Regionalising hydrologic response under a changing climate

"Prediction in Ungauged Climates"

"Prediction Under Change"



National Research FLAGSHIPS
Water for a Healthy Country
CSIRO

State Government Victoria
Department of Sustainability and Environment

Australian Government
Department of Climate Change and Energy Efficiency
Bureau of Meteorology

MURRAY–DARLING BASIN AUTHORITY

WG1: Top-Down Modelling Working Group

- Co-chair (with Ian Littlewood and Barry Croke) of the TDWG.
- The primary aim of the TDWG is to use parametrically-efficient, lumped, simple rainfall-runoff models to:

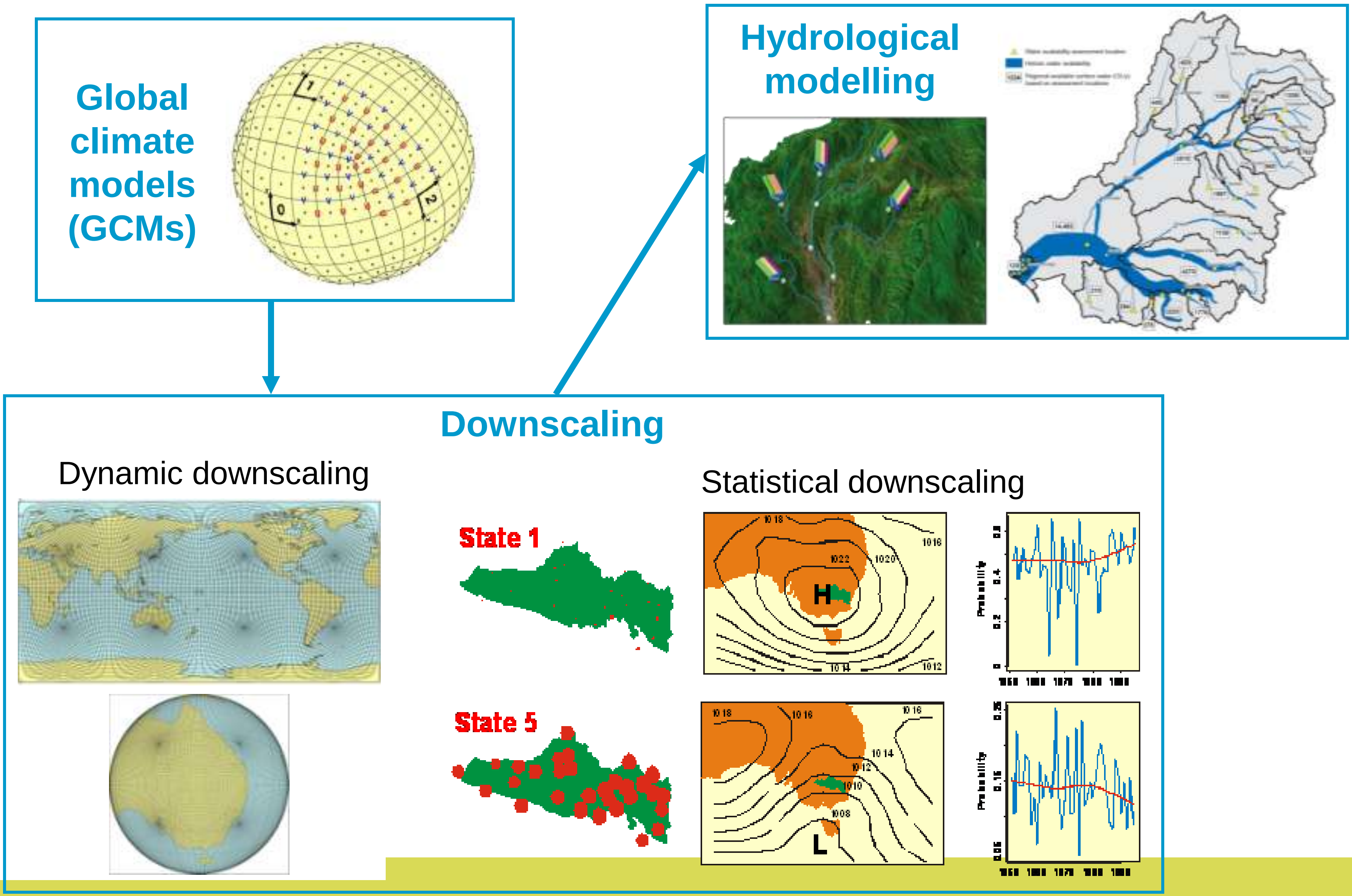
  1. Regionalise hydrologic response to ungauged catchments.
  2. Gain understanding of dominant hydrological processes in order to improve our models.
  3. Add complexity to the models only if warranted by the available data (may require incorporation of new data sources, eg remotely sensed soil moisture, LAI etc),

- Further information can be found at http://tdwg.catchment.org/

South Eastern Australian Climate Initiative

- Theme 1: Understanding Drivers
  - Better understand the factors that drive changes in both climate and streamflow within south-eastern Australia.
  - Determine how much of the “Millennium Drought” across south-eastern Australia is attributable to climate change.
- Theme 2: Hydroclimate Projections
  - Develop improved long-term hydroclimate projections for south-eastern Australia out to 2100.
- Theme 3: Seasonal Forecasts
  - Improve seasonal climate and hydrologic predictions at lead times ranging from several weeks to nine months.

