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A high resolution multidisciplinary study of palaeoenvironmental changes in the Gulf of Elefsis, Attica, Greece during the last 300 years

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Introduction

We hereby present the first high resolution palaeoenvironmental record of the last 300 years from the area of Attica, South Greece. The very recent environmental changes and the imprint of human activity in marine palaeoenvironmental records are still poorly understood, despite the increasing number of archives from Greece during the last decades (e.g. Kouli *et al.*, 2012; Gogou *et al.*, 2016; and references therein).

Objectives

Through the study of alkenone paleothermometry and a plethora of geochemical, micropaleontological and pollen proxy-indices obtained from the marine multi-core WFS2, we aim to provide insights into the prevailing environmental and climatic dynamics in this region i.e. variabilities in temperature, salinity, humidity vs. aridity, redox conditions, changes in marine productivity and land vegetation patterns throughout the last 300 years, as also as the development of the anthropogenic signal (i.e. inputs of fossil fuel hydrocarbons and their combustion-derived compounds) after the Industrial Revolution Era.

Methodology

The multi-core was sampled at 0.5 cm resolution and the sediment samples have been stored at -20ºC. 52 dried samples were extracted with mixture of organic solvents and analyzed by column chromatography and gas chromatography coupled to mass spectrometry for the determination of lipid biomarkers, namely *n*-alkanes, *n*-alkanols, sterols, alkenones, diols and keto-ols, fatty acids. For the reconstruction of past Sea Surface Temperatures (SSTs) the alkenone unsaturation index ($U^{k'}_{37}$) was calculated according to Gogou *et al.* (2016). Land plant wax *n*-alkanes (Ter *n*-alkanes) as well as steroidal alcohols (sterols) were used as proxies (Gogou *et al.*, 2007) to track ecosystemic and environmental changes in the terrestrial and marine realm. The productivity from Prymnesiophyte and other nannoplankton algal species is reflected by the abundance of long-chain alkenones and diols/ keto-ols, respectively (Marlowe *et al.*,1984).

The Unresolved Complex Mixture (UCM) of aliphatic hydrocarbons, a commonly observed persistent contaminant mixture in marine sediments consisting of branched alicyclic hydrocarbons (Gough and Rowland, 1990), is used as an indicator of the contribution from anthropogenic activities i.e. chronic oil pollution (Wang *et al.*, 1999).

The Carbon Preference Index of long chain *n*-alkanes (CPI_{NA}) has been used as indicator of terrestrial organic matter supply with CPI values in fresh leaves being typically >4 (Collister *et al.*, 1994), while fossil fuel *n*-alkanes present CPI_{NA} values ~1 (Wang *et al.*, 1999).

Fifty samples were prepared and analyzed for stable isotopic composition of C and N ($\delta^{13}C$ and $\delta^{15}N$).

Pollen analysis was performed on 46 samples. Pretreatment followed classical palynological protocol including spiking and sieving through a 10 μm mesh. Pollen concentrations were calculated based on the known amount of "exotic" spores added and is expressed as grains or cysts per gram of dry sediment. Percentage and concentration pollen diagrams were constructed using TILIA Graph software. The PDI (Pollen Disturbance Index: Kouli, 2015) sum includes selected anthropogenic indicators (e.g. *Centaurea*, Cichorieae, *Plantago, Pteridium, Sarcopoterium*) and is used to explore pastoral activities in the borderlands of Elefsis Bay.

Results & Discussion

The alkenone-derived SSTs at Elefsis Bay drop by almost 1ºC from the end of the 17th to the beginning of the 18th century. This cooling is probably synchronous to one of the coldest intervals (ad 1645–1715) of the 'Little Ice Age' (LIA), characterized by a prolonged episode of volcanic and low solar activity known as 'Maunder minimum' (MM) (Xoplaki *et al.*, 2005). After that and throughout the 18th century, SSTs stabilize at a mean temperature of 23ºC. During the 19th century a gradual increase of SSTs is observed. After the last decades of the 19th century (marking the beginning of the Industrial Era in Greece) the SST turns back to an increasing mode. The trend of the SST values shows a decrease during the 20th century, possibly reflecting the result of a combination of events that have thereafter affected the temperature and other physicochemical characteristics of the study area.

The significant population rise and the related urban activities in the Athens metropolitan area during the second half of the 19th century resulted to a noticeable decrease of CPI, and a radical increase of UCM, attributed to enhanced terrestrial inputs (Ter *n*-alkanes) thus marking the entrance to the Industrial Era.

