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Submarine river canyons and the shelf nutrient hypothesis: mechanisms for deep sea oxygen depletion during glaciations?

I. Tsandev (1), C. Rabouille (1), C. P. Slomp (2), and P. Van Cappellen (3)

(1) Utrecht University, Geochemistry, Utrecht, Netherlands (tsandev@geo.uu.nl), (2) Laboratoire des Sciences du Climat et de l'Environnement, CNRS, Gif sur Yvette, France, (3) School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, Georgia

The exposure of continental shelves, due to sea level fall during glacial transitions, created an abundance of reactive organic matter on exposed continental shelves available for erosion. Additionally, sea level fall possibly induced the formation of submarine river canyons for large rivers, which could then deposit their particulate load directly to the deep-sea by shunting material down-slope via gravity flows. If these processes were in effect during glacial times, their impact on the functioning of the deep ocean is potentially significant. Here we examine, with a model of the marine phosphorus, organic carbon and oxygen cycles, the impact of shelf erosion and particulate matter re-routing to the open ocean in the context of glacial-interglacial transitions. Starting from an existing scenario for glacial climate change we implement shelf erosion and submarine canyon formation and find that deep sea oxygen levels are lowered significantly, particularly due to the supply of new material from the shelves, and to a much lesser extent due to particulate organic matter bypassing coastal waters. Deep-sea oxygen levels can lower to nearly 100 μM if eroded shelf material is deposited to the sea as an episodic event at the end of the glacial stage. If erosion is more moderate and continuous instead, the same total amount of material can drive deep-sea oxygen levels to 120 μM. In both cases, the glacial ocean's oxygen content would have been significantly lower than interglacial stages. Primary production and carbon burial are affected as well, due to the fertilization of the ocean by large amounts of particulate organic material. The ocean's tendency for reduced primary production and carbon burial and increased ventilation under glacial climate change is reversed in the late glacial period by the supply of material eroded from exposed continental shelves. Redox dependent burial of phosphorus then causes a decrease in the amount P buried because of lower oxygen concentrations but without that mechanism having a major impact on the other biogeochemical cycles.