CONDUCTIVITY AND TEMPERATURE AS INDICATORS OF HYDROTHERMAL ACTIVITY: A COMPARISON OF TWO SUBMARINE VOLCANOES (GREECE)

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BACKGROUND

An efficient method to study the characteristics of submarine volcanoes is to employ sensors aboard ROV/AUV, able to continuously record CTD data in situ (Conductivity, Temperature, Depth) in the water column (Christopoulou *et al.*, 2016). The Generalized Moments Method (GMM) is a relatively new method used broadly in various fields to understand the random processes that drive various systems (Lovejoy *et al.*, 1995) and has been previously applied on submarine volcanoes (Bakalis *et al.*, 2017; Bakalis *et al.*, 2018; Dura *et al.,* 2021).

This study focuses on the application of the GMM within the northern caldera of Santorini and in the submarine volcano Avyssos, Nisyros. Santorini and Nisyros are active submarine volcanoes (Nomikou, 2004) along The Hellenic Volcanic Arc, that has resulted from the ongoing subduction in the Eastern Mediterranean region (Papanikolaou *et al.*, 2001). Both volcanoes have given large historical eruptions in the past. The Minoan eruption (3.6 ka) in Santorini, for instance, after which volcanic activity was concentrated mainly in the intercaldera area, building up the Kameni islands. In the Nisyros area the only reported historical explosions are related to the formation of several phreatic craters inside the caldera (Dietrich *et al.,* 2018). To this date, explorations of the caldera floors in both submarine volcanoes have failed to find any high-temperature hydrothermal vents (Nomikou, *et al.*, 2013a).

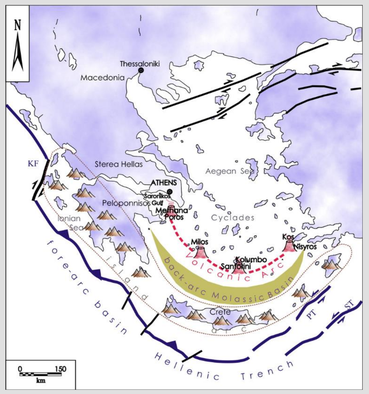


Fig. 1. Location of Santorini and Nisyros along the Hellenic Volcanic Arc (Nomikou *et al.,* 2012).

Exploration

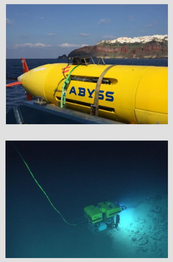


Fig. 2. Images of the AUV taken from the Santorini mission in 2017 (above; photo credit to crew members of the R/V Poseidon crew), and ROV Hercules conducting CTD measurements in Avyssos caldera (below; photo credit to crew members of the E/V Nautilus).

GMM:

1. Time Series

$$y_n(\Delta) = \sqrt{\left(x(n+\Delta) - x(n)\right)^2}$$

2. Moments

$$\rho(q,\Delta) = \frac{1}{T-\Delta}\sum_{n=1}^{T-\Delta}\left(y_n(\Delta)\right)^q$$

3. Structure Function

$$z(q) = hq - \frac{C}{a-1}(q^a - q)$$

Δ is the lag time

T is the total length of the trajectory

q = 0.25, 0.5, 0.75, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

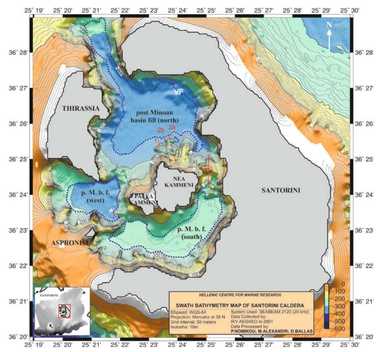
HIGHLIGHTS

- The overall behavior is subdiffusive (0<γ<1), apart from the conductivity in Santorini, which is superdiffusive (1<γ<2).
- Both submarine volcanoes have a non-conservative field (H>0). The value of C is close to 0, which indicates a slightly inhomogeneous mean field.
- The Levy index in Santorini (a = 1) corresponds to a Cauchy-Lorentz distribution while in Nisyros (a = 2) to a lognormal distribution.
- Volcanic activity inside each caldera has nearly the same multifractal behavior everywhere, but the underlying mechanisms governing each volcano may differ.

Bibliography

SANTORINI

Survey date and time: March 25, 2017, 22:00-23:00 | Duration: 60 mins



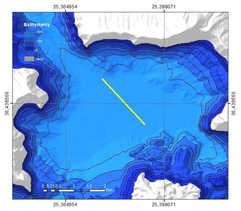


Fig. 3. Left: Swath bathymetry map of the Santorini caldera (Nomikou *et al.,* 2010). Right: The area covered by AUV Abyss during the 60 minute interval studied here. The vehicle was always closest to the seafloor.

