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Mechanisms controlling export production at the LGM: Effects of changes in oceanic physical fields and atmospheric dust deposition

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Using a biogeochemical ocean model that includes the iron cycle, we carry out preindustrial (control, CTL) and glacial (Last Glacial Maximum, LGM) climate simulations focusing on changes in export production (EP). The model successfully reproduces general trends of a paleoclimate reconstruction of EP at the LGM except over the Atlantic Ocean. By conducting a series of sensitivity simulations, we investigate the mechanism controlling EP at the LGM in each basin. In the Southern Ocean, the model successfully reproduces the dipole pattern of the paleoreconstruction: the higher-latitude decrease and lower-latitude increase of EP. It is found that the lower-latitude increase of EP comes from iron fertilization effects by enhanced dust deposition, while the higher-latitude decrease of EP is caused by the reduction of surface shortwave due to spreading of sea ice there. We also find that increased dust input in other basins remotely affects EP in the Southern Ocean. In the Pacific Ocean, the model suggests that iron fertilization effects are dominant in open ocean regions. In the Atlantic Ocean, the model simulates overall reduction of EP, whereas the paleo reconstruction suggests the increase in some regions. We propose that the Atlantic response is strongly affected by distribution of iron limitation in a control climate. In our CTL simulation, the biological production is limited not by iron but by phosphate in the Atlantic Ocean, which leads to the decrease of EP in spite of the significant increase of dust deposition there. It is implied that the accurate evaluation of iron limitation in the present ocean is critical for evaluating changes in EP and associated reduction of atmospheric CO_2 concentration at the LGM.