Risk in Climate Models

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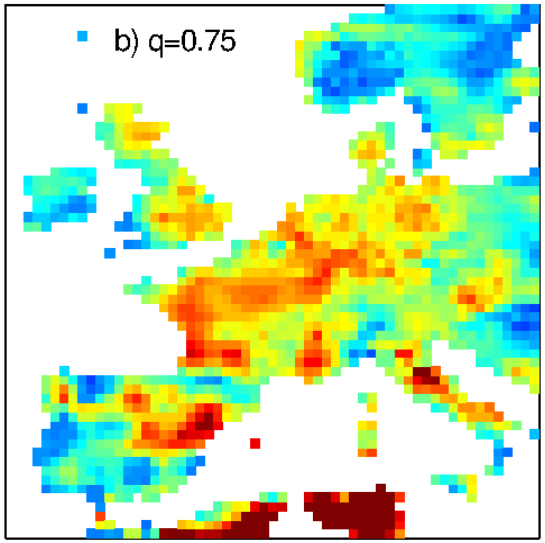
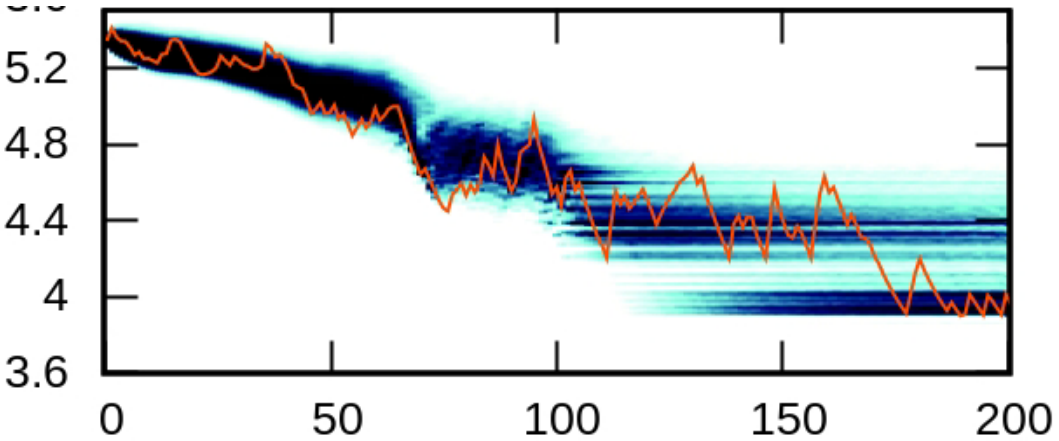
Grantham Research Institute on Climate Change and the Environment



Risk Management and Climate Change

The Law Society

14th January 2014



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CATS CENTRE FOR THE ANALYSIS OF TIME SERIES

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Centre for Climate Change Economics and Policy

Weather and Climate Models

- Global Circulation Models (GCMs): Computer representations of the system on three dimensional grids.
- Weather: Atmosphere only. May cover only a limited region.
- Climate: Atmosphere + ocean + land surface + ???

$$\frac{D\mathbf{u}}{Dt} = \frac{-\nabla p}{\rho} - 2\boldsymbol{\Omega} \times \mathbf{u} - \mathbf{g} - \frac{\eta}{\rho}\nabla^2\mathbf{u}$$

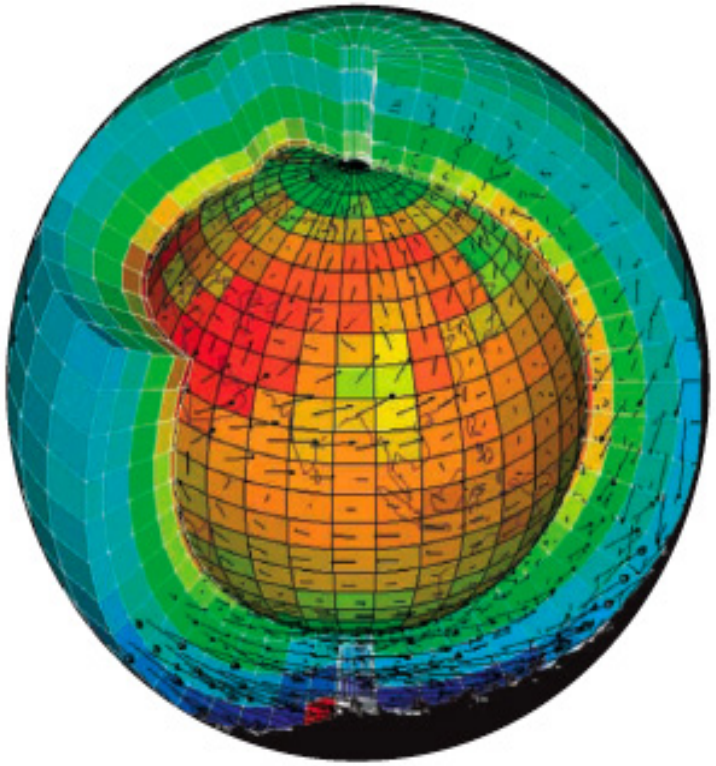
Conservation of momentum

$$c_p \frac{DT}{Dt} = \frac{1}{\rho}\frac{Dp}{Dt} + Q$$

Conservation of energy

$$\frac{D\rho}{Dt} = -\rho\nabla \bullet \mathbf{u}$$

Conservation of mass



$$p = \rho RT$$

Equation of state

Figure source: Emily Black / NERC

Source of Confidence in Forecasts

Weather Forecasting

- Large archive of forecast/verification pairs.
- New, “out-of-sample”, data gathered frequently.
- The skill of the forecast is relatively easily assessed. (Even for probability forecasts.)
- Confidence comes from assessments of skill.

