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Speleothem palaeo-rainfall archives in southwest and southeast Australia

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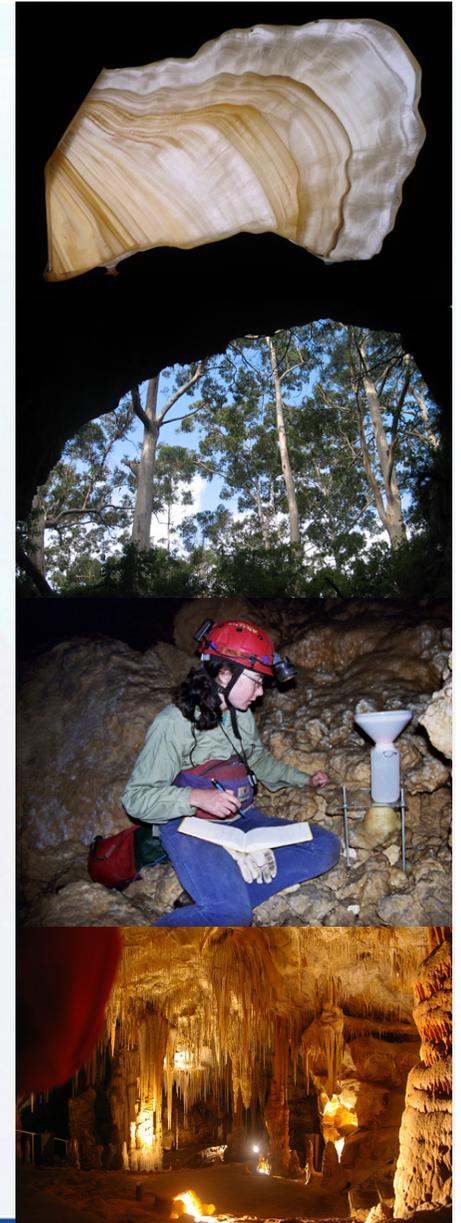
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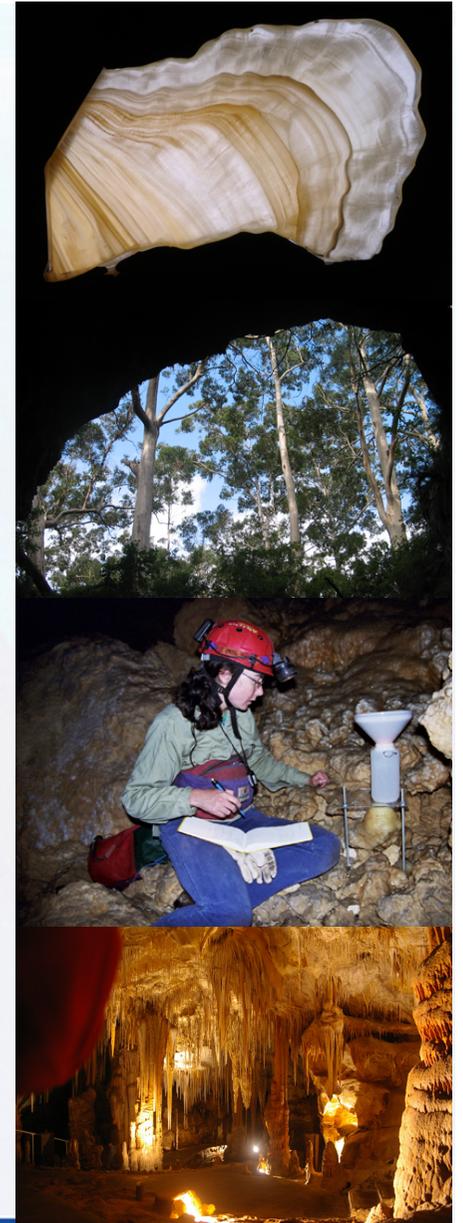
Background

- ***Progress, limitations & potential***
- Two areas
 - SWWA (Perth region and Margaret River)
 - SEA (Alpine NSW and Sydney basin)
- ***Goal: Reconstruct rainfall variability for last 1k using multiple proxies in speleothems (sub-decadal or better)***
- Emphasize: Challenging project
 - Decadal signal is relative small
 - Mid-latitude sites with multiple climate modes
 - Finding recent material & uncertainties in age measurements
- Why?
 - Important issue (natural rainfall variability)
 - Modern speleothem studies & cave monitoring work = important groundwork (7 papers + more in progress)



