Increased Risks of Extremes in the Murray-Darling Basin under Climate Change

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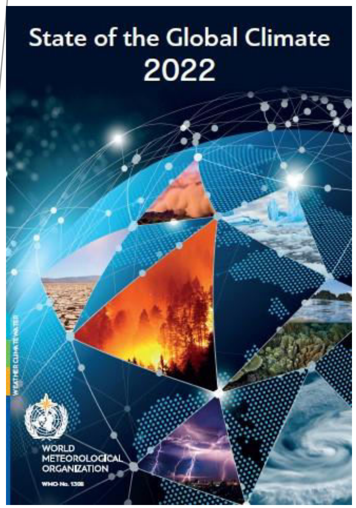
More extreme events under climate change

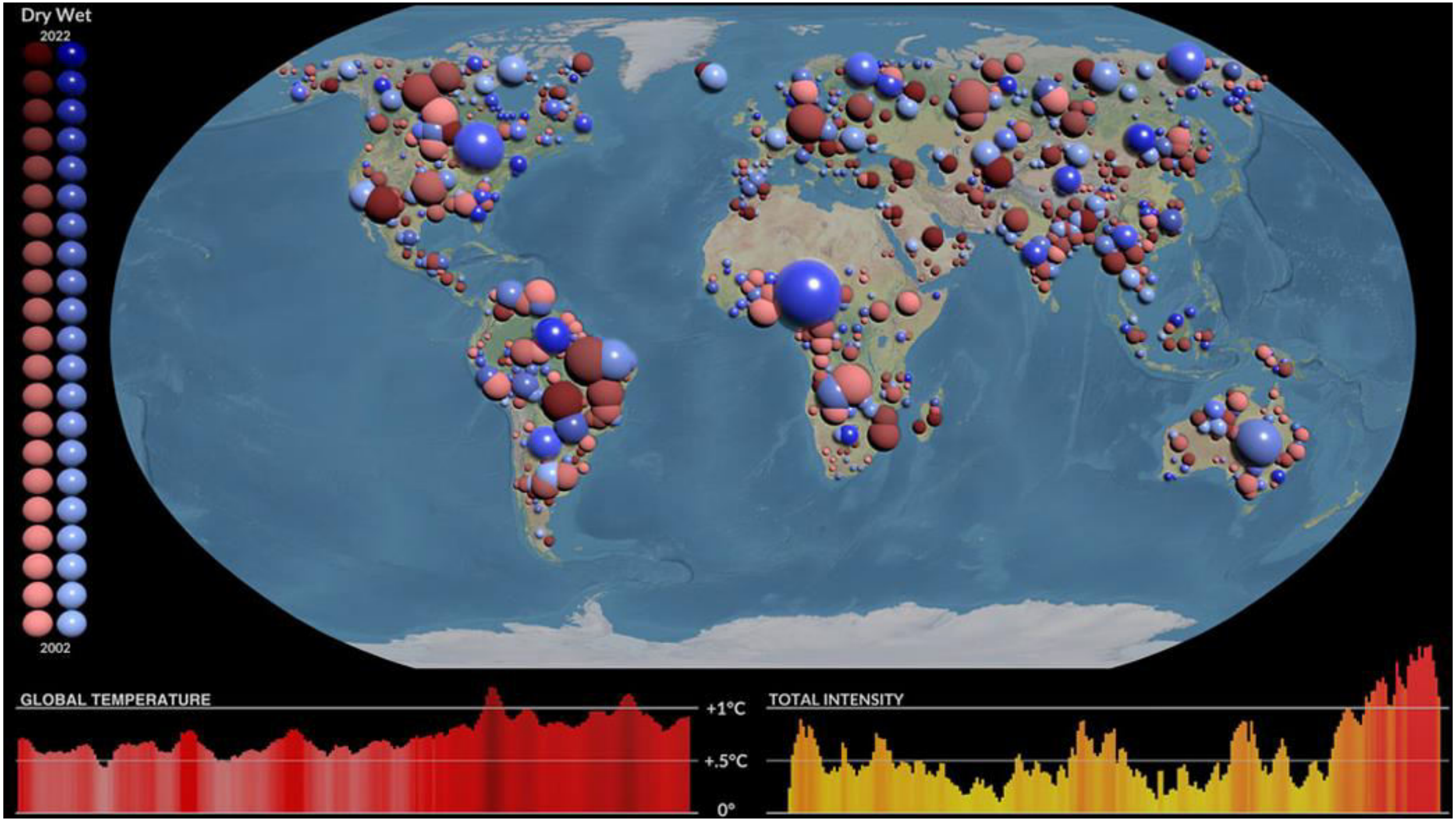


- **Drought gripped East Africa**

- **Record breaking rain in Pakistan**

- **Record breaking heatwaves in Europe**

More extreme events under climate change



Credits: NASA's Goddard Space Flight Center

Increased flooding in a warming climate?

Global warming will result in increased floods because:

- The air's water holding capacity increases by ∼7%/◦C
- Warmer ocean evaporates more water into the air

nature climate change

Article

https://doi.org/10.1038/s41558-022-01539-7

Reconciling disagreement on global river flood changes in a warming climate

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Shulei Zhang[1], Liming Zhou[2], Lu Zhang[3,4], Yuting Yang[5], Zhongwang Wei[1], Sha Zhou[6], Dawen Yang[5], Xiaofan Yang[6], Xiuchen Wu[6], Yongqiang Zhang[7], Xiaoyan Li[6] & Yongjiu Dai[1]

LETTER

https://doi.org/10.1038/s41586-019-1495-6

Changing climate both increases and decreases European river floods

Günter Blöschl[1,37]*, Julia Hall[1,37], Alberto Viglione[1,2], Rui A. P. Perdigão[1], Juraj Parajka[1], Bruno Merz[3], David Lun[1],

news & views

FLOOD TRENDS

Not higher but more often

Heavy precipitation has increased worldwide, but the effect of this on flood magnitude has been difficult to pinpoint. An alternative approach to analysing records shows that, in the central United States, floods have become more frequent but not larger.

