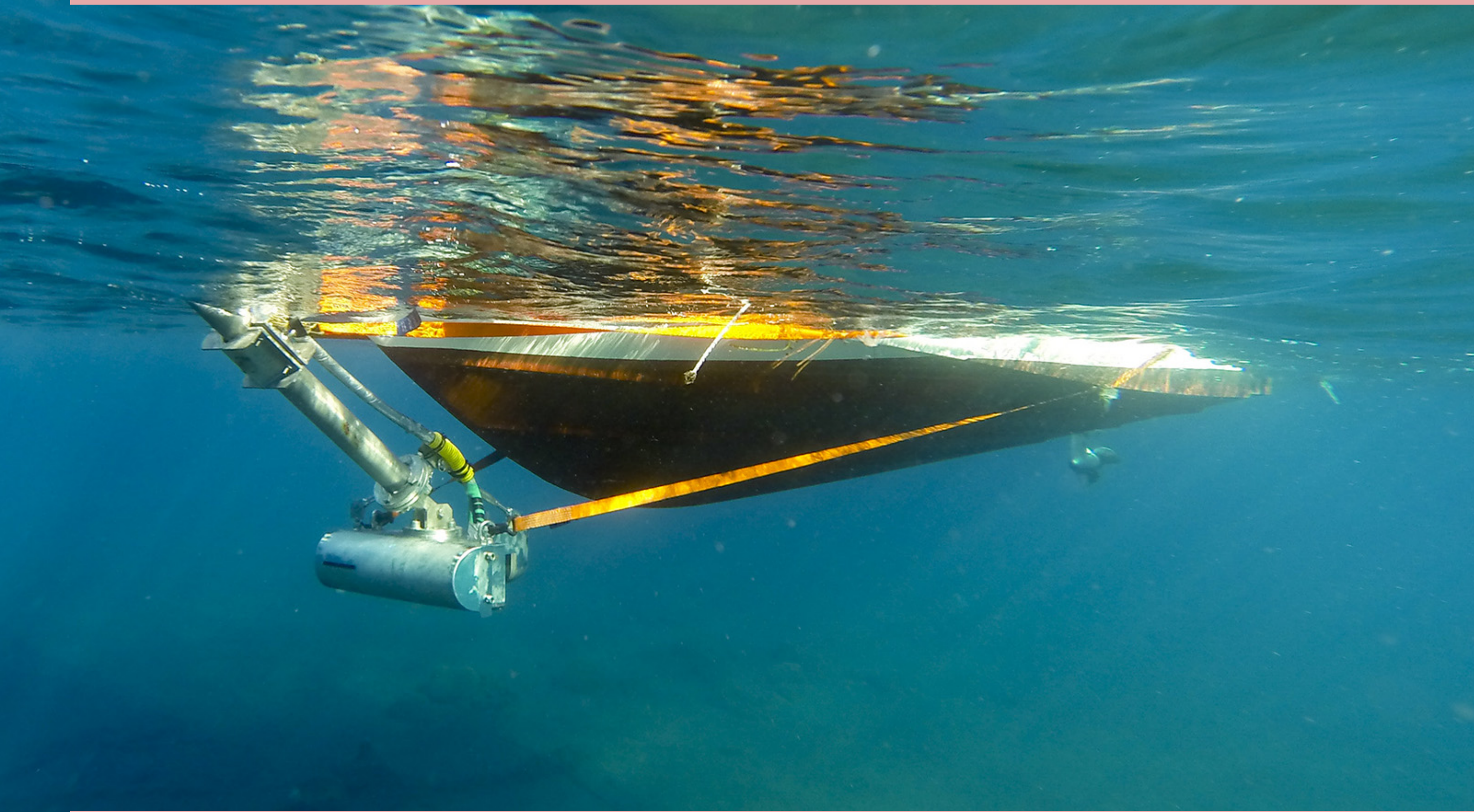
ISSN 1590-2595
anno 2019 numero 51



MISCELLANEA INGV

Abstracts Volume

Giornate INGV sull'ambiente marino
INGV Workshop on Marine Environment

Rome, 26th | 27th June 2019

51

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

REGISTRAZIONE AL TRIBUNALE DI ROMA N.174 | 2014, 23 LUGLIO

Rappresentante legale: Carlo DOGLIONI
Sede: Via di Vigna Murata, 605 | Roma

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

ISSN 1590-2595
anno 2019 numero 51

MISCELLANEA INGV

Abstracts Volume

Giornate INGV sull'ambiente marino
INGV Workshop on Marine Environment

Rome, 26th | 27th June 2019

Editors: Leonardo Sagnotti, Laura Beranzoli, Cinzia Caruso, Sergio Guardato, Simona Simoncelli

Accepted 18th September 2019 | *Accettato 18 settembre 2019*

How to cite | *Come citare* AA. VV., (2019). Giornate INGV sull'ambiente marino - INGV Workshop on Marine Environment, Rome, 26th - 27th June 2019, Abstract Volume. Edited by L. Sagnotti, L. Beranzoli, C. Caruso, S. Guardato, S. Simoncelli. Misc. INGV, 51: 1-126.

Cover Multibeam sensor munted on the INGV vessel for bathymetric surveys at Lipari island (Italy) | *In copertina Sensore multibeam installato su una imbarcazione INGV per rilievi batimetrici a Lipari* (©INGV)

INDEX

Preface

On 26 and 27 June, 2019, the Environment Department of Istituto Nazionale di Geofisica e Vulcanologia (INGV) organized a first internal workshop dedicated to the scientific and technological research on the marine environment. This volume contains the extended abstracts of the presentations given in the workshop.

INGV promotes the development of research, observational infrastructures and services related to the marine environment in the broad sense for a variety of stakeholders. These activities, mostly carried out within the framework of the Environment Department, are dispersed in different Sections of INGV, involving various groups of researchers, technologists, technicians and project managers.

The workshop aim was to present the state-of-the-art of the activities around the marine environment and promote the exchange of knowledge, ideas and expertise among colleagues. More than 60 INGV scientists attended the workshop with a lively interest and active participation to constructive debates.

This volume includes 35 extended abstracts grouped three categories: (1) Research, (2) Infrastructures and (3) Services for the Society.

The *Research* Section has 23 abstracts on topics ranging from fluid geochemistry of natural marine emissions in both volcanic, hydrothermal and sedimentary settings, crustal structures and imaging, the evolution of the physical state of the Mediterranean, observed sea level trends and future projections, paleoclimate reconstructions and proxies for the occurrence of paleo-tsunami.

The *Infrastructures* Section includes 6 abstracts presenting the state of the art and the perspectives of INGV research facilities, the development of original devices and techniques for the monitoring of a variety of physical phenomena in the Mediterranean environment, with specific attention on areas of active volcanism and tectonics, as well as the management of specific databases.

The *Services for the Society* Section also includes 6 abstracts related to original experimental devices developed for security in harbor environments, as well as to operational oceanography and to third mission initiatives aimed to raise public awareness toward environmental pollution and marine sciences.

The large variety of the topics presented and the relatively high number of attendees respect to the youthfulness and limited dimension of the marine environmental research area at INGV compared to its traditional disciplines, is an incitement to promote further this kind of initiatives based on in-person discussion and mutual update.

We take the opportunity to express our thankfulness to all the attendees.

The Workshop Organisation Committee
Leonardo Sagnotti, Laura Beranzoli, Cinzia Caruso, Sergio Guardato, Simona Simoncelli

RESEARCH

Tracking methane from the seafloor to the atmosphere: results from submarine multidisciplinary observatories and water column monitoring

Francesco Italiano, Cinzia Caruso, Gianluca Lazzaro, Manfredi Longo, Davide Romano, Sergio Scirè Scappuzzo

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy

francesco.italiano@ingv.it

Introduction

Methane is a typical greenhouse gas, about 80 times more effective than carbon dioxide and thus able to contribute significantly to the global warming, including the warming up of the oceans. It is well known that gas-hydrates have a delicate equilibrium and are very sensitive to temperature and pressure changes. A slight increase in the water temperature affects their stability and thus their conversion from solid state to a gas phase and the consequent release of methane at the seafloor. Some marine areas might release large amounts of methane and the methane transfer from the seafloor to the atmosphere may become an important issue in the very next future, due to its effects on the climate changes. Currently, the cumulative effect of the possible mechanisms responsible for the injection of methane from the marine sediments, through the water column into the atmosphere, remains poorly constrained.
To better understand the processes governing the release of methane from the seabed to the atmosphere and forecast possible negative environmental effects, it was carried out an interdisciplinary marine expedition in the Black Sea relying on four European Research Infrastructures (EMSO, ICOS, ACTRIS and EuroFleets). The cruise was organized in the frame of the E.U. project ENVRIplus, WP4, Task 4.2 - Marine/Atmosphere common operation of platforms. Here we report the first results gained by the cruise carried out over a study area located in the euxinic area xx miles off the coast at a depth of about 120m (Figure 1).

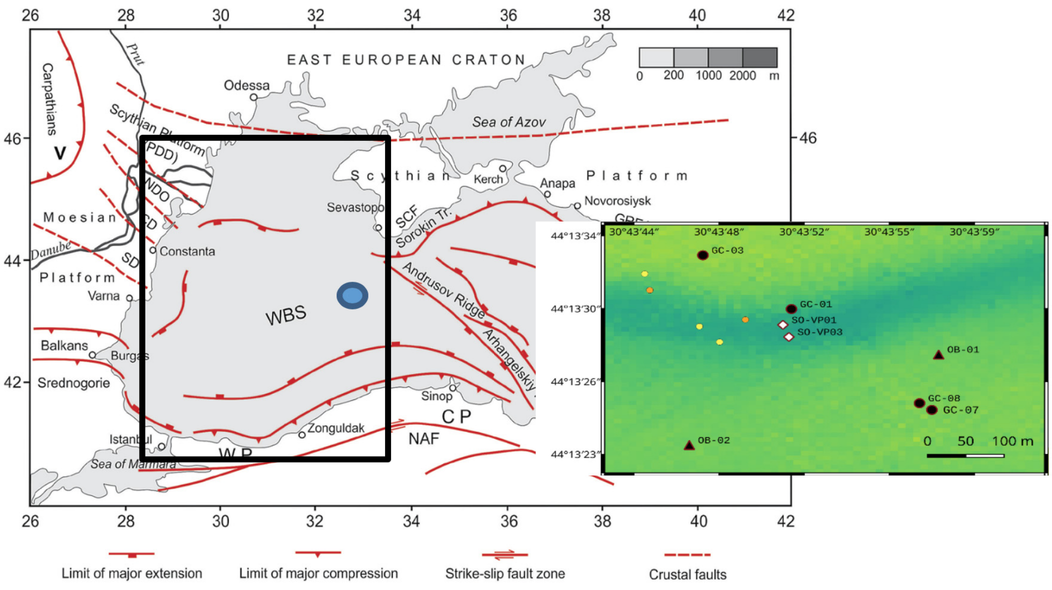


Figure 1 The working area in the Black Sea with the sampling and deployment site (modified after Oaie et al., [2016]). The working area is located in the euxinic area and it is crossed by several tectonic lines.

The Black Sea is the water reservoir with the highest amount of dissolved methane due to large number of vigorous methane-rich seeps from the continental shelf to the deepest part of its basins. The experiment included geophysical investigations to recover a detailed bathymetry and to locate the methane flares; vertical casts with the collection of water samples by niskin bottles; coring of the seafloor sediments and the deployment of a multidisciplinary seafloor observatory for mid to long term data acquisition of temperature, Electrical Conductivity, pH, dissolved CH_4, and acoustic data. We account for the methane concentration in sea water measured on samples collected by niskin bottles during vertical casts at different depths, as well as for the deployment of a multidisciplinary seafloor observatory (EMSO-MedIT 001).
After a five-days long monitoring period, the observatory was recovered and, after downloading of the data, it was re-deployed for a mid-term monitoring activity.

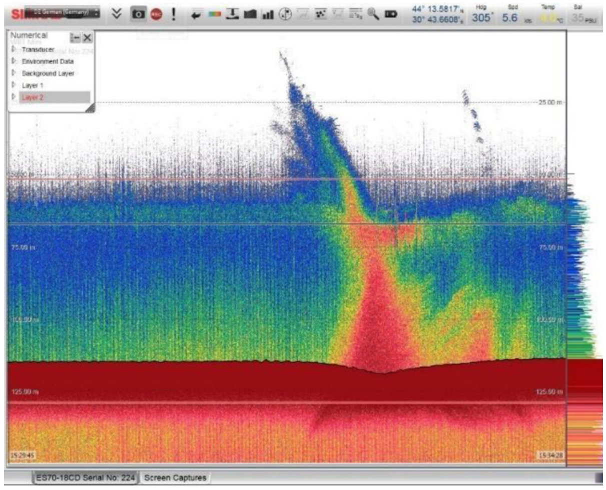


Figure 2 One of the flares detected by the geophysical investigations. The shape of the flare clearly shows two different domains: from the surface to a depth of about 50m in coincidence with the thermocline there are strong currents that are totally absent underneath the thermocline.

Results

1.1 Data from water column

The sea-water samples, collected by Niskin bottles along the water column, have been analyzed on board for pH, and EC. Samples for dissolved gas analysis were collected in 120ml serum-type bottles. They had been delivered to the laboratory for the chemical composition of the dissolved gases. The adopted sampling [e.g. Loreto et al. 2014] and analytical methods [Italiano et al., 2015 and references therein] are standard procedures reported elsewhere.

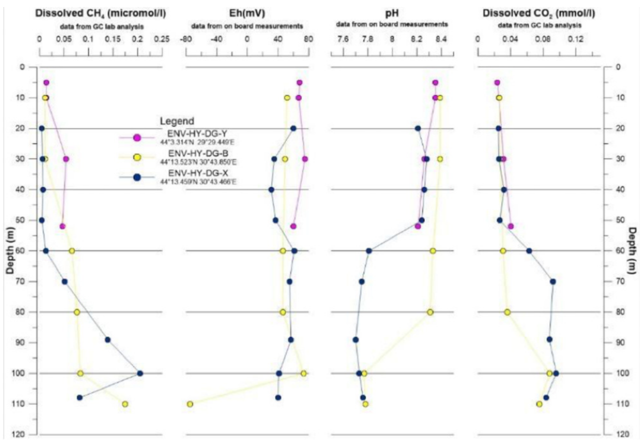


Figure 3 Plot of concentration of CH_4, CO_2 and pH values along the water column for three vertical profiles. It is worth of notice the coherence in terms of decrease of the pH values with increasing CO_2 contents and for all the measured parameters the different behavior above and below the thermocline.

Figure 3 shows the results of both on-board (Eh, pH) and laboratory (gas composition) analyses. It is evident the sudden change of all the parameters below the thermocline (50 meters water depth), where the absence of marine currents allows stratified water masses. The dissolved CH_4 increases with increasing water depth showing a significant jump at the depth of 100 metres, close to the seabed. It is coherent with the low Eh values (reducing environment) while the presence of dissolved CO_2 fits with the decreasing of pH.

1.2 Data from Sea floor observatory

The first, short-term deployment of the multidisciplinary seafloor observatory (EMSO-MedIT 001, Figure 4, left) allowed to record acoustic signals besides data of dissolved CH_4, temperature, pressure, EC, pH and turbidity over a five-days monitoring period. After the first short-term data acquisition, the observatory was recovered, data downloaded and re-deployed after 12 hours for a three months-long monitoring activity (April-June). In June the observatory was again recovered and redeployed for a further mid-term activity (June-November).
The first data-set has shown how the collected data of dissolved methane are in full agreement with the laboratory results. The CH_4 content increased in coincidence of the coring together with the turbidity. The hydrophone recorded a significant increase of the noise in the frequencies of 350-450 Hz (associated to gas bubbling clusters) and 12-20Hz, related to tremors generated by gases dynamic along the cracks at the seabed (Figure 4, right).

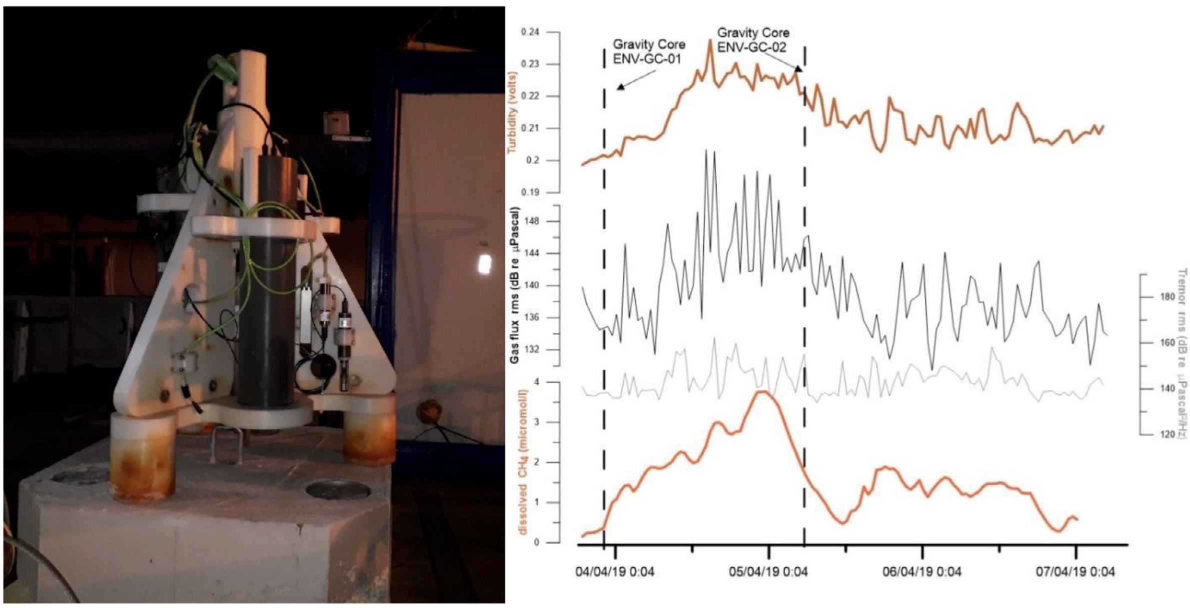


Figure 4 The Multidisciplinary observatory on board of the Mare Nigrum research vessel just before the deployment and the results collected during the first deployment.

Conclusions

The data collected during the cruise confirm that the Black sea is a significant CH_4 reservoir which transfer from the seafloor to the sea-water-atmosphere interface has to be carefully monitored. The analyses carried out on samples collected during the vertical casts show that besides CH_4, the deep sea water masses contain also dissolved CO_2. The sudden change in the behavior of the geochemical parameters along the vertical profile is coherent with the well known currents above the thermocline. The currents probably induce mixings in the water masses and carry away from the venting area the dissolved methane. The first dataset (4-7 April, 2019) from the multidisciplinary observatory has shown coherent changes in the acoustics, dissolved CH_4 concentration in sea water and turbidity (Figure 4). The acoustic data also allowed to reveal changes in the bubbling activity, which is a proxy of the total submarine gas output, induced by human activities (coring) showing that any development of industrial activity aimed to the exploitation of resources located beneath the sea floor, as well as local seismic activity, could produce a potential enhancement of methane release and its transfer to the atmosphere.

References and citations

Italiano F., Yuce G., Uysal I.T., Gasparon M., Morelli G., (2014). *Insights into mantle-type volatiles contribution from dissolved gases in artesian waters of the Great Artesian Basin, Australia*. Chemical Geology, vol 378–379, 75–88.

Loreto M.F., Italiano F., Deponte D., Facchin L., Zgur F., (2015). *Mantle degassing at the top of an unknown submarine volcano in the SE Tyrrhenian Sea.* Terra Nova, 27, 195–205, doi: 10.1111/ter.12148.

Oaie G., Seghedi A., Rădulescu V., (2016). *Natural marine hazards in the black sea and the system of their monitoring and real-time warning*. Geo-Eco-Marina 22/2016, 5-28.

Geochemistry of gases emitted from Kolumbo submarine volcano (Hellenic Volcanic Arc, Greece)

Andrea Luca Rizzo[1], Antonio Caracausi[1], Valérie Chavagnac[2], Paraskevi Nomikou[3], Paraskevi N. Polymenakou[4], Manolis Mandalakis[4], Georgios Kotoulas[4], Antonios Magoulas[4], Alain Castillo[2], Danai Lampridou[3], Nicolas Marusczak[2], Jeroen E. Sonke[2]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy*
[2]*CNRS, Géosciences Environnement Toulouse, 14 Avenue Edouard Belin, Toulouse, France*
[3]*Department of Geology and Geoenvironment, National and Kapodistrian University of Athens, Panepistimiopolis, Zographou, Greece*
[4]*Hellenic Centre for Marine Research, Institute of Marine Biology, Biotechnology and Aquaculture, Heraklion, Crete, Greece*

andrea.rizzo@ingv.it

Introduction

The Hellenic Volcanic Arc (HVA) is located in the South Aegean Sea (East Mediterranean) and results from the subduction of the African plate below that European (Figure 1a). Kolumbo submarine volcano is located in the middle of HVA (Fig 1a), 7 km northeast off Santorini Island (Figure 1b). This volcano is part of a chain of 25 submarine cones and craters [Nomikou et al., 2012], and extends NE of Santorini along the floor of the Anhydros basin (Figure 1b). The largest and most active of these cones is Kolumbo (Figure 1c), which last erupted in 1650 AD with seventy people offshore or along the NE coast of Santorini died. The cone consists of a crater that is 1.7 km in diameter and up to 500 m deep (Figure 1c).

Kolumbo is crossed by a regional volcanic line, which is called Christianna-Santorini-Kolumbo [CSK, Nomikou et al., 2013] that likely controls the pathways of hydrothermal circulation within the region (Figure 1b). In 2006, an extensive hydrothermal vent field was discovered at 500 m depth in the crater floor of this submarine volcano [Sigurdsson et al., 2006]. Kolumbo crater today emits high-temperature CO_2-rich fluids (Figure 1d) that reduce seawater pH to 5, indicative of an active degassing from magmas [Carey et al. 2013].

There are marked geochemical differences between Kolumbo and Santorini magmas despite their close temporal and spatial association [Rizzo et al., 2015; 2016; Klaver et al., 2017]. This suggests that the two magmatic systems could tap different mantle source volumes and/or that crustal contamination is variably occurring.

The depth of the magma chamber beneath Kolumbo is constrained between 5 and 7 km [Dimitriadis et al., 2009], where modern-day microseismicity is also located [Dimitriadis et al., 2009]. The aim of this work is to summarize and re-elaborate the results of two recent geochemical studies carried by Rizzo e al. [2016; 2019], in order to define the chemical and isotope composition of fluids discharged at the bottom of the crater and reconstruct the P-T conditions of the hydrothermal system.

Results

In May 2014, during the 4-SeaBioTech survey on RV AEGAEO, seven chimneys bubbling gas with variable fluxes were sampled on the floor of Kolumbo submarine crater (Figure 1e).

The composition of submarine gases emitted from Kolumbo crater floor is dominated by CO_2

that has concentrations up to 99.1%. O_2 and N_2 are present in concentrations that reach 5.1 and 21%, respectively, in the most air contaminated samples. CH_4 ranges between 1052 and 5521 ppm, while C_2H_6 and C_3H_8 between 95-128 ppm and 14-20 ppm, respectively. Helium varies between 9 and 40 ppm, while H_2 and CO are in the range 170-716 ppm and 2-7 ppm, respectively. ^{20}Ne ranges between 0.082 and 4.2 ppm, while ^{40}Ar between 69 and 834 ppm. Relative ratios between O_2 and N_2, ^{20}Ne and ^{40}Ar, indicate that gas samples are contaminated by AIR rather than ASW, which was likely assumed during sampling or extraction procedures. For this reasons, the chemistry of gases was corrected for air contamination.
Hydrothermal gas Hg(0) concentrations vary between 61 and 1301 ng·m^{-3}.
The ^{3}He/^{4}He ranges between 6.8 and 7.1 Ra (Figure 2). The ^{4}He/^{20}Ne ratio varies in the range 9-270, while ^{40}Ar/^{36}Ar varies between 296 and 316, further indicating the presence of air contamination.
The isotope composition of carbon ($\delta^{13}C_{CO2}$) varied between -0.04‰ and 1.15‰ V-PDB (Figure 3). The isotope composition of CH_4 varied over a narrow range for both carbon (-18.8< δ^{13}C<-17.6‰ V-PDB) and hydrogen (-118.6< δD<-115.4‰ V-SMOW).
Data of chemistry and isotope composition are reported in Rizzo et al., [2016; 2019] tables.

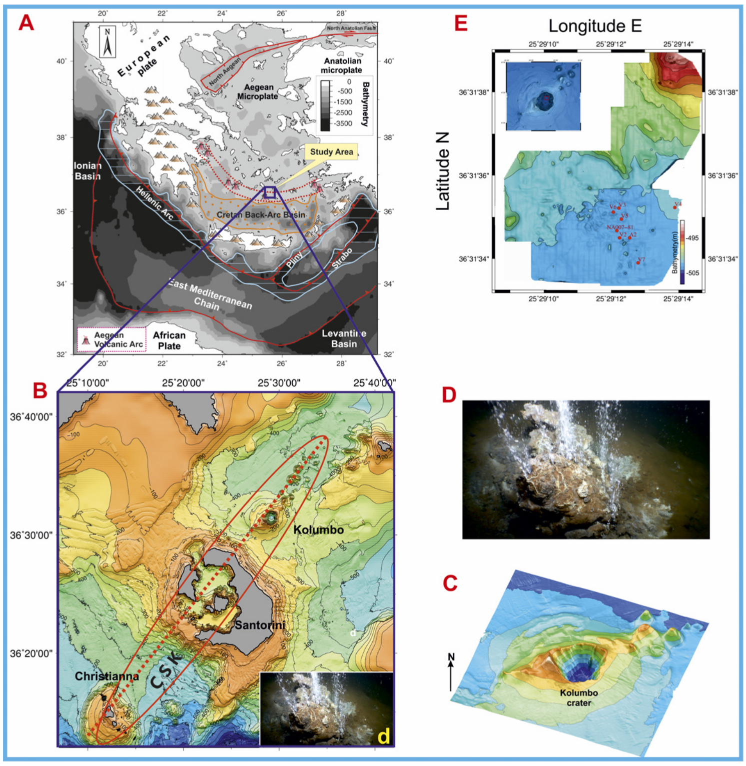


Figure 1 A) Map of the present day geodynamic setting of the HVA (redrawn from Rizzo et al., [2016; 2019]. The study area B) is located in the center of the HVA. C) 3D Bathymetric map of Kolumbo submarine volcano, showing the shape of the crater; D) Active hydrothermal vent collected in this work; E) High resolution swath bathymetric map of Kolumbo crater bottom with the location of the sampled hydrothermal chimneys.

Discussions and concluding remarks

The ^{3}He/^{4}He signature of 7.0 Ra measured in Kolumbo gases is at the lower limit of MORB-like mantle (8±1 Ra) and is higher than the signature proposed for European sub continental lithospheric mantle (6.3±0.4 Ra) (Figure 2). This highlights that magma degassing beneath Kolumbo and feeding its hydrothermal system has a ^{3}He/^{4}He representative of the primary source, which is poorly or not contaminated by the recycling of crustal material in the wedge or within the crust. Instead, fluids and rocks from the neighboring Santorini volcano show ^{3}He/^{4}He ≤4 Ra [Rizzo et al., 2015], that results from crustal contamination. In fact, a recent study on seawater pools within Santorini caldera found ^{3}He/^{4}He up to 7.0 Ra [Moreira et al., 2019] (Figure 2), confirming previous inferences on local crustal contaminations and supporting the mantle

beneath Kolumbo and Santorini can be considered homogeneous. An immediate implication is that magmas feeding Kolumbo derive directly from the mantle, confirming the presence of two distinct plumbing systems beneath Santorini and Kolumbo volcanic systems inferred by recent volcanological and geochemical investigations [Dimitriadis et al., 2009].
The $^3He/^4He$ values measured in Kolumbo gases are also the highest ever measured in gases and rocks belonging to the HVA (Figure 2). Before discovering this submarine volcano as well as the recent evidences from Santorini submarine fluids [Moreira et al., 2019], the highest $^3He/^4He$ were measured in gases from Nisyros (6.2 Ra), located at the eastern side of the arc [Shimizu et al., 2005] (Figure 2). The new evidences point towards a homogeneous and MORB-like mantle below the central and eastern part of the HVA (from Santorini-Kolumbo up to Nisyros-Kos) where some extents of crustal contamination locally decrease the mantle signature.

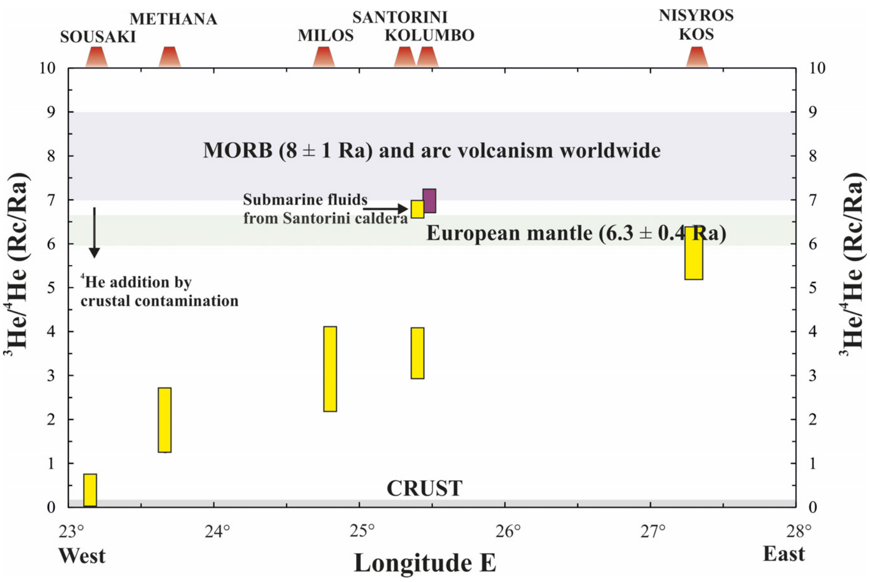
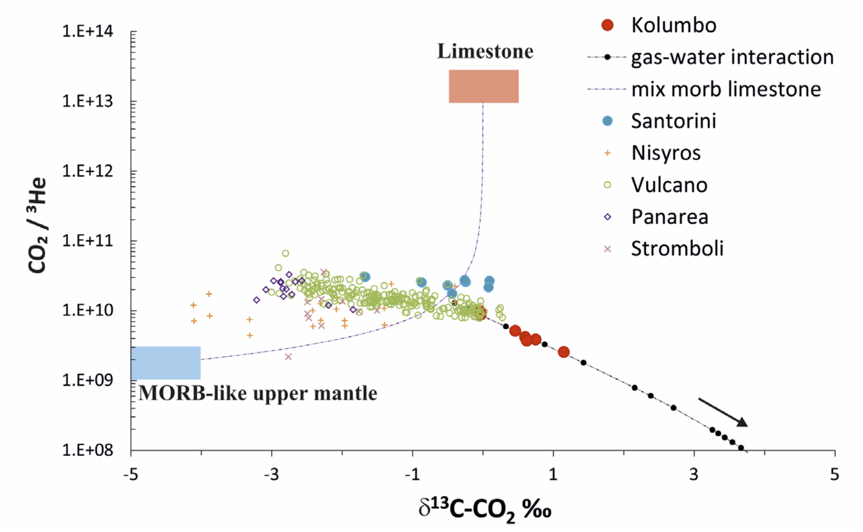


Figure 2 Along-arc variations of 3He/4He [Shimizu et al., 2005; Rizzo et al., 2016 and references therein] in the HVA, redrawn from Rizzo et al., [2019)].

The chemistry of gases coupled to the isotope composition of carbon ($\delta^{13}C_{CO2}$) shows that partial dissolution of CO_2 in seawater modifies the pristine composition of magmatic fluids (Figure 3), although the CO_2 concentration is always >97%. The species of gas mixture dissolve in liquid water according to Henry's law. The partial dissolution of CO_2 also modifies the isotope composition of gaseous carbon ($\delta^{13}C_{CO2}$), due to the isotopic fractionation between gaseous CO_2 and dissolved inorganic CO_2(aq) (DIC). This effect can be better evaluated in Figure 3 and is modeled by Rizzo et al., [2019]. The restored composition of gases before gas-water interaction process yields $\delta^{13}C_{CO2}$ of -0.4‰ (Figure 3), which is above the typical mantle range (8‰<δ^{13}C<-4‰, Sano and Marty, 1995), indicating the contamination by limestone (-1‰<δ^{13}C<+1‰). The original $\delta^{13}C_{CO2}$ of Kolumbo gases is comparable to fluids from Nea Kameni fumaroles that vary in the range -0.2±2.7‰ [Parks et al., 2013] (Figure 3). Submarine fluids collected within Santorini caldera yield similar $\delta^{13}C_{CO2}$ values [Moreira et al., 2019]. Within the HVA, the $\delta^{13}C_{CO2}$ values measured in gases from Kolumbo and Santorini are also comparable to those found by Brombach et al., [2003] in Nisyros fumaroles (Figure 3). These evidences strongly indicate that the contamination by limestone has a regional extension and is occurring directly in the mantle wedge, as observed at Stromboli volcano in the Aeolian volcanic arc [Gennaro et al., 2017] (Figure 3).
Based on $\delta^{13}C_{CH4}$ versus $CH_4/(C_2H_6+C_3H_8)$ and δD_{CH4} versus $\delta^{13}C_{CH4}$, CH_4 originates from a mixing between oxidized thermogenic and abiogenic CH_4 formed in high temperature (>200° C) magmatic-hydrothermal systems.
Hydrothermal gas Hg(0) concentrations show a wide range of values (61 and 1301 ng·m^{-3}) among the different samples, indicating that the variability in chemistry of fluids is related to variable flux

of gas emitted from the hydrothermal vents located at the crater floor. In general, the Hg(0) concentrations measured from Kolumbo fluids are about 10 times higher than those previously reported for Santorini fumaroles (9 to 121 ng·m^{-3}; [Bagnato et al., 2013]) and for the worldwide aerial volcanic Hg(0) (4 to 125 ng·m^{-3}).

Figure 3 Plot of $\delta^{13}C_{CO2}$ versus $CO_2/^3He$, redrawn from Rizzo et al., [2019]. ^3He data are taken from Rizzo et al., [2016], while CO_2 data from Rizzo et al., [2019]. Data for Santorini, Nisyros, Vulcano and Panarea are from Rizzo et al., [2015]; Brombach et al., [2003]; Paonita et al., [2013]; Tassi et al., [2014], respectively.

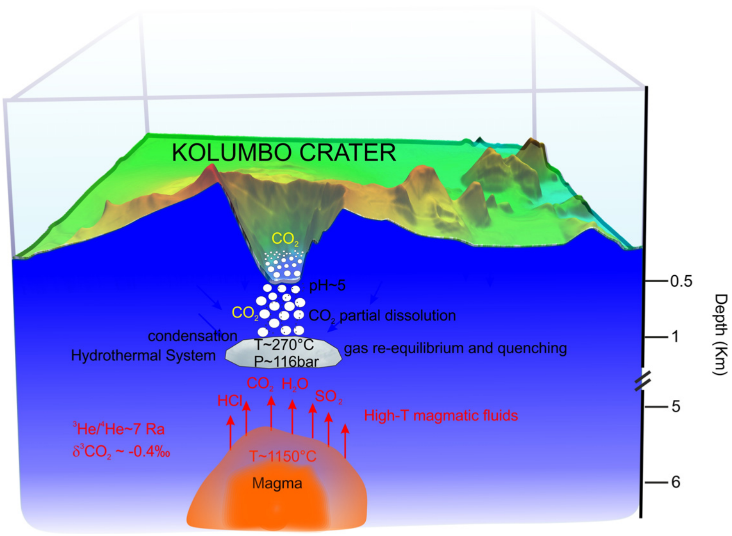


Minor reactive species (H_2-CO-CH_4) and CO_2 corrected for gas-water interaction process were used for calculating temperature (T) and pressure (P) conditions at which gas species equilibrated in the hydrothermal system beneath Kolumbo crater. We assumed that gas species attained chemical equilibrium in the hydrothermal system and are quenched during upraise toward the surface.

In detail, we based on the approach proposed by Chiodini et al., [2006] for Panarea submarine gases. We calculated a T ~ 270°C, P_{CO2} ~ 30 bar and P_{H2O} ~ 36 bar that sum to a total pressure of ~66 bar. Considering that Kolumbo gases are emitted at 500 m b.s.l., which corresponds to a pressure of ~50 bar, the hydrothermal system must be located at a pressure of ~116 bar (~1000 m b.s.l.) (Figure 4).

In conclusion, the geochemical study of chemical and isotopic composition of fluids emitted from Kolumbo submarine volcano revealed that this volcano is probably the most active of the HVA and the associated volcanic hazard is potentially high. With this in mind, the development of a regular geochemical monitoring program for this potentially dangerous submarine volcano is strongly suggested.

Figure 4 Sketch of the hydrothermal system beneath Kolumbo, redrawn from Rizzo et al., [2019].



References

Bagnato E. et al., (2013). *Nea Kameni volcanic centre, Santorini (Greece).* Geochemical Journal, Vol.47.

Brombach et al., (2003). *Geochemical evidence for mixing of magmatic fluids with seawater, Nisyros hydrothermal system, Greece*. Bull. Volcanol. 65, 505–516.

Carey S. et al., (2013). *CO_2 degassing from hydrothermal vents at Kolumbo submarine volcano, Greece, and the accumulation of acidic crater water*. Geology 41, 1035–1038.

Chiodini G. et al., (2006). *Geochemistry of the submarine gaseous emissions of Panarea (Aeolian Islands, southern Italy): magmatic vs. hydrothermal origin and implications for volcanic surveillance*. Pure Appl. Geophys. 163, 759–780.

Dimitriadis I. et al., (2009). *Seismicity and active tectonics at Coloumbo Reef (Aegean Sea, Greece): monitoring an active volcano at Santorini Volcanic Center using a temporary seismic network.* Tectonophysics 465, 136–149.

Gennaro M.E., Grassa F., Martelli M., Renzulli A. and Rizzo A.L., (2017). *Carbon isotope composition of CO_2-rich inclusions in cumulate-forming mantle minerals from Stromboli volcano (Italy).* J. Volcanol. Geotherm. Res., 1–9 (in press), http://dx.doi.org/10.1016/j.jvolgeores.2017.04.001.

Klaver M., Carey S., Nomikou P., Smet I., Godelitsas A. & Vroon P., (2017). *A distinct source and differentiation history for Kolumbo submarine volcano, Santorini volcanic field, Aegean arc*. Geochemistry Geophysics Geosystems 17, doi:10.1002/ 2016GC006398.

Moreira M., Escartin J., Scelin L., Ruzié-Hamilton L., Nomikou P., Mével C., Andreani M., (2019). *New insights into the plumbing system of Santorini using helium and carbon isotopes.* Geochem. Persp. Let. 10, 46-50. doi: 10.7185/geochemlet.1914.

Nomikou P., Papanikolaou D., Alexandri M., Sakellariou D. & Rousakis G., (2013). *Submarine volcanoes along the Aegean volcanic arc*. Tectonophysics597-598, 123–146.

Paonita A. et al., (2013). *The episodic and abrupt geochemical changes at La Fossa fumaroles (Vulcano Island, Italy) and related constraints on the dynamics, structure, and compositions of the magmatic system.* Geochim. Cosmochim. Acta 120, 158–178.

Parks M.M. et al., (2013). *Distinguishing contributions to diffuse CO_2 emissions in volcanic areas from magmatic degassing and thermal decarbonation using soil gas 222Rn–δ13C systematics: Application to Santorini volcano, Greece*. Earth Planet. Sci. Lett.,377-378, 180-190, doi: 10.1016/j.epsl.2013.06.046.

Rizzo A.L. et al., (2015). *New mafic magma refilling a quiescent volcano: Evidence from He-Ne-Ar isotopes during the 2011–2012 unrest at Santorini, Greece*. Geochem. Geophys. Geosyst., 16, 798–814, doi: 10.1002/2014GC005653.

Rizzo A.L. et al., (2016). *Kolumbo submarine volcano (Greece): An active window into the Aegean subduction system.* Scientific Reports. Nature Publishing Group 6, 28013.

Rizzo A.L. et al., (2019). *Geochemistry of CO_2-Rich Gases Venting from Submarine Volcanism: The Case of Kolumbo (Hellenic Volcanic Arc, Greece).* Front. Earth Sci. 7:60. doi: 10.3389/feart.2019.00060.

Sano Y. & Marty B., (1995). *Origin of carbon in fumarolic gases from island arcs*. Chemical Geology, 119, 265-274. http://dx.doi.org/10.1016/0009-2541(94)00097-R.

Sigurdsson H. et al., (2006). *Marine investigations of Greece's Santorini Volcanic Field*. EOS, Transactions American Geophysical Union 87, 337.

Shimizu A., Sumino H., Nagao K., Notsu K. & Mitropoulos P., (2005). *Variation in noble gas isotopic composition of gas samples from the Aegean arc, Greece*. J. Volcanol. Geotherm. Res.140, 321–339.

Tassi F. et al., (2014). *Compositional spatial zonation and 2005–2013 temporal evolution of the hydrothermal-magmatic fluids from the submarine fumarolic field at Panarea Island (Aeolian Archipelago, southern Italy).* Journal of Volcanology and Geothermal Research 277, doi: 10.1016/j.jvolgeores.2014.03.010.

Evaluating environmental impact coming from hydrothermal vents by geochemical and acoustic data: the case study of Panarea hydrothermal system

Cinzia Caruso, Gianluca Lazzaro, Manfredi Longo, Davide Romano, Sergio Scirè Scappuzzo and Francesco Italiano

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy

cinzia.caruso@ingv.it

Atmospheric CO_2 diffuses passively into global ocean surface waters and causes an increase in the partial pressure of the CO_2 and thus a reduction in seawater pH. With the current rate of pH change standing at 0.015 units per decade [Haugan and Drange, 1996] it is probable that by 2100 a global surface water reduction in pH of up to 0.5 units will occur. Little is known about how marine organisms will be affected by both long and short term seawater acidification, increased carbon dioxide partial pressure and other pH associated changes to ocean chemistry [Turley et al., 2006]. However, it is likely that marine organisms would be affected by a number of troubles such as difficulty in acid–base regulation, growth, reproduction, feeding and ultimately mortality [Kurihara et al., 2004; Kurihara and Shirayama, 2004]. A chronic reduction of surface water pH to below 7.5 would be severely detrimental to the acid–base balance of many species. Monitoring, in the form of time series data, is essential to understand oceanic processes from the surface to the oceanic sub-bottom. Panarea, the smallest of the Aeolian Islands, represents, along with the islets that surround it, the emerging part of a bigger volcanic apparatus.

Figure 1 Submarine hydrothermal system off the island of Panarea.

The offshore area around the island hosts the most active submarine hydrothermal system in the Mediterranean, characterized by hot and acid waters vents and widespread CO_2 emissions discharged through local tectonic structures even at low depths (5 - 30 m) [Italiano et al., 1991]. These features make Panarea an ideal natural laboratory for the study of processes related to seabed CO_2 leaks, ocean acidification and warming. In order to investigate all these questions, a multidisciplinary seafloor observatory connected to a buoy, has been deployed offshore Panarea, in the middle of the islets, operating and transmitting data in near-real-time [Italiano et al., 2011].

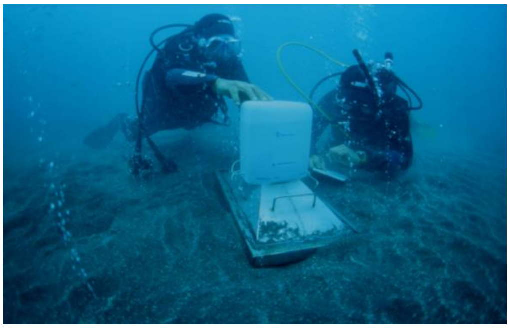


Figure 2 Gas output measurement performed by scuba-divers (ranging around 107 liters per day during quiet periods).

	Vol. %
CO_2	92-99
H_2S	0.1 ÷ >3
H_2	< 0.0001-0.1
N_2	0.2 – 0.5
He	0.0008 – 0.002
Ar	0.0008 – 0.005
CH_4	0.0001 – 0.2
CO	<0.0001-0.001

Table 1 The table reports the composition of the gas mixtures vented at the Panarea seafloor. Gases are CO_2-dominated with variable contents of reactive (CO, H_2, CH_4 etc) and inert (N_2, He etc) gas species.

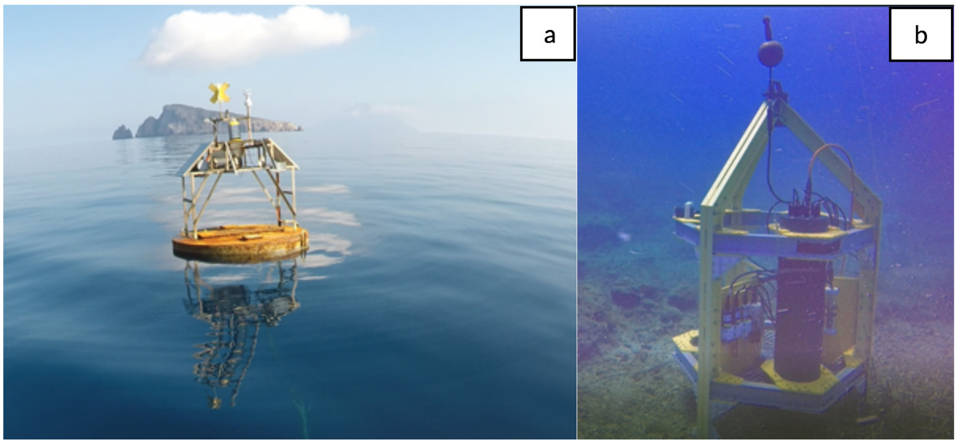
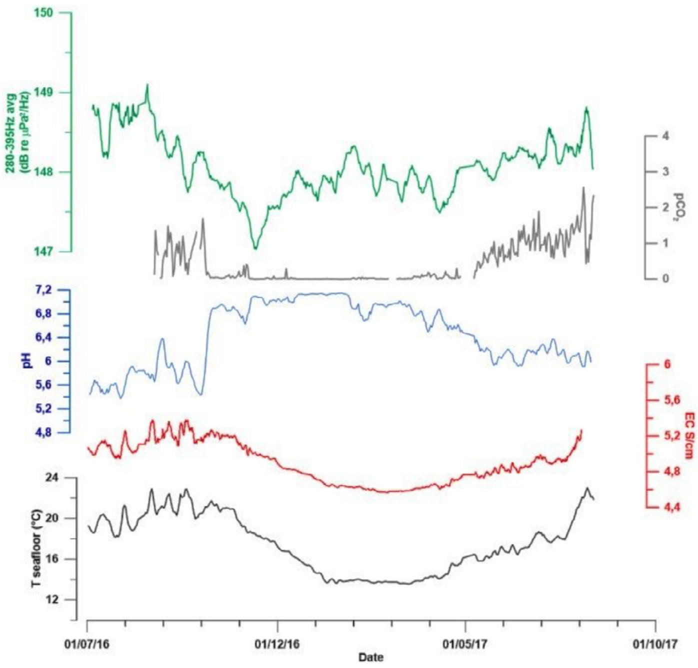


Figure 3 The pictures show the whole system made of a multidisciplinary submarine observatory (b) and a buoy (a). The observatory operates in near-real-time mode and is equipped with a multi-parametric sensors suite. The buoy allows data communication and to check the status of all the probes.