Climate Forecasting

- Few forecast/verification pairs exist for multi-decadal forecasts. (Arguably none given the timescales one which models are updated.)
- New, “out-of-sample” data will only be available when it is of only historical value.
  And will be too few to assess the skill of a probabilistic forecast.
- Forecast skill can not be assessed.
- Confidence comes from physical basis of the models.

Decision Making in the Context of Climate Change

One might wish to know:

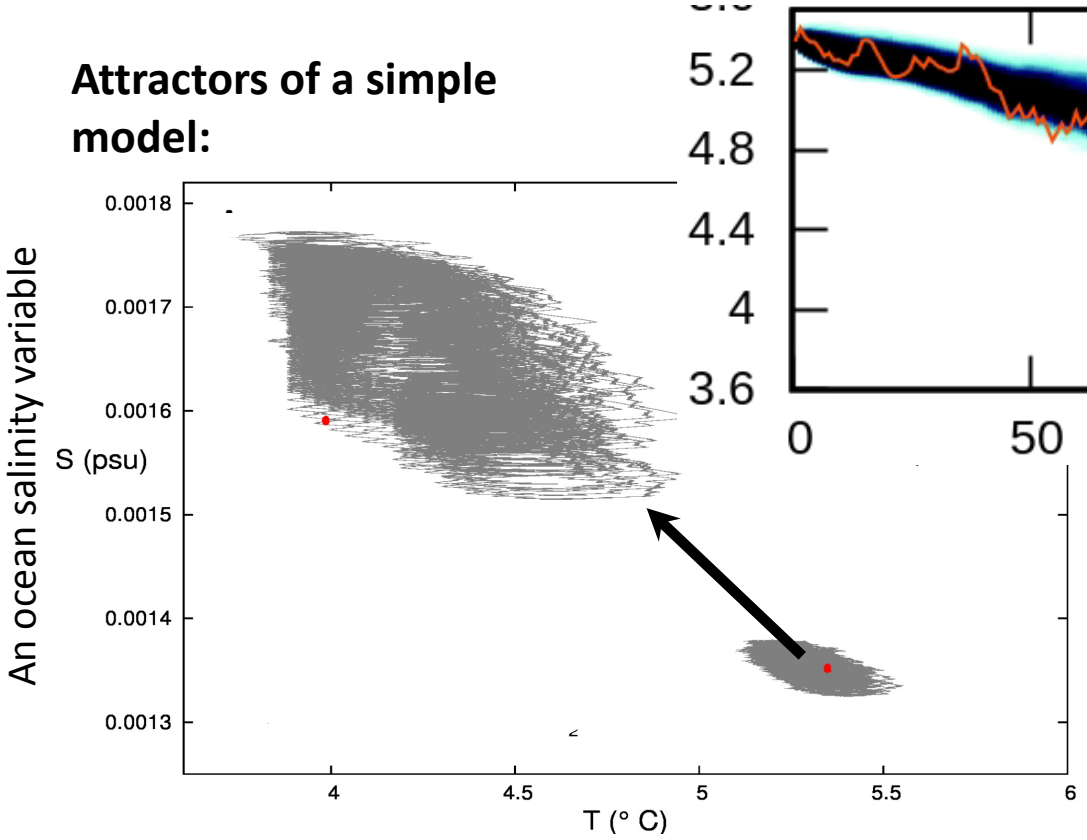
1. your risk **now** given that the past is known not to be a good guide for the present let alone the future.
2. your risk in the future.

First consider (2) – the future.

If we had a perfect model:

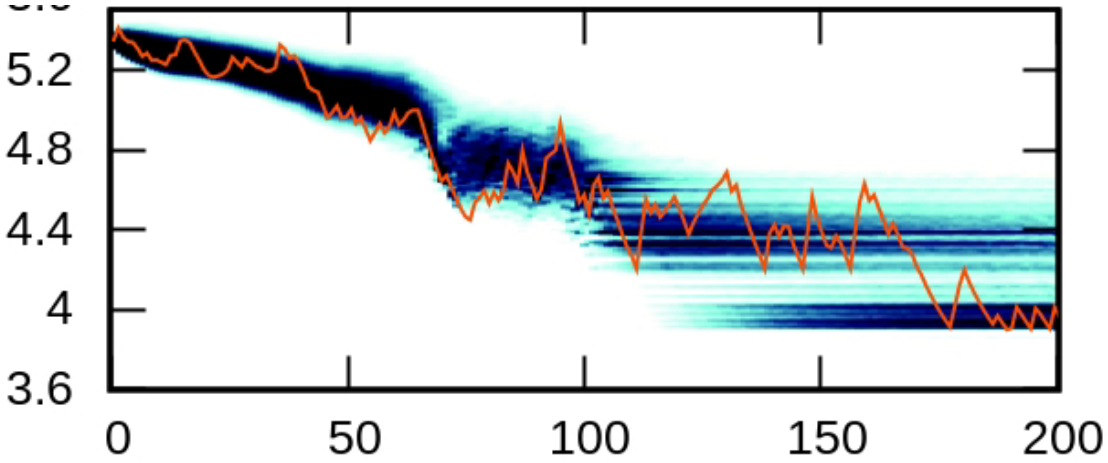
- We could generate probabilities of future climate conditioned on uncertainty in the state of climate today.

