The British Prime Minister, Tony Blair, has described climate change as the world's greatest environmental challenge. **Dave Tappin** and **John Rees** outline some of the ways in which the BGS is helping to meet that challenge.

The big picture

Is the Earth's climate warming? If so, how fast is this happening? And is the warming due to human causes? These questions have been hotly debated for the past ten years. The prediction that global warming will change our planet at unprecedented rates presents the most pressing challenge facing the global community. Should we try to mitigate the effects, adapt to them, or try to do both?

Most earth scientists accept that global warming is happening and is caused by human activities taking place over the past 250 years — our consumption of the Earth's carbon resources at increasing rates. Fossil carbon in the form of coal, oil and gas, that has taken hundreds of millions of years to accumulate, has been consumed over just a few centuries. The result is a rapid increase in atmospheric carbon dioxide leading to rising temperatures and significant changes in climate. A major secondary impact is rising sea level. One remedy would be to cut carbon dioxide emissions, but while the political aspects of this are assessed, scientists are being asked to explain the underlying causes of the changes, predict their impact and develop a response.

For over 170 years the BGS has been the main repository of geological data for the UK as well as providing strategic information on its geology for the national good. We recognise that global warming will have an increasing impact on our environment so we are developing new research programmes to focus more closely on why and how this will take place and what its effects on the UK will be. There is now a general recognition that future climates may be much warmer than any experienced for millions of years so that our understanding of past 'deep-time' climates is highly relevant.

Our climate change research is mainly funded from our core programme but additional finance comes from commercial research partnerships. The main themes align with the NERC science programme, especially 'Climate Change', 'Earth System Science', 'Natural Hazards' and 'Sustainable Use of Natural Resources'.

Climate change

Our research into the impacts of climate change is based on the knowledge that the UK's weather will change as global temperatures rise. We can appreciate what has happened in the past from climate records that show the 1990s to be the warmest decade in central England since records began in the 1660s. The growing season for plants in central England has lengthened by about one month since 1900. Heatwaves have become more frequent in summer, and now there are fewer frosts and winter cold spells. Generally, over the past 200 years winters have become much wetter relative to summers throughout the UK and a larger proportion of winter precipitation now falls on heavy rainfall days than was the case 50 years ago.

Forward modelling of climate change in Britain indicates that the changes already experienced will continue, possibly at increased rates. Extreme weather is predicted to become more common, with winters becoming wetter and stormier and summers becoming hotter and drier. One of the major impacts of global warming is that as the ice sheets melt and

The size of the polar ice caps is a key climatic indicator.

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Tropical storms may become more frequent.

a warmer sea expands, sea level will rise. We know that, after adjusting for natural land movements, the average sea level around the UK is now about 10 cm higher than it was in 1900.

The overall theme of our research is sustainability: how can we continue to use and defend our natural resources under the climate changes predicted? Climate change is relevant to almost every aspect of our programme and provides a link between our various activities, such as research into groundwater resources, soils and the engineering properties of rocks.

Consequences

Groundwater provides about 30% of the overall water supply in the UK, rising to over 70% in the south-east. Wetter winters will lead to more groundwater recharge, but water from heavy storms runs off directly to rivers and other surface watercourses, so the increase may be limited. Drier springs and autumns will reduce the length of the recharge season so, overall, less water may enter the underground systems. Hotter summers will lead to an increase in demand for groundwater resources, especially if the flow in rivers is reduced. Rising sea levels may lead to the loss of groundwater resources in very low-lying coastal areas, as sea water flows into local aquifers and the fresh water lens.

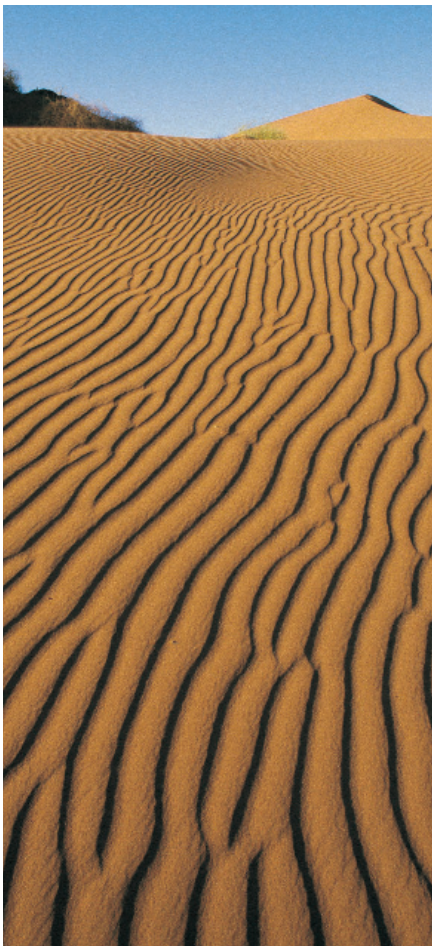
Soils form the interface between the atmosphere and geosphere through which nutrients and pollutants circulate. They are major carbon sinks and the carbon stored helps maintain soil fertility, helps store water and prevents wind and water erosion. In the past there has been little attention to the protection of soils and to a long-term understanding of their development and function in terms of climate change. In response to new legislation, regulatory agencies and industry (including agriculture) will require data on the sustainability of soil use across a wide range of functions. Our programme focuses on improving our understanding of the coupling of the whole of the near-surface environment with the atmosphere and hydrosphere.

The water content of soil and rock significantly affects their physical properties. Drier climates will lead to shrinkage, especially in peats and clays. The drying of peats in lowland situations may result in lower land elevations that may in turn result in increased flooding during wetter winters. Increased expansion and contraction in clays during drier summers and wetter winters could result in increased subsidence. Wetter weather will result in a rise in the water table leading to increased slope instability, and landslides. Our research is at a site-specific scale and focuses on ground stability, geomorphology and erosion. We are also developing methods to predict change in order to underpin this new approach.

Rising sea levels will increase the effects of coastal erosion and inundation by the sea. Areas of low-lying coast will be most affected, especially those on the east coast of England, where long-term subsidence exacerbates the risk.

Mitigation

The BGS is an acknowledged leader in 'carbon sequestration', the artificial reduction of atmospheric carbon dioxide. One method we are helping to evaluate at the Sleipner Field in the North Sea is the injection of 'warm' carbon dioxide back into the source rock. Another option is to store the carbon dioxide as gas hydrate. This has long-term benefits because the frozen gas is more stable than when warm. In collaboration with Leicester University we are carrying out laboratory experiments to determine stability under different temperature and pressure conditions. We are also studying gas hydrates in situ to determine their stability in relation to climate change and to large-scale catastrophic landslides.



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Increased desertification is a problem in Africa.

Past climates

For 10 000 years, since the last ice age, our climate has steadily warmed. BGS and NIGL scientists have been studying how ice ages are initiated. We have a specific project on how the British ice sheets have evolved fluctuated, especially the climate controls operating in the north Atlantic. A new programme in collaboration with the British Antarctic Survey and the University of Bristol is researching the initiation and evolution of 'deep-time' extreme warm climates. This research is supported by the development of new techniques, such as the chemical analysis of organic plant material to identify environments of deposition.

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