Ghosts in the machine:
Climate modelling, uncertainty and user expectations

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Signposting This Talk

1. Climate Scenarios/Projections: What are they? How are they developed? And why do they matter?

1. Climate Adaptation: How, and why, should we adapt? UK context.

1. UKCP09 Projections: Entwining user expectations and the quantification of uncertainty?

2. Modelling Uncertainty: Changing relationships for producers and users of climate science?

Climate Scenarios/Projections

- What are climate scenarios or projections?

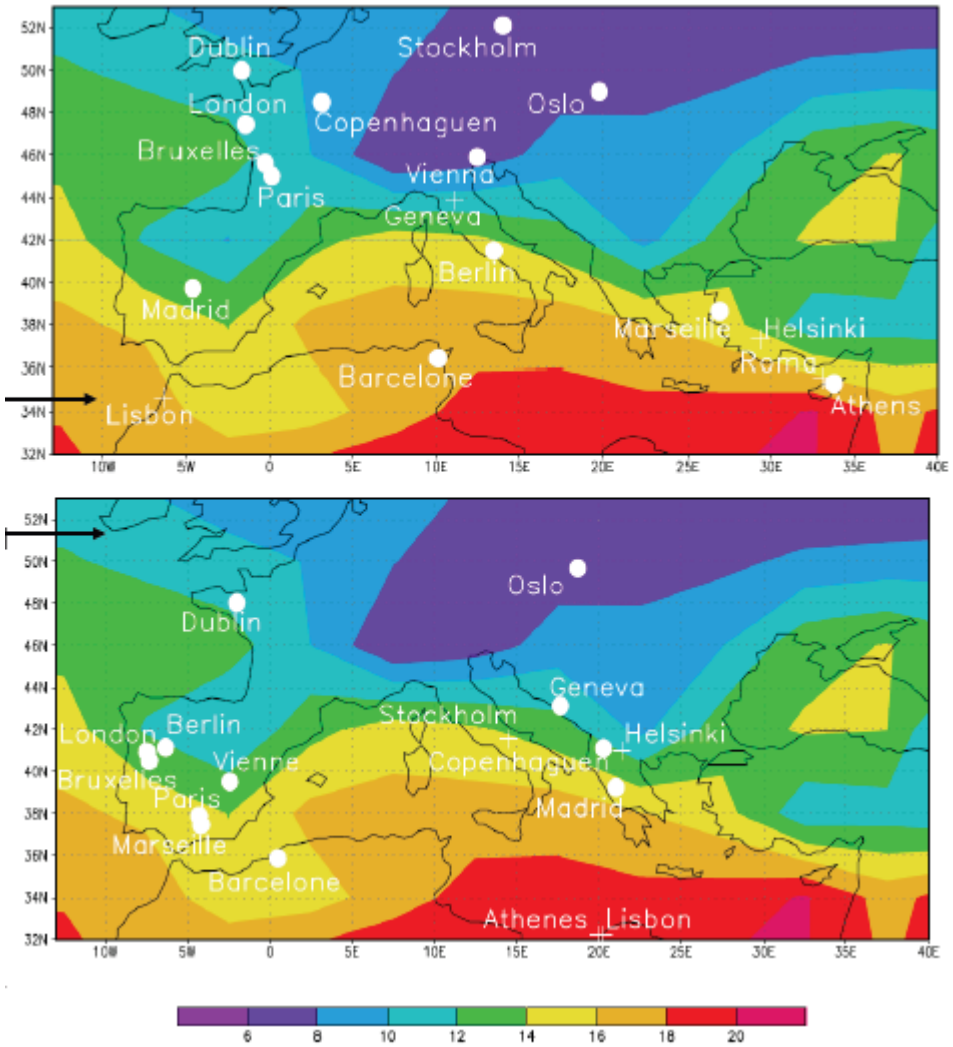
- Consistent and plausible representations of future climates

- Based on computer simulations to allow us to visualise how the climate may change under different social and economic futures

- Not concerned with daily weather but average weather and weather extremes on 10, 20 and 30 year timescales.

- Used by governments, businesses and third sector to design strategies to lessen exposure to climate risks and exploit opportunities

- Relocation of European cities in 2080s under SRES A2 scenarios (see Hallegatte et al 2007)



Why Adapt?

- Widespread consensus that climate change is happening, in large part due to human activities.
- "But knowing that the climate is getting warmer *on average* is of limited use in designing detailed adaptation decisions" (Frigg et al 2013).
- Need to understand local scale impacts but also need "reliable answers" to support decision-making (cf. Oreskes et al 2010; Tang & Dessai 2012).

