Climate Change Prediction: Uncertainty, Risk and CO_2 Stabilisation

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Abstract

Our ability to predict the physical state of future climate lies at the heart of the stabilisation question. Uncertainties in the prediction process associated with both natural climate variations and with the representation of physical processes in the model make it difficult to give definitive answers to questions about safe stabilisation. How are we to progress in the presence of uncertainty?

In recent years we have made significant progress in quantifying uncertainties in climate model predictions by varying poorly-constrained parameters in models. This allows us to make probabilistic statements about future change – e.g. "there is a 5% chance that the global mean temperature rise for a doubling of CO_2 will be greater than 4.9°C". Under certain assumptions these probabilistic predictions can be used to make statements about stabilisation levels – e.g. "we are 95% sure that if we stabilise CO_2 at 2.5 time pre-industrial levels, global warming will be less than 6°C". Further examples will be given in the talk with a particular focus on regional climate change.

Introduction

Complex Global Circulation Models (GCMs) are the only tools capable of making detailed predictions of the geographical pattern of climate change and of changes in phenomena such as extreme storms. Because of their complexity, assumptions must be made when building models and these assumptions lead to uncertainties in predictions. In the absence of a perfect GCM, the only way forward is to produce an *ensemble* of predictions in which uncertainties are sampled. This ensemble or probabilistic technique has been shown to be of use in many areas of weather and short-term climate prediction.

Method

Here we produce an ensemble of 128 equilibrium climate change predictions (at double pre-industrial levels of CO_2) by systematically varying poorly constrained model parameters. The approach builds on that used by Murphy et al. (2004) in that multiple parameters are varied simultaneously to account for interactions between physical processes. Atmospheric parameters are varied and a simple 50m "slab-ocean" is used in order to achieve equilibrium in relatively few simulation years.

(Work under way in which parameters are varied in a coupled atmosphere-ocean model will also be reported).

Results

The figure gives an example of the predictions that can be made using this ensemble approach. The top left panel shows a frequency histogram (grey bars) of the global mean temperature change for a doubling of CO_2 from pre-industrial levels. The smoothed curve is a rendition of this histogram assuming temperature change is distributed as a log-normal. The 95th percentile of the distribution is highlighted in red, i.e. assuming all model versions to be equally likely, there is a 5% chance that the global mean temperature change for a doubling of CO_2 will be greater than 4.9°C.

If we take an arbitrary threshold for "dangerous" climate change to be 6°C and assume a linear relationship between temperature and CO_2 then we can easily transform the histogram on the top right of the figure to that on the top left – a frequency histogram of the level of atmospheric CO_2 for such a change. We may then interpret the 5th percentile of this distribution as meaning there is a 5% risk that if we stabilise CO_2 at 2.5 pre-industrial levels then global mean temperature rise will be 6°C or greater. Alternative statements about confidence (see abstract are also possible).

The GCM approach allows us to go further. We may examine the stabilisation question in the context of regional climate change. The middle and bottom panels of the figure show the 2xCO_2 temperature change and CO_2 stabilisation level for the arbitrary threshold of 6°C for two regions; Northern Europe and Southern South America, this time examining summer temperature change. The main point is that the risk associated with a particular CO_2 stabilisation level will be different for different countries. Further examples will be given at the meeting.

