Multiparameter techniques for seafloor vertical deformation assessment in the Campi Flegrei volcanic area

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Abstract

The Campi Flegrei caldera is well known for being one of the most volcanically risky areas in the world. Notably, it has an extension of about 120 square km, and 40% of its area is submerged forming the Gulf of Pozzuoli. A remarkable expression of the local volcanic dynamics is the slow ground displacement across the whole caldera. This peculiarity makes this area a natural laboratory for developing and testing innovative methods to assess seafloor deformation. Until 2008 no seafloor deformation measurements were performed in the submarine part of the caldera, while ground deformation measurements have been extensively and routinely acquired on land since the beginning of the last century. In 2008 CUMAS, a multisensor prototype buoy, was deployed in the Gulf of Pozzuoli within a program of extension of the land-based geophysical monitoring network toward the marine sector of the caldera. CUMAS, placed at 2.5 km from the coast in about 100 m water depth, was able to acquire the first sea floor deformation measurement in the submerged portion of the caldera. In 2016, a new marine monitoring network, MEDUSA, was deployed to achieve a larger coverage of the Gulf of Pozzuoli incorporating CUMAS. MEDUSA marine network presently consists of four instrumented buoys hosting geodetic GPS receivers on the top. Moreover, each buoy is connected through a cable to a seafloor module equipped with oceanographic and geophysical sensors including a bottom pressure recorder (BPR). One of the buoys is also equipped with a tide gauge. Using the GPS, BPR and tide gauge data provided by MEDUSA, we were able to assess the seafloor deformation field in the Gulf of Pozzuoli for the first time: we estimated a seafloor vertical displacement of about 10 cm ±1 cm over a period of twenty months embracing 2016 to 2018. The presentation is aimed at giving details about the design of MEDUSA and about the multiparameter data analysis leading to the deformation field estimation.

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Multiparameter techniques for seafloor vertical deformation assessment in the Campi Flegrei volcanic area

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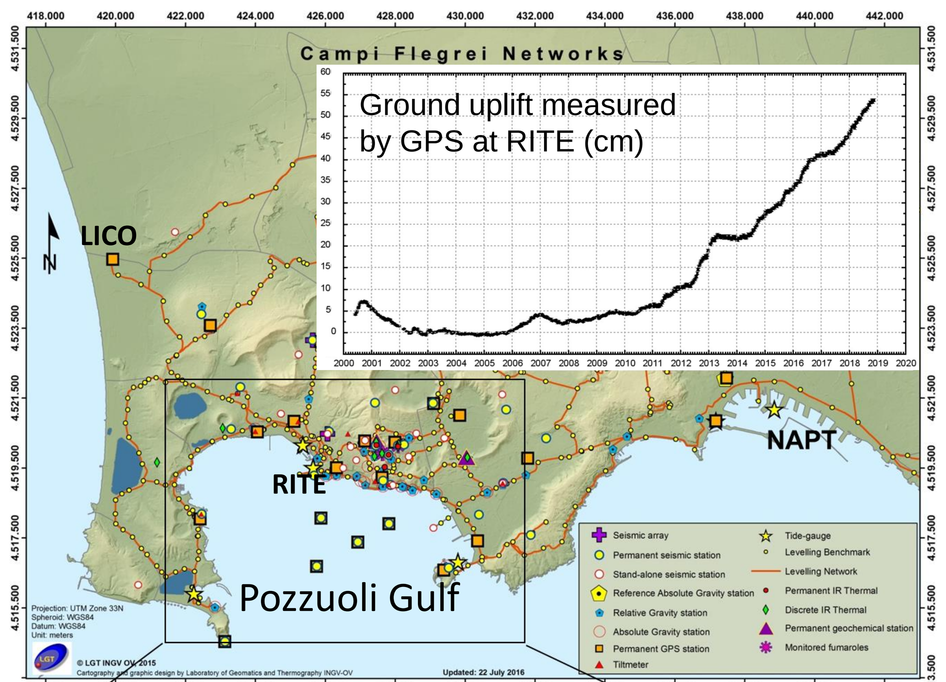
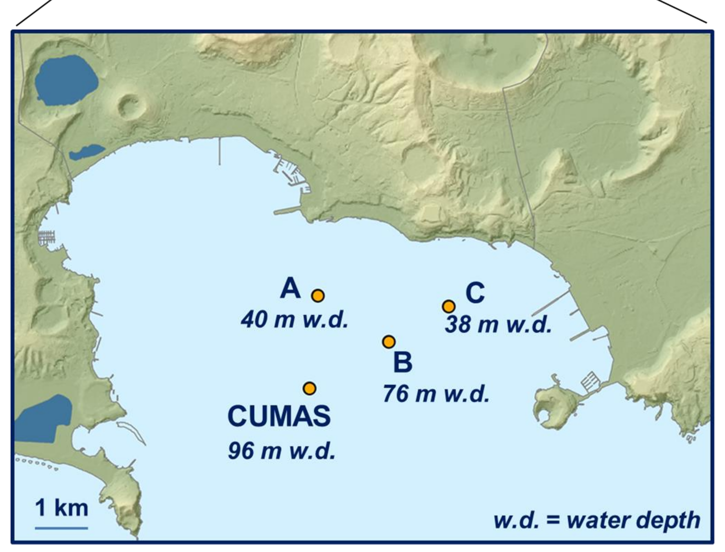
Abstract

