

# Water availability across Australia during the last 2000 years: implications for water security

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Kiem, A.S., Johnson, F., Westra, S., van Dijk, A., Evans, J.P., O'Donnell, A., Rouillard, A., Barr, C., Tyler, J., Thyer, M., Jakob, D., Woldemeskel, F., Sivakumar, B. and Mehrotra, R. (2016): Natural hazards in Australia: droughts. *Climatic Change*, doi:10.1007/s10584-016-1798-7.

Background:

- Collaboration through the OzEWEX ‘Trends and Extremes’ working group

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The Effect of Historical and Future Climate Changes on Natural Hazards in Australia

Issue Editors: Seth Westra, Christopher J. White, Anthony S. Kiem  
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In this issue (8 articles)

Editorial

Introduction to the special issue: historical and projected climatic changes to Australian natural hazards  
Seth Westra, Christopher J. White, Anthony S. Kiem  
[Download PDF \(625KB\)](#) [View Article](#) Pages 1-19

OriginalPaper

Natural hazards in Australia: floods  
Fiona Johnson, Christopher J. White, Albert van Dijk, Marie Ekstrom...  
[Get Access](#) Pages 21-35

OriginalPaper

Natural hazards in Australia: droughts  
Anthony S. Kiem, Fiona Johnson, Seth Westra, Albert van Dijk...  
[Get Access](#) Pages 37-54

OriginalPaper

Natural hazards in Australia: storms, wind and hail  
Kevin Walsh, Christopher J. White, Kathleen McInnes, John Holmes...  
[Get Access](#) Pages 55-67

OriginalPaper

Natural hazards in Australia: sea level and coastal extremes  
Kathleen L. McInnes, Christopher J. White, Ivan D. Haigh, Mark A. Hemer...  
[Get Access](#) Pages 69-83

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## Natural hazards in Australia: droughts

- Droughts have significant economic, social and environmental impacts but understanding and quantifying these impacts is complex
- Impacts of drought emphasised in Australia because agriculture and water storage/supply infrastructure and systems are designed based on an incomplete understanding into Australia's environment
  - Large spatial and temporal hydroclimatic variability not properly considered
  - Leads to vulnerability and overexploitation of water resources.

## Natural hazards in Australia: droughts

- Droughts are a recurrent and natural part of the Australian hydroclimate, with evidence of drought dating back thousands of years.
- Ability to monitor, attribute, and forecast drought is exposed as insufficient whenever a drought occurs.
- Unlike other hydroclimatic hazards, we currently have limited ability to tell when a drought will begin or end.
- Managing drought is complex due to the variety of temporal and spatial scales at which drought occurs and the diverse direct and indirect causes and consequences of drought

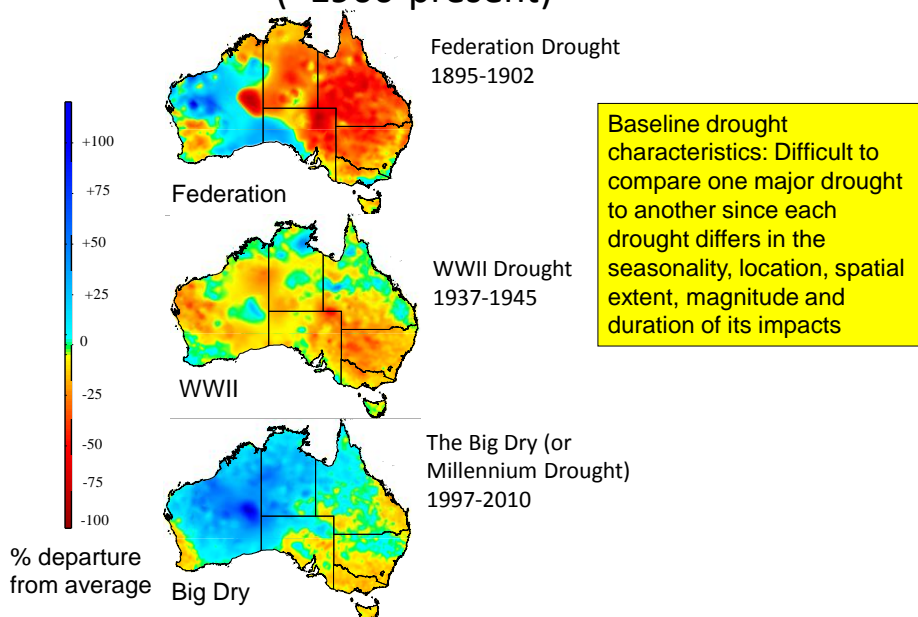
## Natural hazards in Australia: droughts

