Adapting to a changing climate

The British Geological Survey's climate change programme is just two years old, but is already tackling some of the toughest questions to emerge from climate science. Mike Ellis explains how.

What will the climate – and indeed the weather – be like in the future? And how will our environment, all of it – urban, rural, chemical, physical, biological – respond to climate change? These two fundamental questions are still not resolved, but the answers will lie at the very heart of any strategy for adapting to climate change.

Palaeoclimate and palaeoenvironments

Future climates are difficult to predict. Not only is the system chaotic but we don't yet know all the feedbacks that affect it. Feedback means a knock-on effect – when the impact of one change effectively increases, or decreases, the effect of further change. The rapid loss of Arctic ice in 2007, and faster rise in sea levels than models had predicted, show that our poor understanding of these feedbacks limits our ability to see into the future.

But to look ahead it is sometimes useful first to look back. Our geological past offers a unique insight into how the Earth responds to different conditions. Ocean and lake-sediment cores are beginning to reveal, in startling detail, how the Earth system responds to relatively sudden changes. For example, close to 55 million years ago, an amount of carbon dioxide (CO_2) roughly equivalent to our current known reserves of fossil fuel was injected into the atmosphere – a massive change by any standards. Incredibly, some of the cores BGS is looking at have such high resolution that scientists can interpret how the Earth responded almost year by year.

One of the most significant climate changes in Earth's history occurred about 450,000 years ago (the so-called mid-Pleistocene transition), when climate cycles changed from around 40,000 to 100,000 years. No one knows why, and until we understand these sorts of changes we can't hope to predict future climate with any certainty. To find answers, BGS scientists are taking part in the first ever expedition to the Bering Sea by the Integrated Ocean Drilling Program (IODP). This lets us use ocean sediment cores to compare changes in the Arctic ocean environment to global climate change, to tackle questions of how the Earth system works as a system. Information in the cores will show us how closely Earth's environmental response is linked to changes in climate, and how the system varies during and after these rapid changes.

The last time the Earth's atmosphere had a CO_2 concentration of 365-415 parts per million was during the Pliocene, around 3 million years ago, and the planet was on average 3-4°C warmer (probably a lot more in the northern hemisphere). If man-made emissions continue at present rates we will reach the higher of these levels soon after 2020. So we have to find out – and soon – how the environment differed when average global temperature was this high. One way of doing this is by looking at sea-surface temperatures in the Pliocene. BGS is a partner in the USGS PRISM climate project, one goal of which is to find clues to sea-surface temperatures in the ratio of heavy to light oxygen isotopes preserved in clam and planktic fossils. This will help show how heat was transported through the world's oceans, and it's vital that we understand how this part of the system operated in the warmer Pliocene world if we are heading in the same direction.

BGS will use this data in its new

IODP scientists onboard JOIDES *Resolution* celebrate the collection of the longest-ever core by the hydraulic Advanced Piston Corer, from 458.4 metres below the sea floor.

Flooding in Cockermouth, Cumbria, in November 2009. The scale of events like these depends on the climate and the sensitivity of the specific environment. BGS models will assess such sensitivity to future climates.

palaeoclimate modelling initiative, which links the state of the Earth system during the Pliocene to that of the Anthropocene, the name being given to the potentially newest geological period – an epoch born of human influence on our home planet. New palaeoclimate models are being developed, for example, to investigate the role of modern land-use in determining what the climate might have looked like had it not been for the development of civilizations. And we are investigating the role of oceanic heat transport in providing thresholds or tipping points in a changing climate.

The environment is a dynamic system as we have seen, and we are considering it from every angle. Feedbacks to the climate system revolve around the fate of stored carbon, whether in soils, methane sources or permafrost. BGS is looking at all of these, investigating carbon cycling in soils and biomass, changes in carbon pools in UK soils, and the stability of methane in wet and frozen environments. (We look at carbon capture and storage too – ways of capturing CO_2 as it is generated and storing it away from the atmosphere.) Based on new evidence, BGS scientists have also developed new ideas about how the British ice sheet behaved during the last ice age, and the relative chronology of the advance and retreat of glaciers. This will give us a better understanding of ice-sheet dynamics in a warming world, which in turn will provide further insight into the dynamics of the retreating Greenland ice sheet.

All of these efforts will reduce our uncertainty about future climates and the state of the Earth's system in a warmer and rapidly changing climate. But this is only half of the problem. The other half may be more complex, and will involve a much broader range of disciplines.

Modelling the environmental impact

Lots of work has gone into modelling future climates, but relatively little into how the environment as a system will respond. Translating probabilities of climate change into probabilities of environmental impact is one of the most significant challenges ahead for the climate change community. Scientists from BGS are collaborating with colleagues from a range of other disciplines to develop a model to assess environmental sensitivity to climate change – ESC. Environments do not behave in a linear way and environmental responses (in terms of frequency of landslides, say, or the form that a water channel wants to take, or changes to an ecosystem within that channel) are extraordinarily difficult to predict. They are subject to many complex processes and we are only beginning to understand how these processes are linked.

And it isn't only the extreme events that may be important – a greater number of apparently less significant events could make a considerable difference to the conditions in which extreme events take place. The ESC model will link the dynamics of these processes – hillslope and cliff stability, ground and surface water flow, sediment transport, channel form, ecological processes, coastal processes, and many more. Rather than reinvent wheels, we aim to combine existing models on a common platform, designing new components where necessary. An ESC model will provide a quantitative assessment of how a specific environment will respond to a different distribution of weather events, at a scale that will be directly useful to people who need to make decisions about urban and rural adaptation strategies.

The application of an ESC model would not be possible without the long history of monitoring and evaluating Britain's environment by BGS and its sister organisation CEH – the Centre for Ecology & Hydrology. Such long-term studies are crucial for providing the initial conditions for an ESC model, because unlike climate modelling, the ESC model cannot assume that the environmental system starts in equilibrium.

One of the main drivers of environmental change over hundreds to thousands of years is base-level change – the combination of shifts in sea and land levels. We can see from studies of earlier ice sheets that land sinks and rises with glacial movement, while the existence of organisms that are sensitive to salinity tell us about changes in sea level. Base level and climate set the pace for erosion, and BGS is reassessing erosion across the UK and feeding this information into dynamic models to assess the sensitivity of specific environments to climate change.

The BGS climate change programme has existed in its present guise for a little more than two years but already has ties to more than 20 UK universities as well as sister agencies, CEH, the British Antarctic Survey and the National Oceanographic Centre in Southampton. The few aspects touched on here don't do justice to the very broad scope of the programme, a scope that will certainly expand because, ultimately, we are driven by the need to serve the national interest in the best way possible. So BGS will continue to be responsive to the fundamental questions about climate change that emerge from the scientific community and wider society.

MORE INFORMATION

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www.bgs.ac.uk/research/climatechange

Pliocene Research Interpretation and Synoptic Mapping (PRISM)
http://geology.er.usgs.gov/eespteam/prism

NERC Isotope Geosciences Laboratory
www.bgs.ac.uk/nigl/Climate_RatesChange.html

FURTHER READING

US National Research Council (Washington DC) (2010) *Landscapes on the Edge: New horizons for research on Earth's surface.*