Water resources management under uncertain climate change predictions: linking hydrology to decision-making

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EPSRC ReCoVER-BRIM workshop on
The Influence of Weather and Climate Variability on Water Resources Management

23rd Jan 2017 University of Exeter

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Water and Environment research @ Civil Engineering, Bristol University

bristol.ac.uk/engineering/research/water

Radar hydrology
Rainfall measures
Hydroinformatics

Water quality
Diffuse pollution

Hydrology
Terrestrial hydrometeorology
Predictions in ungauged basins
Water and health

Uncertainty analysis
Water resources management
Landslides

2010 *2013* *2016*

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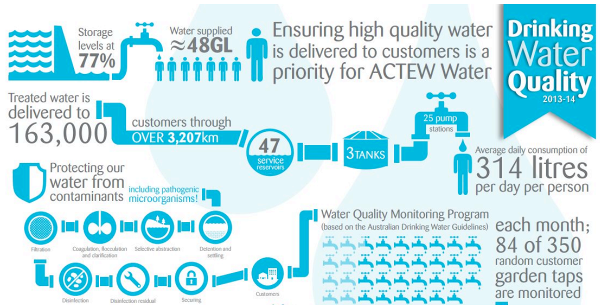
We use a holistic, mechanistic, integrated approach



human behaviour and decisions

Socio-economic infrastructure

Natural infrastructure

Built infrastructure

additional services human demand

natural services natural demand

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The water challenge

> Increasingly variable hydrological conditions
> Fast-changing water demand
> Need to reconcile human needs and natural environment conservation

→ Shift from "investing in centralized, large-scale, physical infrastructures" ('hard path')

to

"improving the productivity of existing infrastructures by efficient management" ('soft path')

concepts

Soft water paths

Peter H. Gleick

Not a moment too soon, the world is awakening to the need to rethink fundamentally the way freshwater resources are distributed, managed and used. In an era of technological breakthroughs and the wonders of the information revolution, millions die each year from preventable water-related diseases, and hundreds of millions more suffer from debilitating illnesses. Despite massive investment and effort, by the end of the twentieth century 2.4 billion people (more than lived on the entire planet in 1940) lacked sanitation services of the standard available to most citizens of ancient Rome. More than a billion people still lack adequate, clean drinking water.

No single factor is responsible for this communities and private companies to collaborate to meet water-related needs, rather than merely to supply water. The productive use of water can be improved by rational application of technology and economics, and by decision-making at the right scale. Ecological health must be considered a fundamental component of water policy. This contrasts with the unshakeable belief of most policy-makers that large, centralized water systems are the only way to meet unrelenting growth in demand, and that such demand is an inevitable outcome of growth in population and gross domestic product (GDP).

Yet the link between economic growth and water demand can be broken. From 1900 to the mid-1990s, the GDP of the United States rose by a factor of 20. Total water

Water management

The soft path seeks to improve the overall productivity of water use and deliver water services matched to the needs of end users, rather than seeking sources of new supply.

such as steel production or chemical manufacturing, to industries such as service provision, telecommunications and computing. This has fuelled a further divergence between economic production and water use. Hong Kong and California, for example, have doubled their economic productivities per unit of water use over the past 30 years.

Gleick (2002) *Nature*

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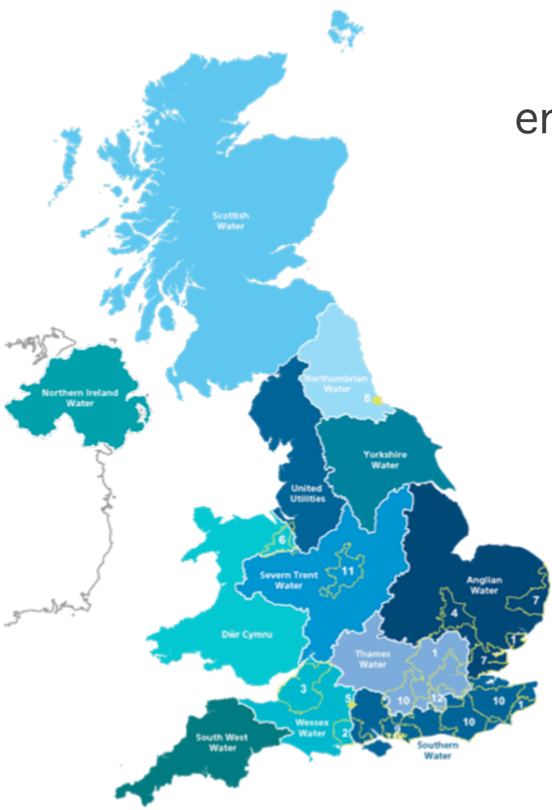
The UK management and regulatory framework



Environment Agency
environmental regulator

Ofwat
economic regulator

24 water companies
water and sewerage providers

Asset Management Period 2015-2020 (AMP6) priorities:
> increase water efficiency
> shift from ‘capex’ to ‘totex’
> find ‘no-build’ solutions
> consider entire catchments rather than individual WRS components

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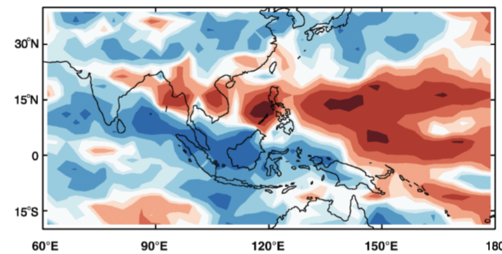
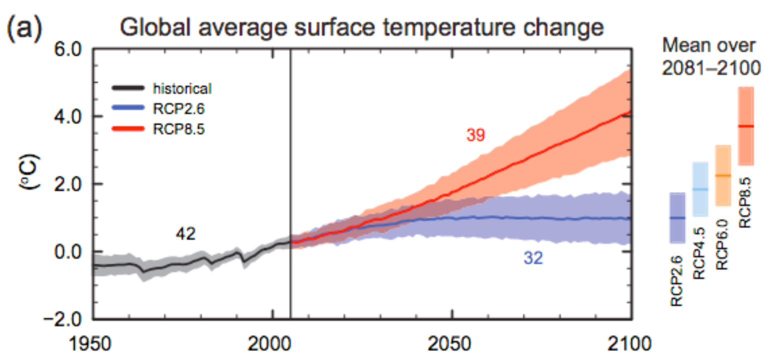
Two methodological challenges need to be addressed to support better water resources management