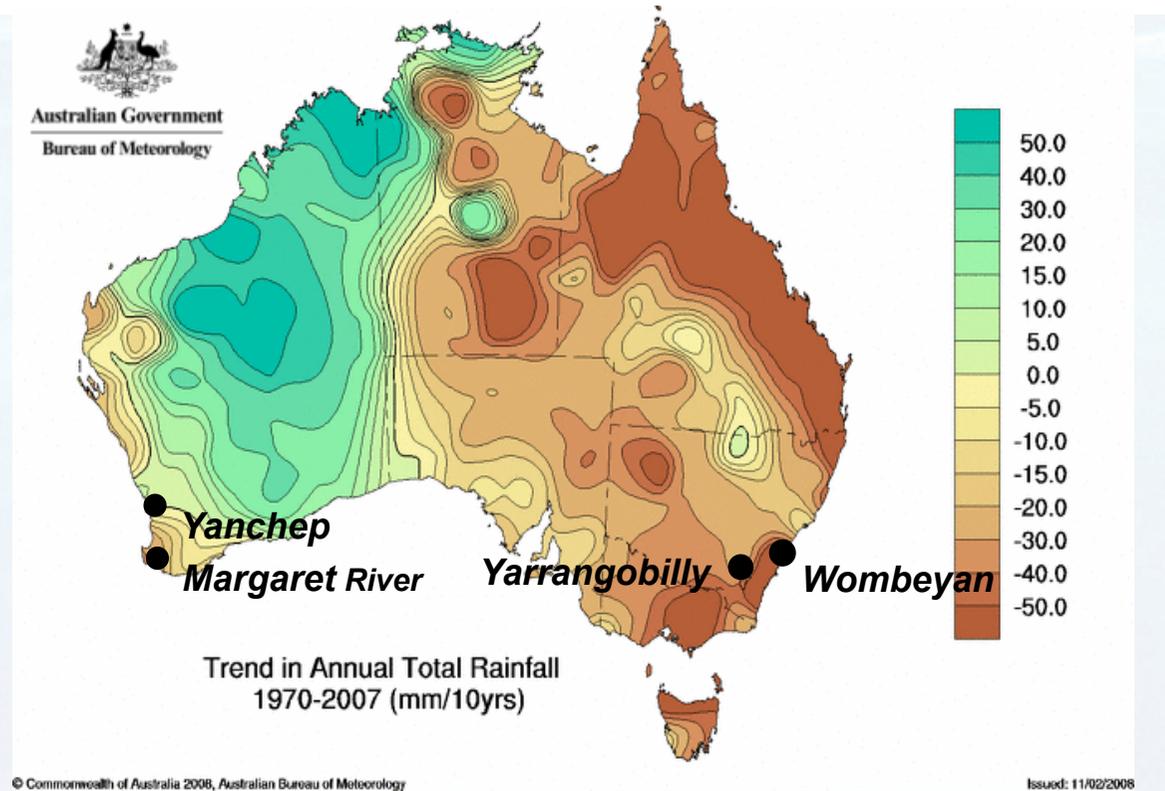
Outline

- Sites
- Table of records to date
- **SWWA**
 - Calibration work
 - Records
 - Issues
 - Future work
- **SEA**
 - Alpine NSW emerging records & potential
 - (Russell Drysdale) Sydney basin records



Study sites

- Decadal-scale dry periods
 - SWWA (1970+)
 - SEA (1990+)



Extreme event or baseline shift?

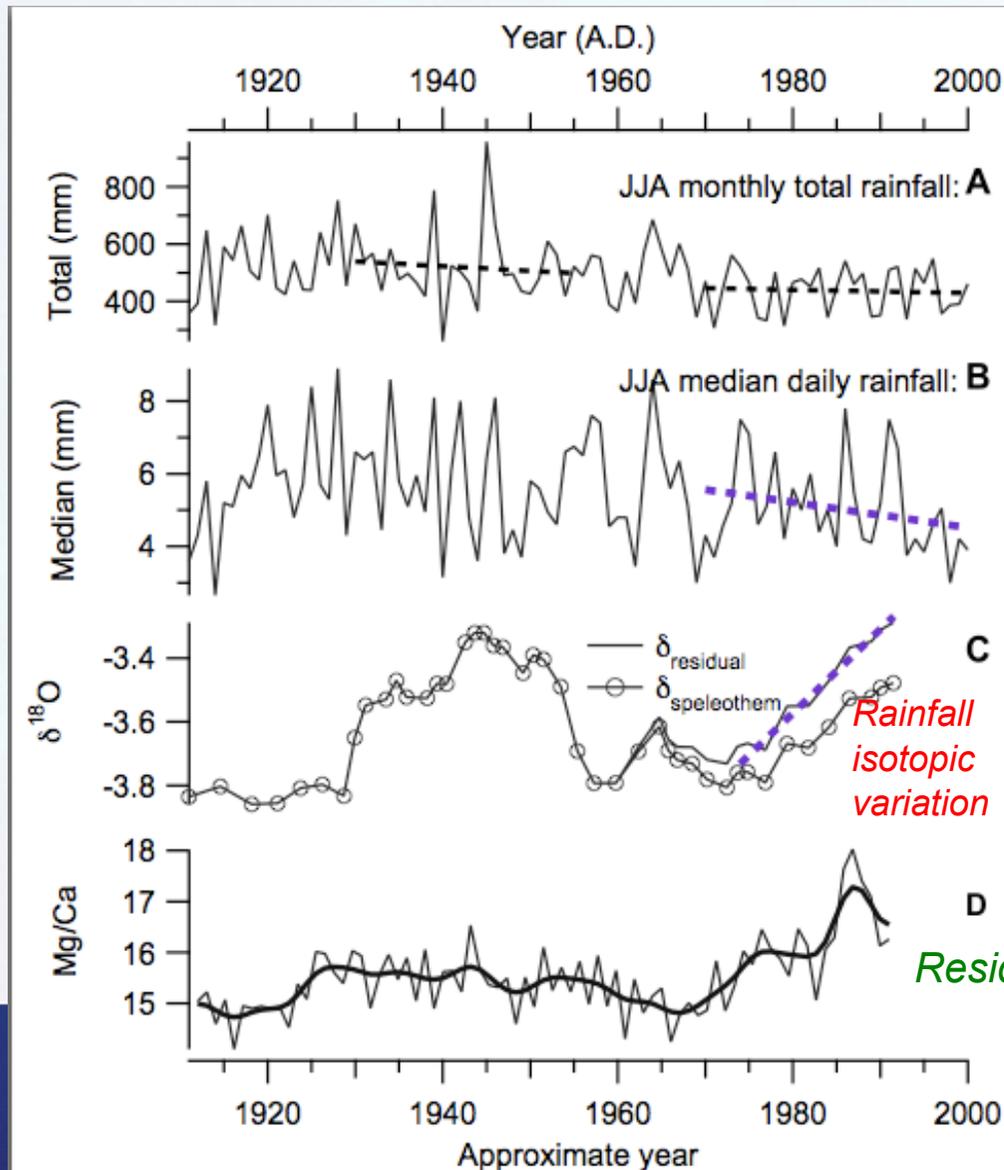
Region	Site	Record	Resolution	Complete	Comments
Southwest WA					
Perth	Yanchep	1750-2004AD	Annual (TE's, lamina), 1-2 a ($\delta^{18}\text{O}$)	Y	Influenced by land use?
Margaret River	Golgotha Cave GL-S2	2.6 ka (hiatus 400-1400AD)	2-4 a ($\delta^{18}\text{O}$ TE's)	Y	
	Golgotha Cave GL-S1	0 - 8 ka	decadal	N	
	various	Modern x3	Sub-annual-annual	N	
Southeast Australia					
Alpine NSW, Kosciusko	Harrie Wood Cave HW-S1	1920-2005AD, 15-14 ka	Sub-annual-annual	N	
Alpine NSW, Kosciusko	Harrie Wood Cave HW-S2	1920-2005AD, 10-8.6 ka	Sub-annual-annual	N	
TAS	Florentine Valley	0-2 ka	5-10 a ($\delta^{18}\text{O}$), annual (TE)	More age estimates	unpublished

