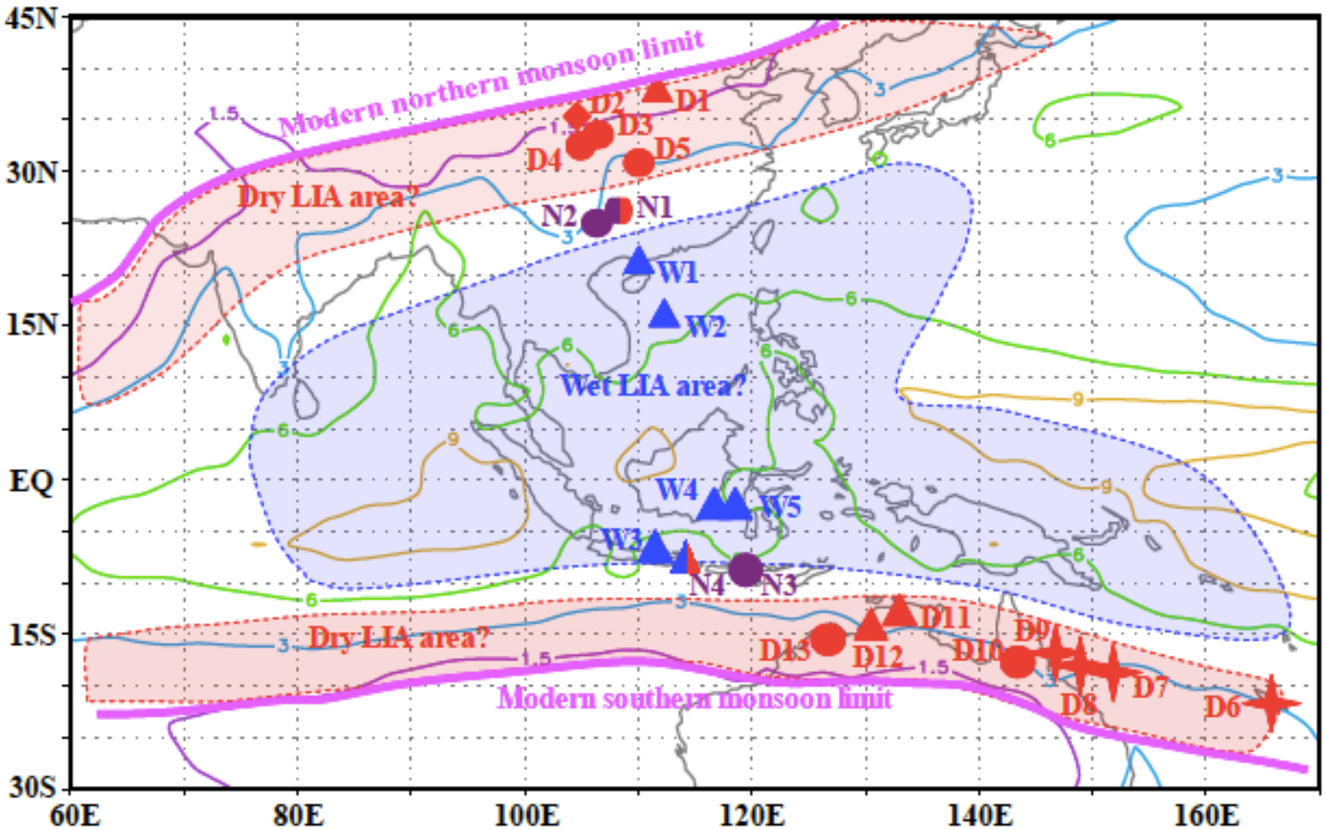
Australasian Monsoon Variability During the Common Era Inferred from Indo-Pacific Speleothem Records

Michael L. Griffiths
Dept. Environmental Science

WILLIAM PATERSON UNIVERSITY

Hydroclimate records from the Australasian monsoon region for the Common Era

Little Ice Age

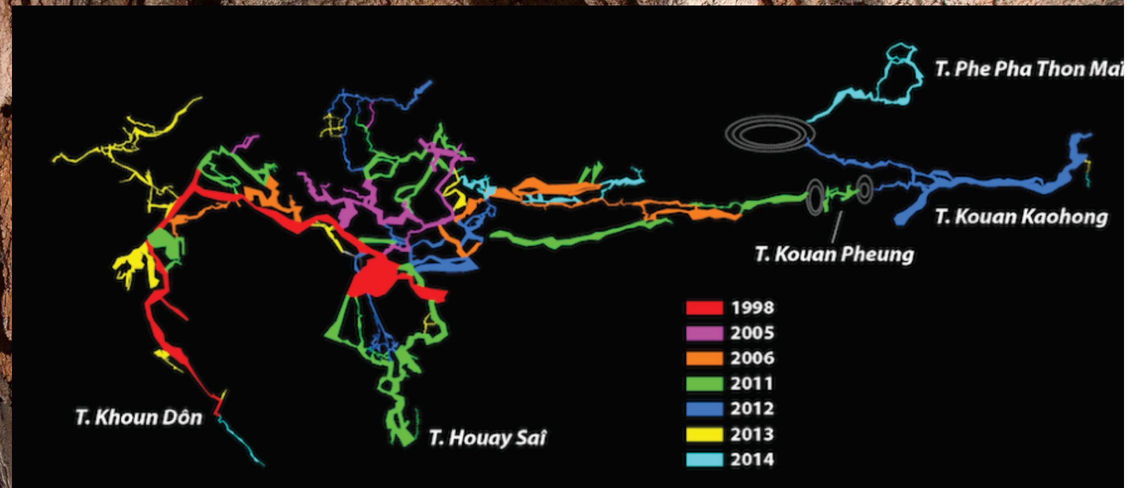


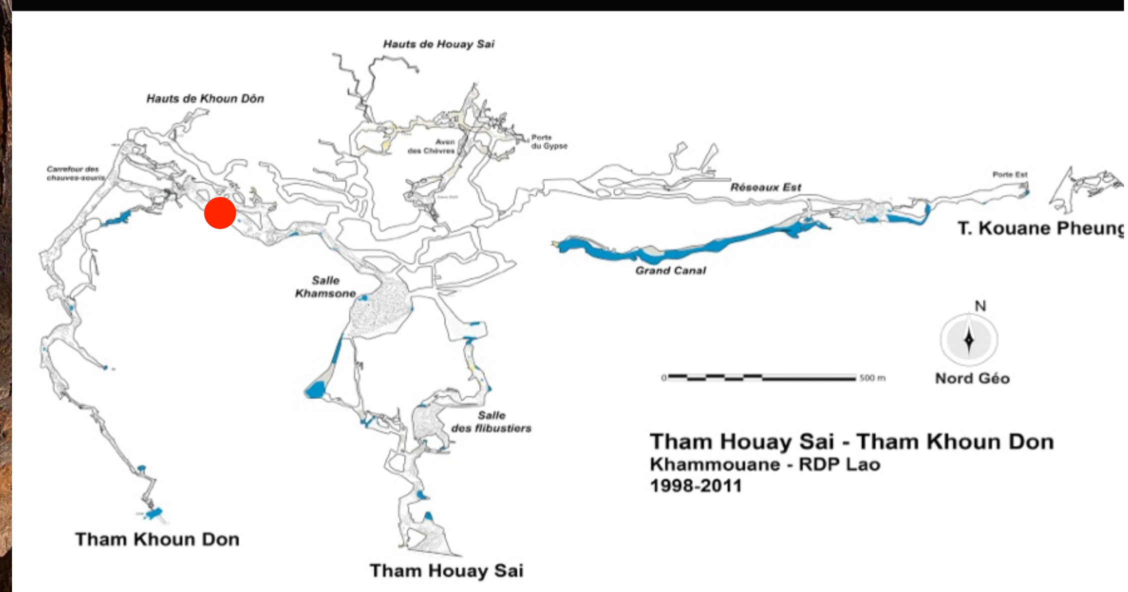
DRY away from equator whilst WET towards equator

Yan *et al.*, 2015; *Nat. Geo.*

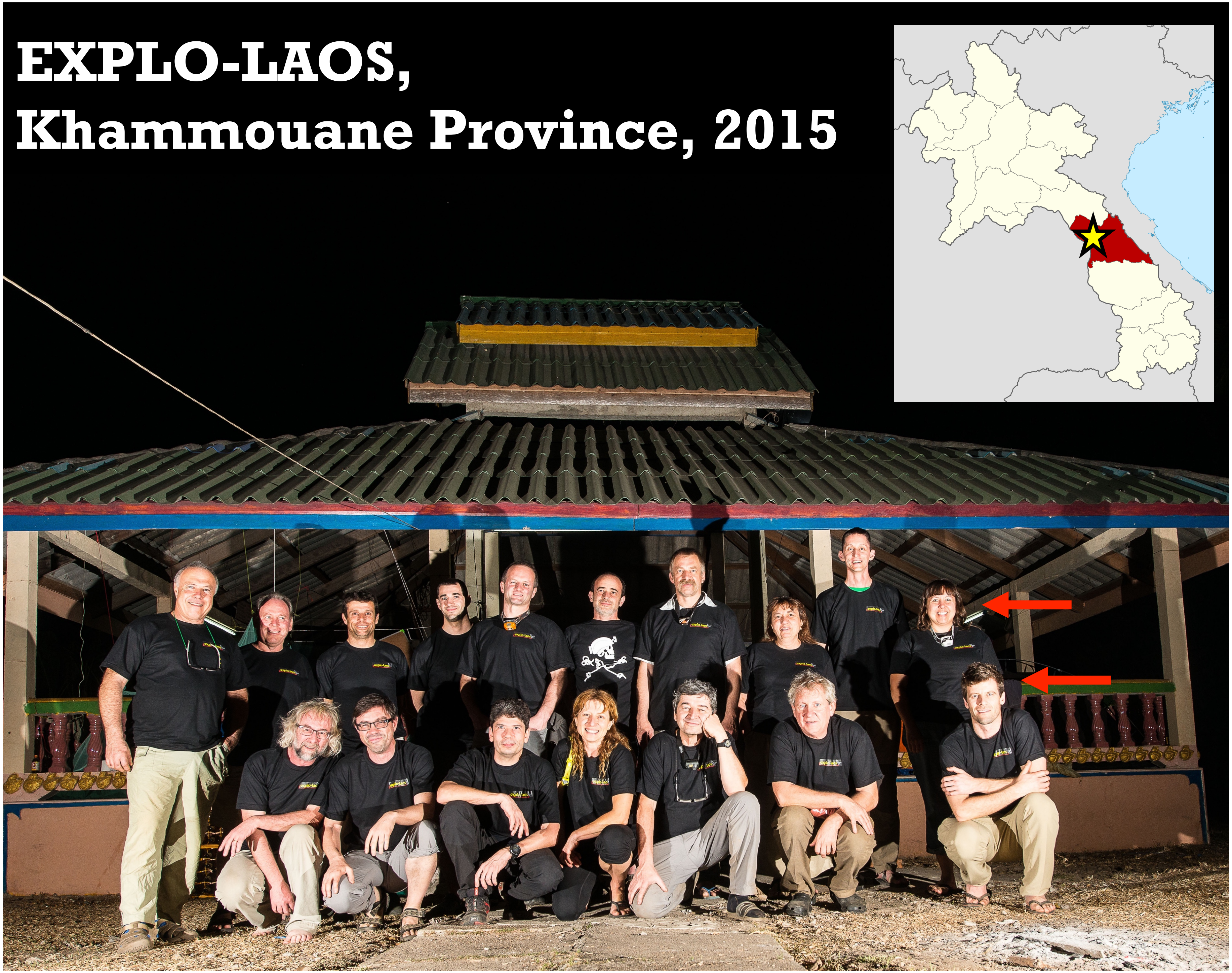
Tham Khoun Don-Houay Sai, Laos

Photo: *Serge (speleomag.com)*

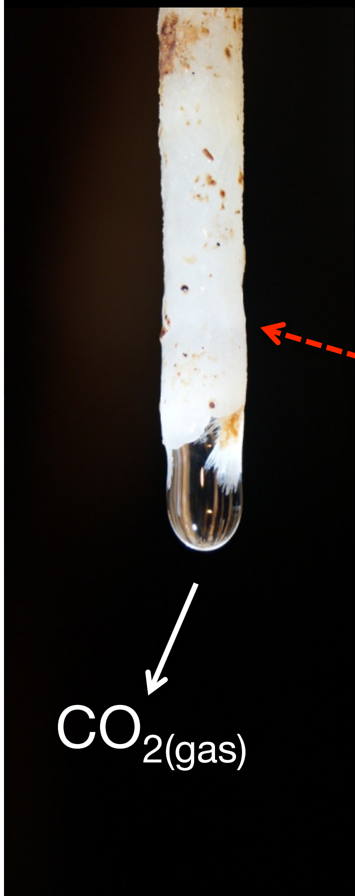




Map: *Explo-Laos*


EXPLO-LAOS,
Khammouane Province, 2015

Speleothems: “Fossilized Groundwater”



