Insights into drought from palaeoclimate data

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The problem:

Detection and attribution of drought (including multi-year and megadroughts) can be difficult due to:

- lack of long-term and high quality instrumental data
- uncertainty if instrumental data samples the full range of unforced variability
- uncertainty if model output captures multi-decadal characteristics of drought

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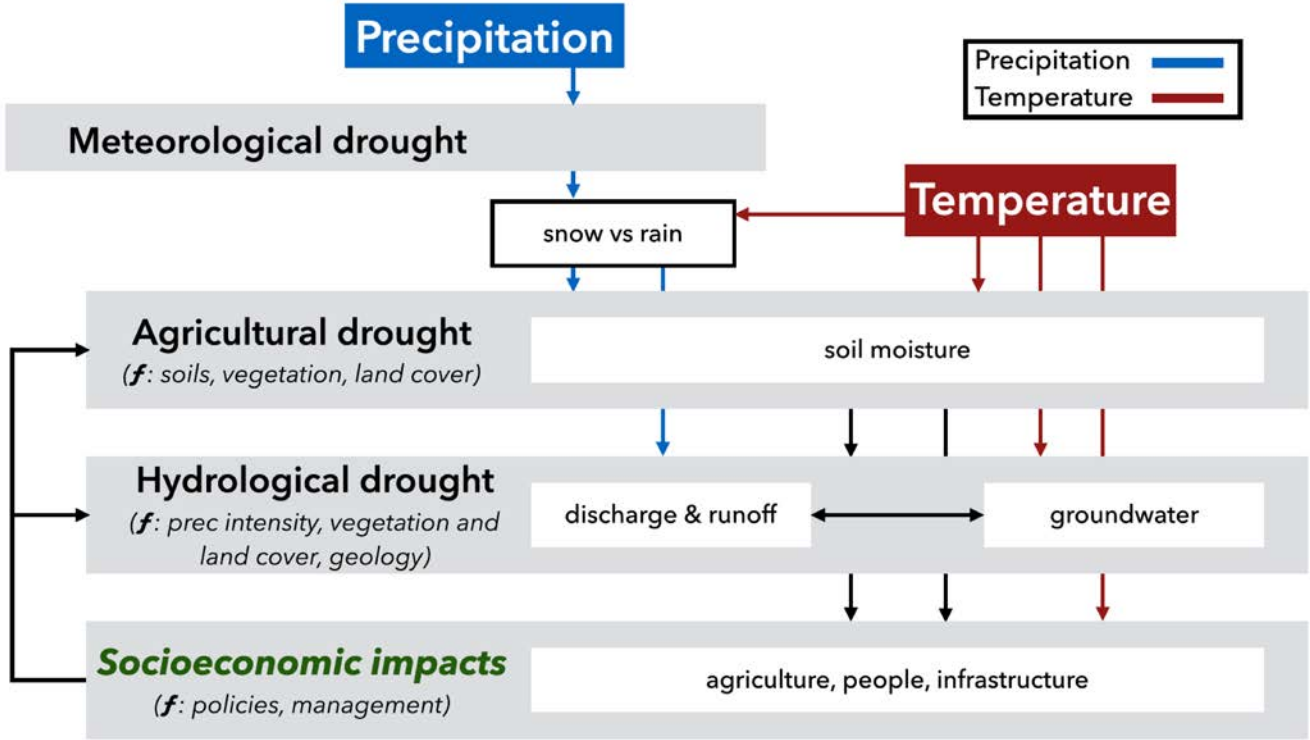
Paleoclimate reconstructions

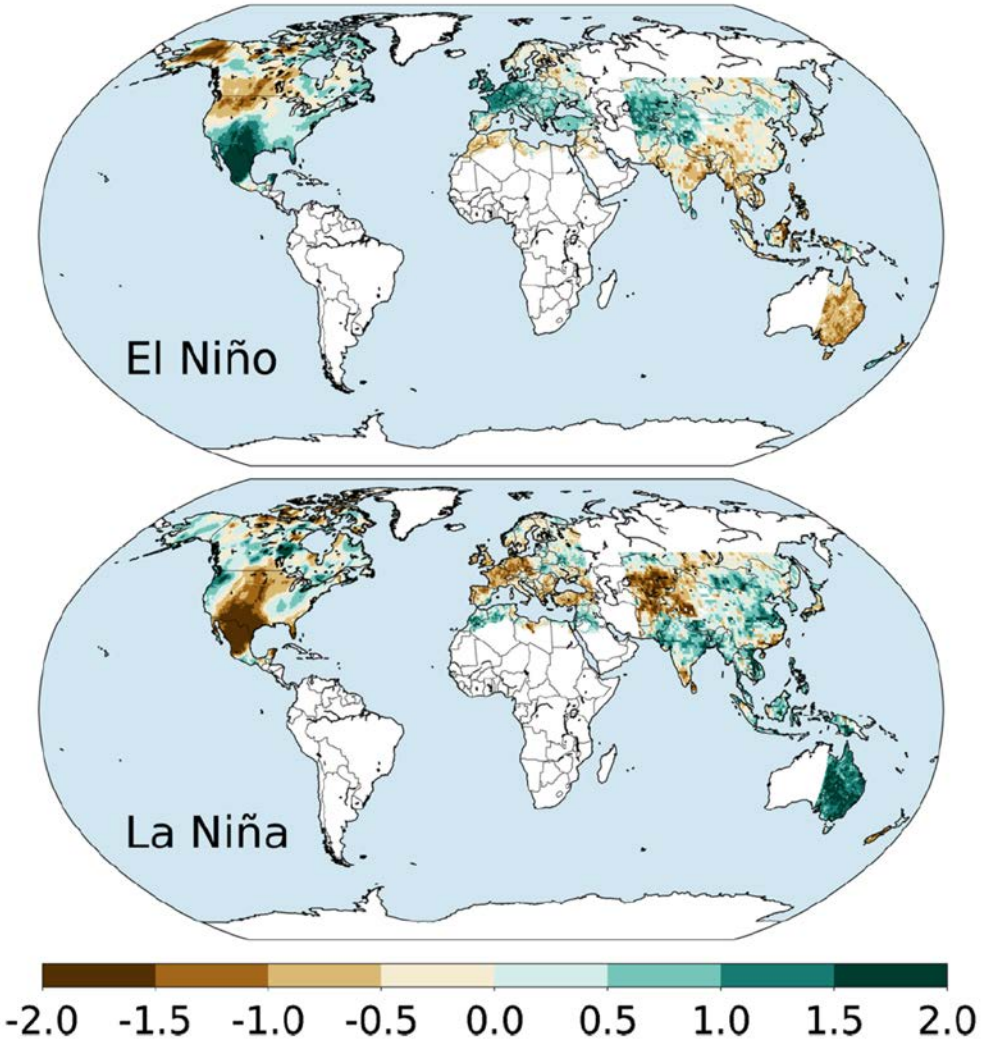
- Indirect: rely on statistical mapping of paleo-measurements to a reconstruction target
- Assume stationarity: relationships observed in instrumental period hold into the past



