From prediction to scenario analysis: an Australian perspective

Bryson C. Bates

27 October 2014

CSIRO

Presentation outline

- Aspects of urban water planning
- Predictions, forecasts, projections and scenarios
- Issue of stationarity
- Sources and propagation of uncertainty
- Climate change impact assessments
- Approaches to system planning
- Climate Futures web tool
- Robust adaptation strategies
- Prudent action under uncertainty

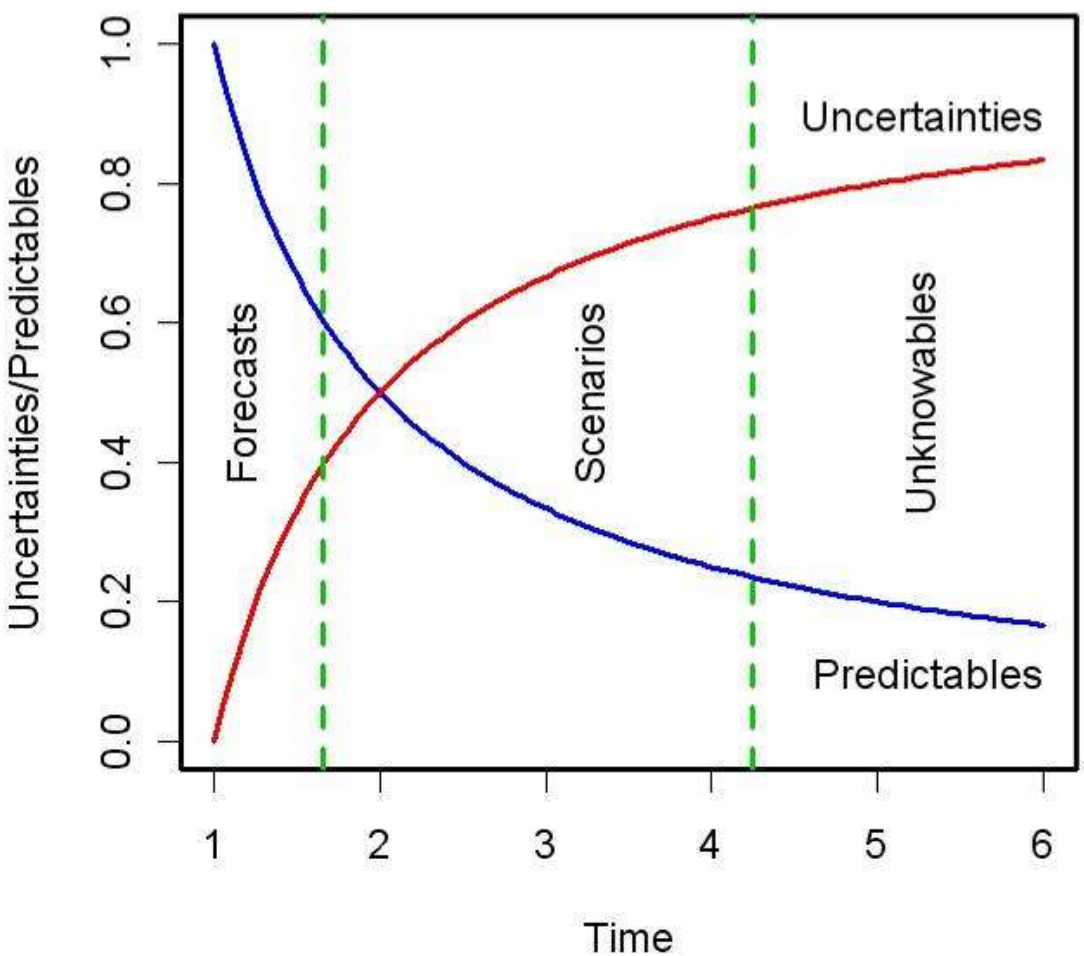
Aspects of urban water planning

Marsden, Jacob and Assoc. (2006) – urban water supplies

- Extent past changes in streamflow and/or groundwater recharge recognised
- Degree of reliance on historical record
- Level of service requirements
- Degree of reliance on reductions in water demand
- Willingness to consider non-traditional sources – Fritz Holzwarth: “Water recycling is the resource of last resort”
- Extent to which climate change projections considered
- Extent to which contingency plans and triggers identified and articulated

Predictions, forecasts, projections and scenarios

Adapted from Postma and Liebl (2005)



