British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

www.bgs.ac.uk

Effects of climate change on groundwater resources

Previous and future research

Dr Chris Jackson
23rd May 2007

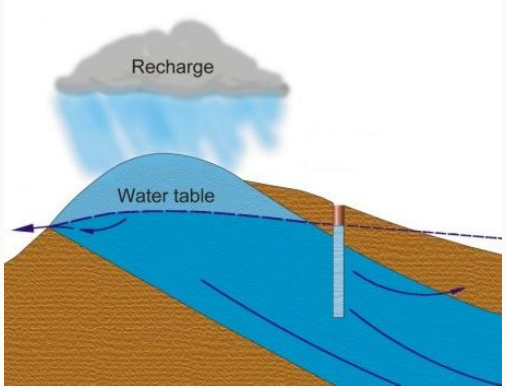
Acknowledgements
John Bloomfield (BGS)
Michael Cheetham (BGS)
Andrew McKenzie (BGS)
Christel Prudhomme (CEH)

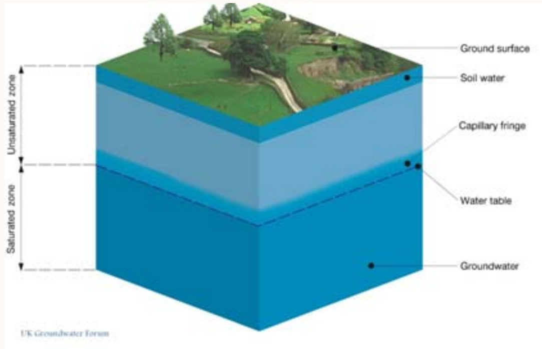
Maclean Building
Crowmarsh Gifford
Wallingford OX10 8BB
Tel 01491 838800

NATURAL ENVIRONMENT RESEARCH COUNCIL

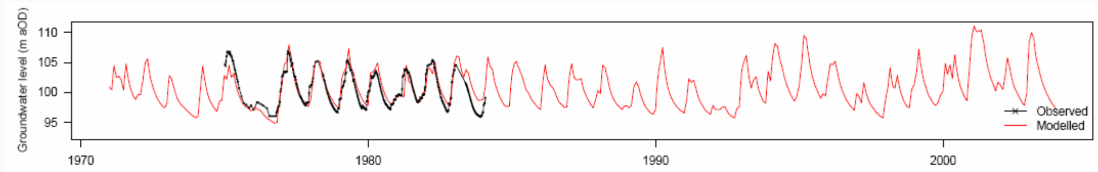
Effects on:

