Refining the alkenone-\(p\)CO\(_2\) method: Nutrient constraints and the effect of growth rate

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The alkenone-\(p\)CO\(_2\) method is one of the most widely used approaches to reconstruct the atmospheric CO\(_2\) level in the Cenozoic. Based on the fractionation of stable carbon isotopes between dissolved CO\(_2\) and biomass of haptophyte algae, this relationship (known as \(\varepsilon\)) scales inversely with growth rate and positively with CO\(_2\) [1]. Recently published records of alkenone-derived CO\(_2\) from late Pleistocene samples, however, are poorly correlated with ice core CO\(_2\) records, indicating that improvements to the current methodology are needed. Models and experiments indicate that algal growth rate as represented by the physiological parameter ‘\(b\)’ – which must be specified in order to reconstruct CO\(_2\) levels – are sensitive to nutrient concentrations (e.g., phosphorous, [2]) as well as other environmental conditions [3]. Here we revise the relationship between seawater reactive phosphate concentration and \(b\) using published core-top \(\varepsilon\) data. The sediment-based data show a shallower slope of the phosphate-\(b\) regression than the widely used relationship derived from suspended organic matter. Further, we show that the archaeal lipids often co-occurring with alkenones in the sediments may be used to estimate past changes of seawater nutrient levels and therefore to calibrate ‘\(b\)’. Applications of this refined alkenone-\(p\)CO\(_2\) method to two published datasets yield similar trends and magnitude of \(p\)CO\(_2\) changes over the last glacial-interglacial cycle, matching the ice-core records.