Prediction

Specific statement about the future

Forecast

Most likely picture of the future

Projection

What could happen if certain assumed conditions prevail in the future

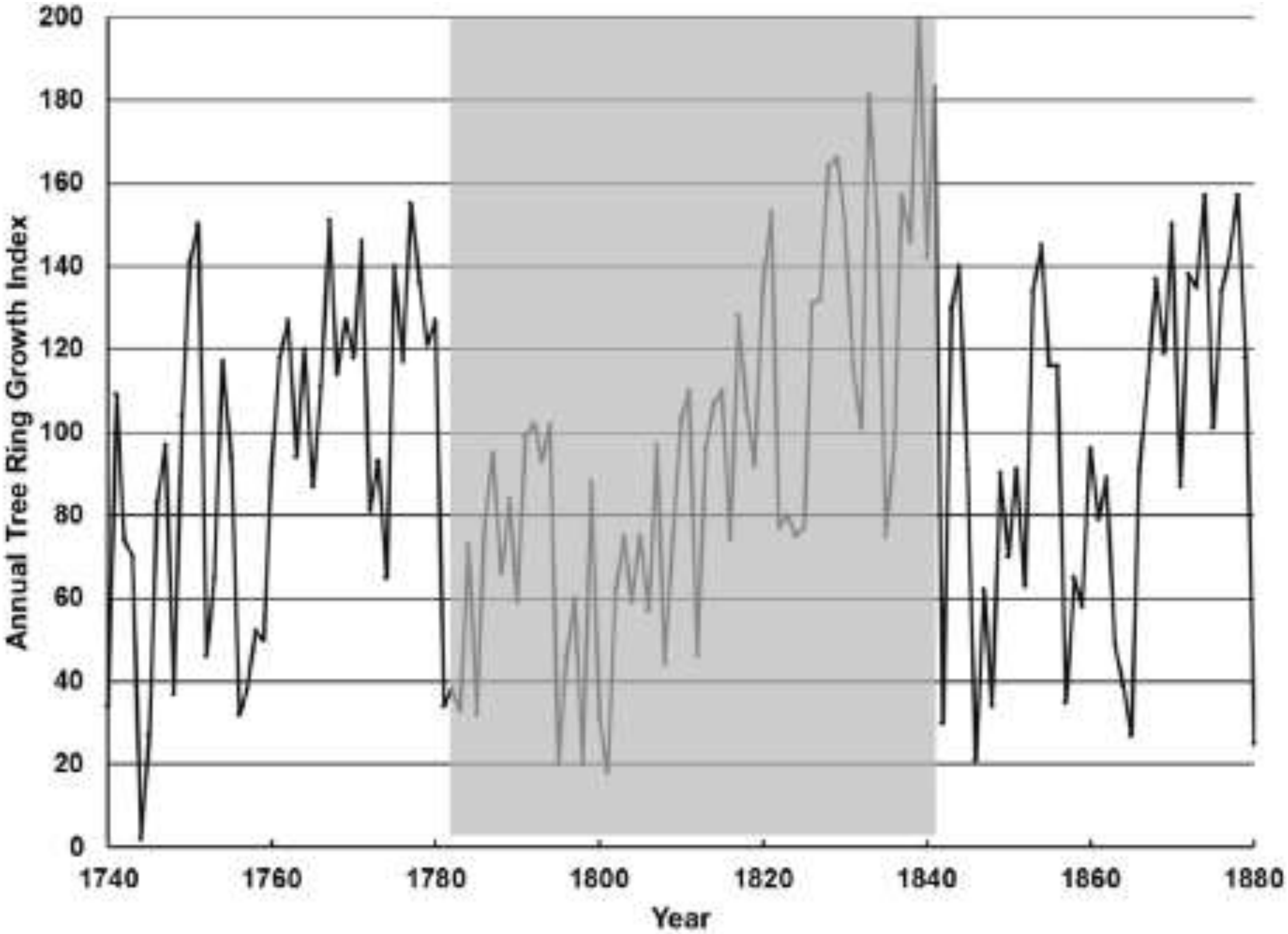
Scenario

A series of events that could lead from present to plausible but not assured future situation

Sources of uncertainty

- *Ignorance*: lack of complete knowledge about processes, 'natural' variability
- *Randomness*: stochastic or chaotic nature of natural forcing, errors in observational data, independence/interdependence
- *Structural uncertainty*: simplification, choice of model configuration, internal physics, spatial and temporal averaging
- *Parameter uncertainty*: 'tuneable' parameters in model schemes and numerical algorithms
- *Initial and boundary conditions*

