Combined hydrologic and climate uncertainty

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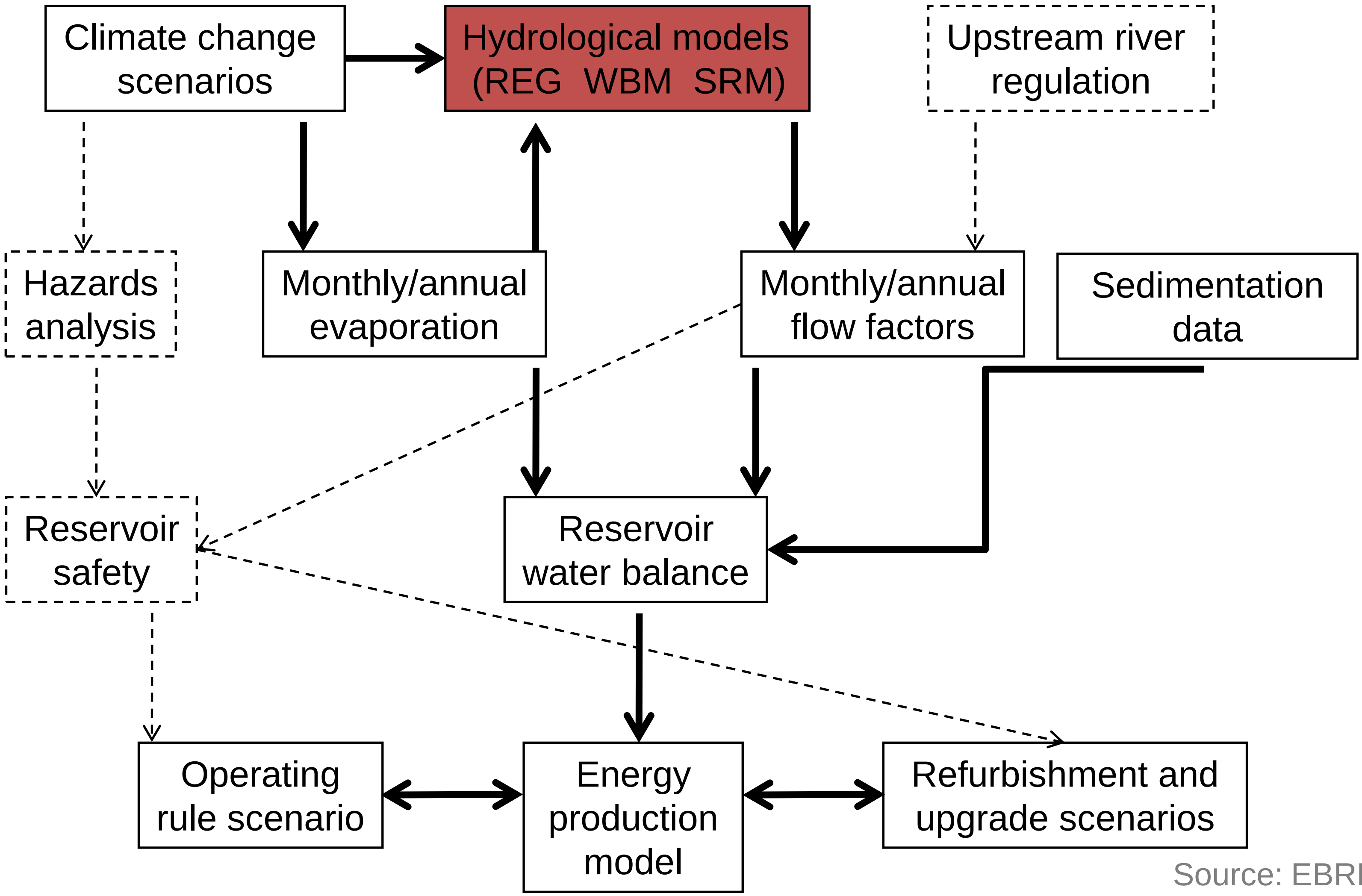
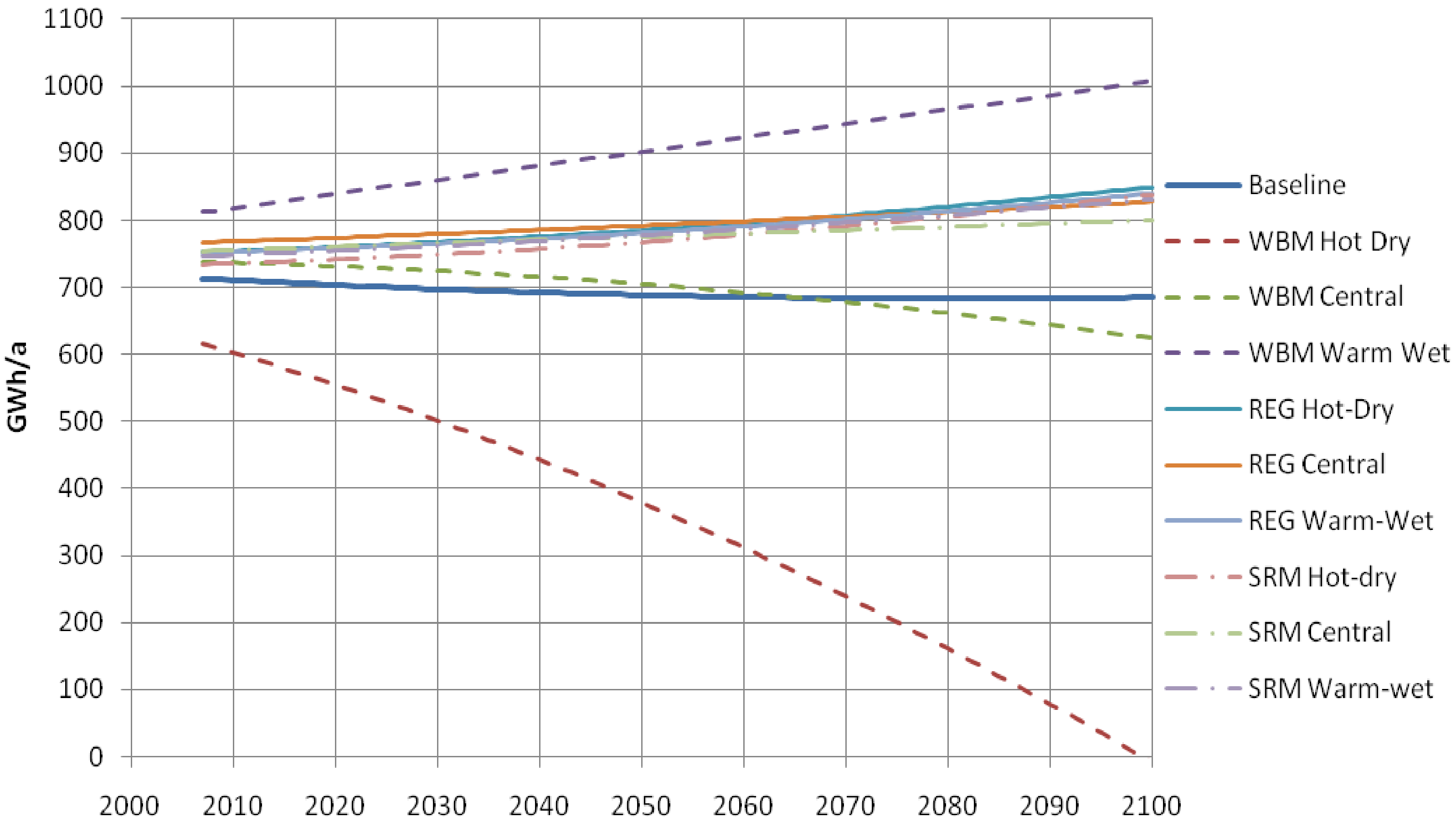
Photo: Michael Friedhoff

Recap: Hydrological uncertainties in perspective (hydropower)



Source: EBRD (2012)

Typical outcome: “the uncertain outlook”



Model simulations of future annual energy production at Kairakkum, Tajikistan. Source: EBRD (2011)

An optimistic view

TOWARD A NEW GENERATION OF WORLD CLIMATE RESEARCH AND COMPUTING FACILITIES

BY J. SHUKLA, T. N. PALMER, R. HAGEDORN, B. HOSKINS, J. KINTER, J. MAROTZKE, M. MILLER, AND J. SLINGO

To accelerate progress in understanding and predicting regional climate change, national climate research facilities must be enhanced and dedicated multi-national facilities should be established.

Weather and climate are undisputedly major factors for the well-being and development of society, impacting all scales from individual lives to global economies (Sachs 2008). Societies have flourished by adapting to and taking advantage of current climate conditions. However, this relationship between climate and society is fragile and volatile: during the past 25 years, weather-related disasters have caused more than 600,000 fatalities and $1.3 trillion (U.S. dollars) of economic losses. This paper is part of an ensemble of papers proposing an international multidisciplinary prediction initiative (Shapiro et. al. 2010).

Considering the increasing frequency of extreme weather and climate events (Alley et al. 2007) together with our enhanced vulnerability (WMO 2006) to weather and climate hazards caused by rapid economic and population growth, mortality and economic losses will continue to rise. As the Stern report has emphasized (Stern 2007), climate change is a trillion-dollar problem: inaction will be many times costlier than cutting greenhouse gas emissions, which itself could cost the world economy as much as 1% of its gross domestic product (GDP).

The Intergovernmental Panel on Climate Change (IPCC) has alerted society to the risk the world faces from climate change, and governments are formulating climate-change-related policies. However, formulating cost-effective and responsible mitigation and adaptation strategies raises questions about specifics of climate change. How far can greenhouse gas concentrations rise before dangerous climate changes are inevitable? How big an investment does society need to adapt to already inevitable climate changes? How will climate change regionally, not just in terms of temperature but of other key variables such as precipitation and storminess? For example, what is needed to ensure that people in regions at risk of increased drought will

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The abstract for this article can be found in this issue, following the table of contents.

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"Soon the societal demand for policy-relevant climate predictions will be so great that the most advanced technology and the best available talent must be brought to bear to address this great challenge."

