

Craig Wallace discusses the key achievements from one of the Natural Environment Research Council's most high profile programmes.

RAPID CLIMATE CHANGE

Yesterday, today and tomorrow (and the day after that)

To most, the idea that climate change might trigger abrupt changes in the global ocean circulation needs no introduction. People may have heard about it through measured scientific appraisal or through the marginally more dramatic Hollywood hyperbole of ‘The Day After Tomorrow’. In any event, to improve our understanding of such risks and, perhaps more crucially, our ability to detect change, the UK-led Rapid Climate Change programme was born in 2001. Seven years later the programme prepares for its transition into the next phase, Rapid-WATCH. This follow-on programme aims to secure a decade’s worth of measurements of the Atlantic Heat Conveyor, or to be technically precise, the Atlantic Meridional Overturning Circulation. But what have we achieved and learnt in those first seven years?

Climatologists have long known of the potential of global climate change to interfere with the global ocean circulation pattern – and in particular the Atlantic Heat Conveyor. Warm up, or dilute, any body of sea water, and you’ve just reduced its density making it less likely to sink. Do both, and you could be in real trouble, especially if your sinking water just so happens to sustain a circulation pattern that ensures the UK’s temperate climate.

By 2001, most of the world’s climate research centres were reporting that a slowdown in the Atlantic Heat Conveyor could readily be seen in their climate projections for this century. In some cases, the slowdown was marginal. In others, it was substantial, and in a small but worrying number, it was large. By this time, leading UK and European scientists were outlining how a prototype monitoring system for the Atlantic Heat Conveyor might work and what research questions should be addressed to increase our knowledge of the risks. In 2001, The Natural Environment Research Council approved funding for a bold seven-year programme, Rapid Climate Change (usually shortened to RAPID), tasked specifically with improving our ability to

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quantify the likelihood and size of future rapid climate change.

The strategy was threefold. Firstly, what might we learn from historical episodes of abrupt climate change that could help us better understand the present and future risk? Secondly, and in need of the most resources, design, deploy and maintain a monitoring system capable of detecting changes in the Atlantic Heat Conveyor over time. And, thirdly, investigate how we might refine our projections of future changes, and knowledge of what impacts these might bring.

Past rapid changes

So what have we learnt from looking at the past? Well, one of the most readily observable episodes of abrupt climate change occurred about 8200 years ago – the aptly-named 8.2kyr (kilo-year) event – often quoted as a potential analogue for how any future abrupt change might unfold.

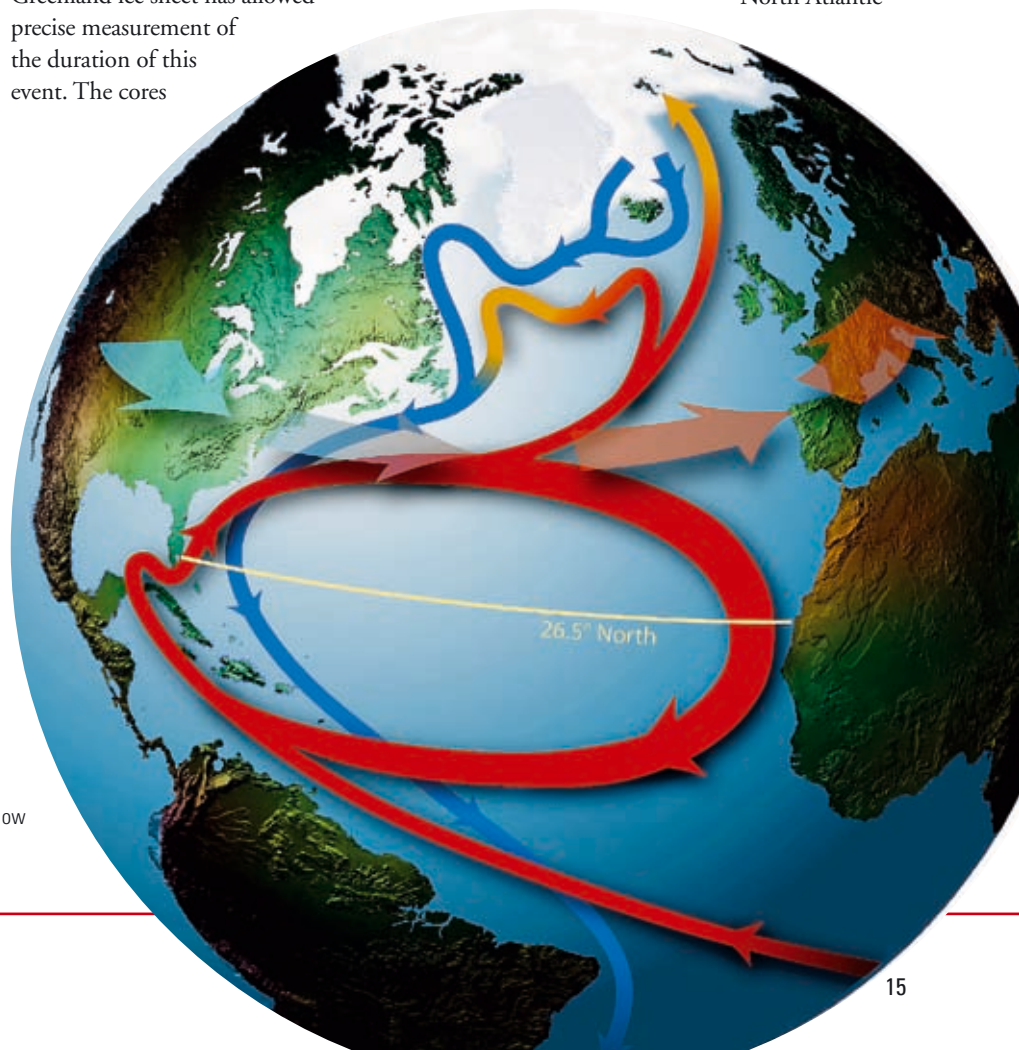
For the first time, high-resolution analysis of ice cores recovered from the Greenland ice sheet has allowed precise measurement of the duration of this event. The cores