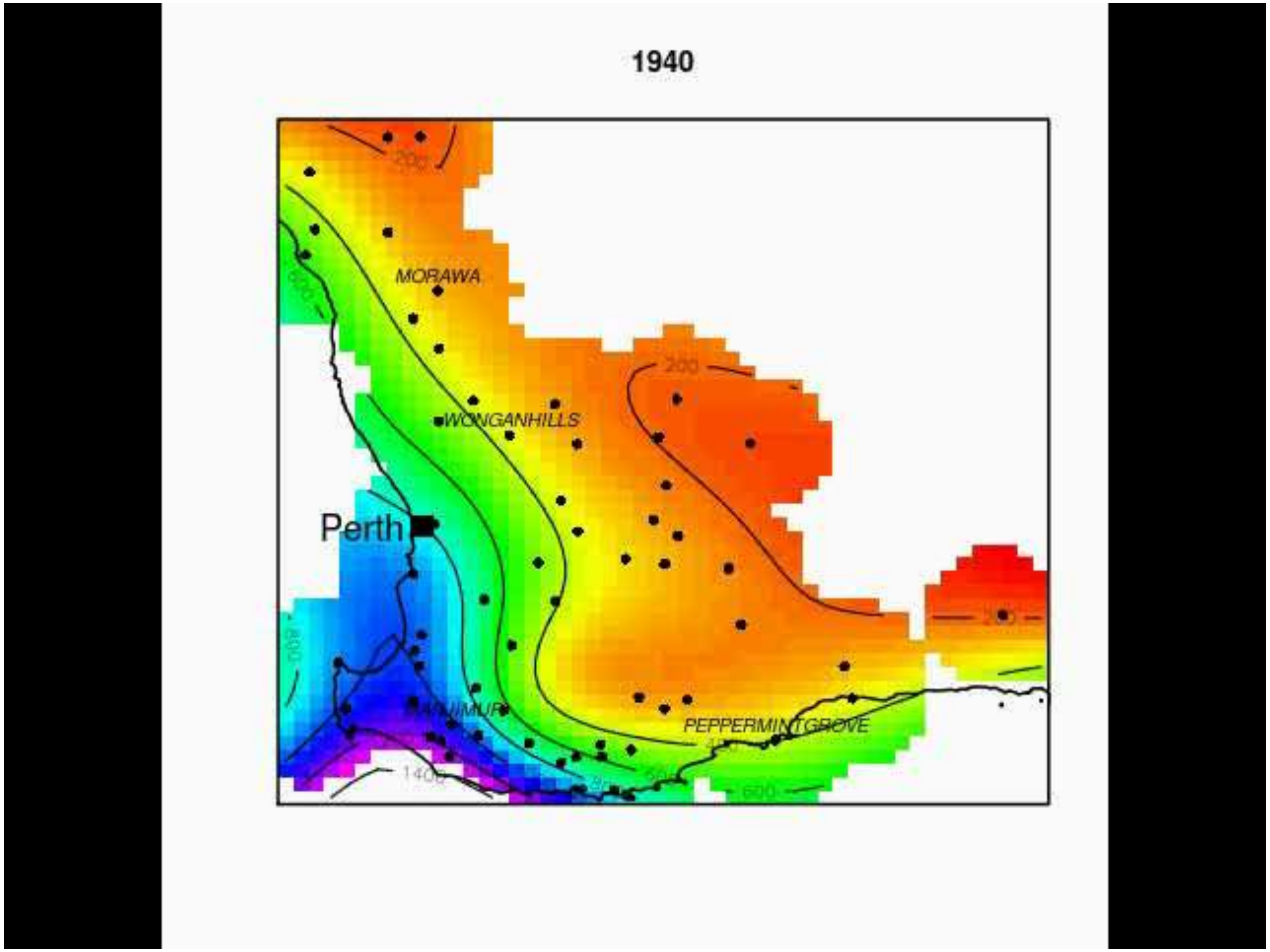
Issue of stationarity



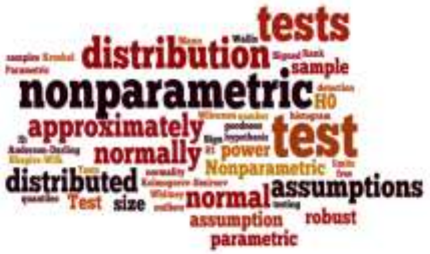
Lettenmaier and Burges (1978)