B. Cook et al., 2018, *Current Climate Change Reports*

Drought Atlases

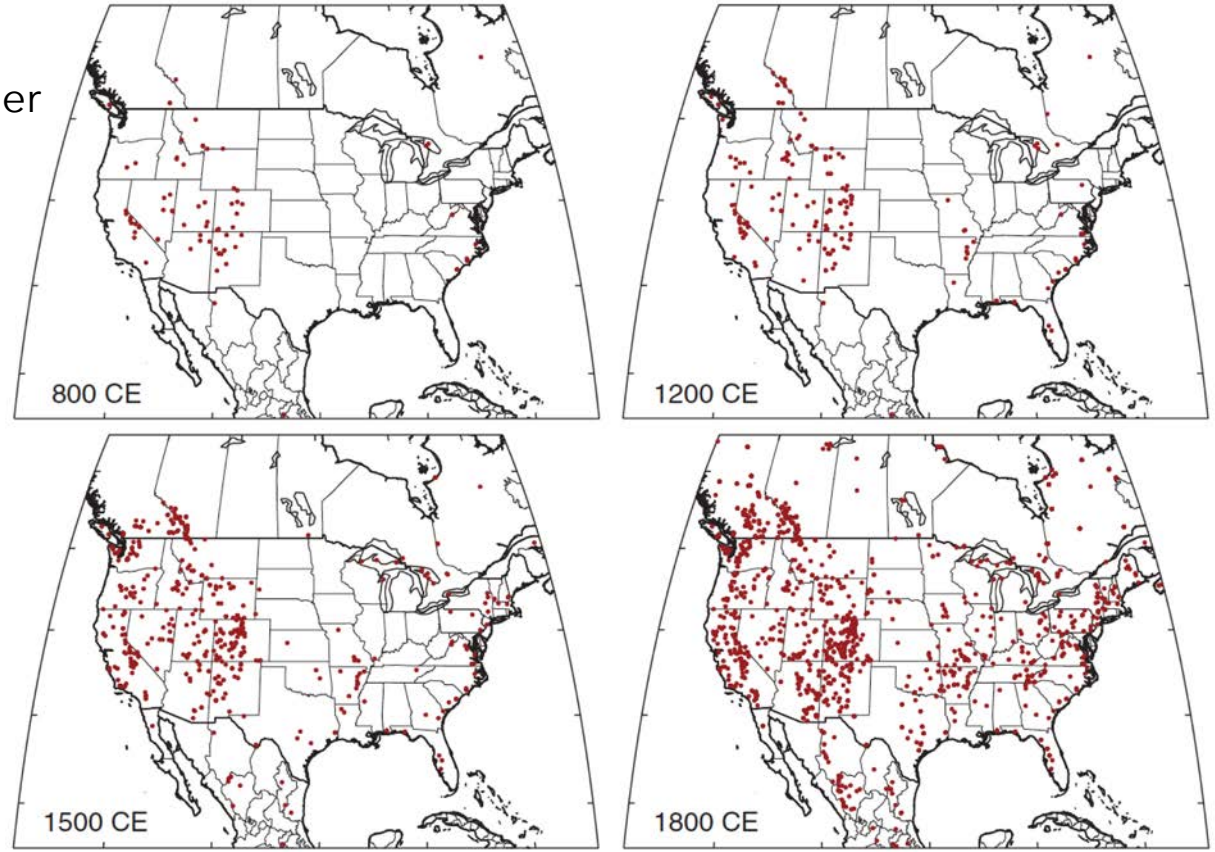
- Spatial reconstructions of Palmer Drought Severity Index (~soil moisture) based on networks of tree ring records
- Multi-century reconstructions exist for North America, Old World, Monsoon Asia, Australia-New Zealand
- Limited input data and reconstructions for Southern Hemisphere



B. Cook et al., 2018, *Current Climate Change Reports*

North America Drought Atlas

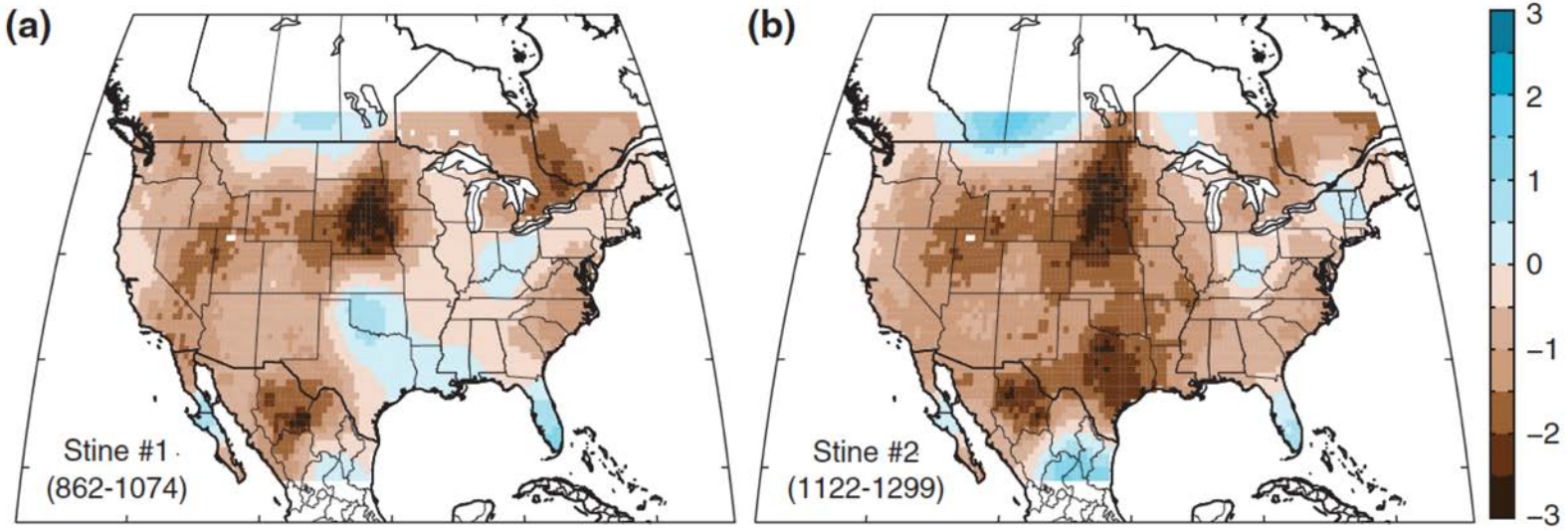
- Spatial reconstructions since 800 CE of summer (JJA) Palmer Drought Severity Index (~soil moisture)
- Based on 1,936 tree-ring chronologies