Modelling climate impact on water



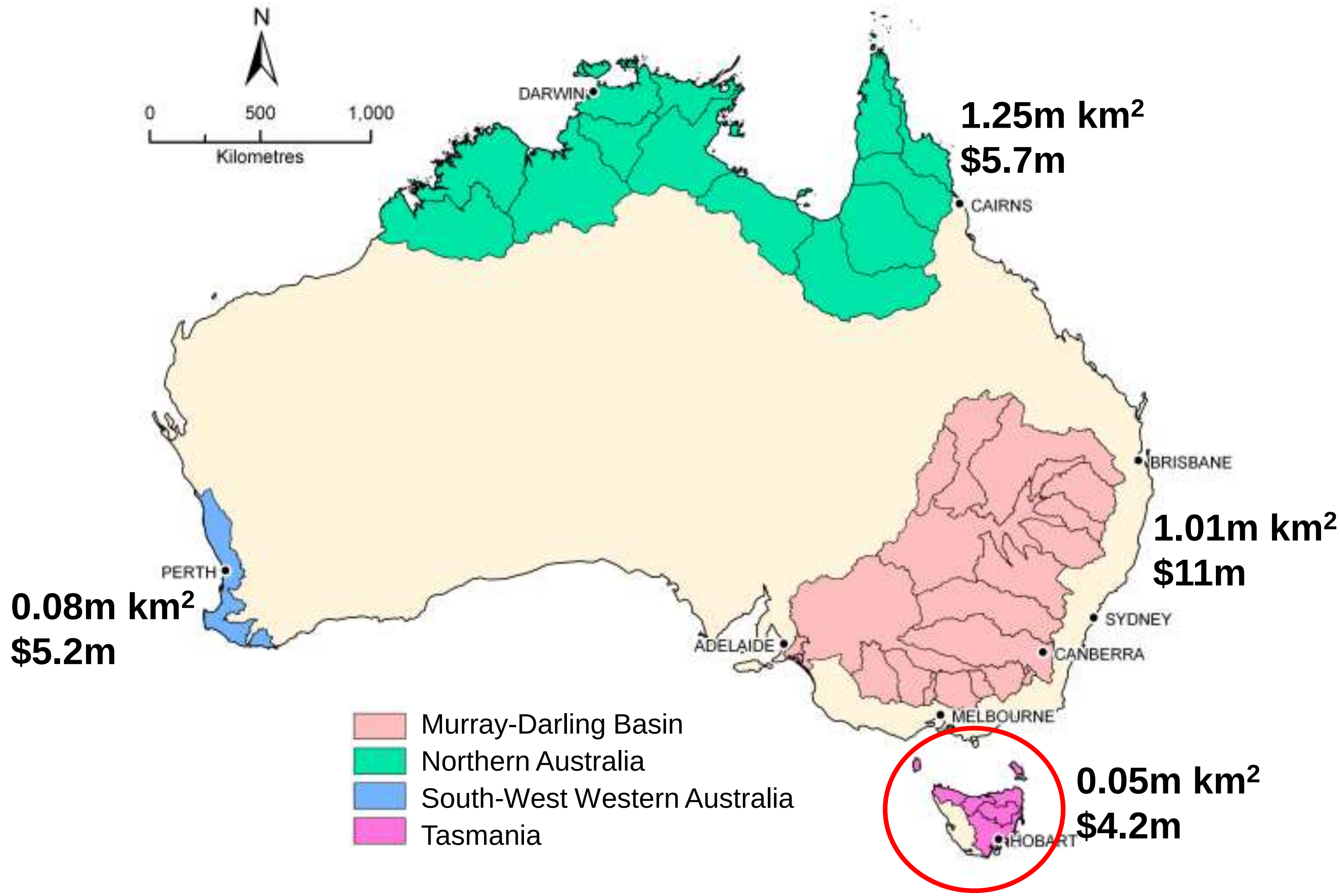
Example – Sustainable Yield assessments

- The Australian Government has tasked CSIRO with carrying out ‘sustainable yield’ assessments across the major river systems in Australia.

- The primary aim of these assessments is to determine current and future water availability and use. This requires:

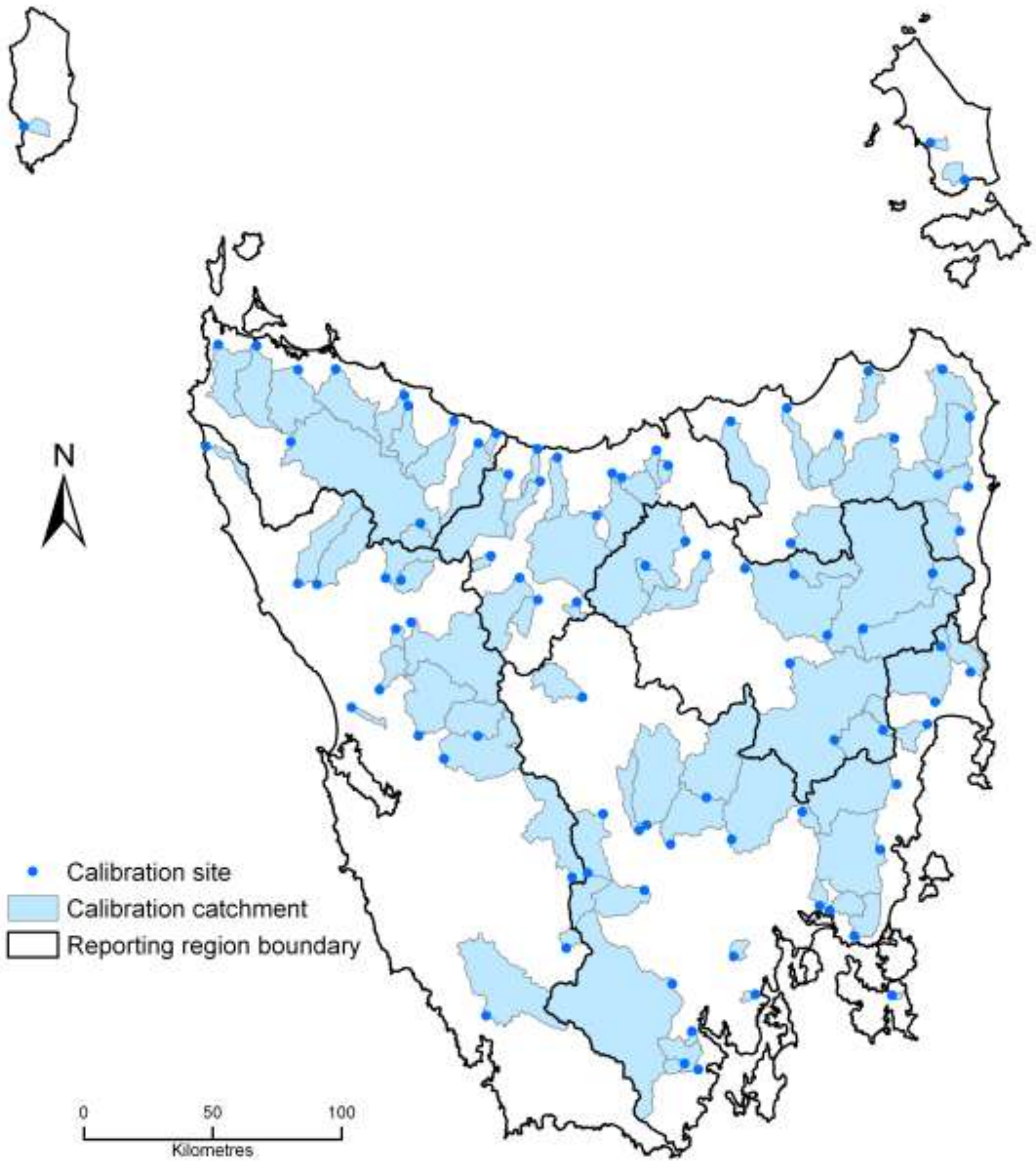
  1. Regionalisation of hydrologic response to ungauged catchments.
  2. Assessment of changes in rainfall/PET across the entire region.
  3. Determine impact of these changes in rainfall and PET on runoff across both gauged and ungauged catchments.

Sustainable Yield assessments

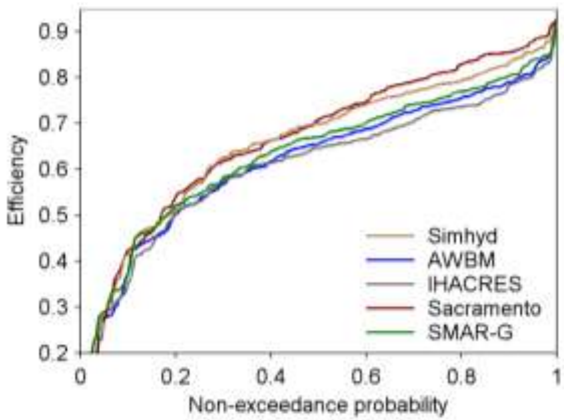


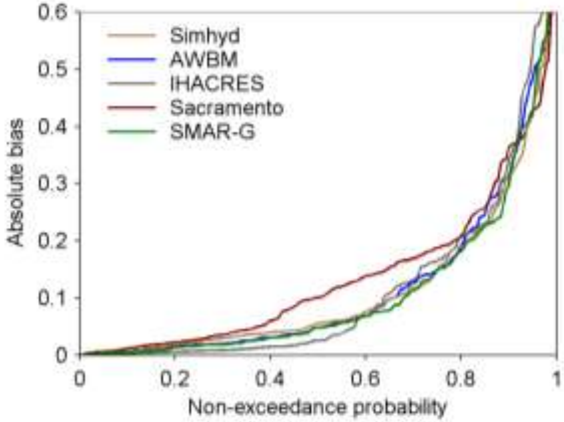
1a. Regionalise current streamflow

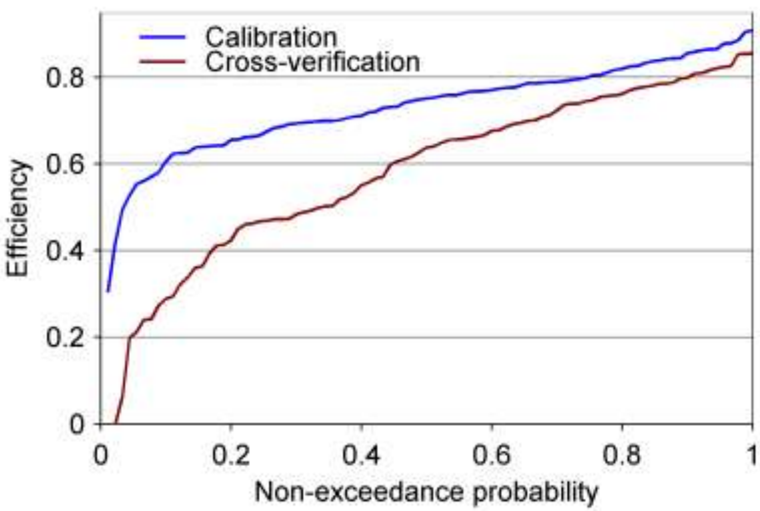
- Calibrate 5 models (SIMHYD, Sacramento, IHACRES, SMARG, AWBM) to 90 unregulated catchments
- Evaluate model performance through cross-validation using parameters from the nearest neighbour
- Choose optimal model and regionalise to ungauged areas.