Attractors of a simple model:



An ocean salinity variable

An ocean temperature variable closely linked to Thermohaline Circulation

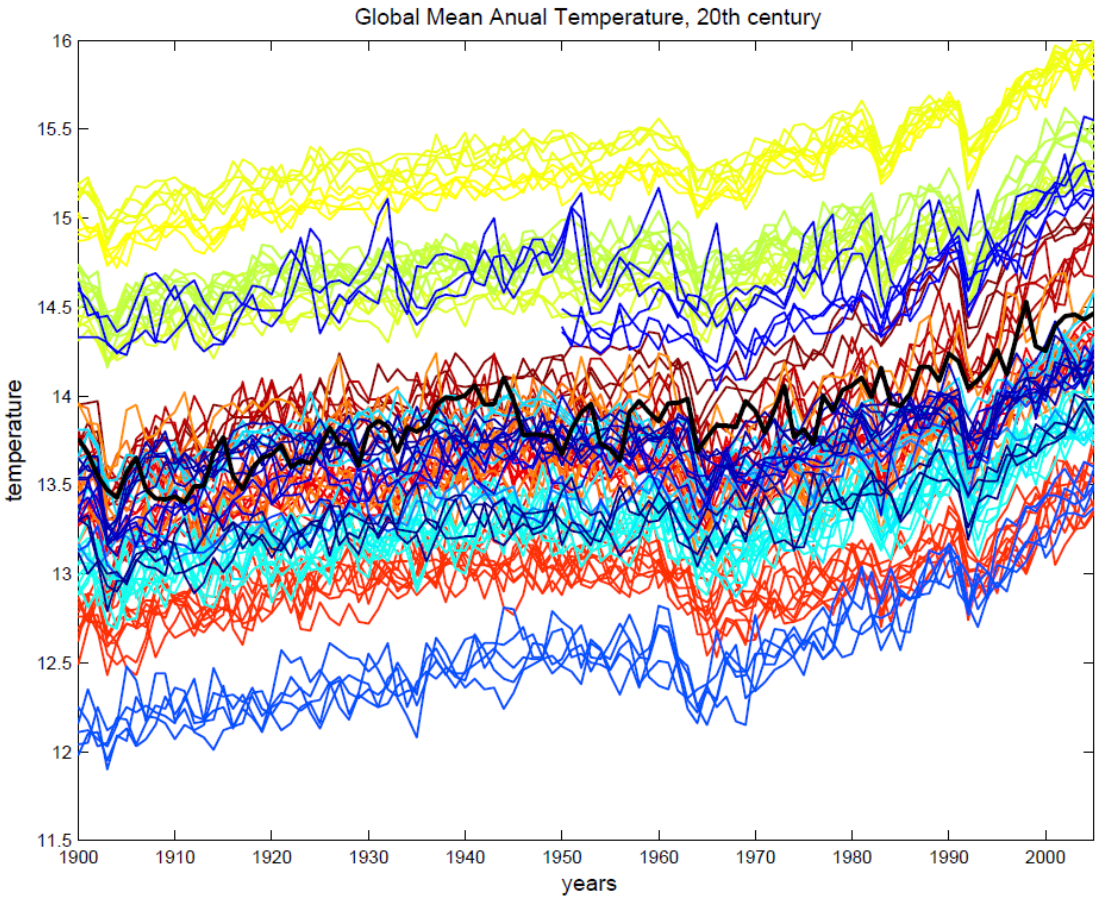


Daron and Stainforth, Env.Res.Lett., 2013

But

- We don't have large "initial-condition" ensembles, and
- And we don't have a perfect model.
  - Indeed our models are very far from perfect.

