Is probabilistic climate change information necessary to inform adaptation?

Ana Lopez

Grantham Research Institute, LSE

Centre for Climate Change Economics and Policy

Outline

- Are probabilistic projections robust?
- Why does this matter?
- What are the alternatives?

Are probabilistic projections robust?

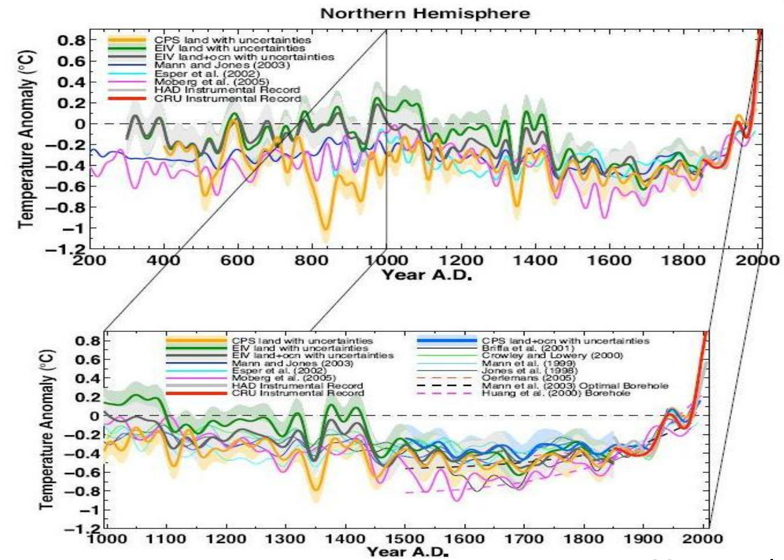
Probabilistic projections depend on

- **observations** and/or **climate model data**
- **statistical methodology**

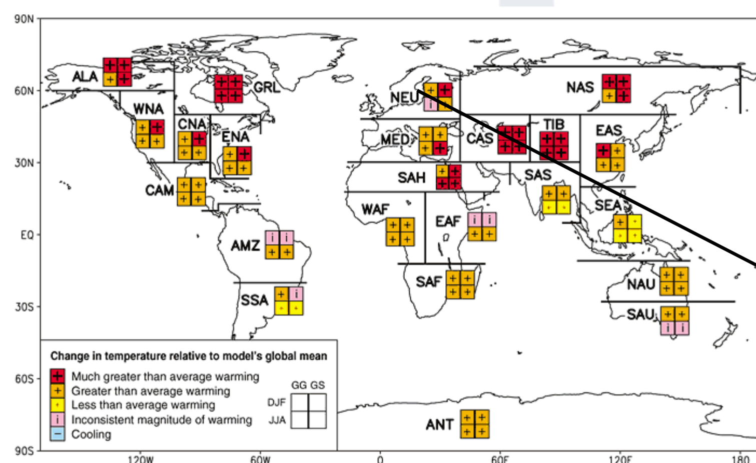
Dependence on observations and/or climate model data

Relying only on **observations** for future projections can be tricky under a changing climate: non-stationary system.

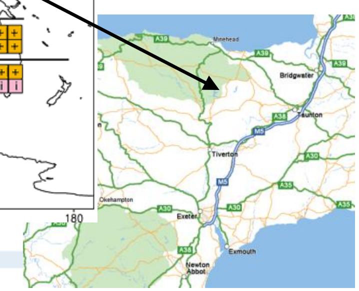
Using **model data** for regional/local changes might not be robust:
There is considerable confidence that climate models provide credible quantitative estimates of future climate change, particularly at continental scales and above (IPCC 4AR, Solomon, Qin et al. 2007)



Mann et al,PNAS(2008)



Giorgi regions



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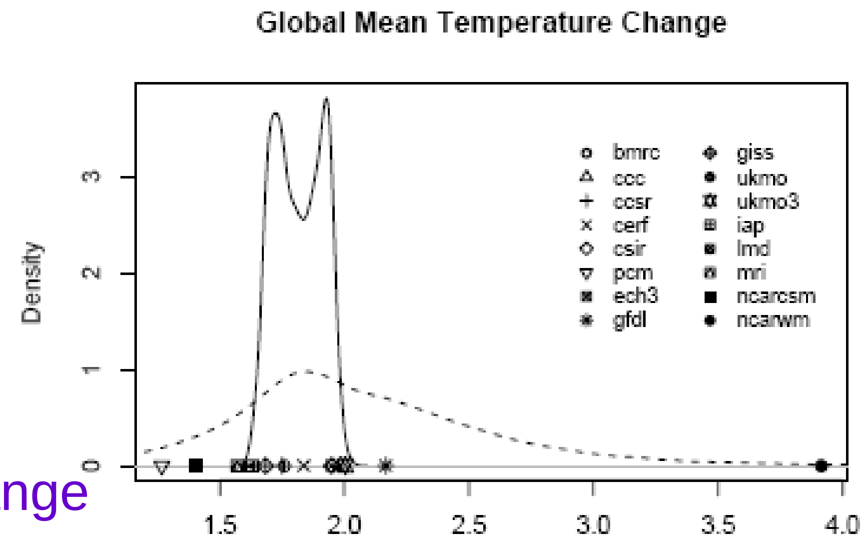
changing statistical model