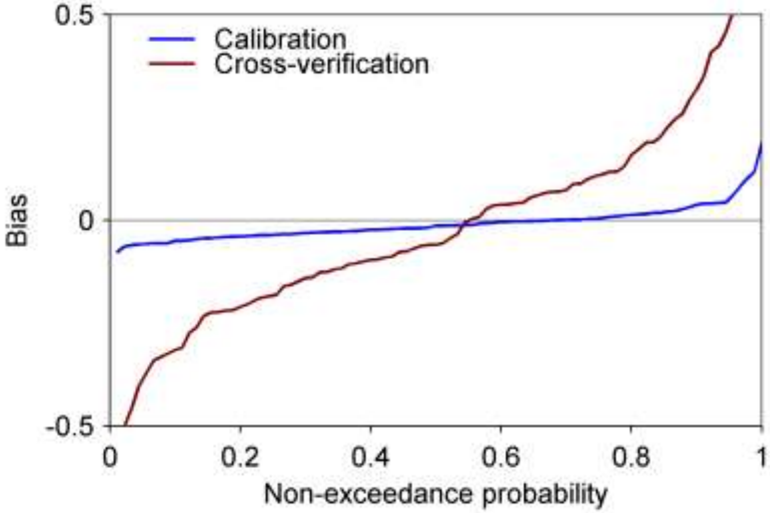


1b. Assess regionalisation results

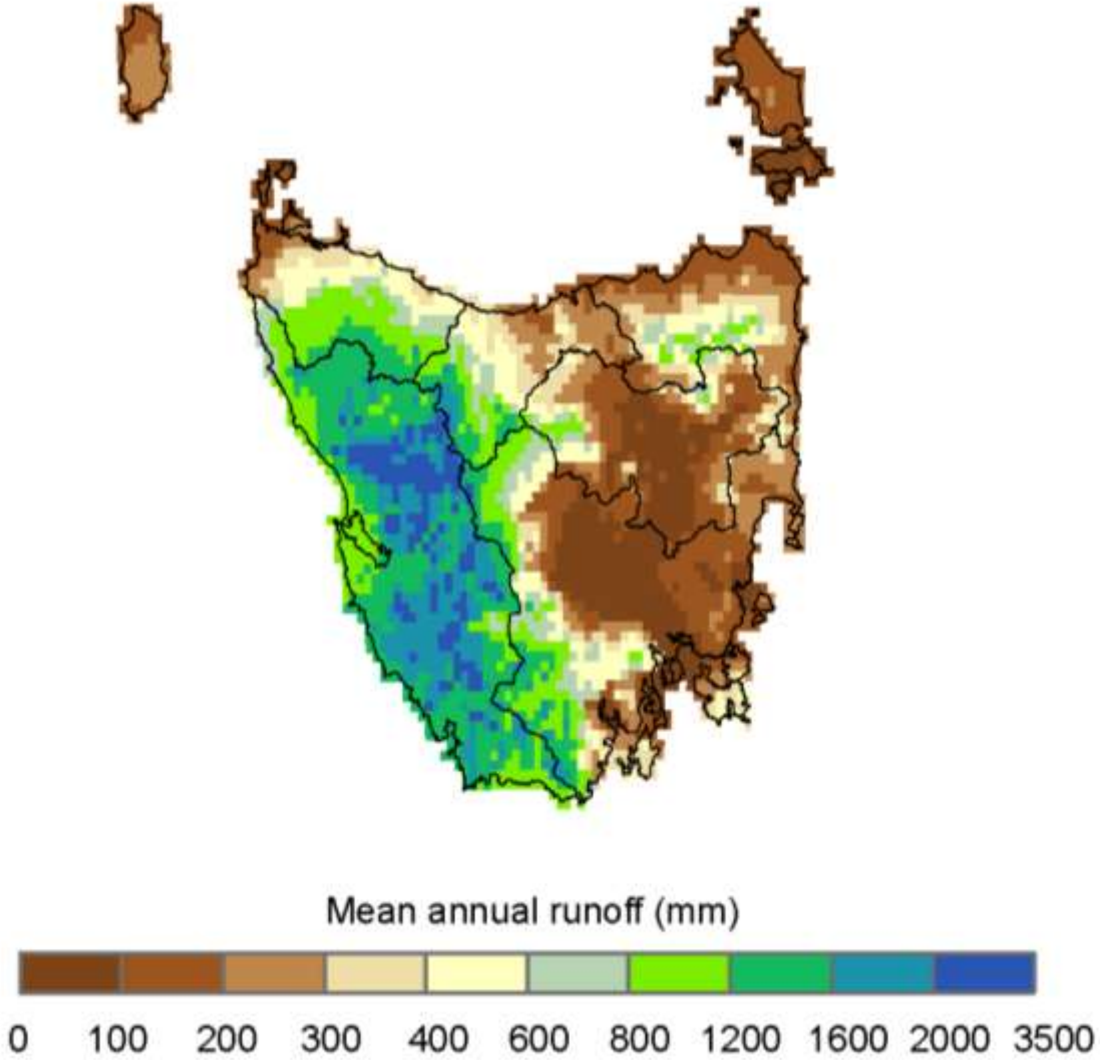




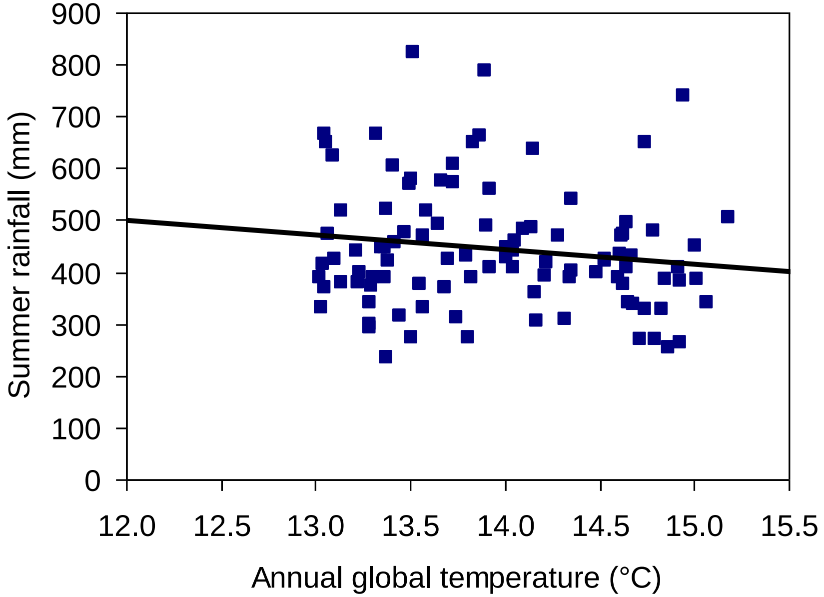


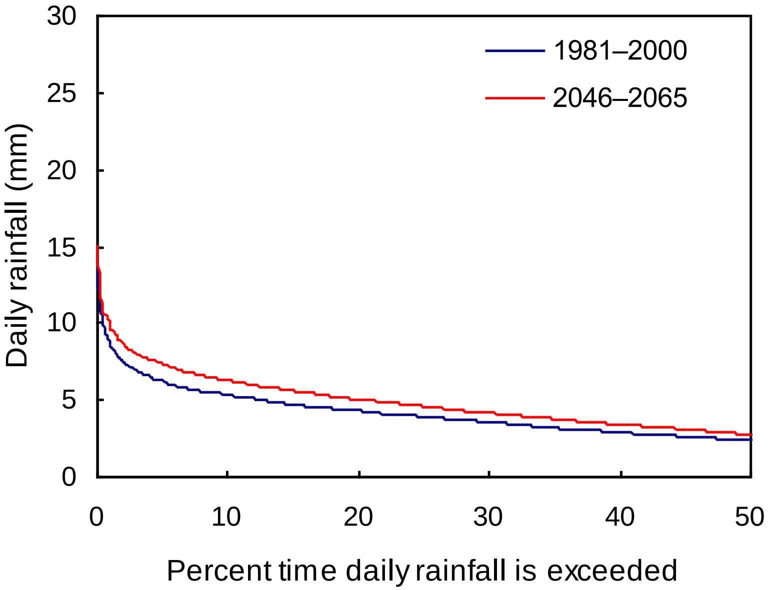


1b. Regionalise hydrologic response



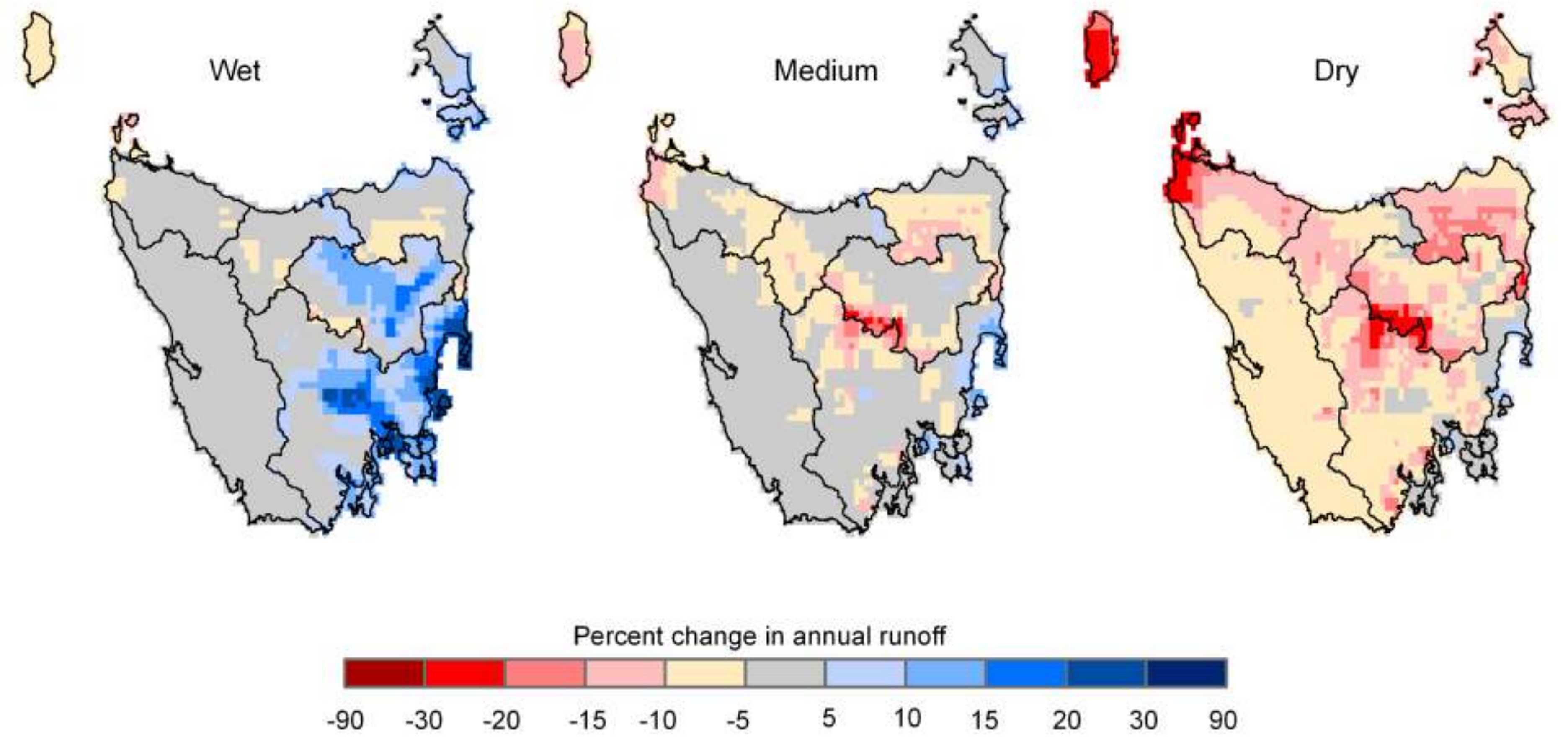