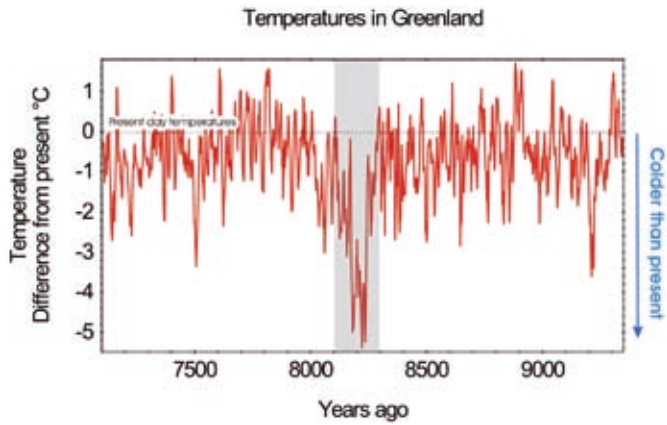
allowed the team to identify a broad cool episode lasting approximately 150 years and a central 69-year period during which most of the cooling – up to 6°C over Greenland – would have occurred.

RAPID-funded research of ocean sediment cores has also provided the first direct evidence that this cooling coincided with a slowdown in the deep return leg of the Atlantic Heat Conveyor, the North Atlantic Deep Water. This was most likely caused by the sudden, catastrophic drainage of dammed glacial lakes over North America releasing vast amounts of fresh water into Arctic, slowing the northwards heat transport and cooling the North Atlantic region.

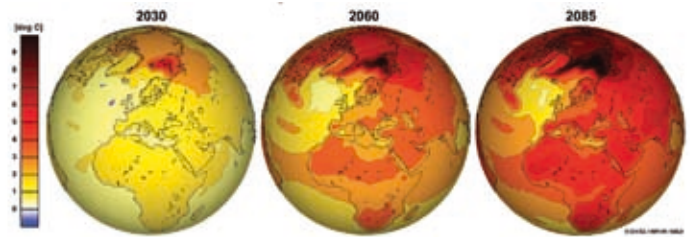
Ice and sediment aside, work has also clarified how the cooling signal from the 8.2kyr event manifests itself in cave stalagmite records. Work here has shown the signal to be weaker than expected and that many cave records, instead, are more sensitive to variations in atmospheric circulation systems, such as the North Atlantic

The North Atlantic and Arctic Oceans are critical components of the ocean-climate system. Warm tropical waters flow northward, releasing heat to the North Atlantic region, and eventually flow into the depths of the Arctic Ocean. Cold waters sink in the North Atlantic and flow southward to drive the Atlantic Heat Conveyor.





The North Atlantic region cooled significantly 8200 years ago (light blue in the graph). The period of greatest cooling lasted around 60 years.



Even a moderate slowdown of the system has a discernible climate signal – note the offsetting of projected greenhouse warming over the Atlantic by 2085 in one climate model simulation. Source: IPCC Fourth Assessment Report

Oscillation, which determines how stormy one winter is from the next over the North Atlantic region.

The first daily measurements

So, we are learning more about the nature of historical changes, but what of changes today? Can we tell yet if the Atlantic Heat Conveyor is slowing down? The short answer is ‘not yet’. But we can be confident that we have the right tools in place to let us know if it is. It’s a question of time. The first RAPID equipment was deployed in 2004 at a latitude of 26.5°N, between the Canary islands and Miami. This is an obvious location to monitor the circulation because it is where the maximum northwards heat transport occurs. Farther north, the majority of the surface heat is released to the atmosphere where winds carry it to Europe.

