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Sensitivity Simulations on the Deglacial Rise in CO_2: the Last Glacial Maximum to the Present according to the UVic Model

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The University of Victoria Earth System Climate Model of intermediate complexity (v. 2.9) is used to investigate carbon cycle dynamics from the Last Glacial Maximum (LGM) to the present. Incorporating an ocean GCM (with 1.8° x 3.6° resolution and 19 levels), a simple 1D atmosphere, a representation of land surface processes and vegetation (TRIFFID), and a comprehensive carbon cycle, this particular model is able to perform transient simulations over the entire glacial termination and interglacial period within an efficient time frame. From a spin-up generated for LGM conditions, two types of transient experiments were conducted: (1) prescribed carbon (PC) simulations, where the carbon reservoirs in simulations beginning from the LGM are forced to adjust to the atmospheric CO_2 trends in the Vostok and the Taylor Dome/Law Dome ice cores, and (2) free carbon (FC) simulations, where carbon reservoirs, including atmospheric CO_2, evolve with no outside influence beyond prescribed orbital forcing and glacial ice retreat. Within these two formats, a variety of sensitivity studies tested a 700 PgC deglacial release of carbon (approximating permafrost release), CO_2 and CH4 radiative forcing, and different weathering rates. A comparison of the prescribed and free carbon simulations provides useful details about the important processes involved in the deglacial increase in CO_2 and why the model's FC simulations failed to reproduce the $\sim$90 ppm post-glacial CO_2 rise. In particular, the model's PC simulations accurately revitalized the deep North Atlantic circulation following the timing established in proxy records [Galbraith et al., Nature (449), 2007] and produced a much better-circulated ocean than the FC simulations (which only provide a modest increase of 20 ppm CO_2 over the entire period and a largely-unrecovered North Atlantic meridional circulation). It was further determined that the warming effect of radiative forcing from greenhouse gases (and not ice-albedo warming) is predominantly responsible for the recovery of North Atlantic deepwater formation and greater ocean circulation, which in turn leads to less deep-ocean carbon storage and a carbon source to the atmosphere and terrestrial reservoirs. Furthermore, much greater sediment storage in the FC simulations (versus the PC simulations) implies another 200 PgC potential source to the atmosphere. Sensitivity simulations also reveal that weathering rates have a non-negligible effect on atmospheric CO_2 on these time scales, contributing to the order of 10 ppm the resulting CO_2 in the FC simulations. Varying the extent of Antarctic ice shelves also yields a 5-10 ppm effect on CO_2 during the Holocene in most experiments.