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The biological carbon pump in the ocean: Reviewing model representations and its feedbacks on climate perturbations.

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The ocean-sediment system, as the biggest carbon reservoir in the Earth's carbon cycle, plays a crucial role in regulating atmospheric carbon dioxide concentrations and climate. Therefore, it is essential to constrain the importance of marine carbon cycle feedbacks on global warming and ocean acidification. Arguably, the most important single component of the ocean's carbon cycle is the so-called "biological carbon pump". It transports carbon that is fixed in the light-flooded surface layer of the ocean to the deep ocean and the surface sediment, where it is degraded/dissolved or finally buried in the deep sediments. Over the past decade, progress has been made in understanding different factors that control the efficiency of the biological carbon pump and their feedbacks on the global carbon cycle and climate (i.e. ballasting = ocean acidification feedback; temperature dependant organic matter degradation = global warming feedback; organic matter sulphurisation = anoxia/euxinia feedback). Nevertheless, many uncertainties concerning the interplay of these processes and/or their relative significance remain. In addition, current Earth System Models tend to employ empirical and static parameterisations of the biological pump. As these parametric representations are derived from a limited set of present-day observations, their ability to represent carbon cycle feedbacks under changing climate conditions is limited. The aim of my research is to combine past carbon cycling information with a spatially resolved global biogeochemical model to constrain the functioning of the biological pump and to base its mathematical representation on a more mechanistic approach. Here, I will discuss important aspects that control the efficiency of the ocean's biological carbon pump, review how these processes of first order importance are mathematically represented in existing Earth system Models of Intermediate Complexity (EMIC) and distinguish different approaches to approximate biogeochemical processes in the sediments. The performance of the respective mathematical representations in constraining the importance of carbon pump feedbacks on marine biogeochemical dynamics is then compared and evaluated under different extreme climate scenarios (e.g. OAE2, Eocene) using the Earth system model 'GENIE' and proxy records. The compiled mathematical descriptions and the model results underline the lack of a complete and mechanistic framework to represent the short-term carbon cycle in most EMICs which seriously limits the ability of these models to constrain the response of the ocean's carbon cycle to past and in particular future climate change. In conclusion, this presentation will critically evaluate the approaches currently used in marine biogeochemical modelling and outline key research directions concerning model development in the future.