Geophysical Research Abstracts,
Vol. 11, EGU2009-9693, 2009
EGU General Assembly 2009

Role of the feedbacks between ocean /ice-shelves /streams in Heinrich events: from a conceptual to a 3D model

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It is now widely accepted that Heinrich events are associated with internal oscillations of the Northern Hemisphere ice sheets leading to periodical large surges of ice in the ocean. It has been proposed that these large-scale surges likely occur when basal ice reaches the melting point in regions where subglacial sediment allows very strong sliding. Attempts to simulate such mechanism with ice-sheet models indeed succeeded to produce oscillations ("bin-purge" oscillations in the HEINO inter-comparison framework). However these results are still controversial because the oscillation periods were very dependent on numerical methods and, more importantly, because they did not take into account longitudinal stresses (within the Shallow Ice Approximation). It has been suggested that this approximation is therefore not suitable for these simulated events.
Using a 3D ice sheet model, GRISLI, in which ice streams velocities are obtained with more realistic equations and longitudinal stresses are accounted for, no oscillations can be obtained with only the proposed ice sheet-ice stream system.
We suggest here that feedbacks between ocean (mainly its thermohaline circulation), ice shelves and ice streams play a significant role in the production of ice surges. With a conceptual ice-sheet /shelf /ocean model we demonstrate the ability of this simple model to produce instabilities of the Northern ice sheets in agreement with many features suggested by data. Finally, by replacing the conceptual ice-sheet /stream model by GRISLI coupled to the ocean model, we still get oscillations although with a different shape and period.
This constitutes a new mechanism to explain the origin of Heinrich events. To demonstrate its realism, the conceptual ocean model will be replaced by a more sophisticated ocean model.
The recent breakup of some ice shelves in Antarctica and the associated changes on ice streams velocities, combined with proxies showing the glacial thermohaline circulation variability and the probable presence of huge ice shelves close to the deep water formation areas, strongly suggest the need of considering a system involving the feedbacks between ice-streams, ice-shelves and ocean.
Moreover, in the context of a future global warming climate, if the West Antarctic ice-sheet reveals less stable than previously supposed (as recently suggested) the study of the coupled ice-streams /shelves /ocean system will be crucial to understand the occurrence of new abrupt climate changes.