CMIP5 timeseries of Global Mean Temperature through the 20th Century



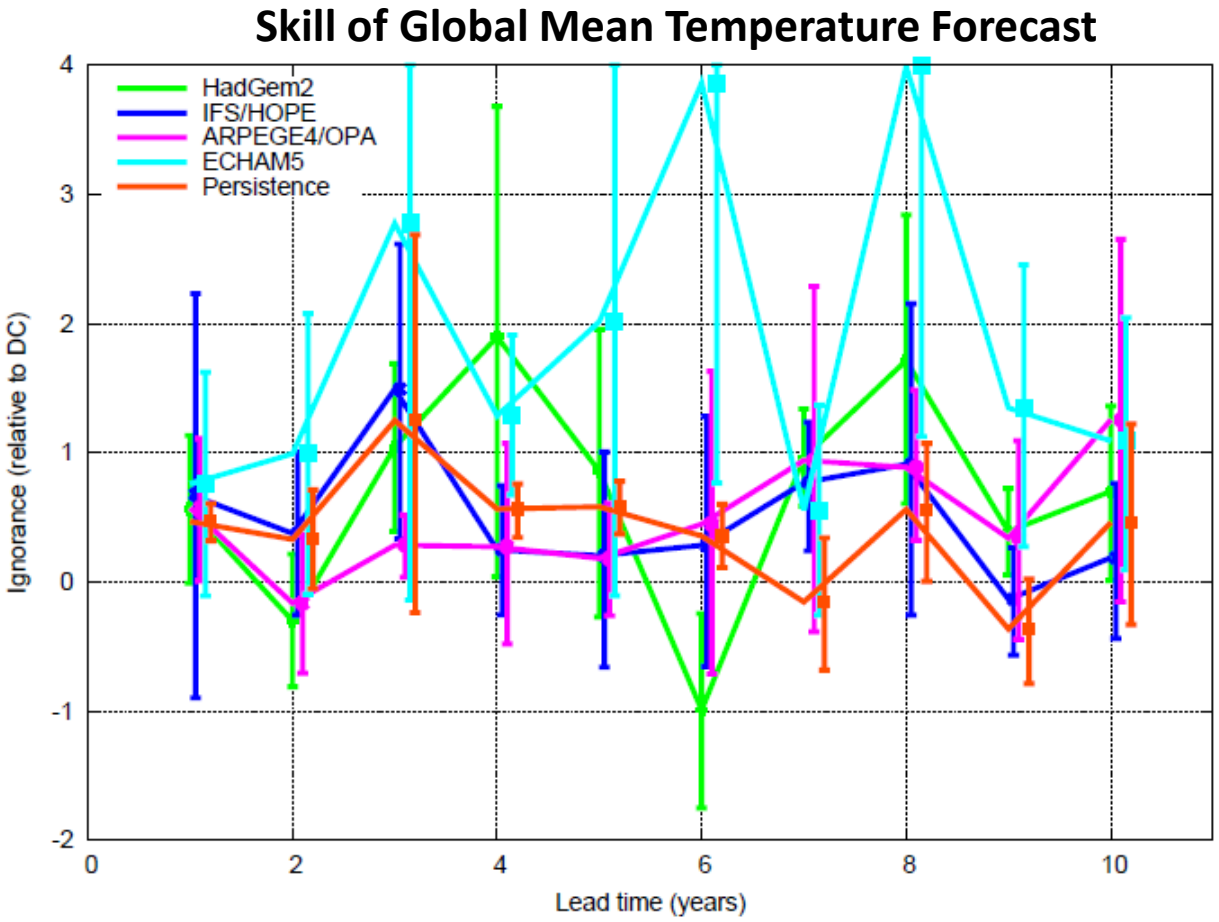
Plot produced by Dr. A. Lopez.

Over Up To Ten Years Lead Times a Simple Statistical Model Out-Performs the GCMs

Forecast skill (ordinate) at various lead times (abscissa).

Skill measured in terms of ignorance relative to the statistical method (dynamic climatology).

smaller values = more skill values below zero are better than the statistical method