B. Cook et al., 2016, *WIRES Climate Change*

North America Drought Atlas

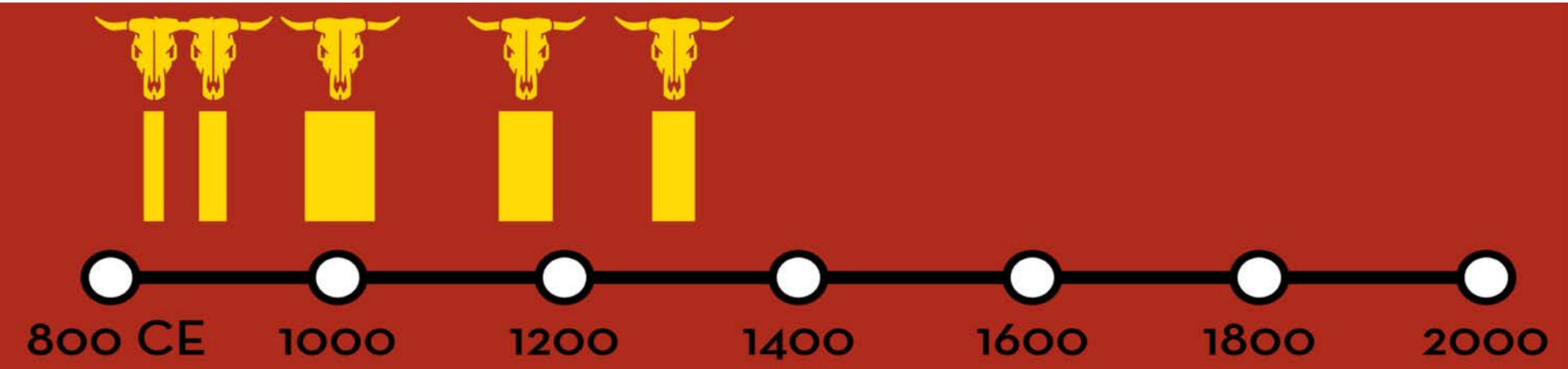
- The five most severe and persistent western USA droughts occurred during the Medieval Climate Anomaly (850-1299 CE)
- The most widespread lasted from 1130-1164 CE and affected ~40% of western USA



B. Cook et al., 2016, *WIRES Climate Change*; Ault et al., 2018, *Journal of Climate*

North America Drought: Hypothesis testing with a Linear Inverse Model

- H_0: *Given enough time, these megadroughts are inevitable and purely a consequence of internal variability* (Ault et al., 2018, *J. Climate*).
- 1,000 x 1,000 year runs, forced only with global SST variability (no trends) from 1950-2000



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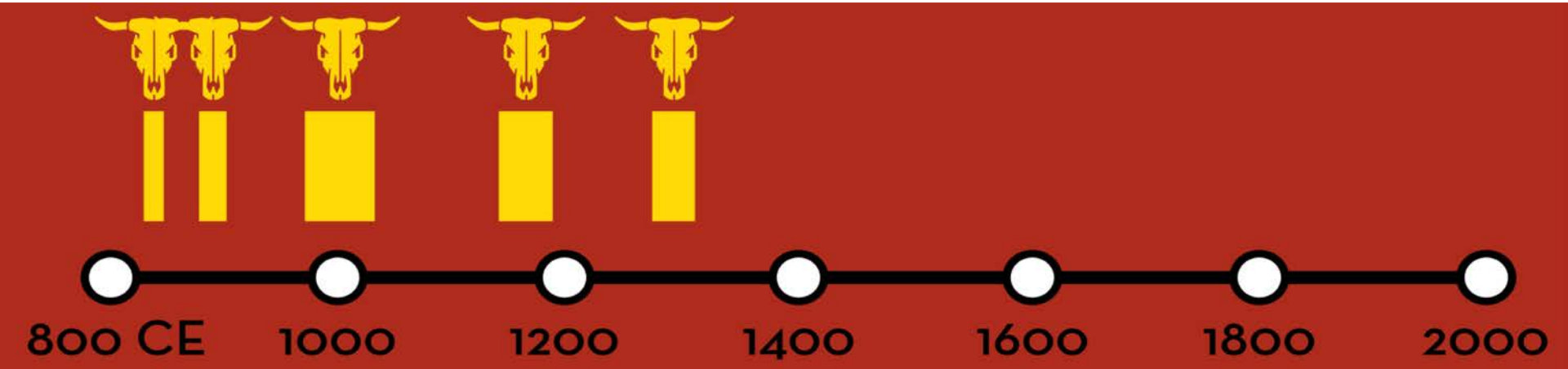
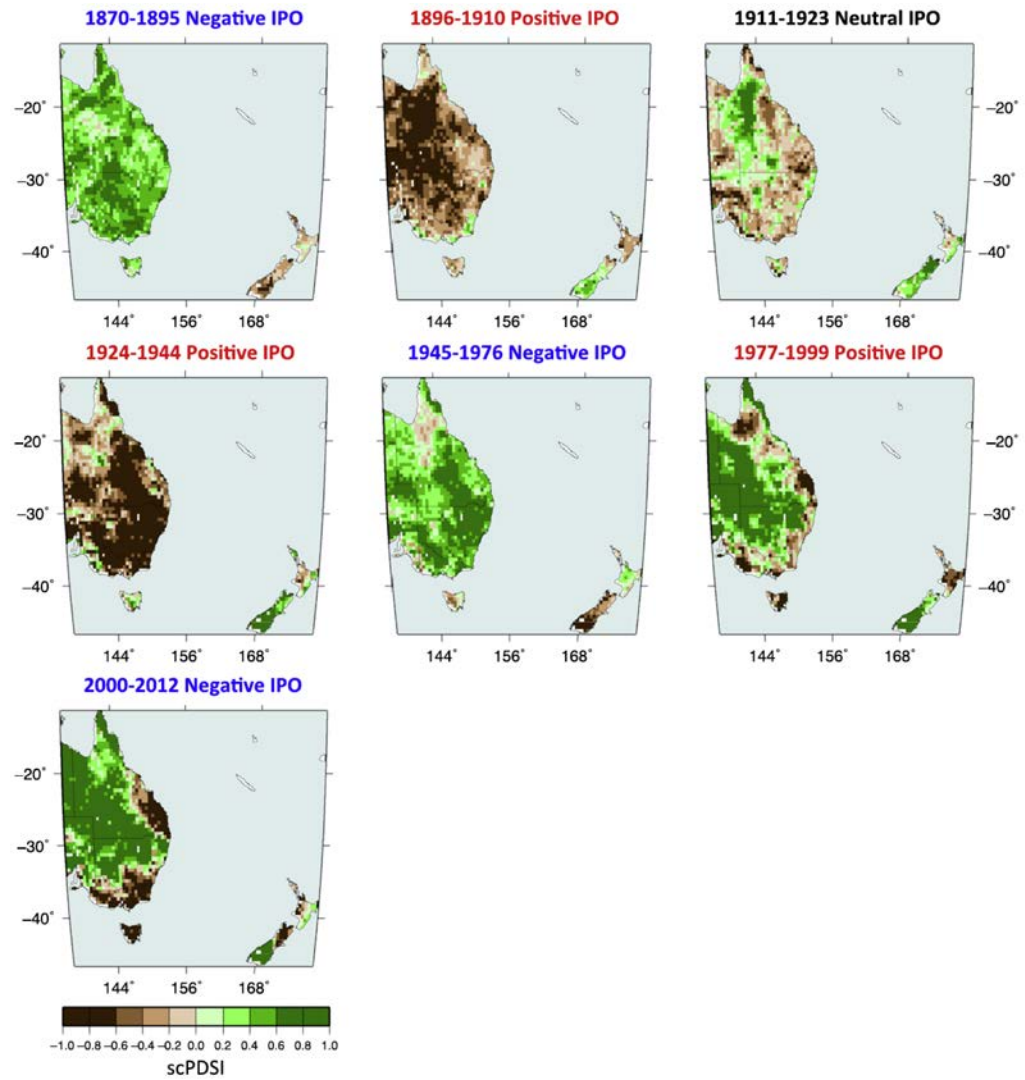
- 1,000 x 1,000 year runs, forced only with global SST variability (no trends) from 1950-2000
- Around 35% of LIM runs produce megadroughts with same (or greater) duration, spatial-scale and magnitude as the most severe reconstructed megadrought
- Clustering of megadroughts during Medieval times is significant and can't be explained by internal variability alone