Calibration

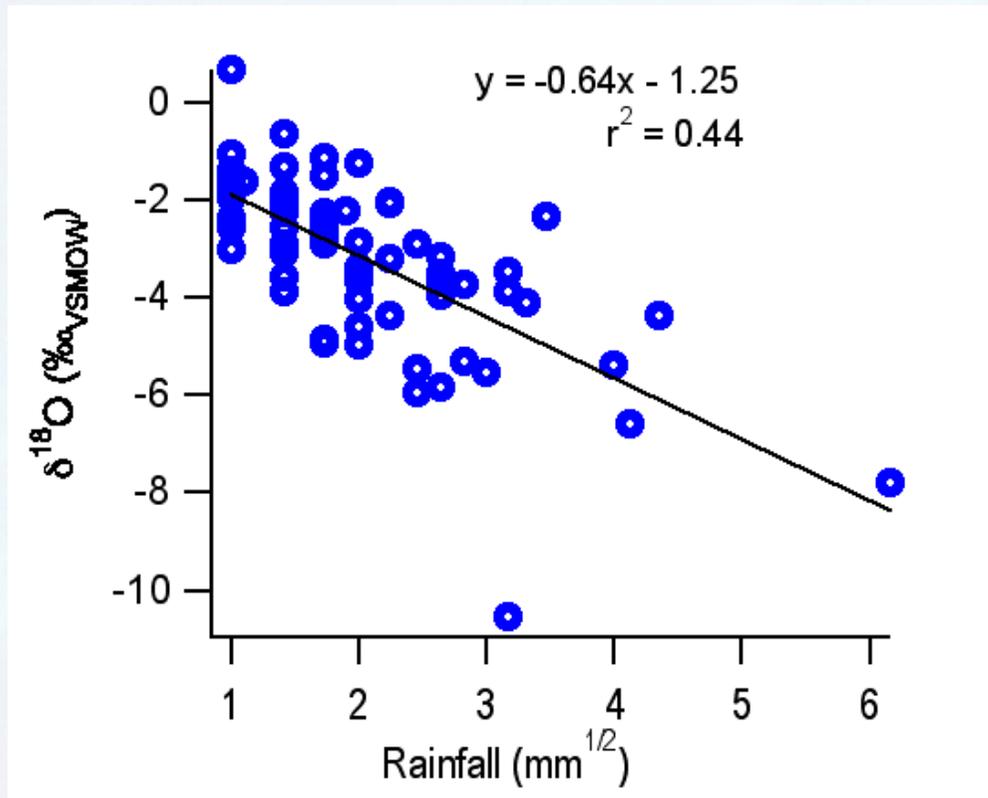
Modern speleothem record



- Speleothem $\delta^{18}\text{O}$
 - Rainfall $\delta^{18}\text{O}$
 - Post-1970 rise \Rightarrow rainfall decrease
 - Reduction in higher magnitude events
 - 1930-55: elevated $\delta^{18}\text{O}$ not related to amount change
 - Source/trajectory effects could also vary year to year

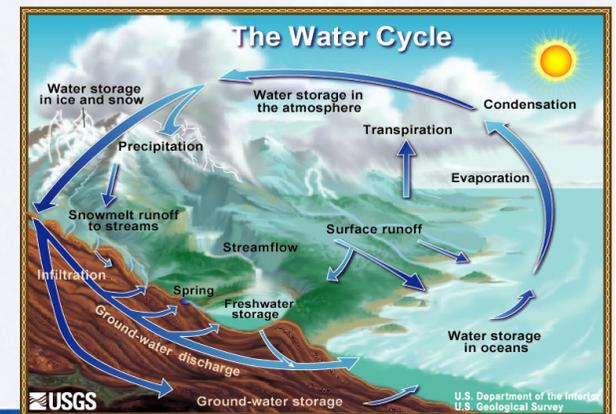


SWWA rainfall $\delta^{18}\text{O}$ (1)