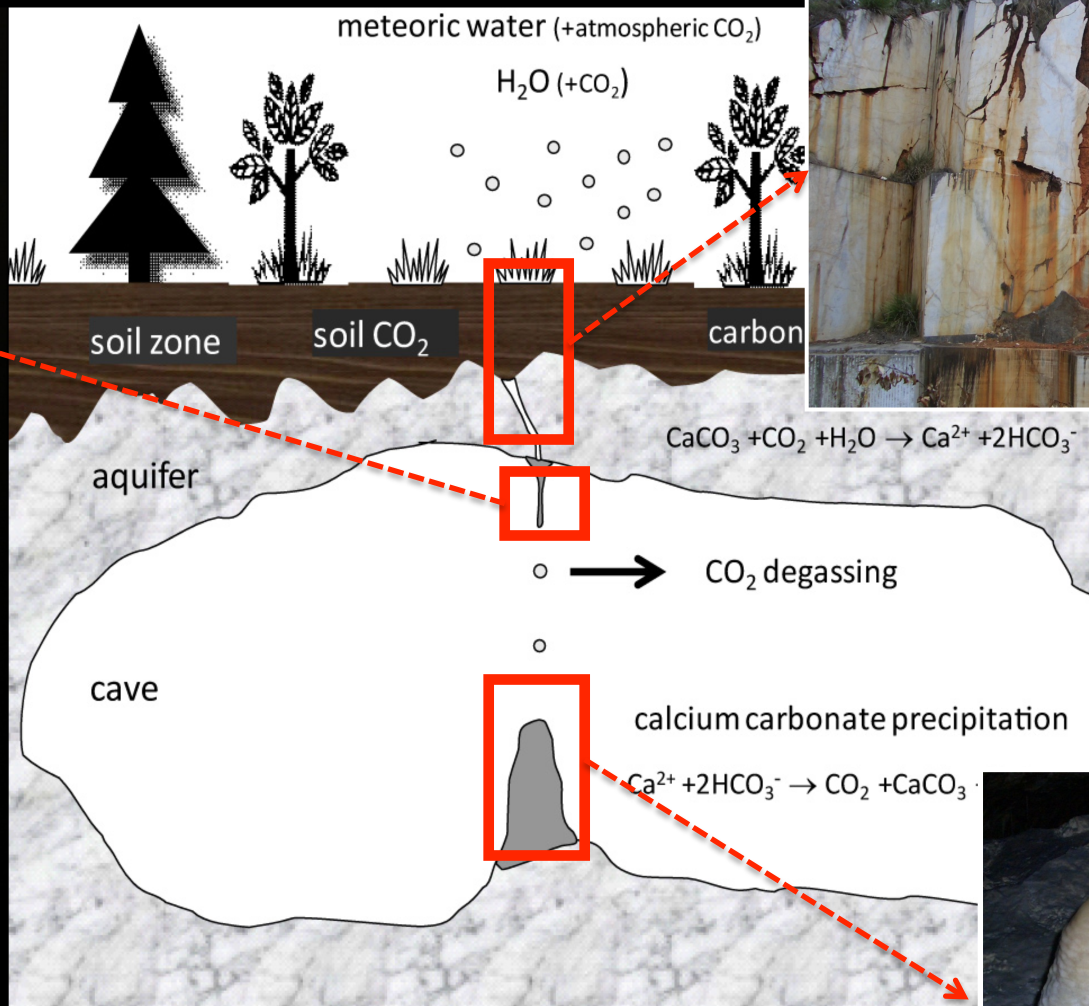
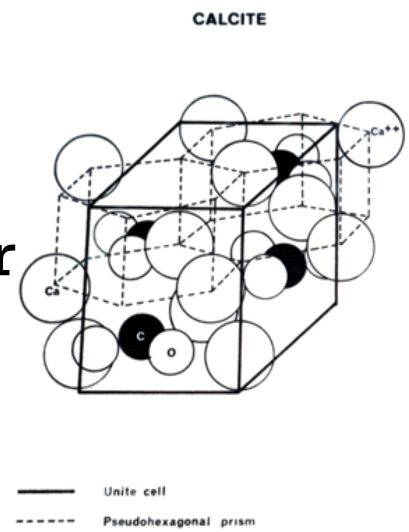
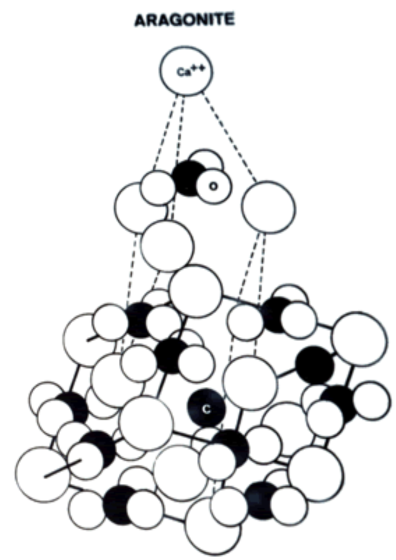


Image: *Frisia and Borsato, 2010.*

Reconstructing past climate using carbonate mineral deposits

$CaCO_3$ can be either calcite or aragonite





$CaCO_3$

Trace amounts of other elements, e.g. Mg, Sr, U can substitute for Ca in the crystal structures

The carbon atom can be stable ^{12}C or ^{13}C or radioactive ^{14}C

The oxygen atoms can be ^{16}O, ^{17}O, or ^{18}O

Environmental effects on speleothem $\delta^{18}O$

$$\delta^{18}O = \left\{ \frac{\left(^{18}O/^{16}O\right)_{Sam.} - \left(^{18}O/^{16}O\right)_{Std.}}{\left(^{18}O/^{16}O\right)_{Std.}} \right\} \times 10^3$$

Assuming equilibrium deposition:

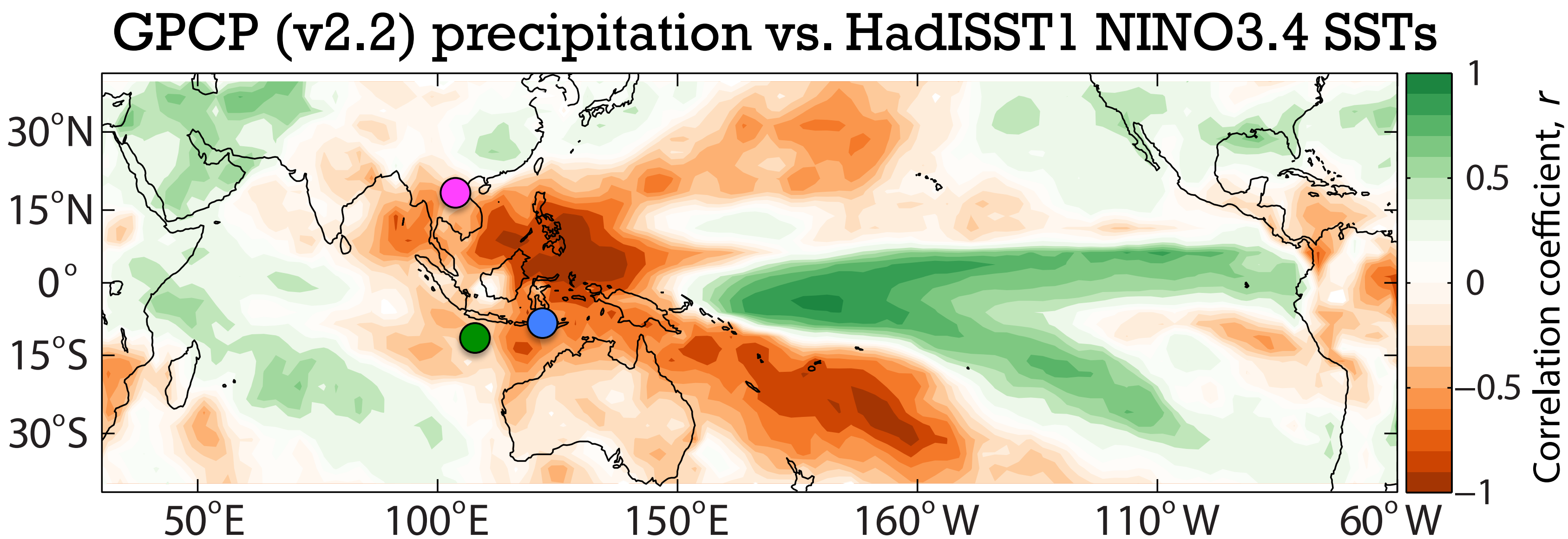
$\delta^{18}O_{calcite} = f\ [\delta^{18}O_{water}$, Cave T (MAT)]

$d\delta^{18}O/dT = -0.23$ ‰ /C

Accounts for most of variability

(precipitation $\delta^{18}O$ + hydrology + (fractionation/kinetics?)

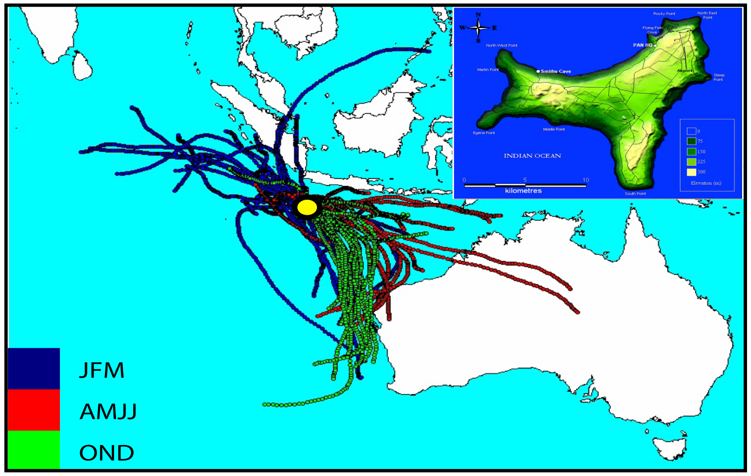
Indo-Pacific hydroclimate over the past 1-2 millennia

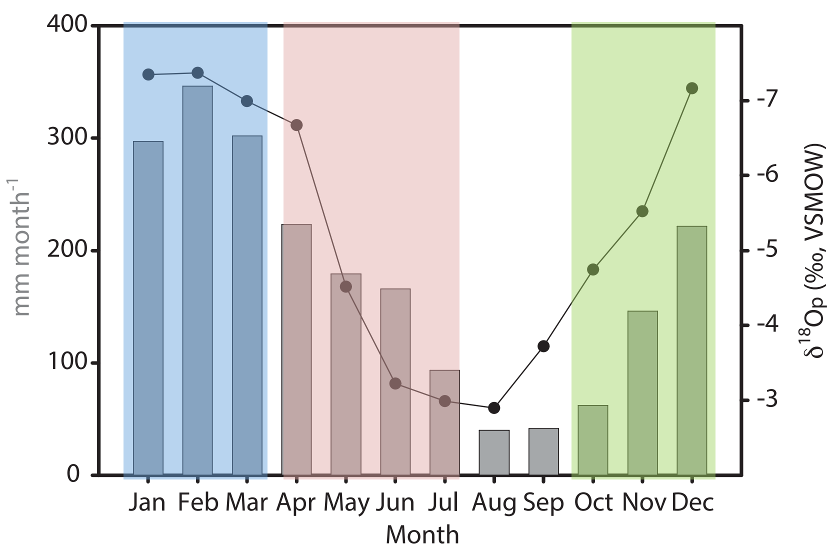


- Christmas Island (~1375-2003 C.E.)
- Flores (~0-2000 C.E.)
- Northern Laos (~0-2008 C.E.)