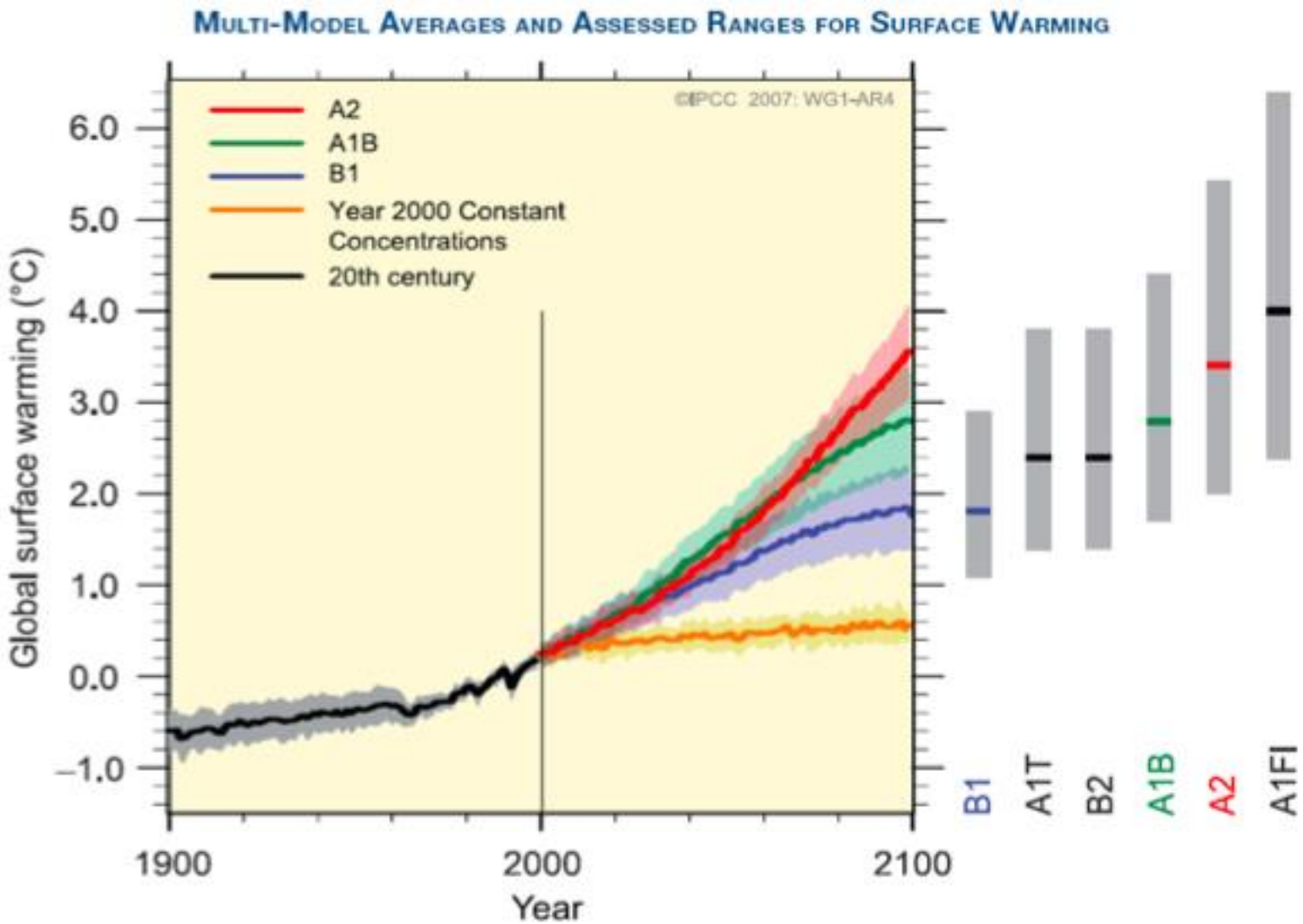
Changing Climate

- Are societies adapting “well” to a changing climate?



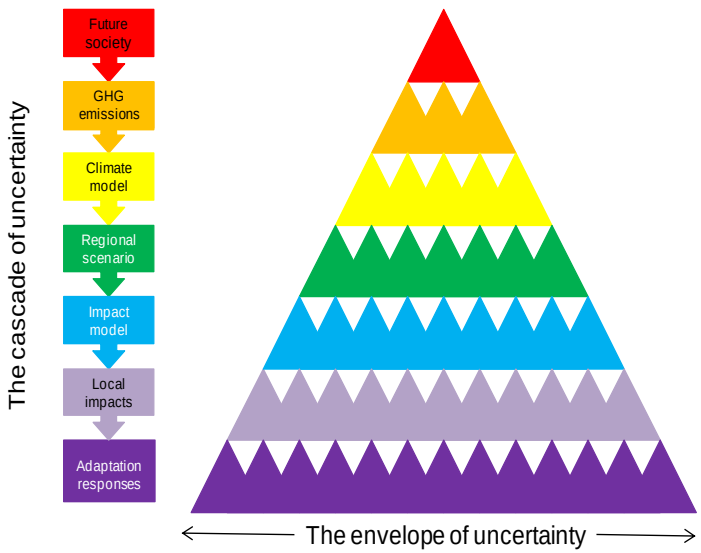



Climatic Lock-In



The Challenge

- Climate variability and change are a major threat for the sustainable development of society
- Adaptation to the impacts of climate change is unavoidable
- There are significant uncertainties about how regional climate will change in the future
- Informing adaptation decisions will require new kinds of information and new ways of thinking and learning (NRC, 2009)



