

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

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An aerial satellite image of a forested landscape. A yellow arrow points to a specific area in the lower-middle part of the image. In the top right corner, there is a red location pin and the text 'Yarrangobilly Caves'. The terrain is mostly green with some brown patches, indicating a forested area with some cleared land or different vegetation types.

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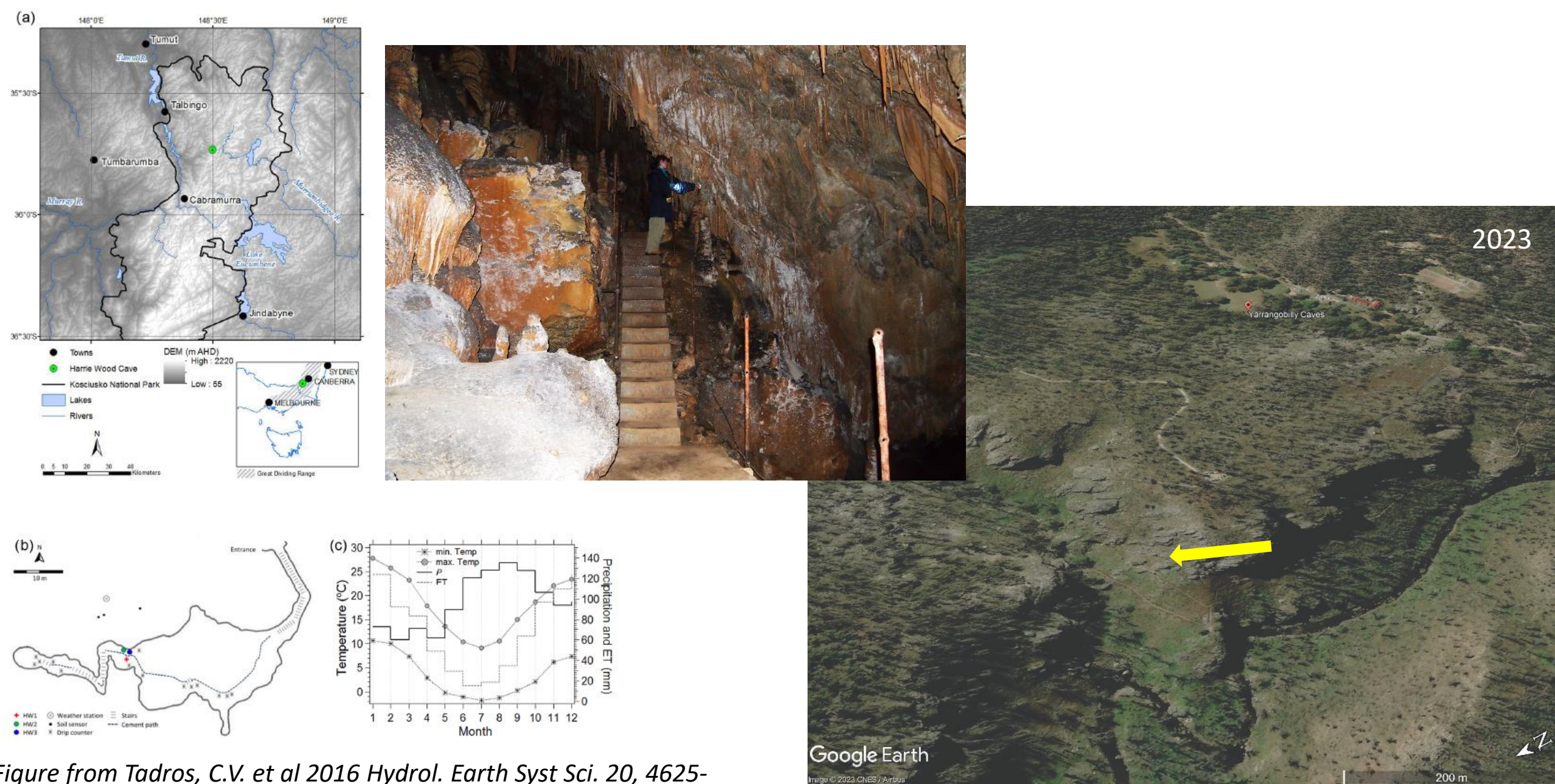
Gregoire Mariethoz (UNIL, Switzerland)

Google Earth

IMAGES / Airbus

200 m

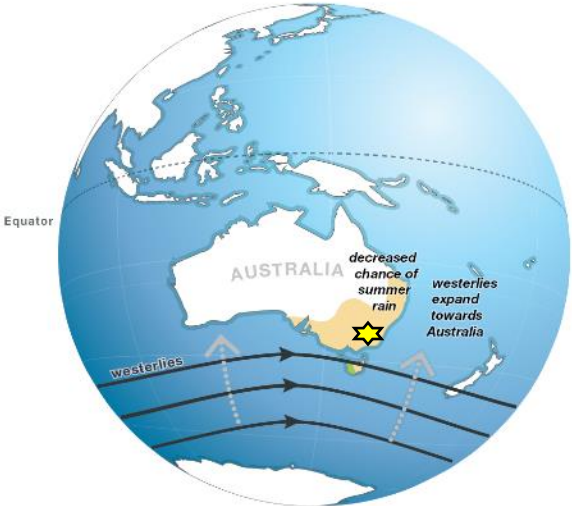
Harrie Wood Cave, Snowy Mountains, Ngarigo Country