The observatory is able to operate down to a water depth of 4000 m in an extreme, hydrothermal, marine environment, and to collect data from probes for acoustic signals, dissolved CO_2, temperature, Ox, H_2S and CH_4, pressure, EC, pH.
The actual settings allow the data collection three times per hour along with 20 seconds of hydro-acoustic signals to reduce power consumption and data transmission issues. The main aim to collect acoustic data is to study the bubbling frequencies variation, typically in the range between 70 Hz and 2 kHz, related to the changes of the gas flow rate from the hydrothermal vents as a proxy of changes of the total submarine gas output. These results show how, aside from occasional gas burst events, the leaking gas is relatively stable in terms of flux rates. Collected data showed as the submarine vents are affected by seasonal trends and changes due to tides, thus the raw data were filtered before any analysis [Caruso et al., 2019].

Figure 4 Example of raw data coming from the observatory. From the bottom to the top we can see variation over time of Temperature, Conductivity, pH, dissolved CO_2 and acoustic spectral energy variation related to hydrothermal underwater emissions (280-395 Hz range). Noise variation over time, in a definite frequency range, could be considered as a proxy of the total submarine gases output. All parameters show an evident seasonal trend due to natural forces.



This indicates that in hypothetical situations with stable water column or low currents, and low tide, can induce accumulation of dissolved CO_2 in the seafloor. Monitoring is an environmental safeguard.

References

Haugan P.M. and Drange H., (1996). *Effects of CO_2 on the ocean environment*. Elsevier Volume 37, Issues 6–8, June–August 1996, Pages 1019-1022 https://doi.org/10.1016/0196-8904(95)00292-8.

Turley C., Blackford J.C., Widdicombe S., Lowe D., Nightingale P.D. and Rees A.P., (2006). *Reviewing the Impact of Increased Atmospheric CO_2 on Oceanic pH and the Marine Ecosystem*. Cambridge University Press.

Kurihara H., Shirayama Y., (2004). *Effects of increased atmospheric CO_2 on sea urchin early development*. Mar. Ecol. Prog. Ser. 274:161–169.

Kurihara H., Shirayama Y., (2004). *Effects of increased atmospheric CO_2 and decreased pH on sea urchin embryos and gametes*. In: Heinzeller T., Nebelsick J.H., (eds) Echinoderms: München. Proc. 11th Int. Echinoderm Con. A.A. Balkema, Leiden, p 31–36.

Italiano F. and Nuccio P.M., (1991). *Geochemical investigations on submarine volcanic exhalations to the East of Panarea, Aeolian Islands, Italy*. Jour. Volc. and Geoth. Res., 46, 125-141.

Italiano F., Maugeri R., Mastrolia A., Heinicke J., (2011). *SMM, a new seafloor monitoring module for real-time data transmission: an application to shallow hydrothermal vents*. Procedia Earth and Planetary Science 4 (2011) 93 – 98.

Caruso C., Lazzaro G., Longo M., Romano D., Scirè Scappuzzo S. and Italiano F., (2019). *New insights into submarine hydrothermal system phenomena revealed by acoustic monitoring technologies*. Abstract Book della Società Geologica Italiana, "La geologia marina in Italia, Terzo Convegno dei geologi marini italiani - Roma, 21-22 febbraio 2019", numero di pagina. https://doi.org/10.3301/ABSGI.2019.02.

Geochemistry of REE and trace elements in shallow hydrothermal vent system at Panarea island (Italy)

Fabio Sposito[1,2], Manfredi Longo[1] and Lorenzo Brusca[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy*

[2]*Università degli Studi di Palermo, Dipartimento delle Scienze della Terra e del Mare (DiSTeM), Palermo, Italy*

fabio.sposito@unipa.it

The Rare Earth Elements (REE; lanthanides and yttrium) are important tracers of natural and anthropic geochemical processes. In this paper we show some recent progresses concerning the study of REE geochemistry in natural system.

Specifically, the REE behaviour was investigated in SHVs (shallow sea-water hydrothermal vents) in the sourranding area of Panarea Island (Eolian Island, Italy) [Italiano & Nuccio, 1991]. The variability of pH (4.1 – 8.2) and Eh (-235 – 186 mV) conditions is responsible of the chemical composition and fractionation of REE, having a wide range of concentration values, spanning from 55.9 to 23594.4 ng l^{-1}. ΣREE (total REE concentration) is higher than REE reference seawater value [Censi et al., 2007] up to three order of magnitude and are inversely correlated relative to pH values.

The pH and Eh conditions play a key role on water composition in terms of trace elements, controling the precipitation of Fe and Al-bearing minerals inducing changes in REE fractionation [Inguaggiato et al., 2015]. As a result, REE Patterns normalized to PAAS show different trends respect the reference seawater values (Figure 1). Two different pattern trends have been observed: type-1, increasing trend from La to Lu, reflecting carbonate complexation of REE due to seawater influence; Type-2, caracterised by Light REE depletion (LREE: La-Sm), probably due to adsorption to Al and Fe-Oxyhydroxides.

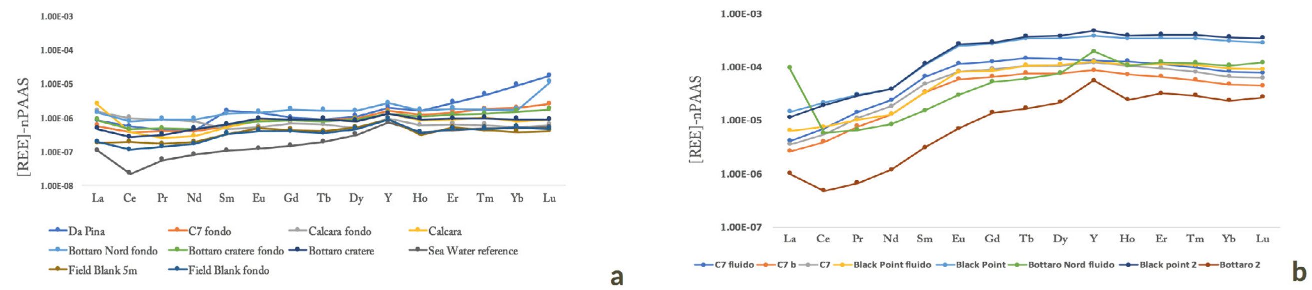


Figure 1 PAAS-Normalised REE Patterns: a) Pattern type-1; b) Pattern type-2. seasonal trend due to natural forces.

In particular LREE depletions (Ce_N/Lu_n <1.0) are observed respect MREE (Middle REE: Eu-Dy) and HREE (Heavy REE: Ho-Lu)). Plotting Ce_N/Lu_N vs ΣREE, an hyperbolic array is displayed (Figure 2) formed by two end-members: EM1 (green dot in figure 2) characterised by higher Ce/Lu and Low Al and Fe concentrations (REE Pattern type-1); EM2 (red dot in figure 2) with Lower Ce/le and high Al and Fe concentrations (REE Pattern Type-2).

All these evidences demonstrate that the amplitude of LREE decrement is controlled by Fe and Al-bearing minerals. Since a positive correlation among REE-Al-Fe is observed (Figure 3), the simultaneous variation of these elements indicates the involvement of Al and Fe controlling REE abundance.

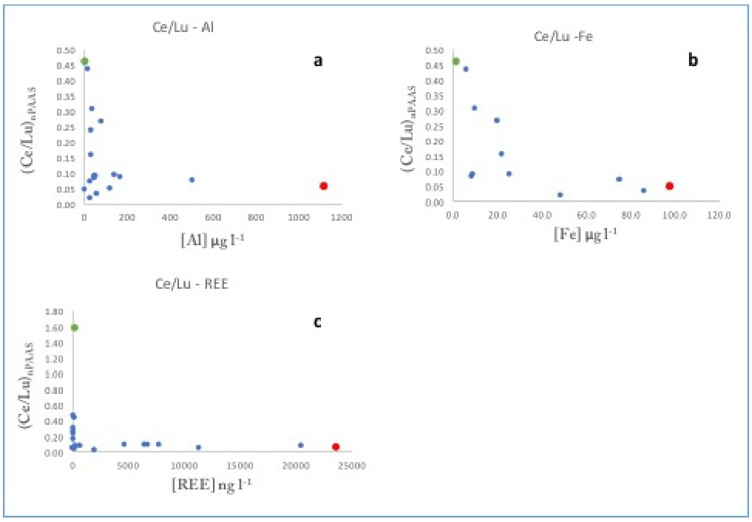


Figure 2 Correlation between Al-Fe-REE concentrations and Cen/Lun ratio.

Furthermor minor Ce anomaly (>0.6) have been calculated respect the well documented Ce anomaly in seawater (0.2) [Alibo & Nozaki, 1999]. Probably the redox condition (Eh <0 mV) do not allow the oxidation of Ce(III) to Ce(IV), as a result the preferential scavenging activity over REE(III)s is inhibited.

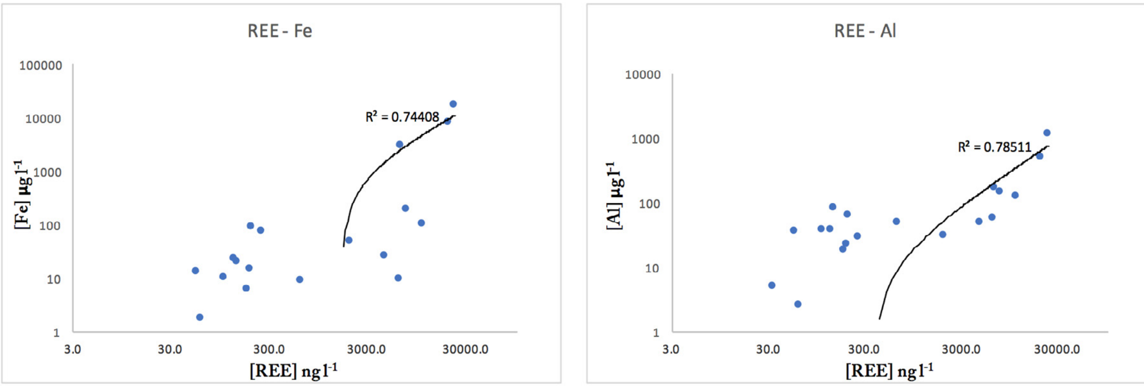


Figure 3 Correlation between Al-Fe-REE concentrations and Cen/Lun ratio.

References and citations

Alibo D.S. and Nozaki Y., (1999). *Rare earth elements in seawater: particle association, shale normalization, and Ce oxidation.* Geochim Cosmochim Acta 63, 363–372.

Censi P., Sprovieri M., Larocca D., Aricò P., Faiano F., Mazzola S. and Ferla P., (2007). *Alteration effects of volcanic ash in seawater: Anomalous Y/Ho ratios in coastal waters of the Central Mediterranean Sea.* Geochimica et Cosmochimica Acta 71 (22), 5405-5422.

Inguaggiato C., Censi P., Zuddas P., Londono J.M., Chacòn Z., Alzate D., Brusca L. and D'Alessandro W., (2015). *Geochemistry of REE, Zr and Hf in a wide range of pH and water composition: The Nevado del Ruiz volcano-hydrothermal system (Colombia).* Chemical Geology 417, 125-133.

Italiano F. and Nuccio P.M., (1991). *Geochemical investigations of submarine volcanic exhalations to the east of Panarea, Aeolian Islands, Italy.* Journal of Volcanology and Geothermal Research, 46, 125-141.

Environmental processes at the land-sea interface at Vulcano island (Italy)

Paolo Madonia

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Palermo, Italy

paolo.madonia@ingv.it

Vulcano, the southernmost island of the Aeolian Archipelago, has been characterized by an intense fumarolic activity since its last eruption from La Fossa cone (1888-1890). According to Badalamenti et al., [1991] fumarolic gases consist of water vapour (80-96 % vol) associated to CO_2 (3-17%) and minor amounts of acidic species (SO_2, H_2S, HCl and HF). The main fumarolic field is located in the northern, internal sector of the 1888 crater; other exhaling areas are found in the peripheral zones of the crater, at Palizzi and, close to the sea, in the Baia di Levante area, in the north, and at Gelso, in the south (Figure 1).

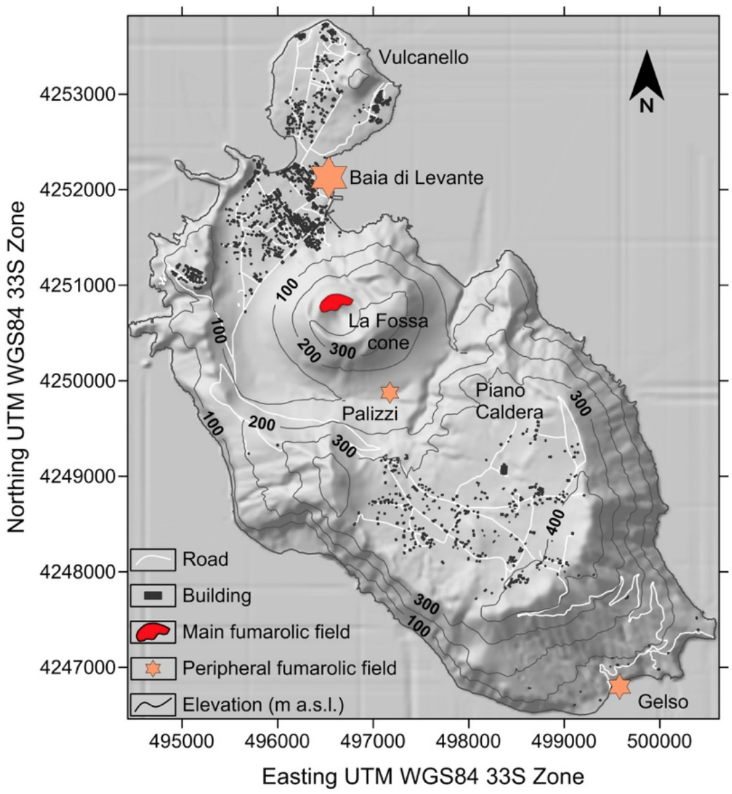


Figure 1 Map of Vulcano Island showing the location of the fumarolic fields.

The fumarolic field of Baia di Levante (Figure 1) is partly sub-aerial and partly submerged, with maximum depths not exceeding few meters, and it is located in an area with a strong touristic vocation and frequentation, where volcano-hydrothermal activity represents, at the same time, a landmark, the main cause of hydrogeological instability and a severe risk for human health. This last subject is well evidenced by what happened in April, 2015 when a French child closely approached an undersea vent, located at about 1 m depth, remaining seriously asphyxiated.

The evolution, both in space and time, of the Baia di Levante area is controlled by complex interactions between volcanic, tectonic, morphogenetic and anthropic processes, mostly linked to the shallow circulation of hydrothermal fluids. Figure 2 synthetically illustrates the main features of this system:

1. a degassing vent (mv in Figure 2a-b), over-pressured with respect to the atmosphere and mainly emitting CO_2, which has shown a huge flow increment since 2009;
2. an artificial reef ('ar' in Figure 2a), built between 2004 and 2005 for mitigating the intense erosion of the northern sector of the fumarolised cliff;
3. an artificial pool ('ap' in Figure 2a) created by tourists for accumulating warm water;
4. a retrograding detachment front in the sector of the fumarolised cliff closer to the "Faraglione" ('df' in Figure 2a), where fast marine erosion is fostered by deterioration of mechanical properties of the rocks due to hydrothermal alteration. The comparison with Figure 2c gives an idea of the time scale of this phenomenon, which creates more critical risk conditions in the sea-facing flank of La Fossa cone, in the sector between Punte Nere and the area run by the tsunamigenic 1988 landslide [Madonia et al., 2019].

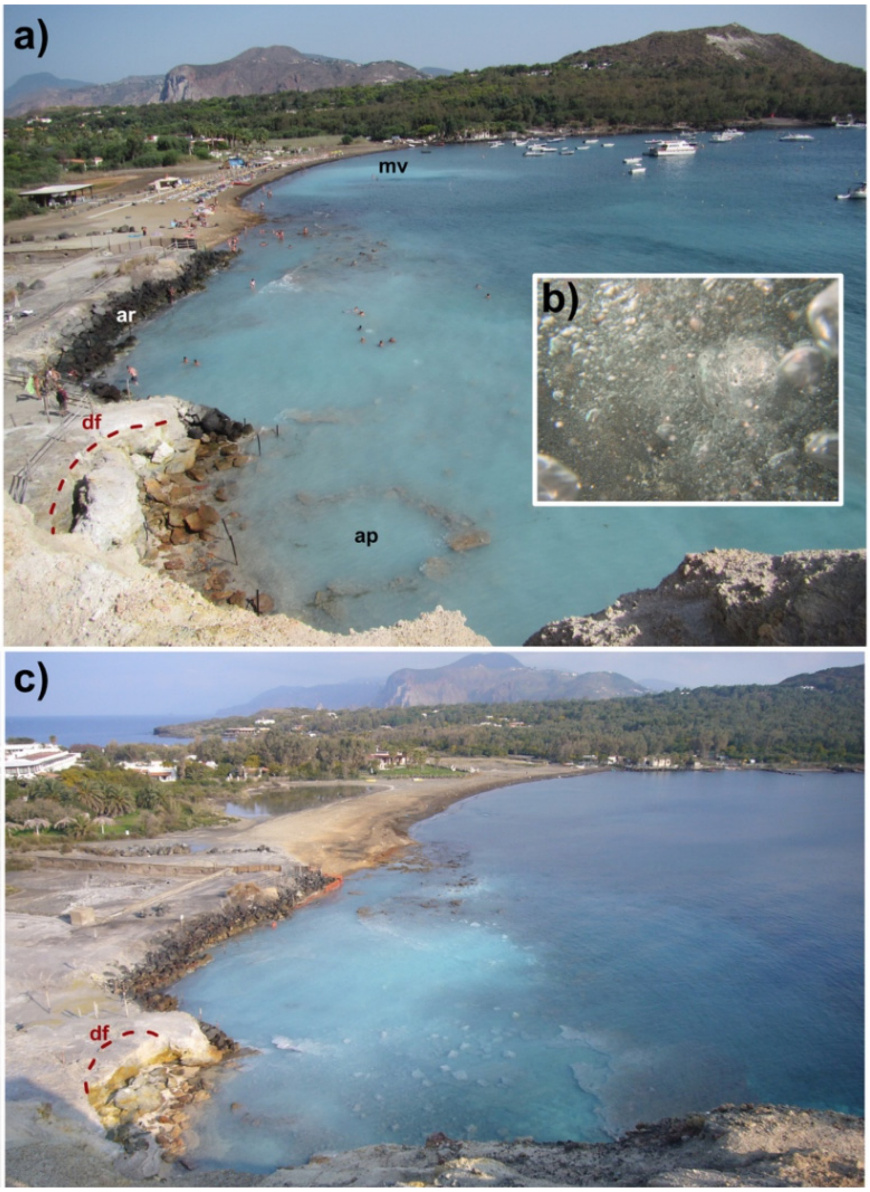


Figure 2 The Baia di Levante area in September, 2015 (mv = main vent, ar = artificial reef, df = detachment front, ap = artificial pool); b) Underwater picture of the main vent of Baia di Levante (September, 2015); c) The Baia di Levante area in March, 2007 (df is the same trace of picture a); d) Underwater picture of the main vent of Gelso (July 2012).

The spatial distribution of the shallow-undersea degassing vents is not constant in time: what changes is not the position of the vents, which are mostly located along fractures of the hard sea bottom, made of lavas erupted during the "Faraglione" cycle [De Astis et al., 2006], but their degassing rate. A peculiar example is the vent "mv" (Figure 2a-b), well known to the researchers since the 1980's, which has shown a huge degassing rate increase, previously dated to August,

2009 [Madonia et al., 2013], now dated back to August, 2009 at least (data from the revision of the personal photo-database of the author; see for comparison the picture of Figure 2c, shot on March, 2007).
The variability of degassing rate creates severe implications in term of the related gas hazard. In fact, the shallow hydrothermal vents are the main point of interest for tourists visiting the Baia di Levante area, who are attracted by the phenomenon itself and like to spend time (up to tens of minutes) bathing in the warm water around the vents; sometimes they build artificial barriers, made of small rock blocks, for creating pools where accumulating water warmer than in the surroundings ('ap' in Figure 2a). Severe gas hazard conditions can be present in the immediate proximity of the vents, where bubbles blow up in the atmosphere releasing hydrothermal gases in concentrations noxious for humans, especially in case of high atmospheric pressure and absence of wind.
Another relevant theme is the acceleration of the coastal erosion, fostered by hydrothermal alteration. Circulation of chemically-aggressive hydrothermal water transforms the pristine volcanic minerals into phases like gypsum, anhydrite and clay minerals as kaolinite and montmorillonite [Madonia et al., 2019], significantly reducing the mechanical resistance of the rocks to the action of wave erosion. A general retreatment of the coastline has been observed in the last twenty years, inducing to build up an artificial reef made of rock blocks (in the first years of the 2000's) for mitigating this phenomenon ('ar' in Figure 2a). Where the cliffs have remained unprotected its retreatment has advanced in the order of meters during the last years ('df' in Figure 2a and 2c, for comparison).

References

Badalamenti B., Chiodini G., Cioni R., Favara R., Francofonte S., Gurrieri S., Hauser S., Inguaggiato S., Italiano F., Magro G., Nuccio P.M., Parello F., Pennisi M., Romeo L., Russo M., Sortino F., Valenza M. and Vurro F., (1991). *Special field workshop at Vulcano (Aeolian Islands) during summer 1988: geochemical results.* Acta Vulcanol. 1, 223–228.

De Astis G., Dellino P., La Volpe L., Lucchi F., Tranne C.A., (2006). *Geological map of the island of Vulcano (Aeolian Islands), scale 1:10,000*. Printed by Litografia Artistica Cartografica, Firenze, Italy.

Madonia P., Cusano P., Diliberto I.S. and Cangemi M., (2013). *Thermal anomalies in fumaroles at Vulcano island (Italy) and their relationship with seismic activity.* Phys. Chem. of the Earth 63, 160–169.

Madonia P., Cangemi M., Olivares L., Oliveri Y., Speziale S. and Tommasi P., (2019). *Shallow landslide generation at La Fossa cone, Vulcano island (Italy): a multidisciplinary perspective*. Landslides (2019) 16:921–935, doi: 10.1007/s10346-019-01149-z.

The Diamante-Enotrio-Ovidio seamounts: the easternmost Volcanic-Intrusive Complex formed along the northern Ionian subduction slab-edges (Southern Tyrrhenian Sea)

Riccardo De Ritis[1], Fabrizio Pepe[2], Barbara Orecchio[3], Daniele Casalbore[4,5], Massimo Chiappini[1], Marta Corradino[2], Rinaldo Nicolich[6]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Geomagnetismo, Aeronomia e Geofisica Ambientale, Roma, Italy*

[2]*Università degli Studi di Palermo, Dipartimento delle Scienze della Terra e del Mare (DiSTeM), Palermo, Italy*

[3]*Università degli Studi di Messina, Dipartimento di Scienze Matematiche e Informatiche, Scienze Fisiche e Scienze della Terra (MIFT), Messina, Italy*

[4]*Consiglio Nazionale delle Ricerche, Istituto di Geologia Ambientale e Geoingegneria, Roma, Italy*

[5]*Università Sapienza di Roma, Dipartimento di Scienze della Terra, Roma, Italy*

[6]*Università di Trieste, Italy*

riccardo.deritis@ingv.it

Volcanic-Intrusive complexes often formed along lateral slab-edges as a consequence of subduction-induced mantle flow. In this work, we investigate this process in the southern Tyrrhenian Sea where a large volcanic-intrusive complex developed as an effect of decompression melting of upper mantle material that flows along a lateral slab-edge. The volcanic-intrusive complex comprises the Diamante, Enotrio, and Ovidio seamounts and extends 50×40 km in the NS and EW directions, respectively (panel a in Figure 1).

The Tyrrhenian Sea is a Neogene to Recent basin developed in the upper plate of the Tyrrhenian-Ionian subduction system within the frame of Eurasia-Africa convergence. Tomographic cross-sections show the presence of orogen-perpendicular lithospheric-scale structures that accommodated strike-slip displacements during slab tearing propagation [Rosenbaum et al., 2008 and references therein]. Beneath the Calabrian Arc, the lower plate of the Tyrrhenian-Ionian subduction system is represented by the Ionian slab dipping ~70 – 80° north-westward [Chiarabba et al., 2008; Neri et al., 2009; Orecchio et al., 2014; Piromallo and Morelli, 2003; Scarfì and Barberi, 2018; Wortel and Spakman, 2000]. The upper plate of the Tyrrhenian-Ionian subduction system includes the back-arc domain of the SE Tyrrhenian Sea (Marsili Basin), volcanic seamounts distributed along an arc-shaped structure, the fore-arc region including the Calabrian-Peloritan Arc, and farther to the southeast the Calabrian accretionary wedge.

This study is based on the integration of high-resolution geophysical data sets, such as multibeam bathymetry, multichannel seismic-reflection data, magnetic anomalies and seismological data (panels b-c-d-e-f-g in Figure 1). The use of different geophysical methods allowed obtaining experimental values for a variety of physical properties whose integration have been fundamental to understanding the dynamic and spatiotemporal evolution of the Diamante, Enotrio, and Ovidio volcanic-intrusive complexes.

The study area corresponds to the intra-slope ridges separating the Sapri and Paola basins. The bathymetry ranges from 120 m to 3000 m below sea floor, and is characterized by a complex morphology due to the occurrence of seamounts, volcanic cones, fault scarps, ponded basins, channelized features (canyons and gullies) and pockmarks. The seamounts form two chains: the southern chain is formed by the E-W alignment of Palinuro, Glabro, Enotrio and Ovidio seamounts (panel a in Figure), whereas the northern chain is mainly formed by Diamante and an easternmost, unknown seamount (the Scalea seamount).

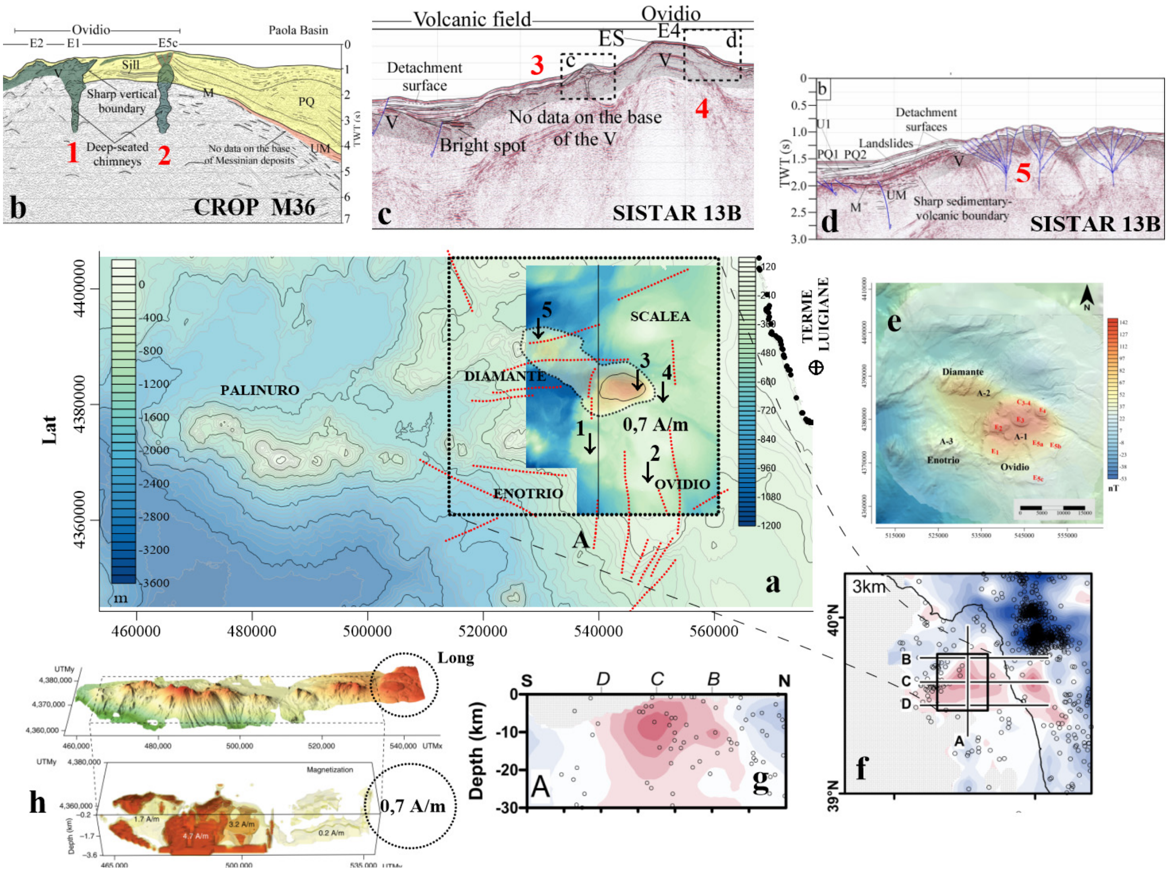


Figure 1 a) EMODnet Bathymetry Consortium [2016] multibeam dataset together with the high-resolution Marine Geohazard along the Italian Coast (MaGIC) Project multibeam bathymetry (left corner). The xy section of the magnetic inversion results (-4000 m depth) is overlapped as contouring and color scaled image; the main directions of the structural features of the area are also reported as red dotted lines (CROOP project). The numbered locations refers to the main volcanic features identified in the seismic profiles (panels b-c-d). b-c-d) interpreted seismic lines belonging to the M36 Croop and Sistar 13b projects, e) magnetic anomaly map of the study area together with the main volcanic edifices' numeration. f) seismic tomography: xy section at 3 km of depth. g) tomographic vertical section of the A profile (panel f). h) Palinuro chain and the magnetization contrasts obtained inverting a shipborne magnetic dataset; the magnetization peak obtained inverting the Ovidio anomaly has been added at the easternmost side of the chain [modified by Cocchi et al., 2017].

On seismic profiles, a volcanic belt is inferred throughout the area beneath Ovidio and Diamante seamounts, above the upper continental crust diffusely intruded by volcanics. Volcanic rocks locally reach the seafloor forming volcanic edifices pertaining to the Diamante and Ovidio seamounts (panels b-c-d in Figure 1). Here, magmatic intrusions obscure at depth the seismic signal of Plio-Quaternary and older sedimentary deposits. The only exception is beneath the E5c volcanic edifice, where the seismic expression of Unit PQ deposits is well preserved (panel b in Figure 1). Sills are inferred on the base of the high-amplitude, continuous and layered reflectors in the lower PQ sedimentary levels at NW of the chimney of the E5c volcano. A wedge-shaped feature is recognized along the SSE side of the E4 volcano (panel c in Figure 1). Three fault systems associated with positive flower structures are identified in the north-western sector of the volcanic field (panel d in Figure 1). These fault systems offset both the volcanics and the sedimentary cover of the Diamante volcano and reach the sea floor. Generally, the faults are reverse with small offsets and converge at depth into a vertical fault. Southeast dipping reverse and north-west-dipping extensional faults are detected in the western and eastern flanks of the Diamante volcano, respectively.

Magnetic anomaly A is the largest magnetic dipole of the northern offshore of the Calabrian Arc (panel e in Figure) overlapping the Diamante, Enotrio, and Ovidio seamounts (DEOS). This anomaly is characterized by a direct polarity and likely derives from the superimposition of almost three magnetic sub-anomalies, namely A-1, A-2 and A-3, placed 14 km apart. The grid of the magnetic surveys was not suitably dimensioned with respect to the wavelengths of these sub-anomalies (around 5-10 km), and therefore it does not properly define each feature separately. The inverse modeling results are shown as 3D highlights the source geometry and its relationship with the seafloor (panel a in Figure 1).
P-wave velocity plates at 3, 6, and 9 km depth indicate that the whole resolved area is characterized by high-velocity values, with variations greater than 8% with respect to the starting model. In this high-velocity domain, the target area shows nil-to-moderate variations (~0 to 2%) that tend to increase in the north-western sector. The vertical section A shows that the southern sector is characterized by lower velocity values than the northern one (panels f-g in Figure 1). The Diamante, Enotrio, and Ovidio seamounts are located in correspondence to a low Vp/Vs anomaly, reaching minimum values of about 1.66.
The volcanic nature of the DEOS is witnessed by the typical morphologies of the seamounts, the analysis of seismic facies, the existence of magnetized material as well as by the 3D velocity model. Moreover, sheet and pillow lavas were observed through ROV dives on the top of the Ovidio (E1 in panel a-e in Figure 1) seamount [Cocchi et al., 2017]. The normal polarity of the composite magnetic anomaly A suggests that the volcanic edifices and the emplacement of these magnetic sources most likely occurred during the Brunhes Chron. Thus, the DEOS activity should be younger than 0,7 Myr.
The Lowstand Infralittoral Prograding Wedge - LIPW (panel c in Figure 1) formed seaward of the lower edge of abrasion platforms under the combined action of the local storm-wave base level and across-shore currents can be used as a paleo sea level indicator to infer vertical tectonic motion [Casalbore et al., 2017; Chiocci and Orlando, 1996; Pepe et al., 2014]. By considering that a) the depth of LIPW recognized in the flank of the E4 is 200 m, b) the depth of LIPW formation is estimated around 20 m for the Tyrrhenian Sea [Pepe et al., 2014], and c) the minimum sea level reached during the Late Quaternary fluctuations was about 120 m below the present level [Bintanja et al., 2005], it is reasonable to assume that the area where the E4 volcano formed experienced at least 60 m of subsidence.
The formation and evolution of the DEOS volcanic-intrusive complex can be framed within the deformation history of the Ionian slab and the mantle flow path. Around 0.6 Ma, a STEP fault associated with lateral lithospheric tearing formed at the northern edge of the Ionian slab. By considering that the STEP faults played an important role in controlling the magma uprising in the whole eastern side of the Tyrrhenian domain [Rosenbaum et al., 2008], we propose that the formation and upwelling of subduction-induced mantle flow that fed the PVC and DEOS volcanic-intrusive complex was controlled by the STEP fault that limits the northern edge of the Ionian slab. The DEOS volcanic-intrusive complex developed within a strike-slip deformation belt that accommodated the bulk of the shear strain along the roughly E-W trending STEP fault. Thus, the ascent of the melts and their final emplacement was favored by transpressive and transtensive deformation.
Our results, integrated with literature data, are significant for the understanding of the magmatic processes related to the slab tearing occurred in the northern Tyrrhenian-Ionian Subduction System, providing original evidences about the processes driving evolution of the subduction-induced mantle flow around the slab edges.

References

Bintanja R., van de Wal R.S.W. & Oerlemans J., (2005). *Modelled atmospheric temperatures and global sea levels over the past million years*. Nature, 437(7055), 125.

Casalbore D., Falese F., Martorelli E., Romagnoli C. & Chiocci F.L., (2017). *Submarine depositional terraces in the Tyrrhenian Sea as a proxy for paleo-sea level reconstruction: Problems and perspective.* Quaternary International, 439, 169–180.

Chiarabba C., De Gori P. & Speranza F., (2008). *The southern Tyrrhenian subduction zone: deep geometry, magmatism and Plio-Pleistocene evolution*. Earth and Planetary Science Letters, 268 (3-4), 408-423.

Chiocci F.L. & Orlando L., (1996). *Lowstand terraces on Tyrrhenian Sea steep continental slopes*. Marine Geology, 134(1-2), 127-143.

Cocchi L., Passaro S., Tontini F.C. & Ventura G., (2017). *Volcanism in slab tear faults is larger than in island-arcs and back-arcs.* Nature Communications, 8 (1), 1451. https://doi.org/10.1038/s41467-017-01626-w.

Neri G., Orecchio B., Totaro C., Falcone G. & Presti D., (2009). *Subduction beneath southern Italy close the ending: Results from seismic tomography*. Seismological Research Letters, 80(1), 63-70.

Orecchio B., Presti D., Totaro C. & Neri G., (2014). *What earthquakes say concerning residual subduction and STEP dynamics in the Calabrian Arc region, south Italy*. Geophysical Journal International, 199(3), 1929-1942.

Pepe F., Bertotti G., Ferranti L., Sacchi M., Collura A.M., Passaro S. & Sulli A., (2014). *Pattern and rate of post-20 ka vertical tectonic motion around the Capo Vaticano Promontory (W Calabria, Italy) based on offshore geomorphological indicators.* Quaternary International, 332, 85-98.

Piromallo C. & Morelli A., (2003). *P wave tomography of the mantle under the Alpine-Mediterranean area.* Journal of Geophysical Research: Solid Earth, 108(B2).

Rosenbaum G., Gasparon M., Lucente F.P., Peccerillo A. & Miller M.S., (2008). *Kinematics of slab tear faults during subduction segmentation and implications for Italian magmatism*. Tectonics, 27, 1-16. https://doi.org/10.1029/2007TC002143.

Scarfì L. & Barberi G., (2018). *Slab narrowing in the Central Mediterranean: the Calabro-Ionian subduction zone as imaged by high resolution seismic tomography*. Scientific Reports, March, 1–12. https://doi.org/10.1038/s41598-018-23543-8.

Wortel M.J.R. & Spakman W., (2000). *Subduction and slab detachment in the Mediterranean-Carpathian region*. Science, 290(5498), 1910-1917.

Volcanism at the edge of a subduction plate: geophysical and morphological data revel a new set of volcanic structures in the Southern Tyrrhenian Sea

Luca Cocchi[1], Riccardo De Ritis[1] and Guido Ventura[2]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Geomagnetismo, Aeronomia e Geofisica Ambientale, Roma, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Sismologia e Tettonofisica, Roma, Italy*

luca.cocchi@ingv.it

In the Southern Tyrrhenian sea the eastward-retreating of Apennines-Maghrebides subduction system is responsible for intense volcanism which manifests itself as island arc, back-arc and slab-tear volcanoes. The well known seamounts Vavilov and Marsili represent surficial expression of an upraising of deep asthenospheric melts as consequence of a stretching and rupture of the European plate during episodic back arc extensions [Malinverno and Ryan, 1986].
An important advancement in marine geology and study of submerged volcanism in the Tyrrhenian sea was driven by the integration of passive and active geophysical survey techniques (multibeam survey, seismic sounding and potential field acquiring) that permitted to unveil details of submerged volcanic structures and better constraint their interpretative modelling.
Volcanism at the edge of the subduction is still enigmatic because lacks of comprehensive geological and geophysical data [Gover and Wortel, 2005]. Until today, an estimation on the real budget that tear faults counts in the global volcanism is unknown.
Here, we present new data from Palinuro volcanic chain (Figure 1) and surrounding volcanoes overlapping the E-W striking tear of the roll backing Ionian Slab in Southern Tyrrhenian Sea [Cocchi et al., 2017].

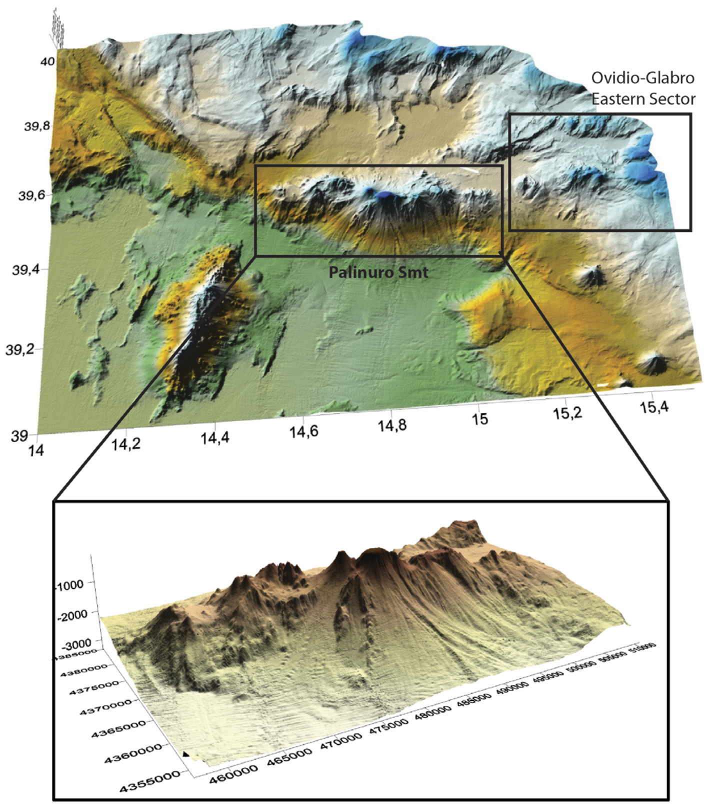


Figure 1 Shaded relief swath bathymetry of Marsili basin and Palinuro area. As inset 3D view of Palinuro Smt (data from EMODnet).

In particular, we show new potential field data and modelling of an unknown volcanic structure located offshore the Cilento coast, north-westward of the Palinuro tear fault.
New multibeam and shipborne magnetic data highlight a spreading-like volcanic complex with a local lows of magnetization close its centre probably related to an uprising of the isotherms (Figure 2) or due to juxtaposing of separate volcanic edifices intruding a thick sedimentary sequence.

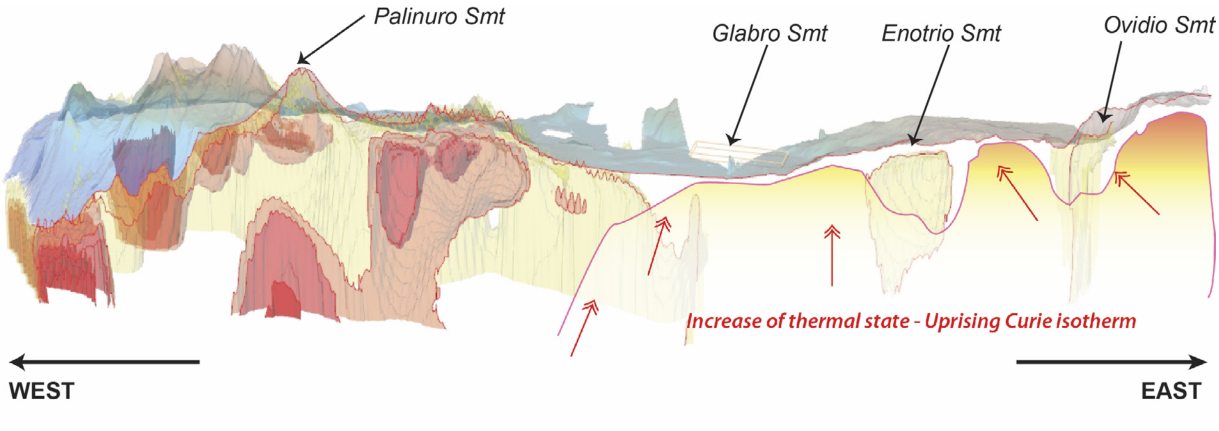


Figure 2 X-Z slice of 3D inverse magnetic model of Palinuro STEP volcanic chain (model redrawn from Cocchi et al., [2017]).

Volcanic and geophysical features indicate that this volcanic complex emplaces on the continental scarp.
The geophysical modelling suggests a prevailing lateral growth of the volcano, similar to volcanic features observed east of Palinuro, which can point out the same or a similar volcanic/geodynamic process. This suggests that deformation related to crustal-lithosphere slab tear faults overlaps a larger area than that previously assumed (i.e the E-W elongated Palinuro-Glabro volcanic chain), underlining the relevance of tear faults in the evolution of a subduction system.

References

Cocchi L., Passaro S., Caratori Tontini F., Ventura G., (2017). *Volcanism in the slab tear faults is larger than in island-arcs and back-arcs.* Nature Communication, 8:1451, doi: 10.1038/s41467-017-01626-w.

EMODnet Bathymetry Consortium. (2018). *EMODnet Digital Bathymetry* (DTM 2018). EMODnet Bathymetry Consortium. https://doi.org/10.12770/18ff0d48-b203-4a65-94a9-5fd8b0ec35f6.

Govers R. and Wortel M.J.R., (2005). *Lithosphere tearing at STEP faults: response to edges of subduction zones.* Earth Planet. Sci. Lett. 236, 505–523.

Malinverno A. and Ryan W.B.F., (1986). *Extension of the Tyrrhenian Sea and shortening in the Apennines as a result of arc migration driven by sinking of the lithosphere.* Tectonics 5, 227–245.

Morphostructural analysis of the Graham volcanic field offshore southwestern Sicily (Italy)

Danilo Cavallaro, Mauro Coltelli

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy

danilo.cavallaro@ingv.it

In 2012 the INGV carried out a multidisciplinary oceanographic cruise focused on the seafloor mapping and on the geophysical and geochemical monitoring of some volcanic centres located in the NW sector of the Sicily Channel [Coltelli et al., 2016].
High-resolution multibeam bathymetric data and ROV images allowed to characterize in detail the Graham volcanic field located 35-50 km offshore southwestern Sicily [Cavallaro and Coltelli, submitted]. The field is located on the western side of a relatively shallow (maximum depth of about 350 m) submarine relief, which includes the Terrible and Nerita banks (Figure 1). The field comprises a ten of monogenetic tephra cones showing steep slopes and pointy or flat tops and arranged along a N-S trending and 12 km long belt at 150-250 m b.s.l. It includes the relict of the short-lived "Ferdinandea Island" formed during the well-documented 1831 "Surtseyan-type" eruption and presently shaping, together with another submarine cone, the Graham Bank (Figure 2).
The morphostructural analysis of the field has been achieved to measure the main morphometric parameters of the cones, proving the monogenetic nature of this volcanism. This latter represents a peculiarity since it took place within a nearly N-S oriented lithospheric-scale transfer (the Capo Granitola-Sciacca Fault Zone, [Civile et al., 2018]), and thus outside the typical geodynamic settings of other volcanic fields worldwide such as subduction and rift zones.
The distribution and shape of the cones provide important insights into the interaction between volcanism and tectonics. The alignment of the volcanic cones within the field and the main axis of the clusters in which they are grouped (Figure 1) reveal two preferred directions, N-S and NW-SE, respectively, consistent with those of the main tectonic structures of the Sicily Channel. The analysis of some morphological parameters, such as level of erosive activity of the cones slopes, presence and depth of summit abrasion platforms and depositional terraces, in relationship with sea-level change and in analogies with other submarine volcanic cones worldwide (e.g. the satellite shoals of Surtsey volcano, Island; [Romagnoli and Jakobsson, 2015]), allowed to constrain the age of the volcanism at the Late Pleistocene-Holocene.
Numerous mass transport deposits and pockmarks were also identified in the surroundings of the volcanic fields, suggesting the occurrence of diffuse slope failures and fluid releases, respectively (Figure 1).
ROV dives (Figure 2) allowed to image the top (at 9-23 m bsl) of the shoal representing the remnant of the short-lived "Ferdinandea Island", characterized by volcanic knolls and furrows. ROV videos also imaged the blocky facies on the lava flow (the only ones recognised in the entire field) identified on the western flank of the Graham Bank.
During the cruise three OBS/H (Ocean Bottom Seismometers with Hydrophones) were also deployed close to the Graham Bank to record seismo-acoustic signals, being this region characterized by a diffuse degassing activity and by moderate seismicity [Coltelli et al., 2016]; here a large seismic gap was identified and associated with the geothermal and volcanic activity of the field [Calò and Parisi, 2014]. A strong hydrothermal activity from the Graham Bank was documented by both ROV videos and high-frequency events recorded by the OBS/H. Finally, rock and gas samples were also collected from the sea bottom at the base of the Graham Bank.

The composition of the gas sample indicates a significant mantle component while the rock sample was a piece of a hardened tephra layer probably consisting in the products of the 1831 eruption.