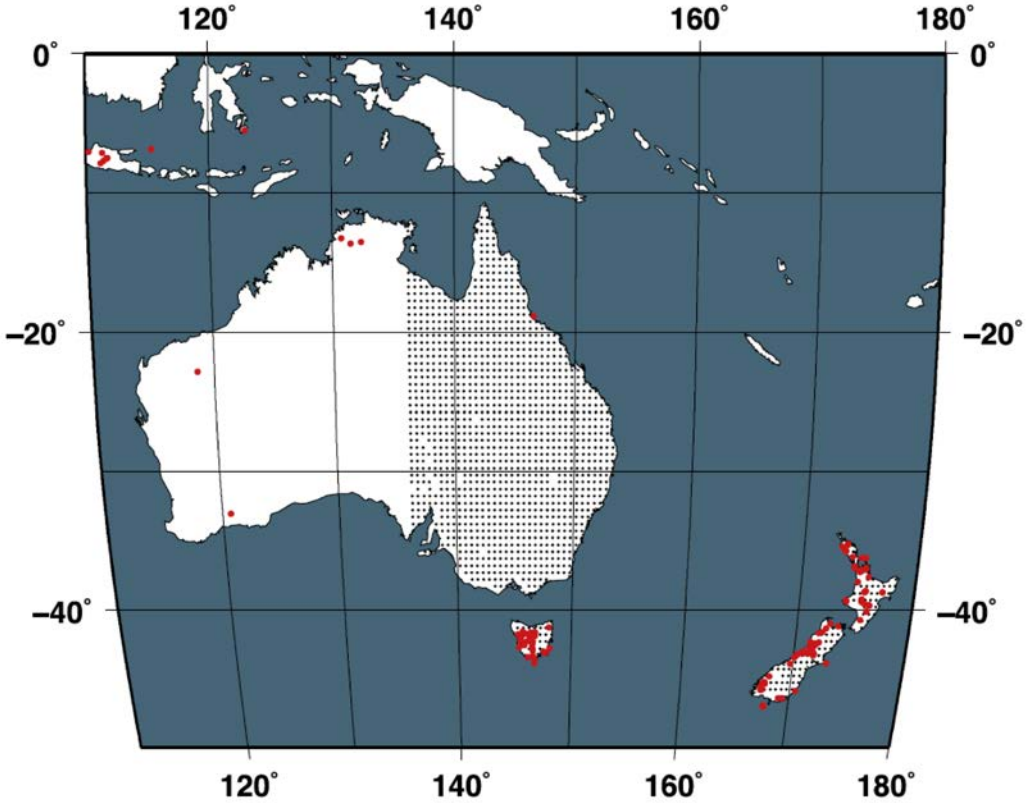




Australia-NewZealand Drought Atlas

- Spatial reconstruction for 1500–2012 CE of summer (Dec-Feb) Palmer Drought Severity Index (~soil moisture) for New Zealand and Eastern Australia
- Based on 176 drought-sensitive tree ring records, and 1 coral record
- Suggests strong link between IPO and Eastern Australia/NZ droughts

