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Simulating the effects of oceanic variability on millennial-scale iceberg discharges: focus on Heinrich events

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Ice core data and marine and continental records reveal the existence of pronounced millennial time-scale climate variability during the last glacial cycle. Greenland ice core records show abrupt transitions known as Dansgaard-Oeschger (DO) events within decades from cold (stadial) to relatively warm (interstadial) conditions, followed by a slow cooling lasting several centuries and a more rapid fall through stadial conditions. Two types of explanation have been suggested: periodic external forcing and internal oscillations in the climate system, for which ocean circulation is the main candidate. On the other hand, six periods of extreme cooling registered in the Northern Hemisphere, known as Heinrich events, have been found to be coeval with increased deposition of ice-rafted debris, which is interpreted as enhanced discharge of icebergs into the North Atlantic Ocean. Recently, the coupled effects between ocean circulation and ice-sheets dynamics have been suggested to play a major role in triggering Heinrich events. This interpretation of Heinrich events being responding to changes in the oceanic patterns (or at least not being a pure internal and spontaneous manifestation of ice sheets), takes the advantage to provide an explicit relationship between DO events and the periodic iceberg surges. In particular, Alvarez-Solas et al, (2010) showed in a box model that a series of DO events favors the occurrence of a Heinrich event through a resonance phenomenon, giving an explanation to the denominated Bond cycle. Here this hypothesis is reassessed within a more realistic modeling framework by forcing a 3D state-of-the-art ice-sheet model with the output of abrupt climate change simulations carried out with a coupled climate model of intermediate complexity. These show the main expected characteristics of such events: an abrupt warming of the North Atlantic and Atlantic Meridional Overturning Circulation (AMOC) intensification followed by a progressive cooling and AMOC reduction and a more drastic fall into a stadial condition. Interestingly, stadial periods are characterized by the occurrence of a subsurface warming up to 3 K in regions where deep water formation takes place (Nordic and Labrador Seas). Preliminary results show that subsurface warming is a crucial mechanism to destabilize the Labrador Sea ice shelves favoring the acceleration of the Laurentide ice streams. Iceberg production is then enhanced during stadial periods. However, this pattern is not monotonically present through all DO events: the combination of both a characteristic ice-shelf break-up and re-developing time larger than the DO forcing period and the fact that ice-streams need to flow extremely fast to create major calving rates explains the different magnitude of iceberg discharge during different stadial periods. These results suggest that this double requirement accounts for the necessity to undergo several DO events to create an iceberg surge great enough to be considered as a Heinrich event.

Reference:

Alvarez-Solas, J. and Charbit, S. and Ritz, C. and Paillard, D. and Ramstein, G. and Dumas, C. 2010. Links between ocean temperature and iceberg discharge during Heinrich events. Nature Geoscience. 3(2):122-126