Suckling and Smith,
Journal of Climate, 2013

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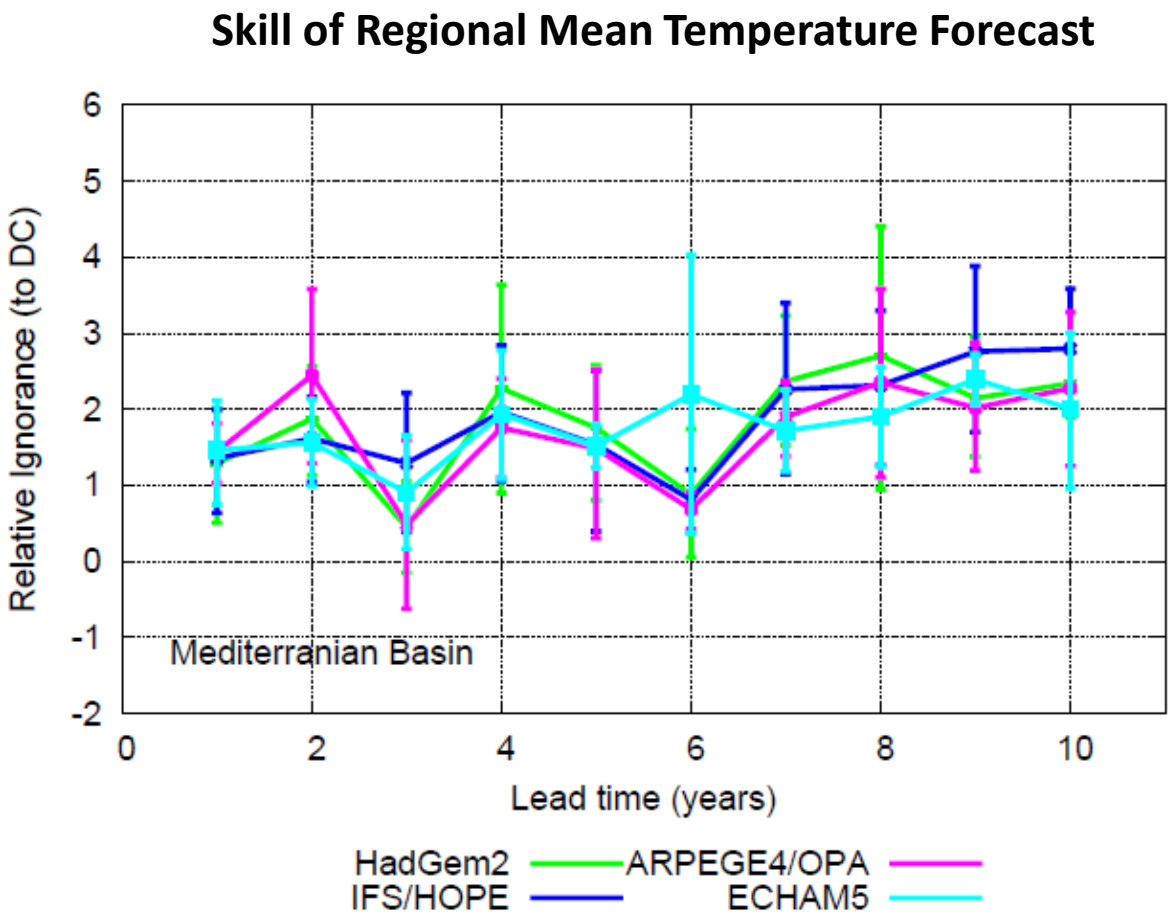
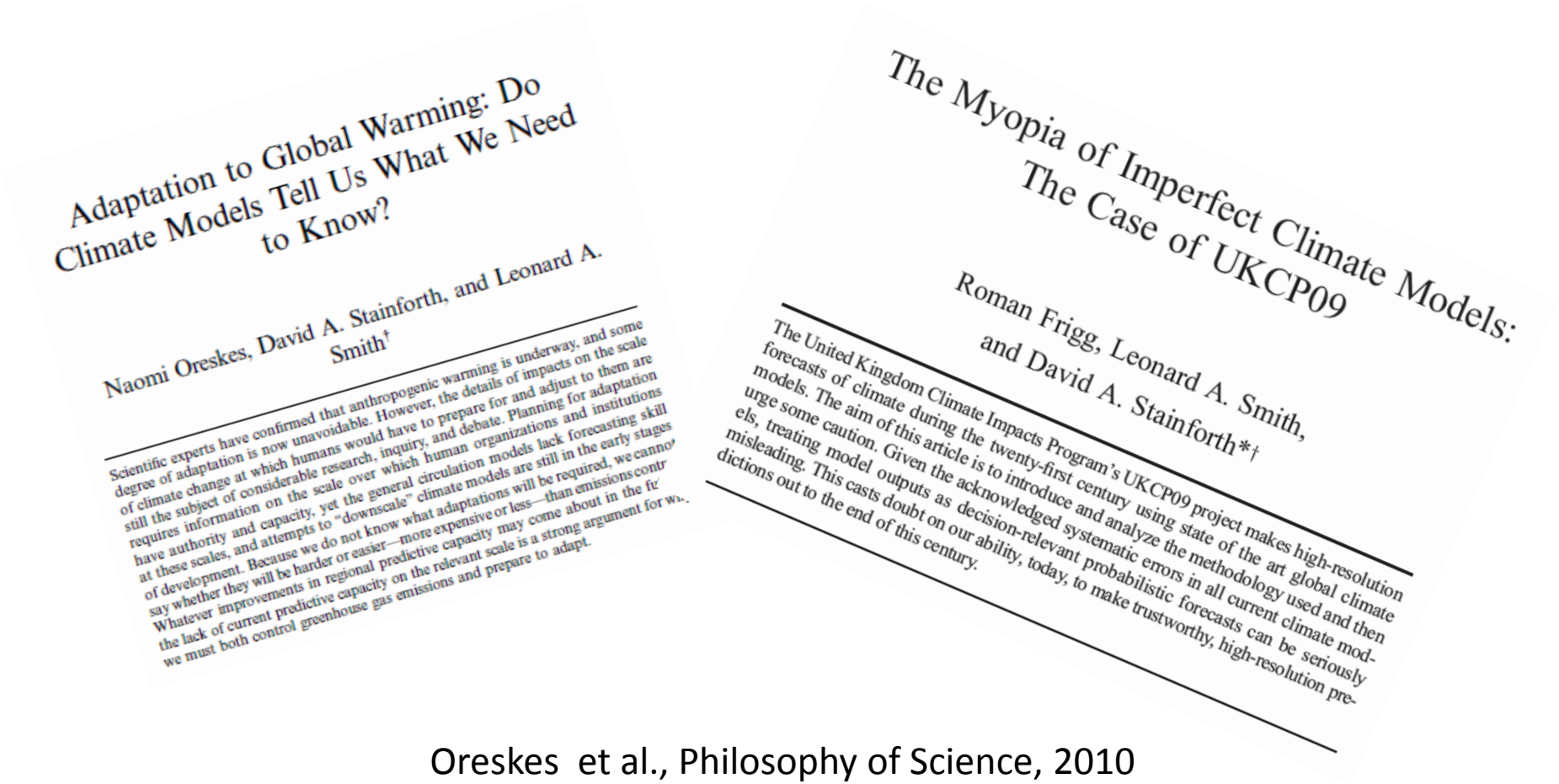


Suckling and Smith,
Journal of Climate, 2013

Not Just Imperfect But Demonstrably Inaccurate



Adaptation to Global Warming: Do Climate Models Tell Us What We Need to Know?