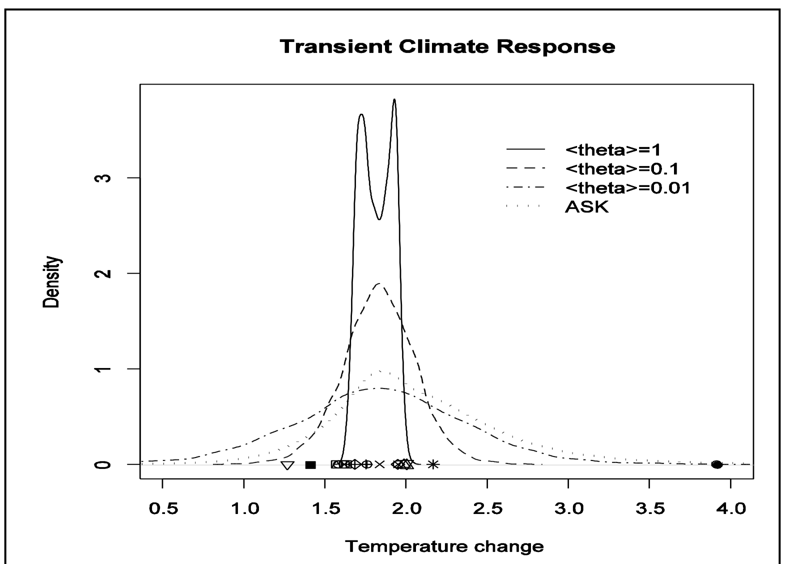
Different **statistical methodologies** generate different PDFs of future changes, largest differences in the tails (extremes).

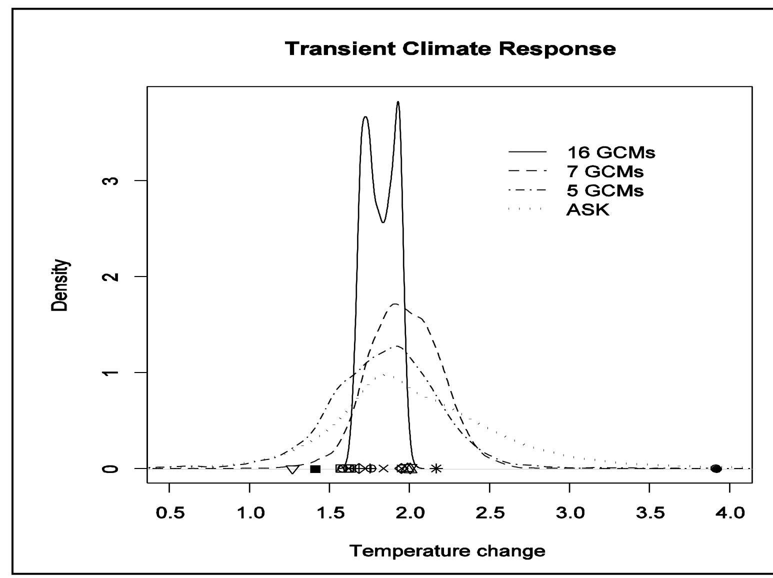


Example I: global mean temperature change

changing sampling, same stat model

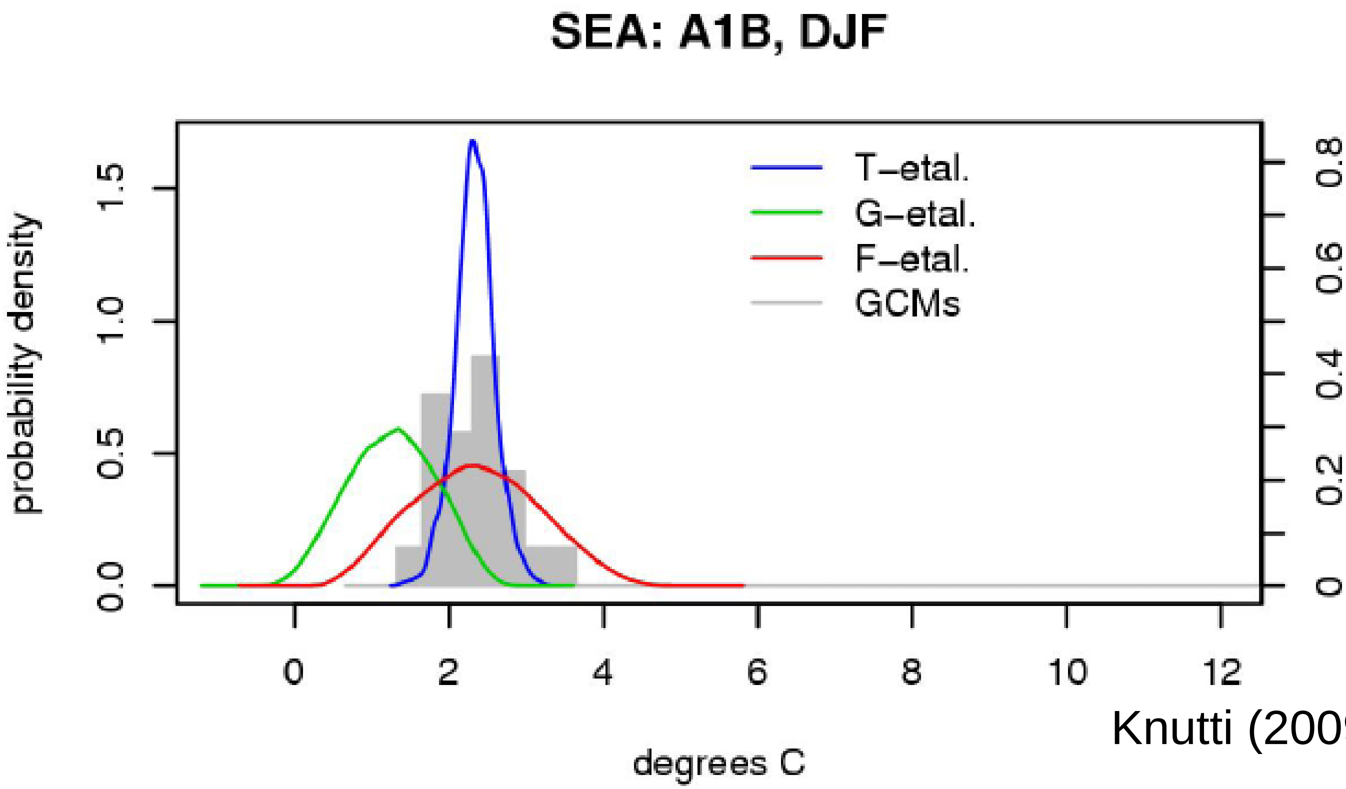
changing stat model's parameters, same data