2. Determine future rainfall and PET





- Calculate change in seasonal rainfall per degree global warming for 15 of the 23 GCMs in IPCC AR4
- Scale daily rainfall amounts differently depending on their size

3. Assess changes in future runoff

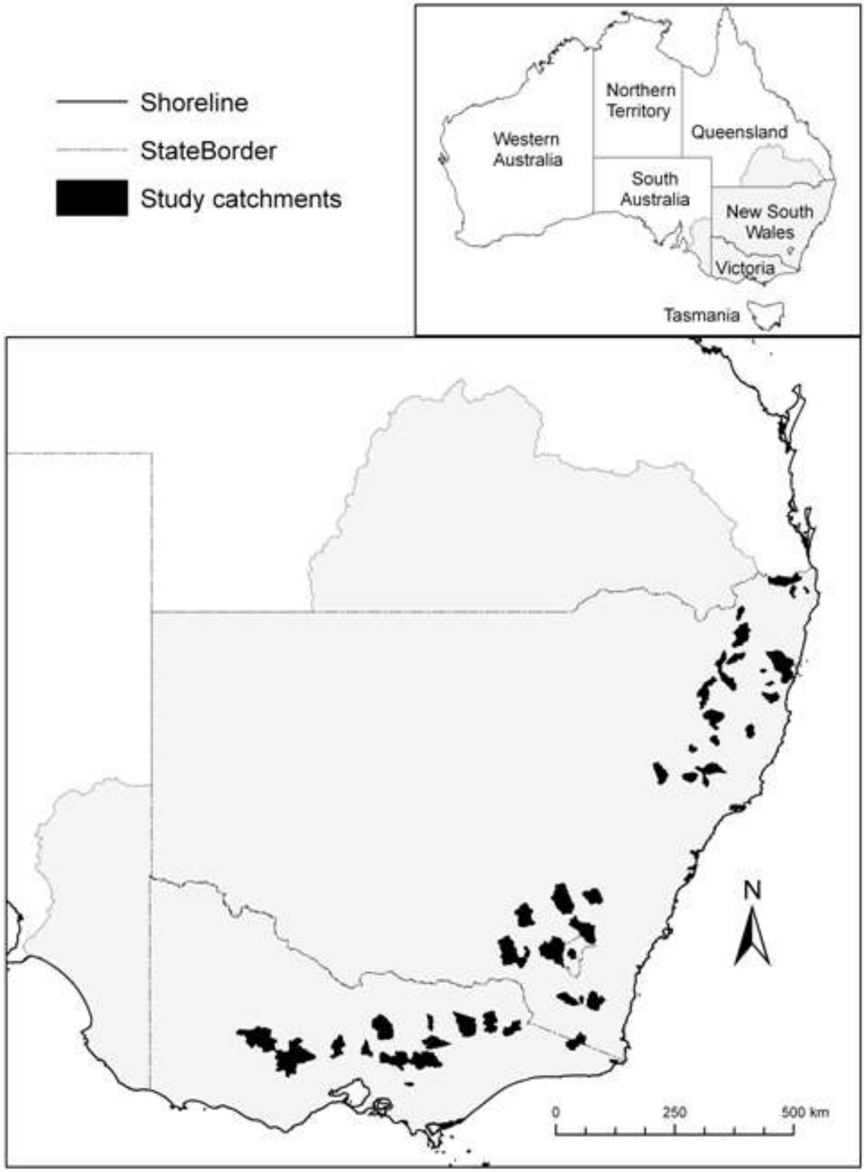


So, what's the problem?