Treble et al., EPSL 2005

- Rainfall $\delta^{18}\text{O}$
 - Daily sampling (2000)
 - **Inverse “amount” effect**
 - $\delta^{18}\text{O} = aP + b$



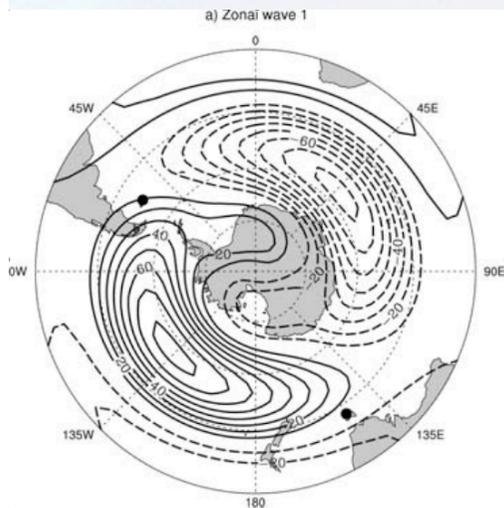
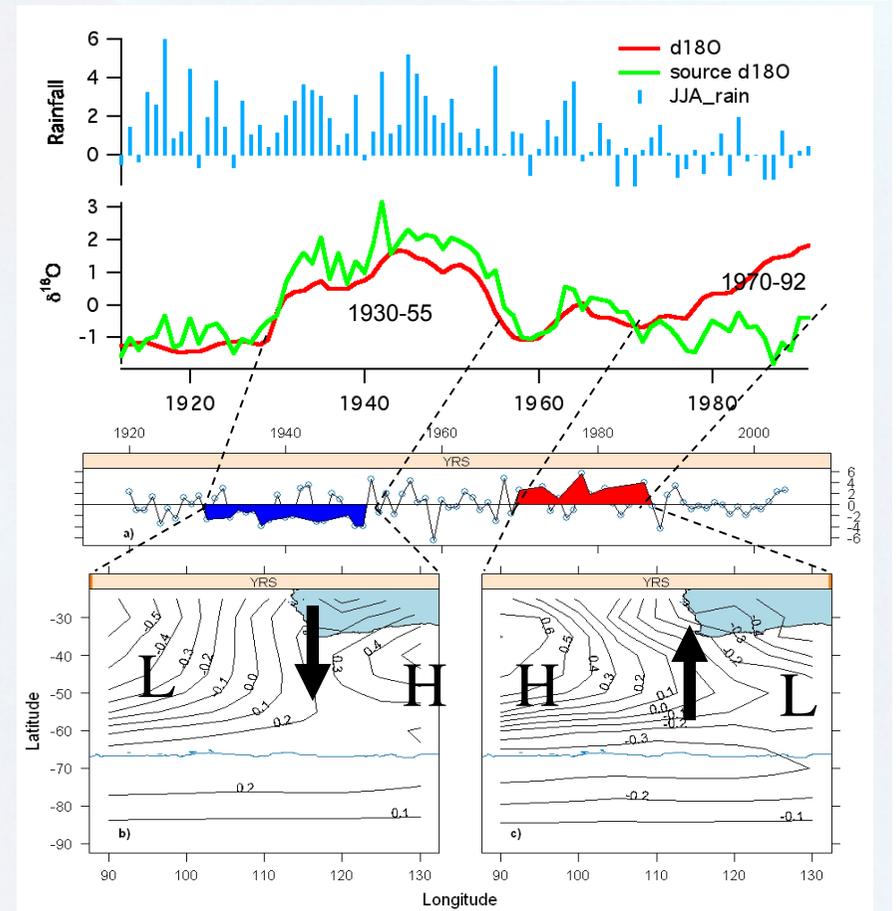
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SWWA rainfall $\delta^{18}\text{O}$ (2)



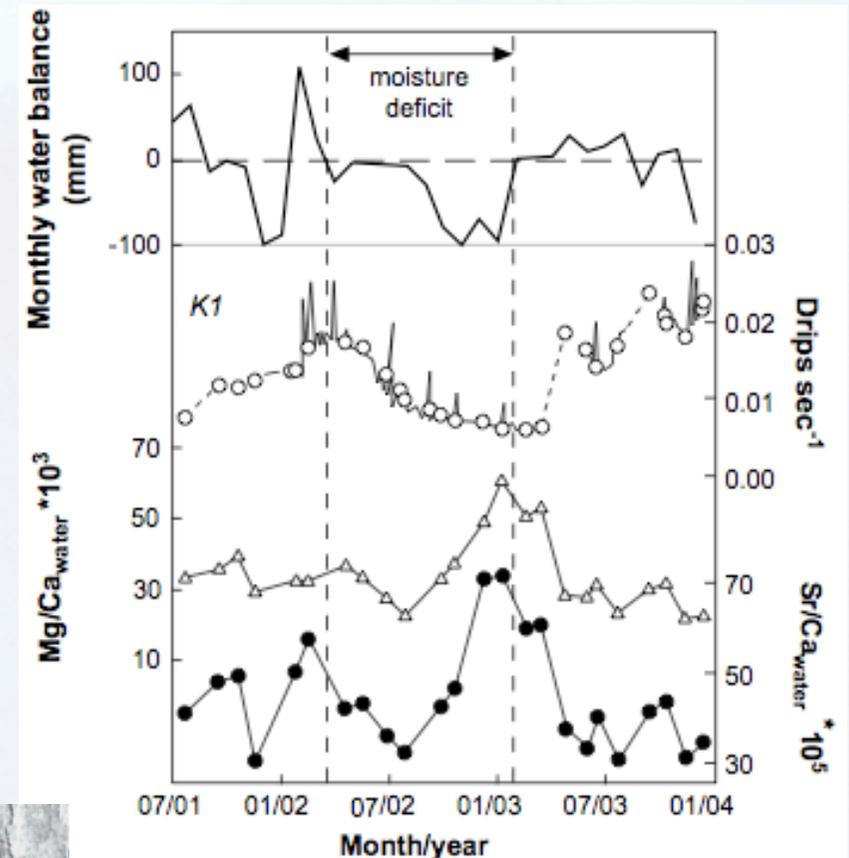
- Fischer & Treble JGR (atm) 2008
 - Perth GNIP & HADSLP2
- $\delta^{18}\text{O} = aP + b$ {20% variance}
- $\delta^{18}\text{O} = aP + b + c(\text{CI})$ {50% variance}
- Zonal Wave 1 (ZW1)
 - Trans-Polar Index (TPI)
 - 1930-55: ZW1 -ve phase; flow from lower latitudes
- Good news: climate mode proxy!