Lopez et al , J.of Climate(2006)

Example II: regional temperature change



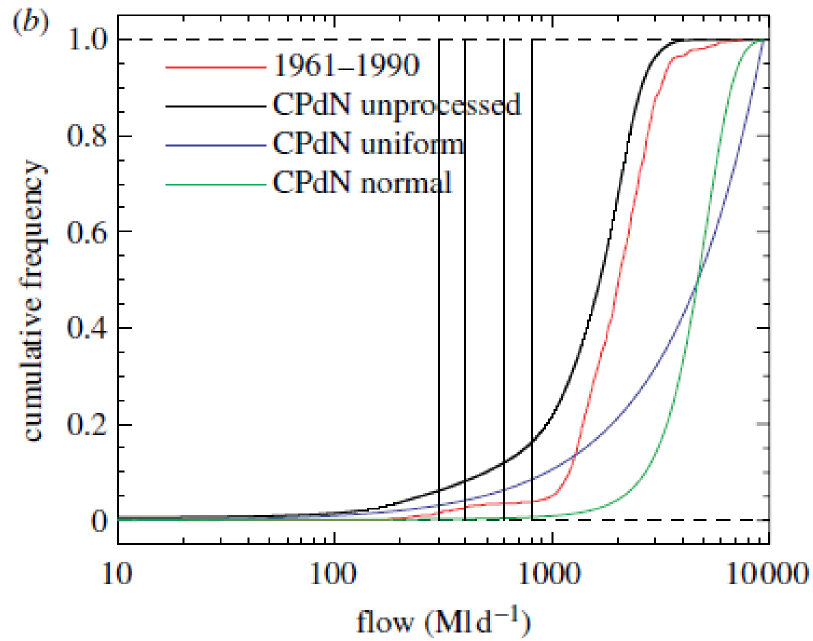
Knutti (2009)

Thus PDFs are dependent on data and methods, with largest differences in the tails: **extremes**

Why does it matter?

I) Probabilistic projections <u>represent uncertainty conditional on the approach</u>, <u>do not capture the full uncertainty</u>. Thus, overconfidence in projections can lead to mal adaptation.

“ Governments expect decisions to be based on the ‘best possible’ science. But the science of climate prediction is unlikely to fulfil the expectations of decision-makers and, through over-precision, could potentially lead to mal-adaptation if misinterpreted or used incorrectly. These epistemological limits to climate prediction should however not be interpreted as a limit to adaptation, and climate adaptation strategies can be developed in the face of deep uncertainties “
(Commission of the European Communities (2009))



July monthly discharge of Thames at Teddington. Illustration of how meeting environmental flow targets depends on sampling strategy. New et al (2007)

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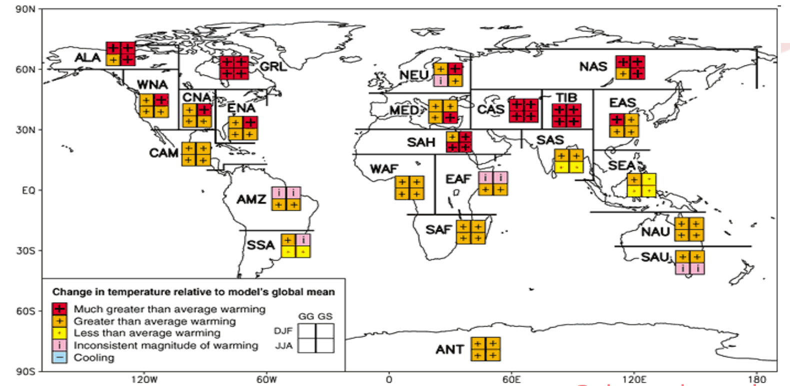
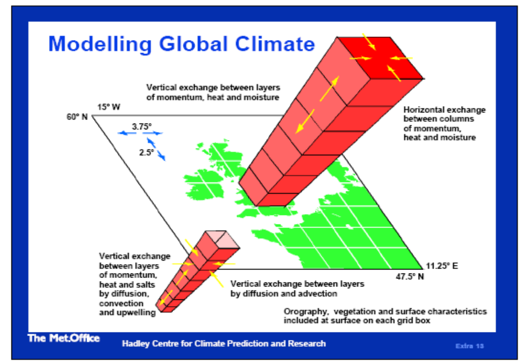
II) Fit for purpose?

