Climate change – the past is

Trevor Maynard discusses the predictive worth of climate models.

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How good are climate models? Might they be missing non-linear behaviour that typifies the real world? Can the climate of the past guide us in what to expect in future? These and other questions are discussed in a piece of research commissioned by the Environmental Research Group for the UK actuarial profession. Making use of money made available by the Research Steering Committee, Dr Stephan Harrison has produced a discussion note on these topics for the profession. Stephan's paper takes as read that climate change is happening in a big way. And so it should. We sincerely hope that this is no longer an area of debate for a learned profession such as ours.

Is the past a good guide to the future?

Well, as you would expect the answer is 'sometimes'. The past at least shows us the level of extremes that are undeniable. When challenged with 'it couldn't possibly get that bad' it is a powerful argument indeed to be able to say 'it did before'. It is a brave (or stupid?) person that assumes that the past cannot or will not repeat itself.

So, what do we mean by 'climate models'? In Stephan's paper he refers to general circulation models (GCMs). The most complex of these now couple together the oceans, the atmosphere, the biosphere (trees, etc), and other factors. They subdivide these into a three-dimensional grid; each grid box contains within it key data such as pressure, humidity, temperature, etc. These conditions are used to simultaneously evolve the model one step at a time using the laws of physics, eg fluid dynamics equations. The models are therefore based on 'reductionism', ie simple models of nature, created and tested over many years by scientists. The grid size is important. The more grid points, the more features the models can pick up. For example, early models covered the UK in just four grid cells (horizontally); the latest Japanese Earth Simulator has many hundreds.

A key quote from Stephan's paper is: 'The interactions between the non-linear atmosphere, hydrosphere, biosphere and geosphere, and society are complex and form one of the main sources of uncertainty in our predictions of future climate and environmental change.' Note his mention of 'society' in the model. The actions of society determine the impact of natural events, for example the design of a city determines how well it can cope with a flood; of course, crucially, the actions of society determine how much carbon dioxide we emit over the next 100 years with profound implications.

Stephan's paper considers some limitations of models in various categories:

- **Theoretical limitations** – a key point that Stephan raises is that at certain scales the climate may display non-linearity. He reminds us that non-linear behaviour means that initial condition errors are magnified forward in time, possibly leading to the onset of chaos and unpredictability. As a result, it may not be possible to model certain large-scale features of the environment. Professor Lenny Smith of the London School of Economics, who also attends the Climate Change Working Party, speaks at greater length on this subject in his recent book, *Chaos: A Very Short Introduction*. For this reason, information about the past is a vital tool for understanding the future.
- **Forcing uncertainty** – we do not know how much CO^2 is likely to be emitted. A recent paper argues that emissions are at the high end of what was allowed for in earlier projections, ie the reality is worse than the previous 'best estimate'.
- **Model inadequacy** – the models are just models after all. They are based on our understanding, which is not perfect; Stephan gives the example that ice sheets are breaking up faster than our models say they should. Climate happens on all scales from large to small. Some processes are smaller than the grid size and so are not picked up properly. One of Stephan's examples is cloud formation.
- **Model uncertainty** – this is a topic familiar to actuaries. For many years guidance on financial condition reports and now individual capital assessments (ICAs) have urged us to consider the possibility that our parameters may be wrong. Actuaries might be more comfortable calling this 'parameter uncertainty'. Examples closer to home are: mortality predictions have been wrong year after year, and asbestos reserves rose steadily over time. Sometimes the real world just doesn't behave in line with our expectations! Climate scientists are also aware of this and run so-called 'ensembles' of models with slightly different initial conditions then observe the outputs. You may have heard of an initiative called *www.climateprediction.net* where you can download software and run a climate model on your home PC. One of the main architects of that model, Dr Dave Stainforth, sits on our Climate Change Working Party. His work (*et al.*) showed that for some plausible sets of parameters the sensitivity of the climate to

a good guide to the future!

carbon dioxide is much worse than the mean outcome, and by symmetry some sets show better than mean sensitivity too. We should bear in mind that we are urged by our regulator to consider 99.5 percentile events – to ensure the solvency of the various institutions we work in (not quite sure why pension funds don't have this requirement?). If governments had to do this they might be considering the extinction of humanity according to these models. So, if you take nothing else from this article and Stephan's paper, it is that climate change predictions that you hear about are usually just 'best estimates' – and they are bad enough.