[1] Integrate "built" infrastructure and "information" infrastructure



[2] Estimate long-term costs and benefits in face of future uncertainty



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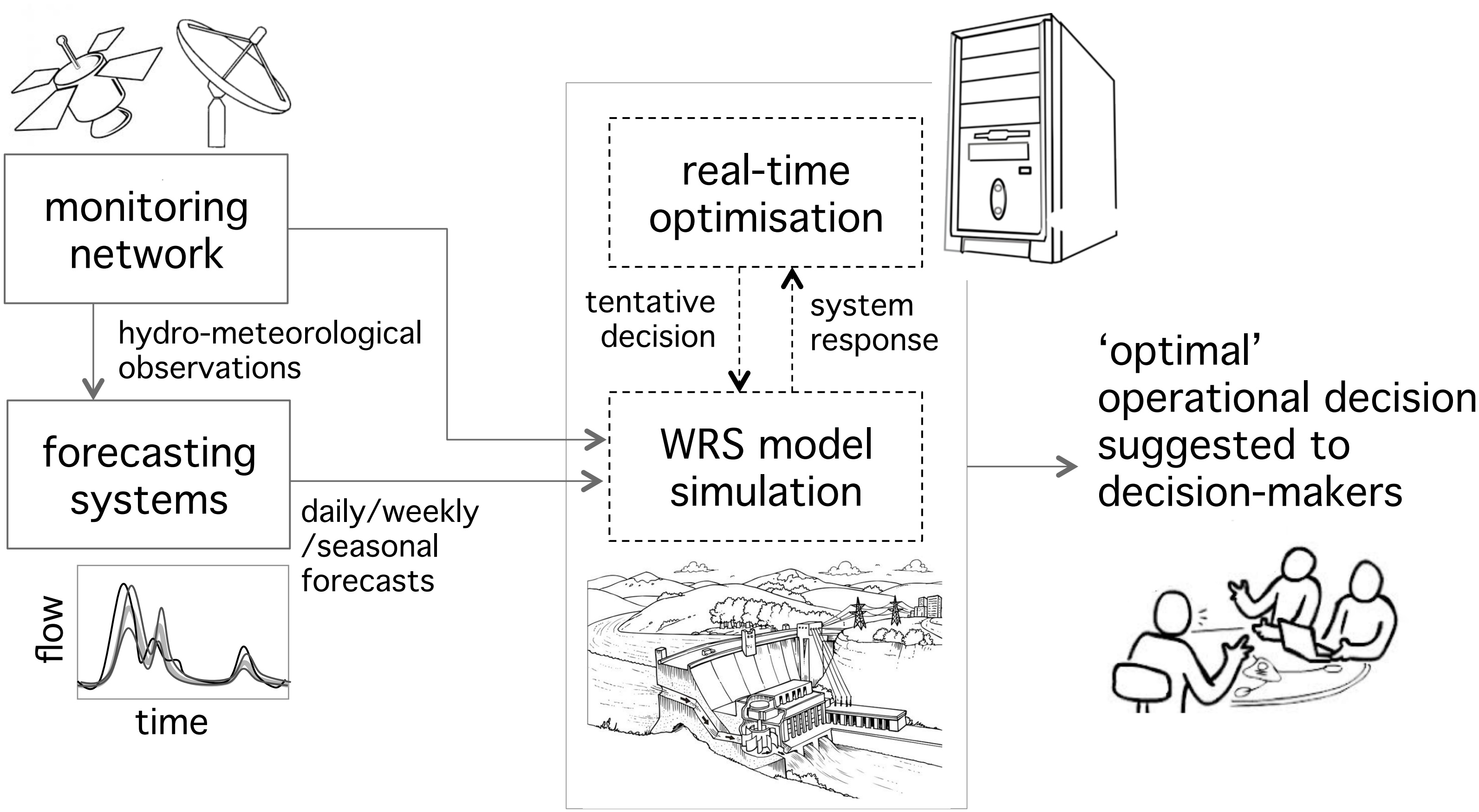
[1] Increasing efficiency by connecting ‘built’ and ‘information’ infrastructures



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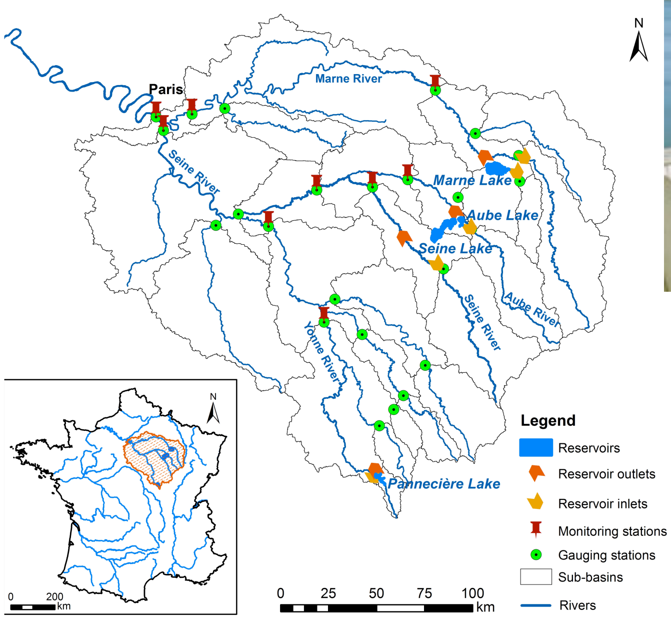
Example from 4-reservoirs system in the Seine river basin, France

How much can we improve the efficiency of existing infrastructure by making the best use of model forecasts?