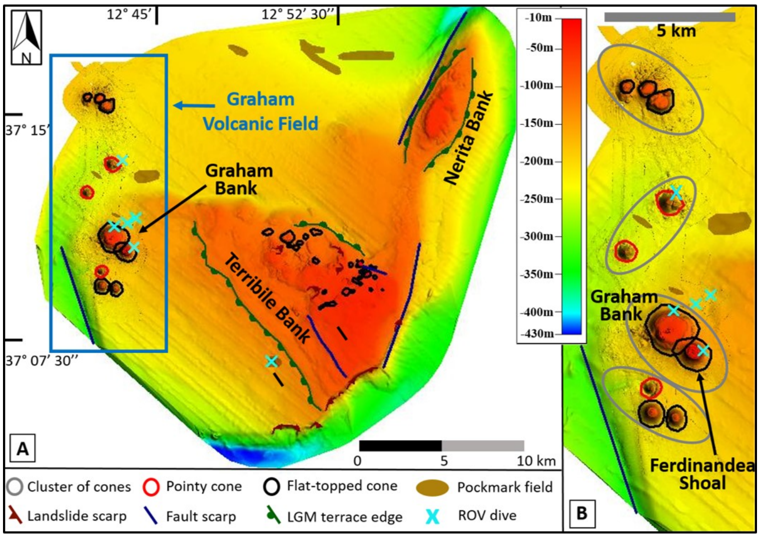


Figure 1 A Bathymetry map of the study area displaying the Graham, Nerita and Terribile banks and the ten of cones forming the Graham volcanic field. The blue box shows the Graham volcanic field, which is zoomed with higher resolution on Figure B; here the clusters of cones are also displayed. ROV dives location are also indicated on both the figures.

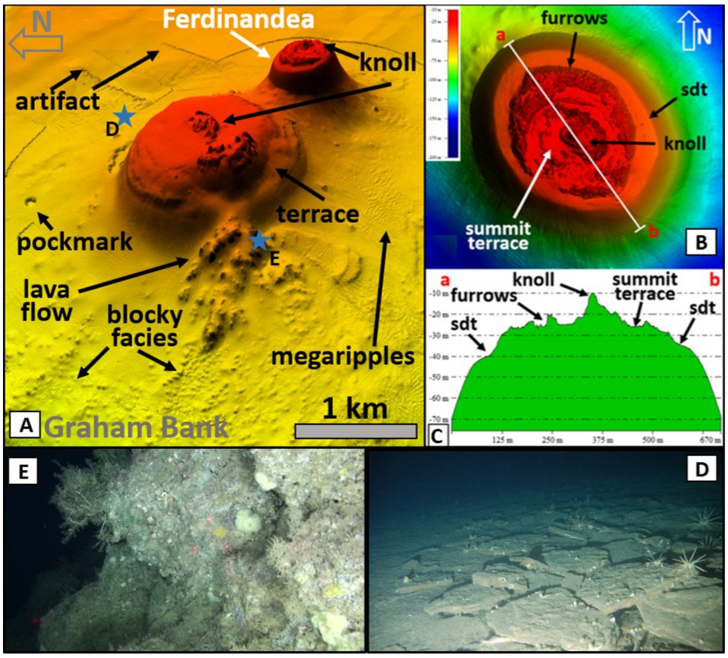


Figure 2 A 3D view (vertical exaggeration = 4x) of the Graham Bank viewed from the west; the blue stars indicate the location a ROV photos imaged on Figures 2D-2E and displaying pieces of semi-consolidated pyroclastic layers on the seafloor and the lateral front of a lava flow on the low western side of the biggest cone of the Graham Bank, respectively. B Very high-resolution shaded relief image bathymetry of the Ferdinandea shoal, with a NW-SE topographic profile (C) well imaging the knoll, furrows, summit terrace and submarine depositional terrace (SDT).

References

Cavallaro D. and Coltelli M., submitted. *The Graham volcanic field offshore southwestern Sicily (Italy) revealed by high-resolution seafloor mapping and ROV images*

Civile D., Lodolo E., Accaino F., Geletti R., Schiattarella M., Giustiniani M., Fedorik J., Zecchin M. and Zampa L., (2018). *Capo Granitola-Sciacca Fault Zone (Sicilian Channel, Central Mediterranean): Structure vs magmatism*. Mar. Pet. Geol. 96, 627-644.

Coltelli M., Cavallaro D., D'Anna G., D'Alessandro A., Grassa F., Mangano G., Patanè D. and Gresta S. (2016). *Exploring the submarine Graham Bank in the Sicily Channel*. Ann. Geophys. 59 (2), S0208. https://doi.org/10.4401/ag-6929.

Romagnoli C. and Jakobsson S.P., (2015). *Post-eruptive morphological evolution of island volcanoes: Surtsey as a modern case study*. Geomorphology 250, 384–396.

The EARTHCRUISERS project (EARTH CRUst Imagery for investigating SEismicity, volcanism and marine natural Resources in the Sicilian offshore)

Mauro Coltelli[1], Domenico Patanè[1], Danilo Cavallaro[1], Marco Firetto Carlino[1], Graziella Barberi[1], Luciano Scarfì[1], Salvatore Rapisarda[1], Giuseppe D'Anna[2], Gioacchino Fertitta[3], Antonio Costanza[2], Luca Cocchi[3], Filippo Muccini[3], Paolo Stefanelli[3], Francesco Mazzarini[4], Massimiliano Favalli[4], Luca Nannipieri[4]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Nazionale Terremoti, Italy
[3]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Geomagnetismo, Aeronomia e Geofisica Ambientale, Italy
[4]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy

mauro.coltelli@ingv.it

The EARTHCRUISERS project was developed for the MIUR's call "Progetti Premiali 2015" by the "Istituto Nazionale di Oceanografia e di Geofisica Sperimentale" (Trieste, Italy) in collaboration with the "Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo" (Catania, Italy) and "Stazione Zoologica Anton Dohrn" (Naples, Italy).
The main goals of the project are: (i) to identify and characterize the main crustal tectonic structures offshore Sicily and the Aeolian Islands, (ii) to better understand the geodynamic processes controlling seismicity and volcanism affecting this region, and (iii) to furnish a useful tool to estimate seismic, tsunamigenic and volcanic hazard in the highly populated coastal sectors. Furthermore, in order to contribute at the Blue Growth objectives, the project aims to analyze some relevant issues related to mineral prospecting offshore, such as the characterization of the hydrothermal systems in the Tyrrhenian Sea and the impact of the exploitation of oil and gas fields on the marine environment in the Sicily Channel.
To achieve these objectives the acquisition of multibeam and sidescan sonar, multi-channel seismic reflection, magnetic and gravimetric data is planned. Nearly 2500 km of multi-channel seismic reflection lines will be acquired during the project in the Marsili Basin (Tyrrhenian Sea) and Mt. Etna offshore. This large amount of data will allow to: better understand the relationship between tectonics and evolution of volcanism; identify active faults and volcanic bodies; better constrain the seismo-stratigraphic and structural setting of the study areas, and investigate the eventual occurrence of unstable volcanic slopes which could lead to landslide and tsunami.
Finally, the deployment offshore southeastern Sicily of a temporary Ocean Bottom Seismometer (OBS) network will carry out for monitoring the natural seismicity in the area of VEGA platform, the largest oil extraction site in Italian seas. Data collected will be used to study the eventual correlation between local seismicity and oil extractive activities.

From land to sea: active tectonic studies in offshore areas, results and technological developments

Pierfrancesco Burrato[1], Fabrizio Pepe[2], Luigi Ferranti[3], Carmelo Monaco[4], Marco Sacchi[5]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Sismologia e Tettonofisica, Roma, Italy
[2]Università degli Studi di Palermo, Dipartimento delle Scienze della Terra e del Mare (DiSTeM), Palermo, Italy
[3]Università degli Studi di Napoli Federico II, Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse (DISTAR), Napoli, Italy
[4]Università degli Studi di Catania, Dipartimento Scienze Biologiche, Geologiche e Ambientali (DiBGA), Italy
[5]C.N.R. Istituto di Scienze Marine (ISMAR), Napoli, Italy

pierfrancesco.burrato@ingv.it

We present the results and technological developments obtained during active tectonic studies performed in several offshore areas located around Southern Italy during the last years (Figure 1). We have blended our individual skills to form a research group devoted to investigating active crustal deformation in areas adjacent to the coast of Southern Italy, with the aim to bridge the gap between the onshore and offshore realms.

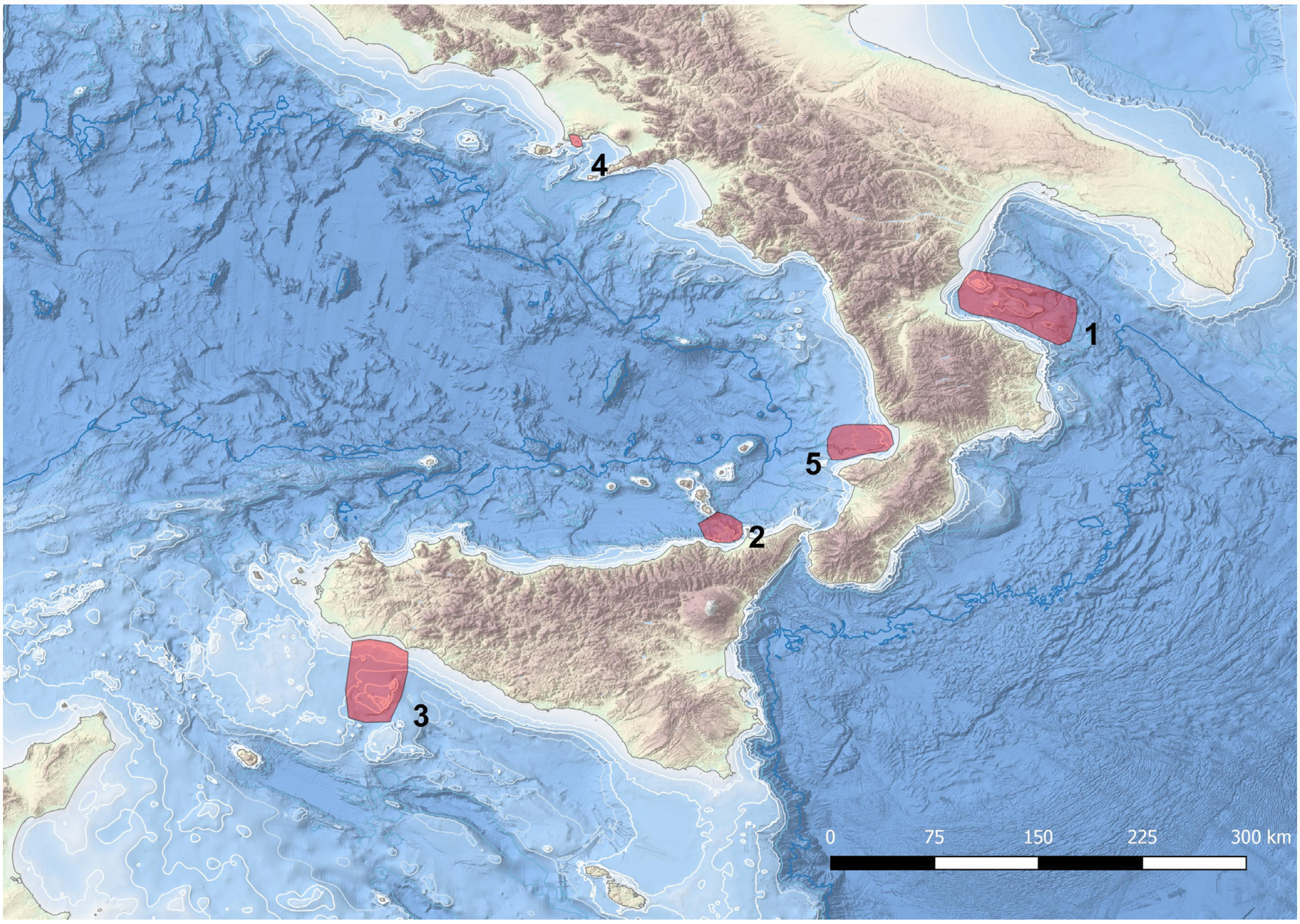


Figure 1 Map showing in red the studied areas that are discussed in this work. 1: Amendolara Gulf [Ferranti et al., 2014]; 2: Gulf of Patti [Cultrera et al., 2017a; 2017b]; 3: Sicily channel [Ferranti et al., 2019]; 4: Gulf of Pozzuoli [Sacchi et al. 2014]; 5: Sant'Eufemia Gulf [Pepe et al., 2014].

Our research is based on a multi-scale and multi-resolution approach that includes high resolution seismic data acquired at sea and joined with coastal morpho-tectonic and structural geological studies, and complemented with other active deformation data such as seismicity, Global Positioning System (GPS) and Interferometric Synthetic Aperture Radar (InSAR). Need and opportunities of such an endeavor arise from the basic observation that, although most population centers lie close to the coastal areas, very little is known about active structures at the sea. However, hints of active deformation occurring offshore are offered by physical correlation with known or proposed onland seismogenic sources, macroseismic fields of historic events, and the occurrence of tsunamis.
The capability of our group stems from the long-term experience for most types of marine geological and geophysical surveys, and for structural-stratigraphic analysis of tectonically active areas. We regard the land-sea correlation issue as a key missing link that has hampered, so far, a sound interpretation of active structures in the submerged realm. Starting from this basis, we focused our attention on key sectors of the Southern peninsular Italy and Sicily where active tectonics has been inferred offshore, but detailed information on deformation structures is missing. We present here case-histories from five areas (Figure 1) where we used different approaches and different technologies. We would like to highlight the necessity of using multi-scale and multi-resolution seismic acquisitions for characterizing the active structures from deep to shallow levels and for constraining their activity in the long- and short-term (i.e., Pliocene and latest Pleistocene to Holocene).
The core dataset involves very high-resolution, single-channel (SCS) and multi-channel (MCS) data acquired with a series of seismic sources, including multi-tips Sparker array, to provide detailed images of the most recent (e.g. Middle-Late Pleistocene) activity of targeted structures. These data were supplemented by ultra-high-resolution (CHIRP) seismic lines, and multibeam bathymetric data to get a snapshot of the current deformation close or at the seafloor, as well as public (VIDEPI project) and unpublished MCS profiles. In addition to data acquired onboard oceanographic research vessels, we complement the dataset by using a Sparker System mounted onboard a trailer-transportable boat suitable to acquire for nearshore surveys. Using additional datasets (seismicity, structural analysis, InSar, GPS etc.), the goal is a parameterization of active structures [e.g. Ferranti et al., 2014], and the calculation of accurate rates of their movements [e.g. Pepe et al., 2014].
During the years we experimented new technologies such as during the ultra-high-resolution 3D survey performed in the Gulf of Pozzuoli in 2018 (area 4 in Figure 1), during which we used two sparker seismic sources, four 24-channels streamers and DGPS systems for positioning with a decimetric precision. During this survey we studied the faults associated with the resurgent dome of the Campi Flegrei caldera and the geometry of the depositional system that registered different phases of uplift and subsidence. Another example of technological development is the ultra-high-resolution seismic reflection grid acquired in 2019 in the Sant'Eufemia Gulf (area 5 in Figure 1) in the frame of the EPAF Project (Earthquake Potential of Active Faults using offshore Geological and Morphological Indicators, founded by the MAECI). In this case, the purpose of the seismic investigation was to trace the geometry of active faults using innovative technology for the offshore imaging of seismic stratigraphy and tectonic structures, with a horizontal and vertical resolution of less than 1 m.

References

Cultrera F., Barreca G., Ferranti L., Monaco C., Pepe F., Passaro S., Barberi G., Bruno V., Burrato P. and Mattia M., (2017a). *Structural architecture and active deformation pattern in the northern sector of the*

Aeolian-Tindari-Letojanni fault system (SE Tyrrhenian Sea-NE Sicily) from integrated analysis of field, marine geophysical, seismological and geodetic data. Ital. J. Geosci., 136, 3, 399-417, doi: 10.3301/IJG.2016.17.

Cultrera F., Barreca G., Burrato P., Ferranti L., Monaco C., Passaro S., Pepe F. and Scarfi L., (2017b). *Active faulting and continental slope instability in the Gulf of Patti (Tyrrhenian side of NE Sicily, Italy): a field, marine and seismological joint analysis*. Nat. Hazards, 86, 2, 253-272, doi: 10.1007/s11069-016-2547-y.

Ferranti L., Burrato P., Pepe F., Santoro E., Mazzella M. E., Morelli D., Passaro S. and Vannucci G., (2014). *An active oblique-contractional belt at the transition between the Southern Apennines and Calabrian Arc: The Amendolara Ridge, Ionian Sea, Italy*. Tectonics, 33, 11, 2169-2194, doi: 10.1002/2014TC003624.

Ferranti L., Pepe F., Barreca G., Meccariello M. and Monaco C., (2019). *Multi -temporal tectonic evolution of Capo Granitola and Sciacca foreland transcurrent faults (Sicily channel)*. Tectonophysics, doi: 10.1016/j.tecto.2019.05.002.

Pepe F., Bertotti G., Ferranti L., Sacchi M., Collura A. M., Passaro S. and Sulli A., (2014). *Pattern and rate of post-20 ka vertical tectonic motion around the Capo Vaticano Promontory (W Calabria, Italy) based on offshore geomorphological indicators*. Quat. Int., 332, 85-98, doi: 10.1016/j.quaint.2013.11.012.

Sacchi M., Pepe F., Corradino M., Insinga D.D., Molisso F. and Lubritto C., (2014). *The Neapolitan Yellow Tuff caldera offshore the Campi Flegrei: Stratal architecture and kinematic reconstruction during the last 15 ky*. Marine Geology, 354, 15-33, doi: 10.1016/j.margeo.2014.04.012.

Multi-proxy study in Augusta Bay (Eastern Sicily, Italy) expands understanding of offshore tsunami deposits

Alessandra Smedile[1], Flavia Molisso[2], Catherine Chagué[3], Marina Iorio[2], Paolo Marco De Martini[1], Stefania Pinzi[1], Philip E.F. Collins[4], Leonardo Sagnotti[5], Daniela Pantosti[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Sismologia e Tettonofisica, Roma, Italy*
[2]*Istituto di Scienze Marine CNR –ISMAR, Napoli, Italy*
[3]*UNSW, Sydney, Australia*
[4]*Brunel University, London, United Kingdom*
[5]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Geomagnetismo, Aeronomia e Geofisica Ambientale, Roma, Italy*

alessandra.smedile@ingv.it

Tsunami deposits are important archives for understanding tsunami histories and dynamics. While most research has focused on onshore preserved remains, offshore deposits have received less attention, although they may offer a higher potential in terms of preservation and spatial coverage. Offshore evidence of palaeotsunamis has been sparsely studied compared with the onshore record and a unique toolkit for the identification of offshore tsunami deposits has not been defined yet. In fact, approaching offshore analysis, as for any other environmental analysis, requires much attention and a multitude of methodologies and proxies is needed to identify and characterize tsunami deposits (for example, shallow geophysics, sedimentological and textural, micropalaeontological, and geochemical features). In 2009, during a coring campaign with the Italian Navy Magnaghi, four 1 m long gravity cores (MG cores) were sampled from the northern part of Augusta Bay, along a transect spanning from 60 to 110 m water depth (Figure 1), in the same area where a core (MS06) was collected in 2007, about 2.3 km offshore Augusta at a water depth of 72 m [Smedile et al., 2011].
Core MS06 consisted of a 6.7 m long sequence that included 12 anomalous intervals interpreted as the primary effect of tsunami backwash waves in the last 4500 years. In this study, tsunami deposits were identified, based on sedimentology and displaced benthic foraminifera (as for core MS06) reinforced by ITRAX X-ray fluorescence (XRF) data [Smedile et al., 2019]. Two erosional surfaces (L1 and L2) were recognized coupled with grain size increase, abundant *Posidonia oceanica* seagrass remains and a significant amount of *Nubecularia lucifuga*, an epiphytic sessile benthic foraminifera considered to be transported from the inner shelf. Relative maxima of Ti/Ca and Ti/Sr, coinciding with peaks in organic content (Mo inc/coh) suggest terrestrial run-off. Units L1 and L2 were attributed to two distinct historical tsunamis (AD 1542 and AD 1693) by indirect age-estimation methods using ^{210}Pb profiles and the comparison of Volume Magnetic Susceptibility data between MG and MS06 cores (Figure 2). One most recent bioturbated horizon (Bh), despite not matching the above listed interpretative features, recorded an important palaeoenvironmental change that might correspond to the AD 1908 tsunami (Figure 2).
Amongst all the techniques applied, sedimentology and micropalaeontology (displaced benthic foraminifera) remained the most informative, corroborated by the XRF results. Comparison of multiple cores collected at different depths along the shelf provided important insights about the dynamics of tsunami backwash and its imprint in the offshore stratigraphic sequence not easily gained from a single core. Moreover, a strong textural signature (sand-sized unit) to the morpho-bathymetry arrangement related to the core position was verified.

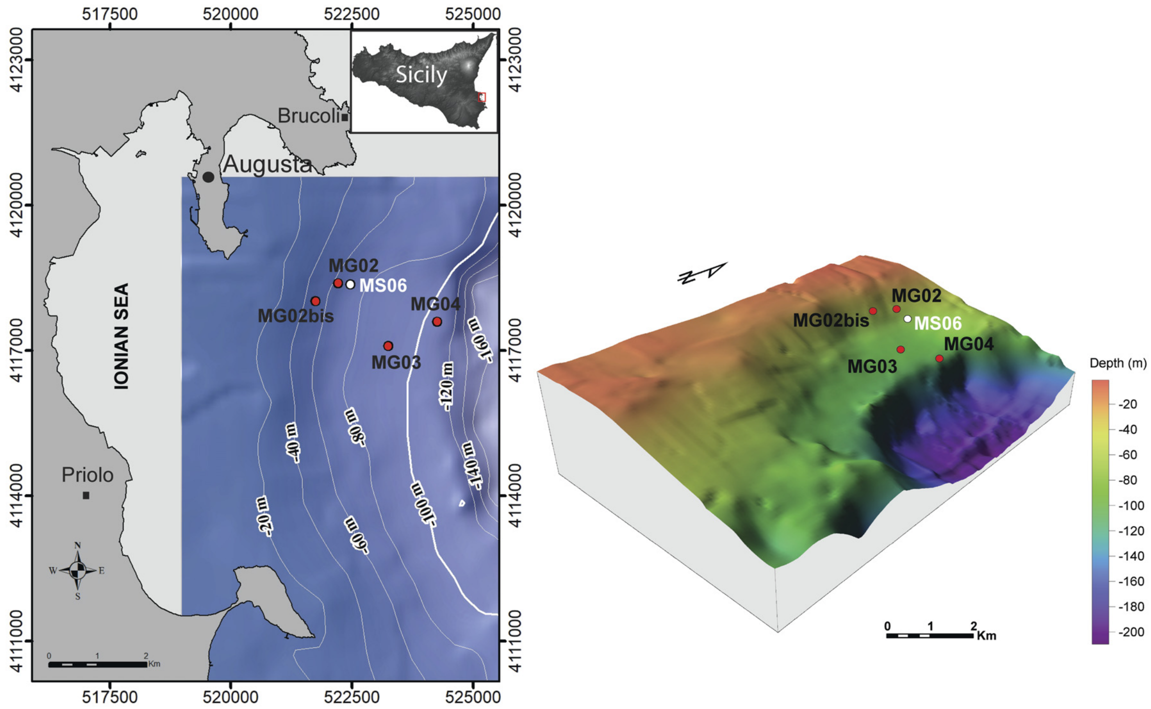


Figure 1 Map (on the left) of Augusta Bay area modified from Smedile et al., [2011] and compiled using bathymetric contours (spacing 20 m) enhancing the topography; on the right a digital elevation model [modified after Pirrotta et al., 2013] showing the sea floor morpho-bathymetry after the Last Glacial Maximum. In both images the location of cores 'MG' (red dots) discussed in this study and the location of core MS06 (white dot) are shown. The location study site is also shown in a geographic map of Sicily in the inset on the upper right.

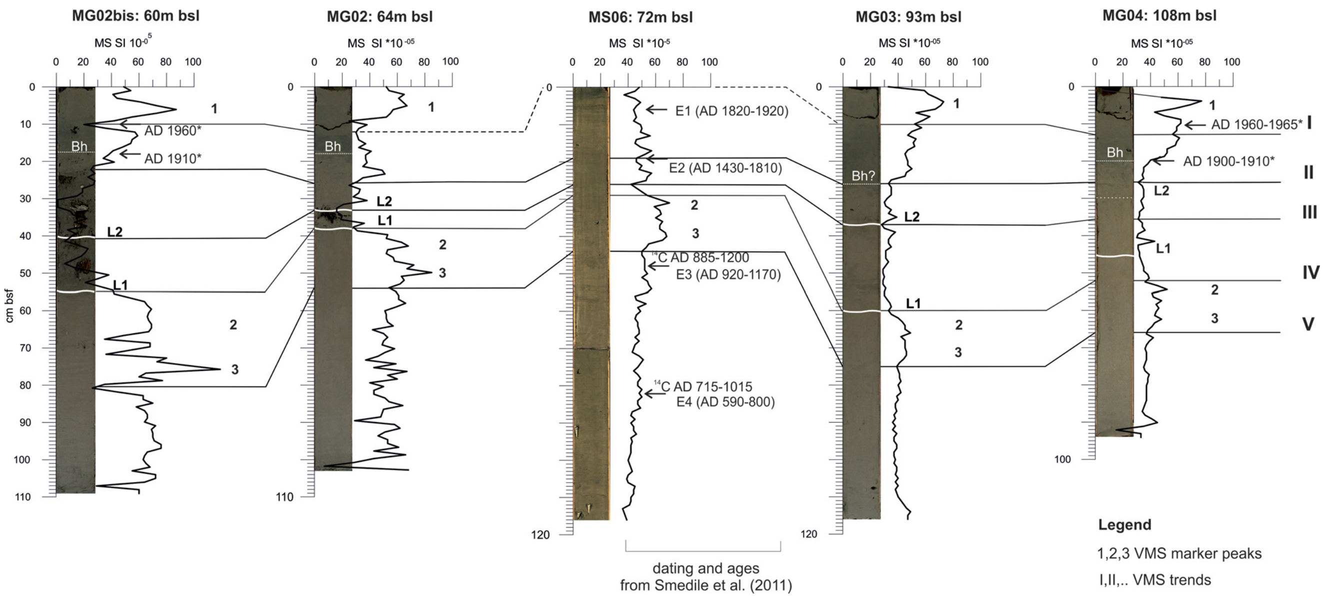


Figure 2 Photographs of cores MG displaying only the three main identified units (L1, L2 and Bh), MS06 core photograph of the uppermost 116 cm and relative volume magnetic susceptibility (VMS) plots. Cores are organized following their depth distribution along the shelf. In core MS06 already published 14C calibrated ages and modelled ages obtained for the three uppermost backwash tsunami signatures are also shown. Ages with asterisks are derived from 210Pb chronology. The VMS correlations are based on the five highlighted increasing/decreasing VMS trends (labelled with roman numerals at the right side of the picture) as well as on the three recognized VMS marker peaks (numbers next to each VMS peak). Such correlation allowed the transfer of 14C dating, carried out on core MS06 [Smedile et al., 2011] to MG cores.

This work adds to previous studies in highlighting the growing potential of offshore investigations for reconstructing the palaeotsunami record of critical relevance to test tsunami hazard models and scenarios.

References

Smedile A., De Martini P.M., Pantosti D., Bellucci L.G., Del Carlo P., Gasperini L., Pirrotta C., Polonia A. and Boschi E., (2011). *Possible tsunami signatures from an integrated study in the Augusta Bay offshore (Eastern Sicily-Italy).* Marine Geology, 281, 1–13.

Smedile A., Molisso F., Chagué C., Iorio M., De Martini P.M., Pinzi S., Collins P., Sagnotti L. and Pantosti D., (2019). *New coring study in Augusta Bay expands understanding of offshore tsunami deposits (Eastern Sicily, Italy).* Sedimentology, doi: 10.1111/sed.12581.

Calcareous nannofossils a proxy resource for paleoclimatic and paleoenvironmental reconstructions: data from South Adriatic Sea, Central and Northern Tyrrhenian Sea

Antonio Cascella[1], Sergio Bonomo[1,2], Bassem Jalali[3], Marie-Alexandrine Sicre[3], Nicola Pelosi[2], Sabine Schmidt[4], Fabrizio Lirer[2] and Giovanni Sarti[4]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione Pisa, Italy*
[2]*Istituto di Scienze Marine (ISMAR), Consiglio Nazionale delle Ricerche (CNR), Naples, Italy*
[3]*Sorbonne Universités (UPMC, Univ. Paris 06) CNRS-IRD-MNHN, LOCEAN Laboratory, Paris, France*
[4]*UMR5805 EPOC, Université de Bordeaux, Pessac, France*
[5]*Universita di Pisa, Dipartimento di Scienze della Terra, Pisa, Italy*

antonio.cascella@ingv.it

Calcareous nannofossils are the fossil remains of Coccolithophores (calcareous nannoplankton) and are valuable source of information for paleoclimatic studies [Baumann et al., 2005] (Figure 1).

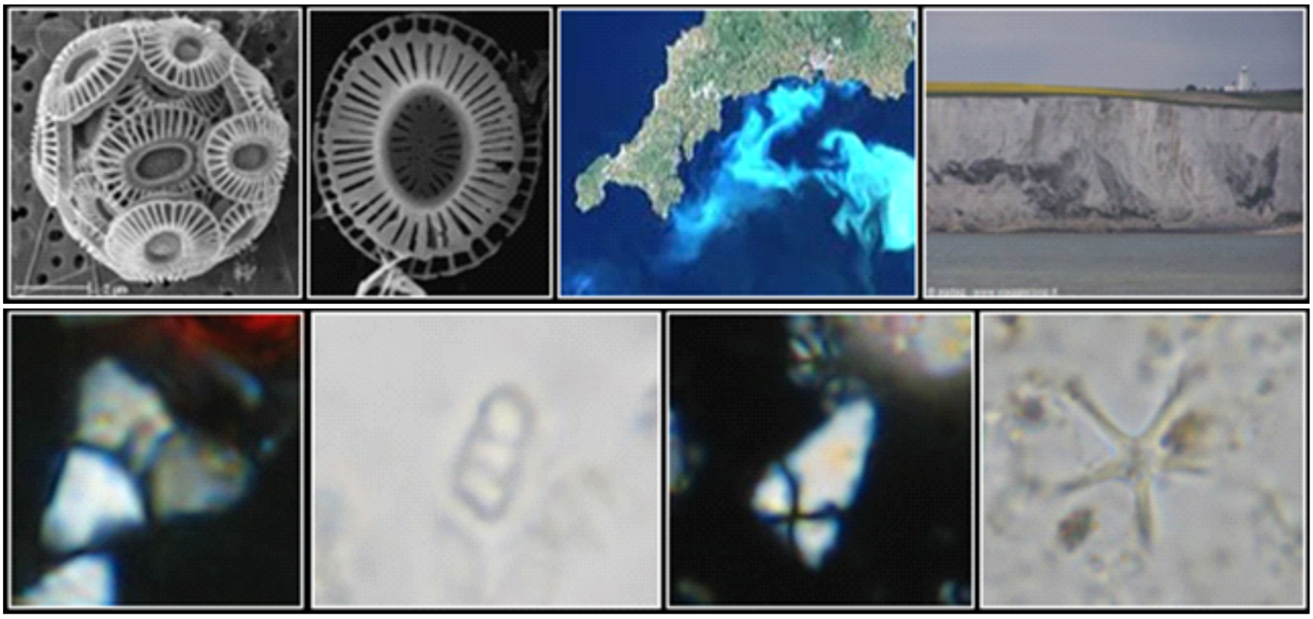


Figure 1 Calcareous nannoplankton/nannofossils: up, from left to right: Coccosphera of Emiliania huxleyi, dominant living specie (7 µm); Coccolith of E. huxleyi (4µm); satellite image of coccolithophores "bloom"; the Cliffs of Dover: made up by the precipitation of billion fossil coccoliths. Down, from left to right: Quadrum trifidum (Campanian, Late Cretaceous. Size: 8µm); Istmolithus recurvus (Late Eocene. 7µm); Sphenolithus heteromorfus (middle Miocene. 9µm); Discoaster pentaradiatus (late Miocene. 10µm).

Coccolithophores are single cell calcareous algae whose ecology and vital functions are driven by environmental parameters within the ocean euphotic zone (e.g., temperature, salinity, sunlight, and nutrient supply). Therefore, changes in abundances of selected taxa have been used to reconstruct variations of physical and environmental parameters and their relation with climate change and human activity. In addition, reworked coccoliths (RC) (i.e., the nannofossils which have been removed from their original sedimentary layer and redeposited in a younger

layer) have been used to reconstruct regional scale runoff and/or precipitation changes [Bonomo et al., 2016; Cascella et al., 2019], and may be useful to understand the effects of global warming on the spatial and temporal variability of heavy rainfall events and floods.
Here we resume the results of two studies that have explored calcareous nannofossils as a proxy of past climate and environmental changes over the past ~3000 years in the Central Mediterranean Sea. Paleoclimatic data have been acquired through the high-resolution study of calcareous nannofossils preserved in four sediment cores recovered in the Southern Adriatic Sea (SAS), Central and Northern Tyrrhenian Sea (CTS, NTS) [Cascella et al., 2019] (Figure 2), obtained within the framework of the NEXTDATA Project (http://www.nextdataproject.it).

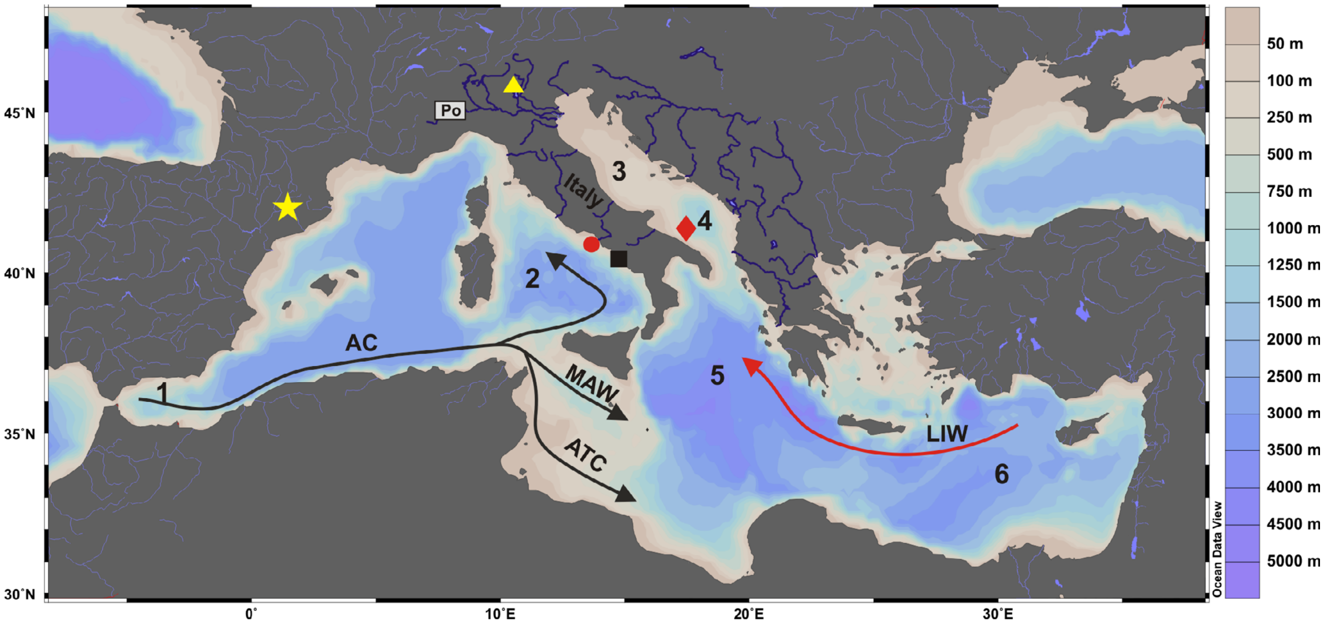


Figure 2 Location of the cores: SW104-ND14Q (red diamond), C5 Composite (red dot), SW104_NDT20bis and NDT20bis (red pentagon), and C90 (black square, [Lirer et al., 2013]), Basa de la Mora (yellow star, [Moreno et al., 2012]), and Ledro(yellow triangle, [Wirth et al., 2013]). Bathymetric map of the Mediterranean Basin, main surface (black arrow) and intermediate circulation pattern (red arrow). AC: Algerian Current; MAW: Modified Atlantic Water; ATC: Atlantic Tunisian Current; LIW: Levantine Intermediate Water. Numbers 1-6: 1-Alboran Sea; 2-Tyrrhenian Sea; 3-Adriatic Sea; 4-South Adriatic Pit, SAP; 5- Ionian Sea; 6 Levantine Sea. The main catchment basins of river flowing into the Adriatic Sea are reported (blue thick lines).

Cascella et al. [2019] highlight the value of %RC as a proxy for reconstructing regional scale precipitation and runoff from *Core SW104-ND14Q* and *Core C5 Composite* (SAS and CTS, respectively) showing a relationship between RC abundances, flood frequency across the Southern Alps [Wirth et al., 2013], Iberia Peninsula [Moreno et al., 2012] and a negative correlation with the North Atlantic Oscillation (NAO) index of Trouet et al. [2009] (Figure3).
The *Core SW104-ND14Q* also show that lowest coccolithophorids productivity in SAS took place during extended weakest NAO phases, i.e. primarily the Little Ace Age (LIA, ~1300 to ~1850 CE) and two other intervals (200BCE and 500CE), as a result of large fresh water discharge and subsequent stratified surface ocean reducing nutrient supply and production of coccolithophorids in the open SAS (Figure 4). Outside these periods of negative NAO, whether and to what extent other factors such as the circulation mode of the North Ionian Sea [Civitarese et al., 2010] may have played a role on the hydrology and productivity of the open SAS remains an open question.

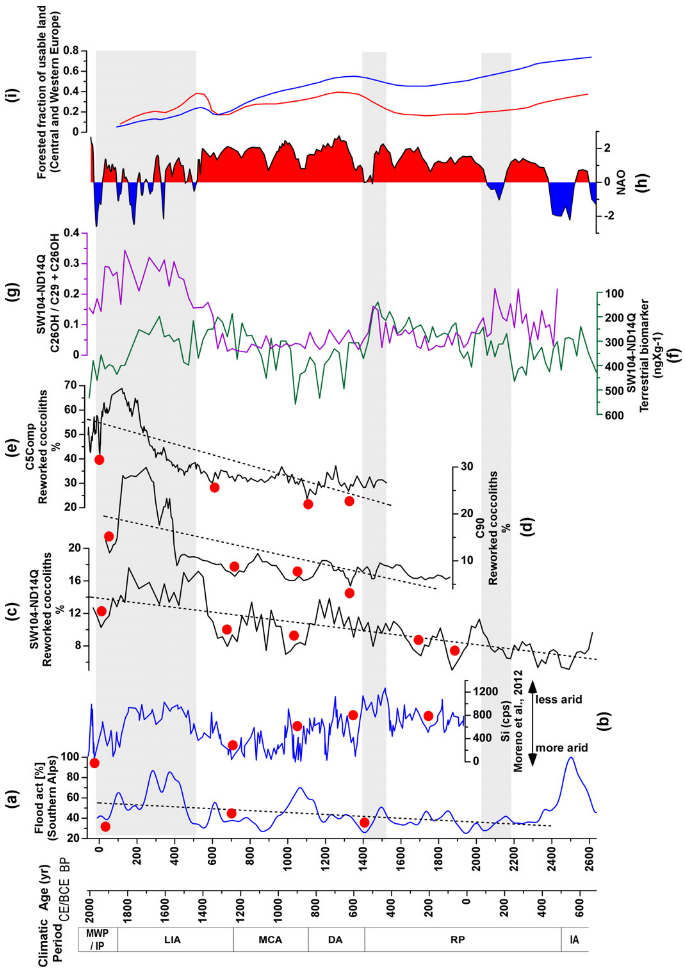


Figure 3 Comparison in time domain between (a) Flood frequency reconstruction from Southern Alps [Wirth et al., 2013], (b) Si fluctuations [Moreno et al., 2012], (c) SW104-ND14Q, (d) C90, and (e) C5Comp reworked coccoliths, (f) Terrestrial biomarker concentration [Jalali et al., 2018], (g) SW104-ND14Q C26OH/C29+C26OH ratio, and (i) Forest fraction of usable land [Kaplan et al., 2009]. The red dots mark the dry spells. The light grey bands highlight the relationship between C26OH/C29+C26OH ratio and negative (h) NAO states. The climate periods are from Margaritelli et al., [2016] [after Cascella et al., 2019].

The study of cores from NTS (i.e., Core SW104_NDT20bis, NDT20bis), recovered in front of the Arno River mouth, is in progress and aims to reconstruct the runoff history of the catchment of Arno river (Tuscany, Italy) over the past ~2000 years [Sarti et al., 2019]. Preliminary unpublished data suggest that changes in %RC seem to highlight the main intense rainfall and flood episodes of the Arno hydrographic basin.

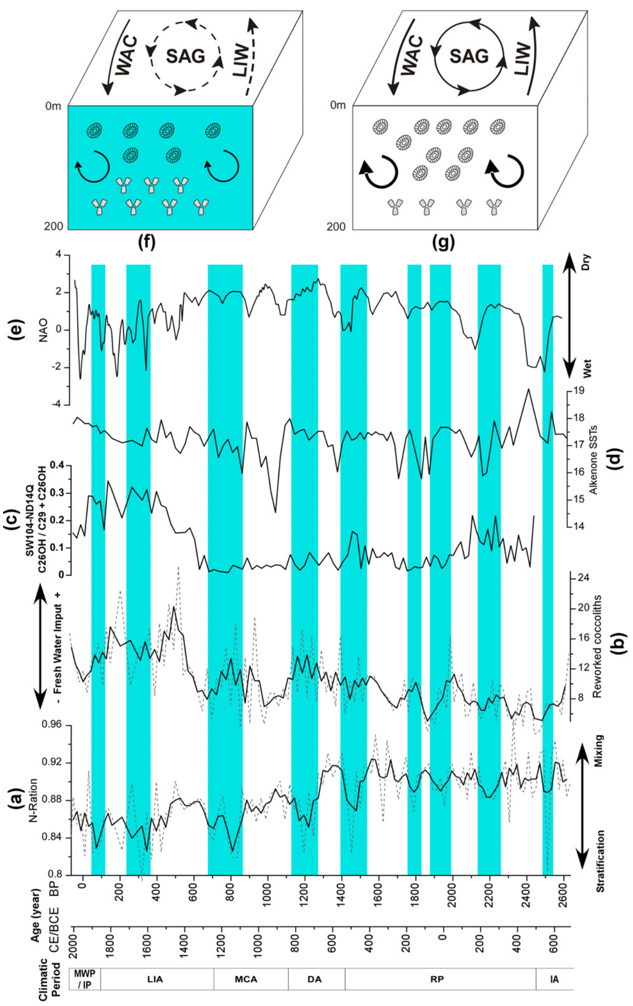


Figure 4 Schematic view of inferred relationship between (a) SW104-ND14Q N-Ratio and (f, g) SAS hydrology. (b) %RC fluctuations, (c) C26OH/C29+C26OH ratio, (d) SSTs fluctuations, and (e) winter NAO index [Olsen et al., 2012; Trouet et al., 2009] are reported. The light blue bands highlight the N-Ratio during periods of stratified surface water (diagram f). The climate periods are from Margaritelli et al. [2016] [after Cascella et al., 2019].

References

Bonomo S., Cascella A., Alberico I., Sorgato S., Pelosi N., Ferraro L. et al., (2016). *Reworked Coccoliths as runoff proxy for the last 400years: The case of Gaeta Gulf (central Tyrrhenian Sea, Central Italy)*. Palaeogeography, Palaeoclimatology, Palaeoecology. Elsevier B.V. 459: 15–28: doi: 10.1016/j.palaeo.2016.06.037.

Cascella A., Bonomo S., Jalali B., Sicre M.-A., Pelosi N., Schmidt S., Lirer F., (2019). *Climate variability of the last ~2700 years in the Southern Adriatic Sea: Coccolithophore evidences*. The Holocene. doi: 10.1177/0123456789123456.

Civitarese G., Gačić M., Lipizer M. and Eusebi Borzelli G.L., (2010) *On the impact of the Bimodal Oscillating System (BiOS) on the biogeochemistry and biology of the Adriatic and Ionian Seas (Eastern Mediterranean)*. Biogeosciences 7(12): 3987–3997: doi: 10.5194/bg-7-3987-2010.

Lirer F., Sprovieri M., Ferraro L., Vallefuoco M., Capotondi L., Cascella A. et al., (2013) *Integrated stratigraphy for the Late Quaternary in the eastern Tyrrhenian Sea*. Quaternary International 292: 71–85. doi: 10.1016/j.quaint.2012.08.2055.

Moreno A., Pérez A., Frigola J., Nieto-Moreno V., Rodrigo-Gámiz M., Martrat B. et al., (2012). *The Medieval Climate Anomaly in the Iberian Peninsula reconstructed from marine and lake records*. Quaternary Science Reviews: doi: 10.1016/j.quascirev.2012.04.007.

Trouet V., Esper J., Graham N.E., Baker A., Scourse J.D. and Frank D.C., (2009). *Persistent positive North Atlantic oscillation mode dominated the Medieval Climate Anomaly*. Science (New York, N.Y.) 324(5923): 78–80. doi: 10.1126/science.1166349.

Sarti G., Bertoni D., Bini M., Cascella A., Bonomo S., Lirer F., Novi L., Raffa F., Ribolini A., Mencaroni M., Casarosa N., (2019). *From Romans to artificial pebble beaches: human and natural influences on the Arno River delta history morpho-sedimentary evolution, (Tuscany, Italy)*. 20th Congress of the International Union for Quaternary Research (INQUA). 25th and 31st July 2019 Dublin, Ireland.

Wirth S.B., Glur L., Gilli A. and Anselmetti F.S., (2013). *Holocene flood frequency across the Central Alps – solar forcing and evidence for variations in North Atlantic atmospheric circulation*. Quaternary Science Reviews 80: 112–128. doi: 10.1016/j.quascirev.2013.09.002.

The role of fixed multidisciplinary observatories in the exploration of ocean processes and the solid earth from the seafloor

Nadia Lo Bue, Laura Beranzoli, Mariagrazia De Caro, Gianfranco Cianchini, Davide Embriaco, Paolo Favali, Gioacchino Fertitta, Francesco Frugoni, Alessandra Giuntini, Nicola Marcucci, Giuditta Marinaro, Stephen Monna, Caterina Montuori, Tiziana Sgroi, Riccardo Vagni

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Geomagnetismo, Aeronomia e Geofisica Ambientale, Roma, Italy

nadia.lobue@ingv.it

Knowledge of the oceans is still lacking in spite of their impact on climate, energy, food, and other resources of the global Earth system. While the shallow and intermediate layers are better known, exploration of the deep Ocean still remains a challenge for both science and technology. The new achievements in engineering and technology get in the last decades have improved human activities in the deeper waters allowing to acquire new knowledge in several domains including geophysics and oceanography.
Since the 90's INGV has focused on geophysical processes occurring in deep ocean and sea by developing seafloor multidisciplinary (fixed) observatories (Figure 1) addressing the study of complex systems such as submarine volcanos and tectonic structures, oceanographic processes, submarine noise, through the integration of different types of geophysical data (Figure 2).