So, if the climate models are beset with difficulties, what can we do? Stephan argues that past climate information can be extracted from a number of sources: ice cores, tree rings, isotopes in shells, gravel size in ocean deposits, there is an ever-growing list. These can show us what the climate was like in the past and how it behaved in those times when carbon dioxide levels were higher, like today. Unfortunately there is nothing to cheer us up here either, summed up dryly by Stephan: 'Unfortunately, the pattern that emerges does not give us grounds for optimism.' The paper notes that rapid change has happened regularly in the past. This is particularly the case at regional levels. Stephan was also one of the authors in the recently published Lloyd's paper on rapid climate change (see *www.lloyds.com/360*), which highlights the possibility of rapid changes in the climate from various sources including sea level (due to ocean current reorganisation or ice sheet collapse, flooding caused by sea-level rise or heavy rain, or flash events and drought). A key conclusion is that current climate models understate this risk.

Stephan quotes Wally Broecker, an internationally respected climate scientist who wrote in 1999: 'No one understands what is required to cool Greenland by 16 °C and the tropics by 4 ± 1 °C, to lower mountain snowlines by 900m, to create an ice sheet covering much of North America, to reduce the atmosphere's CO^2 content by 30% or to raise the dust rain in many parts of Earth by an order of magnitude. If these changes were not documented in the climate record, they would never enter the minds of the climate dynamics community.' The implication being that the world has surprises to throw at us that we can barely imagine. And if we can't imagine them, it is unlikely that our models will contain them.

In November, an Institute sessional meeting supported by the environmental research group will be held on the subject of climate change and its impact on actuaries, targeting not just general insurance actuaries but those involved in life, pensions, health, and asset management whose business may be hit even harder by the economic impacts of the coming changes. The evening will be highly interactive and will focus on a number of questions of crucial importance to actuaries.

The paper concludes with a consideration of the use of model results by policymakers. Stephan says: 'It would appear that end-users of the models have largely failed to recognise the lack of predictive skill at the regional level and the inability of models to produce rapid climate change and sea-level rise in their predictions.' This lack of skill should not be taken by climate sceptics to yet again conclude that we need take no action, however, because: 'It seems likely that the models will underestimate rather than overestimate the climate sensitivity over the long run, because they omit relevant variables.'

What should we do?

There are many things we can do as individuals and these are of course a matter of personal choice. Fundamentally, as professionals, we have to ensure that those we advise are aware of the issues and are basing decisions on consideration of a world that will be different under climate change.

Pension actuaries can urge the trustees they advise to require that their fund managers pursue responsible engagement strategies with the boards of companies in which they invest. Actuaries in this field might also consider the impact of climate change on the large property portfolios such funds hold; are these properties adapted to climate change? How much will it cost to change them? Are these factors already allowed for in the price – or could a sudden price correction take place?

Similar issues arise for life insurance actuaries. With-profits contracts will be affected by lower returns from asset portfolios in the future; the Stern report suggests that growth in GDP will be affected regardless of the action we take. Are our boards aware of this? Do our ICAs and reserves allow for lower growth assumptions in the future?

Are our products suitably resilient to change? Some are arguing that longevity rates will further lengthen in the UK as warmer winters reduce cases of pneumonia in winter among the elderly. Can we really continue to guarantee mortality 40 years into the future? Could we ever? Studies show that catastrophes lead to economic issues in local areas, which in turn have an impact on health; do health insurance contracts allow for this?

General insurance actuaries can ensure that the capital models allow for an increasing frequency of extreme natural catastrophe events and urge their underwriters to ensure the cost of capital is taken into account in their pricing calculations. Do liability underwriters anticipate claims on professional indemnity (PI) policies from architects and surveyors who did not allow for climate change in their designs and costings? What about actuaries' PI cover?

The key point is that as professionals we must ensure that consideration of climate change and indeed other issues in the 21st century, for example extreme population growth and peak oil issues, are taken into account in the forward planning of those we advise. We must encourage them to move beyond the typical three-year planning horizon.

Dr Stephan Harrison's paper helps us see that climate change may be occurring faster than climate models suggest, and that rapid change is possible particularly on a regional level. We are grateful for his work and commend the paper to actuaries. We hope its insights into the volatility of the past climate will be a call for action among the profession. □

The full article by Dr Harrison can be found at *http://climatechange.pbwiki.com/LessonsFromPast* along with some further discussion and comments by the author. The climate change wiki is part of the output of the Climate Change Working Party announced earlier this year. Visit *http://climatechange.pbwiki.com* for more debate on climate change. You can subscribe to the site for regular updates of new information.

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