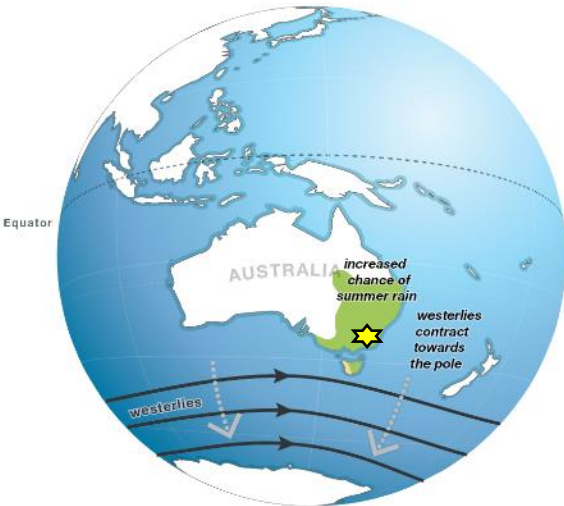
The climate drivers

La Niña

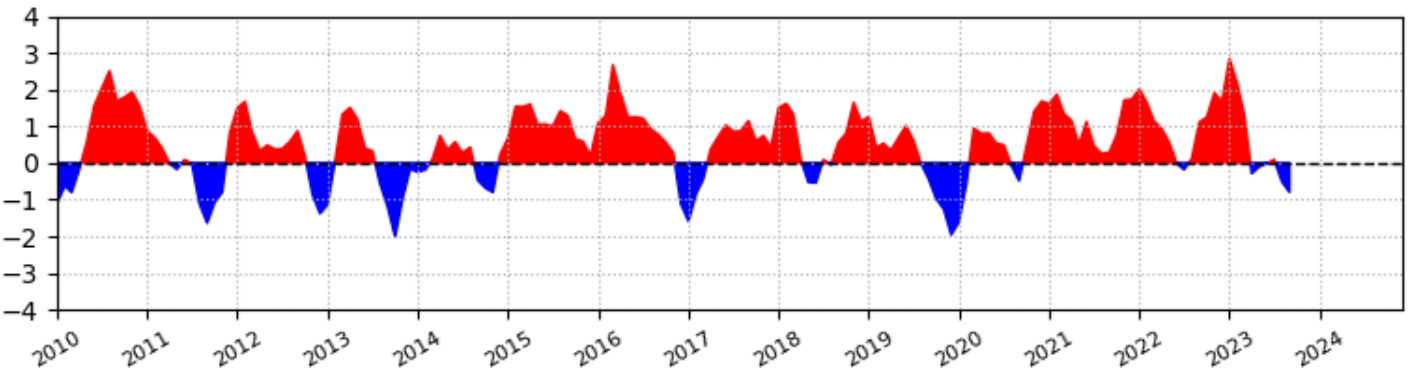
Southern Annular Mode (Antarctic Oscillation)



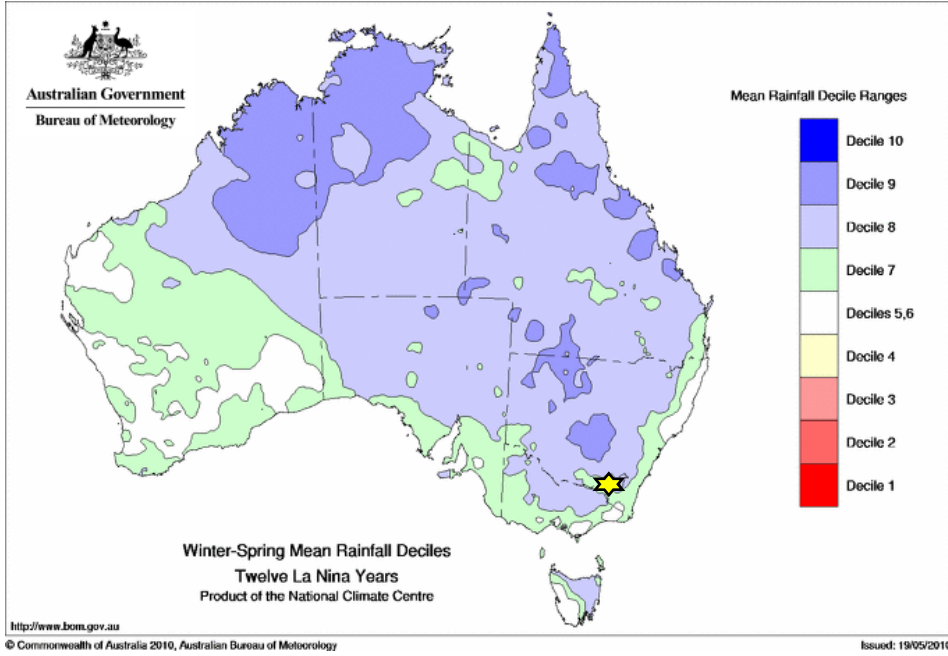
Southern Annular Mode (SAM): Negative phase (summer)



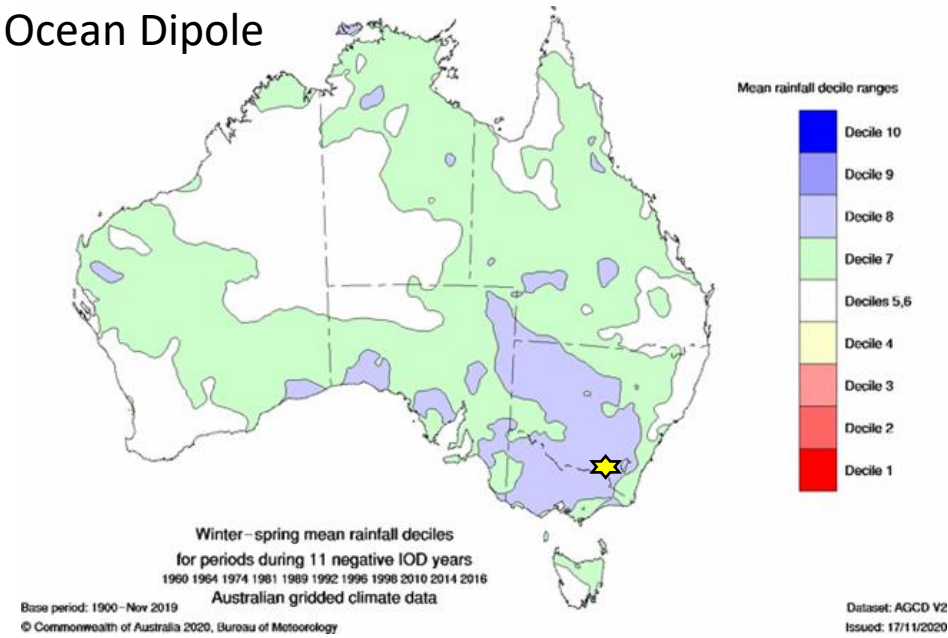
Southern Annular Mode (SAM): Positive phase (summer)