The equipment provides a continuous measurement of the free ocean flow. Previously, scientists relied on occasional ship-based measurements – just five comprehensive measurements since 1957. In the first full year of measurement we have already seen two crucial results. Firstly, confirmation that the monitoring approach works: it gives us an extraordinarily accurate measurement of the system. Secondly, we now have an indication of how the system varies from one day to the

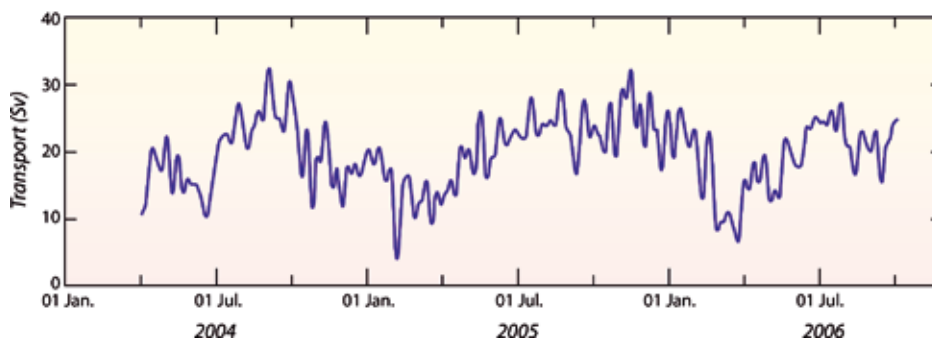
next. The results have revealed this short-term variability to be large – more so than previously thought. Knowledge of this variability is vital if we are ever to know, with confidence, that a longer-term change is underway.

Researchers have also deployed equipment farther north allowing scientists to understand how the strength of the circulation is related geographically, and how changes in the circulation strength may be communicated from one place to another. More data awaits analysis. As the time series grows, so too will our ability to distinguish any real trend caused by greenhouse gas emissions from the background noise of the system.

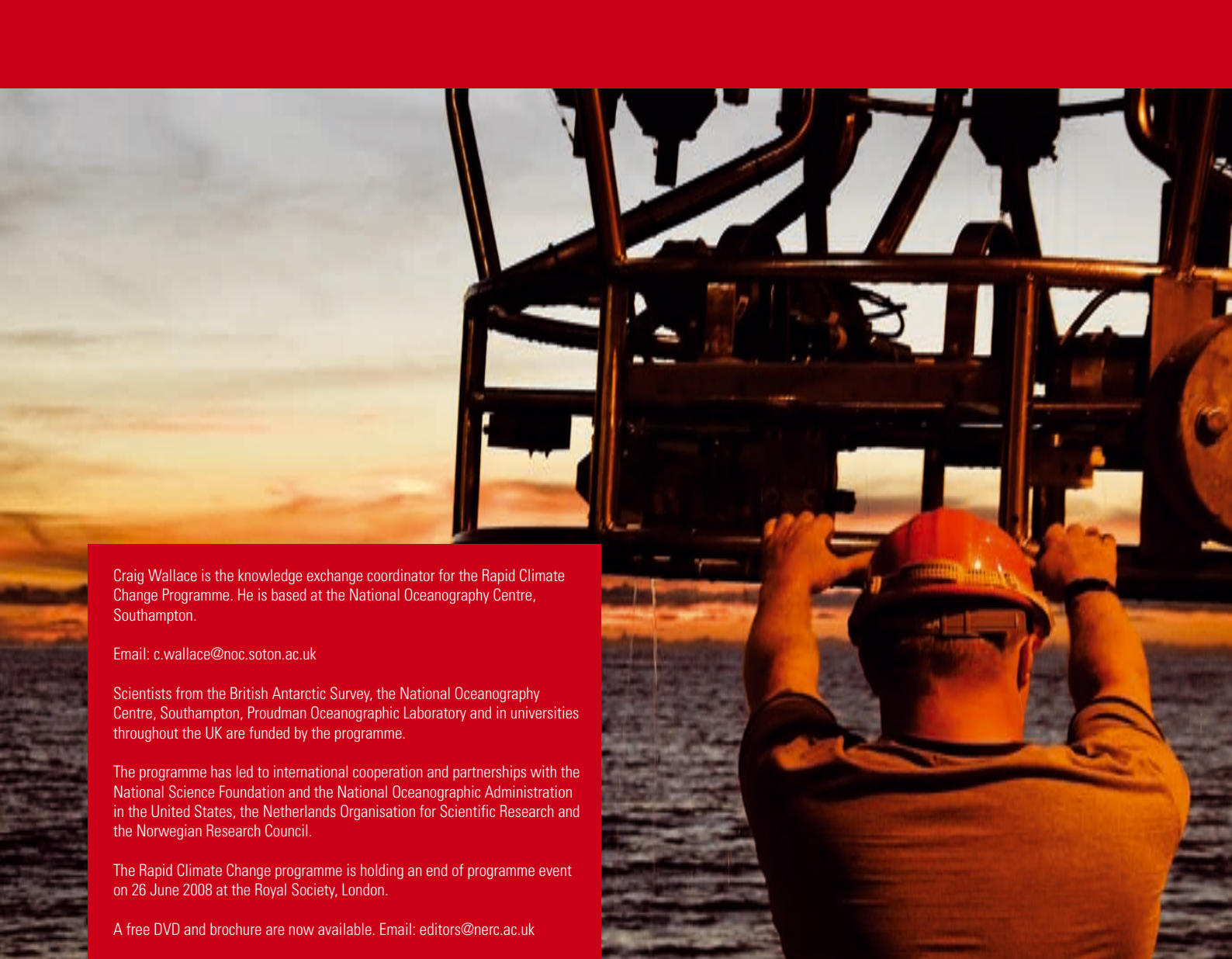
In looking to the future, one need only consult the recent UN Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report for an indication of the level of uncertainty surrounding projections of future changes to the Atlantic Heat

