



Water levels in the Mekong Basin could rise or fall with climate change — models cannot say which.

Climate models at their limit?

Estimates of climate-change impacts will get less, rather than more, certain. But this should not excuse inaction, say **Mark Maslin** and **Patrick Austin**.

For the fifth major assessment of climate science by the Intergovernmental Panel on Climate Change (IPCC), due to be released next year, climate scientists face a serious public-image problem. The climate models they are now working with, which make use of significant improvements in our understanding of complex climate processes, are likely to produce wider rather than smaller ranges of uncertainty in their predictions. To the public and to policymakers, this will look as though the scientific understanding of climate change is becoming less, rather than more, clear.

Scientists need to decide how to explain this effect. Above all, the public and policymakers need to be made to understand that climate models may have reached their limit. They must stop waiting for further certainty or persuasion, and simply act.

Why do models have a limited capability to predict the future? First of all, they are not reality. This is perhaps an obvious point, but it is regularly ignored. By their

very nature, models cannot capture all the factors involved in a natural system, and those that they do capture are often incompletely understood. Science historian Naomi Oreskes of the University of California, San Diego, and her colleagues have argued convincingly that this makes climate models impossible to truly verify or validate¹.

The more-concrete, less-philosophical problems can be illustrated by following the path of cascading uncertainties that are building up in the models used today.

One of the first inputs into any climate model is the expected accumulation of greenhouse gases and aerosols in the atmosphere by the end of the century. These projections are based on economic models that predict global fossil-fuel use over 100 years given broad assumptions about how green the global economy will become. The economic collapse of 2008 showed dramatically, and to our cost, how difficult it is to predict changes in the economy. And economic unpredictability is just the beginning.

Another layer of uncertainty comes from how the global climate models are weighted. For example, in the most recent IPCC assessment, released in 2007, the economic scenarios were input into more than 20 general circulation models. Every model has its own design and parameterizations of key processes, such as how to include the effects of clouds; and every model and its output was assumed to be equally valid, even though some perform better than others in certain ways when tested against historic records. The differences between the models will be exacerbated in the 2013 IPCC assessment, because many, but not all, of the models have improved spatial resolution.

The outputs from the circulation models are then often used to drive detailed regional climate models to predict local environmental variations. Such regional models have huge uncertainties, thanks largely to the fact that precipitation is highly variable over small scales of time and space. This leads to a large range of potential futures, some of which contradict others. For example, detailed hydrological modelling of the Mekong River Basin using climate model input from the UK Met Office's HadCM3 model projects changes in annual river discharge that range from a decrease of 5.4% to an increase of 4.5% (ref. 2). Changes in predicted monthly discharge are even more dramatic, ranging from a fall of 16% to a rise of 55%. Advising policymakers becomes extremely difficult when models cannot predict even whether a river catchment system will have more or less water.

Projected regional changes are then used as a basis for 'impact models' that estimate the effect on the quality of human life. But these effects often depend more on the relative resilience of a given society than on the magnitude of environmental change. Even the most advanced socioeconomic models, which look at the monetary costs arising both in market and non-market sectors, often fail to account adequately for major aspects of human suffering that are hard to quantify³.

STRUGGLE WITH EXTREMES

A key debate has emerged between scientists about how well models can predict extreme climates. On the optimistic side, Tim Lenton of the University of Exeter, UK, has argued that, with more research, models will help to provide an early warning system of climatic tipping points such as the melting of the Greenland ice sheet, the dieback of the Amazon rainforest and the shift of the West African monsoon⁴. By contrast, Paul Valdes of Bristol University, UK, argues that climate models are too stable, built to 'not fail' rather than to simulate abrupt climate change⁵. When the current IPCC models were tested against four major past climate changes, he notes, two were unable to even get the basic

climate before the shift correct and the other two had to be fed parameters up to ten times greater than would be realistic to produce the abrupt shift.

The climate models, or 'climate simulators' as some groups are now referring to them, being used in the IPCC's fifth assessment make fewer assumptions than those from the last assessment, and can quantify the uncertainty of the complex factors they include more accurately. Many of them contain interactive carbon cycles, better representations of aerosols and atmospheric chemistry and a small improvement in spatial resolution.

Yet embracing more-complex processes means adding in 'known unknowns', such as the rate at which ice falls through clouds, or the rate at which different types of land cover and the oceans absorb carbon dioxide. Preliminary analyses show that the new models produce a larger spread for the predicted average rise in global temperature. Additional uncertainty may come to light as these models continue to be put through their paces. Dan Rowlands of the University of Oxford, UK, and his colleagues have run one complex model through thousands of simulations, rather than the handful of runs that can usually be managed with available computing time. Although their average results matched well with IPCC projections, more extreme results, including warming of up to 4 °C by 2050, seemed just as likely⁶. As computing power becomes more accessible, that 'hidden' uncertainty will become even more obvious.