Figures from the Australian Bureau of Meteorology and US NCAR



Indian Ocean Dipole



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

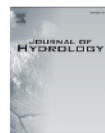


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Unsaturated zone hydrology and cave drip discharge water response: Implications for speleothem paleoclimate record variability

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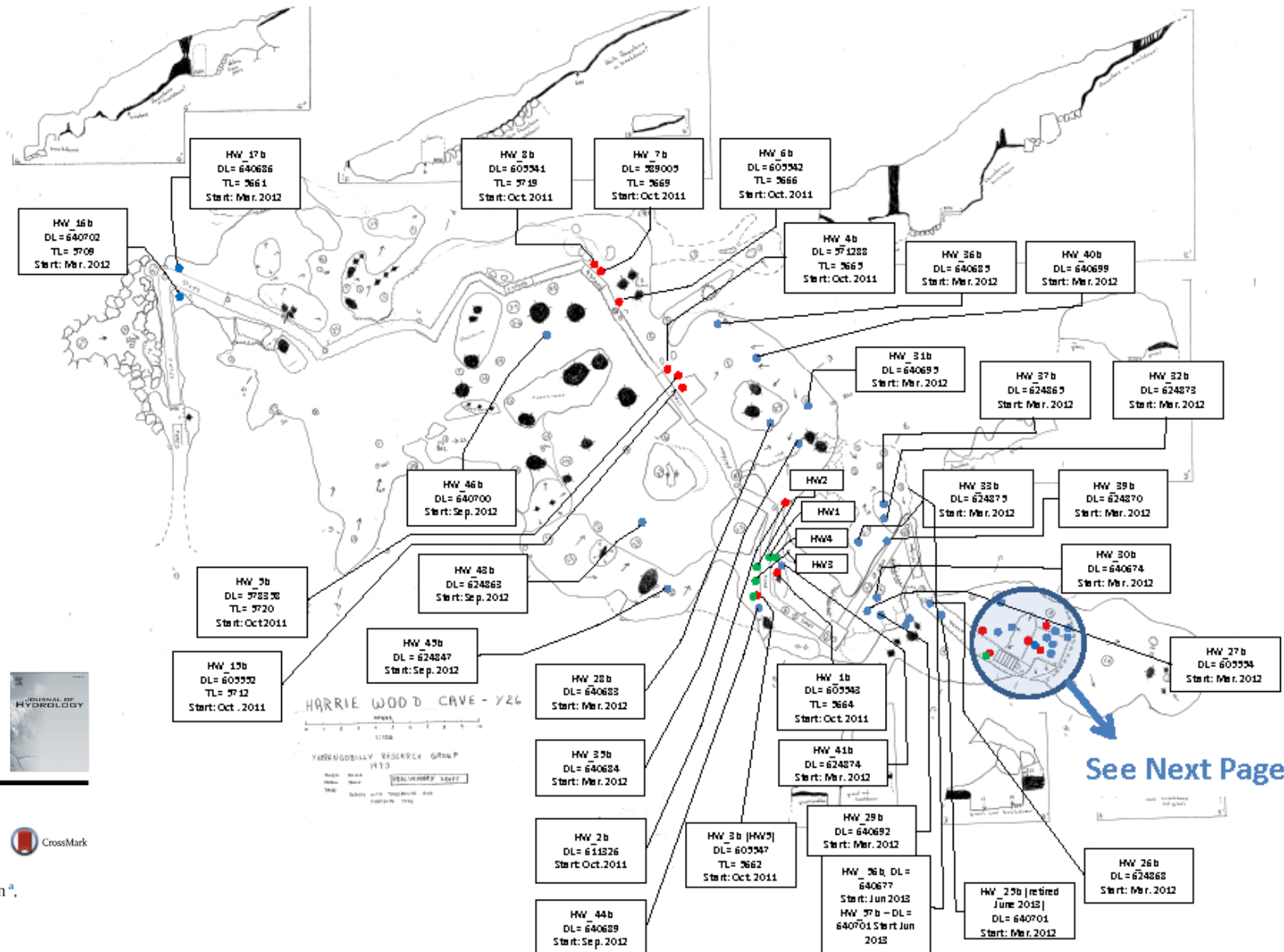
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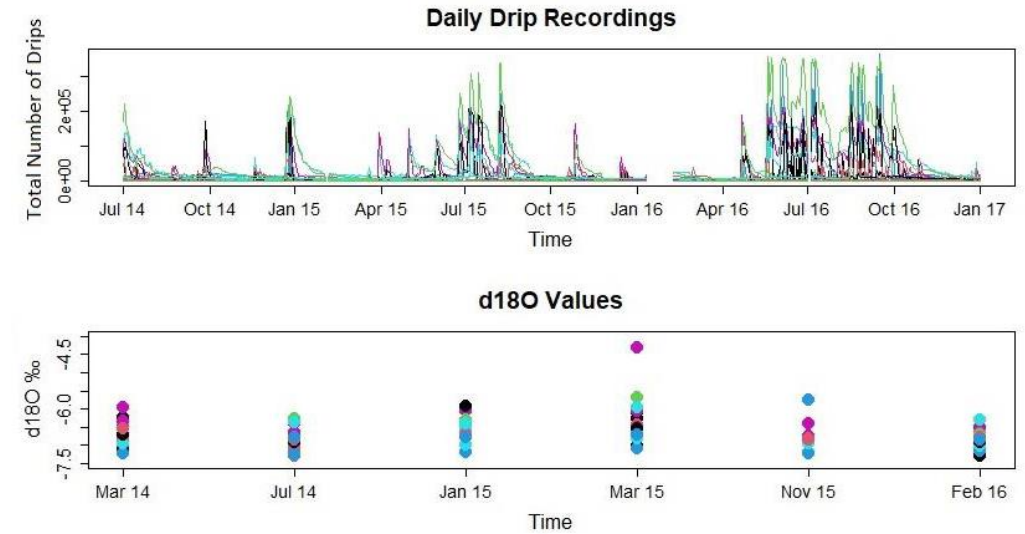
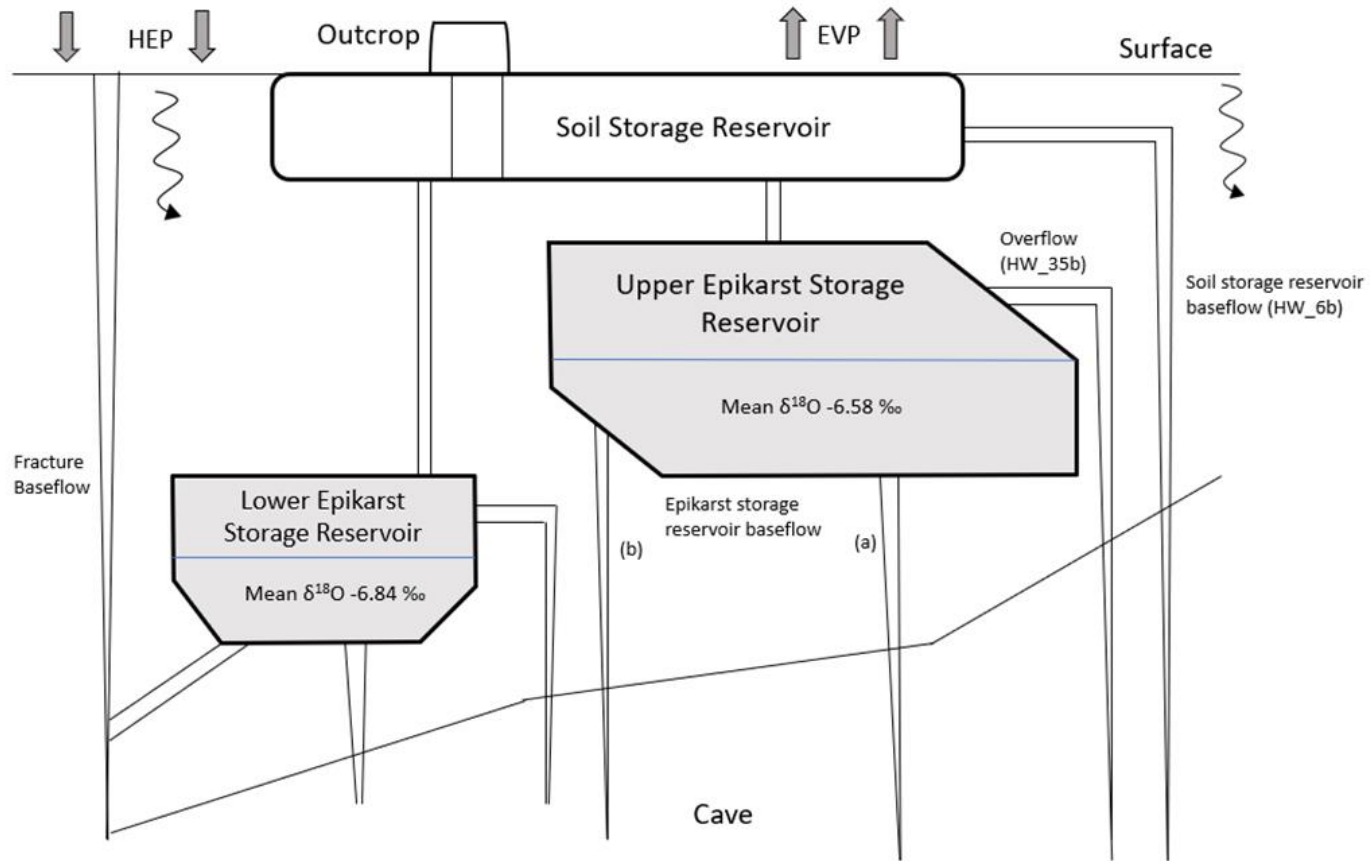
^c NSW National Parks and Wildlife Service, Tumut, NSW 2720, Australia