Palmer et al., 2015, *Environmental Research Letters*



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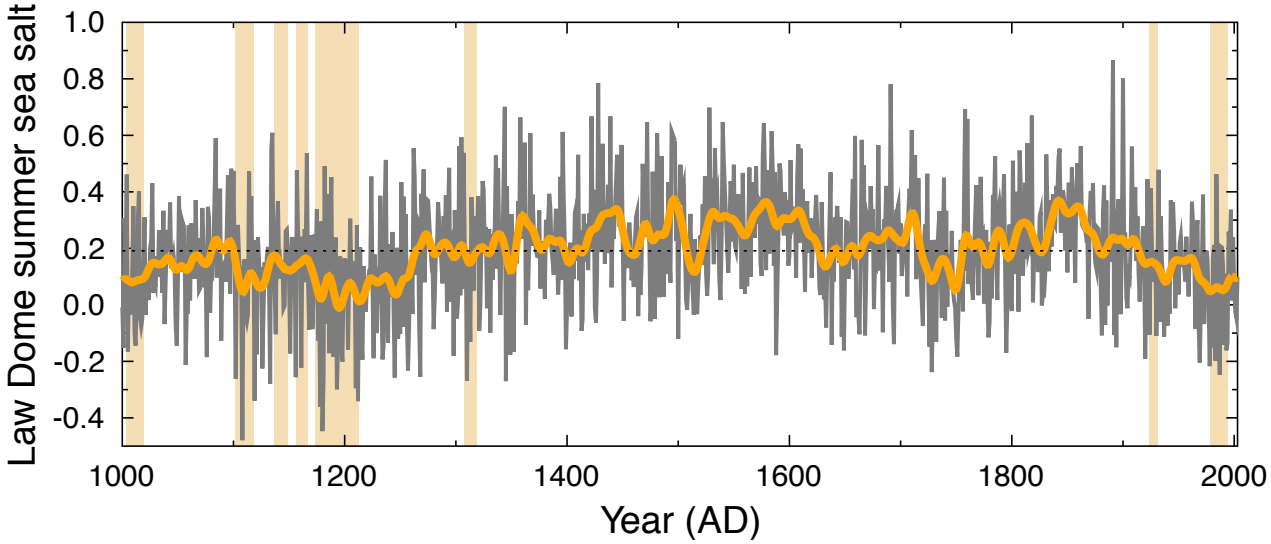
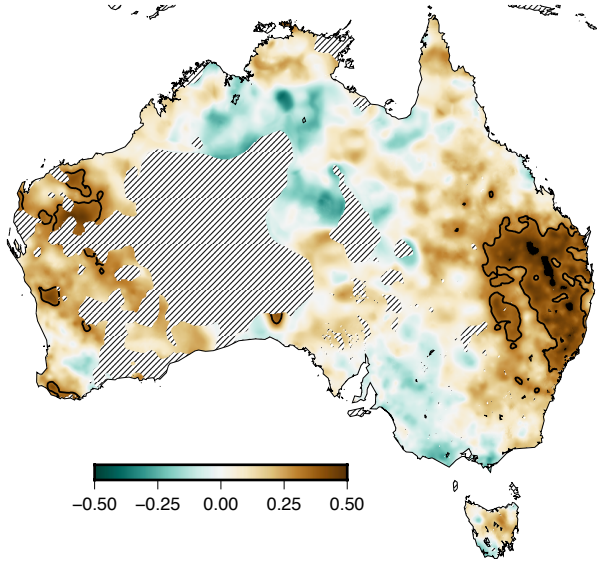
- **Caveat**: no input data for most of the Australian reconstruction region

Palmer et al., 2015, *Environmental Research Letters*

SE rainfall and IPO reconstructions derived from the Law Dome ice core

- IPO positive phase increases drought risk in Australia
- Eight megadroughts are identified including one 39 year drought (1174–1212 CE), which occurred during an unprecedented century of aridity (1102–1212 CE).