Ficchì et al (2015) *JWRPM*

Optimal Operation of the Multireservoir System in the Seine River Basin Using Deterministic and Ensemble Forecasts

A. Ficchì[1]; L. Raso[2]; D. Dorchies[3]; F. Pianosi[4]; P.-O. Malaterre[5]; P.-J. Van Overloop[6]; and M. Jay-Allemand[7]

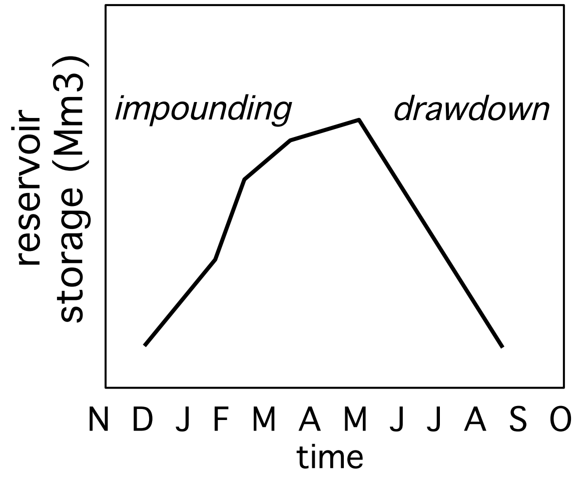
Abstract: This article investigates the improvement of the operation of a four-reservoir system in the Seine River basin, France, by use of deterministic and ensemble weather forecasts and real-time control. In the current management, each reservoir is operated independently from the others and following prescribed rule-curves, designed to reduce floods and sustain low flows under the historical hydrological conditions.

www.uni-kassel.de/fb14/wasserbau/CLIMAWARE/home/home.html

Methodology: we simulate and compare...

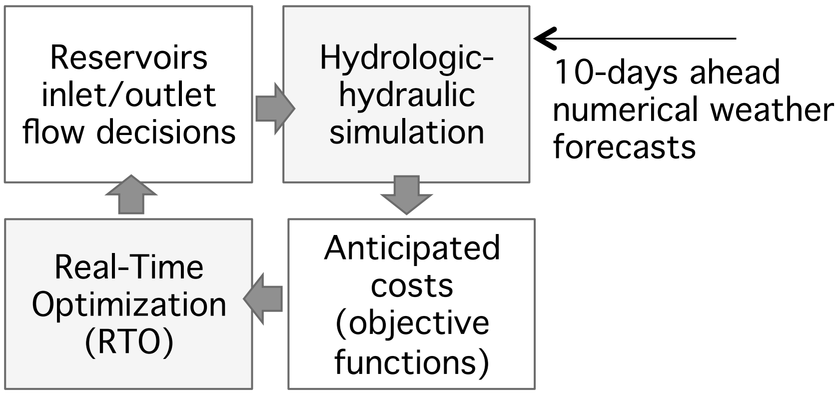
Current operation:

> each reservoir operated as individual facility
> each reservoir operated to follow its "Rule Curve"



Proposed new operation:

> one coordinate approach to operate all reservoirs jointly
> coordinate operation based on forecasts and RTO



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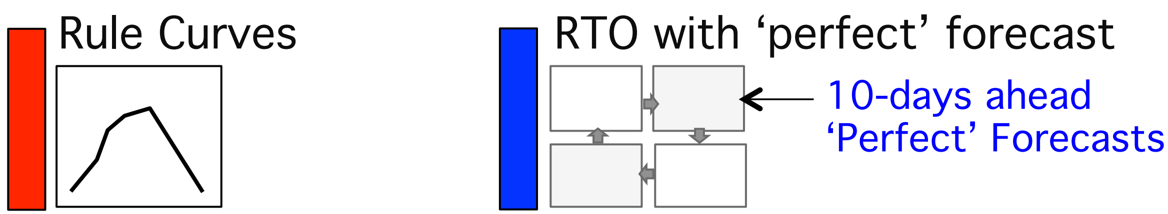
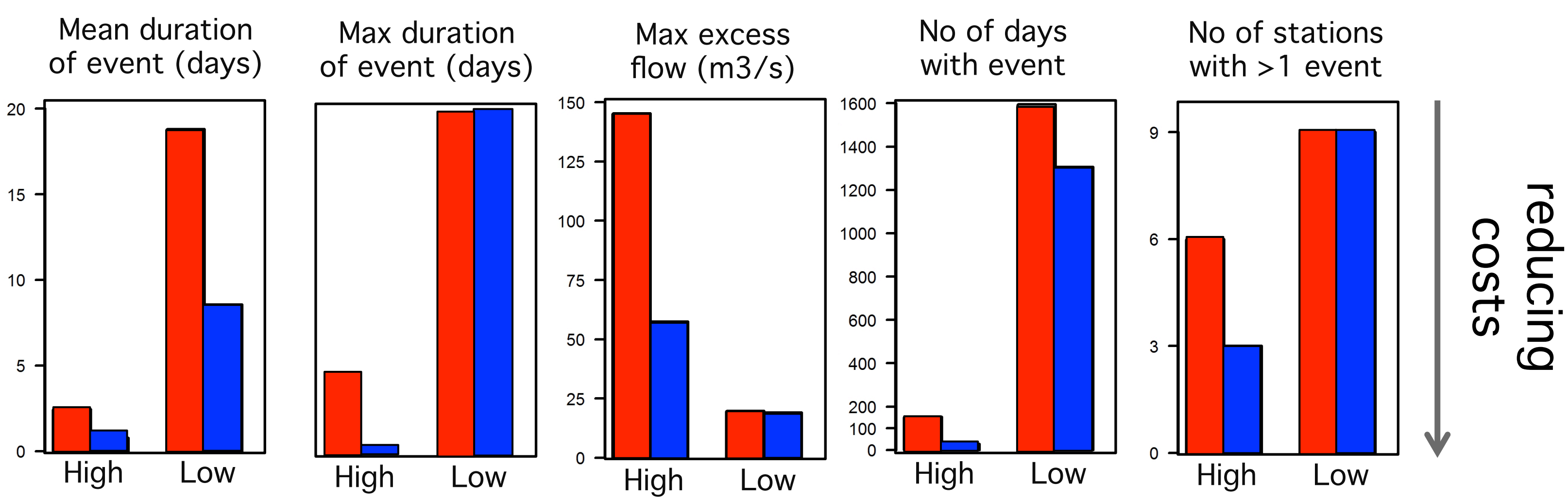
Results: (i) assessing the potential of proposed new operation approach