Christmas Island: climatology

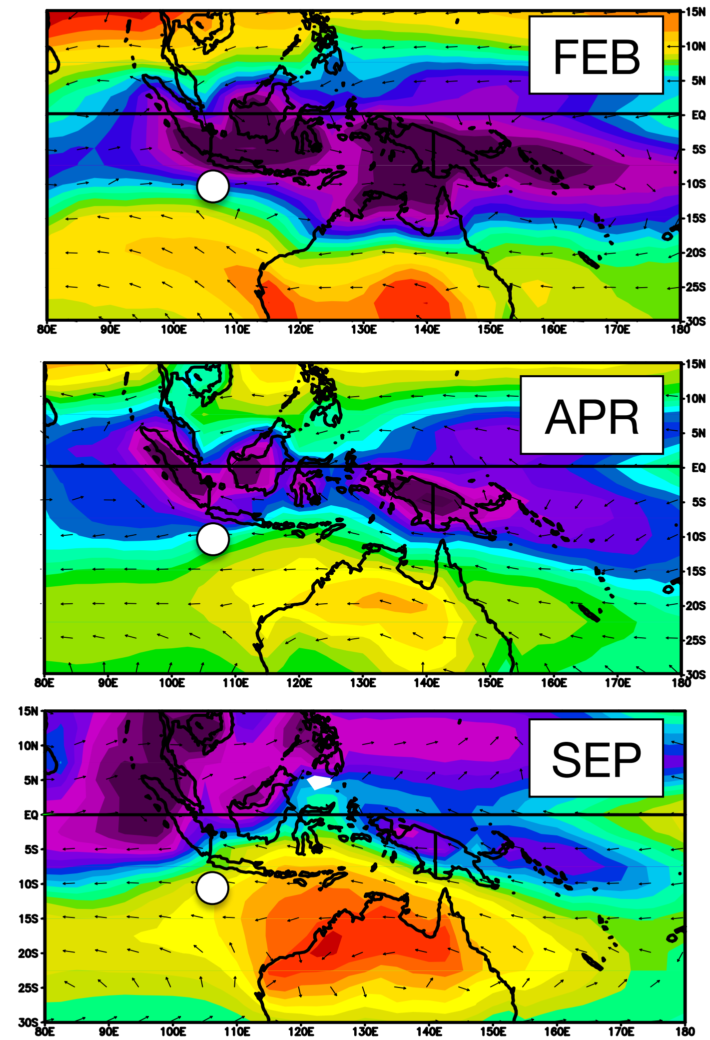
HYSPLIT back trajectories (rain events > 90th percentile)





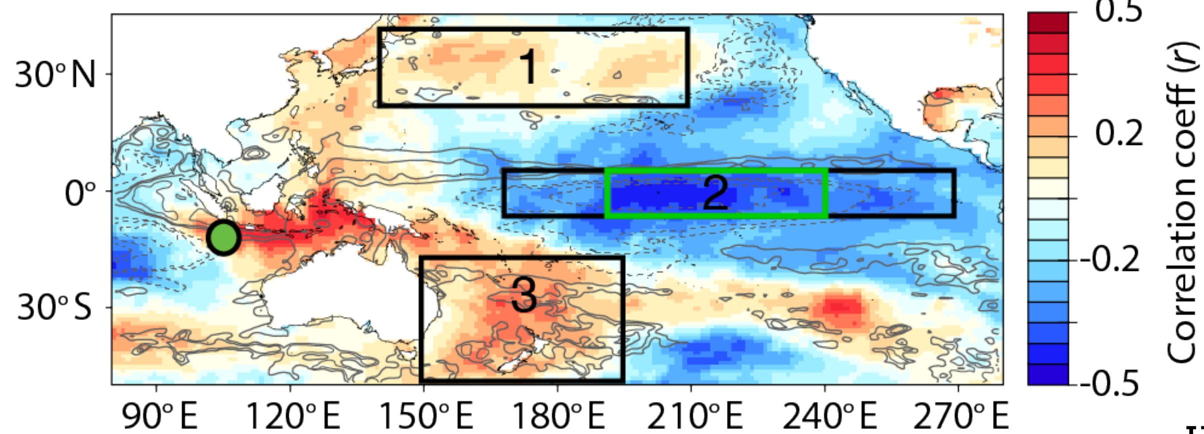
Source: BOM and IsoGSM

Outgoing Longwave Radiation (OLR)



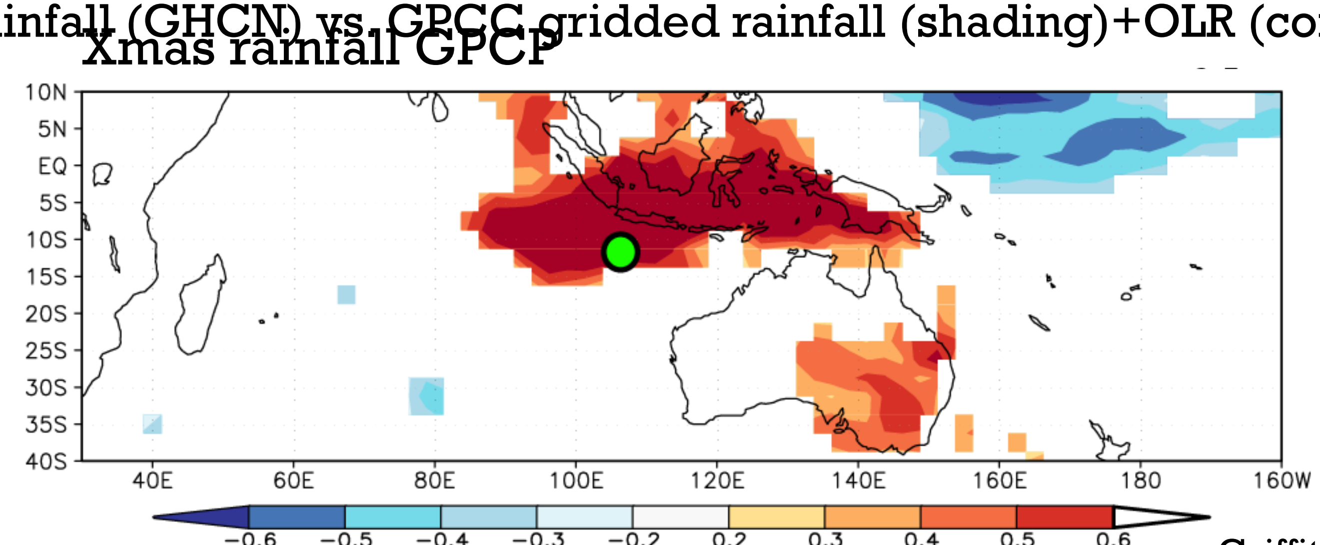
Instrumental precip: ENSO/IPO influence

Xmas rainfall (GHCN) vs. SST (shading)+sea surface height (contours)



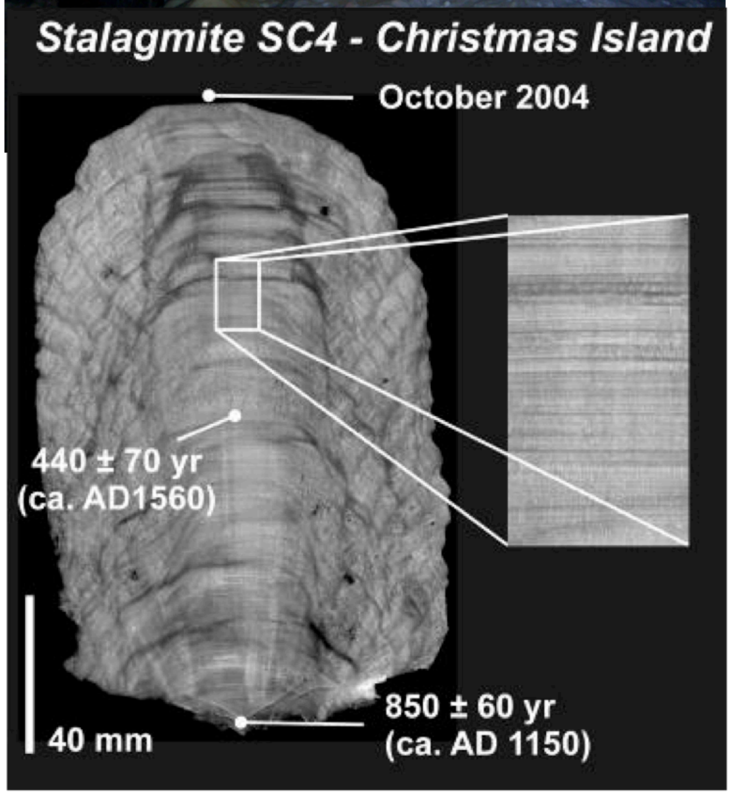
Henley *et al.*, 2015.

Xmas rainfall (GHCN) vs. GPCC gridded rainfall (shading)+OLR (contours)

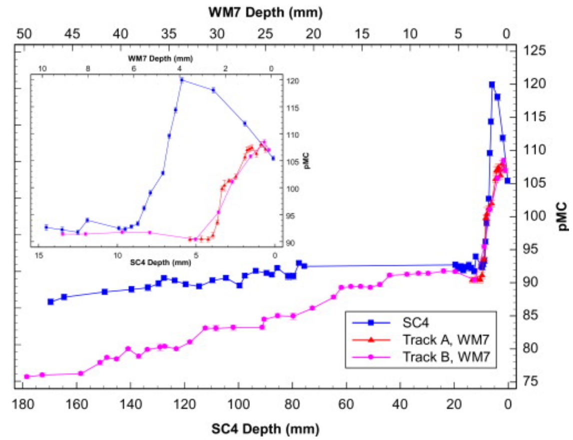


Griffiths *et al.*, *in prep.*

Speleothem: SC4 (Smith's Cave)

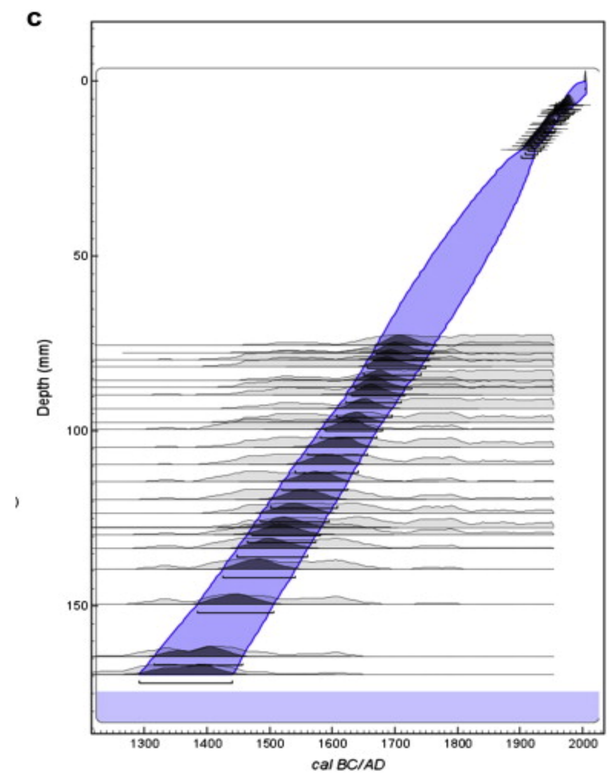


^{14}C chronology



"Bomb peak"

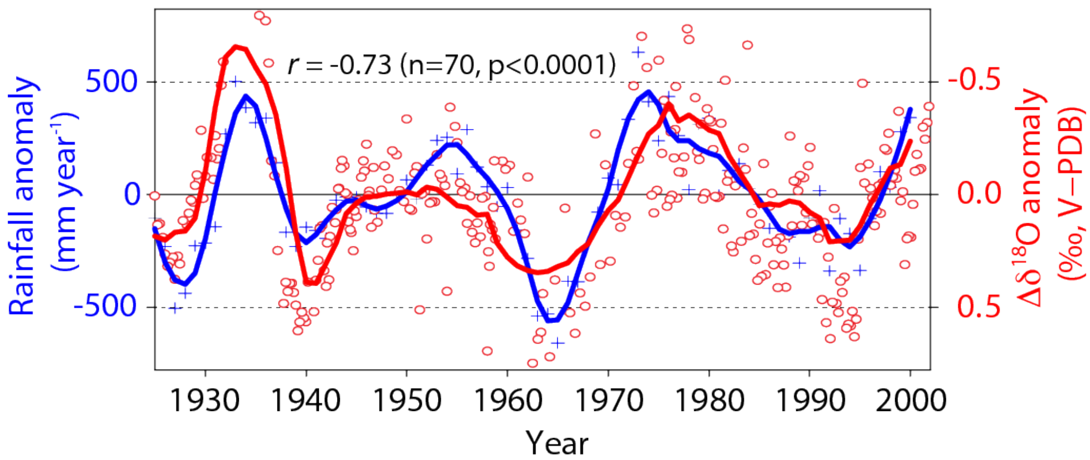
44 ^{14}C ages used to construct *Oxcal* age model