Shukla et al. (2010: 1412)

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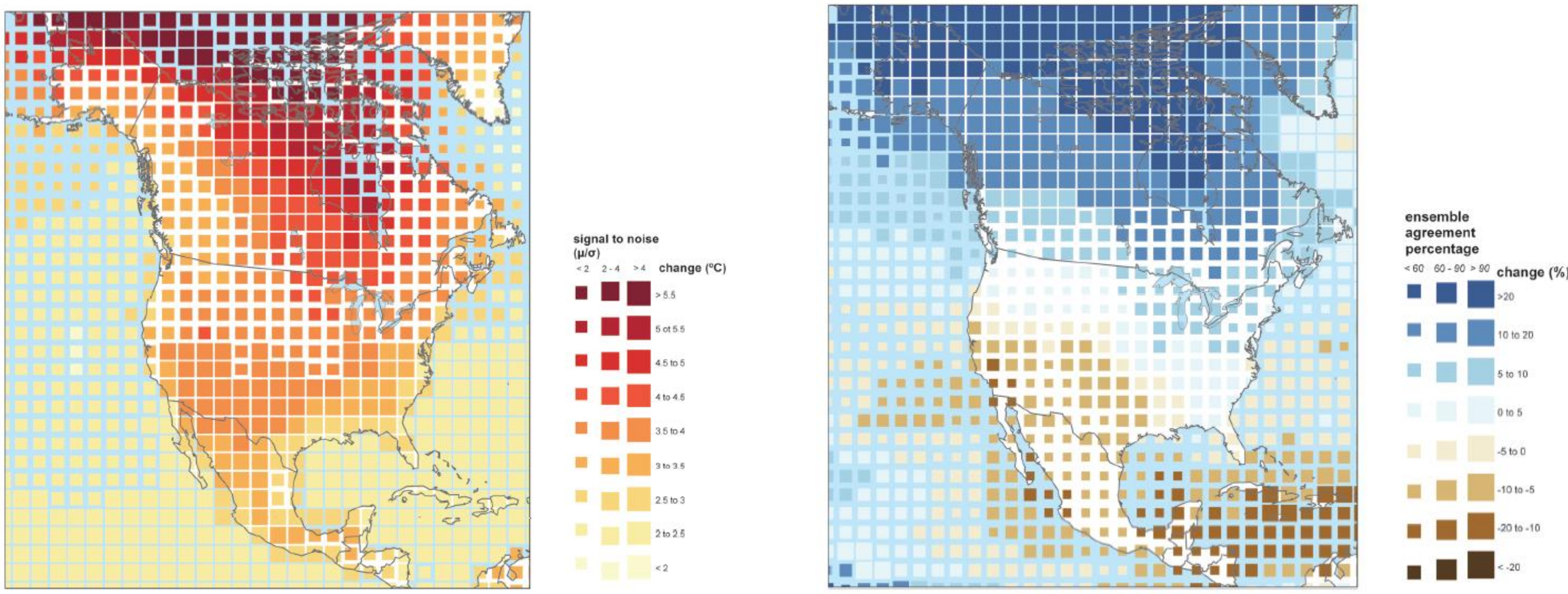
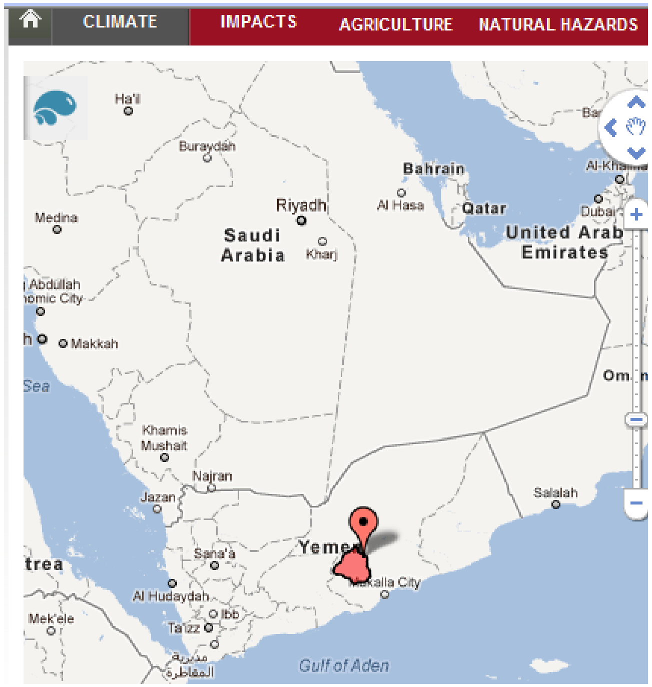
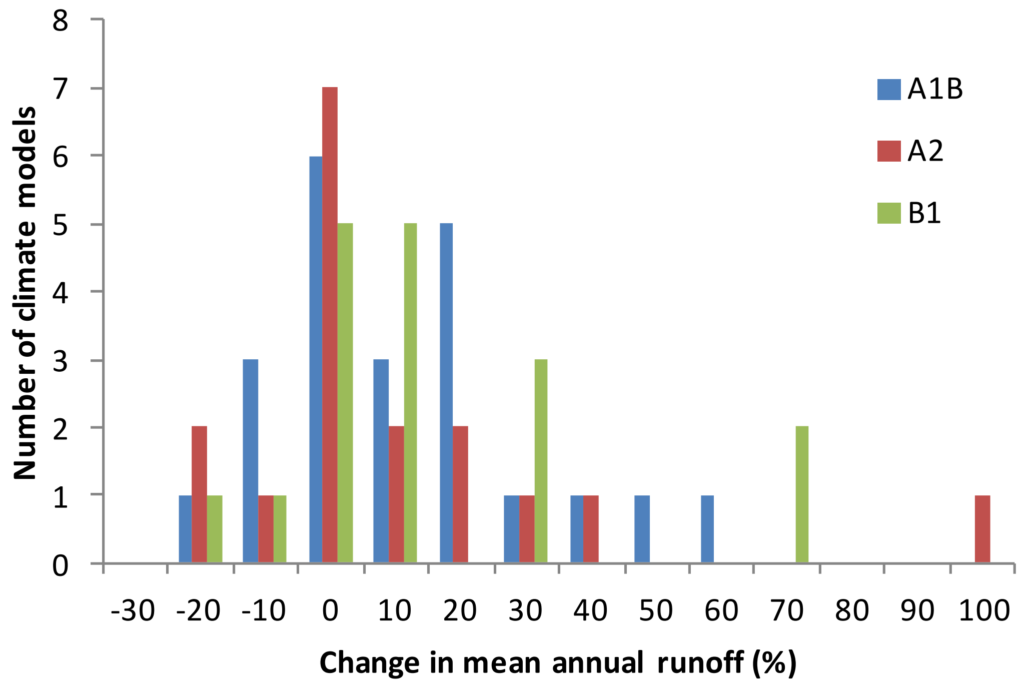
Exhibit 1: Country climate summaries



Change in average annual temperature [left] and precipitation [right] by 2100 from the 1960-1990 baseline climate, averaged over 21 CMIP3 models. The size of each pixel represents the level of agreement between models on the magnitude of the change. Source: UK Met Office Hadley Centre.

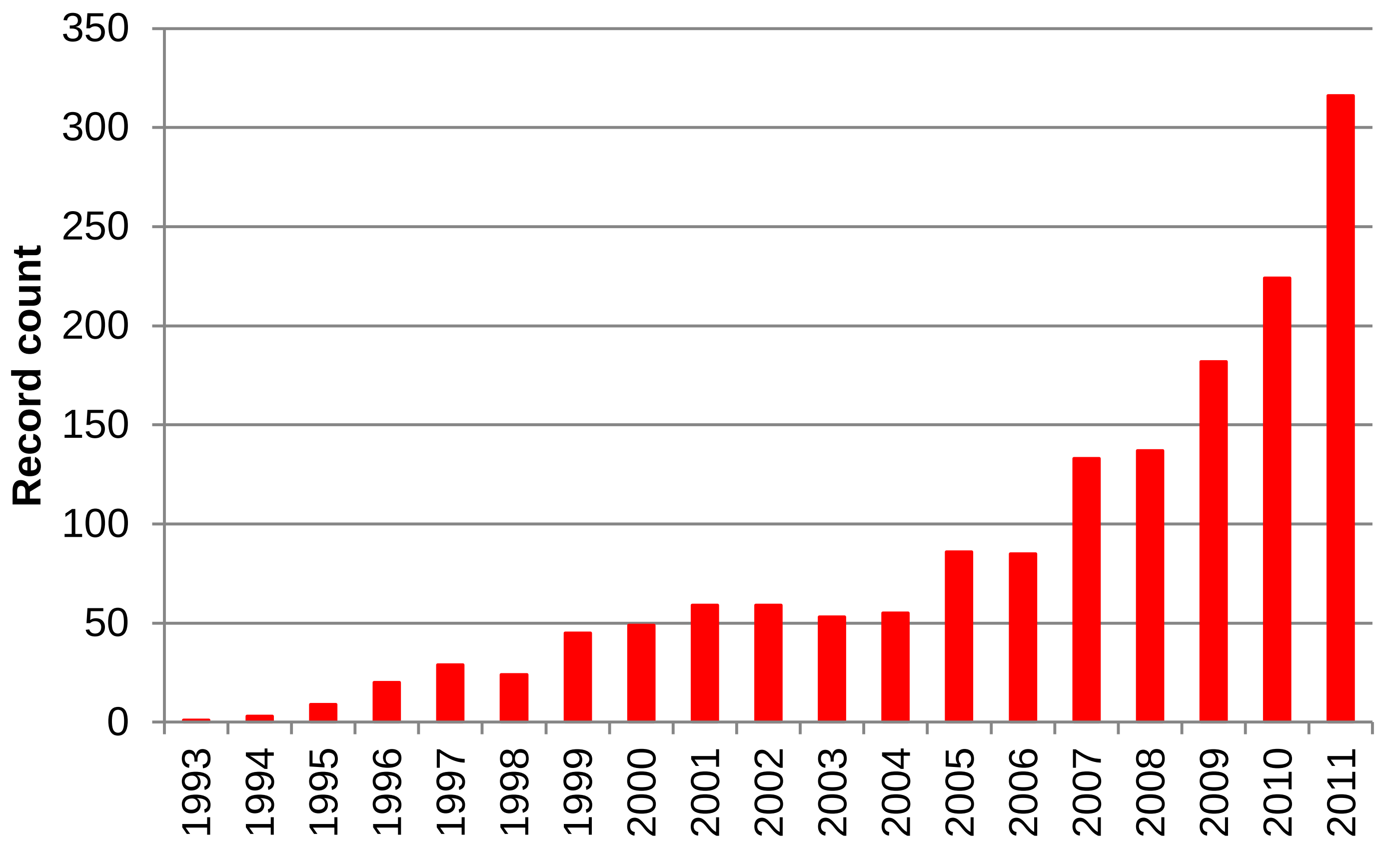
Exhibit 2: Climate Change Knowledge Portal





Example output from the WBG Climate Change Knowledge Portal for river basin 5438 in Yemen. The histogram shows the distribution of projected changes in mean annual runoff under three emissions scenarios (A1B, A2 and B1) for 2050-2059. Source: Wilby (2012)