Simulation over 15-year period (01/08/1973-01/11/1988)



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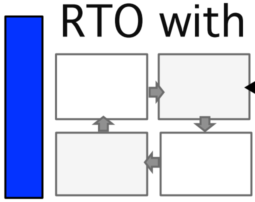
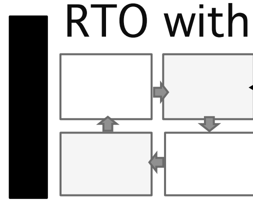
Results: (ii) assessing the value of available forecasts for RTO

RTO with PF



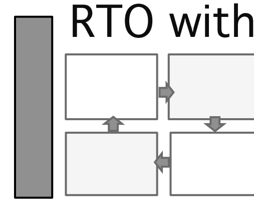
10-days ahead 'Perfect' Forecasts

RTO with DF



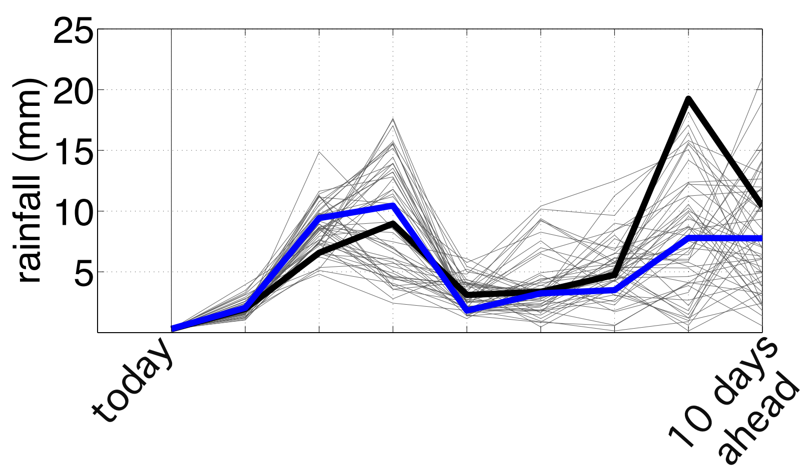
10-days ahead Deterministic Forecasts

RTO with EF



10-days ahead Ensemble Forecasts

DF and EF produced
by the European Centre for Medium-Range Weather Forecasts (ECMWF)



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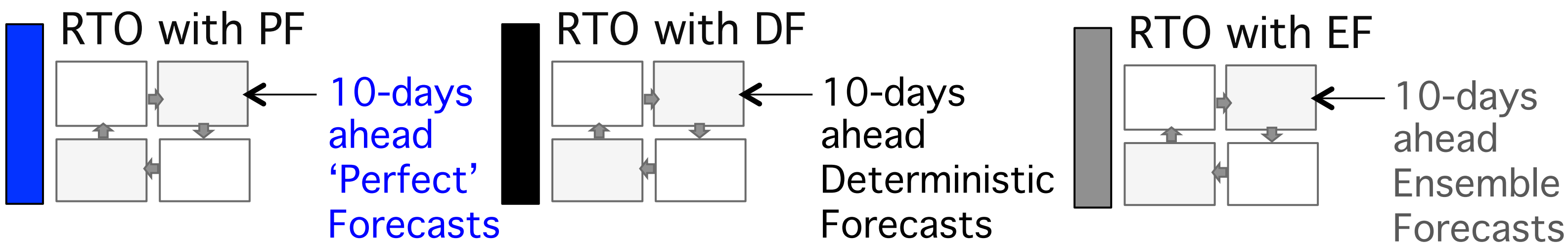
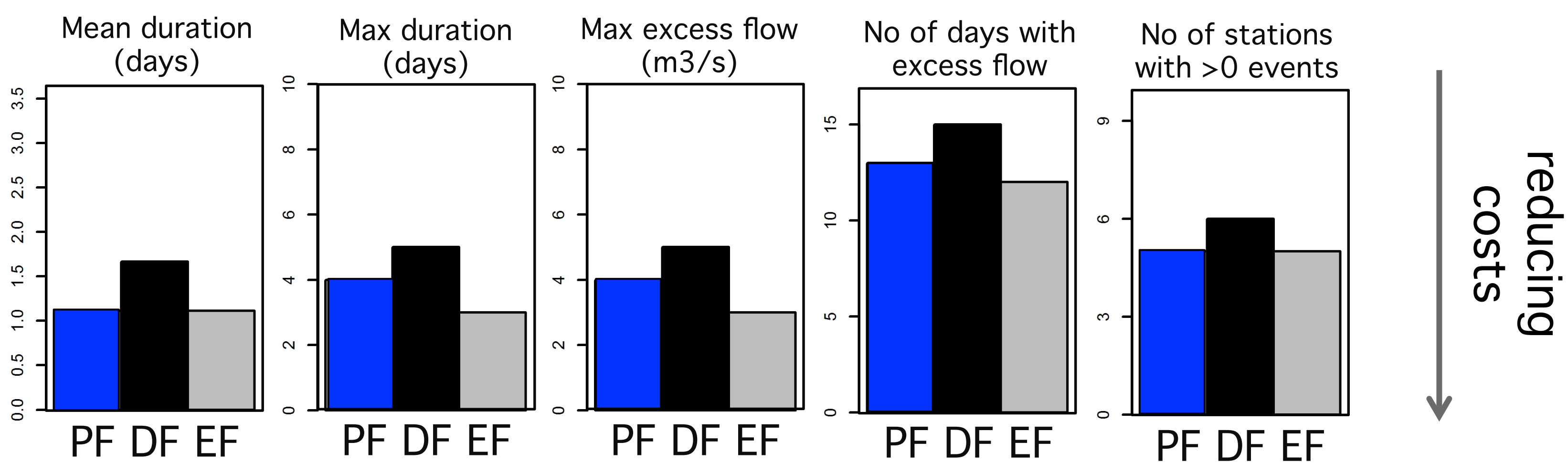