Monitoring at Harrie Wood Cave



Conceptual model of cave hydrology

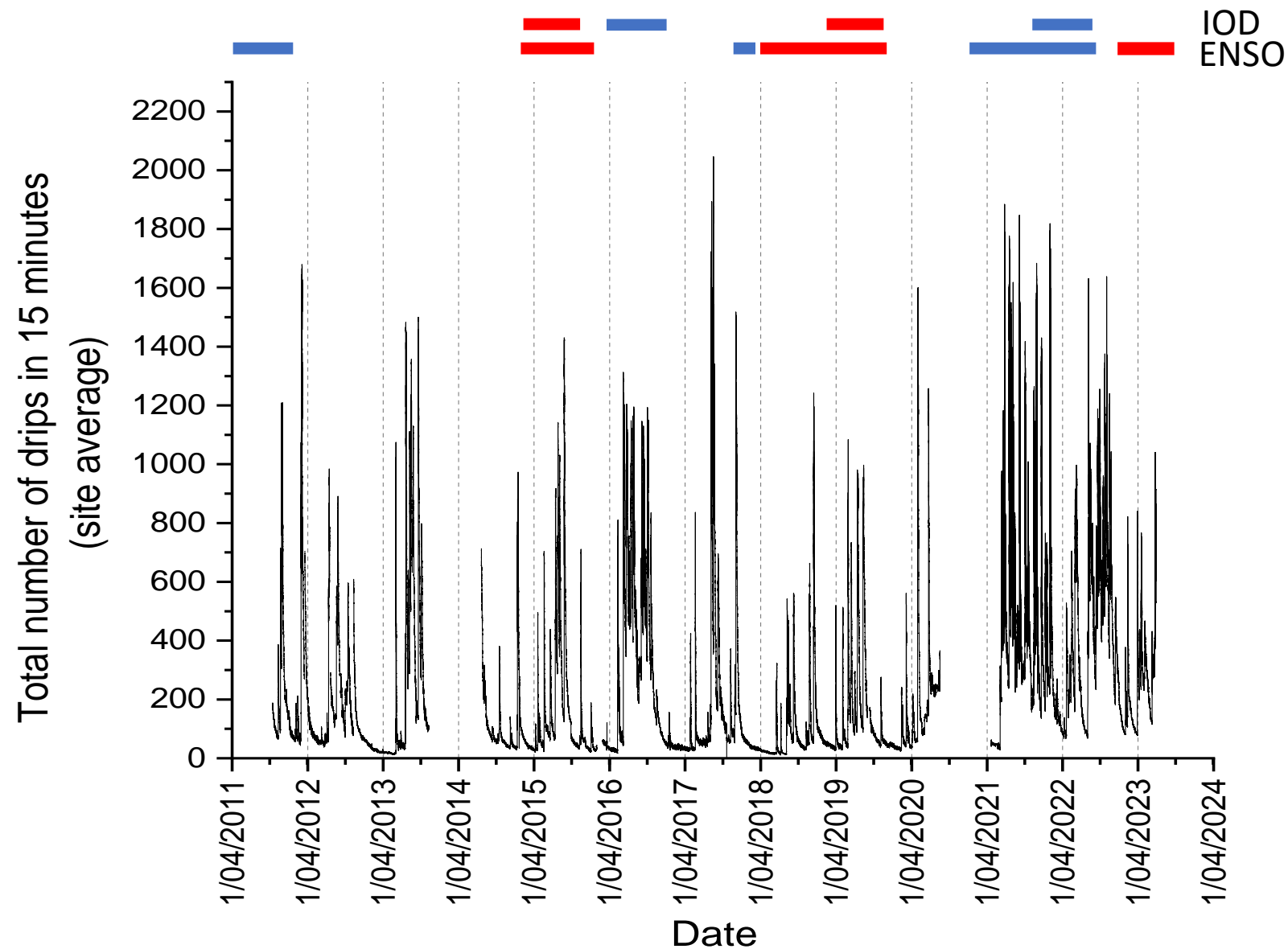


Drip water stable isotope composition has low variance over time as well as spatial variability in the cave.

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>



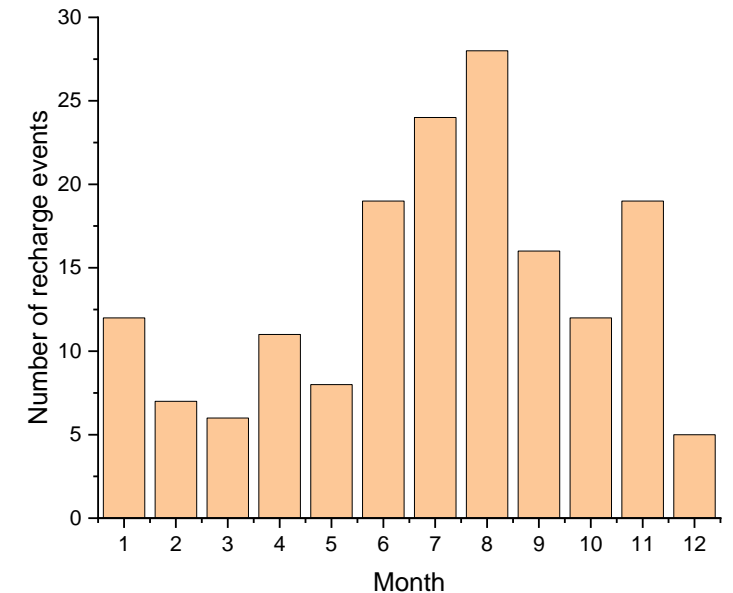
Twelve years of drip water hydrology



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.



