Are twelve years of hydrological monitoring at a SE Australian alpine cave enough to provide insights into the speleothem paleoenvironmental record?

Andy Baker, Rebecca Chapman (UNSW Sydney, Australia)

Pauline Treble, Carol Tadros, Liza McDonough (ANSTO, Australia)

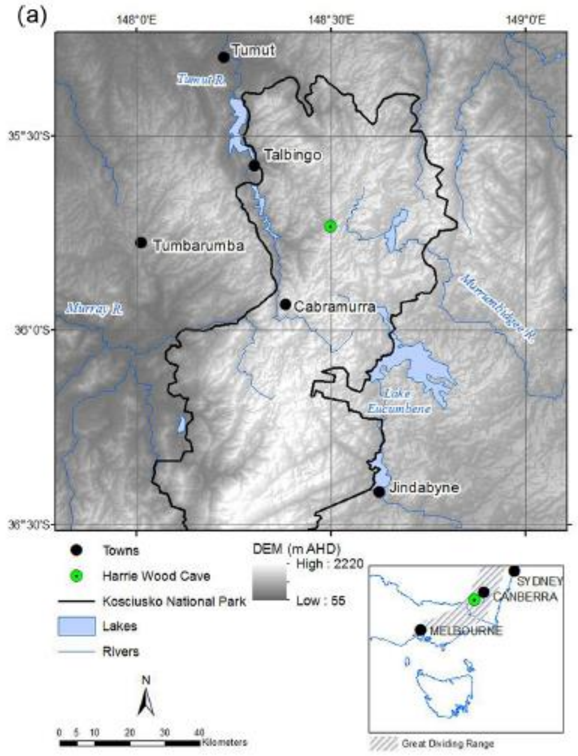
Romane Berthelin (HSM Montpellier, France)

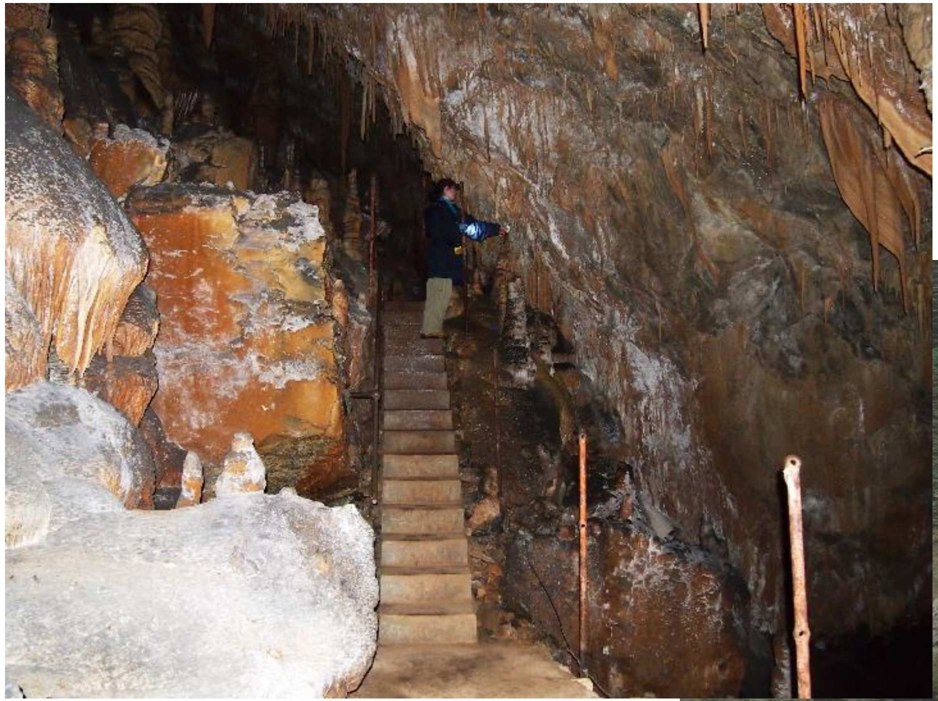
Andreas Hartmann (TU Dresden, Germany)

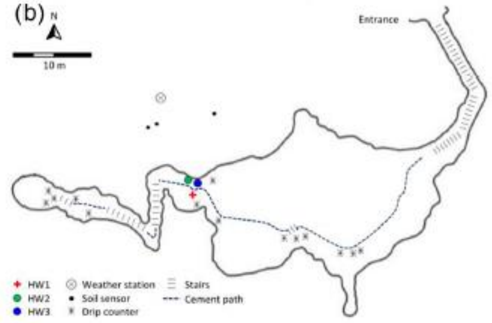
Monika Markowska (MPIC, Germany)

Gregoire Mariethoz (UNIL, Switzerland)

Harrie Wood Cave, Snowy Mountains, Ngarigo Country







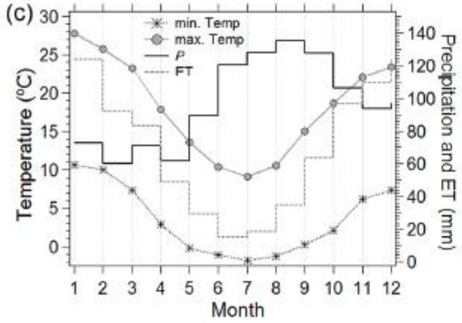
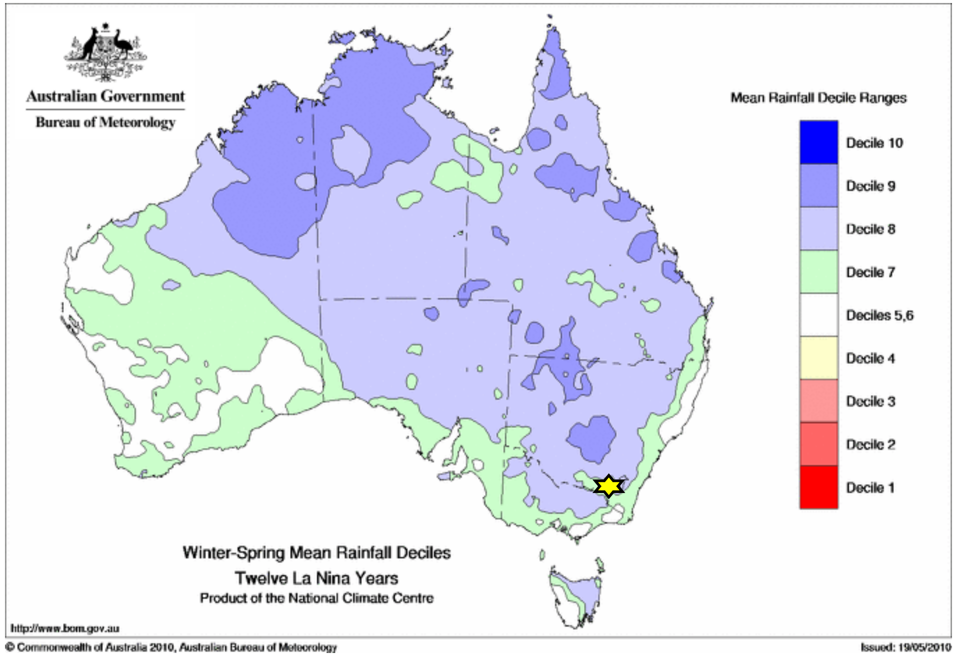


