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Glacial Ocean Carbon and Oxygen Cycles: Biological Pump or Disequilibrium?

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Increased ocean carbon storage and reductions in deep ocean oxygen content during the cold phases of the Pleistocene ice age cycles have been mostly attributed to a stronger biological pump. However, recent studies have emphasized that changes in air-sea disequilibrium played a major role. Here we diagnose a data-constrained model of the ocean during the Last Glacial Maximum to decompose carbon and oxygen cycling into its different components. Individual drivers such as temperature, sea ice, circulation and iron fertilization have been quantified for each component. We show that due to differences in air-sea gas exchange between carbon and oxygen, the components respond differently, which complicates/invalidates interpretations of oxygen changes in terms of carbon. We find changes in disequilibrium dominate both carbon and oxygen changes, whereas the biological pump was not more efficient in terms of global changes for both elements. However, whereas for carbon both the physical and the biological disequilibrium play important roles, for oxygen the biological disequilibrium is dominant, while the physical disequilibrium is negligible. Moreover, whereas for carbon temperature (amplified by physical disequilibrium) and iron fertilization (amplified by biological disequilibrium) are the dominant drivers, oxygen disequilibrium changes are driven mostly by sea ice, with iron fertilization playing a secondary role.