Simulation over flood event in February, 2007



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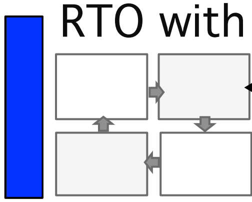

RTO with PF

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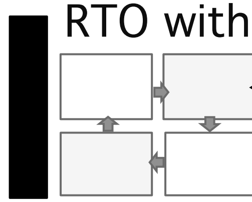
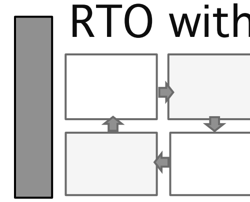


RTO with DF

10-days ahead Deterministic Forecasts

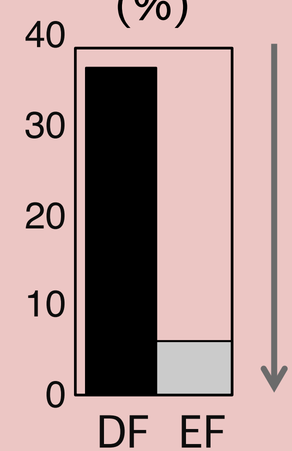


RTO with EF

10-days ahead Ensemble Forecasts

Simulation over flood event in February, 2007

Average cost normalized wrt cost with PF (%)



→ Explicit consideration of forecast uncertainty can almost fill the performance loss due to forecasts inaccuracy

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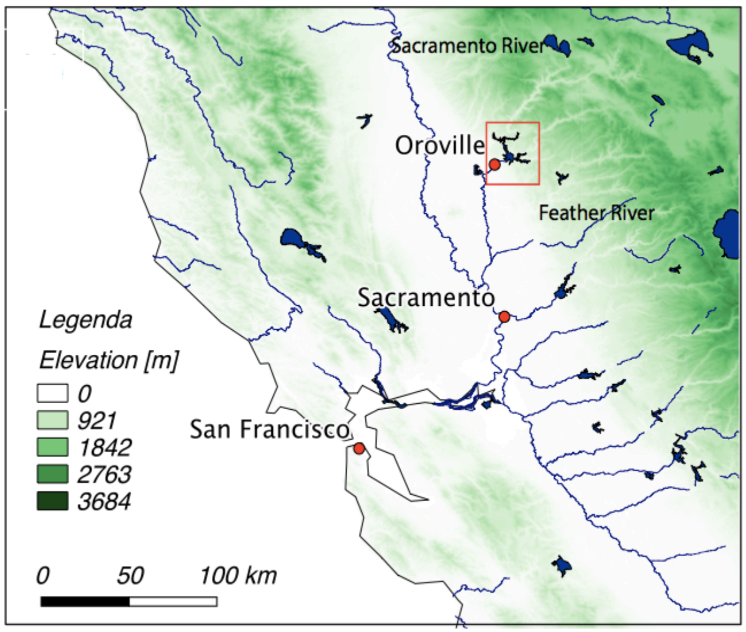
Example/2: Value of seasonal forecasts for reservoir operation in California



Anghileri et al (2016) *WRR*

Value of long-term streamflow forecast to reservoir operation for water supply in snow-dominated catchments

D. Anghileri,[1] N. Voisin,[2] A. Castelletti,[1,3] F. Pianosi,[4] B. Nijssen,[5] and D.P. Lettenmaier[6]

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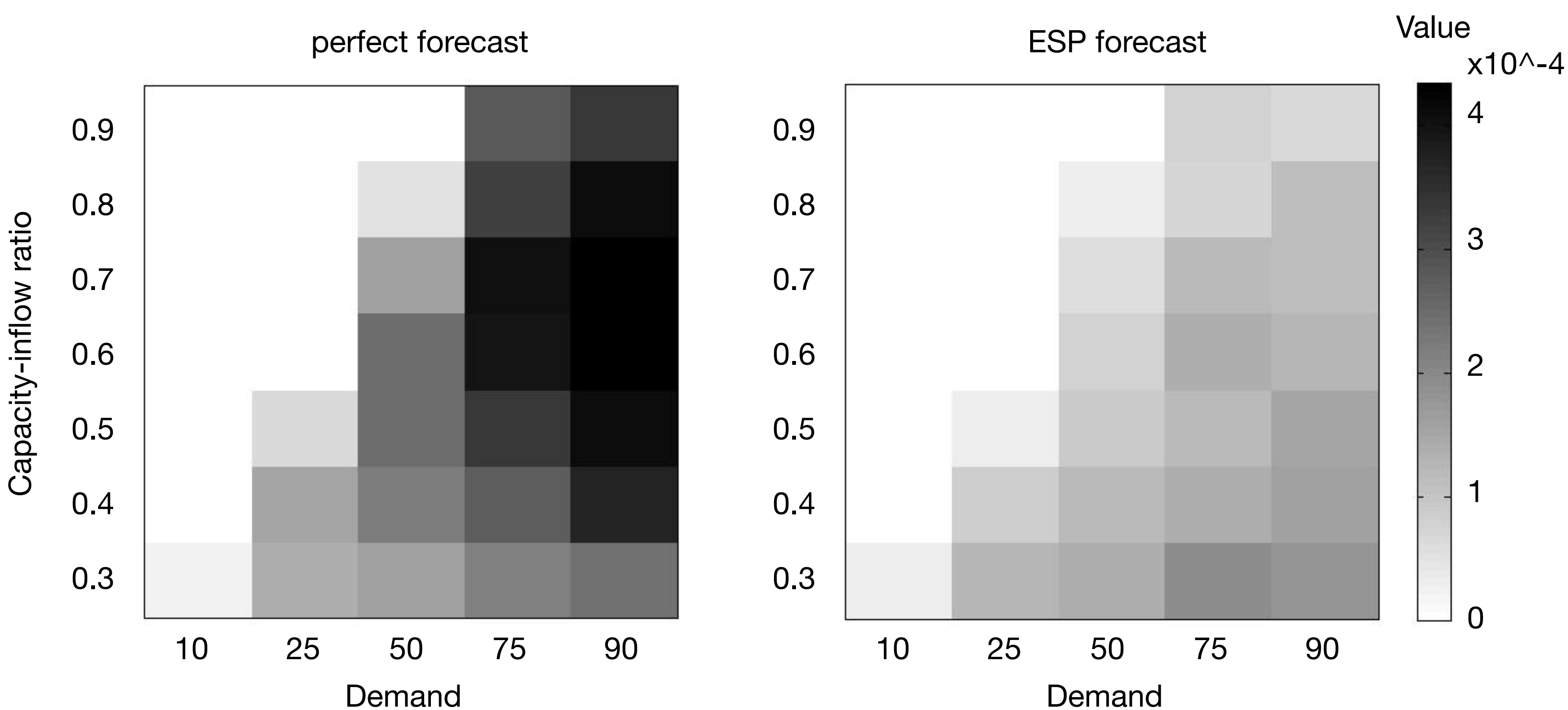
Example/2: Value of seasonal forecasts for reservoir operation in California