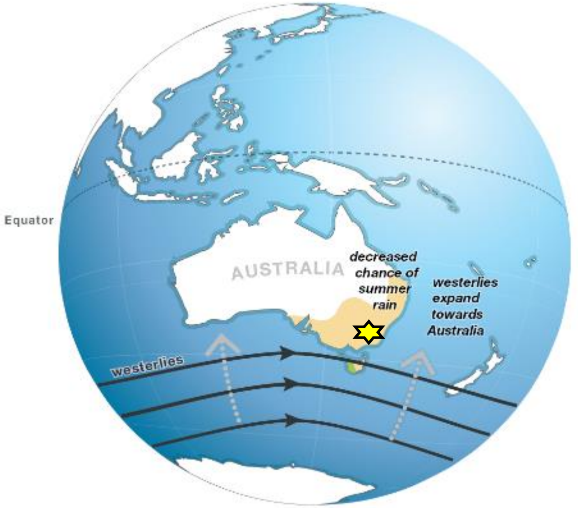
Figure from Tadros, C.V. et al 2016 Hydrol. Earth Syst Sci. 20, 4625-

The climate drivers

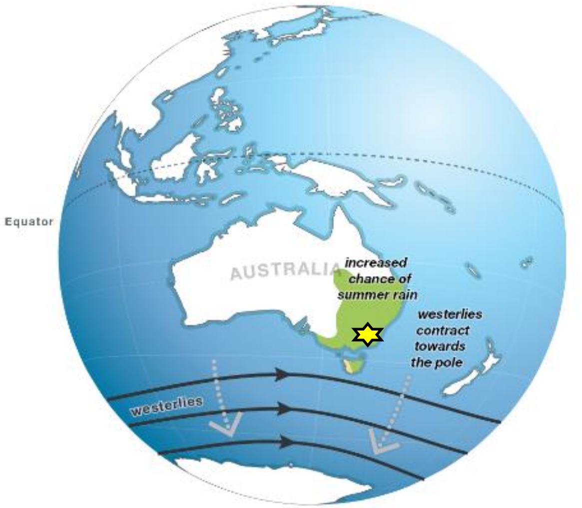
La Niña



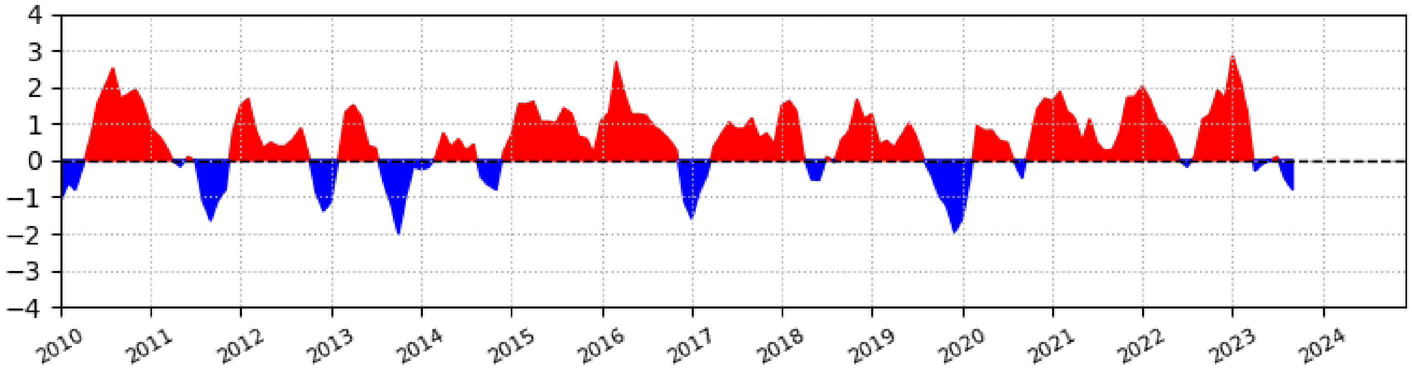
Southern Annular Mode (Antarctic Oscillation)



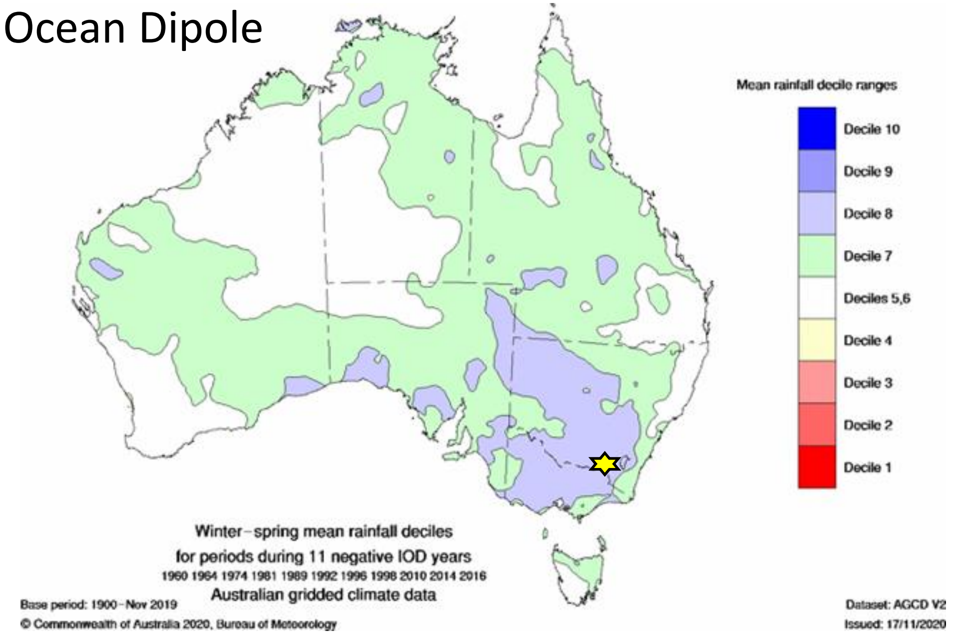
Southern Annular Mode (SAM): **Negative phase (summer)**



Southern Annular Mode (SAM): **Positive phase (summer)**



Indian Ocean Dipole



Figures from the Australian Bureau of Meteorology and US NCAR

Hydrological monitoring started in 2011, expanded in 2014-2017.

