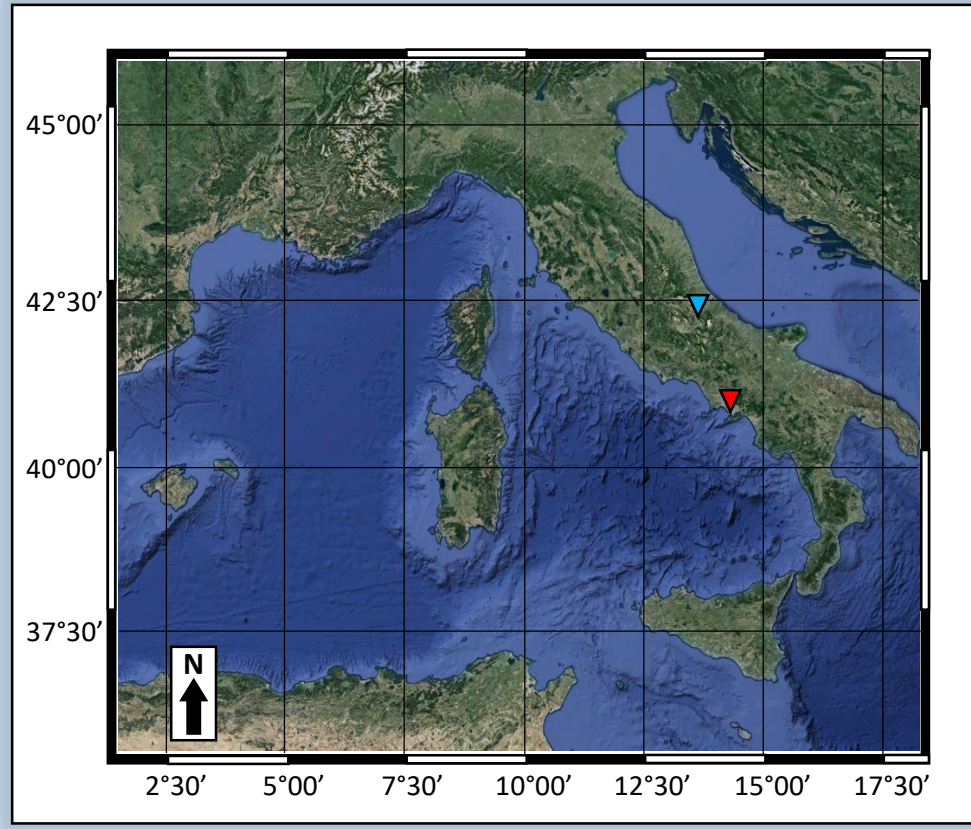
Luca Samperi, Ph.D

Research Fellow

Istituto Nazionale di Geofisica e Vulcanologia, Catania, Italy



Station location



AQG in **OV** is located in the Historical Building on Mt. Vesuvius, in a room on the ground floor and on a concrete pillar completely isolated from the building. Since 1986, the site is routinely accessed for absolute gravimetric measurement in the frame of the volcano monitoring

Since 2018, **Popoli** is routinely accessed for absolute gravimetric measurement in the frame of the gravimetric national reference network G0

▼ Osservatorio Vesuviano, Napoli

Latitude 40.82775°  
 Longitude 14.39722°  
 Elevation 607.00 m a.s.l.



▼ Popoli, Pescara

Latitude 42.173806°  
 Longitude 13.8317°  
 Elevation 244.37 m a.s.l.