Naomi Oreskes, David A. Stainforth, and Leonard A. Smith†

Scientific experts have confirmed that anthropogenic warming is underway, and some degree of adaptation is now unavoidable. However, the details of impacts on the scale of climate change at which humans would have to prepare for and adjust to them are still the subject of considerable research, inquiry, and debate. Planning for adaptation requires information on the scale over which human organizations and institutions have authority and capacity, yet the general circulation models lack forecasting skill at these scales, and attempts to "downscale" climate models are still in the early stages of development. Because we do not know what adaptations will be required, we cannot say whether they will be harder or easier—more expensive or less—than emissions contr Whatever improvements in regional predictive capacity will be required, we canno the lack of current predictive capacity on the relevant scale is a strong argument for w we must both control greenhouse gas emissions and prepare to adapt.

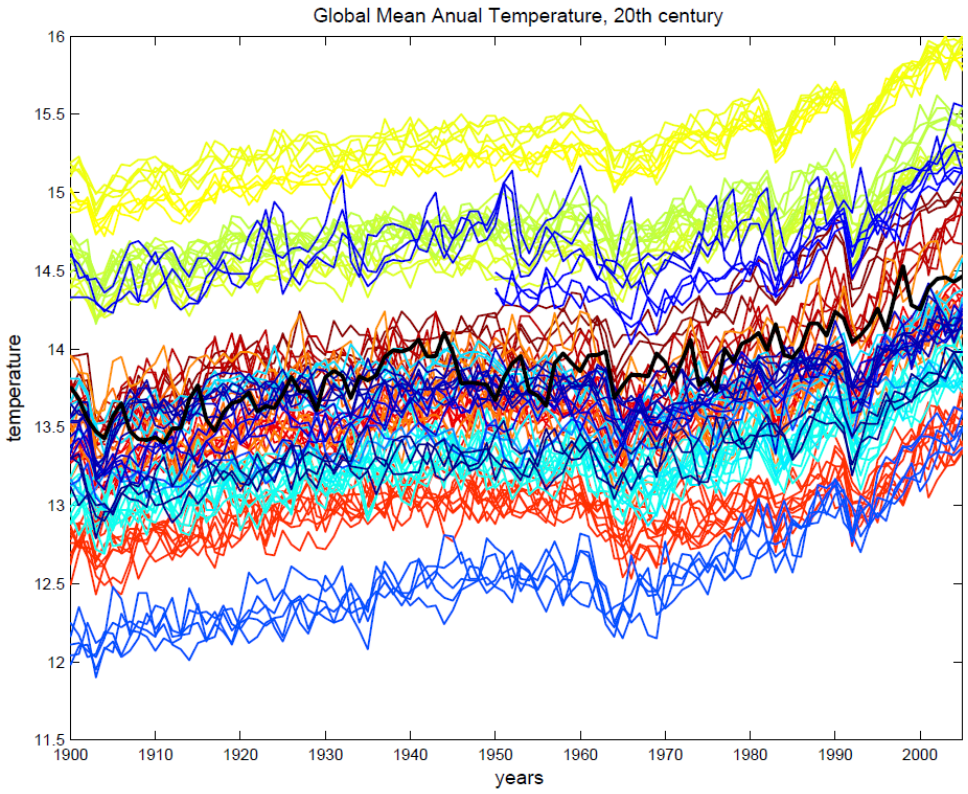
The Myopia of Imperfect Climate Models: The Case of UKCP09

Roman Frigg, Leonard A. Smith, and David A. Stainforth*†

The United Kingdom Climate Impacts Program's UKCP09 project makes high-resolution forecasts of climate during the twenty-first century using state of the art global climate models. The aim of this article is to introduce and analyze the methodology used and then urge some caution. Given the acknowledged systematic errors in all current climate models, treating model outputs as decision-relevant probabilistic forecasts can be seriously misleading. This casts doubt on our ability, today, to make trustworthy, high-resolution predictions out to the end of this century.