Most probabilities are for **changes of climate variables** at **some time slice in the future** and for some **coarse grained region**. For climate impacts we need: climate variables at the **local impact scales**, including their **correlations** at different **temporal** (i.e., inter-annual) and **spatial** (i.e., within a catchment) scales.

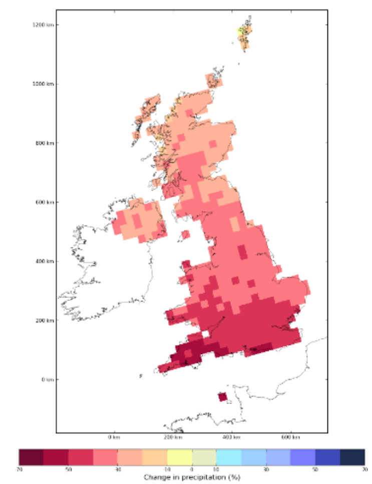


Sub-continental scales

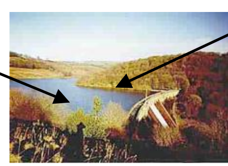


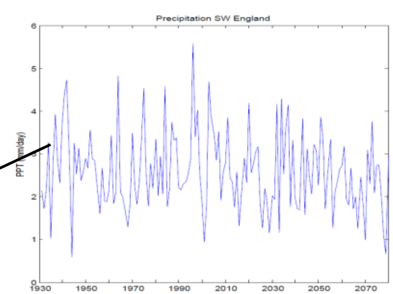
GCM scale

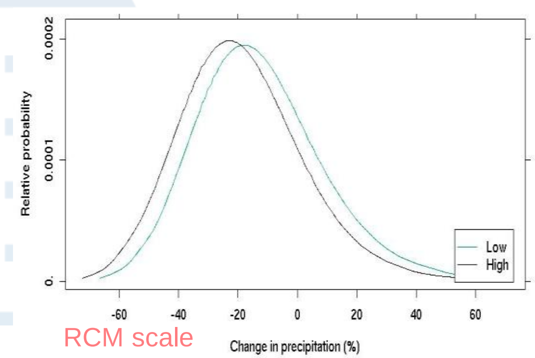
RCM scale



Local scale







RCM scale

Extra steps needed to go from PDF (right) to required time series (top) .

What is the probability of the final product being a plausible future ??

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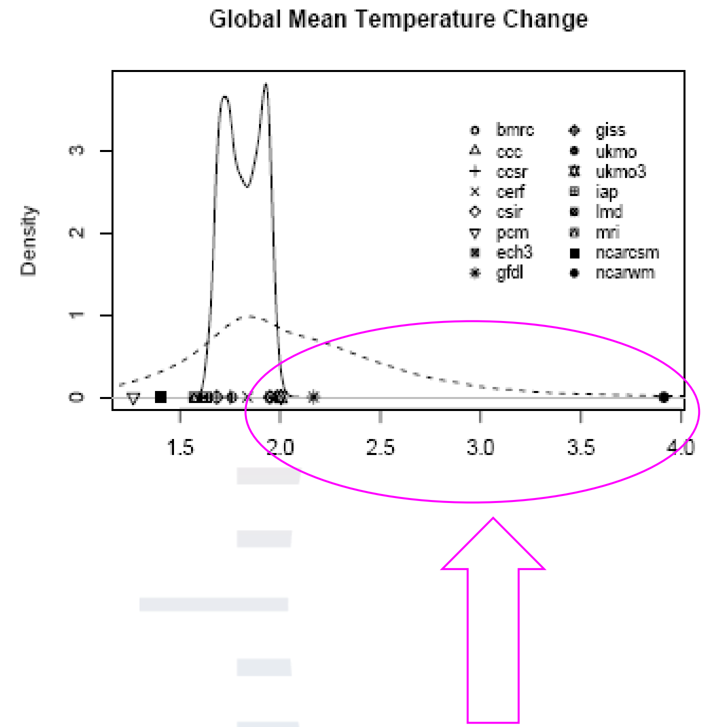
III) And for high stakes, low probability events:

The possibility of catastrophic changes due to non-linear feedbacks and processes that are not known or have not been adequately incorporated in the climate models yet, implies that, even if the previous problems could be overcome, the probability distributions so obtained would not have quantified the likelihood of big surprises.



P(X) = P(X/A) P(A) + **P(X/-A)** P(-A)

X: catastrophe occurs
A: argument (theory/model/calculation)
P(A): probability of correct argument
P(-A): probability of incorrect argument

Relative importance of second term depends on P(X/A) being small (high stakes-low probability risks). **Precisely where probability distributions are strongly dependent on approach and data!**