MEDUSA (Multiparameter Elastic-beacon Devices and Underwater Sensors Acquisition system) is a marine network consisting of four instrumented buoys deployed in the early 2016 to achieve a larger coverage of the marine sector of the Campi Flegrei volcanic area. Each buoy hosts a geodetic GPS receiver on the top and it is connected through a cable to a seafloor module equipped with oceanographic and geophysical sensors including a bottom pressure recorder (BPR). One of the buoys is also equipped with a tide gauge.
Using the GPS, BPR and tide gauge data provided by MEDUSA, we were able to assess the seafloor deformation field in the Gulf of Pozzuoli for the first time: we estimated a seafloor vertical displacement of about 10 cm ±1 cm over a period of twenty months embracing 2016 to 2018.

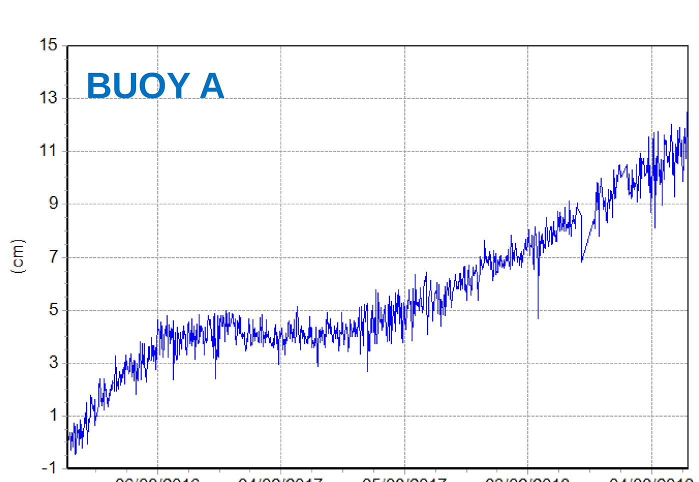


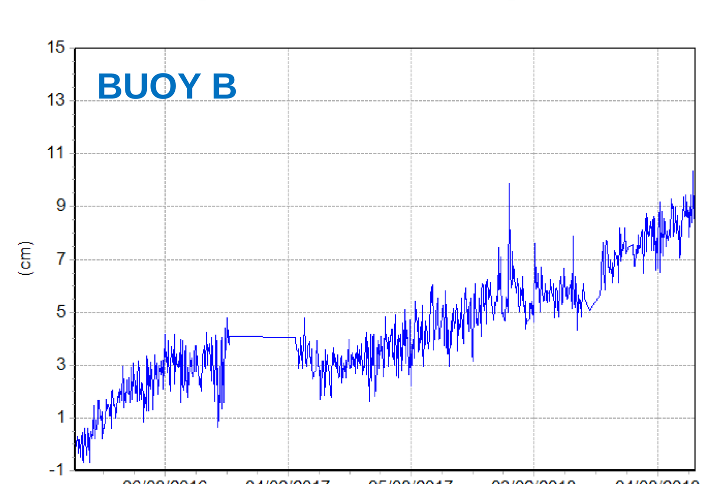
Campi Flegrei is a volcanic caldera located west of Naples, in Southern Italy. This area is characterized for repeated cycles of significant slow uplift followed by subsidence. In the period 1970-1984 the caldera has had significant episodes of uplift with more than 3 m of cumulative uplift measured in the city of Pozzuoli. The area is monitored by multiple networks that are all centrally controlled by the local branch of INGV. During the last eight years a cumulative uplift of about 50 cm was measured by a GPS located in the center of the caldera (RITE station).