Robert M. Hirsch and Stacey A. Archfield

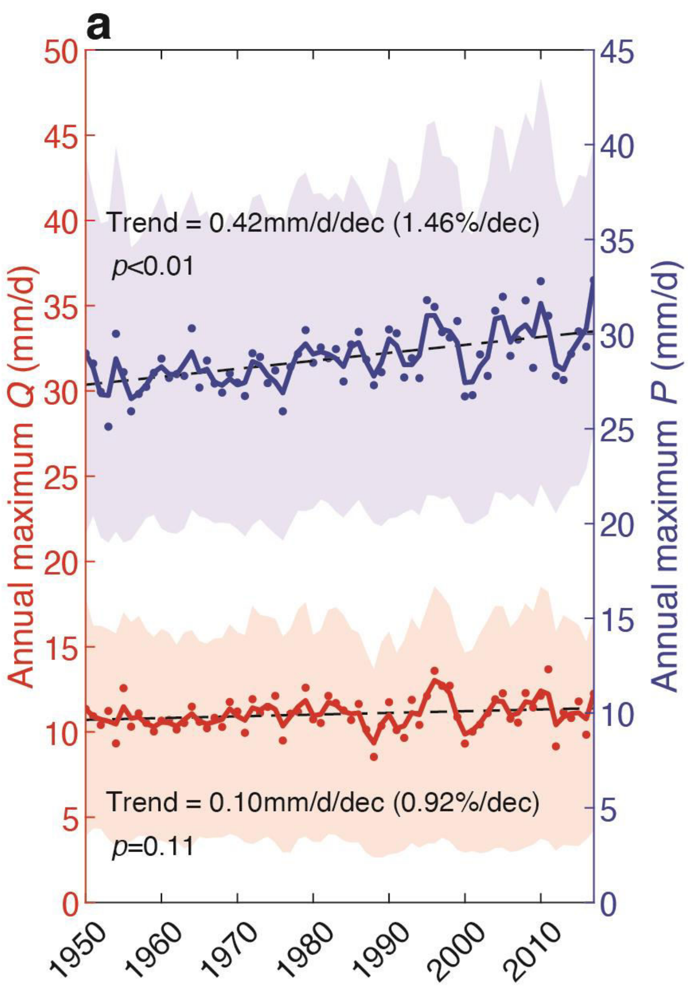
letters to nature

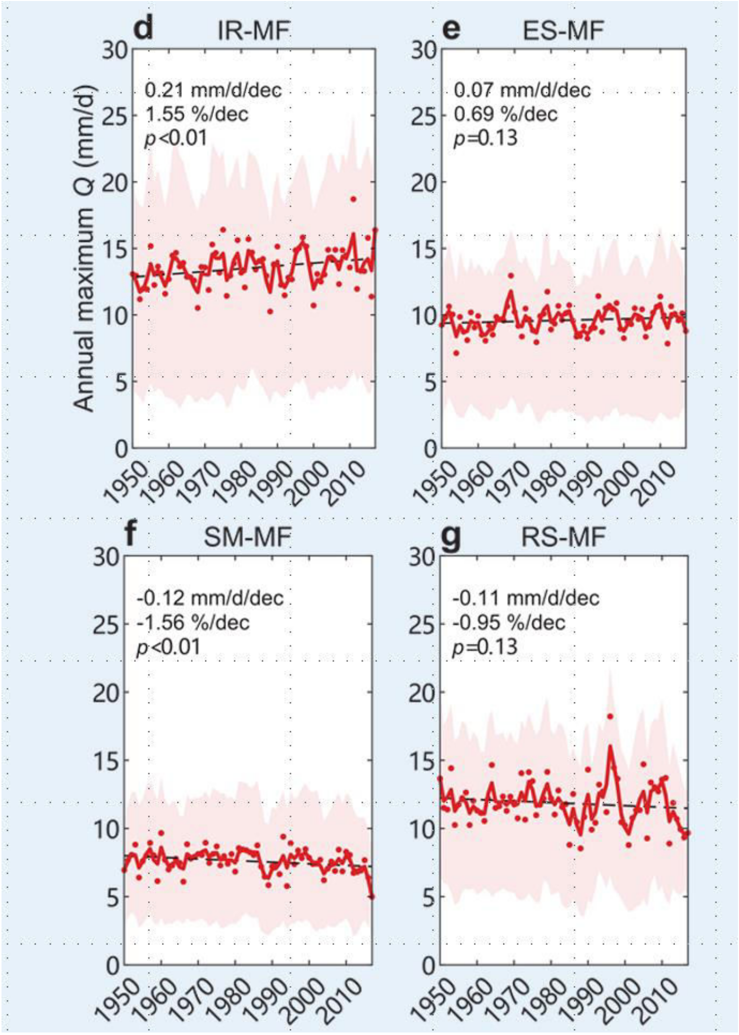
No upward trends in the occurrence of extreme floods in central Europe

Manfred Mudelsee[1]*, Michael Börngen[1], Gerd Tetzlaff[1] & Uwe Grünewald[2]

Increased flooding in a warming climate?

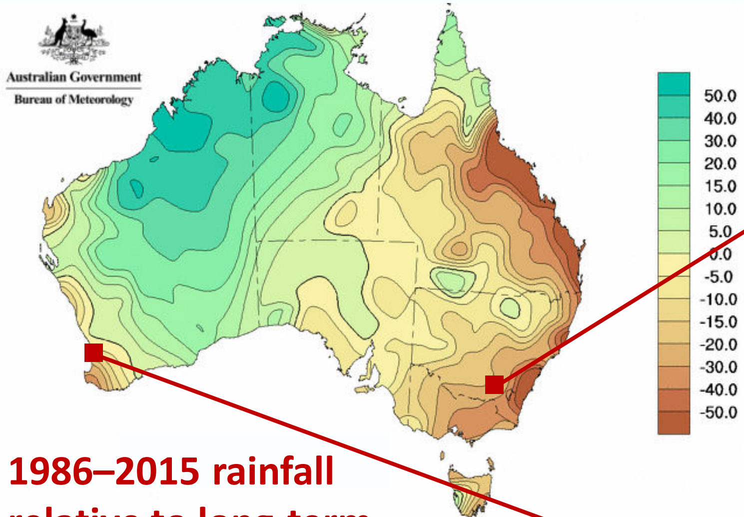
A positive response of rainstorm-induced floods to extreme precipitation increase



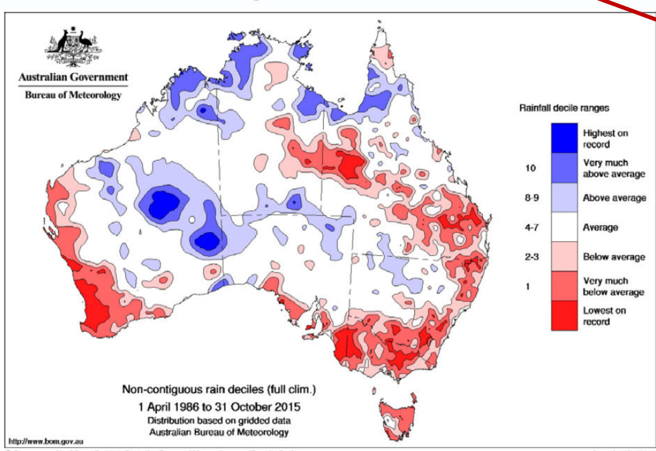


Rainfall trend amplified in runoff

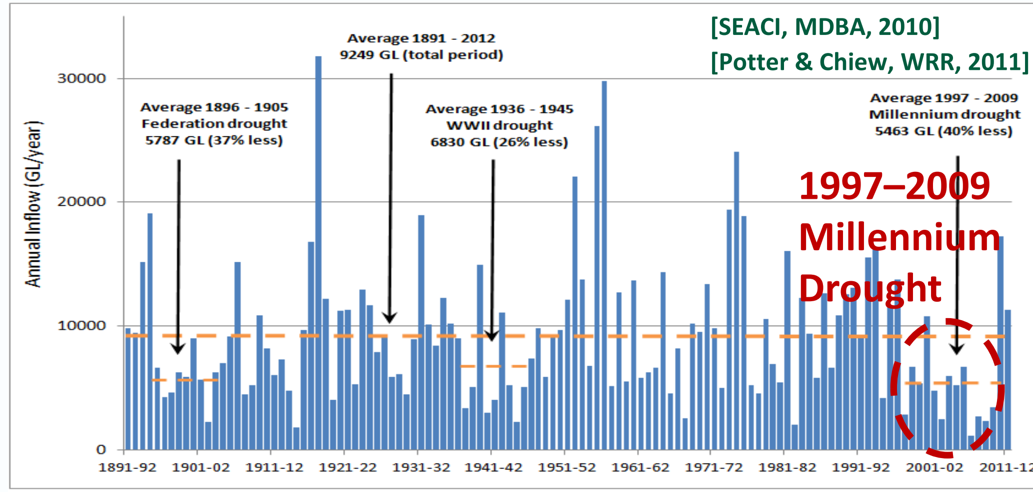
Rainfall trend (1950 to present)



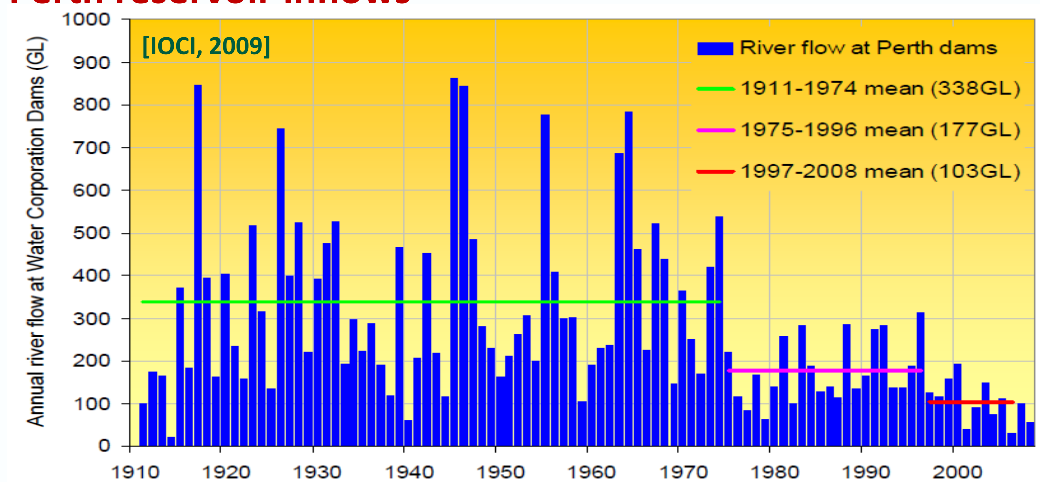
1986–2015 rainfall relative to long-term