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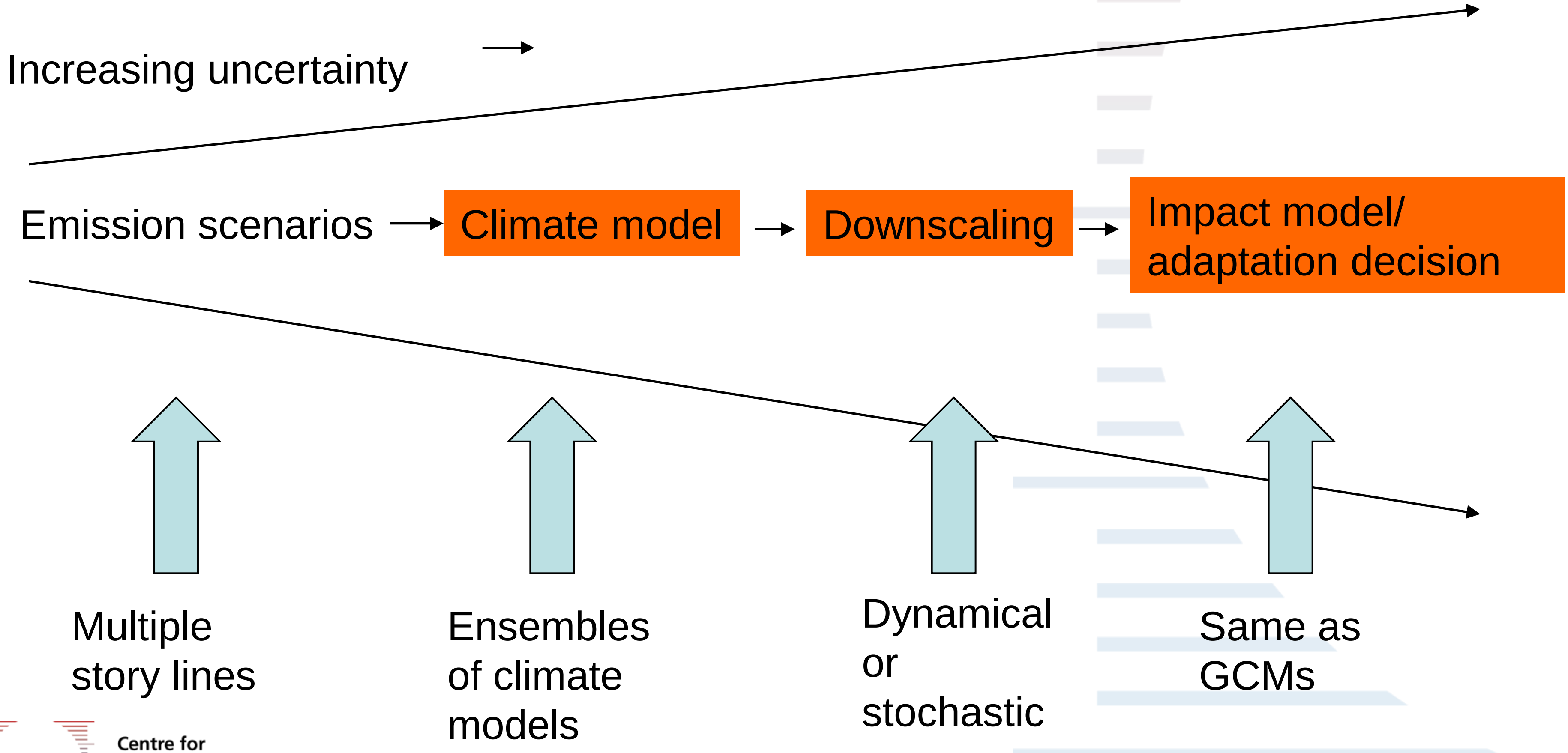
Ord et al (2008,2010), see also L.A.Smith(2009)

What to do instead?

Abandon the end-to-end (top down) approach to adaptation decision making, i.e., the prediction of future impacts based on climate modelling information to subsequently plan adaptation measures in response to these projected impacts:



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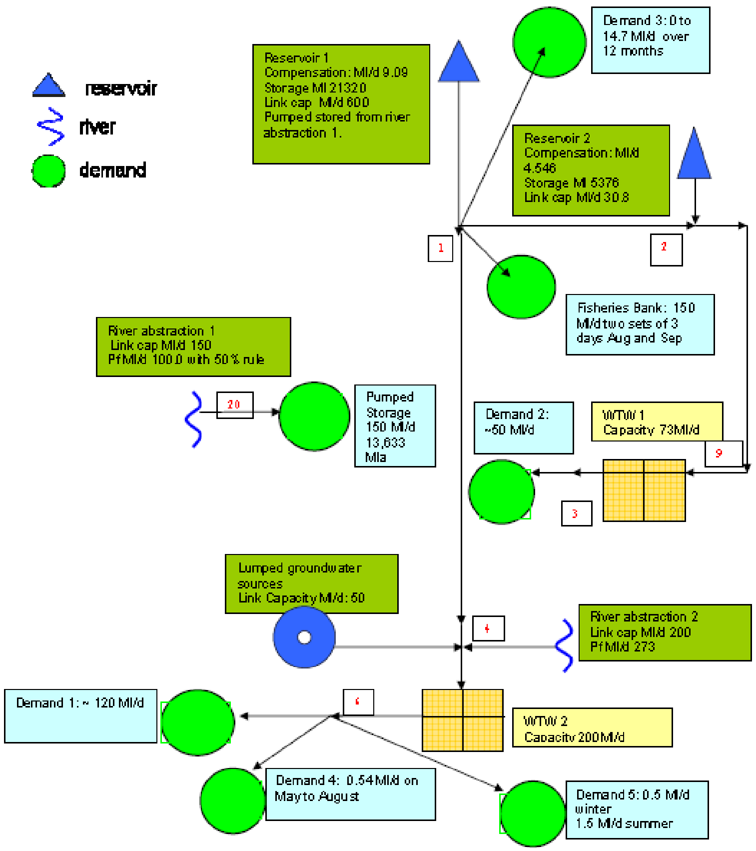
Formulate the adaptation question, then adopt an approach that integrates climatic risks as just one of the inputs within the decision process

- •Formulate adaptation question
- •Evaluate non climatic risks
- •Evaluate vulnerability to climate variability
- •Evaluate climate change risks (based on process understanding, climate *scenarios, etc*)
- •Define and evaluate adaptation pathways.