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Contents lists available at ScienceDirect

Journal of Hydrology

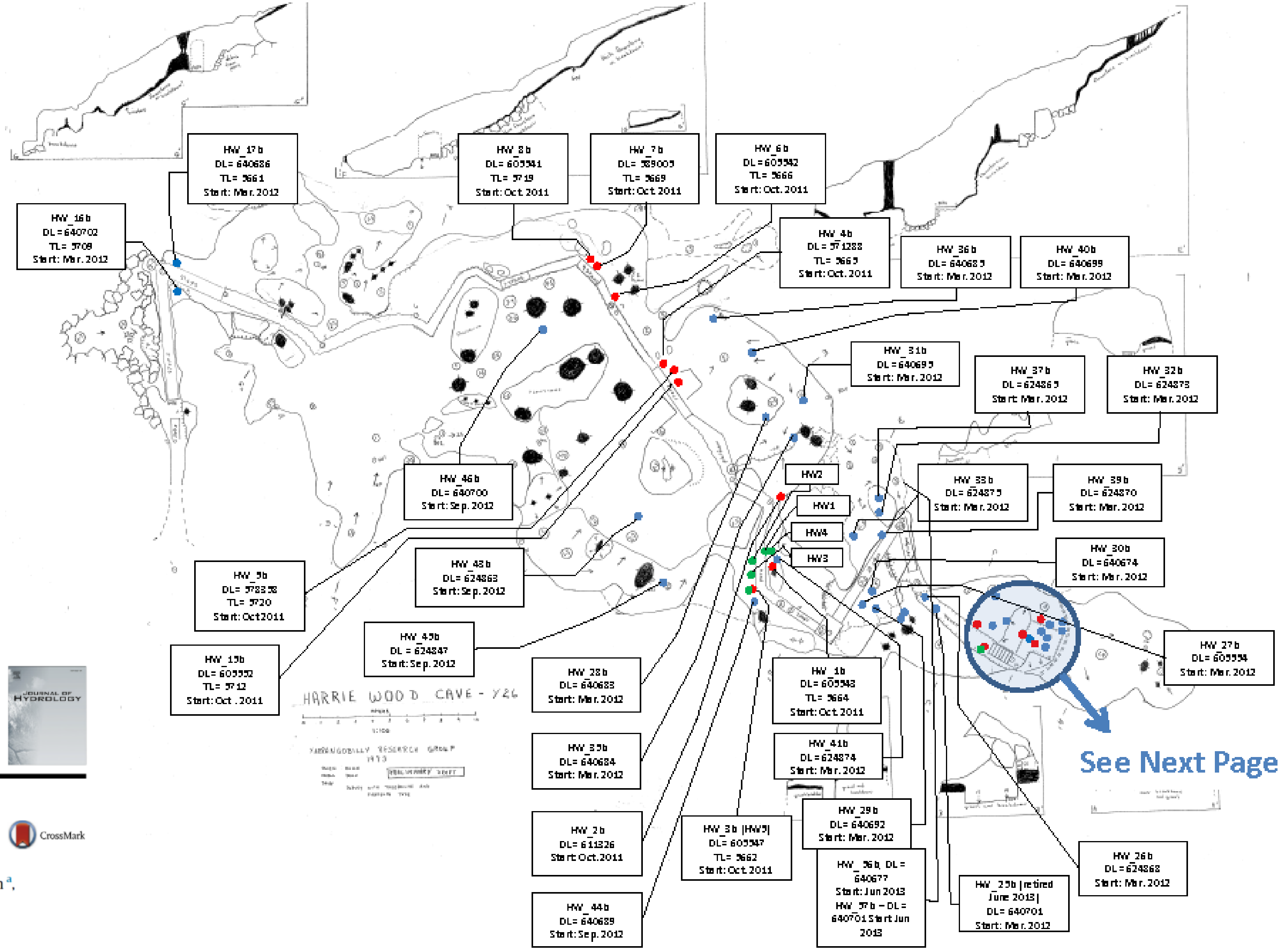
journal homepage: www.elsevier.com/locate/jhydrol

Unsaturated zone hydrology and cave drip discharge water response: Implications for speleothem paleoclimate record variability