NB: Origin and period of record are key considerations

MJJ rainfall 1940 – 2010

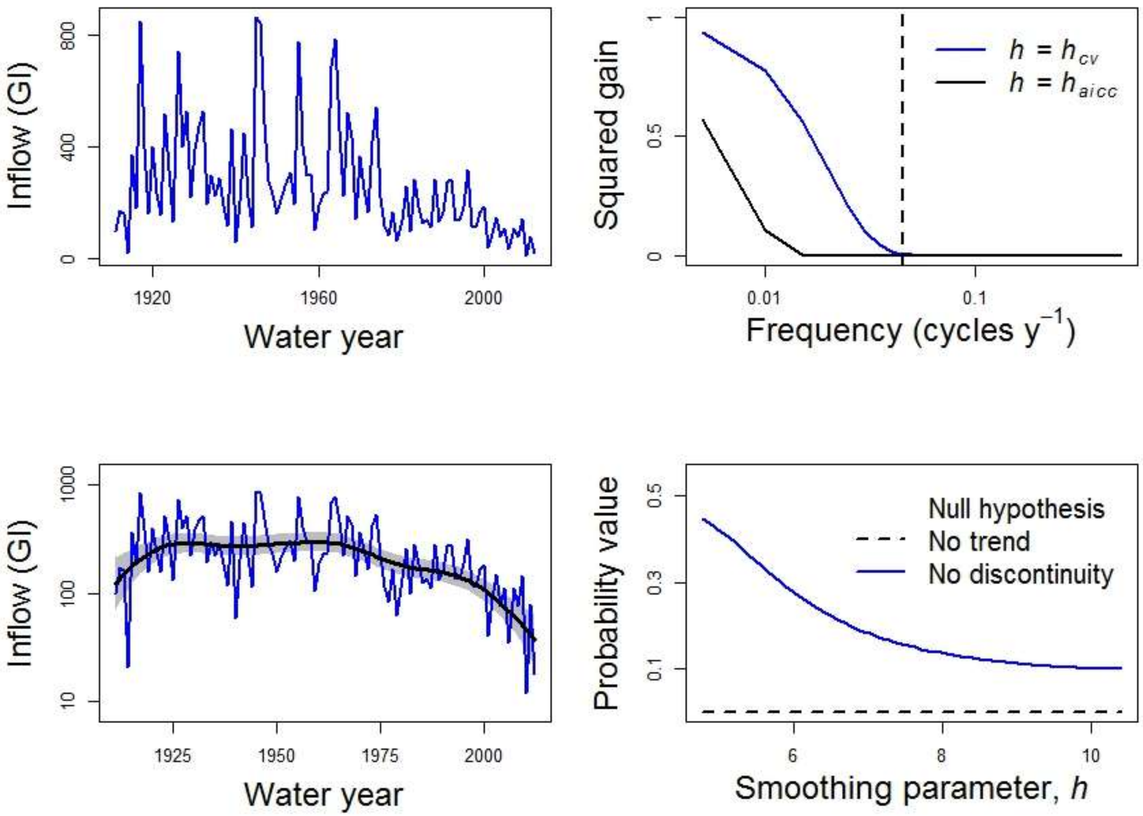


Nonparametric statistics



- Increasing use for trend and change point detection
- Distribution-free: *not* assumption free!
- Assumption: data are *independent* and *identically distributed*
  - Mann-Kendall test (monotonic trend)
  - Pettitt test (change point detection)
- Nothing 'sacred' about a 0.05 probability value
- Multiple testing (comparisons): $P(1 \text{ error in } m \text{ tests}) = 1 - (1 - \alpha)^m$
- Classical tests fallen into disuse in statistical science with advent of modern computers and model-based statistics