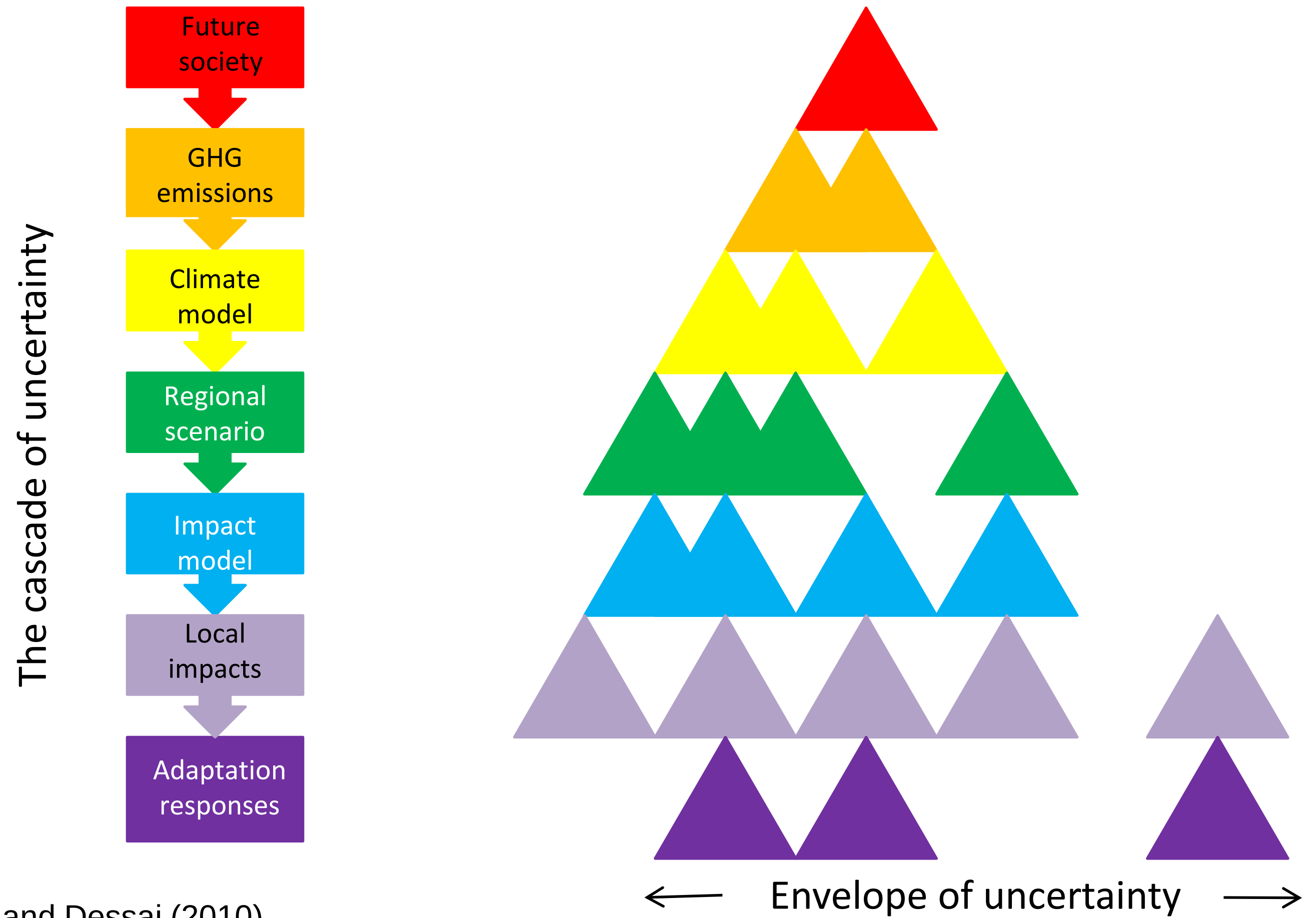
A triumph for decision-making?



Annual count of “climate downscaling” publications between 1993 and 2011 identified by the Web of Science [9 June 2012]. Note that the count combines all types of downscaling study – statistical and dynamical. Source: Wilby and Dawson (2012)

"If you do not expect the unexpected, you will not find it"

Heraclitus *ca* 550-475BC



Adapted from: Wilby and Dessai (2010)

Partial analysis of climate impact uncertainty

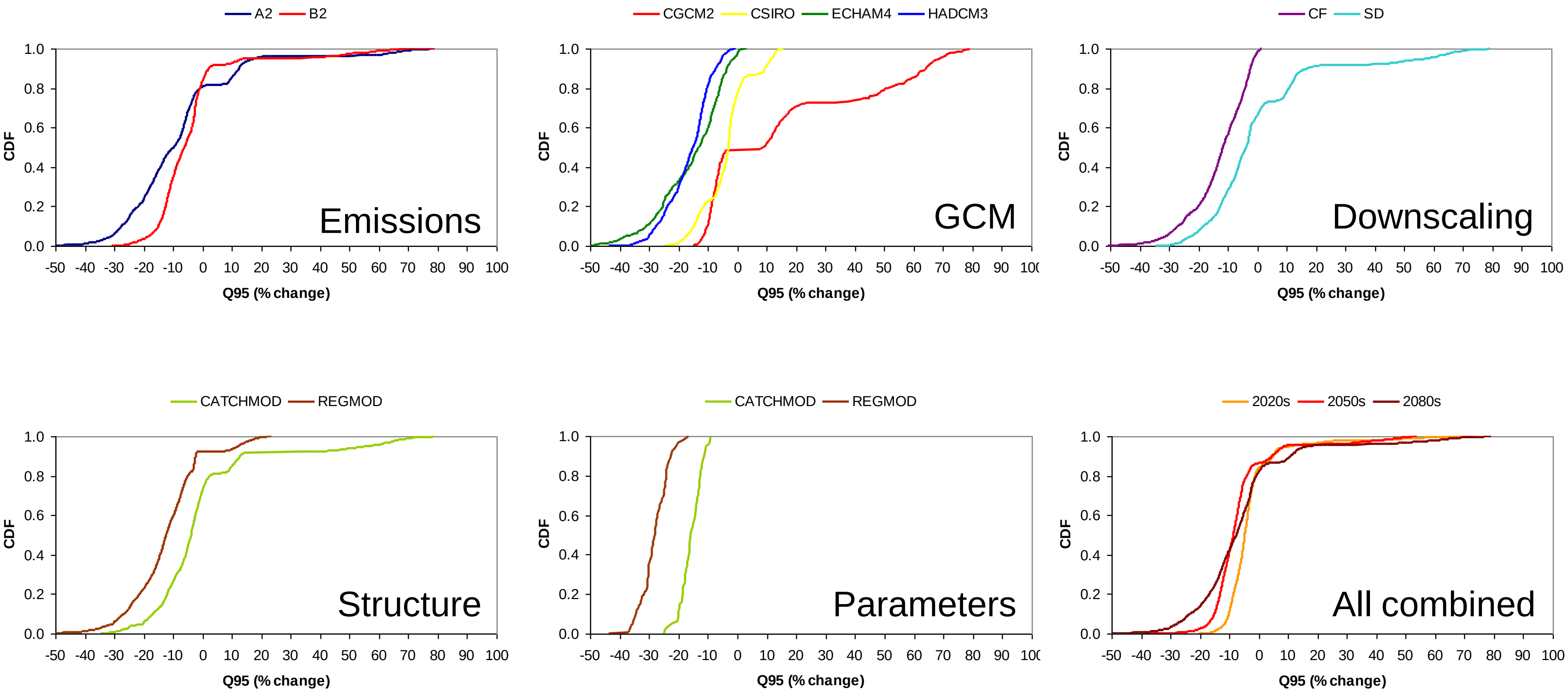
Quantifying uncertainty in projected river flows

River Thames, UK

- *4xGCMs, 2xEmissions, 2xDownscaling methods, 2xLow flows models, 100xParameter sets*
- *Weight GCMs by modified Climate Prediction Index*
- *Weight low flow model structures by r_{adj} statistic*
- *Weight low flow model parameters by N-S score*
- *Emissions and downscaling method un-weighted*
- *Monte Carlo simulation (2000+ runs)*
- *Evaluate using (Q95) low-flow index for River Thames*

Source: Wilby and Harris (2006)

Combining components of uncertainty



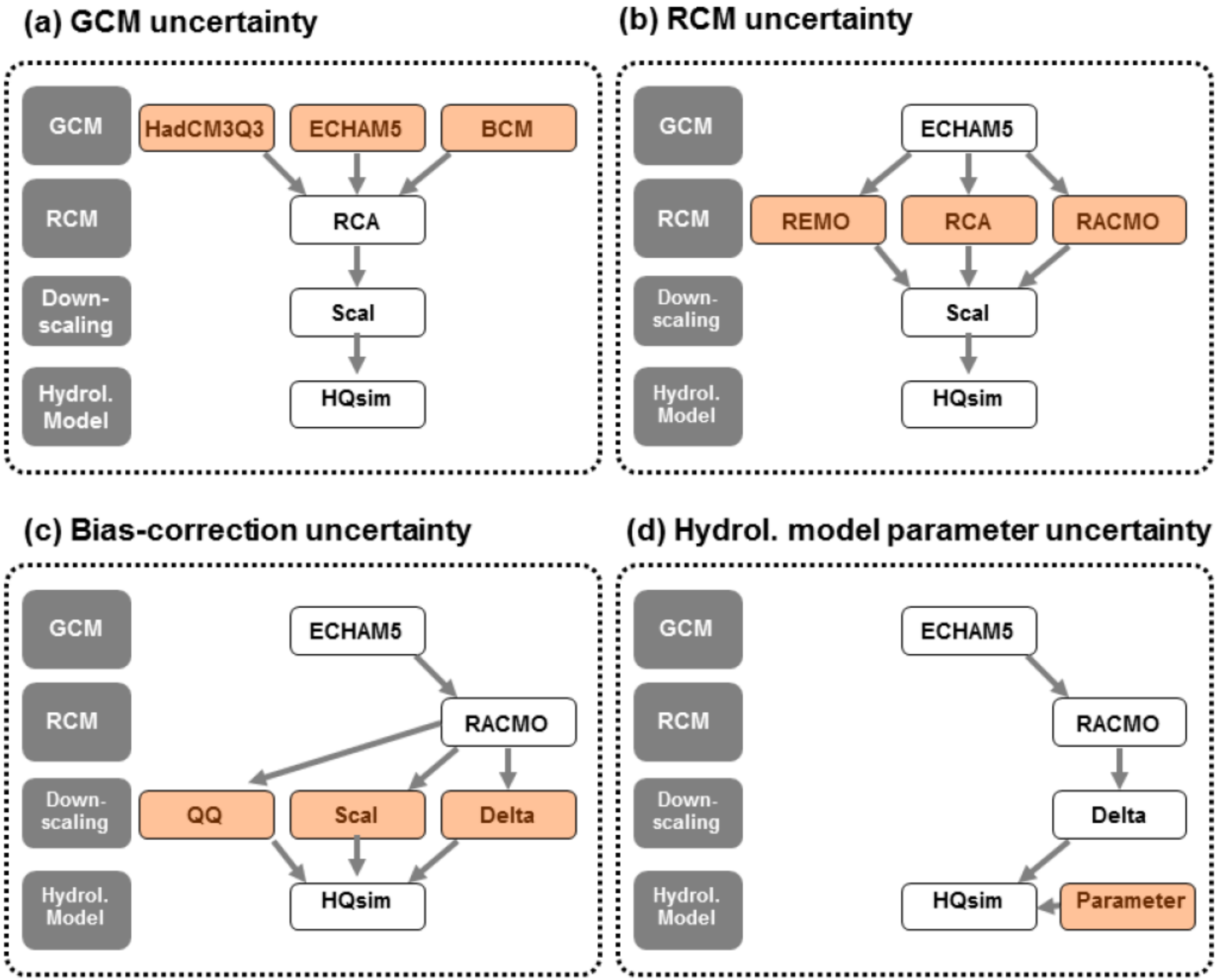
Conditional probabilities of lower summer flows in the River Thames by the 2020s, 2050s and 2080s. Source: Wilby and Harris (2006)

Conditional probabilities of lower summer flows

Uncertainty component	Likelihood	
	Min	Max
Emissions	82	83
GCM	47	100
Downscaling	66	100
Hydrological model	72	92
All weighted/ unweighted	76	82

