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The Holocene's natural carbon cycle according to a model of intermediate complexity: the role of Southern Ocean ventilation

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The role of natural processes and human land use in the 20 ppm CO2 increase during the Holocene has been a source of considerable scientific debate in recent years. For the first time, the University of Victoria Earth System Climate Model (UVic ESCM) v. 2.9 is used to investigate the Holocene's natural carbon cycle (excluding land use) from 8000 to 150 years BP. Several sets of initial conditions for 8000 BP were obtained from equilibrium simulations. One set was evolved transiently from the Last Glacial Maximum (with atmospheric prescribed CO2). Prescribed forcing for 8000 BP yielded an oscillatory solution from which three more sets of initial conditions were obtained with different ocean circulation states. These were applied to transient simulations forced by time-varying orbital parameters, land ice, and prescribed winds. A number of sensitivity studies were also carried out. These include (1) forcing atmospheric carbon to follow the Taylor/Law Dome trends, (2) using different prescribed winds, (3) artificially injecting carbon into the atmosphere for 1000-2000 year intervals, as well as (4) changing the model land ice. All model results with freely-varying atmospheric CO2 produce a decline in atmospheric CO2 to 245-253 ppm over the course of the Holocene instead of the increase to 280 ppm (as observed in Antarctic ice cores), although the magnitude of the decline depends strongly on initial conditions and the centennial and millennial-scale variability in overturning in the Southern Ocean. Furthermore, it was found that atmospheric CO2 has a nearly 10 ppm sensitivity to changes in Antarctic land ice due to the former's influence on the meridional overturning circulation. Despite the importance of winds on the meridional overturning circulation, we find that they have a relatively minor effect for most simulations when compared to using the NCEP wind climatology. However, the carbon injection experiments suggest that carbon initially released in the atmosphere can, through feedbacks, lead to as much as a doubling of the initial injection, depending strongly on the timing of the release.