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Non-Redfield composition of organic production and its effect on ocean carbon storage in glacial model simulations

Malin Ödalen (1), Jonas Nycander (2), Andy Ridgwell (3), Kevin Oliver (4), and Johan Nilsson (5)

(1) Dept of Meteorology, Stockholm University, Stockholm, Sweden (malin.odalen@misu.su.se), (2) Dept of Meteorology, Stockholm University, Stockholm, Sweden (jonas@misu.su.se), (3) Department of Earth Sciences, University of California-Riverside, Riverside, CA, USA (andy@seao2.org), (4) National Oceanography Centre, University of Southampton, Southampton, UK (K.Oliver@noc.soton.ac.uk), (5) Dept of Meteorology, Stockholm University, Stockholm, Sweden (nilsson@misu.su.se)

During the latest glacial cycles, atmospheric CO_2 was lowered by about 100 ppm. It is likely that most of this CO_2 went into the ocean, which is by far the largest reservoir of carbon on Earth and thus has the largest capacity for increased carbon storage. One of the processes that has been suggested to be dominant in this transition is an increased efficiency of the biological carbon uptake in the surface ocean and/or of the export of organic carbon to the deep ocean. The magnitude of this biological carbon uptake is limited by the amount of available nutrients, which are essential for the production of organic matter. It is commonly assumed in both theoretical and numerical models that the ratios of these elemental nutrients to carbon are constant. This may be true on average, but they have proven to be highly variable on a local scale and between species of organisms. If the number of carbon atoms that are taken up per nutrient atom can increase when nutrient availability is scarce, this variability is likely to significantly impact the potential for oceanic CO_2 uptake during glacials. In this sensitivity study, we test a phosphate concentration dependent model and how it might influence the oceanic CO_2 storage in an Earth system model of intermediate complexity (cGENIE). We make simulations of glacial-like changes in dust, albedo, orbital parameters, wind-fields and remineralisation depth, separately and in combination, and compare model versions with Redfield and non-Redfield composition of organic production. The results indicate that the effect of non-Redfield composition in production of organic matter is significant and cannot be ruled out as a contributor to the oceanic uptake of CO_2 during glacials. We suggest that this type of simple nutrient concentration dependent model of organic new production could improve the ability of climate models to accurately simulate the role of ocean biology. This will be beneficial when attempting to simulate glacial cycles as well as other climate scenarios.