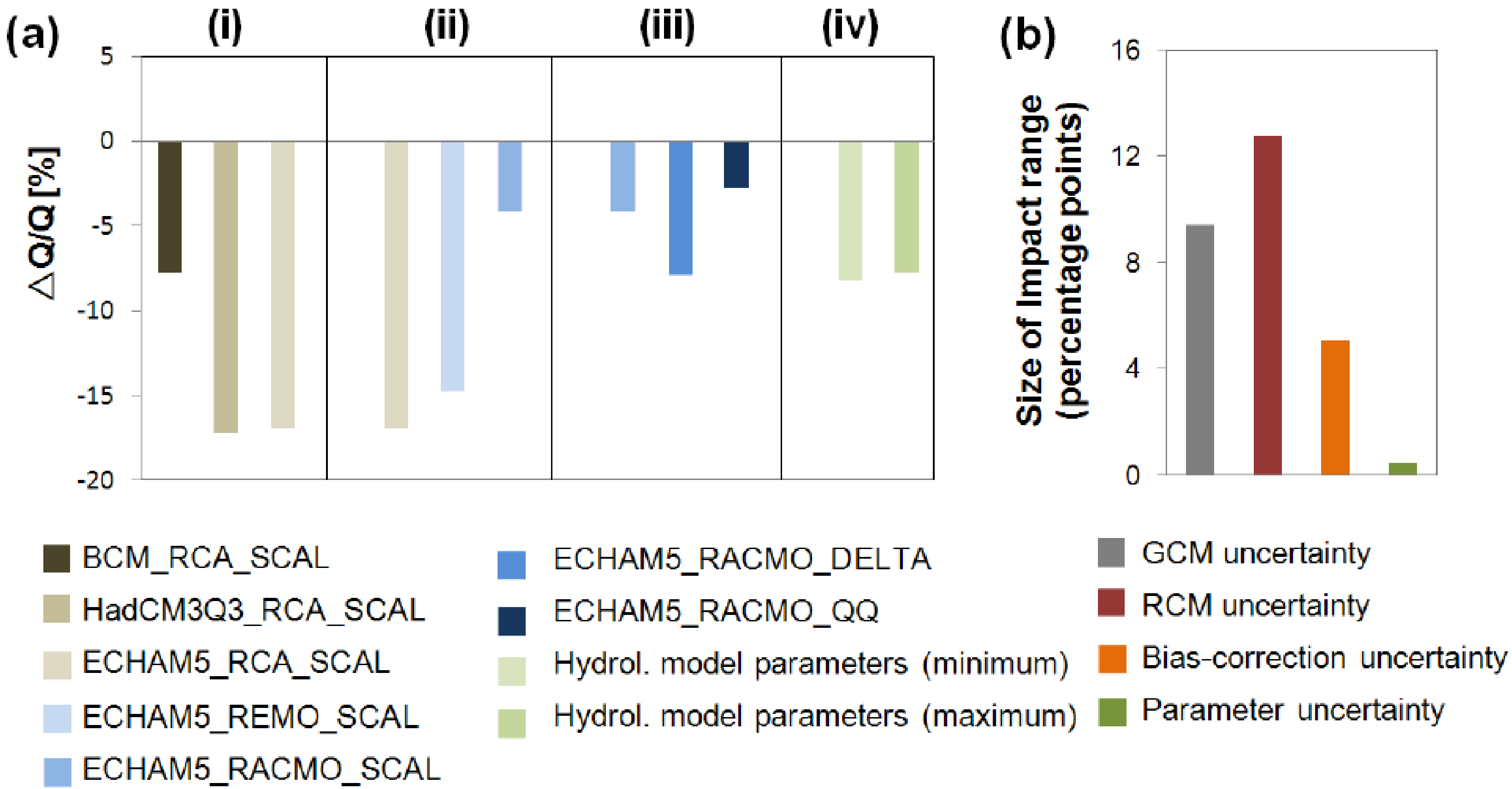
Source: Wilby and Harris (2006)

Quantifying uncertainty in the Lech, Austria



Source: Dobler et al. (submitted)

Quantifying components of uncertainty



(a) Uncertainty in the projection of mean annual runoff (Q) resulting from (i) GCM, (ii) RCM, (iii) bias-correction and (iv) hydrological model parameters. **(b)** Size of impact range originating from each uncertainty source. Source: Dobler et al. (submitted)

Living with uncertainty (UK water sector)

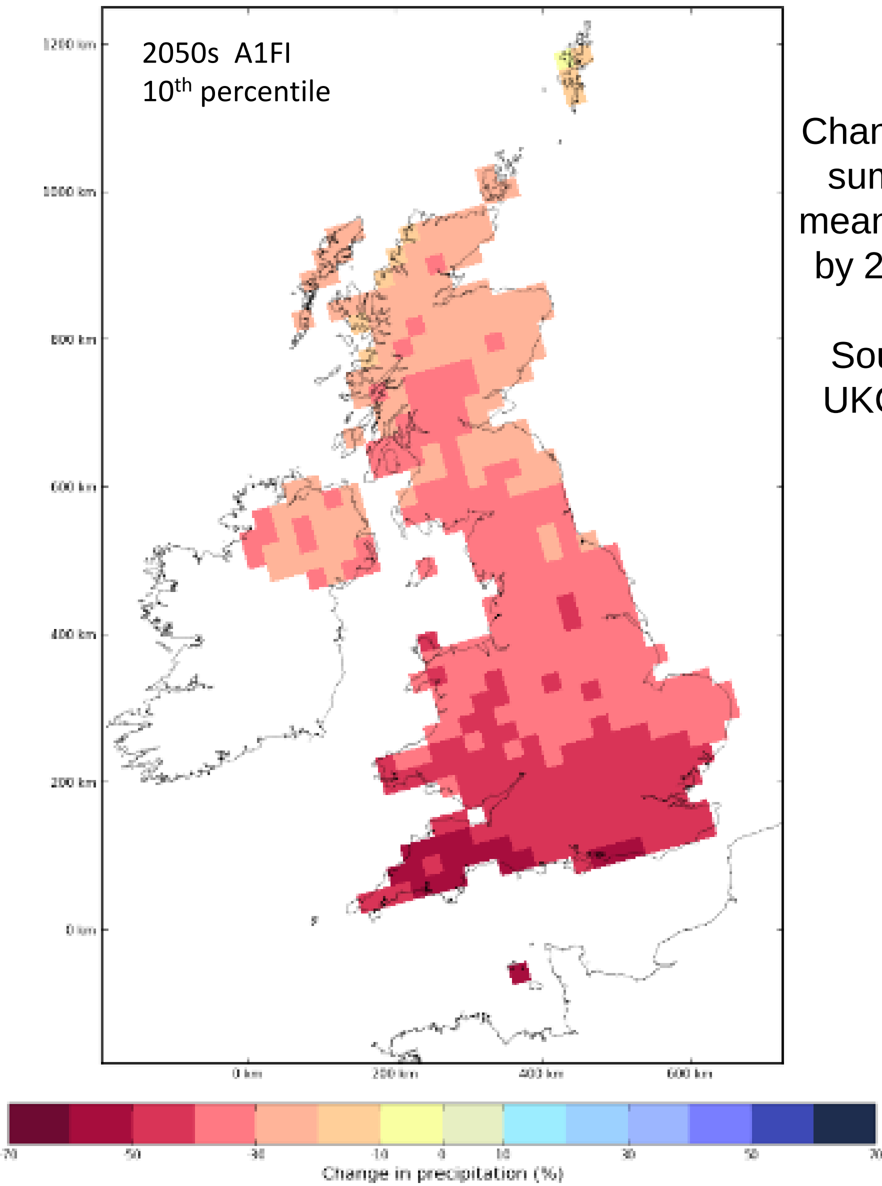
Walham, Gloucester July 2007
Source: Pitt Review

Kerang, Victoria January 2011
Source: http://www.uhavta1.ausequine.com/kerang_floods_2011.htm

Setting the scene

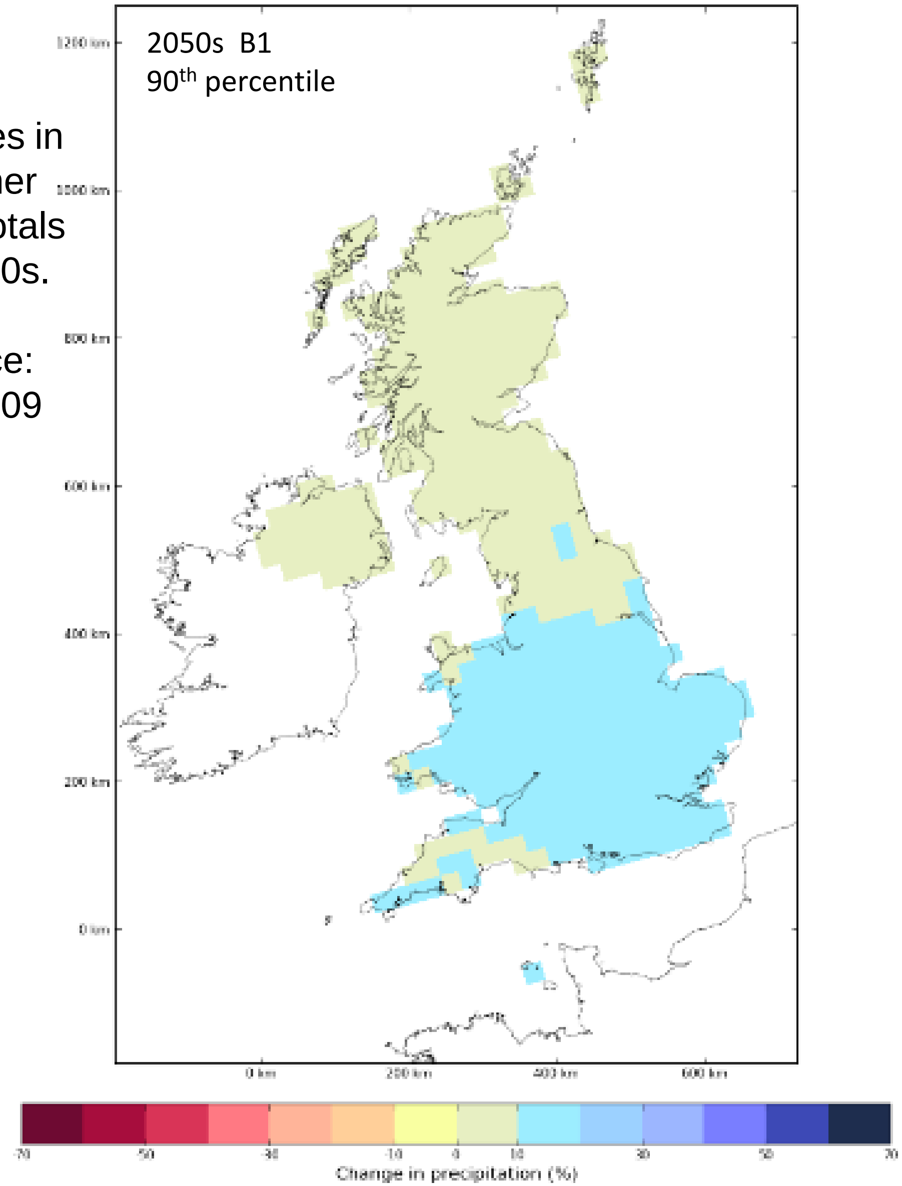
2008 Climate Change Act 2008		
2009	2010	2011
UKCP09 projections CCRA begins	RCEP *Adapting Institutions* Flood and Water Management Act Coalition Government PSAs scrapped First Reporting Power reports National Indicators scrapped	Foresight *Future Farming* RCEP *Demographic Change* National Flood Risk Management Strategy *UK National Ecosystem Assessment* Foresight *International Dimensions* UKCIP role moved to EA
2012 Climate Change Risk Assessment (CCRA) 2012		
2013 National Adaptation Programme 2013		