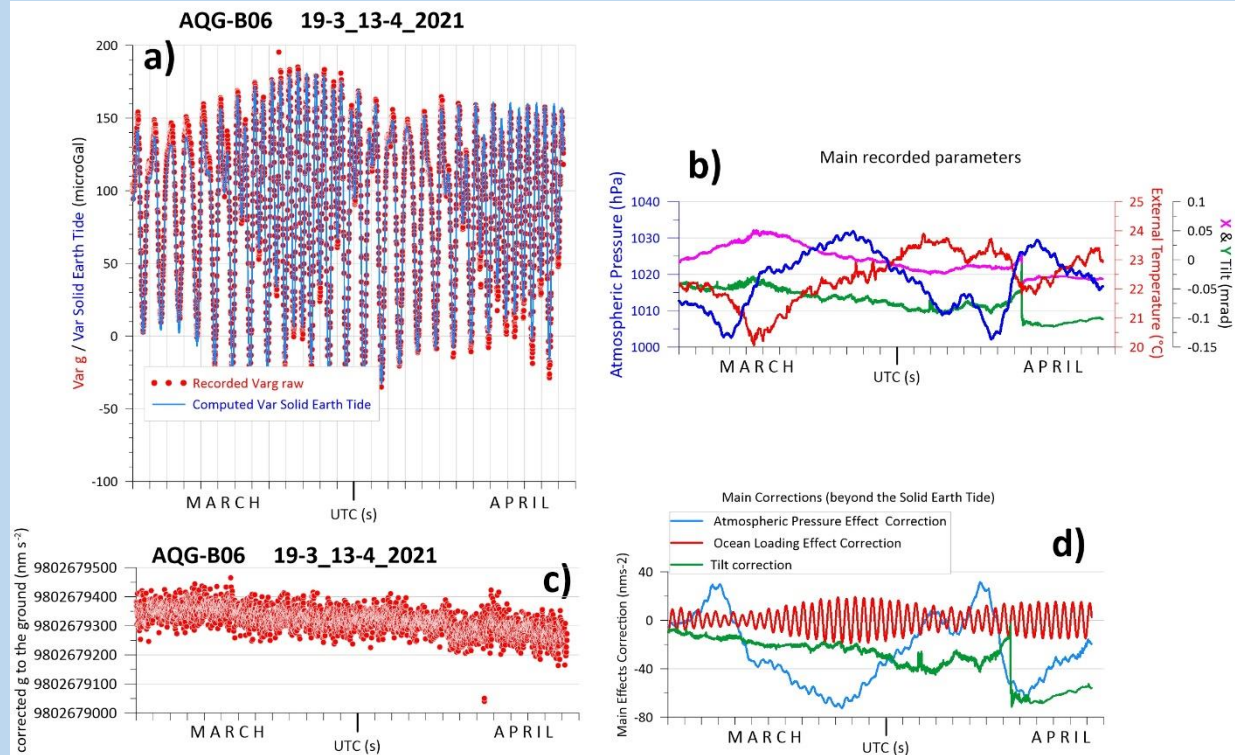




AQG-B06 was acquired by INGV- Napoli Osservatorio Vesuviano (OV) in 2021 as part of the PON-GRINT - PIR\_00013 Project. It is maintained by OV. Firstly it was subjected to a series of tests in the OV Gravity Laboratory in Naples



Latitude 40.81930°  
 Longitude 14.18270°  
 Elevation 18.00 m a.s.l.



The test lasting approximately 1 month showed excellent solid earth tide response, but significant changes in tilts and a linear drift of approximately -10  $\mu$ Gal in total. Considering that the site is somewhat disturbed AQG was moved to OV-Vesuvius to begin data acquisition in a volcanic active area

# AQG at OV Historical Building on Mt. Vesuvius

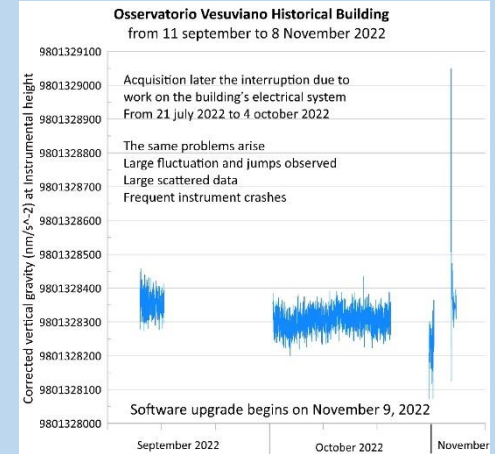
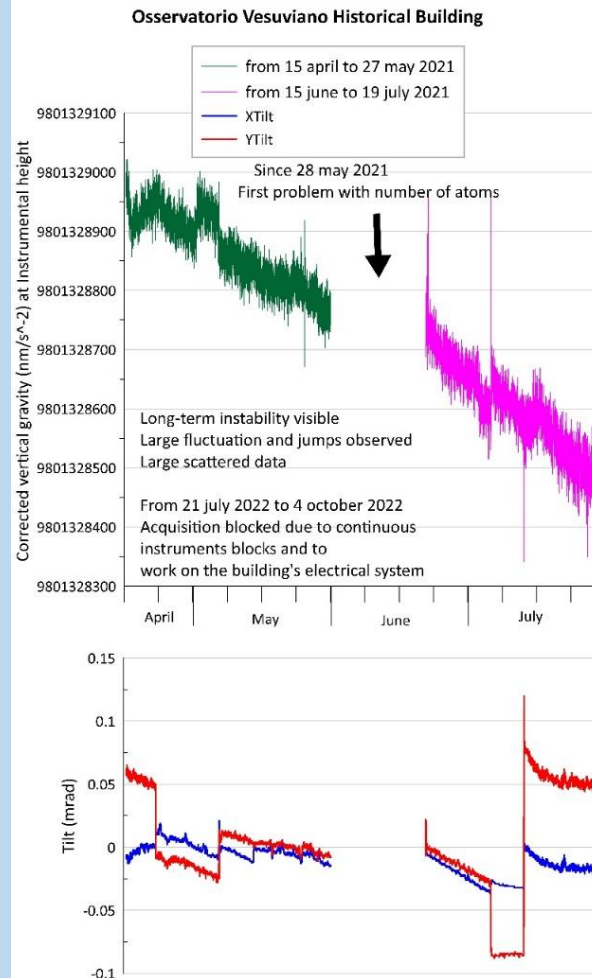
Registration from April to July 2021.  
 The first major problem occurs at the end of May (arrow) due to problems with the number of atoms.

It is observed:

- Long term instability and tilt drift
- Very noised data, fluctuation and several jumps
- Long term instability is about  $-15 \mu\text{Gal}/\text{month}$  over the global time interval, similar to that observed in laboratories.