UK Context: Since 2008 – Top-down

- Legally binding commitment to reduce GHGs by 80% by 2050
- Statutory requirements to encourage adaptation
- Enframing science-first in the legislation – finer resolutions

Climate Change Act 2008

2008 CHAPTER 27

An Act to set a target for the year 2050 for the reduction of targeted greenhouse gas emissions; to provide for budgeting; to establish a Committee on Climate Change; to confer powers to establish trading schemes for the greenhouse gas emissions or encouraging activities that reduce such emissions or remove greenhouse gas from the provision about adaptation to climate change; to confer powers to make schemes for providing financial incenti domestic waste and to recycle more of what is produced; to make provision about the collection of household waste make provision about charging for single use carrier bags; to amend the provisions of the Energy Act 2004 about rene obligations; to make provision about carbon emissions reduction targets; to make other provision about climate chang purposes. 9

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BE IT ENACTED by the Queen's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual Commons, in this present Parliament assembled, and by the authority of the same, as follows:—

UK 2012 Climate Change Risk Assessment

Committee on Climate Change

Funded by:

defra

Department of Energy & Climate Change

Department of the Environment

The Scottish Government

Llywodraeth Cynulliad Cymru Welsh Assembly Government

UKCIP

Met Office

Environment Agency

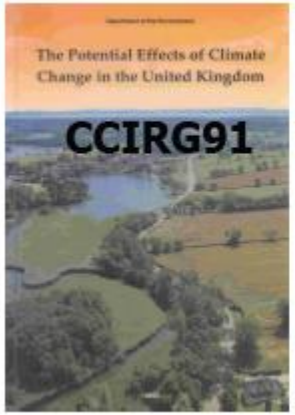
UK Climate Scenarios: History

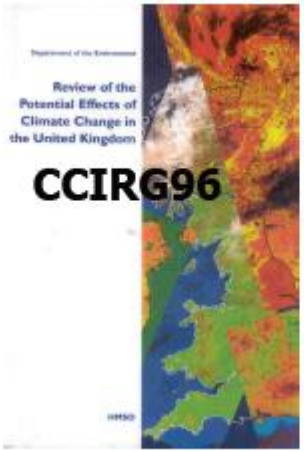
- UK scenarios produced since early 1990s – now on fifth generation

- Advances with each set of projections:
  - Increased number of scenarios considered (from 1 to 4)
  - Finer spatial resolutions (from 300km to 50km grids)
  - Temporal scale improvements (seasonal to monthly averages)
  - Wider range of climate variables (from temp & precipitation to 13 others)

- Getting decisions 'right' relies on a robust evidence base. Uncertainty inherent in building scenarios can undermine this.

- Making uncertainty explicit has led to a move away from single projections to embrace more probabilistic ones.





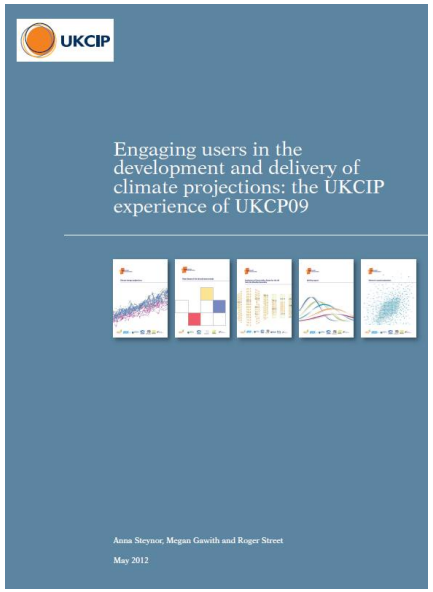
Stakeholder Engagement

"consult[ed] widely with a broad spectrum of users to establish an understanding of their requirements and expectations of climate change information…" (UKCIP 2012).

- Broad spectrum or usual suspects?

- Users only consulted once methodology was agreed and comments restricted to presentation and use of the projections

- Do users' need uncertainty to be quantified or was this just science-first?



UKCP09 Projections

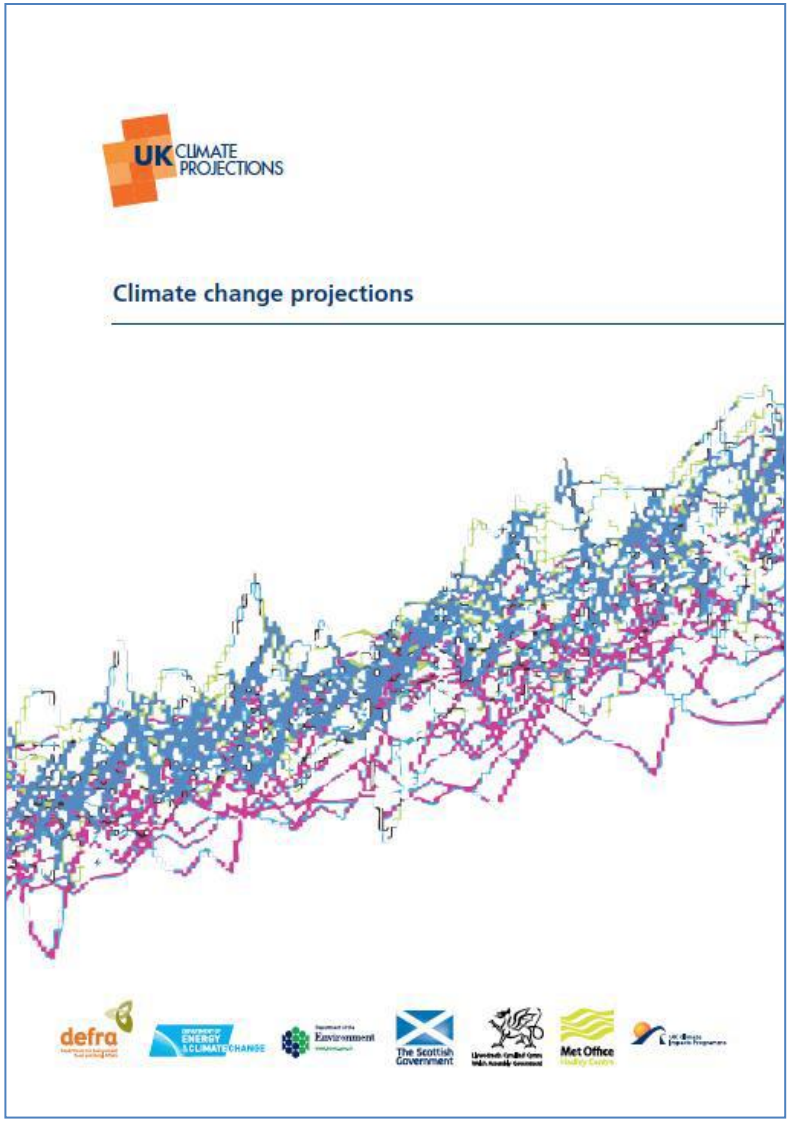
- UK's first probabilistic projections, using models information other than HadCM3

- Designed to explicitly treat uncertainties:
  - Model uncertainty – incomplete understanding of the climate system (PPEs)
  - Natural climate variability from internal and external factors
  - Emissions uncertainty – release of future greenhouse gases
  - Downscaling uncertainties

- Cost £11million and designed to inform adaptation decisions

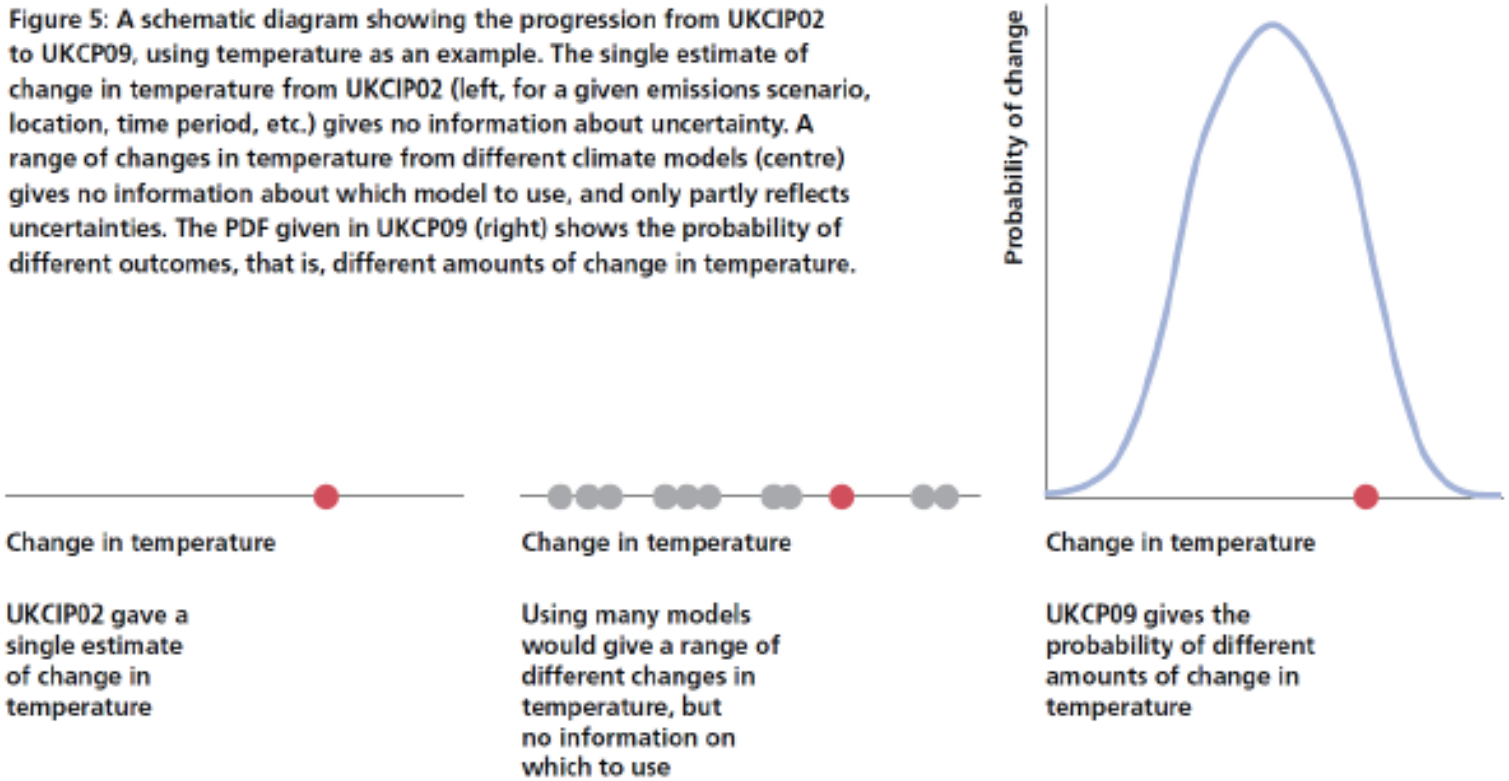
- Online user interface (beginner, intermediate & advanced)

- Steered by 3 expert groups



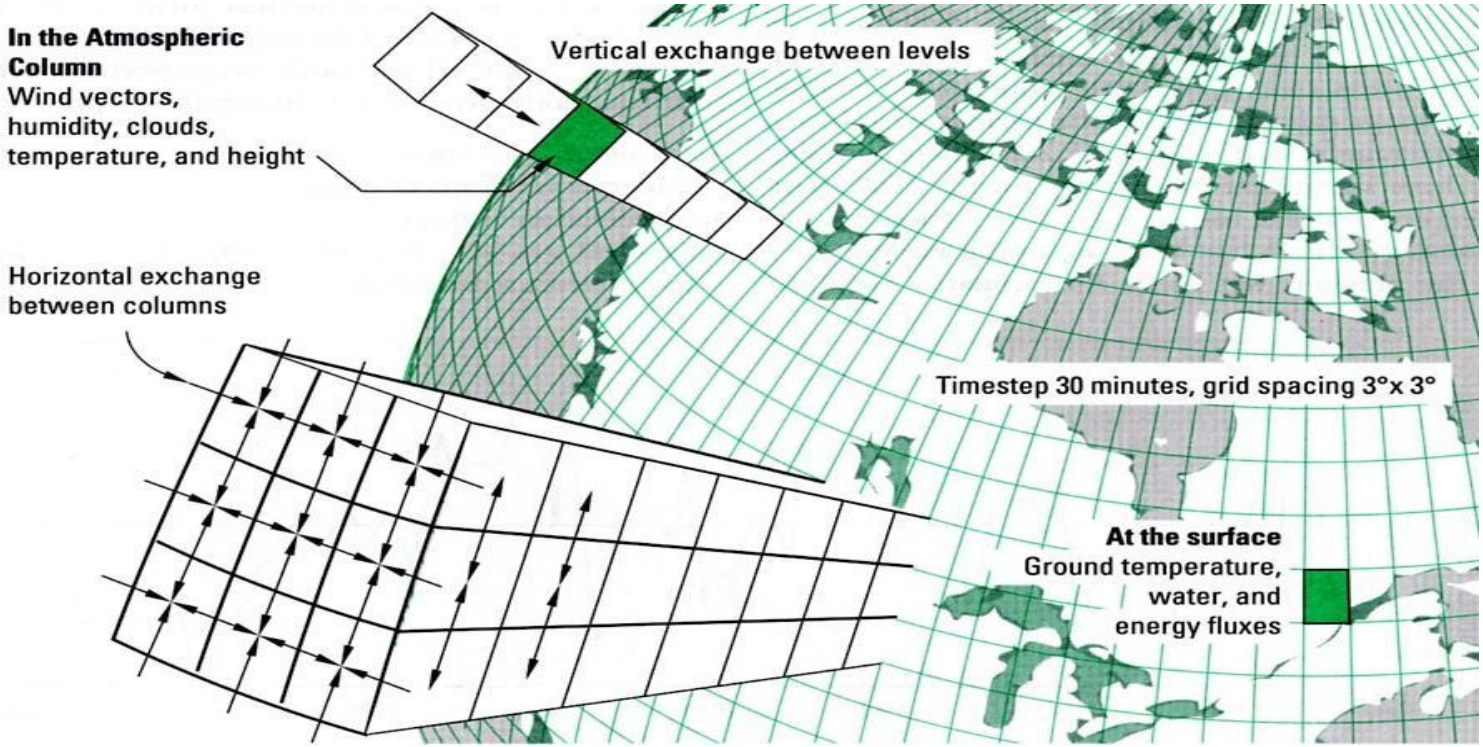
Transition from UKCIP02 to UKCP09

Figure 5: A schematic diagram showing the progression from UKCIP02 to UKCP09, using temperature as an example. The single estimate of change in temperature from UKCIP02 (left, for a given emissions scenario, location, time period, etc.) gives no information about uncertainty. A range of changes in temperature from different climate models (centre) gives no information about which model to use, and only partly reflects uncertainties. The PDF given in UKCP09 (right) shows the probability of different outcomes, that is, different amounts of change in temperature.



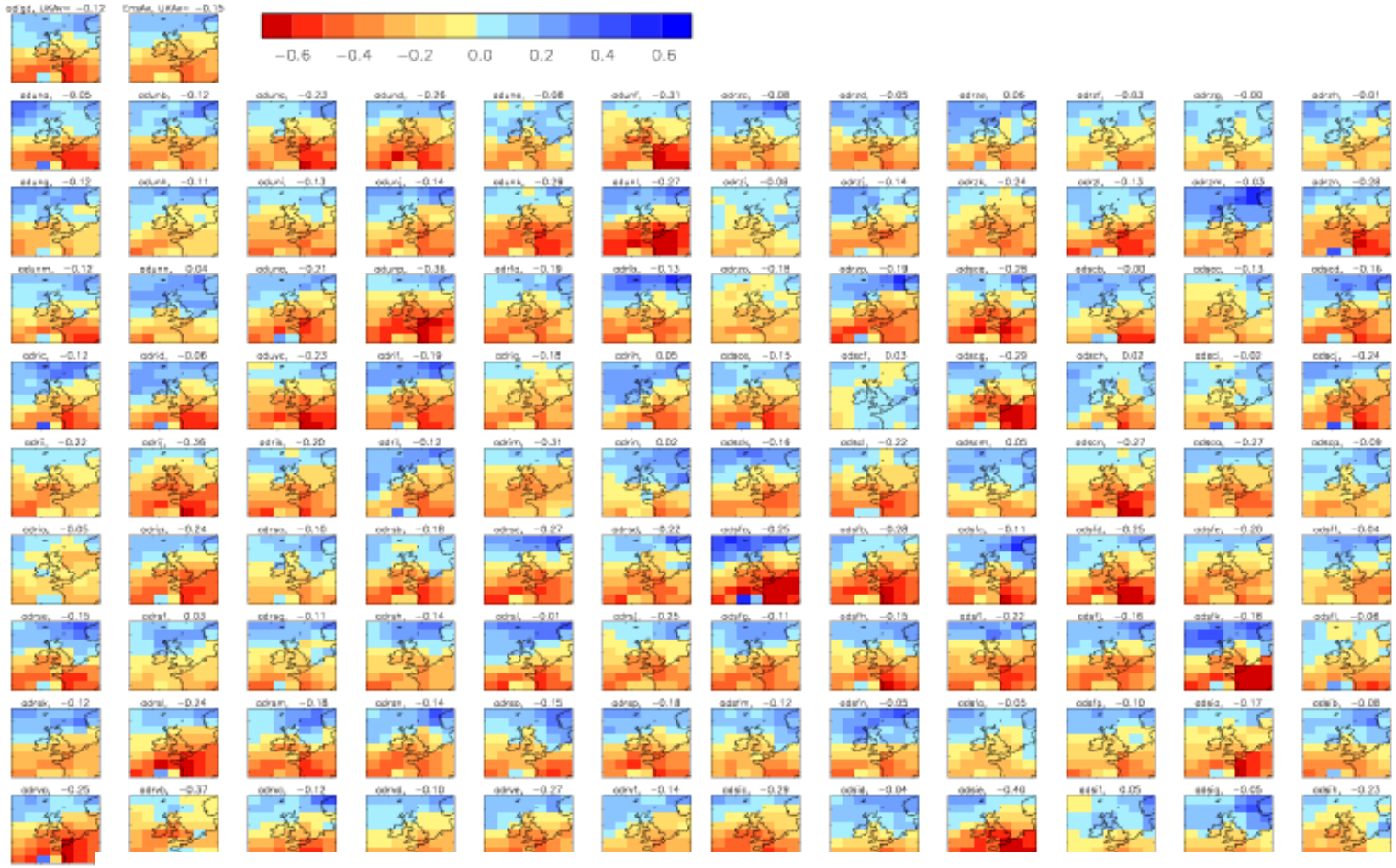
- Applies only to UKCP09's land projections and not it's marine ones.

Probabilstic Modelling: How?



- Projections generated using GCM, HadCM3, and combined with elaborate (Bayesian) statistical techniques.
- HadCM3: 300km resolution, full atmospheric model coupled with a slab ocean model
- But Beddington Report (2010), from the Government's Chief Scientific Advisor, hints at computing resource constraints and lack of investment in capacity

Reality of Modelling



- Perturbed Physics (or Parameter) Ensemble (PPE) – Controlling model parameters (n=31) are selected by experts and then varied within the model runs (n=280)

- Emulator then used to ‘fill in the gaps’ between the 280 model runs

"Peer" Review

Limitations: shall we wait for improved projections?

The procedure used in UKCP09 to convert the ensembles of climate model simulations into probabilistic estimates of future climate necessitates a number of expert choices and assumptions, with the result that the probabilities we specify are themselves uncertain. We do know that our probabilistic estimates are robust to reasonable variations within these assumptions, and this is covered in some detail in Annex 2 of the UKCP09 report *Climate change projections*. Although it is important that prospective users understand the limitations and caveats, it is also worth emphasising that (a) current models are capable of simulating many aspects of global and regional climate with considerable skill; and (b) they do capture, albeit imperfectly, all the major physical and biogeochemical processes known to be likely to exert a significant influence on global and regional climate over the next 100 yr or so.

As our understanding of the climate system and our ability to represent it in models gets better, as statistical methods to convert model results into probabilistic projections are developed further, and as computing power increases, it is likely that uncertainties will become smaller, although natural variability will always provide an irreducible level in the long term. The consequence of these expected improvements is that the shape of a given PDF is likely to change in the future. Users need to understand clearly that, if they choose to adapt to a climate change corresponding to a specific probability level, this is likely to change in future projections — and the changes are likely to be greater at the extremes of probability levels (that is, 10 and 90%). If our understanding of climate processes, and model representations of them, does not change substantially in future, then we foresee a general reduction in uncertainties (except that due to long-term natural variability) because of improvements in our ability to represent processes currently modelled, and we would hence expect the shape of the PDF to change, with a reduction in its width. However, we do not know in what way this reduction in width will occur; in particular it may not be in a symmetrical manner. Although we cannot say what the next generation of PDFs will look like, it is likely that the spread of plausible changes they would indicate would be encompassed by the corresponding PDFs shown in UKCP09. Thus, in the absence of any major change in model projections, users who are incorporating the probabilities given in UKCP09 into their decision-making are likely to find that their decisions are robust to changes in the next generation of projections.

- External "peer" review, was it too late?
- Political concerns about rubber stamping the projections?
- Reputational risks of overselling the science
- Insistence on issuing a health warning over the limits of UKCP09

Modelling Community Concerns

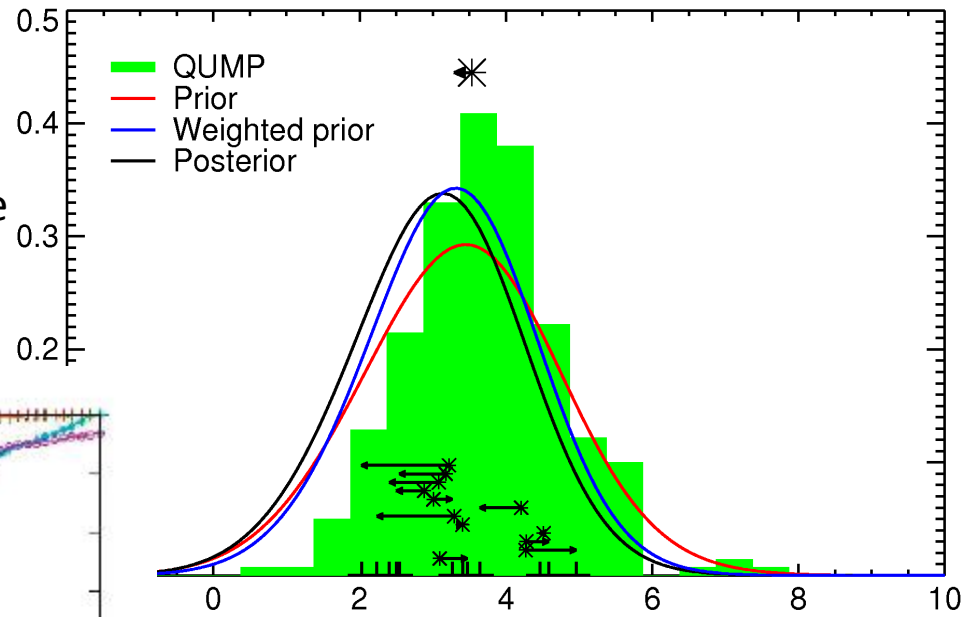
- Frigg et al (In Press) structural model error – assumes HadCM3 can be compared with the "truth" (cf. multi-model ensemble)

- Question marks remain over the trustworthiness of the forecasts for quantitative decision support (Frigg et al In Press).

- Projections were, initially, spatially incoherent – weather station observations could not be inputted for local-scale forecasts

Presentational Convenience?

"To reduce this uncertainty to a single probability distribution in order to generate probabilistic scenarios… misrepresent[s] the state of current scientific knowledge" (Hall 2007: 1129)



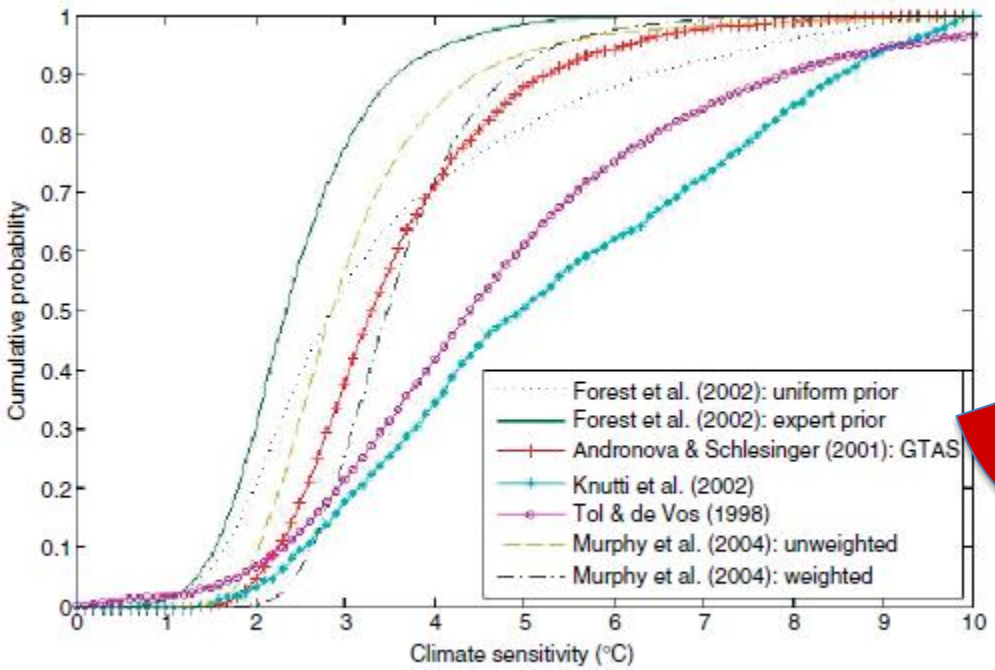


Figure 1. Some published cumulative probability distributions for climate sensitivity

How uncertain is radiative forcing?

Who is the "User"?

- Particular kind of user is imagined in UKCP09:

  - UKCIP's user interface (beginner, intermediate, advanced)
  - Is technically proficient (i.e. PhD in atmospheric sciences or related fields)
  - Has the time, inclination and resources to invest in tailoring, mining and implementing the data/tool

- Potential challenges:

  - Scientific advances outstrip the rate at which users can absorb them (cf. Bayesian statistics)
  - Becoming over, not under, reliant on climate experts
  - Extra workload involved

Do We Need Climate Models to Adapt?

- Assess vulnerabilities – areas known to be prone to at risk – and build in resilience (cf. Sarewitz 2011)
- But what about places where the risks are not readily apparent?

Summary: Part 1

- Does getting the biggest computer possible, adding in all the latest techniques and parameters, always provide the “right” answer?
- UKCP09 projections are state-of-the-art science, combining methodological novelty and innovation
- In science-first, “top-down”, approaches user input becomes tokenistic as ambiguities over uncertainty are reduced to purely technical things
- Quantifying uncertainty is not only a technical problem but a social one as well

Summary: Part 2

- Only a particular kind of uncertainty is being tackled (internal modelling – epistemic) – not the complete picture
- Rather than bring producers and users of climate science together, modelling uncertainty potentially reaffirms their differences
- Dialogue of between scientists and decision-makers needs to be "honest" with the confidence to say "no" – shifting responsibility
- Does quantifying uncertainty produce better decisions? Does the visualisation of uncertainty help users make better decisions? And does uncertainty change the relationship between producers and users of climate science?

- Principal Investigator: Prof Suraje Dessai
- PostDocs: Dr James Porter & Dr Geoff Whitman
- Funded by a European Research Council (ERC) Starting Grant under the domain of Social Science & Humanities (Environment and Society panel; SH3)
- €1.045 million grant spread over 4 years (1 April 2012 – 31 March 2016)
- Fieldwork just beginning so watch this space!

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