Strategy 0: Scenario-led

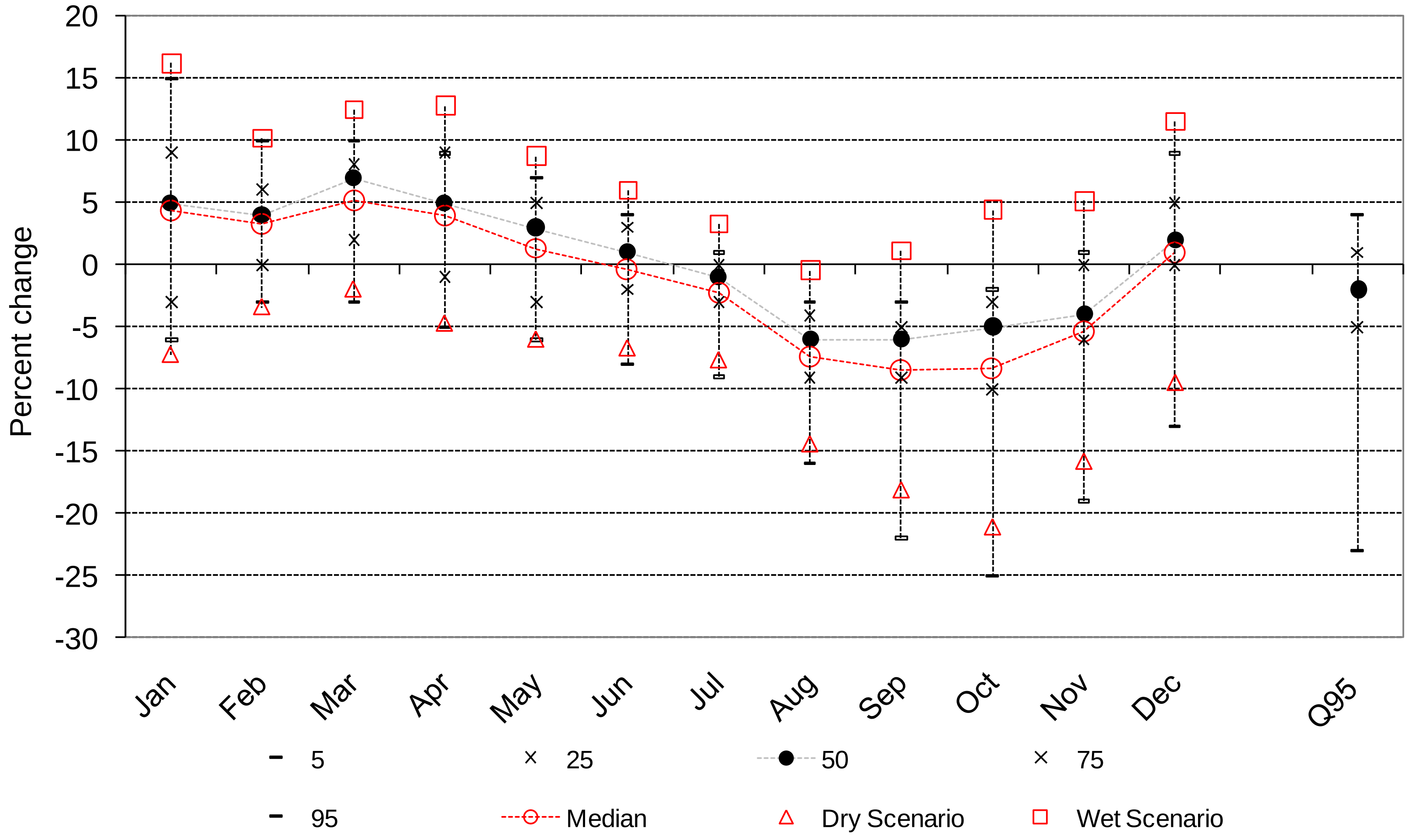


Changes in summer mean totals by 2050s.

Source: UKCP09



Traditional (supply-side) planning



Climate change flow factors (2020s) for the River Itchen at Highbridge. Data source: UKWIR (2007)

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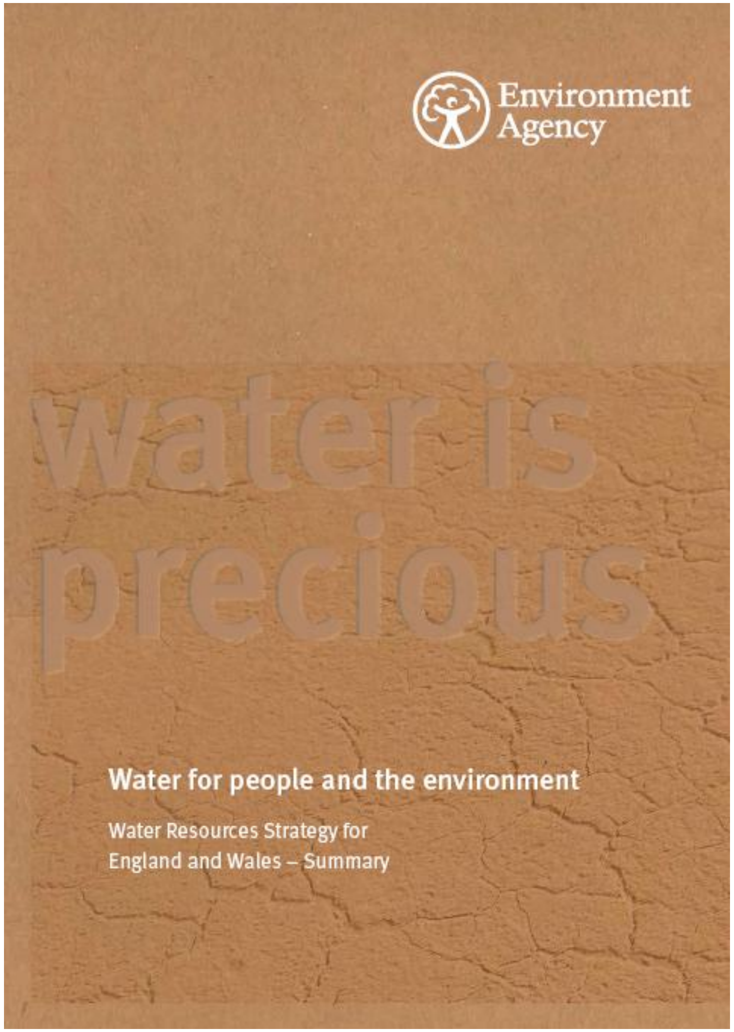
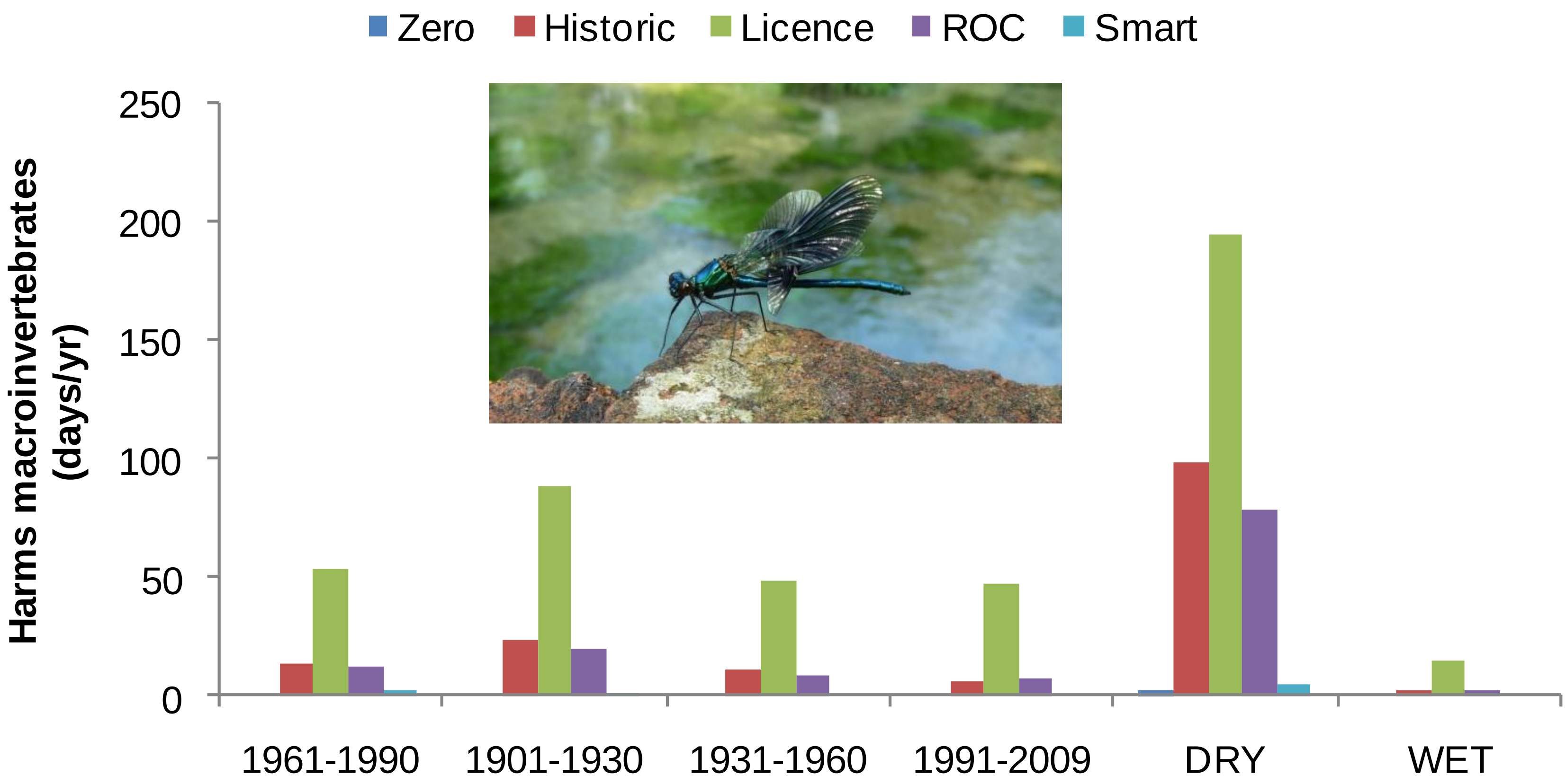
Strategy 1: Low regret measures



Source: EA (2009)