The response to solid Earth-Tide is good

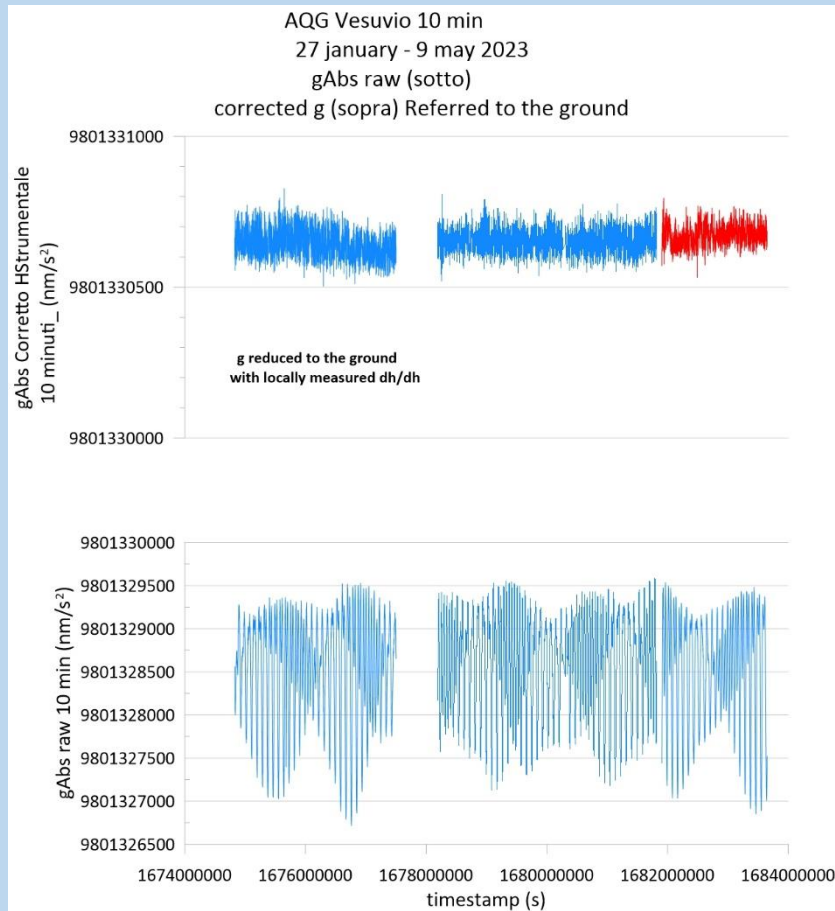
The instrument was switched off in Autumn, following continuous blocks, occurring in particular after power failure and for maintenance work on the building's electrical system



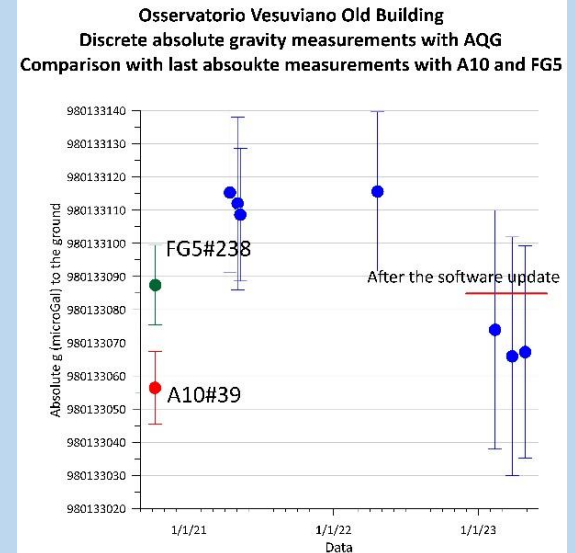
Restart of recording after works on the power line.

The instrumentation continues to crash and the data are still very disturbed.

The Manufacturer deemed it necessary to update the software