- Groundwater storage
- Groundwater recharge

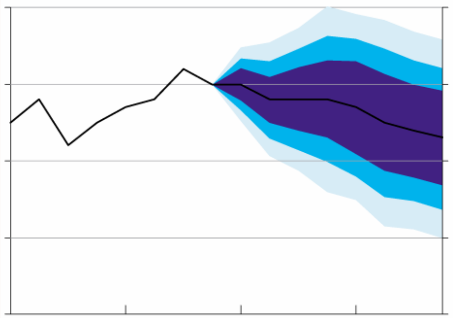




Modelling issues



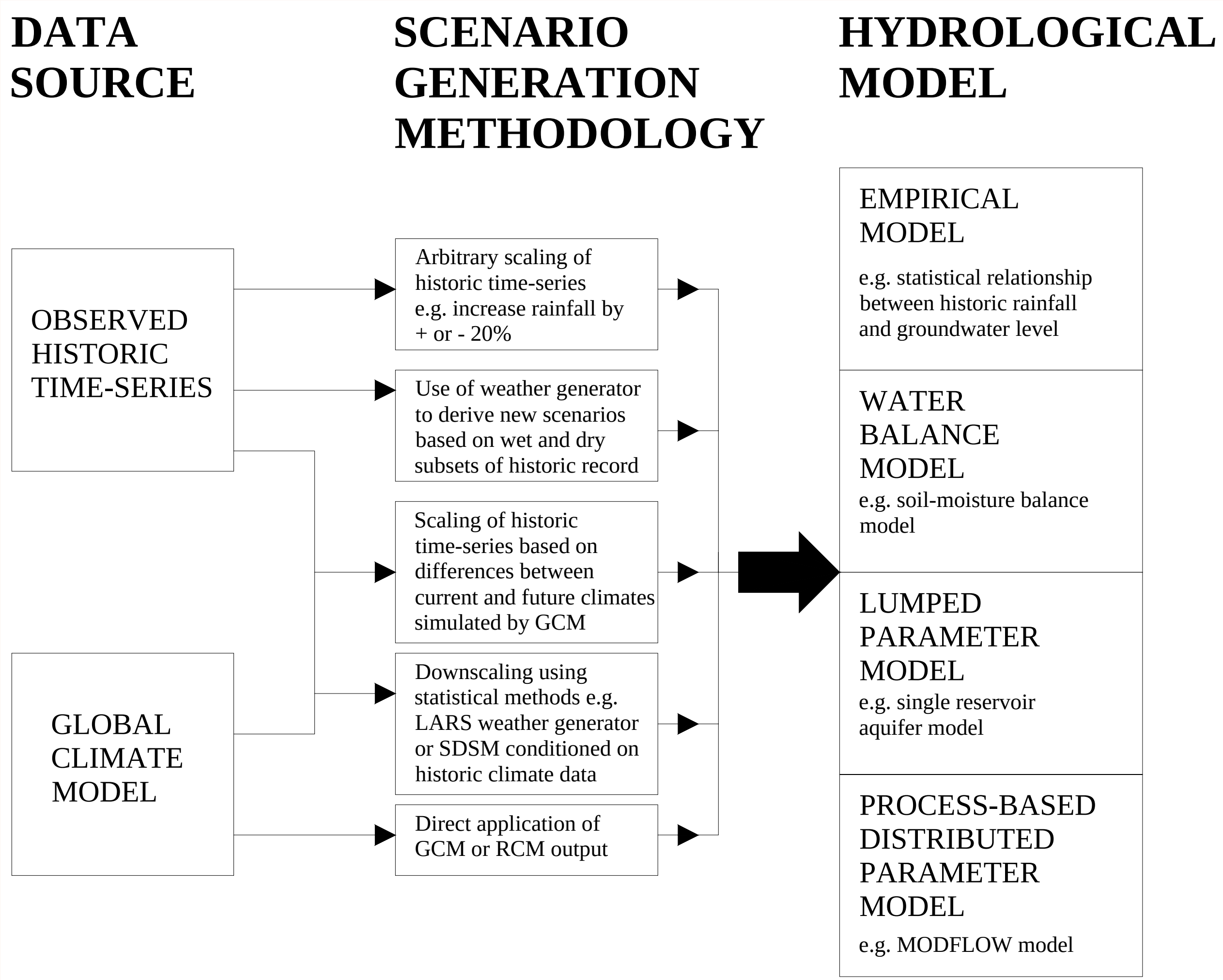
Sources of uncertainty



~~Groundwater quality~~

~~UKWIR research~~

Approaches to modelling effects



Introduction

Groundwater resource studies

Recharge

Modelling effects of climate change

Uncertainty

Summary

Summary of recent groundwater studies

- 16 papers in peer-reviewed literature specifically on the effects of *climate change on groundwater resources* since 1999.