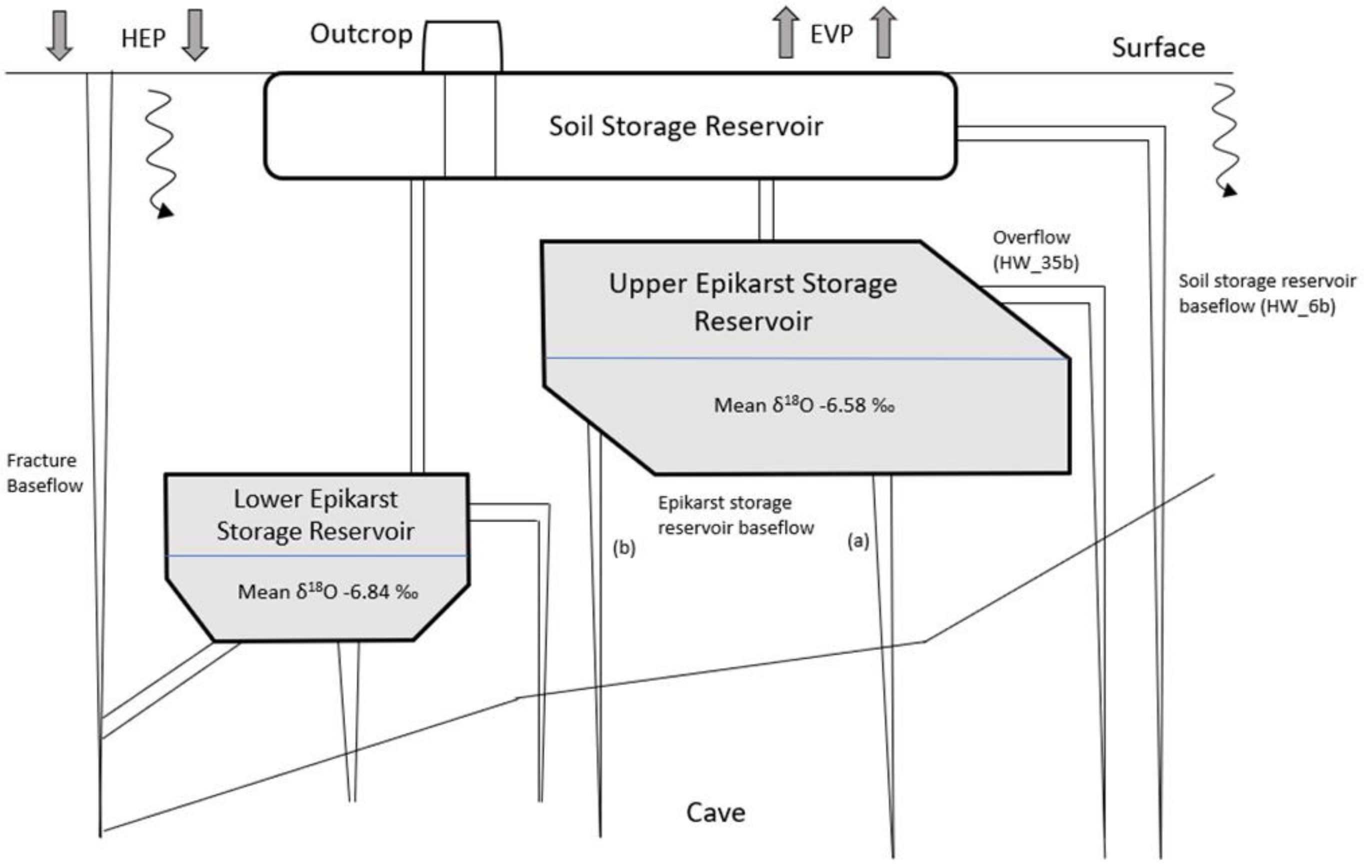
Monika Markowska [a,b,*], Andy Baker [b], Pauline C. Treble [a], Martin S. Andersen [b], Stuart Hankin [a], Catherine N. Jex [b], Carol V. Tadros [a,b], Regina Roach [c]

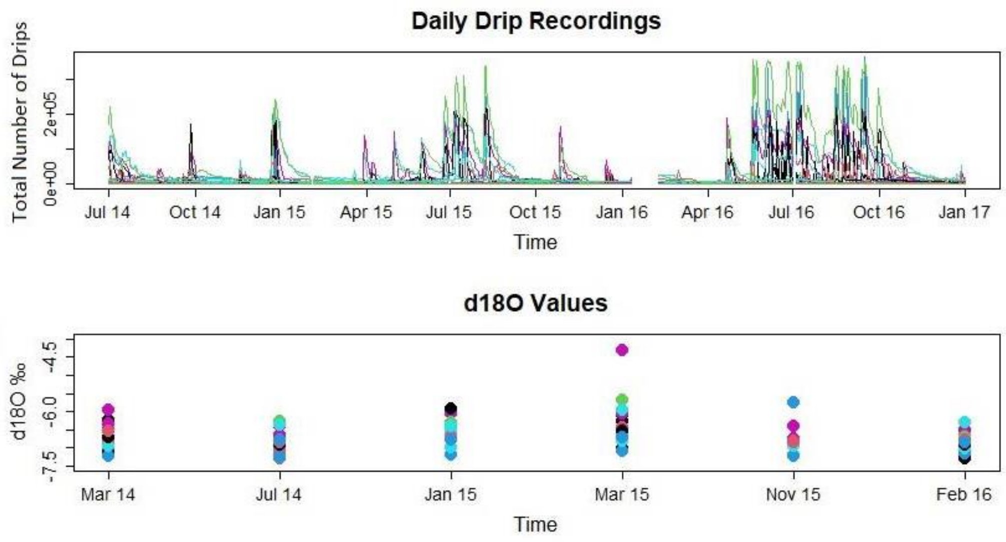
[a] Institute for Environmental Research, Australian Nuclear Science and Technology Organisation, Lucas Heights, Sydney 2234, Australia
[b] Connected Waters Initiative Research Centre, UNSW Australia, Kensington, Sydney 2052, Australia
[c] NSW National Parks and Wildlife Service, Tumut, NSW 2720, Australia

