

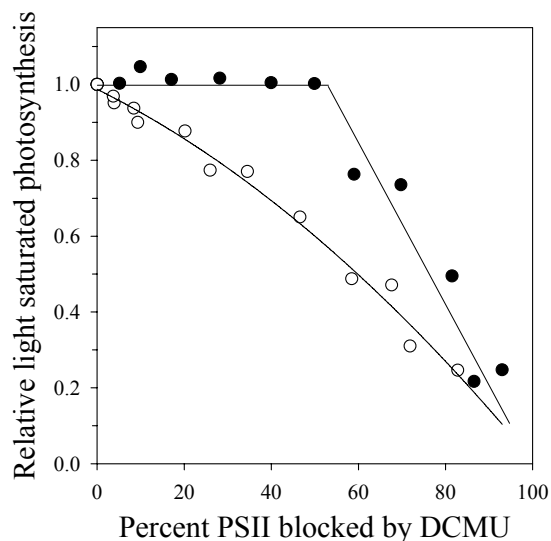
SUPPLEMENTARY INFORMATION:

Part I: ProMolec and *Prochlorococcus* PCC 9511

The ProMolec experimental design was optimal for observing E_k -independent behavior. First, synchronization of cell cycles ensured that most cells were simultaneously engaged in the same metabolic pathways. Second, *Prochlorococcus* PCC 9511 does not utilize NO_3 as a nitrogen source, but rather is a dedicated NH_4 consumer. Consequently, photosynthate was not required for NO_3 reduction, which strengthened the relationship between photosynthate production and carbon fixation in the morning. Finally, *Prochlorococcus* is a prokaryote, which means it employs the same electron transport components for both photosynthesis and respiration. While this configuration is economical, it restricts respiratory electron flow during daylight hours, making photosynthesis the dominant source of ATP and reductant during carbohydrate synthesis.

Part II: Photoinhibition and electron turnover

Low-light acclimated phytoplankton exposed to saturating irradiance absorb far more light energy than can be accommodated by downstream electron transport components, promoting enhanced heat dissipation and photoinhibition (PSII down-regulation). Photoinhibition, however, does not necessarily decrease the light-saturated electron flux because turnover rates of the remaining functional PSII centers can increase. In contrast, light harvesting capacity in high-light acclimated phytoplankton closely matches the capacity for downstream utilization, such that PSII turnover time approximates τ_{PSII}^* . In this case, loss of functional PSIIs will decrease electron flux, but the risk of photoinhibition is minimal precisely because light harvesting closely matches utilization. This relationship between photoacclimation and PSII turnover can be demonstrated by titrating phytoplankton grown at different light levels with the PSII inhibitor DCMU. As illustrated in the figure below, low light acclimated cells can tolerate losses in PSII exceeding 50% (solid symbols) while high light cells show immediate limitation by PSII upon DCMU addition (open symbols) [data from M.J. Behrenfeld, O. Prasil, Z.S. Kolber, M. Babin, & P.G. Falkowski. (1998) Compensatory changes in photosystem II electron turnover rates protect photosynthesis from photoinhibition. *Photosynth. Res.* 58:259-268).



Part III: Amino acid synthesis

The very first metabolic step toward amino acid generation is the oxidation of GAP into 3-phosphoglyceric acid (3-PGA), which releases both ATP and NADH. 3-PGA is the precursor for three of the 20 amino acids. It is also transformed into phosphoenolpyruvate (PEP) and pyruvate, which are precursors to six additional amino acids. These steps both generate and consume ATP and NADH, as well as release CO₂. The remaining amino acids are derived from 2-oxoglutarate and oxaloacetate, which again produces CO₂, ATP and NADH, while also consuming some ATP and NADH. An interesting difference between prokaryotic and eukaryotic phytoplankton is that the former appear to have an incomplete Citric Acid cycle, missing the step between 2-oxoglutarate and succinyl-CoA. Consequently, amino acids are formed from oxaloacetate in prokaryotes through β -carboxylation of PEP (i.e., CO₂ fixation), rather than through the production of oxaloacetate by the Citric Acid cycle in eukaryotes (which releases CO₂). This difference between prokaryotes and eukaryotes alters product-yield ratios during amino acid synthesis and may influence the partitioning of GAP between amino acid pathways and parallel oxidative pathways (e.g., pentose-phosphate pathway).

Part IV: Atmospheric composition over the Phanerozoic

The O₂:CO₂ ratio data presented in the manuscript were calculated from the oxygen (dashed line) and CO₂ (solid line) concentrations reported by Berner (2006) and Falkowski *et al.* (2005) shown in the figure below.

