22 April 2020 Public Lecture
Professor Vicky Pope

Climate Change: how can mathematics help us to respond?

Supplementary Answers to Questions raised by the audience.

From Tony Kypreos : thanks for excellent lecture, how can advances in satellites - providing smaller boxes of data - frequency and fidelity help with climate modelling.
Answer: There are two ways that observations help with climate modelling and understanding climate change. The first way is for process studies where highly detailed complex measurements are needed. These process studies are then used to develop and test the cruder "parameterisations" that are used in climate models. Satellites can provide a global context. Detailed process studies often require things like specialist aircraft campaigns. Very high-resolution (i.e. smaller boxes of data) satellite observations are particularly useful for weather forecasting, less so for climate. The second way is for climate monitoring and evaluating models. One of the most important things for climate change research is having continuous records. In this respect continual improvements in observations, that are driven by the need of weather forecasting, can make climate monitoring more tricky. New measurement techniques need to be built around the ability to compare with previous measurements.

From Rebecca Louie : Thank you for the wonderful talk! I do not come from the mathematics space, I'm tuning in on behalf of a sustainability nonprofit. Might you be able to recommend vetted mathematics / data sources /resources that help distill findings for the less math-inclined?
Answer: There are a number of websites that I would trust. This is not a comprehensive list and if anyone has any other suggestions we can add these.
https://www.carbonbrief.org/
https://theconversation.com/uk/topics/climate-change-27
https://www.metoffice.gov.uk/weather/climate-change/what-is-climate-change
https://climate.nasa.gov/
https://nsidc.org/cryosphere/climate-change.html
https://www.theccc.org.uk/
IPCC used to have a really good set of frequently asked questions in earlier reports. Some of these seem to have been removed. However, there is one for the 1.5° report produced recently.
https://www.ipcc.ch/site/assets/uploads/sites/2/2018/12/SR15_FAQ_Low_Res.pdf

Chris Budd reminded me that the mathematician leading on work to redefine the mathematics of climate models to support new technologies is Beth Wingate at Exeter University.

I mentioned in my talk that at the core of a climate model are the Navier stokes equations. Those of you that did fluid dynamics at University or use a more complex form rotating sphere, and form part of the primitive equations.
https://en.wikipedia.org/wiki/Primitive_equations

From J : Following on from air quality question. Very good to see "the problem in the round" approach. Especially consequences of cleaning particulate emissions. Iron Salt Aerosol is possibly one very significant technology I've come across that could harness this in a positive way. (This is very different form conventional ocean iron fertilisation. I

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understand there were moves towards field trials of this. Are you aware of more work on this? http://ironsaltaerosol.com/

Answer I don't know anything about this possible approach. If people reading this have more information, they can always share it with the organisers.
From mondarn : You mentioned not knowing the effects of cirrus cloud reflection - for what other unknowns do we need to find new methods of measurement.

Answer: The impact of clouds on climate has always been a focus of climate science and modelling because it is such an important feedback in global warming. There have been massive improvements in the way the cloud is represented but it still contains uncertainties. Related to this the impact of aerosols (the particles that give so many problems with air pollution) is also still a major uncertainty, despite being better measured and understood than it was 20 years ago. The possibilities for methane release as temperatures warm in the Arctic both from the land and the ocean are not well understood. Lack of measurements are certainly contributory factor in this case. The recent IPCC report open oceans and ice certainly highlighted to me the major potential impact of ice melting, particularly in the Antarctic. This is an important area because it could have a big impact on sea level rise. Again good observations for process studies are difficult in this region.

Many of our long-term datasets of climate and the impacts of climate change are gathered in observations that were collected for other purposes. They have to be carefully evaluated to create a climate quality datasets. Part of our understanding is monitoring this long-term change. In the past investments in satellite measurement technologies were primarily driven by the needs of weather forecasting. It is only relatively recently that climate focused campaigns have received significant funding. The climate community has identified a set of Essential Climate Variables for measurement. As well as importance they also assess feasibility. Some of the important climate variables are difficult to measure. More information can be found here.
https://climate.copernicus.eu/
https://public.wmo.int/en/programmes/global-climate-observing-system/essential-climate-variables

this article is a few years old but relevant.
https://www.carbonbrief.org/reducing-uncertainty-should-be-priority-in-climate-modelling-say-scientists

From Howard Beck : Do you have suggestions regarding how climate and environmental risks can be communicated to improve political decision making?