- To improve understanding and management of drought, [three research challenges](#):
  - (1) defining and monitoring drought characteristics (i.e. frequency, start, duration, magnitude, and spatial extent) to remove confusion between drought causes, impacts and risks and better distinguish between drought, aridity, and water scarcity due to over-extractions;
  - (2) documenting historical (instrumental and preinstrumental) variation in drought to better understand baseline drought characteristics, enable more rigorous identification and attribution of drought events or trends, inform/evaluate hydrological and climate modelling activities and give insights into possible future drought scenarios;
  - (3) improving prediction/projection of drought characteristics with seasonal to multidecadal lead times and including more realistic modelling of the multiple factors that cause (or contribute to) drought.

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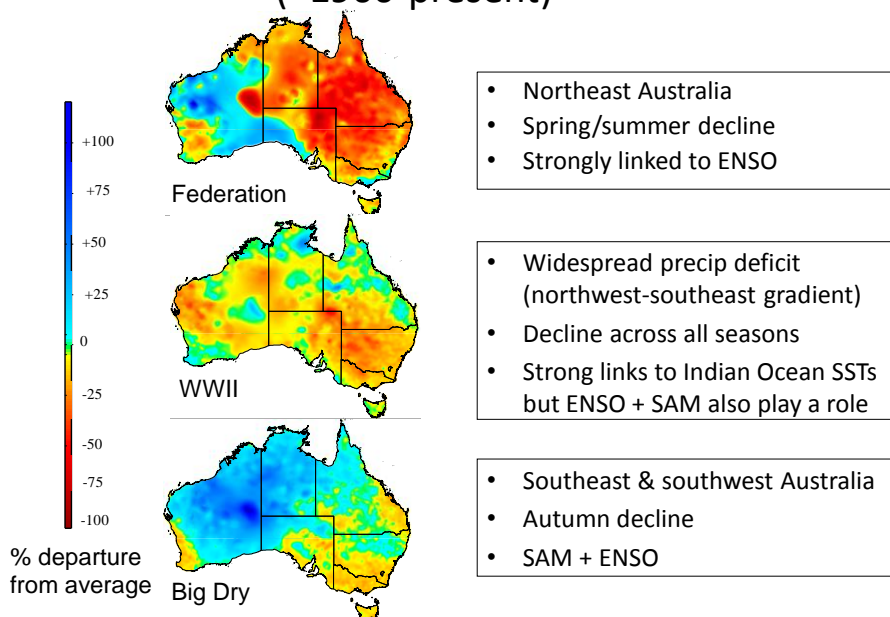
## Australia's drought history – instrumental (~1900-present)



## Australia's drought history

- Droughts caused by a variety of both ocean-atmospheric and hydrological factors:
  - Large-scale ocean-atmospheric processes (ENSO, etc)
  - Precipitation deficits (or absence of extreme rainfall events)
  - Evapotranspiration, temperature and wind
  - Soil moisture deficits
  - Land-surface feedbacks
- But it is rare, especially during the short period covered by Australia's instrumental hydroclimate records, that these factors are in similar states across multiple drought periods – [makes attribution, modelling, prediction and management difficult](#)

## Australia's drought history – instrumental (~1900-present)



## Australia's hydroclimatic history

- Pre-instrumental (prior to ~1900)...a quick summary of things I know about:
  - Pauline's work from yesterday
  - Russell Drysdale and co (UMelb): speleothems (cave deposits)
  - Tessa Vance and co (UTas/ACE CRC): ice cores
  - Kathy Allen and co (UMelb/UTas): trees and ANZDA
  - Jacky Croke and co (UQ): sediments/flood deposits
  - Ian Goodwin and co (MacquarieU): coastal erosion and offshore sand deposits
  - Nerilie Abram and co (ANU): corals
  - Plus lots of others emerging or already existing but not yet explored or tailored for hydrological insights....