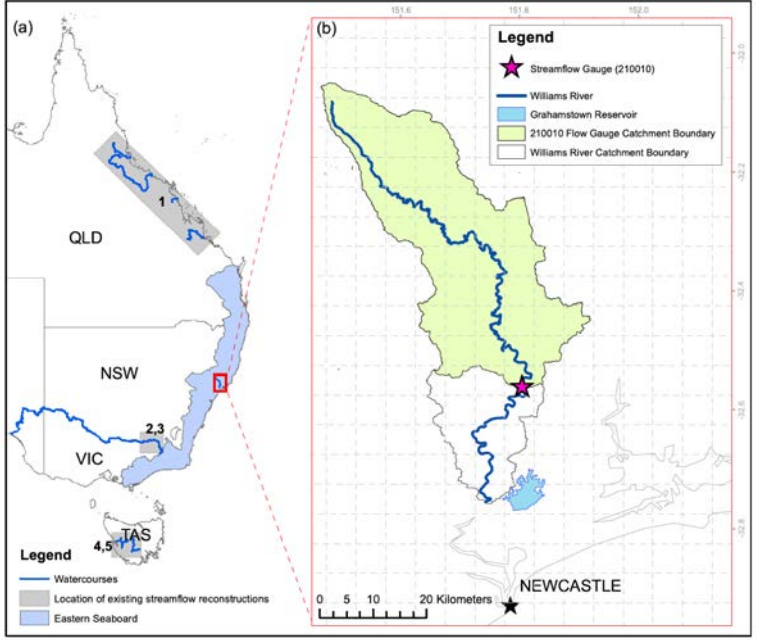


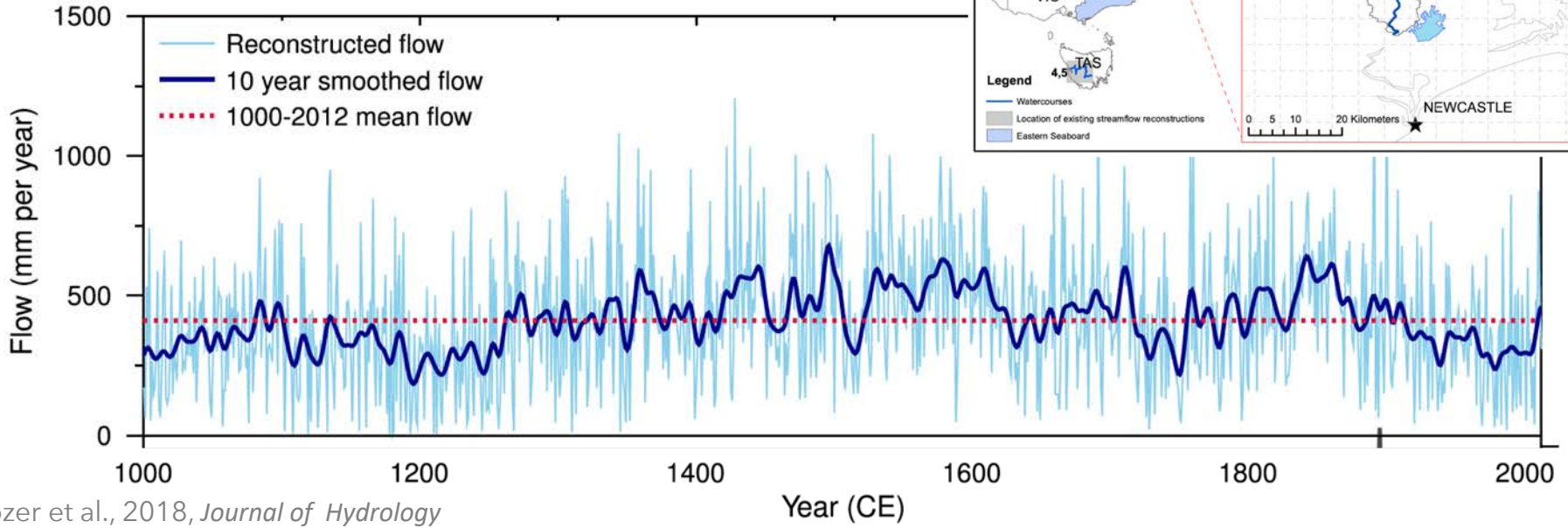


Vance et al., 2013, *Journal of Climate*; 2015, *Geophysical Research Letters*

Catchment reconstructions: Williams River, NSW

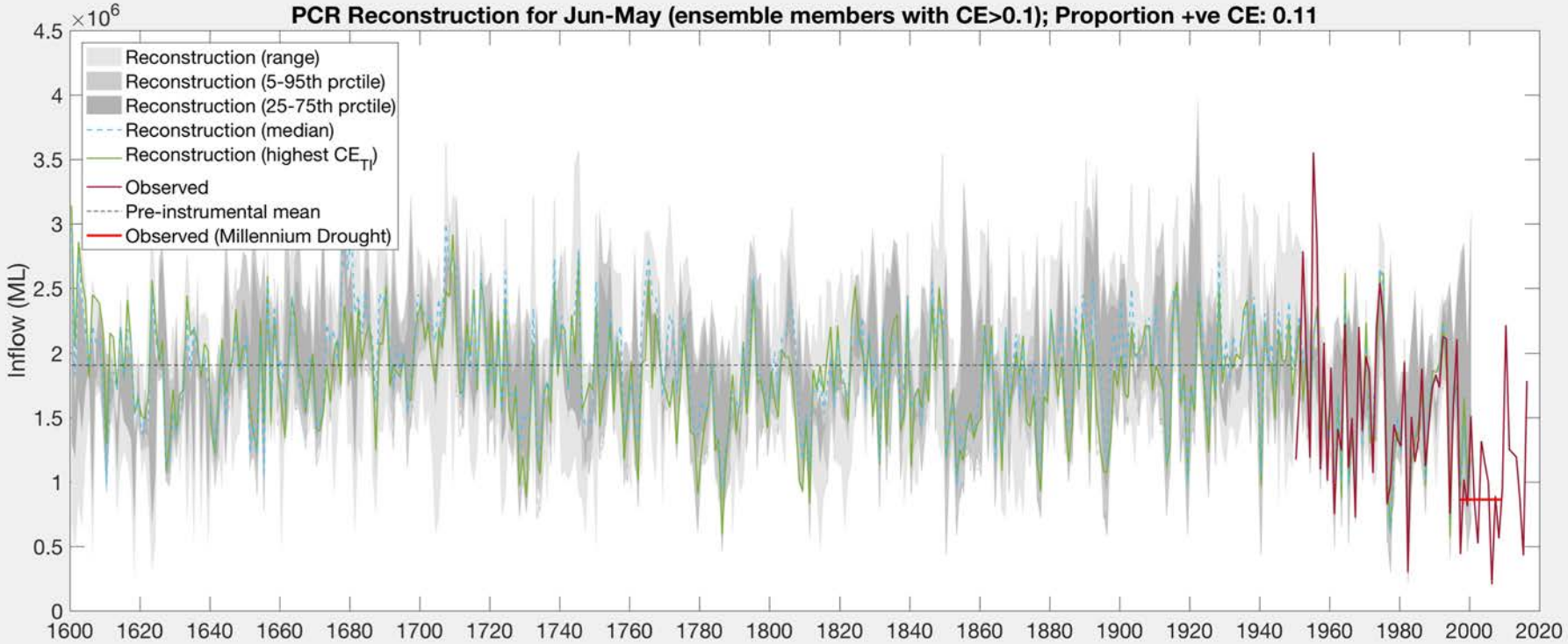
- Deliver stakeholder-relevant information
- Based on Law Dome ice core





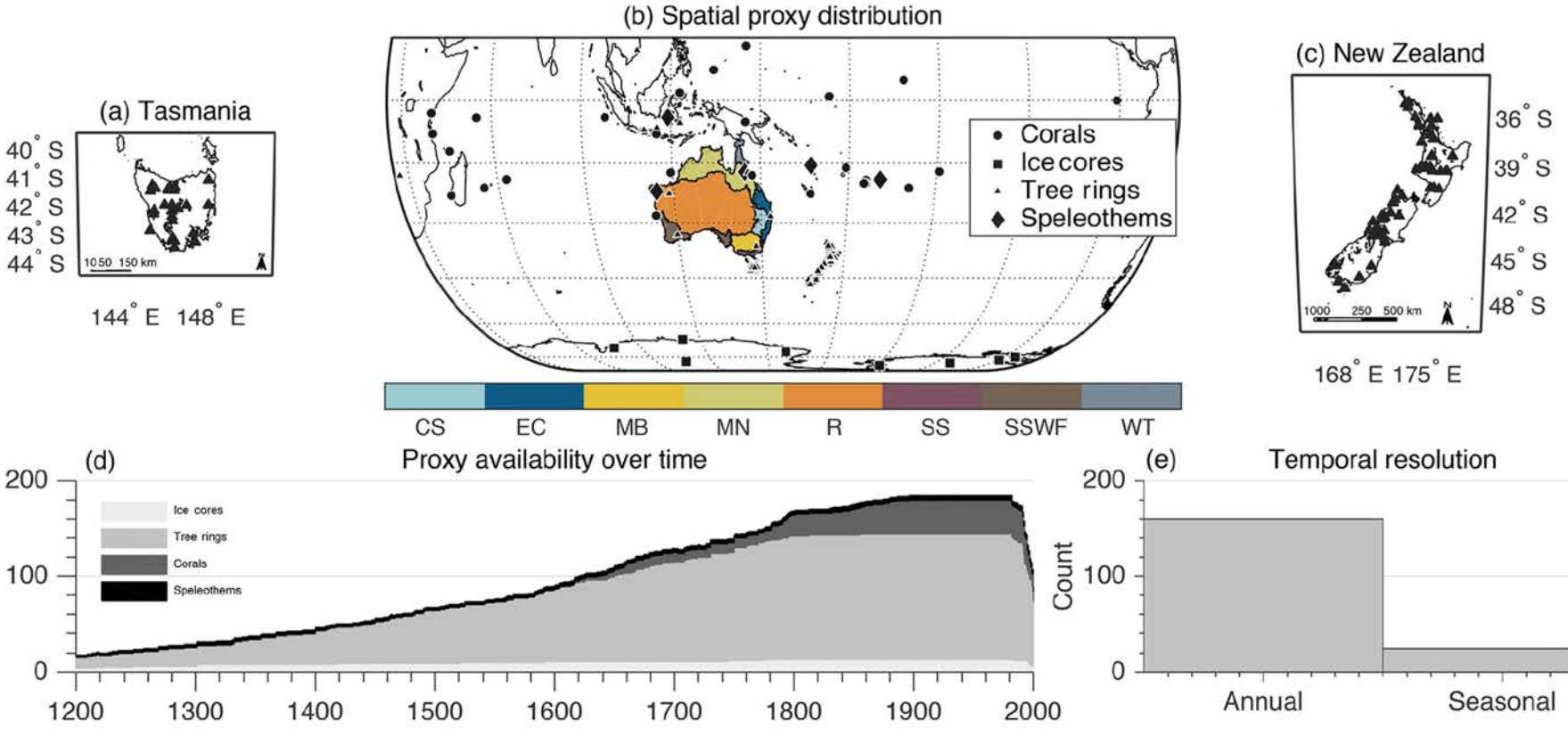
Tozer et al., 2018, *Journal of Hydrology*

