The Big Picture

Planet Earth: the most complex system anyone has ever tried to understand. It seems like **Sarah Cornell** and colleagues like a challenge.

The idea that our planet operates as a whole system, with the ice sheets, oceans, atmosphere, land and life itself all connected and influencing one another, has driven much recent environmental research. Indeed, research supported by NERC has placed UK scientists at the forefront of discoveries in all these fields.

But producing a complete picture of major global environmental change, in particular climate change, is an enormous and intricate challenge. There is more pressure than ever for science to give a robust indication of what the future may hold, yet if today's climate models are to predict future changes, they must include the connections and feedbacks between living organisms and the physical environment. So who is putting all these research findings together in a useful way? Enter the QUEST programme. QUEST stands for 'Quantifying and Understanding the Earth System' and is NERC's £21 million programme to join up the knowledge about all the components to improve understanding of the whole system.

Why have both quantifying and understanding in the programme title? Clearly, there is a need to quantify processes that are included in numerical models, and QUEST scientists are building on long-standing and close cooperation with the Hadley Centre for Climate Change Research. In particular, the recognition now that human activities are changing the chemistry and physics of the atmosphere has given a new urgency to develop models that will help us explore the scale and nature of those consequences. However, some features of the system, such as plankton ecology, need to be better understood in order to be represented mathematically. And certain processes are known to be important – society's adaptation to environmental changes, for instance – but there are limits to their predictability.

> An urgent question is: how much climate change is dangerous?

Describing the outcomes of possible responses by society to different degrees of climate change will be valuable information for those people responsible for making decisions today that affect the future. So QUEST is not just about modelling – projects also include lab and field experiments, direct and remote-sensing observations, and even socio-economic analysis. In fact, finding better ways to make these different aspects of scientific understanding contribute to the big picture of global change is one of the main reasons NERC created QUEST.

When NERC first mooted the idea of such a programme back in 2002, everyone concluded that this kind of science required a new approach with more coordination across normal research discipline boundaries. As a result each QUEST project is a multi-institute consortium, bridging the modelling and observations communities. QUEST also has resources for events, scientist exchange programmes and working groups, encouraging new interdisciplinary approaches and better relationships with policy makers and industry.

The programme itself came into existence towards the end of 2003, when QUEST's leader, Colin Prentice, took up his post at the University of Bristol. Now, groups from over 25 universities and research institutions are part of the QUEST community.

The programme is already producing visible results. A paper led by programme scientist Marko Scholze in the *Proceedings of the National Academy of Sciences* (August 2006) analysed output from the climate models used by the Intergovernmental Panel on Climate Change (IPCC), the world's leading authority on climate change, and found a new way of cutting through the uncertainty. The team mapped out where in the world the IPCC's climate models all agree with one another (and also where the outputs disagree), highlight-ing areas that will be prone to droughts, floods, fire risks and serious habitat losses. This approach means we can confidently say that the more intense the future global warming, the harsher the consequences will be.

The resulting maps can be the starting point for discussions about how to pre-empt those risks and adapt.

Right from the start, QUEST's research was designed to tackle science questions that have big implications for society's responses to climate change. The first, 'How important are the feedbacks between climate and the biosphere?' is addressed by three projects looking at the contemporary climate. QUEST is developing tools to explore the processes that contribute to the greenhouse gas content of the Earth's atmosphere. The projects will incorporate atmospheric chemical reactions and ecosystem dynamics into the standard climate models.

The second research theme looks back in time, asking 'What are the natural regulators of atmospheric composition?' Scientists are making global reconstructions of past climatic conditions using ice-core data, tree ring and sediment records and other climate proxies (that is, indirect indicators of past climates). Climate models can then be used to 'predict the past' to give a better picture of what the future might hold.

The third main research theme tackles the complicated question of how much climate change is 'dangerous' to ecosystems and to the human societies that depend on them, and what may be done to mitigate that change. This theme requires highly interdisciplinary approaches, and we are forging new relationships across the natural and social sciences. We will also assess the global potential for land management activities to draw down carbon dioxide or offset fossil fuel use, and evaluate present-day mitigation practices. All of these themes have been shaped in part by the potential users of QUEST's findings. Colin argues that often, 'research that's needed isn't done, while the research that is done isn't understood'. Jo House, QUEST's science and policy officer, is responsible for building relationships with policy makers, government departments, the business sector and other organisations, to make sure that QUEST research gives useful information to their real-world challenges.

Over the summer, QUEST has really focused on its policy networks. Colin and another QUEST scientist, Peter Cox, held a private climate change briefing with David Milliband, the new Secretary of State for Environment, Food and Rural Affairs. They pointed out that while emissions reduction policies are going in the right direction, stabilising atmospheric carbon dioxide concentrations in the atmosphere will require targets that are much lower than half or even a third of present day emissions, because in the long run, emissions at that level still exceed the limits that vegetation and the oceans can absorb.

The Atlas will be a place where scientists, policy makers and even school teachers and pupils can obtain global data essential for Earth system science.

While part of QUEST's remit is to provide usable science to policy makers, we also need policy input. Meetings with teams of policy makers at Defra and DfID have shaped the planned outputs for the mitigation research activities and set priorities for the coming year's programme of working groups and briefings.

So what will be the final outcome from QUEST? QUEST's vibrant community of scientists, working across their discipline boundaries, will ensure that the next climate models will be Earth system models, building in scientific understanding of living processes as well as physical ones. QUEST research will improve the predictive power and the usability of these models. QUEST's goal is to make a real difference in a changing world.

The prototype Earth System Atlas is now up and running …

QUEST is compiling data on past climates, vegetation, carbon exchanges and other variables into an accessible and usable online global data atlas. The prototype Earth System Atlas is now up and running. The Atlas will be developed in partnership with US scientists, and will be a place where scientists, policy makers and even school teachers and pupils can obtain global data essential for Earth system science.

Dr Sarah Cornell is the science manager of QUEST, based at the Department of Earth Sciences, University of Bristol. Email: sarah.cornell@bristol.ac.uk. Tel: 0117 331 5136.
The Earth System Atlas prototype can be seen at http://earthsystematlas.sr.unh.edu/