Quaternary Science Reviews 24 (2005) 1109–1110

Context

The Goldilocks abrupt climate change event

One important reason to understand past climate changes is to help improve the predictions for the future. However, this is more often said than actually done. There are, of course, many very good reasons why this is so; the inevitable disparities in timescales (millions of years compared to decades), difficulties in proxy interpretation and the often very different focuses of the paleoclimate and modelling communities. Occasionally though, a particular period or event presents itself as an almost ideal case study for model-data comparisons. The article by Alley and Ágústsdóttir in this issue is a review of one such case: the 8.2 kyr event.

The complex coupled ocean-atmosphere models being analysed for IPCC 4th Assessment Report need to be validated against more interesting climate changes than are available in the instrumental record. In particular, they need to be able to test their ocean responses to climate change. The spread in model projections for the North Atlantic meridional overturning circulation (MOC) as a function of increasing anthropogenic described in the IPCC Third Assessment Report was extremely large, ranging from a 14 Sverdrup (Sv) decrease to a 2 Sv increase by 2100. In part, this uncertainty stems from modellers tuning for the existence of a stable North Atlantic circulation, but not being able to tune for its sensitivity for lack of appropriate data.

Useful model-data comparisons have a number of pre-requisites: wide-spread and clear data on the event is crucial, but even more important is the existence of a plausible and interesting candidate for the forcing. Without this, modellers simply do not know what to do. Changes in MOC have of course been deduced for many paleoclimatic periods, but one further set of constraints prevents modellers being able to take full advantage of that data. Simply put, for fully coupled GCMs, the initial conditions need to be close to those of the present day, and the period of time needs to be short enough to be tractable with current computer resources (i.e. decades to centuries, not millennia). This mitigates against the use of variability during the Last Glacial such the Dansgaard-Oeschger and Heinrich events (since the base glacial climate is still not well modelled) and possibly the Younger Dryas as well (a good example of an effect with an as-yet-unquantified cause).

The 8.2 kyr abrupt climate change event would therefore appear to have it all: well-dated and wide-spread data, a relatively short duration, a Holocene base climate close to modern (only remnant ice sheets, minor changes in greenhouse gases compared to the pre-industrial, relatively small insolation differences), a potentially important ocean response, and crucially, a quantifiable hypothesis for a cause—the catastrophic draining of Lakes Ojibway and Agassiz.

The challenge for the paleo-community is to further map out the patterns of climate response associated with this event, and crucially, to present it as a coherent set of target data for modellers who will not necessarily be familiar with the primary sources of data or their uncertainties. In particular, criteria for whether this event is present (or not) in any particular record need to be more firmly established.

For the modellers, this is a 'Goldilocks' event. It is not so small or short term that there is no impact in the record, and it is not so large that anything that precipitates a MOC collapse will do. Instead, it is just about the right size and duration. This event is an abrupt climate change forced (it appears) by an even more abrupt forcing. No thresholds appear to have been crossed. While this event therefore cannot be used to fully address the potential bifurcation structure of the North Atlantic circulation, it may tell us much about the restoring processes, including non-local salinity feedbacks, that generally keep the MOC stable. Appropriately, these processes are highly relevant for the climate of the 21st century.

Experiments with intermediate complexity models (Renssen et al., 2001) or using generic freshwater hosing in full GCMs (Rind et al., 2001; Vellinga and Wood, 2002) suggest a significant sensitivity to the base climate. Therefore ensembles of simulations will be essential. The multiple proxies involved pose another challenge to modellers to ensure that paleo-climatically important tracers (water isotopes, vegetation, dust, methane, etc.)

0277-3791/$ - see front matter
doi:10.1016/j.quascirev.2005.01.015

are included within the latest generation of Earth System Models in order to allow more direct comparisons of model output to paleo-proxies.

Modellers may also be able to answer questions that puzzle the paleo-community: why isn't there a noticeable isotopic signal in the North Atlantic south of Iceland? Does the entry point of the water or its sediment load matter? How much of a depleted source water effect is there in the isotope signals? What are the key processes that influence any tropical response? Modelling results will then hopefully be assimilated by the paleo-community and stimulate suggestions for other analyses and interpretations.

For assessing future climate changes, this event is potentially one of the most relevant episodes in paleoclimate so far analysed. The Alley and Ágústsdóttir review is a key step but there is still a lot of work to do.

References

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