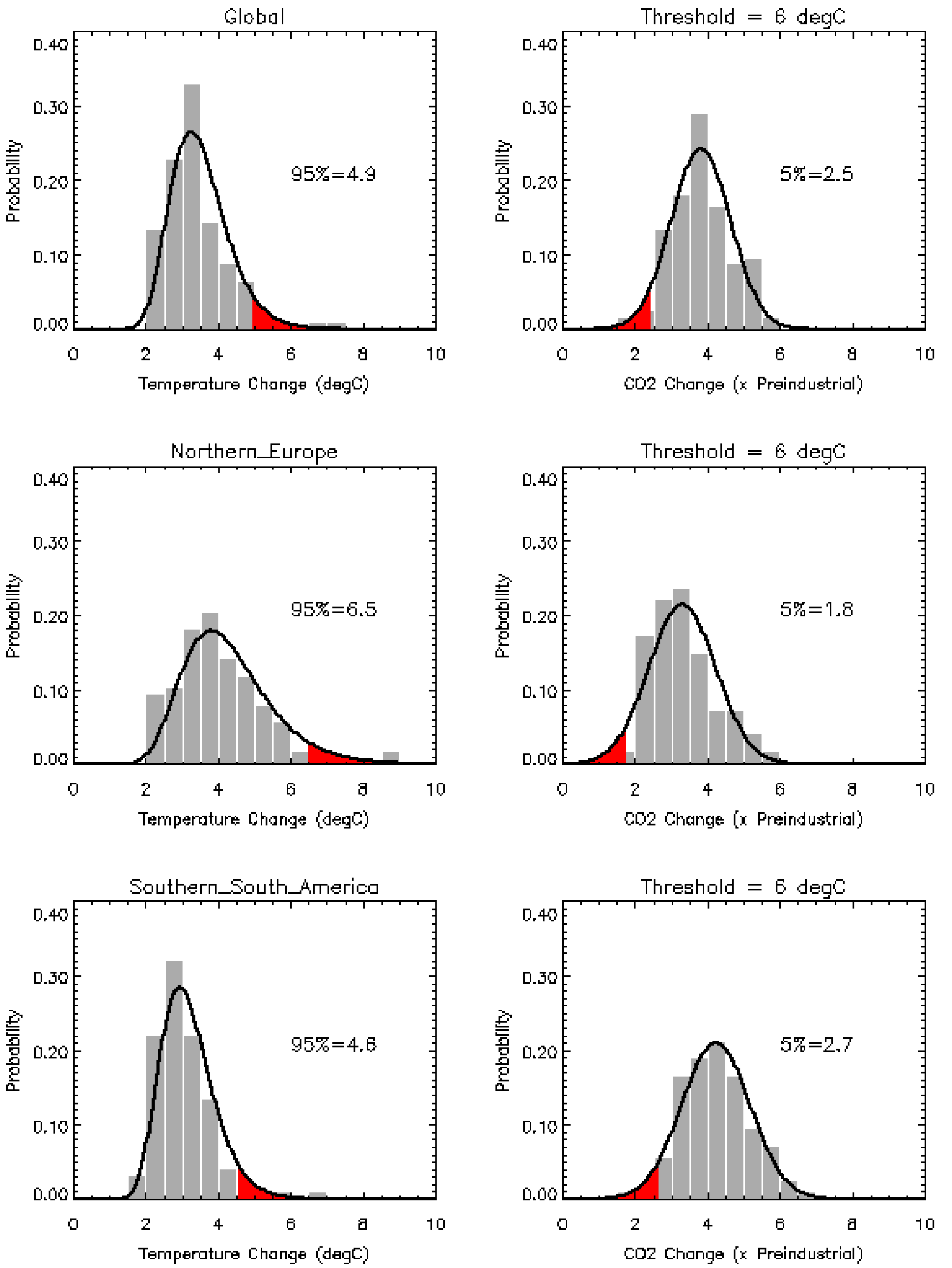
Future Work

The ensemble approach seems the only way to proceed in the absence of a perfect model of the climate system. The science of probabilistic climate prediction is still in its infancy and the current work addresses only uncertainty in one component of the climate model (the atmosphere). Future research plans will also be discussed with a view to producing robust probabilistic predictions.

Reference

Murphy, J. M., D. M. H. Sexton, D. N. Barnett, G. S. Jones, M. J. Webb, M. Collins and D. A. Stainforth, 2004: Quantification of modelling uncertainties in a large ensemble of climate change simulations. Nature 430, 768-772.

Figure



Frequency histograms (grey bars) and smoothed renditions of those histograms from an ensemble of 128 versions of the Hadley Centre GCM in which poorly constrained model parameters are varied. The left hand panels show histograms of global, annual mean (top), Northern European summer (middle) and Southern South America (bottom) temperature change for a doubling of atmospheric CO_2. The right had panels show histograms of CO_2 stabilisation levels for a threshold of 6°C. The red shading indicates the upper and lower 5th percentiles of the respective distributions.