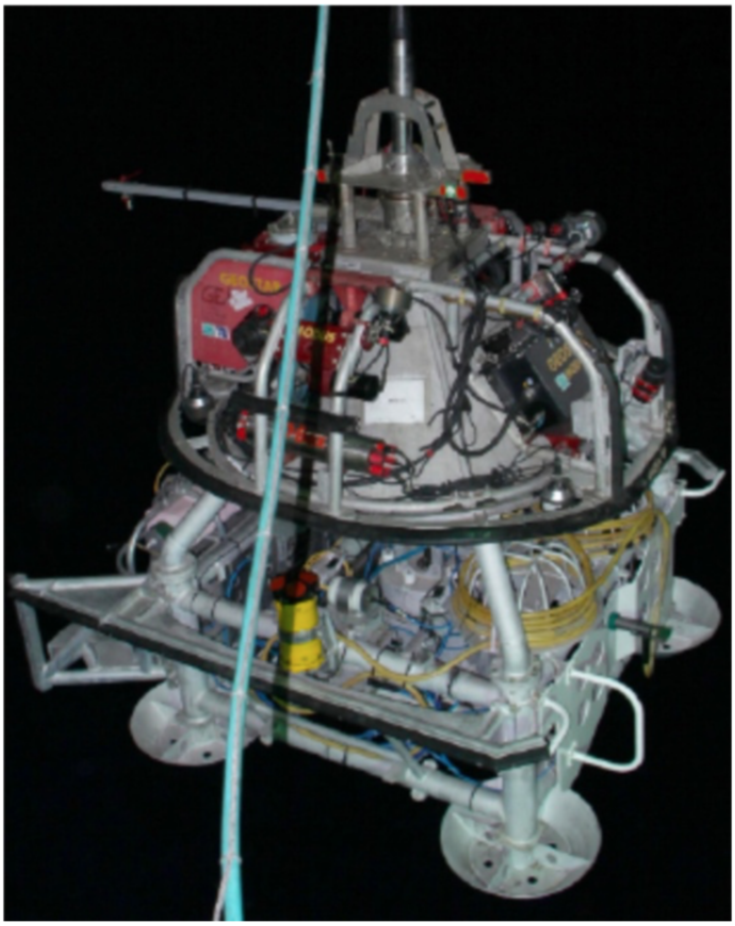


Figure 1 The NEMO-SN1 muldisciplinary observatory during deposition operation.

Figure 2 List of scientific instrumentation on board the NEMO-SN1 observatory.

Sensor	Rate	Model
3-C broad-band seismometer	100 Hz	Guralp CMG-1T (0.0027-50 Hz)
Absolute Pressure Gauge (APG)	15 s	Paroscientific 8CB4000-I
Differential Pressure Gauge (DPG)	100 Hz	Prototype Univ. California-St. Diego
Hydrophone (Geophysics)	100 Hz	OAS E-2PD
Hydrophone (Geophysics)	2000 Hz	SMID (0.05-1000 Hz)
4 Hydrophones (Bio-acoustics, INFN)	96 kHz	SMID (100-70000 Hz)
3-C Accelerometer + 3-C Gyro (IMU)	100 Hz	Gladiator Technologies Landmark 10
Gravity meter	1 Hz	Prototype IFSI-INAF
Scalar magnetometer	1s/min	Marine Magnetics Sentinel (3000 m)
Vectorial magnetometer	1 Hz	Prototype INGV
ADCP	1 profile/h	RDI Workhorse Monitor (600 kHz)
CTD	1 s/h	SeaBird SBE-37SM-24835
3-C single point current meter	2 Hz	Nobska MAVS-3

Accurate knowledge of the time reference, component orientation, and optimal sensor installation procedure, guarantee high quality data from the broadband seismometer on-board the observatories. The observatories, then, are a reference observation point for studies that integrate land and seafloor seismic data, such as in the location of marine earthquakes or calculation of 1D and 3D tomography models. Thanks to seafloor seismological data many tomographic studies have been improved as for the case of Gibraltar and Calabrian subduction zone [Monna et al., 2013; Montuori et al., 2007]. Furthermore, several seismological events escaped from land stations have been instead detected by seafloor stations, highlighting the crucial role that benthic observatories have in recording important data for the characterization of marine tectonic structures [Sgroi et al., 2007].
Multiparameter analysis performed on GEOSTAR observatory data shed light on the nature of the mysterious Marsili Seamount, where different indicators point to hydrothermal activity that is taking place. Data recorded by NEMO-SN1 observatory allowed us to follow the pyroclastic activity of Mt. Etna from the explosive eruption, to the lava fountain episodes, to the ash dispersion which reached the water column above the seafloor observatory [Lo Bue et al., 2015; Giovanetti et al., 2016; Sgroi et al., 2019].
Background noise in the sea environment, both natural and anthropic, can be misleading and effort to correctly discriminate the nature of the signals is a necessary requirement [Monna et al., 2005; De Caro et al., 2014; Embriaco et al., 2014].
Through the years, the multidisciplinary benthic observatories have produced original oceanographic data, highlighting that deep layers are not in a steady state has been thought for a long time, but rather is continuously evolving. These data are crucial in understanding deep processes (such as mixing, turbulence, bottom-up diffusion), and how internal instability can affect ocean circulation. In fact, to know the mechanism and rates that control the bottom flows it is essential to quantify the re-transfer towards the upper layers of the energy stored at the seafloor [De Lavergne et al., 2017]; this re-transfer could contribute to the acceleration in the rising trends that affect climate variability such as thermohaline circulation, sea level rise and ocean acidification. Deep ocean data are needed to initialize and constrain ocean models and improve their representation of mixing of heat downwards/upwards [Ferrari et al., 2016] within the deep ocean. The characterization of the unexplored deep dynamics aims to provide essential outcomes for encouraging, in the next future, new tailored parameterizations able to represent the dynamics below a depth of 2000 m. In this sense, oceanographic data provided by EMSO fixed observatories might significantly contribute to improving our comprehension of the deep dynamics in the Mediterranean Sea giving an important contribution in filling the knowledge gas for deep ocean processes [Lo Bue et al., 2019].

References

De Caro M., Monna S., Frugoni F., Beranzoli L., Favali P., (2014). *Seafloor seismic noise at Central-Eastern Mediterranean sites*, Seismol. Res. Lett., 85, 5, doi: 10.1785/0220130203.

de Lavergne C., Madec G., Roquet F., Holmes R.M. & McDougall T.J., (2017). *Abyssal ocean overturning shaped by seafloor distribution*. Nature volume 551, pages 181–186.

Embriaco D., Marinaro G., Frugoni F., Monna S., Etiope G., Gasperini L., Polonia A., Del Bianco F., Favali P., Çağatay M.N., Ulgen U.B., (2014). *Combined gas seepage and seismological monitoring along the North-Anatolian Fault in the Sea of Marmara (Turkey) by benthic observatory*. Geophys. J. Int. 196 (2): 850-866. doi: 10.1093/gji/ggt436.

Giovanetti G., Monna S., Lo Bue N., Embriaco D., Frugoni F., Marinaro G., De Caro M., Sgroi T., Montuori C., De Santis A., Cianchini G., Beranzoli L., Favali P., (2016). *Observing Volcanoes from the Seafloor in the Central Mediterranean Area*. Remote Sens., 8, 298.

Lo Bue N., Sgroi T., Giovanetti G., Marinaro G., Embriaco D., Beranzoli L. and Favali P., (2015). *Investigation of active volcanic areas through oceanographic data collected by the NEMO-SN1 multiparametric seafloor observatory*. EGU2015 SESSION OS4.7 Seafloor Observatories.

Monna S., Frugoni F., Montuori C., Beranzoli L., Favali P., (2005). *High quality seismological recordings from the SN-1 deep seafloor observatory in the Mt. Etna region*. Geophys. Res. Lett., Vol. 32. doi:10.1029/2004GL021975.

Sgroi T., Di Grazia G. and Favali P., (2019). *Volcanic tremor of Mt. Etna (Italy) recorded by NEMO-SN1 seafloor observatory: a new perspective on volcanic eruptions monitoring*. Geosciences 2019, 9(3), 115; https://doi.org/10.3390/geosciences9030115.

Preliminary observations from data recorded by OBS in the Ionian Sea (Italy) during the SEISMOFAULTS experiment

Tiziana Sgroi[1], Laura Beranzoli[1], Antonio Costanza[2], Giuseppe D'Anna[2], Mariagrazia De Caro[1], Gioacchino Fertitta[2], Francesco Frugoni[1], Nicola Mario Marcucci[1], Stephen Monna[1], Caterina Montuori[1], Andrea Ursino[3]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Geomagnetismo, Aeronomia e Geofisica Ambientale, Roma, Italy*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Nazionale Terremoti, Gibilmanna, Italy*
[3]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*

tiziana.sgroi@ingv.it

The Ionian Sea area is a known site of seismic hazard. Several historical high-magnitude earthquakes occurred in the area (e.g., 1193, M=6.6; 1693, M=7.4; 1908, M=7.2) [Boschi et al., 1997], whose tectonic sources and generation mechanism are still debated. Due to the lack of a seafloor seismic network the detection and location of marine earthquakes are often elusive. The SEISMOFAULTS experiment [http://www.seismofaults.it/] was performed between 2017 May and 2018 May to increase knowledge on the seismicity in the western Ionian Sea. Seven broad-band Ocean Bottom Seismometers and Hydrophones (OBS/H; Figures 1a and 1b) were deployed during the experiment and recovered at the end of the experiment. The extension of the network was ~150 x 100 km^2 with a ~30 km station interspacing. The OBS/H are broadband instruments built at the INGV OBS Lab Gibilmanna.

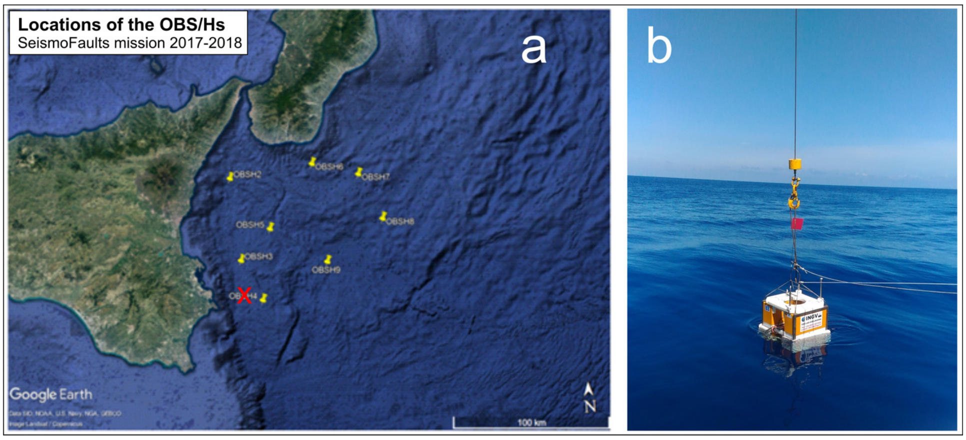


Figure 1 (a) Map of Ocean Bottom Seismometers and Hydrophones (OBS/H) deployed during the SEISMOFAULTS experiment. (b) Example of OBS/H during the deployment.

About 549 Gb (data and metadata) were recorded. The data formats available are: Güralp Compressed Format (GCF) and Seismic Analysis Code (SAC). Data were organized in a simple filesystem archive. The first step was the estimation on ship of the time digitizer clocks drift, after the OBS/Hs were recovered at the end of the experiment. Estimated time drifts for the whole mission period were < 0.5 s for all OBS/Hs. A linear correction of the time drift was applied to the data.
Quality analysis showed a high recording rate and good quality of the data (Figures 2a and 2b).

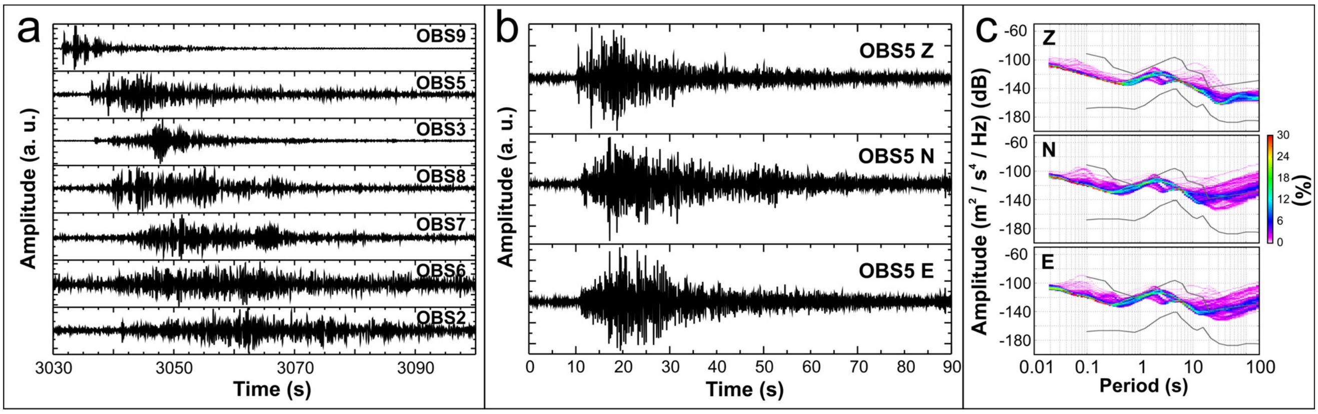


Figure 2 (a) Waveforms of a local event (2017, July 19, M=2.4) recorded on all OBSs (z-component); (b) waveform of the previous local event recorded on the three components of OBS5; (c) probability density function calculate in summer (2017, July 11-17) for the three components of OBS5.

Probability density functions were constructed for the seismic data recorded during one week in different seasons (Figure 2c). In general, the spectral curves are within the Peterson [1993] model limits, except for the expected high noise on the horizontal components at low frequency. We found that the OBS/H recorded seismic data from events at different epicentral distance ranges (i.e. local, regional and teleseismic). During the experiment about 2400 local events were recorded by the INGV land networks ($0.4 \leq M_L \leq 3.9$).
These events include earthquakes from Etna, northern Sicily, southern Tyrrhenian and western Ionian Seas. Identification of P-wave and S-wave arrivals was performed on a subset of 43 earthquakes that occurred in the western Ionian Sea. Travel times from OBS/H and land stations were integrated to locate these events. We used the Hypoellipse code [Lahr, 1989], by considering simultaneously six different 1D velocity models and taking into account the topographic height of the seismic stations, as well as the negative values of OBS/H stations (zero is the sea level). Statistical analysis shows that the addition of OBS/H data significantly improves the estimate of hypocentre location. A comparison of the locations performed with land seismic network only, with the ones that combined land and marine stations, shows a difference in the azimuthal GAP that can go up to about 150°. A sensitive reduction of horizontal and vertical errors (up to 9 km and 12.5 km, respectively) is also observed.
Thanks to the use of OBS/Hs we could obtain detailed locations of earthquakes in the offshore area of Ionian Sea. A well constrained hypocentral distribution is crucial to better define the tectonic structures that are able to generate such destructive earthquakes as the ones that occurred in historical and recent times in this area.

References

Boschi E., Guidoboni E., Ferrari G., Valensise G. and Gasperini P., (1997). *Catalogue of the strong earthquakes in Italy from 461 BC to 1990*. ING&SGA, Bologna, 973 pp.

http://www.seismofaults.it/

Lahr J.C., (1989). *HYPOELLIPSE/version 2.0: a computer program for determining local earthquake hypocentral parameters, magnitude, and first motion pattern*. Open-File Report - U. S. Geological Survey, 95, 89–116.

Peterson J., (1993). *Observation and Modeling of Seismic Background Noise*. US Geological Survey Open File Report. US Geological Survey: Albuquerque, NM, USA, pp. 93–322.

Velocity structures and kinematics in the Ionian Sea (Italy) from seismological data recorded by NEMO-SN1 seafloor observatory

Tiziana Sgroi[1], Graziella Barberi[2], Alina Polonia[3], Andrea Billi[4]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Geomagnetismo, Aeronomia e Geofisica Ambientale, Italy*

[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy*

[3]*Consiglio Nazionale delle Ricerche, CNR-ISMAR, Bologna, Italy*

[4]*Consiglio Nazionale delle Ricerche, CNR-IGAG, Roma, Italy*

tiziana.sgroi@ingv.it

In the Western Ionian basin high magnitude earthquakes have occurred in the past and in recent times (e.g. 1193, M 6.6; 1693, M 7.4; 1908, M 7.2; 1990, M 5.7), sometimes followed by violent tsunamis [Boschi et al., 1997; Bianca et al., 1999]. The sources and mechanism related to the generation of these events are still either unknown or debated due to the inadequacy of the monitoring network to detect offshore medium-low-magnitude earthquakes and to the lack of a satisfactory velocity model to locate these events. In the periods October 2002-February 2003 and June 2012-May 2013 the NEMO-SN1 seafloor observatory operated about 25 km from the eastern coast of Sicily at 2100 m of depth. During the two periods, NEMO-SN1 recorded several hundreds of local events. Thanks to the good signal-to-noise ratio [Monna et al., 2005] of the seismological signals, the seafloor observatory recorded medium-low-magnitude earthquakes linked to the explosive eruption of Mt. Etna volcano occurred between October 2002 and January 2003, and, in addition, an intense microseismicity not recorded by any land station [Sgroi et al., 2007].

We integrated the travel times of about 1000 earthquakes recorded by NEMO-SN1 and by the land stations with the aim of improving the location of these events. Moreover, thanks to the seismological data recorded by NEMO-SN1 we were able to calculate a new 1D velocity model for the Western Ionian Sea. The first step was the preliminary relocation of the whole dataset (Figure 1a). From this dataset, we selected 108 best quality hypocentres (GAP ≤ 220°; rms ≤ 0.5 s; P and S phases number ≥ 8) and 33 seismic stations to ensure the best possible coverage of earthquakes and stations around NEMO-SN1. Since the inversion involves the use of a starting velocity model [Kissling et al., 1994], we considered five initial reference models [Steinmetz et al., 1983; Hirn et al., 1991; De Voogdt et al., 1992; Continisio et al., 1997; Polonia et al., 2016] to better represent the structural heterogeneity and velocities in the offshore area of Sicily and south Calabria. Then, we computed the new 1D velocity model using the VELEST software [Kissling, 1995]. We performed many trials, adjusting the layer thickness of the initial model to better estimate the depth of the main discontinuities and the Moho. The minimum misfit of the travel-time residuals was achieved after many inversions and the output model was considered to be stable. The new 1D velocity model for the Ionian Sea consists of six layers above the Moho, located at a depth of 21 km (Figure 1b). The thickness of the layers and velocities are in agreement with the lithostratigraphic interpretation proposed by Polonia et al., [2016]. We used this new model to relocate the earthquakes of the whole dataset. The final relocations show a major concentration of earthquakes in the Mt. Etna volcano sector (in relation to its volcanic activity); a minor and more dispersed seismicity is evident in the Ionian Sea. Although events originated in the depth range 0-80 km, most of the earthquakes have hypocentral depths less than 30 km. An important achievement was the improvement in the

location of earthquakes using the new velocity model, particularly in the Ionian offshore area, in terms of RMS, GAP, and horizontal and vertical errors.
To infer the kinematics of earthquakes occurred in the Ionian basin, we computed 66 new fault plane solutions, by applying the standard FPFIT procedure [Reasenberg & Oppenheimer, 1985]. The events had a minimum number of eight clear polarities and most of the selected 66 faults plane solutions did not have discrepant polarities. The map of distribution of focal mechanisms and the EW and NS sections (Figure 2) show that earthquake kinematics are rather homogeneous. Normal, normal-to-strike-slip and strike-slip faulting mechanisms prevail, showing a depth distribution in good agreement with the regional structural model.

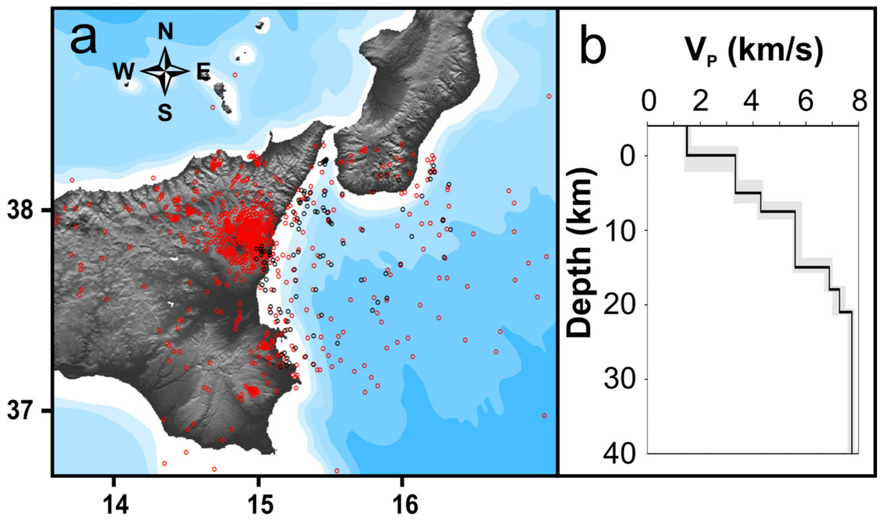


Figure 1 Preliminary location of the seismicity recorded by NEMO-SN1 (red dots); black dots represent the events used for the 1D velocity model computation through the VELEST inversion. (b) The new velocity model for the Western Ionian basin: The depth 0 km refers to the depth of the NEMO-SN1 observatory and the layer above this depth represents the water column.

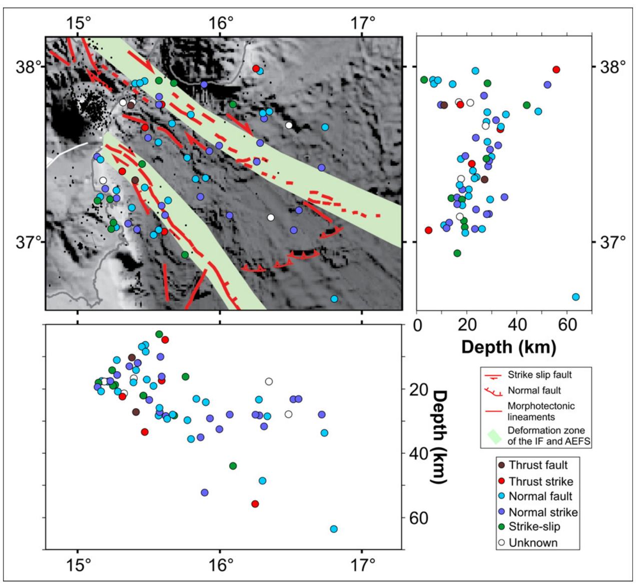


Figure 2 Structural map (modified from Polonia et al., 2016) with indicated the Ionian and Alfeo-Etna fault systems and EW (bottom left) and NS (upper right) sections of the 66 new focal mechanisms; black dots represents the entire dataset relocated using the new velocity model. Prevalent normal, normal-strike and strike-slip mechanisms characterize the Ionian Sea kinematics.

References

Bianca M., Monaco C., Tortorici L. and Cernobori L., (1999). *Quaternary normal faulting in south-eastern Sicily (Italy): a seismic source for the 1693 large earthquake*. Geophysical Journal International, 139, 370–394.

Boschi E., Guidoboni E., Ferrari G., Valensise G. and Gasperini P., (1997). *Catalogue of the strong earthquakes in Italy from 461 BC to 1990*. ING&SGA, Bologna, 973 pp.

Continisio R., Ferrucci F., Gaudiosi G., Lo Bascio D. and Ventura G., (1997). *Malta escarpment and Mt. Etna: early stages of an asymmetric rifting process? Evidences from geophysical and geological data*. Acta Vulcanologica, 9, 45–53.

De Voogd B., Truffert C., Chamot-Rooke N., Huchon P., Lallemant S. and Le Pichon X., (1992). *Two-ship deep seismic soundings in the basins of the Eastern Mediterranean Sea (Pasiphae cruise)*. Geophysical Journal International, 109, 536–552.

Hirn A., Nercessian A., Sapin M., Ferrucci F. and Wrrtlinger G., (1991). *Seismic heterogeneity of Mt. Etna: structure and activity*. Geophysical Journal International, 105, 139–153.

Kissling E., Ellsworth W.L., Eberhart-Phillips D. and Kradolfer U., (1994). *Initial reference models in local earthquake tomography*. Journal of Geophysical Research, 99, 19635–19646.

Kissling E., (1995). *Velest Users Guide*. Internal report Institute of Geophysics, pp. 26, ETH Zurich.

Monna S., Frugoni F., Montuori C., Beranzoli L. and Favali P., (2005). *High quality seismological recordings from the SN-1 deep seafloor observatory in the Mt. Etna region*. Geophys. Res. Lett. 2005, 32, L07303.

Polonia A., Torelli L., Artoni A., Carlini M., Faccenna C., Ferranti L., Gasperini L., Govers R., Klaeschen D., Monaco C., Neri G., Nijholt N., Orecchio B., and Wortel R., (2016). *The Ionian and Alfeo–Etna fault zones: New segments of an evolving plate boundary in the central Mediterranean Sea?*. Tectonophysics, 675, 69–90.

Reasenberg P. and Oppenheimer D., (1985). *FPFIT, FPPLOT and FPPAGE: FORTRAN computer programs for calculating and displaying earthquake fault-plane solutions*. U.S. Geol. Surv., Open File Rep., 85–739.

Sgroi T., Beranzoli L., Di Grazia G., Ursino A. and Favali P., (2007). *New observations of local seismicity by the SN-1 seafloor observatory in the Ionian Sea, off-shore eastern Sicily (Italy)*. Geophysical Journal International, 169, 490-501.

Steinmetz L., Ferrucci F., Hirn A., Morelli C. and Nicolich R., (1983). *A 550 km long Moho traverse in Tyrrhenian Sea from OBS recorded Pn waves*. Geophysical Research Letters, 10 (6), 428-431.

Acoustic T-phases recorded by seafloor observatories at the Tyrrhenian and Ionian deep sites

Mariagrazia De Caro[1], Caterina Montuori[1], Francesco Frugoni[1], Stephen Monna[1], Fabio Cammarano[2], Laura Beranzoli[1]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Geomagnetismo, Aeronomia e Geofisica Ambientale, Roma, Italy
[2]Università Roma TRE, Dipartimento di Scienze Geologiche, Rome, Italy

mariagrazia.decaro@ingv.it

T-phases are acoustic waves, generated by earthquakes, that propagate within the ocean's low-velocity waveguide (SOund Fixing And Ranging or "SOFAR" channel). T-phases can travel over great distances (~1000 km) with little loss in signal strength and can be recorded by seismometers after the P and S arrivals (hence T or Tertiary phases). These waves were at first recorded at coastal seismic stations but more recently, also by Ocean Bottom Seismometers (OBS) at depths that are greater than the SOFAR channel. T-phases are interesting for a number of reasons, in particular they might give information on the structure of subduction zones [e.g. Okal, 2008].
In this work, we analyzed high quality 3-component time series recorded by seismometers on-board seafloor observatories. On these waveforms a number of T-phases generated at nearby subduction zones were identified. Seafloor observatories have been deployed in recent years in the Italian seas. The SN1 observatory, node of EMSO (European Multidisciplinary Seafloor and water-column Observatory Research Infrastructure, www.emso.eu), was deployed in the Ionian Sea at 2100 m b.s.l offshore Eastern Sicily (Figure 1).

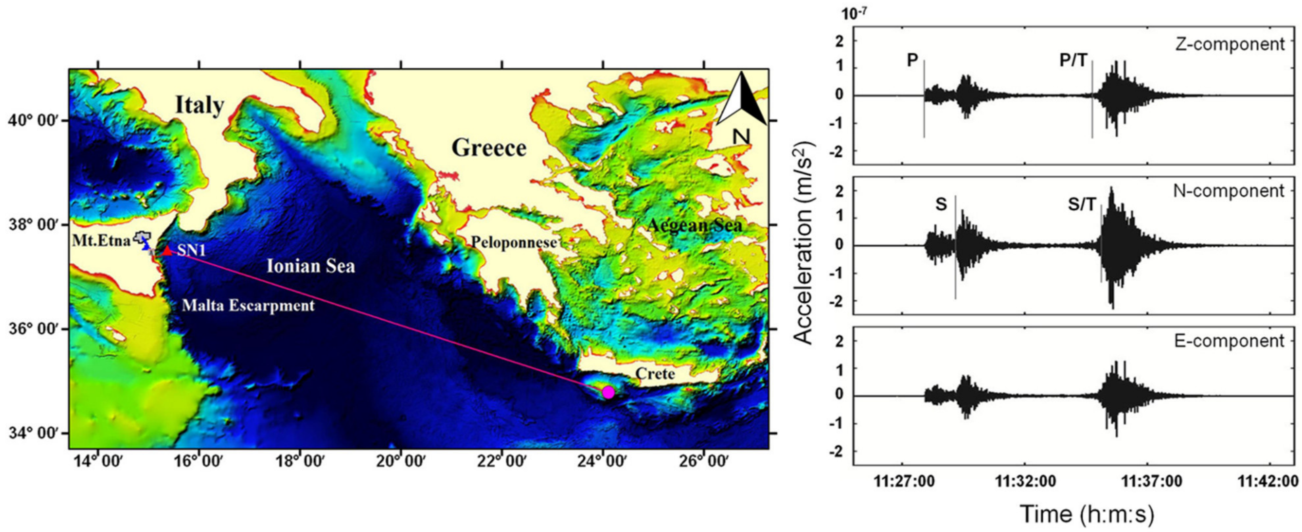


Figure 1 Example of earthquake recorded at the seafloor observatory SN1. Left: bathymetric map of the eastern Mediterranean Sea. Darker colors in the bathymetry correspond to greater depths. The red triangle shows the location of the SN1 seafloor observatory. The fuchsia dot indicates the location of a M_L 5.1 regional earthquake that occurred in the Hellenic arc (epicenter at 34.82° N–24.11° E) on 6 April 2013. Right: Z–N–E component seismograms of this event. The body waves and the P to T (P/T) and S to T (S/T) converted T phases are highlighted on the trace (band-pass filtered 2-12 Hz). The bathymetric data have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu/

The GEOSTAR observatory was deployed at 3200 m b.s.l during the ORION experiment at the base of the Marsili seamount (Figure 2).

To investigate how the T-phases are generated by earthquakes in two subduction zones, Calabrian and Hellenic arcs, we measure some properties of the recorded waveform. In particular, we evaluate how the energy of the T-phase observed at deep seafloor sites changes with earthquake magnitude, depth and wave propagation path. T-phase energy is calculated by the envelope e(t) and energy flux (TPEF). A linear relationship between the maximum amplitude of the envelope and the T-phase energy flux (TPEF) and the local Magnitude of crustal earthquakes and slab earthquakes from Hellenic and Calabrian subduction zones, was found. A polarization analysis on the three seismic components was performed to investigate the possible factors that affect the T phase energy loss along the propagation paths from epicenters to the seafloor receiver.

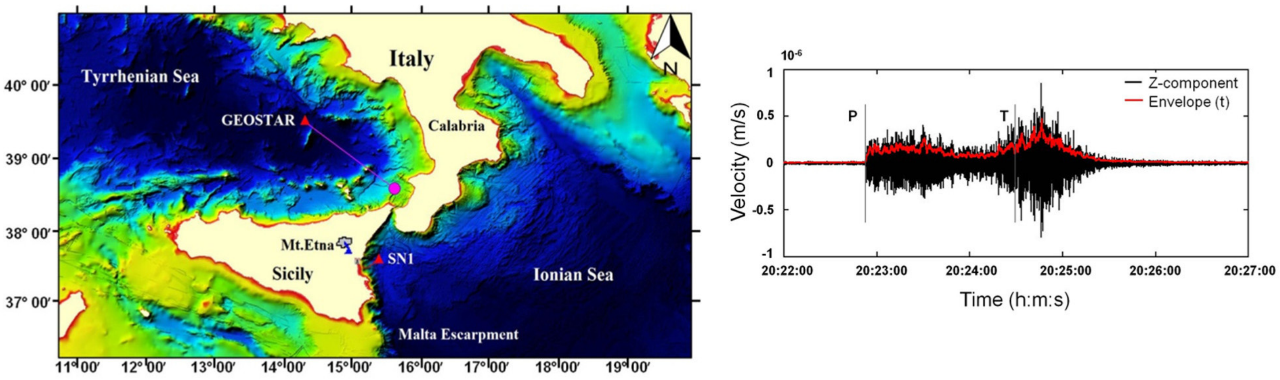


Figure 2 Example of earthquake recorded at the seafloor observatory GEOSTAR. Left: bathymetric map of the Tyrrhenian Sea. Darker colors in the bathymetry correspond to greater depths. The red triangle shows the location of GEOSTAR. The fuchsia dot indicates the location of a M_L 3.1 local earthquake (focal depth 166 Km) that occurred in the Calabrian arc (epicenter at 38.52°N–15.63°E) on 5 November 2004. Right: Z-component seismogram (band-pass filtered 4-12 Hz) of this event and its envelope.

References

Okal E., (2008). *The generation of T waves by earthquakes*. Adv. Geophys. 49, 2–65, https://doi.org/10.1016/S0065-2687(07)49001-X.

Relative Sea Level Rise Projections in the Mediterranean: Multi Hazard Implications and Flooding Scenarios

Marco Anzidei[1], Petros Patias[2], Charalampos Georgiadis[2], Fawzi Doumaz[1], Dimitrios Kaimaris[2], Christos Pikridas[2], Carlo Alberto Brunori[1], Xenia Loizidou[3], Melania Michetti[4], Demetra Petsa[3], Demetra Orthodoxou[3], Silvia Torresan[4], Emanuela Furlan[4], Lucia Trivigno[5], Antonio Falciano[5], Michele Greco[5,6], Enrico Serpelloni[1], Antonio Vecchio[7], Luca Pizzimenti[1], Manuela Volpe[1], Roberto Basili[1], Stefano Lorito[1], Alessandro Bosman[8], Daniele Casalbore[9]

[1]*Istituto Nazionale di Geofisica e Vulcanologia INGV, Osservatorio Nazionale Terremoti, Roma, Italy*
[2]*Aristotle University of Thessaloniki, Greece*
[3]*ISOTECH LTD Environmental Research and Consultancy, Cyprus*
[4]*Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy*
[5]*Centro di Geomorfologia Integrata per l'Area del Mediterraneo*
[6]*Engineering School, Università della Basilicata, Potenza, Italy*
[7]*Lesia Observatoire de Paris, Section de Meudon, France*
[8]*Consiglio delle Nazionale Ricerche, IGAG, CNR, Istituto di Geologia Ambientale e Geoingegneria, Rome, Italy*
[9]*Università degli Studi di Roma La Sapienza, Italy*

marco.anzidei@ingv.it

Sea level rise (SLR) is one of the main global threats caused by climate change. Recent studies [Church et al., 2013; Vecchio et al., 2019] and the IPCC reports (www.ipcc.ch) show that global sea levels could rise up to 0.8-1.0 m or even more and up to 2 m by 2100. When in combination with vertical land movements (VLM) for natural or anthropogenic causes, changes in relative sea levels are particularly crucial in subsiding coasts, accelerating land flooding [Anzidei et al., 2017].
In this study, we show some results of the SAVEMEDCOASTS Project (*Sea Level Rise Scenarios along the Mediterranean Coasts*, www.savemedcoasts.eu), funded by the European Commission (Agreement Number: ECHO/SUB/2016/742473/PREV16). The project aims at responding to natural disasters prevention for people and assets in the Mediterranean coastal zones laying at less than 2 m above sea level (Figure1). The expected SLR rise will mainly affect the low elevated coastal plains, amplifying the effects of storm surges and tsunami.
We focus on ultra high-resolution and multi-hazard – multi-temporal marine flooding scenarios expected until 2100 AD in targeted zones of the Mediterranean basin, prone to be flooded in the next decades [Lambeck et al., 2011; Anzidei et al., 2014; Antonioli et al., 2018]. In order to evaluate the potential flooding scenarios, we used the following data sets: i) the RCP4.5 and RCP8.5 climate change scenarios released by the IPCC, calibrated for the Mediterranean region; ii) ultra-high resolution Marine and Terrain Digital Models obtained from multibeam bathymetry, UAV and Lidar surveys; iii) rates of ground vertical movements and sea level trend from instrumental data (i.e. GPS and tide gauges); iv) surf-zone hydrodynamics, atmospheric and wave conditions. From the analysis of these data-sets we provid detailed multi-temporal scenarios of the expected inland extension of marine flooding due to SLR for 2100, that will exacerbate the effects of storm surges and tsunamis, in particularly when in combination with land subsidence. Here we show results for the Venice lagoon, Lipari Island, Cinque Terre, Lefkada island (Figure 2) and the Nile and Rhone deltas. A first assessment of the direct and indirect economic impacts of coastal flood risk, for some of these areas, is provided. Finally, information are transferred to society, policy makers and stakeholders through a website and a Web-GIS platform populated with collected data, videos and photo galleries, project results and guidelines, to improve governance and raise community awareness towards these related hazards on coastal populations.

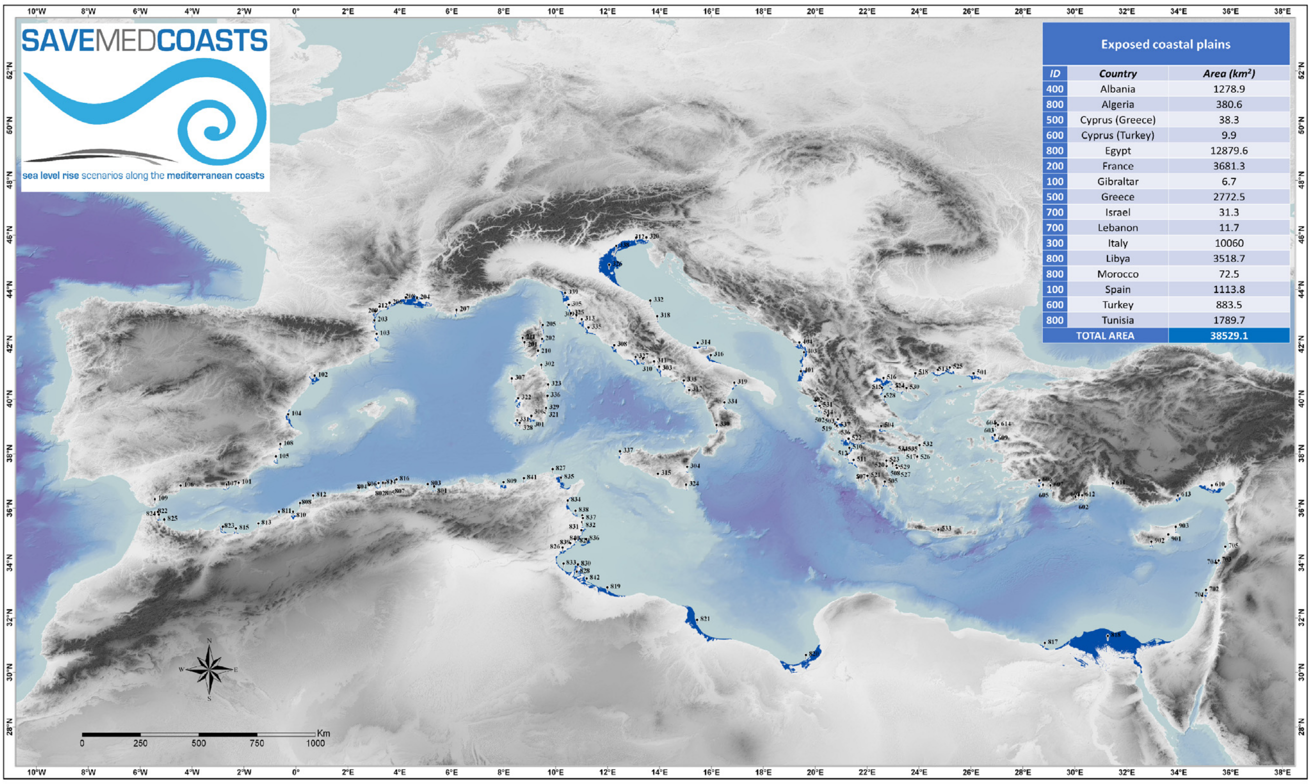
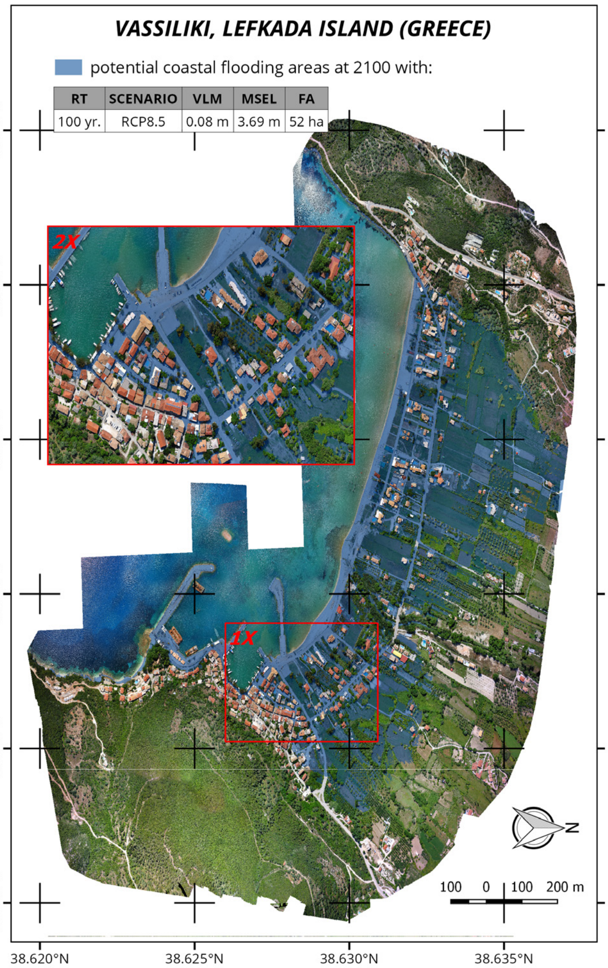


Figure 1 The 163 main coastal plains of the Mediterranean region (in blue) located at <2 m above sea level, highlighted by the geospatial analysis of SAVEMEDCOASTS. In the table, the extension of the coastal zones exposed to sea level rise, are reported.

Figure 2 Vasiliki bay, Lefkas Island (Greece). Map of the potential flooding scenario for storm surge in a sea level rise condition for 2100 (RCP 8.5) and the return time of 100 years. The expected flooded zone corresponds to a surface of 52 ha of extension (in light blue).



References

Antonioli F., Anzidei M., Amorosi A., Presti V.L., Mastronuzzi G., Deiana G., De Falco G., Fontana A., Fontolan G., Lisco S., Marsico A., Moretti M., Orru P.M., Sannino G., Serpelloni E., Vecchio A., (2017). *Sea-level rise and potential drowning of the Italian coastal plains: Flooding risk scenarios for 2100*. Quaternary Science Review, 158, 29–43.

Vecchio A., Anzidei M., Serpelloni E. and Florindo F., (2019). *Natural Variability and Vertical Land Motion Contributions in the Mediterranean Sea-Level Records over the Last Two Centuries and Projections for 2100*. Water 2019, 11, 1480. doi: 10.3390/w11071480.

Anzidei M., Lambeck K., Antonioli F., Furlani S., Mastronuzzi G., Serpelloni E., Vannucci G., (2014). *Coastal structure, sea-level changes and vertical motion of the land in the Mediterranean*. The Geological Society of London, Special Publications, 388. http://dx.doi.org/10.1144/SP388.20.

Anzidei M., Bosman A., Carluccio R., Casalbore D., d'Ajello Caracciolo F., Esposito A., Nicolosi I., Pietrantonio G., Vecchio A., Carmisciano C., Chiappini M., Chiocci F.L., Muccini F., Sepe V., (2017). *Flooding scenarios due to land subsidence and sea-level rise: a case study for Lipari Island (Italy)*. Terra Nova 29 (1), 44-51.

Church J.A., Clark P.U., Cazenave A., Gregory J.M., Jevrejeva S., Levermann A., Merrifield M.A., Milne G.A., Nerem R.S., Nunn P.D., Payne A.J., Pfeffer W.T., Stammer D. and Unnikrishnan A.S., (2013). *Sea Level Change. Supplementary Material*. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Stocker T.F., Qin D., Plattner G.-K., Tignor M., Allen S.K., Boschung J., Nauels A., Xia Y., Bex V. and Midgley P.M. eds.) *AR5 Sea Level Change Supplementary Material, Chapter 13*.

Lambeck K., Antonioli F., Anzidei M., Ferranti L., Leoni G., Scicchitano G., Silenzi S., (2011). Sea level change along the Italian coast during the Holocene and projections for the future. *Quaternary International* 232, 250-257.

Monitoring and long-term assessment of the Mediterranean Sea physical state through ocean reanalyses

Simona Simoncelli, Claudia Fratianni, Gelsomina Mattia

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Italy

simona.simoncelli@ingv.it

The near real time monitoring and long-term assessment of the physical state of the ocean are crucial for a wide user community providing a continuous and up to date overview of key indicators computed from reanalysis datasets. This constitutes an operational warning system on particular events, stimulating the research towards a deeper understanding of oceanographic phenomena and consequently increasing user awareness and products' uptake.
The Mediterranean Sea physical reanalysis [MEDREA, Simoncelli et al., 2014, Simoncelli et al., 2016] data set has been produced in the framework of MyOcean Project and distributed thought Copernicus Marine Environment Monitoring Service (CMEMS) catalogue (http://marine.copernicus.eu) since 2014 and yearly extended. It covers the time period 1987-2018 at 1/16° of spatial resolution forced by ERAInterim atmospheric reanalysis [Dee et al., 2011] and provides daily and monthly fields of temperature, salinity, sea surface height and currents. It assimilates along track sea level anomaly and temperature and salinity profiles. This data set is one of the most used by CMEMS users for many applications and studies among which the study of: the connectivity of Marine Protected Areas [Rossi et al., 2014]; the double diffusion processes [Meccia et al., 2016]; the cause of mass mortality that hit gorgonian forests at Montecristo Island [Turicchia et al., 2018]; the Mediterranean overturning circulation [Pinardi e al., 2019].
Estimated Accuracy Numbers and metrics [Simoncelli et al., 2016] of sea surface temperature, salinity and height as well as heat, water and momentum fluxes at the air-sea interface have been operationally implemented and it constitutes a real time monitoring of the data production quality. Its consistency analysis against available observational products, or budget values recognized in literature, guarantees the high quality of the numerical dataset and warns of potential anomalies or peculiar events.
The results of the reanalysis validation procedures are published and yearly updated in the QUality Information Document (http://marine.copernicus.eu/documents/QUID/CMEMS-MED-QUID-006-004.pdf) as certification of product's accuracy and indication of product's usability.
Ocean Monitoring Indicators (OMIs) of some Essential Ocean Variables have been identified and developed in the framework of the CMEM Multi Year Products Working Group and operationally implemented to contribute to the CMEMS Ocean State Report (http://marine.copernicus.eu/science-learning/ocean-state-report/), a regular annual reporting on the state and health of the Global Ocean and European Seas based on marine environment monitoring capabilities [von Schuckmann et al., 2016 and 2018].
Ocean Heat Content estimate, its time evolution and trend is a crucial OMI to detect ocean warming in a changing climate context [von Schuckmann et al., 2016 and 2018]. OHC is defined as the deviation from a reference period (1993-2014) and is closely proportional to the average temperature change from the sea surface to 1000 m depth, with a reference density of 1026 kg/m^3 and a specific heat capacity of Cp=4000 J/kg°C [von Schuckmann et al., 2009].
Figure 1 shows the timeseries of yearly OHC anomaly computed in the Mediterranean Sea over the time span 1987-2018 in the layer (L6) among surface and 1000m of depth and five intermediate layers: from the surface to 30m (L1), 30–150m (L2), 150–300m (L3), 300–600m (L4),

and 600–1000m (L5). Meccia et al., [2016] demonstrate that MEDREA fidelity is the highest above 1000m where data are assimilated. OHC presents negative anomalies (L6) in the periods 1987-1989 and 1993-1999, peaking in 1990-1991 and 2001 and remaining close to zero or slightly negative between 2002 and 2006. It is always positive after 2007 and reaches its maximum value in 2016. Looking at the sub-layers' OHC anomalies the largest positive values reside in L4 (300-600m) indicating a main warming of Mediterranean intermediate waters after 2005.