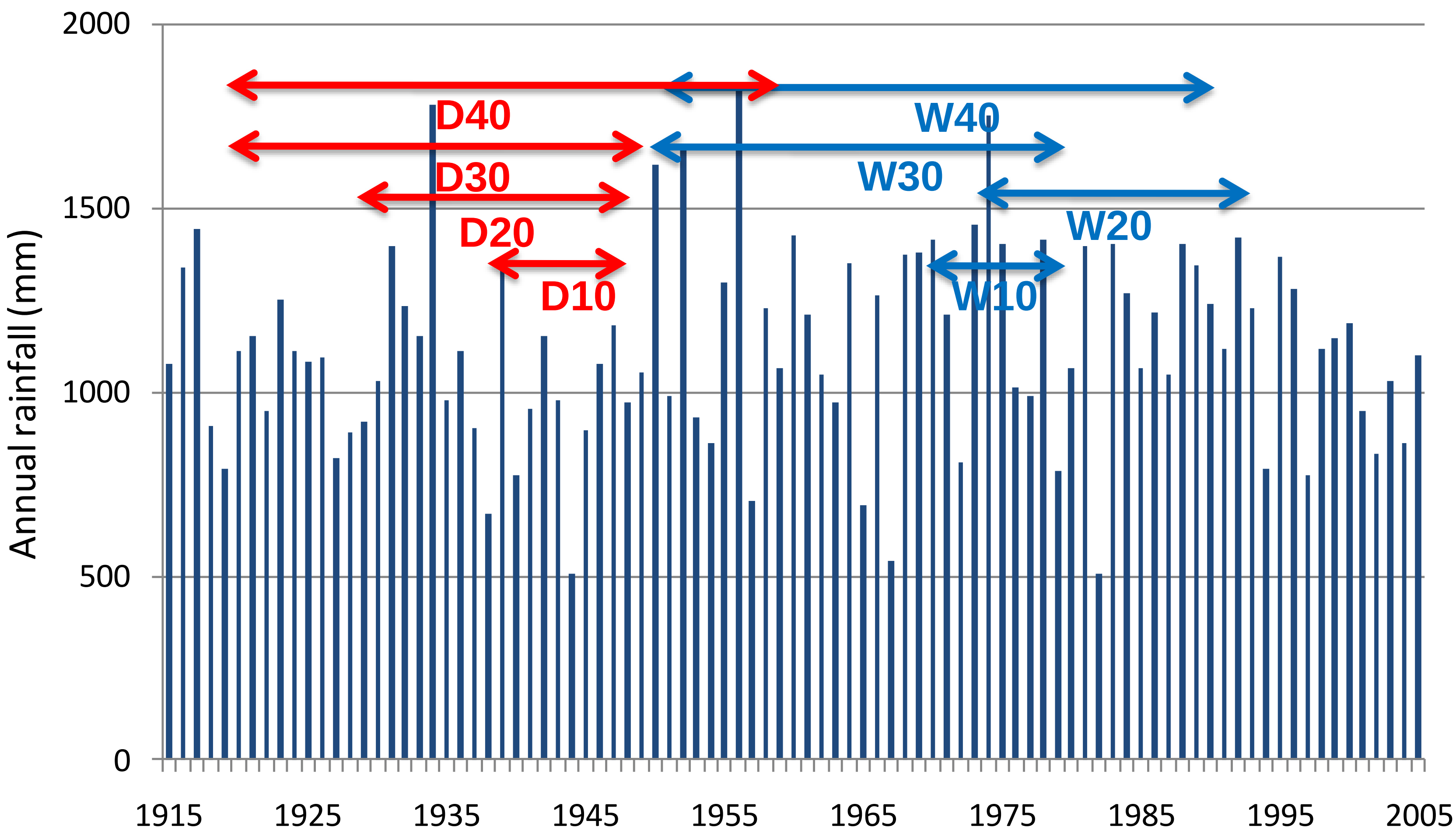
- As we have seen, large scale "climate change impact on runoff studies" use rainfall-runoff models in conjunction with future climate projections from GCMs/RCMs.
- These conceptual rainfall-runoff models need calibration.
- The question therefore is, are the rainfall-runoff model parameters calibrated using historical data valid under future climatic conditions?

Vaze et al. 2010: Study area and data

- South-eastern Australia
- 61 catchments with daily streamflow data for at least 60 years
- Less than 20% missing data
- Unregulated catchments, with areas between 50 - 2000 km^2