Murray River Basin inflows

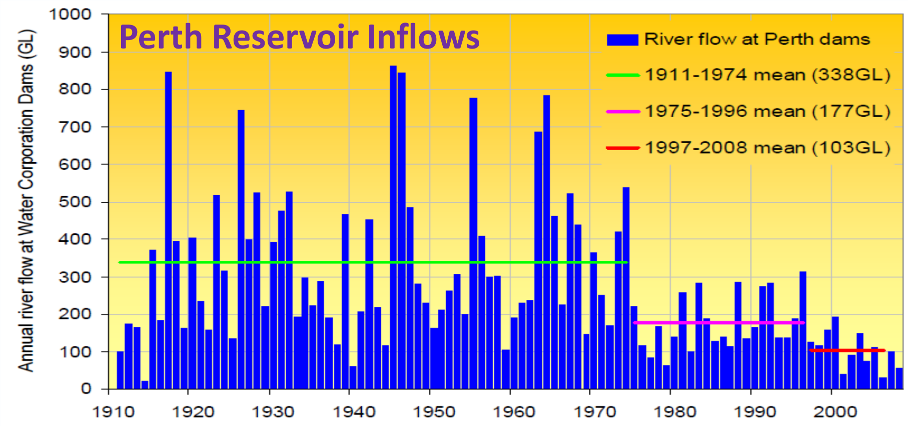


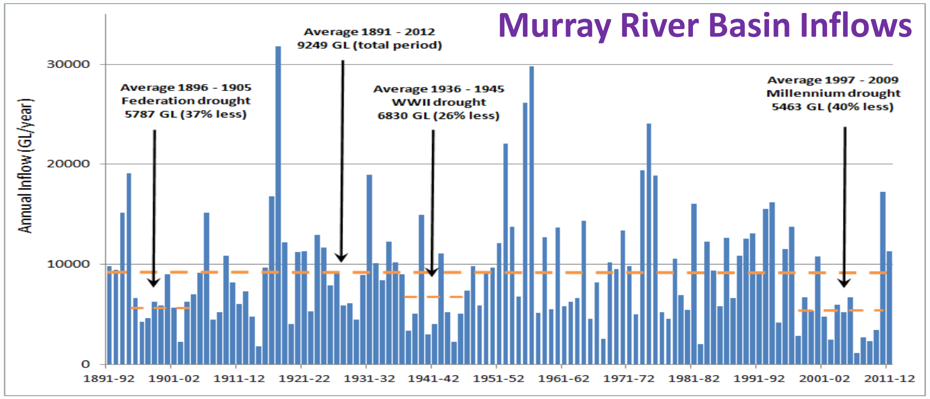
Perth reservoir inflows



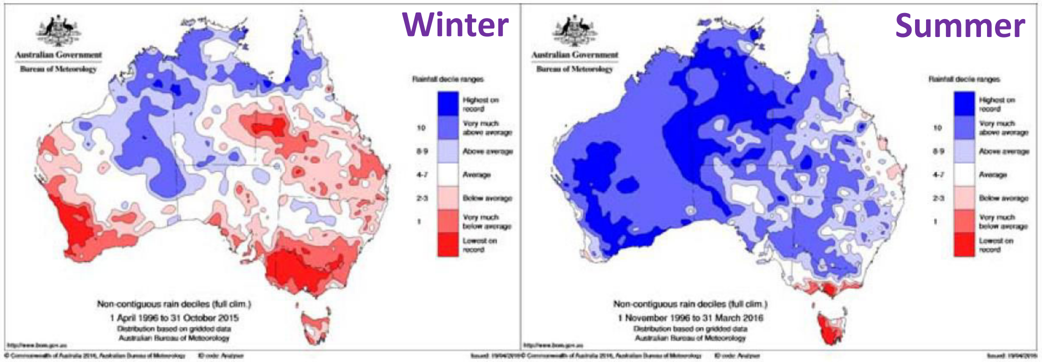
Potential drivers and hydrological responses

Declining trend in water availability in the far south-west and far south-east .....



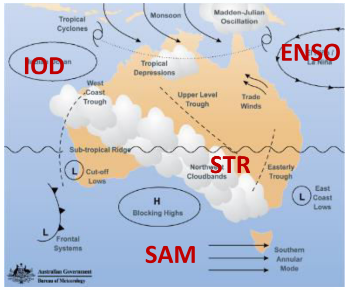


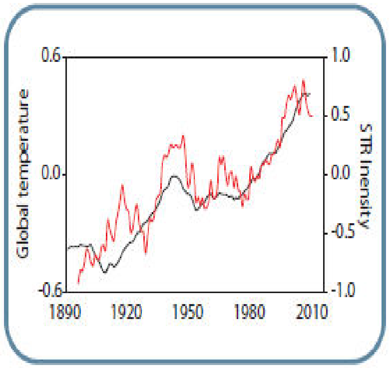
..... due to decline in winter rainfall .....



Rainfall Decile (1986–2015) relative to long-term average

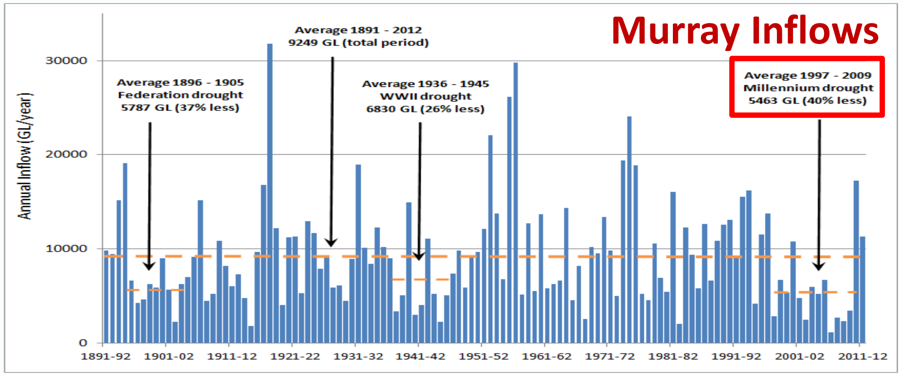
..... caused by expanding Hadley cell pushing winter storm tracks further south.



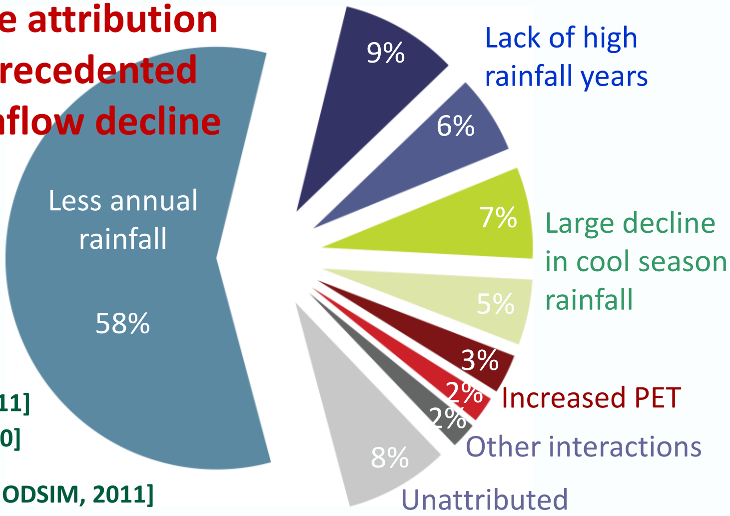


Millennium Drought : attribution analysis

Murray Inflows

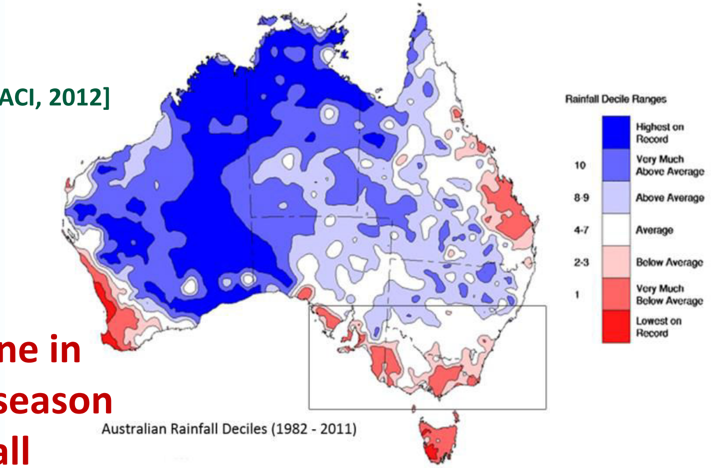


Climate attribution of unprecedented streamflow decline

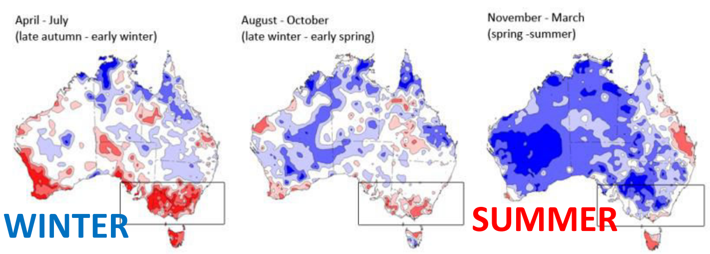


[Potter & Chiew, WRR, 2011]
[Potter et al., JHydrol, 2010]

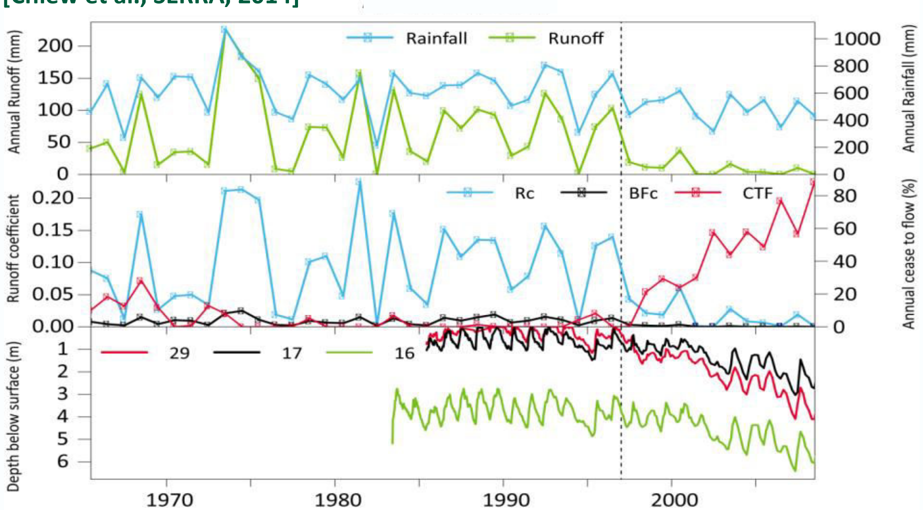
[SEACI, 2012]



Decline in cool season rainfall



[Petheram et al., MODSIM, 2011]
[Chiew et al., SERRA, 2014]

