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Stability Behaviour of the Atlantic Thermohaline Circulation Under Different Climate Conditions: The Thermal Component

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During the Last Glacial Maximum the Atlantic Thermohaline Circulation (THC) was characterized by a southward shift of the North Atlantic deep water (NADW) formation sites and a relatively shallow NADW- overturning cell, compared to the present mode of operation. Furthermore, abrupt climate events during the last glacial are associated with rapid changes in the THC and accompanying changes of the inter-hemispheric northward oceanic heat transport.

Using an interhemispheric box model of the Atlantic THC, coupled to a moist energy balance model of the atmosphere we present a new approach, which is based on the assumption that a completely sea ice covered North Atlantic would inhibit the generation of deep water. Therefore we introduce a dependence of the overturning strength from the sea ice extent in the North Atlantic. This approach can be viewed as a loss of efficiency of the inter-hemispheric density gradient in driving the overturning with cooler climate conditions. The transition from the present day climate to a colder climate forces the Atlantic THC to collapse in an intermediate climate state. This change in the stability behaviour is a consequence of the model response to gradual changes in the outgoing infra-red radiation at the top of the atmosphere. At cooler climate states the increasing atmosphere-ocean temperature contrast and associated ocean heat loss dominates the insulating effect of sea ice on North Atlantic temperature and promotes a sea ice growth. This effect is amplified by a weaker overturning circulation and decreased northward oceanic heat transport, which leads to a positive feedback loop and the existence of multiple equilibria in an intermediate climate state. Based on the reduction of the system to key variables governing the stability, we will also discuss the internal and structural stability of the system with the aid of numerical and analytical solutions to gain a deeper understanding of the underlying dynamics. A comparison with proxy records and more complex circulation models shows that the presented concept is in agreement with elements of rapid climate change in time and space. This suggests that the influence of a changing background climate on the thermal component of the Atlantic THC is a key component of abrupt climate changes, which complements the traditional freshwater forcing approach to a unified concept.