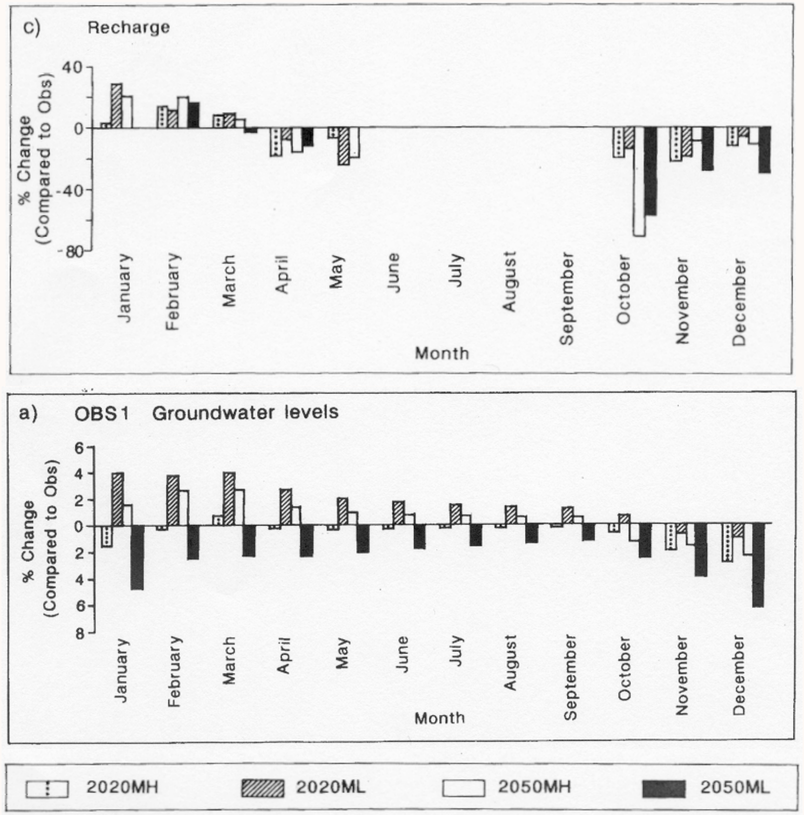
- Almost all studies use a historical weather sequence rather than stochastic weather generation, thus preserving the temporal and spatial structure of present weather patterns.

- Only Brouyère et al. (2004) present results for a Belgian aquifer applicable to the early part of the 21st Century (2010 to 2039).
  - Most scenarios produce a reduction in groundwater levels.
  - No enhancement of seasonal variations in groundwater levels.

- Younger et al. (2002): Yorkshire Chalk aquifer
  - Results for 2036-2045: year-round increases in baseflow are likely.
  - Decreases in river flow were only predicted to occur under the ‘fossil-fuel free energy future’ scenario.
- Results from the studies vary widely ranging from large increases in baseflow (Loáiciga, 2000) to large decreases in baseflow (Gellens and Roulin, 1998). Predicted recharge rates also vary significantly as do future potential groundwater levels.

Yusoff et al. (2002)

Special publication of Geol. Soc.



HadCM2
MH & ML
scenarios

(2020-2035)
(2050-2065)

HadCM2 Global Climate Model

Observed historic time-series

↓

Scaling of historic time-series based on differences between current and future climates simulated by GCM

↓

MODFLOW groundwater model

Yusoff et al. (2002)

- Consistent decrease in recharge during autumn (17 to 35%) – reduced summer rainfall and increased autumn PE.

- Groundwater levels:

  -0.7m to 0.5m change in GWL

- Limbrick et al. (2000). Impacts of climate change on nitrogen transport in the Kennet catchment.

  Three (HadCM) scenarios showed reduction in groundwater storage and recharge due to a shortening of the recharge season and reduction in total annual run-off.

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
www.bgs.ac.uk

Introduction

Groundwater resource studies

Recharge

Modelling effects of climate change

Uncertainty

Summary

Recharge

- Studies restricted to assessment of recharge assume that total GW discharge = total GW recharge under future conditions.
- Consider the inter-annual or sub-annual variations in groundwater discharge rate and the degree to which an aquifer transforms a recharge time-series.
- Aquifer responses might show a significant lag, which may not be apparent by simply equating total recharge to total discharge.

Calculating recharge: soil moisture balance

- Assume all parameters except rainfall & temperature remain constant.
- Neglect land-use change and socio-economic change.
- Neglect changes in soil characteristics and their impact on agricultural practice.
- Reduced plant stomatal conductance (Eckhardt and Ulbrich, 2003: reduction by up to 40% in increased CO_2 atmospheres).

