You could say we don't know what we don't know when it comes to predicting climate change, but a multi-disciplinary project is working hard to put a finger – and a figure – on that uncertainty. Andy Challinor explains how the blanks are being filled in.

Fully EQUIPed

– how climate scientists are quantifying uncertainty

With so many uncertainties and apparently conflicting predictions associated with climate change and its impacts, you could be forgiven for wondering whether it's even possible for us to know how best to adapt to the changes that are heading our way.

Environmental science is replete with models simulating the effects of climate change, but each simulation can only give us one of a range of possible outcomes. This is because our climate is fundamentally chaotic and even immeasurably small changes in the state of the atmosphere today can make a large difference to the situation in a few weeks' time. Also, we don't know exactly what the future emissions of greenhouse gases will be, or precisely how the climate will respond to them.

So, our observations and climate models can't tell us the whole story, and without any clear indication as to whether some predictions may be more trustworthy than others – and how large the uncertainties are in those predictions – it is very difficult for anyone to know how to act on the information.

Despite not having the full picture, scientists are confident that we can find solutions. But first we need to understand the limits of our knowledge – we need to 'quantify uncertainty'. This simple phrase is central to much work and debate in science, particularly climate science.

Simply put, quantifying uncertainty means working out the full range of things that could happen, and how likely each possibility is. We also need to know the likely consequences of each possible outcome – what would this mean for society?

EQUIP – End-to-end Quantification of Uncertainty for Impacts Prediction – is a collaborative research project which is taking a holistic look at the climate and its impacts, and assessing the risk and uncertainty associated with climate change. This kind of integrated, multi-disciplinary approach is the only way to properly understand our options for adapting to climate change, and EQUIP brings together researchers from the UK climate-, statistical- and impact-modelling communities to work closely together for the first time on this topic.

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We want to move beyond the idea that uncertainty simply cascades through models – for example that CO_2 increase is a bit uncertain, corresponding change in temperature more so, changes in rainfall even more so, and possible impacts – like the effect of weather extremes on human health or crop yield – even more so.

A holistic approach means examining the physical and biological mechanisms involved – for example increases in CO_2 leading to higher temperatures, which in turn alter the time that crops take to reach maturity – together with socio-economic data that helps us understand the decisions taken by people who use climate information. This is important, because if you look at climate alone you might not be able to say anything that's useful for decision-makers. Our approach lets us explore further; to ask, for example, how can new crop varieties be developed and used as the climate changes? In this way our projections can go beyond the theory and affect real-world decisions.

So far so good, but how do we do it? Our approach still lies with climate prediction models, run many times to produce sets of multiple projections known as ensembles. But we look at the implication of this diverse range of climate outcomes for real-life decisions. We focus mainly on what may happen within the next few decades, rather than over centuries. This timescale is one over which we can be relatively confident that uncertainties in projections of future greenhouse gas emissions will only have a small effect on our predictions – because the near-term changes are strongly influenced by greenhouse gases we've already emitted.

Ensembles capture a range of future possibilities, but there are lots of sets of ensembles out there and lots of ways of using them. So EQUIP focuses on specific impacts and decisions in three areas: crops, marine ecosystems, and droughts and heatwaves. By focusing on specific sectors in this way, the project is developing risk-based predictions that will, for example, assess the likelihood of a range of possible health and food-production outcomes over the next few decades – things like crop yields and incidences of heat waves.

Our risk-based predictions will enable policy-makers and individuals to take the right decisions in the face of climate variability and change. We are exploring a framework for quantifying uncertainties that can be applied to other problems, and this work will feed directly into future Intergovernmental Panel Climate Change (IPCC) and Met Office assessments of climate change.

Crop production

As population increases, and emerging economies shift from eating vegetables to meat, more and more land is needed to grow food. Add to this the challenge of adapting food production to climate change, and it is clear that ensuring a stable food supply is critical. The numerous food price spikes of recent years, some associated with crop failure in Russia and Australia, are testimony to this.

Our first study has focused on the impact on crop yields of a hotter, drier regional climate. We used a regional-scale crop model to look at the potential for adaptation to climate change using a range of measures, including drought and heat tolerance associated with plant breeding and biotechnology. This process can be applied to any region and any crop where data is available, and EQUIP is integrating this approach closely with the design and evaluation of the climate ensembles on which the crop predictions rely.

Marine ecosystems

Marine ecosystems supply us with things like food, renewable energy and transport, as well as equally important but less tangible services such as tourism, climate regulation and the breakdown of waste. The way we have exploited the seas, together with environmental change, is affecting marine ecosystems at such a pace that their ability to adapt – and our ability to find effective scientific solutions – is severely challenged. These changes will affect the fundamental structure of marine ecosystems, the habitats of marine plants and animals, and the food chain – and consequently the quality and quantity of marine resources available to support humans.

Our knowledge of how marine ecosystems are changing is currently limited to the time over which observations have been made. EQUIP's simulation models will allow us to project the impacts of climate change forward in time, and extend our horizon beyond these observations to look at the cumulative effects of change on the entire food web. We can already simulate a range of different possible ecosystem states, and have made significant progress in quantifying the uncertainties associated with our simulations.

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Droughts and heatwaves

Information on droughts and heatwaves is critical to let us assess water resources and understand how climate change may affect life in large European cities, for example.

European mean temperatures, and the frequency and intensity of heatwaves, have already changed significantly because of increases in greenhouse gases. They are expected to increase in the future, along with the frequency and severity of droughts. But we have only a sketchy understanding of the extent of these changes in the next few decades, and at the moment it's far from clear how to determine the best- and worst-case scenarios given the uncertainties in model predictions and climate variability.

EQUIP's robust estimates of uncertainty will be a big step forward in this area, enabling us to better understand how we can adapt to these predicted changes. For example, one of our projects will assess the extent to which climate change might affect water availability, and will lead to more effective water management in London. ■

FURTHER INFORMATION

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For more information on EQUIP visit **www.equip.leeds.ac.uk**