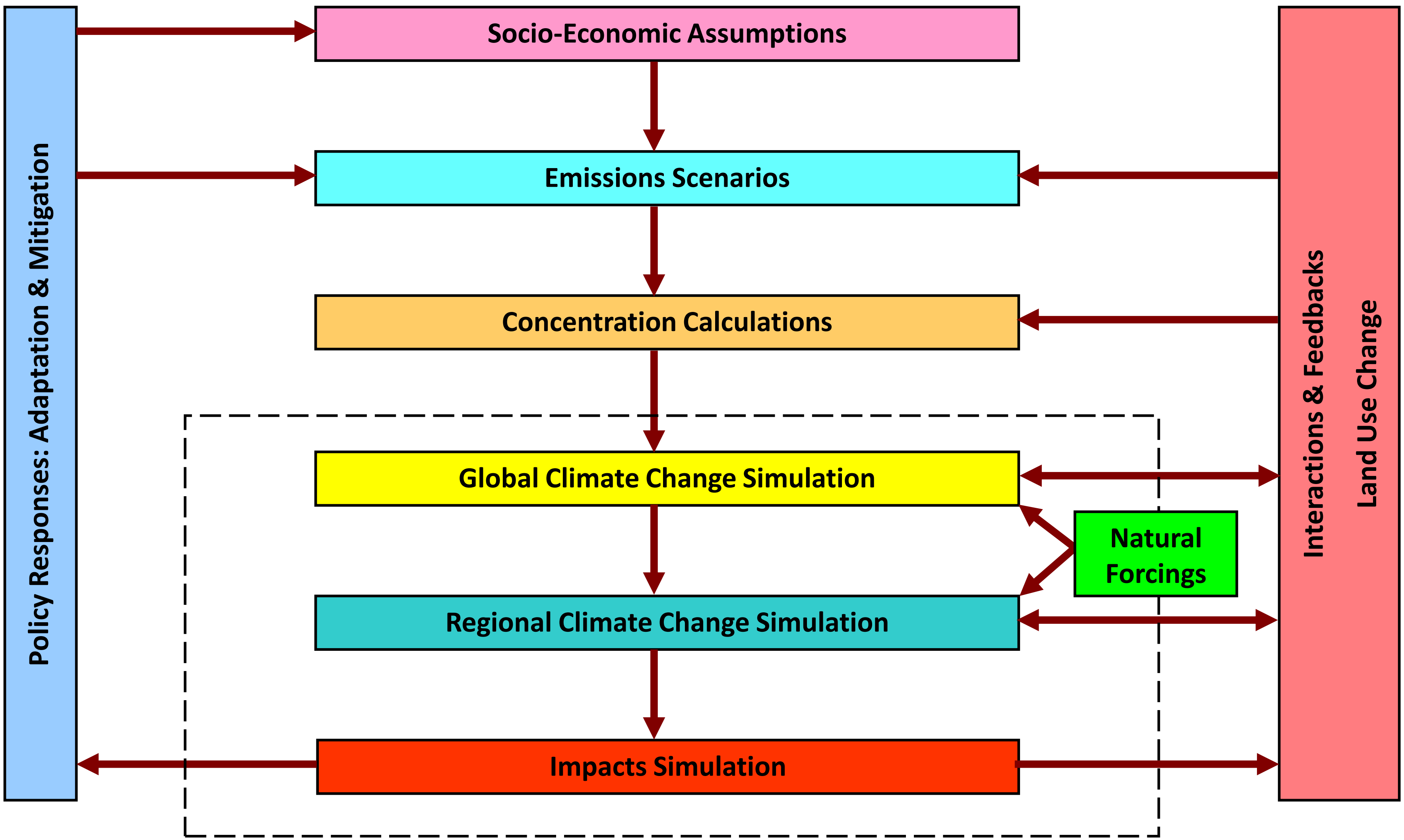
IWSS annual dam inflows



- 1911 to 2012
- $r_{1:3}$ = 0.34, 0.37, 0.30
- Pettitt test
  - K_T = 1644 at 1975
  - p-value = 5.4 x 10^{-7}

The uncertainty cascade

Adapted from Mearns et al (2001)