# Australia's hydroclimatic history

- Pre-instrumental (prior to ~1900)

And other info from West Aust that Pauline presented yesterday...

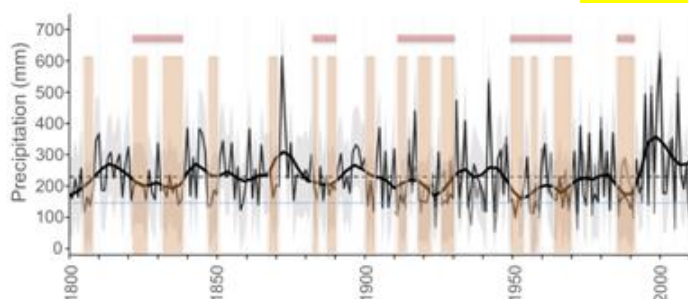
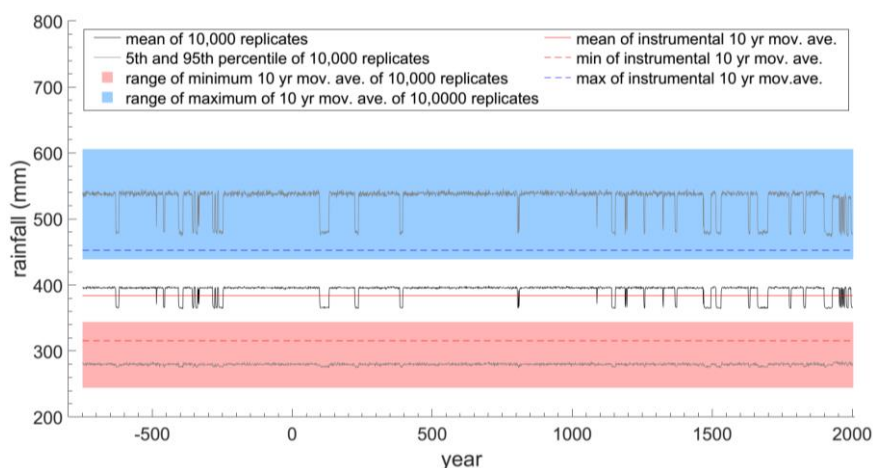


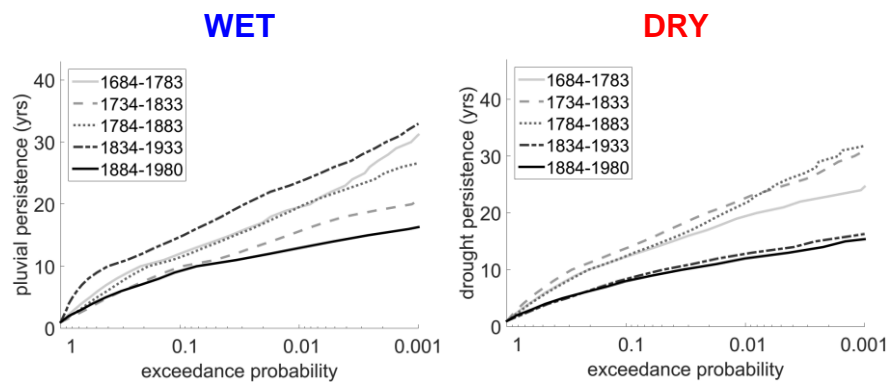
Figure 4: Adapted from O'Donnell et al. (2015). Reconstructed rainfall in the Pilbara region (northwest Australia) from tree rings. Dashed line = long-term average rainfall (1802-2012), dotted blue line = -1SD, Orange shading = multi-year drought, red shading = extended drought periods (20-year loess curve below long-term average).