Monitoring at Harrie Wood Cave



Conceptual model of cave hydrology

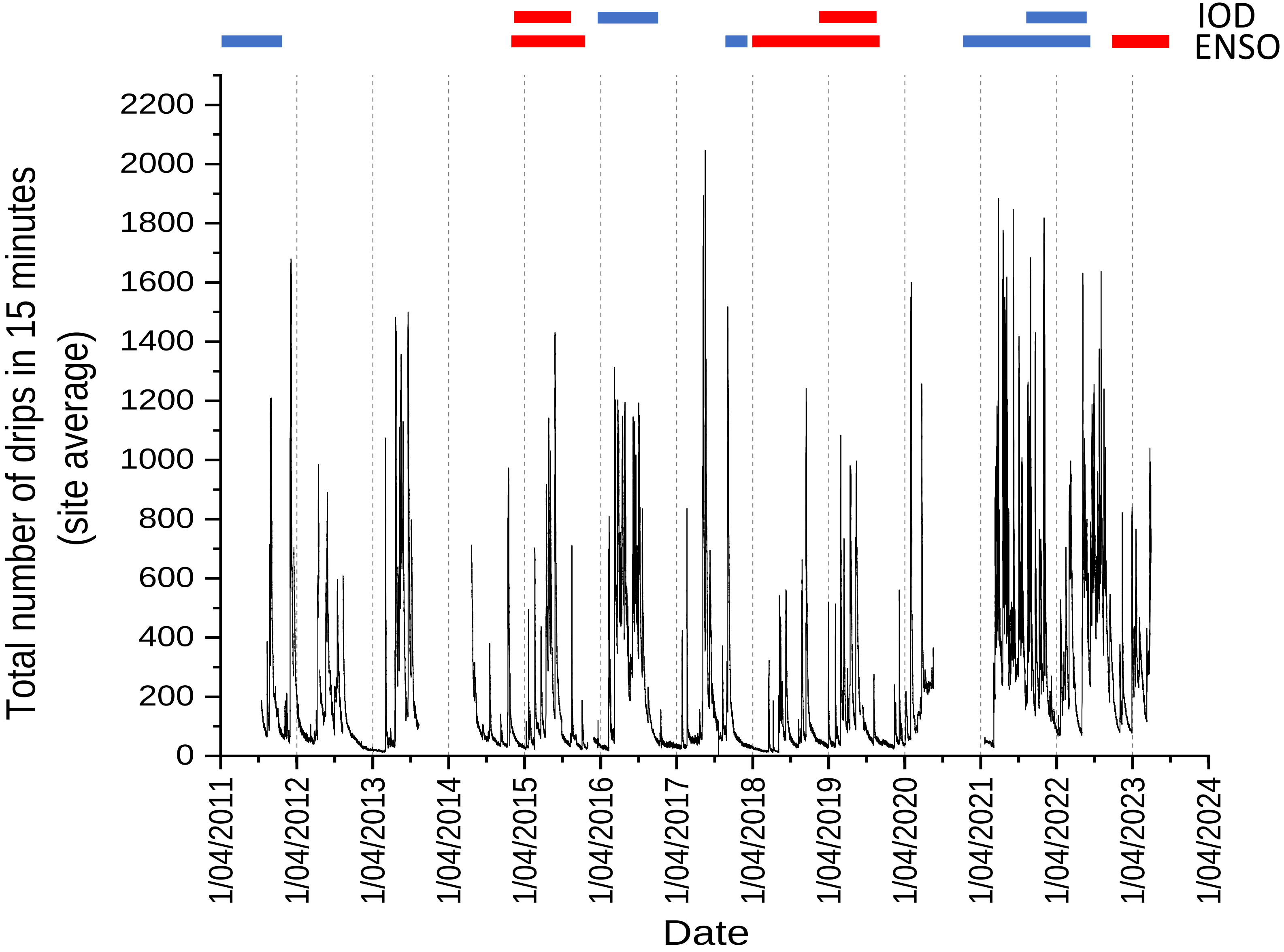




Drip water stable isotope composition has low variance over time as well as spatial variability in the cave.

Chapman, R.G., Laffan, S., McDonough, L.K., Markowska, M. and Baker, A., 2023. Spatiotemporal variation in cave percolation waters: a functional approach. Earth ArXiV https://doi.org/10.31223/X5Q08Z

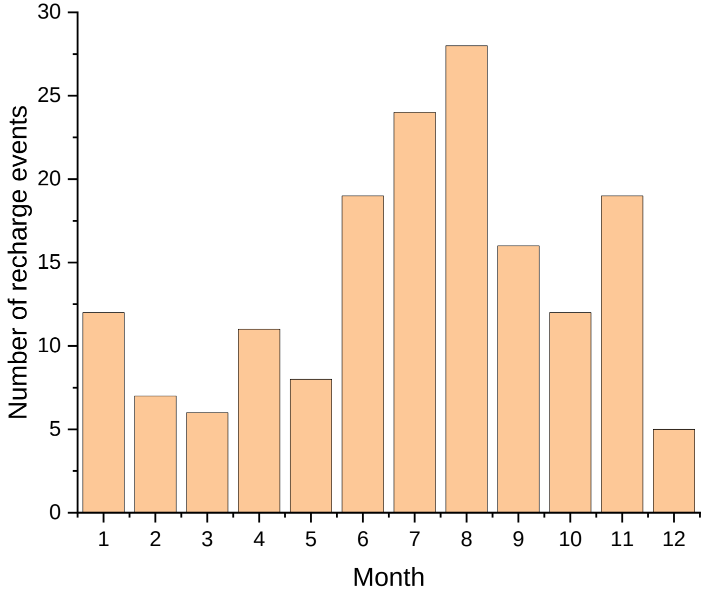
Twelve years of drip water hydrology



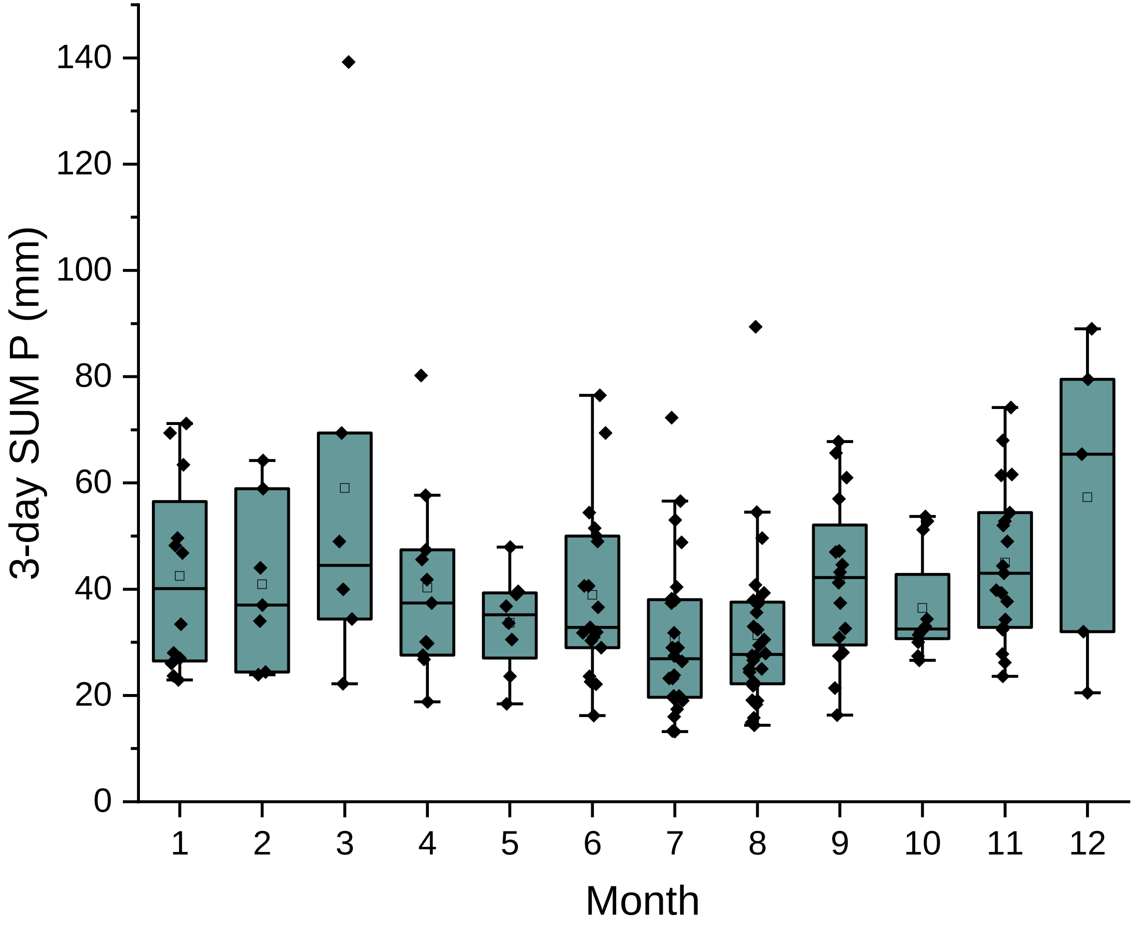
175 recharge events (so far).