Zonal Wave 1
(Hobbs & Raphael, 07)

Trace elements as rainfall proxies

- **Long duration monitoring:**
 - 5 yrs (SWWA) & 10 yrs (Wombeyan)
 - Drip water chemistry, rain chemistry, cave temperature, drip rates, pH, cave CO₂, rel. humidity, pressure, modern calcite precipitates
- Complex signals
- Multiple factors
 - *Climatic: aquifer residence time, cave CO₂, fluid saturation wrt Ca, drip rate*
 - Non-climatic: aquifer mixing



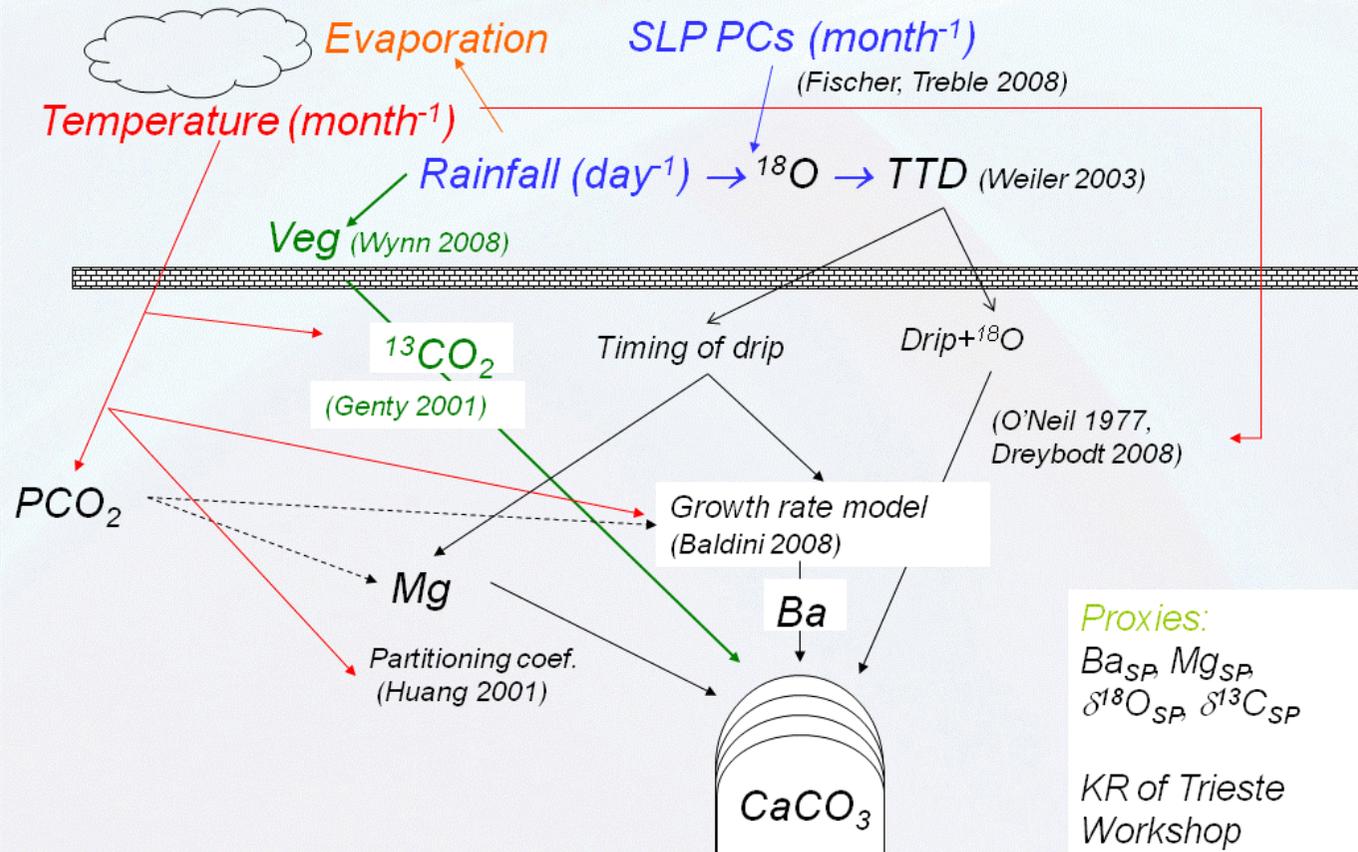
McDonald et al., GRL 2004

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Fischer and Treble (12pm Tues talk)