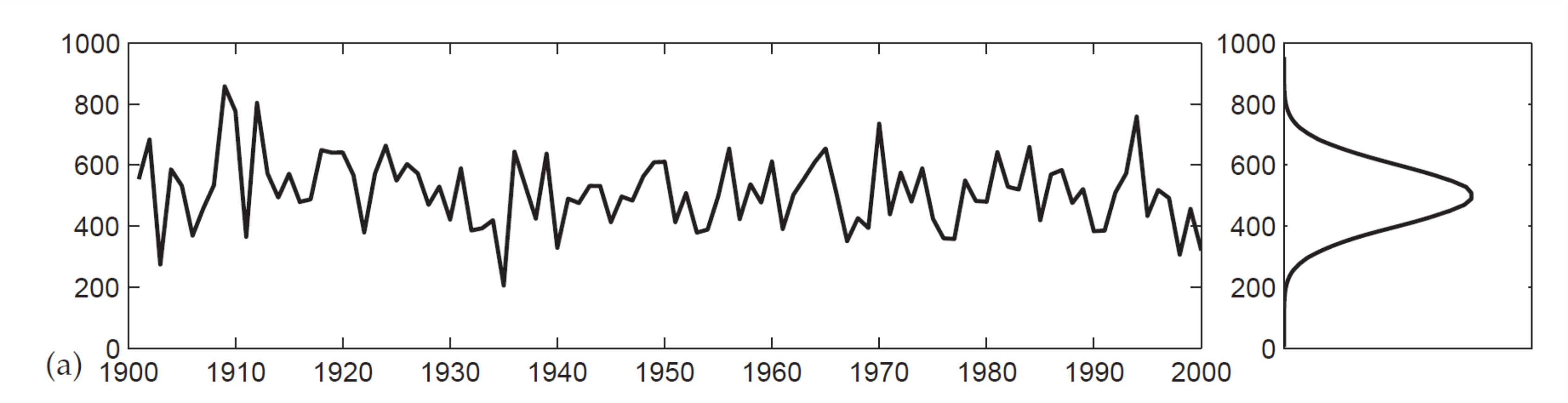


Change in dominant processes (hydrologic non-stationarity)

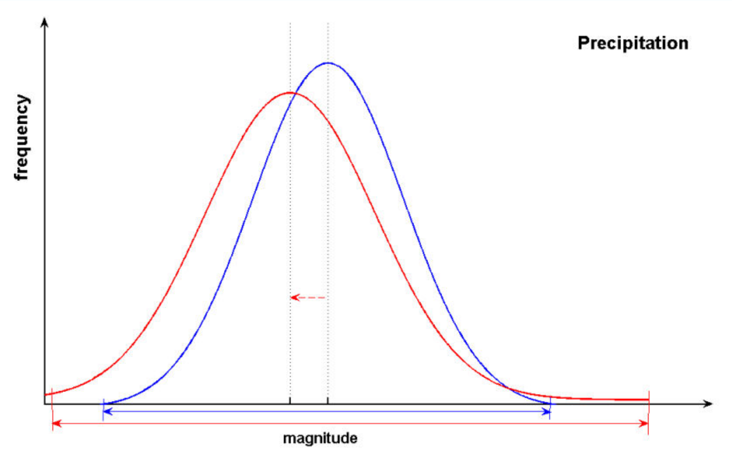
Stationarity assumption

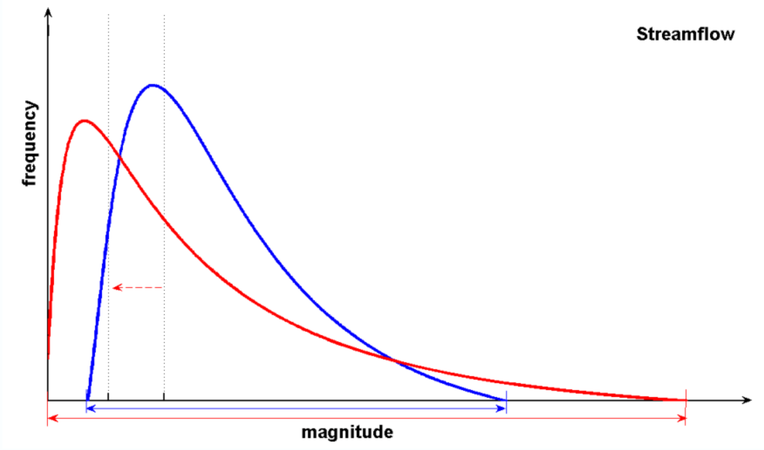
- Stationarity means that the statistical properties of hydrologic variables in the future will be similar to the past.

