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## The thermal threshold of the Atlantic overturning circulation and stadial/interstadial periods in glacial climate

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By using results of a state-of-the-art climate model (MIROC), we conducted sensitivity simulations by an ocean general circulation model (COCO) in order to evaluate role of thermal, freshwater, and wind-stress sea surface conditions in controlling the Atlantic meridional overturning circulation (AMOC) in glacial climate. It is demonstrated that slight differences in sea surface conditions could lead to very different response of the AMOC; a certain condition leads to the stronger AMOC and slightly different sea surface fluxes result in the weaker AMOC than today. We found the response of the AMOC to the thermal condition (i.e., strength of surface cooling) is a key for understanding the behavior of the AMOC in glacial climate. It is implied that two very different states of the AMOC may be possible during glacial periods depending on degree of sea surface cooling: moderate cooling results in strengthening of the circulation whereas sufficient cooling leads to weakening of the circulation. The model results indicate that this is related to response of deep convection in the northern hemisphere; moderate cooling enhances deep convection whereas sea ice covers there entirely and prevents deep convection under sufficient cooling. This suggests existence of thermal threshold of the AMOC during a glacial period: the weak glacial (stadial) AMOC suddenly shifts to the strong (interstadial) AMOC when surface cooling becomes smaller than this threshold. It is speculated that this thermal threshold may be related to existence of stadial and interstadial periods of glacial climate.

Keywords: The Atlantic deep circulation, Climate model, Glacial abrupt climate changes