Catchment reconstructions: Lake Eildon inflow, Vic



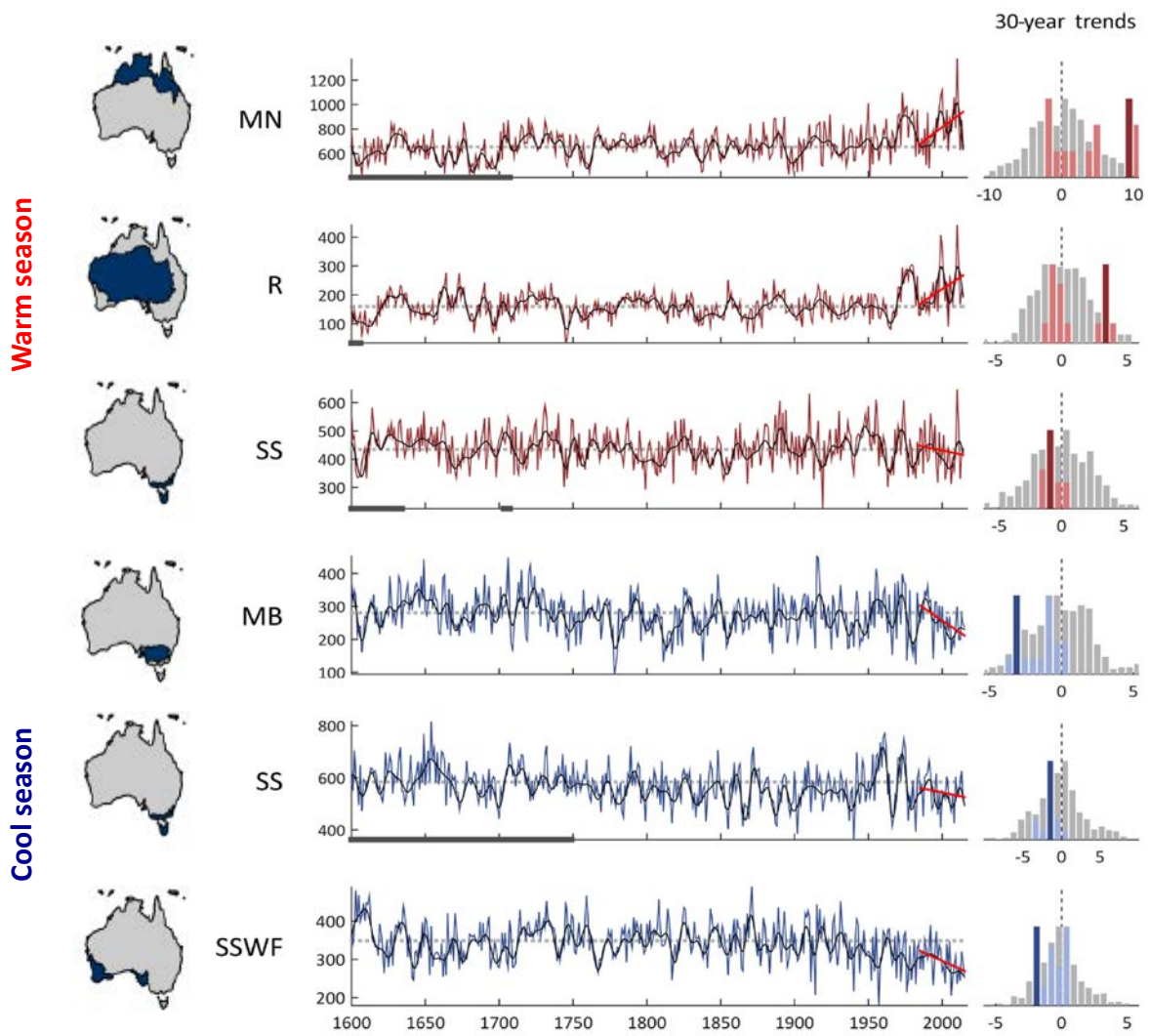
Henley et al., in prep,

Rainfall reconstructions for 8 Natural Resource Management (MNR) regions



Freund et al., 2017, *Climate of the Past*

NMR rainfall since 1600 CE



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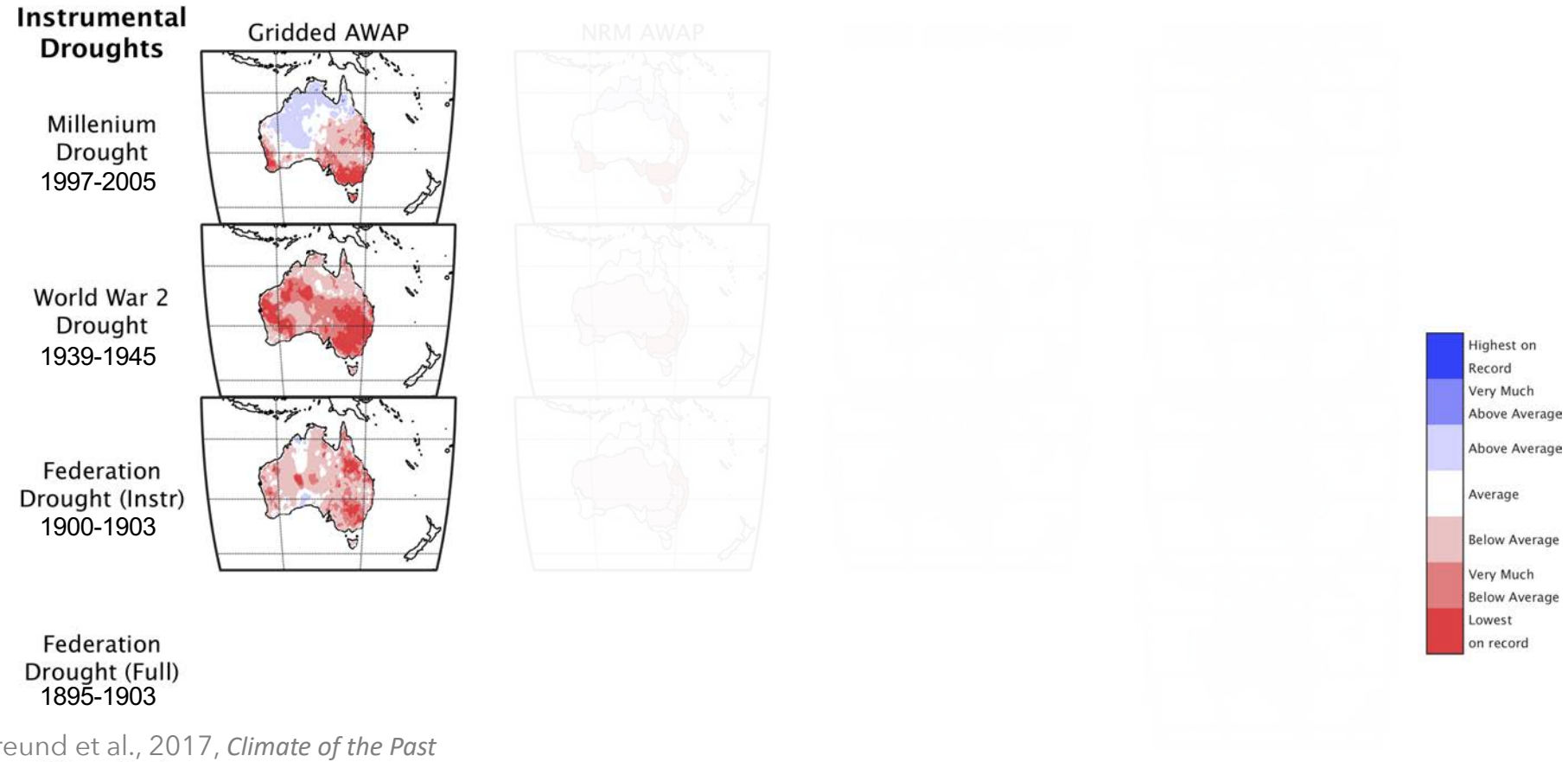
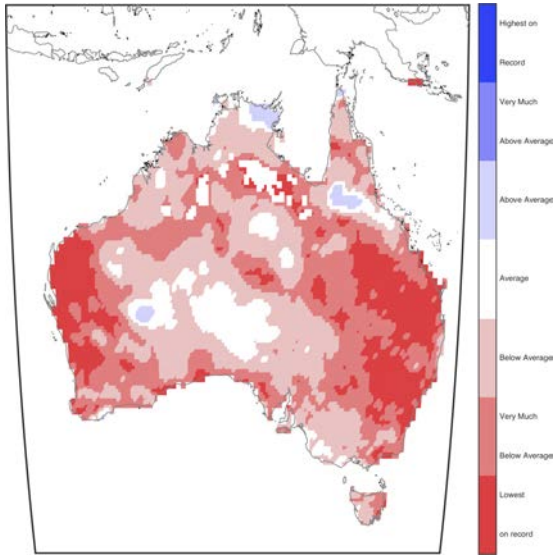