## Reconstruction result - Wombeyan

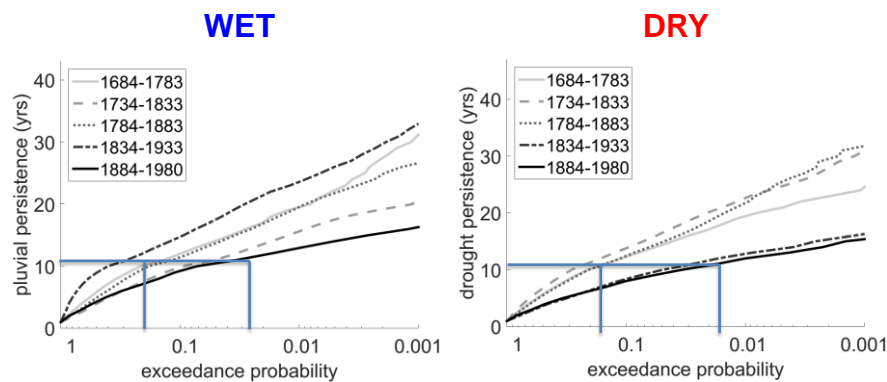


Ho, M., Kiem, A.S. and Verdon-Kidd, D.C. (2015): A paleoclimate rainfall reconstruction in the Murray-Darling Basin (MDB), Australia: 2. Assessing hydroclimatic risk using preinstrumental information on wet and dry epochs. *Water Resources Research*, 51, doi:10.1002/2015WR017059.

# Exceedance Probability: Upper Murray



# Exceedance Probability: Upper Murray



Probability of both dry and wet periods exceeding a decade at least 10 times more likely prior to 1883 than suggested by instrumental records.

## More pre-instrumental information.....

AGU PUBLICATIONS

Geophysical Research Letters

### RESEARCH LETTER

10.1002/2014GL062447

#### Key Points:

- One kiloyear Interdecadal Pacific Oscillation and Australian drought record
- Twelfth century was exceptionally and in eastern Australia
- Australian water policy needs to account for future megadroughts

#### Supporting Information:

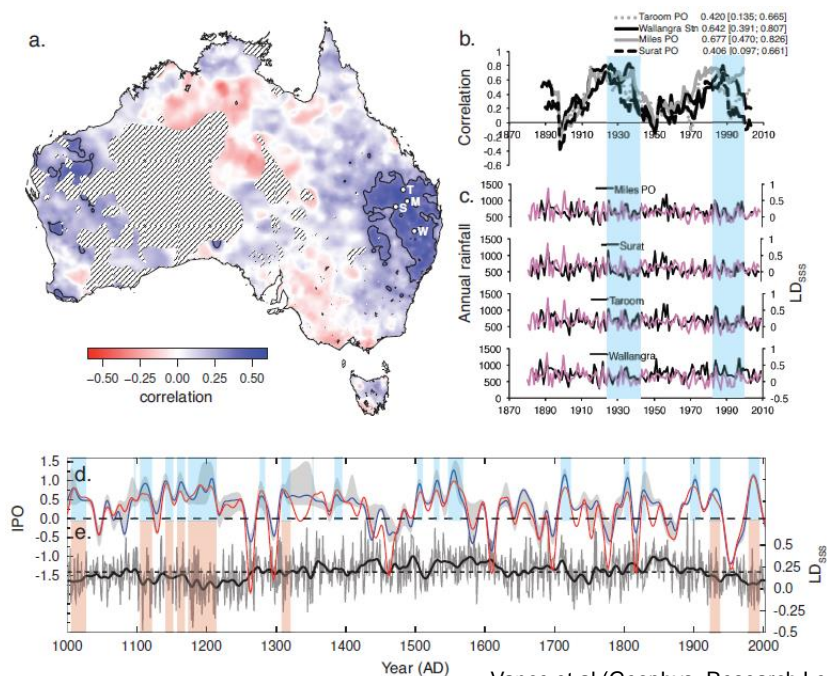
### Interdecadal Pacific variability and eastern Australian megadroughts over the last millennium

T. R. Vance<sup>1</sup>, J. L. Roberts<sup>1,2</sup>, C. T. Plummer<sup>3</sup>, A. S. Kiem<sup>4</sup>, and T. D. van Ommen<sup>1,2</sup>

