Helen Snaith highlights some of the achievements of this £5 million NERC research programme.

Coupled Ocean Atmosphere Processes and European Climate

Events in recent years, such as floods and the heat wave of 2003, have made us increasingly aware of the changes in our climate. But how do these events compare to the normal state of affairs? What is normal anyway? How much does the climate system vary about this normal state? How do the components of this complex system interact to control the climate? Can we use knowledge of these interactions to help predict the weather decades ahead? And how do we make these predictions useful to society?

These are all questions at the heart of NERC's Coupled Ocean Atmosphere Processes and European Climate (COAPEC) programme. Between 2000 and 2005, COAPEC funded 20 research projects and 12 student projects, supported by a core team of four researchers, with the goal of finding out how the interactions between the Atlantic Ocean and the atmosphere affect the climate, especially in Europe.

First of all we needed to understand the measurements we already had on natural variations in the climate, particularly the relationship between the atmosphere, the ocean and the cryosphere (ice components). Research by students at the universities of Sheffield and Reading showed how climatological datasets fail to capture some of the details. For example, they don't fully capture the small but intense storms called polar mesocyclones, nor the fact that storms, rather like London buses, tend to come in clusters. Researchers at the National Oceanography Centre, Southampton investigated how heat is transferred between the oceans and the atmosphere. Their much-improved dataset of the global heat transfer between the ocean and the atmosphere is consistent with our present understanding of ocean circulation.

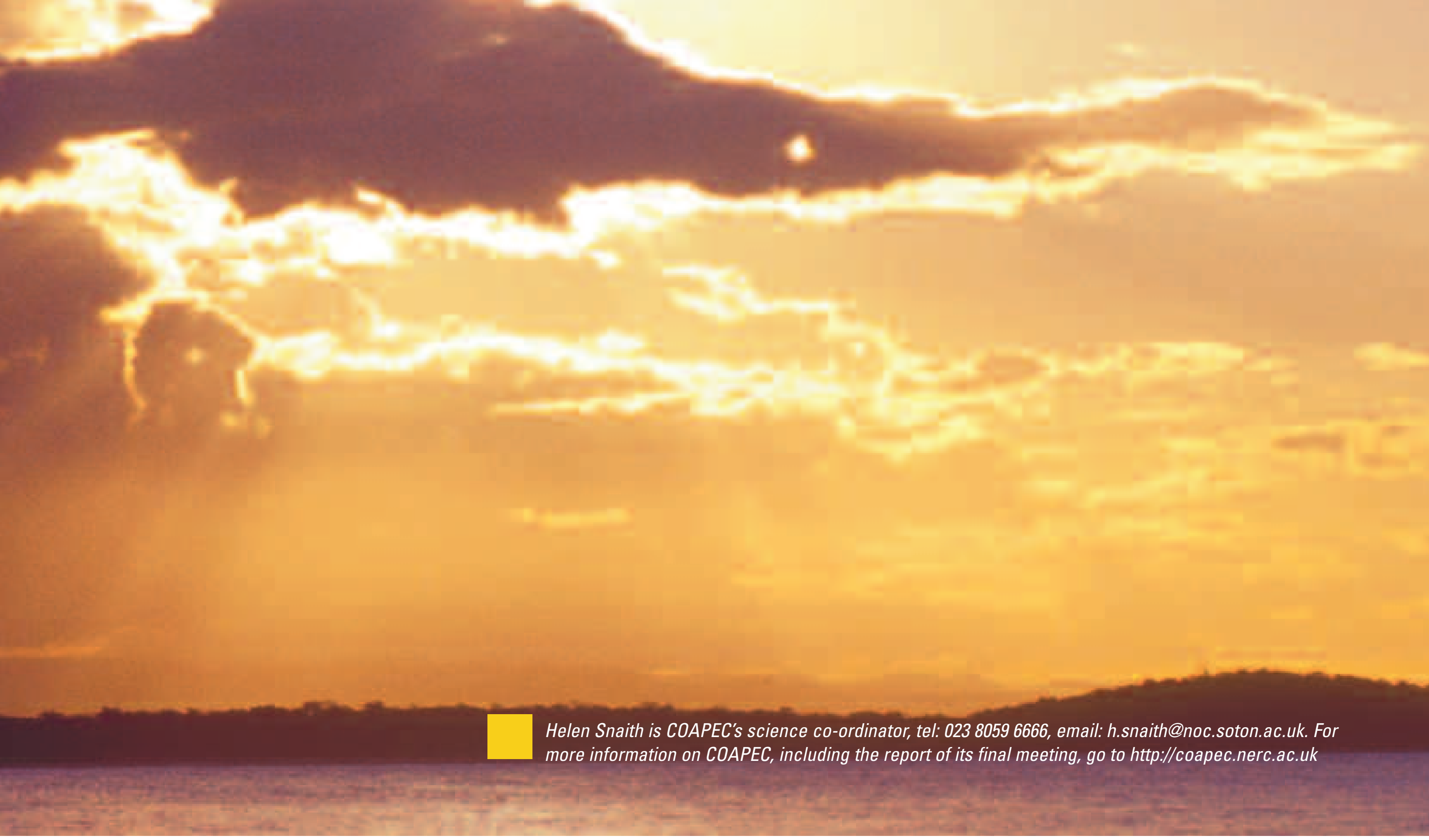
Climate scientists use computer programmes that simulate the Earth's climate as one of their main research tools. These are called climate models. The Hadley Centre made 1,000 model years of data, from their HadCM3 climate model, available to COAPEC researchers. Research at the University of East Anglia has shown that HadCM3 is remarkably good at reproducing key North Atlantic circulation features, despite its coarse spatial resolution.