GCM selection problem

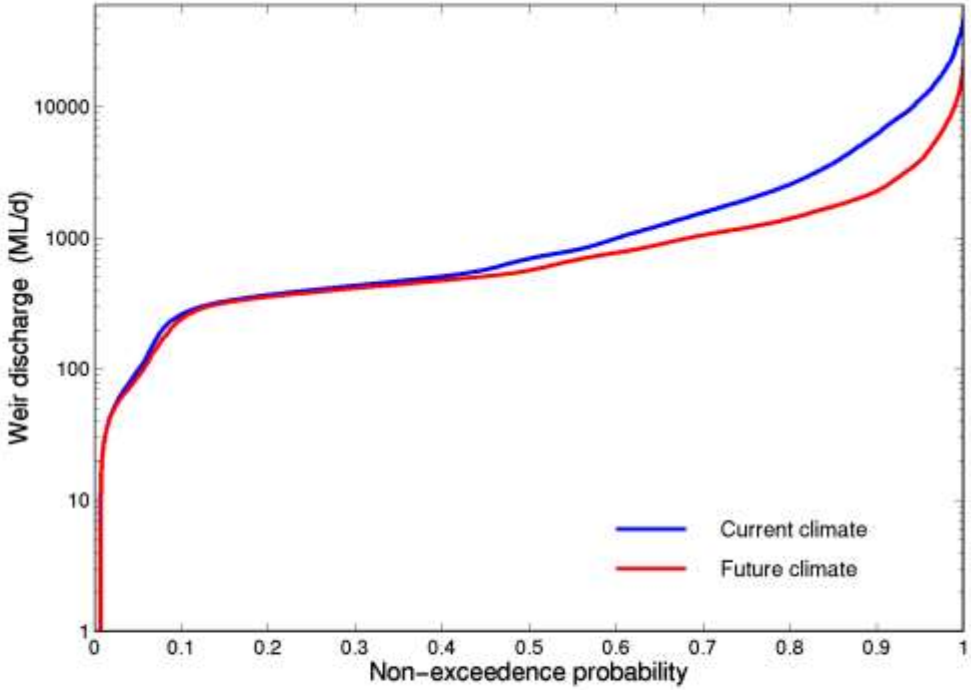
Climate Model	van Oldenborgh (realistic ENSO)	Perkins (Aust)	CMAR (Aust)	Maxino (MDB)	Charles (SE MDB MSLP)
GFDL2.0	Yes	Yes	Yes	No	Yes
GFDL2.1	Yes	Yes	Yes	No	Yes
ECHAM5	Yes	Yes	Yes	No	No
GISS-ER	No	Yes	Yes	No	No
CSIRO Mk3	No	Yes	No	Yes	No
MRI-CGCM	No	No	No	Yes	Yes
CGCM3.1	No	No	No	Yes	No
IPSL-CM4	No	No	No	Yes	—

Climate change impact assessments

- Changes in water use efficiency of plants?
- Changes in meteorological risk of bushfire?
- Changes in vegetation composition and structure?
- GCMs are not physically (and hence statistically) independent
- Hydrological model parameters – sensitive to climate?
- Statistical downscaling – a growing cottage industry?
- Changes in antecedent conditions?
- Changes in flow regime, not just the mean!
- Water planner: "Current (*circa 2006*) drought in western Victoria is worse than worst case scenario for 2070 – please explain?"