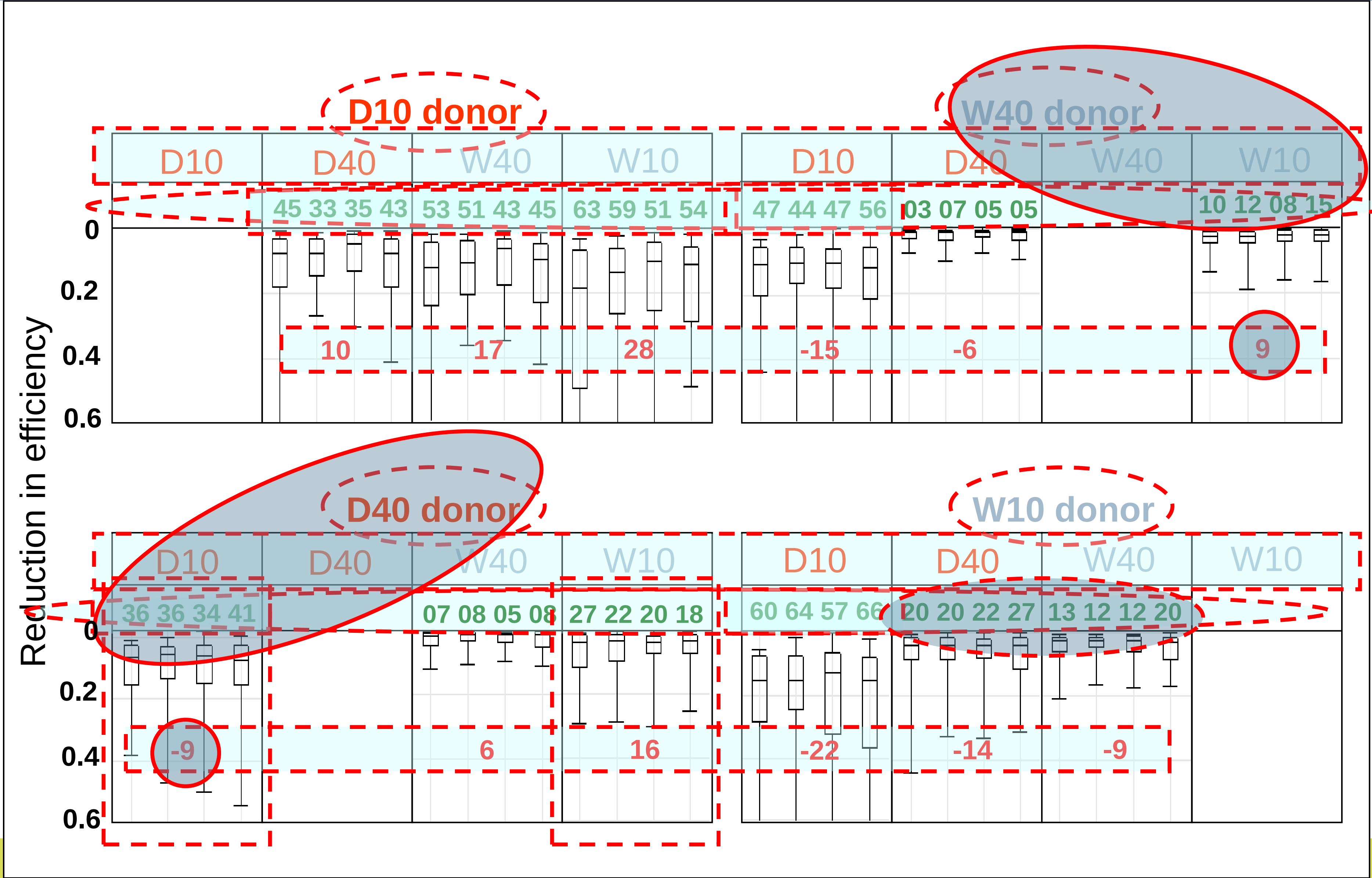
Determination of dry and wet periods



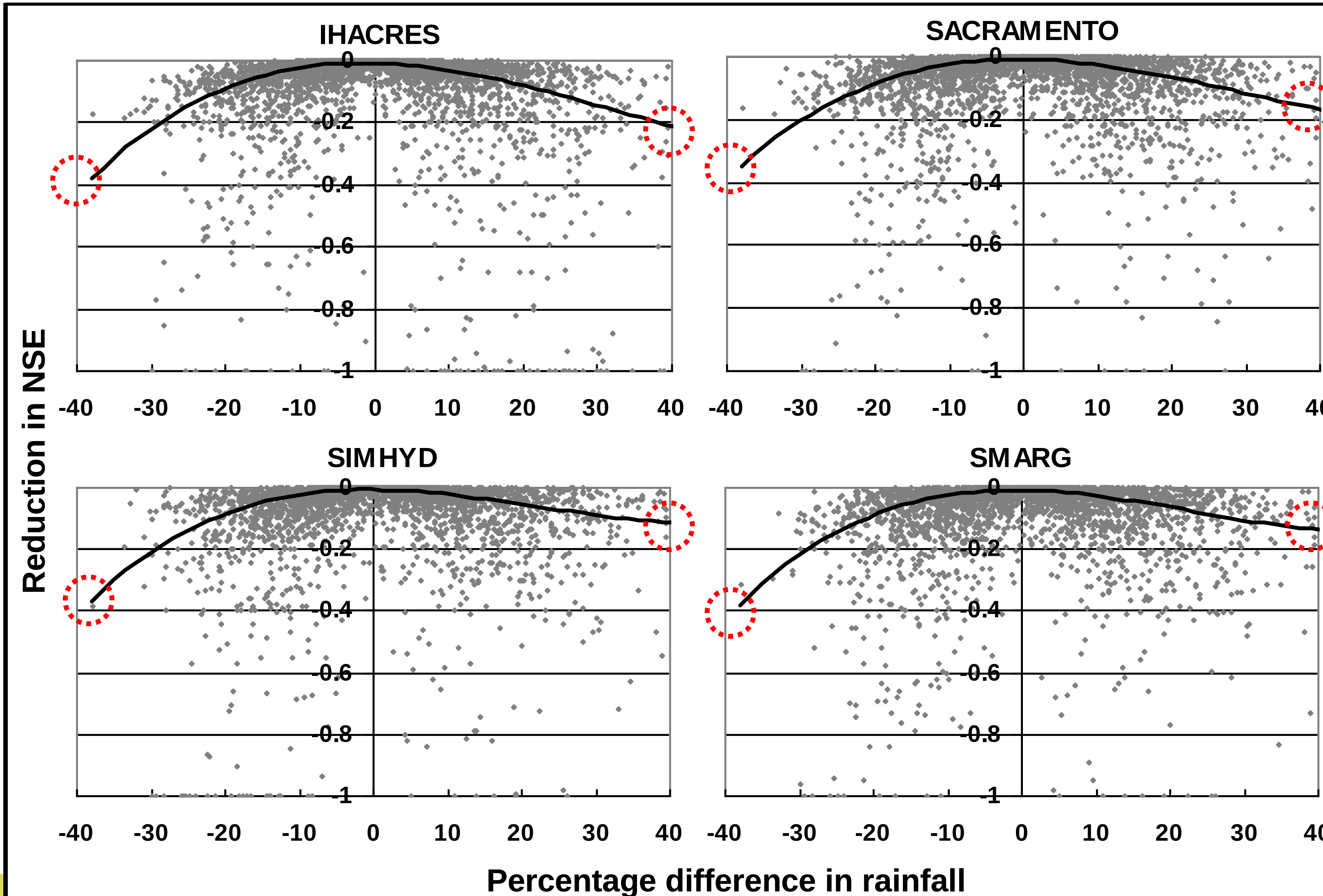
Modelling methodology

- Four conceptual rainfall-runoff models used – SIMHYD, Sacramento, SMARG and IHACRES
- Model calibration
  - The four rainfall-runoff models were calibrated against observed streamflow data for each of the eight individual calibration periods.
- Model simulation
  - The calibrated parameter values for each data period were used to simulate runoff over the remaining seven data periods.
  - The simulation efficiencies were then compared to the calibration efficiencies in those periods to assess whether a model calibrated over a dry (or wet) period can adequately reproduce the hydrologic response of a wetter (or drier) period.