Oreskes et al., Philosophy of Science, 2010
Frigg et al., Philosophy of Science, 2014

Not the End of The Story

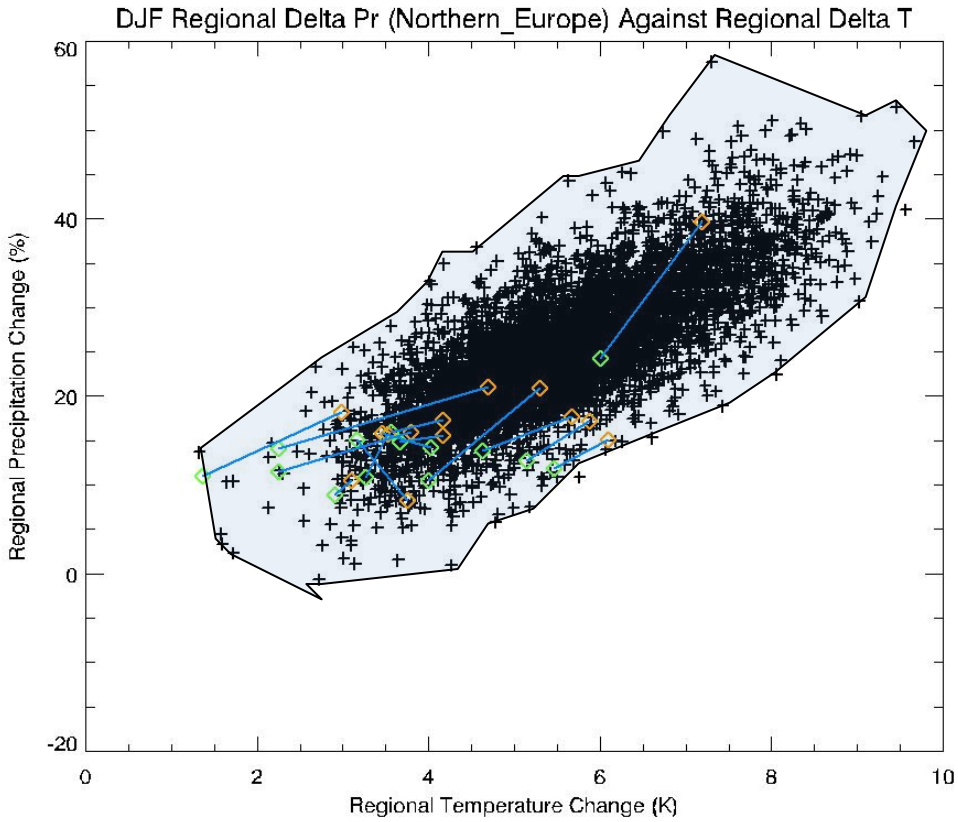


- They may not be sufficiently realistic to provide probability predictions
- BUT they all show warming in response to increased atmospheric greenhouse gases.
- They all demonstrate warming and a world of increased risks.

As we would expect from physics.

Exploring Scenarios and Possible Outcomes

- Greater exploration of uncertainty in these models helps us understand the range of possible outcomes.
- Some (or all) impacts could include the possibility of zero change. But they can't all do so together. Global constraints mean that climate change poses an immense threat to society.



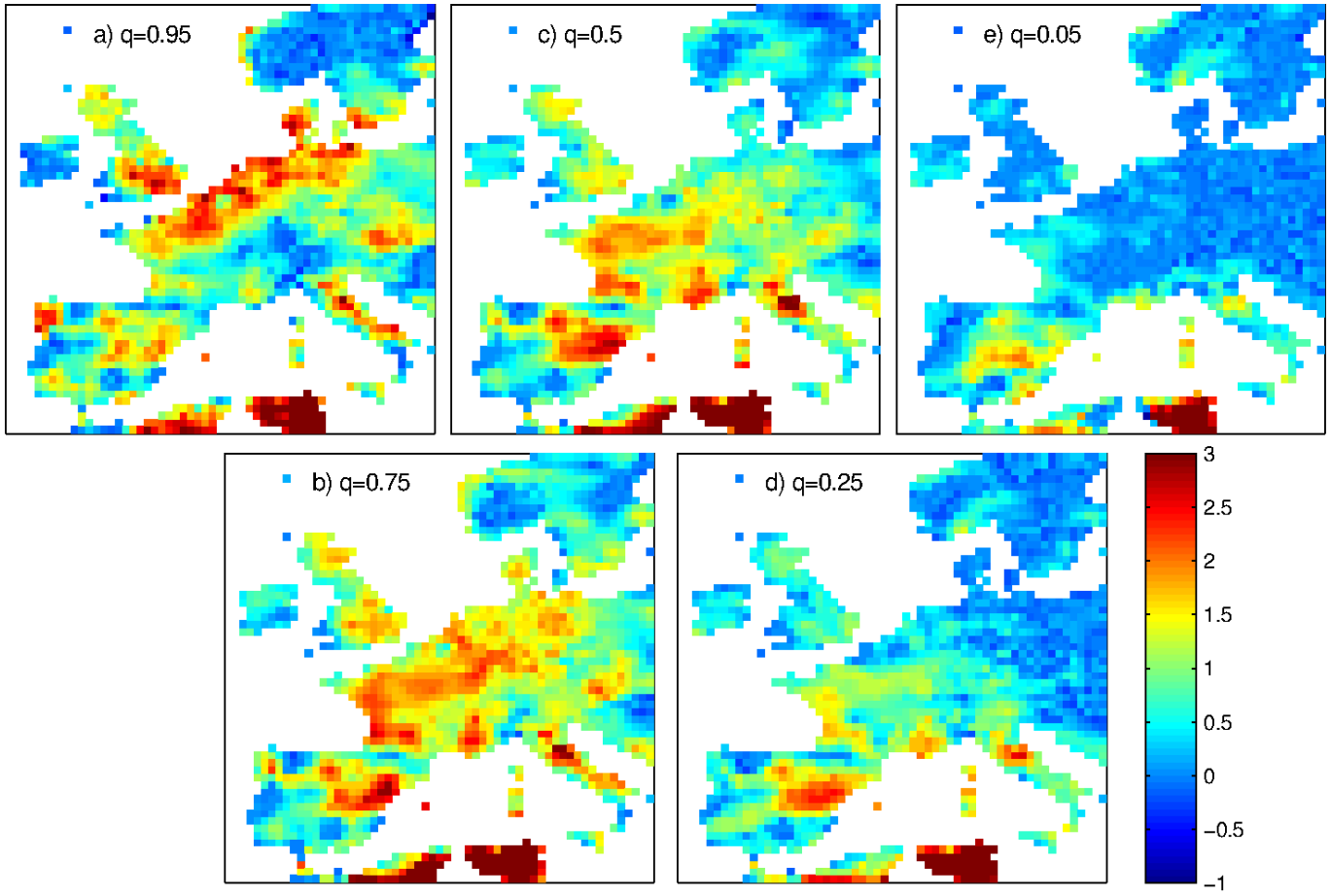
Stainforth et al., Phil. Trans. Roy. Soc. A, 2007

