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The PhytoSCALE project: calibrating phytoplankton cell size as a proxy for climatic adaptation

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The Cenozoic fossil record reveals that coccolithophores (marine unicellular haptophyte algae) were globally more common and widespread, larger, and more heavily calcified before 34 million years ago (Ma), in a high-CO_2 greenhouse world. We have recently demonstrated that changes in atmospheric CO_2 have, directly or indirectly, exerted an important long-term control on the ecological prominence of coccolithophores as a whole [1]. On closer inspection, this macroevolutionary pattern primarily reflects the decline in abundance and subsequent extinction of large-celled and heavily calcified lineages, while small-sized species appear to have been more successful in adapting to the post-34 Ma "icehouse" world. Coccolith size (length) is a proxy for cellular volume-to-surface ratios (V:SA), as determined from fossil coccosphere geometries. Algal V:SA provides physiological constraints on carbon acquisition and other resource uptake rates, affecting both photosynthesis and calcification, and is therefore considered to be a key indicator of adaptation. As a general rule, small cells have faster growth rates than large cells under similar environmental conditions, giving small species a competitive advantage when resources become limiting. Our research aims to bridge the gap between short-term experimental observations of physiological and phenotypic plasticity in the modern species *Emiliania huxleyi* and *Coccolithus pelagicus*, and time series of the long-term phenotypic variability of their Cenozoic ancestors. Single-clone growth experiments revealed significant plasticity in cell size and coccolith volume under growth-limiting conditions. However, the range in coccolith size (length) remained relatively constant for single genotypes between various growth conditions. With these new data we test to what extent the size variation observed in the fossil time series is a reflection of anagenetic changes (i.e. evolution of an ancestral species to a descendant species without split of lineage), or changes in the frequency and distribution of closely related species of different size and different ecological preferences.

[1] Hannisdal, B., Henderiks, J., and Liow, L.H.: Long-term evolutionary and ecological responses of calcifying phytoplankton to changes in atmospheric CO_2, Global Change Biology, 18(12), 3504-3516, 2012.