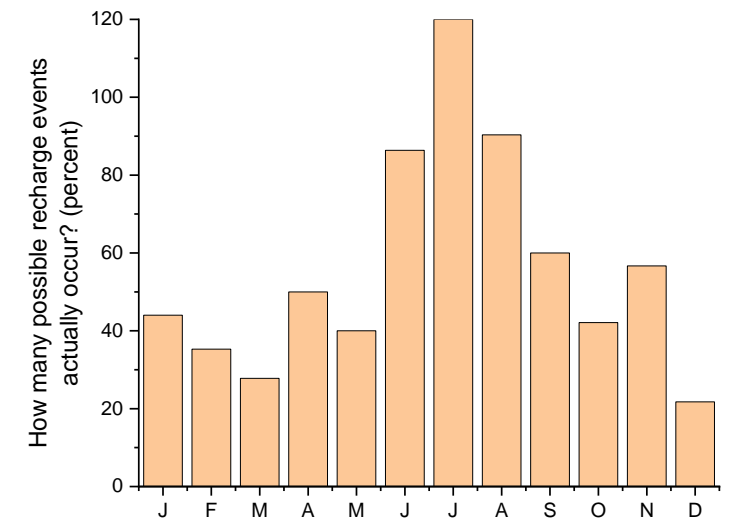
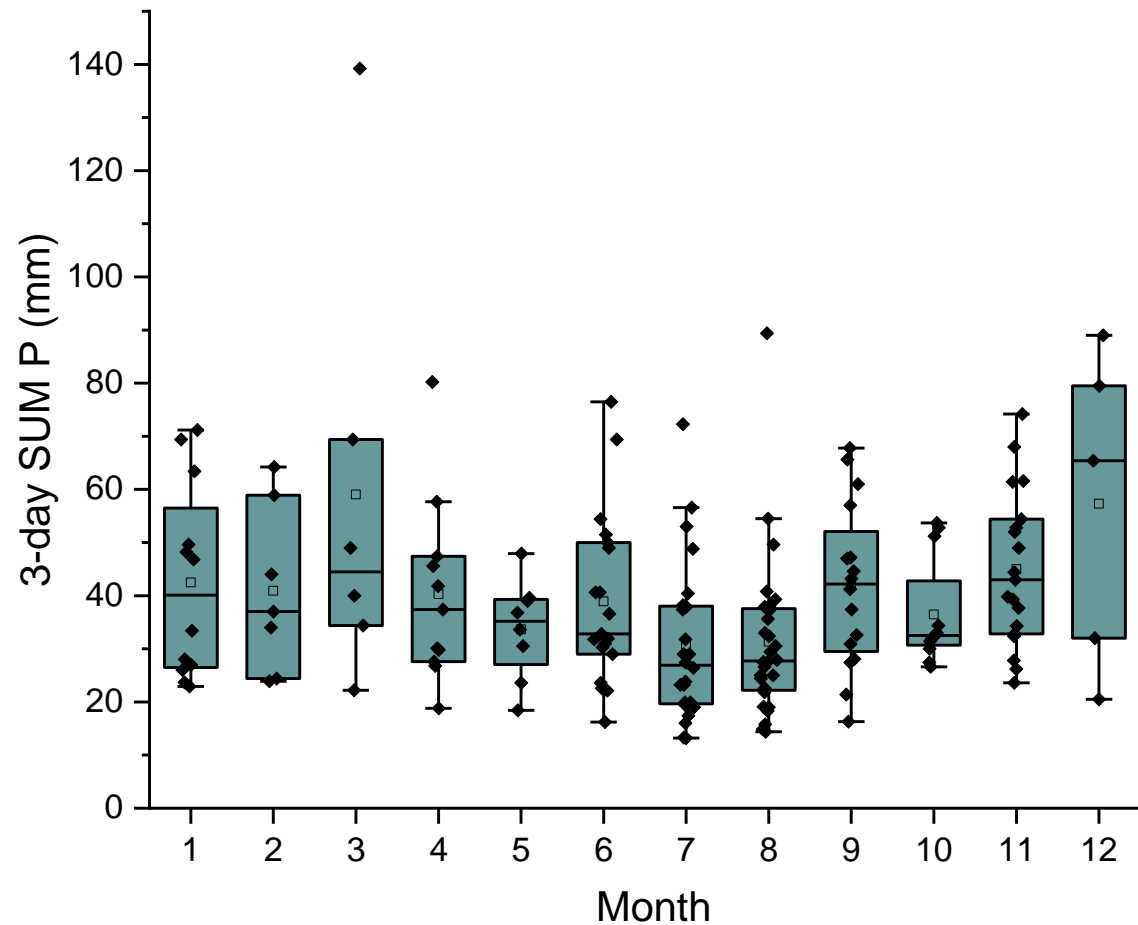
~13 to 25 mm of precipitation is needed,
winter bias to recharge

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

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

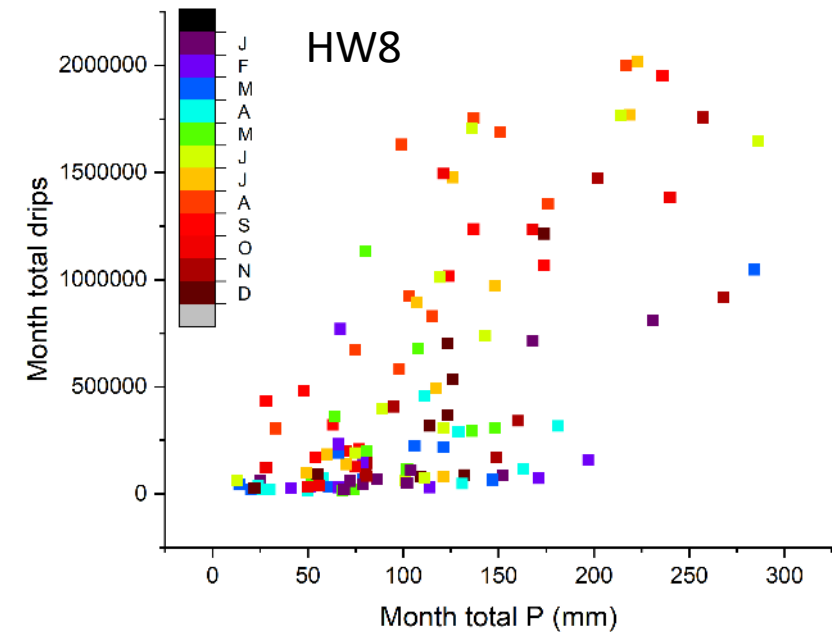
In summer, you need around 20-25 mm of precipitation
over a three-day period.

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

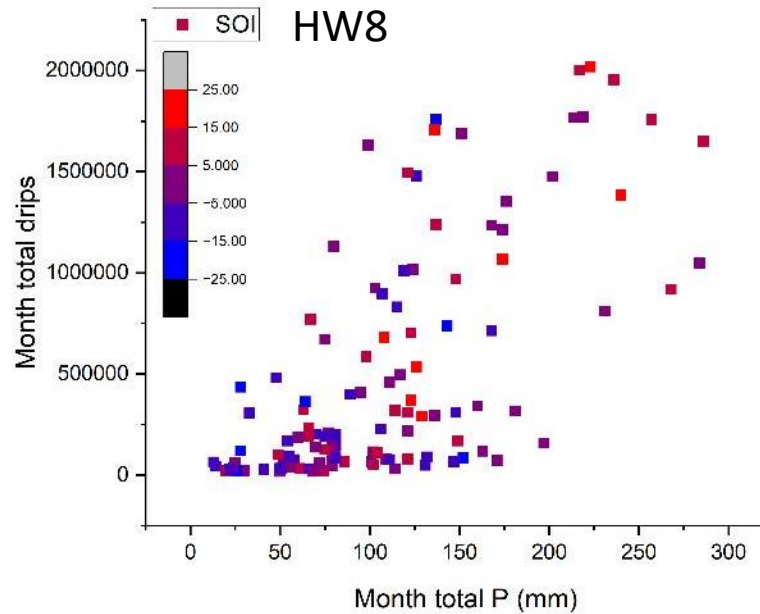


Are twelve years of monitoring enough?