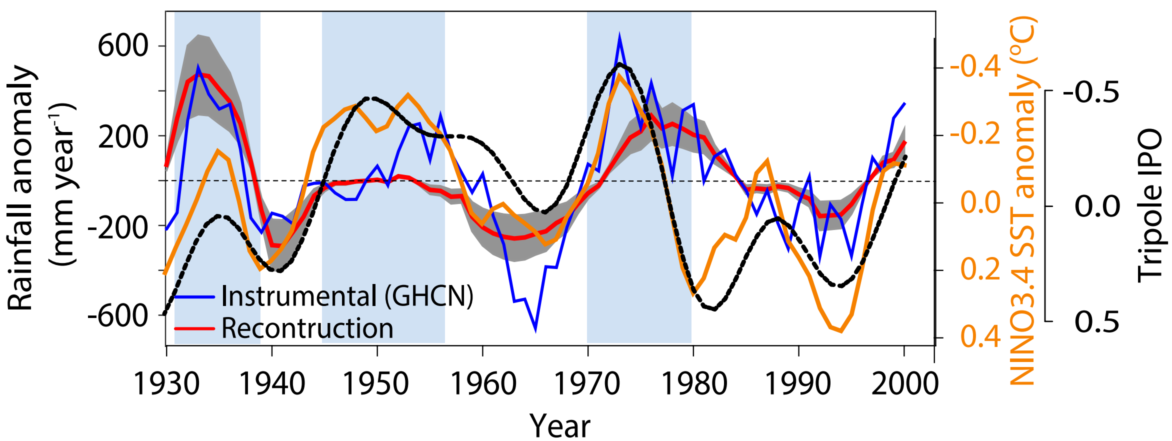
Hua *et al.*, 2014; *Quat. Geochron.*

Modern SC4 $\delta^{18}O$: strong "amount effect"

Xmas rainfall (GHCN) vs. SC4 $\Delta\delta^{18}O$

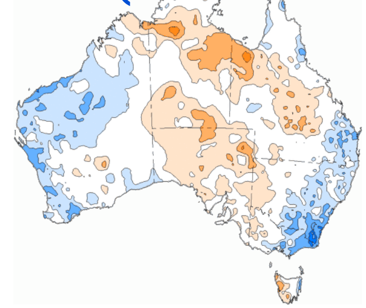


+500 mm = -0.5‰

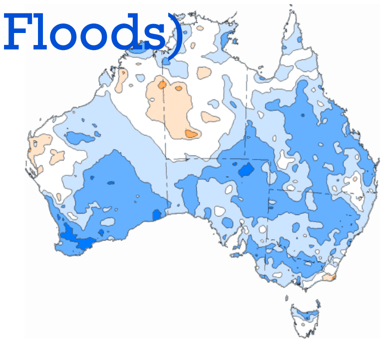


Henley *et al.*, 2015.

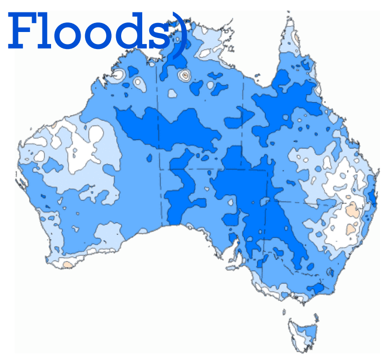
1934 (Melb. Floods)



1955 (QLD, Hunter Floods)

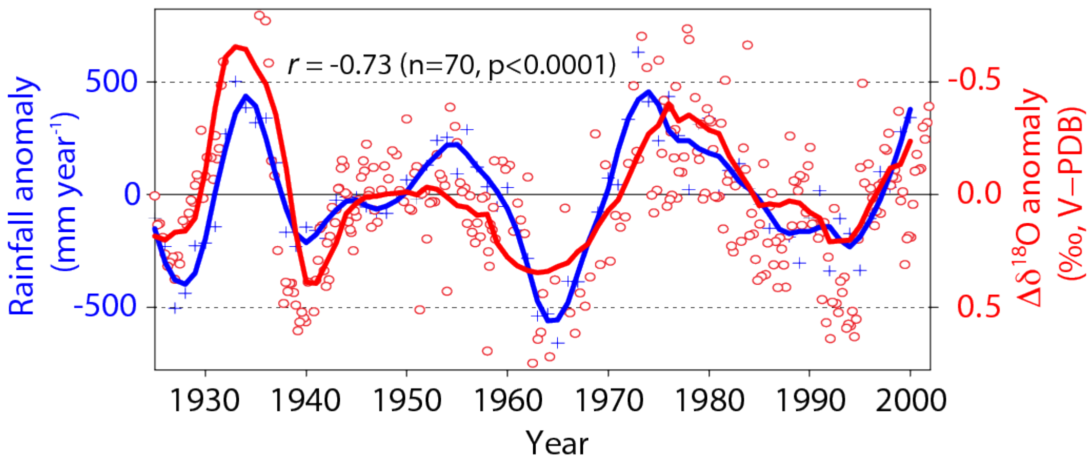


1974 (QLD, NSW Floods)

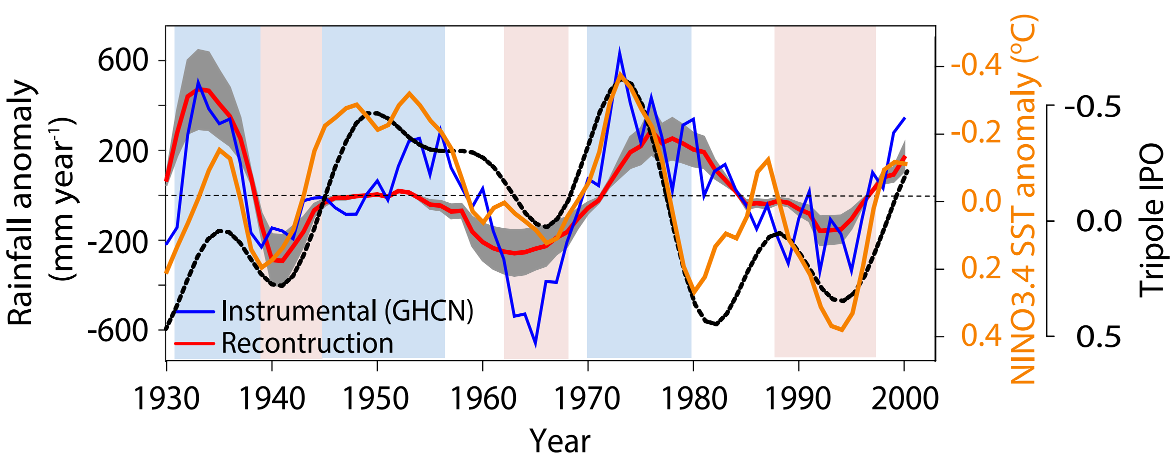


Modern SC4 $\delta^{18}O$: strong "amount effect"

Xmas rainfall (GHCN) vs. SC4 $\Delta\delta^{18}O$

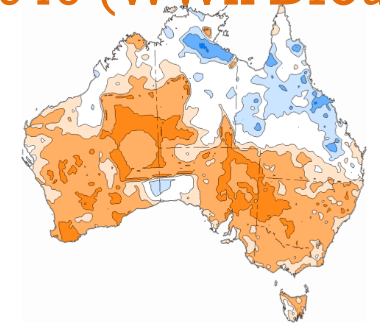


+500 mm = -0.5‰

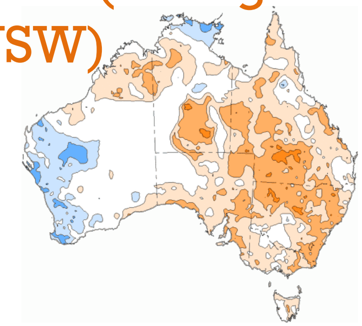


Henley *et al.*, 2015.

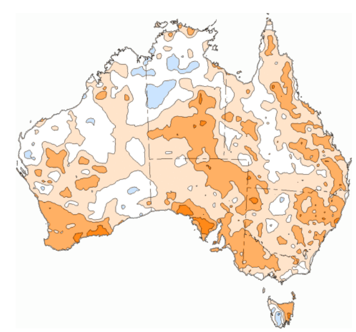
1940 (WWII Drought)



1965 (Drought begins NSW)

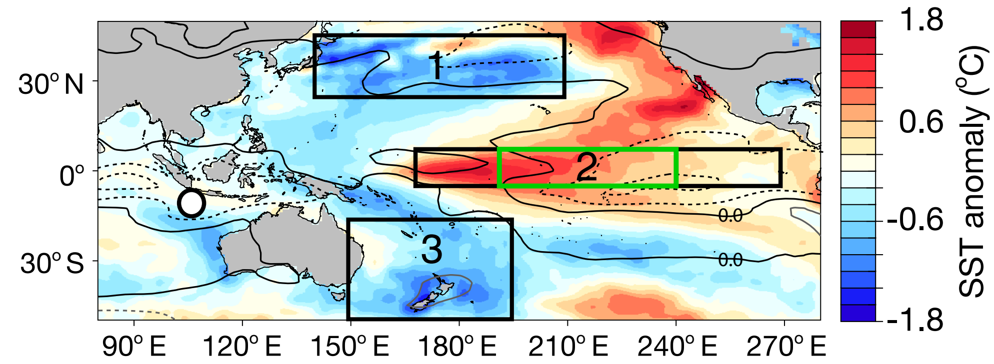


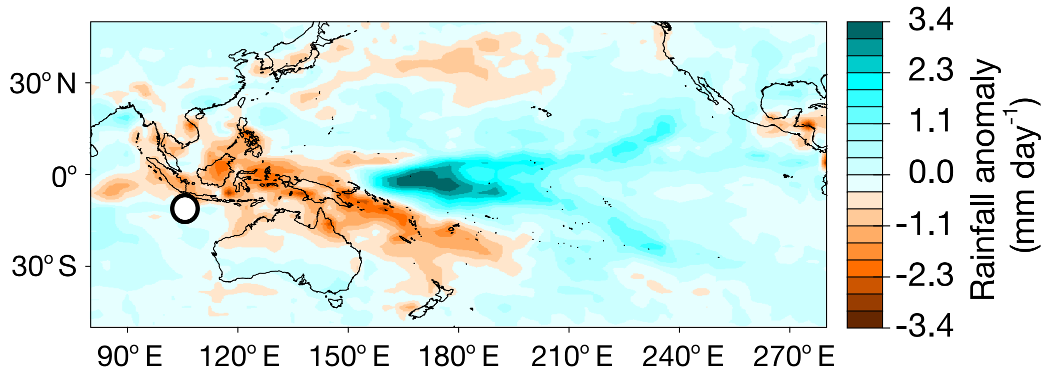
1994



Modern SC4 $\delta^{18}O_c$: Pacific influence

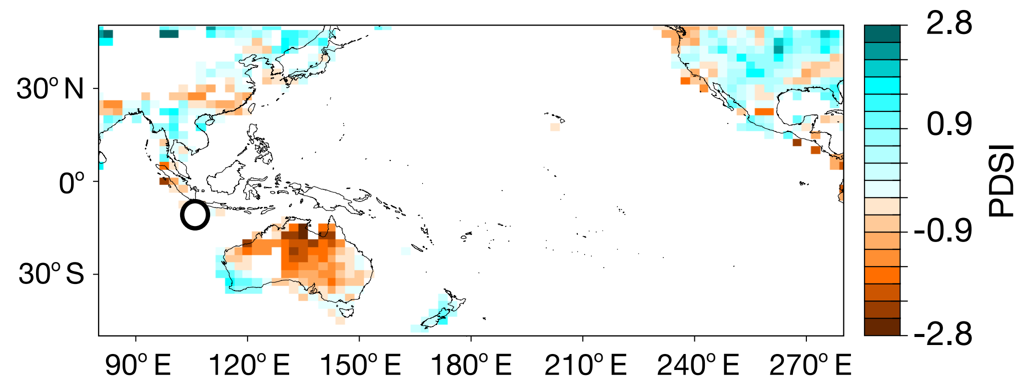
Mean (NOAA OI) SST (shaded) + zonal winds (contours) for years in the lower quartile minus years in the upper quartile for the XI reconstruction.