Past



Future

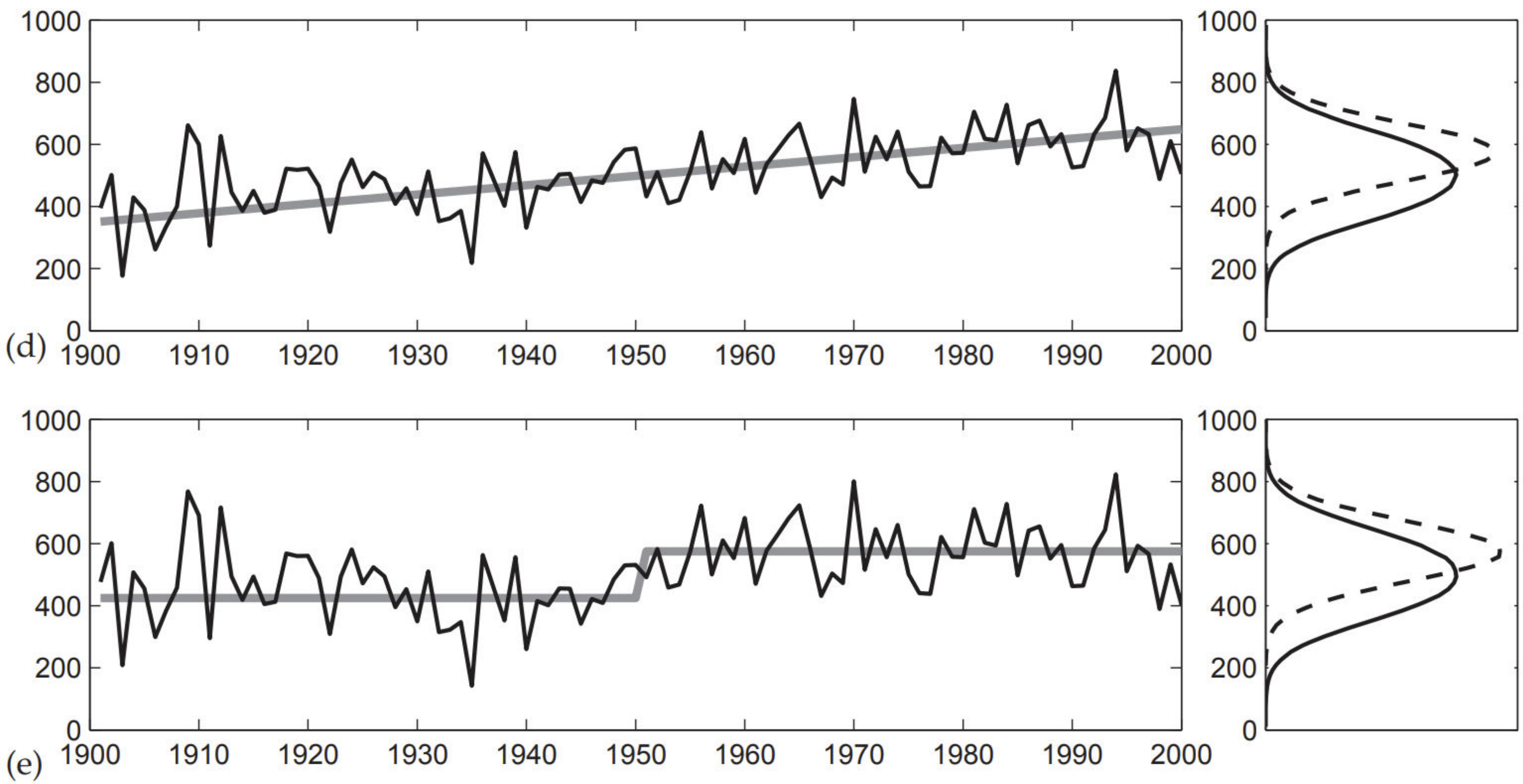




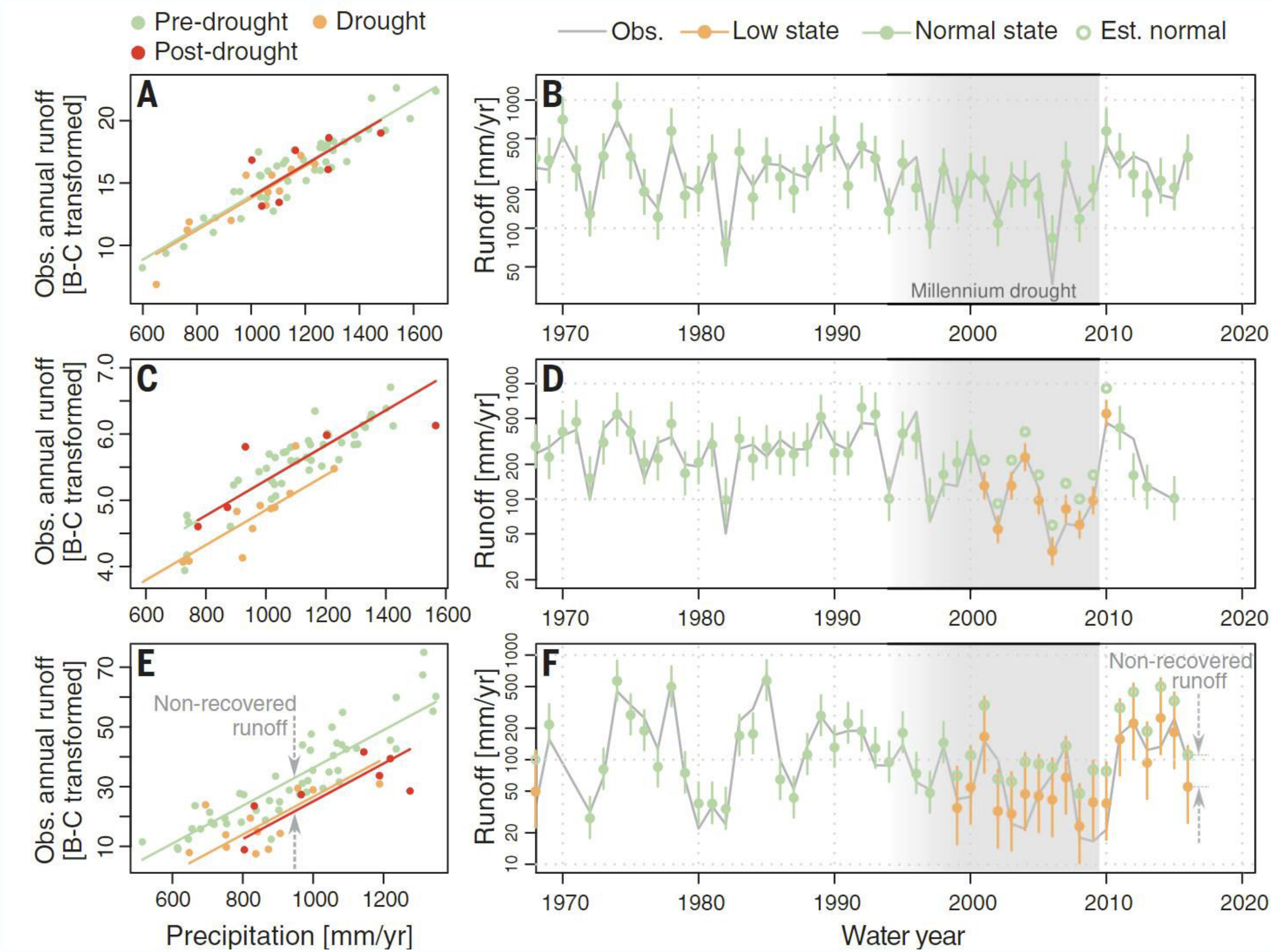
CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

P. C. D. Milly,[1*] Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

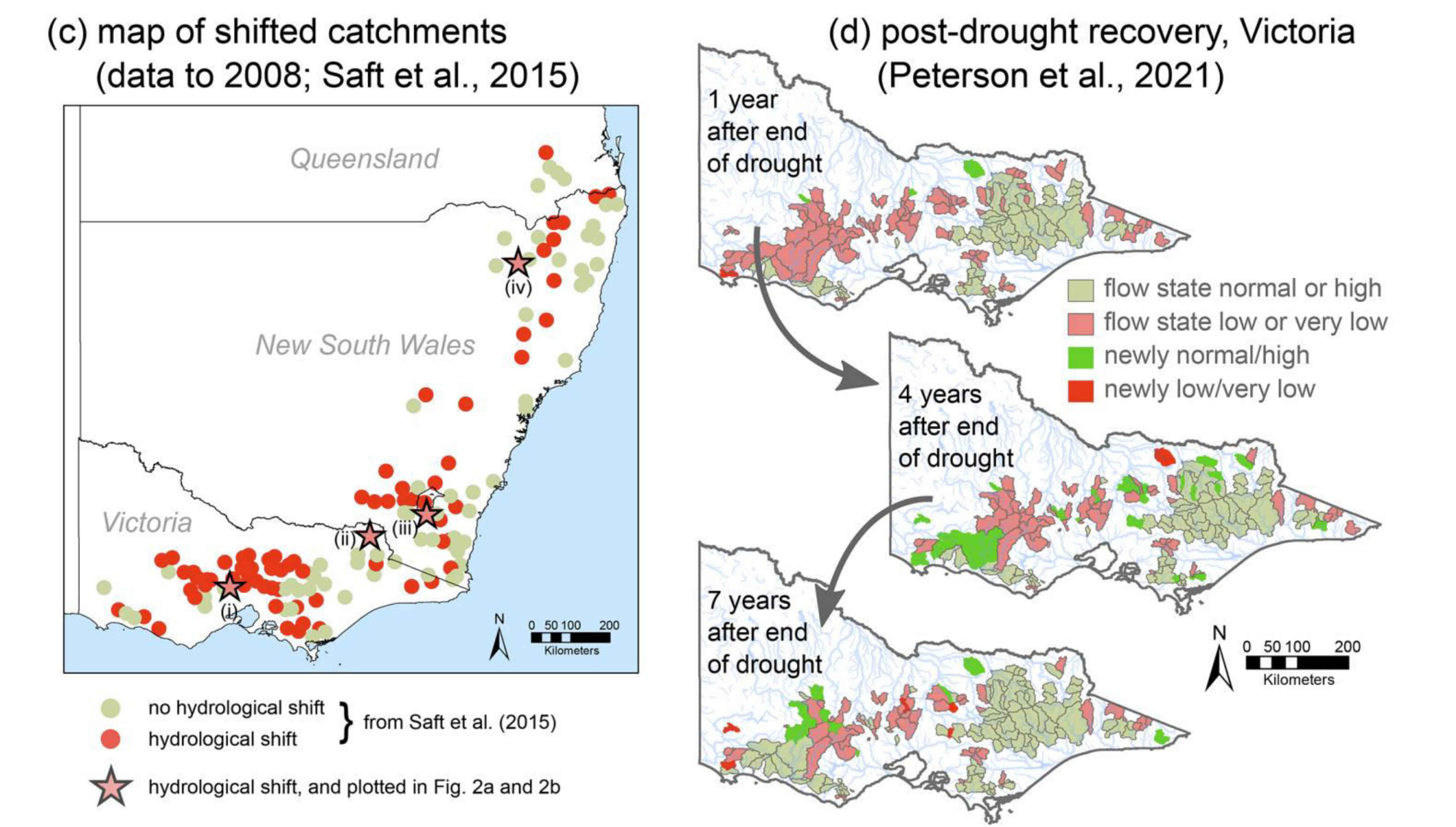


Hydrologic non-stationarity: Victorian examples



Peterson et al., (2021), Science

Hydrologic non-stationarity: Victorian examples



Fowler et al., (2022), HESS

Nonstationarity: from detection to management

Symptoms → **Data** → **Detection** → **Drivers** → **Attribution** → **Management**

Symptoms
- Magnitude
- Frequency
- Timing

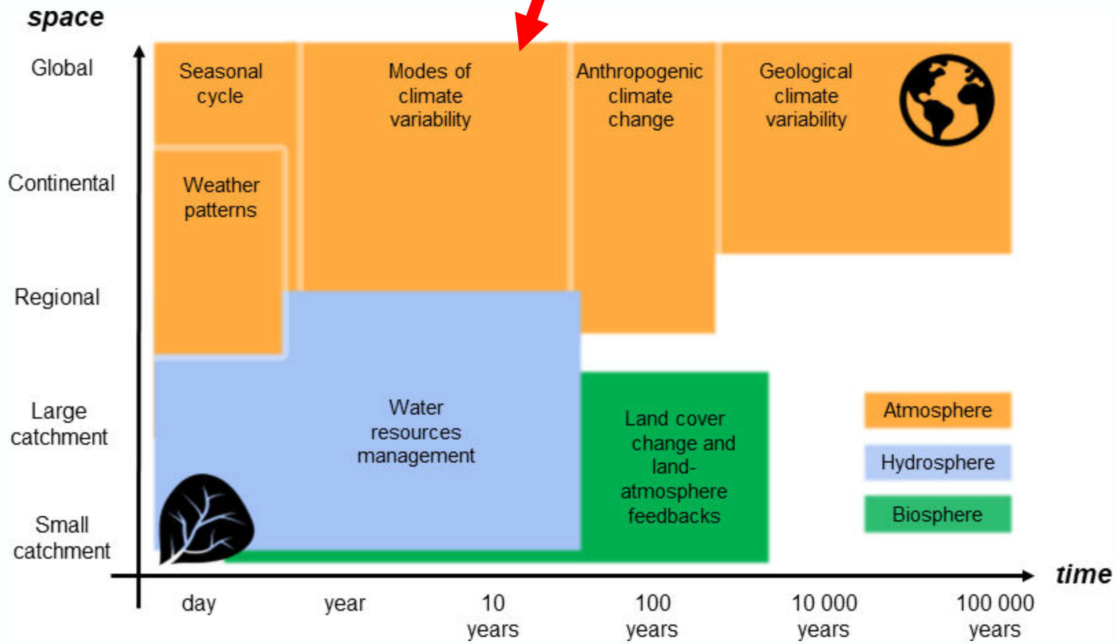
Data
- Data quality and homogeneity
- Record length and completeness