Fast response to rainfall (within 48 hours).

Despite little seasonality in precipitation, there are more events in winter and spring and less in summer and autumn.



~13 to 25 mm of precipitation is needed, winter bias to recharge

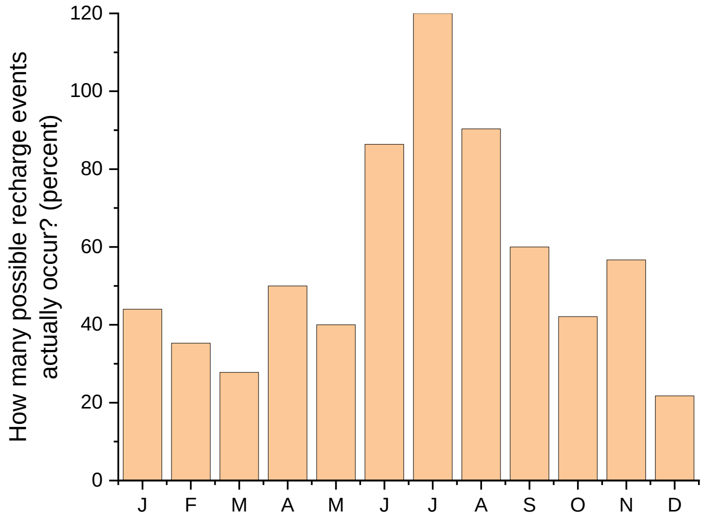


How much precipitation (rain or snow) fell before each recharge event?

In winter, you need ~13 mm of precipitation over a three-day period.

In summer, you need around 20-25 mm of precipitation over a three-day period.

All possible winter events lead to recharge, but less than half of all events in summer.

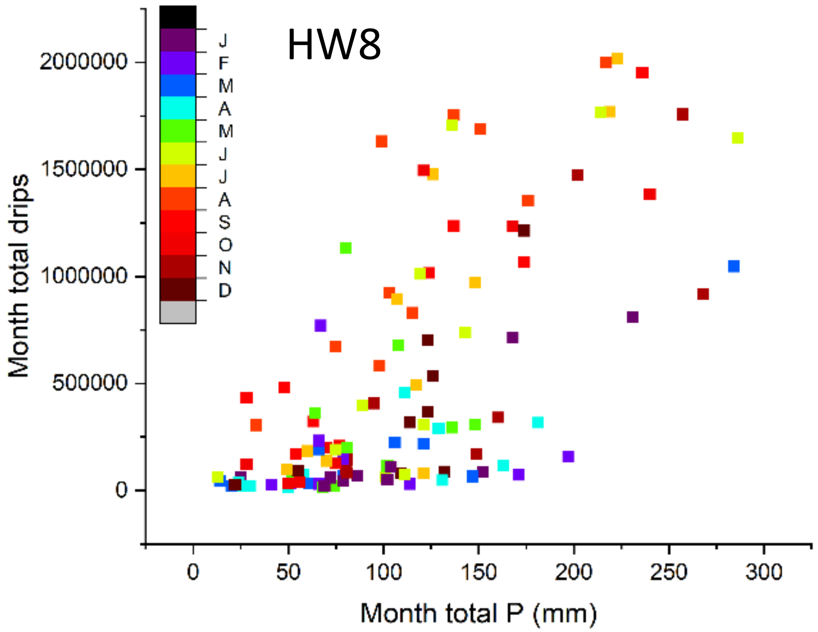


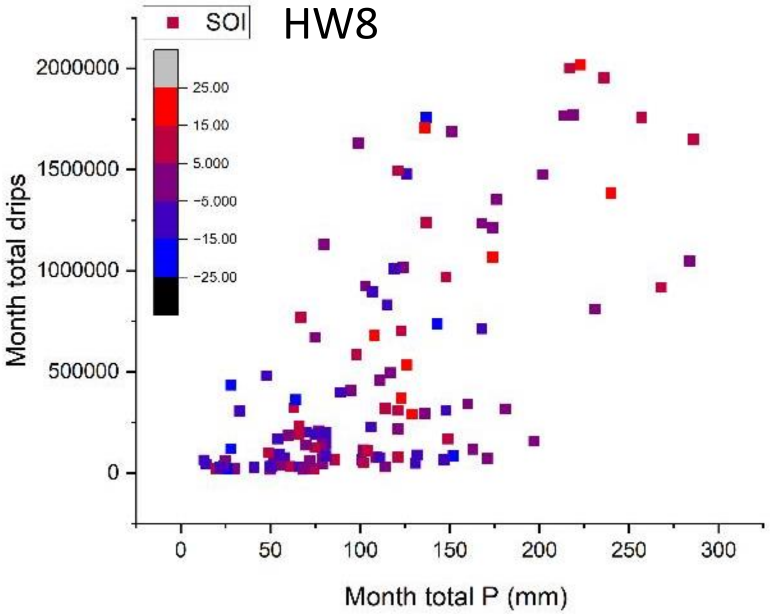
Are twelve years of monitoring enough?