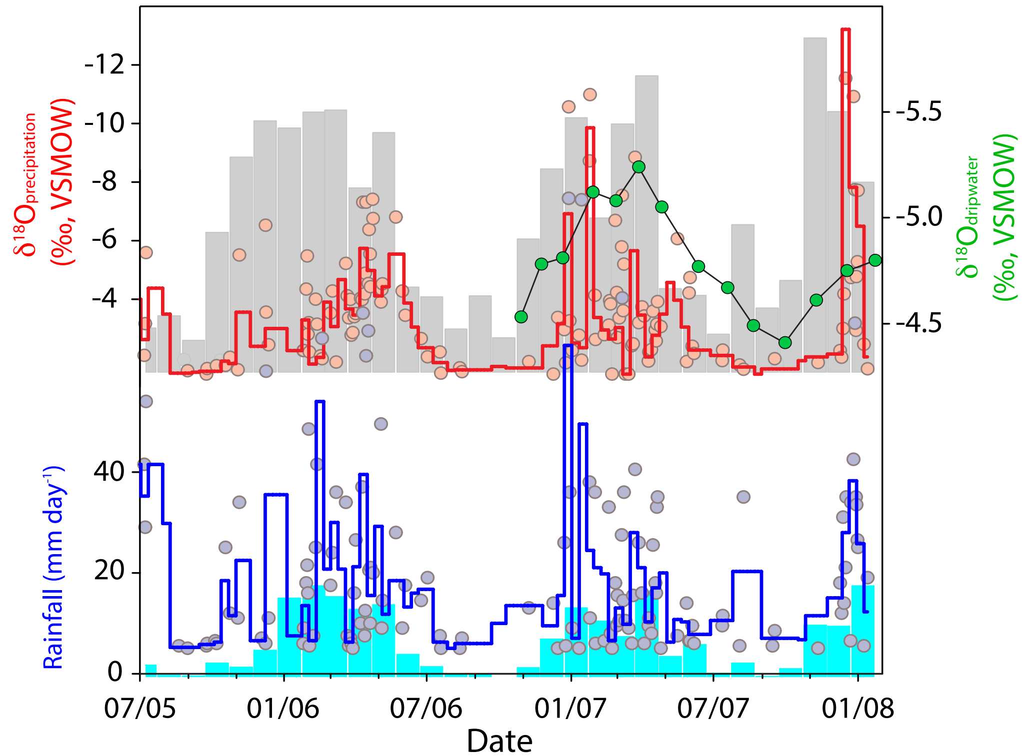


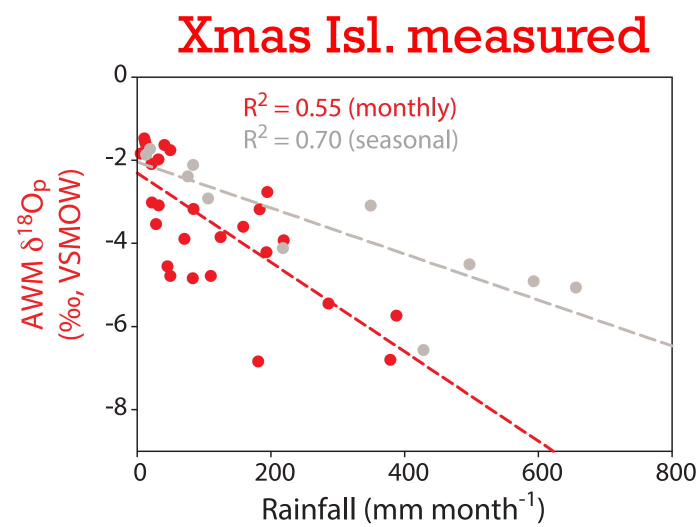
GPCP rainfall

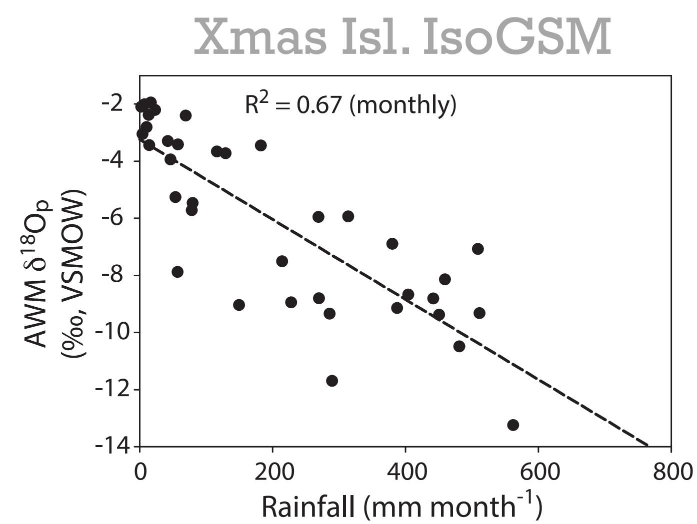
Palmer Drought Severity Index (PDSI)



Modern rainfall and drip-water $\delta^{18}O$



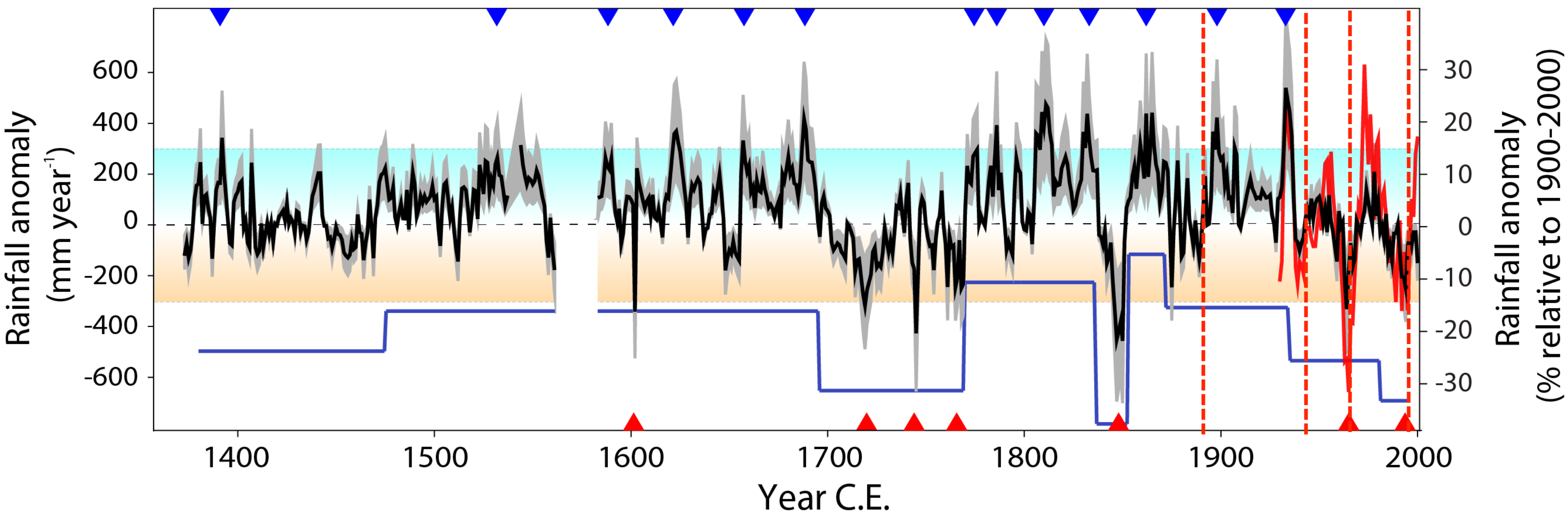




- Isotopically depleted monsoon-season rainfall ⇒ similar cave drip-water pattern though small seasonal range.
- Overall good correspondence with IsoGSM precipitation $\delta^{18}O$.

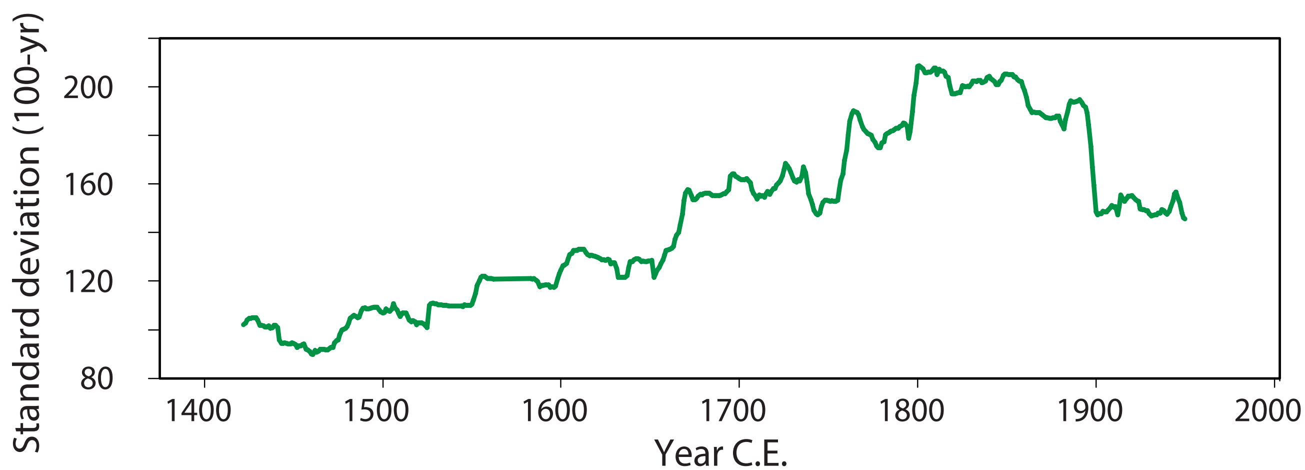
Yoshimura *et al.*, 2008; *JGR*

Xmas Isl. hydroclimate reconstruction

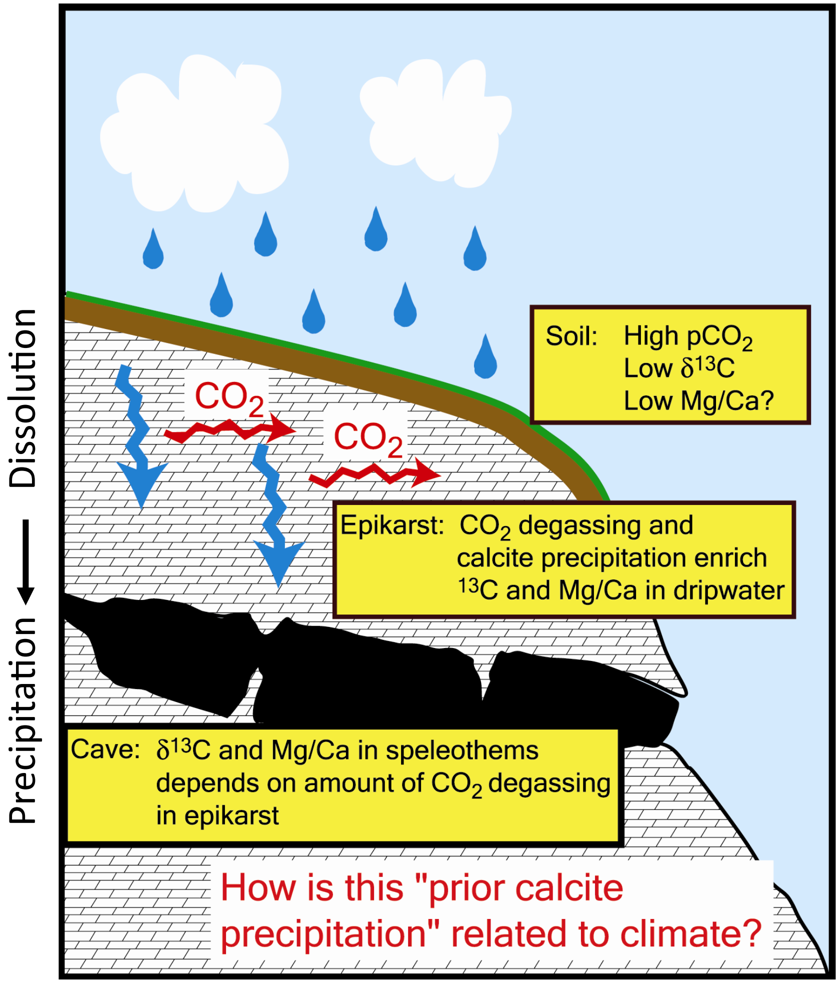


Dry: 1350-1480, ~1550s, 1700-1770, ~1850, 1890s, 20th century (Federation drought, WWII drought, 1960s,1990s)