From Ranger et al (2010), see also Willows and Connel (2003)

Framework for adaptation decision making

Illustrative example: water resources



Objective water company has to meet water demand in its catchment region until the late 21st century at minimum cost.

The decision-maker has **two decision criteria:**

- a 'failure rate', defined as the number of times supply does not meet demand over the relevant time horizon (in our case 2006-2079); and
- the costs of adaptation options that are designed to reduce this rate

There are two broad types of adaptation options: **reducing demand or increasing supply**.

Adaptation options

The decision-maker is given four adaptation options:

- Increasing the storage capacity during high flows by increasing the storage capacity of ‘reservoir 1’ by 18% (denoted, *BIG*).
- Reducing demand of the largest users (‘demand 1’) by 15%; a targeted demand management initiative aimed at part of the resource zone (*DEM1*).
- Reducing demand for all major demands (1, 2 and 3) by 15% (*allDEM*). This option could represent a demand management programme across resource zones, since demands 2 and 3 represent water transfers to a neighbouring zone.
- A combination of the ‘BIG’ and ‘allDEM’ options.

To explore robustness of these options generate plausible climate futures (river runoff for the catchment) with a PPE (climateprediction.net).

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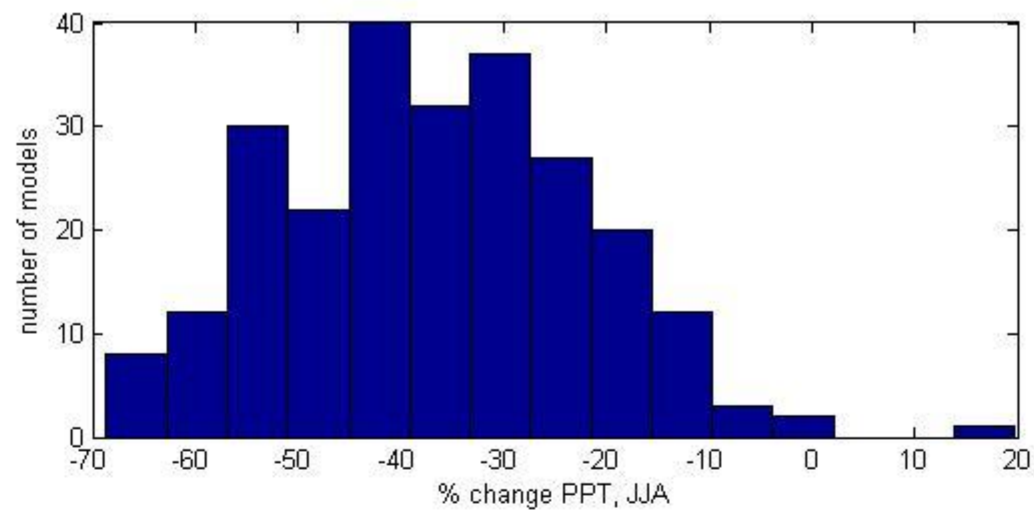
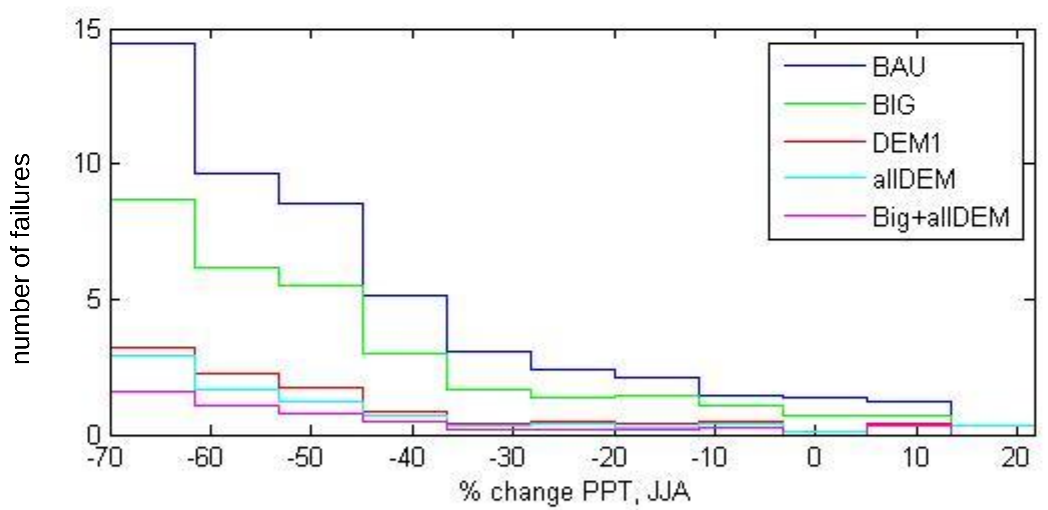
Effectiveness of adaptation options to reduce the risk of failure across the range of uncertainty in climate projections : we look for **robustness across climate uncertainty**

Metric representing range of plausible climates generated using a PPE (246 model runs). NOT a PDF, only illustrates range of possible futures.