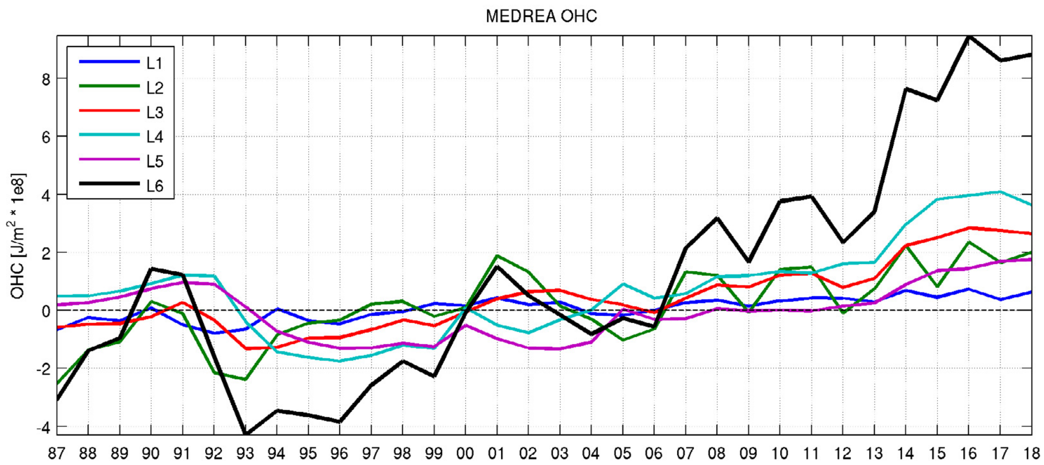


Figure 1 Ocean heat content anomaly timeseries in the Mediterranean Sea computed from MEDREA over the time period 1987-2018 in different layers: from the surface to 30m (L1), 30–150m (L2), 150–300m (L3), 300–600m (L4), 600–1000m (L5), and 0-1000m (L6).

Figure 2 shows the heat content trend computed in the upper 1000m in the time period 1987-2018. A generalized warming tendency (1.0893 W/m^2yr) characterizes the entire Mediterranean basin with the largest values in the Tyrrhenian Sea, in the Adriatic-Ionian region, the Aegean and the southern Levantine basin, while damped warming is found in correspondence of the Ierapetra gyre (southeast of Crete Island). The spatial pattern in Figure 2 is consistent with the largest warming of intermediate waters (L4) in Figure 1. In fact, Mediterranean intermediate waters form in the Levantine (Levantine Intermediate Waters) and the Cretan Sea (Cretan Intermediate Waters) and spread to the Ionian and Southern Adriatic region due to the circulation.
The warming and drying of the Levantine regional climate is the driver that favors the formation of warmer and saltier intermediate waters in either the Levantine or Cretan Sea [Schroeder et al., 2017].

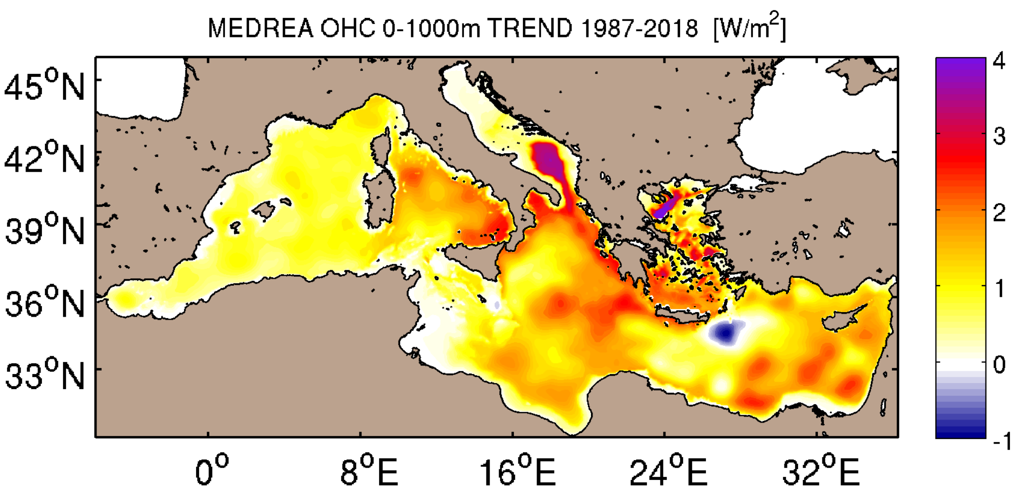


Figure 2 Ocean Heat Content anomaly [Watt/m^2] computed in the layer 0-1000m over the time period 1987-2018.

MEDREA is able to reproduce both Eastern Mediterranean Transient and Western Mediterranean Transition phenomena and catches the principal water mass formation events reported in literature [von Schuckmann et al., 2016 and 2018]. This achievement allows to monitor constantly the climatic changes in the Mediterranean Sea and their possible effects on the Mediterranean ecosystems.

References

Dee D.P., Uppala S.M., Simmons A.J., Berrisford P., Poli P., Kobayashi S. et al., (2011). *The ERA-Interim reanalysis: configuration and performance of the data assimilation system*. Q.J.R. Meteorol. Soc., 137: 553-597. doi: 10.1002/qj.828.

Meccia V.L., Simoncelli S., Sparnocchia S., (2016). *Decadal variability of the Turner Angle in the Mediterranean Sea and its implications for double diffusion*, Deep Sea Research Part I: Oceanographic Research Papers, Volume 114, 2016, Pages 64-77, ISSN 0967-0637, https://doi.org/10.1016/j.dsr.2016.04.001.

Pinardi N., Cessi P., Borile F. and Wolfe C.L., (2019). *The Mediterranean Sea Overturning Circulation*. Jour. Phys. Oceanogr., 49, 1699–1721, https://doi.org/10.1175/JPO-D-18-0254.1.

Rossi V., Ser-Giacomi E., López C. and Hernández-García E., (2014). *Hydrodynamic provinces and oceanic connectivity from a transport network help designing marine reserves*. Geophys. Res. Lett., 41, 2883-2891. doi: 10.1002/2014GL059540.

Schroeder K., Chiggiato J., Josey S.A., Borghini M., Aracri S., Sparnocchia S., (2017). *Rapid response to climate change in a marginal sea*. Scientific Reports. https://doi.org/10.1038/s41598-017-04455-5.

Simoncelli S., Fratianni C., Pinardi N., Grandi A., Drudi M., Oddo P. & Dobricic S., (2014). *Mediterranean Sea physical reanalysis* (MEDREA 1987-2015) [Data set]. Copernicus Monitoring Environment Marine Service (CMEMS).

Simoncelli S., Masina S., Axell L., Liu Y., Salon S., Cossarini G., Bertino L., Xie J., Samuelsen A., Levier B., et al., (2016). *MyOcean regional reanalyses: overview of reanalyses systems and main results*. Mercator Ocean J. 54. Special Issue on Main Outcomes of the MyOcean2 and MyOcean Follow-on projects. https://www.mercator-ocean.fr/en/science-publications/mercator-ocean-journal/newsletter-54-focusing-on-the-main-outcomes-of-the-myocean2-and-follon-on-projects/.

Storto A., Masina S., Simoncelli S. et al., (2019). The added value of the multi-system spread information for ocean heat content and steric sea level investigations in the CMEMS GREP ensemble reanalysis product. Clim. Dyn. 53: 287. https://doi.org/10.1007/s00382-018-4585-5.

Turicchia E., Abbiati M., Sweet M., Ponti M., (2018). *Mass mortality hits gorgonian forests at Montecristo Island*. Dis Aquat Org 131:79-85. https://doi.org/10.3354/dao03284.

von Schuckmann K., Gaillard F. and Le Traon P.-Y., (2009). *Global hydrographic variability patterns during 2003-2008*, Journal of Geophysical Research, 114, C09007, doi: 10.1029/2008JC005237.

von Schuckmann et al., (2016). *Ocean heat content*. In: The Copernicus Marine Environment Monitoring Service Ocean State Report, issue 1, Journal of Operational Oceanography, Volume 9, 2016 - Issue sup2: The Copernicus Marine Environment Monitoring Service Ocean, http://dx.doi.org/10.1080/1755876X.2016.1273446.

von Schuckmann et al., (2018). *Ocean heat content*. In: The Copernicus Marine Environment Monitoring Service Ocean State Report, issue 2, Journal of Operational Oceanography, 11:sup1, s1-s142, doi: 10.1080/1755876X.2018.1489208.

River runoff and Dardanelles Strait implementations in the Mediterranean Sea numerical modelling system

Damiano Delrosso[1,4], Emanuela Clementi[2], Gerasimos Korres[3], Nadia Pinardi[4]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Italy*
[2]*Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC), Sede di Bologna, Italy*
[3]*Institute of Oceanography, Hellenic Centre for Marine Research (HCMR), Greece*
[4]*Alma Mater Studiorum - Università di Bologna, Dipartimento di Fisica e Astronomia, Italy*

damiano.delrosso@ingv.it

Introduction

This contribution aims at presenting the numerical model developments recently implemented in an eddy-resolving Mediterranean Sea modelling system based on the Ocean General Circulation Model (OGCM) NEMO (Nucleus for European Modelling, [Madec et al., 2017]. In this implementation the model has a horizontal resolution of 1/24° and it is resolved over 141 z vertical levels [Clementi et al., 2017]. The developments are related to the implementation of an increased number of freshwater river outlets and to the improvement of the Dardanelles Strait representation in the numerical modelling system.

River runoff implementation

The river runoffs in the starting version of the Mediterranean Sea numerical system are implemented as Surface Boundary Conditions (SBC), meaning that freshwater input is added through the top model cells where the river mouths are defined. In addition to the volume flux, which represents the river discharge measured at gauge stations and usually available as monthly climatologies, specific values of salinity have been associated to the river inputs.
Two numerical experiments have been performed in order to evaluate the impact of an increased number of freshwater inputs (see Figure 1) on the thermohaline properties of the Mediterranean Sea and on its circulation structures: 7 rivers have been implemented (green dots in Figure 1) in the first experiment (simrs_v1), while 32 additional rivers (red dots in Figure 1) have been included in the second experiment (simrs_v2). The newly added rivers were those around the basin presenting a mean annual discharge larger than 50 m^3/s over the period 2000–2010 according to the climatological values derived from the PERSEUS project (http://www.perseus-net.eu).
Numerical results have been compared with respect to in situ observations (Argo floats, XBTs and gliders) showing that the temperature error is almost the same in both experiments, being approximately 0.65°C in the surface layer, 0.95°C in the thermocline (30-60m) and decreasing down to 0.2°C at largest depths. Experiment simrs_v2 shows an improvement in the salinity skill at Mediterranean Sea basin scale from the sea surface down to 60m depth. On the contrary, a worsening can be noticed from 60m down to 300m depth. Finally, results are very similar from 300m down to 2000m depth, as shown by the Root Mean Square Error values (RMSE) of Salinity, presented in Table 1. The salinity skill scores varies also among the different sub-regions of the Mediterranean Sea. In particular, simrs_v2 shows better performances in the Adriatic Sea than simrs_v1 above 30m depth, while it shows worse performances below 30m depth.

Depth range [m]	Salinity RMSE simrs_v1 [PSU]	Salinity RMSE simrs_v2 [PSU]	Salinity RMSE increase/decrease [%]
0-10	0.36	0.33	-9
10-30	0.34	0.31	-9
30-60	0.32	0.31	-3
60-100	0.29	0.30	+3
100-150	0.24	0.25	+4
150-300	0.13	0.14	+7
300-600	0.09	0.09	0
600-1000	0.05	0.05	0
1000-2000	0.03	0.03	0

Table 1 Root Mean Square Error (RMSE) of salinity for experiments simrs_v1 and simrs_v2 (columns two and three, respectively), and RMSE percentage increase/decrease for salinity (column four) in experiment simrs_v2 with respect to simrs_v1. Statistics consider the whole Mediterranean Sea basin.

Further tests would be needed in order to improve the accuracy of the thermohaline properties, for example by implementing estuary box models to better represent the salinity at the river mouth [Verri et al., 2019] or through a better calibration of the vertical mixing parameterization at river outlets.

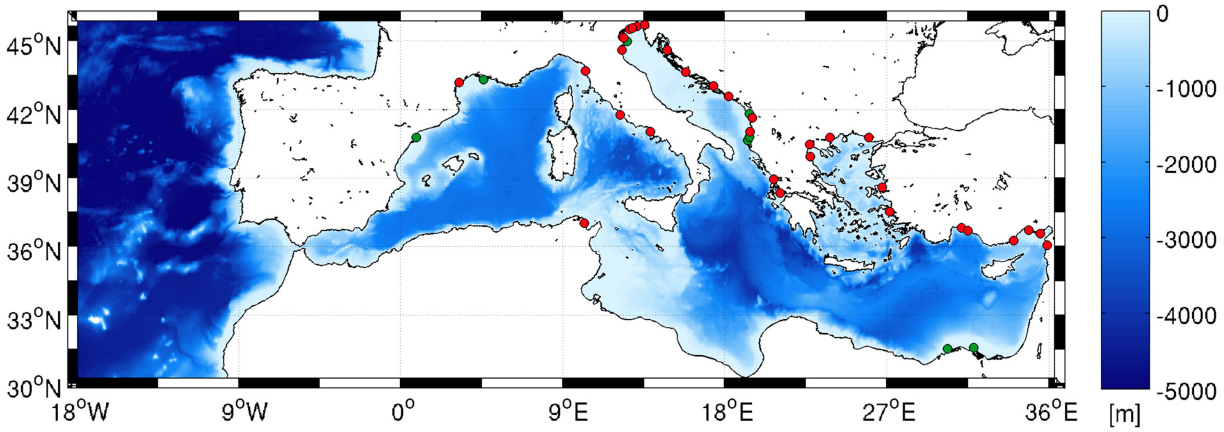


Figure 1 Model domain, bottom topography and location of river inputs: green dots represent the 7 river sources included in both experiment simrs_v1 and simrs_v2, red dots represent the 32 additional rivers implemented in experiment simrs_v2.

The Dardanelles Strait implementation

The second model upgrade consists of a modified implementation of the Dardanelles Strait, a narrow strait connecting the Mediterranean Sea and the Black Sea through the Marmara Sea. The improvement brought the implementation of the Dardanelles from a Surface Boundary

Condition (SBC) to a Lateral Open Boundary Condition (LOBC). In the SBC case, the Dardanelles system is parameterized like a river where monthly climatological values of salinity and volume flux are imposed [Kourafalou and Barbopoulos, 2003].
In the LOBC case, salinity, temperature, volume flux and sea surface height are partially provided as daily values of the CMEMS GLO-MFC system (Global Ocean Monitoring and Forecasting Center, GLO-MFC, in the framework of the Copernicus Marine Service, CMEMS, http://marine.copernicus.eu/) and partially as daily climatologies from the Turkish Straits System (TSS) box model [Maderich et al., 2015]. Specifically, barotropic and baroclinic velocities are computed from the TSS box model volume flux, while the sea surface height and the temperature fields are provided by the CMEMS GLO-MFC. The TSS box model provides the salinity fields for the upper layers of the Dardanelles Strait (from the surface down to 13m depth), while for the deepest layers (from 13m depth down to the bottom) a constant value of 38.6 PSU is used.
Numerical experiments have been set up to evaluate the performance of the new system with the Dardanelles Strait implemented as LOBC (expB) with respect to the previous implementation (expA) and the ability in reproducing temperature and salinity fields, in particular in the Aegean Sea area. ExpB shows a quite significant improvement of surface salinity above 10m depth with an error reduction from 0.65 to 0.55 PSU, whereas the salinity skill scores are comparable going deeper. Concerning temperature, expB presents a general improvement with respect to expA along the whole water column in the Aegean Sea with an error reduction of about 7.5%, without considering the depth range between 1000 and 2000m, where the number of available observations is very low.
The BSW outflow from the Dardanelles Strait has been significantly modified by the new implementation, which affects also the circulation of the North Aegean Sea, as shown in Figure 2 after two years of integration.

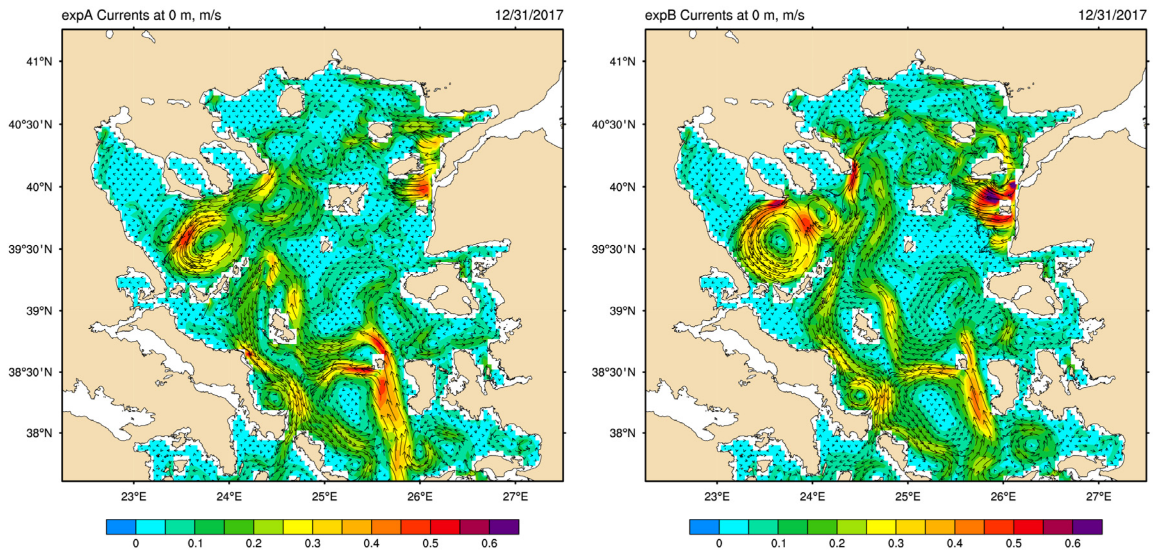


Figure 2 Surface currents for expA (left panel) and expB (right panel) for the 31st of December 2017, after two years of integration for both the experiments.

Conclusions

The comparison of modelled and observed salinity shows an improvement of the model skill at the surface thanks to the increase of the number of rivers in the model implementation, while a slight increase of the error is found at greater depths.

Finally, the introduction of the Dardanelles Strait as a Lateral Open Boundary Condition resulted in a significant improvement in representing the thermohaline properties of the surrounding area.

References

Clementi E., Pistoia J., Delrosso D., Mattia G., Fratianni C., Storto A., Ciliberti S., Lemieux B., Fenu E., Simoncelli S., Drudi M., Grandi A., Padeletti D., Di Pietro P. and Pinardi N., (2017). *A 1/24 degree resolution Mediterranean physical analysis and forecast modeling system for the Copernicus Marine Environment Monitoring Service*. In: Operational Oceanography serving Sustainable Marine Development. Proceedings of the Eight EuroGOOS International Conference, pp. 275 – 284. 3-5 October 2017, Bergen, Norway. E. Buch, V. Fernandez, D. Eparkhina, P. Gorringe and G. Nolan (Eds.) EuroGOOS. Brussels, Belgium. 2018. D / 2018 / 14.040 / 1 ISBN 978-2-9601883-3-2. 516 pp.

Kourafalou V.H. and Barbopoulos K., (2003). *High resolution simulations on the North Aegean Sea seasonal circulation*. Annales Geophysicae, 21, 251–265. doi: http://www.ann-geophys.net/21/251/2003/.

Madec G., Bourdallé-Badie R., Bouttier P.-A., Bricaud C., Bruciaferri D., Calvert D. and Vancoppenolle M., (2017). *NEMO ocean engine (Version v3.6)*. Notes Du Pôle De Modélisation De L'institut Pierre-Simon Laplace (IPSL). Zenodo. http://doi.org/10.5281/zenodo.1472492.

Maderich V., Ilyin Y. and Lemeshko E., (2015). *Seasonal and interannual variability of the water exchange in the Turkish Straits System estimated by modelling*. Mediterranean Marine Science, 16(2), 444-459.

Verri G., Clementi E., Bryan F., Coppini G., Tseng Y., Pinardi N., (2019). *A box model to represent estuarine dynamics in mesoscale resolution ocean models.* Submitted to Ocean Modelling, Under Revision.

Relative sea-level trend from tide gauge observation

Marco Olivieri and Simona Simoncelli

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Italy

marco.olivieri@ingv.it

Introduction

The relative sea level (RSL) is the height of the sea surface measured at the pier of a harbor by means of a tide gauge (TG); the measurement is performed respect to a local reference frame, that usually is the pier itself or the sea bottom. The TG measures the combined effect of the absolute sea-level change and of the vertical land movement (VLM) at the site. While the overall sea level results from the different types of tides plus the long-term changes of the sea height, the ground deformation is the result of subsidence plus other phenomena such as tectonics, glacial isostatic adjustment, earthquakes, volcanism and so on.
Measuring the long-term component of the rate of RSL change is a complex task that plays a crucial role for the comprehension of the local transposition of the global sea-level rise linked to the climate change [IPPC AR5 report, Stocker et al., 2013]. The main reason of the complexity is the presence of different tides with amplitudes that prevail in the signal. This prevalence complicates the assessment of the long-term component by enlarging the error bar associated to the trend. Furthermore, the assessment of the long-term trend is complicated by the strong autocorrelation of TG time-series (i.e. RSL height at a generic sample of the time-series more likely equals the height at the next sample) that can be verified by statistical tests. Direct consequence of autocorrelation is that the least square (LSQ) method cannot be applied because one of the underlying rules is violated. For the above reasons, a more sophisticated approach is proposed with the goal of providing a robust assessments of the rate of RSL change over time and of its associated error. The methodology is then applied to the case of the Napoli Mondracchio (Southern Italy) TG time-series.

Methodology

The first stage of the proposed workflow aimed at analyzing one TG time-series, that could have gaps or different sampling rate over different epochs, consists in the application of the EMD (Empirical Mode Decomposition). This is an adaptive method by which any arbitrary data set can be deconvolved into a finite and often small number of oscillatory Intrinsic Mode Functions (IMFs), with increasing instantaneous period, plus a residual (RES) which can be a monotonic or a single-extremum function [Huang et al., 1998].
Since its introduction by Huang et al., [1998], EMD has found a large number of applications in different fields of physics and geophysics [Huang and Shen, 2005; Huang and Wu, 2008]. To mention some of the benefits of using EMD in sea–level analysis from TG observations, it does not require the removal of trend, IMFs are mutually orthogonal functions, each IMF can have variable period and amplitude. EMD can better reproduce non stationary and non linear phenomena characterizing the sea–level variability [Galassi and Spada, 2015]. EMD is here used to remove noise, tides and all those periodic signals and to obtain the aperiodic component of the time series (i.e. RES in the EMD method). It is noteworthy here that, RES time-series does not follow any a-priori assumption neither on the periodicity of the removed oscillatory signals

neither on the linearity of the residual itself. However, RES time-series is still strongly autocorrelated and the LSQ regression remains inappropriate. The second phase is devoted to determine the mean rate and its error. To mitigate the autocorrelation and keep the associated errors small, we downsample the time series averaging each set of six (for the case of monthly mean time-series) samples assigning the time stamp of the mean of the six times to the average value. This is a preferable option with respect to the standard running mean since it use each sample of the time-series only once. Then, a three points derivative (namely OUT(J)= 1/2 * (DATA(J+1) - DATA(J-1)) / (T(J+1)-T(J-1)) where OUT(J) is the derivative, T(J) is the time and DATA(J) is the sea-level height at sample J) is applied to the resulting time-series. Statistic test, not displayed, can confirm the removal of the autocorrelation. The final time-series describes the rate of the RSL change over time by representing its distribution, mean, variance, median and the other modes, if needed can be analyzed.

Application: Site 105 Napoli Mandracchio (Italy)

As an example, we applied the above methodology to the time series recorded at one of the TGs placed in the gulf of Naples (Italy), namely the TG labelled with id 105 at the PSMSL archive [PSMSL, 2015]. This is a RLR (Revised Local Reference) monthly mean time series that covers the time span 1896-1922.

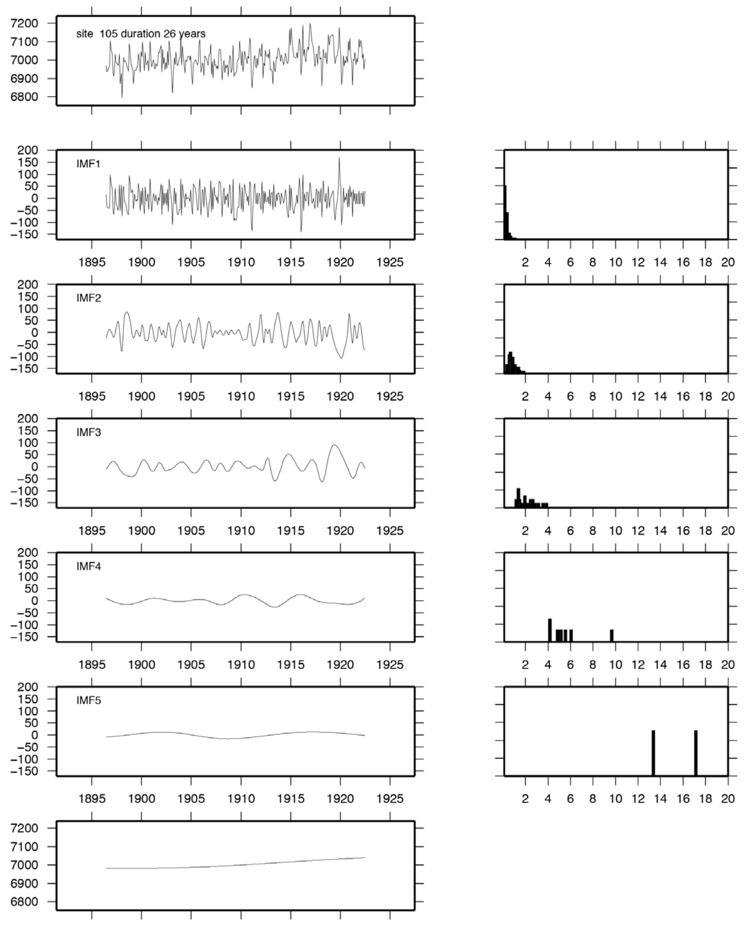


Figure 1 Left column (from top to down): the original TG 105 time-series, each of the IMF resulting from the EMD analysis and the monotonic residual RES. Right column: Each panel represents the frequency content, as percent, of the instant periods (in years) of the corresponding IMF.

The TG 105 RSL time series change, estimated by the difference between first and last sample is 38±2 mm that corresponds to an average rate of about 1.5±0.1 mm/yr. Conversely, the trend of the time series, as determined by means of standard least square (LSQ) regression results in a rate of 2.5±0.5 mm/yr even though in this case, according to the above discussion, the strong time-series autocorrelation leads to an underestimation of the error-bar associated to the trend. Figure 1 shows the original time-series, the resulting IMFs time-series, the periodicity of each IMF and the residual. EMD analysis highlights that: i) harmonic components of the original signal do not have constant amplitude and period; ii) the long-term trend represented by the residual (RES) is monotonic but in this case does not show a constant trend. Figure 2 shows the result of downsampling and derivation as applied to RES and its distribution. Rate values do not follow a normal distribution around the mean. This might results from a not steady process of rise for RSL over the time span of about three decades. This observation is confirmed by the relevant discrepancy between the mean 2.1±1.2 mm/yr and the median 2.8±1.0 mm/yr.

Conclusions

This work describes a methodology for removing the high frequency content of a time series, for assessing the rate of RSL change in a robust manner and for providing realistic estimates of the associated error. The analysis of TG 105 time series helps to understand the limits of LSQ linear regression. In particular, this approach provides non realistic values for the error associated to the resulting trend. For the case described above, we remark that, the three methods (LSQ trend, mean and median of the distribution) give close central values 2.5, 2.2, 2.8 mm/yr respectively, but the last two values have a much larger associated error-bar that should be considered more realistic, given the above considerations. Finally, the discrepancy between mean and median and the not-gaussian distribution confirm that the rise over that epoch was not a steady process suggesting that either some acceleration occurred or the time span is too short to remove oscillations (tides) at longer periods.

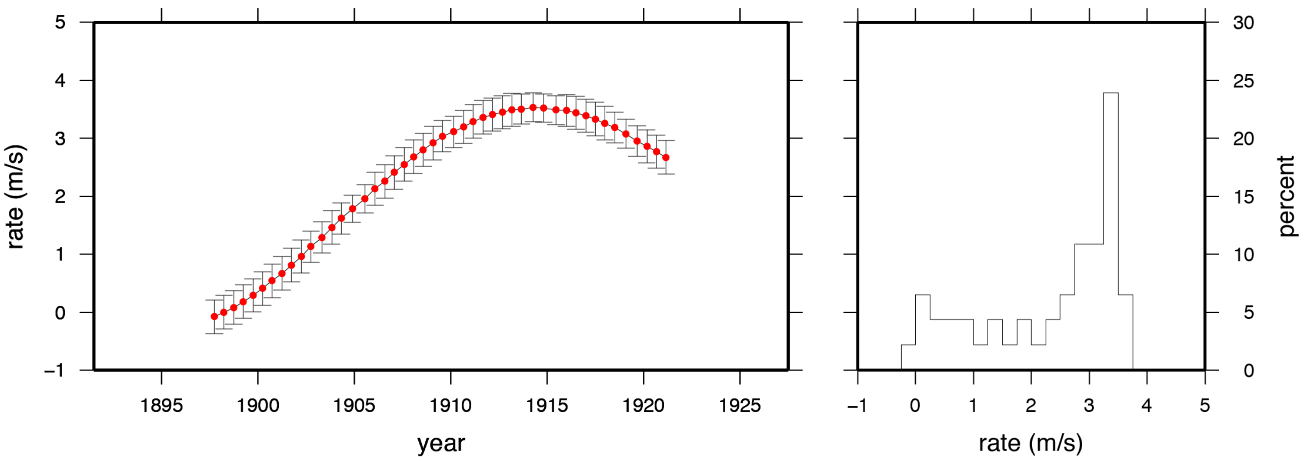


Figure 2 (left panel) The result of the downsampling and derivation of the EMD residual (open red circles). Error-bars result from averaging and discrete derivation process. These do not account for the uncertainty resulting from the EMD analysis. (right panel) Frequency distribution, in percent, of the rate.
This considers only the central values (open red circles) plotted in left panel.

Acknowledgements

This work was partly funded by the Italian project FISR 2016 “Centro di studio e monitoraggio dei rischi naturali dell’Italia Centrale”. Figures are drawn by using GMT [Wessel & Smith, 1998].

EMD code was originally developed by Lionel Ludet in [2009]. Data for the TG at Napoli Mandracchio have been retrieved from the PSMSL site (www.psmsl.org). The authors thanks Laura Beranzoli for the fruitful review.

References

Huang N.E., Shen S.S., (2005). *Hilbert–Huang transform and its applications*. Vol. 5. World Scientific.

Huang N.E., Shen Z., Long S.R., Wu M.C., Shih H.H., Zheng Q., Yen N.-C., Tung C.C., Liu H.H., (1998). *The empirical mode de- composition and the Hilbert spectrum for nonlinear and non–stationary time series analysis.* Proceedings of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences 454 (1971), 903–995.

PSMSL, Permanent Service for Mean Sea Level, (2015). *Tide Gauge data*. http://www.psmsl.org/obtaing, [Online; retrieved 01- February-2019].

Stocker T.F., Qin D., Plattner G.-K., Tignor M., Allen S.K., Boschung J., Nauels A., Xia Y., Bex V., Midgley P.M., (2013). *Climate Change 2013. The Physical Science Basis.* IPCC, Working Group I Contribution to the IPCC Fifth Assessment Report (AR5).

Wessel P., Smith W.H.F., (1998). *New, improved version of Generic Mapping Tools released*. Eos T. Am. Geophys. Un. 79 (47), 579.

INFRASTRUCTURES

InSEA Project: Initiatives in Supporting the consolidation and enhancement of the EMSO infrastructure and related Activities

Angelo De Santis on behalf of the InSEA Project Team*

*InSEA Project Team:
Angelo De Santis[1] (Scientific Coordinator), Massimo Chiappini[1] (Administrative Responsible), Giuditta Marinaro[1], Sergio Guardato[5], Marco Borra[2], Fabio Conversano[2], Giuseppe D'Anna[6], Domenico Di Mauro[1], Valeria Cardin[3], Roberto Carluccio[1], Simonepietro Canese[4]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Geomagnetismo, Aeronomia e Geofisica Ambientale, Roma, Italy
[2]Stazione Zoologica Anton Dohrn di Napoli (SZN), Italy
[3]Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), Italy
[4]Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), Italy
[5]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Italy
[6]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Nazionale Terremoti, Italy

email: angelo.desantis@ingv.it

The observation of the phenomena occurring on our planet was in the past based mainly on ground monitoring with both temporal and spatial approaches. On the other hand, in the part covered by the oceans until a few years ago the monitoring was carried out through discrete measurement campaigns in time and space with the disadvantage of not having information on the variability of oceanic processes. Only more recently, since the 90s of the last century, technology has allowed the installation of multidisciplinary systems on the seabed for long periods (years), even at great depths (thousands of meters). From the circumscribed campaigns in space and time, we have therefore moved on to the installation of observatories on the seabed, to record in a continuous way the physical and chemical parameters, in order to know the state of the oceans and of the whole planet. This produces two advantages:

1. A spatial improvement of the observations, because they extend from land to the previously less known and more extensive part of the planet, i.e. the oceans that cover seven-tenths of the Earth's surface;
2. A scientific improvement, because the oceans represent a fundamental element in the processes at the base of the Earth's climate, whose knowledge on large time scales makes it possible to understand the future evolution of these processes [e.g. Favali et al., 2015].

The possibilities provided by the new technologies have allowed the launch on a global and almost contemporary scale of multi-year programs aimed at the permanent installation and management of multidisciplinary and interdisciplinary systems on the seabed and along the water column. These systems are capable of producing data even in time real, being wired through electro-optical cables capable of powering, receiving data on the ground via optical fibres and controlling at the same time the submarine systems.
These programs involve many countries: United States of America (OOI-Ocean Observatories Initiative; http://oceanobservatories.org), Canada (ONC-Ocean Networks Canada; http://oceannetworks.ca), Japan (DONET-Dense Ocean floor Network System for Earthquakes and Tsunamis; http://www.jamstec.go.jp/donet), China (ECSSOS-East China Sea Seafloor Observation System), Australia (IMOS-Integrated Marine Observation System; http://imos.org.au), Taiwan (MACHO-Marine Cable Hosted Observatory; http://scweb.cwb.gov.tw/macho-web).

EMSO (European Multidisciplinary Seafloor and Water Column Observatory; http://www.emso.eu) is the European response to these initiatives with which it is in close collaboration also through common projects. The motto common to all these programs is: "Observing the Ocean to Save the Earth", to underline the importance of studying the oceans through time series of data to improve our understanding of their fundamental role in regulating terrestrial processes.

EMSO is a European research infrastructure (RI) that aims to explore the oceans, to better understand the phenomena occurring within and below them and to explain the fundamental role that these phenomena play in the wider and more complex terrestrial systems. EMSO is a distributed infrastructure in the seas around Europe, ranging from the Arctic to the Atlantic, through the Mediterranean, up to the Black Sea, and consists of a system of nodes, normally observatories, located in key marine areas for the understanding of the complex phenomena occurring at sea. The Observatories are multidisciplinary platforms positioned along the water column and on the seabed. They constantly measure multiple biogeochemical and physical parameters in long time series for the study of climate changes, marine ecosystems and natural hazards and their mitigation.

EMSO offers data and services to a broad and diverse user group, ranging from scientists and industries to institutions and policy makers. It is a fundamental infrastructure to provide information relevant to the definition of environmental policies based on scientific data. EMSO shares scientific structures (data, tools, computing and archiving capacity) in a common European strategic framework.

EMSO is an infrastructure declared Landmark (i.e., it has been included among the pan-European research infrastructures considered successful) in the latest ESFRI Roadmap (European Strategy Forum on Research Infrastructures), published in March 2016. In addition, EMSO has become an ERIC (European Research Infrastructure Consortium) since October 2016, becoming an international legal entity created for pan-European research infrastructures. EMSO ERIC is currently supported by eight countries (Italy, France, Great Britain, Spain, Portugal, Ireland, Greece and Romania) with Italy hosting the registered office. Each country is represented by one or more Representing Entities, and INGV plays this role for Italy. In addition, INGV is the leader of the Joint Research Unit (JRU) EMSO-Italy, which is participated by several other research bodies (CNR, INFN, OGS, SZN, ENEA, ISPRA) and by universities, through the CONISMA consortium (35 universities involved in marine science). The JRU aims to aggregate and strengthen the Italian community and its role within the pan-European research infrastructure. Finally, EMSO is usefully inserted in the PNIR (Programma Nazionale delle Infrastrutture di Ricerca) among the EU-RIs, that is the European research infrastructures of interest for Italy, responding to all the characteristics necessary for its inclusion, that is to say: scientific, technological and managerial quality; added value at European level; high level connected services; free transnational access on a competitive basis (peer review); results available in open form.

In the seas surrounding Italy, EMSO has two permanent observing sites: one in the Western Ionian Sea (eastern Sicily) and the other in the Ligurian Sea, while some others have been indicated in the Tyrrhenian Sea (Campania) and in the Adriatic (Puglia) as multiparametric monitoring pilot sites. All these sites are being consolidated and strengthened through the current InSEA project.

According to the extended title of the InSEA project, its main goal is to launch initiatives to support the consolidation and enhancement of EMSO's infrastructures and its activities, which are positioned in the Italian territory and surrounding seas, with particular interest in the less developed member state (MS) regions (Campania, Calabria, Puglia and Sicily) or in transition regions (TR) (Abruzzo and Molise). The final scientific objective of the project is to improve the ability of the research infrastructures (RI) to record the geophysical and environmental processes of the marine environment in the seas of the MS / TR areas of the national territory, in order to monitor the state of the seas due to climatic changes or anthropogenic effects and natural hazards.

The project is developed according to 6 Objectives of Realization (ORs) that intend to contribute to the achievement of the main Project target. They consist in the upgrading of localized marine infrastructures (OR1, OR2 and OR5), distributed or supporting laboratories (OR3 and OR4) and spatial measurement activities to support those activities of surveys in fixed time series points (OR6). The co-proposing bodies of OGS, ISPRA and SZN, partners in the JRU of EMSO-ERIC participate in these activities.

The close interconnection of the various ORs (see Figures 1 and 2) and their products will represent a leap forward in the capabilities of the entire RI to acquire important scientific data to take advantage of advanced and excellence research in the fields of geophysics, geology, geochemistry, volcanology, oceanography and biology.

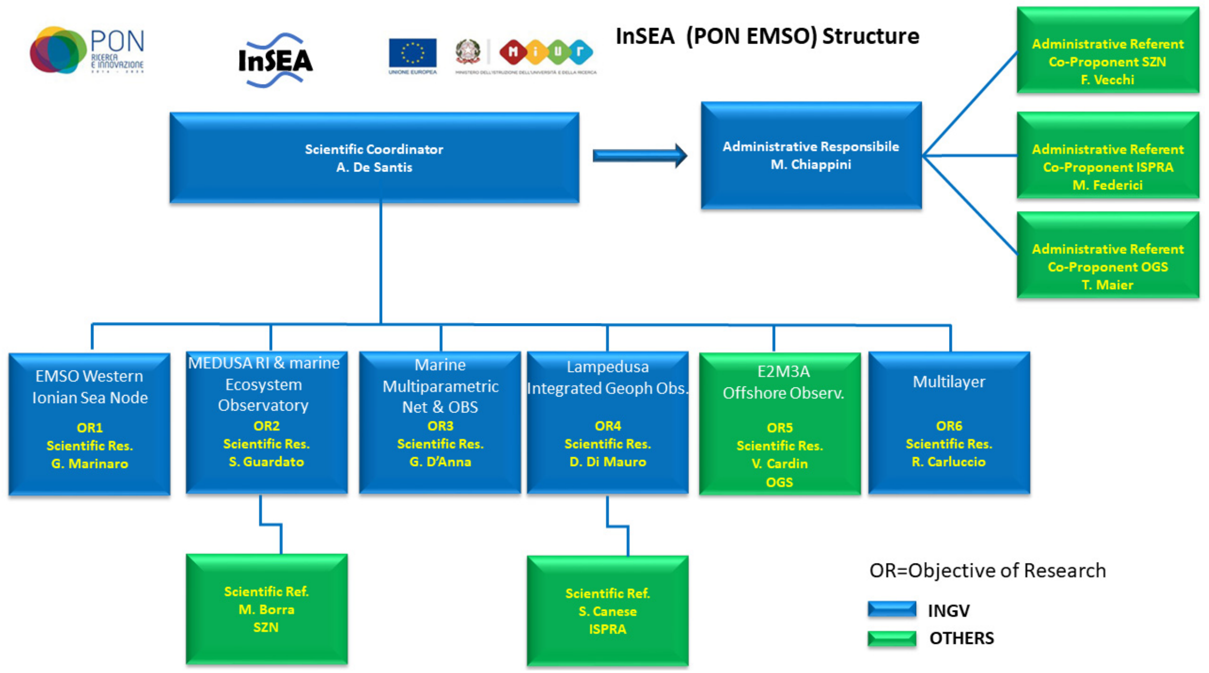


Figure 1 Organigram of the InSEA Project.

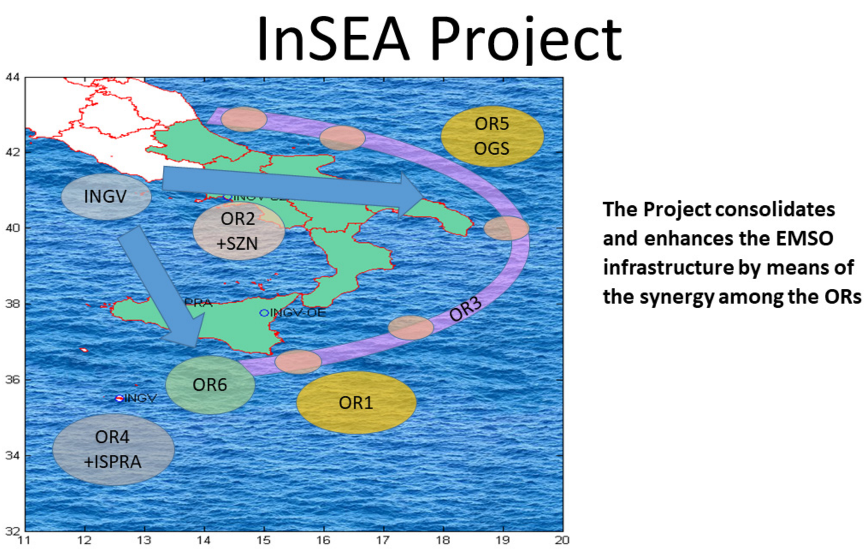


Figure 2 Spatial inter-connection among the different ORs and scientific Institutions involved in the InSEA Project.

The most relevant resources for each OR and how these will affect the existing RIs are presented as follows.
OR1 Western Ionian EMSO Node:

- Complete / partial systems (frame / acquisition / control / transmission / sensors) for 3/4 submarine multiparametric observatories.
- A power supply and two computer servers with NAS system for Catania ground station.
- Complete data center for Portopalo ground station.
- Reinforcing of winch and ROV.
- 1 smart cable system with some instrumented repeaters.

For the consolidation and reinforcing of the EMSO sites of SN1 (Catania) and SN2 (Porto Palo) in Sicily:
OR2- RI MEDUSA and Marine Ecosystem Observatory.

For the site in the Gulf of Pozzuoli (INGV):

- Assets for upgrading the MEDUSA out of water infrastructure (EMERGED-Top).
- Resources for expansion and upgrading of the CUMAS multi-parametric submarine module, (EMERGED-Bottom).

For the site in the Gulf of Naples (SZN):

- Mooring not wired in stand-alone mode.
- Infrastructure at the bottom (seabed platform) connected to a surface buoy.

These assets will improve the geodetic / acoustic / oceanographic monitoring capacity at the EMSO-MedIT site of the Gulf of Pozzuoli and its extension in the waters of the Gulf of Naples.

OR3- Marine Multiparametric Network and OBS:

- 7 submarine multi-parameter modules (MSM) of which 5 installed and 2 to be used to replace the operating ones at the scheduled deadlines for cleaning and calibrating the sensors in order to guarantee continuity of operation and data flow.
- 6 + 6 Broad Band Ocean Bottom Seismometers (BB-OBS / BB-OBS TR).
- 1 ultrasound tank.
- 1 winch with cable for a remote control deck unit acquired in EMSO MedIT.

To extend EMSO multi-parameter monitoring activities in MS and TR areas with relocatable systems (BB-OBS) and fixed at hydrocarbon extraction platforms.

OR4 - Lampedusa Integrated Geophysical Observatory:

- Magnetometers, solar compass and magnetotelluric station for the geomagnetic station.
- No. 3 complete systems of Ocean Bottom Magnetometer (OBM).
- Instrumentation for oceanographic boat and ISPRA ROV.
- n.1 Complete Digisonde.

To enhance the Integrated Geophysical Observatory of Lampedusa for the improvement of the calibrations of marine magnetic measurements in SN1 and SN2, and the use of ionospheric radio transmissions for both ship and buoy operations. The completed and integrated stations will also be key points of integrated geophysical observation at the southern of Europe. To reinforce the instrumental equipment of the M / V Lighea and the ISPRA ROV.

OR5-E2M3A offshore observatory:

- Buoy hull and acoustic releases for structural purposes of E2M3A and safety.
- Meteorological station.
- Instrumentation for the increase and diversification of biogeochemical measurements.
- Acoustic profilers for spot current measurements along the water column.

For the improvement and enhancement of the E2M3A (OGS) observatory.

OR6 Multilayer:

- Innovative systems for the observation of geophysical / environmental parameters from aircraft.
- Completion / integration provision for the AUV.

For the enhancement of the RI in the sites SN1 and SN2 (Sicily) from aircraft and marine AUV.

Reference

Favali P., Beranzoli L. and De Santis A., (2015). *Seafloor Observatories: A new vision of the Earth from the Abyss*. Springer – Praxis Publ. UK, 676 pp.

MEDUSA: the innovative research infrastructure for monitoring shallow waters sea floor displacement in Campi Flegrei

Gian Paolo Donnarumma[1], Prospero De Martino[2], Giuseppe Pucciarelli[2] Giovanni Iannaccone[2], Sergio Guardato[2]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Geomagnetismo, Aeronomia e Geofisica Ambientale, Roma, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli - Osservatorio Vesuviano, Italy

gianpaolo.donnarumma@ingv.it

MEDUSA (Multiparametric Elastic-Beacon Devices and Underwater Sensors Acquisition system) is a marine research and monitoring infrastructure of the volcanic activity in the Campi Flegrei, realized as sea-extension of geophysical instrumentation networks existing on the land.
The infrastructure is composed of four almost identical systems; each system consists of an instrumented geodetic buoy and a cabled seafloor multi-parametric module, positioned on depths varying from 38 to 96 m. The systems are installed in the Gulf of Pozzuoli at a distance from the coastline that varies from 1 to 2.4km according to a specific geometric configuration, following the model of the deformation, in order to extend the land monitoring network around the Campi Flegrei Caldera maximum uplift point, and measure the seafloor vertical deformation field in water.

Figure 1 Campi Flegrei monitoring network and MEDUSA infrastructure location.