Wet: ~1500-1900, 1930s, 1950s, 1970s

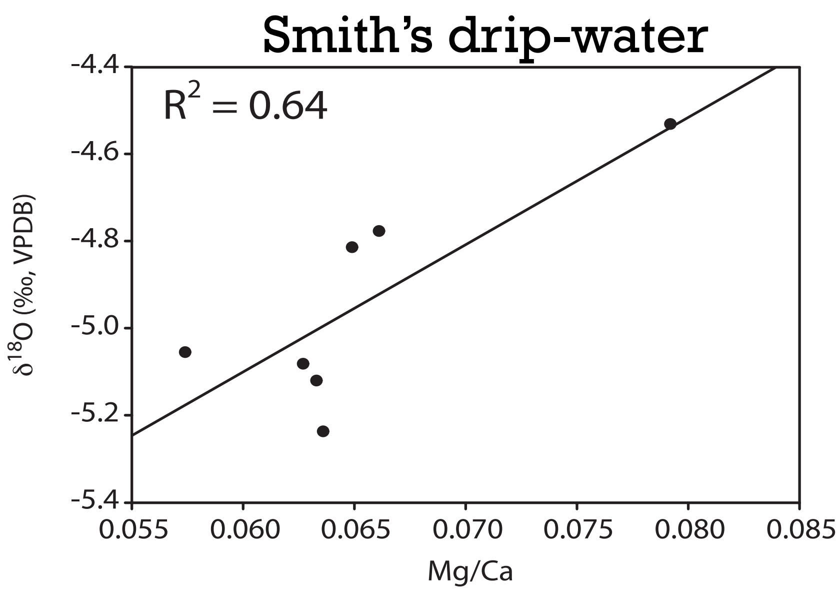


Karst hydrology: $\delta^{13}C$ and Mg/Ca

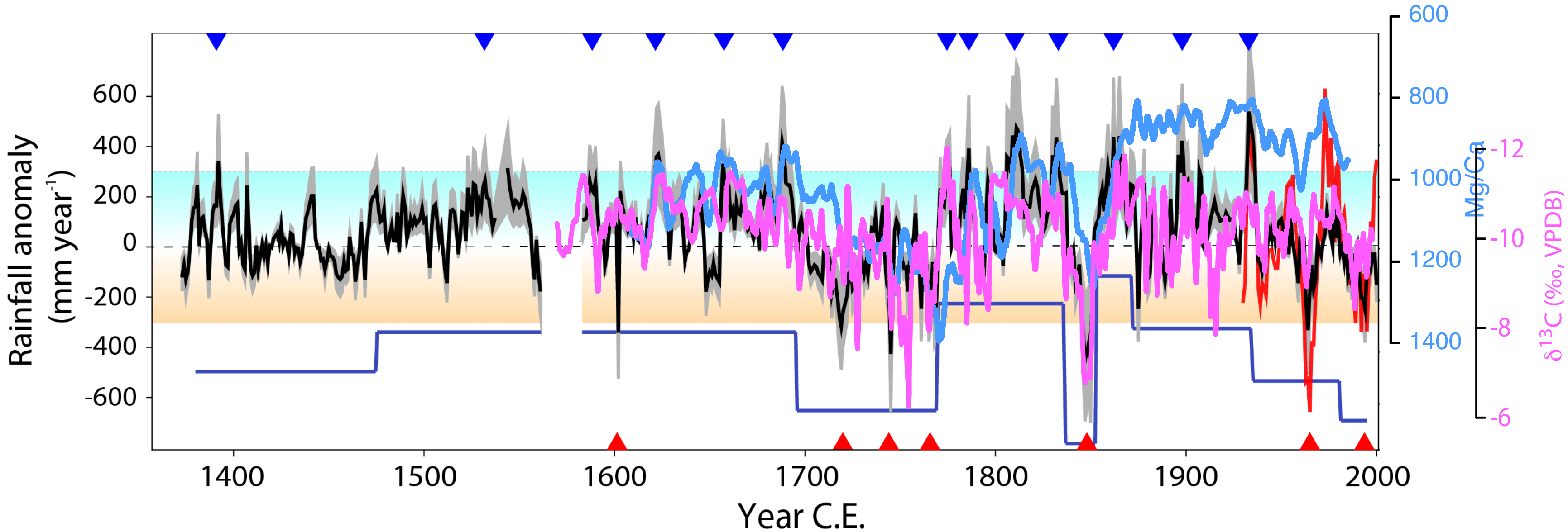


Drier periods: higher Mg/Ca and $^{13}C/^{12}C$

Wetter periods: lower Mg/Ca and $^{13}C/^{12}C$



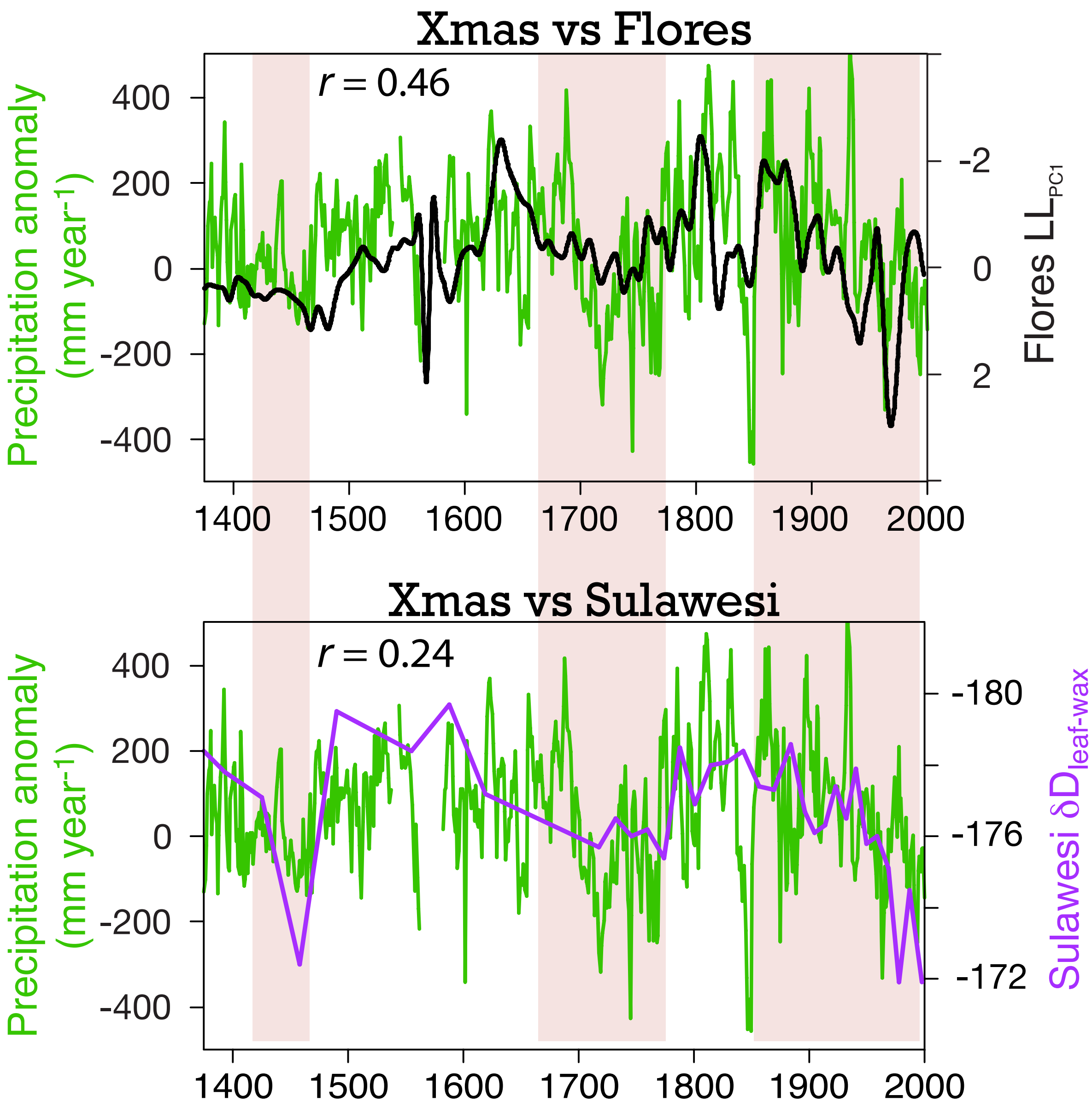
Karst hydrology: $\delta^{13}C$ and Mg/Ca