Detection
- Regression
- Pooled methods
- Synthetic time series
- Change points
- Circular statistics

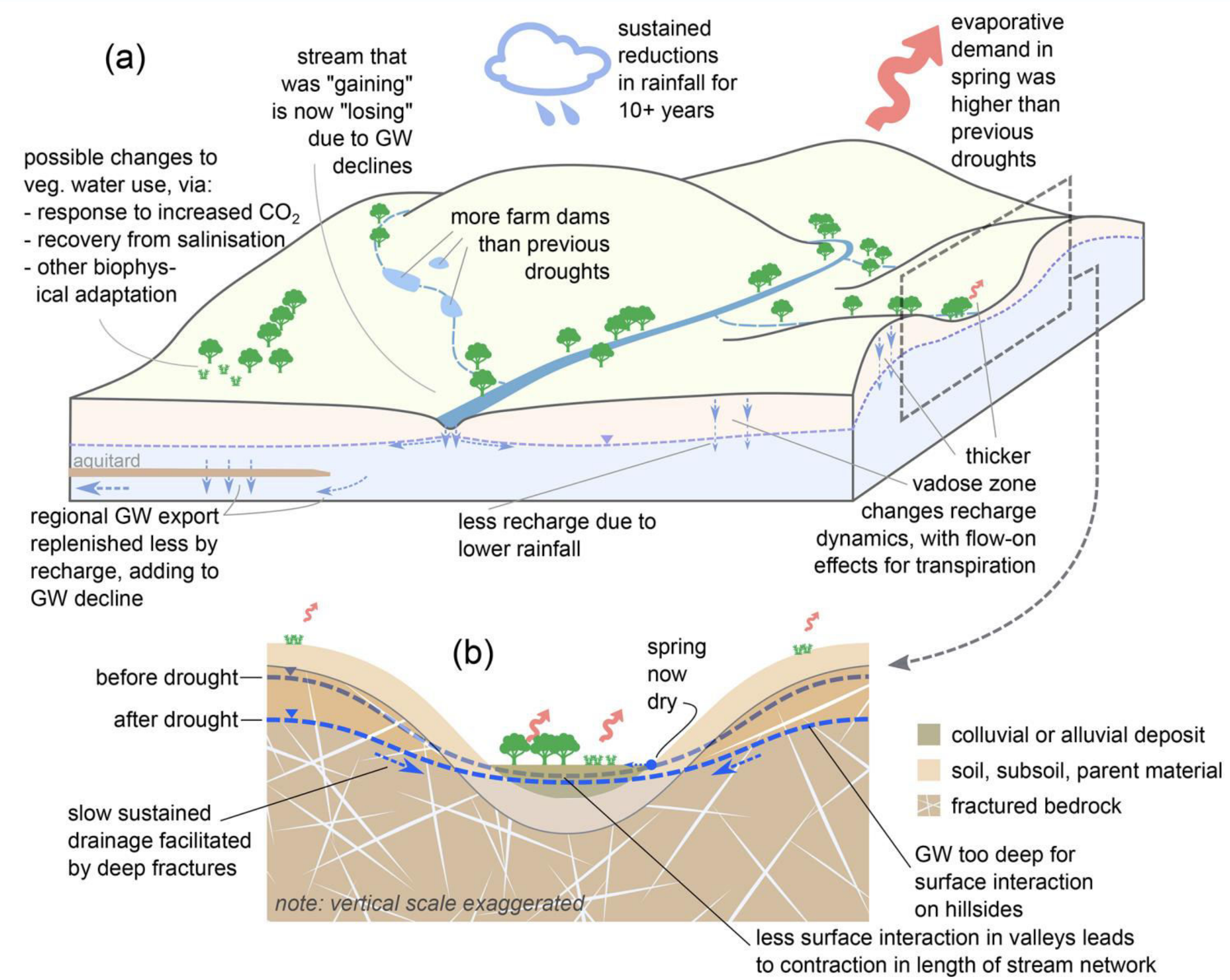
Drivers
- Climate
- Land cover
- Water management
- Feedbacks
- Compound drivers

Attribution
- Exploratory data analysis
- Empirical
- Simulation based
- Event attribution

Management
- Engineering design
- Climate models
- Hybrid approaches
- Validity of models

