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Assessing the impact of late Pleistocene megafaunal extinctions on global vegetation and climate

Marc-Olivier Brault (1), Lawrence Mysak (2), H Damon Matthews (3), and Christopher Simmons (2)

(1) McGill University, Geography, Canada (marc-olivier.brault@mail.mcgill.ca), (2) McGill University, Atmospheric and Oceanic Sciences, Canada, (3) Concordia University, Geography, Planning and Environment, Canada

The end of the Pleistocene marked a turning point for the Earth system as the climate gradually emerged from millennia of severe glaciation in the Northern Hemisphere. It is widely known that the deglacial climate change was accompanied by an unprecedented decline in many species of large terrestrial mammals, featuring among others the near-total eradication of the woolly mammoth. Due to an herbivorous diet that involved the grazing of a large number of trees, their extinction is thought to have contributed to the rapid and well-documented expansion of dwarf deciduous trees in Siberia and Beringia, which in turn could have affected the surface albedo of Northern Continents, and contributed to the changing climate of the period. In this study, we use the University of Victoria Earth System Climate Model (UVic ESCM) to simulate the possible effects of megafaunal extinctions on Pleistocene climate change. We have introduced various hypothetical scenarios of megafaunal extinctions ranging from catastrophic to more realistic cases, in order to quantify their potential impact on climate via the associated biogeophysical effects of expanding vegetation on regional and global temperature. In particular, we focus our attention on a Maximum Impact Scenario (MIS), which represents the greatest possible post-extinction reforestation in the model. The more realistic experiments include sensitivity tests based on the timing of extinction, the amount of tree clearance associated with mammoth diets, and the size of mammoth habitats. We also show the results of a simulation with free (non-prescribed) atmospheric CO_2. For the most extreme extinction scenario, we obtained a surface albedo increase of 0.006, which resulted in a global warming of 0.175°C. Less extreme scenarios produced smaller global mean temperature changes, though local warming in some locations exceeded 0.3°C even in the more realistic extinction scenarios. In the simulation with freely evolving atmospheric CO_2, the biogeophysical-induced warming was amplified by a biogeochemical effect whereby the replacement of high-latitude tundra with shrub forest led to a release of soil carbon to the atmosphere and a small atmospheric CO_2 increase. Overall, our results suggest the potential for a small, though non-trivial, effect of megafaunal extinctions on Pleistocene climate change.