MEDUSA acquires more than 150 channels with sampling frequencies ranging from one sample per minute to 200 samples per second. All data is transmitted in real-time, with a 5GHz Wi-Fi transmission system, to the operations room of the Vesuvius Observatory in Naples where they are stored and analyzed; all the data are made available through a dedicated website that allows users to view and download information in different file formats (http://portale.ov.ingv.it/medusa/). We show a subset of the data acquired by MEDUSA and, in particular, innovative analysis

techniques and methods for measurement of the seafloor movements caused by the bradyseism, observed in the last three years in the Gulf of Pozzuoli.
Seismic recordings of local and regional earthquakes obtained by the hydrophones, show high quality signal highlighting an improved signal to noise ratio than the co-located OBS (Ocean Bottom Seismometer).
The long time-series of the geodetic GPS data acquired on the MEDUSA buoys show an accurate and stable agreement of the vertical seafloor displacement measured with the land GPS stations.
The high quality of this data also allowed to confirm the vertical deformations verified with the data acquired by the high-precision pressure sensors (BPR, Bottom Pressure Recorder) installed on the seabed and the radar tide gauge installed on one of the geodetic buoys.
The use of GPS, BPR and tide gauge data provided by MEDUSA, have allowed assessing for the first time the seafloor deformation field in the Gulf of Pozzuoli: we estimated a seafloor vertical displacement of about 10cm (+/- 1cm) over a period of 20 months from 2016 to 2018.
The infrastructure also provides environmental information, as well as seismological and

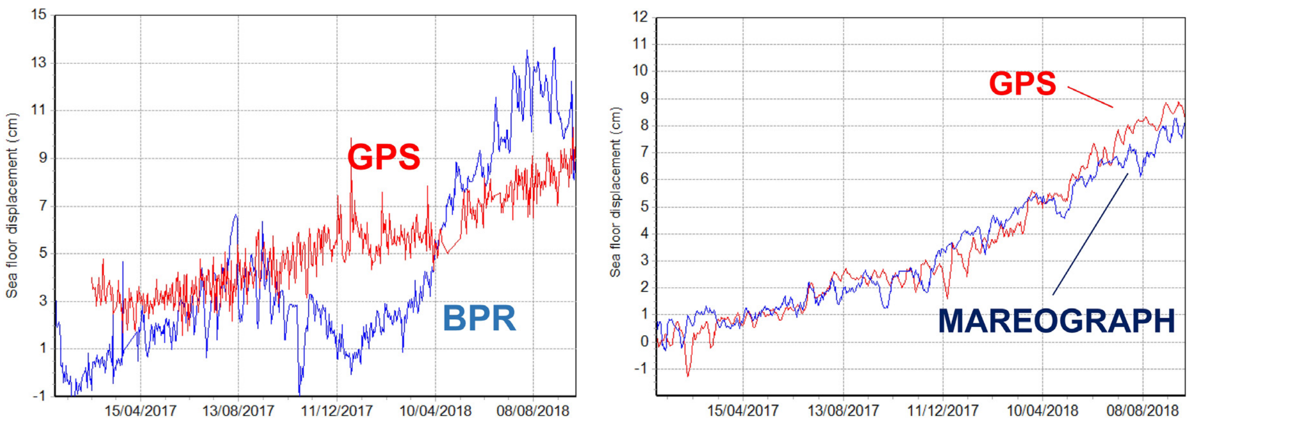


Figure 2 GPS-Geodetic data series (vertical component) related to Bottom Pressure Recorder and Tide Gauge data.

geodetic information. On the buoys in fact are installed measurement systems that provide meteorological data (atmospheric pressure, wind direction and speed, air temperature), mareographic data (tide level acquired directly in the sea), information on underwater currents (direction and speed of the current) and temperature on the different seabed locations.
MEDUSA has performances comparable to the multi-parametric stations of the ground monitoring networks and represents the extension into the sea of the Campi Flegrei geophysical monitoring network. Moreover, being the first system in the world of this type, is taken as a reference model for future acquisition systems in the marine environment in shallow waters.

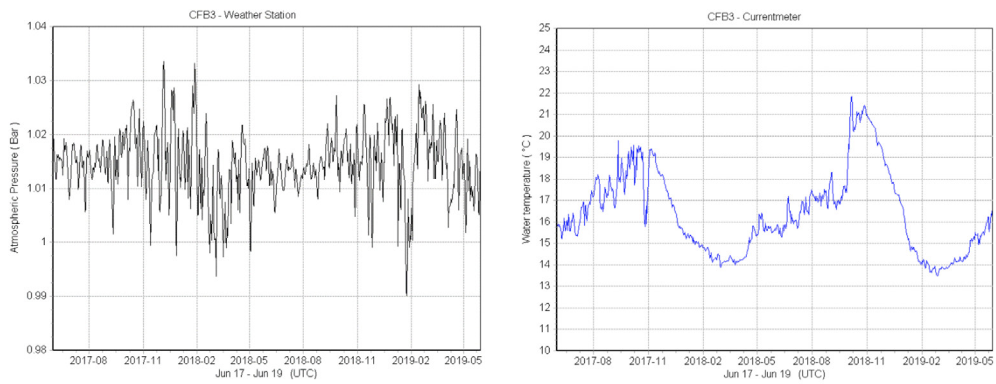


Figure 3 Data acquired on the CFB3 buoy - atmospheric pressure and water temperature at a depth of 39m.

MEDUSA_cGPS: seafloor deformation monitoring of the Campi Flegrei caldera

Prospero De Martino, Giuseppe Brandi, Mario Dolce, Gian Paolo Donnarumma, Sergio Guardato, Giovanni Iannaccone, Giovanni Macedonio

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli – Osservatorio Vesuviano, Italy

prospero.demartino@ingv.it

The Campi Flegrei caldera is one of the most hazardous and populated volcanic 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.
Until 2011 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 (Figure 1a).
In 2008 CUMAS, a multiparameter prototype platform, consisting of a buoy and a seafloor module, was deployed in the Gulf of Pozzuoli and a continuous GPS (cGPS) station was integrated on top of the buoy in late 2011. The results have shown, for the first time, the relevance of the GPS technique in the seafloor displacement measurements [De Martino et al., 2014].

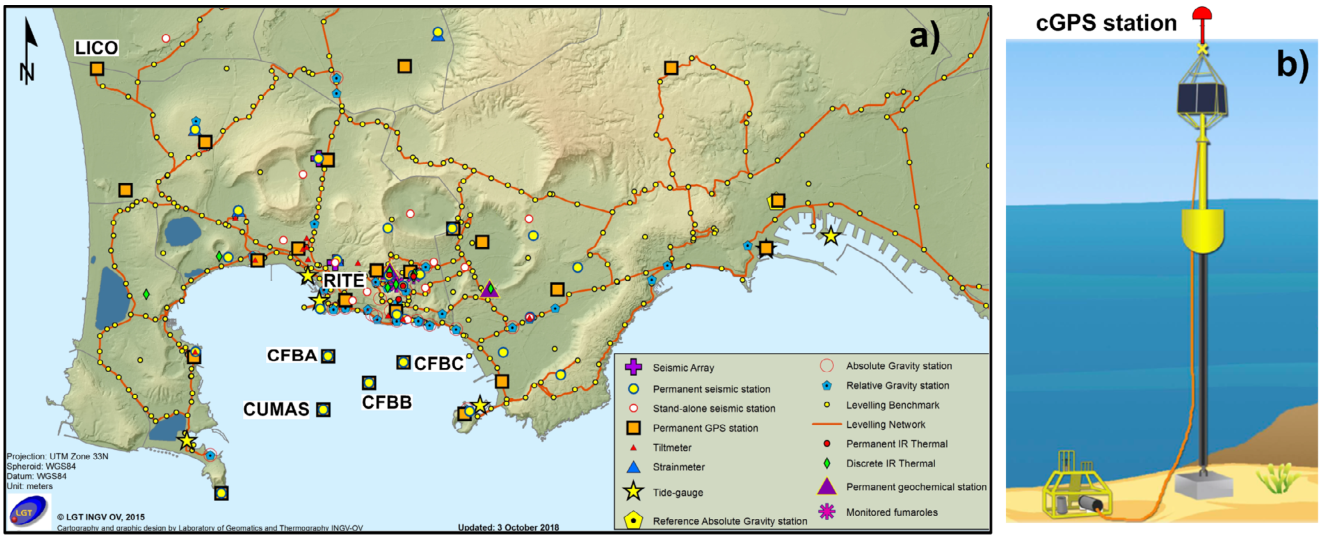


Figure 1 a) Campi Flegrei monitoring networks; b) Layout of the MEDUSA instrumented buoy.

In 2016, a new research and monitoring marine infrastructure named MEDUSA, incorporating CUMAS, was deployed to achieve a larger coverage of the Gulf of Pozzuoli (Figure 1a). MEDUSA infrastructure presently consists of four instrumented buoys with geodetic cGPS stations on the top and connected by cable to the seafloor modules hosting geophysical and oceanographic sensors (Figure 1b) [Iannaccone et al., 2018].
The GPS data are processed in kinematic mode in order to take into account the movements of the buoys. The LICO land station (Figure 1a), located outside the Campi Flegrei caldera, at a distance of about 10 km from the Gulf of Pozzuoli, is the selected reference station for the GPS seafloor data processing [De Martino et al., 2014].

The Campi Flegrei caldera is known worldwide to be a site of continuous slow vertical ground movements (bradyseism). The most recent uplift episodes occurred in years 1970- 1972 and 1982-1984 with a cumulative vertical displacement of about 3.5 m measured at the town of Pozzuoli. A new uplift phase started in November 2005 and, with increasing rates over time, is still ongoing.
The overall uplift at RITE cGPS station, located at Pozzuoli (Figure 1a), in the area of maximum vertical displacement, is about 60 cm from 2005 to date (Figure 2).
The Figure 2 summarizes the vertical displacement observed on land at RITE cGPS station and those measured by the four cGPS stations installed on the top of the MEDUSA buoys. From April 2016 to May 2019, the maximum seafloor uplift of about 15 cm was measured by the CFBA cGPS station, the closest one to the area of maximum vertical displacement. The pattern of the observed vertical displacement is similar at all the cGPS stations (on-land and in the marine sector) and the measured uplift decreased progressively with the distance from the caldera center. The seafloor vertical deformation followed the same pattern observed on land.

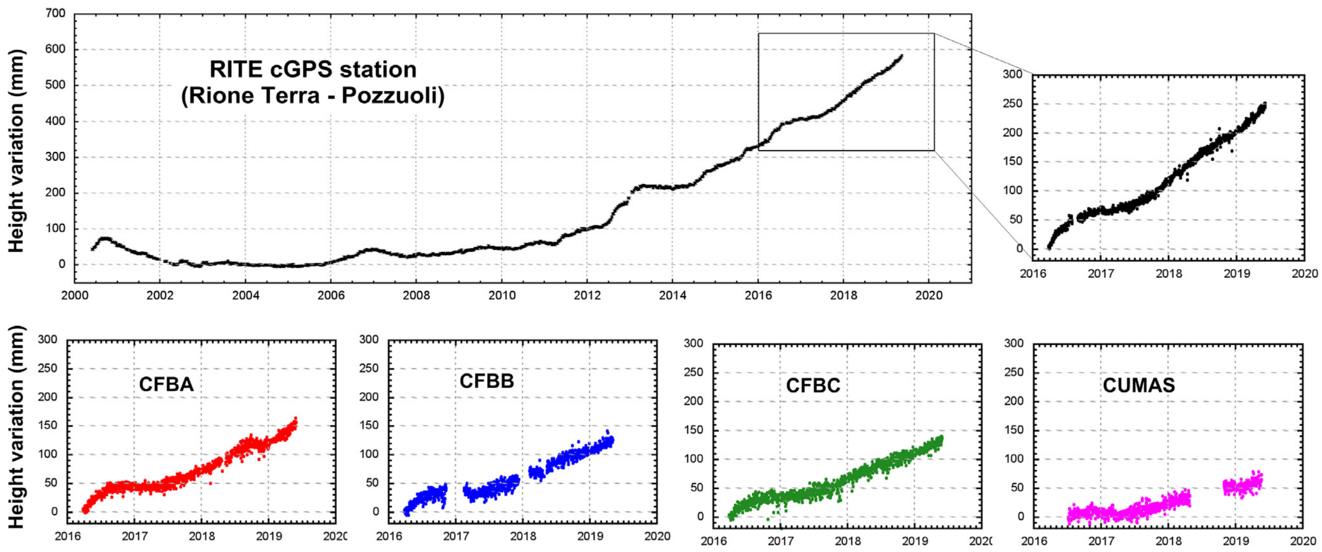


Figure 1 GPS time series of vertical component for RITE station and for MEDUSA cGPS stations.

The deformations of the aerial and submarine parts of the Campi Flegrei caldera are consistent with a single point source model, located about 0.5 km south of RITE cGPS station at a depth of 3-4 km.
This unprecedented conclusion could not be achieved until the installation of the cGPS stations on the four MEDUSA buoys [Iannaccone et al., 2018].

References

De Martino P., Guardato S., Tammaro U., Vassallo M. & Iannaccone G., (2014). *A first GPS measurement of vertical seafloor displacement in the Campi Flegrei caldera (Italy)*. Journal of Volcanology and Geothermal Research, 276, 145–151.

Iannaccone G., Guardato S., Donnarumma G.P., De Martino P., Dolce M., Macedonio G., Chierici F., Beranzoli L., (2018). *Measurement of seafloor deformation in the marine sector of the Campi Flegrei caldera (Italy)*. Journal of Geophysical Research: Solid Earth, 123, 66–83.

Crustal imaging of the Italian offshore through multi-channel seismic reflection data

Marco Firetto Carlino, Danilo Cavallaro and Mauro Coltelli

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy

marco.firettocarlino@ingv.it

The seismic reflection method yields an Earth image represented by a seismic section; although it has been mostly used for the mineral exploration and the development of oil and gas fields, it represents a fundamental tool to explore the crustal structure, potentially also down to the Moho. Reflection seismology was recently applied at INGV - Osservatorio Etneo for crustal imaging, to better understand the relationship between tectonics and evolution of volcanism at Mt. Etna and Aeolian Island volcanoes and identifying active faults and volcanic bodies.
Nearly 1410 km of marine multi-channel seismic (MCS) reflection profiles were acquired in 2014, in the Ionian and Tyrrhenian Seas, during the TOMO-ETNA experiment (FP7 projects MED-SUV and EUROFLEETS II). The MCS sections, targeted to deep exploration, were acquired using an active seismic source of 16 air-guns (4340 cu. in.) and a 3000 m long, 240-channels digital streamer as receiving system [Figure 1]. High-resolution seismic profiles were also collected using two smaller air-guns (270 cu. in.) and a 96 channels, 300 m long digital streamer [Firetto Carlino et al., 2016], (Figure 1).

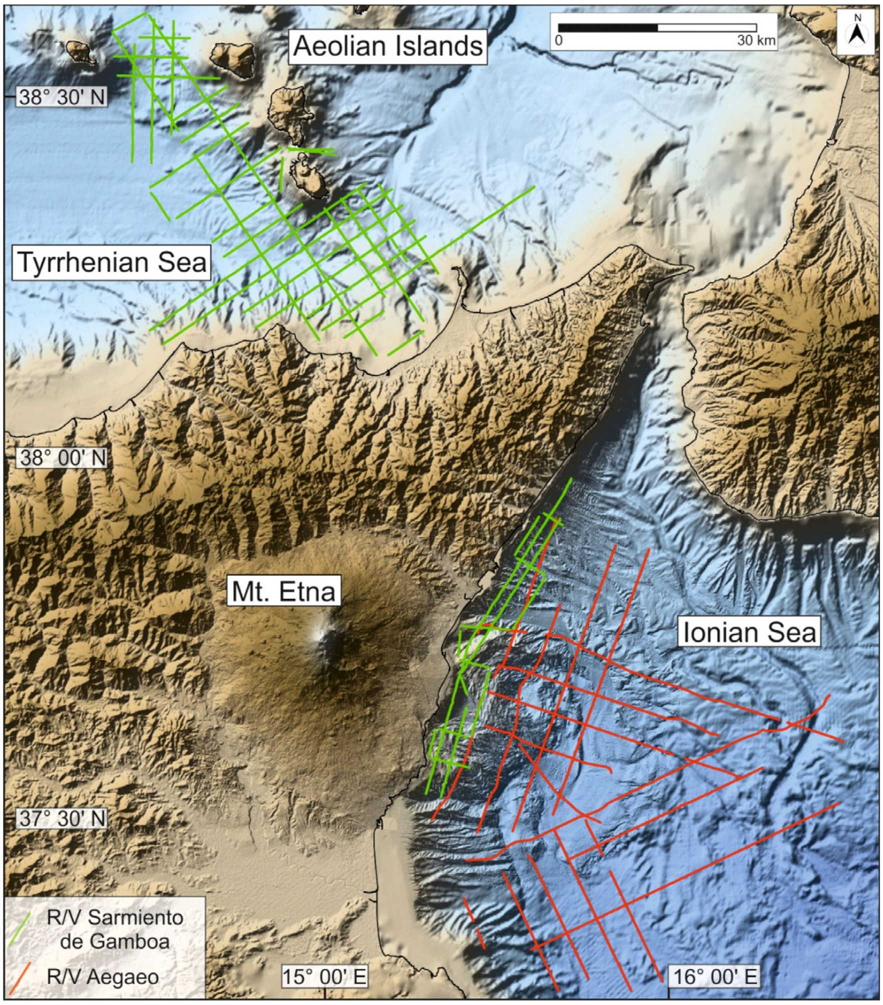


Figure 1 Acquisition map in the Ionian and Tyrrhenian Seas during the TOMO-ETNA cruises on board of the R/V "Sarmiento de Gamboa" (red lines) and R/V "Aegaeo" (green lines).

Seismic data acquired using an active source and an array of receivers, can be thought as a scalar field, where signal amplitude is the function of both space and time variables. Each time the source is triggered, a wave-field is registered. Multichannel seismic data processing consists in applying a set of algorithms to the registered wave-fields in both the time and space domains, aimed to extract from each seismogram a time series yielding Earth reflectivity [Yilmaz O., 2001].
MCS data interpretation manly consists in picking the main seismic horizons and faults; the results are integrated with other data and information, to better constrain the seismo-stratigraphic and structural setting of southern Italy, for the wider understanding of tectono-magmatic interaction.
Processed high-resolution seismic sections, acquired during the TOMO-ETNA experiment, show an overall good quality, with a vertical resolution of ca 2-3 m. Preliminary processing of seismic data targeted to deep exploration show well defined horizons down to 8-10 s two-way travel time, locally ascribable to reflections from the Moho.

References and citations

Firetto Carlino M., Zgur F., Bruno P.P., Coltelli M., Sormani L., Cavallaro D., Ibànez J.M., Patanè D., (2016). *Acquisition and preliminary analysis of multi-channel seismic reflection data, acquired during the oceanographic cruises of the TOMO-ETNA experiment*. Annals of Geophysics, 59, 4, S0430; doi: 10.4401/ag-7083.

Yilmaz O., (2001). *Seismic data analysis: processing, inversion, and interpretation of seismic data.* Society of Exploration Geophysicists; http://dx.doi.org/10.1190/1.9781560801580.

A Database of seismic lines off-shore of eastern Sicily: SOME - Seismic multichannel data Off-shore Mount Etna

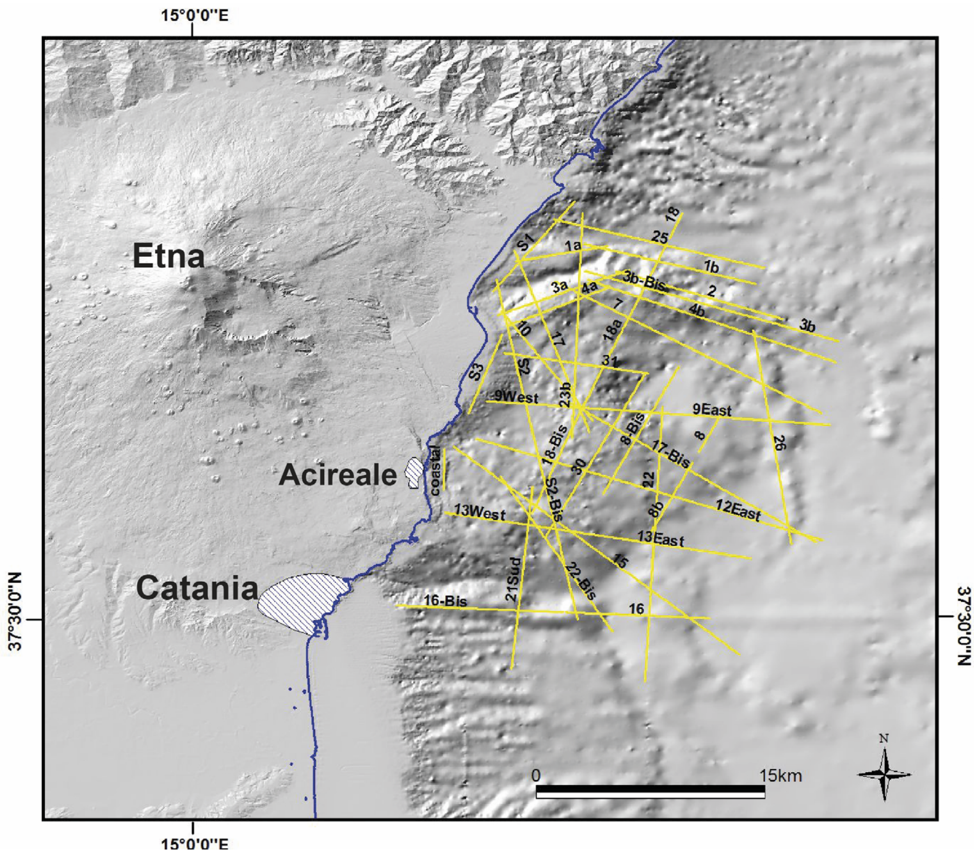
Francesco Mazzarini[1], Massimiliano Favalli[1], Luca Nannipieri[1] and Mauro Coltelli[2]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Pisa, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy

francesco.mazzarini@ingv.it

We present a database of seismic lines containing multichannel high-resolution seismic data acquired in 2005 off-shore Catania (eastern Sicily). Recent studies define a complex structural setting of the area offshore Mount Etna due to the co-occurrence of continental slope dynamics, magmatic and tectonics processes [Chiocci et al., 2011; Mazzarini et al., 2014 and references therein].
The investigated area consists of a sea sector from Catania to Taormina (latitude 37° 25’ 00”N - 37° 50’ 00”N and from the coast to longitude 15° 30’ 00”E) extending from depths of 100-2000 m (Figure 1).

Figure 1 Map of the seismic lines included in the data base (yellow lines) and the corresponding codes.



The database has a very simple structure and consists of 39 records representing the seismic lines (Figure 2) and a folder (NAV-DATA) common to all the seismic lines with the NCDP Total Position data, in UKOOA format. Each record consists of a folder containing: i) the text file of the metadata, with the name of the line, seismic data acquisition (i.e. recording parameters such as record length, sample interval, shot points interval), the applied filters (low and high frequencies cut-offs), record length, number of traces and CDP, and the data

format; ii) the seismic line in SEG_Y format (https://pubs.usgs.gov/of/2001/of01-326/HTML/FILEFORM.HTM); iii) a visualisation of the line from a raster format (.BMP). The data are organized in files and are stored in a Linux server file system.
The data can be browsed at http://some.pi.ingv.it by clicking on the code of the seismic lines. The custom CGI (Common Gateway Interface) interacts with the users accessing to the database and then processes the information provided by users during registration and after a preliminary check sends them the access account (Figure 2a, b). A quick look of each seismic line is displayed by clicking on the code of the line (Figure 2c). The users are requested to register if they wish to download the desired lines through the website. The Data access and downloading functions are performed by means of the CGI web service.
New options will be added to the landing page such as the functions for selecting the data, estimating the amount of the selected data and visualizing the metadata of the lines.

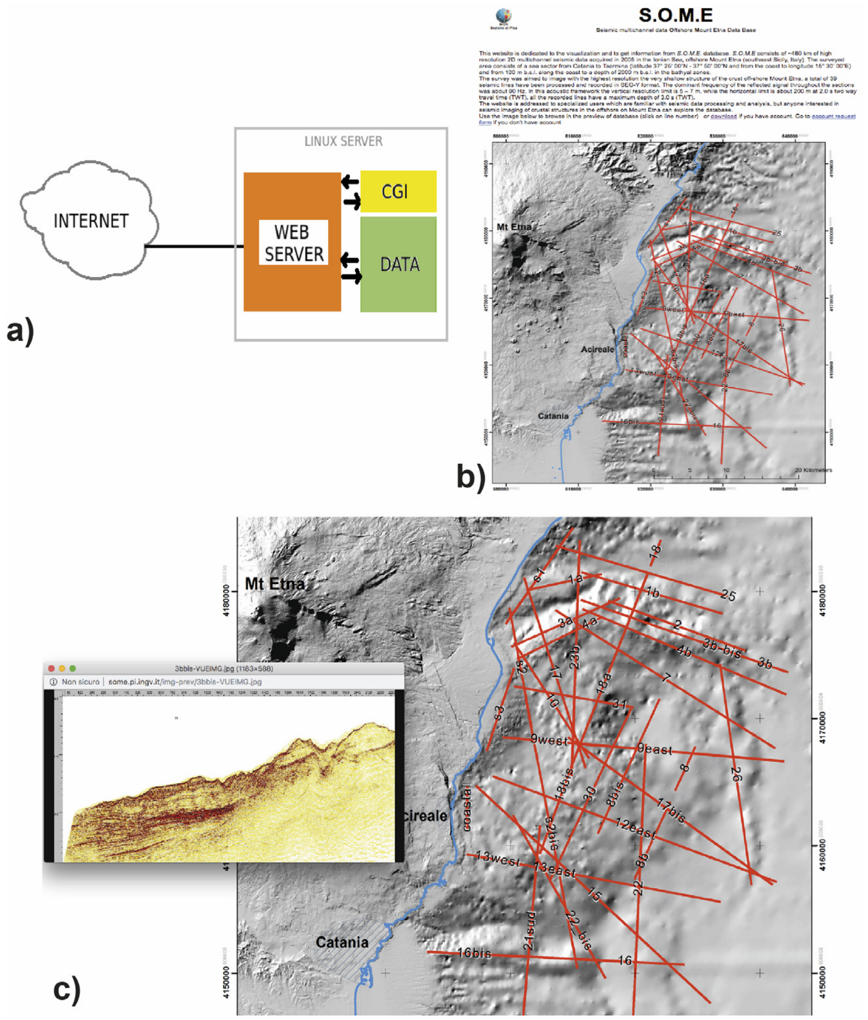


Figure 2 a) Structure of the website http://some.pi.ingv.it; b) Landing page of website with seismic line in red; c) Screen shot of the query of the database, clicking on a label of a line (line 3b-bis in this case) a quick look (.BMP) file of the selected line appears (inset on the left side).

References

Chiocci F.L., Coltelli M., Bosman A. and Cavallaro D., (2011). *Continental margin large-scale instability controlling the flank sliding of Etna volcano*. Earth and Planetary Science Letters, 305, 1-2, 57-64.

Mazzarini F., Isola I., Bisson M., Nannipieri L., Favalli M., Fornaciai A., Tarquini S., (2017). *Seismic lines offshore Mount Etna (SOME) open database*. Annals of Geophysics, 60, 5, 2017, S0557, doi: 10.4401/ag-7346.

Mechanical design of a tide gauge station for Ustica

Antonio Costanza, Giuseppe D'Anna, Gioacchino Fertitta, Alessandro Amato

Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Nazionale Terremoti, Italy

antonio.costanza@ingv.it

There are many scientific experiences related to the sea-level measurement with different techniques [Blomenhofer and Hein, 1994; Key and Parke, 1997; Pellegrinelli et al., 2009] where methods, data analysis and comparisons are discussed, but no technical information are provided about the mechanical aspects of the structure required for the acquisition. In order to fill this lack, in this work we show some mechanical design steps, with technical information, of a particular tide gauge station, highlighting the significant mechanical stresses and deformations arising from the interaction between the structure and the sea.

The structure of a tide gauge station, with submerged sensor, consists of a surge pipe anchored to a pier and partially immersed in seawater. Despite such conceptual simplicity, this design required a careful analysis under different points of view to ensure a long life in the harsh environment in which the station will be installed and to guarantee an optimal sea-level monitoring.

A new tide gauge station will be installed on a pier of Island of Ustica; the building plan was developed thanks to a collaboration between INGV, ENEA, CNR, ISPRA, the Navy Reserve and the Museum of the Island of Ustica. This installation will be the first sea-level monitoring system in the Island. The installation area was chosen in order to ensure a good sea-level monitoring. The signals will be acquired and transmitted in real-time to the tsunami warning center CAT (Centro Allerta Tsunami) of the INGV [Amato et al., 2018] and the new station will be included in the RMN (Rete Mareografica Nazionale). The stations of the RMN use microwave level sensors combined with a second float level sensor based on shaft-encoder technology; in addition, a hydrometric ultrasound sensor is used as comparison.

In the new tide gauge station of Ustica, the miniTIDE model by VALEPORT, with acetal housing, will be used; this tide gauge was supplied by ENEA. The miniTIDE is fitted with a temperature compensated piezo-resistive pressure transducer with a resolution of 1mm and an accuracy of ± 10mm. For the scheduled installation, the tide gauge will be vertically inserted inside a suitably dimensioned surge pipe. To clarify this point, in Figure 1a-b the assembly of all 3D models of the station is shown: two pipes are attached to the pier (1), the surge pipe (2) that houses the tide gauge, and the support pipe (3) that holds in place the photovoltaic panel (4) and the electronic box (5). A ladder (6), attached to the pier, will allow to perform installation and maintenance. The surge pipe has a total length of 7.35m, while the support pipe of photovoltaic panel has a total length of 4.65m; the overall length of pipes is 12 m (namely two bars of 6m). The tide gauge is not visible in the assembly because it is located inside the surge pipe (2), in proximity of the lower end of the same, where an axial shoulder is designed to allow a precise positioning of the sensor along the vertical. In the immersed part of surge pipe, lateral holes, suitably sized, produce a low-pass hydro-mechanical filter to minimize the oscillations generated by the wave motion.

In Figure 1c-d the constraint system to the pier is shown. The plate (I) must be bound to the dowels with nut and lock nut system to avoid spontaneous unscrewing which may be caused by pipes vibrations. On the base plate (I), which will be anchored to the pier, two discharges are machined to ensure a proper plate-concrete contact in correspondence of the dowels area. On the plate (I) the cradles (II) will be welded; on the plates (III) the cradles (IV) - identical to II - will be welded and, through the tie rods (V), the cradles (II) and (IV) will grip on the pipes. The tie rods (V) are M12 threaded rods, welded on the holes of plate (I) with circular beads. The plates (III) are constrained to the tie rods (V) with nut and lock nut system to prevent spontaneous unscrewing.

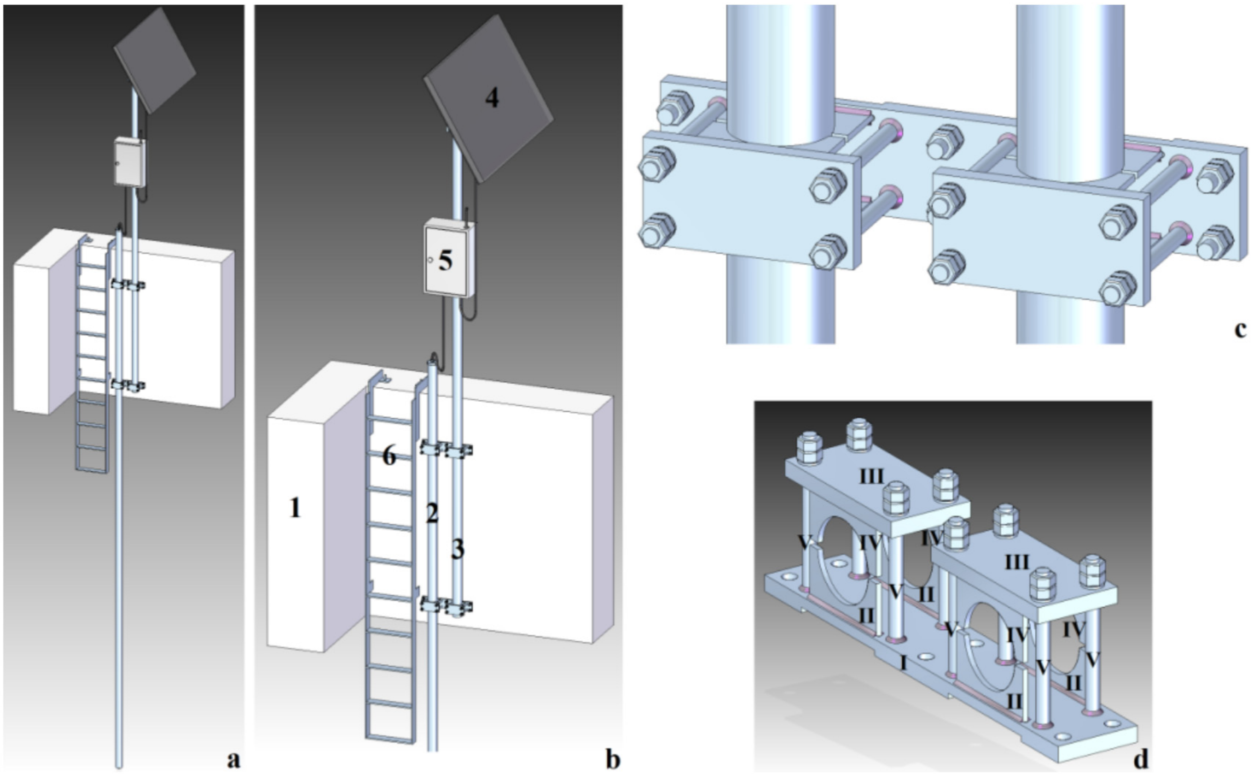


Figure 1 a) 3D assembly models of the tide gauge station; b) detail of the emerged part; c) detail of the mechanical constraint system; d) numbering of the constraint system.

All the materials are chosen to withstand the aggressive agents of the marine environment. The entire structure must be made of AISI 316 stainless steel; this material also ensures a good machinability. In order to avoid galvanic corrosion, it is of fundamental importance to use the same materials for all the parts that are in contact. Only the ladder may be realized with aluminum or other material, because it will be removed after the assembly and maintenance operations.

A modal FEM analysis of the clamped surge pipe [Callahan and Baruh, 1999; Cammalleri and Costanza, 2016; Wang and Lai, 2000] was performed to avoid dangerous resonances caused by the wave motion forcer. The elastic deformation of the free bottom-end of the surge pipe, caused by the drag force, was evaluated in order to minimize the inclination and the variation of quote of the tide gauge. After these analyses, the surge pipe was chosen (outside diameter 76.1mm, wall thickness 4mm) among those commercially available.

The static and fatiguing sea-loads were considered in the structural FEM dimensioning of the constraining system; the trial and error method were used for the choice of resistant sections [Shigley, Mischke and Budynas, 2005; Mischke, 1987]. Both the forces parallel to the pier and those orthogonal to it were considered. Figure 2a shows the Von Mises stress in the welded joint caused by the drag force parallel to the pier (1000N). It should be noted that the stress increases in the extremities, due to the stress concentration caused by the shape discontinuity. Figure 2b-g show the total displacements, the Von Mises stress and the safety factor of the

compressed area (cradles and surge pipe), caused by the drag force orthogonal to the pier (1000N) and the preload of the tie rods (12500N for each tie rod with friction coefficient of 0.15 in the screw-nut contact and a tightening torque of 30N×m). The yield stress is exceeded in the coupling areas with cradles and this causes a local and superficial plasticization which ensures a good coupling of the cylindrical surfaces in contact. The plasticization of the pipe is mostly at the external surface and this ensures the integrity of the inner surface.
After the installation, the acquisition results will be examined to verify the goodness of the mechanical design presented.

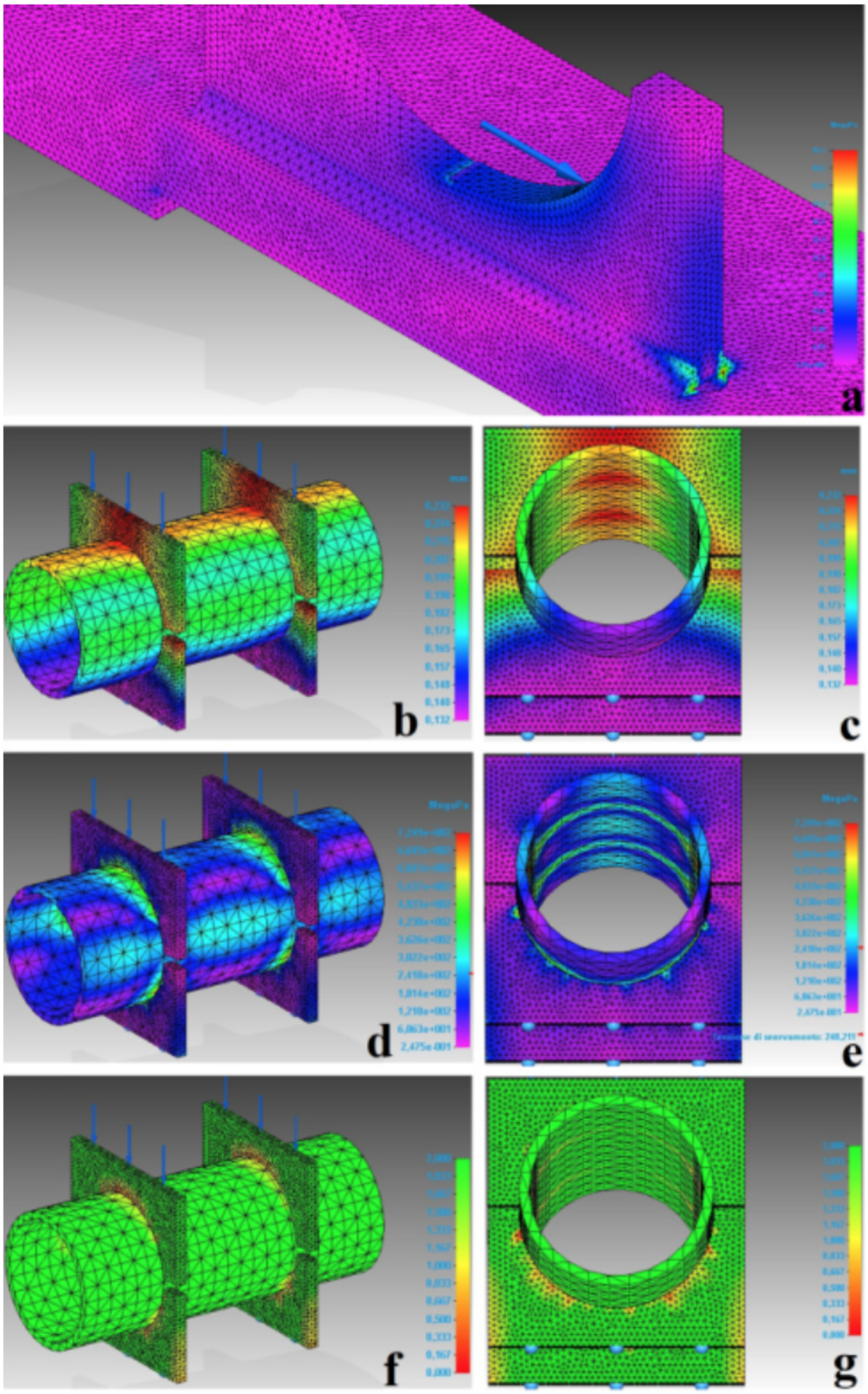


Figure 2 FEM analysis. a) Von Mises stress in the welded joint; b-c) total displacements; d-e) Von Mises stress; f-g) safety factor of the compression area of the surge pipe.

References

Amato A. and the CAT Team, (2018). *Il Centro Allerta Tsunami (CAT) dell'INGV*. In: Rischio sismico in Italia: analisi e prospettive per una prevenzione efficace in un Paese fragile (a cura di: Fiore A. e Ottaviani V.), vol. 1/2018, Società Italiana di Geologia Ambientale (SIGEA).

Blomenhofer H. and Hein G.W., (1994). *Calibrating the TOPEX/POSEIDON altimeter using DGPS in buoys*. In: Third International Conference on Differential Satellite Navigation Systems, Royal Inst. of Navigation, London, April, pp. 18-22.

Callahan J. and Baruh H., (1999). *A closed-form solution procedure for circular cylindrical shell vibrations*. International Journal of solid and structures, 36, pp. 2973-3013.

Cammalleri M. and Costanza A., (2016). *A closed-form solution for natural frequencies of thin-walled cylinders with clamped edges*. International Journal of Mechanical Sciences, 110, pp. 116–126, doi: 10.1016/j.ijmecsci.2016.03.

Key K.W., Parke M.E. and Born G.H., (1997). *Mapping the sea surface using a GPS buoy*. Marine Geodesy.

Mischke C.R., (1987). *Prediction of stochastic endurance strength*. Journal of Vibration, Acoustics, Stress and Reliability in design, vol. 109, n. 1, pp. 113-122.

Pellegrinelli A., Bencivelli S., Lovo S., Crocetto N., Perfetti N., Ricchieri F. and Russo P., (2009). *La stazione mareografica integrata di Porto Garibaldi*. In: 13th National Conference ASITA, Bari, 1-4 December, 2009.

Shigley J.E., Mischke C.R. and Budynas R.G., (2005). *Progetto e costruzione di macchine*. MCgraw-Hill.

Wang C. and Lai J.C.S, (2000). *Prediction of natural frequencies of finite length circular cylindrical shells*. Applied Acoustic, 59, pp. 385-400.

Offshore Seismic Monitoring: deployment of a seismometer on the bottom of a conductor pipe of the oil platform Rospo Mare C

Giuseppe D'Anna, Antonio Costanza, Gioacchino Fertitta

Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Nazionale Terremoti, Italy

giuseppe.danna@ingv.it

Extending seismic monitoring to offshore areas is among main INGV's aims; OBS Lab is contributing to the achievement of this goal with technological development of submarine systems and scientific missions. Offshore real-time systems not only provide oceanographic data but also allow improving the hypocenter computation, under certain operative conditions. On May 2018 a Framework Agreement to start a scientific collaboration was signed by the Ministry of Economic Development - General Department for the Safety of Mining and Energy (DGS-UNMIG), the INGV and Assomineraria (an Italian association for the Mining and Oil Industry). Subsequently, DGS-UNMIG, INGV, and EDISON Spa, as member of Assomineraria, signed an Implementing Agreement for the purpose planned in the Framework Agreement.
As a first implementation of the Agreement, the conductor pipe D (c.p. D) of the platform Rospo Mare C (RSM-C), in the offshore of Vasto (CH), was made available for seismic and multiparametric monitoring by EDISON. An Ocean Bottom Seismomenter (OBS) will be installed on the bottom of this conductor pipe to acquire the seismic data; these will be transmitted in real-time, through the EDISON network, to the INGV seismic monitoring center.
Oil platforms are subject to winds, sea currents and waves. The forces exerted by these agents excite the vibrational mode shapes of these complex structures. In addition, the extraction process generates mechanical noise too. As the vibrations propagate to every part of the structure and to the surrounding seabed, they can interfere with the seismic data acquisition system, reducing the signal to noise ratio. A preliminary analysis was carried out in order to evaluate this reduction. In this regard, a FEM modal analysis of the conductor pipe D, appropriately constrained, was carried out, following the method described in [Cammalleri and Costanza, 2016]. For the same purpose, the natural frequencies of other existing platforms were collected from literature [Jiammeepreecha et al., 2008; Raheem et al., 2012; Weldeslassie, 2014]. The selected works refer to platforms structurally similar to RSP-C, all supported by four legs. Furthermore, the frequencies of marine waves (in the area of the RSM-C) and those related to Von Karman's vortices (caused by sea currents flowing around the c.p. D) were considered. All these frequencies are summarized in Table 1.

Table 1 Frequencies to evaluate the signal to noise ratio.

[Hz]					
	Nat. Freq. of platforms structurally similar to RSP-C				
Nat. freq. c.p. D	[Jiammeepreecha]	[Raheem]	[Weldeslassie]	Marine waves	Von Karman
0,3	0,8	1,1	0,25	0,05 - 0,15	0,03
0,8	0,8	1,1			0,06
1,5	2	1,4			0,12
2,5		3,6			0,15
3,7		3,6			

The frequencies of marine waves and of Von Karman's vortices are very close to the first natural frequency of the c.p. D. The platforms structurally similar to RSP-C have the first five natural frequencies in the range 0.25-3.6 Hz, close to the first five natural frequencies of the c.p. D (0.3-3.7 Hz).
The preliminary analysis shows that the installation of an OBS on the bottom of the c.p. D is feasible but some disturbances and noise are to be expected, especially between 0.1 and 5 Hz, which is also an important frequency range for seismic data analysis. The seabed inside the conductor pipe is constituted of pelites with a low resistance to the penetration. For this reason, the sensor must be buried in order to achieve a good coupling with the sediments.
The installation system, shown in Figure 1a, minimizes the influence of disturbances on the acquired data, by burying the sensor in the sediments. In order to facilitate the burying and the extraction process two conical caps are attached to the bottom and top side of the sensor. The system includes a hydraulic circuit (in red) which conveys a flow of water, from the top of the c.p. D to the seabed. A downward jet of water, coming out from below the seismic sensor, digs a hole in the sediments, where the sensor is slowly self-buried under its own weight. The assembled system consisting of sensor and two cones weighs 16.6 kg in air, and 7.9 kg in water. The hydraulic circuit can be activated again in the recovery phase to facilitate the recovery of the sensor from seafloor. In order to optimize the burying system, a dispersing nozzle was designed, Figure 1b-c, which, in addition to digging out the sediments, moves them away from the central area. This nozzle produces a downward jet to dig the sediments, but also five upward jets, parallel to the generatrix of the lower cone, to remove the sediments dug from the central area. Fluid dynamic analyses with finite element method were carried out in order to design the channel sections and orientations (Figure 1d-e). The flow rates in the six channels obtained by the numerical simulation were finally verified by the experimental tests (Figure 1-f).

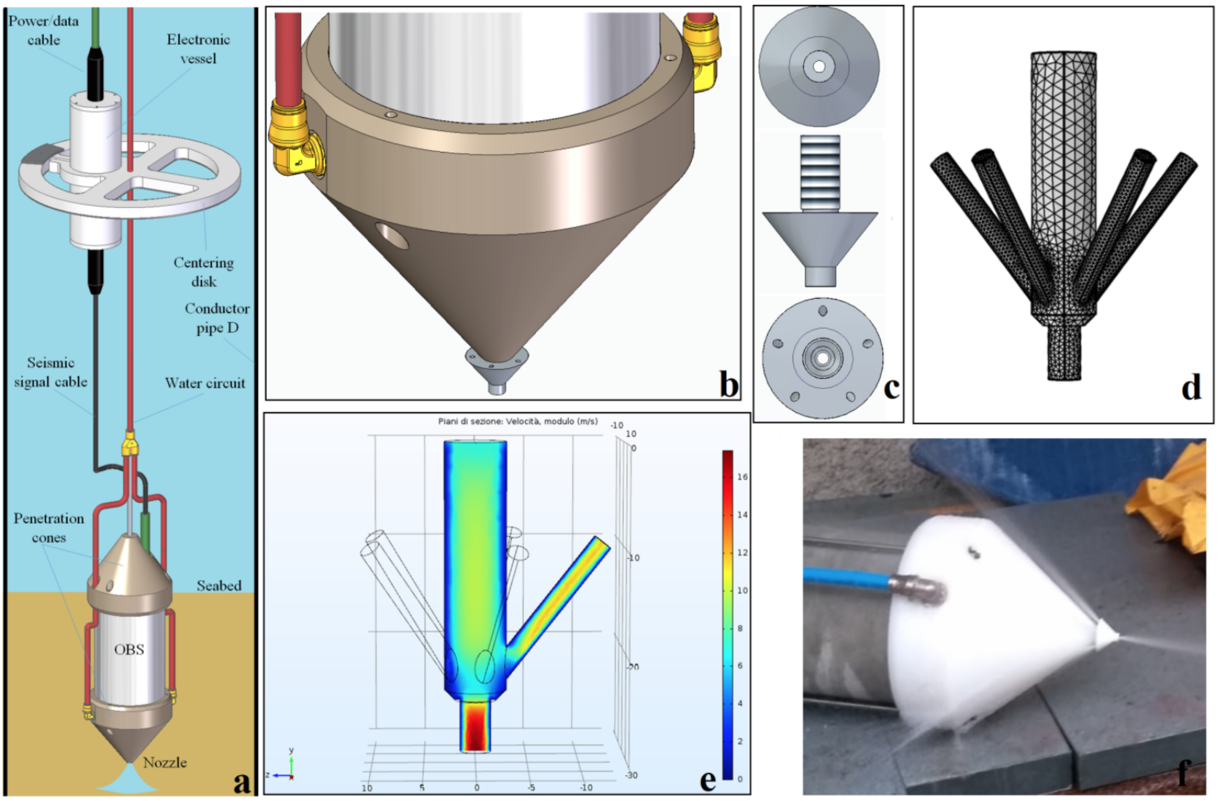


Figure 1 a) Self-buried system; b) 3D assembly of the dispersing nozzle with the system; c) views of the nozzle; d) discretized liquid domain of the nozzle; e) velocity (modulus) on the diametral level; f) experimental test on flow rates.

