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Glacial Climate Stability: Pathway to understand abrupt glacial climate shifts

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The glacial climate is marked by abrupt, millennial-scale climate changes known as Dansgaard-Oeschger cycles that have been linked to variations in the Atlantic meridional overturning circulation (AMOC). The most pronounced stadial coolings, Heinrich Stadials (HSs), are associated with massive iceberg discharges to the North Atlantic. This motivates scientists to consider that the North Atlantic freshwater perturbations are the main driver of the associated abrupt transitions between weak and strong AMOC states. 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 HSs.

In this context, we show that both, changes in atmospheric CO_2 and ice sheet configuration can provide important controls on the stability of the AMOC, 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 glacial/deglacial climate changes. The simulated global climate responses—including abrupt warming in the North Atlantic, a northward shift of the tropical rain belts, and Southern Hemisphere cooling related to the bipolar seesaw—are generally consistent with empirical evidence. Furthermore, we show that the AMOC strength under Marine Isotope Stage (MIS) 3 conditions is characterized by a Hopf Bifurcation. The simulated AMOC self-oscillation (resonance) appears to characterize a $\sim$1000-year cycle that is comparable with observed small DO events during the MIS 3. We will discuss the potential dynamics of these changes that are associated with a delicate combination of atmospheric CO_2 and ice sheet configuration.