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Stability of the Atlantic meridional overturning circulation during Marine Isotope Stage 3 in a comprehensive climate model

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The origin of millennial-scale Dansgaard-Oeschger events during Marine Isotope Stage 3 (MIS3) is controversial, but there is strong evidence that variations in the strength of the Atlantic meridional overturning circulation (AMOC) were involved. Here, the stability of the AMOC to North Atlantic freshwater perturbations is systematically studied using a state-of-the-art comprehensive coupled climate model (Community Climate System Model version 3, CCSM3) under MIS3 boundary conditions. Results from a series of equilibrium freshwater hosing/extraction experiments forced with 38 ka before present boundary conditions and freshwater perturbations ranging from -0.2 to +0.2 Sverdrups (Sv) are used to construct an AMOC stability diagram. Without freshwater perturbation, the model simulates an equilibrium North Atlantic overturning-maximum of 15 Sv under MIS3 boundary conditions, which is 1 Sv stronger than in the pre-industrial control run, and the southward flow of North Atlantic deepwater occurs at shallower levels than under modern conditions. This MIS3 climate state is remarkably unstable with respect to minor North Atlantic freshwater perturbations, dropping to 9 Sv in response to a 0.04 Sv freshwater hosing and increasing to 18 Sv upon a 0.02 Sv freshwater extraction. The associated changes in global climate are largely consistent with MIS3 stadial-interstadial climate differences suggested by proxy records. Moreover, no evidence for multiple climate equilibria under MIS3 boundary conditions is found in the coupled atmosphere-ocean system. Instead, our results suggest substantial global climate shifts associated with a non-catastrophic threshold for freshwater perturbations varying in the narrow interval between -0.02 and +0.04 Sv. Thus, minor perturbations in the hydrologic cycle (e.g. related to ice-sheet processes) had the potential to trigger global Dansgaard-Oeschger climate transitions.