After the first intervention by the Manufacturer to upgrade the software which lasted about 4 weeks the instrumentation seems more stable and less noised but a small long-term drift is still observed. A second update is necessary. Although data are still noised, the long-term drift is no longer observed.



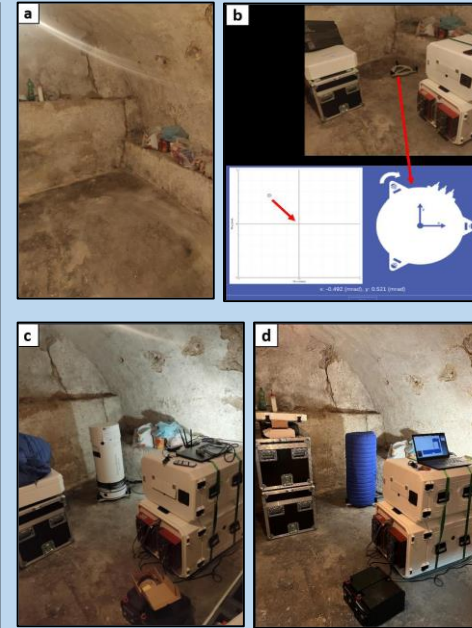
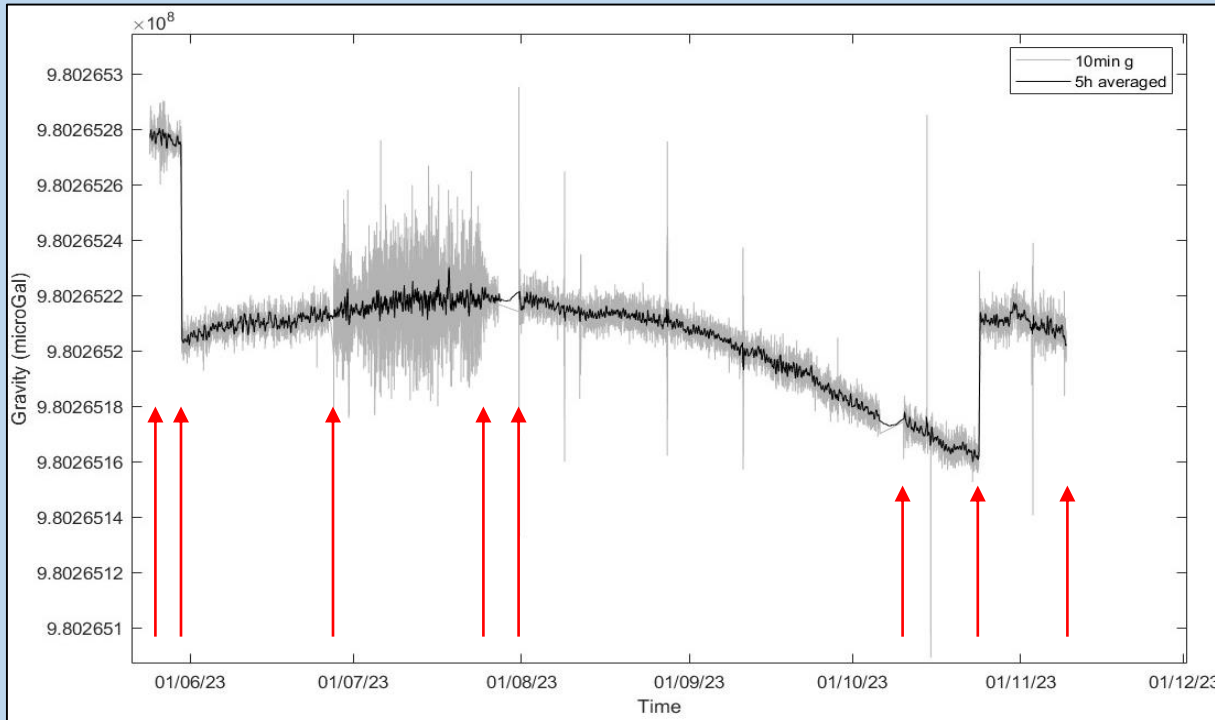
Comparison of the absolute values measured with AQG, during some sessions of approximately 1 hour (discrete measures) or averaged over short intervals of recordings, with the latest values measured in the same place in October 2020 with the A10#39 and FG5#238 absolute gravimeters.