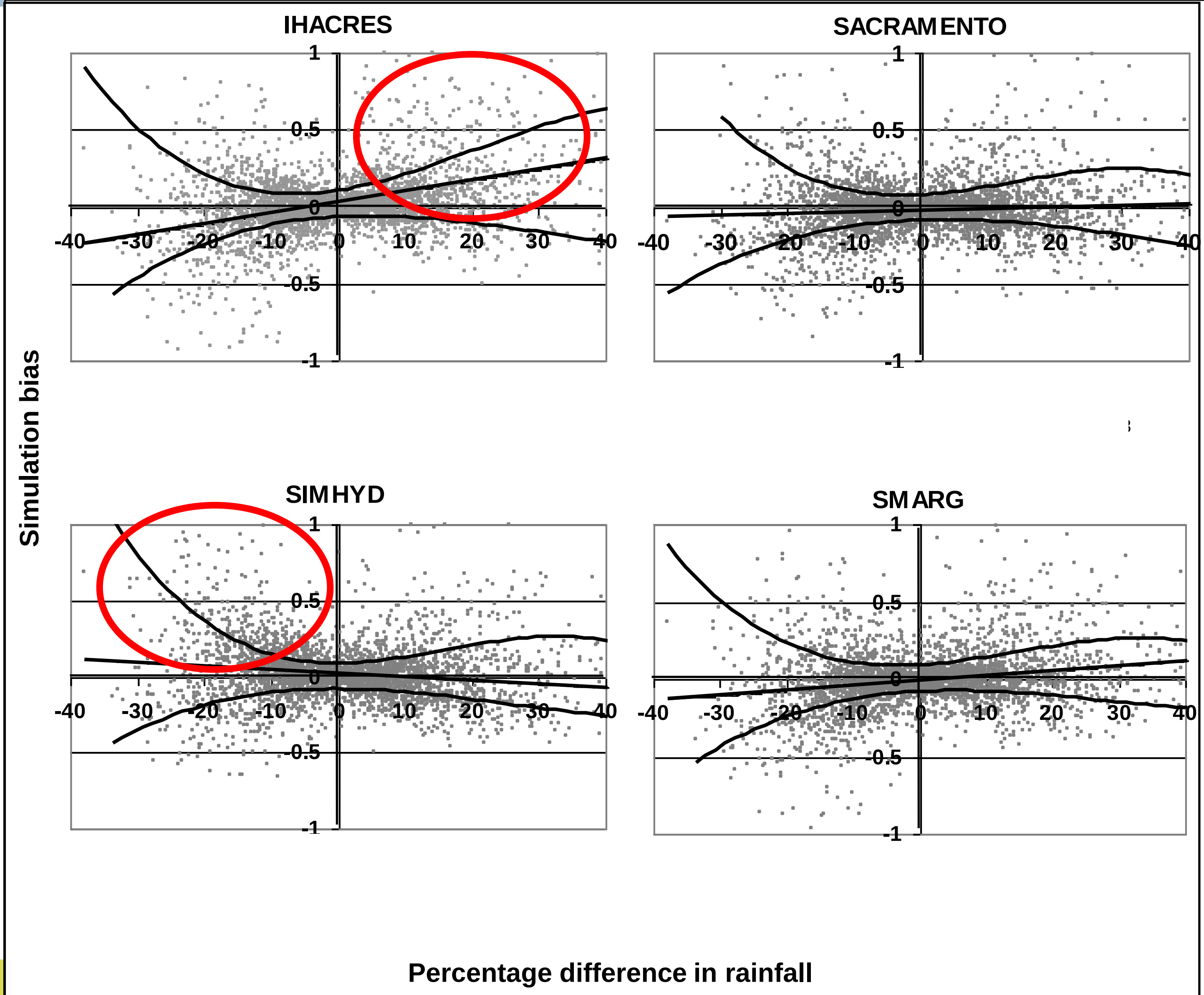
Model simulation – NSE comparison



Model simulation – NSE comparison



Model simulation – bias comparison



Summary of Vaze et al 2010

- Rainfall-runoff models, when calibrated using more than 20 years of data, can generally be used for climate impact studies where the mean annual rainfall in the future period and in the calibration period differ by less than 15 percent.

- It is generally more difficult for a model calibrated over a wet period to predict runoff over a dry period compared to a model calibrated over a dry period to predict runoff over a wet period.

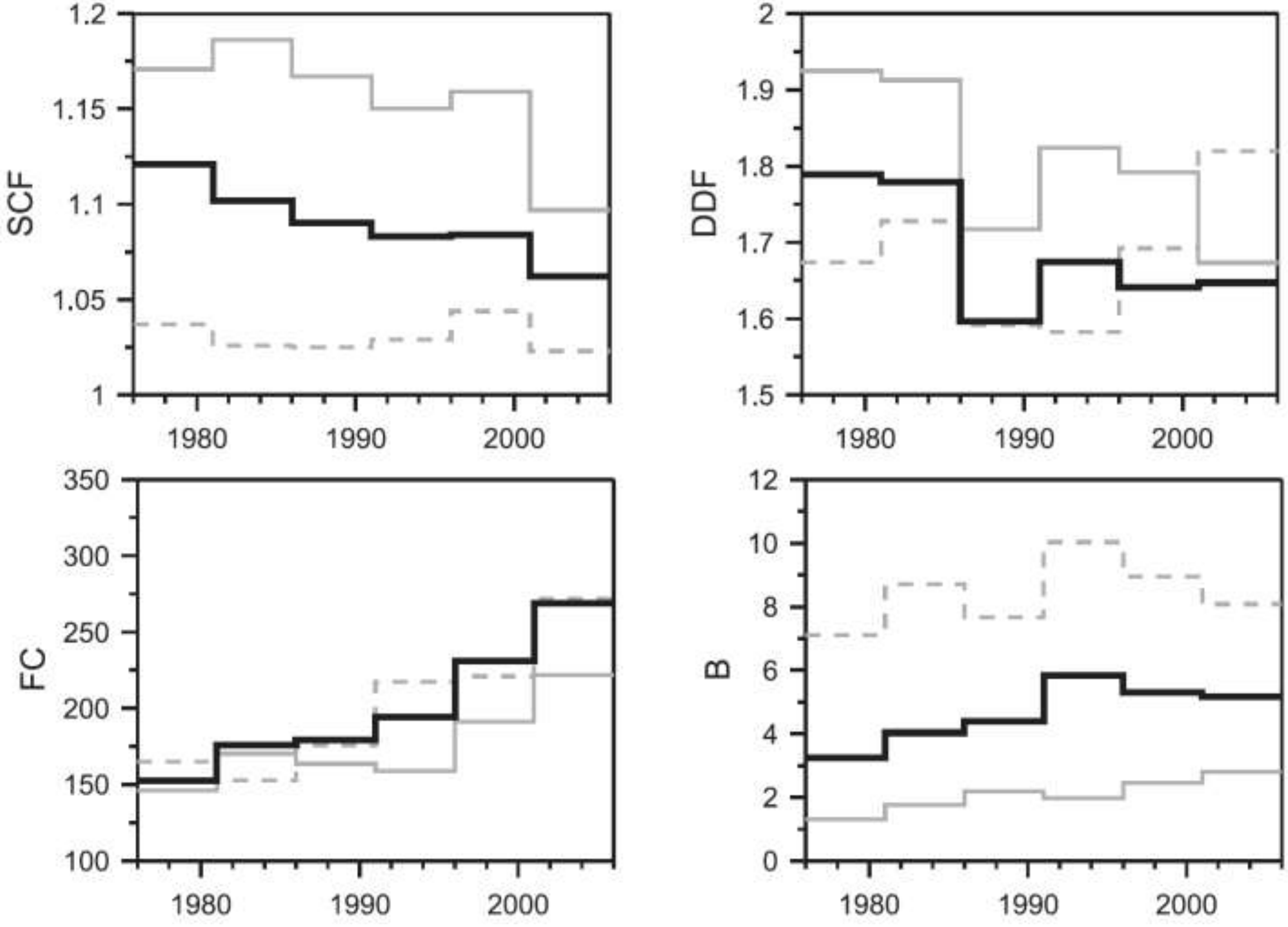
Merz et al 2011

- Examined the impact of a changing climate on model parameter values of the HBV model, and the implications for predicting water yield.