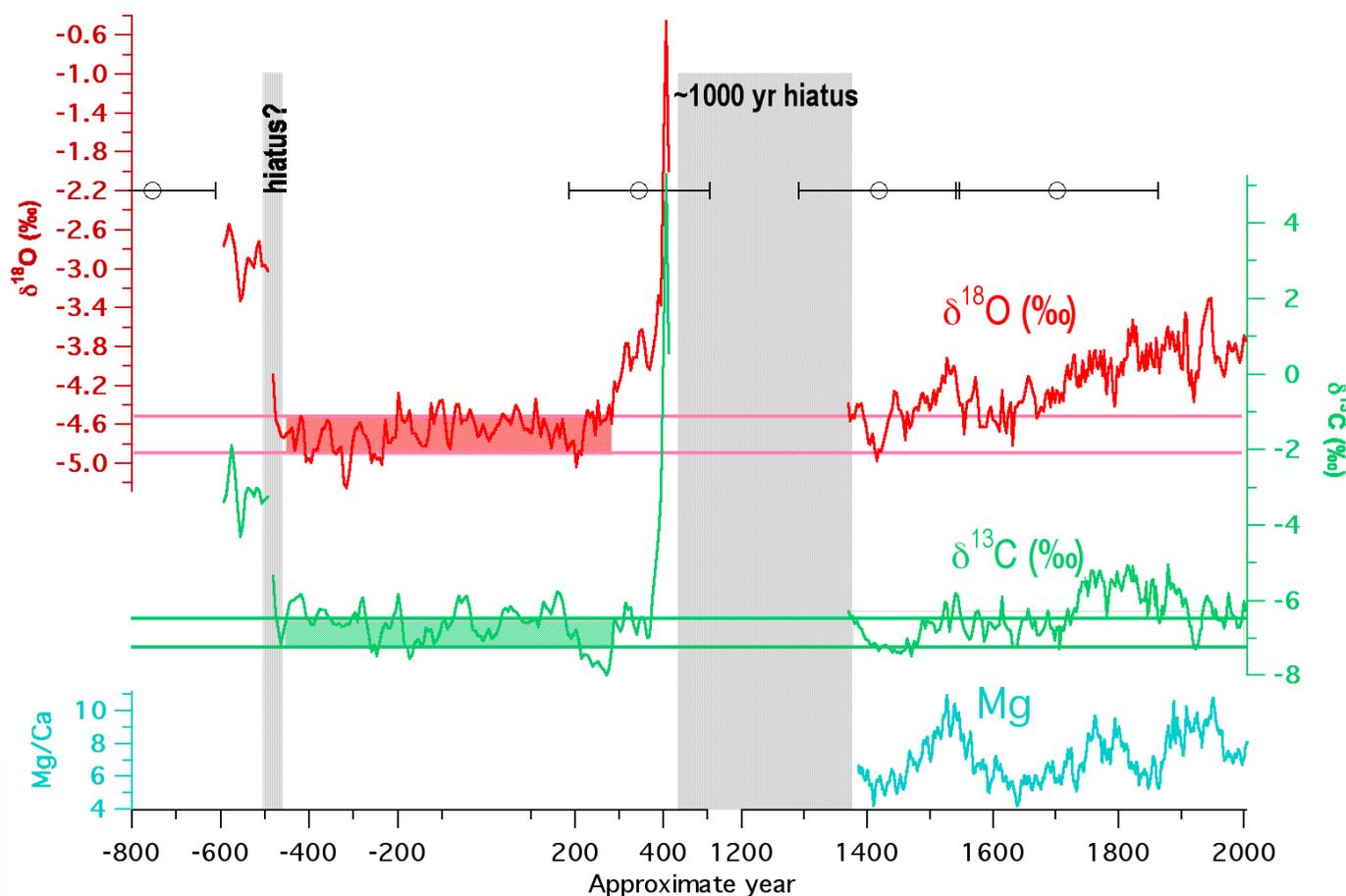
Speleothem Forward Model (SFM)



Speleothem records

Margaret River record

- 2.6 ka record (2-4 yr resolution)
 - 1000 yr hiatus (400-1400AD; duplicated)
 - $\delta^{18}\text{O}$ large +ve trend since 1600 (+1‰)