Pre-upgrade AQG absolute value is approximately +25 and +56  $\mu\text{Gal}$  respect to FG5 and A10 values.

After the software upgrade the AQG g values are -17 and +13  $\mu\text{Gal}$  respect to FG5 and A10 values.

Relative gravity measures showed a gravity increase of 30  $\mu\text{Gal}$  from 11/2020 to 3/2022 followed by a gravity decrease of -11  $\mu\text{Gal}$  from 3/2022 to 4/2023. It seems coherent with AQG data trend mainly respect to FG5 value.

**It is decided to move the equipment to Popoli...**



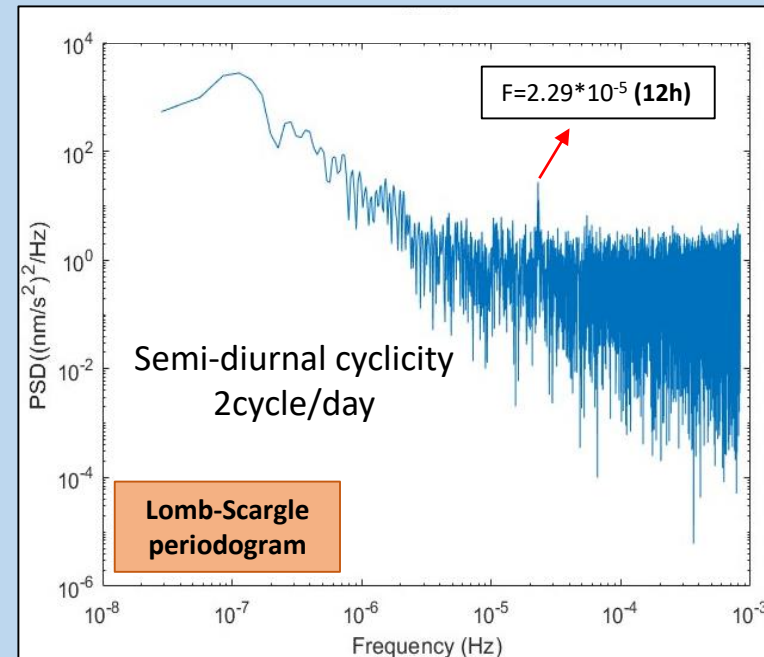
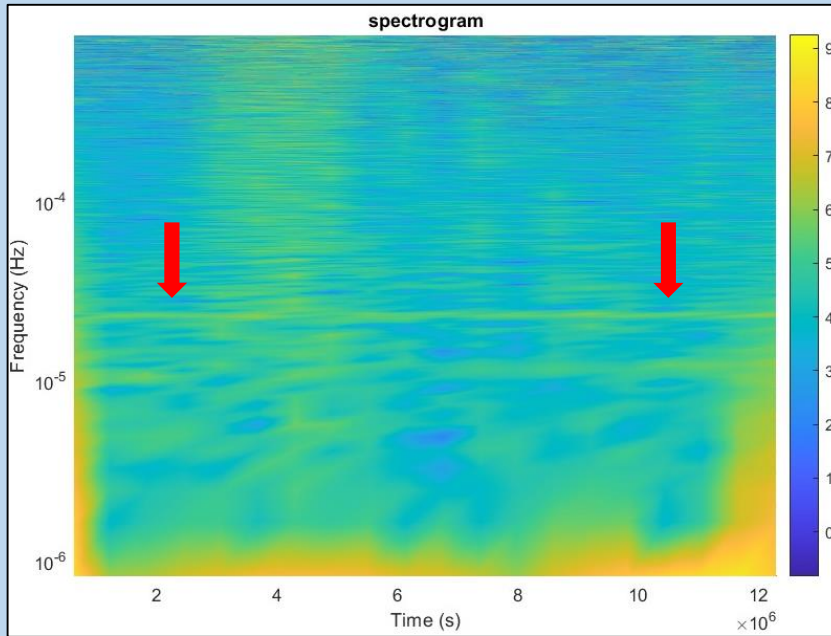
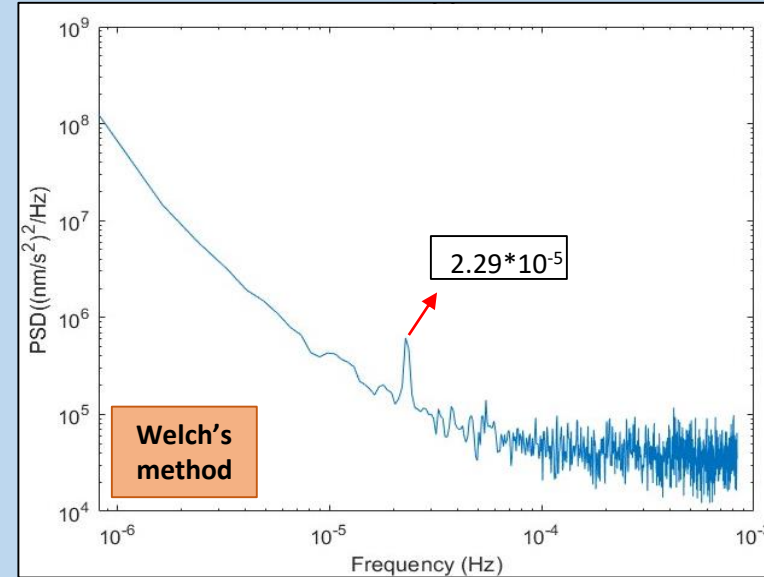
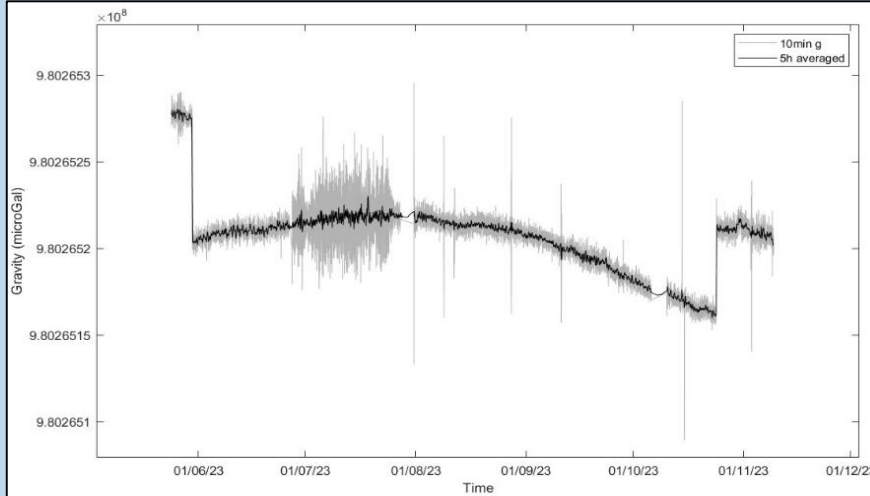
**a)** Site preparation for the AQG-B06 installation.  
**b)** Tripod positioning for the manual levelling.  
**c-d)** Pictures of the instrument installed. Necessary to use the insulating cover because of the low temperature in the site.

- May 24<sup>th</sup> installation
- May 30<sup>th</sup> VGG value change
- June 27<sup>th</sup> instrument restart
- July 24<sup>th</sup> filter application
- August 1<sup>st</sup> instrument restart
- October 10<sup>th</sup> instrument restart
- October 24<sup>th</sup> levelling
- November 9<sup>th</sup> tilt calibration procedure and uninstallation