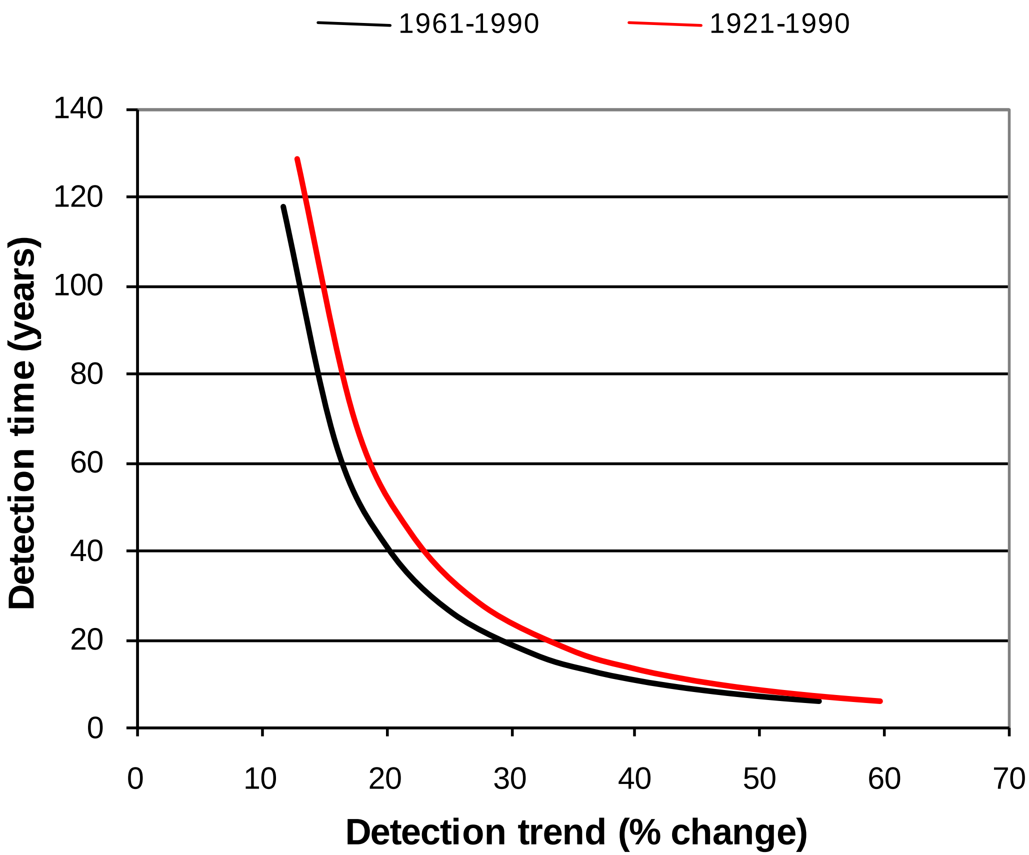
- Compulsorily convert all permanent abstraction licenses to **time-limited** status, to provide flexibility to respond to climate change.
- Increase the **connectivity** of water supply infrastructure to improve resilience of existing resources and provide additional security from extreme events.
- All abstractors to consider accepting a **reduction in the reliability of supply** as an option for resolving future deficits.
- Increase levels of **metering** with suitable tariffs to improve water and economic efficiency whilst protecting vulnerable groups.
- Support **water neutrality** where new development is planned and require developers to produce water cycle studies for proposed housing developments.
- Identify **water efficiency** standards for non-household buildings at a regulatory level and a voluntary code beyond that.
- Further **leakage control** based on alternative methods of setting targets that better reflect the costs to society and the environment.
- Introduce further **incentives** for the purchase and fitting of water efficient equipment and appliances.

Strategy 2a: Modify operations



Mean annual frequency of ecologically harmful flows (<224 Ml/d) in the River Itchen under various abstraction license conditions, climate variability and change. Source: Wilby et al. (2011).

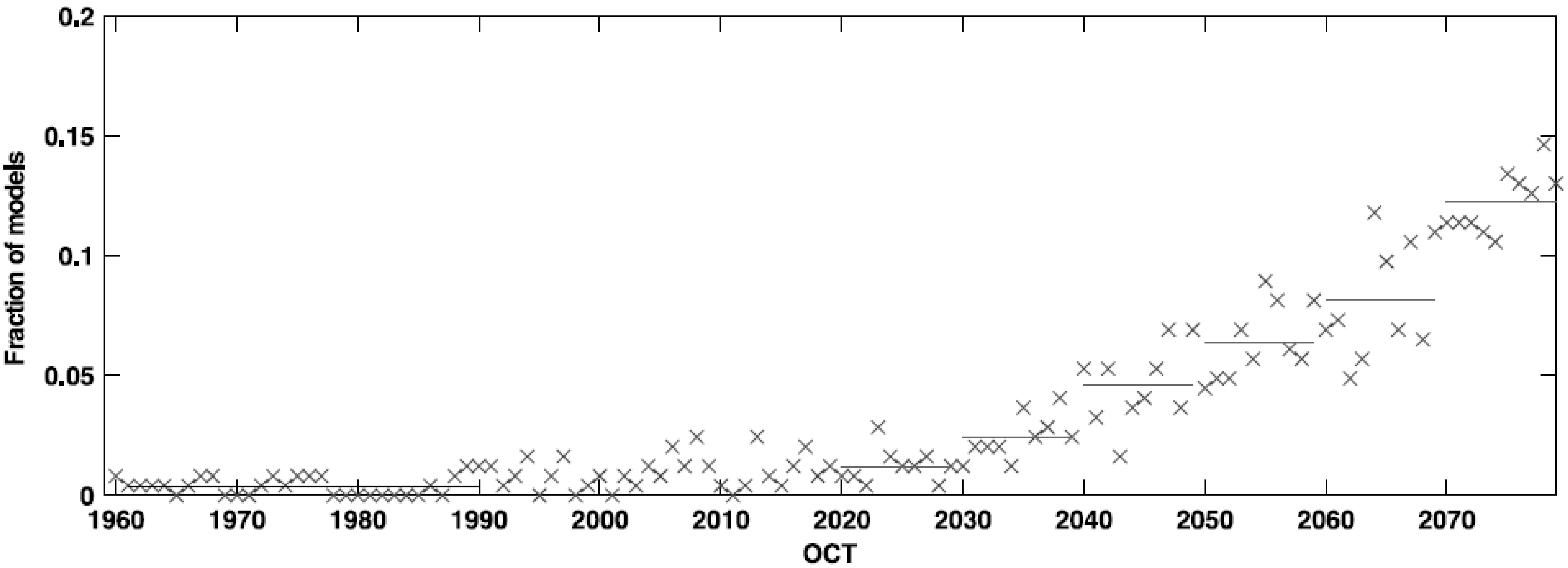
Strategy 2b: Wait and see (delay investment)



Detection times (years from 1990) for summer low flows in the River Itchen using two different periods to estimate variance (**1961-90** and **1921-90**).

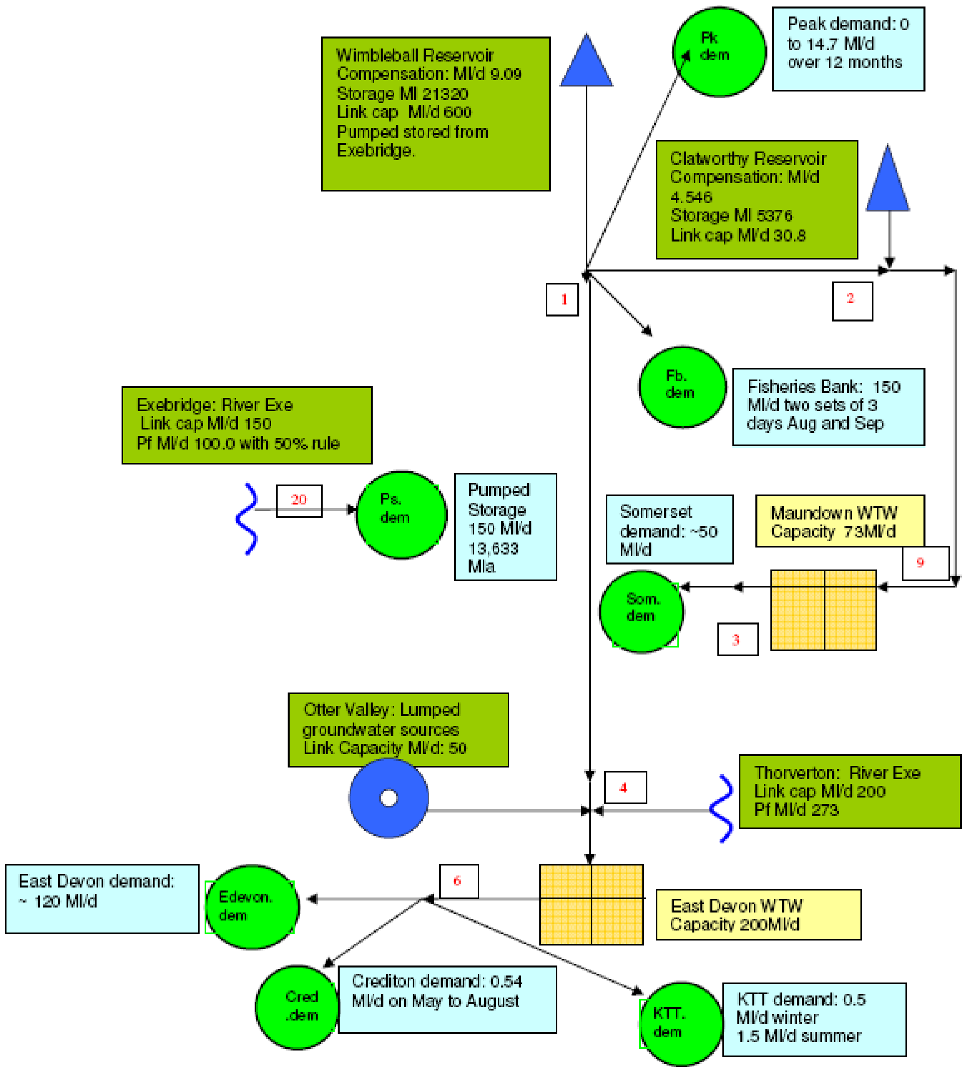
Source: Wilby (2006)

Strategy 2c: Accept lower levels of service



The business as usual scenario for East Devon: the fraction of *CP.net* projections that fail to meet average water demand in October under SRES A1B. Source: Lopez et al (2009)