So what do we do?

- Don’t expect robust probabilities on multi-decadal timescales; particularly at regional scales.
- Support research to explore the space of possible models and impacts.
- Use models (and scientific understanding) to tell stories of how the risk events that your interested in may change.
- Use observations to paint a picture of how probabilities have changed from the past to now.
  (Is that as good a basis as any for future changes in the short term?)
- Support better understanding of how confidence can arise from uncertainty.

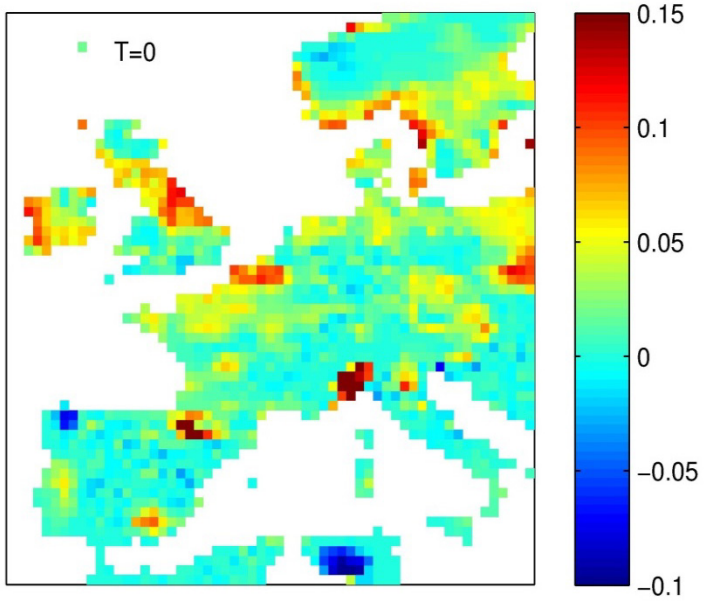
Getting More From Observations

Observed minimum changes in summer temperature distributions at various quantiles:

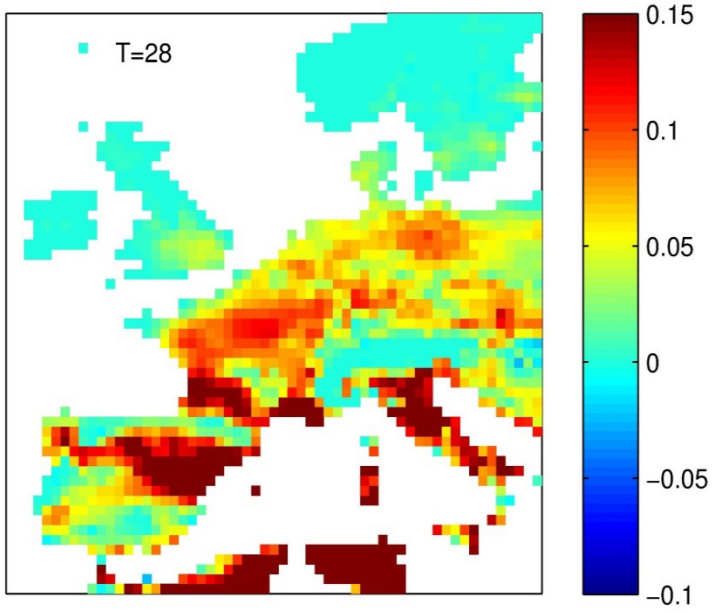


Mapping Climate Change …, Stainforth et al., Env.Res.Lett., 2013

Change in fraction of winter nights above 0°C



Change in fraction of summer days above 28°C



Mapping Climate Change …, Stainforth et al., Env.Res.Lett., 2013

Public and Policy Communication

CATS

Confidence From Uncertainty: **Interpreting Climate predictions**

Find out about:

- the different flavours of uncertainty
- why uncertainty isn't the same as knowing nothing (or even knowing nothing useful)
- how responding to climate change is a one-shot bet
- why we need to communicate about uncertainties

www.ConfidenceInClimate.net

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