Anghileri et al (2016) *WRR*



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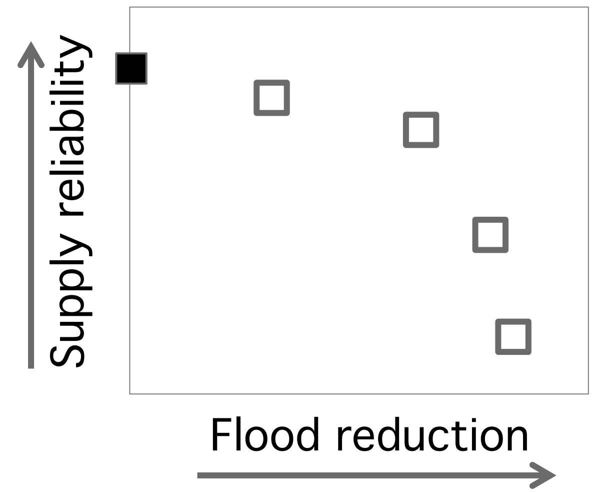
Potential for future research and applications

> Explore the use of water supply reservoirs for flood control purpose



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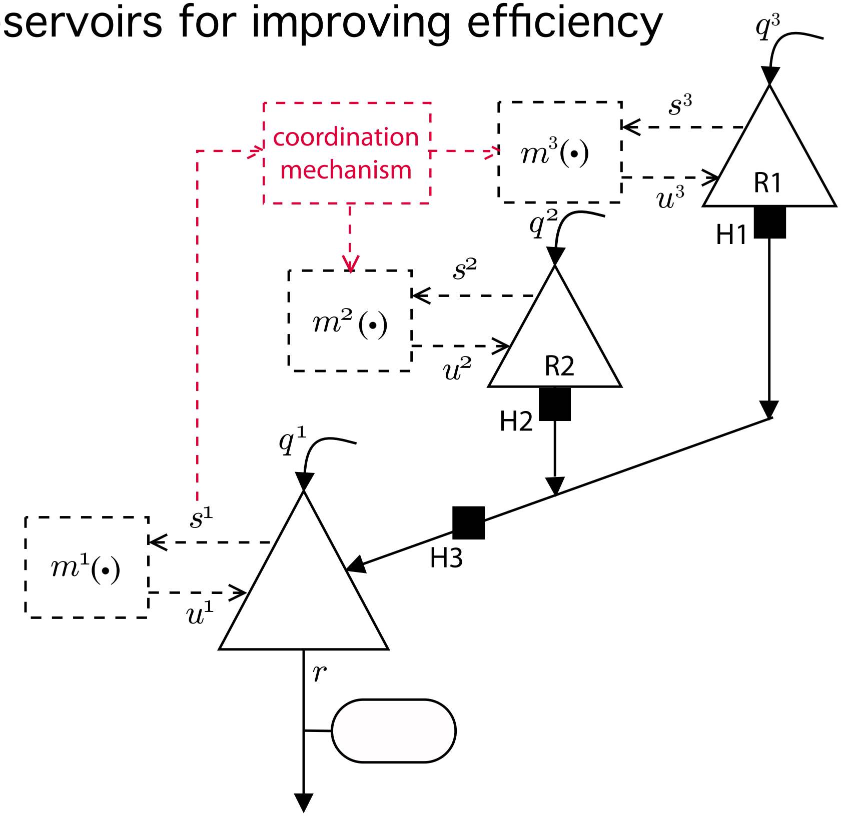
Potential for future research and applications

> Explore the use of water supply reservoirs for flood control purpose

> Explore coordinate operation of reservoirs for improving efficiency



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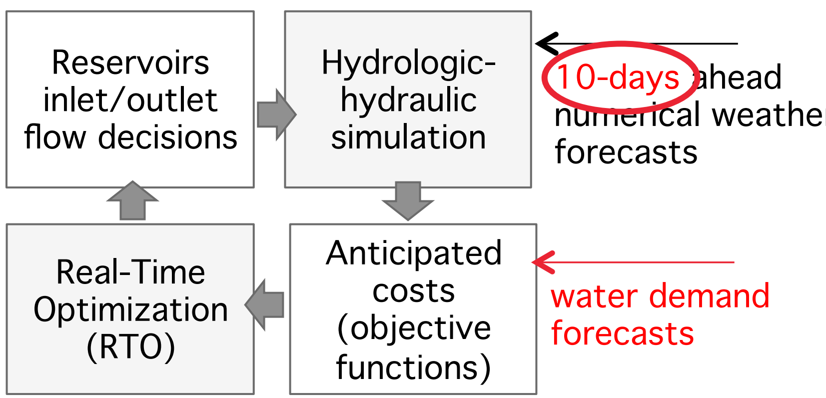
Potential for future research and applications

