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Benthic-Pelagic Coupling in Biogeochemical and Climate Models: Existing Approaches, Recent developments and Roadblocks

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Marine sediments are key components in the Earth System. They host the largest carbon reservoir on Earth, provide the only long term sink for atmospheric CO_2, recycle nutrients and represent the most important climate archive. Biogeochemical processes in marine sediments are thus essential for our understanding of the global biogeochemical cycles and climate. They are first and foremost, donor controlled and, thus, driven by the rain of particulate material from the euphotic zone and influenced by the overlying bottom water. Geochemical species may undergo several recycling loops (e.g. authigenic mineral precipitation/dissolution) before they are either buried or diffuse back to the water column. The tightly coupled and complex pelagic and benthic process interplay thus delays recycling flux, significantly modifies the depositional signal and controls the long-term removal of carbon from the ocean-atmosphere system.
Despite the importance of this mutual interaction, coupled regional/global biogeochemical models and (paleo)climate models, which are designed to assess and quantify the transformations and fluxes of carbon and nutrients and evaluate their response to past and future perturbations of the climate system either completely neglect marine sediments or incorporate a highly simplified representation of benthic processes. On the other end of the spectrum, coupled, multi-component state-of-the-art early diagenetic models have been successfully developed and applied over the past decades to reproduce observations and quantify sediment-water exchange fluxes, but cannot easily be coupled to pelagic models. The primary constraint here is the high computation cost of simulating all of the essential redox and equilibrium reactions within marine sediments that control carbon burial and benthic recycling fluxes: a barrier that is easily exacerbated if a variety of benthic environments are to be spatially resolved.
This presentation provides an integrative overview of the benthic-pelagic coupling that accounts for the complex process interplay from the euphotic ocean to the deep sediment. It explores the intensity of the benthic-pelagic coupling across different environments and from the seasonal to the geological timescale. Different modelling approaches of coupling sediment and water column dynamics in regional/global biogeochemical models and (paleo)climate models are critically evaluated and their most important limitations, as well as the implications for our ability to predict the response of the global carbon cycle to past or future perturbations is discussed. Finally, the presentation identifies major roadblocks to the development of new model approaches and highlights how new techniques, new observational and laboratory data, as well as a close interdisciplinary collaboration can overcome these roadblocks.