CTD data profiling to assess the natural hazard of active submarine vent fields: the case of Santorini Island

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BACKGROUND

Almost three quarters of known volcanic activity on Earth occurs in underwater locations. The presence of active hydrothermal vent fields in such environments is a potential natural hazard for the environment, the society, and the economy. Despite its importance for risk assessment and risk mitigation, monitoring of the activity is impeded by the remoteness and the extreme conditions of underwater volcanoes. Kolumbo underwater volcano, 7 Km NE of Santorini island, featuring an active hydrothermal vent field, which has shown near–explosive dynamics in the recent years (Carey et al., 2013). CTD (conductivity, temperature, depth) time series from an earlier expedition in 2010–2011 (Bakalis et al., 2017), which investigated mainly the northern part of the vent field, have been used to develop an advanced mathematical model based on the Generalized Moments Method to describe the underlying mechanisms governing the hydrothermal vent activity. The model was further tested successfully in the inactive caldera near Nisyros Island (Dodecanese, Greece) (Bakalis et al., 2018).

The submerged volcanic activity of Santorini and the large difference of population present on the island between the winter and summer seasons, all within a partially enclosed system, make Santorini and its nearby active hydrothermal vent fields (e.g. Kolumbo) an ideal place for detailed investigation. The main objective of this work is to study high–frequency recorded CTD data in the water column over the Santorini caldera and the active neighboring hydrothermal vent fields. The data will be used to create depth profiles of the oceanographic properties such as conductivity, temperature and salinity and map their anomalies over active vents.

THE GEOMAR MISSION

In 2017, GEOMAR in collaboration with the National and Kapodistrian University of Athens, used an Autonomous Underwater Vehicle (AUV) to investigate the evolution of the NE–trending Santorini–Kolumbo line, where it also collected CTD data. The mission lasted 25 days, 19 of which were onboard operations. Detailed CTD 3D profiles have been reconstructed from the raw data to study Kolumbo's active hydrothermal vent field and Santorini's vent field (Camilli et al., 2015) to a full extent. Here we present the results from the 15-hour survey held on the 25th March 2017, during the POS510 expedition targeting the Santorini vent field located in the North Basin of the Santorini Caldera, as seen in Fig. 3.

RESULTS

In Fig. 4, the depth profiles of the Temperature (T), Conductivity (C), Salinity (S) and Sound Velocity(V) are presented, respectively. The change in temperature seems to follow a typical open–ocean CTD profile, with higher values near the surface and the thermocline zone, which tend to become smaller as the depth reaches its maximum values near the seafloor and above the vent field. This behavior is evident in the profiles of salinity, conductivity and sound velocity, as well. However, an anomaly emerges at the depth of 350 m in the C and S profiles, as the CTD sensor is placed directly above the vent sources, as can be seen at the profiles recorded between 250 and 350 m. The anomaly is attributed to existing vent activity, which is not so intense as to change the local thermodynamics of the system and have a significant impact on the T profiles, but is recorded in the high–sensitivity C and S sensors, indicating that hydrothermal fluids are entering the water column from the crust in a weak, but continuous fashion.

DISCUSSION

As the present results are the first ones produced from this expedition, they provide strong motivation for further investigation. CTD anomalies in depth profiles will be fully documented, while a 3D map of vent activity have been constructed from measurements at constant depth of AUV operation (Fig. 5.). These steps are crucial towards developing a supervised machine–learning algorithm able to provide a reliable description of the dynamic conditions over the hydrothermal vent field in near–real–time fashion and potentially provide the means to predict explosive conditions. The impact on developing appropriate mechanisms and policies to avoid the associated natural hazard is expected to be immense.

ACKNOWLEDGEMENT

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BIBLIOGRAPHY

- Bakalis, E., et al., 2017. Breathing modes of Kolumbo submarine volcano (Santorini, Greece), Sci. Rep. 7, 46516.
- Bakalis, E., Mertzimekiset al., 2018. Temperature and Conductivity as Indicators of the Morphology and Activity of a Submarine Volcano: Avyssos (Nisyros) in the South Aegean Sea, Greece, Geosciences 8, 193.
- Camilli R., et al., 2015. The Kallisti Limnes, Carbon Dioxide-Accumulating Subsea Pools. Scientific Reports 3:2421.
- Carey S., et al., 2013. CO_2 Degassing from Hydrothermal Vents at Kolumbo Submarine Volcano, Greece and the Accumulation of Acidic Crater Water. Geology 9:1035-1038.
- Hannington, M., et al., 2017. Rifting and Hydrothermal Activity in the Cyclades Back-arc Basin: Cruise Report of RV Poseidon, POS510, Catania-Heraklion 06.03.17-29.03.17, 361 p.
- Nomikou P., et al., 2014. The emergence and growth of a submarine volcano: The Kameni islands, Santorini (Greece). GeoResJ 1–2:8–18.
- Nomikou P., et al., 2016. Post-eruptive flooding of Santorini caldera and implications for tsunami generation. Nature Communications | 7:13332 | DOI: 10.1038/ncomms13332.