> Explore the use of water supply reservoirs for flood control purpose
> Explore coordinate operation of reservoirs for improving efficiency
> Explore using RTO linking to UK forecasting systems, and in particular
  - including water demand forecasts
  - expanding forecast lead-time from decadal to seasonal scale



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[2] Estimate long-term costs and benefits in face of future uncertainty

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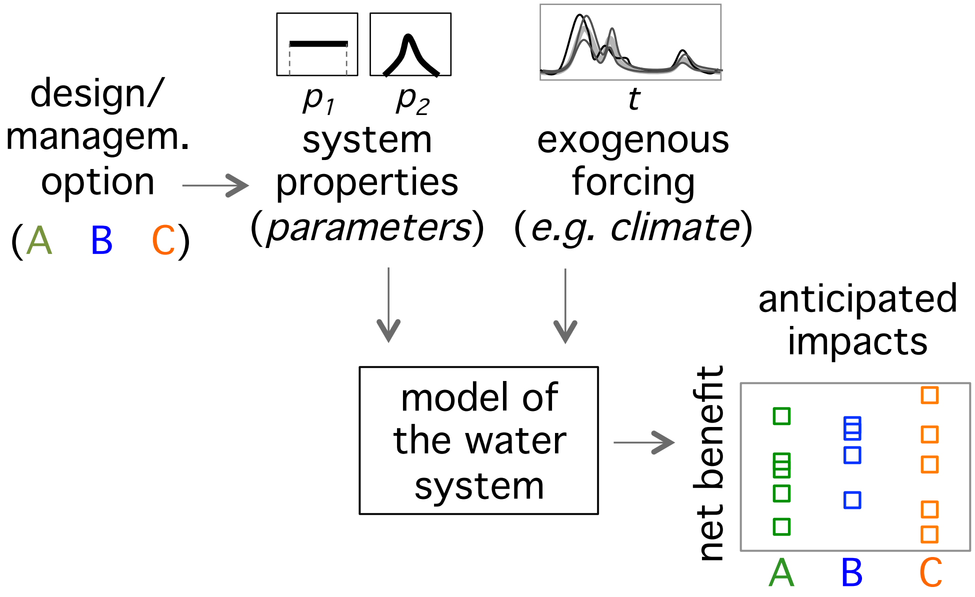
The traditional 'top-down' planning approach... and the problem of uncertainty



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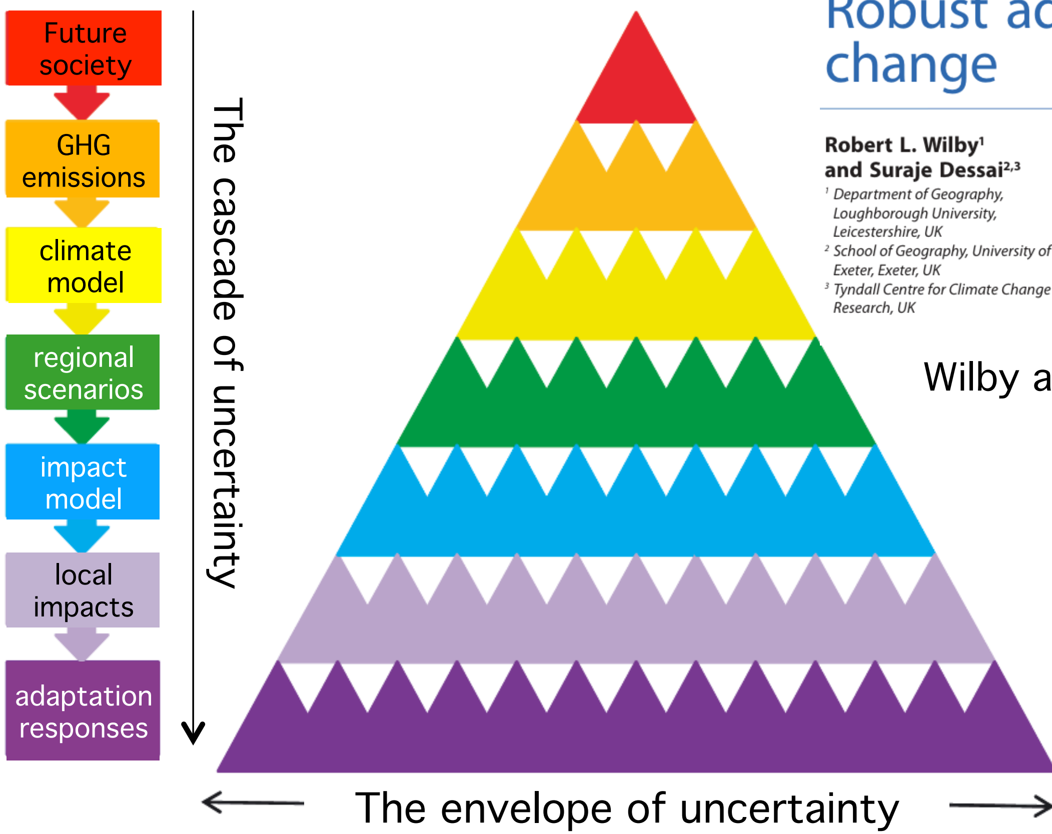
The problem has been long-debated for climate impacts assessment



Robust adaptation to climate change

Robert L. Wilby[1] **and Suraje Dessai**[2,3]
[1] *Department of Geography, Loughborough University, Leicestershire, UK*
[2] *School of Geography, University of Exeter, Exeter, UK*
[3] *Tyndall Centre for Climate Change Research, UK*

adaptation is gaining ground (UNDP, 2007; Parry *et al.*, 2009). This poses a challenging question: how can we ensure that adaptation measures realize societal benefits now, and over coming decades, despite uncertainty about climate variability and change?