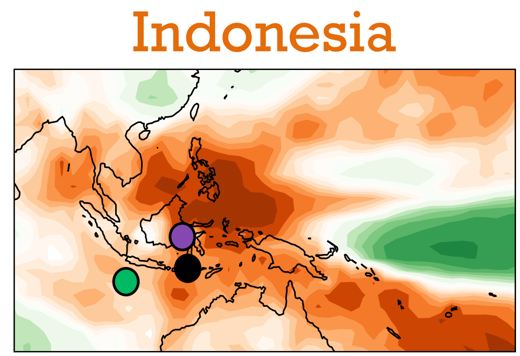


Drier periods: higher Mg/Ca and $^{13}C/^{12}C$

Wetter periods: lower Mg/Ca and $^{13}C/^{12}C$

Western Pacific hydroclimate: last ~750 years

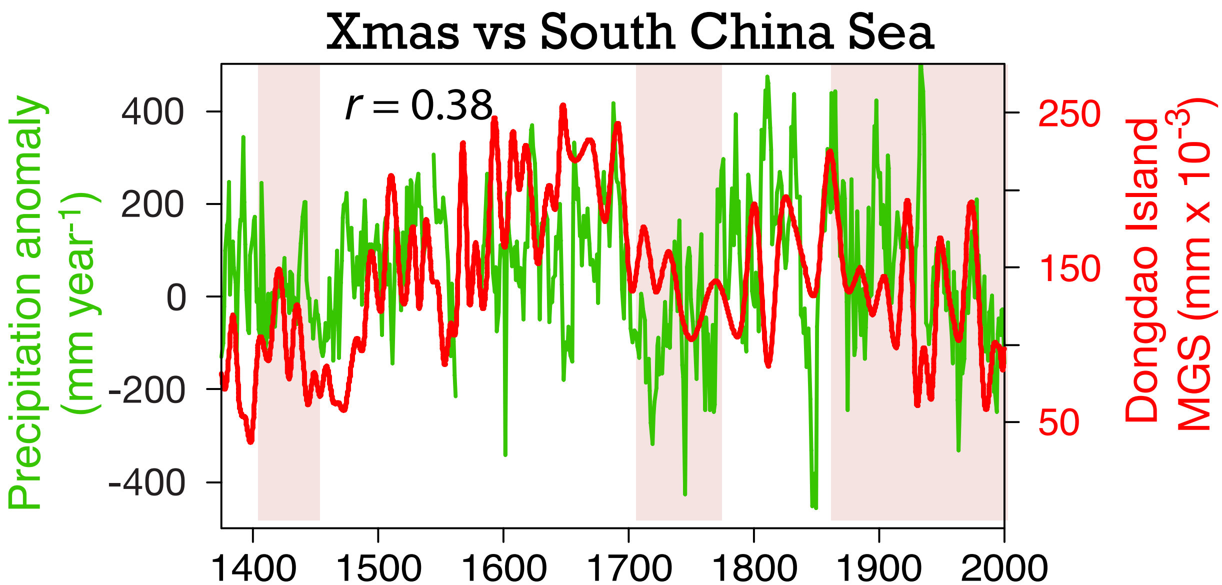


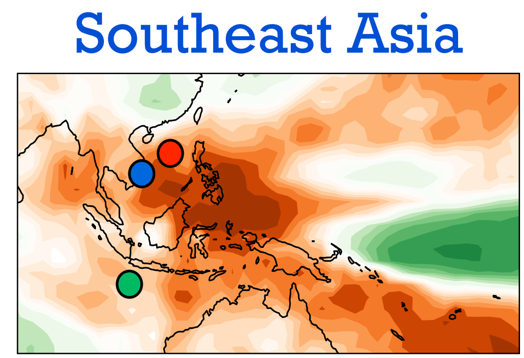


Griffiths *et al.*, 2016; *Nat. Comm.*

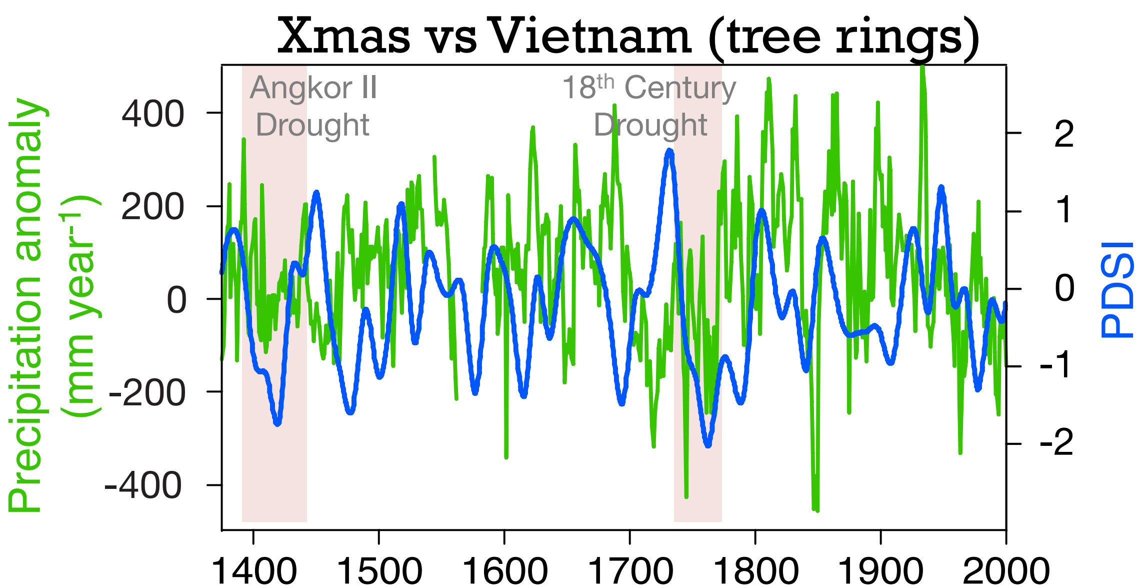
Tierney *et al.*, 2010; *JGR*

Western Pacific hydroclimate: last ~750 years

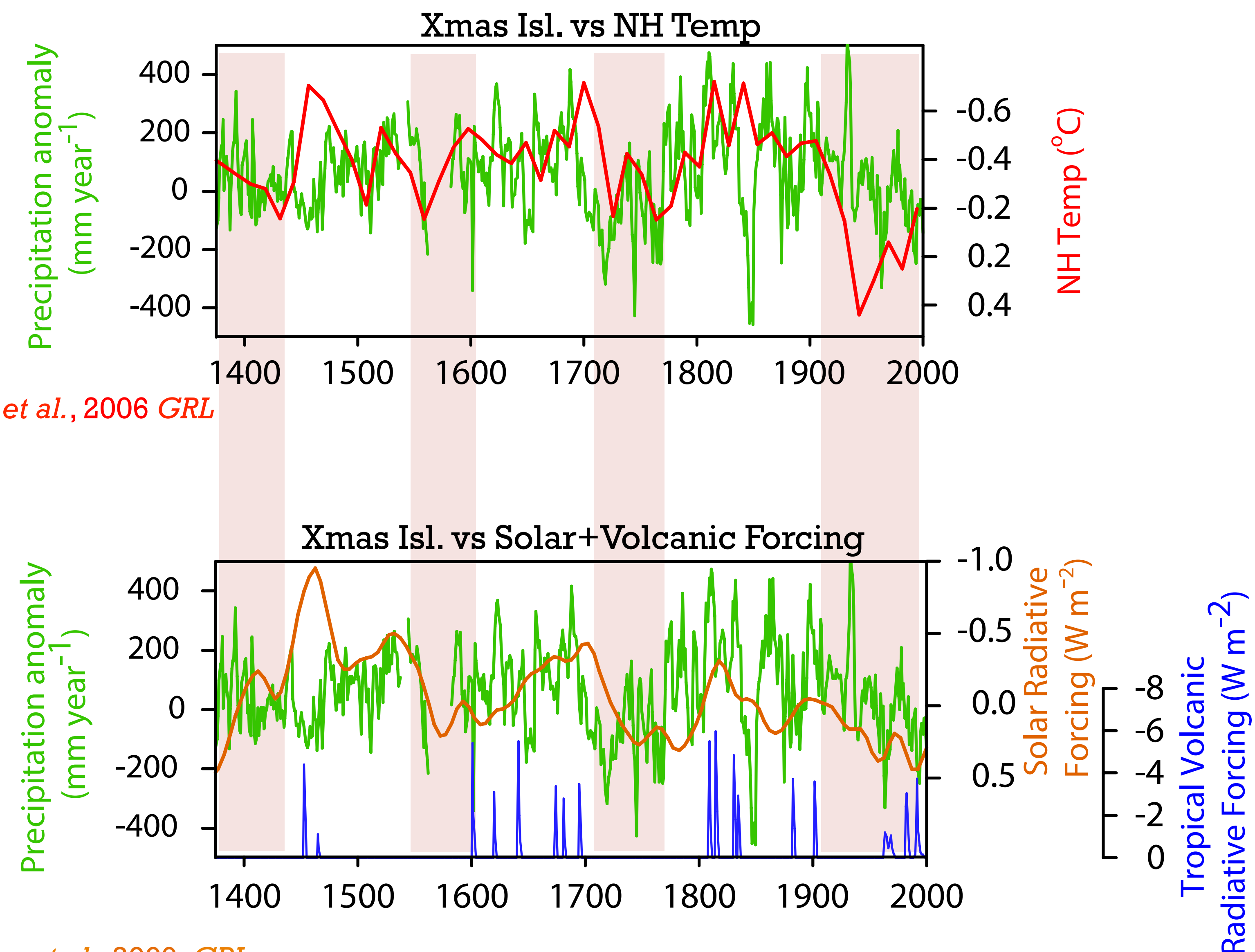




Yan *et al.*, 2011; *Nat. Comm.*
Buckley *et al.*, 2010; *PNAS*



Western Pacific hydroclimate and NH Temp

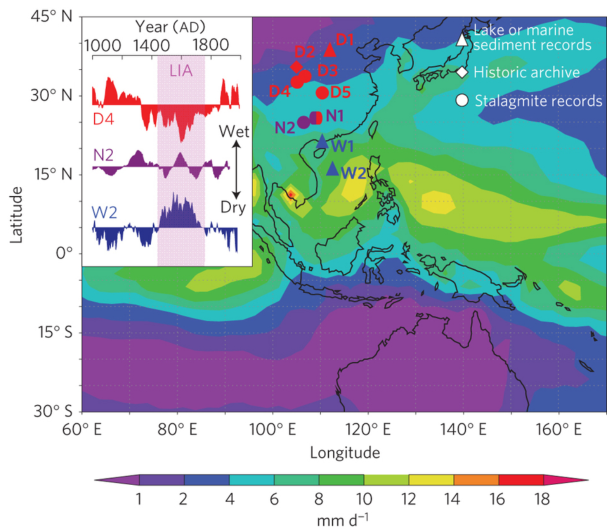


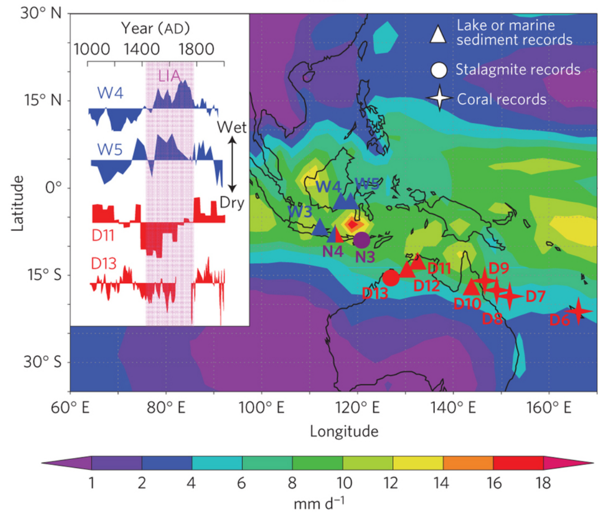
D'Arrigo *et al.*, 2006 *GRL*

Steinhilber *et al.*, 2009; *GRL*

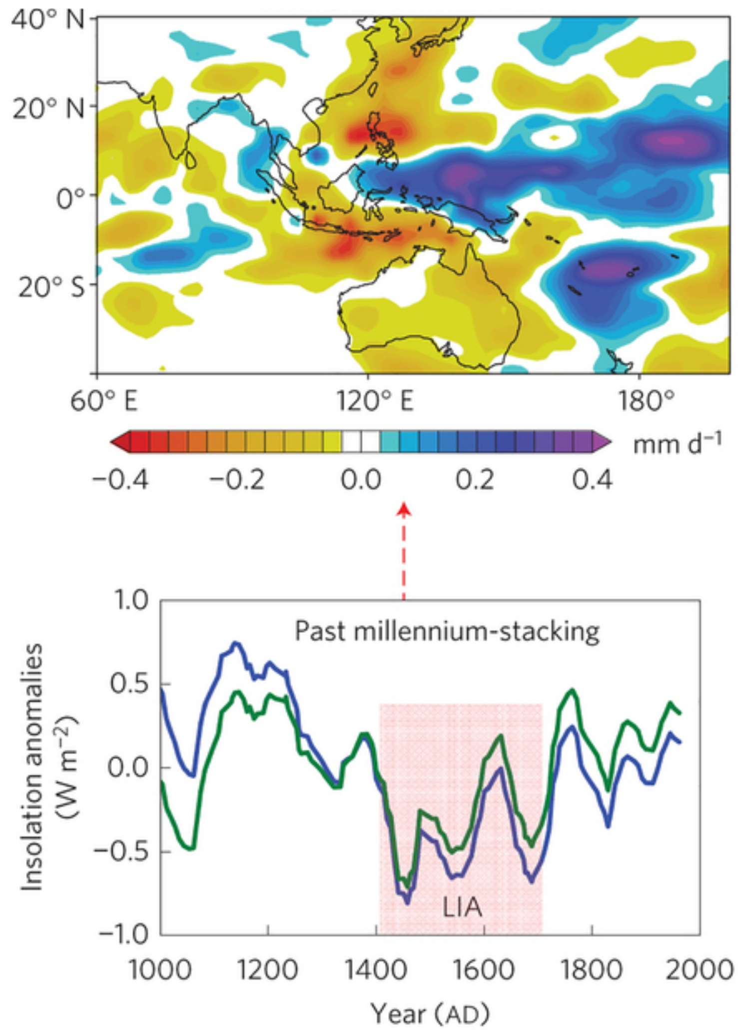
Mann et al., 2005; *J. Climate*

Equatorward contraction of the ITCZ during the LIA





MPI-ESM simulated precipitation anomaly for 1690-1740 CE



Yan *et al.*, 2015; *Nat. Geo.*

Poleward expansion of the ITCZ during the MCA

North Atlantic Drift Ice
(Bond et al., 2001)