The whole system was tested in shallow waters. The burying (Figure 2a-b-c) lasted about 10 minutes, while the extraction (Figure 2-d) lasted about 4 minutes. The tests were carried out with the nominal flow rate of 0.2 L/s (12 L/min).

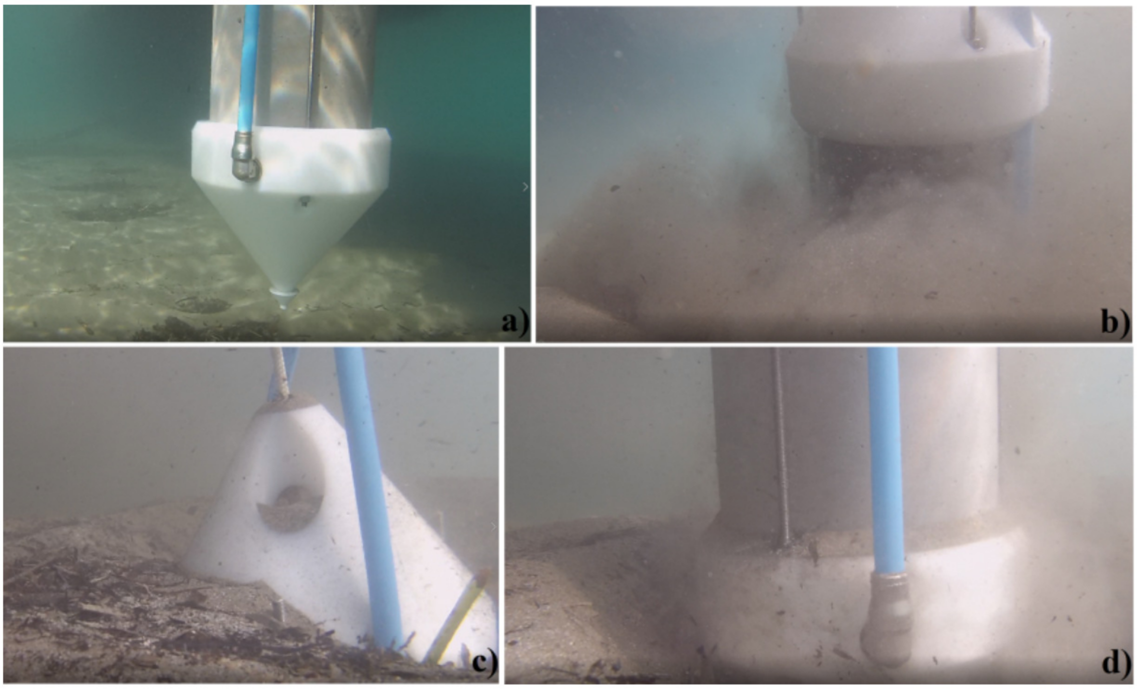


Figure 2 a): system before the contact with the seabed. b): during self-burying. c): sensor completely buried. d): during the extraction phase.

The system is essentially composed by an underwater seismometer, Nanometrics Trillium OBS 120 s, placed on the bottom of the c.p. D, and by a data acquisition system based on a Guralp DM24 digitizer inside the electronics vessel (Figure 1a and 3). A 150 m long marine cable, carrying data, GPS signals and power, connects the vessel to the surface unit. The core of the surface unit is a Guralp EAM-U digital acquisition system, hosting a SEEDLink server. The server will be accessible from the INGV seismic monitoring center, where a SEEDLink client will continuously receive the seismic data [https://ds.iris.edu/ds/nodes/dmc/services/seedlink/, https://geofon.gfz-potsdam.de/waveform/seedlink.php].

References

Cammalleri M. and Costanza A., (2016). *A closed-form solution for natural frequencies of thin-walled cylinders with clamped edges*. International Journal of Mechanical Sciences, 110, pp. 116–126, doi: 10.1016/j.ijmecsci.2016.03005.

Jiammeepreecha W., Chucheepsakul S., Kantiyawichai K., (2008). *Dynamic Analysis of Offshore Structures in the Gulf of Thailand by Using Abaqus Program*. In: Conference Paper, Conference: Proceedings of the 13th National Conference on Civil Engineering, At Chonburi, Thailand, May 2008.

Raheem A.S.E., Aal A.E. M.A., Shafy A.G.A. and Seed A.F.K., (2012). *Nonlinear Analysis of Offshore Structures Under Wave Loadings*. In: Conference Paper, 15 WCEE, Lisbon.

Weldeslassie M.W., (2014). *Investigation of Which Sea State Yield the Dominating Contribution to Fatigue Accumulation in Offshore Structures*. Master's Thesis.

A revision of the OBSP after the Tomo-ETNA experiment

Gioacchino Fertitta, Antonio Costanza, Giuseppe D'Anna

Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Nazionale Terremoti, Italy

gioacchino.fertitta@ingv.it

In 2014 INGV acquired 18 new Ocean Bottom System for Seismic Prospecting (OBSP). These systems, being intended for seismic surveying, are complementary to the other family of OBS's in the INGV availability, with the broad-band instrument-type instead. Compared to the broad-band version, the OBSP is relatively low weight (about 50 kg) and small size, being built around a single 17" glass sphere. The maximum deployment time is also shorter, up to 4 months, depending on the configuration.
The Tomo-ETNA experiment [Coltelli et al., 2016], aimed at studying the Etna volcano inner structure, was the first test-bench for the OBSP. The experiment produced encouraging results for the OBSP project, but some flaws became also evident. The OBSP system was made up of a set of three geophones, mounted on an auto-leveling support, and a low power data acquisition system (DAS) with a local recording system. The OBSP can be equipped with an additional sensor, such as a low frequency hydrophone or an absolute pressure sensor. Hydrophones are useful to record pressure waves associated with seismic events, while absolute pressure sensors to detect tsunami waves and to monitor subsidence phenomena. This type of monitoring has been already undertaken by INGV with different instruments in the gulf of Pozzuoli achieving remarkable results [Iannaccone et al., 2018; Chierici et al., 2016]. The OBSP deployment technique is by free fall; at the end of a short in time scientific campaign, an acoustic-release system starts the recovery of the system, by releasing a couple of ballasts with the burn-wire method.
The recorder and the geophones are installed inside a glass sphere (Benthos-type). A polyethylene cover encloses the sphere, providing protection against impacts. A polyethylene disk, attached to the higher portion of the cover, provides mechanical support for the localization devices and for a ring-molded syntactic foam. The version in Tomo-ETNA experiment had a radio- and a flash-beacon anchored to the disk. These instruments, both with long cylindrical shape, extended well above the OBSP profile, rising the position of the center of mass and making the OBSP less stable. Before the experiment took place, the stability was verified by observing the instrument floating in an open-top tank. However, the OBSP behaved differently under the action of sea currents and waves.
After surfacing, some OBSPs did not reach the correct orientation automatically; this made the localization difficult. This experience showed that the floating stability had to be improved. In order to achieve this goal, the beacons were replaced with a custom localization system. The new system is based on a single electronic board, featuring both an embedded radio transceiver and a LED driver. As the radio antenna can operate from inside the glass sphere, there is no portion of the radio outside it; the flash lamp is outside the sphere instead. It is made of a string of LEDs, enclosed in a waterproof Plexiglas housing, producing 360° beam-angle light pulses. In order to bring the center of mass to the lowest possible position, other modifications were also considered. Inside the glass sphere, the Tomo-ETNA version had a fixed ballast, consisting of a set of plastic bags filled with lead spheres. The ballast is necessary to find a good balance between the buoyancy force and instrument weight. These forces determine some critical parameters, such as the fall and emersion velocity, as well as the strength that keeps the instrument anchored to the seabed and coupled to the sediments. Therefore, the ballast is

designed to provide a specific amount of downward force, depending on the overall mass and volume of the OBSP.

As the ballast weight cannot be set arbitrarily, only its position could be modified. In the new version, the internal ballast has been moved outside and under the sphere, attached to the plastic cover bottom face. The lead-filled bags have been replaced with a steel plate of opportune size and weight to match the effect of the old ballast.

In July 2019, a fleet of three new OBSPs will be deployed in the Strait of Sicily, a stretch of sea between Sicily and Tunisia, at depths ranging from 100 to 200 m. This mission is aimed at studying local regional earthquakes as well as capturing seismic events possibly induced by an oil field in the area, named VEGA-A. Two OBSPs will be equipped with a low-frequency hydrophone. As subsidence phenomena are likely to occur near oil extraction fields, the third one will be equipped with an absolute pressure sensor (BPR, Bottom Pressure Recorder).

As the Tomo-ETNA experiment involved artificial waves, see Figure 1, this campaign will be the first attempt to record earthquakes with the OBSP. For this purpose, the front-end electronics of the data acquisition system will implement a bandwidth extension method, which will increase the seismometer period. Regarding this method, two different options are being considered. The first is a revised version of the Lippmann method [Romeo and Braun (2007)], implemented with a custom pre-amplifier board, which transforms a set of three 4.5 Hz geophones into a 5 s period velocimeter. The same board can be found inside a new seismic sensor, entirely developed at INGV, the OBS & Earth Lab 3D 5 s. This sensor has gone through a long series of tests on land, producing satisfactory results (Figure 2). The second option is the implementation of a digital filter to invert the geophone transfer function. In this case, the final period depends on the digital filter parameters, so its value is configurable. Automatic calibration, lower power consumption and self-noise, are the most interesting features that this option would introduce. However, this implementation has not been fully tested yet.

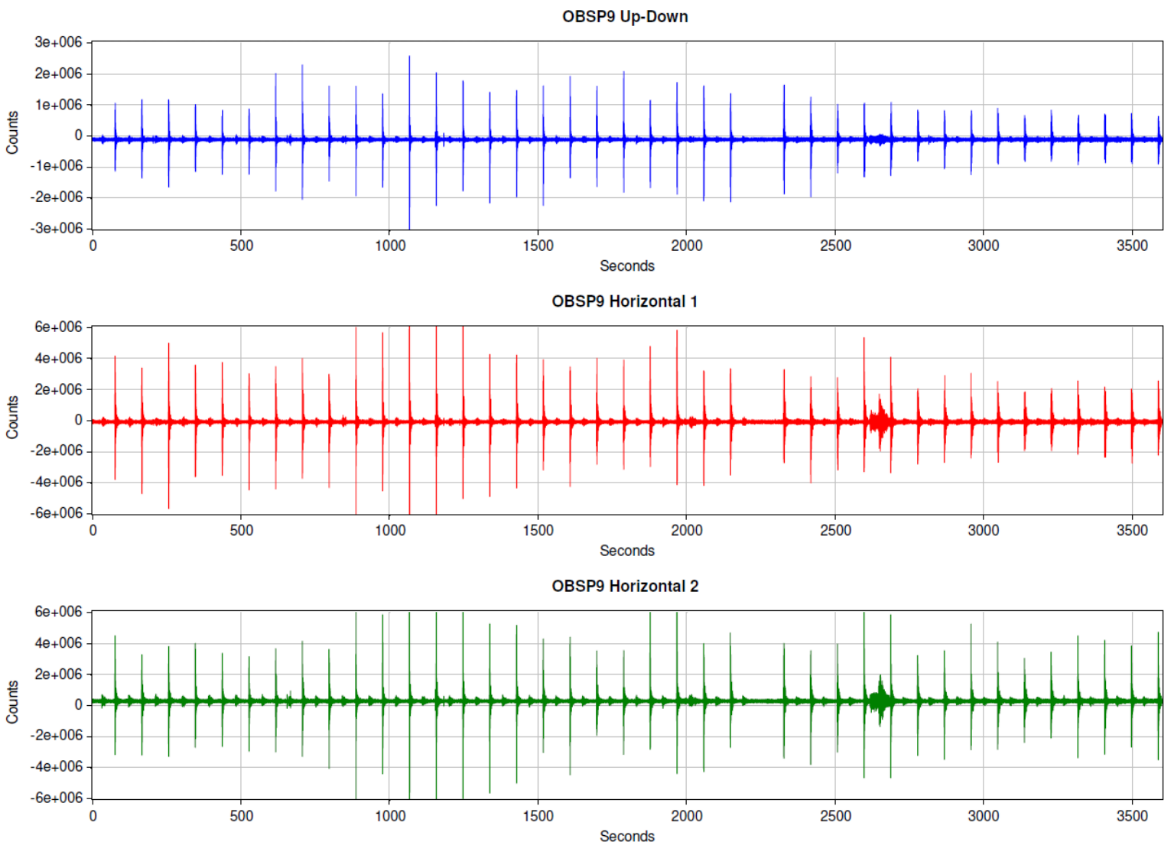


Figure 1 Sequence of pulses acquired during the Tomo-ETNA experiment by the OBSP number #9.

Compared to the INGV broadband OBS, the OBSP is anchored less firmly to the seabed. In addition, the broadband OBS relies on a shield to isolate the seismic sensor from marine currents. Lacking these important features, the OBSP should be affected by marine currents more than the broadband OBS, even though the smaller cross-section could mitigate this effect. However, the results of the Tomo-ETNA experiment, in particular the quality of the data-set, indicate that the OBSP could be able to record regional earthquakes. Hopefully, the new mission will prove this statement true and help understand more precisely the limitations of the OBSP.

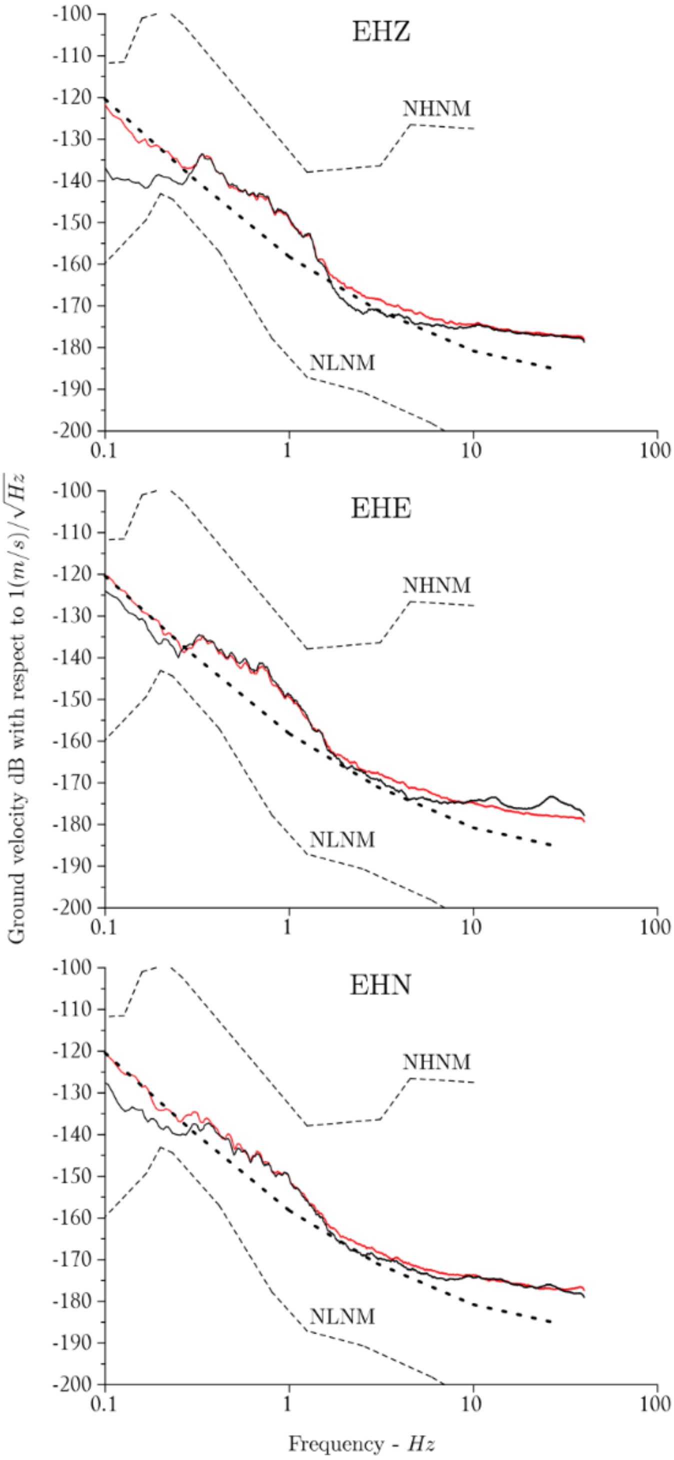


Figure 2 Ambient noise simultaneously acquired by two different seismic sensors: the Lennartz LE-3D 5/S (solid red) and the OBS & Earth Lab 3D-5s (solid black). Dashed curves show the standard noise models, high and low. The dotted curve represents the Earth Lab 3D-5s theoretical self-noise.

Figure 3 The OBSP version 2014.

References

Iannaccone G., Guardato S., Donnarumma G.P., De Martino P., Dolce M., Macedonio G., Chierici F., Beranzoli L., (2018). *Measurement of seafloor deformation in the marine sector of the Campi Flegrei caldera (Italy)*. Journal of Geophysical Research, 123, doi: 10.1002/2017JB014852.

Coltelli M. et al., (2016). *The marine activities performed within the TOMO-ETNA experiment*. Annals of Geophysics, 59(4), S0428, doi: 10.4401/ag-7081.

Chierici F., Iannaccone G., Pignagnoli L., Guardato S., Locritani M., Embriaco D., Donnarumma G.P., Rodgers M., Malservisi R. and Beranzoli L., (2016). *A new method to assess long-term sea-bottom vertical displacement in shallow water using a bottom pressure sensor: Application to Campi Flegrei, Southern Italy*. Journal of Geophysical Research, 121, doi: 10.1002/2016JB013459.

Romeo G. and Braun T., (2007). *Appunti di sismometria*. Quaderni di Geofisica n° 46.

Marine Open Data: a way to stimulate ocean science through EMODnet and SeaDataNet initiatives

Simona Simoncelli[1], Michele Fichaut[2], Dick Schaap[3], Reiner Schlitzer[4], Alexander Barth[5] and Claudia Fratianni[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Bologna, Italy*
[2]*Ifremer, Brest, France*
[3]*MARIS, Netherland*
[4]*AWI, Germany*
[5]*University of Liege, Liege, Belgium*

simona.simoncelli@ingv.it

A clean and healthy ocean can be achieved, restored and preserved through constant and systematic monitoring of the marine environment, which allows to understand its complex dynamics and exploit its natural recourses through a sustainable development approach. Marine monitoring is a complex and multidisciplinary activity that measures, evaluates and determines physical and biogeochemical parameters at multiple scales through a variety of sensors characterized by different accuracy. The management and long term preservation of the deriving marine data represents a societal priority which enables to assess the past and present ocean state, to predict its evolution and to understand/mitigate the impact of human activity and climate change on it.
Nowadays it is necessary to transform and adapt data management activity to the present societal challenges ensuring that data sampled for a specific purpose would be available to the scientific community to be reused multiple times and for multiple purposes. Data sharing approach and open data policy maximize users' uptake, promoting knowledge and innovation and, at the same time, reducing costs, avoiding duplication of efforts. Open data revolution can be achieved only if the scientific community defines and adopts common vocabulary, formats and standards that enable a rapid and efficient access to the data. The FAIR (Findable Accessible Interoperable and Reusable) data management principles [Wilkinson, M. D. et al. 2016] and a linking data approach are the foundation of this revolution which boosts innovation, maximize scientific knowledge and reduce uncertainties but preserving transparency and traceability.
To tackle this challenge, in 2009 the European Commission - DG MARE launched EMODnet (European Marine Observation and Data Network) [Martín Míguez B. et al., 2019], whose objective was to centralize and organize marine data in a unique infrastructure. EMODnet involves more than 150 institutions which collect multidisciplinary observations in the marine domain, verify their quality, apply common format and standard and share them through seven EMODnet thematic portals (bathymetry, biology, chemistry, geology, physics, seabed habitat, human activities). EMODnet encompasses the entire marine data value chain deriving information from data, creating data products targeted to multiple user communities, from academia to public institutions, from intergovernmental bodies to private companies.
EMODnet relies on SeaDataNet (https://www.seadatanet.org/), a distributed Marine Data Infrastructure for the management of large and diverse sets of data deriving from in situ of the seas and oceans, to preserve, curate and provide access to the data. In fact, SeaDataNet is a diffuse network of data centers which have been working jointly in the latest 20 years in the framework of various EU funded projects, and represents a benchmark in the marine domain for the definition of vocabulary and standards. In the framework of SeaDataCloud project (H2020), SeaDataNet, supports several EMODnet thematic lots like bathymetry, biology, chemistry and

physics, managing multidisciplinary in situ data, applying a quality assurance strategy, quality control procedures, developing software/tools and deriving data products such as temperature and salinity data collections and climatologies for the EU marginal seas (Mediterranean, Black Sea, North Atlantic, Baltic Sea, North Sea, Arctic Ocean) and the global ocean.

SeaDataNet partnership has worked jointly to implement and progressively refine a unique Quality Assurance Strategy (QAS), shown in Figure 1, aimed at continuously improving the quality of the database content and creating the best data products. The QAS consists of four main phases: (1) all data and metadata are harvested from the central Common Data Index (CDI) service; (2) file and parameter are aggregated to generate a metadata enriched ODV (Ocean Data View) collection; (3) Quality Check (QC) analysis on regional ODV collections further validates (secondary QC) the data and the Quality Flags assigned by data providers (primary QC); (4) analysis and correction of the detected data anomalies from NODCs (National Oceanographic Data Centers), which finally updates the corrected data within the infrastructure. The approach is iterative to continuously upgrade the quality of database content and data products. Phases 2 and 3 rely on ODV software (https://odv.awi.de/) for the aggregation and quality check of data following the guidelines developed within SeaDataNet projects. Phase 3 is implemented within a Work Package, coordinated by INGV, and provides validated aggregated data sets for all EU marginal seas in ODV collection format. These data sets are then used to compute temperature and salinity climatologies through the DIVA software tool (Data-Interpolating Variational Analysis, http://modb.oce.ulg.ac.be/mediawiki/index.php/DIVA) which allows to spatially interpolate (or analyze) those observations on a regular grid in an optimal way.

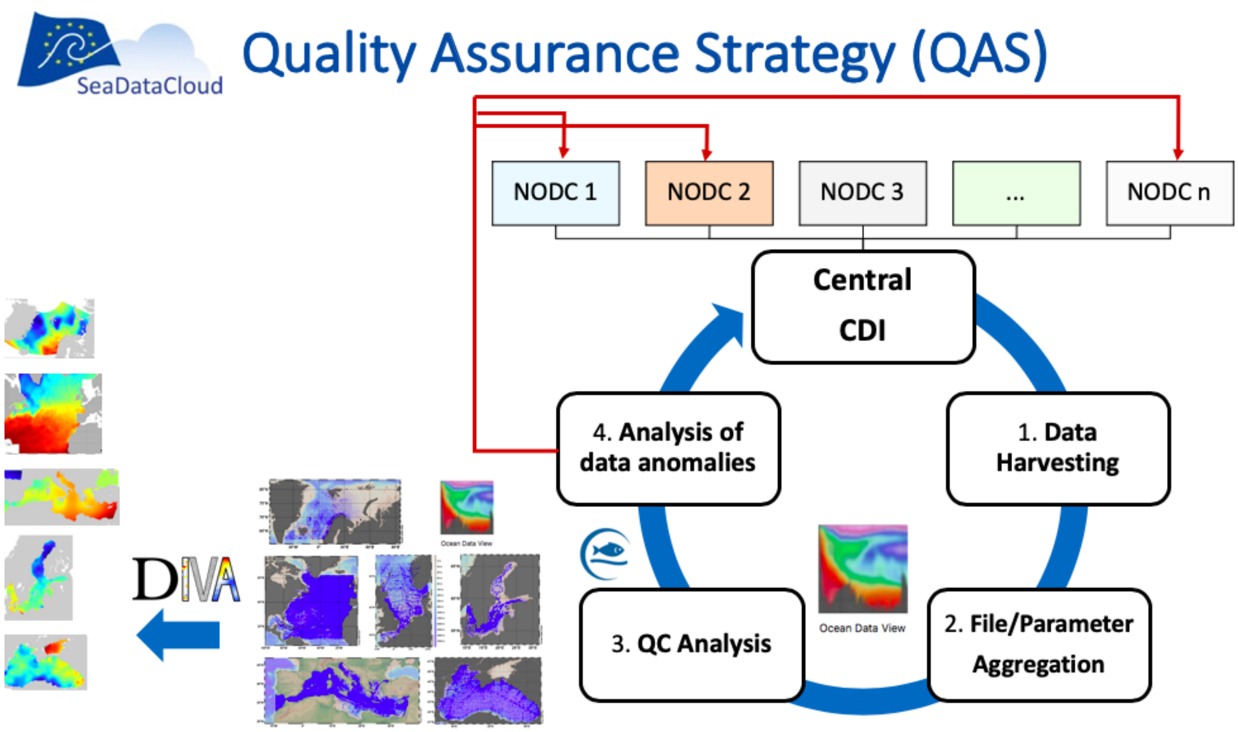


Figure 1 SeaDataCloud Quality Assurance Strategy: (1) data harvesting from the data infrastructures; (2) file and parameter aggregation; (3) secondary quality check analysis; (4) correction of data anomalies.

All SeaDataCloud products are available through a dedicated web catalogue (https://www.seadatanet.org/Products#/search?from=1&to=20) together with their Product Information Document (PIDoc) containing all specifications about product's generation, quality assessment and technical details to facilitate users' uptake. Digital Object Identifier (DOI) are assigned to products and relative PIDocs following the linking data approach to foster transparency of the production chain and acknowledge all actors involved from data originators to product generators. An example of it, is the Mediterranean Sea - Temperature and salinity Historical Data Collection [Simoncelli et al., 2018a] and its PIDoc [Simoncelli et al., 2018b] displayed in Figure 2.

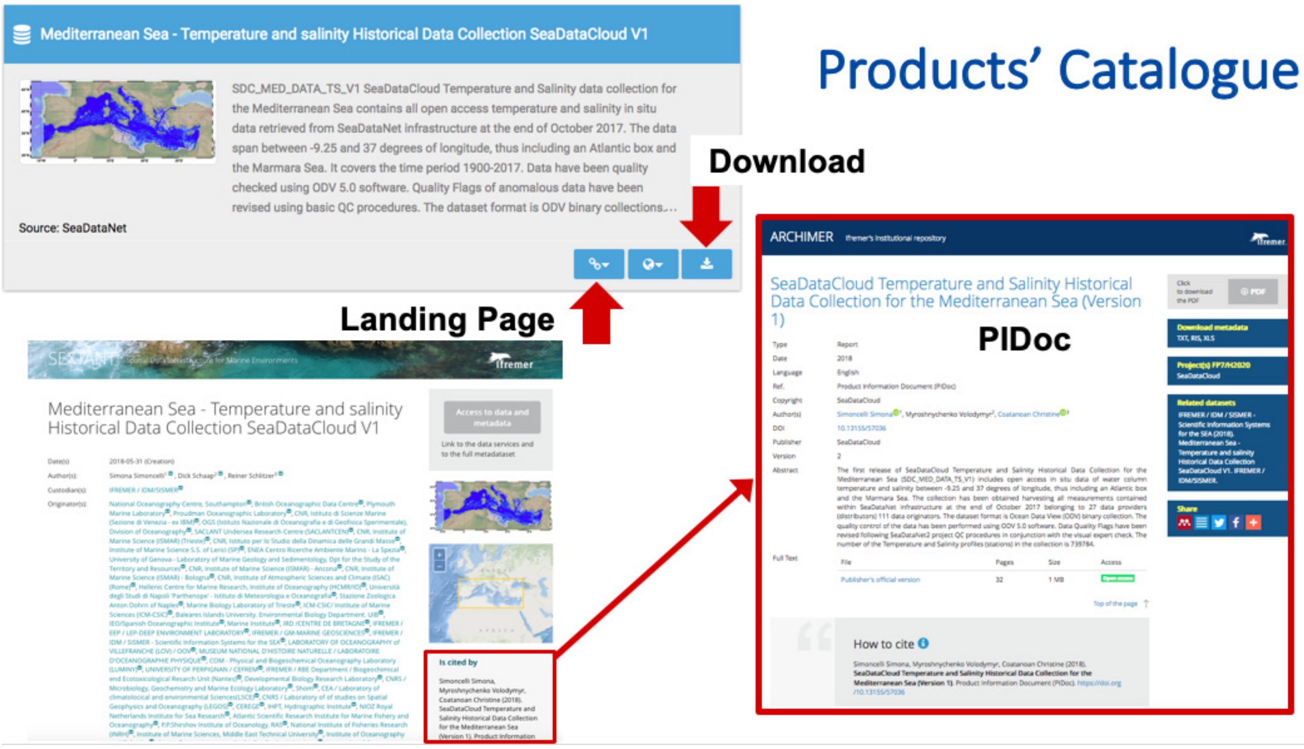


Figure 2 How to access SeaDataCloud products and the relative Product Information Document from the web catalogue at https://www.seadatanet.org/Products#/search?from=1&to=20: the Mediterranean Sea Temperature and salinity Historical Data Collection is used as example.

References

Martín Míguez B. et al., (2019). *The European Marine Observation and Data Network (EMODnet): Visions and Roles of the gateway to marine data in Europe*. Front. Mar. Sci. doi: 10.3389/fmars.2019.00313.

Simoncelli S., Schaap D., Schlitzer R. (2018a). *Mediterranean Sea - Temperature and salinity Historical Data Collection SeaDataCloud V1*. https://doi.org/10.12770/2698a37e-c78b-4f78-be0b-ec536c4cb4b3.

Simoncelli S., Myroshnychenko V., Coatanoan C. (2018b). *SeaDataCloud Temperature and Salinity Historical Data Collection for the Mediterranean Sea (Version 1)*. Product Information Document (PIDoc). https://doi.org/10.13155/57036.

Wilkinson M.D. et al., (2016). *The FAIR Guiding Principles for scientific data management and stewardship*. Sci. Data 3:160018 doi: 10.1038/sdata.2016.18.

SERVICES FOR THE SOCIETY

The Mediterranean Forecasting System and its Calibration and Validation procedure

Claudia Fratianni[1], Damiano Delrosso[1,2], Paolo Oliveri[1], Pierluigi Di Pietro[1], Gelsomina Mattia[1], Simona Simoncelli[1]

[1]*Istituto Nazionale di Geofisica e Vulcanologia – Sezione di Bologna, Italy*
[2]*Università di Bologna Alma Mater Studiorum, Dipartimento di Fisica e Astronomia, Italy*

claudia.fratianni@ingv.it

INGV has developed fully operational short term forecasting system at the Mediterranean basin scale, which has demonstrated to be a valuable asset for the Institution, the Research Community, and for the Community at large.
The INGV Mediterranean Forecasting System (MFS-INGV) provides daily forecasts and weekly analysis of the main physical parameters in the Mediterranean Basin (http://medforecast.bo.ingv.it/). The available variables provide continuous monitoring of the flow field evolution in the recent past and daily 10-days forecast, contributing to enhancing understanding of the ocean and supporting better management of the marine environment (marine security, fisheries, environmental and resources protection, naval operations and tourism).
The system consists of a coupled hydrodynamic-wave model based on NEMO code with a data assimilation component. The model horizontal resolution is 1/16 of a degree and is resolved over 72 unevenly spaced vertical levels, from surface up to 5500m. The system also manages an operational database, both in real time and delayed mode, which provides all the boundary conditions (initial conditions, lateral and atmospheric forcing fields) and the observed data to be assimilated, constraining the forecast error below acceptable values.
MFS-INGV forecasting system was further developed to upgrade the system in order to include forcing from two different atmospheric datasets, thus allowing to estimate the uncertainty associated to the atmospheric forcing and introduce elements of ensemble forecasting.
The atmospheric forcing used at current stage of development is provided by ECMWF (https://www.ecmwf.int) and COSMOME (http://www.cosmo-model.org/), while as lateral open boundary condition, the model is nested in the Atlantic, into the Copernicus global ocean analysis and forecast system (http://marine.copernicus.eu/). All the assimilated measurements are also provided by the Thematic Assembly Centers of Copernicus (http://marine.copernicus.eu/).
The preliminary investigation about the introduction of COSMO wind forcing made us confident that the two datasets are consistent each other, yet retain a fair amount of variability to allow the model to evolve into different states of dynamical equilibrium (Figure 1). This expansion to COSMO forcing is aimed at obtaining more robust and performing forecasts, that could be used for short term downstream applications focused on monitoring the marine environment and improved services dedicated to users.
Simultaneously to these model development, a quantitative evaluation of the operational forecasts is necessary to evaluate the performance of the system to understand the error origins and thus improve the system. This can be done by using independent observation data, such as the marine data recorded by fixed observations.
Those observations are acquired at key geographic sites and represent a huge and extensive source of information on the real sea conditions. These kind of data, however, require a special effort to be used in the model evaluation, since marine environment is not the ideal condition for electronic devices working over the long-term and steadily, resulting in sampling discontinuities and requiring frequent maintenance and sensors' calibration.

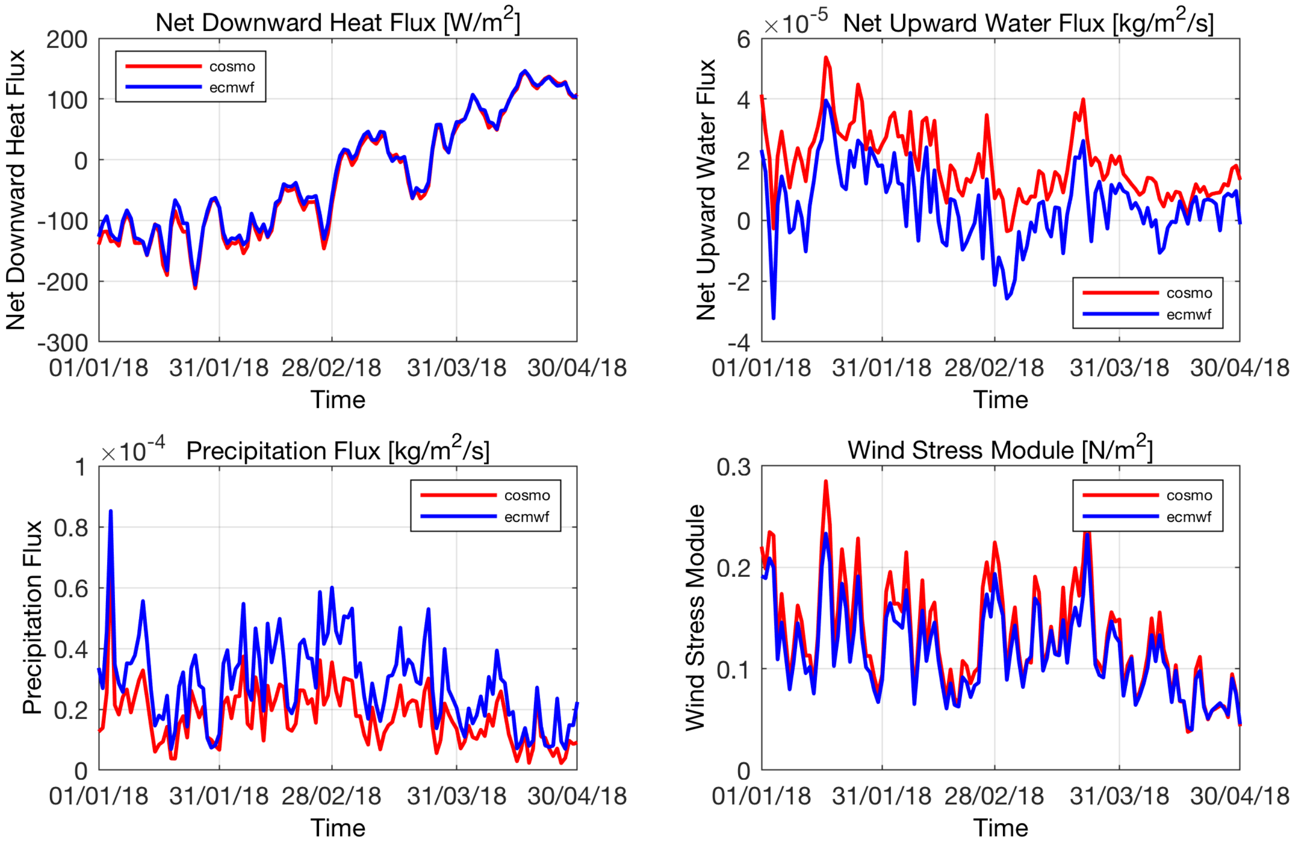


Figure 1 Time series of Heat and Precipitation Fluxes and Wind Stress from ECMWF (blue) and COSMO (red)

During the last years the INGV team developed a web based LAMP service (http://calval.bo.ingv.it/) to calibrate and validate the near real time products. However, this service has become slow and inefficient, due to:

- *presence* of not 'registerd' data providers;
- *increment* in the amount of managed data and poor data quality;
- *difference* of the original goal (quality evaluation of MFS) and the updated goal (provision of flexible evaluation system between ocean data model, e.g. analysis, reanalysis, and *in situ* data, e.g. moorings, gliders, vessels, etc);
- *presence* of not completely free and open source tools;
- *lack* of service portability;
- *difficulty* to maintain, update and publish the system with a DOI;
- *inability* to update the front end to a web 2.0 compliant platform.

The INGV team thus proceeded to revise the whole service taking into account all the above issues and-and taking advantage of:

1. *Interpreted programming language* (ease of use and portability);
2. *Vectorized numerical data analysis* (flexibility and speed);
3. *Output data storage* (efficiency and standardization);
4. *Versioning system for software maintenance update and online publication.*

The new kernel takes care of:

1. *Ingestion* of trusted data only from certified international data assembly centers;
2. *Relocation* of the evaluation schema to any other area of interest (from the Global Sea to

a high resolution area);

3. *Standardization* of model data post processing and observations data quality assessment, using original quality controls (if available), spike removal and iterative statistical quality checks, by computing standardized anomaly and the probability distribution (kernel density estimation) and finally returning the best possible hourly and daily time series;
4. *Computation of evaluation methods* with skill scores in terms of RMSE (root mean square error) and statistical bias.

Further efforts will be invested on:

- Adding more data providers (SeaDataNet, EMSO, EMODnet), more products and variable/observation to evaluate (reanalyses, new CMEMS products, biogeochemistry, etc.);
- Setting up online publication (for ex. ZENODO);
- Renovation of the website interface and migration from Google Maps API to OpenStreetMaps;
- Probing for new possible valuable user services (coastal monitoring focus, early-warning system implementation, marine activities support, etc.).

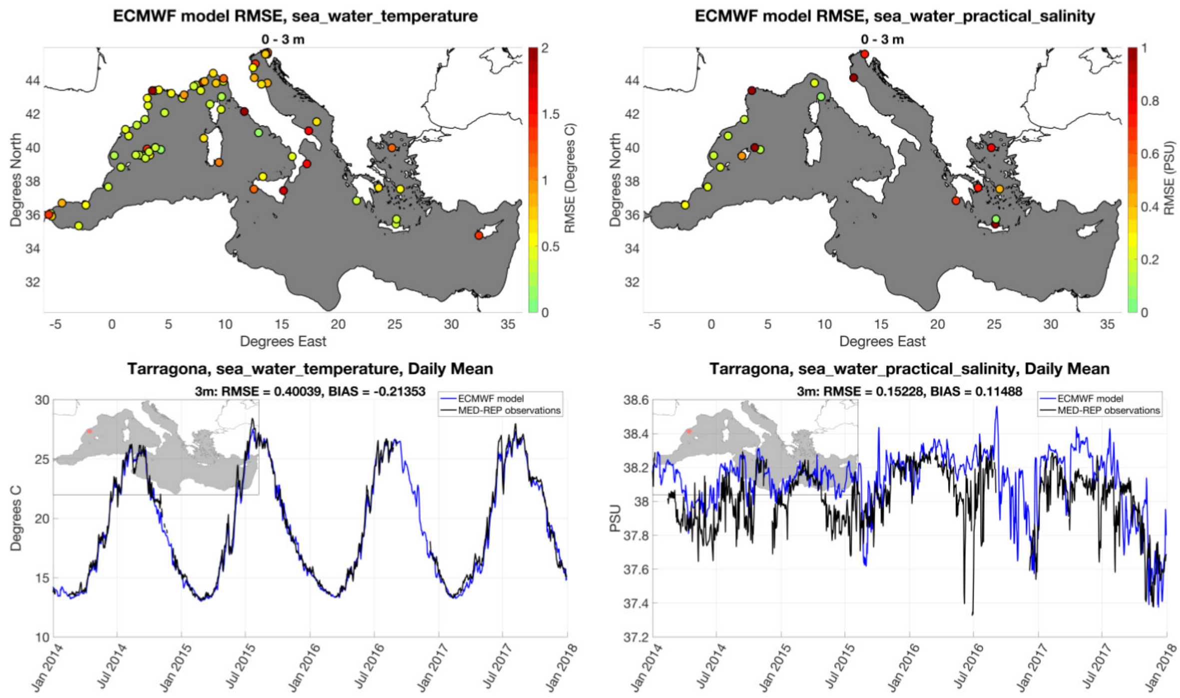


Figure 2 An example of evaluation of the system forced by ECMWF atmospheric fields for sea water temperature (left column) and salinity (right). The upper panel represents the model RMSE computed on layer 0 - 3m for all the analyzed platforms, while the bottom panel represents the model performance in terms of RMSE and bias at Tarragona buoy (Spain).

The SPOT project (potentially triggerable offshore seismicity and tsunamis) in the Italian offshore O&G fields

Mauro Coltelli[1], Roberto Basili[2], Danilo Cavallaro[1], Francesco E. Maesano[2], Jakub Fedorik[3], Marco Firetto Carlino[1], Lorenzo Lipparini[1], Stefano Lorito[4], Fabrizio Romano[4], Luciano Scarfì[1], Mara Monica Tiberti[2], Giovanni Toscani[3], Manuela Volpe[4]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania - Osservatorio Etneo, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Sismologia e Tettonofisica, Roma, Italy
[3]Università di Pavia, Dipartimento di Scienze della Terra e dell'Ambiente, Pavia, Italy
[4]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Nazionale Terremoti, Italy

mauro.coltelli@ingv.it

The SPOT project (potentially triggerable offshore seismicity and tsunamis) was conceived by the Ministero dello Sviluppo Economico - Direzione Generale per la Sicurezza anche ambientale delle attività minerarie ed energetiche – Ufficio Nazionale Minerario per gli Idrocarburi e le Georisorse (DGS-UNMIG) with the technical support of the Dipartimento nazionale della Protezione Civile (DPC), following the recommendations of the Commissione Grandi Rischi. The project aimed at helping the Italian Authorities to be compliant with the Offshore Oil and Gas Operations Safety European Directive and the resulting national regulations. The project involved four research institutes: Istituto di Scienze Marine of Consiglio Nazionale delle Ricerche (ISMAR-CNR), Istituto Nazionale di Geofisica e Vulcanologia (INGV), Centro Europeo di Formazione e Ricerca in Ingegneria Sismica (EUCENTRE), and Rete dei Laboratori Universitari di Ingegneria Sismica (ReLUIS). The project started on 1st February 2017 and ended on 31nd October 2018.
The marine areas, which represent the focus of the project, were identified by considering a buffer of 15 km around all the active offshore exploitation platforms (Figure 1).

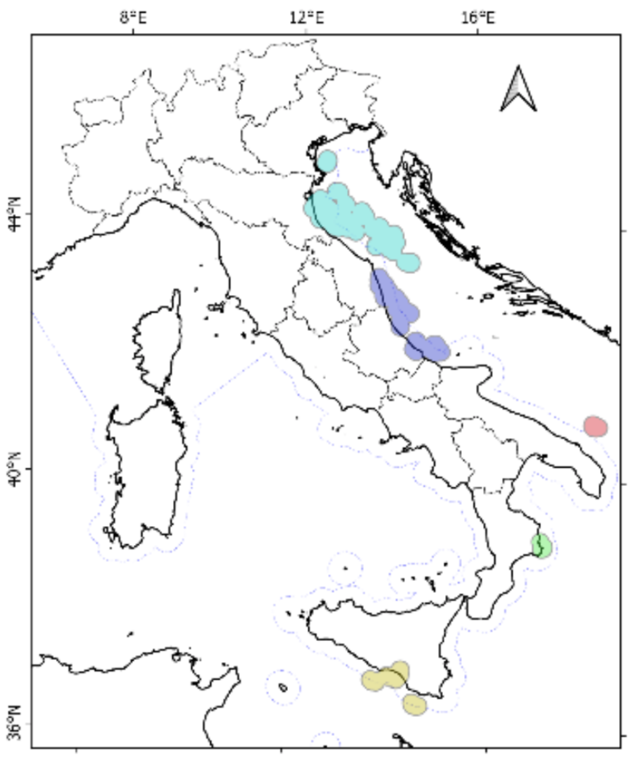


Figure 1 Marine areas around the active Oil and Gas offshore fields studied in the SPOT project.

Such areas were investigated in order to assess the existence of potentially seismogenic faults, as a preparatory step for the assessment of potentially triggered seismicity connected with oil and gas extractive operations.
The most relevant tasks involving INGV were related to the identification and characterization of potentially seismogenic faults, the assessment of their earthquake production rates and the modelling of tsunamis caused by the sea-bottom displacement produced by such earthquakes. To this end, INGV interpreted hundreds of multichannel seismic reflection profiles (SNAP database), calibrated with the stratigraphy of well logs and integrated with other geophysical/geological data (VIDEPI database and literature), both offshore and on coastal areas. The analysis was focused on the recognition of the faults cutting the upper brittle crust, whose width is in the range of those producing earthquakes of engineering relevance based on common fault scaling relations.
The descriptive parameters of the identified faults were used to estimate their natural earthquake rates and then to select a limited number of scenarios for theoretical M6.5 events. The impact of these earthquakes along the coasts was modelled in terms of expected ground shaking (by EUCENTRE) and tsunamis (by INGV). In turn, these models have been used to estimate potential human and economic losses in a multi-hazard approach to risk assessment (by EUCENTRE and ReLUIS).
The main results achieved by INGV researchers working in the SPOT project were:

- over 80 potentially seismogenic faults have been mapped (Figure 2), reconstructed in 3D, and parameterized according to international standards for hazard analysis;
- characterization of the potential reactivation of all parameterized faults through the slip tendency analysis with an example of estimating the slip rate on a structure in central Adriatic;
- evaluation of seismicity rates in the study areas based on the CPTI15 earthquake catalog, considering the completeness (historical and statistical) and declustering analyses, in accordance with the MPS (seismic hazard map) of CPS (seismic hazard centre of INGV);
- parameterization of earthquake ruptures to define 11 shaking and tsunami scenarios aimed at assessing their impact and damage on offshore infrastructures and the adjacent coast (Figure 2);

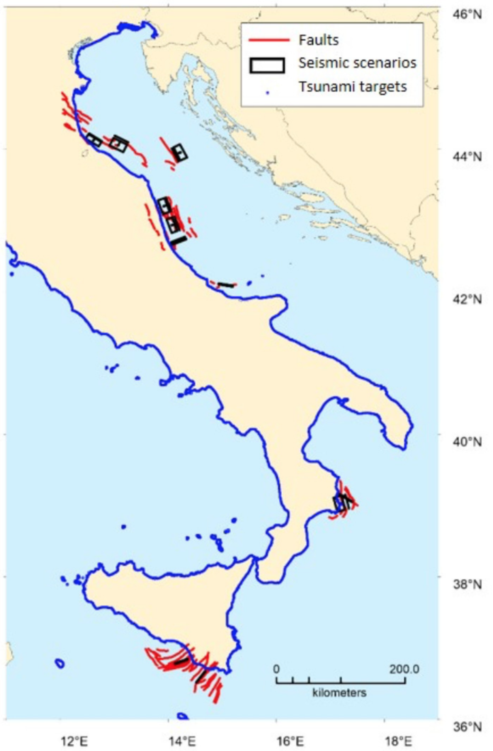


Figure 2 Potentially seismogenic faults mapped in offshore study areas of SPOT project.

modelling of tsunamis caused by earthquakes for the 11 proposed scenarios up to a minimum water depth of 10 and 5 m (22 simulations) by applying the Energy Grade Line method to extrapolate the height of the water column on the coast (Figure 2).

