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Self-sustained millennial-scale oscillations of the Atlantic Ocean meridional overturning circulation in a coupled climate model and their possible link to the timing of Dansgaard-Oeschger climate variations

M. Schulz, M. Prange and A. Klocker

Research Center Ocean Margins, University of Bremen, PO Box 330440, 28334 Bremen, Germany (mschulz@palmod.uni-bremen.de / Fax: +49-421-218-7136 / Phone: +49-421-218-7136)

The onset of Dansgaard-Oeschger interstadials appears to be separated by multiples of approx. 1500 years. The origin of this pacing and its frequency stability (estimated to be approx. +/-12 to 20 %) remain unknown. It has been surmised that the stability of the pacing period makes an origin within the climate system rather unlikely and that the regularity of the Dansgaard-Oeschger cycles would be easier to reconcile with an extraterrestrial cause. In contrast, it was recently suggested that synchronized oscillations within the climate system have the potential to reconcile the stability of the glacial 1500-year pacing cycle with an origin within the Earth's climate system. A prerequisite for this hypothesis is the existence of self-sustained climate oscillations at millennial timescales. Here we use an ocean-atmosphere-sea ice model (ECBILT-CLIO 3) to show that the coupled climate system can indeed exhibit unforced climate variability at millennial timescales. Upon setting orbital parameters to cold northern-hemisphere summer conditions or by increasing precipitation in the Labrador-Sea catchment area, the model enters a state in which the rate of North-Atlantic Deep-Water formation oscillates between 18 and 30 Sv. The period of the oscillations ranges from 400 to 3100 years. The modeled oscillations are associated with on- and off-states of deep convection in the Labrador Sea while convection in the Norwegian-Greenland Seas remains active during all phases of the oscillations. Net freshening of the Labrador Sea, induced by the altered boundary conditions, leads to the development of a halocline which inhibits deep convection. Subsequently, the

halocline is eroded through advection of salty water from the Norwegian-Greenland Seas until convection restarts. The oscillations represent a 3D phenomenon, linked to the intricate interaction between two deep-water formation sites in the North Atlantic. The oscillations of the oceanic circulation are accompanied by air-temperature variations of approx. 4 ˚C over Greenland and 0.8 ˚C over Antarctica. The timing of these air-temperature changes is in accordance with the seesaw concept.