**5 months-life  
 AQG-B06 at  
 Popoli station...**



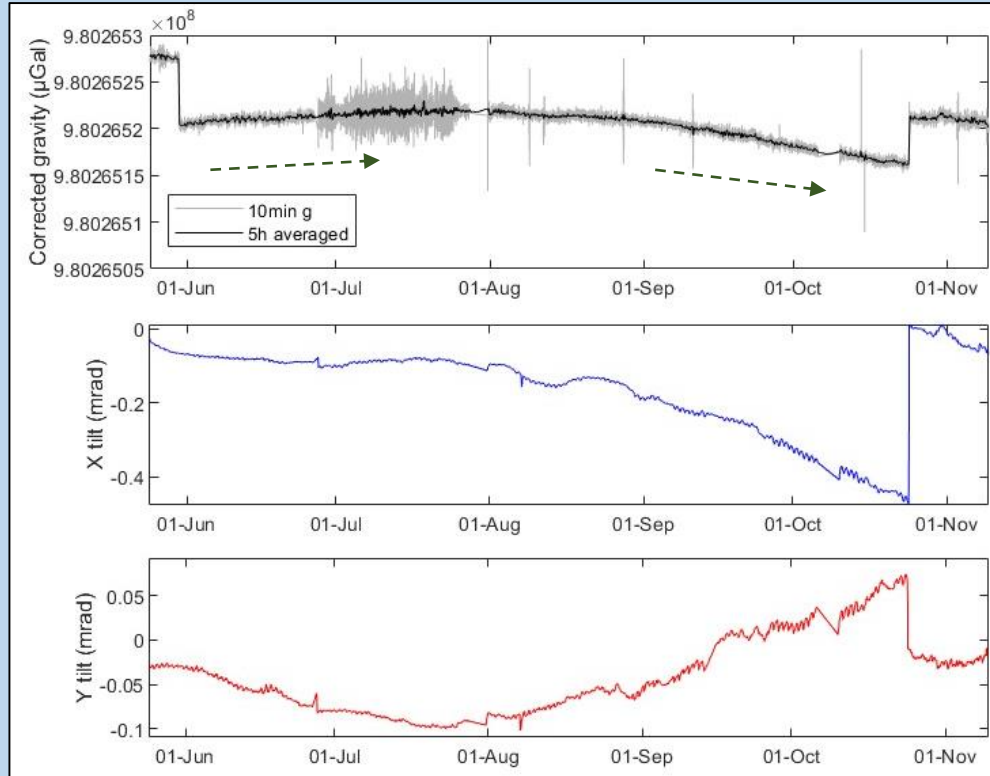
Signal processing



High PSD is to research at low frequencies.  
 In particular, Lomb-Scargle method detect a cyclical high PSD peak at 12h



Comparison to previous measurements



$\pm 30 \mu\text{Gal} = \Delta g$  during 5 months tracking

After filter provided by the Manufacturer g value inverted the trend showing the typical drift.  
 Drift roughly continued after the levelling operation.

Date Time UTC [from-to]	Meter and measured height (m)	g at ground ( $\mu\text{Gal}$ )
12-13 June 2018 14:25÷06:25	FG5#238 1.2957	980265322.7 $\pm$ 4.0
26 Sept. 2018 10:00÷11:00	A10#39 0.72	980265306.3 $\pm$ 3.1
02-03 Oct. 2018 12:01÷05:33	FG5#238 1.2957	980265320.4 $\pm$ 4.0
05-06 Oct. 2020 11:48÷07:35	FG5#238 1.2982	980265305.8 $\pm$ 4.0
06 Oct 2020 10:26÷11:26	A10#39 0.72	980265308.7 $\pm$ 3.6
06 Oct. 2020 11:42÷12:42	A10#39 0.72	980265307.56 $\pm$ 3.5
07-08 May 2022 10:23÷06:29	FG5#238 1.3022	980265316.6 $\pm$ 4.0
03-04 Dec. 2022 12:22÷06:59	FG5#238 1.2947	980265278.2 $\pm$ 3.7
23-24 May 2023 18:04÷07:04	FG5#238 1.3022	980265277.5 $\pm$ 4.0

-209.6  $\mu\text{Gal}/\text{m}$  is VGG for the reduction to the ground

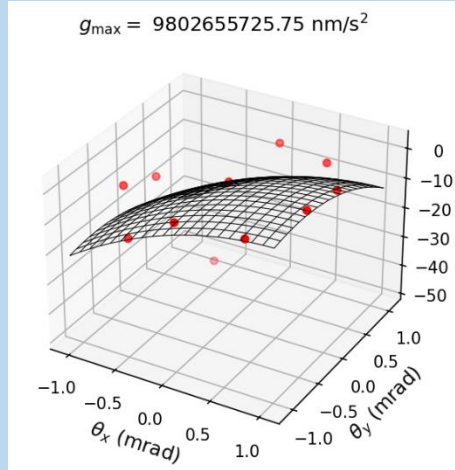
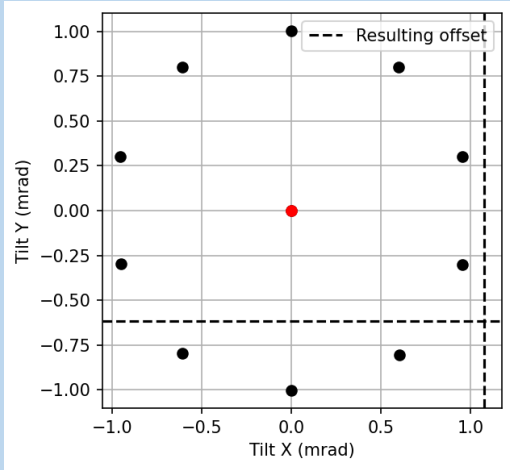
Compared to discrete measurements provided by other absolute gravimeter, AQQ measurements show about -40  $\mu\text{Gal}$



