Feedback mechanisms between climate and the Redfield ratio

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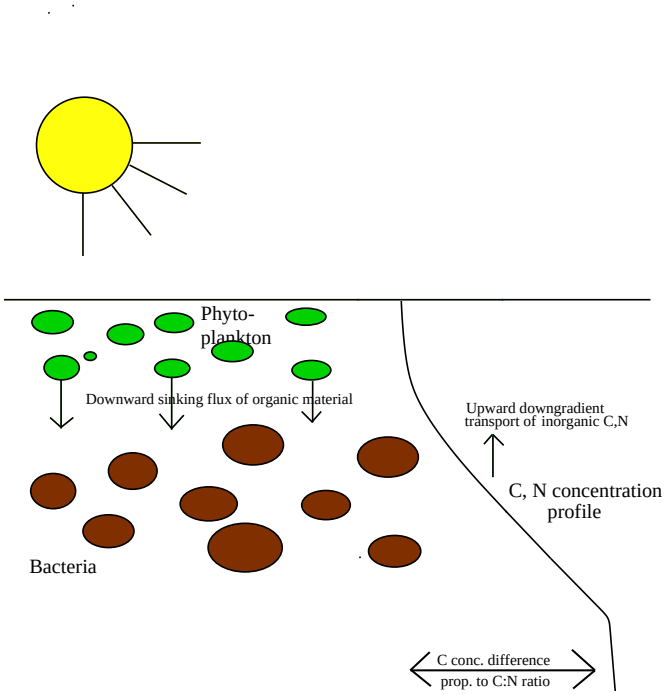

Fig.1 The growth, sinking, and remineralisation of phytoplankton give rise to a difference in carbon concentration between the ocean surface and the deep waters proportional to the carbon:nutrient ratio of the organic material.

Introduction

The partitioning of CO_2 between the atmosphere and the ocean depends on the carbon:nutrient (Redfield) ratio of oceanic phytoplankton sinking into the deep ocean [1]. Broecker [2] has argued that the Redfield ratio should have been 30 % higher during glacial times than during interglacials to explain the low glacial atmospheric carbon concentrations which are still an enigma today. Stimulated by this analysis, we have investigated the influence of external climatic conditions on the chemical composition of phytoplankton.

The Phytoplankton Internal Nitrogen and Carbon (PINC) model

Our PINC model is based on Kooijman's Dynamic Energy Budget (DEB) theory [3]. Following the DEB philosophy, we discern structural mass, an organic carbon reserve, and a nitrogen reserve (see Fig.2). The ratios of these three components with respect to each other determine the carbon:nutrient ratio of the organisms.

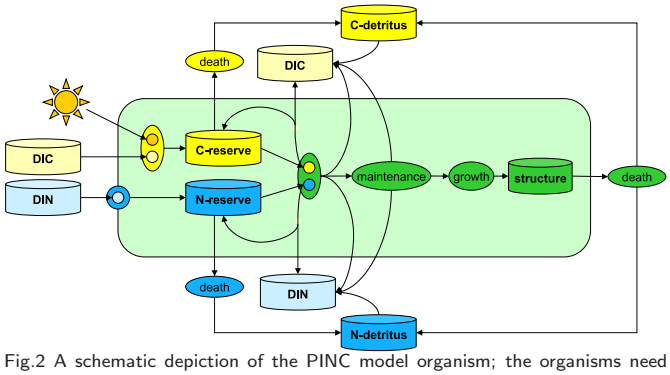

Fig.2 A schematic depiction of the PINC model organism; the organisms need DIC and light to form C-reserve; only DIN is needed to form N-reserve. The dead organic material is divided into N-detritus and C-detritus which remineralise into DIN and DIC respectively.

Results

We have modelled the influence of mixed-layer depth and temperature on the stoichiometry of a phytoplankton population in a water column. Except if the mixed-layer depth is very small, we have (see Fig.3):

- C:N ratio increases with decreasing mixed-layer depth
- C:N ratio increases with decreasing temperature

We performed simulations in which we used Last Glacial Maximum mixed-layer depths and SST that we obtained from [4] for various regions on the globe. We compared the results with simulations with pre-industrial mixed-layer depths and SST for these same regions. On average, the LGM C:N ratio is approximately 10 % higher than today.

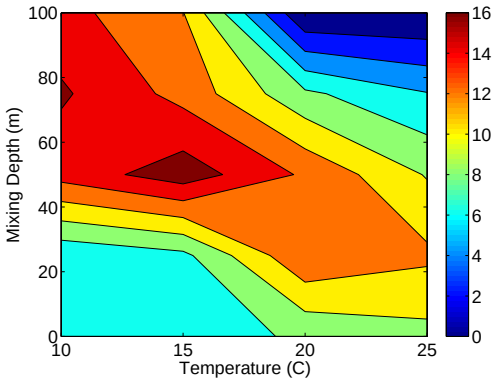

Fig.3 Carbon:nutrient ratio of detritus 30 m below the mixed layer as a function of mixed-layer depth H_m and temperature

References

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