Flow duration curve

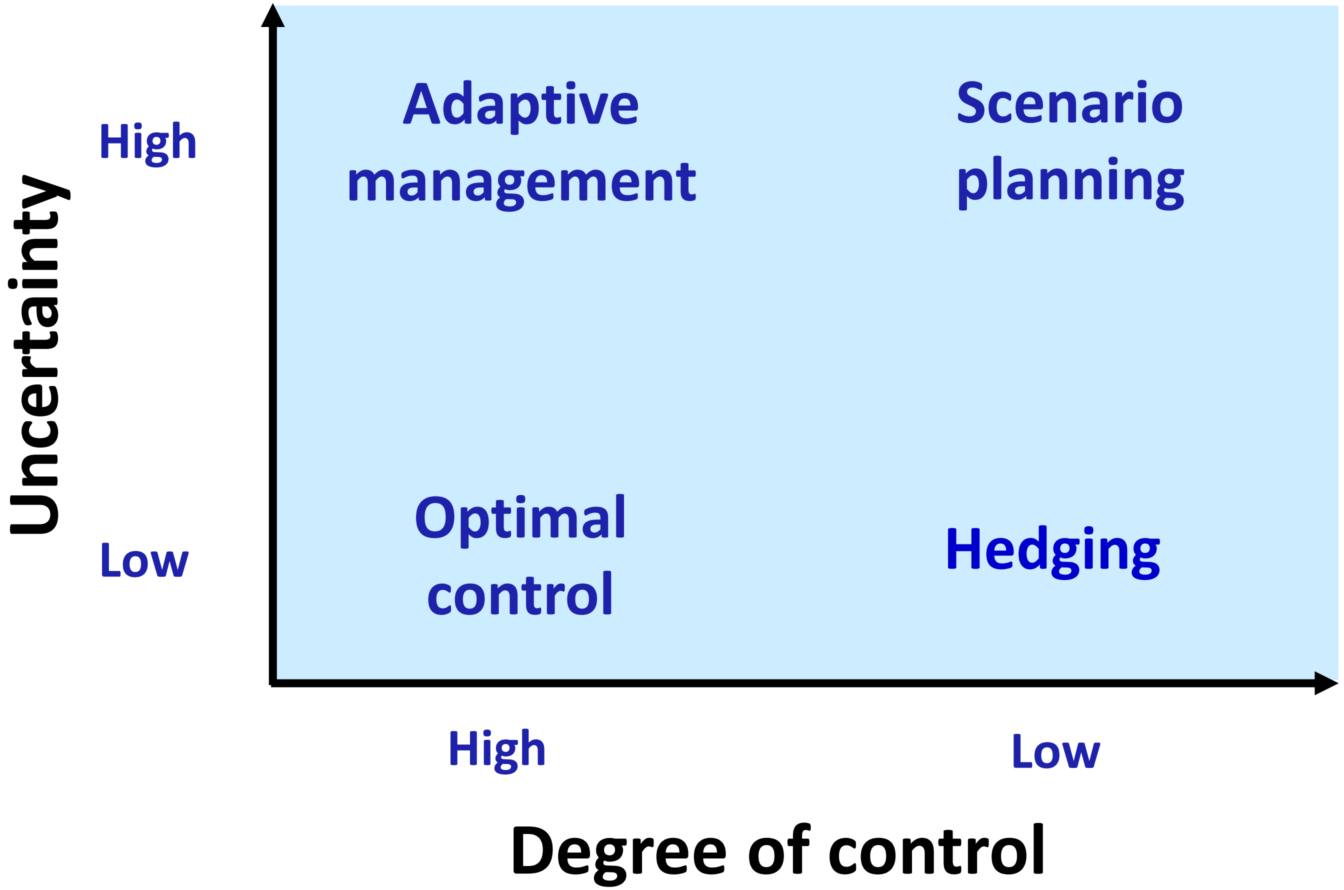
Viney et al (2007)



- Murrumbidgee @ Maude Weir
- Downscaled CSIRO Mark 3 GCM
- 30-yr time slice of SRES A2 centred at 2050
- ~ 8% rainfall decrease
- 0.9 °C increase in maximum temperature
- 45% of the 52% reduction in flows occurs for highest 50%

Approaches to systems planning

Adapted from Peterson et al (2003)



Climate futures web tool

Southern Victoria and Tasmania – 2060 under RCP4.5
GCM simulated winter rainfall (% change) and temperature (°C warming)

LIKELIHOOD	PROPORTION OF MODELS
Not projected	No models
Very low	< 10 %
Low	10 to 33 %
Moderate	33 to 66 %
High	66 - 90 %
Very high	> 90 %

		June - Aug temperture (°C)			
		Slightly warmer 0 to +0.5	Warmer +0.5 to 1.5	Hotter +1.5 to +3.0	Much hotter > +3.0
June - Aug rainfall (%)	Much wetter > +15.0		1 of 34 models		
	Wetter +5.0 to +15.0		3 of 34 models	1 of 34 models	
	Little change -5.0 to +5.0		15 of 34 models	1 of 34 models	
	Drier -15.0 to -5.0		8 of 34 models	2 of 34 models	
	Much drier < -15.0		3 of 34 models		