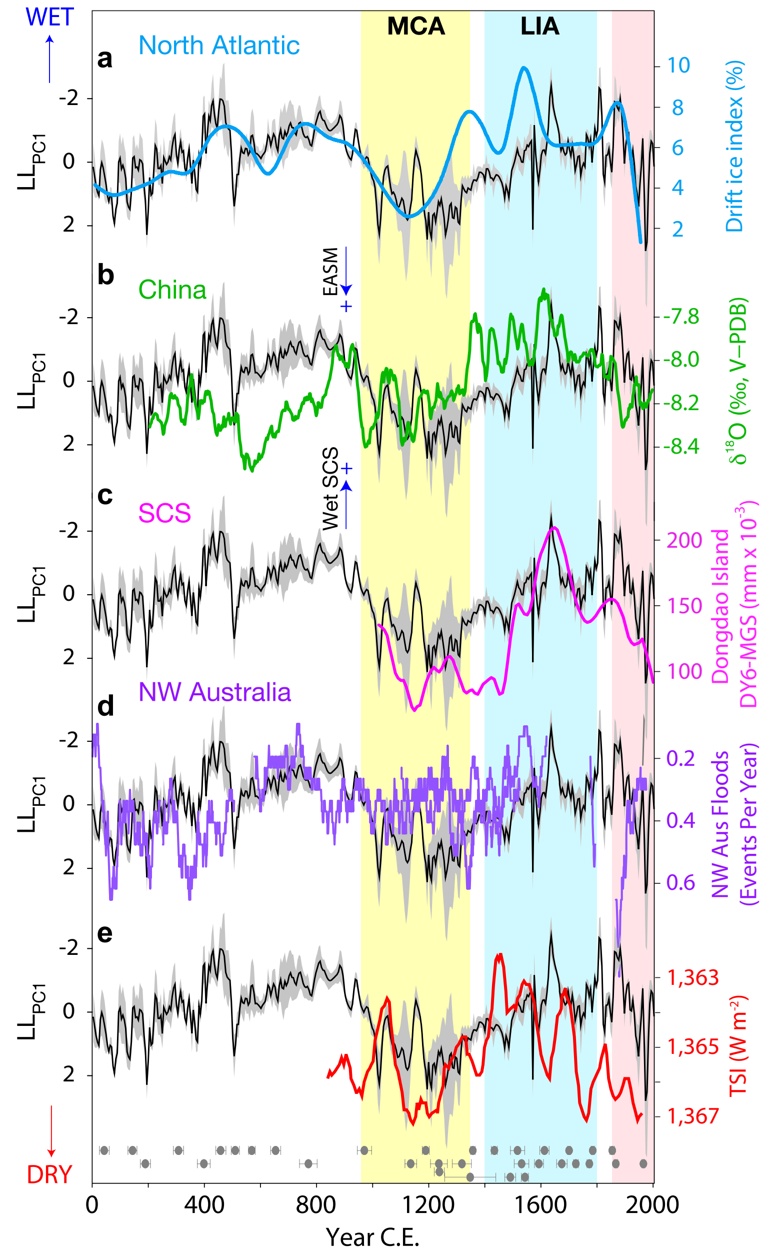
Chinese speleothem
(Zhang et al., 2008)

South China Sea
(Yan et al., 2011)

NW Australia
(Denniston et al., 2015)

TSI
(Bard et al., 2000)

Flores multiproxy reconstruction

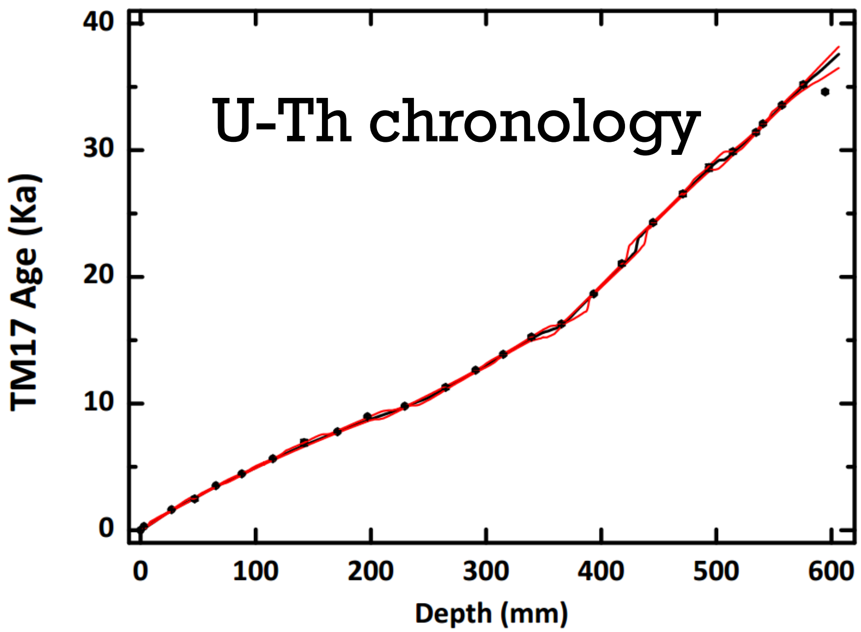


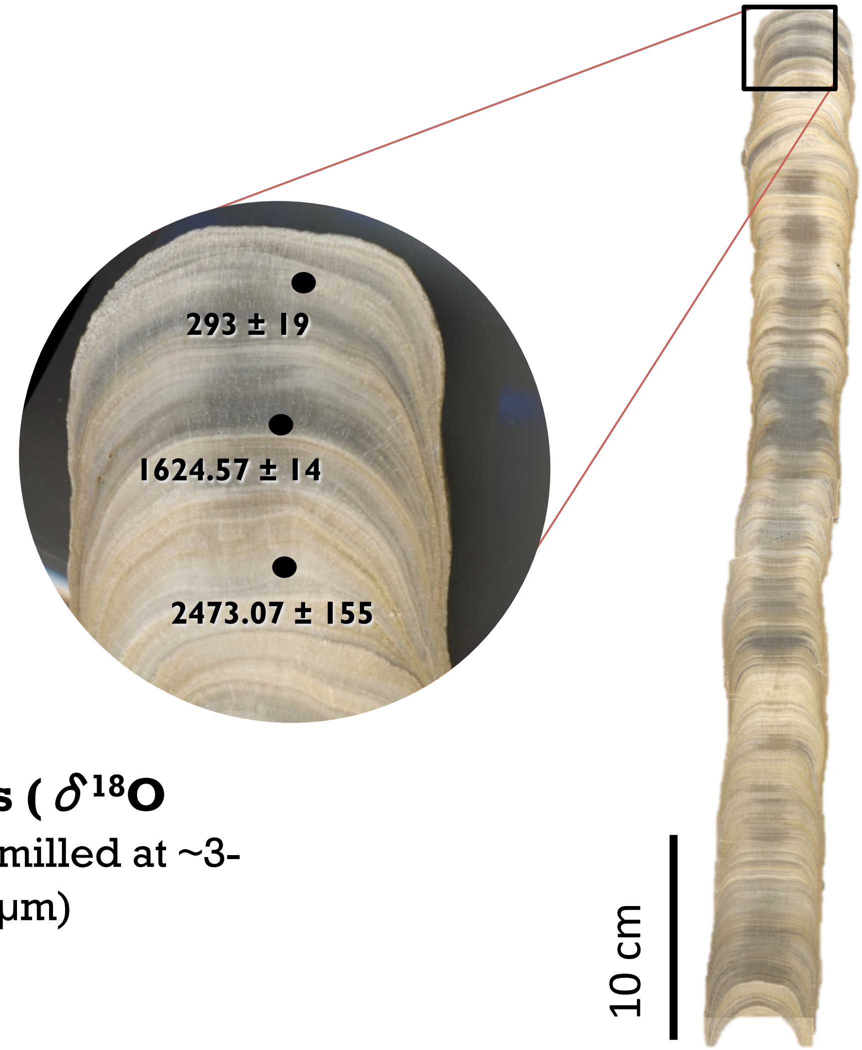
Griffiths *et al.*, 2016; *Nat. Comm.*

Tham Mai Cave, Luang Prabang Province, Laos

Giant Huntsman spider
(*Heteropoda maxima*)

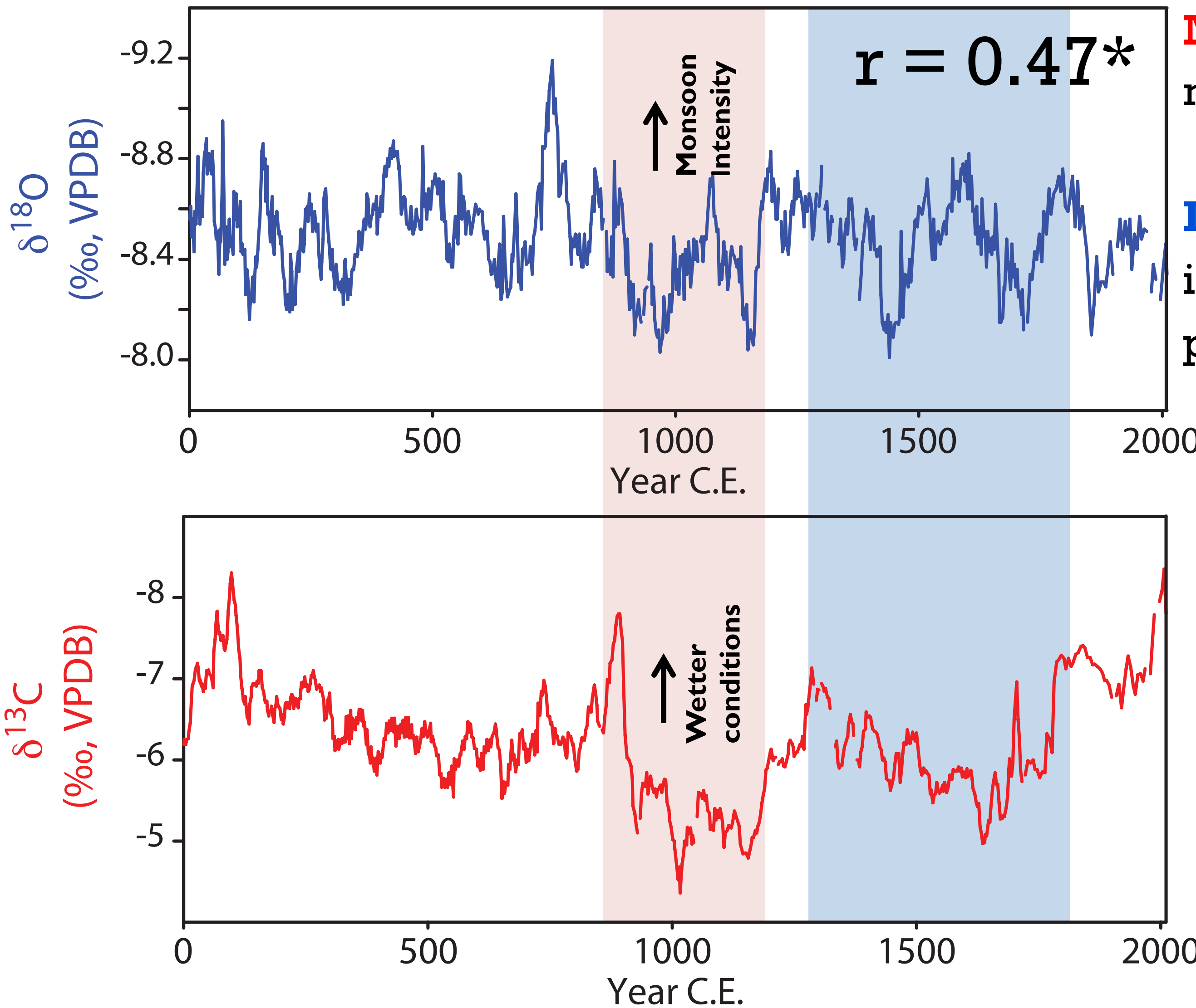
Speleothem TM-17





Isotope analyses (δ^{18}O and δ^{13}C): Micromilled at ~3-year resolution (50 μm)

SE Asian monsoon variability during the Common Era



MCA: Dry/decreased monsoon

LIA: Wetter (?) with interspersed drier periods

Conclusions

- Similar to other proxies (e.g. tree rings, corals), spelethems from the western Pacific have the potential to provide multi-proxy and well calibrated hydroclimate reconstructions that will be useful in model-proxy syntheses.

- New speleothem hydroclimate records from Indonesia suggest a strong link between decadal-scale rainfall variability and NH temperatures. Recent 20th century drying trend may hint at what lies ahead as the planet continues to warm.

- In light of recent findings (e.g. Yan et al., 2015), along with the new record from Laos, it is likely that the Australasian ITCZ contracted/ expanded in response to radiative-forced shifts in temperature.

Acknowledgements

Collaborators: Kathleen Johnson, Russell Drysdale, Mike Gagan, John Hellstrom, Jian-xin Zhao, Gideon Henderson, Hongying Yang (student), Jessica Wang (student), Ben Cook, Ali Kimbrough, Julie Cole, Quan Hua.

Funding: National Science Foundation; NOAA/UCAR C&GC Fellowship; William Paterson University.