Conveyor. There may be agreement on the sign of the change this century – a slowdown of sorts is ‘very likely’ – IPCC code for greater than 90 per cent chance. But climate models do not agree on the size of this change. It could be anywhere between a zero and 50 per cent departure relative to the average 1961-90 modelled strength. And, while the models agree the chances of a total collapse are small, the probability could be anywhere between zero and nine per cent.

This was most likely caused by the sudden, catastrophic drainage of dammed glacial lakes over North America.



The first continuous, daily measurements of the Atlantic Meridional Overturning Circulation. (The strength of ocean currents is measured in Sverdrups (Sv), one Sv equals a million cubic metres per second.)



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Scientists from the British Antarctic Survey, the National Oceanography Centre, Southampton, Proudman Oceanographic Laboratory and in universities throughout the UK are funded by the programme.

The programme has led to international cooperation and partnerships with the National Science Foundation and the National Oceanographic Administration in the United States, the Netherlands Organisation for Scientific Research and the Norwegian Research Council.

The Rapid Climate Change programme is holding an end of programme event on 26 June 2008 at the Royal Society, London.

A free DVD and brochure are now available. Email: editors@nerc.ac.uk

'Temporal variability of the Atlantic Meridional Overturning Circulation at 26.5°N'. *Science*, 317, 935-8, 'Flow compensation associated with the Meridional Overturning Circulation at 26.5°N in the Atlantic'. *Science*, 317, 938-9. (August 2007). The journal *Nature* listed these papers as two of the top ten science achievements in 2007.

Narrower bands of uncertainty are always desirable: I am mindful of the challenge decision makers face and in particular those who must gear their business or policy decisions around climate risks.

A key step towards constraining future predictions is to understand why the models give such a wide range of predictions in the first place. RAPID has funded a major project to compare the response of the Atlantic Heat Conveyor to a variety of climate change scenarios in a suite of UK climate models – each with differing physics and levels of complexity. Initial simulations are already complete and more results are to follow soon.

Running a computer climate model is a costly business, especially as they become better at resembling the real world. The pressure on computing resources becomes immense if you need to run your model hundreds or thousands of times to work out probabilities of an event occurring. Pioneering work by RAPID scientists has led to powerful statistical tools that allow scientists to run approximations of a climate model many times extremely quickly, providing very efficient route to obtaining a large set of results from which to calculate probabilities. These tools are known

in the trade as 'emulators' and the applications extend beyond climate science to any modelling problem which involves a wide set of starting conditions that you might want to change. The tools hold particular benefits for price modelling, for example, calculating the cost to insurers of extreme weather events. The programme's researchers are already talking to the financial services sector about future collaborations.

The level of interest in the programme has been quite remarkable. RAPID's core team has worked hard to ensure key results reach as many users in science, business and policy as possible. These stakeholders are feeding back what kind of information they need the RAPID programme to supply. The core team has held high profile press conferences and briefings with the UK and the international media. They have worked with artists, writers and filmmakers, and educators. And they have even developed educational material on rapid climate change for the national curriculum.

The question of whether or not the Atlantic Heat Conveyor is changing (and what it might do in the future) will not be answered quickly. But with the advent of Rapid-WATCH* later this year, we can be certain at least, that the research community is better placed to provide society with advance warning of any imminent change. ❖

*Rapid-WATCH (*Will the Atlantic Thermohaline Circulation Halt?*)