All the information processed in the project has been provided to the DGS-UNMIG on GIS files for their institutional purposes. The results will be considered for updating the DISS (Database of Individual Seismogenic Sources) and for creating the tsunami hazard map for the Italian coasts performed by CAT (Tsunami Alert Centre of INGV). The analysis conducted and the experience gained in SPOT project could also support the activities of the CMS (Underground Monitoring Centre of INGV).

Geomatics for underwater electromagnetic harbour protection systems and Newtonian systems for coastal navigation safety – Theory

Osvaldo Faggioni, Maurizio Soldani

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Geomagnetismo, Aeronomia e Geofisica Ambientale, Roma, Italy

osvaldo.faggioni@ingv.it

The effectiveness of magnetic signal measurements in harbours is very uncertain. The phenomenon of interference of the background field with the useful signal is accentuated if the latter is coming from a labile, quasi-point-like and kinetic source, such as divers. The problem is not of a technological nature, as commercial magnetometers guarantee redundant reading sensitivity with respect to the signal sought. It is constituted by the environmental noise that can heavily over-modulate the target signal in amplitude. Moreover, the wavelengths of these signals are inside the noise band and therefore the "FFT techniques of signal strengthening" are structurally inadequate.

INGV has provided a solution based on a new specific metrological approach to detect labile elementary signals in a high noise environment. This new measurement technique is known as "singular magnetic metrology". The classification of low amplitude signals in high noise is obtained by observing the magnetic field simultaneously at different points distant *L* from each other. This distance is such that the noise signal is correlated and the target signal is decorrelated. This measure (of singularity) is based on the space stability of each magnetic signal.

The topic researches developed by INGV have been supported by national and European projects (European Defence Agency and Piano Nazionale della Ricerca Militare, Italian Ministry of Defence, SEGREDIFESA/DNA).

The magnetic field is observed by means of several sensors aligned and distant *L* from each other, with *L* is such that one sensor records the total magnetic field with the target signal while other sensors record only the total magnetic field (for this application it's only the noise), see Figure 1-A. This procedure is objective since the filter function obtained to avoid the noise from the target signal is a measured function [Faggioni, 2018]. INGV has provided MINIDIFE, the L-calculation method and its use technique both in the "self-reported intelligence" (old standard) and in the "self-informed" version (new standard), see Figure 1-B. The final technique ("OC" - OVER_CROSSED intelligence) is currently undergoing theoretical development. With the expansion of the elementary cell from 2 to 3 instruments, also the central transit ambiguity of the target was exceeded (Figure 1-C): the third sensor has the role of comparison and verification in the case of "zero difference" is recorded between the two sensors considered.

This new measurement technique has significant experimental implications and provides the effective ability to detect the signals of labile, quasi point-like and kinetic sources in a high noise environment [Faggioni et al., 2018, Faggioni et al., 2010]. From the metrological point of view, the singularity approaches required to formalize the metrological concepts of "Informative Energy" and "Passive Energy" and the numerical ones of "Information Content" of the record and "Information Capacity" of elementary signal [Faggioni, 2018]. In the new measurement technique, the concepts of useful signal and noise is overcome with the introduction of the concepts of informative energetic group value and information capacity value of each elementary signal.

Marine magnetometric surveys for the research of small sinking metal sources (and often covered by silt) require high sampling density and precision in the localization of the sampled points. In addition, from the point of view of the information analysis, a high precision is required to define the signal band of the micro-sources (targets).

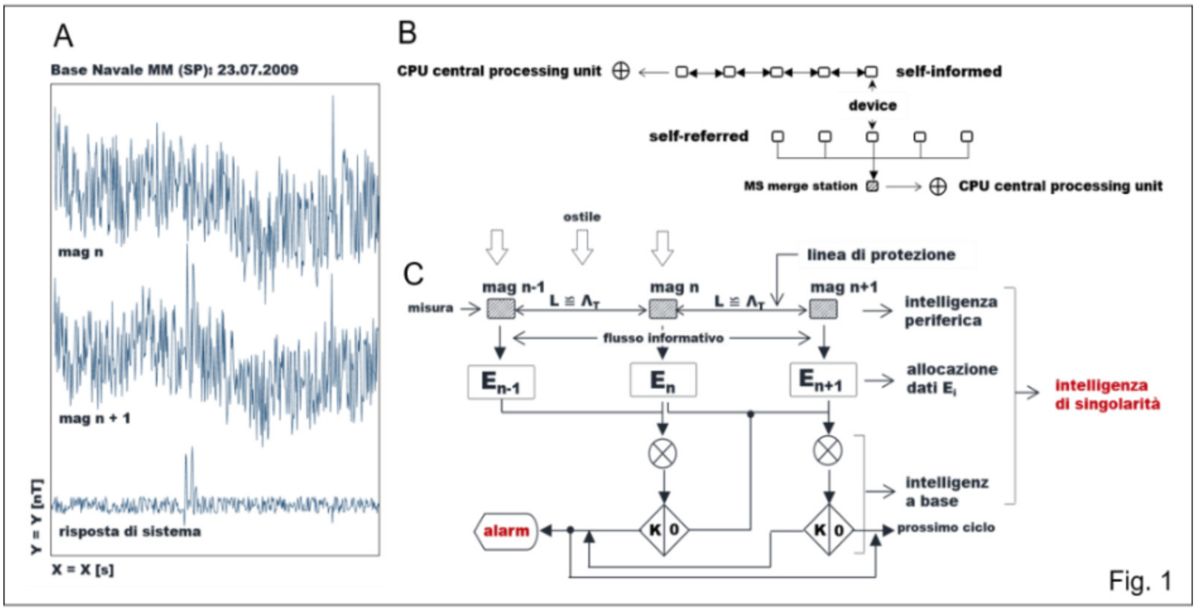


Figure 1 Measure of singularity: system architecture and performances.

The metrological problems for magnetic underwater HD surveys are the temporal reduction of the detection and the isolation of the band containing the target signals [Di Gennaro et al., 2008]. In a standard signal extraction actions from the detected field (so-called temporal reduction) or in the classification of the component bands of (so-called extraction of the anomaly field by reference field) produce the effective reading of the signals generated by the micro-sources. In particular, the reference adopted for the construction of terrestrial magnetic fields (IGRF) does not have adequate detail for this purpose. INGV has produced and formalized a new method of classification of the magnetic field bands of the micro-sources, which has allowed us to overcome the problem of detail by producing effective actions to detect extremely paying targets (recovery of mines, projectiles and unexploded rockets or bins and tracking low voltage power lines). As is known in high detail surveys in shallow waters (coastal areas, ports, etc.), the gradiometric systems (and in general for the control of temporal variations) are operationally not very effective because they have low evolutionary nautical response to towing and need of high sustenance speeds and heavy towing cables. For these reasons the surveys performed with this class of instruments, theoretically the most suitable for high detail, do not give adequate operational answers. INGV has proposed a marine survey method called HD (High Definition) for reading signals from micro-targets that bases its effectiveness on two specific steps: 1) a temporal reduction for controlled comparison; 2) a detailed reference field suitable for the production of the anomaly field associated only with micro-sources.
This temporal reduction is performed by comparison with a proximity reference station (terrestrial or underwater). The critical point of this technique is the verification of the spatial coherence of the reference station with the entire detection area. It is necessary to verify with a good approximation that the temporal variations measured by the reference station are constant, and therefore applicable, to the entire surface surveyed. The proposed technique is the "TT technique" (Time Track course, time route). The magnetic field from the observatory to

the farthest point of the array is measured by means of a straight run back and forth, before starting to perform the survey [Faggioni et al., 2002]. The data are organized in two distinct series (S_O series "out" from the observatory to the remote point and S_I series "in") the values of S_I are reversed and compared by overlapping (S_O ∩ S_I). The result of the subtraction cannot be null since the data series considered are of type and the rest of the difference will be equal . The two series are time reduced by comparison with the magnetogram of the reference station, if the reference station is coherent with the whole path, after TT reduction the result of the comparison (S_O - S_I) will result equal to zero (except for numerical approximations). In case of need more TT can be performed.

The computation of the Spectral Reference Field (SRF) (Figure 2-B) starts from the square mesh normalization of the 2D HD data. This field includes possible signals from very superficial artificial micro-sources (HD targets), signals of crustal and epicrostal origin, possible residues of the F(s) component that survived the TT technique, and, in remote cases, signals from large artificial sources (wrecks), irrelevant to the purpose of the HD survey. The contribution due to the "IGRF component" has to be considered a constant (field carrier) since its latitudinal gradient is too low to produce a differential effect measurable in the low extension typical of HD surveys.

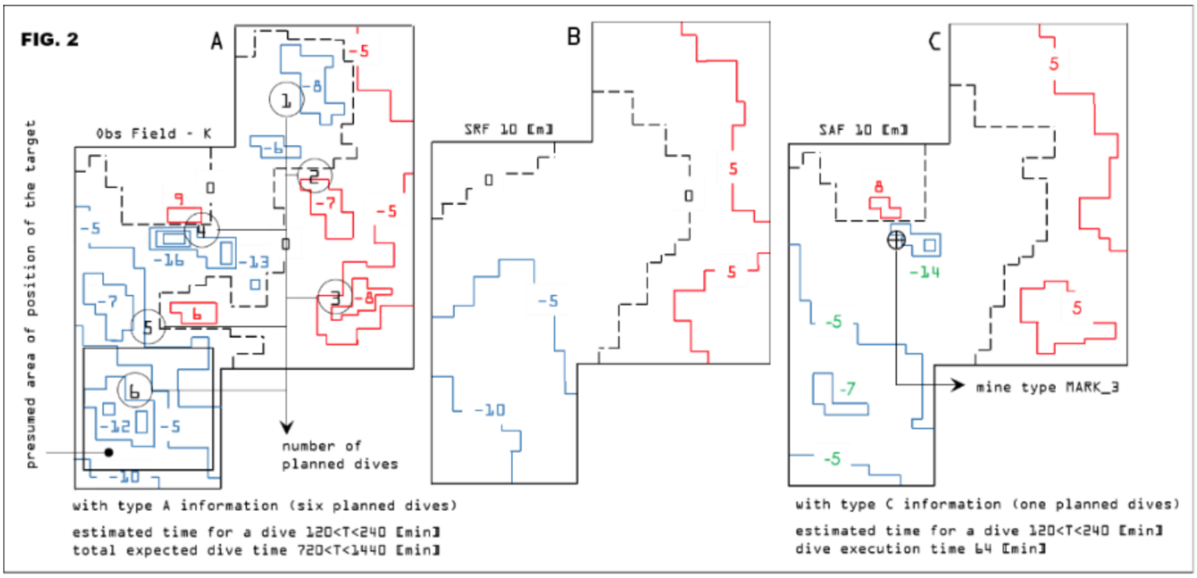


Figure 2 Example of High Definition survey: HD (A), Spectral Reference Field SRF (B) and Spectral Anomaly Field SAF (C).

The HD field (Figure 2-A) is substantially composed of two variation components: the low frequency of epicrostal natural origin (or, possibly, coming from large wrecks that can be easily identified a priori) (Figure 2-B) which is the Spectral Reference Field and the high frequency corresponding to the range of targets (artificial bottom micro-sources). The SRF (Figure 2-B) corresponds to the filter "D_LP of the total magnetic field in HD (Figure 2-A) and in theory its FFT^{-1} produces the Spectral Anomaly Field (SAF). In general, however, to obtain the SAF spectrum it is preferred to proceed in TD: HD – (FFT^{-1} SRF) = SAF. This method allows to avoid the HF instability due to the transit of SAF data through the Fourier protocol (1, -1).

During the last decade the national port community observe some anomalous tidal fluctuations. These events, known as "supersecche" and "super high" tides are due to the hydrostatic compensation of the weight change of the atmosphere. In harbours, this phenomenon is higher than the off-shore one (where the hydrostatic compensation factor *J* is 1cm for 1hPa) [Faggioni et al., 2006]. INGV provided the geodetic interpretation of the phenomenon and the metrological solution for its measurement and forecast. The horizontal component of the compensation motions is inhibited towards the coast and the consequent compensation defect is discharged on the vertical component amplifying thrust and delocalization of compensating mass in this direction. A campaign of tidal measurements of the atmospheric pressure and of the corresponding variation of sea level (supported by UE-EFRD and several Port Authorities) allowed to calculate *J* factors for several ports and the respective *K* (delay times) of the arrival of tide wave compensation (forced) with respect to the transit of the atmospheric pressure change (forcing): hydro-barometric forecasting of the first-order [Faggioni et Al. 2013]. Subsequently, with the aim to improve the precision of the measurement and the forecasting of the phenomenon, a comparison was made between the amplitude and the time of arrival of tide wave with the variation of acceleration of gravity due to the change in weight of the atmosphere: hydrobarometric forecasting of the second-order. The experiments related to the studies of the second-order were carried out in the Gulf of La Spezia. The quantitative values of the harbor *J* factor were approximately twice (or major) compared to the off-shore ones, while those of *K* were variable from some hours to more than a day.

References

Faggioni O., (2018). *The Fourier Notation of the Geomagnetic Signals Informative Parameters*. Scientific Research Publishing, Journal of Signal and Information Processing, vol. 9, n. 3, pp. 153-166, Wuhan, China.

Faggioni O., Soldani M., Cozzani G. and Zunino R., (2018). *Informative signal analysis: metrology of the underwater geomagnetic singularities in low-density ionic solution (sea water)*. Scientific Research Publishing, Journal of Signal and Information Processing, 2018, vol. 9, n. 1, pp. 1-23.

Faggioni O., Soldani M. and Leoncini D.A., (2013). *Metrological Analysis of Geopotential Gravity Field for Harbor Waterside Management and Water Quality Control*. Hindawi Publishing Corporation, International Journal of Geophysics, vol. 2013, 12 pp. - Special Issue on Geophysical Methods for Environmental Studies, New York.

Faggioni O., Soldani M., Gabellone A., Hollett R.D. and Kessel R.T., (2010). *Undersea harbour defence: a new choice in magnetic networks*. Elsevier B.V., Journal of Applied Geophysics, vol. 72, n. 1, pp. 46-56, Amsterdam, The Netherlands.

Di Gennaro E., Bovio E., Baralli F., Faggioni O. and Soldani M., (2008). *Clearance operation of Teulada Site (Italy): a novel approach for short term MCM missions in seafloor hard conditions*. CD-ROM Proceedings of UDT Europe 2008 Conference, June 11-13, Glasgow, UK.

Faggioni O., Arena G., Bencivenga M., Bianco G., Bozzano R., Canepa G., Lusiani P., Nardone G., Piangiamore G.L., Soldani M., Surace L. and Venzano G., (2006). *The Newtonian approach in meteorological tide waves forecasting: preliminary observations in the East Ligurian harbours*. Ed. Compositori, Annals of Geophysics, vol. 49, n. 6, pp. 1177-1187, Bologna, Italy.

Faggioni O., Caratori Tontini F., (2002). *Quantitative evaluation of the time-line reduction performance in high definition marine magnetic surveys*. Kluwer Academic Publishers, Marine Geophysical Researches, vol. 23, n. 4, pp 353–365, Norwell, MA.

Geomatics for underwater electromagnetic harbour protection systems and Newtonian systems for coastal navigation safety – Applications

Maurizio Soldani, Osvaldo Faggioni

Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Geomagnetismo, Aeronomia e Geofisica Ambientale, Italy

maurizio.soldani@ingv.it

Two examples of systems for harbour protection and port navigation safety are shown with the results obtained during several operative tests performed to develop a new anti-intrusion undersea system based on a magnetometer self-informed network (our goal is to detect the presence of underwater threats, such as terrorist divers in harbours) [Faggioni et al., 2018; Nasta et al., 2015].
The main purpose of the magnetic system is to fill the gaps of classical sonar systems, whose performances deteriorate, due to reflections and attenuations, in the boundary of the volume of water to be controlled (sea bed, docks...) [Gabellone et al., 2007].
Our experiments took place in port protection scenarios, characterized by medium-high environmental noise with a relevant human origin magnetic noise component. Divers performed approach runs above the array. The system has two different input signals: the magnetic background field (natural plus artificial) and a signal composed by the same magnetic background field superimposed on the target magnetic signature. The system uses the first signal (background field) as filter for the second one (background field plus the target signature) to detect the target presence [Faggioni et al., 2010]. The effectiveness of the procedure is related to the position of magnetic field observation points (reference devices and sentinel devices): sensors must obtain correlation in the noise observations (all the sensors record the same background field) and de-correlations in the target signal observations (only one sensor records target signature) [Faggioni et al., 2009].

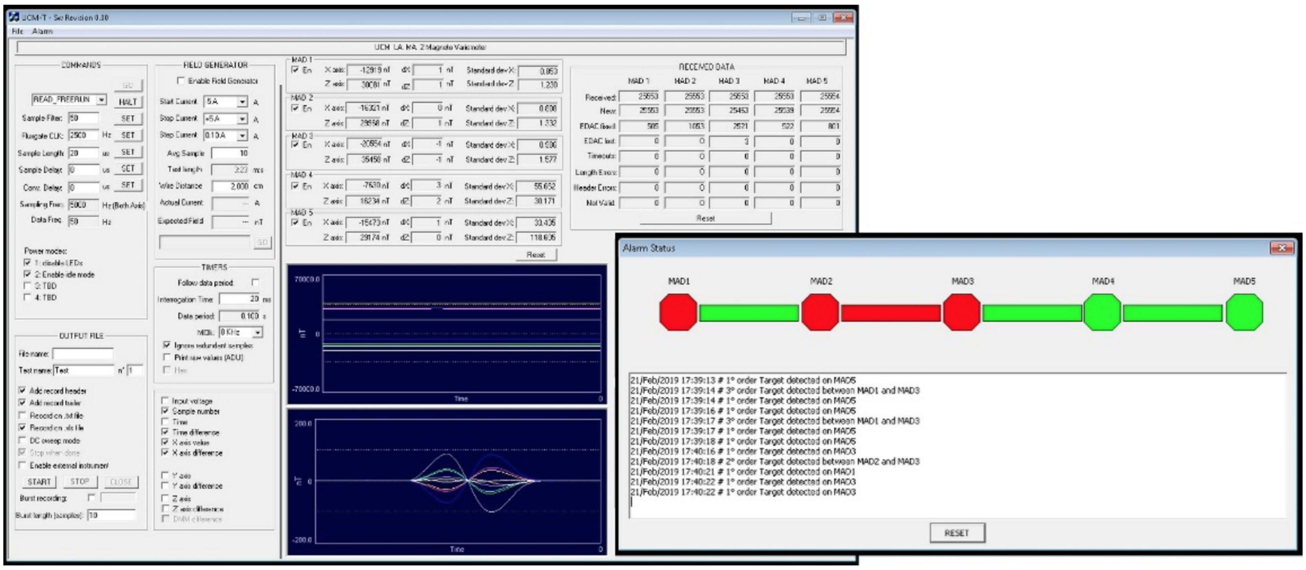


Figure 1 Alarms generated by a diver.

To generate alarms when a target is detected, we have developed a software program that processes data acquired by magnetometers and turns on a red light and a beep sound when a magnetic anomaly is identified. Figure 1 shows alarms generated while a diver was crossing the barrier swimming first above the sensors n. 1 and then halfway between n. 2 and n. 3.
A multi-year study carried out in several Italian ports allowed us to obtain an estimate of the hydro-barometric transfer factor J_{ph} from atmospheric pressure variations to consequent sea level fluctuations (Newtonian correlation between atmospheric weight variations and sea level adjustments) [Faggioni et al., 2013].
We analyzed many occurrences of this phenomenon (meteorological tides, i.e. due to variations in atmospheric pressure) in Italian ports (data acquired by means of Italian National Tide-gauge Network, managed by ISPRA - Italian Institute for Environmental Protection and Research) and for each of them we calculated the value of the hydro-barometric transfer factor as:

$$J_{ph} = \Delta h / (\Delta p \; [cm \cdot hPa^{-1}] \qquad (1)$$

where is the variation of sea level, while represents the gradient of atmospheric pressure [Faggioni et al., 2006]. Then, a multi-year statistical analysis on all the events that have occurred allowed us to obtain, port by port, an estimate of the J_{ph} factor. It often assumes, in many ports, values even double compared to the typical 1 cm · hPa-1 of the offshore. The knowledge of the J_{ph} factor is very useful in Harbour Waterside Management (optimization of ship navigation, dock performances, boat moorings, refloating of stranded ships, ...) to forecast the water depth starting from the expected atmospheric pressure [Faggioni et al., 2008]. Obviously, a low tide within a port hinders navigation; vice versa, a high tide facilitates navigation.
The effects of pressure variations on water depth have been applied to bathymetric maps in several Italian ports: sea level goes down consequently to an atmospheric pressure increase, and goes up consequently to a pressure decrease; then, pressure variations change the bathymetry of a basin. A pressure change can be converted, through J_{ph}, into an expected sea level variation and then into a new bathymetric map.
To automate this, a software program is being developed for dynamic updating bathymetry maps in harbours (Figure 2), depending on the sea level measured in real time (by means of mareographic stations) or the expected atmospheric pressure.
Two-threshold levels variable ship by ship, depending on its draft, divide the harbour basin into three zones characterized by different colours (green, yellow and red); these colours indicate three water depth ranges (respectively deep or allowed for that vessel, shallow or warning, forbidden). By varying the sea level, an area that initially was allowed (green), can become a warning (yellow) or prohibited area (red): this implements what is called a "virtual traffic light" customized for each ship.
In the dynamic bathymetric map of the port of Livorno shown in Figure 2 (thresholds 9 and 12m, respectively), the same point (UTM coordinates: easting 604625 m, northing 4822760 m, at the center of the white circle) changes from green to yellow light. In fact, its depth decreases from 12.44m to 11.71m, due to sea level variation from 13/01/2017 10:10.00 UTC to 14/01/2017 01:30.00 UTC; more generally, the "green channel" inside the white circle becomes narrower.
Experimental tests carried out on the magnetic detection system, in undersea environments with high magnetic noise, has provided extremely positive operational results in detecting intruders transiting in its proximity, both in the case of divers equipped with commercial air tanks and in the case of rebreathers. In the context of antiterrorism systems for harbour protection, the magnetic detection system is required to support the acoustic component in peripheral acoustic shadow zones close to the seabed, docks and so on.

This abstract also highlights the importance of analysis of hydro-barometric inversion in harbour safety. Its applications for Harbour Waterside Management allow us to improve the effectiveness in maritime works and to optimize ship navigation, dock performance, boats mooring and refloating of stranded ships.

The authors wish to thank ISPRA for providing meteo-mareographic data acquired in Italian ports. These activities were possible thanks to funding from the Italian Ministry of Defence (for harbour protection) and several Italian Port Authorities (for coastal navigation safety). The authors also thank SkyTech Srl and Dr. Davide Leoncini for their contribution in the software development.

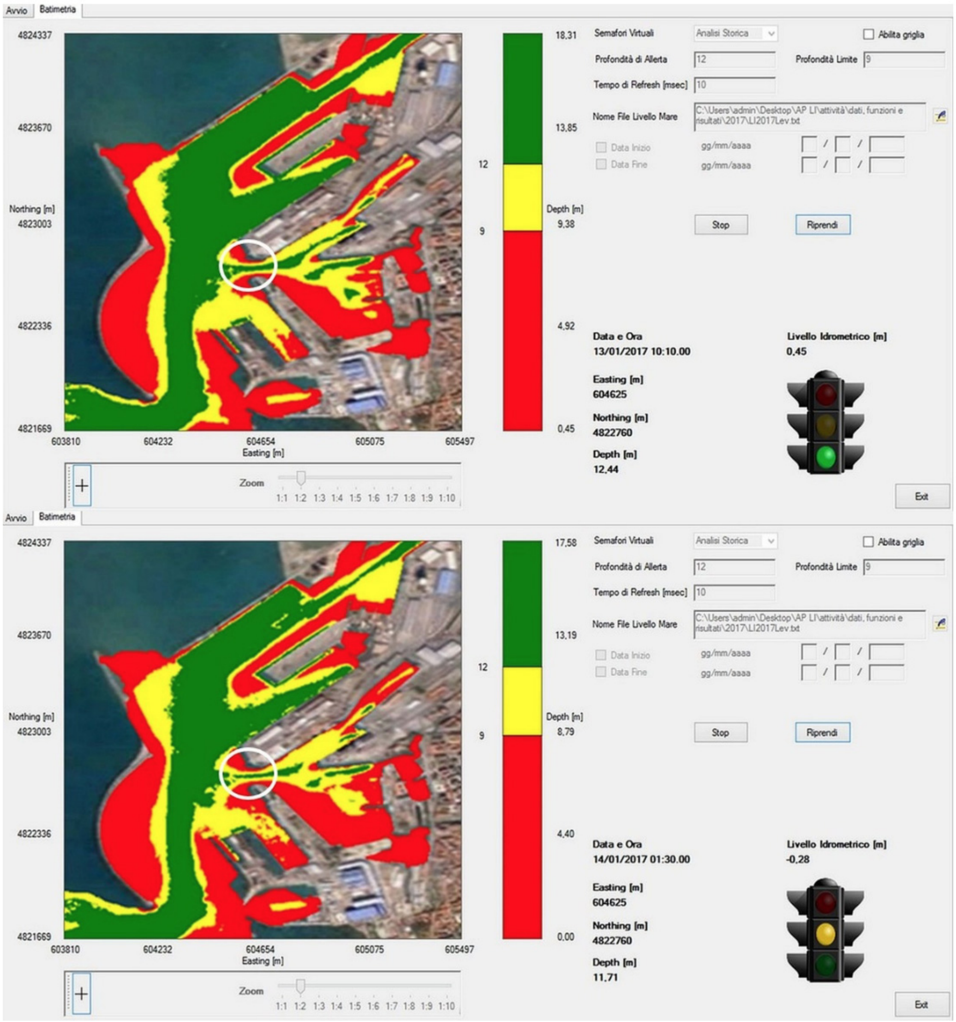


Figure 2 Dynamic bathymetric map in the port of Livorno (thresholds 9 and 12 m, respectively) from 13/01/2017 10:10.00 UTC to 14/01/2017 01:30.00 UTC.

References

Faggioni O., Soldani M., Cozzani G. and Zunino R., (2018). *Informative signal analysis: metrology of the underwater geomagnetic singularities in low-density ionic solution (sea water)*. Scientific Research Publishing, Journal of Signal and Information Processing, vol. 9, n. 1, pp. 1-23, Wuhan, China.

Nasta S., Faggioni O. and Soldani M., (2015). *Underwater magnetometric detection of quasi-punctiform kinematic sources: from the metrology of the field to the metrology of the singularity*. CD-ROM Proceedings of MTS/IEEE OCEANS'15 Conference, May 18-21, Genova, Italy.

Faggioni O., Soldani M. and Leoncini D.A., (2013). *Metrological Analysis of Geopotential Gravity Field for Harbor Waterside Management and Water Quality Control*. Hindawi Publishing Corporation, International Journal of Geophysics, vol. 2013, 12 pp. - Special Issue on Geophysical Methods for

Environmental Studies, New York.
Faggioni O., Soldani M., Gabellone A., Hollett R.D. and Kessel R.T., (2010). *Undersea harbour defence: a new choice in magnetic networks*. Elsevier B.V., Journal of Applied Geophysics, vol. 72, n. 1, pp. 46-56, Amsterdam, The Netherlands.
Faggioni O., Soldani M., Leoncini D., Gabellone A. and Maggiani P.V., (2009). *Time domain performances analysis of underwater magnetic SIMAN Systems for port protection.* Dynamic Publishers, Journal of Information Assurance and Security, vol. 4, n. 6 - Special Issue on Information Assurance and Data Security, pp. 538-545, Atlanta, Georgia.
Faggioni O., Soldani M., Piangiamore G.L., Ferrante A., Bencivenga M., Arena G. and Nardone G., (2008). *Harbour Water Management for port structures and sea bottom design, coast proximity navigation management, water quality control.* Proceedings of Mediterranean Days of Coastal and Port Engineering, October 7-9, Palermo, Italy.
Gabellone A., Faggioni O., Soldani M. and Guerrini P., (2007). *CAIMAN Experiment*. CD-ROM Proceedings of UDT Europe 2007 Conference, June 5-7, Napoli, Italy.
Faggioni O., Arena G., Bencivenga M., Bianco G., Bozzano R., Canepa G., Lusiani P., Nardone G., Piangiamore G.L., Soldani M., Surace L. and Venzano G., (2006). *The Newtonian approach in meteorological tide waves forecasting: preliminary observations in the East Ligurian harbours*. Ed. Compositori, Annals of Geophysics, vol. 49, n. 6, pp. 1177-1187, Bologna, Italy.

Scientific outreach to reduce the gap between society and the marine science research

Marina Locritani[1] and Giuliana D'Addezio[2]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Fezzano, La Spezia, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Sismologia e Tettonofisica – Laboratorio Divulgazione Scientifica e Attività Museali, Roma, Italy

marina.locritani@ingv.it

The research community has the responsibility to sharing knowledge about environmental concern and technological innovations with the aim to increase the awareness in people about the protection of the environment and the human species. The Laboratory of INGV for Marine Technologies called "Laboratorio per le Tecnologie Marine (LTM)" starting the outreach activity in Porto Venere, in the year 2010, with the aim to disseminate toward schools and general public the marine environment value, the great problems that affecting it and the activities that the research community take every day to face these topics [Merlino et al., 2014].
Researchers use a lot of outreach instruments to reach the same objective: capture people interest! One of the best ways is to involve society in an active path, stimulating them emotions and personal thinks. During the years was been organized: didactical laboratories, workshops, conferences, dissemination events, work related learning projects, citizen sciences projects, educational games [Locritani et al., 2017] and documentaries. The development of educational game is an important step to reduce the gap between science and kids or young people. The LTM designed four different games dedicated to the students from Elementary to High school (Figure 1).

Figure 1 Educational games realized by the Porto Venere LTM. The first one game called "Octopus game" (figure a) is dedicated to Elementary school students and concern the marine ecosystem. The second one game called "MEMORY" speak about Earthquakes, Volcanoes and Environment is created for Middle school students (figure b). The third one game called "Alien Species" (figure c) is a memory for Middle school students and the last one game called "MAREOPOLI" (figure d) describes the historical evolution of the tide theory and the scientific related issue about it and is addressed to High school students.

Figure 2 Some of the covers of the courses present in the ENVRIplus e-learning platform (https://training.envri.eu/course/index.php?categoryid=16). The platform included: Aquatic domain, Solid Earth, Atmospheric domain, Ecosystem/Biosphere and Multi-domain topics.

In the last years the collaboration with the Unità Funzionale Sistemi Integrati per le Infrastrutture Ambientali Marine (INGV) and with the Laboratorio di Divulgazione Scientifica e Attività Museali (INGV) in the framework of ENVRIplus Project (H2020 n. 654182), allowed us to enlarge the audience to the European context. Our role in the project was been to implement an e-learning platform (Figure 2) for the teachers and the students [D'Addezio, 2018a] and to elaborate the contents of a multi-media educational game (ENVRgame). The e-learning platform was developed on the base of the results of a specific questionnaire devote to catch the teachers needs and help in feeding the platform with targeted contents [D'Addezio et al., 2018b]. The questionnaire was been compiled from 137 teachers from 29 countries. Moreover, others specific questionnaires have been implemented and used to evaluate, during the years and different projects [Locritani et al., 2019] the effect of the outreach events in the involving people or students. Some results highlight that younger students are most receptive then the older ones [Locritani et al., 2015].

References

Locritani M., Merlino S., Abbate M., (2019). *Assessing the citizen science approach as tool to increase awareness on the marine litter problem.* Marine Pollution Bulletin, special issue 6IMDC, 140 (320-329).

D'Addezio G., Locritani M., (2018a). *Teacher experiences, views and proposals: first results from a questionnaire developed in the frame of ENVRIPLUS project*. American Geophysical Union, Fall Meeting 2018, abstract #ED13D-0779.

D'Addezio G. and Amici S., (2018b). *Involving student in research: the school-work interchange experience at Istituto Nazionale di Geofisica e Vulcanologia (INGV)*. AGU Fall Meeting Abstracts. 2018.

Locritani M., Garvani S., Di Laura F., Merlino S., Talamoni R., (2017). *Giocando verso uno Sviluppo Sostenibile: il contributo della sede INGV di Portovenere nella realizzazione di giochi didattico-scientifici.* Miscellanea INGV. N° 39. pagg. 22. ISSN 2039-6651.

Locritani M., Batzu I., Carmisciano C., Muccini F., Talamoni R., La Tassa H., Stroobant M., Guccinelli G., Benvenuti L., Abbate M., Furia S., Benedetti A., Bernardini M.L., Centi R., Casale L., Vannucci C., Giacomazzi F., Marini C., Tosi D., Merlino S., Mioni E., Nacini F., (2015). *Feeling the pulse of Public Perception of Science: does Research make our hearts beat faster?* OCEANS'15 MTS/IEEE. Paper in conference proceedings.

Merlino S., Stroobant M., Locritani M., Talamoni R., Furia S., Muccini F., Abbate M., Nacini F., Mori A. e Carmisciano C., (2014). "ALLA SCOPERTA dei TESORI del MARE" Scienza e Tecnologia, Memoria Popolare e Identità Culturale di una città della costa ligure. Miscellanea INGV n. 22, ISSN 2039- 6651, Anno 2014

SEACleaner project: citizen science and marine litter monitoring

Marina Locritani[1] and Silvia Merlino[2]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Fezzano, La Spezia, Italy
[2]Consiglio Nazionale delle Ricerche – Istituto di Scienze Marine - CNR-ISMAR, Pozzuolo di Lerici p/o Forte Santa Teresa, La Spezia, Italy

silvia.merlino@sp.ismar.cnr.it
marina.locritani@ingv.it

The problem of marine litter (ML) induced in the last years a general growing interest towards micro and macro plastic pollution. The scientific community has recently intensified the efforts on this issue, amongst the others by describing the abundance, the typology and the distribution of litter in several pelagic and coastal areas, also taking advantage of specific Directives at European level such as the Marine Strategy Framework Directive (MSFD), which defines ML as one of the 11 principal descriptors.
The SEACleaner project [Merlino et al., 2015a], developed by CNR-ISMAR in collaboration with INGV and the Ligurian Cluster of Marine Technology (DLTM), has been monitoring some specific coastal sites inside 5 Italian Marine Protected Areas (MPAs) surrounding the Pelagos Sanctuary, since 2013. The Project, borne as citizen science and educational approach, involves non-governmental organizations (NGOs), volunteers and high school students in beach surveys (Figure 1).
The protocol used to classify beached litter in term of number, category and size, has been implemented following the recommendations of the MSFD [Merlino et al., 2015a] and it allows students and volunteers to easily contribute to the beached macro ML research, overcoming the lack of current data on beached ML and, at the same time, providing correct information and

Figure 1 Monitoring activity in Regional Park of Migliarino, San Rossore, Massaciuccoli. The figure shows the beach of San Rossore (panel a), the activity of litter collection by some students (panel b), the activity of litter counting (panel c) and the activity of litter cataloging in term of typology and size categories (panel d) as suggest the specific SEACleaner protocol.

raising public awareness of this problem. An assessing study [Locritani et al., 2019] highlights in fact that citizen science approaches increase knowledge and sensitiveness on the ML problem in students that participated to SEACleaner project. The results of the scientific monitoring results carried on in 11 beaches located in 5 MPAs [Giovacchini et al., 2018], highlights differences in the abundances and typologies of ML, depending on the proximity to the rivers and on the kind of the beach, which can be summarized as Urban (in residential and touristic areas, cleaned on regular basis), Urbanized (close to urban centers, low human presence but less regular cleaning), Natural (MPAs restricted areas, not cleaning). In detail, Natural sites, and particularly MPAs close to river mouths, show a higher density of macro ML compared to other areas, probably due to the lack of frequent cleaning activities. The prevailing typology of ML found in each beach is related to its "Urbanization" class, with Natural beaches showing the highest percentage of plastic and the lowest percentage of litter categories related with touristic presence.
SEACleaner is now focusing on micro-plastic surveys (Figure 2) in the same area of previous macro ML study was conducted. This will allow to verify if the accumulation of macro-plastic on the beaches favors fragmentation and so the generation of micro-plastic, causing the less accessible MPAs to become possible sources of micro-plastic.

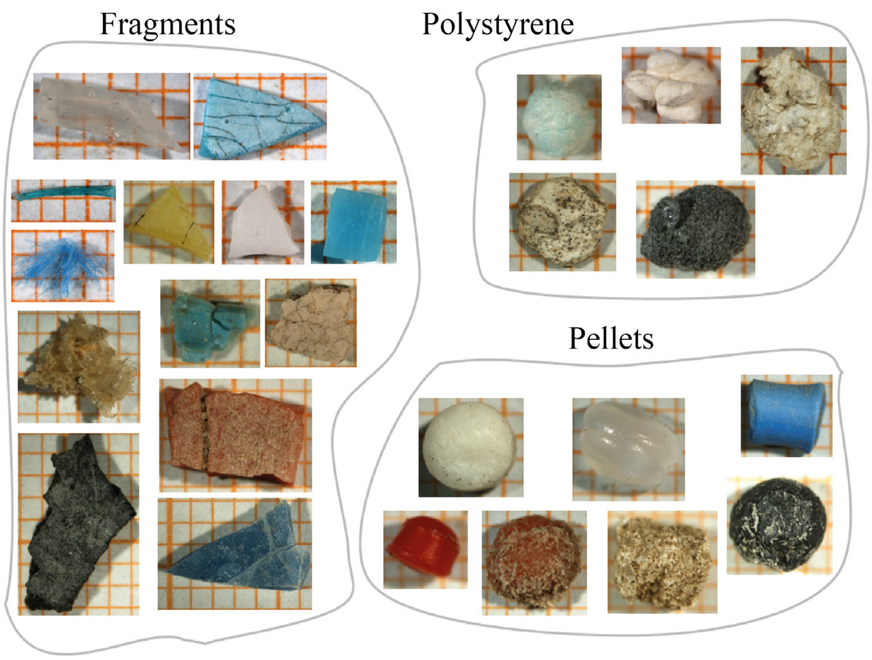


Figure 2 The classification of micro-plastics collected during SEACleaner projects. Each micro-plastic was been classified for: color, size, degradation.

References

Locritani M., Merlino S., Abbate M., (2019). *Assessing the citizen science approach as tool to increase awareness on the marine litter problem*. Marine Pollution Bulletin, special issue 6IMDC, 140 (320-329).

Giovacchini A., Merlino S., Locritani M., Stroobant M., (2018). *Spatial distribution of marine litter along italian coastal areas in the Pelagos Sanctuary (Ligurian Sea - NW Mediterranean Sea): a focus on Natural and Urban beaches*. Marine Pollution Bulletin.

Merlino S., Locritani M., Stroobant M., Mioni E., Tosi D., (2015a). *SeaCleaner: Focusing Citizen Science and Environment Education on Unraveling the Marine Litter Problem*. Marine Technology Society Journal. Blue Futures: Educating the Next Generation. Vol. 49, N. 4 – July/August 2015.

Merlino S., Locritani M., Giovacchini A., Strada S., Lavarello I., Lombardi D., (2015b). *Marine litter in the Pelagos Sanctuary: alone we can do so little. Together we can do so much!* Innovation in environmental education: ICT and intergenerational learning. 24-25 September 2015 – Florence, Italy. Paper in conference proceeding.

QUADERNI di GEOFISICA

ISSN 1590-2595 http://istituto.ingv.it/it/le-collane-editoriali-ingv/quaderni-di-geofisica.html/

I QUADERNI DI GEOFISICA (QUAD. GEOFIS.) accolgono lavori, sia in italiano che in inglese, che diano particolare risalto alla pubblicazione di dati, misure, osservazioni e loro elaborazioni anche preliminari che necessitano di rapida diffusione nella comunità scientifica nazionale ed internazionale. Per questo scopo la pubblicazione on-line è particolarmente utile e fornisce accesso immediato a tutti i possibili utenti. Un Editorial Board multidisciplinare ed un accurato processo di peer-review garantiscono i requisiti di qualità per la pubblicazione dei contributi. I QUADERNI DI GEOFISICA sono presenti in "Emerging Sources Citation Index" di Clarivate Analytics, e in "Open Access Journals" di Scopus.

QUADERNI DI GEOFISICA (QUAD. GEOFIS.) welcome contributions, in Italian and/or in English, with special emphasis on preliminary elaborations of data, measures, and observations that need rapid and widespread diffusion in the scientific community. The on-line publication is particularly useful for this purpose, and a multidisciplinary Editorial Board with an accurate peer-review process provides the quality standard for the publication of the manuscripts. QUADERNI DI GEOFISICA are present in "Emerging Sources Citation Index" of Clarivate Analytics, and in "Open Access Journals" of Scopus.

RAPPORTI TECNICI INGV

ISSN 2039-7941 http://istituto.ingv.it/it/le-collane-editoriali-ingv/rapporti-tecnici-ingv.html/

I RAPPORTI TECNICI INGV (RAPP. TEC. INGV) pubblicano contributi, sia in italiano che in inglese, di tipo tecnologico come manuali, software, applicazioni ed innovazioni di strumentazioni, tecniche di raccolta dati di rilevante interesse tecnico-scientifico. I RAPPORTI TECNICI INGV sono pubblicati esclusivamente on-line per garantire agli autori rapidità di diffusione e agli utenti accesso immediato ai dati pubblicati. Un Editorial Board multidisciplinare ed un accurato processo di peer-review garantiscono i requisiti di qualità per la pubblicazione dei contributi.

RAPPORTI TECNICI INGV (RAPP. TEC. INGV) publish technological contributions (in Italian and/or in English) such as manuals, software, applications and implementations of instruments, and techniques of data collection. RAPPORTI TECNICI INGV are published online to guarantee celerity of diffusion and a prompt access to published data. A multidisciplinary Editorial Board and an accurate peer-review process provide the quality standard for the publication of the contributions.

MISCELLANEA INGV

ISSN 2039-6651 http://istituto.ingv.it/it/le-collane-editoriali-ingv/miscellanea-ingv.html

MISCELLANEA INGV (MISC. INGV) favorisce la pubblicazione di contributi scientifici riguardanti le attività svolte dall'INGV. In particolare, MISCELLANEA INGV raccoglie reports di progetti scientifici, proceedings di convegni, manuali, monografie di rilevante interesse, raccolte di articoli, ecc. La pubblicazione è esclusivamente on-line, completamente gratuita e garantisce tempi rapidi e grande diffusione sul web. L'Editorial Board INGV, grazie al suo carattere multidisciplinare, assicura i requisiti di qualità per la pubblicazione dei contributi sottomessi.

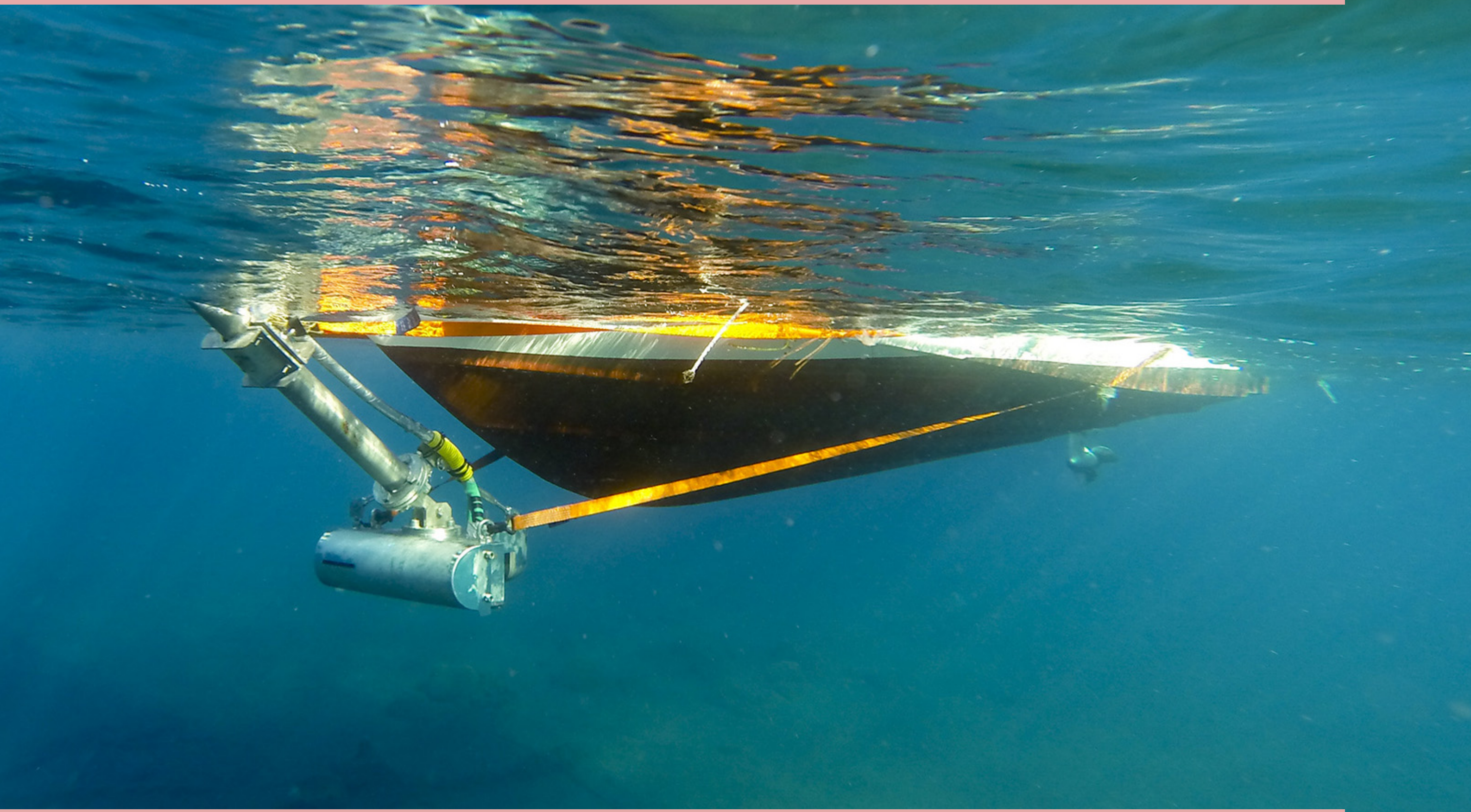
MISCELLANEA INGV (MISC. INGV) favours the publication of scientific contributions regarding the main activities carried out at INGV. In particular, MISCELLANEA INGV gathers reports of scientific projects, proceedings of meetings, manuals, relevant monographs, collections of articles etc. The journal is published online to guarantee celerity of diffusion on the internet. A multidisciplinary Editorial Board and an accurate peer-review process provide the quality standard for the publication of the contributions.

Coordinamento editoriale e impaginazione
Francesca DI STEFANO, Rossella CELI
Istituto Nazionale di Geofisica e Vulcanologia

Progetto grafico e impaginazione
Barbara ANGIONI
Istituto Nazionale di Geofisica e Vulcanologia

Via di Vigna Murata, 605
00143 Roma
tel. +39 06518601

www.ingv.it



ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA