Centre for Climate Change Economics and Policy

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Uncertainty in climate change adaptation

Suraje Dessai

Sustainability Research Institute and ESRC Centre for Climate Change Economics and Policy, School of Earth and Environment, University of Leeds, UK

Climate Change Impacts, Adaptation and Mitigation (CC-IAM) Research Group, Faculty of Sciences, University of Lisbon, Portugal

Outline

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- What is adaptation to climate change?
- Why is there uncertainty about future climate?
- Dealing with uncertainty in climate adaptation decision-making

What is adaptation to climate change?

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In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate (IPCC SREX, 2012).

Complex societal process of activities, actions, decisions and attitudes that reflect existing social norms and processes (Adger et al. 2005)

Adaptation to climate change does not happen in isolation – multiple actors and multiple stresses and stimuli

Why is adaptation necessary?

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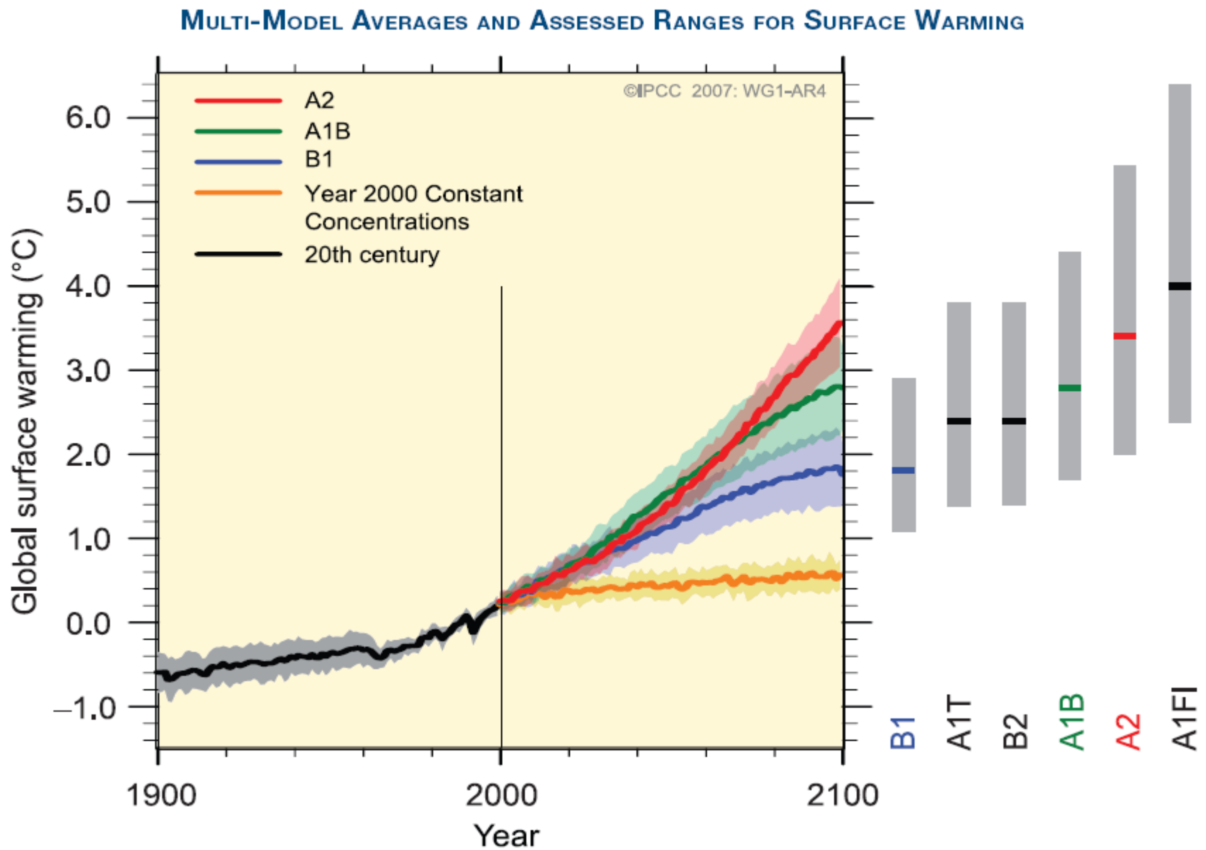

Even if atmospheric composition were fixed today, global-mean temperature and sea level rise would continue due to oceanic thermal inertia

Climate change sea level rise commitment

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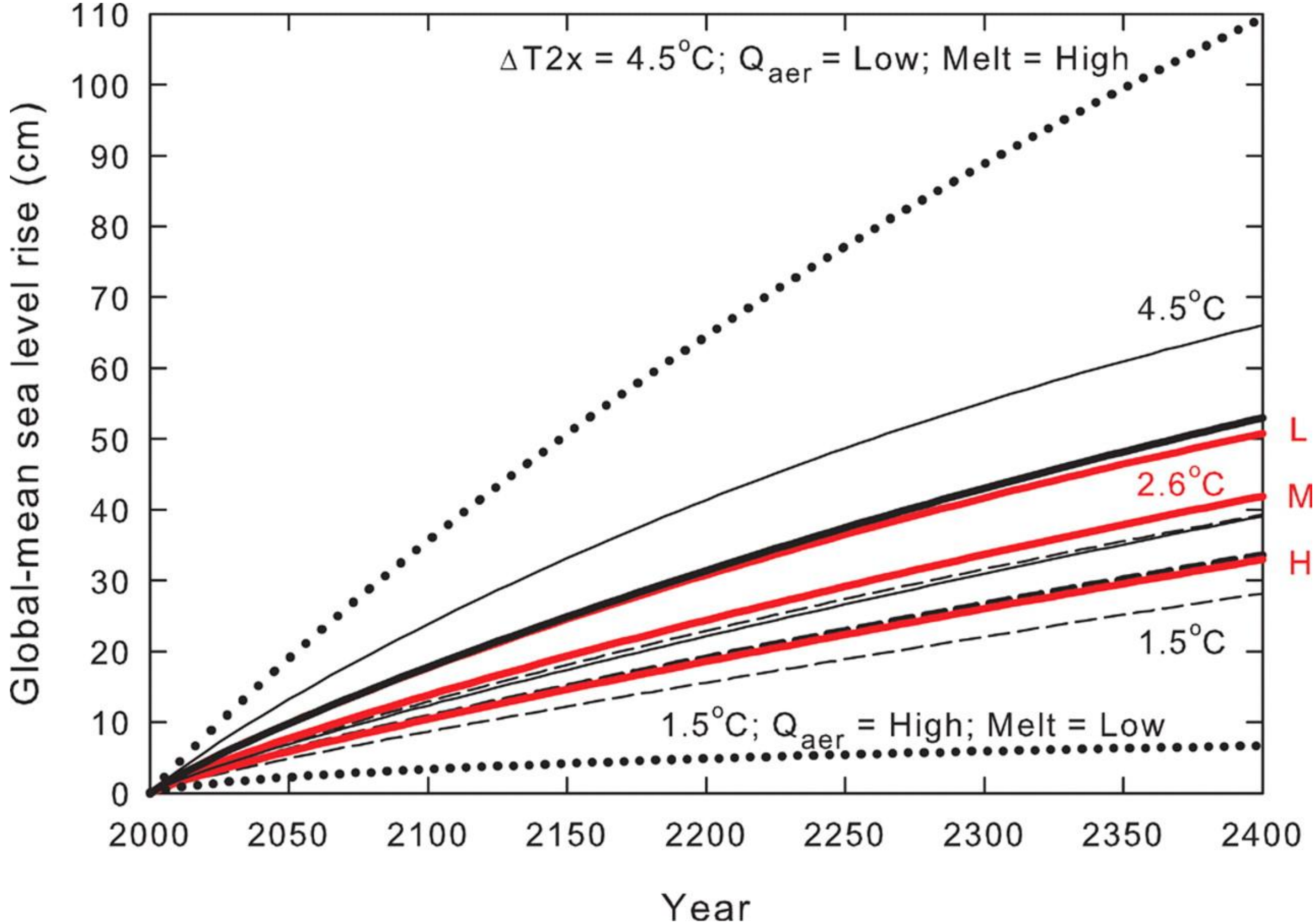

T. M. L. Wigley Science 307, 1766 -1769 (2005)

Constant concentrations after 2000, for different climate sensitivities and aerosol forcing levels (L, M, and H on the right of figure indicate low, mid-, and high magnitudes for aerosol forcing, respectively)

Climate variability causes damages

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There is evidence that societies are not “well” adapted to current climate variability

Adaptation highlights from IPCC AR4

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Adaptation to climate change is already taking place, but on a limited basis

Adaptation measures are seldom undertaken in response to climate change along

Many adaptations can be implemented at low cost, but comprehensive estimates of adaptation costs and benefits are currently lacking

Adaptive capacity is uneven across and within societies

There are substantial limits and barriers to adaptation

Adaptation concepts

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Adaptation is a process

Adaptation is made up of actions throughout society, by individuals, groups and governments

Adaptation can be motivated by many factors, including the protection of economic well-being or improvement of safety

It can be manifested in myriad ways: through market exchanges, through extension of social networks, or through actions of individuals and organisations to meet their own individual or collective goals

Adger, W. N., et al. (2005), Successful adaptation to climate change across scales, *Glob. Environ. Change-Human Policy Dimens.*, *15*(2), 77-86.

Adaptation concepts

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Adaptation is happening across scales, from the international to the national to the local

These levels of actions take place within hierarchical structures such that the levels interact with each other.

Individual adaptation actions are therefore not autonomous but constrained by institutional processes such as regulatory structures, property rights and social norms associated with rules in use

Adger, W. N., et al. (2005), Successful adaptation to climate change across scales, *Glob. Environ. Change-Human Policy Dimens.*, *15*(2), 77-86.

Adaptation concepts

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Adaptation can involve both **building adaptive capacity** thereby increasing the ability of individuals, groups, or organisations to adapt to changes, and **implementing adaptation decisions**, i.e., transforming that capacity into action.

Actions associated with building adaptive capacity: communicating climate change information, building awareness of potential impacts, maintaining well-being, protecting property or land, maintaining economic growth, or exploiting new opportunities.

Adaptation decisions happen without a particular context so it is difficult to separate climate change adaptation decisions from actions triggered by other events

Adger, W. N., et al. (2005), Successful adaptation to climate change across scales, *Glob. Environ. Change-Human Policy Dimens.*, *15*(2), 77-86.

Adaptation concepts

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Classification of purposeful adaptation:

- Share loss, bear the loss, modify the event, prevent effects, change use or change location (Burton et al. 1993).
- Reducing the sensitivity of the effected system (e.g., increasing reservoir storage)
- Altering the exposure of the system (climate change mitigation)
- Increasing the resilience of social and ecological systems (generic actions to enhance well-being) (Adger et al. 2005)

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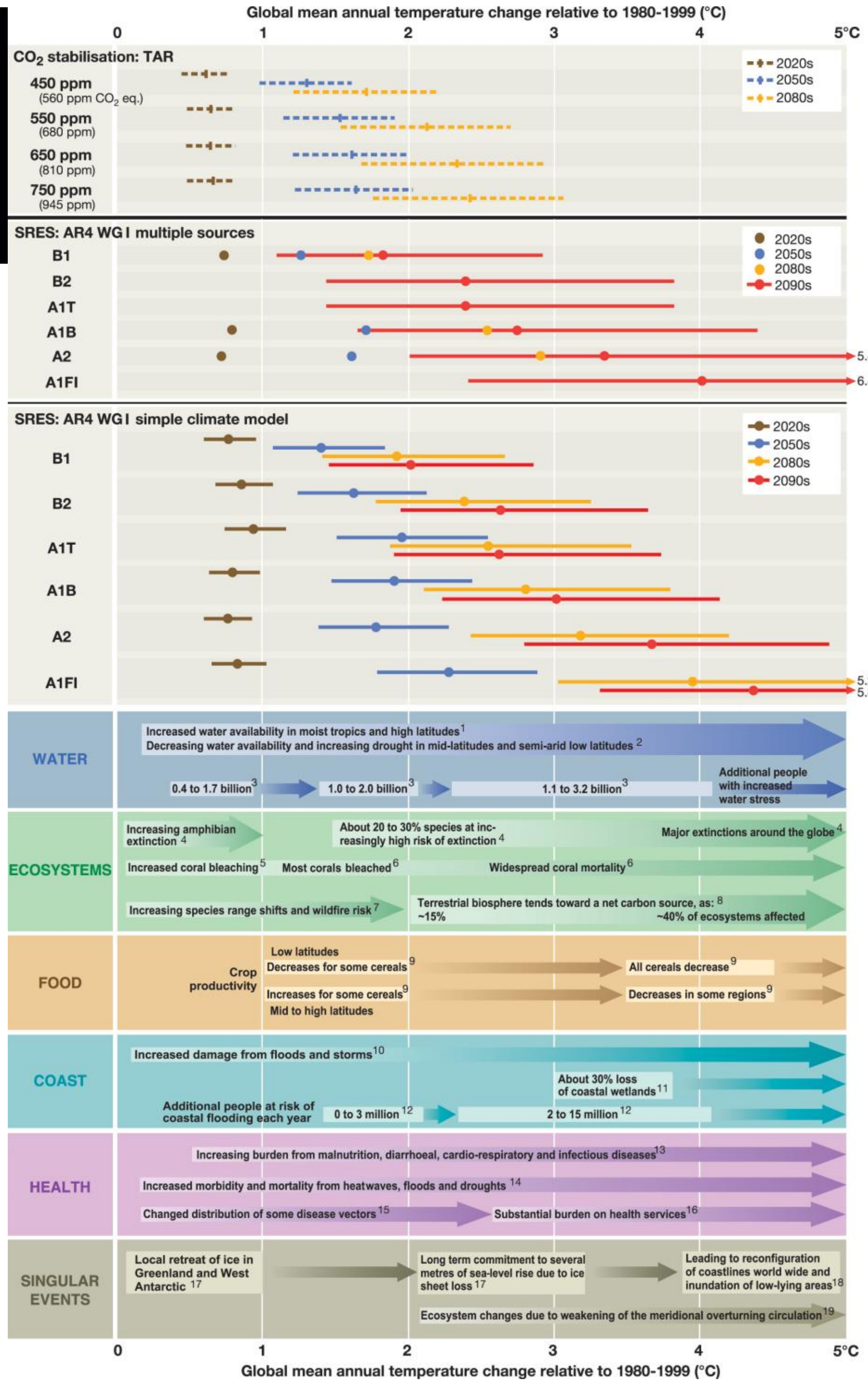

IPCC (2007) Climate change 2007: Impacts, adaptation and vulnerability

“Top-down” and “bottom-up” approaches used to inform climate adaptation policy

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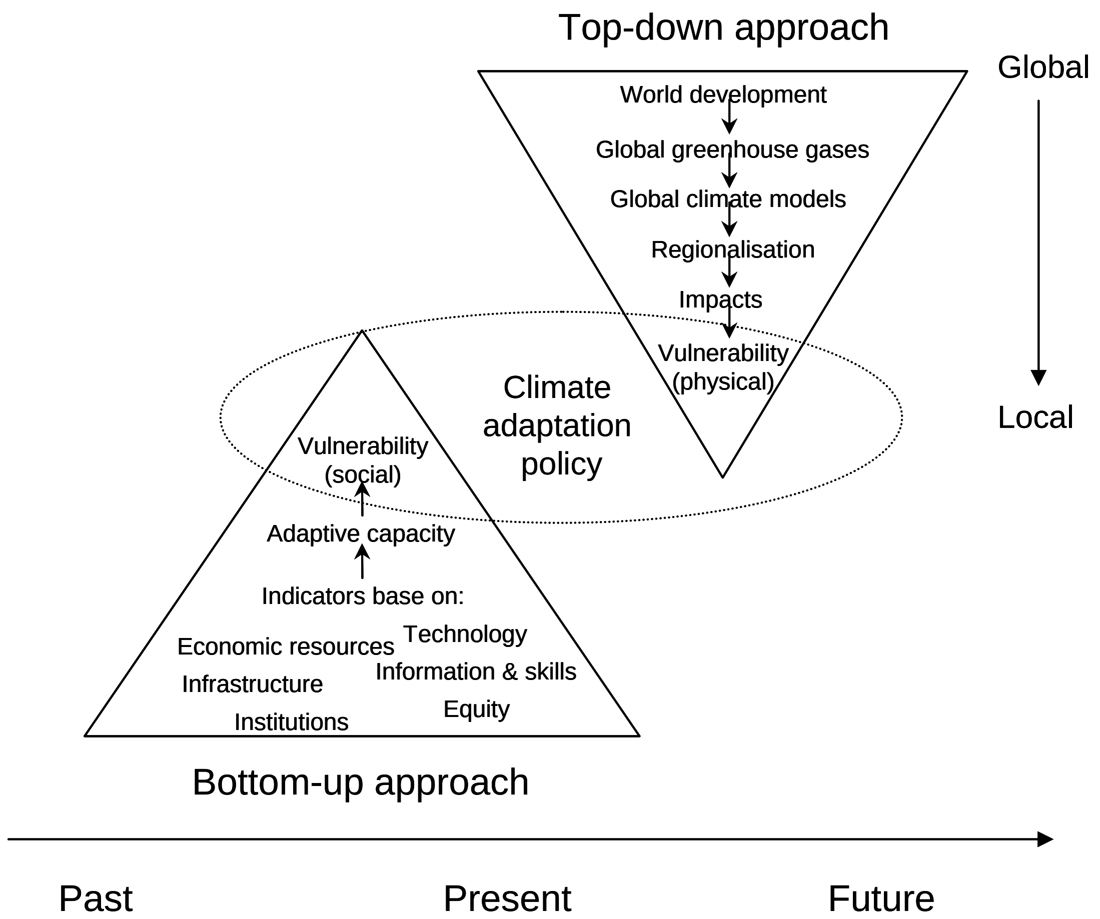

Dessai, S. and M. Hulme, Does climate adaptation policy need probabilities? Climate Policy, 2004. 4(2): p. 107-128.

Adaptation and risk management

TABLE 1 | Generations of Risk Assessment as They Apply to Climate Change, Particularly Adaptation. Years are Book-ended with the Formation of the IPCC (1988), the United Nations Framework Convention on Climate Change (UNFCCC, 1992), and Major IPCC Assessment Reports

Assessment	Policy Question	Stage of Risk Assessment	Methodological Approaches	Scenario Requirement	Years
First generation	Is climate change a problem?	Scoping the question, risk identification	Sensitivity analysis	Incremental scenarios for primary climate variables	1988–1992
Second generation	What are the potential impacts of unmanaged climate change?	Risk analysis	Scenario-driven impact assessment	Climate model derived scenarios for multiple variables at global and regional scale	1988–2001
Third generation	How do we effectively adapt to climate change?	Risk evaluation	Risk assessment Vulnerability assessment	Model derived scenarios for many variables, consistent with other scenarios, integration at a range of scales	1995–2007
Fourth generation	Which adaptation options are the most effective?	Risk management	Risk management Mainstreaming adaptation	Dynamic scenarios of climate and other key drivers, conditional probabilities	2001 ongoing
Fifth generation	Are we seeing the benefits?	Implementation and monitoring	Implementation, monitoring and review	Updating scenarios through observation and learning by doing	2007 ongoing

Jones, R. N. and Preston, B. L. (2011), Adaptation and risk management. WIREs Clim Change, 2: 296–308. doi: 10.1002/wcc.97

Four domains of adaptation research

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TABLE 1 | Classification of Lessons and Themes Emerging from Adaptation Research

	Risk Assessment and Impact Response	Vulnerability and Adaptive Capacity	Resilience	Implementing Practical Polices
Economic	Methods for assessing costs and benefits of adaptation	Importance of poverty/development in constraining/enabling adaptation	Prioritization of short-term economic goals can lead to systemic mal-adaptation	Designing appropriate metrics of adaptation policy outcomes
Governance	Coordinating role of government	Policies often fail to reach the most vulnerable; improved governance is required to enhance adaptive capacities	Participatory and adaptive institutions required with capacity to govern system processes	Mainstreaming climate into existing programs; the potential of boundary organizations in facilitating adaptation
Private action	Outcomes of autonomous adaptation	Individual barriers to successful adaptation	Communities as active participants in managing resources for resilience	Practices of communicating climate impacts and assessing decision-making processes

Eakin, H. C. and Patt, A. (2011), Are adaptation studies effective, and what can enhance their practical impact?. *WIREs Clim Change*, 2: 141–153. doi: 10.1002/wcc.100

Why is there uncertainty about future climate?

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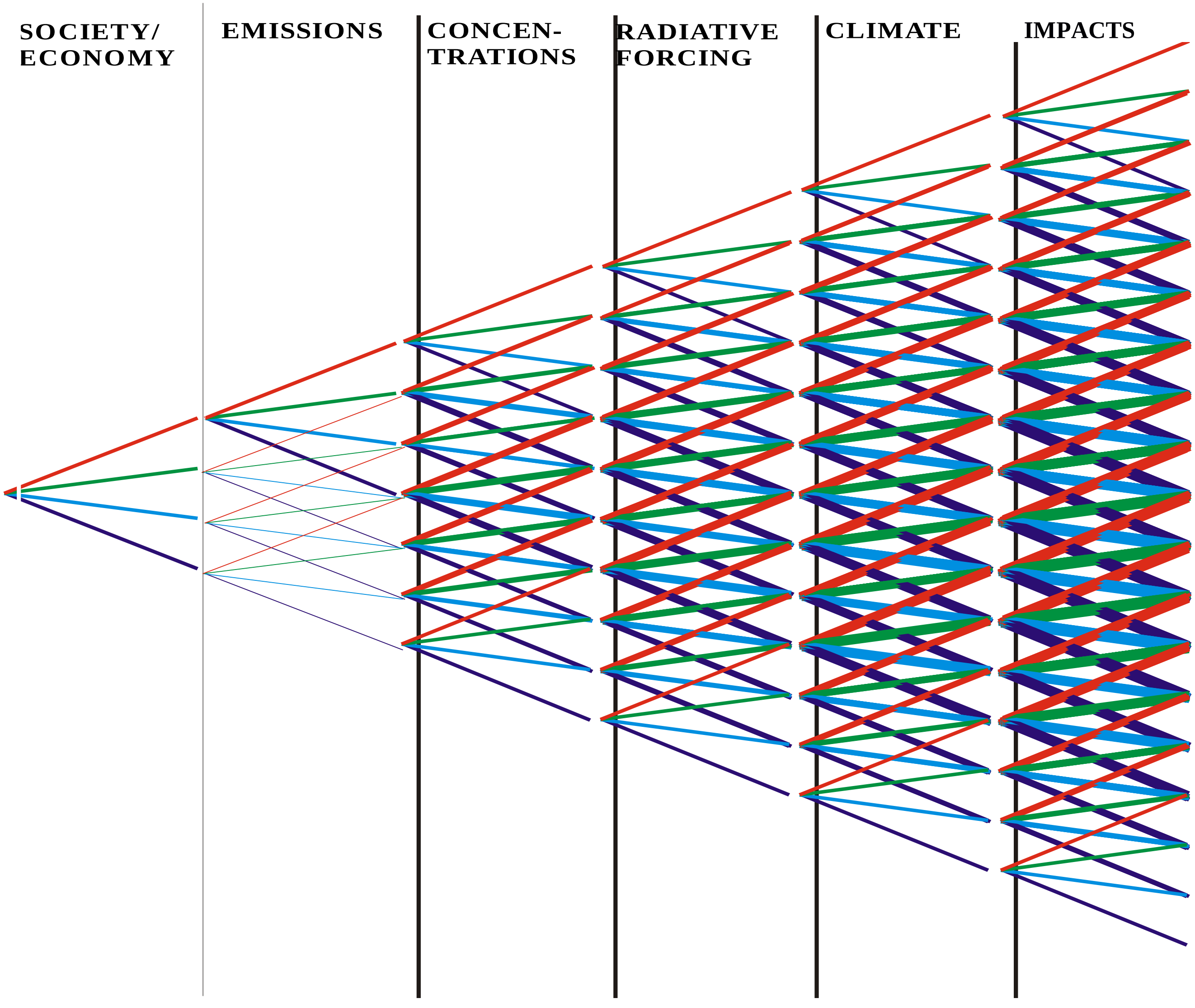

Lobell et al. 2008 *Science*

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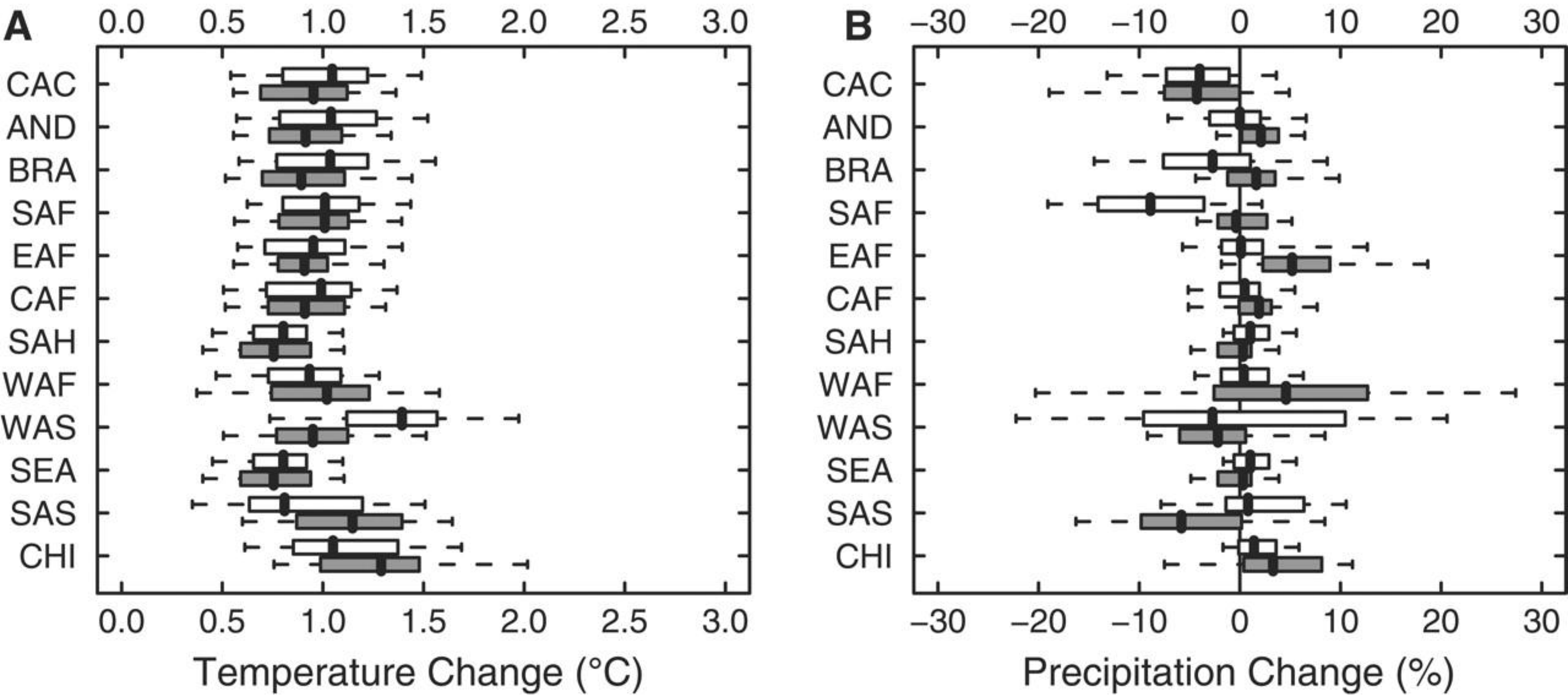
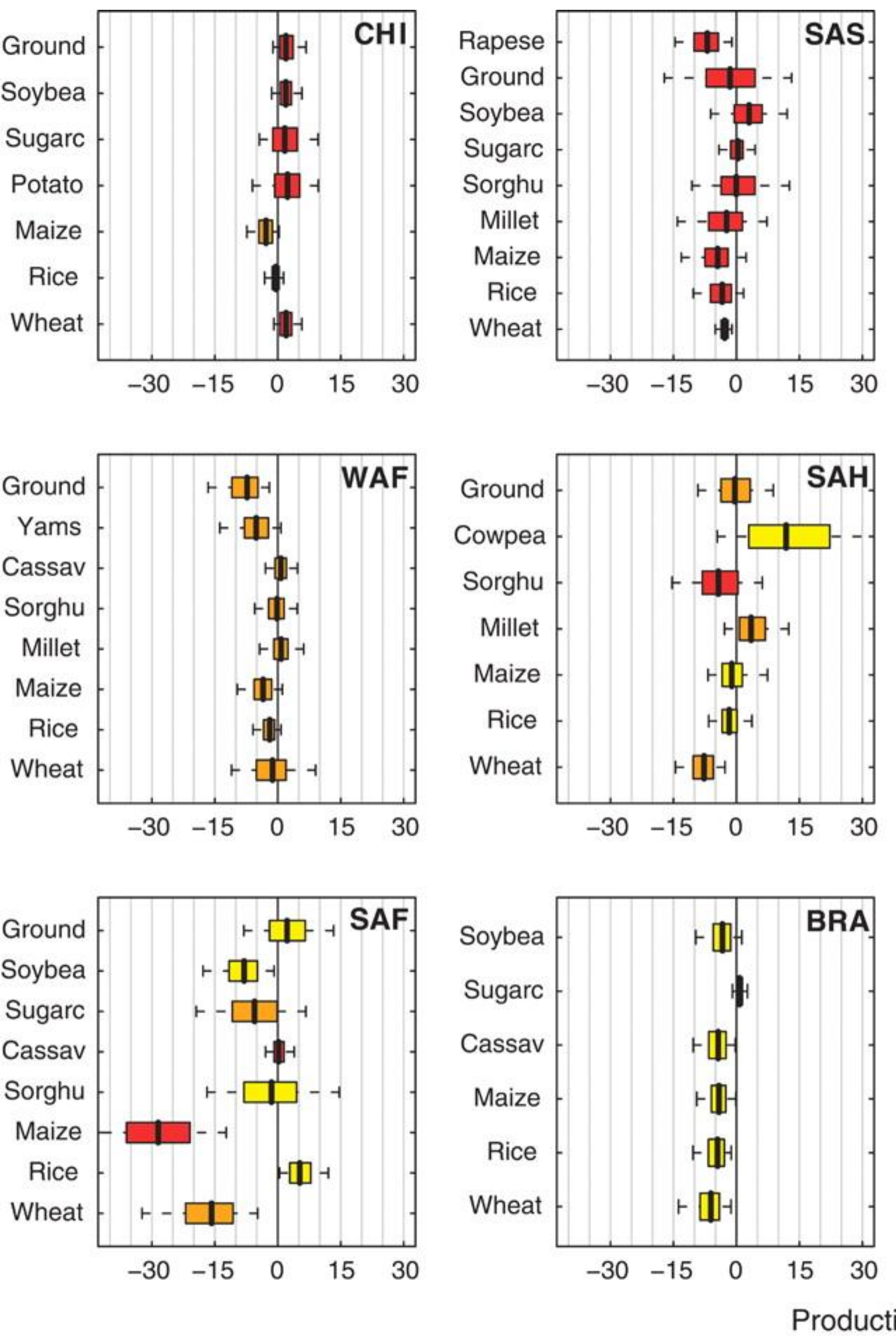
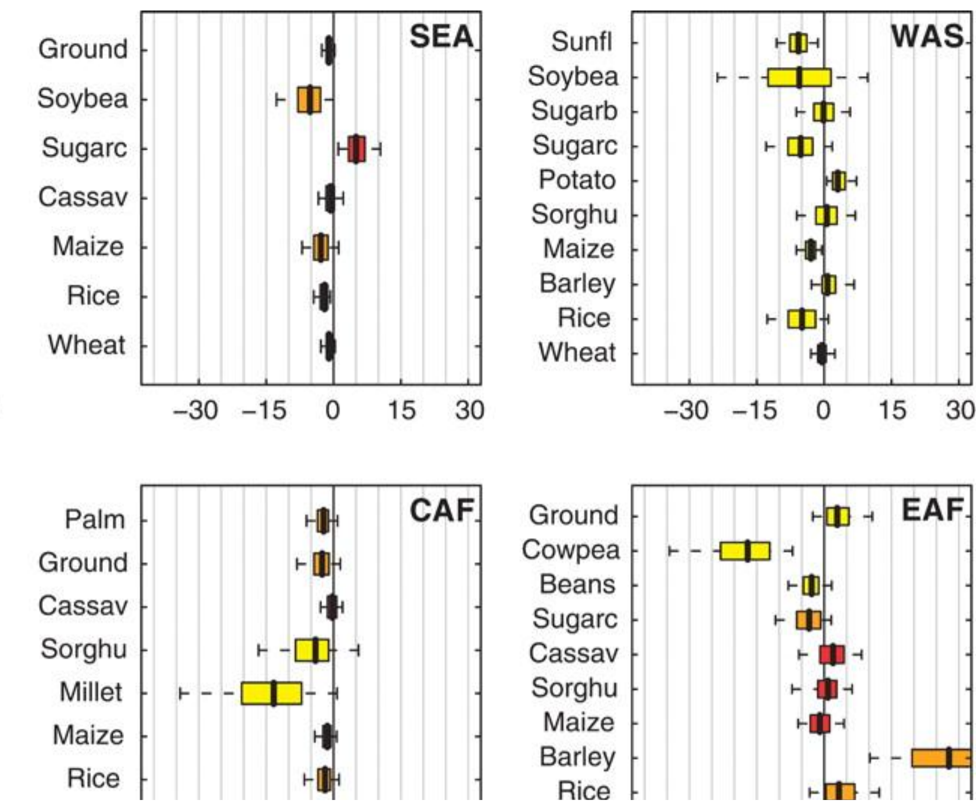


Summary of projected (A) temperature (° C) and (B) precipitation (%) changes for 2030 (the averages from 2020 to 2039 relative to those from 1980 to 1999) based on output from 20 GCMs and three emission scenarios. Gray boxes show DJF averages and white boxes show JJA averages. Dashed lines extend from 5th to 95th percentile of projections, boxes extend from 25th to 75th percentile, and the middle vertical line within each box indicates the median projection.

Probabilistic projections of production impacts in 2030 from climate change (expressed as a percentage of 1998 to 2002 average yields). Red, orange, and yellow indicate a Hunger Importance Ranking of 1 to 30 (more important), 31 to 60 (important), and 61 to 94 (less important), respectively. Dashed lines extend from 5th to 95th percentile of projections, boxes extend from 25th to 75th percentile, and the middle vertical line within each box indicates the median projection.

End-to-end uncertainty quantification

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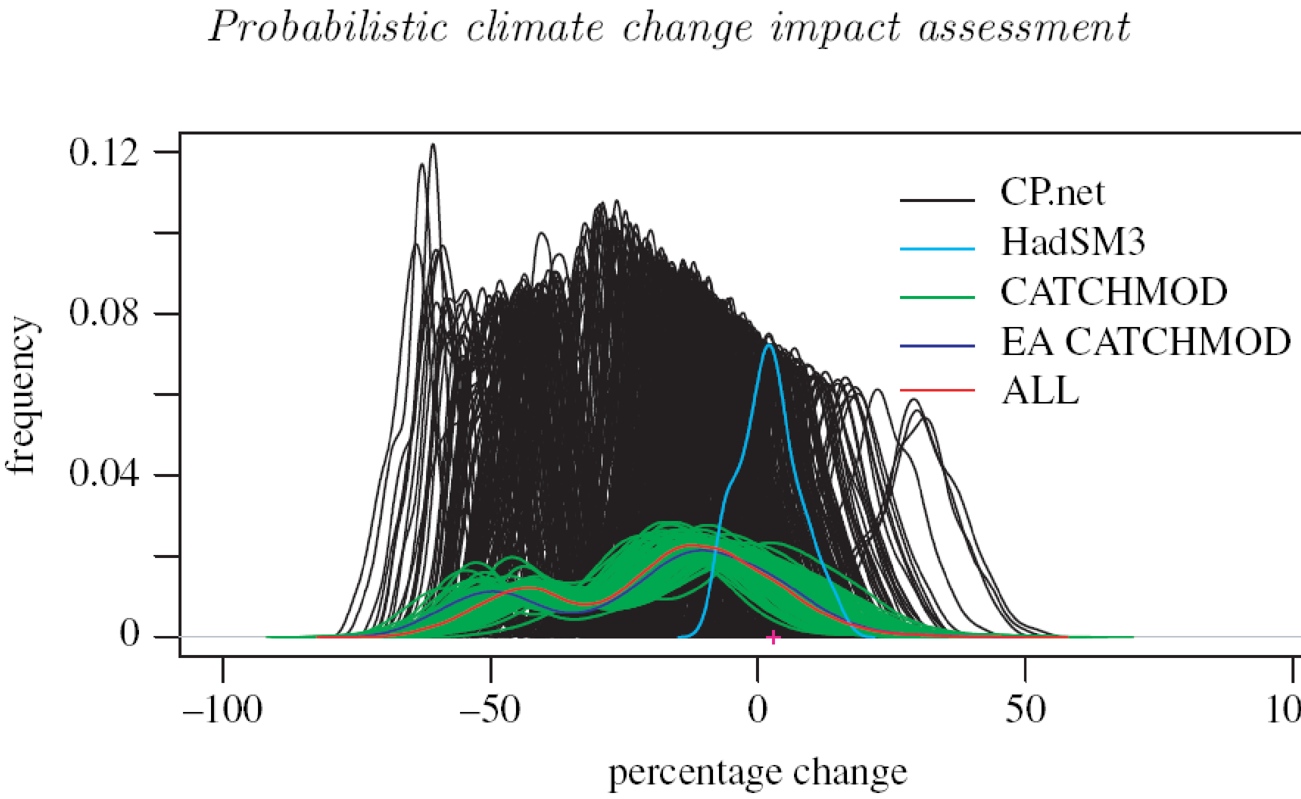
Changes in mean river runoff ($2xCO_2$-$1xCO_2$) at the Thames



New, M., et al. (2007), Challenges in using probabilistic climate change information for impact assessments: an example from the water sector, *Philos T R Soc A*, 365(1857), 2117-2131.

Multiple routes of uncertainty assessment

Table 6.1 Main characteristics of a selected number of climate change impact studies.

	New and Hulme (2000), Prudhomme et al. (2003)	Wilby and Harris (2006)	Dessai and Hulme (2007)	Lopez et al. (2009)	Manning et al. (2009)
GHG emissions	4	2	40	1 (SRES A1B)	4 (most results for SRES A2)
Carbon cycle response	1 model		1 model with uniform PDF		
Global climate sensitivity	Triangular PDF		Multiple PDFs from the literature		
AOGCM	7	4	9	21 + 1 (w/u[a] 246 simulations)	2
Downscaling		2 statistical downscaling	19 RCMs (dynamical downscaling, but not linked to above)	Bias correction and temporal downscaling using a gamma transform	14 RCMs + stochastic weather generator
Impacts	1 hydrological model	2 hydrological model structures + 2 sets of hydrological model parameters (w/u)	Simple linear transfer function	1 hydrological model (w/u) and water resource model	1 hydrological model (w/u)
Unit of assessment	Flood regime of 5 small catchments	Low flows in the Thames	Additional water required due to climate change in the East of England	Reservoir storage level and supply failure under a number of supply and demand scenarios	Abstraction availability in the Thames

[a] with uncertainty analysis

Dessai, S. and J.P. van der Sluijs (2011) Modelling climate change impacts for adaptation assessments, 83-102. M. Christie, A. Cliffe, P. Dawid and S. Senn (eds.) *Simplicity, Complexity and Modelling*. Wiley.

Dealing with uncertainty in climate adaptation decision-making

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There are significant (deep/severe) **uncertainties** about how regional climate (and its impacts) will change in the future

Stationarity is dead (Milly et al. 2008): plan for the unexpected/surprises

Flexible and **adaptive** strategies are more likely to be robust to uncertainty as opposed to static strategies (Hallegatte 2009; Lempert and Groves 2010)

Informing adaptation decisions will require **new kinds of information** and new ways of thinking and learning (NRC, 2009

3 paradigms of uncertain risks

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'deficit view'

- Uncertainty is provisional
- Reduce uncertainty, make ever more complex models
- *Tools:* quantification, Monte Carlo, Bayesian belief networks

'evidence evaluation view'

- Comparative evaluations of research results
- *Tools:* Scientific consensus building; multi disciplinary expert panels
- focus on robust findings

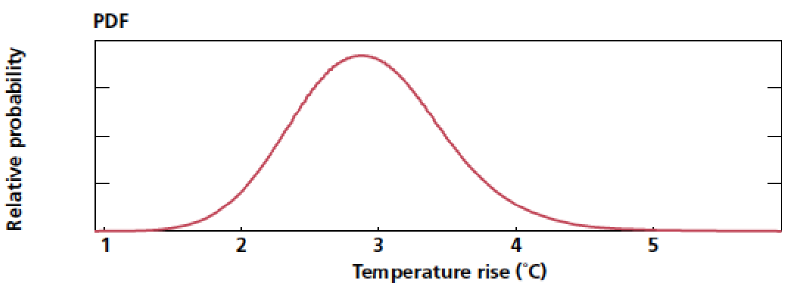
'complex systems view / *post-normal* view'

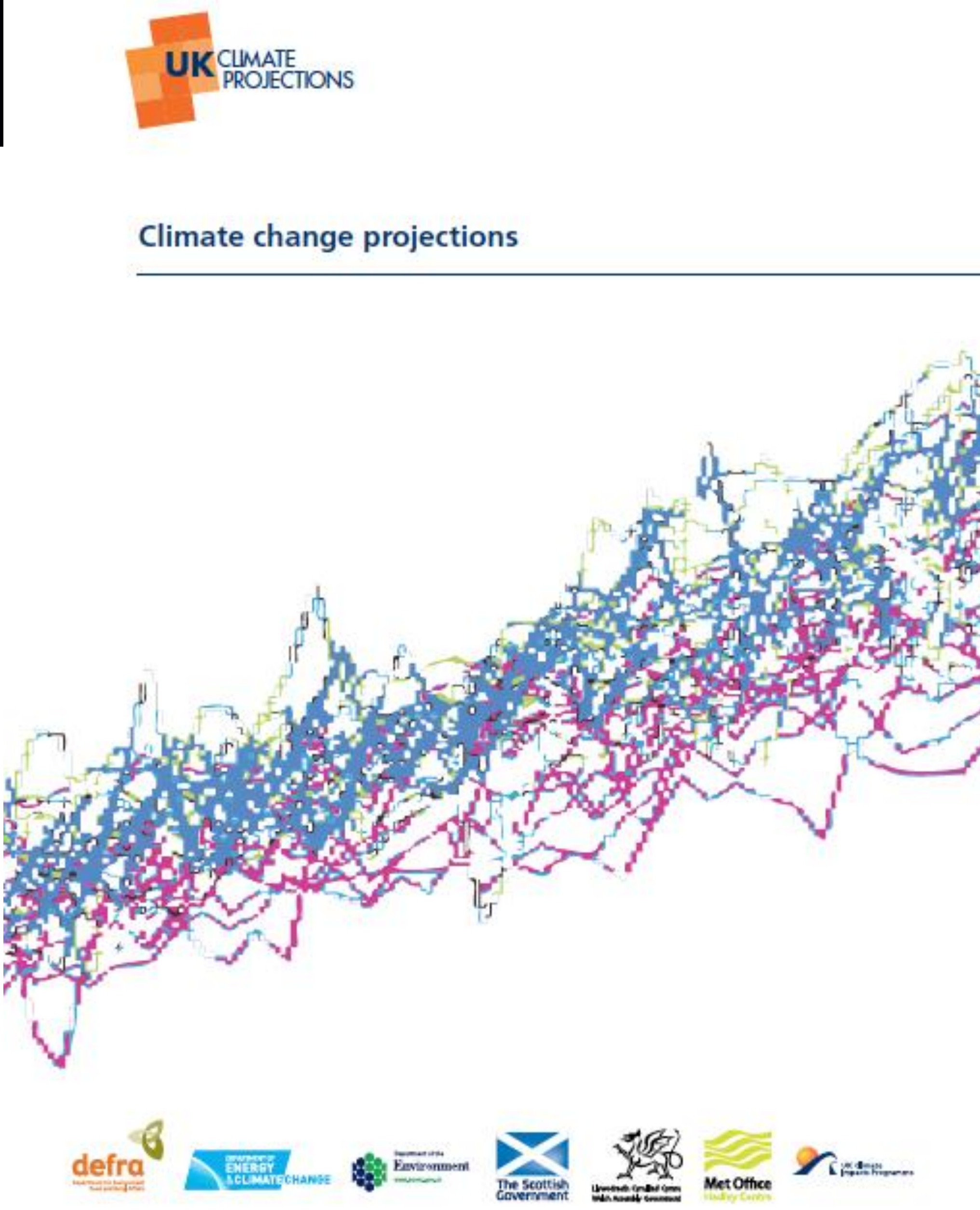
- Uncertainty is intrinsic to complex systems
- Uncertainty can be result of production of knowledge
- Acknowledge that not all uncertainties can be quantified
- Openly deal with deeper dimensions of uncertainty
  (problem framing indeterminacy, ignorance, assumptions, value loadings, institutional dimensions)
- *Tools:* Knowledge Quality Assessment
- Deliberative negotiated management of risk

Jeroen van der Sluijs

UKCP09 projections

- First projections designed to treat uncertainties explicitly (Murphy et al. 2009)
- More informative but also more complex than previous scenarios (Murphy et al. 2009)
- Designed to inform adaptation decisions
- Cost £11 million
- User Interface
- Reviewed by Steering and User group and 5 experts





UKCP09 map

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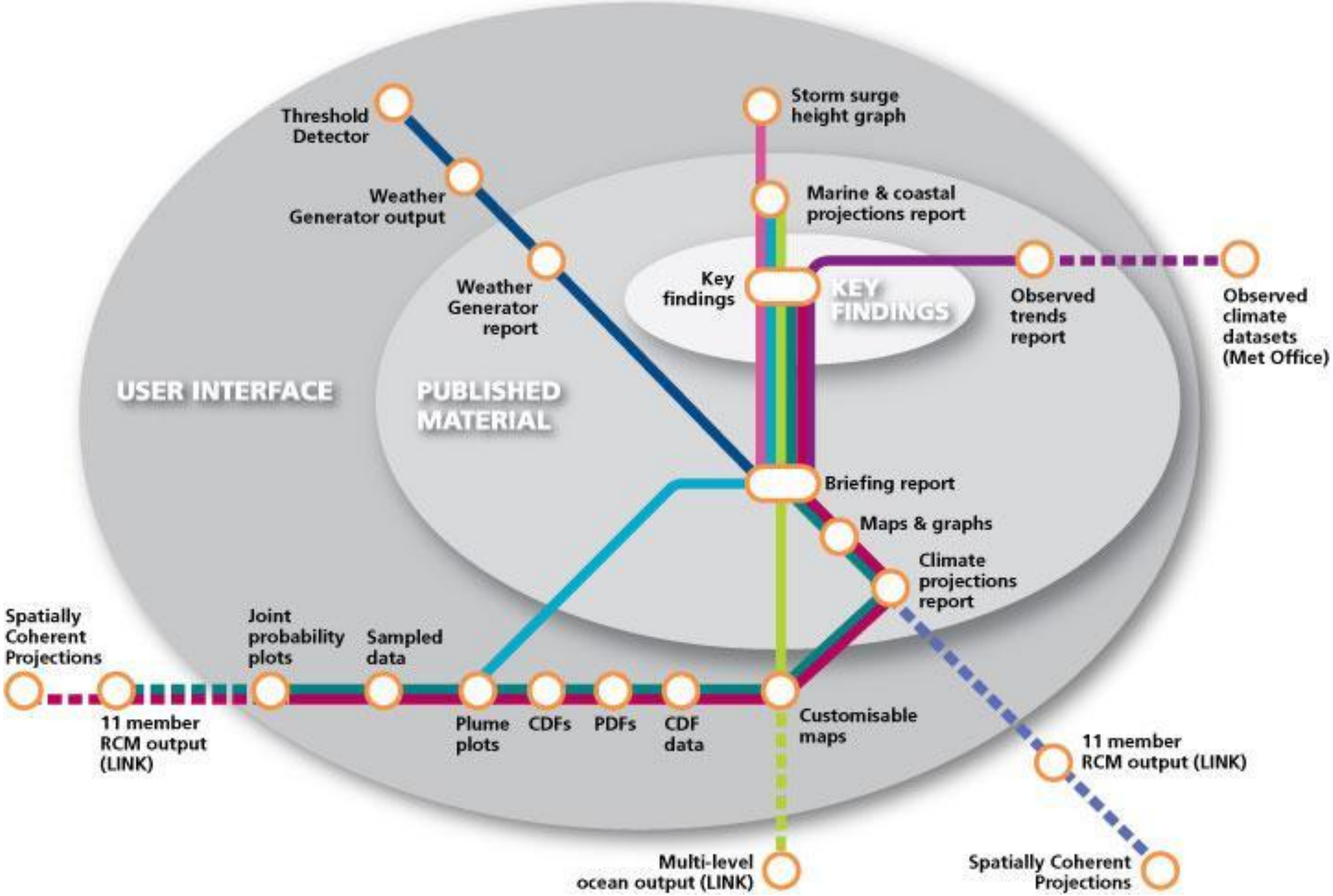

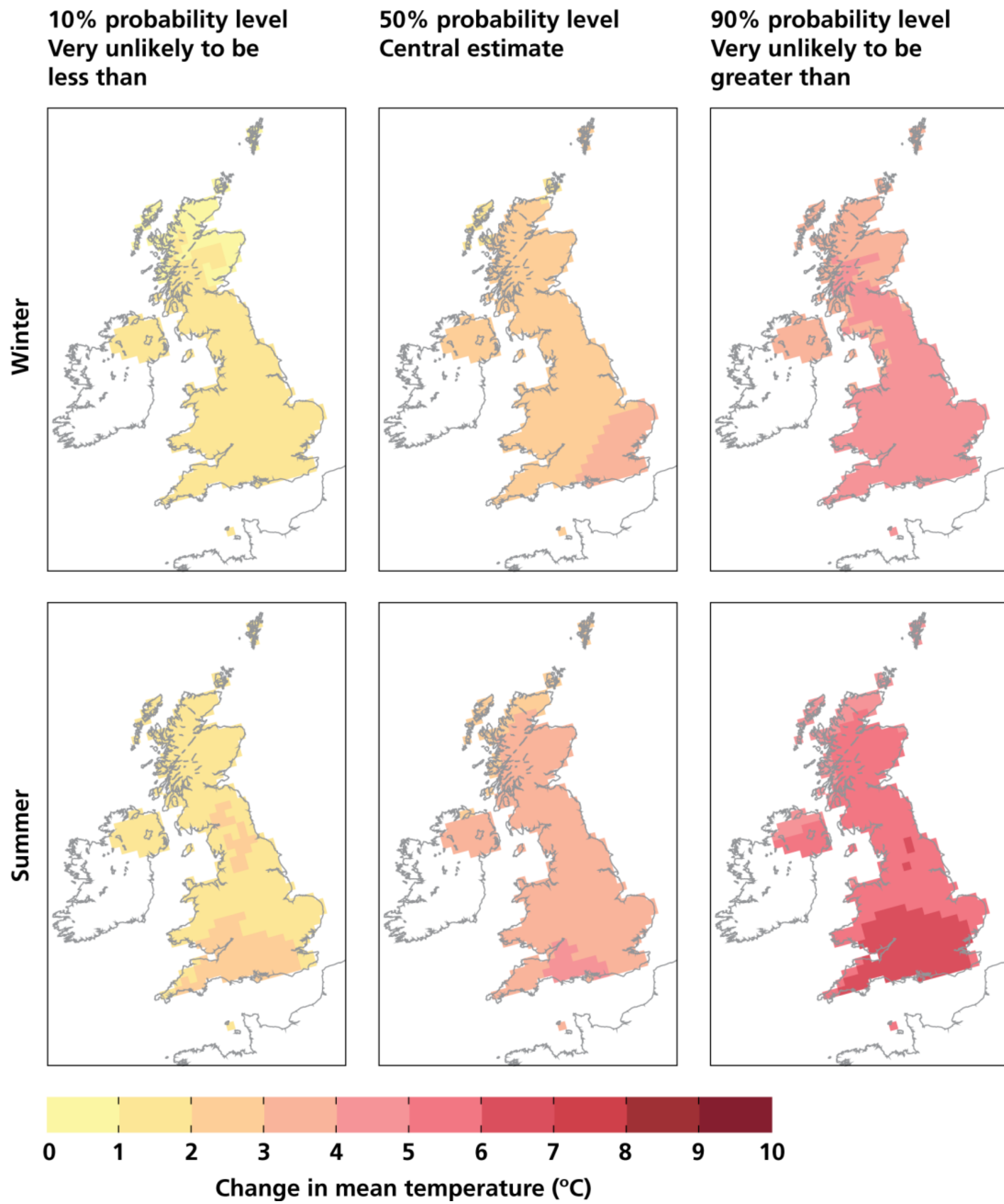

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Figure 4.4: 10, 50 and 90% probability levels of changes to the average daily mean temperature (ºC) of the winter (upper) and summer (lower) by the 2080s, under Medium emissions scenario.

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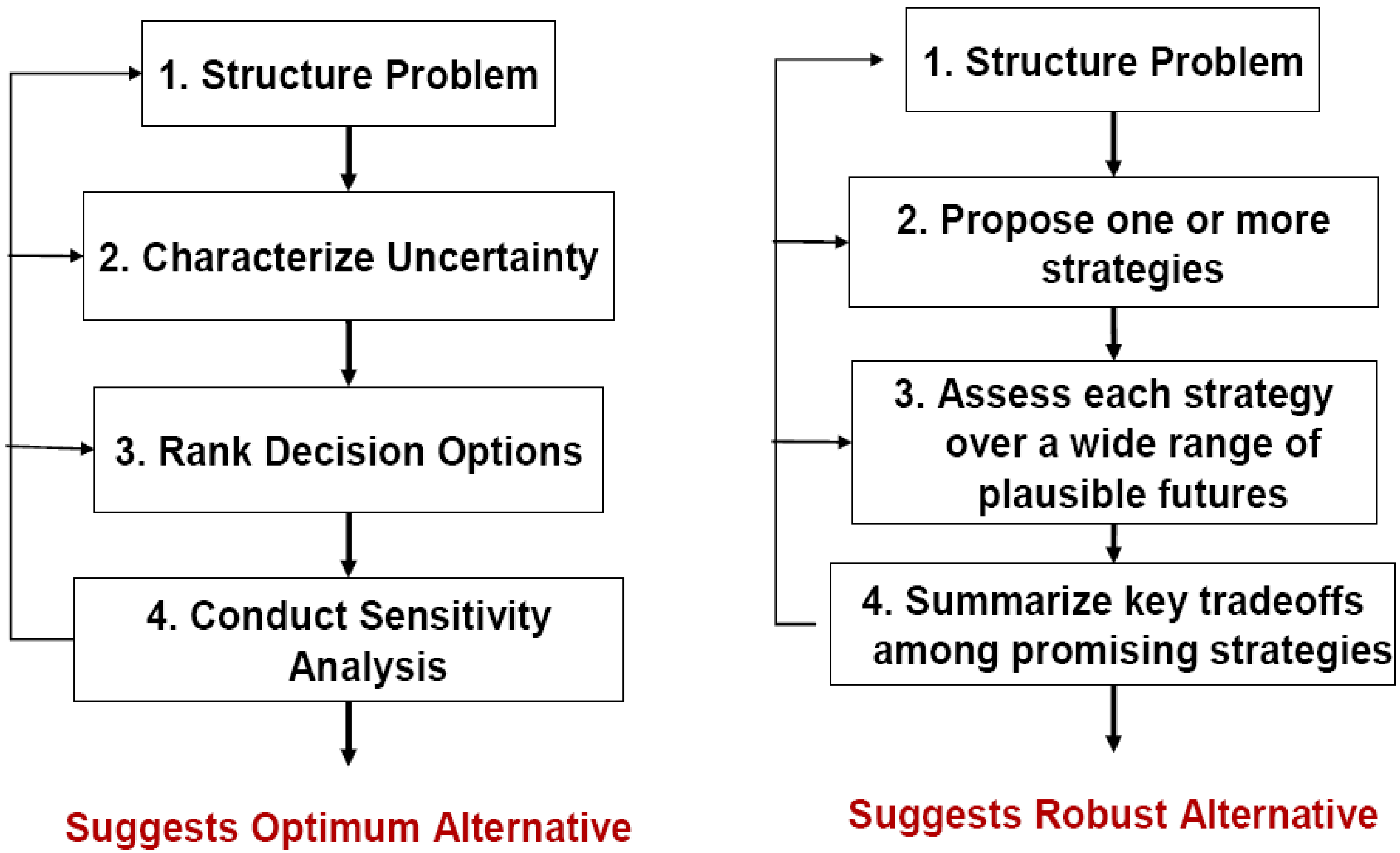
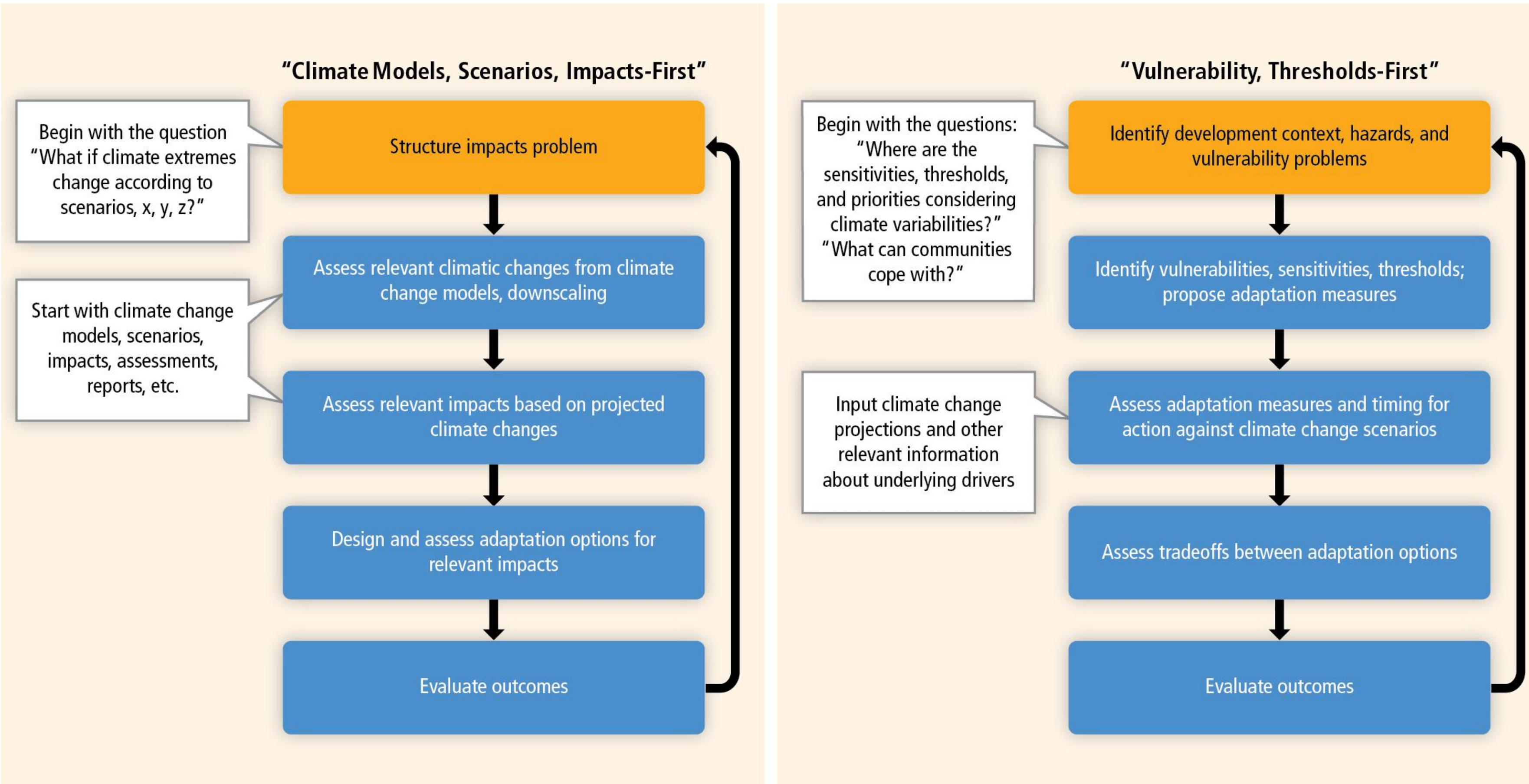
Jeroen van der Sluijs

Two problem framings

Predict-then-act approach | Assess-risk-of-policy framework

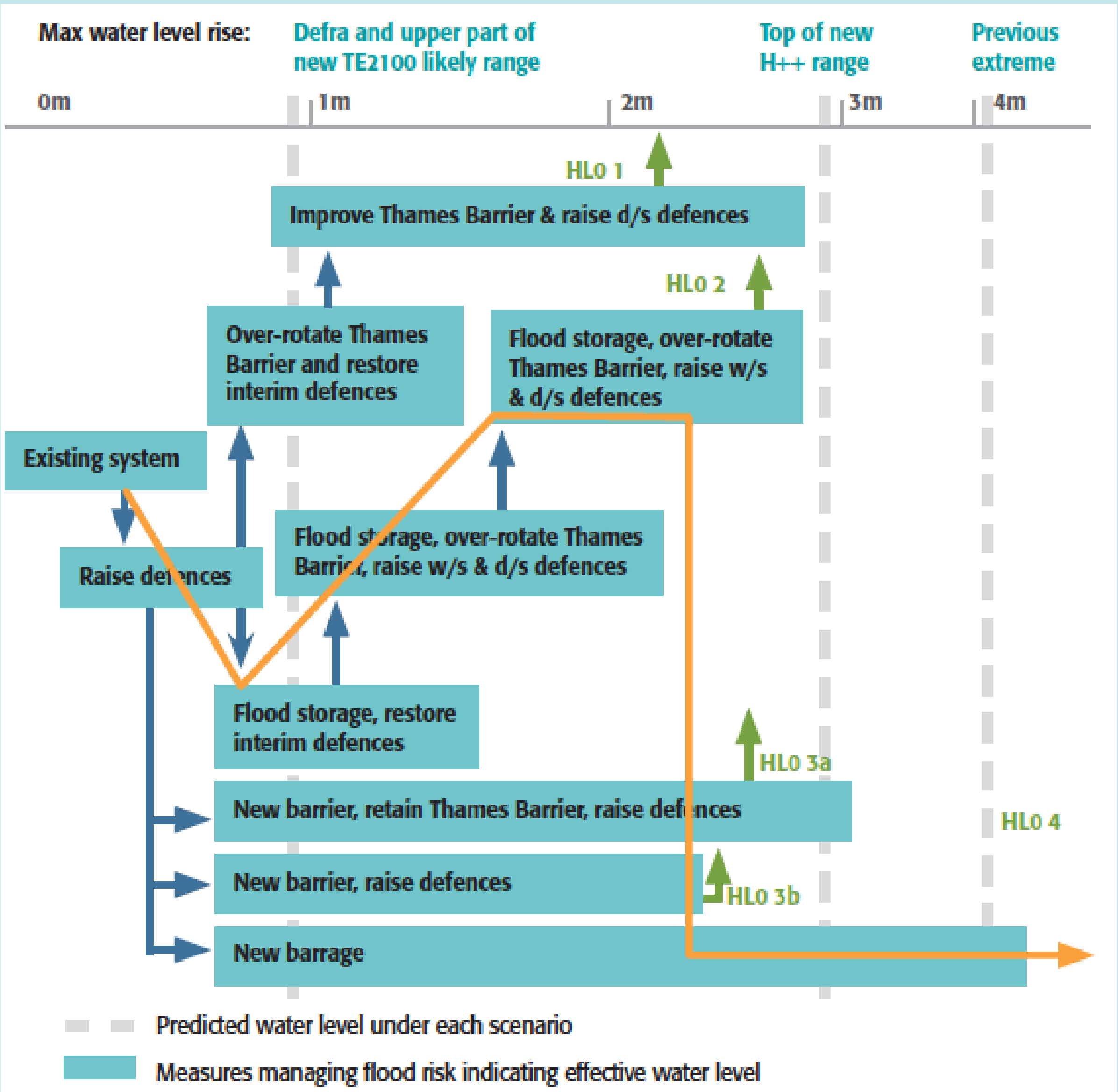


Lempert, R. J., D. G. Groves, et al. (2006) A general, analytic method for generating robust strategies and narrative scenarios. *Management Science* 52(4): 514-528.



Top-down scenario, impacts-first approach (left panel) and bottom-up vulnerability, thresholds-first approach (right panel) – comparison of stages involved in identifying and evaluating adaptation options under changing climate conditions (IPCC SREX, 2012).

Box 6.1 The Use of Decision Route Maps in Thames River Planning, UK



High-level adaptation options and pathways developed by TE2100 (on the y-axis) shown relative to threshold levels increase in extreme water level (on the x-axis). The orange line illustrates a possible 'route' where a decision maker would initially follow HLO 2 then switch to HLO 4 if sea level was found to increase faster than predicted.

This decision route map shows a range of potential actions to respond to various scenarios of sea level rise affecting the Thames River Barrier, designed to keep London from being flooded. The map should be read from left to right. Options to the left are designed to deal with relatively low sea level rise. If it becomes apparent that sea level rise is greater than that particular option can withstand, it is no longer viable. Boxes to the right are viable in responding to a greater rise in sea level, but also may require more aggressive action and be more costly. Those interventions that have a longer line can withstand more flood risk. The long diagonal arrow is an example of a chosen decision route.

— Adapted from Tim Reeder and Nicola Ranger, WRR Expert Paper

Info-gap decision theory for water resources planning

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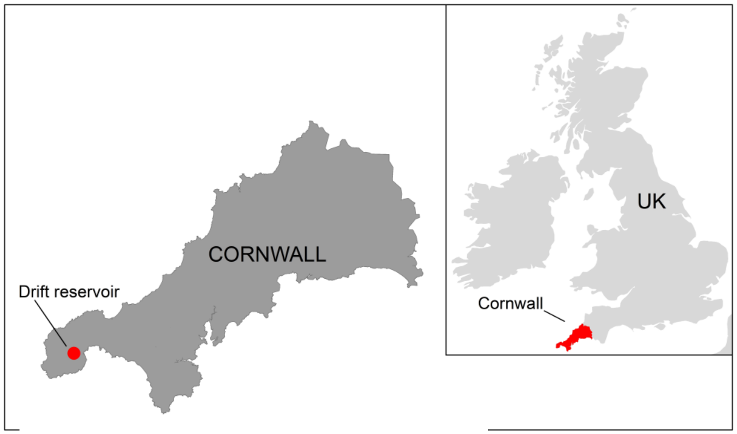

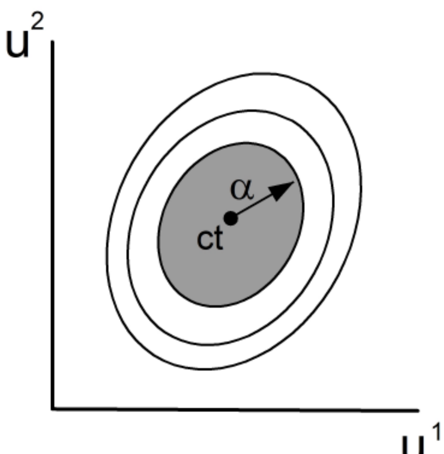

An Info-Gap exploration of uncertainty (Hine and Hall 2010)

Steps

A. Build and calibrate the simulation model of the system analysed

B. Characterise the uncertainty

C. Define the performance criteria

D. Quantify the uncertainty

E. Identify Robust Management Strategies Using MCDA

Parameters that are evaluated for uncertainty: 3 related to supply (impact of climate change), 5 related to demand (population changes) and 1 related to cost for electricity.

Brett Kortleing and Zoran Kapelan

1. System model (reward function)

$$storage_t = \min\{Res_{cap}, \max[0, Res_t + inflow_t - envflow_t - demand_t]\}$$

Measurement of source water - 5%

Climate change on catchment - 10%

Climate change on source yields - Mid to dry

Distribution input + 2.5%

Demand forecast + 10%

(population &economic growth)

Climate change impact on demand

+ 20% of 1.4%

Robustness of strategies

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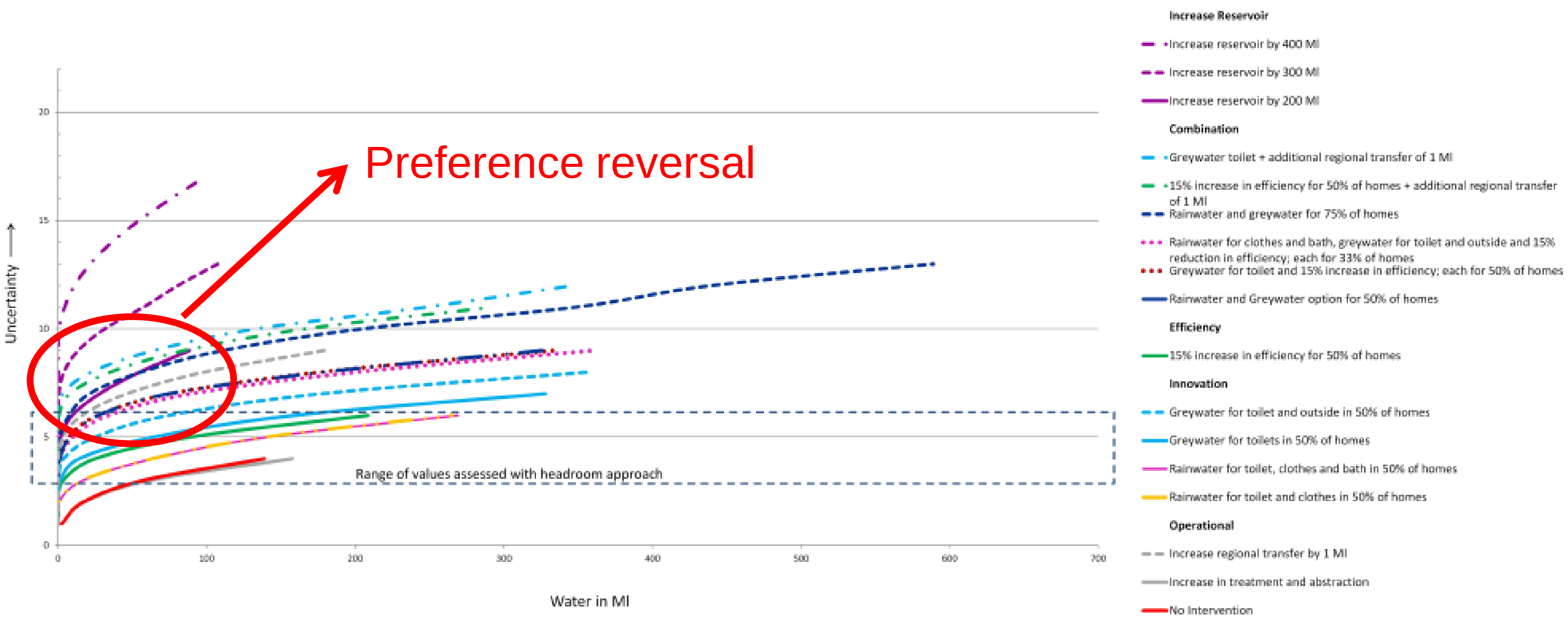


Robustness of different management strategies as assessed by a reservoir risk measure (RRM); the product of the probability of the reservoir falling below the drought management curve and the average volume (Ml) of water deficit below this curve.

Multi-Criteria Decision Analysis performance evaluation

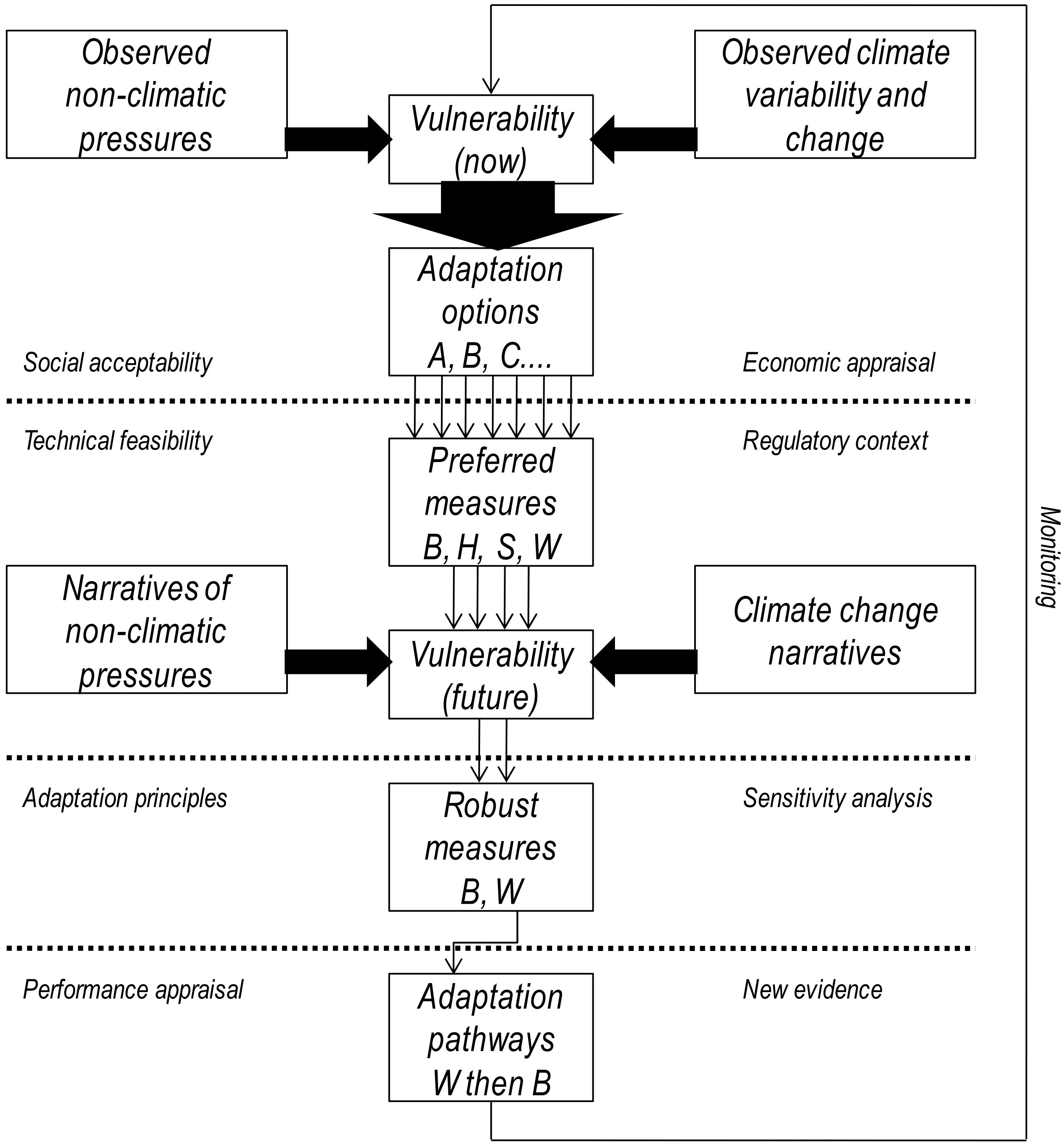
Equal Weighting		Emphasis on Water Availability		Emphasis on Environment		Table Legend
Low Uncertainty	High Uncertainty	Low Uncertainty	High Uncertainty	Low Uncertainty	High Uncertainty	*Refer to 4.2 for more details
G(t)/E at 50%	R/G at 75%	G(t)/E at 50%	R/G at 75%	R/G/E at 33% each	R/G at 75%	Res + XXXMl = Reservoir increase
R/G/E at 33% each	E at 50% & T + 1Ml	Res + 400Ml	E at 50% & T + 1Ml	R/G at 75%	E at 50% & T + 1Ml	G = greywater, (t) = toilet, (o) = outside
R/G at 75%	G(t) at 50% & T + 1Ml	Res + 300Ml	G(t) at 50% & T + 1Ml	G(t)/E at 50%	G(t) at 50% & T + 1Ml	R/G = Rainwater and greywater
R/G at 50%	Res + 400Ml	Res + 200Ml	Res + 400Ml	R/G at 50%	Res + 400Ml	E = Efficiency
G(t+o) at 50%	Res + 300Ml	R/G at 75%	Res + 300Ml	G(t+o) at 50%	Res + 300Ml	R/G/E = Rainwater, Greywater, Efficiency
E at 50% & T + 1Ml		G(t) at 50% & T + 1Ml		E at 50% & T + 1Ml		G(t)/E = Greywater for toilet, Efficiency
G(t) at 50% & T + 1Ml		E at 50% & T + 1Ml		G(t) at 50% & T + 1Ml		& T-1Ml = extra regional transfer of 1Ml when reservoir below the operating curve
G(t) at 50%		R/G/E at 33% each		E at 50%		
E at 50%		R/G at 50%		G(t) at 50%		"at x%" denotes the adoption rate of the management option.
Res + 400Ml		G(t+o) at 50%		Res + 400Ml		

Emphasis on Local self-sufficiency		Emphasis on Cost		Emphasis on Carbon		Emphasis on Social Acceptability	
Low Uncertainty	High Uncertainty	Low Uncertainty	High Uncertainty	Low Uncertainty	High Uncertainty	Low Uncertainty	High Uncertainty
R/G/E at 33% each	R/G at 75%	R/G at 75%	R/G at 75%	R/G/E at 33% each	G(t) at 50% & T + 1Ml	R/G/E at 33% each	G(t) at 50% & T + 1Ml
R/G at 75%	E at 50% & T + 1Ml	R/G/E at 33% each	E at 50% & T + 1Ml	G(t)/E at 50%	Res + 400Ml	G(t)/E at 50%	R/G at 75%
G(t)/E at 50%	G(t) at 50% & T + 1Ml	G(t)/E at 50%	G(t) at 50% & T + 1Ml	E at 50% & T + 1Ml	R/G at 75%	R/G at 50%	Res + 400Ml
R/G at 50%	Res + 400Ml	R/G at 50%	Res + 400Ml	E at 50%	E at 50% & T + 1Ml	E at 50% & T + 1Ml	E at 50% & T + 1Ml
G(t+o) at 50%	Res + 300Ml	G(t+o) at 50%	Res + 300Ml	Res + 400Ml	Res + 300Ml	E at 50%	Res + 300Ml
G(t) at 50%		G(t) at 50%		Res + 300Ml		R/G at 75%	
Res + 400Ml		E at 50%		Res + 200Ml		G(t+o) at 50%	
E at 50%		G(t) at 50% & T + 1Ml		R/G at 50%		G(t) at 50% & T + 1Ml	
Res + 300Ml		E at 50% & T + 1Ml		G(t) at 50% & T + 1Ml		G(t) at 50%	
Res + 200Ml		Res + 400Ml		G(t) at 50%		Res + 400Ml	

A Framework for Robust Adaptation

Wilby, R. L. and S. Dessai (2010). "Robust adaptation to climate change." *Weather* 65(7): 180-185.

Dessai, S. and R. Wilby. “How Can Developing Country Decision Makers Incorporate Uncertainty about Climate Risks into Existing Planning and Policymaking Processes?” World Resources Report, Washington DC.



Concluding remarks

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Climate models have been crucial to make the case for mitigation

Uncertainty dominates regional/local climate and impact projections

Adaptation efforts should not be limited by the lack of reliable foresight about future climate conditions

Where uncertainty dominates robust decision-making methods are likely to be more useful to decision-makers than traditional “predict and provide” methods

Extras

Where next?

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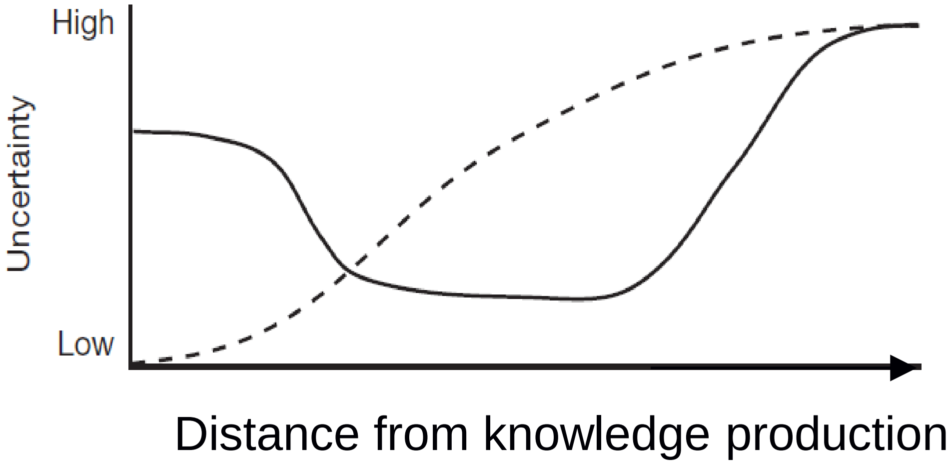
- What kinds of information work best throughout the adaptation journey?
  - From useful to usable/actionable to valuable
- What is social status of techno-scientific knowledge in adaptation to climate change?

European Research Council
Supporting top researchers from anywhere in the world

Project ICAD: Advancing Knowledge Systems to Inform Climate Adaptation Decisions



MacKenzie's (1990) & Lahsen (2005)

http://www.see.leeds.ac.uk/research/sri/project-icad/

ICAD Project: What makes UKCPO9 Credible/Legitimate?

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Knowledge producers & knowledge translators say…

- *"UKCIP02 had the same level of uncertainty, but this was more hidden from users. **UKCP09 makes the uncertainty transparent so the projections are more robust**" (Knowledge producer K)*

- *"[Using Bayesian probabilistic projections] I think it's useful and it's something that **without it we'd have to construct multi-model ensembles to present the uncertainties** in that way. There is value in doing it" (Knowledge translator B).*

ICAD project

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*"I think it [Bayesian probabilistic projections] enhances credibility. Importantly, **it makes people realise the inherent uncertainties and should lead to better planning**" (Knowledge producer H)*

"The data was relatively easy to use, the issue is the amount of data that is available to use. **What to do and how to use it? Is the issue**. There's a proliferation of data, so a kind of overload." (Knowledge translator C)

*" The UKCP09 data and tools are **so wide ranging it is difficult to know which is the best method / tool / dataset to use**" (Severn Trent Water Ltd. 2011, p. 28)"*

Jones and Preston 2011

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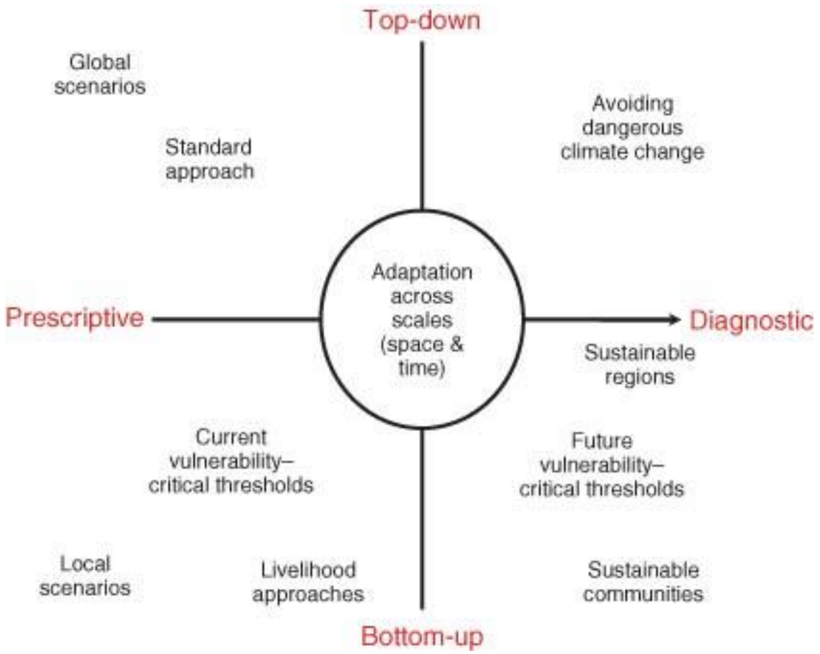

Selected reference points for assessments mapped on top-down/bottom-up and prescriptive/diagnostic axes. Top-down bottom-up relates to scale approaches that can be geographic or institutional and prescriptive/diagnostic describe whether an assessment looks forward or backwards in time from a given reference.