Glacial Climate Stability

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Various climate archives suggest that abrupt climate changes are an intrinsic characteristic of glacial cycles. Especially millennial-scale climate variability and Dansgaard-Oeschger events have been linked to changes in the Atlantic meridional overturning circulation (AMOC). To reproduce the associated abrupt transitions between weak and strong AMOC states a common trigger mechanism is related to the timing of North Atlantic freshwater perturbations that is mainly motivated by unequivocal ice-rafting events during Heinrich Stadials (HS). However, recent studies suggest that the Heinrich ice-surging events are triggered by ocean subsurface warming associated with an AMOC slow-down. Furthermore, the duration of ice-rafting events does not systematically coincide with the beginning and end of the pronounced cold conditions during HS.

In this context we show that both, changes in atmospheric CO_2 and ice sheet configuration can provide important controls on abrupt glacial/deglacial climate shifts, using a coupled atmosphere-ocean model. Our simulations reveal that gradual changes in Northern Hemisphere ice sheet height and atmospheric CO_2 can act as a trigger of abrupt climate changes. Furthermore, the interplay between changes in ice volume and atmospheric CO_2 determines that windows of AMOC bi-stability exist during intermediate conditions between peak glacial and interglacial states. This fits to data observations that e.g. MIS 3 was characterised by pronounced millennial scale climate activity while the last glacial maximum and the Holocene interglacial were not. Since millennial-scale changes in CO_2 are themselves thought to be linked to AMOC changes (with a weakened AMOC giving rise to a gradual CO_2 increase and vice versa), our results suggest that CO_2 might also represent an internal feedback to AMOC changes by enabling rapid transitions between contrasting climate states without the necessity to invoke additional processes like North Atlantic ice rafting events.