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Glacial abrupt climate changes and millennial oscillations in a coupled climate model

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Large millennial oscillations are a common feature of the past glacial periods. Rapid transitions between cold stadials and warm interstadials occurred over several decades or less in these oscillations. The millennial oscillations also appear to have been significantly modulated by the nature of glacial background climate. Here we show that the abruptness of the transitions between stadials and interstadials, the quasi-periodicity and many other features of the millennial oscillations can be simulated in a climate model of reduced complexity, the McGill Paleoclimate Model-2 with glacial conditions. Our results also show that a moderate global cooling forces the Atlantic Meridional Overturning Circulation (MOC) into an unstable state and hence causes the flip-flop of the Atlantic MOC between a strong mode and a weak mode. In a warm climate, the strong mode is stable, whereas in a cold climate, the weak mode is stable. The simulated millennial oscillations result from strong interactions between the atmosphere, ocean and sea ice. In addition to the background atmospheric and terrestrial conditions, internal oceanic feedbacks and sea ice thermal effects, the process of sea ice brine rejection is demonstrated to play a necessary role in the oscillations.