COAPEC researchers looked at a wide range of physical processes that could be important in controlling the North Atlantic region's climate. University of Liverpool researchers used models to find out why the heat content in the North Atlantic Ocean has increased over the tropics and subtropics, but decreased over high latitudes during the past 50 years. They found it was because the ocean circulation had changed, and so had the transfer of heat between the ocean and atmosphere. These changes were both in response to changes in the winds that force the ocean. Further model studies showed that changes in the horizontal ocean circulation can also influence storm tracks over Europe and thus weather patterns. The National Oceanography Centre, Southampton developed a simplified model of the coupled system. It showed that, over long periods of time, small-scale ocean eddies can influence the atmosphere by changing large-scale temperature patterns.

> Sea-ice is far more sensitive to changes in climate than the climate is to changes in sea-ice.

Not only local processes have been investigated. Researchers at the University of East Anglia found that climate events in the Pacific strongly influence tropical Atlantic variability. This variability directly influences European climate.

Sea-ice plays an important role in the coupled ocean-atmosphere system, largely by changing the exchanges between the two components. However, there are few data to validate sea-ice models and much of the system's physics is still poorly understood. Researchers at University College London used new data from satellites to constrain some of the poorly known model



Helen Snaith is COAPEC's science co-ordinator, tel: 023 8059 6666, email: h.snaith@noc.soton.ac.uk. For more information on COAPEC, including the report of its final meeting, go to http://coapec.nerc.ac.uk

Doug Steley/Alamy

parameters. These parameters will now be used to improve our knowledge and modelling of sea-ice. Arctic sea-ice has reduced over the past 40 years. University of Bristol researchers investigated the effects of this reduction. It appears that sea-ice is far more sensitive to changes in climate than the climate is to changes in sea-ice.

Changes in the Atlantic Ocean's northward heat transport are closely related to variation in the thermohaline circulation, as warm tropical surface waters move across the Atlantic to the north of Europe. COAPEC's core team found that coupled model simulations can, to some extent, predict the thermohaline circulation. This circulation pattern influences European air temperatures. Researchers at the University of Reading have found that changes in North Atlantic Ocean heat transport are largely balanced by equal and opposite changes in the atmospheric heat transport. This compensation reduces the effect of changes in the thermohaline circulation on Europe's climate. NERC's Rapid Climate Change programme is now continuing to investigate the thermohaline circulation.

We hope that if we can better understand how the oceans and the atmosphere interact, we can better predict Europe's climate, from seasons to decades ahead. Researchers at the University of Reading showed that North Atlantic sea surface temperature has a significant role in the predictability of European climate. The temperature in the western Atlantic as winter starts and during May give useful predictive information on European climate conditions during the following winter. Statistical models developed at the University of Reading also show there are key regions in the western Atlantic where the sea surface temperature patterns can influence the air temperatures in the north-east Atlantic from days to months later. At the Rutherford Appleton Laboratory, researchers used an adjoint model (which allows a model to be run backwards) to show that spring air temperatures are sensitive to the previous year's sea surface temperature. Looking much further afield, a student project at the University of East Anglia found that the Southern Ocean could influence European climate a decade later. Their model showed that within ten years of changing the ocean circulation pattern around Antarctica by adding freshwater, there was a response in atmospheric circulation across Europe.

The climate*prediction*.net project involved the public in our efforts to improve our knowledge of predictability. The enormous number of climate predictions from this project generated a wealth of information, which is still being analysed.

Society could benefit greatly from better seasonal forecasts and predictions of climate change (natural or through human activity). Researchers at the University of Birmingham found the number of deaths in the UK could be related to simple winter climate indicators, such as maximum temperature or number of days below a threshold temperature. So climate predictions could well help the health service plan for cold winters.

But there's still a significant gap to be bridged if society is to make good use of specialised scientific knowledge. Scientists need to understand what kind of information decision-makers can act on and the organisational and decision-making contexts in which potential users operate. Researchers at the University of Reading worked with the National Grid Company to more fully comprehend how the energy industry uses energy demand forecasts, and to provide a framework by which they could incorporate seasonal forecasts.

Training researchers, at both post-doctoral and postgraduate level, has been a keystone of the COAPEC programme. As a result, the UK now has a strong base of researchers with experience of using climate models. They are now working in NERC centres and universities, across a range of research projects, including NERC's Quantifying the Earth System (QUEST) and Rapid Climate Change programmes. They're also working in operational centres, such as the Met Office and the European Centre for Medium Range Weather Forecasts.