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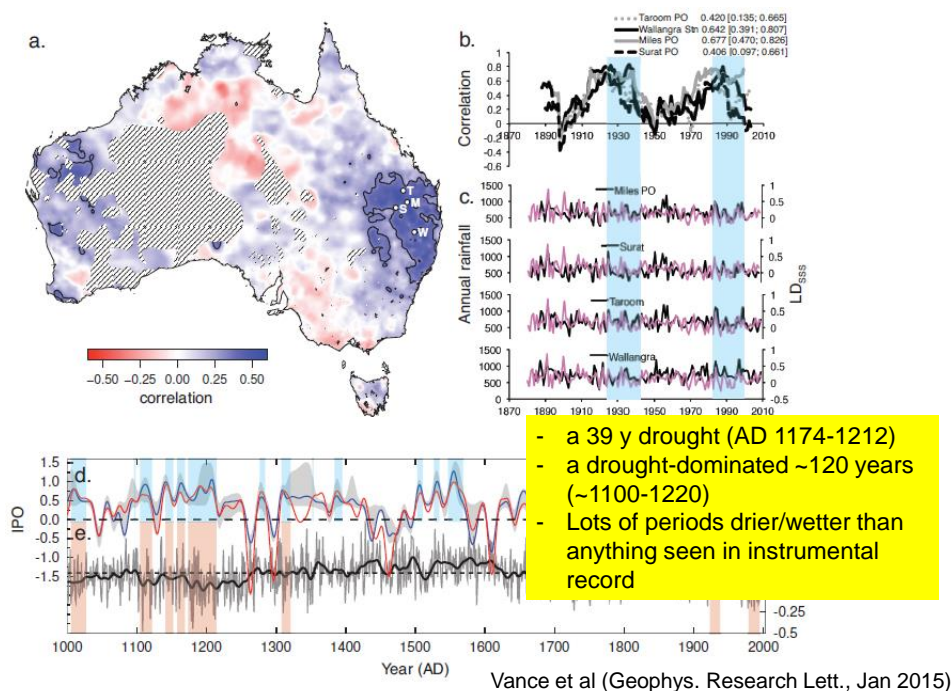
**Abstract** The Interdecadal Pacific Oscillation (IPO) influences multidecadal drought risk across the Pacific, but there are no millennial-length, high-resolution IPO reconstructions for quantifying long-term drought risk. In Australia, drought risk increases in positive phases of the IPO, not low suitable rainfall events and

- Ice cores from Antarctica (Vance et al 2015)
  - Changes to sea salt in ice cores at Law Dome is linked to changes in wind circulation patterns in the Indian and Pacific Oceans which is linked to changes in ENSO/IPO which is linked to rain/hydrology in eastern Australia
  - Use these links to reconstruct 1000y ENSO/IPO/east Aust rainfall



Vance et al (Geophys. Research Lett., Jan 2015)





- See also the ~500yr east Aust/NZ drought atlas (~1550-2012) based on tree rings and corals



## Multiple lines of evidence suggest....

- Droughts similar to, and longer than, 'Big Dry' (1997-2008), WWII (1935-1945) and Federation (late 1890s) droughts **have occurred on a regular basis in Australia's past (last 2700 yrs)**
- Six megadroughts (> 10 yrs) occurred between AD 1000-1320 **including a 39 y drought (AD 1174-1212)**
- Wet epochs that are **wetter and longer than anything seen in the instrumental record** have occurred several times over the last 2750 years
  - ~1400-1450, 1500-1620, mid-1800s

## Multiple lines of evidence suggest....

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- Six megadroughts (> 10 yrs) occurred between AD 1000-1320 **including a 39 y drought (AD 1174-1212)**

- W This challenges the underlying assumptions governing water resources planning and management:
  - se 1) That droughts > 5 y are rare (~3 in 100 yrs)
  - se 2) That droughts > ~15 y are not possible
  - 3) That flood/drought risk is stationary
  - 4) That IFDs, ARIs, AEPs etc established based on instrumental record are sufficient...

## Exciting work with lots of potential....but...

- How do we best use the palaeoclimate info:
  - To put instrumental record into context and improve understanding of past and future drought?
  - To provide practically-useful information to water resource managers and other decision makers?
  - To answer key policy questions? What are the key policy questions that this info can help with?
- How to deal with inherent uncertainties with the palaeo info? Different temporal/spatial scales? Different accuracies on dating? Different target locations/seasons? Different purposes for which the palaeo records were originally developed?
- What about climate models and other data sources (radar, remote sensing, reanalysis etc)?

## Exciting work with lots of potential....but...

- Need to bring the various communities and fields of science involved together to get the most we can out of this work:
  - Palaeoclimatologists of various persuasions, hydrologists, climate modellers, water resource managers etc..
- And to properly understand historical water availability across Australia so we get some realistic insights into future water availability.
- How to do that??

# Proposal

- ....