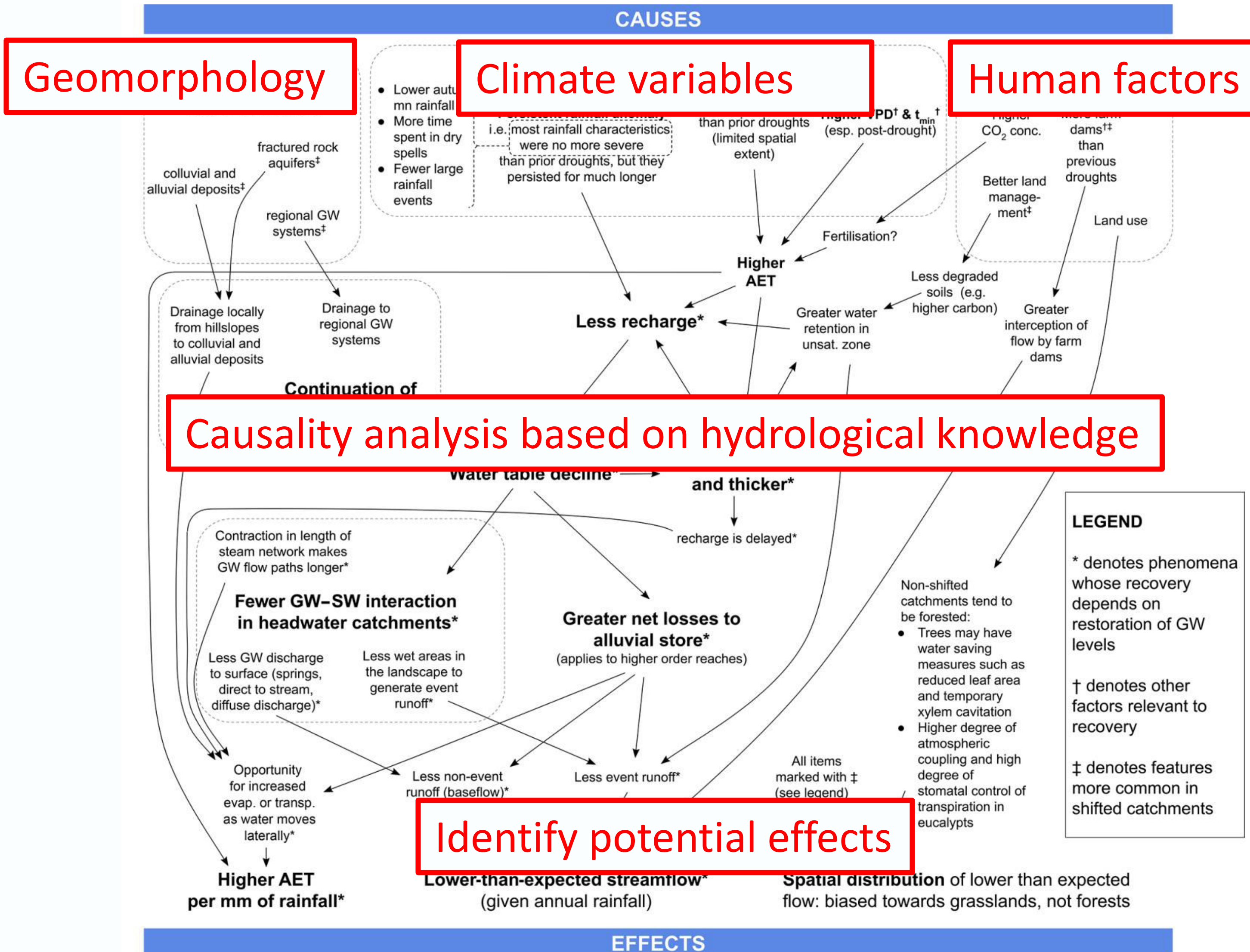


Hydrologic non-stationarity: **diagnostic analysis**



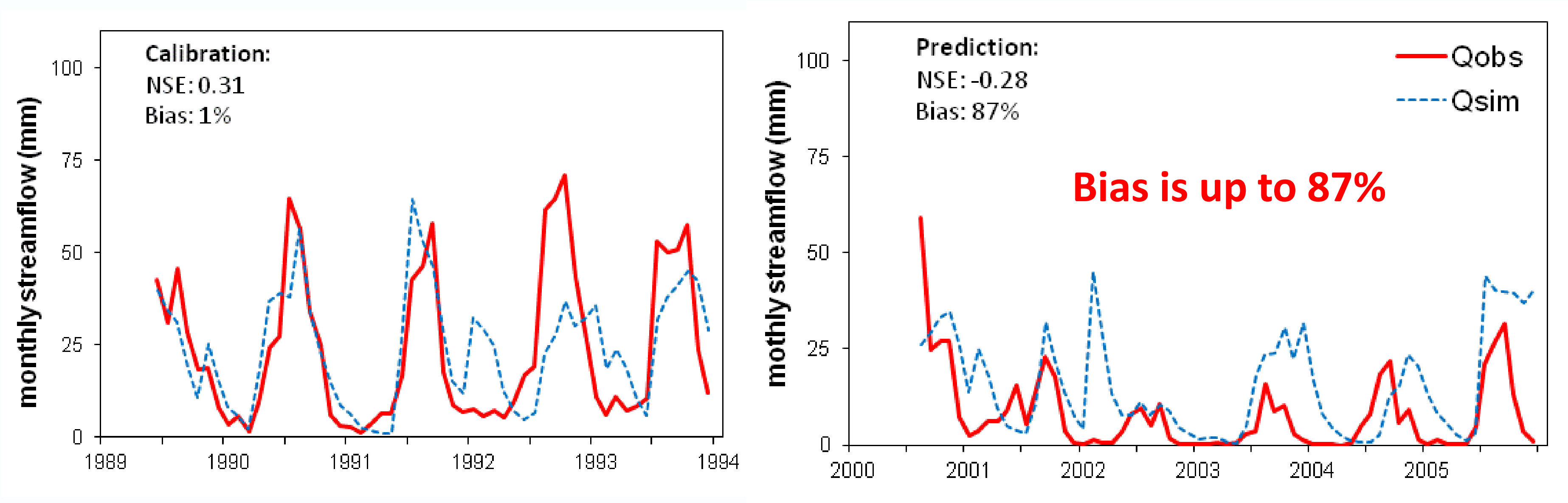
Fowler et al., (2022), HESS

Hydrologic non-stationarity: **causality analysis**



Fowler et al., (2022), HESS

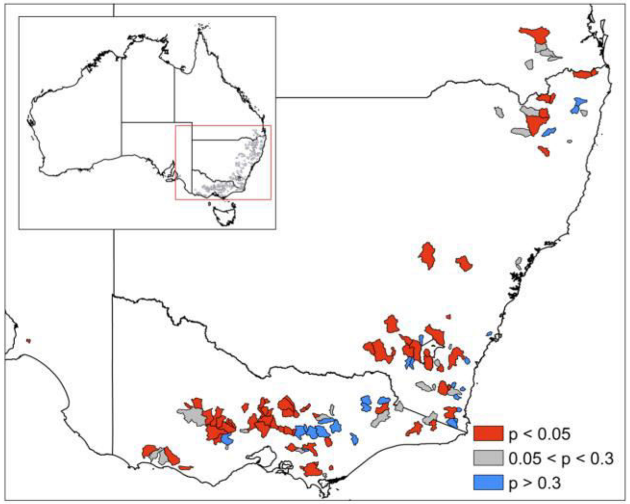
Hydrologic non-stationarity: **implications**

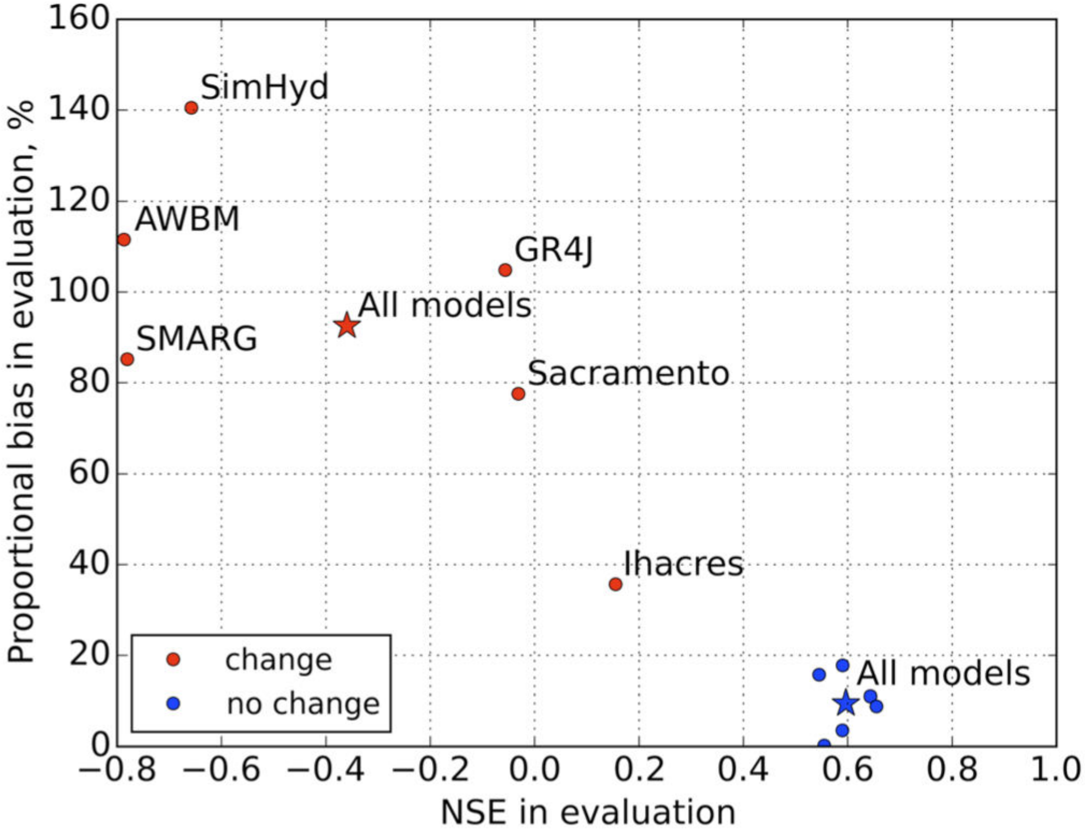


"past" **"future"**

- Calibration: 1989-1994; Prediction: 2000-2006
- A good calibration, but poor prediction for the Millennium drought .

How to reduce uncertainty in future runoff projection？





How to reduce the effect of non-stationarity on runoff projection？

- **Better objective function?**

Water Resources Research

RESEARCH ARTICLE

10.1029/2017WR022466

Improved Rainfall-Runoff Calibration for Drying Climate: Choice of Objective Function

Keirnan Fowler[1], Murray Peel[1], Andrew Western[1], and Lu Zhang[2]

[1]Department of Infrastructure Engineering, University of Melbourne, Melbourne, VIC, Australia, [2]Land and Water, CSIRO, Canberra, ACT, Australia

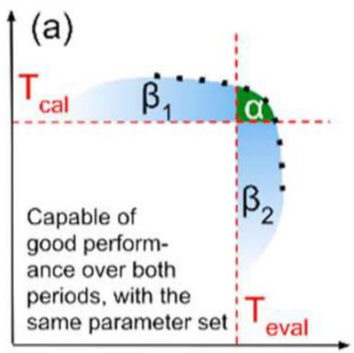
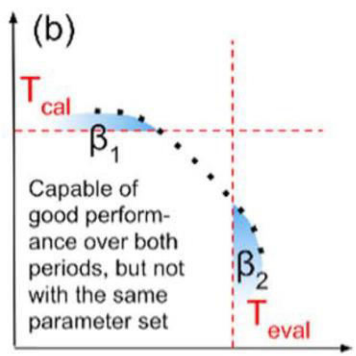
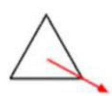
Key Points:
- "Least squares" approaches should not be used to calibrate models for a drying climate
- Sum-of-absolute-error calibration

We recommend future studies to avoid least squares approaches (e.g., NSE or KGE) and adopt the Refined Index of Agreement or Split KGE.

Fowler et al., (2018), WRR

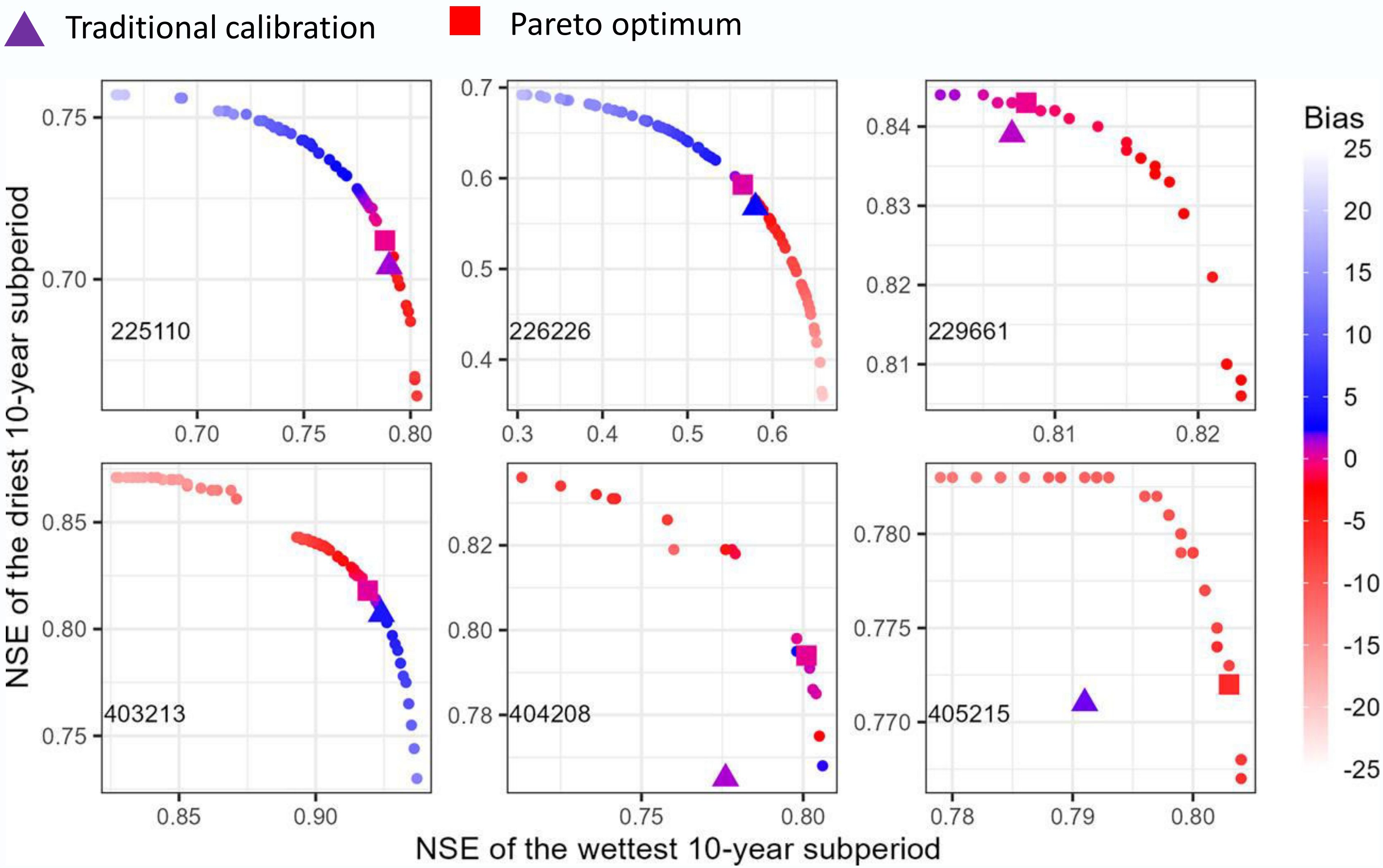
How to reduce uncertainty in future runoff projection？