STABLE AND CONFIDENT

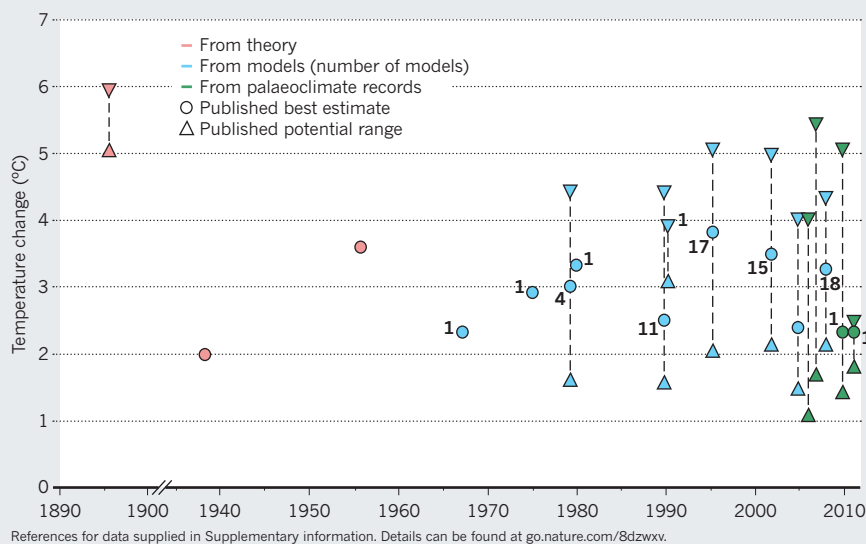
None of this means that climate models are useless. The present models are clearly able to reproduce natural climate variability over the past 150 years, and have provided an essential test of the theoretical link between CO₂ and global temperatures. Their vision of the future has in some ways been incredibly stable. For example, the predicted rise in global temperature for a doubling of CO₂ in the atmosphere hasn't changed much in more than 20 years (see 'Prediction stability').

This message of stability and confidence is often lost on the public: when Andreas Schmittner of Oregon State University in Corvallis published a value for the climate's sensitivity to a doubling of CO₂ that was on the low side of previous estimates⁷, the media declared that "climate sensitivity was overestimated". This was despite some significant criticisms of the study and the fact that the findings still fell within the range of those in all the IPCC reports. This is a sad indicator of the headlines we might expect in the wake of the next IPCC report.

One approach to tackling the public-perception problem is to subtly rephrase the conclusions, placing the uncertainty on the

PREDICTION STABILITY

Estimates of climate sensitivity — the rise in global temperature caused by a doubling of atmospheric carbon dioxide levels — have remained fairly steady for decades.



date by which things will happen, rather than onto whether they will happen at all. A recent study, for example, showed that the politically expedient 2 °C limit will be reached between 2040 and 2100, depending on our emission pathway and the model used⁸. This 'when' not 'if' approach is powerful.

In the face of scientific uncertainty, various philosophies for decision-making have arisen. But perhaps the best approach is to ensure that policies include 'win-win' strategies. Supporting a huge increase in renewable energy would reduce emissions and help to provide energy security by reducing reliance on imported oil, coal and gas.

"The biggest obstacle is the unwillingness of politicians to act in the long-term interests of society."

Measures that lessen car use will increase walking and cycling, which in turn reduces obesity and heart attacks. No one can object to creating a better world, even if we turn out to be extremely lucky and the scale of climate change is at the low end of all projections.

The biggest obstacle is the unwillingness of politicians to act in the long-term interests of society. Politicians use public opinion and scientific uncertainty as excuses for inaction. They used to say "we need to wait until scientists prove that mankind is causing climate change". That hurdle has, arguably, passed, so now they have moved on to "we need to wait until scientists can tell us exactly what will happen and what the costs

are", or, "we need to wait for public opinion to be behind action". The former will never occur, because modelling can never provide that level of certainty. The latter is a slight of hand. Politicians often take action without public support, from wars to bank bailouts, taxation to health-care reforms.

Greater knowledge and improved models will always be desirable, but they are not a panacea for political and public reticence to action on climate change. Despite the uncertainty, the weight of scientific evidence is enough to tell us what we need to know. We need governments to go ahead and act, as both the United Kingdom and Mexico have done in making national laws that contain carbon reduction targets of 80% and 50%, respectively, by 2050. We do not need to demand impossible levels of certainty from models to work towards a better, safer future. ■

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