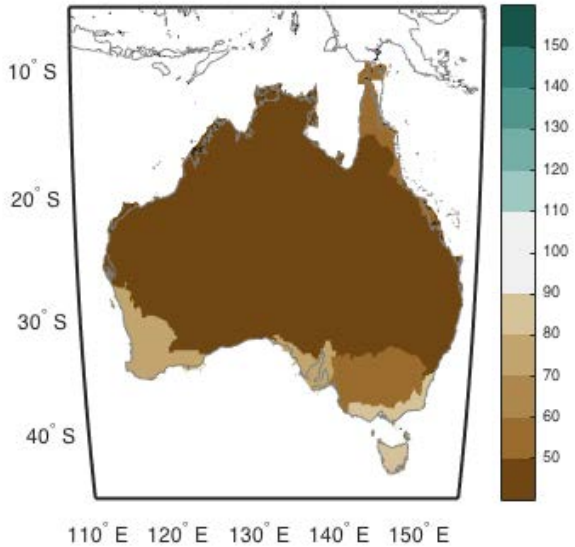
Freund et al., 2017, *Climate of the Past*

Paleoclimate context for current drought (dry-season, 2018)

Instrumental
AWAP
(1900-2018)



Rainfall deficits
as percentages from normal
(1600-2018)



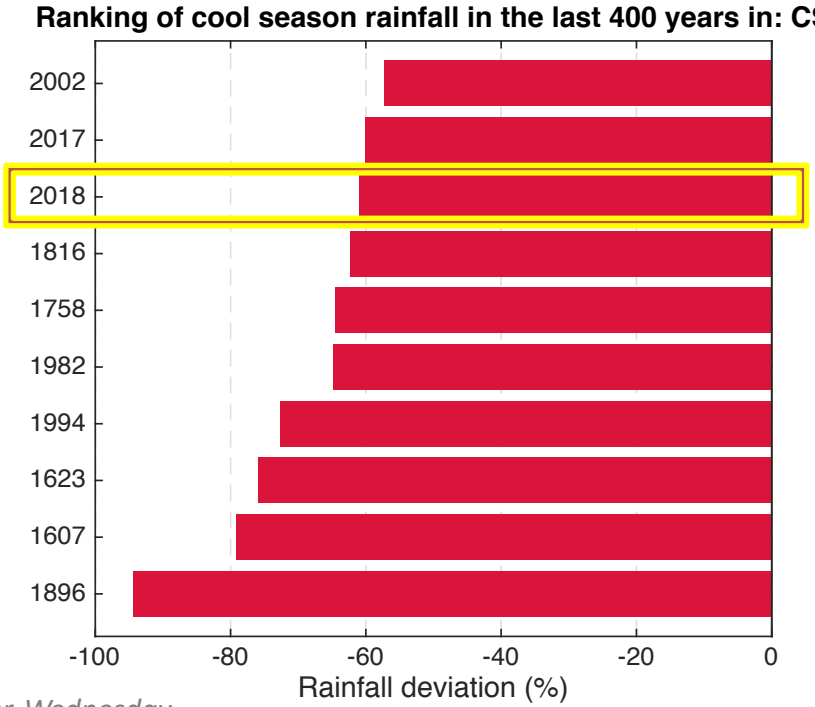
Central Slopes: -60%
East Coast: -56%
Murray Basin:-43%
Monsoonal North:-72%
Rangelands:-61%
Southern Slopes:-11%
Southern & South-Western Flatlands:-29%
Wet Tropics:-45%

Ballis and Freund, 2018 CLEX Workshop, *Poster, Wednesday*

Paleoclimate context for current drought (dry-season, 2018)

10 lowest seasons since 1600
(central slopes)

Rainfall deficits
as percentages from normal (1600-2018)



Ballis and Freund, 2018 CLEX Workshop, *Poster, Wednesday*

Insights into drought from palaeoclimate data

- Rainfall/inflow in Millennium Drought and current drought are unusual, but not unprecedented, in the context of the last 400 years.
- Millennium Drought and current drought may not be unusual in context of earlier parts of the last millennium.
- Megadroughts as bad, or worse, than the largest reconstructed droughts of the last millennium can occur purely from internal SST variability.
- Pacific SST variability is an important driver of megadrought (Australia & USA)
- Clustering of megadroughts in medieval times (850-1299) is likely to have been forced, and understanding extreme megadroughts in the 12th Century is an important target for future research.

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