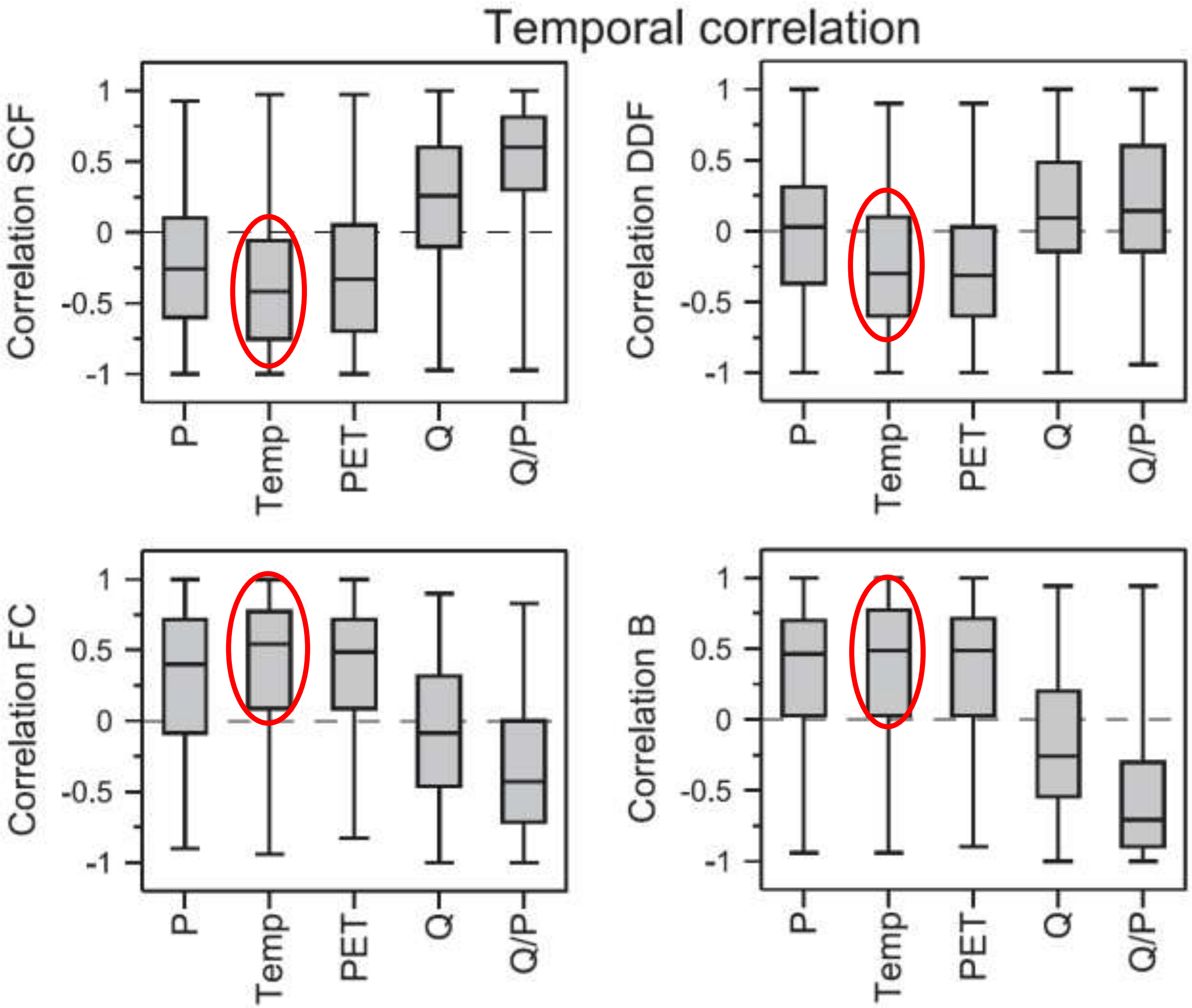
- They found that some model parameters varied in a systematic way with observed changes in climate (temperature increase of 2 °C over the 30-year study period).

- These changes in model parameters can have a significant impact on catchment hydrologic response, and will affect the climate impact on runoff and the regionalisation of hydrologic response under a changed climate.

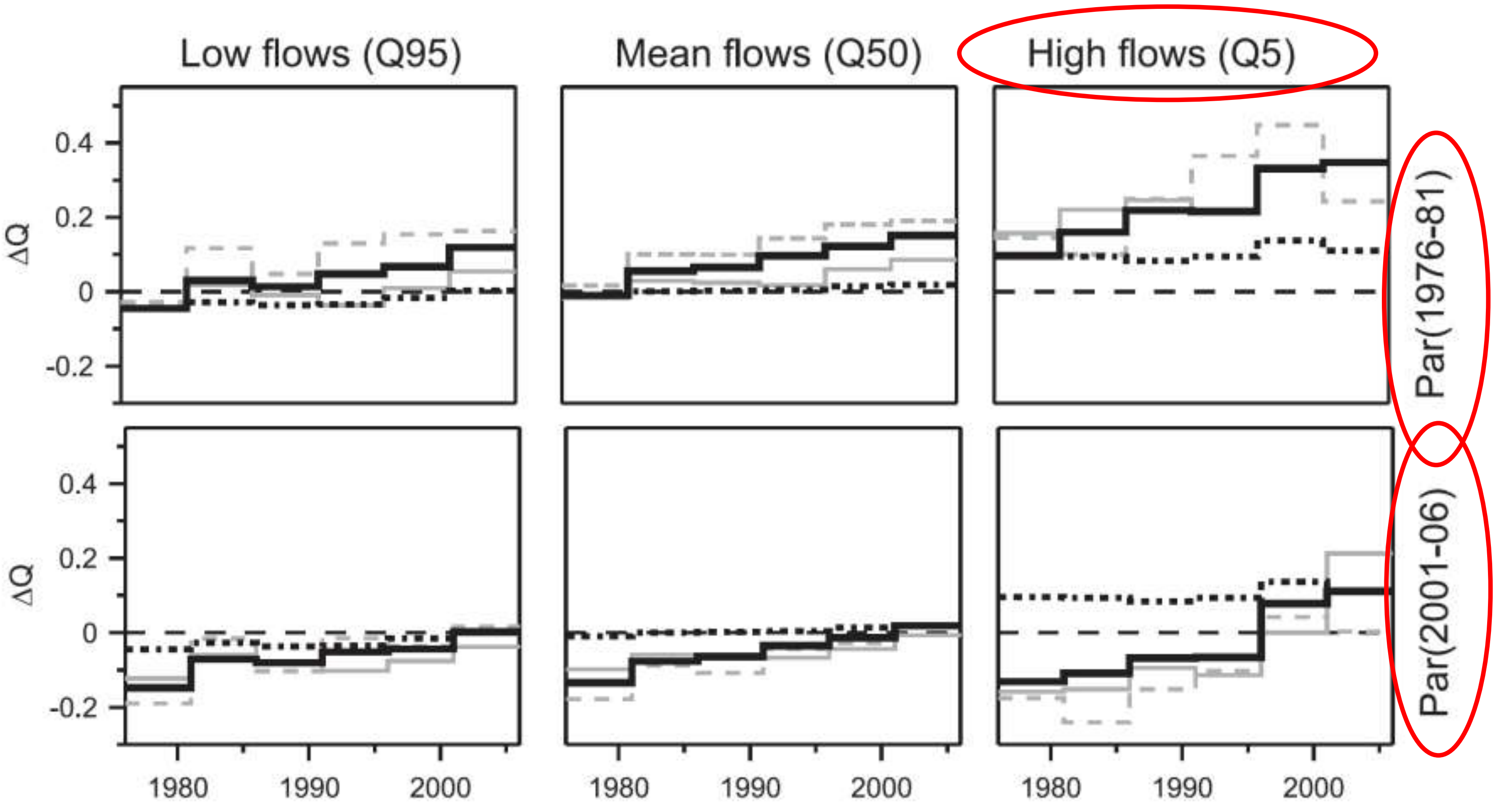
Calibrated parameter values



Correlation with climate variables



Impact on climate change projections



Summary

- In some regions, the current generation of hydrological models may be usable in climate change studies (at least if the change in precipitation is less than around 15%) and there is little change in the dominant hydrological processes, eg snowmelt timing.

- However, where the dominant catchment hydrological processes undergo a dramatic change, current models may significantly under/over estimate the hydrological impacts of climate change.

So, what can we do?

- We need to gain a greater understanding of the rainfall-temperature-runoff relationship, so that we can predict when hydrological processes may change, requiring new/different hydrological models. This could allow us to:
  - Derive models with time varying parameters which allow us to explicitly model changes in hydrological processes.
  - Make use of other inputs which may allow us to implicitly model changes in hydrological processes, eg length of growing season, APET or soil moisture as derived from remotely-sensed data.
    - This will require the development of models which are less reliant on calibration and more reliant on process understanding (which is one of the key tenets of PUB).

References

- Merz, R., Parajka, J., Bloschl, G., 2011. Time stability of catchment model parameters: Implications for climate impact analyses. Water Resour. Res., 47, 2531.

- Post, D.A., Chiew, F.H.S., Teng, J., Viney, N.R., Ling, F.L.N., Harrington, G., Crosbie, R.S., Graham, B., Marvanek, S., McLoughlin, R. 2011. A robust methodology for conducting large-scale assessments of current and future water availability and use: A case study in Tasmania, Australia. J. Hydrol. (In Press).

- Vaze, J., Post, D.A., Chiew, F.H.S., Perraud, J.M., Viney, N.R., Teng, J., 2010. Climate non-stationarity - Validity of calibrated rainfall-runoff models for use in climate change studies. J. Hydrol., 394(3-4), 447-457.