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
www.bgs.ac.uk

Validating recharge calculations

- Rarely validated by direct comparison with observed data.
- Tend to be assessed by examining the results of groundwater flow models to which the calculated recharge is applied.
- Method of calculating PE: Penman-Monteith, Thornthwaite, Blaney-Criddle?
- Recent research as part of the LOCAR Programme (Mathias et al., 2005; Mathias et al., 2006) suggests the concept of ‘field capacity’ applied in soil-moisture balance methods may not be valid for the Chalk.
- Likely that vegetation on chalk soils, transpires at the potential rate for the majority of the year due to the hydraulic properties of the bedrock.

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
www.bgs.ac.uk

Introduction

Groundwater resource studies

Recharge

Modelling effects of climate change

Uncertainty

Summary

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Leavesley (1994) *Climatic Change*

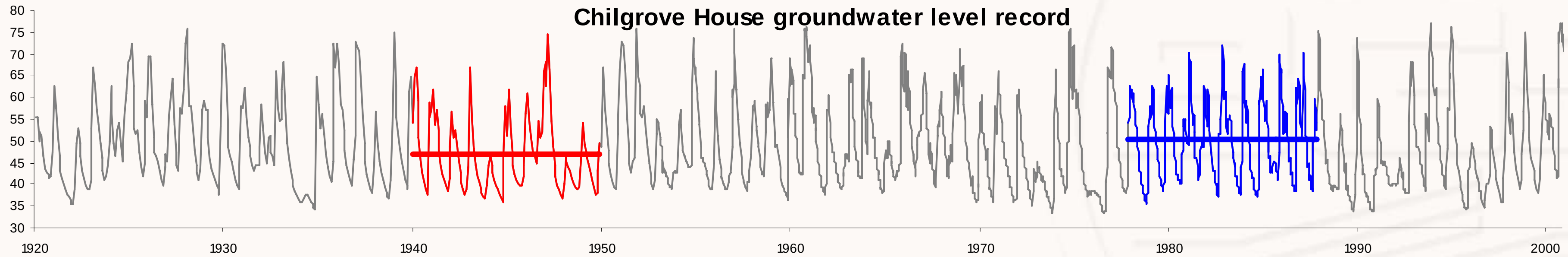
- Four groups of models:
  - Empirical
  - Water balance
  - Conceptual lumped parameter
  - Process based distributed parameter.
- Use of conceptual models, based on effective parameters, to investigate future scenarios is questionable because they are based on historic data and therefore, only represent the relationship between the input stimuli and output response for the period in which they were developed.
- Process based models can better simulate conditions outside of the range of those found during the calibration period, however, it is possible that characteristics of a basin might change during the period of modified climate, which these models can not simulate adequately.
- The usual problems!
  - The limited length of the historic data record.
  - Minimal or no information on the acceptable range of parameter values.
  - Incorporation of model and data errors in parameter values.
  - Inter-correlation of parameters that inadvertently improve the simulation.
  - Non-uniqueness of parameter sets.
  - Dependence of model parameters on sequence of climate variables.

Leavesley (1994) *Climatic Change*

- Model suitability criteria Klemes (1985):
  - The model structure must have a sound physical basis.
  - Each structural component must permit separate validation.
  - The model must be geographically and climatically transferable.

- How do you validate the use of a model for CC impact assessment - quantitative measures of model performance in terms of its ability to simulate new conditions.

- Assessment of climatic transferability of a model.



