The acoustic signature of shallow hydrothermal brine of Panarea: source mechanism recognition and behaviour changes over mid-term observations

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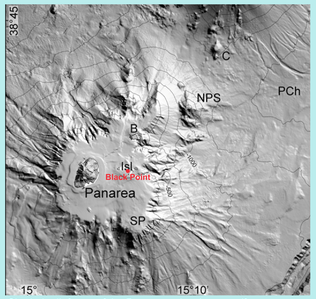
THE TEST SITE

Panarea island, in the eastern sector of Aeolian Arc (Southeastern Tyrrhenian Sea, Italy), hosts one of the biggest shallow hydrothermal field of the Mediterranean Sea, characterized by gas vents and hot hydrothermal springs with peculiar features. The so-called **"Black Point" spring** shows unique characteristics with respect to the surrounding field.

Location of the Panarea volcanic group in the Aeolian archipelago (from Lucchi *et al.*, 2013).



Shaded relief map of the Panarea volcanic group (from Romagnoli *et al.*, 2013).


Pole beacon of the fixed underwater observatory installed nearby the hot hydrothermal spring of the Panarea shallow hydrothermal field.

METHODS AND INSTRUMENTATION

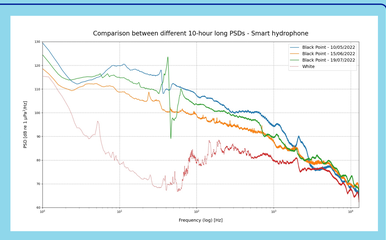
Deployment of the icListen smart hydrophone in the proximity of "Black Point" vent.

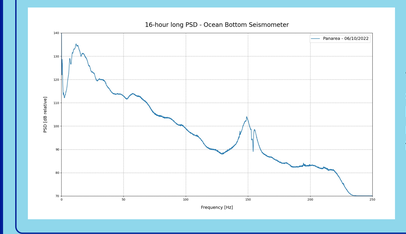
In the period between May-July 2022, three short-time deployments of an **icListen smart hydrophone** were carried out in the proximity of the thermal emission. The identification of acoustic sources related to the variety of processes linked to fluid dynamics of "Black Point" gave a new comprehension to the spectral envelope of the long-term data acquired by the pre-existent **multiparameter observatory**. Focussing on the new findings, spectral analysis has been computed over a 5 month-long period data series.
The application of customized thresholding algorithms allowed the identification of acoustic sources related to bubble nucleation processes induced by the turbulent flowing fluid throughout uneven conduits.
From the beginning of October 2022, the sensors set was completed by a **Trillium Compact Ocean Bottom Seismometer**, which provides the three components of translational ground motion in the **wide band [120 s – 250 Hz]**.
A deeper understanding of the hydrothermal flow mechanisms will be reached thanks to the appliance of innovative, multiparametric approaches.


Multidisciplinary seafloor observatory installed close to the "Black Point" vent. This fixed observatory is connected by an umbilical cable to a surface buoy, which provides power to the whole system by solar panels and a battery pack.

RESULTS

The performed **spectral analysis** permitted the identification of different energetic frequency peaks and narrow tones, diverging from the ambient background noise.
The bandwidth extension, comprising both infrasonic and audible bands, suggests the coexistence of **different source mechanisms**, similarly to deep hydrothermal sites.



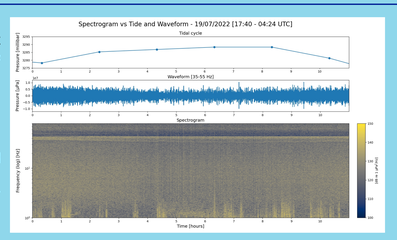


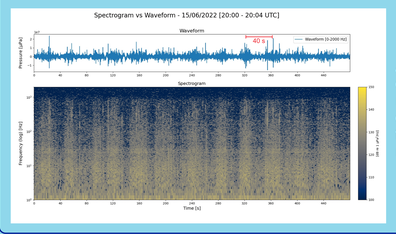
The deployment of an OBS in October 2022 further confirmed the mechanisms behind the fluid dynamics. Narrow peaks (~25 Hz and ~150 Hz) highlight the **resonance of the conduit** crossed by ascending turbulent flow.

Pressure perturbation associated with **mass flux variation** at the vent orifice may represent one of the possible monopole acoustic sources at the "Black Point" vent. From the equation:

$$P(r) \approx \frac{3\pi D P_p}{16r}$$

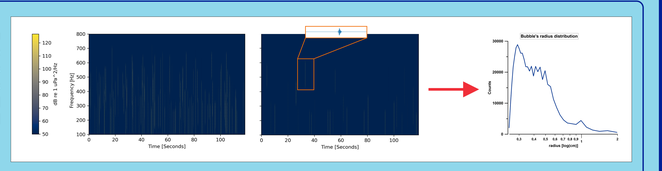
a rough approximation of fluid flow velocity has been performed as a proxy of the pressure field radiated from the source.
The **estimated mean fluid velocity** covers the range [0.35 – 0.65] m/s. These values are coherent with *in situ* observations.

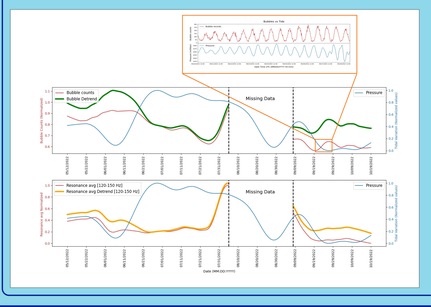




A quasi-stationary 40 s periodicity has been observed, likely due to pulsating exit flow dynamics. **Bubble nucleation** represents one of the key factors in the hydrothermal flow dynamics of "Black Point" vent. Bubble's radius as well as the frequency of events can give fundamental information for monitoring volcanic activity.

A **threshold algorithm** has been developed to discriminate the oscillation signature of bubbles from the background noise. This algorithm was instructed to record the emission rate of bubbles and the frequency peak.





The variation over time of both bubbles counts and resonance energy level has been extracted. Time series of bubble counts shows a **clear modulation induced by the tidal cycle**. Both time series synchronously diverge with respect to natural forces, likely **triggered by endogenous input**.

CONCLUSIONS

- Stationary and almost persistent acoustic contributions in well defined frequency ranges highlight different mechanisms
- Natural forces induce modulation in the behaviour of the hydrothermal vent flow dynamics
- A deep understanding of the acoustic sources shed light over the behaviour of the hydrothermal reservoir, acting as a powerful proxy to identify fluid flux change induced by magmatic contribution over long-term deployments
- Passive acoustics may represent a useful, sustainable and safe method for investigation of hydrothermal vents, as direct measures can be challenging due to the extreme environmental conditions
- Coupling passive acoustic signals with broadband seismic data allows to better define the evolution of the hydrothermal field activity over time

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