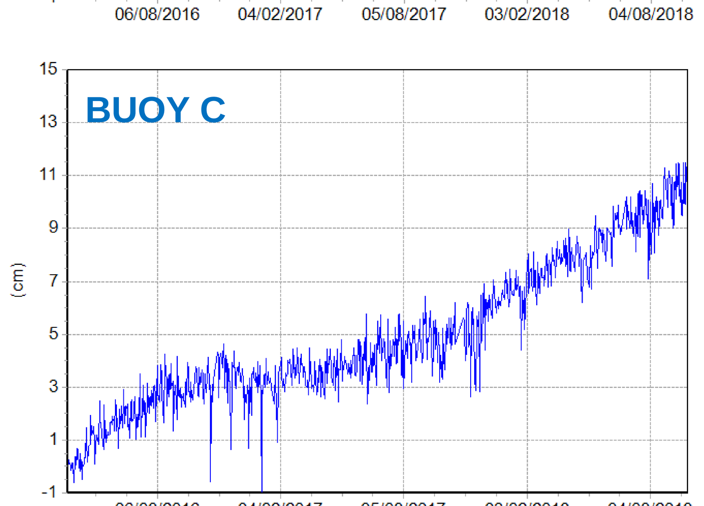


A marine monitoring system (named MEDUSA) formed by 4 nodes has been installed in the early 2016 in the marine sector of Campi Flegrei.
Each node is formed by a buoy plus a sea floor module. The left side figure reports the buoy location with the sea depth

SEA FLOOR VERTICAL DISPLACEMENT MEASURED BY GPS (from 1 April 2016 to 30 September 2018)

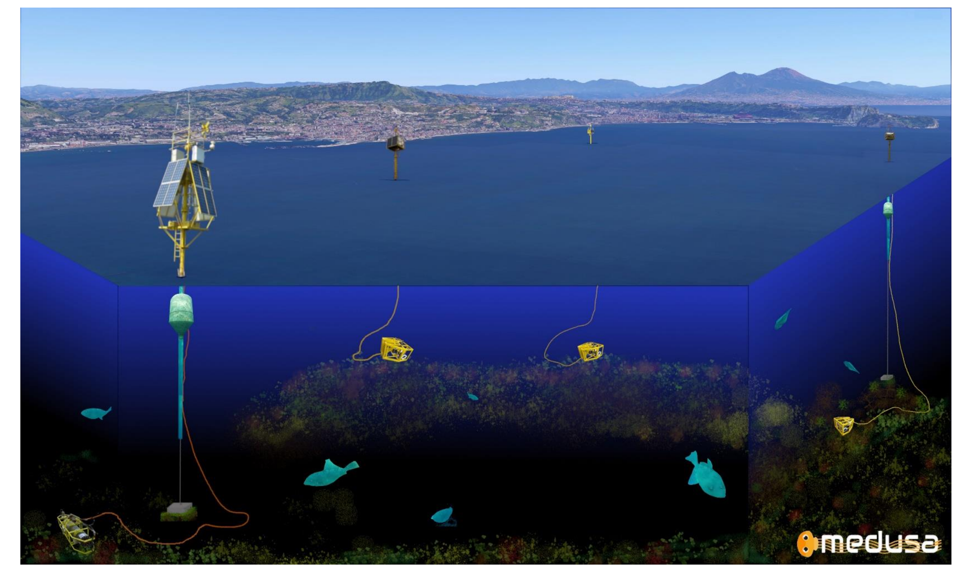






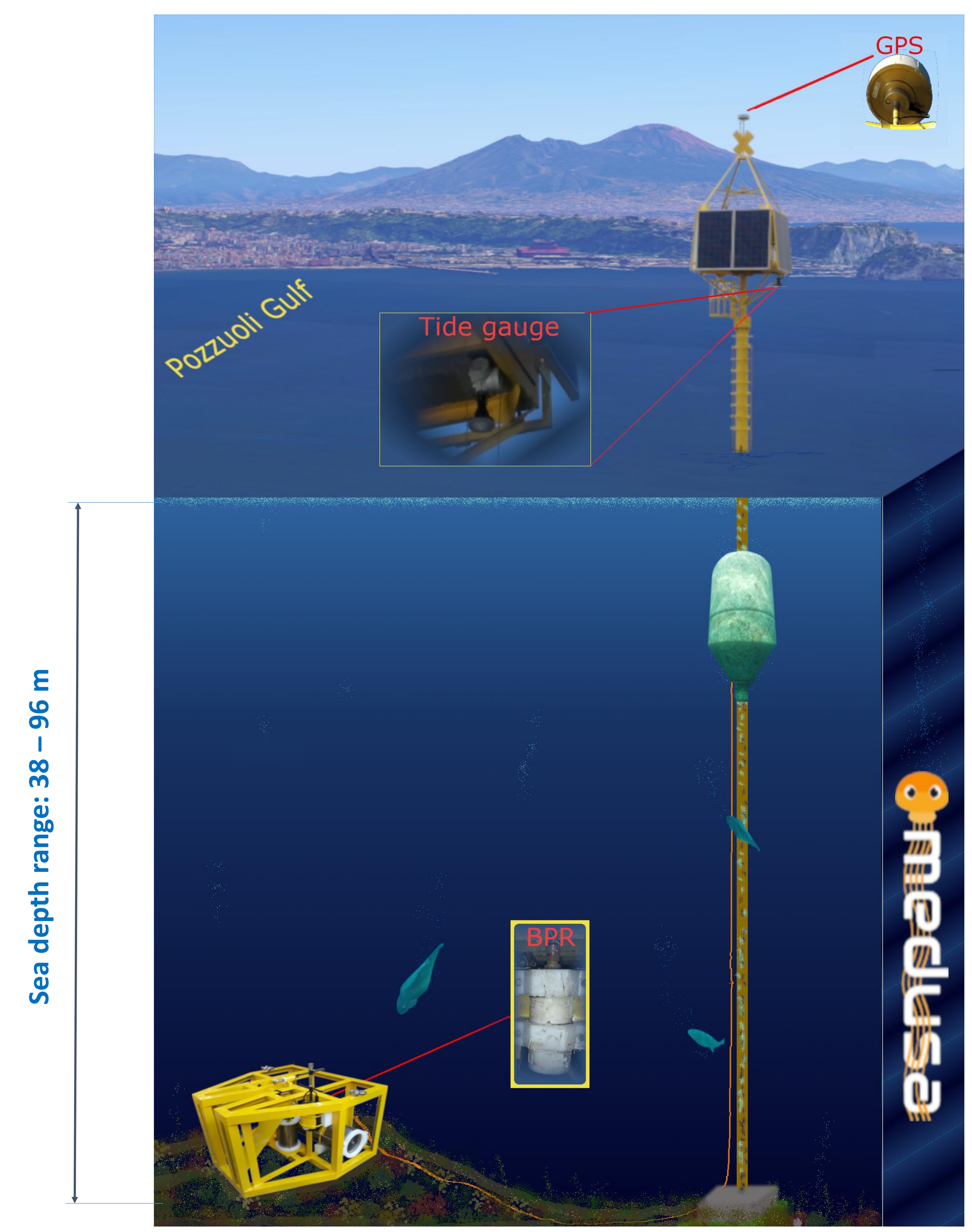
GPS data are acquired at 30 s sampling intervals and processed in kinematic mode. The reference station chosen to process the GPS seafloor data is the LICO station (see previous map), located outside the Campi Flegrei caldera, at a distance of about 10 km from the caldera center

THE MEDUSA SYSTEM



medusa
http://portale.ov.ingv.it/medusa

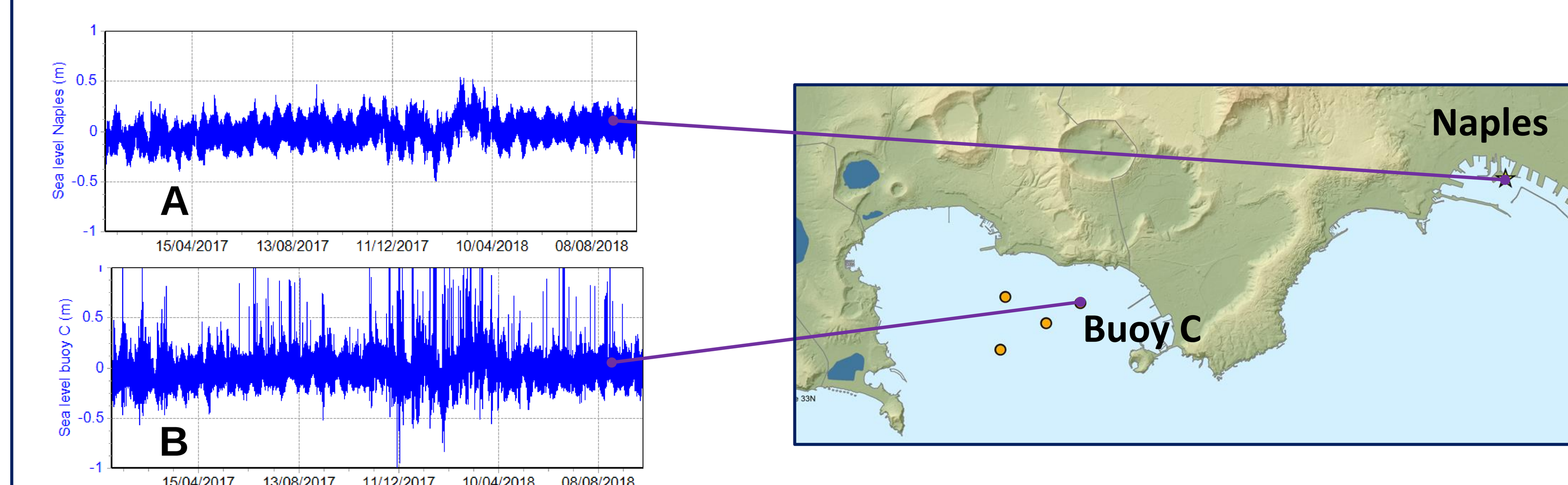
MEDUSA is made up of four marine monitoring stations each one consisting of a buoy equipped with CGPS and connected by cable to a seafloor module hosting geophysical and oceanographic sensors. A tide gauge station is also installed on the C buoy.
All data acquired by the MEDUSA's sensors are transmitted by radio in real-time and continuous mode to the Monitoring Center in Naples. The sea depth ranges from 38 m (buoy C) to 76 m up to 96 m (CUMAS).
More information can be found in the MEDUSA site, scanning the QR code

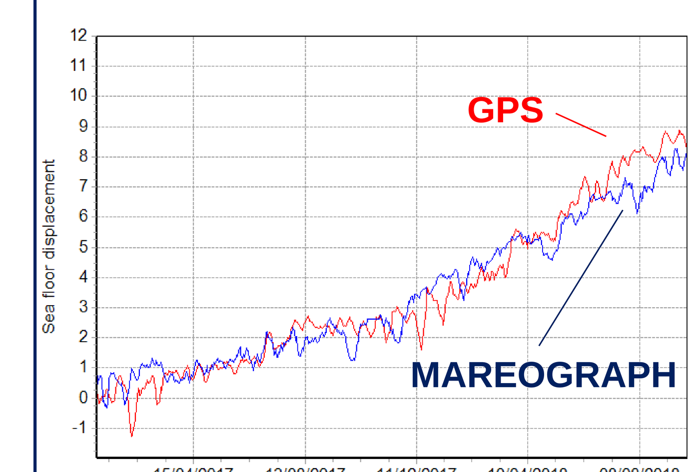


Each seafloor module includes the geophysical and oceanographic sensors; in particular, a three-component broadband seismometer (Trillium) a low-frequency hydrophone and an BPR (Paroscientific 8CDP-130I). A single-point, three-component, water-current meter and a water-temperature sensor were also installed on the C buoy module to monitor the marine environment. Status and control sensors are also presents in the module.