During the same interval, an increase in the abundance of alkenones and of specific sterols, reflects the higher productivity

from algal species linked to enhanced continental inputs and consequently increased nutrient supply to the coastal environment.

Pollen assemblages indicate the existence of a diverse Mediterranean plant landscape, while prominent is the imprint of the human activities on the vegetation. Evergreen *Quercus*, accompanied by *Pistacia* and *Phillyrea*, are the most conspicuous taxa featuring the occurrence of Mediterranean macchia. Thermophilous deciduous oaks woodlands compose a significant part of the vegetation, especially at the lower part of our record. Mountainous forest is underlined by the presence of *Abies*, while a big variety of herb taxa fill in the landscape. *Olea* is a major component of the vegetation throughout the entire record. Olive cultivation is intensified after the first quarter of the 18th century and seems to be one of the major human activities in the area. Anthropogenic indicator pollen implies the decrease of pastoral activities during the 19th century and since the end of the 20th century. During the 19th and most of the 20th century the impact of grazing activities on vegetation is more pronounced. A very distinct transitory drop in human indicators is recorded in mid- 18th century. This temporal retreat in olive cultivation and grazing activities can be connected with the societal instability during the Greek War of Independence. Finally since the last quarter of the 19th century and until the mid-20th century a gradual retreat of *Pinus* is recorded, probably associated with the start of the Industrial Period in Greece and the increased requirement for fuel like firewood.

Conclusions

Our study revealed marine and terrestrial environmental and ecosystem responses to climatic variability along with land-ocean interactions in the Elefsis Bay, South Greece, during the last 300 years. Distributions of the lipid markers indicated the impact of both marine and terrestrially derived organic matter inputs in the study area, which were highly intensified after the onset of the Industrial Era in Greece. Vegetation patterns denote the significant role of human activities in shaping the landscape of the Elefsis region.

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References

Collister, J., Rieley, G., Stern, B., Eglington, G., Fry, B., 1994. Compound-specific d13C of leaf lipids from plants with differing carbon dioxide metabolisms. Organic Geochemistry 21, 619-627

Gogou, A., Bouloubassi, I., Lykousis, V., Arnaboldi, M., Gaitani, P., Meyers, P.A., 2007. Organic geochemical evidence of Late Glacial–Holocene climate instability in the North Aegean Sea. Palaeogeography Palaeoclimatology Palaeoecology, 256, 1–20.

Gogou, A., Triantaphyllou, M., Xoplaki, E., Izdebski, A., Parinos, C., Dimiza, M., Bouloubassi, I., Luterbacher, J., Kouli, K., Martrat, B., Toreti, A., Fleitmann, D., Rousakis, G., Kaberi, H., Athanasiou, M., Lykousis, V., 2016. Climate variability and socio-environmental changes in the northern Aegean (NE Mediterranean) during the last 1500 years. Quaternary Science Reviews 136, 209–228.

Gough, M.A., Rowland, S.J., 1990. Characterization of unresolved complex mixture of hydrocarbons in petroleum. Nature 344, 648-650.

Kouli, K., 2015. Plant landscape and land use at the Neolithic lake settlement of Dispilió (Macedonia, northern Greece). Plant Biosystems 149, 195–204.

Kouli, K., Gogou, A., Bouloubassi, I., Triantaphyllou, M.V., Ioakim, C., Katsouras, G., Roussakis, G., Lykousis, V., 2012. Late postglacial paleoenvironmental change in the northeastern Mediterranean region: Combined palynological and molecular biomarker evidence. Quaternary International 261, 118–127.

Marlowe, I.T., Green, J.C., Neal, A.C., Brassell, S.C., Eglington, G., Course P.A., 1984. Long chain alkenones in the Prymnesiophyceae. Distribution of alkenones and other lipids and their taxonomic significance. British Phycological Journal 19, 203-16.

Wang, Z., Fingas, M., Shu, Y. Y., Sigouin, L., Landriault, M., Lambert, P., Turpin, R., Campagna, P., Mullin, J., 1999. Quantitative Characterization of PAHs in Burn Residue and Soot Samples and Differentiation of Pyrogenic PAHs from Petrogenic PAHs-The 1994 Mobile Burn Study. Environmental Science and Technology 33, 3100-3109

Xoplaki, E., Luterbacher, J., Paeth, H., Dietrich, D., Steiner, N., Grosjean, M., Wanner, H., 2005. European spring and autumn temperature variability and change of extremes over the last half millennium. Geophysical Research Letters 32, L15713