Answer: Generally, communication about climate change and environmental risk needs to relate to people's experience. People tend to understand the consequences better if they have experienced flooding and drought or other natural disasters. This is true of both the general public and policymakers. Of course, we have to bear in mind that policymakers cannot be too far ahead or behind public views, or they will not be able to take the public

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with them. It is often the case that governments, and indeed the rest of us, prepare for the last emergency and not the next one. We are seeing this debated every day in the press at the moment. Far Eastern countries seem better prepared for Covid-19 than we were for a variety of reasons. One of these is that they have experienced similar things in the past.

On a more general presentation issues, we need to present results in a variety of ways to appeal to different audiences. Those of us with a mathematical or scientific way of thinking will want to see graphs and diagrams, as they encapsulate so much of the information in a way that is easy to understand. Many other people frame their thinking more in terms of words or their emotional response. They need information to be presented more as storylines of what might happen. In good communications of climate change (of which there are a few in the links above) you will see information presented in different ways. Hopefully that will appeal to a wide range of audiences.

From Phil White: To what extent is more work needed on modelling, and to what extent are we in the 'close enough' position and just need to focus on communicating it?
From Chris : Good overview of the Climate change challenge Vicky. Wouldn't it be more sensible to invest money into alternative climate prediction/ forecasting approaches using specific machine learning or AI centres or Centres for Doctoral Training, rather than throwing £1bn into a high energy consuming supercomputer.

The model results are certainly good enough to tell us that we need to do something to mitigate climate change and adapt to it. However, we also need to have tools at hand to understand the impacts of the solutions that we put in place. Eg I mentioned the unintended consequence of introducing diesel cars in my talk. The complex climate models that I talked about can help with this, but there are also other tools that are important. We cannot represent every process and impact so we use simpler models to explore the links between these. There are still difficulties in linking these different types of models and ensuring that they are providing useful information. There is a famous quote 'that all models are wrong but some models are useful'. This is true whatever the complexity. It is also important that scientists have time to think so that they can use information intelligently and challenge each other. The biggest and best computer can sometimes absorb everybody's energy in making the code work, doing model runs and trying to get data out of the machine.

The question of AI centres and machine learning is an interesting one. Machine learning is heavily used in weather and climate science already for initialising weather forecasts (using data assimilation) and generating probabilistic climate projections to assess and quantify uncertainty. It could be used to create simple fast models and people are starting to do this. It could be particularly useful in areas where climate models fail, such as ice dynamics. It could also be used to speed up parts of model (for example, parameterisations, which use empirical methods already).

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From **Frances** : Excellent talk Vicky, thank you. The complexity of the systemic view with large data sets and feedback loops etc does not lend itself to driving government action and clear choices: how can we encourage an approach that avoids the 'diesel problem'? Do entities like the Climate Change Committee provide the necessary bridge?

Answer: It's my belief that climate resilience needs to be built into broader decision-making rather than taking outputs from climate models and saying this is a climate choice that we need to make. In many cases the impacts of climate change are actually of secondary importance but could provide a tipping point in systems that are already highly stressed, such as ecosystems or water resources. The climate change committee provide a very important function and have generated some very useful resources. I wonder if they could strengthen their work with more practical knowledge of the impact of decisions.

From Pearse Murphy : You mentioned the models not accounting for low probability high risk situations, could you give some examples and are they being modelled/considered elsewhere?

Answer: Examples include rapid melting and loss of ice from the Antarctic and Greenland, methane release in the Arctic, vegetation loss e.g. of rainforests. These would have a global impact. However, many catastrophic effects could happen on a regional local scale for example in ecosystems or specific societies. This article is helpful on global tipping points.
https://www.carbonbrief.org/explainer-nine-tipping-points-that-could-be-triggered-by-climate-change

From CAudibert's: Thanks Vicky. Many large corporations expect being bailed out by governments in the Coronavirus pandemic. If we envisaged an economic recovery bill in the UK what could be realistically included in terms of green stimulus legislation?

Answer: This is a question for all of you. It's not a science question and we all need to contribute to the debate. Scientists can provide some of the evidence to support the decision making, as I mentioned above, e.g. to avoid unintended consequences.