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Reconstructing ocean temperatures using coccolith clumped isotopes

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Reliable temperature reconstructions of the ocean are often difficult to obtain due to the limitations of widely used proxies. The application of clumped isotope thermometry to coccolith calcite, which is geographical and chronological ubiquitously distributed, and whose production is limited to the photic zone, may provide ocean's temperature information when and where other proxies have been shown inaccurate or not applicable.

To evaluate the potential of coccolith clumped isotopes in paleoceanography we compare the temperatures derived from the fine fraction (<11µm), a pure mixed coccolith fraction (2-10 µm), and to a fraction of carbonate fragments from unidentified sources (<2 µm), with coeval alkenone sea surface temperatures (SST) from ODP Site 982 in the North Atlantic covering the last 16 Ma. The similarity in magnitudes and trends from the <11 and 2-10 µm size fractions, and trace element analysis of the <2 µm size fraction, suggest that for this site and time interval, exclusion of small unrecognizable fragments is not necessary to obtain reliable temperatures. The warmer values of alkenone SSTs compared to coccolith clumped isotope-derived temperatures cannot be explained by diagenetic processes, but may be related to temperature overestimations by alkenone calibrations, which assume a warm season and/or shallow production of coccolithophores in the study area.

Vital effects in coccolith clumped isotopes potentially associated to carbon limitation may also help to explain the differences in cooling magnitudes compared to the alkenone record. To further investigate vital effects in clumped isotopes, we compare calcification temperatures of three pure coccolith size fractions (3-5, 5-8, and 8-10 µm), and relate them to vital effects observed in their $\delta^{13}C$ and $\delta^{18}O$. The analysis of the fine fraction of Holocene sediments (<10 or <8 µm) showing a range of temperature and CO_2 concentrations also provide information on the potential effects of carbon availability in coccolith clumped isotopes, and suggests calcification of coccolithophores may occur in deeper habitats than those considered by alkenone calibrations. Our study shows clumped isotope thermometry applied to coccolith calcite as a promising alternative proxy for calcification temperature of coccolithophores.