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The Meltdown: Abrupt climate change since the last Ice Age

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During this century, climate is expected to change at an unprecedented rate. Climate change is one of the most critical issues facing society, but there are still many unanswered questions about how different parts of the Earth's system will respond. This National Meeting, which took place at University College London on 18th October 2017, had a broad programme that addressed mechanisms of abrupt (decadal-centennial) environmental change during the last 21,000 years as inferred from proxy data and climate models, past interactions between humans and climate, and whether lessons from the past can help us to understand future environmental change. The meeting was organised by Dr Ruza Ivanovic (University of Leeds) and chaired by Professor Dame Jane Francis (British Antarctic Survey). All presentations are available on the RMetS website.

Dr Liz Thomas (British Antarctic Survey) began with an introduction to ice cores as records of past climate change, outlining how atmospheric composition can be inferred from air bubbles trapped within the ice, and temperature can be estimated from isotopic ratios. Ice core records for the last 120,000 years demonstrate that a number of abrupt climate shifts (e.g. Dansgaard-Oeschger events, Heinrich events, the 8.2 kyr event) interrupted the transition from glacial conditions to the warm climate of the present. Many of these events occurred on human-relevant timescales, with freshwater releases from ice sheets and consequent changes in ocean circulation playing an important role.

Dr Lauren Gregoire (University of Leeds) followed up on this subject, showing how climate and ice sheet models are used to decompose the drivers and mechanisms of progressive and abrupt deglacial changes. Lauren also provided an interesting insight into how we can explore uncertainty in model simulations using techniques such as Latin Hypercube Sampling. Orbital forcing was identified as the biggest contributor to North American ice volume loss during the deglaciation, with ice sheet instabilities and mass balance feedbacks playing a significant role in rapid climate and sea level events. Similar instability mechanisms are valid for modern marine-based ice sheets, therefore constraining the rates and styles of past retreats may improve our ability to predict future changes.

Mechanisms of abrupt climate change often involve the atmosphere and/or terrestrial biosphere. However, using evidence from deep-sea corals, Dr Andrea Burke (University of St Andrews) argued that fast changes can also originate in the oceans, with sea ice in the Southern Ocean playing a vital role in deglacial atmospheric CO_2 changes on centennial and millennial timescales. Sea ice concentrations influence the dynamics of the large-scale ocean circulation. In the modern Southern Ocean, steeply dipping isopycnals close to the sea ice edge connect the carbon-rich deep waters with the sea surface and the atmosphere, acting as conduits for CO_2 exchange. With more extensive sea ice at the Last Glacial Maximum, the diffusive boundary between the surface and deep ocean shoaled, isolating the carbon-rich abyssal waters. Deglacial changes in the carbon content of the deep ocean mirrored atmospheric CO_2 changes, suggesting that loss of CO_2 from the abyssal ocean to the atmosphere was a primary driver of the long-term CO_2 trend. Changes in the surface ocean, which coincided with abrupt atmospheric CO_2 increases, reflect a rapid transfer of carbon from the deep ocean to the sea surface and atmosphere.

In the context of anthropogenic climate change, adaptation is key to reducing and managing potential risks, but how did abrupt climatic transitions in the past influence early human societies? Dr William Davies (University of Southampton) explored this topic, focussing on the ecological and demographic responses in Europe during the period 21,000 to 8000 years ago, a time when the prevailing economic organisation was hunter-gatherer-fishers who relied heavily on environmental productivity. William outlined the timings of key population events (refuge, expansion, contraction, and re-expansion), and concluded that early humans showed varied and flexible responses to environmental change. Evidence of resource intensification and diversification demonstrates that environmental events created both constraints and opportunities, and that early humans adapted to adverse and unstable climatic conditions. However, these were low density, mobile groups. How would today's deeply politicised and overpopulated societies cope with similar environmental stresses?

There is little question that humans are the main driver of current and future climate change, but did our ancestors have a measurable impact on the environment? Dr Joy Singarayer (University of Reading) outlined the debate around the agreed onset of the Anthropocene, the geological epoch during which human influences on the climate outweigh natural forcing. Did the Anthropocene begin in the 1950s with the advent of nuclear weapons testing, during the 18th Century with the Industrial Revolution, or perhaps even 8000 years ago with early agricultural intensification? This is an important question when thinking about long-term human disturbances and setting a baseline for conservation. Using evidence from climate and vegetation/carbon cycle models, Joy suggested that both human and natural emissions are required to explain atmospheric CO_2 and CH_4 increases during the last 2500 to 3000 years. If land use changes have been causing significant biogeochemical and biogeophysical impacts on local to global scales for the past 3 millennia, then the pre-industrial might not be an appropriate benchmark against which we should be measuring anthropogenic effects.

The meeting closed with a discussion, led by Professor Paul Valdes (University of Bristol), tackling the question of whether past abrupt events can help us to understand the future. A key message from Jane's opening statement was that it is our duty as scientists to communicate current and future climate change in a wider context, and one of the most pertinent points of the afternoon was that 'rapid' deglacial CO_2 events are not a direct analogue for the future because the magnitudes and rates of change were much smaller and slower than anthropogenic projections. However, abrupt deglacial temperature changes occurred on human-relevant timescales, with localised effects that were (in some cases) larger than predicted future anthropogenic changes. These case studies can therefore provide a testbed for identifying key drivers and mechanisms of change, which may help to improve our understanding of current and future climatic transitions.