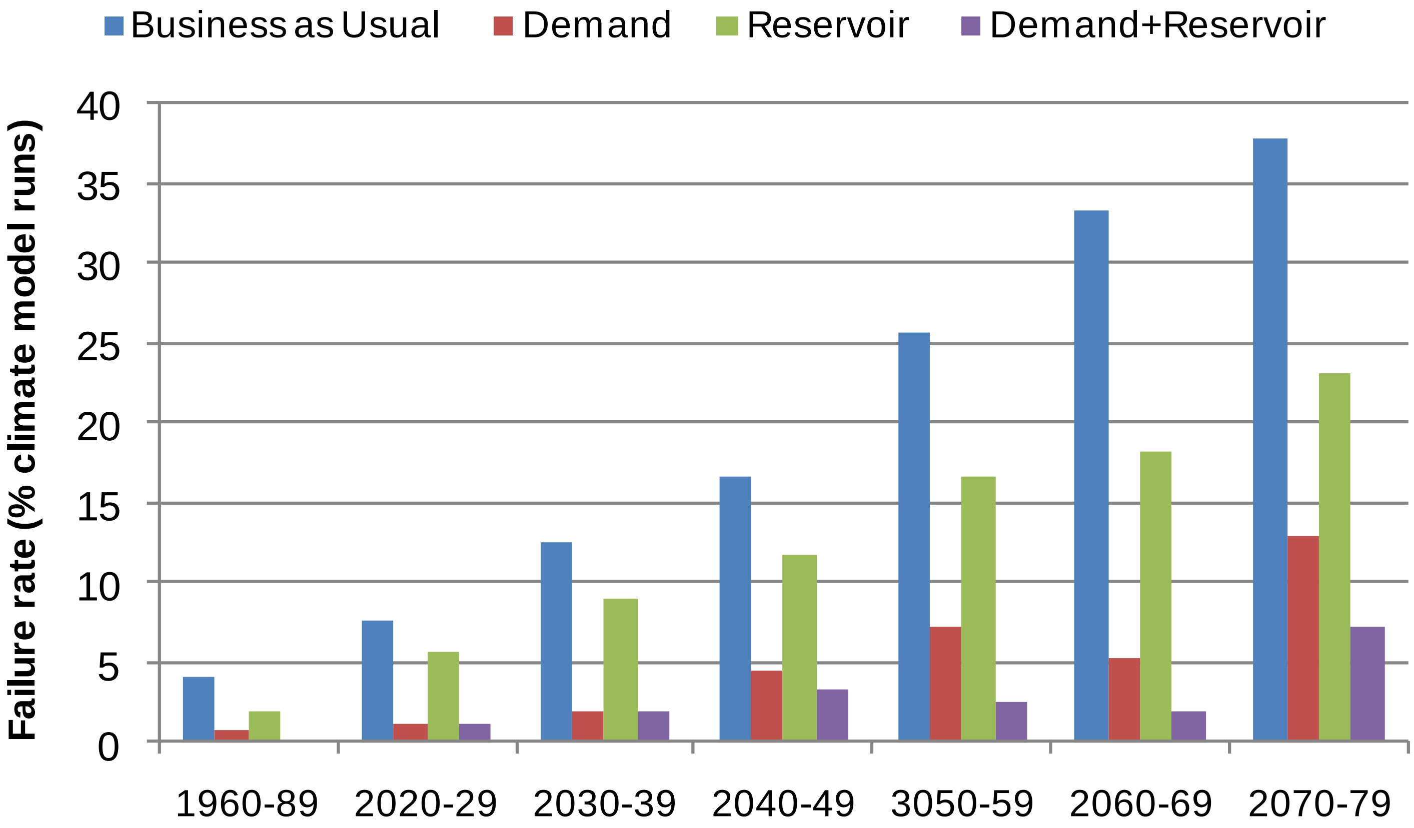
Strategy 3: Evaluate adaptation portfolios…



Schematic of the Wimbleball water resource zone. Reservoirs, river abstraction points, and groundwater sources are represented by triangles, curvy lines, and punched circle, respectively. Solid circles represent different demands. WTW indicates water treatment works, and the arrows show the direction of flow between different sources and demands.

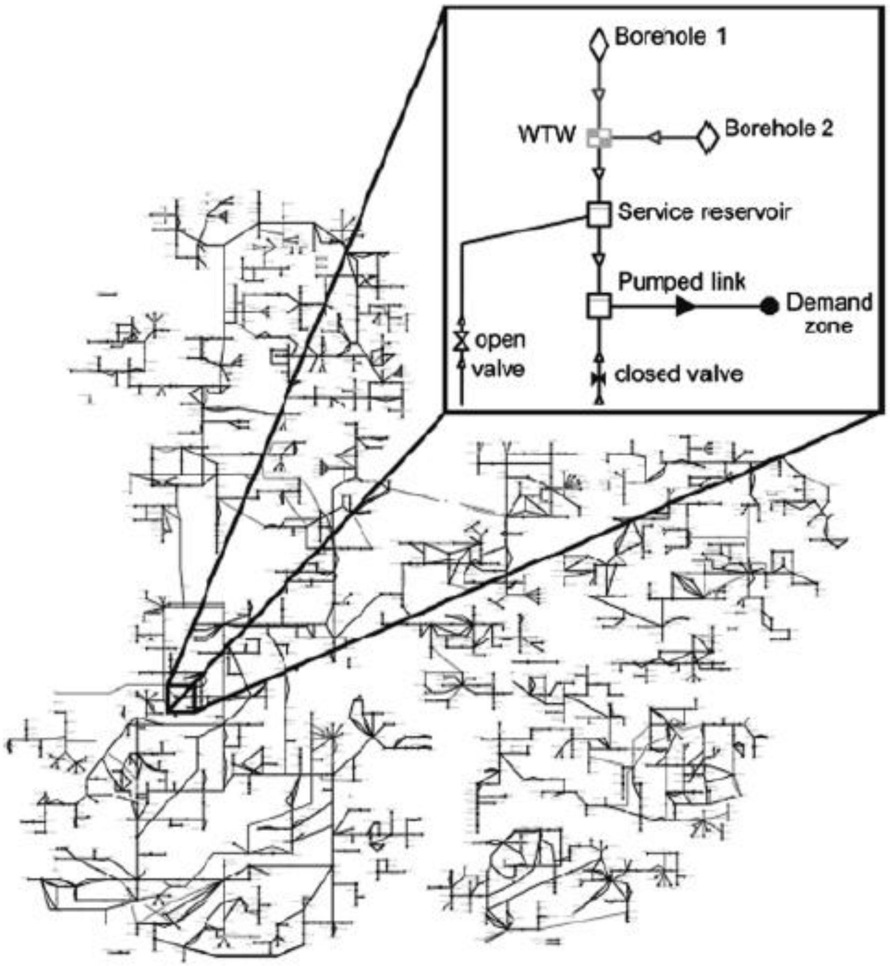
Source: Lopez et al. (2009)

…to identify robust options



Percentage of model runs with <u>single</u> year supply failure in East Devon under SRES A1B emissions. Source: Lopez et al (2009)

Strategy 4: Improve asset/network resilience



Source: Henriques & Spraggs (2011)

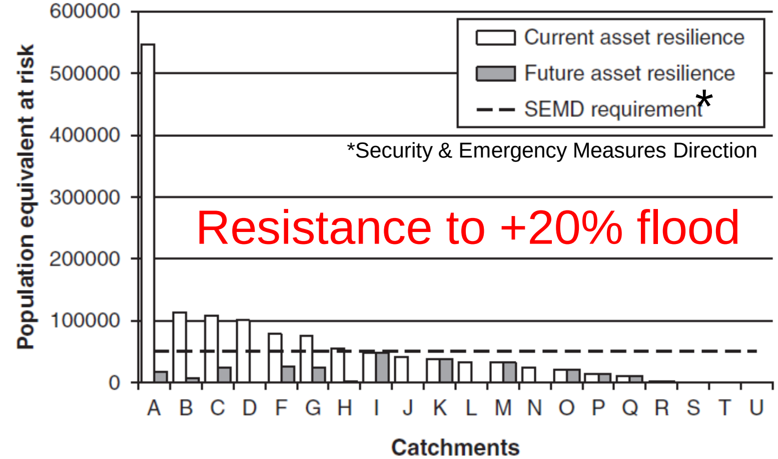


Figure 6 | Population equivalent at risk in case of widespread flooding. Results shown per catchment before and after implementation of flood mitigation options.

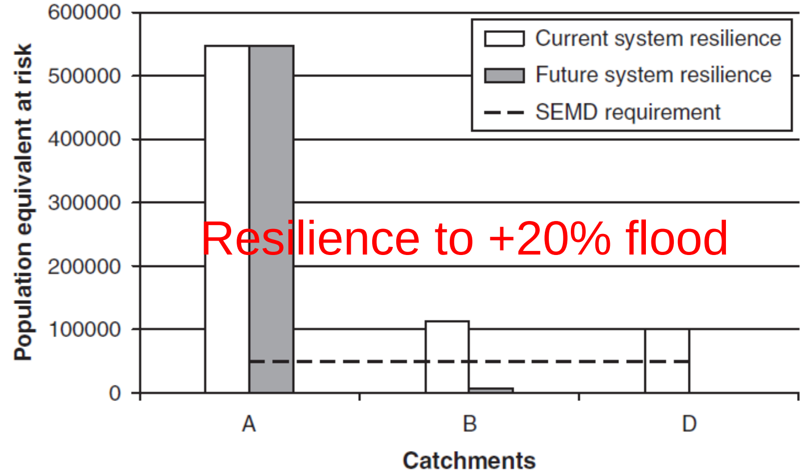


Figure 7 | Population equivalent at risk in case of widespread flooding for three example catchments before and after implementation of improved system resilience.

Strategy 5: Apply safety margin(s)

Annex B: Climate Change

B1. There is an increasing body of scientific evidence that the global climate is changing as a result of human activity. Past, present and future emissions of greenhouse gases are expected to cause significant global climate change during this century. The nature of climate change at a regional level will vary: for the UK, projections of future climate change indicate that more frequent short-duration, high-intensity rainfall and more frequent periods of long-duration rainfall of the type responsible for the 2000 floods could be expected. Sea levels will continue to rise. These kinds of changes will have implications for river flooding and also for local flash flooding. There are several indications that the climate in the UK is already changing. Central England's temperature rose by almost 1°C during the twentieth century. Heat waves have become more frequent in summer and there are now fewer frosts and winter cold spells. Winters over the last 200 years have become wetter relative to summers; a larger proportion of winter precipitation in all regions now falls on heavy rainfall days than was the case 50 years ago.

B2. To help organisations (including local authorities and regional planning bodies) to assess their vulnerability to climate change and plan appropriate adaptation strategies, the Government established the UK Climate Impacts Programme (UKCIP).[13] Scenarios of future climate change in the UK[14] were produced for the UKCIP in 2002 and published by the Department for Environment, Food and Rural Affairs (Defra). Over the next 2-3 years, this climate change scenario information will be revised, expanded and developed to better meet stakeholder needs.

B3. The companion guide supporting the PPS *Planning and Climate Change*[15] will provide guidance on how planning should secure new development and shape places resilient to the effects of climate change.

B4. The Foresight project on future flood risk reported in April 2004.[16] The project found that, using the UKCIP02 climate change projections, together with scenarios of potential economic and social changes, annual damage from flooding may rise from around £100 million to between £460 million (under the community orientated *Local Stewardship scenario*) and £2,500 million (under the more consumerist *World Markets scenario*) by 2080.

B5. Global sea level will continue to rise, depending on greenhouse gas emissions and the sensitivity of the climate system. The relative sea level rise in England also depends on the local vertical movement of the land, which is generally falling in the south-east and rising in the north and west. Allowances for the regional rates of relative sea level rise shown in Table B.1 should be used as a starting point for considering flooding from the sea, along with the sensitivity ranges for wave height and wind speed in Table B.2, in preparing flood risk assessments.

[13] www.ukcip.org.uk

[14] Defra, 2002. *Scenarios of future climate change in the UK* http://www.ukcip.org.uk/scenarios/ukcip02/documentation/ukcip02_scientific_report.asp

[15] see footnote 1

[16] DTI, 2004. *The Foresight Future Flooding project* www.foresight.gov.uk/Previous_Projects/Flood_and_Coastal_Defence/Reports_and_Publications/Project_Outputs/Outputs.htm

Table B.1 Recommended contingency allowances for net sea level rise

Administrative Region	Net Sea Level Rise (mm/yr) Relative to 1990			
	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
East of England, East Midlands, London, SE England (south of Flamborough Head)	4.0	8.5	12.0	15.0
South West	3.5	8.0	11.5	14.5
NW England, NE England (north of Flamborough Head)	2.5	7.0	10.0	13.0

Table B.2 Recommended national precautionary sensitivity ranges for peak rainfall intensities, peak river flows, offshore wind speeds and wave heights.