- **Pareto front?**

Coverage		Diagnosis notes
		Parameter sets that meet acceptance thresholds do exist within the model structure. In this case, the priority is improving the calibration method, so that when the DSST is repeated a more suitable parameter set is identified.
		The model structure is flexible (it can fit data it is calibrated to) but not transferable (good parameter sets in one period are poor in others). Focus on model structure: given the absence of performance problems in each period individually, it is relatively less likely (but not impossible) that data errors are the salient cause.

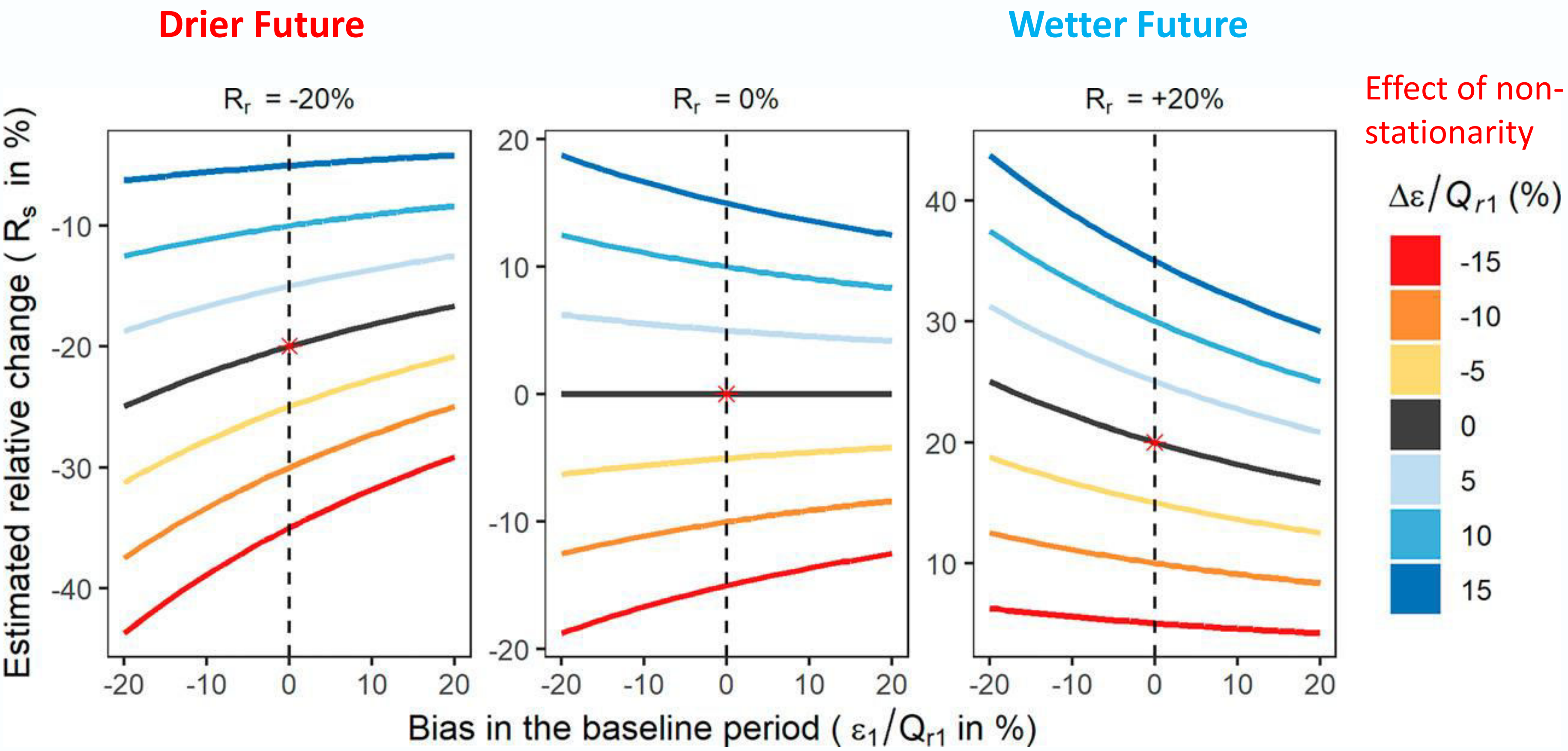
Fowler et al., (2018), WRR

Considering Pareto front



Zheng et al., (2022), JHM

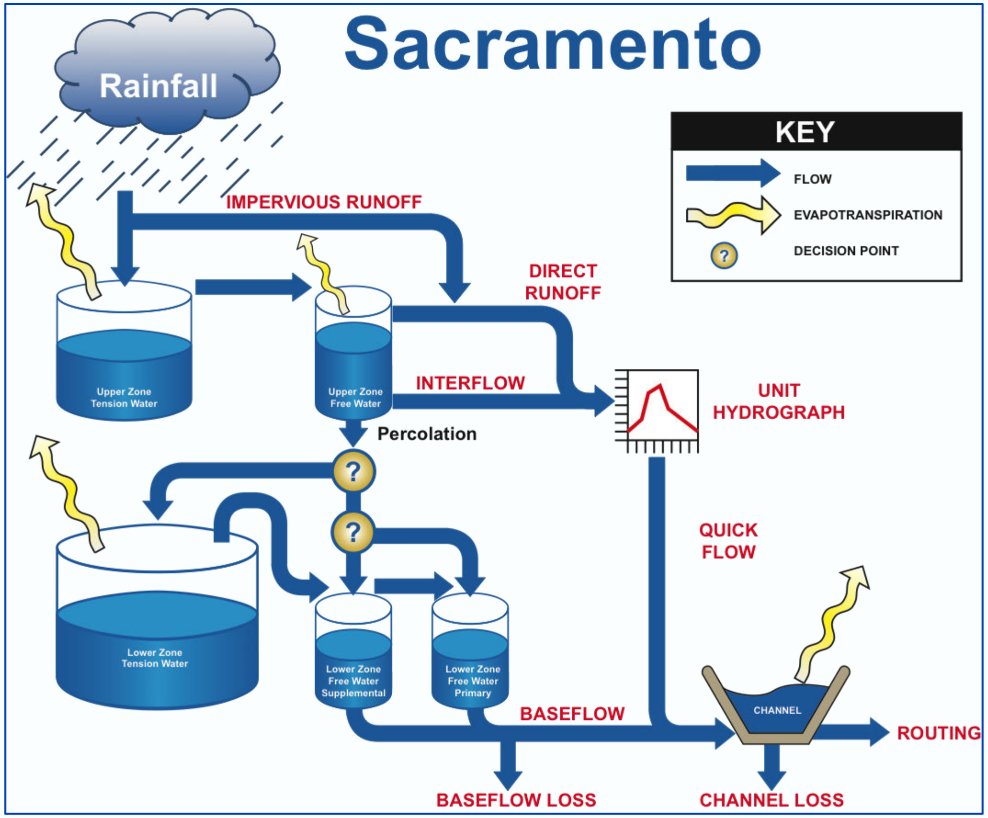
Effect of non-stationarity on future runoff projection



Zheng et al., (2022), JHM

How to reduce uncertainty in future runoff projection？

- Improve hydrological model



Effect of elevated CO_2

Surface-groundwater linkage

Differential effect of soil moisture on runoff and ET

Summary：

- The Murray-Darling Basin has experienced increased extreme events, significantly affecting ecosystem health and environment.
- Extreme events such as droughts can result in hydrological non-stationarity increasing uncertainty in future runoff projection.
- Current hydrological models need to be improved in order to provide more robust future runoff projection.

Thank you!