The scientific community is developing regional climate downscaling (RCD) techniques to reconcile the scale mismatch between coarse-resolution OA/GCMs and location-specific information needs of needed for model calibration may be of dubious quality or patchy, the links between regional and local climate are poorly understood or resolved, and where technical capacity is not in place. Another concern is that high-resolution downscaling can be misconstrued as accurate downscaling (Dessai *et al.*, 2009). In other words, our ability to downscale to finer time and space scales does not imply that our confidence is any greater in the resulting scenarios.

Wilby and Dessai (2010) *Weather*

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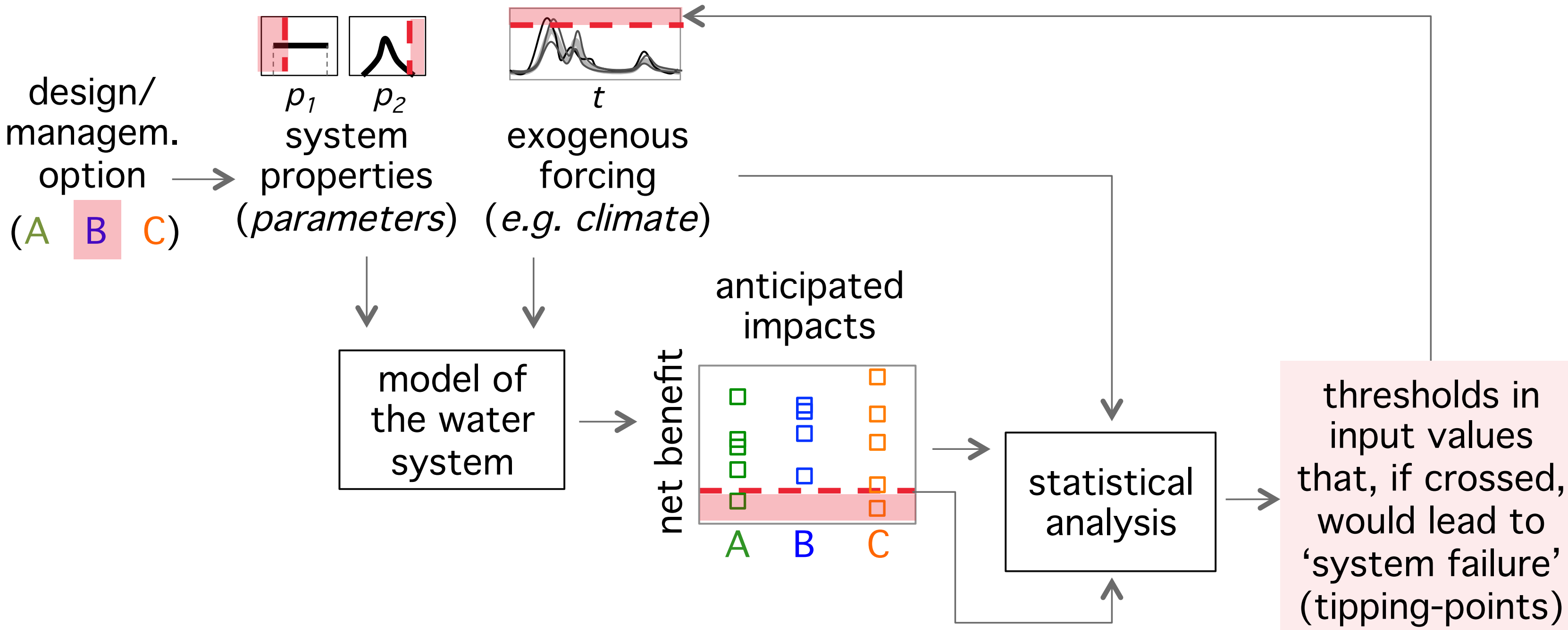
A way out of the ‘uncertainty-dilemma’: the ‘scenario-discovery’ approach



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The ‘scenario-discovery’ approach can be implemented by Global Sensitivity Analysis (GSA) techniques

e.g. Almeida et al (2016) *HESSD*

Nat. Hazards Earth Syst. Sci. Discuss., doi:10.5194/nhess-2016-278, 2016
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Published: 12 September 2016

Natural Hazards and Earth System Sciences
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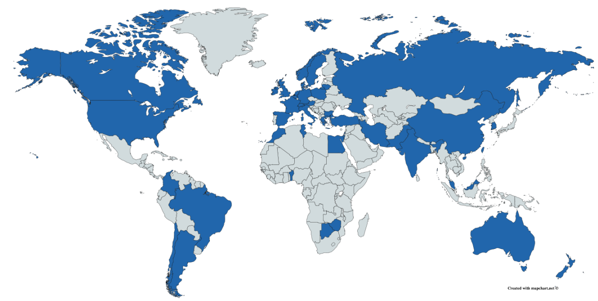
Dealing with deep uncertainties in landslide modelling for disaster risk reduction under climate change

Susana Almeida[1], Elizabeth Holcombe[1], Francesca Pianosi[1], Thorsten Wagener[1,2]

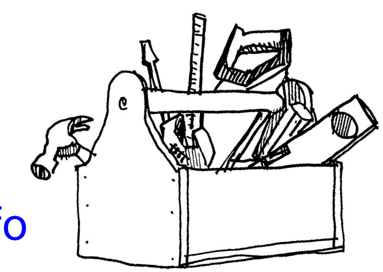
[1]Department of Civil Engineering, University of Bristol, Bristol, BS8 1TR, United Kingdom
[2]Cabot Institute, University of Bristol, Bristol, BS8 1TR, United Kingdom

Correspondence to: Susana Almeida (susana.almeida@bristol.ac.uk)



Over 700 users of SAFE in >50 countries

@Bristol we have recently developed several GSA methods and an open-source Toolbox: www.safetoolbox.info



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Concluding remarks

> We possess the tools to better characterise uncertainties in weather and hydrological predictions and their implications for water resources (floods and droughts)

> Explicit consideration of such uncertainties can significantly improve water resource planning and management

> We need to keep advancing our techniques and demonstrating them in real-world applications

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