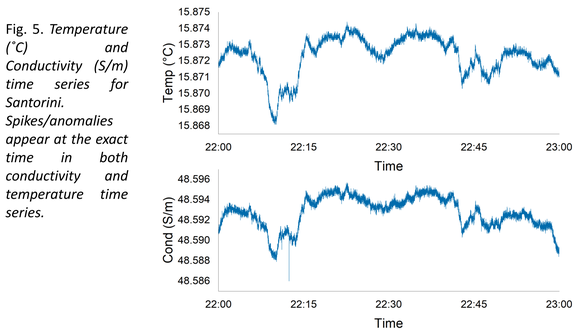


Fig. 5. *Temperature (˚C) and Conductivity (S/m) time series for Santorini. Spikes/anomalies appear at the exact time in both conductivity and temperature time series.*

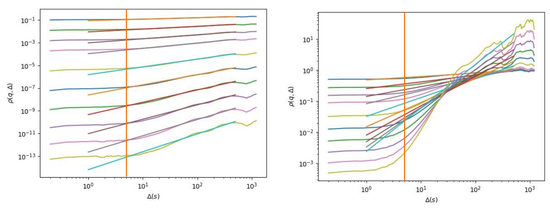
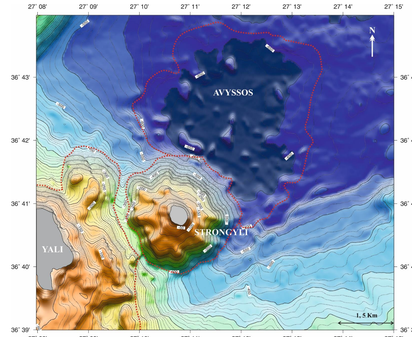


Fig. 7. *Statistical moments of conductivity (S/m) (left) and temperature (˚C) (right) as derived from the data in Santorini. Moments have two distinct regimes for both parameters, with a turning point at Δ=5s, and show dependence on the different lag times.*

NISYROS

Survey date and time: October 11, 2010, 01:00-02:00 | Duration: 60 mins



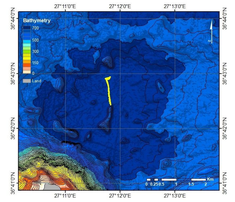


Fig. 4. Bathymetry map of the Avyssos caldera (Nomikou, *et al.*, 2013b). Right: The area covered by ROV Hercules during this 60 minute interval studied here. The vehicle was always closest to the seafloor.

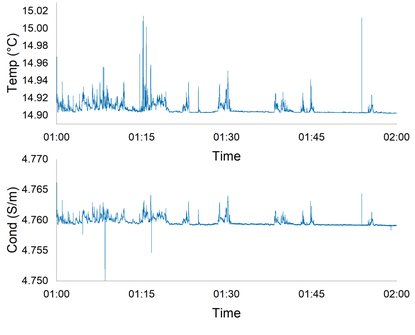


Fig. 6. *Temperature (˚C) and Conductivity (S/m) time series for Nisyros. Spikes/anomalies appear at the exact time in both conductivity and temperature time series.*

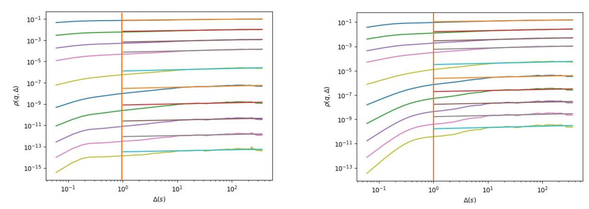


Fig. 8. *Statistical moments of conductivity (S/m) (above) and temperature (˚C) (below) as derived from the data in Nisyros. The moments have two distinct regimes for both parameters, with a turning point at Δ=1s, and show dependence on the different lag times.*

Table 1. A comparison of the values of various parameters for the data examined. γ is the exponent that classifies the type of the process, a is the Levy index, H defines the scaling of the mean field, C measures the mean homogeneity of the field

	Santorini				Nisyros			
	γ	a	H	C	γ	a	H	C
T	0,931±0,005	1	0,417±0,004	0,109±0,007	0,171 ± 0,001	2	0,137±0,012	0,041±0,005
C	1,115±0,003	1	0,480±0,007	0,132±0,014	0,211 ± 0,001	2	0,162±0,004	0,052±0,002

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