SEAFLOOR DISPLACEMENT MEASURED BY THE TIDE GAUGE (from 1 January 2017 to 30 September 2018)

We compare sea level data recorded by the tide gauge of the C buoy with the one of Naples used as stable reference level.
The raw records of the two mareographs sampled every 60 s have been averaged on a time window of 7 days. The difference between the Naples and C buoy averaged records represents the vertical movement of the sea-floor. The data time series are 21 months long, from January 1, 2017 to September 30 2018

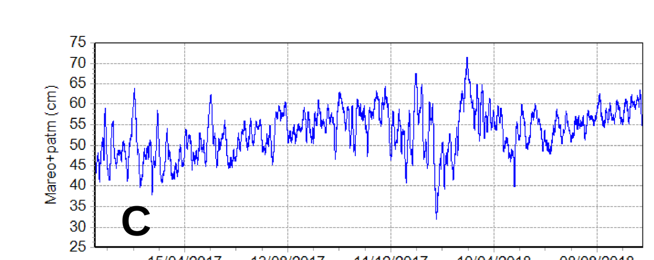




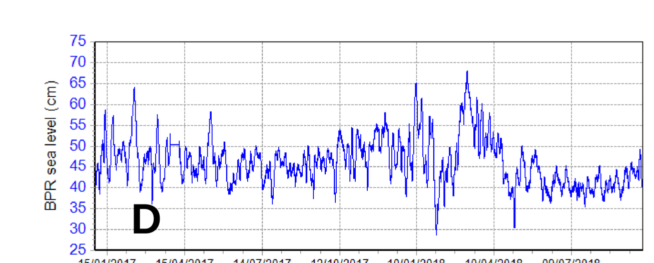
Seafloor vertical displacement measured by C buoy mareograph (blu line) is computed by the difference between the data of the time-series of two previous figures (A - B).
The red line represents again the vertical displacement measured by the GPS located on the same buoy.

SEAFLOOR VERTICAL DISPLACEMENT MEASURED BY BPR (from 1 January 2017 to 30 September 2018)

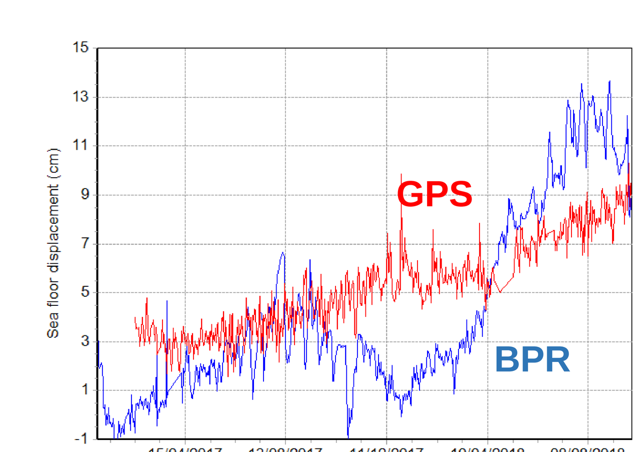
We analyzed data of the Bottom Pressure Recorder (BPR) mounted on the seafloor module of the buoy B (depth of 76 m). Similarly to the tide gauge analysis, we compare the sea-level data measured by the BPR with those recorded by the mareograph of Naples used as stable reference level.



Seal level recorded by the Naples mareograph adjusted by the changes in barometric pressure (inverted barometer effect)



Sea level changes measured by the BPR of buoy B. BPR data have been divided for density of the sea water and gravitational acceleration. The density has been obtained by the temperature of the water measured by the current meter of the buoy C



Comparison of the sea floor displacement measured by the BPR and GPS. The BPR displacement has been obtained as difference of time-series C – D (see previous figures).
The trend of the two measures is consistent. A periodic component not yet correctly interpreted remains probably due to temperature variations. We are working to model the density variation of the water column over time.