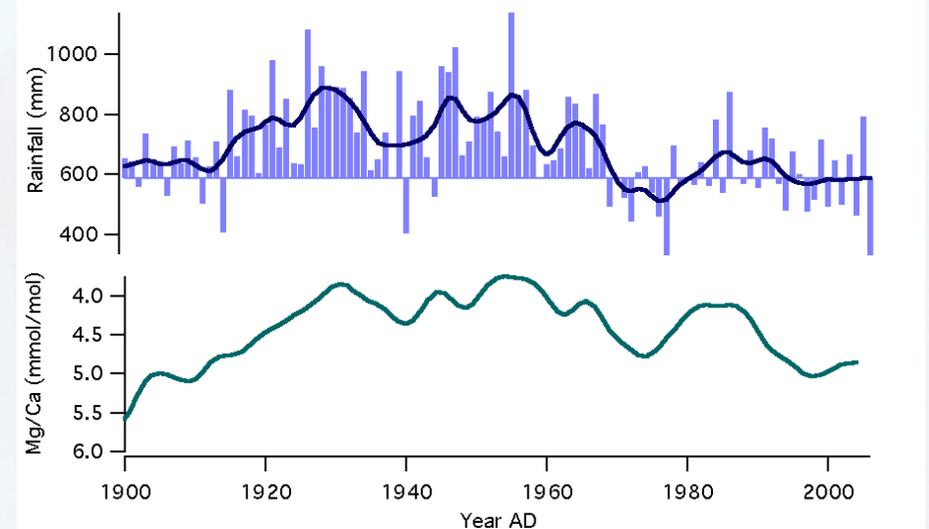
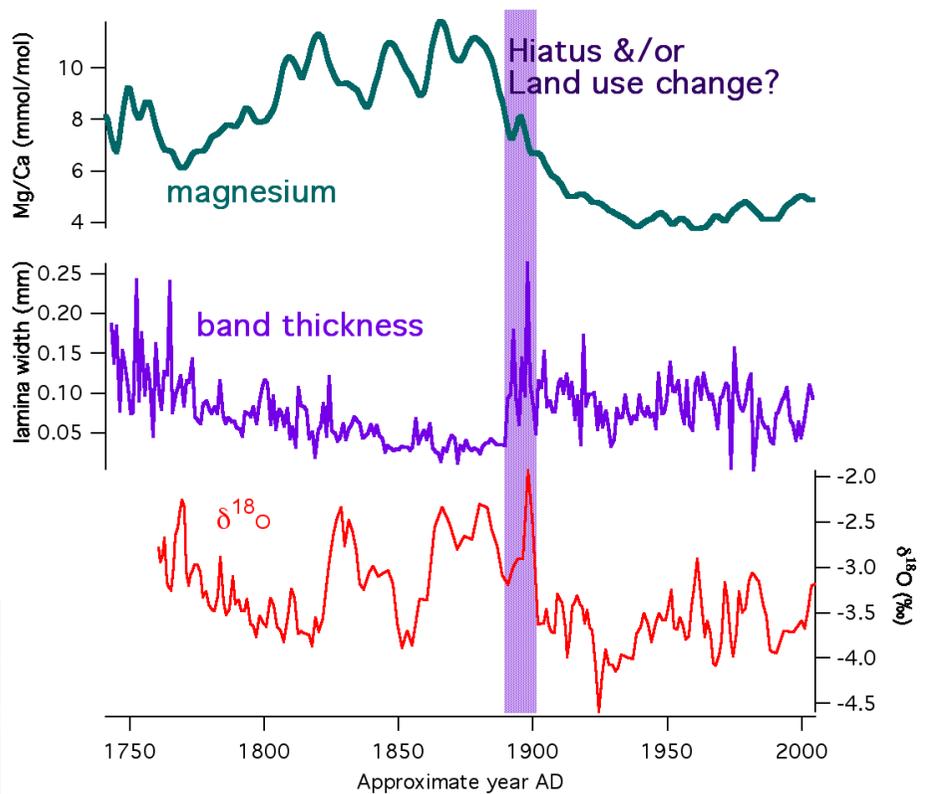
- $\delta^{18}\text{O}$ 1‰ trend
- Possibilities:
 - amount effect? (1‰ very large, drying not supported by other proxies)
 - source changes? (not supported by other records with climate mode connection (Law Dome SAM Goodwin et al. 07, ZW3 index van Ommen & Morgan, 2010))
 - hydrological? Typ short-duration & not supported by other proxies
- Duplicate record required

Duplicate records



Land-use, cave exploration etc responsible for modern crusts?

Yanchep (Perth) region



- Approx 250 yr record
- Complicated by:
 - hiatus (decades long?)
 - **chronological uncertainty**
 - land use change?
 - **calibration uncertainty**

SEA records

- **Yarrangobilly, alpine NSW**
- **Wombeyan, Sydney basin (Russell)**

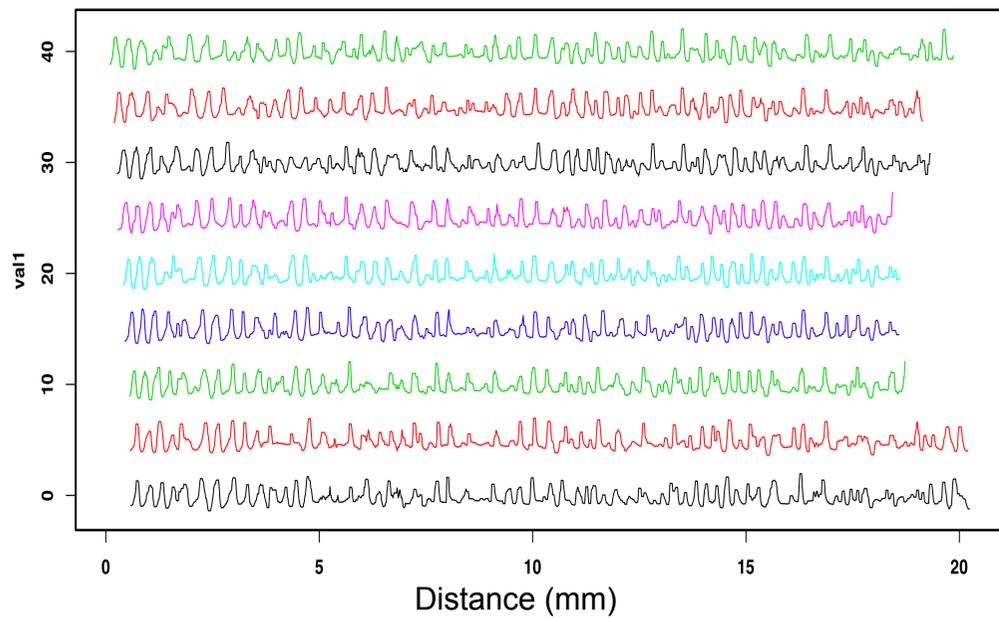
SEA records

- Yarrangobilly, alpine NSW
 - Headwaters of Murray River catchment
- Currently working on calibration of modern record
 - 2 stalagmites with high resolution (sub-annual) records spanning the instrumental period