Introduction

Groundwater resource studies

Recharge

Modelling effects of climate change

Uncertainty

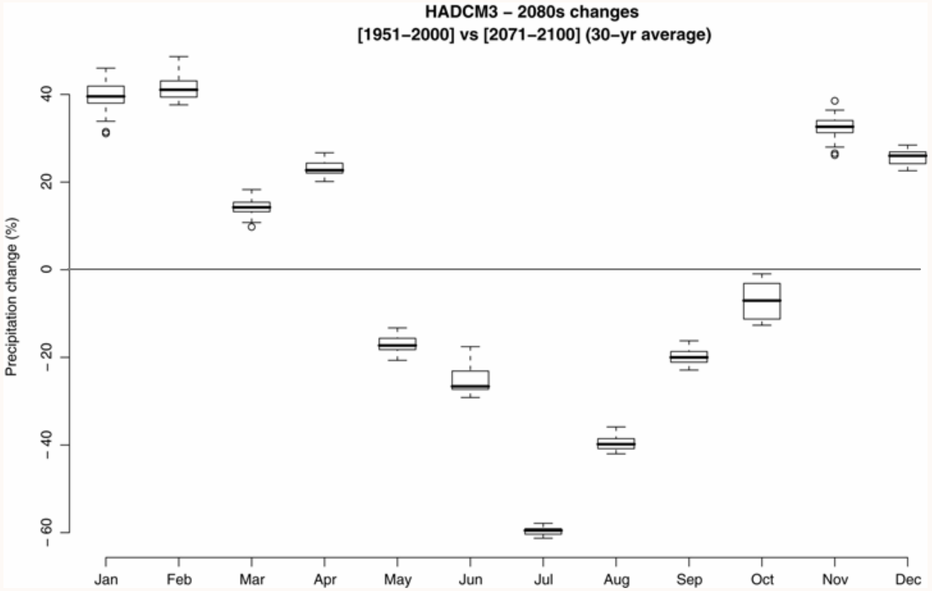
Summary

Sources of uncertainty

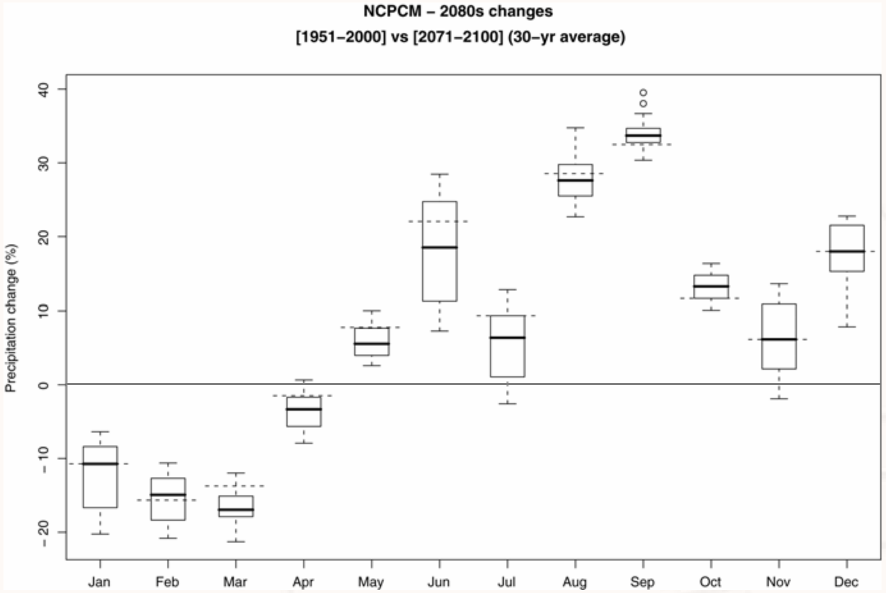
- Ability of GCMs to reproduce current climate.
- Downscaling of GCM output to define regional climate change scenarios.
- Formulation of RCMs.
- CO_2 emission scenarios.
- Groundwater / hydrological models.
    - Calibration period.
    - Structure.
    - Non-uniqueness.
    - Observed data.
    - Etc.