Performance of adaptation options



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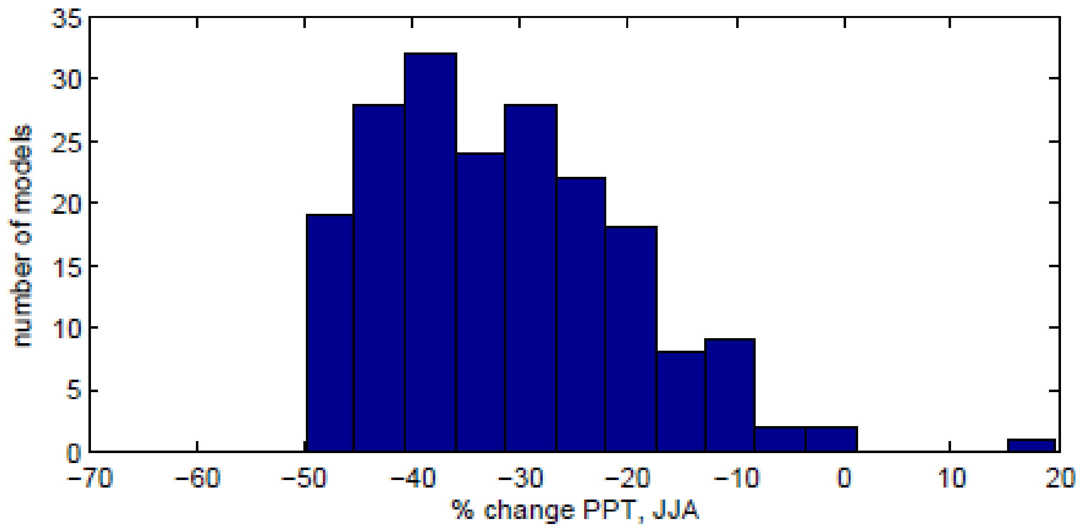
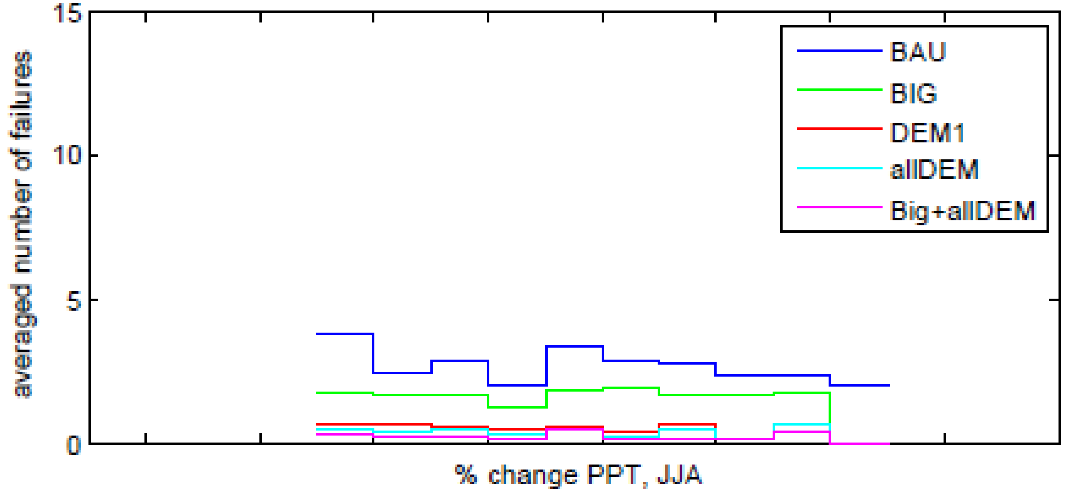
Effectiveness of adaptation options to reduce the risk of failure across the range of uncertainty in climate projections : we look for **robustness across climate uncertainty**

100 random samples for changes larger than -50%.