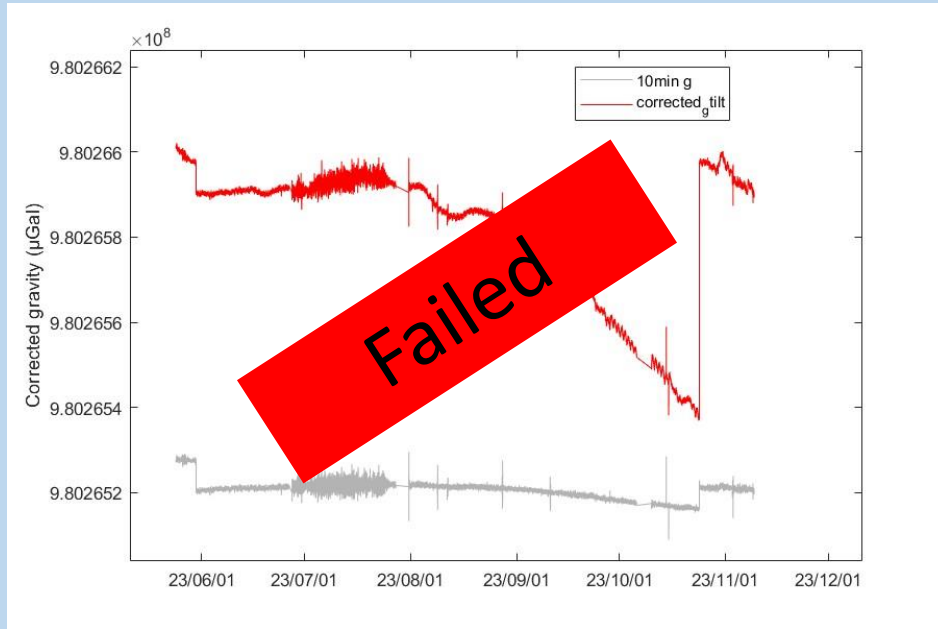
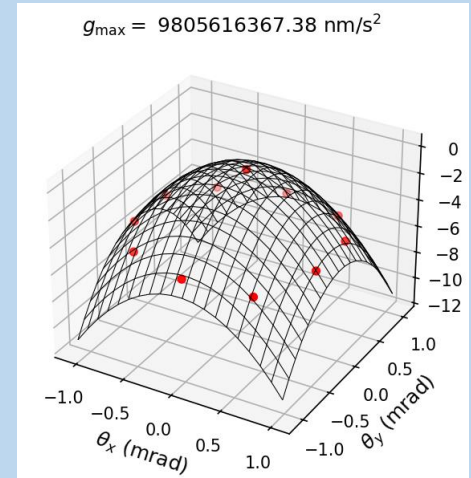




Tilt\_calibration procedure

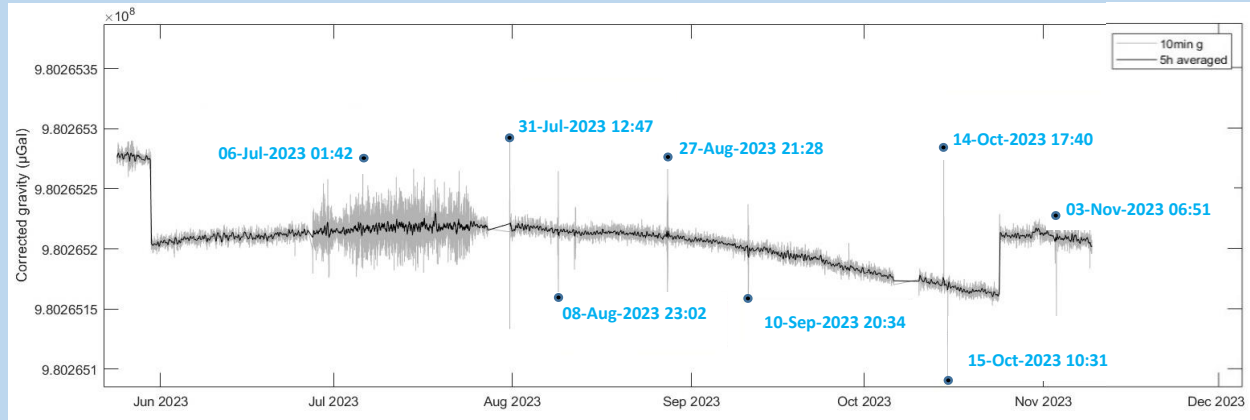


How it should appear



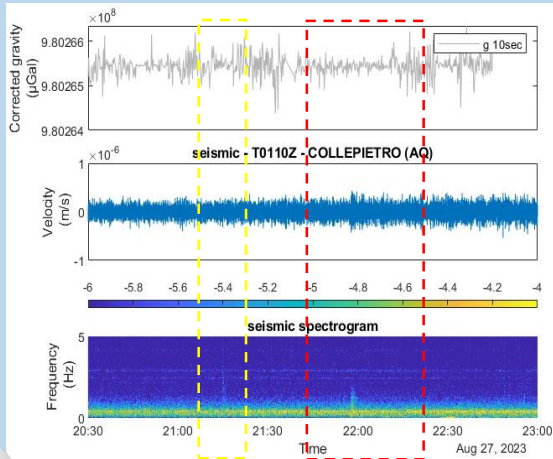
← g after tilt calibration procedure and processing

Spikes identification

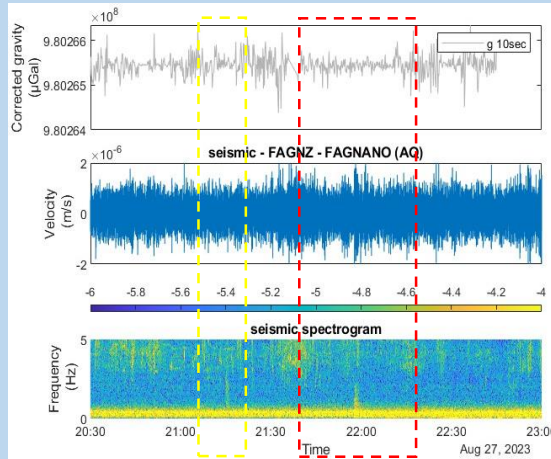


Regional earthquake: date 2023-08-27 21:14:23 Md 2.6 Campi Flegrei, Napoli, Italy