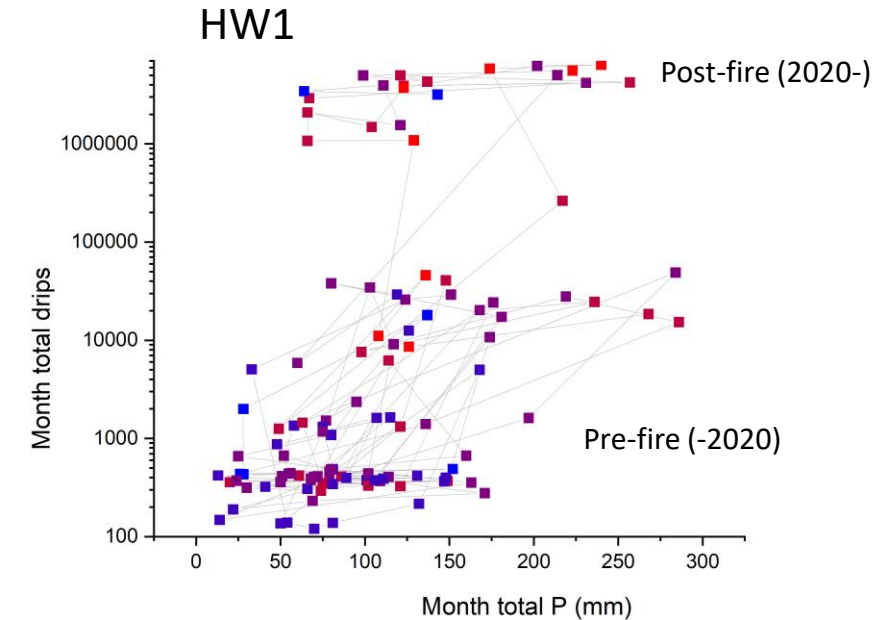
Seasonal climate



Climate drivers



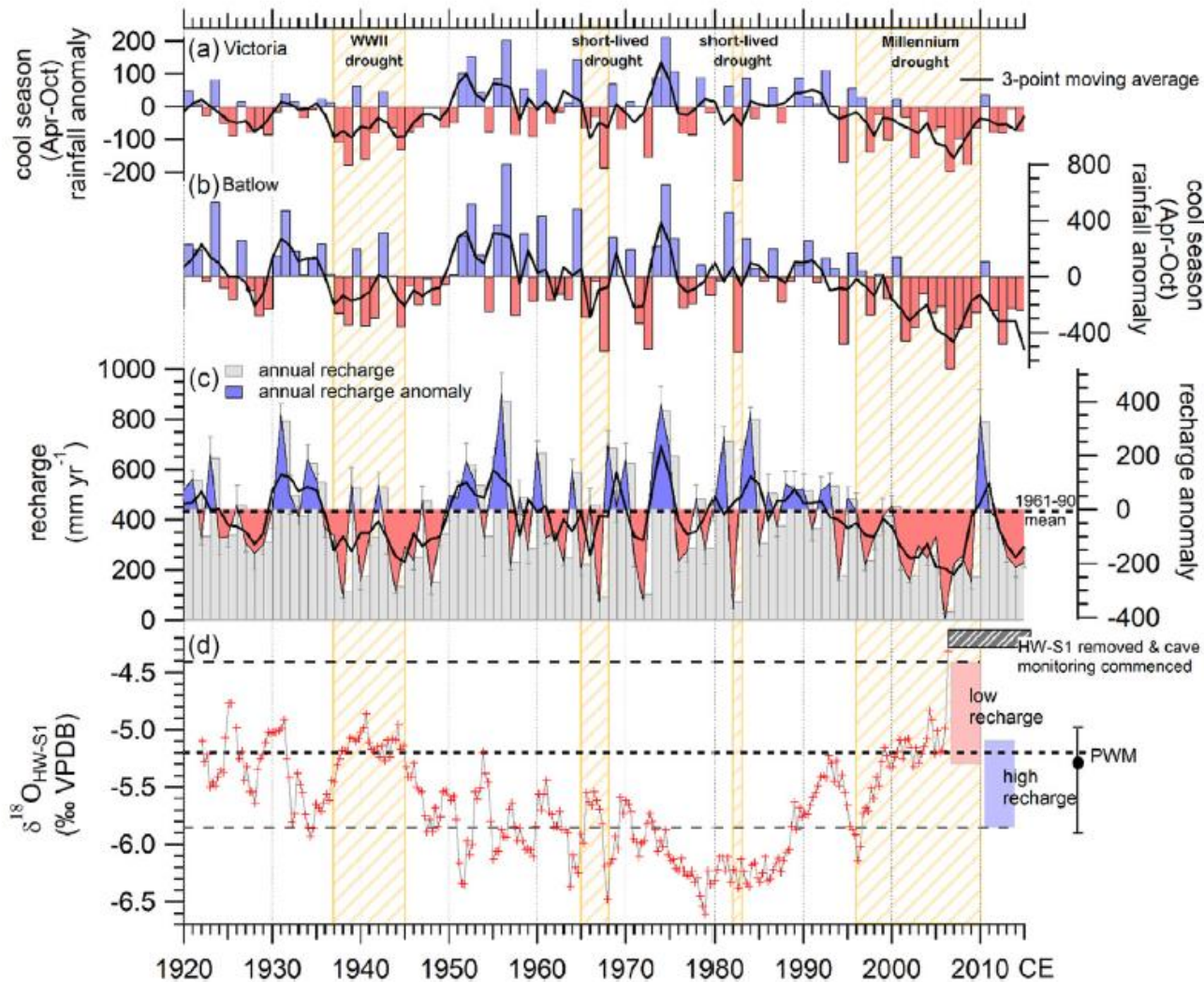
Fire



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

Comparison with the speleothem oxygen isotope record



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

More positive $\delta^{18}\text{O}$ = less recharge (drier)
More negative $\delta^{18}\text{O}$ = more recharge (wetter)