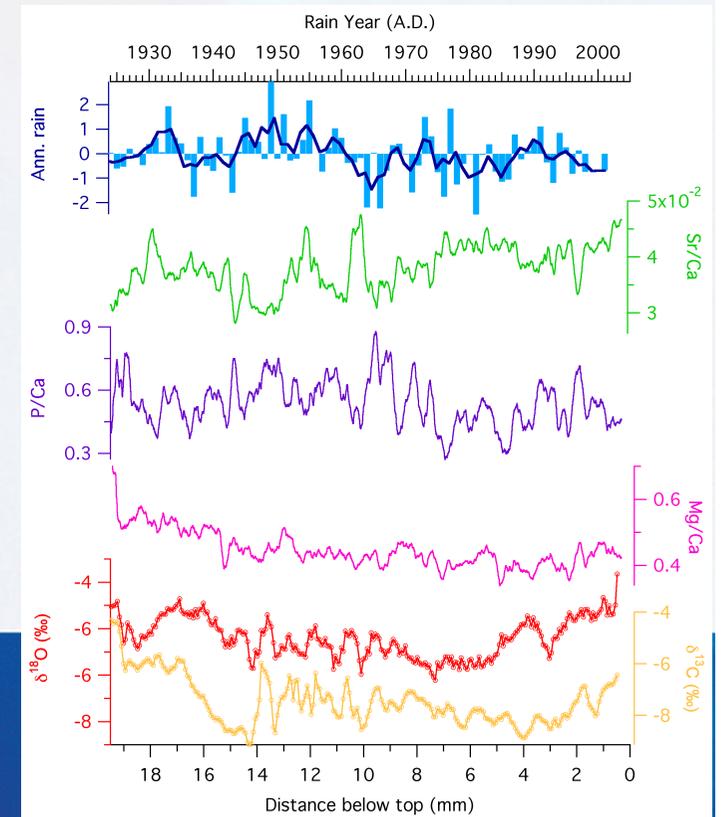
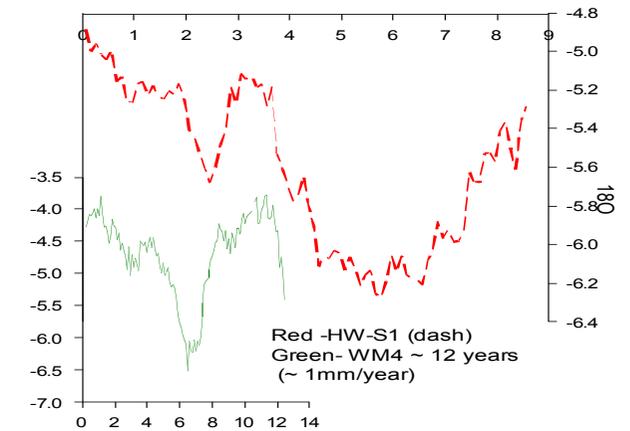
Yarrangobilly, alpine NSW

- 1910-2006AD growth
 - ^{14}C bomb curve
 - Annual trace element cycles



Yarrangobilly, alpine NSW

- Rel. drier post-1960 recorded in Sr/Ca and P/Ca ratios
- Drip water monitoring site
- Similar $\delta^{18}\text{O}$ trend cf. Wombeyan
 - Recording regional signal
 - Near to high resolution airmass/rainfall $\delta^{18}\text{O}$ monitoring site
 - Well-defined $\delta^{18}\text{O}$ -rainfall relationship



(Speleothem records ctd.)

Wombeyan Caves

Conclusions



- Progress, limitations & potential...
- Emerging high resolution records
 - Potential for understanding how climate modes have varied in the past
 - Developing thorough understanding of proxies
- Limitations
 - Uncertainties may not be resolved by replication
- Speleothem records important contribution to understanding past changes in Sthn. Aus rainfall
 - E.g. other SWWA proxies (tree rings and LD snow record) disagree on context on post-1970 dry

SWWA (so far...)

- Paleo records (2 complete/1 progress)
- Modern (x3 additional)
- **Challenges**
 1. Calibration
 - thorough understanding of multiple, complex processes on proxies
 - » 5 papers + more in progress (Treble et al. EPSL 2003; 2005; GCA 2005; Pages News 2008; & Fischer & Treble JGR, atmospheres, 2008)
 2. Chronology
 - » Good for modern record (^{14}C bomb spike; $\pm 5-10$ yrs)
 - » 2K period U/Th age errors $\pm 100-150$ yrs (based on typical SW U concs, growth rates etc.)
 - » Annual lamina/trace element cycles in one of the paleo records
 3. Locating material

Yarrangobilly

- Good potential for other material
- Preservation of ash
- Investigate a geochemical bush fire “fingerprint”