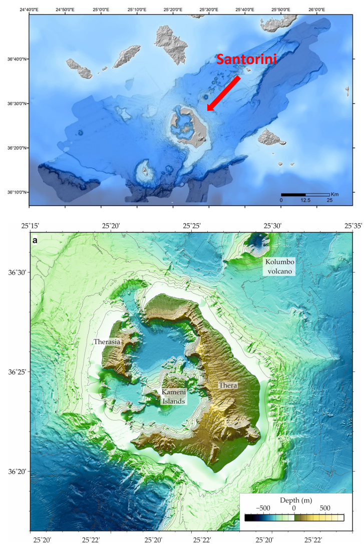

Fig. 1. *High resolution bathymetric Map of Santorini volcano (Nomikou et al., 2016).*

Fig. 2. *AUV-Abyss (GEOMAR) operations on board R/V POSEIDON (March 2017) (photo credits to Sven Peterson).*

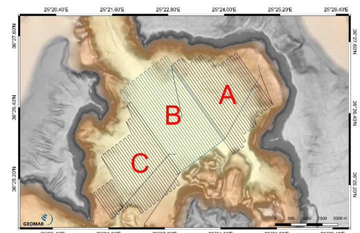

Fig. 3. The area of the North Basin of the Santorini caldera that was surveyedwith AUV during POS510. (Nomikou et al., 2014; Hannington, M., et al., 2017).

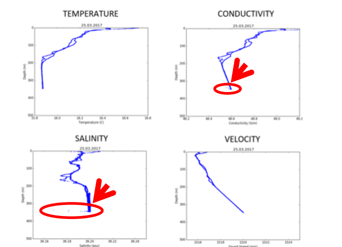

Fig. 4. Temperature, Conductivity, Salinity and Sound Velocity profiles according to the 25-3-2017 survey in the North Basin of Santorini. Anomalies in the profiles are circled with ovals. We estimate the percentage of change according to the following equation:

Conductivity: $100*|C_{max} - C_{average}|/C_{average} = 100*|48.5524 - 48.59047|/48.59047 = 0.0783$ %

Salinity: $100*|S_{max} - S_{average}|/S_{average} = 100*|39.168 - 39.19991|/39.19991 = 0.0814$ %

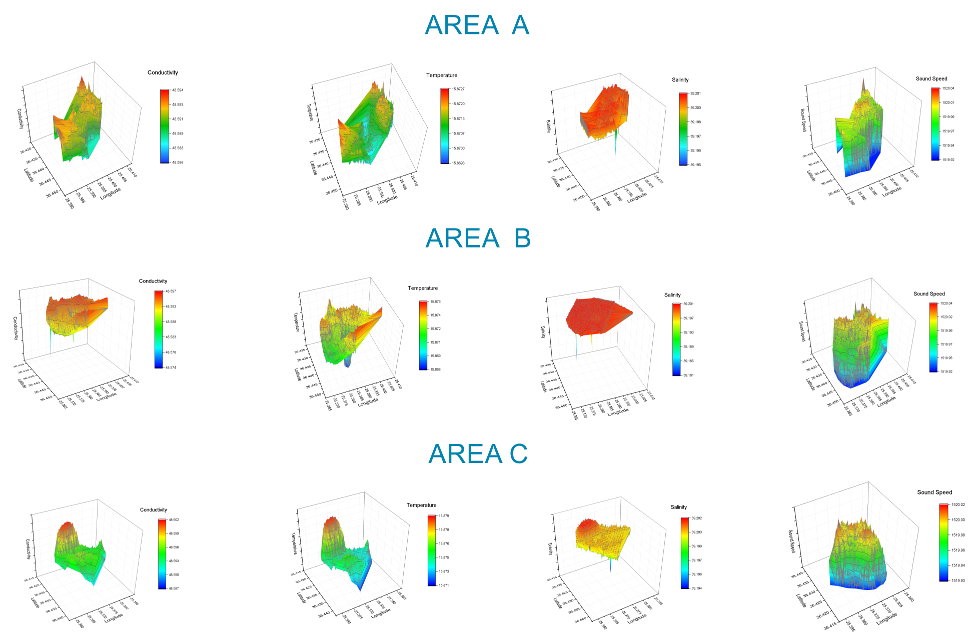

Fig. 5. *Reconstructed 3D maps from recorded data of conductivity (S/m), temperature (˚C), salinity and sound velocity (m/s), for the three separate areas in March 2017, investigated in 3 separate days: the 11th March (Area A), the 25th (Area B) and the 26th (Area C).*