Note change in performance of adaptation options



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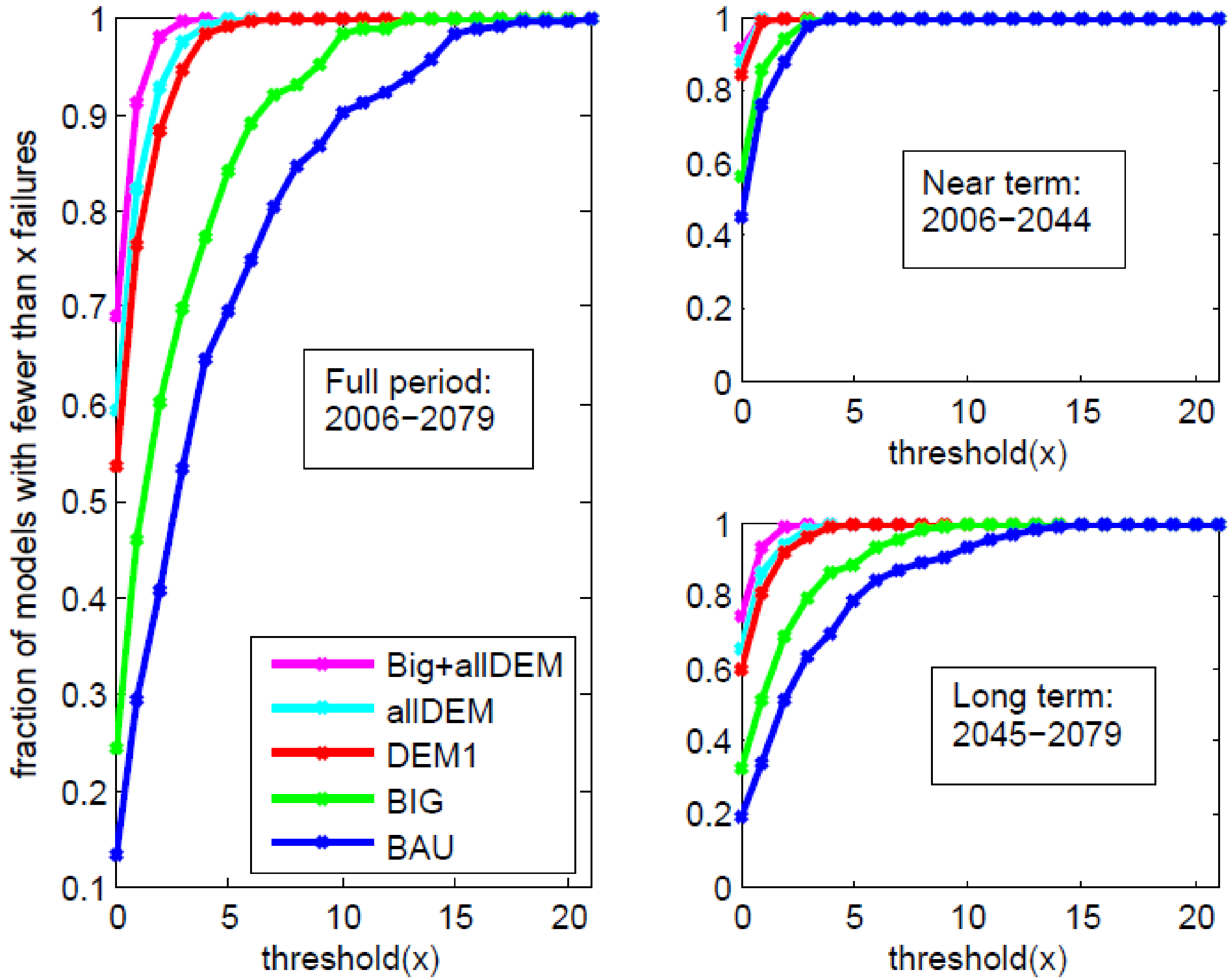
Effectiveness of adaptation options to reduce the risk of failure across the range of uncertainty in climate projections : **timing of the decision**



In addition to the key objective, to reduce the supply failure rate below a threshold, our water company has a second criterion: to use the least cost options to achieve this. Therefore, in order to evaluate options and decide between them, we must also consider their costs.

Adaptation option	AISC (pence/cubic metre) [37]	Yield (Ml/day)	Water saved (Ml/day)	Total cost (over 25 years) £million
BIG	300-1000	15 25		410-1368 684-2281
DEM1	140-160		18	230-262
allDEM	140-160		28	356-408
BIG+allDEM	300-1000 (reservoir) 140-160 (metering)	15 25	28 28	766-1776 1040-2689

Based on these estimates and the strong assumptions underlying them, the demand management options are significantly less costly than the option which increases supply by extending an existing reservoir.

Conclusions case study

- When trustworthy probabilistic information is not available, robustness-based decision methods provide invaluable insights.
- The fact that the system is robust to cope with known climate variability is important to build robustness to uncertainty in changes in future climate projections.
- In this case study demand management options (soft options) are more robust than increasing supply only (hard options). The latest is never optimal.
- This approach can help to identify sequencing of adaptation options: In the first part of the 21st century, demand only measures seem to be enough to reduce the risk of failure for 80% or more of the plausible climate projections. The risks increase in the second part of the 21st century and at that point supply infrastructure may need to be created. However, since the planning period for enlarging a reservoir is about 10-15 years, there is enough time to wait until possibly better climate information is available.
- The demand reduction options are cheaper that the hard infrastructure options (according to our crude costs estimates), and are effective at reducing the risk of failure across the range of uncertainty in climate until the 2050s. Thus they appear as the more robust management options under the assumptions of this case study.

Conclusions

Because of the large uncertainties in climate modelling and climate change projections, the interpretation of climate risk information and its use for adaptation decision making should be carried out with extreme caution.

Modelling tools can potentially be of great help to inform adaptation to climate change when correctly used, but over interpretation of their projections could lead to mal-adaptation.

Planning for robust adaptation to climate change should start with a clear understanding of the current system's vulnerabilities and the measures that have to be taken to make it resilient. Adaptation to future climate change can then be built upon this knowledge. However, due to the large irreducible uncertainties about the future climate and socio-economic trends, the design of adaptation pathways that are robust to these deep uncertainties seems to be the way forward.

> "Society will benefit even much more from a greater understanding of the vulnerability of climate-influenced decisions to large irreducible uncertainties than it will from extremely expensive attempts to increase the accuracy and precision of climate predictions. An alternative approach to the conventional one based on climate prediction would therefore focus on exploring how well strategies perform across wide ranges of assumptions and uncertainties (Robust Adaptation Decision-Making)" (Commission of the European Communities (2009))

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