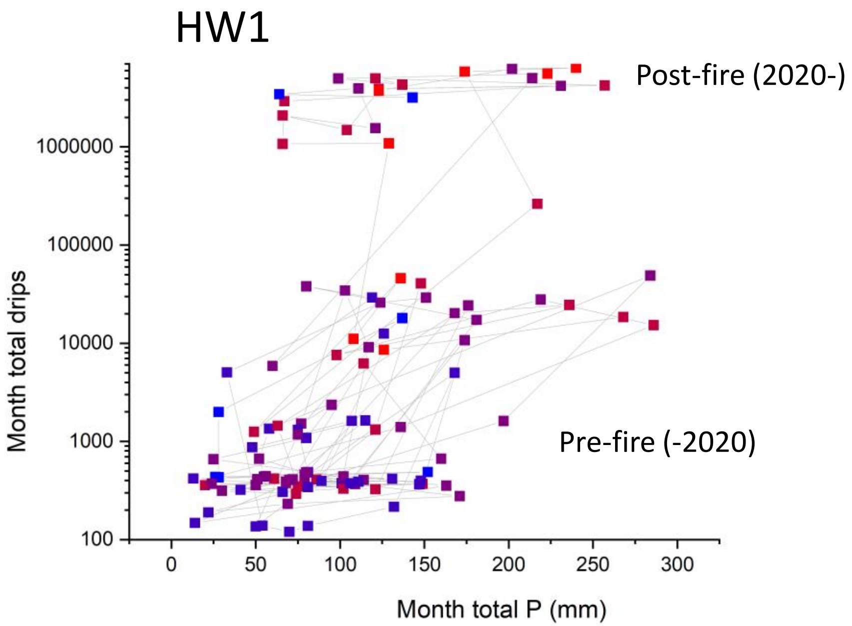
Seasonal climate

Climate drivers

Fire





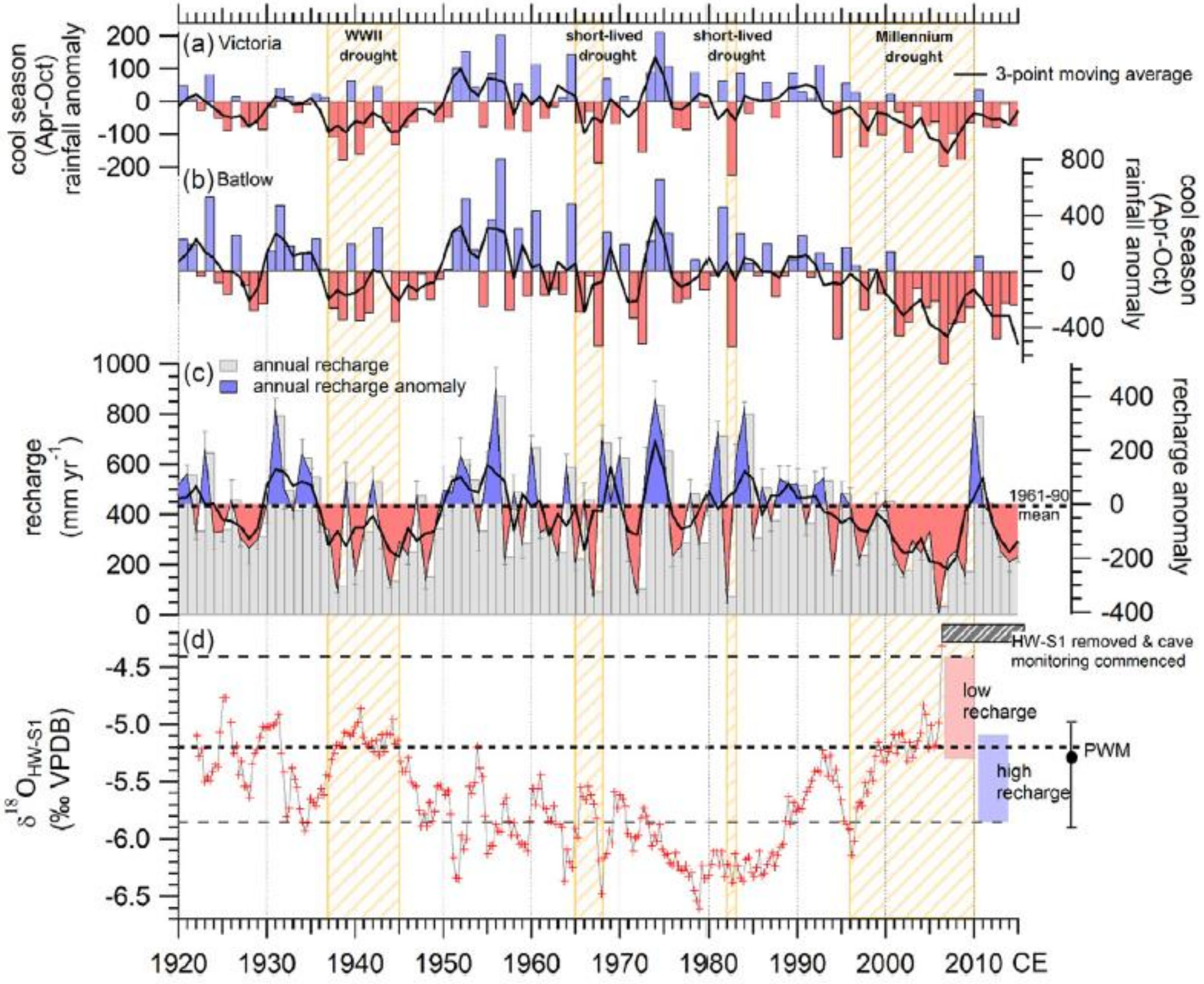


A typical drip (14 of 16 long term monitoring sites): HW8
General linear regression: r = 0.87 explained by month total P and P in July-Sept). Monthly IOD and SOI is not significant.

A post-fire non-linear drip (2 of 16 long term monitoring sites): HW1

Monthly drip data infilled where there are small data gaps using MPS: Tumbulto J et al 2019 J. Hydrol. 569: 573-586

Comparison with the speleothem oxygen isotope record



Stalagmite δ^{18}O for the last 100 years is a record of potential groundwater recharge and the climate drivers for groundwater recharge.