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



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

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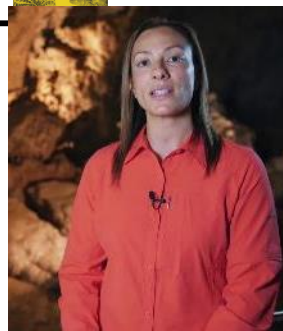
^b School of Biological, Earth and Environmental Sciences, UNSW Sydney, Sydney, NSW, 2052, Australia

^c Climate Geochemistry Department, Max Planck Institute for Chemistry, 55128, Mainz, Germany

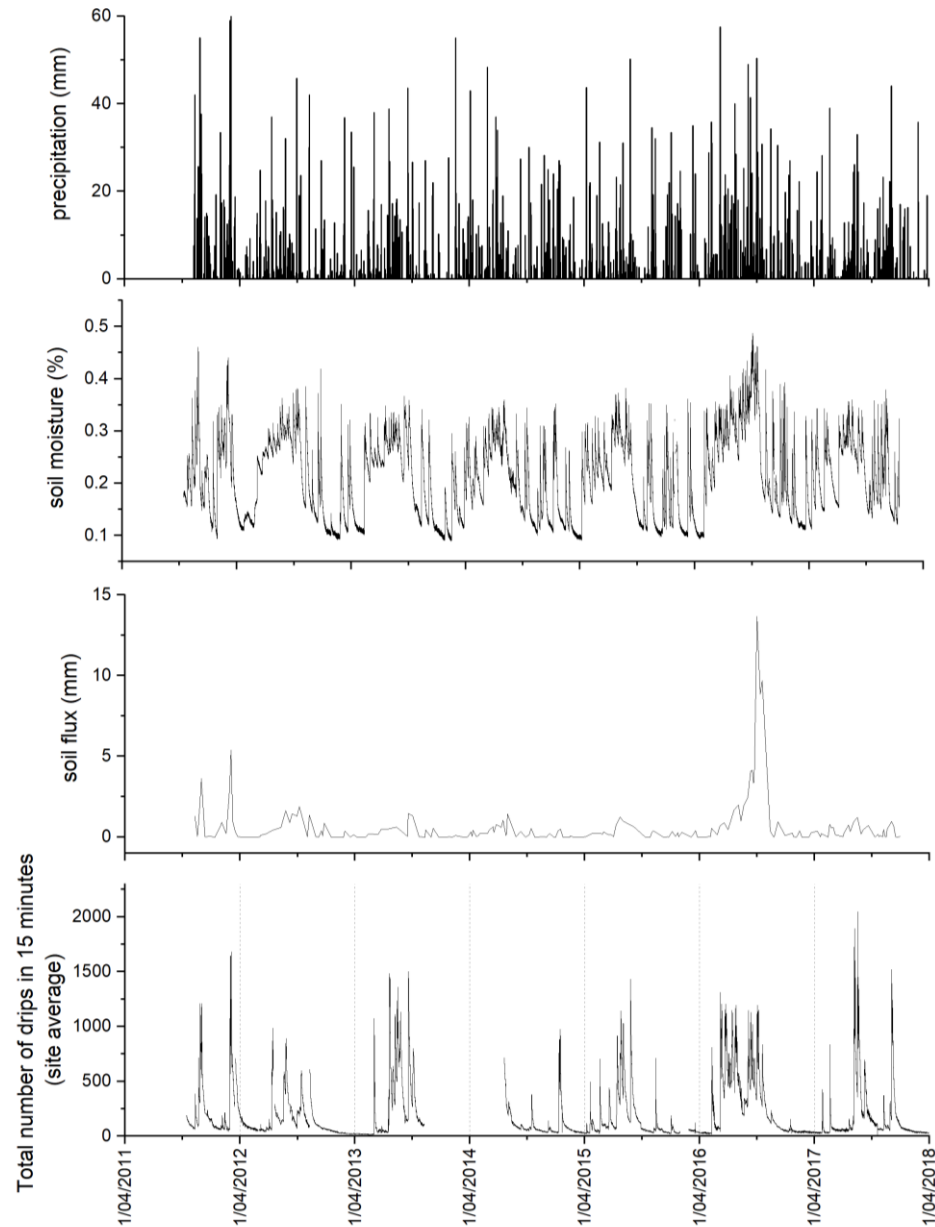
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Monitoring data helps constrain hydrological models

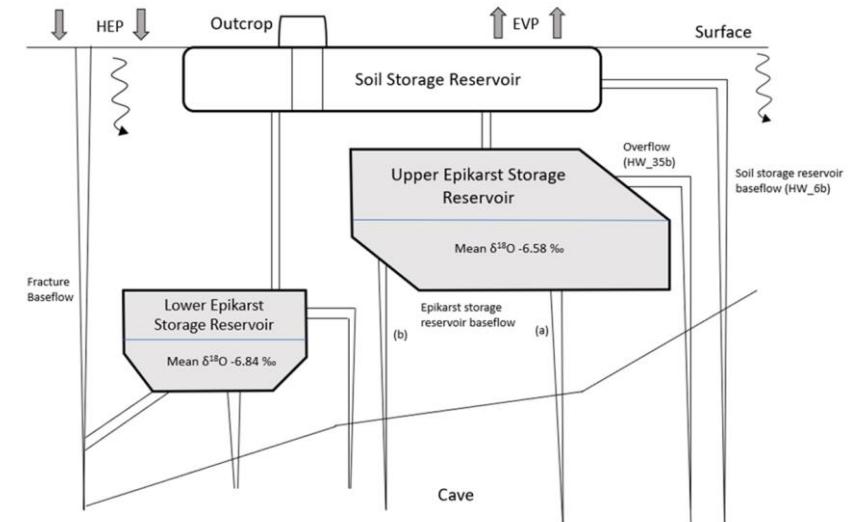


For example, a soil drainage model based on soil moisture data suggests a higher recharge period in winter 2016

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).

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