Parameter	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
Peak rainfall intensity	+5%	+10%	+20%	+30%
Peak river flow	+10%	+20%		
Offshore wind speed	+5%		+10%	
Extreme wave height	+5%		+10%	

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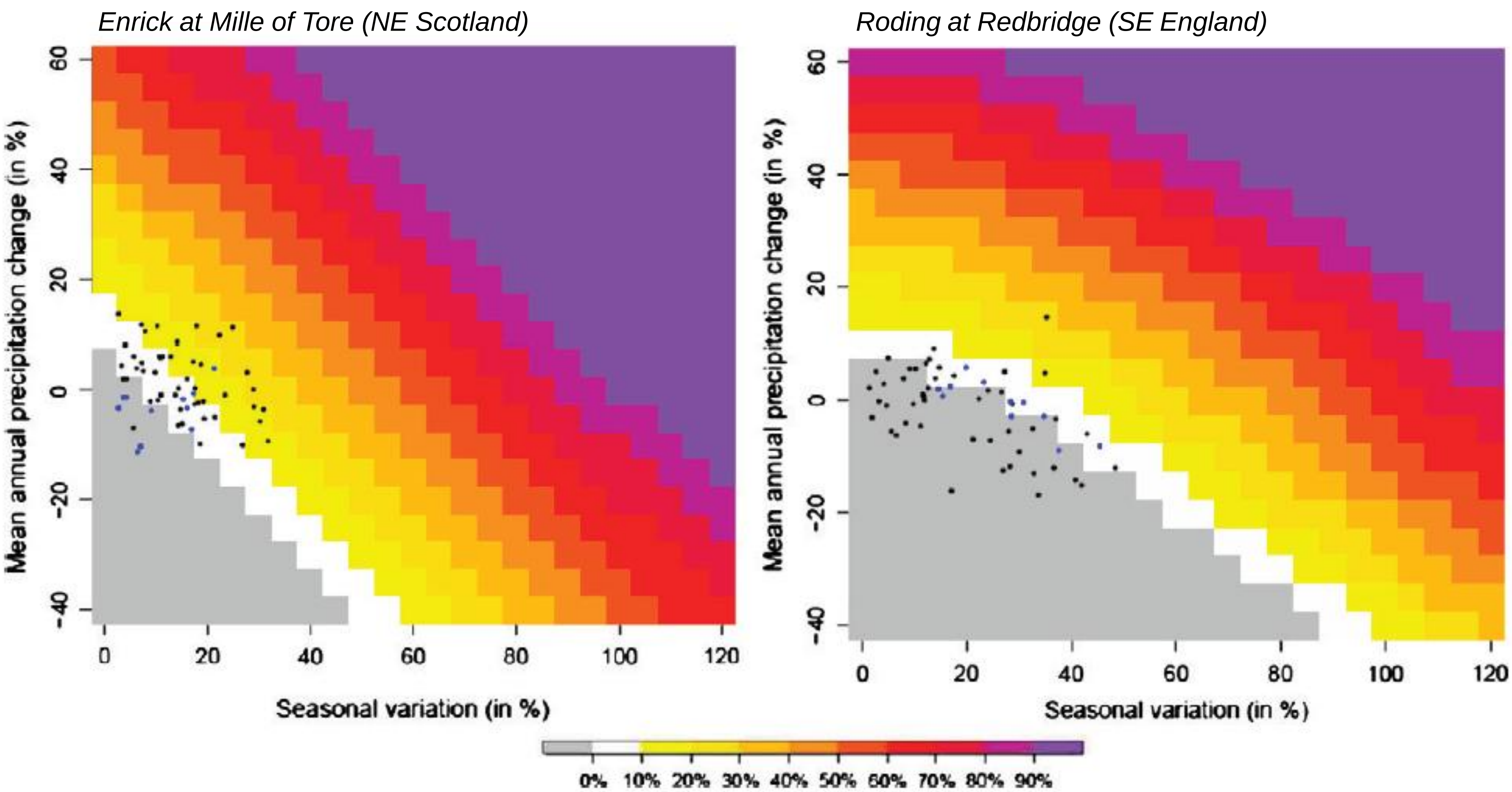
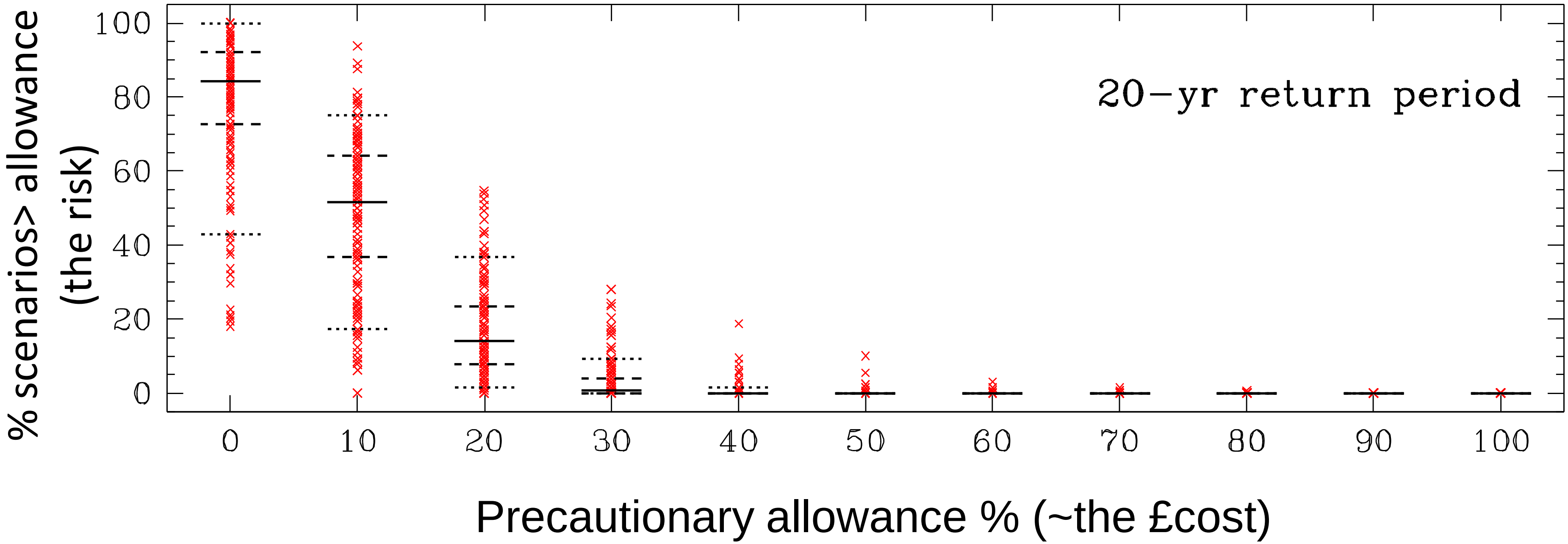
Response surfaces



Percentage changes in 20-yr flood peak (using coloured squares) against percentage changes in mean annual precipitation (y-axis) and seasonal variation in the changes (x-axis). Source: Prudhomme et al. (2010a)

Trading uncertainty for cost

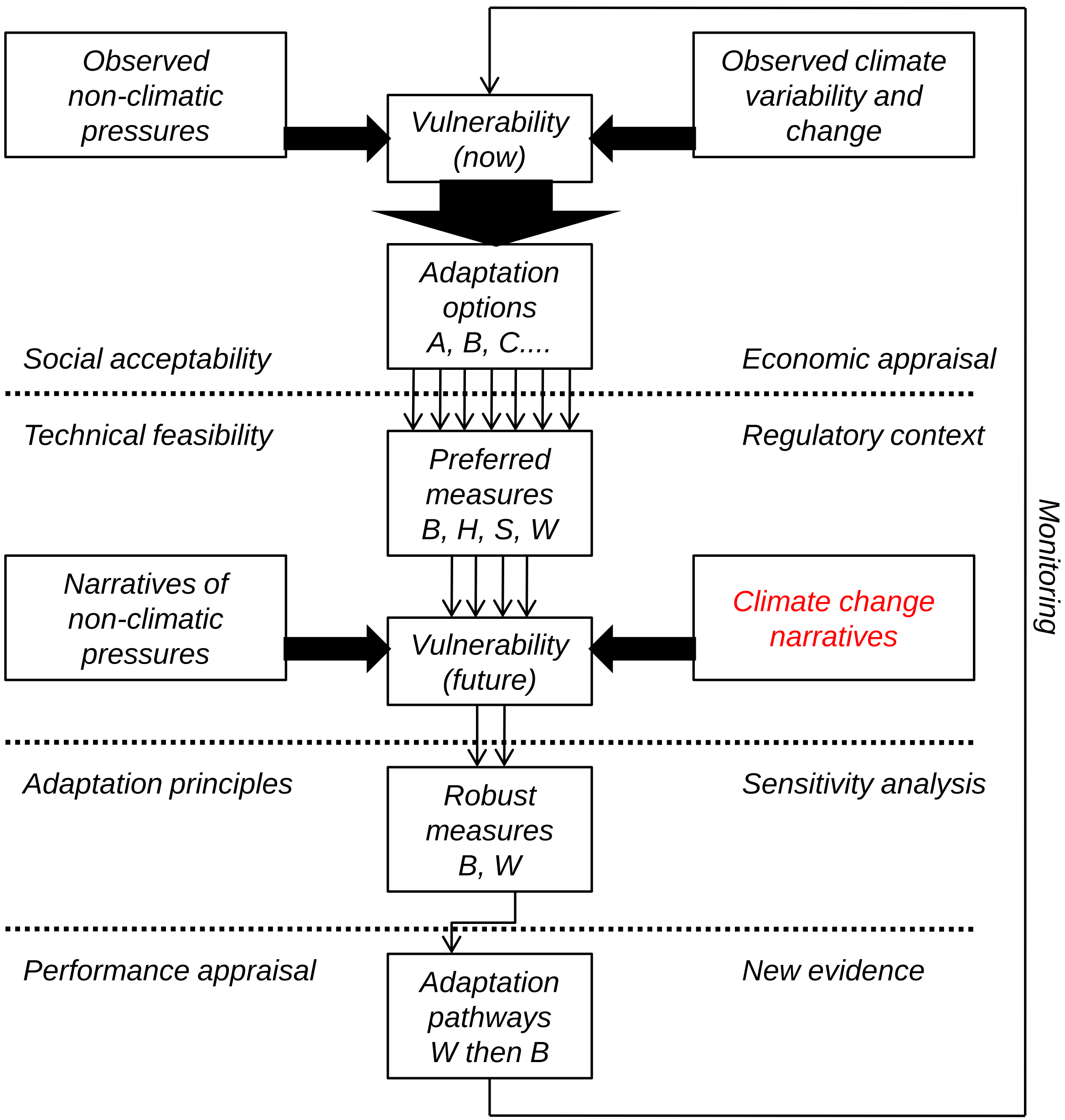


Percentage of model runs exceeding a given 20-year flood safety margin based on 155 UK catchments and 16 AR4 GCMs (2080s, A1B emissions scenario). Each cross for a given allowance shows the results for one catchment. The 50th, 30th and 70th, and 10th and 90th percentiles (solid, dashed and dotted lines respectively) are shown for each ensemble. Source: Prudhomme et al. (2010b)

Concluding remarks

- Is uncertainty a red herring or, worse, a mill-stone?
- What has been the opportunity cost?
- What are the alternatives to the uncertainty paradigm?

Options-led perspective



Source: Wilby & Dessai (2010)

Discussion time

Derwent Reservoir in summer 1995. Courtesy of Nick Jackoby