Sources of uncertainty

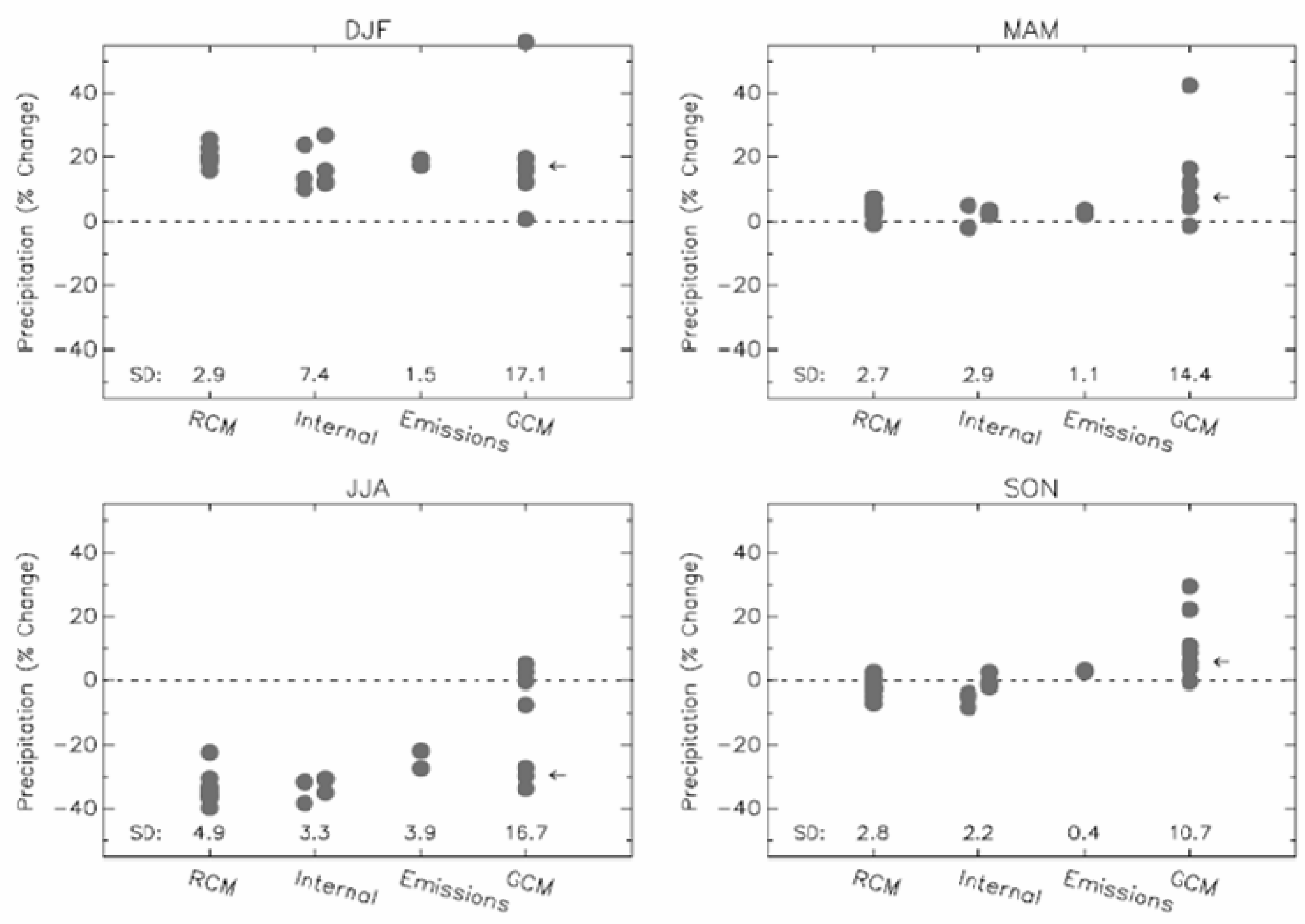
UK HADCM3 – 2080s changes
[1951-2000] vs [2071-2100]
(30-yr average)



USA NCAR PCM – 2080s changes
[1951-2000] vs [2071-2100]
(30-yr average)



Rowell (2006) *Climatic Change*



Summary

- Recharge
  - Not assume that change in recharge = change in resource.
  - Put in context of socio-economic change.
  - Calculation of P.E.
  - SMD approach valid?
- Specific climate change predictions and therefore impact assessments tend to have a short shelf life.
- Significant variation in effects predicted.
- Assess the suitability of hydrological / groundwater models for assessment of CC effects over long periods: climate transferability.
- Quantify and present uncertainty associated with assessments:
  - Apply multiple GCMs.
- Lots to do!