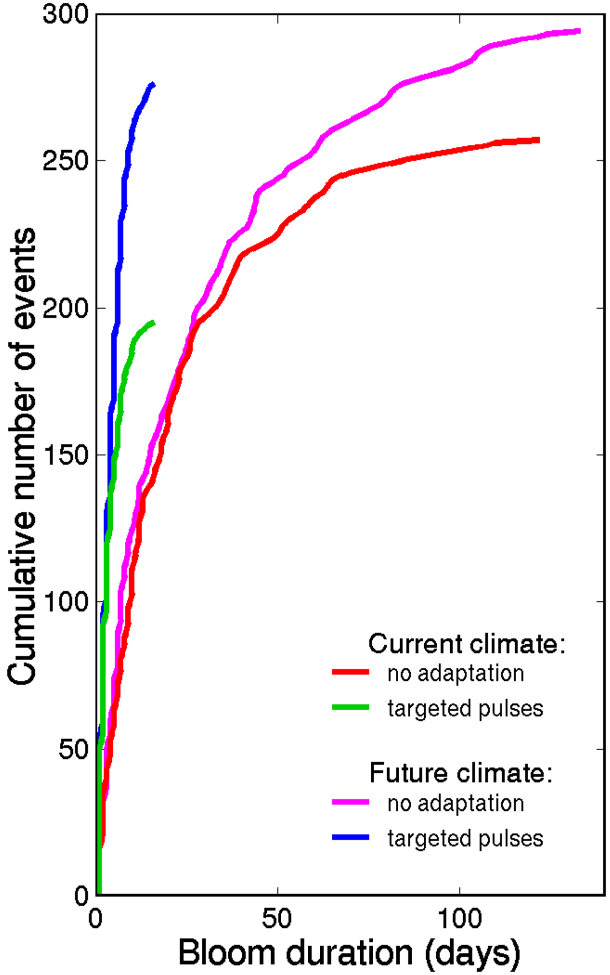
CSIRO

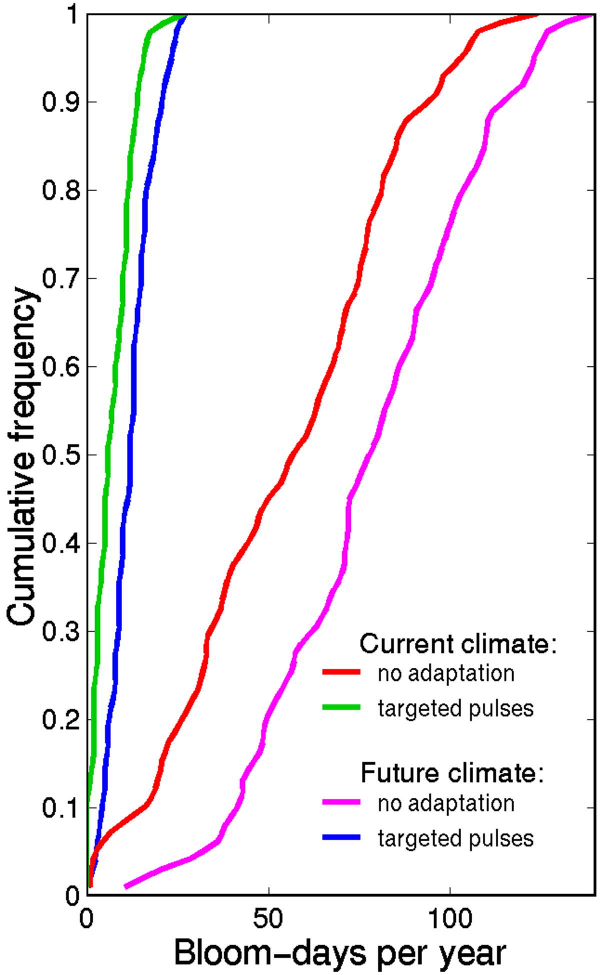
Robust adaptation strategies

Lempert and Schlesinger (2000); Pittock et al (2001);
Dessai et al (2009); Hallegatte (2009)

- Climate change – an additional dimension of risk
- Adopt most robust solution, not ‘best’ under one scenario
  - No-regret: benefits even in absence of climate change
  - Reversible: short-lived, cheap-to-retrofit design
  - Safety margin: over-design at null or low cost; “safe to fail, not fail safe”
  - Soft: e.g. State or city water plans
- Reduced sensitivity to emissions scenario/RCP selection, model error and (probably irreducible) uncertainty
- More likely to succeed than 'optimal' solutions based on projections – cannot attribute probabilities
- Must be efficient economically and socially acceptable

Algal bloom manipulation





Viney et al (2007)

Prudent action under uncertainty

- Preparedness, not prediction
- Reliability, resilience and <u>immediate</u> net benefits
- Consider
  - Small number of projections and scenarios (avoids "paralysis by analysis")
  - Low probability, high impact events (<u>not</u> "most likely" or "best guess")
  - Compare costs of immediate adaptation and retrofitting
- <u>Continuous</u> cycle of planning and evaluation
  - Contingency plans with trigger points for alternative courses of action
  - Quantify planning, resourcing and construction lead times
  - Identify means for reducing lead times
  - Maintain/enhance observational networks in a considered fashion
- Adaptive governance arrangements and markets (pricing)
- Assess socio-political acceptability <u>well</u> in advance