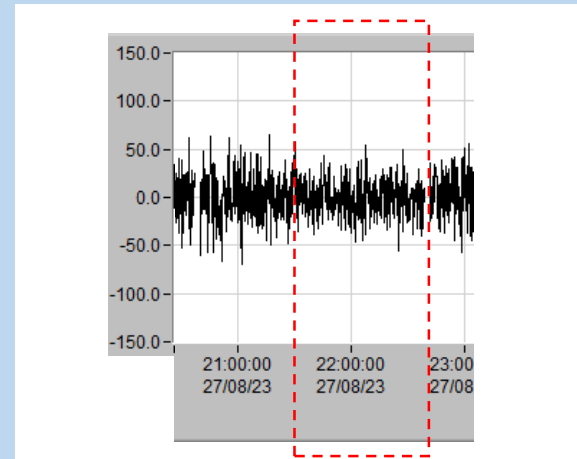
Teleseism: date 2023-08-27 21:45:02 Mwp 5.6 Colombia



AQG-B06

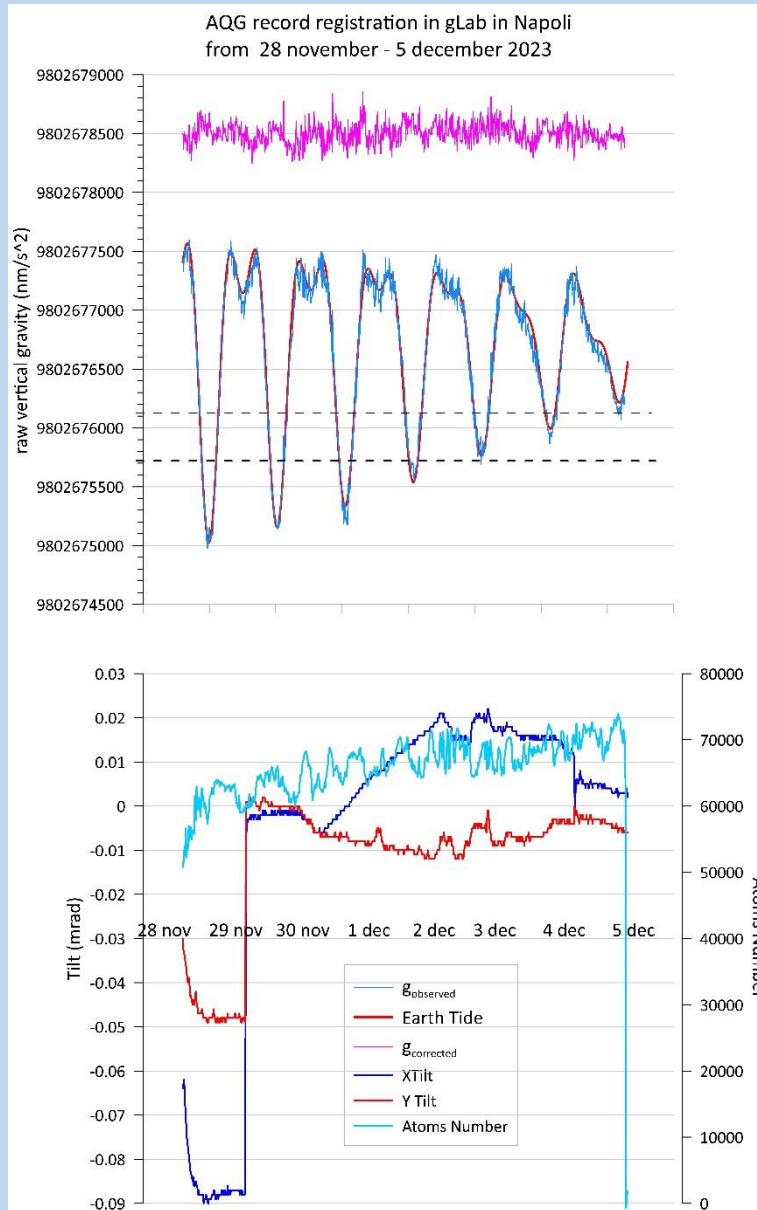


AQG-B06



AQG-B03

## Last period in Napoli



In early November 2023, AQG was moved from Popoli to the gLab in Napoli to be checked before being installed in a National Reference Station in Napoli.

The records were good, in particular the long-term drift was not observed although tilt fluctuation are observed again.

However, after some days (without any apparent external problems) the gravimeter blocked and the acquisition was interrupted after a sudden drop in the number of atoms. The system would not restart indicating a laser error.

**With the coordination of the Manufacturer, a series of tests are still being carried out to identify the cause of the problem, probably this time concerning the hardware.**

## Conclusions

Our group mainly worked on a volcanic frame, analyzing and monitoring volcanic activity. No experiences related to continuous and absolute measurements in seismic areas.

Currently, our objective is to create a Gravimetric Reference Network fixing absolute station on stable area, in order to analyzing and monitoring the gravimetric long term variations, then helpful even for volcanic area and seismic area investigation throughout the Italian regions including the Italian islands. New AQG instruments are desired soon

### However...

after several measurements attempts in different places (Vesuvio, Popoli and Napoli), AQG-B06 does not provide us expected results.

They remain to be understood the issues we identified so far:

Long-term drift at Vesuvio station of approximately  $-15 \mu\text{Gal}/\text{month}$  which seems resolved after the software upgrade, although it recurred to Popoli after restarting the instrument as noted above.

Unstable tilt.

Noised data, fluctuations in recording and frequent jumps especially after interruptions in acquisition. Many issues also seem roughly resolved by the software upgrade.

Peaks along the g series are frequent and they do not seem to be linked to seismic events so far.

It remains to understand the latest problems probably associated with the hardware





**Thank you for your attention**