More positive δ^{18}O = less recharge (drier)
More negative δ^{18}O = more recharge (wetter)

(For much of stalagmite deposition, the SAM /AAO covers its full range, including negative SAM and drier summers)

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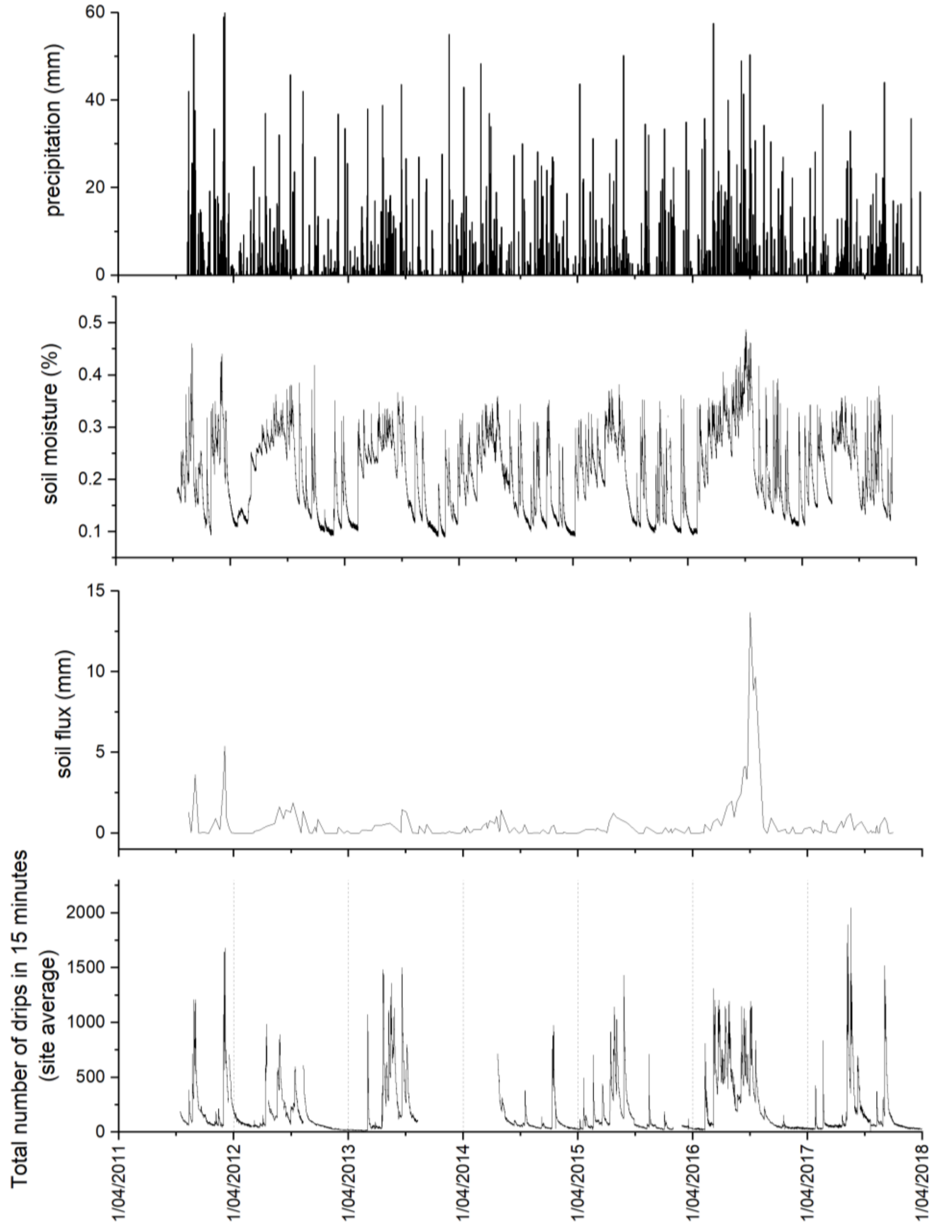
journal homepage: www.elsevier.com/locate/quascirev

Recharge variability in Australia's southeast alpine region derived from cave monitoring and modern stalagmite δ^{18}O records

Carol V. Tadros [a, b, *], Monika Markowska [c, a], Pauline C. Treble [a, b], Andy Baker [b, a], Silvia Frisia [d], Lewis Adler [e], Russell N. Drysdale [f]

[a] ANSTO, Lucas Heights, NSW, 2234, Australia
[b] School of Biological, Earth and Environmental Sciences, UNSW Sydney, Sydney, NSW, 2052, Australia
[c] Climate Geochemistry Department, Max Planck Institute for Chemistry, 55128, Mainz, Germany
[d] School of Environmental and Life Science, University of Newcastle, Callaghan, NSW, 2308, Australia
[e] Bioanalytical Mass Spectrometry Facility, Mark Wainwright Analytical Centre, UNSW Sydney, Sydney, NSW, 2052, Australia
[f] School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Parkville VIC, 3052, Australia

Monitoring data helps constrain hydrological models

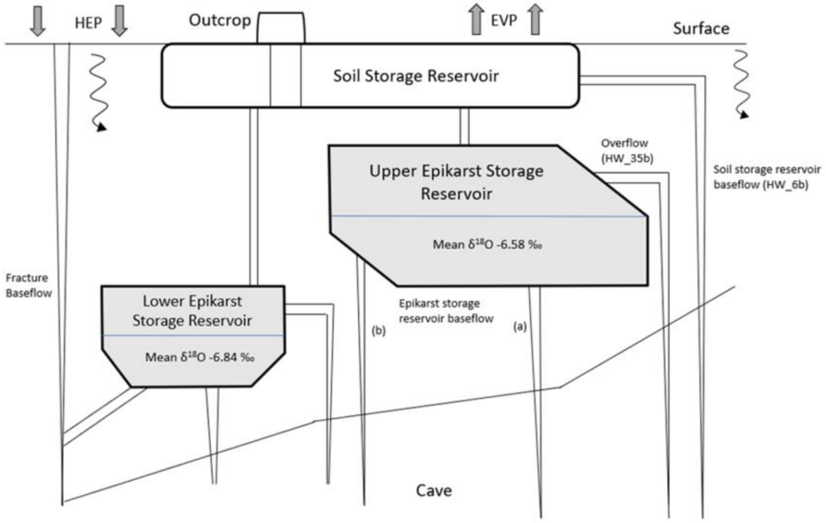


For example, a soil drainage model based on soil moisture data suggests a higher recharge period in winter 2016

Cave drip hydrology does not show this.

Agrees with our conceptual model – increase in soil drainage activates overflow drips from a karst water store.

Implications for the speleothem record – variable and potentially non-linear response to increasing precipitation.



Soil moisture model method: Berthelin, R. et al 2023 Hydrol. Earth Syst. Sci.,27, 385-

Conclusions

Long-term monitoring of cave hydrology AND soil moisture helps identify the role of seasonality and climate drivers in the speleothem record (but not long enough to quantify the role of SAM/AAO).

AND the data can be used to constrain hydrological models that can help a process understanding of cave hydrology and which be used to investigate a wider range of climate and environmental changes (coming soon for SAM/AAO).

a.baker@unsw.edu.au

@andbaker@aus.social