Managing Water Resources under Climate Uncertainty: Challenges & Opportunities

Bryson C. Bates
Climate Change Adaptation Conference
30th June 2010
Preliminary comments

- Climate has changed, & will always change
- Uncertainty & surprise are inevitable; risk is certain
- Climate variability will continue at all temporal scales
- Believe/disbelieve – manage the risk
- The science is incomplete
- Cannot wait for full scientific certainty
- Eliciting information about climate vulnerability & coping mechanisms can be illuminating
- Climate is not the only source of water stress – population growth; rising water demand for economic growth; environmental water allocations; agriculture; pollution, ...
Distinguishing characteristics

- Extent to which 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
- Extent to which climate change projections considered
- Extent to which contingency plans & triggers identified & articulated

Marsden, Jacob & Assoc. (2006)
Approaches to systems planning

(Adapted from Peterson et al., 2003)

- **Adaptive management**
- **Scenario planning**
- **Optimal control**
- **Hedging**

Uncertainty:
- High
- Low

Degree of control:
- High
- Low
The uncertainty cascade

Policy Responses: Adaptation & Mitigation

Socio-Economic Assumptions

Emissions Scenarios

Concentration Calculations

Global Climate Change Simulation

Regional Climate Change Simulation

Impacts Simulation

Interactions & Feedbacks

Land Use Change

Natural Forcings

(Adapted from Mearns et al., 2001)
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 & temporal averaging
- **Parameter uncertainty**: 'tuneable' parameters in model schemes & numerical algorithms
- **Initial & boundary conditions**
## Selection of AR4 GCMs

<table>
<thead>
<tr>
<th>Climate Model</th>
<th>van Oldenborgh (realistic ENSO)</th>
<th>Perkins (Aust)</th>
<th>CMAR (Aust)</th>
<th>Maxino (MDB)</th>
<th>Charles (SE MDB MSLP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GFDL2.0</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>GFDL2.1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>ECHAM5</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>GISS-ER</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>CSIRO Mk3</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>MRI-CGCM</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CGCM3.1</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>IPSL-CM4</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>_</td>
</tr>
</tbody>
</table>
Probabilistic scenarios: limitations

- Propagation of uncertainty through nonlinear models amplifies uncertainty
- Rigorous exploration of entire uncertainty space would be labour intensive & computationally expensive
  - models & ensembles samples drawn from populations
  - statistical independence questionable
  - estimates of pdfs highly conditioned on models & methods used
  - therefore, can only represent fraction of total uncertainty
- Prudent policy action could be deferred if levels of uncertainty prove to be irreducible or increase
- Current projections could be biased & level of uncertainty understated
- Maladaptation could occur if projections are accepted without question, misinterpreted or used incorrectly
### Storylines – SE Australia

#### 2050 A1FI

<table>
<thead>
<tr>
<th>Temp/rainfall*</th>
<th>Slightly warmer</th>
<th>Warmer</th>
<th>Hotter</th>
<th>Much hotter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Much drier</strong></td>
<td>No evidence</td>
<td>No evidence</td>
<td>Very unlikely 1 model IPSL-CM4</td>
<td>Very unlikely 1 model CSIRO-Mk3.5</td>
</tr>
<tr>
<td><strong>Drier</strong></td>
<td>No evidence</td>
<td>Very unlikely 2 models GISS-AOM PCM</td>
<td>As likely as not 11 models</td>
<td>Very unlikely 2 models CGCM3.1(T63) MIROC3.2(hires)</td>
</tr>
<tr>
<td><strong>Little change</strong></td>
<td>No evidence</td>
<td>No evidence</td>
<td>Unlikely 4 models</td>
<td>No evidence</td>
</tr>
<tr>
<td><strong>Wetter</strong></td>
<td>No evidence</td>
<td>No evidence</td>
<td>Unlikely 3 models</td>
<td>No evidence</td>
</tr>
<tr>
<td><strong>Much wetter</strong></td>
<td>No evidence</td>
<td>No evidence</td>
<td>No evidence</td>
<td>No evidence</td>
</tr>
</tbody>
</table>

*Classes are changes per degree of global warming*
Robust adaptation strategies

- Work well under present conditions & wide range of plausible climate futures
- Insensitive to resolution of uncertainties
- Reduced sensitivity to violated assumptions (possibly at expense of optimal performance)
- More likely to succeed than 'optimal' decision/policy making based on predictive accuracy of climate models
- Must be efficient economically & socially acceptable

(Lempert & Schlesinger, 2000; Pittock et al., 2001; Dessai et al., 2009)
Algal bloom manipulation

- Murrumbidgee River at Maude Weir
- ‘Downscaled’ CSIRO Mk 3 GCM run
- 30-yr time slices of SRES A2 scenario
- Present versus 2050 (1 x versus 1.7 x CO$_2$)
- ~ 8% rainfall decrease
- 0.9 ºC increase in max temperature
- 45% reduction for highest 50% of flows

(Viney et al., 2007)
Prudent action under uncertainty

- Preparedness rather than the prediction paradigm
- Uncertainty is an essential source of opportunity, discovery & creativity – knowledge, data & models will remain imperfect
- Use scenarios/storylines as well as the historical record
- Develop robust planning paths/trajectories well in advance
- Manage climatic risk – continuous risk planning & evaluation
  - maintain/enhance observational networks
  - build capability & synthesis in climate risk assessment
  - look for low probability, high impact events (not the most likely)
  - identify triggers for action (vulnerability assessment)
  - develop contingency plans: paths & trajectories; not just the 'next source'
    - quantify lead-time; identify means of cutting construction times
- Assess socio-political acceptability well in advance
- Adaptive governance arrangements & markets (pricing)
Planning without action is a daydream
Action without planning is a nightmare

Japanese Proverb
Definitions

- **Optimal control**: planning strategies that attain a desired aim by optimising a defined criterion (e.g. minimum cost)
- **Hedging**: planning strategies designed to eliminate or minimise exposure to risk
- **Adaptive management**: structured, iterative decision-making process in the presence of uncertainty
- **Scenario planning**: testing the viability of alternative strategies by exploring the implications of what is possible

Increasing uncertainty; decreasing control